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Biobased economy: outlook on sustainable supplies and future demand

Seminar Danish Energy Foundation

8th April 2013, Copenhagen - Denmark

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Why biobased economy?

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Energy system transformation…

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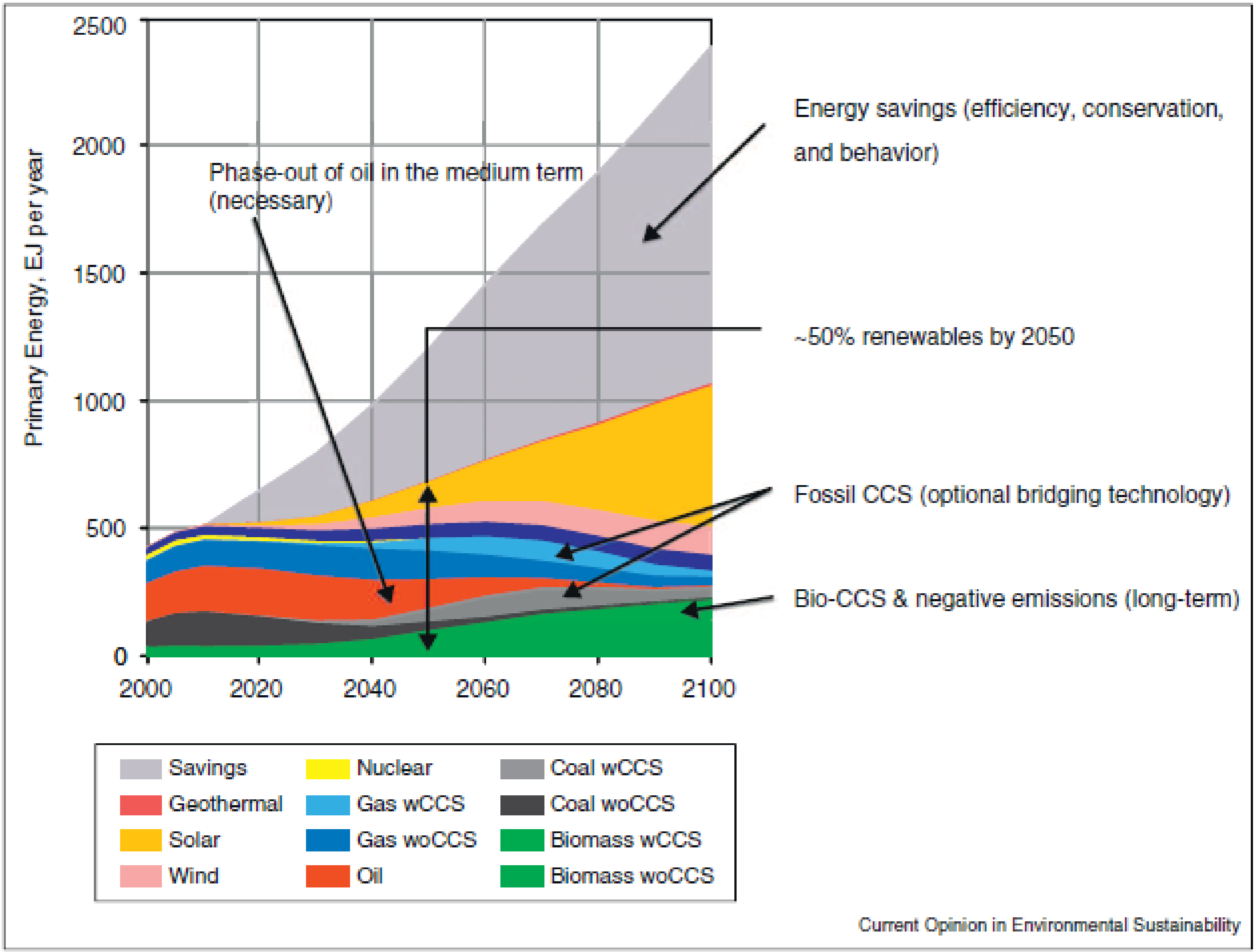

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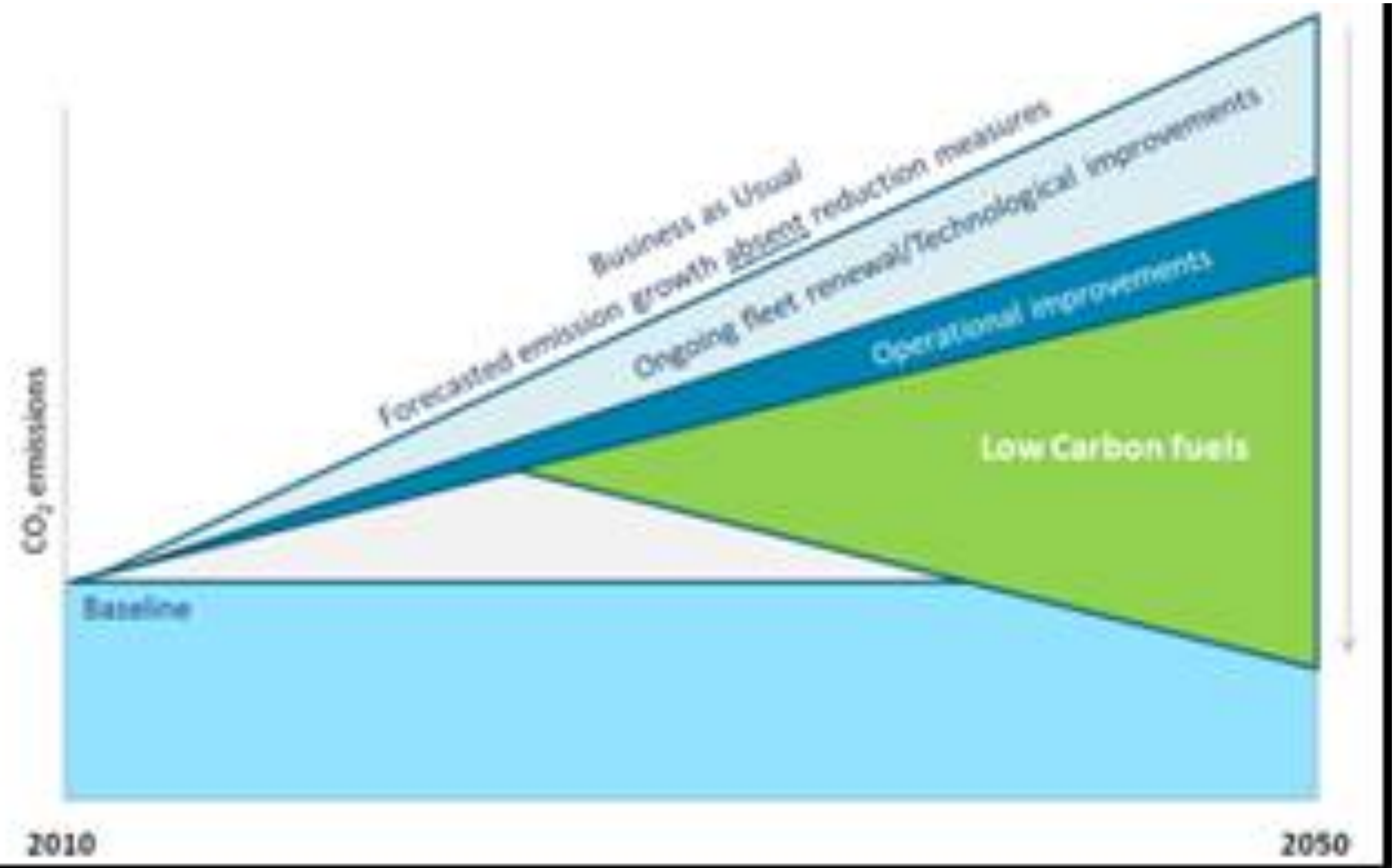
[GEA/van Vuuren et al CoSust, 2012]

Advancing markets…pushed by technological progress and pulled by high oil prices

- Advanced biofuels…(strong economic perspective)
- Biorefining, biochemicals, biomaterials…
- Aviation and shipping…

- Likely to compete for the same resources…
- Should meet the same sustainability criteria… (but that is not the case today!)
- Competition or synergy?

Breakdown of CO2 reduction options for aviation till 2050



[IIATA, 2010]

Biobased chemicals; not covered in current global scenario's (to date…)!

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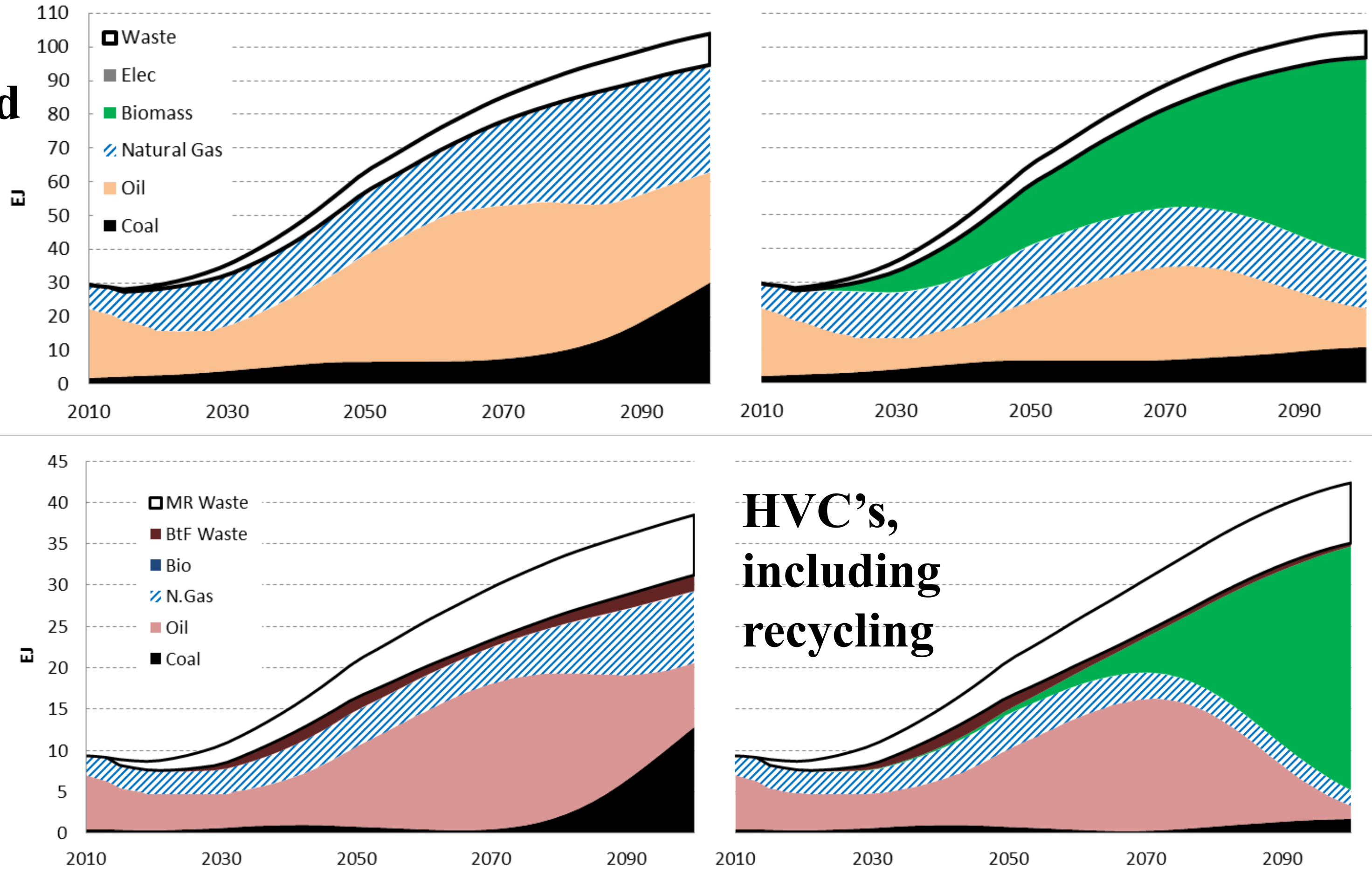
Energy demand for major Chemicals towards 2100 with and without Biomass deployment



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[Daioglou et al., 2013 (forthcoming)]

Biofuels; they are not going away.

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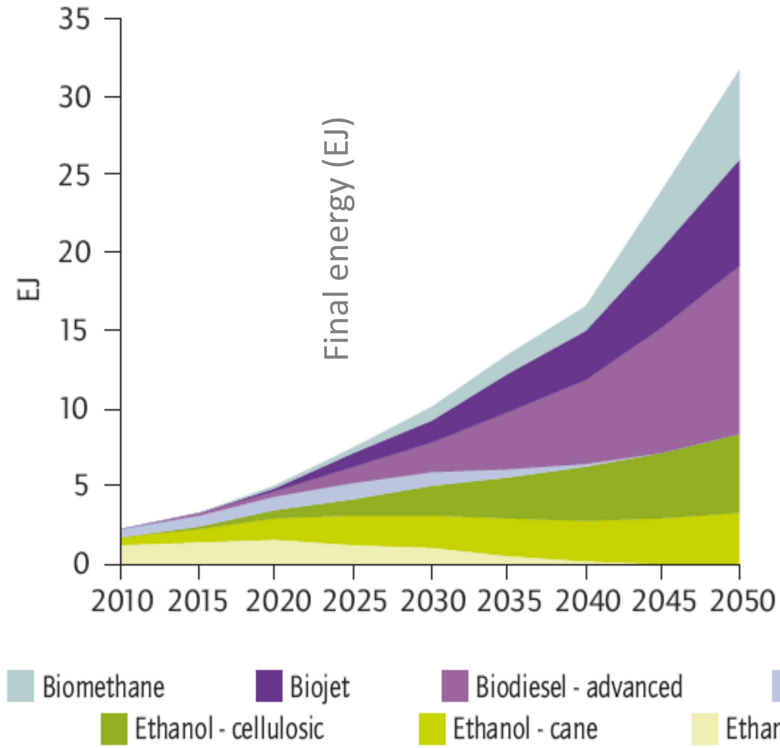
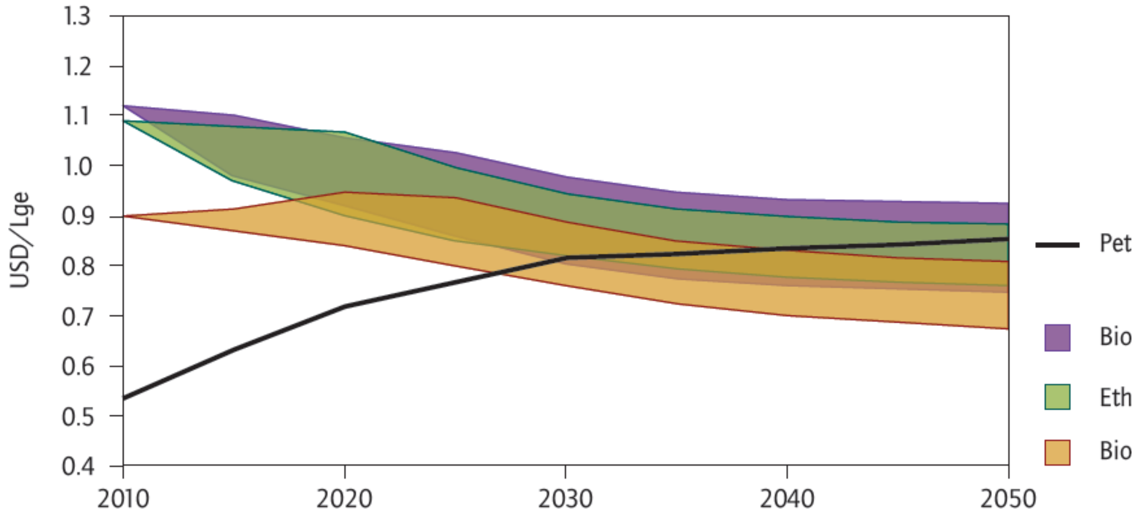


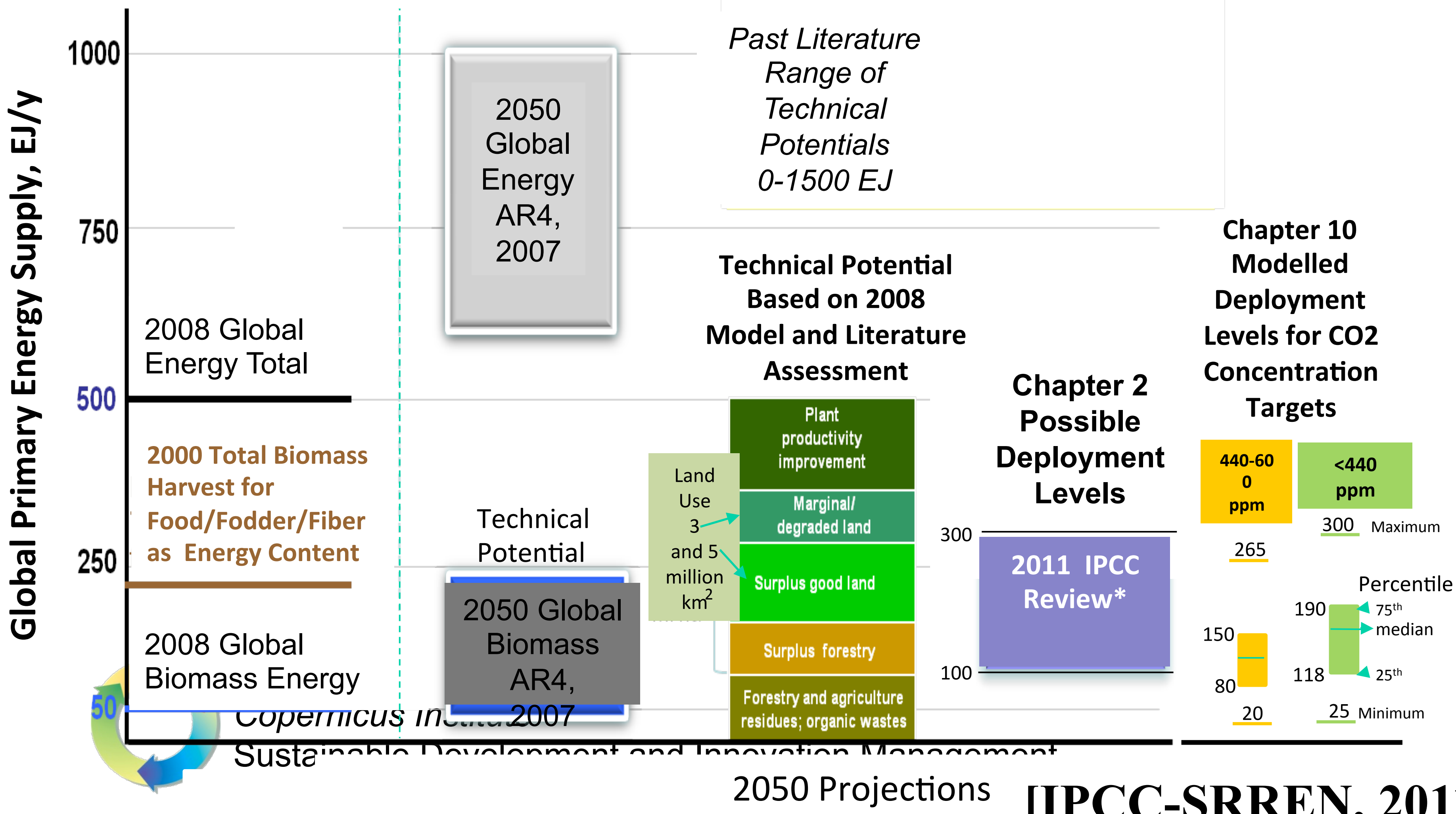


- Large-scale deployment of advanced biofuels vital to meet the roadmap targets
- **Advanced biofuels reach cost parity around 2030 in an optimistic case**

[IEA Biofuels Roadmap]

Biomass resources; potentials <-> preconditions

2050 Bioenergy Potentials & Deployment Levels



[IPCC-SRREN, 2011]

