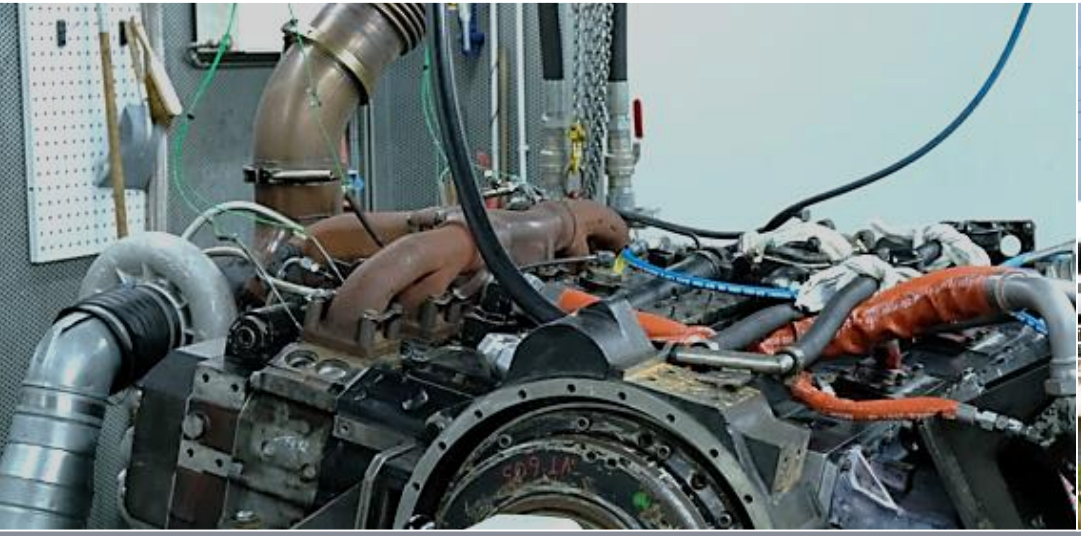
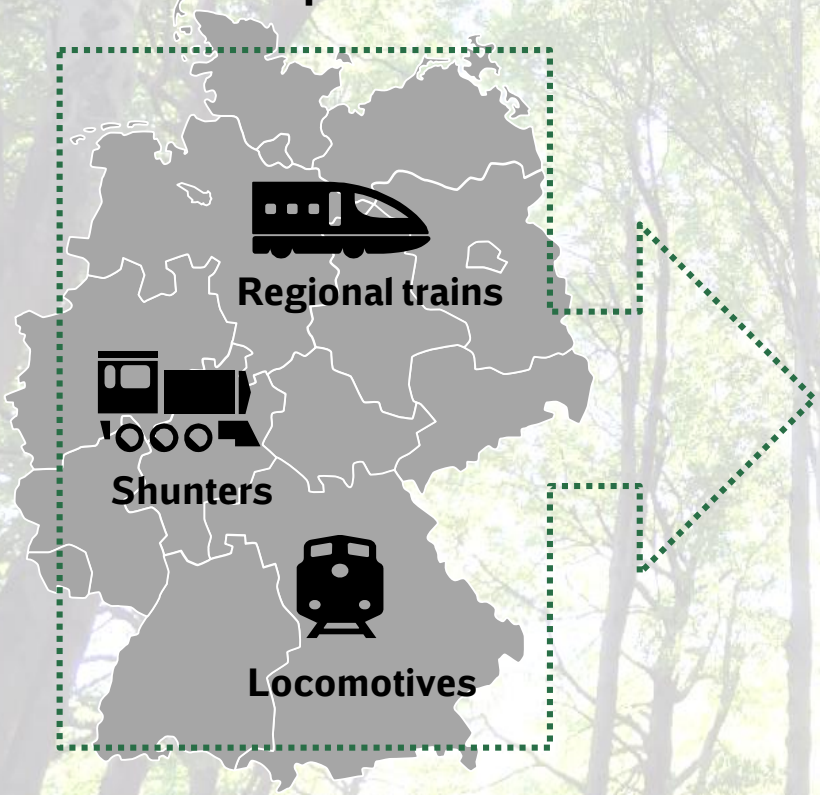


Testing of alternative fuels with DB's advanced TrainLab

Deutsche Bahn AG | TTL1 | Mario Lichtenberg | Zurich | 13.11.2019

Alternatives to the fossil diesel are needed in order to achieve the climate targets **where electrification is no option.**

More than 2000 diesel vehicles in operation at DB



Fuel cell

Fuel cell trains running on **"green" hydrogen** can be used on routes entirely without catenary

Battery

Use of traction batteries to **bridge short sections** with no catenary

Alternative fuels

Substitution of fossil fuels by biogenic or synthetic alternatives mainly for long heavy duty services

Three main technologies to replace fossil diesel.

