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Gasaufbereitung mit Membranen

Gas Treatment Using Membranes

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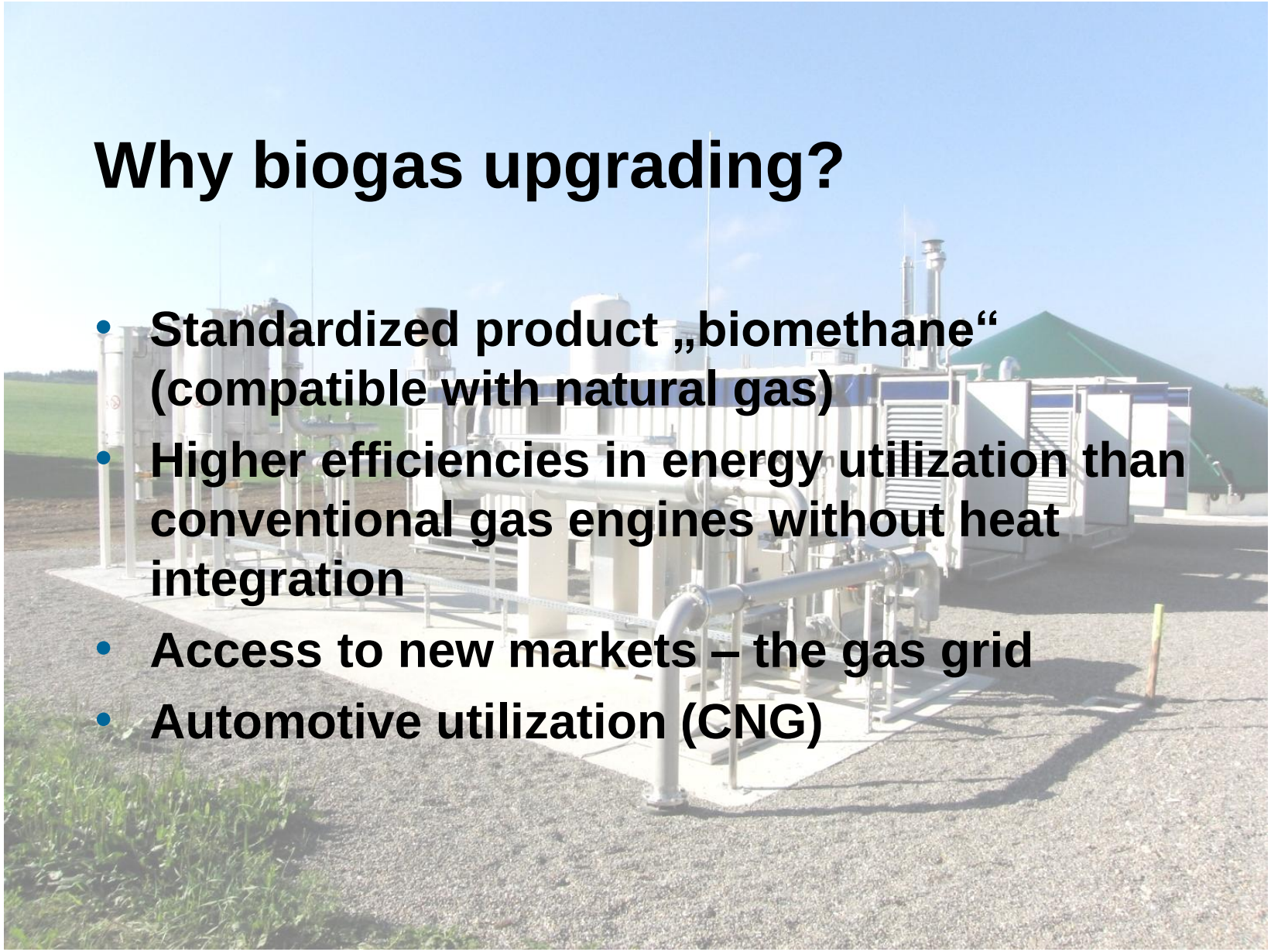
Internationale wissenschaftliche Konferenz
Regenerative Energien als Zukunftstechnologien

Agenda

- Short intro – why biogas upgrading?
- Quality issues
- Gas permeation process
- Scale-up to pilot and full scale - process integration
  - Two-stage grid injection (Bruck/Leitha)
  - Single-stage CNG production (Margarethen/Moos)
- Energy demand
- Biogas pretreatment (desulphurisation)
- Costs
- Technology roll-out & future



Why biogas upgrading?

