IMPROVING INDUSTRIAL ENERGY EFFICIENCY THROUGH THE IMPLEMENTATION OF WASTE HEAT RECOVERY SYSTEMS

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ABSTRACT

Improving the energy efficiency of industrial processes and the facilities in which they are carried out is often considered to be one of the most promising ways to begin reducing global greenhouse gas emissions. One of the best ways for organizations to reduce their energy consumption without having to carry out extensive equipment and facility overhauls is waste heat recovery or energy recycling. Waste heat recovery involves tapping into previously discarded thermal energy streams and reusing it for various purposes within a facility (space heating or cooling) or within the process itself (pre-heating air and boiler makeup water). Despite the numerous social and economic benefits that are available through waste heat recovery, several economic and technical barriers still exist to its wide-scale implementation. This paper provides an overview of the current state of waste heat recovery systems available in industry, offers a discussion of the major barriers to their wide-spread implementation, and lastly concludes with new data with several new case studies from Canadian manufacturers which have successfully harnessed waste heat within their facilities.

Keywords: waste heat recovery; energy efficiency; barriers; feasibility.

AMÉLIORER L'EFFICACITÉ ÉNERGÉTIQUE DANS L'INDUSTRIE GRÂCE À LA MISE EN ŒUVRE DE SYSTÈMES DE RÉCUPÉRATION DE LA CHALEUR PERDUE

RÉSUMÉ

L'amélioration de l'efficacité énergétique des processus industriels et des aménagements dans lesquels ils s'effectuent est souvent considérée parmi les façons les plus prometteuses de réduire les émissions des gaz à effet de serre. Actuellement, la récupération de la chaleur perdue, aussi connue comme le recyclage d'énergie, est un des meilleurs moyens pour que les organisations réduisent leur consommation d'énergie sans effectuer des énormes révisions d'équipement et d'aménagements. La récupération de l'énergie perdue consiste à exploiter les flux d'énergie thermique précédemment mis en décharge et les réutiliser pour des fonctions diverses dans l'aménagement (soit chauffage ou refroidissement des espaces) ou dans les processus eux-mêmes (préchauffage d'air et eau d'appoint des chaudières). Malgré les nombreux avantages sociaux et économiques de la récupération de l'énergie perdue, plusieurs obstacles économiques et techniques existent toujours contre sa mise en œuvre à grande échelle. Cet article présente un aperçu de l'état actuel du système récupérateur de chaleur disponible, propose des forums de discussion au sujet des obstacles contre sa mise en œuvre à grande échelle, et termine avec de nombreuses études de cas de fabricants canadiens qui ont réussi à employer des systèmes récupérateurs de chaleur dans leurs aménagements.

Mots-clés : la récupération de la chaleur perdue; l'efficacité énergétique; obstacles; faisabilité.

NOMENCLATURE

BF	by-product fuels
CHP	combined heat and power
CIPEC	Canadian Industry Program for Energy Conservation
DOE	Department of Energy
EU	European Union
GHG	greenhouse gas
ISO	International Organization for Standardization
MEPS	minimum energy performance standard
ORC	organic Rankine cycle
PWC	Pratt and Whitney Canada
SILC	Sustainable Industry Low Carbon
SME	small and medium enterprises
SPIRE	Sustainable Process Industry through Resource and Energy Efficiency
WHR	waste heat recovery
Subscripts	
t	tonne
e	equivalent

1. INTRODUCTION

In today's modern society it is quite evident that the world is at our fingertips, one need only take a look around. A large portion of today's prominent industries have either been created or drastically altered by the use of fossil fuels. It is the general belief that the use of fossil fuels has allowed today's society to experience current freedoms and liberties. However, our dependence on a finite fuel source will lead to catastrophe if today's consumption practices are not curbed and the process of weaning ourselves from environmentally-degrading energy sources does not begin.

Unfortunately, for a vast majority of industries, greenhouse gas (GHG) emissions are determined to a large extent by the energy needs of the buildings they occupy and by the fuel and electricity consumption of equipment they purchase [1]. Most of the energy consumed by the industrial sector is used to power the motors of auxiliary equipment, produce heat to generate steam, or to provide space heating and cooling.

