

# **CO<sub>2</sub> capture behind the waste incineration plants – status quo and outlook**

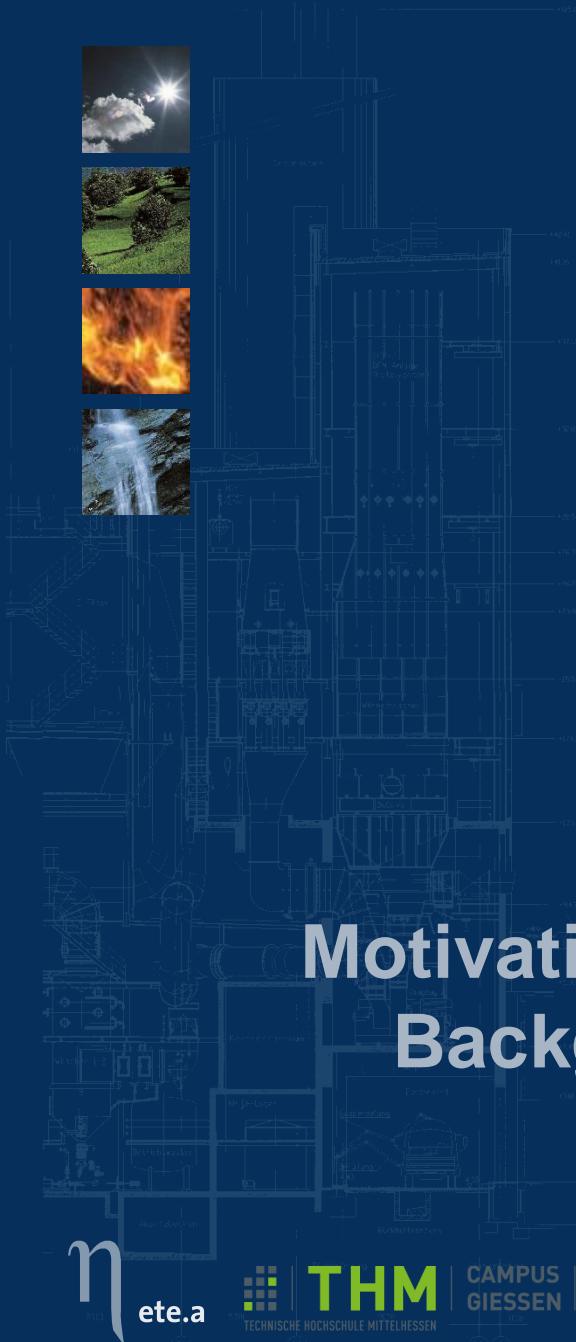
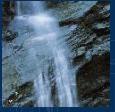
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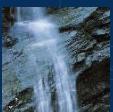
# 14<sup>th</sup> Specialized International Conference Waste to Energy 2023 28. and 29. March | Prague (Cz)





