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

25.09.2018, Nora Meeting, Newport

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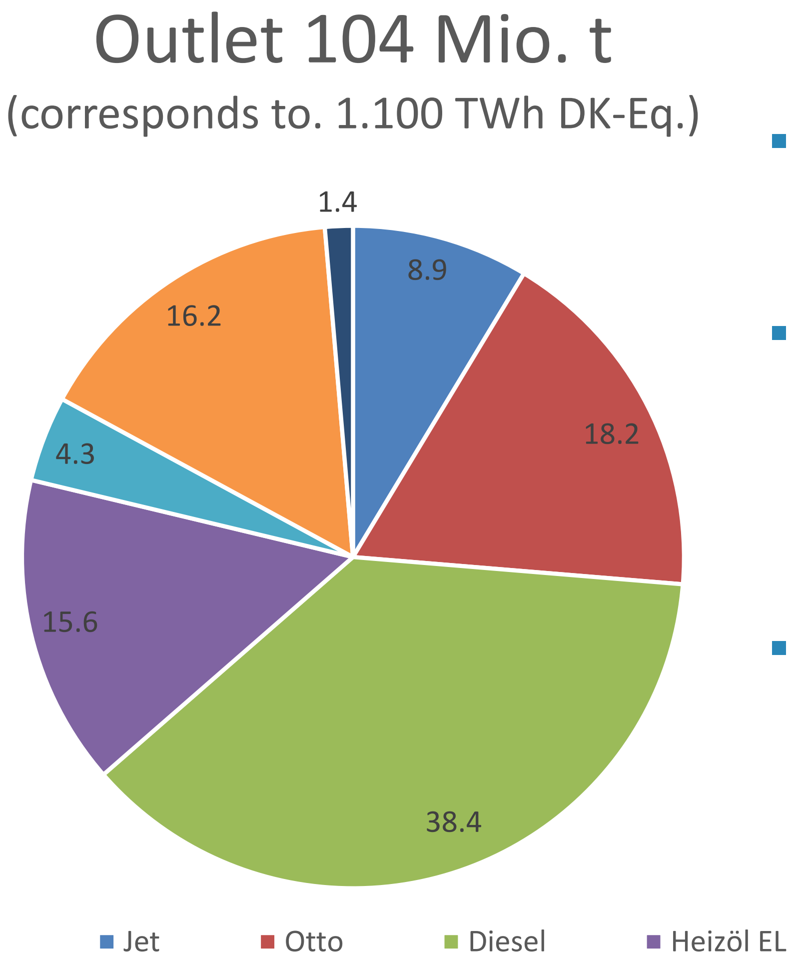
Market for Mineral oil products – example Germany 2016

