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Experimental Studies on Utilization of Biogas with Biodiesel/Diesel Blends in a CI Engine

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Abstract: The utilization of raw biogas for the current study of gaseous alternatives for diesel engines. Due to the fact that gaseous fuel cannot burn by compression, biogas cannot be used alone to power a diesel engine. It can be given to CI engines that are running on dual fuel by combining air and biogas in a system. In order to create a homogeneous mixture, the venturi gas mixer device used in this study produces a diesel engine that burns biogas, biodiesel, and diesel. On the performance and emission characteristics of the dual-fuel engine in contrast to diesel, experimental research was conducted. The results demonstrated that biogas introduced at a flow rate of 1L/min functioned better and generated less emissions than biogas introduced at other flow rates. However, the dual-fuel mode with a BD10 BG@1L/min biogas flow rate showed an average drop in BTE of 9.94% and an average increase in BSFC of 8.82% when compared to diesel. CO and HC emissions are up 5.18 and 3.01 percent, respectively, in comparison to diesel, but NOx emissions are down 14.91 percent on average.

Keywords: Alternative Fuel, Biogas, Biodiesel, Diesel Engine, Dual-fuel, Venturi Gas Mixer

1. Introduction

India, one of the fastest-developing nations with steady economic expansion, has a multiplicative effect on the need for transportation. This demand directly relates to fuel usage. Due to a lack of fossil fuel sources, India relies heavily on imported fuels, which has a significant impact on the country's economy. Biodiesel may now be extracted at reasonable costs and quantities thanks to recent research and studies. The combination of fossil diesel and biodiesel offers several advantages, including lower pollutants, improved engine performance, greater cetane ratings, less wear on the engine, low fuel use, and reduced oil usage.It is evident that using bio-diesel boosts the engine's efficiency. The Indian economy will be greatly impacted by this. Diesel fuels have a significant impact on a nation's industrial sector.

The objective of this paper is to eliminate biodiesel with the other fuels the percentage in biodiesel blend of algae biodiesel indicates suffix B20 numerical. The percentage of algal

