The Home Energy Resources Unit (HERU) – Conversion of household waste into heating fuel

Driving energy and resource efficiency through chemical engineering

Introduction

Meeting European environmental legislation is becoming more challenging due to the limitations of many existing processes. Domestic and industrial waste disposal is particularly challenging. Recycling, is restricted to certain materials and relies on effective sorting mechanisms and, hence, consumer behaviour.

A novel system dubbed the Home Energy Resources Unit (HERU), aims to address this by providing a waste-to-energy system suitable for domestic use.[1] The system enables most items currently collected for disposal to be used as an energy source that might power a home boiler, thereby moving away from the linear approach to consumerism (buy, use, dispose) to a circular one, where 'wastes', emissions and energy leakage are minimised in material loops. The HERU enables the almost-complete utilisation of waste materials including paper, plastics, and organic waste, diverting many materials from landfill. Materials which cannot be used, such as glass and tin cans, could still be retained for recycling.

The process uses heat treatment to break materials down at temperatures up to 300°C and produces an average of 2.6 times the amount of energy used to run the HERU itself.

Some waste is inevitable, and cannot be **prevented** or **re-used**. In this case, recovery is the ideal approach. This can be recovery of the **materials**, such as through composting or recycling, or recovery of the **energy** such as with the HERU. Final disposal of the waste is always a last resort.

[1] ***http://bit.ly/2Sfc94u***

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Using heat pipe technology within the pyrolysis reactor

The HERU system, (Figure 1), uses pyrolysis to thermochemically convert any feedstock into three energy vector phases; namely biochar (solid), bio-oil (liquid), and syngas (gas). The gas and liquid phases can then be fully combusted to release their energy content, which is then used to heat water.

Pyrolysis as a chemical engineering process has been around for a long time and was intended to be used for many applications, but it was largely unsuccessful because of the production of harmful gases, such as dioxins. The HERU utilises heat pipe technology which enables uniform temperature distribution within the reactor, preventing the formation of such harmful compounds.

A heat pipe is a passive thermal transfer device that can transport large amounts of heat over relatively long distances isothermally. No moving parts are required in a heat pipe. The main structure of a heat pipe consists of an evacuated tube that is partially filled with a working fluid that exists in both liquid and vapour phases. The heat pipe within the HERU operates by having an evaporator located at the bottom of the heat pipe and a condenser located at the top (Figure 2). When a high temperature is applied at the evaporator section, the working fluid in the liquid phase evaporates and flows with high velocity towards the cooler end of the pipe (the condenser). As soon as the vapour reaches the condenser section, it condenses and gives up its heat. The liquid working fluid returns to the evaporator part of the pipe by the influence of gravity.

Figure 1. Home Energy Resource Unit (HERU)

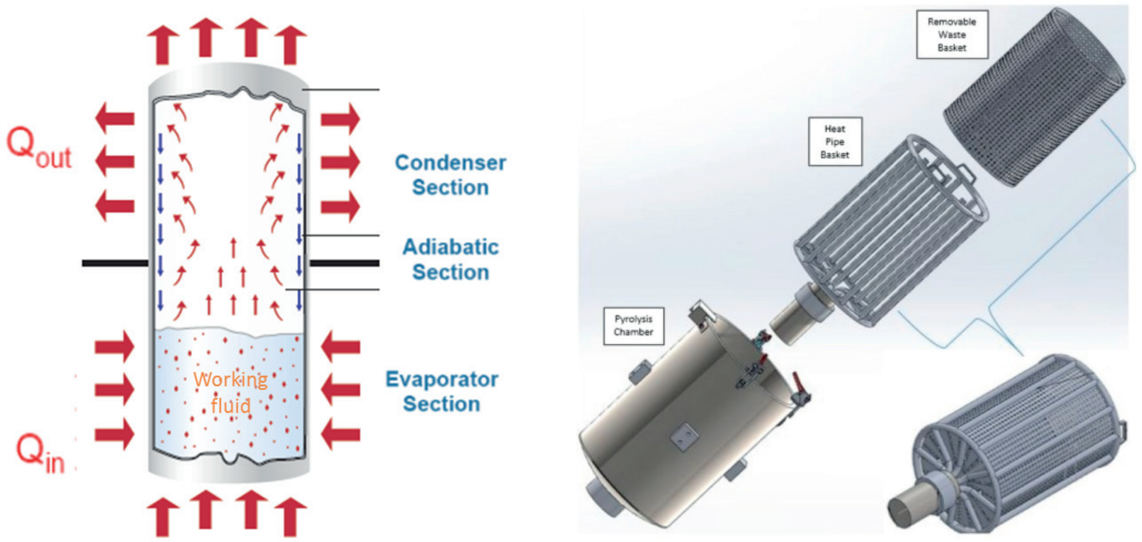

*Figure 2. Internal parts of HERU (**Jouhara et al, 2017: doi.org/10.1016/j.energy.2017.02.044**)*

The operating temperature of the HERU never exceeds 300°C, allowing this system to be used within households and still maintain high energy recovery.

