

**IEA Bioenergy Agreement: 2022-2024**  
**Task 33: Gasification of Biomass and Waste**  
**Second semi-annual Task meeting, 2022**  
**Hybrid meeting in Vienna, Austria and virtual**

**18.-20. October 2022**

**Minutes**

Prepared by Dr. Jitka Hrbek, BOKU, AT  
and  
Berend Vreugdenhil, TNO, NL

**The list of attendees on 18. October 2022:**

| <b>Name</b>                        | <b>Country</b>  | <b>Affiliation</b>  | <b>email</b>                     |
|------------------------------------|-----------------|---------------------|----------------------------------|
| <b>Berend Vreugdenhil</b>          | The Netherlands | TNO                 | Berend.vreugdenhil@tno.nl        |
| <b>Jitka Hrbek</b>                 | Austria         | BOKU                | Jitka.hrbek@boku.ac.at           |
| <b>Christoph Pfeifer</b>           | Austria         | BOKU                | Christoph.pfeifer@boku.ac.at     |
| <b>Guanyi Chen (online)</b>        | China           | Tanjin University   | chen@tju.edu.cn                  |
| <b>Donatella Barisano (online)</b> | Italy           | Enea                | donatella.barisano@enea.it       |
| <b>Joakim Lundgren</b>             | Sweden          | LTU                 | Joakim.lundgren@ltu.se           |
| <b>Thomas Kolb (online)</b>        | Germany         | KIT                 | Thomas.kolb@kit.edu              |
| <b>Sabine Fleck (online)</b>       | Germany         | KIT                 | Sabine.fleck@kit.edu             |
| <b>Robert Baldwin (online)</b>     | USA             | NREL                | Robert.baldwin@nrel.gov          |
| <b>Rajesh Badhe (online)</b>       | India           | Indian Oil          | badher@indianoil.in              |
| <b>Mohan Rao (online)</b>          | India           | Indian Oil          | mohanrd@indianoil.in             |
| <b>Benjamin Berger (online)</b>    | Belgium         | ECAM                | brg@ecam.be                      |
| <b>Neil Bergamini Gomez</b>        | Belgium         | ECAM                | nb4@cerdecam.be                  |
| <b>Chourouk Nait Saidi</b>         | France          | ATEE                | c.naitsaidi@atee.fr              |
|                                    |                 |                     |                                  |
| Apologized                         |                 |                     |                                  |
| <b>Patricia Thornley</b>           | UK              | Aston University    | p.thornley@aston.ac.uk           |
| <b>Fernando Preto</b>              | Canada          | CanmetENERGY-Ottawa | Fernando.preto@NRCan-RNCan.gc.ca |
|                                    |                 |                     |                                  |
| Observers                          |                 |                     |                                  |
| <b>Henrik Thunman</b>              | Sweden          | Chalmers            | Henrik.thunman@chalmers.se       |

## IEA Bioenergy Agreement: 2022-2024

### Task 33: Gasification of Biomass and Waste

First Semi-Annual Task Meeting, 2022

Hybrid meeting in Petten, NL and virtual

18.-20. May 2022

The agenda of the Task 33 meeting was as following:

18.10.2022      Task meeting  
19.10.2022      Workshop “Valuable (by-)products of gasification”  
20.10.2022      Site visit “Waste-2-Value”

#### 18.10.2022 – Task meeting - agenda

| Item                                                                                                                                                                                                                               | Time                                          | Who                                             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|-------------------------------------------------|
| Welcome (Members/Guests)                                                                                                                                                                                                           | 8:00 – 8:30                                   | All                                             |
| General issues <ul style="list-style-type: none"><li>• Website</li><li>• Task budget</li><li>• Workshop T44</li><li>• Agenda towards end of triennium</li></ul>                                                                    | 8:30 – 9:15                                   | Jitka<br>Berend<br>Berend<br>All                |
| Country updates (China/India)                                                                                                                                                                                                      | 9:15 – 10:15<br>Break around 9:55             | Rajesh, Guanyi                                  |
| Update on the ITP's (H <sub>2</sub> and BECCUS)                                                                                                                                                                                    | 10:15 – 10:45                                 | Joakim/Patricia                                 |
| Country update (UK, France, Belgium, Italy, Germany,)                                                                                                                                                                              | 10:45 – 12:30                                 | Patricia, Chourouk, Benjamin, Donatella, Sabine |
| Lunch                                                                                                                                                                                                                              | 12:30 – 13:30                                 |                                                 |
| Country update (Sweden, NL, Austria)                                                                                                                                                                                               | 13:30 – 14:30                                 | Joakim, Berend, Jitka                           |
| Subtask results integrated in website <ul style="list-style-type: none"><li>• Graphic representation</li><li>• Website layout</li><li>• Subtask layout</li><li>• Progress on subtask</li><li>• Front page tekst – layman</li></ul> | 14:30 - 15:30<br>15 minute brake around 15:00 | All                                             |
| Additional budget topics                                                                                                                                                                                                           | 15:30 - 16:30                                 | All                                             |
| Country update (US and Canada)                                                                                                                                                                                                     | 16:30 – 17:15                                 | Bob, Fernando                                   |
| Closing the meeting → Any other business                                                                                                                                                                                           | 17:15 – 17:30                                 |                                                 |

## 19.10.2022 – Workshop - agenda

|                                               |                                                                                                                                  |                                                        |
|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|
| 9.00-9.15                                     | Welcome                                                                                                                          | Christoph Pfeifer<br>Jitka Hrbek<br>Berend Vreugdenhil |
| 9.15-9.45                                     | Keynote 1: “Actual trends in gasification technology”                                                                            | Berend Vreugdenhil, TNO                                |
|                                               |                                                                                                                                  |                                                        |
|                                               | <b>Session 1:<br/>CHP/Co-firing/High temp. heat</b>                                                                              |                                                        |
| 9.45-10.05<br><b>CANCELED AT SHORT NOTICE</b> | “Synthesis gas based on biomass and its contribution to the future of energy supply”                                             | W. Schmid-Schmidsfelden, Gresco power                  |
| 10.05-10.25                                   | “The benefits of manure gasification”                                                                                            | C. Spaans, Mavitec (online)                            |
| 10.25-10.45                                   | “Experimental study on the impacts of steam injection and air enrichment on two-stage downdraft wood gasification”               | Arnaud Rouanet, UC Louvan                              |
| 10.45-10.55                                   | <i>Q&amp;A Session 1</i>                                                                                                         |                                                        |
|                                               |                                                                                                                                  |                                                        |
| 10.55-11.10                                   | Coffee break                                                                                                                     |                                                        |
|                                               |                                                                                                                                  |                                                        |
|                                               | <b>Session 2:<br/>Negative emissions through gasification</b>                                                                    |                                                        |
| 11.10-11.40                                   | Keynote 2: “Negative emissions”                                                                                                  | Tobias Pröll, BOKU                                     |
| 11.40-12.00                                   | “Negative Emissions through staged gasification from SynCraft – an evaluation”                                                   | Marcel Huber, SynCraft                                 |
| 12.00-12.20                                   | „Added value through carbon sequestration in agriculture“                                                                        | Nina Schaaf, MCI                                       |
| 12.20-12.40                                   | “Negative CO <sub>2</sub> emissions by gasification of torrefied biomass into syngas, biochar and liquid CO <sub>2</sub> ”       | Rober Berends, Torrgas (online)                        |
| 12.40-12.50                                   | <i>Q&amp;A Session 2</i>                                                                                                         |                                                        |
|                                               |                                                                                                                                  |                                                        |
| 12.50-13.45                                   | Lunch                                                                                                                            |                                                        |
|                                               |                                                                                                                                  |                                                        |
|                                               | <b>Session 3:<br/>Synthesis</b>                                                                                                  |                                                        |
| 13.45-14.15                                   | Keynote 3: “Conversion of Renewable Synthesis Gas”                                                                               | Reinhard Rauch, KIT                                    |
| 14.15-14.35                                   | “Development of gasification solutions towards production of materials, based on the experiences from the GoBiGas demonstration” | Henrik Thunman, Chalmers/Joakim Lundgren, SFC          |
| 14.35-14.55                                   | “Overview on research activities at TU Wien for the production of sustainable fuel-based energy carriers”                        | F. Benedikt, TU Wien                                   |
| 14.55-15.15                                   | “Waste-2-Value”                                                                                                                  | Matthias Kuba, BEST                                    |
| 15.15-15.25                                   | <i>Q&amp;A Session 3/1</i>                                                                                                       |                                                        |
|                                               |                                                                                                                                  |                                                        |
| 15.25-15.40                                   | Coffee break                                                                                                                     |                                                        |
|                                               |                                                                                                                                  |                                                        |
|                                               | <b>Session 3 -continuing</b>                                                                                                     |                                                        |
| 15.40-16.00                                   | “Gasification of RDF in High Temperature Winkler (HTW® 2.0) Process”                                                             | E. M. Moghaddam, Gidara                                |

|             |                                                                   |                                         |
|-------------|-------------------------------------------------------------------|-----------------------------------------|
| 16.00-16.20 | "Gaya project"                                                    | Marion Maheut, ENGIE                    |
| 16.20-16.40 | "Waste to chemicals"                                              | A. Angeletti, NextChem                  |
| 16.40-17.00 | "Novel gasification with bio-thermo-chemical coupling technology" | Beibei Yan, Tianjin University (online) |
| 17.10-17.20 | <i>Q&amp;A Session 3/2</i>                                        |                                         |
|             |                                                                   |                                         |
| 17.20-17.30 | Wrap up                                                           |                                         |

#### 20.10.2022 – Site visit Waste-2-Value

The Waste2Value project upcycles residual waste into eco-friendly, CO<sub>2</sub>-neutral fuels. A pilot plant in Vienna's Simmering district employs a thermochemical gasification process to convert waste materials into so-called syngas. In a second process step, the syngas can be upcycled into a wide range of liquid fuels – including green diesel and kerosene, green natural gas and green hydrogen – which can subsequently be used in the transport sector and/or the energy industry. These fuels are 100% renewable if the feedstock is from renewable sources. Waste2Value is piloting the use of sewage sludge, residues from the pulp and paper industry and damaged timber. However, another option would be to add non-renewable fossil-based waste such as non-recyclable plastics, which would allow this kind of waste material to be recycled.