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biodiesel by volume in the biodiesel blend is indicated by the suffix B20 following the numerical signature. In order to establish a baseline for comparison, experiments were also carried out utilizing diesel and AOME as the fuel. For both the biodiesel and biogas dual fuel mode of operation as well as the diesel and biodiesel single fuel mode, experiments were carried out at varying loads and rated RPM. Performance and emission characteristic of baseline diesel engine run is used to compare. There have been studies conducted all around the world on the viability of using various renewable liquid and gaseous fuels. The volumetric percentage of algal biodiesel in the biodiesel blend is indicated by the suffix B20 that follows the numerical signature. In order to establish a baseline for comparison, experiments were also carried out utilizing diesel and AOME as the fuel. For both the biodiesel and biogas dual fuel mode of operation as well as the diesel and biodiesel single fuel mode, experiments were carried out at varying loads and rated RPM. To compare engine behaviour in terms of combustion, performance, and emission characteristics, a baseline of a normal diesel run is employed. There have been studies conducted all around the world on the viability of using various renewable liquid and gaseous fuels. Engine performance is increased when these modified vegetable oils are used in place of base vegetable oils. . This increase in performance is ascribed to the changed fuels' efficient atomization in the injector nozzle and their significantly lower viscosities. It was determined that the performance of non-edible oils such cotton seed oil Ayade and Latey, [14)]and rice bran oil Barik and Murugan[15)]was satisfactory. Vegetable oils have long been used as a fuel source for diesel engines. During the 1900 Paris Exposition, Rudolph Diesel's engine was powered by peanut oil. Despite being technically feasible, vegetable oil as a fuel failed to gain popularity because it was more expensive than petroleum-based fuels.Later, the many circumstances mentioned previously led to a resurgence of interest among researchers in using vegetable oil as a diesel engine substitute. As the amount of biodiesel in the fuel blend increased, so did the density and viscosities of the blends. It also guarantees that the oil flows smoothly and lessens filter blockage. Without changing the engine, some researchers Ali and Salih[10)], Araki et al.[13)] conducted trials on diesel engines utilizing non-edible vegetable oils as alternate fuels and discovered that the BSFC, maximum brake thermal efficiency, and emissions like CO, HC all rose. Desalination with nanofluids has been reviewed by Dharamveeret al.[21)] The energy and exergy of active solar stills were examined by Kumar and Singh [22)] using a compound parabolic concentrator.By adjusting injection timing and injection pressure, Shanker, et al.[23)] examined the performance of a C.I. engine running on biodiesel fuel. FEA was used by Anup et al. [24)] to study the refrigerator compartment and optimize thermal performance. Optimized thermal performance of a small heat exchanger by Kumar and Singh [25)]The effects of active and passive solar still behaviour on energy matrices and environmental economics were examined by Dharamveer and Samsher[26)]. The Nth identical photovoltaic thermal (PVT) compound parabolic concentrator (CPC) active double slope solar distiller with helical coiled heat exchanger was the subject of an analytical research by Dharamveer et al. [27)] employing CuO nanoparticles. With the use of CuO nanoparticles, Dharamveer et al. [28)] performance of an active single slope solar distiller with a helically coiled heat exchanger and N-identical PVT-CPC collectors was evaluated.Using CFD, Kumar and Singh [24)] conducted a comparative analysis of single phase microchannel heat flow experiments. Thermal analysis of coal and waste cotton oil liquid produced by pyrolysis of diesel engine fuel was carried out by Subrit and Singh [30)]. By using biodiesel pamitran et al. [31)] in place of conventional diesel fuel, emissions of unburned hydrocarbons, carbon monoxide, and particulates are significantly reduced. Using the trans-esterification process, crude oil is transformed into methyl ester of oil (biodiesel). Without modifying the engine, Karanja oil's methyl and ethyl ester Jagadish and Gumtapure[19)]is also a fuel option for compression ignition engines.The different unfavourable combustion characteristics of Neat vegetable oils are caused by higher viscosity.Vegetable oil viscosity levels can be reduced using four well-known techniques: dilution, pyrolysis, micro-emulsion, and trans-esterification. The performance, combustion, and emission characteristics of a dual fuel mode diesel engine employing biogas and biodiesel are also covered in-depth analyses of numerous publications. Many affluent nations across the world have tried using biogas and vegetable oils as diesel engine fuel. Vegetable oil has been used as pure, esterified, or combined with diesel in the majority of research studies. Tests showing the possibilities and issues with this fuel source have been carried out by numerous researchers, engine makers, and consumers in various nations.However, there are a number of actual issues that prevent the addition of this source to the electricity grid. The literature on economic assessment is reviewed later in this essay. As can be seen from the literature above, a diesel-biogas dual fuel diesel engine's performance, combustion, and emission characteristics mostly depend on two variables. These are the engine operating parameters and the mixing equipment in use. Venturi mixers provide a homogeneous charge into the engine cylinder, eliminating the potential of heterogeneous combustion, resulting in complete combustion. The beta ratio of venture connect convergent angle. The existing body of research is lacking in this field, which includes this.

2. Experimental setup

This section provides a detailed description of the equipment used in this study, including information on its features and measuring capabilities.The measurements include performance based on data as well experimental setup and procedure. Instrumentation is crucial to any experimental investigation because it offers the data needed for analysis.

Table 1.List of materials and equipment used for experimental test.

