



## 2<sup>nd</sup> Generation Biogas

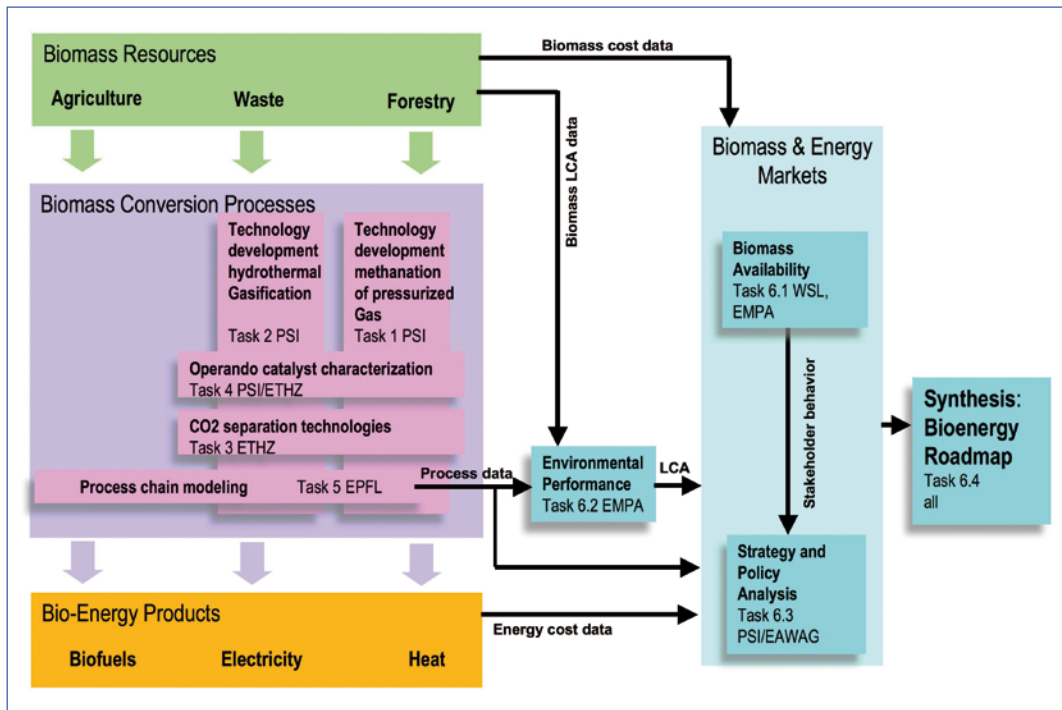
# New Pathways to Efficient Use of Biomass for Power and Transportation

### Scope of project

Two main goals have been set for the project:

- Demonstrate the technical feasibility of new highly efficient process paths to pipeline-grade methane from a very broad range of biomass (wood, solid agricultural residues, manure, sludges etc)
- Assess the impact of such technologies in the complex environment of biomass resources, end-uses and environmental performance, with the ultimate goal to draw a roadmap towards clean and eco-efficient use of biomass in Switzerland in 2030.

In an interdisciplinary effort involving groups from all the institutions of the ETH domain we will work towards these goals. The collaborative structure of the project team is shown in the figure below.



The collaborative structure of the project team

### Goals and activities

#### Task 1: Technology development methanation of pressurized gas

Planning and engineering of the new dedicated 10 kW experimental set-up (COSYMA II) is done. Manufacturing of the set-up and sampling

tools and the experimental work on COSYMA II started in 2008.

For the preparation of these experiments, sooner tests at lower pressure on the already existing set-up COSYMA I in Güssing are considered.

**Main Investigator**  
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#### Project Partners

PSI  
ETHZ  
EPFL  
Empa  
Eawag  
WSL

If needed funding is available, we will measure bubble size distribution and gas phase concentration profiles not only on the 10 kW set-up, but also at the 1 MW Synthetic Natural Gas (SNG) Process Demonstration Unit (PDU) plant in Güssing.

### Task 2: Technology development hydro-thermal gasification

- The continuous lab-scale (1 kg/h) PDU has been improved and operated for a total of ca. 900 h (mainly salt recovery tests).
- Continuous separation of various salts from supercritical water has been achieved.
- The main bottleneck for achieving a high thermal efficiency has been identified.
- Additional funding for studying salt-organic interactions is available from BFE.
- The High Pressure Differential Scanning Calorimeter has been acquired and is in operation.
- Feeding of real biomass in the PDU has been abandoned → justification for pilot plant ( $\geq 100$  kg/h). Palm oil pyrolysis condensate remains «acid test».

