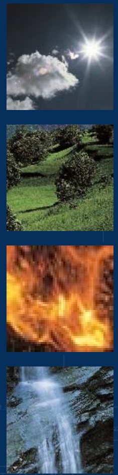

# Significance and challenges for flue gas treatment systems in waste incineration

**Rudi Karpf**

**THM Technische Hochschule Mittelhessen, Gießen**
**ete.a Ingenieurgesellschaft mbH**

TOTeM 46 – November 21-22, 2019 | Pisa Italy

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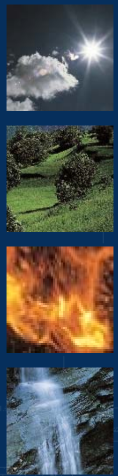
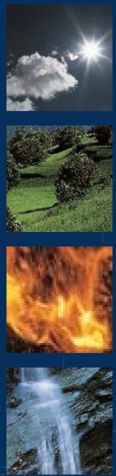


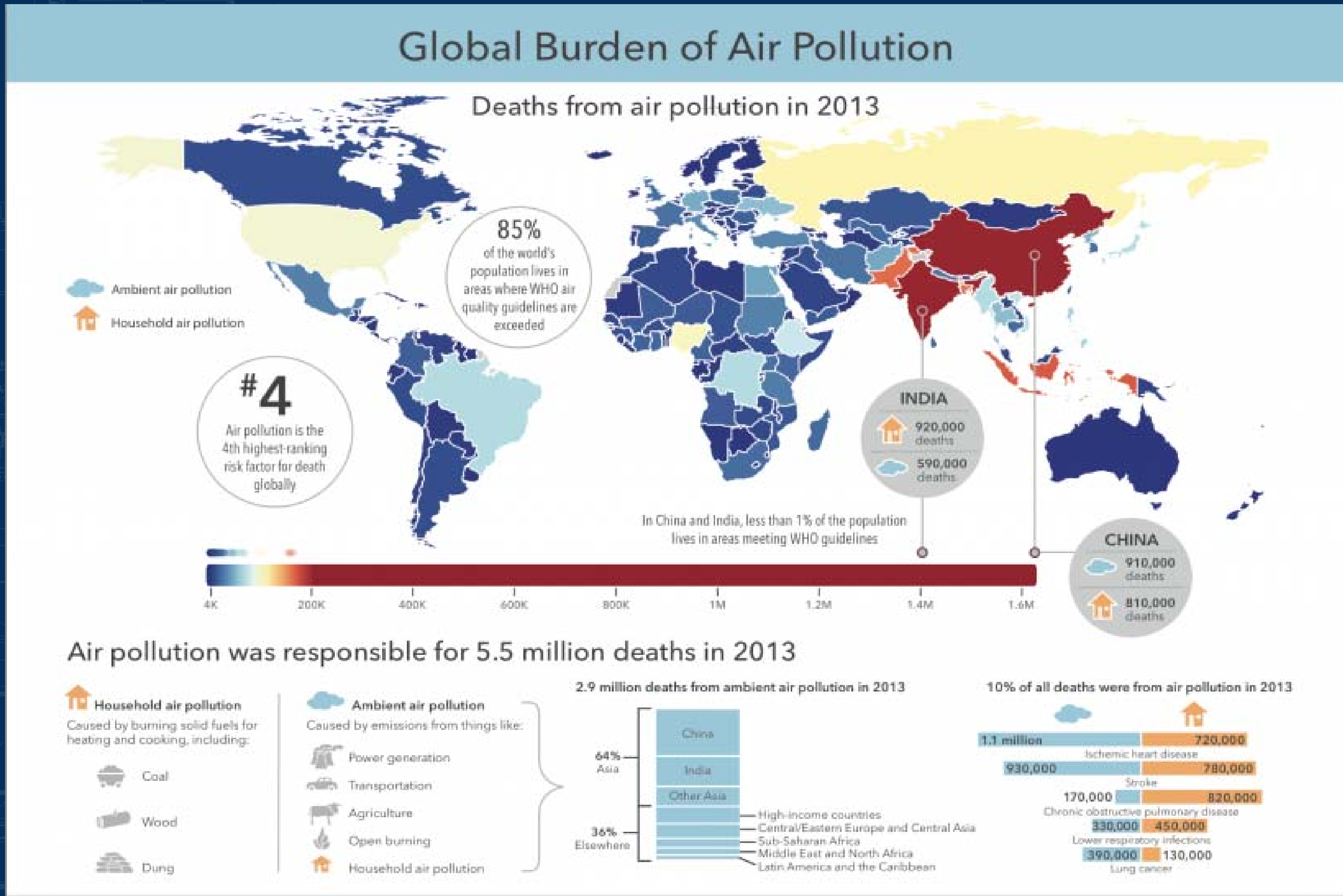
Source: © picture-alliance/AP

# Introduction

## Motivation and Background



# Significance of flue gas treatment




Source: WHO Global Burden of Disease Study 2013

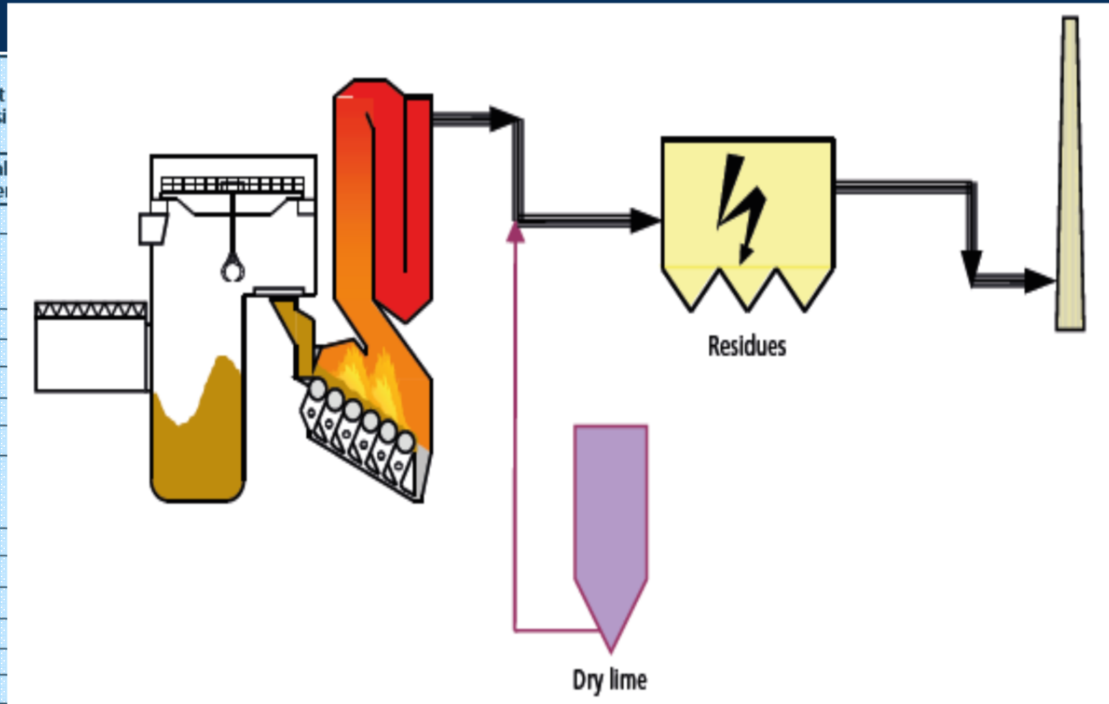
# Development of flue gas treatment systems according the legal requirements using the example of Germany

