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Closing the Carbon Cycle
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Environmental Evaluation of the Production of Platform Chemicals from different Feedstock

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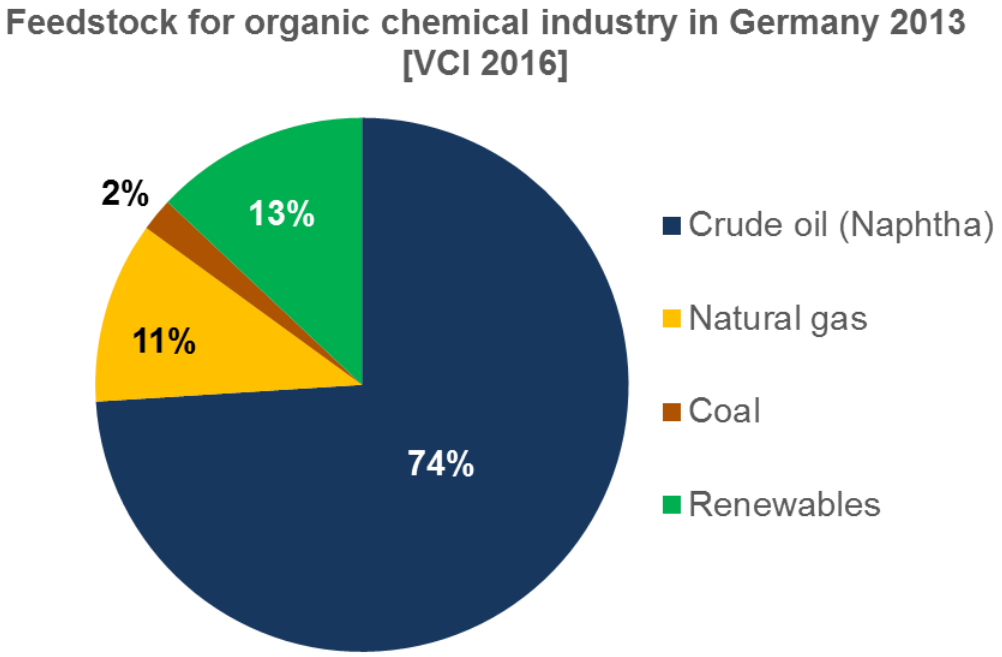
Why look into feedstock alternatives?

- **Limitation** of fossil resources
- Decrease the **ecological effects** of chemicals production
- **Public pressure** for integration of more renewable and secondary resources instead of fossils
- Decrease **import dependency** from countries with uncertain political conditions
- Availability of **renewable energy sources**



BUT: Do alternative Feedstocks really lead to greener production?

Ecological Impact Categories

Global Warming Potential

Relevant Substances:

CO_2, CH_4
NO_X, CFCs

Consequences:

Global warming,
Climate change,
Natural desasters

Fossil Resource Depletion

Relevant Resources:

Crude oil, Hard coal, Lignite,
Natural gas, Peat, Uranium

Consequences:

Diminishing of limited resources

Photochem. Ozone Creation Potential

Relevant Substances:

VOC, NO_X, SO_2
CO

Consequences:

Smog formation,
Effect on human health

Acidification Potential

Relevant Substances:

NO_X, SO_2, NH_3, H_2S
HCN, HCL, HF

Consequences:

Acid rain,
Soil acidification

Eutrophication Potential

Relevant Substances:

Nitrate, Phosphate
NH_3, NO_X

Consequences:

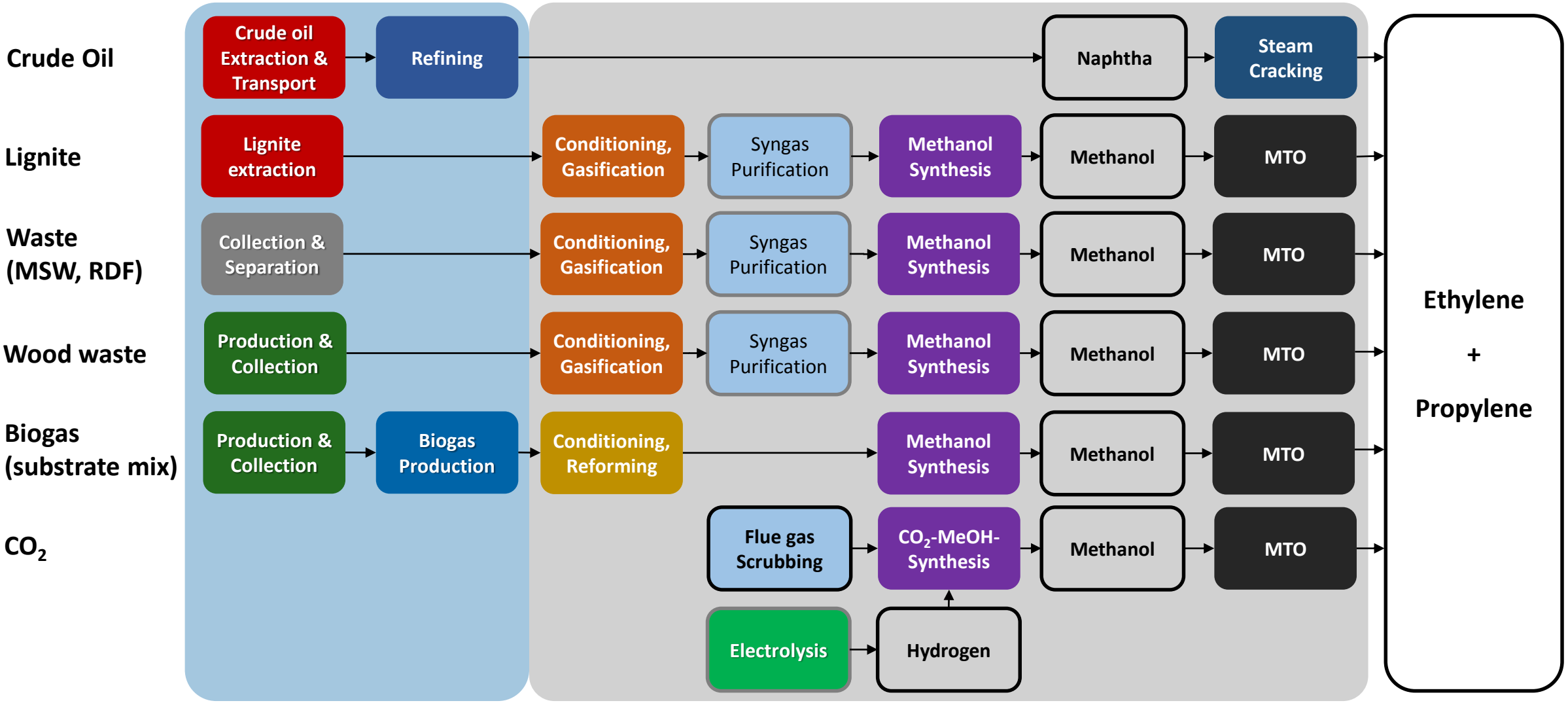
Algae formation,
Oxygen deficiency,
decreasing biodiversity