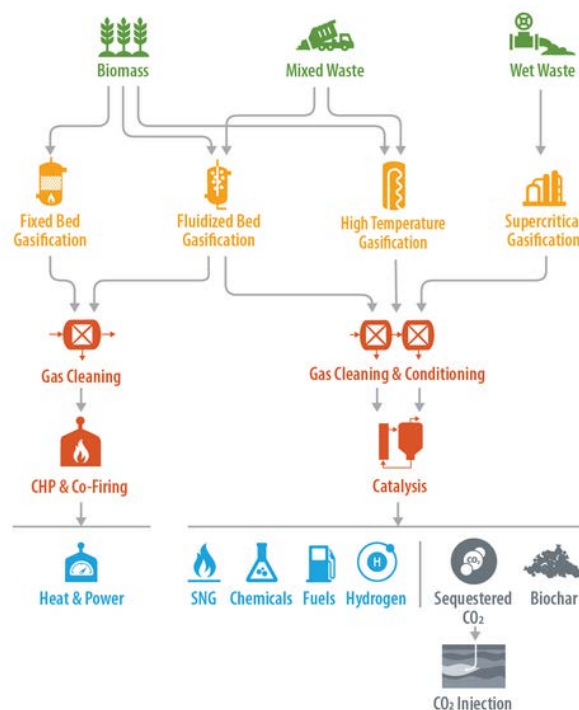
## Task 33 Meeting discussions

Meeting Minutes from the last online meeting approved.

### Task website

The Task 33 website will be re-designed again. The ExCo aim is to have the same website layout for all the Tasks. The works on the new website are now ongoing.

On the 8.11. an online meeting (ETA Florence and subtasks leaders) will take place, where the details regarding the visibility of subtasks publications can be discussed.



### Subtasks

The progress on subtasks presented. (6 subtasks on CHP, Biofuels, Biochemicals, SNG, Hydrogen and GHG balance). Berend sent a link to sharepoint at TNO, where the data regarding subtasks could be stored and actualized.

### Task and Intertasks projects

In this triennium 2 inter-tasks projects will be realized (Hydrogen, GHG balance)

In Task budget some money left, thus Berend appealed to Task members to prepare proposals for Task project realization. Following proposals were prepared:

| Topic                                           | Budget    | Who             |
|-------------------------------------------------|-----------|-----------------|
| Deep cleaning for fuels and chemicals synthesis | 25000 EUR | Austria         |
| Negative emissions                              | 35000 EUR | Austria         |
| Status report gasification 2024                 | 15000 EUR | Austria         |
| H2 – a synthesis report                         | 40000 USD | US, SWE, NL, UK |
| Position paper on chemicals                     | 10000 USD | US, NL          |

Based on online voting by Task members, following projects ranking was achieved:



1. Economy of gasification – project proposed during the Task meeting, at the moment no project leader found
2. Hydrogen and synthesis report
3. Report on deep gas cleaning
4. Status report on gasification

### Workshop by Task 44

Berend will give a presentation in the workshop and asked the Task members for relevant contributions.

### Next Task meetings

1. Spring 2023 USA/Canada
2. Fall 2023 France
3. Spring 2024 China/India
4. Fall 2024 Brazil – End-of-triennium conference

## Budget overview

| INCOME                                                                                 | Triennium budget (USD)                    |           |           |           |
|----------------------------------------------------------------------------------------|-------------------------------------------|-----------|-----------|-----------|
|                                                                                        | (based on final triennium work programme) |           |           |           |
|                                                                                        | 2022                                      | 2023      | 2024      | Triennium |
| Number of participants                                                                 | 12                                        | 12        | 12        |           |
| Annual cost per participant (USD/year)                                                 | \$15.000                                  | \$15.000  | \$15.000  |           |
| Task income                                                                            | \$180.000                                 | \$180.000 | \$180.000 | \$540.000 |
| Less 10% to Strategic Fund                                                             | \$18.000                                  | \$18.000  | \$18.000  | \$54.000  |
| Net Task income                                                                        | \$162.000                                 | \$162.000 | \$162.000 | \$486.000 |
| Funds carried forward from previous triennium - not assigned                           | \$10.289                                  |           |           | \$10.289  |
| Funds carried forward - assigned to projects from previous triennium (to be finalized) | \$0                                       |           |           | \$0       |
| Other income (e.g. from Intertask projects)                                            | \$18.750                                  | \$19.250  | \$15.000  | \$53.000  |
|                                                                                        |                                           |           |           |           |
| Net available funds                                                                    | \$191.039                                 | \$181.250 | \$177.000 | \$549.289 |
|                                                                                        |                                           |           |           |           |
| SPEND                                                                                  | Triennium budget (USD)                    |           |           |           |
|                                                                                        | (based on final triennium work programme) |           |           |           |
|                                                                                        | 2022                                      | 2023      | 2024      | Triennium |
| 1a Salaries / benefits - Task Management                                               | \$55.500                                  | \$55.500  | \$55.500  | \$166.500 |
| 1b Salaries / benefits - Dissemination                                                 | \$20.667                                  | \$20.667  | \$19.667  | \$61.001  |
| 2. Support services                                                                    | \$2.000                                   | \$2.000   | \$2.000   | \$6.000   |
| 3. Materials / supplies                                                                | \$0                                       | \$0       | \$0       | \$0       |
| 4. Travel                                                                              | \$9.000                                   | \$9.000   | \$9.000   | \$27.000  |
| 5. Other expenditure                                                                   | \$11.000                                  | \$11.000  | \$7.000   | \$29.000  |
| 6. Overhead                                                                            |                                           |           |           | \$0       |
| 7. Projects / Subcontracts / Consultants                                               | \$61.000                                  | \$20.000  | \$20.000  | \$101.000 |
|                                                                                        |                                           |           |           |           |
| <b>TOTAL</b>                                                                           | \$159.167                                 | \$118.167 | \$113.167 | \$390.501 |
|                                                                                        |                                           |           |           |           |
| <b>Carryover to the next triennium</b>                                                 |                                           |           |           | \$158.788 |

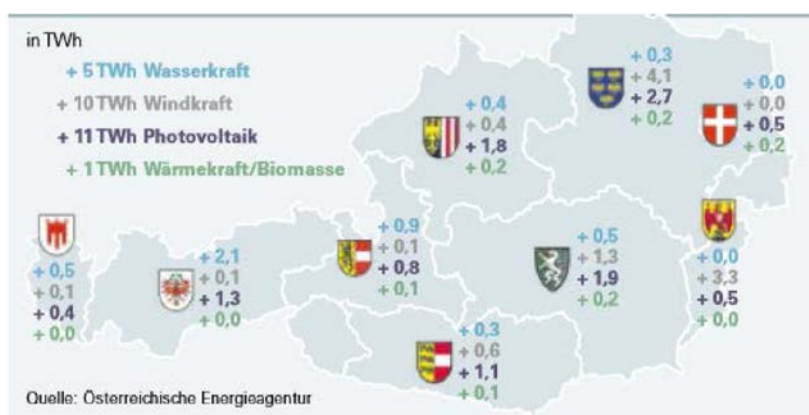
## Country Reports Update

### Austria, Jitka Hrbek, BOKU Vienna

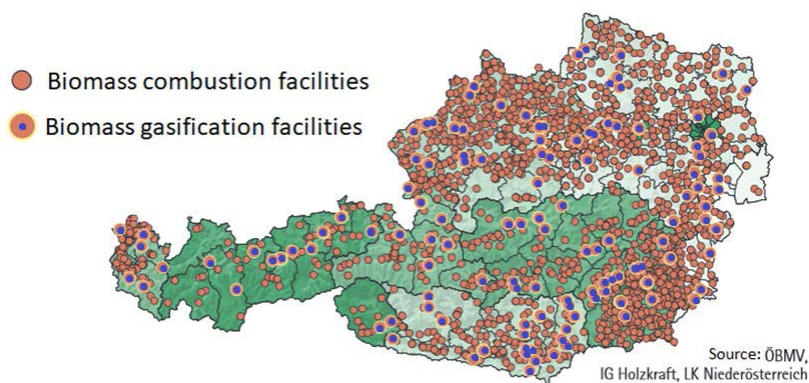
Energy consumption and generation, overview on bioenergy, research on gasification, industrial activities and implementations were presented.

In Austria, energy consumption is covered by around two thirds by mostly imported fossil fuels. Contrary to imports, renewable sources predominate in domestic energy production with a share of around 82 %. Here, bioenergy and hydropower should be mentioned as the most important renewable energy sources.

Anyway, there is still demand on renewable power generation. The details can be seen in the following map.



Nowadays, there are about 150 operational gasification facilities producing 1611 GWh power/y and 3936 GWh heat/y.



| Overview wood gas systems                                        |                                         | Wood gas CHP plants                      |                                       | Feed-in of wood gas into gas network | Local green gas | Wood diesel | Hydrogen | Biochar |
|------------------------------------------------------------------|-----------------------------------------|------------------------------------------|---------------------------------------|--------------------------------------|-----------------|-------------|----------|---------|
| Plant manufacturer                                               | Rated thermal input gasifier kW from-to | Electrical power kW from-to <sup>a</sup> | Thermal power kW from-to <sup>a</sup> |                                      |                 |             |          |         |
| Burkhardt GmbH                                                   |                                         | 50-180                                   | 110-270                               |                                      |                 |             |          |         |
| Entrenco GmbH                                                    |                                         | 25-50                                    | 60-120                                |                                      |                 |             |          |         |
| Fröling Heizkessel- und Behälterbau GmbH                         |                                         | 46-56                                    | 95-115                                |                                      |                 |             |          |         |
| GLOCK ecotech GmbH                                               |                                         | 18-50                                    | 44-110                                |                                      |                 |             |          |         |
| Hargassner GmbH                                                  |                                         | 20                                       | 60                                    |                                      |                 |             |          |         |
| Holzenergie Wegscheid GmbH                                       |                                         | 65-133                                   | 130-270                               |                                      |                 |             |          |         |
| LIPRO Energy GmbH & Co. KG                                       |                                         | 30-50                                    | 60-90                                 |                                      |                 |             |          |         |
| Polytechnik Luft- und Feuerungstechnik GmbH                      | 400-1,500                               |                                          |                                       |                                      |                 |             |          |         |
| ReGaWatt GmbH                                                    | 1,600-8,000                             | 420-2,300                                | 870-5,600                             |                                      |                 | ○           | ○        |         |
| Spanner Re <sup>3</sup> GmbH                                     |                                         | 35-600                                   | 79.55-1,200                           |                                      |                 |             |          |         |
| Stadtwerke Rosenheim GmbH & Co. KG                               |                                         | 50-180                                   | 110-380                               |                                      |                 |             |          |         |
| Syncraft <sup>®</sup> GmbH                                       | 700-3,000                               | 200-1,000                                | 155-1,540                             |                                      | x               |             | ○        | x       |
| URBAS Stahl- und Anlagenbau GmbH                                 | 500-2,000                               | 120-600                                  | 250-1,000                             |                                      |                 |             |          |         |
| Windhager Zentralheizung GmbH                                    | 7-100                                   |                                          |                                       |                                      |                 |             |          |         |
| Xylowatt S.A.                                                    | 2,800-7,300                             | 750-2,000                                | 1,500-4,000                           |                                      |                 |             | ○        | x       |
| <b>System designer</b>                                           |                                         |                                          |                                       |                                      |                 |             |          |         |
| BEST – Bioenergy and Sustainable Technologies GmbH <sup>1)</sup> | 100-35,000                              | x                                        |                                       |                                      | x               | ○           | ○        |         |
| GET – Güssing Energy Technologies GmbH                           |                                         | x                                        |                                       | x                                    | x               | ○           | ○        | x       |
| Güssing Renewable Energy GmbH                                    | 4,500-45,000                            | 1,200-2,400                              | 1,400-24,000                          |                                      |                 | ○           | ○        |         |
| Pörrner Ingenieurgesellschaft mbH                                | 500-45,000                              |                                          |                                       |                                      |                 |             |          |         |
| Repotec/Aichernig Engineering GmbH                               |                                         | x                                        |                                       | x                                    | x               | ○           | ○        | x       |
| ERNEUERBARE ENERGIE – Ing. Leo Riebenbauer GmbH                  |                                         | 18-540                                   | 44-810                                |                                      | x               | ○           | ○        | x       |
| SMS group Process Technologies GmbH                              | 1,000-20,000                            |                                          |                                       |                                      |                 |             |          |         |

