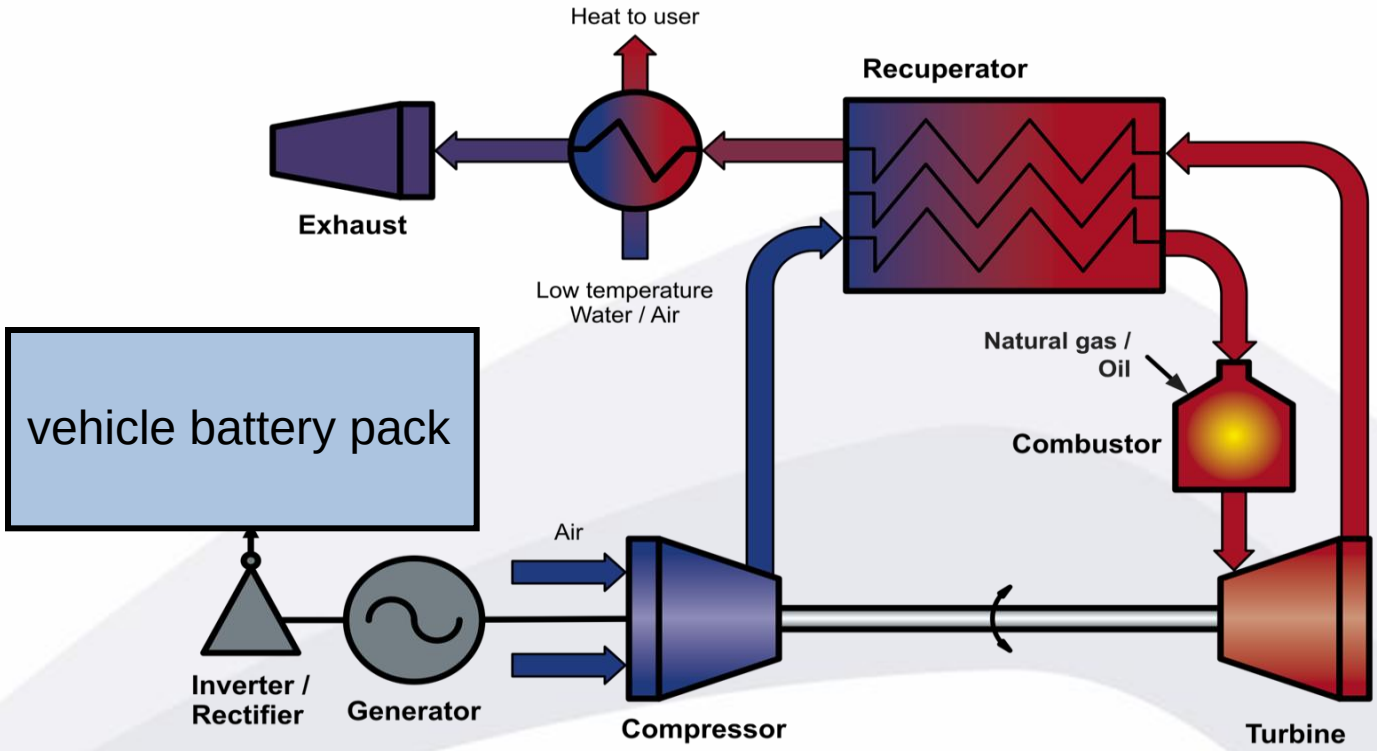
MTT Range Extender for EV's and PHEV's

Micro turbine based superior Range Extender technology

MTT range extender system design

MTT's RE system is based on the use of COTS automotive turbocharger components which result in:

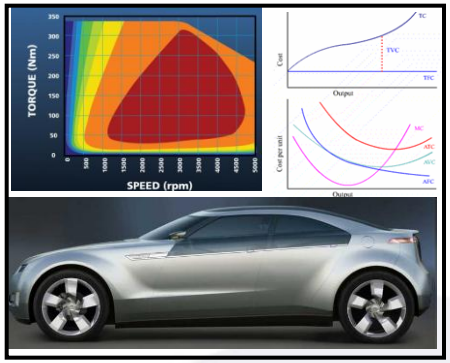
- high performance and efficiency
- reliability and cost effectiveness



