A Systematic Review of Reduction of GHG Inventory in Automobiles Manufacturing Sector

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Abstract

A global movement, low carbon economies are being pursued by many nations to promote ecologically sustainable economic growth. For industrial sustainable growth, the accompanying Greenhouse Gas (GHG) emissions have grown to be a serious concern. Automobiles manufacturing sector is facing on-going challenge to reduce the GHG emissions in an effort to reduce the burden on the environment as well as to comply with the environmental regulations employed by different countries. As the number of automobiles manufactured is increasing every year so the GHG emissions associated with their manufacturing process, polluting the environment. First step in this process is the calculation of GHG emissions during the manufacturing process. Various research studies are showing the different GHG emissions level in different countries. This review article compares the GHG emissions per vehicle in different countries, which is due to different manufacturing techniques, energy mix and emission factors. Salon is responsible for 1.8 tons of CO_2 in Chongqing, China, which is an average sized gasoline car. SAIPA automobile manufacturing in Iran is reporting 0.69 tons of CO_2 per produced vehicle in their plant. GHG emissions during the manufacturing of the medium size passenger car is 6.5 tons of CO_2. In this study, relevant research articles have been compared to find out the most significant area in which improvement can be done and what improvements have been proposed so far.

Keywords: Automotive Manufacturing, Energy Consumption, Greenhouse Gas Emissions, Paint Shop.

1. Introduction

Recent trends in GHG emissions indicate a large rise; according to NOAA's Global Monitoring Lab, only CO2 emissions increased over the past 40 years, rising from about 339 ppm to 414 ppm. The main GHG gases released by various businesses are CO_2, CH_4, and N_20, with CO_2 being the main cause of climate change. Given that the industrial sector is responsible for 10% of global greenhouse gas emissions, industrial sustainability should be a priority for all industrial activities. Through sustainable challenges, governance structures, steering committees, councils, and adherence to local rules and regulations, sustainable development is the secure path to a more sustainable and environmentally friendly planet.

The automobile sector is an important part of the manufacturing sector and transportation is the basic need of every human now. Production of vehicles is increasing every year with the increasing population of the world so as the GHG emissions from the manufacturing of these automobiles. In this regard, it is important to gather global studies on the quantification of greenhouse gas (GHG) emissions from the production of automobiles (Tan et al., 2011).

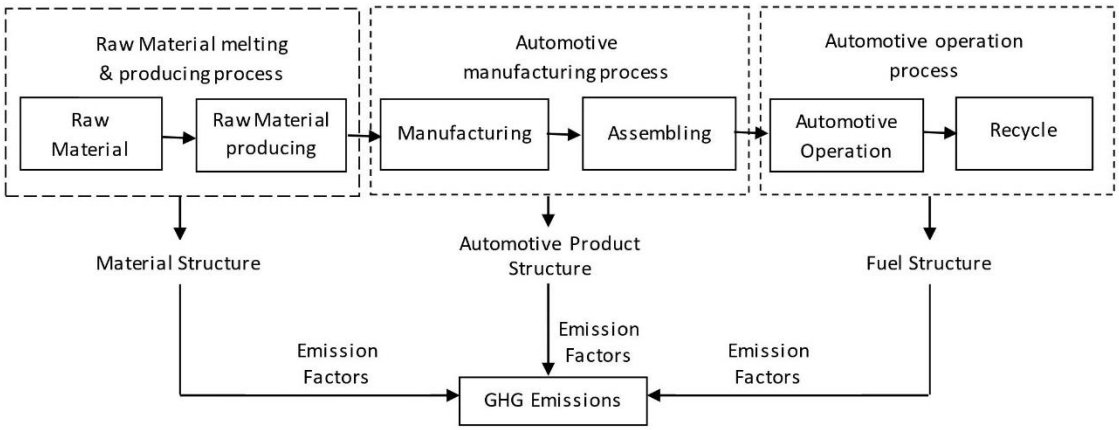

Figure 1. Automotive industry whole life cycle GHG emission calculation roadmap

After the quantification of the greenhouse gas (GHG) emissions through Lifecycle analysis (LCA), next step is to identify the significant areas in the automobile manufacturing. In this study, reduction opportunities have been explored from various research literature studies so as to identify the possible reduction opportunities and to classify them with respect to their volume.

1.1 Objectives

The objective of this study is given below in the form of a research question:

1. What is the most significant area in automotive manufacturing in which reduction of greenhouse gases can be made?
2. What are the possible energy & GHG reduction opportunities in that area along with the percentage of energy savings?