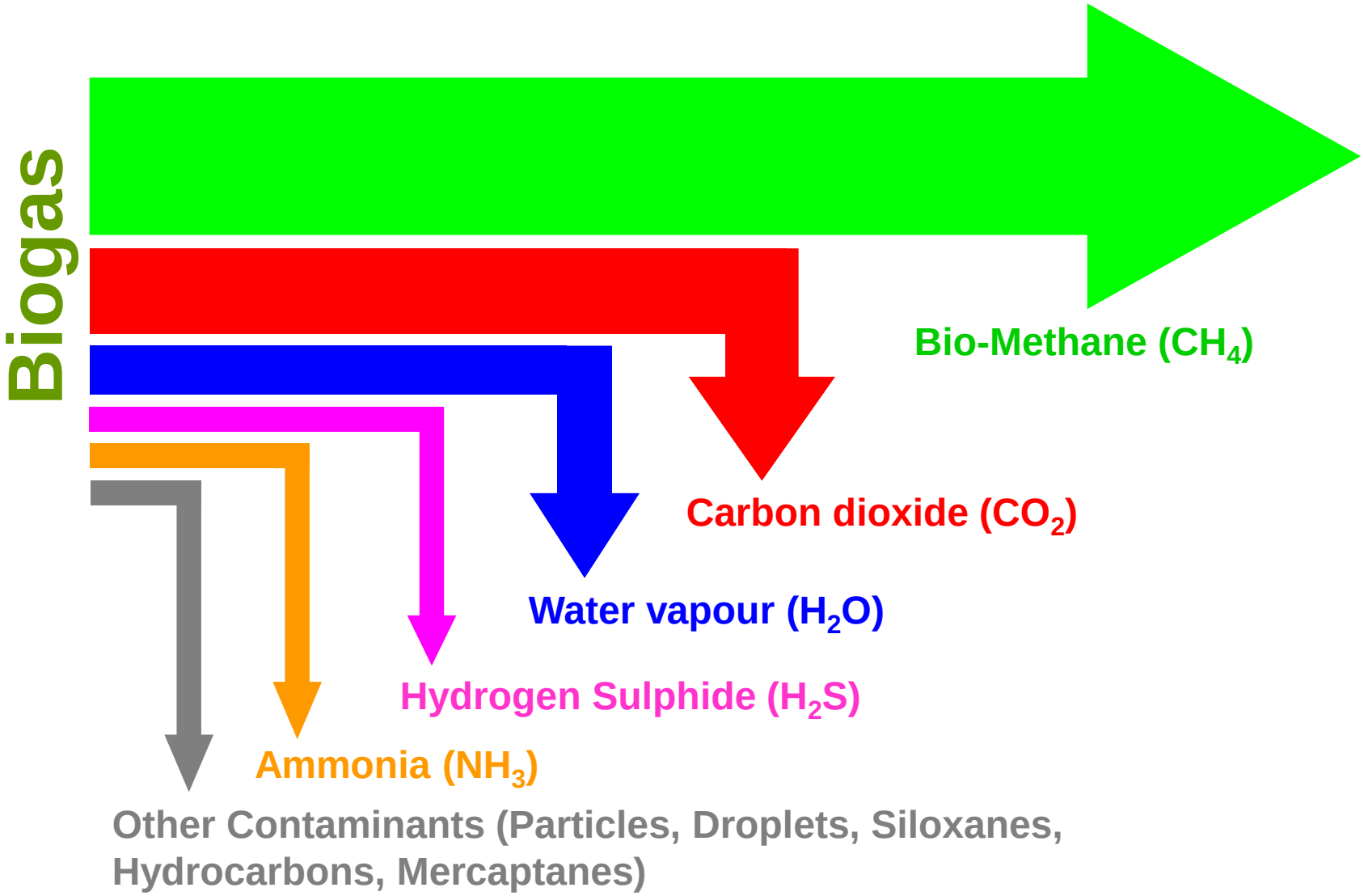
- Standardized product „biomethane“ (compatible with natural gas)
- Higher efficiencies in energy utilization than conventional gas engines without heat integration
- Access to new markets – the gas grid
- Automotive utilization (CNG)

Biogas Composition and Gas Grid Standards

Parameter	Raw Biogas	Quality according to Austrian Standard OEVGW G31 / G33	Unit
Methane (CH_4)	45 - 70	unspecified (> 97.0)	mol%
Carbon dioxide (CO_2)	30 - 45	≤ 2.0	mol%
Ammonia (NH_3)	< 1,000	technically free	mg/m^3_{STP}
Hydrogen sulphide (H_2S)	< 5,000	≤ 5	mg/m^3_{STP}
Oxygen (O_2)	< 2	≤ 0.5	mol%
Nitrogen (N_2)	< 8	≤ 5	mol%
Water (H_2O) - Dewpoint	< 37 @ 1bar	≤ - 8 @ 40bar	C
Upper Heating Value	6.7 – 8.4	10.7 – 12.8	kWh/m^3_{STP}
Wobbe-Index	6.9 – 9.5	13.3 – 15.7	kWh/m^3_{STP}

ÖVGW G31 defines natural gas, **ÖVGW G33** specifies grid injection standards for biogases – German standards **DVGW G260/G262**

Biogas Upgrading – A Separation Problem



Biogas Upgrading Steps

1
- Preconditioning / pretreatment
- Removal of particles, droplets, siloxanes, other trace components