| Pollutant | Unit | TA Luft 1974 versi[on] General requiremen[ts] | | | | | | | YAV |
|---|---|---|---|---|---|---|---|---|---|
| $O_2$-reference percentage | Vol.-% dry | | | | | | | | |
| Dust | mg/m³ | 100 | | | | | | | |
| Total Organic Carbon (TOC) | mg/m³ | - | | | | | | | |
| Hydrogen chloride (HCl) | mg/m³ | 100 | | | | | | | |
| Hydrogen fluoride (HF) | mg/m³ | 5 | | | | | | | |
| Carbon monoxide (CO) | mg/m³ | 1,000 | | | | | | | |
| Sulphur dioxide ($SO_2$) | mg/m³ | - | | | | | | | |
| Nitrogen oxide ($NO_2$) | mg/m³ | - | | | | | | | 100[5) 7)] |
| Ammonia ($NH_3$) | mg/m³ | - | | | | | | | - |
| *Heavy metals* | | | | | | | | | |
| Mercury (Hg) | mg/m³ | - | | | | | | | .01[5) 6)] |
| | | | | | | | | | nts |
| Dioxins and furans | ng/m³ | - | | | | | | | |
| Class I | mg/m³ | 20*** | | | | | | | |
| Class II | mg/m³ | 50*** | 1 | 0.5 | 0.5 | | 0.5 | 0.5 | 0.5 |
| Class III | mg/m³ | 75*** | 5 | 0.05 | - | - | 0.05* | 1[4)] | 0.05 |

The concentration data is based on standard temperature and pressure, dry state, for each oxygen reference value; DAV indicates daily average value; HHAV indicates half hourly average value; YAV indicates yearly average value; Heavy metals class I: Σ Cd/Tl; Heavy metals class II: Σ Sb, As, Pb, Cr, Co, Ni, Cu, Mn, V, Sn; Heavy metals class III: Σ As, benzopyrene, Cd, Co(aq), Cr(IV)
* not applicable to use of coal, untreated wood only; ** combustion capacity > 6t/h or new facilities; *** related to the former classification

1) excluding Sn; 2) applicable to Tl (single substance); 3) applicable to Pb, Co, Ni, Se, Te; 4) applicable to Sb, Cr, CN, F, Cu, Mn, V, Sn; 5) not applicable to use of existing plants with RTI < 50 MW; 6) to be valid as of 2019; 7) not applicable for existing plants; 8) applicable to Mercury if the emission value is always < 20 % of the requested emission value

RTI: Rated Thermal Input

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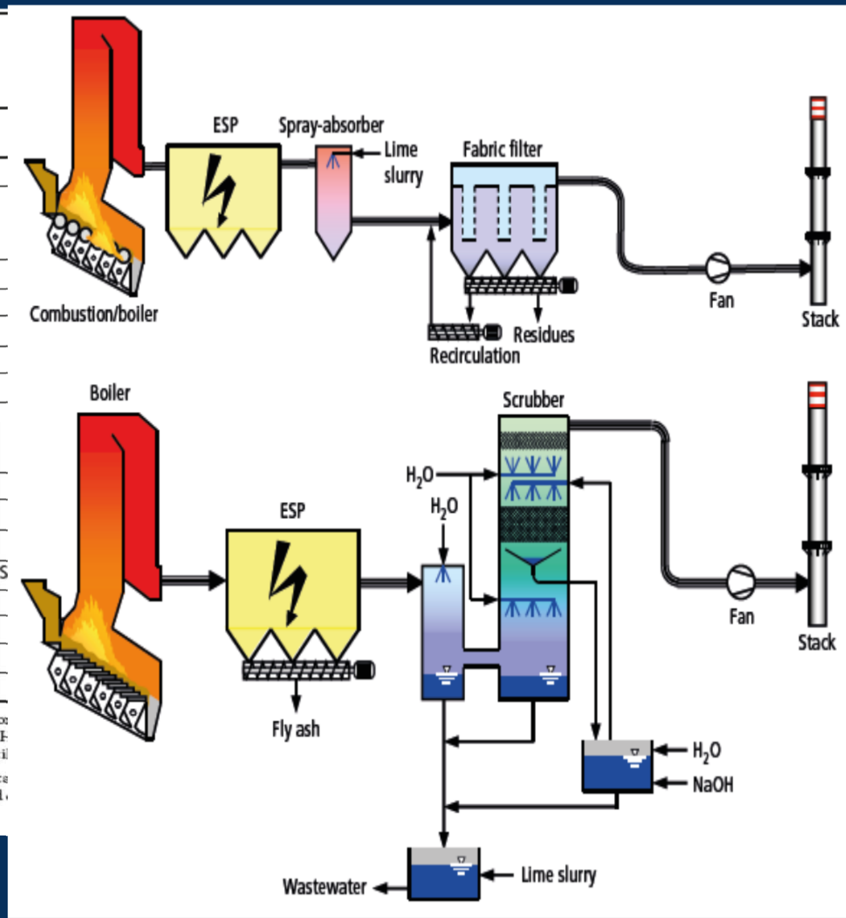
# Development of flue gas treatment systems according the legal requirements using the example of Germany

| Pollutant | Unit | TA Luft 1974 version | TA Luft 1986 version | …chV …ion |
|---|---|---|---|---|
| | | General requirements | General requirements | YAV |
| $O_2$-reference percentage | Vol.-% dry | 11 | | |
| Dust | mg/m³ | 100 | 30 | |
| Total Organic Carbon (TOC) | mg/m³ | - | 20 | |
| Hydrogen chloride (HCl) | mg/m³ | 100 | 50 | |
| Hydrogen fluoride (HF) | mg/m³ | 5 | 2 | |
| Carbon monoxide (CO) | mg/m³ | 1,000 | 100 | |
| Sulphur dioxide ($SO_2$) | mg/m³ | - | 100 | |
| Nitrogen oxide ($NO_2$) | mg/m³ | - | 500 | 100 5) 7) |
| Ammonia ($NH_3$) | mg/m³ | - | - | - |
| *Heavy metals* | | | | |
| Mercury (Hg) | mg/m³ | - | - | 0.01 5) 6) |
| | | | | |
| Dioxins and furans | ng/m³ | - | - | |
| Class I | mg/m³ | 20*** | 0.2 | |
| Class II | mg/m³ | 50*** | 1 | |
| Class III | mg/m³ | 75*** | 5 | |

The concentration data is based on standard temperature and pressure, dry state, for each o… …rly average value;
Heavy metals class I: Σ Cd/Tl; Heavy metals class II: Σ Sb, As, Pb, Cr, Co, Ni, Cu, Mn, V, Sn; H…
* not applicable to use of coal, untreated wood only; ** combustion capacity > 6t/h or new faci… …not applicable for
1) excluding Sn; 2) applicable to Tl (single substance); 3) applicable to Pb, Co, Ni, Se, Te; 4) applica…
existing plants; 6) applicable to Mercury if the emission value is always < 20 % of the requested…
RTI: Rated Thermal Input