1	CI engine, and
2	Biogas
3	gas mixer
4	Biodiesel
5	Measurements apparatus.
6	Exhaust gas analyzer
7	Computer (desktop)

Table 2.Engine Specifications

S.No	Component	Specification
1	Engine make	Kirloskar,Model TV1
2	Engine type	1 cylinder, 4stroke, water cooled
3	Rated Power	5.2 kW (7 BHP) @1500 rpm
4	Cylinder Volume	661cc
5	Compression Ratio	18
6	Injection timing (diesel)	23° bTDC
6	Dynamometer	Eddy current, water cooled
7	Piezo Sensors	Range 5000 PSI
8	Crank Sensor	Resolution 1^0, Speed 5500 RPM
9	Load Sensor	Load cell, type strain gauge,
10	Software	"Engine soft", Engine Performance analysis software

Fig.1: Kirloskar Diesel Engine Set-Up

3. Materials and Methods

In order to investigate the effects of raw biogas mass flow rates on diesel engine performance and emission parameters under specific operating conditions, computational and experimental analyses are presented in this chapter. Under these conditions, a gas mixing device is used to operate a diesel engine in dual fuel mode with biodiesel and biogas. This also includes gas mixture models of the venturi type that can be used to analyze the flow properties. The computational techniques that are offered with the required illustrations to construct a gas mixer will use the numerical analysis. Investigation of direct injection type four stroke diesel with dynamometer will be employed. The next sections include a comprehensive explanation of the study's methodology and required materials..

3.1 Test Fuels

From an Indian Oil Pvt. Ltd. retail station close to our campus, diesel was purchased. Additionally, algal oil that was acquired from a neighborhood retail pharmaceutical shop was transesterified to create biodiesel. Fig.2 illustrates how biodiesel is made from vegetable oil. The measurements and comparisons between the parameters of biodiesel and regular diesel fuel are shown in Table 3.

3.2 Biodiesel production

Direct usage, blending, micro emulsion, thermal cracking, and trans-esterification the most popular method are some of the ways biodiesel can be produced.

Table 3.Composition of different feedstock's raw biogas (Wierzbicki, 2012)

Component	Composition		
	agricultural biogas	treatment plant biogas	landfill biogas
CH4	45–75%	57–62%	37–67%
CO2	25–55%	33–38%	24–40%
O2	0.01–2.1%	0–0.5%	1–5%
N2	0.01–5.0%	3.4–8.1%	10–25%
H2S	10–30000 ppm	24–8000 ppm	15–427 ppm

Fig. 2:Some feedstock's for biogas production

3.3 Transesterification

Oil is trans-esterified with an alcohol (methyl or ethyl) to produce biodiesel, a fuel with lower viscosity and cleaner burning characteristics. Trans-esterification is frequently utilised in the industrial setting to produce biodiesel. The biodiesel and glycol are produced in existence of NaOH or KOH based on weight around 1%.

This happens as a result of a series of three reversible reactions in which triglycerides are first changed to diglycerides, then to mono-glycerines, and finally to esters and glycerol from mono-glycerines. During trans-esterification referred to methyl ester. Figure depicts the trans-esterification of algal oil's chemical reaction. In Table4, the qualities of the algae-based biodiesel are assessed and compiled.

Table 4. Properties of fuels

Property	**Algae Oil**	**AOME (Bio Diesel)**
Density at 40 ºC (g/m3)	0.871	0.864
Specific Gravity at 40 ºC	0.916	0.894
Flash point (°C)	145	130
Kinematic Viscosity, 40 ºC(mm2/s)	5.76	5.2
Iodine Value (g/100g oil)	124	75
Acid Value (mg KOH/ g oil)	0.46	0.374
Calorific value (kJ/kg)	37200	

4. Experimental process

4.1 Methodology

A carefully thought-out methodology will be used to address the general and specific objectives of this effort. To complete this study, various techniques will be used in combinations. Results of the analysis of experiment and mixer device manufacturing biodiesel outputs created the purchase of diesel fuel.

5. Result and Discussion

Experimental analysis presents emission characteristics related to operation. Dual fuel mode biodiesel engine performance and emission are also covered in this paper along with how variations in load, biogas flow rate, and biogas substitution percentage impact these factors.

5.1 Engine Performance Characteristics

The parts that follow provide explanations of a diesel engine's performance characteristics under various engine loads when it used diesel fuel and diesel combined with biogas as a dual fuel, including brake thermal efficiency and brake-specific fuel consumption.

