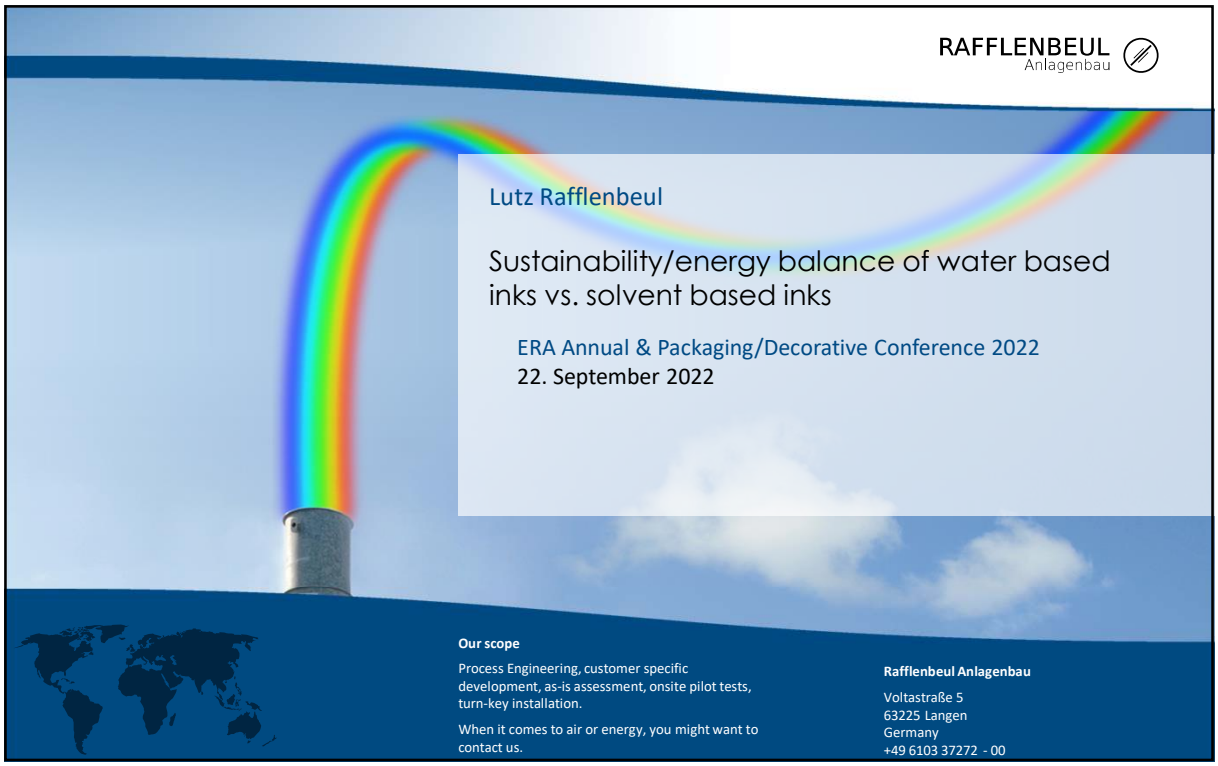
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Anlagenbau
Lutz Rafflenbeul
Sustainability/energy balance of water based inks vs. solvent based inks
ERA Annual & Packaging/Decorative Conference 2022
22. September 2022
Our scope
Process Engineering, customer specific development, as-is assessment, onsite pilot tests, turn-key installation.
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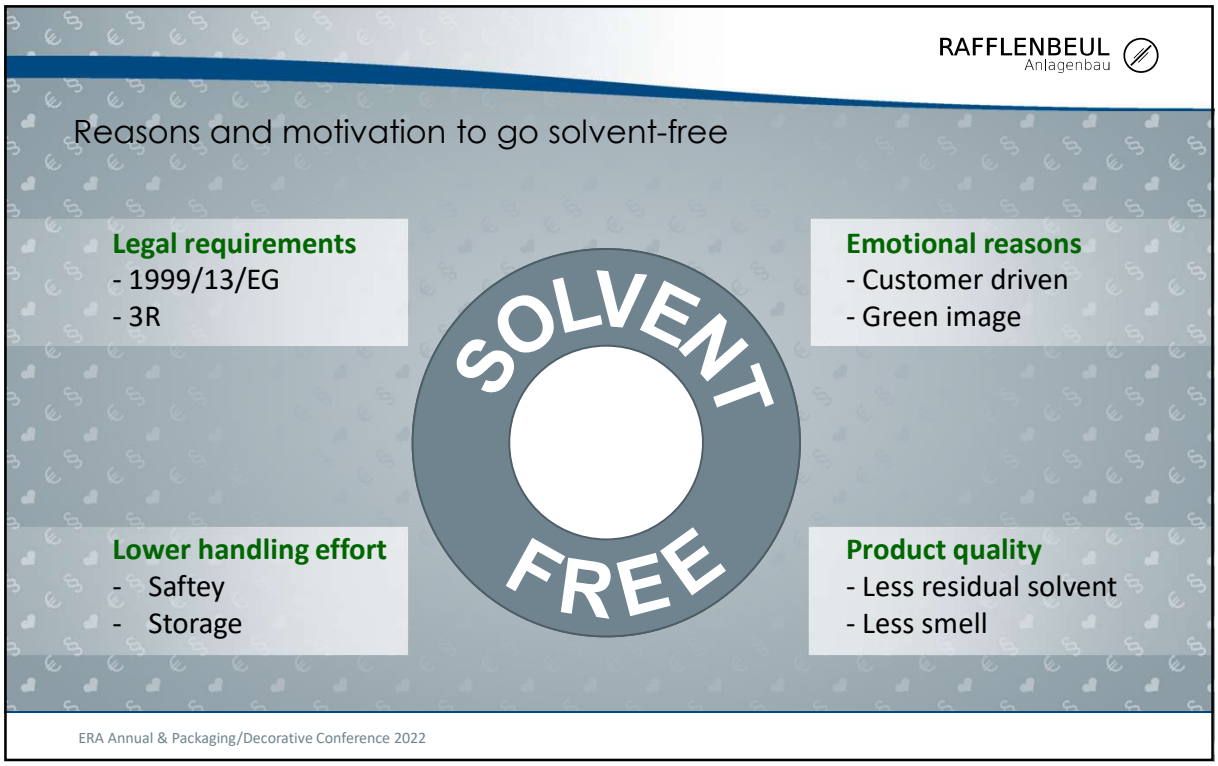
Rafflenbeul Anlagenbau
Voltastraße 5
63225 Langen
Germany
+49 6103 37272 - 00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Reasons and motivation to go solvent-free
Legal requirements
- 1999/13/EG
- 3R
Emotional reasons
- Customer driven
- Green image
SOLVENT FREE
Lower handling effort
- Saftey
- Storage
Product quality
- Less residual solvent
- Less smell
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...but should we go for it?

