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WASTE HEAT RECOVERY

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ABSTRACT

Fuels are one of the most common requirements in industries for heating/cooling processes or producing any form of work, but due to inefficiencies in many industrial appliances (machines, oven, furnaces, etc.), a lot of heat that is produced by burning fuels (like LPG, coal, fossil fuels) is getting wasted. This heat is directly released into the atmosphere after its original purpose has been served, which eventually leads to global warming. Waste heat recovery (WHR) is the study of reutilizing *this* heat for various other industrial processes based on the grade of heat loss. In this paper, a review of various articles that focuses on industries where WHR methods are used prominently has been provided.

***Keywords*—Industrial waste heat recovery, Oven, Furnace, Global Warming, Waste Heat Potential, Organic Rankine Cycle, Sustainable development, Renewable Energy.**

INTRODUCTION

With the increasing global trend, environmental concerns have become one of the most discussed topics all over the world. Industries in the modern era are trying to focus more on becoming utmost environment-friendly sites along with efficient production. Waste heat recovery with its wide range of applications and solutions provide both the above-mentioned advantages to the industries.

Industrial waste heat is regenerated in various industrial processes where directly or indirectly burning of fuel is involved. As we know, never, the entirety of the generated heat is utilized, hence resulting in the generation of waste heat. This waste heat is dumped or released directly into the atmosphere causing global warming. Depending on the exhaust temperature waste heat can be classified into three grades viz. High temperature (>400°C), medium temperature (200°C - 400°C), low temperature(<200°C), after having a brief idea of its potential and quality, appropriate WHR methodologies can be applied to obtain maximum efficiency.

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ABBREVIATIONS and ACRONYMS

WHR-Waste Heat Recovery
IWHR- Industrial Waste Heat Recovery
LPG- Liquified Petroleum Gas
NPG- Nonequilibrium Plasma Generator
MEW-Material Energy and Waste
MHD- Magneto-hydro-dynamic generator
EU- European Union

LITERATURE REVIEW

As we move forward along with the growing technologies the risk on our environment is also increasing. Industrial sector is one of the leading contributors towards pollution and global warming. Hence, use of Waste Heat Recovery Systems (WHR-S) in industry is one of the most crucial areas of research. These systems include regenerative and recuperative burners, Economizers, waste heat boilers, air pre-Heaters, plate heat exchangers, heat pipe systems, heat recovery steam generators, heat pumps, direct electrical conversion devices, that provide us a wide array of applications in various industries. Thermodynamic cycles such as Rankine Cycle and

Kalina Cycle can be referred for getting a clear idea for conversion of waste heat to electrical energy. Recovering waste heat in the low temperature range is considered to be more challenging than medium and high temperatures **[1].** As *Tianqi et al.* **[2]** demonstrates how organic Rankine cycle is used for waste heat recovery in a 'Proton Exchange Membrane Fuel Cell '(PEMFC). PEMFC is very efficient solution with very few emission-related issues then many other renewable sources of energy. Use of oil & natural gas for combustion in vehicles contributes largely towards production of greenhouse gases that leads to global warming and pollution. Also, these fossil fuels are non-renewable. Hence, using waste heat recovery systems that are based on Rankine cycle in vehicles plays a crucial role. For WHR in vehicles, selection of a proper working fluid, expansion device and heat recovery system are very important **[3].**

When we discuss about WHR in low temperature range, residential and commercial settings are best for research across the globe as the heat getting wasted in these settings is generally in low temperature range. Most of the energy is used for water heating and air conditioning. For WHR in this sector we usually focus on discarded heat from drains and condenser heat pumps **[4].**

EU nations being among the most industrialized nations, it showcases a great opportunity for research and application of waste heat recovery technologies. *Rafaela et al.* in **[5]** discusses about various conventional and new WHR technologies along with potentials. In EU nations, the largest amount of waste heat is in food and tobacco, pulp and paper, basic metals, chemical industry and non-metallic minerals. For adapting waste heat recovery, as a solution for environmental and economic challenges for a particular industry, it is very important to have a systematic and planned approach. It is also important to understand other options like renewable energy sources and energy management that can be utilized in the facility. Creating a framework of waste heat and its utilization is a great approach **[6].** Heat from flue gases is the most recognized form of waste heat in this study. But there can also be other sources of heat that are usually neglected. For example, heat from cooling water, heated wash water, blow-down water, hot products that are discharged after processing or after reactions are complete, hot by-products from processes or combustion of solid materials, steam leaks, hot surfaces etc. These sources can also be analyzed for getting better outputs from the setup **[7].** Economic analysis for entire setup for WHR becomes very important when we consider small- and large-scale industries. Return on investment (ROI) is one of the most crucial factors when we speak about profit of a particular industry. *Sarah Bruckner et al.* explains in **[8]** about a very generalized and efficient way for conducting economic analysis. The suggested method differs from commonly opted economic feasibility ones which uses payback period or interest rate as a decision-making factor for investments, both variable figures. This method analyses three different consumer types (Industry, real estate, enthusiast) and it shows the economic feasibility of the technology according to the consumer type and the technology operating hours.

