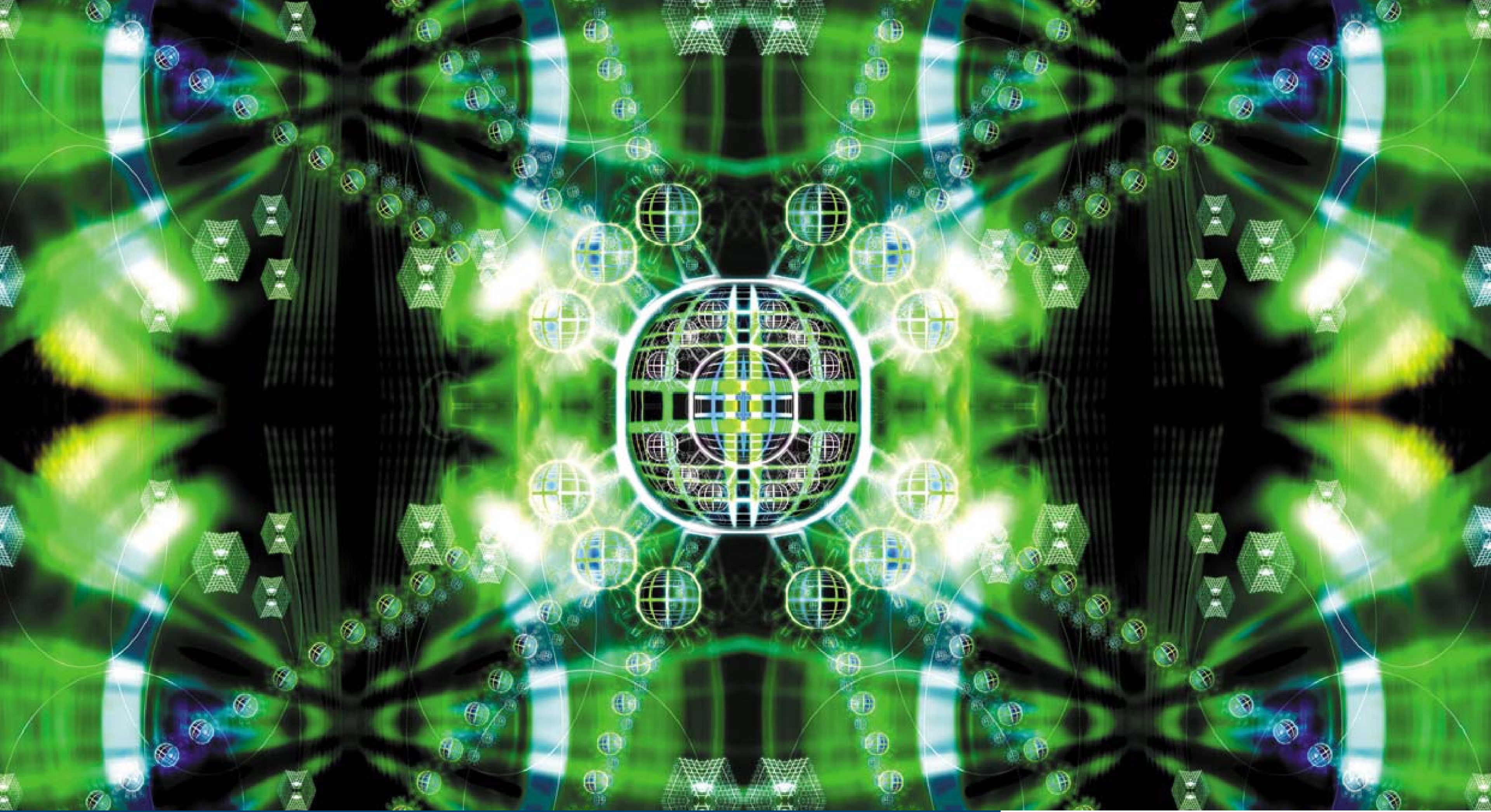

Research Area Energy / Program Renewable Energies

# Refining Biomass into Chemical Energy

Karl-Friedrich Ziegahn, Topic Speaker

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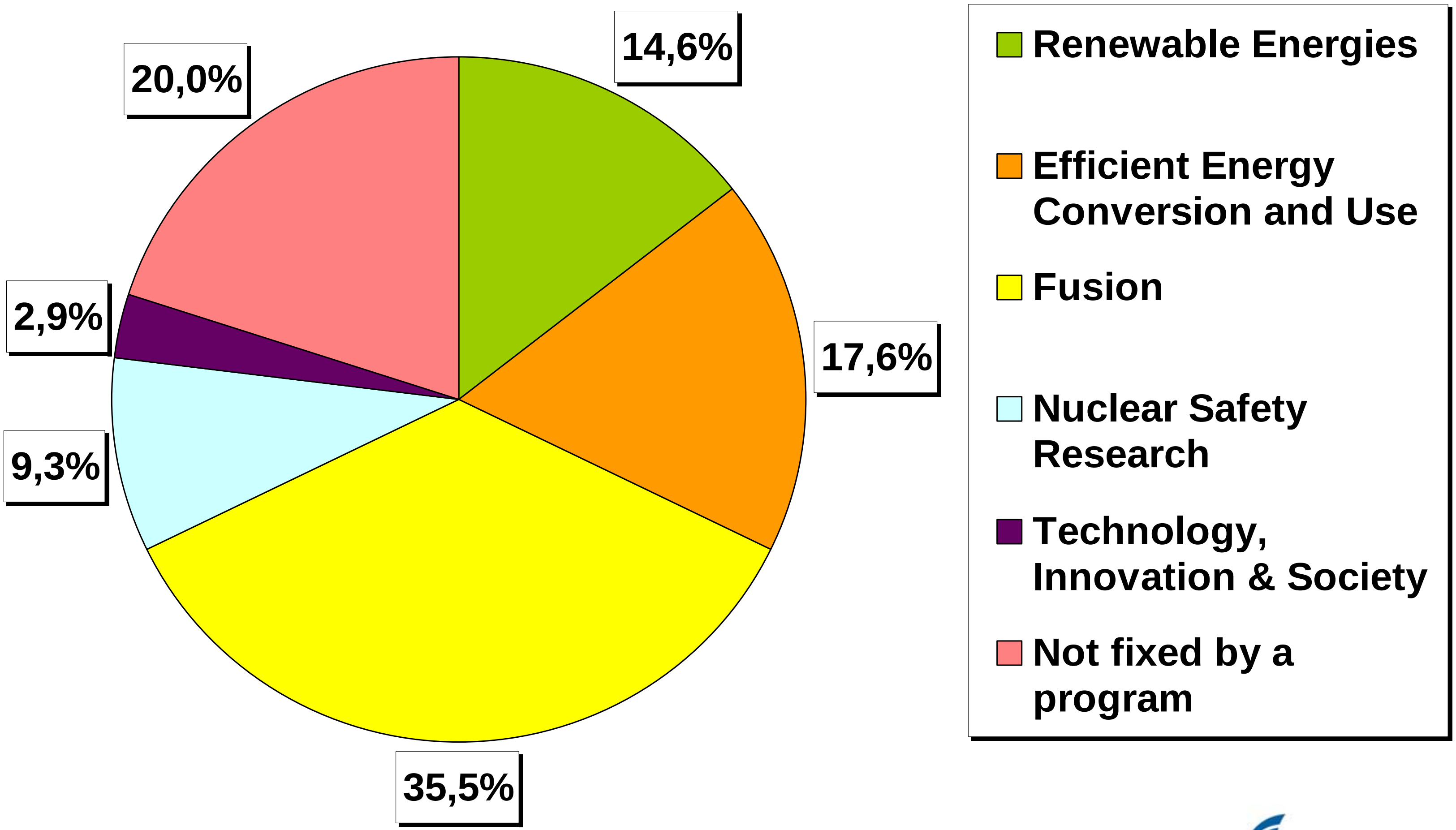
# Helmholtz Research Area »Energy«: Share of the Programs