Diesel

Fuel cell

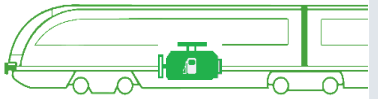
- **Hydrogen** as an energy source can be **carried or produced on board**
- Hydrogen is converted to water vapour using (atmospheric) oxygen with the released energy being available as electric power
- **Batteries are required** for load peaks and energy recovery

Battery

- Battery storage systems provide traction energy
- **Use/recovery of braking energy**
- Hybridisation of established vehicle concepts (combustion-engine and electric traction)

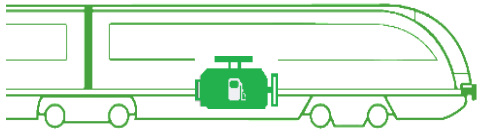
Alternative fuels

- Substitution of fossil fuels by **biogenic or synthetic alternatives**
- Direct combustion in conventional engines allows the continued **use** of diesel vehicles with **minimal adaptation**



Alternative fuels as an **ideal** complement **for** transport of **heavy loads and challenging driving profiles**.

Development status:



- Biogenic and synthetic fuels available in **limited quantities**
- Lack of raw materials and production capacity for widespread use
- **If demand rises** use of synthetic fuels is **conceivable from mid-2020s**
- Use in **rail** transport **not tested yet**

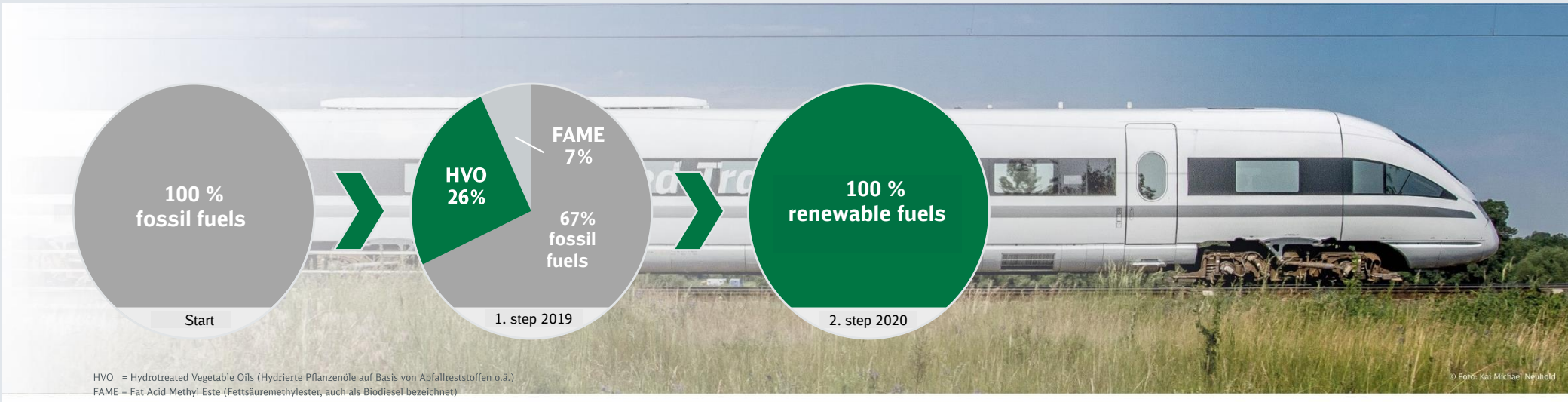
Advantages

- Continued operation of diesel fleets **without expensive upgrades**
- **Solution** for areas of application in which battery/fuel cell technology is not an alternative
- Alternative fuels have the potential to be **CO_2-neutral** depending on production process
- **Migration** of tank infrastructure relatively **simple and inexpensive**

Disadvantages

- **Local emissions** from combustion process
- Production **capacity** for renewable fuels **must be set up**
- Synthesis process is **very energy-intensive**
- Profitable fleet application difficult at the moment due to **high price**

Roadmap: DB has **started testing** of alternative fuels **with the advanced TrainLab** by August this year.

