International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** VIII **Month of publication:** August 2022

DOI: https://doi.org/10.22214/ijraset.2022.46427

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VIII August 2022- Available at www.ijraset.com

Pine Needle Gasification: An Approach Towards Renewable Energy Production and Life Cycle Assessment of Chir Pine

Aman Minhas[1], Rajeshwar Singh Banshtu[2]
[1]M.Tech Scholar, [2]Associate professor Department of Civil Engineering, National Institute of Technology Hamirpur- 177005 HP, India

Abstract: Today Indian subcontinent is facing severe energy crisis as our conventional resources are deteriorating day by day posing an alarming threat to our energy security. In view to fulfill our increasing energy needs new and renewable feedstock is need of time. Pine needle Biomass which is renewable energy source may prove to a good resort to accomplish are future endeavors. In India, western Himalayan state like Jammu & Kashmir, Himachal Pradesh, and Uttarakhand has great potential of pine needle biomass feedstock for gasification .Pine Biomass can be effectively harnessed to generate producer's gas using various co-current throatless gasifiers.

In this paper, overview of Bio-briquetting, quality assessment of Producer's gas, Life cycle assessment of Pine biomass is done along with various other social and environmental factors.

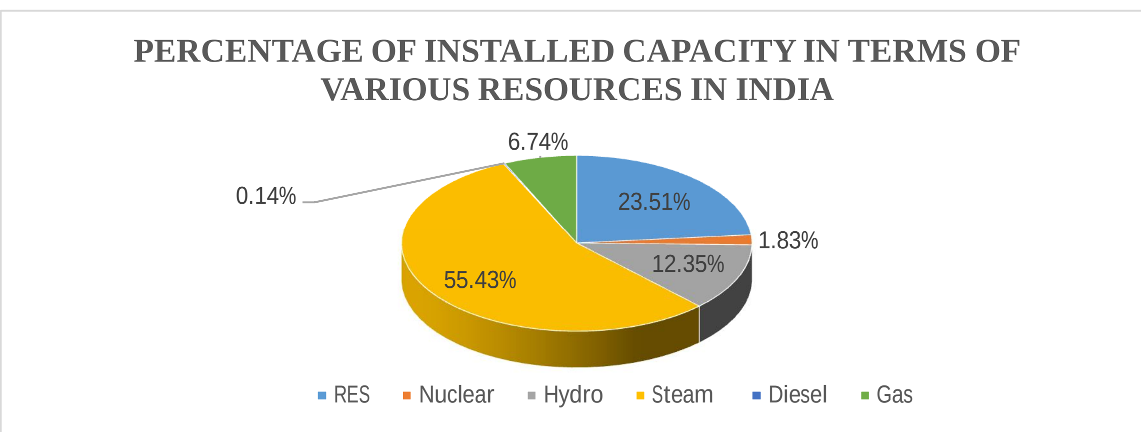
Keywords: Bio-briquettes, Biomass, Gasification, Producer's gas, LCA, Green Building

I. INTRODUCTION

In recent days, UN Climate summit of COP26, meeting held in Glasgow, UK many countries including India took joint resolution showing their commitment towards reducing net carbon emissions and promote green & Non-fossil fuel based energy systems to accomplish green energy and sustainable energy goals in their countries.

India also took few ambitious targets some of which have 2030 deadline. These include shifting to non-fossil fuel-based energy capacity upto 500 GW, lowering total projected carbon emission by 1 billion tonnes, meeting 50% of the country's energy demands through renewable sources and lowering the carbon intensity of the economy to sub 45% level. The last target, which is the most ambitious of all, is India's commitment to achieve net-zero emissions by 2070.

India, which largely depends on fossil fuels for its energy needs requires huge amount of capital to achieve these targets. Forest Biomass like pine needle need to be essentially utilized for electricity production especially in Himalayan states. Moreover, pine forest leads uncontrolled forest fires in summer seasons which leads several crore loss to Govt. of these states. In Himachal Pradesh 1071 Hectares of land was affected by forest fires in year 2010-11 which lead to annual loss of 3.5 crores. Around 1200 to 2500 forests are reported in Himachal every year affecting flora and fauna of thousands of hectares of land.