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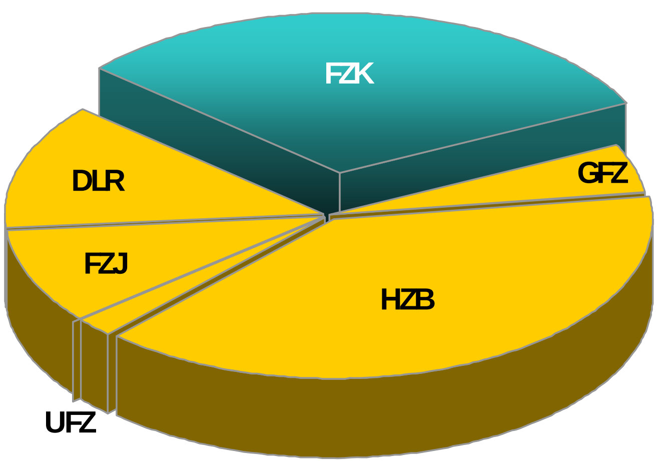
# Program Renewable Energies (EE)

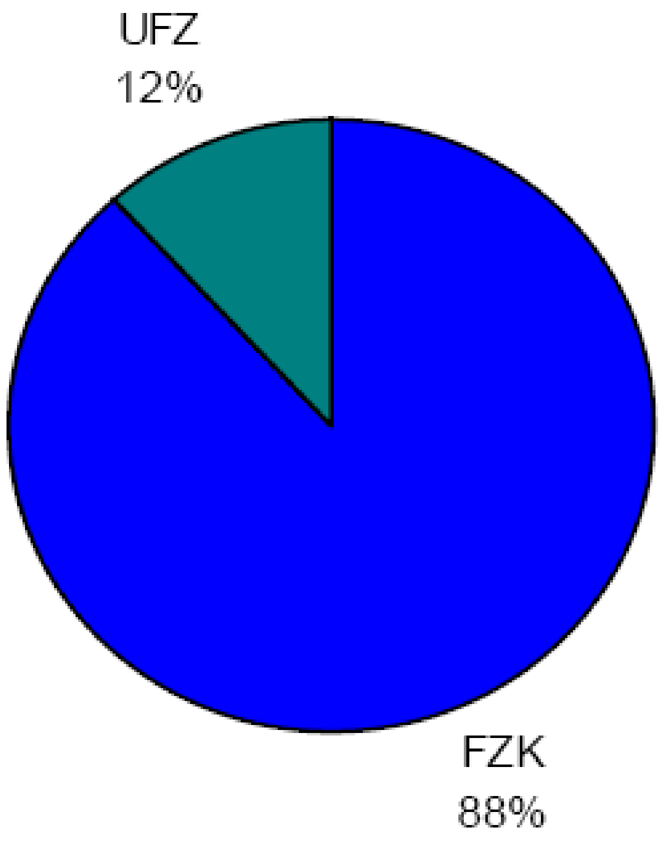
## Program Speaker: Prof. Dr. Bernd Rech (HZB)

| 169 | 36 | 32 | 100 |
|---|---|---|---|
| Thin Film Photovoltaic's | Concentrating Solar Systems | Geothermal Technologies | Refining Biomass into Chemical Energy |
| **U. Rau (FZJ)** | **R. Pitz-Paal (DLR)** | **E. Huenges (GFZ)** | **K.-F. Ziegahn (FZK)** |
| No FZK-Participation | No FZK-Participation | IKET, ITC-CPV, IAI | ITC-CPV, ITC-TAB, IMVT, IKET, IHM, IAI |




**Program Shares of the Centers**

# Topic 4: Refining Biomass into Chemical Energy




Topic budget 2010:
12.15 Mio. €

Accumulated topic budget 2010 – 2014:
63.7 Mio. €

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# Human forces of the topic

**Contributing Centres:** FZK, UFZ

**Personnel:** (FTE) 29.6 scientists, 5.2 doctoral students,
46 scientific support personnel

**Contributing principal investigators:**

FZK: Prof. Dr. Eckhard Dinjus (ITC-CPV)
Dr. Nicolaus Dahmen (ITC-CPV)
Prof. Dr.Ing. H. Seifert (ITC-TAB)
Prof. Dr.-Ing. Thomas Kolb (ITC-TAB)
Dr. Georg Müller (IHM)
Dr. Peter Pfeifer (IMVT)
Dr. Lutz Gröll (IAI)