The concept of energy security is context dependent; globally, energy security is defined as the availability of a regular supply of energy at an affordable price while respecting environmental concerns (European Commission, 2012). Therefore, policies and schemes relating to increasing efficiency in the use of fuel to improve global availability, reducing cost of energy, and reducing emissions are related to energy security **[9]**. Analyzing and studying various equipment used in industries helps us understand working requirements of WHR technologies. For this purpose, we study and analyze an MHD generator for NPG system which uses a light metal fuel for burning in pure oxygen to generate output power **[10].** By doing a thorough study on a local gas roasting oven that uses LPG as a fuel, helps us understand why it becomes important for us to use WHR where fossil fuels are involved. By increasing efficiency of these ovens, we reduce fuel usage and avoid unnecessary losses **[11].** Every technology that is introduced to humans cannot be directly manufactured without analytical and modelling data backing it up. By preparing a model, we get a clear idea of how system is actually going to work, combining this with economic data, we get the entire overview of the system. Perfect example for this would be an efficiency assessment done by *Iñigo et al* in **[12]**, where a systematic process evaluation based on modelling as well as a waste heat recovery evaluation for a continuous heat treatment process of an 'Aluminum Die-Casting plant' is performed. The process is represented by production and energy dynamic (time-dependent) models combining thermal phenomena with production and economic considerations. This helps us evaluate energy consumption, resource utilization and production plan **[12].**

Now, since we have abridged in detail about many different aspects regarding waste heat recovery, one that stands at pinnacle is the 'Heat potential' available for WHR. Waste heat potential can be defined as, amount of recoverable heat at a given temperature from the source. This typically depends upon the temperature of the source. Higher the temperature higher is the quality of waste heat, conventionally **[1].** In this review, we have studied and considered two different methodologies for estimating waste heat potential. *Sarah Brueckner et al in* **[13]** gives us categorized method to evaluate heat potential on industrial level. Besides the obviously necessary distinction between theoretical, technical and economic potential, we get a new approach that is classified in three dimensions: study scale, data collection and approach/perspective (bottom up vs. top down). Following this schematic, previous regional waste heat studies are reviewed. In **[14]** there is another method proposed by *Laia Miró et al* that revolves around transferring key figures among different countries and regions for better estimations. This is done since no accurate and specific data is available across the globe for WHR. In this literature, all the difficulties regarding transfer of data from one region to another is identified and reviewed. Three methods published in the period 2002– 2010 have been found in the literature, which are potentially transferable to other regions **[14].**

One of the most current and widely discussed factors that could lead to the ultimate end of man's existence and the world at large is global warming. Global warming, described as the greatest environmental challenge in the 21st century, is the increase in the average global air temperature near the surface of the Earth, caused by the gases that trap heat in the atmosphere called greenhouse gases (GHGs). These gases are emitted to the atmosphere mostly as a result of human activities, and can lead to global climate change.

Automotive industry is one of the major contributors of man-made CO2 gases. It shares approximately 17% in global warming by CO2. The desire of car makers for making heavy cars for luxury of people has caused more production of CO2. **[15].** With this scenario, all things being equal, more GHGs are expected to be emitted into the atmosphere, leading to more global warming.

By now we are familiar with the adverse effects of excessive use of fossil fuels. These options, along with being non-renewable they are also very harmful for our environment. Whenever we study about these fuels, discussion on sustainable development becomes more important. Sustainable development is defined as development of a society without compromising on resources for future generations. A sustainable society cannot be realized without more efficient approaches and technologies. A lower- level guideline is required for systematic analysis of manufacturing processes. Proper handling of material, energy and waste can help us achieve sustainability **[16].**

Lastly, heat can also be generated by using waste that Is created by our regular production and consumption. This can be an alternative to many fuels and energy recovery from waste represents an effective measure to reduce landfilling and avoid disposal emissions while simultaneously reducing the equivalent demand for primary energy supply. Municipal solid waste has seen increasing annual volumes for many decades in contemporary Europe and constitutes, if not properly managed, an environmental problem due to local pollution and greenhouse gas emissions **[17].**

CONCLUSION

In this study, we have reviewed various articles, literatures and thesis for getting an overall idea of Waste heat recovery. Waste heat recovery, is the need of the hour since our planet is going through a lot of damage that is caused by non-renewable sources of energy.

For summarizing, we can say that industrial waste heat recovery includes three basic steps;

1. Waste heat potential calculation.
2. Selection of appropriate WHR technology.
3. Economic analysis of that technology.

Waste heat potential calculations can be performed either by using existing data of that particular industry, or by transferring figures based on the climate and type of industry, or using instrumentation for recording all the required parameters. Based on these calculations, we can select appropriate technology for heat recovery. Selection of technology heavily depends upon heat potential as well as budget of the investor. Hence, a technology that fits perfectly in both the parameters can be consider perfect for that industry.

Economic analysis plays a crucial role in this entire process, because 'to make the facility profitable' is also one of the criteria of waste heat recovery. For economic analysis methods provided in this review are frequently used in industries.

Through this study of WHR, we understand why it is important for us to save fuels, reduce global warming and protect our environment, along with same production rate and industrial development. At places where we cannot use renewable energy sources, WHR can make thing easy. Also, we have hybrid options for using both of them at the same time.

Global warming is an alarming situation. We need to make for efforts towards environment-friendly technologies for sustainable development. We would like to conclude that, use of WHR systems in industries helps us save fuels that are non-renewable, helps us improve efficiency, reduces global warming and helps us develop sustainably.

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