Driving forces, dimensions, scales…

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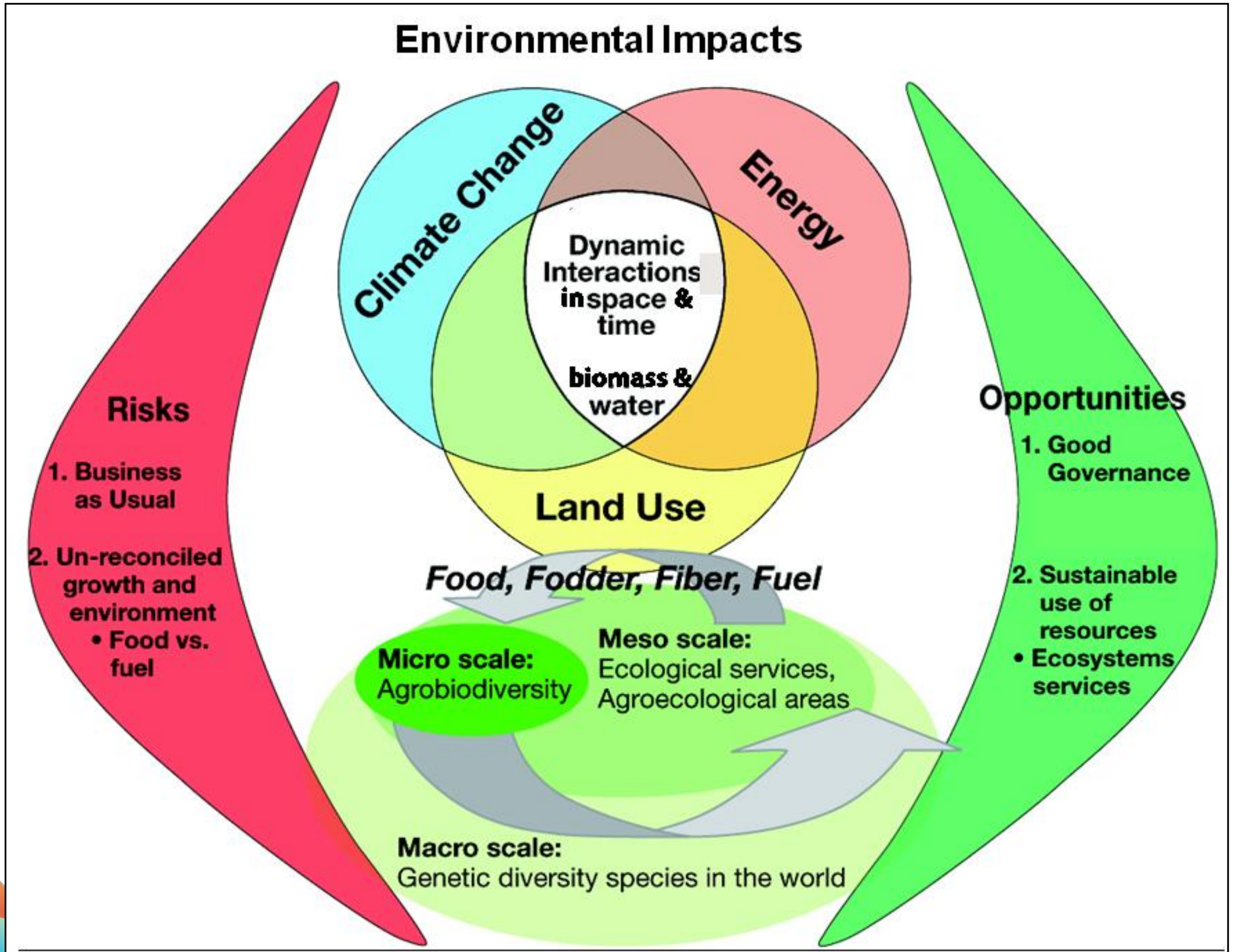

[IPCC-SRREN, 2011]

Key factors biomass potentials

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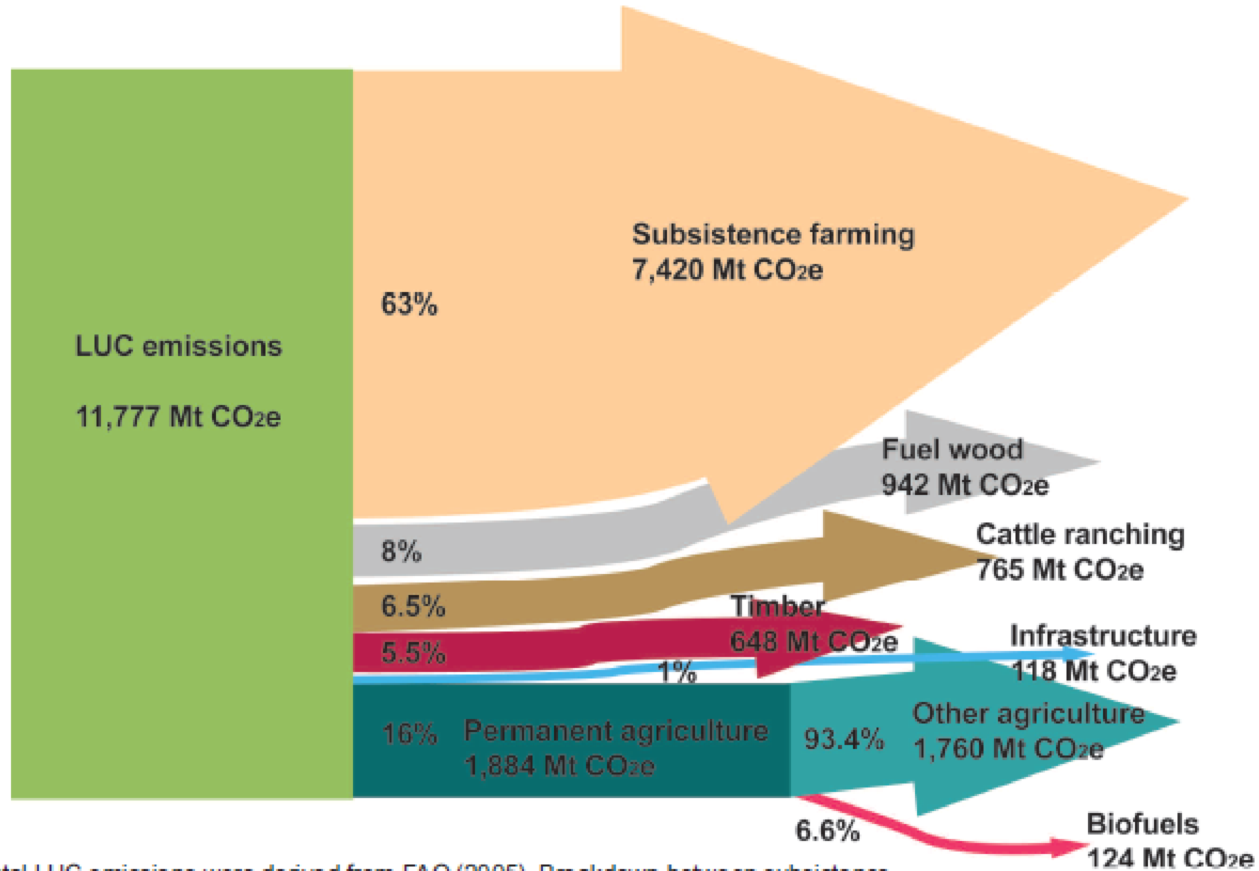
Issue/effect	Importance
Supply potential of biomass	
Improvement agricultural management	***
Choice of crops	***
Food demands and human diet	***
Use of degraded land	***
Competition for water	***
Use of agricultural/forestry by-products	**
Protected area expansion	**
Water use efficiency	**
Climate change	**
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

Contributors to land use change…

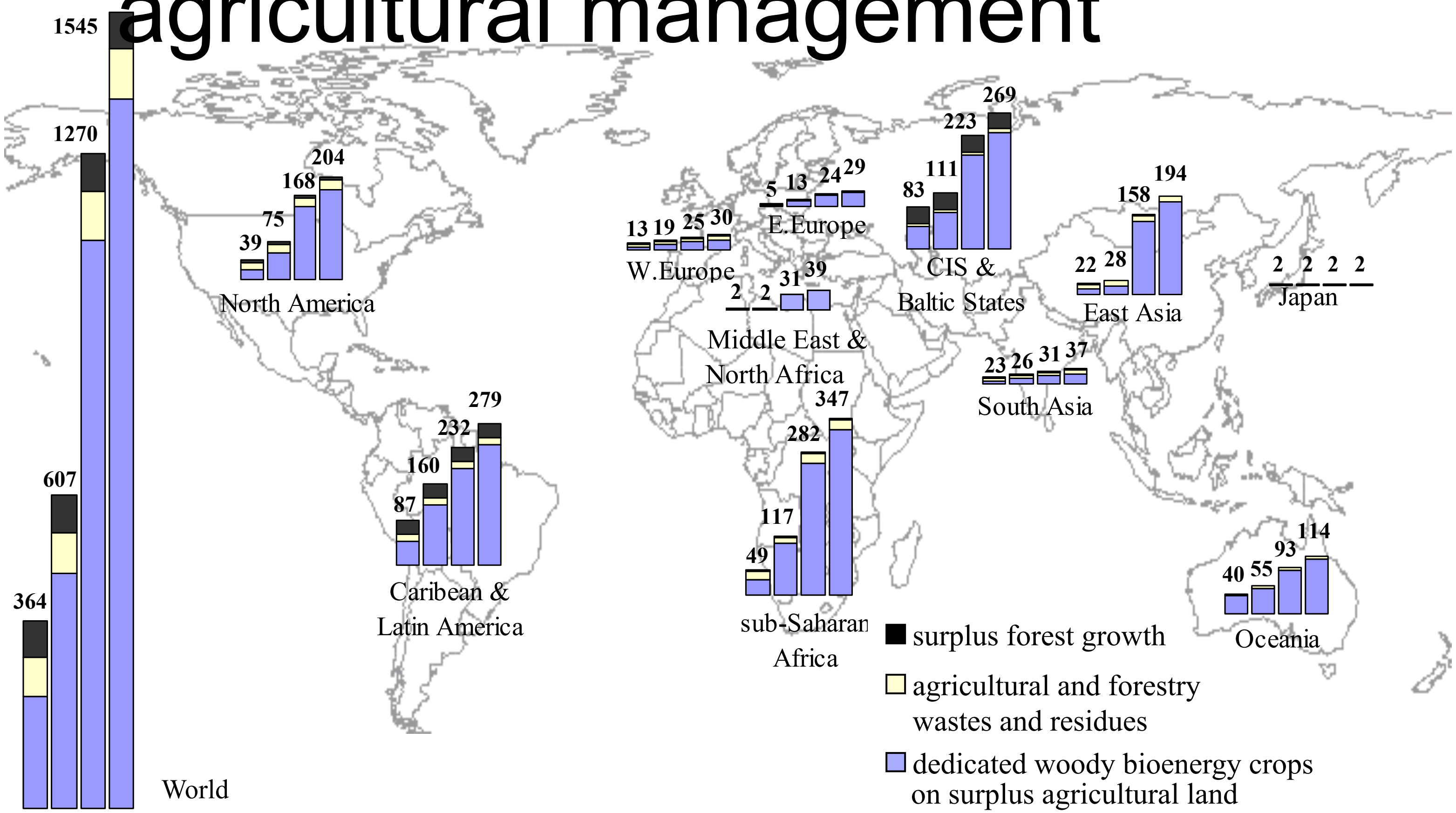


Total LUC emissions were derived from FAO (2005). Breakdown between subsistence farming, fuel wood, cattle ranching, timber and permanent agriculture were taken from FAO (1980). The contribution of biofuels was based on the proportion of commercial agricultural output allocated to biofuels over the period 2000 - 2005.

Cope
Susta

Bioenergy production potential in 2050 for different levels of change in agricultural management

Source: Smeets, Faaij 2007
Progress in Energy & Combustion Science



Total bioenergy production potential in 2050 based on system 1 to 4 (EJy-1; the left bar is system 1, the right bar is system 4

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GHG mitigation peformance

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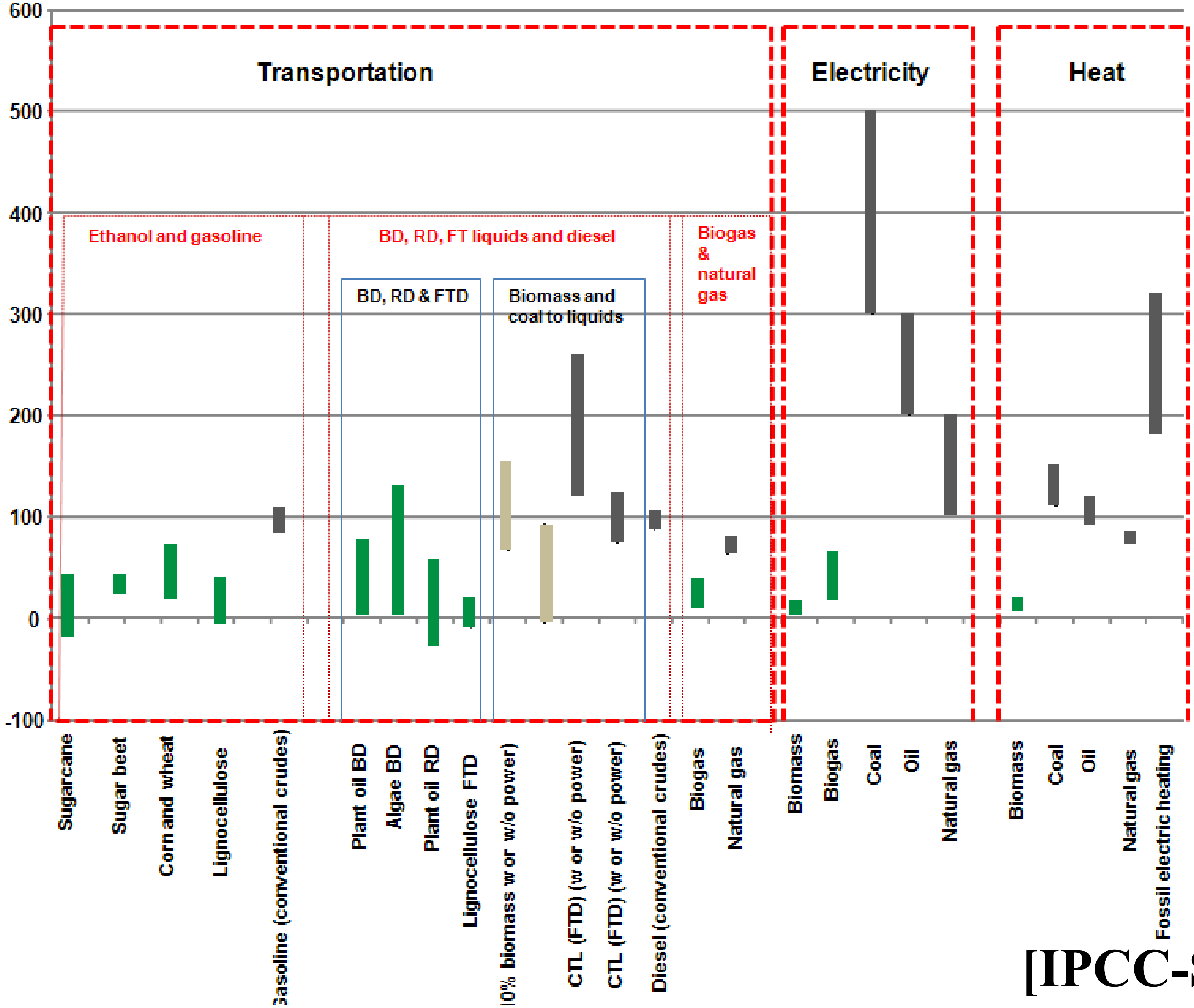
GHG/MJ of major modern bioenergy chains vs. conventional fossil fuel options



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

[IPCC-SRREN, 2011]

Direct land use change GHG emissions examples

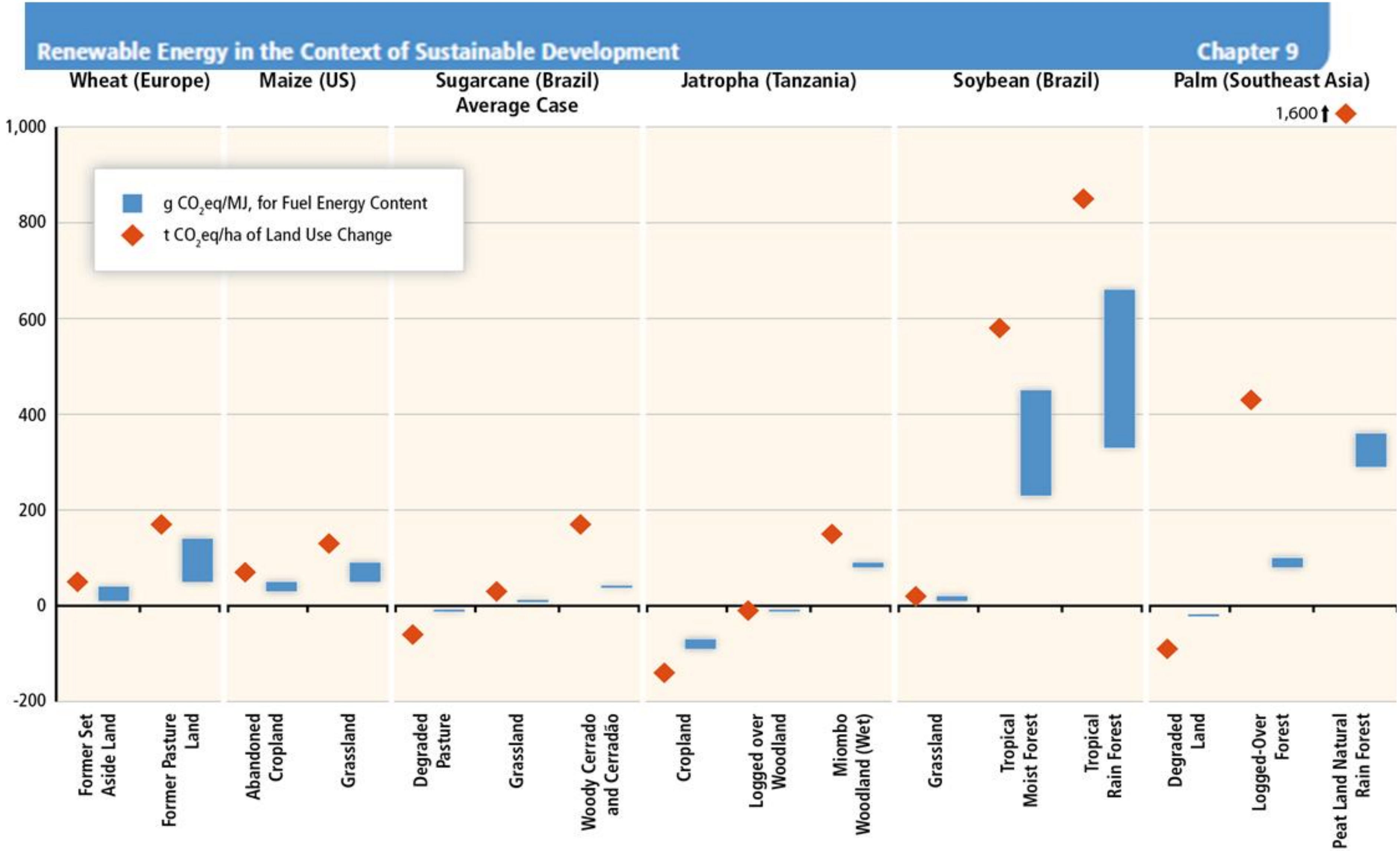


Figure 9.10 | Illustrative direct LUC-related GHG emission estimates from selected land use types and first-generation biofuel (ethanol and biodiesel) feedstocks. Results are taken from Hoefnagels et al. (2010) and Fargione et al. (2008) and, where necessary, converted (assuming a 30-year timeframe) 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).

INTERGOVERNMENTAL PANEL ON climate change

Site and prior use specific ....

