USELF
Ukraine Sustainable Energy Lending Facility

FICHTNER

Technical and commercial Aspects for the Development of Biomass and Biogas Projects

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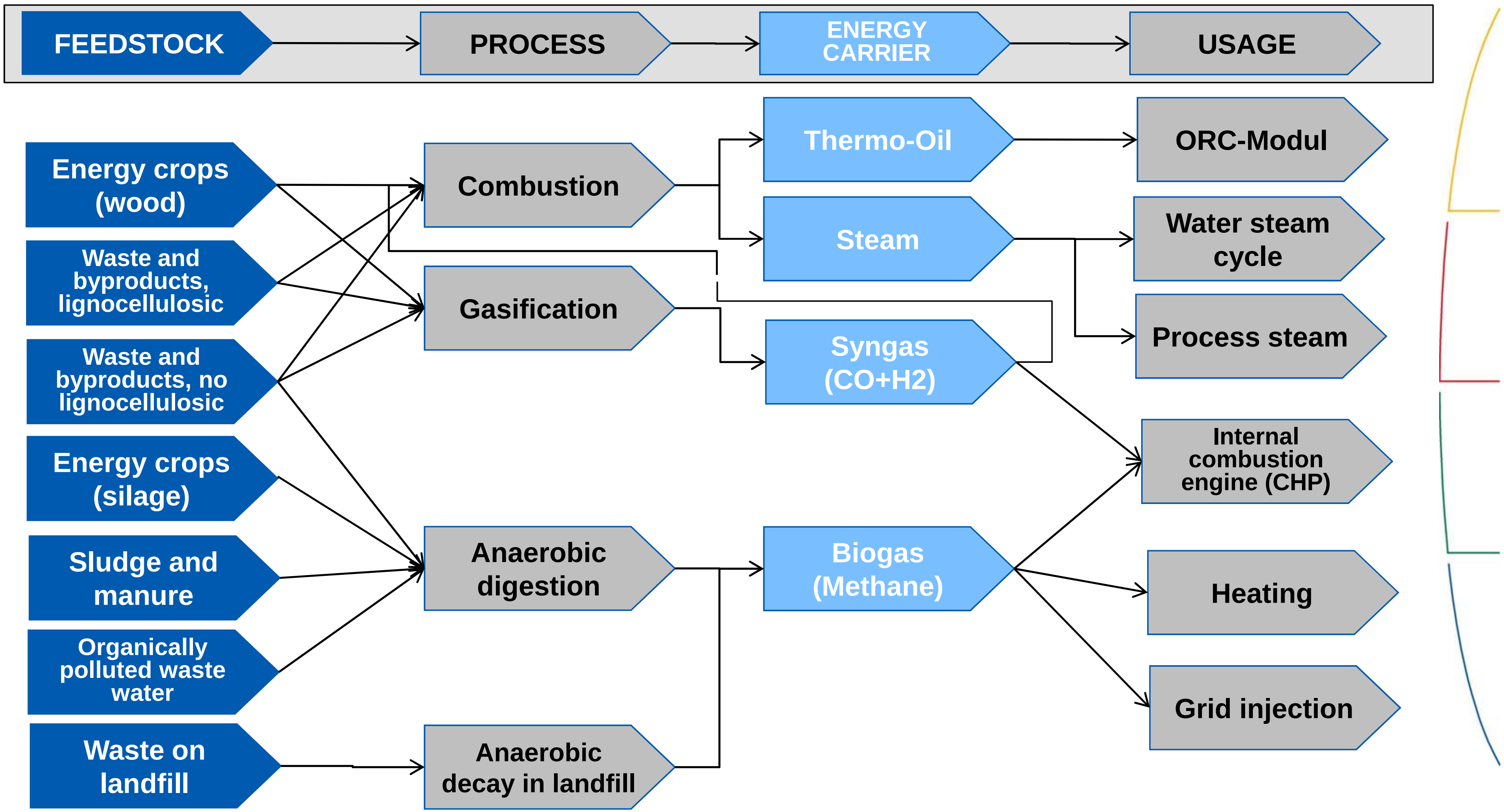
Content of the presentation

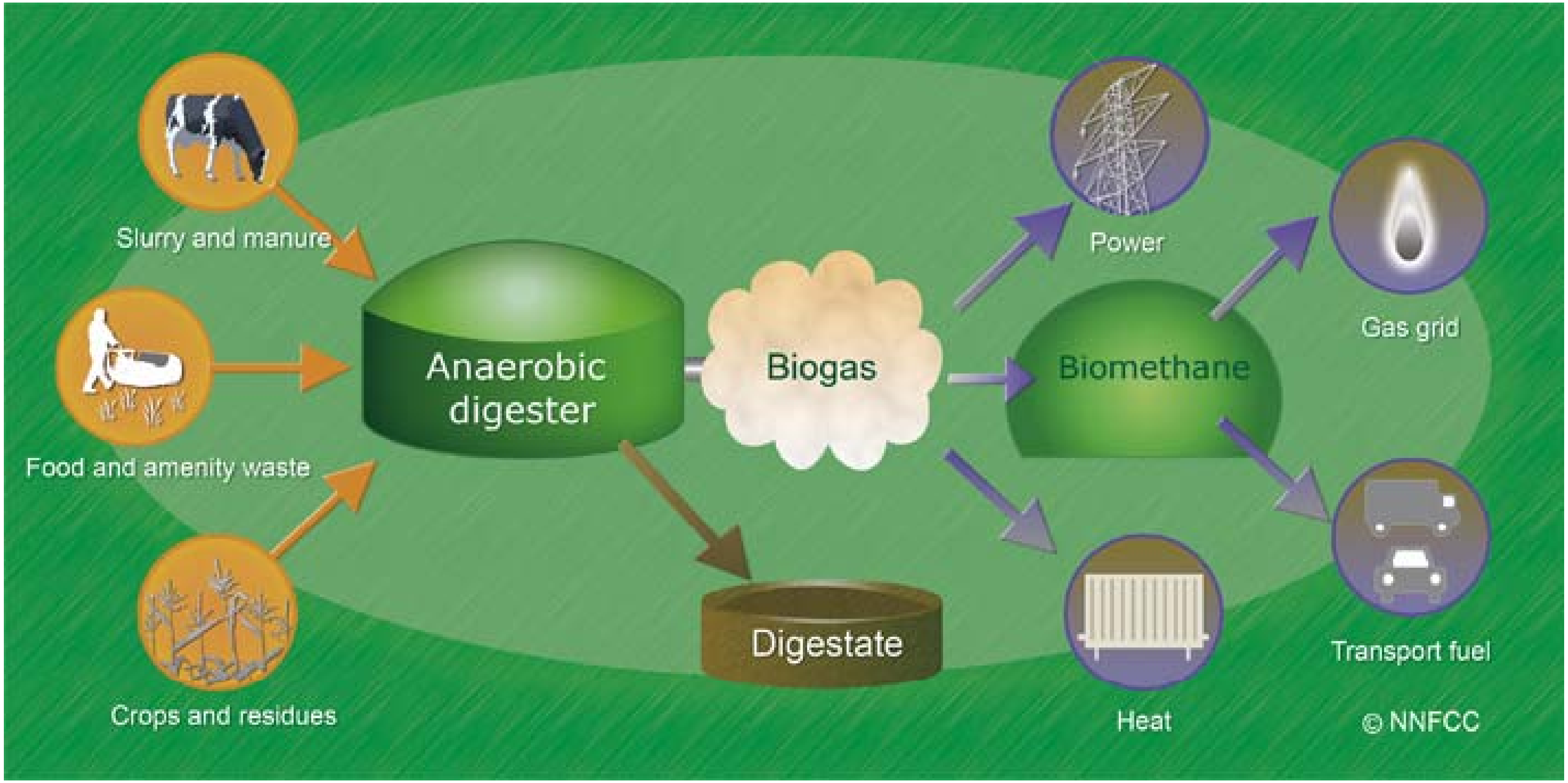
- Pathways for biomass utilization
- Biogas
  - Biogas fundamentals
  - Biogas production technologies
  - Potential feedstock
  - Special case: Landfill gas
- Thermal processes
  - Combustion
  - Gasification
  - Potential feedstock
- Requirements and constraints for project development

Usual pathways for biomass utilization



Part 1: Biogas

Biogas Fundamentals (1): Basic components



Source: NNFCC UK

Biogas Fundamentals (2): Process distinctions

Temperature

- **Psychrophilic**
  - < 20°C
  - No technical application
- **Mesophilic**
  - 20°-40° (opt. 35°)
  - High stability
  - Long retention time
- **Thermophilic**
  - 50°-60°
  - Sensitive process
  - Smaller reactor
  - Disinfection

Water content

- No clear treshhold
- **Dry** >20 % DS
- **Wet** < 15% DS
- Wet process with more experience

Operating regime

- **Batch**:
  No technical application
- **Fed-batch**
- **Continous**

Stages

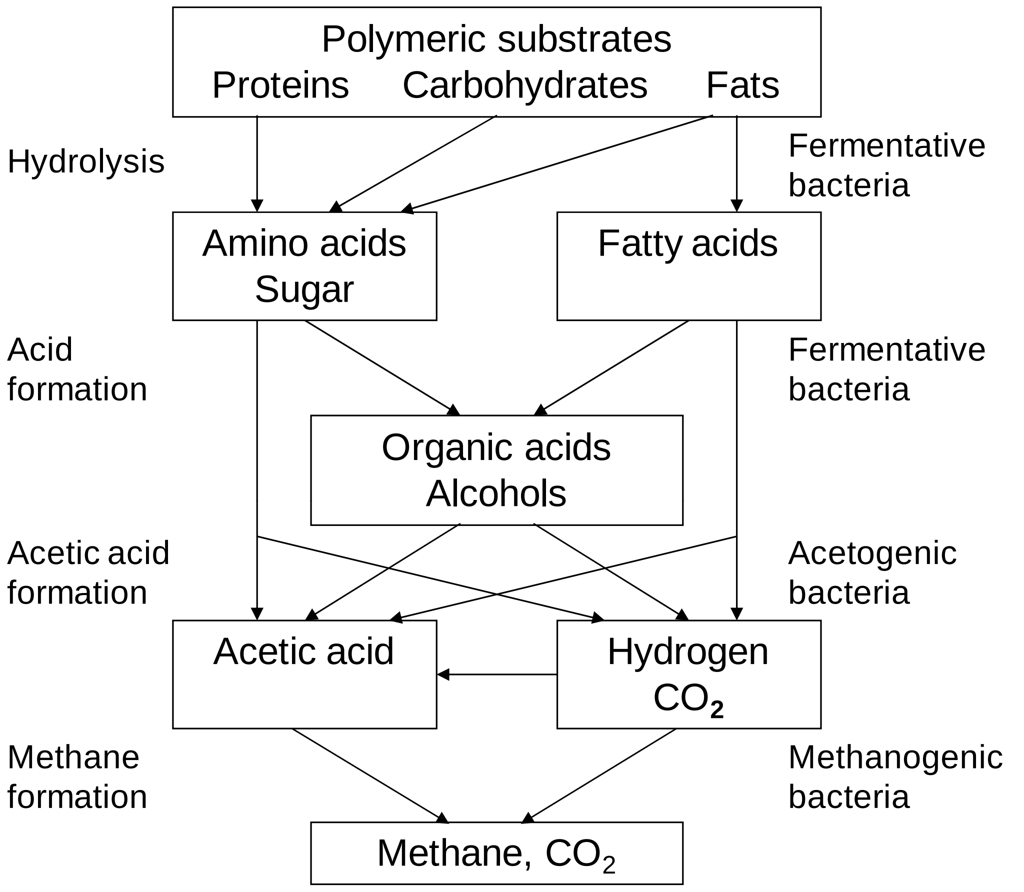
- **One Stage**
  - Hydrolysis and methane formation in one reactor
- **Two stages**
  - Hydrolysis and methane formationin two reactors
  - Better adjustment of reaction conditions
  - More equipment

