Life Cycle Assessment (LCA) of Thermal Processes
–
Examples for Gasification and Pyrolyses to Transportation Biofuels, Electricity and Heat

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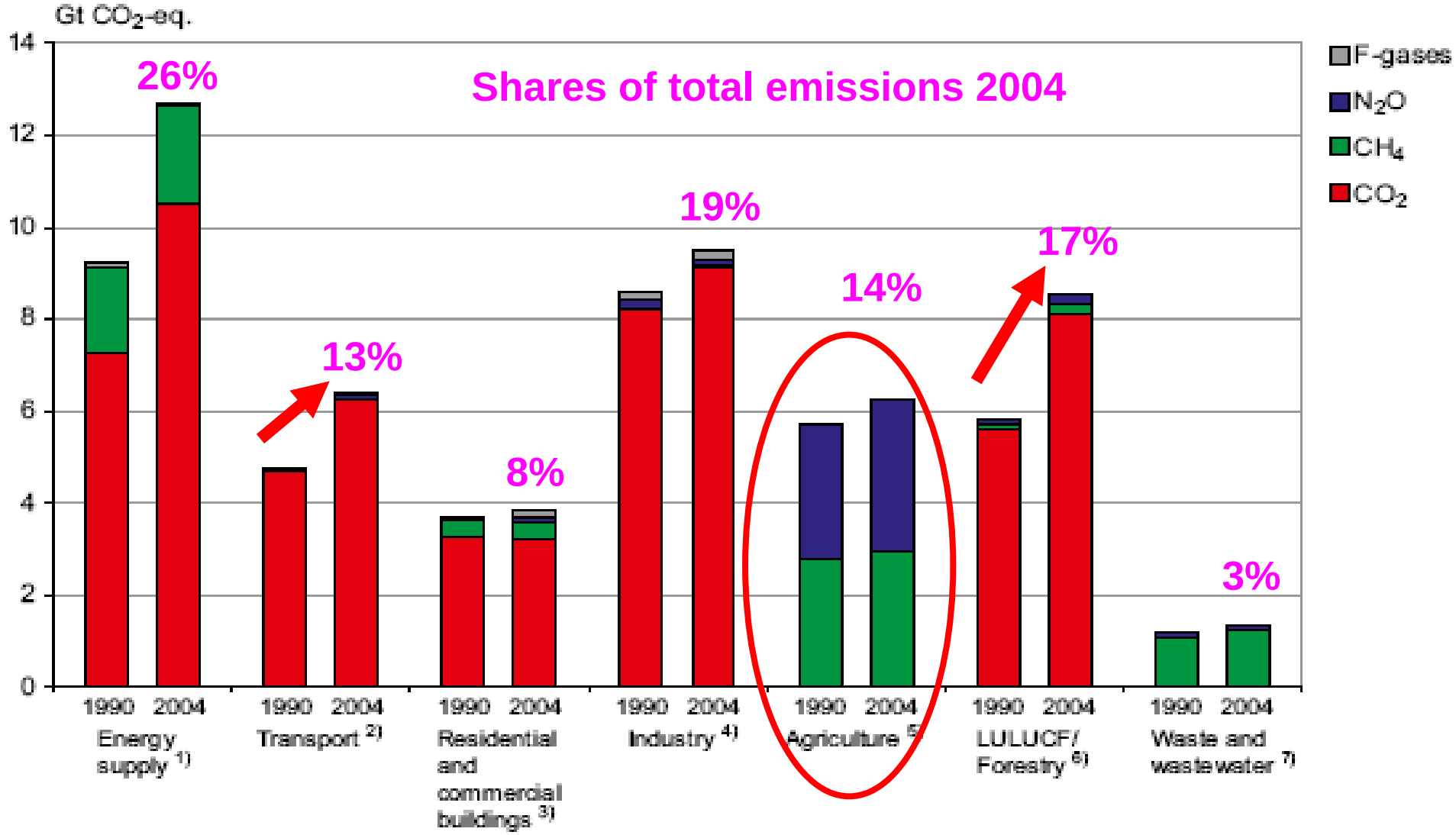
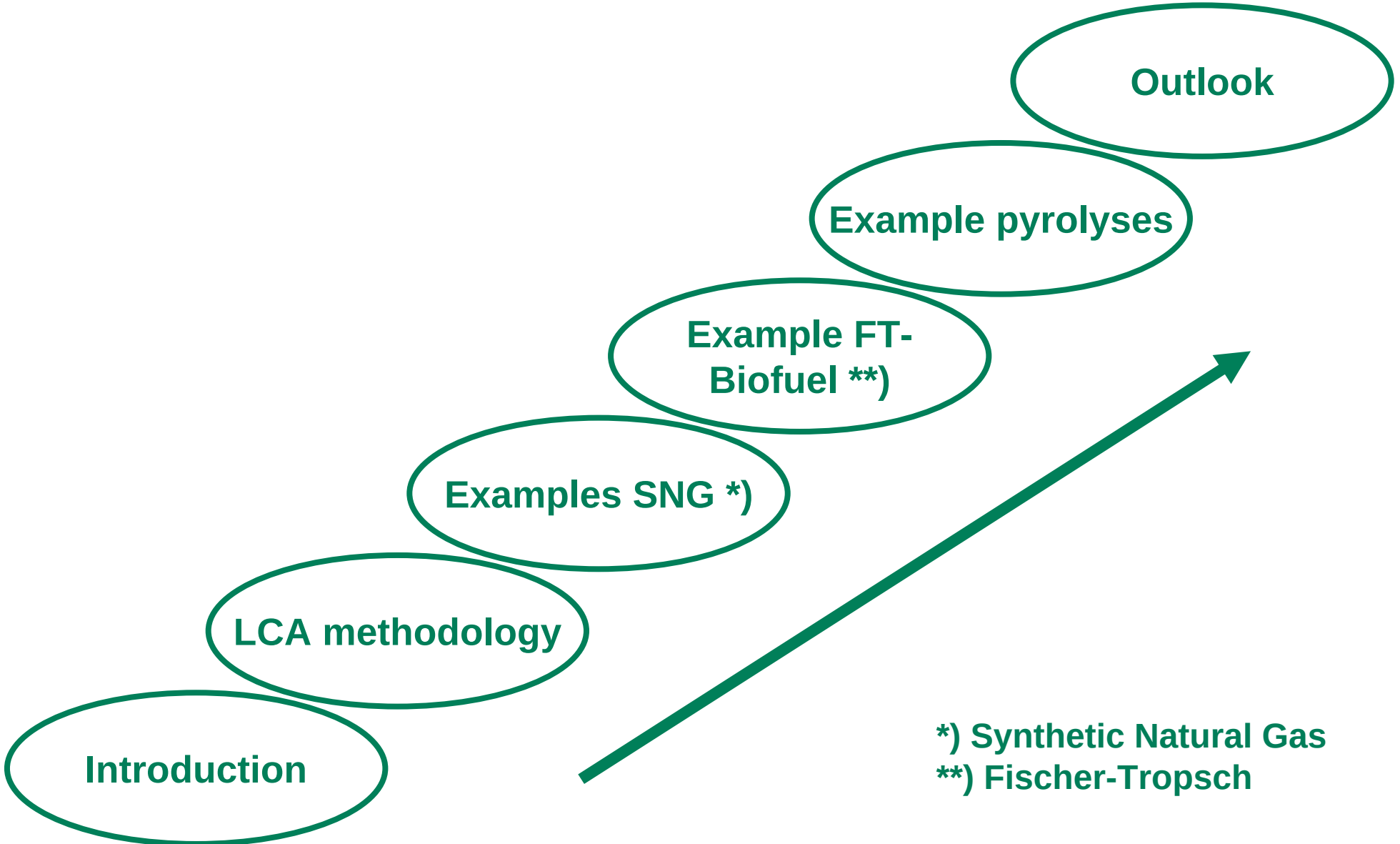
York, UK, October 12, 2010

Development Greenhouse Gas Emissions per Sector 2004



Source: www.ipcc.ch

Outline

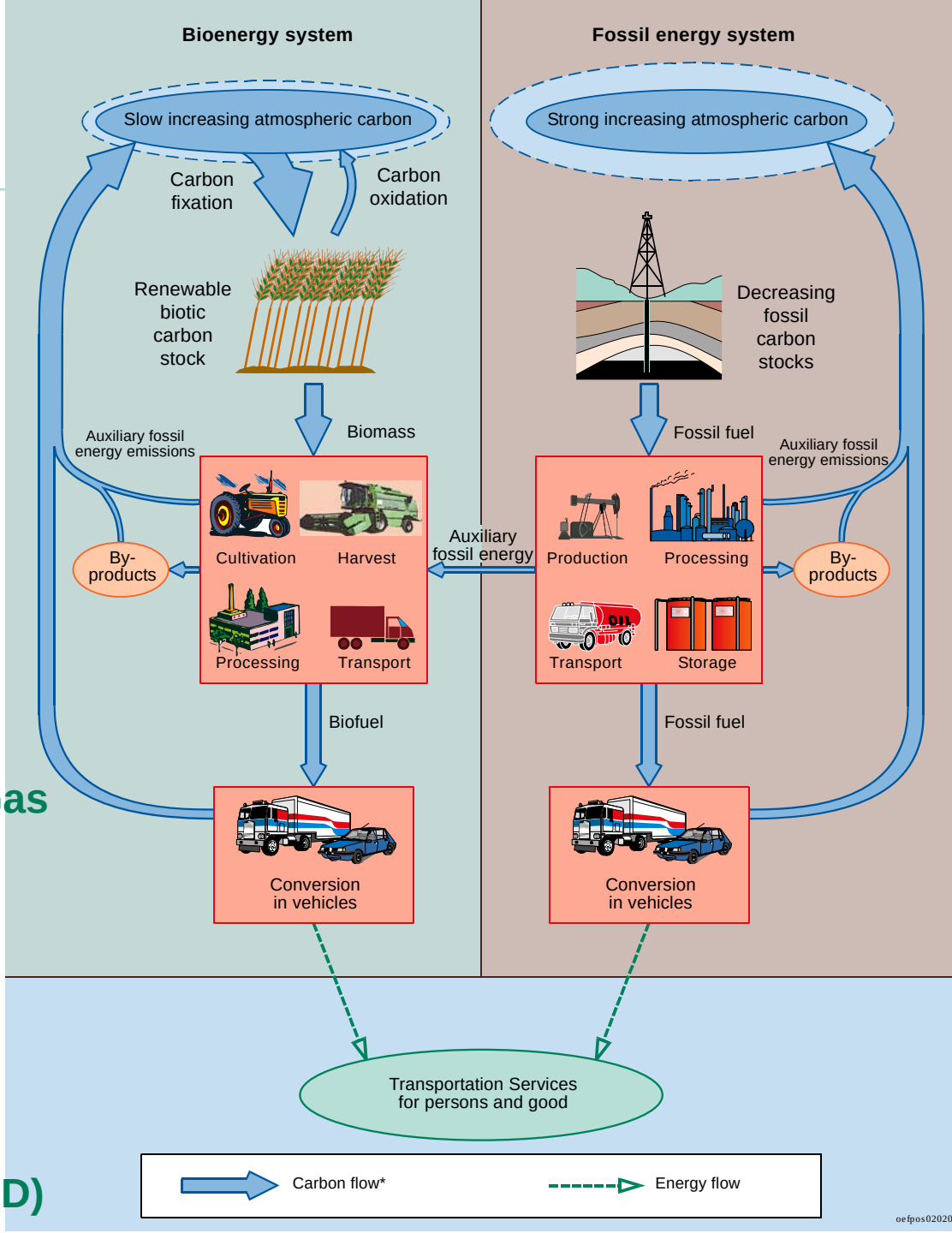

Outlook
Example pyrolyses
Example FT-Biofuel **)
Examples SNG *)
LCA methodology
Introduction
*) Synthetic Natural Gas
**) Fischer-Tropsch

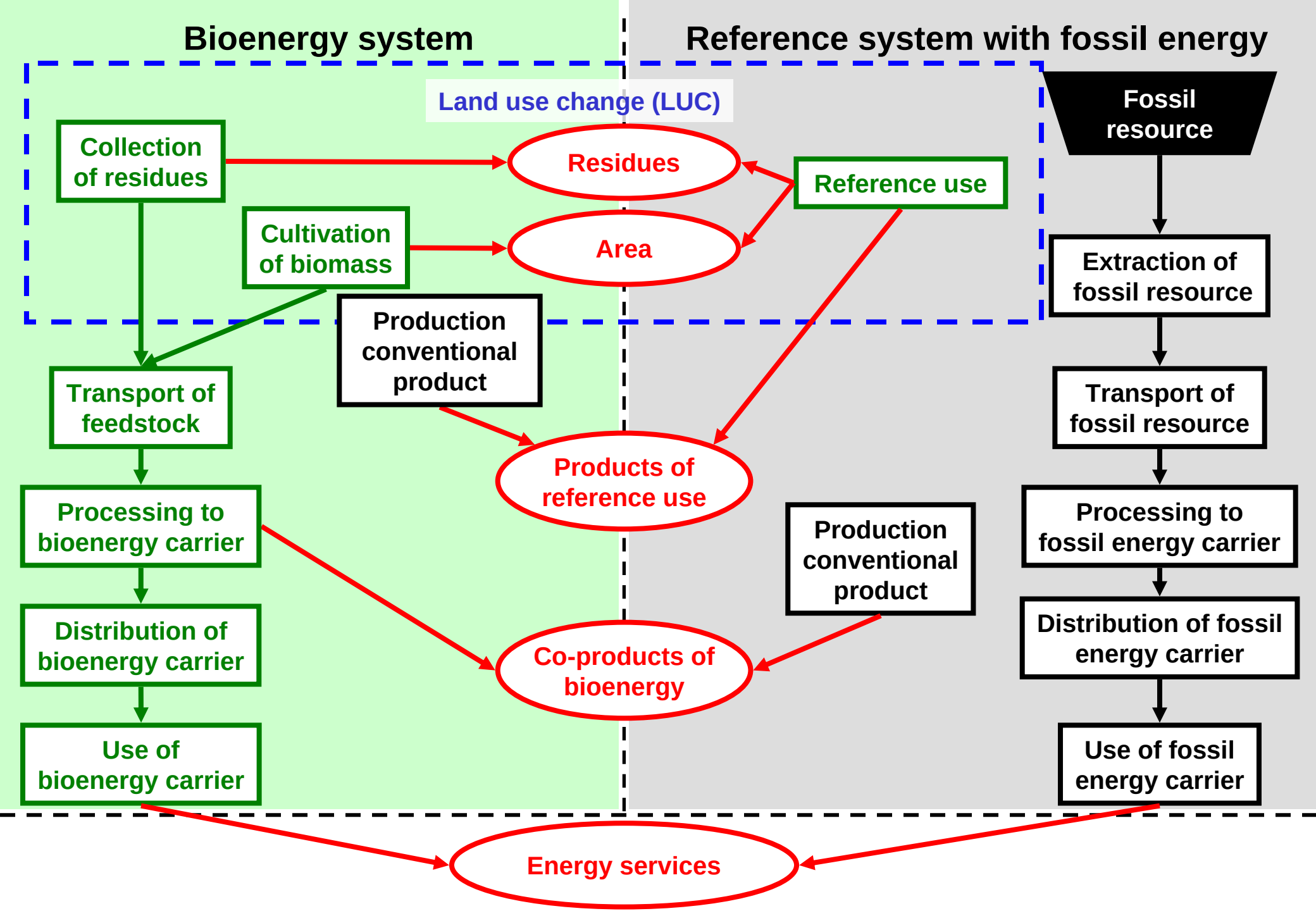
Life Cycle Assessment

Life Cycle Assessment *(LCA) is a method to estimate the material and energy flows of a product (e.g. transportation) to calculate the environmental effects in the total lifetime of the product „from cradle to grave“*