5.2 Brake thermal efficiency (BTE)

This slows down the biogas-air charge's rate of combustion and reduces flame propagation, which lowers the dual-fuel mode brake's thermal efficiency, as shown in Fig. 3. A comparable pattern was noted by (Rosha et al., 2018). On the other hand, as the biogas flow rate rises, BTE falls during dual-fuel mode operations. This is because a higher biogas induction rate causes the flame propagation speed to be reduced even more, which lowers BTE. In comparison to diesel mode, BD10D90 + BG@1L/min, BD20D80 + BG@2L/min, and BD35D75 + BG@4L/min flow rates, respectively, saw average BTE reductions of 15.94%, 20.04%, and 23.58%.

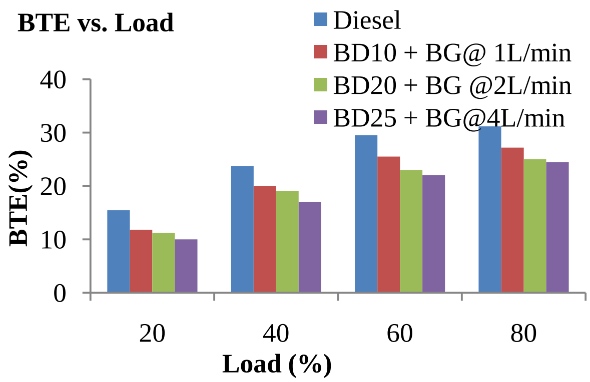

Fig. 3: Variation of brake thermal efficiency versus engine load.

5.3 Brake specific fuel consumption (bsfc)

Fuel heating value affects fuel economy for various brake applications (Sandalc et al., 2019). The brake-specific fuel consumption for diesel and biogas mixes in proportion to engine load is shown in Fig. 5. Even when the engine was only partially loaded, it was observed that both modes consumed a significant amount of fuel specifically for the brakes. This is brought on by a lower output power at a lighter load. Due to an increase in combustion rate brought on by a high air-fuel ratio and high combustion temperature, it was shown to be less for both modes of operation under high engine load. Table 7 represents quantitative consumption of both diesel and dual fuel operation. Fig. 6 shows that, throughout the load range, feeding biogas results in higher fuel usage than diesel mode. This is because biogas burns slowly and has a low energy density, which results in increased BSFC when using a dual fuel system. Additionally, because raw biogas has a higher percentage of non-combustible components than finished biogas, it has a lower fuel quality.

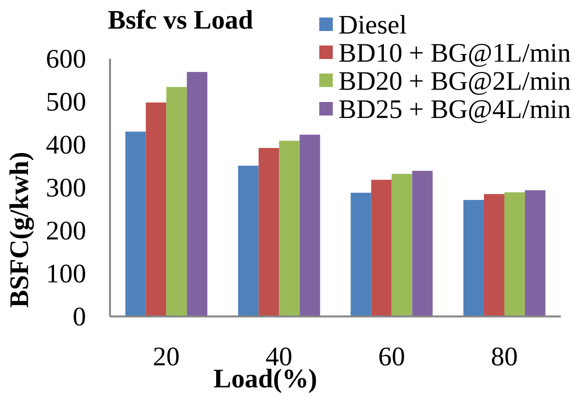

Fig. 4: Variation of brake specific fuel consumption with respect to engine load

5.4 Exhaust Gas Emissions

Knowing an individual fuel's exhaust emissions is crucial for future emission control methods, such as searching for substitute fuels that produce fewer emissions or tuning engine operating settings. The emissions from pure diesel and dual fuel biogas-diesel diesel engines are covered in this section. Now, using the Automobile Exhaust Gas Analyzer SV-50 to measure CO, CO2, HC, O2, and NOx emissions at various loads with varying biogas flow rates, these emissions are compared to neat diesel fuel emissions and briefly reviewed in this section.