Biogas Fundamentals (3): Stages of Fermentation

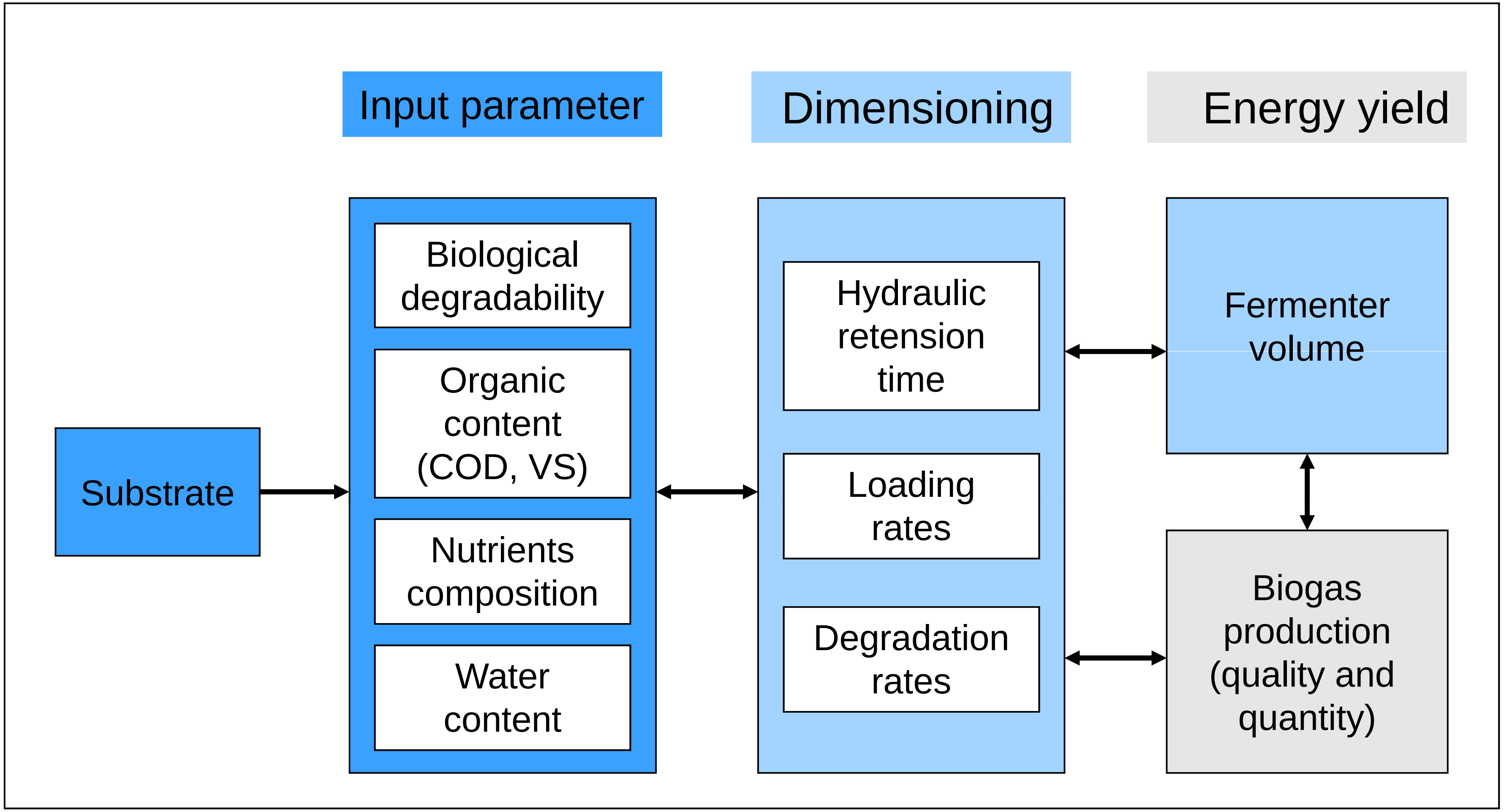
The Two-Stage Anaerobic Process relating to The Four Stages of Fermentation

First process stage = Hydrolysis stage

Second process stage = Methane stage



Biogas Fundamentals (4): Process parameters



Biogas: Potential Feedstock (1)

Energy Crops

- High specifiy biogas yield
- Technical optimization of fermentation
- Additional income from fallow fields

- *Controversial ethical discussion (“burning bread”)*
- *High price*
- *If not from own production: Dependency from market fluctuations*
- *Seasonal arising*

Feedstock Supply

Energy crops to the extend required

Waste / byproducts

- Low specific price
- Indepent from market development
- Environmental friendly disposal
- If waste water: Climate protection, Kyoto-Protocoll
- Fertilizer properties of residue better than of manure
- Often continuous arising

- *Often low energy yield*

Potential Feedstock (2)

Data to be defined for process design

- Amount of feedstock: Total amount, continuous supply
- Quality
  - Water content: Dimension of storage, fermentation technology and reactor volume
  - Organic content (e.g. COD, BOD): Decisive for biogas yield.
    - Concentration: Yield per Volume
    - Total amount: Total yield
  - Constancy of feedstock properties: Technology to be designed to handle the maximum input.

Potential Feedstock (3)

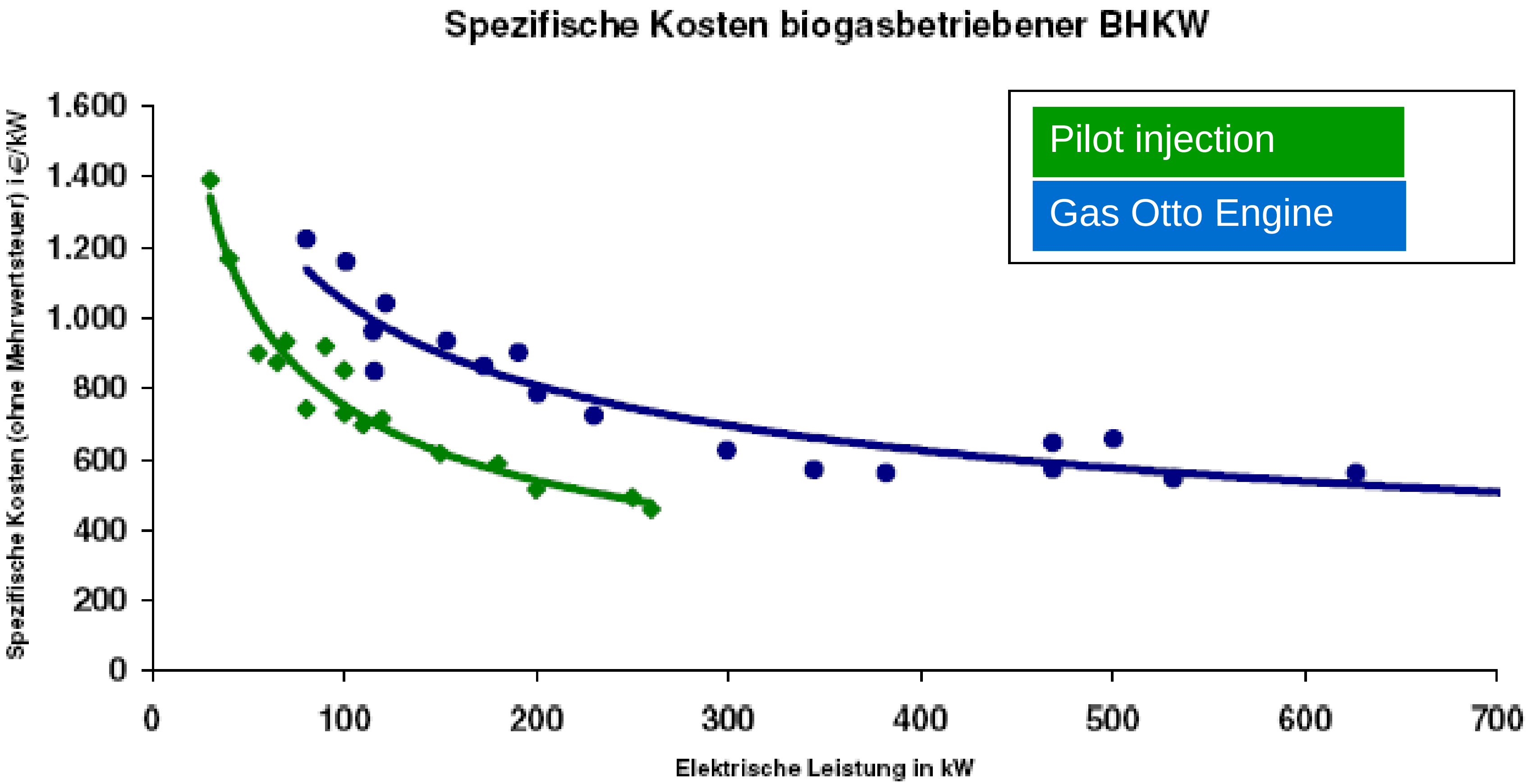
- **Co-fermentation of several feedstock types results in broader range of bacteria and a more stable process.**
- **If waste is fermented, there might be legal requirements for sanitation and disinfection of the material (e.g. by high temperature)**
- **Special case: Mono-fermentation of chicken manure critical due to high ammonia content.**

Biogas: Engines / CHP Units

Advantage Gas Diesel with pilot injection		Advantage Gas Otto Engine
• Lower capital cost • Use of standard-engines • Higher efficiency for small scale plants.	⟷	• Lower emissions • Lower maintenance requirements • Large units available (> 1MW) • Higher lifetime (65,000 h vs 35,000 h) • No additional fuel required

Quelle: .....

