



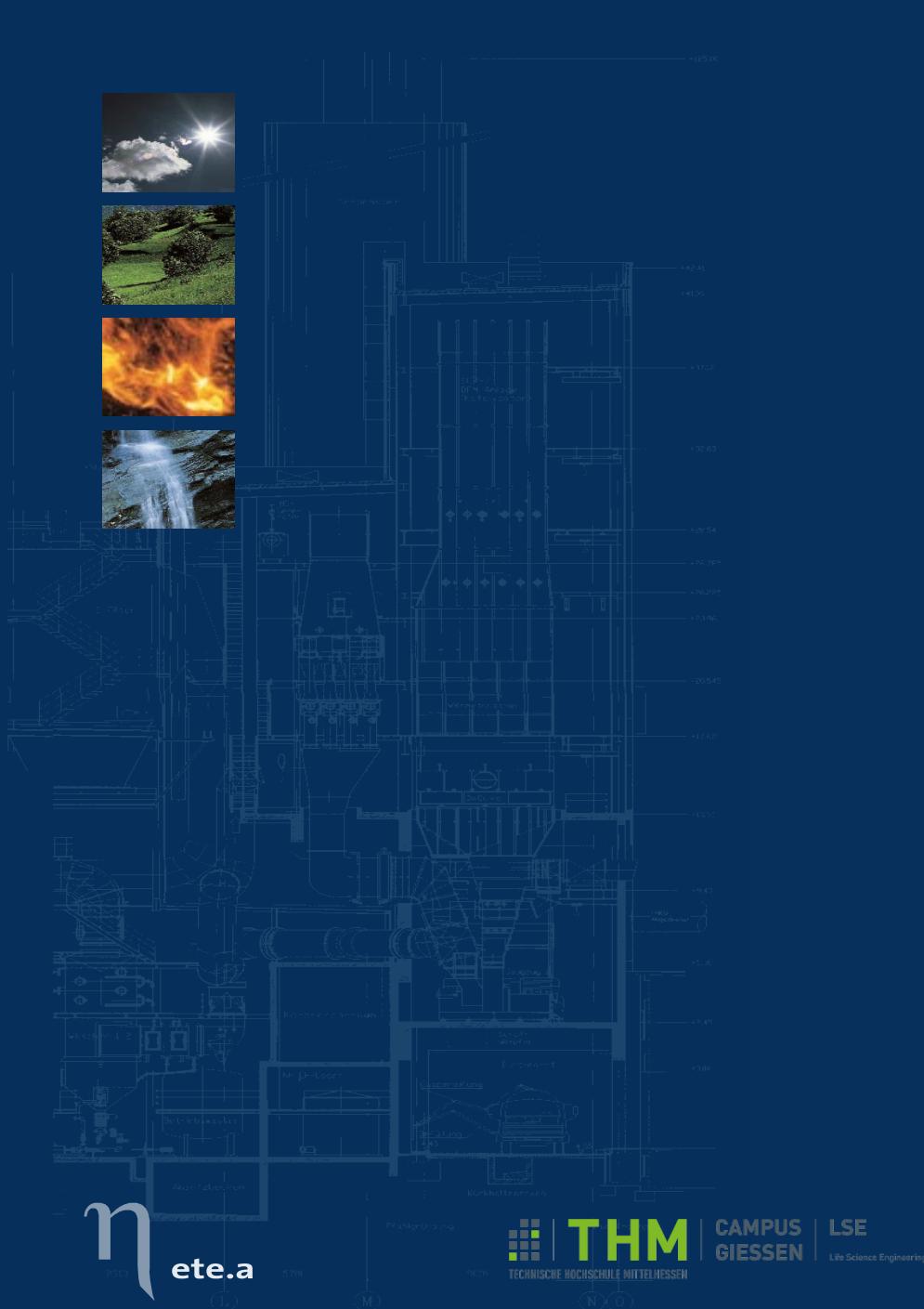
# Transposing the BAT conclusions for waste incineration into national law

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4<sup>th</sup> Steinmüller Engineering Conference on 27<sup>th</sup> April 2023  
Halle 32, old factory building of the former L. & C. Steinmüller



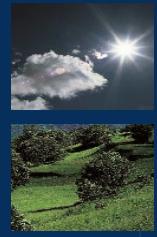
# Motivation and background



On December 3, 2019, the WI BREF was published in the EU Official Journal

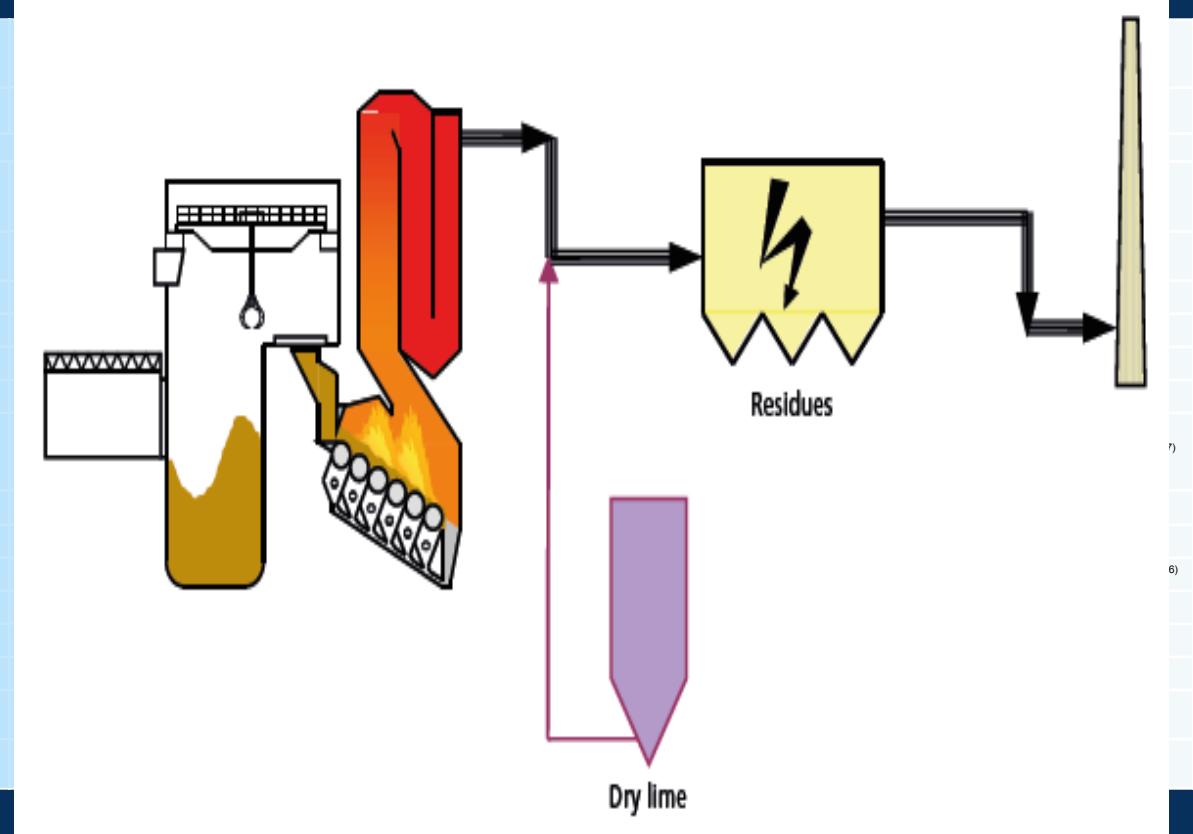
The implementation in national law takes place primarily via the 17<sup>th</sup> BImSchV, but also in an administrative regulation adapted to the TA Luft and the annexes to the Wastewater Ordinance

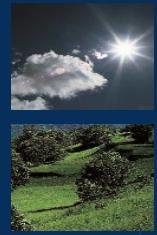
What are the consequences of the emission limits for flue gas treatment systems of existing and new plants



## Development of flue gas treatment systems according the legal requirements using the example of Germany

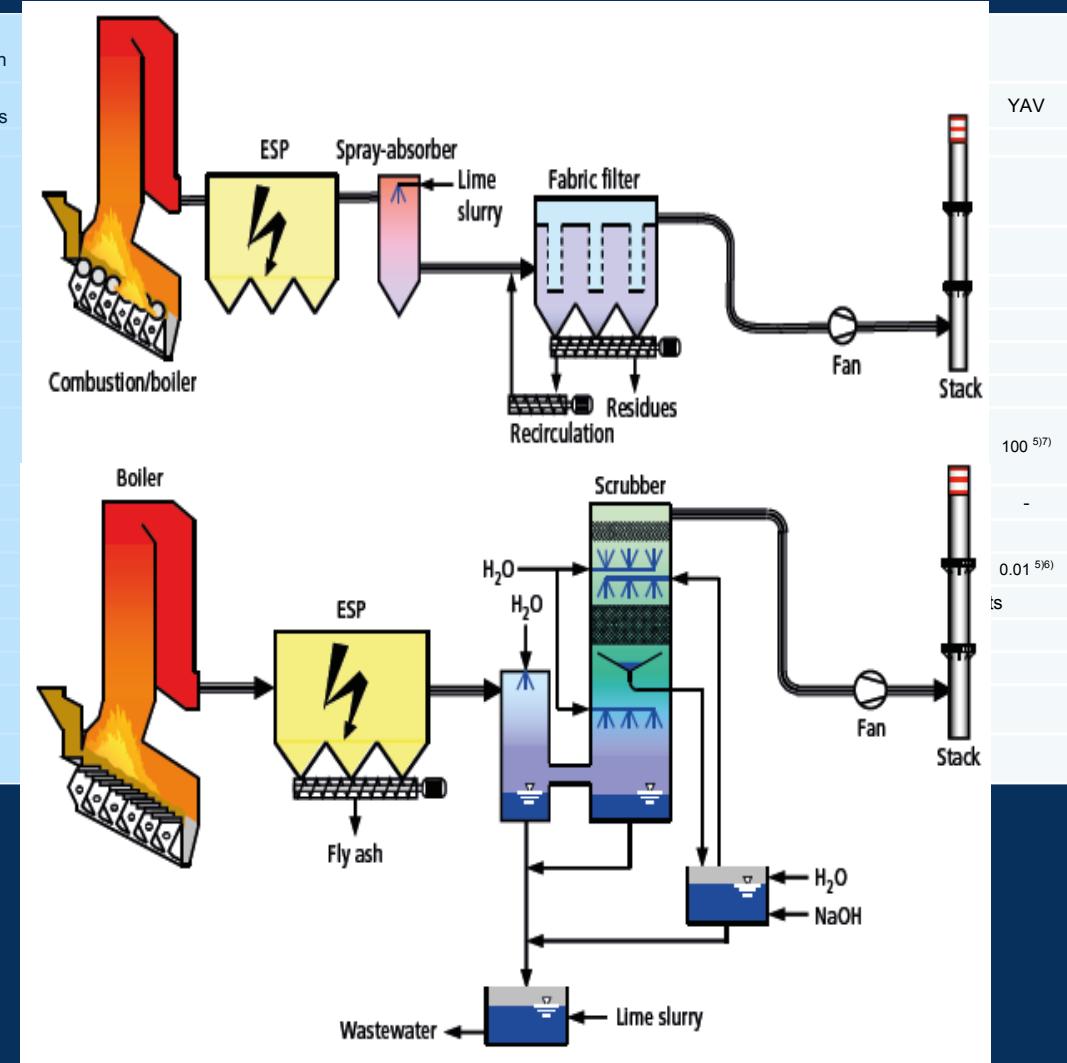
|                                      |                      | TA Luft<br>1974 version |
|--------------------------------------|----------------------|-------------------------|
| Pollutant                            | Unit                 | General<br>requirements |
| O <sub>2</sub> -reference percentage | [Vol.-% dry]         | 11                      |
| Dust                                 | [mg/m <sup>3</sup> ] | 100                     |
| Total Organic Carbon (TOC)           | [mg/m <sup>3</sup> ] | -                       |
| Hydrogen chloride (HCl)              | [mg/m <sup>3</sup> ] | 100                     |
| Hydrogen fluoride (HF)               | [mg/m <sup>3</sup> ] | 5                       |
| Carbon monoxide (CO)                 | [mg/m <sup>3</sup> ] | 1000                    |
| Sulphur dioxide (SO <sub>2</sub> )   | [mg/m <sup>3</sup> ] | -                       |
| Nitrogen oxide (NO <sub>2</sub> )    | [mg/m <sup>3</sup> ] | -                       |
| Ammonia (NH <sub>3</sub> )           | [mg/m <sup>3</sup> ] | -                       |
| Heavy metals                         |                      |                         |
| Mercury (Hg)                         | [mg/m <sup>3</sup> ] | -                       |
| Dioxins and furans                   | [ng/m <sup>3</sup> ] | -                       |
| Class I                              | [mg/m <sup>3</sup> ] | 20***                   |
| Class II                             | [mg/m <sup>3</sup> ] | 50***                   |
| Class III                            | [mg/m <sup>3</sup> ] | 75***                   |

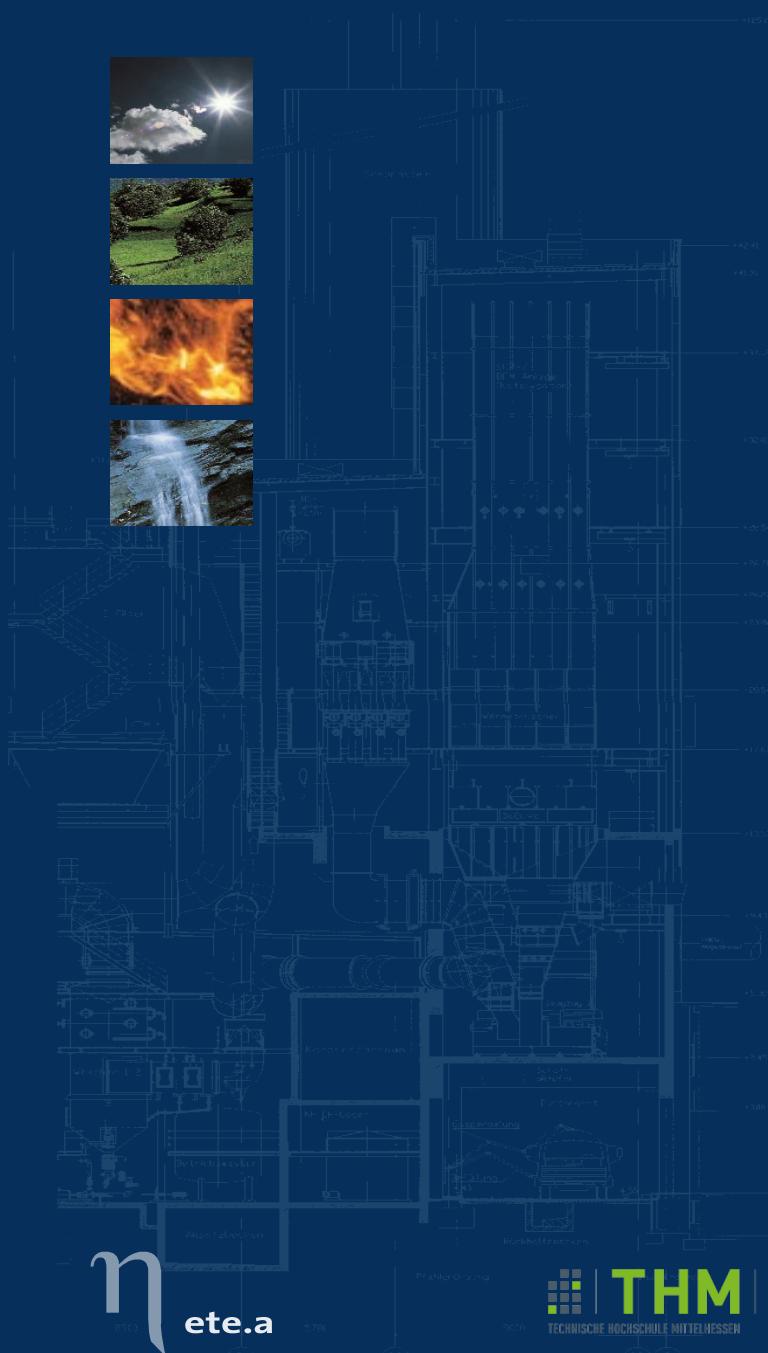
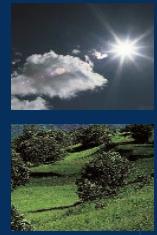




## Development of flue gas treatment systems according to the legal requirements using the example of Germany

| Pollutant<br>O <sub>2</sub> -reference percentage | Unit<br>[Vol.-% dry] | TA Luft<br>1974 version |                      |
|---|----------------------|-------------------------|----------------------|
|   |                      | General requirements    | General requirements |
| Dust  | [mg/m <sup>3</sup> ] | 100                     | 30                   |
| Total Organic Carbon (TOC)                        | [mg/m <sup>3</sup> ] | -                       | 20                   |
| Hydrogen chloride (HCl)                           | [mg/m <sup>3</sup> ] | 100                     | 50                   |
| Hydrogen fluoride (HF)                            | [mg/m <sup>3</sup> ] | 5                       | 2                    |
| Carbon monoxide (CO)                              | [mg/m <sup>3</sup> ] | 1000                    | 100                  |
| Sulphur dioxide (SO <sub>2</sub> )                | [mg/m <sup>3</sup> ] | -                       | 100                  |
| Nitrogen oxide (NO <sub>2</sub> )                 | [mg/m <sup>3</sup> ] | -                       | 500                  |
| Ammonia (NH <sub>3</sub> )                        | [mg/m <sup>3</sup> ] | -                       | -                    |
| Heavy metals                                      |                      |                         |                      |
| Mercury (Hg)                                      | [mg/m <sup>3</sup> ] | -                       | -                    |
| Dioxins and furans                                | [ng/m <sup>3</sup> ] | -                       | -                    |
| Class I   | [mg/m <sup>3</sup> ] | 20***                   | 0.2                  |
| Class II  | [mg/m <sup>3</sup> ] | 50***                   | 1                    |
| Class III   | [mg/m <sup>3</sup> ] | 75***                   | 5                    |



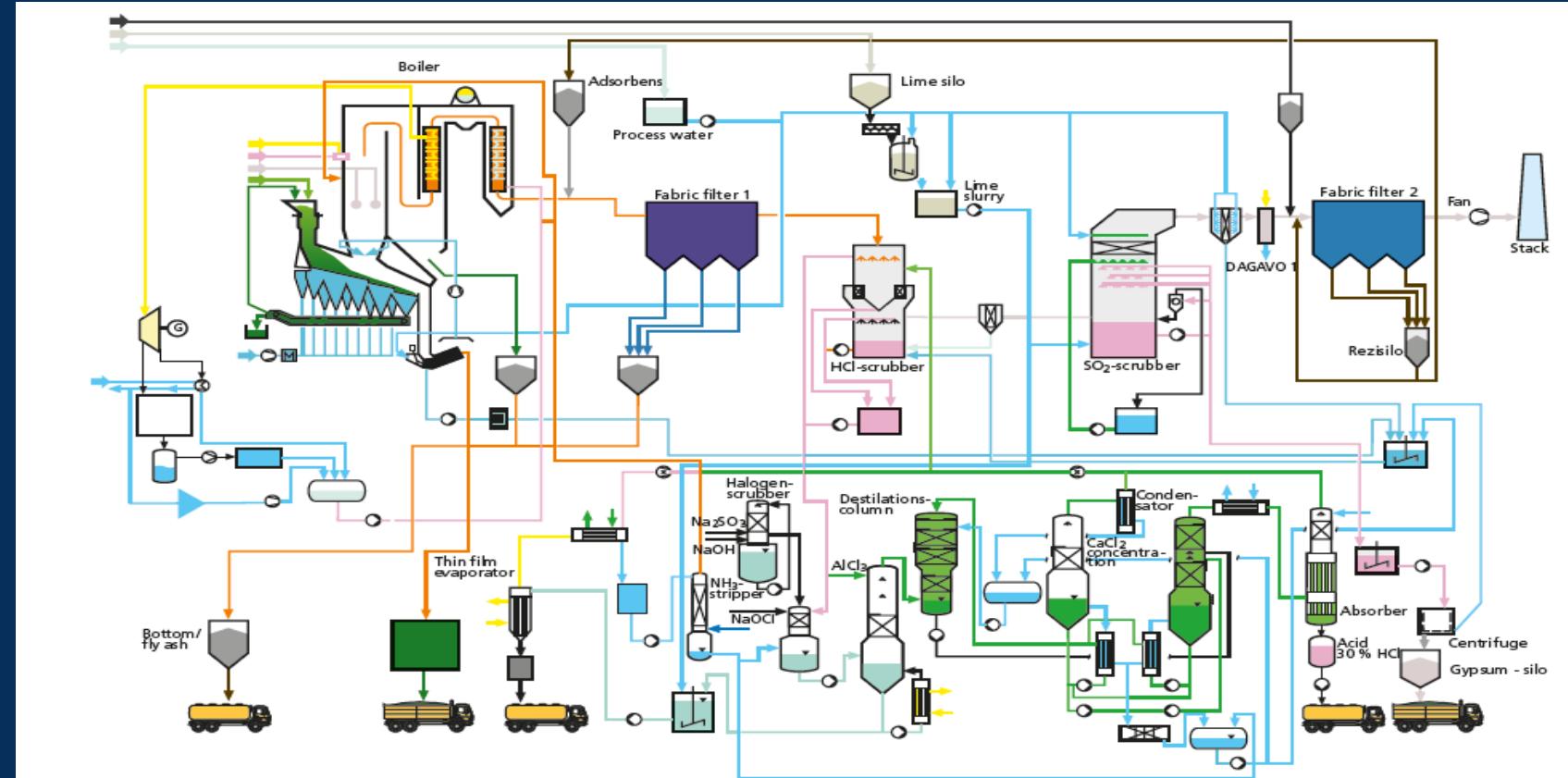


## Development of flue gas treatment systems according the legal requirements using the example of Germany

|                                      |                      | TA Luft<br>1974 version | TA Luft<br>1986 version | 17. BlmSchV<br>1996/2003 version |      | EU Guideline 2000/76 |      | 13. BlmSchV<br>2004 version<br>50 MW < RTI < 100 MW | TA Luft<br>2002 version<br>RTI < 50 MW | 17. BlmSchV<br>2013 version |   |                              |
|--------------------------------------|----------------------|-------------------------|-------------------------|----------------------------------|------|----------------------|------|---|--|-----------------------------|---|------------------------------|
| Pollutant                            | Unit                 | General<br>requirements | General<br>requirements | DAV                              | HHAV | DAV                  | HHAV | DAV   | General<br>requirements                | HHA<br>V                    | DAV                                       | YAV                          |
| O <sub>2</sub> -reference percentage | [Vol.-% dry]         | 11                      | 11                      | 11                               | 11   | 11                   | 11   | 6   | 7 - 11                                 | 20                          | 20  | 5<br>(10 for RTI < 50 MW)    |
| Dust                                 | [mg/m <sup>3</sup> ] | 100                     | 30                      | 10                               | 30   | 10                   | 30   | 20  | 20                                     | 20                          | 20  |                              |
| Total Organic Carbon (TOC)           | [mg/m <sup>3</sup> ] | -                       | 20                      | 10                               | 20   | 10                   | 20   | -   | 50                                     |                             |   |                              |
| Hydrogen chloride (HCl)              | [mg/m <sup>3</sup> ] | 100                     | 50                      | 10                               | 60   | 10                   | 60   | -   | 30                                     | 60                          | 60  | 10                           |
| Hydrogen fluoride (HF)               | [mg/m <sup>3</sup> ] | 5                       | 2                       | 1                                | 4    | 1                    | 4    | -   | 3                                      |                             |   |                              |
| Carbon monoxide (CO)                 | [mg/m <sup>3</sup> ] | 1000                    | 100                     | 50                               | 100  | 50                   | 100  | 150   | 150                                    |                             |   |                              |
| Sulphur dioxide (SO <sub>2</sub> )   | [mg/m <sup>3</sup> ] | -                       | 100                     | 50                               | 200  | 50                   | 200  | 850   | 350 - 1300                             |                             |   |                              |
| Nitrogen oxide (NO <sub>2</sub> )    | [mg/m <sup>3</sup> ] | -                       | 500                     | 200                              | 400  | 200**                | 400  | 400   | 150 - 500                              | 400                         | 150<br>(200 for RTI < 50MW) <sup>6)</sup> | 100 <sup>5)7)</sup>          |
| Ammonia (NH <sub>3</sub> )           | [mg/m <sup>3</sup> ] | -                       | -                       | -                                | -    | -                    | -    | -   | -                                      | 15                          | 10  | -                            |
| Heavy metals                         |                      |                         |                         |                                  |      |                      |      |   |  |                             |   |                              |
| Mercury (Hg)                         | [mg/m <sup>3</sup> ] | -                       | -                       | 0.03                             | 0.05 | 0.05                 |      | 0.03  | 0.05                                   | 0.05                        | 0.05                                      | 0.03<br>0.01 <sup>5)6)</sup> |
| Dioxins and furans                   |                      |                         |                         | Single measurements              |      | Single measurements  |      | Single measurements                                 |  | Single measurements         |   |                              |
| Class I                              | [mg/m <sup>3</sup> ] | 20***                   | 0.2                     | 0.05                             | -    | 0.1                  |      | 0.1   | -                                      |                             |   | 0.1                          |
| Class II                             | [mg/m <sup>3</sup> ] | 50***                   | 1                       | 0.5                              |      | 0.5 <sup>1)</sup>    |      | 0.5*  | 0.5 <sup>3)</sup>                      | 0.5 <sup>3)</sup>           |   | 0.5                          |
| Class III                            | [mg/m <sup>3</sup> ] | 75***                   | 5                       | 0.05                             |      | -                    | -    | 0.05*   | 1 <sup>4)</sup>                        |                             |   | 0.05                         |



## Development of flue gas treatment systems according the legal requirements using the example of Germany





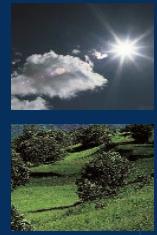
## Significance of flue gas treatment

What was the experience with such complex plants?

- There was no market for the by-products
- The energy expenditure and plant construction was very high

 While these insights were gained, waste incineration underwent a metamorphosis from mere waste disposal to energy recovery from waste

From then on, energy efficiency was in the focus and became an important design criterion both for new and modified plants



## Challenges for flue gas treatment systems in the future

Challenges for flue gas cleaning will continue to be high pollutant removal efficiency and very high efficiency in the use of energy and consumables (minimum consumption of resources)

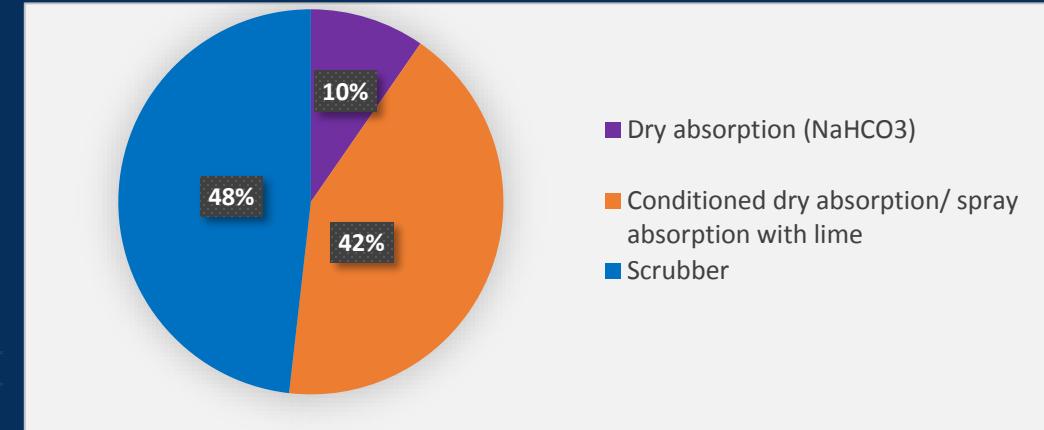
The present-day flue gas treatment systems are unique in design and their specific configuration often reflects the development of the emission limits over time



# Process overview of the executed flue gas treatment plants Impact on the possible emission reduction



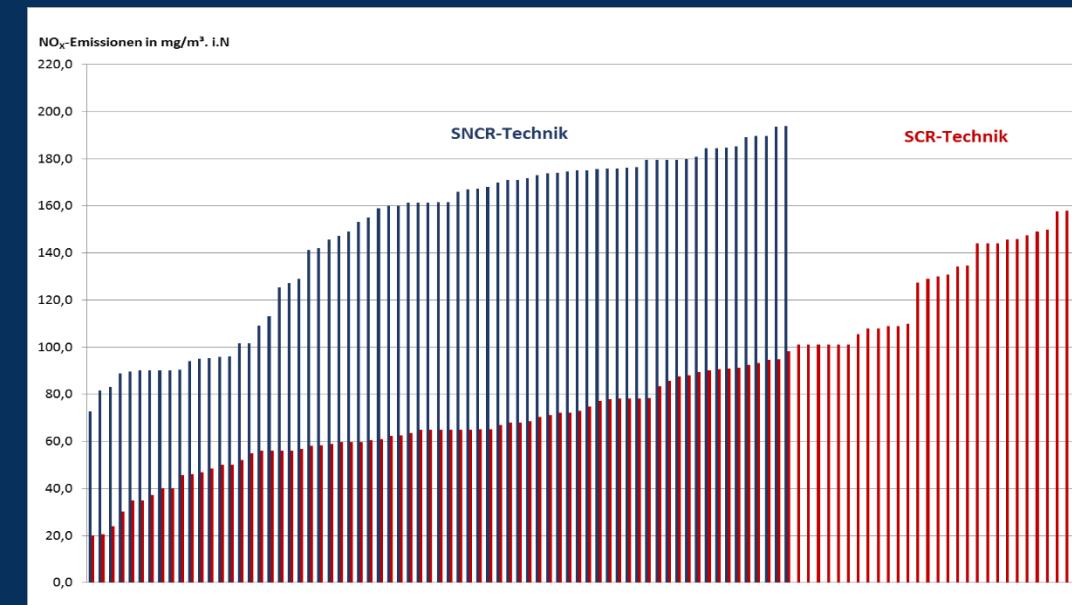
## Separation of acid gases based on German WtE plants



Source: ITAD, Düsseldorf



## Separation of NOx based on German WtE plants

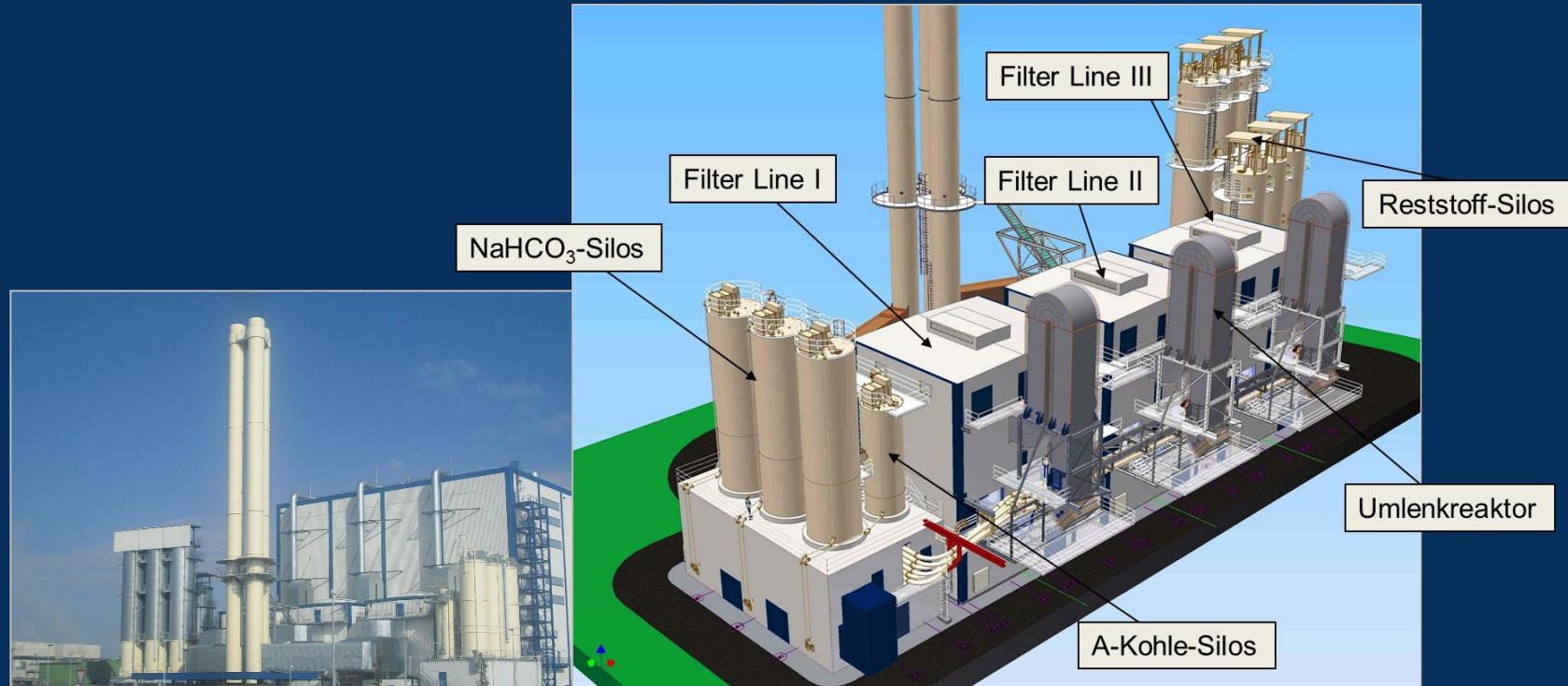


Source: M. Treder: ITAD Emissionsbericht 2016, vorläufig, unveröffentlicht, Düsseldorf 10.09.2017

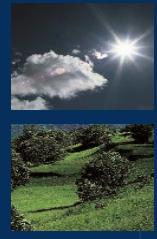


# Simple plant construction

## SNCR – one-stage dry sorption with $\text{NaHCO}_3$

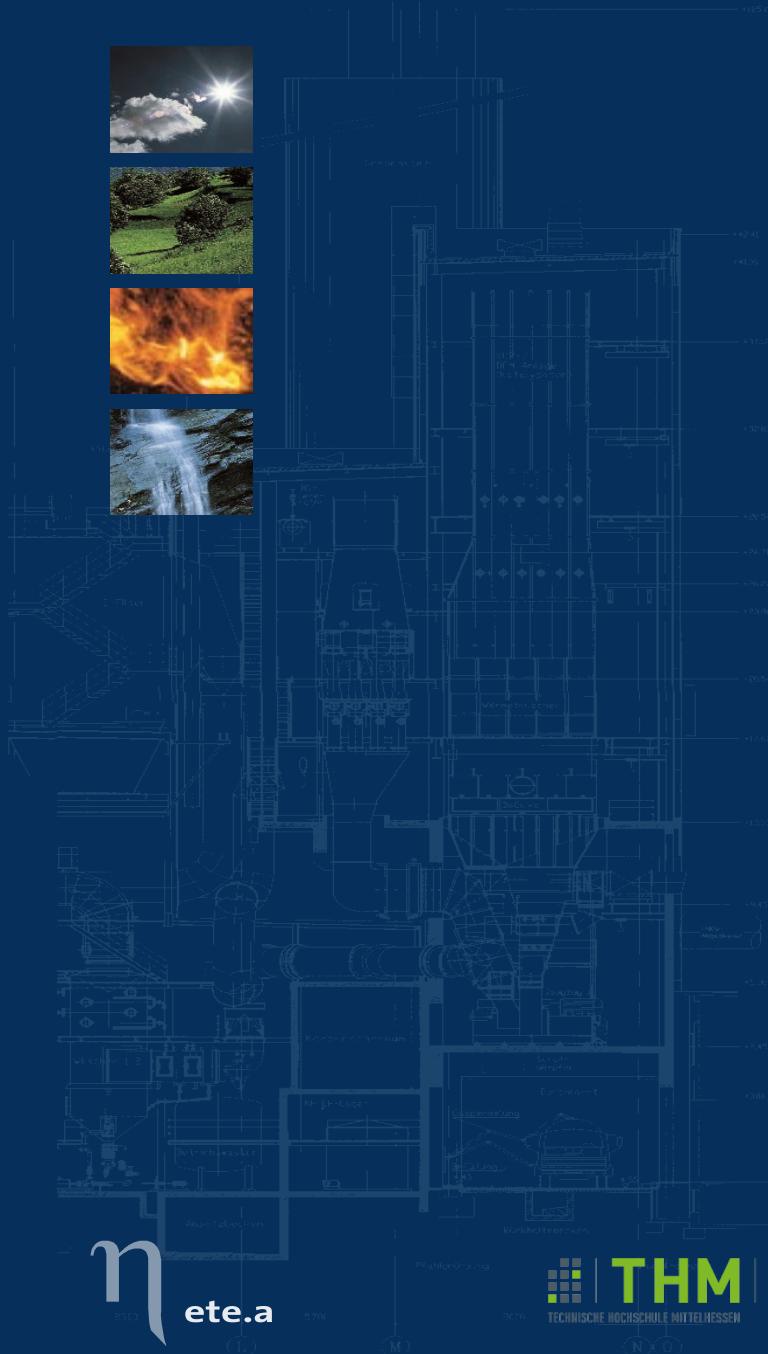


Source: Lühr-Filter, Stadthagen



## Complex plant construction

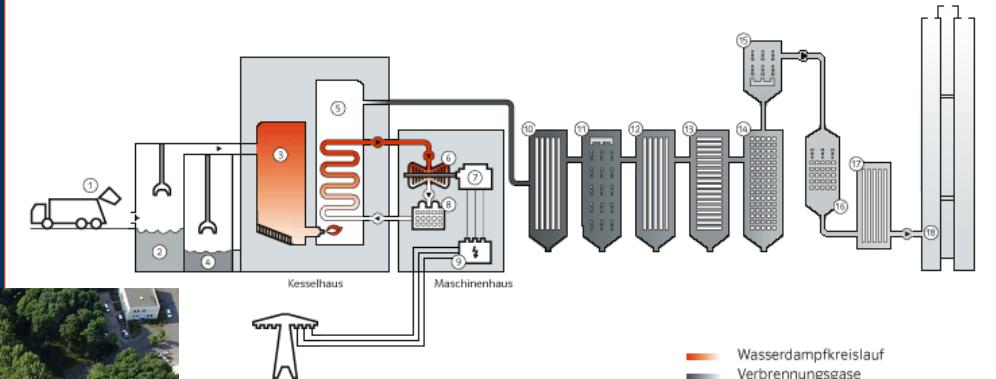
ESP – Spray-dryer – ESP – 2-Stage scrubber – Aerosol-separator – SCR – Fabric filter



Source: Interargem, Bielefeld

### Die Müllverbrennungsanlage Bielefeld

Technische Anlagenübersicht der Stationen

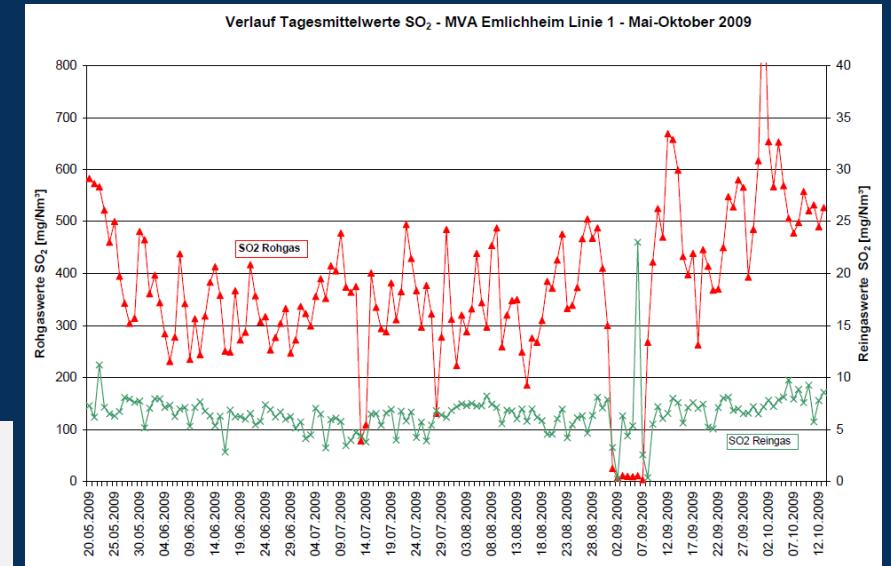
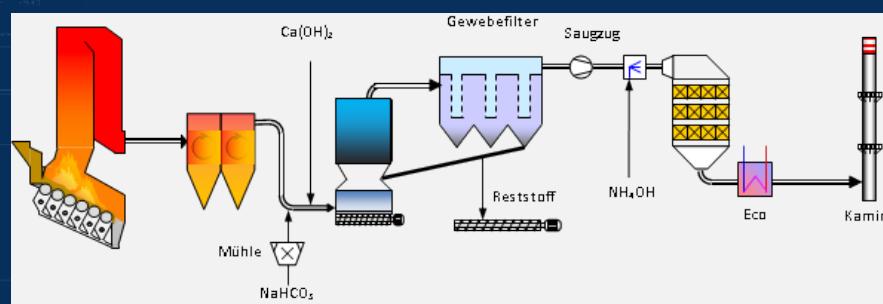
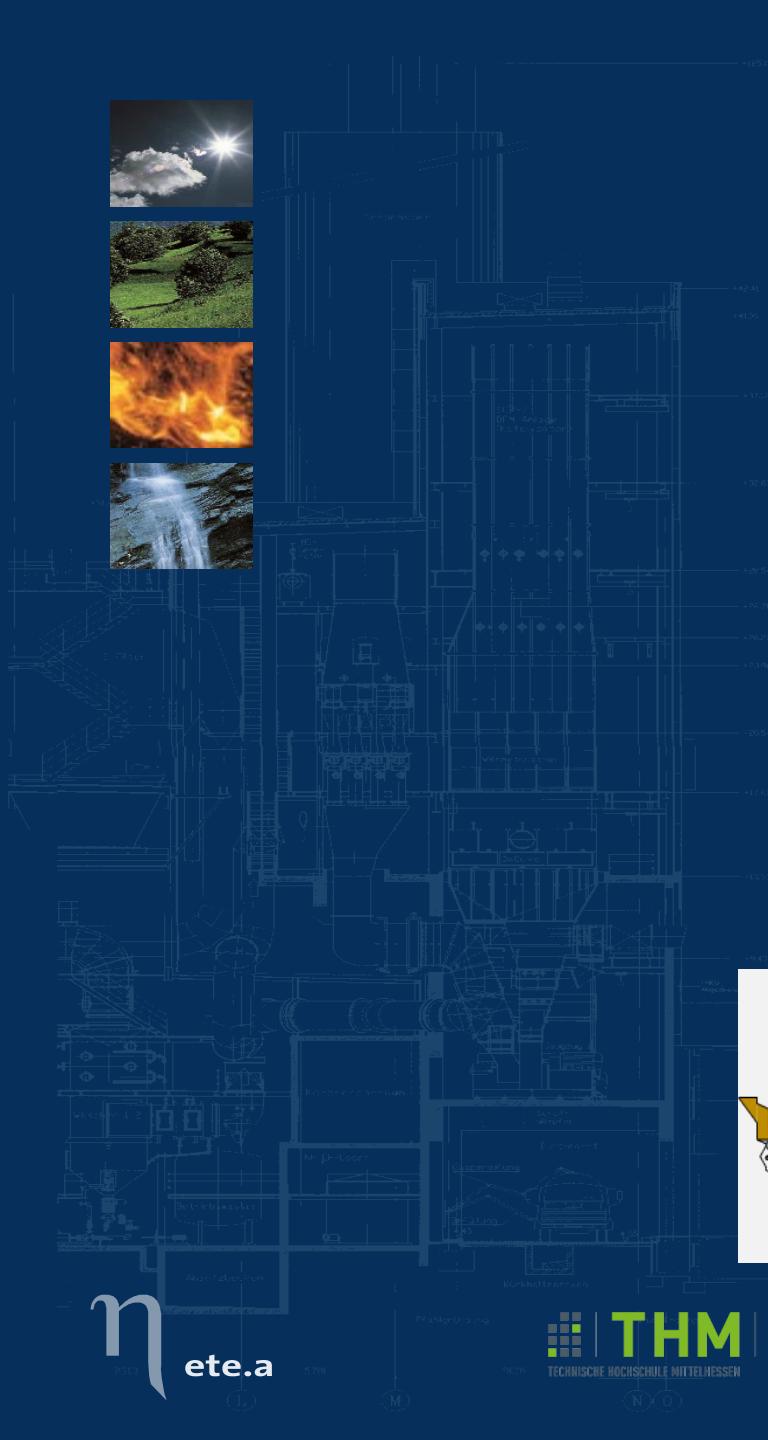


Wasserdampfkreislauf  
Verbrennungsgase

- 10 Elektrofilter I  
Abscheiden der Staubpartikel
- 11 Sprührocker  
Verdampfen des Wäscherwassers
- 12 Elektrofilter II  
Abscheiden der Salz- und Staubpartikel
- 13/14 Vorräucher/Hauptwässcher  
Abscheiden von Schadgasen, Chlor-/Fluorwasserstoff, Quecksilberverbindungen, Schwefeldioxid
- 15 Aerosolabscheider  
Abscheiden von Flüssigkeitströpfchen und Staubpartikeln
- 16 Katalysator  
Umwandlung der Stickoxide, Zersetzung der Dioxine und Furane
- 17 Gewebefilter  
Abscheiden von Schwermetallresten, Resten von Dioxinen, Furanc und Reststaub
- 18 Kamin  
Höhe 107 m  
Austrittstemperatur ca. 110 °C

## Examples for high efficient flue gas treatment systems

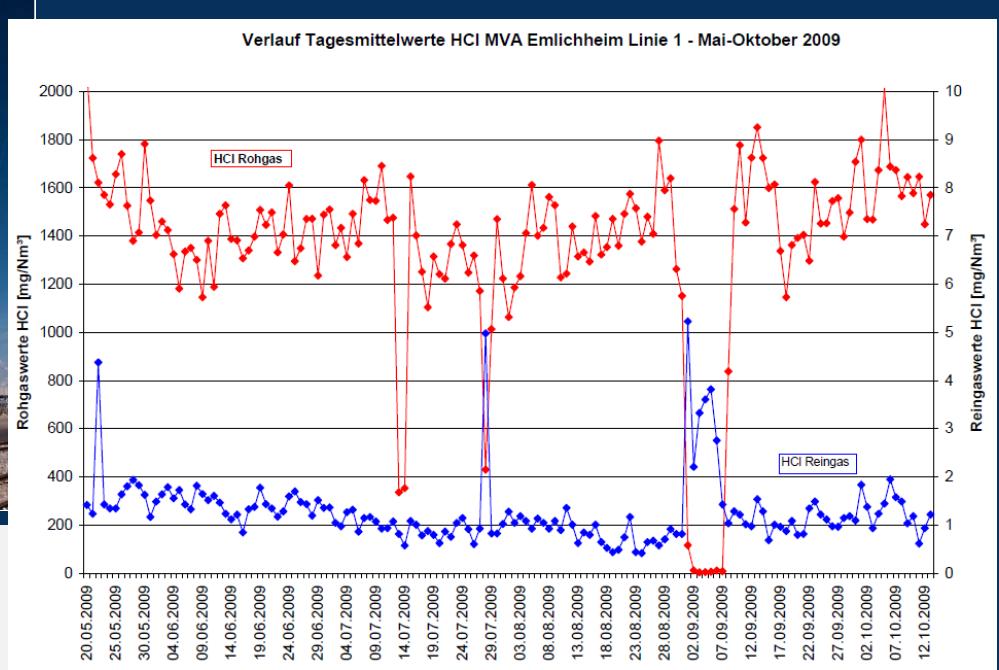
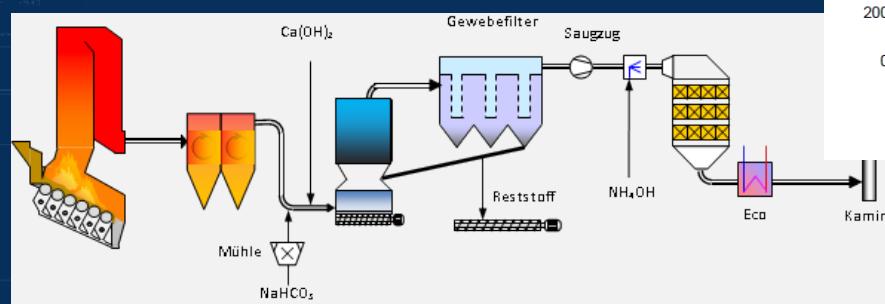
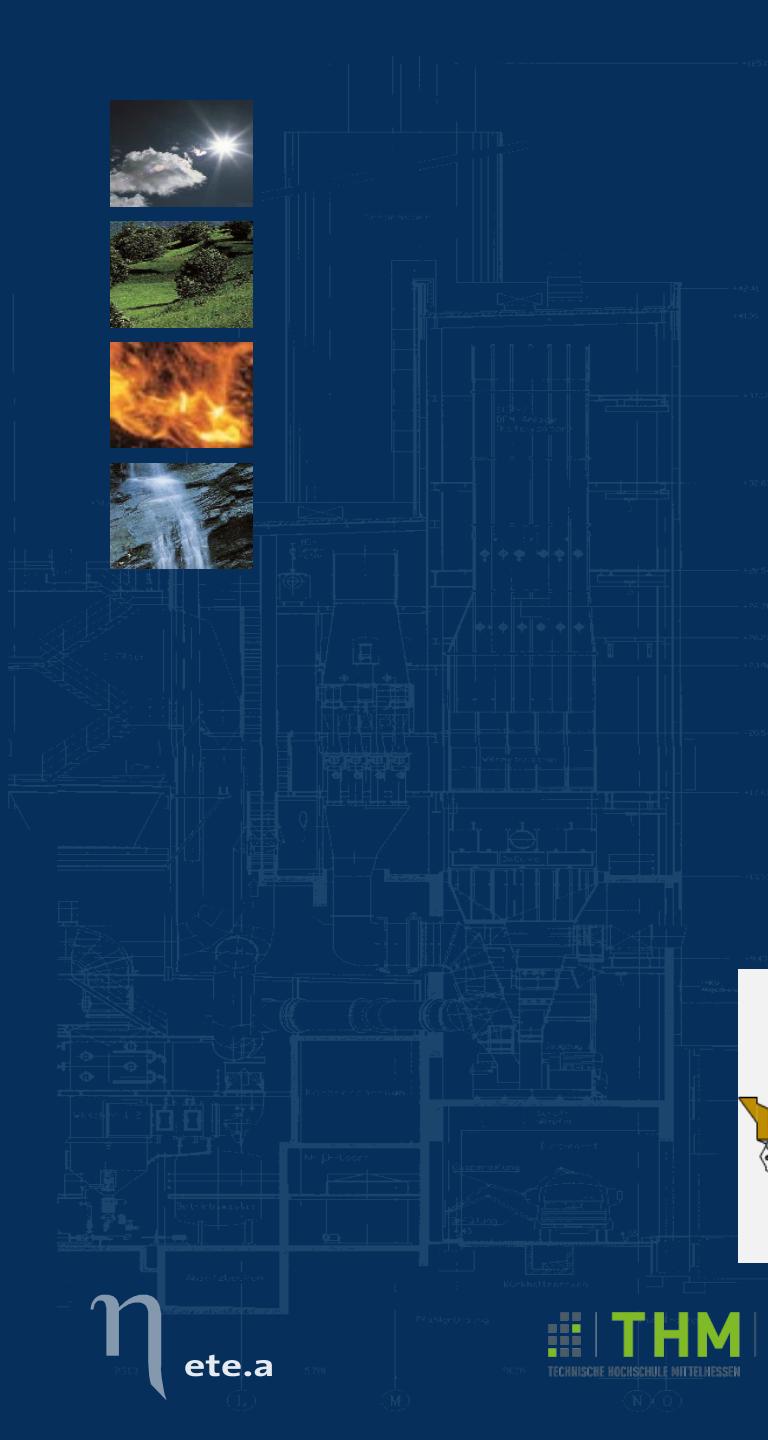
Waste incineration plant EVI-Europark (Germany)



Source: Dr. Buhlmann; Trockene Rauchgasreinigung der MVA-EVI-Europark; 5. Tagung- Trockene Abgasreinigung für Feuerungsanlagen und andere thermische oder chemische Prozesse Essen, 12. - 13. November 2009

## Examples for high efficient flue gas treatment systems

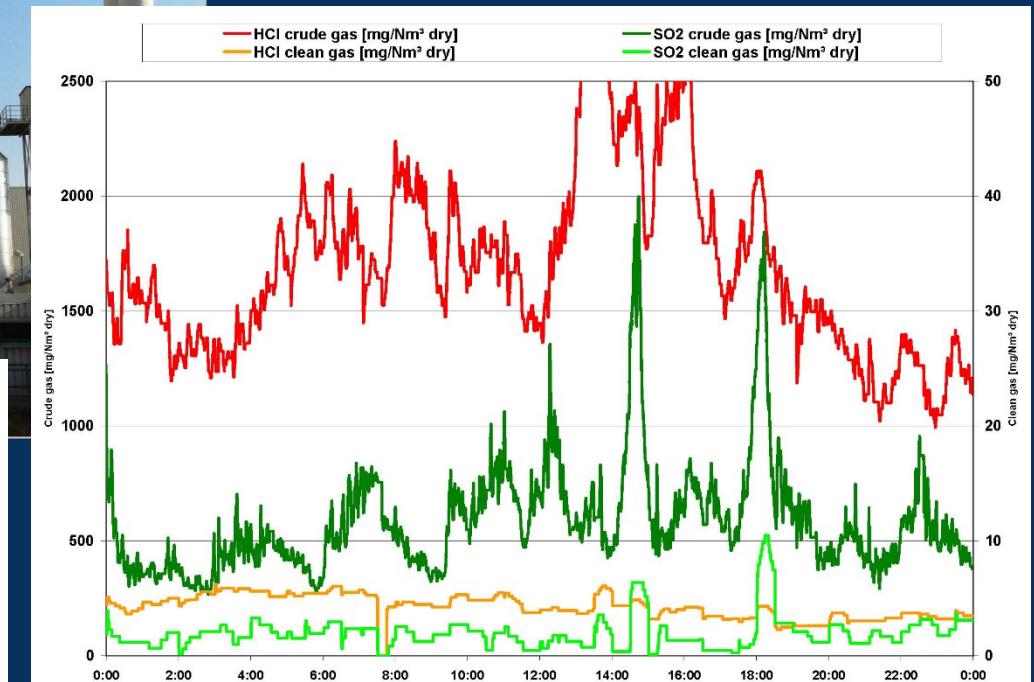
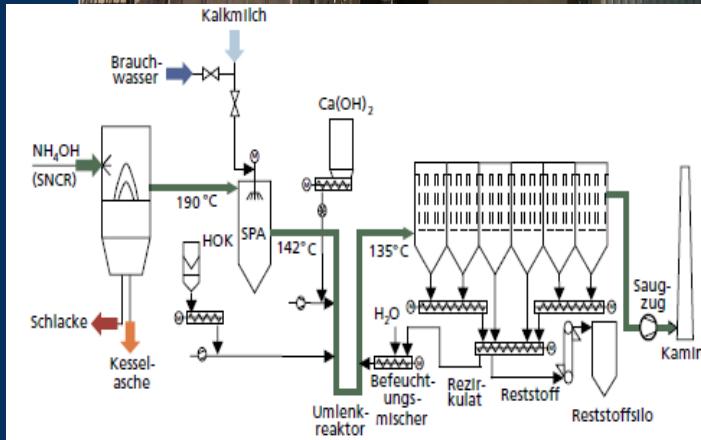
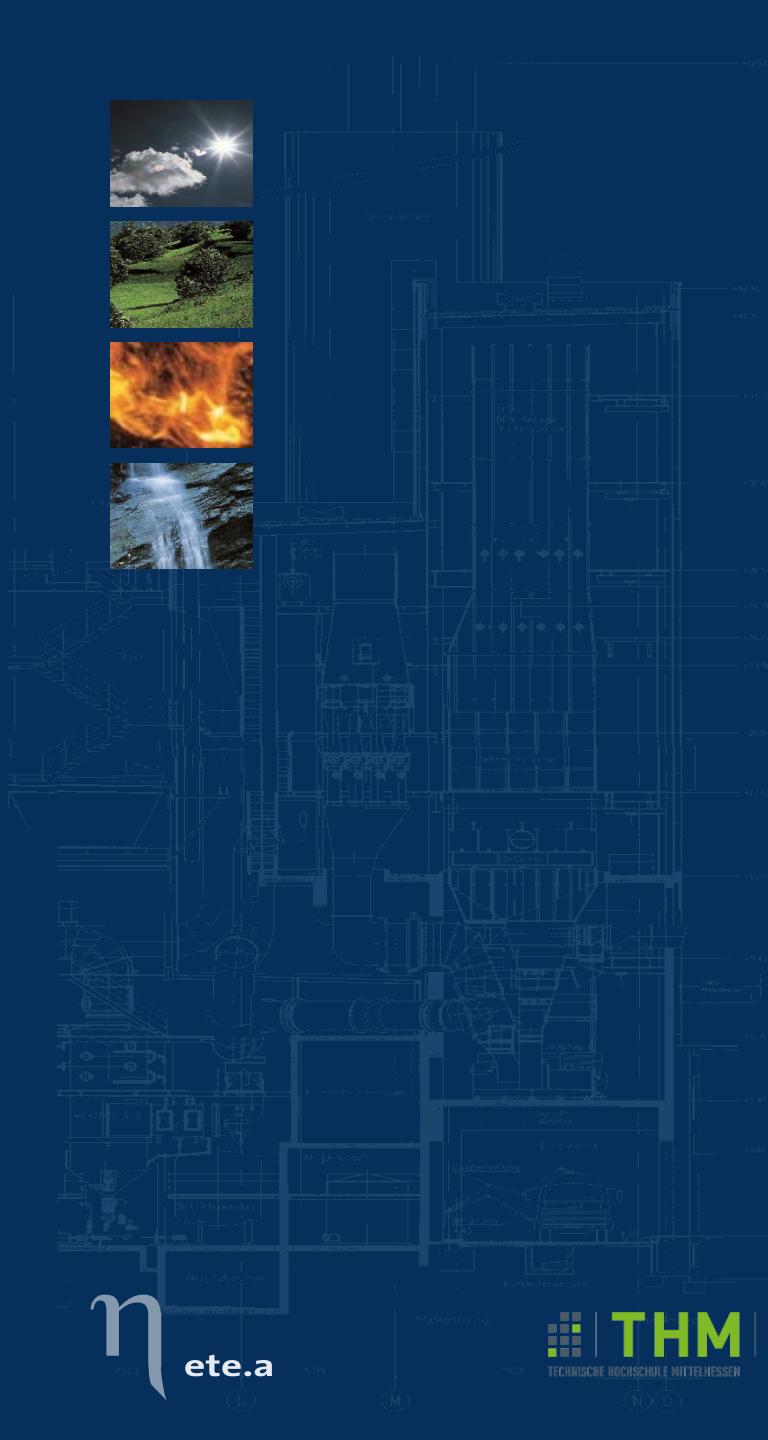
Waste incineration plant EVI-Europark (Germany)



Source: Dr. Buhlmann; Trockene Rauchgasreinigung der MVA-EVI-Europark; 5. Tagung- Trockene Abgasreinigung für Feuerungsanlagen und andere thermische oder chemische Prozesse Essen, 12. - 13. November 2009

## Examples for high efficient flue gas treatment systems

Waste incineration plant Rothensee (Germany)



Source: R. Margraf; Dry, Semi-dry or Wet – Which System Fits Best Depending on the Overall Conditions?, IRRC, Vienna 2017



## Challenges for flue gas treatment systems in the future

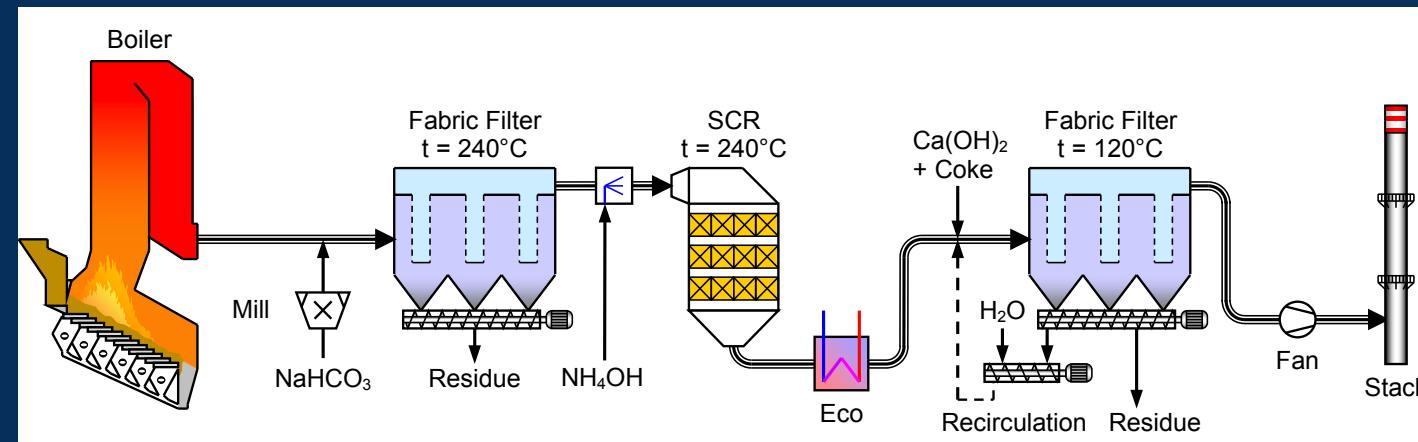
Increasing energy efficiency of flue gas treatment processes

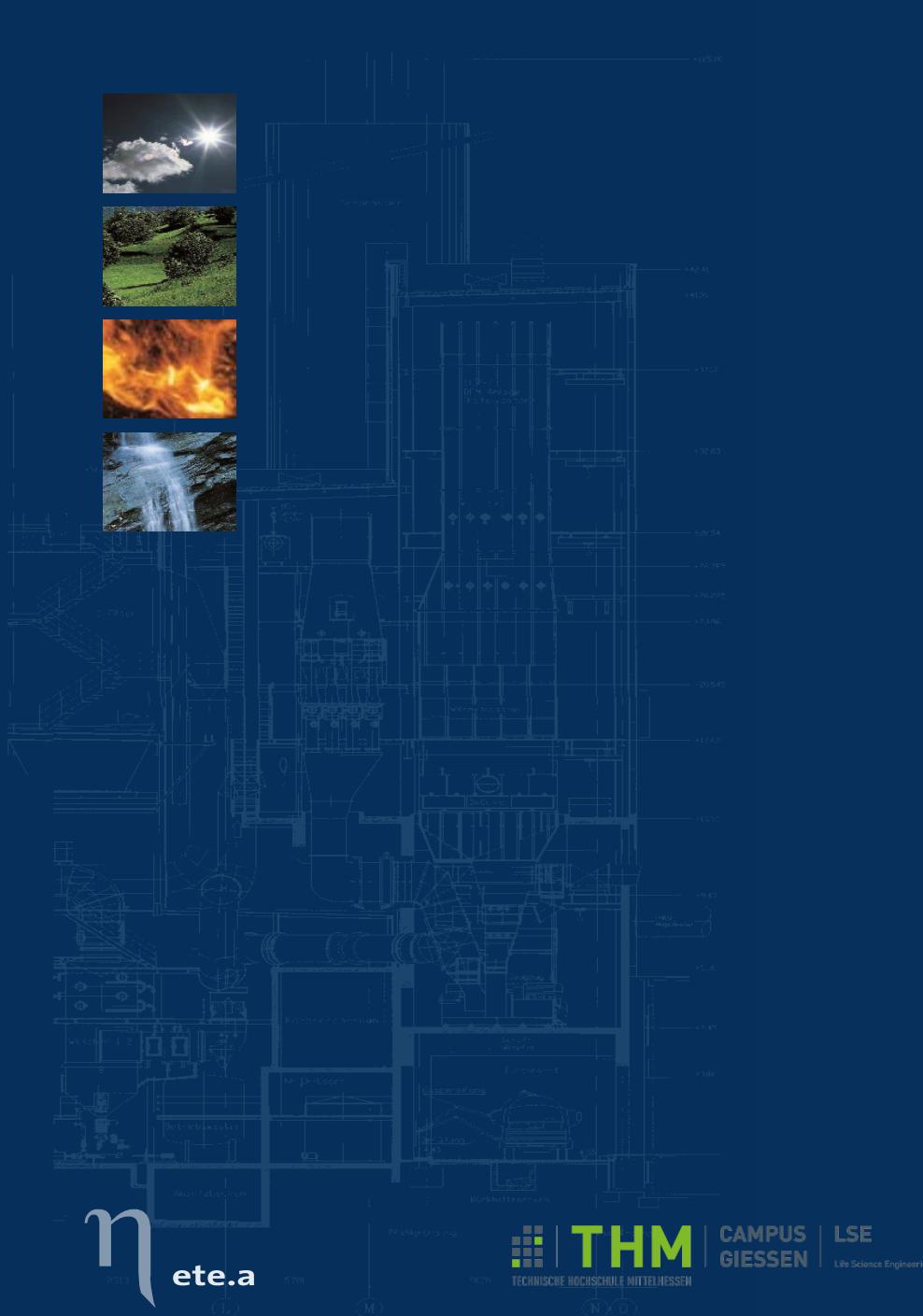
→ Modern-day aim is to have efficient plant-wide processes, but also plant design and configuration



Another challenge for flue

the design of  
development of new  
intelligent combination  
like the following





# Future expectations

## Implementation of the new emission limits



## Comparison of the existing to the new BAT emission limits

| Parameter                                | Unit                                    | Existing<br>emission<br>limits<br>17. BlmSchV | BAT<br>emission<br>limits<br>existing plants | BAT emission<br>limits<br>new plants | Monitoring<br>frequenz | Kind of<br>average<br>values |
|--|---|---|--|--------------------------------------|------------------------|------------------------------|
| Dust                                     | mg/m <sup>3</sup> STP dry               | 5   | < 2-5  | < 2-5                                | continually            | DAV                          |
| HCl                                      | mg/m <sup>3</sup> STP dry               | 10  | < 2-8  | < 2-6                                | continually            | DAV                          |
| HF                                       | mg/m <sup>3</sup> STP dry               | 1   | < 1  | < 1                                  | continually            | DAV                          |
| NO <sub>x</sub> (SCR)                    | mg/m <sup>3</sup> STP dry               | 150   | 50-150                                       | 50-120                               | continually            | DAV                          |
| SO <sub>x</sub> as SO <sub>2</sub>       | mg/m <sup>3</sup> STP dry               | 50  | 5-40   | 5-30                                 | continually            | DAV                          |
| Hg                                       | mg/m <sup>3</sup> STP dry               | 0,05  | 0,035  | 0,02                                 | continually            | HHAV                         |
|  |   | 0,03  | 0,01   | 0,01                                 | continually            | DAV                          |
|  |   | 0,01  | 0,005  | 0,005                                | continually            | JAV                          |
| NH <sub>3</sub>                          | mg/m <sup>3</sup> STP dry               | 10  | 2-10   | 2-10                                 | continually            | DAV                          |
| CO                                       | mg/m <sup>3</sup> STP dry               | 50  | 10-50  | 10-50                                | continually            | DAV                          |
| Cd + Tl                                  | mg/m <sup>3</sup> STP dry               | 0,05  | 0,005-0,02                                   | 0,005-0,02                           | every 6 month          | DAV                          |
| ΣSb+As+Pb+Cr+<br>Co+Cu+Mn+Ni+V<br>+ (Sn) | mg/m <sup>3</sup> STP dry               | 0,5   | 0,01-0,3                                     | 0,01-0,3                             | /                      | DAV                          |
| PCDD/F                                   | ng I-TEQ /m <sup>3</sup> , STP dry      | /   | < 0,01-0,06                                  | < 0,01-0,04                          | every 6 month          | DAV                          |
|  |   |   | < 0,01-0,08                                  | < 0,01-0,06                          | monthly                | DAV                          |
| PCDD/F + PCBs                            | ng WHO-TEQ /m <sup>3</sup> ,<br>STP dry | 0,1   | < 0,01-0,08                                  | < 0,01-0,06                          | every 6 month          | DAV                          |
|  |   |   | < 0,01-0,1                                   | < 0,01-0,08                          | monthly                | DAV                          |
| TVOC / C <sub>ges.</sub>                 | mg/m <sup>3</sup> STP dry               | 10  | < 3-10                                       | < 3-10                               | continually            | DAV                          |



On behalf of the  
German Federal  
Environment Agency

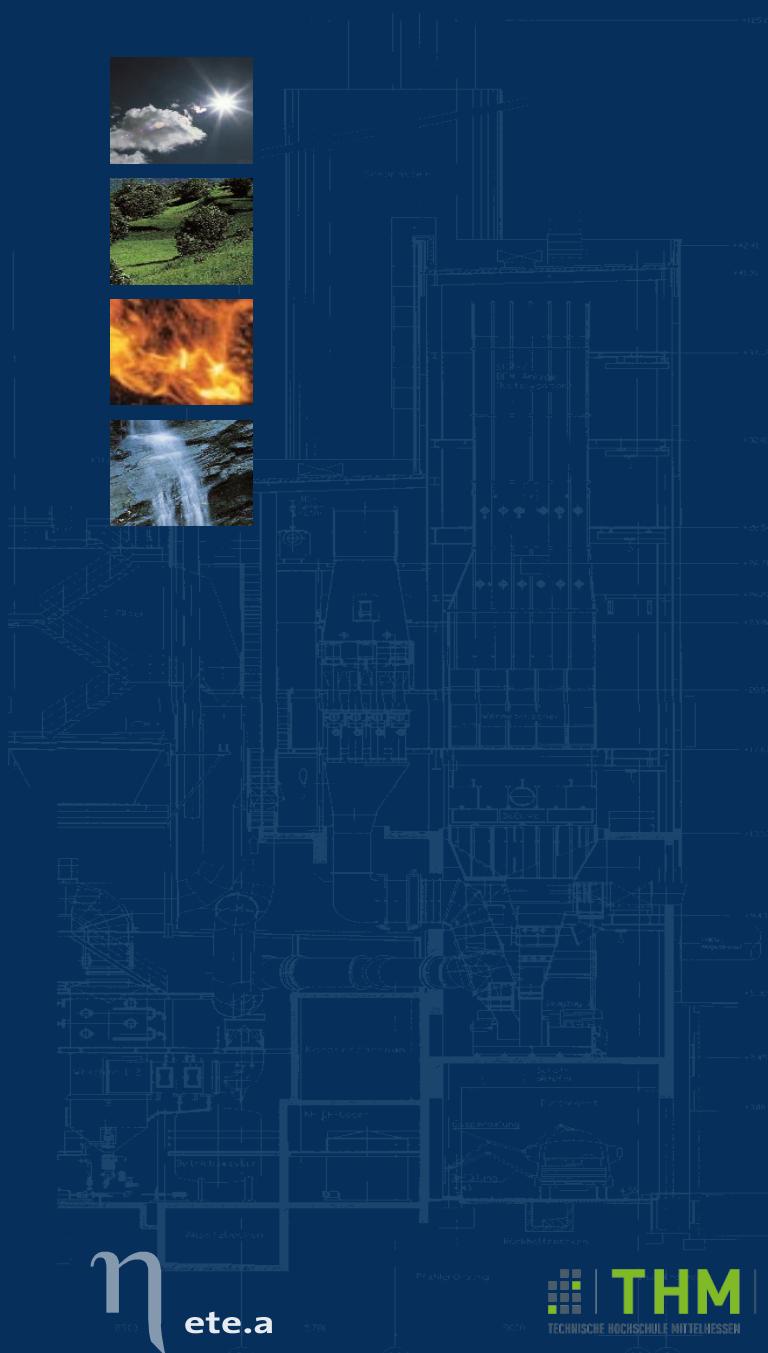
## Cost evaluation by the stricter emission limits

The consequential costs arising from the tightening of limit values for emissions into the air were determined as part of a data collection

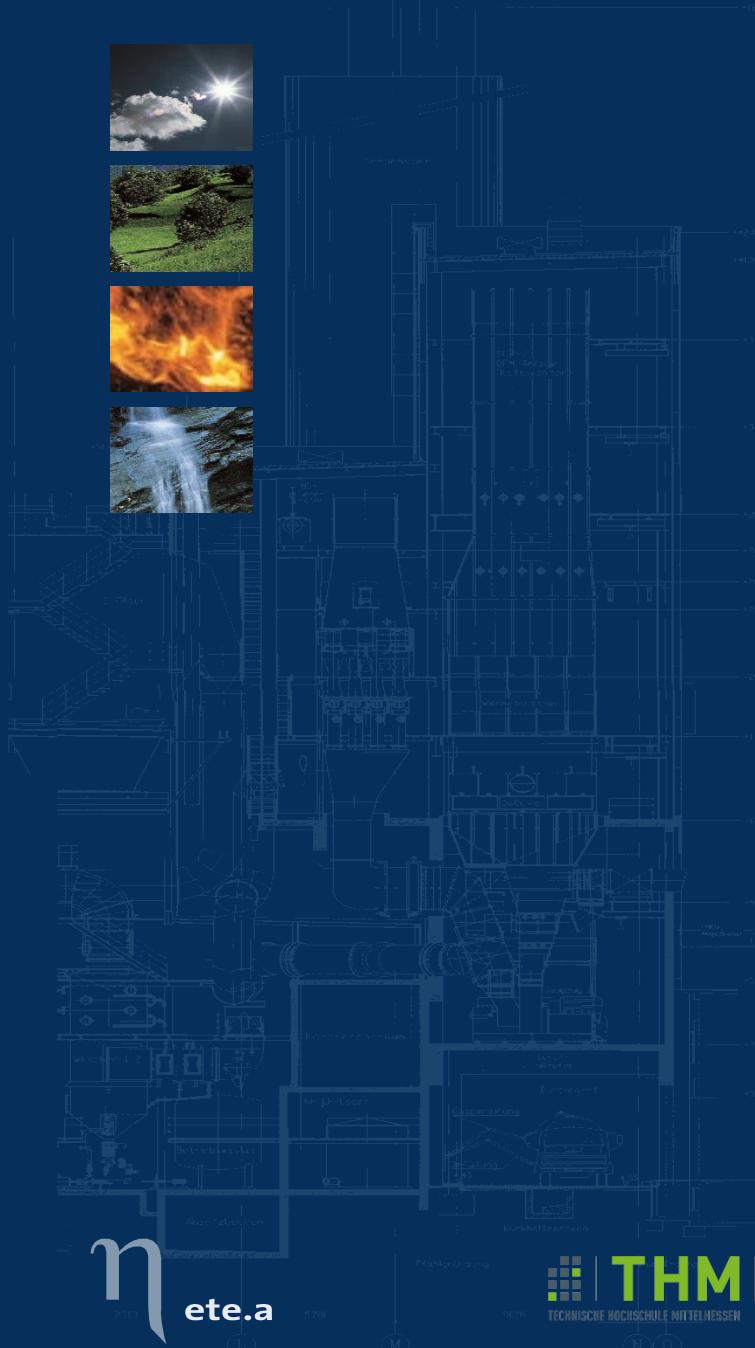
210 existing plants in Germany were considered, of which 96 were municipal waste (including RDF), 28 were sewage sludge and 30 were hazardous waste incineration plants and 56 were biomass plants are considered for two limit value scenarios

The upper values of the BAT associated emission bandwidth are to be assumed for scenario 1 and the medians of the ranges (daily mean values) for scenario 2, with the respective exceptions for the parameter mercury

## 4<sup>th</sup> Steinmüller Engineering Conference on 27<sup>th</sup> April 2023, Gummersbach

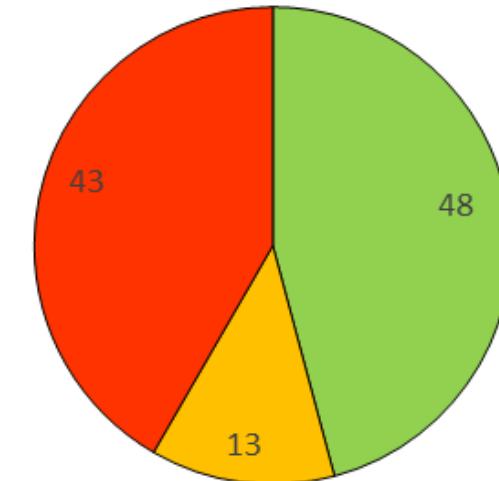


| parameter  | unit                                    | existing<br>emission<br>limits<br>17. BlmSchV | emission<br>limits<br>szenario 1 | emission<br>limits<br>szenario 2 | monitoring<br>frequenz | kind of<br>average<br>values |
|--|---|---|----------------------------------|----------------------------------|------------------------|------------------------------|
| <b>dust</b>  | mg/m <sup>3</sup> STP dry               | 5   | 5                                | 3,5                              | continually            | DAV                          |
| <b>HCl</b>   | mg/m <sup>3</sup> STP dry               | 10  | 8                                | 5                                | continually            | DAV                          |
| <b>HF</b>  | mg/m <sup>3</sup> STP dry               | 1   | 0,9                              | 0,9                              | continually            | DAV                          |
| <b>NO<sub>x</sub> (SCR)</b>                        | mg/m <sup>3</sup> STP dry               | 150   | 150                              | 100                              | continually            | DAV                          |
| <b>SO<sub>x</sub> as SO<sub>2</sub></b>            | mg/m <sup>3</sup> STP dry               | 50  | 40                               | 22,5                             | continually            | DAV                          |
| <b>Hg</b>  | mg/m <sup>3</sup> STP dry               | 0,05  | 0,035                            | 0,02                             | continually            | HHAV                         |
|  |   | 0,03  | 0,01                             | 0,01                             | continually            | DAV                          |
|  |   | 0,01  | 0,005                            | 0,005                            | continually            | JAV                          |
| <b>NH<sub>3</sub></b>                              | mg/m <sup>3</sup> STP dry               | 10  | 10                               | 6                                | continually            | DAV                          |
| <b>CO</b>  | mg/m <sup>3</sup> STP dry               | 50  | 50                               | 30                               | continually            | DAV                          |
| <b>Cd + Tl</b>                                     | mg/m <sup>3</sup> STP dry               | 0,05  | 0,02                             | 0,0125                           | every 6 month          | DAV                          |
| <b>ΣSb+As+Pb+Cr<br/>+Co+Cu+Mn+Ni<br/>+V + (Sn)</b> | mg/m <sup>3</sup> STP dry               | 0,5   | 0,3                              | 0,155                            | /                      | DAV                          |
| <b>PCDD/F</b>                                      | ng I-TEQ /m <sup>3</sup> ,<br>STP dry   | /   | 0,06                             | 0,035                            | every 6 month          | DAV                          |
|  |   |   | 0,08                             | 0,045                            | monthly                | DAV                          |
| <b>PCDD/F +<br/>PCBs</b>                           | ng WHO-TEQ<br>/m <sup>3</sup> , STP dry | 0,1   | 0,08                             | 0,045                            | every 6 month          | DAV                          |
|  |   |   | 0,1                              | 0,055                            | monthly                | DAV                          |
| <b>TVOC / C<sub>ges.</sub></b>                     | mg/m <sup>3</sup> STP dry               | 10  | 10                               | 6,5                              | continually            | DAV                          |



## General retrofit requirements

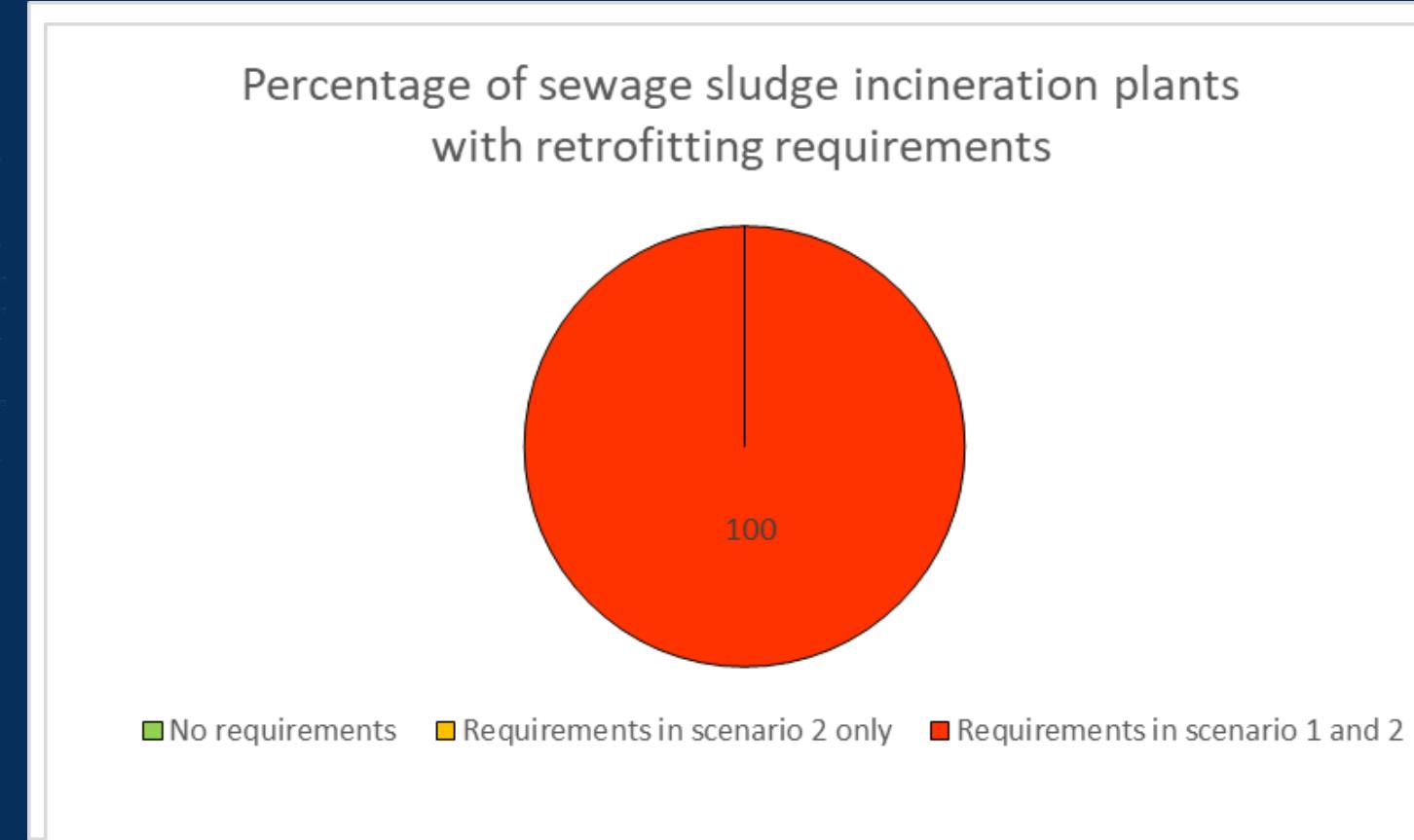
Percentage of municipal waste incineration plants  
(incl. RDF) with retrofitting requirements



■ No requirements ■ Requirements in scenario 2 only ■ Requirements in scenario 1 and 2

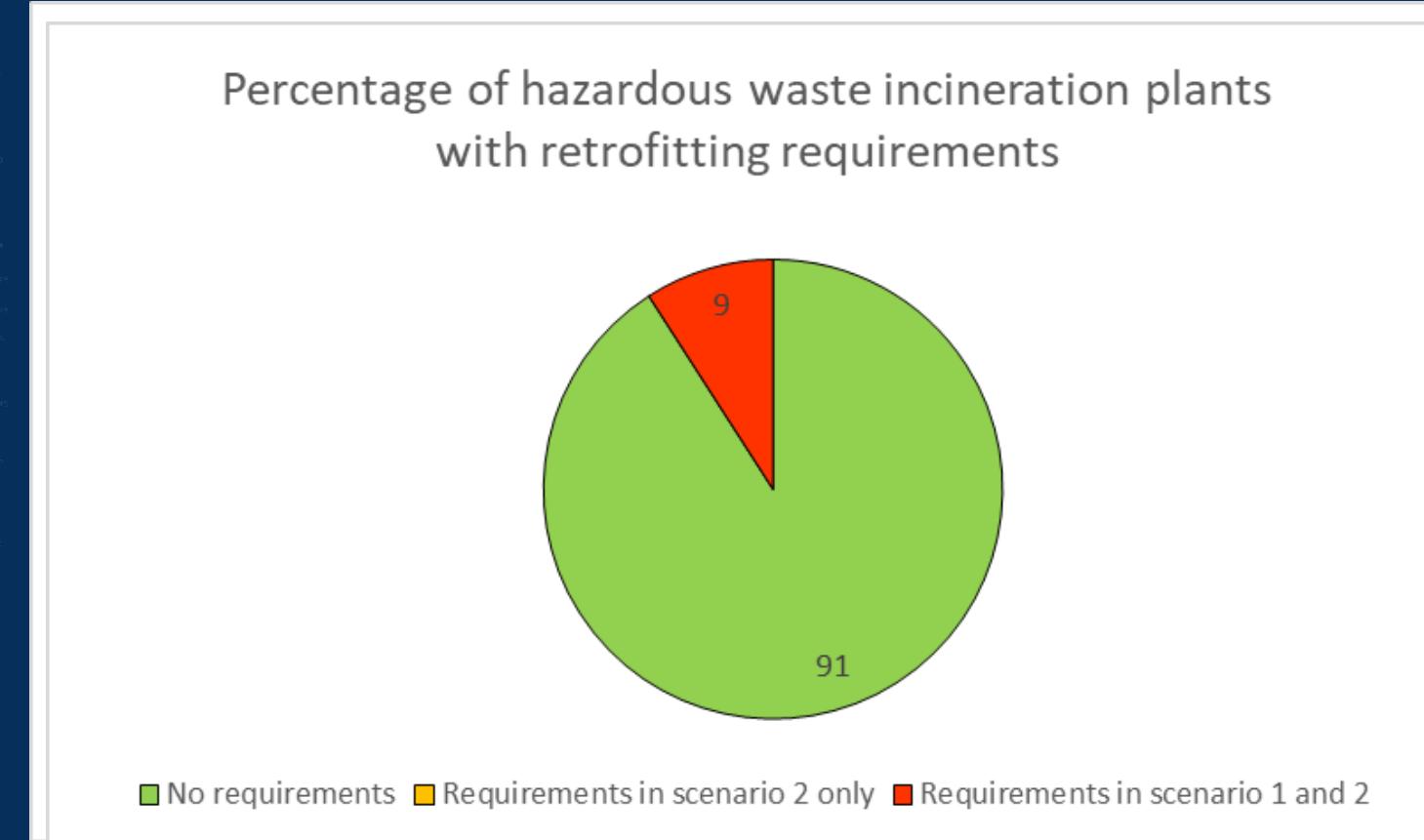


## General retrofit requirements



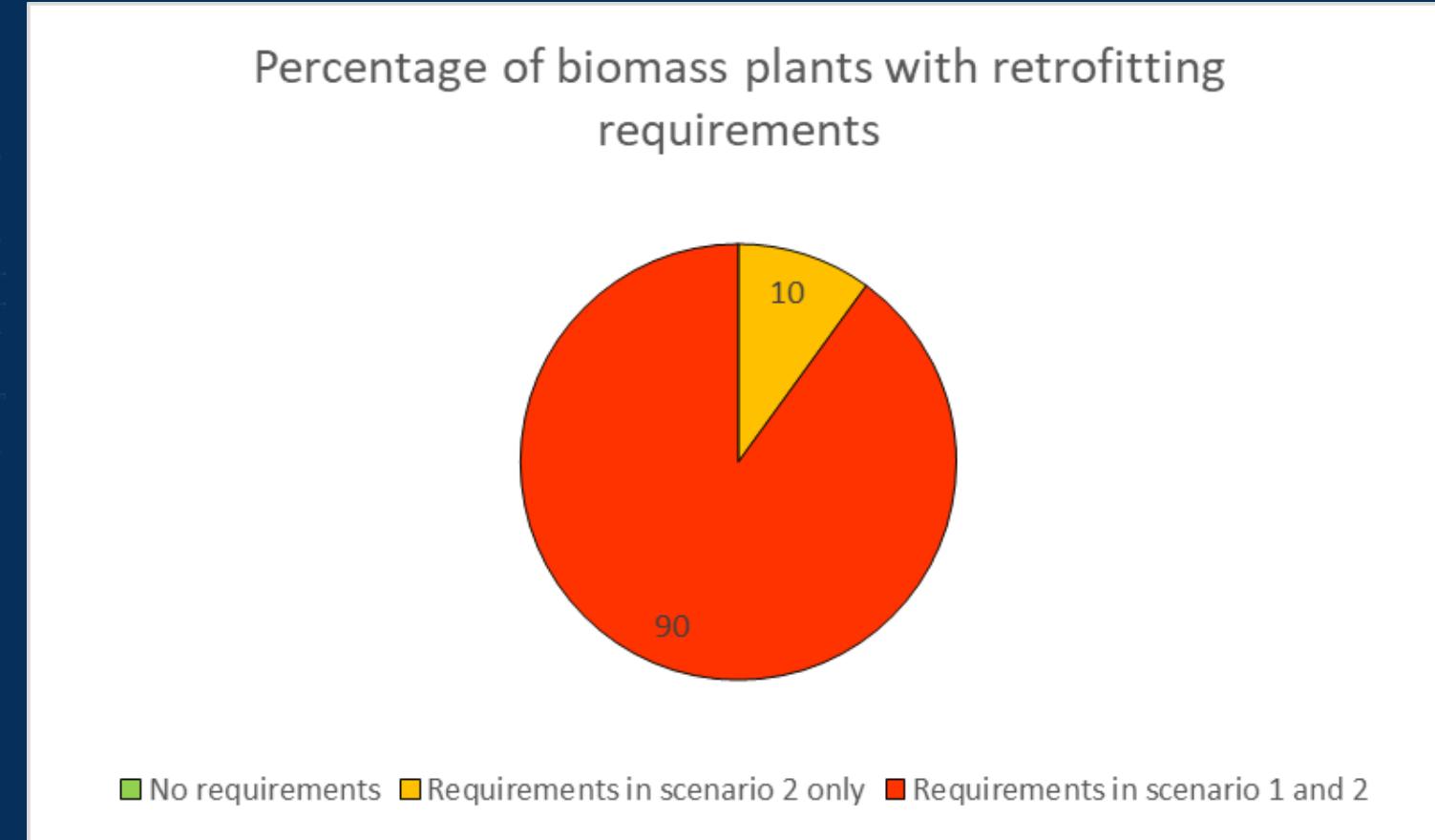


## General retrofit requirements

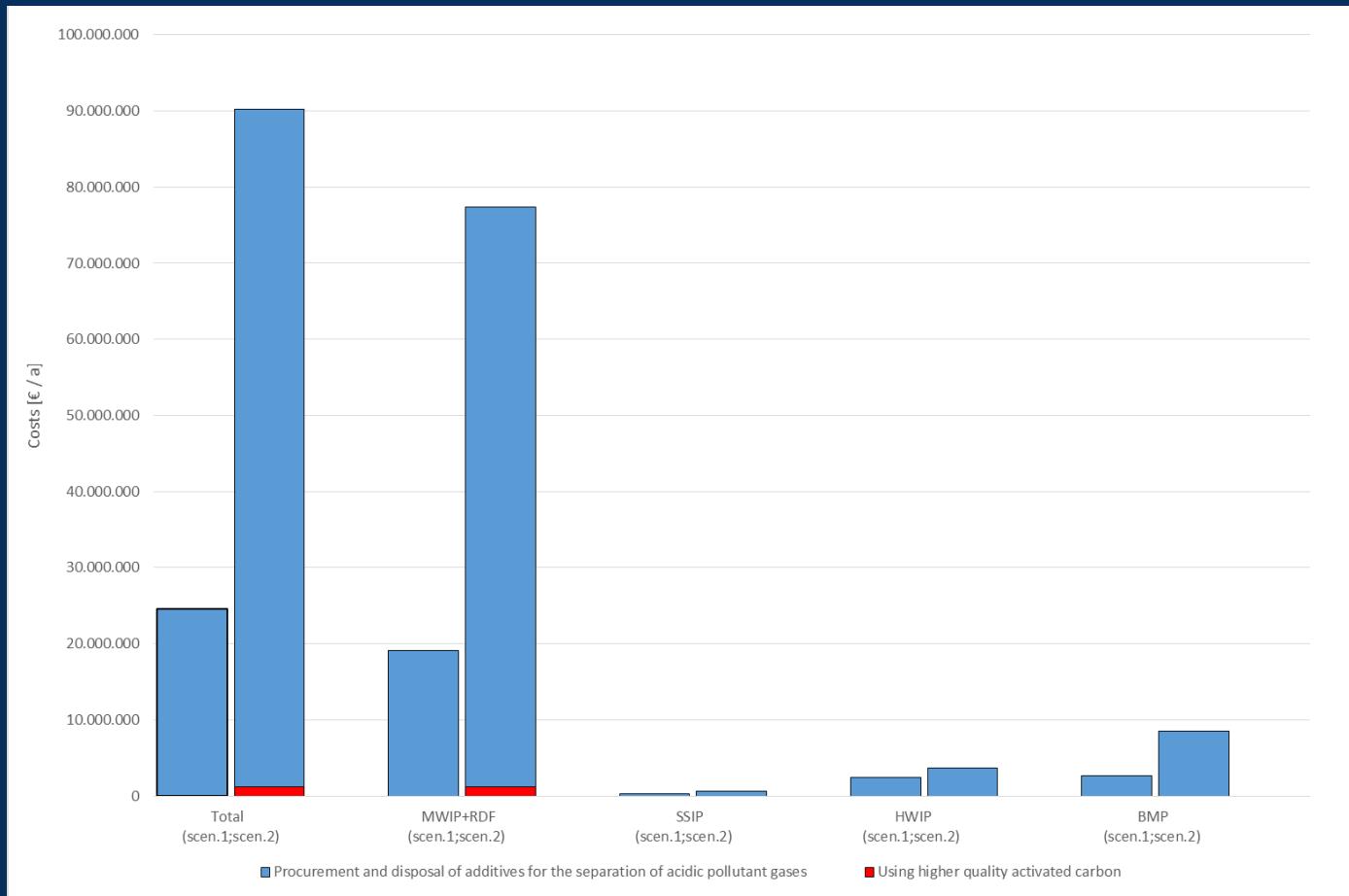




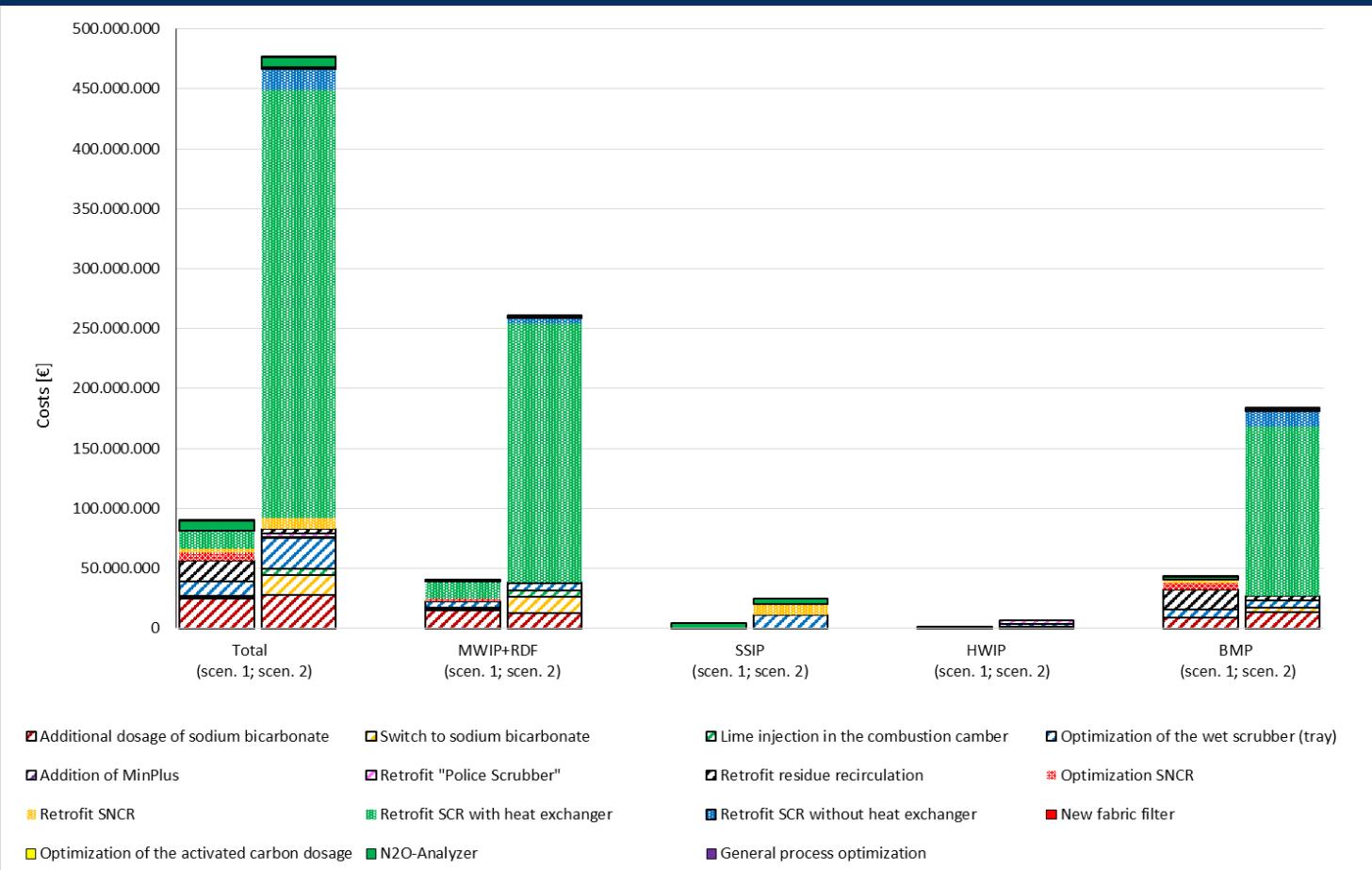
## General retrofit requirements



# Recurring follow-up costs (extrapolated) of the system stock for the respective scenarios [€/a]



# One-off follow-up costs (extrapolated) of the system stock for the respective scenarios [€]





# Conclusion



## Conclusion

As already mentioned above in the context of energy efficiency, it is not important to develop entirely new systems or processes,

**we have very efficient processes,**

but rather to combine available processes in an intelligent manner and exploit synergies!

Depending on the defined emission limit values, there is a corresponding investment requirement



Thank you for your attention!