Environmental Assessment of Biorefinery Systems

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Life Cycle Analyses of Greenhouse Gas Emissions and Cumulated Primary Energy Consumption

JOANNEUM RESEARCH/Austria

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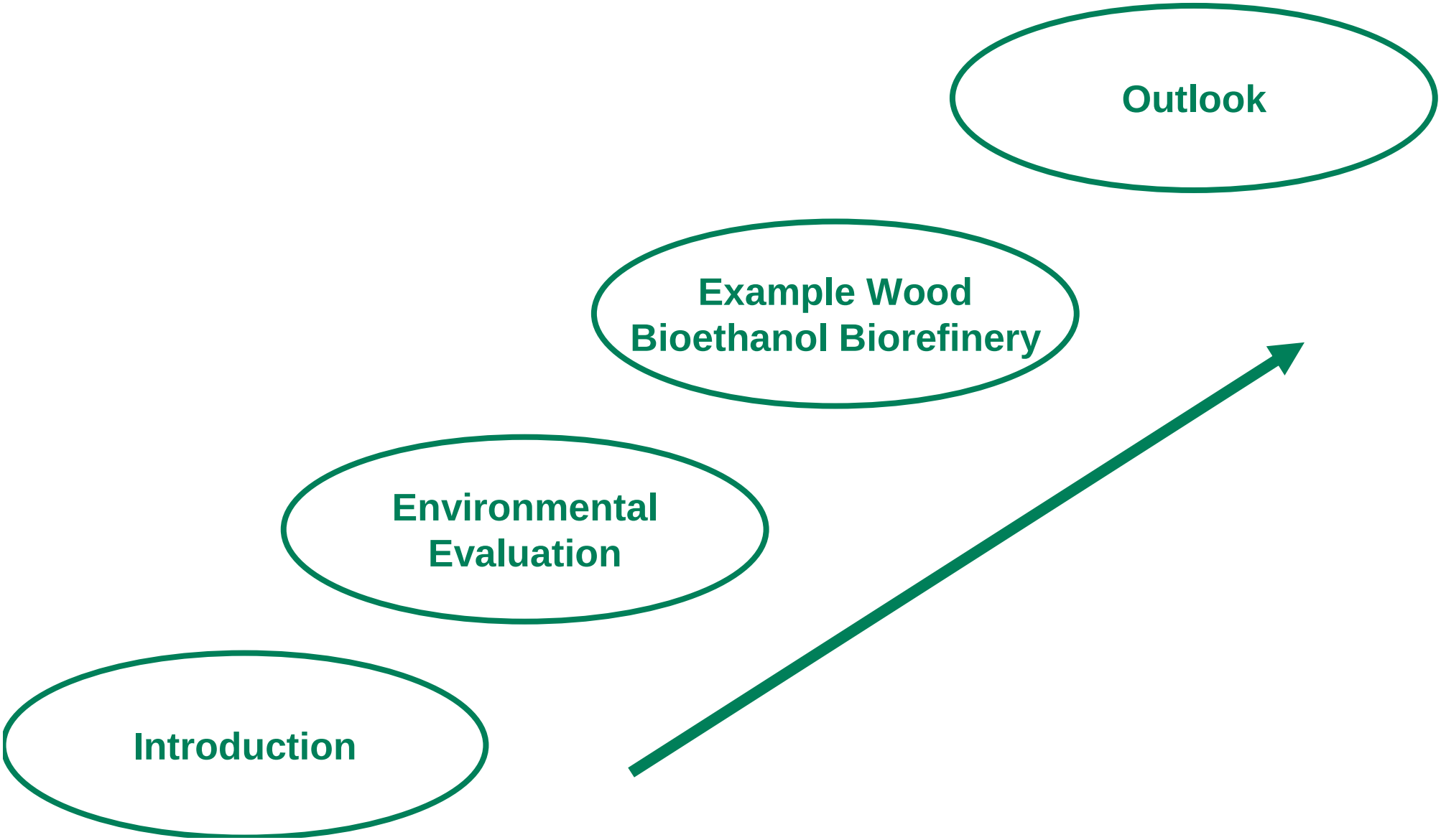
Biorefinery Training Course of IEA Bioenergy Task 42 "Biorefinery"

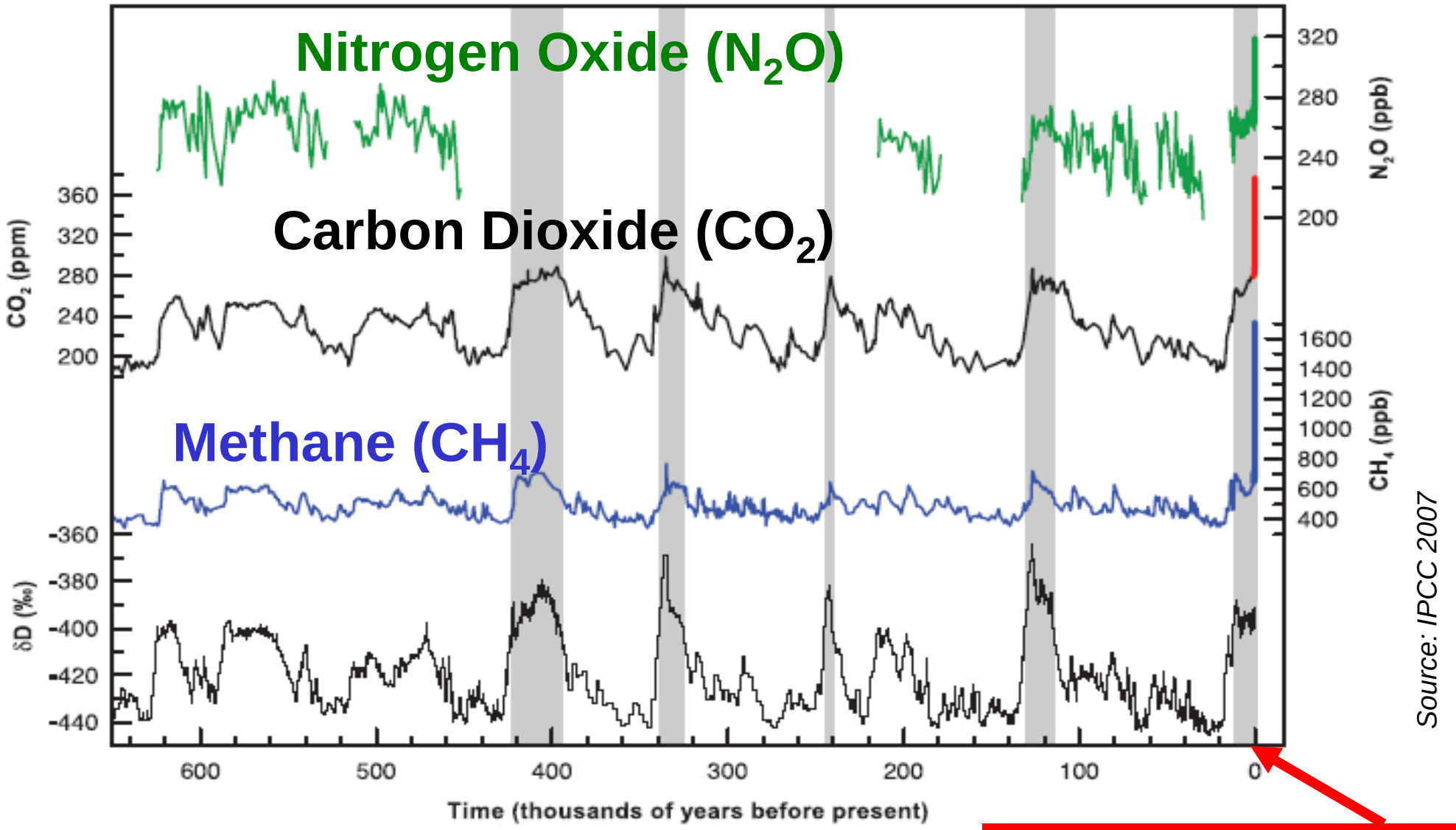
"Biomass Valorization Congress"

Amsterdam, The Netherlands, September 13, 2010

Outline

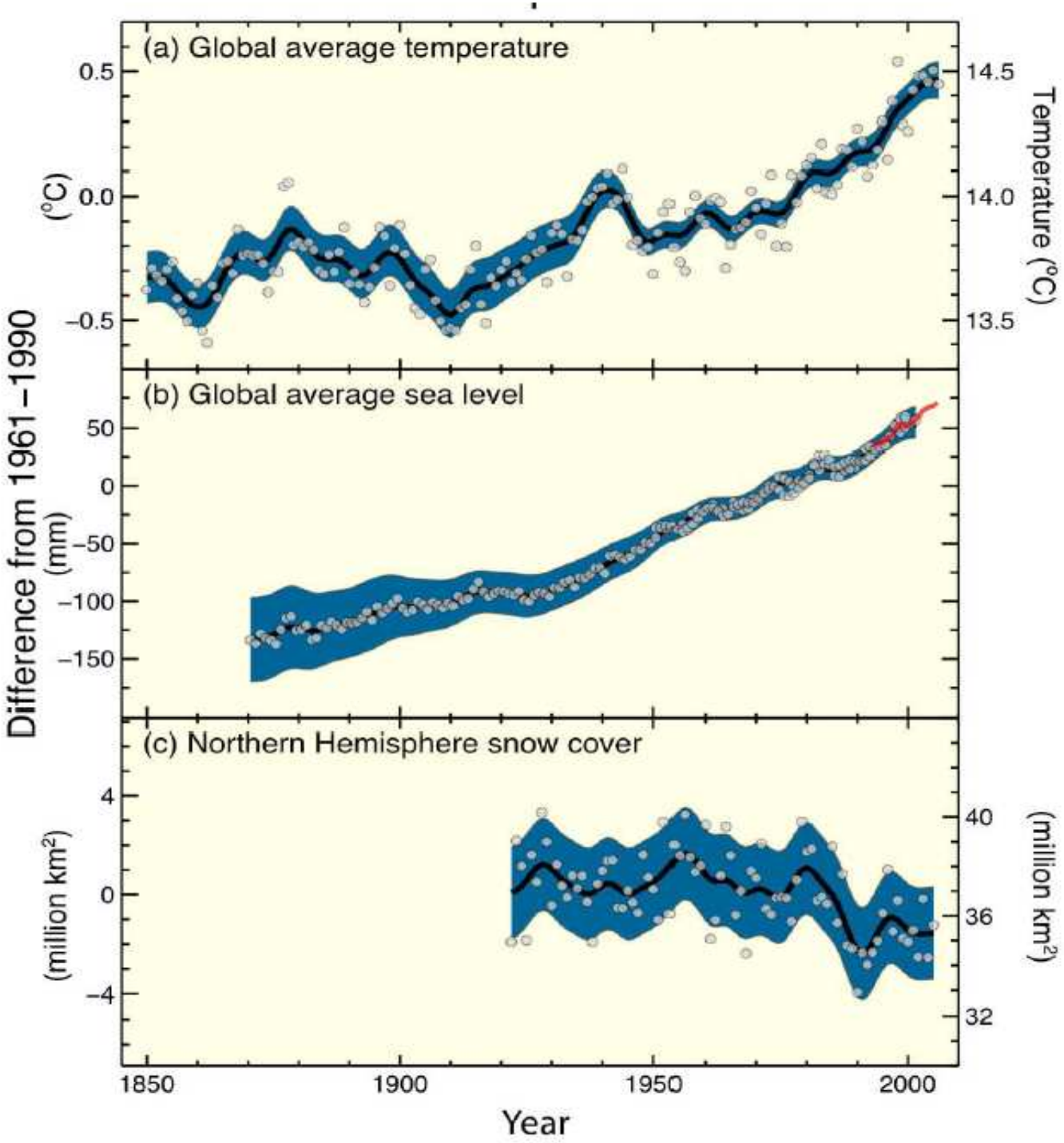

Outlook
Example Wood Bioethanol Biorefinery
Environmental Evaluation
Introduction