x = implemented commercial plants; ○ = no commercial systems available yet; <sup>1)</sup> research facility; <sup>3)</sup> given information applies to one module.  
Company information, table makes no claim to completeness.

Research on thermal gasification of biomass and waste takes place in Austria at the following institutions:

- BOKU Wien (University of Natural Resources and Life Sciences Vienna)
- TU Wien (Vienna University of Technology)
- BEST (Bioenergy and Sustainable Technologies)
- TU Graz (Graz University of Technology)
- MCI (Management Centre Innsbruck) – Josef Ressel Zentrum

The research areas as well as actual projects were presented, such as e.g. CarbonNeutralLNG (Trully Carbon Neutral electricity enhanced Synthesis of Liquefied Natural Gas from biomass). The aim of the project is decarbonisation of industrial processes with efficient fluidized bed systems. BOKU is a partner in this project and coordinator is Friedrich-Alexander-Universität Erlangen-Nürnberg.

Austrian companies, which are active in area of thermal gasification were introduced. Companies such as Aichernig Engineering GmbH, GET, Güssing Renewable Energy, GE Jenbacher, Glock Ökoenergie, Hargassner, Fröling, Syncraft, Gresco Power and Urbas were presented.

## Belgium, Benjamin Berger, ECAM

### Bioenergy status

- Bioenergy and waste represent 8% of total energy consumption for approximately 2 Mtoe
- Biomass (mainly solid) represents 80% of renewable energies in heating
- Main biomass plants (direct combustion) are now closed in Belgium so biomass for electricity is really low at the moment

### Project TTCogen

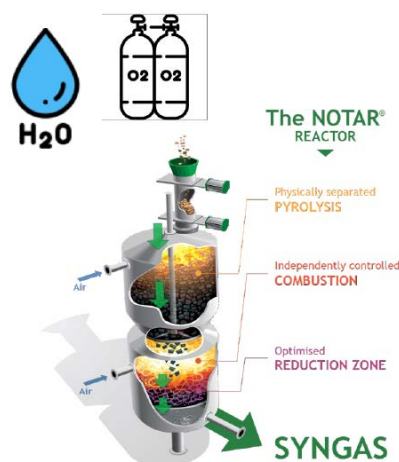
- HCCI engine using gas at high temperature without cooling and cleaning
- Compression ratio designed to have inlet above tar dew point
- Duration 4 years
- Full experim. Setup: gasifier from CMD + Engine and Auxiliaries (Cogengreen)
- Goal: setup validated on more than 1000 op.h for 2025
- **Now end of year 1, gasifier from CMD expected to be shipped in January 2023, Cogeneration**

engine expected from Cogengreen partner (BE) in January 2023

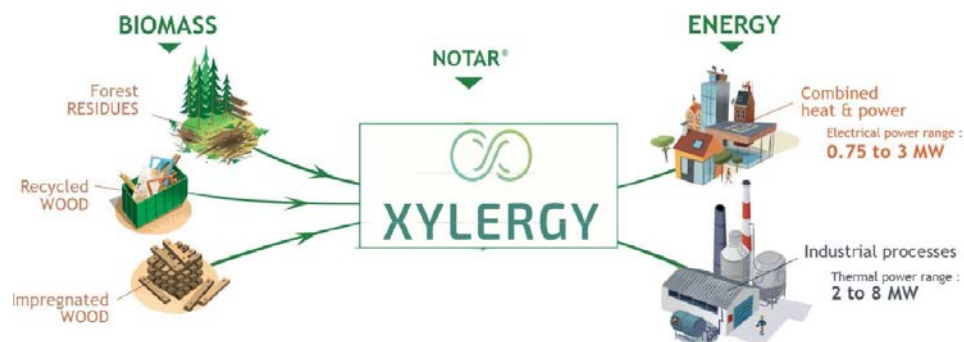
- First experimental campaign expected April 2023

#### Enerbio

- Downdraft gasification (NOTAR) using superheated steam and O<sub>2</sub>-enriched air
- High efficiency and high LHV
- Enhance tar reforming
- Pilot scale – up to 200 kW of syngas LHV
- Federal funding
- Partners: UCLouvain, UMon, ULB, CRA-W
- Duration 4 years
- Results of steam and oxygen enriched gasification presented during the workshop



#### Xylergy – new company that bought Xylowatt



Belgium – Mont-Godine hospital

Japan – Masumoto (first NOTAR in Asia)

#### RESOLIA

- New company specialised in district heating
- District heating in Malenpré (South Belgium) using biomass boiler for heat production
- Study to extend the district heating network and add electricity production through Spanner Gasifiers
- Expected commissioning in 2023

## Project Psyche

- Interreg project from Ugent – UCLouvain – Hauts de France
- Low TRL

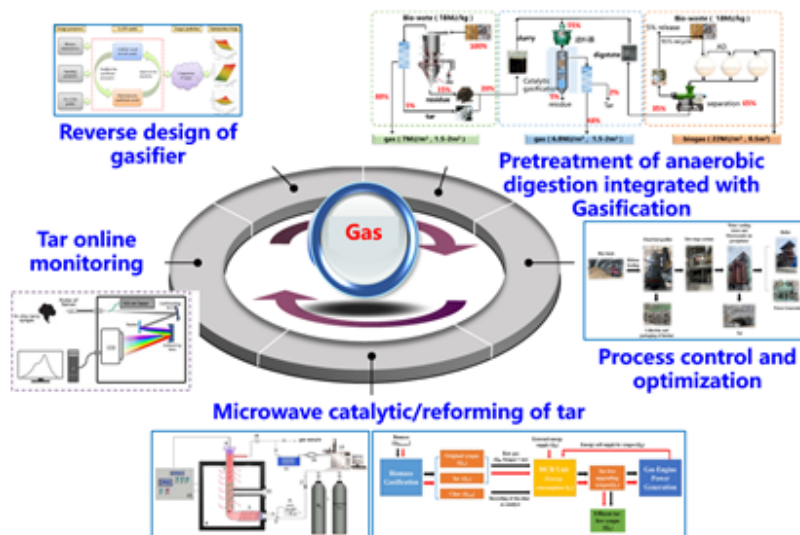
## China, Guanyi Chen, Tianjin University – update needed

Policy frame and background information were presented. Large amount of biomass/wastes are currently still not well used and even treated in rural area e.g. MSW, agricultural waste and forest residues and industrial solid waste.

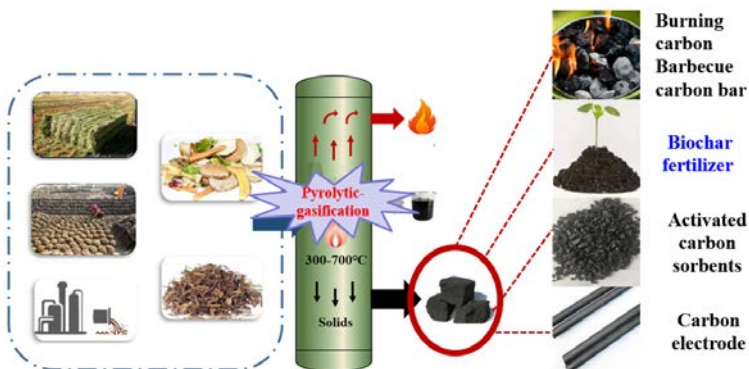
Gasification is a re-growing interest in China because of gas demand.

Research developments

Developments regarding fuel gas production (e.g. bioethanol or polygeneration) were presented.



Gasification for carbon-based products were presented.



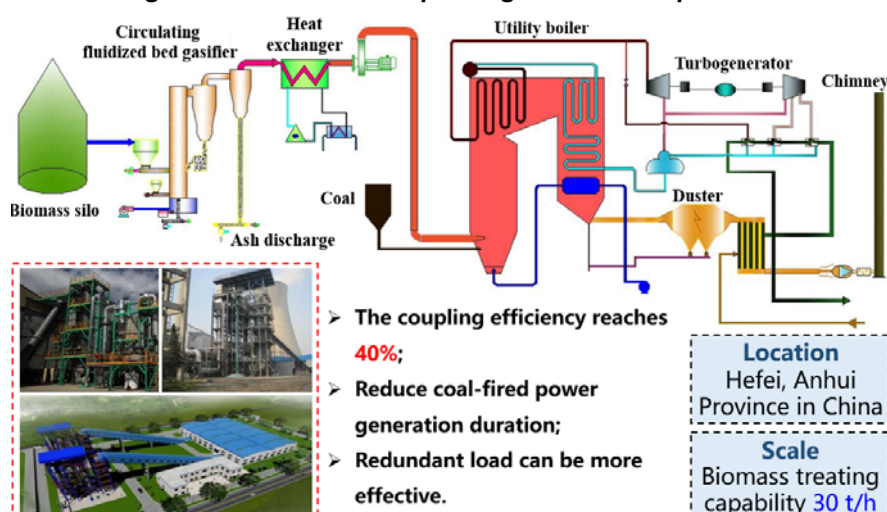
## Actual demonstrations in China

In total, 84 biomass gasification plants are running in China, and more than 20 plants are under construction presently.