UFZ: Prof. Hauke Harms

**Topic speaker:** Dr. Karl-Friedrich Ziegahn

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# Utilization of Biomass

- **Direct energetic utilization** in heating and power plants to produce heat and electricity
- **Indirect energetic utilization** by conversion in chemical energy carriers such as petrol, gas or hydrogen
- **Material utilization** to produce basic chemicals, working materials or agents such as pharmaceuticals

In any case fossil resources are substituted

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# Refining Biomass into Chemical Energy – Proposal description

**1 Challenges**

**2 Biomass to Liquids - Second generation biofuels**

2.1 Previous work and current activities

2.2 Contents and goals

2.3 Expected results, milestones

**3 Hydrogen, Methane, and Fuels from Thermochemical Processes**

3.1 Previous work and current activities

3.2 Contents and goals

3.3 Expected results, milestones

**4 Methane from Bio-chemical Processes**

4.1 Previous work and current activities

4.2 Contents and goals

4.3 Expected results, milestones

**5 Summary**

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# Refining Biomass i… Chemical Energy – Proposal descripti…

**1 Challenges**

**2 Biomass to Liquids -**

2.1 Previous w…

2.2 Contents

2.3 Expecte…

**3 Hydrogen, Met… Processes**

3.1 Prev…

3.2 Co…

3.3 E…

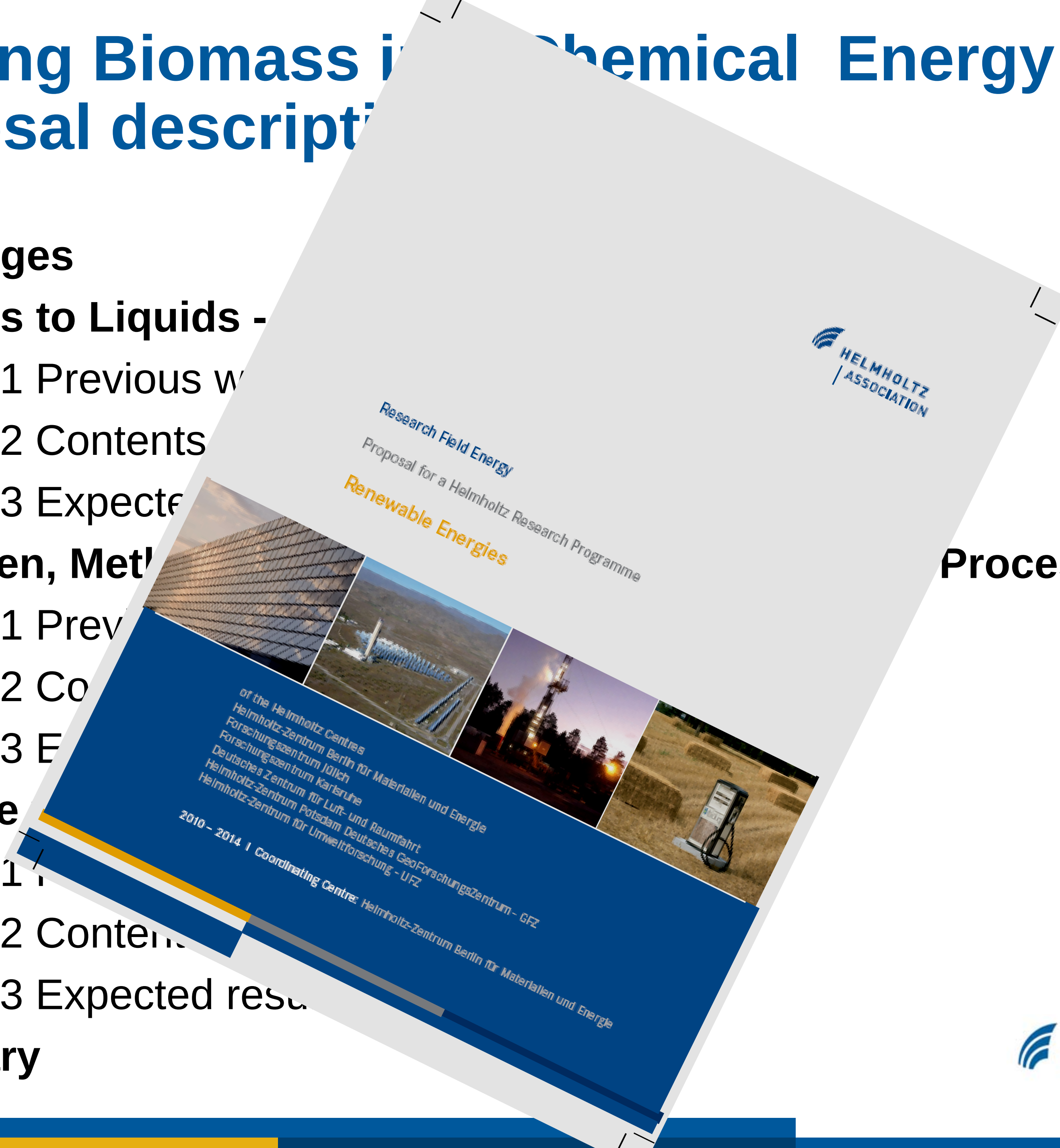
**4 Methane**

4.1 …

4.2 Conten…

4.3 Expected resu…

**5 Summary**

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# Helmholtz Program *Renewable Energies*
## Topic 4 »Refining Biomass into Chemical Energy«

**Embedding the topic in related other Helmholtz research activities:**

- Close links to the research area *Earth and Environment* ➔ biomass production
- Co-operation with the program *Efficient energy conversion and usage* ➔ joint use of the energy experimental center of FZK
- Joint work with the program *Technology, Innovations and Society* for a holistic systems analysis

# Sub topics and research goals

**1. Biomass to Liquids - Second generation biofuels**

*1.1 The bioliq pilot plant: stage 2 & 3*

*1.2 Fast pyrolysis and biosyncrude preparation*

*1.3 Biosyncrude gasification*

*1.4 Syngas cleaning*

*1.5 Chemical synthesis*

# Sub topics and research goals

**2. Hydrogen, Methane, and other fuels generation by thermo-chemical processes**

**3. Methane from Bio-chemical Processes**

*3.1 Enzymatic, thermal and physical methods for pre-, intermediate or posttreatment of substrates for the fermentation process*