Broken promise
- Is it less or free?
- Is it green?

Higher effort
- No purchase savings (yet)
- Higher drying costs

Impact on production
- Printing speed
- Doctor plate lifetime

Less adjustment
- Main parameter: heat

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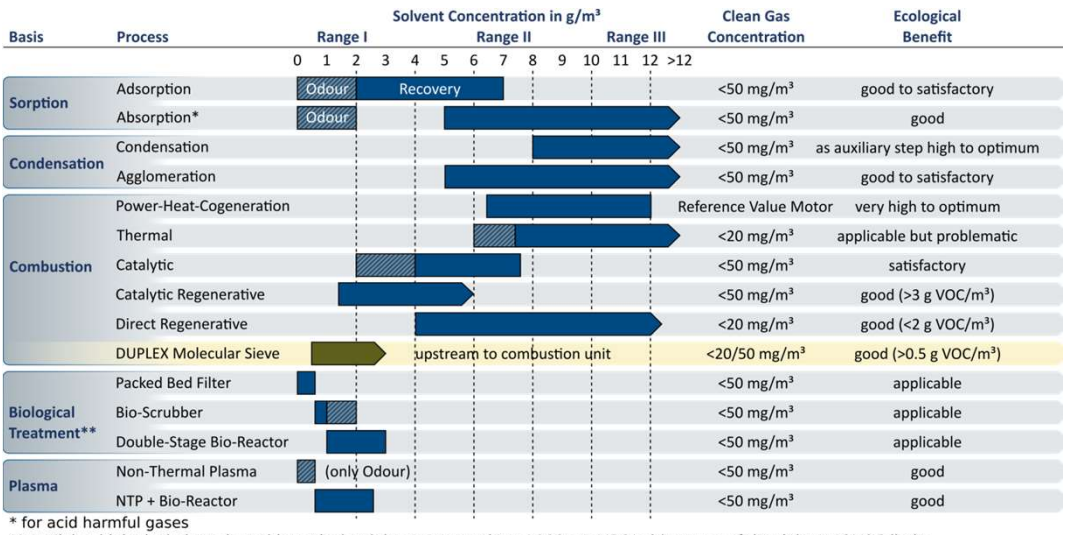
VOC-Exhaust needs treatment