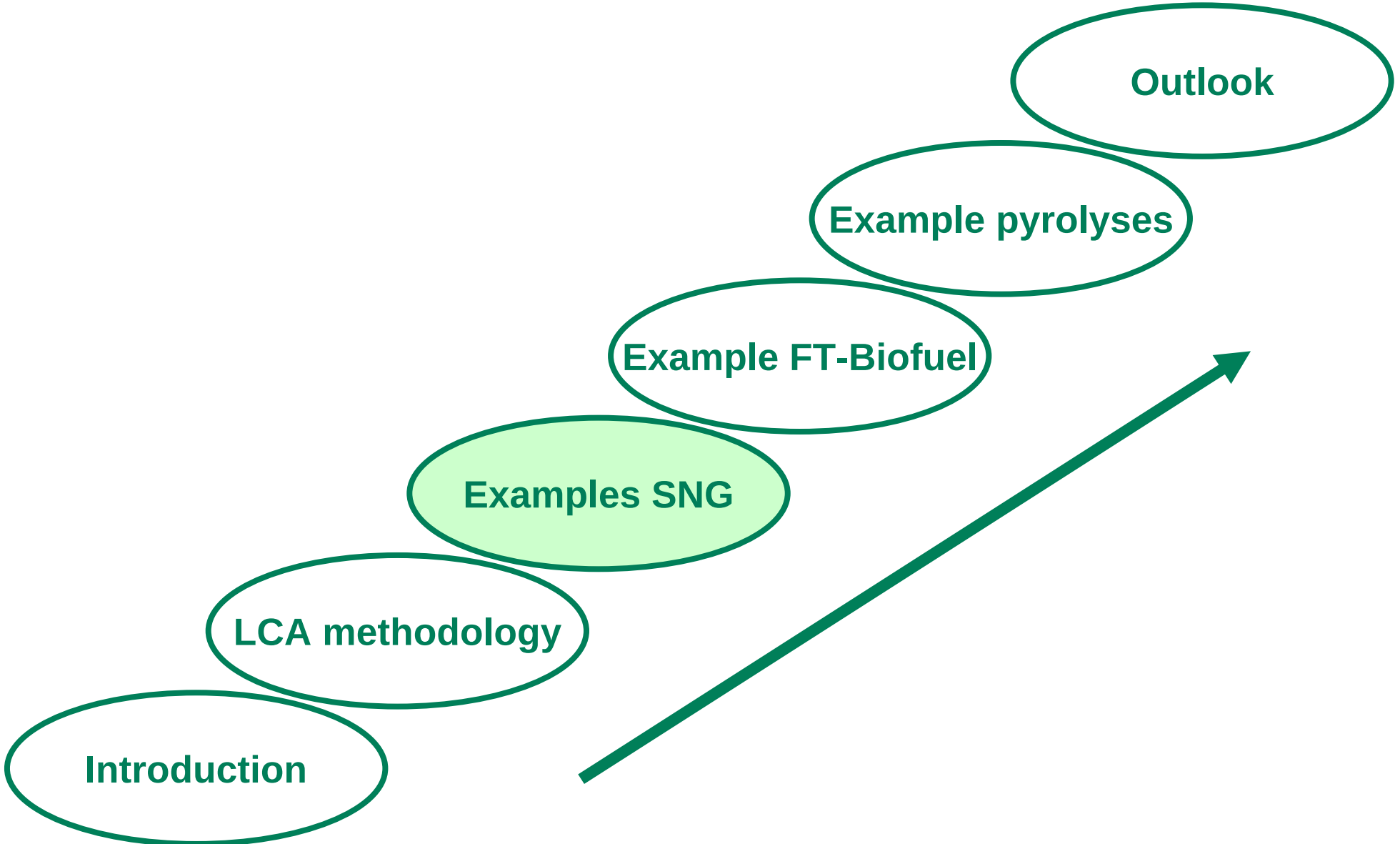
Methodology according to

- ✓ **ISO 14,040 „Life Cycle Assessment“**
- ✓ **Standard Methodology of IEA Bioenergy Task 38 „Greenhouse Gas Balances of Bioenergy Systems“**
- ✓ **JRC/CONCAWE/EUCAR: Well-to-Wheels analysis of future automotive fuels and powertrains in the European context**
- ✓ **EU-Directive on Renewable Energy (RED)**




Bioenergy system
Reference system with fossil energy
Land use change (LUC)
Collection of residues
Residues
Reference use
Fossil resource
Cultivation of biomass
Area
Extraction of fossil resource
Production conventional product
Transport of feedstock
Transport of fossil resource
Products of reference use
Processing to bioenergy carrier
Processing to fossil energy carrier
Production conventional product
Distribution of bioenergy carrier
Co-products of bioenergy
Distribution of fossil energy carrier
Use of bioenergy carrier
Use of fossil energy carrier
Energy services

Outline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SNG for Heat

Feedstock:

- Forest residues
- Miscanthus
- Short rotation forestry (SRF)

Types of gasifiers:

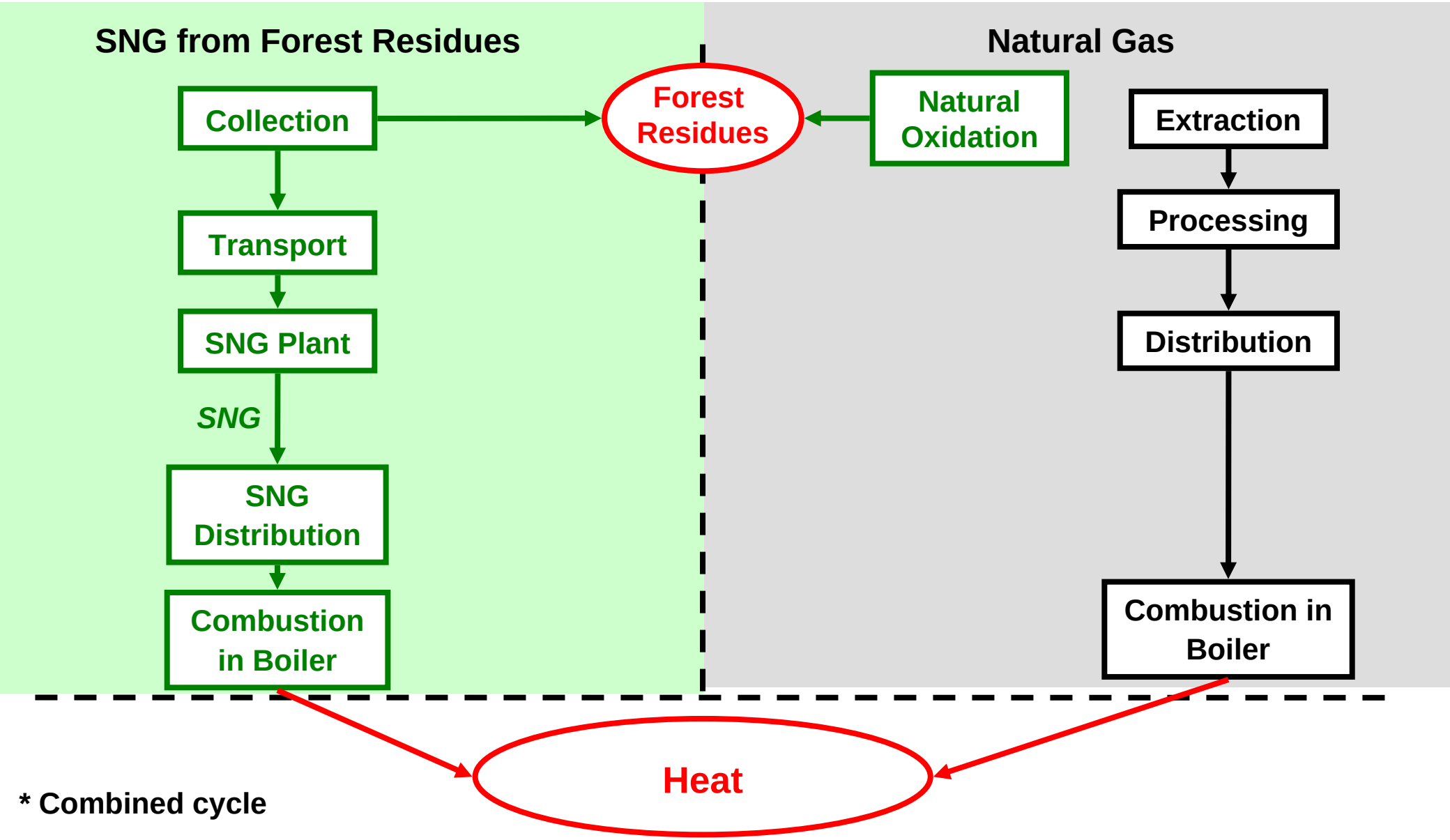
- O_2-blown entrained flow (EF)
- O_2-blown circulating fluidised bed (CFB)
- air-steam blown indirect*)

Comparison to:

- natural gas
- direct combustion of feedstock at consumer side

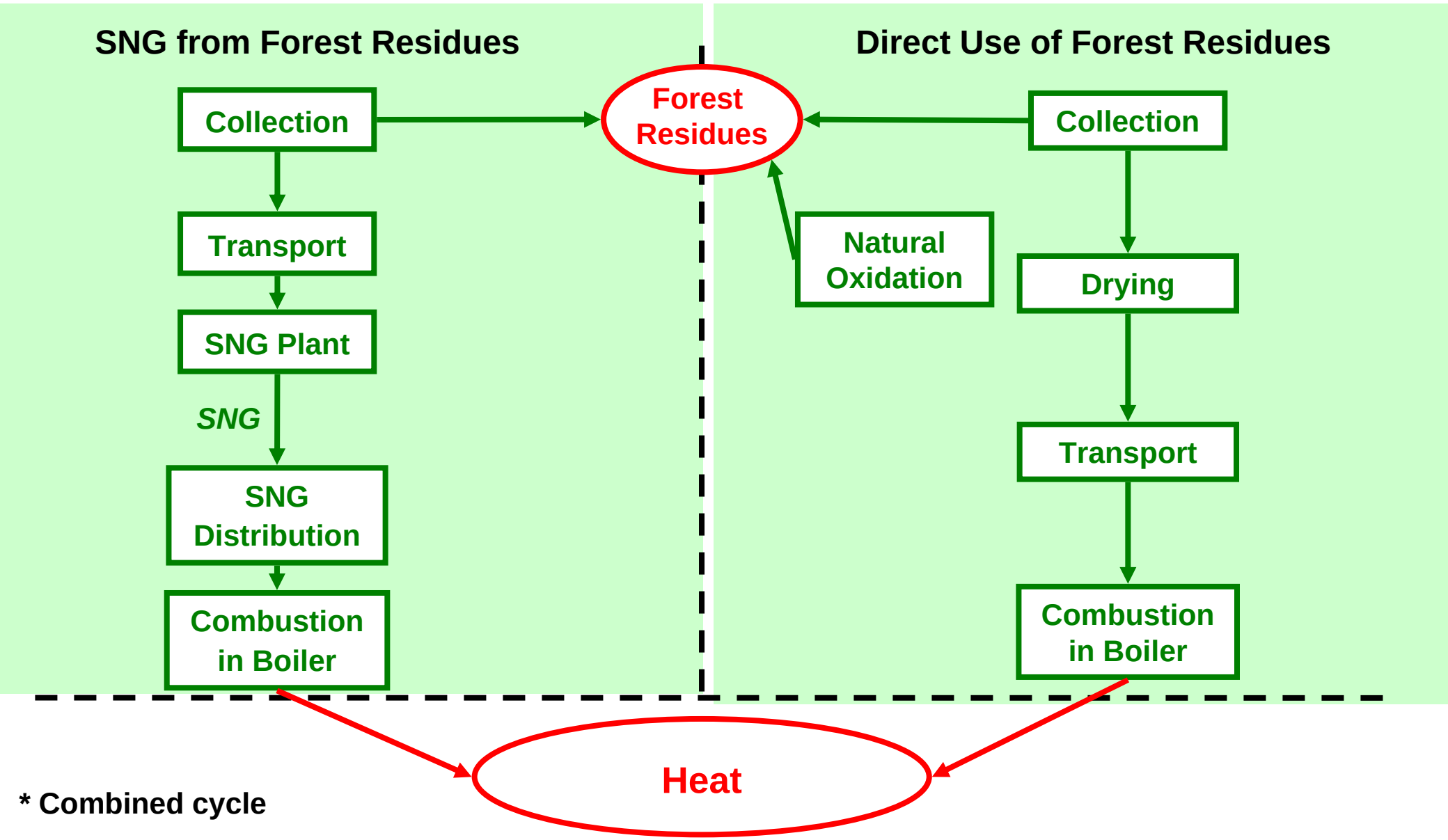
**) also with CCS – carbon capture&sequestration*

