rijksuniversiteit groningen

New Energy Coalition

Outlook biobased economy

Expertsessie biomassa Metropoolregio Amsterdam,
Hoofddorp, 29 Oktober 2018

Prof. Dr. André Faaij, Distinguished Professor Energy System Analysis & Chief Scientist NEC

De menukaart (50 slides):

- Nederlandse biomassa (vooral afval en residuen.
- Biomassa benutting (en vraag) in Nederland.
- Import: Beschikbaarheid Europese biomassa (en duurzaamheid).
- Import: beschikbaarheid biomassa mondiaal (integrale scenario's).
- Biomassa uit (productie)bos en GHG balansen.

New government agreement…

Tabel: Indicatieve toedeling 49%-reductieopgave in 2030		
Domein	**Reductie in 2030 (Mton)**	**Maatregelen**
Industrie	1	Recycling
	3	Procesefficiency
	18	Afvang en opslag koolstofdioxide
Transport	1,5	Zuiniger banden, Europese normen, elektrische auto's
	2	Biobrandstoffen en maatregelen steden
Gebouwde omgeving	3	Optimalisatie energiegebruik kantoren
	2	Isolatie woningen, warmtenetten en warmtepompen
	2	Zuiniger nieuwbouw
Elektriciteit	1	Zuiniger verlichting
	12	Sluiten kolencentrales
	2	Afvang en opslag koolstofdioxide in AVI's
	4	Extra wind op zee
	1	Extra zonne-energie
Landgebruik en landbouw	1,5	Slimmer landgebruik
	1	Minder methaanuitstoot
	1	Kas als energiebron

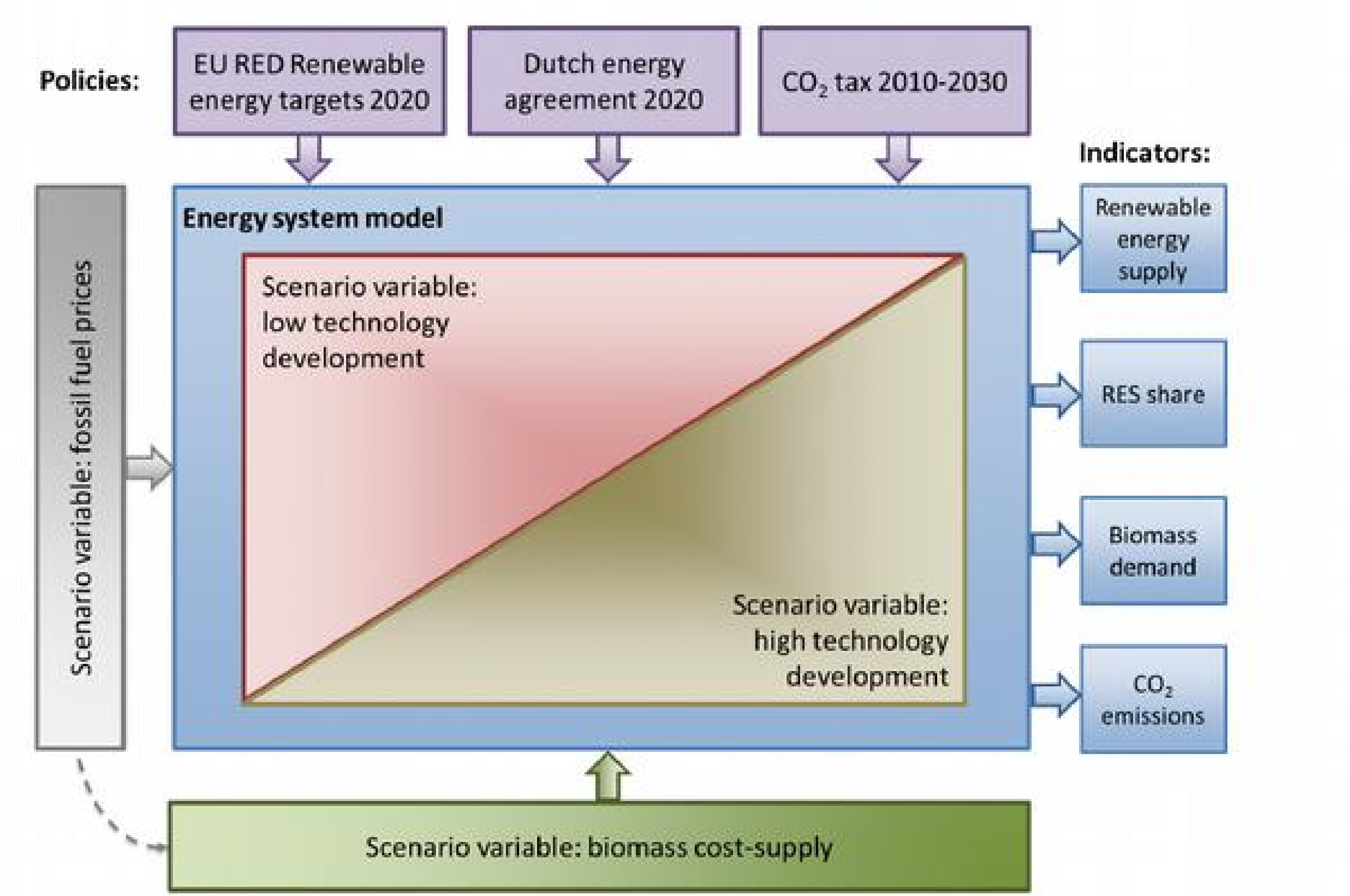
NL RE targets: RED: 2020: 14%

Indicative Contribution of R.E. options (in PJ).

Source	2013	2020	2023
Wind on off-shore	3,1	27,0	60,0
Wind on -shore	20,6	54,0	63,0
Solar PV	0,9	11,6	12,4
Cofiring	6,1	25,0	25,0
Waste Incineration	13,3	11,7	12,0
Biomass CHP	3,5	13,6	18,0
Biomass Heat	19,0	31,6	34,1
Biofuels	18,0	35,6	34,6
Renewable Heat	6,1	36,3	46,3
TOTAL	105,5	261,6	335,4
Percentage R.E.	4,4%	14%	16%

Compared to 2013:
- Doubling the amount of biomass in 6 years
- Tripling wind on-shore
- 20 fold wind off-shore (equal shares).

Basic design modelling framework (MARKAL-UU-NL) to analyses biomass deployment in the Netherlands on medium term [Tsiropoulos et al., 2018]



Technology and biomass utilisation options for progressive and conservative futures [Tsiropolous et al., 2018]

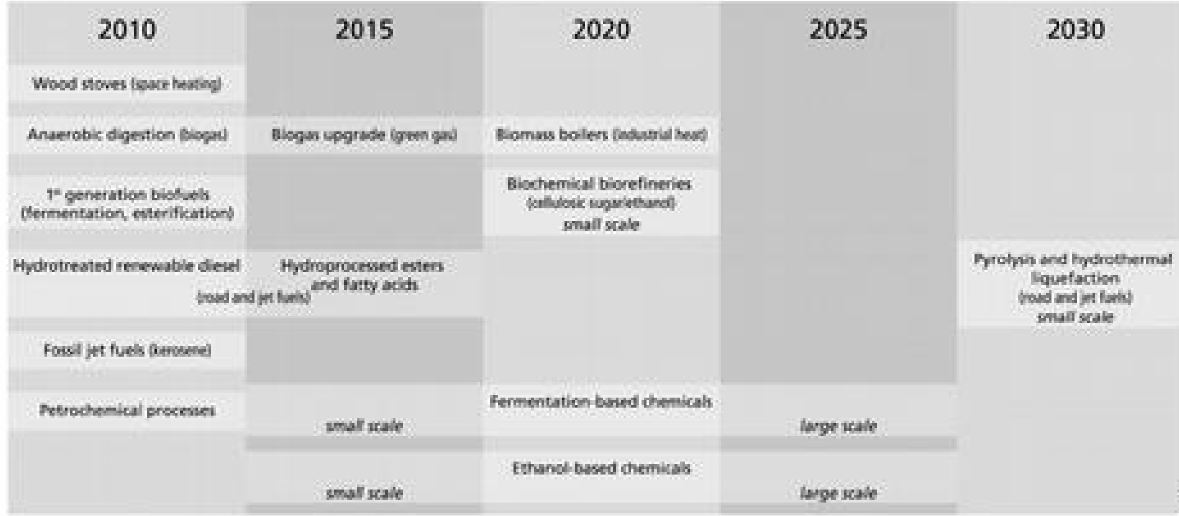


Figure 4.4 Low technology development scenario (LowTech) for conversion technologies added in MARKAL-NL-UU

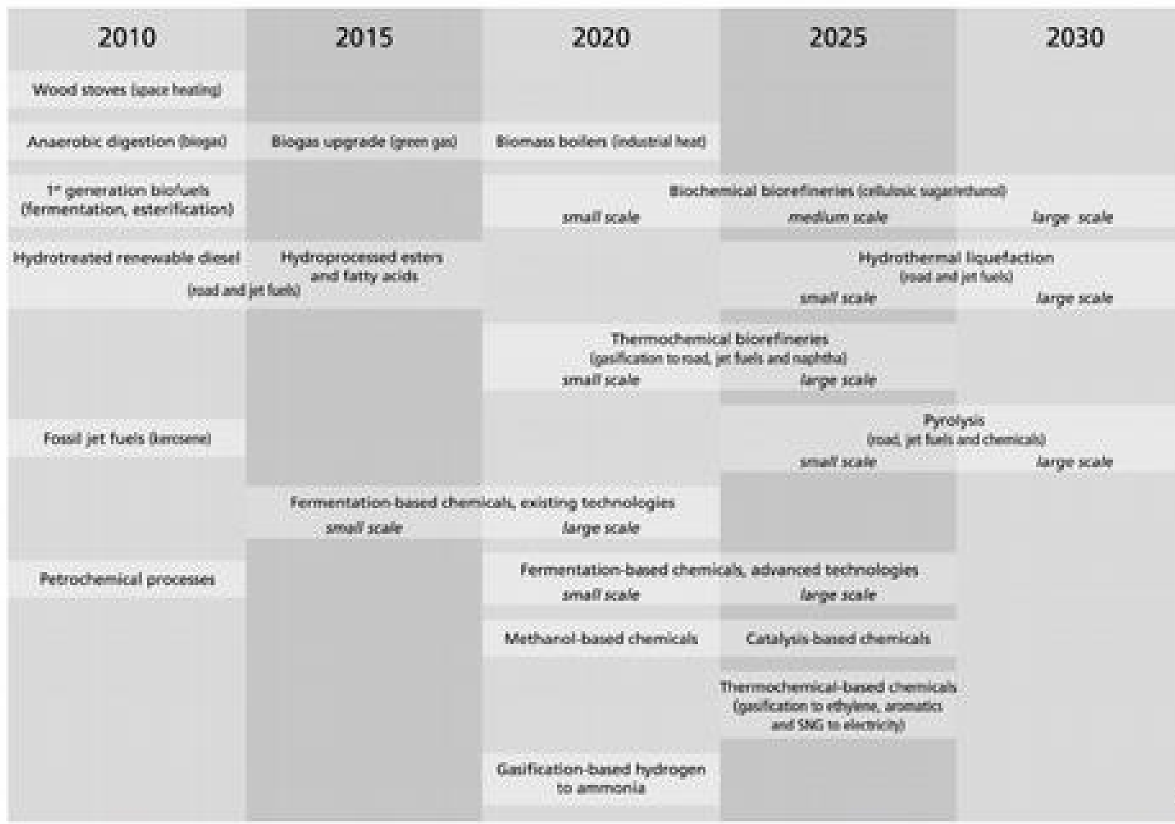


Figure 4.5 High technology development scenario (HighTech) for conversion technologies added in MARKAL-NL-UU

Available domestic and imported biomass potential in MARKAL-NL-UU for the Netherlands (NL) in 2010-2030 (rounded figures) [Tsiropoulos et al., 2018]

[PJ]	2010		2020		2030	
	NL	EU	NL	EU	NL	EU
Crops	2	32	13	89	22	101
Crop residues	8	52	7	50	7	51
Wood crops	0	0	1	15	2	16
Forestry products and residues[a]	46	235	52	235	59	254
Waste domestic	88		80		83	
Used cooking oil EU		5		5		5
Extra-EU imports solid biomass			400			
Extra-EU imports liquid biomass			50			
Total domestic	144		153		172	
Total import	772		843		878	

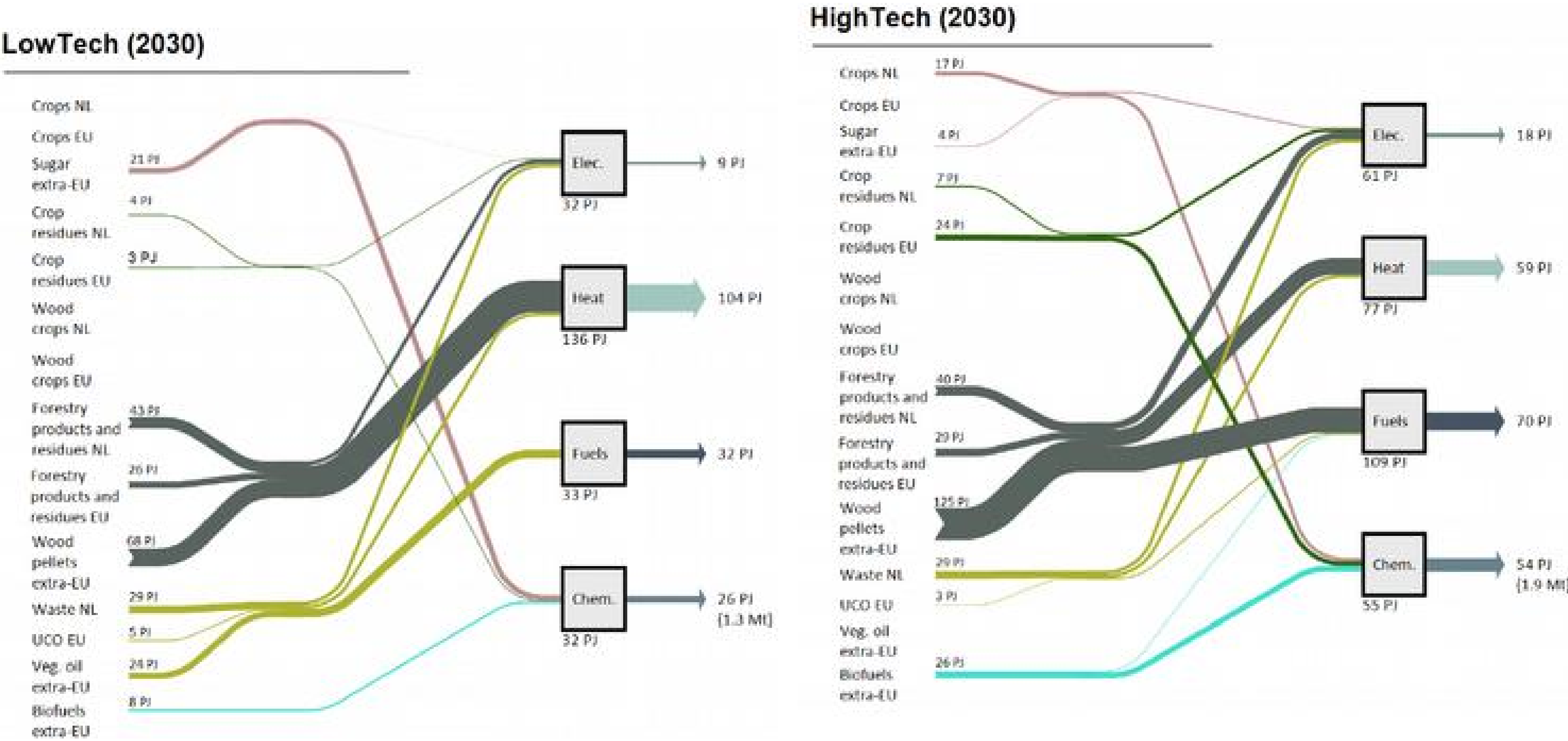
[a]Fuelwood for wood stoves is added ad hoc to the total domestic potential. It is 15, 18, and 20 PJ for 2010, 2020 and 2030, respectively, and is reported under forestry products and residues.