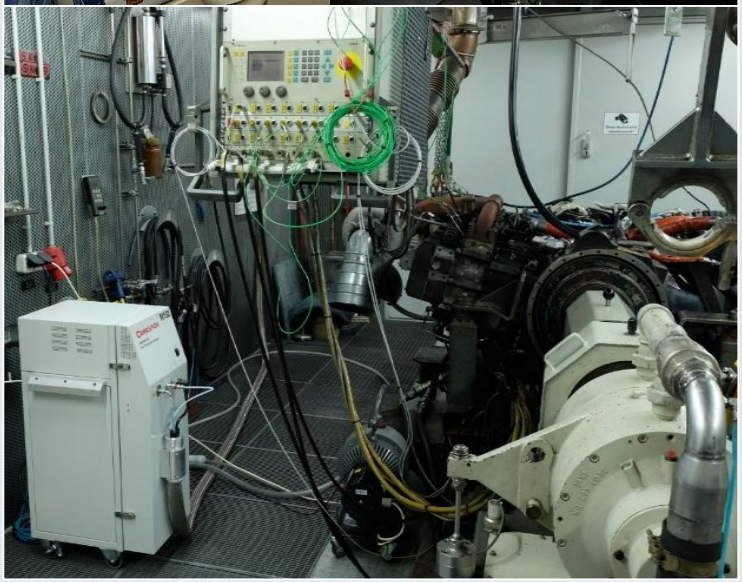


Alternative fuels for more sustainability

DB's advanced **TrainLab promotes the strategy** to phase-out fossil fuels and contributes the ambitious **climate goals** of Deutsche Bahn.

- Fuel **trials with advanced TrainLab** with up to **33% renewable** fuels without changes to the diesel engine
- Engine **bench tests** with **up to 100% renewable** fuels
- Trails with **100% renewable** fuel using the advanced **TrainLab** commence in **2020**
- **DB Energy** is **partner** for fuel **supply** and fueling stations

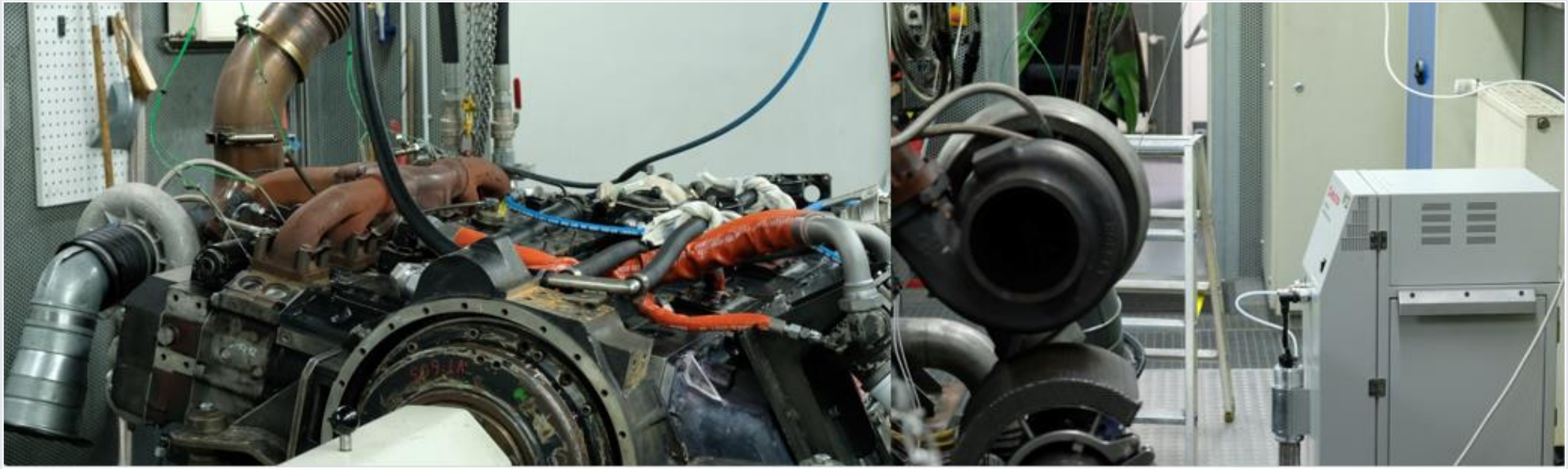
Detailed engine bench tests for proving **compatibility of alternative fuels** with a **railway diesel engine.**