#### Main results

- A new in-house catalyst formulation exhibited a high sulfate tolerance in batch tests with glycerol and  $K_2SO_4$  (to be confirmed).
- The thermal process efficiency is very sensitive to the preheat and salt separator temperatures → increase preheat T, decrease separator T.
- «Sticky» type-2 salts (e.g.  $Na_2SO_4$ ) can be separated smoothly by adding a type-1 salt (e.g.  $KNO_3$ ).
- Addition of salts (e.g.  $Ca(NO_3)_2$ ) to the process represents a degree of freedom to achieve near-complete (sub-ppm) removal of sulfates.
- Some salts (e.g. nitrates) may react with organic biomass constituents, forming gas and presumably coke (e.g. brown liquid before catalyst from 20% EtOH/1%  $KNO_3$ ).

### Task 3: CO<sub>2</sub> separation technologies

Task 3 of the project is aimed at investigating and comparing the separation processes needed for the upgrade of the Synthetic Natural Gas (SNG), produced in 2<sup>nd</sup> generation biomass conversion processes. The typical composition for the different routes investigated (pressurized methanation and hydrothermal gasification) is

reported in the table below. The resulting gas can be integrated to the grid provided some specifications are fulfilled.

#### Main results

Methane is obviously the most valuable product and its recovery has to be maximized. On the other hand, rather pure carbon dioxide (95% minimum) may also represent a valuable product. In order to meet the pipeline specification, the SNG needs to be upgraded by separation of carbon dioxide, water and hydrogen. The bulk  $CH_4/CO_2$  separation is currently done at the Güssing Pilot Demonstration Unit by absorption with an amines solution. Membrane and adsorption techniques are investigated as alternative separation processes.

### Task 4: Process chain modeling

Work in task 4 has been focused on preliminary studies to provide a solid basis for the development of optimal flowsheets using thermo-economic modeling. A comparison of the use of energy wood for heat, combined heat and power, and fuel production with respect to energy efficiency and climate change potential has been done. The data collection included the identification and appropriate definition of candidate biomass feedstock for thermochemical conversion, a survey and characterization of potential conversion routes and the collection of basic performance data for the most important routes.

#### Main results

To systematically address the thermo-economic flowsheet modeling, process integration and optimization, a rational methodology for the conceptual, thermo-economic process design

Components		Specifications			
		Güssing (SNG via pressurized methanation)	Hydrothermal (SNG via hydro- thermal gasification)	Pipeline (Pipeline feed-in NG)	Storage (CO <sub>2</sub> for storage)
CO <sub>2</sub>	% vol	36	28-60	<6	>95
CH <sub>4</sub>	% vol	57	40-70	>96	-
H <sub>2</sub>	% vol	2.5	1-10	<5	-
CO	% vol	0.10	0.1-1	<1	-
Hydrocarbons	% vol	0.05	1-3	Not specified	-
NH <sub>3</sub>	% vol	ppm	Traces	Not specified	-
N <sub>2</sub>	% vol	2.50	0	-	-
H <sub>2</sub> O	% vol	1.23	1-10	60% R.H.	-

of biofuel production plants has been developed and submitted for publication.

The development of the technology models has been continued from previous work. The existing model for hydrothermal gasification (task 2) has been critically reviewed and adapted to the modeling framework used in task 4. Technology limits have been identified in accordance with task 2 and a MSc-thesis has been initiated at LASSC (University of Liège, Belgium) in order to provide accurate equations of state in the supercritical domain. In coordination with task 3, a thermo-economic model for the separation of CH<sub>4</sub> and CO<sub>2</sub> with membranes has been developed and a benchmark case for a typical mixture for 1<sup>st</sup> generation biogas has been calculated. A more general model for this technology is currently implemented in order to investigate the effects of properly integrating the separation with the gasification and methanation studied in task 1.

In order to treat the environmental aspects in the process design and optimisation, a tool for linking the LCIA database from ecoinvent with the in-house modeling framework has been developed. This will make it possible to perform the process optimization with regard to energetic, economic and environmental criteria.

#### **Task 5: Biomass availability, environmental performance, strategy and policy analysis**

The following results have been already achieved:

- A GIS model on the spatial distribution of wood resources in Switzerland has been established that will be used for modeling environmental impacts of 2<sup>nd</sup> generation methanation with respect to plant scale and location.
- Data on the bioenergy potential (Oettli et al. 2005) has been combined with energetic efficiency and environmental impacts of various production pathways (Zah et al. 2007) for analyzing the overall technical potential of bioenergy in Switzerland.
- Project collaboration with Task 4 on environmental impacts of different plant scales and configurations has been established.

## Publications

- Methodology for the optimal thermo-economic, multi-objective design of thermochemical fuel production from biomass. Presented at ESCAPE17, Bucharest, 2007 and submitted in extended form to Computers and chemical engineering, 2007.
- Darbellay Nicole, Modélisation thermo-économique de la production thermochimique de carburant liquide à partir de la biomasse. Master Diploma thesis (2007).
- Luterbacher Jeremy, Process development and environmental systems analysis of a catalytic hydrothermal methane production process. Master Diploma Thesis (2007).