Quantifying climate change impacts of biomass and bioenergy systems

Annette Cowie, Neil Bird
with input from Gerfried Jungmeier, Francesco Cherubini, Göran Berndes

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- "Greenhouse gas balances of biomass and bioenergy systems"
- Task leader:
  Neil Bird, Joanneum Research, Austria
  Co-leader: Annette Cowie
- Participating countries:
- Austria, Australia, Belgium, Brazil, Finland, Germany, Netherlands, Norway, Sweden, USA

IEA global human CO_2 annual emissions vs. IPCC SRES scenario projections

We are currently on track for a warming of 4 to 7° over pre-industrial levels by 2100 (*Hadley centre*).

This level of temperature rise threatens the stability of the global ecosphere as we know it.

- Hundreds of millions of people affected by water stress
- 30–40% of species at risk of extinction
- 30% of global coastal wetlands lost

(*IPCC – impacts of 4° rise*)

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Objectives of Task 38

- Develop, demonstrate and promote standard methodology for GHG balances
- Increase understanding of GHG outcomes of bioenergy and carbon sequestration
- Emphasise overall atmospheric impact, whole life cycle
- Promote international exchange of ideas, models and scientific results
- Aid decision makers in selecting most effective mitigation options

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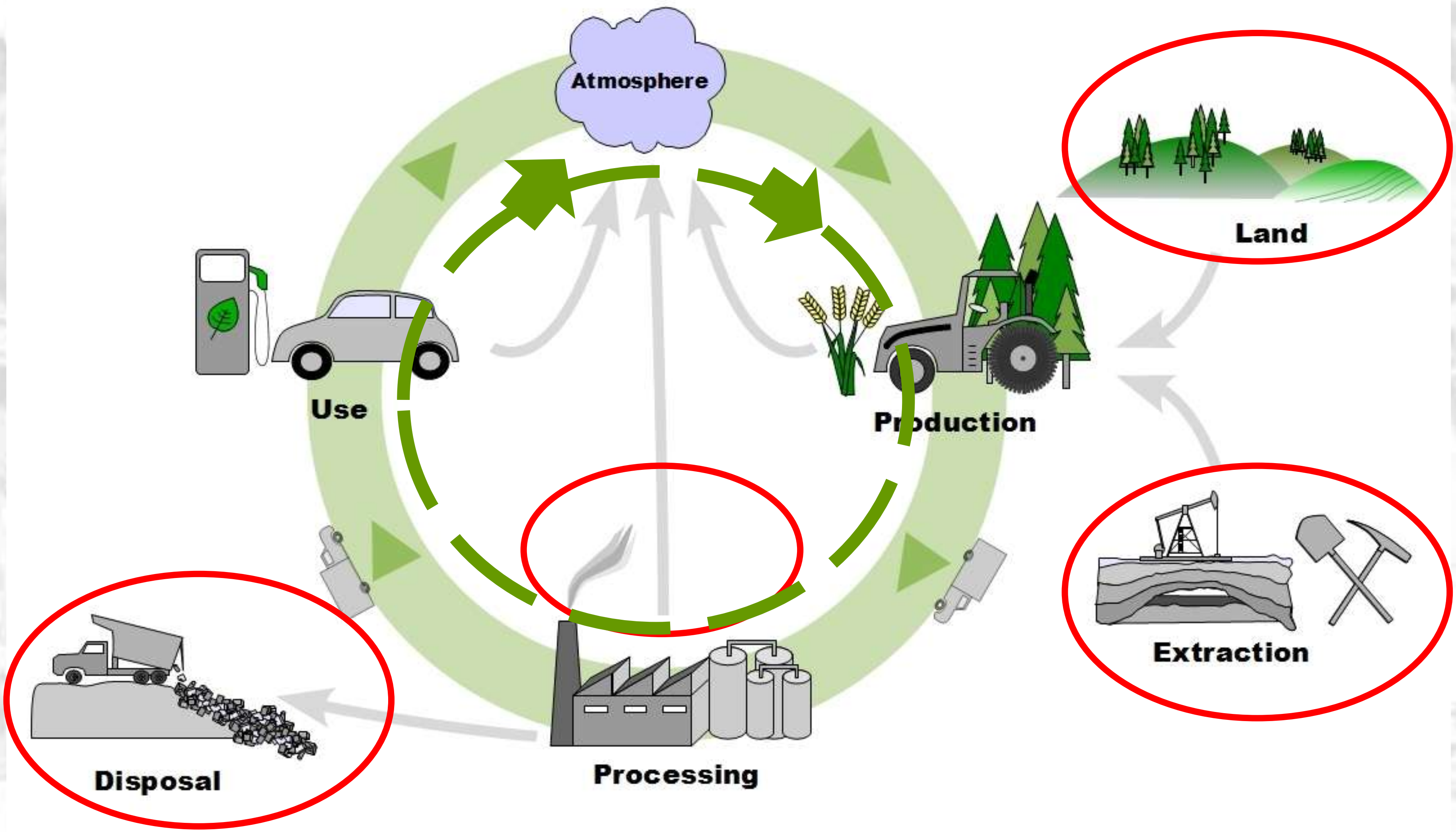
Life cycle assessment

- All environmental impacts (GHG emissions, human toxicity, eutrophication, acidification, abiotic resource depletion, water, biodiversity etc)
- "Cradle to grave" - ie production to disposal/recycling
- Applied to a product or service, per "functional unit"
  eg gCO_2e/loaf of bread
- Can be expressed as combined damage indicator eg EcoIndicator 99 – normalised and weighted

Life cycle approach

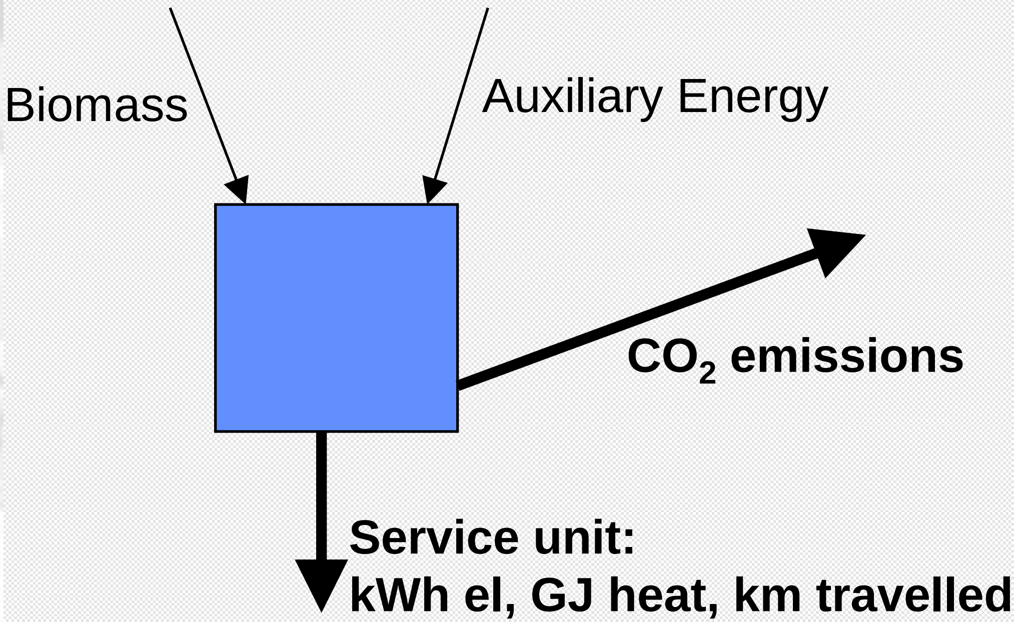


Production chain emissions

- Energy inputs for solid biomass fuels from ag or forestry residues: 2-5% of energy content
- Dedicated energy crops and refined biomass (eg pellets): around 10%
- Liquid biofuels significantly higher, studies differ considerably: 15 – 70%

Calculating the benefits of bioenergy

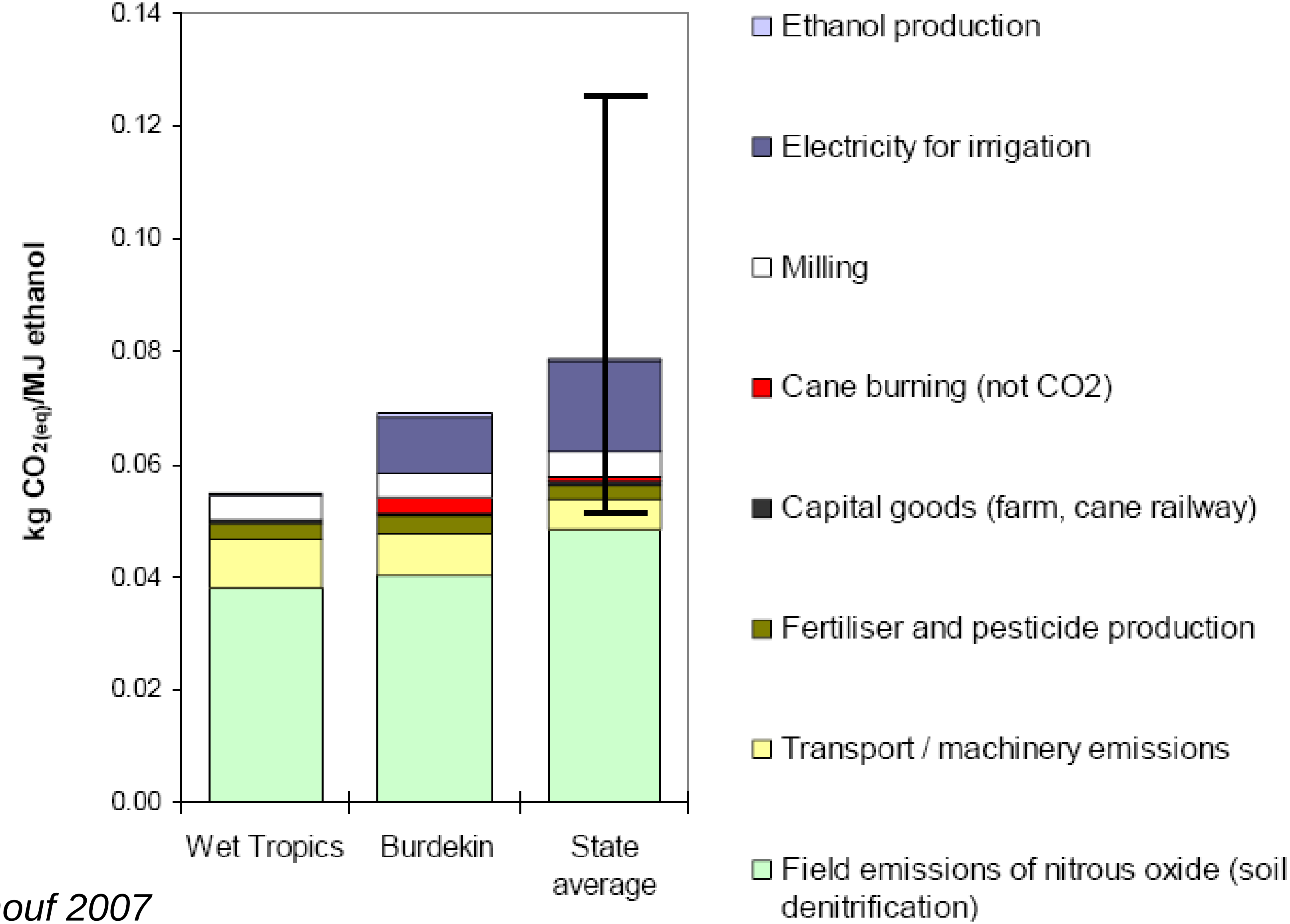
- Emissions intensity:
- CO_2 emissions per unit *useful output* (kWh electricity, GJ heat, GJ biofuel, km travelled)



