Executive Summary

Electric power is the main source of energy to turn the wheels of growth and prosperity of any nation these days. In developing counties like India there are many areas especially remote rural parts where electricity is yet a distant dream. Extending grid power to these areas is uneconomical and at times not possible because of inaccessible terrain. For electric power generation at large and small scale, combustion of fossil fuels is very common. But their limited resources and impact on environment forces the researchers, world over to explore new frontiers of alternate energy sources. For the new and alternative sources, the essential condition is that, they must be renewable and also support sustainable development.

Out of these alternate energy sources, biomass gasification is an age old technology that was taken off around Second World War. The interest in this technology is renewed because of soaring fuel prices. In today’s energy scenario, biomass gasification can give a ready solution for power crisis in rural areas and make them energy independent. For power generation using producer gas requires a prime mover. Reciprocating internal combustion engine and gas turbine are the two feasible prime mover options. As the present work is focused on development of rural technology, therefore using gas turbine is not a viable option because of complicated technology involved and high initial capital cost of gas turbine. The second option of prime mover is then opted for the present work because reciprocating internal combustion engine are easily available in market and their capital cost is very low.

It is reported that in past decade, negative impact on forest ecosystems of India has been posed by several invasive species, lantana being one of them. Out of many weeds lantana has spread more and posing even higher degree problems. The massive growth of lantana may be dedicated to large number of fruits per plant and its ability to grow under wide climatic conditions. It is already mentioned that lantana is a weed and posing serious problems but every negative thing has some positive aspects as well. This work tries to explore the positive aspect of lantana by exploring it as a biomass gasifier feed.
Biomass gasification is the process of conversion of solid carbonaceous biomass into combustible gas by partial combustion. Producer gas is the result of gasification process; it is a mixture of carbon monoxide, hydrogen, methane, carbon dioxide and nitrogen. This resultant gas is more versatile than the original solid biomass. For gasification of biomass three types of gasifiers are used and reported in the literature namely updraft, down draft and fluidized bed biomass gasifiers. Out of these, down draft biomass gasifiers are used for power generation application because of low tar production during gasification.

In the present work, a downdraft biomass gasifier was designed and developed for lantana gasification. Producer gas coming out of gasifier contained particulate matter, tar oils and moisture and hence was inappropriate for engine operation; which is one of the main objectives of this work. To eradicate these impurities a series of gas cleaning systems were developed. In the series of equipment a cyclone separator was designed to separate particulate matter from the hot gas coming out from the gasifier outlet. To separate tar oil vapours, gas was allowed to cool in a cooler below 200°C and then the liquid vapours were separate out by using sand bed filter and wood wool. Further the gas was cooled below 100°C to condense water vapour and then again allowed it to pass through bed of glass wool and wire mesh so that fine water droplets were absorbed.

The suitability of producer gas for engine operation was yet to be established. For establishing the producer gas as engine fuel the first step was to find out its composition. Therefore, gas was analyzed in a gas chromatograph. The composition of the gas was found to be approximately 20% carbon monoxide, 20% hydrogen, 3-5% carbon dioxide, 1-3 % methane and remaining nitrogen. The resulting gas composition and calorific value was in line with the reported literature.

The clean engine grade gas was to be used for engine operation to generate electrical energy. But the existing engine was designed and manufactured for commercial petrol fuel operation, so the first modification required in the
existing petrol engine was in carbureten. Petrol carburetor was designed for approximately 16:1 air/fuel ratio. And the required air fuel ratio for producer gas operation was 1.1:1 to 1.5:1. For that purpose a gas carburetor was designed for producer gas operation. Secondly, existing petrol engine was having a compression ratio of eight which was found to be insufficient for producer gas. So the compression ratio was then changed to 11 for producer gas operation; which found to be sufficient.

Once the setup was complete and ready for experimentation, an electric load panel was fabricated and some thermocouples were put at different locations of gasifier to gather temperature readings. Exhaustive experimentation was carried out on the setup. Gasifier readings were taken at different sets of equivalence ratio and corresponding gasifier temperatures and gas compositions were noted down. Then using empirical relations gas high and low heating values, gas yield and gasifier thermal efficiency was calculated. After these experiments optimum equivalence ratio was obtained in terms of gas composition and calorific value. Now, the gasifier was run with this equivalence ratio and engine was tested with producer gas. The engine was already tested on petrol for baseline data. Furthermore two other gaseous fuels were also tested on the same engine so that comparison can be carried out with producer gas. The engine output was found to be 2.5 kW with petrol, LPG and enriched biogas, as the calorific values of all the three fuels was same, while with producer gas engine output was found to be 2.0 kW i.e. 20% de-rating of the engine. Several runs of engine testing were carried out for reliability of data taken and then 20% de-rating of engine was established with producer gas. Engine performance and emission test were carried out with all the fuels available. And then the performance & emission characteristics of the engine were compared with different fuels. On the performance part, graphs for brake thermal efficiency, relative air fuel ratio (\(\lambda\)), exhaust gas temperature were plotted and compared with other fuels. For emission characteristics, % of carbon monoxide, carbon dioxide, nitrogen oxides, unburned hydrocarbons were recorded with the help of gas analyser. The results were plotted and compared with petrol and other gaseous fuels.
To summarize, physico-mechanical, physico-chemical and physico-thermal characteristics of lantana were found to be suitable for gasification. Behavior of lantana chips was normal during gasification. Thermal efficiency of the developed downdraft biomass gasifier for lantana was found to be almost same as reported in the literature. The producer gas generated by the gasifier was of high quality in terms of composition and calorific value. The carbon dioxide was low and percentage of carbon monoxide and hydrogen was found in line of the reported literature. However, much data was not available on lantana gasification for comparison of obtained results. Gasifier was able to supply constant and reliable engine quality producer gas.

The engine was found to be power de-rated by 20% with producer gas. The brake thermal efficiency of the engine with producer gas was found to be 27% while that with petrol was about 28%. In the engine exhaust the carbon monoxide, nitrogen oxides, carbon dioxide and unburned hydrocarbons were found to be low with operation on producer gas when compared with petrol, LPG & enriched biogas.

From the present work some important conclusions can be drawn such as: the problem of lantana, as a weed can be solved by using the same for biomass gasification, lantana is a good feed for downdraft biomass gasifier; producer gas from lantana biomass and downdraft biomass gasifier is a good fuel for engine operation, small petrol run generator set can be modified and run with producer gas with little de-rating in power; the emission from the engine was found to be very low implying that producer gas a cleaner fuel, the developed technology i.e. downdraft biomass gasifier with small power generating unit can give a sustainable development option in remote rural areas and make them energy independent.