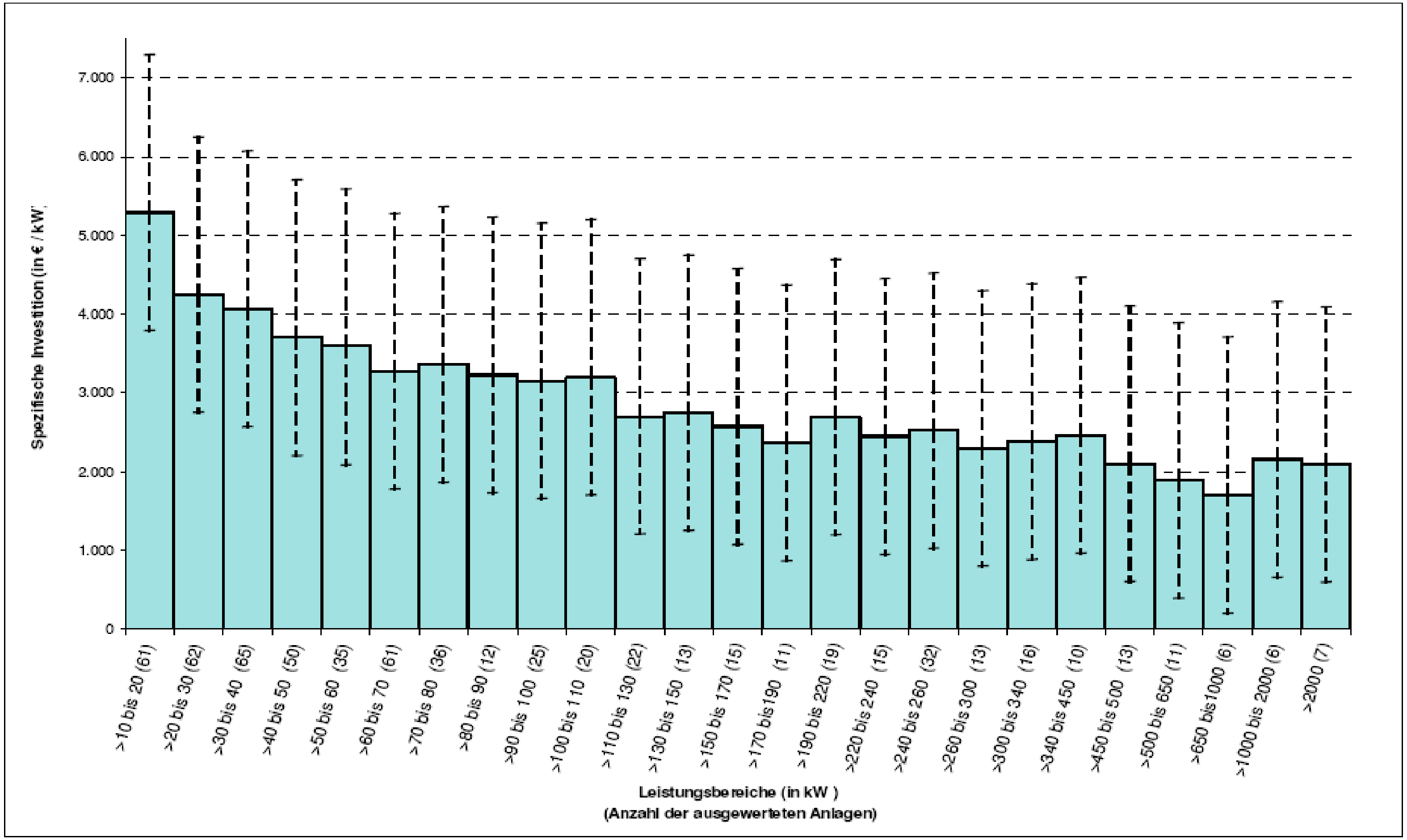
Biogas: Capital Cost CHP Units



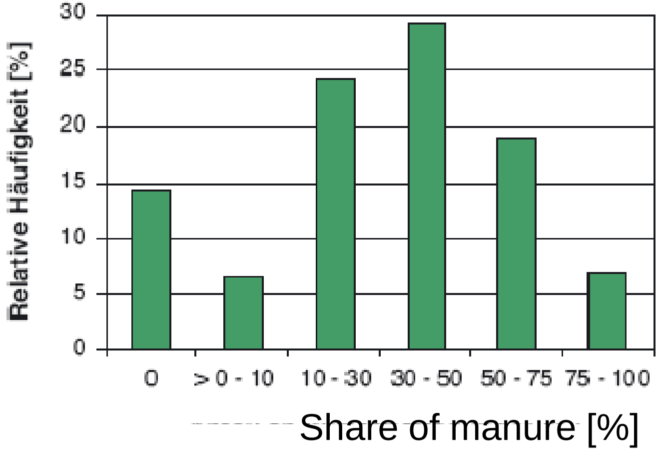
Source: FNR Handreichung Biogas

Biogas: Cost of equipment

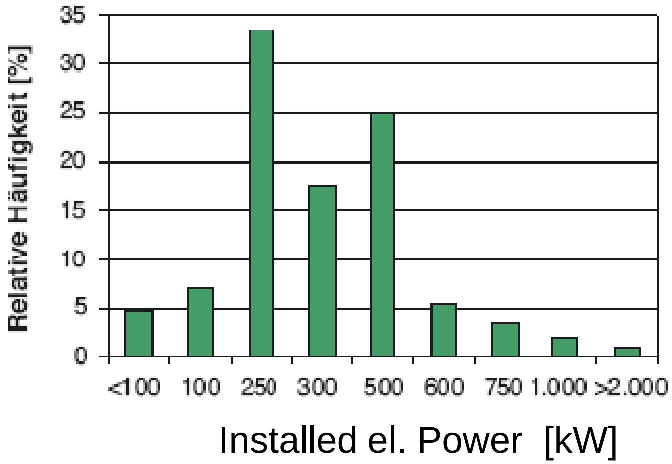
Specific capital costs for energy crop fermentation (Germany 2004)



Biogas: Statistical data from Germany and conclusions (1)



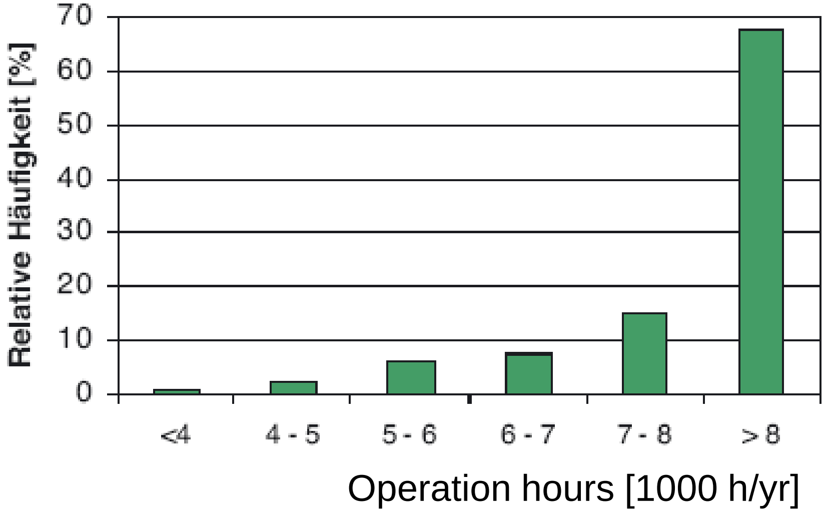
- Most of the plants use Co-fermentation
- There are about 15 % plants based on energy crops only



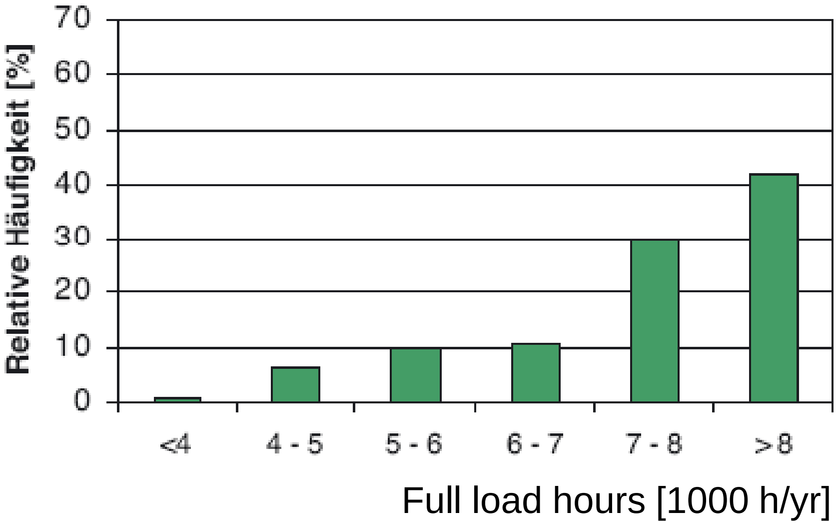
- Typical plant size in Germany 250-500 kW
- In Ukraine typical size may be higher because of larger farms

Source of diagrams: FNR

Biogas: Statistical data from Germany and conclusions (2)



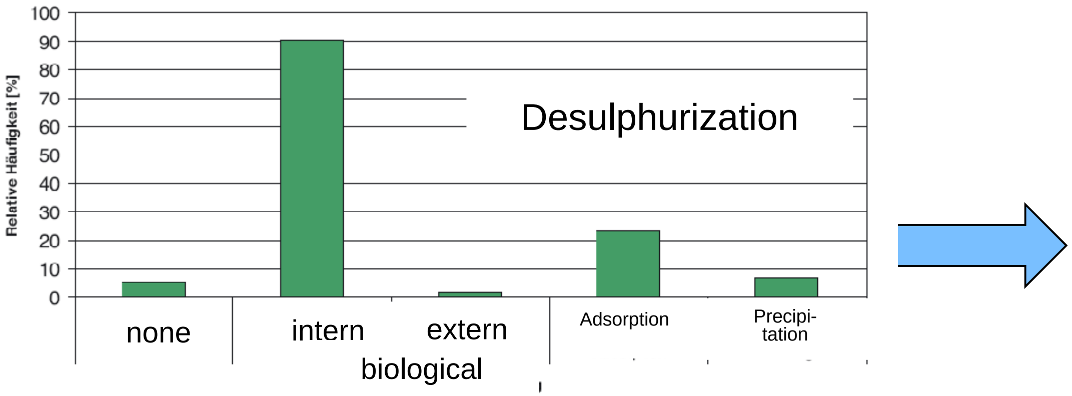
- 66% of the plants achieve more than 8000 hours of operation per year
- This is not necessarily full load operation!