Recent studies have shown that, even with up-to-date plants and industrial processes, industrial energy efficiency can be improved by as much as 20% or more [2]. As a result, it is currently thought that one of the best ways to reduce global energy consumption, and therefore emissions, is through the improvement of industrial energy efficiency. In fact, the EU's Sustainable Process Industry through Resource and Energy Efficiency, or the SPIRE program, believes that process industries are uniquely positioned to drive environmental initiatives from the bottom-up, as they sit at the core of every value chain – from raw materials to final products [3]. They have the greatest capacity to invoke wide-scale change by curbing consumption requirements at the processing level, thereby making industrial facilities and their products more eco-friendly and also cost-effective.

Numbers from the latest Industry Canada Small Business Statistics Report [4] clearly indicate the dominance of SMEs (small and medium enterprises) within the country:

- 1,568 companies or roughly 0.1% of Canadian businesses have more than 500 employees;
- 18,112 companies or 1.6% are medium-sized enterprises, employing between 100 and 499 personnel;
- 1,084,536 remaining companies employ 100 employees or less.

SMEs often stand to benefit the most from improvements in energy efficiency, while simultaneously, are the least likely to pursue such gains due to inadequate resources and in-house expertise, or a lack of positive industrial examples to follow. However, these numbers also indicate the potential impact that wide-scale efficiency improvements could have on Canadian industry, from both an environmental and economic perspective.

This paper provides an overview of existing waste heat recovery technologies and discusses several barriers which currently prevent its wide-scale usage. Additionally, the paper promotes the development of waste heat recovery projects within Canadian industry, because this offers manufacturers an opportunity to reduce future costs, while reducing GHG emissions. New data on raw fuel consumption and on cost has been collected directly from Canadian manufacturers and used to develop several case studies in an attempt to demonstrate the potential benefits that can stem from the utilization of existing energy recovery technologies. The information contained within these case studies is new and fills an important gap in current energy efficiency data: that techniques and technologies available for companies to improve their energy efficiency is always cited, but quantitative numbers outlining the results that can be achieved by utilizing such techniques is rarely made available. In publishing this hard data smaller companies will hopefully be encouraged to pursue waste recovery and other energy reduction projects of their own.

2. WASTE HEAT RECOVERY (WHR) POTENTIAL

Since the industrial sector is prone to numerous sources of inefficiency – oversized motors, compressed air leaks, idle-power requirements – the best area for facilities to focus their energy efficiency strategies is often left unclear. Likewise, limitations on time and resources make it extremely important for actions to remain focused on measures that will deliver the largest energy gains and emission reductions for companies (i.e. the best return on their investment).

Currently, one of the best ways for companies to reduce their energy consumption without the need for vast equipment, system, or facility overhauls is through the implementation of waste heat recovery (WHR) technologies. It offers the industrial sector an incredible opportunity to save energy and improve efficiency. In fact, the American Department of Energy (DOE) estimates that somewhere between 20-50% of industrial energy input is presently lost as waste heat in the form of hot exhaust gases, cooling water, or from equipment surfaces and heated products [5].

Specifically, waste heat refers to heat that is generated in industrial processes (via fuel combustion or chemical reaction) and released into the surrounding environment without being put to practical use [5, 6]. While it is obvious that energy lost in waste heat streams cannot be fully recovered, much of it could be recuperated and employed in a number of different ways including generating electricity, pre-heating combustion air & furnace loads, as well as absorption cooling and space heating [5]. By recovering various waste heat streams the amount of fuel consumed by industries could be significantly reduced. This could in turn lower GHG emission levels and improve the environmental footprint of products and services overall.

3. WHR TECHNOLOGIES

A number of technologies to recover energy from gas, liquid, and even solid waste streams are already in existence and have been around for quite some time. Certain technologies are more common than others, depending on the accessibility of the waste stream, as well as the feasibility of installing a particular recovery system. In general, there are four (4) main types of technologies which are utilized during waste heat recovery: (1) direct usage, (2) heat exchangers, (3) heat pumps, and (4) vapour recompression. The first two technologies involve utilizing waste heat “as is” or in other words, the quality of the waste heat is already adequate for use, while the other two technologies involve waste heat upgrading or boosting the energy level of a particular waste stream so that it can become more useful. Heat exchangers and heat pumps have the widest range of applicability, regardless of industry type, while vapour recompression tends to be limited to larger plants and complex process systems [7].

