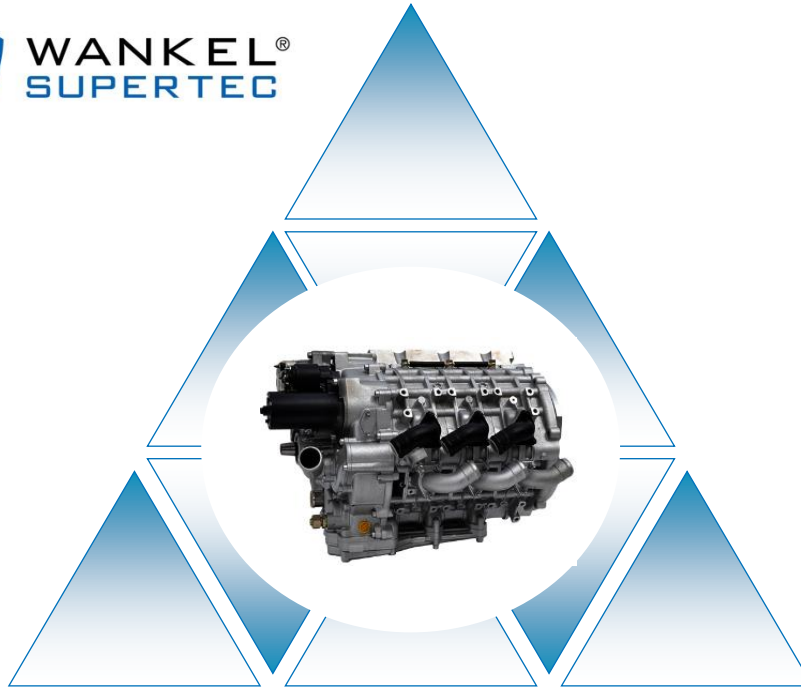




Verwendung nachhaltiger Kraftstoffe für den Betrieb von Wankelmotoren
-
Utilization of Sustainable Fuels for Powering Rotary Engines



Existing fields of business:

- Light Aircraft & Drones
- Power Generation
- Marine

New field of business:

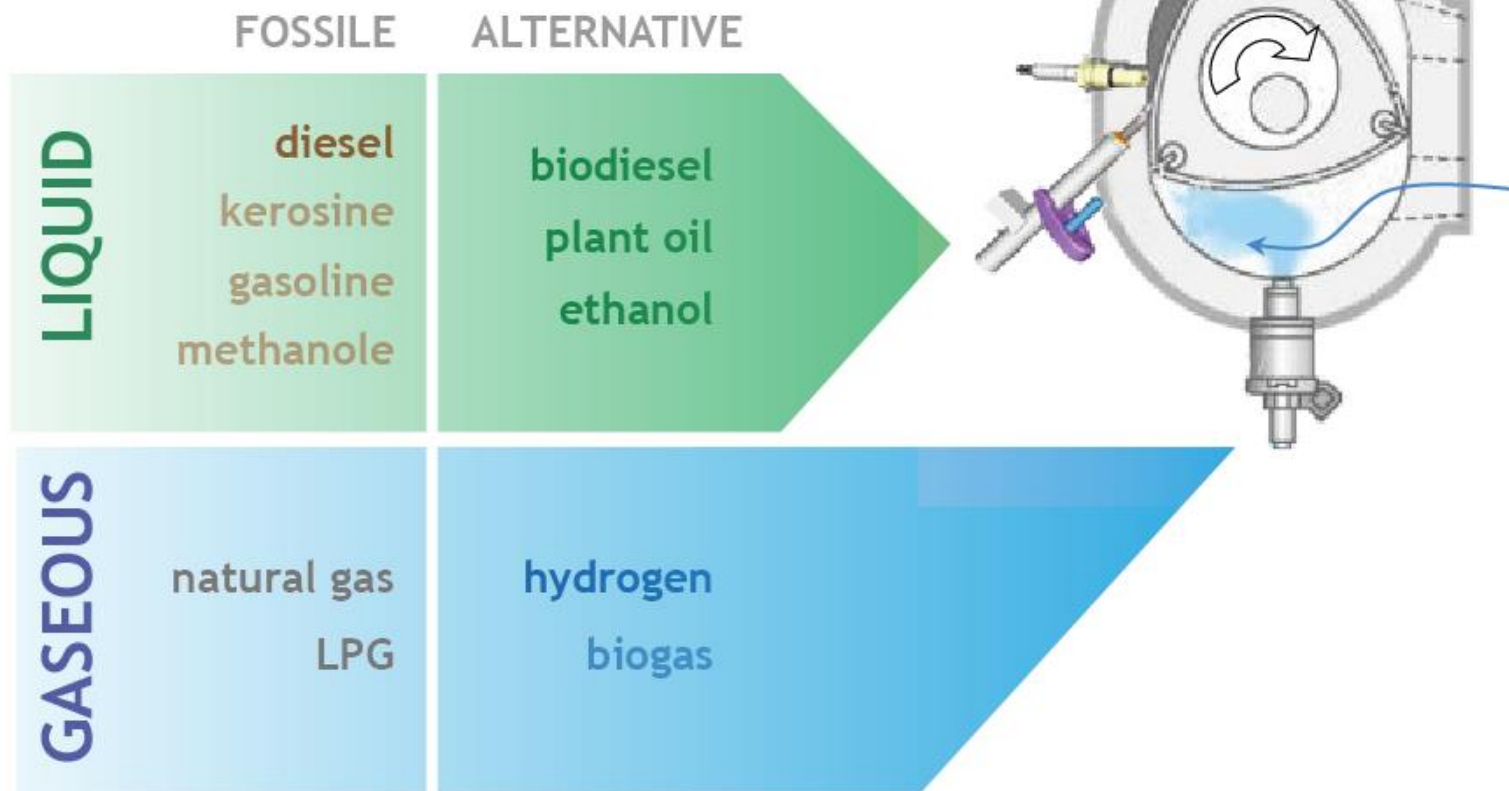
- Hydrogen engines & dual-fuel range extenders for electric vehicles