5.5 Exhaust Emissions of Carbon Monoxide (% Vol.)

Fig. 5 illustrates how CO emissions for diesel fuel and diesel with biogas blends vary depending on load. When using dual fuel, higher CO levels than diesel are seen. This is because biogas burns more slowly than diesel because of the presence of carbon monoxide (CO), reduces oxygen levels due to the induction of biogas, and has a higher specific heat than diesel. The afore mentioned factors that lead to incomplete combustion of some fuels and significant CO output. It also rises as the flow rate of biogas rises. This is because the high biogas flow rate reduces O2 availability in the combustion chamber and further raises CO2 concentration.Average CO emission increases from diesel mode for the BD10D90 + BG@1L/min, BD20D80 + BG@2L/min, and BD25D75 + BG@4L/min flow rates were 10.18%, 19.91%, and 31.86%, respectively. The quantitative value of carbon monoxide emissions is displayed in Table 4.6 below.

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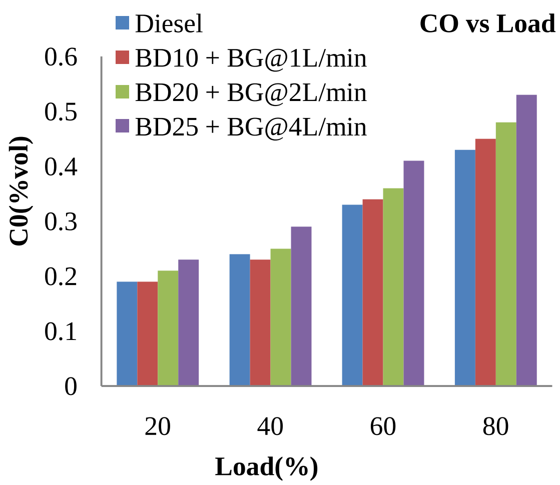

Fig. 5: Load based Co emission variation

5.6 Exhaust Emissions of Hydrocarbons (ppm Vol.)

Fig. 6 represents unburnt emission for diesel and biogas. Under all test conditions, the emission of unburned hydrocarbons (UHC) from dual fuel operation is higher than that of diesel. The average unburnt HC emission increase for the diesel mode for the following flow rates: BD10D90 + BG@1L/min, BD20D80 + BG@2L/min, and BD + BG@4L/min was 6.01 percent, 19.29 percent, and 30.94 percent, respectively. The HC emissions' numerical values are displayed in Table 4.9 below.

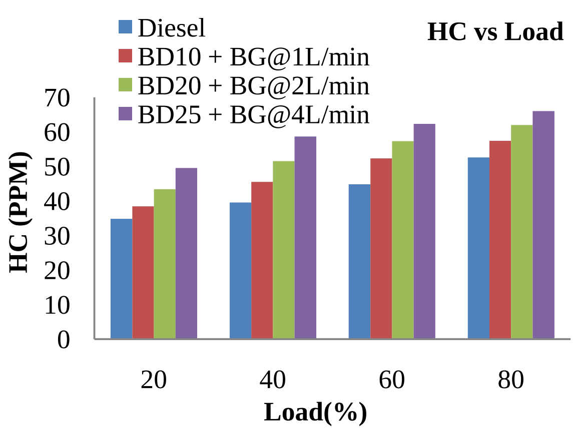

Fig.6: Load based HC emission variation

5.7 Nitrogen Oxide Exhaust Emissions (ppm Vol.)

The availability of oxygen, higher combustion temperatures, and the amount of time that oxygen-nitrogen interactions remain active before reaching a substantial completion level are the primary determinants of NOx production (Bouguessa et al., 2020). Fig. 7 represents Nox emission for dual and diesel engine.

Average NOx emission reductions from diesel mode for the BD10D90 + BG@1L/min, BD10D90 + BG@2L/min, and BD25D75 + BG@4L/min flow rates were 19.91%, 27.33%, and 39.16%, respectively. The NOx emissions' numerical figures are displayed in Table 4.10 below.