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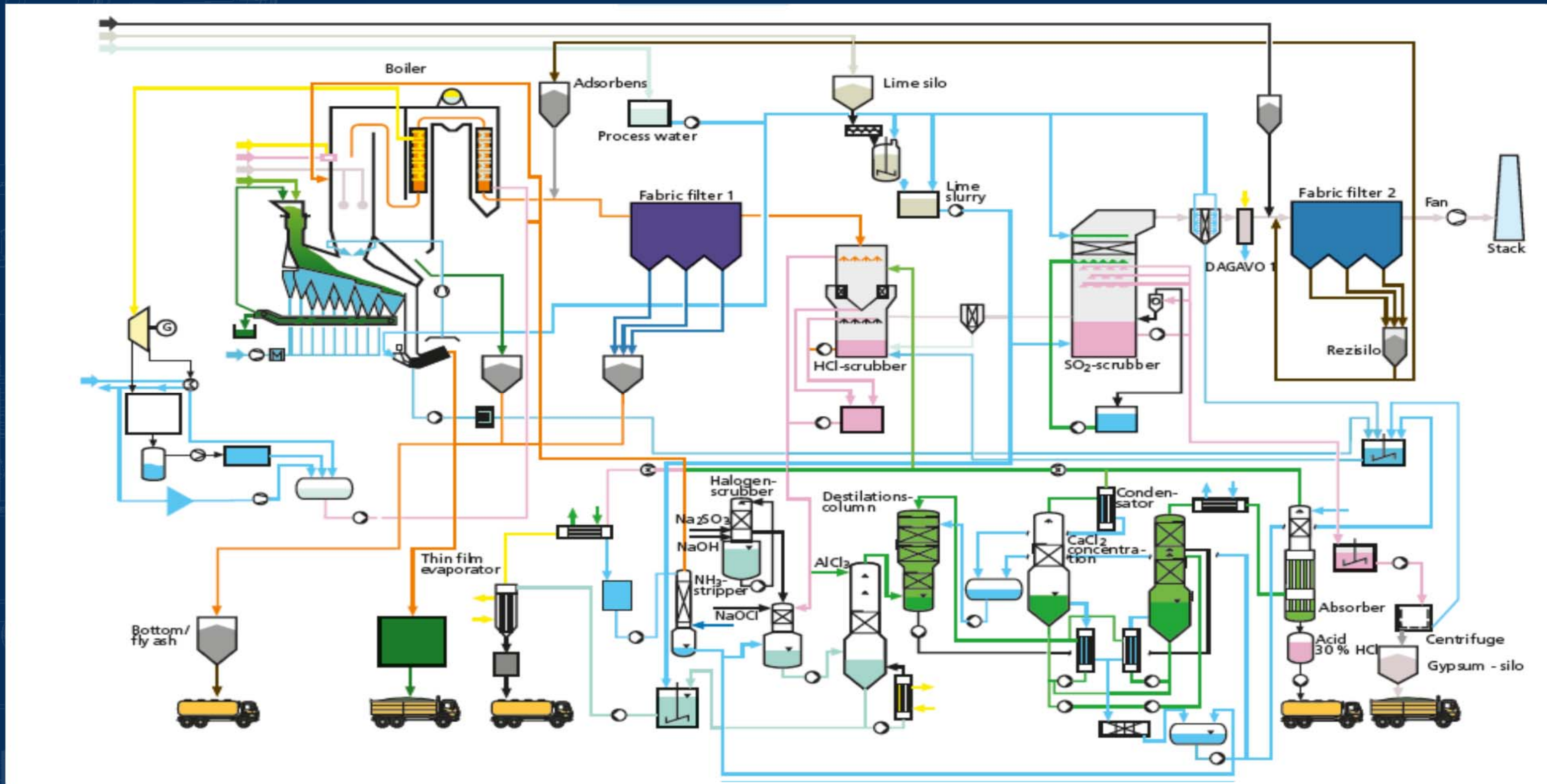
# Development of flue gas treatment systems according the legal requirements using the example of Germany

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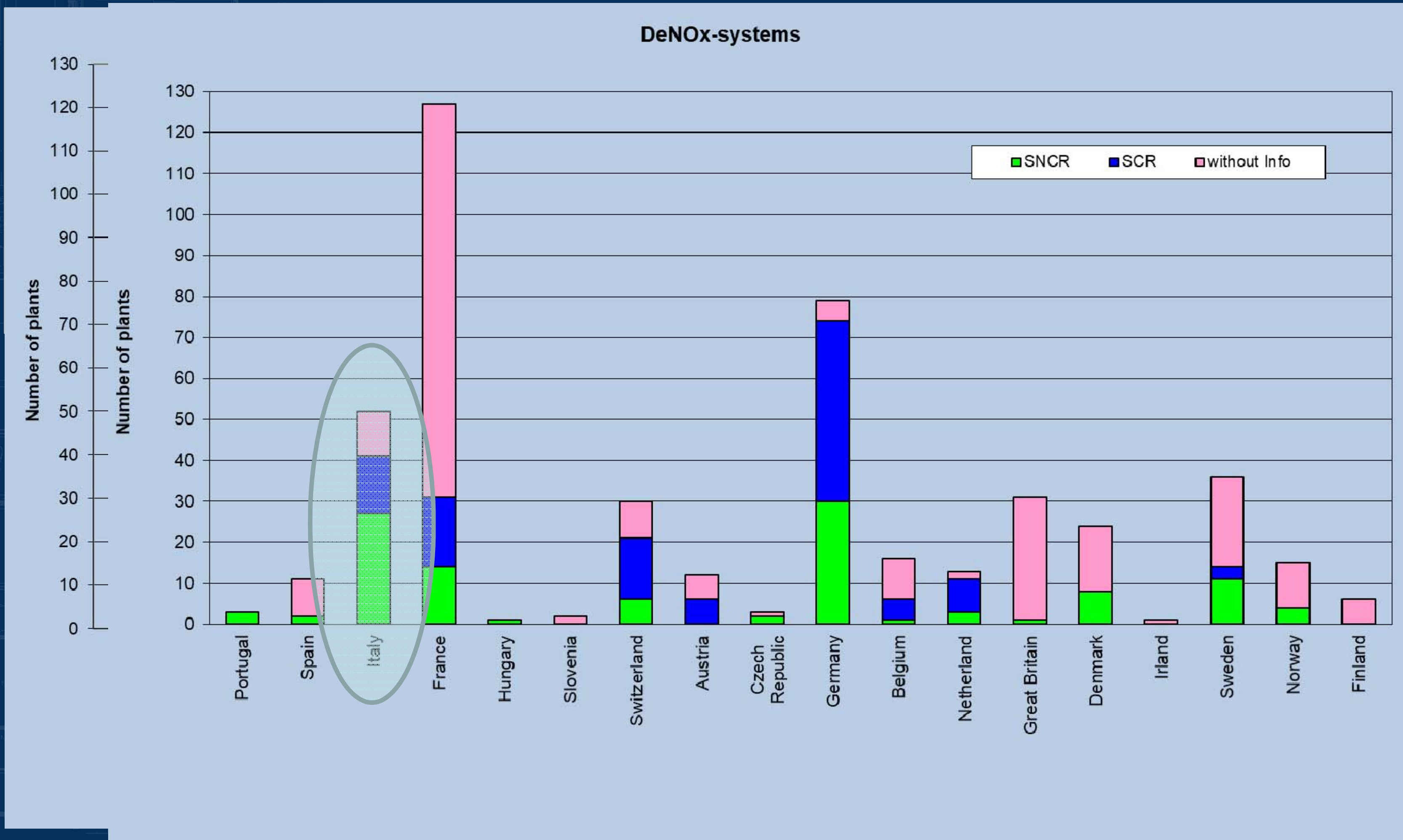
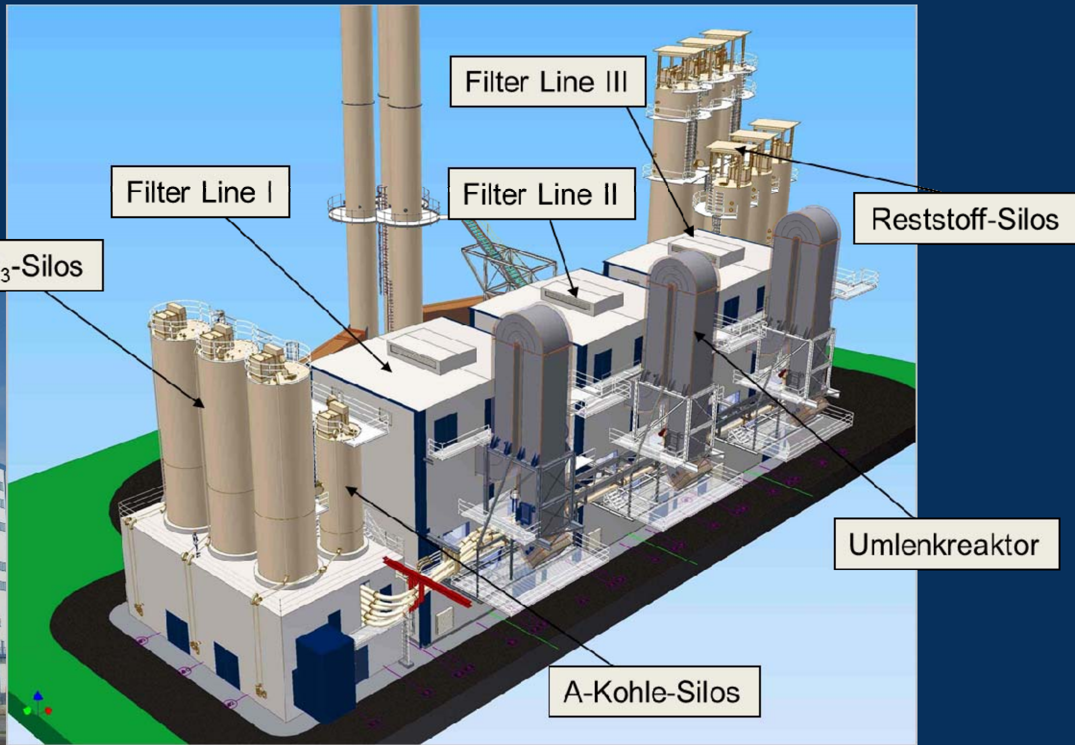
## Separation of acid gases based on German wte plants