3.1. Direct Usage

As the name direct usage implies, certain waste streams may be harnessed directly for use after discharge. Several examples of direct WHR strategies include syphoning hot boiler gases for drying purposes, compensating hot water usage in a system with expelled heat exchanger cooling water, or extracting hot air from a mechanical room to heat a storage or shop area.

One of the main issues surrounding the idea of direct usage is the potential for contaminants within the waste stream to infiltrate clean air and water systems. As a result, practically all direct usage projects should integrate the use of an adequate filtration system to prevent cross-contamination. With the exception of filtration requirements, minimal alterations and capital are required to permit the use of many waste heat discharge streams directly, making it one of the most simple and cost-effective WHR strategies to implement.

3.2. Heat Exchangers

When waste heat cannot be used directly, heat exchangers are often used to transfer heat from one stream to another. Heat exchangers are specialized pieces of mechanical equipment which are designed to allow highly efficient heat transfer between two fluid streams (a liquid or a gas) without having them mix [7]. The fact that the two streams can remain separate during the heat extraction process means that contamination is prevented, which is of high importance in many industries, including food processing and medical equipment manufacturing.

Available in a number of different designs and configurations, they are used widely throughout industry and the technology is well-established. The various designs of heat exchangers are suited to meet a wide-range of needs, as well as numerous material, temperature, and operating conditions [7]. As a result, when selecting a heat exchanger for a specific application, it is important to ensure that the best equipment for a system's design is chosen. Seeking advice from equipment manufacturers and suppliers can help reduce maintenance requirements and minimize costs by improving operational efficiency.

3.3. Heat Pumps

Heat pumps, or waste heat upgrading devices, are frequently used within industry as a means to increase the effectiveness of waste heat streams which would typically be classified as low-grade or at a temperature below what is necessary to perform useful work. They transfer heat by circulating a refrigerant through continuous cycles of evaporation and condensation. Heat pumps use an external energy source (i.e. electricity) to improve waste heat quality, essentially working as a refrigeration cycle in reverse [8].

The main operation of a heat pump cycle, as demonstrated in Fig. 1 below, relies on the exchange of a refrigerant between two heat exchanger coils. In the first coil the liquid refrigerant is evaporated at low pressure by the low temperature incoming waste heat stream. The refrigerant vapour is then compressed and its temperature is increased due to an absorption of mechanical energy from the compression process. This high temperature refrigerant vapour is then passed through the second heat exchanger coil, where the absorbed heat is released to the fluid to be heated as the refrigerant condenses back to a liquid. It is through this process that waste stream temperatures are increased enough so that they can be put to use for things such as space and domestic hot water heating.

3.4. Vapour Recompression

Like heat pumps, vapour recompression is used during instances where waste heat is unusable at its current temperature and needs to be transformed into a usable state. Unlike heat pumps however, vapour recompres-

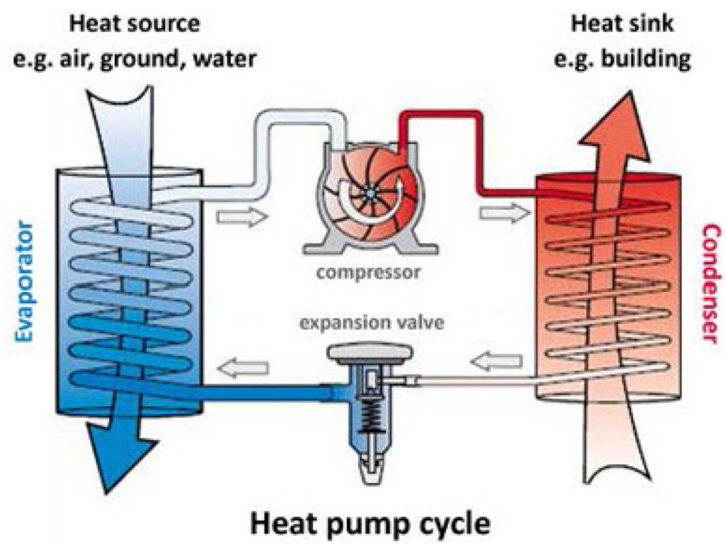

Fig. 1. Heat pump cycle [9].

sion is utilized only for very specific cases: where the waste heat stream is in the form of low temperature vapours.

The process involves compressing waste stream vapours so as to facilitate the absorption of energy from the surroundings, thereby increasing the vapour temperature [7]. The newly compressed vapour is then returned to the process stream for use in supplying heat for evaporation purposes – the most common application for vapour recompression cycles. It is more efficient than conventional heat pumping, but far less flexible in its application [7]. Vapour recompression can be achieved either mechanically or thermally, with each having its own set of pros and cons.

