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Editor in Chief
Dr. Selahaddin Orhan AKANSU

HYDROGEN ROMANTIC

by Anna Green

About the Book

The idea of the Hydrogen Romantic book came to my mind after working for several years with the leading hydrogen energy scientists and observing their activities. One of those scientists, Dr. Turhan Nejat Veziroglu, has devoted his life to this topic, becoming much loved and respected around the world. In addition to all the momentous events in which Dr. Veziroglu has been involved, his memories are very interesting. Such a life is almost like navigating the pages of history, allowing admirers to gain information without being bored. I asked him to spend one hour with me every day, so I could interview him. During those one-hour periods, I asked him questions, and I recorded his responses. After I finished the interviews, I listened to the recordings. From this, I wrote the book. In addition, I did research on the sections dealing with the historical events. I've added this research as narratives in the book.

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PREFACE

Dear readers, researchers, scientists and industrialists,

The developments about energy and environment are changing rapidly in the whole world. Each living thing needs energy to live. Environment which has a vital importance for life is affected in the result of energy usage. For the reason of not using the environment in the correct manner, our world has been exposed to global warming. The damage that is given to the environment must be in the minimum grade during producing and consuming the energy, which is an indispensable element of many areas such as life, comfortability, production, and so on…

Scientists and industrialists are making intense studies, research and developments, about clean, sustainable, renewable, portable, and different resources originated procurable energy applications. Beside these storage of the energy in appropriate conditions is needed in terms of sustainability.

In this scope, Erciyes Energy Association, targets to provide a different dimension to its studies by making scientific studies, gathering the researchers, who make studies about energy and environment subjects, together in the scientific activities that are organized via its structure, making research and development works in the areas in question by following the innovations with the technology, giving technical educations in terms of supporting the young scientists who wants to work in these subjects, and generating not only domestic but also international collaborations.

In accordance with these purposes in the international activity named as "International Conference on Energy, Environment and Storage of Energy (ICEESEN)", which is started to be arranged in 2020, the technological developments about energy and environment was discussed with many participants coming from many countries.

In order to share the qualified studies made in similar subjects together with the studies made in this activity, an international journal named as “Energy Environment & Storage (enenstrg)” was published in the beginning of year 2021.

“Energy Environment & Storage” has an editorial board in which international prestigious scientists takes place. The studies that are published in the scope of the journal are exposed to extensive assessment of specialized arbitrators.

We are happy to present the first issue of “Energy Environment & Storage” journal that is based on providing contributions to the science World, and we hope to meet in next issues.

Dr. S. Orhan AKANSU

AIM AND SCOPE

Energy, Environment and Storage papers consider the prospects of energy technologies, environment, materials, process control and industrial systems. The Energy, Environment and Storage will be published 3 times per year.

Contributions describe novel and significant applications to the fields of:

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- Aerospace and Energy Applications
- Combustion
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- Off-grid Energy Systems
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- Water and Wastewater Pollution
- Water and Wastewater Management
- Waste Management
- Global Warming and Climate Change
- Environmental Ecosystem
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- Ecological Applications or Conservation

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Research Article *Energy, Environment and Storage* (2021) 01-01-1-6

Energy, Environment and Storage

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Numerical Investigation of The Effect of Finned Obstacle on Heat Transfer Characteristics in a Rectangular Channel

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ABSTRACT: Nowadays, with the development of technology and science, heat transfer holds an important place in engineering applications. In industrial areas, heat increases give rise to overheating, causing system errors. Passive techniques are frequently used to prevent from such disruptions. In this work, fins which are passive techniques which provide heat transfer development with high efficiency and low cost were investigated. To improve heat transfer, finned structures should be well optimized. On the other hand, the designer can prevent mixing the incoming air with the heated air with a bad design, which may cause a negative effect rather than improve heat transfer.In this work, in contrast to previous works that is smooth tube and 0 degree rectangular finned tube, four fin structures were designed and flow and heat-transfer characteristics numerically analyzed. These are crescent finned tube, 20 degree symmetrical imperforated rectangular finned tube, 20 degree asymmetrical imperforated rectangular finned tube and 20 degree symmetrical perforated rectangular finned tube banks with six rows. In this investigation, the geometric parameters were not changed and their effects on flow and heat transfer properties in different Reynolds numbers on these models were examined.The results indicate that the symmetrical structure has better heat transferability and higher friction loss compared to the asymmetrical structure and the perforated fin is higher than imperforated fin but the overall performance is not always superior. Therefore, both symmetrical and perforated finned tube is designed and analyzed with the highest heat transfer potential, it is seen that in terms of heat transferability this model is better than other designs.

Keywords:Finned-tube heat exchangers, Nusselt number, CFD-Fluent, Performance evaluation criteria, Model analysis, Numerical simulation.

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1. INTRODUCTION

Many overheating can cause some problems for industrial applications. Active and passive methods to overcome this heating problem has been described [1]. One of them is active methods [2]. In these methods, mixing the liquid, vibrating surface; Some external power output is needed, such as Magnetic field use and jets shot is needed as some external power output. Another method is passive methods [3]. Additional geometric or surface modification techniques often implemented in devices such as existing material or expanded surface [4].

Expanded surfaces, one of the passive methods, are widely used in engineering disciplines that require heat movement related to energy transitions. Addition the component named fin to the heating surface improves the convective heat transfer coefficient or increases the heat transfer area of the surface, which leads to an increase in heat dissipation performance, maintaining the reliability and durability of devices. Since they are proven to be easy to manufacture, inexpensive and efficient, fin arrays are used in heat exchangers, cooling of gas turbine blades, cooling of electronic devices and other application areas that require high heat flux removal rates [5-8].

With each new design, the thermal losses of power electronic devices increase and the dimensions decrease, so various fin geometries such as rectangular, cylindrical, ring, pin wings and square are used to strengthen the heat transfer area of the surface[8-14].

2. MODEL DEFINITION AND NUMERICAL SOLUTION METHOD

2.1 Physical Model

Figure 2.1 and figure 2.2 demonstrate the schematic diagram of the six-row circular pipe set and the geometric definition of the finned pipe.

Figure 2.3 - 2.7 represent the geometric shapes 0 degree rectangular finned tube, crescent finned tube, 20 degree

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symmetric imperforated rectangular finned tube, 20 degree asymmetric imperforated rectangular finned tube and 20 degree symmetric perforated rectangular finned tube respectively. Air flows over the model in the xdirection. Figure 2.2. shows the geometric properties and structure of the finned piece. The abbreviations Fw, Fh, Fp, Di, Do, S_1 and S_2 are fin width, fin height, fin pitch, inner diameter, outer diameter, transverse and longitudinal pipe spacing, respectively. The fins are spread evenly around the pipe and are advanced in the Z direction. The scheme of the pipe row arrangement and the geometric details of the finned tube are as follows;

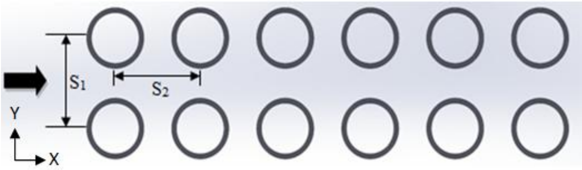

Figure 2. 1. Pipe set sequence.

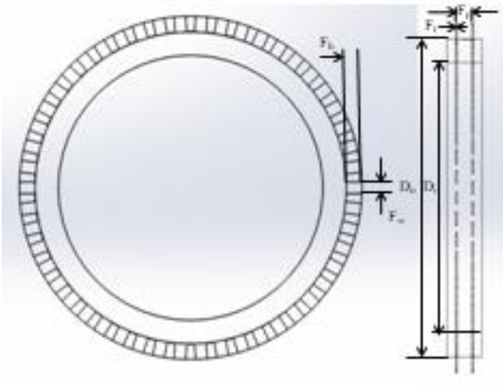

Figure 2. 2. Geometric definition of finned tube.

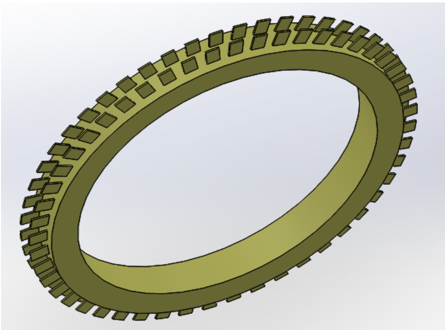

Figure 2.3. 3D view of 0 degree rectangular finned tube, Model 2

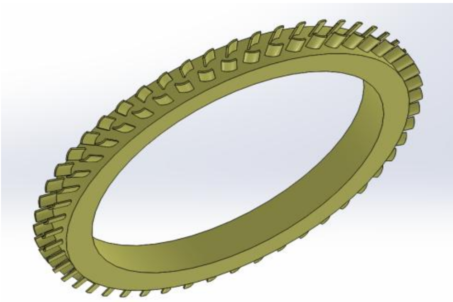

Figure 2. 4. 3D view of crescent finned tube, Model 3

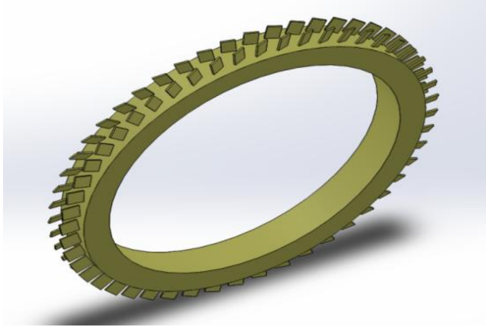

Figure 2. 5. 3D view of a 20 degree symmetric imperforated rectangular finned tube, Model 4

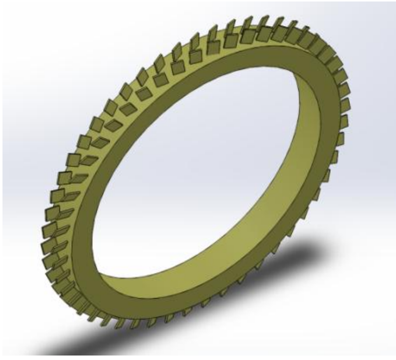

Figure 2.6. 3D view of a 20 degree asymmetric imperforated rectangular finned tube, Model 5

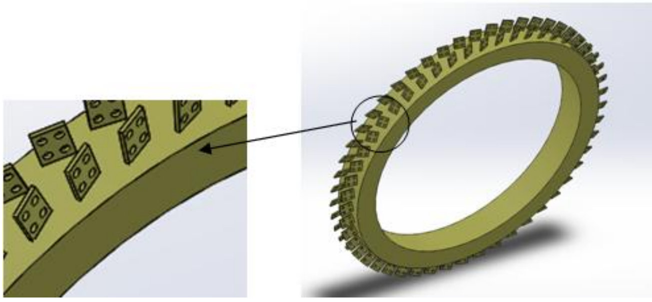

Figure 2. 7. 3D view of a 20 degree symmetrical perforated rectangular finned tube, Model 6

Table 2.1. Geometric parameters of finned tube clusters (six rows).

D_0 (mm)	D_i (mm)	$\frac{S_1}{D_0}$	$\frac{S_2}{D_0}$	$\frac{F_h}{D_0}$	$\frac{F_w}{D_0}$	$\frac{F_p}{D_0}$	Ft (mm)
40	34	1,5	1,5	0,05	0,04	0,05	0,2

Table 2.2. Smooth tube and finned tube models

Model 1	Smooth (without fins around) tube
Model 2	0 degree rectangular finned tube
Model 3	Crescent finned tube
Model 4	20 degree symmetric imperforated rectangular finned tube
Model 5	20 degree asymmetric imperforated rectangular finned tube
Model 6	20 degree symmetrical perforated rectangular finned tube

2.2 Boundary Conditions

The calculation area consists of eight boundaries as shown in Figure 2.8: Inlet velocity, outlet pressure, two symmetrical boundaries, two periodic boundaries and two wall boundaries. The boundary conditions of the computational area and finned tube wall are as follows;

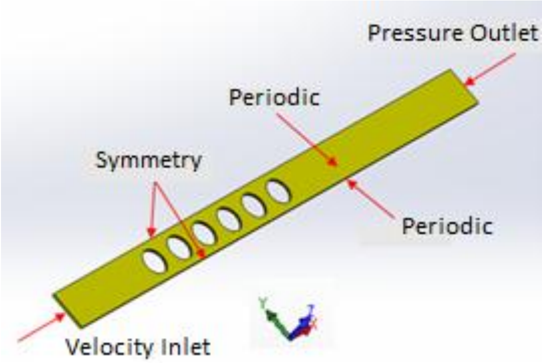

Figure 2. 8. Boundary conditions of the computational area.

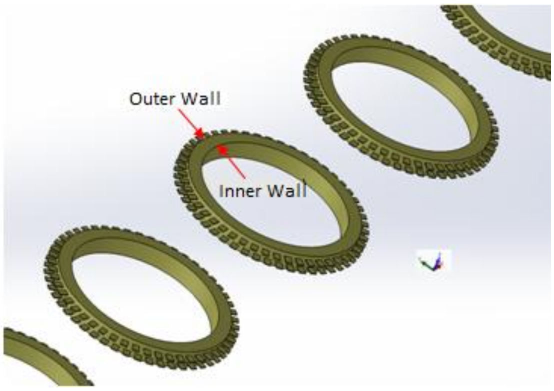

Figure 2. 9. Boundary conditions of the finned tube wall.

The working area is extended to three times the pipe diameter in upstream and seven times the pipe diameter in the downstream to stabilize the velocity at the inlet and avoid creating a non-recirculating flow at the outlet. At the entrance, the air enters the calculation area along the x direction at a constant temperature (423 K).

2.3 Numerical Solution Method

Finite volume method based on computational fluid dynamics software ANSYS FLUENT was used to solve a series of smooth finned tube.To guarantee accuracy and improve convergence, the Coupled - Pseudo Transient algorithm was chosen to solve the pressure and velocity domain. Standard discretization programs for pressure terms and quadratic spatial extraction arrangements for convection and discretization terms are used. Convergent criteria were defined for all simulations. Therefore, their residual values are less than 10^{-6} for energy equation and 10^{-4} for other equations.

2.4 Mesh Production

The computational area created using GAMBIT program is shown in Figure 2.10-14. This entire computing area consists of three parts: the entrance zone, middle zone, and exit zone. Different mesh shapes were applied to different regions. We applied a structured hexagonal mesh for both the entrance zone and exit zone. Because the fluid and interface of the finned tube are irregular and complex, an unstructured tetrahedral mesh has been applied to the central region. Moreover, a finer tetrahedral mesh was applied to the pipe wall region to ensure computational accuracy. Computational mesh configuration is as follows;

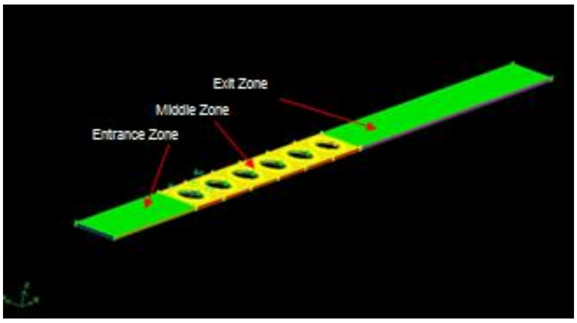

Figure 2. 10. General mesh area.

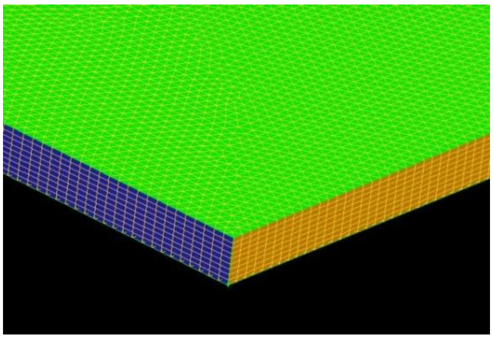

Figure 2. 11. Part of the entrance zone mesh

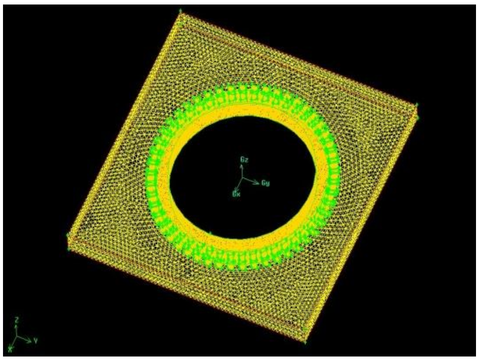

Figure 2. 12. Part of the middle zone mesh.

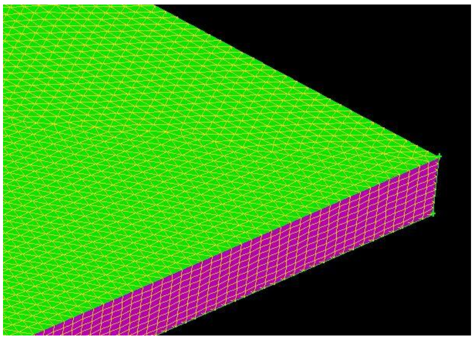

Figure 2. 13. Part of the exit zone mesh.

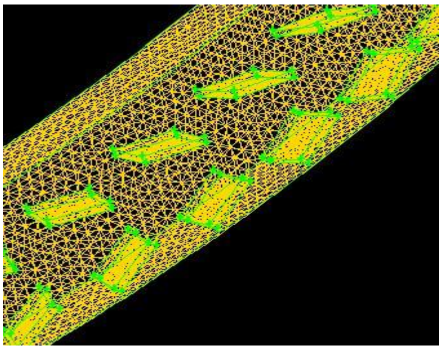

Figure 2. 14. Part of the finned tube mesh structure.

2.5 Mesh Independence

Mesh independence testing is necessary to ensure the accuracy of the numerical results obtained as a result of the analysis. Two separate works were made for approximately 2 million and 6 million meshes. When Re = 6000, Nu values were obtained as 48.08 and 50.55, respectively.Here, number of mesh was chosen as 6 million cells. Therefore, the mesh structure was adjusted to be around 6000000 in each geometry.

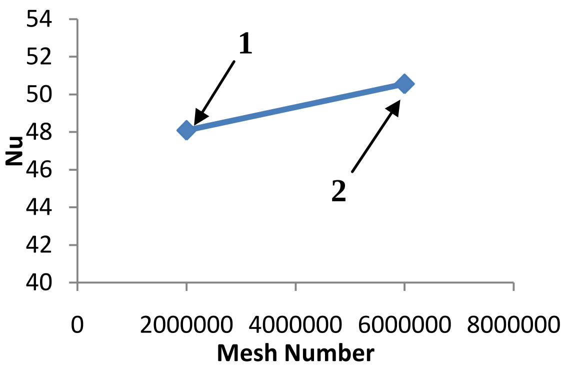

Figure 2. 15. Mesh structure vs Nu

It was inevitable to demonstrate the accuracy of the model and the solution method to ensure the accuracy of the simulation results. Because there was no experimental data for the finned tube in this study. Therefore, a numerical analysis was performed on a smooth pipe for verification. The smooth pipe used has the same geometry parameters as the set of smooth pipes tested by analysis.

The inlet velocity is 2-10 m / s in the range of values corresponding to Re number between 5000 and 10,000. Figure 2.16 shows the comparison of numerical resultsand experimental correlations [15,16]. When the results obtained in the verified Model 1 are compared with the correlations of Nu-Lu and Nu-Zhukauskas, validation has been achieved since we reached close values.

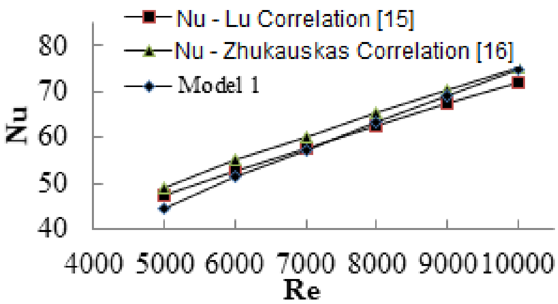

Figure 2. 16. Comparison of numerical results and experimental correlations

Consistent results between both numerical computation and experimental correlation results in Model 1 show that the applied numerical solution method can accurately predict the heat transfer and flow properties of finned tube arrays.

After verification, the results were obtained by analyzing Model 3, Model 4, Model 5 and Model 6.

2.6 Model Validation

Table 2.3. Pressure, velocity and temperature data of models at Re = 4000

	Re=4000					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Pressure (Pin-Pout)	32-6	315.7-12.5	43.9-6.3	49.3-6.4	49.3-6.4	48-6.4
Velocity (Maximum)	5	14.2	5.43	5.98	5.9	5.9
Temperature (Finned circumference)	330-396	313-390	318-417	319-417	318-418	319-418

Table 2.4. Pressure, velocity and temperature data of models at Re = 6000

	Re=6000					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Pressure (Pin-Pout)	60-9.8	1918-65.1	84.7-10.4	94-10.7	91.8-10.7	91-10.7
Velocity (Maximum)	7.18	37.9	7.78	8.39	8.29	8.28
Temperature (Finned circumference)	316-396	318-417	318-418	319-418	319-418	319-418

Tablo 2.5. Pressure, velocity and temperature data of models at Re = 8000

	Re=8000					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Pressure (Pin-Pout)	95.4-14.6	4641.9-149.2	138.5-15.6	152.4-15.9	148.2-15.9	146.6-15.9
Velocity (Maximum)	9.39	62.8	10.2	10.8	10.7	10.6
Temperature (Finned circumference)	316-409	318-412	319-417	318-418	319-418	319-418

3. CONCLUSIONS AND RECOMMENDATIONS

Basically, model validationwas done toconfirmtheaccuracy of thisstudy [17]. As a result of thiscomparison, compliance has beenachievedaccordingtoreference [17]. Itwasobservedthatbetterresultswereobtained in terms of heat transfer in Model 2, which has thesamevalues as theliteraturebetween Model 1 and Model 2. Andthen Model 3, Model 4, Model 5 and Model 6 weredesignedandanalyzedandcomparedwiththespecified Reynoldsrange (2000-10000) using CFD-FluentCode [18].

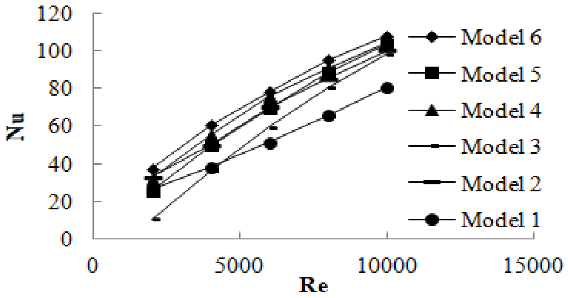

Figure 3. 1. Comparison of performanceparameters (Re-Nu) in finnedtubes.

As shown in Figure 4.1 Nusselt number is one of the most important parameters used in the heat transfer comparison. According to the increasing Reynolds number, designed model shows the variation of the Nusselt number. Nusselt numbers of the models increase with the increase of Reynolds numbers. As can be seen, in the specified Reynolds range, the Nusselt number, in other words, the heat transference, is the highest geometric design in the 20degree symmetrical perforated rectangular finned tube (Model 6), while the lowest geometric structure is seen in the smooth pipe (Model 1). Thelowest Nusselt number was obtained from crescent-finned tube (Model 3) among the designed models.

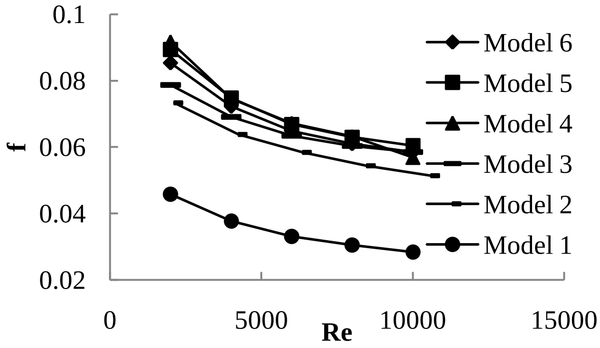

Figure 3. 2. Comparison of performance parameters (Re-f) in finned tubes.

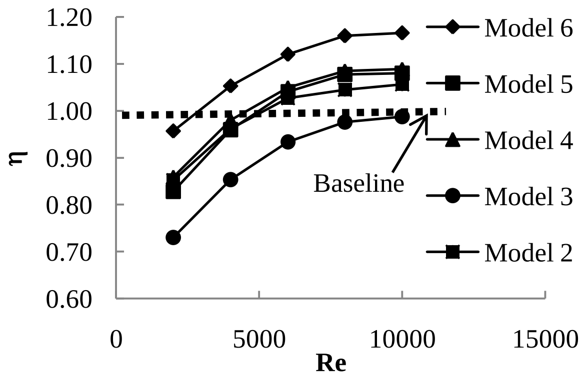

Figure 3. 3. Comparison of performance parameters (Re-η) in finned tubes.