CO_2 is not the whole story

- Non-CO_2 GHG can be significant

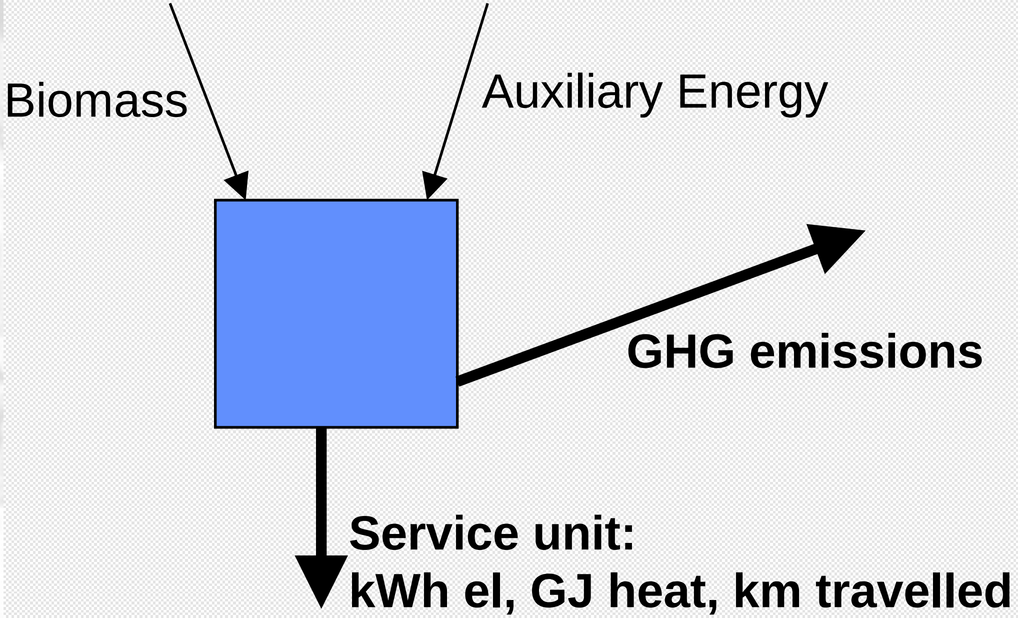
Greenhouse gas emissions



Renouf 2007

Consider all GHs

- Non-CO_2 GHG can be significant
- Emissions intensity: *GHG emissions* per unit output



Consider carbon stock change

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- Adjust emissions intensity for C stock change in biomass or soil
- “direct land use change dLUC”
- change in management practice
- **Δ long term average C stock**
  - Biomass
  - Soil carbon

Biomass C stock change

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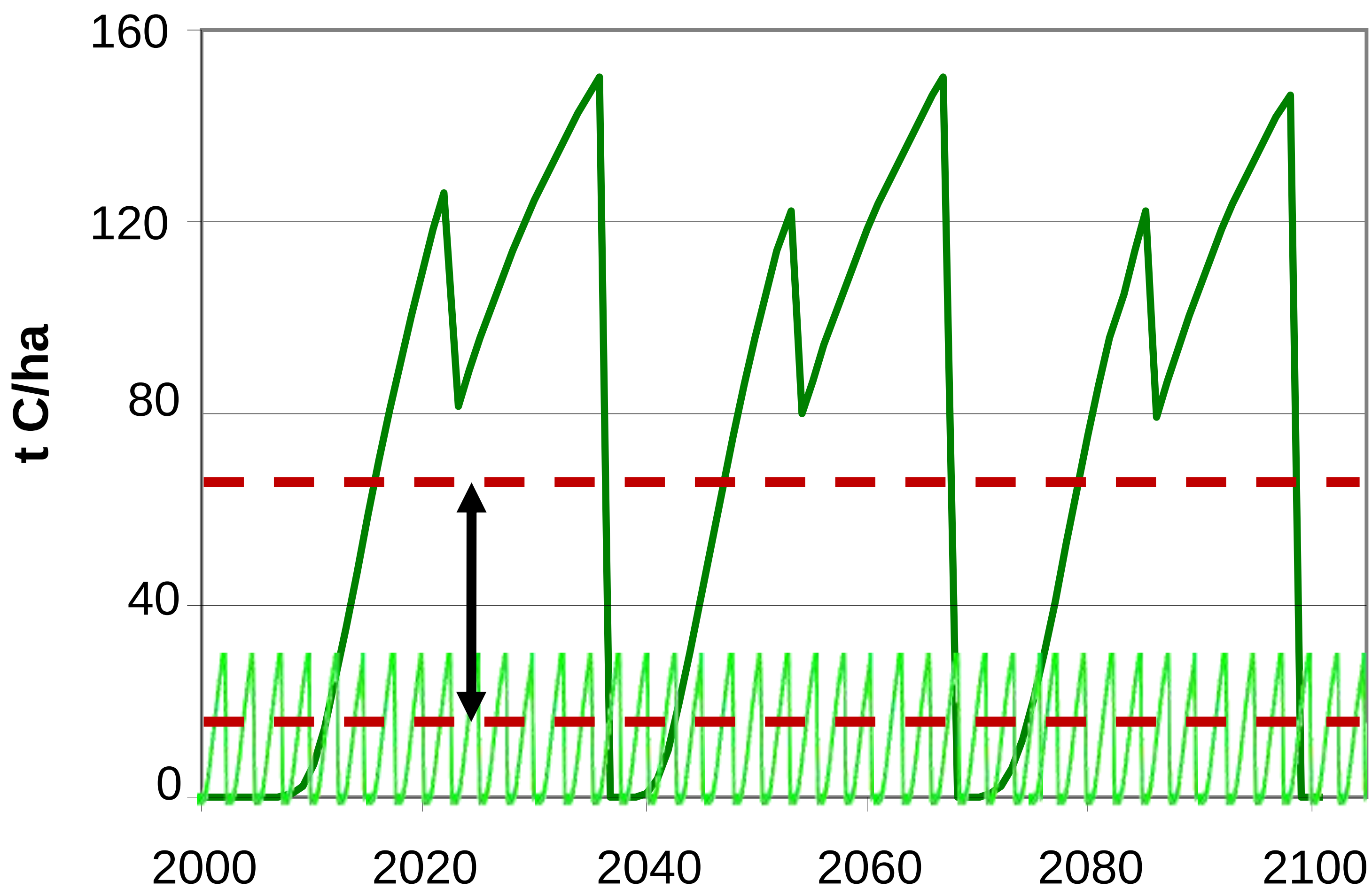


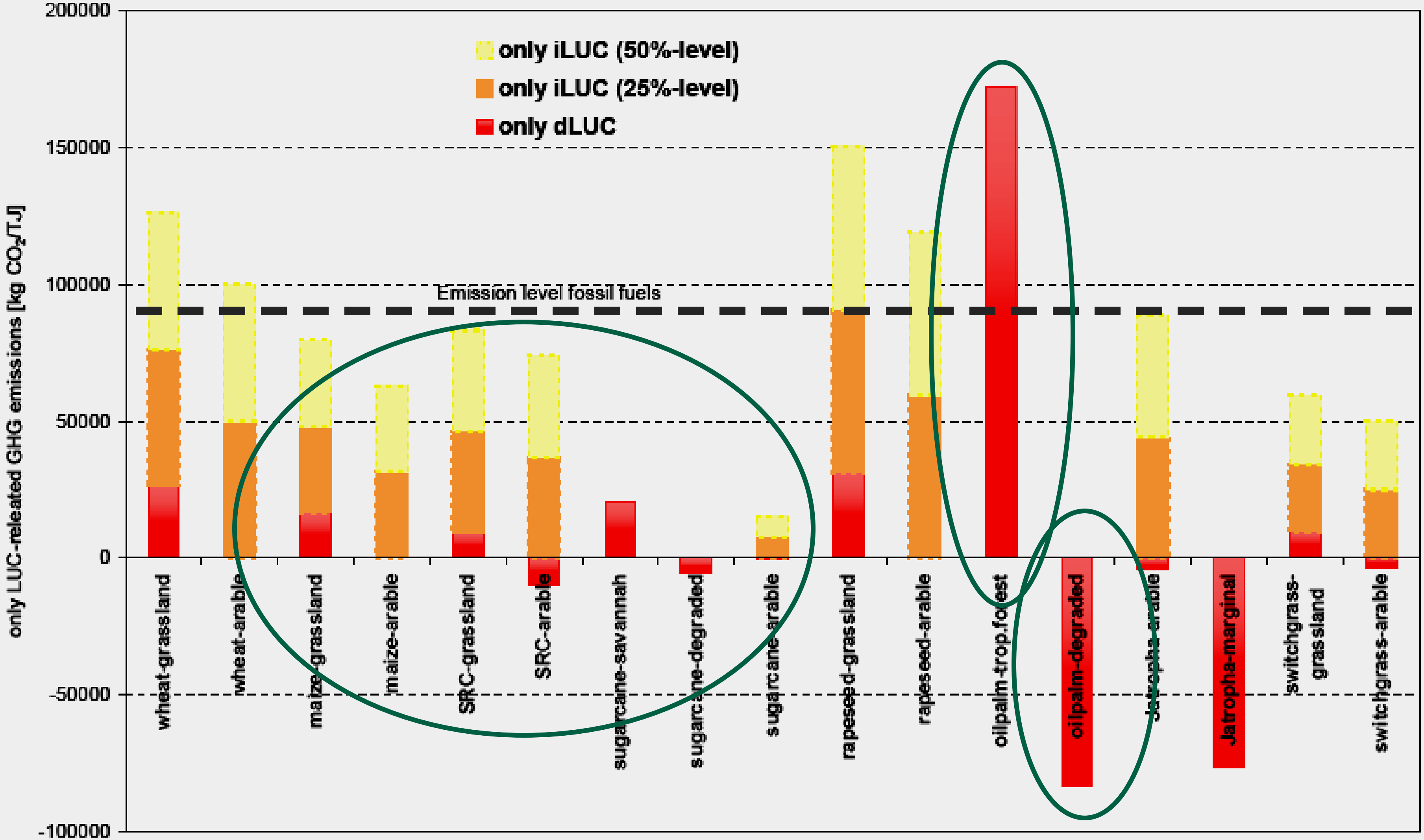
Indirect landuse change

- Outside system boundary
- Form of “leakage”
- Off-site carbon stock change, methane, nitrous oxide emissions
  - logging
  - fire
  - drainage of peatlands




Direct + Indirect GHG from LUC

Öko-Institut e.V. Institut für angewandte Ökologie Institute for Applied Ecology



Data only for LUC-induced GHG emissions, excluding life-cycles

Fritsche, 2009

Research sponsored by Umwelt Bundes Amt

Simple measures can be misleading:

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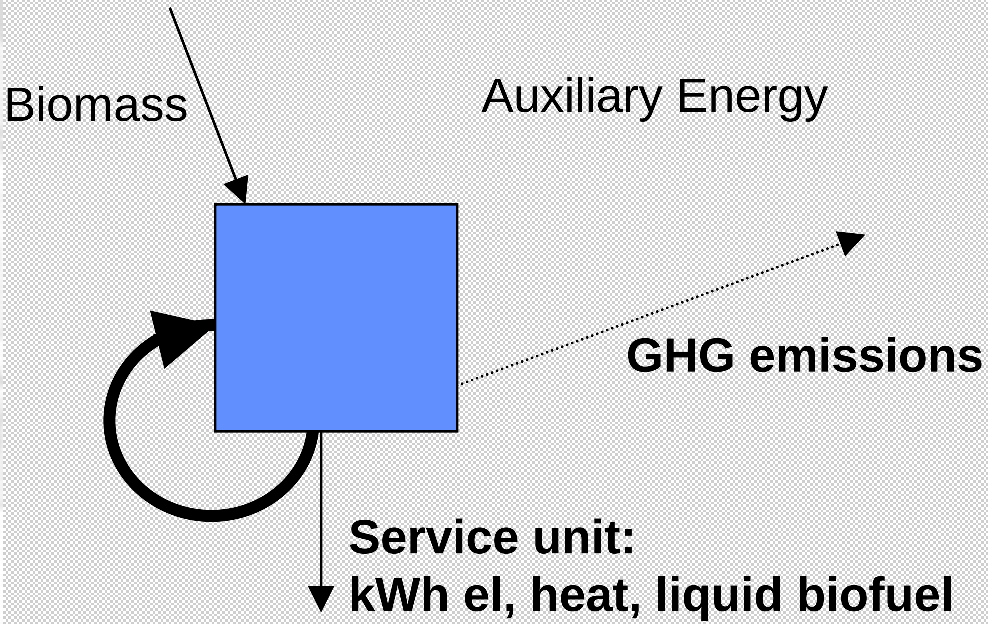
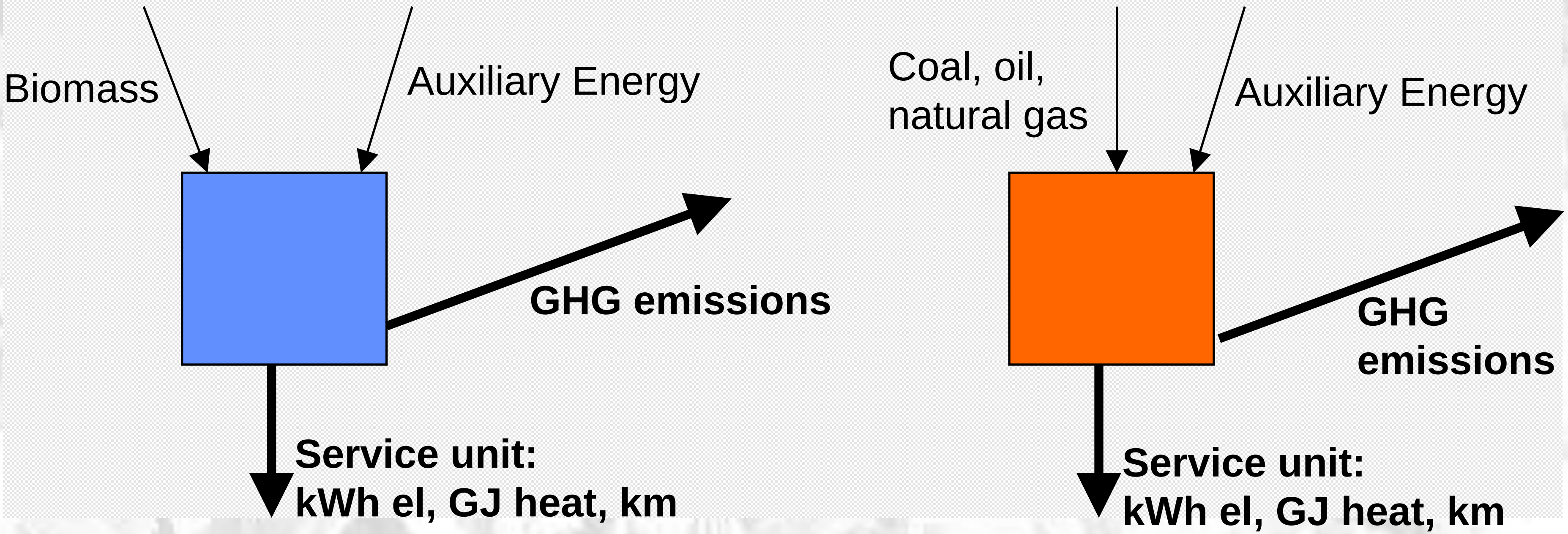
- emissions per unit output can be manipulated