Source: As per latest report of Central Electricity Authority GOI

Pine forests are available easily upto 450m to 2300m altitude with various varieties *like* Pinus wallichina, Pinus roxburghii, & Pinus gerardiana. Annual gross pine yield in HP is estimated to be around 1.33 million tonnes which can have annual energy potential feedstock of nearly 500 MW. A thermochemical gasification of pine needle can have 150 MW of installed capacity of electricity generation units which can be supplied to remote villages of Himachal Pradesh. Pine gasification may become a source of employment for rural people and meanwhile also protect forests from fire.

This article reviews literature for efficient conversion of Pine needle as an energy feedstock in gasifiers, Bio Briquetting of pine with suitable binder along with its other social and environmental aspects in society.

II. METHODOLOGY

A. Materials & Methods

Pine collection is done from kuthera and Majhog villages near Hamirpur District of Himachal Pradesh. Samples collected are then studied in laboratory for proximate and ultimate analysis using CHN/O analyzer as per ASTM guidelines. Gross calorific value HHV and LHV's of Pine needles are estimated using bomb calorimeters. Bio-briquettes are made using composite binder in various shape, texture and sizes. These briquettes under controlled combustion in co-current gasifiers used to generates producer's gas. Producer's gas is a mixture of CH_4, N_2, CO_2 and CO in various proportion which can be fed to IC engine with or without modification to generate electricity. Quality of Producer's gas produced depends on various parameters like fuel/O2 ratio, briquette quality and method or type of gasifiers adopted. Life cycle assessment, LCA of Pine briquettes is done by drawing comparisons with other low cost biomass commercially available for briquette making.

1) *Bio-Briquetting:* Bio Briquettes are made using hydraulic pelette press using various composite binders. Binders improve energy content, combustion characteristics, mechanical durability, and density of fuel briquettes. Various organic and inorganic can be blended in optimum ratios to obtain best yield at varying temperature in gasifiers. Various binders are summarized in Table 1

Table1

SNo.	Briquette binders	Properties	Examples
1.	Inorganic Binders	High expansibility, high adsorbent quality, high strength, good acid resistance	Bentonite,Magnisium chloride, sodium silicate,Magnisium oxide, calcium oxide, Iron oxide
2.	Organic Binders	High moldability, high carbon content, good cohesiveness, good polarity, high compressive strength	Starch, lignin liquor, coal tar
3.	Composite Binders	high mechanical strength, high drop strength	Thermoplastic phenolic resin , Coal tar pitch phenolic resins

2) *Thermo Chemical Conversion:* Pine briquettes are thermo-chemically processed in co-current/downdraft gasifiers to generate Producer's gas. This fuel gas after passing through scrubbers gets filtered and can be fed directly to run shafts of IC engines to produce electricity. Producer gas can be also be used to heat the boilers to run Steam engine.

Figure1 summarises gasification process of pine biomass.