Basis	Process	Clean Gas Concentration	Ecological Benefit
Sorption	Adsorption	<50 mg/m³	good to satisfactory
	Absorption*	<50 mg/m³	good
Condensation	Condensation	<50 mg/m³	as auxiliary step high to optimum
	Agglomeration	<50 mg/m³	good to satisfactory
Combustion	Power-Heat-Cogeneration	Reference Value Motor	very high to optimum
	Thermal	<20 mg/m³	applicable but problematic
	Catalytic	<50 mg/m³	satisfactory
	Catalytic Regenerative	<50 mg/m³	good (>3 g VOC/m³)
	Direct Regenerative	<20 mg/m³	good (<2 g VOC/m³)
	DUPLEX Molecular Sieve	<20/50 mg/m³	good (>0.5 g VOC/m³)
Biological Treatment**	Packed Bed Filter	<50 mg/m³	applicable
	Bio-Scrubber	<50 mg/m³	applicable
	Double-Stage Bio-Reactor	<50 mg/m³	applicable
Plasma	Non-Thermal Plasma	<50 mg/m³	good
	NTP + Bio-Reactor	<50 mg/m³	good

* for acid harmful gases
** Applying biological plants is problematical at inlet concentrations >200 mg VOC/m³ because of the tightened VOC limits.

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Energy balance

- The energy provided by the solvents is many times higher than the energy required for their evaporation.
- Example: Drag air carries around 3 g/m³ and requires heating by approx. 50 K.

$$P_{solvent} = 3\frac{g}{m^3} \times 26\frac{kJ}{g} = \mathbf{78}\,\frac{\boldsymbol{kJ}}{\boldsymbol{m^3}}$$

$$P_{heating} = 50\ K \times 1.3\frac{kJ}{m^3 K} = \mathbf{65}\,\frac{\boldsymbol{kJ}}{\boldsymbol{m^3}}$$

Solvent	Evaporation Enthalpy	Combustion Enthalpy	Ratio
Water	2,44 kJ/g	0 kJ/g	0 ×
Ethanol	0,88 kJ/g	27 kJ/g	30 ×
Ethyl acetate	0,41 kJ/g	24 kJ/g	58 ×
MEK	0,43 kJ/g	34 kJ/g	78 ×

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Trade-off

Do not do things by halves!

“the lower the VOC load,
the less economical the combustion is”

“If the exhaust treatment is not dispensed with or
reduced in size, it does not become economical”

If VOC cleaning is not needed, the operating costs determine the profitability.

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Flexible packaging example

Ink system	Solvent	Water
# machines	3	3
Exhaust air	40,000 m³/h	40,000 m³/h
Heating power	650 kW	900 kW
Printing speed	~ 300 m/min	< 200 m/min
Natural gas per year	~270.000 m³	~510.000 m³*

*scaled to solvent production output

- With an average solvent concentration of 4 g/m³ the heating power provided is:
- $W_{heating} = 4\frac{g}{m^3} \times 40{,}000\frac{m^3}{h} \times 26\frac{kJ}{g} \times 4{,}100\frac{h}{year} \mathrel{\widehat{=}} 470{,}000\frac{m^3}{year}\ natural\ gas$

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Energy recovery

A **temperature difference** of 1 K at a volume flow of 3,000 m³/h corresponds to a heat power of:

$$P = 1\ K \times 1.2\frac{kJ}{m^3 K} \times 3{,}000\frac{m^3}{h} = 1\ kW$$

1 kW continous heating power cost approx.:

$$K = 1\ kW \times 8{,}600\frac{h}{a} \times 0.08\frac{€}{kWh} \approx 750\frac{€}{a}$$

Example:

40,000 m³/h at a stack temperature of 70 °C correspond to costs of around 550,000 Euro per year.