Expand system boundary: consider reference system

- *Emission reduction* per unit useful output



Reference energy system

- Fossil energy source
- Conversion efficiency
- Displacement factor
- = $efficiency_{bio}$ /$efficiency_{ref}$ x $CO2_{ref}$/$CO2_{bio}$
- Always <1

Reference land or biomass use

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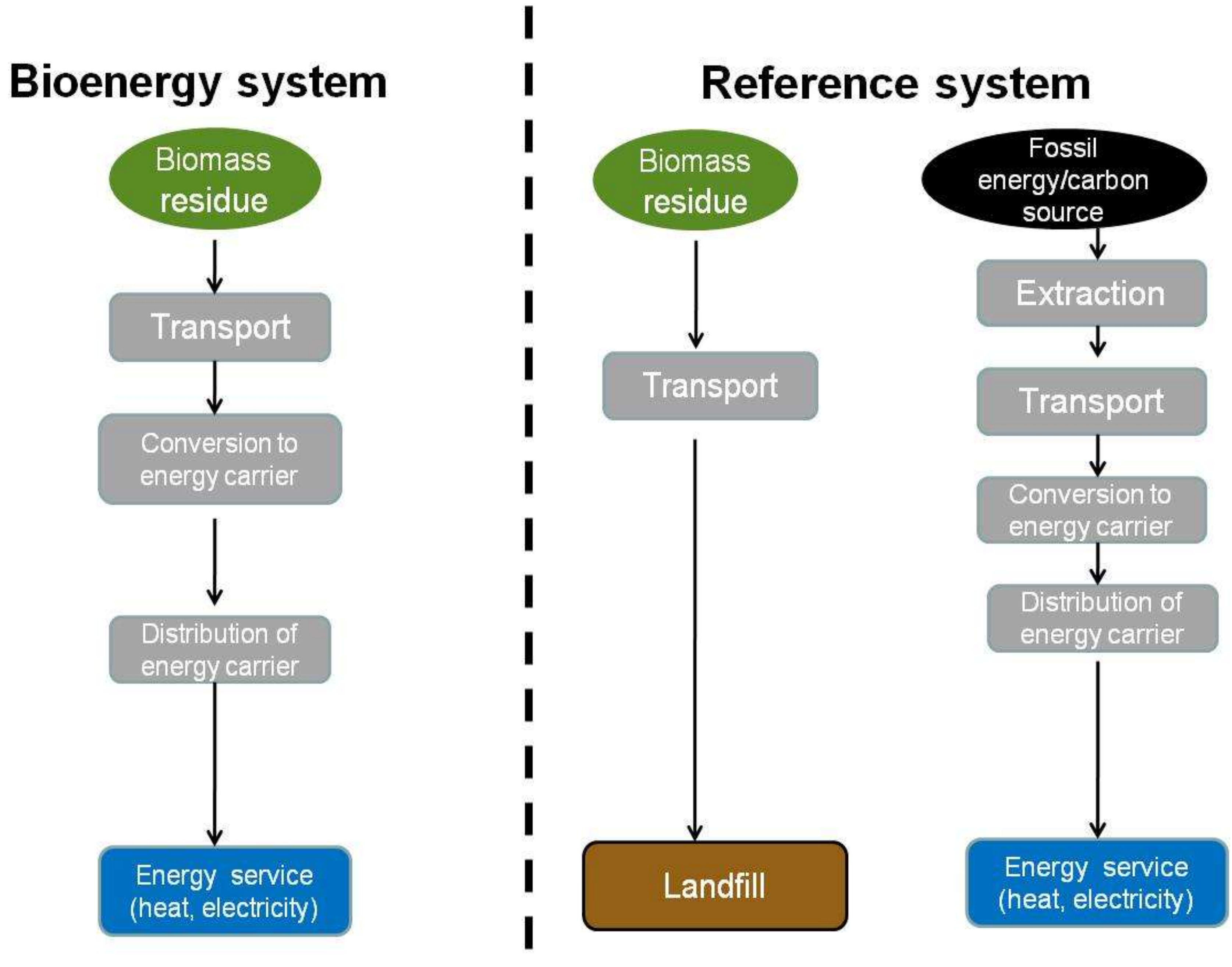
- Waste or diverted from alternative use?
- Marginal or degraded land?
- Integrated food/feed/timber/biomass systems?



Bioenergy system
Biomass residue
Transport
Conversion to energy carrier
Distribution of energy carrier
Energy service (heat, electricity)
Reference system
Biomass residue
Transport
Landfill
Fossil energy/carbon source
Extraction
Transport
Conversion to energy carrier
Distribution of energy carrier
Energy service (heat, electricity)


NIGHTLY
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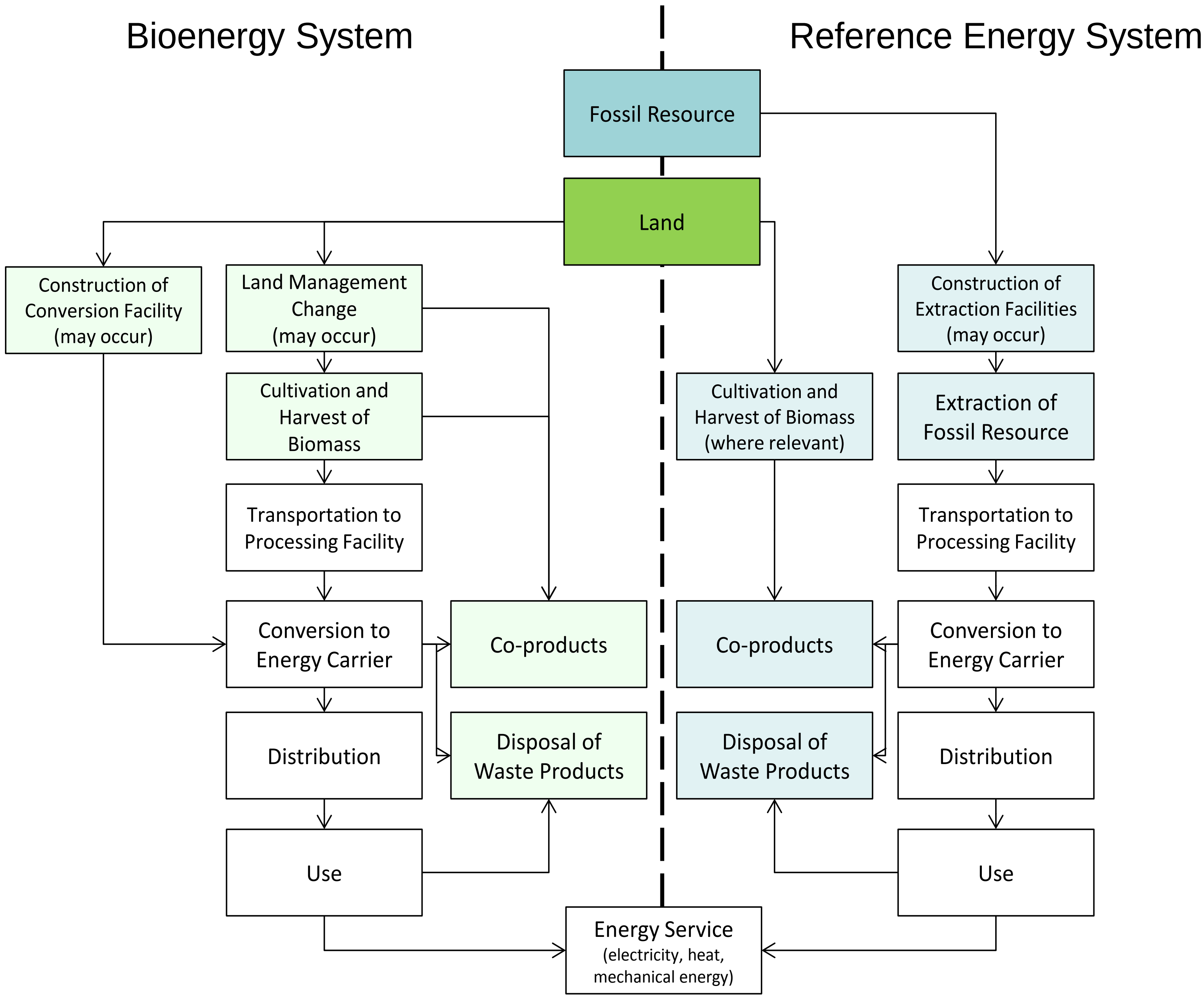
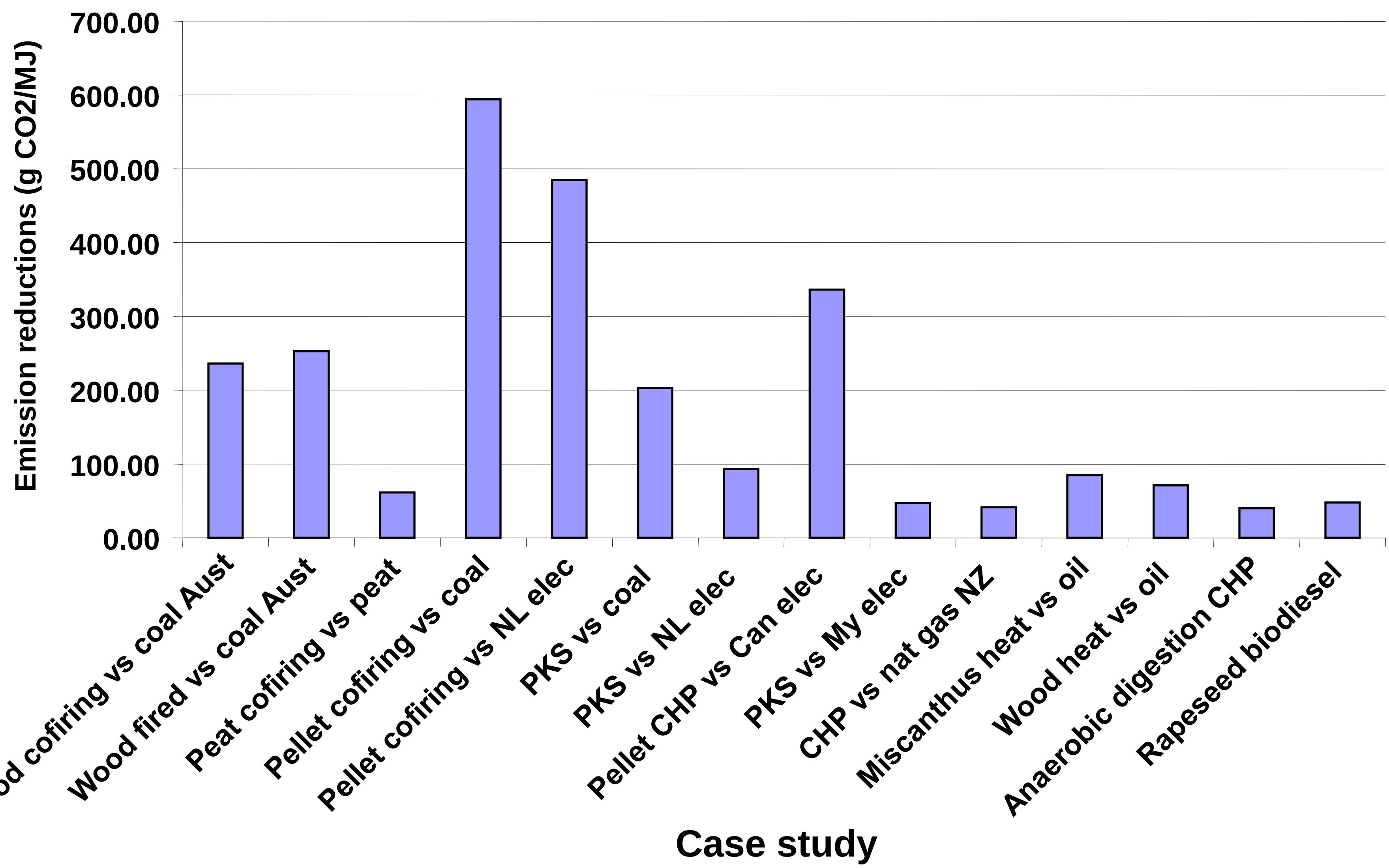
COLE PORTER'S