Nusselt number is the most significant indicator of the heat transfer improvement method. In addition to this, the friction coefficient is another important parameter. The thermal performance factor obtained from the Nusselt and friction factor is an indicator of how much the heat transfer amount has improved compared to the previous situation. Analyzes were performed using CFD-Fluent Code [18] (Standard Model was selected as k-ε model and Enhanced Wall Treatment was applied near the wall) according to 6 different models and 5 different Reynoldsnumbers. While performing the analyzes, the flow and heat transfer properties of these models designed at different Reynolds numbers were examined by keeping the geometric parameters constant.

As a result of the analysis, it has shown that the performance evaluation criteria are not always superior to Model 1 taken as the baseline.

It has shown that the symmetrical structure has a higher heat transfer and friction loss compared to the asymmetric structure and perforated finned geometry has a higher heat transfer and friction loss compared to imperforated finned geometry. Based on this, when both symmetrical and perforated finned pipes (Model 6), which have the highest heat transfer potential, are designed and analyzed. It has been seen as a result of the analysis that they can transfer heat better than other finned pipes.

Furthermore, in this work, Nusselt numbers (Nu), friction losses (f) and performance evaluation criteria (η) were calculated against Reynold numbers and the results were analyzed using the CFD-Fluent Code [18].

- The model is consistent with the literature.
- The highest Nusselt number was obtained in Model 6, andtheleast in Model 1.
- The friction factor decreases as the Reynolds number increases and occurs at least Model 1.
- As the Reynolds number increases, so does the performance evaluation criteria. Performance evaluation criteria are mostly seen in Model 6. The structure with the least evaluation criteria is Model 3.
- Each model designed was found to have a higher Nusselt number than a straighttube (Model 1), but the crescent finned tube (Model 3) was worse in its design than the straight tube as opposed to improving the heat transfer, but resulting in more friction loss due to the finned structure of the design.
- The 0 degree rectangular finned tube (Model 2) has an advantage over the smooth tube (Model 1) in terms of heat transferability. Furthermore, more friction loss was determined as expected due to its fin structure.
- As a result of the analyzes made by changing the fin profile, it has been calculated that the heat transfer is at most 20 degrees symmetrical perforated rectangular finned tubes (Model 6).
- Numerical data for Nu and f correlate well; this can aid engineering applications of the heat exchanger for clean gas situations.
- In subsequent studies, analysis can be made by changing the finned angles or increasing or decreasing the number of holes on the finned structure.
- It will be appropriate to make designs according to the appropriate Reynolds number when it is desired to increase the heat capacity in machines such as economizers, recuperators, heat exchangers.

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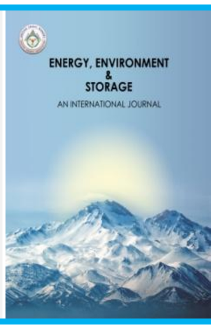

Evaluation of Carbon Footprint in a Waste Recovery/Recycle Facility

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ABSTRACT. The greatest danger for a healthy world is releasing greenhouse gases into the environment as a result of the industrialization activities in all countries. These released gases play an important role in damaging the health of human beings as well as of destroying nature. In addition to sustainable development practices in order to reduce emissions, it is also necessary to implement clean environment rules. In this study, the carbon footprint of a Waste Recovery/Recycle Facility within the borders of Kayseri Province as results of its operations was evaluated. Correspondingly, the amount of carbon footprint of transportation of waste collection, heating, and electricity usage in the plant site during operations has been examined. Tier 1 and Tier 2 methodologies developed by the Intergovernmental Panel on Climate Change (IPCC) were used to determine the carbon footprint of the facility. As a result, transportation activity due to waste collection contributes to the highest share of carbon footprint with 76.8%. The carbon footprint, which is caused by consumption of natural gas for heating with 23.1%, follows the transportation. Electricity usage has a share of less than 0.1%. The total CO_2 emission of the plant was 132711 tons, while the CO_2 emission amounts of transportation, heating and electricity use were found to be 102000 tons, 30700 tons and 11 tons, respectively.

Keywords: Greenhouse gases, sustainable development, waste recovery, CO_2 emission, carbon footprint.

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1. INTRODUCTION

The international policy community is highly concerned with anthropogenic CO_2 emissions, as it is believed to trigger global warming and its consequences can adversely affect global welfare. The largest share (58.6%) contributing to greenhouse gases is CO_2 emissions released from the burning of fossil fuels. Other contributing gases are total collective CH4 and N2O, respectively 14.3% and 7.9% in terms of CO2 equivalent [1].

With the scientific evidence obtained within the scope of the World Meteorology Organization (WMO) Global Climate Research and Monitoring Project, it was stated that human activities damaged the global climate balance in the first half of the 1970s, and the First World Climate Conference was held in 1979 under the leadership of WMO [2,3]. In this conference, where the first serious step was taken in order to protect the global climate system, the importance of the issue was brought to the attention of the world countries for the first time [4]. In the "Changing Atmosphere Conference" held in Toronto, Canada in 1988, the IPCC was established with the joint initiative of the United Nations Environment Program and the World Meteorological Organization [5]. The Panel, established to assess the risks of climate change caused by human activities, is an international organization [6]. The first and most important step taken in the international arena was the United Nations Framework Convention on Climate Change (UNFCCC), which was opened for signature at the United Nations (UN) Environment and Development Conference held in Rio de Janeiro in 1992. It entered into force in 1994 [7,8]. In this agreement, Turkey has been involved in both Annex I that requires historical responsibility and Annex II that requires financial responsibility [9]. As the UNFCCC could not determine a work program based on precise data to reduce carbon footprint and could not cooperate between countries to reduce greenhouse gas emissions, different regulations are required to reduce greenhouse gas emissions in the fight against global warming. At the 3rd Conference of the Parties held in 1997 in Kyoto, Japan, the Kyoto Protocol, which is a recommendation and has a binding feature to cover the gaps in the UNFCCC, was established and entered into force in 2005 [10,11]. In this conference, many countries supported the reduction of greenhouse gas emissions by 15% of the 1990 level until 2010 [11]. The agreement, to which 196 countries are

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parties, has reached a wide participation and has the highest number of participants among international environmental agreements [4].

The atmospheric greenhouse gas stock needs to be stabilized below 550 ppm in carbon dioxide equivalent to provide the 2^{o}C target [1,12]. Therefore, all countries are making efforts towards sustainable production in order to determine their greenhouse gas inventories and reduce CO_2 emissions all over the world. With the Kyoto Protocol, climate change issues occupy an important place in the political and institutional agenda of the countries and the countries that signed the protocol have accepted their responsibility to take action against global warming [13].

The term of carbon footprint was derived from the concept of ecological footprint and can be defined as measure of the total amount of CO_2 emission caused by a direct or indirect activity or by a product at each stage of its life in nature is defined as the carbon footprint [14-16]. The direct carbon footprint refers to carbon dioxide emissions from the combustion of fuels including consumed for heating and transportation purposes. Indirect carbon footprint covers carbon dioxide emissions caused by the entire life cycle of a product from the raw material used in its production to its final disposal [17]. Besides, the carbon footprint is conceptually used as an indicator of global warming potential [12,16-20]. The carbon footprint is usually computed for a specific time period such as 100 years and is expressed in units of mass of carbon dioxide equivalents per unit time or per unit product (i.e. kg CO_2 equivalent) [12,16,21]. In estimating the carbon footprint, data of the activity is multiplied by standard emission factors [22]. According to the Kyoto protocol, the total CO_2 equivalent of six greenhouse gases, which are methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride, are taken into account in addition to CO_2 emission [23].

The studies on climate change revealed that most of the carbon footprint that causes climate change in cities occurs in regions where transportation is intense. Especially in cities, CO_2 emissions are increasing due to the high use of personal vehicles, density of fossil fuel use and being commercial focus centers. Mehrotra et al. [24] reports that 75% of the carbon footprint is formed in cities and 95% of fossil fuels are consumed in cities. According to the data of the International Energy Agency (IEA), the transportation sector is the sector that produces the highest amount of carbon footprint after the electricity and heat generation sectors, and more than 70% of this footprint is due to road transport [4,25].

In this study, the carbon footprint for a waste recovery facility was estimated. The facility is located in İncesu within the boundaries of Kayseri District. In the facility, the wastes including plastic drums, Intermediate Bulk Containers (IBC) and sheet metal barrels were separated, sorted, cleaned and then recovered. In the scope of the study, the carbon footprint estimation was performed in three categories consisting of transportation, heating, and electricity consumption due to facility activities. The Tier approach in the IPCC manual was used [26].

2. MATERIALS AND METHODS

2.1 Description of Waste Recovery Facility

In this study, carbon footprint estimation was investigated in a waste recovery facility in 2018. The facility operates as a hazardous waste recovery located within the borders of İncesu district of Kayseri Province. The facility is built on a 1200 m^2 closed area and consists of administrative building, contaminated packaging areas, washing area, wastewater treatment plant, clean packaging field, press area, non-hazardous waste field and transformer center. At the facility, 6 workers work for 8 hours, one shift per day. Waste is collected from waste producers operating in Kayseri Organized Industrial Zone and neighboring provinces (Gaziantep and Yozgat), 2 times a day with 3 separate waste transportation vehicles to the facility. Waste comes from Gaziantep at a distance of 330 km and Yozgat at a distance of 160 km once a month to the waste recycling facility. The types of waste brought to the recycling facility include plastic drums, IBC tanks and sheet metal barrels. The facility has potential to recycle 1200 tons of Intermediate Bulk Container (IBC) and 1800 tons of barrels per year. Hazardous wastes separated according to their types are kept in the contaminated waste storage area prepared separately for each of them to be taken to the washing unit. Each waste received into the washing unit is treated separately according to the chemical substance it is exposed to. Pressurized water and solvent are used in the washing unit. Sheet metal barrels and plastic drums are washed by adding hot water and chemicals using a gun. The wastes that cannot be recovered are passed through the washing unit and then pressed to the iron and steel rolling mill facilities. In addition, small-sized wastes contaminated with hazardous chemicals brought to the facility are separated according to their types and stored on an impermeable concrete floor. The waste material, which is passed through the crushing machine, is taken into the washing baskets and passed through the washing process. Cleaned crushed small materials are pressed and sent as metal raw materials. Crushed and cleaned small plastic parts are stored in sacks and sent to the plastic industry as raw material. The wastewater generated in the washing unit is treated in the treatment plant.

2.2 The Methodology of Carbon Footprint Estimation

In the facility, the carbon footprint estimation was performed in three categories: transportation, heating, and electricity consumption. The 2006 IPCC Manual uses three methodologies for estimating fossil fuel emissions. In these approaches called Tier 1, Tier 2, and Tier 3, as the Tier level increases, the number of data and details used increase [26]. Generally, Tier 1 Tier 2 methods are used for CO_2 emission caused by natural gas and electricity consumption, respectively. In the Tier 3 method, facility-specific fuel consumption and emission factors are used, so it is considered to be a realistic calculation. The difference between Tier 2 and Tier 3 methods from Tier 1 method is the use of fuel consumption and distribution values. In the Tier 2 method, carbon footprint calculation is made by dividing fuel consumption into groups and selecting the appropriate emission factor. In the Tier 3 method, detailed procedures such as the length of the road traveled by the vehicles, the ratio of the weight of the carried weight to the length of the road traveled are included in the carbon footprint calculation and selecting the appropriate emission factor [26].

The Tier 1 method is a simple method with limited data. This method, which is generally used for the transportation sector, is based on the burning of fuels. The principle of this method, which is widely used in CO_2 calculation and also called top-down, is the estimation of the carbon footprint in proportion to the fuel burned. Firstly, the amount of fuel consumption in the facility is determined and it is multiplied by conversion factor to calculate the energy content of the fuel (Eq. 1). Secondly, carbon content of fuel is computed by using energy content and appropriate carbon emission factor (Eq. 1). Thirdly, carbon emission is calculated from the amount of carbon exposed to combustion by using the oxidation factor of the fuel based on the fuel type, (Eq. 3). Finally, the carbon footprint calculation is completed by converting the carbon emission into CO_2 (Eq. 4). Table 1 shows net calorific values and carbon emission factors of fuels.

$$EC\ [tJ] = FC\ [t] * 10^{-3} * CF\ [tJ/kt] \quad (1)$$

$$CC\ [Gg\ C] = CEF\ [tC/tJ] * EC\ [tJ] \quad (2)$$

$$CE\ [Gg\ C] = CC\ [Gg\ C] * COF \quad (3)$$

$$CO_2\ Emission\ [Gg\ CO_2] = CE * \frac{44}{12} \quad (4)$$

Where, EC is energy content, FC is fuel consumption, CF is conversion factor, CC is carbon content, CEF is carbon emission factor, CE is carbon emission and COF is carbon oxidation factor.

Table 1. Net Calorific Values and Carbon Emission Factors of Fuels [26]

Fuel Type	Calorific Value (tJ/kt)	Carbon Emission Factor (tC/tJ)
Gasoline	44.8	18.9
Diesel	43.3	20.2
LPG	47.3	17.2
Natural Gas	48.0	15.3

The Tier 2 method was used in estimating the carbon footprint resulting from the use of electricity at the facility, as the emission factors are country specific (Eq. 5).

$$CO_2\ Emission\ [ton\ CO_2] = Electricity\ Consumption\ [kW] \times CEF\ [kg/kW] \quad (5)$$

Estimated emissions from road transport are based on two independent data sets as fuel consumption and vehicle kilometers [26].

3. RESULTS

3.1 Carbon Footprint Estimation for Transportation

In the transportation-related carbon footprint estimation, the collection of wastes from producers, worker service, transportation of wastes within the facility, transportation of products purified from contaminated wastes to rolling mills and other industrial facilities were considered. Vehicles with a waste transportation license that travel between the facility and the waste producers twice a day have an important share in the carbon footprint of the facility by consuming fuel. There are 6 vehicles in total, including one authority vehicle, one worker service ring vehicle, three waste transport vehicles and one forklift. Only diesel fuel is used in vehicles. Based on the distance traveled by the vehicles belonging to the facility, the total amount of fuel consumed was calculated. The distance traveled by the vehicles was defined as the distance between the facility and target points (worker settlements, waste producers) and the average distance was determined using google map. For the service vehicle, the distance between facility site and the point of departure was measured as 40 km in average and 80 km in total for round trip using the Google Map distance calculation tool. The trip value of 80 km is valid for the authority vehicle. The distance between the facility site and Kayseri Organized Industrial Zone, where waste is collected with 3 separate vehicles twice a day, is 30 km. The location of facility site, worker settlements and waste producers were shown in Figure 1. The total capacity of 3 vehicles is 22 tons. The distance covered by 3 vehicles in a day has been calculated as 360 km. In addition, assuming that the forklift travels 10 km per day, it has been taken into account that 6 vehicles travel 530 km in a day. The facility works 6 days a week, an average of 300 days a year (12 days are considered public holidays) in one shift. In total, 6 vehicles in the facility travel 530 km per day and 159000 km per year. Waste is collected from Yozgat and Gaziantep once a month and a distance of 980 km in a month and a total of 11,760 km per year is covered. A total distance of 170760 km/year is covered for the waste collected from the neighboring regions and surrounding provinces. Considering the brand, model and other characteristics of the vehicles in the facility, if it is assumed that 24 L of fuel is consumed per 100 km on average, 40982.4 L diesel fuel is consumed if 6 vehicles travel a total of 170760 km per year. In order to calculate the energy consumption, the specific weight of diesel fuel (0.7798 kg/L) was used to find the value in tons of fuel [27].

Figure 1. The location of Waste Recovery Facility (1), waste collection points (2) and settlements of workers (3).

The amount of fuel (ton) = 40982.4 L * 0.7798 kg/L*10^{-3} = 31.96 ton

The conversion factor and carbon emission factor are selected from Table 1 as 43.3 and 20.2 used to calculate energy consumption by Eq. 1, respectively.

EC [tJ] = 31.96 ton * 10^{-3} * 43.3 tJ/kt = 1.38 tJ

CC [Gg C] = 1.38 tJ*10^{-3}* 20.2 tC/tJ = 0.028 Gg C

In the next step, to find the amount of oxidized carbon, carbon content was converted into carbon dioxide using the percentage of oxidation of fuels. Petroleum-derived liquid fuels are oxidized at a rate of 99% (UN, 1994).

CE [Gg C] = 0.028 Gg C * 0.99 = 0.0277 Gg C

CO_2 Emission [Gg CO_2] = 0.0277 x $\frac{\mathbf{44}}{\mathbf{12}}$ = 0.102 Gg CO_2

CO_2 Emission [ton CO_2] = 0.102 Gg CO_2 * 10^6≅ **102000 t CO_2**

The carbon footprint arising from transportation has been calculated in 3 categories: in-plant, waste collection and worker service ring. The majority of estimated carbon footprint is because of waste collection from producers than worker service ring and in-plant activities. The ratios of carbon footprint estimation for three categories are given in Figure 2.

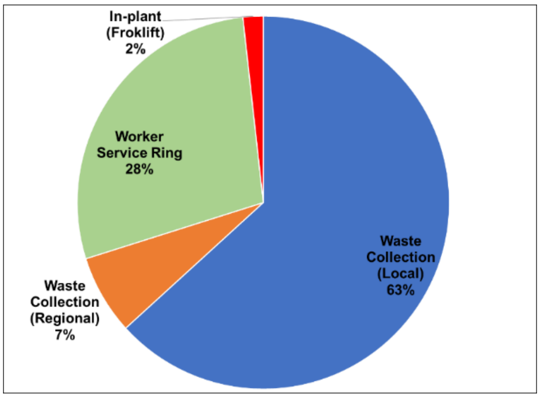

Figure 2. The ratios of carbon footprint estimation for waste collection, worker service ring and in-plant activities.

3.2 Carbon Footprint Estimation for Heating

The facility is used for natural gas steam boiler, treatment plant and administrative building (cooking, heating, emergency shower and hot water supply). The amount of natural gas consumption was obtained from the values stated in the monthly invoices. Since natural gas is among the fuel types due to its structure, the carbon footprint resulting from heating was calculated similar to transportation according to Tier 1 method, one of the IPCC methodologies.

According to the invoice information received from the facility, an average of 1200 m^3 per month and 14400 m^3 per year of natural gas is consumed. The specific gravity of natural gas is 0.798 kg/m^3 [27]. The weight of 14400 m3 natural gas is approximately 11.491 tons. Using the net calorific value of natural gas and conversion factor given in Table 1 and the amount of fuel consumed, the energy consumption amount was determined with the help of Equation 1.

EC (TJ) = 11.491*10-3 kt * 48.0 tJ/kt = 0.55 tJ

CC (tC) = 0.55 tJ * 15.3 tC/tJ = 8.415 tC

In the next step, gas was converted into carbon emission using the percentage of oxidation of fuels in order to find the amount of oxidized carbon. The oxidation percentage of gaseous fuels is 0.995. Then, carbon dioxide emission is calculated using Equation 4.

CE (tC) = 8.415 tC * 0.995 = 8.37 tC

CO_2 (tCO_2) = 8.37 tC * $\frac{\mathbf{44}}{\mathbf{12}}$ = 30.7 tCO_2**≅30700 t CO_2**

3.3 Carbon Footprint Estimation for Electricity Consumption

The facility is used in the electric press area, washing area, machine park and administrative building. It is used extensively in the field of washing and pressing. The machines used for in the facility including scale, spiral, hydraulic crane, press, polyp, chemical treatment, washing, transformer, treatment plant and crushing machines provide their energy from the electricity network. According to the invoice information provided by the facility, the electricity consumption value is on average 1932 kW per month and 23184 kW per year. The emission factor used in the calculations is taken from the International Energy Agency (IEA) report. This report contains emission factors determined specifically for countries. Due to country-specific emission factors, Tier 2 method was used to determine the carbon footprint resulting from electricity consumption. The emission factor values were determined for Turkey 0.478 kg CO_2/kW reported by Turkish Statistical Institute [27].

In the first stage, the emission factor given was multiplied by the electricity consumption value received from the facility in order to find the amount of carbon dioxide generated in ton value.

CO_2 Emission [ton CO_2] = 23184 kW * 0.478 kg CO_2/kW * 10-3 t/kg ≅ 11 t CO_2

The amounts of carbon footprint for activities and their rates in Waste Recovery Facility are summarized in Table 2.

Table 2. The amounts of carbon footprint for activities and their rates in Waste Recovery Facility

Activity	The amount of Carbon Footprint (t CO_2 eq.)	The activity ratio (%)
Transportation	102000	76.8
Heating	30700	23.1
Electricity	11	<1
Total	**132711**	**100**

4. CONCLUSIONS

In this study, the carbon footprint caused by the activities of a Waste Recovery/Recycling Facility has been evaluated. The carbon footprint of the facility has been determined under 3 main headings, which are transportation, heating and electricity usage. The largest share in the carbon footprint created by the facility comes from transportation with 76.8%. The second largest share is the heating-related carbon footprint with 23.1%. The carbon footprint resulting from the use of electricity in the facility has the lowest share (> 0.1%). In calculating the carbon footprint due to electrical use, the emission factor determined by the International Energy Agency to Turkey were found to be used annually 11 tons of CO_2. The total carbon footprint amount caused by the activities of the facility has been determined as 132711 tons of CO_2. Published by TurkStat in 2017 greenhouse gas emissions reported in Turkey's total carbon footprint amounts it is expressed in 475.1 million tons of CO_2. to about 3,600 times. The potential carbon footprint in Turkey is equal to about 3600 times of the amount of the carbon footprint caused by the facility.

In order to reduce carbon footprint of transportation, waste collection can be optimized. In the optimization of transportation, the frequency of collection waste from facilities can be reduced by collecting waste with the larger vehicles. On the other hand, the Recover/Recycle Facility can be moved far closer to Kayseri Organized Industrial Zone where the waste is collected; therefore, the distance between them will be shorter and the fuel consumption of the vehicles will decrease. Among other sources, the carbon footprint resulting from the use of electricity is negligible.

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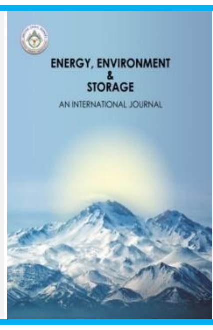

Numerical Investigation of the Effects of Window Height and Gas Thickness on Heat Transfer and Gas Flow in Double Pane Windows

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ABSTRACT.Double pane window is an effective way to reduce the heat loss from windows in buildings. There are many studies on the thermal performance of these window applications for different parameters such as optimum gap width, suitable filling fluid and different applications such as film coatings on panes to obtain different surface emissivity values or placing venetian blinds inside the gap, etc. These investigations are mostly based on the laminar flow assumption inside the gas gap between the two panes for the same window height. In this research, effect of the window height and gap width on the gas flow in the gap and heat transfer over double pane for three cities of Turkey representing different climates were numerically investigated with turbulent flow and ideal gas assumptions inside the gap for air and argon. In the calculations, natural convection for pane surface facing indoors and forced convection for pane surface facing outdoors was assumed as boundary condition. The numerical results shown that also the window height such as gap width has an effect on the heat transfer and gas flow of the double pane window. Thereby, the window height should be taken into consideration for determining the optimum gap width in the double pane window applications.

Keywords:Double pane window, energy saving, natural convection in rectangular cavity

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1. INTRODUCTION

Decreasing the energy demand of buildings is a hot topic of science nowadays. The windows used for utilizing the day light are thermal holes of the building both in winter and summer times. Double pane window is an efficient way to reduce the heat loss from indoors in winter. It consists of two glass panes and a filling gap commonly filled by air between the panes. Optimum gas thickness or width value (L) of this gap is investigated in literature for a long time for different parameters.

The heat transfer through a double-pane window is analyzed numerically by a finite difference technique [1]. The thermally optimum air-layer thickness between the two panes for different climates is determined. Four different cities of Turkey, representing different climate conditions are considered: Ankara, Antalya, Kars and Trabzon. The height of the window, H is chosen 80 cm. The effect of air-layer thickness varies between L=3 and 40 mm on the average Nusselt Number and the heat flux through the inner pane. It was shown that energy losses through the double-pane windows can be considerably reduced by optimizing the thickness of air layer. Instead of assuming the panes as isothermal surfaces [1], much more realistic boundary conditions considered for panes for the same window. It was shown that filling the space between the glass panes with a gas having a lower thermal conductivity instead of air reduces the insulating value of the window [2].

The optimum air layer thickness of double-glazed windows is determined using the degree day method. Calculations were obtained for İskenderun, Kocaeli, Ankara and Ardahan which are in different climate zones of Turkey. The results showed that the optimum air layer thickness varies between L=12 and 15 mm depending on the climate zone, fuel type and base temperature [3]. Also a thermo economical optimization of multiple pane window applications for İskenderun, İzmir, Kocaeli, Sinop, Malatya, Ankara, Van and Ardahan cities which are located in different climatic regions of Turkey was carried out using the degree-day method. The results showed that the optimum number of panes in Turkey varies between 2 and 4 depending on the climate zone and fuel type [4].