2. Literature Review

The automotive industry is an example of a conventional industrial sector that has produced billions of vehicles for use in modern society. Global vehicle production increased quickly over the previous century due to persistent economic growth, reaching an all-time high of 90.8 million in 2015. Automobile sector is now a major user of energy in the world and a significant cause of greenhouse gas (GHG) emissions during its lifecycle. Focusing on automobile manufacturing process, it uses a substantial amount of energy to produce a single vehicle. Every year, millions of tons of greenhouse gases (GHG) are released into the environment as a result of the production of vehicles. According to estimates from the International Energy Agency (IEA), 37.4% of the world's energy-related CO2 emissions in 2013 came from the manufacturing and construction sector, to which the automotive industry contributes significantly.

Despite the benefits vehicles bring to the society, they have caused significant energy and environmental concerns. Especially, as the external effect of vehicle production, millions of tons of Greenhouse Gas (GHG) are emitted into the atmosphere every year. As estimated by International Energy Agency (IEA), CO2 emissions from the manufacturing and construction sector, to which the automotive industry is an important contributor, accounted for 37.4% of global energy-related CO2 emissions in 2013 (Hao et al., 2017)

According to data from the European Commission, transport is the only major sector in the EU where greenhouse gas emissions are still rising. The increasing urbanization of world population and the complexity of achieving sustainable mobility arises, in part, because many cities require reconstruction to accommodate mass-transit to reduce greenhouse gases (GHG) emissions, as well as the accommodation of alternative fuels and the reduction of fossil fuels with the advent (Morgadinho et al., 2015).

China produces passenger cars with ordinary internal combustion engines with GHG emissions rate of 9.6 tons per vehicle, which is 54% more than the US which is doing the same at the rate of 6.2 tons per vehicle (Tan et al., 2011). In china, an internal combustion engine vehicle production consumes 63.5 GJ of energy and greenhouse gas emissions of 10.0 t CO2e (Hao et al., 2017). In Iran, each vehicle produced had a carbon intensity of 0.69 tons of CO2e, with purchased electricity and production processes responsible for 50.5% and 49.5%, respectively, of greenhouse gas emissions reported by SAIPA (Javadi et al., 2021).

According to the studies, automobile manufacturing has the energy consumption paint shop (27-50%), HVAC (11-20%), lighting (14-15%), compressed air (9-14%), welding (9-11%) and materials handling/ tools (7-8%) (Giampieri et al., 2019).

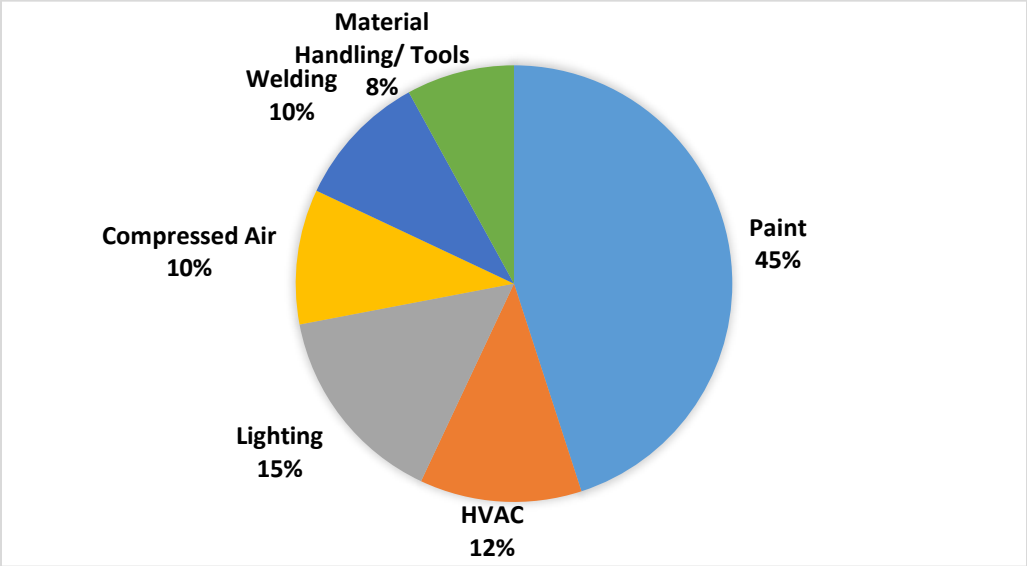

Figure 2. Energy consumption of processes of automotive manufacturing

Looking at the pie chart, it is quite evident that paint is the single most energy consumer in the automobile manufacturing setup. Paint shop is the place where painting of the automobiles along with their paint curing is done. If we look deep into the paint shop, energy consumption is further sub-divided to the pre-treatment (14%), building (11%), electro-dip coating (10%), booths (13%), ovens (31%), work decks (13%) and rest (8%) (Zahler & Iglauer, 2012)

