

# Sustainability of Fatty Acid Methyl Esters (FAME)



## Assessment of Improving Options

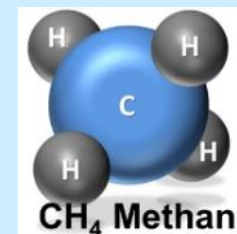
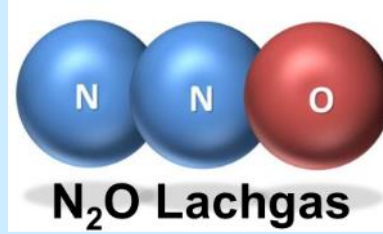
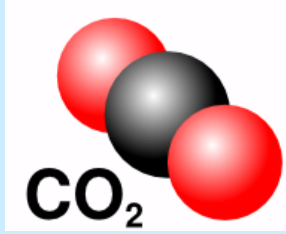
Gerfried Jungmeier

National Workshop Biofuels

Vienna, September 29, 2016

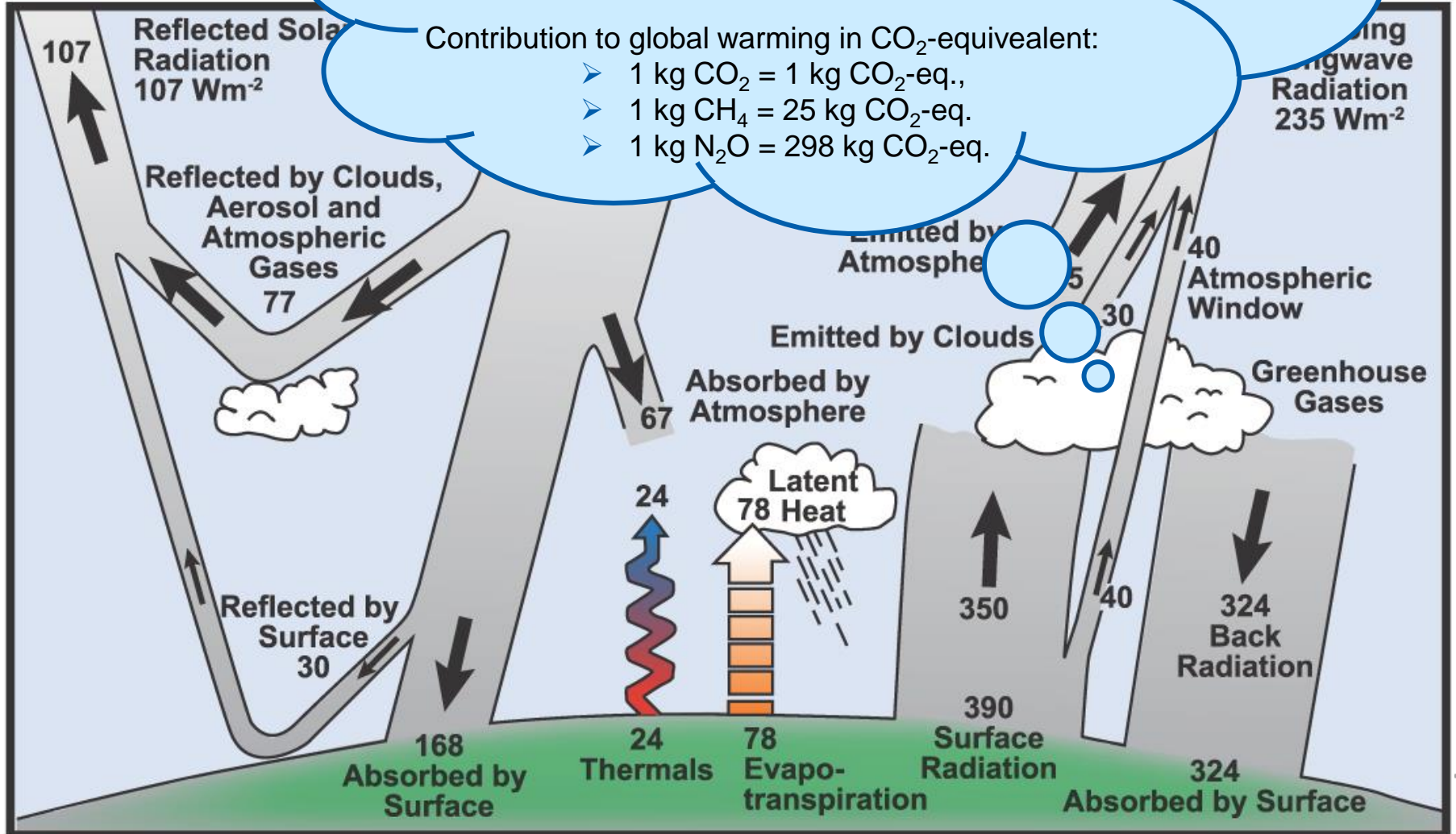
The

IT!



Contribution to global warming in CO<sub>2</sub>-equivalent:

- 1 kg CO<sub>2</sub> = 1 kg CO<sub>2</sub>-eq.,
- 1 kg CH<sub>4</sub> = 25 kg CO<sub>2</sub>-eq.
- 1 kg N<sub>2</sub>O = 298 kg CO<sub>2</sub>-eq.