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Fluid flow and heat transfer in double, triple and quadruple pane windows having height of H=100 cm were investigated numerically. About 50% or 67% of energy savings could be made if the double pane window is replaced by triple or quadruple pane windows, respectively. [5]. A parametric study was carried out numerically to investigate fluid flow and heat transfer characteristics in double, triple and quadruple pane windows (having height of H=100 cm) considering various gap widths together with different emissivity coatings. Computations were performed for both air-filled and argon-filled windows. The results showed that the most reasonable gap width is 12 mm for all cases considered in this study [6]. The regularities of heat transfer through a triple-pane glass window with air and argon fillings have been investigated by the method of numerical modeling. The thermal resistances of the triple-pane window (having height of H=108 cm) as functions of the gas-interlayer thickness and of temperature on the window′s exterior surface have been found [7].

Innovative solutions were also proposed for double pane windows and water-flow double-pane window design is an innovative concept that involves a controlled flow of water within the cavity between the two glass panes [8]. As the heat extracted by flowing water is much higher than by ventilating air, the room heat gain can be reduced considerably and at the same time, the window can serve as a water pre-heating device. The integrative thermal performance of a water-flow absorbing window having height of H=125 cm was compared with the conventional single and double pane absorptive glazing [9]. Another innovative solution proposed is supply air window. The supply air window is a variation of the multiple pane window in which air is pulled in from outside and is heated through conduction, convection and radiation in the cavity. An experimental rig was designed, constructed and used to measure the flow field and temperatures with the aim of validating the CFD models with a window having 99 cm height [10].

A two-dimensional numerical analysis for thermal control strategies on potential energy savings in a double-pane window integrated with see-through a-Si photovoltaic (PV) cells with low-emittance (low-e) coatings was investigated. Aspect ratio (height/gas width ratio, H/L) of window was given as 10. [11]. A reference window with empty gap was compared with windows where the gap contains fins arranged in such a way as to reduce heat transfer. In this study, the window height was chosen as H=49.6 cm. Convective heat transfer inside the gap of double glazed windows was studied numerically using a commercial CFD code (FLUENT v6.3), for different Rayleigh Numbers and aspect ratios [12].

The studies mentioned above for optimum gap width value or air-layer thickness were performed for only one window height value. Studied window height values in literature are varying between H=49 cm and 125 cm. Effect of window height or aspect ratio (height/gas thickness, H/L ratio) on determining the optimum gap was not considered in literature. In the previous studies, constant temperature boundary condition (uniform temperature distribution) or forced convective boundary condition was used as boundary condition. Constant temperature boundary condition or uniform temperature distribution assumption on pane surface would not be a realistic approach in terms of naturel convection realization in the air gap, because the air circulation between the panes is occurred by the temperature gradient on the pane surfaces [6]. However, this problem was not investigated in detail as a function of the pane height in literature. Consequently, in order to see the effect of window height on heat transfer, double pane window was modeled numerically for different window heights. For a realistic approach, while boundary condition on the inner pane surface side of indoor was taken as naturel convective, the boundary condition on the outer pane surface by outdoor was selected as forced convection. Thus, the convective effect caused by the probable wind was taken into consideration. In addition, the flow is assumed to be turbulent rather than laminar flow assumption in the above studies. The numerical analyses are performed for three different cities Antalya, Kayseri and Kars of Turkey representing different outdoor climate conditions.

2. MATERIALS ANDMETHODS

2.1 Problem Description And Numerical Method

In this study, flow and heat transfer characteristics of double pane window for various gas thicknesses with different heights was investigated numerically. Schematic representation of the double pane window is shown in Figure 1. Panes are 4 mm ordinary glass. Indoor temperature (Tin) is assumed constant as Tin=20 °C for thermal comfort. Outdoor temperature (Tout) values are assumed equal to the winter design temperatures of each city as stated in Table 1. Operation pressure (P) was set as the atmospheric pressure values for the cities altitude values as stated in Table 1. In addition, also temperature difference (ΔT=Tin-Tout) between indoors and outdoors can be seen in Table 1.

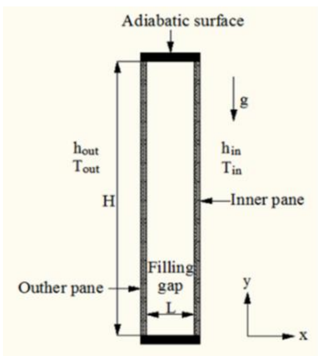


Fig. 1. Schematic representation of the double pane window

Table 1 Design winter temperatures and atmospheric pressures for the cities considered in this study

City	Tout [°C]	ΔT=Tin-Tout[°C]	P [Pa]
Antalya	3	17	100800
Kayseri	-15	35	89095
Kars	-27	47	81980

For numerical and parametric calculations, thermo-physical properties (specific heat, dynamic viscosity and thermal conductivity) of air were taken as fourth degree polynomial (=a+bT+cT2+dT3+eT4) as a function of temperature (T [K]). The a, b, c, d and e constants of polynomial equation can be seen Table 2. The thermo-physical properties (specific heat, dynamic viscosity and thermal conductivity) of argon were taken as; Cp=519 J/kgK, μ=(0.066T +2.97)·10–6 Pa.s, and k=(0.0516T + 2.3)·10–3 W/mK, respectively [7,13]. For calculation of flow and heat transfer between two panes, air and argon were treated as incompressible ideal gas.

Table 2 The constants for thermo-physical properties of air

	Cp(T)	μ(T)	k(T)
a	1,03E+03	1.660072E−06	2.064614E−03
b	−2.989620E−01	6.693351E−08	8.731414E−05
c	8.350206 E−04	−4.120350E−11	−2.641003E−08
d	−5.536863E−07	1.728613E−14	4.008917E−12
e	1.239482E−10	−2.921590E−18	0

The forced convection heat transfer coefficient (hout) is selected constant as 15 W/m2K. As stated in Ref.[2] changing this value from 15 to 30 W/m2K did not influence a lot, just suggesting a negligible 2.6% increase in heat flux and no considerable effect on the curves of optimum gap value. The natural convection heat transfer coefficient (hin) is calculated by Average Nusselt Number ( ), Prandtl Number (Pr) and Rayleigh Number (Ra) by the following correlations determined for heat transfer from hot vertical surfaces according to Ref [14] :

$$h_{in} = \frac{k\overline{Nu}}{H} \quad (1)$$

$$\overline{Nu} = \left\{0.825 + \frac{0.387[Ra]^{1/6}}{\left[1+(0.492/\Pr)^{9/16}\right]^{8/27}}\right\}^2 \quad (2)$$

$$Ra = \frac{\rho\beta\Delta TH^3}{\nu\alpha}, \quad \Pr = \frac{\nu}{\alpha}, \quad \nu = \frac{\mu}{\rho},$$

$$T_f = \frac{T_s + T_{in}}{2}, \quad \beta = \frac{1}{T_f} \quad (3)$$

For the calculation by means of the polynomial function (=a+bT+cT2+dT3+eT4) of thermal conductivity (k), thermal diffusite (α), density (ρ) and kinematic viscosity (ν) values of the indoor air in the above equations, the average value (Tf) of inner pane surface temperature (Ts) on the surface facing indoors and indoor temperature (Tin) was used. Thermo physical properties (density, specific heat, thermal conductivity) of the pane are taken as ρ=2700 kg/m³, Cp=840 J/kgK and k =0.78 W/mK, respectively.

Two-dimensional model of double pane window was built and mesh structure was created in GAMBIT software. It was imported to ANSYS FLUENT Version 15 [15] which was used for numerical simulation of air flow and heat transfer in the double pane window. Double pane windows vertical inner and outer pane surfaces were set as convective heat transfer wall boundaries. Horizontal walls are defined as adiabatic wallswith zero heat flux. The flow is assumed to be turbulent and steady. The RNG k-epsilon model is selected with enhanced wall treatment. A comparative numerical study with other turbulence models was conducted by the authors [16]. Results of the numerical study of the different turbulence models are compared with an empirical equation in literature [14] and RNG k-epsilon model with enhanced wall treatment is found to be the most suitable turbulence model for this problem. The SIMPLE algorithm was used for the velocity–pressure coupled relations among the governing equations. The convergence criterion for continuity equation and energy equation was 10-5 and 10-6, respectively.

According to the Eqs.1-3, the natural convection heat transfer coefficient (hin) values are varied by the surface temperature on the surface facing indoors (Ts). Therefore, the surface temperature should be known. However, this surface temperature value will be determined by the FLUENT calculations. Thus, for predicting the real value of hin the calculation loop in Figure 2 is considered.

2.2 Code Validation

In order to validate the results a numerical study was performed for a rectangular cavity of H/L=4 (H=40 cm, L=10 cm). This rectangular cavity filled with air is heated from vertical one side and cooled from the other side with horizontal adiabatic walls. The numerical simulation results with the RNG k-epsilon model and the enhanced wall treatment were compared with the empirical correlations of the average Nusselt Number from literature [14] which can be seen in Table 3. These correlations are:

$$Nu_L = 0.22\left(\frac{Pr}{0.2+Pr}Ra_L\right)^{0.28}\left(\frac{H}{L}\right)^{-1/4} \quad (4)$$

$$\begin{bmatrix} 2 < \frac{H}{L} < 10 \\ Pr < 10^5 \\ 10^3 < Ra_L < 10^{10} \end{bmatrix} \quad (5)$$

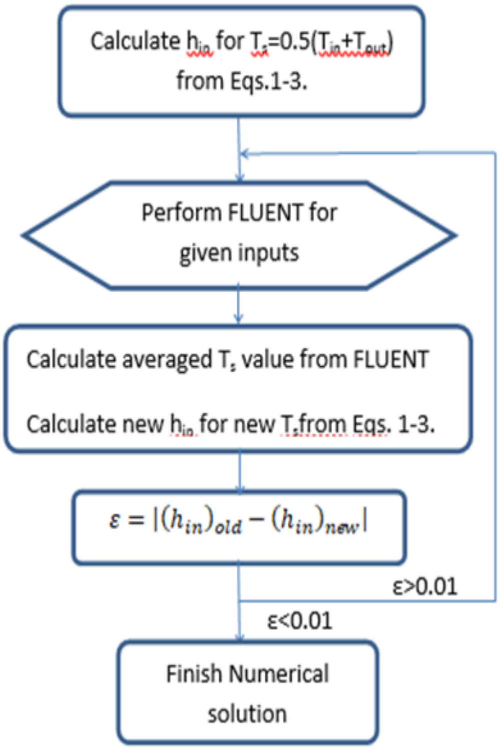


Fig. 2. Calculation Loop of hin value

Itwasobservedthattheagreement of thepresentsolutionandempiricalcorrelation is excellentandthecode is validfornumericalsimulationwiththeselectednumericalparameters.

Table 3 Comparison of the Nusselt Number for various Rayleigh Numbers

H/L	Ra	PresentStudy	Ref.[12]	Error %
4	1x106	7.04	7.01	0.004
4	1x107	13.21	13.24	0.002

2.2 Mesh Independency

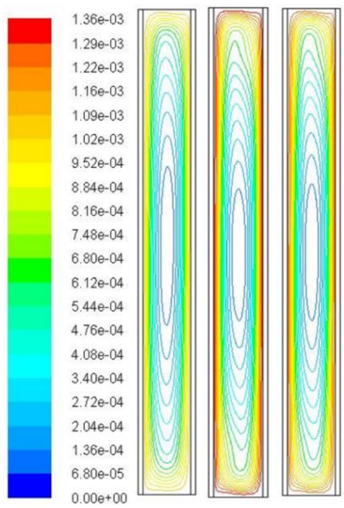
The solutions are performed for different mesh sizes for the windows which has the highest aspect ratio (=533) as 1600 mm/3 mm and the smallest aspect ratio (=10) as 400 mm/40 mm for Kayseri city. Meshing was performed with quadrilateral mesh elements with map option that creates a regular structured grid in GAMBIT. The results are given in Table 4. Both for two different gaps 3 mm and 40 mm, the difference in total heat flux (q) is not considerable for different mesh sizes. In terms of cost and accuracy, a uniform mesh size of 1 mm is adopted for solutions.

Table 4 The q [W] values for various grid sizes

Grid size[mm]	H=40 cm, L=40 mm	H=160 cm, L=3 mm
2	47.10	-
1	46.42	75.73
0.5	46.07	75.73
0.25	46.00	75.73

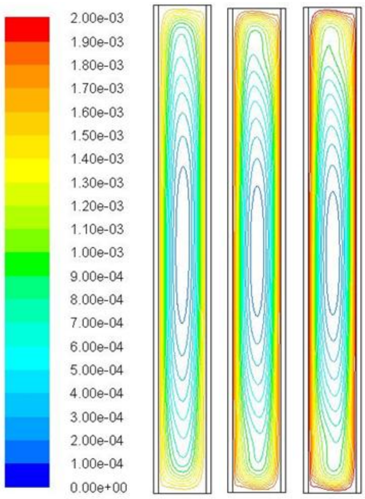
3.RESULTS

The results obtained from the numerical solution is presented and discussed in this section. The streamlines of the highest gap width value of 40 mm was presented for various cities for 40 cm air filled window (Figure 3) and 40 cm argon filled window (Figure 4). It can be seen that the flow is one circulation region as the fluid rises along the hot side and falls down along the cold side for all investigated window heights, gap widths, fluid types and for all cities.



(a) (b) (c)

Fig. 3. Streamlines at L=40 mm, H= 40 cm for air filled window a) Antalya, b) Kayseri, c) Kars



(a) (b) (c)

Fig. 4. Streamlines at L=40 mm, H= 40 cm for argon filled window a) Antalya, b) Kayseri, c) Kars

Velocity profiles at y=0.5H for the highest and smallest window height and the examined cities are shown in Figure 5 and Figure 6 for air and argon filled windows, respectively. The obtained velocity profiles are similar curves to each other for all cases. Generally, increasing the window height caused higher fluid flow velocity for both air and argon. The velocities with argon are higher slightly than velocities reached with air. As expected, the low design winter temperatures cause higher gas velocities. Thereby, the velocity values are the highest for Kars city which has the lower design winter temperature as 0.17 m/s and 0.18 m/s in 160 cm window with 40 mm argon and air filled gap, respectively. The lowest values are obtained for Antalya city which has the higher design winter temperature as 0.08 m/s and 0.09 m/s in 40 cm window with 40 mm argon and air filled gap, respectively. For Antalya city, air flow velocity is increased 37.5% for H=160 cm window compared with H=40 cm window for L= 40 mm air filled gap. Air flow velocity was increased 25% for Kayseri and 21.4% for Kars by increasing the window height from 40 cm to 160 cm for air filledwindow. For Argon filled window by increasing the window height from 40 cm to 160 cm, these values are increased 33%, 23% and 20 % for Antalya, Kayseri and Kars, respectively.

Longitudinal temperature variation on surfaces facing indoor and outdoor of the pane versus the pane height can be seen in Figure 7 and Figure 8, for air and argon filled windows, respectively. These figures are important in terms of the reliability of the results providing with constant (uniform) temperature boundary condition assumption in the literature. According to these figures, at lower L values (3 and 6 mm), the longitudinal temperature variation is nearly constant along the pane (almost uniform temperature distribution). However, as expected, there is a temperature difference between the bottom and top of the pane similar with Ref.6. The differences on the outdoor surface is lower than those the indoors surfaces. In addition, the difference values reached for Kars city with low design temperature are higher than those for Antalya city with high design temperature. Namely, while the highest difference occurs for indoors surface of Kars city, the lowest difference occurs for outdoors surface of Antalya city. The temperature difference values for other cases are between these highest and lowest values. For L=3 mm and H=40 cm, the highest and lowest temperature values between the bottom and top of the pane are 0.25 and 0.03°C with air and 0.34 and 0.03°C with argon, respectively. Also for L=6 mm, the highest and lowest temperature values increase to 2.84 and 0.28°C with air and 3.4 and 0.32°C with argon, respectively. Also for L=15 mm and L=40 mm (in parentheses), the highest and lowest temperature values are about 18.67 (18,52) and 3.05 (3.35) °C with air and 17.59 (17.67) and 2.68 (2.83) °C with argon, respectively. The temperature differences reached with H=160 cm and L=3 - 6 mm are nearly those of temperature differences reached with H=40 cm. However, the difference values calculated for L> 6mm higher than those of temperature differences reached with H=40 cm. The difference with L=40 mm and H=160 for air and argon increase to 22.18 and 20.86 °C, respectively. Consequently, for L>6 mm, the temperature distribution was changed from uniform distribution to non-uniform distribution. As expected, lower design temperature occurs at the bottom region of the pane and higher temperatures occur at the upper region. Air circulation at the gap region was caused by this temperature difference. According to these figures, it was concluded that the calculations with constant temperature boundary condition assumption along the pane surface is not realistic for L>6 mm. Another result is that, as expected, while the temperature values at the outer pane surfaces are decreasing,temperature values at the inner pane surfaces are increasing with increasing L values. Namely, the temperature difference between inner and outer pane surfaces increases as a function of L thickness.

As the mentioned in the previous section, for the natural convection or the natural convection heat transfer coefficient (hin) calculations inside the room, average of the surface temperature value of surface facing indoors of inner pane was used. For that purpose, the surface average values of the curves of the Figure 7 and Figure 8 were calculated by FLUENT. Thus, the variation of the calculated average temperature values versus L was traced. The averaged temperature (Tinpane) value of the inner pane surface facing indoors and the averaged temperature (Toutpane) value of the outer pane surface facing outdoors for air filled and argon filled window of Kars city can be seen in Figure 9 and Figure 10, respectively. As the gap width L increases, the inner pane surface temperature increases rapidly for L<15 mm both for air and argon. For L>15 mm, the temperature curves show asymptotical behavior. However, the outer pane surface temperature curves exhibited a converse characteristic behavior. As the gap width increases outer pane surface temperature decreases up to L<15 mm. In addition, the calculated temperatures for inner and outer surfaces decrease and increase slightly for H<80 cm, respectively. Obtained values are higher for argon compared with air.

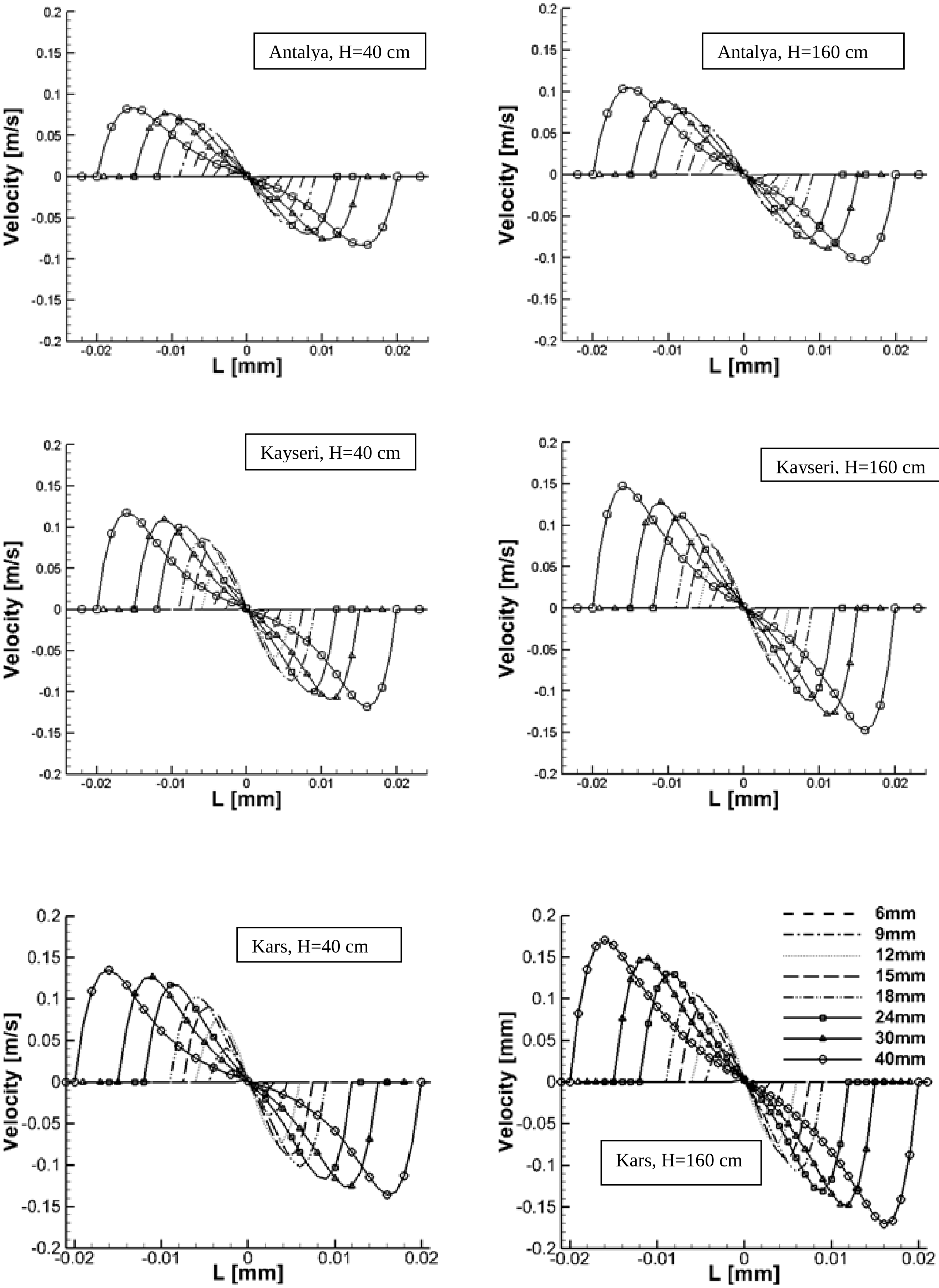


Fig. 5. Velocity profiles of air filled window for different cities for various window heights (at y=0.5H).

