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"Economic Analysis of Integration of Biomass Gasifier with ON/OFF Grid to meet the Electrical Energy Requirement of CHIDASHIMUL Dairy Industry" - A Case Study.

Prof. N G. Ajjanna[1], Dr.H.B. Suresh[2], Dr.L.K. Sreepathi[3].

[1]Asst.professor, Ph.D. scholar, Dept. of E&E, JNNCE, Shimoga, Karnataka, India
[2]Professor, Dept. of E&E, JNNCE, Shimoga, Karnataka, India.
[3]visiting professor, IIT Dharwad, Karnataka, India.

Abstract- *Electrical energy is crucial for dairy industry since milk is susceptive to degradation. To meet the increasing demand, the clean and sustainable energy the biomass is being considered as an alternative sustainable renewable energy source. Among the various methods for biomass conversion, biomass gasification is a key process for converting biomass into gaseous fuel for heat and electrical power generation. This research paper delves into the estimation and analysis of electrical energy consumption in the dairy industry and evaluates the economic feasibility of integrating biomass gasifiers with the existing diesel generator for both OFF and ON Grid applications. The study was carried out at Chitradurga Davanagere Shimoga Milk Union Limited (CHIDASHIMUL) dairy industry, Machanahalli, Shimoga district, Karnataka, India. The findings of the study and analysis indicate that the annual electrical energy consumption of dairy industry is 35,42,800 units. By integrating a 1500 KVA biomass gasifier with the existing 1500 KVA Diesel generator, the diesel consumption is reduced by 80 % and supplies power to the ON/OFF grid. Further, by installing 1500 KVA biomass gasifier, the estimated running cost savings is Rs 15 Lakhs/annum and payback period is 9 years. Additionally, CO_2 emissions are projected to decrease by 43 tonnes/annum. The study results were shared with the Chitradurga Devanagere Shimoga Milk Union Limited dairy industry for their consideration regarding implementation.*

Keywords- Biomass Gasifiers, CO_2 emission, Dairy industry, Payback period.

1. Introduction

The CHIDASHIMUL dairy industry is located at Machanahalli, Shimoga district, Karnataka, India, handles 2,50,000 liters of milk per day, consumes an average electrical energy of 2,95,000 units/month. CHIDASHIMUL dairy industry has an annual turnover of Rs.1,03,509 Crore during the year 2023-24 with an annual electrical energy charges of Rs 8.5 crores. In dairy Industry paramount importance in supplying milk daily to the publics and in providing income for farmers. Large quantity of milk need to be processed, packed, stored and distributed every day, requiring a significant amount of electrical energy. Energy is largely dependent on the fossil fuels do fill the gap between the energy consumption and energy production [1] and also Effective energy management in dairy industry will help to save electricity, benefiting the utility, customer and society as a whole. In the event of a power grid failure, immediate access of electrical energy is essential for critical loads. Diesel generators are commonly installed in all dairy industry to provide backup power, as they can be started and stopped quickly without any issues. However, the availability of diesel is depleting, costly and causing environmental pollution, there is a need to find alternative solutions to reduce reliance on diesel consumption and maintain reserves for future needs. Biomass gasification is one of the most efficient way to convert the energy submerged in biomass. In the long term, the use of this new technology will reduce the too-high pressure on natural resources, especially in developing countries [2] Lowering the compression ratio and introducing a combustion system that utilizes spark plugs can enable diesel engines to operate using producer gas. Another approach is to run the diesel engine in dual fuel mode, where the engine uses diesel for 0 to 80% of its output power while using producer gas. An additional 20% of diesel is needed to ignite the fuel mixture. In the event of a failure or malfunction of the above methods, the engine can revert to normal diesel operation. This provides added flexibility and reliability [3]. 75 KVA biomass gasifier was demonstrated that, the dual fuel gasifier can be operated for 465 hours, out of which 190 hours continuously. The gasifier was operated automatically 24 hours a day & only small adjustments of the feeding rate were necessary once or twice a day. The operation was successful, and the output was as expected [4].