Development of Greenhouse Gas Concentration in Our Atmosphere



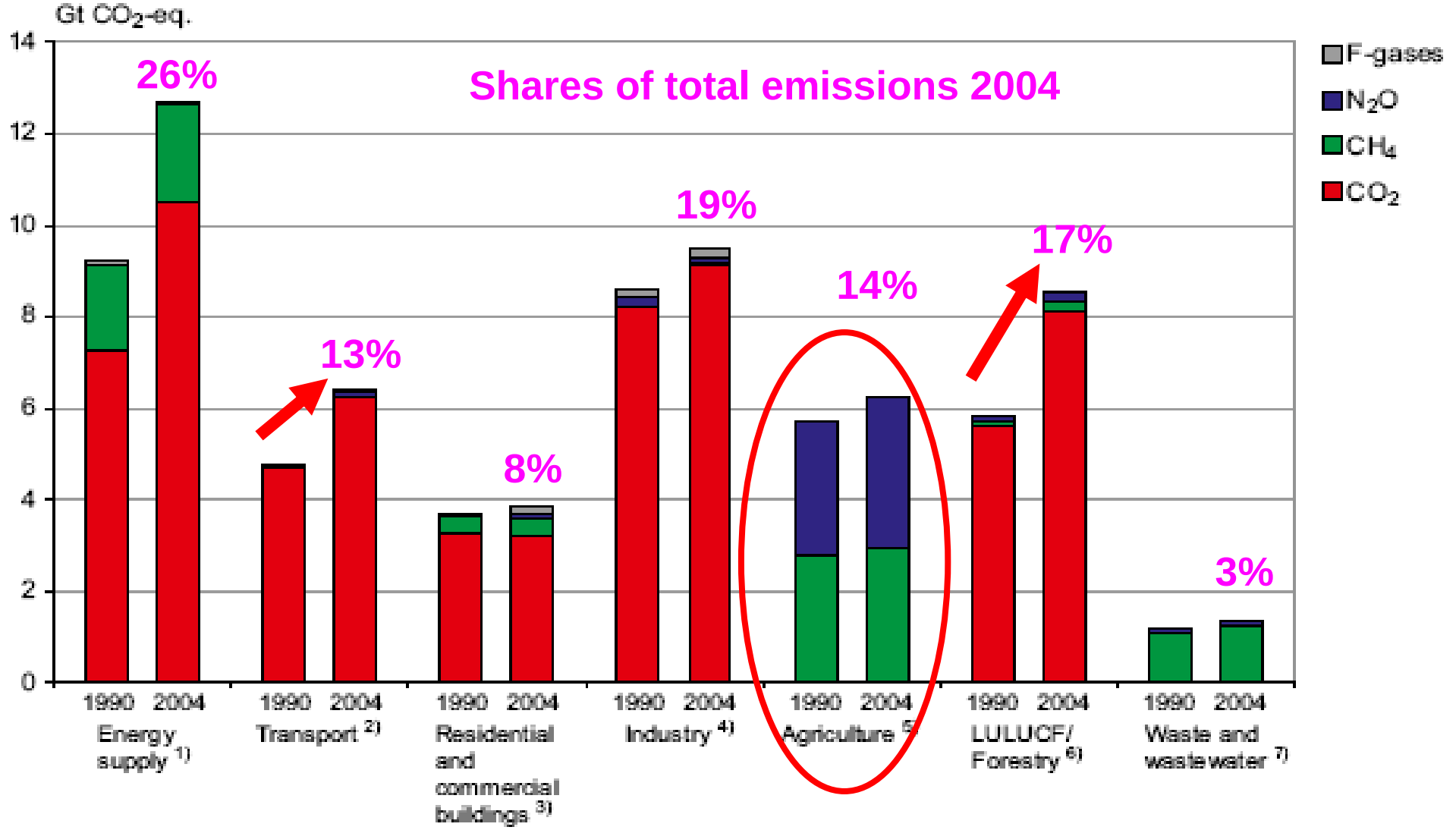
Source: IPCC 2007

Observed Changes



Source: IPCC 2007

Development Greenhouse Gas Emissions per Sector 2004



Source: www.ipcc.ch

Indicators for „Sustainable Biofuels“

- Greenhouse gas balance (> 35% / 45% / 60%reduction)
- Land use change
  - Change of carbon storage pools
  - Loss of biodiversity
  - Competition
    - agriculture for food and feed
    - forestry: construction materials, wooden products, local energy use
  - Others: soil erosion, water resource, plant protection agents, GMOs...

Environment

Economic prosperity, e.g. labour creation, land ownership

Social welfare, e.g. working conditions, healthiness

Sustainability

Perspective

Certification of biomasse raw materials and biofuels

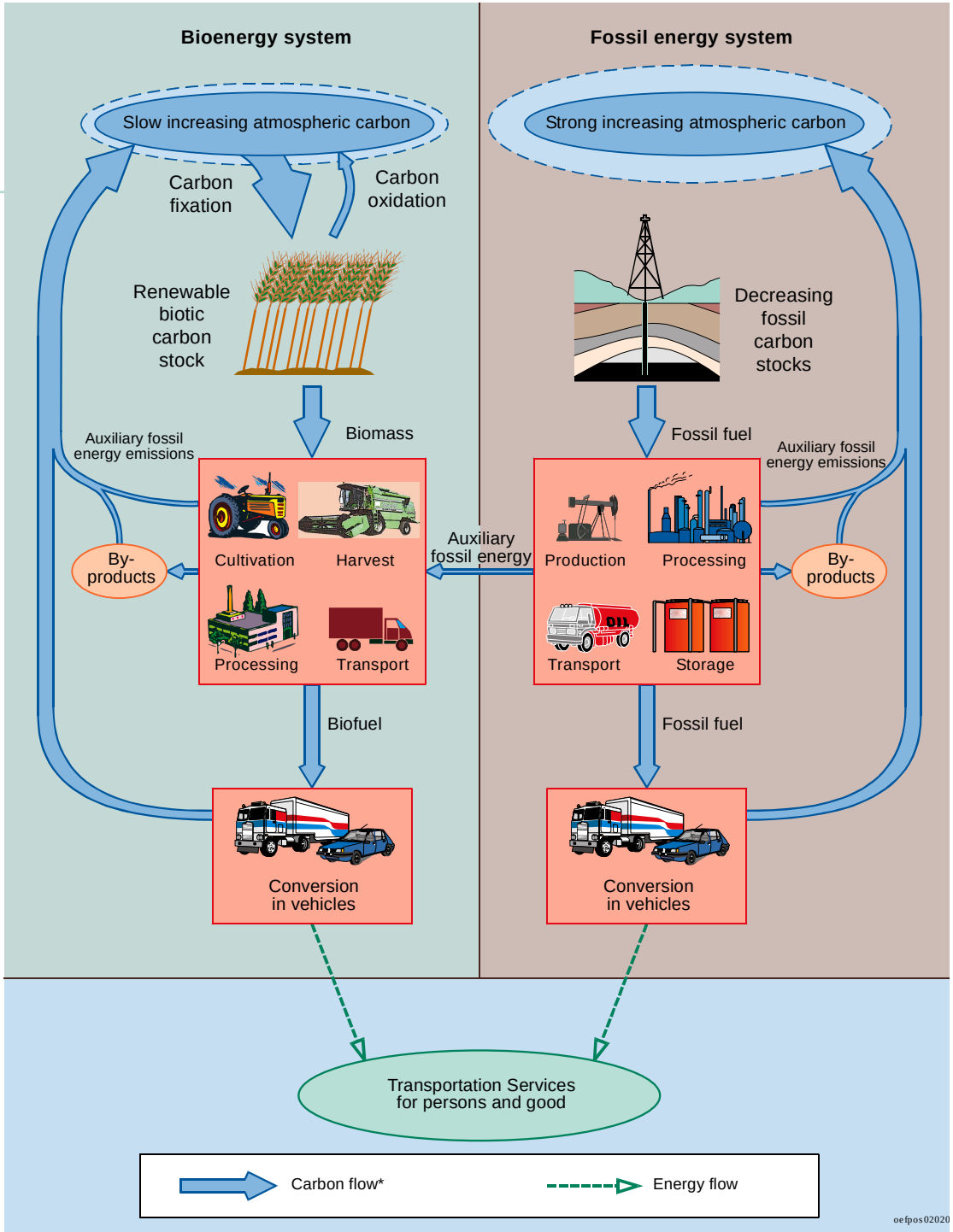
Life Cycle Analyses

According to

- **ISO 14 040**
  „Life Cycle assessment“

- **Standard Methodology of IEA Bioenergy Task 38**
  „*Greenhouse Gas Balances of Bioenergy systems*“

- **Recommendations of COST Action E9 „*Life Cycle Assessment of Forestry and Forest Products*“**



Criteria for Environmental Assessment

- **Greenhouse gas emissions [t CO_2-eq.] including**
  - ✓ **Carbon dioxide (1 kg CO_2 = 1 kg CO_2-eq)**
  - ✓ **Methane (1 kg CH_4 = 25 kg CO_2-eq)**
  - ✓ **Nitrous oxide (1 kg N_2O = 298 kg CO_2-eq)**

- **Cumulated primary energy demand [$PJ_{primary\ energy}$] shared in**
  - ✓ **biomass (e.g. wood, straw)**
  - ✓ **fossil energy (e.g. oil, coal, natural gas)**
  - ✓ **others (e.g. hydro power, waste, nuclear)**

- **Indicators for environmental evaluation**
  - ✓ **Specific GHG reduction [t CO_2-eq/$t_{biomass}$] or [t CO_2-eq/ha]**
  - ✓ **Specific fossil energy reduction [$TJ_{fossil\ energy}$/t_{wood}]**