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

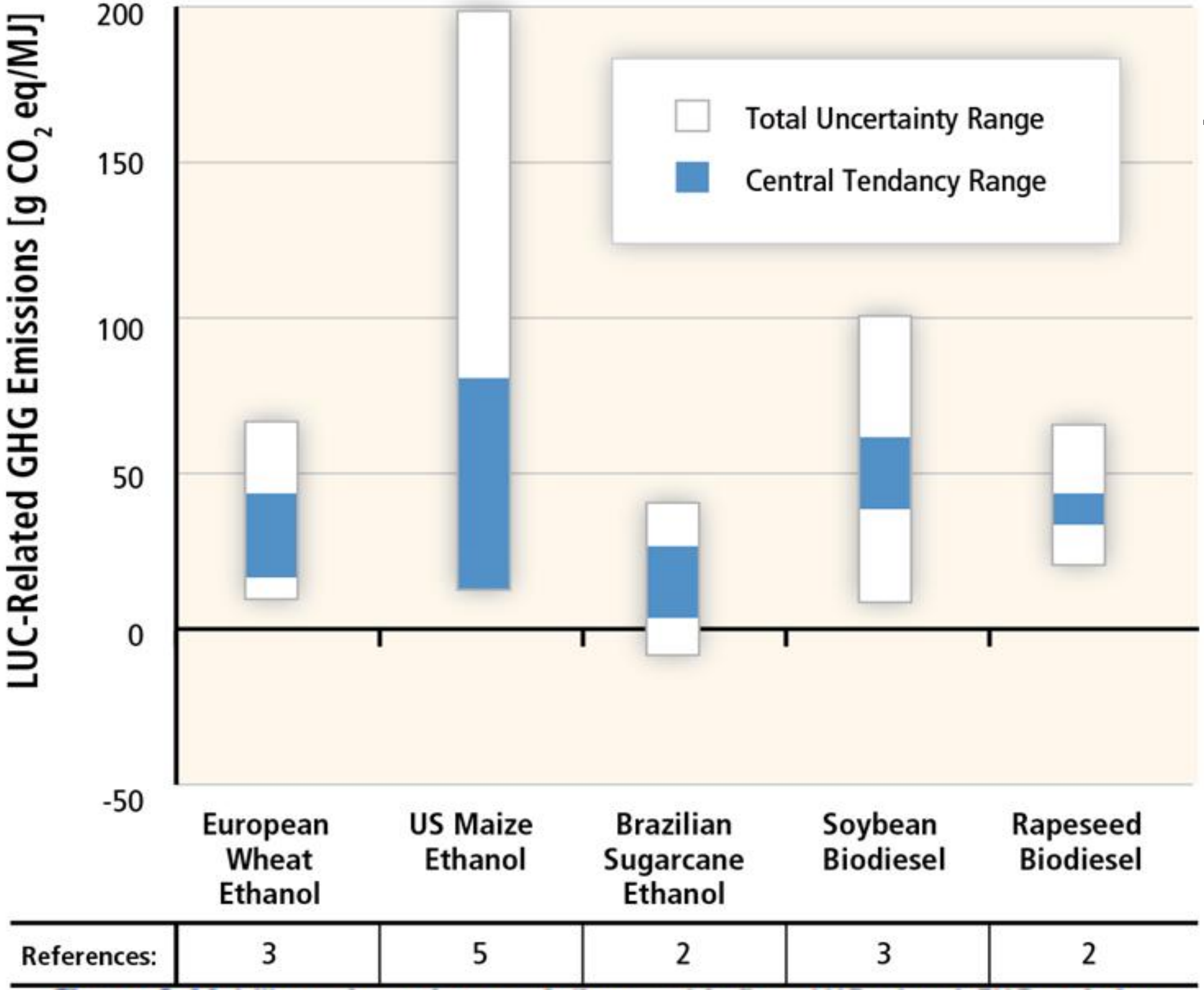


Figure 9.11 | Illustrative estimates of direct and indirect LUC-related GHG emissions induced by several first-generation biofuel pathways, reported here as ranges in central tendency and total reported uncertainty. Estimates reported here combine several different uncertainty calculation methods and 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)

GHG emissions per km driven

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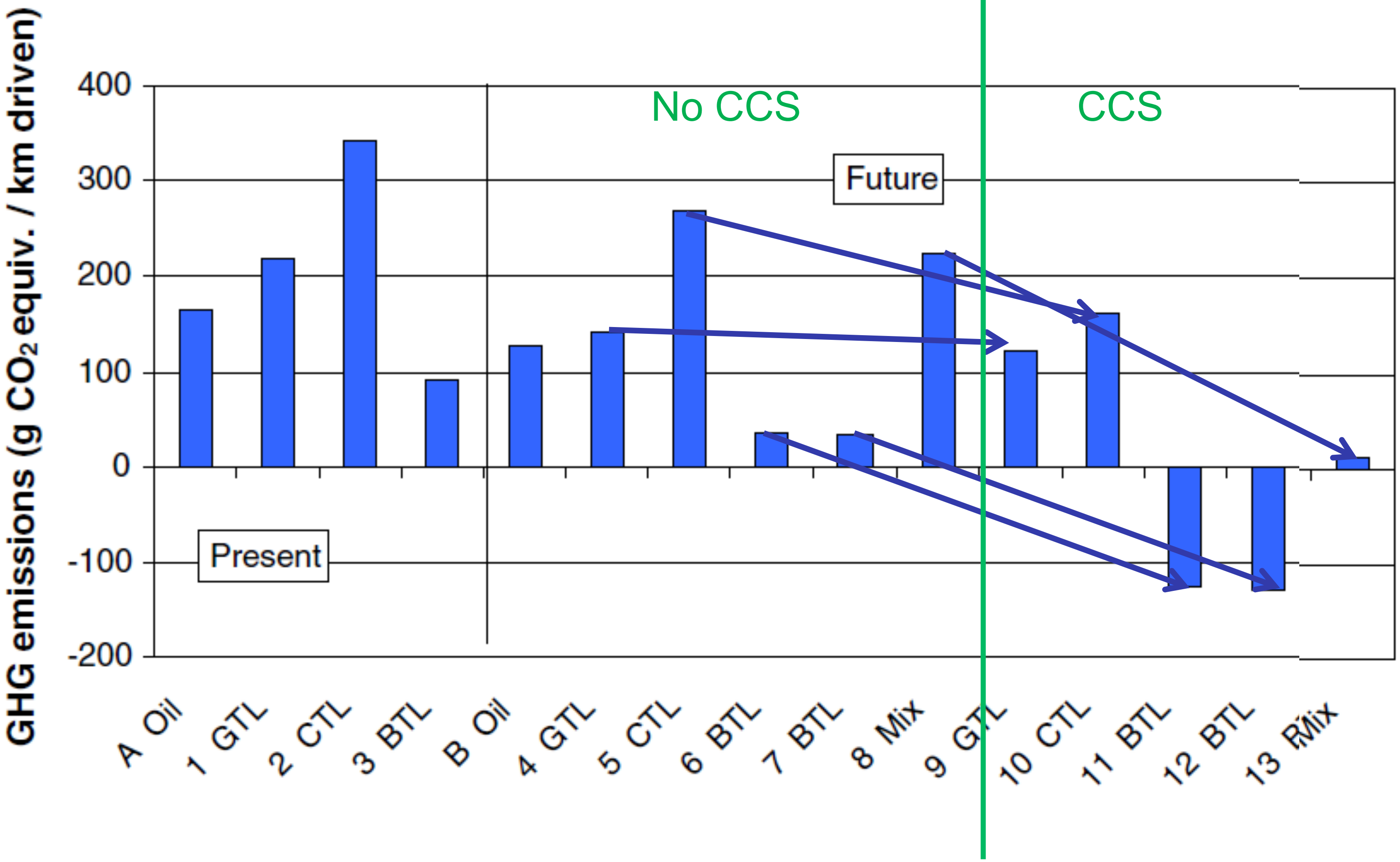

[Van Vliet et al., 2009]

iLUC; scientific status, gaps next steps…

Confrontation bottom-up vs. top down iLUC modelling

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Key steps iLUC modelling efforts:

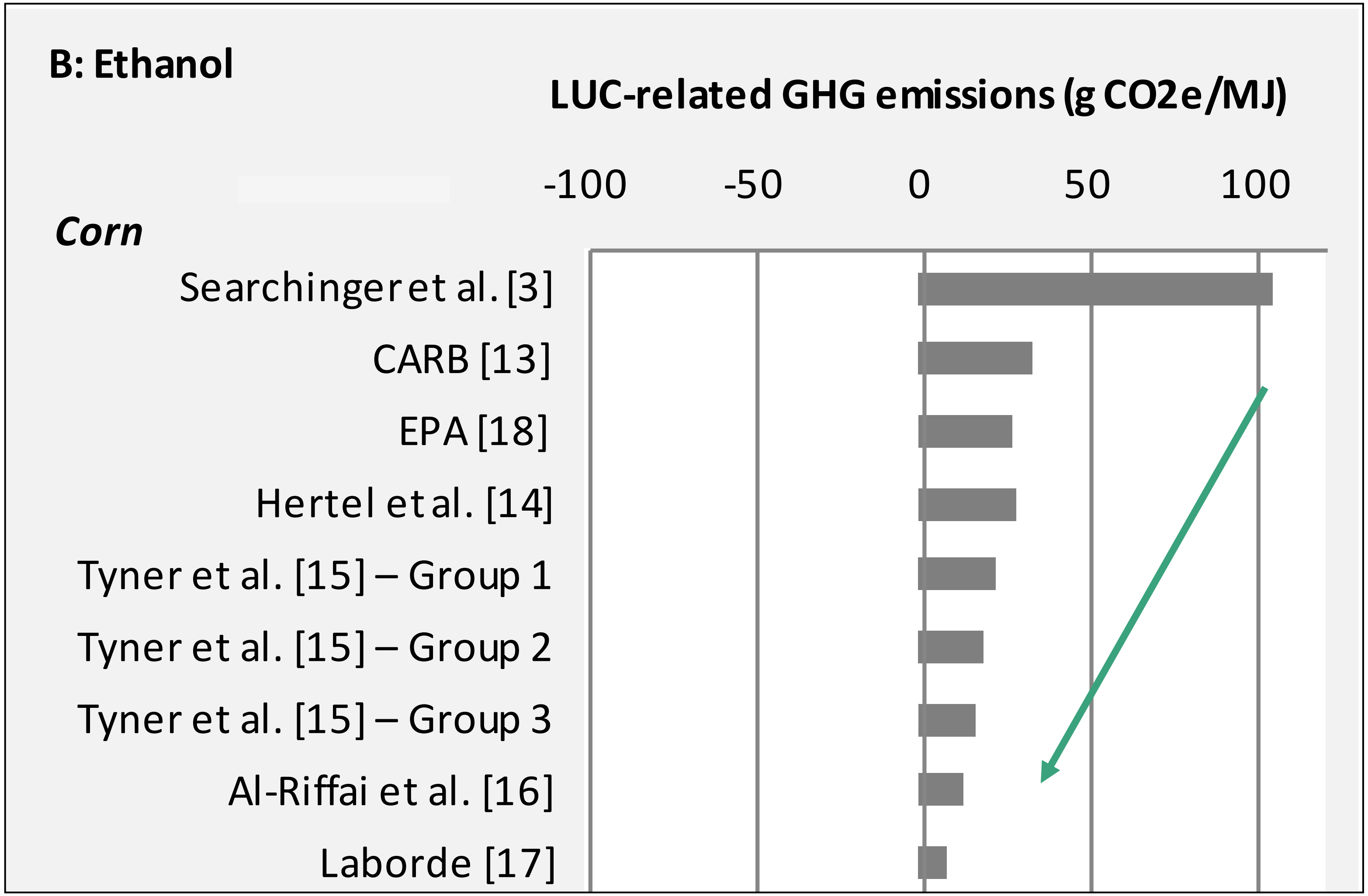
- CGE; historic data basis
- Model shock, short term, BAU, current technology.
- Quantify LUC
- Quantify GHG implications (carbon stocks)

Bottom-up insights:

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

[IEA & other workshops, 2011-2013; pubs under

Example: Corn ethanol
Results from PE & CGE models



[Wicke et al., Biofuels, 2012]

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:

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

<u>Versus</u>

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

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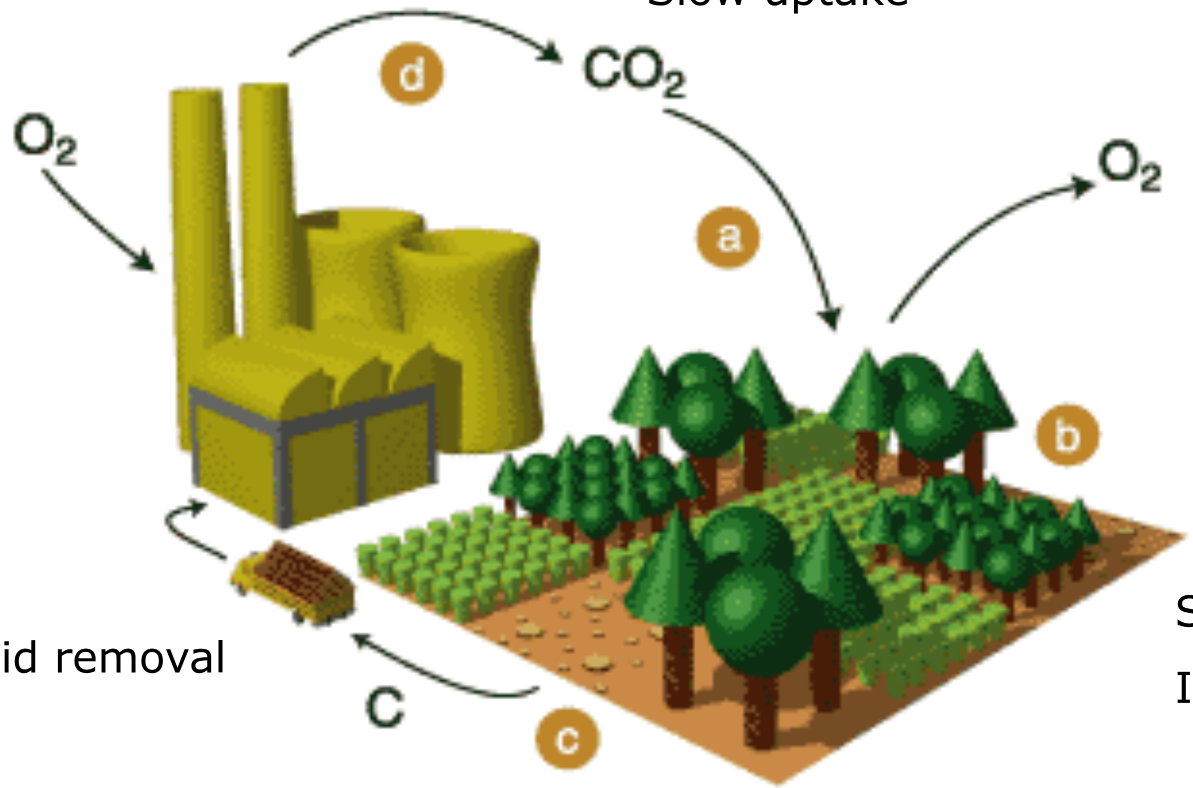
Ins and outs carbon debt debate

Basic principle of GHG emission reductions through bioenergy

Slow uptake



Rapid removal

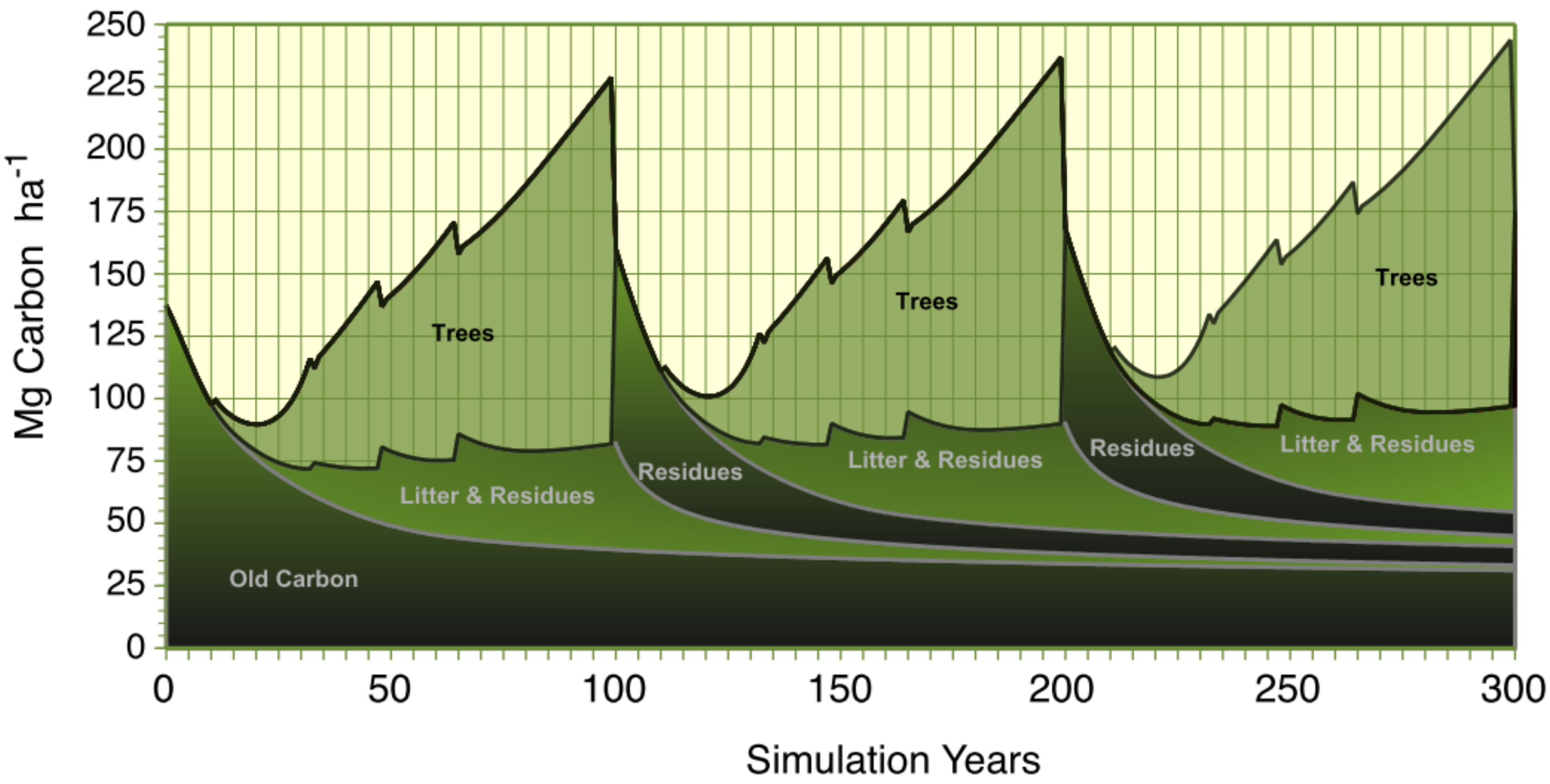
Source: adapted from IEA Bioenergy Task 38

The fact that bioenergy is ultimately renewable is not debated, but the ***time*** until the repayment of any potential carbon debt is repaid is under debate

Two very important methodological choices:

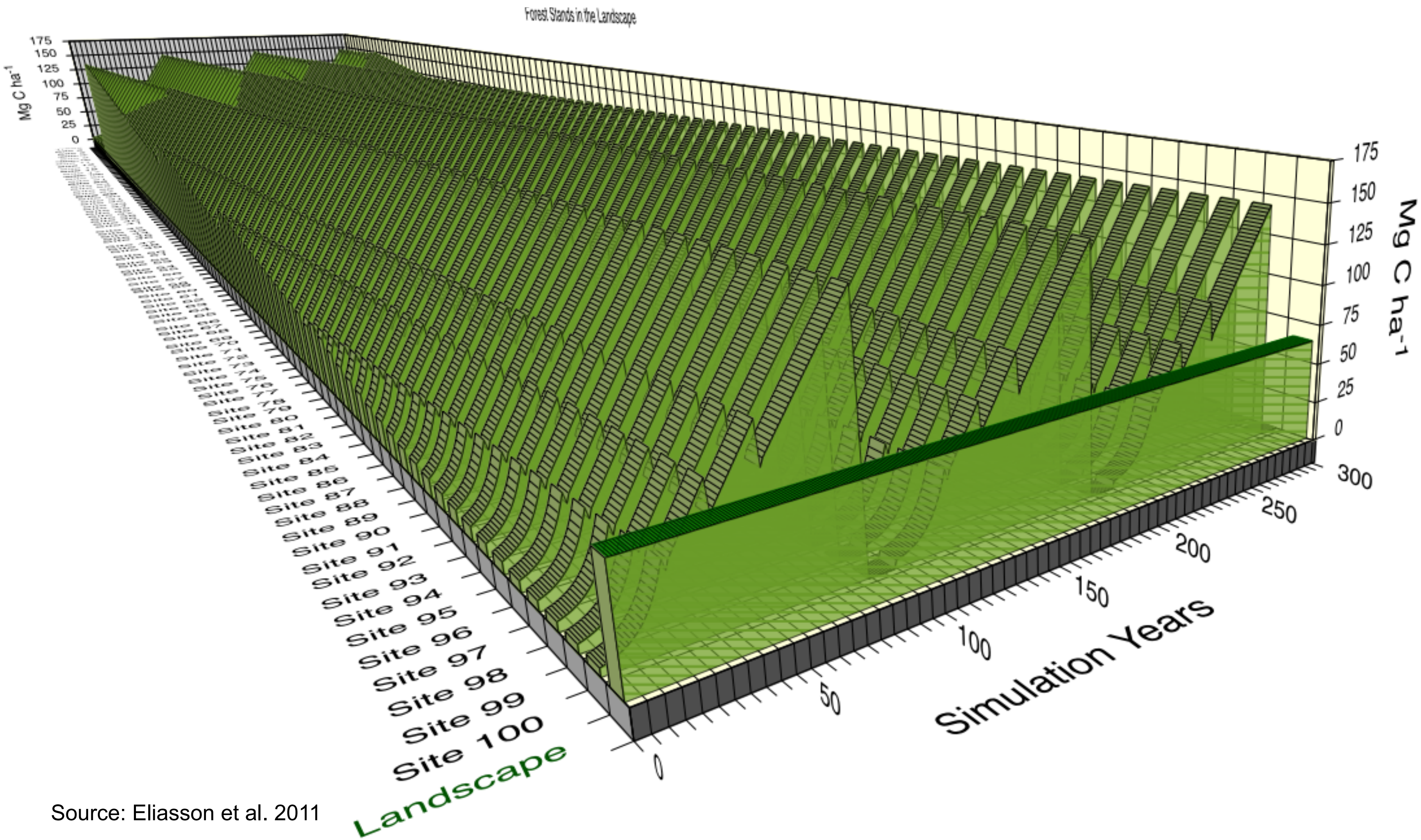
1. Does the analysis consider the stand-level and/or the landscape level
2. Does the study analyse the time until the initial carbon-debt is repaid, or does it compare the carbon flows of a bioenergy scenario with a reference scenario (e.g. a no-use scenario)