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

# Simple plant construction
## SNCR – one-stage dry sorption with $NaHCO_3$




Source: Lühr-Filter, Stadthagen

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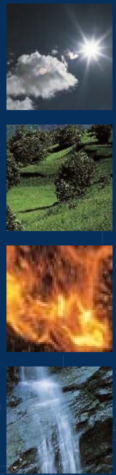

# Complex plant construction

## ESP – Spray-dryer – ESP – 2-stage Scrubber – Aerosol-separator – SCR – Fabric filter



Source: Interargem, Bielefeld

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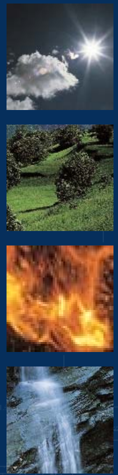

# challenges

## at emission control systems

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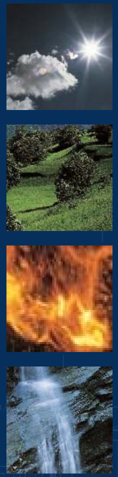
# Revision BREF WI



| Process Parameter | Unit | Emission limits of 17. BImSchV | | | BAT AEL's Existing plants | BAT AEL's New plants | Monitoring frequency |
|---|---|---|---|---|---|---|---|
| | | DAV | HAV | JAV | DAV | DAV | |
| **Dust** | mg/m³, i.N.tr. | 5 | 20 | - | <2-5 | | continuous |
| **HCl** | mg/m³, i.N.tr. | 10 | 60 | - | <2-8 | <2-6 | continuous |
| **HF** | mg/m³, i.N.tr. | 1 | 4 | - | <1 | < 1 | continuous |
| **$NO_x$ (SCR)** | mg/m³, i.N.tr. | 150 | 400 | 100 | 50-150 | 50-120 | continuous |
| **$SO_x$ als $SO_2$** | mg/m³, i.N.tr. | 50 | 200 | - | 5-40 | 5-30 | continuous |
| **Hg** | mg/m³, i.N.tr. | 0,03 | 0,05 | 0,01 | <0,005-0,02 | | continuous |
| | | | | | 0,001-0,01 | | Long-term monitoring |
| **$NH_3$** | mg/m³, i.N.tr. | 10 | 15 | - | 2-10 | 2-10 | continuous |
| **$N_2O$** | | | | | No value | | yearly |
| **CO** | mg/m³, i.N.tr. | 50 | 100 | - | 10-50 | | continuous |
| **Cd + Tl** | mg/m³, i.N.tr. | | 0,05 | | 0,005-0,02 | | every 6 Month |
| **∑Sb+As+Pb+Cr+Co+ Cu+Mn+Ni+V+(Sn)** | mg/m³, i.N.tr. | | 0,5 | | 0,01-0,3 | | |
| **∑As+Benzo(a)pyren+ Cd+Co+Cr** | mg/m³, i.N.tr. | | 0,05 | | - | | yearly |
| **PCDD/F (*)** | ng I-TEQ /m³, i.N.tr. | | - | | < 0,01-0,06 | < 0,01-0,04 | every 6 Month |
| | | | | | < 0,01-0,08 | < 0,01-0,06 | monthly |
| **PCDD/F + Dioxin like PCBs** | ng WHO-TEQ /m³, i.N.tr. | | 0,1 | | < 0,01-0,08 | < 0,01-0,06 | every 6 Month |
| | | | | | < 0,01-0,1 | < 0,01-0,08 | monthly |
| **TVOC / $C_{ges.}$** | mg/m³, i.N.tr | 10 | 20 | - | < 3-10 | | continuous |