*3.2 Microbiological processes and the metabolism*

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# The bioliq Two-Stages Principle

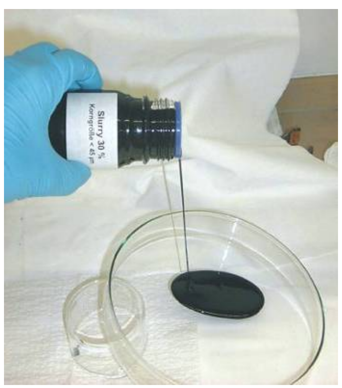
Biomass to Liquid Karlsruhe

**Source: Regional distributed biomass**

***Energy density [GJ/m$^3$]:***

**Straw: 1,5**

**Slurry: 25**



**Fuel: 36**

***Transportation distance***

**~ 25 km**

**First stage: Decentralized production of an energy-rich intermediate product – ‚Bio Crude Oil'**

**250 km**

**Second stage: Central production of synthesis gas and fuel**

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# Stage 1 (Fast Pyrolysis) in operation since 2008

Pyrolysis plant

Sand loop and reactor

Slurry mixing

Lurgi

Biomass conditioning

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# Bioliq pilot plant status and targets

| Phase | 1 | 2 | 3a | 3b |
|---|---|---|---|---|
| Process | Fast pyrolysis | Gasification | Synthesis I | Synthesis II |
| Technology | Twin-screw mixer reactor | High-Pressure – Entrained Flow gasifer | Gas conditioning and methanol synthesis | MtS-Synthesis (Methanol to Synfuel) |
| Product | BioSynCrude | Synthesis gas | Methanol | Fuels, Chemicals, Heat, electr. power |
| Status | Finished | Applied | Draft | Accepted |
| Investment | 8,2 m€ | 24,85 m€ | 13,5 m€ | - |
| Partner | FNR, Lurgi | FNR, Lurgi | Lurgi, Südchemie | Lurgi, FNR, Südchemie |

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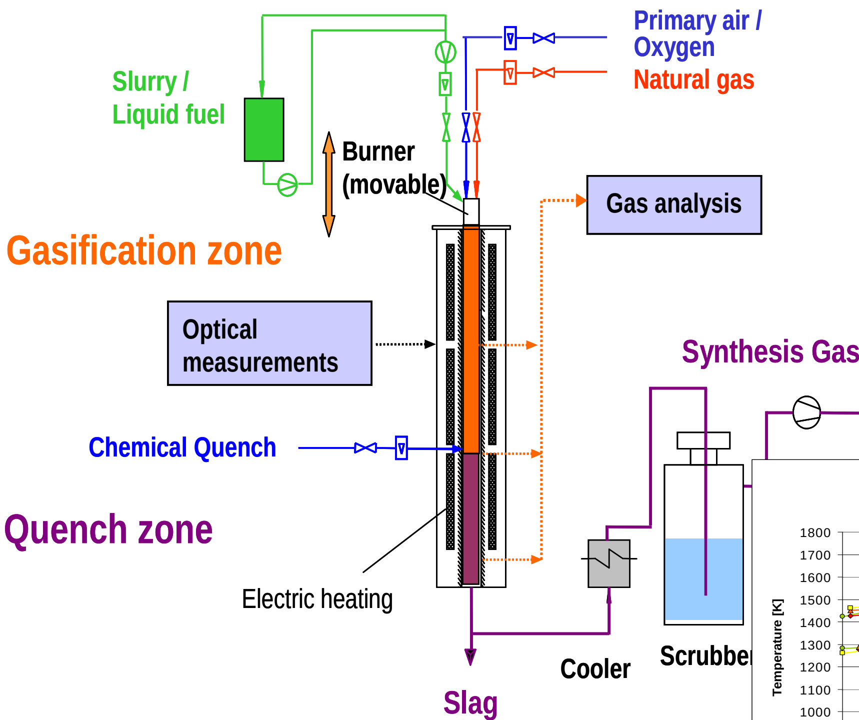
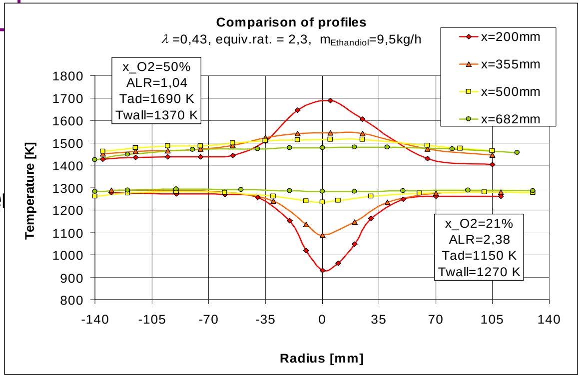
# Gasification of BioSyncrude in bioliq-Gasifier

## Current activities

- design of entrained flow gasifier for bioliq-project
- qualification of liquid fuels for entrained flow gasifier
- gasification of model fuel in REGA atmospheric gasifier
- implementation of fuel lab for physical / chemical characterization of slurry




REGA entrained flow gasifier




qualification of slurry in REGA



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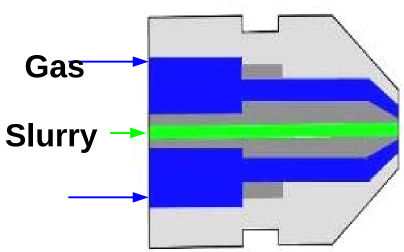
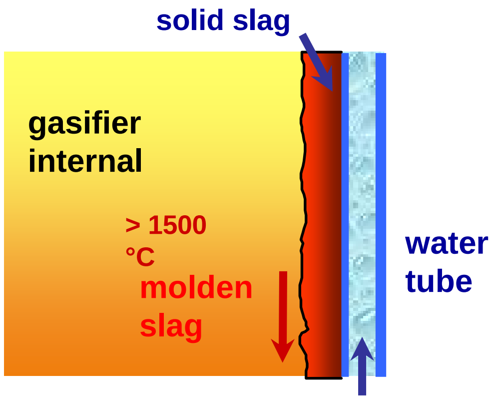
# Gasification of BioSyncrude in bioliq-Gasifier