### Representative gasification plants in China

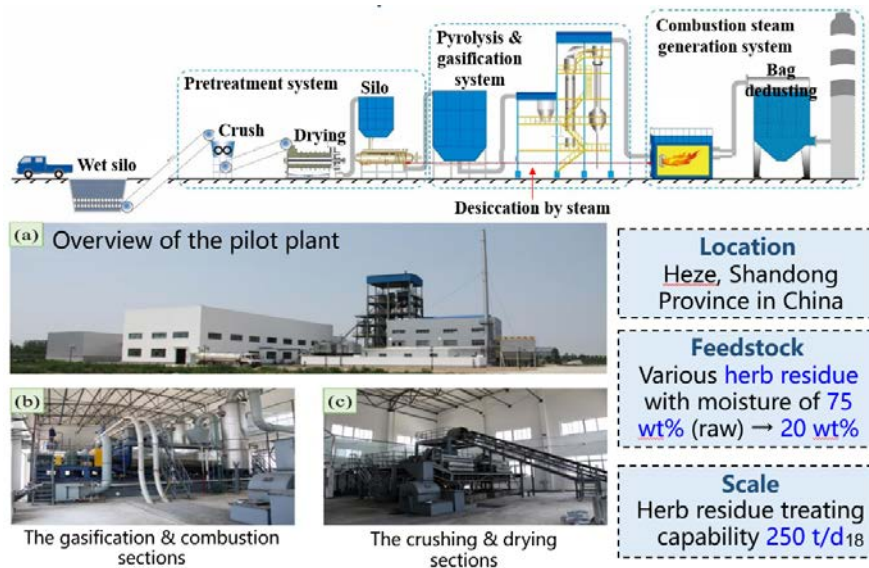
| No. | Location                            | Company                                                | Description                                                                                                                                                                                                                                                                                        |
|-----|-------------------------------------|--------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | <a href="#">Jingmen</a> , Hubei     | <a href="#">Debo Bio-energy technology</a> ., Ltd.     | <ul style="list-style-type: none"> <li><b>Rice husk</b> gasification coupled with coal combustion for power generation (10.8 MW).</li> <li><b>CFB</b> with the feedstock of 8 t/h.</li> <li>Bio-char is utilized as a fertilizer.</li> </ul>                                                       |
| 2   | <a href="#">Anji</a> , Zhejiang     | <a href="#">Debo Bio-energy technology</a> ., Ltd.     | <ul style="list-style-type: none"> <li><b>Bamboo</b> gasification for poly-generation of steam and bio-char.</li> <li><b>CFB</b> (7 t/h) + steam boiler (10 t/h).</li> <li>Char is sold for production of activated carbon.</li> </ul>                                                             |
| 3   | <a href="#">Heze</a> , Shandong     | <a href="#">Baichuan Tonochuang Energy</a> ., Ltd.     | <ul style="list-style-type: none"> <li><b>Chinese medical residue</b> (as received, 150 t/d) gasification producing heat and steam.</li> <li><b>CFB</b> (10 t/h) + combustion of syngas + heat recovery boiler</li> <li>The steam and heat are recycled to medicine production process.</li> </ul> |
| 4   | <a href="#">Jingning</a> , Zhejiang | <a href="#">Litian Environmental technology</a> ., Ltd | <ul style="list-style-type: none"> <li><b>MSW</b> gasification</li> <li>Four <b>Fixed bed gasifiers</b> (200 t/d in total)</li> <li>Gasified gas is combusted and clean treatment of MSW is achieved.</li> </ul>                                                                                   |

### Traditional gasification – coal fired power generation coupled with biomass gasification



### Gasification of industrial bio-waste

Feedstock: herb/medicine residues



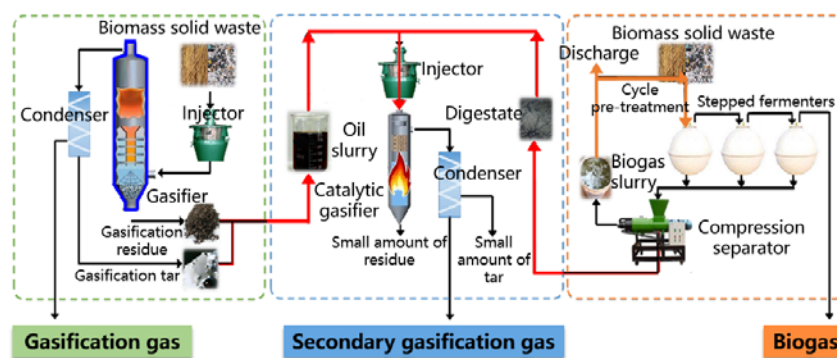
Further, gasification of brewing waste, of solid waste slurry, of MSW as well as high-temperature gasification of MSW and mobile small-scale waste gasification presented. The details can be found in the presentation.

#### Future perspectives

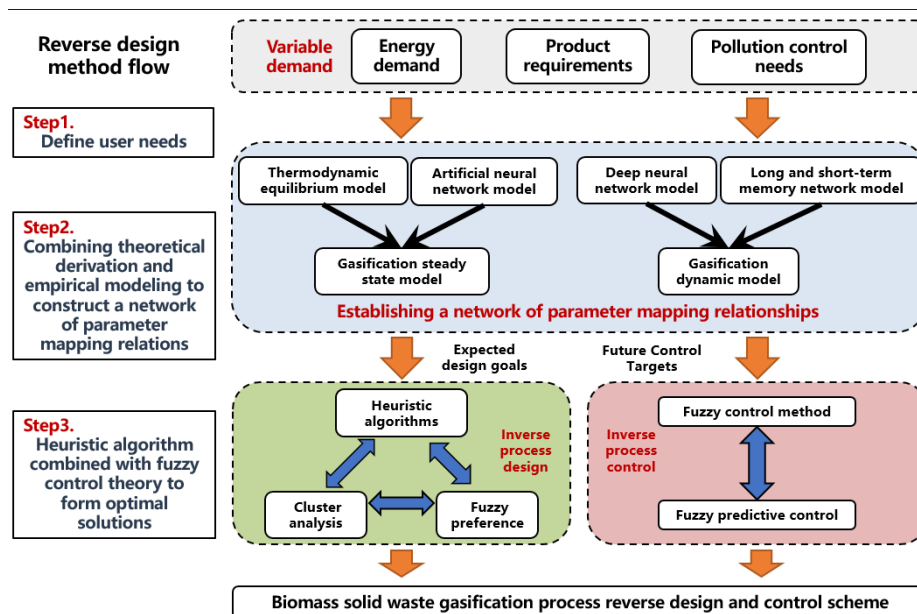
- biomass gasification with CCS
- biomass to hydrogen
- biochar applied in steel industry for carbon reduction
- polygeneration of hydrogen and carbon based fertilizer
- gasification of landfill excavation waste

Gasification at TJU and TJUC were presented.

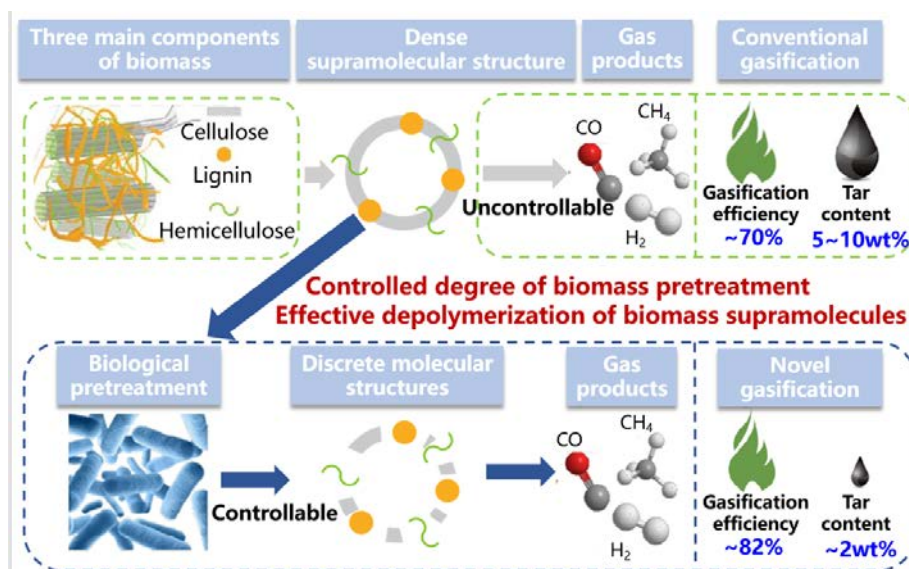
#### Secondary gasification technology for tar and other by-products