# Motivation and Background

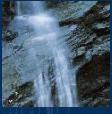




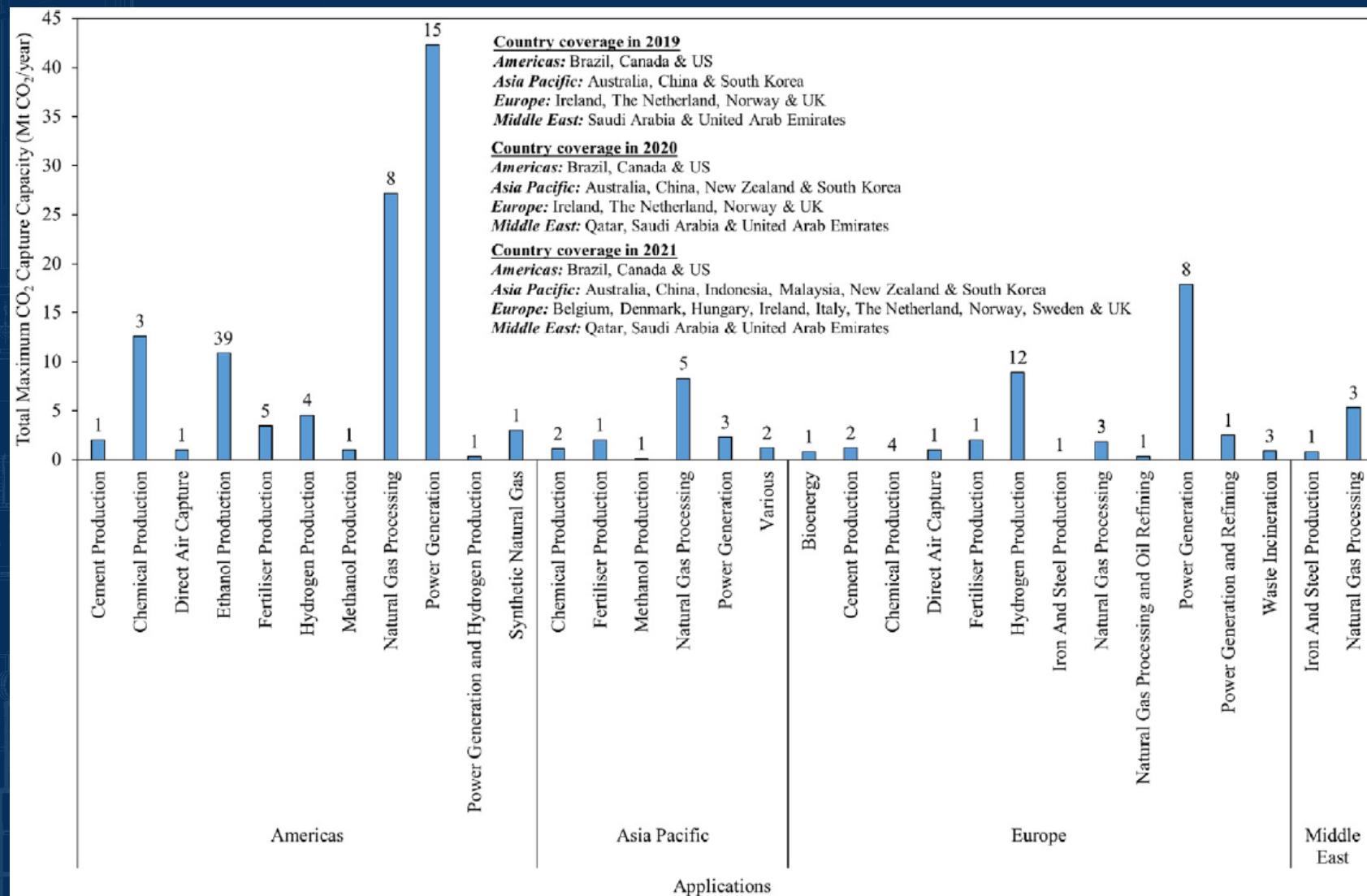
# Motivation for CO<sub>2</sub>-Capture

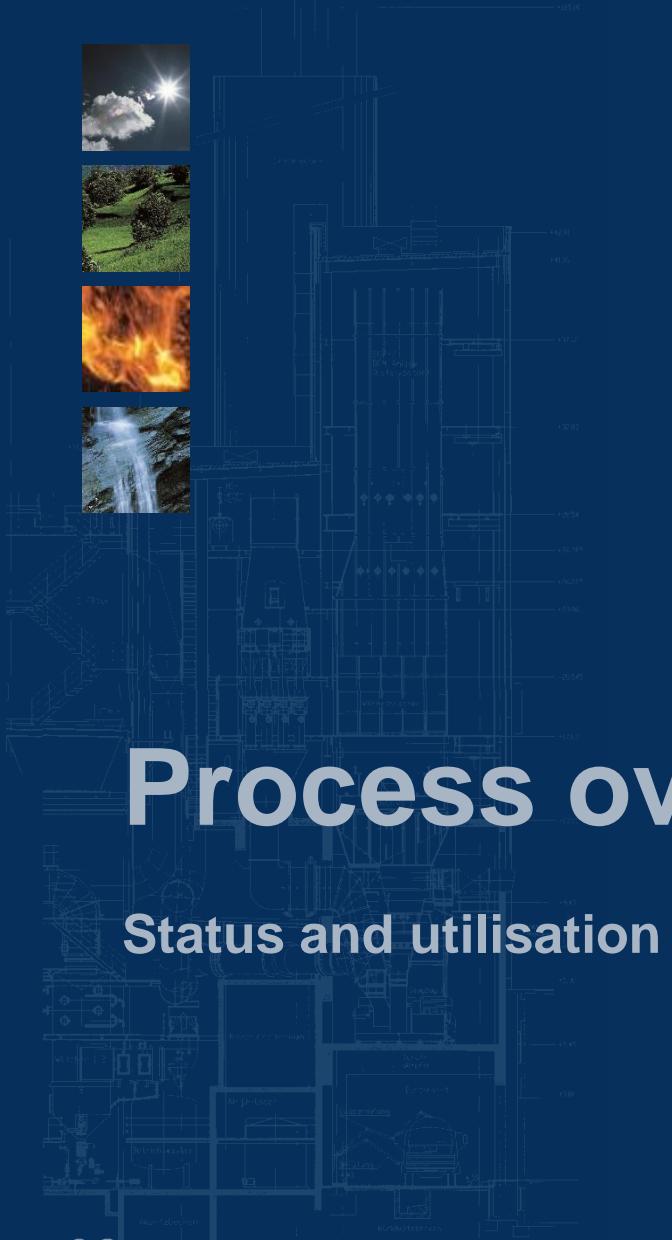
- Challenge – to counteract the effects of the climate change
- *The Paris Climate Agreement and the Green Deal form the legal framework*
- The goal for Germany – CO<sub>2</sub>-neutrality by 2045
- Inclusion of waste incineration in the Fuel Emissions Trading Act (BEHG) from 01.01.2024