Background	▪ Fossil diesel (max. 7% FAME) meets EN 590 and engines are optimised for EN 590 certified fuels only ▪ Renewable fuels act chemically similar but have some different properties (e.g. density) and meet EN 590 (R33) or EN 15490 (HVO)
Proof of compatibility and pre-analysis of emissions	▪ Bench test comparison of fossil diesel, a blend with 33% renewable BlueDiesel and a 100 % renewable HVO diesel ▪ Check engine compatibility, performance and consumption by using standard testing cycle ▪ Measure all relevant engine parameters and exhaust emissions ▪ For CO2-reduction a detailed environmental balance will be prepared (“Well-to-Wheel”)

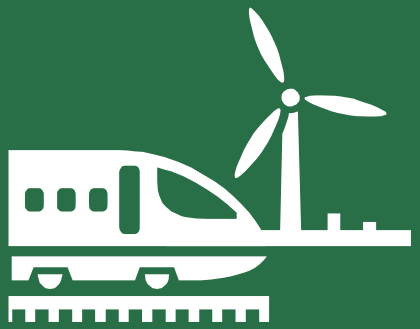
Results: A one week bench test cycle shows that **combability with unmodified engine** for both alternative fuels **is given.**

- **No performance degradation** with both alternative fuels detected
- **+6% fuel consumption with HVO** by using standard testing cycle
- **Still equal local CO2 emissions** but reduced CO2 footprint due to production process but
- **No significant changes in limited exhaust emissions** compared to fossil diesel
- To utilise the full emission reduction potential of alternative fuels, **modifications to the engine controller** are **advisable**



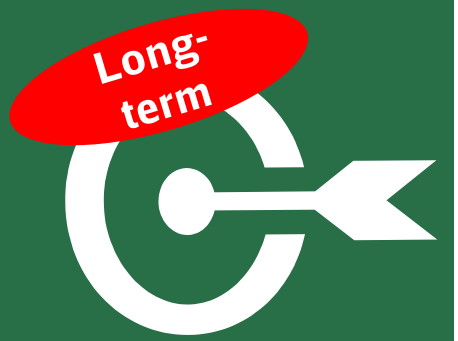
Further applications requires defined **framework conditions.**

Further applications



- **Gain long-term experience** e.g. maintenance of gaskets
- Field tests for **small fleets** e.g. in regional services
- Complete change to renewable fuels currently not possible due to **restricted amounts**

Framework conditions to enable broader usage



- **Cooperation with** Karlsruher Institut of Technology **(KIT) in "reFuels" initiative:** develop a strategy for broader usage and research with automotive and oil companies
- Take account to **the political and economic interests** - today **synthetic fuels** are only available for high prices and in small amounts
- Setting up **fuelling stations**

Thank you for your attention!
Any questions?

Source: Internet

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The *advanced TrainLab* will cover the considerable need for testing new technology for use in vehicles

Research and partner models

- Testing environment for partnerships with universities and research institutions
- Operational collaboration as part of pilots

Testing of on-board components

- ETCS components of various manufacturers
- Component testing from automotive sector (e.g. sensor technology)
- Basic technology required for automatic train operation

Automatic train operation

- Automatic train operation GoA level 2-4
- Part of LivingLab

Sensor technology and geolocation

- Supplier selection
- Recording condition of vehicles and infrastructure
- Track-specific geolocation

Testing of driving assistance systems

- Smart traffic management
- Simulation and train control systems
- Saving of traction power

Real environmental influences

- Aerodynamic measurements
- Acoustic measurements
- Interdisciplinary trials and tests

Supplier qualification

- Qualification of manufacturers from e.g. the automotive sector
- Provisioning as test and trial vehicle for technology partners

Data communication

- Improvement of vehicle IT and software
- Mobile broadband radio data communication (5G)
- Testing of new radio technology and components

Homologation

- Execution of type tests
- Proof of compliance