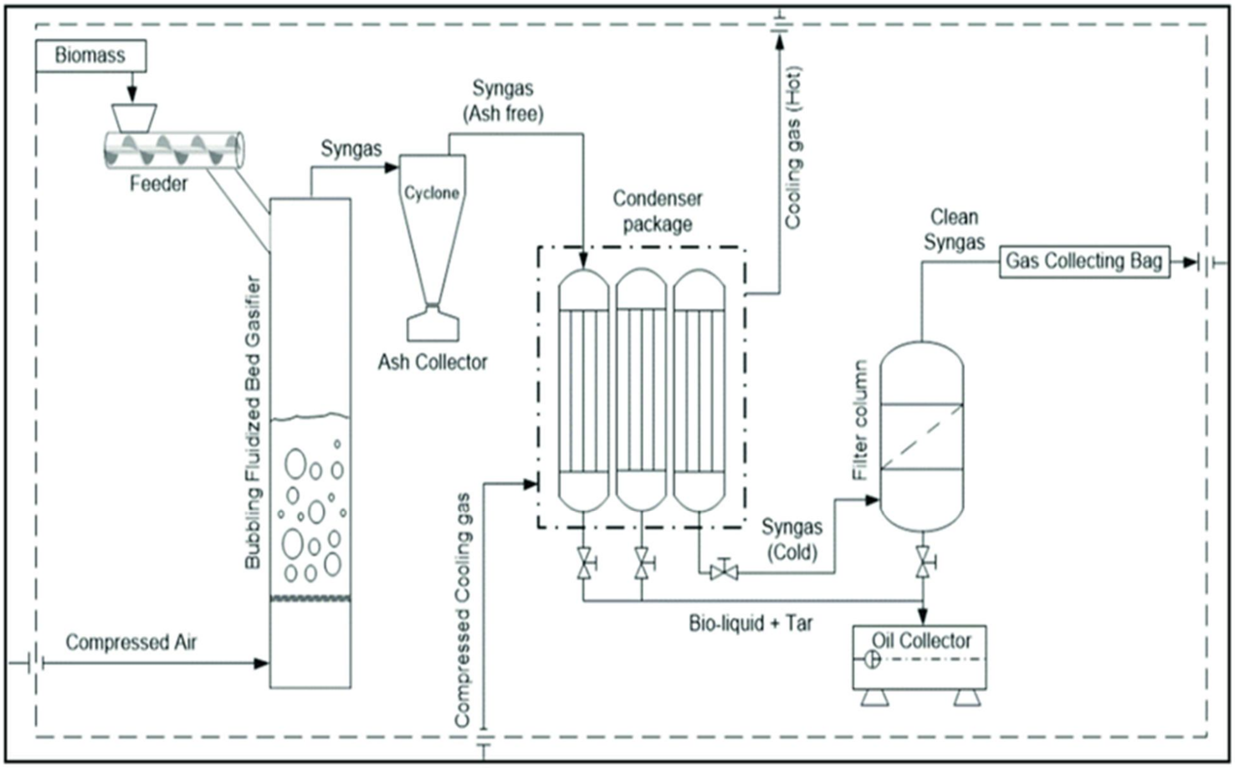


Fig1

B. Chemical Analysis

1) *Proximate analysis:* Proximate analysis is done to quantify fuel by various properties like fixed carbon content, ash content, volatile carbon & moisture content. Pine sample is thermo chemically heated and broken down chemically to estimate ash and carbon content produced during pyrolysis.

Table 2: Gives estimated percentage of fuel ash%, moisture% and fixed carbon % by weight.

Table 2

S No	Components	Percentage (%)
1.	Moisture content	9.76
2.	Ash Content	4.37
3.	Volatile matter content	70.03
4.	Fixed carbon content	15.83

2) *Ultimate Analysis:* For determination of carbon, hydrogen, nitrogen, and oxygen, the ultimate analysis of biomass and oil samples is done using a CHN/O analyzer [1]. Pine compositional quantification is done using ASTM D_{3176} standard test for ultimate analysis Table 3 lays down ultimate analysis of pine.

Table 3

C %	H %	N %	O %	S %	Moisture %	Ash %
53.66	5.52	0.59	32.56	0.2	4.02	3.44

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VIII August 2022- Available at www.ijraset.com

3) *Calorific Value:* Heat Value is one of major parameter which determines combustion characteristics of Pine needle biomass. Instruments used for heat quantification of constant volume samples are Calorimeters. Bomb calorimeter is used to measure Gross calorific value GCV or High heat value HHV's of bio briquettes as per ASTM on dry basis in Laboratory. Low Heat Value or LHV of pine is estimated by applying suitable corrections to HHV values. Heat values of Pine Briquettes on dry basis at constant volume in

Table4

HHV_v(high heat value) in cal/g	LHV_v (low heat value) in cal/g
4648.66	4462.24

Heat value of Producer gas is found out in similar manner using Junker's Calorimeter. Quality of producer gas depends largely upon stoichiometry of air/fuel ratio, type and method of gasifier adopted in the field. Air supplied to gasifier is usually less then ambient stoichiometric air unlike IC engines where various temperature stages require idle combustion of fuel.

