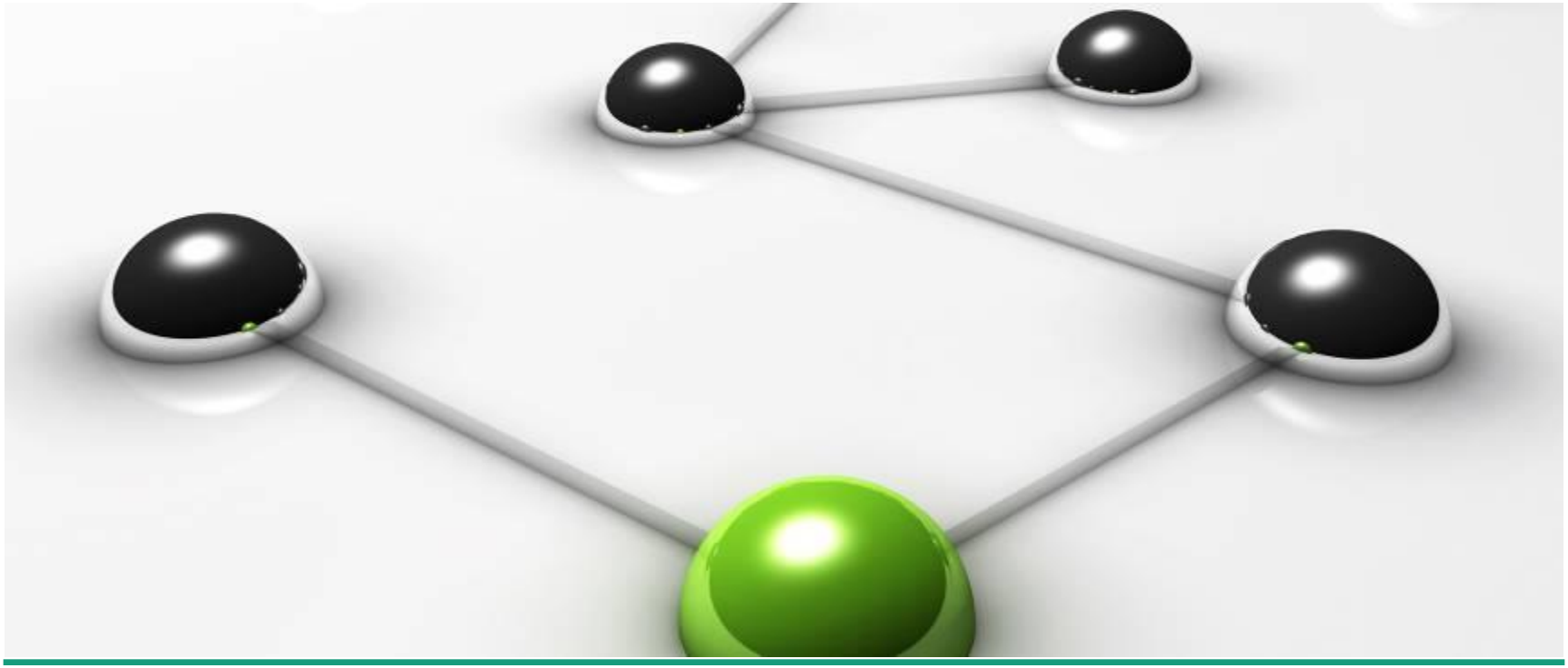
Fuel flexibility in gasification: experiences and challenges

Tim Schulzke, Group Manager Thermochemical Processes and Hydrocarbons



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Outline

1. Fraunhofer-Gesellschaft and Fraunhofer UMSICHT
2. Fundamentals of solid fuel gasification
3. Gasification plants at Fraunhofer UMSICHT
4. Bandwidth of fuels used
5. Challenges for future plants
6. Summary

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Patron Joseph von Fraunhofer (1787 – 1826)

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Scientist

➔ Discovery of the »Fraunhofer lines« in the Sun's spectrum

Inventor

➔ New manufacturing methods for reamfree glas and lenses

Entrepreneur

➔ Director and co-partner of a glass factory

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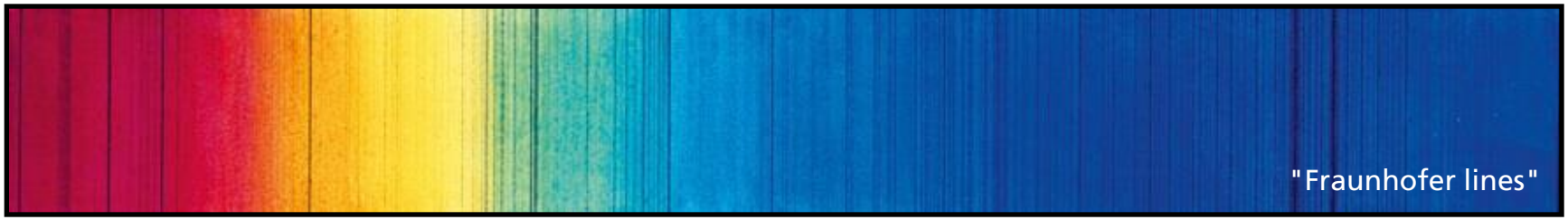