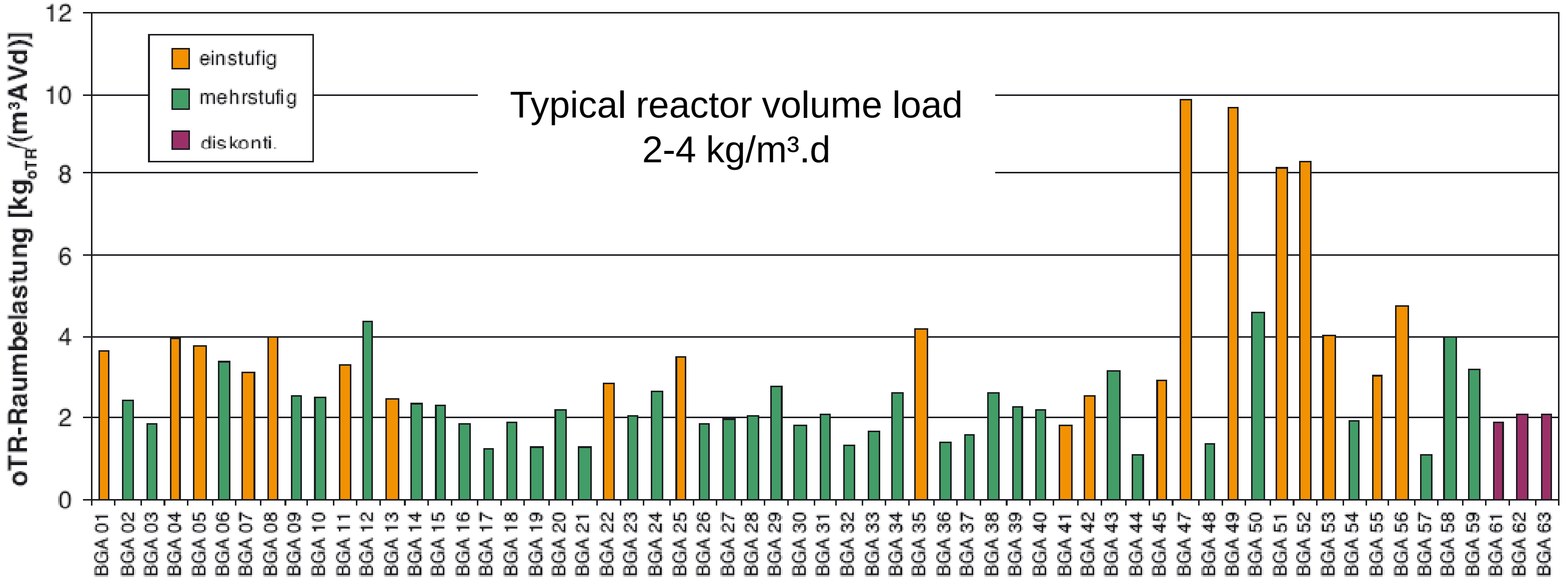
- More than 8000 full load hours can be achieved, however…..
- About 50% fail to achieve 7500 full load hours
- Careful assumptions regarding availability in business plan!

Source of diagrams: FNR

Biogas: Statistical data from Germany and conclusions (3)



- In most cases the simple internal biological fermentation is sufficient



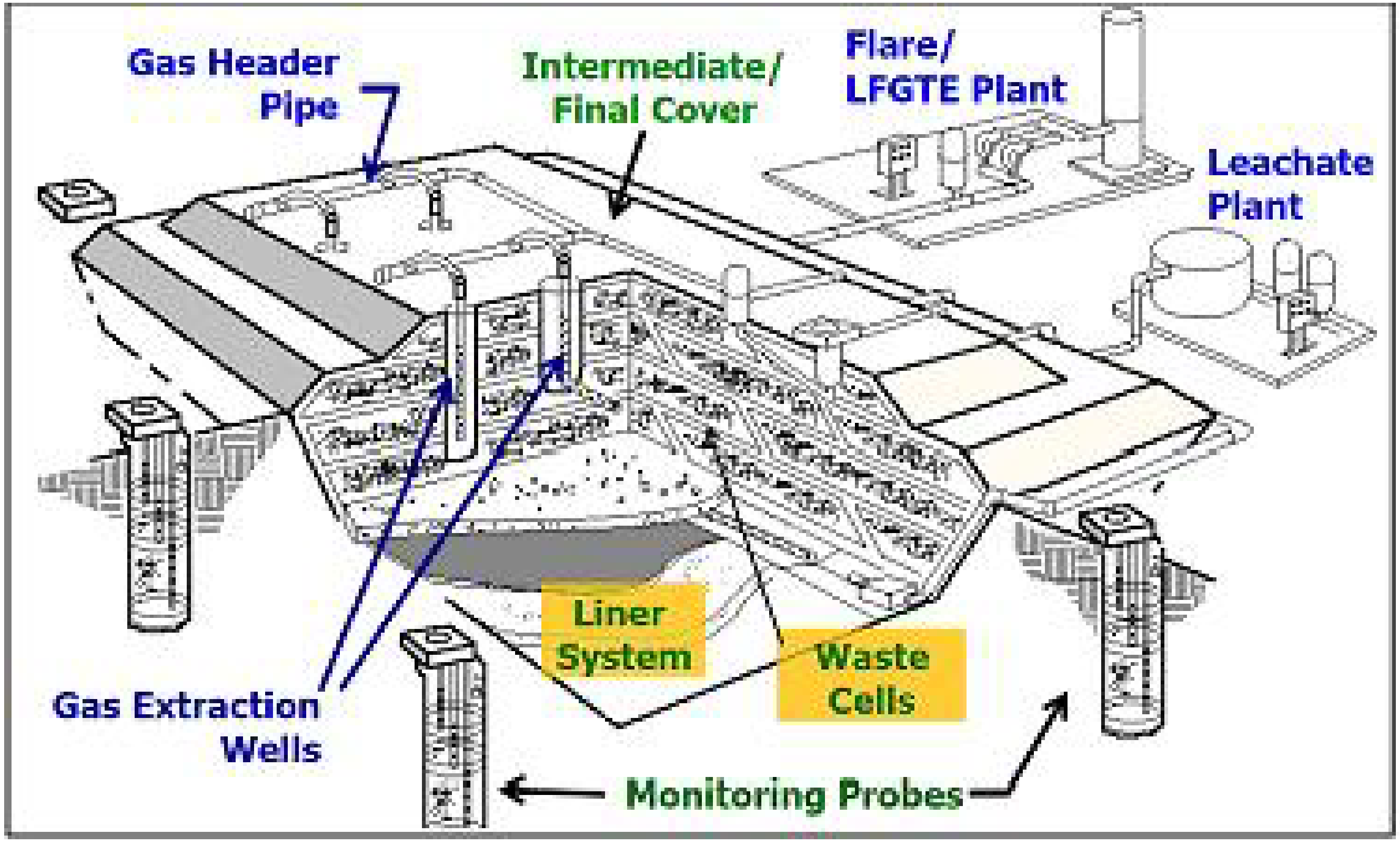
Source of diagrams: FNR

Special case: Landfill gas (1)

- **Municipal solid waste contains significant amount of organic waste which, in the absence of air, starts a fermentation process producing methane.**
- **The gas should be collected and burned because of the high greenhouse activity of methane**
- **The landfill is a biogas reactor, but**
  - The feedstock is not defined
  - the content is not mixed or stirred
  - the reaction conditions are not defined
  - air access can not be excluded
  - no new feedstock is supplied
- **Projects have to deal with high uncertainties in landfill gas production rate and properties.**

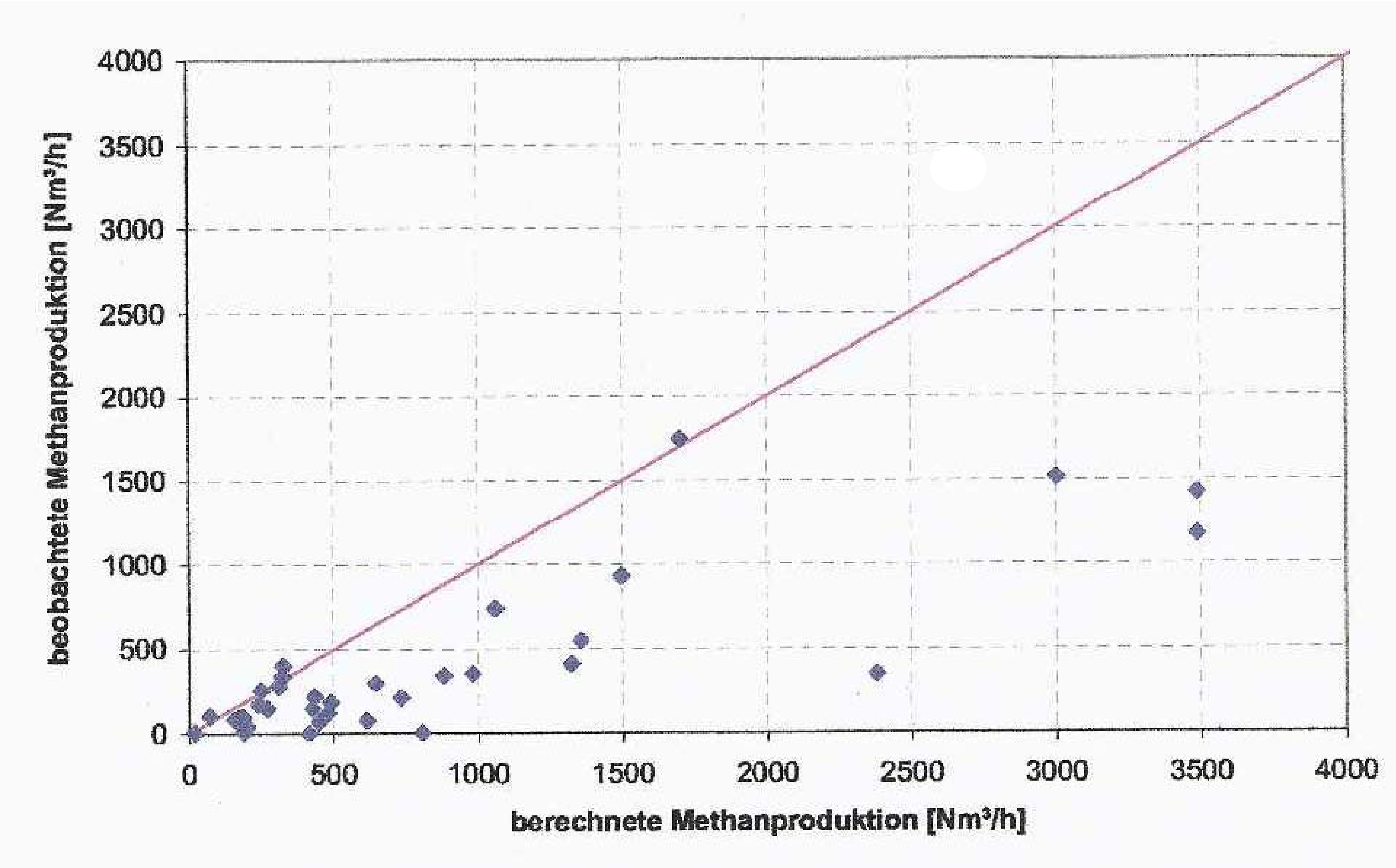
Special case: Landfill gas (2)