# The FOUR Factors Greenhouse Gas

## Future Energy System

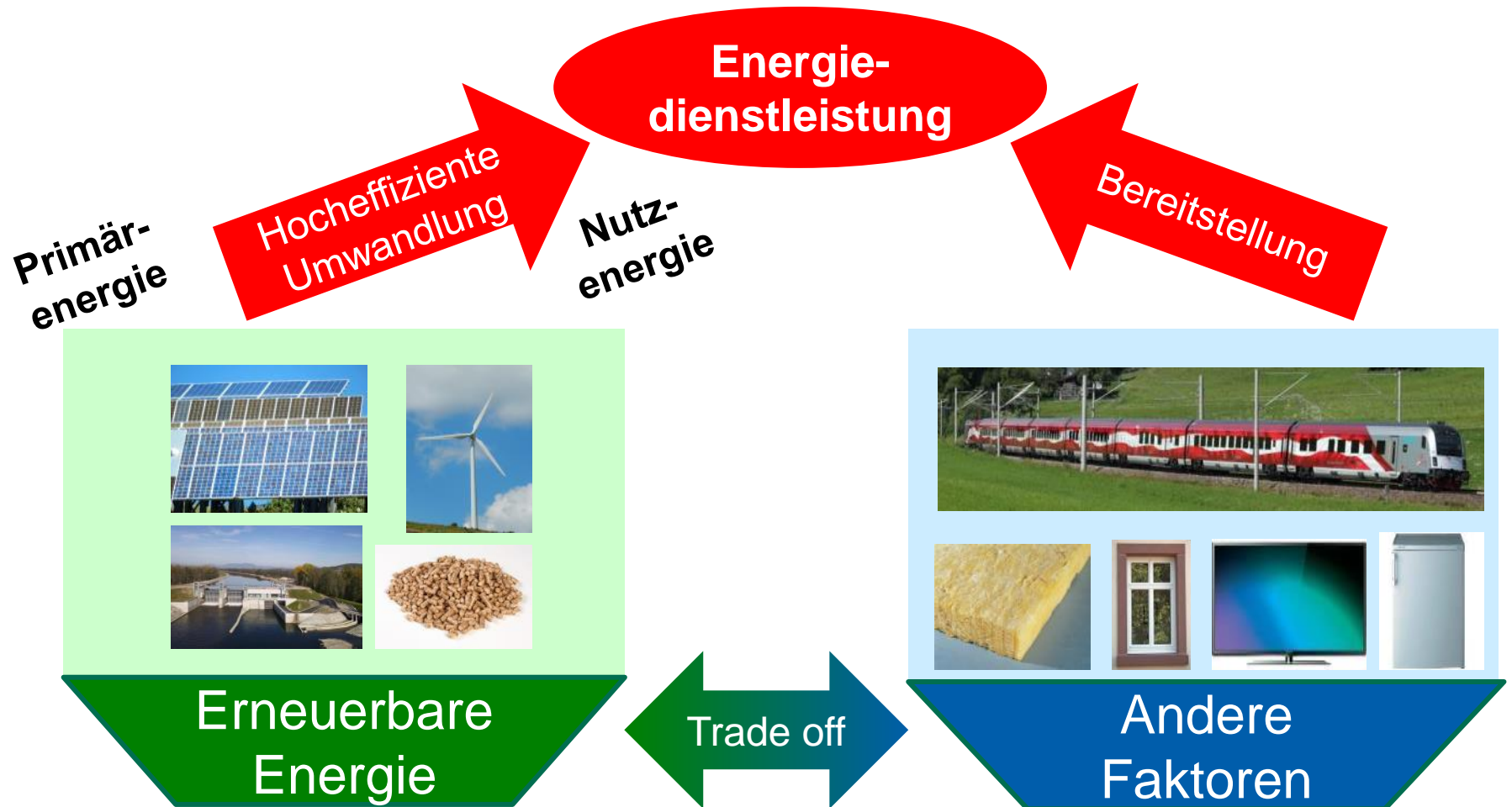
$$tCO_2eq = \frac{t}{P}$$

Activity focus of NEW Research Group  
"Future Energy Systems & Lifestyle"  
since January 1, 2016

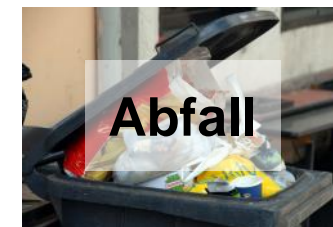
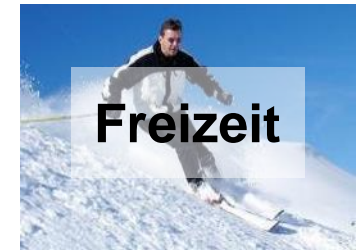


- 2) Energy-efficiency
- 3) services per person
- 4) number of people

# Kennzeichen zukunftsfähiger Energiesysteme



# Kennzeichen der Lebensstile



# Aims

---

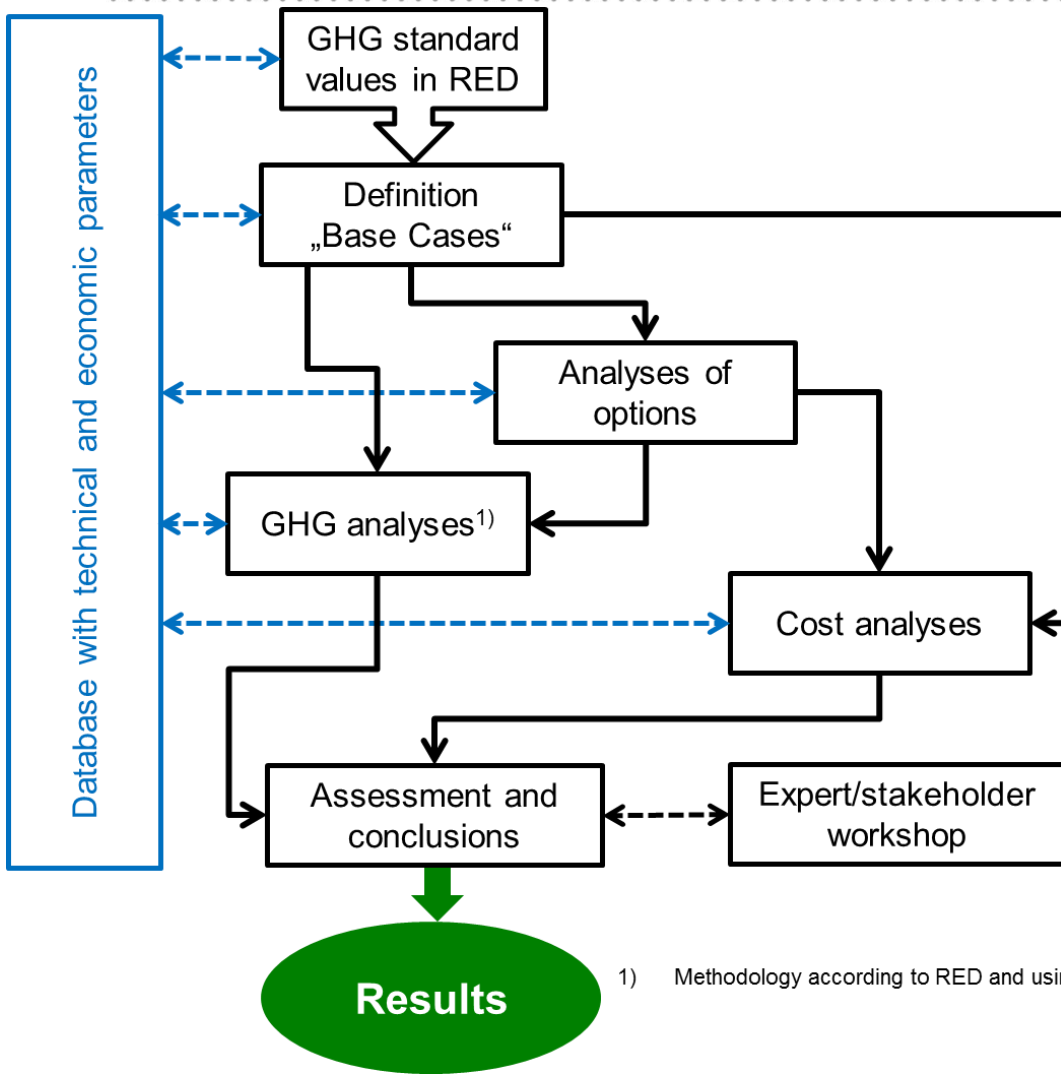
- **Greenhouse Gas (GHG) balances of FAME** from various resources have been set in the RED.
- Due to technology and scientific progress it is feasible that there are several ways to **improve the GHG balances of FAME**.
- This Supporting Action aims at analysing the **various options available in improving the GHG balance of FAME**.
- **Assessment of 10 options** to improve the GHG balance of biodiesel.