2
- Biogas desulphurization

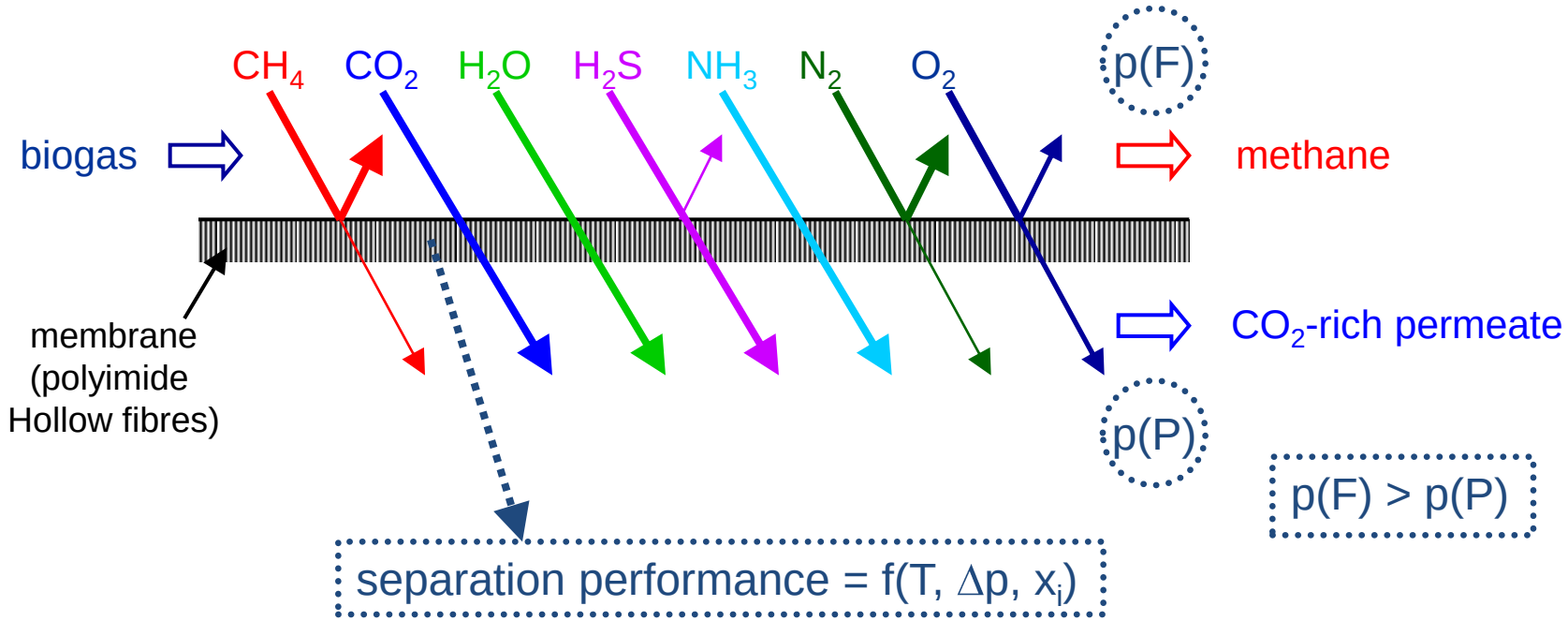
3
- Compression

4
- Biogas upgrading
- Separation of CO_2 and H_2O

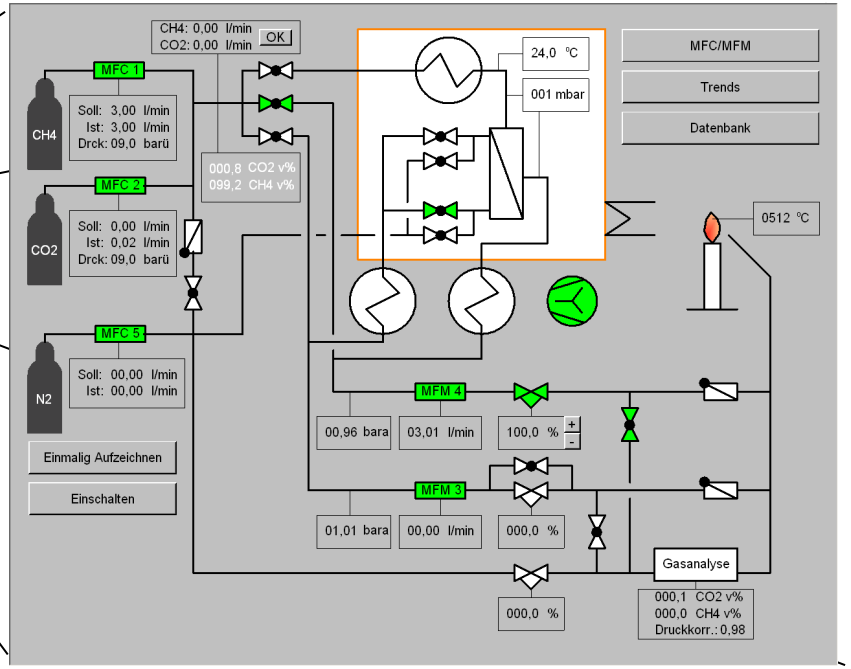
5
- Final conditioning
- Dewpoint control, adjustment of heating value, offgas treatment

Upgrading of Biogas using Gas Permeation (GP)

- <u>Separation principle:</u> different permeabilities of methane and components to be separated.
- Important parameter: permeability ratio = selectivity.
- After compression biogas is fed to membrane modules.

