Adapting Waste Heat Recovery Technologies for Low Carbon Off-Highway Vehicles

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Introduction and Objectives

Waste Heat Recovery (WHR) technologies aim at recovering part of the otherwise wasted heat in the exhaust of a combustion engine and convert it to useful power, resulting in lower fuel consumption and pollutant emissions. The project's consortium consisting of Brunel University, Entropea Labs and Mahle Powertrain have jointly optimised ORC technologies for other applications in the past. Experience gained in the design and manufacturing of the components for Organic Rankine Cycle WHR systems for large displacement diesel engines is applied to increase the Off-Highway Vehicle (OHV) diesel engine fuel economy by 10% or higher. The project is funded by Innovate UK and is running between June 2015 and May 2017. The proposed technology is modular, non-invasive and reversible, enabling it to be scaled across the range of new engine production irrespective of manufacturer while also being retrofittable to the large number of OHV engines already in service. Moreover, the technology and expertise has the potential to be further exploited by adapting it and scaling it to other transport and stationery power generation applications. The specific objectives of the project are:

1. ORC Model Development for ORC WHR applications
2. Engine Simulation Development
3. ORC WHR Component Development
4. ORC WHR system performance demonstration and validation On-Engine
5. Validate retrofit capability in preparation for On-Vehicle demonstration

Motivation and Potential Impact

Given that the Off-highway vehicle (OHV) sector accounts for approximately a 15% of all UK surface transportation emissions, the expected impact from the realization of this project on non-invasive, reversible, Organic Rankine Cycle Waste Heat Recovery (ORC WHR) is:

1. Retrofitability and scalability of ORC WHR technology
2. Lower risk component design with advanced and tried methods being used
3. >10% fuel efficiency increase may be achieved which compares well with competing technologies
4. £1 billion (€1.4 billion) in fuel savings for Off-Highway Vehicle (OHV) fleet operators in the UK alone
5. Enable OEMs to meet future pollution reduction legislation requirements