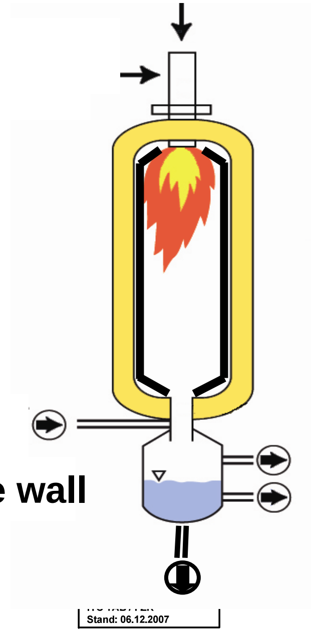
## Expected Results, Milestones

- Operation of Pilot-Gasifier with Slurry from Fast Pyrolysis Plant, Operational Parameters based on Slurry Qualification from REGA experiments, 2012
- Control of Slagging Behavior by Temerature Contol and Flux Additive, 2012
- Recovery of Minerals from Slag for Utilization as Fertilizer, 2013
- Burner Nozzle for $O_2$-atomization implemented, 2014

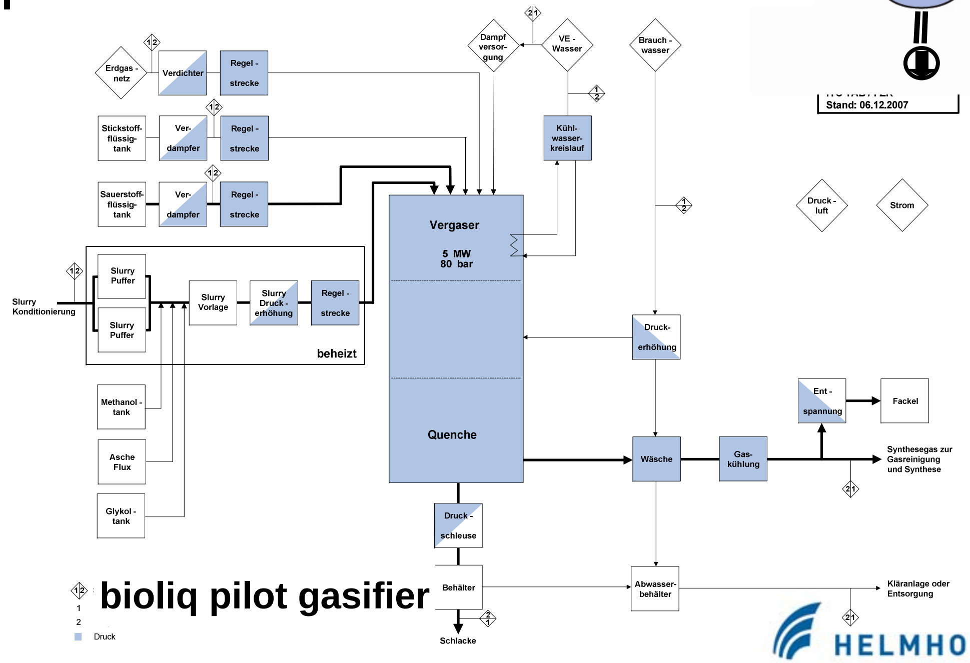



air blast atomizer




entrained flow gasifier with membrane wall




bioliq pilot gasifier

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# Gasification of BioSyncrude in bioliq-Gasifier

## Expected Results, Milestones

- **Operation of Pilot-Gasifier with Slurry from Fast Pyrolysis Plant, Operational Parameters based on Slurry Qualification from REGA experiments, 2012**
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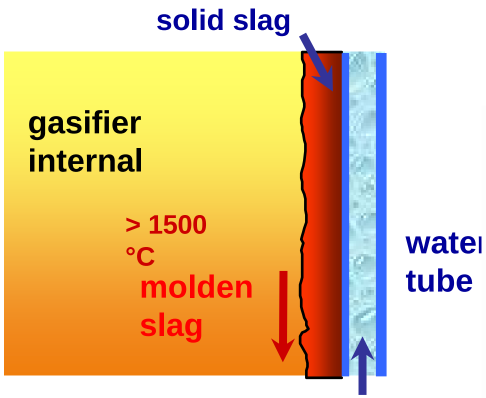
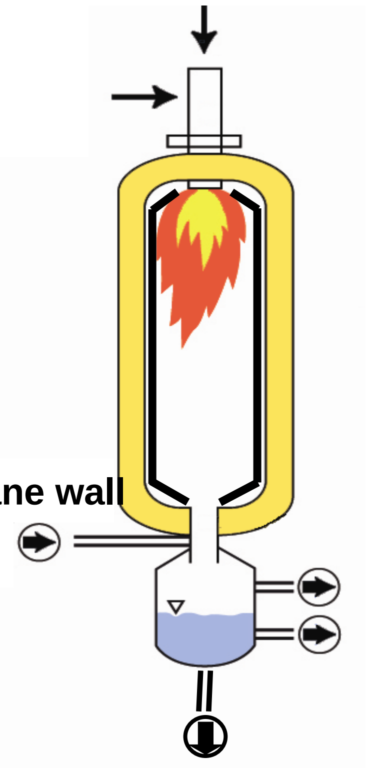
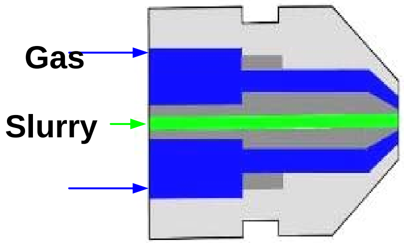
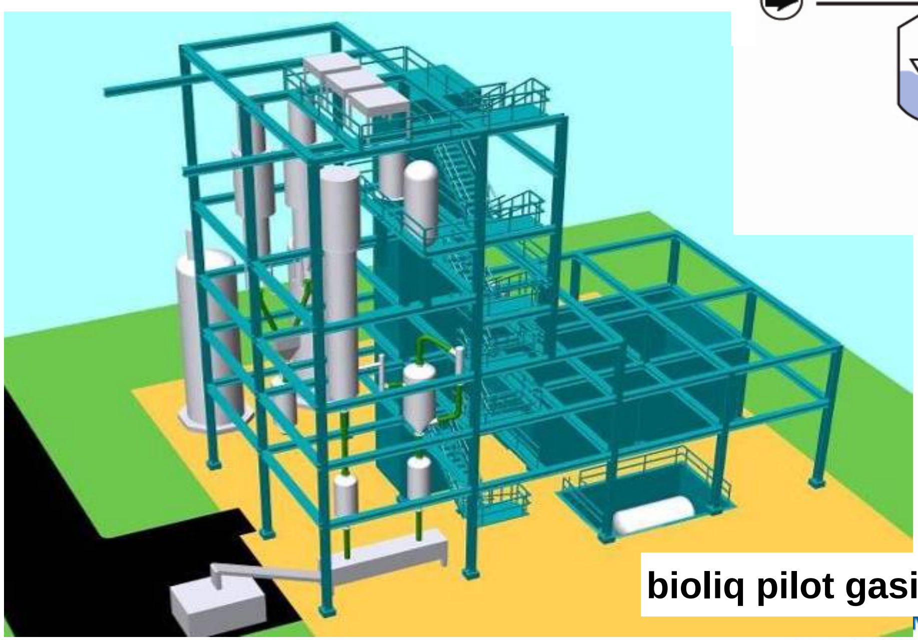