The 'waste' feedstock for this system does not require any pre-treatment steps which might create behavioural barriers for consumers. It converts these materials into heating fuel and a biochar that can be used as a composting agent in the garden or in water filtration. The suitability as a water filter of biochar produced in the HERU is currently the subject of research at Brunel University London, UK.

The 'waste' materials are loaded into the chamber through the top of the HERU unit, which is then sealed by a lid. A temperature control unit regulates the heater power supply, using a feedback loop from the temperatures developed at the heater and the inside of the chamber. The whole structure is covered by white insulation to minimise any heat loss to the surroundings.

Other emissions from the process include aqueous discharge and air emissions. The aqueous waste has been tested and is considered safe to discharge to a sewer. The discharge is primarily water but contains low levels of pyrolysis oil, particulates, inert ash and detergent. Air emissions are expelled via a conventional domestic boiler exhaust and is processed by a water filtration system and the boiler prior to discharge. Tests have demonstrated this is safe for release, meeting standards required to protect human health and the environment, falling within parameters of current boiler exhaust emissions.

The unit it designed to be similar in use and maintenance to other domestic appliances in the home, such washing machines and dishwashers. Similar to these devices, the HERU requires a water supply, a standard 13 Amp electrical power supply and a sewer pipe connection to flush the ash produced with water. When installed it can be synchronised with the existing domestic gas or oil-fired boiler so that the boiler becomes a hybrid water heating system – meaning it can run via the HERU or revert back to oil or gas as and when needed.

HERU coefficient of performance (COP)

The heat pipe within the pyrolysis chamber allows the process of converting municipal solid waste (MSW) into hot water to be an efficient, cost effective, and compact unit. One of the key advantages of the HERU is that there are no toxic gases produced when using the heat pipe basket to provide the heat for the HERU reactor. This enables uniform heat flux from all directions, effectively converting the feedstock into fuel.

Pyrolysis experiments carried out on the HERU unit show that, on average, the reactor requires 5.5 kWh of electricity to treat 7 kg of MSW. Therefore, the power consumption per kg of feedstock is 0.78 kWh/kg. A recent independent study carried out on the HERU by Ricardo found that using the HERU would save a household 72 kg of CO_2 annually, increasing to 1,200 kg if powered by renewable energy-derived electricity. The report concluded that the HERU has the lowest global warming impact compared to collection of both co-mingled and separated waste streams for delivery to either landfill or further treatment processes.

The average COP for the HERU unit based on mixed municipal solid waste is 2.6. This means that for every 1 kWh of electricity used, 1.6 kWh is produced by HERU.

Therefore, the HERU system can produce energy (hot water) from most domestic materials at low CO_2 emissions and a high COP. The HERU could be in the market in less than two years' by 2021. It is currently being tested at various locations in the UK and its results are being monitored and analysed.

With appropriate waste sorting, the HERU system could divert the majority of household waste, which has a variety of wider benefits:

- Compact, user friendly technology
- Reduced need for waste collections
- Generates heat at a place where it can be used (in the home)
- Domestic energy generation can reduce energy bills for the consumer

At a higher level, home waste-to-fuel appliances may be a disruptive technology. Wide adoption of this technology has the potential to reduce demand for inefficient and expensive waste infrastructure, generate carbon savings and help address fuel poverty.

Lessons for chemical engineers

- Materials that are considered as 'waste' are actually valuable resources that can be used in processes such as HERU to heat water.
- Efficient waste-to-energy processes can help meet domestic and industrial environmental targets.

  The HERU system enables mixed waste to be all used at once with no pre-treatment, offering flexible, simple and safe use for domestic purposes.
- Similar waste-to-energy units can be custom built to industries that produce high volumes of waste, improving their efficiency with the least environmental impact.
- The heat pipe technology allows for uniform heat flux throughout the reactor, resulting in complete thermo-chemical conversion via pyrolysis.

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