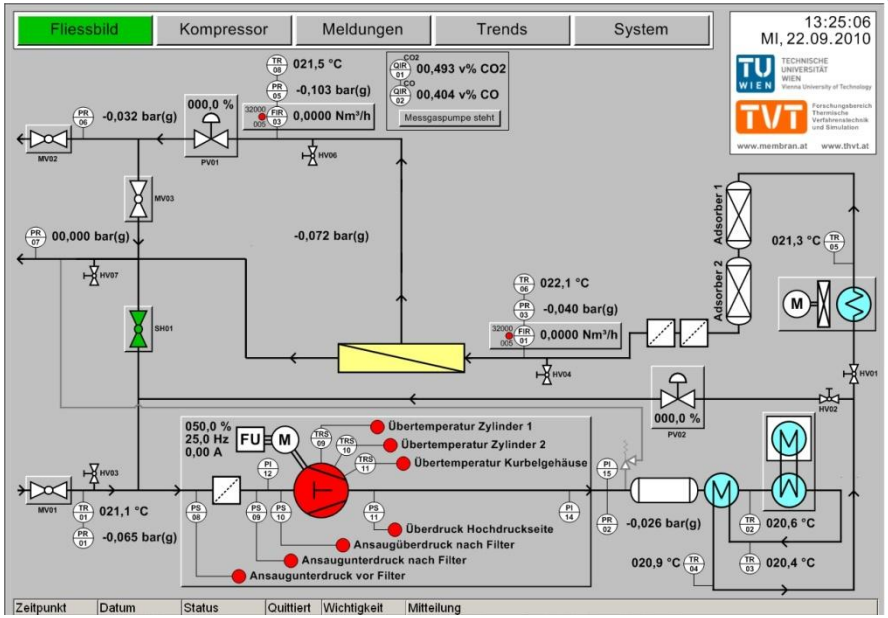


Membrane Test Equipment at TU Wien



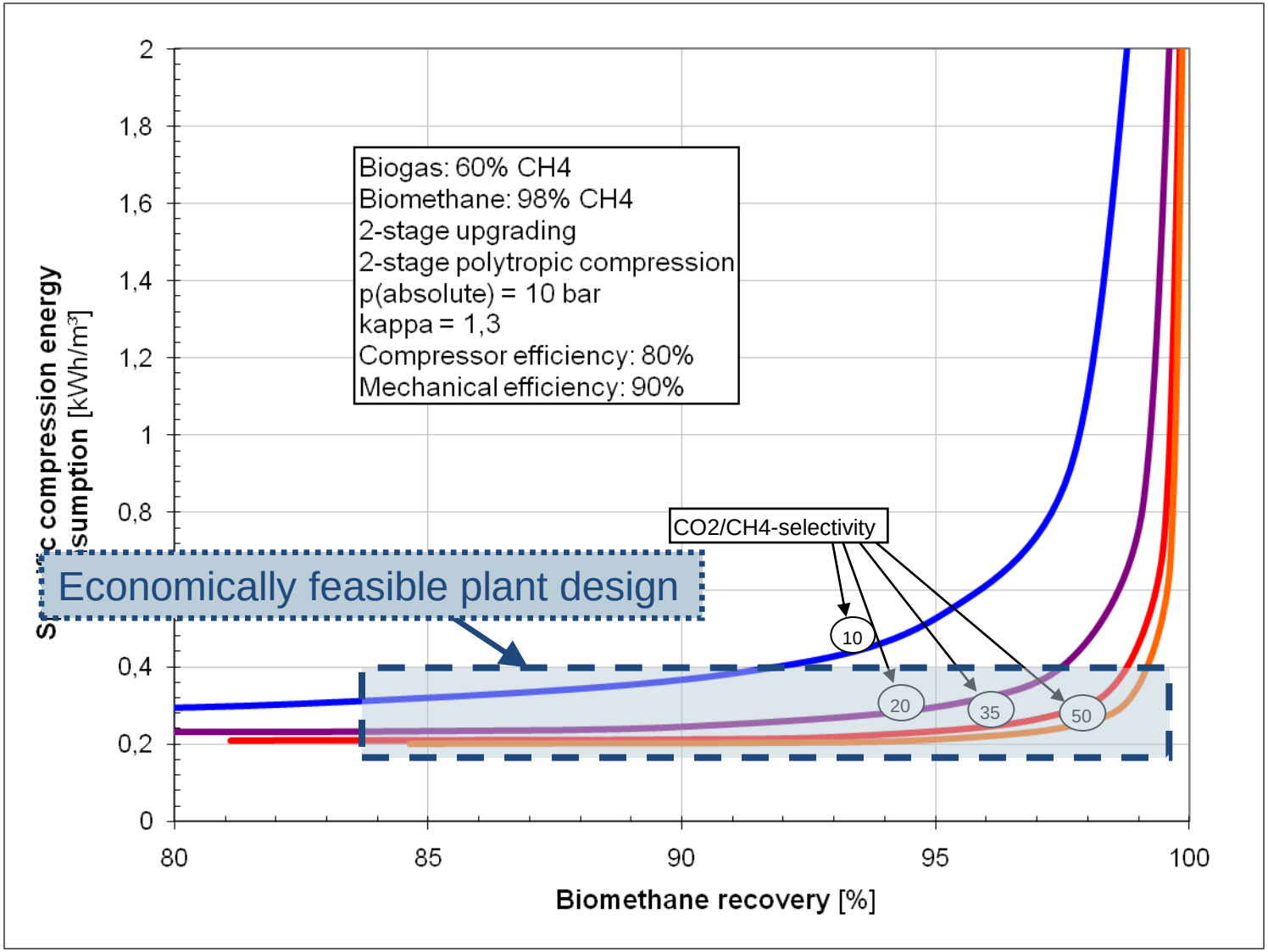
- Preparation of $CO_2/CH_4/N_2$ gas mixtures with mass flow controllers
- Thermostatic chamber
- Industrial NDIR gas analyzer for CO_2 and CH_4 + gas chromatography / mass spectrometry
- Test control, visualization and data collection using a PLC with HMI/SCADA system

Pilot Test Equipment at TU Wien

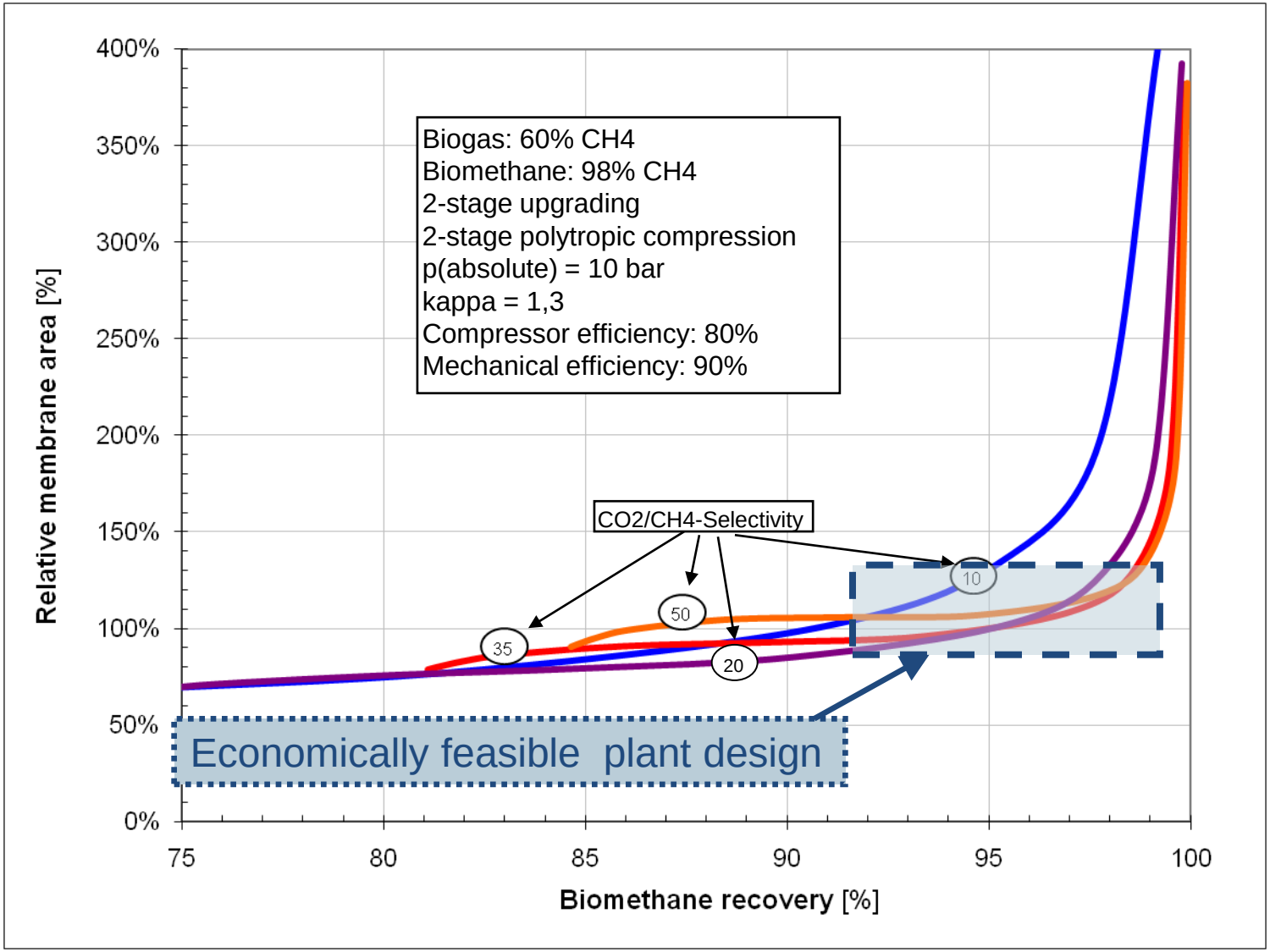


- Mobile pilot plant for flexible treatment of many gas mixtures including H_2
- Magnet-coupled two-stage piston compressor (up to 15 bar, 0-6 m³/h)
- Fully automated upgrading plant for remote operation (industrial PLC)
  - 3 adsorber fillings in series
  - Cryo condenser
  - Reheater
  - One/two stage membrane separation with/without gas recycling
  - NDIR online continuous gas