TNO eRange control for optimized efficiency

E-horizon

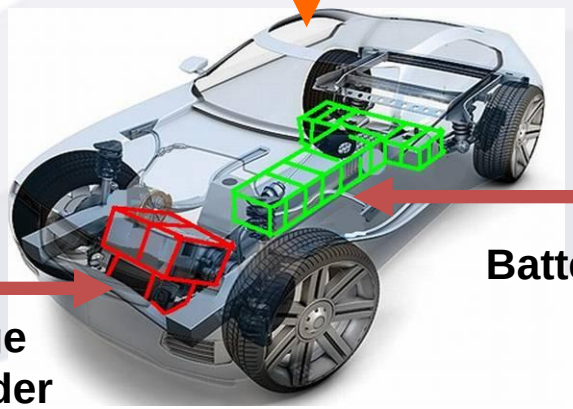
Vehicle model



Accurate range prediction & powertrain control

Vehicle CAN

Ambient conditions



Battery

Range Extender

MTT micro gas turbine as range extender

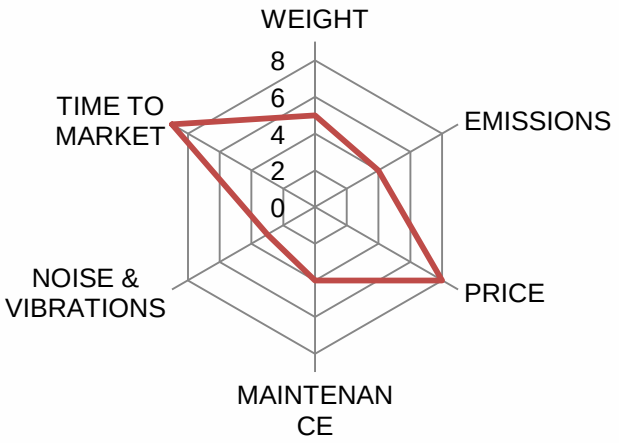
The MTT micro gas turbine is very suitable to be used as Range Extender. It offers the following advantages over other types of small combustion engines:

- **Small system with high power density**. A small size minimizes the sacrifice of cabin space.
- **Lower weight**. A lower weight improves overall vehicle efficiency which increases range realizes lower costs / km.
- **Lower noise level, less vibrations**. Low noise and vibration (NHV) levels improve the drivers comfort and reduce the impact on the environment (e.g. less noisy for pedestrians).
- **Clean combustion and low emissions**. Required to meet (future) regulations and to reduce emission levels (CO2, NOx).
- **Fewer components.** Results in a higher reliability and lower maintenance costs.
- **Suitable for flexible fuels and clean fuels.** Compressed natural gas (CNG) and LPG can be used as a gas turbine is multi fuel.
- **Potential low cost price.** Essential for making electric driving reality.

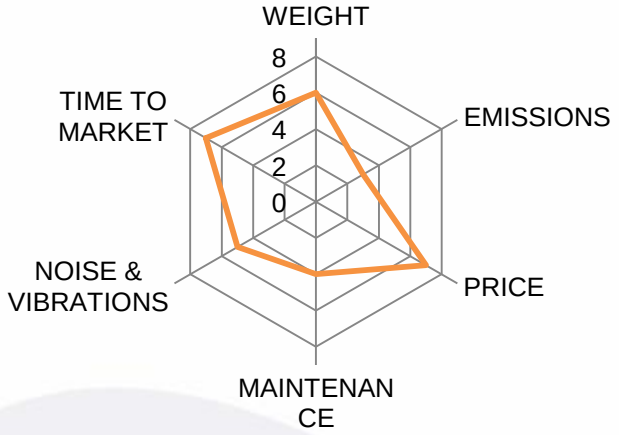
Combined with **eRange** control, it adds intelligence to the RE system, thus allowing an even smaller, lighter and less powerful Range Extender to be used. This will further improve overall vehicle efficiency.