Innovative design of gasification: reverse design

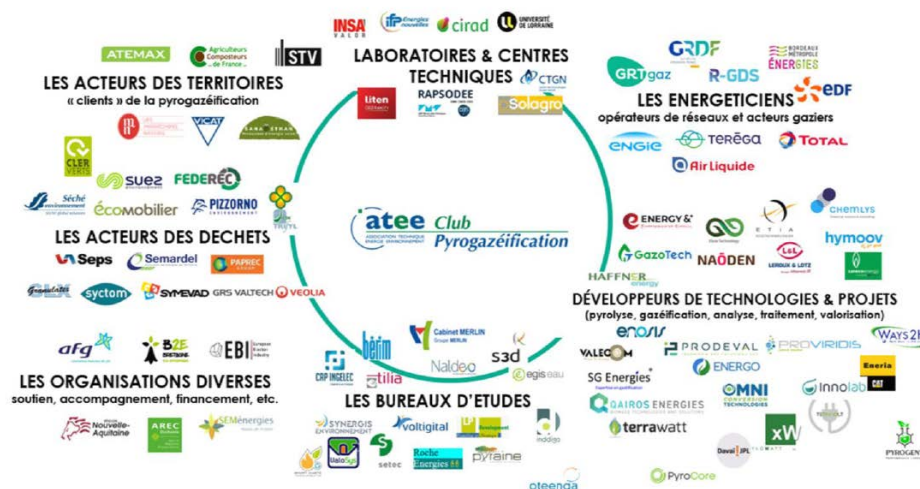


## Bio-thermal coupling technology



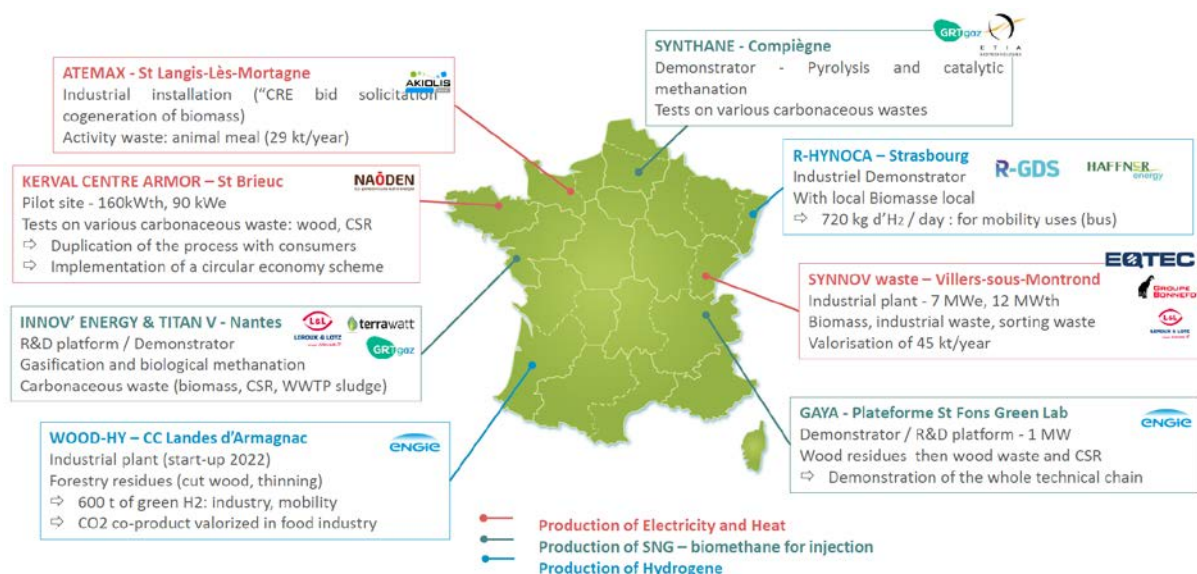
## France, Chourouk Nait Saidi

ATEE “Pyrogasification Club” – a French association was introduced

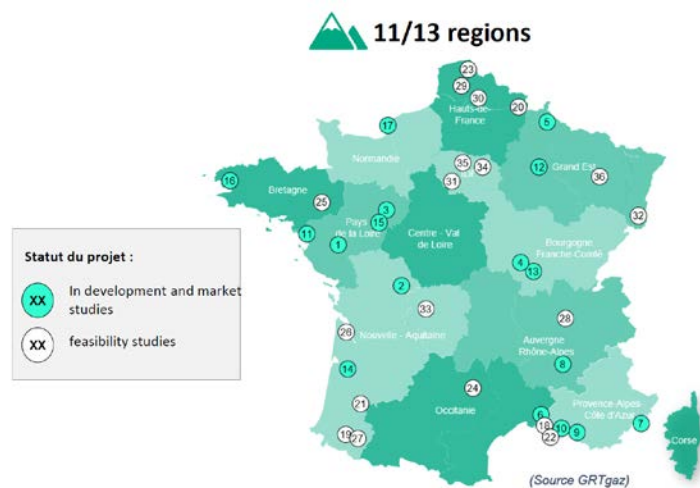


Production of SNG and biomethane strategy as well as scenarios for 2030 and 2050 were presented.

Gasification and SNG valorization – overview of some gasification plants



Overview on gasification for biomethane injection projects



### Gaya project

- industrialization is planned with project “Salamandre” (biomethane 20 MW)



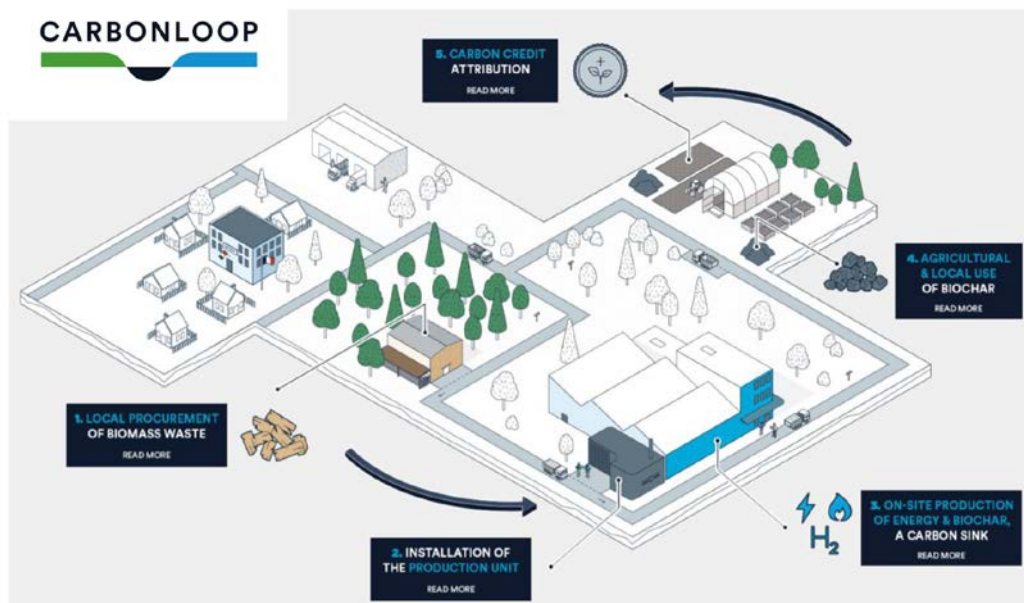
### Biofuels

#### BioTfuel project

- the process chain was validated and optimized on a wide range of biomasses
- gasification 15 MWth
- commercialization ongoing

### Green hydrogen and biochar

**Carbonloop – production of hydrogen for mobility**



## India, Mohana Rao, Indian Oil Corporation Ltd.

India energy share was presented; coal is dominating in energy mix. Bioenergy share in total energy consumption is about 26%. Ambitious target of 500 GW RES capacity by 2030.

The current availability of biomass in India is estimated at about ~750 million metric tons per year with surplus availability of at about 230 million metric tons per annum equivalent to potential of about 28 GW.

### Bioenergy deployment

|                                 |                                                                                                                                                                                                                                                                                                                                                                  |
|---------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Biomass power</b>            | <ul style="list-style-type: none"> <li>• Biomass gasification – electricity generation &amp; thermal energy generation</li> <li>• Bagasse based cogeneration</li> <li>• Biomass co-firing in existing coal based power plants</li> </ul>                                                                                                                         |
| <b>Compressed Bio Gas (CBG)</b> | <ul style="list-style-type: none"> <li>• Sustainable Alternative Towards Affordable Transportation (SATAT) scheme launched by MoPNG in Oct'18</li> <li>• PSU Oil Marketing Companies invite Expression of interest to procure CBG from potential entrepreneurs</li> <li>• As on 31<sup>st</sup> Aug'22, 3497 LOIs issued &amp; 37 plants commissioned</li> </ul> |
| <b>Bio-ethanol</b>              | <ul style="list-style-type: none"> <li>• Second generation (2G) ethanol bio-refineries using cellulosic and lignocellulosic materials like rice/ wheat straw, corn cobs, cotton stalk, etc.</li> <li>• PSUs Oil Companies are in the process of setting up 12 2G ethanol plants in various parts of the country</li> </ul>                                       |

Biomass co-firing in coal based power plants in India is an actual topic. It was decided to co-fire 5-10% of biomass in all thermal power plants.

### **IndianOil commissioned 1. 2G ethanol plant in Panipat**

- Set up based on Praj's proprietary technology processing Rice Straw as feedstock for the production of Ethanol
- Can process 2 lakh tonnes of rice straw annually to generate around 3 crore litres of Ethanol
- Assist to meet India's target of 20% ethanol blending in petrol by 2025

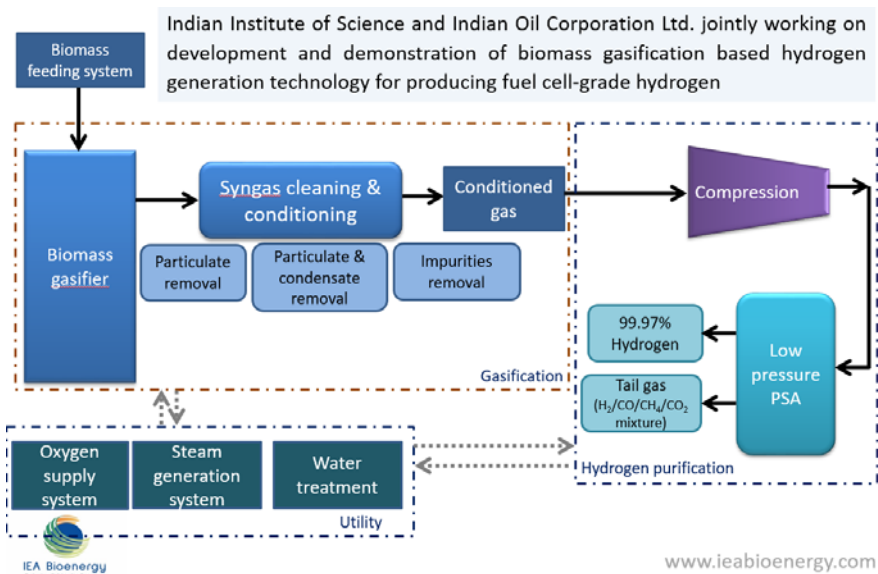
### **National Hydrogen Energy Mission (NHM) announced in the union budget for 2021-22**

- Honorable prime minister launched NHM on India's 75th Independence Day  
Aims to make India a green hydrogen hub as well as export of green hydrogen  
Green H2 spearhead India's transition to clean energy and aid in meeting India's climate targets  
India's total hydrogen demand expected to be nearly double from current 6.7 Mt to 11.7 Mt by 2030  
Govt. has plans to bring down cost of green hydrogen to Rs 160 per kg by 2029-30  
Aims to extend PLI scheme for manufacturing electrolyzers  
Ministry of Power notified Green Hydrogen/ Green Ammonia Policy on 17th Feb, 2022
- Hydrogen/ ammonia produced from biomass named as GREEN
- Waiver of inter-state transmission charges for 25 years to producers of green hydrogen from the plants commissioned before 30th June, 2025
- Open access to be granted for sourcing renewable energy within 15 days of receipt of application