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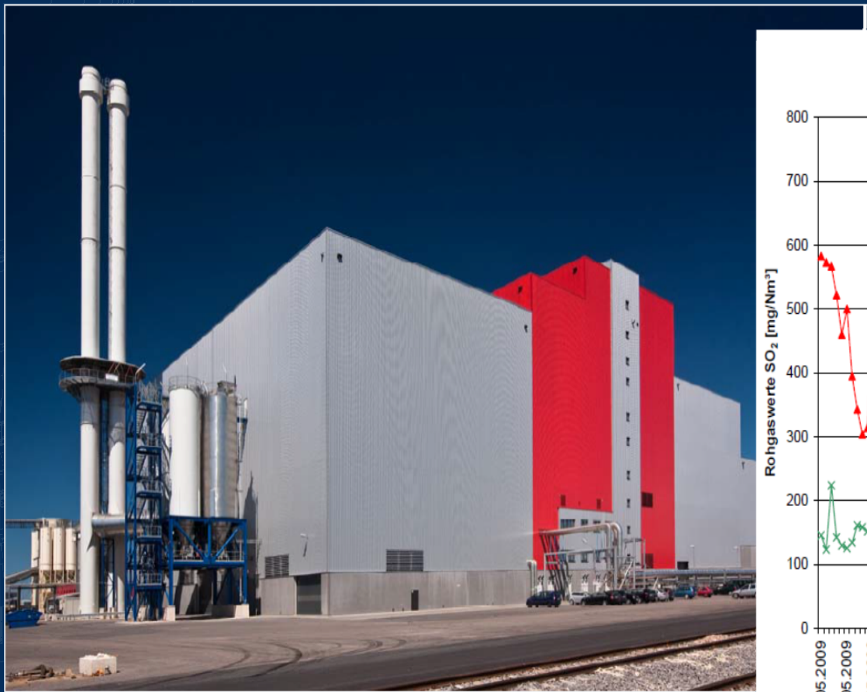
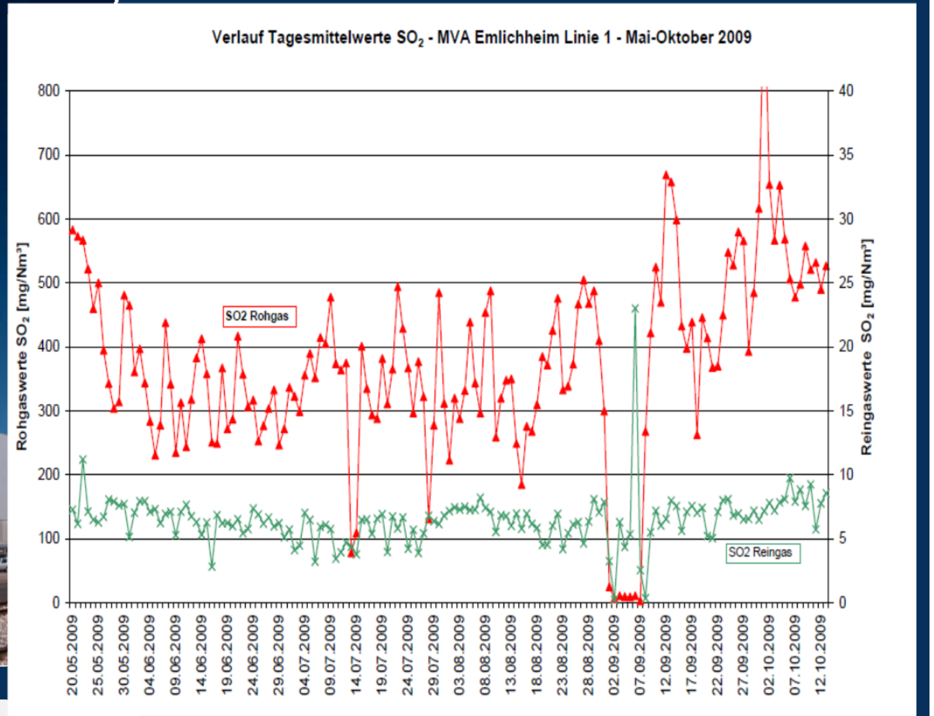
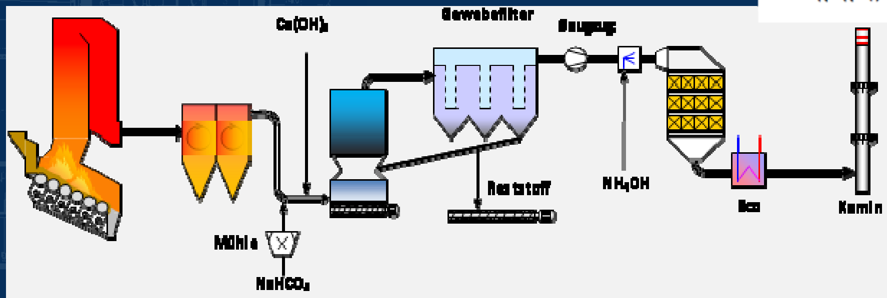
# Waste incineration plant EVI-Europark (Germany)






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

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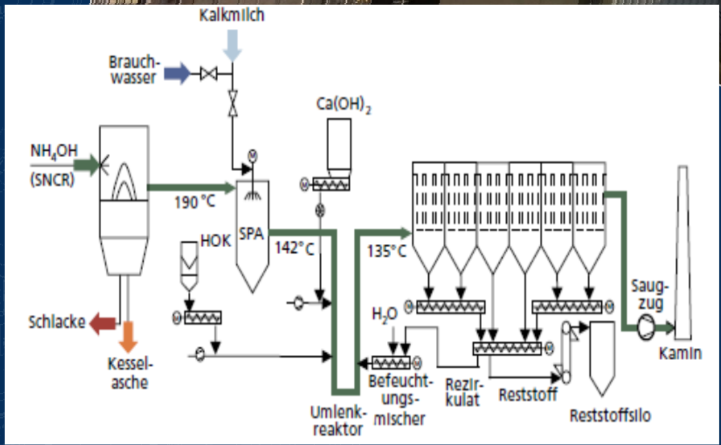
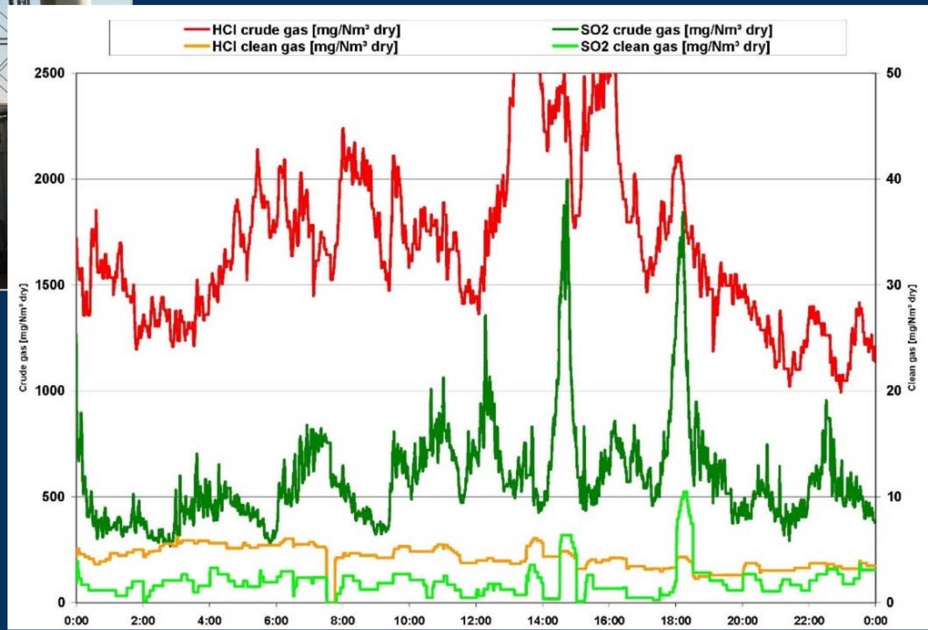
# Waste incineration plant Rothensee (Germany)




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

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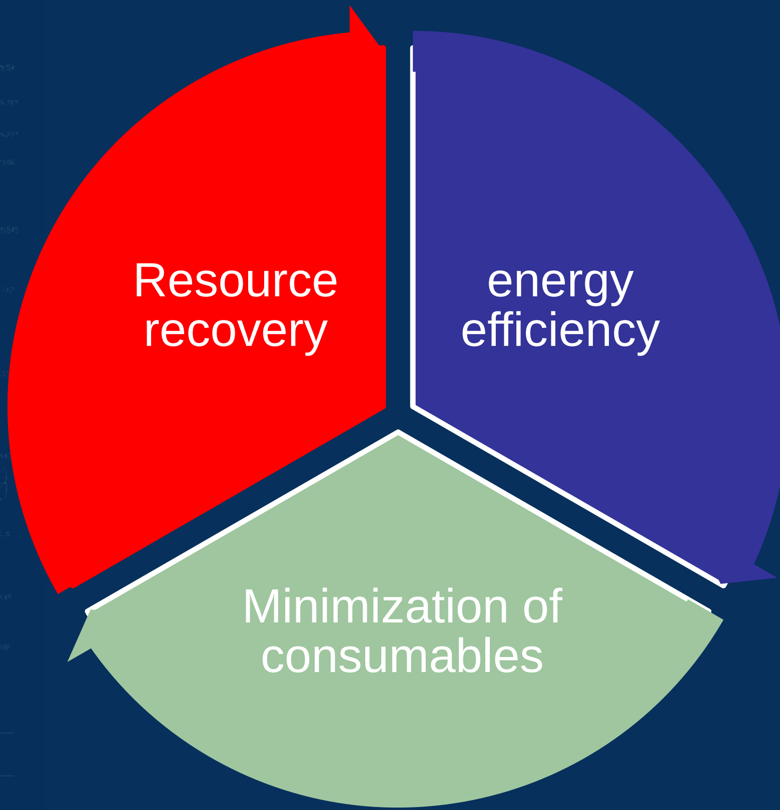
The motivation of today's developments lies not only in efficient emission of harmful gases in topics such as

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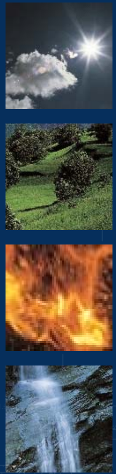
A very comprehensive and detailed study on the net emissions balance as a function of energy expenditure shows that the energy expenditure for a multi-stage flue gas treatment system with minimum emissions is not necessarily higher than that of single-stage systems!

