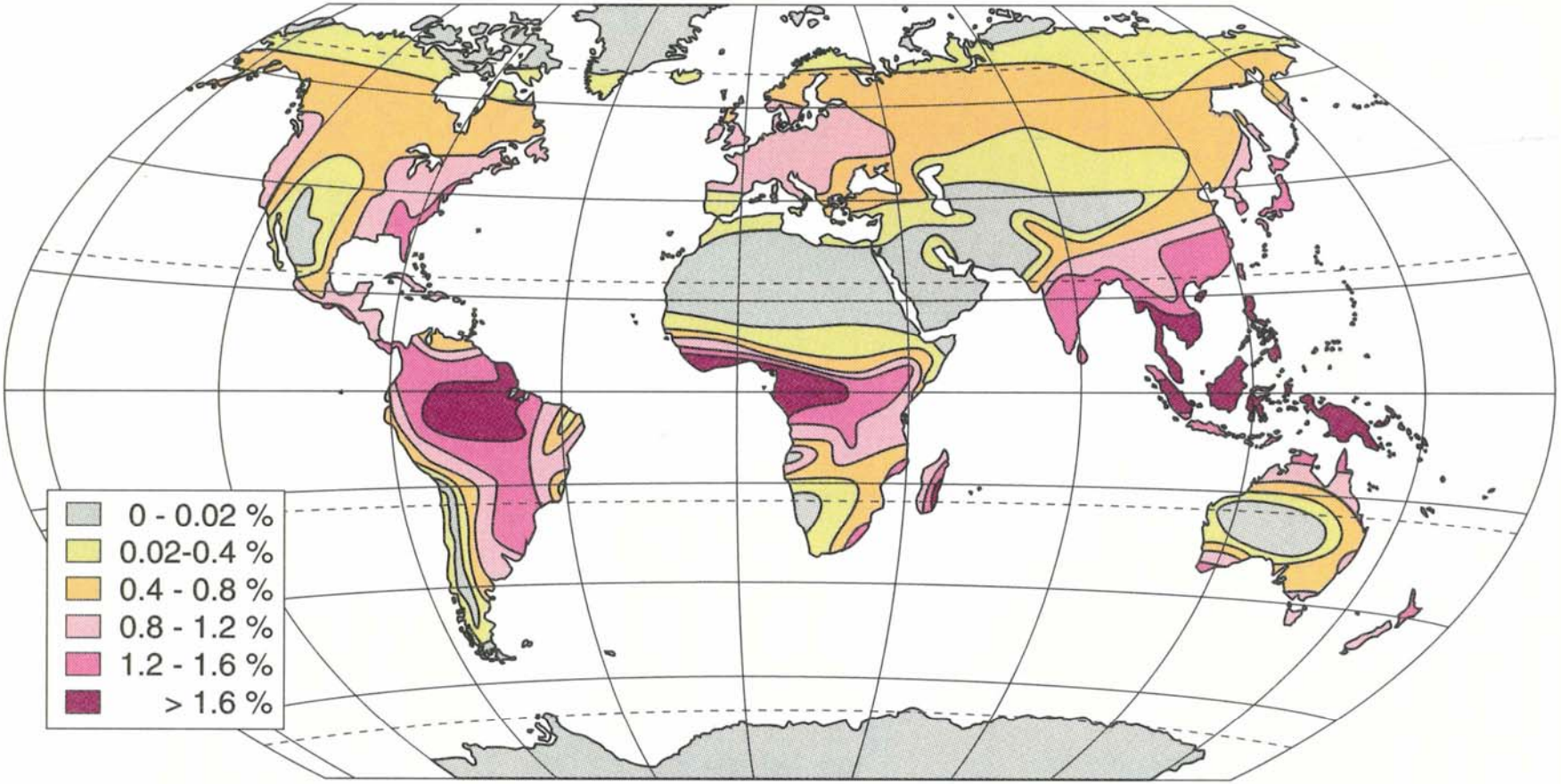
Bioenergy: potentials. limitations

EPS-Summer School
July 17 to 23, 2014

E D Schulze

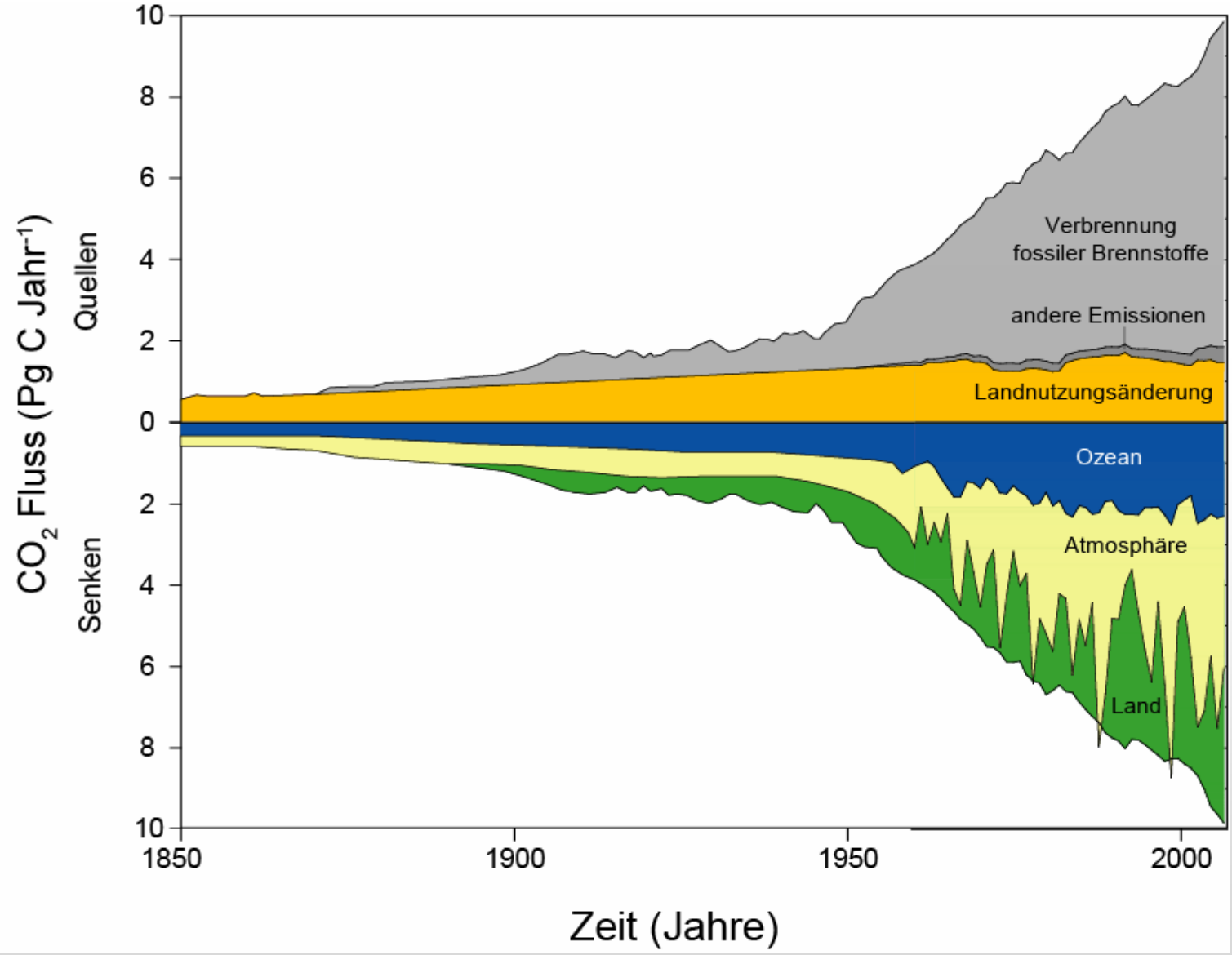
MPI Biogeochemie, Jena



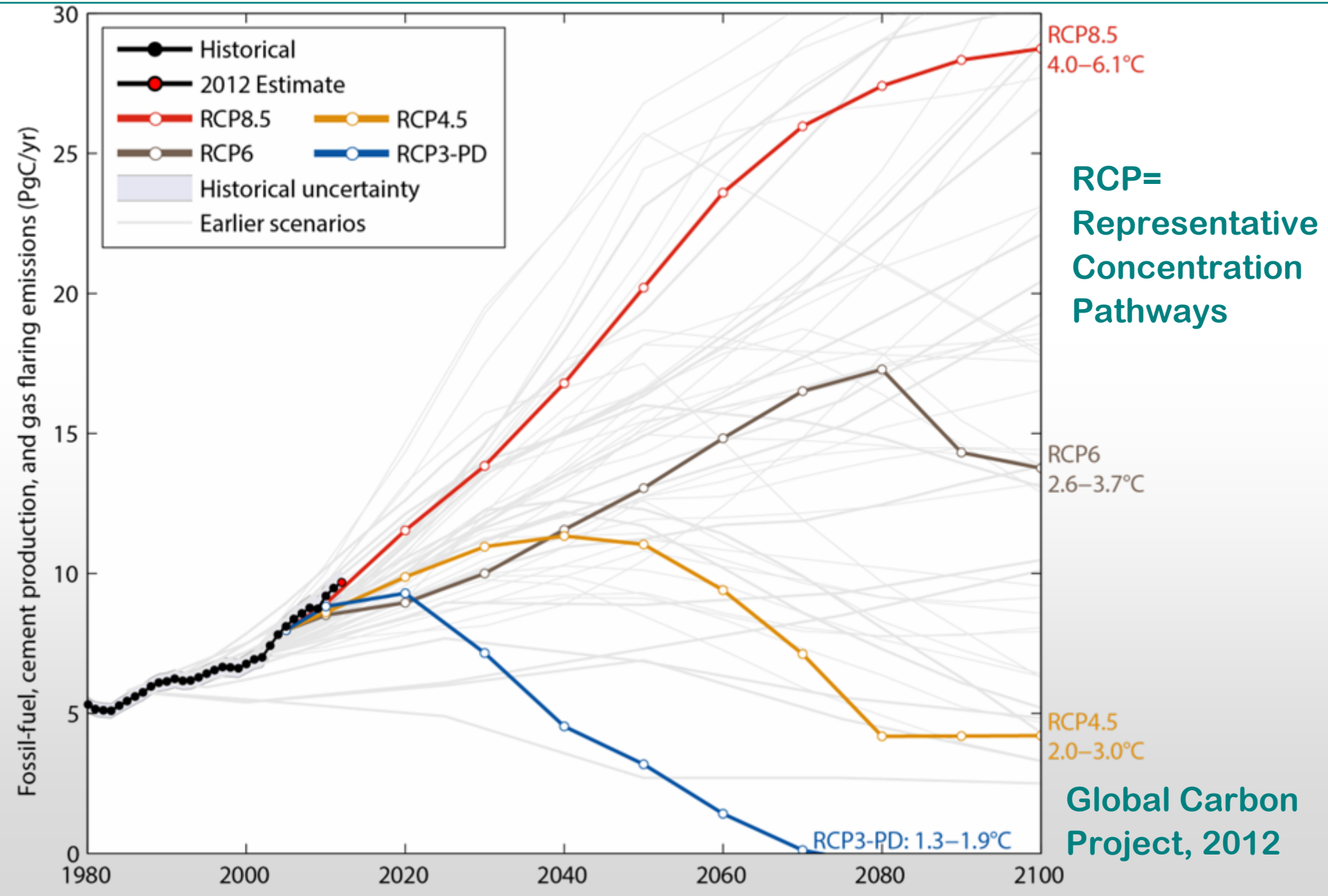
Color chart Ib (cf. page 176): Global distribution of radiation use efficiency of the vegetation. Energy efficiency, i.e. energy content of net primary production, is expressed as percentage of the global annual photosynthetically active radiation. (After Uchijima and Seino 1987)