# 10 Options to improve the GHG balance of FAME

7

- 1) **“Biomethanol”** to substitute fossil methanol in FAME production
- 2) **“Bioethanol”** to substitute fossil methanol for production of FAEE
- 3) **“CHP residues / Renewable heat & CHP”** to provide power&heat
- 4) **“Plant species”** increasing biomass weight without effect on oil seed
- 5) **“Bioplastics&chemicals”** made from process residues and straw
- 6) **“Advanced agriculture”** for N<sub>2</sub>O-reduction and soil-C accumulation
- 7) **“Organic fertilizer”** Use of organic instead of mineral fertilizer
- 8) **“FAME as a fuel”** for cultivation, transportation and distribution
- 9) **“Retrofitting multi feedstock”** in single feedstock FAME plants
- 10) **“Green electricity from PV plant on site”** for FAME production

# Approach

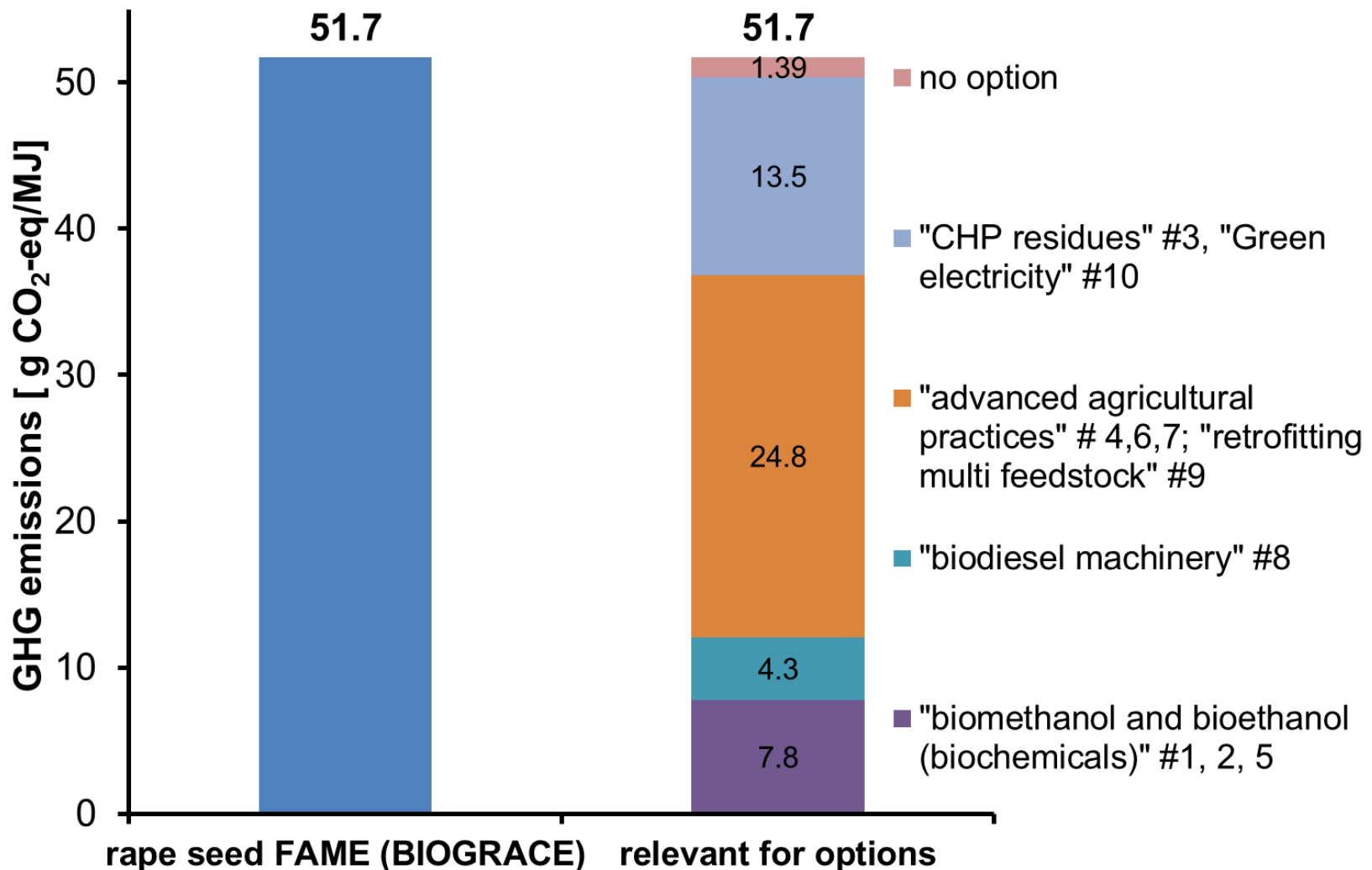


- GHG standard values from RED
- Definition “base cases” using BAT
- Specification and analyses of options to improve the GHG balance of FAME
- Database
- GHG analyses
- Cost analyses
- Overall assessment, “Fact Sheet of options” and conclusions
- Expert/stakeholder workshop

1) Methodology according to RED and using the BioGrace calculation tool



# GHG Emissions Addressed by Options



# Definition of 14 “base cases”- characteristics & combinations

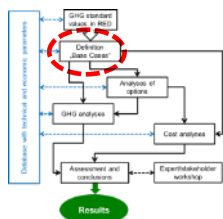
## feedstock types

- Rapeseed
- Sunflower
- Palm oil
- European soybean
- American soybean
- Used cooking oil/animal fat

## 3 FAME production capacities:

- 50,000 t/a
- 100,000 t/a
- 200,000 t/a

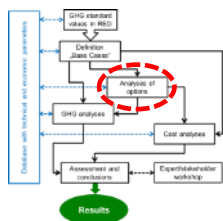
#	Short Name	Feedstock	Capacity [1,000 t/a]
1	Rs-50-BC	Rapeseed	50
2	Rs-100-BC	Rapeseed	100
3	Rs-200-BC	Rapeseed	200
4	Sf-50-BC	Sunflower	50
5	Sf-100-BC	Sunflower	100
6	Sf-200-BC	Sunflower	200
7	F-Sy(am)-100-BC	American soybean	100
8	F-Sy(am)-200-BC	American soybean	200
9	F-Sy(eu)-100-BC	European soybean	100
10	F-Sy(eu)-200-BC	European soybean	200
11	F-Po(CH4 capt)-100-BC	Palm oil	100
12	F-Po(CH4 capt)-200-BC	Palm oil	200
13	F-Wo-50-BC	UCO / animal fat	50
14	F-Wo-100-BC	UCO / animal fat	100



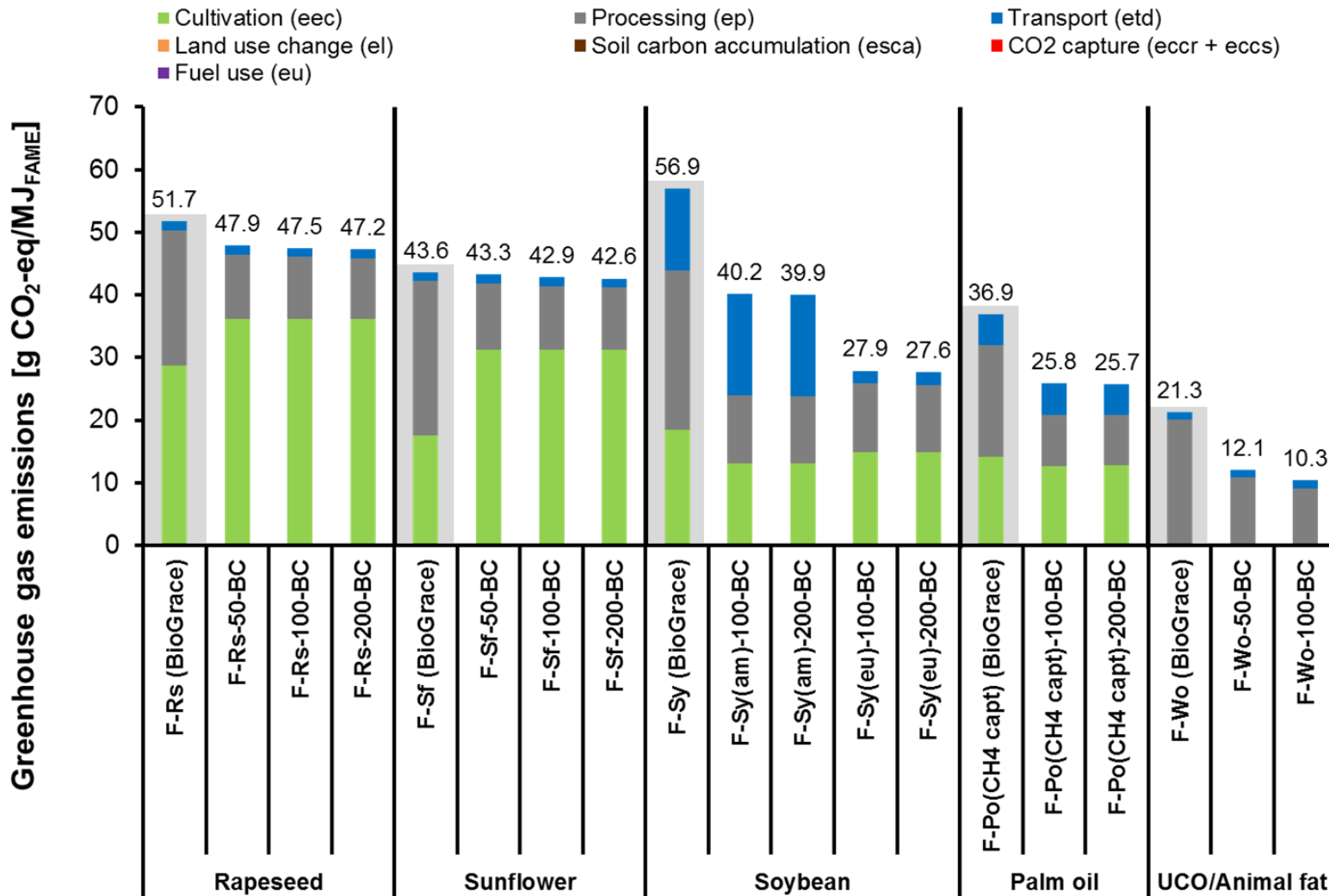
# Specification of 39 GHG reduction options

## Example: “Chemicals” and “Energy supply”

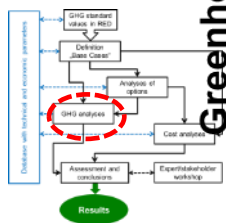
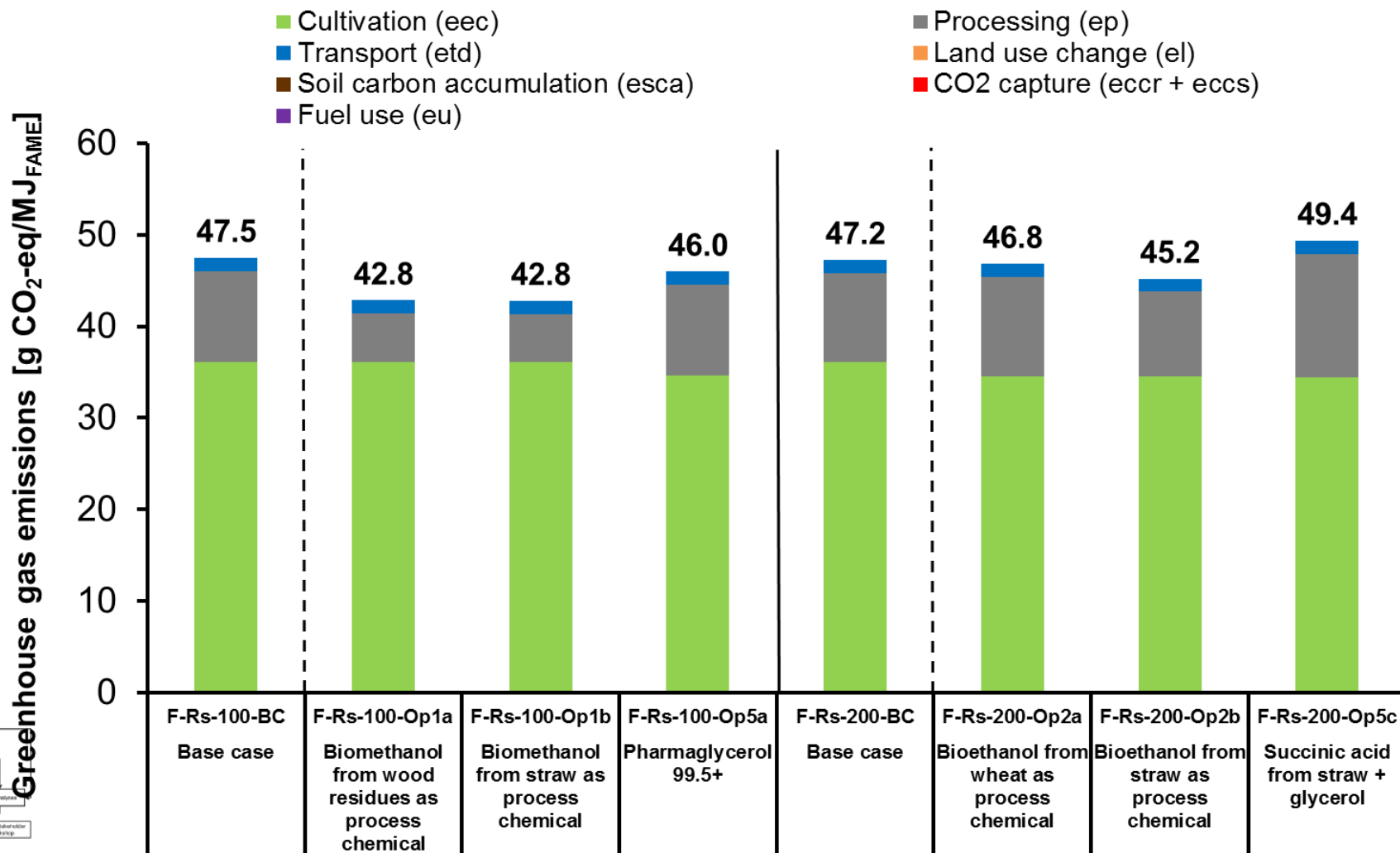
# <sup>1)</sup>	Improvement option	Rapeseed			American soybean	Palm oil (CH <sub>4</sub> capt)	New plant species	UCO / animal fat		Short name	
		50	100	200	100	100	100	50	100		
<b>CHEMICALS</b>											
<b>1</b>	<b>Biomethanol</b>										
1a	Biomethanol from wood residues as process chemical		x							F-Rs-100-Op1a	
1b	Biomethanol from straw as process chemical		x		x				x	F-Rs-100-Op1b F-Sy(am)-100-Op1b F-Wo-100-Op1b	
1c	Biomethanol from glycerol as process chemical		x							F-Rs-100-Op1c	
<b>2</b>	<b>Bioethanol</b>										
2a	Bioethanol from wheat as process chemical				x					F-Rs-100-Op2a	
2b	Bioethanol from straw as process chemical				x					F-Rs-100-Op2b	
<b>5</b>	<b>Bioplastic &amp; -chemicals</b>										
5a	Pharmaglycerol 99.5+				x				x	F-Rs-100-Op5a F-Wo-100-Op5a	
5c	Succinic acid from straw + glycerol	x		x						F-Rs-50-Op5c F-Rs-200-Op5c	
<b>ENERGY SUPPLY</b>											
<b>3</b>	<b>CHP residues</b>										
3b	CHP with refined vegetable oils + steam boiler with vegetable oils				x					F-Rs-200-Op3b	
3c	Steam boiler with vegetable oils				x					F-Rs-200-Op3c	
3f	Wood-to-steam boiler				x					F-Rs-200-Op3f	
3d	CHP with distilled glycerol + co-incineration of FAME distillation residue (BHA) in steam boiler								x	F-Wo-50-Op3d	
3e	Co-incineration of FAME distillation residue (BHA) in steam boiler								x	x	F-Wo-50-Op3e F-Wo-100-Op3e
10	<b>Green electricity</b>		x	x					x	x	F-Rs-100-Op10 F-Rs-200-Op10 F-Wo-50-Op10 F-Wo-100-Op10



# Greenhouse gas emissions of base cases compared to RED values with background data from BioGrace

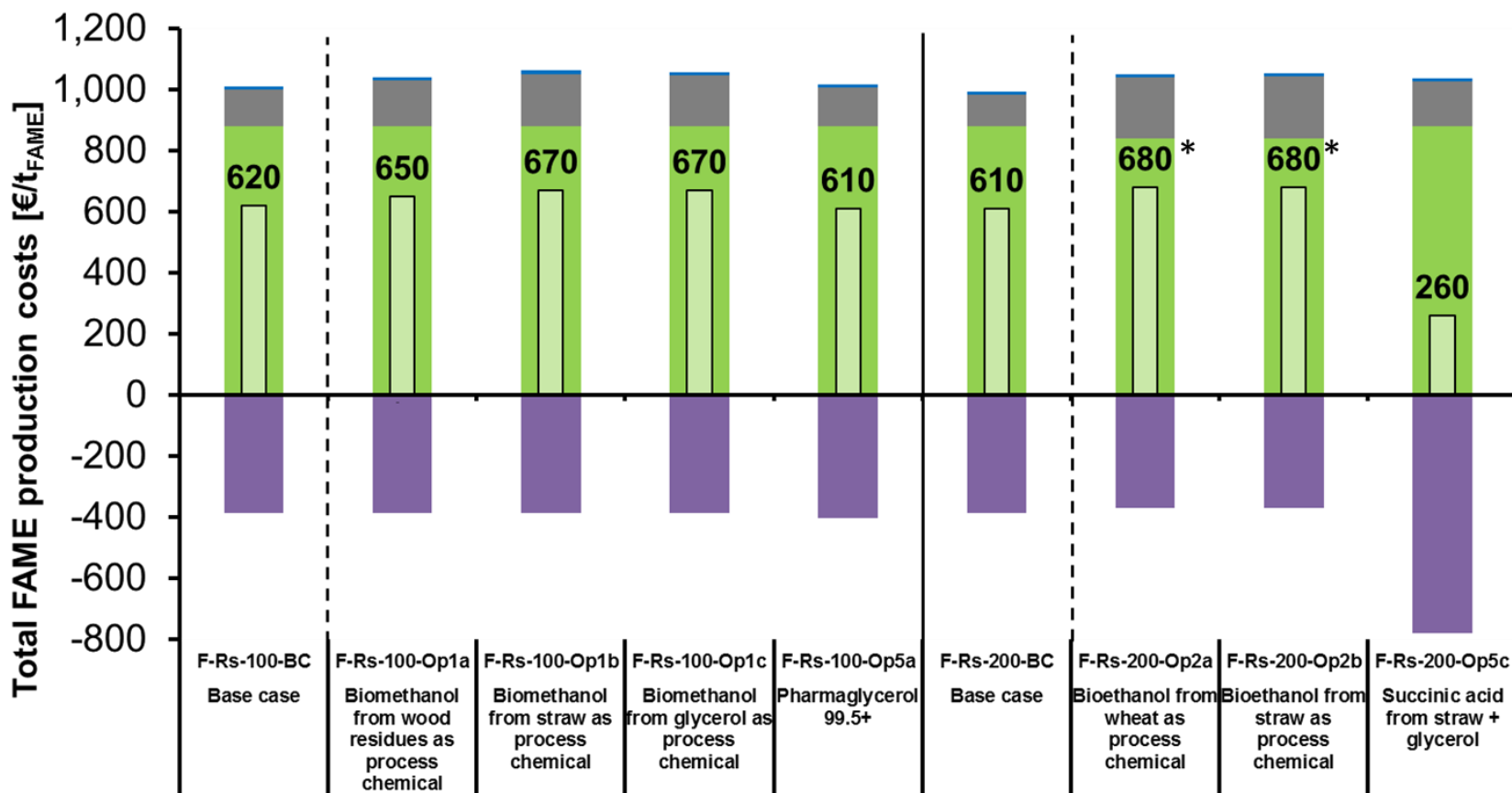


# GHG emissions of improvement options “Biomethanol”, “Bioethanol”, “Biochemicals” (I)

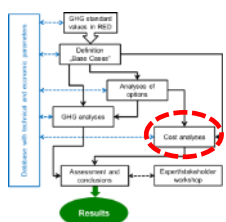


# FAME production costs of improvement options “Biomethanol”, “Bioethanol”, “Biochemicals”

■ Cultivation/Feedstock 
 ■ Processing 
 ■ Co-products revenues 
 ■ Transport&distribution 
 □ Totals

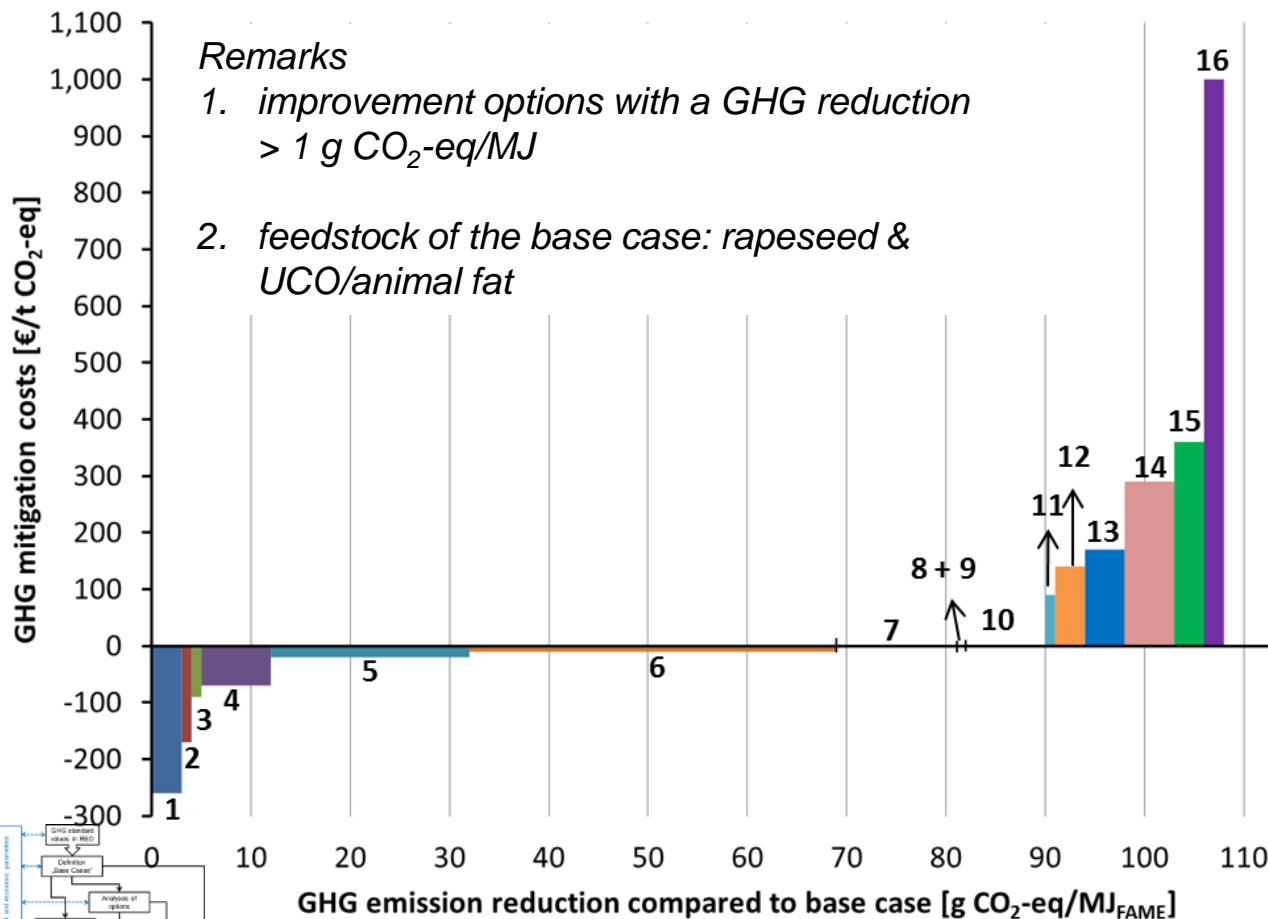


\* Process output is FAEE



# GHG mitigation costs and GHG emission reduction of selected improvement options

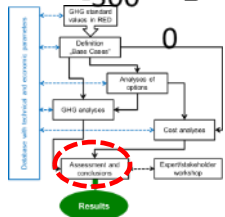
15



### Remarks

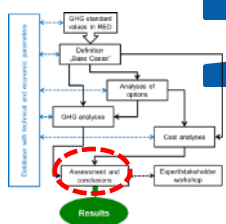
- improvement options with a GHG reduction > 1 g CO<sub>2</sub>-eq/MJ
- feedstock of the base case: rapeseed & UCO/animal fat

- Balanced fertilization (100 kt/a)
- Pharmaglycerol 99.5% (100 kt/a)
- Wood-to-steam boiler (200 kt/a)
- Reduced tillage (100 kt/a)
- Crop residue management (100 kt/a)
- Complete modification to UCO/animal fat (80 kt/a)
- Organic fertilizer (100 kt/a)
- BHA steam boiler (50 kt/a)
- BHA steam boiler (100 kt/a)
- Partial modification to UCO/animal fat (200 kt/a)
- FAME in cultivation (100 kt/a)
- CHP with distilled glycerol + BHA steam boiler (50 kt/a)
- Biomethanol from wood residues as process chemical (100 kt/a)
- Biomethanol from straw as process chemical (100 kt/a)
- Nitrification inhibitors (100 kt/a)
- Bioethanol from straw as process chemical (200 kt/a)