Stand-level



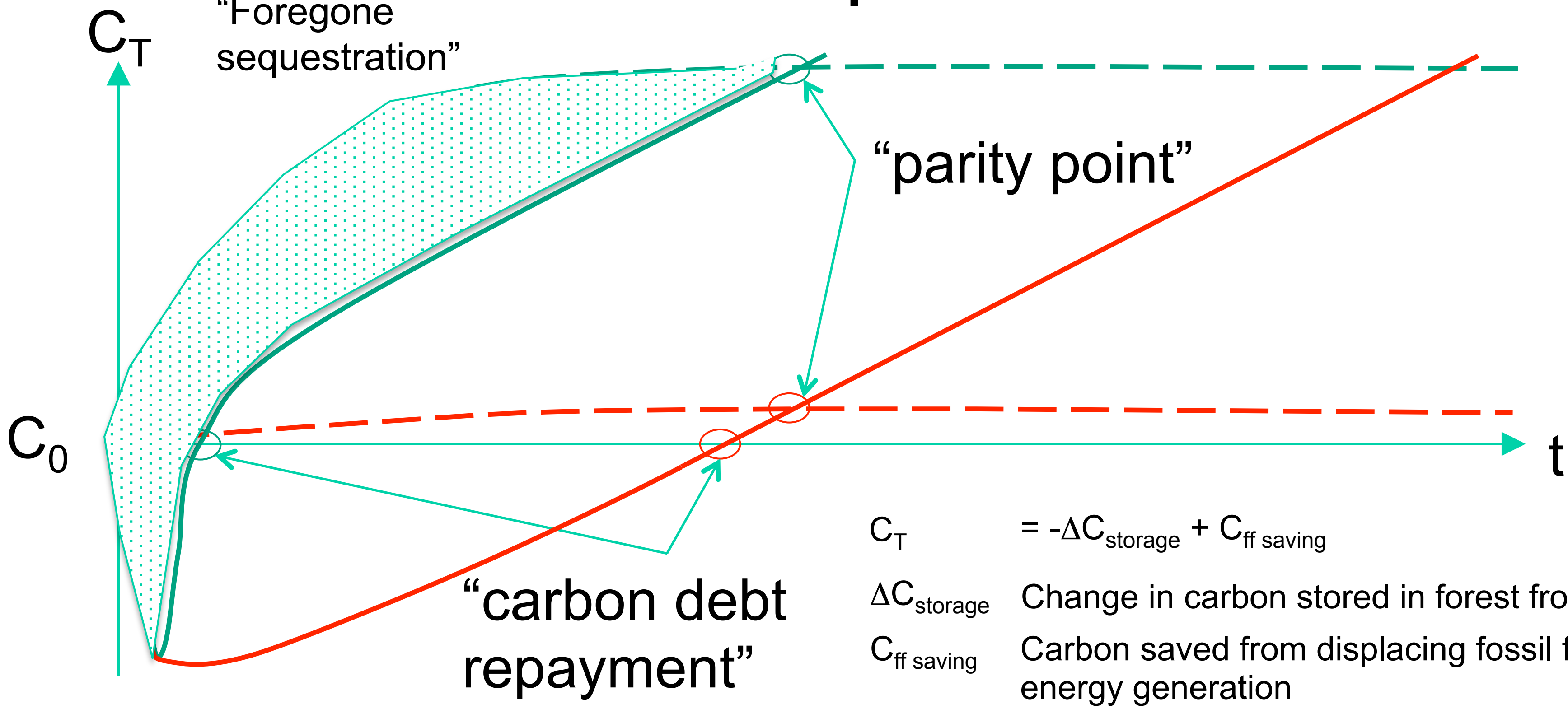
Source: Eliasson et al. 2011

Landscape-level



Source: Eliasson et al. 2011

Carbon debt & parity points – stand & landscape level



C_T	$= -\Delta C_{storage} + C_{ff\ saving}$
$\Delta C_{storage}$	Change in carbon stored in forest from t = 0
$C_{ff\ saving}$	Carbon saved from displacing fossil fuel energy generation

- Bioenergy scenario (landscape)
- Bioenergy scenario (plot)
- No harvest scenario (landscape)
- No harvest scenario (plot)

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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Overview of parity times per biome

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Table 2. Temporal carbon analyses for using residues, depicted by biome.

Biomass type	Biome: reference case	Min	Max	Sources/Studies: feedstock[a] (forest management regime)
Residue	(Sub-) Boreal: BAU + coal based electricity	0	16	[23, 24, 30, 33, 53]: slash
	(Sub-) Boreal: BAU + oil based electricity	3	24	[23, 24, 53]: slash
	(Sub-) Boreal: BAU + natural gas based electricity	4	44	[23, 24, 53]: slash
Roundwood	Temperate southern: Protection[b] + coal electricity	12	46	[29]: whole-trees (existing plantations, 20-25 year rotation)
	Temperate southern: BAU + fossil electricity mix	35	50	[61]: whole-trees (existing plantations, 35 year rotation)
	(Sub-) Boreal: Protection + coal electricity	0	105	[25, 30, 33B]: whole-trees (previously unmanaged forest)
	(Sub-) Boreal: Protection + oil heating	90		[18]: stemwood only (previously unmanaged forest)
	(Sub-) Boreal: BAU + coal electricity	53	230	[21, 30, 53]: whole-trees (previously un-/managed forest)
	(Sub-) Boreal: BAU + coal electricity	17	114	[53]: whole-trees (new plantations, 10-20 year rotation)
	(Sub-) Boreal: BAU + oil electricity	20	145	[53]: whole-trees (new plantations, 10-20 year rotation)
	(Sub-) Boreal: BAU + natural gas electricity	25	197	[53]: whole-trees (new plantations, 10-20 year rotation)
	(Sub-) Boreal: BAU + natural gas electricity	300	400	[53]: additional fellings (in managed forests)
	(Sub-) Boreal: BAU + fossil electricity	0	0	[53]: afforestation

a: Applied definitions:
Slash: residues from timber harvesting including tops and branches (possibly also stumps) of harvested/merchantable trees, whole non-merchantable trees (e.g. standing, cracked deadwood)
Thinnings: pre-/commercial cutting of selected rows/individual trees to allow a stronger growth of remaining trees
Additional fellings: increased harvesting intensity in a defined region i.e. higher biomass outtake than under a BAU scenario (i.e. timber harvest)
b: "Protection" equals no harvest.
c: Mitchell et al. [35] found payback times over 1,000 years but did not account for a full post-harvest carbon cycle and was therefore not included in this comparison.

Source: Lamers and Junginger, 2013, BioFPR, in press

Factors complicating the debate

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- Carbon debt vs. carbon parity
- Stand level vs. landscape level
- Large variety in different sourcing areas (EU, US SE, Ca BC, Russia etc.) and different feedstocks , such as precommercial & commercial thinnings, forest residues left after clear-cut for timber, insect-damaged (e.g. MPB) wood
- Choice of fossil fuel reference system (coal, EU average, NG)
- Use (and substitution/displacement factors) of (by-) products
- What is the reference (aka counterfactual) scenario: protection, use for timber or paper, or land use change (e.g. conversion to agricultural crops, or urban development)?
- Carbon debt vs. carbon credit (in case of man-made plantations)

=> **There is no single correct method**. These choices depend on the specific situation and political preference.

C-debt mitigation options

1. New plantations on degraded/C-poor land -> imminent carbon credit!
2. For managed/commercial forests: Use of fertilizer and weed control (within SFM limits) – increases productivity strongly
3. Increased early stand density & use of pre-commercial thinnings

Options 2 & 3 cause no additional land use and reduce any C-payback times strongly (+ additional output for pulp & timber), but all need incentives

General conclusions

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Payback times reported in scientific literature vary widely, but many of them are based on rather hypothetical scenarios.

Vast majority of currently utilized solid biomass in the EU is still residue based – but primary forest biomass share will increase in the future.

Determining the most adequate method / reference scenario etc. is strongly case–dependent – there is no 'one-size fits all solution'

Challenges for science, business and policy

- ***Land & natural resources (local – global)***
  - Integral land use strategies (agriculture, BBE, nature, rural development)
  - Full impact analyses and optimization;
  - Include 'macro''-themes; iLUC, food security, rural development, water/biodiversity.
  - Governance…
- ***Drive down the learning curves***
  - Technologies (fuels, biomaterials, power, carbon management (CCS)
  - Cropping systems
  - Logistics, markets, CoC
  - Business models & investment.

Thanks for your attention

For more information, see:

- **Sciencedirect/Scopus (scientific)**
- **Google scholar citations (personal)**
- **http://srren.ipcc-wg3.de/report (IPCC)**
- **www.bioenergytrade.org (IEA)**

Perspective on Europe

Yield projections Europe

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Observed yield

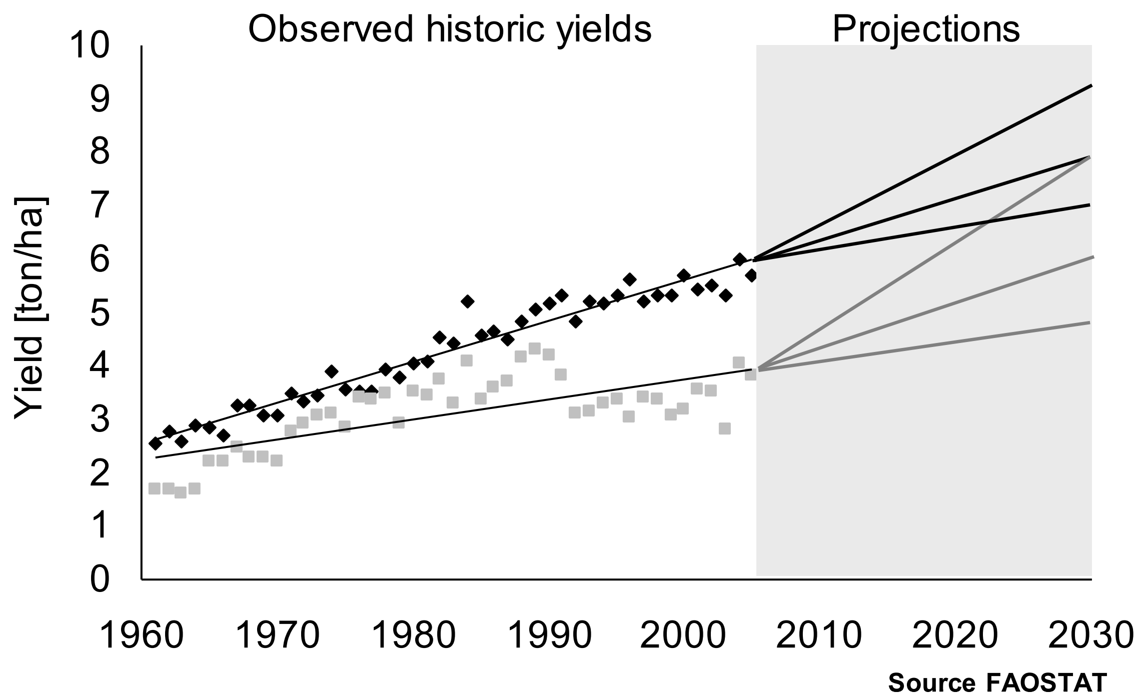
- CEEC and WEC

Linear extrapolation of historic trends

- Widening yield gap

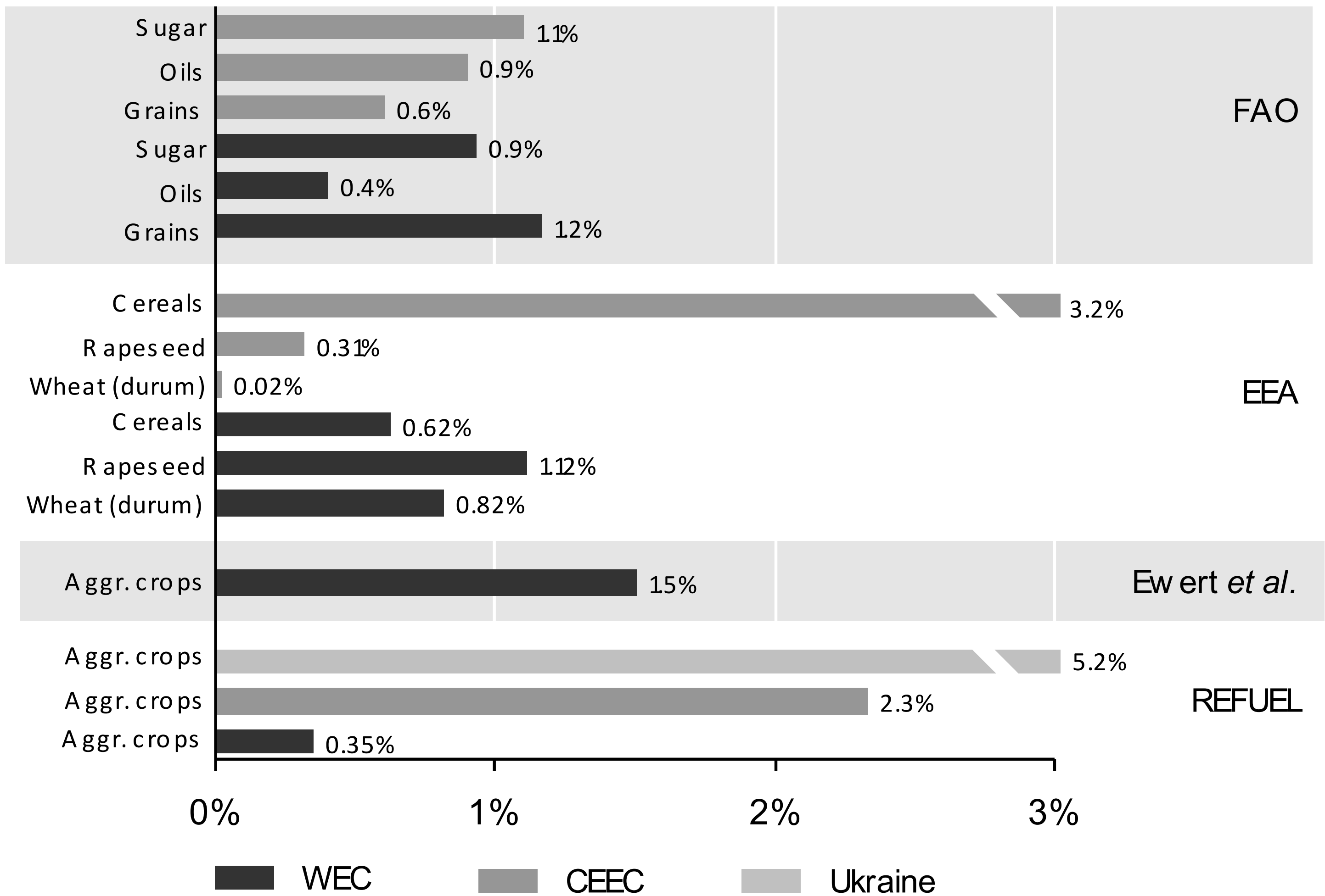
Applied scenarios

- Low, baseline and high



[Wit & Faaij, Biomass & bioenergy, 2010]

Average annual yield growth rate projections for Europe for the period 2000-30 for four studies



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De Wit, et al., RSER 2011

Absolute productivity increases and relative growth rates for the period 1961-2007 and per decade.

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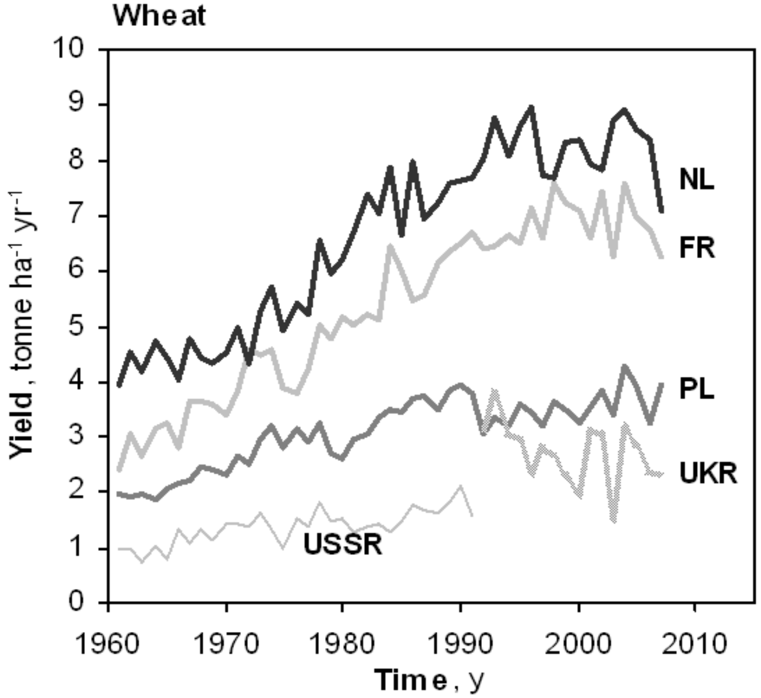
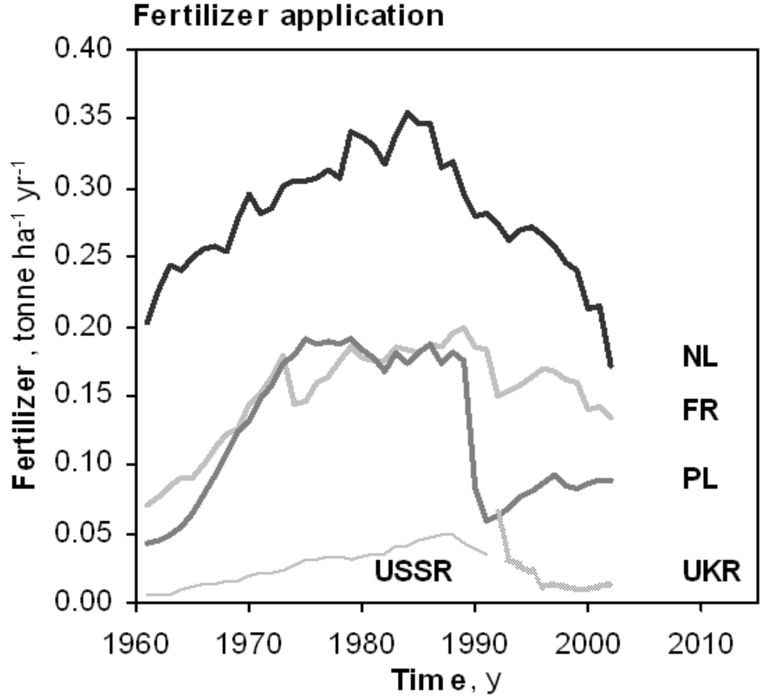
		Absolute 1961-2007 kg ha^{-1} y^{-2} kg $animal^{-1}$ y^{-1}	Relative **1961-2007**	'61-'69	'70-'79 % y^{-1}	'80-'89	'90-'99	'00-'07
France	Wheat	104	**3.6**	5.2	2.5	2.5	1.6	-0.9
	Rapeseed	40	**2.5**	1.4	0.3	-0.3	2.1	1.2
	Sugarbeet	1024	**3.1**	3.6	0.2	2.4	1.0	2.8
	Cattle	2.8	**1.6**	0.5	1.2	0.9	-0.1	0.9
Netherlands	Wheat	110	**2.7**	0.7	3.8	1.4	0.5	-0.6
	Rapeseed	25	**1.0**	-0.6	-1.8	-0.1	0.6	0.2
	Sugarbeet	489	**1.2**	2.6	0.1	1.4	-1.9	2.5
	Cattle	1.1	**0.6**	0.7	0.9	2.1	-0.9	-1.0
Poland	Wheat	39	**1.8**	3.6	2.3	4.1	-0.6	1.6
	Rapeseed	21	**1.4**	1.7	0.4	-0.4	-0.6	4.0
	Sugarbeet	319	**1.2**	3.5	-0.5	2.6	1.0	3.7
	Cattle	2.5	**2.7**	3.6	6.1	4.9	0.6	10.1
Ukraine *(USSR)* [a]	Wheat	*n.a.*	*n.a.*	5.1	1.0	3.6	-4.5	-0.2
	Rapeseed	*n.a.*	*n.a.*	3.5	-2.7	-0.4	-7.4	9.4
	Sugarbeet	*n.a.*	*n.a.*	9.0	0.3	5.0	-3.2	11.3
	Cattle	*n.a.*	*n.a.*	6.3	2.1	2.1	-4.9	1.2

De Wit, et al., RSER, 2012

Developments in yields and inputs





[De Wit et al, RSER 2011]

Selected remarks on yields

- Yield growth projections in WEC at 0.5-1.5% y-1, are modest when compared to historic developments between 1961-2007, but seems high compared to developments in the last two decades. Declining growth rates in the latter period, explained by an expansion in organic farming, set-aside obligations and a decoupling of production support. REFUEL projections (0.4% y-1) for the WEC seem conservative in this respect.