Global change = Δ climate + Δ Land-use

Additional changes in Industry, commerse, and trade

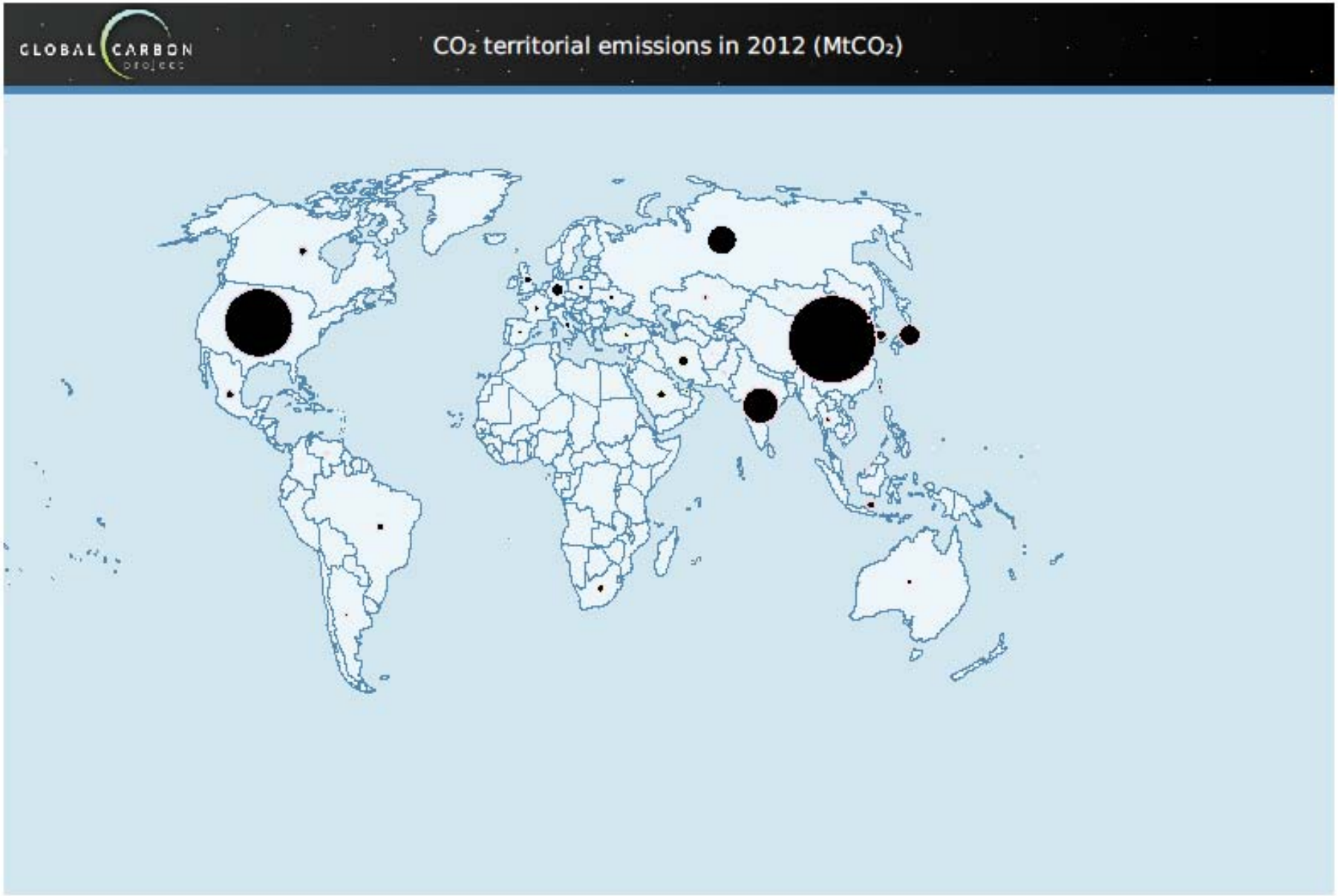


Canadell et al. 2007, PNAS



RCP= Representative Concentration Pathways

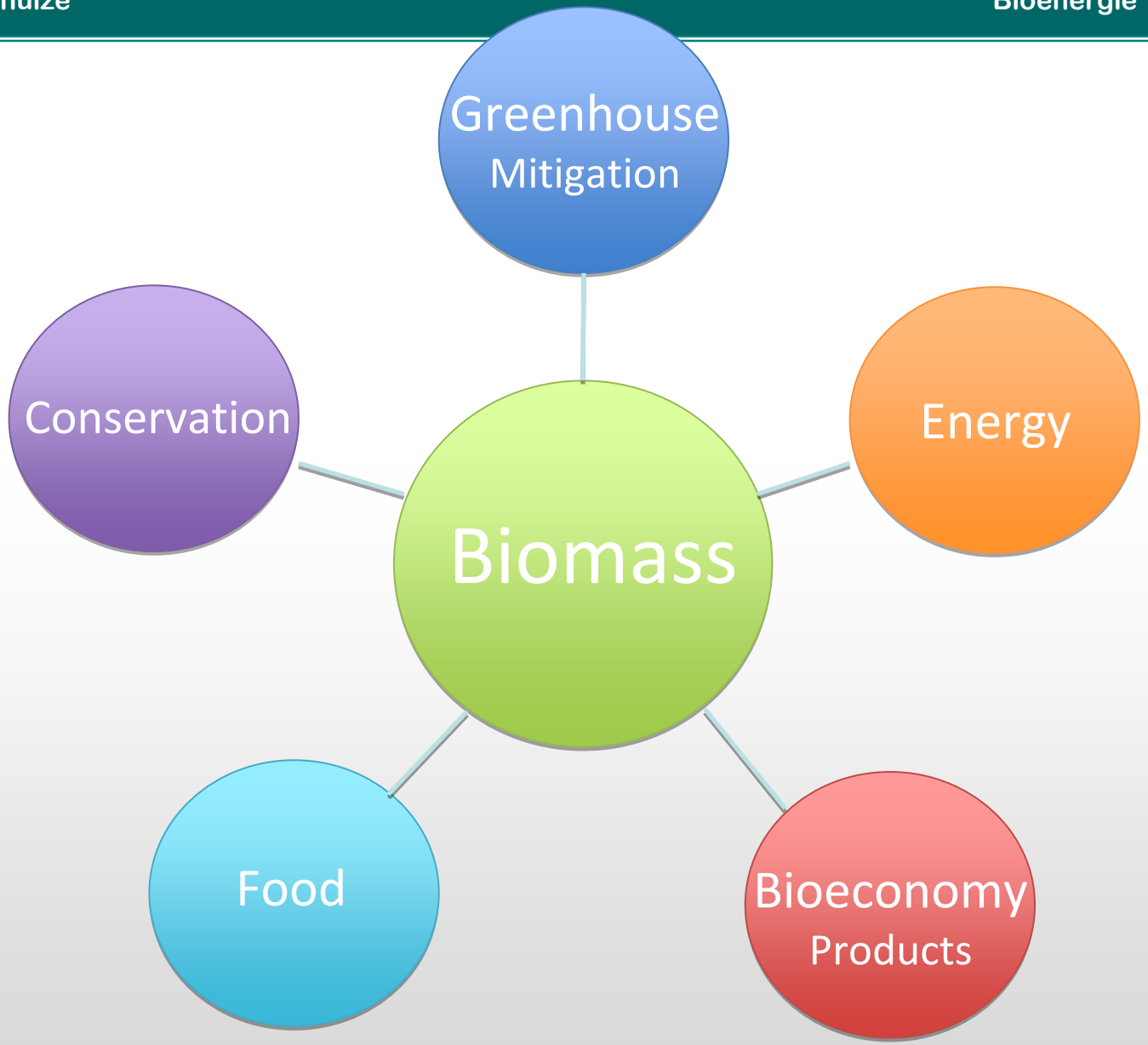
Global Carbon Project, 2012



Global Carbon Project. 2013

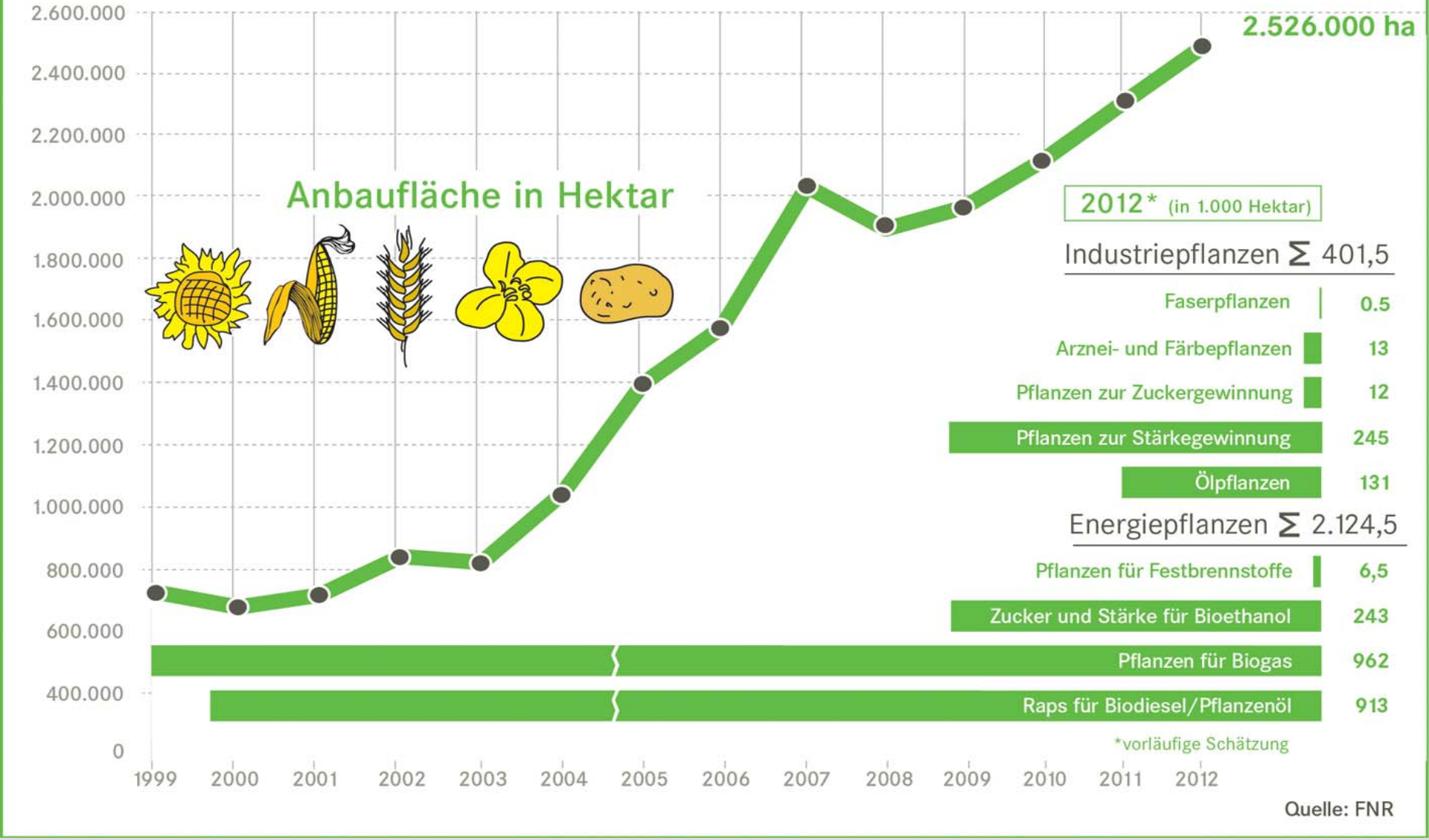
Focus on Bioenergy

- What can bioenergy do?
- The greenhouse gas balance of Europe
- The situation in forestry
- The situation in agriculture
- Global commerce
- conclusions

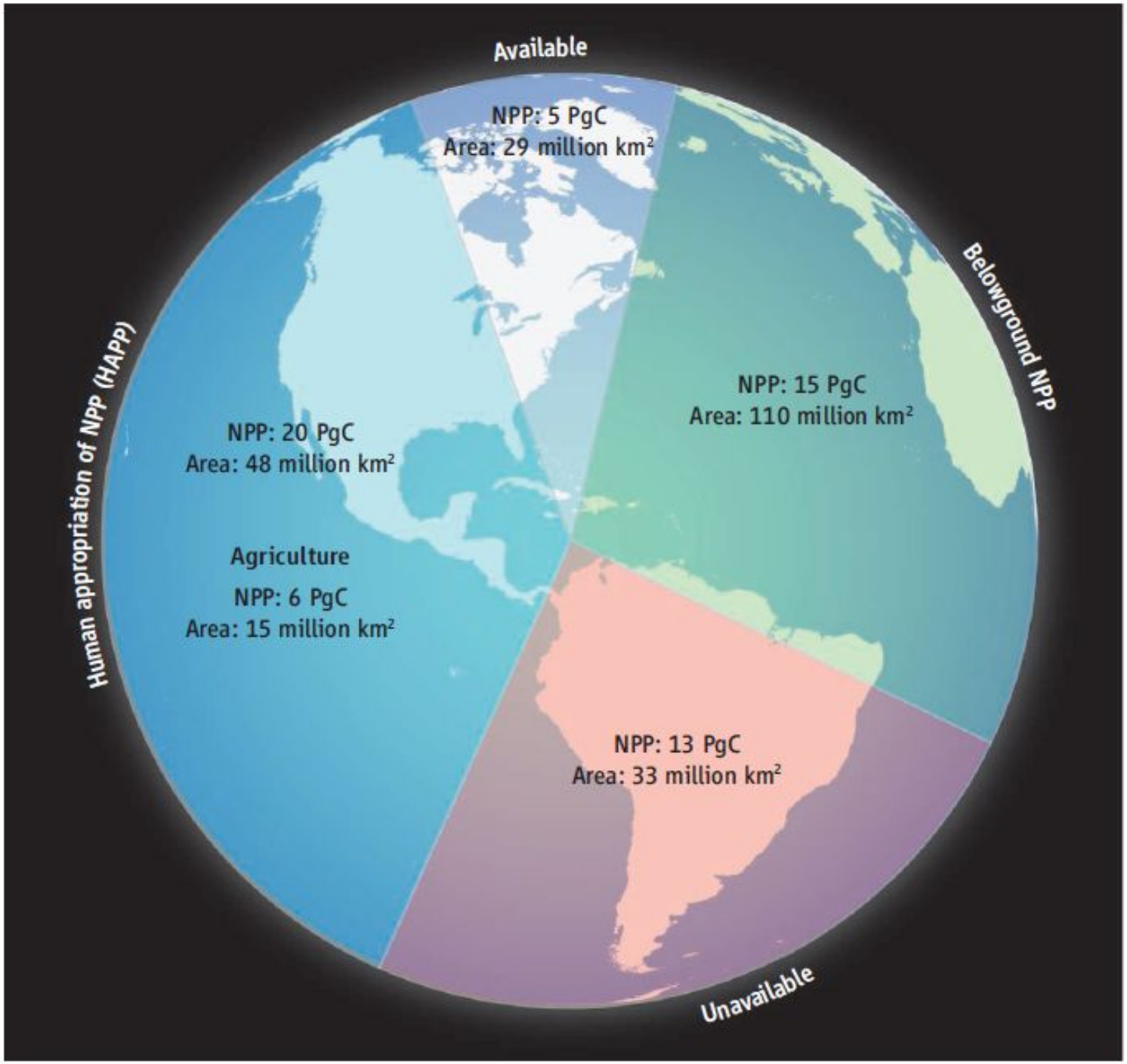


Canadell and Schulze, in preparation

ANBAU NACHWACHSENDER ROHSTOFFE IN DEUTSCHLAND



Zusätzlich zu allen bestehenden Problemen kam die Energiewende:
Eine Verdopplung der Anbaufläche ist geplant



Running, S.
Science
337:1458-1459

Globale NPP:
60 PgC

Human use:
26 Pg (44%)

Germany:
59% of NPP used

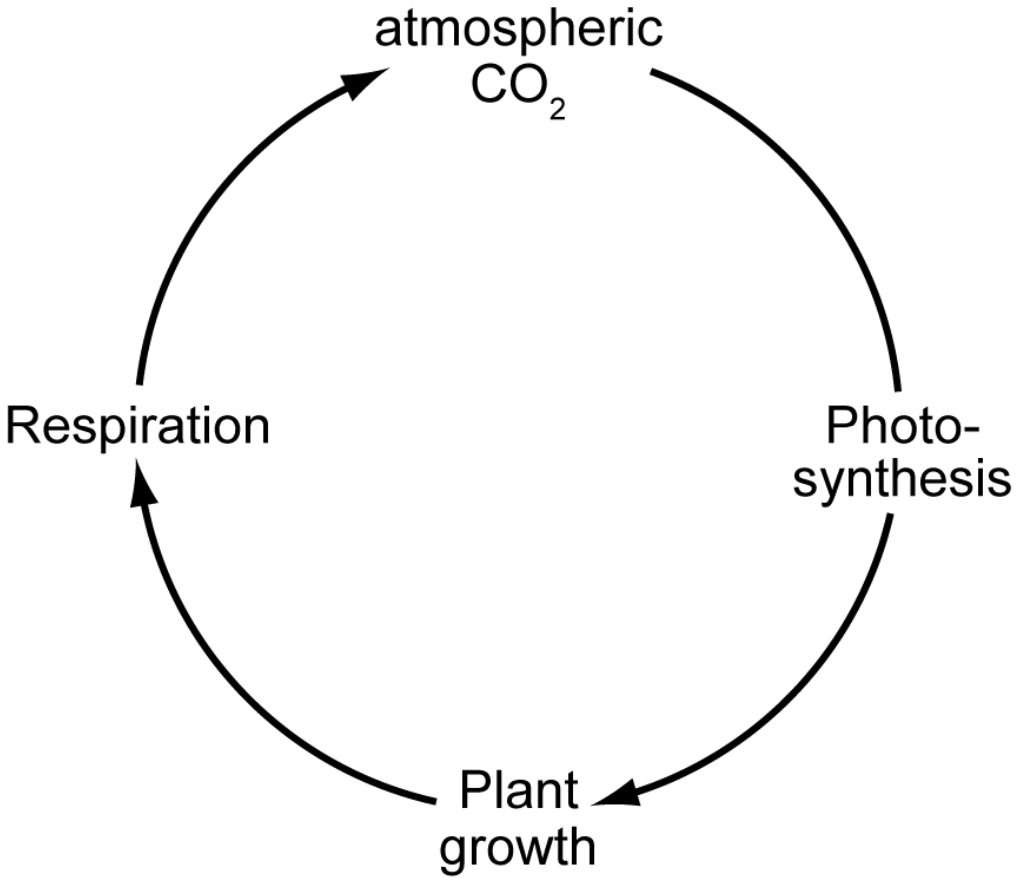
Running, Nature 2012

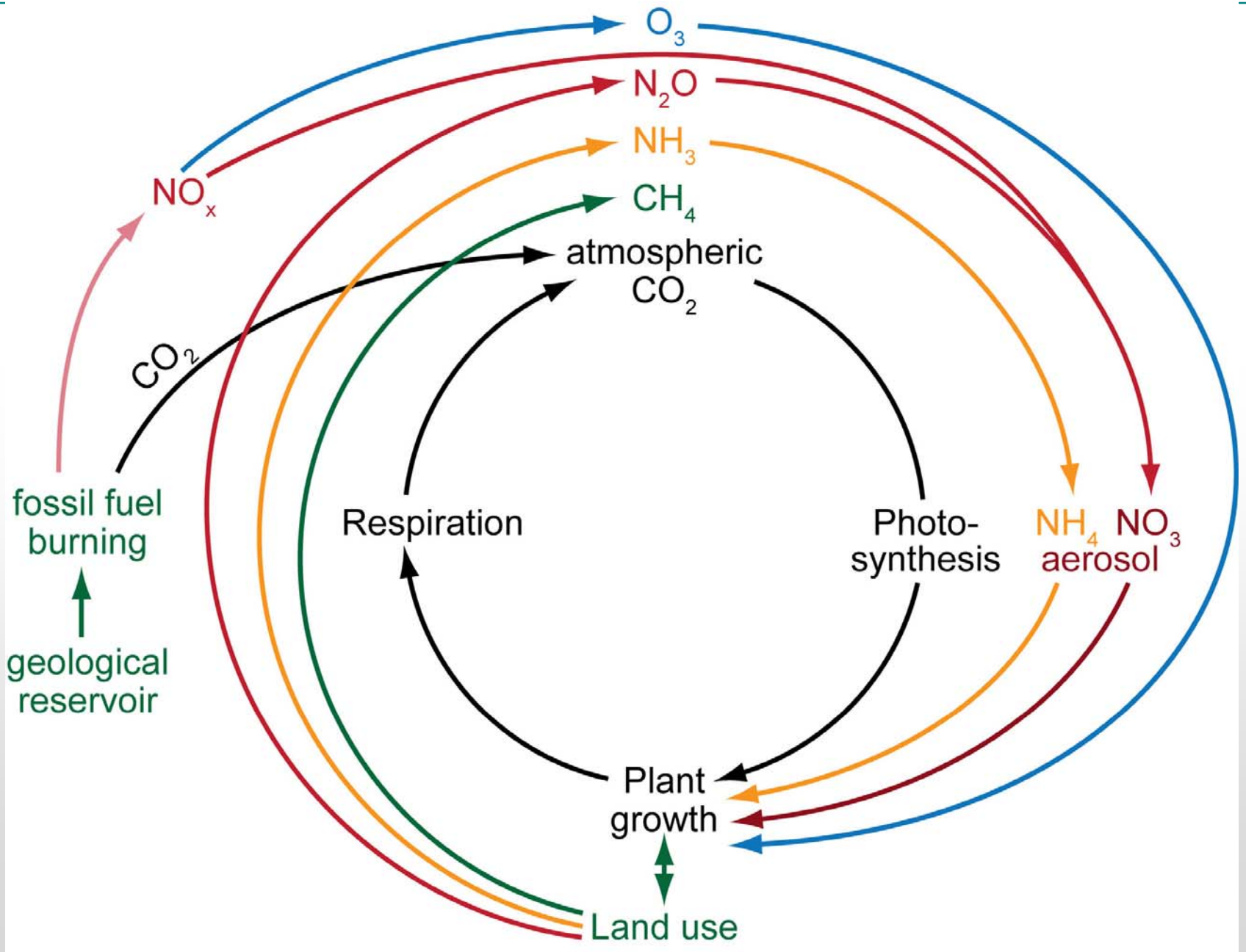
Definition of sustainability: Brundtland-Kommission for Environment and Development of the UN (1987):

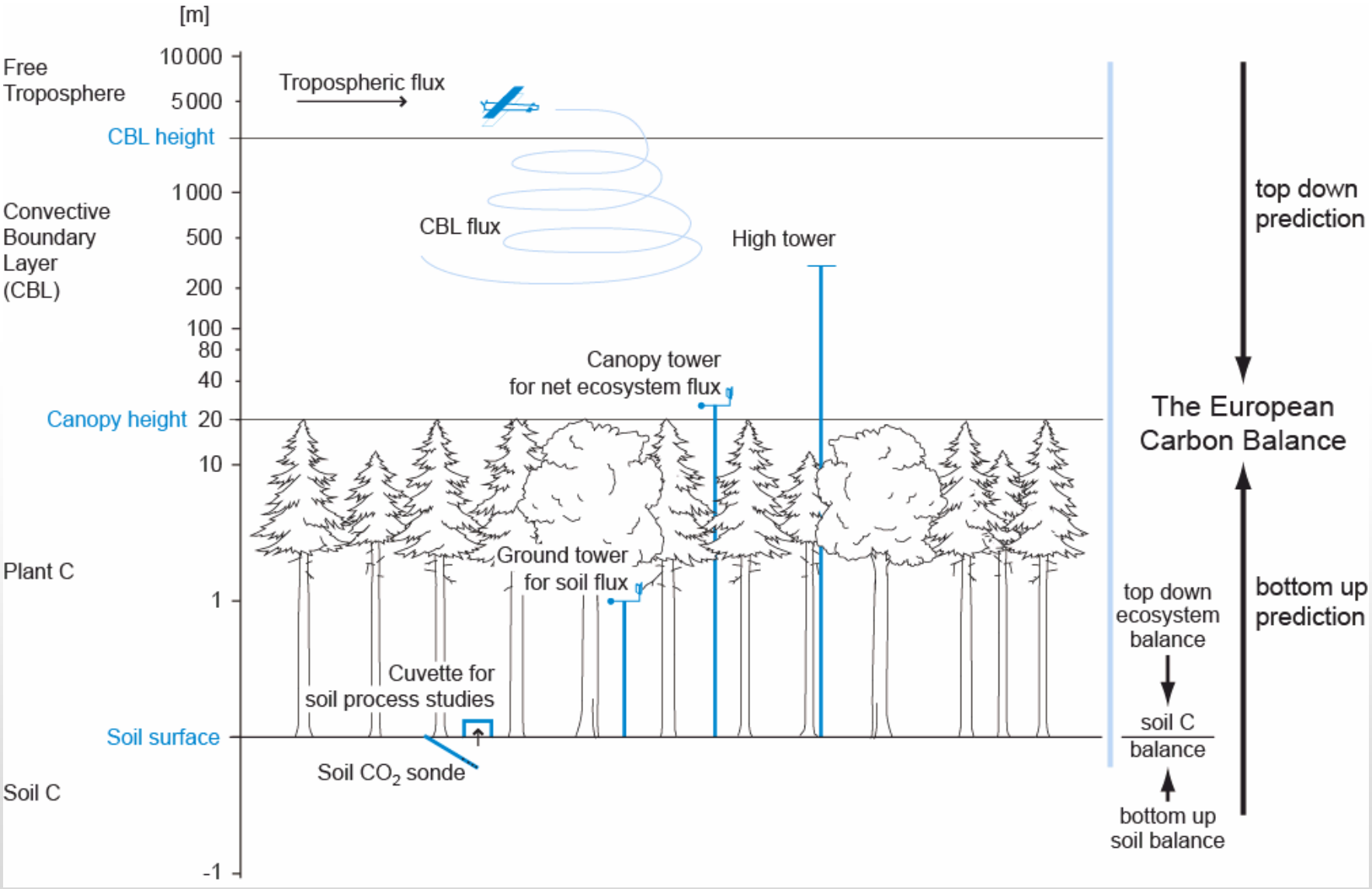
„Development which satisfied the demands of the present Generation without compromising the chances of future generations“

