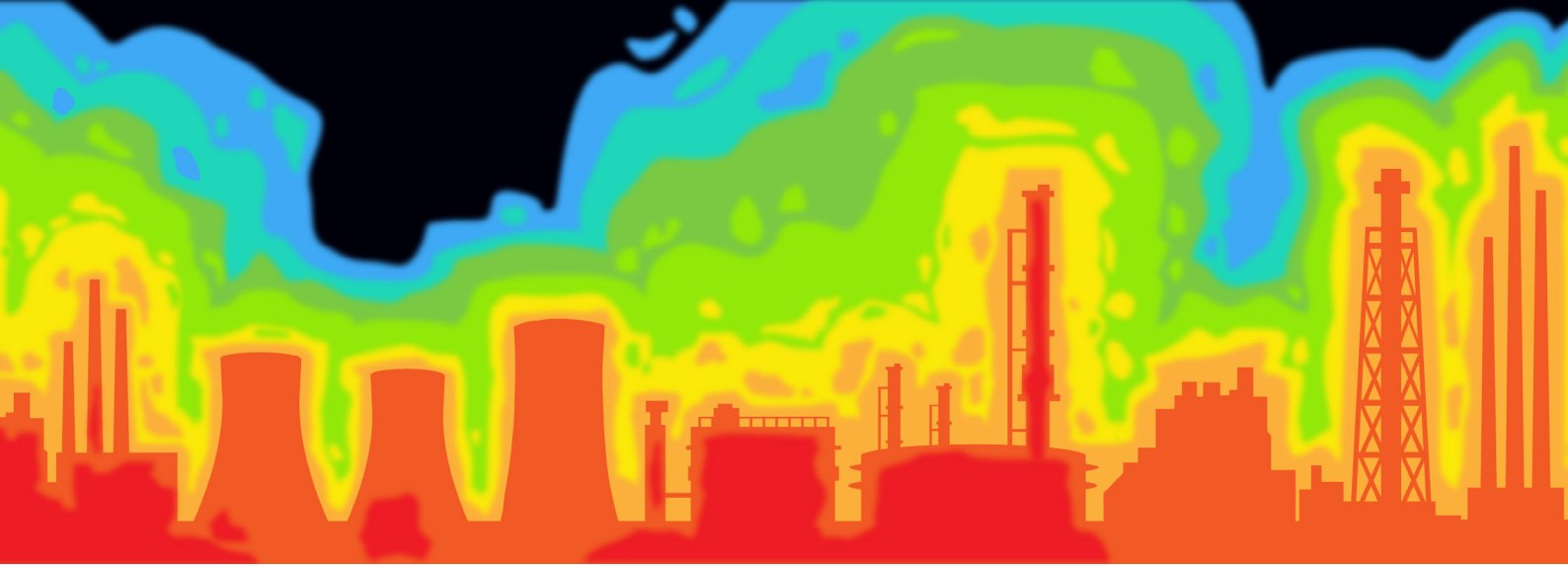

Waste heat: a wasted opportunity?

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Did you know that a large proportion of the energy consumed during the production of many household items is lost to the environment as waste heat? This article will cover the technologies that we have at our disposal to do something useful with it.