This research work explores the integration of Biomass gasifier with existing diesel generator in dual fuel mode. This technology aims to reduce pollution and provide economic benefits and also Fixed bed gasifiers are the most studied and suitable reactors for biomass gasification due to their simple operation and easy construction [13]. A case study was conducted at CHIDASHIMUL dairy industry, Shimoga district, Karnataka, India, where primary data is collected. The primary data includes the technical specifications of the existing diesel generator set such as KVA rating, rated

voltage, rated current, rated frequency, diesel consumption/month, electrical energy generated in units and number of hours of operation. Further, the electrical energy consumption from the grid, sanctioned demand, rating of the existing transformer, tariff paid towards electrical energy and major load details were collected. Based on the data collected, Economic Analysis has been made to arrive the rating of the biomass gasifier to be installed and its economic feasibility to integrate biomass gasifiers with diesel generators for both OFF/ ON Grid applications. The analysis includes the different stages of operation of the biomass gasifier for gas production [9] and the use of gas in multiple modes, such as dual fuel mode with diesel and producer gas at a 20:80 ratio and mono fuel mode with diesel only. The biomass gasifiers installed for captive power generation in medium and large scale industries across India were also discussed.

2. Materials and Methods

For the analysis of integration of biomass gasifier with the existing diesel generator connected to ON/OFF grid to meet the electrical energy requirement, Primary data is collected from CHIDASHIMUL dairy industry and secondary data is collected from 75 KVA biomass gasifier installed at JNN College of Engineering, Shimoga, Karnataka. India.

Primary Data:

Table 1: *Primary data details [7]*

SL.No.	Particular	Rating/Value	Remarks
1	Sanctioned Demand	1200 KVA	Increased from 600-1200
2	Rating of 3 phase Transformer connected in Delta-Star	1500 KVA	Increased from 800-1500
3	Primary voltage	11 KV	3 phase 3 wire system
4	Secondary Voltage	433 Volts	3 phase 4 wire system
5	Rating of Diesel Generator	1500 KVA	Generates 3 phase power at 440V, 50Hz, UPF.
6	Rated 3 phase voltage	440V	Line voltage
7	Rated single phase voltage	230V	Phase voltage
8	Rated frequency	50Hz	Indian standard frequency
9	Rated diesel consumption of DG set in liters per hour	403	At full load.
10	Electrical energy generated in Units/annum.	63,500	From Jan 2023-Dec 2023
11	Diesel consumption in liters per annum.	20,147	From Jan 2023-Dec 2023
12	Annual diesel cost in Lakhs	19.68	From Jan 2023-Dec 2023
13	Total electrical energy consumption/annum in kWh	2.95 Lakh	From Jan 2023-Dec 2023
14	Annual electrical energy cost in Crores	8.24	From Jan 2023-Dec 2023
15	Annual turnover of the plant in Crores	1,03,509	From Jan 2023-Dec 2023
16	Milk procurement in liters/annum	9 crore 13 lakh	From Jan 2023-Dec 2023

Primary data is collected to understand the major equipments available and electrical energy consumption and cash flow in the organization and to decide the rating of the biomass gasifier required for the industry [7].

Secondary data:

Electrical energy generated in units by a 75 KVA biomass gasifier installed at JNN college of engineering, Shimoga, Karnataka. India is as shown in table 2.

Table 2: Electrical energy generated by biomass gasifier installed at JNNCE, Shimoga [6]

SL.No.	Month-year	Fuel (Biomass) consumed in kgs	Electrical Energy Generated in kWh
1	Mar-05	941	237
2	Apr-05	1587	375
3	May-05	1399	765
4	Jun-05	577	105
5	Jul-05	2147	924
6	Aug-05	3211	1490
7	Sep-05	4634	2097
8	Oct-05	4073	2233
Total		18569	8226

Table3: Electrical energy consumption and energy charges at CHIDASHIMUL

Sl. No.	Month	Total Electrical Energy consumed in Units.	Total energy cost in Rs.
1	Apr-22	3,21,269	55,39,076
2	May-22	3,13,356	60,64,028
3	Jun-22	2,90,446	63,12,799
4	Jul-22	2,90,622	61,86,524
5	Aug-22	3,01,028	71,38,576
6	Sep-22	2,89,899	70,20,454
7	Oct-22	2,95,307	74,38,999
8	Nov-'22	2,77,466	72,12,704
9	Dec-22	2,96,219	75,20,588
10	Jan-23	2,89,714	74,35,692
11	Feb-23	2,68,164	68,73,591
12	Mar-23	3,09,322	76,10,703
Total		35,42,812	8,23,53,731
Average		2,95,234	68,62,811