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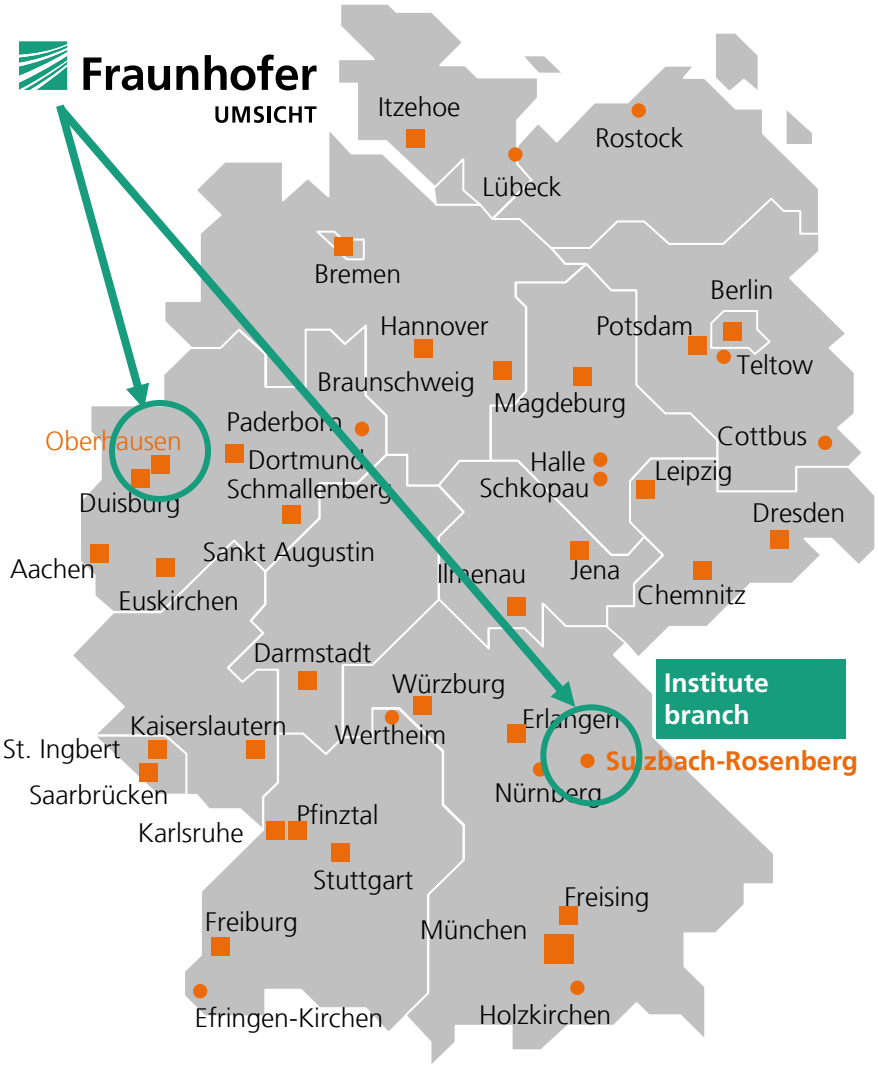
The Fraunhofer-Gesellschaft

- 67 institutes and independent research facilities
- € 2 bn research funds
  - € 1.7 bn contract research
- More than 23 000 employees (m/f)[1]
- 40 facilities in Germany
- 13 institutes in North Rhine-Westphalia
- 4 institutes in the Ruhr area

more information under:

www.fraunhofer.de/en.html



[1] 23 236 (m/f) as per 12-31-2013 including fixed-term contracts of less than 18 months.

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Pioneer of the energy and resource transition

- Core area: Process engineering
  Chemical conversion »From raw material to the product«
- 489 employees (314 permanent staff) in Oberhausen and Sulzbach-Rosenberg
- Operating budget 2015: € 39.1 million
- Our subjects:
  Energy I Processes I Products I Environment I Material I Sustainability
- Our guiding themes:
  Production without raw materials / Energy with prudence
  (= English translation of UMSICHT)

Site Oberhausen

Site Sulzbach-Rosenberg

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Process of Gas Generation from Solid Fuels

The conversion of solid fuels into gaseous energy carrier by means of gasification requires a certain effort, which can be distributed over the major process steps

- Fuel Conditioning,
- Gasification Reactor and
- Gas Conditioning

with varying emphasis.

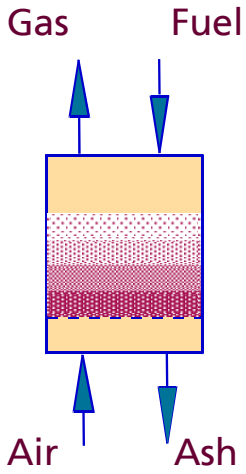
Gasification - Classification by Reactor Typ

fixed bed gasifier

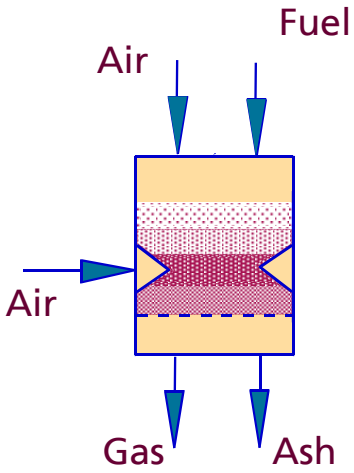
- Drying zone
- Pyrolysis zone
- Reduction zone
- Oxidation zone

fluidized bed gasifier

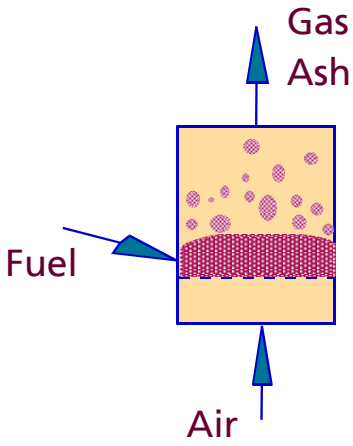
- fluifized bed
- freeboard



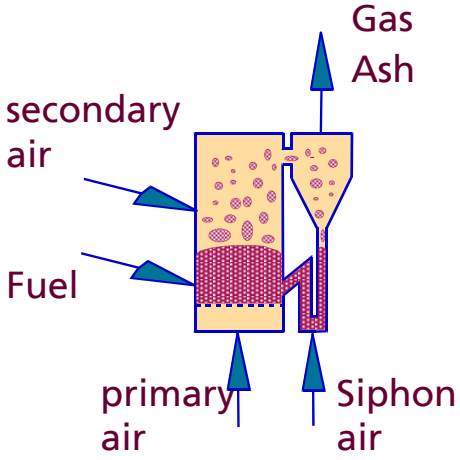
countercurrent



cocurrent



bubbling fluidized bed



circulating fluidized bed

Not shown: entrained flow gasifier (suitable only for very large capacity)

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Gasification in fluidized beds