- **The greenhousegas balance of Europe**

A simplified C cycle




O_3
N_2O
NH_3
CH_4
NO_x
atmospheric CO_2
CO_2
fossil fuel burning
geological reservoir
Respiration
Photo-synthesis
NH_4 NO_3 aerosol
Plant growth
Land use

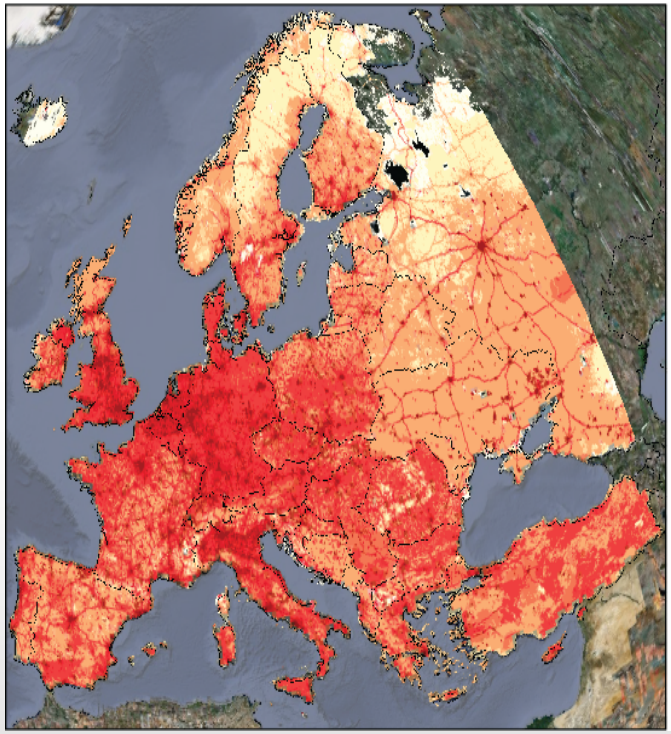


CarboEurope, 2009

Verification of the budgets (10^6 t y^{-1})

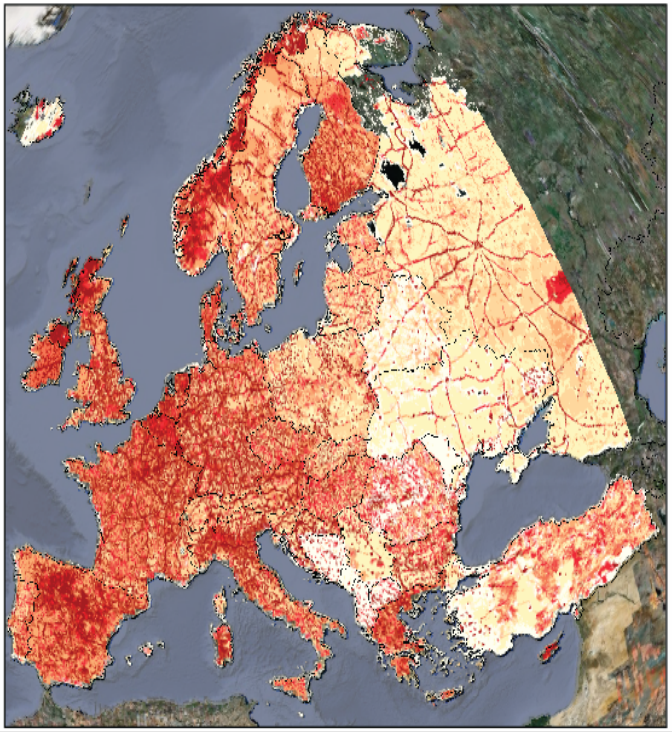
	EU-25 atmosphere-	land-based
CO_2-flux	-134 ± 303	-124 ± 54
CH_4-flux	102 ± 40	60 ± 26
N_2O-flux	58 ± 48	70 ± 35
NO_x-flux	8 to 9	9 to 10
GHG-budget	26 ± 227	6 ± 52

There is no verification for NH_3, NO, wet deposition of N:
There is an urgent need for instrument development



Fossil fuel emission of continental Europe [g CO_2 m^{-2} yr^{-1}]

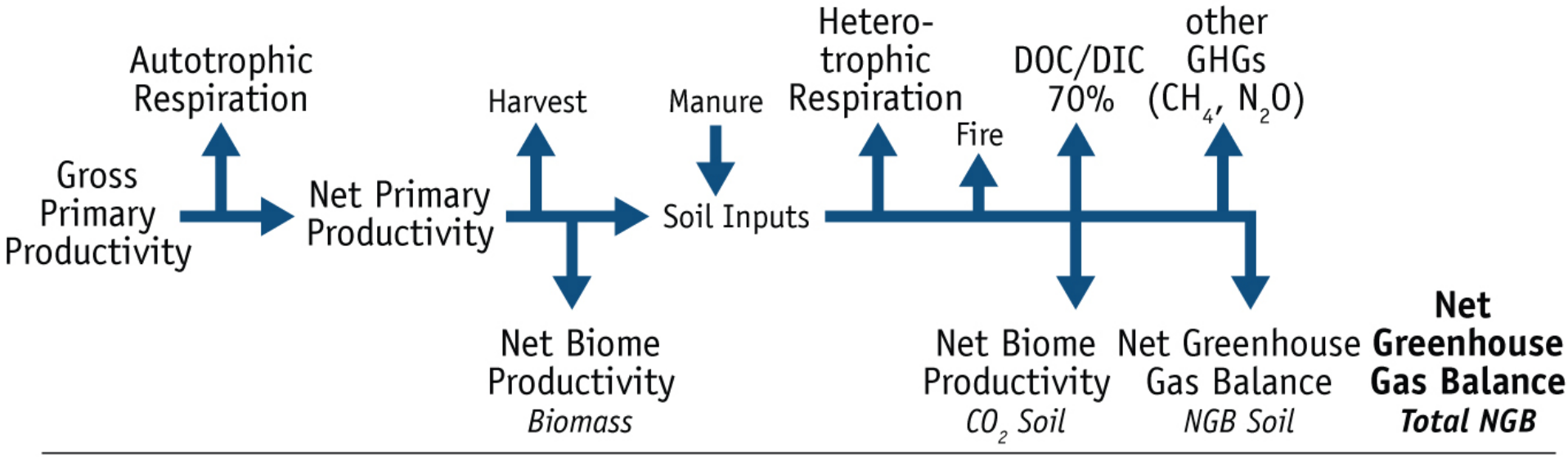
- 0 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- 50 - 100
- 100 - 500
- 500 - 1000
- 1000 - 5000
- >5000



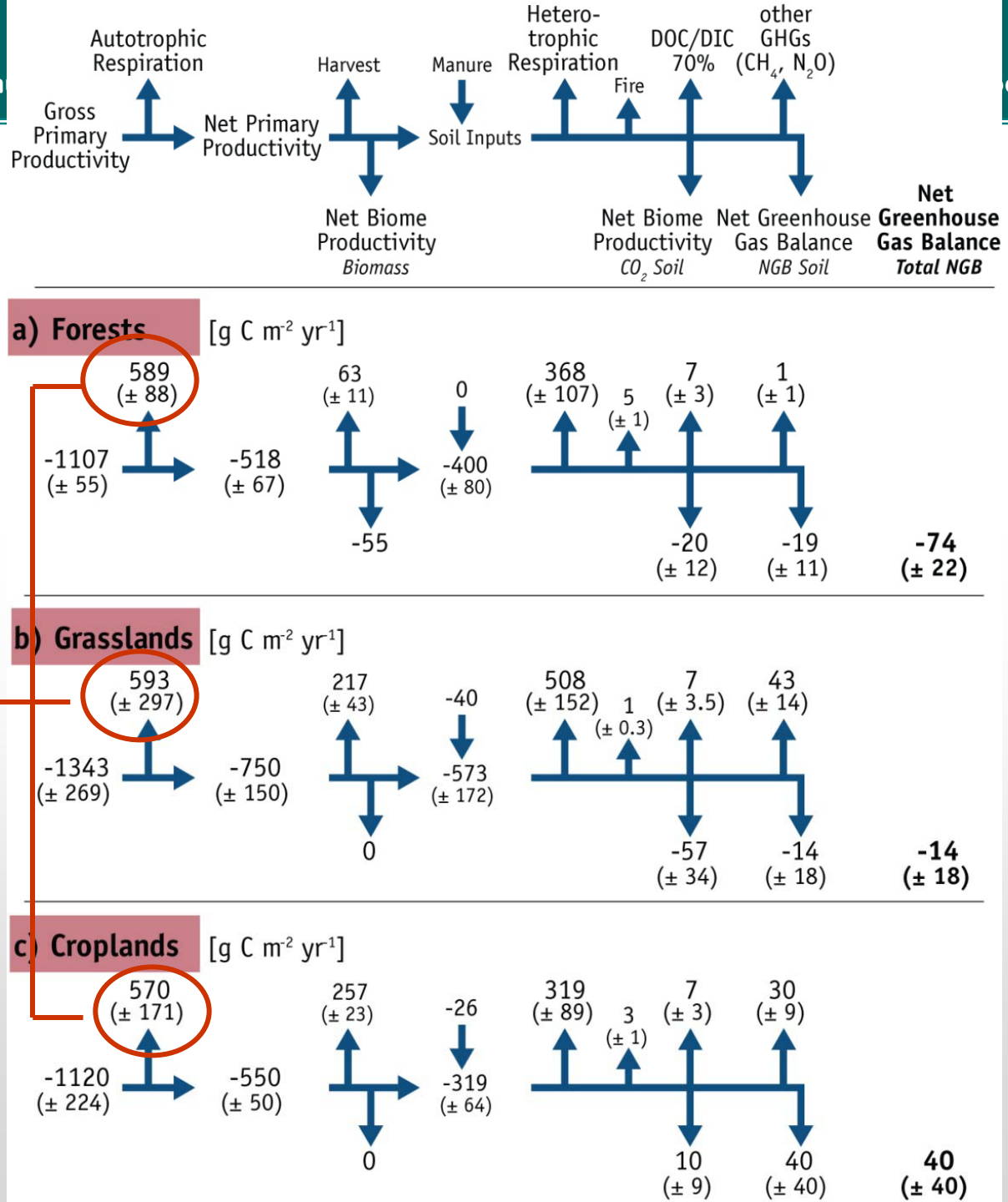
Fossil fuel emission per population [10^6 g CO_2 $person^{-1}$ yr^{-1}]

- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 7.5
- 7.5 - 10
- >10

Schulze et al., 2010
IER Stuttgart

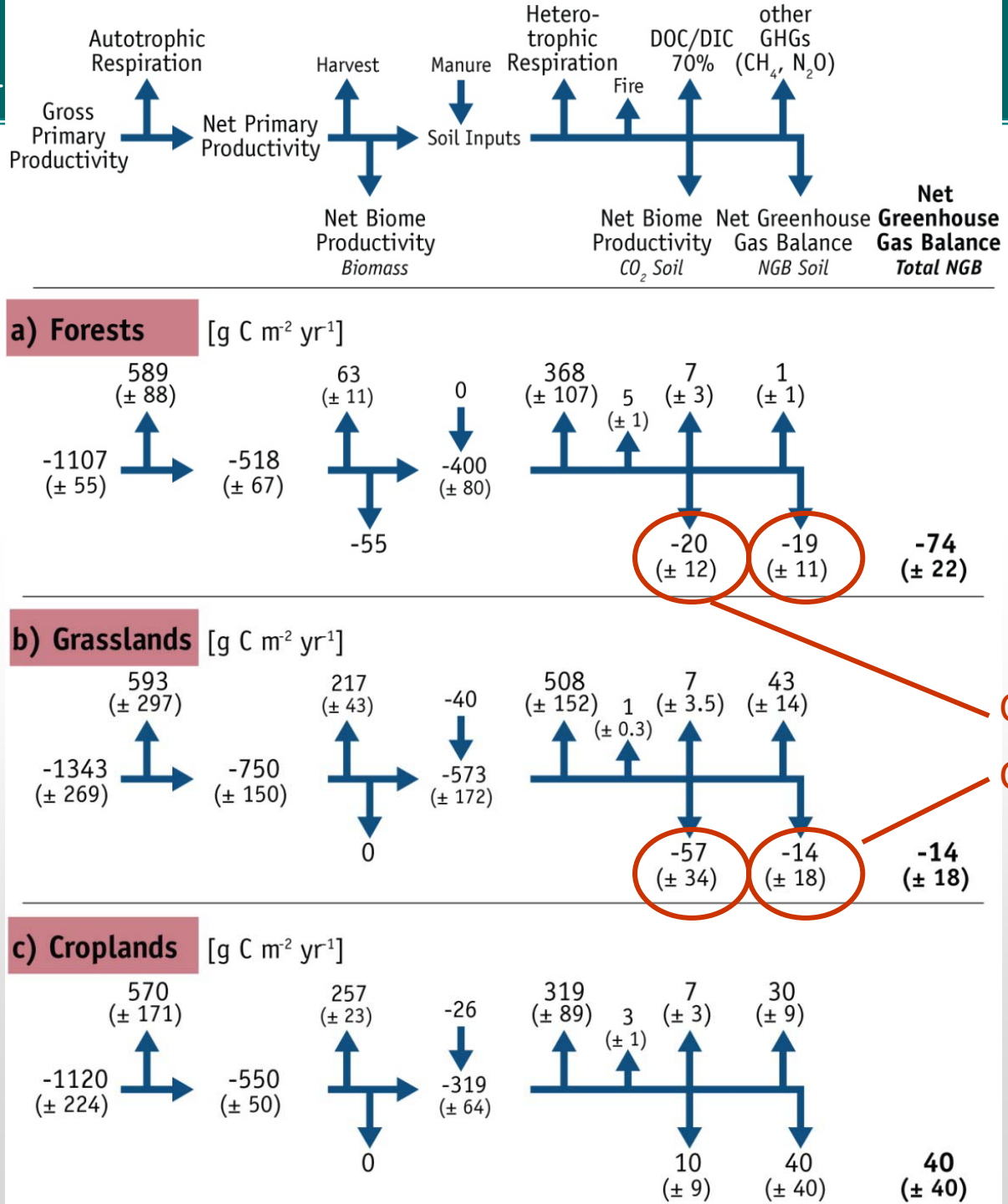


Schulze et al., 2009



at canopy level GPP is very similar

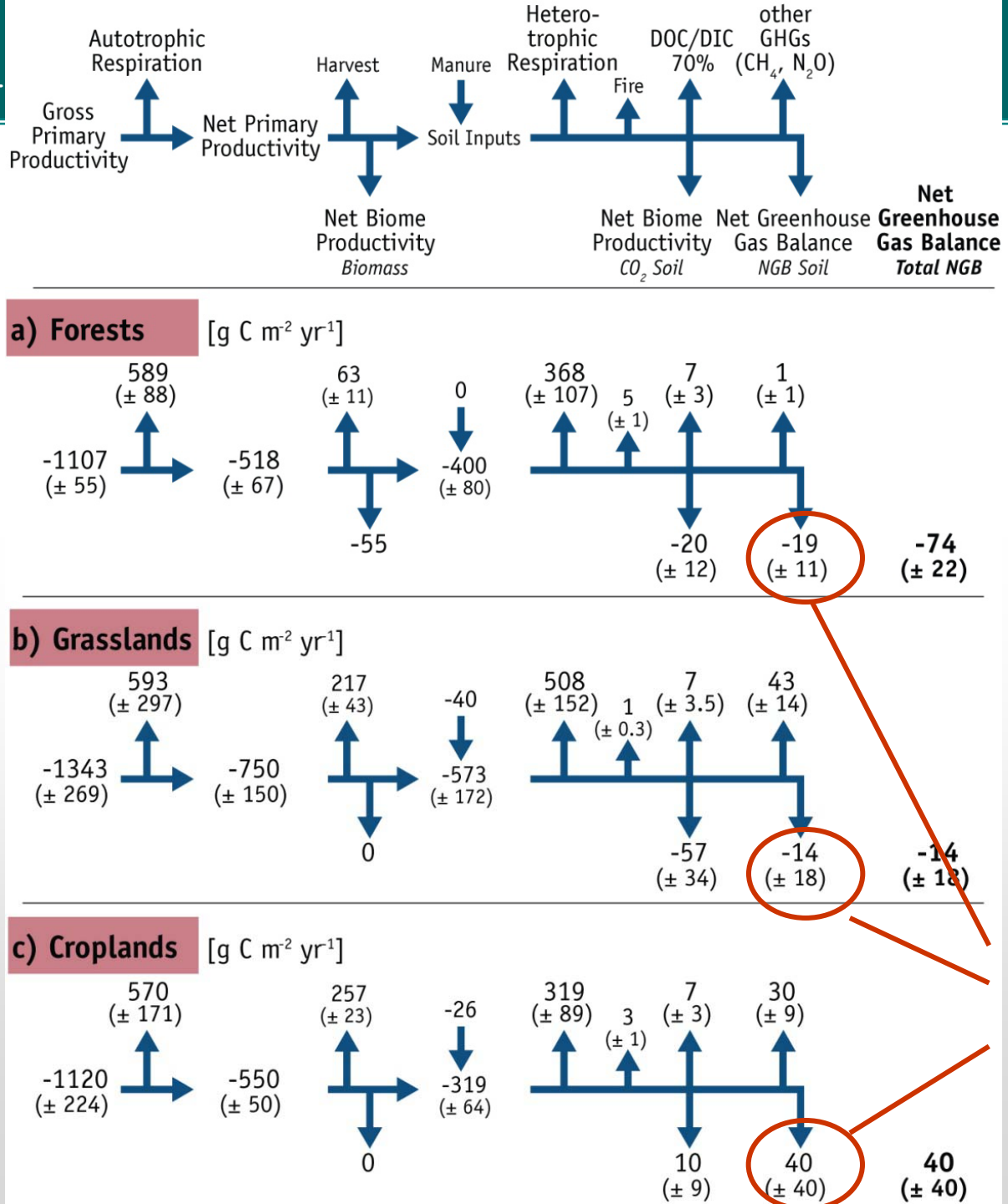
Schulze et al., 2009



C: grass > forest

GHG: grass <forest

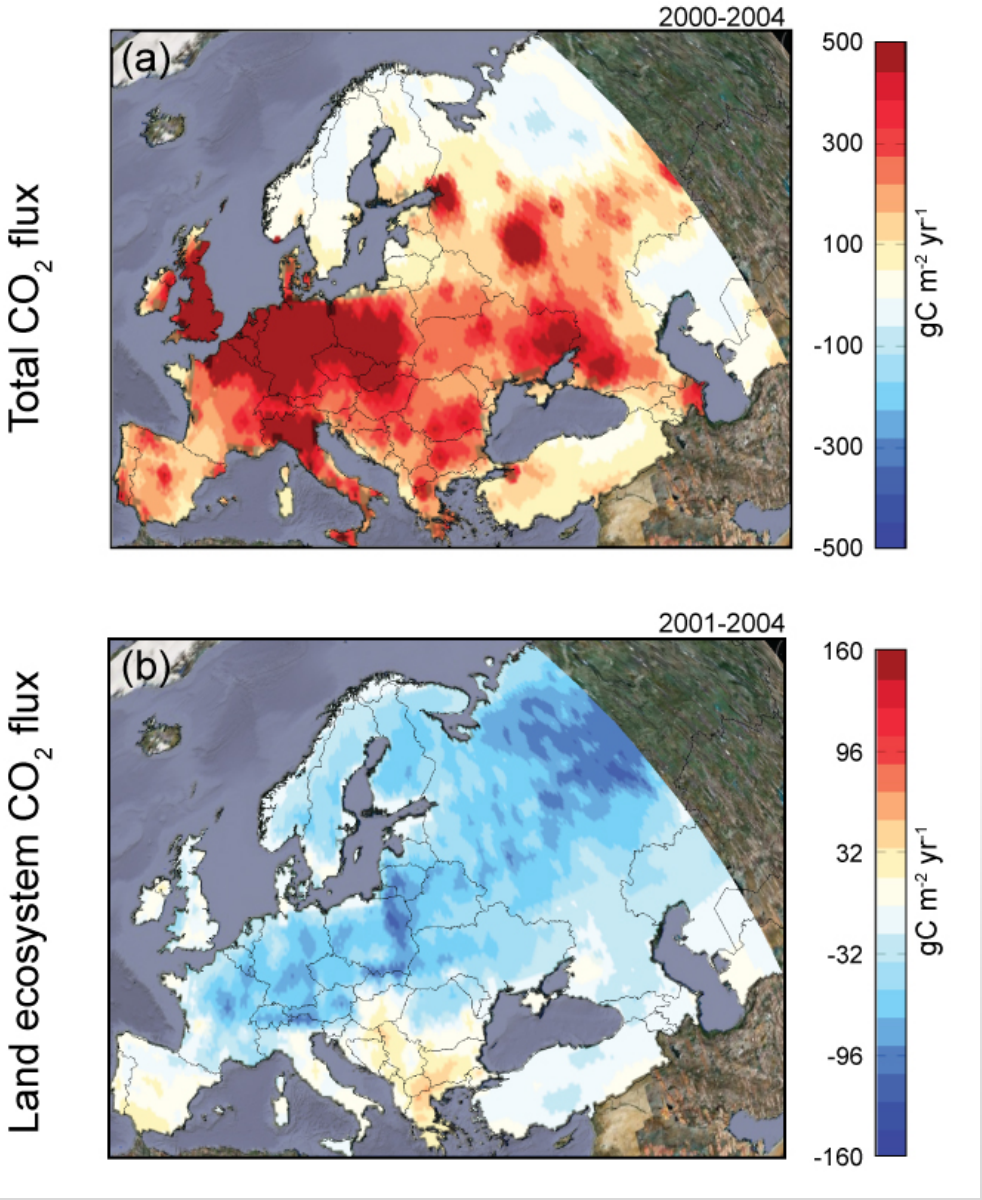
Schulze et al., 2009



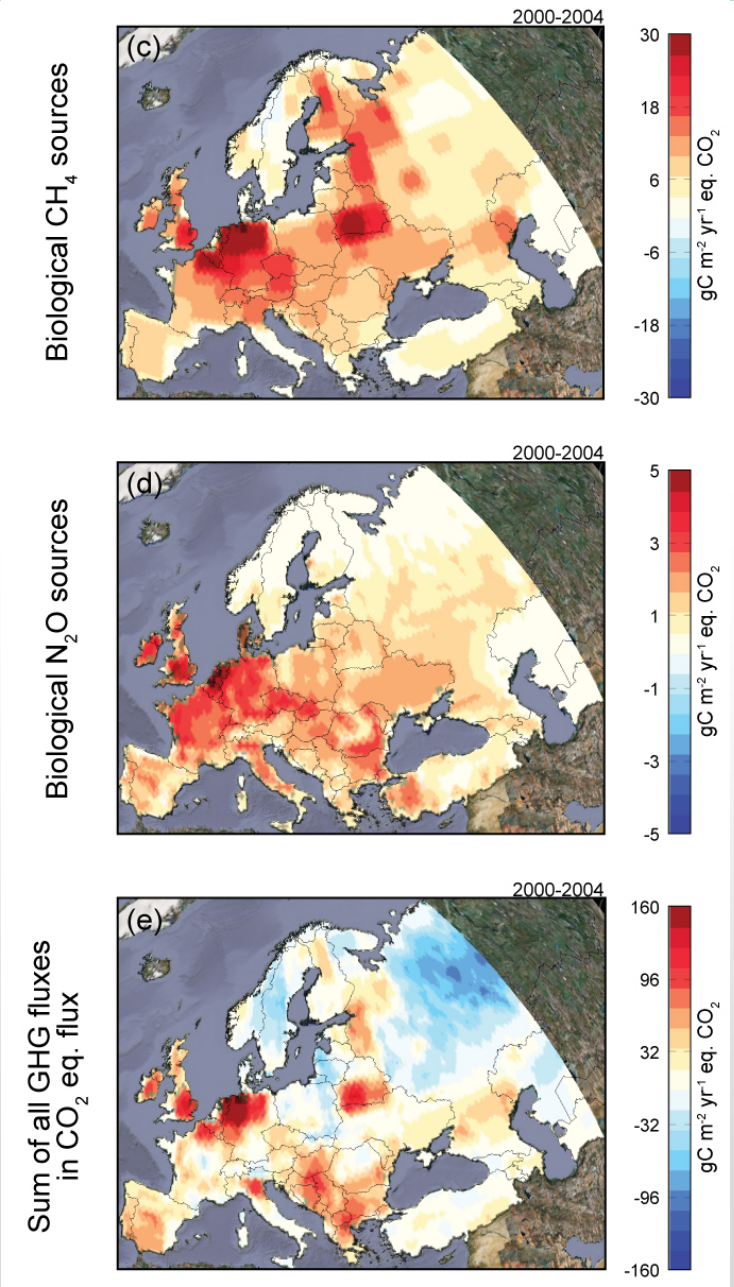
other GHG

- cropland losses = grass+forest

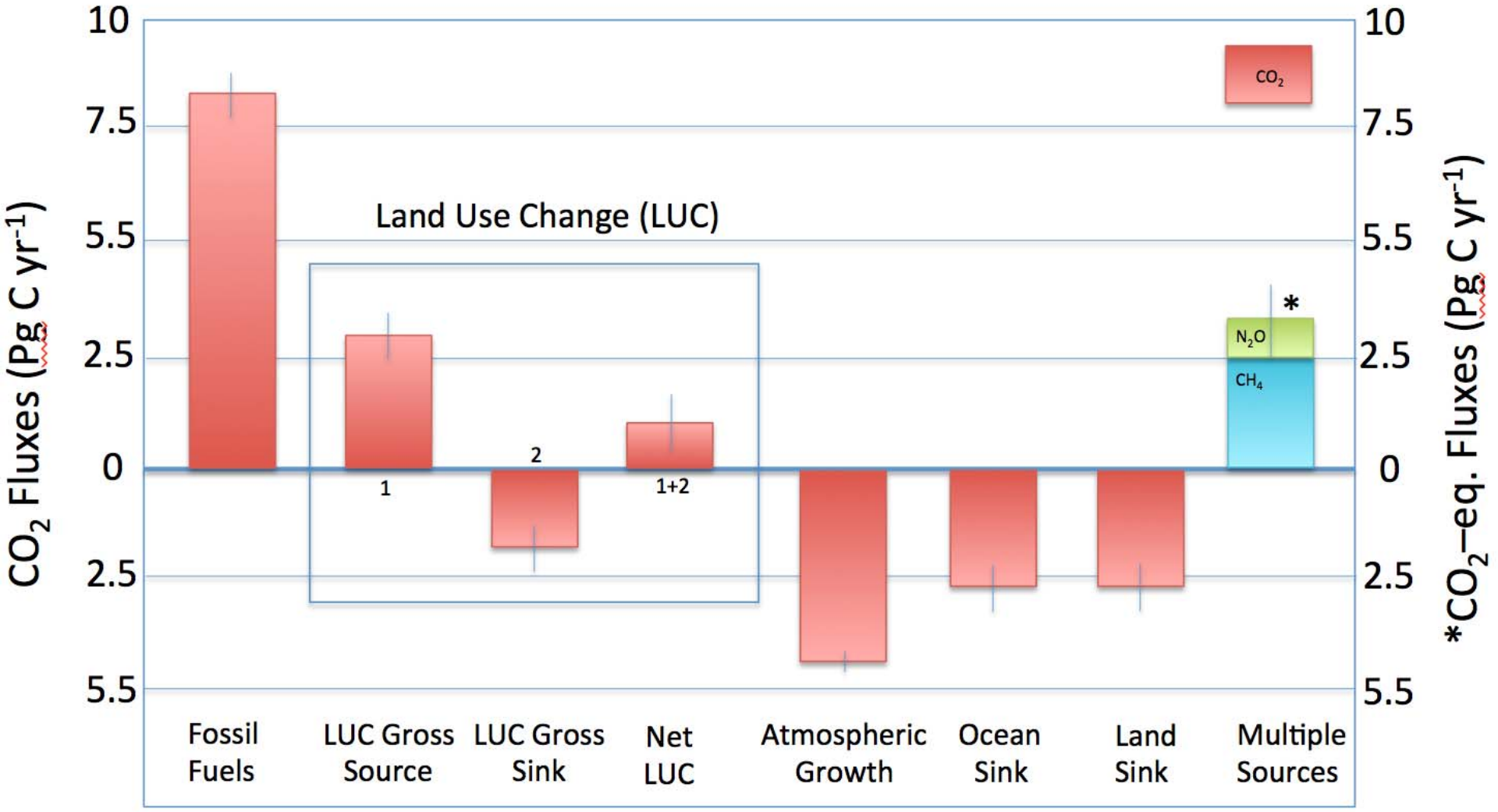
Schulze et al., 2009

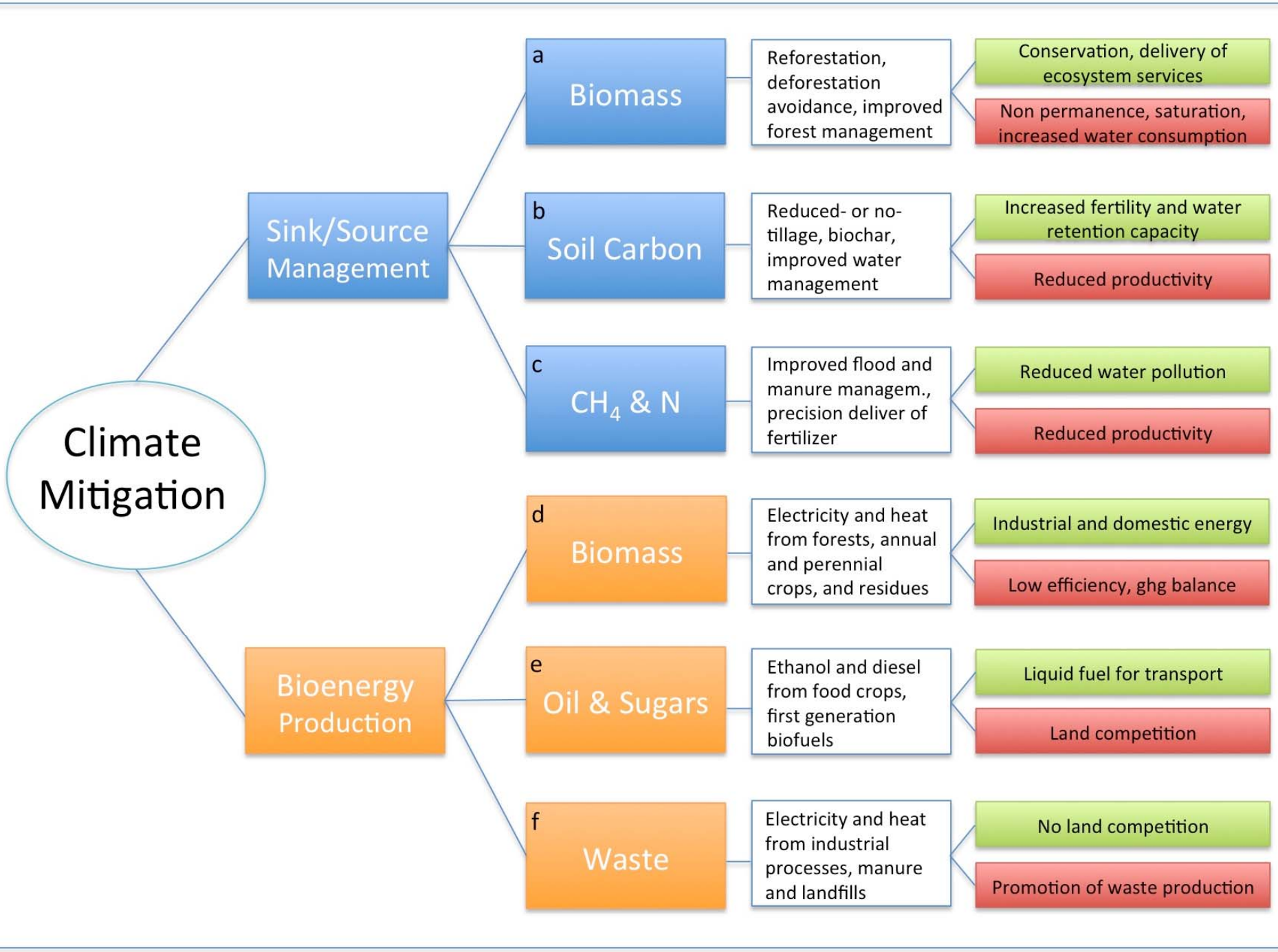


Schulze et al., 2009



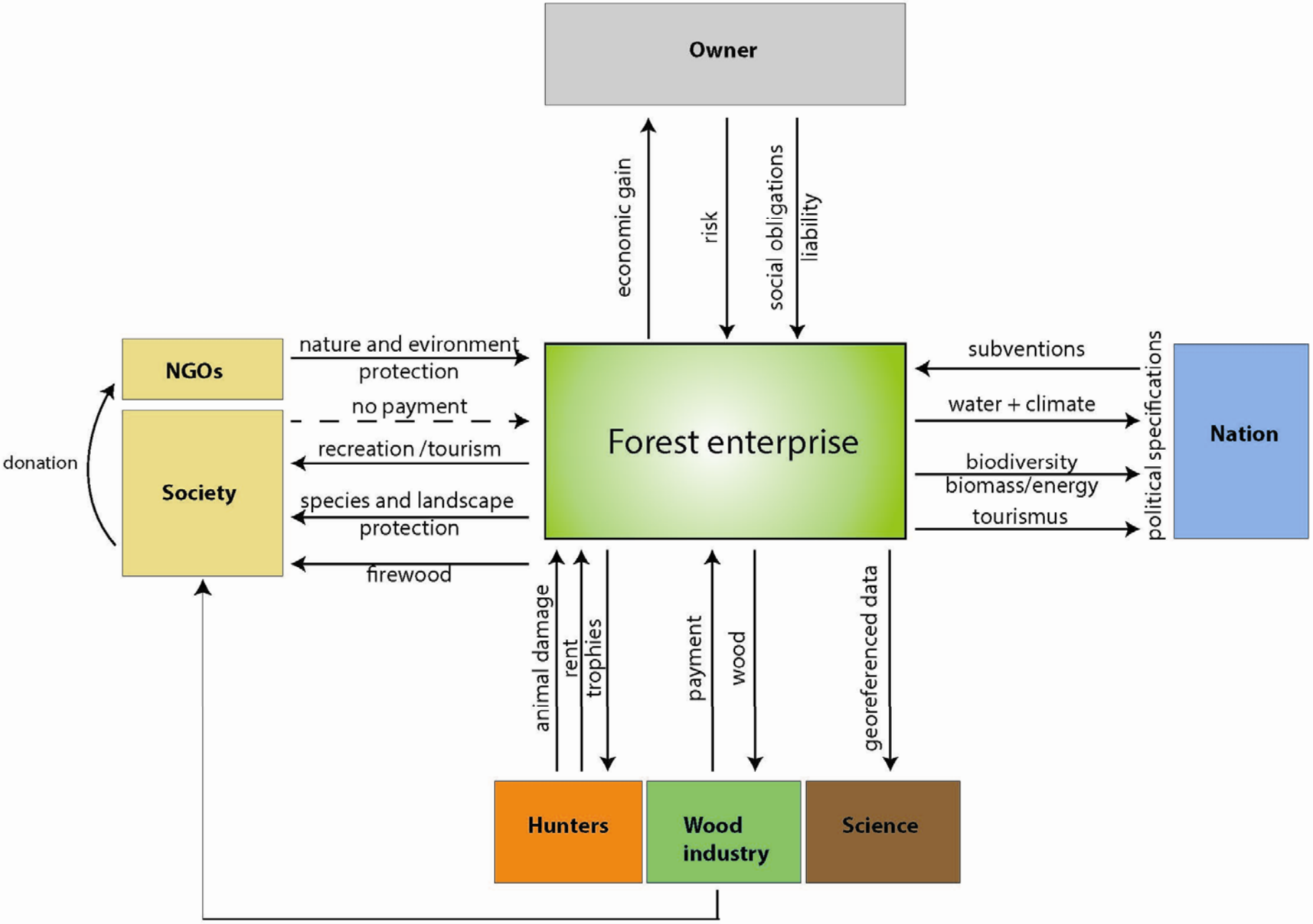
Schulze et al., 2009

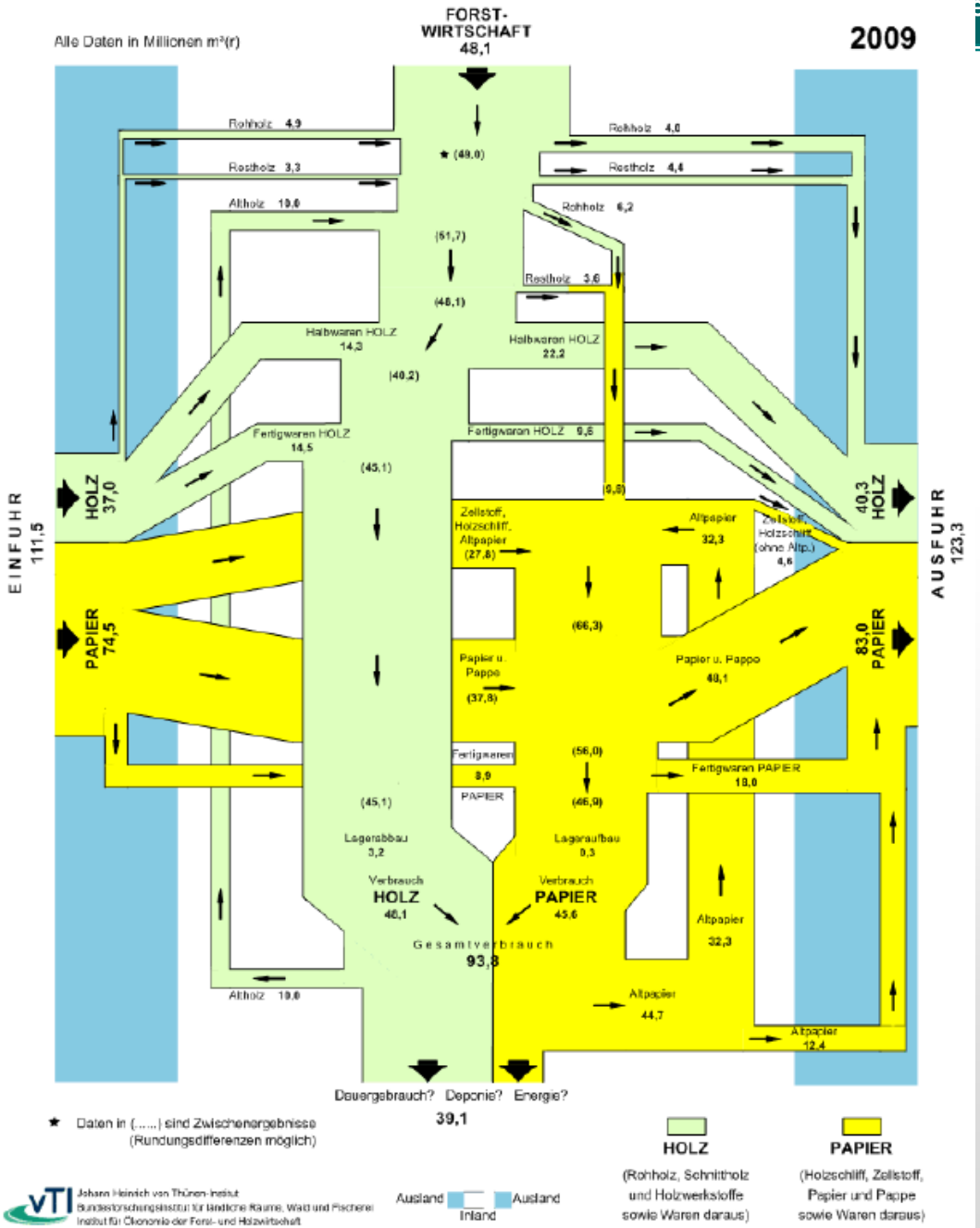

10
7.5
5.5
2.5
0
2.5
5.5
CO_2 Fluxes (Pg C yr^{-1})
*CO_2–eq. Fluxes (Pg C yr^{-1})
Land Use Change (LUC)
CO_2
N_2O
CH_4
*
1
2
1+2
Fossil Fuels
LUC Gross Source
LUC Gross Sink
Net LUC
Atmospheric Growth
Ocean Sink
Land Sink
Multiple Sources


Climate Mitigation
Sink/Source Management
Bioenergy Production
a
Biomass
b
Soil Carbon
c
CH_4 & N
d
Biomass
e
Oil & Sugars
f
Waste
Reforestation, deforestation avoidance, improved forest management
Reduced- or no-tillage, biochar, improved water management
Improved flood and manure managem., precision deliver of fertilizer
Electricity and heat from forests, annual and perennial crops, and residues
Ethanol and diesel from food crops, first generation biofuels
Electricity and heat from industrial processes, manure and landfills
Conservation, delivery of ecosystem services
Non permanence, saturation, increased water consumption
Increased fertility and water retention capacity
Reduced productivity
Reduced water pollution
Reduced productivity
Industrial and domestic energy
Low efficiency, ghg balance
Liquid fuel for transport
Land competition
No land competition
Promotion of waste production

- **The situation in German Forestry**

21/05/2012 09:41


Owner
economic gain
risk
social obligations
liability
NGOs
nature and evironment protection