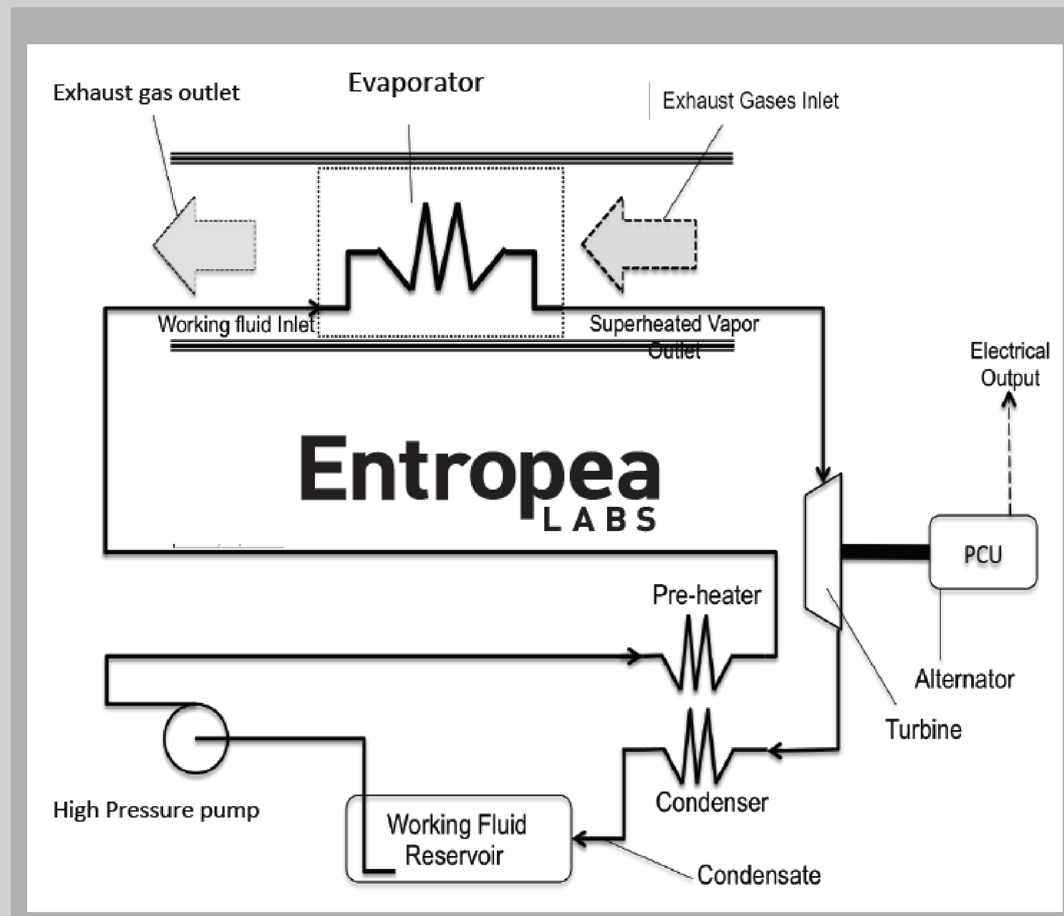

Figure 1: The Organic Rankine Cycle

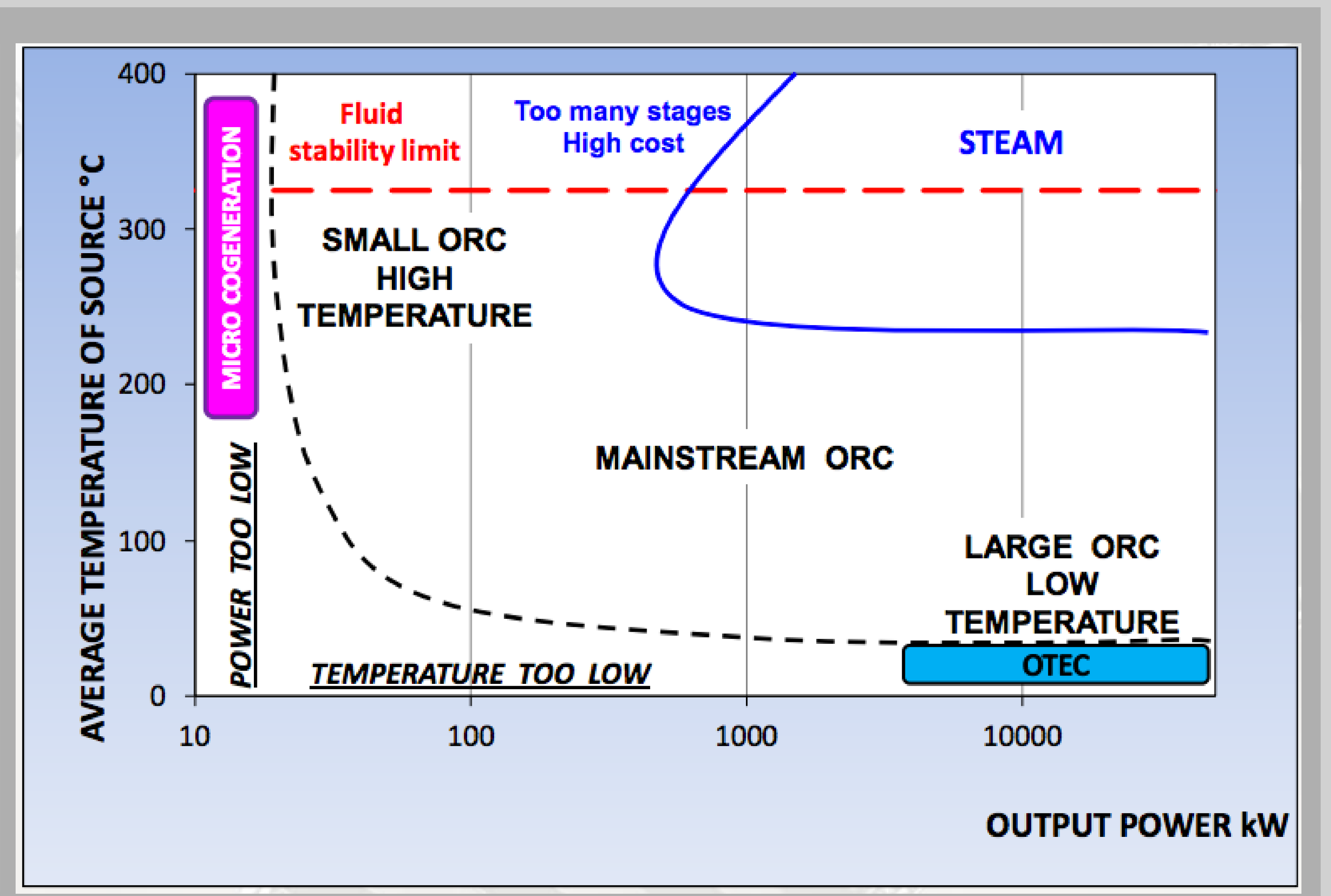

Figure 2: ORC Operating regime

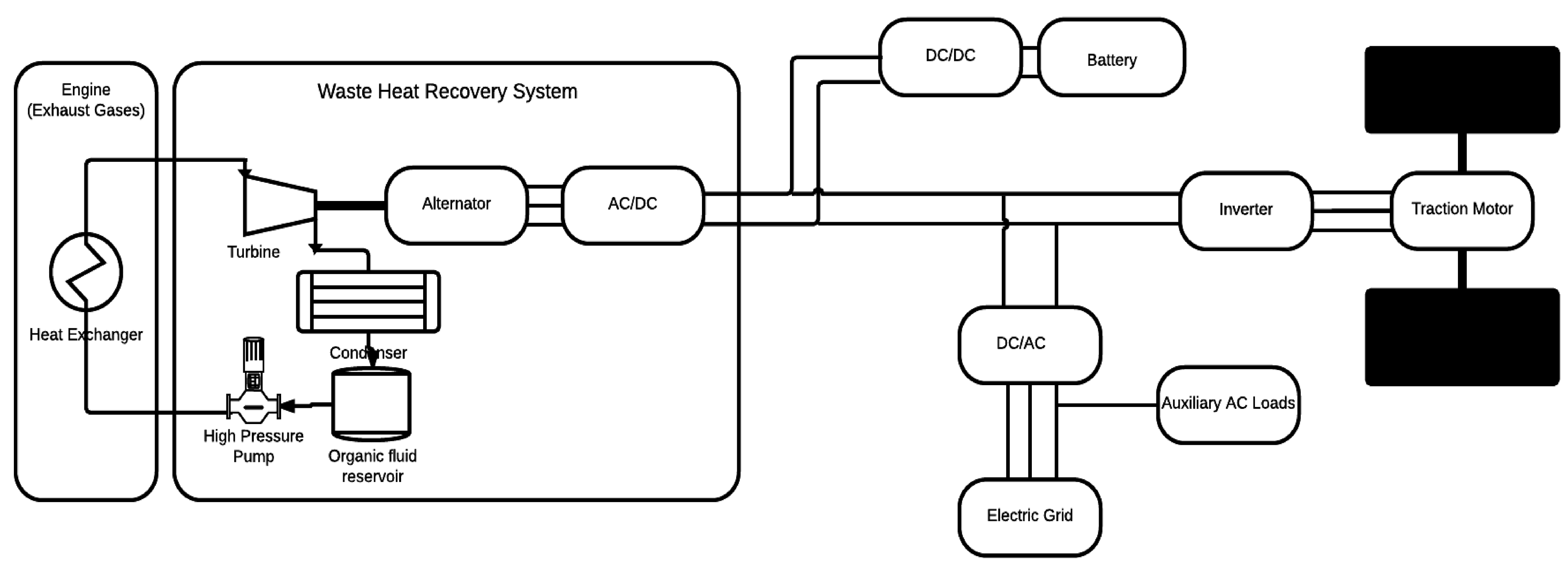

Figure 3: The ORC and Power Conversion Unit (PCU) architecture

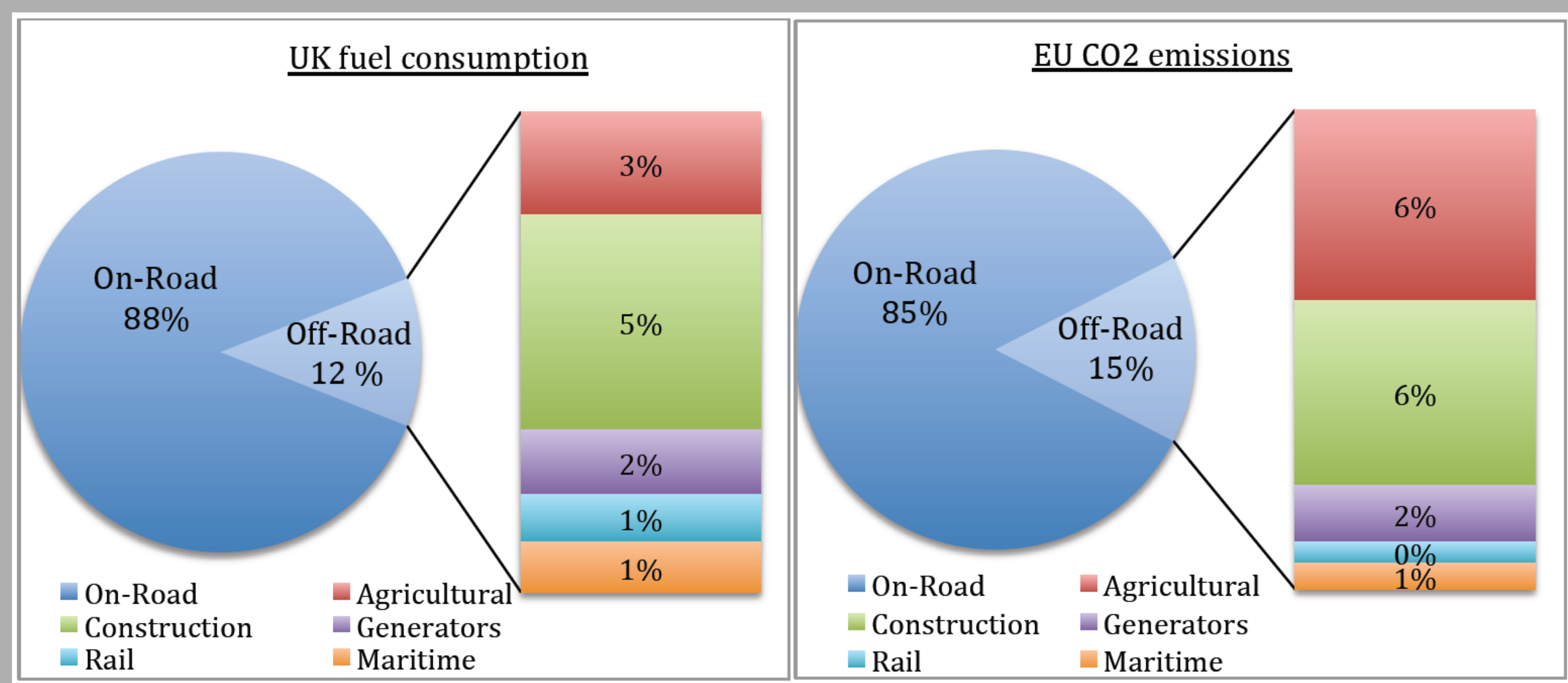

Figure 4: Fuel consumption breakdown in the UK (left) and EU (right) by transportation mode

Working Principles

The Rankine Cycle is a well-known thermodynamic cycle (shown in Fig.1) for which in an actual system the following steps are followed:

1. Pump pressurises fluid
2. The Evaporator extracts thermal energy from the exhaust gas
3. Superheated vapour drives the turbine
4. Electric generator converts mechanical turbine work into electricity
5. Discharged vapour after the turbine is condensed