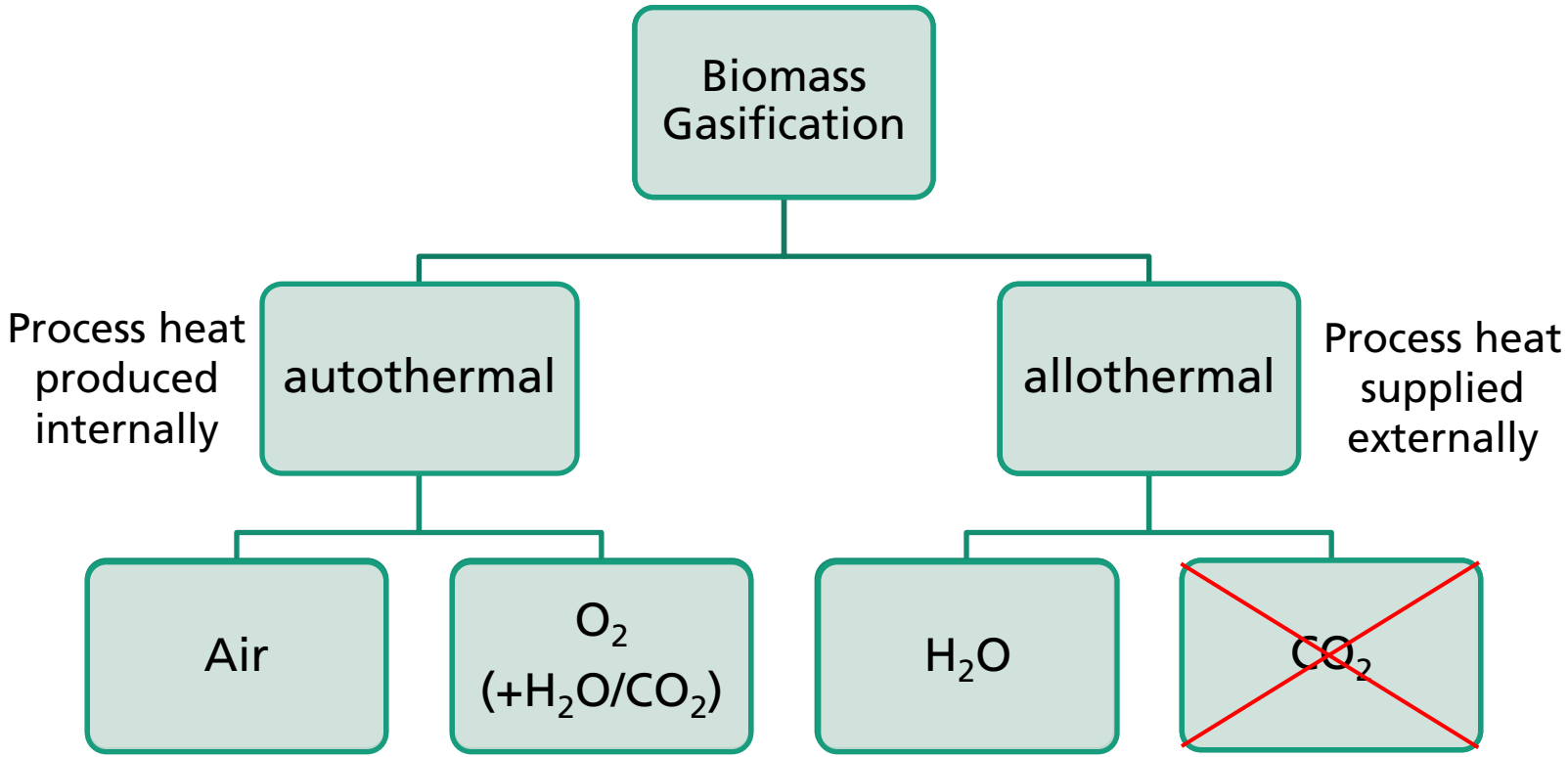
Advantages compared to fixed bed

- solids hold-up: more than 90 % bed material for heat transfer, therefore good controllabilty by fuel and air supply
- marginal temperature differences inside reactor
- Reaction temperature »freely« adjustable
  - »high« for good burn-off, high synthesis gas temperature
  - »low« for problematic fuels (e.g. straw)
- Fuel variability
  - Pellets with high density
  - Shredded material with low density and large fraction of fines
- good scalability over wide range of capacity

Disadvantages compared to fixed bed

- specific investment cost higher in small scale
- fuel must be fed continuously and consistenly

Gasification - Classification by Gasification agent



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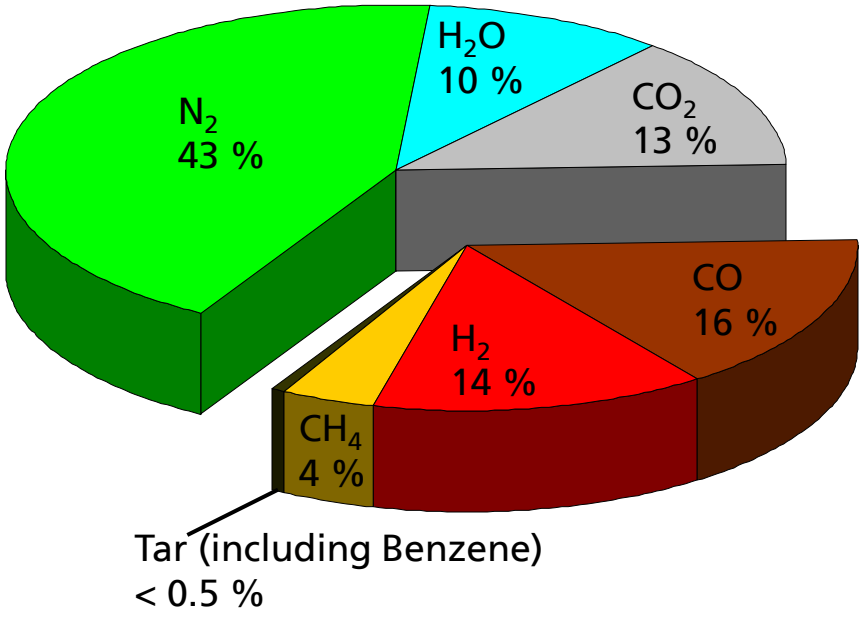
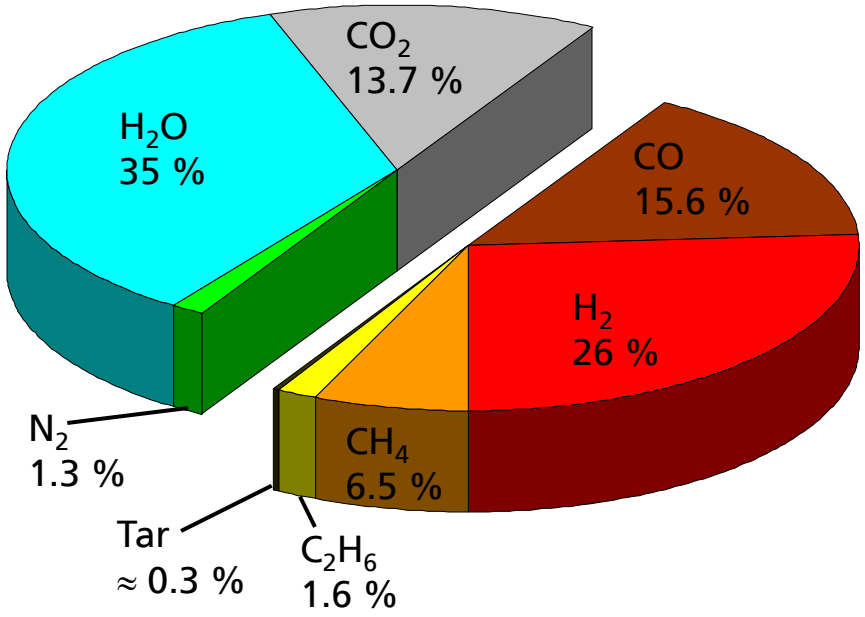
Gas composition– Comparison Air/Steam