- 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

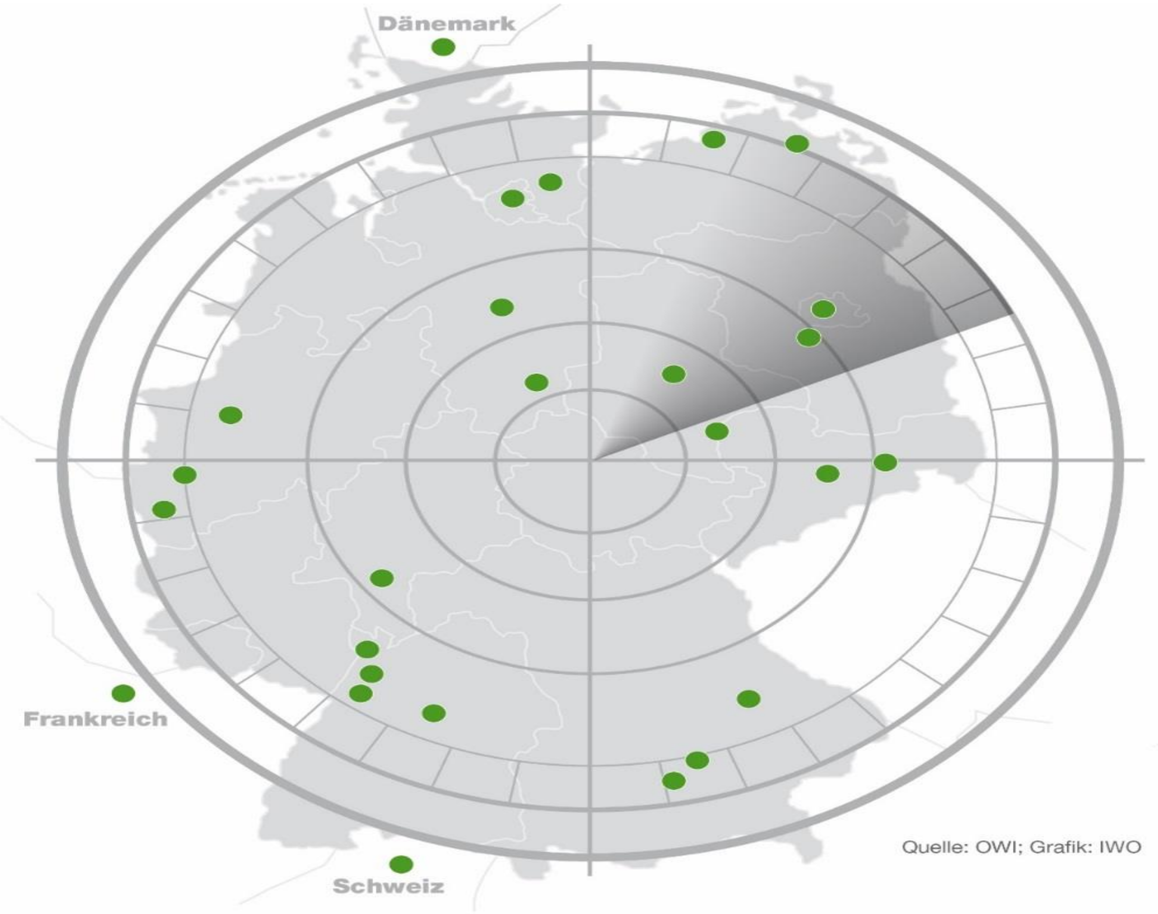
Source: Mineralölwirtschaftsverband

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

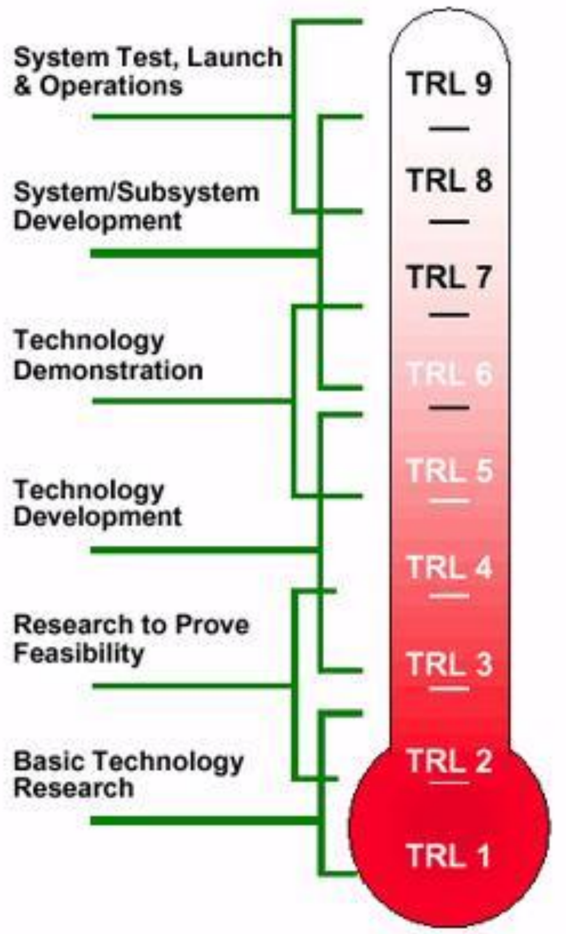
- Research projects which are currently in the state of a Pilot-, Demo- or Laboratory plant.

- A technology readiness level TRL of minimum 4 has to be already achieved

State of the art

- Realized plants
  - Shell / Quatar – 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 (Oxymetylenether) 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_2-neutral liquid „e-fuels“**
  - Diesel
  - Kerosene
  - Blending component to other liquid fuels