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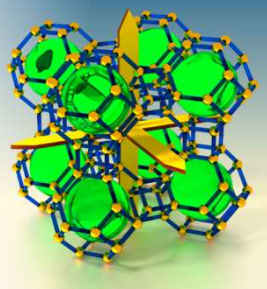
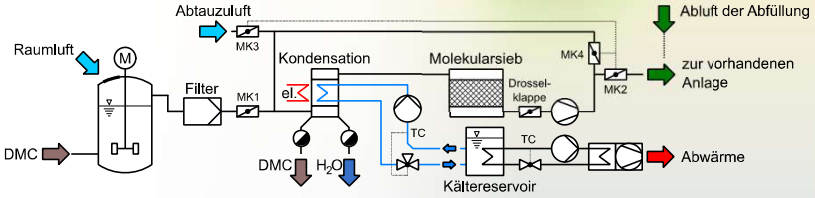
Steps to an energy efficient exhaust treatment

1. **Reduction of the off-gas volume**
   - Efficient collection
   - Air recirculation / concentration control
   - Intermediate adsorption
   - Modification of input materials (if possible)
2. **Efficient purification processes**
   - High efficiency ratio
   - Energy recovery
3. **Process combinations**
   - Plasma-Catalytic
   - Duplex-RTO
   - …





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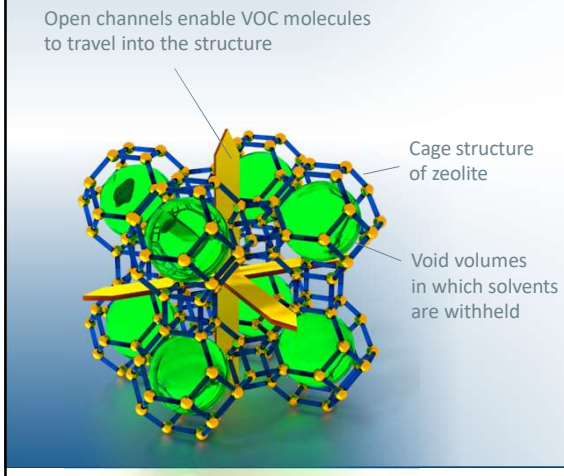
Molecular sieves

Storage of solvent emissions

Short term (< 1 hour)
Smoothening of variations

Mid- and long term (hours to days)
Storage of energy



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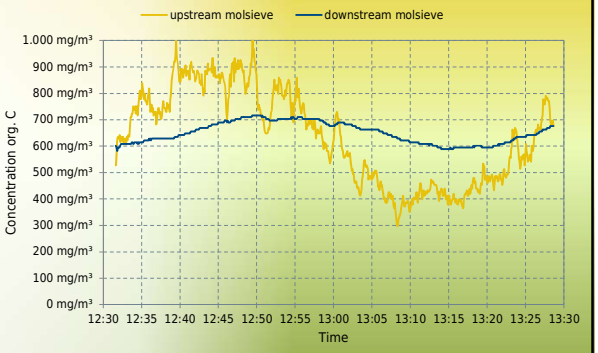
Principle of the curve smoothening

- A varying concentration load curve is homogenized in the molecular sieve.
- Reduced process dynamic **extends the control range** and enables **safety related control**
- **Concentration systems** become two- to three times more efficient



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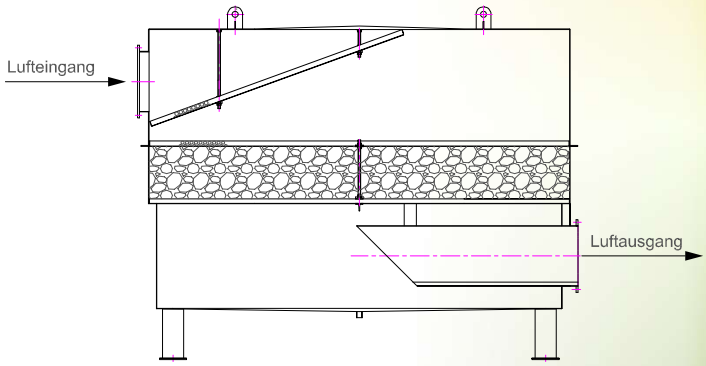
Molecular sieve structure (flat bed)



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Molecular sieve buffer (50,000 m³/h)

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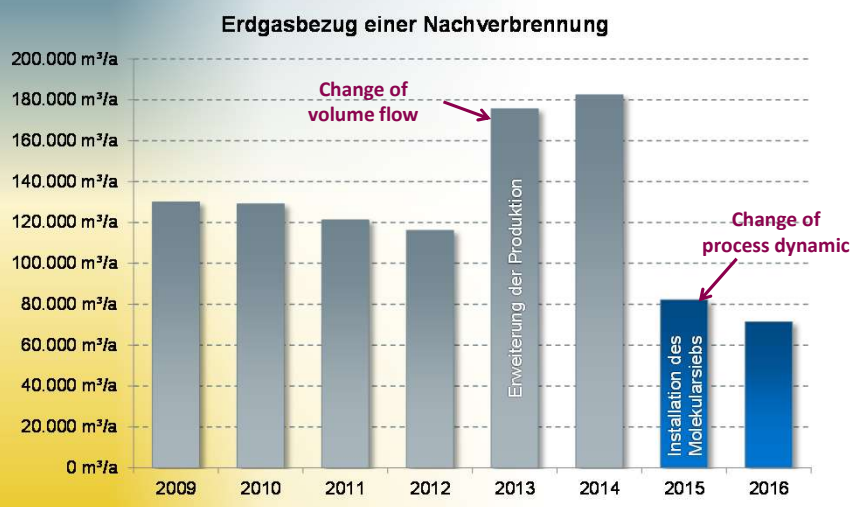

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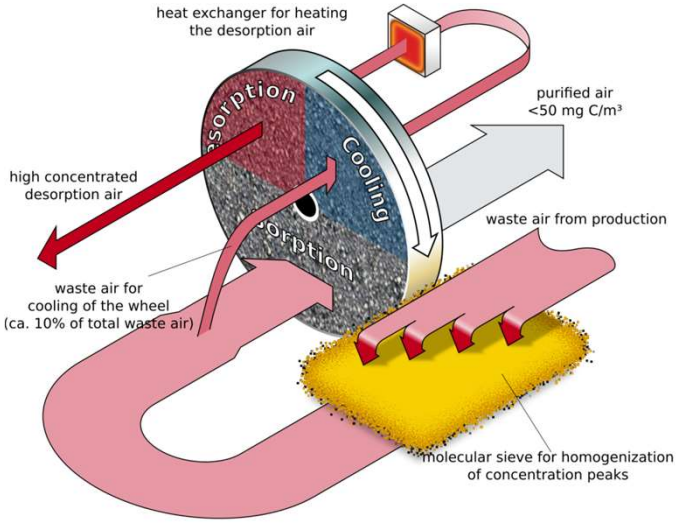
Principle of Duplex system



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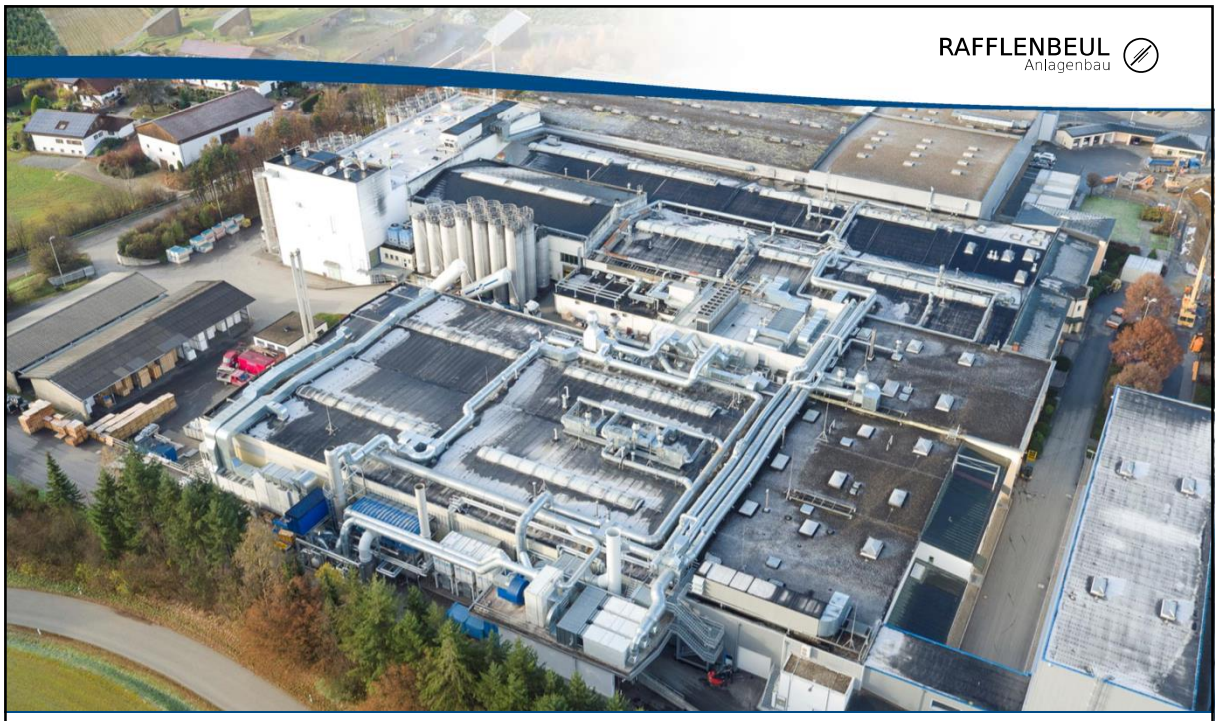