Bioenergy System
Reference Energy System
Fossil Resource
Land
Construction of Conversion Facility (may occur)
Land Management Change (may occur)
Cultivation and Harvest of Biomass
Transportation to Processing Facility
Conversion to Energy Carrier
Co-products
Distribution
Disposal of Waste Products
Use
Construction of Extraction Facilities (may occur)
Cultivation and Harvest of Biomass (where relevant)
Extraction of Fossil Resource
Transportation to Processing Facility
Co-products
Conversion to Energy Carrier
Disposal of Waste Products
Distribution
Use
Energy Service (electricity, heat, mechanical energy)

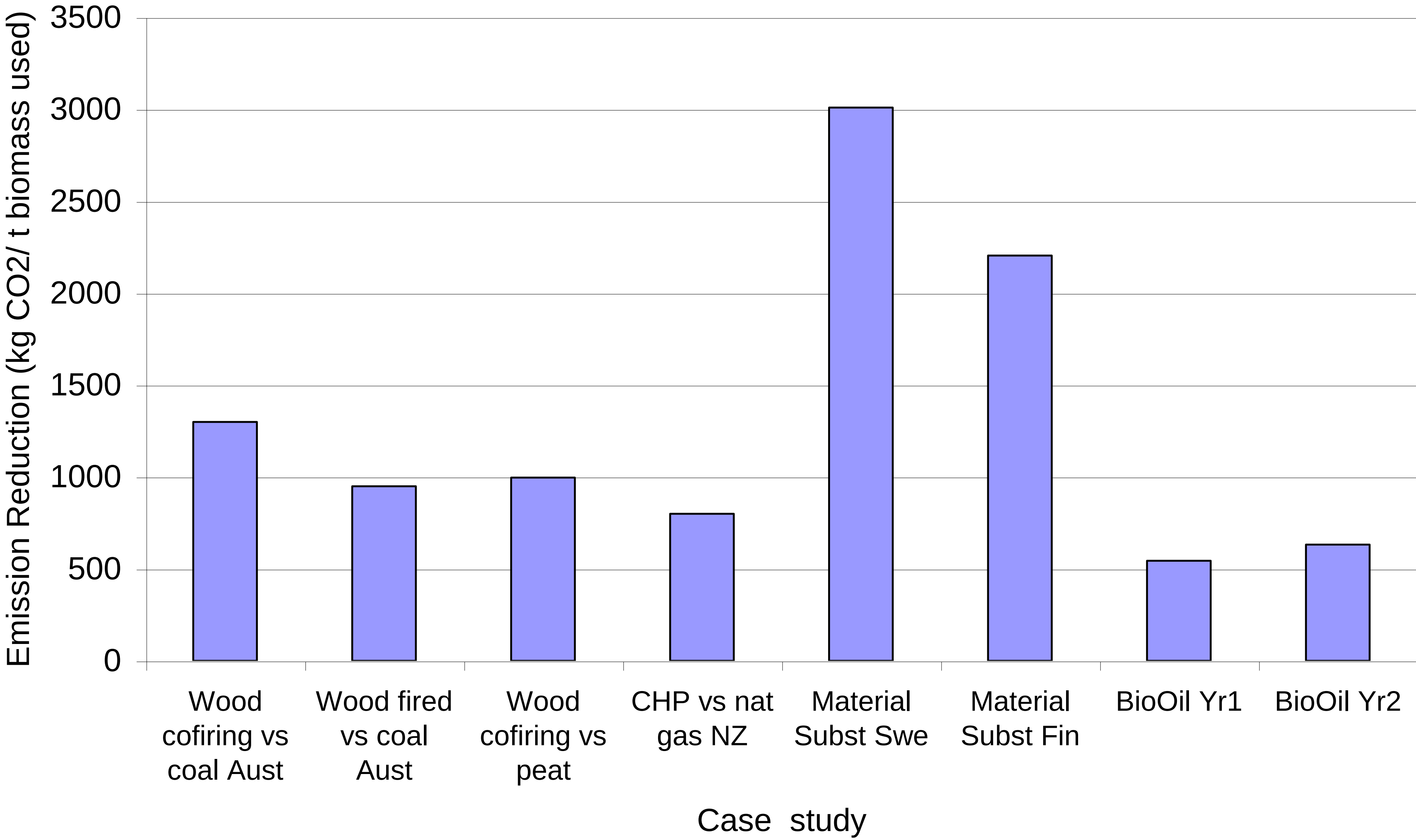
Task 38 Standard Methodology

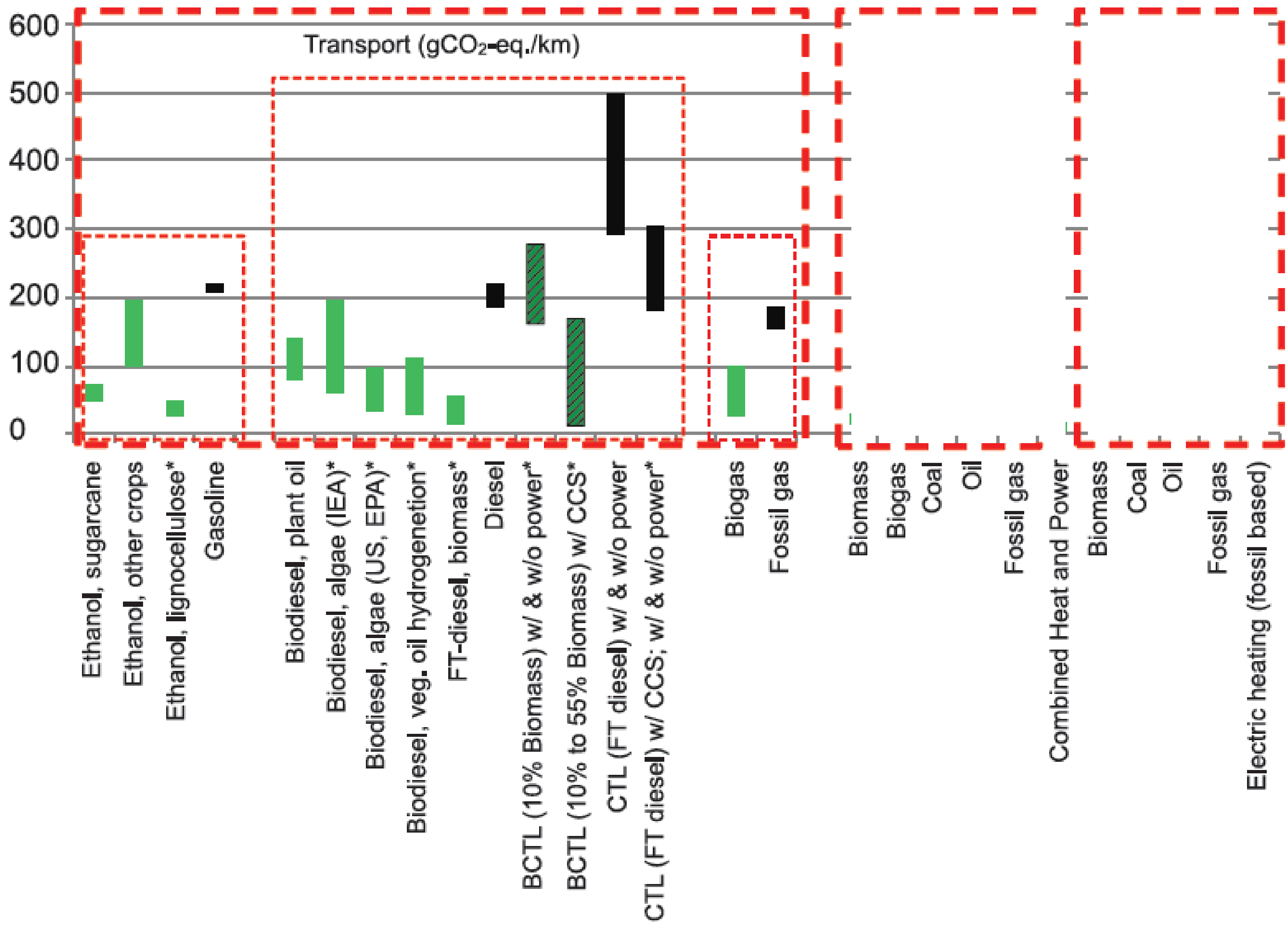
- Compare project with reference
- Consider whole system life cycle
  - Production chain, end of life
- System boundary
  - Deliver equivalent service
- All greenhouse gases CO2 and non-CO2
- C stock change in biomass, soil, ILUC, albedo
- Emissions reduction per unit biomass
- **Result is specific to each situation**