### **Harnessing green hydrogen report by NITI Aayog**

- The world's largest electrolysis capacity of over 60 GW/ 5 million tonnes by 2030 for domestic consumption
- The world's largest production of green steel at 15-20 million tonnes by 2030
- The world's largest electrolyser annual manufacturing capacity of 25 GW by 2028 delivering affordable ones for India and the world
- The world's largest production of green ammonia for exports by 2030
- \$1 billion investment into hydrogen research and development to enable breakthrough technologies
- Project green hydrogen outlook for India was presented

### **Biomass gasification based hydrogen generation**



- Oxy-steam gasification results presented
- Hydrogen separation from syngas presented
- Analysis of bio hydrogen for quantification of impurities specified under ISO presented
- Fuel cell performance evaluation presented

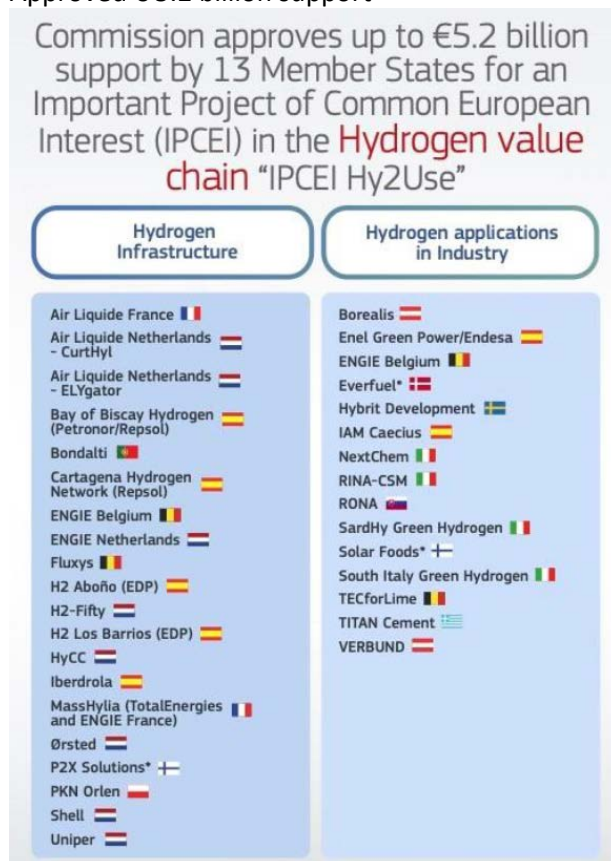
## Italy, Donatella Barisano, ENEA

Gasification and prospective at Italian level as well as update on EU and national projects were presented.



### Projects of common European interest (IPCEI): Hy2Use

- Approved € 5.2 billion support

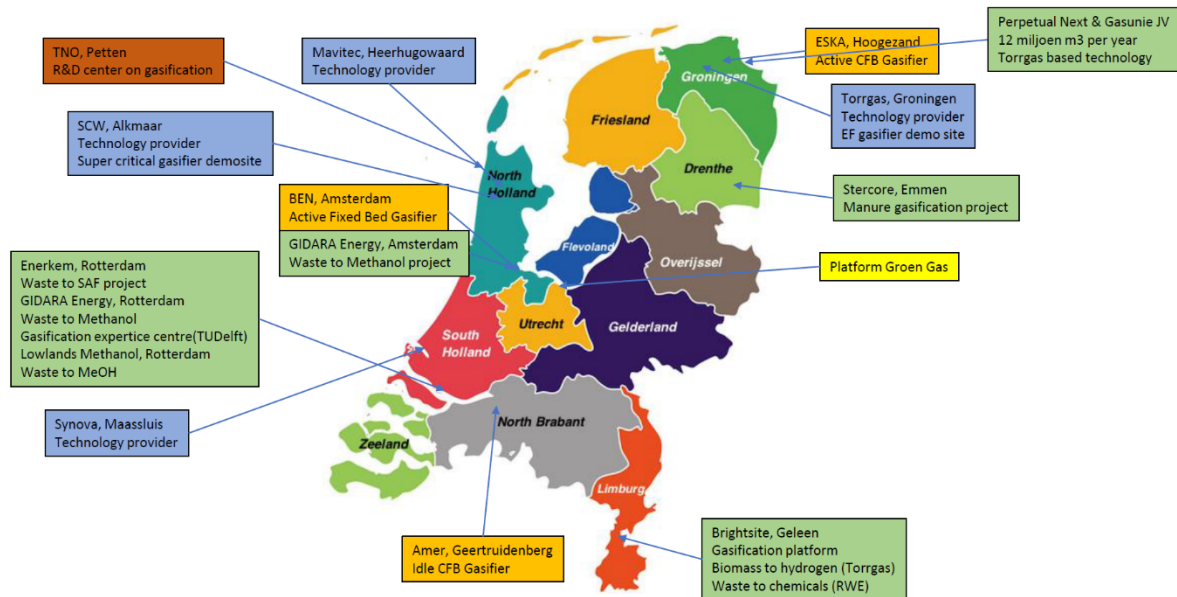


- Development of new technologies for hydrogen production, storage, transport and distribution, as well as on applications in the mobility sector to be also applied to steel, cement and glass industries

Update on EU and national projects was given. Italy is involved in several national and international research programs on gasification. Details can be seen in Donatella's presentation.

# Netherlands, Berend Vreugdenhil, TNO

## Gasification activities in the NL

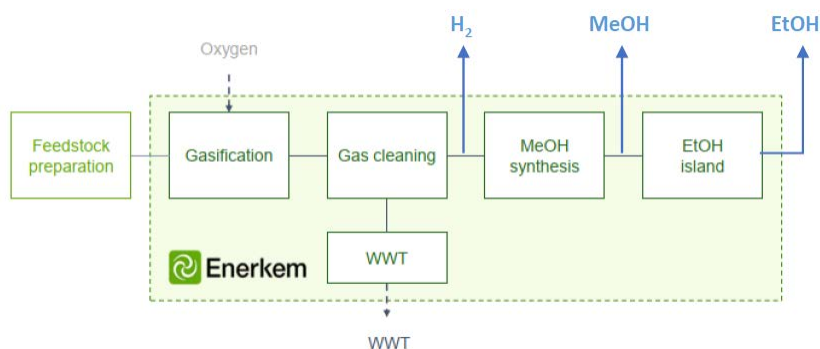


## Stercore

- NGO keeps blocking the construction – main reason because it enables Dutch farmers to keep livestock and produce manure
- Manure to green gas & bio-based carbon factory
  - o Economic due diligence finished
  - o Technical due diligence finished
  - o Technical detailed design and building design finished together with Emmtec Engineering as EPC
  - o Off-take agreement for Bio-LNG with UK/NL oil major agreed upon as a fuel guarantee not depending on the SDE++ scheme
  - o In compliance with first court ruling, expecting final verdict in December
  - o Start building expected Q2-2022

First stage investment approx. 32 Meuro

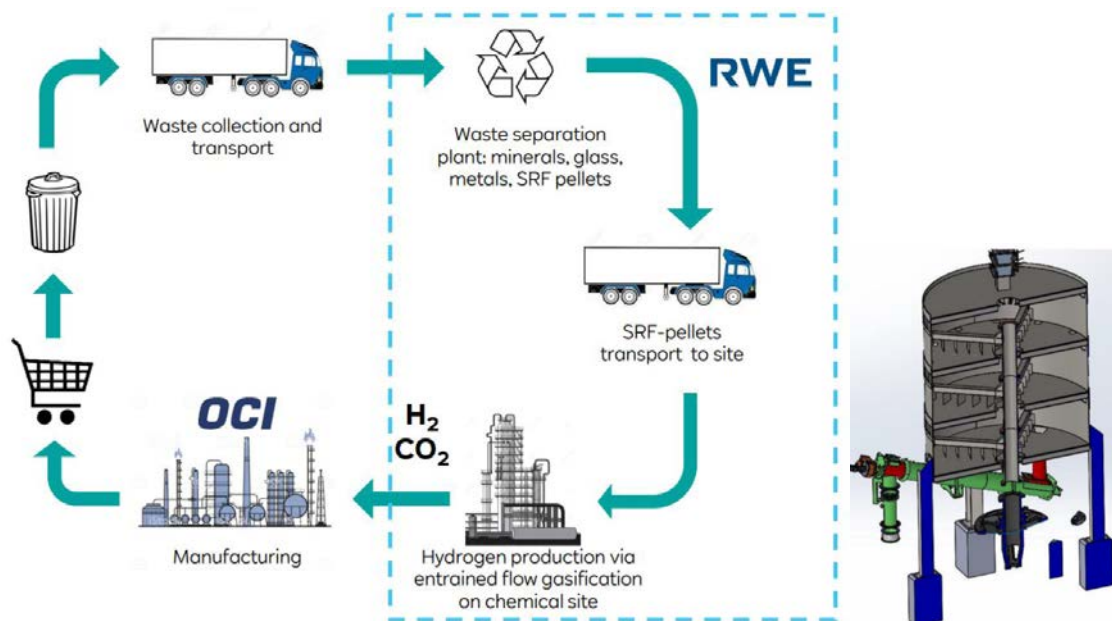
## ENERKEM



- Commercial plant in Canada (Edmonton)
  - o 90 MWth producing IMPCA methanol and ASTM ethanol

- Rotterdam, NL
  - o 400 000 tons of non-recyclable municipal solid waste
  - o Aim was 220 000 tons of methanol per year
  - o Project under review to determine feasibility
- Varennes Montreal, Canada
  - o Project in construction
  - o 200 000 tons/y of non-recyclable residual waste and wood waste
  - o Aim 125 million liters of low carbon fuels/y
- Tarragona, Spain
  - o Project in engineering design
  - o 400 000 tons of non-recyclable MSW
  - o 220 000 tons of methanol

#### FUREC RWE



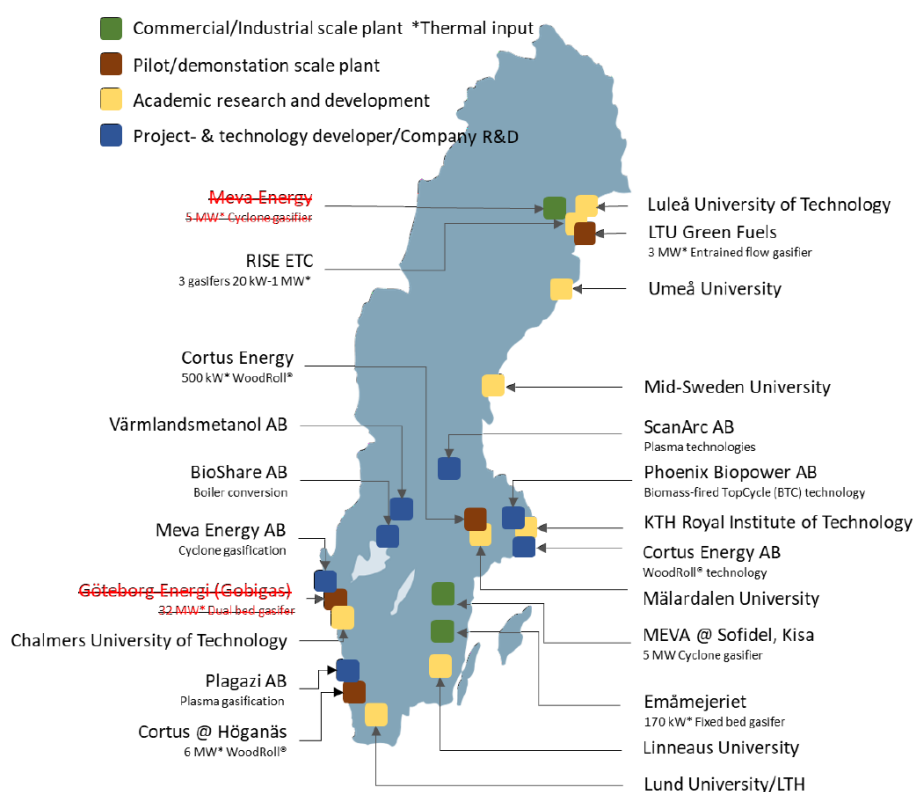
- Waste-2-hydrogen
- “fuse, reuse, recycle”
- Design basics and next steps – multiple hearth furnace pilot plant
  - o Low temperature pyrolysis of lumpy feedstock at 260-320°C in order to enable grinding of fuels like biomass or pelletized RDF

## Sweden, Joakim Lundgren, LTU

Total final energy use in Sweden was presented.

Policy update:

- A reduction obligation for transport fuels that forces fuel distributors to blend in pre-determined and annually increasing shares of renewable fuels into fossil diesel and gasoline was introduced
- Even if it fails to directly promote domestically produced biofuels, it promotes fuels with high GHG-performance
- The new government now proposes to radically lower the shares



### Commercial gasification projects – update

#### Cortus 6 MW WoodRoll® gasifier at the Höganäs steel plant

- The problem with char particles in the pyrolysis gas clogging pipes seems solved
- Integrated operation during > 60 hours was recently performed
- Integrated operation with maximum energy recovery\* during 7 days of continuous syngas production (MS3) (\* more than 90% of the energy comes from pyrolysis gas)

#### Other Cortus WoodRoll® news

- Cortus AB recently got orders for two gasifiers from blueFLUXEnergy AG and HolznerDruckbehälter GmbH in Germany.
- Engineering work has started –gasifiers to be delivered in Q1 and Q2 in 2023.

- The first project is for hydrogen (0.5 MW) and the second for fossil gas replacement in heating furnaces in the brick industry (6 MW).
- Engineering study for a future plant for green diesel production with the Norwegian company BiojetAS.
- Planned plant capacity = 750 tonnes of biomass per day = several parallel WoodRoll® needed (20 times larger than Höganäs).
- A term sheet (preliminary agreement) with the Norwegian company GlocalGreen AS on gasification of forest residues for the production of renewable methanol for shipping.
- New order of an engineering study on a 6 MW WoodRoll® gasifier in Ireland for RNG-production

#### **MEVA**

- EF cyclone gasifier emanated from Luleå University of Technology
- Outputs 1.2 MW<sub>el</sub> and 2.4 MW<sub>th</sub>
- Small fraction fuels (sawdust, wood fibers and agricultural residues)
- Applications: CHP, fossil process gas replacements and industrial drying processes
- Low value wood residue to renewable gas and power (2.4 MW) at IKEA Industry production unit in Zbaszynek, Poland
  - Initial process design work completed, now detailed design
  - Start procurement of time-critical equipment in spring 2023 with start-up of the facility Q3-Q4 2024
  - Environmental impact assessment in progress
- Renewable gas (4.2 MW) for tissue drying at Sofidelmill in Kisa, Sweden
  - Ready for cold tests Q 2023
  - First gas deliveries end of Q 2023
  - Fall 2023 and Spring 2024, plant optimization and evaluation

#### **Uniper and Sasol ecoFT – SkyFuelH2**

- Sasol ecoFT has signed a LOI with Sollefteå municipality in collaboration with Sweden's energy company Uniper
- Investigate the possibility of establishing an industry-scale production facility for sustainable aviation fuel
- 100 000 ton SAF per year = ca 150 MW = 200 MW power + 100 MW biomass
- Proposal for a feasibility study recently submitted to the Swedish Energy Agency

#### **Plagazi AB**

- Plagazi AB has a concept for transforming waste into hydrogen through plasma gasification.
- Several new projects are announced:
  - Köping Hydrogen Park - Three Plagazi plants to recycle 66.000 tonnes of waste annually for production of 12.000 tonnes (51 MW) of hydrogen.
  - Planned to be operational in 2024
  - German project "Havelstoff" located in Brandenburg run together with Neue Energien Premnitz
  - LOI with WIRTZ Energie + Mineralöl GmbH with the intent to form a long-term offtake agreement of 4 000 tons of hydrogen
  - Planned start Q2, 2023
- Potential collaboration with LanzaTech for circular plastics

#### **BIOSHARE**

- The company BioShare granted funding ( $\approx 1,7$  M€, 2020-2024) to demonstrate integrated gasification and pyrolysis at a CHP-plant
- The reactor to be operated during three heating seasons to assess performance and gas quality with different feedstocks
- No updates reported

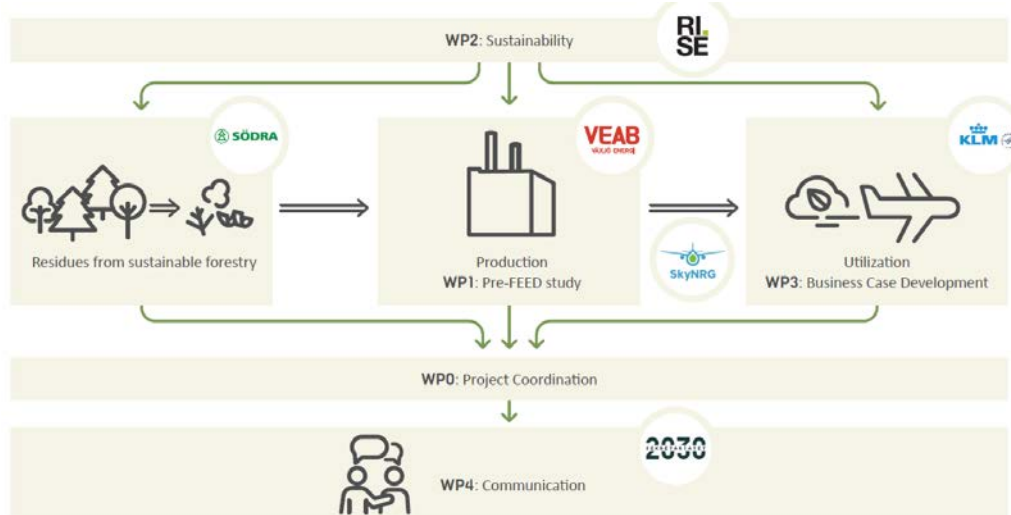
### Phoenix Biopower

- The Biomass-fired TopCycle(BTC) -high-pressure steam treatment and entrained flow gasification
- Gas turbine for power generation
- Aiming at electrical efficiency of up to 60 %
- Two H2020-projects; EUCANwin! and BioFlexGen

### Swedish gasification-related R&D programs

Circular and renewable feedstock to the Swedish chemical industry

From Forest Residues to Sustainable Aviation Fuels (RE\_SAF)



### FerroSilva

- Project funded by the Swedish Energy Agency and an industrial and research consortium,
- Techno-economic conditions for production of sponge iron (DRI)
  - Several options for integrating the production of biogenic syngas with a reduction process with high utilization of the top gas of the DR-process
  - Great GHG-performance –CO<sub>2</sub>-sink with CCS
  - Reduction with syngas from biomass seems competitive against all other current alternatives under Swedish conditions.
- The next step is to build a demonstration plant of 50 ktonDRI

### Large-scale production of biocarbon as renewable feedstock in fossil-free value chains within the iron and steel industry

Aim: Develop a reactor concept enabling large-scale production of biocarbon and which can be integrated into existing fluidized bed boilers.

2022-2026 - funded by Swedish Energy Agency

Partners: Chalmers, Luleå University of Technology, RISE, BioShare, E.ON, Höganäs, SSAB

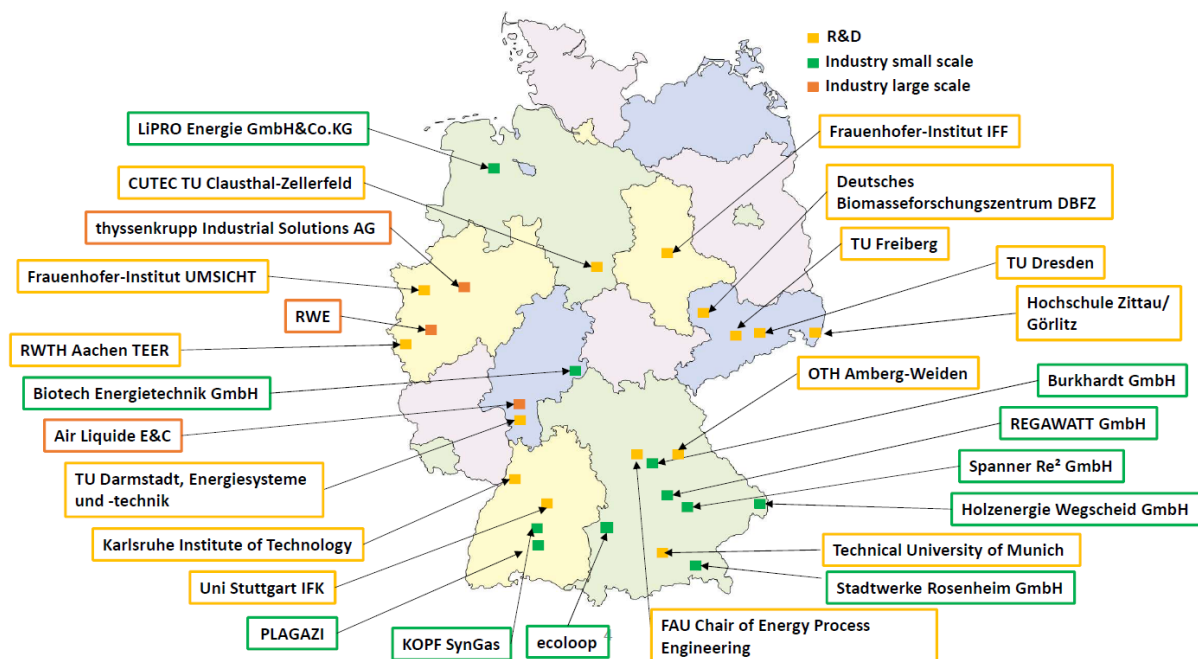
## Catalytic steam reforming of tar and methane at high pressure for H<sub>2</sub> production

Increased the understanding of catalytic steam tar and hydrocarbon reforming of biomass gasification raw gas at pressurized conditions (10-20 bar)

## Germany, Sabine Fleck, KIT

Statistics regarding GHG savings as well as renewable energy for el. power were presented.

