FVV

Kraftstoffstudie

Zukünftige Kraftstoffe für Verbrennungsmotoren und Gasturbinen

Abschlussbericht

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ZUKÜNFTIGE KRAFTSTOFFE FÜR VERBRENNUNGSMOTOREN UND GASTURBINEN

EINE EXPERTISE FÜR DIE FORSCHUNGSVEREINIGUNG VERBRENNUNGSKRAFTMASCHINEN E.V. (FVV)

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Abschlussbericht

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Haftungsausschluss

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Zur Forschungsvereinigung für Verbrennungskraftmaschinen e.V. (FVV)

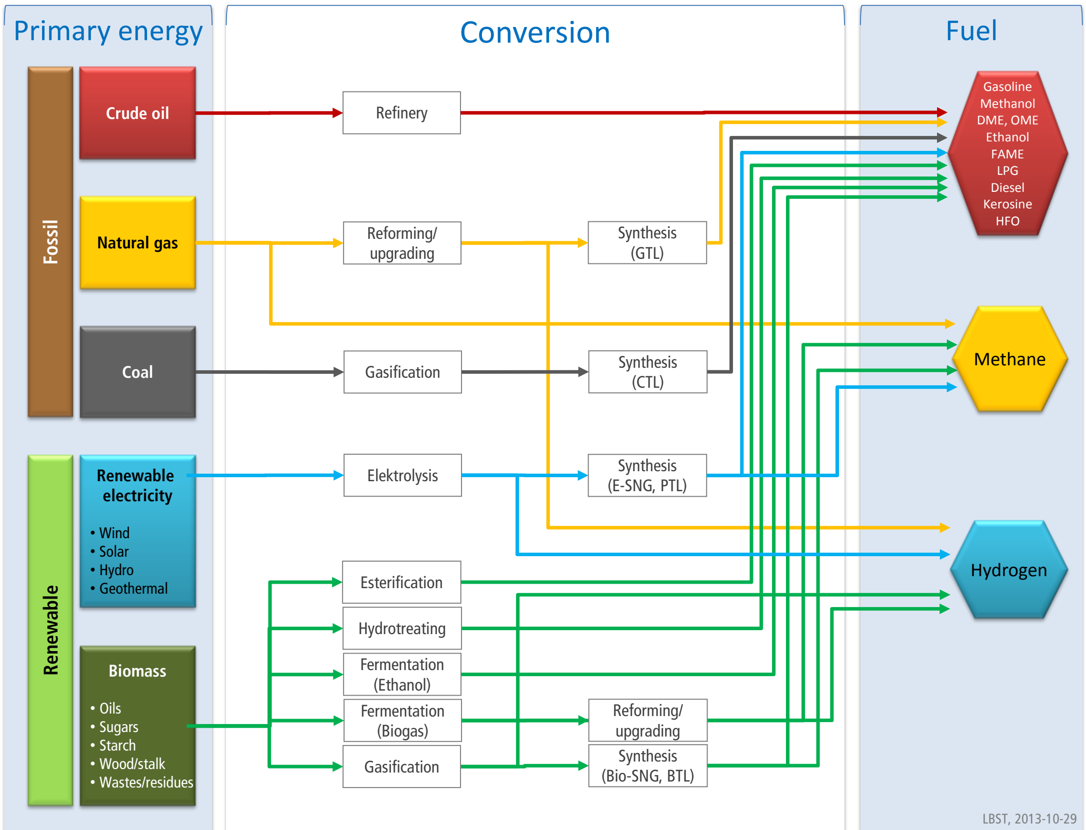
Die FVV wurde 1956 gegründet und hat sich zum weltweit einmaligen Netzwerk der Motoren- und Turbomaschinenforschung entwickelt. Sie treibt die gemeinsame, vorwettbewerbliche Forschung in der Branche voran und bringt Industrieexperten und Wissenschaftler an einen Tisch, um die Wirkungsgrade und Emissionswerte von Motoren und Turbinen kontinuierlich zu verbessern – zum Vorteil von Wirtschaft, Umwelt und Gesellschaft. Außerdem fördert sie den wissenschaftlichen Nachwuchs. Mitglieder sind kleine, mittlere und große Unternehmen der Branche: Automobilunternehmen, Motoren- und Turbinenhersteller sowie deren Zulieferer.

INHALT

EXECUTIVE SUMMARY

With a view to globally and locally changing energy landscapes members of the Forschungsvereinigung Verbrennungskraftmaschinen e.V. (FVV Research Association for Combustion Engines) seek to understand which fuels may become relevant in the foreseeable future in order to derive research and development needs for next generation combustion engines and turbines.

In a first step, a scoping exercise has been done for fuels that could be used in gas engines and turbines in the next decades. For this, relevant new fuels and fuel production pathways have been defined and characterised, including fossil fuels from conventional and unconventional sources and renewable fuels based on biomass and renewable power. The following diagram gives a schematic overview of fuel pathways.



Comprehensive analyses of both promising and exemplary fuels in order to cover the range of possible developments.

From the multitude of fuels, together with the accompanying FVV task force, a roaster of fuels were selected which may require further research and development when used in combustion engines or gas turbines. FVV is already very active on biofuels topics, thus, the fuel selection focussed on fuels that are complementary to the existing FVV research programme. The following 10 fuel pathways have been selected for more detailed analyses:

- GTL from natural gas
- HVO from algae
- E-gasoline/E-kerosine/E-diesel
- E-DME
- E-OME
- E-methanol
- CNG from shale gas
- E-methane
- LNG from natural gas
- CGH_2 via electrolysis of renewable power

For their use in combustion engines and turbines, the above fuel pathways have been comprehensively assessed with regard to

- environmental performance;
- market aspects;
- economics;
- availability and potentials; and
- infrastructure requirements.

The analyses cover a time horizon until 2020 with a perspective towards 2030. In the course of the study, three meetings were held with the FVV task force and one meeting with the FVV board.

Centrepieces for the detailed assessment of the ten pathways are analyses regarding emission limits, fuel costs (incl. production, transport, and distribution) as well as cumulative primary energy efforts, greenhouse gas emissions, and selected pollutant emissions 'well-to-tank'. Natural gas and crude-oil derived gasoline, kerosine, and diesel served as fossil fuel comparators. In addition, methanol and hydrogen derived from natural gas have been included as benchmarks in the economic and environmental assessments.

Key results from the fuel study are compiled below.

Through technology innovation, combustion engines and turbines must be prepared for a range of future fuels.

Plotting the ten selected fuels in a technical ‘fit for purpose’ matrix results in a mixed picture (see table). Just four out of the ten selected fuels are of ‘drop-in’ quality. Most of the fuels selected for detailed analyses differ significantly in their physical/chemical properties from the reference fuels established today. Especially with regard to energy density and handling, many fuel options only partially fit into current applications having evolved and undergone technical optimisation over decades.

Fuel	Cars	Duty vehicles	Ships	Aircrafts	Power / Stationary machines	Mobile machines
▪ Gas to liquids (GTL) ▪ Hydrotreated veg. oils (HVO) ▪ E-gasoline/E-kerosine/E-diesel ▪ Heavy fuel oil to middle distillates						
Dimethyl ether (DME)	Like LPG	Like LPG				
Oxy-methylene ether (OME)	Blend	Blend	Blend			
Methanol (MeOH)					Handling?	
Compressed natural gas (CNG)		Long distance				
Liquefied natural gas (LNG)	Dor-mancy	Dor-mancy?				Dor-mancy?
Hydrogen (CGH2)				LH2?	Existing fleet?	

Already in the past, there was not ‘the one’ fuel to power all possible stationary and mobile applications, not least because the availability of energy resources differs by world region. Considering the transformation processes underway in the energy landscapes worldwide, the number of different fuels may be expected to increase further also in the midterm future.

Combustion engines and turbines continue to take key roles in the future.

Combustion engines and turbines can address many of the upcoming challenges in meaningful ways that arise from changes in the energy system in general and specific applications therein, e.g. with regard to emission reductions.

For the further development and application of combustion engines and turbines, new future fuels bear both challenges and opportunities. Challenges arise from the often deviating fuel characteristics in terms of handling requirements and combustion behaviour and the higher market uncertainties in terms of potentials, relevance, and user acceptance. Opportunities lie in technology innovation to further foster a key role for engines and motors in future energy systems and applications, possibly even providing for a broader market perspective also in countries that today still lack energy supplies and uses.

Technology innovation in combustion engines and turbines also includes embedding them in new application contexts.

In the stationary sector, combustion engines and turbines allow for high operational flexibility. With that, they can become pillars in the transformation of the energy system towards high shares of fluctuating renewable energies. In mobile applications with high performance requirements, combustion engines and turbines operating with energy-rich liquid fuels will remain indispensable for the foreseeable future. For applications in the transportation sector, internal combustion engines can benefit from complementary technologies, especially with regard to electric drivetrains. This does not only apply to cars, but also e.g. to ships or trains on non-electrified tracks.

Alternative fuels and uses having been discussed in the past but not adopted yet should be re-assessed in the light of new applications and requirements.

Examples include

- Efficient neat fuels, especially also gaseous fuels in connection with hybridisation.
- Fuel admixtures for improving combustion processes, e.g. oxygen-rich compounds or hydrogen.
- Methanol in industrial applications for stationary energy storage.
- Wankel engines in conjunction with hybridisation or with otherwise challenging combustibles like hydrogen.

Novel fuels are by no means fast-selling items, but are driven by changing framework conditions.

Out of the ten fuels selected for the detailed analyses, in the short to medium term only GTL and LNG from natural gas are cost competitive. The full costs ('well-to-tank') of the renewable fuels assessed are significantly higher than those of the respective fossil reference fuels within the time horizon until 2020. Fossil and renewable costs will prospectively converge through cost reductions with renewable energies, increasing use efficiency, and increasing costs of fossil energy sources.

In a long term sustainable energy system, renewable electricity is a main pillar because of its technical potentials worldwide.

Against the backdrop of growing availability of renewable electricity in the long run, there is an increasingly important role to take for the direct use of electricity and electricity-based fuels, across all energy sectors and uses. Particularly 'power-to-gas' pathways are likely to play a more prominent role in the future – E-H_2 and synthetic methane (E-CH_4)

derived from renewable power are favourable with regard to emissions, potential overall volume, and energy yield per area.

The synthesis of electrolytic hydrogen with CO_2 or CO including subsequent further processing to fuels with higher compound complexity is possible and has e.g. been demonstrated in the case of E-methanol in Iceland. It has to be noted, though, that, electricity-based fuels with increasing molecular complexity generally demand higher process and energy efforts for their production, thus driving costs with respect to the primary energy consumed and necessary hardware to be invested.

Future research and development efforts in combustion engines and gas turbines should consider a broad range of target fuels (neat and blends).

With an increasing number of fuel options being rolled out or still in the R&D pipeline today, singling out a 'winner fuel' obviously is a risky bet.

The study authors recommend to FVV to consider the following fuel pathways in their plans for a short to medium term research programme for future combustion engines and gas turbines:

- E-H_2 (neat; admixed to methane or diesel; as an input in oil refineries)
- E-OME (admixture to diesel)
- E-kerosine (complementary option to efficiency improvements and the use of biomass)
- Algae (validation in demos)

Corresponding research is recommended because of the potentials of these fuel pathways to solve upcoming challenges and because of the differing characteristics to fuels commonly used in combustion engines and gas turbines today.

In a project meeting with the accompanying FVV industry task force, a number of further topics have been identified for the development of an FVV research programme:

- Methane (CNG)
  - Methane slip with dual-fuel (methane/diesel) engines
  - Efficiency potentials from CNG hybridisation
- Options, potentials, and limits for the admixture of
  - OME to diesel
  - Hydrogen in diesel combustion processes
  - Hydrogen to CNG (HCNG, 'Hythane')
- Dimethyl ether (DME) as a neat fuel
- Neat fuel hydrogen in stationary gas turbines and gas engines

Research needs in the use of novel fuels – be it neat or blended – in optimised combustion engines and gas turbines are evident, especially with regard to novel system contexts (e.g. hybridisation), application contexts (e.g. fluctuating renewable supply, assured power provision), and targets (efficiency, emissions, costs). The resulting broad research and development portfolio will provide an excellent basis for future combustion engines and gas turbines which are robust, efficient, low in emission, and economic.

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