SNG from Forest Residues vs. Natural Gas



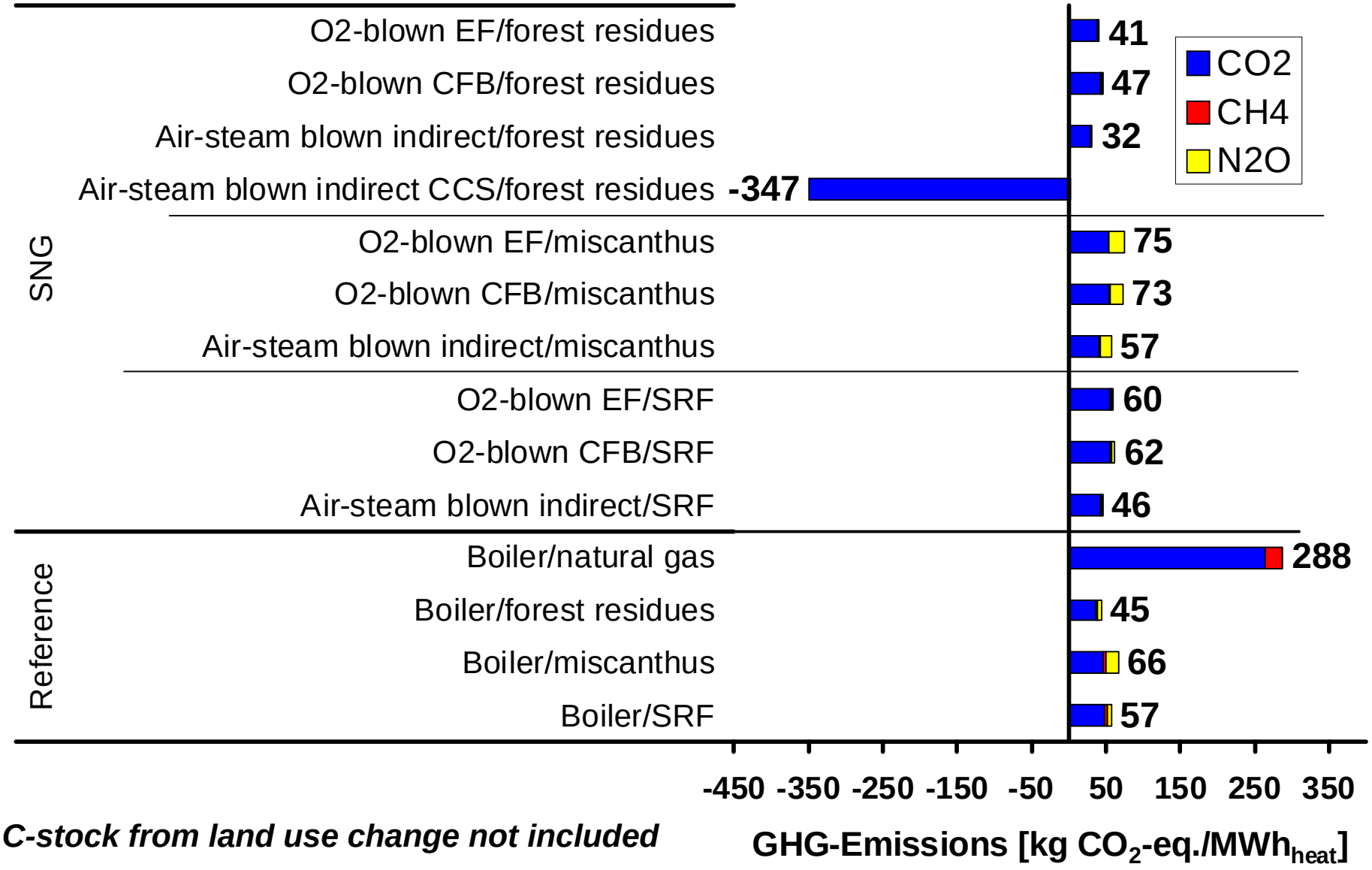
* Combined cycle

SNG from Forest Residues vs. Direct Use for Heating



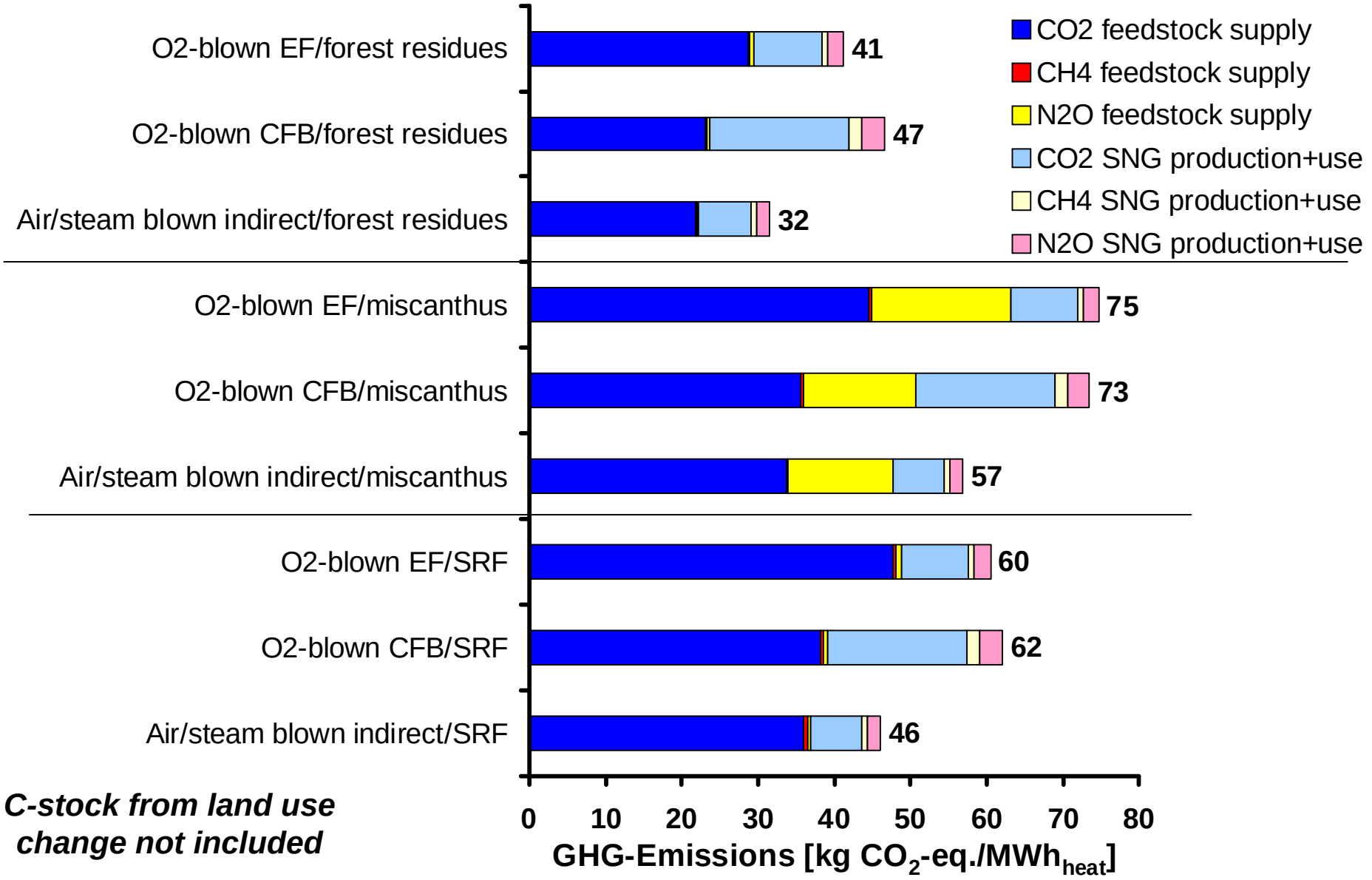
* Combined cycle

Greenhouse Gas Emissions



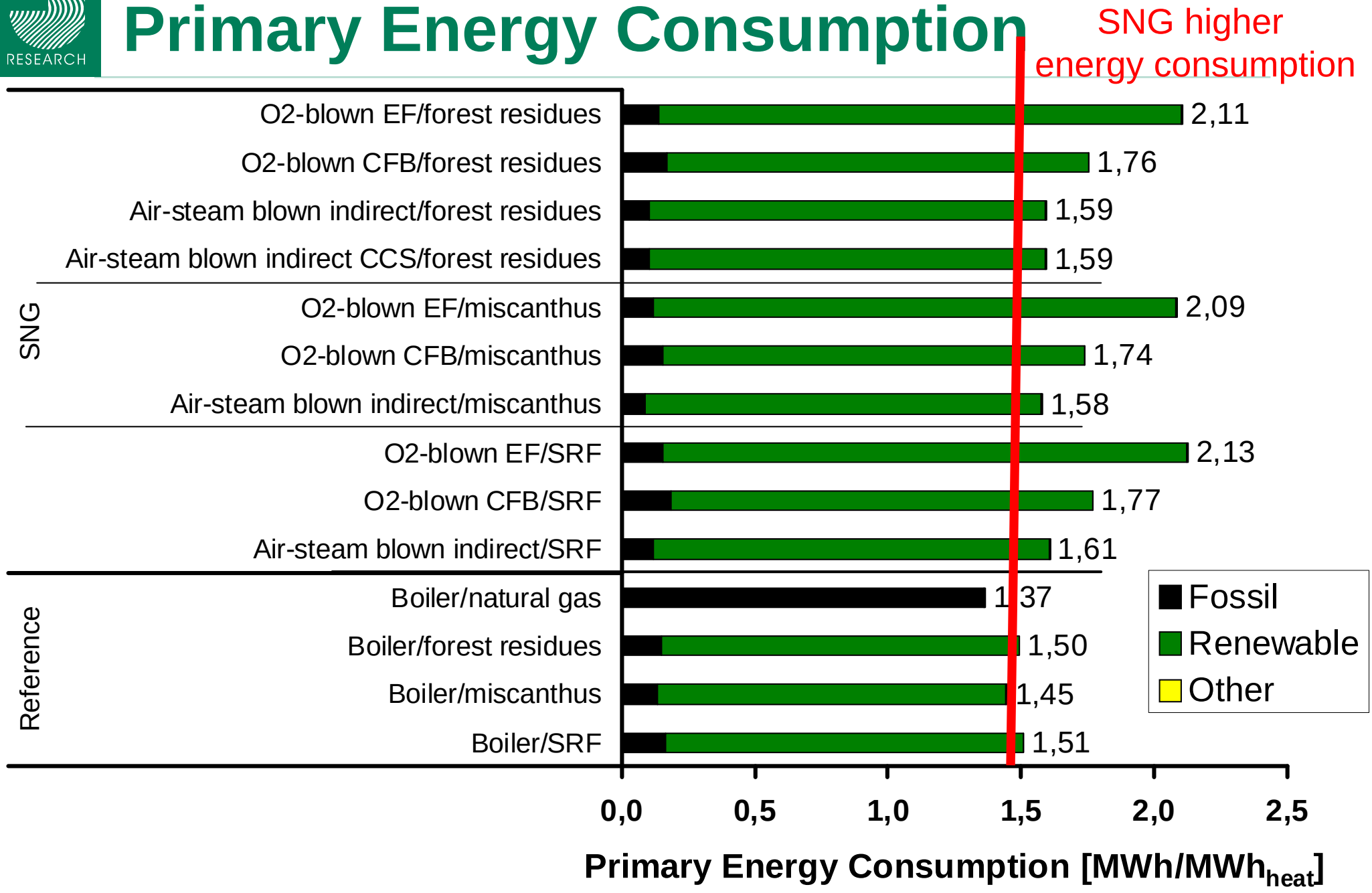
C-stock from land use change not included

Greenhouse Gas Emissions (Details)