Environmental Advantages Biorefineries over Conventional Processes – Principles

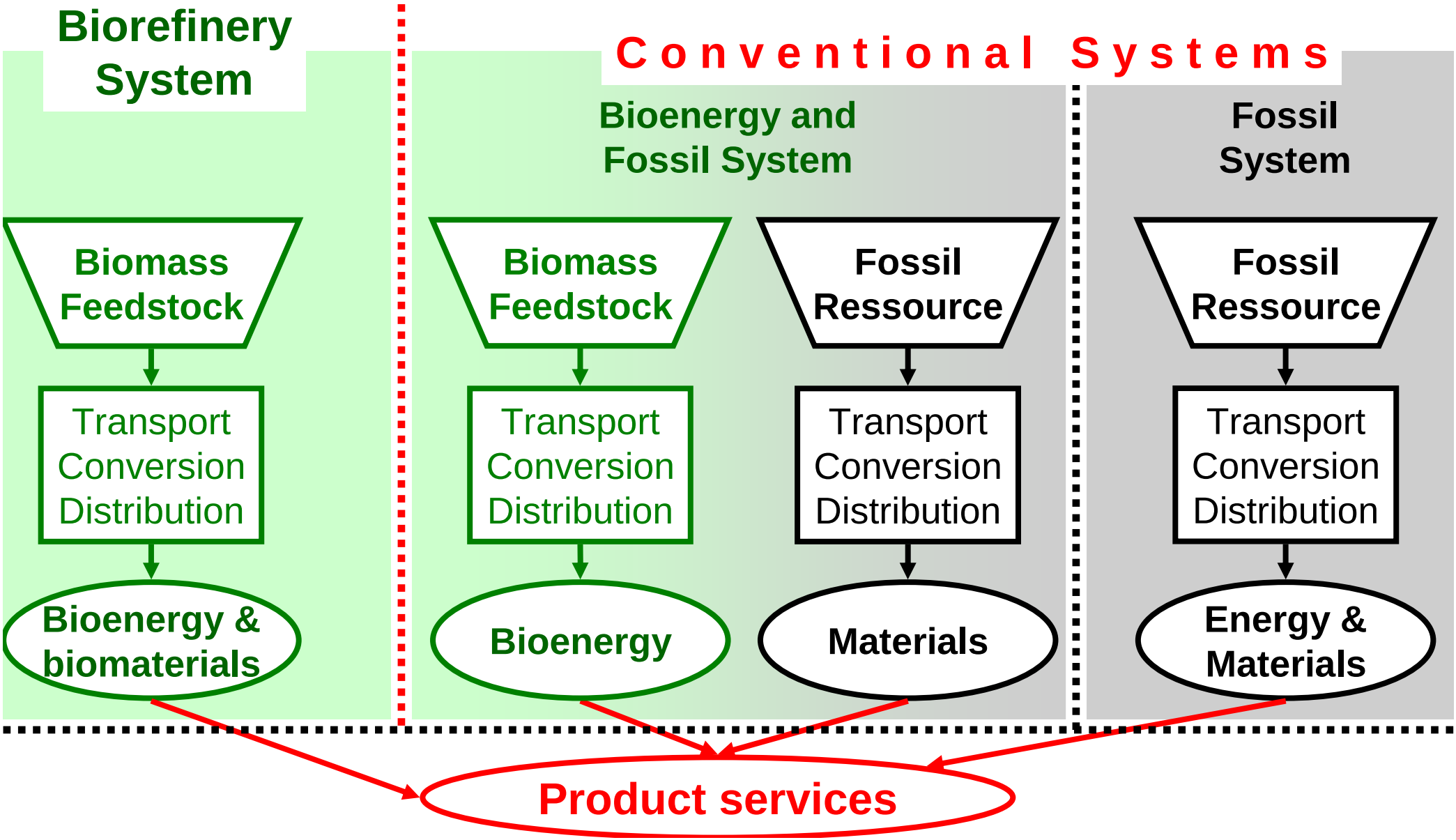
Main question:

What are the conventional processes?

Answer:

- ✓ **Same amount of products with same service**
- ✓ **Same amount and type of biomass input**
- ✓ **Same amount of agricultural/forestry area used**
- ✓ **Conventional Processes for biomass: use for heat and power via different processes**

What are the „Conventional Systems?“



Basics of Comparing Biorefineries to “Conventional Systems”

- ✓ Same amount of products with same services
- ✓ Same amount and type of biomass input
- ✓ Same amount of agricultural/forestry area used
- ✓ Whole chain approach e.g. life cycle, value chain

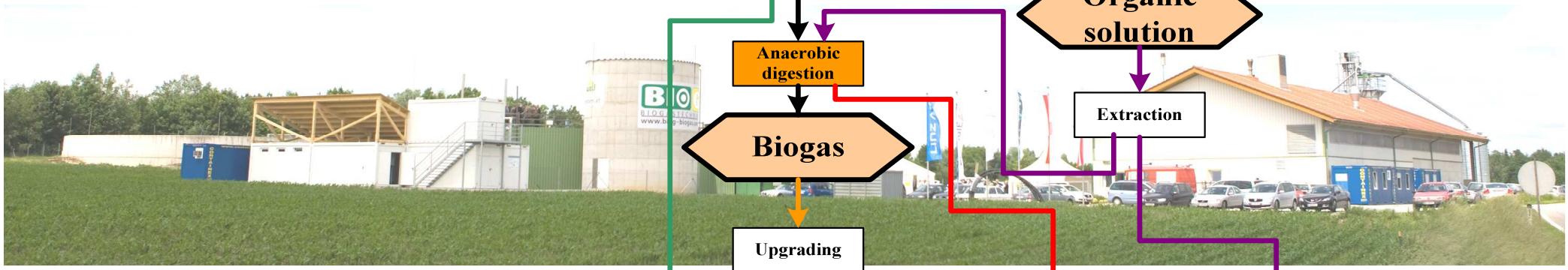
→ These basiscs are applied to two cases

Case 1: Demonstration Plant „Green Biorefinery“, Austria

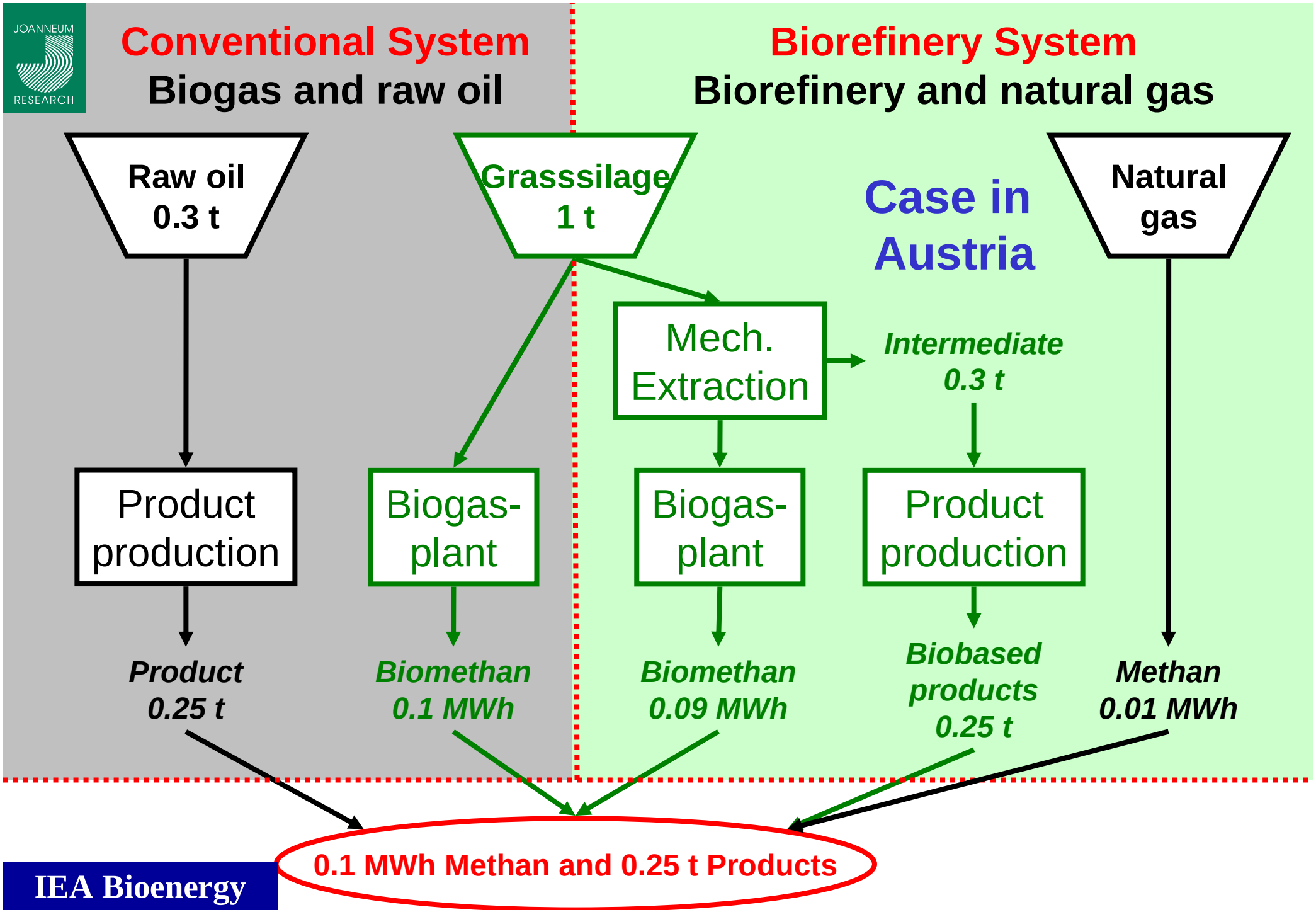
Upgrading of grass silage to

- lactic acid,
- amino acids and
- biogas (biomethan)

“A Two Platform Biorefinery with Grasses for Biomethan - Biogas, organic solution”