Gasification with Air
UMSICHT CFB (≈ 900 °C)



Gasification wth Steam
Güssing FICFB* (≈ 840 °C)



*Pfeifer et al., Presentation at 15th European Biomass Conference, Berlin, 2007

LHV: H_i ≈ 1.38 kWh/scm
LHV, dry: H_i ≈ 1.53 kWh/scm

LHV: H_i ≈ 2.56 kWh/scm
LHV, dry: H_i ≈ 3.48 kWh/scm

Factor 2.25

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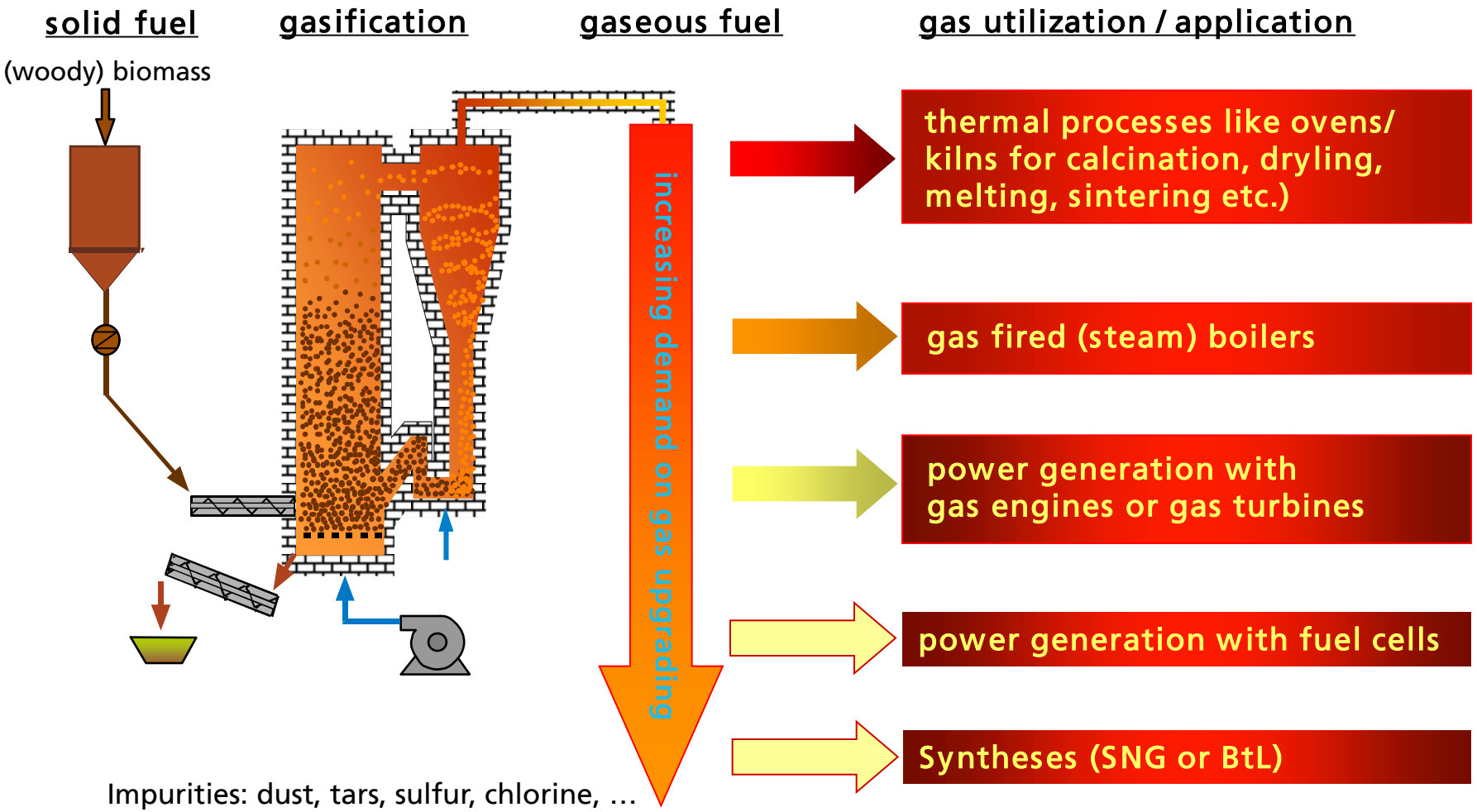
General applications for synthesis gas from biomass



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Challanges for Gasification

3 main difficulties

- Solid Fuel Dosing
  - affects mainly fulidized beds
  - requirements: continuous dosing (potentially against pressure)
  - fuel flowability very different: pellets, wood chips, chaff
- Distribution of gasifying agent over cross section
  - affects mainly fixed beds
  - requirement: even distribution over complete cross section
  - reactive requirement on biomass fuel: no fines allowed
  - main reason for scale-up limit (cocurrent) at about 1 MW fuel input
- Gas Cleaning
  - Tar, Sulfur, Chlorine, Ammonia, …