Compression Energy Consumption per m³ Product

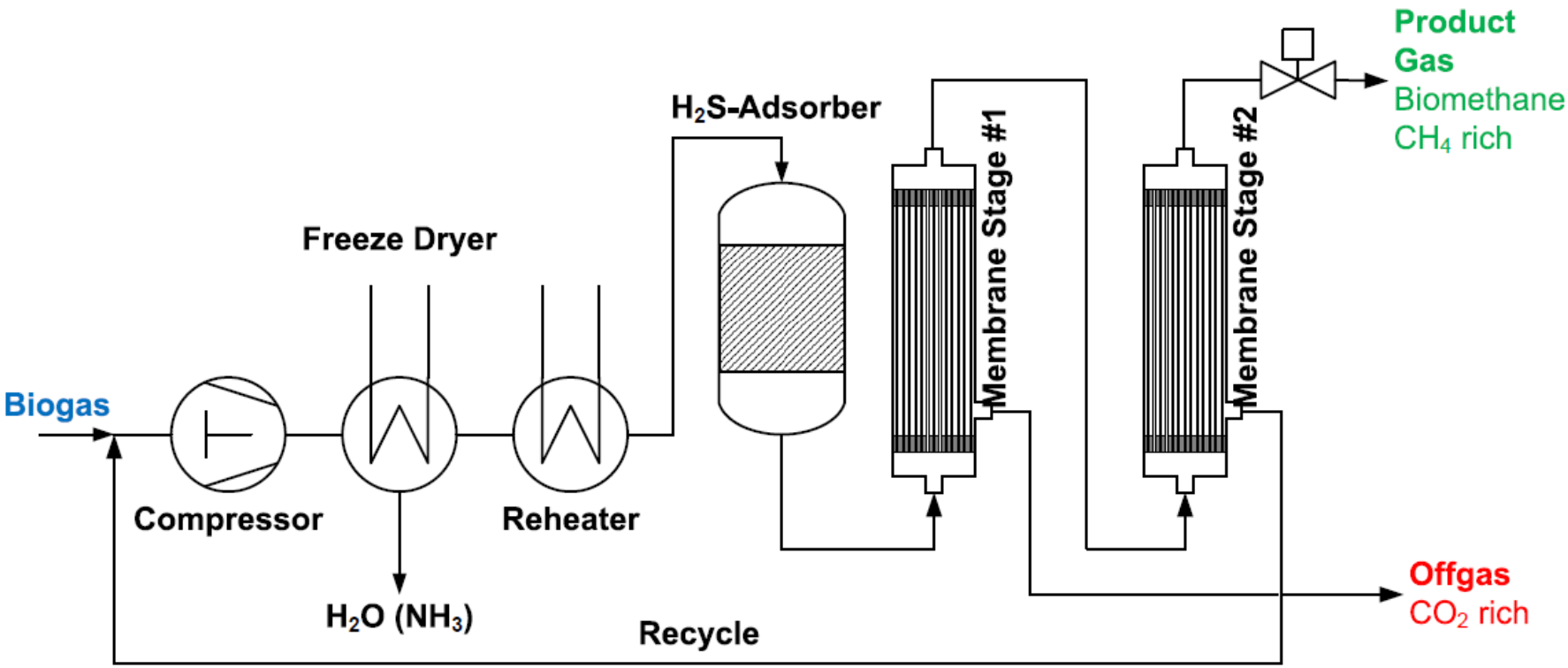


Membrane Area as Function of Recovery

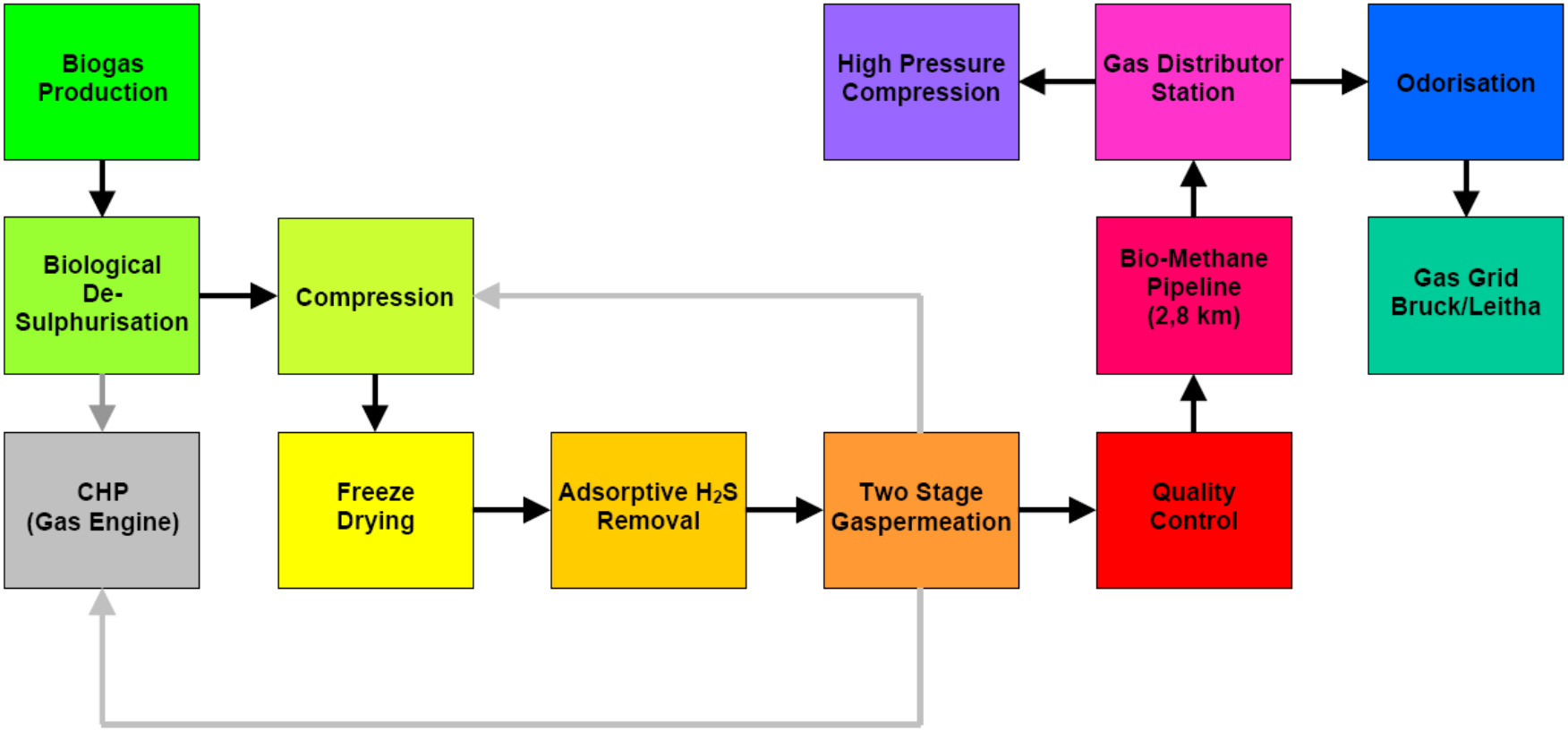