Task 38 Case studies



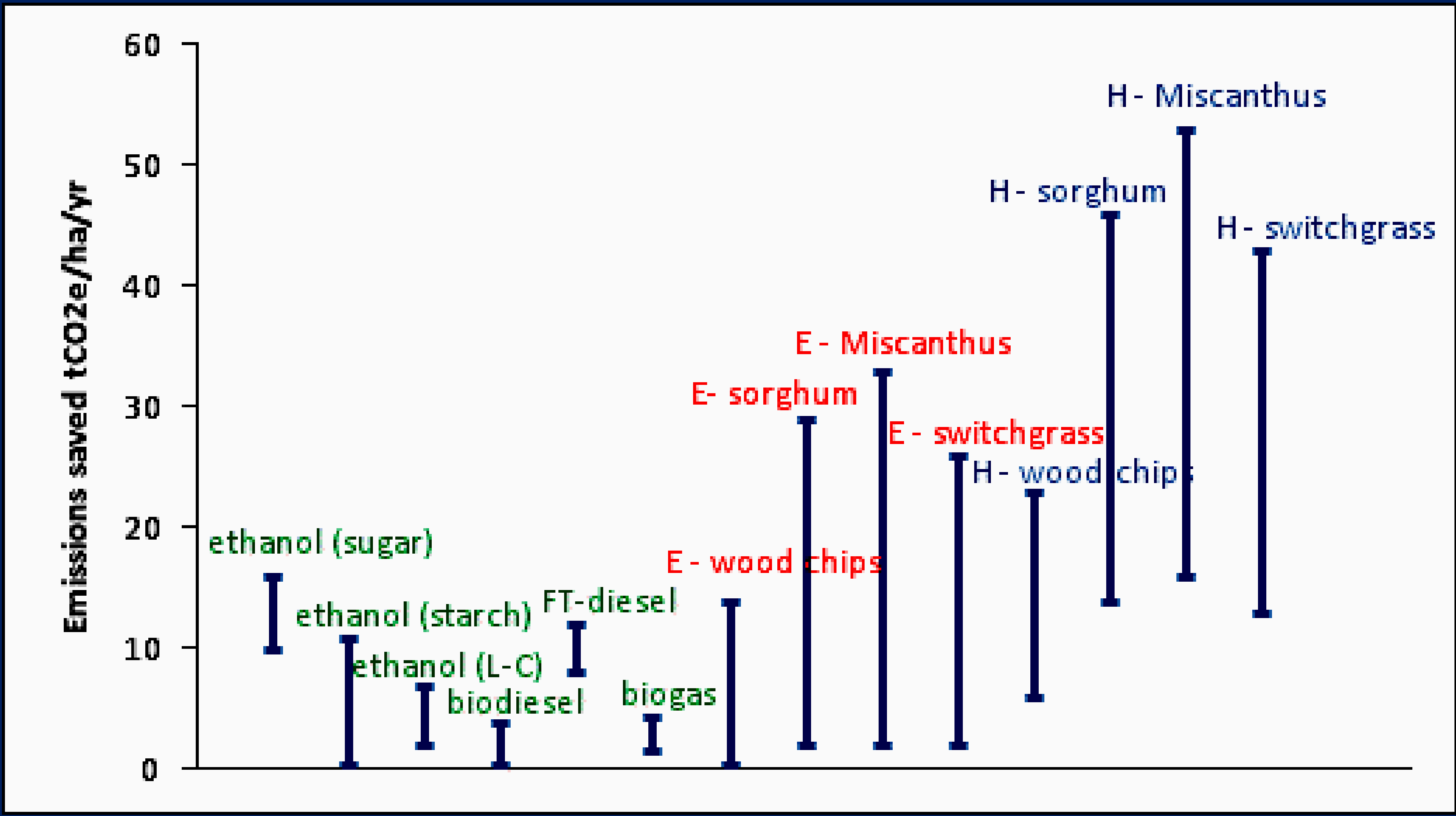
Task 38 Case studies





Excludes indirect land use change

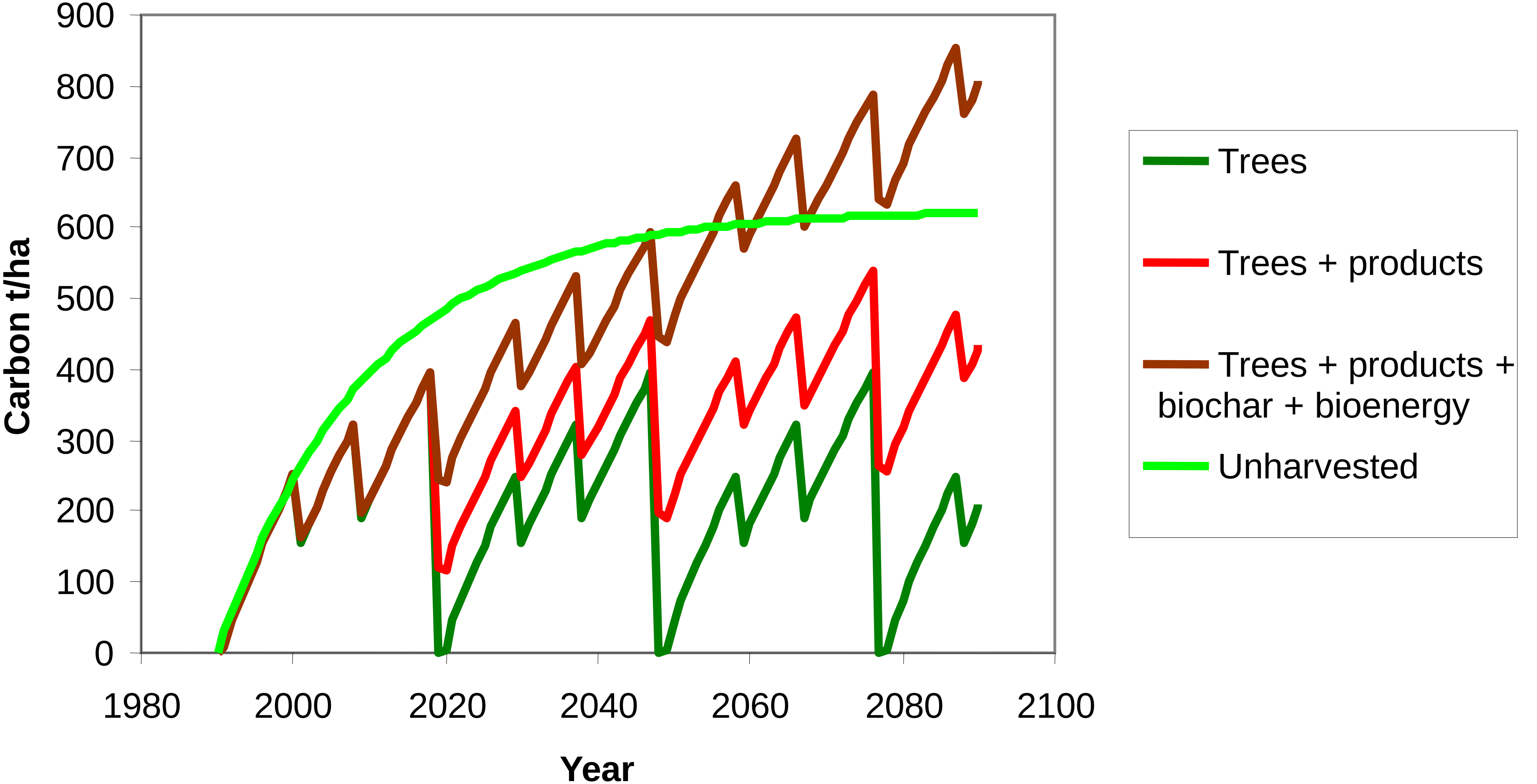
Berndes et al 2011



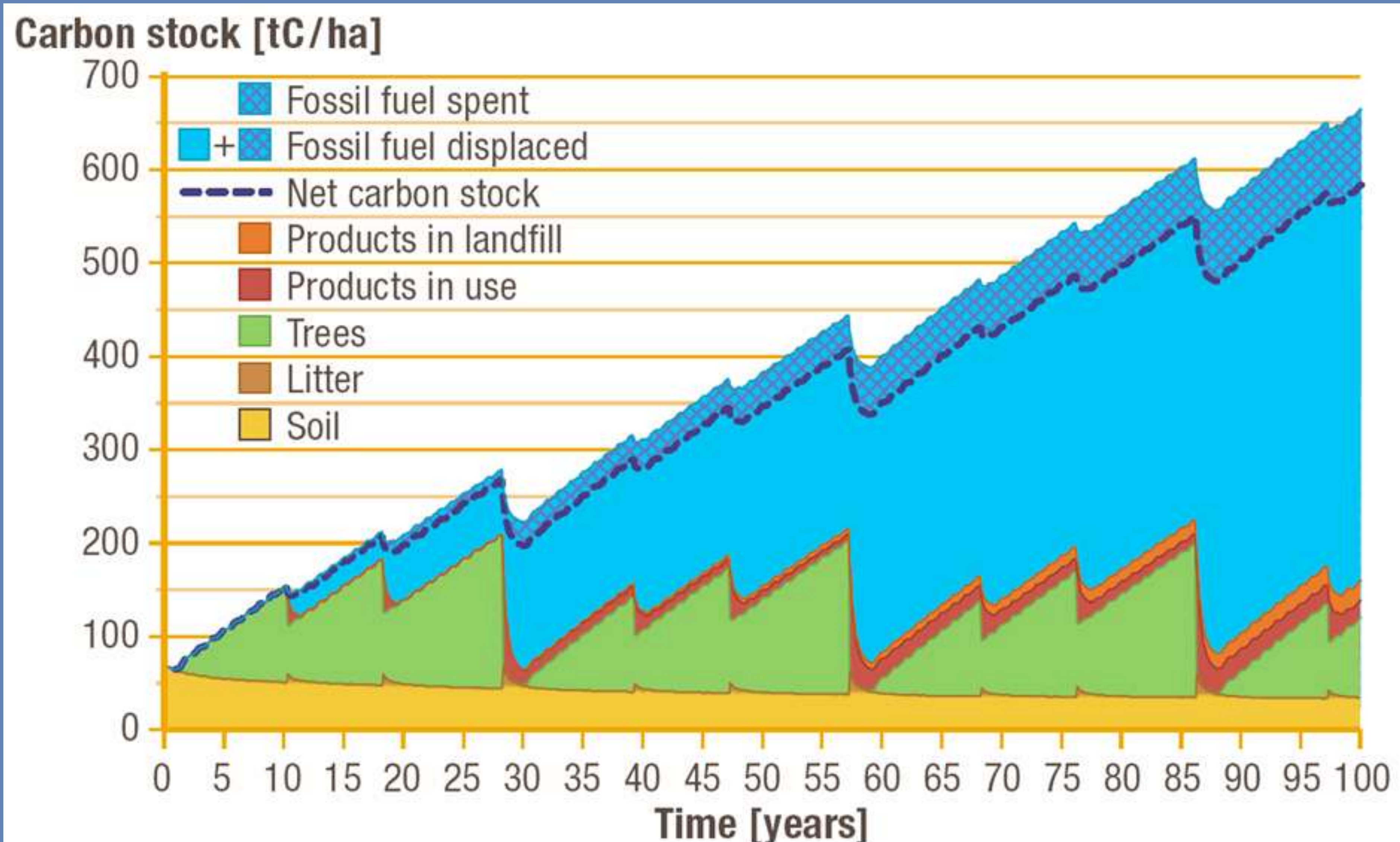
Excludes indirect land use change

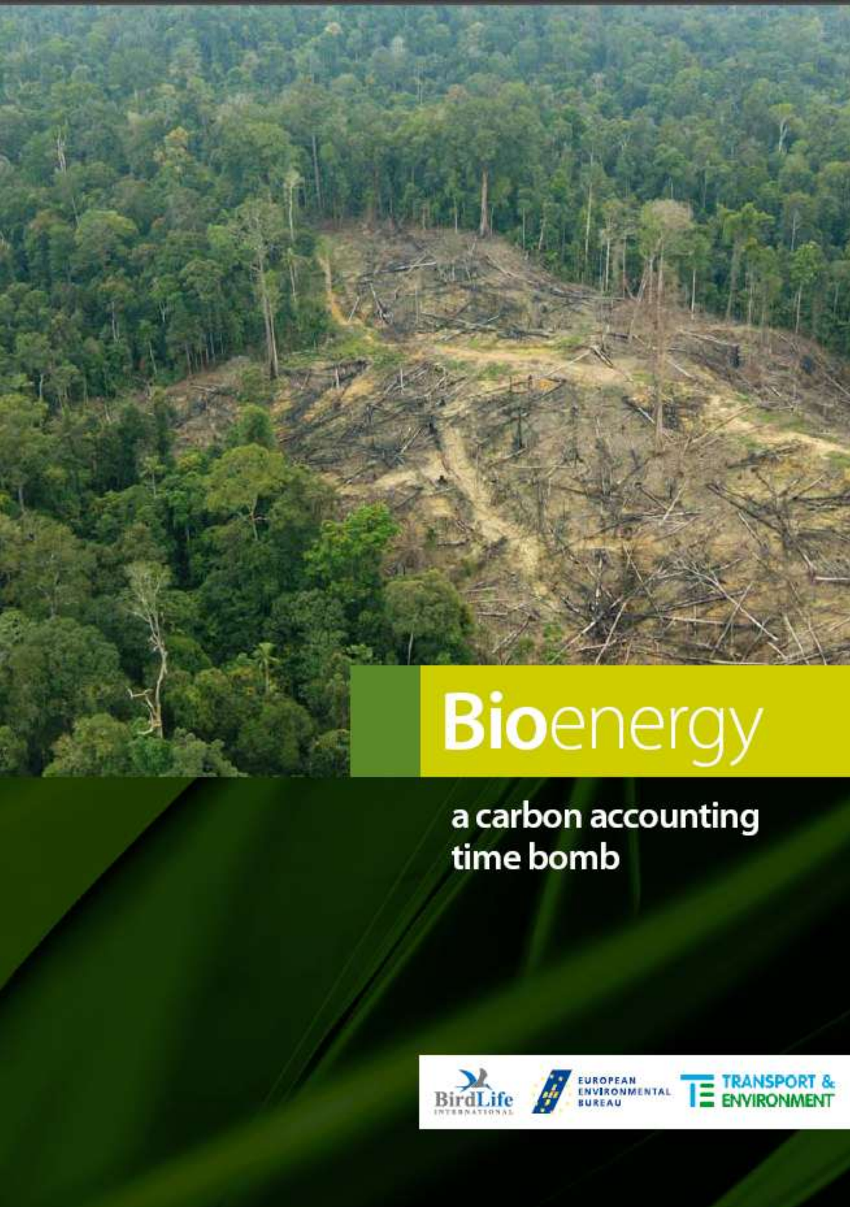
Data from Cherubini et al 2009

Potential mitigation through bioenergy and biochar



Reforestation for timber + bioenergy






Manomet Center for Conservation Sciences June 2010 NCI-2010-03

NATURAL CAPITAL INITIATIVE AT MANOMET REPORT

MANOMET Center for Conservation Sciences

Biomass Sustainability and Carbon Policy Study

Prepared for:

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Biomass better than coal? War over carbon accounting erupts

In Washington, the Environment Working Group has released a study that claims the impacts of the American Clean Energy and Security Act (ACESA)—which has already passed the House of Representatives—would require the equivalent of cutting between 18 and 30 million acres by 2025, and up to 50 million acres by 2030.

"From Maine to Washington state, from Ohio to Florida," the EWG report says, "electric utilities have been embracing "biomass power" as a way to reduce dependence on coal and other fossil fuels and to meet ambitious goals for limiting greenhouse gas emissions. And both state energy policies and the pending federal climate and energy legislation are designed to encourage the trend by providing huge incentives.

Studies cast further doubt on sustainability of bioenergy

Tuesday, June 29, 2010

Two new independent scientific studies launched today cast further doubt on the EU's policy of promoting biomass as fuel for heat and power generation, and biofuels for transport, [1] according to BirdLife International, the European Environmental Bureau and Transport & Environment.