entrained flow gasifier with membrane wall




air blast atomizer



bioliq pilot gasifier

# SynGas Cleaning based on biogenic feedstock

**Aims**

- High temperature and high pressure gas cleaning at an early stage, either in the
- gasifier, at gasifier outlet conditions or significantly above synthesis temperature will be optimum.
- The challenge is a dry, highly integrated and energy efficient gas cleaning process
- enabling clean gas levels for all contaminants of the synthesis catalysts on a 50 ppb level.

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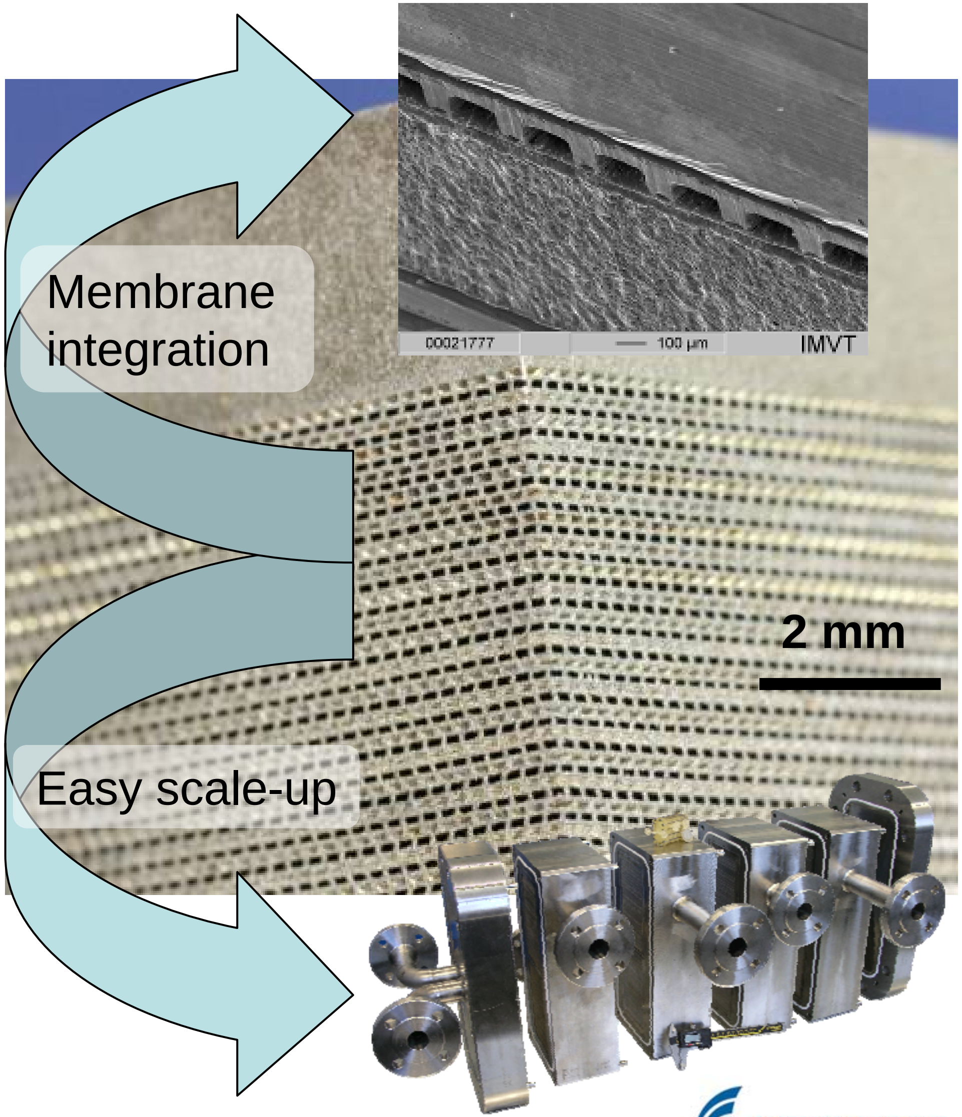
# Microreactors for Gas Cleaning / Synthesis

**General advantages**
- increased heat and mass transport
- narrow residence time distribution (Bo > 200)
- pressure resistant construction

**Advantages for High Temperature High Pressure Water Gas Shift Reaction and synthesis of fuels and chemicals from bio-syngas**
- temperature control (exothermal equilibrium reactions)
- modulation of temperature (with respect to feed composition)
- compact (mobile)
- modular
- energy efficient (recuperation)
- fits to membrane design

