WHR PROJECT

WASTE HEAT RECOVERY PROJECT

PROJECT DETAILS

Cluster: Energy from Biomass
Knowledge provider: Queen's University Belfast (PI Professor Roy Douglas)
Industrial Partners: B9 Organic Energy International Ltd, Thermtech (Workspace), AgriAD – Biogas/ Biogas engines, Northern Ireland Water, McCulla Transport, Belfast City Council (Associate member).
Total project costs: £216,956 over 36 months from June 2014 to May 2017.

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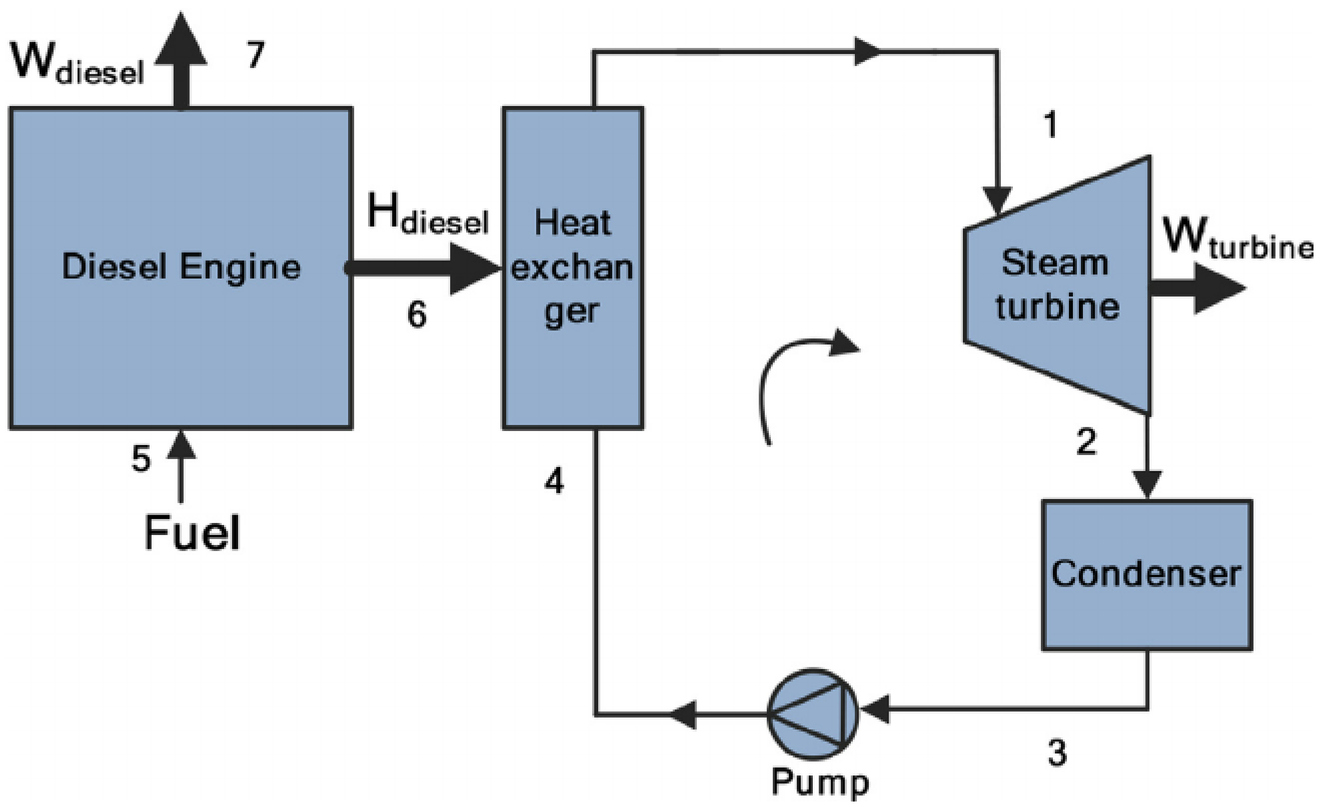
PROJECT BACKGROUND

Internal combustion engines convert the energy in diesel or petrol fuel into mechanical power. However typically they are only around 30% efficient (or 45% for diesel), with much of the energy being converted into heat that normally goes to waste in the exhaust or via the coolant. The desire to improve the efficiency of internal combustion engines in order to minimise carbon emissions has renewed interest in waste heat recovery (WHR) – using the heat produced to drive a generator to make electricity.
Devices based on the organic Rankine cycle (ORC) are potentially of use in the recovery of low-grade heat such as waste heat from internal combustion engines. Numerous variations in practical circuits are proposed but the principle is illustrated in the diagram below (H – heat; W – work).



The Rankine cycle (right) is implemented as a closed loop in which the working fluid is chosen to fit the particular needs of the installation. The steam turbine (top right) can be generalised as the 'expander' stage that extracts mechanical energy from the high pressure working fluid.