6. Condensate is pressurised by the pump to re-start the thermodynamic cycle.

Rankine cycle technology using an organic fluid (instead of steam) becomes advantageous when the available heat source can provide low temperature heat (90 – 400 °C) and when the power requirement is calls for a low-medium range provision (50kW to 3MW) as the cost (fewer units) and reliability (lower operating pressure and temperature) requirements are lowered with ORC (Fig.2)

Utilisation of ORC-generated Electrical Power

1. Additional propulsion (hybridisation of the vehicle)
2. Auxiliary power (cranes, concrete mixers etc)
3. Battery charging
4. Energy feeding back to the grid

(Fig.3)

Results and Future Expectations

The consortium is working towards a 10% or higher increase in fuel efficiency and CO2 emission improvement by implementing In-house codes and methodologies to deliver high-efficiency ORC components. The UK construction and agricultural sector could see a £1 billion drop in fuel costs. The increased savings would further grow the 50,000 strong UK work-force in the mobile machinery sector and increase the £200 million it spends annually on R&D. OHVs in the construction and agricultural sector currently represent 15% of all transport-related CO2 emissions (not including air-traffic) in the EU (Fig.4)[1]. The increase in fuel efficiency associated with retrofitting OHVs with ORC-WHR technologies would help the EU and the UK to achieve its 2050 emissions target.

[1] ARCADIS, RPA, "Study in view of the revision of directives 97/68/EC on non-road mobile machinery (NRMM)", December 2010

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