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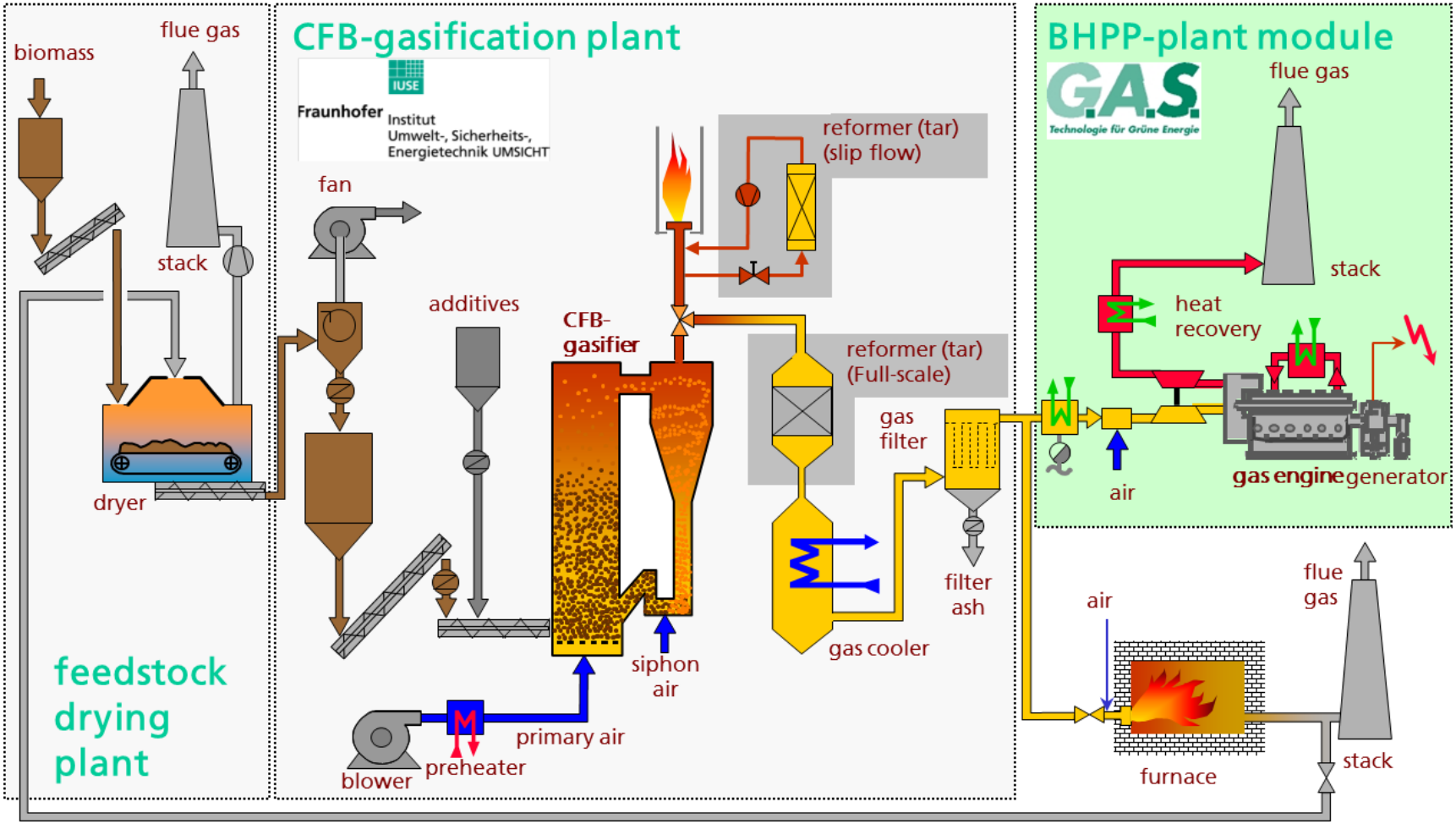
Schematic drawing of fluidized bed gasification plant



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Photograph of fluidized bed gasification plant (500 kW)

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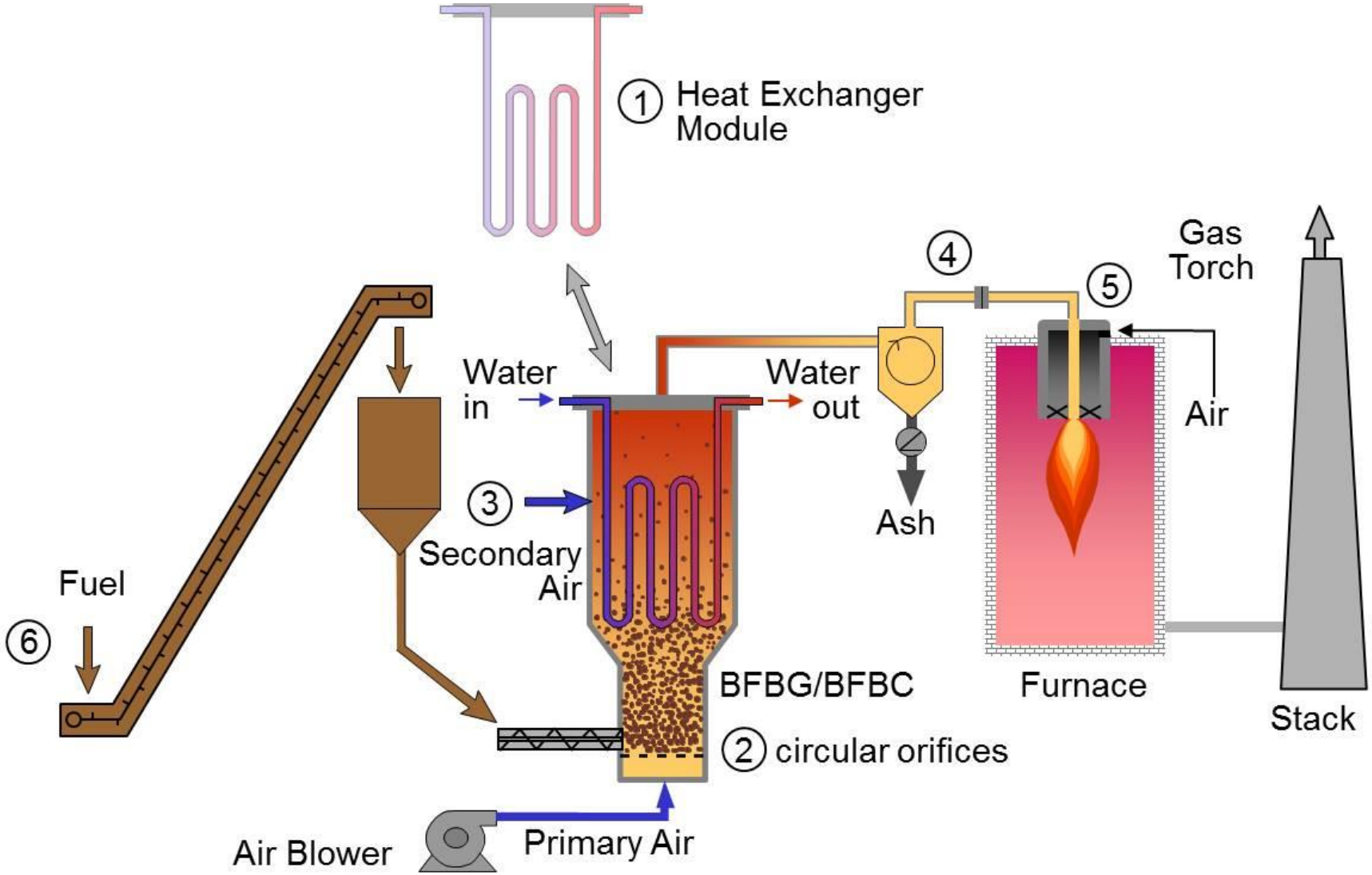
Schematic drawing of fluidized bed gasification plant



