Perspective: Waste Heat to Power — Still Waiting for a Breakthrough

PERSPECTIVE #EI229456
Jay Holman

Global Headquarters: 5 Speen Street Framingham, MA 01701 USA P.508.935.4400 F.508.988.7881 www.idc-ei.com

IN THIS PERSPECTIVE

This IDC Energy Insights Perspective assesses the North American market for waste heat to power and discusses the three primary factors that could move the industry out of its current state of stagnation. These factors are government incentives, new business models, and technological developments.

The Opportunity for Power Generation

More than 1,050TBtu/year of estimated work potential is available in the United States from waste heat generated in the industrial and commercial sectors. The potential may actually be larger, as this estimate is conservative and excludes some sources of waste heat that may be significant (such as cooling water). However, not all of this work potential can be used to generate electricity, as not all waste heat is suitable for capture and reuse. Additionally, of the waste heat that is captured and reused, only a portion will be used to generate electricity; the rest will be used directly as heat. These uncertainties make the actual addressable market for waste heat to power in the United States extremely difficult to estimate, but 1,050TBtu/year is a starting point that allows the size of the market to be put into perspective relative to other sources of clean energy. For comparison purposes, in 2009, approximately 697TBtu of energy was generated by wind and 3,900TBtu of energy was generated by biomass.

The waste heat market size estimate is based in part on a report commissioned by the U.S. Department of Energy (DOE) in 2008 titled, "Waste Heat Recovery: Technologies and Opportunities in U.S. Industry." The report examined over 25 specific industrial processes and applications in the United States that together generate roughly 1,500TBtu of unrecovered waste heat per year (based on a reference enthalpy of 77F [25C]). This translates into an estimated work potential of 600TBtu, once conversion efficiencies are taken into account. However, the report excluded waste heat from commercial boilers (i.e., those found in schools, hospitals, government buildings, and so forth), losses from heated products, heat from cooling water, and other applications.

IDC Energy Insights estimates that, based on the number of commercial boilers in the United States according to a May 2005 report published by the Oak Ridge National Laboratory titled, "Characterization of the U.S. Industrial/Commercial Boiler Population," another 300TBtu of work potential is available from this source. The 2008 DOE report estimates that heat losses from solid streams in the iron and steel industry total 600TBtu/year, which might translate into an additional 150TBtu of work potential. Work potential from cooling water is not included in the 1,050TBtu total work potential of waste heat estimated for the United States, but according to the 2008 DOE report, "large quantities of low-temperature waste heat are available in cooling water."

Numerous additional sources of waste heat exist, but the above estimates include the sources that are most likely to be used for power generation. The sources are summarized in Table 1. Even within the sources covered, there is variability in the quality of the waste heat that impacts its suitability as a source for power generation. Three of the most important variables are temperature, flow rate, and cleanliness of the waste heat. Much of the existing heat recovery that is currently carried out in the United States (and which was excluded from the estimates of work potential above) utilizes "clean, high-temperature waste heat sources in large capacity systems," according to the 2008 DOE report.

While some of the unrecovered high-temperature waste heat in the United States would be straightforward to capture and use with existing technologies, other sources are dirty and expensive to recover because the exhaust gas must be cleaned prior to use. Not only is the cleaning process expensive, but removing dirt from the hot-air stream removes heat at the same time, which then cannot be used for power generation. Other high-temperature waste heat is difficult to recover because of its basic nature, such as solid streams in the iron and steel industry.

Over half of the unrecovered work potential from waste heat outlined in Table 1 is at low temperatures, under 450F (232C). The economic viability of these sources is tied directly to the cleanliness of the waste heat as well as its flow rate. Low-temperature waste heat sources with large flow rates can be economical to exploit with traditional organic Rankine cycle (ORC) technology because they enable large projects with significant electricity generation. Smaller projects at low temperatures are much more challenging to make economically viable, although a few companies are developing technologies to pursue this market.