Principle of landfill gas utilization



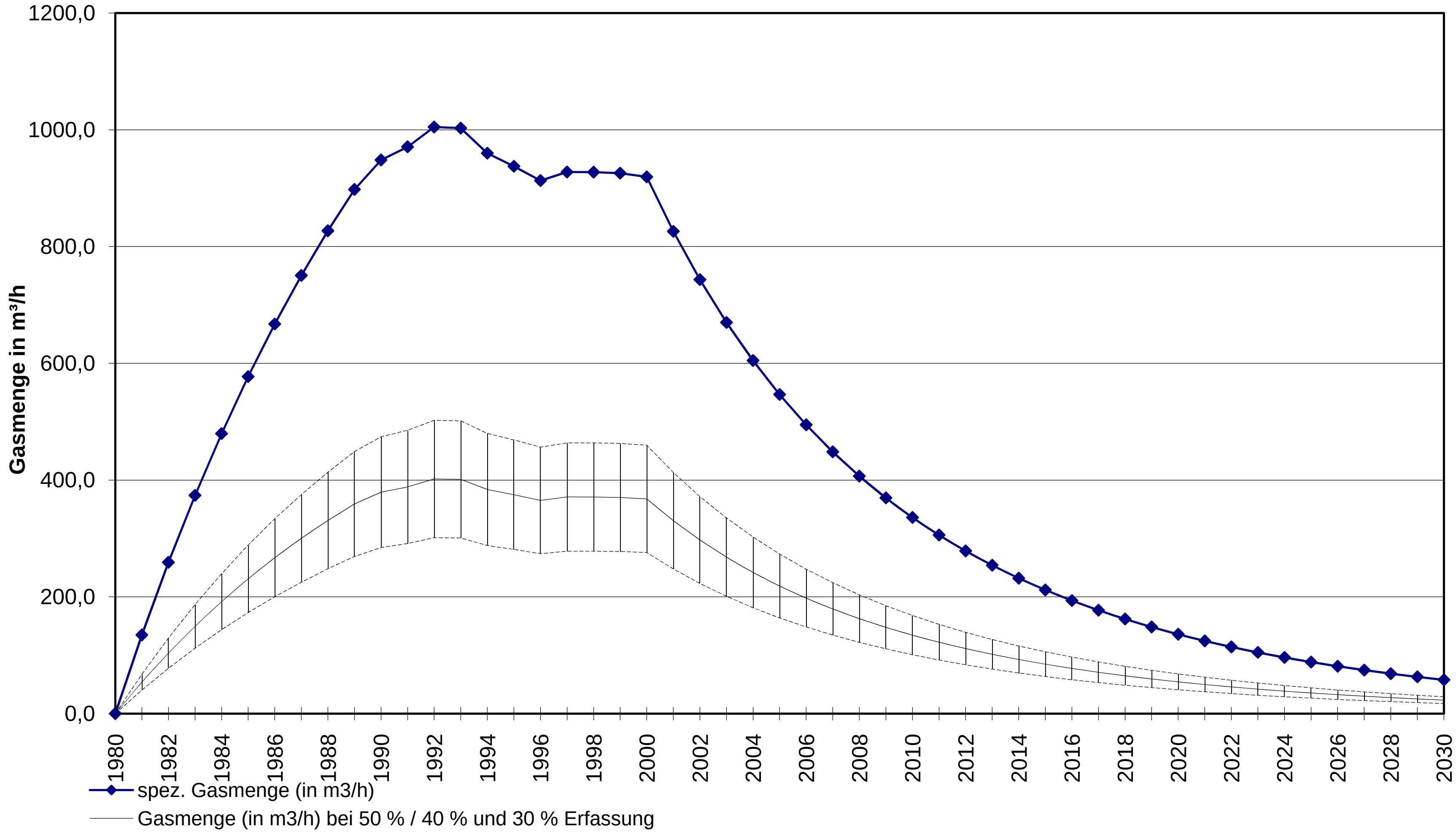
Special case: Landfill gas (3)

Uncertainties of methane prognosis



Source: Bogon, H.: Deponiegasprognose, worauf kommt es an?
www.oekobauconsult.de/Deponiegasprognose_Vortrag.pdf

Landfill gas production: Typical Curve



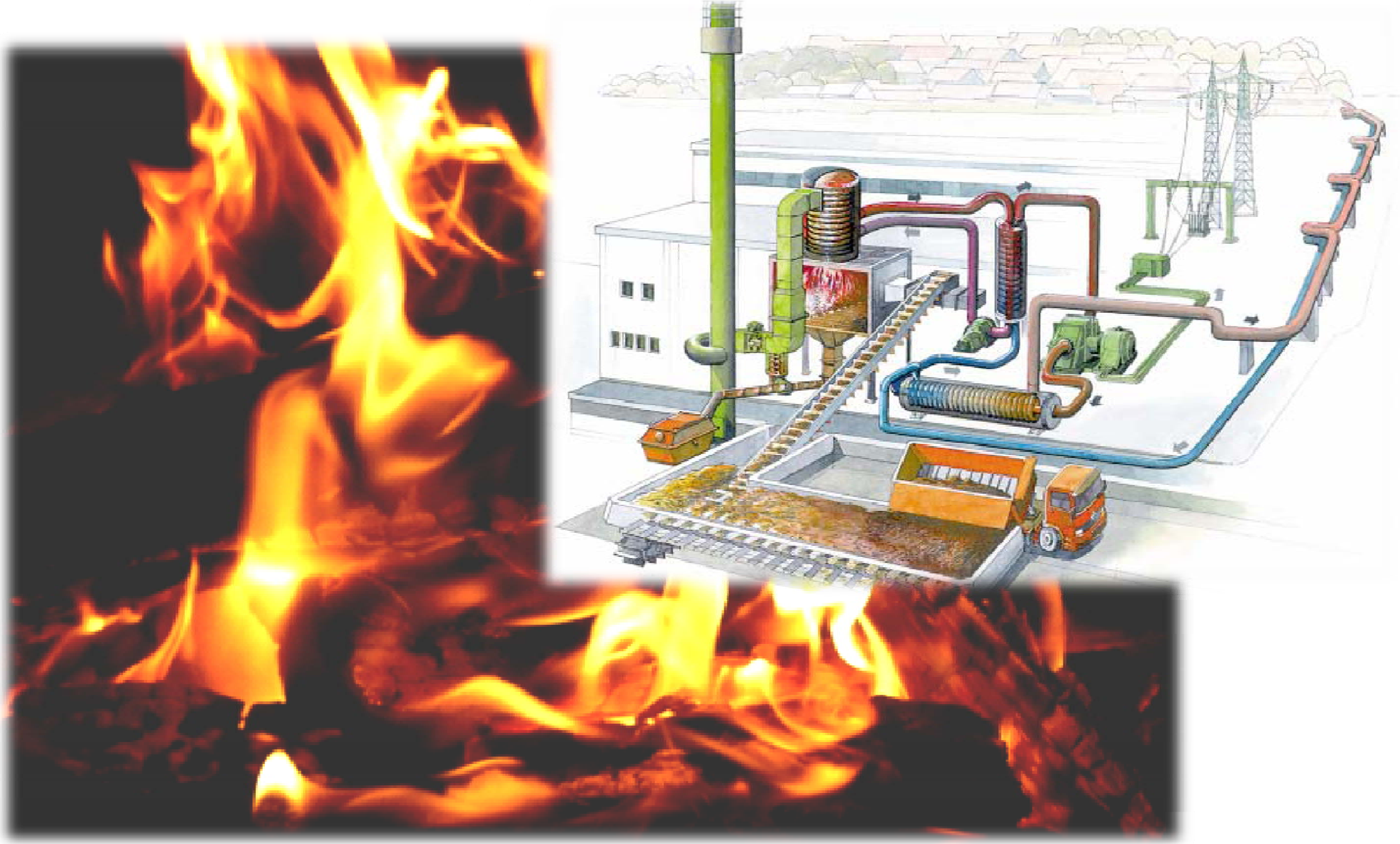
Source: Rettenberger: www.ruk-online.de

Special case: Landfill gas (4)

Aspects to be considered

- There must be a legal basis for gas utilization, e.g. concession.
- Dimensioning of equipment must be done carefully: Start small and extend after gas supply is PROVEN.
- Gas production decreases after closing of landfill: Dimensioning not for peak production.
- Landfill gas is from WASTE and may contain many impurities: Only engines from experienced suppliers should be used.
- As a rule there will be no heat offtake at the landfill: Feed-In tariff decisive for economic viability

Part 2: Thermal Processes



Distinction thermal processes

Combustion	• Air ratio >1 • Hot flue gas
Gasification	• Air ratio < 1 • Syngas (H_2, CO, (N_2))
Pyrolysis	• Air ratio = 0 • Hydrocarbons (gas, oil)