Distribution diagram:

The CHIDASHIMUL dairy industry currently consumes electrical energy from MESCOM (Mangalore Electricity Supply Company), a distribution company during ON grid, produces electrical power from DG set during OFF grid [7]. The Fig. 1 shows single line diagram of a distribution system illustrating the major loads of the dairy industry connected to the electrical supply through circuit breakers During a grid failure, the dairy needs electrical energy for critical loads such as lighting, a boiler for steam production and refrigeration sections for milk storage and temperature control. To address this issue, the work involves the integration of a biomass gasifier with Diesel Generator at 80:20 ratios (producer gas: Diesel). A changeover switch facilitates the transition between the biomass gasifier and critical loads/grid supply.

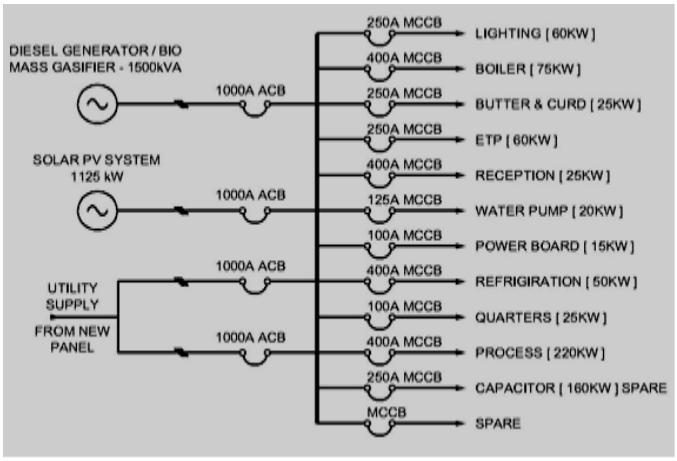

Figure 1: Power Distribution Diagram of SHIDACHIMUL Dairy

Chart 1 [8] displays the installed capacity of biomass gasifier v/s states in India to prove that technology is readily available to install biomass gasifier of 1500 KVA capacity.

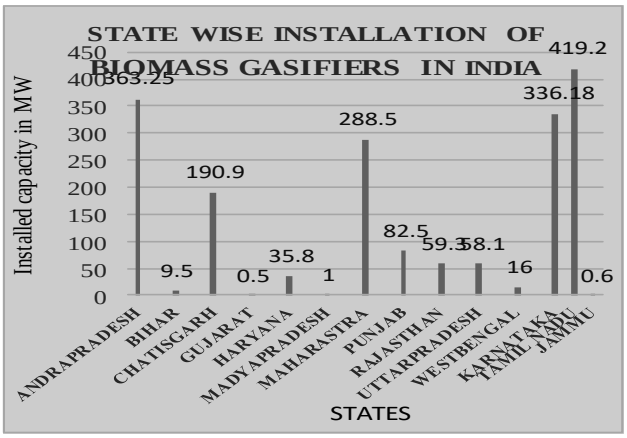

Chart 1: Biomass gasifier state wise installed capacity in India.

The following assumptions were made for economic analysis:

- Cost per kilogram of wood chips to biomass Gasifier is Rs 5.5.
- Fuel considered for the biomass gasifier is 80% wood and 20% diesel.
- 1500 KVABiomass Gasifier is considered for electrical power generation.
- The prevailing market price of 1500 KVA biomass gasifier is Rs 137 lakh.
- A biomass gasifier is assumed to run 20 hours during ON /OFF grids
- Cost per unit of energy supplied from biomass gasifier to dairy during ON grid is Rs 7.5/unit Cost per unit of energy to dairy during OFF grid is Rs 31/unit.

- The life of the biomass gasifier is assumed to be 20 years as per Tata Energy Research Institute data.
- Biomass Gasifier is assumed to operate in dual/Mano mode fuel system.
- Biomass gasifier is assumed to operate 20 hours a day.
- The biomass gasifier has to supply electrical energy to critical loads during OFF grid and feed the power to the gird during ON grid.

Data collection methods:

- Primary data such as energy consumption, energy charges, technical specification such as transformer, diesel generator set, are collected from CHIDASHIMUL, Shimoga Karnataka India.
- Secondary data is collected from 75 KVA Biomass Gasifier installed at JNNCE, Shimoga Karnataka India.
- Prevailing market price of 1500 KVA Biomass Gasifier is collected from India mart, India.