Heat value of producer gas at constant volume in Table 5

HHV_v in kcal/m_3	LHV_v in kcal/m_3
924.23	855.64

C. Composition Analysis

1) *Composition Of Bio Briquettes:* Pine briquettes can be made using hydraulic pellete press with or without use of binder. An optimum amount of binders into bio briquettes with fine texture tends to increase durability and mechanical strength of the briquettes. The Calorific value of fuel briquette depends largely on the particle density which ultimately influences type and particle size of binders used. In laboratory varying size of briquette with composite binders are tested and fuel briquette with higher binder particle size observed to have higher energy content. Organic binders such as molasses, baggage, corn, biosolids, gelatin and microalgae also have good binder characteristics.

Fig 3

2) *Composition of Producer Gas:* Compositional characteristics of producer gas primarily depends upon availability of air circulation inside downdraft Gasifier. A producer gas analyzer is used to pot instantaneous gas composition with time. Rich and cleaner mix of gas is produced by varying air/fuel ratio, optimizing shape and size of throatless gasifier [1].

Table 6

CO %	N_2 %	CH_4 %	CO_2 %	H_2 %
14	59.03	2.38	14	10.57

D. Combustion Analysis

1) *Chemistry Of Reactions In Gasifier:* A Co-current or downdraft gasifier is ideal choice for gasification due to its simplicity in design, cleaner output and higher fuel/gas ratio. Air flow in co-current gasifier is along the direction of loading of fuel. Zoning of gasifiers include pyrolysis zone, combustion zone followed by oxidation and combustion zones. Overall arrangement of these zones is critical design element for co-current gasifier. A throatless gasifier reduce problems of bridging and is most suitable for low heat biomass like pine briquettes.

a) Oxidation reaction:

- $C + O_2 \longrightarrow CO_2$

b) Reduction reaction:

- $CO_2 + C \longrightarrow 2CO$
- $C + H_2O \longrightarrow CO_2 + H_2$
- $CO2 + H_2O \longrightarrow CO_2 + H_2$
- $4.\ C + 2H_2 \longrightarrow H_4$

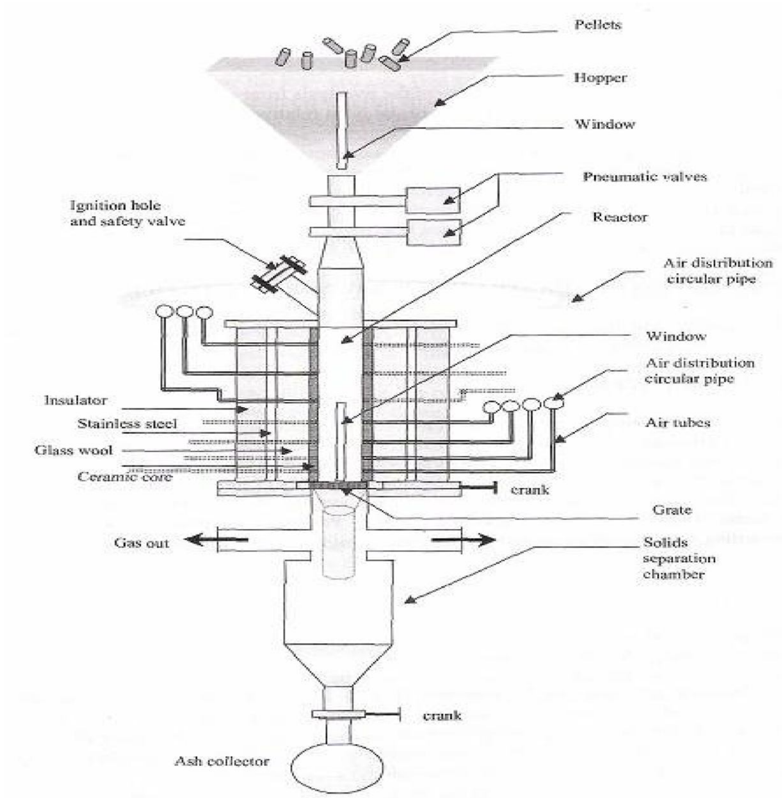


Figure 5: Depicts various zones of downdraft gasifier

2) *Chemistry Of Producer's Gas:* Mix proportion and stoichiometry of producer gas is set in such a way to optimize the overall efficiency of IC engine. A producer gas analyzer is used to set required composition at various air/fuel ratios. Combustion analysis carried out at multiple stages of production. It is subjected to a process intended to improve fuel economics, lower down undesirable exhaust emissions, and to enhance the safety of fuel burning equipment. Heat capacity of gas is measured using Junker calorimeter. Quality of gas produced depends upon Equivalence ratio.