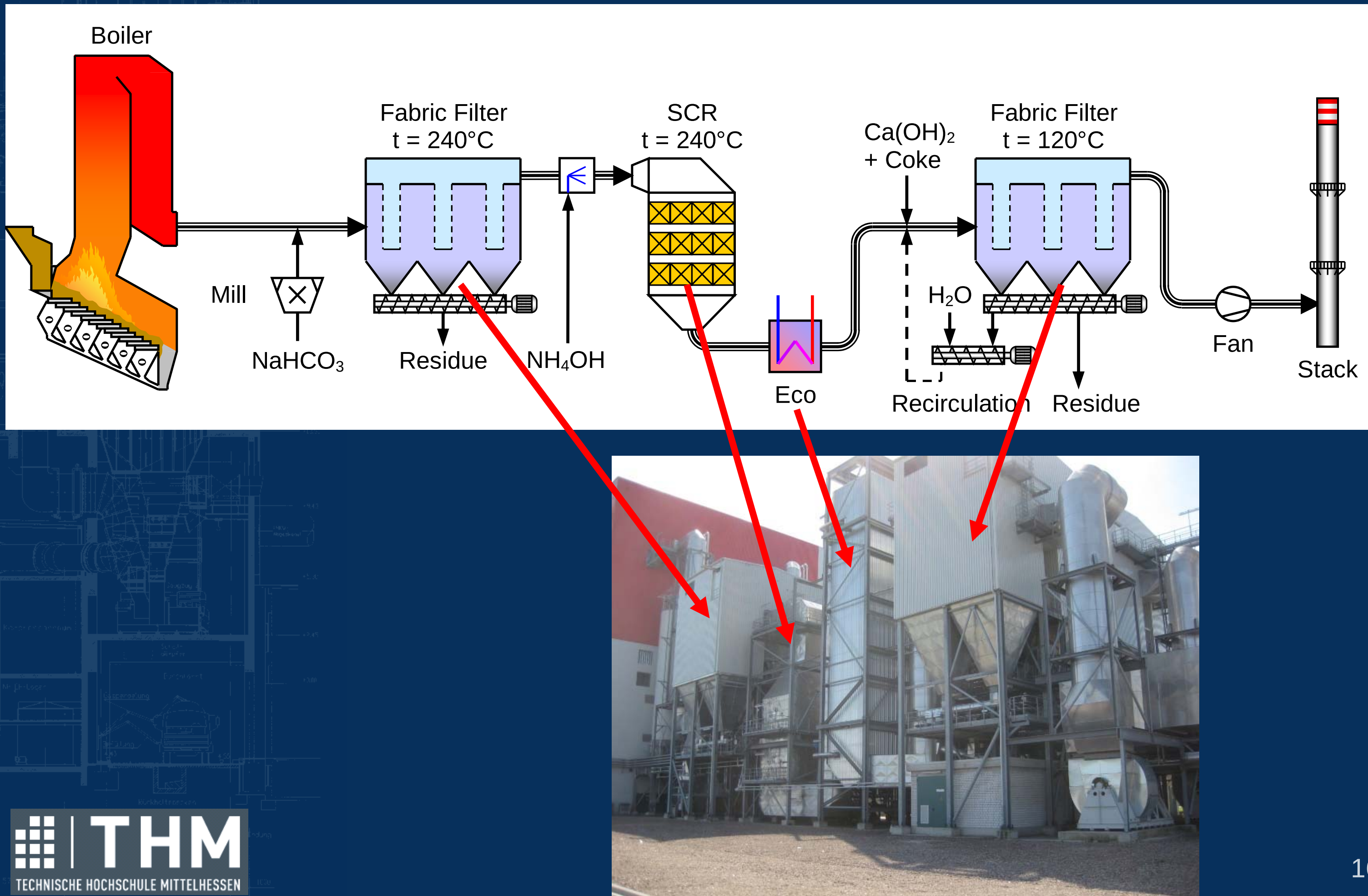
→ Modern-day and future know-how regarding the design of efficient plants will not necessarily imply the development of new processes, but rather place a focus on the intelligent combination and configuration of proven process stages





# Challenges for flue gas treatment systems in the future

One example of this is the Delfzijl waste incineration facility in the Netherlands.

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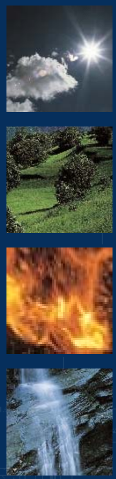
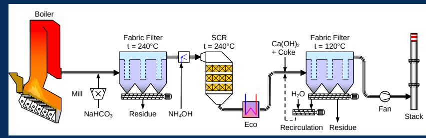
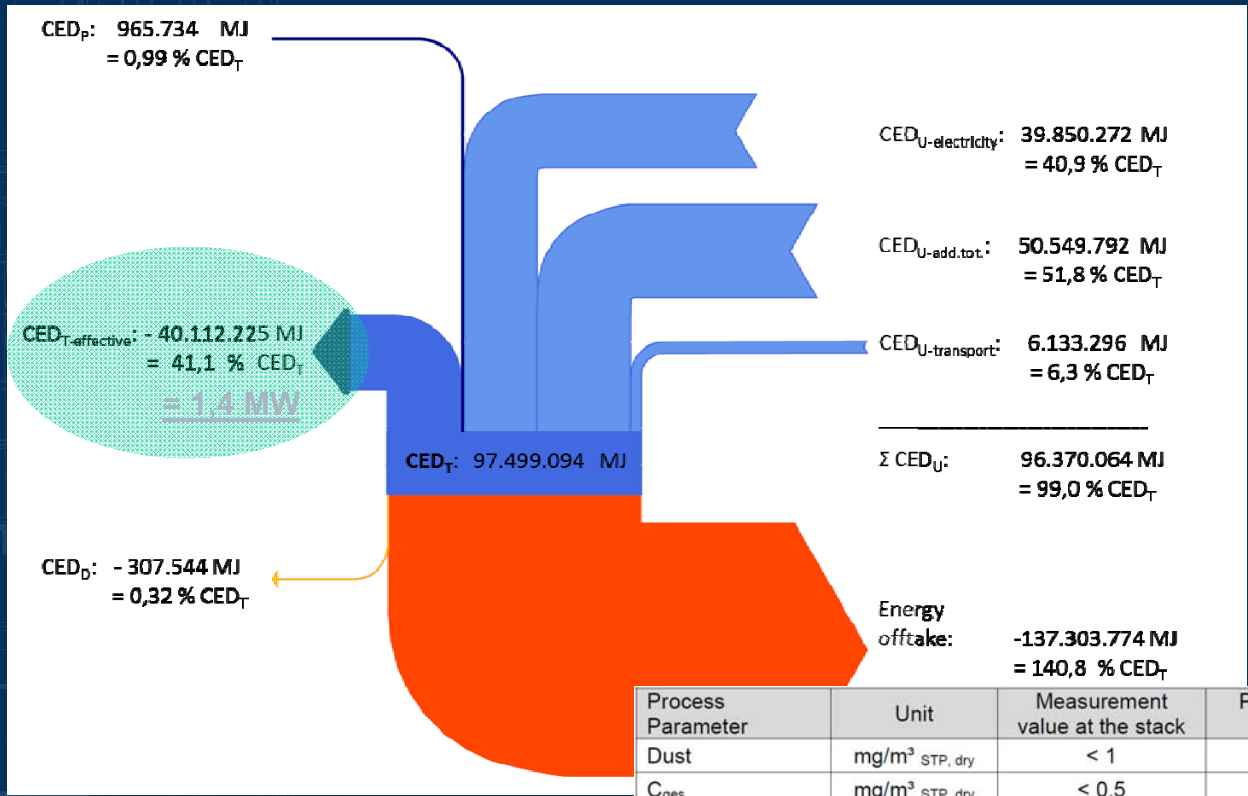