4. BARRIERS OF WHR

While numerous technologies are commercially available for waste heat recovery and a number of industrial facilities have upgraded or are improving their energy efficiency by installing these technologies, waste heat recovery remains relatively unexplored. Despite the significant environmental and energy benefits of waste heat recovery, its implementation still depends primarily on economics and perceived technical risks. In fact, the DOE suggests that most industrial manufacturing facilities are unlikely to invest in WHR projects that have a payback period of more than three years [5].

This is largely due to the fact that heat recovery isn't feasible or possible in certain instances and a number of barriers still exist to its wide-spread implementation, including a lack of regulations and policies to promote its use. Barriers can be both technical and non-technical in nature. They are issues which prevent the successful implementation of WHR and require further research and development to ensure that wide-scale adoption of energy recycling is achieved.

4.1. Low-Grade Waste Heat

WHR opportunities are often categorized by dividing temperature into three distinct ranges: (1) low quality (232°C or less), (2) medium quality (650–232°C), and (3) high quality waste heat (649°C or higher) [5]. Unfortunately, one of the greatest barriers to the implementation of mass WHR remains the unfeasibility of recovery from low-temperature waste streams, which actually possesses the greatest potential based on recoverable volume, as depicted in Fig. 2 [5].

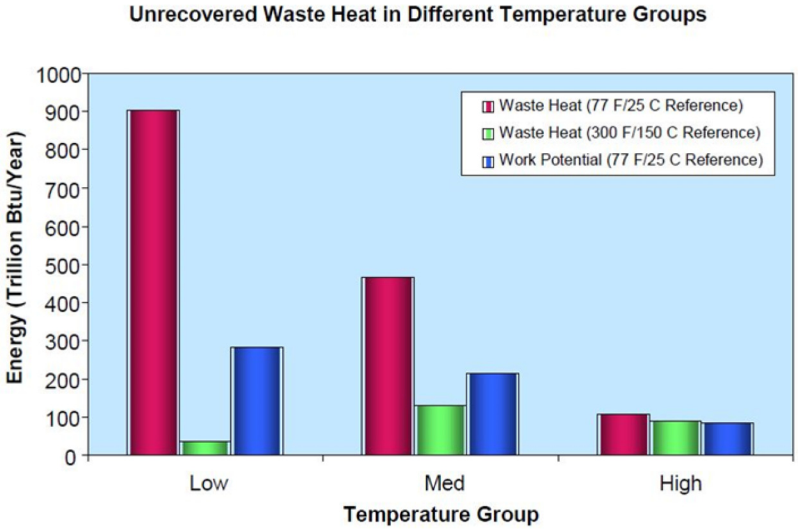

Fig. 2. Recovery potential of various temperature groups [5].

Currently, three major challenges hinder the wide-spread industrial usage of low-temperature waste heat. The first challenge is the frequent corrosion of heat exchanger surfaces as water vapour contained in exhaust gases cool, allowing some of it to condense and deposit corrosive residues on heat exchange equipment [5]. As a result, heat exchangers must be designed to withstand exposure to corrosive deposits. This often requires the use of advanced materials or frequently replacing heat exchanger components, which can lead to large incurred expenses and makes many WHR systems unfeasible.

The second major issue plaguing low-temperature heat exchange is the requirement of large heat exchange surfaces in order to facilitate adequate heat transfer. Heat transfer rates are a function of the thermal conductivity of the heat exchange material, the temperature difference between the two fluid streams, and the surface area of the heat exchanger. Since low-temperature waste heat involves a smaller temperature gradient between two fluid streams, larger surface areas are required to compensate in order to achieve similar heat transfer rates. This often limits the practicality of low-grade heat exchangers.

Lastly, finding a use for low-temperature recovered heat is often more difficult than for the medium and high-temperature ranges. Recovering heat in the low-temperature range will only make sense if a plant has a use for it. Potential end uses include domestic hot water, space heating, and low-temperature process heating. Other options include using a heat pump to upgrade heat to improve its usefulness, as discussed in Section 3.3 above.