Inventory of biomass residue and waste streams in the Netherlands (excluding cropping options) [Dornburg et al., 2000]

Availability of biomass and waste streams within scenario-analyses for The Netherlands

Biomass and waste[a]	Cost (€/tonnes)	LHV[b] (GJ/tonnes)	Amount 'business as usual' (ktonnes)	Amount waste availability scenario (ktonnes)
Biomass				
Wood from fruit farming.	0	10.2	294	294
Thinning, pruning	0	10.2	1700	1700
Straw	100	13.5	723	723
Hemp	0	11.3	5	5
Hay	64	12.7	138	138
Bulb cultivation	0	5.0	75	75
Greenhouse waste	0	2.0	100	100
Chicken manure	0	6.6	2461	2461
Verge grass	0	5.0	468	468
Food and beverage industry	14	2.7	9564	9564
Swill	0	2.0	216	216
Clean wood rests	0	15.6	600	600
Combustible waste[c]				
Waste wood	11	15.4	1005	1390
Organic domestic waste	0	4.0	2655	2222
MSW	0	7.1	8097	12755
Plastic	0	34.4	426	629
Paper/cardboard	0	10.0	4119	4244
Shredded car wrecks	0	15.7	143	143
Sweepings	0	7.5	437	230
Tyres	0	36.0	103	103
Sewage sludge (25% ds)[d]	0	1.5	1604	1604
Non-combustibles				
Ferro	0	0	1202	1723
Non-Ferro	0	0	176	266
Glass	0	0	690	704
Stone, sand, etc.	0	0	10627	18852
Inert sweeping parts	0	0	706	770
Total			48334 (≅237 PJ)	61979 (≅284 PJ)

Biomass supply & demand NL ~ 2030 for ''low tech'' and ''high tech'' futures [Tsiropoulos, 2018]



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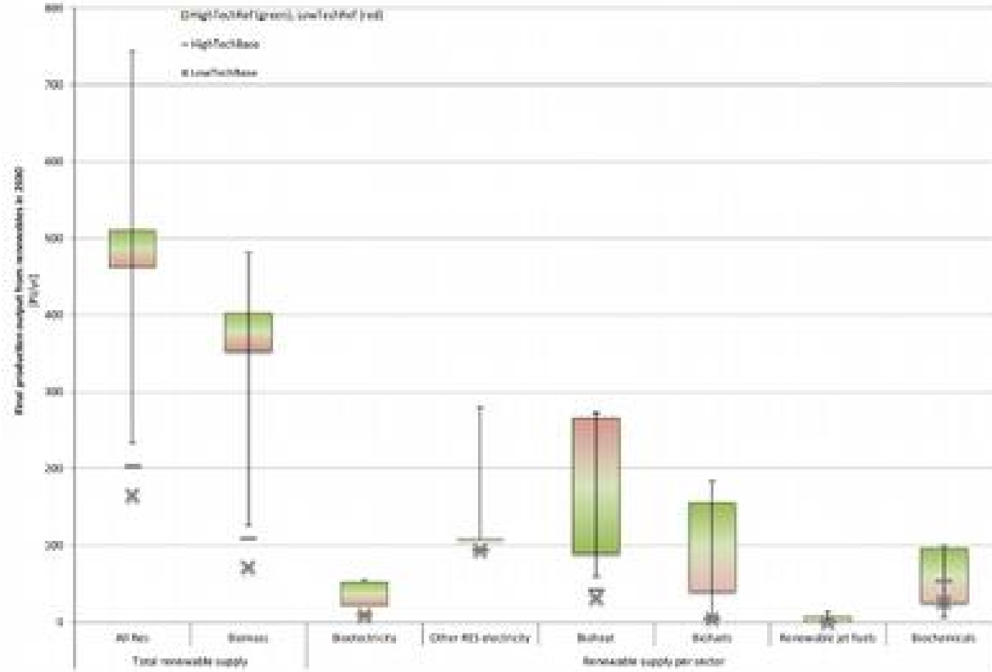
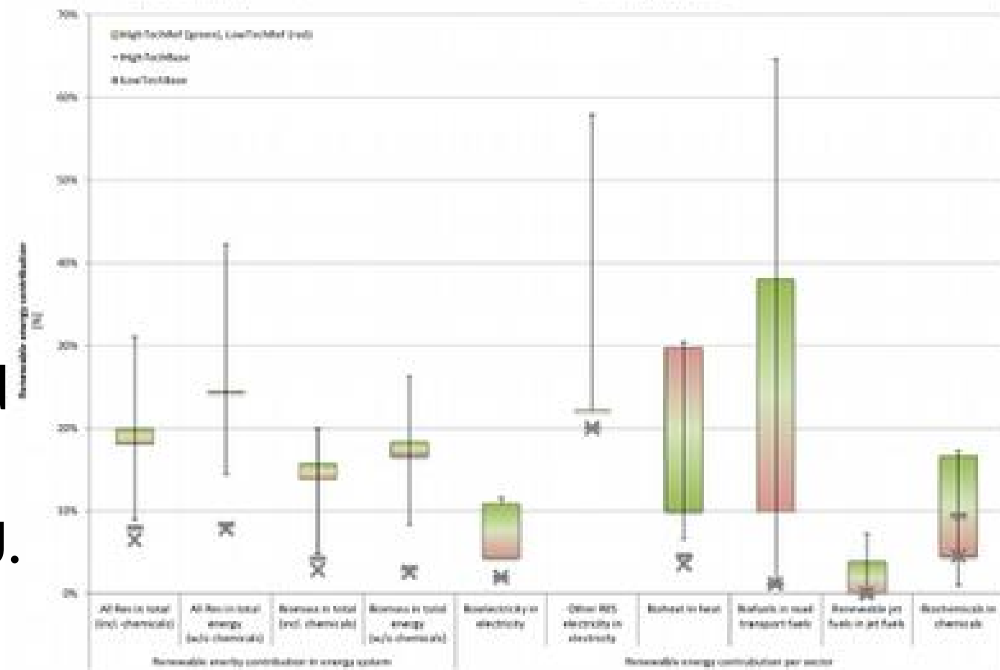
energy valley
GasTerra
ebn

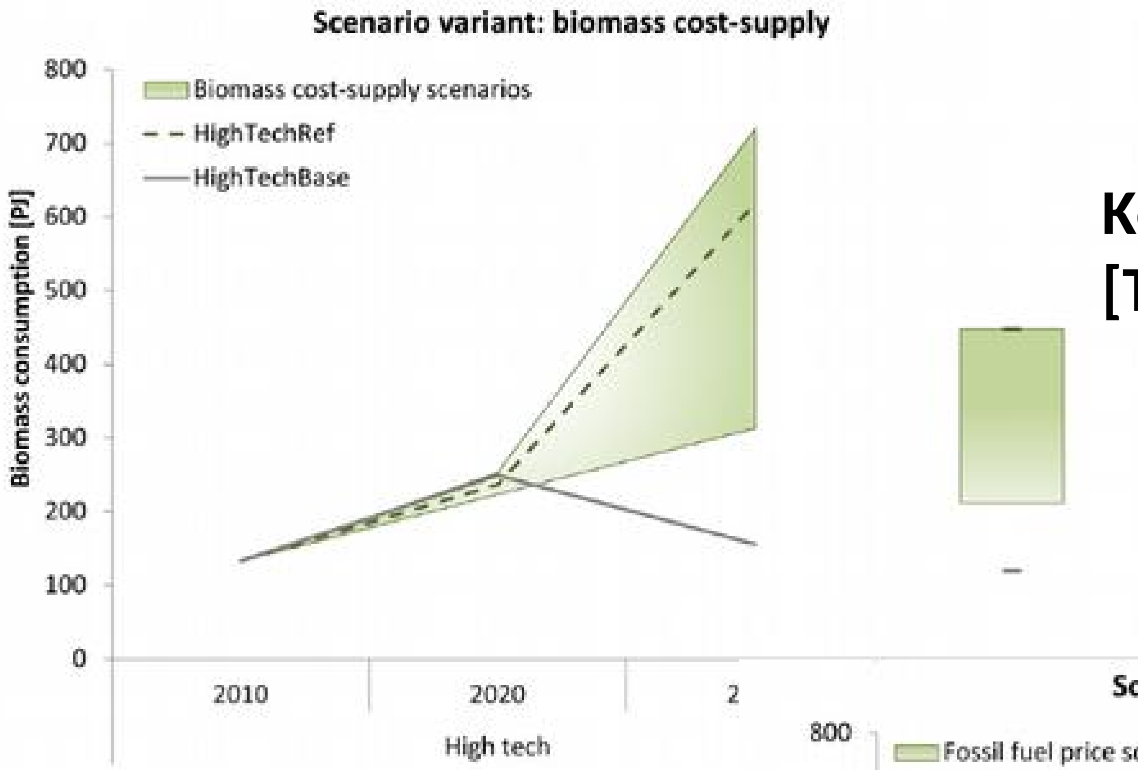
Scenario analyses on possible ranges biomass use for different markets [Tsiropoulos et al., 2018]

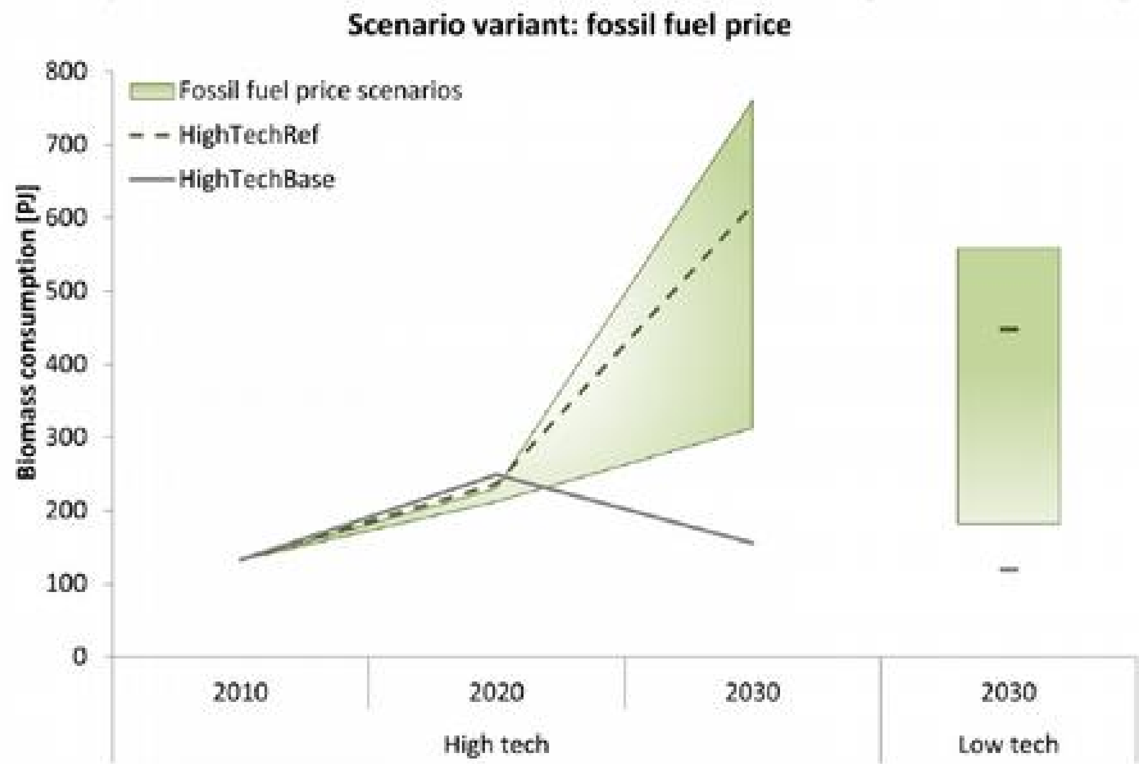




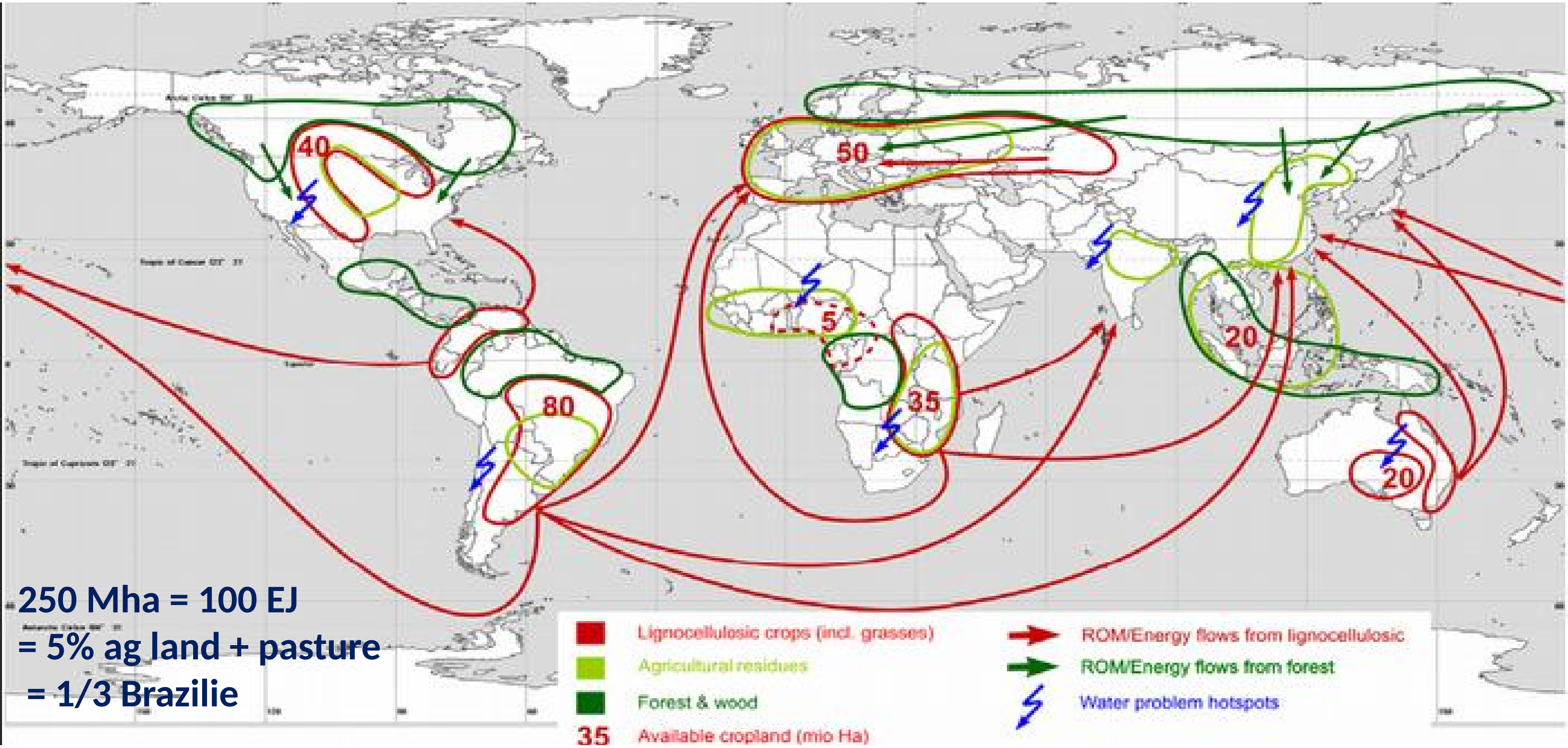
Preliminary biomass demand 2030 following from the ‘’Klimaattafels’’: ~ 400 PJ.

Key sensitivities [Tsiropoulos et al., 2018]





A future vision on global bioenergy markets (2050…)



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

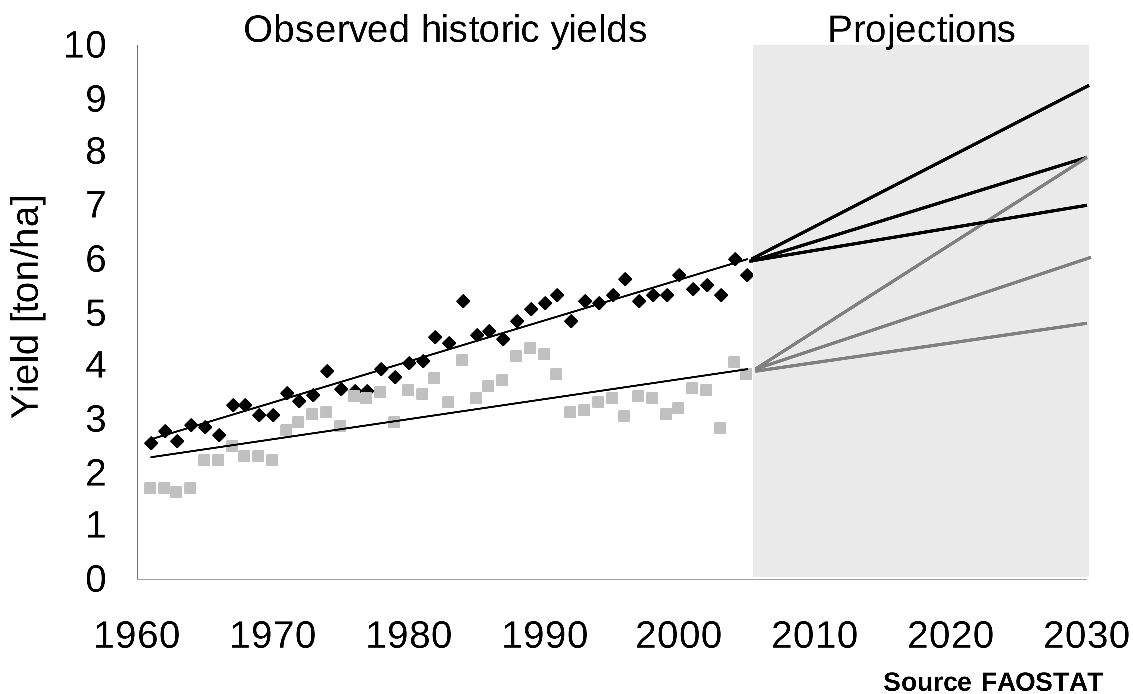
[GIRACT FFF Scenario project; Faaij, 2008]

Yield projections Europe

Observed yield
- CEEC and WEC

Linear extrapolation of historic trends
- Widening yield gap

Applied scenarios
- Low, baseline and high

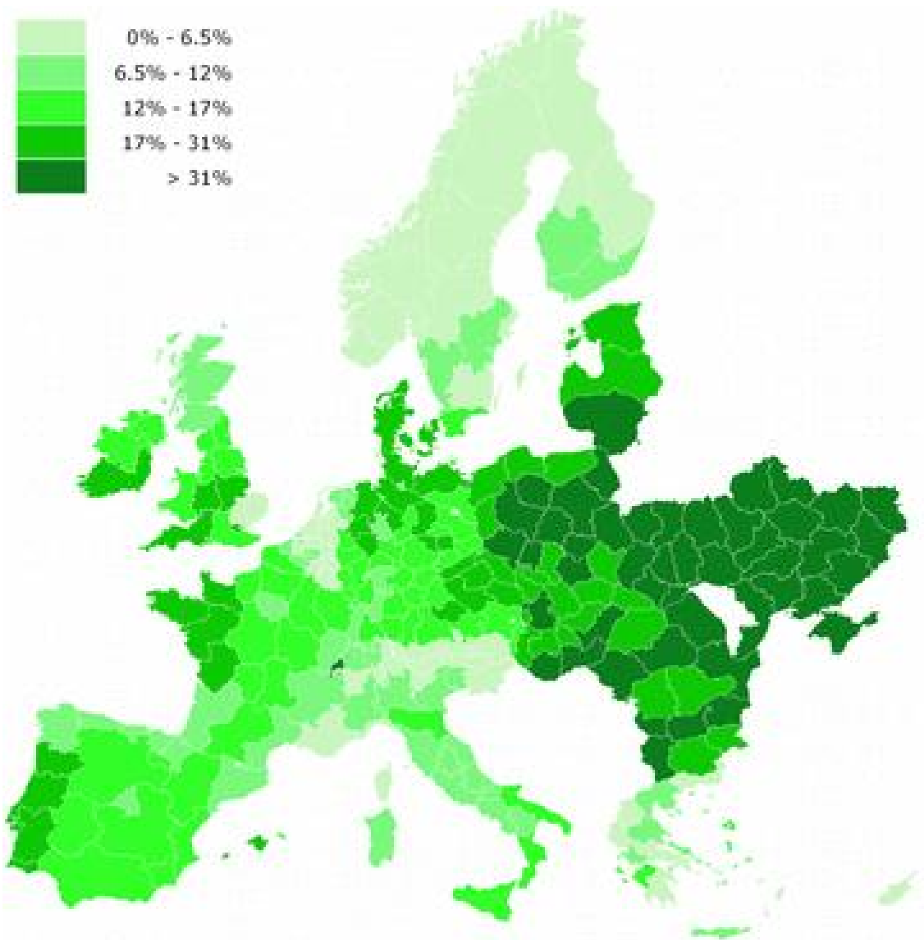


[Wit & Faaij, Biomass & Bioenergy, 2010]