Method - the reduction of the greenhouse gas emissions



# Total maximum CO<sub>2</sub> capture capacity of commercial CCS/CCUS projects worldwide





# Process overview

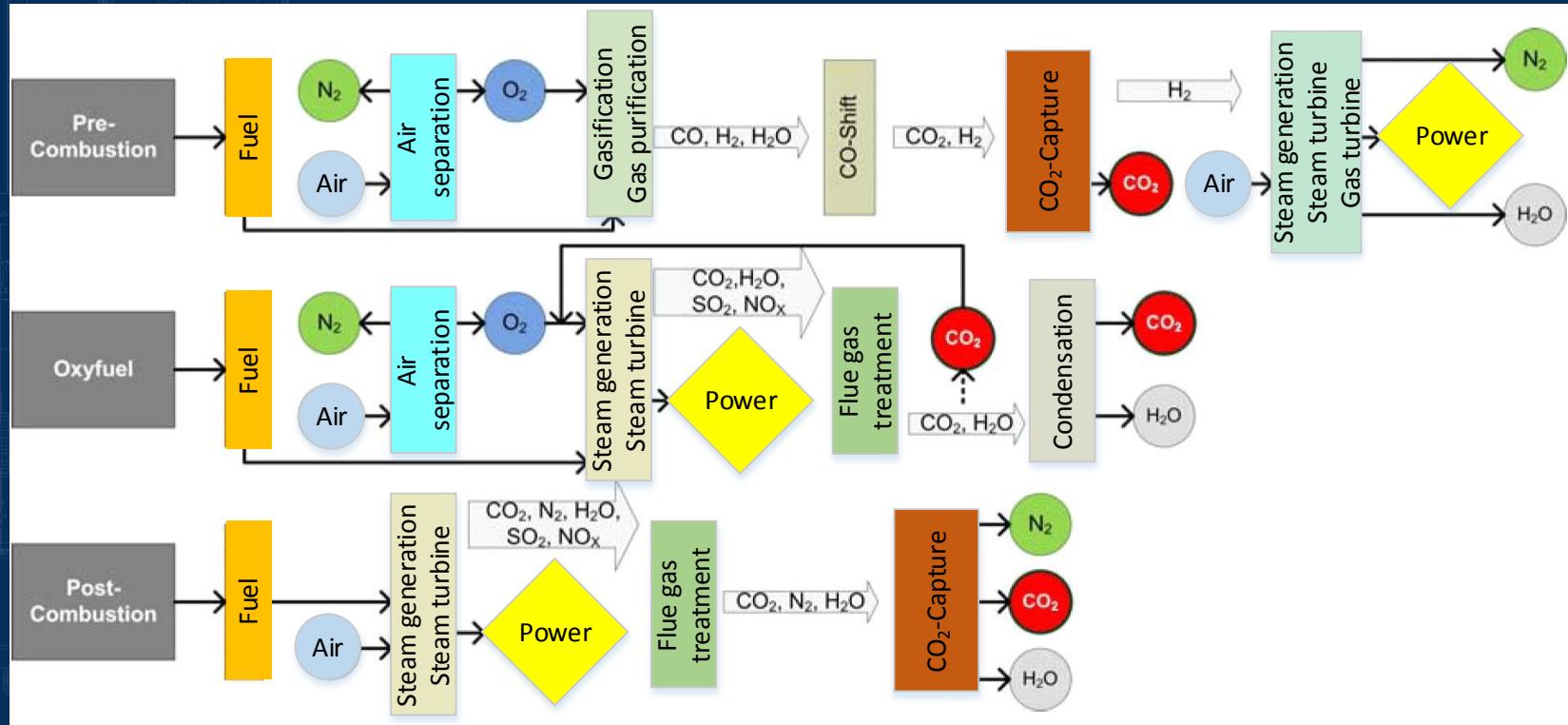
## Status and utilisation behind the waste incineration plants



Source: Baker Hughes Company,2020



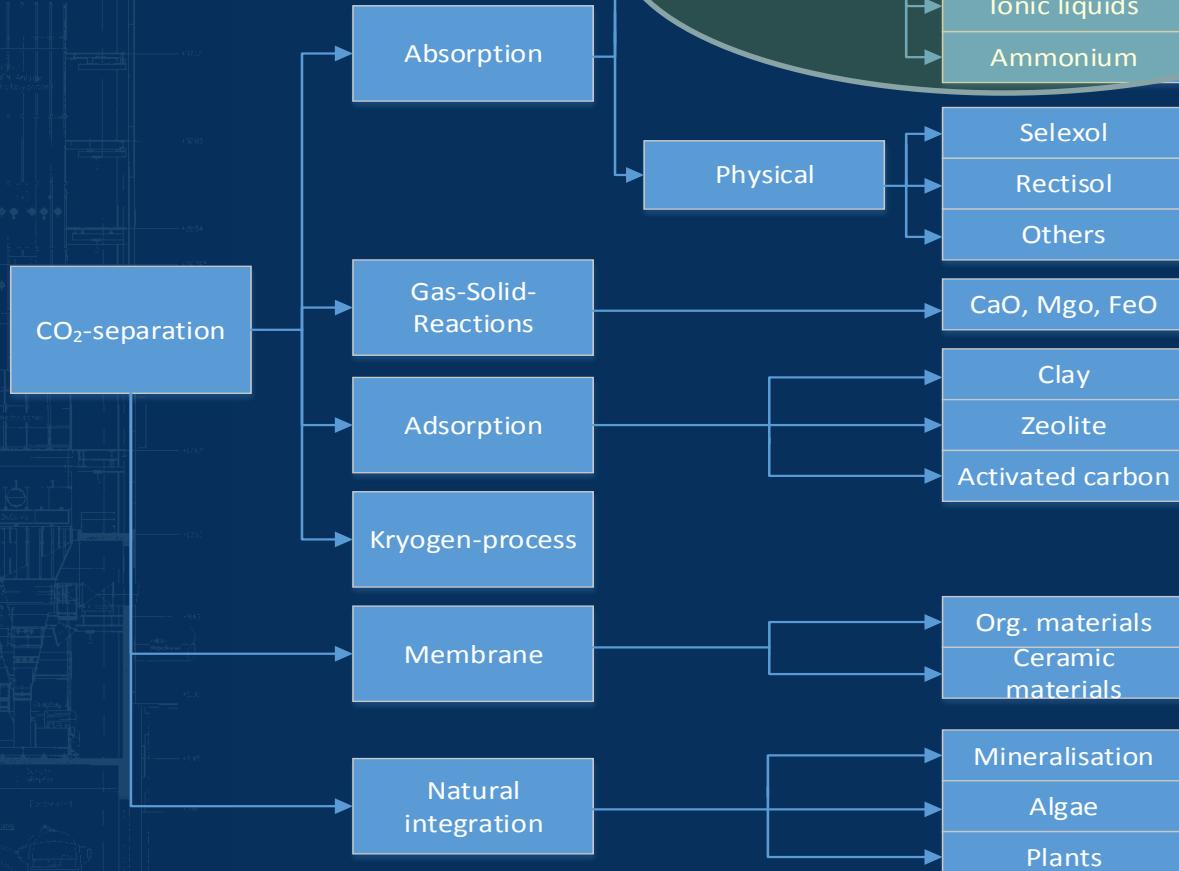
# Process path



Source: Maun, A.: Optimierung von Verfahren zur Kohlenstoffdioxid-Absorption aus Kraftwerksrauchgasen mithilfe alkalischer Carbonatlösungen. Dissertation an der Universität Duisburg-Essen, 2013