Anaerobic digestion	• *Biological process* • *Methane*

Distinction thermal processes

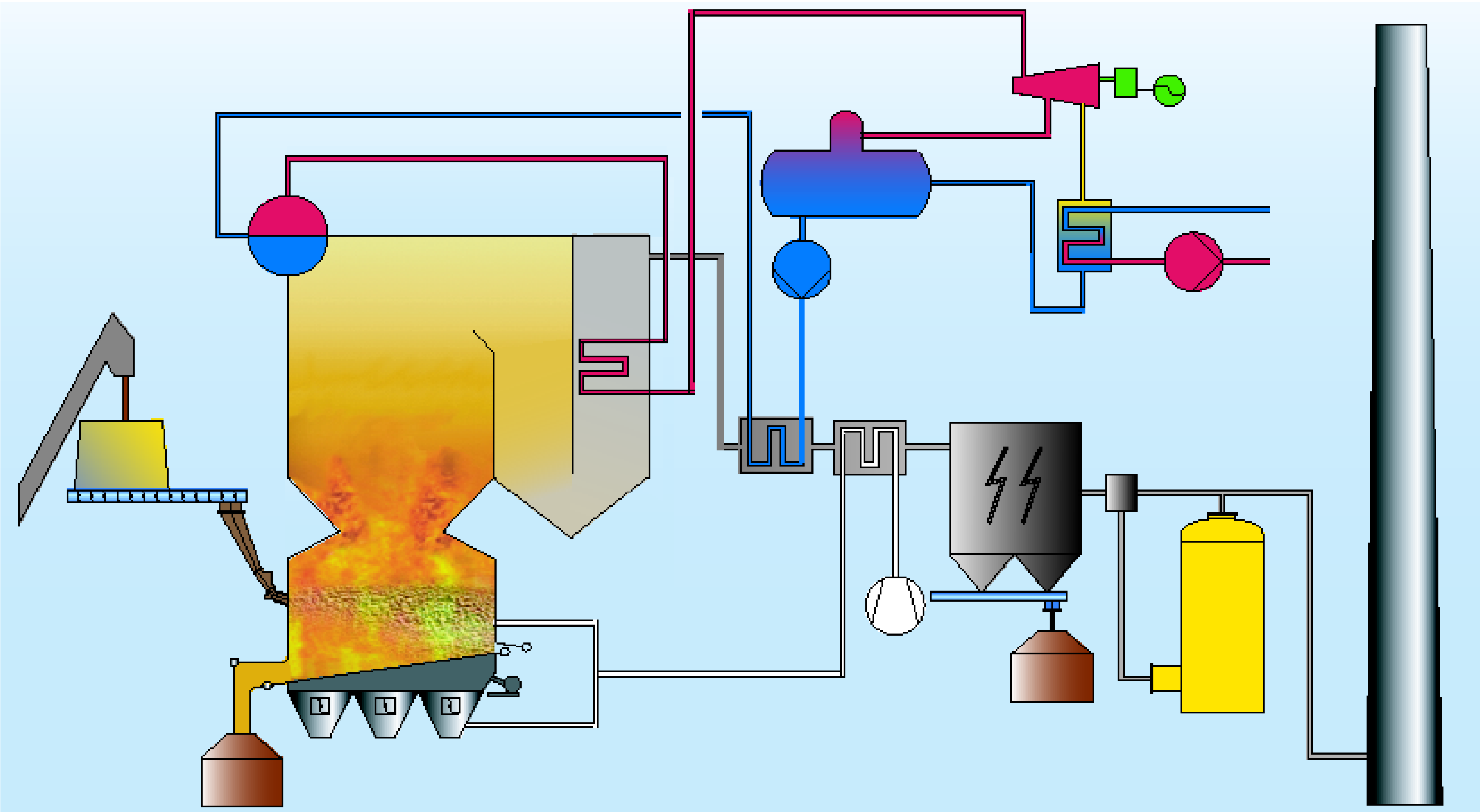
Combustion

- **Air ratio >1**
- **Hot flue gas**

Gasification

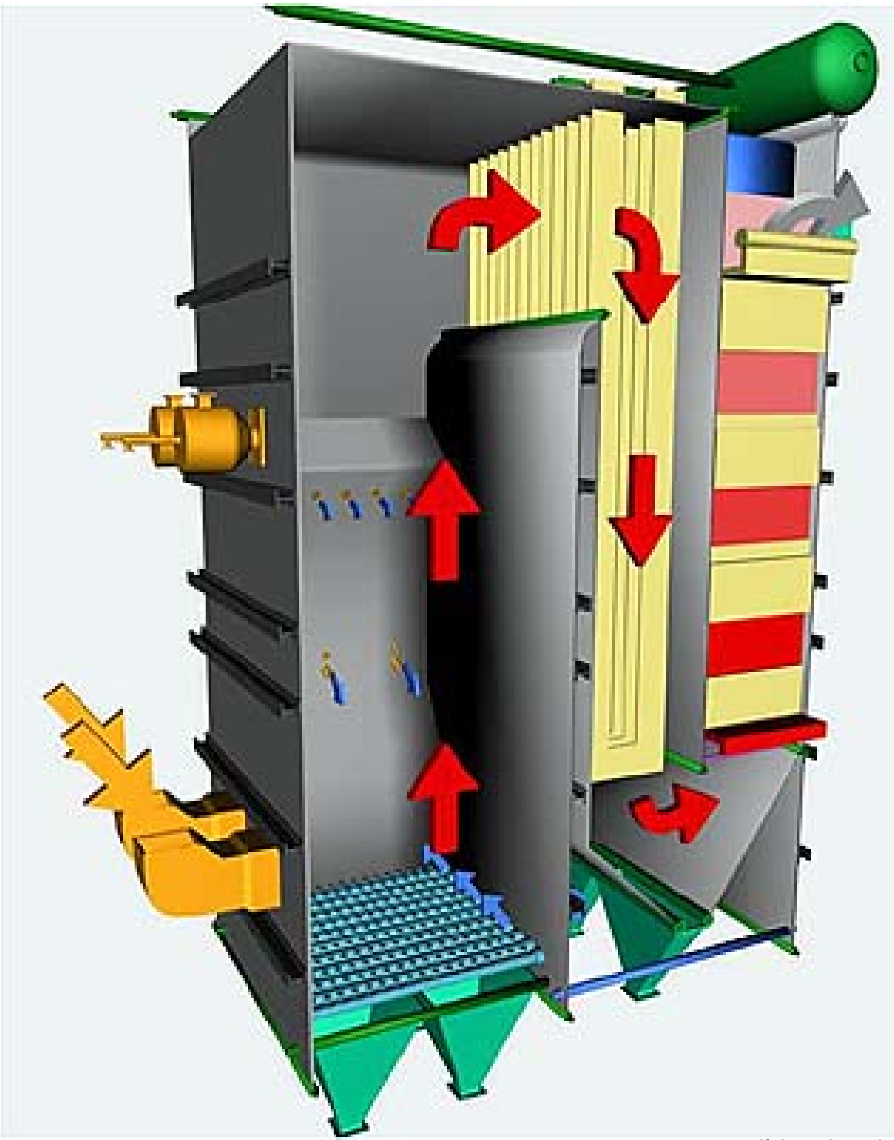
- Air ratio < 1
- Syngas (H_2, CO, (N_2)

Scheme of a conventional Biomass Powerplant



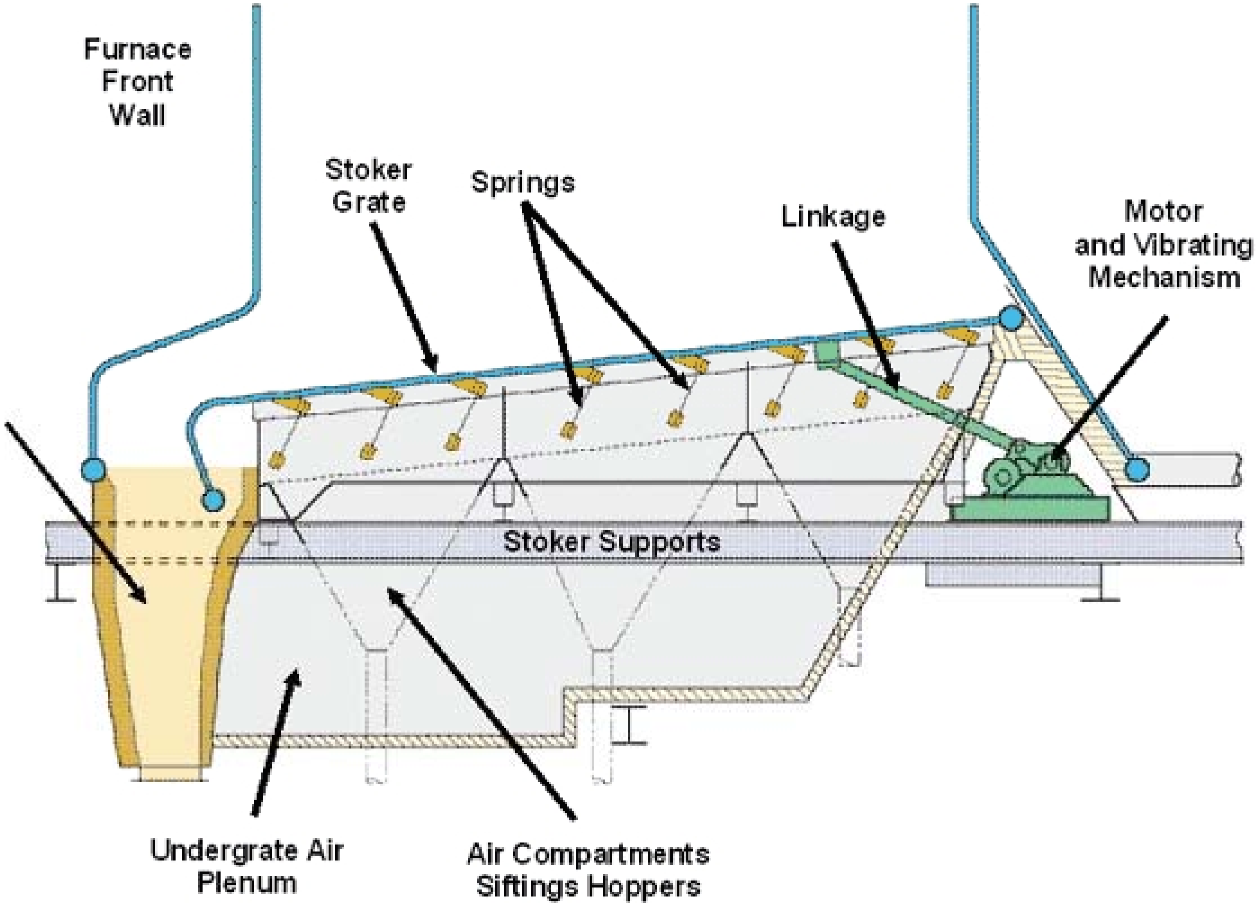
Bildnachweis: Babcock & Wilcox Volund, http://www.volund.dk