### Gasification activities in Germany



### Sülzle Kopf

- FB gasification for sewage sludge with CHP via gas engine
- plant in Koblenz: 440 kWel./525 kWth.
- load change between 500-600 kg/h
- stable gas quality
- Successful acceptance run in 2021
- fuel quality adjustments are currently being made to ensure more stable operation
- plant in Koblenz handed over to customer
- **status October 2022:** plant in batch operation, Kopf SynGas responsible for maintenance, service and operation, due to war in Ukraine deficiency of feedstock

### Blue Energy CHP

Plant out of operation due to lack of approval from licensing authority

Wood oil was initially classified by the authorities as waste and wanted to approve the plant only according to waste law

Currently: Submission of new permit application hope for start up again  
still no progress

### **RWE Phosphorus from sewage sludge**

- Pilot plant in Niederaußem
- Atmospheric entrained flow gasifier
- Three-component fuel mixing, refractory lining, dip quench, liquid ash discharge
- Fuels: Sewage Sludge, Sewage Sludge Ash, Lignite (ca. 130 kg/h, max 800 kWth)
- Temperature ~1,500°C
- Objective: Prove recovery of phosphorus from sewage sludge / sewage sludge ash
- Erection in 2020, Start-Up June 2021
- Funding provided by State of North Rhine Westphalia (Ministry of Economics);  
Total project budget (incl. cost for plant operation): 6.7 Mio. €
- Partners: Fraunhofer UMSICHT, Ruhr Universität Bochum
- Waste gasification
  - first start up campaign in June 2021: fuel supply and gasification operated successfully, dust extraction and steam supply to be reworked
  - second campaign late Nov. 2021 and late Dec. 2021: dust extraction and steam supply worked properly
  - further campaigns with coal executed February, April and May 2022 for operation optimization
- **no update**

### **Plagazi**

- Green hydrogen from any type of waste via plasma gasification
- CO2 is captured in CCS
- 70% of energy need is recycled internally
- Neue Energie Premnitz: Plagazi AB and Richter Recycling GmbH have entered an agreement to conduct a pre-study for constructing a Plagazi waste-to-hydrogen plant in Potsdam. The aim of the project team is to have the plant up and in operation by 2023.
- Dillinger GmbH have entered an agreement to conduct a pre-study for constructing a Plagazi waste-to-hydrogen plant.
- The pre-study will highlight the feasibility to include a Plagazi plant at their steel mill facility in Dillingen, Saar.
- CH: Feasibility study for Automotive Shredder Residue (ASR) Recycling in Switzerland
- **No news**

### **BioTfuel**

Update May 2022:

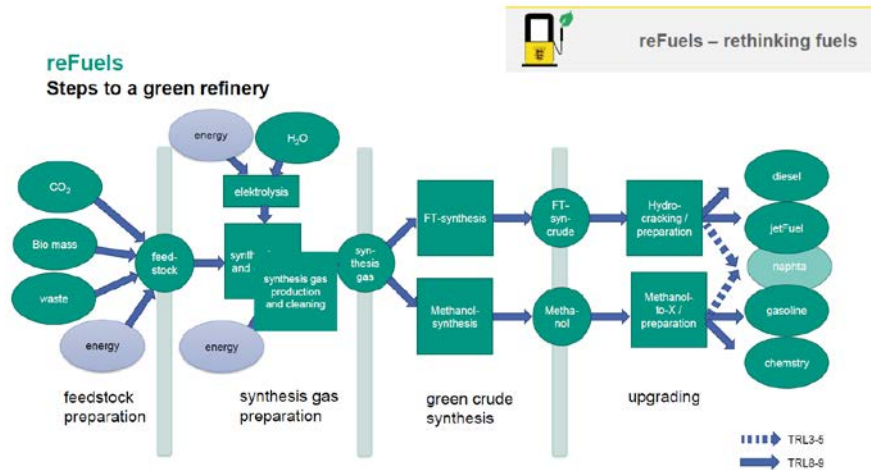
All test series have been successfully completed. The commercialization of the process chain based on PRENFLO gasification process is already in process, not only for SAF but also for methanol and hydrogen applications and many more.

### **Bioliq**

- Scale-up to 100 / 500 MW for project reFuels
- Fuel type specific data derived from experiments with model and technical fuels in campaigns 2021
- Commissioning of new slag lock in October 2022

## reFuels project

- produced on the basis of non-fossil carbon and CO<sub>2</sub> sources
- including advanced 2<sup>nd</sup> and 3<sup>rd</sup> generation biofuels



## USA, Robert Baldwin, NREL

### Fulcrum Bioenergy/Sierra Biofuels:

- MSW feedstock/TRI indirectly heated fluid bed steam reforming gasifier
  - o 350,000 tons per year raw MSW -> 175,000 tons per year prepared MSW
  - o 20 TPH throughput
- **Plant now undergoing start-up operations**
- Johnson Matthey DAVY™/BP fixed-bed FT
- Recently pivoted from jet fuel to FT wax
- Off-take with Marathon Oil Co., Wax to be refined in Marathon's Martinez CA refinery  
*Uncertain whereas Martinez, CA is being converted to renewable diesel facility*
- Other offtakers include United and Cathay Pacific, BP Air, World Fuels
- FT jet fuel capability to be added in Phase II
- Plant is "full scale", 3x scale up planned with parallel trains  
12 new projects currently planned/underway
- More information: <http://fulcrum-bioenergy.com/facilities/>

### Red Rock Bio

- Gasification to Fischer-Tropsch
- Technology providers
- Providers
  - Gasification: TCG Global steam reforming
  - FT technology: Velocys and Emerging Fuels Technology
  - Parallel FT trains
  - Hydroprocessing: Haldor Topsoe
- Feedstock: forest residue (166,000 dry tons/y)
- Products: cellulosic renewable jet, diesel, and naphtha fuels
- Offtakes: Southwest Airlines, FedEx Express
- First commercial project status
- Site: Lakeview, OR

- Anticipated construction completion: Q4 2022

## Other commercialization activities

### San Joaquin Renewables, San Joaquin, CA

- Gasifier: Frontline BioEnergy RNG (pressurized FB, 10 bar, air or O<sub>2</sub> with steam)
- Feedstock: Ag waste
- Product: RNG (15 mill. Gallon-eq.)
- Status: engineering in progress, approvals for injection in existing pipelines received

### Mote

- Gasifier: SunGas Renewables (press. FB, 10 bar with CCS)
- Feedstock: Ag residues
- Product: low-carbon hydrogen
- Status: initial stages of project planning

### Arbor Renewable Gas, Beaumont TX

- Gasifier: SunGas Renewables, MTG: Haldor Topsøe
- Feedstock: woody biomass
- Product: 1 000BPD renew. Gasoline (MTG)
- Commercial production in 2024

### Madera Gas, Houston TX

- Gasifier: SunGas Renewables, with CCS
- Feedstock: woody biomass 100 000 TPY
- Product: RNG (5B SCFY RNG)
- Operation in 2024

### Velocys Natches MS and Immingham UK

- Microchannel FT reactor
- 35M GPY SAF from gasification of woody biomass; no other details available
- Status: Natches, Immingham – start up 2027

### USA Bioenergy – Texas Renewable Fuels

- Gasif.+ FT
- Feedstock: woody biom.
- Product: SAF, renew. Diesel, naphtha
- Status: planning underway for 1. Biorefinery in Bon Wier, Texas

### Lanzatech

- Gasifier: Sekisui (Japan), Ankur (India)
- Feedstock: biomass, MSW
- Product: bio-ethanol and other oxygenates
- Status: developmental work in progress

### Aries Clean Energy

- Downdraft gasifier for biochar and syngas-to-power applications
- Fluid bed gasifier for production of syngas
- Projects:
  - 1) Linden, NJ; fluidized bed gasification of bio-solids (Linden Roselle Sewerage Authority)

Processing 430 TPD biosolids; 22 TPD biochar and power

2) Holloway Bioenergy; Lost Hills, CA

Aries down-draft gasifier; Ag wastes from California's Central Valley

165 TPD ag waste feedstock producing 86 MWe/D and 5,000 TPY biochar

Operational Q3 2021

3) Lebanon, TN

Aries down-draft gasifier; wood wastes and bio-solids diverted from landfill

420KWe/D and biochar

Operational since 2017

Status: 3 projects operational (NJ, CA, TN)

### The political climate

- DOE: Liquid transportation biofuels coming back on the table
  - o Sustainability: >70% life-cycle GHG reduction
  - o Very strong emphasis on waste carbon feedstocks, SAF, and marine diesel products
  - o Variety of SAF pathways under development (in addition to Fulcrum and RRB) gasification => LanzaJet, Vertimass
  - o Pyrolysis => Alder Energy
  - o Arrested anaerobic digestion (volatile fatty acids upgrading) => Alder Energy
- Infrastructure bill (\$1.2T) has large investments in hydrogen
- Nothing specific called out for biomass
- **DOE H<sub>2</sub> Incubator prize – Biomass Super Gasifier – indirectly heated pyrolytic gasification process, hydrogen extracted from syngas, with the remaining syngas used in a solid oxide fuel cell to generate power to run the system**
- DOE has issued a roadmap to stand up 4-5 operating biofuels demonstration plants (each at approx. 1M GPY) by 2030
  - o 3B GPY SAF is target by 2030 (BioEnergy Technology Office)

END