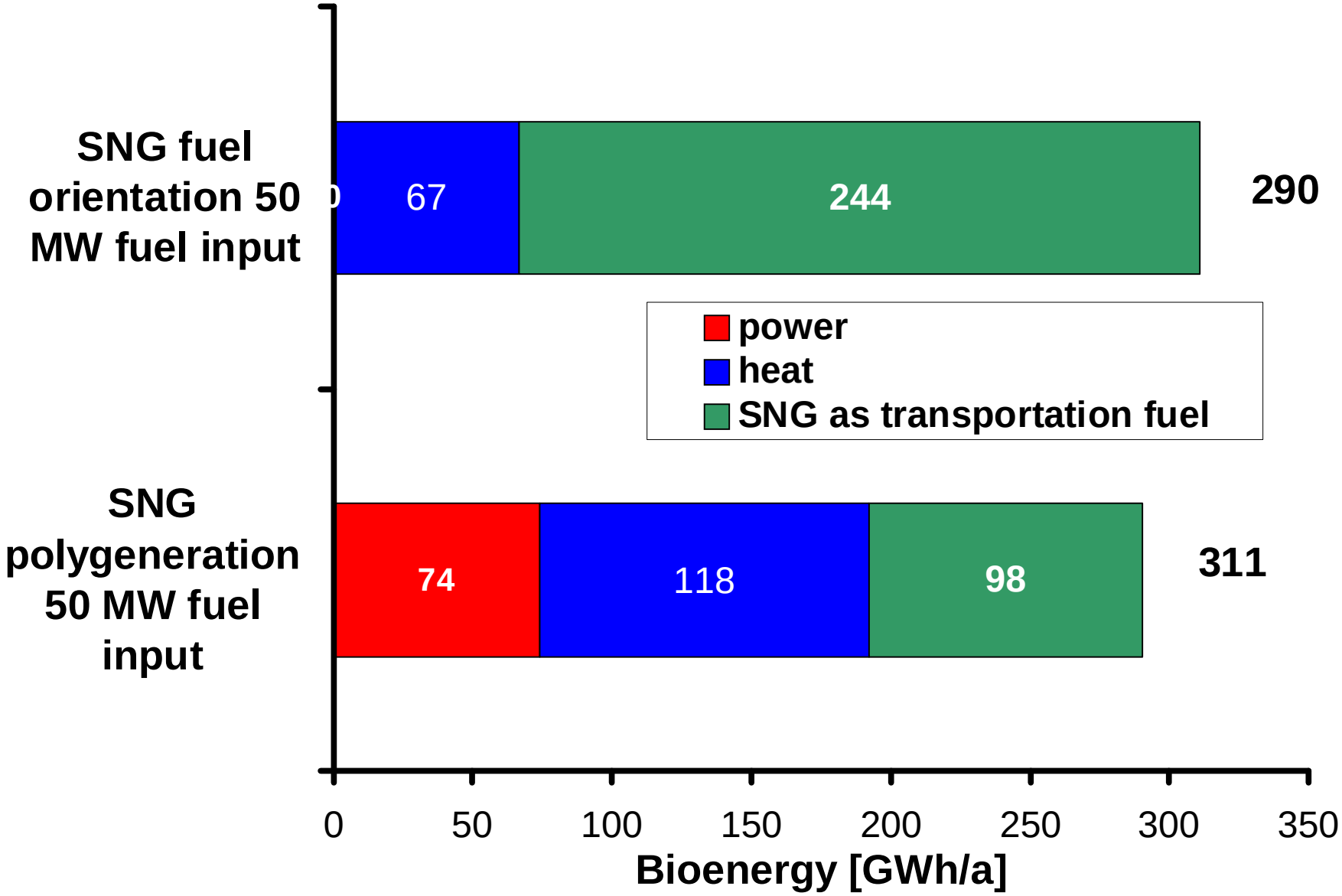


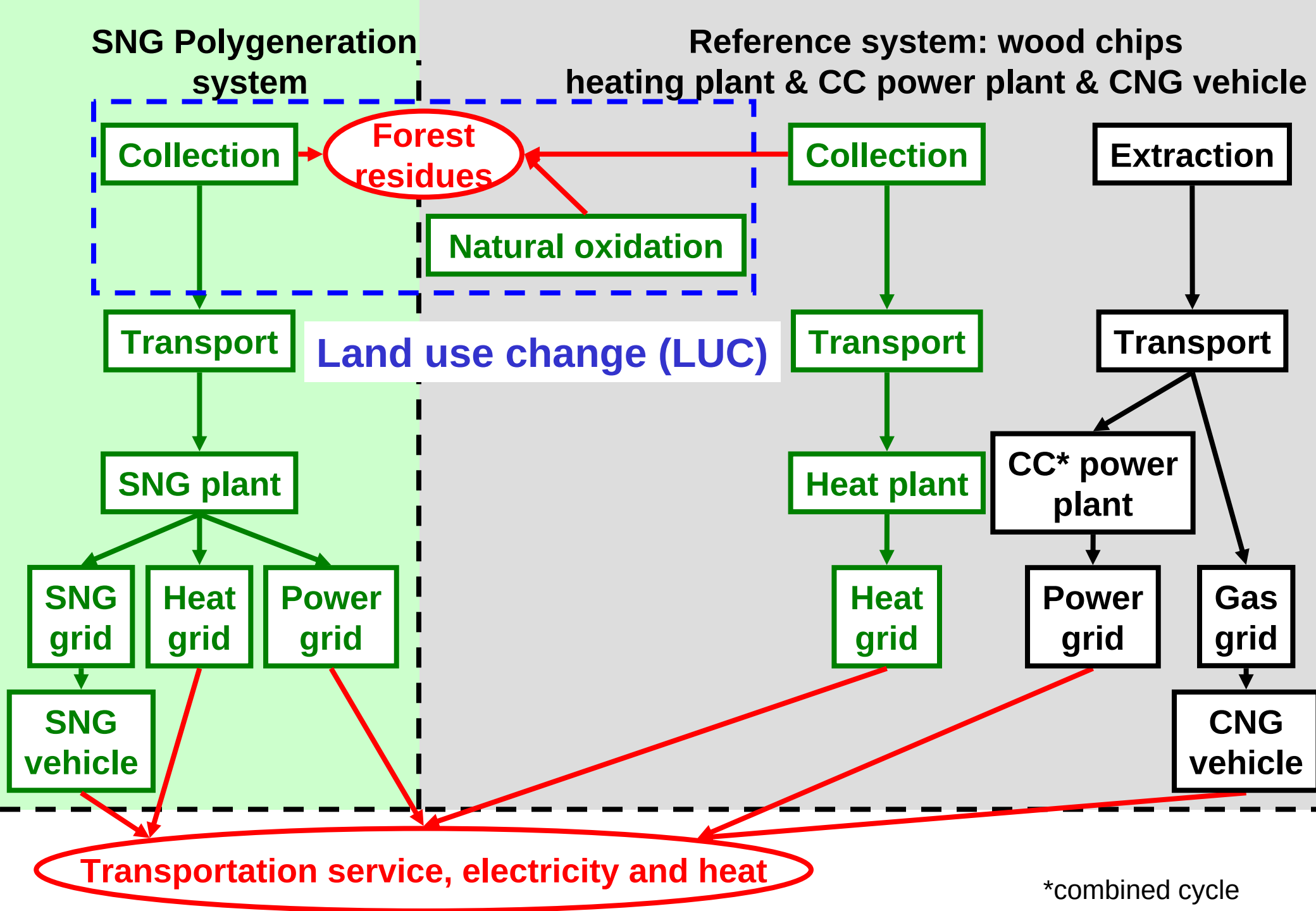
C-stock from land use change not included

Primary Energy Consumption

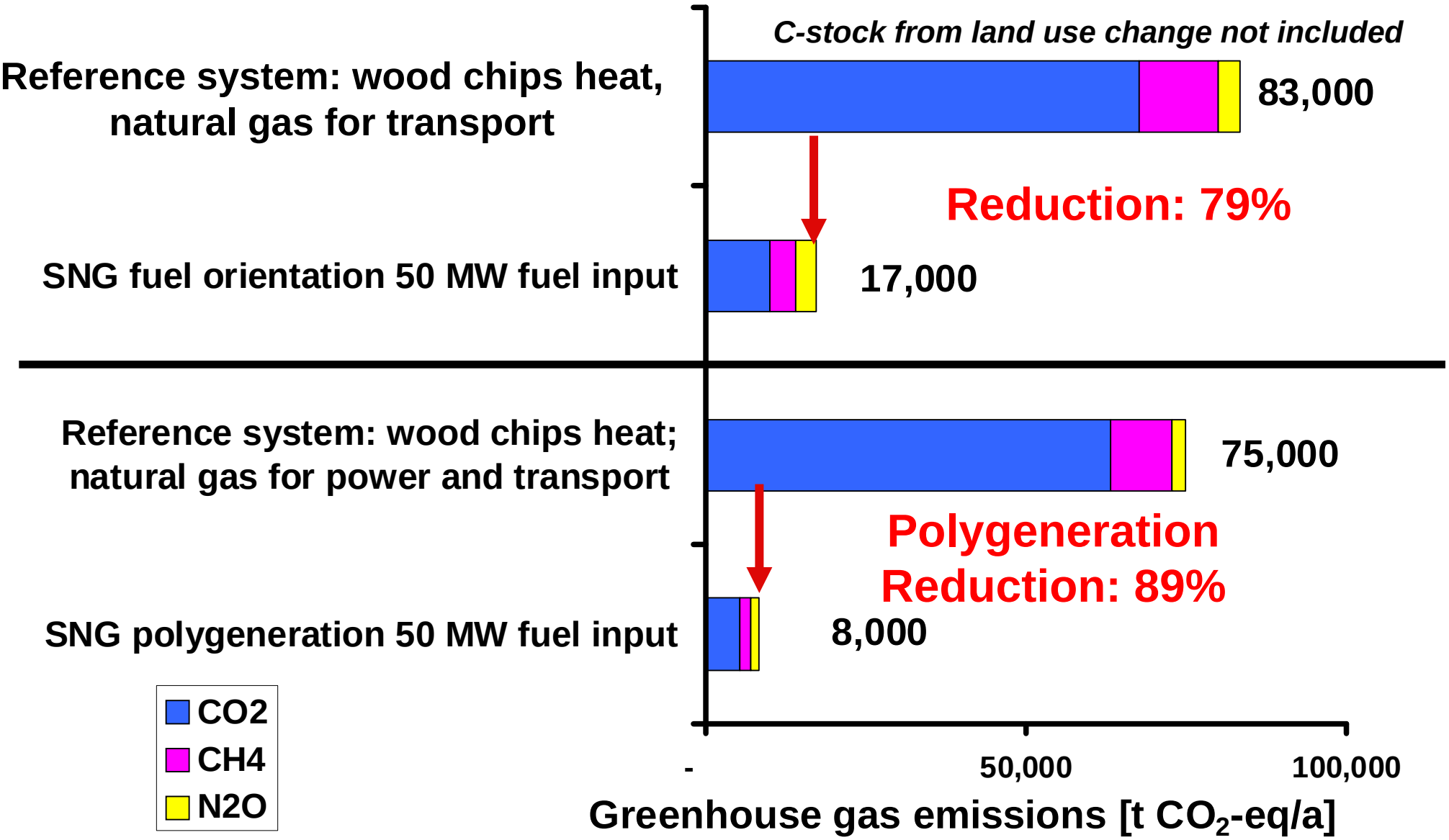


SNG for Transportation Biofuel

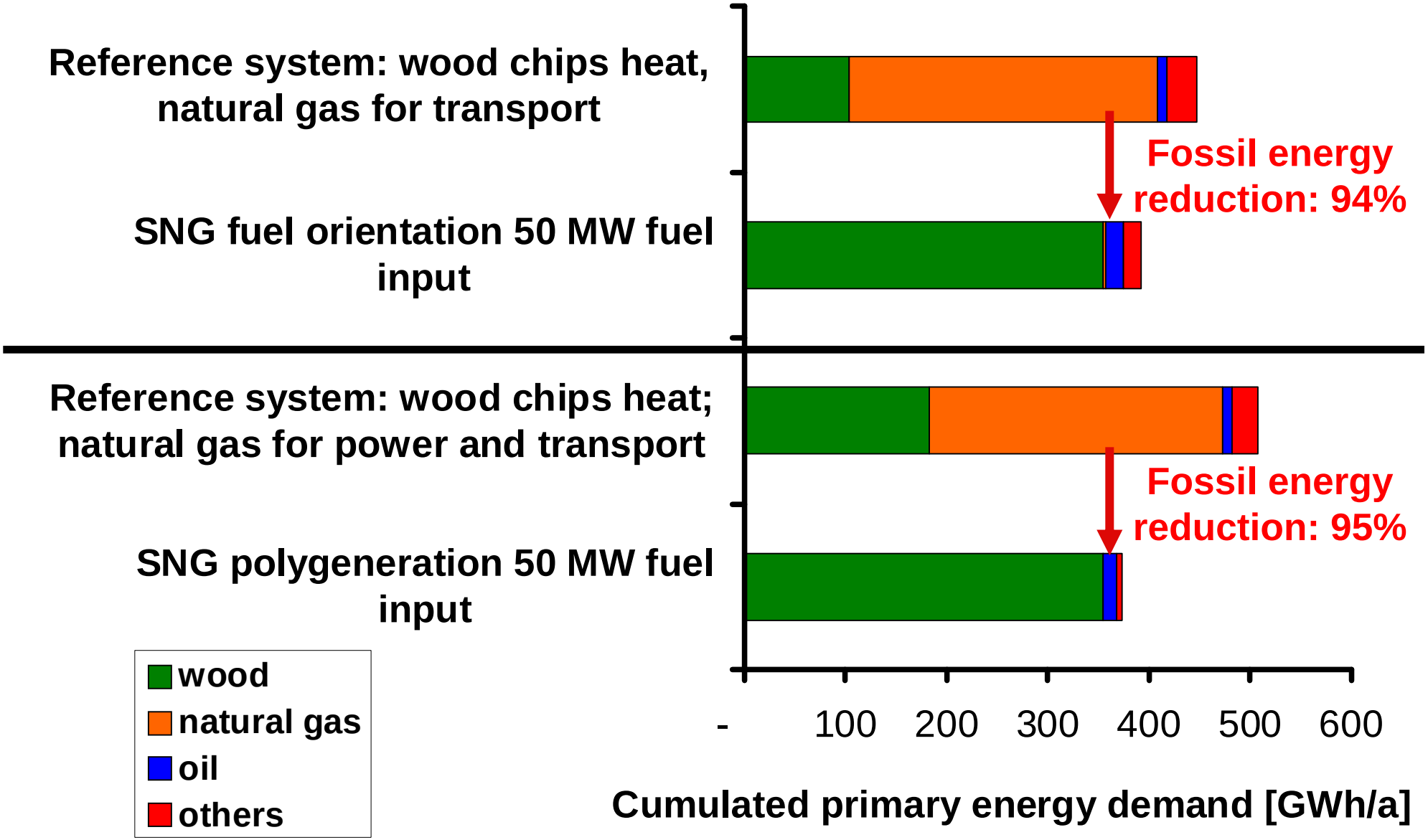



SNG Polygeneration system
Reference system: wood chips heating plant & CC power plant & CNG vehicle
Collection
Forest residues
Natural oxidation
Collection
Extraction
Transport
Land use change (LUC)
Transport
Transport
SNG plant
Heat plant
CC* power plant
SNG grid
Heat grid
Power grid
Heat grid
Power grid
Gas grid
SNG vehicle
CNG vehicle
Transportation service, electricity and heat
*combined cycle

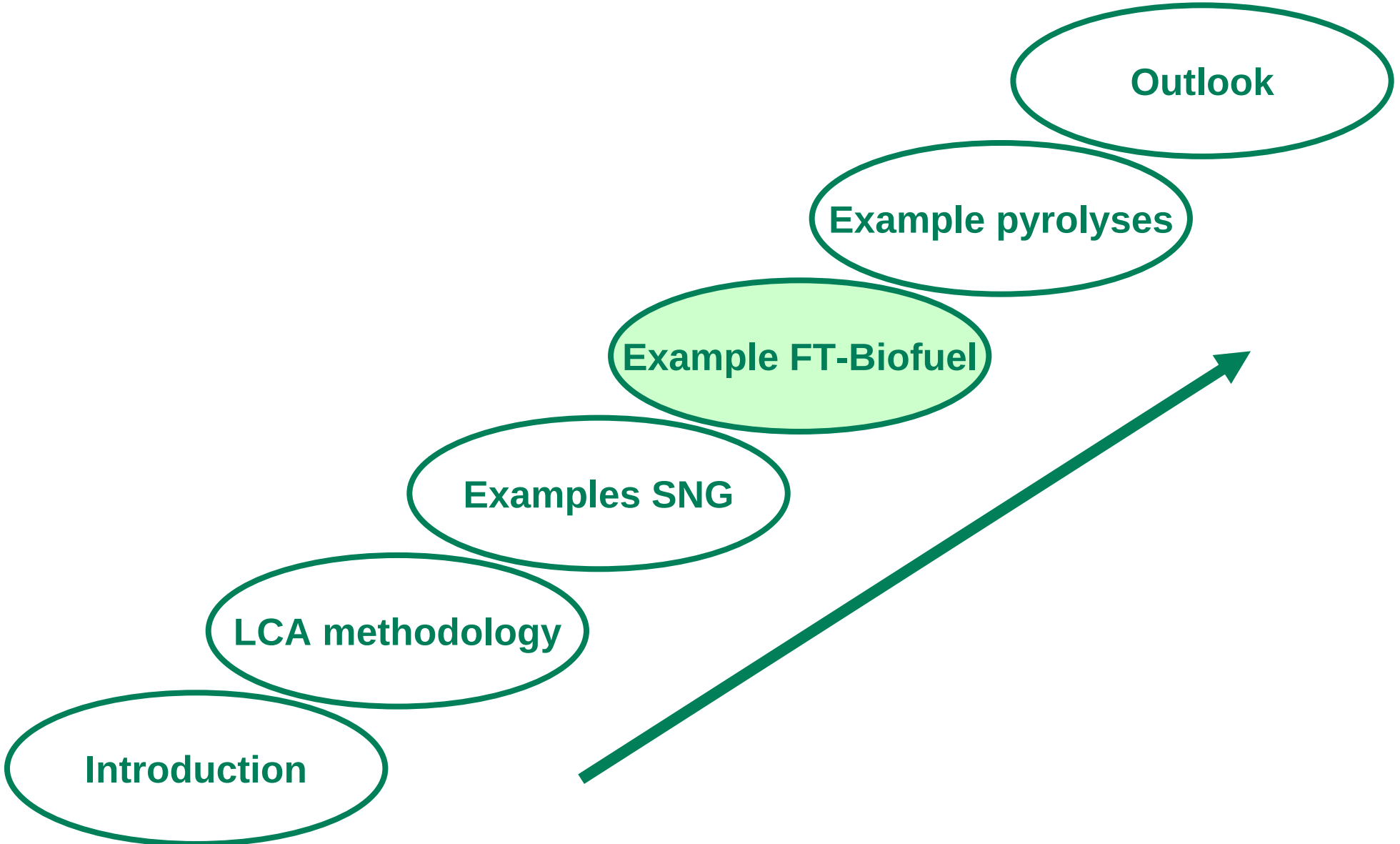
Greenhouse Gas Emissions SNG



Cumulated Primary Energy Demand SNG



Outline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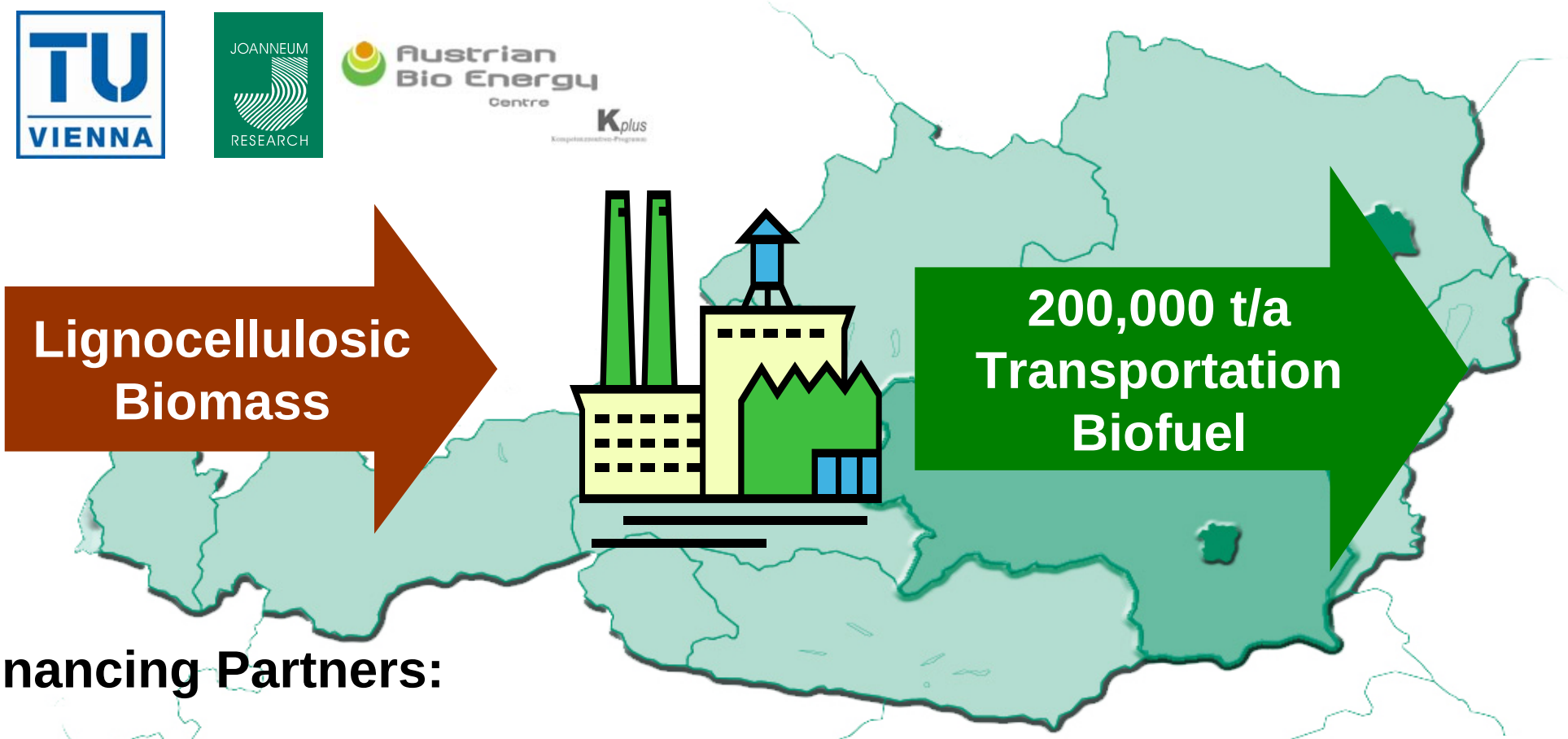
Feasibility Analyses for Fischer-Tropsch-Biofuel Plant

Partners:



Financing Partners:

Characteristics of FT-Biofuel-Plants

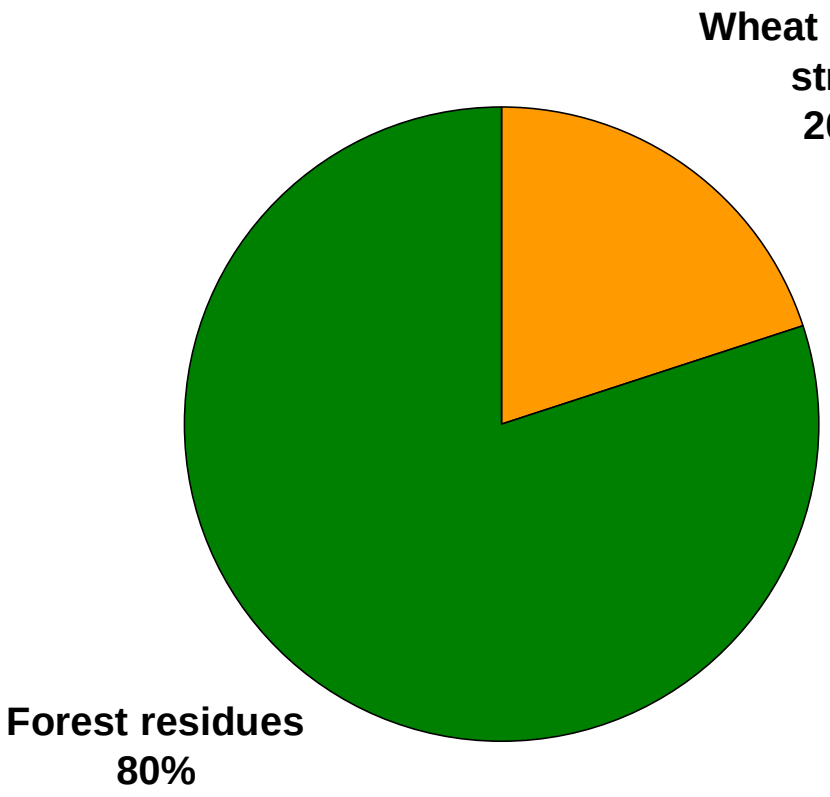
System	No of plants	Biomass Input [MW]	Output Power[1)]	Output Heat [GWh/a]	Output Fuel [GWh/a]
Polygeneration 100 MW (FT-fuels, heat)	5	5 x 100	0	5 x 25.6[3)] 5 x 78.4[4)]	5 x 488
Single product 500 MW (FT-fuels)	1	500	0	0	2,444

[1)] power generated for plant operation only, no power is fed into the grid
[2)] combustion engine, EURO 6
[3)] current feedstock mix
[4)] future feedstock mix

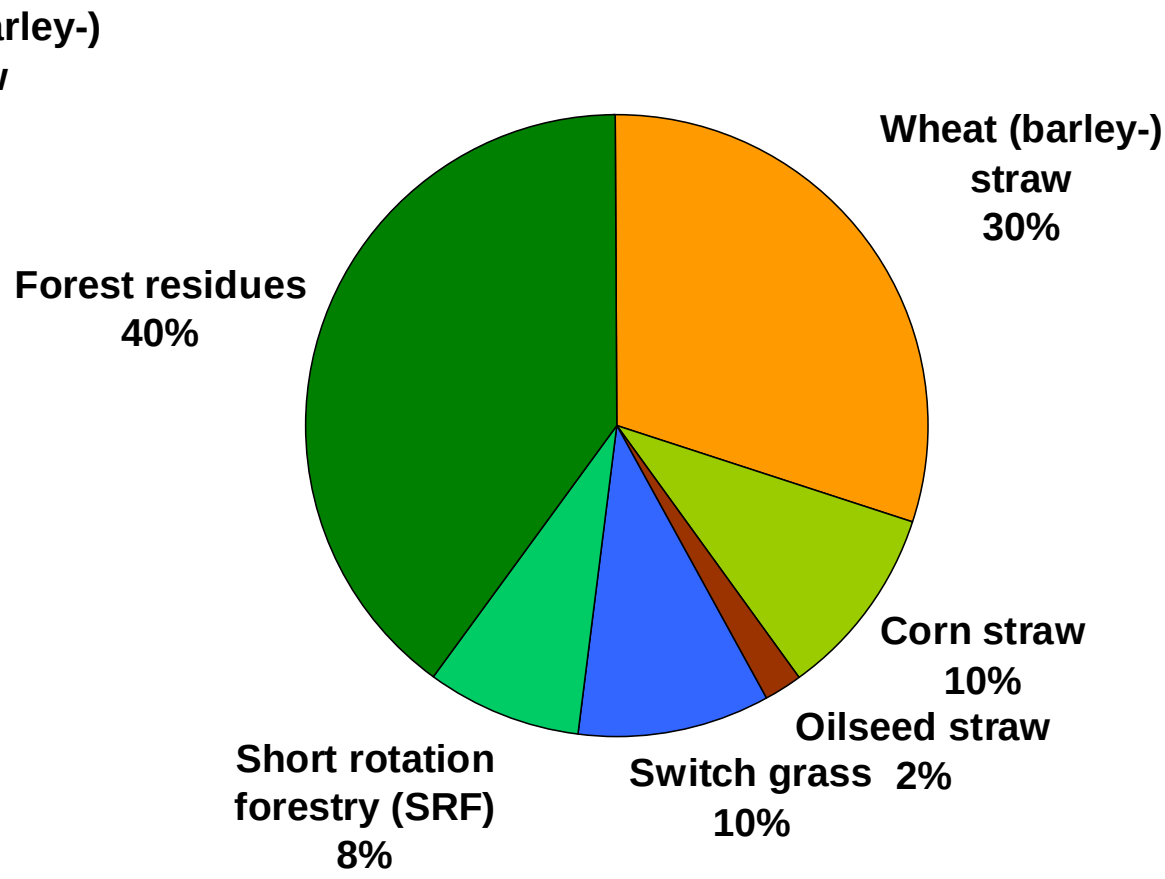
FT-Biofuels are FT-diesel and FT-gasoline
…and comparison to other transportation biofuels

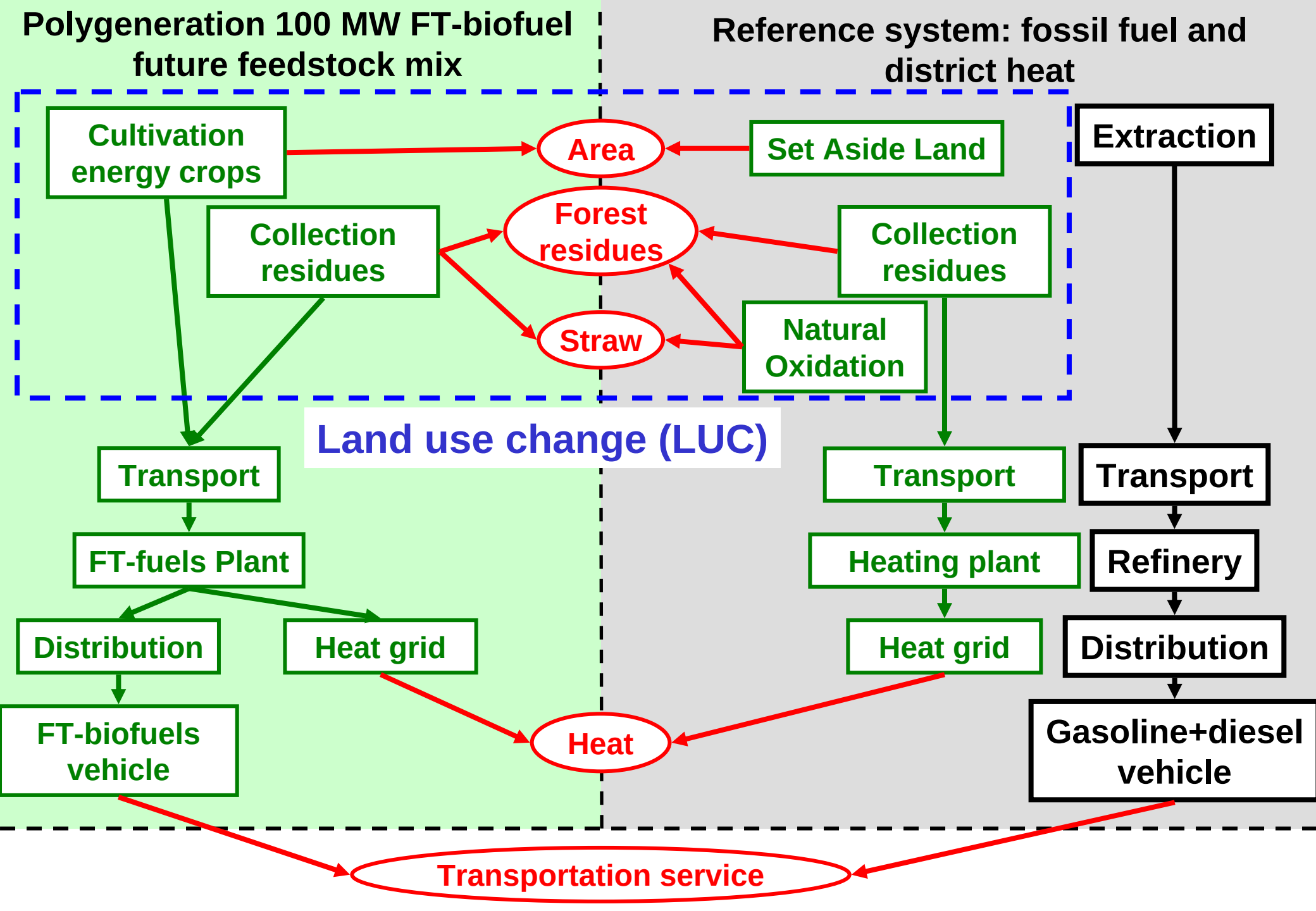
Feedstock Mixes for FT-Biofuels

Current feedstock mix

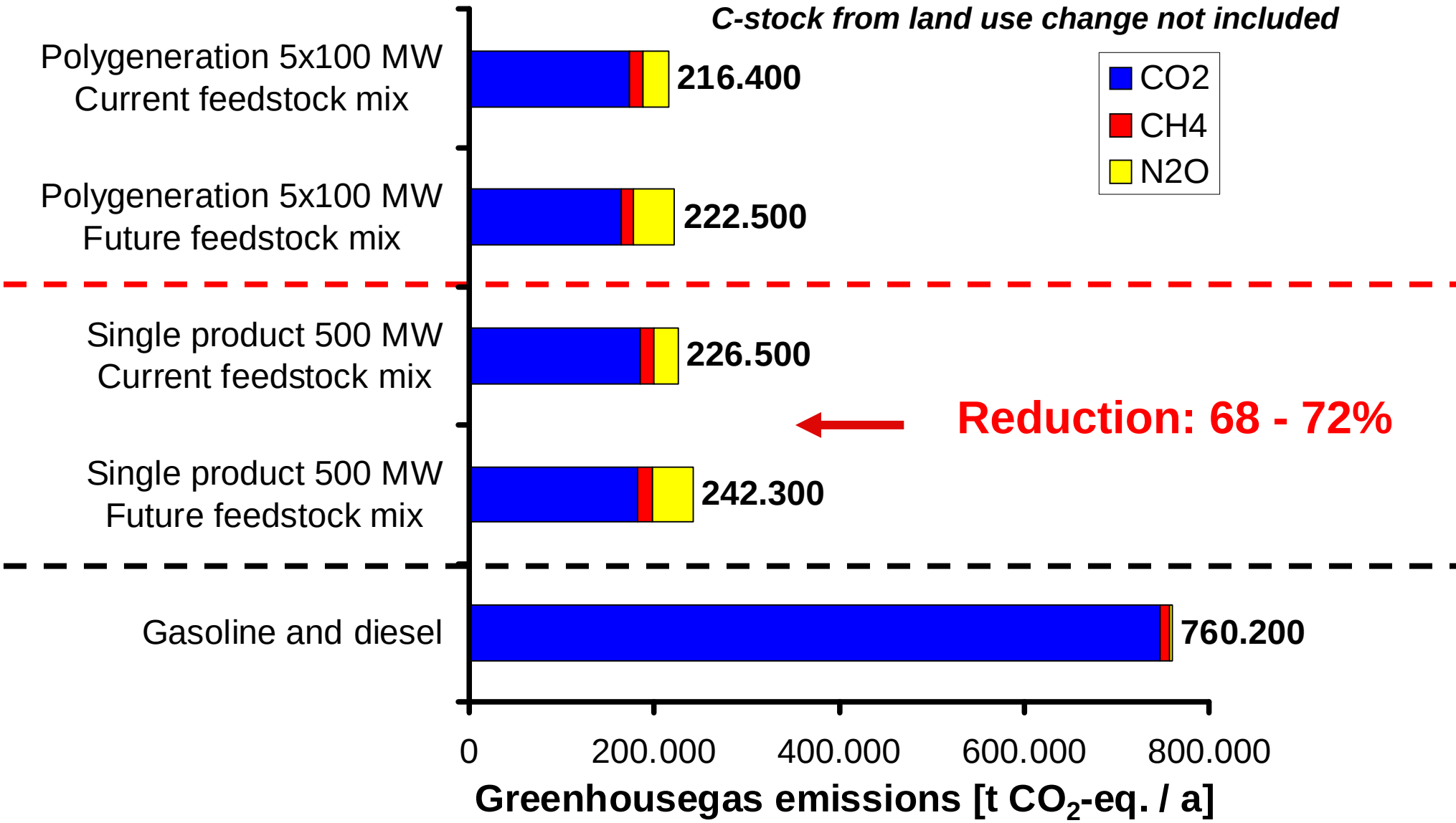


Future feedstock mix

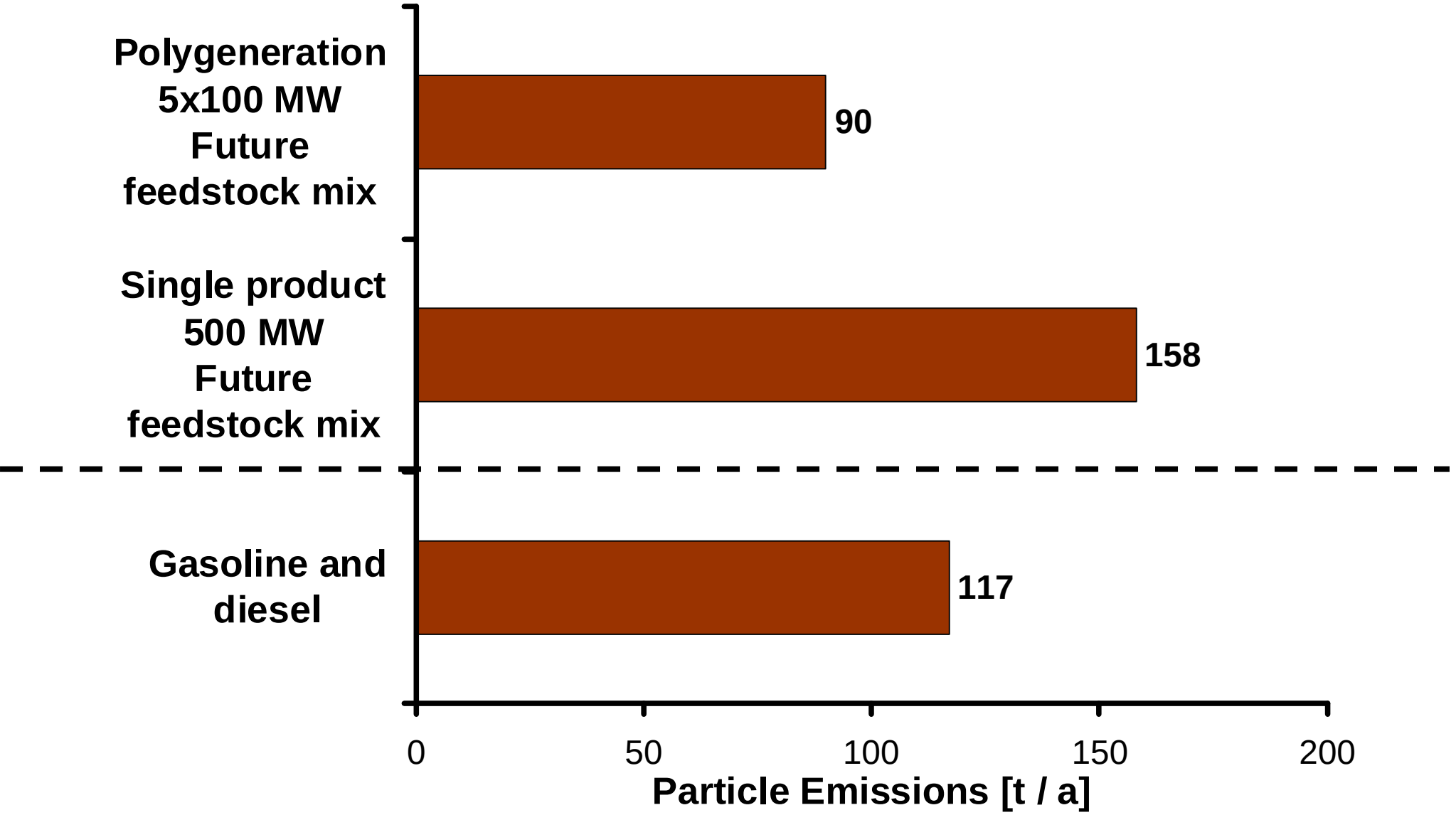



Polygeneration 100 MW FT-biofuel future feedstock mix
Reference system: fossil fuel and district heat
Cultivation energy crops
Area
Set Aside Land
Extraction
Collection residues
Forest residues
Collection residues
Straw
Natural Oxidation
Land use change (LUC)
Transport
Transport
Transport
FT-fuels Plant
Heating plant
Refinery
Distribution
Heat grid
Heat grid
Distribution
FT-biofuels vehicle
Heat
Gasoline+diesel vehicle
Transportation service

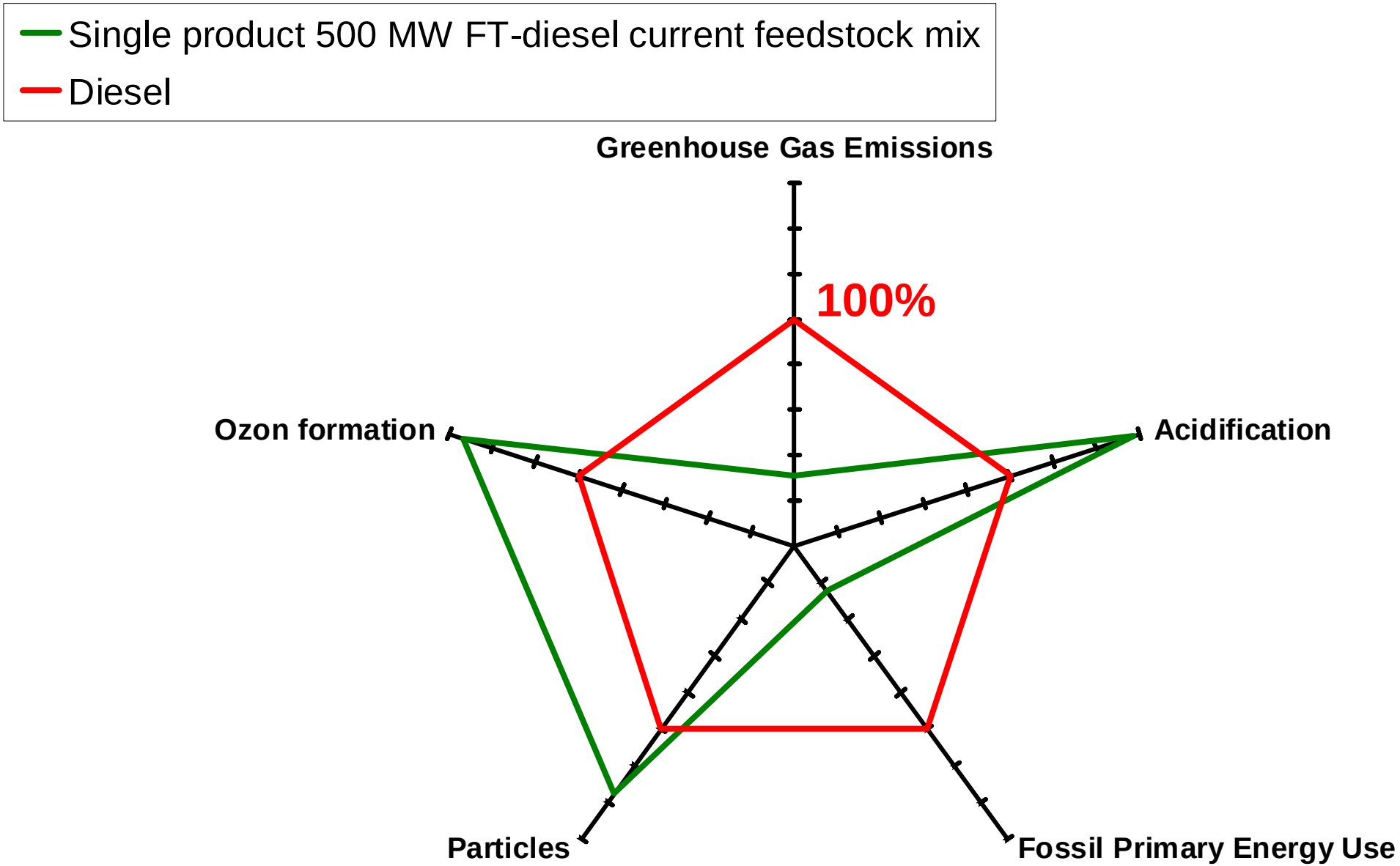
Greenhouse Gas Emissions FT-Biofuels



Particle Emissions FT-Biofuels



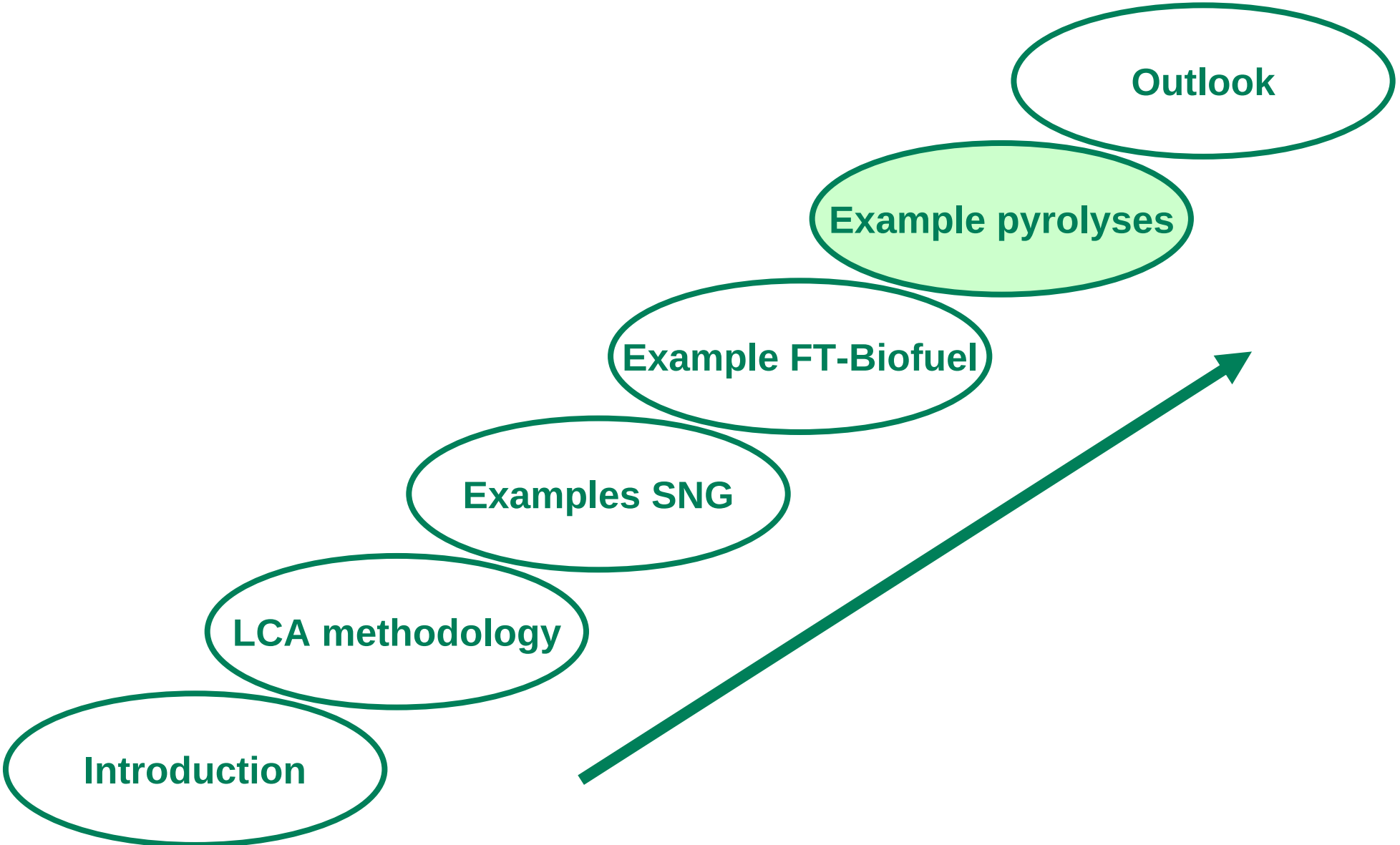
Environmental Assessment FT-Biofuels



FT-Biofuels Compared to other Biofuels and Fossil Fuels

System		Greenhouse gas emissions [g CO_2-eq./km]	Fossil primary energy use [kWh/km]	Acidification [g SO_2-eq./km]	Ozone formation [g C_2H_4-eq./km]	Particles [g/km]
FT-diesel	Single product 500 MW Current feedstock mix	62	0.17	0.78	0.98	0.050
	Single product 500 MW Future feedstock mix	66	0.17	0.77	0.96	0.047
	Polygeneration 100 MW Current feedstock mix	60	0.17	0.76	0.96	0.044
	Polygeneration 100 MW Future feedstock mix	61	0.15	0.71	0.87	0.029
FT-gasoline	Single product 500 MW Current feedstock mix	66	0.19	0.75	0.96	0.042
	Single product 500 MW Future feedstock mix	71	0.18	0.74	0.94	0.040
	Polygeneration 100 MW Current feedstock mix	63	0.18	0.74	0.94	0.035
	Polygeneration 100 MW Future feedstock mix	65	0.16	0.68	0.84	0.019
Other biofuels	Biodiesel Rape seed oil	125	0.18	0.52	0.67	0.041
	Bioethanol Wheat	203	0.51	0.37	0.50	0.046
	Biogas Corn silage	132	0.18	0.39	0.61	0.055
Fossil fuels	Diesel	196	0.70	0.40	0.48	0.032
	Gasoline	242	0.87	0.37	0.43	0.034
	Natural gas	201	0.86	0.21	0.47	0.036