Process Scheme of a Two-stage Membrane System

- **Two-stage separation process** with recycle and a single compressor

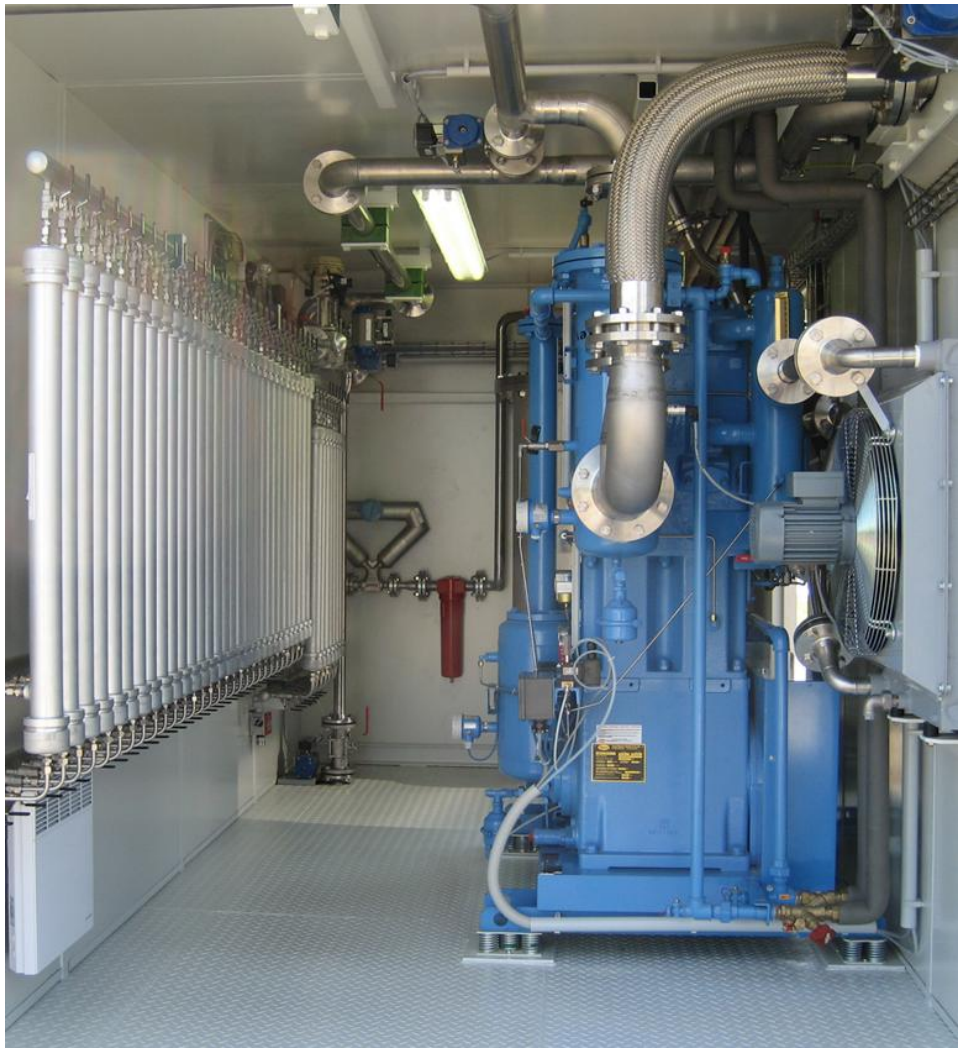


Process Integration (Two-stage design)