no payment
recreation /tourism
species and landscape protection
firewood
donation
Society
Forest enterprise
subventions
water + climate
biodiversity
biomass/energy
tourismus
political specifications
Nation
animal damage
rent
trophies
payment
wood
georeferenced data
Hunters
Wood industry
Science

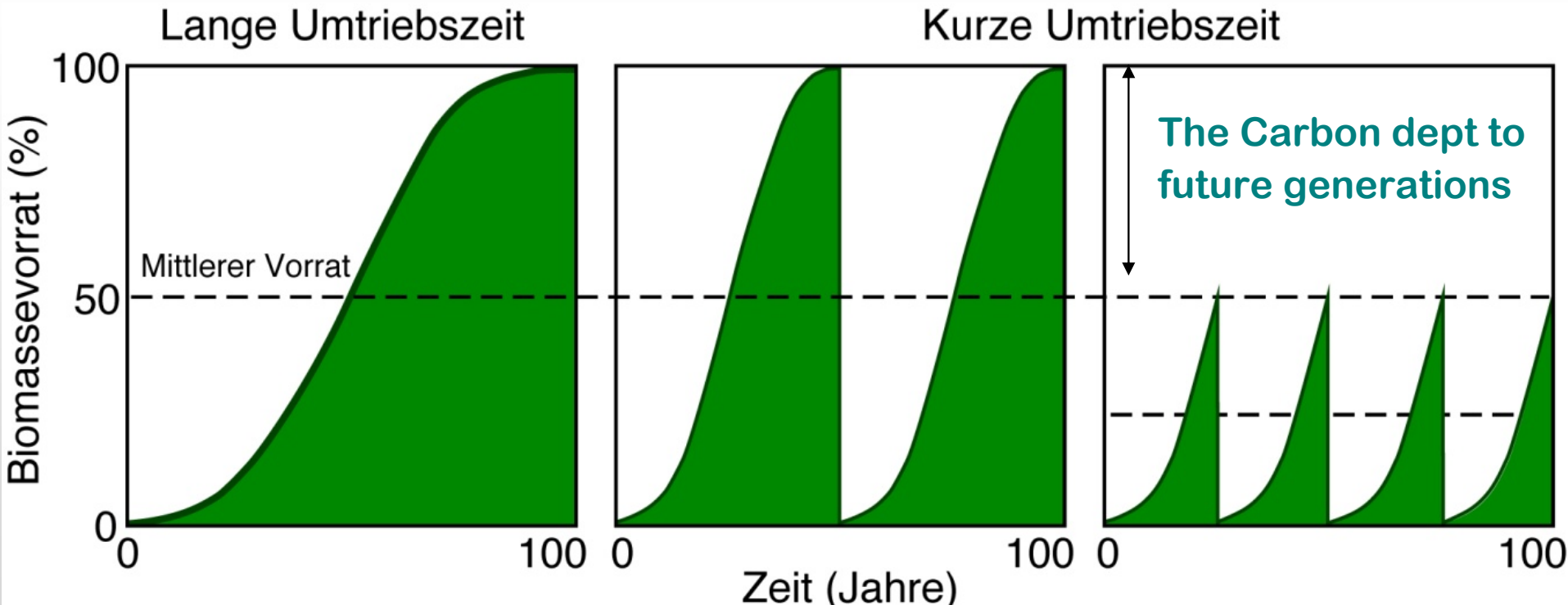

Forst – und Holzwirtschaft
BUNDESREPUBLIK DEUTSCHLAND
Alle Daten in Millionen m³(r)
FORST-WIRTSCHAFT 48,1
2009
Rohholz 4,9
Restholz 3,3
Altholz 19,0
★ (49,0)
Rohholz 4,0
Restholz 4,4
Rohholz 6,2
Restholz 3,6
(51,7)
(48,1)
Halbwaren HOLZ 14,3
Halbwaren HOLZ 22,2
(40,2)
Fertigwaren HOLZ 14,5
Fertigwaren HOLZ 9,6
(45,1)
9,9
EINFUHR 111,5
HOLZ 37,0
PAPIER 74,5
40,3 HOLZ
83,0 PAPIER
AUSFUHR 123,3
Zellstoff, Holzschliff, Altpapier (27,8)
Altpapier 32,3
Zellstoff, Holzschliff (ohne Altp.) 4,6
(66,3)
Papier u. Pappe (37,8)
Papier u. Pappe 40,1
Fertigwaren 8,9
PAPIER
(56,0)
(46,9)
Fertigwaren PAPIER 18,0
(45,1)
Lagerabbau 3,2
Lageraufbau 0,3
Verbrauch HOLZ 46,1
Verbrauch PAPIER 45,6
Gesamtverbrauch 93,8
Altpapier 32,3
Altholz 19,0
Altpapier 44,7
Altpapier 12,4
Dauergebrauch? Deponie? Energie?
39,1
★ Daten in (.....) sind Zwischenergebnisse (Rundungsdifferenzen möglich)
HOLZ
(Rohholz, Schnittholz und Holzwerkstoffe sowie Waren daraus)
PAPIER
(Holzschliff, Zellstoff, Papier und Pappe sowie Waren daraus)
Ausland
Inland
Ausland
Johann Heinrich von Thünen-Institut
Bundesforschungsinstitut für ländliche Räume, Wald und Fischerei
Institut für Ökonomie der Forst- und Holzwirtschaft

Arguments for a reduced rotation:

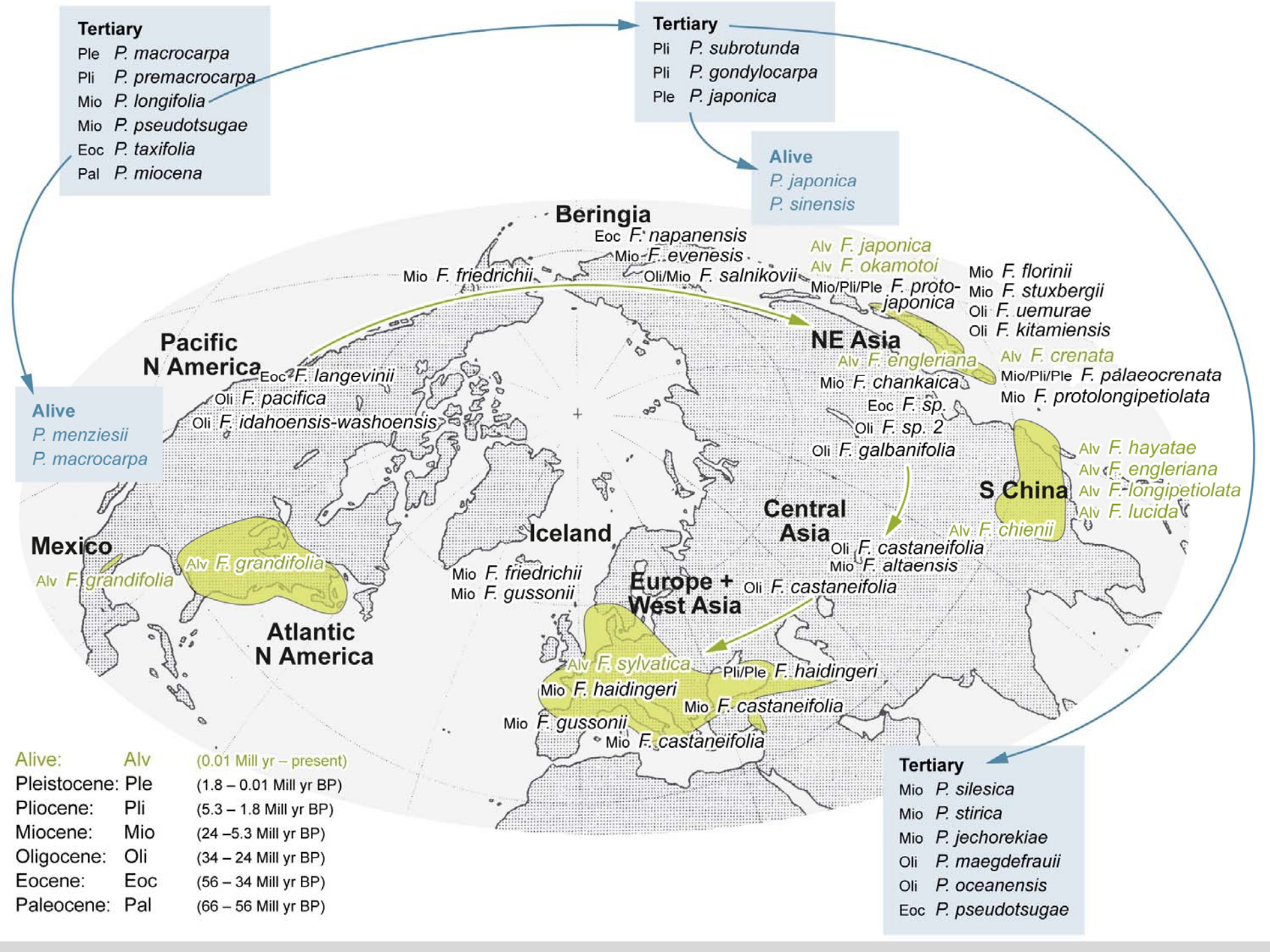
- Risc of windthrow increases for age >60
- Wood industry demands Sapwood
- Preices maximse at 25 cm diameter
- Lower dimensions sold as bioenergy

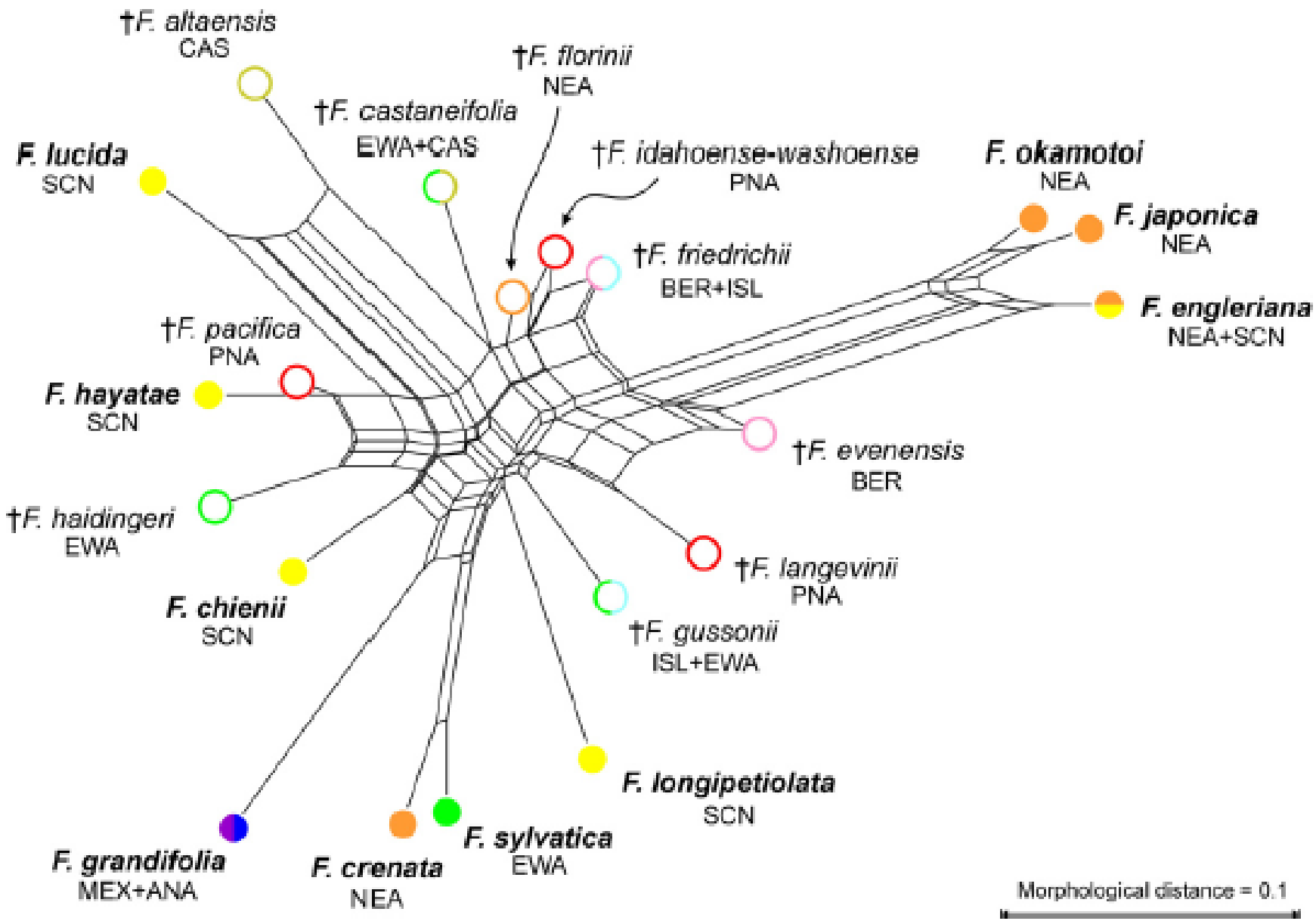
Arguments agains reduced rotation

- No deadwood (Biodiv Hotspot)
- No old trees (Birds)
- Reduced recreation value
- 1 Mill m^3: 5% of fossil fuel consumption
- Douglas fir unwanted by NGO‘s