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Realized gravure printing systems

Teckwah, Wuxi: 160,000 m³/h, 99% autothermic operation

Fuji Seal Poland: 140,000 m³/h, 1.6 MW recovery

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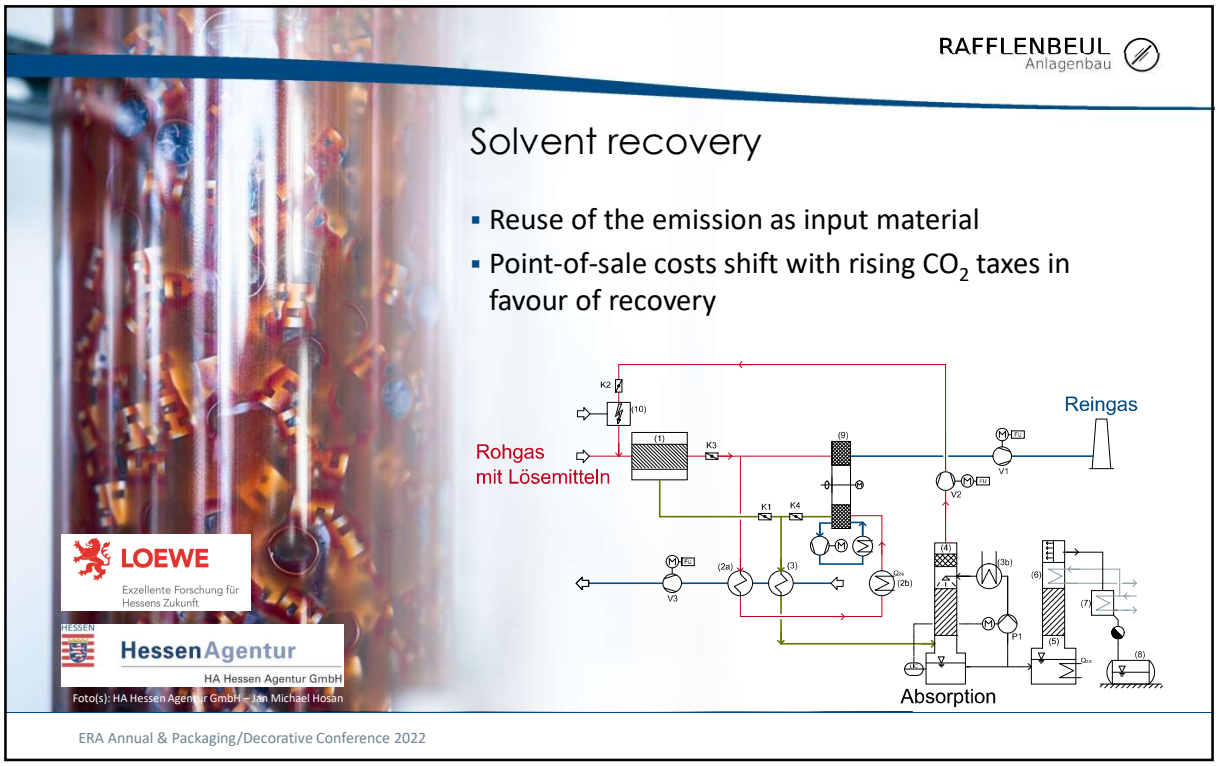
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Solvent recovery
Reuse of the emission as input material
Point-of-sale costs shift with rising CO_2 taxes in favour of recovery
Rohgas
mit Lösemitteln
Reingas
Absorption
LOEWE
Exzellente Forschung für Hessens Zukunft
HessenAgentur
HA Hessen Agentur GmbH
Foto(s): HA Hessen Agentur GmbH – Jan Michael Hosan
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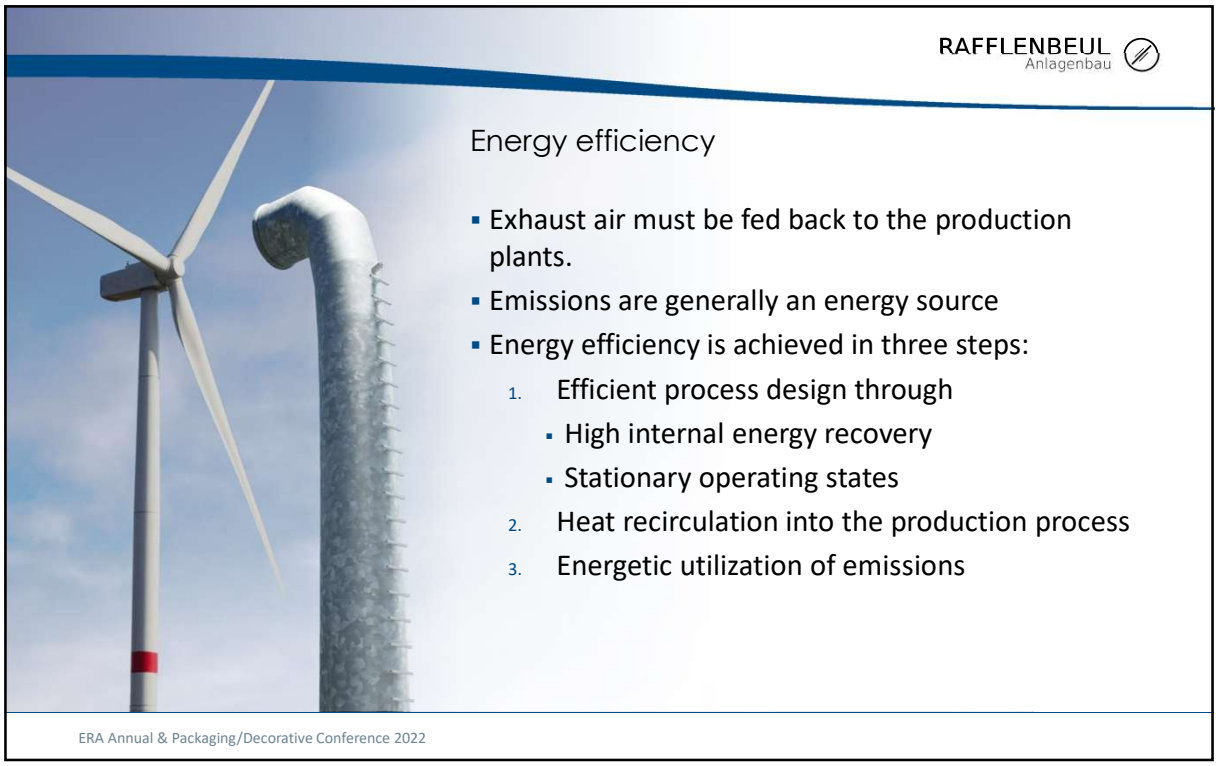
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Energy efficiency
Exhaust air must be fed back to the production plants.
Emissions are generally an energy source
Energy efficiency is achieved in three steps:
1. Efficient process design through
High internal energy recovery
Stationary operating states
2. Heat recirculation into the production process
3. Energetic utilization of emissions
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Exhaust air treatment combined with power generation

- Combined for **power generation** via
  - Cogenerations and
  - Micro turbines
- **Thermal utilization** of emissions through efficient, **controlled concentration**
- **Cooling** from waste heat
- Planning of **production resources** and **input materials** under consideration of exhaust air treatment

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Summary

- Be consistent! Slowly abandoning solvents is expensive.
- Solvents are energy and their thermal use is often most economical
- In addition to the energetic evaluation, other aspects must also be included:
  - Could recovery help to be sustainable?
  - What are the other advantages of not using solvents?

In the European environment, thermally optimized use is still preferable in most cases.

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Lutz Rafflenbeul

Thank you for your attention

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