TABLE 1

Estimated Unrecovered Work Potential Available from Waste Heat in the United States

Waste Heat Source	Estimated Work Potential (TBtu/year)
Over 25 industrial processes and applications	600
Commercial boilers	300
Solid product streams in iron and steel industries	150

Source: DOE, 2008 and ORNL, 2005

Waste heat to power projects are not new, and companies such as Ormat have pursued this market for years. Since 1997, Ormat has developed 24 waste heat to power plants with a total capacity of 160MW gross. The company has developed specialized solutions for energy recovery systems on gas pipeline compressor stations, and this application has been the company's primary area of focus to date. The application has strengths in that it is more straightforward and less complicated than projects in cement plants, steel mills, and other industrial sites, most of which utilize an exhaust gas stream that must be cleaned. However, the company is considering the idea of pursuing smaller projects at industrial sites with a standardized, prepackaged power block optimized for specific applications.

Industry Outlook

Waste heat to power projects have been on a slow growth curve in the United States recently. Because of low electricity prices in most parts of the United States, combined with discounted rates for large industrial customers, electricity from waste heat applications must be extraordinarily cheap for it to compete effectively with electricity from utilities. When the risk that the technology will interfere with industrial processes is factored into the equation, many industrial companies decide it is simply not worth it.

Three factors could influence the situation in the United States in the coming years: increased government incentives, new business models, and recent technological developments. These three factors are explored in greater detail in the sections that follow.

Government Incentives for Waste Heat to Power

Despite the fact that power from waste heat generates no emissions, and is therefore considered to be clean energy, it is often seen as more of an energy efficiency play than a renewable energy play. In both cases, industry members and others feel the technology warrants government incentives similar to those enjoyed by other clean energy technologies, but to date, those incentives have not been realized outside of a few states and local regions. The lack of widespread state or federal incentives to promote waste heat to power generation has been a drag on industry growth.

An Uneven Playing Field in the United States

There is some debate over whether waste heat to power projects should be considered renewable energy projects or energy efficiency projects, particularly when the waste heat is created by burning fossil fuels. It is more than just a question of semantics because the result determines whether waste heat to power projects qualify for incentives designed to promote renewables. Currently, only 4 of 29 states with binding renewable portfolio standards (RPSs) include waste heat as a qualifying resource (Colorado, Connecticut, Nevada, and Ohio), while 2 states with renewable energy goals include it (Indiana and South Dakota). However, the more critical issue for the industry in the United States is that waste heat to power projects do not qualify for either the federal investment tax credit (ITC) or the federal production tax credit (PTC).

While inclusion in state-level RPSs, as well as a smattering of local energy efficiency and clean energy incentive programs, does give waste heat to power projects advantages in some areas over others, the inability to claim federal tax incentives is having a material impact on industry growth. In July 2010, legislation was introduced in the U.S. House of Representatives that would provide a 30% investment tax credit to projects that generate electricity from waste heat produced by industrial processes. Unfortunately, the bill did not become law.

The U.S. Clean Heat & Power Association (USCHPA) is currently pressing for a 10% federal investment tax credit for both combined heat and power (CHP) and waste heat to power. However, to date, no bill has been introduced to that end, and the prospects for a federal tax incentive for these technologies in the near future look dim at this point.

Canada Provides an Attractive Incentive Program

The Ontario Power Authority (OPA) is promoting the adoption of waste heat to power projects up to 20MW in size through a new Energy Recovery Standard Offer Program (ERSOP). 200MW of capacity has been allocated between the ERSOP and a Combined Heat and Power Standard Offer Program (CHPSOP), with a minimum of 50MW allocated to ERSOP and a minimum of 150MW available for CHPSOP projects. Qualifying sources for the ERSOP include both waste heat and by-product fuels, which are fuels such as process off-gases that are derived from an industrial, commercial, or manufacturing activity (excluding mining) and are typically flared.

The contract price for the ERSOP is $90/MWh, although under certain circumstances applicants that incorporate a price reduction will have higher priority for approval. The program includes a peak performance factor, which pays more for electricity delivered during the peak period of 11:00 a.m. to 7:00 p.m. on business days. The launch period for the ERSOP began May 6, 2011, and contract offers will go out in 3Q11.

The ERSOP is expected to give a much-needed boost to the waste heat to power industry in Canada, and many in the industry would like to see a similar program in the United States. However, at this time, such a program does not appear to be on the horizon.

New Business Models Reduce Barriers to Entry

Industrial companies considering implementing a waste heat to power project face two primary risks: a risk that implementing the project will negatively impact their operations and a risk that even a successfully implemented project will fail to deliver anticipated returns. New business models are emerging in the industry to reduce the first risk and eliminate the second risk for companies with viable waste heat resources.

Beyond the purely technical challenges of designing a system that economically captures waste heat and converts it to power is the challenge of convincing an industrial customer to take on a project that may yield a fairly modest return. This is particularly difficult when industrial customers are concerned that implementing the project will negatively impact their operations; they do not want to take on the added risk for a relatively small potential return. Related challenges include difficulties locating the required equipment close to the waste heat source and the disruption caused by the project's implementation.

The size of the return on an investment in waste heat to power projects is typically tied to the cost of the electricity that the project will be displacing. This cost can be quite low for industrial companies, which effectively reduces their incentive to conserve or generate their own electricity. Carbon credits, which would have increased the value of the clean energy generated, have not materialized either and are unlikely to contribute to the value proposition of these systems anytime soon. Renewable energy credits (RECs) would also improve the economics, but as discussed previously, most states with an RPS do not include waste heat to power as a qualifying resource.

Finally, even if a project is deemed economically feasible on paper, there is the risk that the project's output will be lower than expected, or cost overruns will ruin the economics, or a drop in utility electricity rates will reduce the economic benefit.

Waste heat to power service companies are now emerging that take on this latter risk completely by financing, developing, constructing, and even owning the waste heat to power projects. The service company then sells the electricity generated by the projects back to the heat host at a lower cost than electricity from the utility. Alternatively, the service companies can sign a power purchase agreement with a third party (such as the utility) for the electricity from the project and share the revenue from electricity sales with the heat host. Therefore any risks of lower-than-expected system output or external factors that influence project economics are borne by the service company and not the heat host.

Additionally, the service companies work with multiple technology vendors rather than locking into a single partner, enabling them to choose the best technology and partner for a particular project. This reduces some of the risks of disruption associated with the implementation of the projects and allows the heat host to take advantage of the process and industry knowledge acquired by the service provider over multiple projects. Two such waste heat to power service providers are described in the sections that follow.

Recycled Energy Development

Recycled Energy Development LLC, or RED, is based in Westmont, Illinois, and offers both cogeneration (electricity and heat) and waste heat to power services. RED operates by purchasing an industrial company's existing boilers and/or other energy equipment, then recovering waste energy from that equipment to generate electricity and steam, which the host company can then use directly or which RED and the host company jointly sell to a third party. Throughout this process, RED takes care of the development, financing, engineering, installation, and long-term operation of the project. In addition to purchasing the boilers or other energy equipment, RED leases space from the heat host for the equipment used to recover the waste heat.

RED targets large projects in the specialty metals, chemical, food, cement, and glass industries, as well as any other industries with large amounts of waste heat. RED is flexible in who it sells the electricity to and pursues the option that warrants the greatest economic benefit to RED and the project host. This can include selling the electricity back to the host, signing a PPA with a third party, or some combination of the two. When electricity is sold to a third party, the revenue goes toward capital recovery, then operations and maintenance (O&M), and then any profit is split with the host.

RED is technology neutral, looking for the most cost-effective, efficient way to recover energy out of waste heat. The company signed an agreement in 2008 to develop a 40–44MW waste heat to power project with Globe Specialty Metals' unit West Virginia Alloys, at a silicon manufacturing plant. The project, which is the company's first, was anticipated to cost between $45 million and $55 million to complete. Initially slated to be completed in 2010, the project is not yet online as of June 2011.

KGRA Energy

KGRA Energy Corp. was founded in 2009 and is based in Lake Forest, Illinois. The company identifies, finances, engineers, develops and, sometimes, operates and owns waste heat to power projects. KGRA serves as either a provider of engineering, procurement, and construction (EPC) services or a system owner, depending on the preference of the heat host. The company works with a variety of technologies and vendors, selecting the equipment and approach that best suits the project site. KGRA feels that one of the company's strengths is in the area of financing, where the company has developed expertise and where the benefits of a well-structured deal can be material.

KGRA anticipates completing its first project in July 2011, which will be 800kW in size, use ORC equipment provided by TAS Energy, and harvest heat from a thermal oil loop currently used to dry cut lumber, at a facility in Ayden, North Carolina. The company has multiple other projects in various stages of the proposal process. These proposals target heat hosts in the cement, natural gas transmission (compression station), steel, chemical, mining, power plant (including biomass power plants), and pulp and paper industries. While the majority of proposals sell power back to the heat host, KGRA offers the option of signing a PPA with a third party.

Technological Developments: Improving Project Economics

Since the development of the ORC power block, there have not been any major innovations that have opened up new markets or drastically altered the economics of waste heat to power projects. However, a few companies are trying, with activity concentrated in two primary areas. The first area is the development of the Kalina cycle, an alternative to the organic Rankine cycle that utilizes a mixture of water and ammonia as the working fluid. The second area focuses on the development of new expanders for the organic Rankine cycle, with an emphasis on economic electricity production in small waste heat to power projects operating at low temperatures.

Global Geothermal

Global Geothermal Ltd. is a subsidiary of Wasabi Energy Ltd., which is headquartered in Melbourne, Australia. The company owns the rights to the Kalina cycle, which uses an ammonia-water mixture as a working fluid to improve power generation efficiency and flexibility. The technology can be used to generate power from waste heat with temperatures as low as 200F (93C), and the focus is on large projects custom designed for a particular waste heat source. Although the technology has been around for years, there have only been six commercial projects utilizing the technology to date, five of which are currently operating. Total operating capacity of the plants is about 12MW net.

The first commercial project was a 3.1MW waste heat application deployed in 1998 at Sumitomo Metals' Kashima Steelworks in Japan. The second deployment was a low-temperature geothermal project undertaken in 1999 in Húsavík, Iceland. The plant was designed to produce 2MW of output, but according to the 2009 report "Corrosion in the Kalina Cycle" by Peter Whittaker, the maximum output achieved by the plant was 1.76MW. The 2009 report detailed significant corrosion problems experienced by the Húsavík plant, although eventually materials and components were identified that were able to resist the corrosion. According to Global Geothermal, the corrosion at the Húsavík plant was the result of poor operating practice by the owner, including the use of untreated makeup water in the plant, and the lower output of the plant was due to lower-than-expected brine inlet temperature.

Recently, activity has picked up again for the technology. In June 2011, Global Geothermal and Wasabi Energy announced a licensing agreement with FLSmidth, a supplier of engineering, procurement, and construction services to the global cement and minerals industries, to pursue waste heat opportunities in those industries. Wasabi Energy estimates that the market opportunity in these industries is over 9GW globally. FLSmidth's first project with the Kalina cycle will be an 8.6MW plant at the Khairpur Cement Plant in Pakistan.

Although some of Global Geothermal's plants are designed to run unattended, an operator is typically required for routine maintenance, start-up, shutdown, and so forth. This potential requirement, along with the slow uptake of projects using the Kalina cycle, has caused some in the industry to remain skeptical of the technology: there is a perception that if the technology was a game changer, it would have seen wider adoption by now.

ElectraTherm

ElectraTherm Inc., headquartered in Reno, Nevada, has developed the Green Machine, which uses an organic Rankine cycle unit with a specially designed twin screw expander to generate electricity in small-scale projects utilizing hot water in the 190–240F (88–116C) range. The company deployed its 3050 model, with an output of 30–50kW, in a number of demonstration applications, including electricity generation from waste heat from a boiler at a university and two microconcentrating solar power projects. In 2011, the company expanded the range of power output with its Series 4000 Green Machine to 30–65kW.

The Green Machine's small footprint, at 5 x 5ft, enables it to be located close to a waste heat source in a commercial or industrial building, and by productizing the unit, the company should be able to take advantage of economies of scale once volumes pick up. However, capital costs for the units can be a bit high, at $2.50/W to $4/W, and the company has yet to deploy a substantial number of commercial units.

Ener-G-Rotors

Ener-G-Rotors, headquartered in Rotterdam, New York, is developing a unit that converts hot water or low gauge steam, in the 150–300F (65–149C) range, to electricity in small-scale projects. The technology is centered around a new expander, the trochoidal gear engine, which replaces the turbine in a traditional organic Rankine cycle.

The company is finalizing the development of its GEN4 model, which it hopes to deploy in trials in late 2011 and launch commercially in 2012. The units will have an output of 40–60kW. Ener-G-Rotors states that the units will have a 20-year life, with little to no maintenance and, under the right circumstances, will be able to produce electricity at prices as low as $0.015/kWh without government incentives.

Conclusions

The waste heat to power industry continues to have great potential to produce significant amounts of clean energy in the United States, but progress in the industry has been slow, and growth has been almost nonexistent. Projects are getting built here and there, but the industry is not seeing the rapid growth experienced by wind and solar in recent years, despite its credentials as, at best, a renewable source of energy, and at worst, a source of energy efficiency improvements.

Local and state incentives help, but only to the extent that the regions in which they are implemented overlap with substantial waste heat resources. Federal incentives are lacking, and their adoption at levels seen for renewables, (i.e., grants or tax rebates for 30% of project capital costs) would provide a significant boost to the industry. Unfortunately, those incentives are not likely to materialize soon.

New business models that reduce risks for waste heat hosts while optimizing technology selection and financing terms seem to have the greatest potential for introducing growth to the industry, but it remains to be seen whether projects in the pipeline will materialize.

Technology improvements show promise but still need to be proven. The Kalina cycle is getting another chance to prove itself, and if successful, the technology could boost waste heat to power activity in the cement and related industries. Technologies that attempt to make small, low-temperature waste heat to power projects economical face significant hurdles, as even if costs can be taken out of the power block, significant costs remain in project design and engineering and in the heat exchanger that will be required to generate the hot water or steam that these systems utilize.

While pockets of activity in the waste heat to power industry may see growth — for example, GE may have a good business opportunity deploying the Clean Cycle waste heat to power technology recently purchased from Calnetix as a bottoming cycle for its Jenbacher gas engines — in general, the industry is not expected to see significant growth in the near future unless one of the new business models or technologies described in this document really takes hold.

LEARN MORE

Related Research

- *Perspective: U.S. Renewable Energy Update — Wind Takes a Breather While Solar Shines* (IDC Energy Insights #EI228515, June 2011)
- *Perspective: Spring 2011 Clean Energy Outlook — Regulatory Update* (IDC Energy Insights #EI228254, May 2011)
- *Best Practices: Finding the Sweet Spot for Micro CSP — The Holaniku at Keahole Point Case Study* (IDC Energy Insights #EI227275, March 2011)
- *Best Practices: Enbridge's Approach to Greening the Natural Gas T&D Network via Hybrid Fuel Cells* (IDC Energy Insights #EI221326, January 2010)

Copyright Notice