Number of tree species	Central Europe	NE-America	NE-Asia
Broad leaved	55	203	733
Coniferous	8	33	94
Total	63	236	827


Tertiary
Ple P. macrocarpa
Pli P. premacrocarpa
Mio P. longifolia
Mio P. pseudotsugae
Eoc P. taxifolia
Pal P. miocena
Tertiary
Pli P. subrotunda
Pli P. gondylocarpa
Ple P. japonica
Alive
P. japonica
P. sinensis
Alive
P. menziesii
P. macrocarpa
Beringia
Eoc F. napanensis
Mio F. evenesis
Mio F. friedrichii
Oli/Mio F. salnikovii
Alv F. japonica
Alv F. okamotoi
Mio/Pli/Ple F. proto-japonica
Mio F. florinii
Mio F. stuxbergii
Oli F. uemurae
Oli F. kitamiensis
NE Asia
Alv F. engleriana
Alv F. crenata
Mio F. chankaica
Mio/Pli/Ple F. pálaeocrenata
Mio F. protolongipetiolata
Eoc F. sp.
Oli F. sp. 2
Oli F. galbanifolia
Pacific N America
Eoc F. langevinii
Oli F. pacifica
Oli F. idahoensis-washoensis
S China
Alv F. hayatae
Alv F. engleriana
Alv F. longipetiolata
Alv F. lucida
Alv F. chienii
Central Asia
Oli F. castaneifolia
Mio F. altaensis
Iceland
Mio F. friedrichii
Mio F. gussonii
Mexico
Alv F. grandifolia
Alv F. grandifolia
Europe + West Asia
Oli F. castaneifolia
Atlantic N America
Alv F. sylvatica
Pli/Ple F. haidingeri
Mio F. haidingeri
Mio F. castaneifolia
Mio F. gussonii
Mio F. castaneifolia
Tertiary
Mio P. silesica
Mio P. stirica
Mio P. jechorekiae
Oli P. maegdefrauii
Oli P. oceanensis
Eoc P. pseudotsugae
Alive: Alv (0.01 Mill yr – present)
Pleistocene: Ple (1.8 – 0.01 Mill yr BP)
Pliocene: Pli (5.3 – 1.8 Mill yr BP)
Miocene: Mio (24 –5.3 Mill yr BP)
Oligocene: Oli (34 – 24 Mill yr BP)
Eocene: Eoc (56 – 34 Mill yr BP)
Paleocene: Pal (66 – 56 Mill yr BP)


†F. altaensis
CAS
†F. florinii
NEA
†F. castaneifolia
EWA+CAS
F. lucida
SCN
†F. idahoense-washoense
PNA
F. okamotoi
NEA
F. japonica
NEA
†F. friedrichii
BER+ISL
F. engleriana
NEA+SCN
†F. pacifica
PNA
F. hayatae
SCN
†F. evenensis
BER
†F. haidingeri
EWA
†F. langevinii
PNA
F. chienii
SCN
†F. gussonii
ISL+EWA
F. longipetiolata
SCN
F. sylvatica
EWA
F. grandifolia
MEX+ANA
F. crenata
NEA
Morphological distance = 0.1

No Payments for ecosystem services:

- C-sinks, torism biodiversity
- Subventions instead of payment

keine Beteiligung des Erzeugers an der Produktkette

Zahlung
Produkt

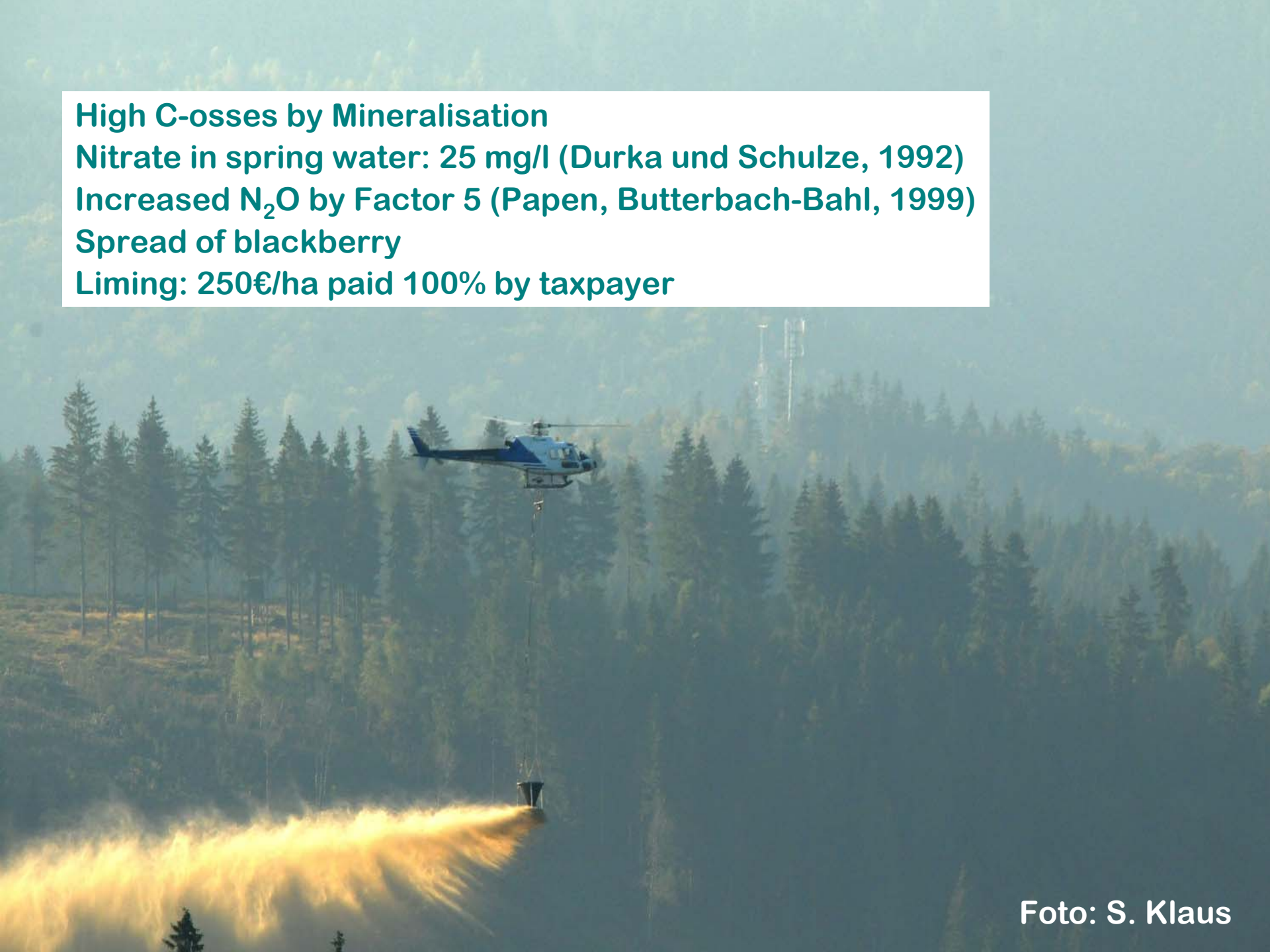
Nutzholz → Abriss → Verkauf an Kraftwerk - Verbrennung

Zellstoff → Recycling → Verkauf an Kraftwerk - Verbrennung

Energie-holz → Hausbrand

Energie-holz → Verbrennung im Kraftwerk

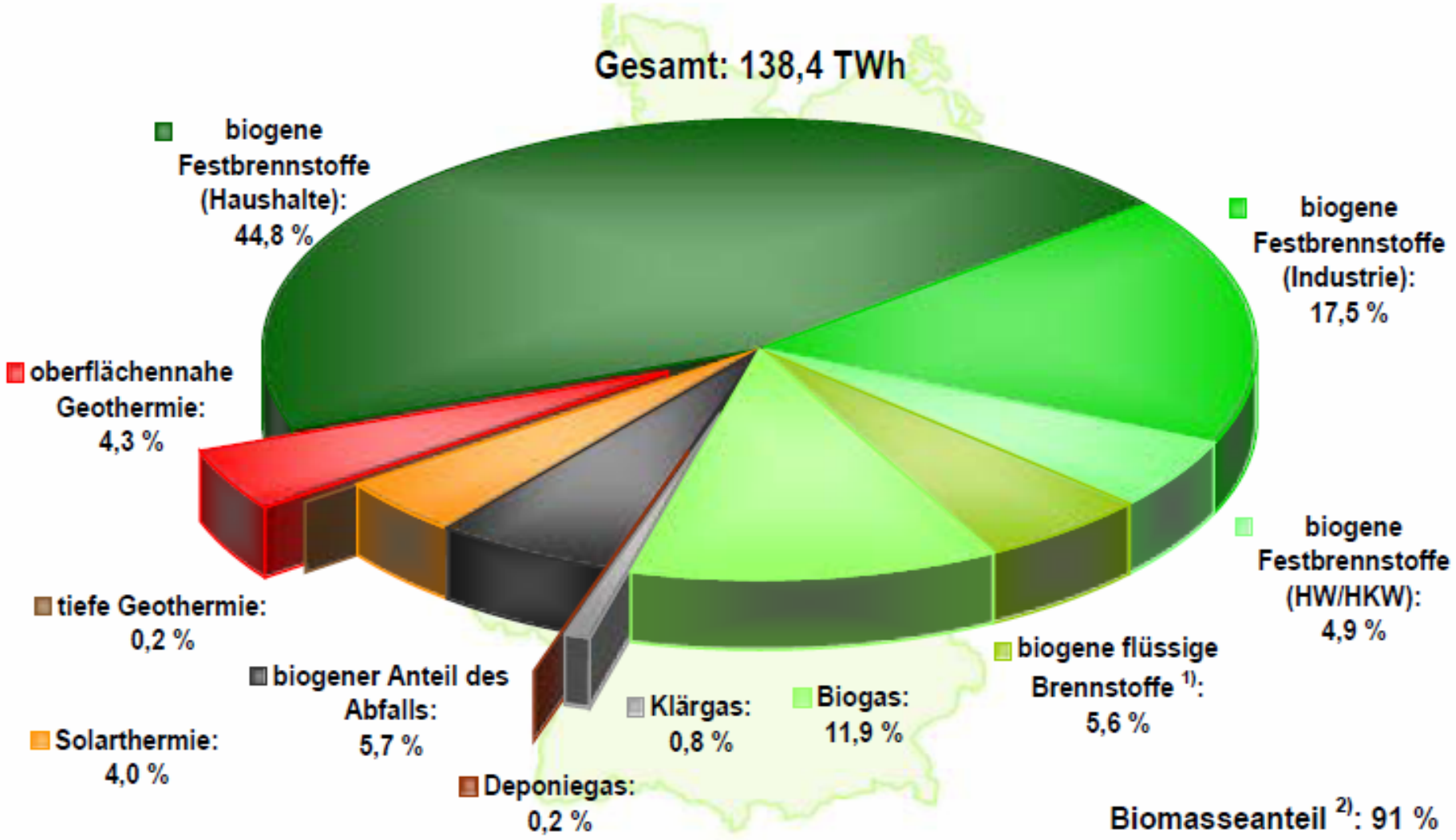
2008/4/18 17:41
Ökostrom ist ökologisch nicht vertretbar



High C-osses by Mineralisation
Nitrate in spring water: 25 mg/l (Durka und Schulze, 1992)
Increased N_2O by Factor 5 (Papen, Butterbach-Bahl, 1999)
Spread of blackberry
Liming: 250€/ha paid 100% by taxpayer

Foto: S. Klaus

Struktur der Wärmebereitstellung aus erneuerbaren Energien in Deutschland im Jahr 2011



1) Inklusive Pflanzenöl; 2) Feste und flüssige Biomasse, Biogas, Deponie- und Klärgas, biogener Anteil des Abfalls; 1 TWh = 1 Mrd. kWh;
Quelle: BMU-KI III 1 nach Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat); Abweichungen in den Summen durch Rundungen; Stand: März 2012; Angaben vorläufig

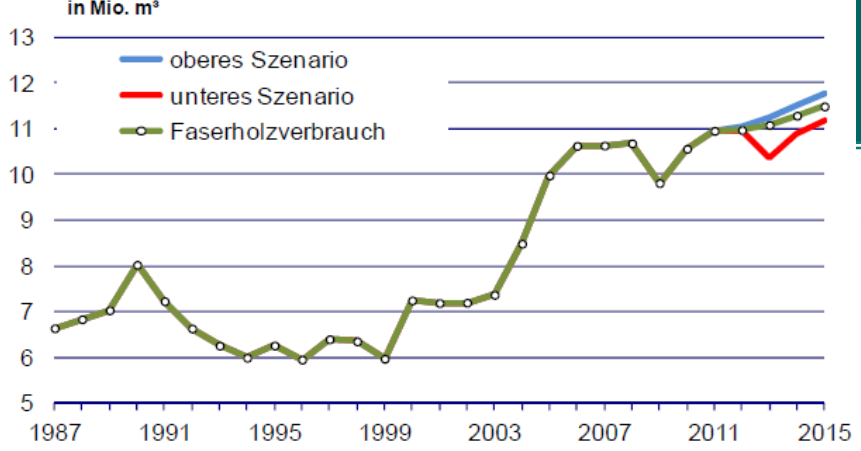
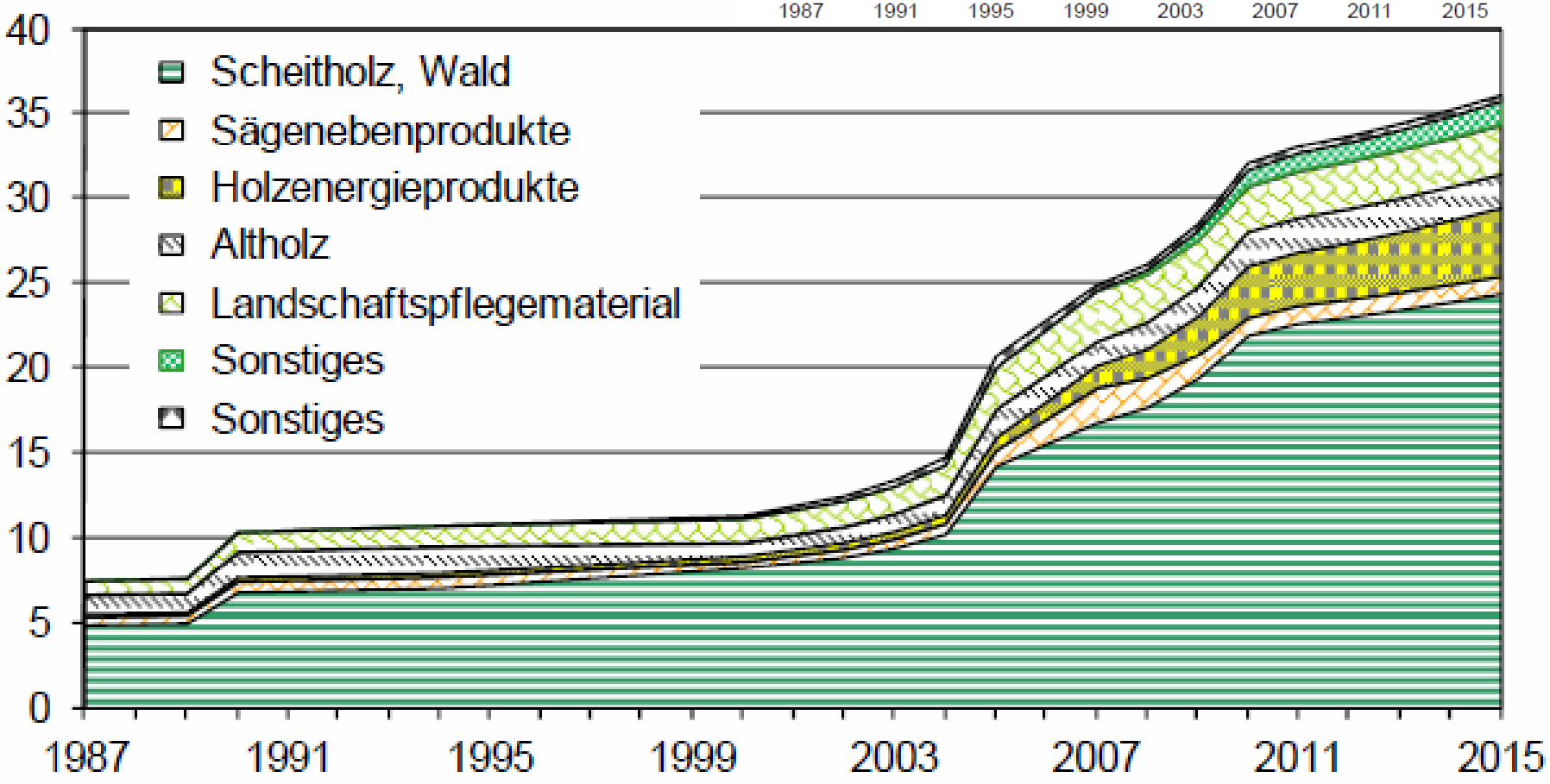