3. Results and discussion:

The performance data of a 75 KVA biomass gasifier installed at JNNCE, Shimoga, Karnataka is shown in the chart 2 and data has been tabulated in table 4. Based on the study, it has been observed that, the plant was operated for a period of 8 months in a year. The average wood consumed per month is 2321kgs to produce 1033 units of electrical energy. The fuel cost is Rs 8123 at a rate of Rs 5.5/kg. The average number of hour of operation of biomass gasifier per month is 51, The specific fuel consumption is 0.4 units per kg of wood. Further, the average char produced/month is 99kg and 0.16 kg /unit of electrical energy. The average yield in kWh/kW/month is 0.27.the cost per unit production is Rs 7.86

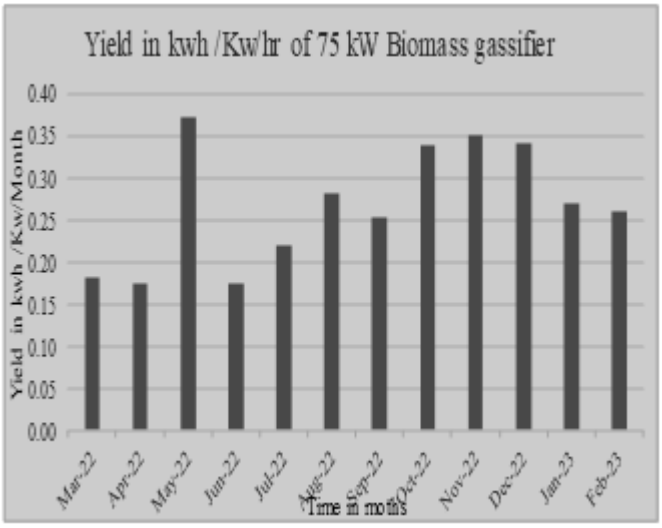

Chart-2: Yield in kwh /Kw/hr. of 75 KVA Biomass Gassifier

Table 4: Estimated data of 75 kVA biomass gasifier installed at JNNCE, Shimoga, Karnataka, India.

Month	Wood consumed in kgs	Electrical Energy Generated in kWh	Fuel cost in Rs at Rs5.5/kg of wood	Number of hours operation of Gasifier	Electrical Energy Generated /Kg of wood	Char produced in kgs	char produced/unit of Electrical Energy	Yield in kwh/kW/Month	Cost/unit production
Mar-05	941.0	237	3293.5	17.5	0.25	103	0.43	0.18	13.90
Apr-05	1587.0	375	5554.5	28.75	0.24	178	0.47	0.17	14.81
May-05	1399.0	765	4896.5	27.45	0.55	81	0.11	0.37	6.40
Jun-05	577.0	105	2019.5	8	0.18	5	0.05	0.18	19.23
Jul-05	2147.0	924	7514.5	56	0.43	48	0.05	0.22	8.13
Aug-05	3211.0	1490	11238.5	70.45	0.46	33	0.02	0.28	7.54
Sep-05	4634.0	2097	16219	111	0.45	145	0.07	0.25	7.73
Oct-05	4073.0	2233	14255.5	88	0.55	200	0.09	0.34	6.38
Total	18569.0	8226	64991.5	407.15	3.11	793	1.30	-	7.90

The study and analysis yields the result that, a 75 KVA biomass gasifier produces 20 units of electrical energy per hour and 1 kilogram of wood produces 0.4 units of electrical energy [6]. This analysis aims to estimate the yield to determine the performance of 1500 KVA biomass gasifier. The electrical energy demand of CHIDASHIMUL dairy is around 2,68,000 to 320,000 units per month. 1500 KVA Biomass gasifier estimated to produce 96,300 units of electrical energy/annum with 1500 KVA DG set to supply electrical power during On/OFF grid. Biomass gasifier is suggested to install to meet the energy requirement of dairy industry from renewable energy sources for reducing grid dependency, increased economic and environmental benefits.