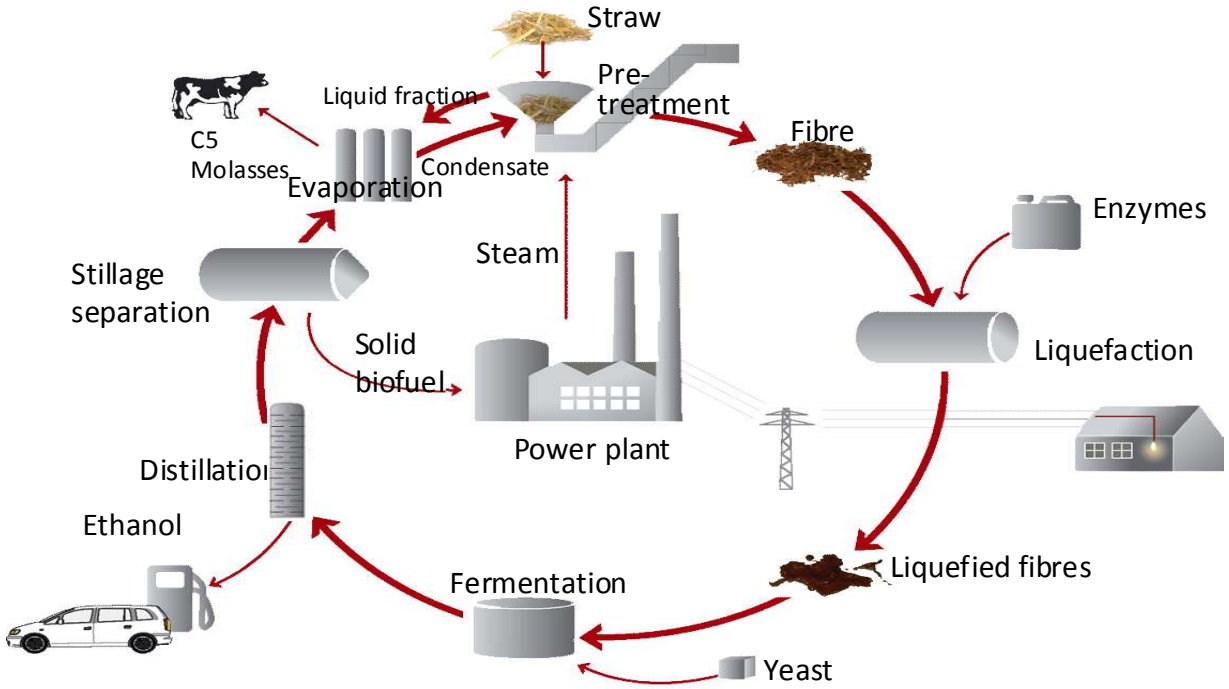


IEA Bioenergy

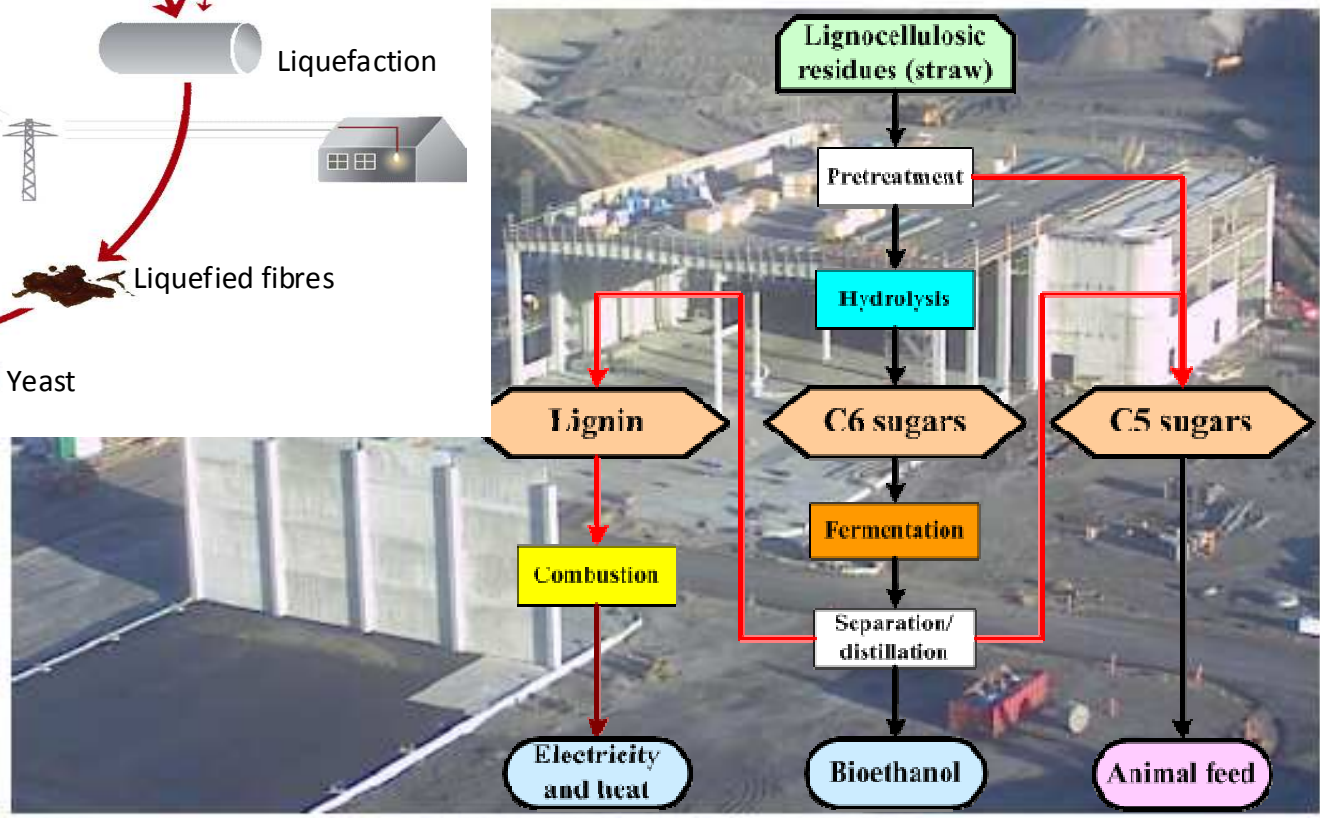

Conventional System
Biogas and raw oil
Biorefinery System
Biorefinery and natural gas
Raw oil
0.3 t
Grasssilage
1 t
Natural
gas
Case in
Austria
Mech.
Extraction
Intermediate
0.3 t
Product
production
Biogas-
plant
Biogas-
plant
Product
production
Product
0.25 t
Biomethan
0.1 MWh
Biomethan
0.09 MWh
Biobased
products
0.25 t
Methan
0.01 MWh
0.1 MWh Methan and 0.25 t Products
IEA Bioenergy

Case 2: Demonstration Plant IBUS Biorefinery Denmark

IEA Bioenergy



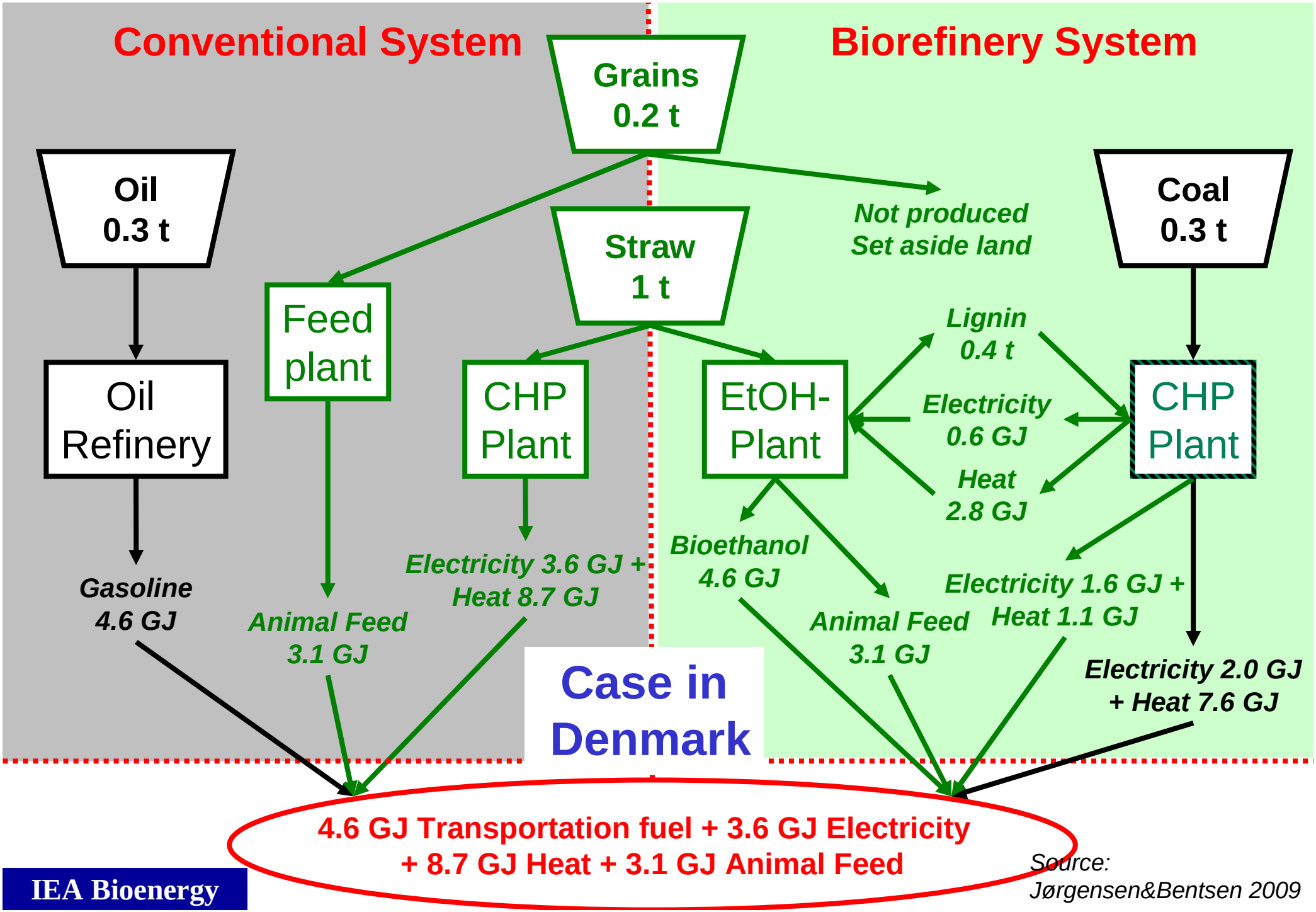
„A Three Platform Biorefinery with Straw for Bioethanol – C6&C5 Sugars and Lignin“