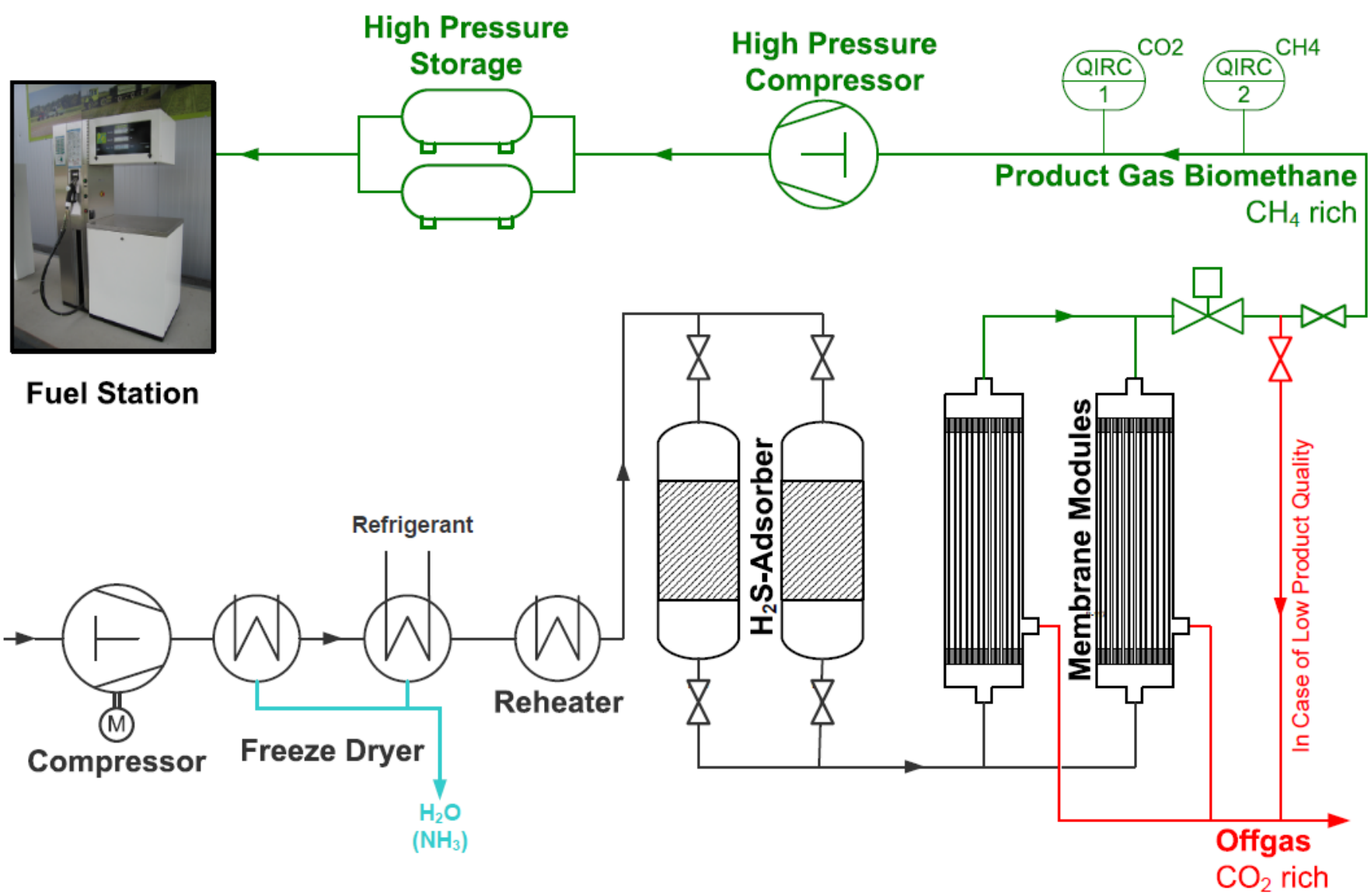


- **Biological desulphurisation prior to membrane treatment**
- **Permeate is recycled to CHP plant – „zero methane“ emission of upgrading system**

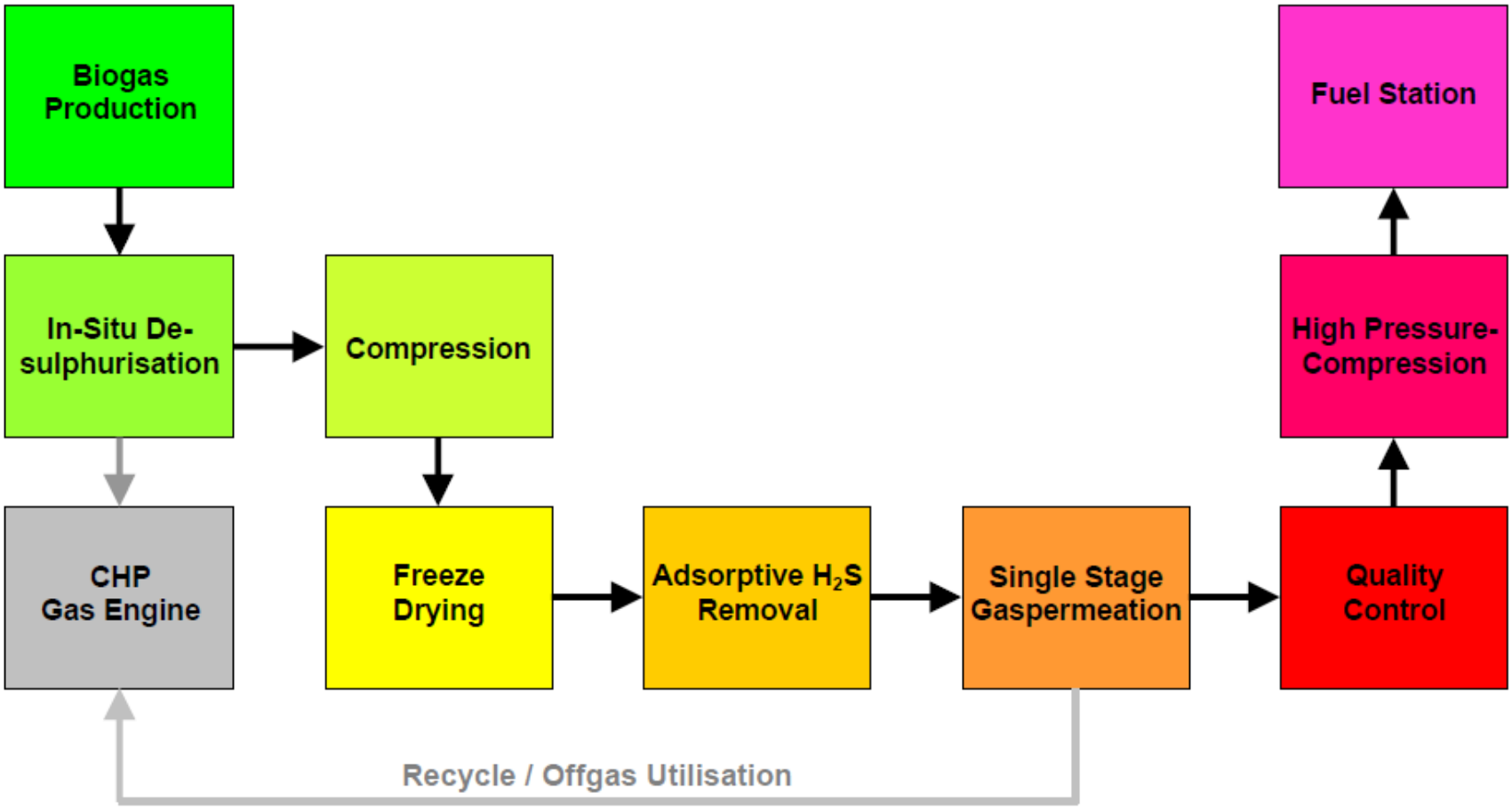
Biogas Upgrading Plant in Bruck/Leitha (Austria)



Biomethane Fuel Station: Single Stage Upgrading



Process Integration (Margarethen am Moos)



- **In-situ desulphurisation (addition of iron salts into the fermentation broth to catch suphides)**
- **Permeate is recycled to CHP plant – „zero methane“ emission of upgrading system**