Equivalence Ratio: Ratio of actual A/F ratio to ideal stoichiometry of A/F ratio.

Losses in gas emission are listed and studied separately:

a) Heat lost due to dry gas.

b) Heat lost due to H_2O from combustion of hydrogen.

c) Heat lost due to moisture content in fuel.

d) Heat lost due from the formation of CO.

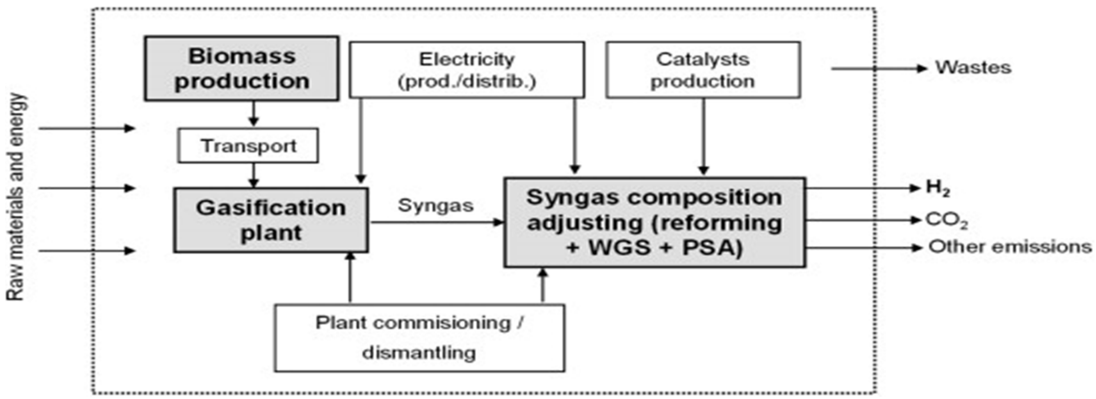
International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VIII August 2022- Available at www.ijraset.com

III. LIFE CYCLE ASSESSMENT

Life cycle assessment of pine briquette is done with view to check overall carbon emission of fuel in its entire lifecycle from manufacturing to residue stage. Net carbon emission of pine briquette is compared with other conventional raw material. LCA is used in conjunction with other environmental tools such as risk assessment and EIA. LCA has several distinct advantages such as systematic estimation of the environmental changes related to the examined process, quantification of emissions and their effects on human health and Eco-system.

A. LCA Assumptions

Scope and boundary description for 1 Nm^3/kg gas based on manufacturing, transport and combustion of briquette in gasifier is done. GaBi software 8.0 is used for standard life cycle assessment of Pine briquettes [2].
Fig 6 depicts boundary of major processes during lifecycle of pine gasification.



B. System Description

Average life cycle of gasification plant is assumed to be 50 years. Yield of compositional elements of producer's gas from various raw materials under study is plotted in terms of total CO_2 emissions.
Table 7: Compares yield of pine with other biomass under study.

Table 7

Biomass	Gas Production (in Nm3/kg)	H_2 %	CO %	CO_2 %	CH_4 %
Pine	1.6	24.9	34.0	23.7	12.8
Eucalyptus	1.8	15.7	40.6	21.6	18.0
Almond pruning	1.7	28.5	35.3	23.1	10.7
Vine pruning	2.0	29.1	49.2	0.0	13.3

CO_2 emissions produced by the different stages of gasification processes are depicted in fig 7.