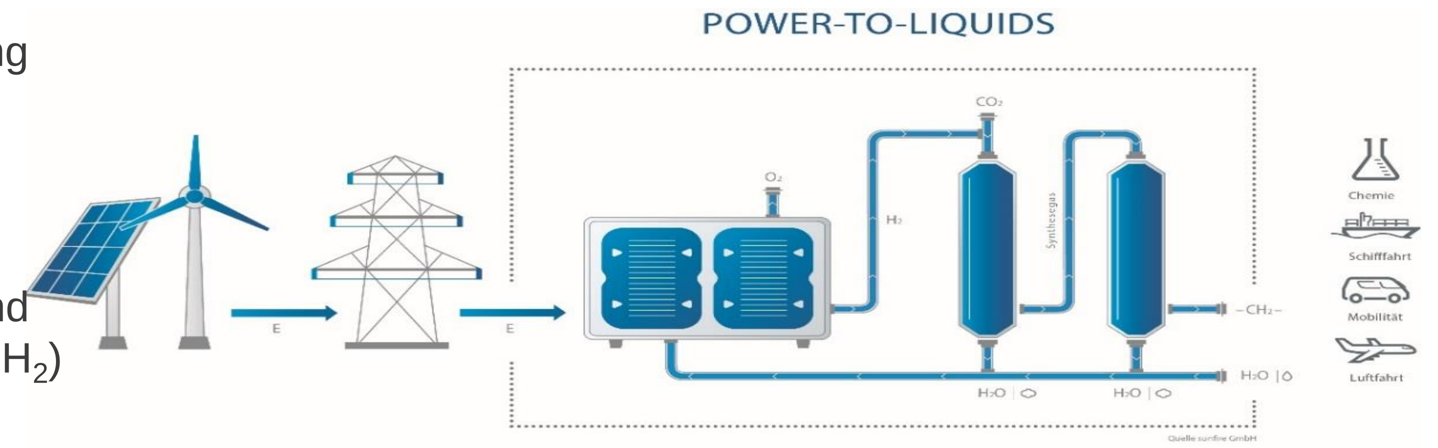
- **Input (regenerative):**
  - Electricity from wind- or solar
  - Water
  - CO_2 from atmosphere, flue gases or separation from Biogas plants

- **Bild: „PTL“-Pilotanlage zur Herstellung von synthetischen flüssigen Energieträgern aus Wasser, CO2 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 (H_2) aus Wasserdampf mittels erneuerbarem Strom



2. **Conversion:** Reverse Shift-Reaktion von Wasserstoff (H_2) und Kohlenstoffdioxid (CO_2) zu Synthesegas ($CO + H_2$) und Wasserdampf (H_2O)

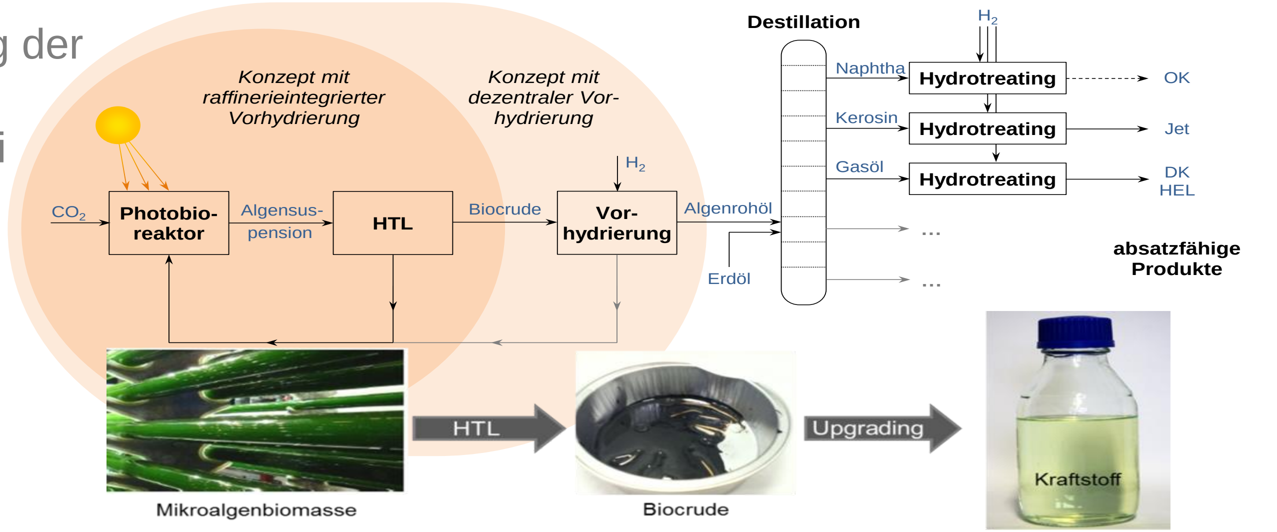
3. **Fischer-Tropsch-Synthesis:** Technisches Verfahren zur Umwandlung von $CO + H_2$ (Synthesegas) in flüssige Kohlenwasserstoffe („Blue Crude“) für die weitere Aufbereitung zu „e-fuels“

