Challenges of Renewable Fuels in Existing Heating Equipment Fit for Purpose Tests

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Market for Mineral oil products – example Germany 2016

Outlet 104 Mio. t
(corresponds to 1.100 TWh DK-Eq.)

- **Naphtha**
  - Outlet: 16.2 Mio. t

- **Heavy fuel oil**
  - Outlet: 4.2 Mio. t
  - Mineral oil tax: 25.00 €/t

- **Domestic heating oil**
  - Outlet: 15.6 Mio. t
  - Mineral oil tax: 61.35 €/m³

- **Jet**
  - Outlet: 8.9 Mio. t

- **Gasoline**
  - Outlet: 18.2 Mio. t
  - Thereof bio.: 1.1 Mio. t
  - Mineral oil tax: 654.50 €/m³

- **Diesel**
  - Outlet: 38.4 Mio. t
  - Thereof bio.: 2.1 Mio. t
  - Mineral oil tax: 470.40 €/m³

Source: Mineralölwirtschaftsverband
Intensive research activities for innovative liquid fuels

- Green perspective as well for Domestic heating oil possible

- Science and industry are already working on new CO2-reduced liquid fuels

- Multiple projects are already realized in pilot / demo or laboratory plants
Science radar

• Out of the study related to research and development activities for „Future Fuels“ of the OWI Institute **38 projects have been chosen**, which are displayed in the **science radar**

• Research projects which are currently in the state of a **Pilot-**, **Demo-** or **Laboratory plant**.

• A **technology readiness level TRL** of minimum 4 has to be already achieved
State of the art

- **Realized plants**
  - Shell / Qatar – Fischer-Tropsch of gas
  - SASOL / RSA – Fischer-Tropsch of coal/gas
  - Nest Oy / EU – Hydro treating of plant oils

- **TRL 7 – 9**
  - Approx. 5 - 8 technologies
  - Mostly on the base of Biomass, Waste
  - Some are electricity based

- **TRL <6**
  - Approx. 20-25 technologies
  - Mostly on the base of Biomass, Waste
  - Some are electricity based
“Biomass-to-Liquid (BTL)”- project at Karlsruher Institut for Technologie (KIT)

- bioliq®-Pilot plant for the production of synthetic fuels out of biomass:
  - gasoline
  - Jet-fuels
  - OME (Oxymethylenether) for Diesel applications
  - More alternative fuels are possible

- Input: biogenic leftovers aus agricultural use (especially straw and residual wood)
  - No additional land use is necessary
  - As well no food competition

Graph: Synthesis plant Bioliq®-Pilotanlage at Karlsruher Institut für Technologie (KIT)

- TRL 6 (out of 1-9)
  - “Technology tested in relevant environment“
- Total investment: 64 Mio €
  - public funding and industrial partners
“Power-to-Liquids (PTL)“Pilot plant at Sunfire Dresden

• Pilot plant for production of a synthetic „Blue Crude“ as first step for CO\textsubscript{2}-neutral liquid „e-fuels“
  • Diesel
  • Kerosene
  • Blending component to other liquid fuels

• Input (regenerative):
  • Electricity from wind- or solar
  • Water
  • CO\textsubscript{2} from atmosphere, flue gases or separation from Biogas plants

• Bild: „PTL“-Pilotanlage zur Herstellung von synthetischen flüssigen Energieträgern aus Wasser, CO\textsubscript{2} und Ökostrom („e-fuels“) am Standort der Firma Sunfire, Dresden

• TRL: 7 (out of 1-9)
  „Test eines System-Prototyps im realen Einsatz“

• Total investment: 10,4 Mio €
  public funding and industrial partners
„Blue Crude“ from Sunfire - Power-to-Liquids in three steps

1. **High temperature- electrolysis:** Erzeugung von Wasserstoff (H₂) aus Wasserdampf mittels erneuerbarem Strom

2. **Conversion:**
   Reverse Shift-Reaktion von Wasserstoff (H₂) und Kohlenstoffdioxid (CO₂) zu Synthesegas (CO + H₂) und Wasserdampf (H₂O)

3. **Fischer-Tropsch-Synthesis:** Technisches Verfahren zur Umwandlung von CO + H₂ (Synthesegas) in flüssige Kohlenwasserstoffe („Blue Crude“) für die weitere Aufbereitung zu „e-fuels“
Conversion of micro algae to fuels: Usage of the complete biomass

1. Hydrothermale Verflüssigung (HTL): Umwandlung der feuchten Biomasse in ein schwerölartiges „Biocrude“ (Spaltungsreaktion bei 280-370°C und 100 bis 250 Bar)

2. „Milde“ (Vor-) Hydrierung: Veredlung zu „Algenrohöl“ durch Zugabe von Wasserstoff (H₂)

3. Weiterverarbeitung in Raffinerieprozessen: Einspeisung optimaler weise vor der Rohöldestillation
„Biomass-to-Liquid (BTL)“: liquid fuels out of micro algae