Fortunately, a number of applications where low-grade waste heat has been cost effectively recovered for use in industrial facilities have been developed in recent years. The success of low-grade WHR is due in large part to Organic Rankine Cycle (ORC) technology, which is based on the thermodynamic process of the same name. A number of studies have been published in recent years which have outlined the benefits and potential of the ORC for heat recovery using heat sources at temperatures in the 200–400°C range [10].

During the ORC heat is transferred to an organic fluid (with a boiling point lower than water) at a constant pressure. The fluid is vapourized and then expanded in a vapour turbine that drives a generator, producing electricity. The spent vapour is then condensed back to a liquid and recycled [11]. The development of ORC technologies has significantly increased the recoverability of waste streams in the low-temperature range, meaning that one of the largest untapped sources of waste heat can now be harnessed more successfully.

4.2. WHR from Solid Streams

Sources of solid waste heat include hot cokes, by-product fuels (BF) slag, as well as cast and hot rolled metal products from furnaces. Current heat losses from solid streams are quite high, totaling around 500 trillion Btu/yr [5]. However, recovering heat from solid streams is often much more difficult, with one of the biggest issues surrounding solid stream recovery remaining transportability and accessibility. It is often difficult to access heated products within a facility and ensuring heat recovery technologies do not impact production quality is of high importance. Even once the issue of access to a heated product is resolved, the issue of transportability remains. If heat is held within a fluid stream it is easy to transport the fluid to an area where heat is required. A heat exchanger can then be used to extract heat from the fluid so it can be utilized in another process or plant area. Heat itself is difficult to transport, so when it is captured in a solid product the lack of mobility of the waste stream significantly reduces the recoverability and usability of that heat [5]. As a result, waste energy recovery is currently not widely practiced with hot solid materials and is considered a barrier to wide-scale implementation.

Currently, one of the most common options for reducing heat losses from cast products is hot charging, in which slabs are brought to a re-heating furnace while still hot. Hot charging is done at a few plants in the U.S.; however, it is usually applied to only a fraction of production due to logistical reasons, such as mismatched capacities and large distances between casters and rolling mills. Despite this, hot charging has the ability to save approximately 0.5 million Btu of energy per tonne of generated product [5]. In order to achieve these savings more research and funding must be devoted to solving the issue of heat recovery from solid waste streams.

4.3. WHR Policies

It is quite clear that, within industry, the economics of WHR, rather than the potential environmental benefits of these projects, still dominate the approval process. Currently, most manufacturing facilities are unlikely to invest in a WHR project with a payback period of greater than three years [5]. This is rather unfortunate as WHR offers considerable potential for saving energy. In fact, SPIRE in the EU has identified recovery of energy from industrial processes as “the single greatest opportunity for reducing energy use” [3]. In addition to emission reduction, potential job opportunities including manufacturing the necessary equipment, and designing, installing, and maintaining recovery systems is another clear social benefit stemming from WHR projects [12].

In recent years, due to advancements in recovery technologies, rising energy costs, and (particularly in Europe) the development of heat recovery policies, industrial facilities and companies have developed a much greater interest in energy recovery applications [10]. The large scale European “20-20-20” Climate and Energy Package, which calls for a reduction in GHG emissions by 20% below 1990 levels, increasing the share of Europe’s energy from renewable sources to 20%, and improving their energy efficiency by 20% by 2020 [13], has been a huge driver for WHR development, as both sets of projects can help the EU reach these targets considerably.

With such a large emphasis on energy efficiency, many European countries have worked to remove existing WHR barriers and implement new heat recovery policies designed to encourage industries to harness this potential energy source. One such example is the SILC (Sustainable Industry Low Carbon) initiative, which aims to help sectors achieve specific GHG emission intensity reductions in order to maintain their competitiveness [10]. The SILC scheme is intended as a practical, industry-based initiative at the EU-level which identifies, develops and deploys both technological and non-technological innovation measures [14]. As part of the initiative, the EU will co-finance up to 75% of the cost of industry-led projects which meet the goals and requirements of the program [14]. WHR projects have benefited considerably from this program, since it removes many of the perceived economic risks for companies.

In North America, especially Canada, several regulatory barriers still stand in the way of wider adoption of waste energy recycling. Fully embracing these opportunities will require re-designing current government policies surrounding energy efficiency requirements [12]. Currently, Canada has many voluntary energy efficiency programs, including CanmetENERGY, CIPEC (Canadian Industry Program for Energy Conservation), and ISO-14001 (Environmental Management Systems). While these programs are an excellent investment for organizations looking to improve their environmental footprint, they do little to enforce energy efficiency standards.