Table 5. Estimated data of performance of 1500 KVA Biomass gasifier

Month/year	Diesel consumption from DG set in litres/month	Electrical Energy Generated in Units from DG set	Energy cost@ Rs 31 per unit without biomass Gasifier	Yield in kwh /KW/hr of biomass Gasifier	Generation in units from 1500 KVA biomass Gasifier@ 0.27	shortage of energy generation from biomass gasifier during grid failure	excess of energy generated from biomass gasifier during grid failure	Revenue generated from biomass Gasifier without Diesel Generator (with biomass gasifier only)	Revenue generated from Biomass Gasifier plant in place of Diesel Generator (DG) @31/unit	Revenue generated from gasifier from excess power generated during grid failure in Rs	Fuel cost to biomass Gasifier = fuel required to generate energy in kwh*cost/kg of wood)	Total fuel cost in Rs
Jan-23	759	2540	78,740	0.18	5,417		2877	40,628	78,740	21,578	12,842	28,590
Feb-23	60	164.9	5,112	0.17	5,217		5052	39,128	5,112	37,890	12,369	13,391
Mar-23	166	539	16,709	0.37	11,148		10609	83,610	16,709	79,568	26,427	29,769
Apr-23	22	60.4	1,872	0.18	5,250		5190	39,375	1,872	38,925	12,446	12,821
May-23	2080	8021	2,48,651	0.22	6,600	1421		49,500	2,48,651	0	15,647	65,377
Jun-23	4160	12927	4,00,737	0.28	8,460	4467		63,450	4,00,737	0	20,056	1,00,203
Jul-23	651	1066	33,046	0.25	7,557		6491	56,678	33,046	48,683	17,915	24,524
Aug-23	2358	6971	2,16,101	0.34	10,150		3179	76,125	2,16,101	23,843	24,063	67,283
Sep-23	2070	5368	1,66,408	0.35	10,535		5167	79,013	1,66,408	38,753	24,975	58,256
Oct-23	2956	9269	2,87,339	0.34	10,235		966	76,763	2,87,339	7,245	24,263	81,731
Nov-23	3315	11568	3,58,608	0.27	8,082	3486		60,615	3,58,608	0	19,159	90,880
Dec-23	1550	4994	1,54,814	0.26	7,800		2806	58,500	1,54,814	21,045	18,491	49,454
Total	20,147	63,488.30	19,68,137	8,226	96,450	12499	42337	7,23,375	19,68,137	3,17,528	2,28,653	6,22,280
Average	1,679	5,291	1,64,011	0.27	8,038	3124.7	4941.4	60,285	1,57,254	37,060	19,054	51,857

Table-5 and chart 3 gives the quantity of diesel consumed in liters by an existing 1500 KVA DG installed at CHIDASHIMUL, Shimoga to produce electrical energy during grid failure, estimated electrical energy generation, the diesel consumption per unit of electrical energy, as well as the cost per unit of electrical energy produced. Additionally, the table includes the annual diesel cost [7].

The findings suggest that, the generation of electrical energy by a DG set for captive power is very costly. Despite this, most industries still use the DG set to produce electrical power during grid failure.1500 KVA capacity DG set is currently is in place at CHIDASHIMUL to offer backup power during grid failures. It consumes an average of 1679 liters of diesel per month to generate 5291 units of electrical energy at a running cost of Rs 1,64,011. The cost per unit of electrical energy is Rs 31. An analysis has been made to consider, replacing the 1500 KVA diesel generator with a biomass gasifier of the same capacity. According to the analysis, the biomass gasifier could produce 8025 units of electrical energy by operating for a period of 20 hours a day using wood chips as fuel, resulting in a monthly cost saving of Rs 1,24,206 with a payback period of 9.1 years. Additionally, this change would reduce CO_2 emissions by 43 tonnes per annum.

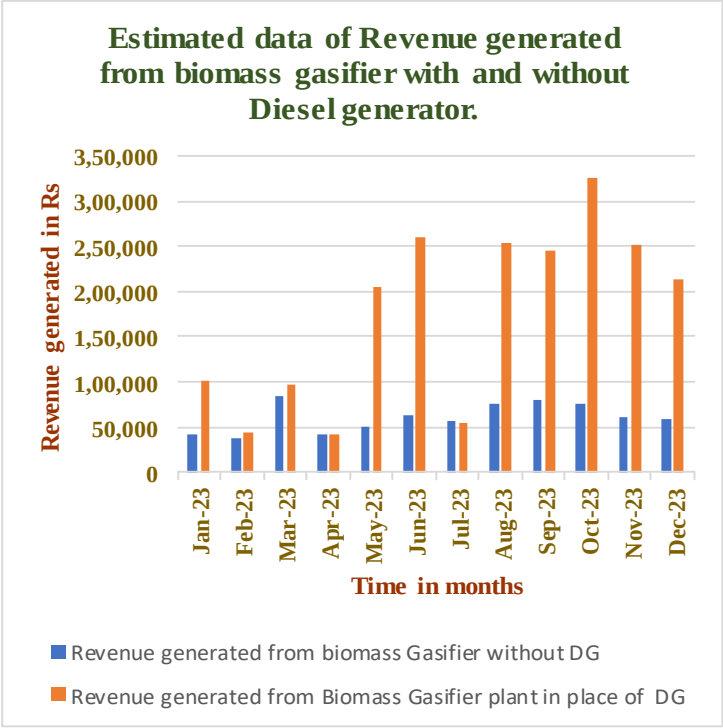

Chart 3: estimated revenue generation in Rs from a 1500KVAbiomass gasifier.

4. Payback period calculation for estimated performance of 1500 KVA Biomass gasifier:

Prevailing market price of a 1500 KVA Biomass gasifier is rupees 137 Lakhs, which produces 96,300 units/annum by running 20 hours a day, Supplies power to dairy both at ON grid/OFF grid, which generates a revenue of 14.94 Lakhs per annum. Cost per unit of energy supplying power during OFF grid by an existing diesel generator is rupees 31, as per the MESCOM rate for HT customers, during ON grid, cost per unit is rupees 7.5. Payback period is 9.1 years. The life of the plant is 20 years [14]. which yields the life time saving of 174 Lakh rupees which reduces CO2 emission by 260 tonnes/annum considering 2.67 kg/unit. Life time reduction in CO_2 emission 5191 tonnes.

5. Conclusion

Biomass gasifiers have low initial investment, high efficiency (>75%), and produce clean exhaust gases. Additionally, biomass is a carbon-neutral fuel, leading to zero net CO2 emissions. An economic analysis and technical feasibility study will be conducted to assess the suitability of this approach for implementation in the dairy industry. Based on the Analysis of Integration of Biomass Gasifier with ON/OFF Grid to meet the Electrical Energy Requirement of CHIDASHIMUL Dairy Industry, the following are the major findings of the research work.

1.Installation of 1500 KVA Biomass Gasifier with a DG set for captive power generation leads to an 80% reduction in CO2 emissions and a 38 % annual savings in the diesel generator cost, contributing to significant cost efficiency [14].

2.The estimated payback period for installation of a biomass Gasifier with existing DG set is 9 years and the life of the plant is 20 years. Over its 20-year lifespan, the system can save Rs 179 Lakhs and result in the reduction of 5,191 tonnes of CO2 emission.

3.The use of biomass gasifier through distributed generation reduces grid dependency and transmission losses, resulting in significant economic and environmental benefits.

4.Both central and state governments are encouraging implementation of renewable energy systems like biomass gasifiers for electrical energy generation for all categories of industrial sectors by giving subsidies [10]. So far None of the Karnataka milk federation industries have not implemented the biomass gasifiers for their energy needs.

5.For energy self-sustainability, the installation of biomass gasifiers for captive power generation is crucial, which also reduces stress on diesel imports and provides economic and environmental benefits.

6.Different sectors of industries have successfully installed these systems to meet their energy requirement. Immediate attention is required by all dairy industries to implement the same and to help the utility grid to manage the demand and supply to society for increased electrification [8].

References

[1] B.S. Dayananda, L.K. Sreepathi. A study on gasification of chicken litter with saw dust in a laboratory scale fluidized bed gasifier. international Journal of Emerging trends in Engineering and Development. 2012;260–5.

[2] Siregar UJ, Lestari A, Rusniarsyah L, Siregar CA. Fuel substitution by wood gasification for diesel electricity generator. IOP Conference Series: Materials Science and Engineering. 2020 Sep 1;935(1):012048.

[3] Sansaniwal SK, Rosen MA, Tyagi SK. Global challenges in the sustainable development of biomass gasification: An overview. Renewable and Sustainable Energy Reviews. 2017 Dec; 80:23–43.

[4] Henriksen U, Ahrenfeldt J, Jensen TK, Gøbel B, Bentzen JD, Hindsgaul C, et al. The design, construction and operation of a 75kW two-stage gasifier. Energy [Internet]. 2006;31(10):1542–53. Available from: https://www.sciencedirect.com/science/article/pii/S0360544205001246

[5] Mathieu P, Dubuisson R. Performance analysis of a biomass gasifier. Energy Conversion and Management. 2002 Jun;43(9–12):1291–9.

[6] Mukhund Rao. Operation and maintenance manual, generation and fuel consumption data sheets of 75 KVA down draft biomass gasifier system installed at JNNCE, Shimoga. Shivamogga; 2005 Jun.

[7] Ravikumar. Files of electrical engineering and diesel generator dept. Shivamogga; 2018 Jul.

[8] BEACH MINERALS COMPANY PRIVATE LIMITED. BIOMASS GASIFICATION BASED POWER GENERATION. Kuttam, Tirunelveli; 2006 Dec.

[9] H.B. Suresh, Dr.L.K. Sreepathi, Dr. H.M. Ravi Kumar. Selection of sustainable energy technologies based on energy Availability - consumption pattern - a region specific analysis. [Shivamogga]; 2014.

[10] MNRE. Bio Energy India. magazine on biomass energy, Govt of India.

[11] Susastriawan AA, Saptoadi H. Effect of Air Supply Location and Equivalence Ratio on Thermal

Performance of Downdraft Gasifier Fed by Wood Sawdust. Journal of Sustainable Development of Energy, Water and Environment Systems. 2023 Mar;11(1):1–10.

[12] Guo F, Dong Y, Dong L, Guo C. Effect of design and operating parameters on the gasification process of biomass in a downdraft fixed bed: An experimental study. International Journal of Hydrogen Energy. 2014 Apr;39(11):5625–33.

[13] Pérez JF, Melgar A, Benjumea PN. Effect of operating and design parameters on the gasification/combustion process of waste biomass in fixed bed downdraft reactors: An experimental study. Fuel. 2012 Jun; 96:487–96.

[14] Business Energy Scotland. Business Energy Scotland. 2024. p. 1–1 Biomass heating – a quick guide.

BIOGRAPHIES:

N G Ajjanna

Received a bachelor's degree in Electrical and Electronics Engineering from Kuvepu University in 1995, and a master's degree in Energy System engineering from Visvesvaraya Technological University in 2001. He is currently doing Research work in the field of Energy Management. Working as an Assistant Professor at the Department of Electrical and Electronics Engineering and coordinator of 400KW RTSPV system installed at JNNCE, Shimoga. His interesting areas include Energy Auditing, Energy conservation, DSM Techniques, and Renewable Energy Technologies. He has published 4 papers at international journals and presented 2 papers at international conferences. He has authored and published a Textbook on Energy Auditing and Demand Side Management.

Dr. H.B. Suresh

Received his B.E. degree in electrical and electronics engineering from Mysore University, India, and his M.E. in energy system engineering from Karnataka University, India. He pursued his Ph.D. program at Jawaharlal Nehru Technological University, India. Currently, he is working as a professor in the electrical and electronics engineering department, at JNNCE, Shimoga. He has presented various papers at conferences in India and published twelve papers in national and international journals and conference proceedings. Currently is guiding two candidates for the Ph.D. program. He is the coordinator for Biofuel Research, Information and Demonstration Centre (BRIDC), JNNCE, funded by Govt. of Karnataka. His areas of interest are sustainable energy technologies, energy conservation, and management, and renewable energy resources. He has delivered more than 100 invited technical talks.

Dr. L.K. Sreepathi

Received his B.E. degree in mechanical engineering from Bangalore University India in the year 1985. He pursued his M. Tech and Ph.D. programs at IIT Bombay from 1988 to 1994 in the area of thermal and fluid engineering. He is the former Vice-Principal of JNN College of Engineering, Shimoga, currently working as visiting professor and green energy coordinator at IIT Dharwad, Karnataka India. He has carried out several research projects funded by CSIR, MNES, AICTE. His areas of interest are biomass gasification, passive cooling of the building, solar energy, rainwater harvesting, etc. He has successfully guided five Ph.D. students. Currently is guiding two candidates for the Ph.D. program. He has presented papers at various conferences in India and abroad and has published more than twenty-five papers in national and international journals and conference proceedings. He was the coordinator for the Chiranthana Green Technology Centre. Currently he is working as visiting professor at IIT Dharwad, Karnataka, India.