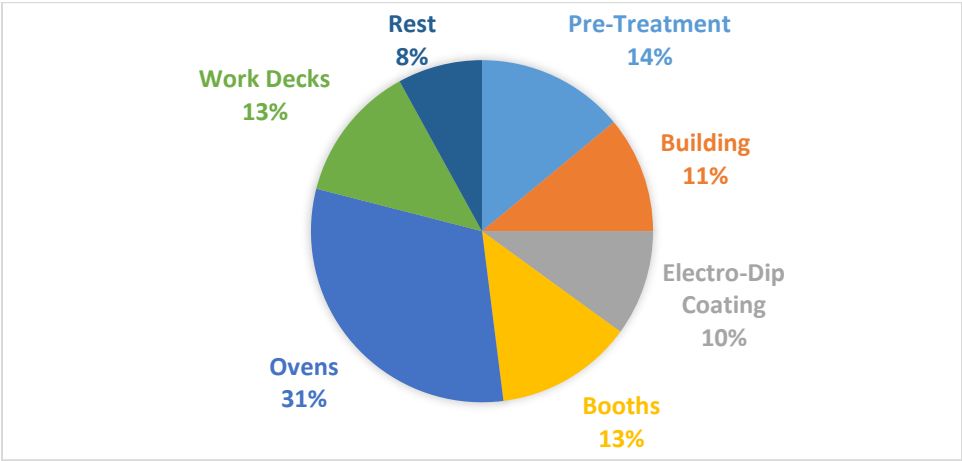

Figure 3. Energy consumption of processes of automotive paint shop

Table 1. GHG reduction studies

Sr No	Author /year	Title	Methodology	Findings
1	Feng and Mears. (2015)	Analysis of HVAC Energy in Automotive Paint Shop	Thermodynamic Simulation Modeling	The painting process uses 60% of the total energy used in automotive assembly plants. The highest savings from altering the operation methods (in this case, changing the setpoint) may be accomplished is 6.3%, which will result in a 21% reduction in emissions to the environment
2	Giampieri et al. (2019)	Moving towards low-carbon manufacturing in the UK automotive industry	Policies	Energy usage in automotive manufacturing for paint shop (27-50%), HVAC (11-20%), lighting (14-15%), compressed air (9-14%), welding (9-11%) and materials handling/ tools (7-8%). Better humidity control strategy along with excess heat recovery can reduce the energy consumption in HVAC and improve paint quality.
3	Daniarta et al. (2022)	Waste Heat Recovery in Automotive Paint Shop via Organic Rankine Cycle and Thermal Energy Storage System—Selected Thermodynamic Issues	Thermodynamic Simulation Modeling in MATLAB with CoolProp	The energy consumption of the press, body, paint, final assembly, and other processes is 12%, 10%, 36%, 10%, and 32%, respectively. With an overall ORC efficiency of 6.7-11%, 800 kW of generated waste heat from the oven may be recovered to provide the net power of 53-89 kW.
4	Zahler and Iglauer. (2012)	Solar process heat for sustainable automobile manufacturing	Pilot Project	Convection ovens, which are normally powered by gas burners and account for 31% of all energy used in paint shops. A solar portion of 25% can be achieved for the ovens with only 250 working days per year and without storage. The solar fraction can be raised even more through the integration of a storage or an absorption chiller.
5	Rao and Gopinath. (2013)	Energy Savings in Automotive Paint Ovens: A New Concept of Shroud on the Carriers	CFD Modeling	In a paint shop, more than 70% of the total energy required for car production is used. When the shroud was used in a real oven with an SUV's BiW, the energy used by the carriers was reduced by almost 20%.
6	Oktaviandri and Safiee. (2018)	Modelling Electrical Energy Consumption in Automotive Paint Shop	Thermodynamic Simulation Modeling	Energy use can be decreased by up to 30% by running Primer and Top Coat for only half the normal working hours. It is possible to achieve energy consumption savings of about 1.42% and a maximum demand decrease of about 1.27% by switching out a high power compressor with a lower power compressor.

3. Methods

As this is a review article, so methodology will be to compare the research articles published in the last 10 years about the reduction of greenhouse gas emissions in the automotive manufacturing sector.