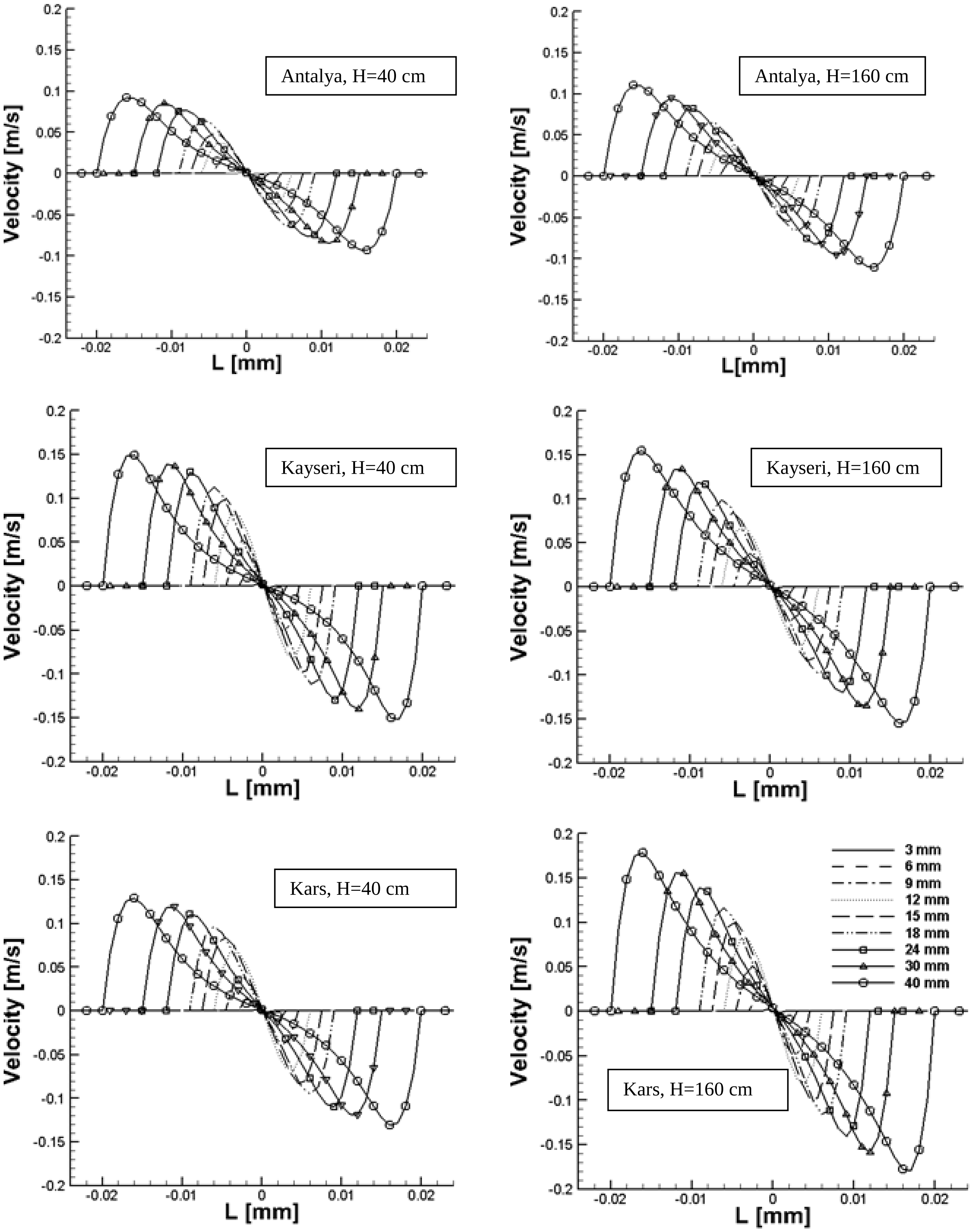
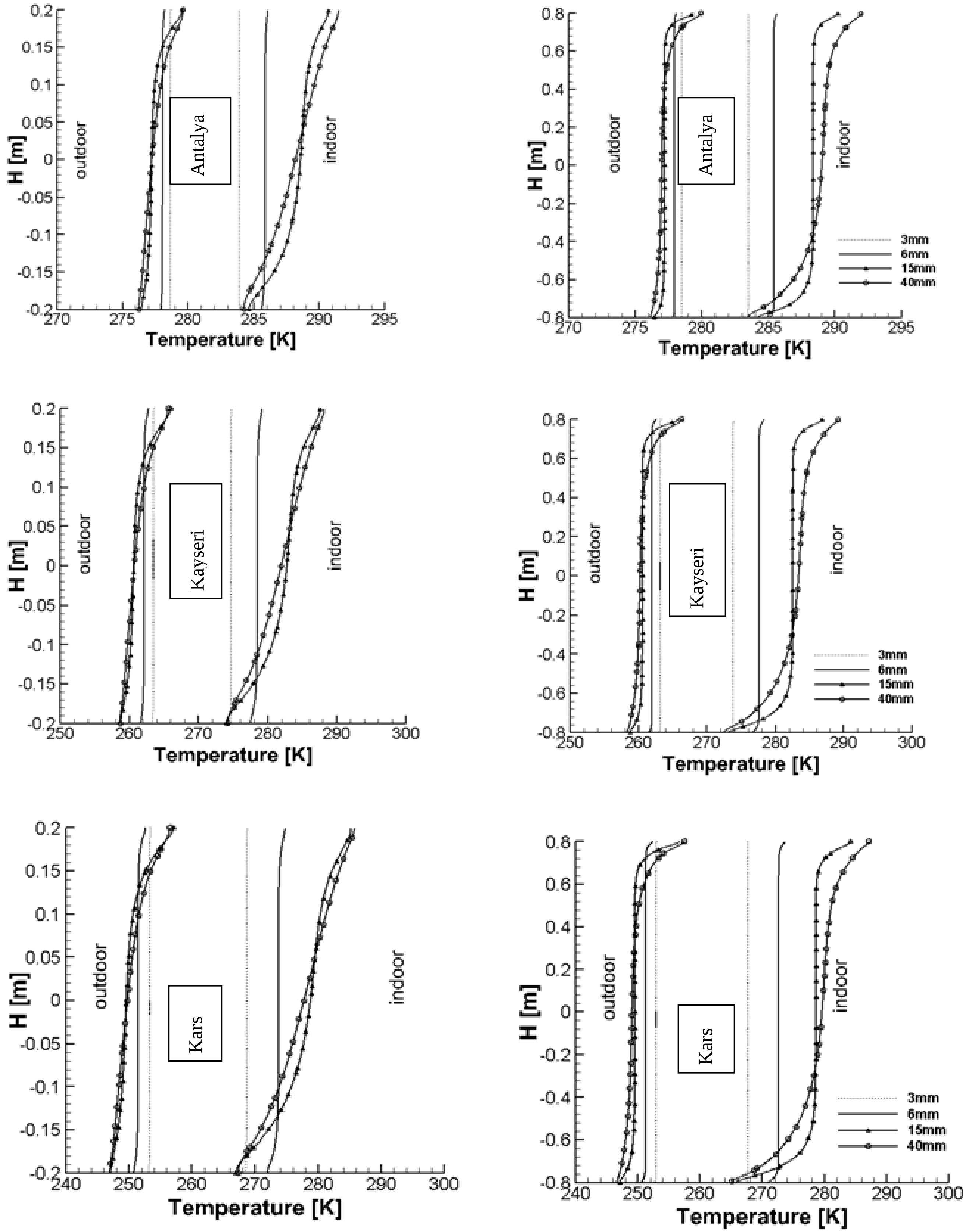
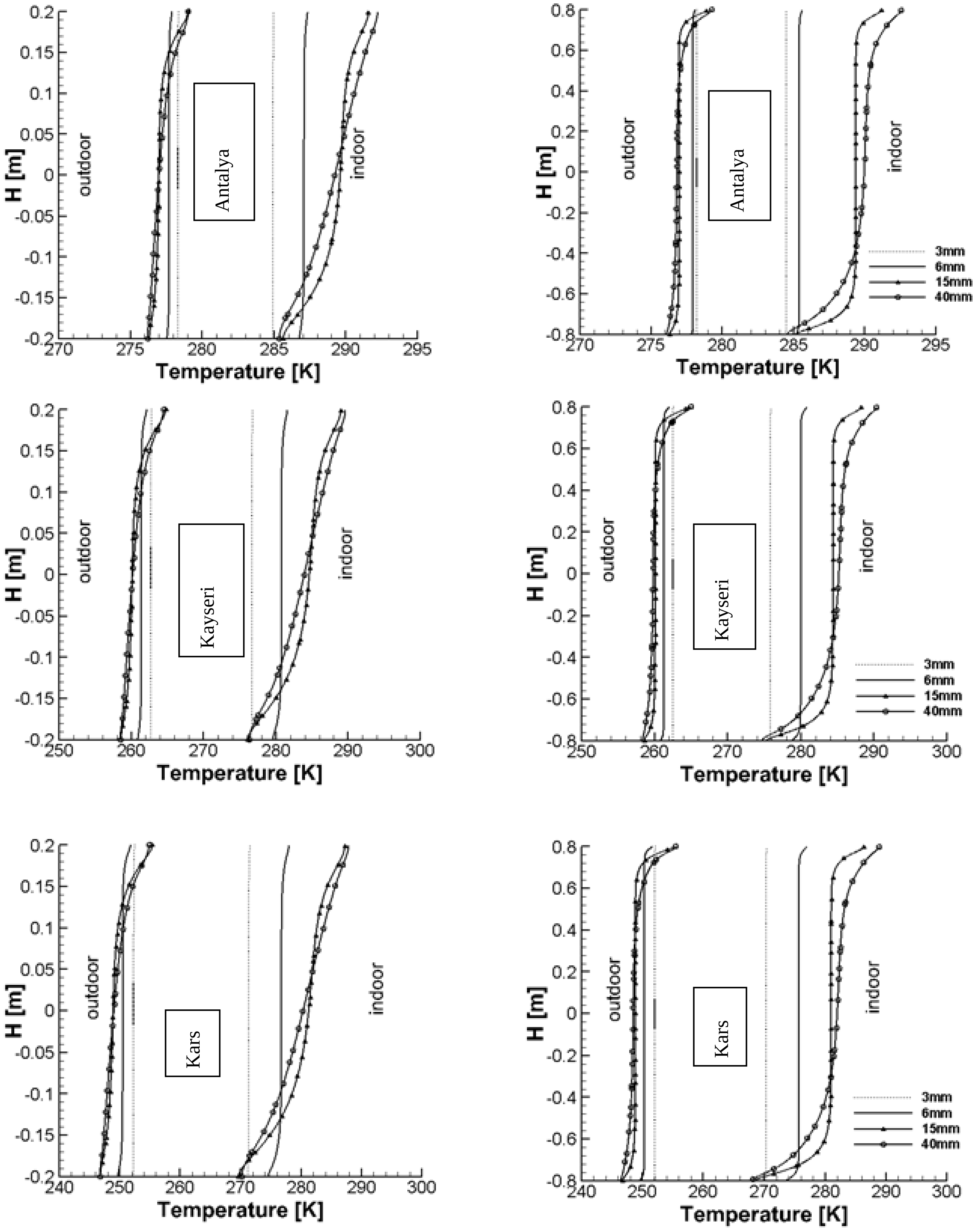


Fig. 6. Velocity profiles of argon filled window for different cities for various window heights (at y=0.5H)



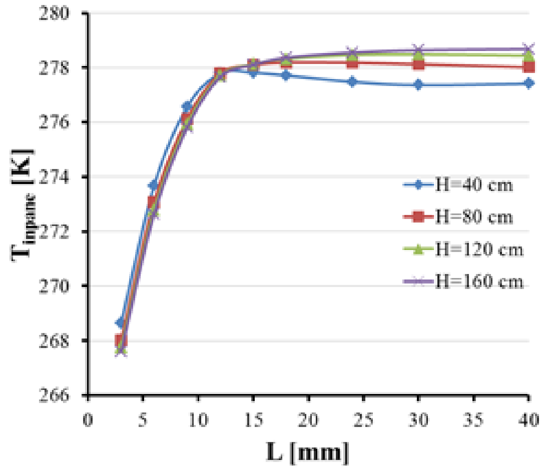
(a) (b)

Fig. 7. Longitudinal temperature profiles on inner (a) and outer (b) pane surfaces for air filled window)

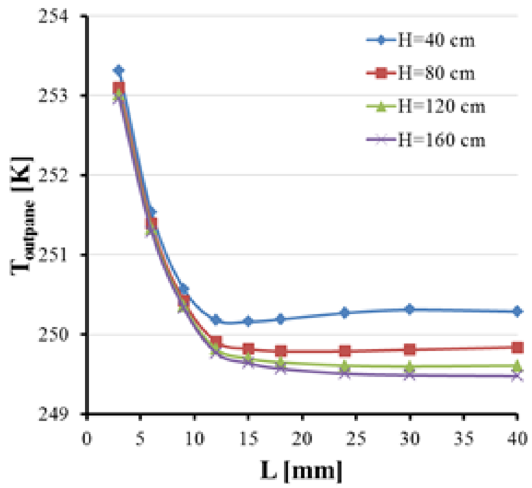


(a) (b)

Fig. 8. Longitudional temperature profiles on inner (a) and outer (b) pane surfaces for argon filled window.

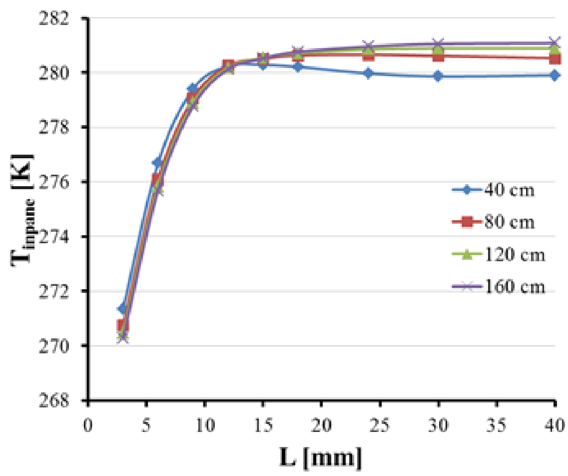


(a)

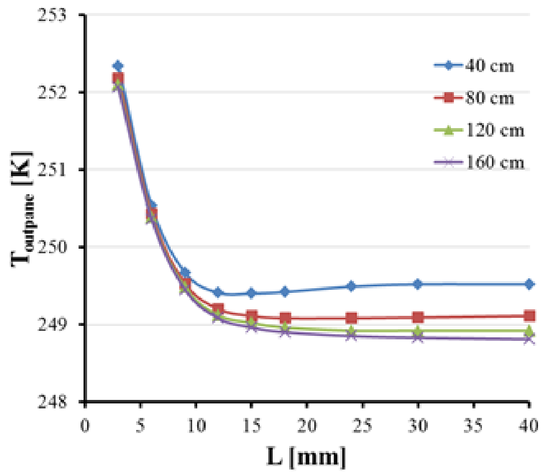


(b)

Fig. 9. The average temperature values versus gap width for air filled window for Kars city on a)inner pane surface, b) outer pane surface



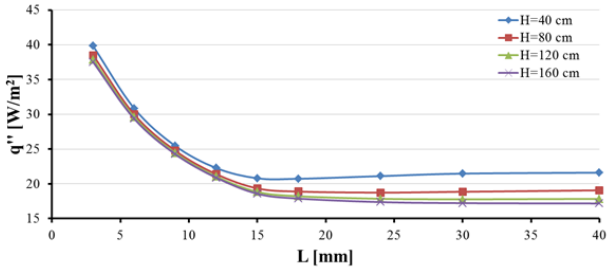
(a)



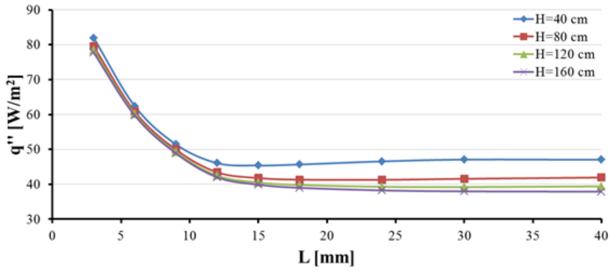
(b)

Fig. 10. The average temperature values versus gap width for argon filled window for Kars city on a)inner pane surface, b) outer pane surface

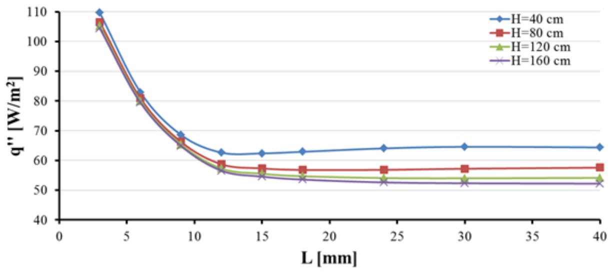
The most important parameter for this study is the heat flux q´´ passing through the system. For energy saving or the lowest heat lost, the heat transfer from the two panes and air gap is desired to be at minimum level. Variation of the heat flux values versus gap width value (L) for the investigated cases are given in Figure 11 and Figure 12 for air and argon, respectively. Generally, for L<20 mm as the L increases, q´´ value decreases rapidly. For L>20 mm it stays nearly constant with an asymptotical behavior. For small H values (H<80 cm) q´´ has a minimum value at a certain L (critical) value. These critical values are around 16, 14 and 13 mm for H=40 cm, for Antalya (ΔT=19 °C, temperature difference between the indoors and outdoors), Kayseri (ΔT=37 °C) and Kars (ΔT=49 °C), respectively. According to these results, critical L values are decreasing by increasing ΔT values. For H=80 cm, these values are increasing to ≈20-25 mm. For H>80 cm, there is not a critical L value. With increasing the L values, q´´ values either stays constant or a small decrease was occurred. These results indicate that critical L values for these windows are at higher L values than the values considered in this study. Another important result is that, q´´ heat flux values are decreased by increasing H values. These figures also showed that H value has a considerable effect on the q´´ results. Filling the gap with argon instead of air does not changed the behavior of the heat flux curves but caused lower heat flux values than air's values. The heat flux values with argon decrease between 12-20% according to air for the investigated cities and all cases in terms of energy saving. As a function of the L, the decrement can be seen in Figure 12 for Kars city. Obtained values of other cities are nearly the same as Figure 13. The figure shows that the decrement caused by argon filling will be affected by height of the pane H.



a) Antalya

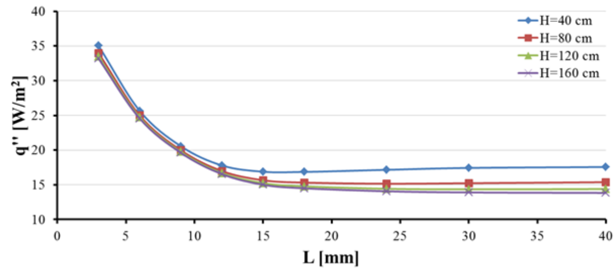


b) Kayseri

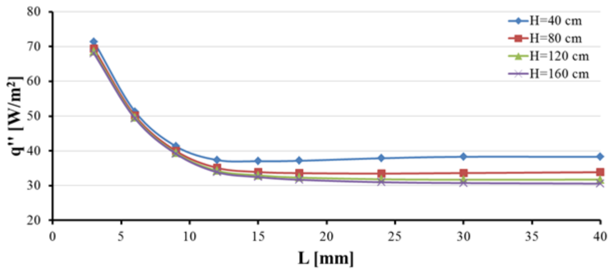


c)Kars

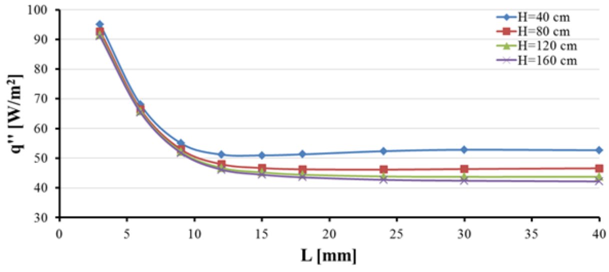
Fig. 11. Average heat flux values versus gap width for various window heights for air filled window



a) Antalya



b) Kayseri



c)Kars

Fig. 12. Average heat flux values versus gap width for various window heights for argon filled window

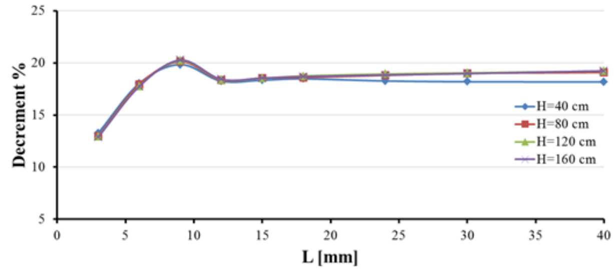


Fig. 13. Comparison of heat flux values versus gap width for argon filled and air filled window for various window heights for Kars city

The Rayleigh Numbers of the gas flow (both air and argon) caused by natural convection in rectangular gas region between two panes for the investigated cases are very important parameters in term of turbulence flow. If Ra values are above the critical value of Ra=1000 stated in literature for the rectangular cavities of vertical heated and cooled surfaces, the turbulence flow occurs as thin boundary layer and vortex at the vertical hot surface, vertical cold surface and corners of the rectangular cavities [13]. The Rayleigh Numbers for the rectangular gas region between two panes for the investigated cases can be calculated by following equation:

$$Ra = \frac{2g(Th - Tl)L^3}{\nu\alpha(Th + Tl)} \quad (4)$$

Where the α, g and ν are thermal diffusivity, gravitational acceleration and kinematic viscosity values of the gas region between two panes. Th and Tl are avarage temperatures panes surfaces facing the gas region. These parameters can be easily calculated by FLUENT. The calculated Ra values can be shown in Table 5 for Antalya and Table 6 for Kars cities of the investigated cases. Table 5 and Table 6 indicates that the turbulence effects begins for L>9 mm. From this point, assuming the flow turbulent in the numerical solution is correct. Espically, the flow has turbulence for the critical L values indicating the lowest heat lost.

Table 5 The Rayleigh Numbers for gas gap between two panes for Antalya

Antalya City				
L (mm)	H=40 cm		H=160 cm	
	Air	Argon	Air	Argon
3	19,0	26,3	16,97	25,0
6	210,3	294,7	201,27	282,4
9	849,9	1153,8	821,75	1116,6
12	2214,5	2942,1	2180,01	2890,9
15	4506,3	5878,8	4555,18	5902,2
18	7807,7	10175,4	8041,11	10358,1
24	18296,7	23932,8	19332,22	24893,5
30	35451,3	46413,8	37975,10	48758,9
40	83587,2	109668,0	90157,67	116128,0

Table 6 The Rayleigh Numbers for gas gap between two panes for Kars

Kars City				
L (mm)	H=40 cm		H=160 cm	
	Air	Argon	Air	Argon
3	57,5	70,6	55,5	68,5
6	645,9	752,9	629,3	736,5
9	2515,3	2841,7	2486,5	2823,8
12	6287,6	6949,2	6379,6	7024,6
15	12298,4	13591,1	12684,0	13915,1
18	21164,6	23427,4	22135,5	24235,1
24	49667,7	55055,7	52865,3	57806,8
30	96504,1	107113,1	103580,5	113245,5
40	229282,5	254141,9	245881,2	268826,5

4.CONCLUSION

This study is aimed to examine the effects of window height (H) and gas thickness (L) on the fluid flow and heat transfer in double-paned windows for some cities with different climates in Turkey. The cities examined here are Antalya, Kayseri and Kars. The traditional working fluids are air and argon. The parametric calculations are performed for H=40, 80, 120 and 160 cm and L=3, 6, 9, 12, 15, 18, 24, 30 and 40 mm. The air and argon are assumed as ideal gas with the atmospheric pressure corresponding to the selected cities altitude values. All thermo-physical properties of the selected gases were calculated as a function of the operation temperature. The numerical calculations were carried out by FLUENT with the natural convection for indoors and forced convection for outdoors boundary conditions. Most important results are summarized as following:

1. The fluid flow in the rectangular region between the panes is formed as one circulation region for all investigated cases and all cities.

2. With the increasing L, the heat flux values decrease for all H values both for air and argon. While the rapid decreasing occur up to L≈15 mm, the constant heat flux (asymptotical behavior) or slightly decreasing and increasing on the heat flux exhibited for L>15 mm.

3. For H<80 cm, the heat flux reach a minimal value at the certain L values both for air and argon. These critical values are about L=16, 14 and 13 mm for Antalya, Kayseri and Kars city with H=40 cm, respectively. For H=80 cm, the calculated values are about 20-25 mm. The critical values reached for H>80 cm occurred at the L>40 mm.

4. Increasing H values caused lower heat flux. For Kars city with double-pane filled by air, the heat flux values reached with L=40 mm are about 65, 58 and 52 W/m2 for H=40, 80 and 160 cm, respectively.

5. Filling the gap with argon instead of air caused lower heat flux. The heat flux values with argon decreased between 12-20% according to those of air for the investigated cities and all cases in terms of energy saving For Kars city, the heat flux values decreased 13 % at L=3 mm and 19% at L=40 mm for argon compared with air.

6. The Rayleigh Numbers calculated for natural convection in the gas region between two panes indicates that the turbulence effects begins for L>9 mm.

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Review Article

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Green Technology Solution to Global Climate Change Mitigation

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ABSTRACT. Climate change is probably the most substantial issue ever to have faced human political, social and financial frameworks. The risks are enormous, with serious vulnerabilities and dangers, the economic matters questionable, the science assaulted, the governmental issues severe and muddled, the psychology perplexing, the effects annihilating, the relations with non-environmental and environmental issues occurring in several directions. Appropriate public health and policy need to be put in place to face the present and impending pollution and climate change difficulties. The question is whether our responses should focus on a mitigation of its rate and magnitude by minimizing carbon emissions of economic activity and adaptation to its unavoidable consequences. In this review, we discuss on climate change, the risk and hazard emanating from GHGs emission and its climatic effects, global actions, meetings and approach to mitigate climate change effects, policies such as economic, regulatory, forest/land use, technological approach. We suggest that the preventative actions including both mitigation and adaptation measures are good options. However, prevention of environmental problems is a key issue to sustainability. The most ideal approach to deal with environmental problem is to prevent it from being created in the first place. Therefore, green technology proffer the solution to climate change and take the lead in preventing environmental problems resulting to a sustainable environment.

Keywords: Green technology, climate change, environmental remediation, sustainability, decarbonized economy.
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1. INTRODUCTION

Industrialization and urban development across the globe continue to result in emission of toxic and harmful material to the environment, also, the continuous combustion of fossil fuel resources to meet energy demand results in release of GHGs emission. Energy demand worldwide continues to increase at an alarming rate. The future projected increase in demand of energy from year 2020 to year 2050 is 250 quadrillion (see Figure 1)

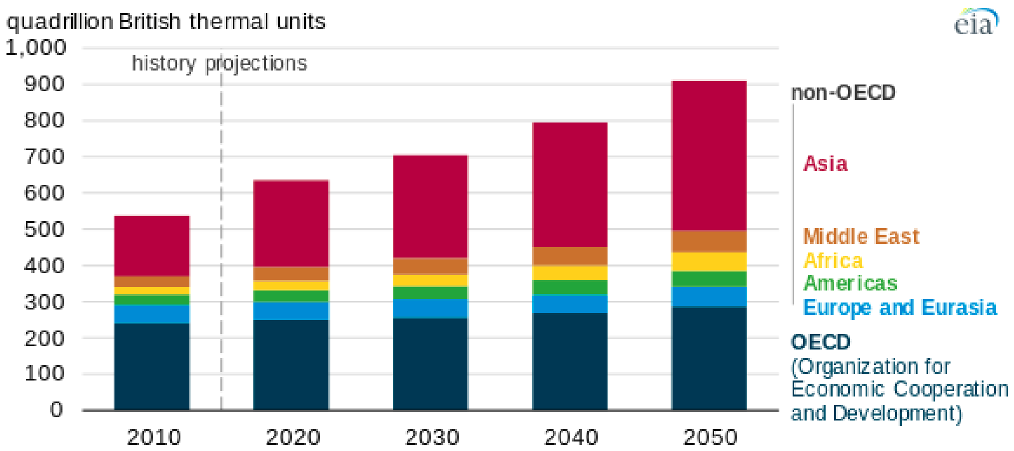

Figure 1: Future projected energy demand [1]

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Statistical data reveals that fossil fuel energy resources is been utilized in meeting these enormous demand of energy (See Figure 2). Fossil fuels (coal, oil, gas) have, and will continue to demonstrate a major role in meeting greenhouse gases emissions. There must be a balance in energy role in economic and social development in order to decarbonize across the globe, dependance on fossil fuel resources must be reduced to transit towards lower-carbon energy sources. The major driver of the industrial revolution is fossil fuel and social, economic, technological advancement which followed. Energy has demonstrated a major positive role in global climate change [2].

