IMPLEMENTATION OF A 150KVA BIOMASS GASIFIER SYSTEM FOR COMMUNITY ECONOMIC EMPOWERMENT IN SOUTH AFRICA

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To my mother, father, siblings, wife and child Nakisani
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SUMMARY

There is growing interest in research and development activities on biomass gasification technologies as an alternative to fossil fuels technologies. However not much has been done in terms of technology transfer, particularly in under-developed and developing countries such as South Africa. This is mainly because of the lack of resources such as funding. Most parts of the under-developed and developing countries fall within rural areas and semi-urban centers, which are endowed with biomass resources. South Africa has a number of sawmill operators who generate tons of biomass waste during processing of timber; the large proportion of this is burned in furnaces as a means for waste management while a very small proportion is collected and used by people in rural areas for cooking their food. The majority of people in rural areas of South Africa are either unemployed or cannot afford the current energy services.

The main aim of this research was to establish the viability of electricity generation for community economic development through biomass gasification, specifically using the locally designed System Johansson Biomass Gasifier™ (SJBG), and to establish the efficiency of the gasifier and associated components with a view of developing strategies to enhance it. The study established the technical and economic feasibility of using the SJBG to generate low-cost electricity for community empowerment. The study also developed strategies to improve the particle collection efficiency of the cyclone. In addition to this, a low-cost gas and temperature monitoring system capable of monitoring gas and temperature at various points of the gasifier was developed. The system was built from three Non-Dispersive Infrared gas sensors, one Palladium/Nickel gas sensor and four type K thermocouples. The study also investigated the impact of fuel compartment condensates on gasifier conversion efficiency. This is an area that has not yet been well researched since much has been done on energy recovery using combined heat and power applications that do not utilize the energy in condensates because these are produced in the gasifier and drained with chemical energy stored in them. The study established that the condensates do not have a significant impact on efficiency.

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<td>CSIR</td>
<td>Council for Scientific and Industrial research.</td>
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<tr>
<td>ER</td>
<td>Equivalence ratio.</td>
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<td>FTIR</td>
<td>Fourier transform infrared spectroscopy.</td>
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<tr>
<td>GC</td>
<td>Gas chromatography.</td>
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<tr>
<td>GC/MS</td>
<td>Gas chromatography mass spectroscopy.</td>
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<tr>
<td>GTMS</td>
<td>Gas and temperature measuring system.</td>
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<tr>
<td>LFL</td>
<td>Lower Flammable Limit.</td>
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<tr>
<td>NDIR</td>
<td>Non-Dispersive Infrared.</td>
</tr>
<tr>
<td>Pd/Ni</td>
<td>Palladium/Nickel.</td>
</tr>
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<td>ROI</td>
<td>Return on investment.</td>
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<tr>
<td>SETA</td>
<td>Sector Education and Training</td>
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<tr>
<td>SJBG</td>
<td>System Johansson Biomass Gasifier</td>
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<td>USD</td>
<td>United States Dollar.</td>
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LIST OF UNITS AND SYMBOLS

B    Moles of steam supplied per moles of biomass.
C    Capacitance.
C-V  Capacitance voltage.
cm$^2$ square centimetre.
CH$_4$ Methane.
CH$_3$OH Methanol.
CO   Carbon monoxide.
CO$_2$ Carbon dioxide.
C$_{(s)}$ Solid carbon/charcoal.
CPU  Central processing unit.
DC   Direct current.
G    grams.
GWh  Gigawatt hours.
HHV  High heating value.
H$_2$ Hydrogen.
H$_2$O Water.
Kmol kilo mole.
KJ/mol Kilojoules per mole of gas
KJ/m$^3$ Kilojoules per cubic meter
KJ/kg  Kilojoules per kilogram.
Kg    kilograms.
kg/s  Kilograms per second.
kg/m$^3$ kilograms per cubic meter.
kg/h  kilograms per hour.
kW$_{th}$ kilowatt thermal.
kJ/kg°C kilojoules per kilogram degree Celsius.
Kcal/m$^3$ kilocalorie per cubic meter.
kPa   Kilopascal.
kV DC kilovolt direct current.
kWh   kilowatt hours.
LHV  Lower heating value.
L/min  Litres per minute.
MI    millilitres.
m/s   metres per second.
MWe   Megawatt electrical.
MJ    Mega joules.
MJ/m³ Mega joules per cubic meter
MJ/kg Mega joules per kilogram.
MJ/Nm³ Mega joules per normal cubic meter.
m³/s  Cubic meters per second.
Nm³/h Normal cubic metres per hour
N₂    Nitrogen.
P     Pressure.
Ppm   Parts per million.
R/s   Revolutions per second.
Sec   Seconds.
SBR   Steam biomass ratio.
SD    Standard deviation.
T     Temperature.
Tₐ    Air inlet temperature.
Tₐ    Reaction temperature.
µV/°C Micro volt per degree Celsius.
V     Voltage.
VDC   Voltage direct current.
°C    Degree Celsius.