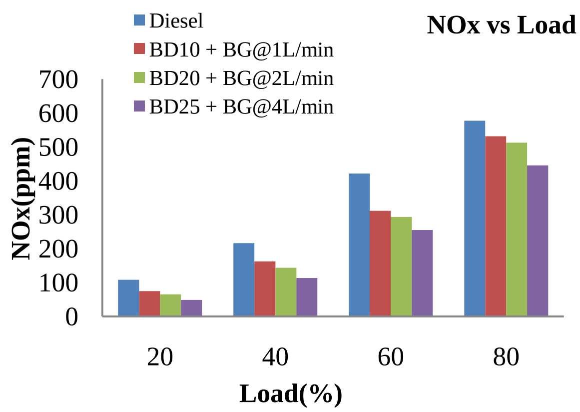

Fig. 7:Variation of NOx emissions with respect to load

6. Conclusions

The following conclusions for the performance of biodiesel and dual mode diesel engine for load conditions.

As the load grows from 20% to 80% while the biogas flow rate increases from 1L/min to 4L/min:

- Reduction 15.94% to 23.57% in brake thermal efficiency and 11.83% to 20.87% increment of BSFC.
- CO emission 10.18% to 31.85%.
- Reduction in NOx emission 19.912% to 39.159% respectively.

1L/min of biogas flow has nearly the same performance and emission characteristics as diesel fuel operation and permits very low NOx levels. This is because a particular biogas has a low methane content.

Nomenclature

RPM Rotation per minute

c_p specific heat capacity (J kg^{-1} K^{-1})

P power (W)

Nm Newton meter

BDC Bottom dead centre

CO Carbon Mono oxide

TDC Top Dead centre

References

1) M. Ali, andM. Salih, "Factors Affecting Performance of Dual Fuel Compression Ignition Engines",*Applied Mechanics and Materials*, (217-222)(2013).https://dx.doi.org/10.4028/www.scientific.net/AMM.388.217.

2) S. Bhuimbar, and S. Kumarappa, "Engine Performance and Emission Characteristics of a Single Cylinder Four Stroke CI Engine on Dual Fuel Mode by Using Compressed Biogas as a Fuel",*International Journal for Research in Applied Science & Engineering Technology*, 3(9),376-382 (2015)..https://www.ijraset.com/fileserve.php?FID=3277.

3) B. Bora, B. Debnath, N. Gupta, U. Saha, and N. Sahoo, "Investigation on the flow behaviour of a venturi type gas mixer designed for dual fuel diesel engines",*International Journal of Emerging Technology and Advanced Engineering*, 202-209 (2013).http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.414.2833.

4) J. Bora, and K.Saha, "Optimisation of injection timing and compression ratio of a raw biogas powered dual fuel diesel engine",*Applied Thermal Engineering*, 111–121(2016). https://dx.doi.org/10.1016/j.applthermaleng.2015.08.111.

5) V. Chintala, and K. Subramanian, "A computational fluid dynamics study for optimization of gas injector orientation for performance improvement of a dual-fuel diesel engine"*Energy*, 709–721. (2013). https://doi.org/10.1016/j.energy.2013.06.009.

6) M. Dahake, S. Patil, and S. Patil, "Performance and Emission Improvement through Optimization of Venturi Type Gas Mixer for CNG Engines", *International research and Journal of Engineering Technology*, 994–999 (2016).

7) D. Danardono, K. Kim, S. Lee, and J. Lee, "Optimization the design of venturi gas mixer for syngas engine using three-dimensional CFD modeling",*Journal of Mechanical Science and Technology* 25 (9), 2285-2296 (2011). https://doi.org/10.1007/s12206-011-0612-8.

8) E. Abo-Serie, M. Ozgur, and K. Altinsik, "Computational analysis of methane-air venturi mixer for optimum design", unpublished, 1-9 (2015). https://www.researchgate.net/publication/281684556.