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Photograph of fluidized bed gasification plant (100 kW)

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Fuels used

Circulating fluidized bed

- Wood flakes from reciprocating saw (FL)
- Shredded demolition wood (DW)
- Shredded plywood (PW) (ammonium sulfate)
- Sewage sludge (SS) (dried, granulated)
- Vulcanized rubber (VR) (Peeled from used tires before retreading)

Bubbling fluidized bed

- Shredded demolition wood (DW)
- Wood chips (WC)
- Shredded willow from short rotation forestry (WS)
- Shredded peat briquettes (PB)
- Wood pellets (WP)
- RRBF (MS) (refined renewable biomass fuel / conditioned MSW from MBT)

Fuels used

Fuel	bulk density	LHV	water content	ash content	particle size
	kg/m³	MJ/kg	weight-%	weight-%	mm
FL	151	16.6	9	0.7	3 - 5
DW		15.4	10.9	3.0	(0)1 - 5
PW		14.8	18.2	1.15	< 30
SS	713	8.75	5.3	47.0	(0)2 - 5
VR	524	41.8*	0.1	< 1	5 - 8
WC	255	16.5	8	0.6	1 - 30
WS		15.5	11.0	1.16	0 - 40
PB		17.9	10.2	2.49	0 - 30
WP	726	18.0	4	0.5	⌀6x20
MS	302	11.0	13-25	22-32	0 – 30

FL: Wood flakes; DW: Demolition wood; PW; Plywood; SS: Sewage Sludge; VR: Vulcanized rubber; WC: Wood chips; WS: Willow from short rotation forestry; PB: Peat briquettes; WP: Wood pellets; MS: Mixed municipal solid waste (from MBT + conditioning)

*34.4 MJ/kg w/o carbon black

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Dosing systems

Circulating fluidized bed

- Storage hopper 10 m^3, 1,4 x 1,4 x 5 m, discharge with screw conveyor
- Screw conveyor for fuel elevation
- Dosing hopper on scales (discharge via vibrating chute): mass dosing
- Rotary valve as pressure lock
- Screw feeder (jacket and shaft cooled)

Bubbling fluidized bed

- Storage hopper 36 m^3, container with pushfloor, discharge with screw conveyor
- Screw conveyor for fuel elevation
- Dosing hopper with frequency controlled screw conveyor discharge: volume dosing $\Rightarrow$ calibration needed for every fuel
- Rotary valve as pressure lock
- Screw feeder (jacket and shaft cooled)

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Challenges

Solid fuel handling

- Flowability of fuel
  -> bridging in storage hoppers / uneven transport on vibrating chute

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Large items contained in MW

Promised to be smaller than 40 mm and free of metals

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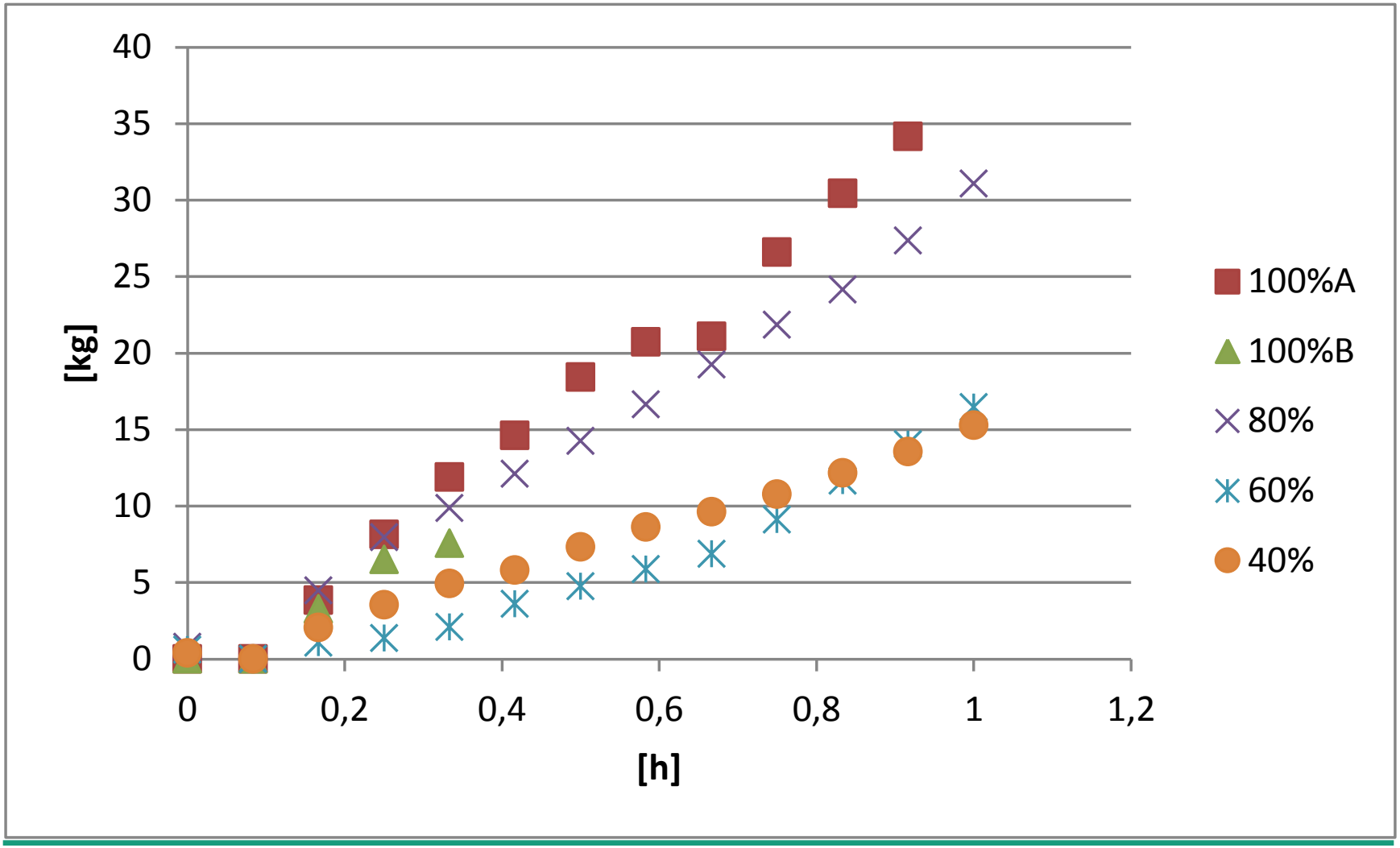
Calibration of dosing screws – 1. batch as delivered