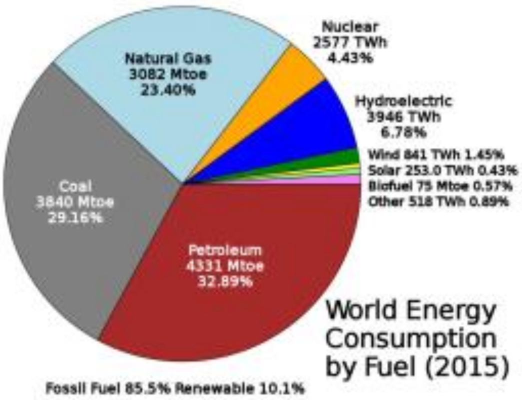

Figure 2: World energy consumption at 2015 [3].

The continuous combustion of fossil fuel has led to the release of toxic substances to the environment thereby leading to pollution and the release of greenhouse gas emissions (GHGS) such as CO2, N2O O3 to the atmosphere; these have resulted in global warming, pollution, climate change, ozone depletion, deforestation and lots more. If appropriate measures are not taken to embrace renewable, green energy resources in order to minimize the utilization of fossil fuel energy resources, we might run out of resources in the future and the environment might become uninhabitable to mankind. Hence the use of green technologies that are environmentally friendly and are not accompanied by the release of toxic GHG to the atmosphere is very pertinent

With the rise of GHGs in the air, long wavelength infrared (IR) radiant heat is reflected and enclosed in the atmosphere, bringing about the heating of the ground surface [4,5] This is further worsened by the diminishing function of the depleting ozone layer, thus allowing the penetration of more UVB radiation onto the earth surface and aggravating the global warming and climate change [4]. Climate change owing to GHG emissions has become a global environmental issue [4] The global temperature has an exceptionally close correlation with the atmospheric CO2 level [4]. There has been a progressive increase in GHG emissions since the industrial revolution [5], owing to the gradual build up and the long retention time of CO2 in the atmosphere [5].

The accumulation of GHGs in the air had resulted in the spontaneous rise in CO2 concentration from 280 ppm to 400 ppm in 2014 [6], accounting for a global temperature rise of 0.5°C, in the previous few decades [4]. About 90% of the heat from global warming is absorbed by the sea, resulting in the rise in ocean surface temperature [5]. global energy demands However, fossil fuels have a great adverse effects, It is the leading source of environmental air pollution and cause of carbon dioxide (CO2) and other

Nonetheless, temperatures at the ground surface have increased equally, with each of the most recent thirty years being progressively hotter than the former since 1850 [5]. Ref. 5 reported the general global average land and sea temperature rise of about 0·85°C, between 1880 and 2012.

1.1 Causes of Climate Change

Climate change is considered to be caused by human activity, primarily the burning of traditional fuels, resulting in a build-up of GHGs [4]. CO2 is the major GHGs generated from human activities, especially fossil fuel combustion, resulting in 6-fold increase between 1950 and today [6]. The progressive rise in man-made emissions of CO2 and other greenhouse gases after the industrial age is drastically shifting the climate, both at the global and local level [7]. Conventional fuel CO2 emissions for the last 10 years have been at the climax of Intergovernmental Panel on Climate Change (IPCC) scheme due to economic advancement in less-industrialized nations [8].

The annual international GHG emissions organised in 2010 were projected at 49 gigatonnes of equivalent carbon-dioxide (GtCO2e) with the majority (about 70%) of total GHG emissions being attributable to the burning of traditional fuel for the generation of energy services, goods or energy extraction [5]. In the United States, CO2 accounted for 82% of greenhouse gas emissions, with 90% originating from combustion of fossil fuels (coal, oil, and natural gas)

and cement making, 9% and 6% attributable to CH4 and N2O, respectively, in 2012 [6]. Furthermore, the climate system shows substantial inertia, and temperatures will probably keep on rising for ages following the stabilization of greenhouse gas levels [8]. Man influences climate mainly through conventional fuel, industrial, agrarian, and other land use emissions that change atmospheric composition [8].

1.2 Impacts of Climate Change

Today, climate change is gaining growing attention globally, due to its increasing diversified and multi-pronged detrimental effects [9]. The effects of climate change on meteorological processes and environmental events are well reported [10]. Climate change is known to alter climate patterns, resulting in outrageous weather occurrences and increases in the frequency and intensity of the events [10, 11]. Severe weather events include heat waves, rising ocean levels, fluctuations in precipitation patterns [9], global temperature increase, cold waves, floods, drought, storms, tropical typhoons, heavy precipitation, snowstorms [10], mounting ocean level, elevated sea stratum, reduced ocean-ice level, and varying trend of sea movement, and freshwater in-flow [8].

The extreme climate events present diverse horrible and interrelated effects, which are progressively intense, prompting deaths, injuries and fatal communicable maladies [5,10]. Effects of climate change can be immediate such as heatwaves and severe weather occurences or indirectly caused by the impacts of climate change on ecological systems such as reduced crop and animal productivity, food instability and undernourishment, air contamination as well as the spread and varying patterns of disease [5,9], socioeconomic structure such as migration, dislodging, mental sickness and conflict [5]. Other impacts of climate change are increasing ocean temperatures and acidity [8], air and water pollution and forest fires [10].

The resulting effects on health can be classified as vector-borne diseases, rodent-transmitted diseases, malnutrition, and respiratory diseases [10]. Another result of harsh weather phenomena is diarrheal or gastrointestinal diseases, which are usually the result of increased precipitation over a short period of time [10]. Globally, over 530 000 people are victims of direct consequence of about 15 000 extreme climate occasions within 20-year (1993 to 2012), resulting in loss of over US$2.5 trillion [10]. Changing climate will affect the basic requirements for sustainable, such as, clean air and water, sufficient food, and adequate shelter [10].

The impacts of climate change are unevenly appropriated, with more serious dangers in the less evolved nations [5]. This current imbalance in danger of being influenced by environmental change is roughly 80 times higher in low income nations than in industralised nations, with females being around 14 more susceptible to death through natural disasters than men [9]. Other populations at risk of climate change include pregnant women, children, older people, people with medical issues or incapacities, poor and marginalised communities, outdoor workers, and people within coastal and low-lying riverine zones [5,10].

1.2.1 Global Warming Leading to Heat Waves

Globally, the average surface temperature has been consistently ascending [9,12] since the late nineteenth century, accounting for an increase of 1.1 °C [12]. The global warming potential (GWP) compares how much heat a greenhouse gas traps compared to a similar mass of $CO2$ [6]. Major bye-products of burning activities such as carbon monoxide (CO) , non-methane volatile organic compounds (VOCs), nitrogen oxides, sulphur dioxide, black carbon and organic carbon aerosols with some secondary contaminants (such as ozone) can possibly raise the global temperature alteration directly or implicitly [7]. CO, non-methane VOCs and nitrogen oxides are responsible for decrease in the oxidant intensity of the atmosphere prolonging the lifespan of methane [7].

Extensive, heat-capturing greenhouse gases (CO2, CH4, N2O, tropospheric ozone, and chlorofluorocarbons) warm the planet's surface around the world, while relatively short-lived particulate matters can either warm or cool the territory [8]. CH4 has a shorter atmospheric lifespan relative to the CO2, however, the former has a stronger heat trapping capacity [6]. In 2013, the Intergovernmental Panel on Climate reported that CH4 has 34 times stronger heat-trapping gas than CO2 over a 100-year time scale [6]. Direct radiative heating is intensified through a sequence of favourable climate feedback [8]; best estimates of anticipated international average temperature upsurge over the 21st century ranges from about 1.8° C to 4.0° C, based on emission condition [8]. The global temperature increase is more pronounced in the tropical zone, with an increase of about 4.0° C [12].

In reality, the vast majority of the documented global warming has happened in the previous forty years, with 2016 and 2017 being confirmed as the hottest years on record [12]. Extreme average global temperature was also documented in the first half of 2010, with heat extremes experienced in many continents [9]. Under a medium to high emission situation, the number of hot days could increase by factors of 2.1, 3.6, and 5.1 compared with 1961–1990, by 2020, 2050 and 2080, respectively [9]. Warming causes direct health risks through exposure to elevated level of heat beyond human tolerance [9]. In numerous urban populaces, an average rise of 2 °C in temperature would raise the yearly mortality rate by an projected factor of at least 2, as a result of hotter heatwaves. Developing nations, are the ones mostly affected by global warming [9].

Heatwaves are becoming more common and more severe than in previous years and consequently more death toll [9]. Heat wave associated with dehydration cause heat stroke, which may result in increased hospital admission cases and or mortality rate [10]. The 2003 European heatwave accounted for over 60,000 unexpected deaths [9] and France being most affected with excess mortality estimate of about 14 800 [10]. In 2009, temperatures in the outer suburbs of Melbourne (Australia) reached 48 °C [9]. The extremely hot heatwaves experienced in the Canada, United States, Asia, Europe, and Russia in 2010 were responsible for instability in power, interfering with transport, cooling, and high death cases. A heatwave with temperature reaching 53.5°C (128°F) was experienced in India and Pakistan in June 2010 [9].

Cardiovascular issues heighten risk as outrageous warmth puts extra burden on the heart [9]. Psychological disability, diabetes, malignant growth, and corpulence likewise raise vulnerability to hyperthermia. Chronic heat exposure incurs significant damage where laborers are incessantly dried out, and the result is emaciating health ,capability, and psychological capacity, which further devastates the workers [9]. Global warming also threatens the ecological frameworks which supply the food, air, and water we depend on for survival [9].

Global warming causes the migration of animal species towards the poles [6] and reduced oxygen level of water bodies' subsurface [8]. World-wide temperature increase thus presents both monetary and health risks [9].

1.2.2 Drought Leading to Food Shortage

Drought occurs as a result of water scarcity owing to a range of climatic origins and a marked decrease in precipitation. A notable example is the water scarcity crisis in Cape Town, in early 2018 [12]. Sub-Saharan Africa has demonstrated a notable drop in precipitation prompting an average decrease in discharge of 40-60% of certain watercourses since the early 1970s. Long-term outrageous drought patterns are seen across Africa, North and South America, the Middle East, China, and other parts of Asia. [9]. At present, approximately 1 billion individuals across the globe live in arid lands, with 20% of them residing in Africa. Arid and dry semi-arid zones in Africa are anticipated to escalate by approximately 11 per cent [9], partly attributable to depleted water resources (Collier et al., 2008), with the likelihood of being unsuitable for crop farming [9].

Climate change will worsen aridity, and cause increasingly outrageous downpour and progressively furious storms, which will interfere with food and water supplies. An average 2 °C increase in world-wide temperature could result in 5 to 20 per cent reduction in cereal grain production across South Asia and Sub-Saharan Africa by [9]. Currently, Nigeria is experiencing declining agrarian productivity due to decreasing precipitation in desert inclined regions in the north prompting expanding desertification, diminishing food productivity [11]. For many individuals these essential requirements for man wellbeing, food, water, and safe house are now being disrupted by outrageous climatic events [9].

Climate change impacts on food security will be most noticeably terrible in nations previously enduring elevated levels of hunger and will aggravate with time [13]. Over 70 per cent of current global populace, equivalent to 4.2 billion individuals reside in the 80 poor food scarcity nations, and in 2010, over 1.2 billion individuals, above 16.7% of the world populace, are hungry and undernourished [9]. In addition, increased population and food scarcity may drive more individuals to look for sustenance from the oceans, resulting in the overdependence on marine food systems. Fish stocks might be stressed as climate variations mounts additional tension on marine food systems [9]. The consequences for global undernutrition and malnutrition resulting from doing nothing in response to climate change are potentially large and will increase over time [13].

1.2.3 Air Pollution, Wild Fire and Human Health

Climate change and air pollution are intrinsically connected since greenhouse gases and air pollutants originate from the same source, fossil fuel combustion [7]. Combustion processes emit both greenhouse gases, like carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), and other air pollutants, like particulate matter (PM), sulphur dioxide (SO2), nitrogen dioxide (NO2) and carbon monoxide (CO) [7]. It is widely recognized that the release of air pollutants, even at low concentrations have significant impacts on human health, with a pronounced influence on respiratory sicknesses [7].

Primary and secondary pollutants have been linked to a various respiratory health impacts, including aggravation of ailments in patients already suffering from chronic respiratory sicknesses, such as, asthma and incessant obstructive pneumonic infection (COPD), resulting in frequent hospitalisations and emergency room visits for the underlying sickness, malfunctioning of the lung, asthma attacks, untimely death and, perhaps, the event of new respiratory issues, like, new-onset asthma [7]. Respiratory health is generally affected by air pollution as well as by climate conditions, particularly in individuals above 75 years of age [7]. Low income nations are progressively influenced by metropolitan air contamination because of accelerated economic and population surge [7]. It has been estimated that current ambient concentrations of particulate matter led to the loss of about 40 months from the average life expectancy in China, but that this loss could be reduced by half by 2050 if climate mitigation strategies are implemented [5].

Climate change related increase in wild fire occurrences will likewise influence particulate concentrations with increased fire risk in Mediterranean nations, particularly in territories with timberland [7]. The 2003 heatwave in Europe is significant since it was linked to records of wildfire and high particulate matter (PM) levels, particularly, the fine particles with aerodynamic diameter 2.5μm, which have longer atmospheric retention time (of the order of days) and may be conveyed by wind over long distances away from the source.

Respiratory diseases are on the rise globally [7]. In summer, each degree Celsius rise in maximum observable temperature over a city specific threshold limit (between 23 and 29°C) is linked to 7% expansion in daily respiratory mortalities [7]. Highly reduced temperatures also negatively impact the respiratory health, with a 3 to 4% rise in daily death and hospitalisations from respiratory illnesses in the populace above 75 years of age for each degree Celsius decline in minimal temperature or minimal observable temperature. . Ozone effect on respiratory admissions is more pronounced in summer [7]. Jamal et al [10] argue that urban air pollution over the globe accounts for 800, 000 deaths annually, with the worst consequences of climate change occurring in developing countries [7]. Changes in climate are anticipated to further exacerbate the impact of air pollution on these infections [7].

1.2.4 Changing Pattern of Disease

Another effect of an unnatural climate change is rise in mortality rate which could be partly attributable to increase in infection transmitting insects. Varying trends of infection are springing up as result of varying environmental scenarios [7]. For instance, the topographical distribution and the paces of development of mosquitoes are exceptionally affected by temperature, precipitation, and stickiness. There have been resurgences of malaria in the highlands of East Africa as of late. The temperature in the highlands of East Africa has ascended by 0.5oC since 1980, much faster than the global mean temperature and this is associated with a sharp increment in mosquito population.

1.2.5 Glacial Ice Melting

Upper-sea heat content has increased significantly since the 1950s, with average universal sea-surface temperature (SST) rising about 0.4°C during this interval [8]. Warming is not evenly distributed in space due to sea movement, space-related variable fluctuations in winds, and relationship with natural modes of climate changes such as El Nino/Southern Oscillation (ENSO) and the North Atlantic Oscillation. Ocean ice level has declined drastically in the Arctic and along the western Antarctic Peninsula (WAP), especially during summer [8].

Arctic ocean ice is diminishing at a rate of about 50 000 km² annually, the Antarctic ice sheet is presently losing 159 billion tons of ice yearly, and ocean levels are rising unavoidably [5]. 80% volume reduction in Arctic sea ice during late summer, and more than five-fold rise in the Greenland ice sheet melt rate was observed, between 1979 and 2012 [6]. Due to thermal increase and melting of land fast ice (glaciers and ice caps and sheets), warming has resulted in increased ocean level, with a prevailing rate of about 3 mm per year [8]. The ceaseless shrinkage of rise ice sheets, glacial retreat and declining Arctic ocean ice all add up to the ocean level rise in numerous locations on the globe [12].

1.2.6 Sea Level Rise- Flooding

As already mentioned global warming, to a large extent also influences the seas, which retain a significant portion of the heat [6,12]. Such atmospheric changes have brought about an increase in temperature of both the top layer (up to 700 m) and in the deeper waters [12]. The aftermaths of the elevation of the height of the sea is flooding and displacements of neighbouring communities [11]. The gradual disappearance of land due to ocean level rise has influenced human settlements for quite a while [12]. An example is the displacement of the Carteret community, a small island which is 1000 miles North East of Australia [11].

Another case is the severe land erosion of the Sundarbans community in the India Ocean region, attributable to global warming [11]. Currently, Nigeria is experiencing increasing occurrence of flooding, and annihilation of means of subsistence due to rising waters in coastal region [11]. Since the late 18th century, the sea level has being rising at rate of 0.3 cm/year [6]. Impacts associated with sea level rise include:thermal expansion, fluctuations in groundwater storage, glacier ice loss, Greenland ice loss, Antarctic ice loss, flooding and warm water fuel hurricanes [6] and increased frequency and intensity of tropical cyclones on coastal communities [12].

1.2.7 Storms/Cyclone/Tonados

Cyclone is another extreme weather event caused by climate change that leads to sea level rise, owing to global warming [12]. The communities residing at the regions nearest to the seas as well as those living in low-lying zones are at risk; this is where a considerable percentage of the world population reside [11]. A typical example is the 1991 cyclone which occurred in Bangladesh, a low-land of which two-thirds is less than five meters above sea level, murdered 138,000 and affected more than 13 million, with a flood 7.2 meters high [11]. Another example is the 29 August 2005 Hurricane Katrina, where winds with speed of about 200 kilometers per hour was lashed out at population residing on the Gulf Coast of the United States, resulting in about 1300 deaths [11]. Changing climate could possibly increase the frequency and intensity of this extreme weather event.

1.2.8 Ocean Acidification

Climate warming influences local wind trends and hence sea movements in multiple dimensions [8]. Warmer SSTs may affect the frequency and strength of tropical storms, increasing the vulnerability of coastal habitats. In the open ocean, rising atmospheric CO2 and the resulting increased oceanic CO2 uptake are the predominant factors of driving ocean [8]. Ocean acidification reflects a series of chemical changes such as elevated aqueous CO2 and total inorganic carbon as well as reduced pH, carbonate ion, and calcium carbonate saturation states [8]. Sea-surface pH is projected to have fall by 0.1 pH units since the pre-industrial generation, a 26% rise in acidity during the last 150 years. Future projections suggest further declines of 0.2 to 0.3 pH units over the century [8].

Sea acidification makes it more complicated for corals to discharge and keep their skeletons [8]. Besides, changing area use and waterway stream can modify stream alkalinity and, in turn, impact coastal inorganic carbon balance. Changing climate may be physiologically tolerable, allowing acclimatization or adaptation, or may be intolerable, promoting migration, change in phenology, or death and local extinction if adaptation is not possible [8]. Some basic habitat-forming marine benthic species, such as oysters or corals, seem susceptible to CO2 and climate variations both directly and through pathogens [8].

1.2.9 Impacts On Ocean Chemistry And The İnhabitants

Direct impacts of variations in sea temperature and chemistry may modify the normal behaviour and demographic qualities (e.g., efficiency) of organisms, prompting alterations in the size, space-related range, and periodic profusion of demography [8]. These transition, in turn, result in modified species communication and trophic routes as change falls from main producers to upper-trophic-level fish, seabirds, and aquatic vertebrates [8]. The impact of rising CO2 on ocean ecosystems include: coastal and benthic habitat degradation, over exploitation of fish stocks, rising aquaculture production, and invasive species [8]. Coastal hypoxia is increasing and expanding globally [8]. Ecosystem deterioration is intense and increasing, especially for waterfront frameworks, with half of salt marshes, 35% of mangroves, 30% of coral reefs, and 29% of seagrasses already either lost or degraded globally [8].

1.3 Global Meeting on Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) is a global agreement on the environment sanctioned by all of world's leading countries, established at the June 1992 Rio Earth Summit [6]. By 2014, the convention comprised of 196 nations or parties with a goal of stabilizing greenhouse gas levels in the atmosphere to a less harmful state [6]. But no limit was set for emissions by 1992 [6]. This resulted in the structuring of target and timetable for emissions of the developed countries, while exempting the United States, in the Kyoto, Japan COP, in 1997. In the conference no binding targets and compliance mechanism for GHGs emissions was given, but it did set up a legally nonbinding target that called for the developed countries to bring their emissions of GHGs back to 1990 levels, while a target of at least 5% reduction relative to 1990 levels within the time frame 2008-2012 was set for the developing nations. Each nation was saddled with the responsibility of reducing GHGs emissions, however, much emphasis was laid on the developed nations, whose parties were enjoined to take the leading role in combating climate change and the attributed adverse effects, since the largest share of historical and current global emissions of greenhouse gases has originated from them [6]. At these summits innovative financing measure called Clean Development Mechanism (CDM), to lower the cost of emissions reductions while assisting the low-income nations to finance their clean energy projects was also established [14].

After the pronouncement of the treaty, several strategies were put in place by many nations, especially the European Union, to cut the release of carbon emission [6]. The exception of United State coupled with the sporadic increase in the developing nations' emission, especially Chinas after year 2000 resulted in overall global emission growth [6]. The United Nations Intergovernmental Panel on Climate Change (IPCC) in 2007, identified elevated global atmospheric and oceanic temperatures, widespread melting of snow and ice, and increased global average sea level as consequence of climate change [6]. At the 2009 climate summit, held in Copenhagen, Denmark, many of the world's leading nations understood "the scientific view of the increase in global temperature should be below 2 degrees Celsius" and 2°C was agreed upon as the threshold at which dangerous interference began. In response, a consensus regarding this was reached with the aim of holding total global warming to below 2°C above pre-industrial levels and this was embraced at the December 2010 Conference of parties (COP) in Cancun [6].

Keeping the universal average temperature rise to less than 2°C to prevent the danger of conceivably calamitous climate change impacts requires cumulative anthropogenic carbon dioxide (CO2) emissions to be kept below 2900 billion tons (GtCO2) before the year 2100 [5]. As of 2011, total emissions since 1870 were about 50% of this, with current patterns expected to surpass 2900 GtCO2 in 15–30 years' time [5]. Most of the past emissions are retained in the air and will stimulate continued warming in the years to come [5]. Ref. 5 reported the progressive rise in GHG level at an irreconcilable rate with the intended limiting warming to 2°C by 2050, thus exceeding the IPCC's "worst case scenario". Hypothetically, the persistence of this scenario may result into a universal mean temperature increase greater than 4°C beyond pre-industrial temperatures by 2100, at which point universal temperature will continue to rise by about 0·7°C every 10 years [5]. To curtail the global GHGs emissions and the attendant effects, President Obama announced a new target to cut net greenhouse gas emissions 26-28% below 2005 levels by 2025 in the 2014 U.S.-China Joint Announcement on climate [6]. In 2015, all parties were committed to developing a follow-on agreement to Kyoto, one that includes commitments by the United States as well as major emitters in the developing world such as China [6].

1.4 Policy on Climate Change

Climate change is probably the most significant issue ever to have faced human social, political, and financial frameworks [15]. The stakes are gigantic, the dangers and vulnerabilities serious, the financial matters questionable, the science assaulted, the governmental issues severe and muddled, the psychology perplexing, the effects annihilating, the interactions with other environmental and non-environmental issues running in numerous directions [15]. To address both the existing and up-coming climate issues, appropriate policy and public health measures must be put in place [7]. Since climate change is a universal issue, with severe effects mostly felt in low income nations, international measures are imperative [7]. Strategies for reducing GHG emissions need to be determined, particularly in nations with the major emission burden [7]. A decarbonizing economy obviously need to include changes in consumption patterns, whether induced by government policy and price increases, or chosen by consumers [15].

1. The major strategies used by the constituted authorities to retard the growth in GHGs emissions of a country could be categorized into 4 groups namely [6]:
2. Economic policy
3. Regulatory policy
4. Technological policy
5. Forestry/land-use policy.

1.4.1 Economic

Economic policy involves the establishment of policies aimed at hiking the price of CO2 and other GHG emissions or subsidizing the cost of carbon-free energy sources such as nuclear power or renewable forms of energy (such as solar and wind) in order to discourage the use of high carbon energy while encouraging the uptake of new technologies. This is done so as to estimate the economic cost of hydrocarbon (HC) fuel (coal, oil, and natural gas) combustion and the impacts of their emissions on humans and the environment. This aim is achieved through a carbon tax or a cap-and-trade system [6]. Carbon pricing is the economist's ideal method of addressing climate change. Such pricing might be accomplished through regional or local explicit carbon taxes or cap-and-trade emissions trading systems (ETS), which are progressively gaining global recognition [5]. A carbon tax sets the carbon price directly, rather than the level of abatement, while an ETS sets the extent of reduction, but the pricing is controlled at the carbon market [5].