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 (H_2)

3. **Weiterverarbeitung in Raffinerieprozessen:**
   Einspeisung optimaler weise
   vor der Rohöldestillation



Projekt „Konversion von Mikroalgen zu Kraftstoffen bzw. Kraftstoffkomponenten“

- TU Bergakademie Freiberg, Institut für Energie-verfahrenstechnik und Chemieingenieurwesen;

- BTU Cottbus-Senftenberg, Fachgebiet Thermodynamik

- **TRL 3-6* (out of 1-9)** *Schätzung OWI
  - Biocrude aus Algen: 3-4*
  - Hydrierung von Biocrude: 4-6*
- **Project volume: 500 T€**
  public funding

„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 ofus 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

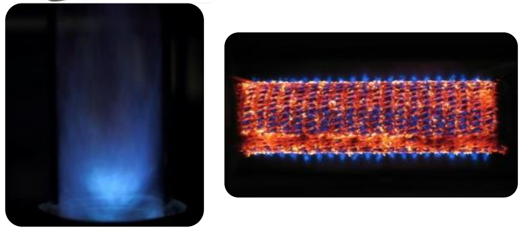
- Save use usage with existing infrastructure
- Downward compatibility with systems in the market
- „Drop-in-Quality“ with possible improvement of fuel quality
- Customer acceptance

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. ….

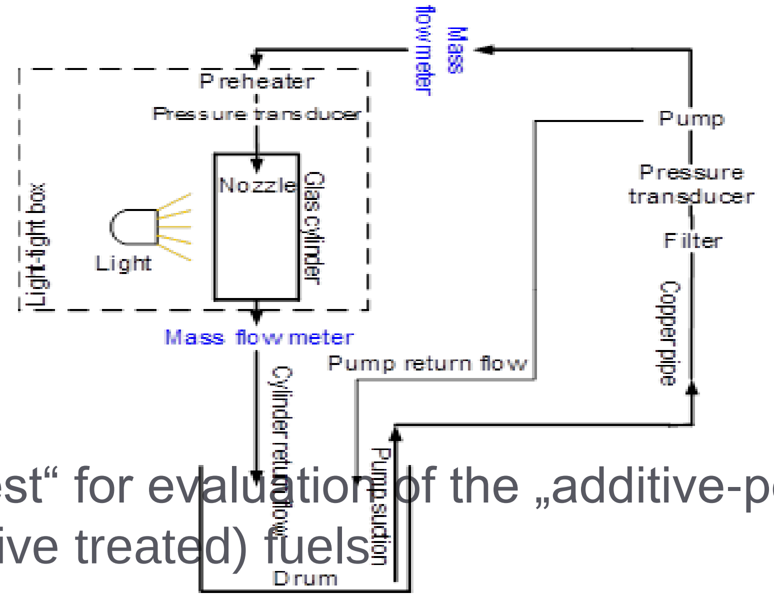
Testing of Fuel and Additive Packages
- task and approach

- **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.**

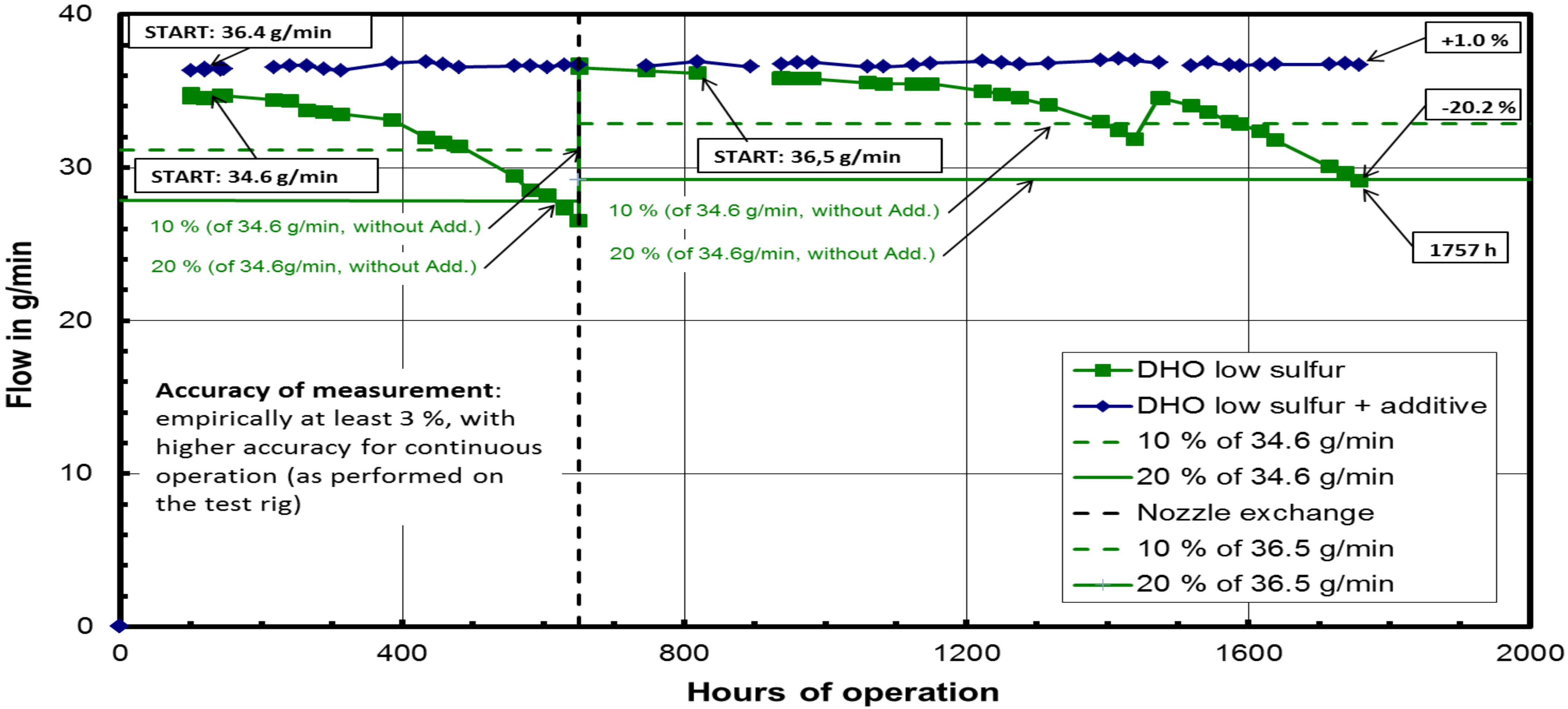
ATES Fuels test bench



- „Stress-test“ for evaluation of the „additive-performance “ ... ve 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

1000
Hours of
operation

with additive

380 Hours of operation

570 Hours of operation
(testing time
380-950h)

50 Hours of operation
(testing time
950-1000h)

1000
Betriebsstunden

without additive

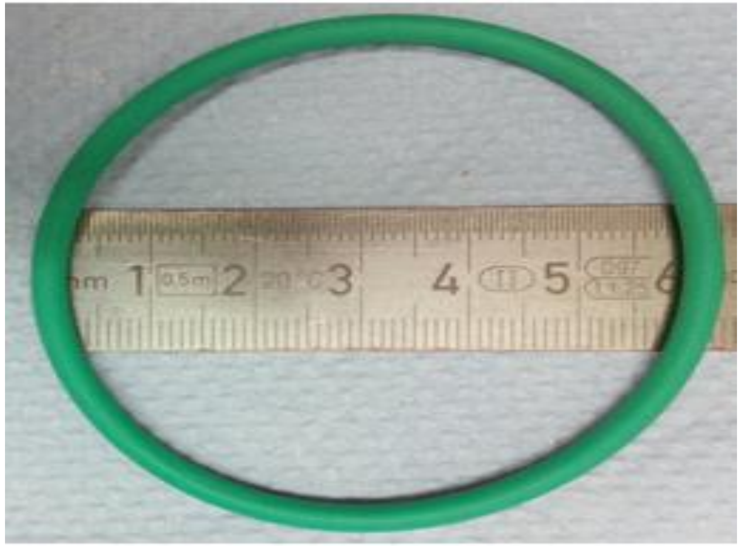
➔ **Additive prevented corrosion in two different heating oils**

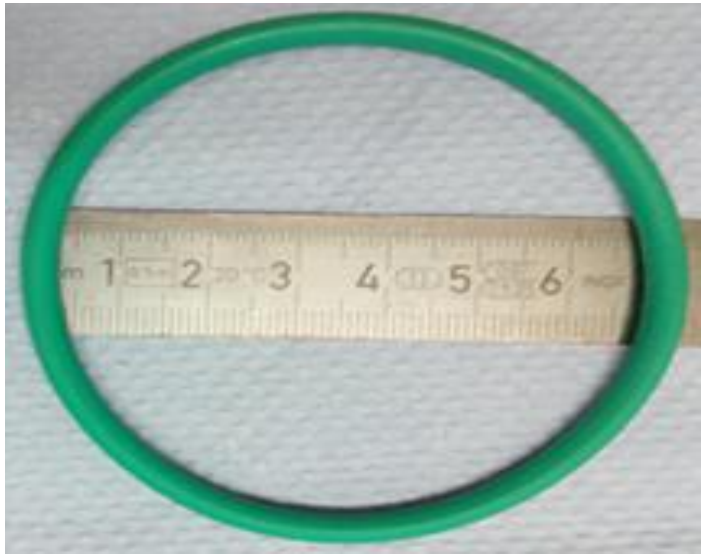
Results - examples

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

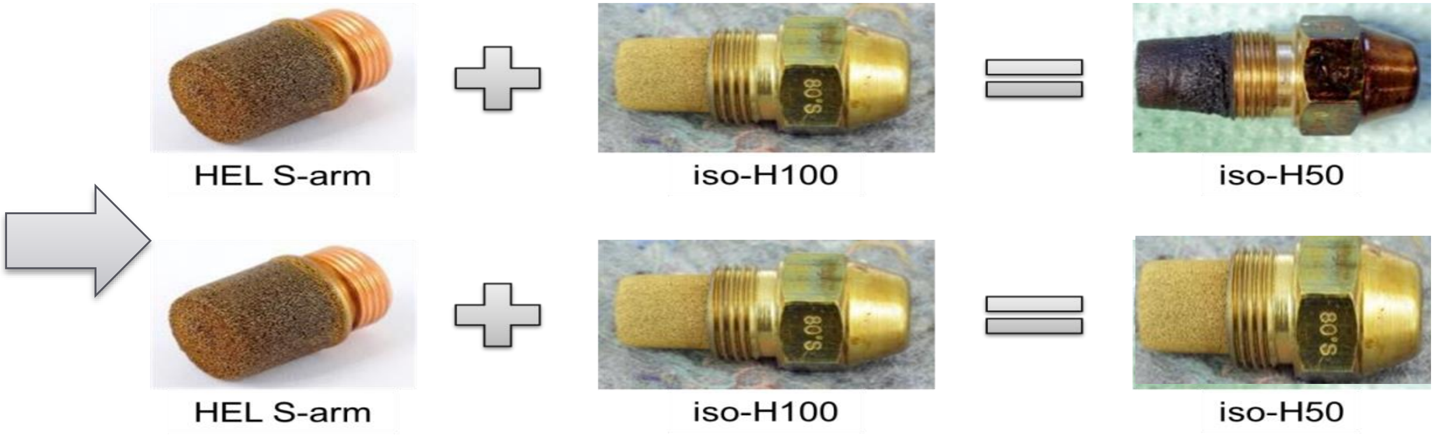
- Alternative EPDM sealings

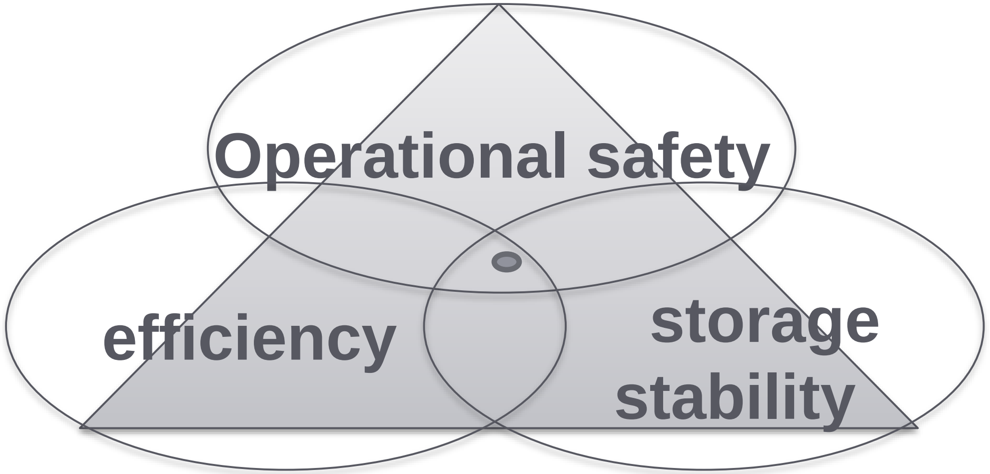
Results – OME Blending and aging

- 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





Looking forward to discussion…

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