Scheme of a Fluidized Bed Boiler for Biomass



Bildnachweis: Austrian Energy & Environment, http://www.aee.co.at

Scheme of water cooled combustion grate

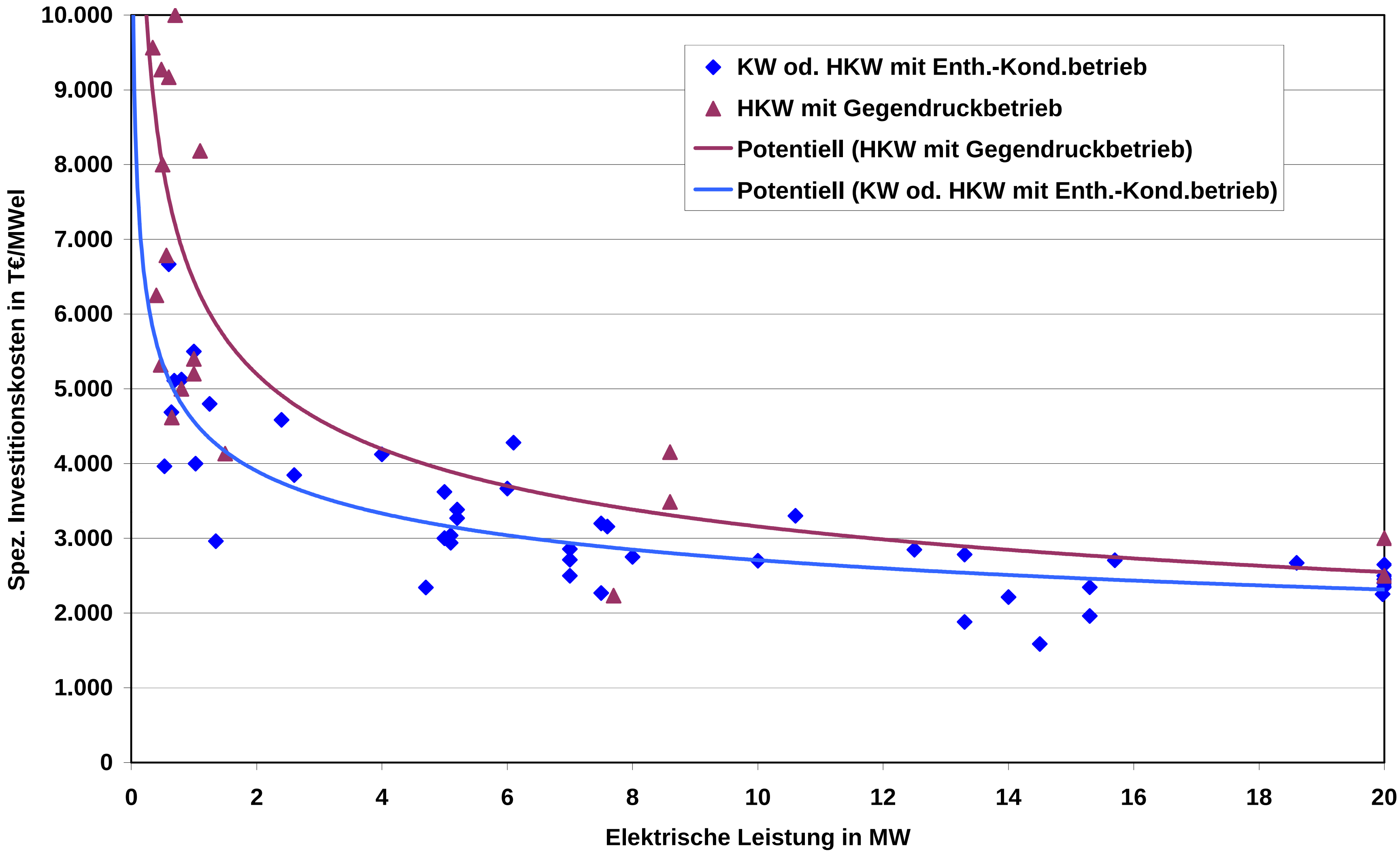


Bildnachweis: Babcock & Wilcox Volund, http://www.volund.dk

Typical key design data for biomass fired plants

	5 MW_{el}	10 MW_{el}	20 MW_{el}
• 10 days storage	• 1.300 m² • 5 m high • 38.500 t/a	• 2.500 m² • 5 m high • 73.500 t/a	• 4.500 m² • 5 m high • 130.500 t/a
• Boiler / furnace	• 6000 to 8000 h/a Steam 420 °C, 60 bar		
	• 5,5 t/h	• 10,5 t/h	• 18,6 t/h
• Flue gas flow • Cleaning residues	• 36.000 m3/h • 80 kg/h	• 69.000 m3/h • 155 kg/h	• 120.000 m3/h • 280 kg/h
• CHP-mode	• 10 MW_{th}, • 3,6 MW_{el}	• 20 MW_{th}, • 7,2 MW_{el}	• 20 MW_{th}, • 16,5 MW_{el}
• Personnel	• 10 - 15	• 15 - 20	• 20 - 22
• CAPEX	• 3000 – 3500 €/kW	• 2500 – 3000 €/kW	• 2000 – 2500 €/kW

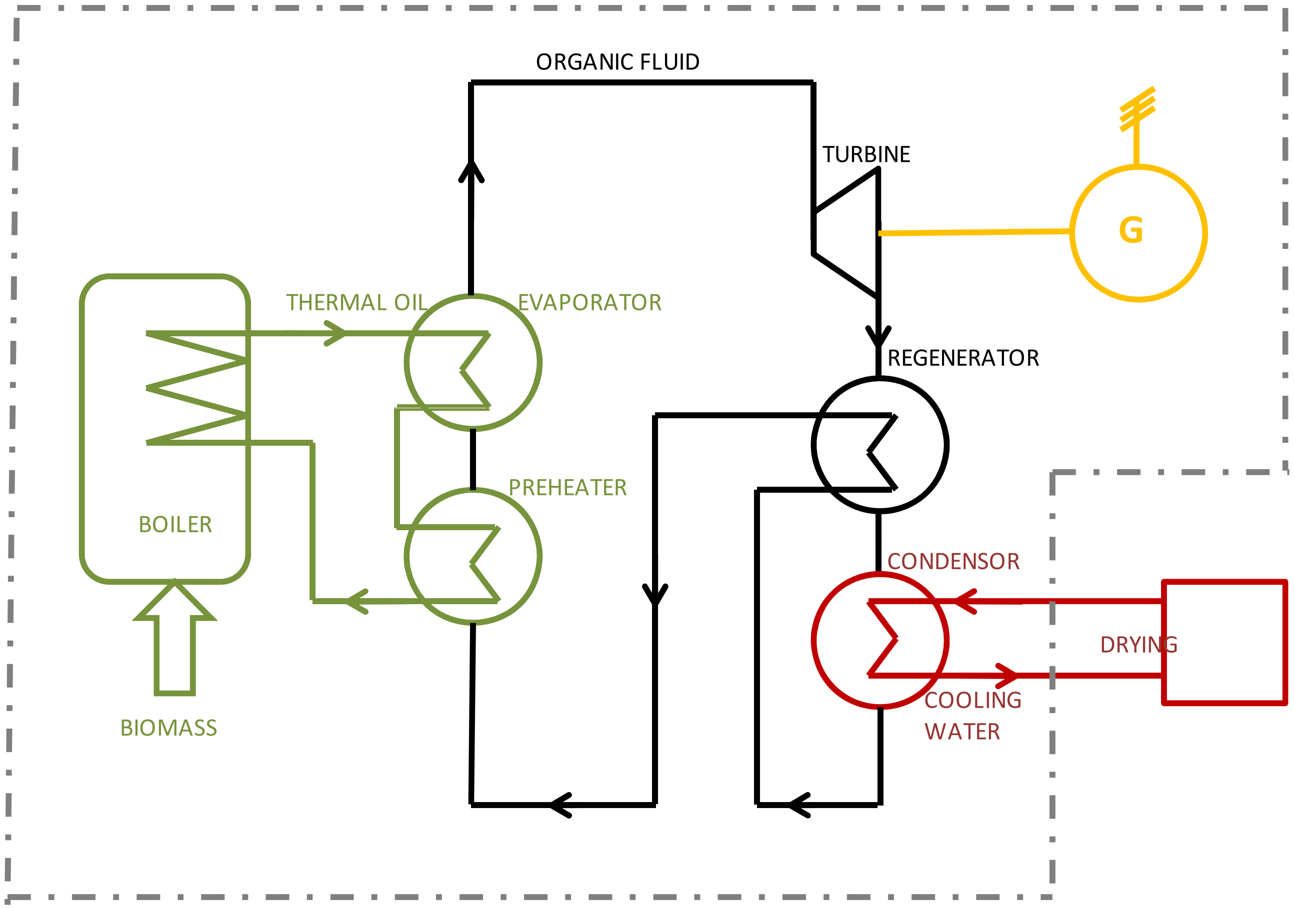
Specific CAPEX for biomass fired powerplants



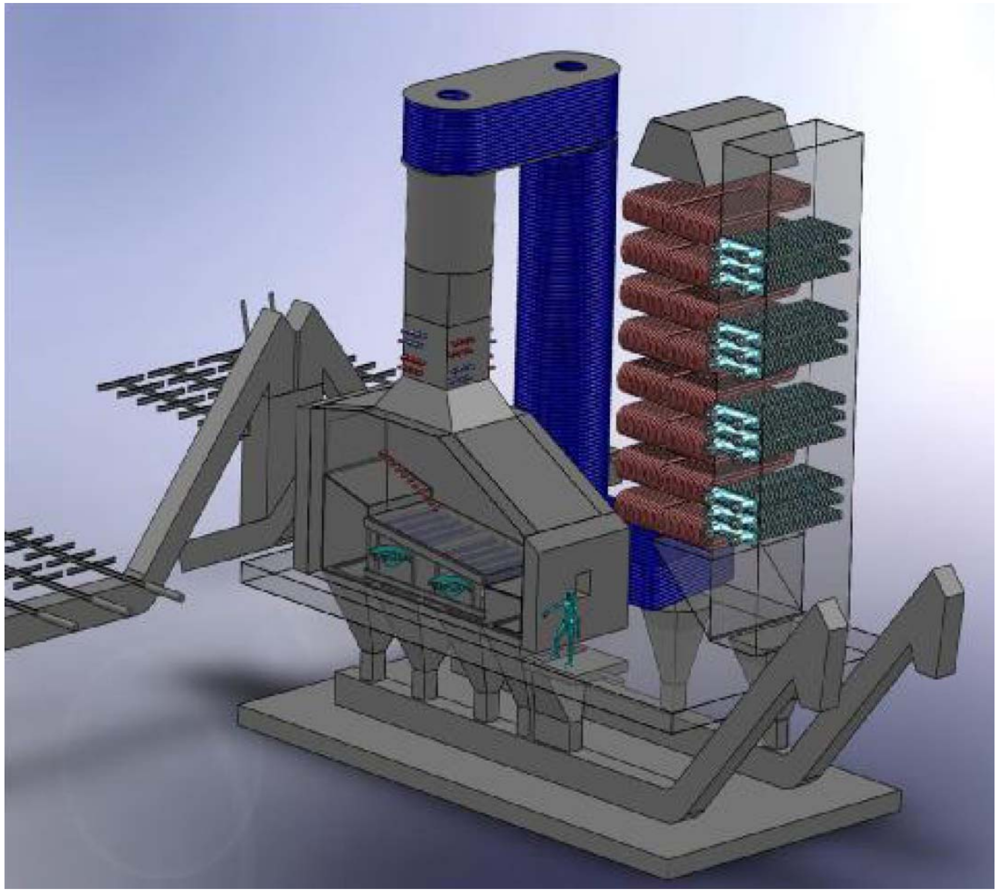
Biomass Combustion: ORC Process

- **The ORC (Organic Rankine Cycle) works like a conventional water/steam cycle, but applies organic liquids instead of water.**
- **ORC-Process has been developed to utilize low-temperature heat (e.g. geothermal power).**
- **Meanwhile there are solutions also for use in biomass plants**
- **Disadvantage:**
  - Low electrical efficiency
  - Heat sink required
- **Advantage:**
  - Predesigned packages
  - Easy operation
  - No Condenser needed
- **Typical application: Pellet factories with constant heat demand**