Biomethane Fuel Station using Membrane Technology

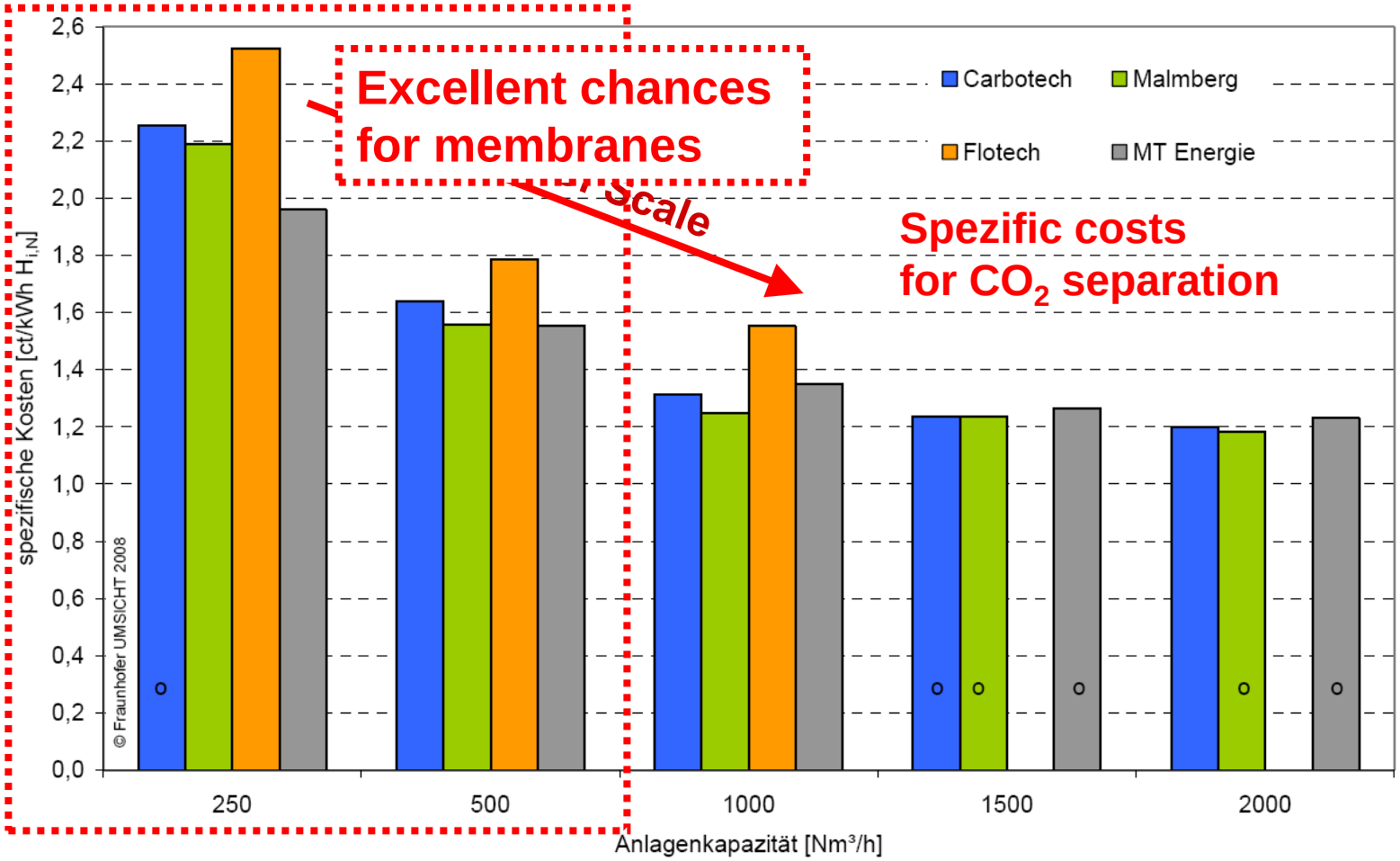
- Permeate recycle to CHP plant
- Further information: **www.methapur.com**
  Biomethane fuel station Margarethen/Moos

Energy Consumption Analysis

- **Main energy consumer of upgrading is the raw biogas compressor.**
- Energy demand for constant product gas quality and quantity depends also on raw biogas methane content.
- **Effect of plant layout** (number of stages) on energy consumption:
  - **Two stage gas grid injection plant:** 0,38 kWh/m³STP of product gas
  - **Single stage Bio-CNG-plant:** 0,28 kWh/m³STP of product gas
- Energy consumption of **<0,2 kWh/m³ STP of raw biogas** possible!
- Related to the methane content of the produced biomethane gas stream:
  - **Two stage gas grid injection plant:** 3,2% (98,1vol% CH_4)
  - **Single stage Bio-CNG-plant:** 2,8% (96,1vol% CH_4)
- All values are valid for a product gas delivery pressure of about 3 bar(g).

Costs for CO_2 Separation

Calculations by Fraunhofer Institut UMSICHT



Offgas Treatment & Costs

- **Offgas treatment** depends on process integration:
  - Mixing with biogas and utilisation in CHP plants
  - Thermal oxidation (flameless oxidation systems or direct combustion of low-cal gas)
  - Catalytic oxidation
  - Further treatment using additional membrane separation stage
- **Specific costs of upgrading** (depends on plant capacity):
  - **Investment** (depreciation 10 years, 8%):
    0,05 – 0,08 €/m³ biomethane
  - **Operation** (> 8000 h/a):
    0,10 – 0,14 €/m³ biomethane

Compatible Desulphurisation Technologies

Compatible:

- External biological desulphurisation in combination with pure oxygen injection
- In-situ desulphurisation using iron salts
- **External chemical scrubber with oxidation using $NaOH/H_2O_2$, recommended for fluctuating H_2S concentrations in the biogas**
- Adsorptive desulphurisation technologies with low excess of O_2 (impregnated activated carbon adsorbents)

Not suitable / incompatible:

- Air injection
- External biological desulphurisation with air injection

Project „BiogasOxiSulf“

Supply of max. 100 Vehicles with Biomethane

- Capacity up to 500 kg/d biomethane
- Operation of the first biogas driven tractor in Austria

Austrian Upgrading Technology - Export to Germany

- Capacity: 500 m³/h biogas, 300 m³/ biomethane, approx. 8 km pipeline to injection point (@ 60 bar)
- Axiom – gas permeation membrane system

Biomethane Grid Injection Wiener Neustadt

- Capacity: 220 (300) m³/h biogas, grid injection @ 4bar
- Axiom – gas permeation membrane system

And finally…

Thank you for your interest!

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- *www.bio-methaneregions.eu*