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

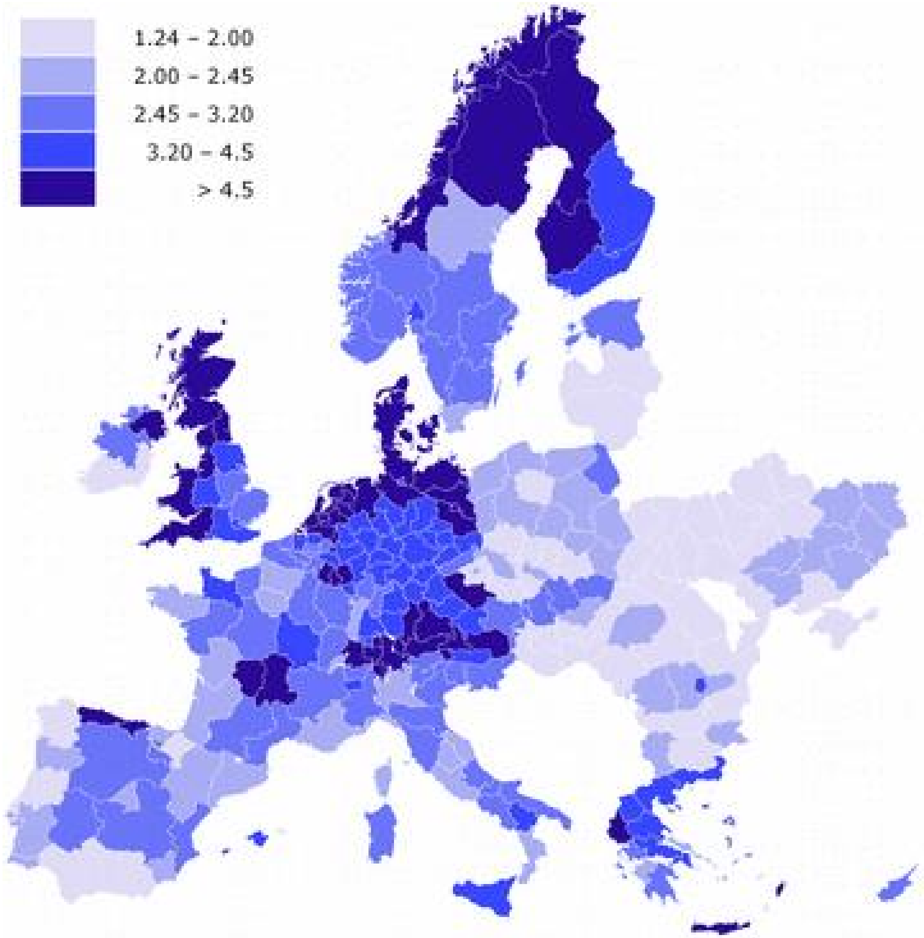


[Wit & Faaij, Biomass & Bioenergy, 2010]

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

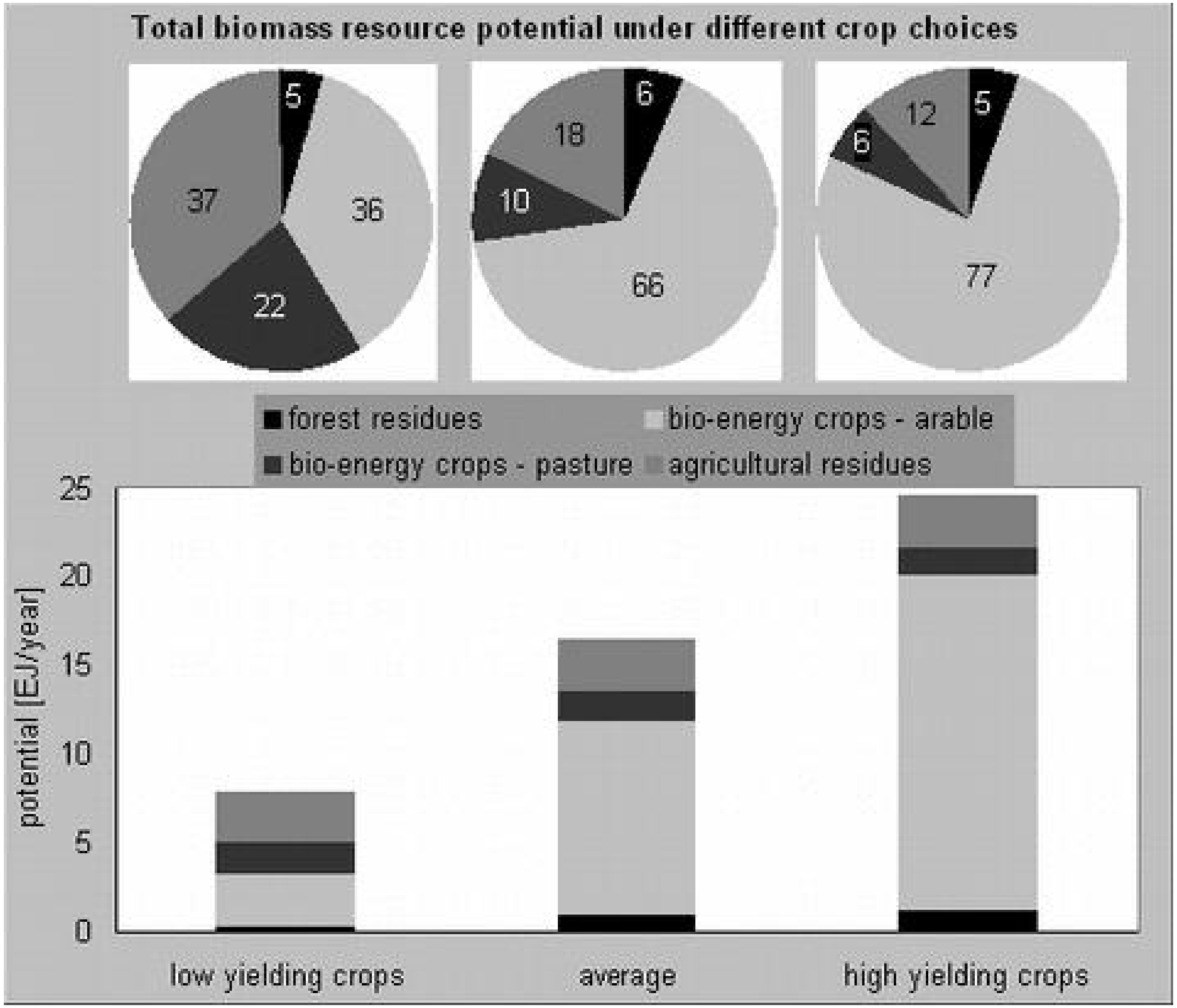


[Wit & Faaij, Biomass & Bioenergy, 2010]

Total energy potential under three different crop schemes.

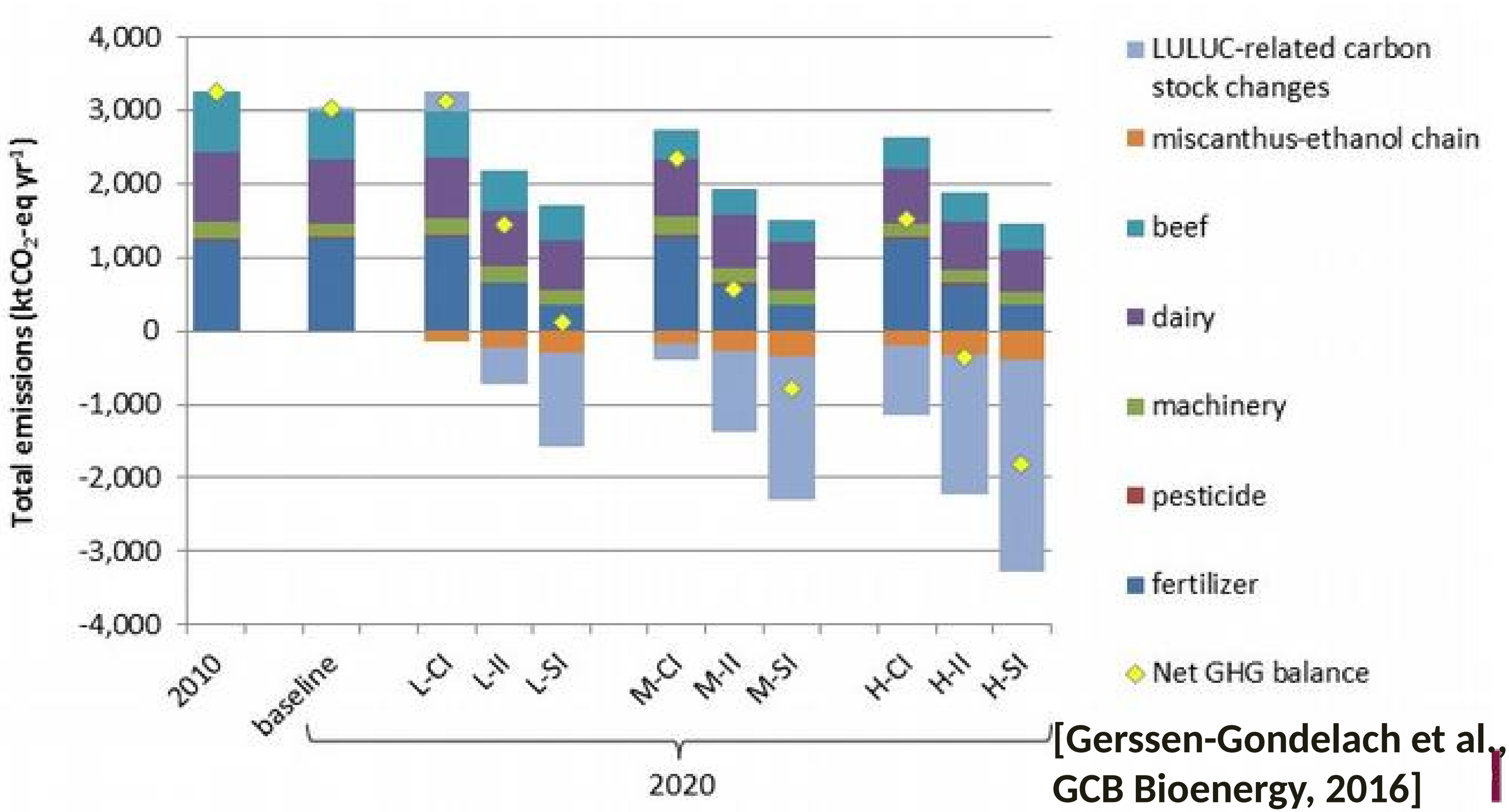
Low yielding crops': all arable land available planted with oil crops. 'High yielding crops': all available land planted with grass crops.

[Wit & Faaij, Biomass & Bioenergy, 2010]

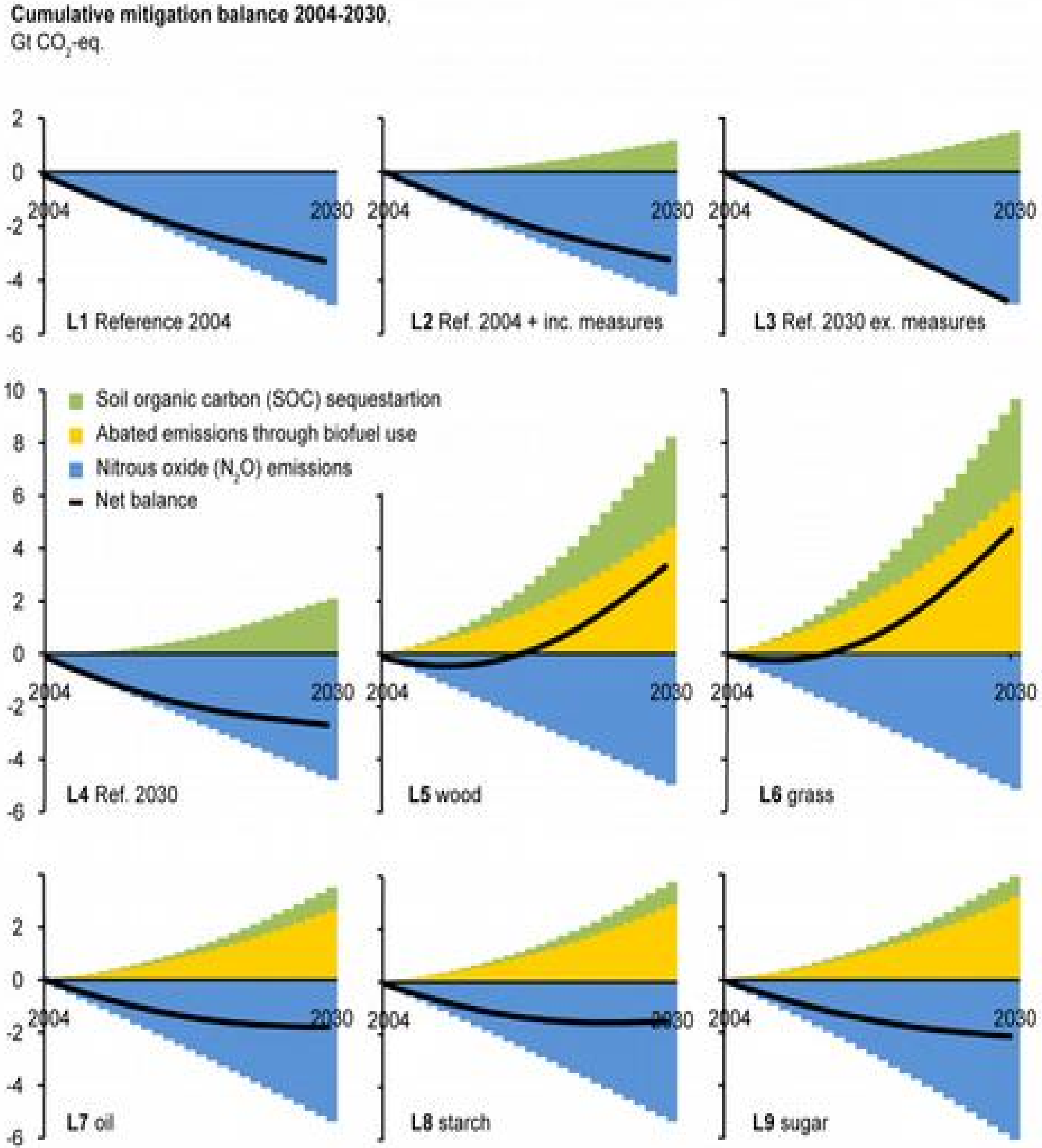


Full impact analysis

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.