Project „AlgenFlugKraft“; „Algentechnikum“ der TU München, Ludwig Bölkow-Campus, Ottobrunn (Bild: © Andreas Heddergott / TU München)
- Produktion biologischer Flugkraftstoffe auf der Basis von Algen
- Algenprozesse in Abhängigkeit von Klima, Algenstämmen und Kultivierungstechnologien
- TRL 3-6 (out of 1-9) Schätzg. OWI
- Total investment:12 Mio € mit staatlicher Förderung und Industriepartnern

Project „Aufwind“; „Algen Science Center“ des Forschungszentrum Jülich GmbH
- Technische und wirtschaftliche Möglichkeiten zur Herstellung von Algen und deren Umwandlung zu Biokerosin
- Züchtung von Mikroalgen in Foto-Bioreaktor-Systemen: platzsparende Aufstellung auf ungenutzten Flächen mit hoher Ausbeute
- TRL: 3-6* (out of 1-9)*Schätzg. OWI
- Total investment: 7,4 Mio € mit staatlicher Förderung und Industriepartnern
Prerequisites for the market introduction of GHG reduced fuels

Important Markets:
• Mobility and Room heating

Lead questions:
• What amounts of fuels can be produced in short middle and long term?
• Direct costs / Total Cost of Ownership TCO?
• Sustainability?
• Technical requirements?
Demands towards innovative liquid fuels

Compliance of Renewable Energy Directive I + II (RED)
• GHG reduction potential has to higher than 70%
• Necessary potential of resources is available
• Avoidance of competition of usage

Demands of the DECHEMA- position paper
• Save use usage with existing infrastructure
• Downward compatibility with systems in the market
• „Drop-in-Quality“ with possible improvement of fuel quality
• Customer acceptance
See www.dechema.de/studien.html

➢ Fuels have to be „Fit-for-Purpose“
„Fit for purpose“: Testing of new fuels before market entry

1. Interaction of material, fuels and components
2. Check of the combustion behaviour
3. Long term testing under laboratory environment
4. Field- and captive fleet tests in model regions
Opportunities in HiL testing

• For specific tests, not always the complete system is required; smaller, less complex test benches.

• Test principle can be transferred to different fuel types and fields of use
  1. Domestic heating
  2. Methanol base fuels, DME, MNE, Octanol, …
  3. Paraffinic fuels, HVO, GtL, …
  4. FAME
  5. ….
Testing of Fuel and Additive Packages
- task and approach

• Identification of claimed effect of additive/fuel – and translation into a value that can be measured
  1. “keeps the system clean” -> detergent => run a fouling test
  2. “prolongs storage time” -> antioxidant => stress the fuel and check oxidation stability
  3. “Corrosion protection” -> corrosion inhibitor => steel pin corrosion test
  4. ….

• These claims should best be verified in the real system; challenge: high fuel consumption and/or test time

• Good experience in different fields of testing: “Hardware in the loop”. Principle: “complete” real system, but no combustion => forced testing and low fuel demand
Example: „Premium“ heating oil

- **Definition according to BDH (German association of manufacturers of heating devices):**
  - 1. Long term storage stability
  - 2. High thermal stability
  - 3. Corrosion protection
  - 4. Protection against water take up
  - 5. Keep-Clean/Clean-Up
  - 6. Resistance against microbial contamination
  - 7. Odor
  - 8. No ash forming additives

- **Approach: use the same base fuel, add the additive to one part and test in a HiL bench. Eventually, the fuel will degrade strong enough to show a deterioration in these values. The Additive should prevent or at least delay this deterioration.**
ATES Fuels test bench

- „Stress-test“ for evaluation of the „additive-performance“ of additive treated and base (not additive treated) fuels
- Hardware-in-the-loop-test principle
  ▶ complete heating-oil-system: filter, pump, pre-heater, nozzle
- Fuel is pumped in a circle through all fuel-leading parts (no combustion)
- Defined fuel-aging: light, heat, oxygen, copper

=> Periodic fuel analysis shows difference between base fuel and additised fuel; further measurements in test bench deliver additional data (keep clean)
Results - examples

➔ Base fuel failed twice, additised fuel retained the initial flow
Results - examples

➔ Additive prevented corrosion in two different heating oils
Results - examples

- HEL-1
- HEL-1+Add.
- HEL-2
- HEL-2+Add

➔ Additive prevented corrosion in two different heating oils
Results – OME and sealings

• Swelling of the sealings (FKM with PTFE Überzug)
• Crosssection of O-Rings increases from 3,5 mm to 4 mm

• Alternative EPDM sealings
Results – OME Blending and aging

• Usage of 15 % and 30 % OME in two different DHOs
• Beide 15 % Blends unauffällig
• 1 Blend 30 % without change
• 2 Blend 30 % from red → green
Results – HVO Blending and deposit formation

Long term Combustion tests

Operational safety

efficiency

storage

stability
Looking forward to discussion...

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