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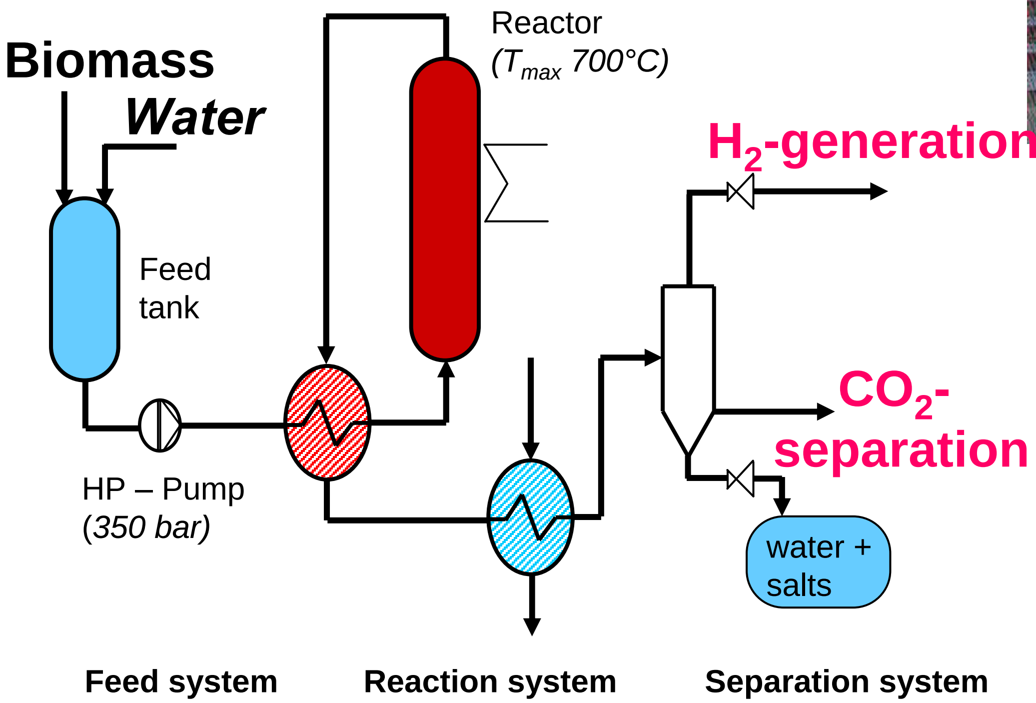
# Hydrogen Generation from green (wet) biomass

## VERENA: Test Facility for the Use of Agricultural Substances

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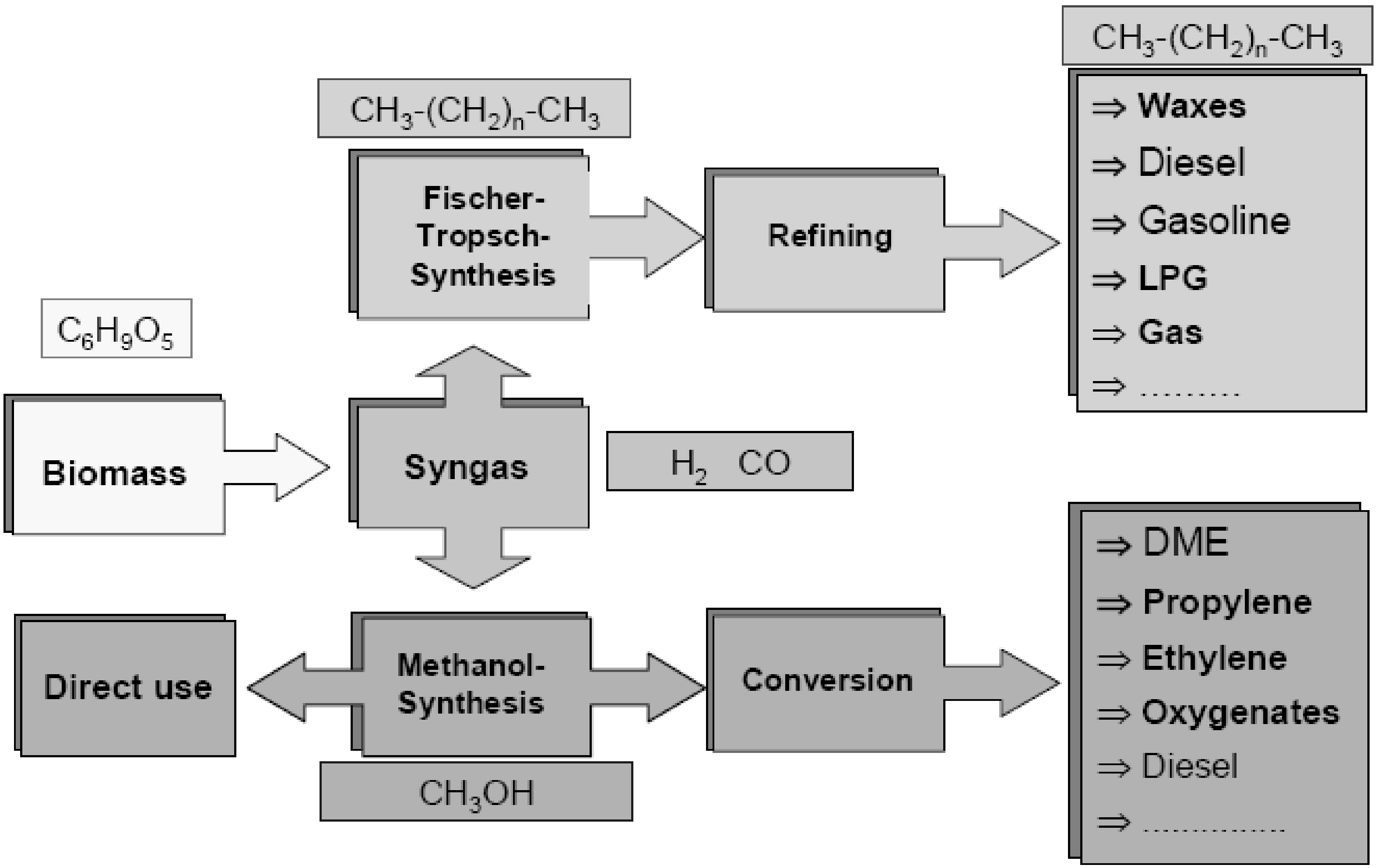
# Chemical synthesis

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# Hydrogen, Methane, and Fuels from Thermochemical Processes

## Goals

• Scale-up step: **VERENA II**. Scale of 1 t/h (the 10 fold throughput of the existing VERENA I plant) of feed solution the production of pure, pressurised hydrogen or methane in long term

• **Hydrothermal biomass liquefaction** below the critical point of water and by means of catalysts for different types of biomass.

• Produce **special chemicals** (e.g. phenol) but also liquid fuels (HTU fuels).