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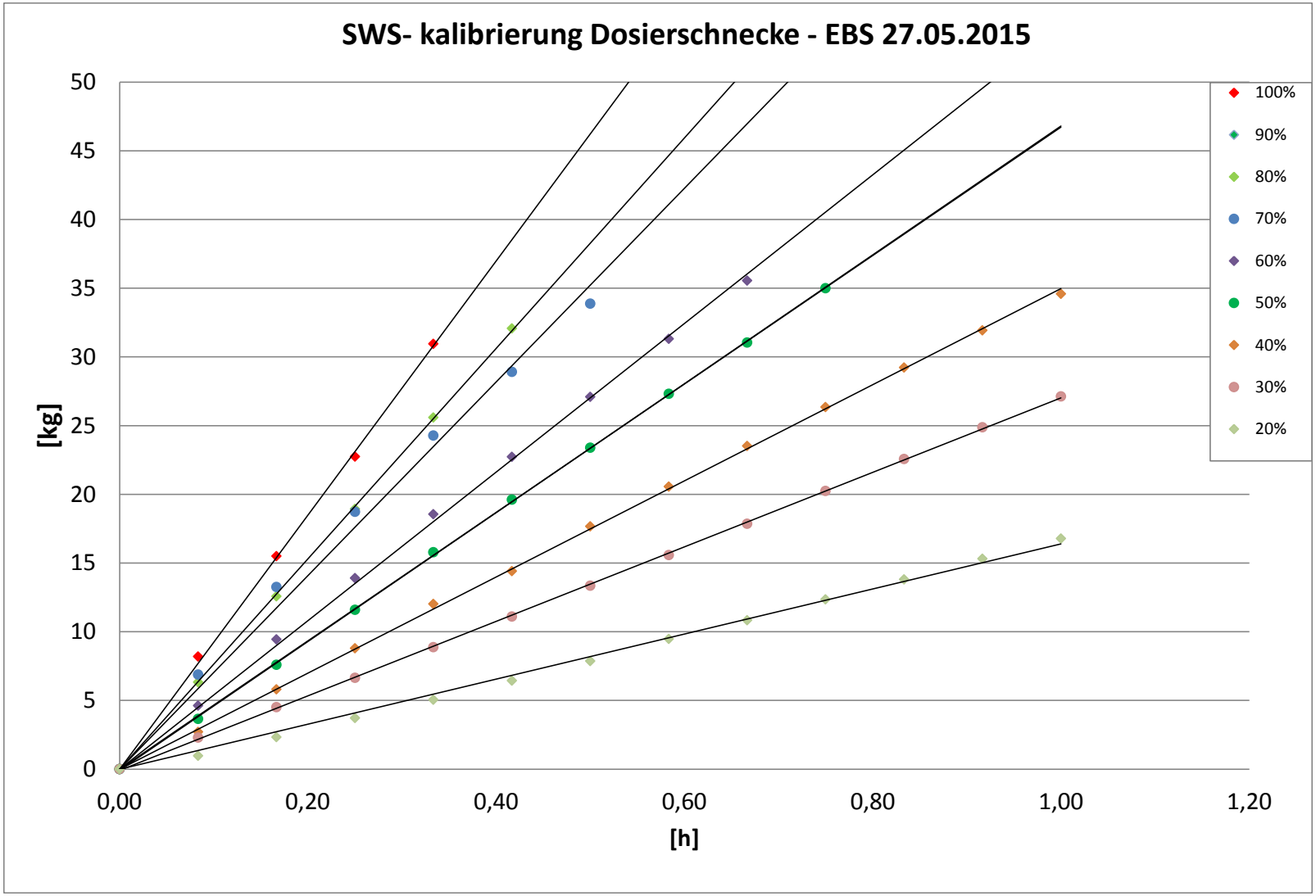
Calibration of dosing screws – 2. batch



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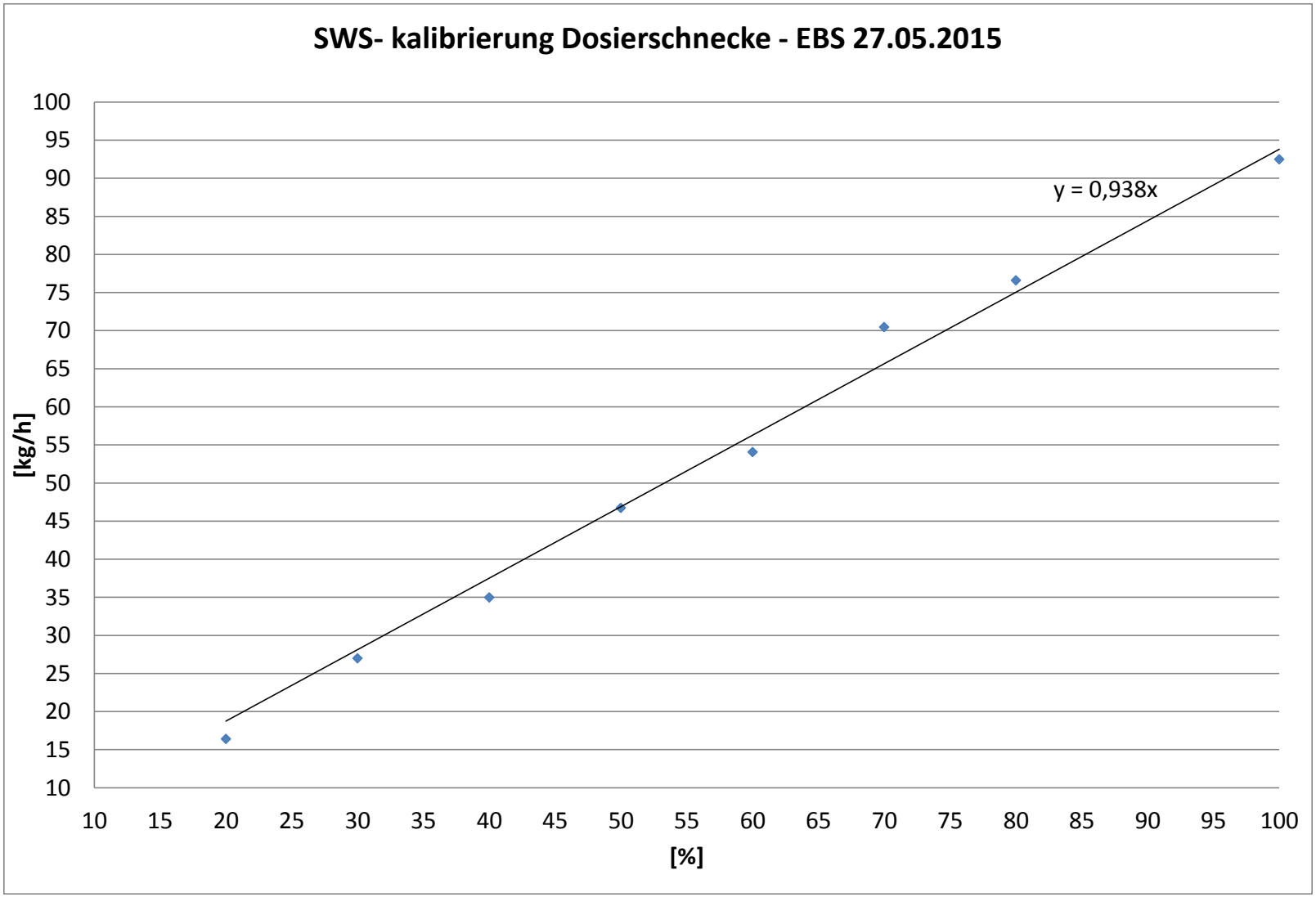
Calibration of dosing screws – 2. batch