Biomass Combustion: Scheme of ORC-Process



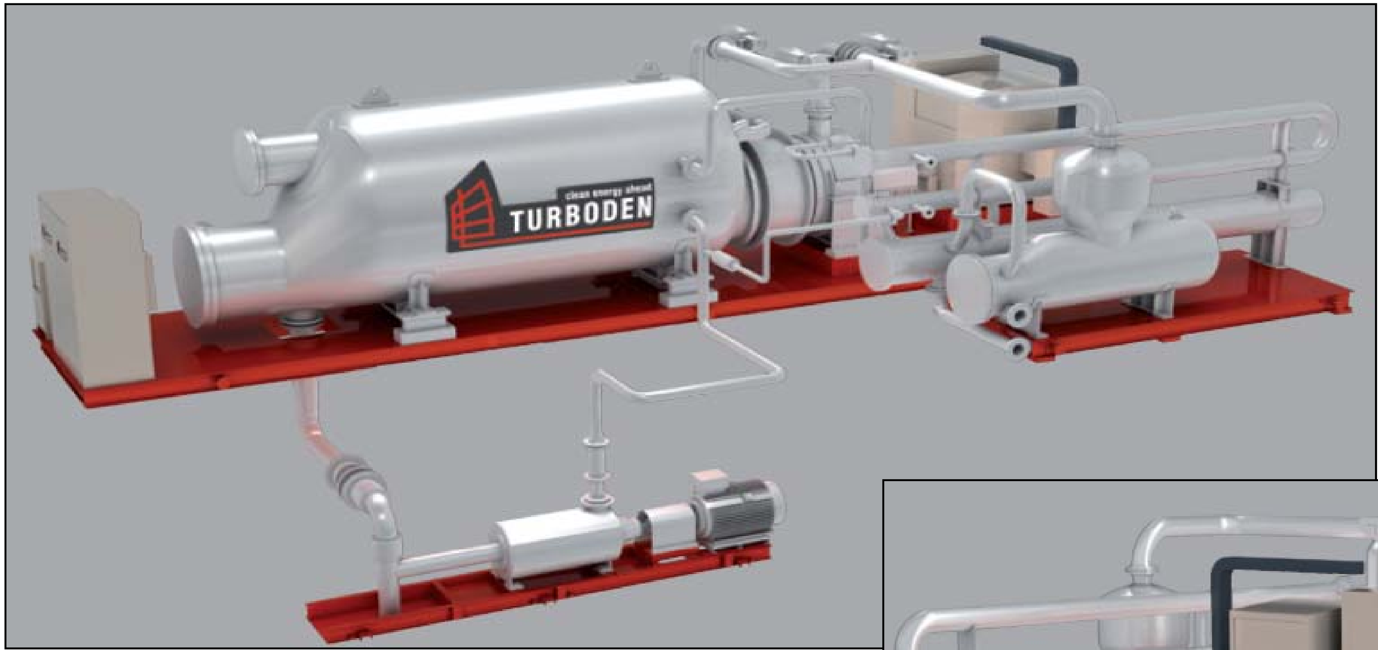
Biomass Combustion: Thermo-Oil Boiler for ORC



Source: Kohlbach

Biomass Combustion: ORC – Module

Example: Turboden



Source: Turboden

Biomass Combustion: Design Data ORC-Packages

Example: turboden

		TURBODEN 10 CHP	TURBODEN 14 CHP	TURBODEN 18 CHP	TURBODEN 22 CHP
		"split"	"split"	"split"	"split"
INPUT - Thermal oil					
Nominal temperature "HT" loop (in/out)	°C	310/250	310/250	312/252	312/252
Thermal power input "HT" loop	kW	4690	6130	8935	10975
Nominal temperature "LT" loop (in/out)	°C	250/130	250/130	252/132	252/132
Thermal power input "LT" loop	kW	450	585	855	1045
Overall thermal input	kW	5140	6715	9790	12020
PERFORMANCES					
Gross active electric power	kW	1001	1317	1862	2282
Gross electric efficiency		0,194	0,196	0,19	0,189
Captive power consumption	kW	51	62	87	107
Net active electric power	kW	950	1255	1775	2175
Net electric efficiency		0,184	0,186	0,181	0,181
Electrical generator		*asynchronous*	*asynchronous*	*asynchronous*	*asynchronous*
		triphase, L.V. 400V	*triphase, L.V. 400V*	*triphase, L.V. 660V*	*triphase, L.V. 660V*
Plant size		Single Skid	Multiple Skid	Multiple Skid	Multiple Skid
Biomass consumption**	Kg/h	2247	2935	4279	5254

Source: Turboden

Distinction thermal processes

Combustion
- Air ratio >1
- Hot flue gas

Gasification
- **Air ratio < 1**
- **Syngas (H_2, CO, (N_2))**

Gasification: Distinctive design features (1)

Gasification means combustion under starved air conditions:
Hydrocarbons + Oxygen ➔ CarbonMonoxide plus Hydrogen

Gasification

- **Fixed bed gasifier**
- **Entrained Flow Gasification**
- **Fluidized Bed**
- **Combinations / others**

- **Gasification medium air**
- **Gasification medium oxygen**
- **Gasification medium steam**
- **Allothermal**
- **Autothermal**

Gasification: Distinctive design features (2)

Gasification: Design features

- Fluidized bed
  - Lower tar content
  - Only for larger plant sizes (> 2 – 5 MW fuel heat)
- Fixed bed
  - For smaller unit sizes (up to 1 MW_{th})
  - Numerous projects failed due to problems with availability and gas quality.

- Gasification with oxygen: Only for large plants.
- Entrained flow gasifier: Pretreatment required, only large plants.

Gasification: Technical problems:

- **Especially in fixed bed gasifier it is difficult to maintain constant reaction condition in the whole reactor.**
- **As a consequence, there are zones where only pyrolysis takes place and tar is created.**
- **Gas scrubbing is possible, but will create a waste water problem.**
- **Gas scrubbing with POME (Biodiesel) is possible.**

Holzvergasungs-Kraftwerk Güssing (2 MW_{el})

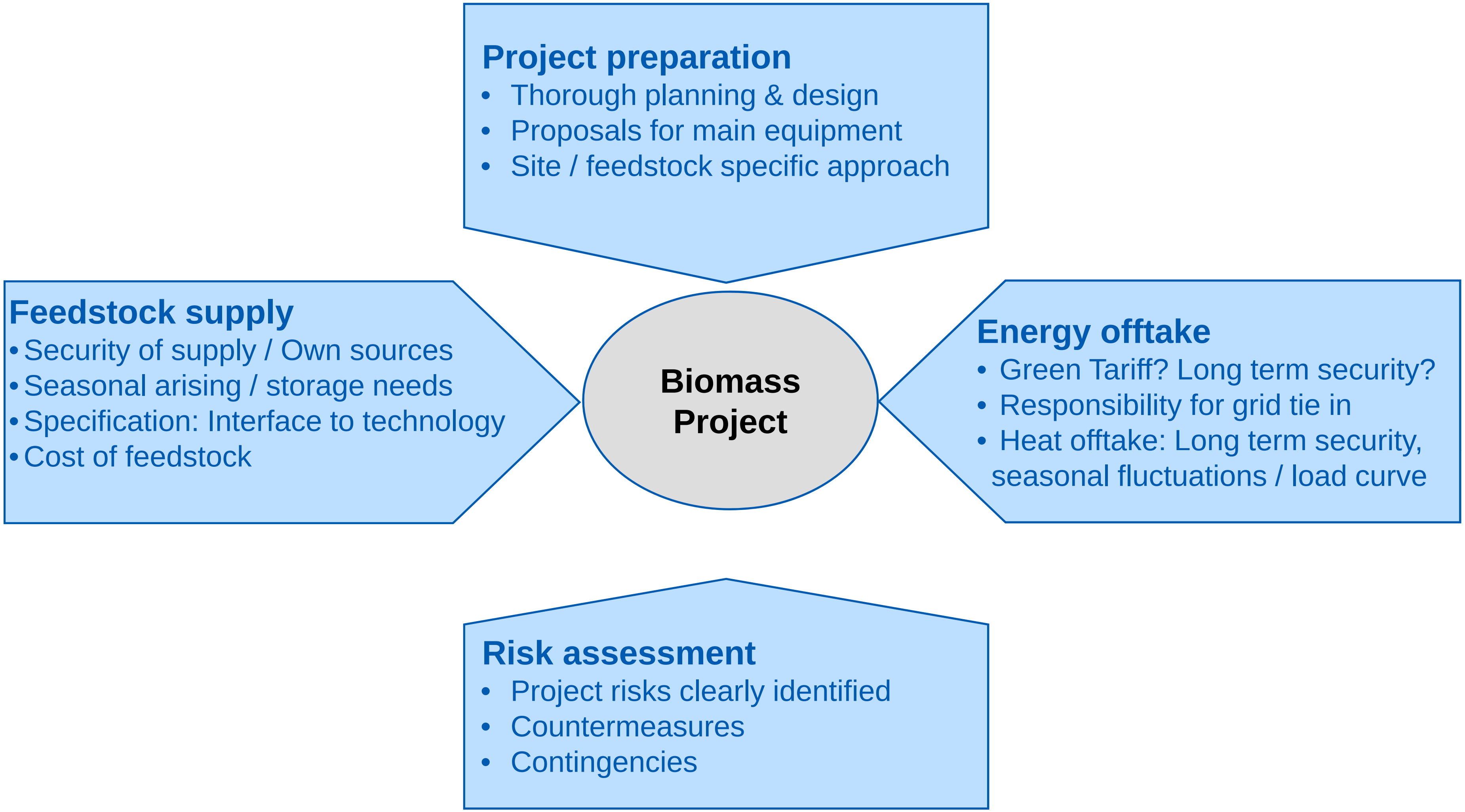
- **Succesfull operation with Jenbacher gas engine**
- **Comparatively large plant**
- **Special design two-stage gasification**

Bildnachweis: RENET Austria, http://www.rer

Gasification: Future options:

- **Biomass gasification as source for synthesis gas provides interesting perspectives for the future:**
  - **Production of synthetic biofuel (BtL, biomass to liquid)**
  - **Production of SNG (Synthetic natural gas)**
  - **Production of Methanol / Ethanol / DME**
- **All these processes will require large entrained flow gasifiers**

Project Development: Requirements and Constraints (1)



Thank you for your attention

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