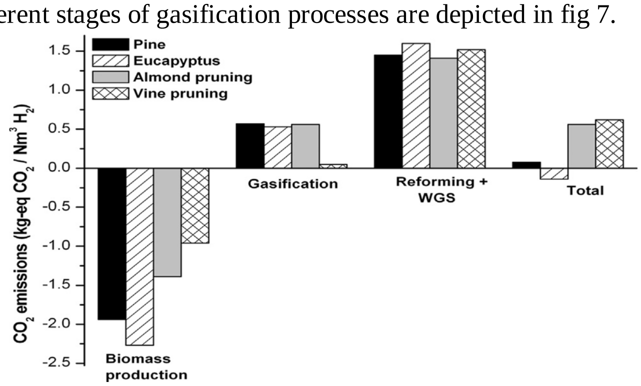


Fig 7

IV. RESULTS AND DISCUSSION

Feasibility Analysis

A throatless gasifier unit is used to check feasibility of full scale pine gasification plant. Overall operational cost, technical viability, economy and other environment factors are most important parameters to be considered before project scale up.

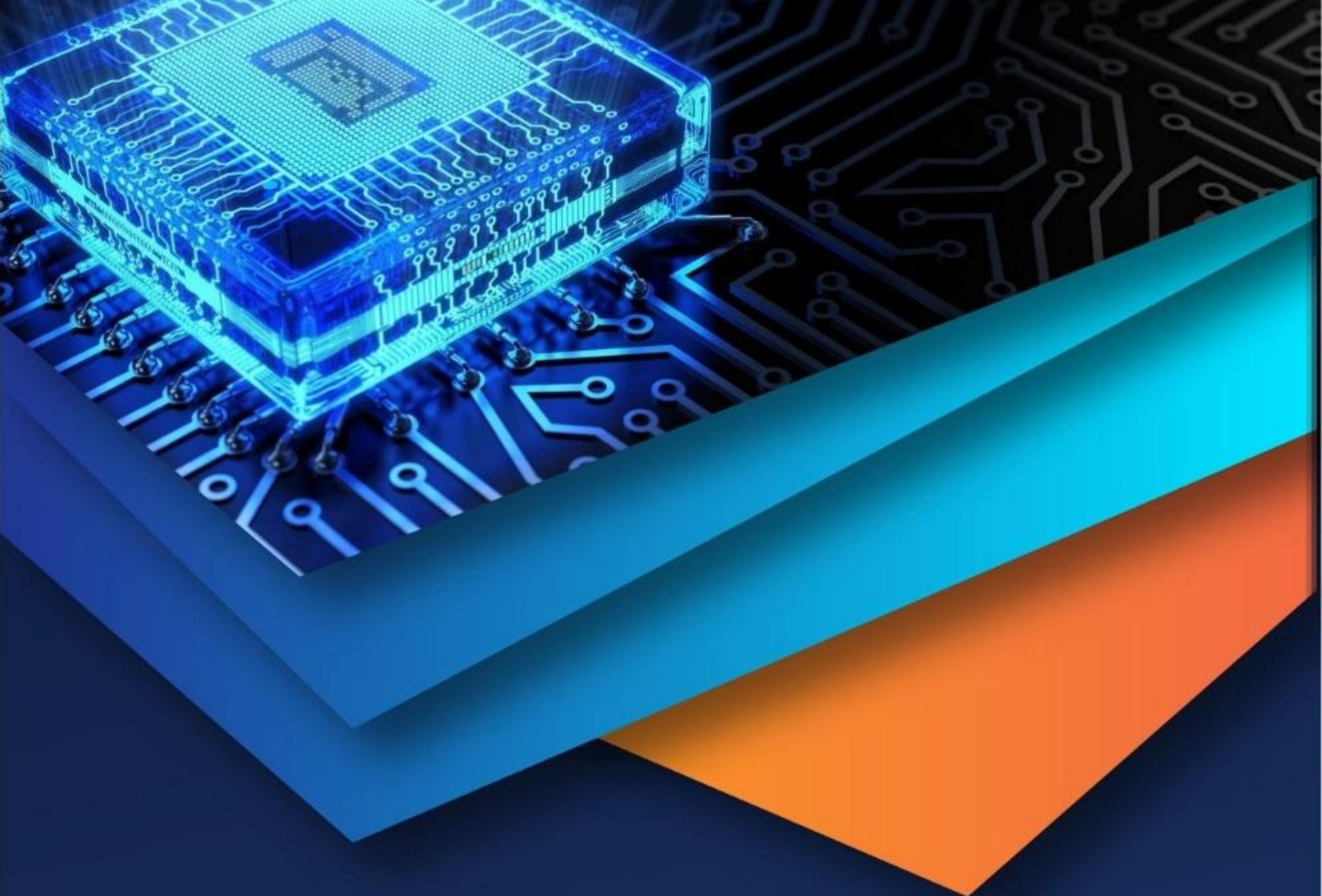
1) *Cost Of 1kwh Of Electricity:* Cost of 1 kg of pine needle in Himachal is around 6-7 Rs. Transportation cost for 1quintal of pine is around Rs 100 per km. Transportation cost may exceeds due to lower density of pine needle when compare to coal, coke, bitumen and other high density of fuels. Briquette and binder cost is around Rs 2 /kg in addition to raw pine needle. Overall consumption rate of 2.5 kg/kWh. Electricity yield around 2.5 Rs per kWh (excluding cost of transportation) which is slightly higher when compare to 1.90 Rs/kWh commercial units in Himachal.
2) *Technical Aspects:* Gasifiers vast biomass requirement make it unfit for continuous source of electricity generation. Process optimization, new design of downdraft gasifier improve process efficiency to great extent if economic factors remain within limits. Throatless gasifier improve problems of bridging and channeling in convention downdraft gasifiers. Tar and carbon content can be reduced by cleaner inputs. Dust particles and carbon removal can be achieved by using dust scrubbers at outlet of gasifier. Efficiency of Producer's gas fed to IC engines may be improved by altering air/fuel ratios
3) *Environmental Aspects*: Pine needle is major cause of forest fire in Himalayan regions. Millions of tons of forest residue covering top soil leads to degradation of top fertile soil [7]. Collection, transportation, briquetting needs large manpower which may generate employment opportunities in rural and remote villages of Himachal Pradesh. Electricity generation through pine biomass not only save environment but also a step towards our energy security. LCA assessment of pine tells us that pine biomass being direct forest derivative do not lead heavy CO_2 emission during controlled combustion in gasifier.