1.4.1.1 Carbon Tax

Carbon tax is the tax paid on carbon content of hydrocarbon (HC) fuel or CO2 generated from these fuel on combustion. This could also be referred to as the social cost of carbon, if the tax paid on these fuels are equivalent to the social cost, business parastatals and other end- users would be discouraged from using them hence minimizing the use of fossil fuels in the most optimum and efficient manner [6]. Carbon tax could also come up in form of removal of pricing grants for the extraction and usage of traditional fuels [5]. In June 2014, about 40 national and more than 20 subnational wards in South Africa were occupied with carbon pricing of divers range and equipment configuration, encompassing about 12% of the annual global GHG emissions [5].

Carbon tax guidelines usually required an organization to make a particular commitment with regards to decrease in air or water pollution for each facility it possesses, regardless of whether a facility or some companies do not meet up with the limit [6]. Carbon taxes were introduced in countries like Norway, and in 1991, this was adopted by some other European countries [6]. In 2012, Australia presented a $24 per metric ton carbon charge for chief industrial emitters and some government parastatals, and much of the revenues raised were circulated to the general public in form of reduced income tax, increased pension and welfare packages. By mid-2014, the tax had cut carbon discharges by as much as 17 million metric tons [6].

1.4.1.2 Cap-and-Trade Emission Trading System (ETS)

Cap-and-trade emission trading system (ETS) is a market based environmental standard focused on reducing pollution, and ensuring that the targeted level of emission is achieved at the least possible cost. It is one of the globally accepted strategy of GHGs emission reduction embraced by the EU Emission Trading System in 2003 [6]. The European ETS is the largest ETS, founded in 2005, and covering over 40 % of yearly GHG discharges from power creation and energy consuming and emission intensive large-scale industry across the EU-28 countries. The cap-and-trade system is a scheme in which the governmental agency set a threshold limit for industries on the emissions of specific pollutant [6]. The governmental agency implements the cap by issuing a limited number of permits, which allows the emission of air pollutants to a certain level [6]. In other words the concerned authority sets a cap on cumulative emissions, at that point issues permits for amounts that exceeds that cap [15,16]. These permits could then be traded with in the secondary market [6]. Industries that are able to efficiently manage and reduce their emissions below their allocations can sell those permits to other organisations that find lowering emissions more expensive [6,15]. The apportioned licenses are gradually reduced in specific fashion, resulting in the overall reduction of the pollution level [6].

The essence of this scheme is to sensitize the industries and other stakeholders in the market about the possibilities of further increase in the price of the pollutants and the rising necessity of investing in a long-term innovations that can reduce or replace CO_2 [6]. For instance, the EU enacted their Emission Trading System to meet the target of 8% below 1990 levels between 2008 and 2012 which they had committed to under the 1997 Kyoto Protocol, however 14% reduction in emission in the participating countries was achieved. The successful achievement of this goal had further prompted the commitment of the EU members leading to the 2014 announcement of cutting GHG emissions to 40% below 1990 levels by 2030 [6].

The cap-and-trade and the carbon tax system are similar strategies used in reducing emissions into the atmosphere, however, the cap-and trade system is more flexible, economically efficient, and business friendly relative to the regulatory-determined carbon tax. Many other countries are beginning to embrace cap-and-trade system. In 2011, China launched pilot carbon trading in cities and provinces, including Beijing, Shanghai, and Shenzhen along with Guangdong and Hubei Provinces, and subsequently announced the launch of its national market in 2016 with the intention of attaining the CO_2 peak by 2030. In a bid to reduce GHGs emissions, the Chinese have begun to establish price reforms on energy, strong fuel economy standards, and intensified effort in deploying clean energy innovative, hence making them world leaders in both manufacturing and utilizing solar and wind energies [6]. China has committed to “increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030 [6]. The South Koreans launched a program in 2015, with the intention of cutting GHG emissions to 30% below the current levels by 2020.

Both carbon tax and cap-and-trade Emission trading systems are good strategies of reducing GHGs emissions, however, the wealthiest in society benefit more from both traditional fuel grant and the existence of external influences at both regional and global levels, since energy usage and related emissions rises with wealth [5]. Globally, about 80% of such sponsorships often favour the wealthiest and 40% of the populace the adoption of low-carbon innovations. Thus the use of both carbon pricing and removal of fossil fuel subsidy may be regressive, as the poorest in the population spend majority of their income on energy, hence, reduced taxation of the low paid may partially settle this situation in the industrialised economies [5]. Other strategies like availability of power saving strategies for poor households, or the launching of electricity tariffs distinguished by utilization rate, are also viable solutions [5]. This is quite different in developing countries. Unlike other territories where the main problems hinge on how to minimize carbon discharges, Africa rather focuses on adjustment of production to changing, and mostly deteriorating, opportunities [16].

1.4.1.3 Clean Development Mechanism (CDM)

Clean Development Mechanism (CDM) serve as an institution that focuses on earning income through CO_2 reduction emissions [16]. CDM is a private sector initiative which allows industries in the high income nations to comply with their domestic emission targets by financing emission reduction projects in low-income countries, where expenses are often cheaper. In the process, one carbon emission reduction credit (CER) is awarded to the party involved per tonne of GHG saved. The CERs in turn can be sold on any of the international carbon exchanges [14].

Unfortunately, underdeveloped continents like Africa scarcely partake in the scheme which involves trading with $2 to $3 billion per annum through the CDM with just 2% ascribed to Africa. As of 2008, only 21 CDM projects out of about 1000 global projects were given to Africa. Examples of the CDM projects include gas recovery project in Nigeria and the West Nile Electrification project in Uganda [16].

Some reasons for the less participation of low-income continents in the CDM projects include:

- Limited capacity to organize and implement reliable CDM proposals due to their detailed, complex nature and financial requirement.
- Financial incapacity to justify the high transaction cost required
- Lack/ inadequacy of sophisticated energy and industrial requirements

Africa has potential for hydro and generation of power source from natural source of methane, but all these are not covered by CDM. It is therefore of paramount importance for Africa to develop technologically and financially so as to be more active in the CDM scheme [16]. Another way forward is to broaden the scope of CDM so that areas covering potential African projects such as power sector, waste disposal and deforestation could be incorporated [16].

1.4.2 Regulatory Policy

Regulatory Policy focuses on the establishment of regulatory guidelines targeted at curtailing GHGs emissions. Regulatory policies include fuel economy standards for vehicles, energy efficiency guidelines for appliances, renewable energy standards that necessitate the incorporation of a minimum level of carbon-free sources into electricity or vehicular fuel cutting down the CO2 emissions from the various facilities like electric power plants [6]

1.4.3 Forestry/Land-Use Policy

Forestry/land-use policy centers around land and forestry policies aimed at lowering GHG emissions from deforestation and agrarian practices. For instance, Brazil, have made huge decreases in their net emissions from deforestation. Currently, deforestation and other land-use changes are responsible for about 10% of global GHG emissions [6].

1.4.4 Technological Policies

Technological policy deals with research-based guidelines aimed at subsidizing and improving the performance of low carbon energies. This incorporates fundamental investigation into green technologies, new materials and applied innovative research and development of advanced energy efficiency methodologies, such as LED lighting, solar panel, and a lower-cost electric vehicle battery. This policy also incorporates the sponsoring of research and development on and commercializing low-carbon energy system such as coal plant with carbon capture and storage [6]. To promote dissemination, enhancement and subsidizing of low developed innovations, private financing is likewise needed. For new innovations, sound research and development (R&D) efforts are imperative [5]. In the USA, Gunderson Health has increased efficiency by 40%, saving $2 million annually, while deploying solar, wind, geothermal, and biomass to significantly reduce its carbon footprint and end its dependence on fossil fuels [5].

2. THE CONCEPT OF GREEN TECHNOLOGY

Green technology is a general name that describes the application of science and technology to produce clean goods and services. Green technology is identical to cleantech/eco-tech which obviously refers to services and goods that can be produced efficiently while generally reducing cost, energy utilization and adverse environmental impacts. Green tech is the utilization of alternative fuel resources and machineries that are safer than conventional fuels and has the potential of resolving the present energy chaos and remediate the environment.
Although the concept of green technology is relatively a new field, it has stirred lots of attention from the research community, industrial and academic sector owing to its promising potential of reducing the use of conventional fuels and its adverse environmental impacts. The main objective of green technology is to ensure safety of the earth, produce a balance to lopsided energy demand and supply and preserve the environment.

New green technological approaches demonstrate the potential to resolve difficult challenges faced by the environment and global energy crises across the world in this 21st era. The most efficient methods are categorized into the following headings: Renewable energy, Clean Water¸ Clean Air, transportation, energy efficient building, recycling, agriculture and coorporate Green Tech.

The traditional energy tandem materials and resources are prone to risk that are detrimental to the ecosystem. Also, the development of current technologies combined with the increasing pressures of population needs/demands has led to rapid growth of industrial evolution and urbanization. This has a visible consequential pressure on nature and has become rapidly intense which has resulted to significant upsurge in industrial pollution, deterioration and contamination of the environment. During the last few decade, the environment has deteriorated in a manner that has not been experienced before in the history of humanity. At present, the environment is exploited at a faster rate and time than it would take for it to be refilled by nature. The type and magnitude of environmental challenges which results in the deterioration of the environment are diverse and interdisciplinary [17].

It is broadly known that there are some problems that are global in nature such as climate change, global warming, ozone depletion, biodiversity loss, forest fires, and extinction of endangered species. While local environmental challenges are water contamination and pollution, land degradation, vehicular and air pollution, domestic solid waste, industrial hazardous waste, soil degradation, deforestation and loss of biodiversity [18,19]. Humankind are both causes and causality of environmental degradation. Various technologies and traditional method have been utilized by mankind to exploit the environment which has resulted in indescribable variation in the ecosystem. For example, the utilization of irrigation and dams, the use of additives and chemicals to the soil and other conventional methods to improve crop yield has also played a major role in environmental degradation. Actually, the misuse of natural resources and developmental sustainability challenges have multifaceted causes and consequences [20].

Having underscored the potentially damaging effects of environmental hazards, a thought provoking question is to whether our action should focus on the prevention of its rate and magnitude with the utilization of decarbonizing strategies and economic activity or by adapting to its inevitable drawbacks (e.g. by intensifying the resistance to adverse weather conditions, heat waves and life-threatening draught). Preventive approach which include both mitigation and adaptation strategies are viable options. Nevertheless, the main approach to sustainability is prevention of environmental problems. The ideal way to tackle environmental hazards is to prevent its creation. That is why the utilization of Green technological approach may take a major lead in the prevention of environmental problems and its totality. Preventing problems is more affordable than fixing it, this is a preliminary ideology for effective and economically feasible manufacturing procedures.

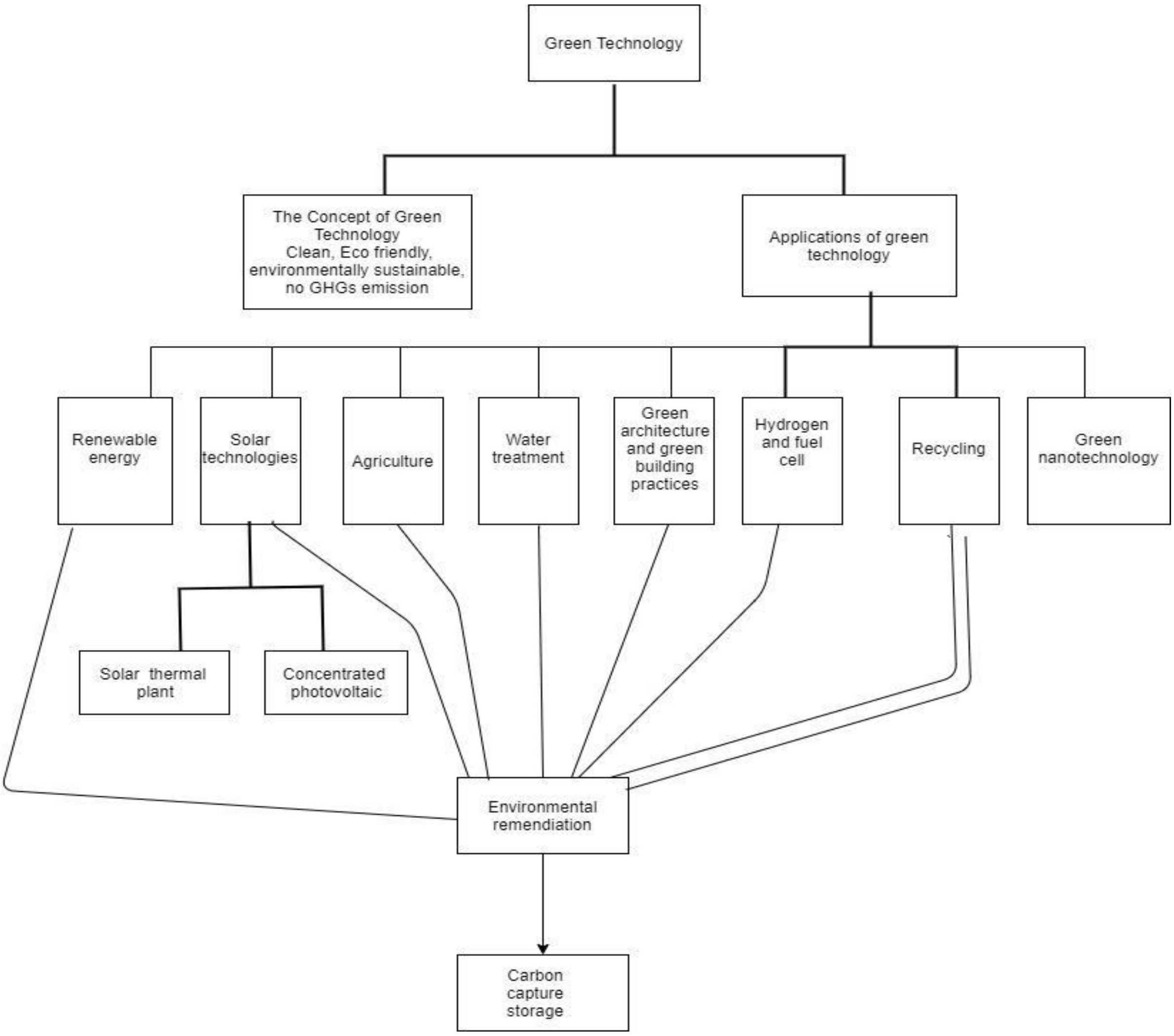

Figure 3: Green Technology

Green technology is an improved application of technique, equipment's and products in a way that leads to the conservation and preservation of the environment, decreased harmful atmospheric effects, reduced depletion or deterioration, zero level GHGs emission, induces environmental safety and preserves all life forms, enhances the utilization of energy forms that are renewable and conserve the utilization of energy resources that are natural (see Figure 3)

Rani et al reported on the overview of green technology on nanotechnology, they reported on the importance of utilizing technologies that permits material engineering of small size particles in the medical, clothing industries, water purifying companies, electronic industries, solar companies in an environmentally friendly, clean, nontoxic and developed manner. [21]

Monu et al repoted on the advantages and disadvantages of green technology, they highlighted the four pillar of green technology policy as energy, environment, economy and social. The study reported that the major goal of green technology is meeting societal needs without depleting or damaging the environment, natural habitat and resources. The study suggested that government and energy cooperation should shift attention on manufacturing and producing products that are reusable in other to maintain a clean environment. They listed the advantages of green technology as it's use does not emit harmful substance to the environment, green technology is beneficial to the environment and the economy, less maintenance are required by green technology, it is readily abundant, the utilization of green technology reduces the emission of CO2 and subsequently reduces global warming while the shortcomings reported in their study is high costs of execution or implementation, limited information are available on the use of green technology, inadequate skill and technical knowhow on green technology. [22]

Zaffar et al reported that green technologies is key towards sustainable development, the study reported that green technology has a positive impact potential towards urbanization, economic growth in the society and in meeting economic sustainability demands. They highlights the merits of green technology as waste management, water recycling air purification and the utilization of conservative energy devices [23].

3. APPLICATION OF GREEN TECHNOLOGY

3.1 Renewable Energy Sources

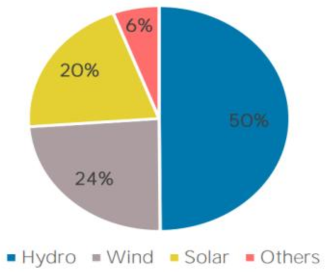

Figure 4. Renewable energy percentage

Renew able energy is the most rapid growing source of energy, accounting for around half of the increase in energy.

Solar power is the use of the sun's energy to generate electricity. "The sun could be the world's largest source of electricity by 2050, ahead of fossil fuels, wind, hydro and nuclear," according to two 2014 reports from the International Energy Agency [6].

Green tech can be employed in methods designed to conserve energy, for example energy-efficient light fixtures. Green tech is likewise employed to generate renewable fuel sources that are cleaner than traditional fuels. Conventional fuels usually generate waste as a by-product of their production. Solar, wind, and hydroelectric dams are all examples of green tech because they are lesser risk to the environment and do not generate fossil fuel waste by-products. Aside the environmental gains of these renewable energy sources, they can likewise be employed to power a home or a utility power plant.

3.2 Solar Technologies

The sun is an enormous source of energy which supply energy to nature, the sun can be used as a green source of energy because it is clean, renewable and environmentally friendly. The sun is the most appropriate source of energy

The world cannot depend on petroleum products/traditional fuels perpetually to run homes, cars and industrial facilities. Green tech incorporates the transformation of renewable resources, like solar light, wind and water to energy that we can utilize. Solar panels, wind turbines and geothermal wells are generally templates of technological innovations that can replace the demand for coal and oil.

According to IRENA, "Renewables are important for us because they offer decentralized solutions, they can support multiple applications such as lighting, cooking, heating, cooling and drying".

Renewable generation capacity by energy source

Toward the end of 2018, worldwide renewable generation capacity added up to 2 351 GW. Hydro represented/covered the biggest percentage of the worldwide total, with a total power of 1 172 GW. Wind and solar energy represented the majority of the rest, with wattages of 564 GW and 486 GW respectively. other alternative sources of energy included 115 GW of bioenergy, 13 GW of geothermal energy and 500 MW of marine energy (tide, wave and ocean energy) [24].

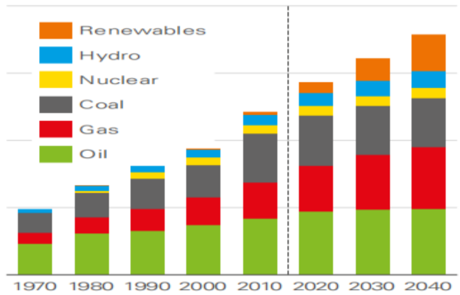

Figure 5. Energy resources according to years.

which supplies directly or indirectly other form of energy resources which are wind and hydro and had the least environmental concern that is, it's use is not accompanied with the release of GHGs emissions and does not contribute to climatic change effects [25]. Photovoltaic cells are utilized in harnessing solar energy. Photovoltaic cells operation involves the use of photoelectric effect to convert photons from sunlight into electricity (See Figure 6)

Figure 6: Solar Technologies [26]

Solar technologies are used in solar thermal plants, concentrating PVS and so on

3.2.1 Solar Thermal Plants

Solar thermal power plants are technologies which utilizes solar heat energy from sunlight, direct solar radiation are harnessed from sunlight through collectors in the solar thermal power plant architecture to generate water heating at temperatures that are low. The large scale application involves the use of solar concentrators (See Figure 4) by parabolic mirrors to provide high temperatures which are in turn utilized for direct and indirect heating processes especially for conventional heat engines [25]

3.2.2 Concentrated Photovoltaic (CPV)

Concentrated photovoltaic (CPV) technology utilizes optical devices which include lenses/mirrors to concentrate direct solar radiation onto a multi-junction semiconducting material to generate electricity as shown in Figure 7 [27]. CPV systems are characterized based on the degree of concentration of solar radiation measured in suns. The range of the solar concentration factor is 2 to 100 suns (low to medium concentration) and measure up to 1 000 suns (high concentration) as presented in Table 2. The orientation of the lenses/mirrors must be permanently in the sun's direction using single or dual-axis tracking system for it to be efficient. Low to medium concentration systems are associated with silicon solar cells, although their efficiency is reduced at higher temperatures, while high concentration systems (beyond 500 suns) are usually hinged with multi-junction solar cells made by group III and V semiconductors including GaAs or In GaAs (1.4 eV), Ge (0.67 eV), and In Gap (1.85 eV) [28]. Theoretical efficiency of 59 % can be achieved with multi-junction cell with band gaps of 0.74, 1.2 and 1.8 eV [28]. Laboratory efficiency of more than 40 % has been achieved with CPV based on multi-junction solar cells [29] while silicon-based commercial CPV modules gives efficiency in the range of 20 % to 25 %. The multi-junction CPV cells are utilized for space applications or solar cell with relatively small area solar with concentration of sunlight owing to their complexity and high cost [30].

Table 1: Description of concentrating photovoltaic cell classes [31].

Class of CPV	Typical Concentration Ratio	Tracking Systems	Type of Converter
High concentration PV (HCPV)	300-1000	Two-axes	III-V multi-junction solar cells
Low concentration PV (LCPV)	< 100	One or two-axis	c-Si or other cells

The limitations of the CPV cell are the high costs of focusing, tracking, and multi-junction solar cells. CPV modules rely on direct sunlight, they require clear skies and high direct solar irradiation for optimal performance and can only be used in certain regions.

Figure 7: Concentrated PV systems [32].

3.3 Agriculture

Green agriculture technology refers to a food supply chain without causing any harmful effect of climate change in the appearance of increasing food demand and global population. The main aim of green technology in agriculture is to achieve the security of food and nutrition via balancing between trade and domestic production. Contributing to achieving enough supply of food to humanity, guarantee a decent livelihood in the local settlements and the utilization of technical and domestic approach to improve food production while maintaining the ecosystem. Green technology can be achieved through the application of the ecological system to agricultural, forestry and fisheries administration in a manner in which the food and nutrition needs of the society can be addressed without endangering the benefit of the upcoming generation, terresstial, acquatic and marine ecosystems. The agricultural segment comprising of livestock, crops, fisheries, forestry, and processing of food is key to transition to green economy. 60% of terrestrial lands are occupied by crops, forest and pastures. 70% of global freshwater are used by the agriculture sector, the agriculture sector is also responsible for livelihood of about 40% of the population of the world. The agricultural sector is largely dependent on resources that are natural for their production and jeopardize the environment.

The contribution of current agricultural practices is one third of the greenhouse gas emissions across the globe, practices with good management can result in a decarbonized economy and also results in the achievement of clean environmental activities and the production of energy resources that are renewable. The agricultural sector can also be the major driver of economic growth and generation of green jobs of the order of millions mostly in the countries that are very poor, the security of food and nutrition will need to be accomplished as a major part of green economy. This is owing to the fact that food and agricultural system are subject to threats from climate change, poverty and the degradation of resources, green economy is designed to tackle these problems. In a world that is constrained of resources, only a system of economy that leads to enhanced well being of humans and social equity while reducing significantly the scarcity of the ecosystem and environmental risks will be able to provide security of food for more than nine billion people, by 2050 [33]

3.4 Water Treatment

Water is an essential element in life. In our world, several regions suffer from water contamination and scarcity. Water treatment is the act of removing undesirable contaminants from water. Undesirable substances may include biological, chemicals and even physical pollutants making it viable to be used in other applications. Water treatment is the solution preferred by many developing countries to reduce water stress. This solution may be focused on different perspectives depending on applications such as industrial and human activity [23]

Today, the practice of green chemistry give rise to the production of chemical and new techniques in a manner that retain and enhance effectiveness while reducing toxicity. Auxiliary constituents are utilized by manufacturing processes and chemical which are not part of the finished product.

The production or utilization of elements and substances which are harmful to environments of humans should be completely avoided or minimized where there is a strong relationship between environmental chemistry and green chemistry. The use of additives that are environmentally acceptable for the treatment of water treatment is one major area where green chemistry is applicable [34].

Green chemistry method for water treatment involves environmentally acceptable processes in the chemical industry, green sustainable technology entail a paradigm shift from conventional concepts or processes that focus largely on chemical yield to clean and environmentally sustainable, economically valuable concepts of eliminating waste at in water or water source while avoiding the usage of toxic or hazardous substance [35].