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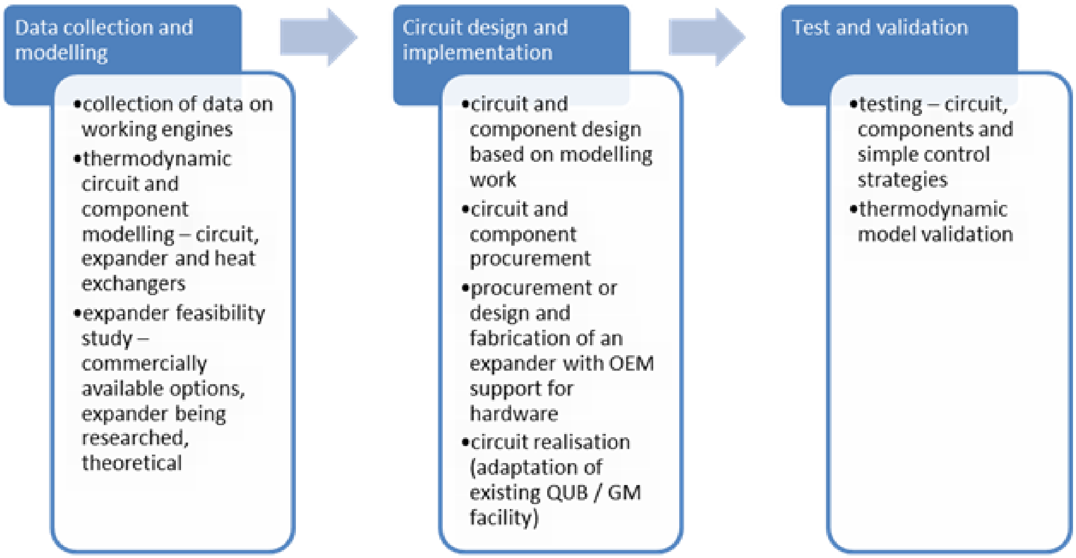
PROJECT OUTPUTS

Project work consisted of a series of stages to establish the way in which ORC methods could be used in practice, essentially using a model to design the circuit and then testing it on a real facility to validate the model. The project stages are shown in the flow diagram below.



Previous work had suggested that the efficiency of recovery would be greater if the cycle operated with super-critical expander inlet conditions (above fluid critical point in pressure and temperature). Super-critical ORC cycle operation presents specific technical challenges compared to subcritical. QUB had already done work in this area and made significance advances in the two main or key areas of technical challenge, expander and heat exchangers. Project stages made use of this knowledge as explained above.

The existing QUB system – using methods licenced from GM – was successfully modified to the new design and used for tests to validate the model [TBC].

An important consideration in designing an efficient circuit for internal combustion engines is that the engine exhaust and coolant each carry a proportion of waste heat typically at different temperatures. At a steady light load approximately 21% of total fuel energy is rejected to the exhaust as heat and 42% to the coolant. At sustained high loads this changes to approximately 44% exhaust and 18% coolant heat rejection. Thus, if an engine operates at high load for longer and more frequent periods of time the available exhaust energy will be high. Conversely if light load is dominant then the available coolant energy will be high. A vehicle engine typically has a diverse duty cycle although trucks undertaking long periods of motorway driving are an exception.

Because of this and because early considerations showed that the added weight and space taken up by a WHR unit in a commercial vehicle were unlikely to be economically justified, modelling work was undertaken on stationary engines. In applications such as power generation, these typically run at fixed loads and considerations of foot print are less exacting than in vehicles.

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IMPACT OF CASE FUNDING

The PI's prior work had established the basic parameters of WHR from engines, largely aimed at mobile engines, although the analysis also applied to stationary ones. It can be considered to have been at TRL 1-2 at that stage. By the end of the project it had advanced to TRL 4 (validation in a laboratory environment). Whilst potential external investors would be given comfort on the technology by the feasibility study, it is recognised that further work would have to be done to show adequate return on investment, specifically to:

i. double the efficiency of WHR over the levels shown in the test;
ii. reduce the total cost per kWh of the WHR device.

One participant concluded that whereas (i) appears feasible with what is known from the modelling in the project, (ii) might be difficult.
The most credible way forward is through further R&D grants to advance the TRL to a stage at which large players, presumed to be in the private sector, could be induced to invest.

BENEFITS FOR CASE MEMBERS

The focus on stationary engines has meant that the main direct beneficiary is AgriAD which runs electricity generators on biogas from its AD plants. The water company can also benefit from the model as it runs CHP plants with biogas from sludge hydrolysis. The transport company can also use the model although the test results are of less direct relevance – its interests were more directly served in a separate but related CASE project on dual fuel systems for trucks.

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