• The use of **microalgae** in a hybrid-process of electroporation and hydrothermal gasification to yield liquid (lipids) and gaseous (hydrogen) fuels

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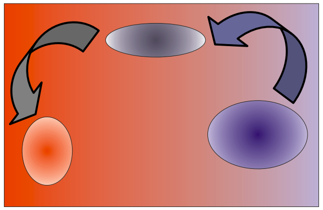
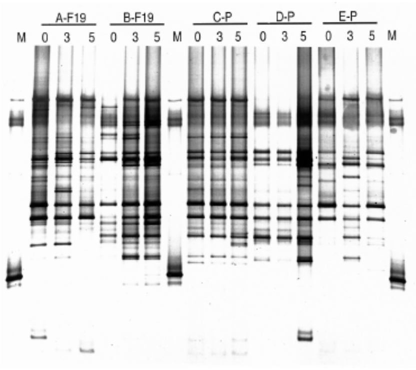
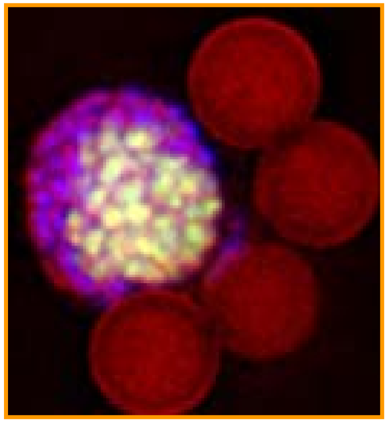
# Functional Description of Biogas-Communities

## Epi-metabolome and thermodynamic analysis

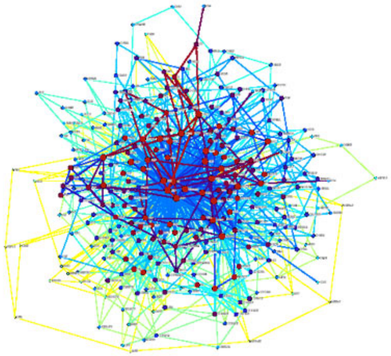


## Molecular diagnostics (submetagenomic)

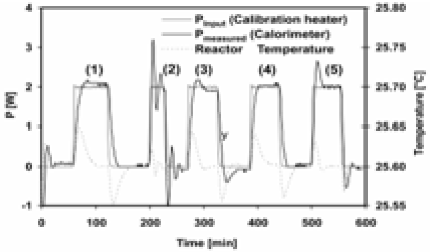


## Metabolic network modelling

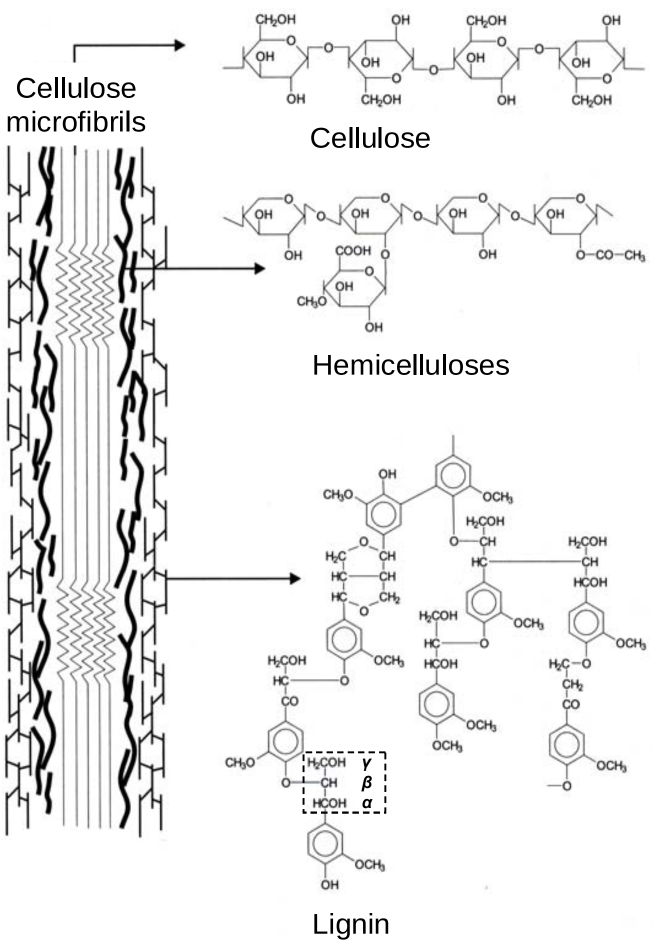


## Disturbance regimes – process optimization



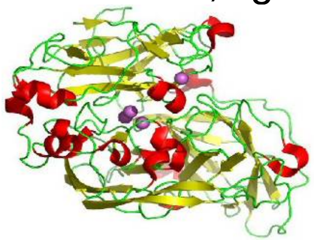

# Availability of Lignocellulosic Feedstocks for Bio-chemical Conversion into Bioenergy

Lignocellulosic materials presently not usable in fermentation for e.g. biogas production




Pre-treatment with lignocellulose-decaying microorganisms / enzymes derived thereof

- fungi with specific natural adaptations & capabilities
- cellulases, hemicellulases, lignin-modifying enzymes



Improved availability of lignocellulosic feedstocks for bioenergy processes

# Strategies for a sustainable biomass utilization

- Strict consideration of **ethical and ecological aspects**, i.e.
  - no competition for food production
  - no threats for bio-diversity e.g. by clearing or mono-cultures
  - minimized impact on soil, atmosphere and water
- **Holistic systems analysis**: net yield and $CO_2$-reduction
- Considering **water** as a prime limiting resource including effects of irrigation
- Soil quality and materials flow balances: fertilizers and pesticides
- Focusing on 2nd generation biofuels
- Production of hydrogen from wet (green) biomass
- Material utilization: benefit from synthesis power of nature
- Application of bio technologies for optimization of biomass production
- Utilization of new biomass resources e.g. algae

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# Summary of the topic *biomass*

- “Refining biomass into energy“ aims at new innovative approaches to
- produce **chemical energy carriers** as fuels for transportation or heat and power production.
- **Second generation** synthetic liquid fuels, such as
  - BtL (biomass to liquid),
  - liquid fuels from hydrothermal upgrading (HTU fuels),
  - co-producing valuable chemicals and
  - gaseous fuels, including hydrogen and methane

are being considered.

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