Kalundborg, Denmark – 7. January 2009

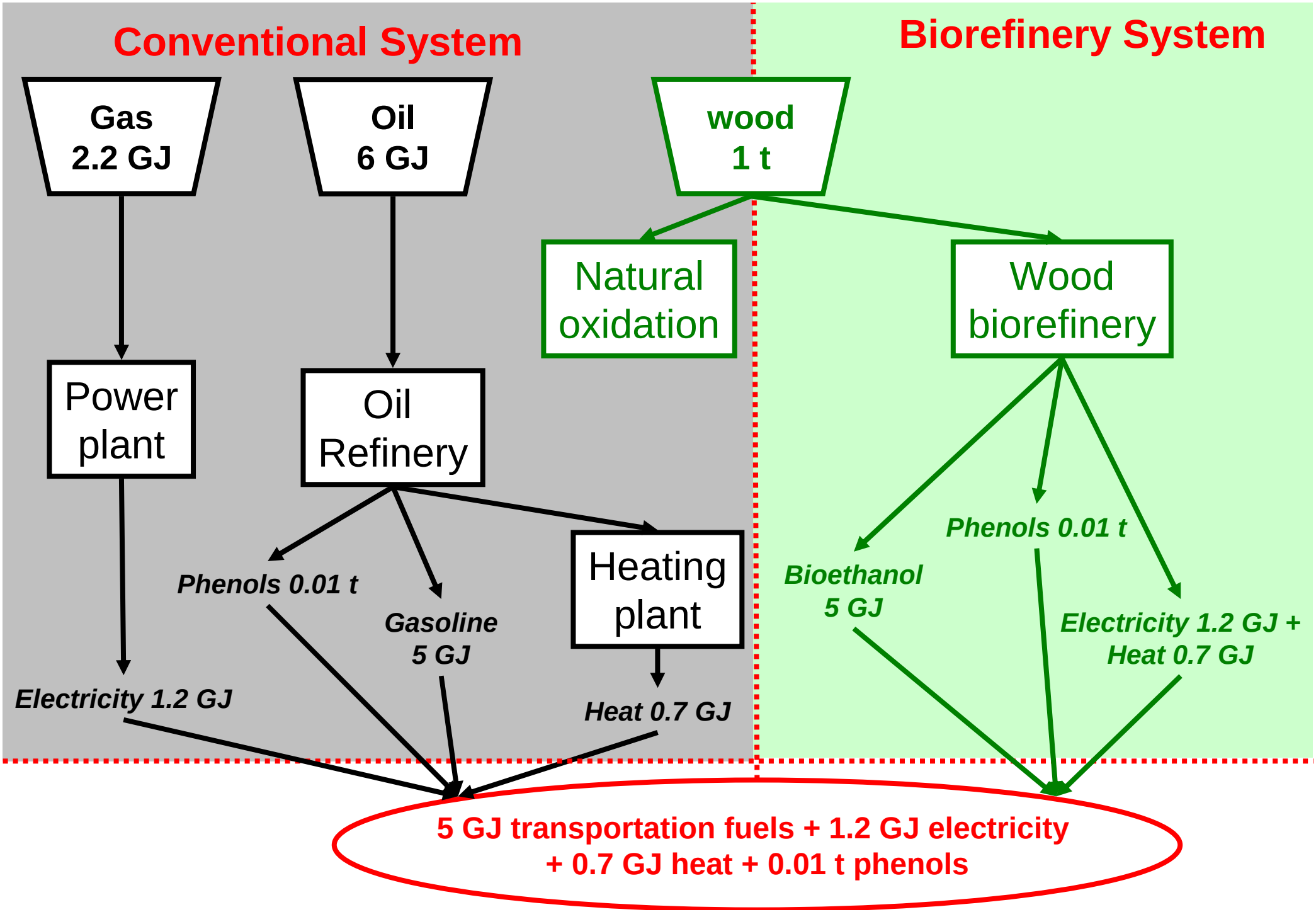
DONG energy

Inbicon

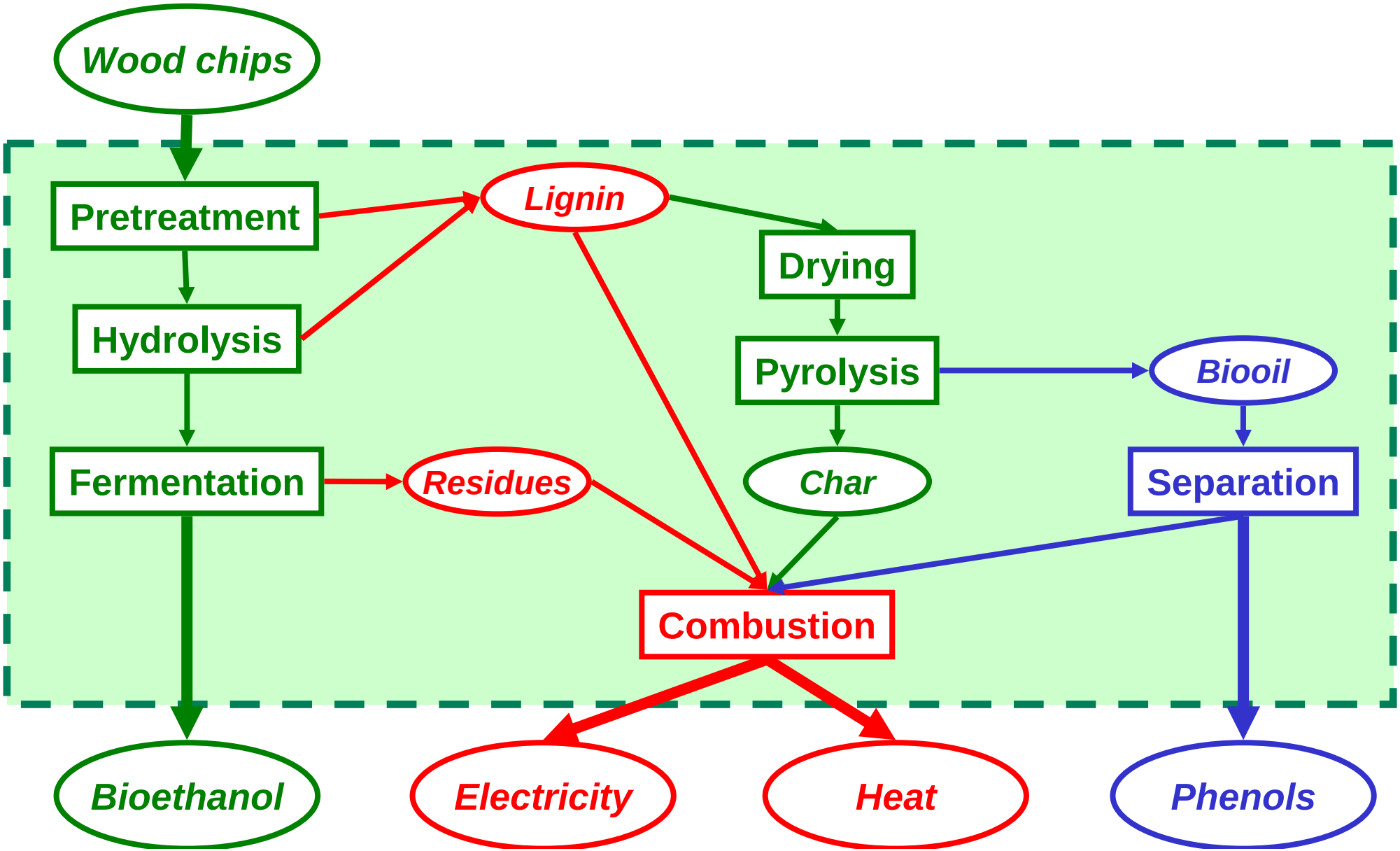


IEA Bioenergy

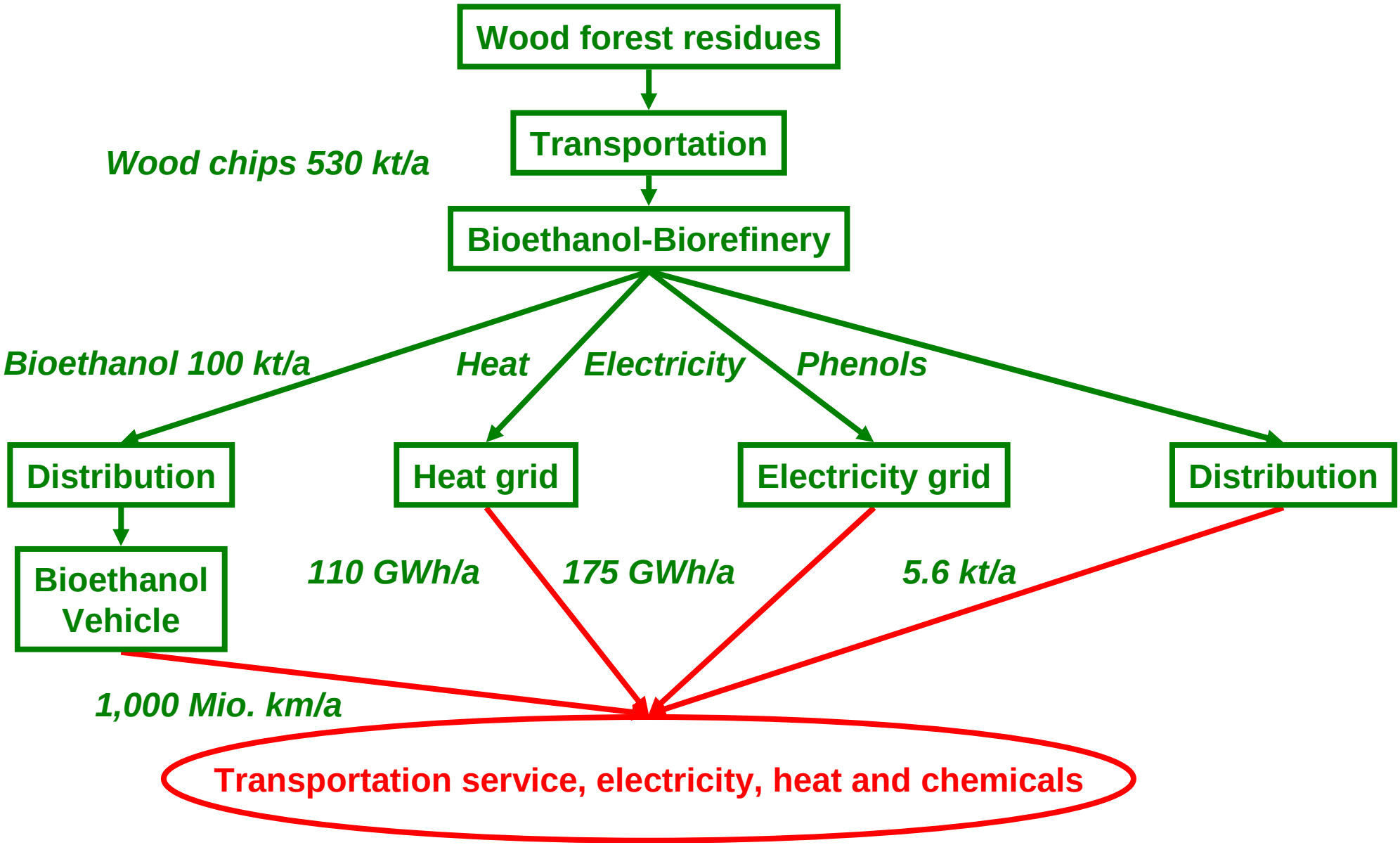
Source: Jørgensen&Bentsen 2009


Conventional System
Biorefinery System
Gas
2.2 GJ
Oil
6 GJ
wood
1 t
Natural
oxidation
Wood
biorefinery
Power
plant
Oil
Refinery
Heating
plant
Phenols 0.01 t
Gasoline
5 GJ
Electricity 1.2 GJ
Heat 0.7 GJ
Bioethanol
5 GJ
Phenols 0.01 t
Electricity 1.2 GJ +
Heat 0.7 GJ
5 GJ transportation fuels + 1.2 GJ electricity
+ 0.7 GJ heat + 0.01 t phenols

Process System: Wood Bioethanol Biorefinery



LCA of Wood Bioethanol Biorefinery



Functional Units for Environmental Evaluation

Each system provides:

- **Electricity**: 175 GWh/a
- **Transportation service**: 1,000 Mio. km/a

  (based on 100 kt/a of bioethanol for passenger car)
- **Phenols**: 5,600 t/a
- **Heat**: 110 GWh/a

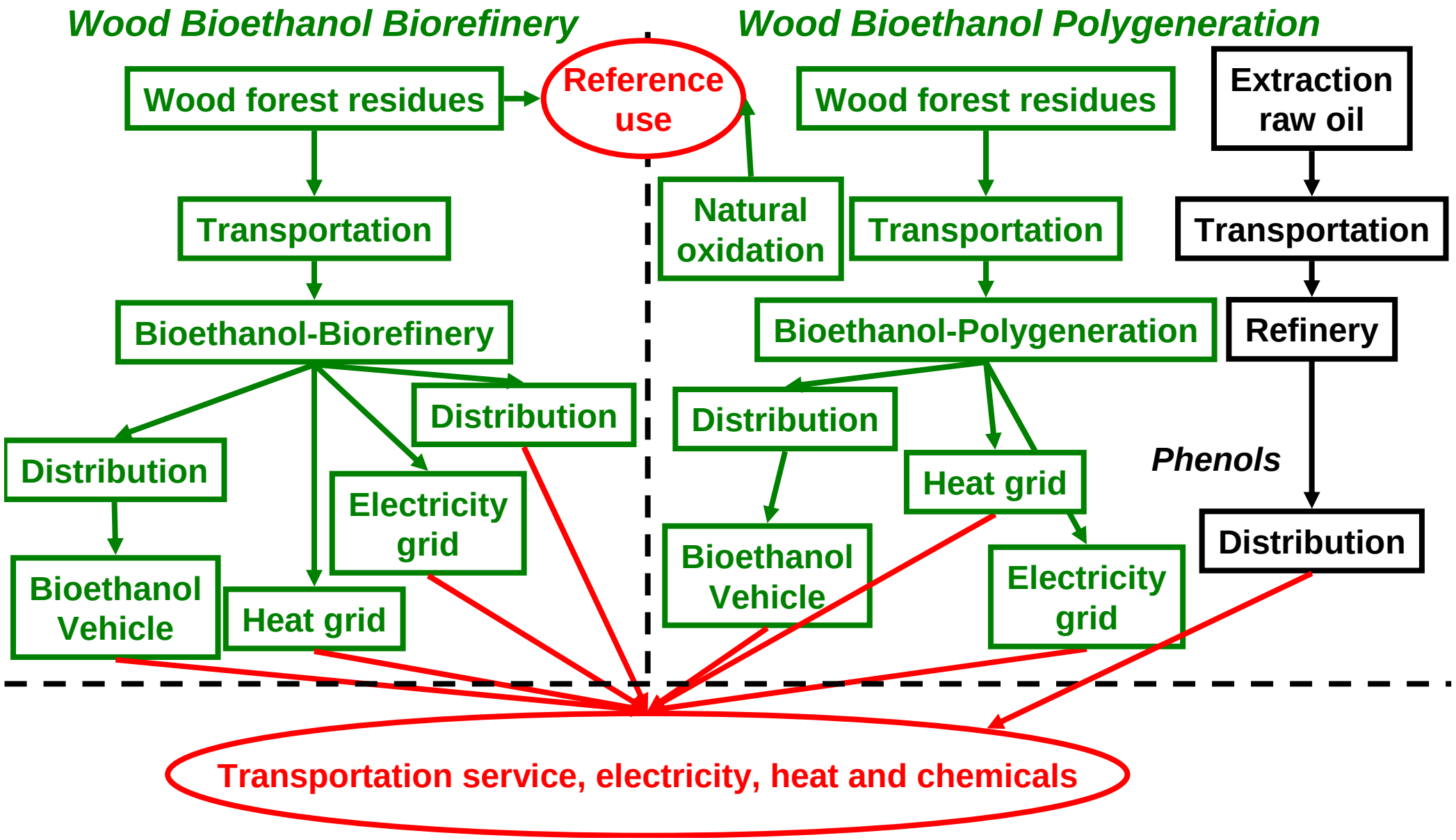
System Description for Example Environmental Evaluation

Systems	Product services			
	Heat 110 GWh/a	Electricity 175 GWh/a	Transportation service *) 1,000 Mio. km/a	Phenols 5,600 t/a
Wood bioethanol biorefienery	wood			
Wood polygeneration, con. phenols	wood			oil
Wood CHP **), gasoline, con. phenols	wood		gasoline	oil
Wood heating, natural gas, gasoline, con. phenols	wood	natural gas	gasoline	oil
Fossil reference system	oil	natural gas	gasoline	oil

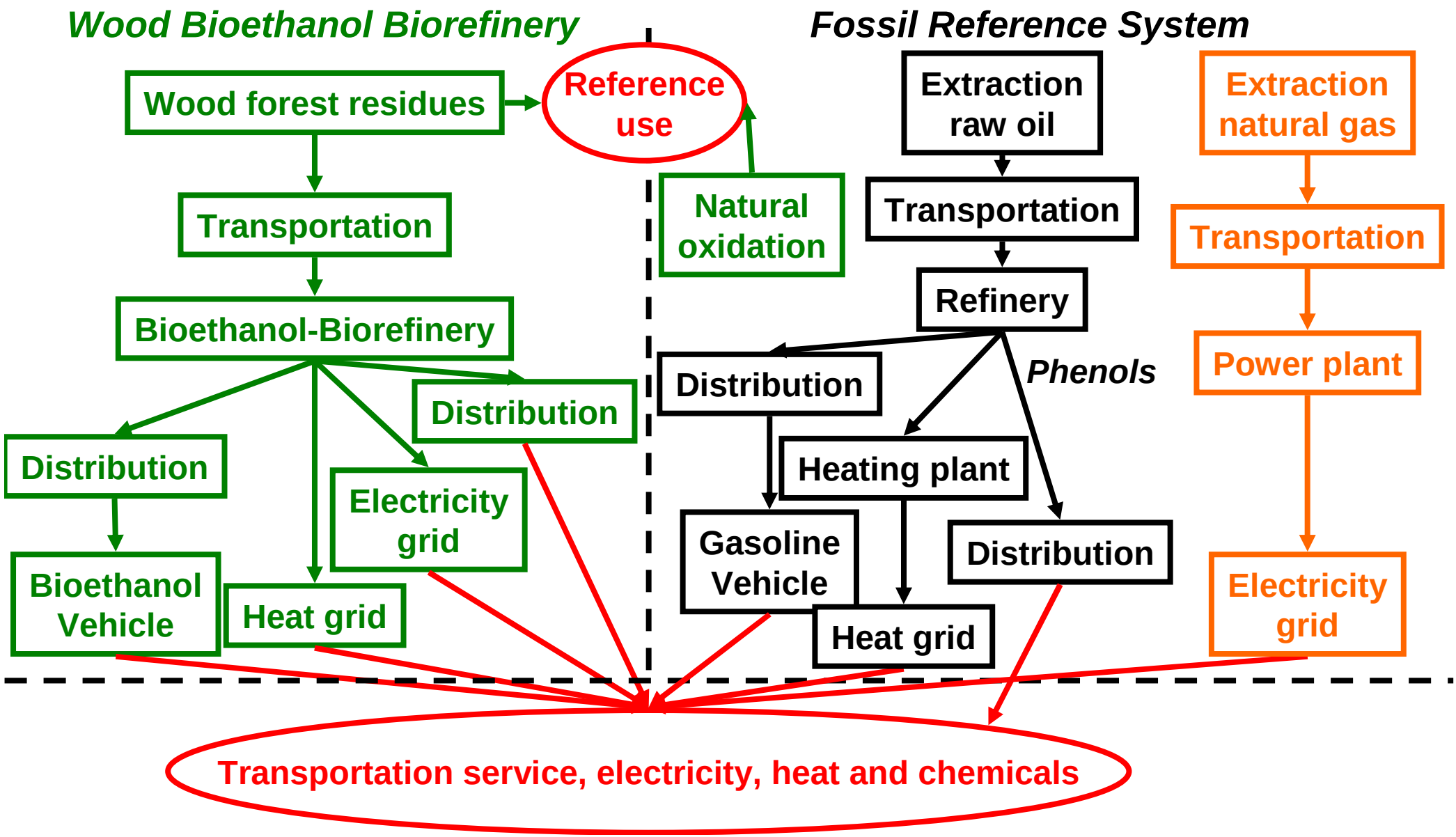
*) Bioethanol: 100.000 t/a
**) Combined heat and power

Conventional systems

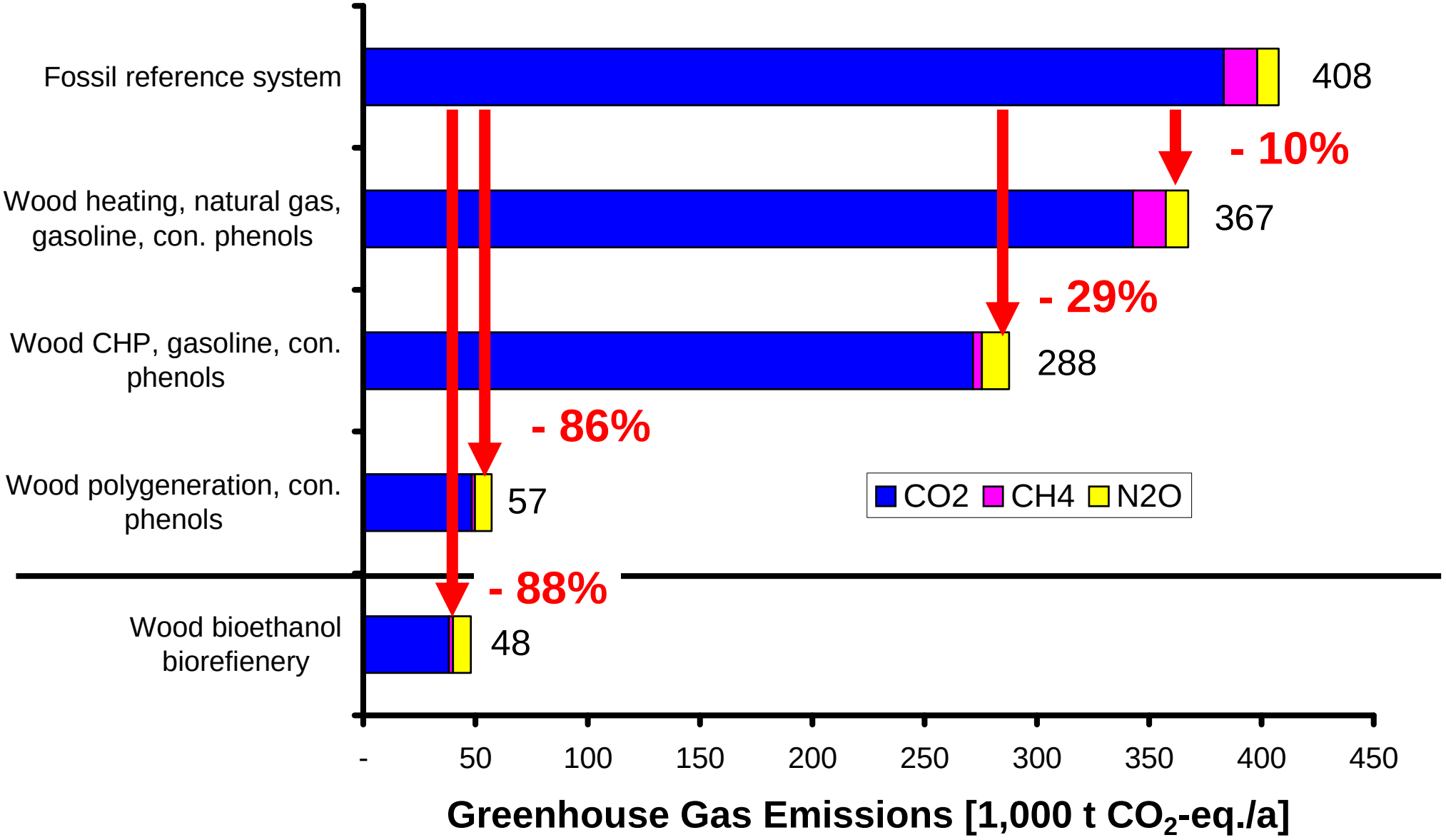
Comparison Wood to Bioethanol Biorefinery and Polygeneration