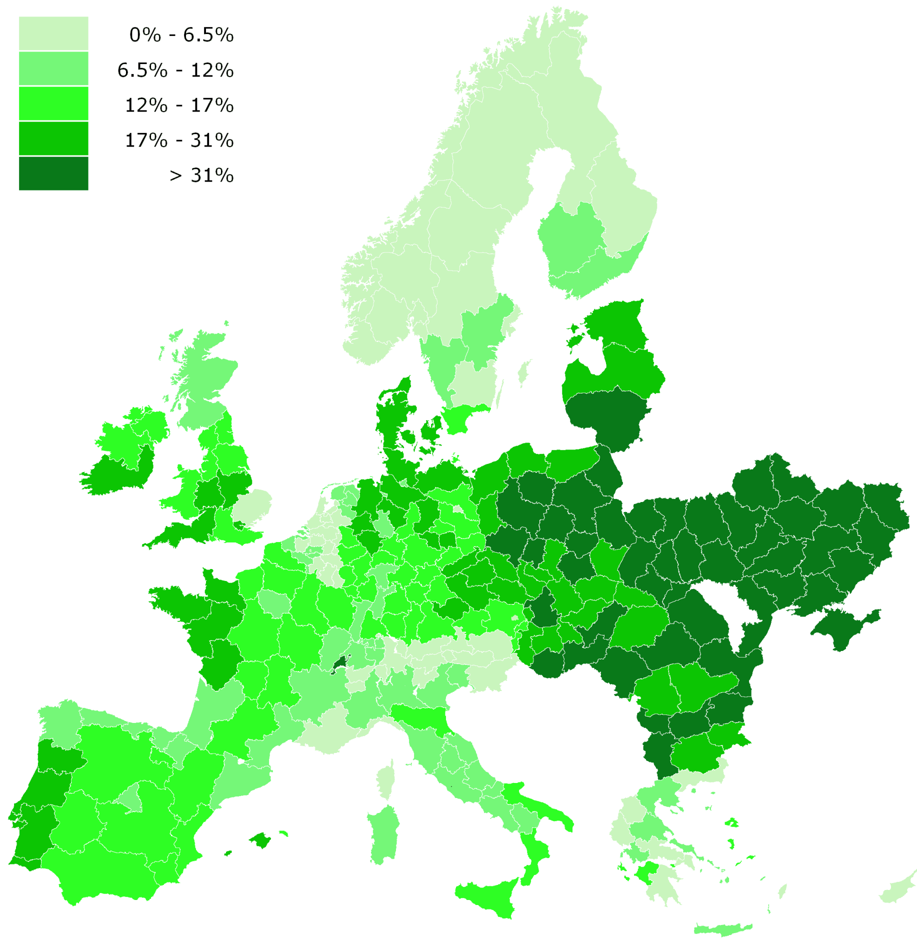
- Projected growth rates for the CEEC around 1% y-1 – as projected by FAO (0.9% y-1) and EEA (1.2% y-1) – seem modest when compared to average growth figures between 1961 and 2007, even more so when compared to growth rates prior to 1990 and past 2000.

De Wit, et al., RSER 2012

Results - spatial production potential

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

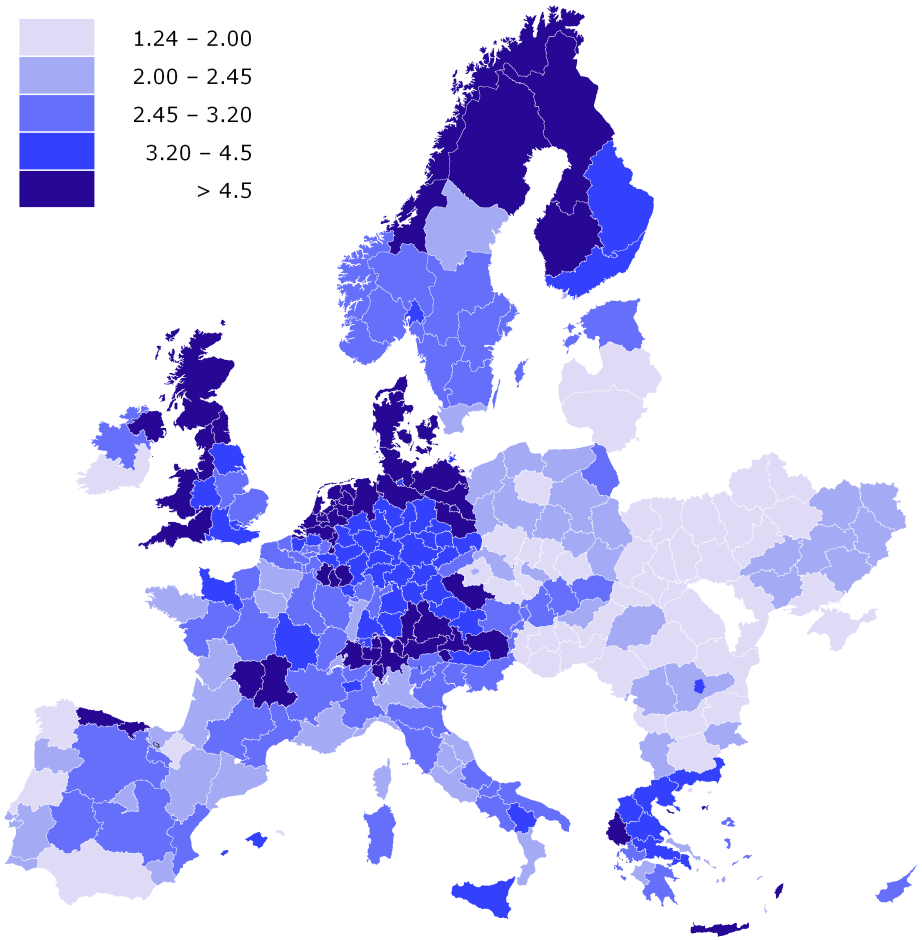


[Wit & Faaij, Biomass & Bioenergy, 2010]

Results - spatial cost distribution

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



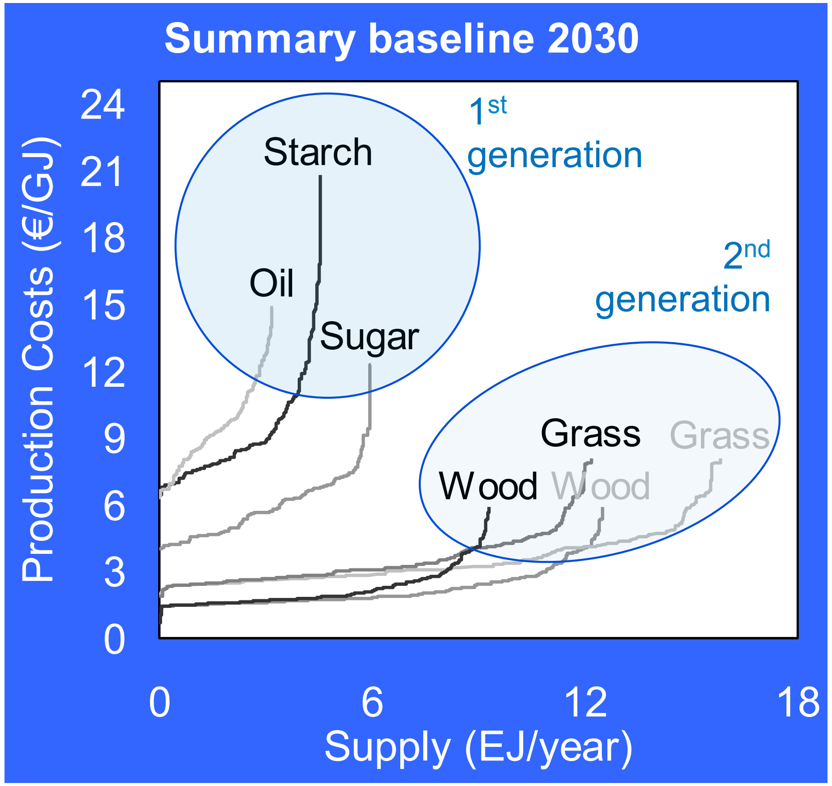
[Wit & Faaij, Biomass & Bioenergy, 2010]

Crop specific supply curves

- 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]

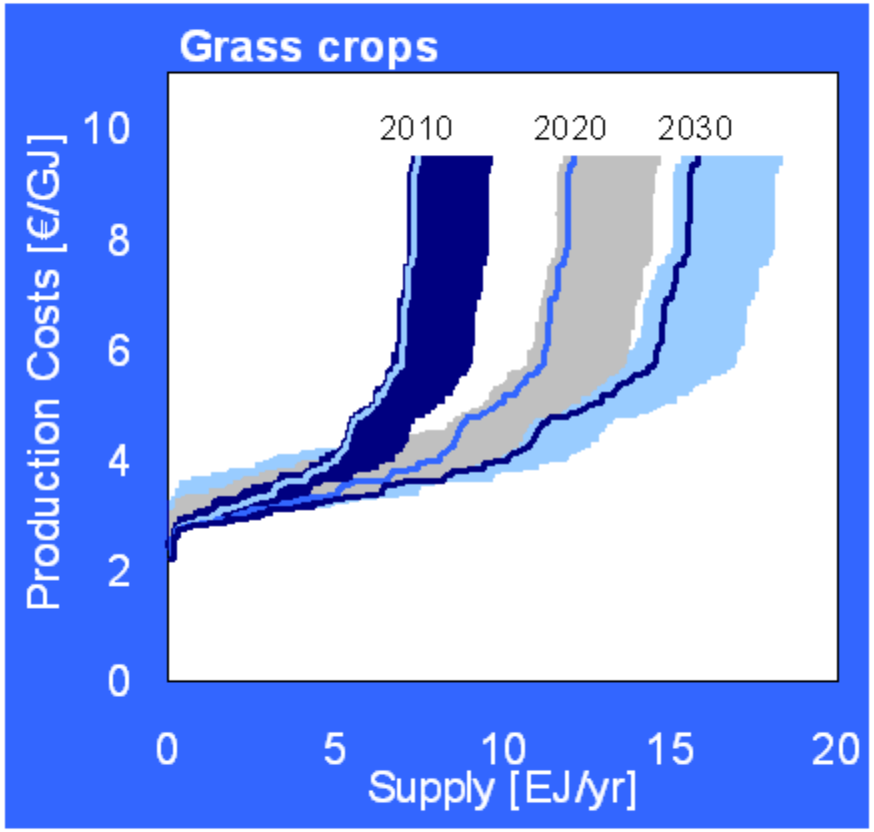
Results – cost-supply curves

Production costs vs. supply potential

for 2010, 2020 and 2030

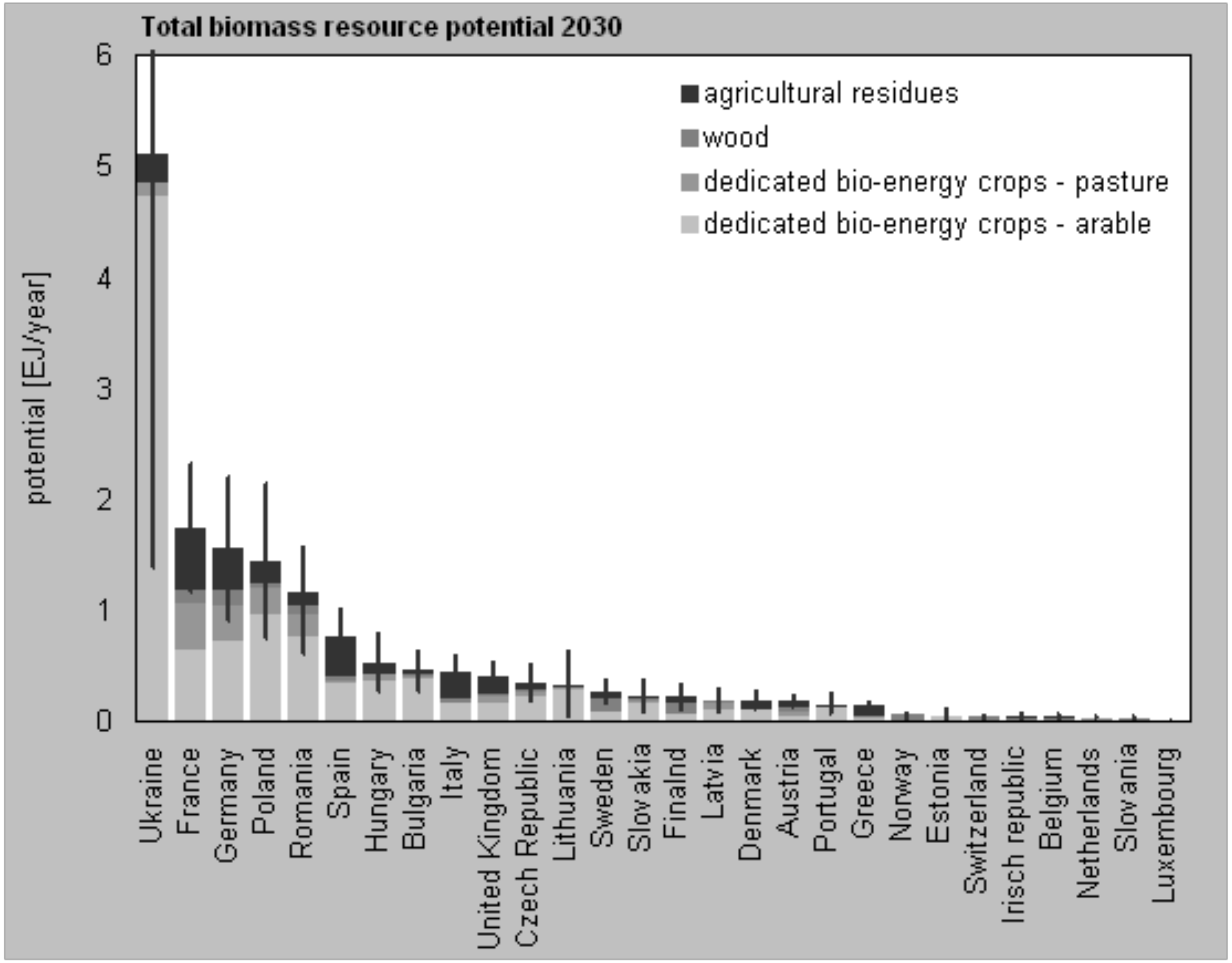
Variation areas indicated around the curves represent uncertainties and scenario variables.

Only CEEC cost level increases



[Wit & Faaij, Biomass & Bioenergy, 2010]

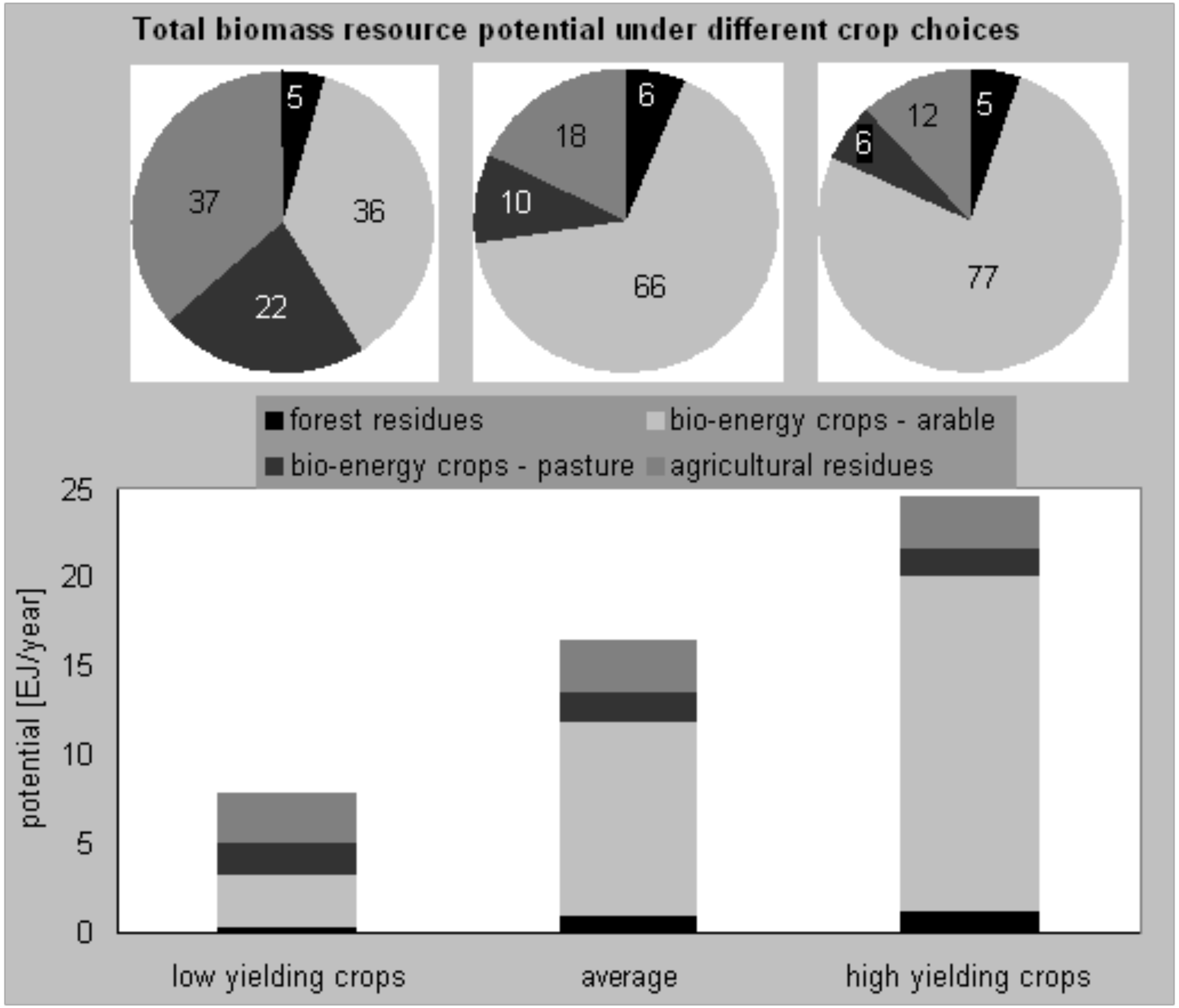
Total annual biomass supply potential, per European country.



[Wit & Faaij, Biomass & Bioenergy, 2010]

Total energy potential under three different crop schemes.

Low yielding crops': all arable land available planted with oil crops. 'High yielding crops': all available land planted with grass crops.



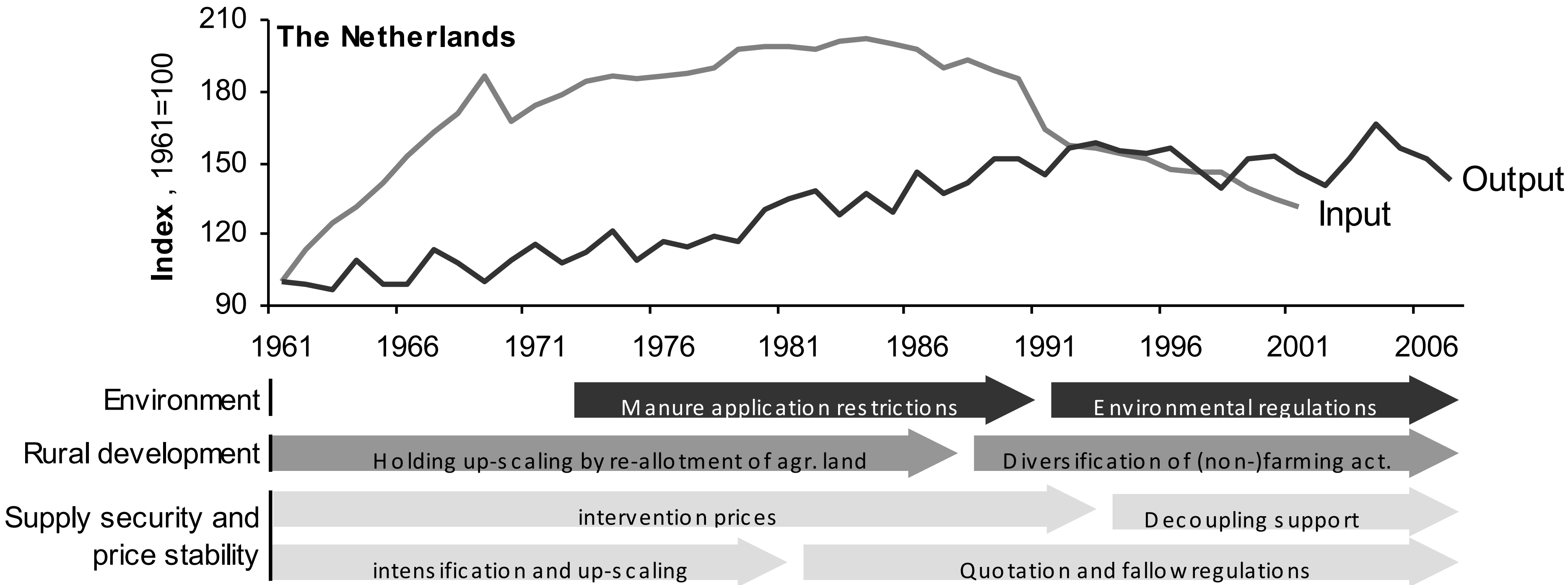
[Wit & Faaij, Biomass & Bioenergy, 2010]

Developments coupled to drivers

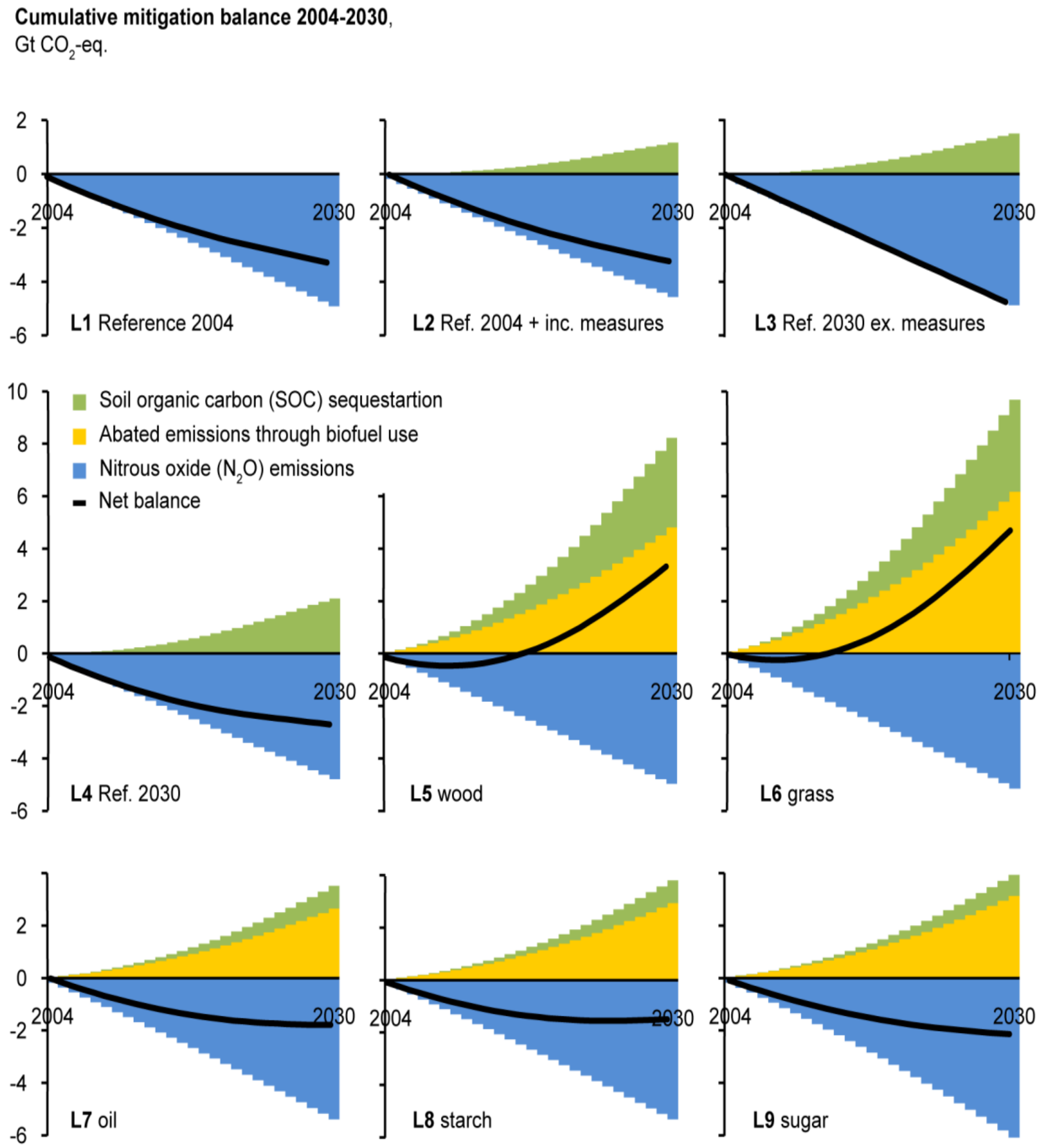
Example: the Netherlands

Inputs (fertilizer, machinery, labour and pesticides)

Outputs (wheat, sugarbeet, rapeseed and cattle)



[De Wit et al, RSER 2011]

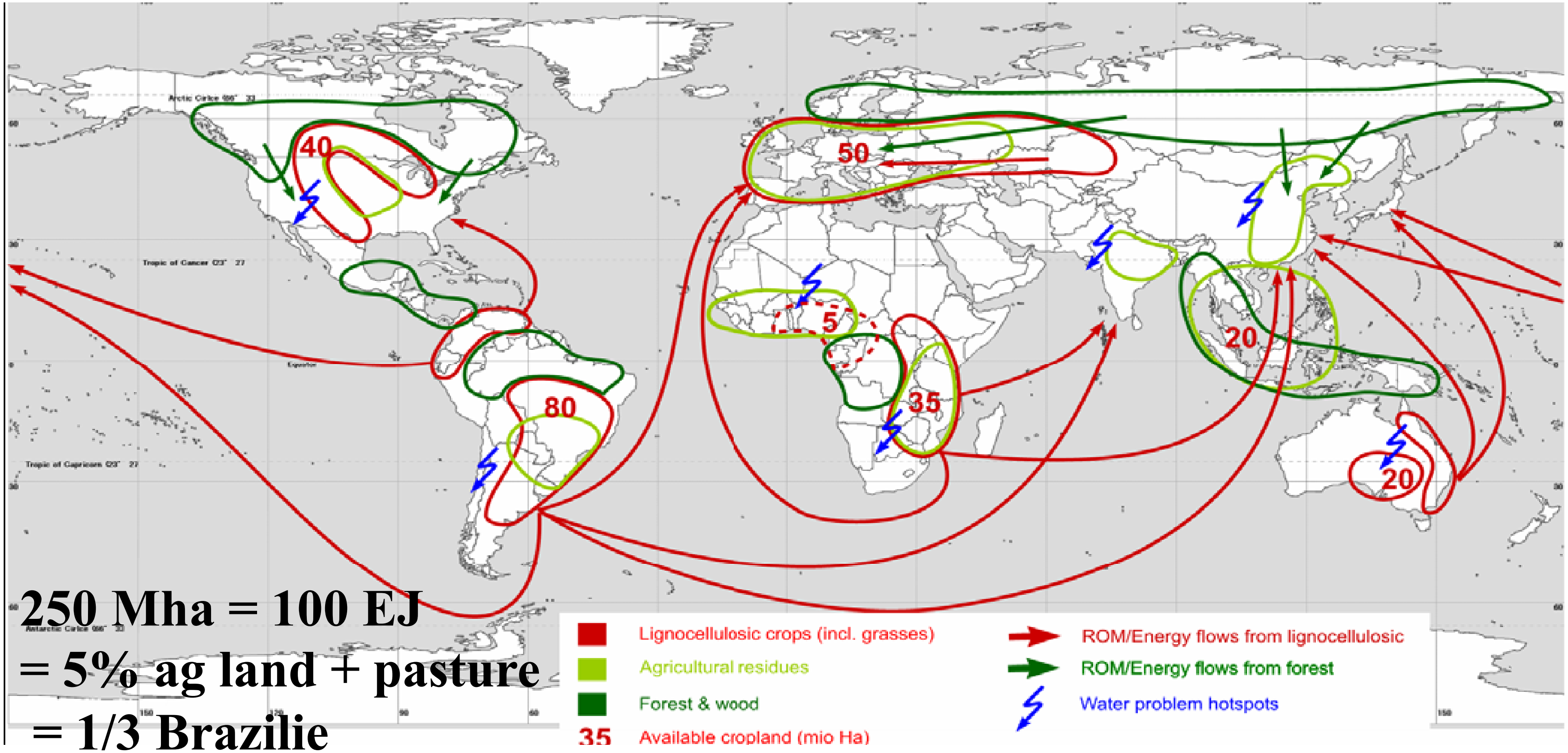


Universiteit Utrecht

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

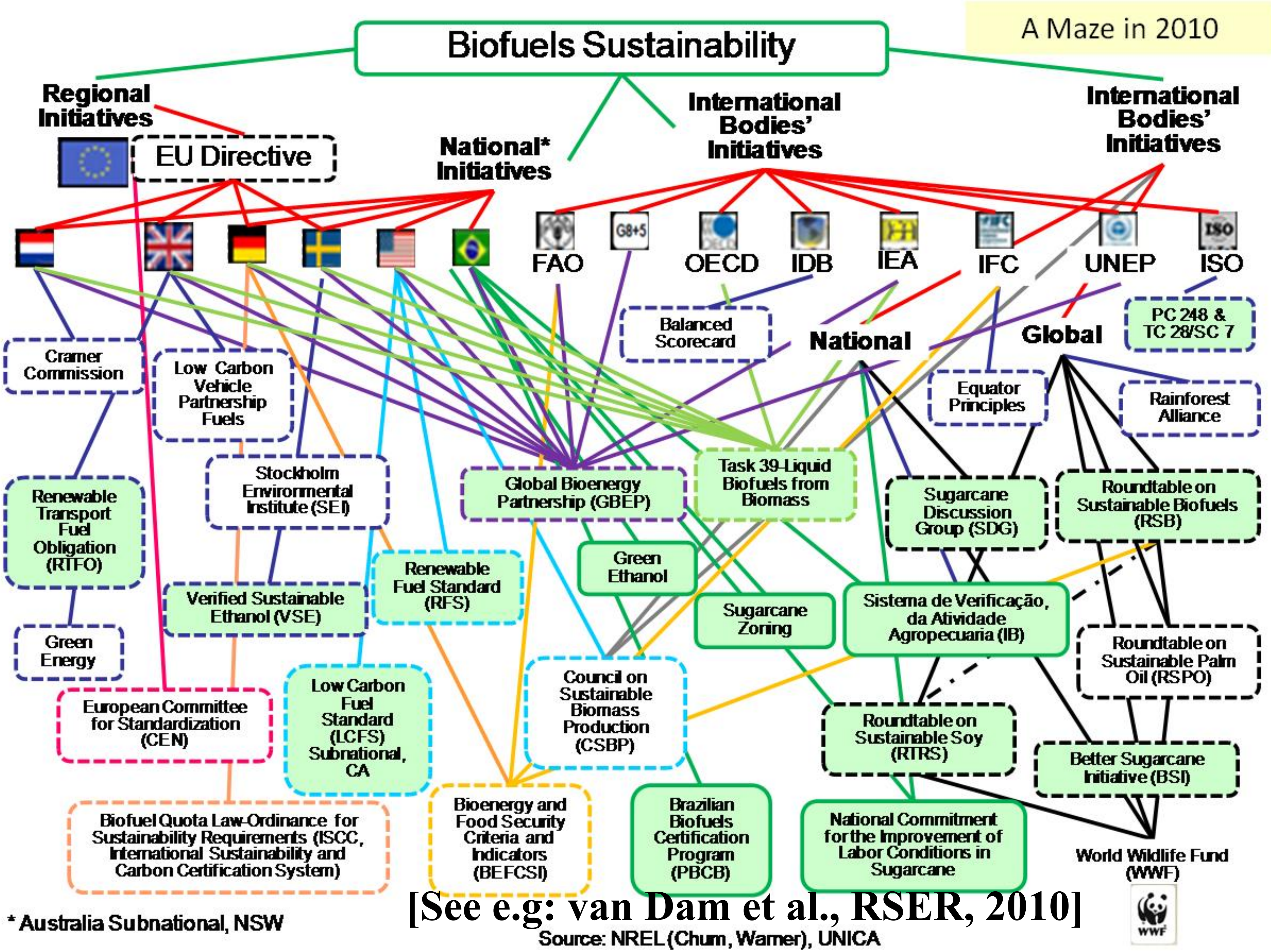
[Wit et al., GCB-B Under review]

A future vision on global bioenergy markets (2050…)



250 Mha = 100 EJ
= 5% ag land + pasture
= 1/3 Brazilie

[GIRACT FFF Scenario project; Faaij, 2008]



[See e.g: van Dam et al., RSER, 2010]

Source: NREL (Chum, Warner), UNICA

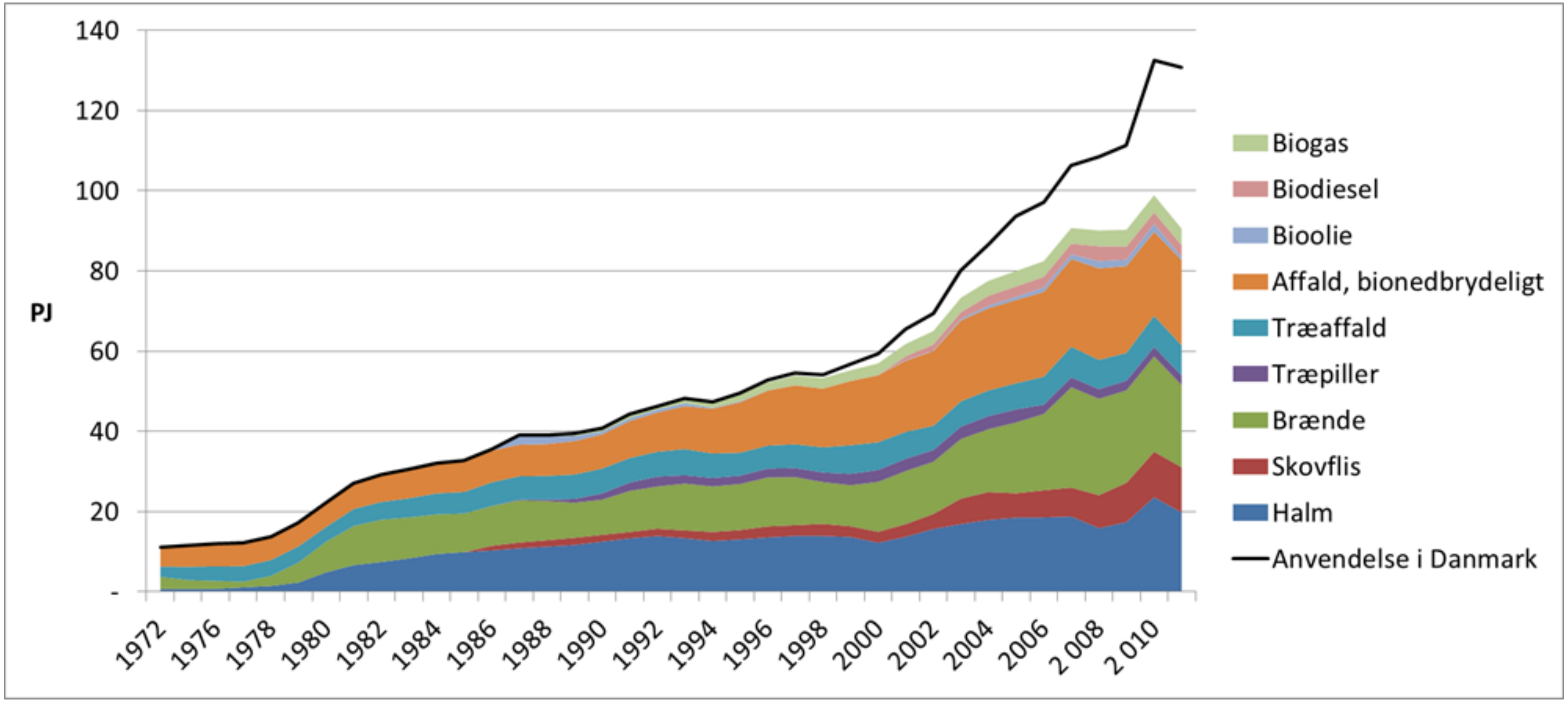
Biomasse i det fremtidige danske energisystem

Energiens Tingsted 2013

Anders Kofoed-Wiuff
Ea Energianalyse

Ea Energianalyse

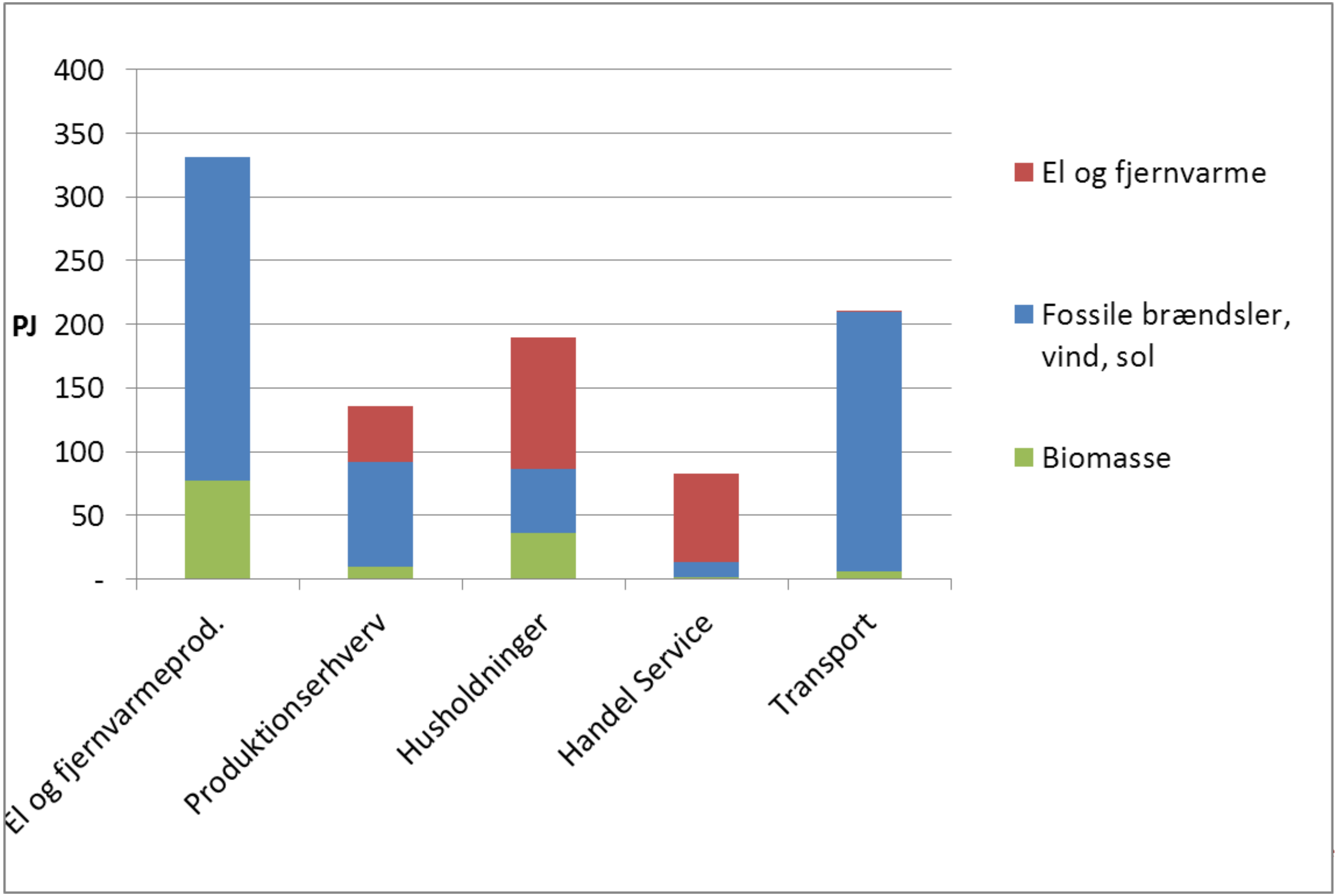
Udvikling i biomasseproduktion og anvendelse



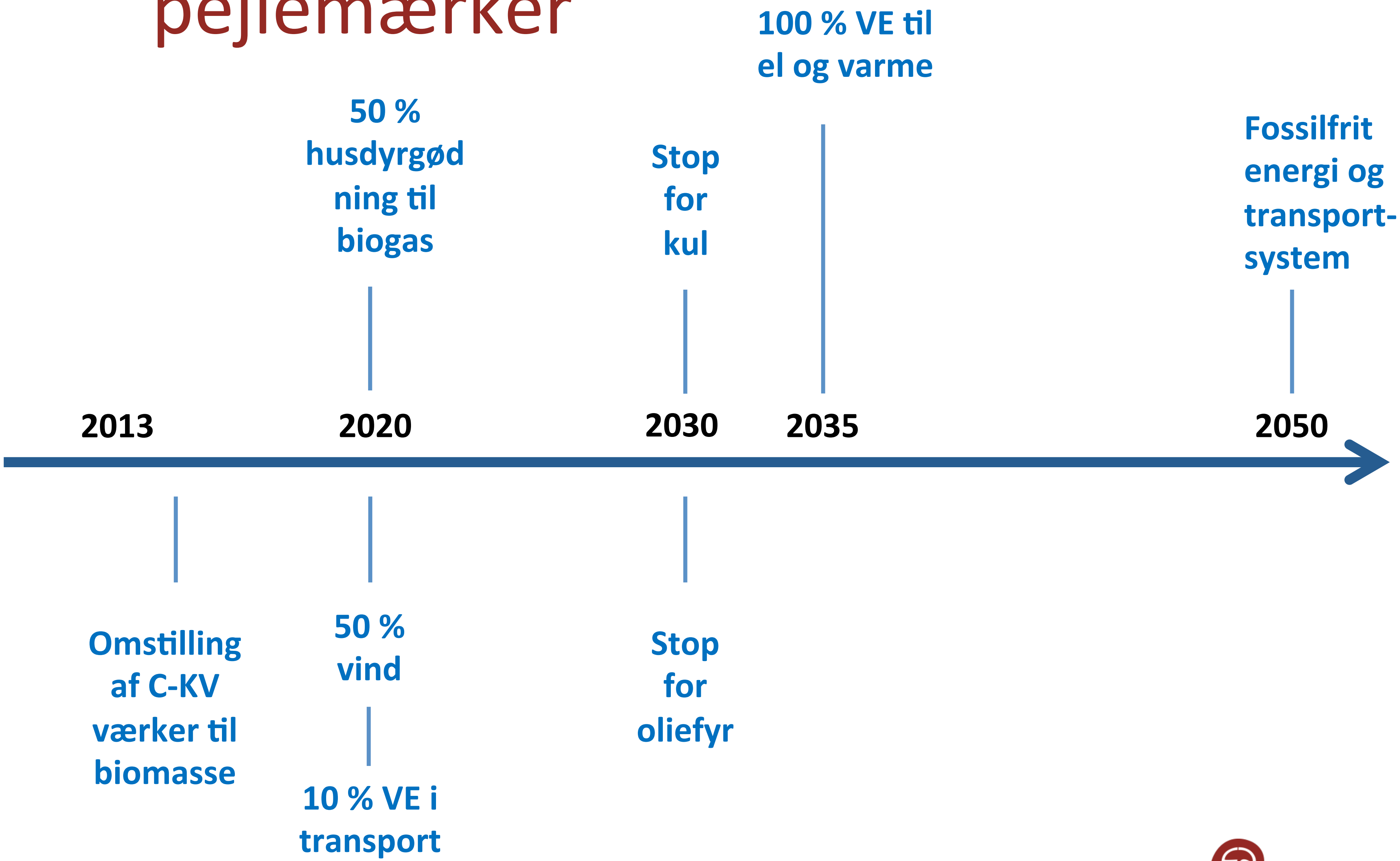
Import består af træpiller (hovedparten), træflis, brænde og biobrændstof

Ea Energianalyse

Hvor anvendes biomassen i dag?



Energipolitiske pejlemærker



Ea Energianalyse

Tabel 2.2 - Klimakommissionens seks reference- og fremtidsbilleder

	Ambitiøse rammebetingelser Lav oliepris Høj CO_2-kvotepris Høj biomassepris	**Uambitiøse rammebetingelser** Høj oliepris Lav CO_2-kvotepris Lav biomassepris
Reference	Ref. A	Ref. U
Fremtid med max. biomasseforbrug på 230 PJ/år	FB A1	FB U1
Fremtid med mulighed for ubegrænset biomasseforbrug	FB A2	FB U2

"For forløbet med den ambitiøse internationale klimapolitik er det antaget, at den internationale efterspørgsel efter biobrændsler vil stige væsentligt, med en flerdobling af prisen på biobrændsler til følge. Det er antaget, at priserne i 2050 når op på <u>et niveau svarende til prisen på de fossile brændsler inkl. CO2-omkostning</u>"

Fremtidens energisystem

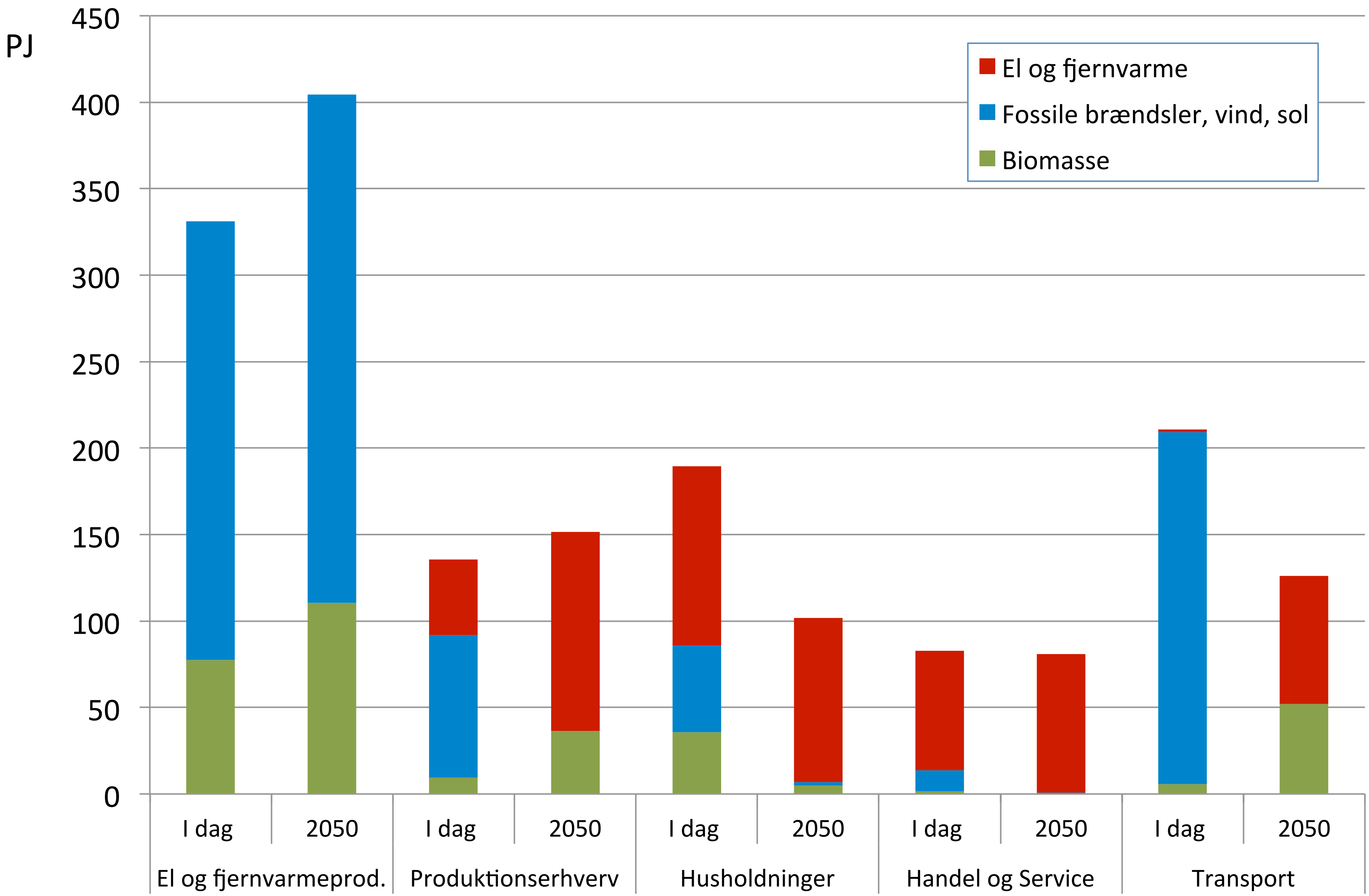
Forbrug

- Husholdningerne
  - Fjernvarme og varmepumper, **biomasse som hygge**
- Handel og service
  - Mest fjernvarme
- Industri
  - **Biomassekedler, grøn gas (KV?)**, elkedler, højtemperatur varmepumper
- Transport
  - El hvor det er muligt – ellers **biobrændstoffer, grøn gas**, brint?

Forsyning

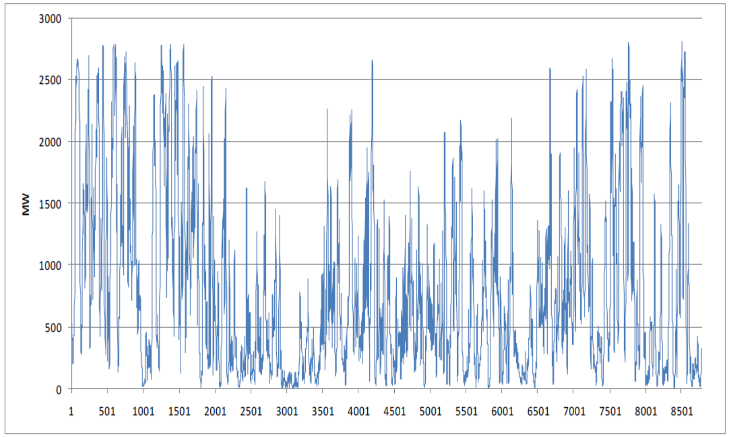
- Elproduktion:
  - Vindkraft med **biomasse/grøn gas som back-up**
- Fjernvarmeproduktion
  - **Overskudsvarme fra bio KV (også fra biobrændstoffabrikker)**, varmepumper, geotermi, sol

Hvor skal biomassen anvendes i 2050?



To hovedudfordringer i fremtidens fossilfri energisystem

- Integration vind
  - Sikre værdi af vinden, når det blæser meget
  - Sikre tilstrækkelig produktionskapacitet, når det ikke blæser.
  - Balancering af vindkraft



- Erstatning af olie i transportsektoren
  - Hvornår slår elbilen igennem?
  - Biomassebegrænsning?
  - Sikre høj effektivitet
  - Sikre fleksibilitet
    - samspil til vindkraft

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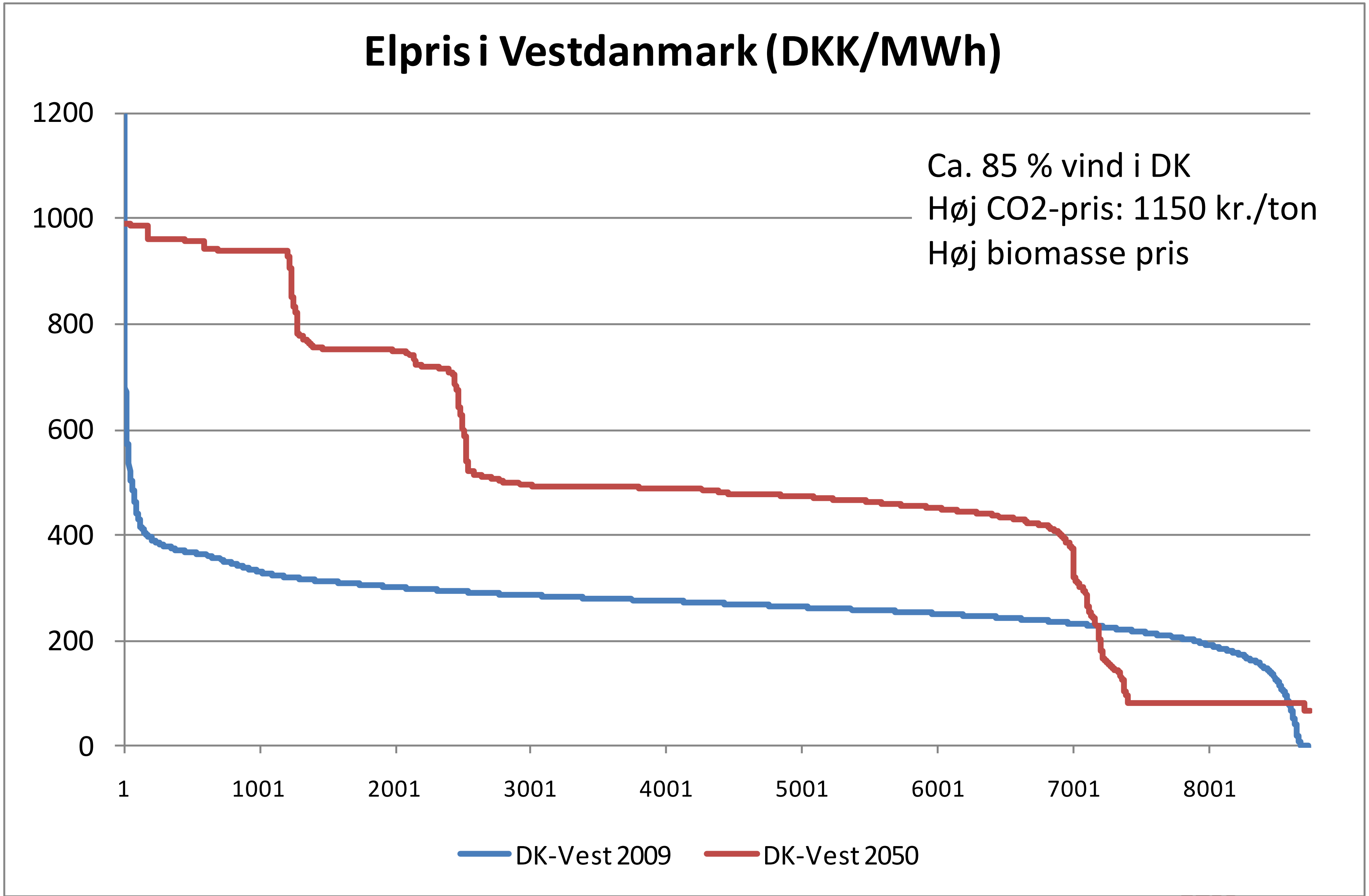
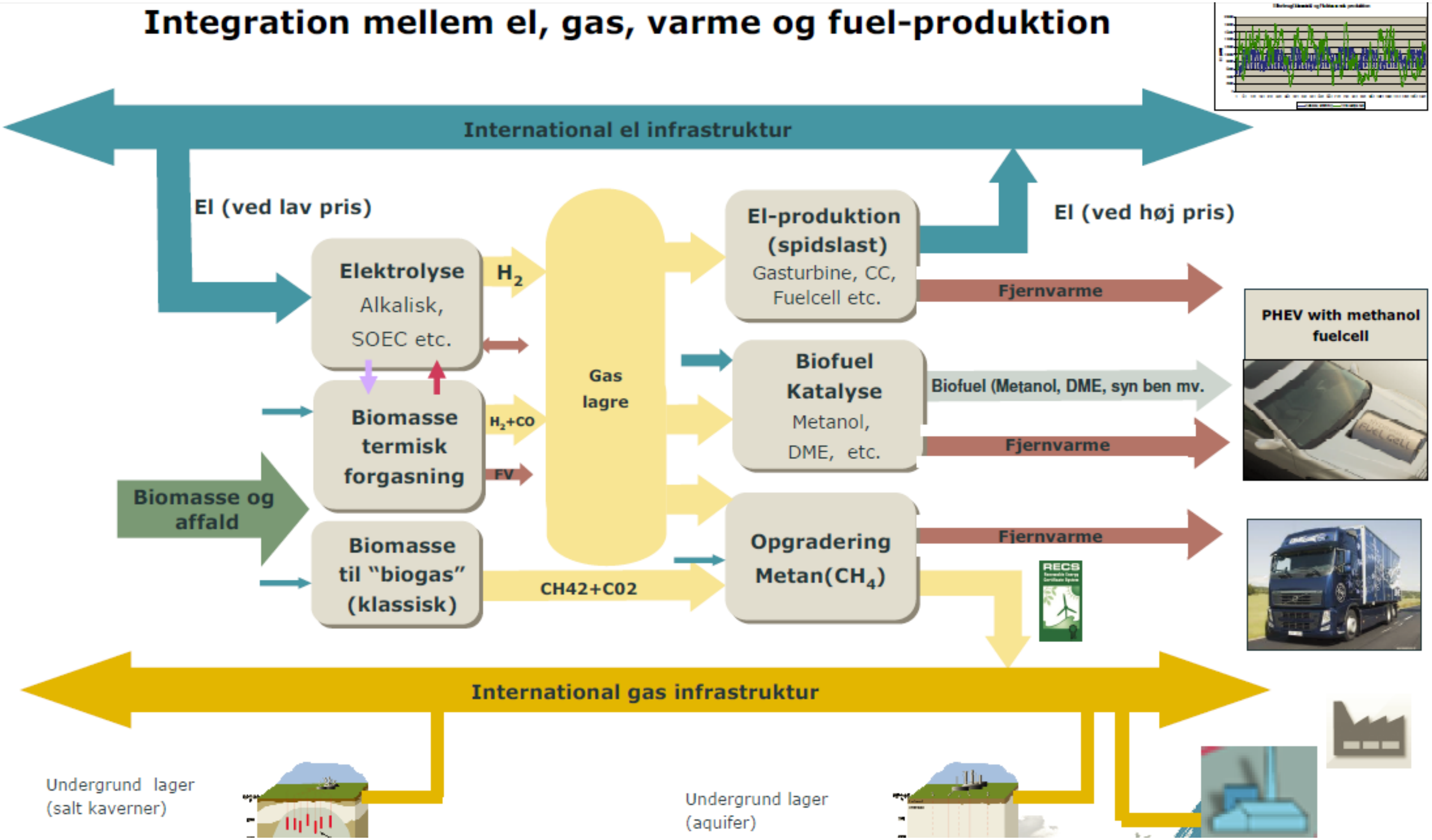
Bio til grundlast eller back-up?

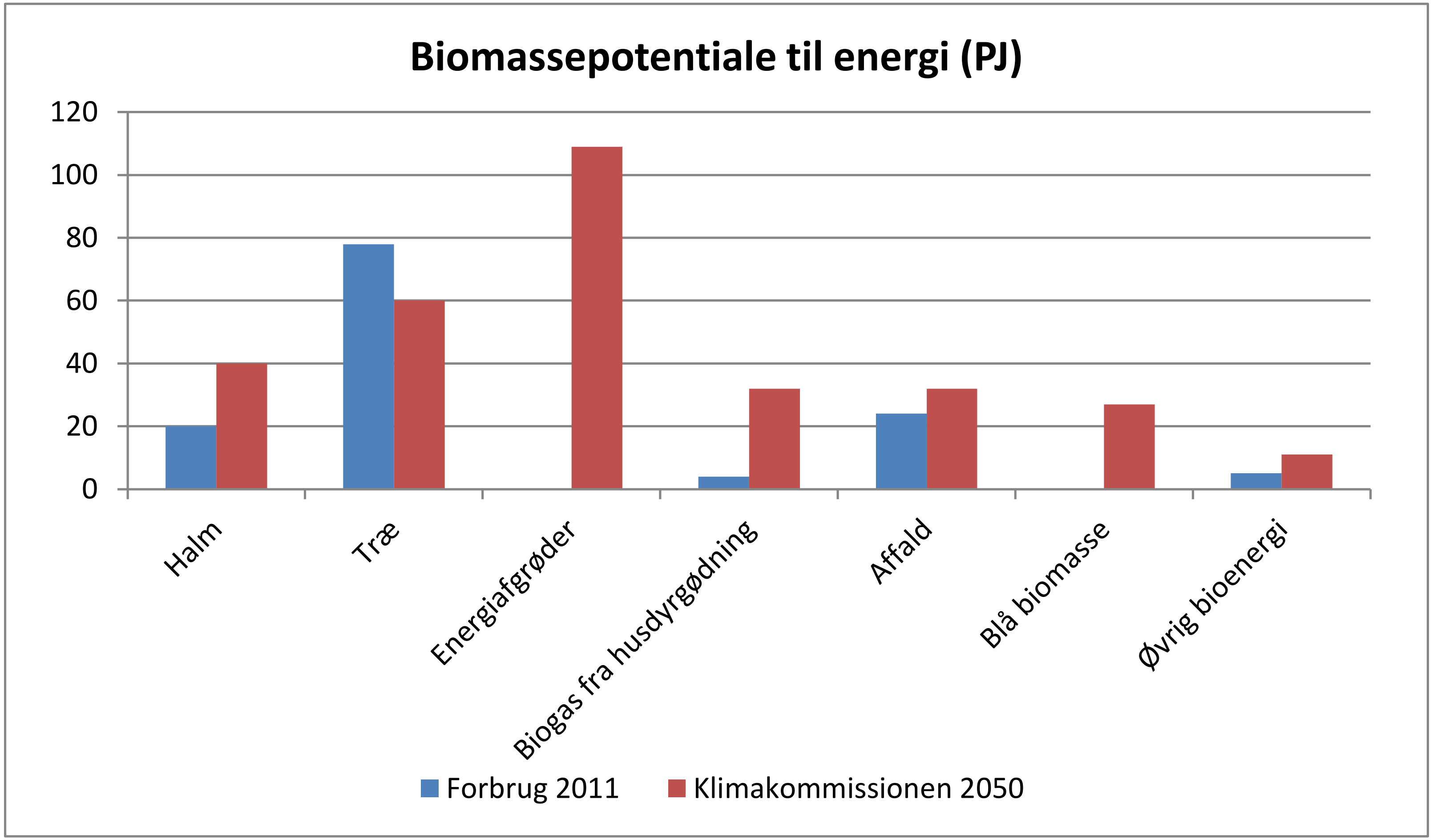


En ny rolle for gassysemet?



Kilde: Energinet.dk

Danske biomasseressourcer



I alt 200-310 PJ afhængigt af om energiafgrøder indgår.
I sommeren 2012 kom ”10 mio. tons planen” med tilsvarende resultater.

Fra 10 mio. ton rapporten

- ”Vi kan øge halmopsamlingen fra markerne med 15 % gennem let optimering af landmændenes høstudstyr.
- Skifte til mere halmrige kornsorter.
- Vi kan fordoble afgrødeproduktionen per hektar ved at lægge om til dyrkningssystemer med længere vækstsæsonen i form af flerårige afgrøder som pil eller græs eller dobbeltafgrøder.
- Vi kan reducere nitratudvaskningen fra landbruget markant ved at omlægge til mere miljøvenlige dyrkningssystemer som flerårige afgrøder, flere efterafgrøder og øget skovrejsning.
- Vi kan øge mobilisering af biomasse fra skovene.
- Vi kan øge væksten i skovene gennem forædling og øget anvendelse af hurtigtvoksende træarter.
- Vi kan høste biomasse fra ca. 70.000 ha engarealer, og samtidig skabe øget biodiversitet ved at de ikke gror til i brændenælder og pil. Samtidig kan man fjerne biomasse og næringsstoffer fra ca. 7.000 ha vejrabatter så der opnås en mere varieret flora.
- Vi kan forbedre udnyttelse af gylle fra den animalske produktion.”

Hovedspørgsmål

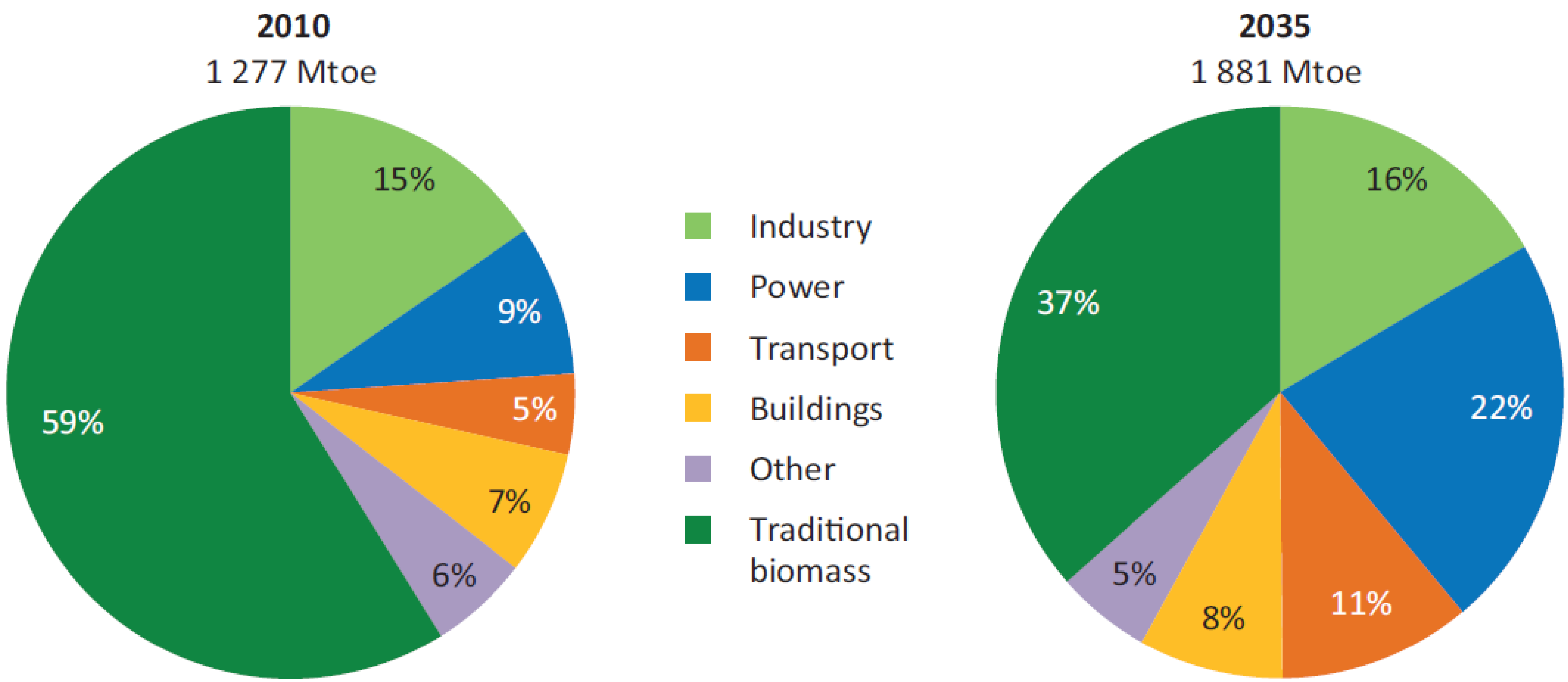
- Hvornår bør biomasseanvendelsen i den danske **el- og varmeforsyning** toppe og på hvilket niveau?
  - Bio som grundlast eller back-up? Fast biomasse eller gas?
  - Varmepumper kan være en energieffektiv varmeleverandør – men kun hvis elektriciteten er produceret på vind, sol eller på kraftvarme.
  - Skal biomassen prioriteres de centrale eller decentrale kraftværker?
- Hvordan anvendes biomasse bedst i **transportsektoren**?
  - Flydende eller gas? Hvordan sikres, at teknologiudviklingen fortsat sker i Danmark?
- Hvordan kan man reducere anvendelsen af fossile brændsler i **produktionserhvervene**, og hvilken rolle kan biomasse spille?
  - Ny stor aftager af biogas?
- Skal Danmark samlet set være importør eller eksportør af **biomasseresurser**?
  - Hvordan kombineres stor bioproduktion og naturhensyn – både i skov og landbrug?

EKSTRA

Udvikling i biomassemarkedet

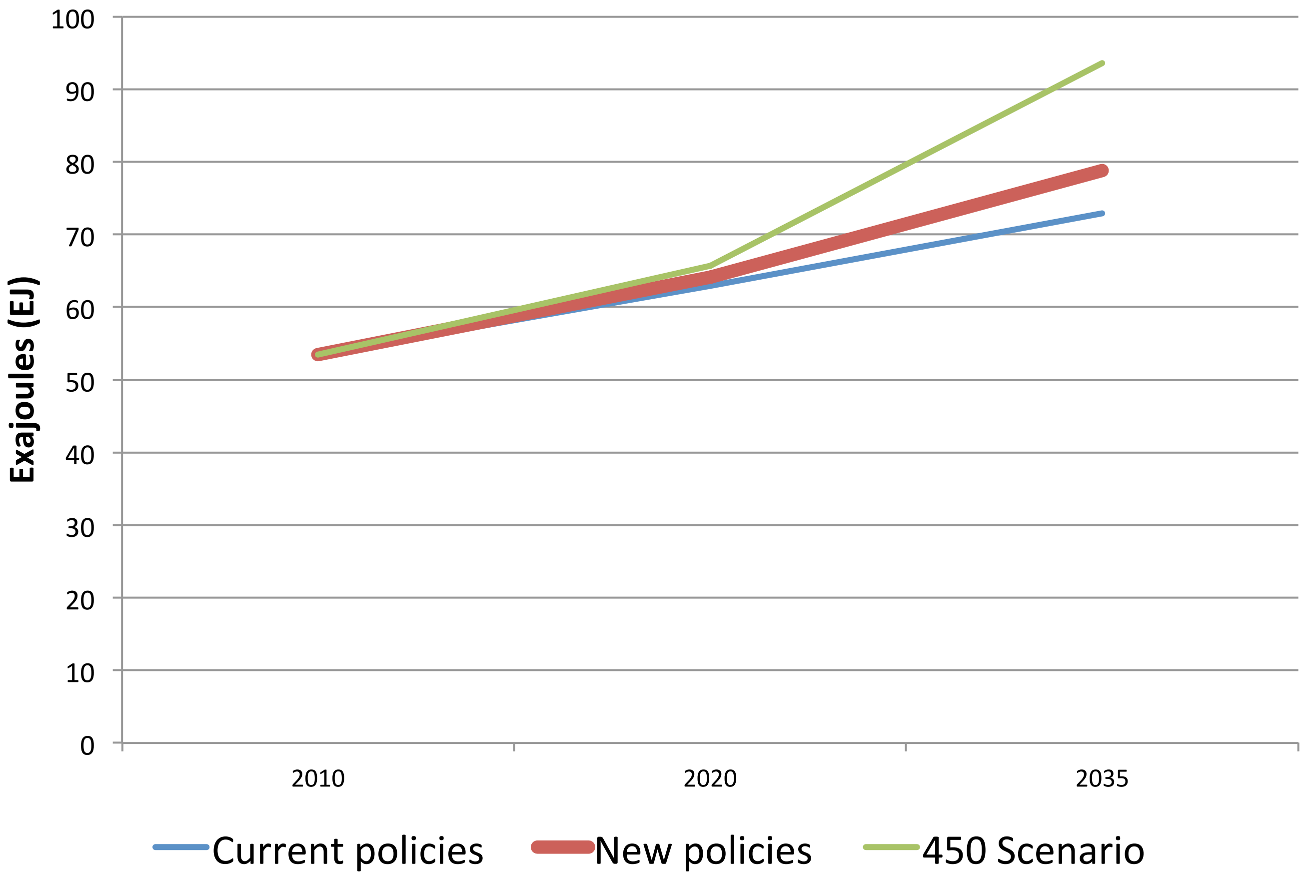
IEA's World Energy Outlook 2012

Figure 7.3 ▷ World bioenergy use by sector and use of traditional biomass in the New Policies Scenario, 2010 and 2035



Verdens forbrug af biomasse til energi stiger fra ca. 50 EJ til ca. 75 EJ i 2035

WEO – Bioenergy scenarios



Ea Energianalyse

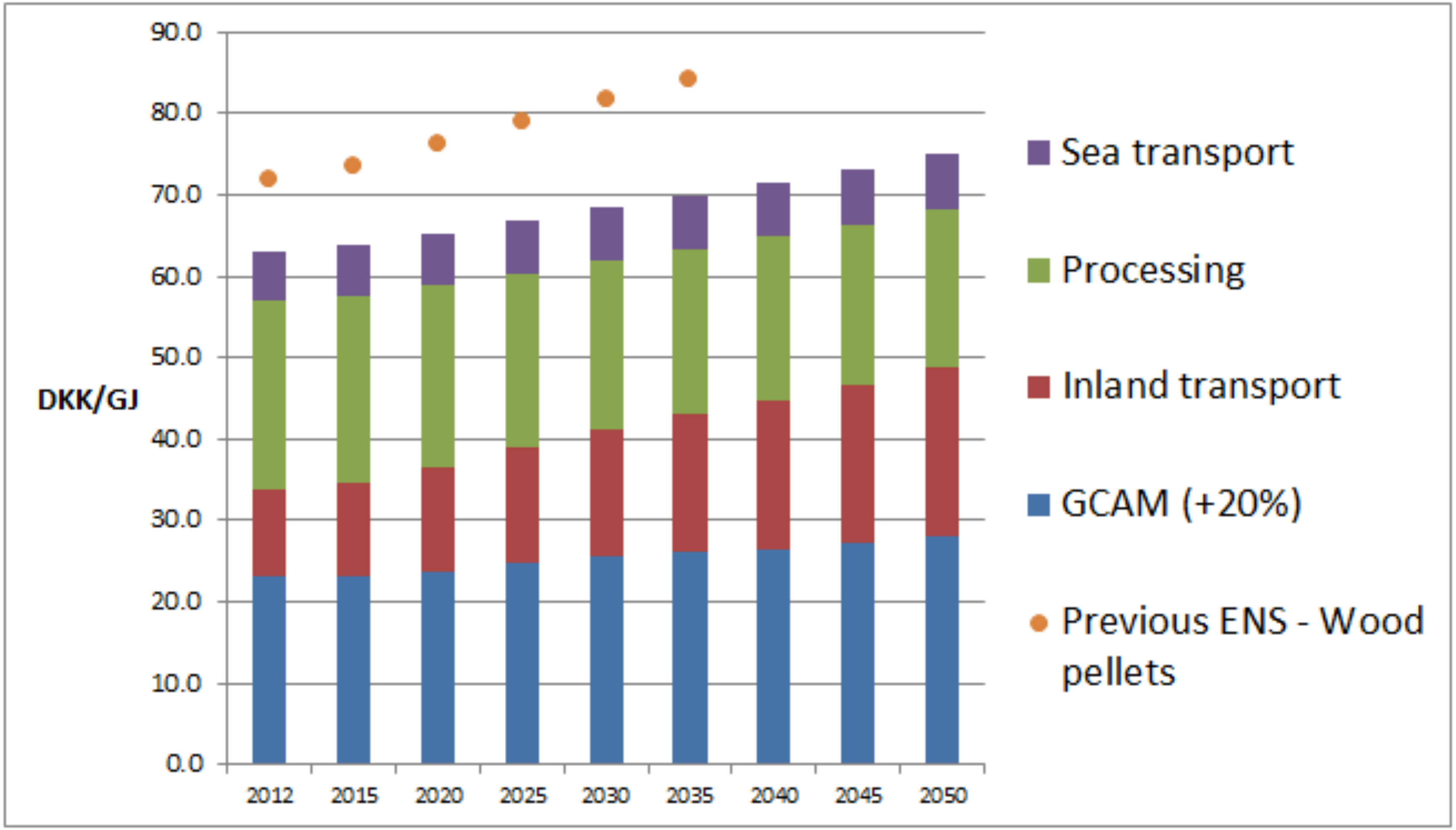
Biomass for energy

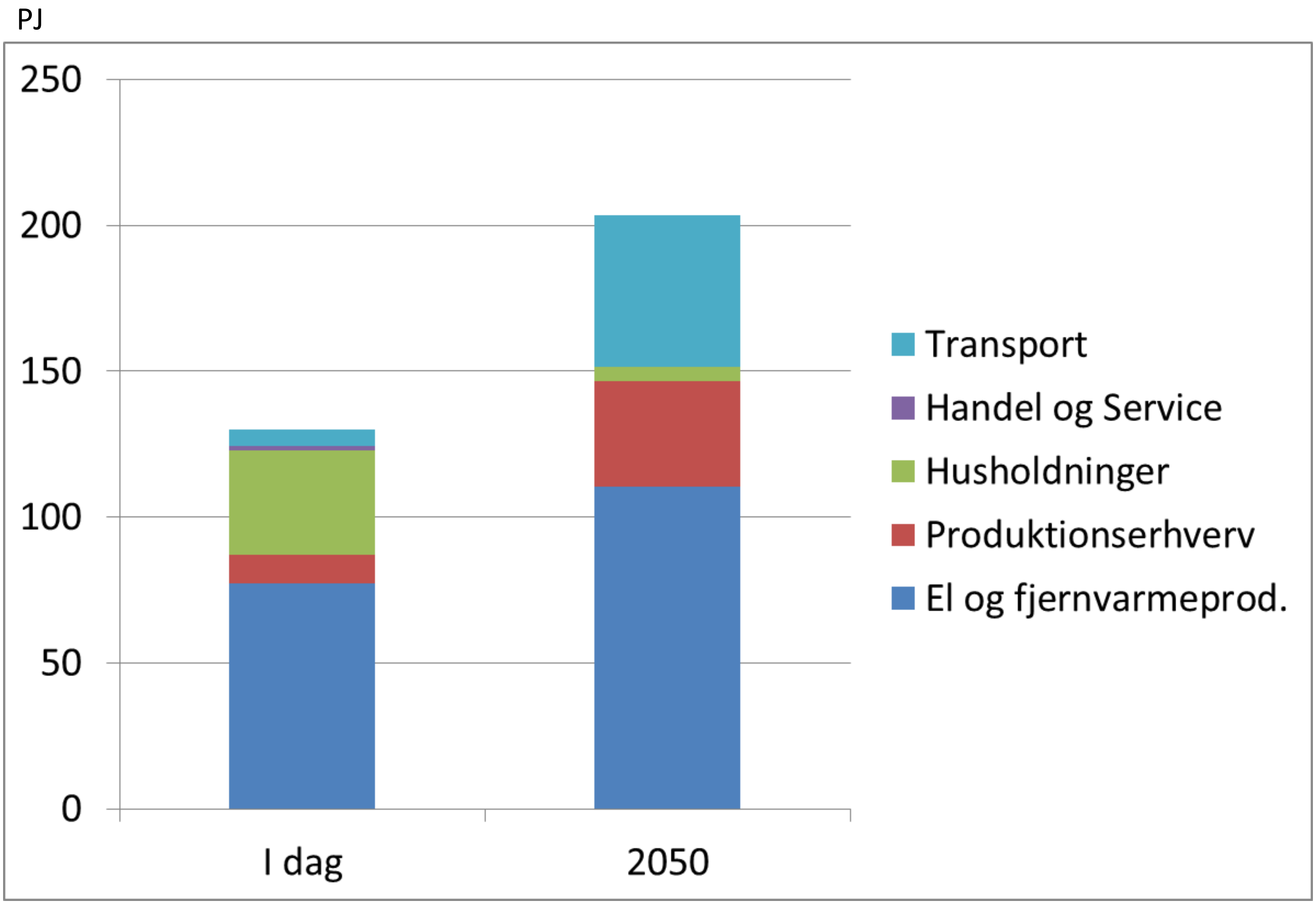
Review of 28 studies, UKERC 2011

Potential for energy 2050	Assumptions
600 – 1.200 EJ/year	Global yield to outpace demand. > 2,5 Gha energy crops. Global population < 9 bio Low meat diet or conversion of unmanaged land and forest. Use of residues.
300-600 EJ/year	Global yield to outpace demand. >1.5Gha enery crops Low population growth ***or*** low meat diet ***or*** conversion of unmanaged land. Use of residues.
100-300 EJ/year	Global yield to balance demand. < 0.5Gha for energy crops, mostly marginal land. Low population growth ***or*** low meat diet ***or*** conversion of unmanaged land. Low utilization of residues.
0 -100 EJ/year	No or low use of energy crops. High meat diet or ex-tensive agriculture (low yields). No growth in managed land. Low utilization of residues.

Wood pellet price projection

CIF Denmark




PJ
250
200
150
100
50
0
I dag
2050
Transport
Handel og Service
Husholdninger
Produktionserhverv
El og fjernvarmeprod.