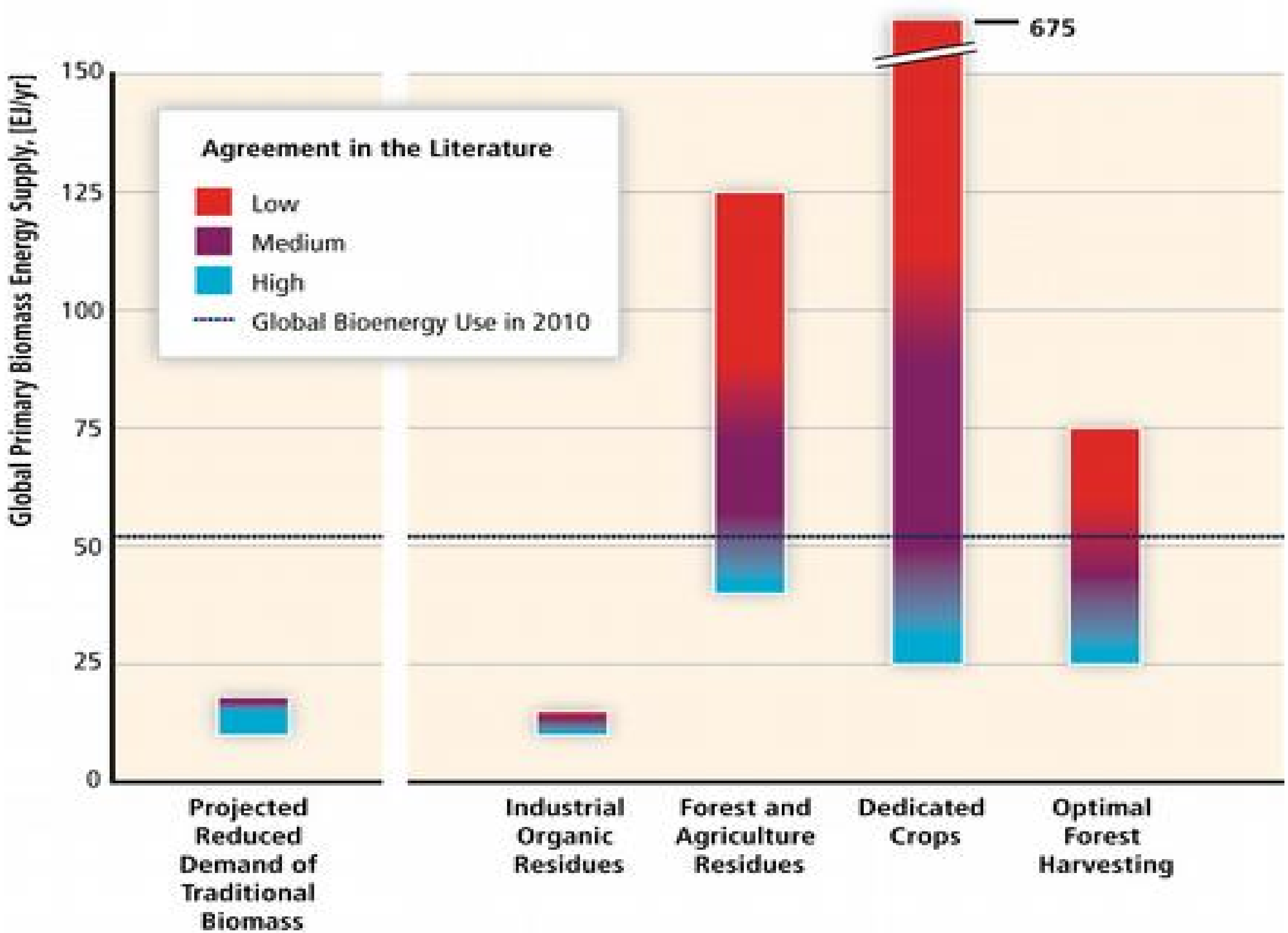
[Gerssen-Gondelach et al., GCB Bioenergy, 2016]



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

[Wit et al., BioFPR, 2014]

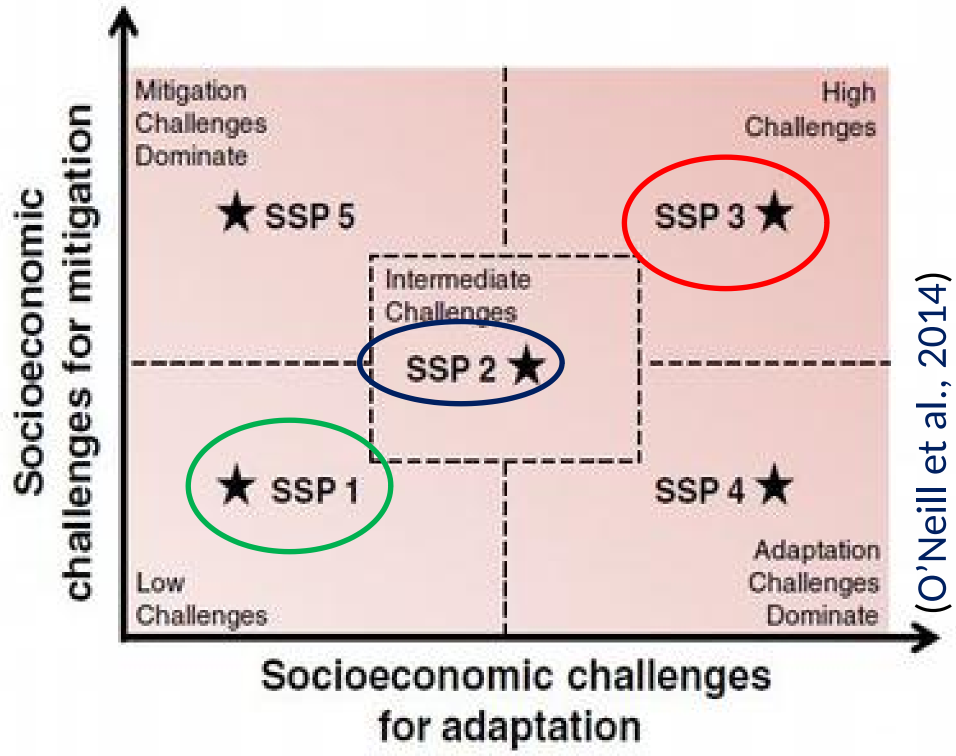
Bioenergy potentials [2050] (colors based on expert opinion). (IPCC – AR5 WGIII, 2014)



Different scenario's for:
Energy, land use, agriculture…

Scenarios

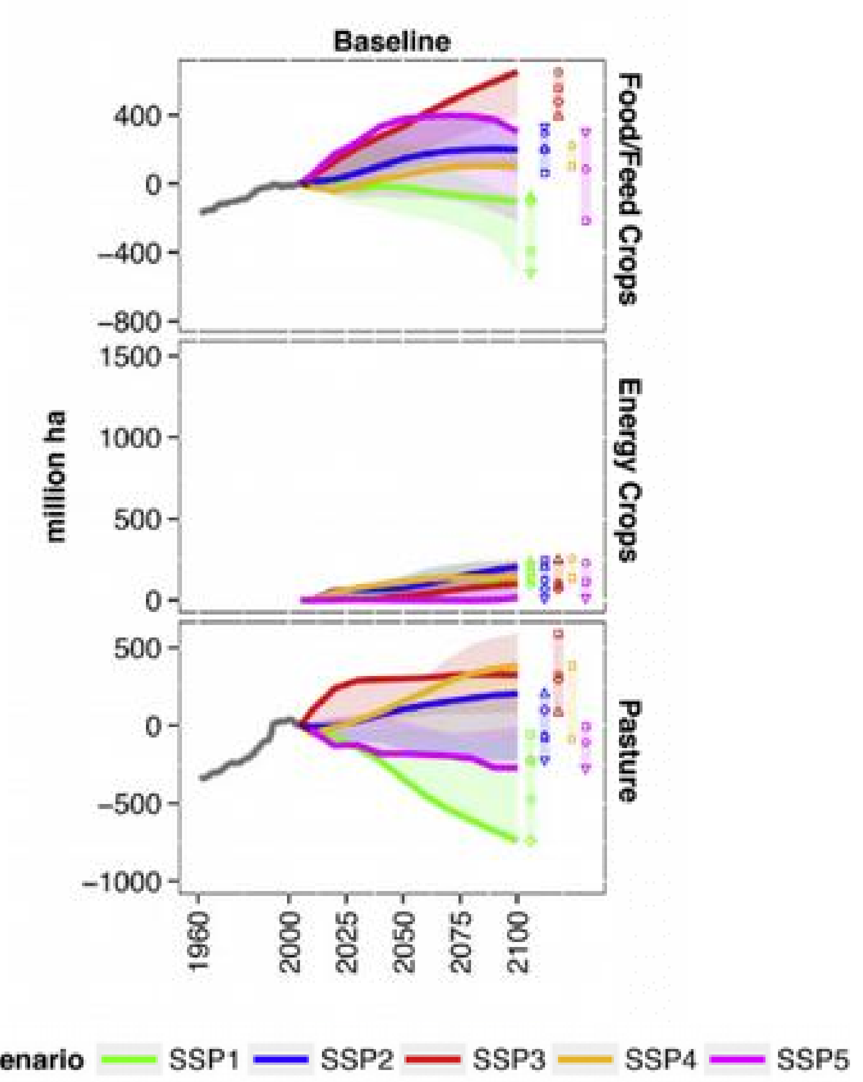
- ***SSP1: Optimistic world*** *(low challenges to mitigation and adaptation)*
- ***SSP2: Middle of the road***
- ***SSP3: Pessimistic world*** *(high challenges to mitigation and adaptation)*



(O'Neill et al., 2014)

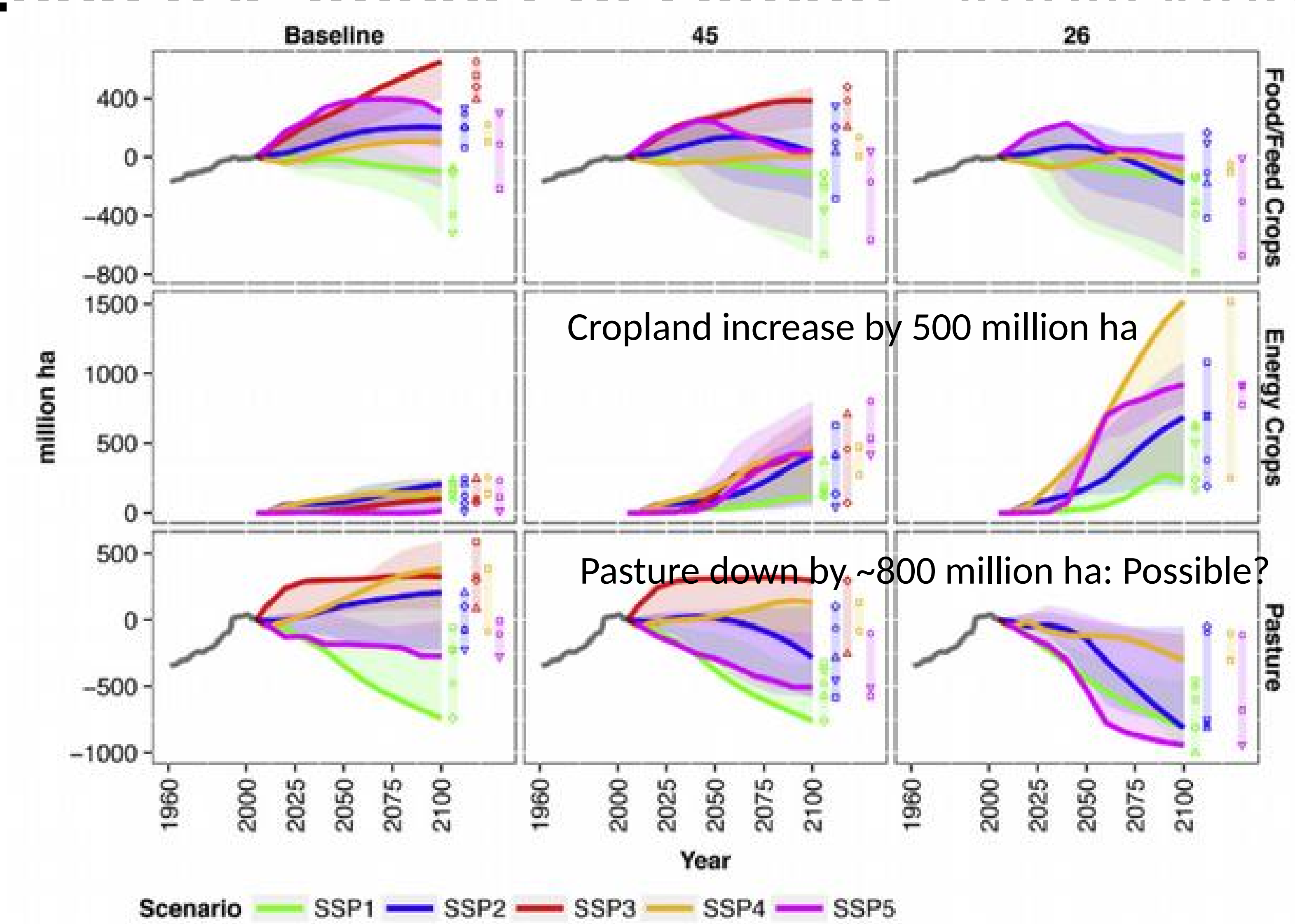
Future land use pathways in SSPs

- Differentiated drivers:
  - Population
  - Economic growth
  - Dietary patterns
  - Technological change (yield)
  - Trade policies
  - Land use regulations



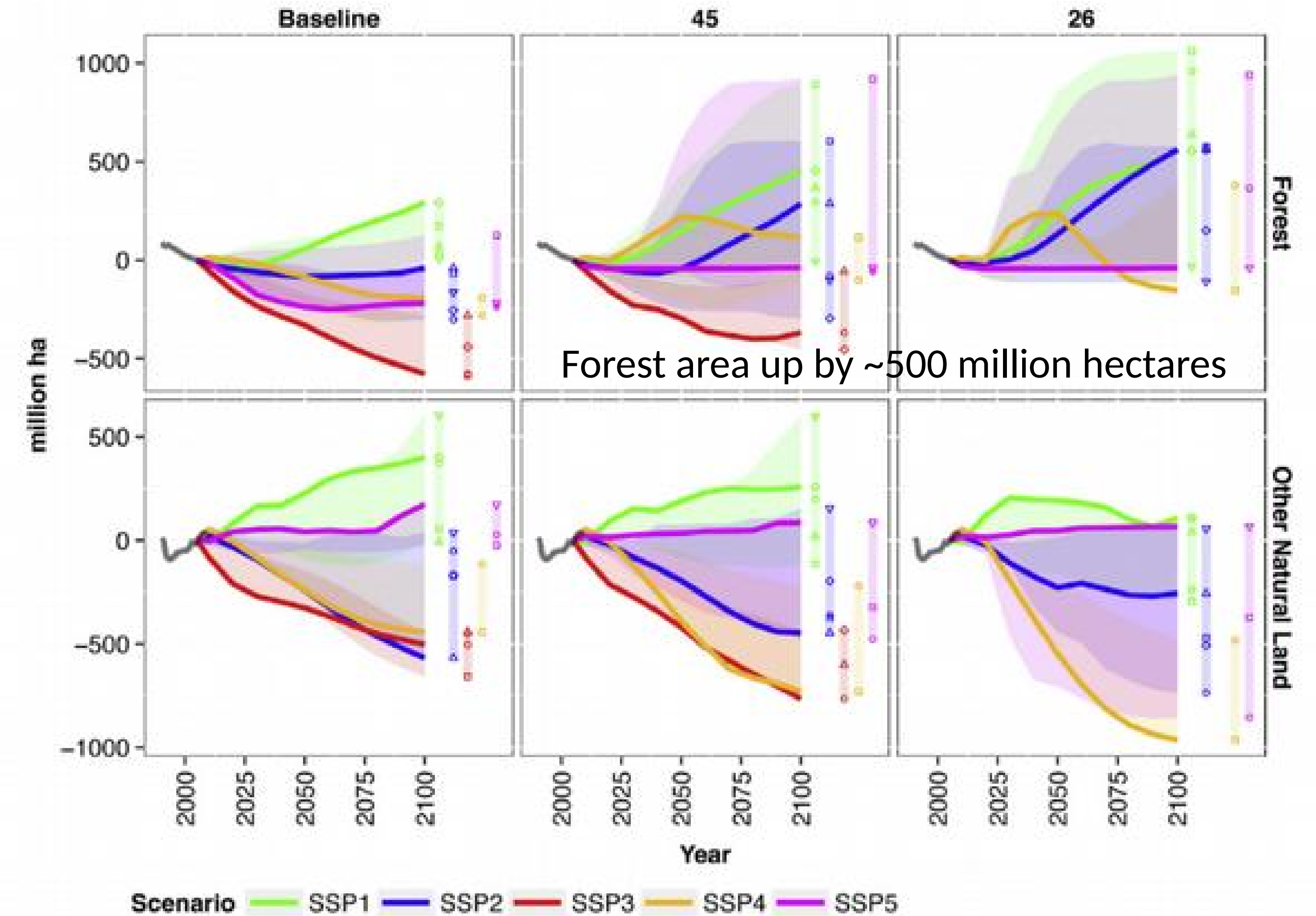
Source: Popp et al., 2017

Land use impact of climate stabilisation



Source: Popp et al., 2017

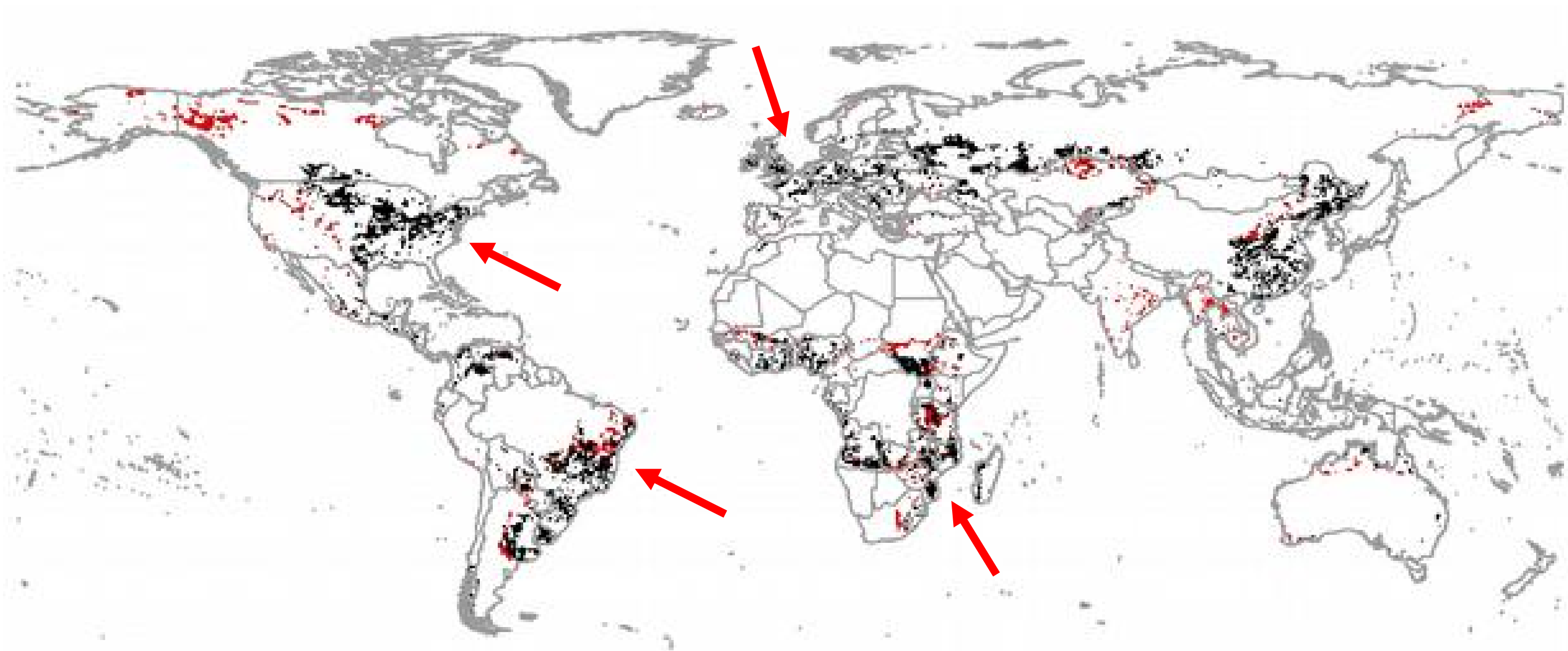
Land use impact of climate stabilisation