9) Z. Aklouche, K. Loubar, A. Bentebbiche, S. Awad, and M. Tazerout, "Experimental investigation of the equivalence ratio influence on combustion, performance and exhaust emissions of a dual fuel diesel engine operating on synthetic biogas fuel",*Energy Conversion and Management*, 291–299 (2017).https://dx.doi.org/10.1016/j.enconman.2017.09.050.

10) M. Ali, and M. Salih, "Factors Affecting Performance of Dual Fuel Compression Ignition Engines"*Applied Mechanics and Materials*, 217-222,(2013),https://dx.doi.org/10.4028/www.scientific.net/AMM.388.217.

11) H. Ambarita, "Performance and emission characteristics of a small diesel engine run in dual-fuel (diesel-biogas) mode",*Case Studies in Thermal Engineering*, 179–191 (2017). https://dx.doi.org/10.1016/j.csite.2017.06.003.

12) M. Arali, R. Anil, and S. Gawade, "Design and Development of Intake Device for Biogas operated 4-Stroke SI Engine", *Energy*, 1-7 (2016),https://www.researchgate.net/publication/32263489.

13) M. Ayade, and A. Latey, "performance and emission characteristics of biogas-petrol dual fuel in SI engine",*International Journal of Mechanical Engineering and Technology (IJMET)*, 7(2), 45-54 (2016).http://www.iaeme.com/IJMET_07_02_006.pdf.

14) D. Barik, and S. Murugan, "Investigation of combustion performance and emission characteristics of a DI diesel engine fueled with biogas-diesel in dual fuel mode', *Energy*, 760 – 771(2014),https://dx.doi.org/10.1016/j.energy.2014.05.106.

15) D. Barik, and S. Murugan, "Experimental investigation on the behavior of a DI diesel engine fueled with raw biogasediesel dual fuel at different injection timing',*Journal of the Energy Institute*, 373-388 (2016)https://dx.doi.org/10.1016/j.joei.2015.03.002.

16) B. Bharathiraja, T. Sudharsana, J. Jayamuthunagai, R. Praveenkumar, S. Chozhavendhan, and J. Iyyappan, "Biogas production – A review on composition, fuel properties, feed stock and principles of anaerobic digestion",*Renewable and Sustainable Energy Reviews*, 570-582 (2018). https://ideas.repec.org/a/eee/rensus/v90y2018icp570-582.html.

17) S. Bhuimbar, and S. Kumarappa, "Engine Performance and Emission Characteristics of a Single Cylinder Four Stroke CI Engine on Dual Fuel Mode by Using Compressed Biogas as a Fuel',*International Journal for Research in Applied Science & Engineering Technology*, 3(9), 376-382 (2015), https://www.ijraset.com/fileserve.php?FID=3277. 75

18) K. John and Vennard. "Elementary Fluid Mechanics", Robert L.Street: John Wiley & Sons (1982).

19) Setia Abikusna, Bambang Sugiart, , IqbalYamin "Utilization Analysis of Bioethanol (Low Grade) and Oxygenated Additive to COV and Gas Emissions on SI Engine", *Evergreen*, 2020 Vol. 07, Issue 01, pp43-50

20) Z. F. Zahara, "Economic Assessment of the Sugarcane-based Bio-refinery in Indonesia", *Evergreen*, 5(2), 67-77 (2018).

21) Y. Furutani, K. Norinaga, S. Kudo, J. I. Hayashi, and T. Watanabe, "Current Situation and Future Scope of Biomass Gasification in Japan", *Evergreen*, 4(4), 24- 29 (2017).

22) K. Tewari, and R. Dev, "Analysis of modified solar water heating system made of transparent tubes & insulated metal absorber," *Evergreen*, 5 (1) 65 (2018). doi:10.5109/1929731

23) Arnan Kuncoro,Widodo Wahyu Purwanto, "Analysis of Energy-Water Nexus Palm Oil Biodiesel Production in Riau Using Life Cycle Assessment and Water Footprint Methods",*Evergreen*,vol. 07, Issue 01, pp104-110, 2020