# Challenges for flue gas treatment systems in the future

## In order to compare different systems the cumulative energy demand was used




Conditions:

- HCl-inlet 1300 mg/m³
- $SO_2$-inlet 500 mg/m³
- Reference period 8000 h

| Process Parameter | Unit | Measurement value at the stack | Permitted emission limits |
|---|---|---|---|
| Dust | mg/m³ STP, dry | < 1 | 10 |
| $C_{ges}$ | mg/m³ STP, dry | < 0,5 | 10 |
| HCl | mg/m³ STP, dry | < 1 | 5 |
| $SO_2$ | mg/m³ STP, dry | < 5 | 25 |
| $NO_x$ | mg/m³ STP, dry | < 70 | 70 |
| Hg | mg/m³ STP, dry | < 0,005 | 0,02 |
| CO | mg/m³ STP, dry | < 10 | 50 |
| $NH_3$ | mg/m³ STP, dry | < 2 | 5 |
| Flue gas temperature | °C | 135 | |

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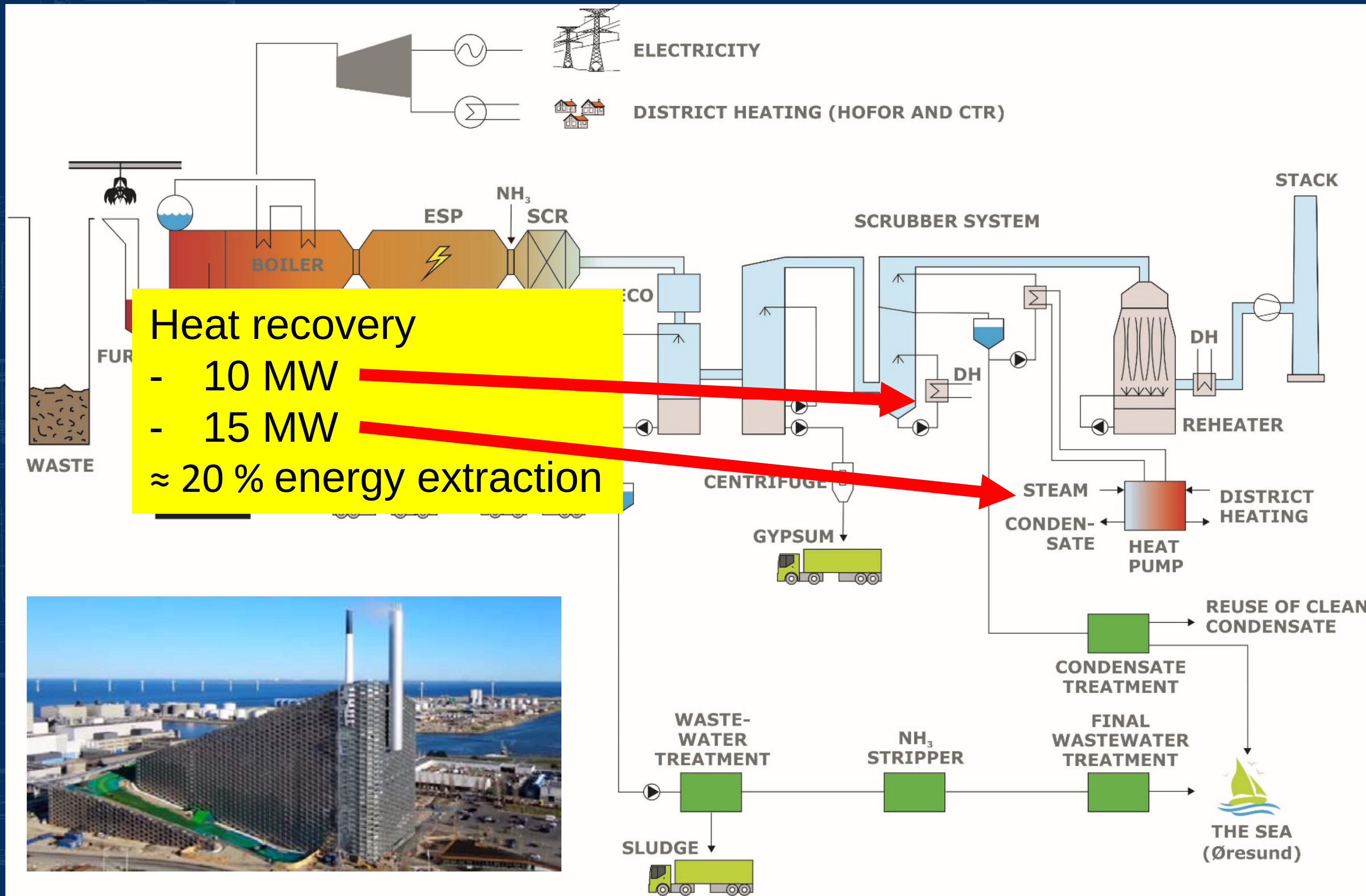
## Wte plant Copenhagen - Amanger

Heat recovery
- 10 MW
- 15 MW

≈ 20 % energy extraction




Source: Hulgaard, T.; Søndergaard, I.: Integrating waste-to-energy in Copenhagen, Denmark. Civil Engineering, Volume 171, Issue CE5, Pages 3-10

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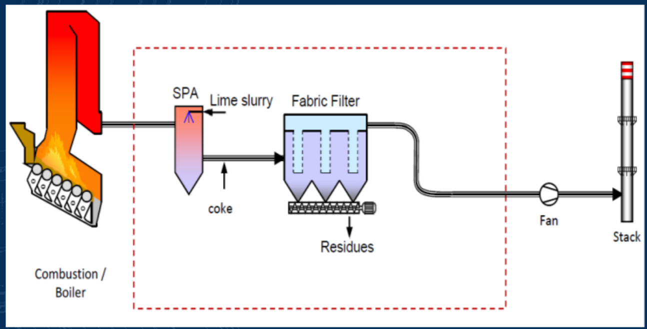
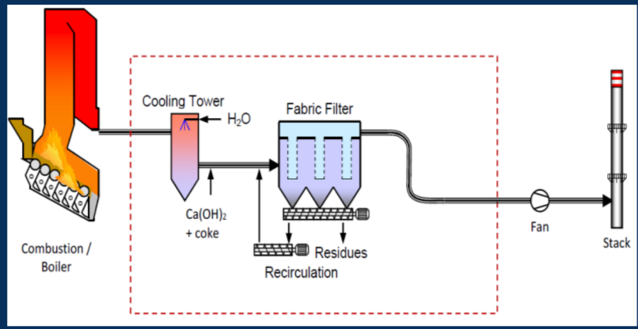
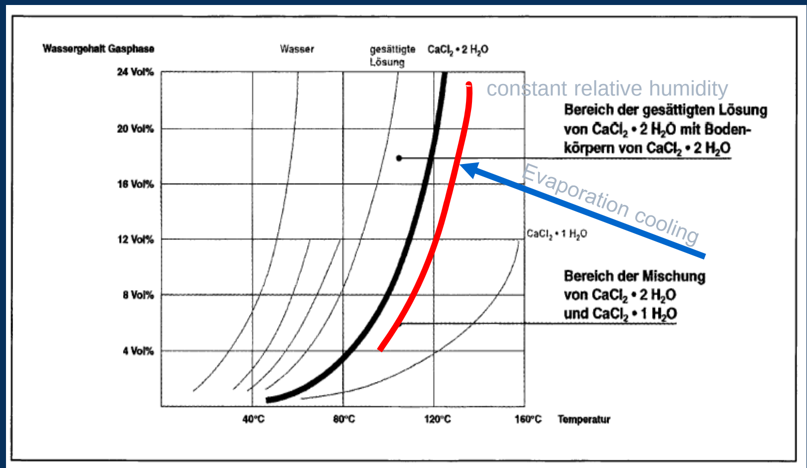
Substitution of a spray absorber to a pure cooling tower