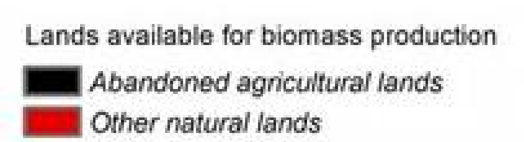
Source: Popp et al., 2017

Supply Energy crops

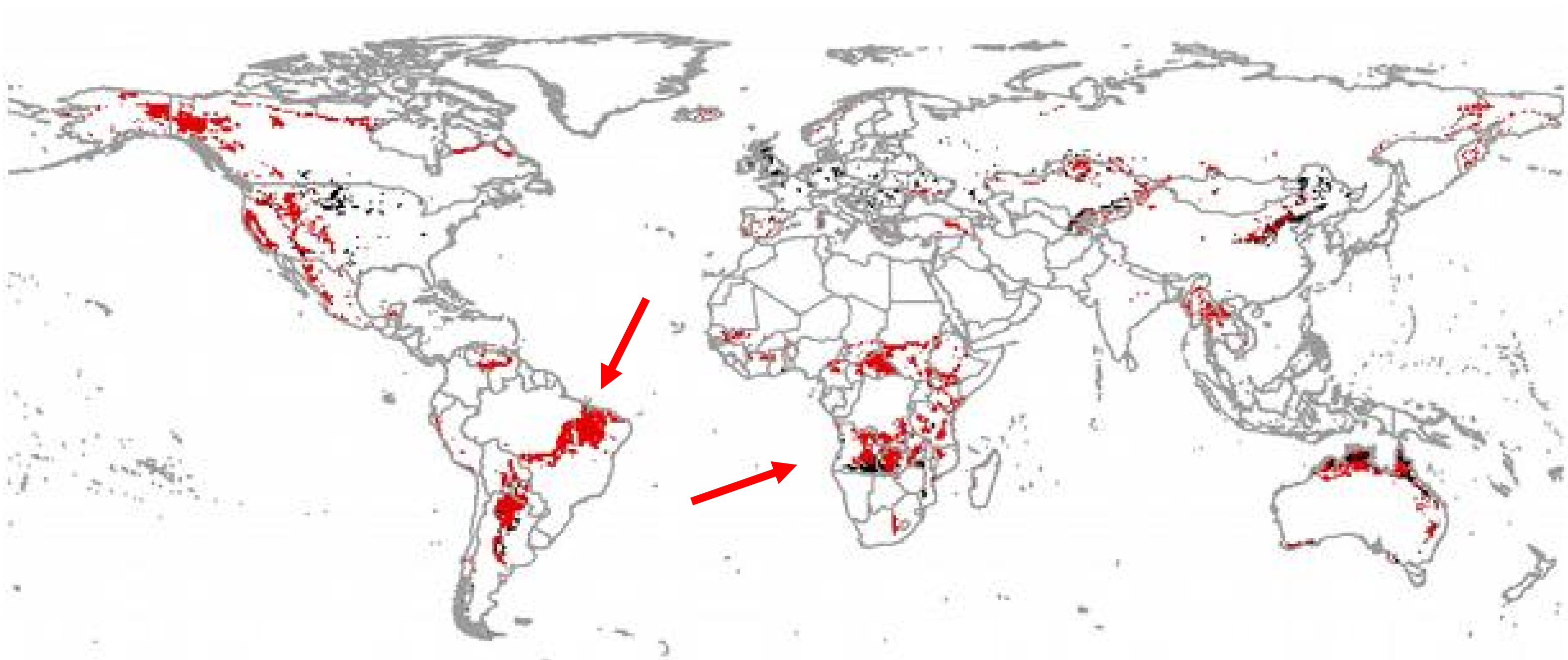
potential future supply of modern biomass from residues and energy crops accounting for the drivers and constraints in a spatially explicit manner (IMAGE)



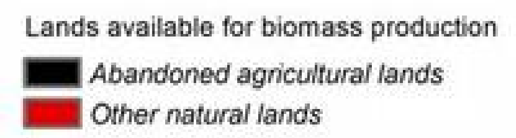
SSP1: Lots of natural lands are protected
High abandonement of productive lands



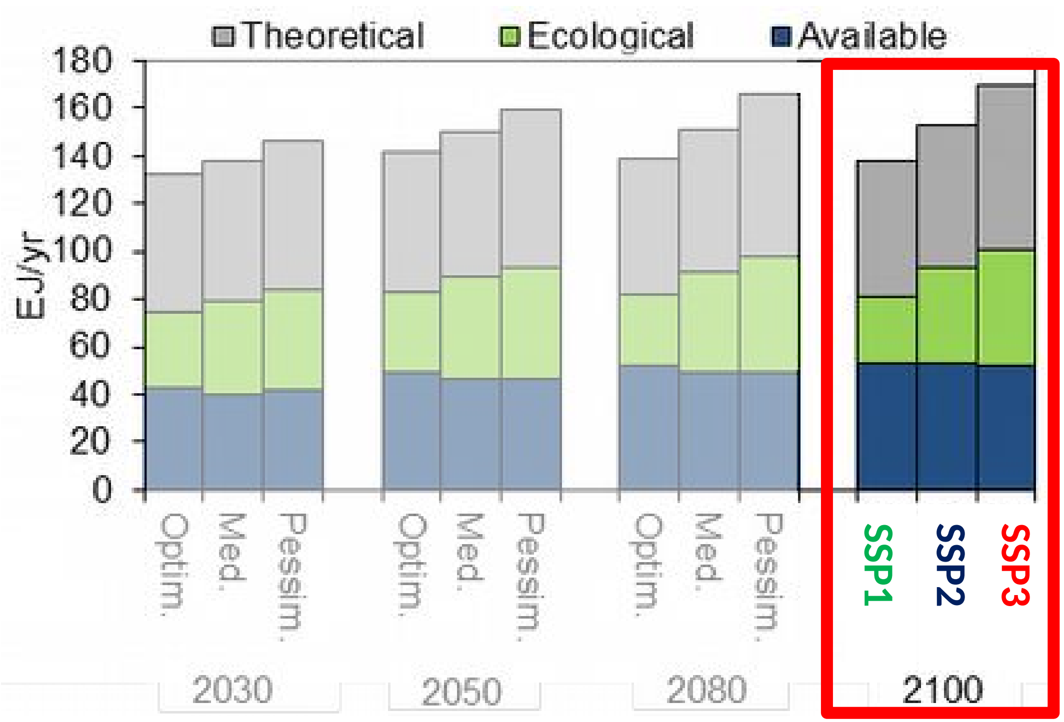
Supply Energy crops



SSP3: Expansion of land for food
Low protection of natural lands



Supply biomass Residues



Theoretical Potential:
Driven by increased demand of agriculture & forestry products

Ecological Potential:
Follows similar trend, but less pronounced

Available Potential:
Opposite trend, very small differences

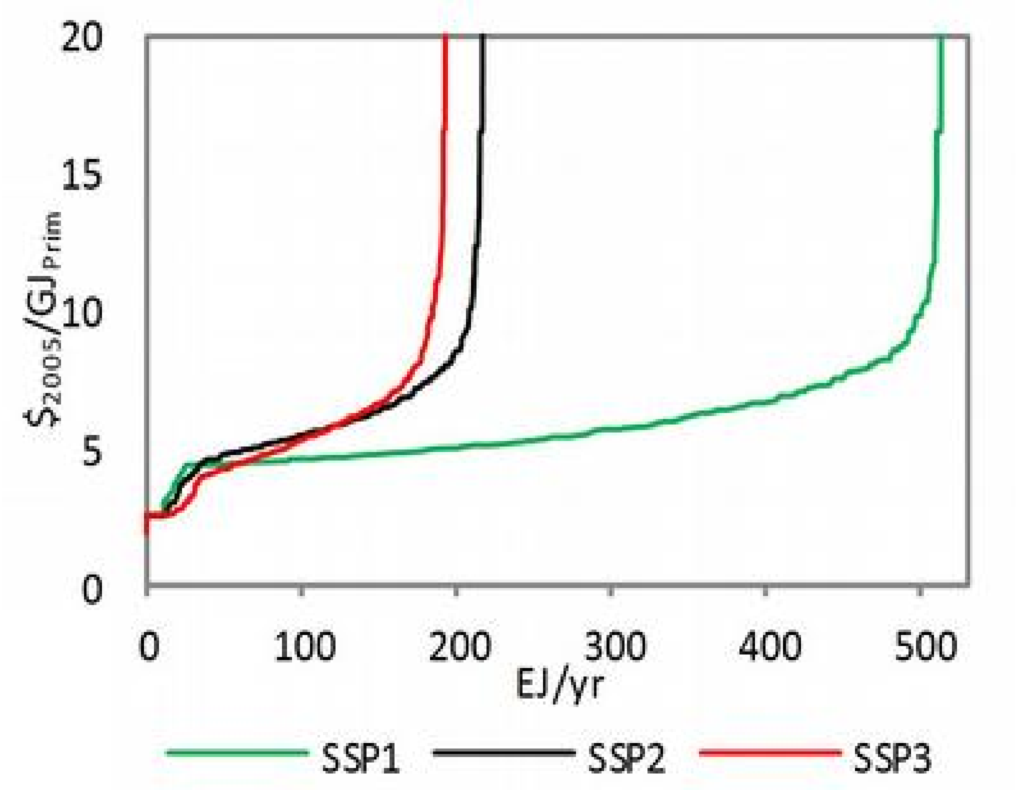
Explanation: competing uses grow significantly from **SSP1** to **SSP3**. Different drivers across scenarios cancel eachother out.

Supply **Curves**

Residue supply-curves consistent

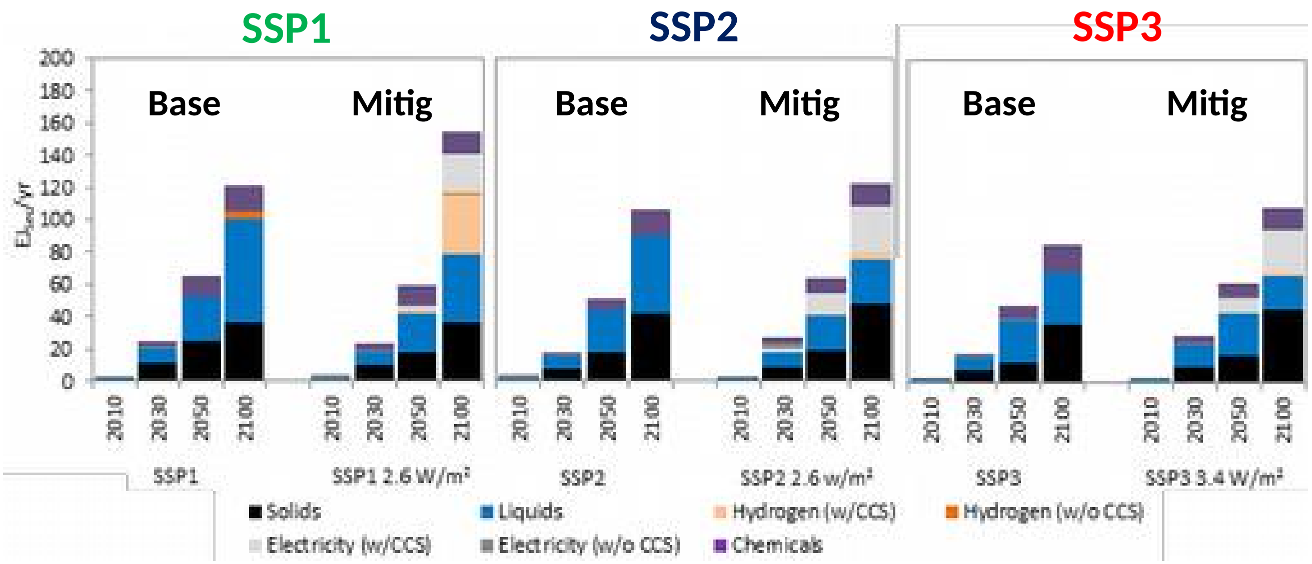
Availability of high quality lands in **SSP1** leads to extremely high and low cost availability of biomass

2100



Demand System

demand for biomass for different energy and chemical purposes in a dynamic energy system model (TIMER)



Baseline Scenarios

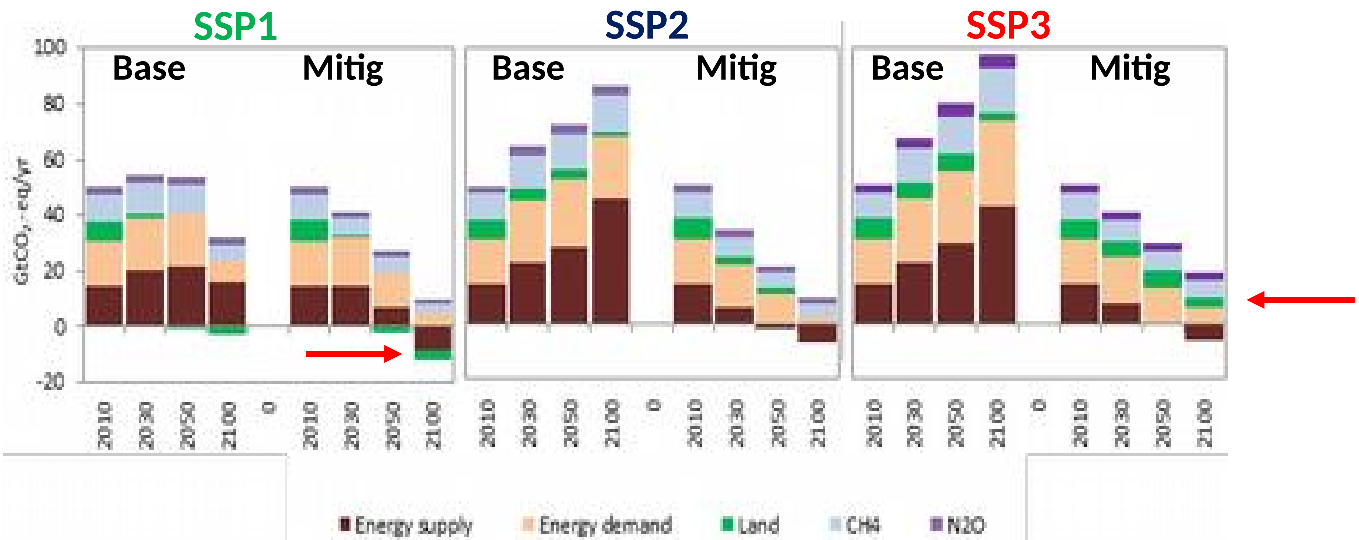
- Liquid bioenergy very important, especially in **SSP1**
- Also some solids and chemicals, especially in **SSP3**

Mitigation Scenarios

- Increased (but not exclusive) use of BECCS. H_2 in **SSP1** → increased technological development

Emissions Integrated

<u>overall</u> <u>greenhouse</u> <u>gas</u> <u>impact</u> of biomass deployment for bioenergy and biochemicals, taking the potential dynamics of future land use and the energy system into account

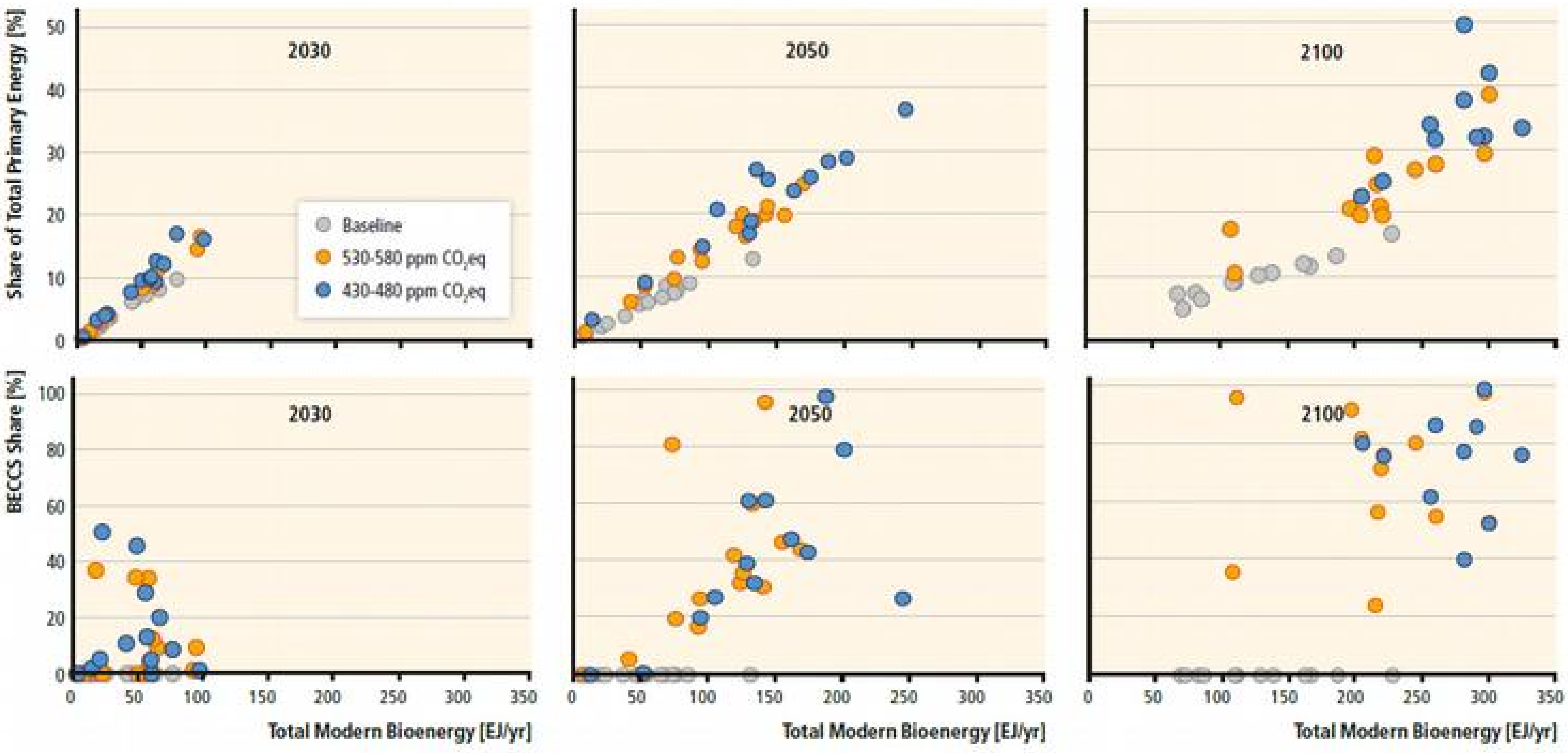


Availability of <u>high quality lands</u> for biomass and <u>protection of carbon stocks</u> in **SSP1** leads to high biomass deploymend **and** land based mitigation!