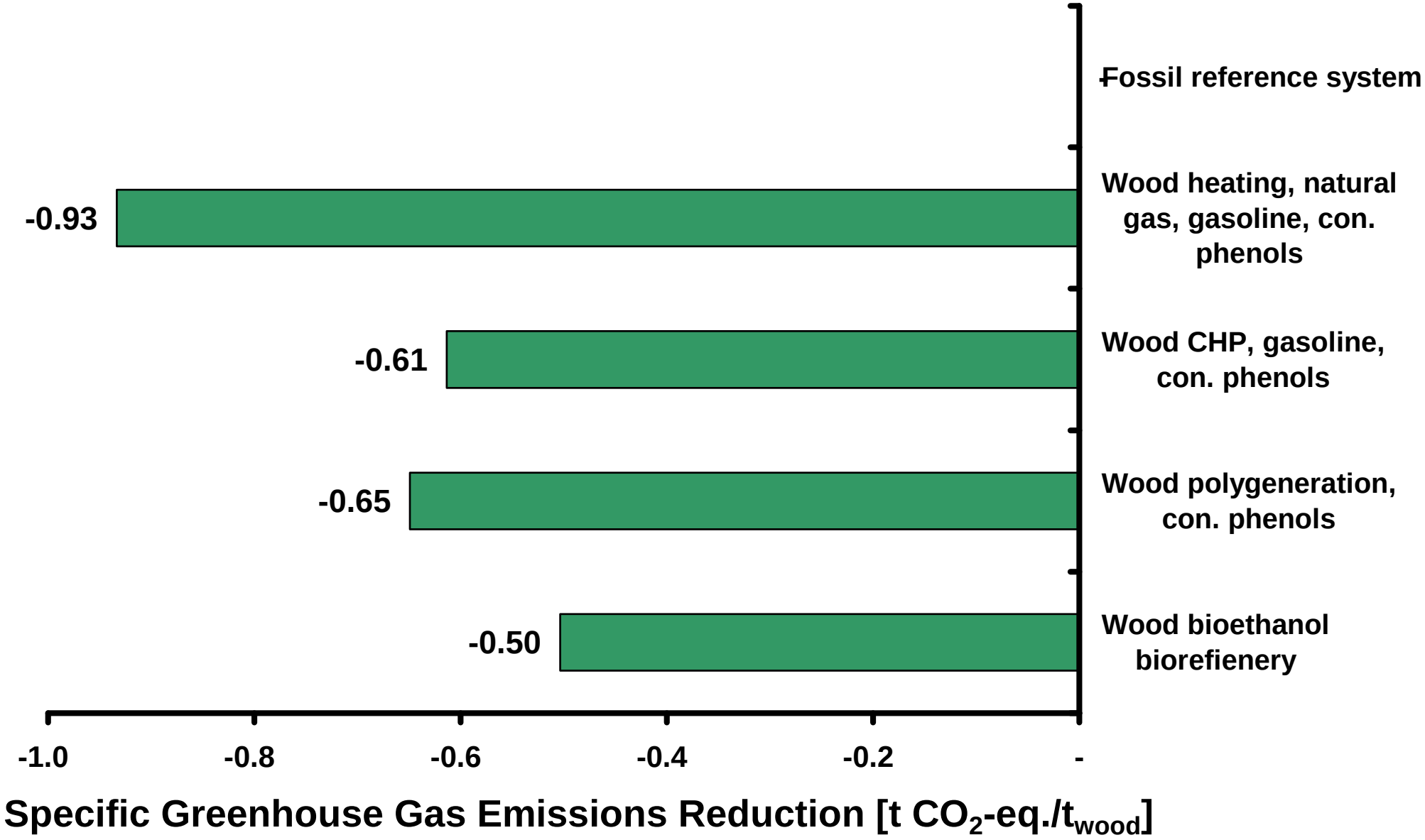
Comparison Wood to Bioethanol Biorefinery and Polygeneration