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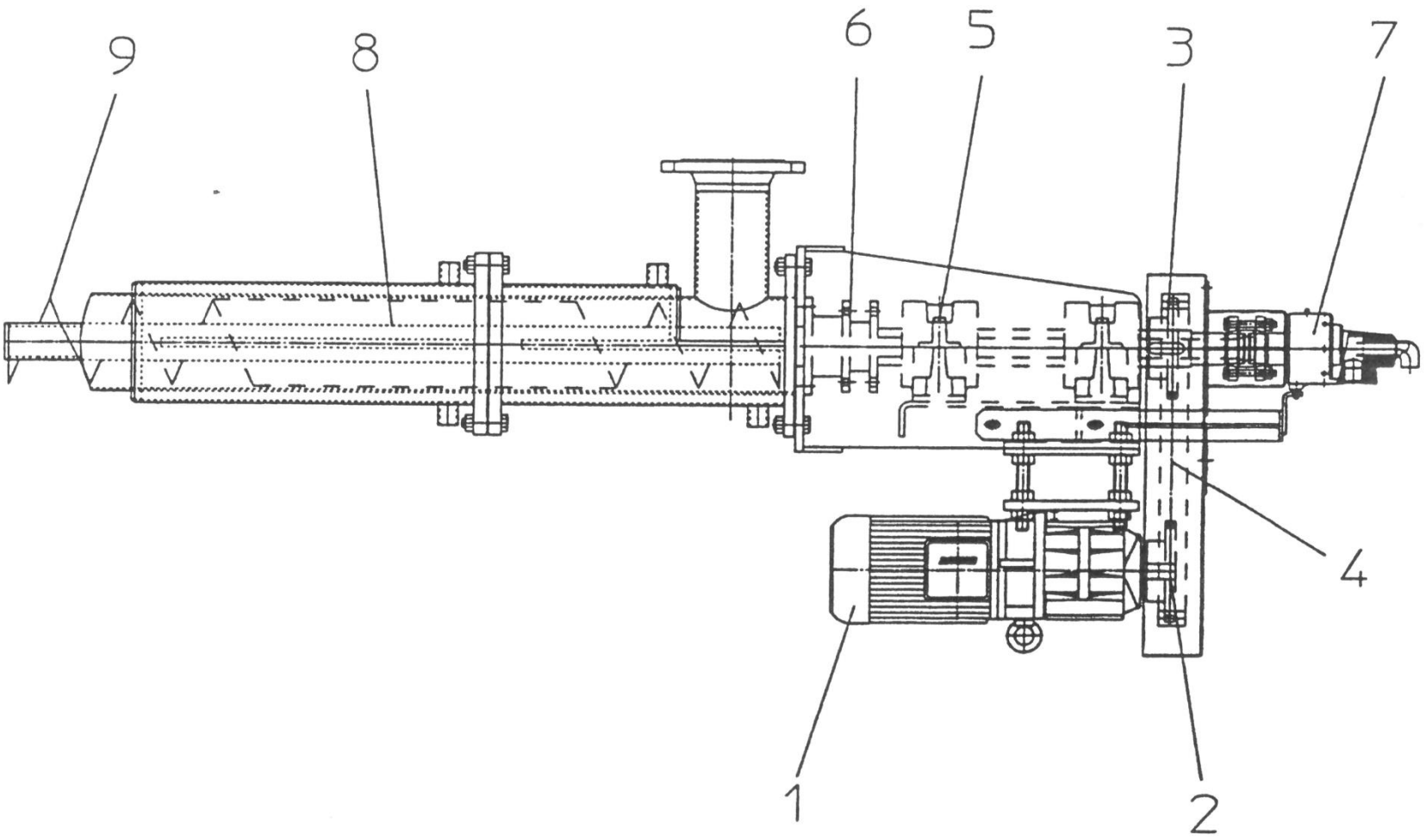
Challenges

Solid fuel handling

- Flowability of fuel
  -> bridging in storage hoppers / uneven transport on vibrating chute
- Melting/Softening in feeding screw

Feeding screw – jacket and shaft cooling



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Challenges

Solid fuel handling

- Flowability of fuel
  -> bridging in storage hoppers / uneven transport on vibrating chute
- Melting/Softening in feeding screw
- High amounts of fines (< 1 mm): discharge with sealing air

Producer gas cleaning

- High sulfur content with SS, PW and esp. VR
  SS and PW needed frequent catalyst regeneration
  gas from VR only usable for combustion (with flue gas desulfurization)
- High ammonia content with SS, PW
  -> installation of ammonia scrubber
- Soot accumulation in circulating fluidized bed with VR
  (extremely different reactivity of rubber and carbon black)
- Variety of contaminants for MSW-based fuel -> combustion preferable

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Summary

Proven fuel bandwidth for gasifier

- Water content from 0 up to 40 %
- Ash content from 0 up to 50 % (ash softening temperature > 950 °C)
- Minimum LHV: 6 MJ/kg (1.7 kWh/kg) as received
- Woody biomass, sewage sludge (dried, granulated), rubber, RRBF, etc.

Challenges

- Gas cleaning to be specially designed for each fuel
- Gas cleaning for high contaminated fuels (gas boiler + steam cycle)
- Minimum flowability required (reproducible)
- Fuels composed of components with very different reactivity may need special attention / reactor design (e.g. rubber: isoprene and carbon black)

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Department Biorefinery & Biofuels

Thank You for Your kind attention!

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