In **SSP2**, about 10% of mitigation is **due to** biomass use, largest contribution from BECCS

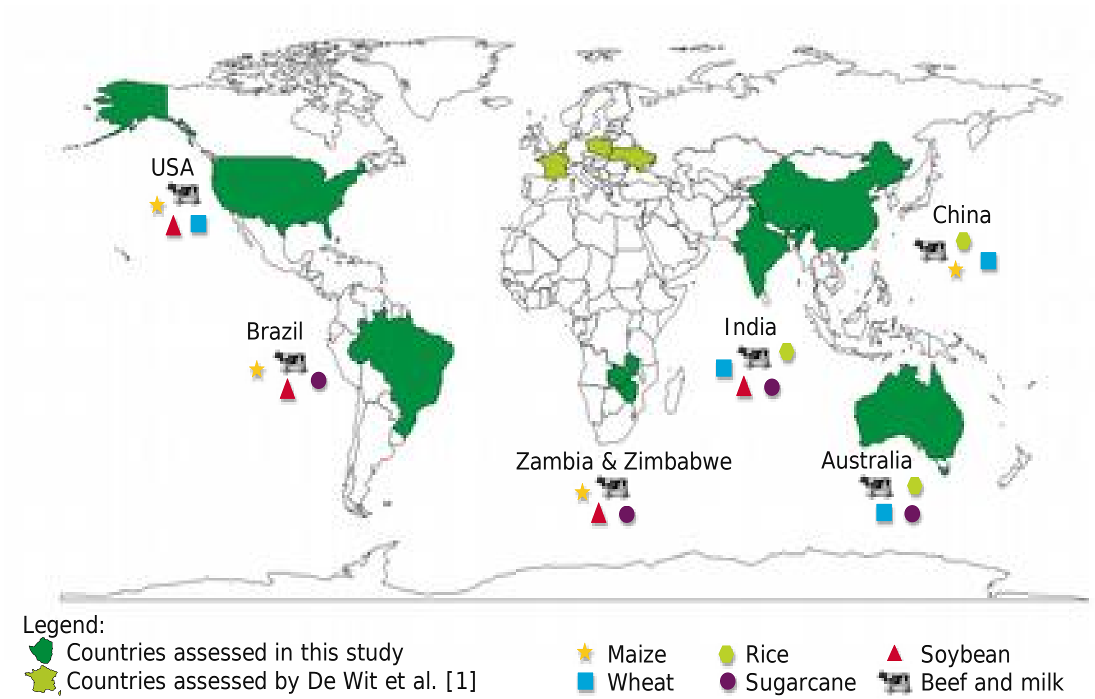
- Higher in **SSP1** (lower LUC, better bioenergy technologies)
- Lower in **SSP3**

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

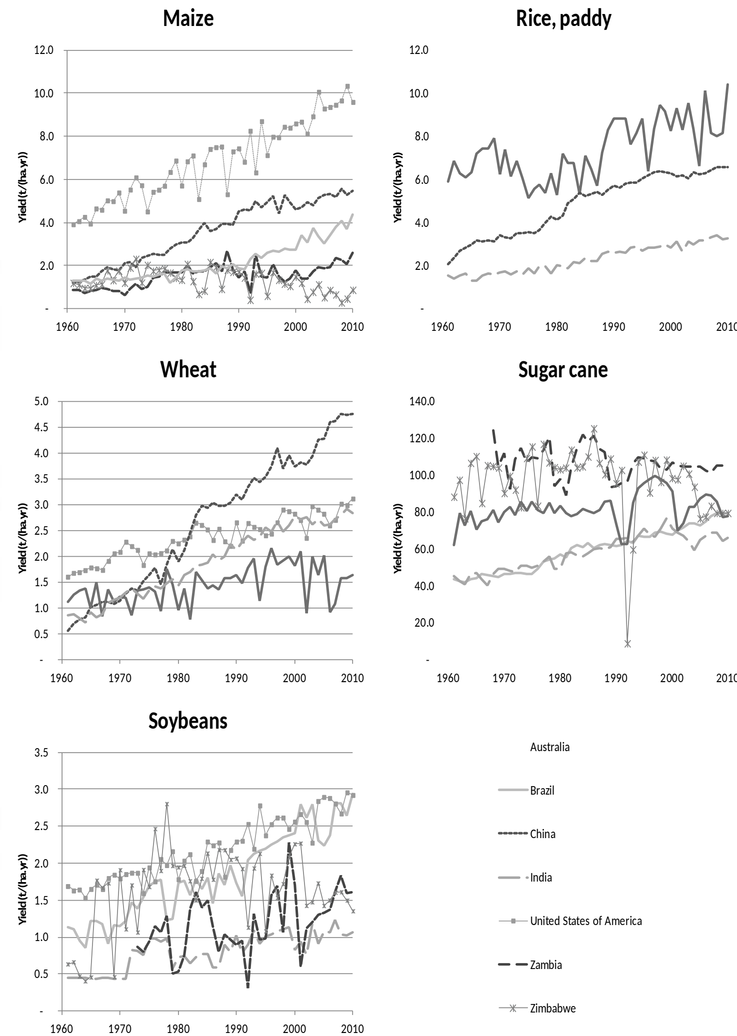


Further investigations yield gaps…

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

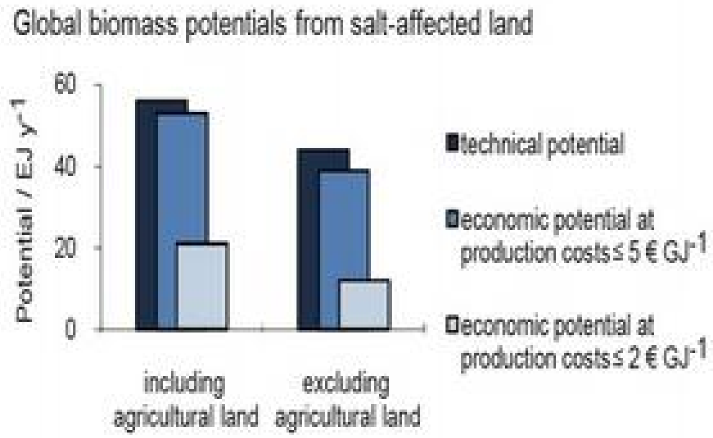


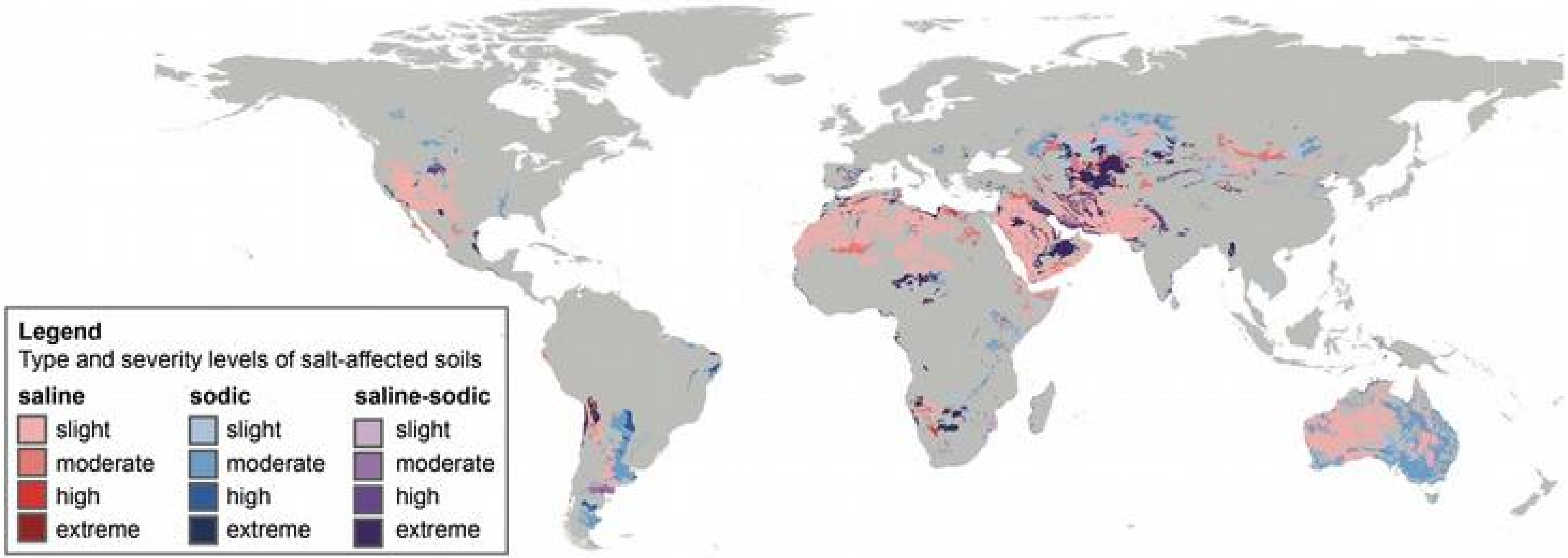
Key options such as intercropping, agro-forestry and multiple harvests poorly included (e.g Camelina).



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

Potential biomass production on saline soils.





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

Confrontation bottom-up vs. top down iLUC modelling

Key steps iLUC modelling efforts:

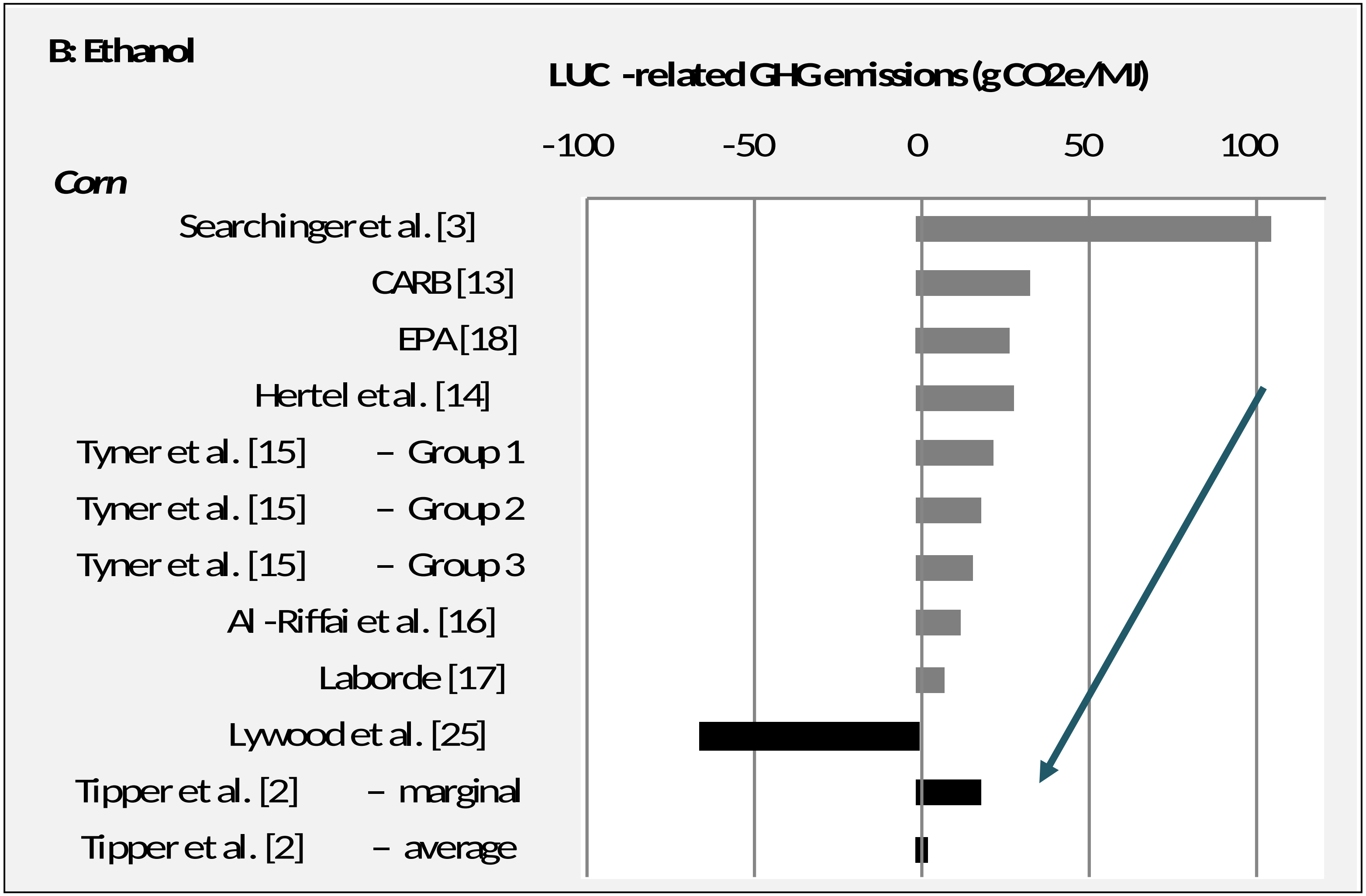
- CGE; historic data basis
- Model shock, short term, BAU, current technology.
- Quantify LUC
- Quantify GHG implications (carbon stocks)

Bottom-up insights:

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

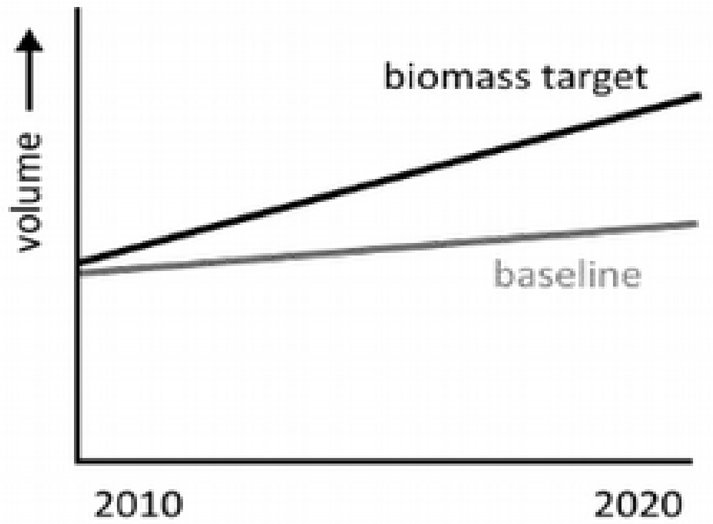
[IEA & other workshops, 2011-2013; Wicke et al, GCB-Bioenergy 2014]

Example: Corn ethanol
Results from PE & CGE models



[Wicke et al., Biofuels, 2012]