Abbildung 3-22: Brennholzverbrauch

in Mio. m³ - kumulativ



Quelle: Mantau, 2004; Mantau/ Sörgel, 2006 ; Hick/ Mantau, 2008 ; Mantau 2012b

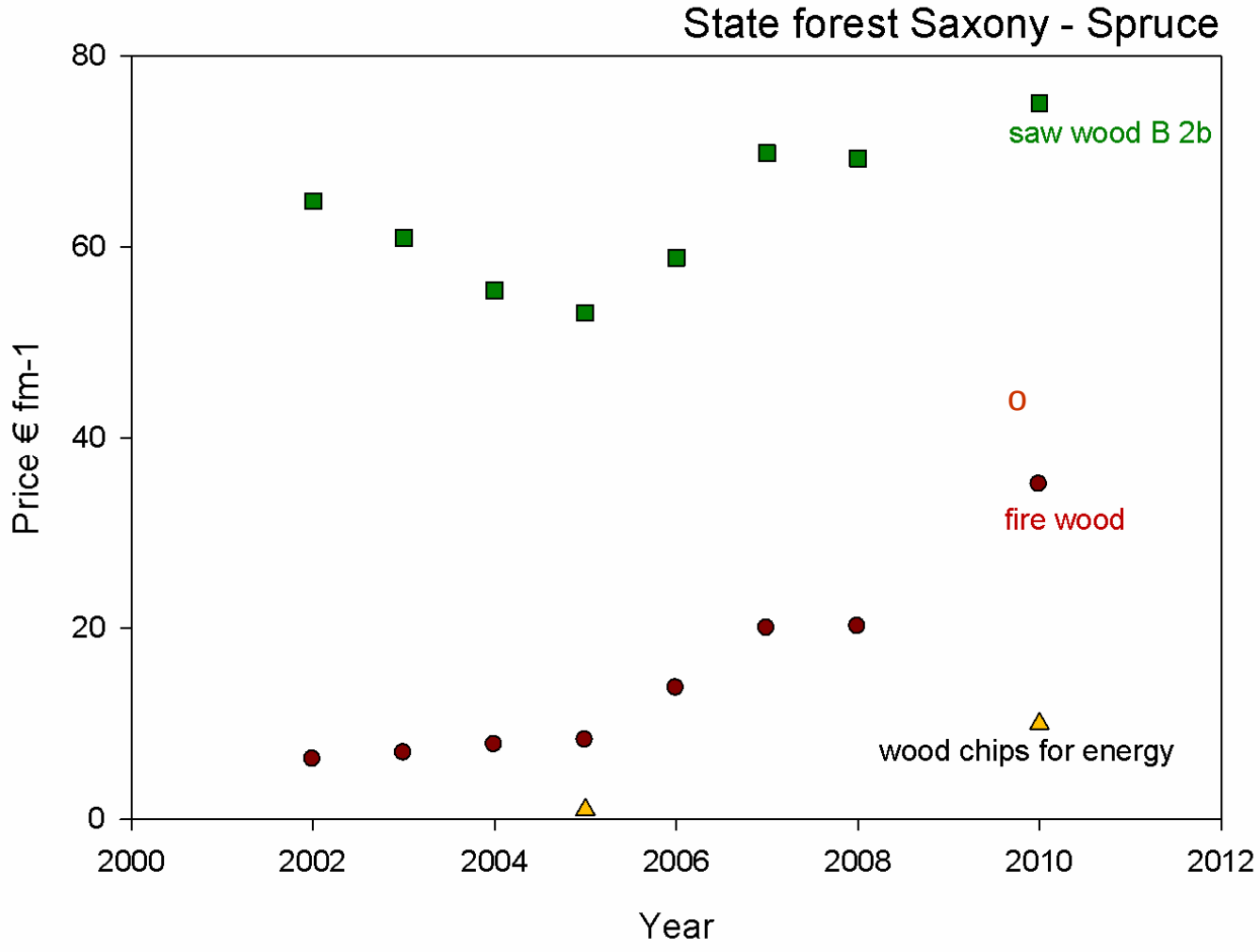
Tabell 1. Anbefalte utslippsfaktorer for peis og vedovn. 2000

	Åpen peis	Vedovn/ lukket peis Produsert før 1998[1]	Vedovn/ lukket peis Produsert 1998 eller senere[2]	Enhet
PM_{10}	17,3	40	6,2	g/kg
CO	126	150	50,5	g/kg
SO_2	0,2	0,2	0,2	g/kg
NO_x	1,3	0,97	0,97	g/kg
N_2O	0,032	0,032	0,032	g/kg
CH_4	5,8	5,8	5,8	g/kg
NMVOC	7,0[3]	6,9	7,0	g/kg
Cd	0,1	0,1	0,1	g/tonn
PAH-total	17,4	52,0	0,0226	g/tonn
PAH-6 (OSPAR)	6,1	8,1	0,045	g/tonn
PAH-4 (LRTAP)	3,0	2,7	0,025	g/tonn

[1] Dette brukes her synonymt med tradisjonelle vedfyrte lukkede ildsteder.

[2] Dette brukes her synonymt med rentbrennende vedfyrte lukkede ildsteder

[3] Faktoren er egentlig for rentbrennende ovn



We pay twice:

1. The subvention for renewable energy
2. The heating cost for Hartz IV

- Wood is renewable but not unlimitedly available

- Increased environmental concern of people:
  - „people“ pay extra for „green“ electricity,
  - „people“ use wood for construction (mainly conifer), and
  - „people“ heat with logs
  - „people“ object against new species.

- At the same time people demand
  - More area for recreation,
  - More area for Nature Conservation,
  - More deciduous forest
  - More deadwood.

- In reality the desire for living environmentally friendly leads to an increased use of forest products and to a limitation of its suppy.

- The „green“ life-style contradicts the additional demands for maintaining diversity and personal recreation in forests

- Pierre Vergniaud: „The Energytransition is like Saturn, it eats is own children “

- **The situation in agriculture**

Accounting of Land use according to Artikel 3.4 (December 2006):

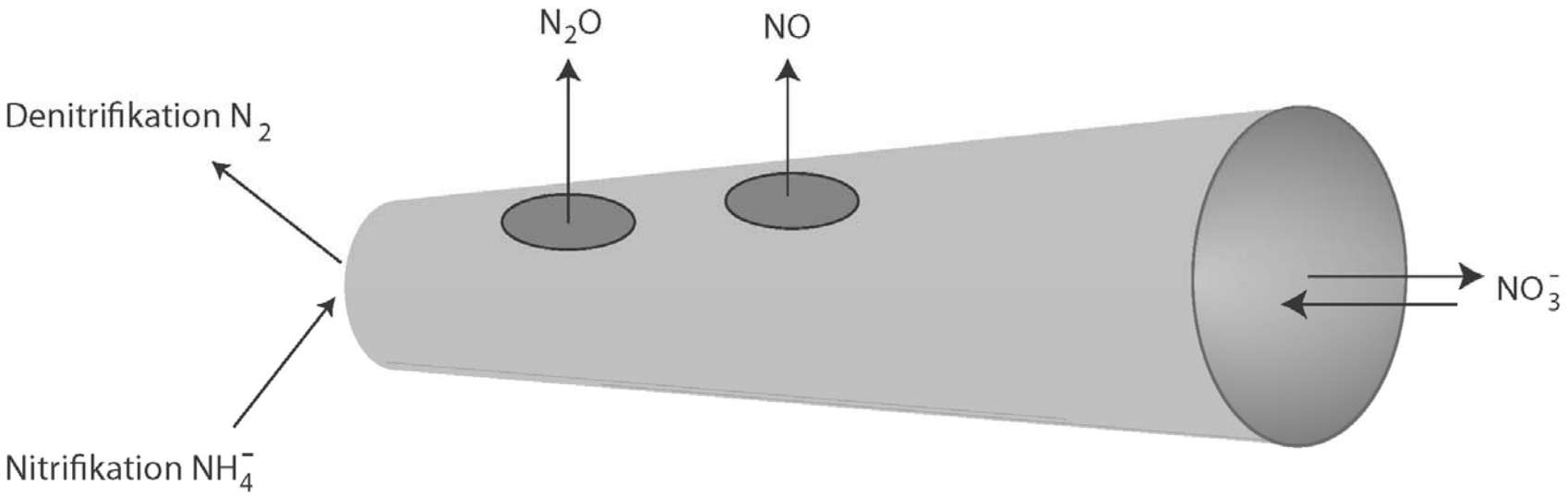
Table 13 EU-15 Member States of elections of activities under Article 3, paragraph 4

Member State	Forest management	Cropland management	Grazing-land management
Austria	Not elected	Not elected	Not elected
Belgium	Not elected	Not elected	Not elected
Denmark	Elected	Elected	Elected
Finland	Elected	Not elected	Not elected
France	Elected	Not elected	Not elected
Germany	Elected	Not elected	Not elected
Greece *)	Not decided	Not decided	Not decided
Ireland	Not elected	Not elected	Not elected
Italy	Elected	Not elected	Not elected
Luxembourg	Not elected	Not elected	Not elected
Netherlands	Not elected	Not elected	Not elected
Portugal	Elected	Elected	Elected
Spain	Elected	Elected	Not elected
Sweden	Elected	Not elected	Not elected
United Kingdom	Elected	Not elected	Not elected

Note: *) At the time of publishing this report, the election of activities under Article 3(4) was not decided.

EEA, 2006

Rapdiesel fails the Sustainability Test of the EU: Nature, 9. August 2012



2 to 7% of the organic and inorganic fertilizer-N are emitted as N_2O (the EU default value is 1%)

- Agriculture causes
  - 50% of European CH4,
  - 70% of European N2O
  - 90% of European NH3
  - 75% of the Global Warming Potentials of GHGs originates from agricuture

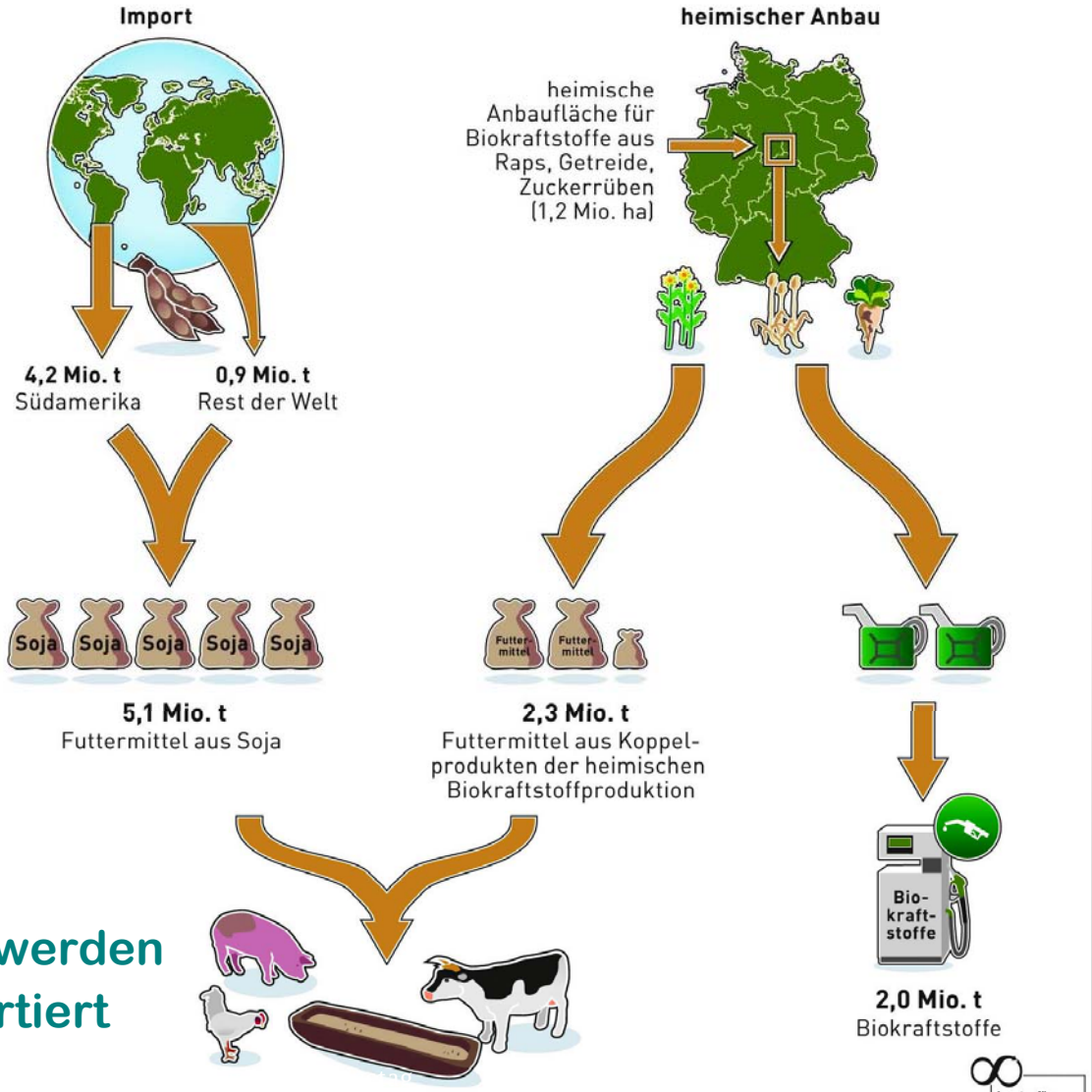
- Biological Emissionen are 30% of the GHG balance

No accounting of GHG‘s, since agriculture serves the food supply (Common Agricultural Practice der EU: CAP)

Schulze et al. Nature Geoscience 2009

Heimische Biokraftstoffe vermeiden Sojaimporte nach Deutschland

Ohne Koppelprodukte aus heimischer Biokraftstoffproduktion müsste Deutschland fast 50 % mehr Soja-Futtermittel importieren.



50% werden exportiert

Hemmerling (2012) Gefällige Naturwissen-schaftler und öffentliche Empörung. Dbk 9/12:4-5

U. Hemmerling ist Vize-Generalsekretär des Deutschen Bauernverbandes

		TG (Mill t)	C (Mill t)
Input	Hey	150	75
	Protein-fodder	2.3 (FG)	1.1
	Import	5.1	2.6
Output	Biofuel	2.0	1.7
	Meat	8.0	1.6
	Milk	31.0	1.5
	Slury	200	1.8
	Methan C-eq		60
	N_2O C-equ		43

Der Spiegel 32/2011:40

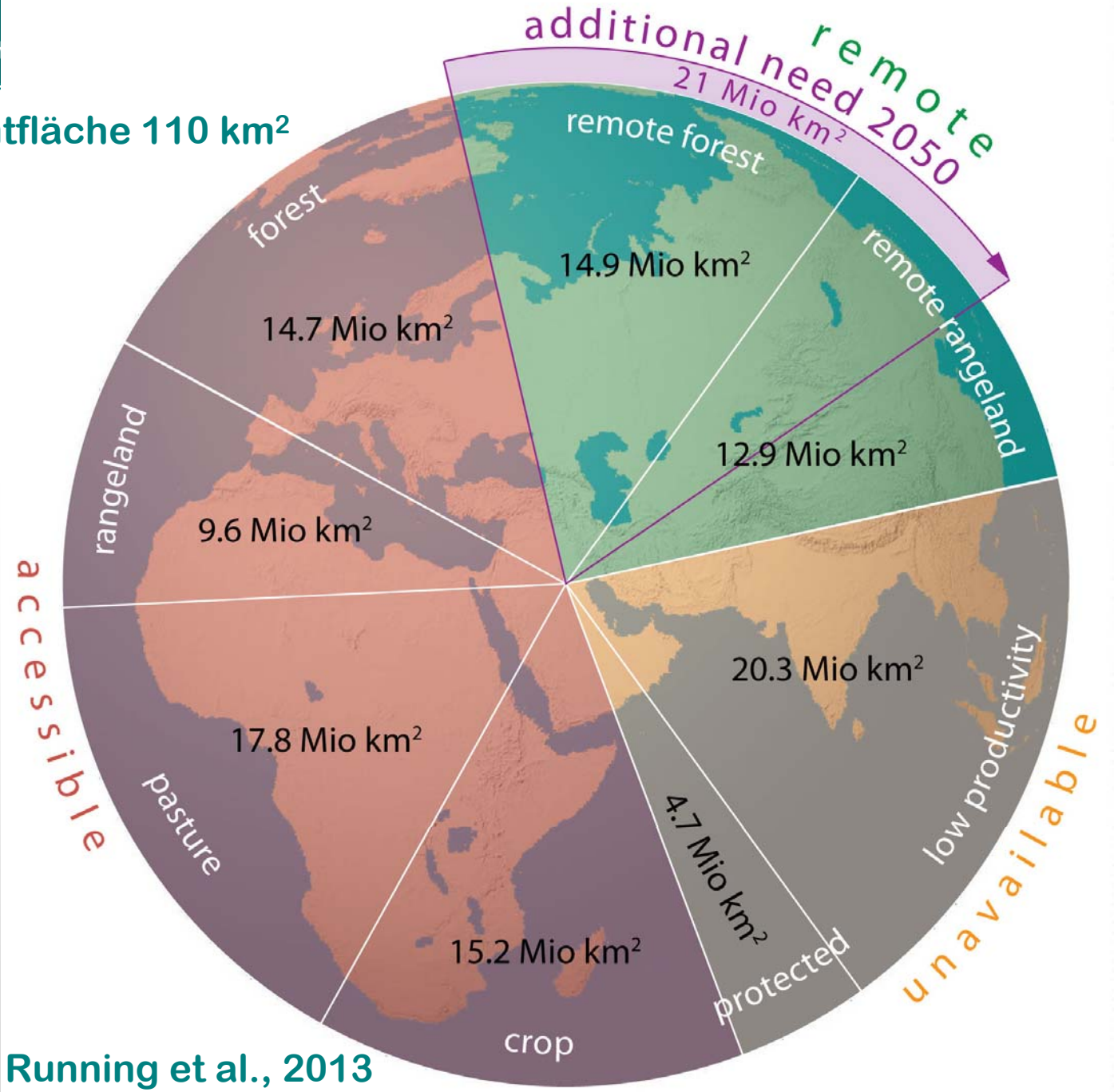
The fertilizer regulations
do not consider the
use of methane fermentation
cake as fertilizer
Thus we have a regional
over-fertilization

Comparison of bioenergy-crops with fossil fuel

Efficiency (gCO2-eq/MJ)	100%	-35% (EU-target 2009)	-50% (EU-target 2017)
Fossil fuel	82.5	53.9	42.1
Sugarcane (9 models)		61.0 ± 23	
Wheat (10 models)	85.9 ± 55		
Maize (12 models)	88.3 ± 29		
Soja (8 models)	110.2 ± 40		
Rapeseed (8 models)	111.5 ± 66		