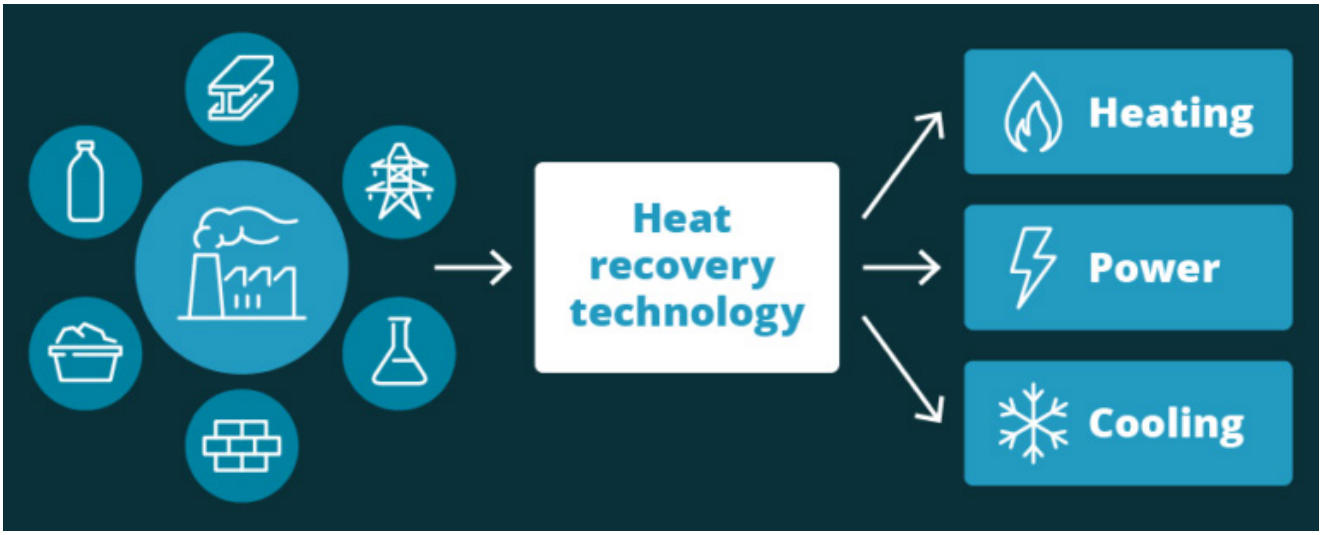
Public awareness around recycling has probably been at its highest in recent years. This is being driven by the alarming impact we are having on the both the environment and climate and the urgent need to reduce this. But, have you ever thought about how sustainable current manufacturing processes are?

You might be surprised to learn that within the UK approximately 20% of the energy that is consumed by industry is unused. This is lost to the environment as waste heat. These industries produce many items ranging from raw materials such as metal, glass and cement, to food and drink and many other household products.

Another surprising example is a typical car engine. Of the energy contained within the fuel, only a third is converted into power that drives the vehicle. The remaining two-thirds is lost through the exhaust as waste heat. Similar observations can be made for the power stations that provide a large proportion of the country's electricity.

Not only is this a waste of energy but it is also a waste of money. Could you imagine buying something, and then throwing two-thirds of it away? So, there are obviously reasons for trying to reduce how much heat is wasted to the environment. But are there technologies that can recapture that wasted heat and do something useful with it?

The answer to that question is yes, and those technologies do different things with that heat. The first example is to use the wasted heat directly to heat something else. A recent example of that can be found within the Bunhill 2 Energy Centre in London. That system extracts waste heat from the London Underground system and supplies that to over 1,000 homes using a network of underground pipes.

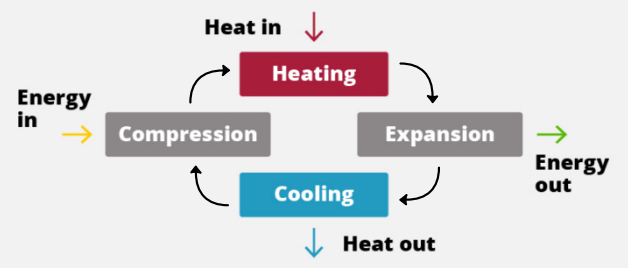


^ *Waste-heat from a variety of industries could be converted into heating, cooling or electricity using heat recovery technologies. Credit: Martin White.*

Alongside using waste heat directly, it can also be upgraded to higher temperatures, or even used to provide cooling. This can be achieved using a group of technologies that are referred to as heat pumps or chillers. These technologies use the waste heat to drive a system that moves heat from one place to another. Within that process the waste heat can be transformed to a more useful form of energy. These technologies operate in a similar way to a fridge, which uses electricity to move heat from inside the fridge and deposit it to the surrounding air.