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Kyoto context

- Bioenergy considered CO_2 neutral
- Assumes fossil energy inputs in energy sector
- Assumes non-CO_2 included in agriculture
- Assumes C stock changes included in land sector
- But usually C stock changes are NOT included

23 OCTOBER 2009 VOL 326 SCIENCE

CLIMATE CHANGE

Fixing a Critical Climate Accounting Error

Timothy D. Searchinger,[1]* Steven P. Hamburg,[2]* Jerry Melillo,[3] William Chameides,[4] Petr Havlik,[5] Daniel M. Kammen,[6] Gene E. Likens,[7] Ruben N. Lubowski,[2] Michael Obersteiner,[5] Michael Oppenheimer,[1] G. Philip Robertson,[8] William H. Schlesinger,[7] G. David Tilman[9]

Rules for applying the Kyoto Protocol and national cap-and-trade laws contain a major, but fixable, carbon accounting flaw in assessing bioenergy.

The accounting now used for assessing compliance with carbon limits in the Kyoto Protocol and in climate legislation contains a far-reaching but fixable flaw that will severely undermine greenhouse gas reduction goals (*1*). It does not count CO_2 emitted from tailpipes and smokestacks when bioenergy is being used, but it also does not count changes in emissions from land use when biomass for energy is harvested or grown. This accounting erroneously treats all bioenergy as carbon neutral regardless of the source of the biomass, which may cause large differences in net emissions. For example, the clearing of long-established forests to burn wood or to grow energy crops is counted as a 100% reduction in energy emissions despite

Cancel carbon neutrality for bioenergy?

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- Not a useful solution
- Doesn’t reflect atmospheric impact
- Does disadvantage all bioenergy
- Ignores future benefits of sustainable bioenergy

LETTERS

edited by Jennifer Sills

A Greener Future for China's Cities

IN THEIR PERSPECTIVE "CLEAN AIR FOR MEGACITIES" (30 OCTOBER 2009, P. 674), D. D. Parrish and T. Zhu highlighted the opportunities and challenges that exist for megacities to address air quality and climate change issues. In China, only 60.5% of the 287 large cities monitored in 2007 had air quality that met the standard of the Ministry of Environmental Protection of China (*1*). However, there is encouraging evidence that China is striving to build more low-carbon cities. In early 2008, the World Wildlife Fund collaborated on pilot programs with Shanghai and Baoding, focusing on how to implement low-carbon development in China's urban areas (*2*). Afterward, Beijing, Shanghai, Tianjin, Shenyang, Wuhan, Hangzhou, and Shenzhen all laid out their respective low-carbon road maps (*3*–*6*).


Shanghai

The World Exposition Expo to be held in May 2010 will offer a glimpse of a greener future for Shanghai. During the construction of the Shanghai Expo Park, energy use efficiency and low greenhouse gas emissions were prioritized in activities such as planning, building, and transportation. For example, 4.5 MW integrated solar systems will be used to power buildings in the Expo Park. The use of this clean power is expected to save an estimated 4100 tons of carbon dioxide emissions annually, compared with coal-fired electric power (*7*).

Addressing air pollutants and climate-forcing agents in Chinese cities will require strategic urban planning, large-scale inputs of finances and technology, new regulations, and lifestyle changes. The carbon emissions during the development of low-carbon cities (mostly existing district-level and larger cities) must also be taken into account. New regulations (*8*) have recently been issued in China to eradicate the corrupt inflation in statistics (*9*) associated with the development of low-carbon cities. If these are carefully implemented, we have every reason to look forward to more low-carbon cities in China.

ZONGMING WANG[1] AND JING MING CHEN[2]*

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10. We acknowledge support from the key project of the Chinese Academy of Sciences (grant KZCX 2-YW-341).

Bioenergy: Counting on Incentives

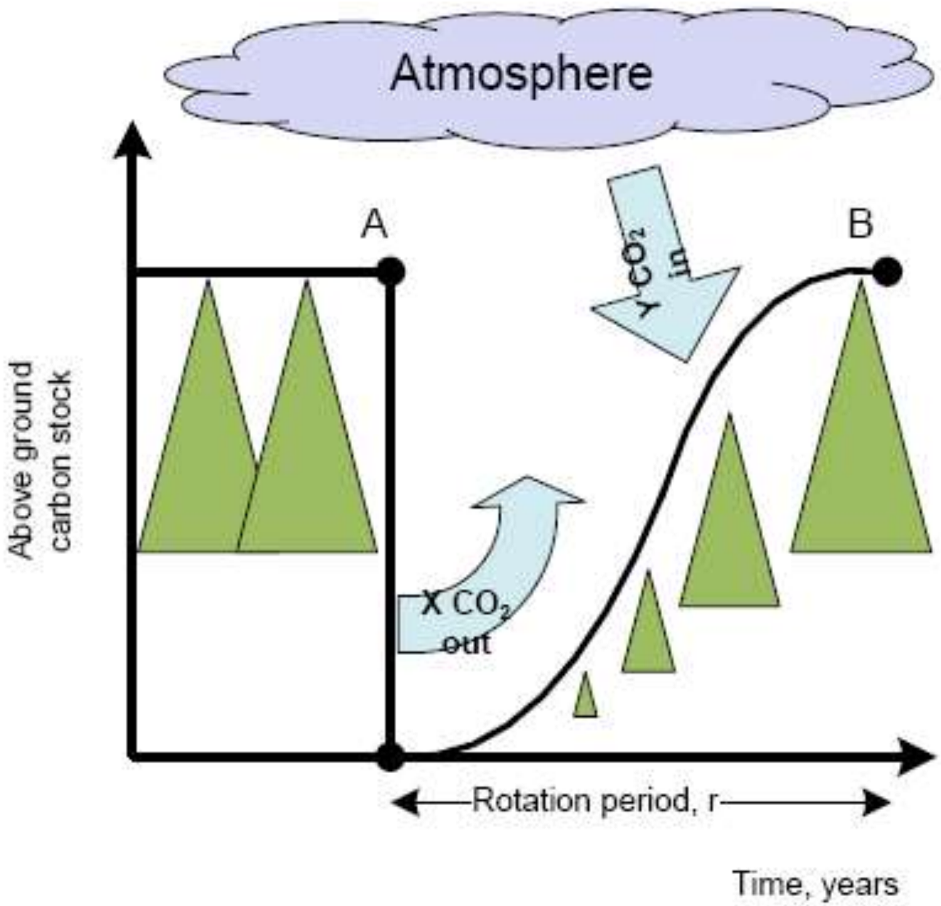
THE SUGGESTION BY T. D. SEARCHINGER *et al.* ("Fixing a critical climate accounting error," Policy Forum, 23 October 2009, p. 527) to account for CO_2 by "tracing the actual flows of carbon" appears to promote an approach to carbon accounting in which emissions and removals from a forest are determined on the basis of gross atmospheric fluxes between the forest, or forest products, and the atmosphere. This contrasts with the current "stock-change" approach, in which the annual removals or emissions from a country's forest are assumed to be equal to the net change in carbon stocks in biomass and soils of the forest estate.

We share the concern of the authors that a "critical climate accounting error" exists within the Kyoto protocol and could undermine greenhouse gas (GHG) reduction goals. However, we feel that their solution would create new, unintended disincentives for the sustainable use of biomass.

The practical problem in the current accounting framework is that some countries do not have commitments under the Kyoto Protocol, and they are therefore not obliged to account for emissions from loss of terrestrial carbon. Furthermore, some countries with commitments choose not to account for some sources of emissions (for example, conversion of natural to managed forest, conversion of grassland to cropland). Therefore, loss of carbon stock associated with the supply of biomass for bioenergy may not be accounted for.

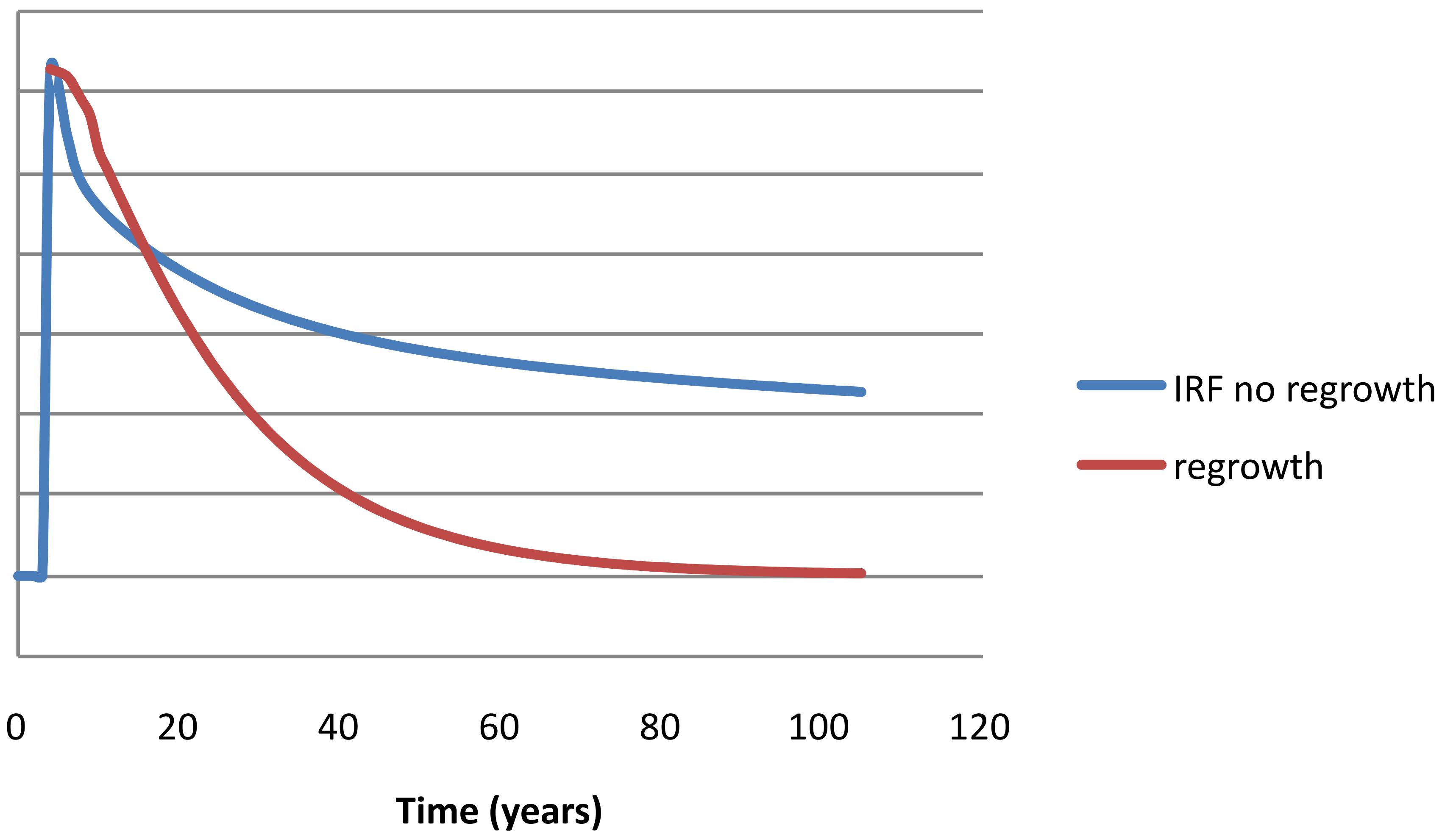
Published by AAAS

Bioenergy: timing of benefits

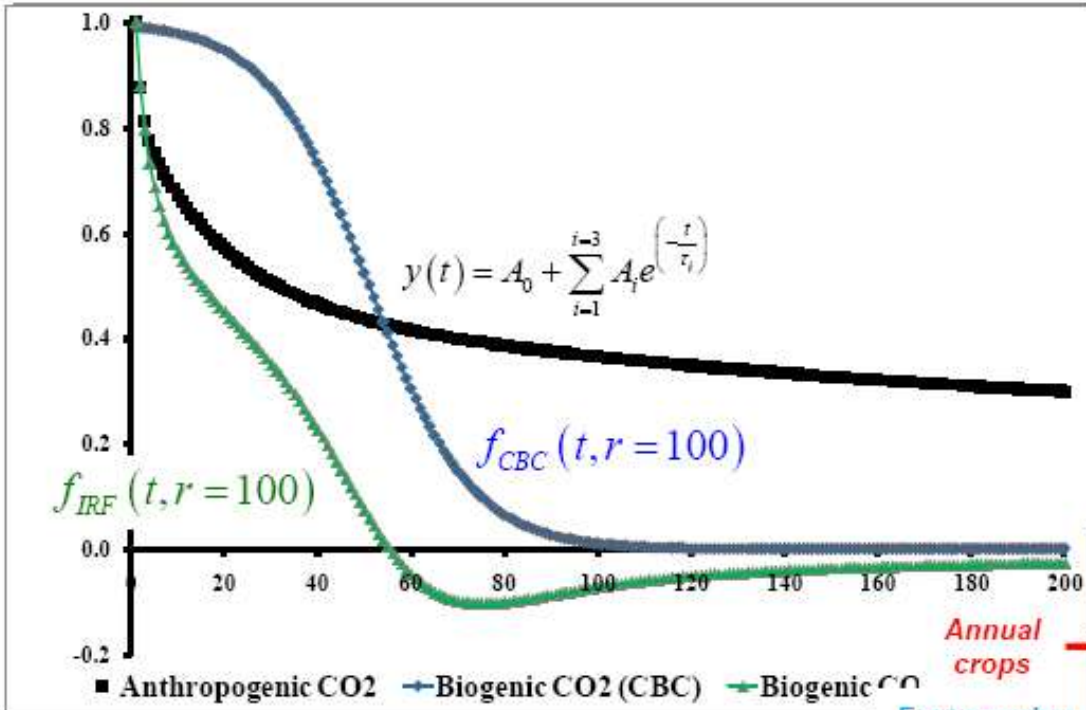


F Cherubini NTNU

Atmospheric [CO2] - impulse response



Atmospheric decays and GWP_{bio}



$$GWP_{bio} = \frac{AGWP_{bioCO_2}}{AGWP_{CO_2}} = \frac{C_0 \int_0^{TH} \alpha_{CO_2} \cdot f(t)\,dt}{C_0 \int_0^{TH} \alpha_{CO_2} \cdot y(t)\,dt}$$

	Rotation r	IRF GWP_{bio} TH = 100	IRF GWP_{bio} TH = 500
Annual crops	1	0.004	0.002
Fast growing biomass	2	0.01	0.003
	8	0.03	0.01
	10	0.04	0.01
	20	0.08	0.02
	30	0.12	0.02
Tropical forest	40	0.16	0.03
	50	0.21	0.04
	60	0.25	0.05
Temperate forest	70	0.30	0.05
	80	0.34	0.06
Boreal forest	90	0.39	0.07
	100	0.43	0.08

F Cherubini NTNU

	r	GWP_{bio} TH = 100	GWP_{bio} TH = 500
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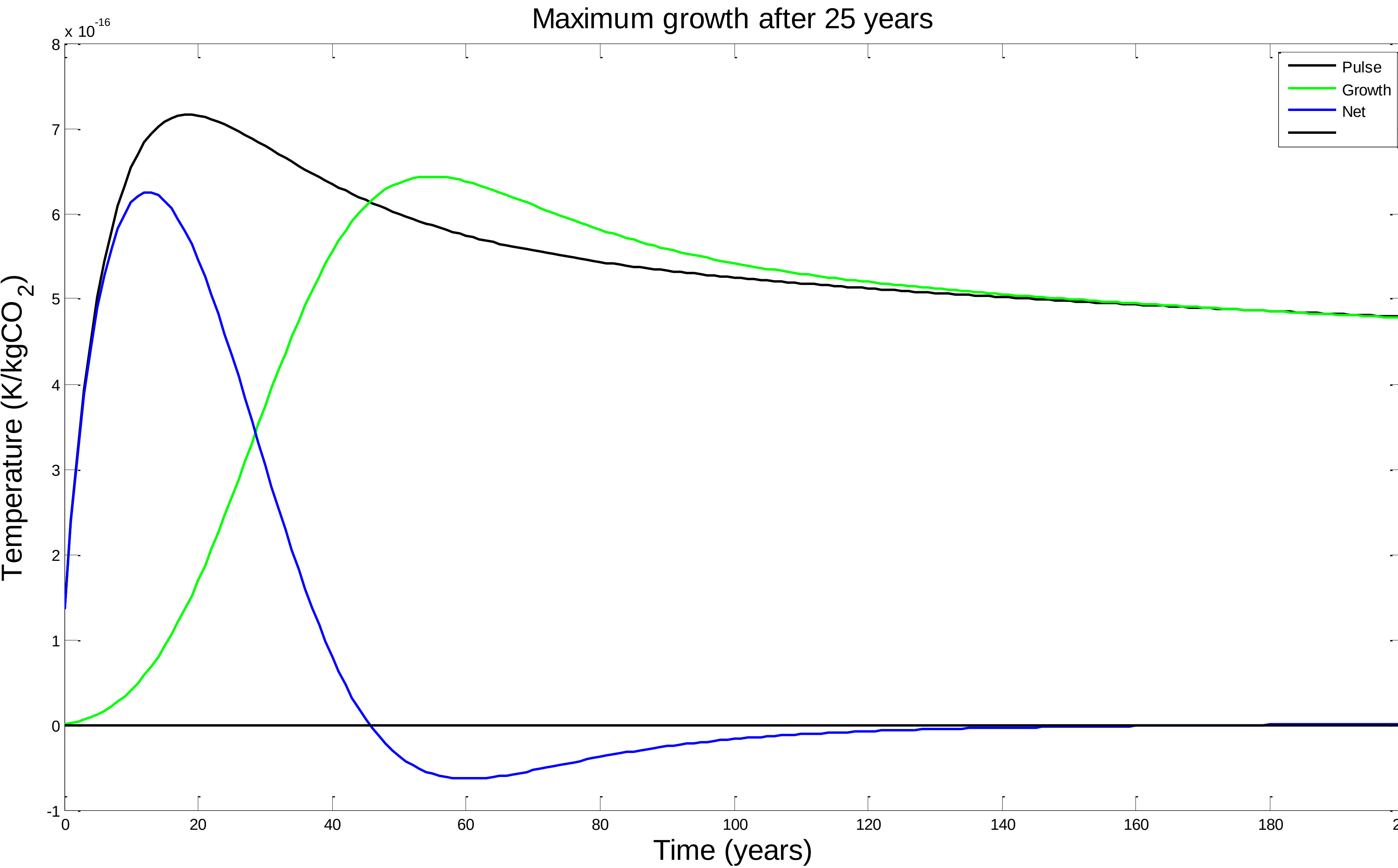
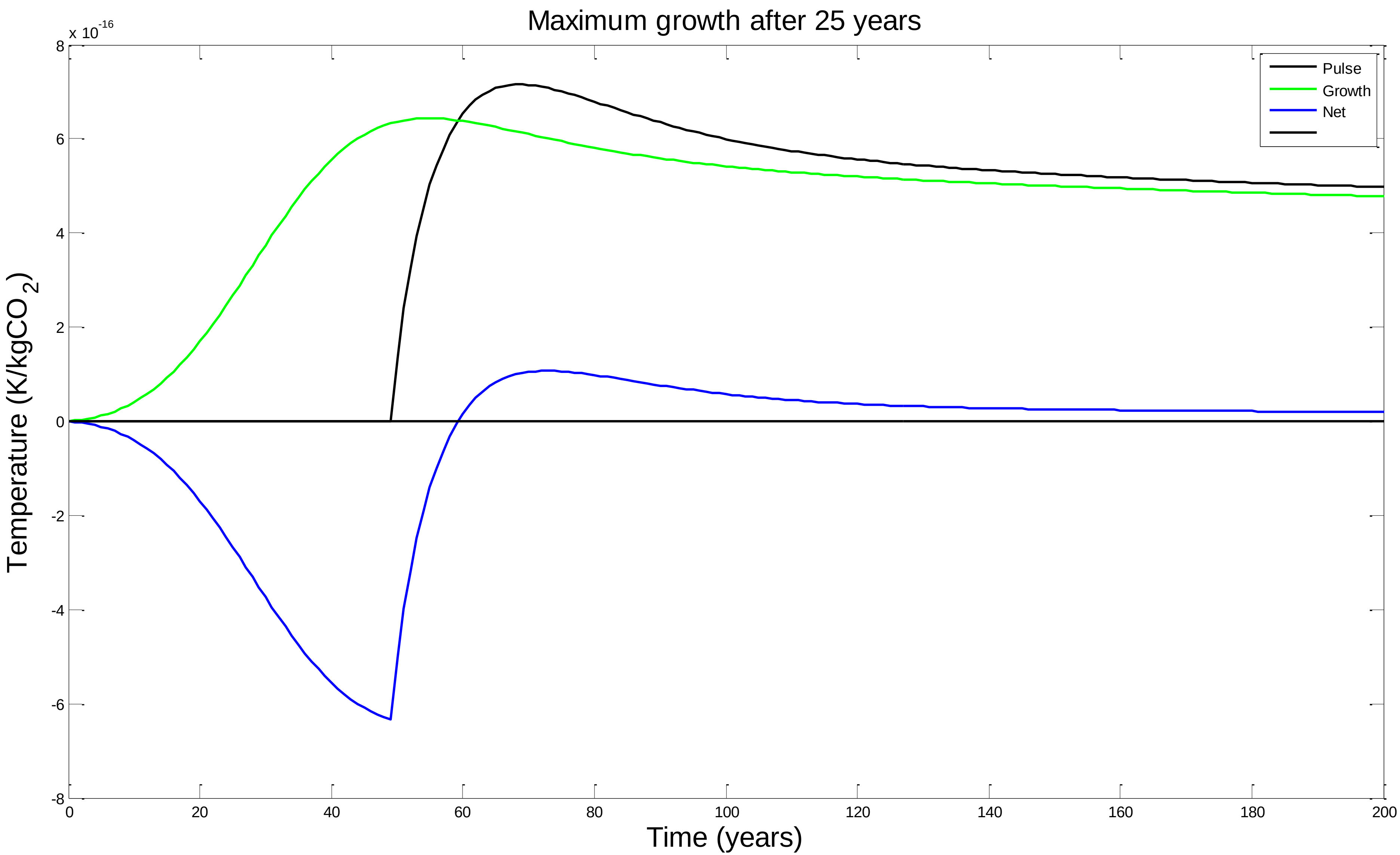
F Cherubini NTNU