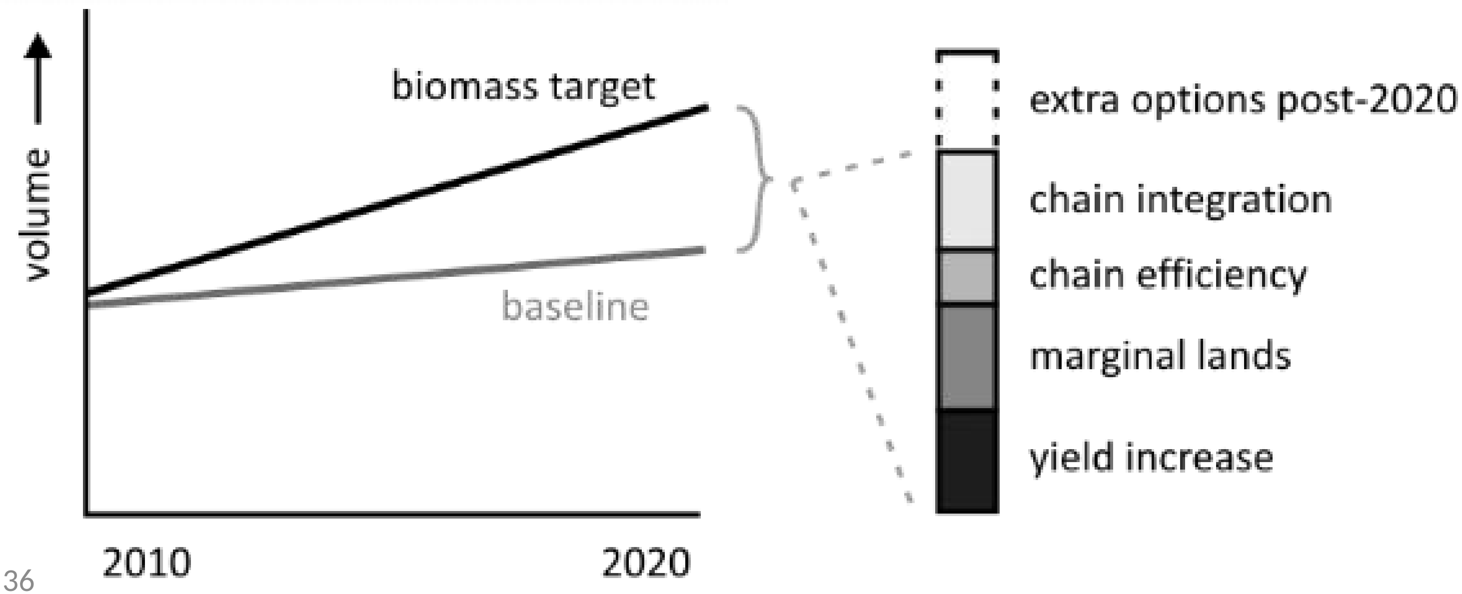
General approach iLUC mitigation

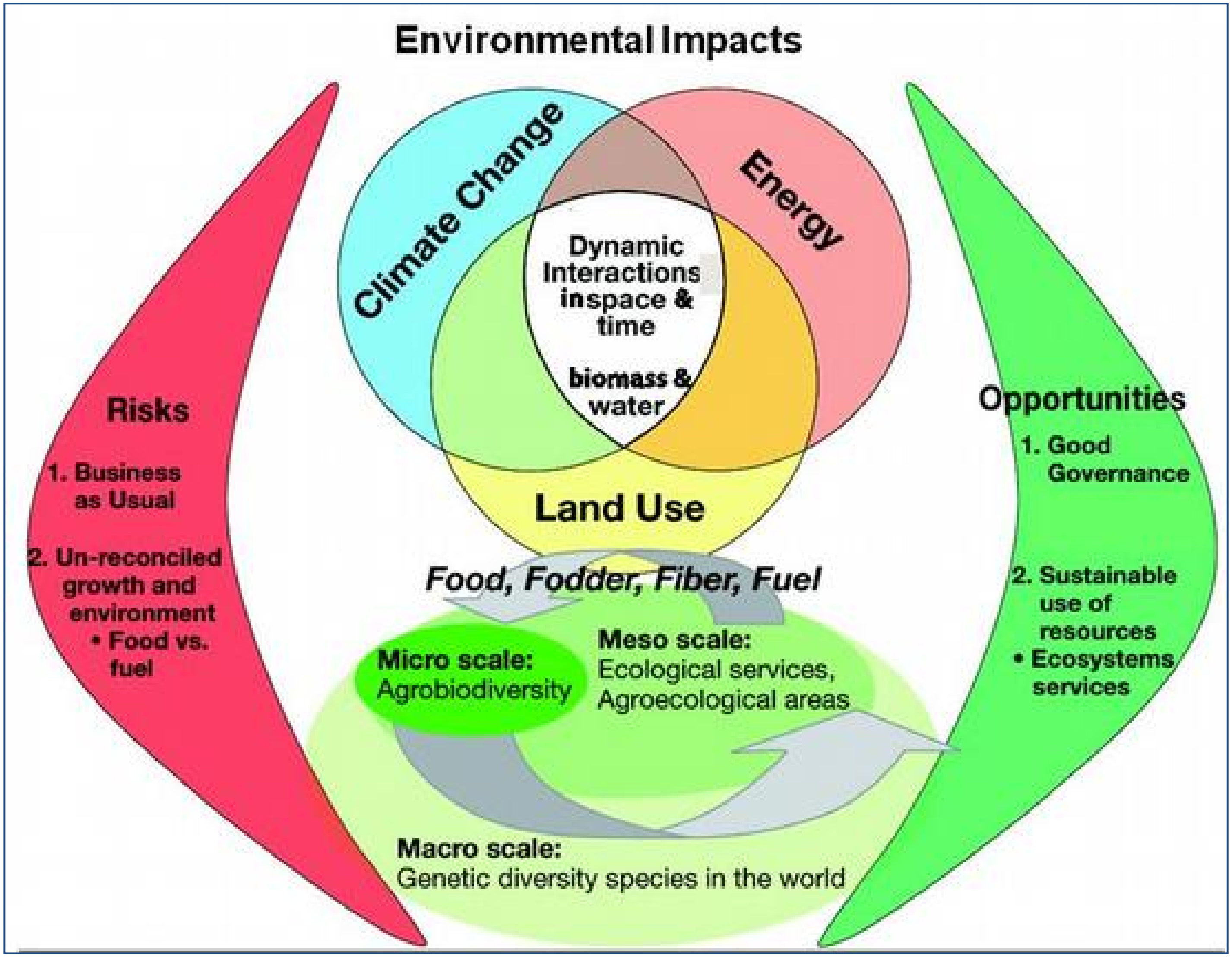


From economic models

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

[Brinkman, et al. , 2015]





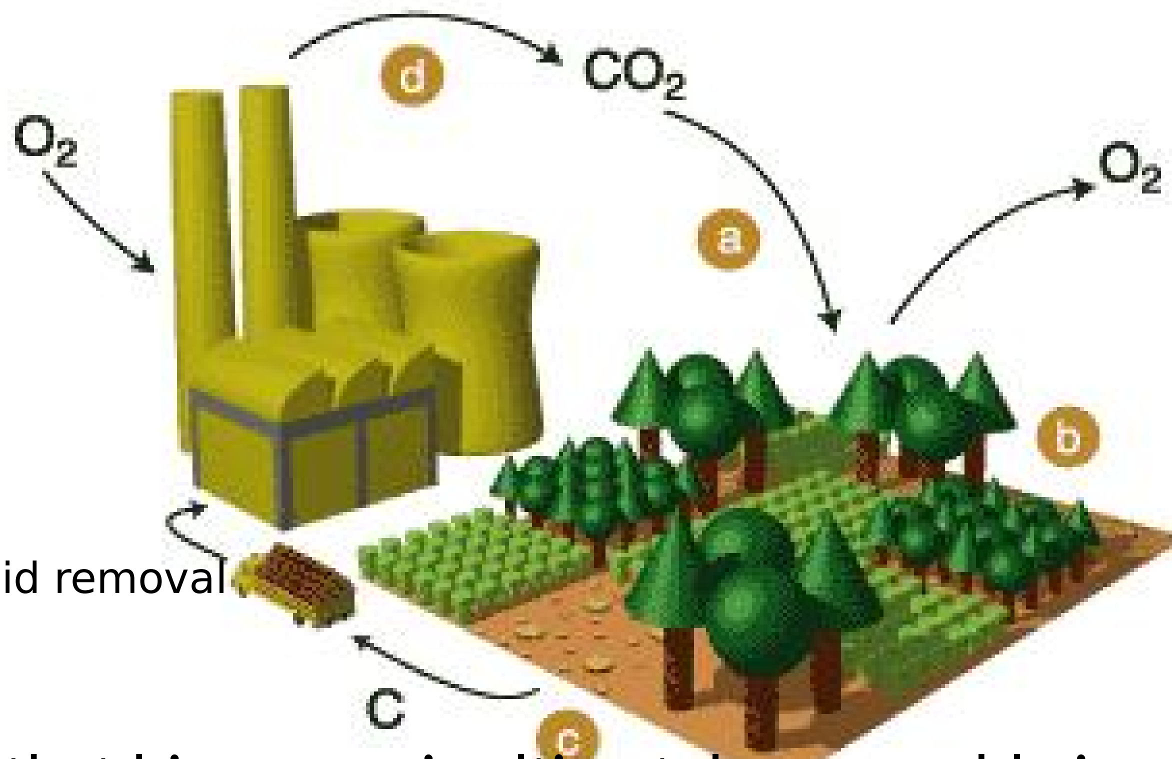
[IPCC-SRREN, 2011]

Summary

- BBE deployment ~300 EJ required post 2050 (mix of advanced fuels, power, heat, biomaterials + bio-CCS) 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.
- Realize the **synergies** with more resilient food production, more **efficient use of natural resources, increased carbon stocks.**
- …and **rural development** + (shift of fossil fuel expenditures to rural areas can amount several trillion U$/yr).
- Logical and efficient pathways and **gradual development of (biomass) markets, infrastructure and technologies**; intersectoral approaches.

Thank you very much for your attention

Basic principle of GHG emission reductions through bioenergy



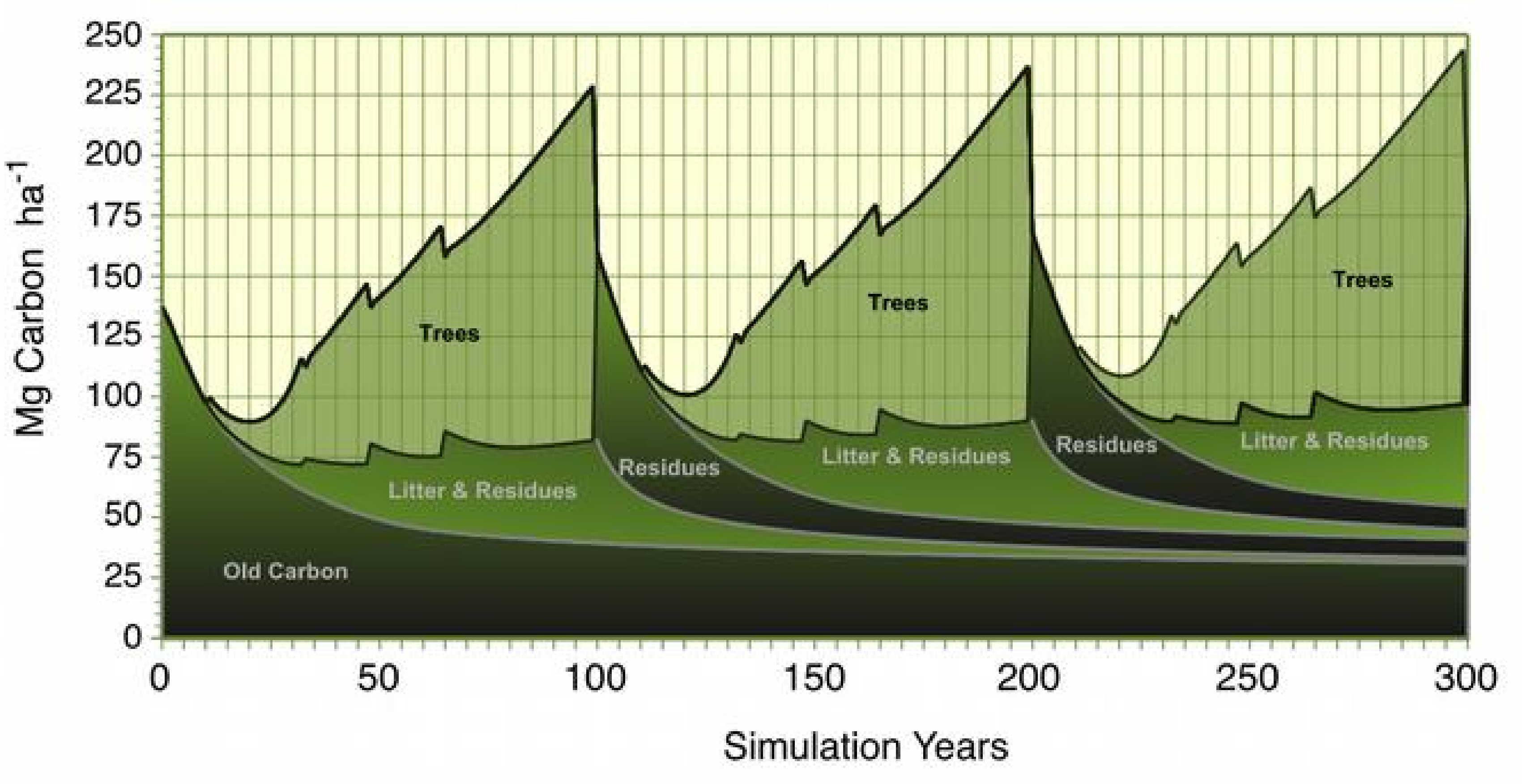
Source: adapted from IEA Bioenergy Task 38

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:

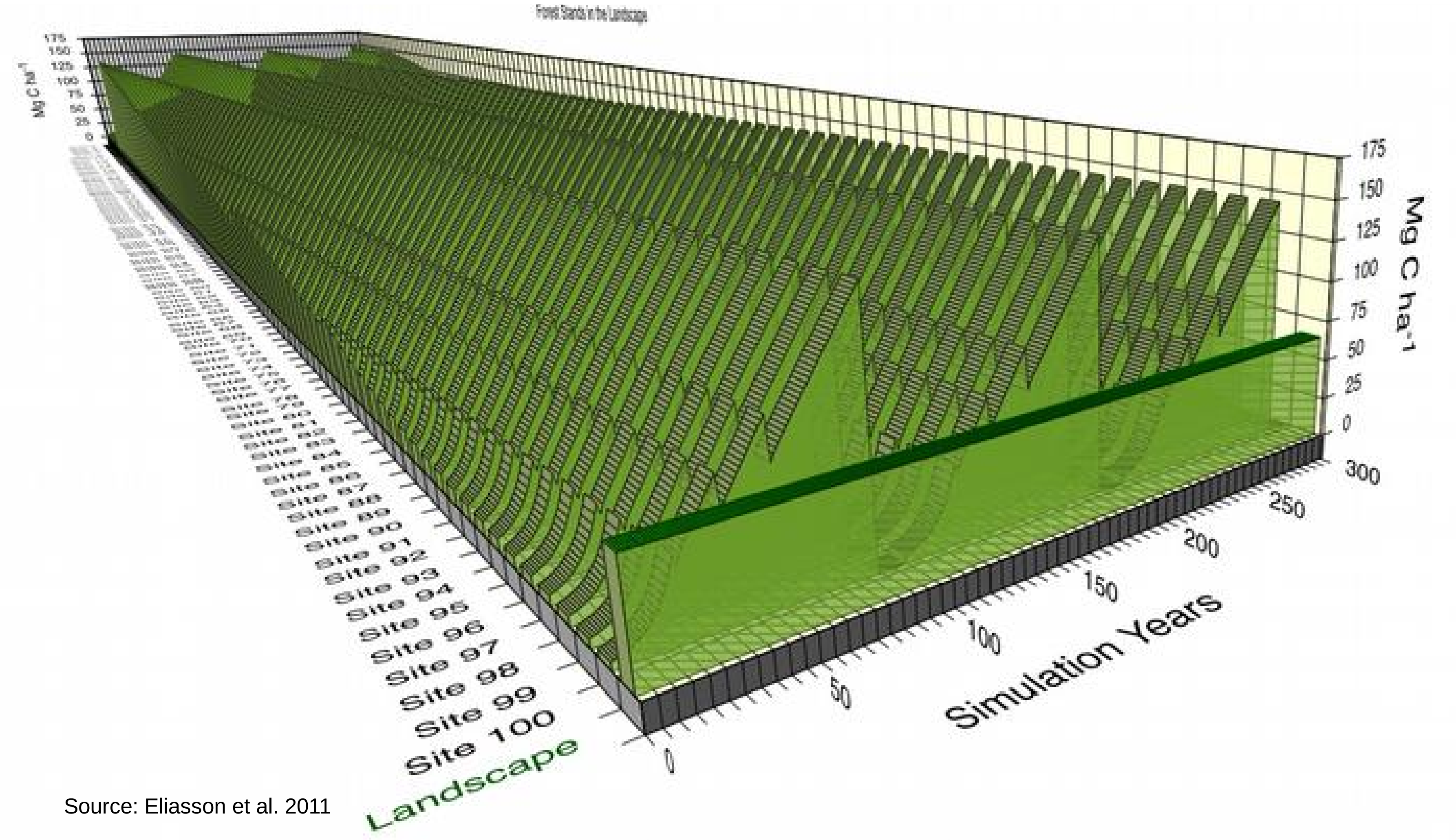
1. Does the analysis consider the stand-level and/or the landscape level
2. Does the study analyse the time until the initial carbon-debt is repaid, or does it compare the carbon flows of a bioenergy scenario with a reference scenario (e.g. a no-use scenario)

Stand-level



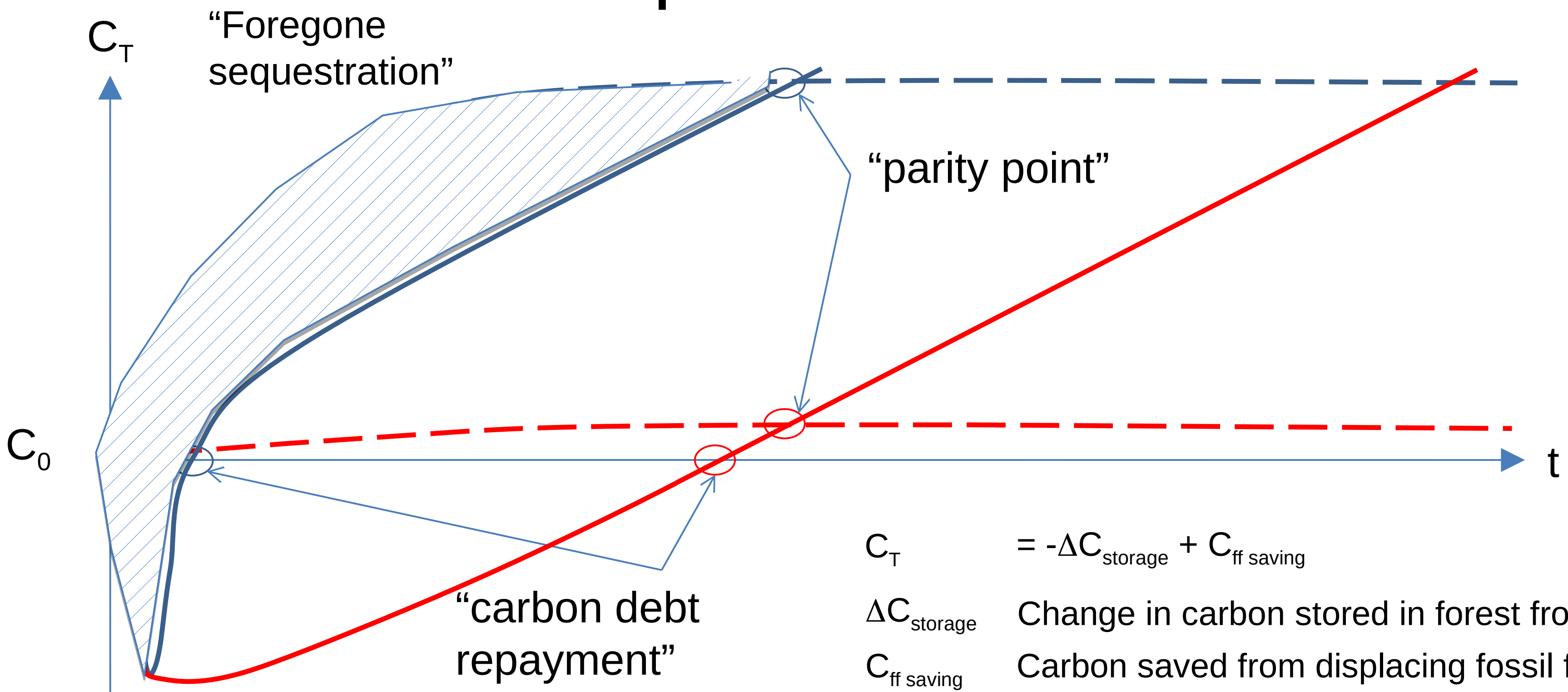
Source: Eliasson et al. 2011

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)

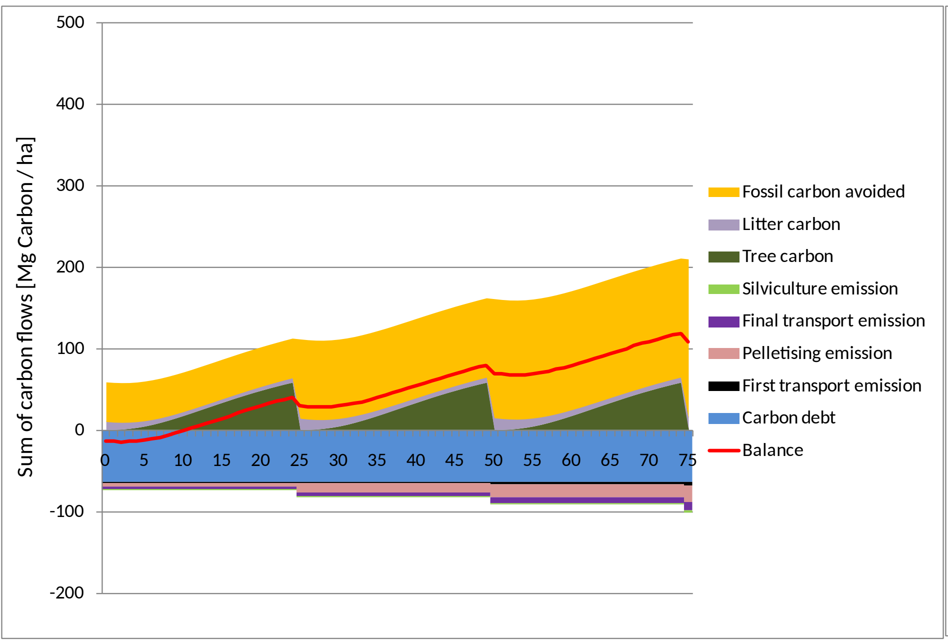
No harvest scenario (landscape)

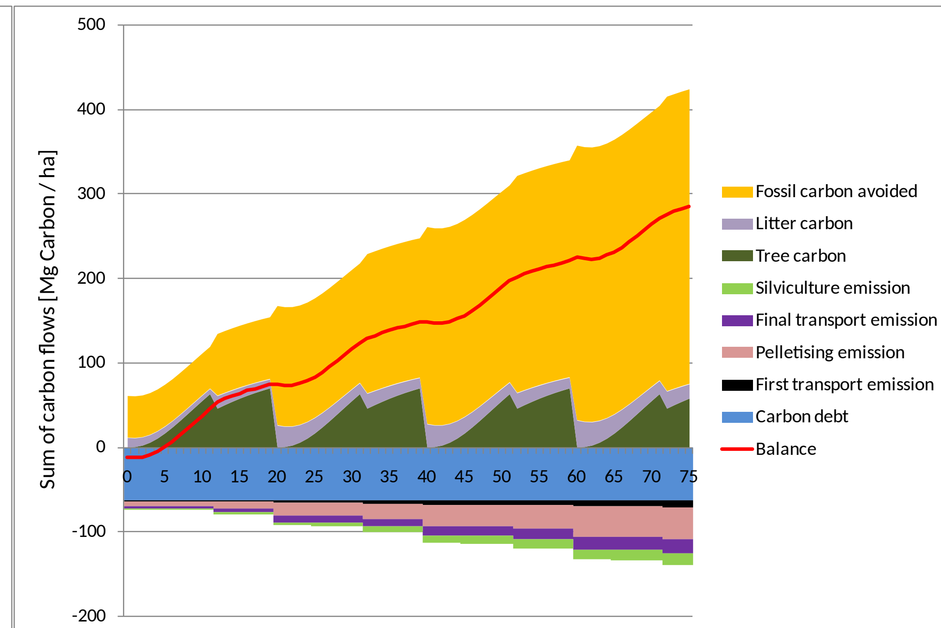
No harvest scenario (plot)

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*

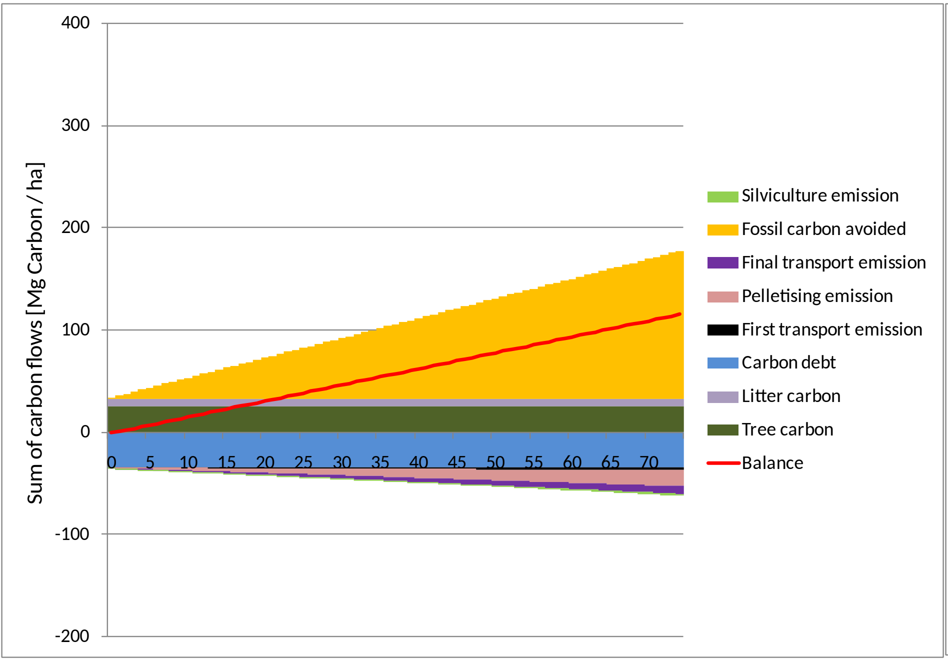
Carbon balance of 1 ha low vs. high productive plantation, (assuming avoidance of coal).

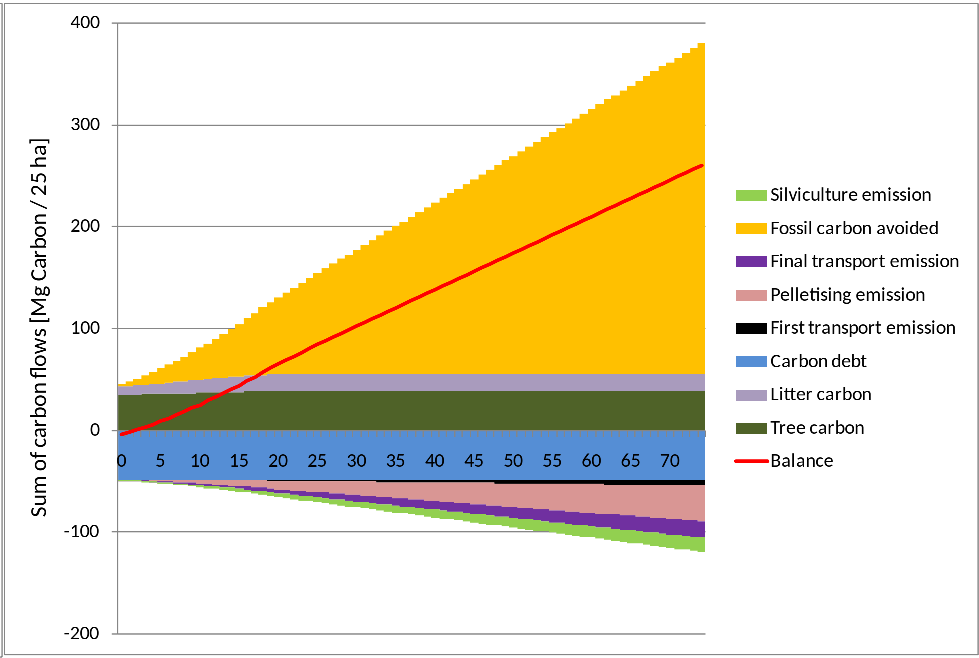




[Jonker et al., GCB-Bioenergy, 2014]

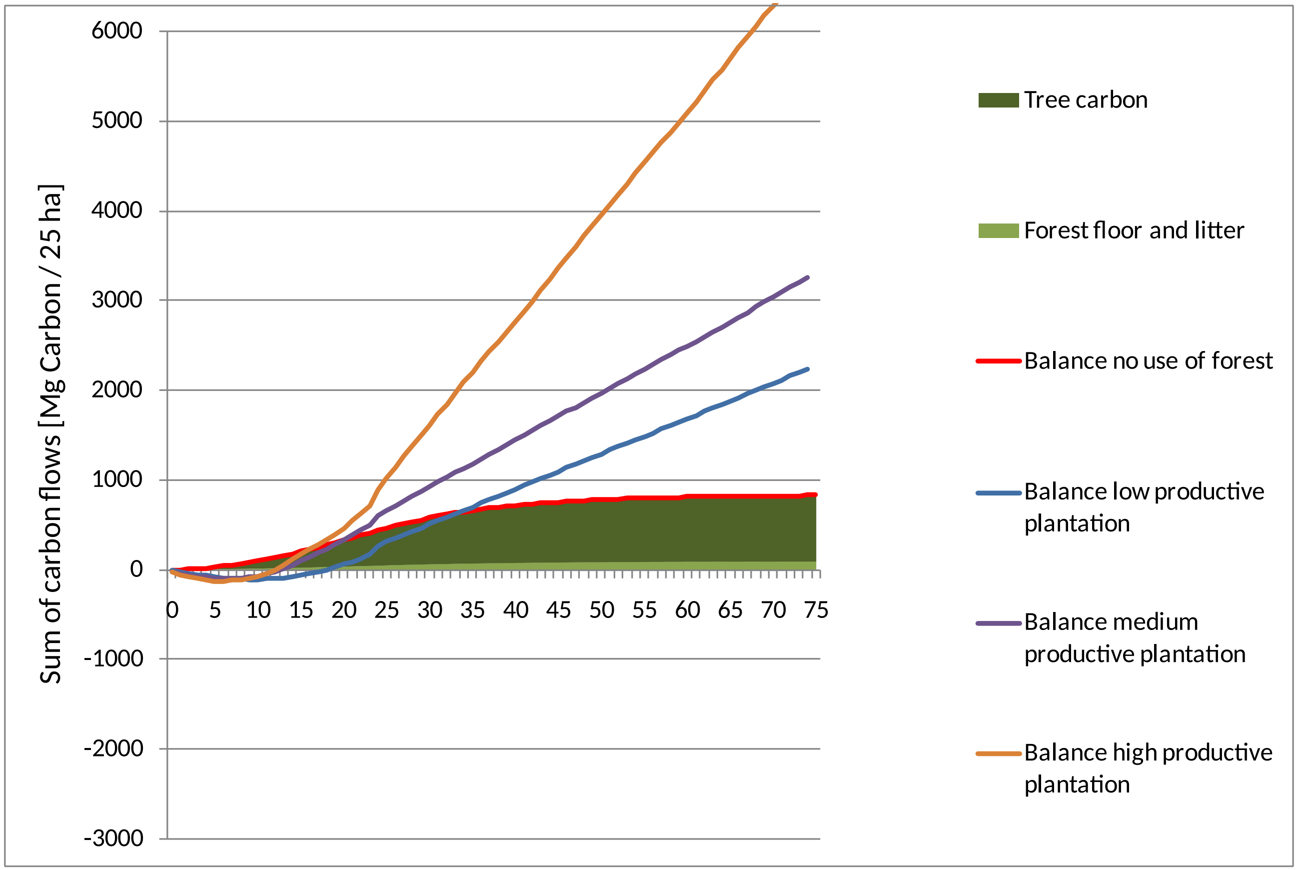
Carbon balance of 1 ha low vs. high productive plantation, using landscape level approach (assuming avoidance of coal)





[Jonker et al., GCB-Bioenergy, 2014]

No use of plantation for fossil fuel substitution



[Jonker et al., GCB-Bioenergy, 2014]

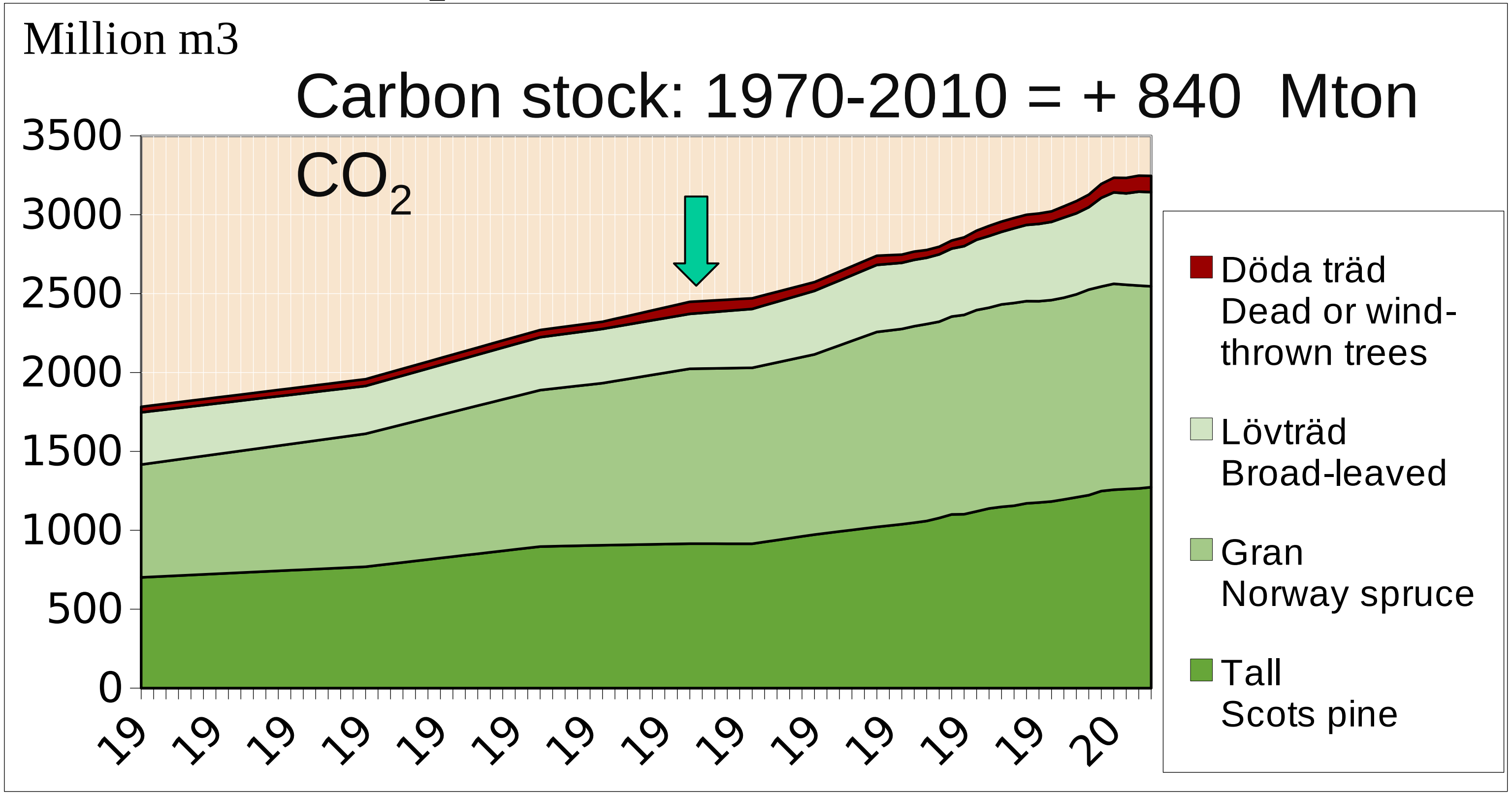
State-of-the-art insights

- First know what you are talking about; natural forest vs. production forest, stand vs. landscape, whole stem vs. residue, etc.
- Reported payback times vary widely; many are hypothetical scenarios.
- Bulk of utilized solid biomass in the EU = residue (!!)
- Best method / reference scenario & management strongly case–dependent – no ‘one-size fits all solution’. Key elements are:
  - 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

Swedish viewpoint
(achievements)

Avoided emissions 1970-2010

Substitution with bioenergy cut emissions of 550 Mton CO_2 in 40 yrs



[Magnus Fridh Swedish Forest Agency]

Bioenergy development in Sweden 1970-2005

The bioenergy share of the total domestic energy consumption

- 1970: 9%
- 1980: 11%
- 1990: 15%
- 2000: 20%
- 2009: 29%

[Magnus Fridh,Swedish Forest Agency]

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