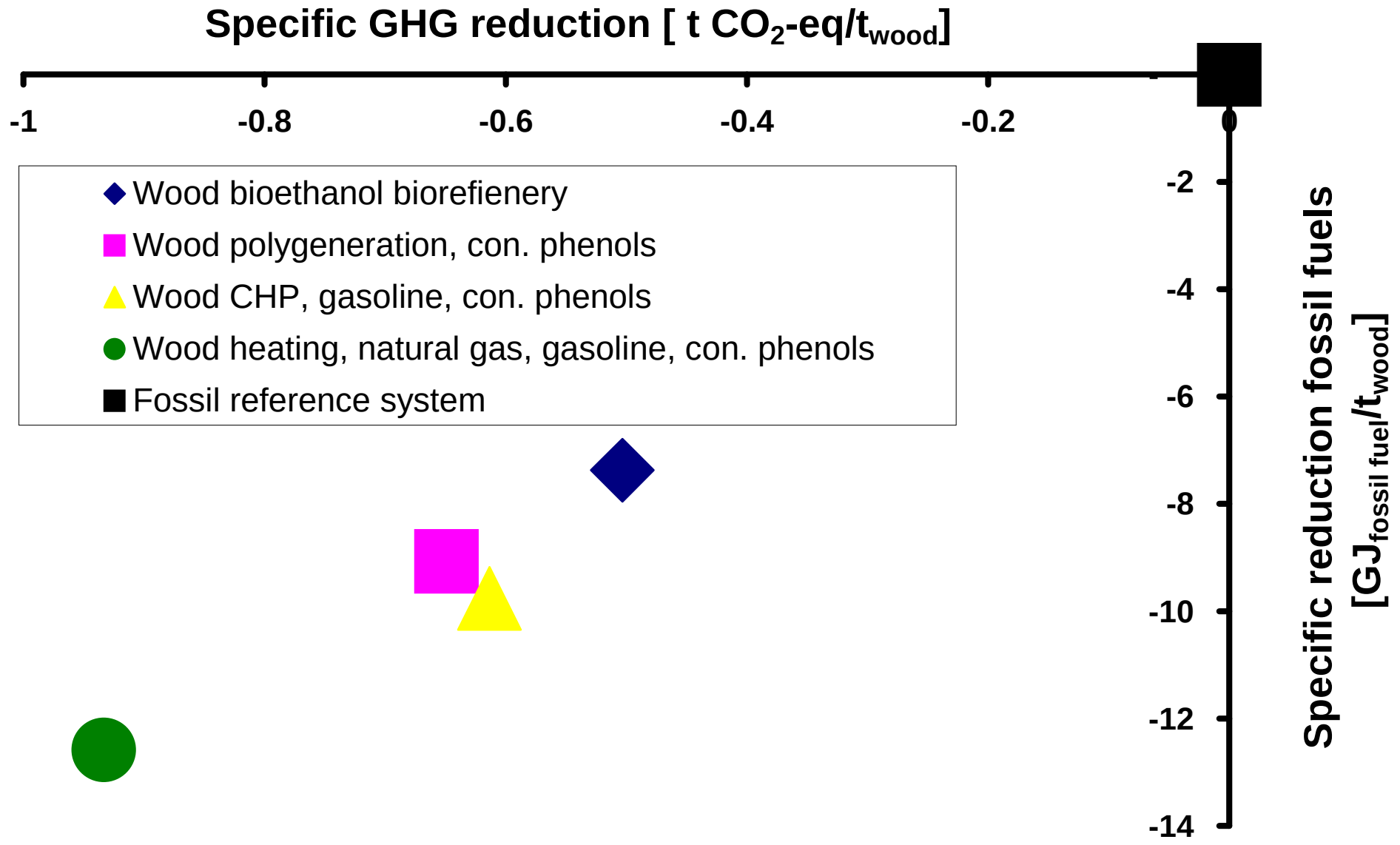
Annual Greenhouse Gas Emissions



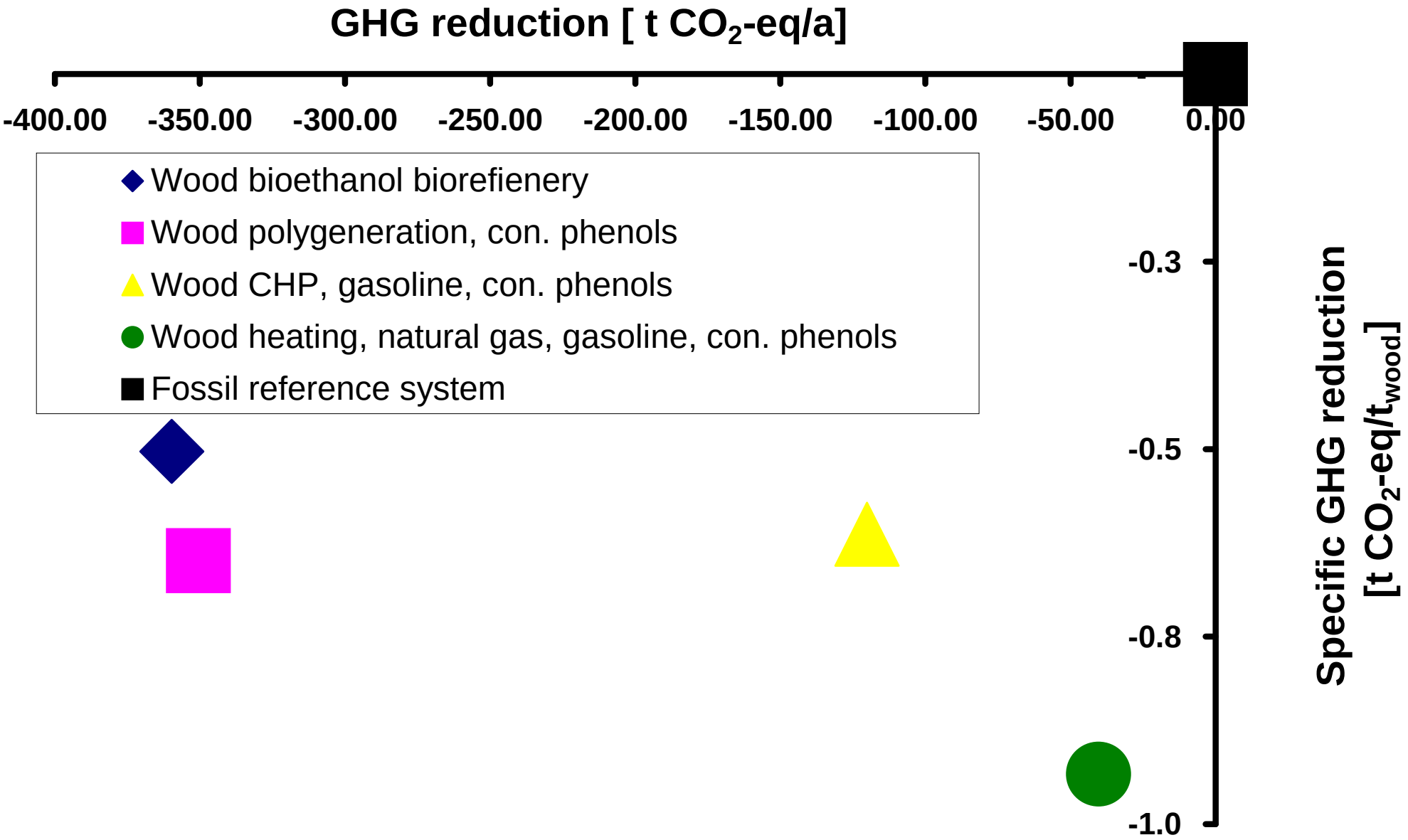
Specific Greenhouse Gas Reduction



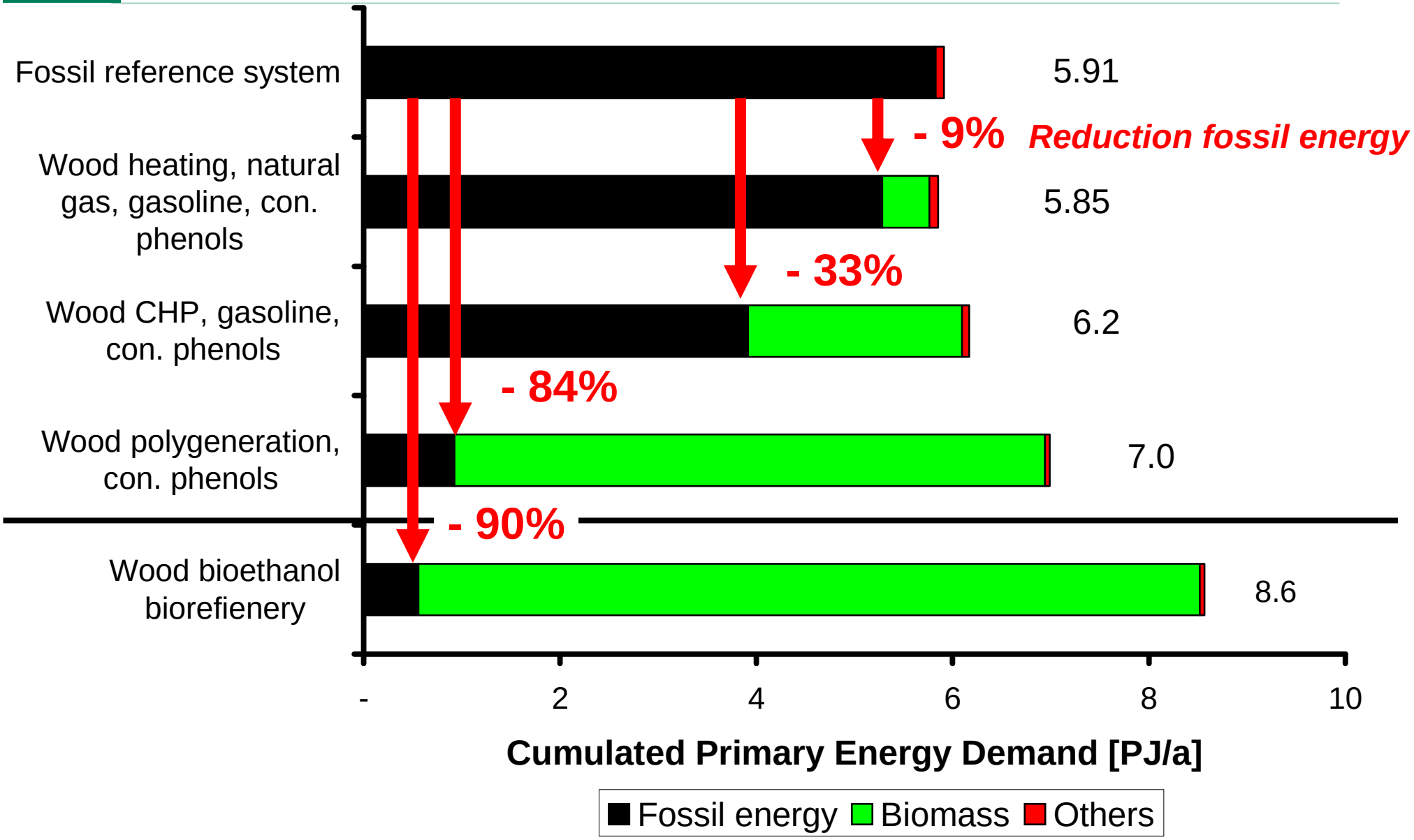
Indicator for Environmental Evaluation: Trade Off (I)



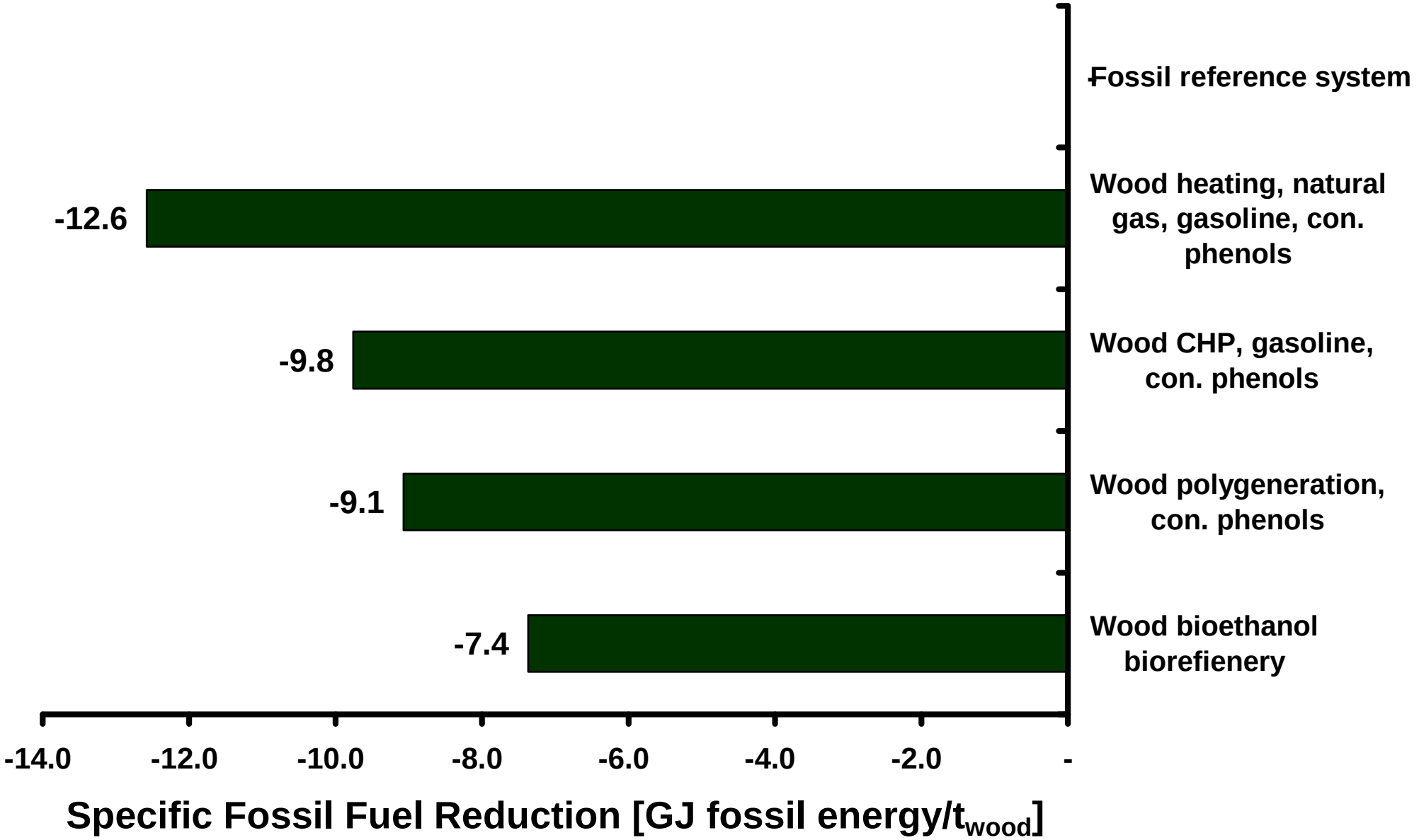
Indicator for Environmental Evaluation: Trade Off (II)



Annual Primary Energy Demand



Specific Fossil Fuel Reduction

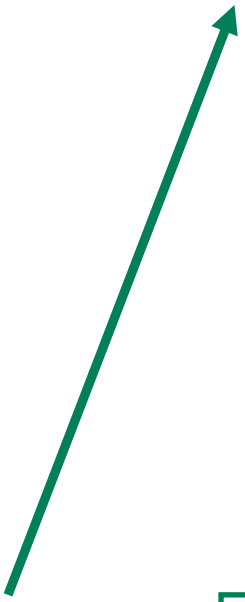


Outlook

Analyses of „Advantages“ of „Biorefinery vs. „Conventional Systems“ in terms of:

- ✓ **€**
- ✓ **t of CO_2-eq saving**
- ✓ **MWh of fossil fuel saving**
- ✓ **energy and mass efficiency of biomass input**
- ✓ **job creating**
- ✓ **…..**
- ✓ **…..**

Conclusions



Indicators developed for environmental evaluation
CO_2-eq and fossil fuel saving (specific/absolut terms)

Reference System includes fossil
and biomass based systems

Evaluation of biorefinery systems is complex

LCA is applicable to biorefinery systems