DeLucia et al., 2012, Env.Science and Policy

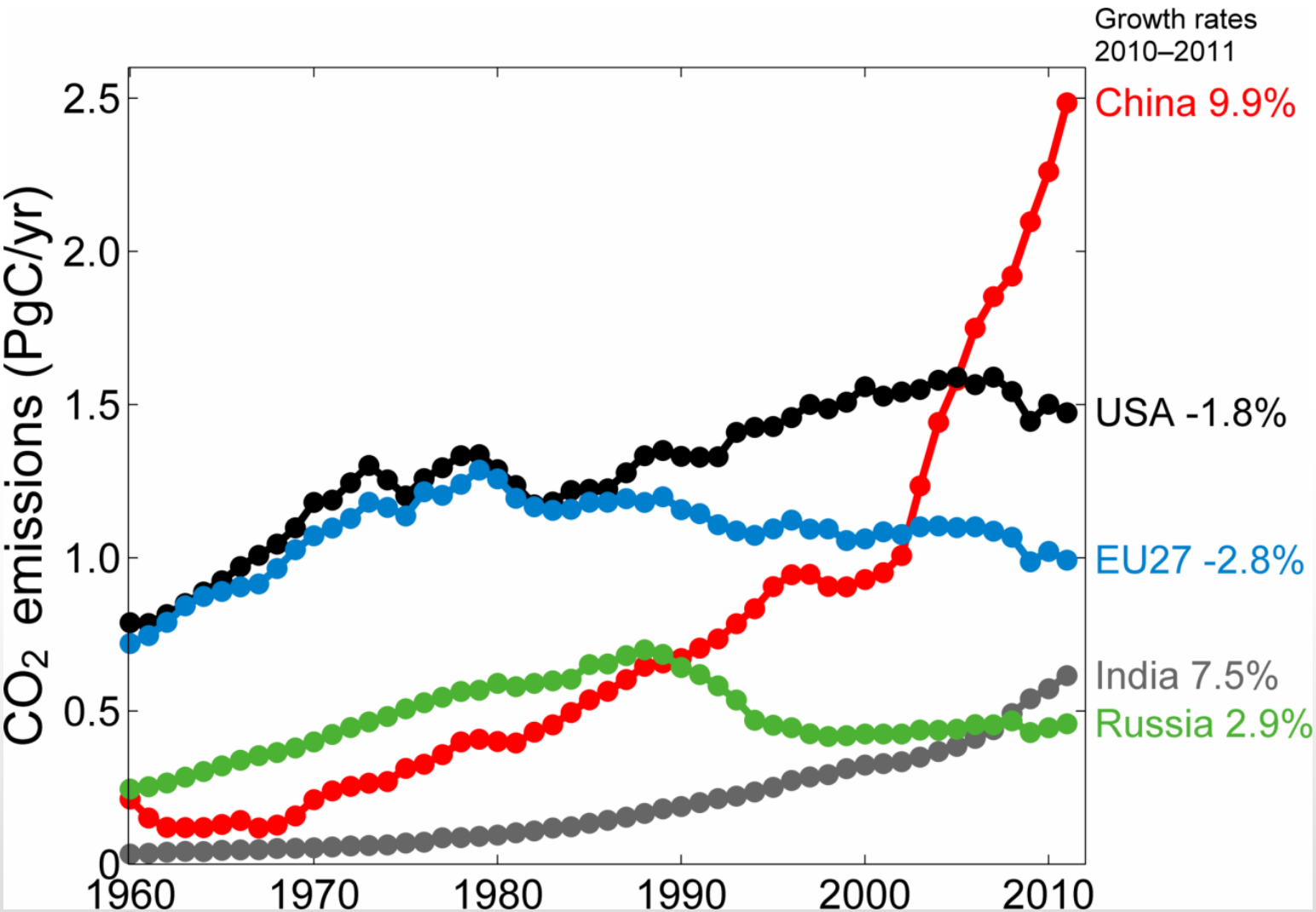
Gesamtfläche 110 km²



Running et al., 2013

- **Global Commerce**

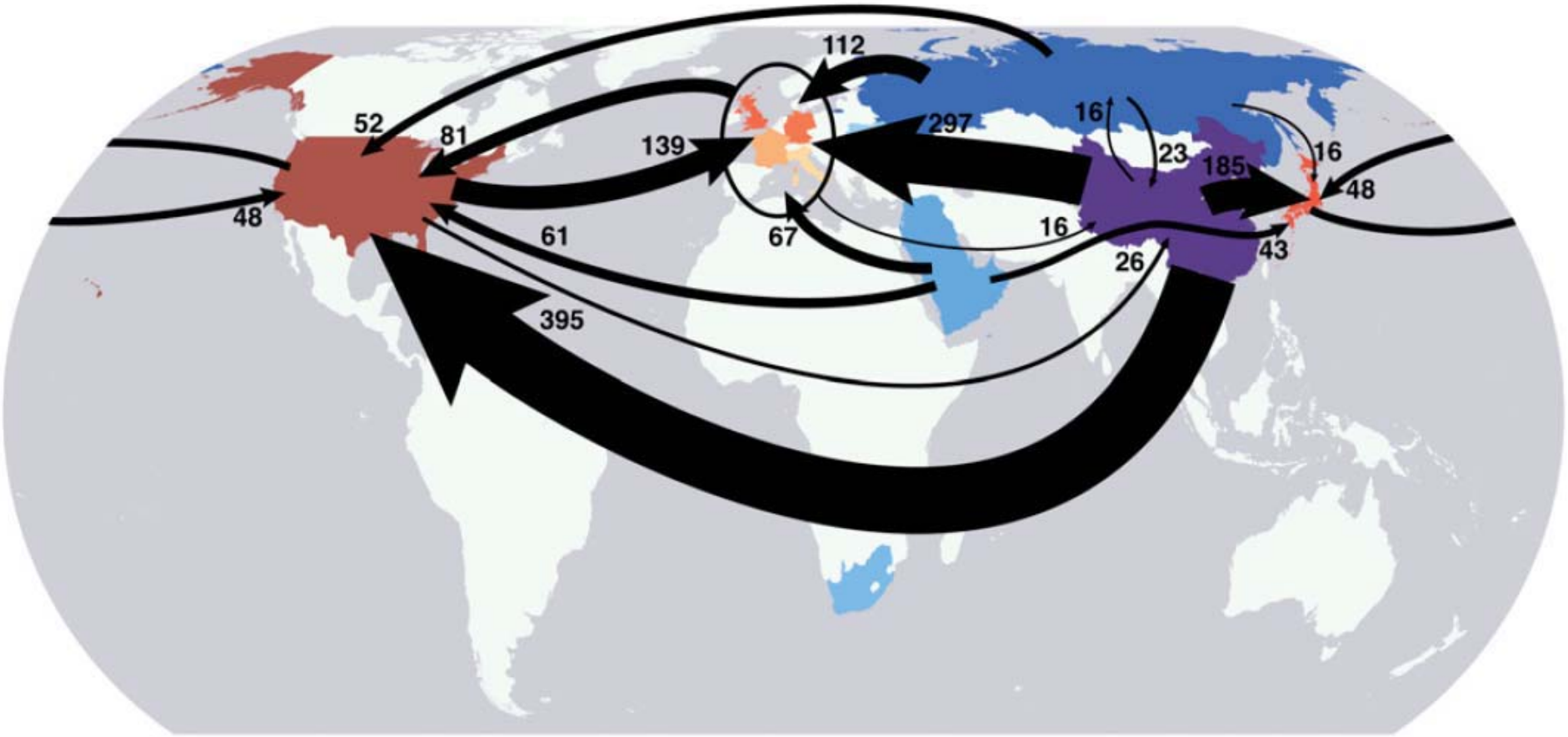
Fossil fuel emissions from the top emitters

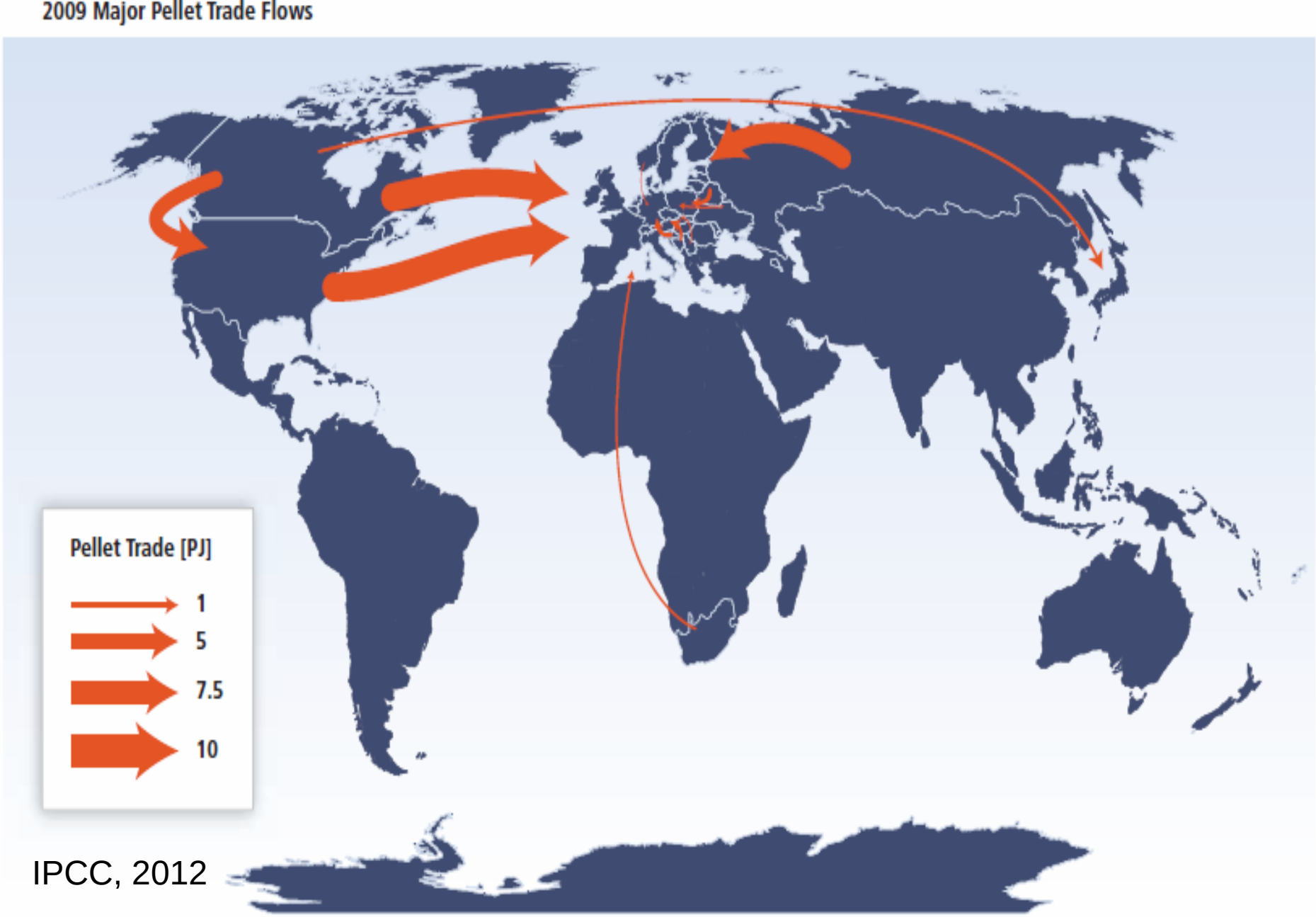


Le Quere et al. 2012, Earth System Science Data-D, to be published Dec. 3
Global Carbon Project 2012, online, data to be published Dec. 3

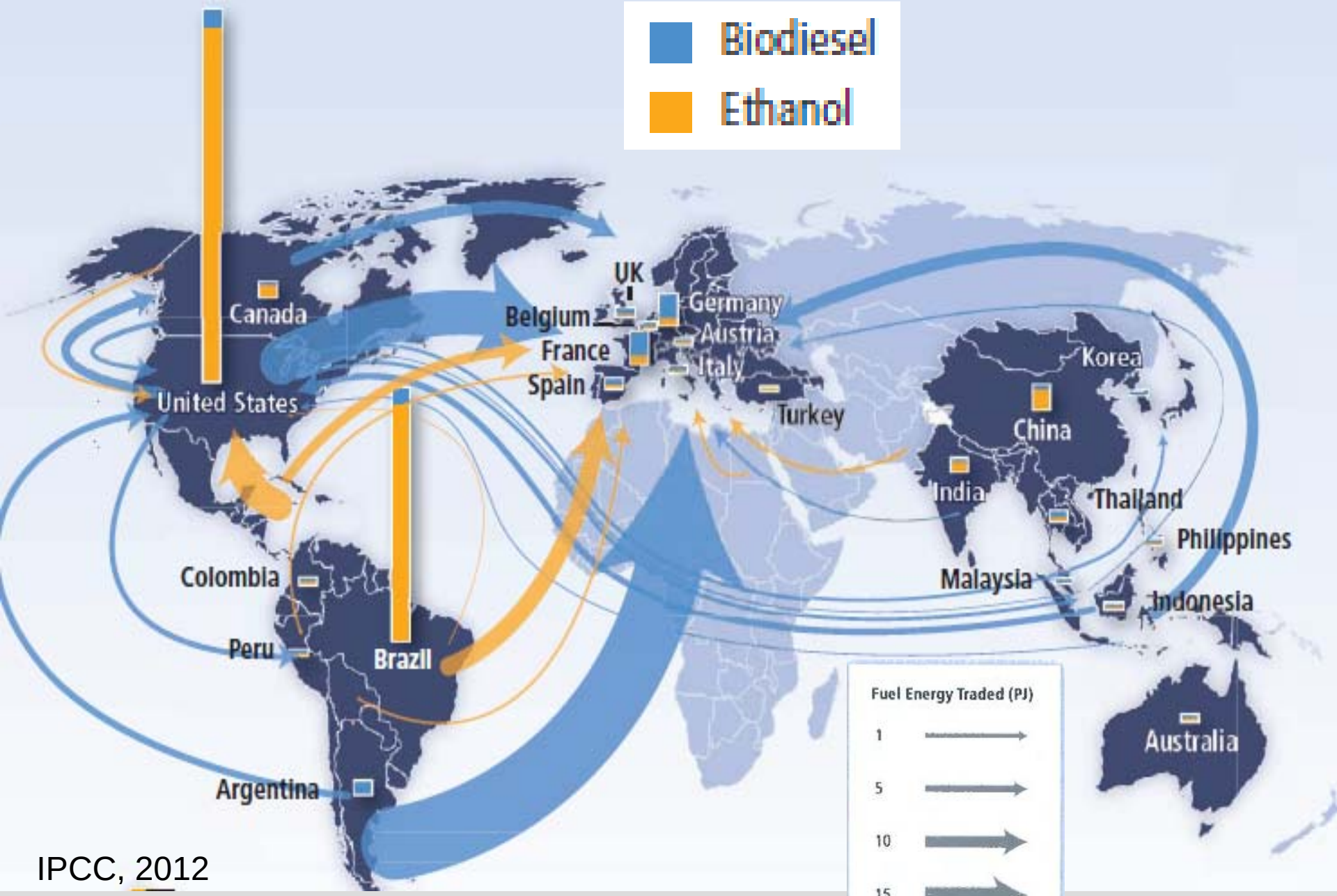
Embedded C in industrial products

Mt CO_2/y

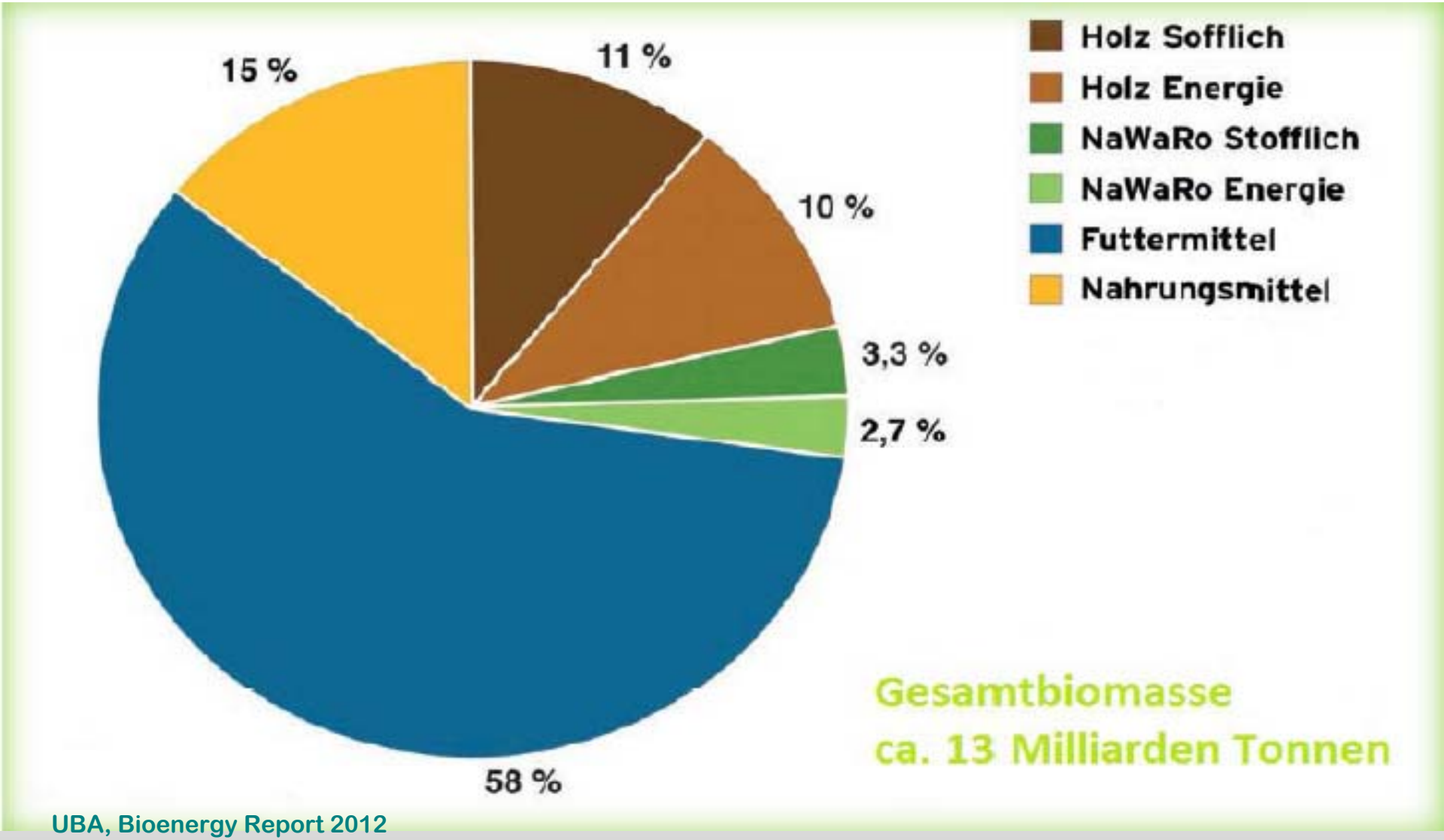




IPCC, 2012


Biodiesel
Ethanol
Canada
United States
UK
Belgium
Germany
Austria
France
Italy
Spain
Turkey
Korea
China
India
Thailand
Philippines
Malaysia
Indonesia
Australia
Colombia
Peru
Brazil
Argentina
Fuel Energy Traded (PJ)
1
5
10
15
30+

IPCC, 2012



UBA, Bioenergy Report 2012

- Conclusions
  - Mankind has reached a limit where natural ecosystems collapse (at least locally)
  - 4 to 6°C global temperature rise will make large areas inhabitable by 2050
  - Bioenergy from agriculture enhances this trend

  - There are few options for Mitigation
    - Save Energy (Shut down advertisement)
    - Emittors must pay
    - Reduce Milk and Meat-consumption (unrealistic)
    - Reduce trade of Biomass (unrealistic)
    - Develop new tecnologies to split water

Thanks