Canada's Energy Efficiency Act is currently the only piece of legislation within the country that is responsible for the enforcement of regulations concerning minimum energy performance standards (MEPS), as well as the labelling of energy-using products and the collection of energy use data [15]. It is important to note that these regulations establish efficiency standards for energy-using products only and do not provide efficiency standards for systems as a whole. The incorporation of a similar MEPS for system efficiencies could be a way to force corporations to improve the overall efficiency of the process streams used throughout their facilities and encourage the utilization of wasted heat sources. The Canadian government has created numerous retrofit and energy efficiency improvement programs in recent years; it's time they begin a number of initiatives to promote the recovery of waste energy streams within industry, much like the Europeans have done. It could benefit Canadian industry tremendously by reducing primary fuel consumption and overall energy costs, increasing productivity and job creation, and preventing millions of tonnes of CO_2 from entering the atmosphere – a win-win for economists and environmentalists alike.

5. WHR SUCCESS STORIES FROM CANADIAN INDUSTRY

This section provides detailed case studies from two companies within Canada: Pratt and Whitney Canada (PWC) and Magna International Inc. The companies were contacted directly as part of an on-going study that is attempting to collect energy consumption and efficiency data from Canadian manufacturers. Obtaining such data is currently difficult due to the sensitive nature of energy consumption, especially within the industrial sector. The data presented in these case studies is new information which has not been made public before.

Most of the research conducted for this study was done by meeting with industry representatives and discussing energy conservation. A lack of transparency currently exists within Canadian industry regarding energy consumption practices. It is practically impossible to find hard energy data from Canadian organizations, even by contacting them directly. Most organizations are comfortable talking about energy consumption practices, about projects they have implemented and the qualitative results they have seen from incorporating such strategies - however getting quantitative numbers is quite challenging. Government agencies and companies often publish reports stating that their energy consumption was reduced over a certain period of time, however a breakdown of how this energy reduction was achieved and the projects used to obtain such results is very rarely given.

This is unfortunate as SMEs would be more inclined to participate in large-scale conservation strategies if they were presented with positive examples from within industry of companies who had successfully undertaken efficiency projects. Being able to provide industrial examples of successful conservation projects is one of the main objectives of the research under taken during this project. Examples of successful waste heat recovery projects from the two companies mentioned above are discussed in-depth in the case studies below.

5.1. Pratt and Whitney Canada

A Canadian jet fan manufacturer, Pratt and Whitney Canada (PWC), is an example of a Canadian company that has been proactive in improving its energy efficiency and environmental performance. The company

Table 1. Natural gas consumption and cost summary for PWC's WHR project.

Consumption period	Gas consumption (m^3)	Average fuel price (CDN)	Heating cost (CDN)	Average temperature change (against 2012 reference year)
Nov-12	444,100	$0.3278	$106,262	
Dec-12	517,000		$112,077	
Jan-13	553,000		$243,266	
Feb-13	535,000		$210,101	
Total	2,049,100		$671,706	
Nov-13	346,000	$0.5168	$81,447	1% warmer
Dec-13	448,000		$188,824	24% colder
Jan-14	481,000		$352,772	3% colder
Feb-14	419,000		$252,434	13% colder
Total	1,694,000		$875,476	10% colder

has recently undertaken a number of energy efficiency initiatives at its manufacturing facilities in Halifax and Montreal.

At its Montreal facility PWC recently invested considerable resources into a WHR project. The project involves extracting heat from a waste water (i.e. cooling water) stream and using it to heat various shop areas. Installation of the project was completed last fall and since its inception the plant has noticed considerable natural gas consumption decrease, and as a result, cost and GHG emission savings. The plant has tracked and compared the consumption practices of this winter (2014) to that of last year (2013) and noticed remarkable improvements.

For the month of November, which was 2% warmer on average as compared to 2012, the plant used 22% less natural gas for heating than during the same time period in 2012. Likewise, December, which was 24% colder on average, saw a 13% reduction in natural gas consumption, January was 3% colder and saw a 13% reduction in consumption, while February was 13% colder and saw a 22% reduction in natural gas usage. During this period it is estimated that PWC were able to off-set 761 tCO_2e and that 355,100 m^3 less natural gas was consumed. As a result, on average 17% less natural gas was used for heating, despite 10% colder temperatures throughout the winter season.