# Process overview

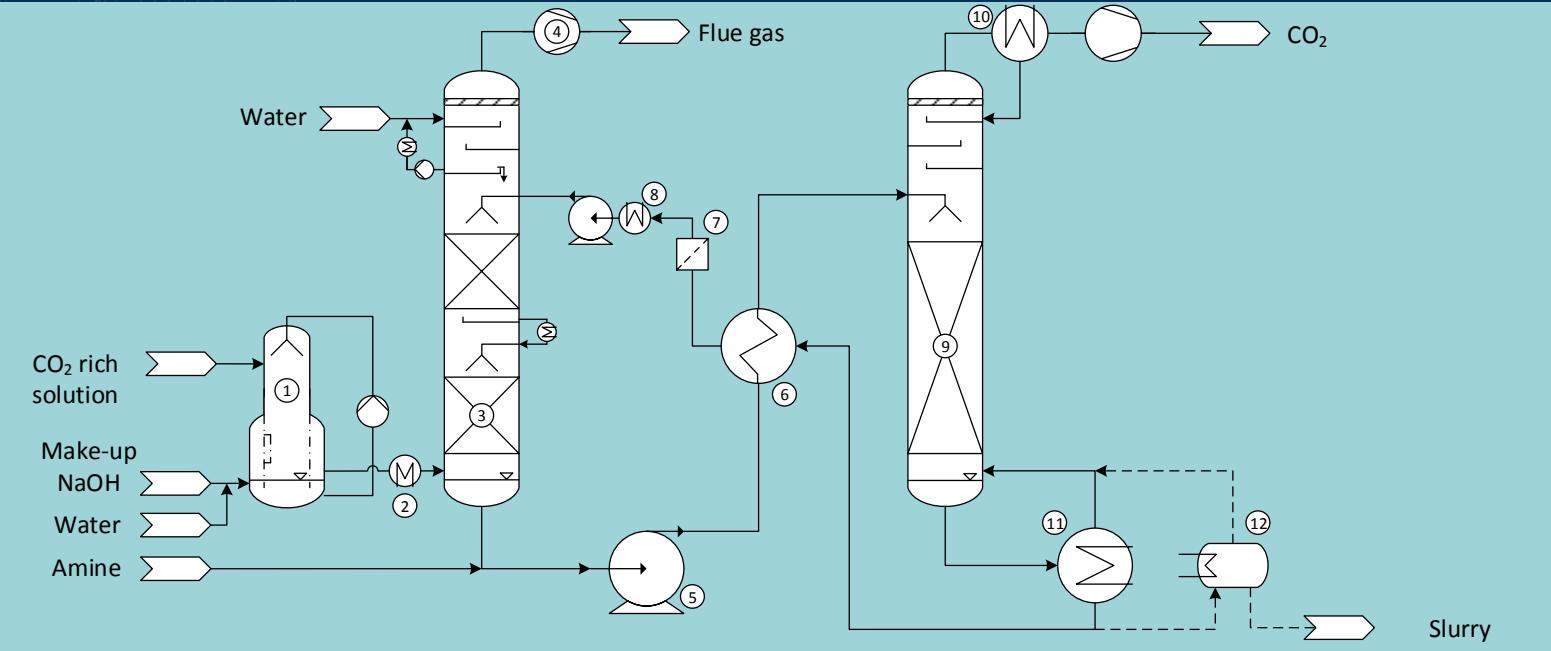


Source: Thomeczek, M.; Fischedick, M.; Görner, K. (Hg.); CO<sub>2</sub>: Abtrennung, Speicherung, Nutzung. Ganzheitliche Bewertung im Bereich von Energiewirtschaft und Industrie. Berlin: Springer-Verlag; 2015



# Process overview

Amine-Scrubber does have the highest TRL (Technology readiness level) of 9



Primary Amine



Secondary Amine

# Process overview

## Different types of Amines used in Amine-Scrubber

Types of Amines	Primary	Secondary	Tertiary	Sterically hindered
Example	MEA Monoethanolamine	DEA Diethanolamine	TEA Triethanolamine	HALS hindered amine light stabilizers
Chemical formula	$\text{H}_2\text{N}-\text{R}_1$ <i>classical Amine</i>	$\text{R}_1-\text{N}-\text{R}_2$ I H	$\text{R}_1-\text{N}-\text{R}_2$ I $\text{R}_3$	$\begin{array}{c} \text{R}^1 \text{ R}^2 \\ \diagdown \quad \diagup \\ \text{N} \end{array}$ <i>energetically optimised Amine</i>
Characteristics				
CO <sub>2</sub> -load / capacity	low	high / moderate	high	high
Enthalpy of reaction	high	moderate	low	moderate / low
Reaction rate	very high	moderate	low	moderate
Enthalpie of evaporation	high	moderate	low	low
Decomposition	high	moderate	low	moderate / low
Corrosivity	high	moderate	low	moderate / low

# Process overview

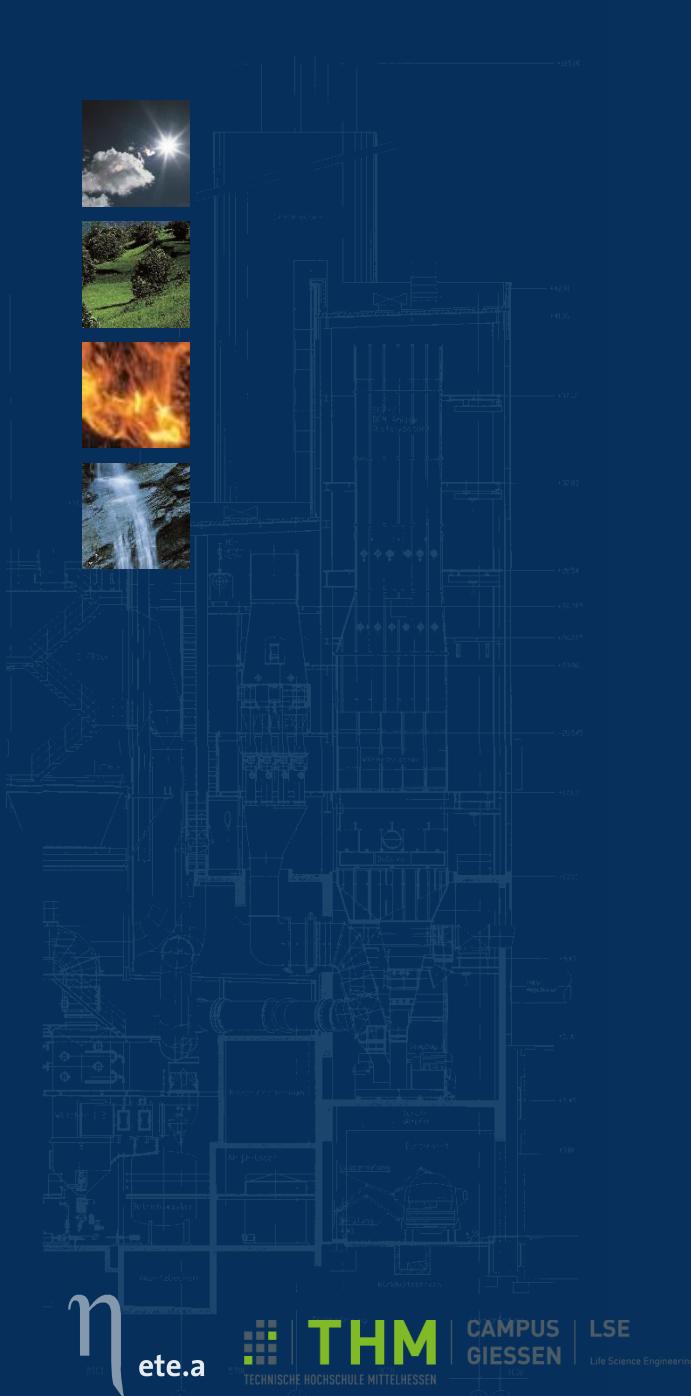
## Characteristic data of technical Alkanolamine-Scrubbers

Process	MEA	DEA	Sulfinol	D/M/X	MDEA	aMDEA
Composition of the washing liquid	MEA (< 30 Ma.-%) in H <sub>2</sub> O	DEA (< 30 Ma.-%) in H <sub>2</sub> O	Sulfolan (40 Ma.-%) + (MDEA)/DIPA (40 Ma.-%) + Water		MDEA <sub>aq</sub> (< 55 Ma.-%)	MDEA (< 55 Ma.-%); Piperazin (< 10 Ma.-%) in H <sub>2</sub> O
Manufacturer	DOW (free)	SNEA	Shell	e.g. BASF (OASE)	e.g. BASF (OASE)	
Operating pressure $p_{\text{Absorber}}; p_{\text{Desorber}}$ [bar a]	> 1; ca. 5	> 1; ca. 4	> 20 bar; ca. 4	> 1; ca. 2	> 1; ca. 2	
Operating temperature T <sub>Absorber</sub> ; T <sub>Desorber</sub> [°C]	ca. 30; 160	> 30; 140	35 ... 140	40...60; 120	> 35; 120	
Primary energy demand e <sub>prim</sub> [kWh/m <sup>3</sup> CO <sub>2</sub> (NTP)]	1,6 – 3,0	1,4 – 1,9	1,1 – 1,9		1,1 – 1,8	

### Decomposition of MEA [Jenkins 2002, Amine Best Practise Group 2007]

Trigger	Product of the decomposition	Characteristics
O <sub>2</sub>	Carboxylic acid (acetic acid, formic acid)	intermediate product
SO <sub>x</sub> , NO <sub>2</sub> , Na, Cl, ...	HSS: formate, acetate, sulfate	corrosive, irreversible
Acetic acid	Ethylenediaminetetraacetic acid (C <sub>10</sub> H <sub>16</sub> N <sub>2</sub> O <sub>8</sub> )	complexing agent, „Ferrous-pump“
CO <sub>2</sub> HEED	Hydroxyethylenthylendiamin (HEED) Ethylenediamin (C <sub>2</sub> H <sub>8</sub> N <sub>2</sub> )	corrosive, irreversible polymer, irreversible

The detergent losses in the MEA-Scrubber are appr. between 1,4 and 2,4 kg/t<sub>CO<sub>2</sub></sub> separated



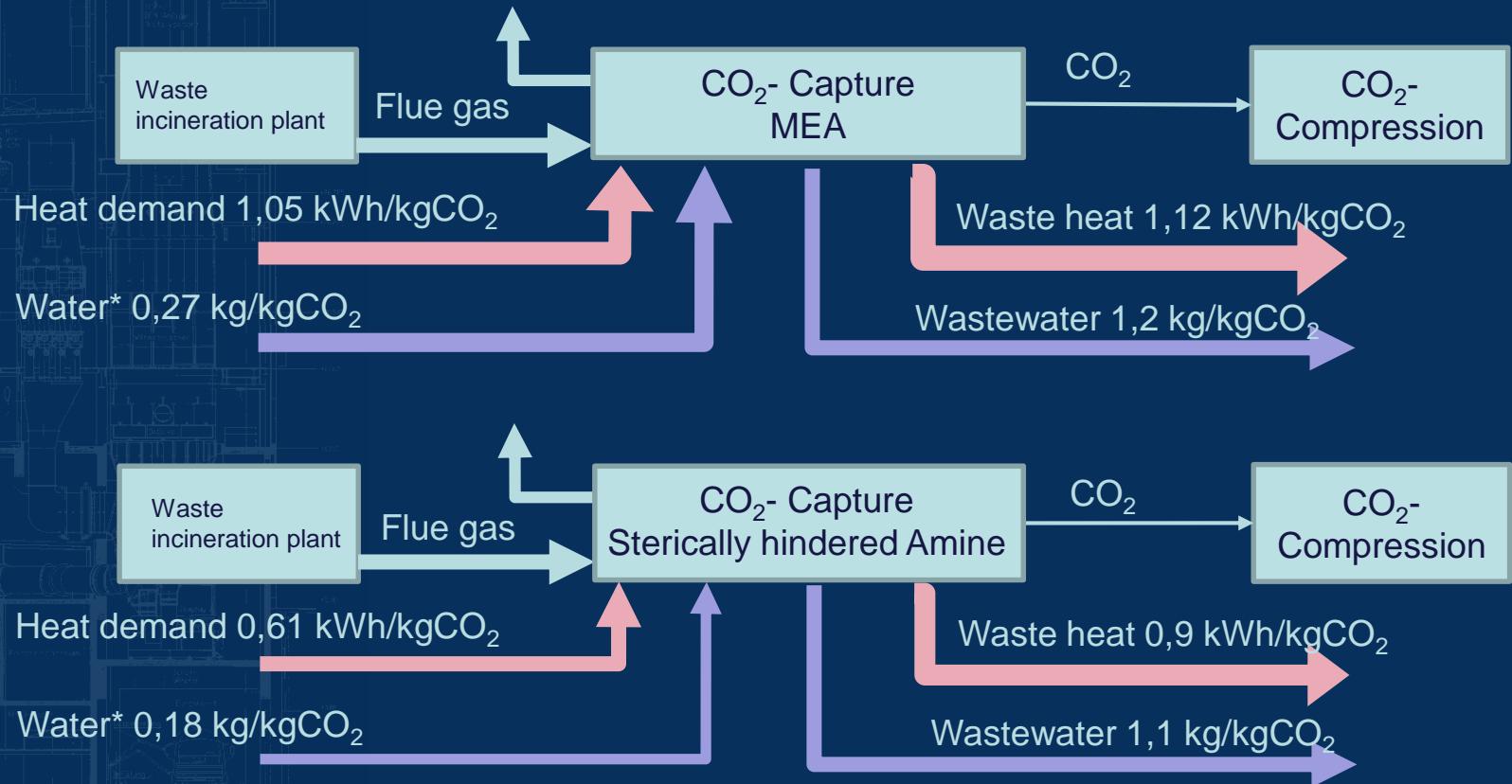
# Balancing Energy demand and CCU



# Process balance

## Comparison of MEA and sterically hindered Amine

Differences particularly in the water- and heat balance:



\* Specification without the needed cooling water

# Retrofits and energy demand

Volume flow, wet =  $100.000 \text{ m}^3/\text{h}_{\text{SPT}}$

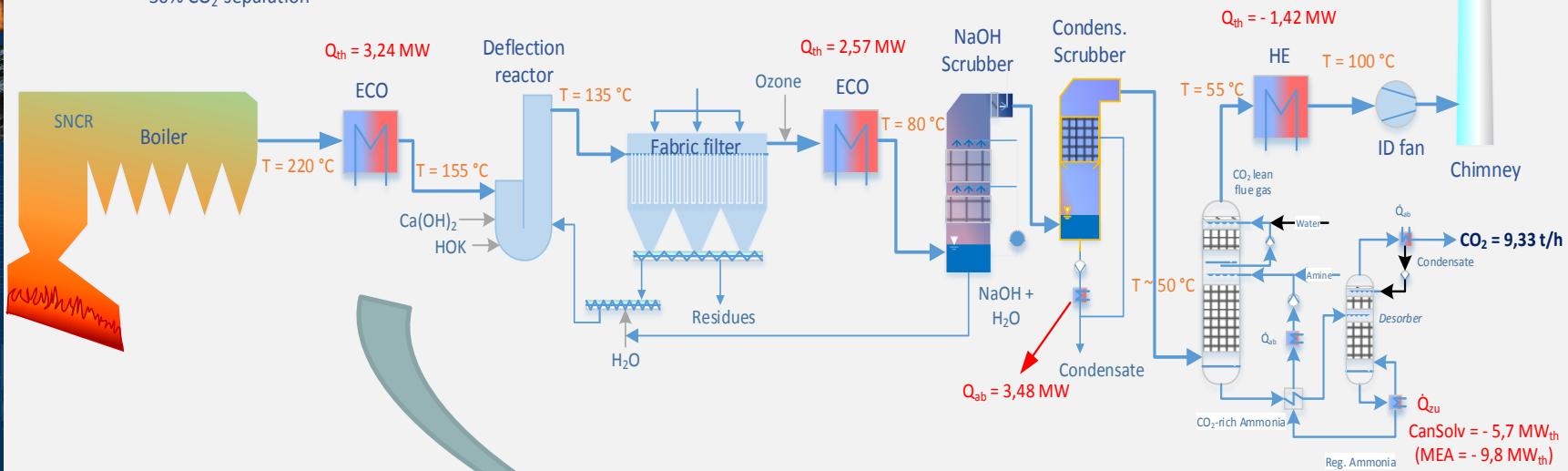
Mass flow =  $127.000 \text{ kg/h}$

$M = 14 \text{ Vol.-\%}$

$C_{\text{CO}_2} = 9 \text{ Vol.-\%}$

Mass flow  $\text{CO}_2 = 0,147 \text{ kg}_{\text{CO}_2}/\text{kg}_{\text{FG}}$

50%  $\text{CO}_2$ -separation





# Balancing - CCU

For the balancing the following parameters was considered for wte plant

Parameter	Unit	Value
<b>Waste amount</b>	t/h	17,4
<b>Lower calorific value</b>	MJ/t	10.800
<b>Biogenic share</b>	Ma.-%	50
<b>Carbon content</b>	Ma.-%	25
<b>Volume flow (dry)</b>	m <sup>3</sup> /h (i.N., tr.)	82.357
<b>Humidity</b>	Vol.-%	12
<b>Volume flow (wet)</b>	m <sup>3</sup> /h (i.N., f.)	93.588
<b>CO<sub>2</sub>-concentration</b>	Vol.-% (tr.)	9,9
<b>O<sub>2</sub>-concentration</b>	Vol.-% (tr)	9,1
<b>Combustion energy</b>	MWh <sub>th</sub> /h	52,2
<b>Efficiency of the steam generation</b>	%	87
<b>Efficiency of the condensing turbine</b>	%	20 - 25
<b>Electrical energy</b>	MWh <sub>el</sub> /h	9,1 - 11,4



# Balancing - CCU

The following parameters for the Amine-Scrubber were considered:

Ammonia-Scrubber	Unit	Value
CO <sub>2</sub> -separation performance	%	90
Separated CO <sub>2</sub> -mass flow	t/h	14,3
Emitted CO <sub>2</sub> -mass flow	t/h	1,6
Spec. Detergent load	m <sup>3</sup> CO <sub>2</sub> /t (i.N. tr)	50
Time of circulation	h	0,5
Needed amount of detergent	t	80,6
Losses of Amine	kg /h	5,74
Energy demand for the regeneration	MWh <sub>th</sub> /h	11,2
Auxiliary energy for pumps etc.	MWhel/h	0,014

One-step synthesis of a methanol via catalytic fixed-bed reactor



Methanol-synthesis	Unit	Value
Stoichiometrical amount of methanol produced	kg CO <sub>2</sub> /kg MeOH	1,4
Pot. Generated methanol mass flow	t MeOH/h	10,6
Heat of reaction	MWh <sub>th</sub> /h	8,2





# Balancing - CCU

## H<sub>2</sub>-Electrolysis

Methanol-synthesis	Unit	Value
H <sub>2</sub> -volume flow	m <sup>3</sup> /h (i.N., tr.)	21.759
spec. Energy demand PEM Electrolysis	MWh <sub>el</sub> / m <sup>3</sup> (i.N., tr.)	0,005
Energy demand for PEM Electrolysis	MWh <sub>el</sub> /h	104,4
Energy demand for desalination	MWh <sub>el</sub> /h	0,07
Demand of auxiliary energy	MWh <sub>el</sub> /h	15,8
<b>Total amount of the electrical energy demand</b>	<b>MWh<sub>el</sub>/h</b>	<b>120,5</b>