# Key aspects of SWOT analysis (I)

- **Biomethanol:** Due to economy of scale biomethanol production at the FAME plant not feasible
- **Bioethanol:** For FAEE fuel certification is missing according to EN14214
- **CHP residues:**
  - All investigated system are commercial solutions
  - FAME processing needs most of the heat on temperature levels above the temperature level generated by CHP solutions
- **New plant species:** Production chains for new emerging crops are under development: demonstration needed and biorefinery approach due to large set of co-products
- **Bioplastic- and biochemical:**
  - Succinic acid - performed on production scale with a mixture of sugar & glycerol
  - Pharmaglycerol - well established and offers an alternative usage for glycerol







# Fact Sheet

## FACT SHEET - Glycerol and FAME distillation residue for process energy supply

### Description

In this improvement option the following possibilities to provide renewable energy for the production of biodiesel are investigated:

- Combined heat and power (CHP) with distilled glycerol and co-incineration of FAME distillation residue in steam boiler:** glycerol is used to generate electricity for the FAME production (refining and esterification) with an adapted CHP engine (~0.4 MWe). Heat is produced by co-firing the biodiesel distillation residue for partly substitution of natural gas.
- Co-incineration of FAME distillation residue in a steam boiler:** heat for the FAME production is generated by co-firing the biodiesel distillation residue for partly substitution of fossil fuels.

The influence on the GHG emission of 50,000 and 100,000 tons FAME (UCO) or animal fat (AF).

### Basic technical and economic System data

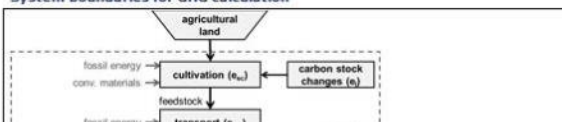
	Unit					
FAME production capacity	[t/year]					
Refining of oil						
Source electricity	[kWh]					
Electricity	[kWh/MJ <sub>FAME</sub> ]					
Source steam	[MJ <sub>th</sub> /MJ <sub>FAME</sub> ]					
Natural gas (distillation)	[MJ <sub>th</sub> /MJ <sub>FAME</sub> ]	0.0029	0.0029	0.0029	0.0029	0.0029
Co-product crude glycerol 80%	[MJ <sub>th</sub> /MJ <sub>FAME</sub> ]	0.0030	0.0017	0.0030	0.0030	0.0030
Co-product bio oil / BHA	[MJ <sub>th</sub> /MJ <sub>FAME</sub> ]	0.0254	-	-	0.0254	-
Source electricity	[MJ <sub>th</sub> /MJ <sub>FAME</sub> ]	0.0000	small-scale production with CHP using (strategic) distill	EU mix 10V	0.0000	EU mix 10V
Electricity	[MJ <sub>th</sub> /MJ <sub>FAME</sub> ]	0.0000				
Source steam		natural gas boiler	natural gas boiler	natural gas boiler	natural gas boiler	natural gas boiler
Natural gas (refining and esterification)	[MJ <sub>th</sub> /MJ <sub>FAME</sub> ]	0.036	0.036	0.036	0.032	0.011
Investment cost (oil refining and esterification)	[€]	210	24.9	212	310	312
Lifetime	[yr]	25	25	25	25	25
Personnel (refining and esterification)	[Number]	19	20	20	19	20

### Background data

	GHG emissions <sup>a</sup> [g CO <sub>2</sub> e/MJ <sub>FAME</sub> ]	Cost [€/MJ <sub>FAME</sub> ]
Natural gas	67.59	0.009

<sup>a</sup> supply of fuel; without burning

### System boundaries for GHG calculation



# Summarizing most important results for each improvement option

compared to fossil fuel reference (83.3 g CO<sub>2</sub>-eq/MJ<sub>FAME</sub>):

Change in GHG emissions	[g CO <sub>2</sub> -eq/MJ <sub>FAME</sub> ]	minus 1.4-2.3
Change in costs	[€/t <sub>FAME</sub> ]	plus 0 - 10
GHG mitigation costs	[€/t CO <sub>2</sub> -eq]	0 - 140
GHG savings compared to fossil reference	[%]	87 - 89%

### SWOT analysis

#### STRENGTHS

- Use of electricity and heat from renewable sources
- CHP with distilled glycerol and co-incineration of biodiesel distillation residue in a steam boiler
- Easy process adaption only in energy supply
- Special fuel burners for biodiesel distillation residue (BHA) are available and field-tested

#### WEAKNESSES

- CHP with distilled glycerol and co-incineration of biodiesel distillation residue in a steam boiler
  - CHP (adapted diesel engine) technology is available, however not field-tested in industry
  - High glycerol purity needed (10 ppm salts), which implies additional costs and energy demand for pharma/glycerol distillation
- Co-incineration of biodiesel distillation residue in steam boiler
  - Based on biodiesel feedstock only partial combustion of BHA possible

#### THREATS

- CHP with distilled glycerol and co-incineration of biodiesel distillation residue in a steam boiler
  - poor economics (glycerin distillation)
- AF and UCO still accountable to advanced biofuel share

distillation residue)  
Co-incineration of biodiesel distillation residue in steam boiler

- Usage of by product (biodiesel distillation residue)

### Conclusions

CHP with distilled glycerol and co-incineration of biodiesel distillation residue in steam boiler

- Commercial solution ("off-the-shelf")
- Additional equipment for glycerol distillation necessary, which causes additional costs and energy demand
- Direct contribution of by product glycerol

Co-incineration of biodiesel distillation residue in steam boiler

- Easy implementation
- Limited GHG reduction potential due to small contribution of energy and heat demand

# Recommendations for future development of the RED GHG-calculation methodology

19

1. **Global warming potential** of  $N_2O$  and  $CH_4$ : actual  $CO_2$ -eq factors
2. Application of **energy allocation**:
  - ✓ Use of by-products for biorefineries excluded from analyses: e.g. biochemicals, bioplastic
  - ✓ straw, crude glycerin → all used co-products
  - ✓ Also apply to:  $e_{sca}$ ,  $e_{ccs}$ ,  $e_{ccr}$
3. GHG emissions of **Best Available Technology**: BAT emission factors in RED;
4. Actual GHG value of **fossil reference**:
  - ✓  $> 83.4$  g  $CO_2$ -eq/MJ
  - ✓ actual calculation&documentation;
5. Emissions from the **fuel in use**:
  - ✓  $e_u \neq 0$  include  $CH_4$  and  $N_2O$ -emissions from vehicle
  - ✓  $CO_2$  from fossil methanol in FAME
6. Use of **biomethane** from the natural gas grid: accordingly to renewable electricity
7. Manufacture of **machinery and equipment**: to be included to avoid “underestimation” (mainly electric and  $H_2$ -vehicles)

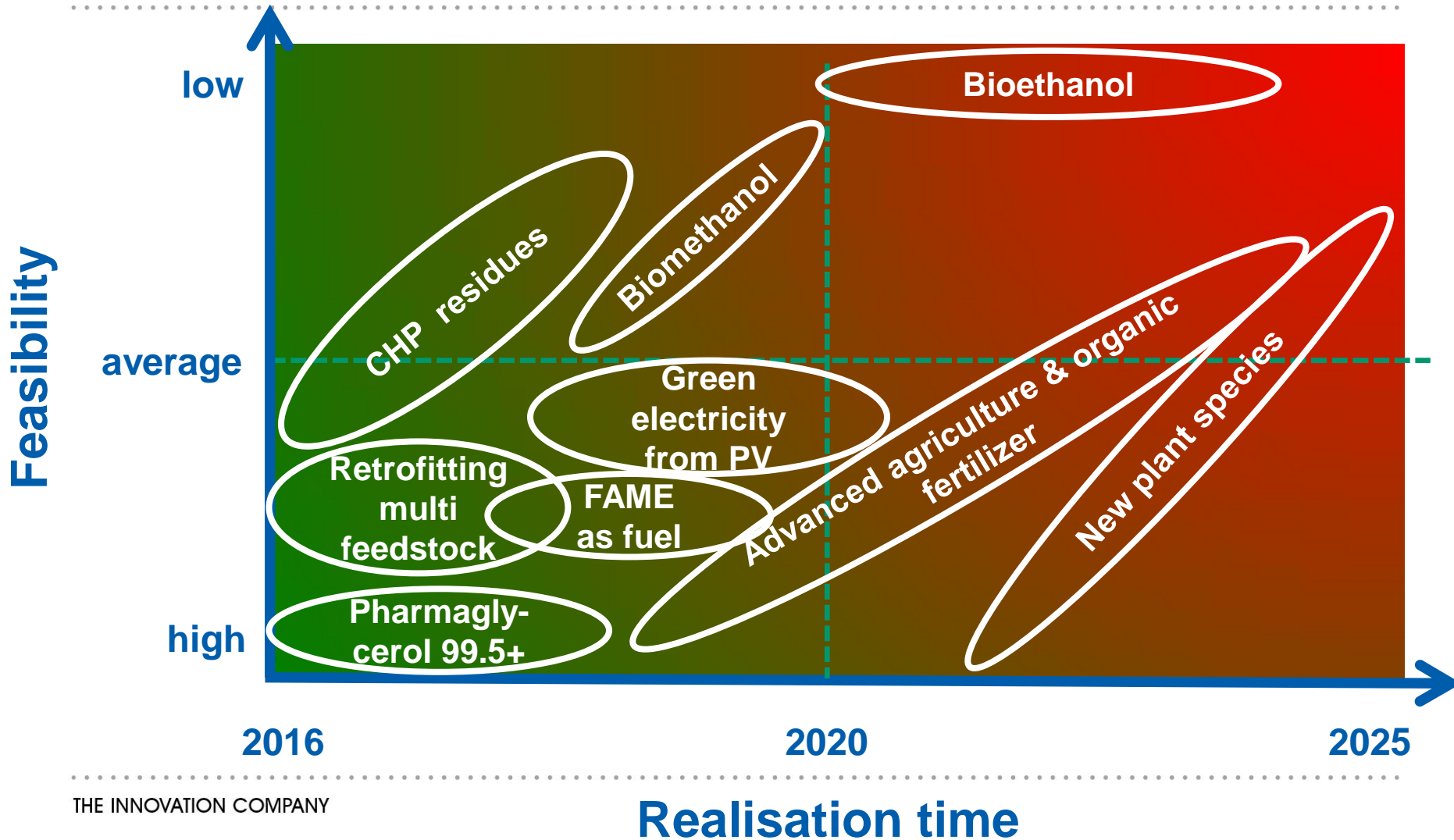
# Summary of Results

---

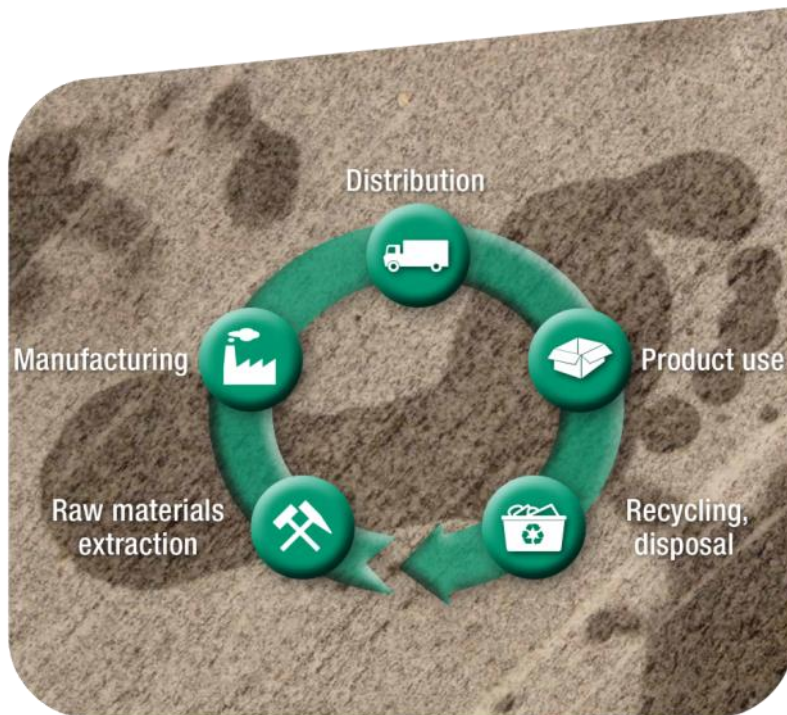
- **Significant GHG reduction** in processing possible if **Best Available Technology (BAT)** is used in processing steps compared to data in BioGrace
  - **GHG reduction options**
    - **agriculture**: relatively **high** reduction potential
    - **processing**: relatively **low** reduction potential
  - **DOWNLOAD:**  
<https://ec.europa.eu/energy/en/studies>
-

# Overall assessment of the improvement options based on feasibility and realisation time

21



# Your Contact



**JOANNEUM RESEARCH  
Forschungsgesellschaft mbH  
LIFE – Centre for Climate,  
Energy and Society**

**DI Dr. Gerfried Jungmeier**

Elisabethstraße 18, 8010 Graz

+43 316 876-1313

gerfried.jungmeier@joanneum.at

[www.joanneum.at](http://www.joanneum.at)