3.5 Green Architecture and Green Building Practices

Residential and commercial buildings utilize one third of energy that are generated globally and two thirds of electricity, building practices produce high amount of CO2 emissions that are disastrous. Also waste products are generated during building constructions and operations, this can contaminate the environment, air quality and affect the health of the workers. Green design or green architecture is a building approach that reducing the dangerous effect on the environment and on the health of human being. The "green" architect or designer ensure that he safeguard water, air, and earth by selecting building materials and construction practices that are ecologically-friendly [23, 34, 35] Green building entails the application of green materials and green technology that are environmentally friendly in building design although green building are costlier than conventional buildings, they are economically beneficial and does not contributes to GHGS emissions unlike conventional buildings, their operational cost is reduced and they enhance a sustainable environment. Green buildings addresses water conservation, waste management, non-toxic materials, energy efficiency, environmental impact, recycled and reused materials [23]

3.6 Hydrogen and Fuel Cells

A lot of research has suggested hydrogen and fuel cells as a very attractive alternative to fossil fuel, hydrogen cells is a viable option for deep decarbonization of the world energy system. Hydrogen fuel is an essential element of a decarbonized and sustainable energy system to generate secure and cheaper non environmental polluting energy. Hydrogen and fuel cells can be produced in large-scale [36]. Fuel cell vehicles has begun, and fuel cells are utilized to power and to heat hundreds of thousands of homes. The major difference since the last hydrogen ‘‘hypecycle’’ in the 2000s is that there is a scale up in manufacturing and cost reduction which lead to the commercialization of hydrogen and fuel cell in many sectors. from portable electronics and backup power to fork-lift trucks. Hydrogen council is recently formed by thirteen international cooperation to place hydrogen as one of the major solutions to the transition of energy. Hydrogen can be obtained from feedstocks processes; it has many useful applications without fuel cells while fuel cell can function using other fuels than hydrogen. Hydrogen and fuel cells can make a significant contribution in several ways across the entire energy system. Infrastructure for hydrogen may be costly but the pathways comprises of various low-cost incremental routes after established networks. [36]

3.7 Recycling

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. - Brundtland Commission, Our Common Future, 1987

According to the Brundtland (1987) meaning of sustainability, it is evident mankind doesn't utilize resources in an eco-friendly approach. In short, resources are utilized so that upcoming generations will be adversely affected.

Recycling is to utilize materials that have already been used in manufacturing of new products, which is one of the three golden rules of sustainability that include reduce, reuse, and recycle. Since crude materials often originate from our most important forests and natural resources, recycling can reduce the demand for raw materials. It also cut back the requirement for extracting, refining and processing crude materials, all of this generate air and water pollution. It decreases greenhouse gas emissions, which assists to tackle climate change.

Material is restored without saving the initial state of used product. With recycling, used products gain commercial relevance once more [37]. Products manufacturing from recycled materials demands lesser energy than making them from new crude materials. It's much better to reuse existing products than to destroy another person's locale or land in the quest for new crude materials.

The enthusiasm for gathering waste resources like paper and reusing them in manufacturing industry has been increased worldwide. Adverse effect in tough environmental challenge in the most recent years has created increasing awareness for recycling. Also, more prominent awareness level about environmental condition and new found scientific discoveries which proposes that cellulose can be utilized commonly to manufacture paper brought about this more significant level of enthusiasm for recycling [38]. In broader terms, recycling is a strategy which is applicable to wastes that cannot be utilized once more or whose formation cannot be hindered [39] .

Green tech is employed in the recycling procedure, together with waste incineration. Reusable material can be utilized when producing plastics, fertilizer, and fuel. Clean tech can likewise be a section of the fabrication processes, for example, procedures to reuse water or waste in the production process.

3.8 Green Nanotechnology

Green nanotechnology (Green nanotech) is a rapid growing area of science which functions on the size of one billionth of a meter, or a nanometre. Materials are maneuvered in manners that will revolutionize the manufacturing industry. Green nanotech requires principles of chemistry, physics and engineering.

Nanotechnology applies to the use and modification of extremely small particles in the order of one billionth of a metre (i.e. 10−9) called nanoparticles. Based on their physiochemical properties, Nanoparticles (NPs) can be generally grouped as organic nanoparticles (such as carbon-based materials, Polymeric NPs and Ceramics NPs) and inorganic nanoparticles (e.g. semiconductor NPs, metal and metal oxide NPs such as silver, zinc oxide)[40-43]. In addition, NPs characteristics depends on general shape which can be classified into various dimensions such as, zero-dimensional (0D), one-dimensional (1D), two-dimensional (2D) and three-dimensional (3D) classifications [44] .

Nanoparticles have gathered momentum in the science domain due to the reinforced properties of materials in the nanosized. These properties and efficacy of nanotechnology-based materials make the use of nanoparticles more sustainable than traditional approaches of cleaning the environment.

Applications of nanoparticles

The applications of nanotech has spread across many disciplines owing to improved properties of materials that are different from their bulk counterpart [45]. Recently, research in nanotech has reached nearly all fundamental disciplines including environmental remediation [46]. As a result of physiochemical nature and the antimicrobial potential of nanomaterials, they are largely employed against different pathogenic microbes and in healthcare, crop protection, water treatment, food safety, and preservation of food [43,47]. Processing of dyes employing biosynthetic nanomaterials presents a sustainable, low-cost and clean alternative by removing complex machinations and formalities [48].

Various other metallic and metal oxide NPs (like Silver NPs, Gold NPs) have also been published in several journals to display efficient catalytic properties towards degeneration of toxic dyes [49].

Nanotech has risen to be a useful strategy for clean-up of oil and gas pollutants as it has the possibility of minimizing the remediation costs and time of massive waste sites and mitigate concentration of pollutants at the scene [50].

With the scientific society and world always in wait for viable approaches for reducing environmental challenges, the removal of harmful precursors and high cost together with harmful strategy has put green nanotech as the forerunner for environmental application.

Based on the literature available, it is obvious that green synthesis of NPs serves two objectives. First, it offers a clean, harmless, ecological technique of fabrication of nanoparticles by removing harmful precursors and toxic wastes and secondly, it functions as an efficient and viable method for environmental clean-up.

4. Environmental Remediation

The rising demand for newly approaches of research in cleaner environment through economic sustainability and eco-friendly means has driven researchers to the use of Greentech as a leading sustainable alternative.

According to ASTM [51,52] , Sustainable remediation based on guidelines, involves coordination of the resource consumption of the remediation effort with the advantages accomplished regarding the economic feasibility, conservation of natural resources and biodiversity, and the improvement of the quality of life in surrounding communities.

Environmental degradation is definitely one of the fundamental issues that faces world presently. Modern technologies are continually being investigated for the clean-up of pollutants of the air, water, and soil [53]. These are the few examples; particulate matter, heavy metals, pesticides, herbicides, fertilizers, oil spills, toxic gases, industrial effluents, sewage, and organic compounds regarding contaminants [54,55]. Various kinds of materials can be used in environmental clean-up and in consequence very diverse approaches can be harnessed for this purpose.

Further dimension of green innovation includes eliminating contaminants from the soil, air and water. These procedures extend from chemical to biological. Industry is liable for a significant part of the pollution and the government has to increase more strict regulations/guidelines to control it. Clean tech is utilized in forms that filter the air by minimizing emission of carbon and gases that are discharged into the environment from production plants.

It is crucial that the materials employed for the remediation of contamination are not another contaminant themselves after they have been utilized. Therefore, to avoid this problem, cleantech materials are keen interest for this area of use.

Environmental remediation depends largely on utilizing different techniques (such as adsorption, absorption, chemical reactions, photocatalysis, and filtration) for the elimination of pollutants from various environmental media (like air and others)

4.1 Carbon Capture and Storage

Preventing hazardous environmental change may well be attainable owing to research suggesting there is sufficient space underground to store all the CO2 taken from the air to keep atmospheric temperatures stable.

Carbon Capture and Storage (CCS) is a technology that can capture up to 90% of CO2 emissions generated from the utilization of coals in production of electricity and manufacturing operation, inhibiting the CO2 from penetrating the environment. The CCS chain comprises of three sections; capturing the CO2, transporting the CO2, and storing the CO2 emissions in underground depleted oil and gas fields or deep saline aquifer formations.

CCS together with other interventions such as nuclear power, renewable energy are carbon abatement technologies that have greatest decarbonisation potential to take CO2 out of the atmosphere [5,56].

The capture and storage of CO2 underground is one of the major aspects of the Intergovernmental Panel on Climate Change's (IPCC) accounts on how to keep global warming below 2°C above pre-industrial levels by 2100 [57]. However, the world adoption of CCS is very slow due to the cost of building capture plant is expensive and the hypothetical future problem of CO2 leaking out of storage site.

5. CONCLUSION

Environmental problem has certain impacts on human quality life. Globally, the living condition of present and future human populations relies on environmentally sustainable ways of living. Environmental clean-up relies mainly on employing different technologies including the aforementioned ones for the removal of pollutants from various environmental media (water, air and soil). The paradigm shift advocated by researchers and environmentalists to tackle the challenges of environmental degradation requires the use of Greentech that generate eventually a desirable sustainable revolution. Our review indicate various ways in which the environmental remediation program may assist to expedite the response to climate change and environmental degradation. Although the threats are great but there are huge opportunities for technological invention especially the Greentech to offer sustainable solutions. Failure to act now is tantamount to environmental disaster.

Furthermore, continuing exploitation and extraction of environmental resources that are conventional will definitely lead to ecological decay as we are experiencing today. Therefore, clamouring for environmental conservation and sustainability should solely focus on clean energy and environmental remediation that is not contaminated. These remediation technologies are well explained in this review. In a nutshell, Greentech proffer the solution to climate change and take the lead in preventing environmental problems resulting to a sustainable environment.

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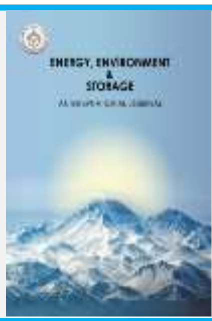

Experimental Study on an SI Engine Mapping Considering Performance, Emissions, and Cyclic Variability

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ABSTRACT. The engine manufacturer has aimed to attain optimum values for engines operating different loads and speeds by utilizing the characteristics of both spark-ignition engines having a ready combustion control and compression ignition engines resulting in low emissions, fuel consumption and, a high engine output power for years. In this regard, the efforts on the improvement in engine performance, emissions, and thermal efficiency of the engines have been constantly continuing to be updated for their whole specifically operating range. In this study, a series of experiments was performed to construct the maps of a two-cylinder, four-stroke spark-ignition engine. Considering the engine characteristics at full load, the engine was tested at seventy operating conditions depending on speed and load. With the obtained data, the engine maps were created for performance, emissions, and cyclic variability of maximum pressure, brake mean effective pressure.

Keywords: Spark ignition engine, Engine mapping, Performance, Emissions, Cyclic variability

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1. INTRODUCTION

Internal combustion engines use approximately one-third of the Daily total World oil production. With the increase in the number of internal combustion engine vehicles, air pollution has been rapidly increasing due to the emitted emissions into the atmosphere. Therefore, the efforts have been getting great attention to deal with the efficient use of fuel in engines and the reduction of pollutant emissions in exhaust gases [1].

Internal combustion engines are classified as spark ignition (SI) and compression ignition (CI) engines according to their combustion characteristics. A conventional SI combustion can be characterized by the flame formation and the development and spread of this flame. The initiation of the combustion reaction is achieved by controlling the spark plug ignition timing. In compression ignition engines, it starts with the spraying of fuel on the compressed air and self-ignition and continues. In both of these combustion events, the improvement of performance and exhaust emissions depends on efficient combustion in a very short time. Adjusting a large number of parameters according to the operating conditions of the engine to keep the combustion efficiency at the maximum level in all operating conditions of the engine provide the most efficient conversion of fuel to energy. Fort his purpose, some operating parameters such as ignition timing, valve timings, compression ratio, and air-fuel ratio change depending on engine speed and load [2]. In addition, the researchers investigated different alternative fuel addition to gasoline, and evaluated their effects on engines' performance and emissions. Topgül et al. [3] examined the effects of excess air coeffcients, ignition timings, compression ratio, and inlet air temperature values on exhaust emissions in a single cylinder, four-stroke, spark-ignition engine. They found that the increase in the ignition advance causes the reduction of CO emissions, and the increase in the ignition advance up to 30 ° CA increased HC emissions.

İsmail and Mehta [4] investigated the effects of hydrogen addition to gasoline on engine performance using mathematical modeling. They reported that hydrogen addition to gasoline at different rates had a positive effect on engine performance. Aktaş and Doğan [5] examined the effects of LPG addition to diesel fuel at different rates on engine performance and emissions in a single cylinder, four-stroke CI engine. The used CI engine was operated at the speed where the maximum torque takes place. Besides, diesel fuel was used as pilot fuel and LPG was added into the cylinder in different proportions by weight. They observed that the addition of LPG to diesel caused the decrease in NOx and soot emissions with HC emission penalty. Özer and Vural [6] performed the study to

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investigate the possibility of acetylene gas as an alternative fuel in a spark ignition engine. They stated that the addition of acetylene by 20% and 30% worsened combustion while different rates of reductions in exhaust gas temperature, HC, CO, CO2, and NOx emissions were detected.

Literature surveys show that various parameters influence engine performance and emissions. Therefore, it is essential to define the characteristics of any engine operating different load and speed conditions to determine the improvement potential in the engine. In this study, a series of experimental studies were carried out to create the engine maps in terms of performance, emission and cyclic variability.

2. MATERIALS AND METHODS

Experimental studies were carried out on a four-stroke spark ignition Lombardini LGW523 engine at the Engine Laboratory of Mechanical Engineering Department of Erciyes University. The technical specifications of the engine are given in Table 1. The schematic view of the experimental setup is also illustrated in Figure 1.

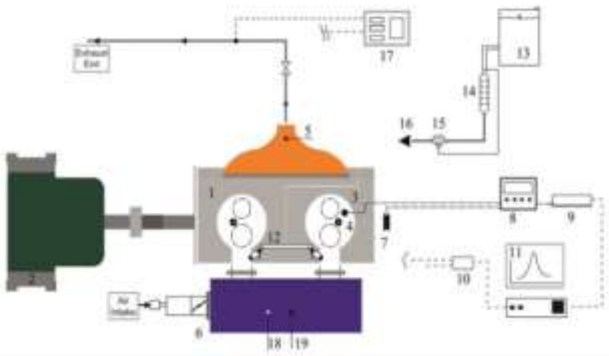
Table 1. Test engine specifications

Numbers of cyclinder	2
Cylinder volume	505 cc
BorexStroke	72x62 mm
Compression ratio	10.7:1
Max. Power	15 kW
Max.Torque	34 Nm 2150 rpm
Cooling type	water

In the experimental study, a 50 kW hydraulic dynamometer was used to enable the engine to be controlled for different load and speed conditions. With this dynamometer, different speeds and torque can be controlled by adjusting engine load using water brake. Emission measurements were carried out using a Bosch BAE-070 gas analyzer whose technical specifications are summarized in Table 2.

Table 2. Exhaust gas analyzer specifications

Parameter	Range	Unit	Sensitivity
HC	0-20,000	ppm	1.0
CO_2	0-20	%	0.1
CO	0-15	%	0.001
O2	0-21.7	%	0.01
Lambda	0.6-1.2	-	0.001
NOx	0-5,000	ppm	1.0



(1)Test engine, (2)dynamometer, (3) in-cylinder pressure sensor,(4)spark plug, (5)exhaust gas temperature-termocouple, (6) throttle (7) encoder, (8) amplifier (9) oscilloscope, (10) data logger, (11) computer, (12) port injector system, (13) fuel tank, (14) scaled container, (15) regülatör, (16) fuel pump, (17) gas emissions device, (18) termocouple for intake air temperature, (19) pressure sensor.

Figure 1. Schematic experimental setup

In-cylinder pressure for combustion analysis was measured using a Kistler 6053CC brand pressure sensor whose specifications are given in Table 3. By setting to a suitable mode and a low pass filter range of 100 kHz to avoid irregularities in the form of signal drift due to noise, vibration, and thermal shock, the Kistler 5018A brand signal amplifier (Table 4) was used to amplify the signal coming from the pressure sensor. In order to display the signal values in voltage unit, and record these data, Pico branded oscilloscope was used with PicoScope-Automotive software.

Table 3. Pressure sensor specifications

Measurement range	bar	0-250 bar
Calibration interval	bar	0-50, 0-100, 0-150, 0-250
Sensitivity	pC/bar	≈ -20
Natural frequency	kHz	160
Operating temperature range	ºC	-20 ile 350

Table 4. Amplificator specifications

Measurement range	pC	±2 -2.2x10^5
Errors		
<10 pC	%	<±2
<100 pC	%	<±0.6
≥ 100pC	%	<±3
Signal mode	pC/s	<±0.03

A rotary type encoder that generates 3-4 V at each 360o rotation was used to determine the crank angle position. During the experiments, the cooling water temperature was kept at 85 ± 2 oC.

Exhaust gas temperature was measured in the line close to the oxygen probe, 10 cm from the exhaust manifold. Experimental studies were conducted at seventy operating points specified in Figure 2 by utilizing the engine characteristics at full load conditions.

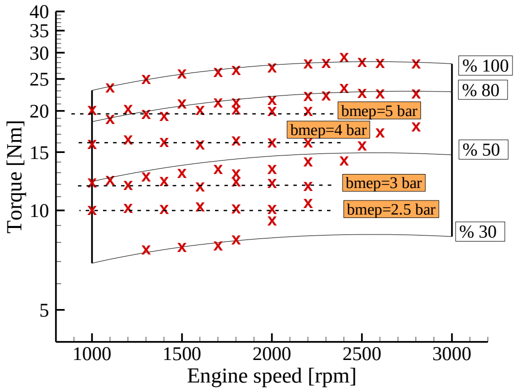


Figure 2. Experimental study points

3. RESULTS

3.1. *Performance and Emissions*

The experiments were commenced with the full load performance test of the engine. With the determination of the engine characteristics at full load, experiments were also carried out for different load conditions, 80%, 50%, and 30% loads at different engine speeds in the range of 1100 to 2800 rpm as shown in Figure 2.

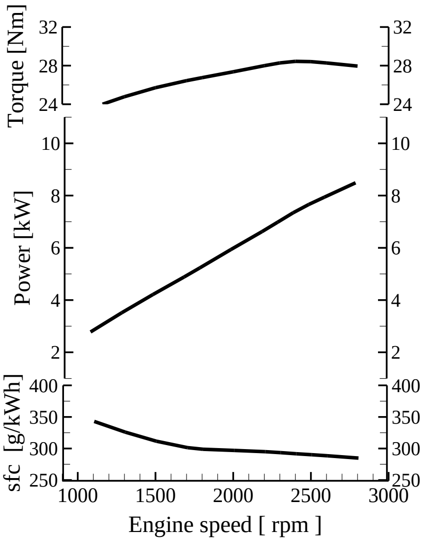


Figure 3. The engine performance characteristics at full load.

Torque, power, and specific fuel consumption obtained at full load are given in Figure 3. As seen in Figure 3, the maximum torque value was obtained at 2300 rpm about 28 Nm at full load condition. Torque variation tends to decrease after this speed value. Specific fuel consumption, on the other hand, is high at low speeds. With the increase of engine speed, specific fuel consumption decreases. This is due to the fact that the specific fuel consumption decreases as the amount of increase in power are greater than the amount of fuel increasing per unit of time.

Figure 4 shows specific fuel consumption variation depending on the engine speed and brake mean effective pressure values. Specific fuel consumption values decrease with the increase of BMEP values, and vary between 297 and 504 g/kWh. The value of BMEP is an average in-cylinder pressure value maintaining the same power value obtained from the related engine cycle, which means BMEP values are relevant to engine load. Therefore, increasing the engine load brings about the engine output power to increase, and the specific fuel consumption values decreased with increasing BMEP values.

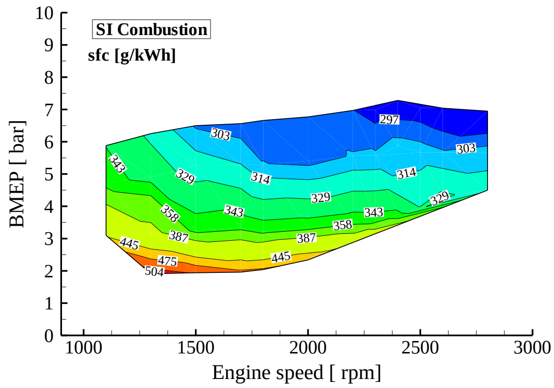


Figure 4. Specific fuel consumption(sfc) map of the engine.

Figure 5 illustrates the brake thermal efficiency distribution at different BMEP and engine speeds. As seen in the figure, the distribution characteristic of the thermal efficiencies is similar to that of sfc, but inversely distributed. This is because sfc and thermal efficiency are inversely linear dependent parameters. Therefore, the thermal efficiency values increase at the operating condition where sfc values decrease and vice versa. The brake thermal efficiency values, hence, varied between 0.17 and 0.29 in the tested operating range.

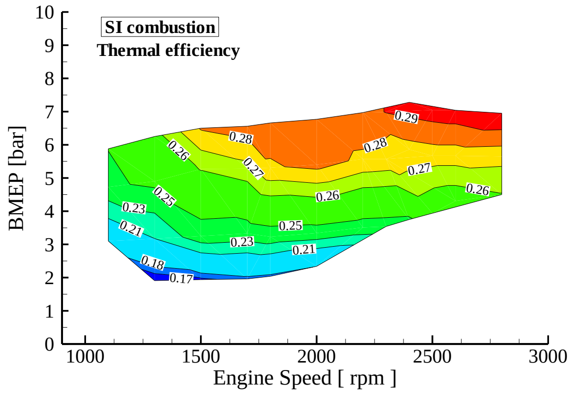


Figure 5. Brake thermal efficiency map of the engine

The major emissions except CO2 emitted from a SI engine are NOx, HC, and CO. NOx formation generally occurs due to three main factors. The first is thermal NOx formation that occurs in high temperature zones in a cylinder. Another mechanism is prompt NOx formation arising with the rapid reactions especially taking place in the rich mixture zones. Finally, NOx formation is also caused by N2 molecules contained in the fuel. However, among these mechanisms for the NOx formation, the thermal NOx formation is particularly dominant [7]. Therefore, the exhaust gas temperature values were measured to be able to assess the relationship between NOx formation and exhaust gas temperature values.

Figure 6.a shows the variation of exhaust gas temperature values. Exhaust gas temperature goes up when both BMEP and engine speed increase. Furthermore, NOx values as shown in Figure 6.b are directly related to exhaust gas temperature, and both of them have similar distribution trends. This is because exhaust gas temperature values imply what level value of combustion temperature occurs in the cylinder. In addition, exhaust gas temperature and NOx values change remarkably by BMEP rather than the engine speed as understood in Figure 6.a-b.

Figure 6.c and d show the CO and HC emissions. Although in-cylinder temperature value is a significant factor for CO formation, a fuel-air ratio, homogeneous in a cylinder, dissociation reactions due to high temperature are also key factors. Low temperature zones particularly close to cylinder walls give rise to CO formation by decreasing oxidation from CO to CO_2 . Besides, CO formation is able to be caused by a local rich-mixture zone due to decreasing O_2 concentration [8]. As shown in Figure 6.c, CO emissions is minimum especially at low speeds and high BMEP values. CO emission values reached the maximum values at the engine speed of 2500 rpm and moderate load levels. In general, both BMEP and engine speed parameters do not have a significant effect on the change in CO formation.

HC formation is related to in-cylinder temperature zones, fuel-air mixture ratio, and homogeneity in the cylinder. The lack of O_2 in local rich mixture zones contributes particularly to HC formation. On the other hand, the quite lean mixture zones also cause HC formation due to low temperature and extinguished flame. In addition to these, another factor for HC formation results from the burning of thin film layers formed on the walls of the cylinder [9]. Figure 6.d shows the distribution of HC emission values measured at different BMEP and engine speeds.

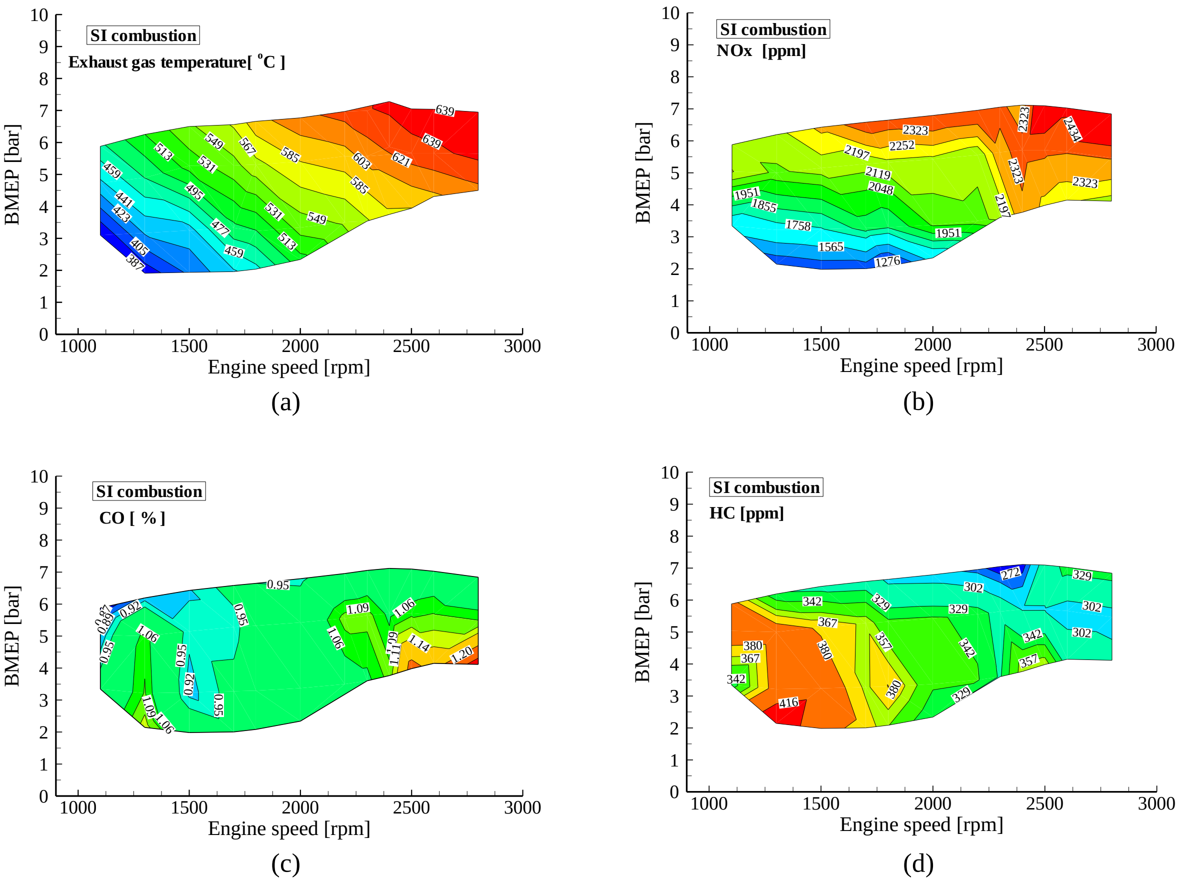


Figure 6. Emissions and exhaust gas temperature (a) exhaust gas temperature, (b) NOx, (c) CO, (d) HC emissions

3.2. *Combustion Analysis*

Figure 7 shows the pressure traces of 300 consecutive cycles and the mean pressure curve representing the engine cycle at the specified operating condition.