Change from lime slurry to dry lime injection




Lower outlet temperatures with the same tower by a longer residence time for pure water droplets




Various fabric filter temperature by moisture control system

# Substitution of spray absorption by a pure water injection (cooling tower) - comparison of operation costs

## Gas composition

| | |
|---|---|
| - flue gas stream | 100.000 $m^3/h$ st. w. |
| - HCl | 1.000 $mg/m^3$ |
| - $SO_2$ | 300 $mg/m^3$ |
| - HF | 20 $mg/m^3$ |
| - $H_2O$ | 15 Vol.% |

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# Substitution of spray absorption by a pure water injection (cooling tower) - comparison of operation costs

| Operation costs | unit | cond. dry absorption | Spray absorption |
|---|---|---|---|
| Lignite coke | €/h | 3,048 | 3,048 |
| Active coke | €/h | 0 | 0 |
| lime $Ca(OH)_2$ | €/h | 21,15 | 26,741 |
| lime CaO | €/h | | 10,71 |
| water | €/h | 2,49 | 2,21 |
| Compressed air (8 bar) | €/h | 54,4 | 54,4 |
| Electrical energy | €/h | 16,24 | 18,56 |
| residues | €/h | 61,56 | 73,32 |
| | | | |
| Sum of operation costs | €/h | 158,89 | 188,99 |
| Difference | €/h | 0 | 30,11 |
| Differenz | % | 0,00 | 18,95 |
| Annual costs at 8000 h/a | €/a | 1.271.084 | 1.511.928 |
| Difference | €/a | - | 240.844 |

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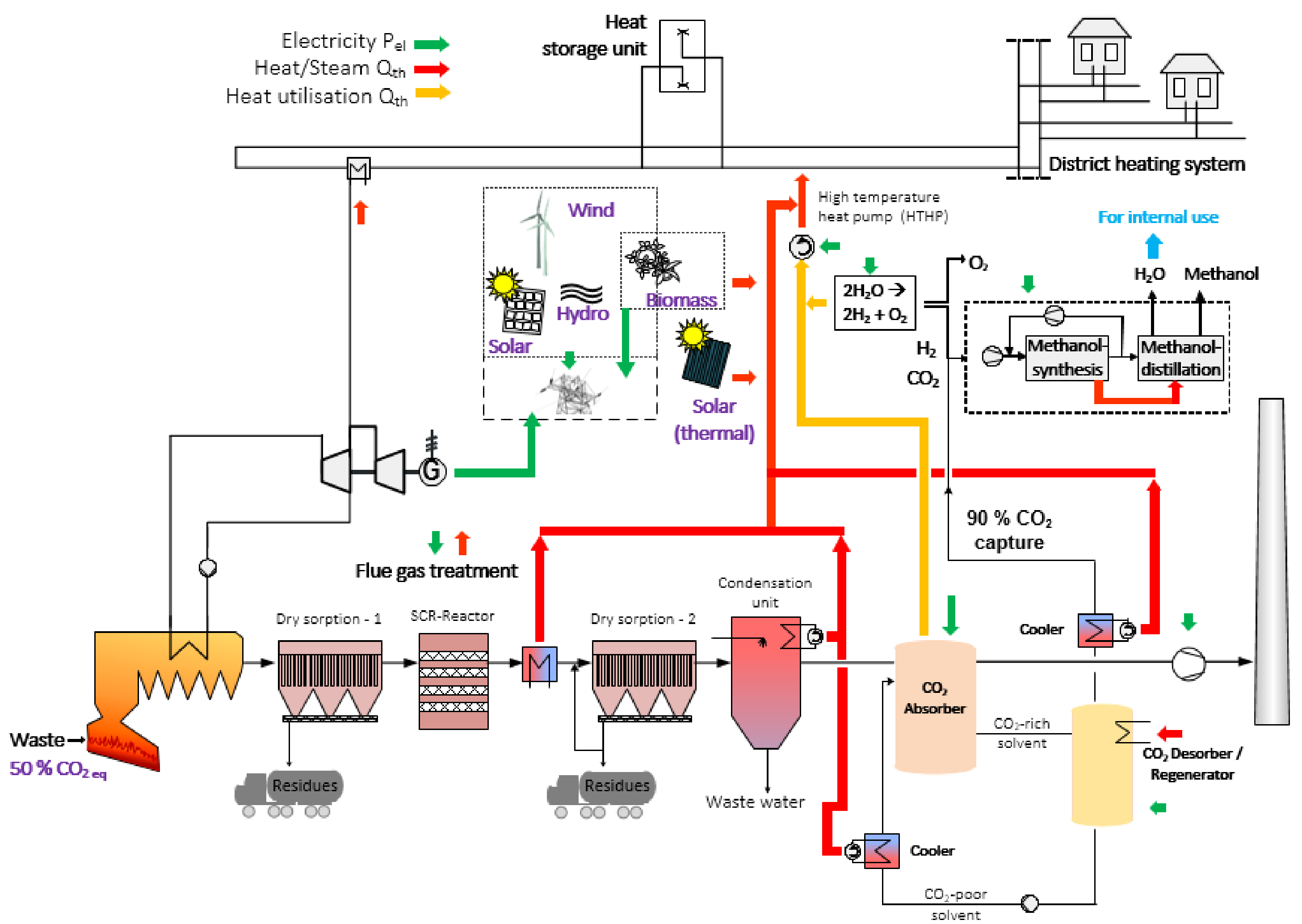
## Challenges for flue gas treatment systems in the future

Apart from energy efficiency, recent discussions indicate the imminent renaissance of recovery of valuable by-products from the flue gas – this time, however, not in the form of producing materials such as gypsum or hydrochloric acid, but in the form of feeding the combustion product $CO_2$ back into the carbon cycle, for instance in the form of methanol!

## Optimized flue gas treatment in adaptation to the future energy market

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## Challenges for flue gas treatment systems in the future

# My appeal is …

**.. as regards the future selection of sites for new plants, this implies that plants should be built at sites where a suitable infrastructure including energy sinks exist!**

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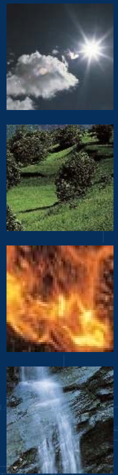
# Summary



# Summary

- The current emission level of flue gas treatment plants behind waste incineration plants limits to the areas of trust of the existing measurement technology, so that there is also basically potential for optimization, but not the ultimate challenges.

- The future challenges lie in addition to an efficient separation of harmful gases in topics such as
  - Energy efficiency,
  - Minimization of consumables
  - Resource recovery.

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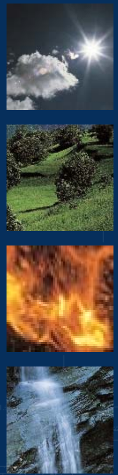

# Summary

- In addition, especially for new plants, the location plays an essential role, so that synergies can be used, which must be taken into account when planning the prophesied mega-cities.

- It will not be important to develop completely new systems or processes, but rather the intelligent combination of existing procedures and the use of synergies.

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# Thank you!