4. Data Collection

Data is collected from the research articles with the system boundaries of manufacturing process only with the approach of cradle to gate approach and operation phase of automobiles is not included in this study.

5. Results and Discussion

As the paint shop is the major energy consumer in the automobile manufacturing setup evident from the literature, so in depth focus on optimization strategies was given to the paint shop to reduce the energy consumption and subsequently greenhouse gas (GHG) emissions. Renewable energy in terms of both solar and wind power depending upon the location of the automobile manufacturing plant, can greatly help to offset the energy requirements of the paint shop. Ovens are the major energy consumer in the paint shop, which helps to cure the paint on the vehicles can be shifted to solar powered paint ovens to the tune of 25-50% solar fraction. HVAC system of the paint shop is a promising area in which better humidity and temperature control through integrated energy management system specially Integrated building management system (iBMS) can help to reduce the energy consumption significantly by installing the sensors on the ventilation to make it demand controlled ventilation and also to recover the energy by energy recovery ventilators and heat exchangers.

5.1 Graphical Results

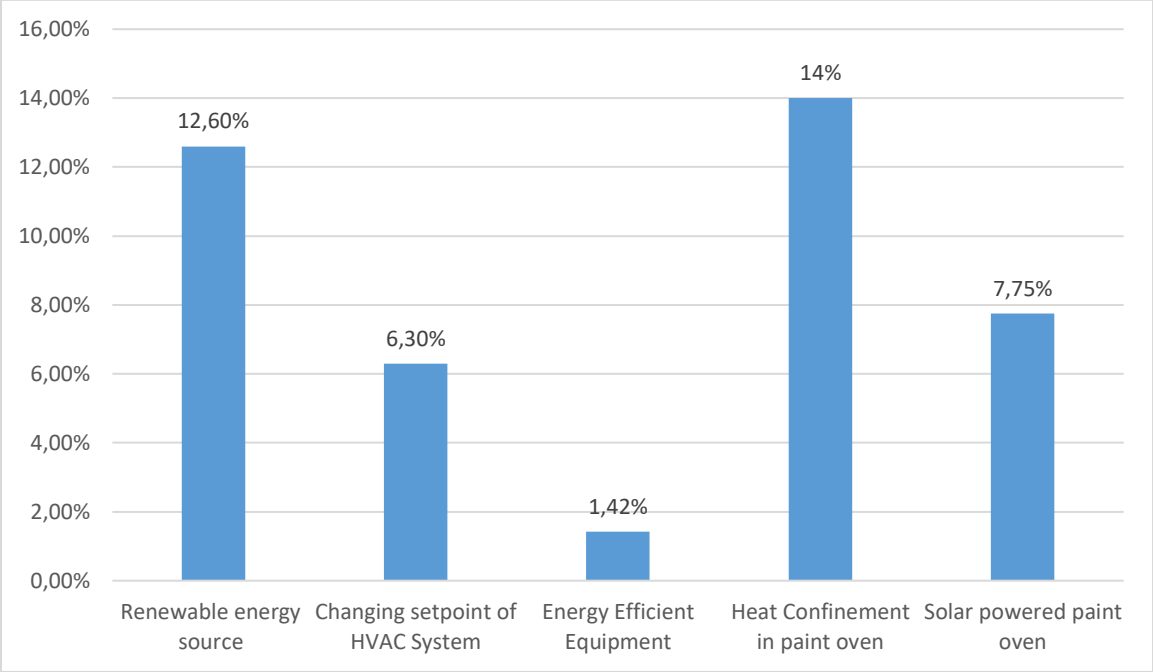

Figure 4. Energy reduction opportunities in paint shop

5.2 Proposed Improvements

As seen from numerical and graphical results, it is evident that paint shop is a promising area for working on reduction of energy consumption and as well greenhouse gases (GHG) reductions.

Potential area is integrated energy & HVAC management system exclusively designed for the paint shop along with heat recovery is the future work in this field. HVAC system of the paint shop is a promising area in which better humidity and temperature control through integrated energy management system specially Integrated building management system (iBMS) can help to reduce the energy consumption significantly by installing the sensors on the ventilation to make it demand controlled ventilation and also to recover the energy by energy recovery ventilators and heat exchangers.

6. Conclusion

Through this study, HVAC system in the paint shop is emerged as the promising area to work in the future to help offset energy requirements in this energy intensive area. Renewable energies are also promising towards the energy reduction of the paint shop and confinement of the heat inside the ovens is reduction possibility on the bigger scale which has been explored as the pilot project till to-date.

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