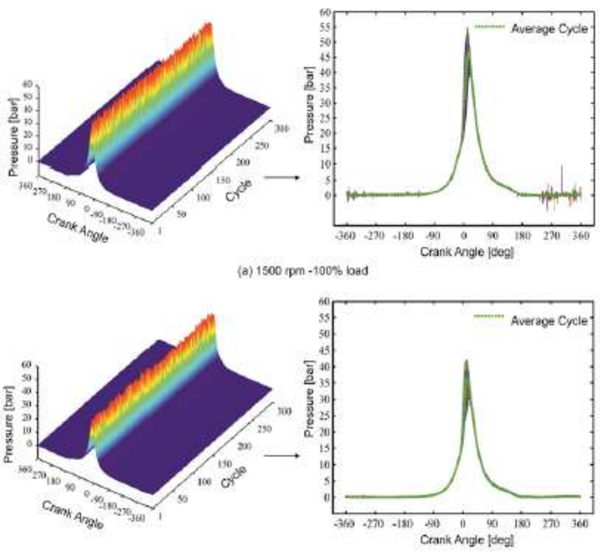


Figure 7. In-cylinder pressure traces

Figure 8 illustrates the pressure traces and corresponding pressure rise rates (PRR) for different loads at the specified engine speeds. As shown in the figure, decreasing operating load caused the peak pressure values to be decreased. Besides, the pressure rise rates decreased when the operating load decreased. The main parameters obtained from these pressure traces are summarized in Table 5.

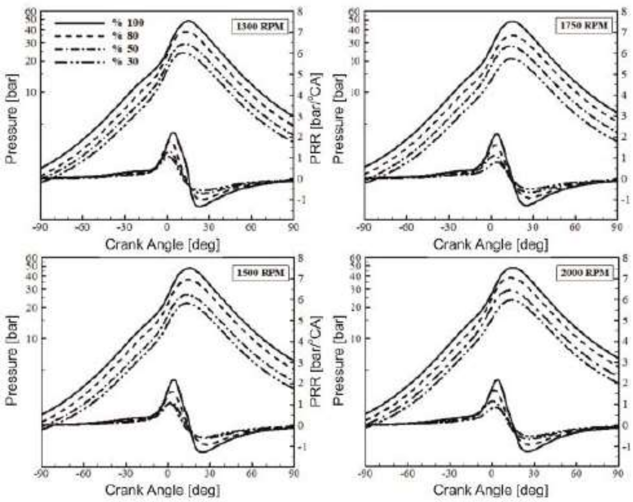


Figure 8 Pressure traces and pressure rise rate(PRR)

Figure 9 shows the heat release rate curves for different engine speeds and loads. Heat release rate (HRR) gives the knowledge what rate combustion reaction occurs in an internal combustion engine [10]. As can be seen in the figure, the heat release rate decreases significantly with the decrease in the load. The reason for this is that the energy content in the cylinder decrease at a low load.

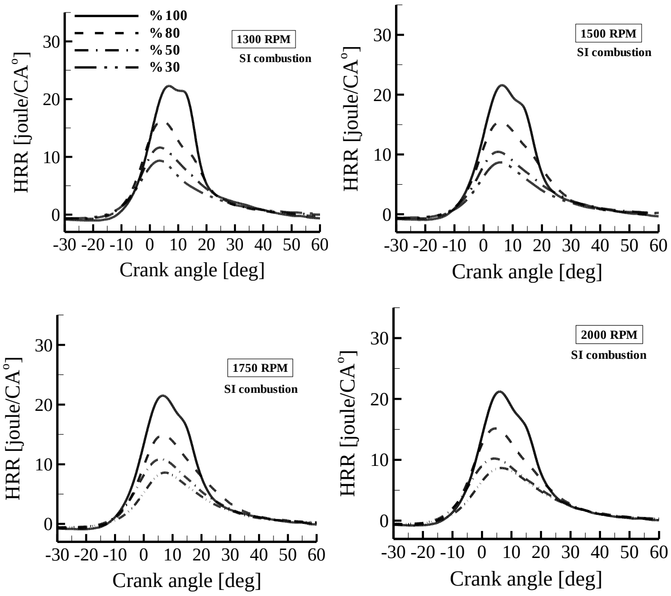


Figure 9. Heat release rate curves at different loads

Table 5. Maximum pressure, its location, and maximum pressure rise rate

1300 rpm				
Load	**%100**	**%80**	**%50**	**%30**
Pmax. [bar]	48.70	38.11	29.14	24.10
Pmax_loc. [CA]	15.30	13.40	12.50	11.50
(PRR)max [bar/°CA]	2.36	1.88	1.43	1.17
1500 rpm				
Pmax. [bar]	47.90	36.87	26.37	21.92
Pmax_loc. [CA]	10.90	11.80	15.40	17.20
(PRR)max [bar/°CA]	2.31	1.71	1.20	0.97
1750 rpm				
Pmax. [bar]	48.15	35.26	27.84	21.06
Pmax_loc. [CA]	15.30	14.60	13.80	14.50
(PRR)max [bar/°CA]	2.32	1.55	1.21	0.87
2000 rpm				
Pmax. [bar]	47.20	33.20	26.78	21.58
Pmax_loc. [CA]	15.70	14.80	13.60	14.60
(PRR)max. [bar/°CA]	2.21	1.38	1.12	0.87

Another investigation in combustion analysis is the mass fraction burned curves to determine the main combustion phases, CA10, CA50, and CA90 [11]. Thus, combustion duration is able to be determined by utilizing these phases. In general, the Wiebe function and Rassweiler&Withrow methods are used to obtain the MFB curves [11]. Wiebe function is a method used especially in an unpredicted combustion modeling study[12-14]. On the other hand, Rassweiler&Withrow method based on pressure rise due to the change in cylinder volume and combustion is the most commonly used in experimental studies.

CA10, CA50, and CA90 combustion phase locations in which 10%, 50%, and %90 of the fuel mass consumed respectively are the main locations to control combustion development [15]. The combustion duration is, generally, considered as the time between CA10 and CA90. CA50 is significant to control combustion as it is regarded as the point where maximum heat release takes place. Therefore, examining these points in combustion analysis gives important insights into combustion development [17]. Figure 10 shows the mass fraction burned curves obtained by Rassweiler&Withrow method at different loads and engine speeds. As seen in the figure, combustion duration in CA prolongs by decreasing engine load. Besides, CA50 locations for most of the operating conditions are close to each other.

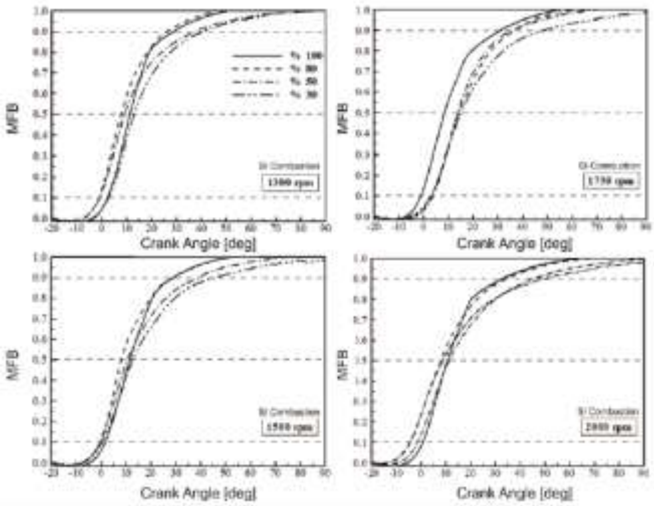


Figure 10. Mass fraction burned (MFB) curves at different loads

3.3 Cyclic Variability

The engine stabilization during its running relies on the engine's control systems responding to varying load and speed conditions. The engine stabilization is determined by assessing the cyclic variability [18-22]. Many parameters can be investigated to evaluate cycle to cycle variation such as indicated mean effective pressure (IMEP), maximum pressure, combustion phase locations, etc. But, the cyclic variation of IMEP is a decisive parameter for performance stabilization while maximum pressure cyclic variation is for combustion stability. Figure 11 shows the coefficient of variation of the indicated mean effective pressure (CoVimep). The maximum CoVimep is 1.86% which means a stable operating as the threshold value is up to 5.0% [23]. If the CoVimep value is high, the power generation at each cycle is highly variable, which in turn it means that the engine runs unstable.

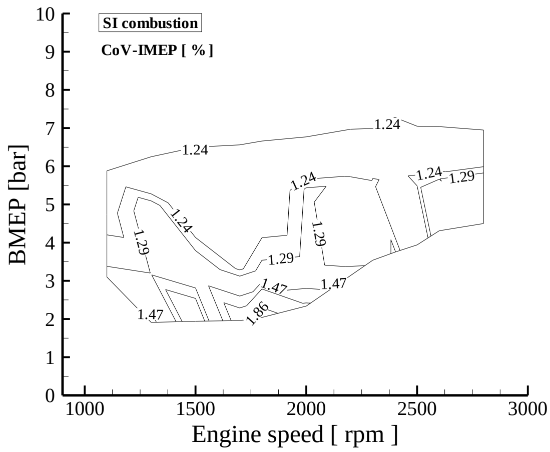


Figure 11. Indicated mean effective pressure coefficient of variation (CoVimep)

Another coefficient of variation is for the maximum pressure values inside the cylinder. This value is especially important in terms of combustion stabilization when it shows the variability of the maximum pressure values reached with heat release. Figure 12 shows the variation of coefficients of maximum pressure (CoVpmax) at different engine speeds and BMEP values. It is seen that CoVpmax values vary between 4.2% and 9.4%, and the engine load rather than the engine speed influences the variation of Pmax values.

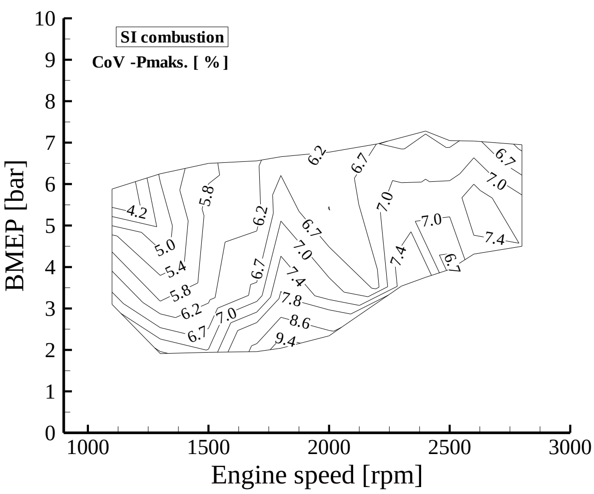


Figure 12. Maximum pressure coefficient of variation (CoVimep)

4. CONCLUSION

The experiments were carried out to determine the characteristics of the engine controlling its electronic control units. This study presented the basic parameters of the engine's characteristics over the map graphs to reveal the improvement potential in the engine for future studies. Based on the results, it can be stated that at the low loads and engine speeds operating conditions, the engine has the potential to be improved in terms of performance as expected in a conventional SI engine.

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Review Article

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Biomass Potential of Kayseri Province

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Abstract: Today the decrease of fossil fuels, which are used nearly in every area from heating to manufacture and transportation, and the environmental pollution, and external dependency in energy sector, has increased the studies about alternative energy sources not only in Turkey but also throughout the world. Among these alternative sources, biomass has a significant importance. In this study biomass potential of Kayseri province was examined. The aim of this study is to set forth the electric and biogas energy potential of the biomass sources found in the Kayseri city. In this context potential biomass and biogas calculations were realized. In the result of the calculations made, the biomass energy value obtained from the sources in hand is 5,41TW/year. Similarly the biogas energy value is 85, 97 million meter cube/year.

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1. INTRODUCTION

Renewable energy sources (RES) are commonly accepted as the key for future life, not only for Turkey but also for the whole world. This is primarily because RES have some advantages when compared to fossil fuels. Renewable energy power plants have far less environmental impacts than fossil-fuel fired power plants. Usage of these technologies reduces the amount of carbon dioxide produced. RES can also contribute to reducing dependence on energy imports and permit diversification of the energy supply. This will not only reduce Turkey's dependence on imports of fuel for producing energy, but will also ensure a continued local source of energy. In the developing countries, RES are more important because many of these nations do not have scarce fossil energy sources such as crude oil and natural gas. Biomass is one of the most promising RES. It is considered as an alternative to conventional energy and has significant potential in Turkey [1] .

Biomass can be defined as the total mass of the organisms that belongs to a kind or various kinds in a certain time period. It is also admitted as organic carbon. There are different biomass sources such as herbal sources, forest and forest products, animal sources, organic wastes, and also industrial and municipal wastes [2]. In this study, biomass potential of Kayseri Province Turkey was investigated.

2. THE LOCATION AND THE PROPERTIES OF KAYSERI PROVINCE

Kayseri is situated in central Turkey. It covers an area of 17,109 km². The steppe climate is dominant in Kayseri. The city's population is 1.421.455 according to 2021 address –based population registration system [3]. There are 16 districts, 17 municipality and 424 villages in the city. The city has three organized industry zones including many factories that make various types of productions ranging from carpet, jean textile to electric cable, aluminum profile, stainless steel and galvanized pipes, office furniture, beds, towel, furniture, fruit juice, biscuits, chicken etc. Many of these productions are exported to European countries, Middle East and Africa. The agriculture of the province involves cereals growing and animal husbandry. In this scope, fruit and vegetable

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agriculture, forage and industrial crop growing are made. Animal husbandry generally includes bovine and ovine

caprine animal breeding, poultry farming. As you can see there are so many industrial and agricultural business branches in Kayseri so there is a huge amount of energy need in the city. Meeting this energy need from Renewable energy sources (RES) will provide many advantages in terms of saving money, providing new working areas, and also giving contribution to national development of the country by decreasing the foreign energy supply. In this study by taking all these into account we made some the evaluation of biomass potential of Kayseri of course formerly by determining the available energy sources and then by specifying the energy potential in terms of biomass energy. At the end with the comparison made between these, we concluded that it's high time; Kayseri province obtained most of its energy from its biomass potential.

3. KAYSERI PROVINCE EXISTING ENERGY SOURCES

When we examine the Kayseri province Electric energy sources according to plant types we see that the active plant number in Kayseri province is 85 and the total power of these are 855 MWe. This means an annual electrical energy production of 2025 GWh. Today sun power plants (SP) has the biggest share with 62 plants in Kayseri, and hydroelectric power plants (HEP) are following these with 11 plants, additionally wind energy power plants (WP) is the third , and natural gas cogeneration plants (CP) are in the fourth rank. As you can see in the Table 1 biogas energy plants (BEP) are in the last order [4].

Table 1: Renewable Energy Producing Plants in Kayseri [5].

Energy Power Plants	Total Plant Number	Total Power (MW)	It's Share in Total Installed Power in Kayseri (%)
BEP[1]	1	5,78	0,68
CP*	6	45,89	5,37
SP[2]	62	275,05	32,17
HEP[3]	11	255,189	29,85
WP[4]	5	273	31,93
TOTAL	**85**	**855**	**100**

*CP : Cogeneration Plant using Natural gas as fuel. This is not a renewable plant but is written here to specify the total electric power sources in Kayseri province

[1]Biogas Energy Plants (BEP) [2]Sun Power Plants (SP) [3]Hydroelectric Power Plants (HEP) [4]Wind Energy Power Plants (WP)

The installed electrical power of the plants in Turkey is 91.267 MW[6]. On the other hand there are new studies for new plant constructions in Kayseri. These are given in Table 2 below

Table 2. Kayseri Province Electric Power Plants under Construction [7].

Plant Type	Power (MW)
1 piece of HEP	12
6 pieces of SP	18
1 piece BEP	19
Total	**49,5**

When we make observation about the electric production plants in terms of plant type in Turkey , we see that the electric power obtained from installed biogas plants is 1138 MW, but the production of Kayseri is 5,78 MW today. With completion of the new plants an additional 49,5 MW will occur. Nevertheless when we look in terms of production of power this will increase from 0,5% to 4,8% . In order to evaluate the biomass potential of Kayseri we have to found new plants and increase the production. Because we have so much potential than we use below study is made to prove this reality.

4. AIM, DATA, AND THE METHOD

The aim of this study is the determination of the biomass energy potential of Kayseri province. First of all we have started making literature scan about biomass energy in the beginning of our study. After evaluating the information obtained, in order to determine the quality and the quantity of the biomass potential of the city, in terms of husbandry, herbal agriculture, and municipal wastes, we have used the data obtained from some statistical institutions such as; Provincial Directorate of Food, Agriculture and Livestock, Turkish Statistical Institute, Kayseri Metropolitan Municipality and Turkish Republic Ministry of Energy and Natural Sources for the calculations.

4.1. Electric Generation Methods Using Biogas and Wastes

Energy can be generated from biomass and waste by using many different technologies by means of indirect or storable interim methods. These technologies can be examined in two groups; biological and thermal methods. Biological methods include: fermentation and thermo-chemical methods divided into subgroups including incineration, gasification and pyrolysis. About 90% of energy generation from waste across the globe is realized by means of the incineration method. Direct incineration is a widely used method in converting waste to energy. Today, many power plants using waste have direct incineration systems. In such plants, as long as the steam temperature and pressure increases, the efficiency of the plant is raised. Heat and electric generation methods using solid biomass and waste are divided into two groups; generation based on incineration, and generation based on gasification techniques. Generation based on incineration: In incineration, the chemical energy of converting fuel to heat energy is transmitted to a heat exchanger and the secondary fluid in the heat exchanger expands in a turbine or a similar system, forming the mechanical energy. Generation based on gasification: In gasification, materials were being reacted at high temperature with a controlled amount of oxygen and/or steam, without combustion and a fuel called syngas is produced [1, s. 3].

5. KAYSERI PROVINCE BIOMASS SOURCES

When we consider the data about biomass we should have to take two kinds of data into consideration. One is theoretical and the other is economic values. For instance, the economic value of the LGF calculated by considering the theoretical amount that is obtained will be 40% of the theoretical amount [1, s. 3]. According to these admittances we calculate the below values.

5.1. Municipal Solid Wastes (MSW)

In reference to the address based population registration system Kayseri province population is 1.421.455 person for 2021 [3]. The average MSW amount per person is 1.16 kg/person/day [8]. Pursuant to this data, the annual MSW amount for a person in Kayseri is 0,42 ton/person. Annual MSW amount for the city is 601.885 ton/year. In 20 years the land field gas (LFG) that is obtained from this MSW amount to be used to provide the primary electricity for the city is calculated as 12,03 billion m^3. But this calculation is theoretical and only 40% of the obtained LFG is usable in practical so LFG gained from the specified MSW is 4,81 billion m^3 for a period of 20 years. Accordingly, the annual value of the LFG potential of municipality for the given waste services is 0,24 million m^3/year [9]. When we calculate the potential energy of this LFG, we will have 1,64 TW/year.

5.2. Animal wastes

Total animal amount of Kayseri is 5.786.379 pieces. This total amount includes 347.594 pieces of bovine animal, 649.606 pieces of small cattle, and 4.789.179 pieces of poultry [10]. The total theoretical manure amount derived from these is 1.811.425 tons/year. The annual manure amount held by a bovine animal is 3,6 tons/year, small cattle is 0,7 tons/year and a poultry is 0,022 tons/year.

In Table 3 annual and net manure amounts according to the total animal amounts by species are given.

Table 3. Kayseri Province Animal Manure Amount

	Pieces	Annual Manure Amount (Ton/ Year)	Total Theoretical Animal Manure Amount	Net Animal Manure Amount After 1/3 Lost
Bovine animal	347.594,00	3,60	1.251.338	834.226
Small cattle	649.606,00	0,70	454.724	303.149
Poultry	4.789.179,00	0,02	105.362	70.241
TOTAL	**5.786.379,00**	**4,32**	**1.811.425**	**1.207.616**

According to these acceptations, when we make the animal waste calculations for the animal types in Kayseri province we get the theoretical bovine animal manure amount as 1.251.338 ton/year, the small cattle amount as 454.724 ton/year, and the poultry manure as 105.362 ton/year. But in order to make an approximate calculation we should consider the lost in the forages (1/3 of the total). Hereunder the new calculations are: bovine manure is 834.226 ton/year, small cattle manure is 303.149 ton/year, and the poultry manure is 70.241 ton/year. In terms of animal manure the practically usable net animal manure for Kayseri is 1.207.616 ton/year. In reference to the acceptances for different animal manures, the biogas production is calculated as 50,5 million m^3/year. The heating amount of 1 m^3 biogas changes between 4700-5700 kcal/m^3. So, by making the calculations according to this data the electricity produced from this is nearly 3,57 TW/year [11].

5.3. Herbal wastes

The herbal statistical data of Kayseri is arranged with regards to Bepa [12]. In this context the herbal production is 584.124 tons. The herbal waste amount corresponding to this amount is 864.165 ton. The economical annual equivalence of this herbal waste is 17.706,7 TOE. The technology used to turn this waste into energy is incineration. 1 TOE is 11.600 kWh, by taking this information into account the electric power obtained from this will be nearly 0,2 TW/year. The biogas that is produced due to this amount of herbal waste is 11,3 million m3/year [13].

6. KAYSERI PROVINCE TOTAL BIOMASS POTENTIAL

In reference to the above information and calculations we can summarize the total biomass potential in Table 4 such as below:

Table 4: Kayseri Province Total Biomass Potential

Type of Biomass Source	Produced Biomass (million m^3)	Electric Power Gained (TW/year)
Animals	**50,6**	**3,57**
Plants	**11,3**	**0,2**
Municipality Waste	**24,07**	**1,64**
Total biomass potential	**85,97**	**5,41**

Seeing from the Table 4, we understand that nearly 60% of the biomass energy of Kayseri can be met by animal wastes, while 13% is met by plants and 27% is met by Municipality waste. (Look Figure 1)

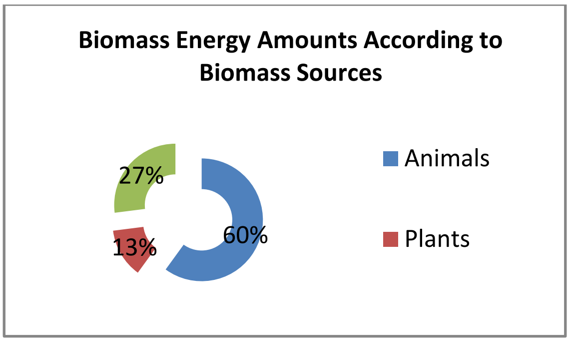

Figure 1: Biomass Energy Amounts According to Biomass Sources

7. CONCLUSION

In this study, the biomass potential of Kayseri province is evaluated according to the renewable energy sources mostly found in Kayseri such as animal, plant and municipal wastes. Effective usage of energy sources in Turkey is very important in terms of dependency on foreign sources. On the other hand using biogas for the generation of electricity provides advantages for clean environment. In comparison to fossil fuels, biomass energy is a clean and sustainable energy source with less air emission values, less waste disposal, and a decreased foreign dependency.

The total electric energy consumption in Kayseri in 2020 is 4,70 TWh. When we evaluate the situation in reference to the above given data and calculations, this is less than the amount that can be produced from biomass energy potential of Kayseri province, this means if we use 87% of total biomass energy potential of Kayseri we can meet the whole energy need of the city. Today according to 2020 data [14] the biomass origin electric power generation in Kayseri is 0,015 TWh , this is only 0,3% of the total consumption of the city. In conclusion, Kayseri province has a big opportunity of producing electricity from its biomass potential.

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