for 17 t/h Waste

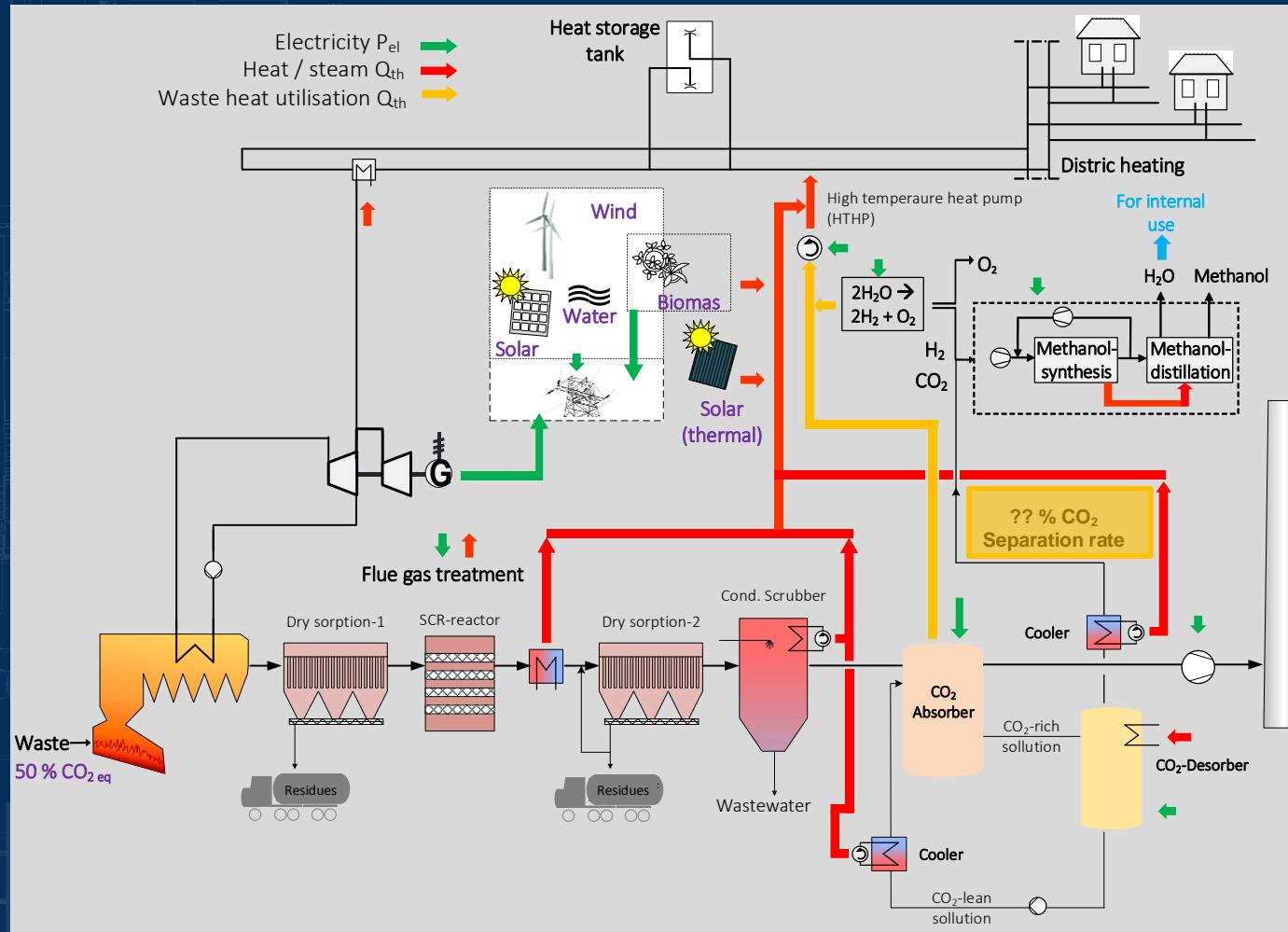




# Conclusions



# Optimised flue gas treatment in adaption to the future energy market





# Conclusion



FRANKFURTER ALLGEMEINE ZEITUNG

07. Februar 2023, Seite 18

## Dänemark erteilt Zulassung für CO<sub>2</sub>-Lagerung in Nordsee

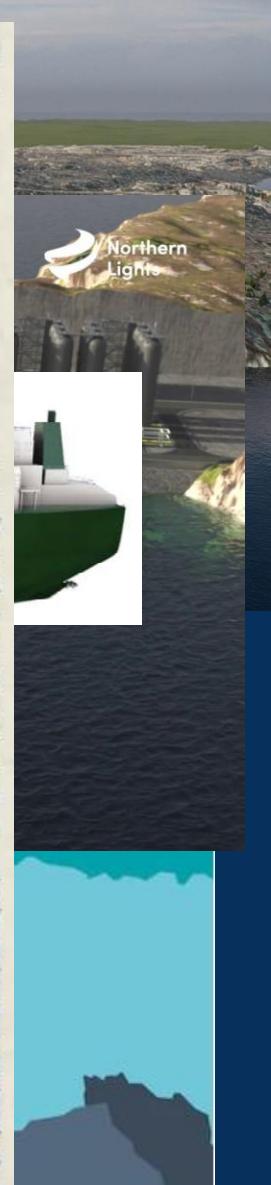
13 Millionen Tonnen sollen jährlich verschwinden.

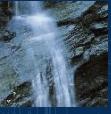
dpa-AFX. KOPENHAGEN. Dänemark hat die ersten Zulassungen für Unternehmen erteilt, die in größerem Umfang CO<sub>2</sub> unter dem Meeresgrund der Nordsee eingelagern können. Entsprechende Genehmigungen gingen an den französischen Mineralölkonzern Totalenergies sowie ein Konsortium, bestehend aus der britischen Chemie-Holding Ineos sowie dem deutschen Gas- und Ölproduzenten Wintershall Dea, einer Tochtergesellschaft des Chemiekonzerns BASF. Dies teilte das dänische Energie-, Versorgungs- und Klimaministerium am Montag mit. Mit Erteilung der Zulassungen könnten die Arbeiten nun sofort beginnen. Im Rahmen der beiden Projekte sollen nach aktuellen Berechnungen ab dem Jahr 2030 jedes Jahr bis zu 13 Millionen Tonnen Kohlendioxid unter dem dänischen Teil der Nordsee eingelagert werden können.

Die dänische Energiebehörde hat dem Ministerium nach eigenen Anga-

ben empfohlen, diese ersten Zulassungen zur Erforschung einer umfangreicher Lagerung von CO<sub>2</sub> unter der Nordsee an die besagten Unternehmen zu vergeben. Es hande sich um einen wichtigen Schritt, um Dänemarks CCS-Strategie zu verwirklichen, erklärte die Behörde. CCS steht für „Carbon capture and storage“. Dabei handelt es sich um die Abscheidung und Speicherung von ausgestoßenem CO<sub>2</sub>, das durch diesen Prozess eingefangen und unter die Erde gepumpt wird.

Das Projekt von Totalenergies trägt den Namen Bifrost, benannt nach der mythischen Regenbogenbrücke, die das Reich der nordischen Götter mit dem der Menschen verbindet. Das Konsortium von Ineos und Wintershall Dea heißt Greensand und hatte von der Energiebehörde schon vor zwei Monaten die Zustimmung zu einem Pilotprojekt zur Lagerung von bis zu 15 000 Tonnen CO<sub>2</sub> in einem ehemaligen Ölfeld erhalten.





# Conclusion

- The technology for the CO<sub>2</sub>-Capture is available and reliable
- Many processes for CO<sub>2</sub>-Capture are still in development – post-combustion to oxyfuel processes
- In Waste incineration the CC (Carbon Capture) is possible without any external energy input
- CCU depends quite a lot from the selected synthesis path, and above of all on the provision of the amount and price of the electrical energy!
- CCS is not yet accepted in Germany (Oxyfuel in Lausitz). Possible utilisation options could be offered via European strategy.



without S<sub>TORAGE</sub> no CC is possible!



Thank you for your attention!