The issue with using waste heat for either heating or cooling is that it is very hard to transport over large distances. It also requires a relatively complex infrastructure to do this. For example, the system capturing heat from the underground requires an underground network of pipes that is over 1.5 km in length. Therefore, there has to be a demand for heating or cooling close to the waste-heat source for these technologies to be successfully implemented.

Thankfully, heat can also be converted into electricity. This electricity can then be used on-site or easily exported to the electricity grid. This is done using a group of technologies referred to as heat engines. Heat engines have had a major role in modern-day life since the industrial revolution and the invention of the steam engine.
Today, they are used in many applications including power stations, car engines and aircraft. In most of these applications the heat is generated from the burning of fossil fuels. However, that heat could come a range of renewable heat sources. This includes energy from the sun, from deep underground, fuels derived from biological matter or from waste heat. As such, there has been a significant amount of research focussed on developing heat engines suitable for waste-heat recovery.



^ *The basic operating principle of a heat engine: the energy input during the compression and heating processes is used to generate a high temperature, high pressure gas that is expanded producing useful energy that can be converted into electricity. Credit: Martin White.*

So, what are the challenges? And why aren't these technologies already more widely implemented?

The first answer is efficiency. For a heat engine, efficiency is defined as the ratio of the amount of electricity that is generated compared to the amount of heat that is put into it. If we think back to the example of a car, we said that two-thirds of the input energy is wasted. So, we can say that 1 unit of energy is generated for every 3 units of heat. Therefore, the efficiency is 33%. Now, for a heat engine, efficiency increases as the temperature of the heat increases. This means that the higher the temperature, the more efficient our system will be. The problem is that, compared to the heat generated from burning fuels, waste-heat streams have a much lower temperature.

For example, burning fossil fuels can generate temperatures as high as a 1,000 degrees celsius, whilst waste heat can range anywhere between 50 to 500 degrees celsius. This means waste-heat recovery heat engines typically have efficiencies in the region of 10 to 20%, which is much lower than the efficiencies of state-of-the-art fossil-fuelled power stations that exceed 50%.

The second challenge is cost. Waste-heat recovery systems are quite expensive, and this is partly related to their low efficiency. As a simple analogy we can consider two systems. System A and System B both cost the same, but System A has an efficiency that is half that of System B. It follows that we would need two of System A to generate the same amount of power. Or, we would need to spend twice as much money. Unfortunately, in the current market, these high costs mean the time it takes to recover any investment is large compared to many other energy technologies.

A third challenge relates to practical aspects such as integrating these systems into existing factories. Many factories were constructed in a time when energy was cheap and there was less concern about the climate. As such, these factories were not designed with waste-heat recovery in mind. This raises challenges in trying to install these technologies in places where access might be difficult, space is at a premium, or the waste heat is hard to capture.

Thus, waste heat represents a significant opportunity to reduce our impact on our environment, and we already have technical solutions that could be used. The challenge to engineers and scientists is to innovate and strive to enhance the design of the systems as much as possible. This means developing new systems that achieve higher efficiencies, are cheaper to manufacture, and more compact and therefore easier to install. Ultimately, this will make waste-heat technologies far more viable from the perspective of the target industries.

Glossary

Heat engine – a technology used to convert heat into mechanical power or electricity.

Heat pump – a technology that upgrades heat to a higher temperature for heating purposes.

Chiller – a technology that uses heat to provide a cooling effect.

Efficiency – the ratio of how much electricity is generated by a heat engine to the amount of heat input.

About the authors

After stumbling into the field of engineering after enjoying maths, physics and product design at school, I went to university to undertake a degree in mechanical engineering. This left with me a passion for renewable energy and I haven't look back since. I now work as a researcher developing new technologies that can reduce our impact on the environment.

Find out more

BBC news article on using waste heat from the London Underground: www.bbc.co.uk/news/uk-england-london-49482840

UK government report on waste-heat recovery in UK industry: www.gov.uk/government/publications/the-potential-for-recovering-and-using-surplus-heat-from-industry

UK government Heat Recovery Support Programme: www.gov.uk/government/consultations/industrial-heat-recovery-support-programme