Carbon Potentials for chemical industry

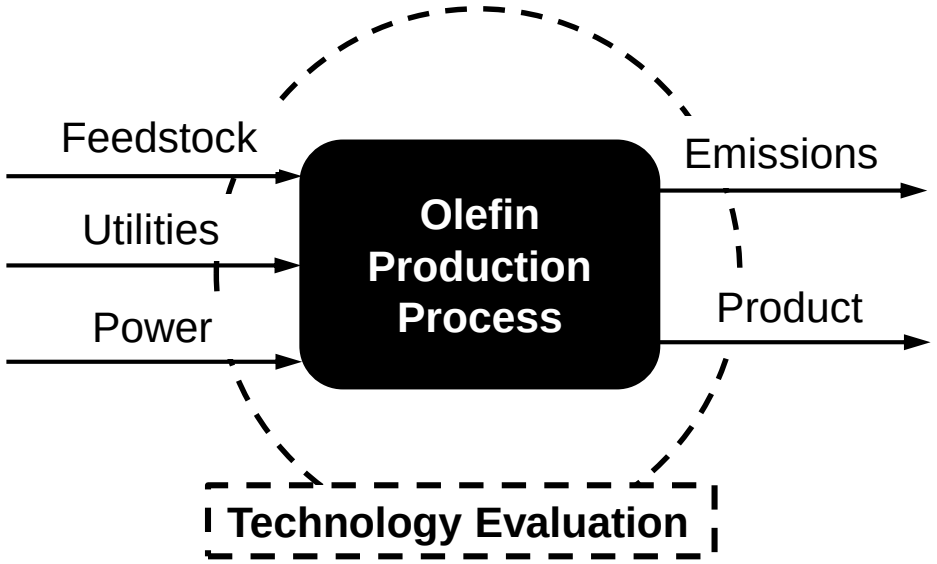
Group	Feedstock		total amount	energy/fuel application	Unit	Carbon potential [Mio t]
Fossil Resources	Crude Oil	domestic	2,4		Mio t	2,0
		imported	83,2		Mio t	70,7
	Natural gas	domestic	6,6		Mrd m3	3,9
		Imported	73,0		Mio t	52,5
	Bituminous coal	domestic	3,8		Mio t	2,5
		imported	43,8		Mio t	28,9
	Lignite		171,6	156,8	Mio t	51,5
	Petcoke		1,9		Mio t	1,8
	Refinery off-gas		3,9		Mio t	2,8
	LPG		2,7		Mio t	2,2
Biomass	Short rotation crops		0,1	0,1	Mio t	0,1
	Biogas		19,5	19,5	Mrd m3	7,4
	Wheat		45,3	2,0	Mio t	0,9
	Rape		4,6	3,1	Mio t	1,4
Biowaste	Straw		8,0		Mio t	3,5
	Forestry waste		0,7	0,7	Mio t	0,3
	Wood waste		6,5	6,5	Mio t	2,9
Waste	Municipal solid waste		14,1	12,2	Mio t	3,5
	Waste based fuel		7,8	5,8	Mio t	3,1
	Sewage Sludge		2,9	1,8	Mio t	1,2
	Plastic waste		1,3	0,7	Mio t	0,9
CO_2	Power generation		311,0		Mio t	84,0
	Industry		61,0		Mio t	16,5

(Estimation from various public sources – preliminary results)

LCA Case Study: Ethylene & Propylene Production (10 Mio t per year in Germany)



Methodology



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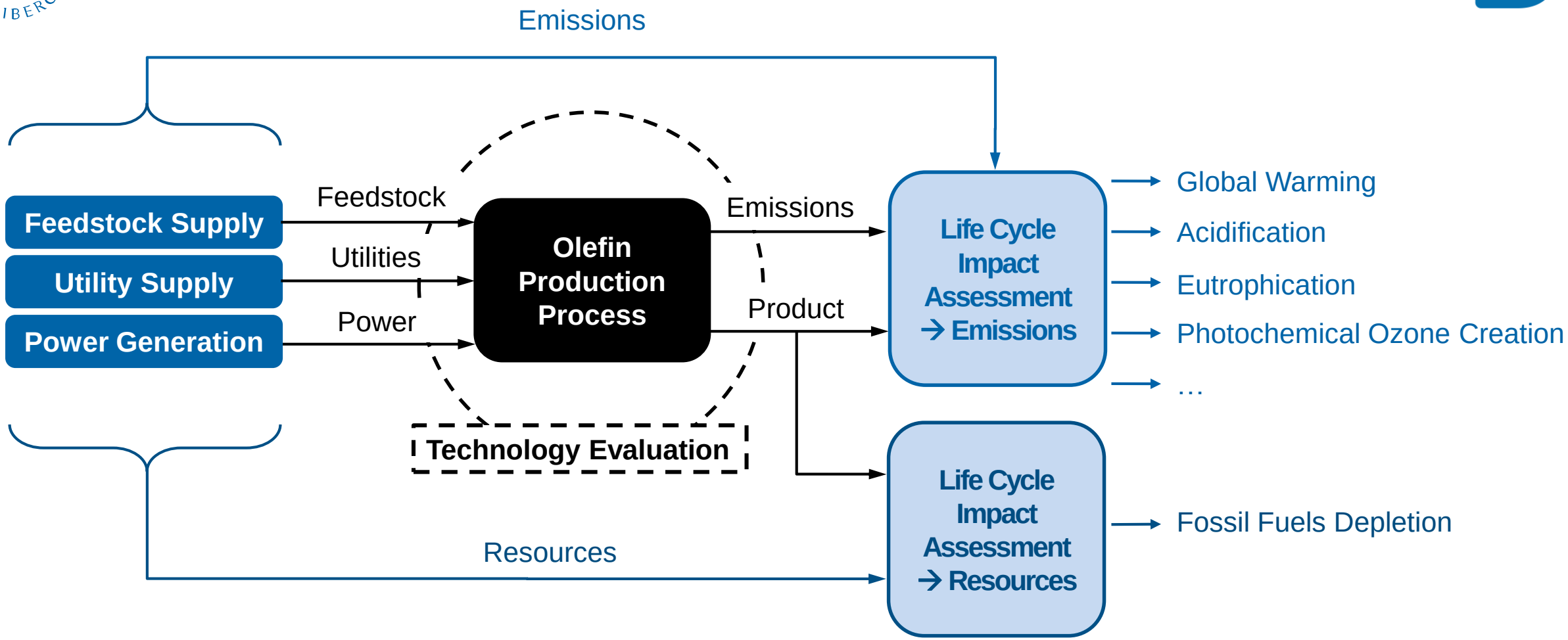
Technology Evaluation

Feedstock		Mixed Waste	Lignite	Wood	Biogas	CO_2-Syngas	Naphtha
		17,5 MJ/kg_{wf}	23,7 MJ/kg_{wf}	19,8 MJ/kg_{wf}	62 Vol-% CH_4 31 Vol-% CO_2	74 Vol-% H_2 25 Vol-% CO_2	44,4 MJ/kg_{wf}
Conversion Technology		Gasification MTO	Gasification MTO	Gasification MTO	Steam Reforming MTO	CO_2-MTO	Steam Cracking
Feed demand	[kg_{waf} / kg olefins]	7,4	4,5	6,4	4,9	5,1	1,7
Cold gas efficiency	-	65%	76%	72%	-	-	-
Carbon product recovery	-	21%	28%	25%	39%	71%	58%
spec. CO_2 production	[kg (CO_2) / kg olefins]	10,7	7,3	8,8	4,7	-3,4	1,3
Process power demand	[MJ_{el} / kg olefins]	6,3	4,5	6,6	0,5	129,3	-0,9

Methodology



GaBi Database Content

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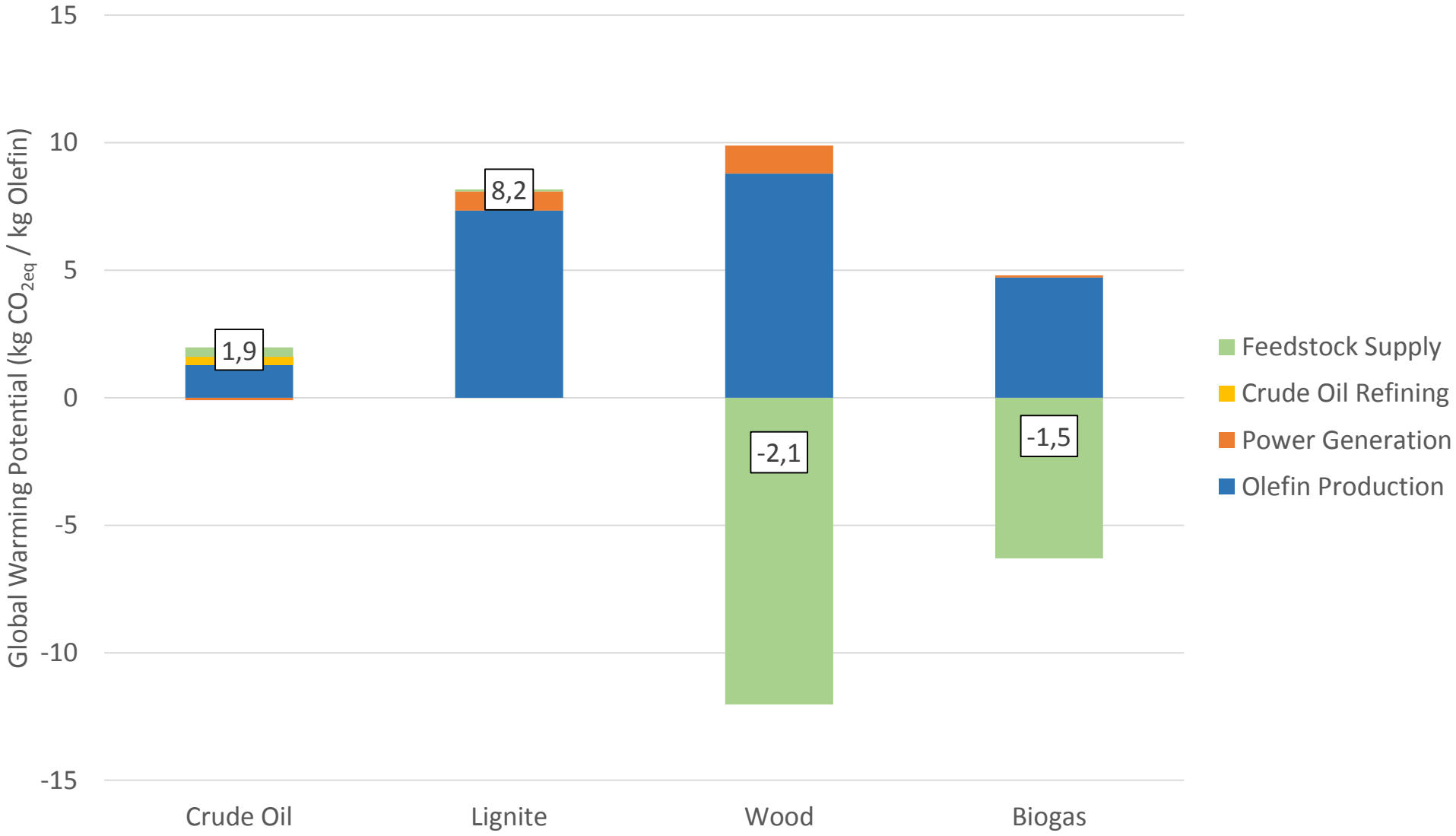
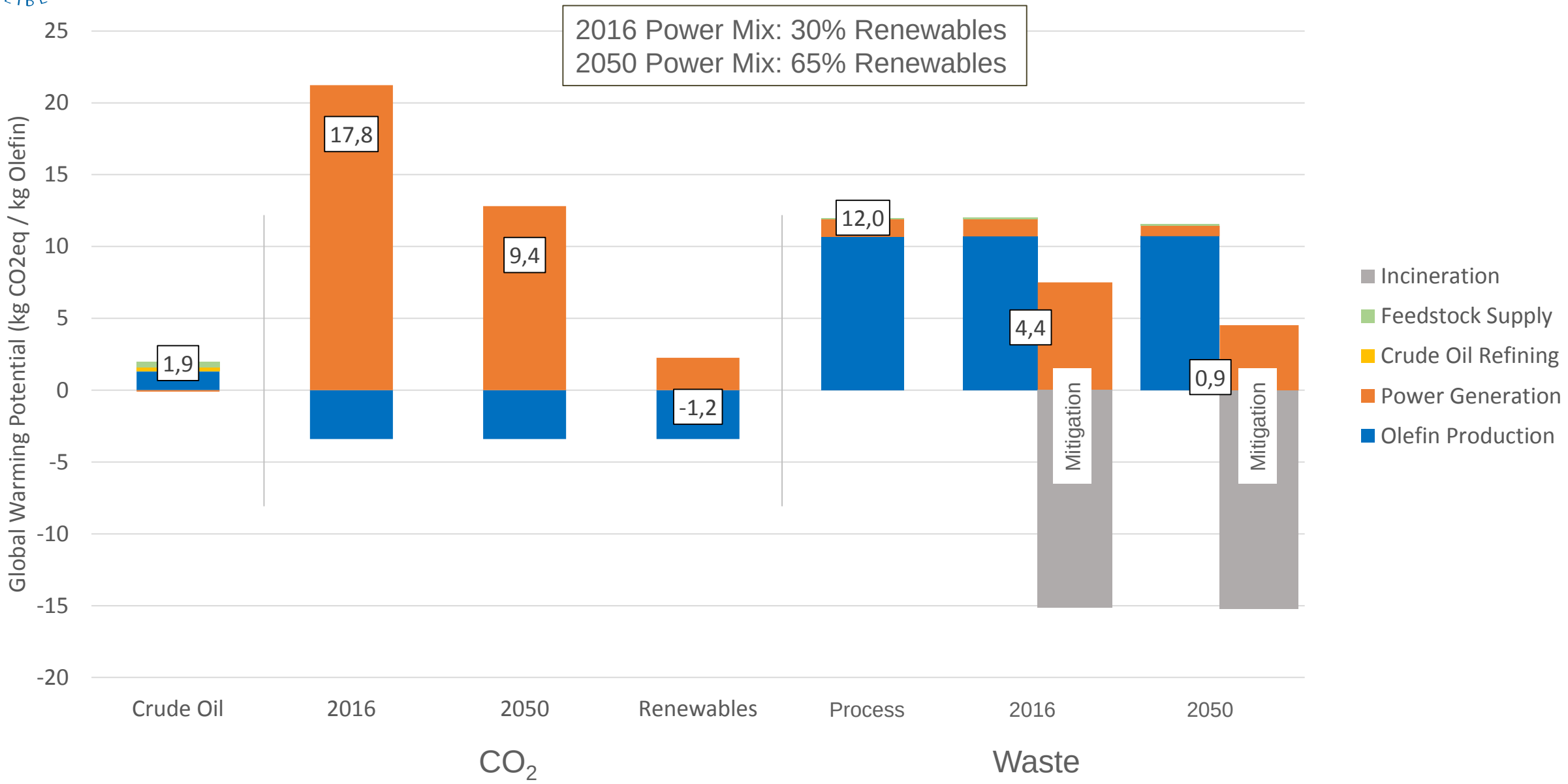
GaBi Product Sustainability Performance

Life Cycle Impact Assessment – Global Warming Potential

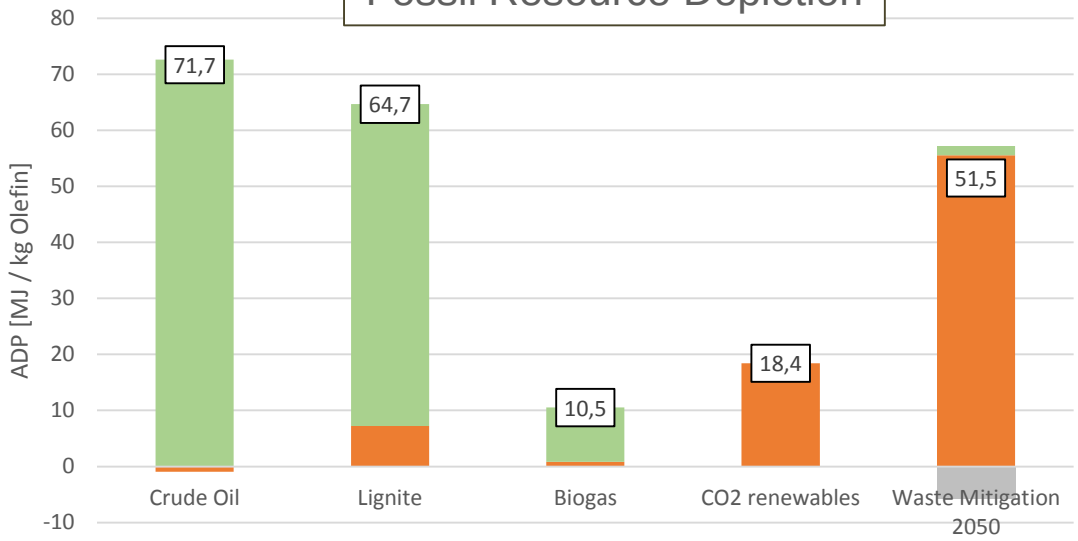


Life Cycle Impact Assessment – Global Warming Potential

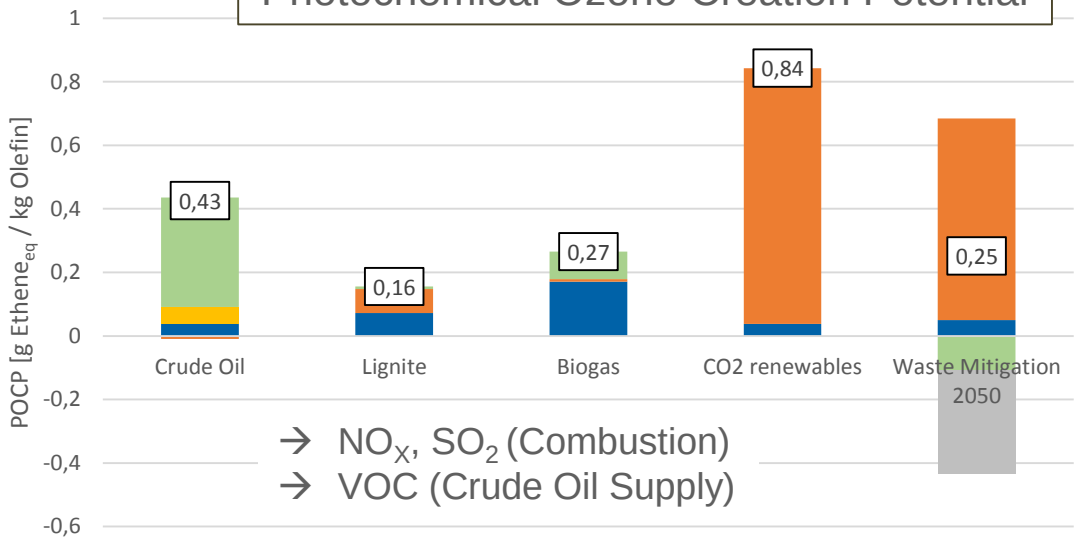


Life Cycle Impact Assessment

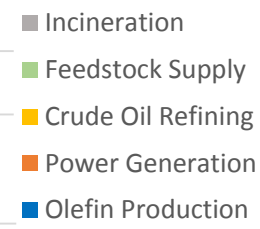
Fossil Resource Depletion



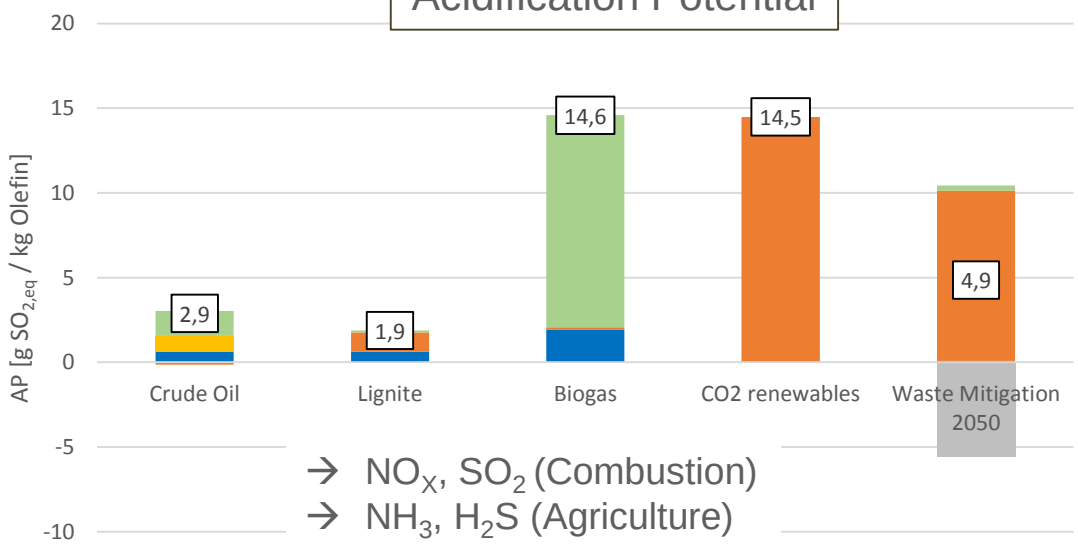
Photochemical Ozone Creation Potential



→ NO_X, SO_2 (Combustion)
→ VOC (Crude Oil Supply)

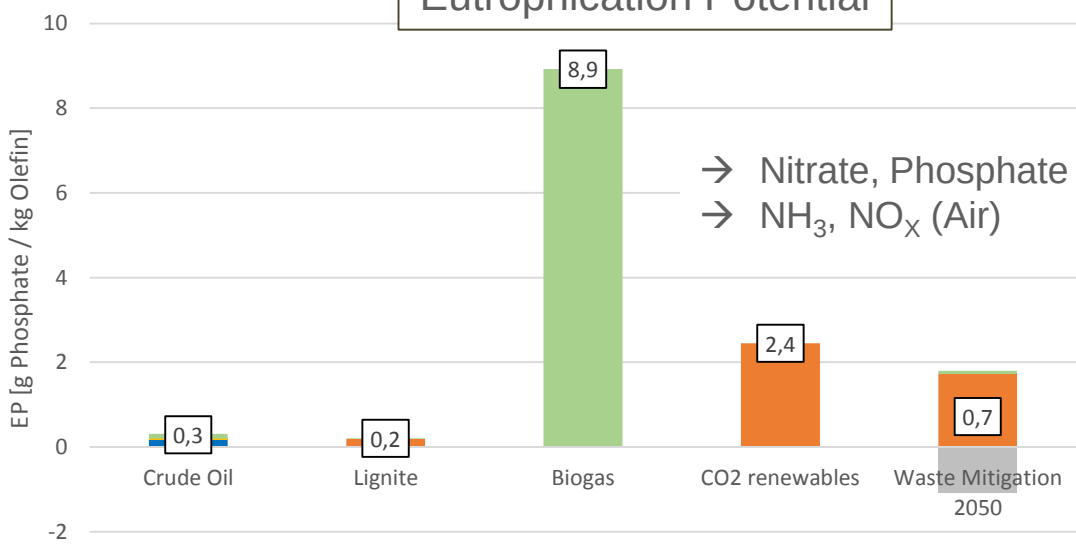


Acidification Potential



→ NO_X, SO_2 (Combustion)
→ NH_3, H_2S (Agriculture)

Eutrophication Potential



→ Nitrate, Phosphate (Water)
→ NH_3, NO_X (Air)

Ecological Impact on Germany

		Germany total[1,2]	German chemical industry total[1,3]	Olefins Production from Crude Oil		Olefins Production from Biogas	
				Germany total	Chem. industry	Germany total	Chem. industry
Global Warming	[kt $CO_{2,eq}$]	832	40	1,8%	38%	-1,4%	-30%
Photochemical Ozone Creation	[t $Ethene_{eq}$]	289	7	1,2%	38%	0,7%	23%
Acidification	[kt $SO_{2,eq}$]	2230	109	1,0%	21%	5,2%	107%
Eutrophication	[t $Phosphate_{eq}$]	694	16	0,3%	15%	10,3%	460%
Fossil Resource Depletion	[PJ]	9980	1070	5,7%	54%	0,8%	8%

[1] German Environment Agency - National Trend Tables for the German Atmospheric Emission Reporting 1990-2015
[2] AGEB 2015 – Energiebilanz der Bundesrepublik Deutschland
[3] VCi 2018 – Rohstoffbasis der chemischen Industrie

Summary

What can we take from this?

- **Significant carbon potential** of alternative feedstocks for the chemical industry available
- Regarding **efficiency**, crude oil based chemical production is a strong benchmark
- Regarding **environmental impacts**, alternative feedstocks can improve chemical production significantly (even leading to negative effective emissions)
- But, **diverse environmental effects** have to be taken into account in the evaluation (especially concerning applications with high energy demand or agricultural feedstocks)

Thank You & Glück Auf!

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