2018: Turnover EUR 290,000; result negative
2019: Turnover EUR 985.000, result positive
Present headcount: 10, therefrom 5 engineers in R&D

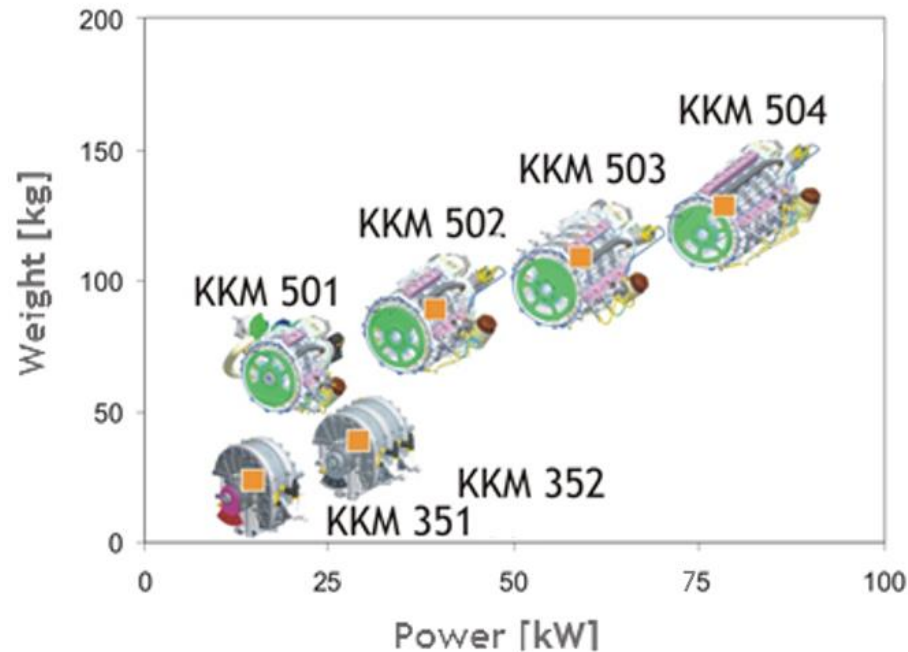
- Wankel SuperTec GmbH („WST“) is specialized in the development of advanced rotary engines
 - Established some 20 years ago out of Cottbus Technical University, it is technology leader in its field
 - WST is the only company producing rotary engines that can run on Diesel fuel
 - Combines attractive, scalable existing business with high growth potential in clean mobility
 - New business model and successful restructuring after change of management in mid-2018:
- ⇒ **From research institute towards industrial company**

Special Features of WST Rotary Engines

- Multi-fuel Capabilities



Weight to power ratios of
WST's KKM 350 and KKM 500 series
fueled with hydrogen



All WST-engines feature

- high reliability
- excellent power to weight ratio
- low vibrations
- multi-fuel capability
- modular design
- WST's own ECU (hardware and software)
- patented sealing and lubrication designs
- increased efficiency and reduced exhaust through proprietary fuel injection and ignition technology

Specifications KKM502 & 503 with Diesel fuel



- KKM502d: maximum permanent power 83 kW for 1 hour at 5,500 RPM
- KKM503d: maximum permanent power 117 kW for 1 hour bei 5,500 RPM

Consumption of Diesel fuel approximately 300g per kWh

Weights without cooling:

	Total weight	Base engine	Starter 12V/2,5 kW	Generator 12/45A	Turbo charger	Exhaust pipe	Air intake pipe	Fuel system	Blowby	Wiring harness /ECU
	Kg	kg	Kg	kg	kg	Kg	kg	kg	kg	kg
KKM 501D & GT 2252	73,2	51,5	5,2	2,2	8,5	0,65	0,5	1,3	0,7	2,6
KKM 502D & GT3071R	98,6	69,3	5,2	2,2	12,8	1,5	1	2	1	3,6
KKM 503D & GTX3576R	127,7	87,1	5,2	2,2	20	2,2	1,5	3	1,3	5,2
KKM 504D & 2x GT3071R	154,4	104,9	5,2	2,2	25,6	3	2	3,7	1,6	6,2

Existing Fields of Business: Light, Small and Low-vibration, High-power Diesel Engines

Wherever excellent power-to-weight ratio, low vibrations and operation with Diesel fuel are important - examples:



Light aircraft & Drones

Equator Aircraft's hybrid amphibious airplane, powered by WST KKM 352 Diesel engine (picture courtesy of Equator Airplane Ltd.)

Power generation equipment II

Deutsche Bahn, Germany's railway company, has since 2015 equipped a total of 60 Diesel lokomotives with our auxiliary power systems, using WST KKM 351 Diesel engine



Power generation equipment I

compact and lightweight 30 kVA power generation unit, equipped with KKM 501 Diesel engine

Marine

small & light C-Fury RIB powered by WST KKM 352 Diesel engine (picture courtesy C-Fury Ltd.)



New Field of Business: Dual-fuel Range Extenders for Electric Vehicles

Main Features

- With rotary engines at the core
- Driven by hydrogen
- But also able to run on conventional fuels

Main Advantages

Over pure battery cars:

- Allows reduction of battery size & costs
- No rare materials needed
- No dependency on charging stations, no long charging stops, no use of conventional electricity

Over fuel cell cars:

- Does not depend on supply of hydrogen
- No rare materials needed
- Easy & cheap to produce and repair
- long life-time

Over conventional engines & range extenders:

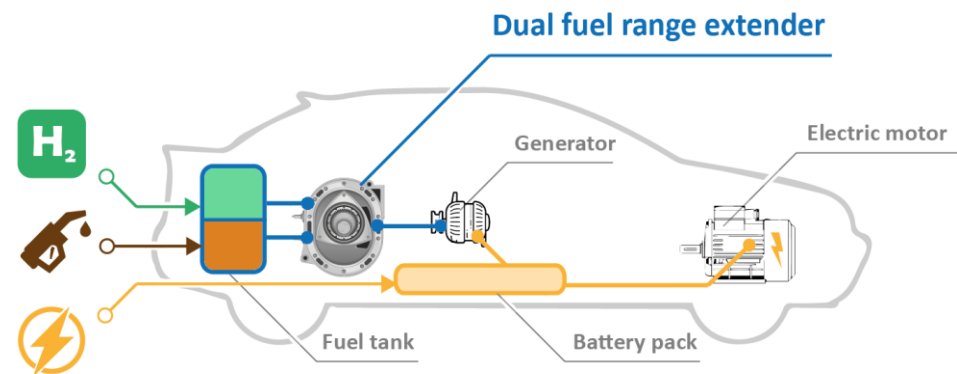
- Pollution-free if run on hydrogen
- Small, light, lowvibrations

disruptive
technology
for
sustainable
mobility



Above: WST range extender prototype

One car - 3 sources of power



Present Stage of Development

H2-Engine

- Development started late 2018
- Ca. 9 months for installation of H2-supply at engine test stand
- First successful test of KKM501H2 in Sept. 2019

Present stage:

- ⇒ Stable operation
- ⇒ 24 kW of mechanical power
- ⇒ Fuel consumption 100g H2/kWh
- ⇒ Efficiency >30%

Further development work:

- ⇒ Optimization of gas injection & ignition
- ⇒ Optimization of lubrication
- ⇒ Longterm testing
- ⇒ Durability of surface materials
- ⇒ Exhaust levels and after treatment
- ⇒ Dual-fuel ability



Above: WST test stand with h2 engine

Subsidiary for EASA-Certified Aviation Engines

- Rotary engines particularly advantageous for aviation, due to light weight and low vibrations
 - Multi-fuel ability of our engines allows CO2-neutral aviation if using hydrogen or biofuels such as Ethanol
 - Use of diesel allows utilization in environments where for reasons of safety and logistics no other fuel is available
- ⇒ ca. 50% of customer inquiries are for use in aviation (drones and light aircraft)

Challenge: So far, engines not EASA-certified

- Requires respective internal organization,
- Continued engine development, and
- Complex certification procedures

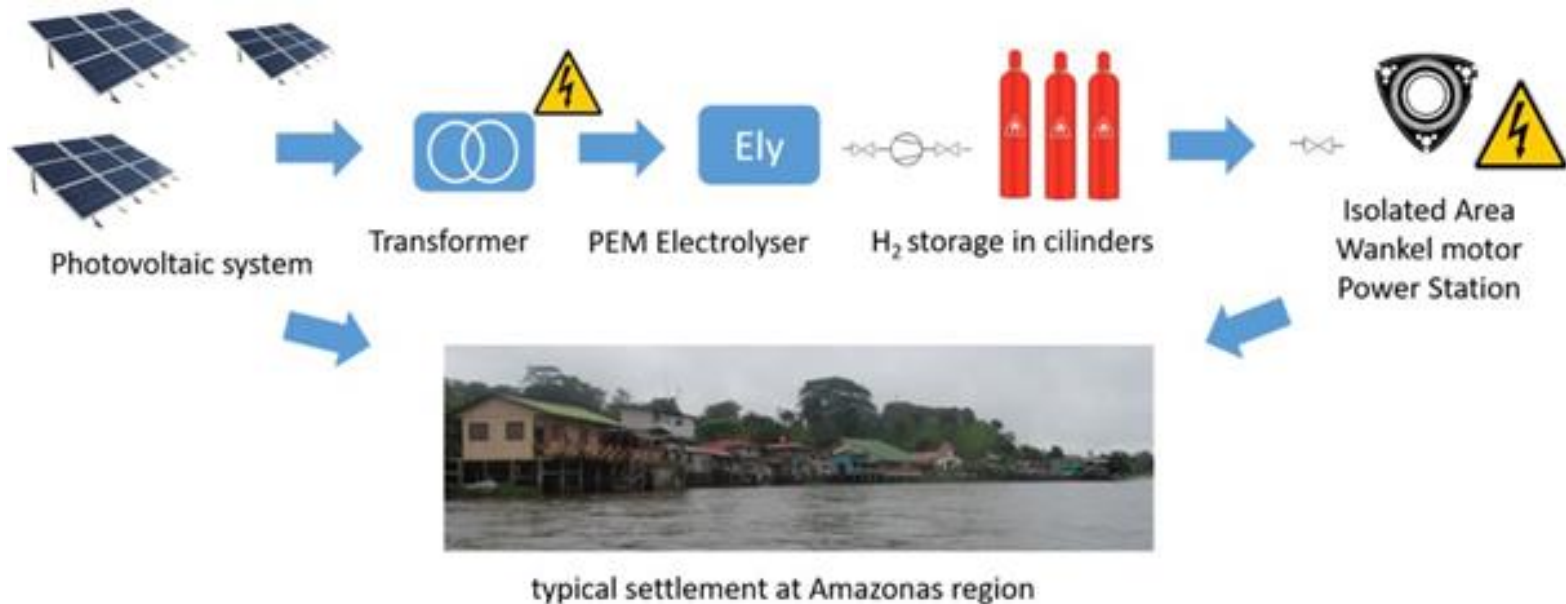


WST-subsiary for development and production of EASA-certified aviation engines agreed as joint venture with leading aviation technology expert

- EASA-accredited independent external expert for aircraft development
- Formerly
 - responsible for EASA-certification of jet turbines at RollsRoyce
 - Development engineer for flight testing at Airbus

⇒ Subsidiary will work exclusively on development and production of EASA-certified aviation engines

Stationary Power Generation for Isolated Areas



- For replacement of diesel-generators so far used in remote locations, like indigenous settlements in the Amazon rainforest
- Business rational:
higher investment costs offset by savings in fuel and fuel logistics
- Energy storage as hydrogen selected over batteries because cheaper for bigger energy quantities
- WST H₂-combustion engine selected for electricity generation from hydrogen, because:
 - Low requirements regarding hydrogen purity
 - Repairable
 - Insensitive to environmental impacts (temperature, humidity, etc.)
 - Cheap to produce at bigger numbers



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