Outline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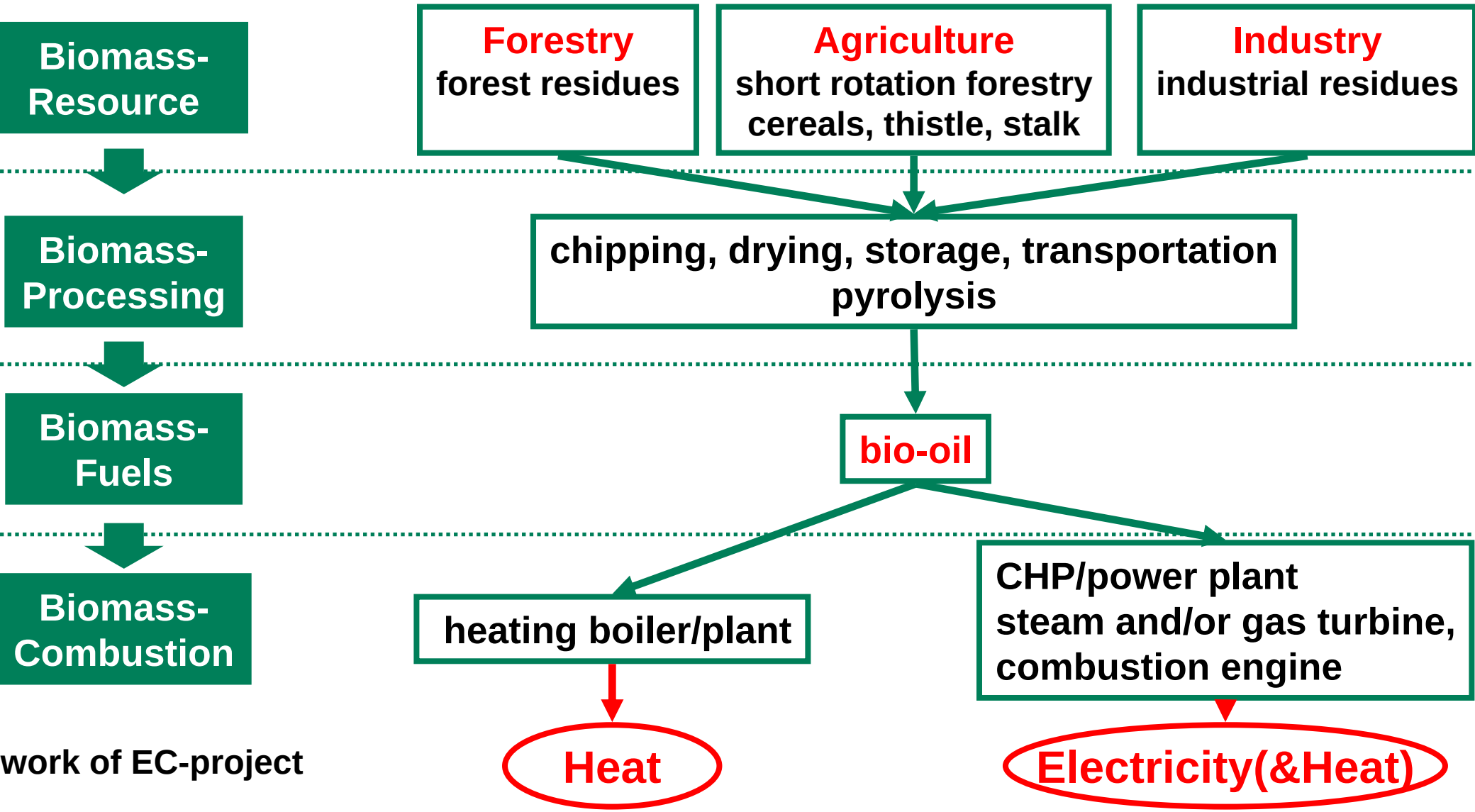
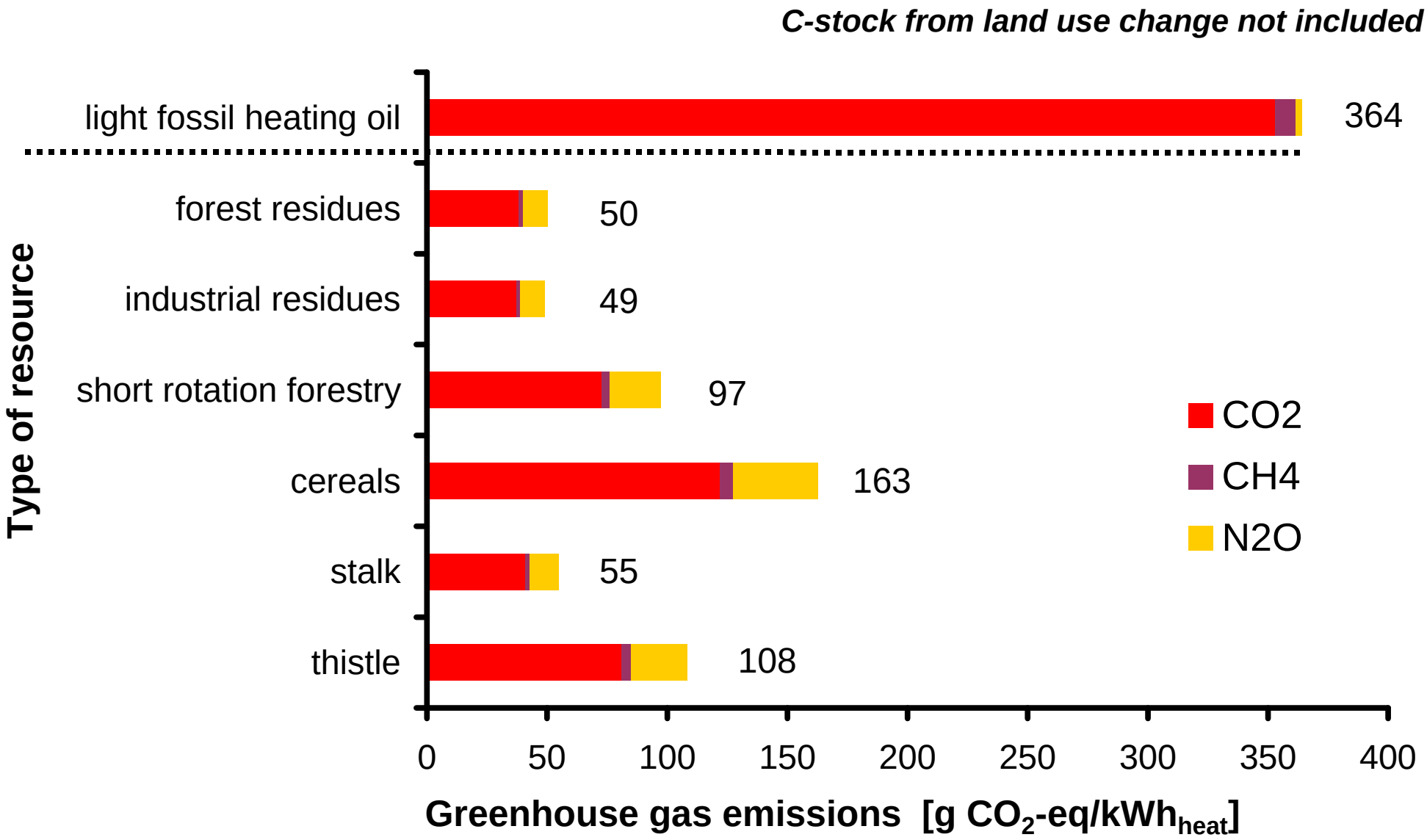
Energy Systems with Bio-oil from Pyrolyses



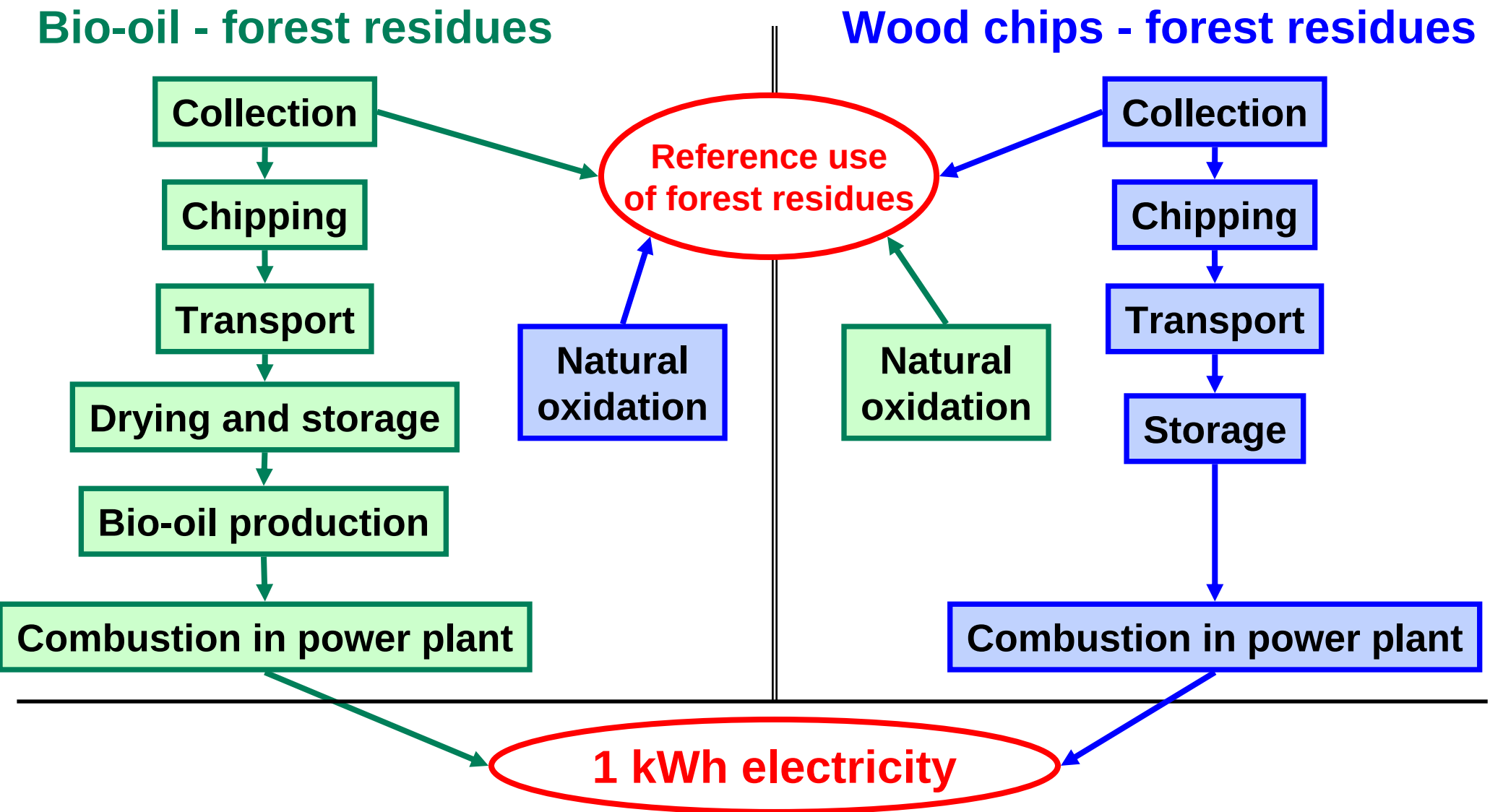
work of EC-project

"PYROLYSES - Opportunities for bio-oil in European heat and power market"

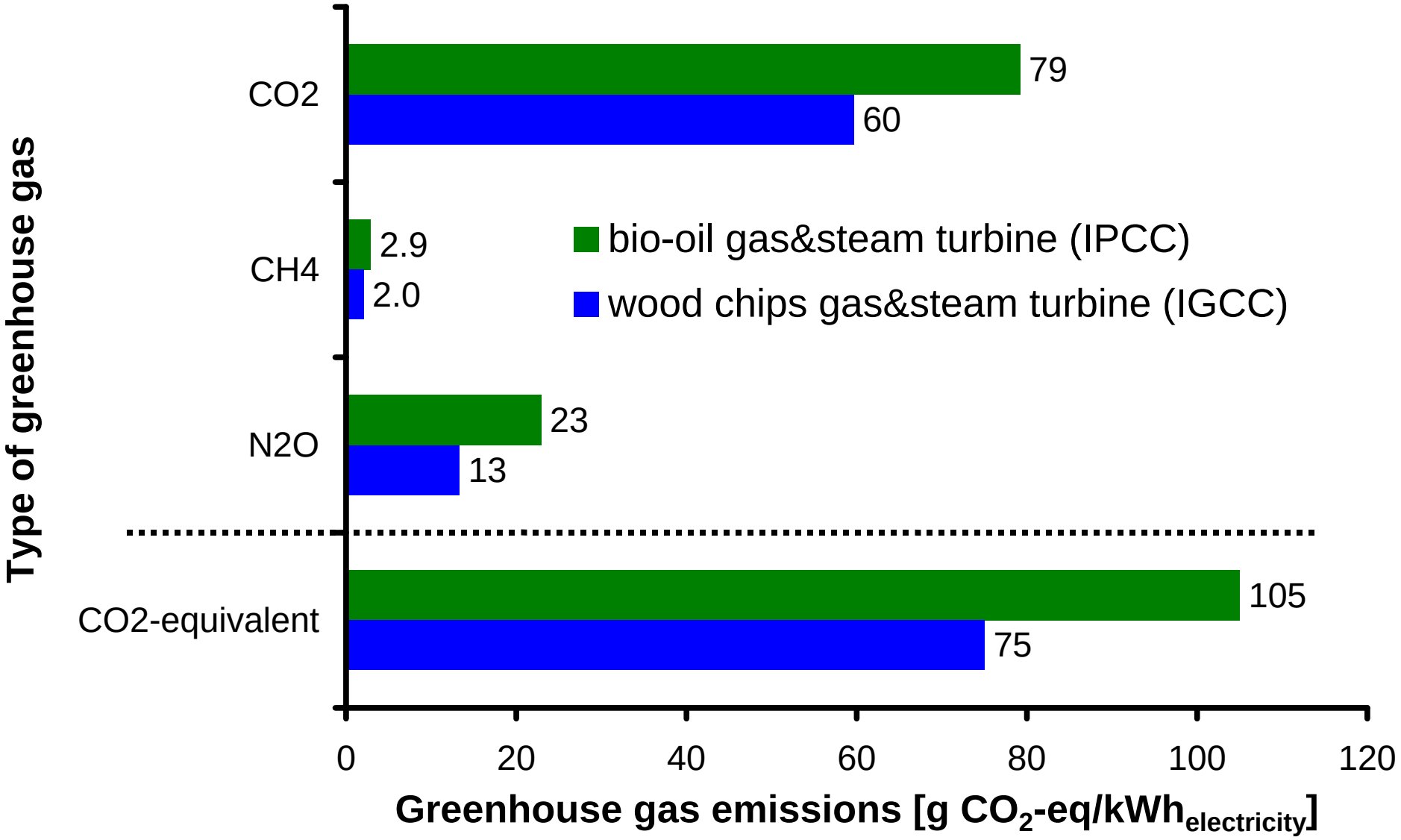
GHG Emissions: Heat Supply with Bio-oil from Different Resources



Electricity from Bio-oil and Wood Chips from Forest Residues



GHG Emissions of Electricity from Forest Residues



Comparison GHG-Emissions Electricity Bio-oil and Conventional Bioenergy

C-stock from land use change not included

Bio-oil Systems

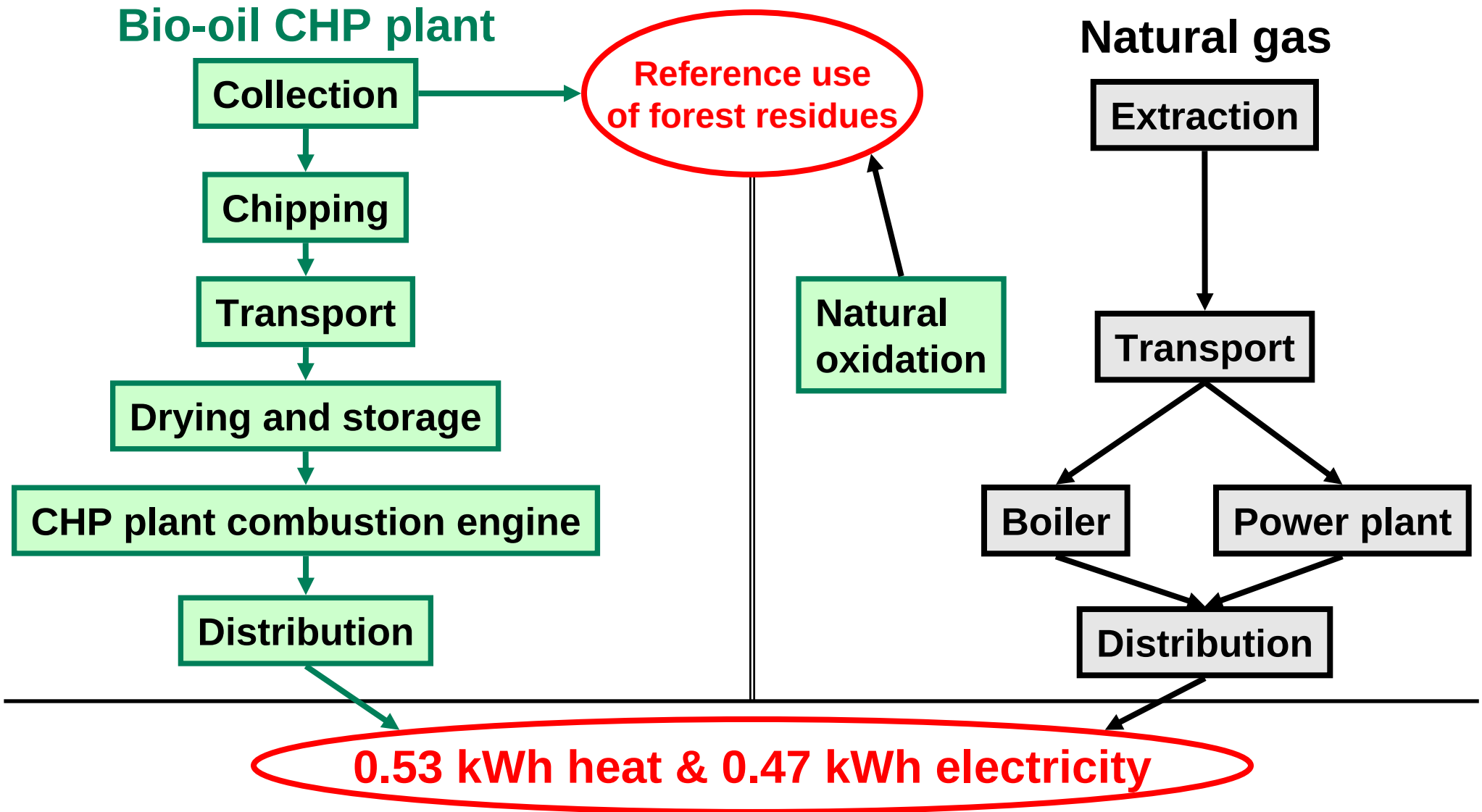
Conventional Bioenergy Systems

Power plant with gas and steam turbine (combined cycle)

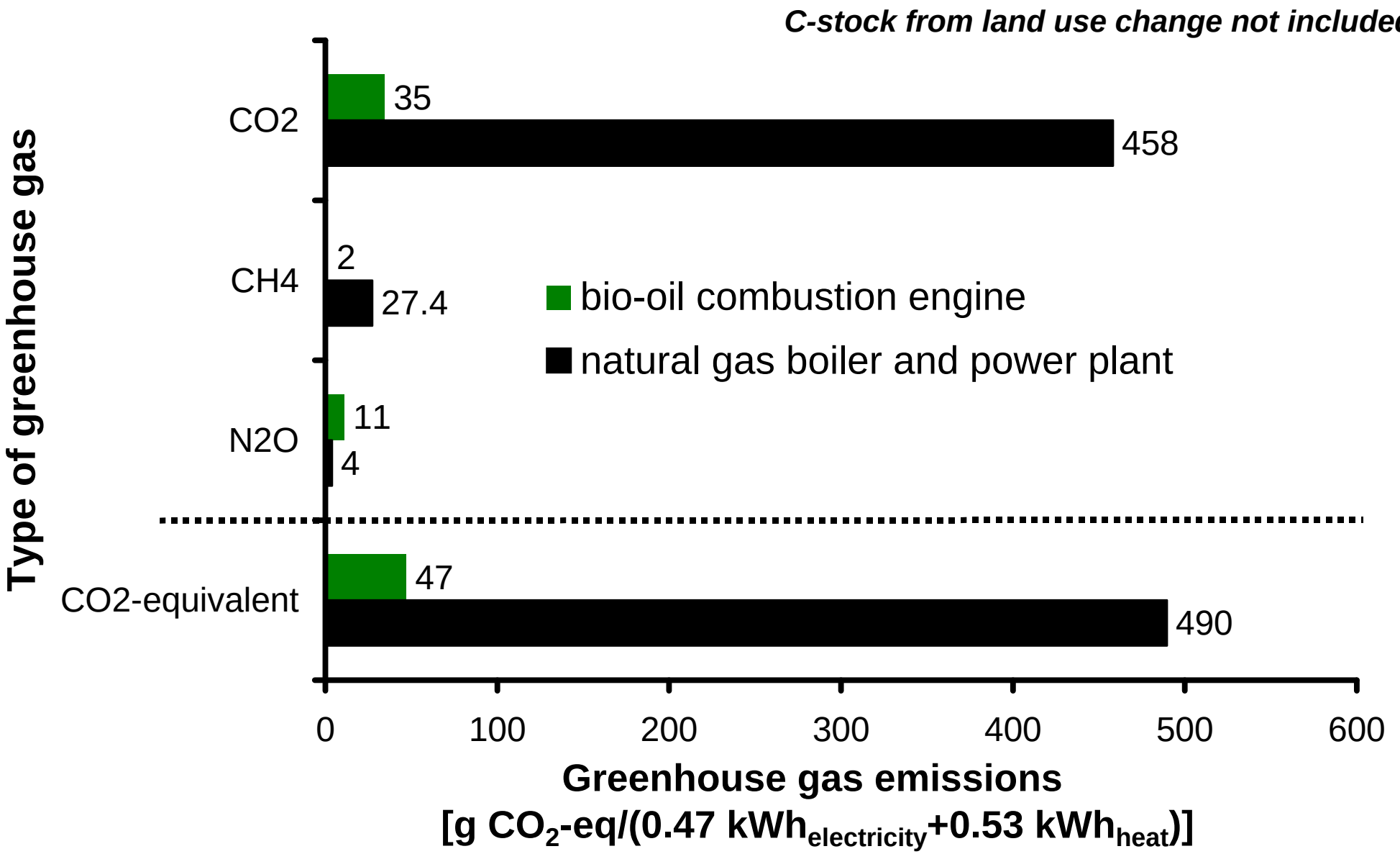
[g CO_2-eq./kWh]		bioenergy forest residues	bioenergy industrial residues	bioenergy short rotation forest	bioenergy cereals	bioenergy stalk	bioenergy thistle
		75.0	72.8	161.0	190.0	63.3	125.0
biooil forest residues	105	40%	44%	-35%	-45%	66%	-16%
biooil industrial residues	102	36%	40%	-37%	-46%	61%	-18%
biooil short rotation forest	197	163%	171%	22%	4%	211%	58%
biooil cereals	333	344%	357%	107%	75%	426%	166%
biooil stalk	111	48%	52%	-31%	-42%	75%	-11%
biooil thistle	219	192%	201%	36%	15%	246%	75%

Bio-oil Systems have higher GHG-Emission compared to conventional bioenergy systems with same biomass resource

Example 3: Electricity&Heat Supply Bio-oil and Natural Gas



GHG Emission Electricity&Heat from Bio-Oil and Natural Gas



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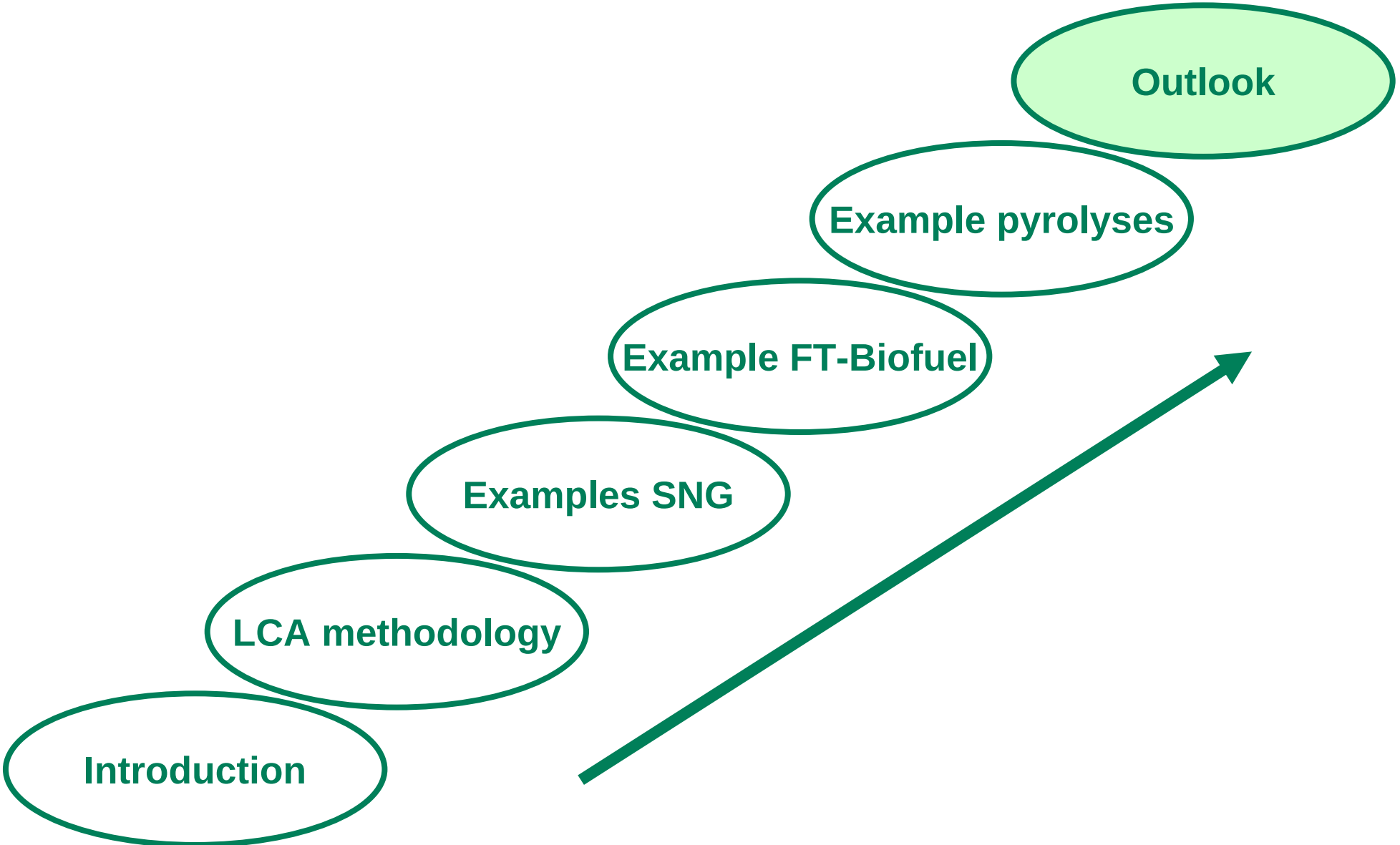
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Conclusions

8) GHG emissions&fossil energy demand of bioenergy are lower than fossil energy systems

7) “conventional bioenergy” might be better than gasification& pyrolyses for heat(&electricity)

6) Use of by-products essential for “good” LCA e.g. heat

5) Use of biofuel essential SNG e.g. heat/transport

4) Type of thermal process influences environmental effects

3) Feedstock relevant for environmental effects: residues < energy crops

2) Reference use of biomass/area essential to be included

1) LCA methodology is ready to be applied