It is also estimated that during this period cost savings of roughly $290,000 occurred as a result of the project's implementation. Due to increases in prices if PWC had of continued heating their plant using strictly natural gas then, using 2012–2013 consumption volumes, roughly $1,164,895 would have been spent on plant heating as opposed to the $875,476 which was actually spent. This project clearly demonstrates the enormous opportunities available for companies to significantly reduce both their cost and emissions through WHR and energy recycling and is summarized in Table 1. It also serves as a positive example to companies who are considering implementing similar projects but are hesitant due to concerns of economic and other risks.

This project clearly demonstrates the enormous opportunities available for companies to significantly reduce both their cost and emissions through waste heat recovery and energy recycling and is summarized in Tables 1 and 2. It also serves as a positive example to other companies who are considering implementing similar projects but are afraid of economic risks.

Table 2. Summary of PWC's WHR project GHG reduction with cost comparison.

	GHG reduction (tCO_2e)	Consumption comparison	Cost comparison
Nov-13	210	-22%	-23%
Dec-13	148	-13%	68%
Jan-14	154	-13%	45%
Feb-14	249	-22%	20%
	761	-17%	30%

Table 3. Magna International Inc. waste heat recovery project summary.

Annual natural gas reduction	Annual CO_2e reduction (t)	Initial capital investment	Project annual savings
240,000	514	$180,000	$52,800

5.2. Magna International Inc.

Magna International Inc. is a global automotive supplier headquartered in Aurora, ON. With 316 manufacturing operations around the world and 46 plants in Canada alone, the company has invested numerous resources toward identifying areas of energy inefficiency and is continually improving their performance through the implementation of numerous energy conservation projects.

One of the main projects implemented at one of Magna's Canadian facilities during 2013 involved reclaiming waste heat from the flue gas stream of a hot stamping process. The outcome of the project is summarized in Table 3. Originally a direct usage approach for the flue gas stream was considered. However, it was later decided that bringing the air directly into the plant could pose too much of a contamination risk – even with adequate filters in place. As a result, it was decided that a heat exchange system would be installed to extract the waste heat from the flue stream and return it to the plant for heating purposes.

Through the project Magna estimates that 240,000 m^3 of natural gas will be saved at the plant, keeping approximately 514 tCO_2e out of the atmosphere annually. The project, with an initial investment of $180,000 is expected to have a payback period of 36 months (i.e. three years) and will save the company $52,800 annually. The company has also indicated that a number of government rebates and energy efficiency incentive programs could help them receive an additional $24,000 in energy rebates or almost 15% of the project's original capital investment. Magna, like Pratt and Whitney, has successfully demonstrated the economic and environmental benefits available to Canadian companies through the implementation of WHR and other energy efficiency initiatives.

6. CONCLUSIONS

It is quite possible for many industries and processes to become more energy efficient with very little overhaul of current facilities. It is also clear that one of the most effective ways this can be done is through wide-scale waste heat recovery. Waste heat recovery can provide both economic and social benefits by utilizing thermal energy that would otherwise be exhausted to the environment and wasted.

While making progress in the area of energy efficiency is often deemed to be too difficult, time-consuming, and expensive, in many instances the exact opposite is true. Often the savings available to manufacturers from energy efficiency projects, such as WHR, far outweigh any incurred project implementation costs, as can be seen from the case studies outlined in Section 6 above.

Currently, a number of barriers still exist to mass WHR technology deployment within Canadian industry including eliminating perceived economic risks and developing appropriate policy mechanisms to promote waste heat recovery development. Research and funding into removing these barriers from the field of energy recycling will go a long way to improving feasibility and visibility of these projects within industry. Governments must do their part to promote the development of WHR projects by increasing funding and implementing incentive programs. As well, an increase in the level of regulation surrounding energy recovery will help promote it within industry.

One of the major barriers of energy recycling remains the mind-set and attitude toward sustainable product development. Instead of viewing efficiency requirements as a problem, they should be viewed as a chance to simultaneously yield economic and environmental benefits. It has been shown that major reductions in industrial energy consumption are possible using current waste heat recovery techniques. If waste heat recovery is to become common place within industry, manufacturers must become open to the idea that energy reduction is worth the effort realizing that "*one of the greatest sources of untapped energy is the energy we waste*" [16].

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