Range extender technologies overview

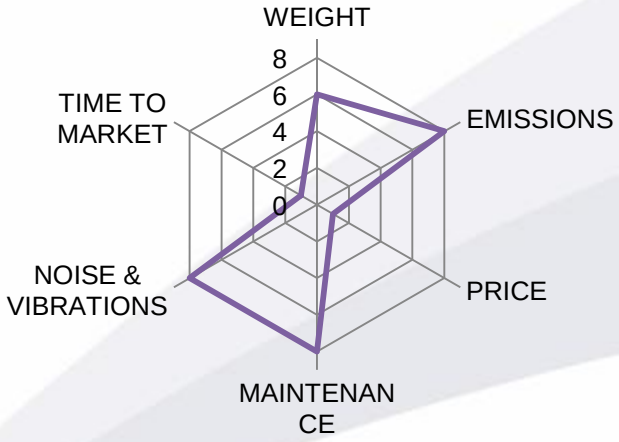
PISTON ENGINE



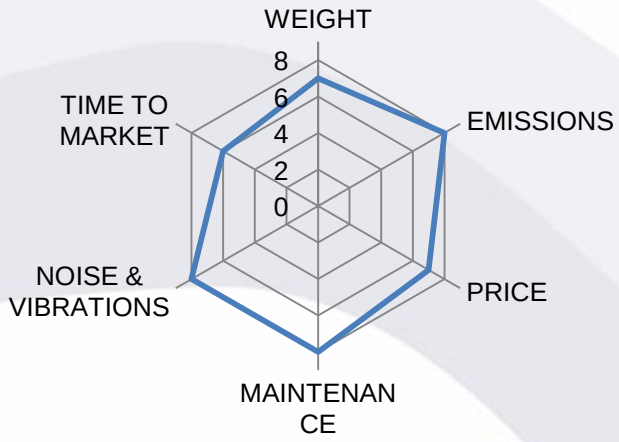
WANKEL ENGINE



FUELL CELL



MTT MICRO TURBINE



MTT turbine RE advantages

The weight impact on energy consumption of an EV is estimated to be around 3,4MJ per 100 km for every 10 kg extra. With current energy prices this means that every **10 kg** of additional weight costs **€ 580,-** during the lifetime of the EV or PHEV.

	Lotus 3cyl	AVL Wankel	ZETEC 4 cyl	Opel 3cyl	MTT turbine RE
Dry weight (kg)	**56** engine excl all fluids and fitting	**80** engine excl all fluids and fitting	**130** engine excl all fluids and fitting	**95** engine excl all fluids and fitting	**46** turbine, recuperator, combustor, generator, power electronics
Operational weight (kg)	**86** inc. oil, coolant, radiator, generator etc	**115** inc. oil, coolant, radiator, generator etc	**170** inc. oil, coolant, radiator, generator etc	**125** inc. oil, coolant, radiator, generator etc	**50** inc. oil & lubrication pump
Higher weight (kg)	**36**	**65**	**120**	**75**	**0**
Lifetime cost increase	**€ 2.087,10**	**€ 3.768,38**	**€ 6.957,00**	**€ 4.348,13**	**€ 0,00**

Calculation based on fuel and energy price levels in NL Feb 2010 : 1kWhe = €0.21 ; 1 Liter of RON 95 gasoline ~ €1.50

*** Source: Extra brandstof verbruik door gebruik van accessoires (TNO Rapport, 2005)**

MTT Range Extender system proposition

MTT Range Extender:

• Fuel:	Various options: gasoline / diesel / CNG / LPG
• Electrical power output:	~ 12kW
• Operating mode:	Intelligent controlled using power need and -consumption, ambient and vehicle parameters (eRange Control)
• Weight:	50kg (all in)
• Operating lifetime:	± 2.000 hrs*, being more than sufficient for EV and PHEV as 90% of the trips the RE is not used

*** Allows a relative cheap recuperator to be used.**

Overview of MTT and risk sharing partners

KNOWLEGE PARTNERS

INDUSTRIAL PARTNERS

Micro Turbine Technology bv:

- **Formed in 2003, located in Eindhoven, the Netherlands**
- **14 FTE (academic level), growing to 16 - 18 FTE in 2010**
  Including partners: ± 35 engineers on development programs
- **Strong partnerships *(participate at risk sharing bases)***
- **Independent assessment by KEMA (October 2009) shows that MTT's technical objectives are feasible**

Business proposal

- **Purchase of field trial units:**
  - Setting up a field trial
- **Exclusivity agreement**:
  - For specific geographical market
  - For specific fuel type
  - For agreed period / first series
- **Technology purchase / licensing**:
  - Use of MTT technology in other applications
  - Marketing of MTT RE technology outside Europe
- **Development / engineering contract**

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