G Peters, CICERO



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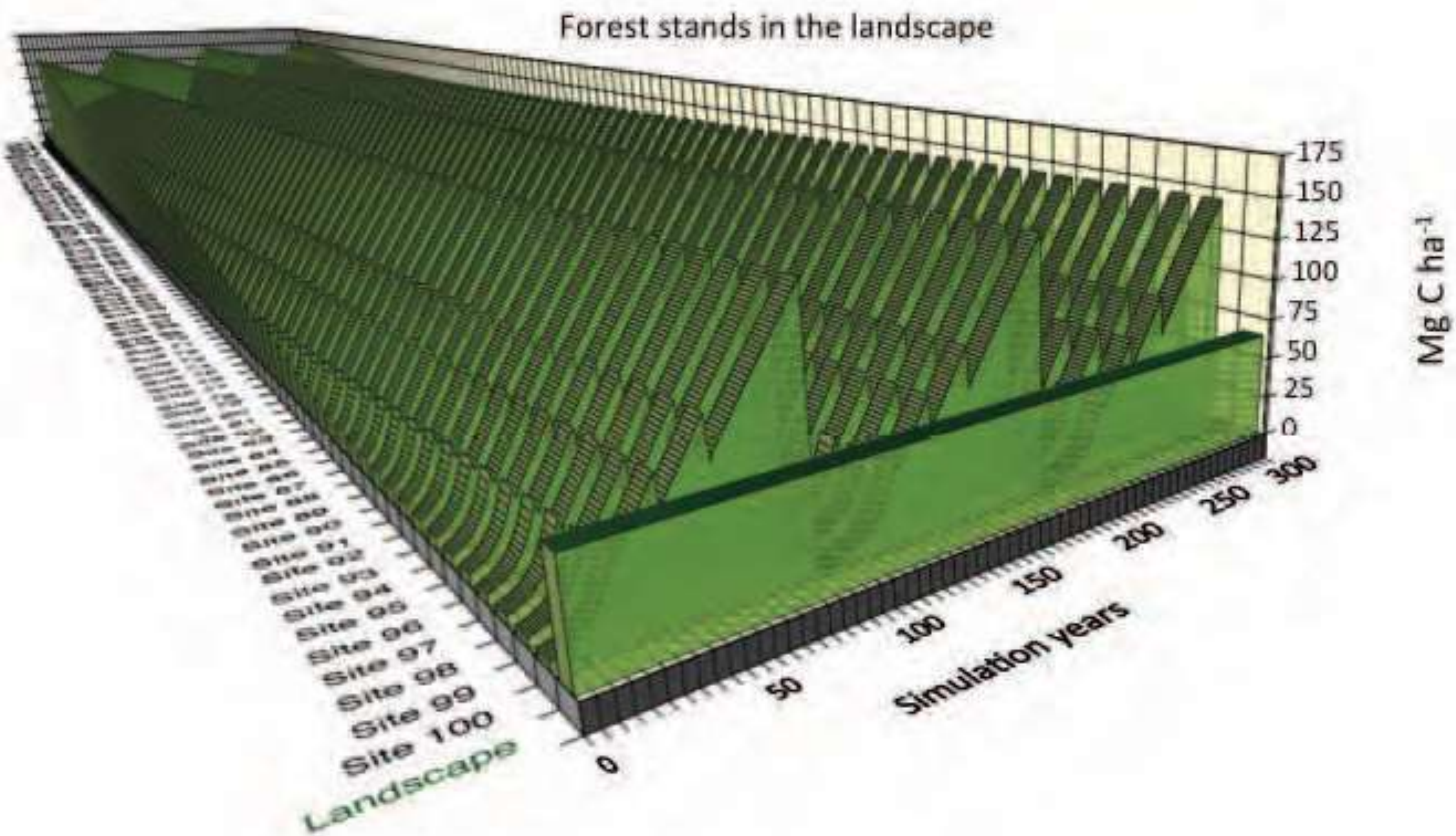
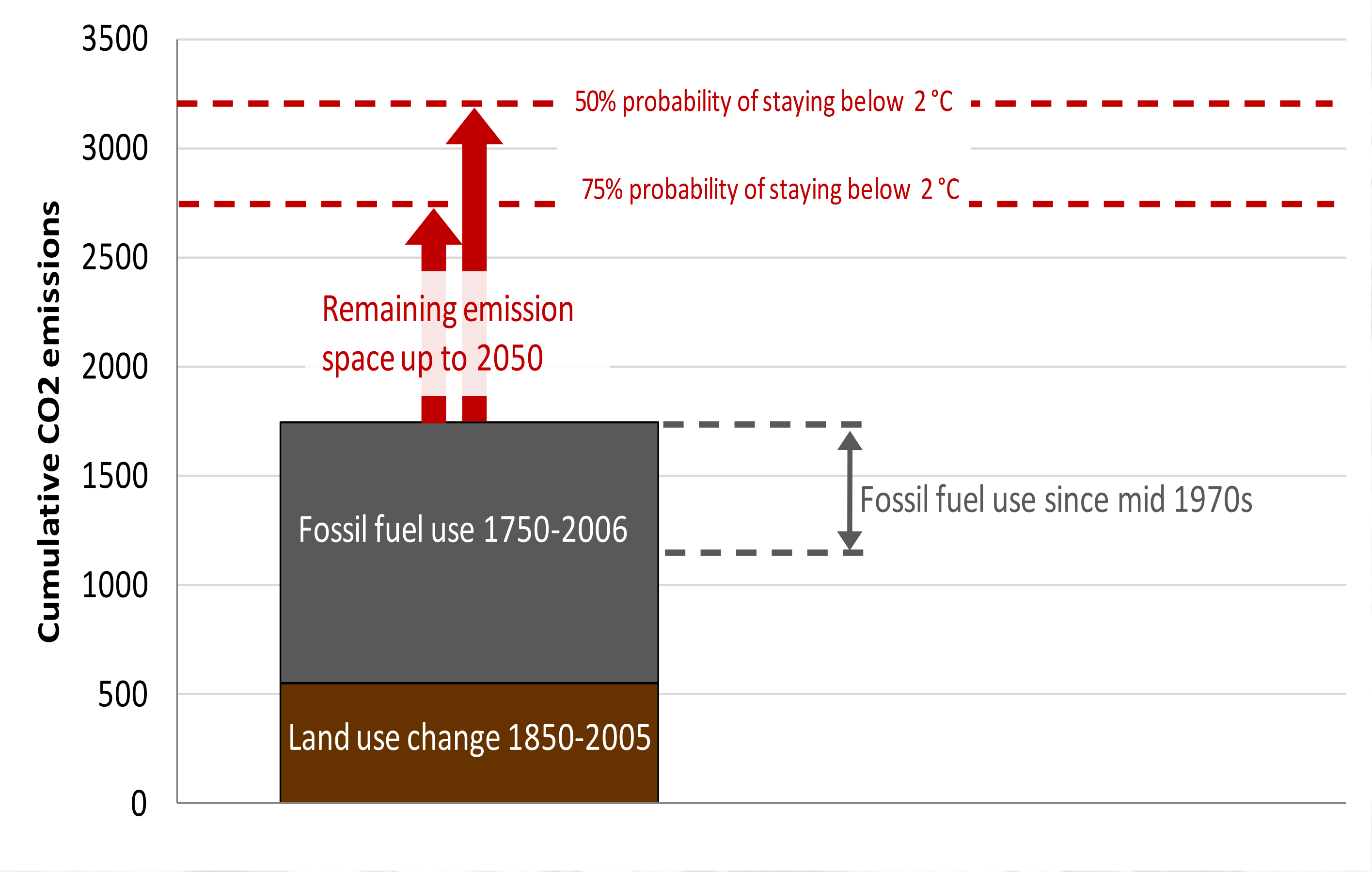


Berndes et al 2011

Investment in low-carbon energy



Berndes et al 2011

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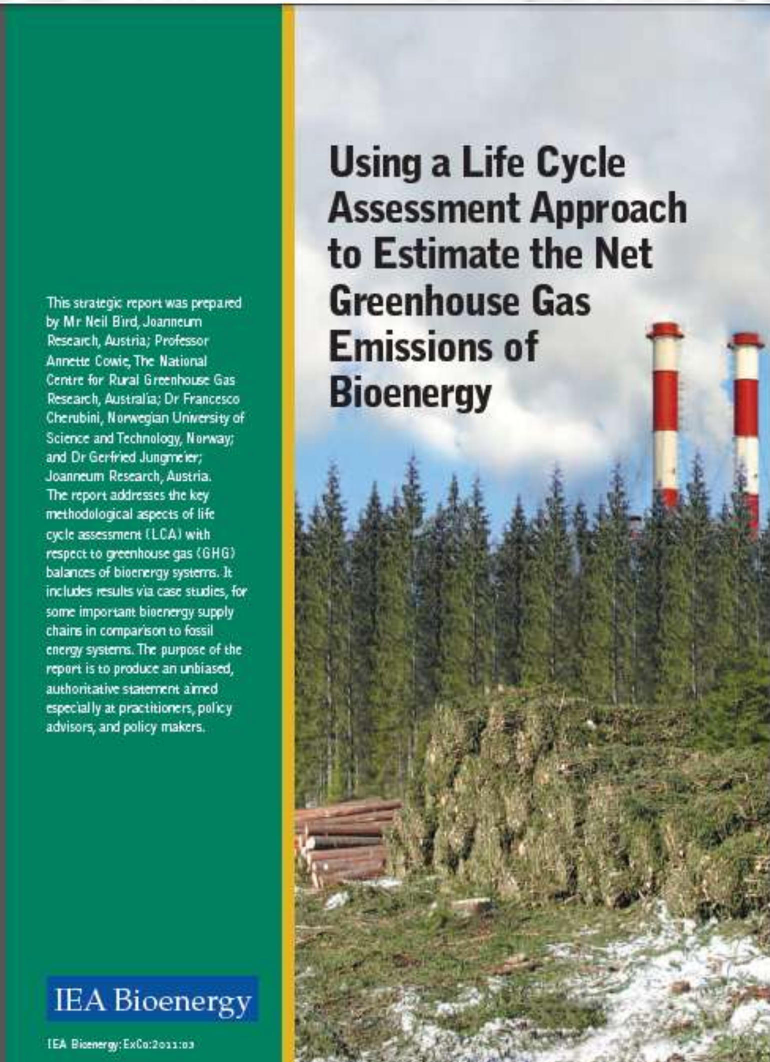

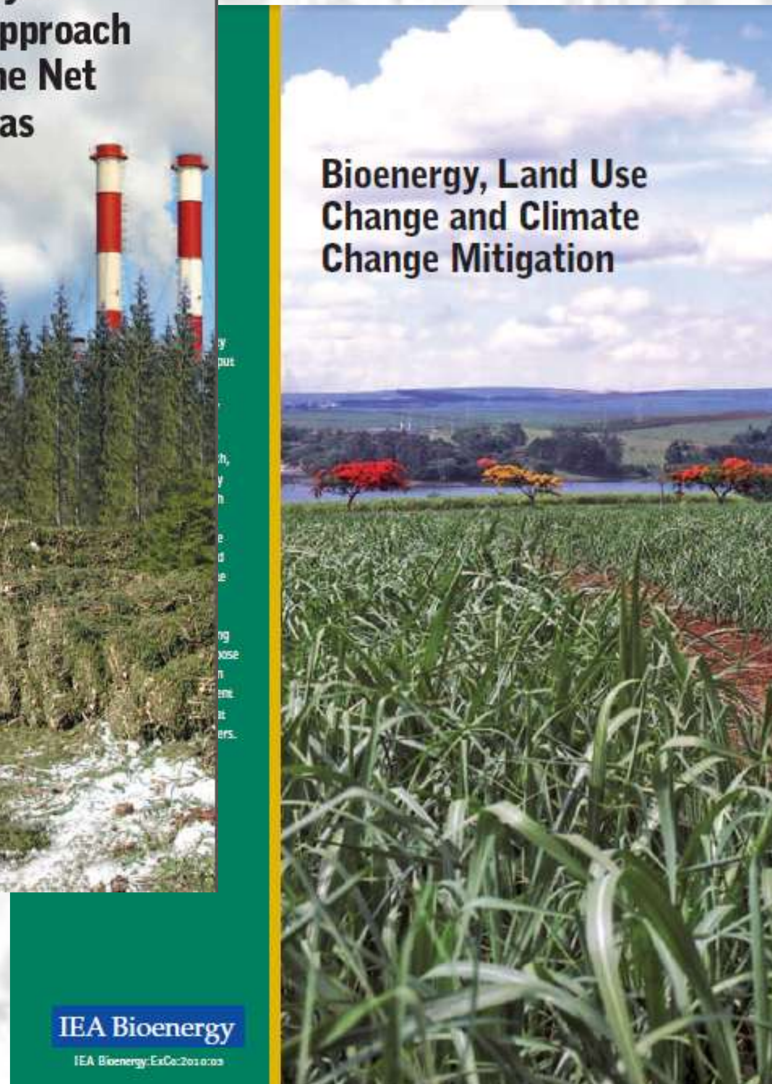

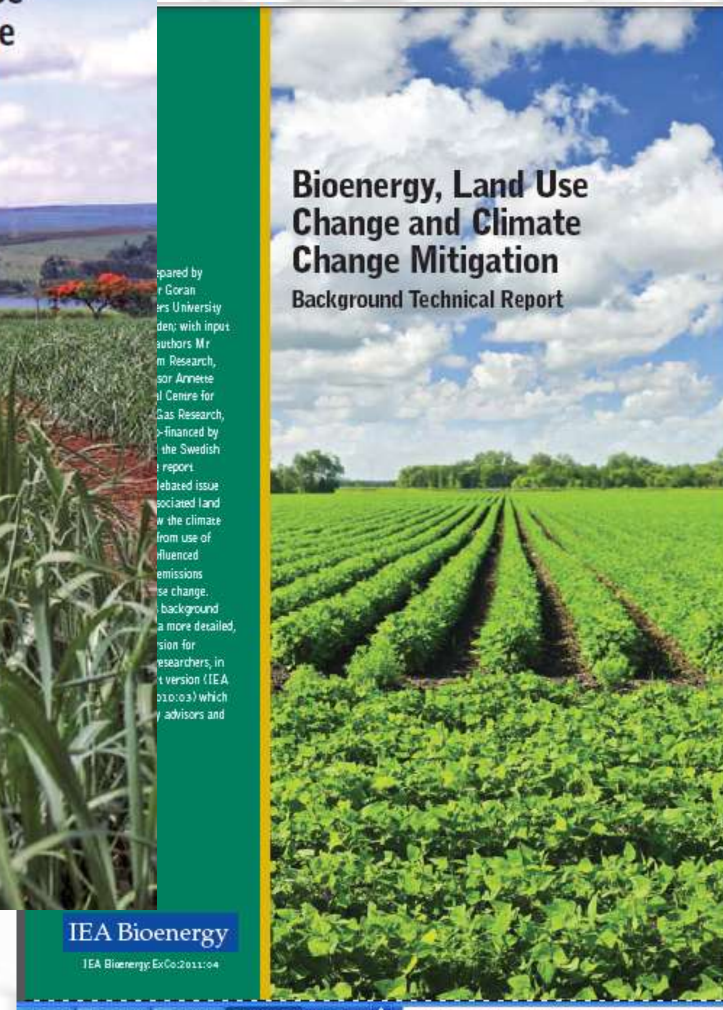

- What is the best use of biomass resources?







- How can land be used to produce biomass without compromising other needs?

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Greenhouse Gas Balances of Biomass and Bioenergy Systems

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