V. CONCLUSION

Pine briquettes may prove to be excellent raw material for gasification. Using pine biomass as fuel not only save environment but also contribute towards our energy security and Sustainable development goals. Process optimization and modern techniques may add up to improved efficiencies and low cost power outputs.

REFERENCES

[1] Dhaundiyal, Alok, and V. K. Gupta. "The analysis of pine needles as a substrate for gasification." Hydro Nepal: Journal of Water, Energy and Environment 15 (2014): 73-81.
[2] Moreno, J., and J. Dufour. "Life cycle assessment of hydrogen production from biomass gasification. Evaluation of different Spanish feedstocks." International Journal of hydrogen energy 38.18 (2013): 7616-7622.
[3] Dwivedi, R. K., R. P. Singh, and T. K. Bhattacharya. "Studies on bio-pretreatment of pine needles for sustainable energy thereby preventing wild forest fires." Current science (2016): 388-394.
[4] Kala, L. D., and P. M. V. Subbarao. "Pine needles as potential energy feedstock: availability in the central Himalayan state of Uttarakhand, India." E3S Web of Conferences. Vol. 23. EDP Sciences, 2017.
[5] Kalinci, Yildiz, Arif Hepbasli, and Ibrahim Dincer. "Life cycle assessment of hydrogen production from biomass gasification systems." International journal of hydrogen energy 37.19 (2012): 14026-14039.
[6] JOUR Chopra, Sangeeta Jain, Anil 2007/05/01A review of fixed bed gasification systems for biomass VoL - 9 Agricultural Engineering International: CIGR Journal
[7] Bisht, Arvind Singh, and Narender Singh Thakur. "Pine needle biomass a potential energy source for himalayan region." 2016 7th India International Conference on Power Electronics (IICPE). IEEE, 2016.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY