Feedstock Evaluation of a Downdraft Biomass Gasifier Coupled with a Tar Removal Mechanism

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List of Conference/Journal Articles

1. Biomass gasification with solutions for elimination of tar from producer gas
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2. Value addition of syngas by resolving issues of tar removal - An enduring challenge
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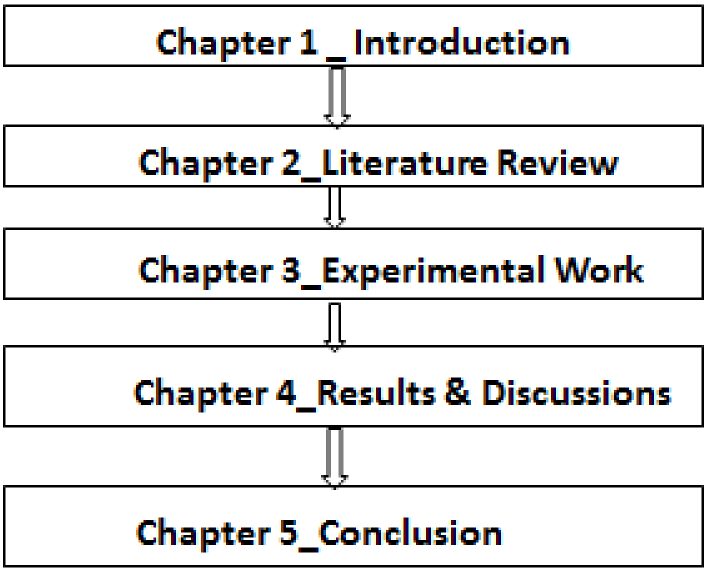
Abstract

Feedstock selection and development of biomass gasifier are basic needs for completion of biomass gasification. The producer gas is emitted with "tar" and some other gases which need proper purification before feeding it to gas generators for electricity production. Here, feedstock evaluation of downdraft biomass gasifier is done and a proposed model for tar removal mechanism is suggested at field level. Producer gas from biomass gasification can replace natural gas as source of heating in water heating systems. Residential water heaters consume a significant portion of natural gas energy in a typical home. A hybrid Solar/Syngas water heating system at domestic level is proposed as cost effective and efficient technology to meet challenges in energy sector of Pakistan. Proximate analysis and ultimate analysis for corncobs were done by TGA and True spec elemental analyzer respectively. HHV of corncobs was determined by bomb calorimeter. In present study proximate analysis gives 60.04% VM(Volatile Matter), 6.61% ASH, 29.85% FC (Fixed Carbon) and ultimate analysis gives 45% Carbon, 5.8% Hydrogen, , 48.5% Oxygen. HHV of corncobs was found 17.41 MJ/kg. In conversion process, thermo grams of corncobs and other biomass samples for temperature change from ambient to specified temperature were compared. Most elevated and quickest change was watched for corncobs because of high part of cellulose, hemi-cellulose in corncobs, which is least in lignin. Current reviews were found in great concurrence with consequences of other revealed information. For locally fabricated downdraft biomass gasifier, present modification in throat diameter (8.6 cm) and throat inclination (48°) of downdraft biomass gasifier provides high yield of gas; 1kg of biomass gives 2.5m^3 of producer gas. Gas analysis by IMR gas analyzer provided information about presence of 17.6% CO, 14.5% H_2, 4.4% CH_4 and some % of other gases when 18kg fuel was gasified. Energy conversion efficiency of corncobs based gasifier was found as 74.7% and temperature in gasification process was 700 °C. This experimental data can validate simulation data by other researchers for locally fabricated gasifiers. Heating Value of gas was 5.2 MJ/m^3. Also, in non-throated gasifier experiment biomass gasification was done at 700° C and gas analysis was done by GC (Gas Chromatography). This analysis provided information about presence of 54.45% CO, 14.82% H_2, 2.56% CH_4 and 28.17% other heavy hydrocarbons when 150g biomass sample was gasified. An innovative approach is presented to remove tar maximally using home electric appliance at small scale which can be up graded for larger scales. At small scale flame quality comparison was done with and without electric appliance scrubber. A high blue quality flame was found with electric appliance scrubber that was the indication for removal of tar. Hybrid Solar/Natural Gas water heating system at domestic level provides natural gas savings by using natural gas as on demand heating source. The gas burner firing efficiency was found to be very consistent and recorded about 70±2% for different storage tank temperatures. The energy factor which reflects the overall performance of the system was found 0.52. The total annual delivered energy and consumption was 125therms and 247therms respectively. By including solar part minimum of 125 therms of natural gas are saved for 60°C hot water. Syngas as replacement of natural gas for water heating purpose at domestic level can save conventional fuels. For proposed solar/syngas water heating system, gas supply efficiency was determined as 47% in syngas heating test and total annual consumption and delivered energy was calculated as 129.2 therms and 131.35 therms. Energy Factor was calculated for water heating system as 0.9 following natural gas parametric scenario.

Keywords: Biomass gasification, Downdraft gasifier, Tar, Scrubber, Proximate analysis, TGA, GC, Water Heating System

Figurative Flow of Thesis



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Chapter 1

Introduction

1.1 Corncobs as Biomass

Biomass, a plant derived organic matter and before utilizing of biomass proximate and ultimate analysis is done to check quality of biomass and mass concentrations of elements respectively. Proximate analysis is important for checking quality of biomass and ultimate analysis gives mass concentrations of elements and is important for heat balance[1]. Pakistan is an agricultural country and has maximal potential of crop residues. Corncobs can be used as they have fewer prices, low ash content and do not create slag. In some biomasses, corn cobs have good calorific value that is enough to produce optimum yield of producer gas. Corncobs are preferred over wheat straw and rice husk because they both are also used in other fields for example as fodder and in Paper industry. Therefore, production and utilization do not have balance between them. In fact many of biomasses other than corncobs have good calorific value but it is not necessary that they would be good in other proximate properties (ash content, moisture content, volatile matter etc.). Pretreatment (drying, size reduction, pelleting and briquetting) is necessary when some of properties not hold in utilizing biomass in thermochemical conversion[2]. Corncobs are proved to be used without any pretreatment that ultimately saves cost and makes this gasification technology more economical[3]. In Figure 1-1 various energy markets or fields are shown.

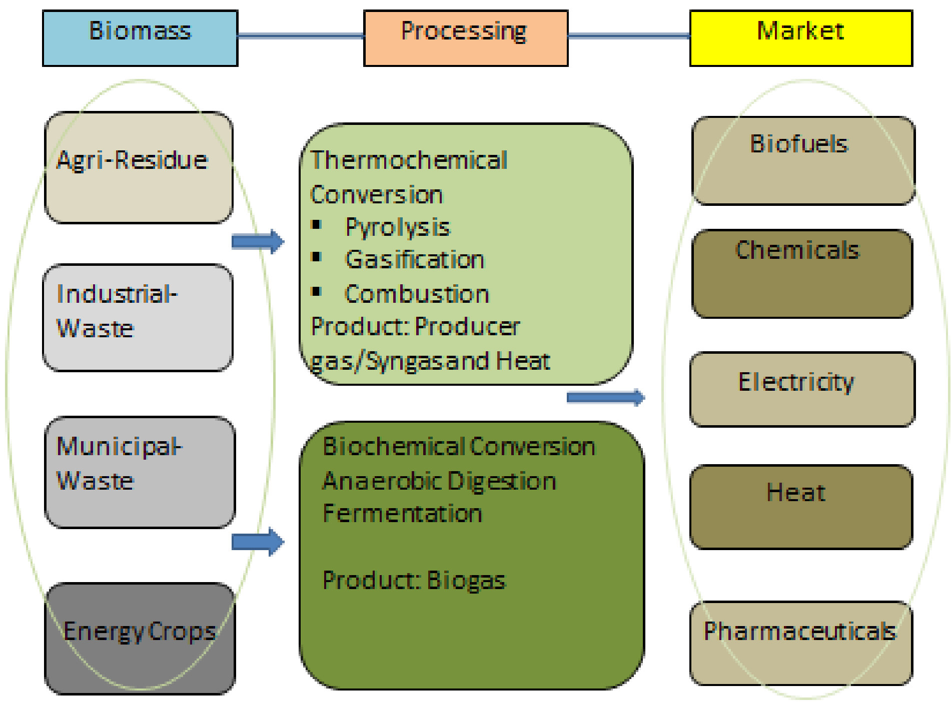

Figure 1-1: Energy Markets

1.2 Biomass Gasification

Biomass gasification is thermochemical conversion method in which carbonaceous solid fuel is converted into gaseous fuel in controlled manner of air. UNIDO promotes biomass gasification by introducing power plants of megawatts in Pakistan to raise economy of Pakistan and also to overcome energy shortfall. UNIDO enhances industrialization process in sustainable way to promote biomass gasification in Pakistan. Temperature and conversion technology matter a lot to get premium product and chemical composition through gasification and biomass affects the efficiency of process. Three demonstration projects are in Kamoki, Jhelum, and Thatta, which will generate electrical power in megawatts from biomass gasification[4].

A process in a controlled environment and partial combustion of biomass occurs; it results in production of a mixture of gas known as “Producer gas”. The name of such process is Biomass gasification. It is process in which carbonaceous solid biomass fuel is converted to gaseous gas which is combustible as well. Biomass gasification involves a sequence of thermo chemical reactions (pyrolysis process, oxidation reactions and reduction reactions) .Energy obtain through sun and wind is renewable energy and these are most popular sources of getting energy. As compare to this form of energy biomass energy is most renewable form of energy production and it is also oldest method to obtain energy. Recent literature shows that electricity obtains through process of biomass rather than through the Sun or through wind source. Sustainable, low-carbon biomass can provide a significant fraction of the new renewable energy we need to reduce our emissions of heat-trapping gases like carbon dioxide to levels that scientists say will avoid the worst impacts of global warming. Purification is needed in combustion process but in gasification process, non-ash fraction of biomass into syngas is primary objective. We do not need purification as we get cleaner products in this process. The purpose of gasification technology is to get fuel rich gas often in this process tar production thus takes place. In conversion process high need is required for getting fuel for transportation and biomass potential is for making chemical production and for electricity use. In gasification technology, controlled emissions and commercially useful products are found. When these parameters are being modified we can enhance on industrial level production of gasification process. Improvement in fixed bed gasifiers and in cooling and cleaning of gas system can perform good role to improve the performance of overall biomass gasification system. Fixed bed gasifiers have a simple construction and operation at high conversion of carbon and long residence time. Removal of tar is a major problem, while recent progress in thermal and catalytic conversion of tar has given reliable options. For average strength of small-scale heat and power applications, fixed bed gasifiers are reliable options. The gas cleaning and cooling system normally consists of filtration through dry filters, cyclones and wet scrubbers. For the production of high quality product gas, the usage of dual fluidized bed gasifiers is credible. Treatment of flue gas can play a viable role to obtain optimum results or efficient performance of technology by improving quality of product. Removal of tar and dust and other particulates from synthetic gas is called treatment of flue gas to protect the environment from harmful substances. Selective catalytic reduction process is required for this purpose. Gas engines usage for power applications should be necessary in this process to get splendid results. Gas turbines usage for power applications are so necessary and gas turbines are used for large scale power generation and deliver 600 MW or more from a 400 MW gas turbine coupled to a 200 MW steam turbine in a co - generating installation. For bringing power to remote sites such as oil and gas fields and installations are such generation used for electricity emergency (base load) and possible for the major electricity grids in many applications e.g. peak shaving to supply emergency peak power. Presence of heat recovery system in industry for electricity generation and building of CHP (combined heat and power) system instead of internal combustion engine system is needed as heat recovery is important part to increase the efficiency of overall system. Four types of reactors are (up draft, down draft, fluidized bed, fixed bed, draft cross) used in this technology for gasification purpose having the following advantages and disadvantages[5].

Some improvements in the system are needed e.g. automated feeding system should be available otherwise process becomes tedious. Due to depleted efficiency of energy conversion, gasifier system modifications are required and they should be carefully done. Accuracy in measurements and collection of data should exist to accomplish this gasification technology effectively. Usage of sensitive gas chromatogram for composition of gas and analytical methods should be done. Additional costs of heat sales that minimize the production cost should available. Therefore, such steps should be taken out to get optimum conclusion. In the drying procedure, biomass fills contain as a rule moistness in the scope of 10 to 35 percent to limit extra cost of drying and to get more transformation proficiency. On the off chance that the temperature gave to biomass surpasses over 100 ° C, steam era happens. In the wake of drying for biomass is warmed, it goes through in pyrolysis organize. Pyrolysis is characterized as a procedure in which the warm deterioration of energizes utilized as a part of biomass when oxygen is truant. Biomass decays in various structures, for example, coal which is strong, fluid tar and gasses. The items delivered in this procedure are reliant on various elements, for example, temperature, weight, living arrangement time and warmth misfortune. In oxidation zone, air is presented in a gasifier and oxidation happens at around 700-1400°C, the strong carbonized fuel responds with oxygen noticeable all around delivering carbon dioxide, and discharging heat. Gasification Process can be seen in Figure1-2.

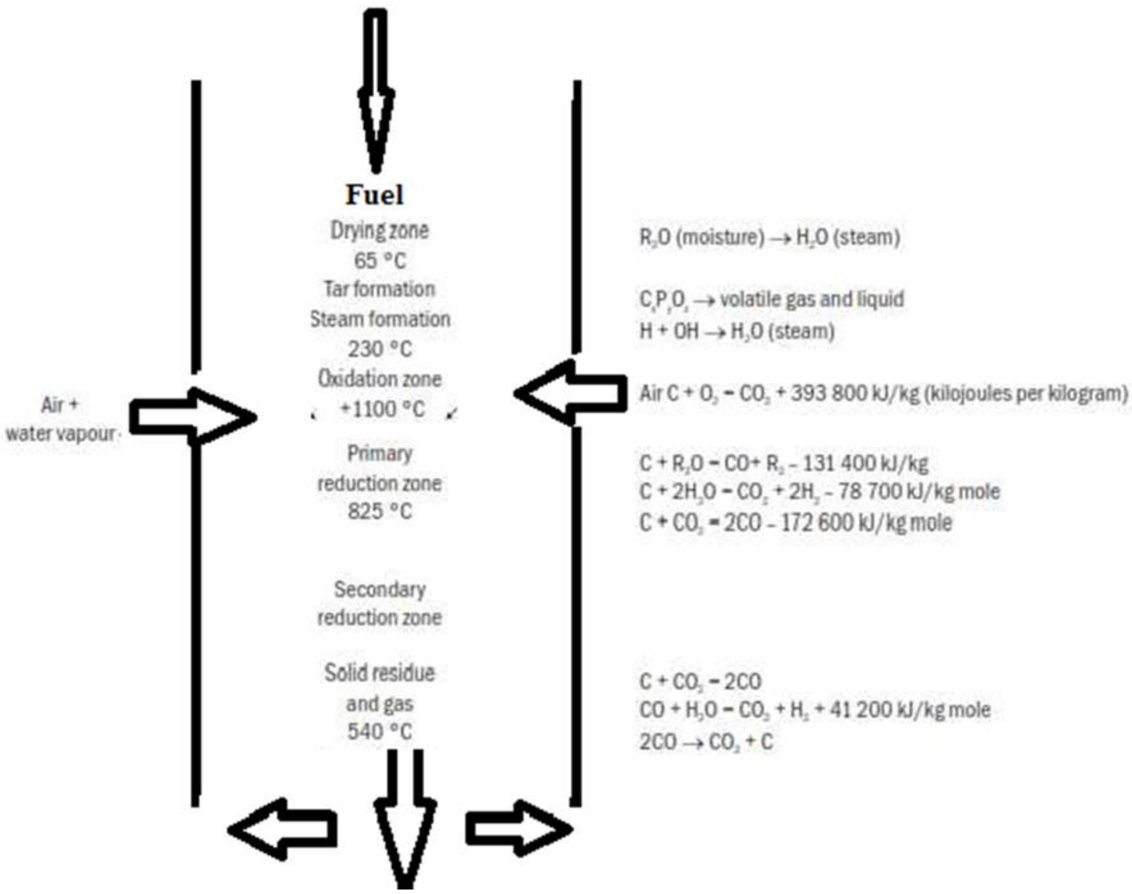

Figure 1-2: Gasification Process.

$C + O_2$	→	CO_2	(-1, 72,600 J/mole)	
CH_4 + H2O	→	$CO + 3H_2$	(-2, 06,400 J/mole)	
$CO + H_2O$	→	$CO_2 + H_2$	(-1, 31,400 J/mole)	
$C + ½ O_2$	→	CO	(Exothermic)	
$C + 2H_2$	→	CH_4	(+75,000 J/mole)	
$C + H_2O$	→	$CO + H_2$	(Endothermic)	
$C + CO_2$	→	2CO	(Endothermic)	
$CO + 3H_2$	→	$CH_4 + H_2O$	(Endothermic)	[6]

1.3 Biomass Gasifiers

For biomass gasification, biomass gasifiers are designed in which a series of thermochemical reactions take place to produce syngas.Downdraft biomass gasifier is good on the basis of less environment problems by less tar production and also good economically. Poorly designed gasifiers give high tar that creates issues in power generation process by clogging engine. Producer gas along with tar content creates issues in its proper utilization. Gasifier population is mentioned in Table 1 and gasifier sizes for application ranges are mentioned in Table 2.

Table 1: Gasifier Population.

Downdraft	75%
Fluidized bed	20%
Updraft	2.5%
Other Designs	2.5%

Table 2: Application Ranges.

Gasifier Design	Application Range
Downdraft	For < 5MW
Updraft	5MW-50MW
fluidized bed	100MW - <1000MW

1.4 Biomass Gasifier Applications

Combined heat and power systems are preferred to achieve high efficiency from biomass gasification process in terms of heat and power. Small level systems are proposed and they are shown in Figure 1-3.

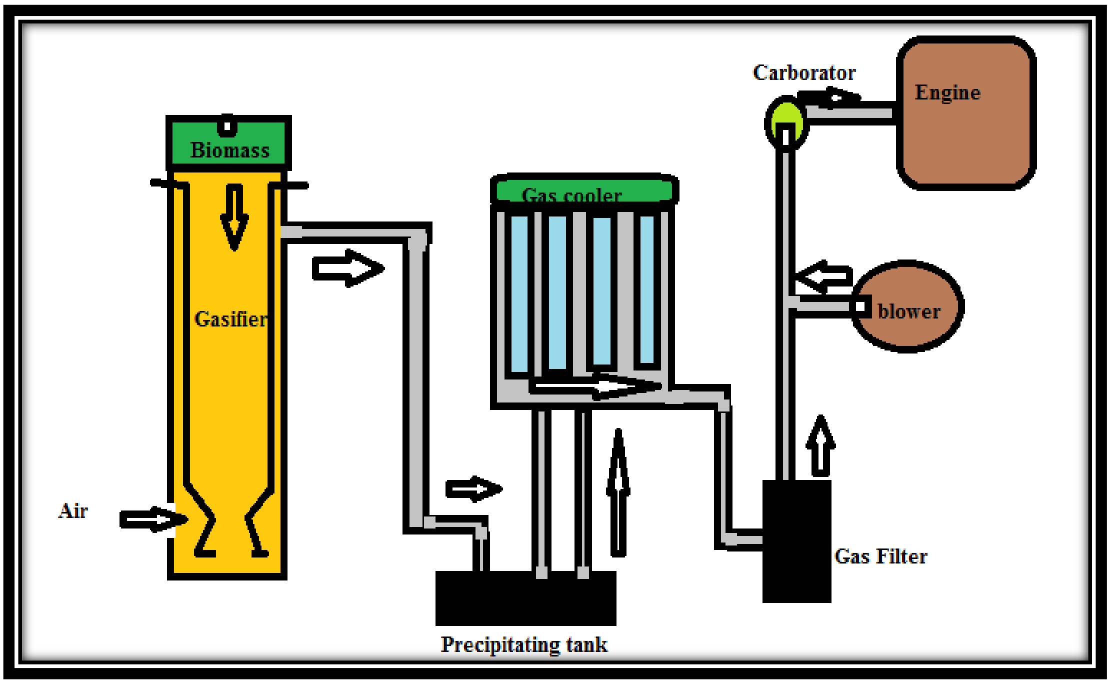

Figure 1-3: Small Level Systems of Gasifier Unit

1.5 Tar and its Classification

In gas quality prerequisite power generators require <100 mg/Nm3 tar content. An adjusted tar division framework is presented by writing or detailed information. In this framework tars are partitioned as essential, optional or tertiary accordingly of research finished up on responses of warm splitting in the gas shape. Essential tars are specified by cellulose inferred yields (laevoglucose and furfurals), lignin determined methoxyphenols and closely resembling hemicellulose inferred yields. Phenolic and olefins are ordinarily named as auxiliary tars. Tertiary tars are characterized into two more classes; alkyl tertiary items that include methyl subordinates of aromatics (toluene, indene and methyl naphthalene) and consolidated tertiary items (benzene and naphthalene).

1.5.1 Tar level in gasifiers and producer gas quality

Comparison of measured tar levels from different biomass gasifier design are mentioned in such a way that in fixed bed gasifier its minimum value is 0.04 g/Nm^3 and maximum value is 6.0 g/Nm^3. For updraft biomass gasifier its minimum value is 1 g/Nm^3 and maximum value is 150 g/Nm^3. Tar tolerances for end use device is given by reported data. Producer gas quality is necessary and average tolerable values of impurities for currently available engines are shown in Table 3[7].

Table 3: Tar Tolerances.

Dust	<50 mg/m^3 gas
Tar	<500 mg/m^3 gas
Acids	<50 mg/m^3 gas

1.6 Solar/Natural Gas Water Heating System

The current facility is installed in TEST lab with three flat plat collectors each of gross area 25ft^2 and optical efficiency of 76.7%, as reported by the manufacturer mounted on the roof top of the Roger's building as shown in Figure 1-4. Collectors absorb solar energy and convert into heat. This heat is stored in solar fluid and transferred to the hot water storage tank for useful purposes. The storage tank has storage capacity of 70 gallons as shown in Figure 1-4. The tank is equipped with a gas burner of 76,000 But/hr. capacity located at the bottom. A blower mounted on the top, facilitate to ventilate gas flume. The tank is featured with immersed steel heating coils that allow heat transfer between solar fluid and potable water. Two thermistors (Pt1000) sensors are installed at the top and bottom tank to monitor and control the stored hot water temperature of the tank. The solar pump station is integrated with operational and safety devices which helps in circulation of solar fluid to transfer heat from collectors to the storage tank shown in Figure 4c. The volume flow rate of glycol and draw hot water is recorded using impulse flow meter giving 1gal for each pulse. Solar flux is measured in W/m^2 using silicon pyranometer smart sensor with measuring range from 0 to 1280W/m^2. Water heating system sections are in Figure 1-5.

Figure 1-4 : Components of the SWHs in TEST lab

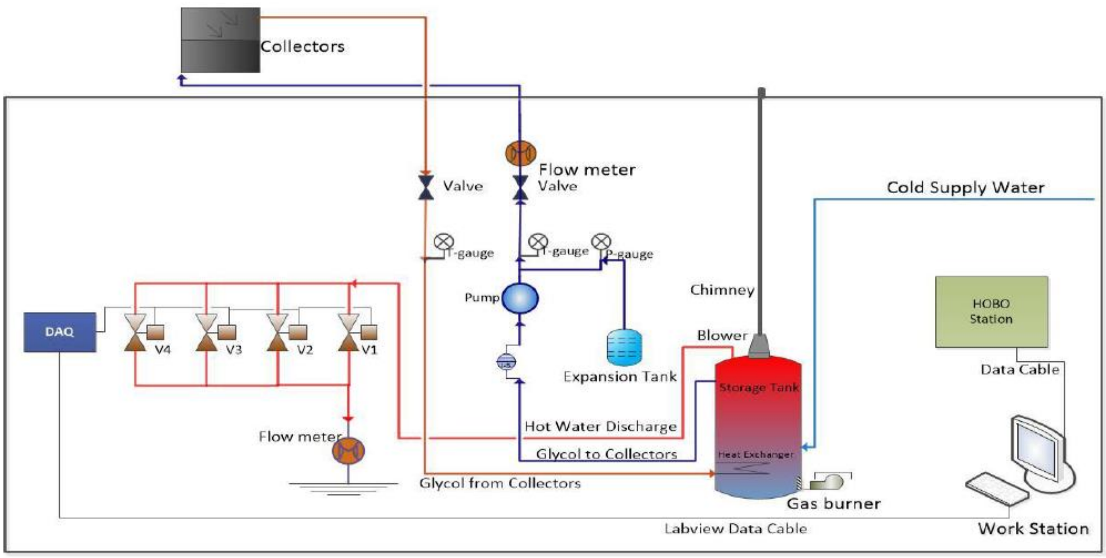

Figure 1-5 : Introduction to water heating system

Summary

Biomass is common material got from living, or starting late living structures. With respect to biomass for imperativeness this is consistently used to mean plant based material, however biomass can also apply to both animal and vegetable derived materials. It is any regular matter-wood, crops, officer benefit stores, kelp, animal wastes – that can be used as an essentialness source. Biomass is likely our most prepared wellspring of imperativeness after the sun. For a large number of years, people have bursted wood to warm their homes and cook their support. Biomass is a renewable imperativeness source since its arrangements are not compelled. People can essentially create trees and cultivating harvests and waste will reliably exist. (Biomass is a) non-fossilized and biodegradable characteristic material beginning from plants, animals and microorganisms. This ought to in like manner consolidate things, by-things, developments and waste from cultivating, officer benefit and related organizations and furthermore the non-fossilized and biodegradable regular divisions of mechanical and metropolitan misuses. The rule limit of the forces is to give warm imperativeness, which is used direct as warmth or changed into various sorts of essentialness, i.e. mechanical or electrical essentialness according to the prerequisites. The genuine wellsprings of warm imperativeness, at this moment, are fossil forces and biomass fills.

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Chapter 2

Literature Review on Some Experimental and Conversion Technologies

2.1 Processing of Biomass Fuels

Prior to its use, the biomass fuel needs to be conditioned according to its application, and optimum utilization. The conditioning of the biomass fuel involves the processes such as:

- Drying,
- Powdering,
- Pelleting, and
- Briquetting

These processes are discussed in the following sections as shown in Figure 2-1.

Drying of Biomass Fuels

Fuel Powdering, Pelleting and Briquetting

Powdering

Pelletizing and Briquetting

Briquettes

Pellets

Figure 2-1: Pellets and Briquettes.

2.2 Biomass conversion technologies

The transformation of biomass to vitality (likewise called bioenergy) envelops an extensive variety of various sorts and wellsprings of biomass, change alternatives, end-utilize applications and framework requirements [8].

Biomass conversion technologies are broadly divided into the following prime categories:

- Thermochemical conversion
- Biochemical conversion

These technologies are briefly described in the following sections.

Thermochemical conversion:
There are three major options under thermochemical conversion, namely:

- Combustion
- Gasification
- Pyrolysis

2.3 Biomass Gasification

Gasification is a midway oxidation handle whereby a carbon source, for instance, coal, normal gas or biomass, is isolated into carbon monoxide (CO) and hydrogen (H_2), notwithstanding carbon dioxide (CO_2) and possibly hydrocarbon particles, for instance, methane (CH_4).

This mix of gasses is known as 'creator gas' or thing gas (or wood gas or coal gas, dependent upon the feedstock), and the correct characteristics of the gas will depend on upon the gasification parameters, for instance, temperature, and besides the gasification master used, for instance, air or steam or oxygen or a mix of these. When using air as the gasification medium, the consequent high nitrogen (N_2) content combines the volume of the thing gad and addition the measure of the downstream gas cleaning equipment.

Low temperature gasification:

If the gasification occurs at a tolerably low temperature, for instance, 700°C to 1000°C, the thing gas will have a by and large anomalous condition of hydrocarbons stood out from high temperature gasification (see underneath). In this manner it may be used particularly, to be scorched for warmth or power period through a steam turbine or, with sensible gas clean up, to run an internal start engine for power time.

High temperature gasification:

Higher temperature gasification (1200°C to 1600°C) prompts to couple of hydrocarbons in the thing gas, and a higher degree of CO and H_2.

This is by and large alluded to as amalgamation gas as it can be used to mix longer chain hydrocarbons using uncommon change frameworks. Gasification innovation can be utilized for:

- Heating water in central heating, district heating or process heating applications
- Steam generation
- Electricity generation or motive force
- As part of systems producing electricity or motive force

Gasification process is actually composed of four distinct processes, namely, combustion, drying, pyrolysis and reduction[9].
Table 4 represents pros and cons of different gasification technologies.

Table 4: Pros and Cons of different gasifiers.

Gasifier	Advantages	Disadvantages
Updraft fixed bed	Develop for warmth Small-scale applications Can deal with high dampness No carbon in fiery debris	Nourish estimate constrains High tar yields Scale confinements Low warming quality Slagging potential
Downdraft fixed bed	Little scale applications Low particulates Low tar	Sustain measure limits Scale constraints Low warming quality Dampness touchy
Bubbling fluid bed	Vast scale applications Feed attributes Direct/circuitous warming Can deliver higher warming quality gas	Medium tar yield Higher molecule stacking
Circulating fluid bed	Substantial scale applications Feed qualities Can deliver higher warming worth gas	Medium tar yield Higher molecule stacking
Entrained flow fluid bed	Can be scaled Potential for low tar Potential for low methane Can create higher warming quality gas	High particle size limitation & high amount of carrier gas

2.3.1 Operating conditions for gasifiers

Operating temperature & Operating pressure

Temperature control of the gasification is a fundamental variable. It relates to the ER, TDR and biomass utilization rate. Increment in temperature expands the development of burnable gasses, diminishes the yield of roast and tar and prompts to more total change of the fuel into item gas [10].

Operating pressure of the gasifier is another important variable. The rate of char gasification and yields of methane increase with increasing pressure, and the impacts are most significant at high temperatures (900°C to 950°C).Small scale gasifiers are normally operated at slightly negative pressure (Vacuum), while large scale gasifier integrated with gas turbines operate at high pressures, since the gas turbines operate at elevated pressure[10].

2.3.2 Gasifier sizing guidelines

Since, the population of downdraft gasifiers is approximately 75%, and they are employed in the small sized applications. They are simple, cost effective and easy to operate. However, they are less efficient. With the passage of time specially designed gasifiers for large applications have been successfully developed, installed and being operated. However, they are expensive, costly, specialized, and fully automatic with electronic control. In fact, they are efficient.

The calculations for the gasifier for producing 11.57 kW_{elec} are illustrated, where the kW_{th} (thermal) in terms of 57.14 kJ/s have been calculated in the above sheet[11].Table 5 represents sizing guidelines of gasifier.

Table 5: Sizing guidelines of gasifier.

Thermal power of gas supplied to engine	57.14	kWth (kJ/s)
Gasifier efficiency	70.00%	
Thermal power input to gasifier by fuel	81.63	kWfuel (kJ/s)
HHV of biomass fuel	14,500	kJ/kg
Biomass fuel consumed	0.0056	kg/s
Biomass fuel consumed	20.27	kg/h
Actual power available	11.57	kWelec
Biomass fuel consumed/h for 1 kWelec	1.75	kg/kWh
Biomass fuel consumed	20.27	kg/h

Hence, the downdraft gasifier is to be sized based on 20.27 kg/h of biomass fuel gasified.

2.4 Limitations of tar removal techniques

Favorable circumstances and detriments of tar dealing with systems are indicated in [12]. Warm devastation does not require driving forces that are costly yet rather require high temperature. Tars cause speedy stimulus deactivation, so impulses ought to be supplanted or recouped a great part of the time; this can be expensive. Tar reuse and start for process warm has issue that warming estimation of tar + sear is more conspicuous than process warm required for gasifiers ,thusly warm imperativeness is wasted by blasting most of the tar + scorch [13].

Summary

It is constantly vital to manufacture the gasifier as applications, sort of fuel accessibility and measure of gas required. Sorts of fuel chose may change the manufactured plan. Extraordinary establishment for gasifier for soft and low thickness fuel. Also dampness substance, unstable matter, vitality substance and so forth must be considered amid the planning. Similarly gasifier applications likewise influence the plan. Before, a scope of trials has been done to limit the operational issues of gasifier.

Gasification has been constantly used on a business scale worldwide for more than 60 years in the refining, fertilizer, and engineered wanders, and for more than 35 years in the electric power industry. Warm decimation does not require impetuses that are exorbitant but rather require high temperature. Tars cause fast impetus deactivation, so impetuses should be supplanted or recovered as often as possible; this can be costly. Tar reuse and start for process warm has issue that warming estimation of tar + sear is more noticeable than process warm required for gasifiers ,as needs be warm imperativeness is misused by bursting most of the tar + smolder. Diverse uses (for example, disconnecting single ring aromatics for use in making fragrant polymers, for instance, plastics and strands requires an irregular condition of dealing with to confine the tar into its parts .Since gasification ruins a weighty segment of the sweet-noticing rings in the biomass, it is not a not too bad framework if the last goal is to make chemicals; pyrolysis or liquefaction should be used.

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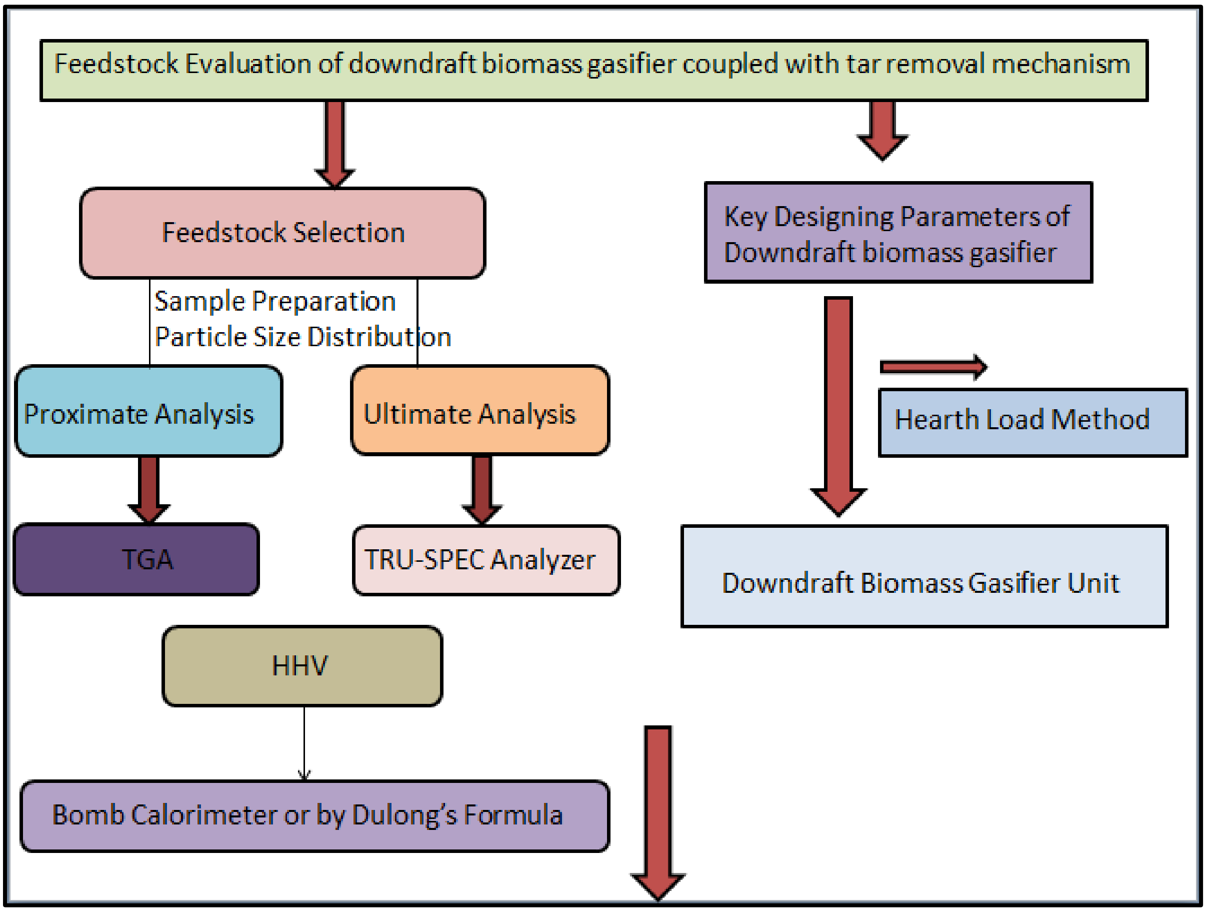
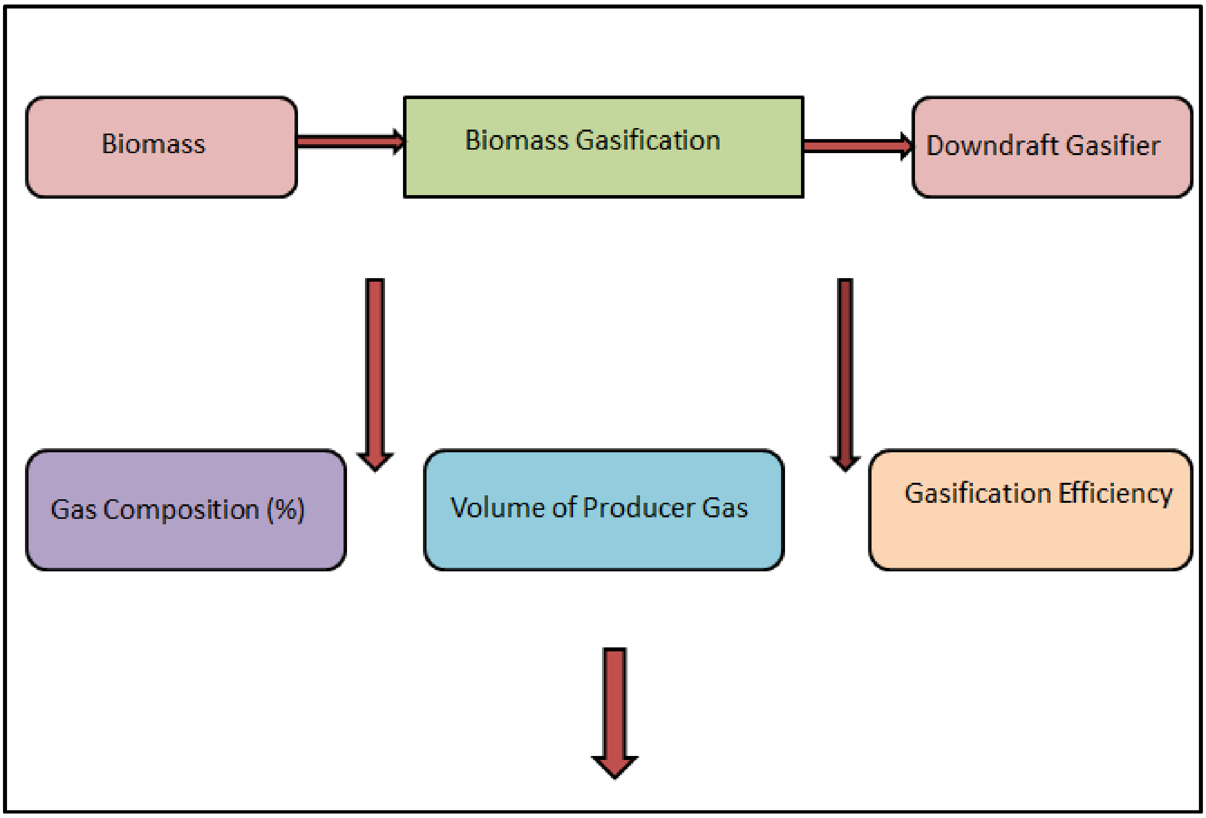
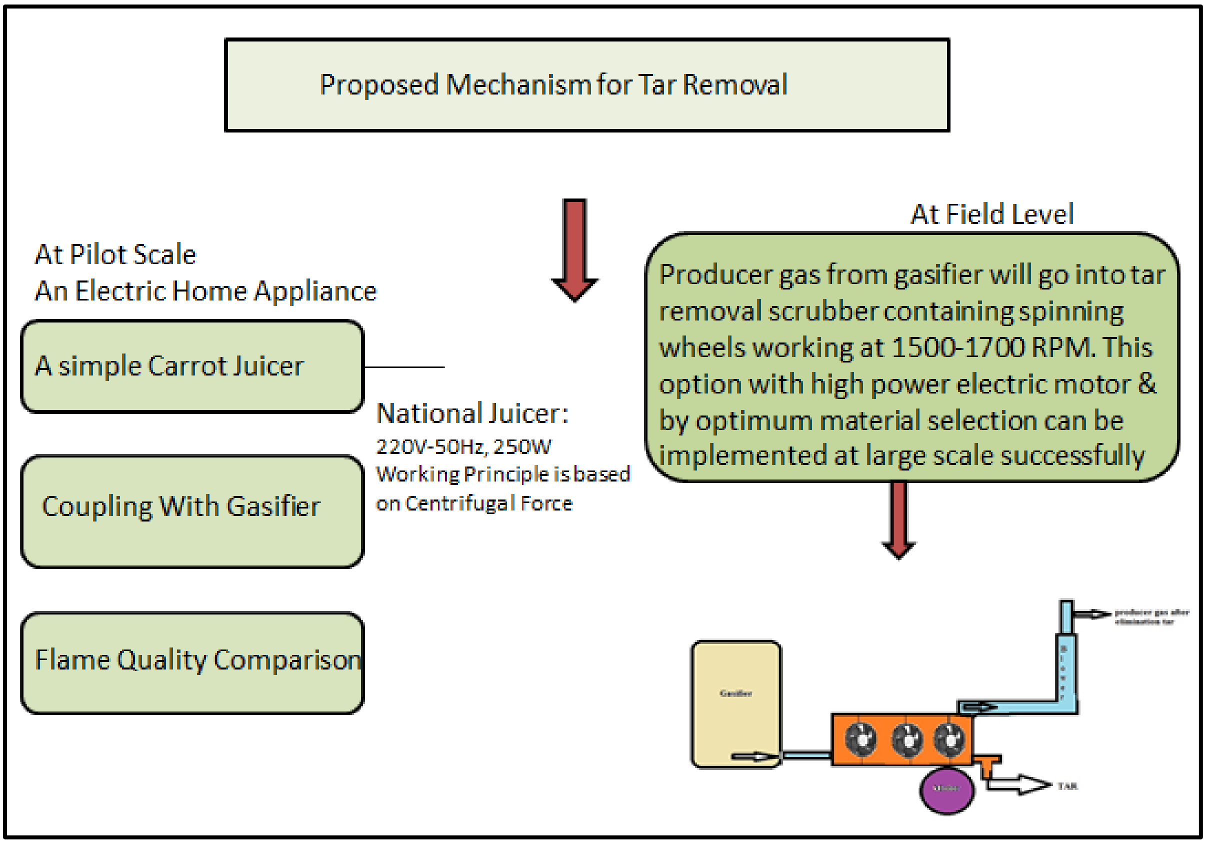
Chapter 3

Experimental Work

(Materials and Methods)




Biomass
Biomass Gasification
Downdraft Gasifier
Gas Composition (%)
Volume of Producer Gas
Gasification Efficiency


Proposed Mechanism for Tar Removal
At Pilot Scale
An Electric Home Appliance
A simple Carrot Juicer
Coupling With Gasifier
Flame Quality Comparison
National Juicer:
220V-50Hz, 250W
Working Principle is based on Centrifugal Force
At Field Level
Producer gas from gasifier will go into tar removal scrubber containing spinning wheels working at 1500-1700 RPM. This option with high power electric motor & by optimum material selection can be implemented at large scale successfully
TAR

3.1 Proximate & Ultimate Analysis

Preparation/Preprocessing for Biomass involves dried corncobs were bought by Cobs mill Faisalabad, Pakistan, milled and sieved to obtain particle size up to 425um as shown in Figure 3-1.

Samples were analyzed at the facilities available at Quaid e Azam University Islamabad. Also, this facility is available at Coal research center, NFC Multan. The biomass was segregated into 425um sizes as shown in Figure 3-1. The proximate and extreme examinations of biomass performed utilizing TGA and Truspec essential analyzer individually. Warming estimation of biomass was resolved utilizing auto bomb calorimeter taking after ASTM strategy D-5496. The example was warmed from encompassing to indicate temperature at different warming rates sanitized nitrogen (99.9%) utilizing a steady stream rate was utilized as cleanse gas to give a latent air. For singe change air at contant wind current rate was utilized for oxidation of scorch.

Figure 3-1: Biomass Samples prepared by Sieve Analysis Method

3.2 Preparation/Preprocessing For Biomass Gasification

The Corn Cobs can be utilized with no before dealing with. It is less expensive than coal and charcoal and offers in every practical sense respite even with volume of gas when separated from different fills. Corn cobs are the most sensible fuel, which can be utilized as a bit of gasifier without palletizing it. They are at the fitting saturation substance when the maize is shelled, which can be plainly utilized as a bit of the gasifier without further drying them. It can be utilized especially in the gasifier accordingly of it honest to goodness size and it doesn't have to cut or palletizing like wheat straw and other thing advancements. It is the most real accumulate stores for downdraught gasifier. It has low singing waste substance when separated from other thing stores. It doesn't make the slagging or cross issues in the gasifier. It is in like way accessible at low costs when showed up diversely in connection to wood, coal and charcoal. It is accessible in immense totals around incalculable. It was extremely easy to gasify most sorts of country waste in the gasifiers. In any case, the capital, upkeep and work drunkards and the regular results (exchange of defer condensates) required in the cleaning the gas, turn away engine applications under by and large conditions. Downdraught equipment is less costly to present, work and make less regular difficulties. Regardless, at present development it is missing to manage cultivating developments without presenting exorbitant additional devices.

3.3 Understanding about Development of Downdraft Biomass Gasifier Using Hearth Load Concept

3.3.1 Designing of Downdraught gasifier

The framework of downdraught gasifier was by and by related to Hearth Load perception. The Hearth load is portrayed as the extent of measure of syngas compacted to standard conditions to the surface zone of the throat at the humblest fringe (Brandini, 1983). It is measured in $m^3/cm^2/hr$. The hearth load can similarly be portrayed as the extent of measure of dry fuel used to the surface range at the most secure impediment (Bs). The hearth stack for this circumstance can be imparted as $kg/cm^2/hr$. Under common conditions one kilogram of dry fuel makes around $2.5m^3$ of producer gas. Outlining out of a gasifier now comes down to assessing the best measure of gas required. This is effectively done by considering the barrel volume and no of unrests and moreover the volumetric sufficiency of an internal begin motor joined to a structure. For this gas aggregate and moreover for B most exceptional respect (0.3-0.9) the zone of the smallest confinement and the breadth of the throat can be figured.

3.1.2 Specification of the Downdraught gasifier

The designing of the gasifier was based on its use and power requirement. The gasifier was designed and fabricated for running of 20 horse power (14.919 kW) power four stroke single cylinder diesel engine.

Distance across of throat = 8.6 centimeter

Fabrication of Throat

The outlining of gasifier, the distance across of the throat was ascertained. For this distance across, the quantity of spouts was changed to three spouts of 1.2 cm measurement as computed. A throat with an incline of around 48 degree and 8.6 centimeter distance across at the at the tightest area as figured amid the outlining was secured in the gasifier in a manner that for any reason like cleaning and study it may take out from the gasifier effortlessly. Under the tightest segment of constriction area of 7.60 centimeter profound and 8.6 centimeter measurement and barrel shaped at the upper end of diminishment zone was welded. The Figure 9 is shown as under. AutoCAD designing for gasifier is shown in Figure 3-2 and Figure 3-3.

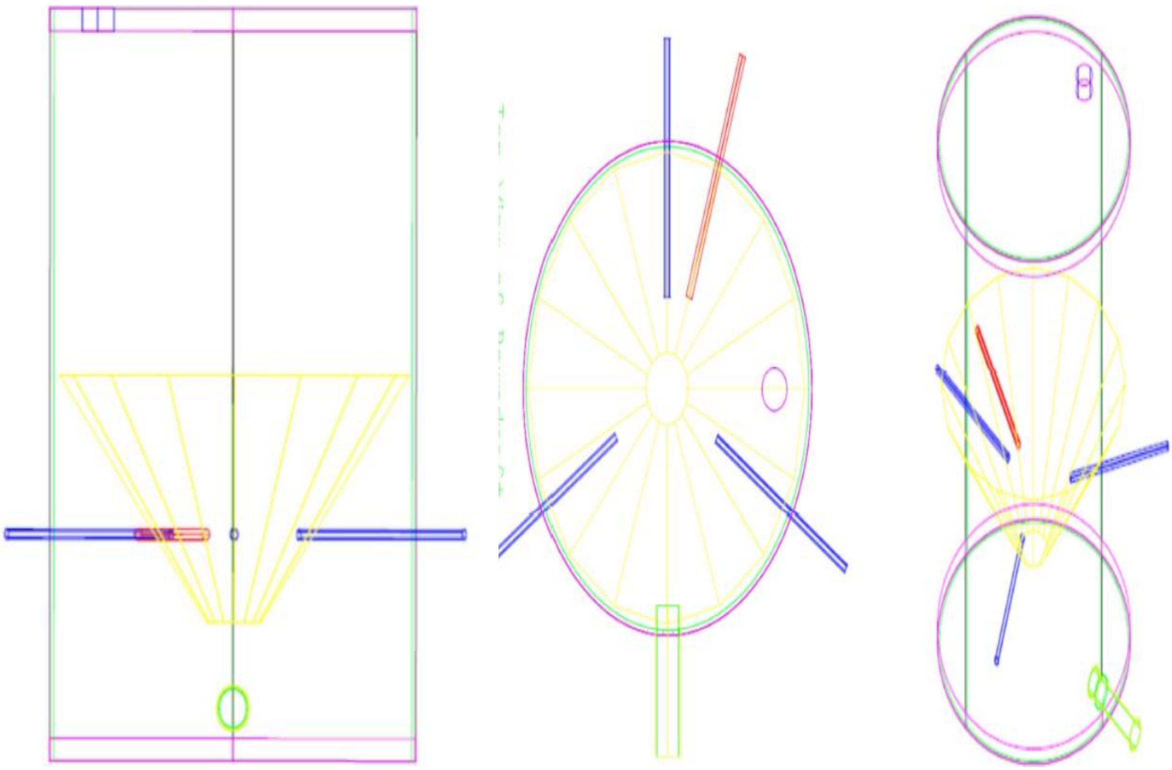


Figure 3-2:AutoCAD GasifierViews

Figure 3-3: Throat of Gasifier and Nozzles Fixing

3.4 Construction of Gasifier

The gasifier was included 16 gage MS sheet. The gasifier was alive and well of 3ft remove crosswise over and 5 ft. of height. The gasifier was fixed closed and light in weight as possible to make transportation less requesting. The fuel compartment was formed as broad as anyone handles the holder enormous size for consistent and long haul operation of the gasifier. The considerable size of fuel compartment has the great position that the forces which have clamminess content more than they require for gasification can be put at the top layer of the gasifiers fuel so it will dry with the internal warmth of the gasifier. This causes the repugnance of gasifier top from over the top warming and reduces the glow incident. The throat in the gasifier was adjusted in a way so that the holder zone may be extended or lessened by raising or cutting down the throat. The opening of the holder for managing of solid fuel into the gasifier was taken as 2 ft. width. The container can be hermetically sealed by utilizing silicon. The schematic outline is appeared beneath in Figure 3-4 and Figure 3-5.

Figure 3-4: Parts and views of downdraft biomass gasifier

Figure 3-5: Downdraft Biomass Gasifier Unit

3.4.1 Biomass Gasification of Corncobs in Downdraft Biomass Gasifier & Value Addition for Producer Gas Using Home Electric Appliance

Materials involve locally designed downdraft biomass gasifier as shown in Fig 2. All views (top view, bottom view, throat of gasifier) and overall picture of downdraft biomass gasifier constructed for experiment is given in Figure 3-6. Downdraft biomass gasifier was developed at Farm Power and Machinery workshop in Agriculture University Faisalabad. Initial particulate gas cleaning system (coal based scrubber for cleaning of producer gas), blower (for creating negative pressure in gasifier and to suck the producer gas from biomass gasifier) and electric home appliance (common fruit juicer) as scrubber for efficient removal of tar at lab scale are shown in Figure 3-7 and Figure 3-8 respectively. Firing torch was used for igniting fuel (corncobs) existing in downdraft biomass gasifier as shown in Figure 3-7. Methodology involves downdraft biomass gasifier set that was charged with 18kg of corncobs and spaces were filled with shredded pages as shown in Figure 3-8. After that biomass gasifier was attached to a coal based scrubber for initial cleaning of producer gas as shown in Figure 3-9. After this coal based scrubber a blower was attached to suck producer gas for end use as shown in Figure 3-8. After the attachment of blower in Figure 3-6 a home electric appliance is used as scrubber to remove tar from syngas that is a juicer of specifications (National juicer: 220V-50Hz, 250W) and working principle is based on centrifugal force for maximum removal of tar as shown in Figure 3-9. This juicer was equipped with 0.5 HP, 1725 RPM electric motor.

Tubing from gasifier was inserted into the inlet of juicer and an outlet was placed in the same opening as mentioned in the Figure 3-9. Tar was separated from producer gas and collected in the pan of juicer as shown in Figure 3-9.
Biomass fuel is ignited through firing valve by firing torch in limited amount of air through air regulating valve as shown in Figure 2. Biomass fuel was gasified through a series of chemical reactions (pyrolysis, oxidation and reduction) in various zones of downdraft biomass gasifier. Full gasification takes place about in three hours and corncobs give about $44m^3$ of producer gas as shown in Fig 4. Experiment was done at Agriculture University Faisalabad in Farm Power and Machinery Workshop.

1. Dry Corncobs

2. Shredded pages

Figure 3-6: Filling of Feedstock

Figure 3-7: Biomass Gasification

1. Gasifier
2. Scrubber
3. Blower
4. Corncobs
5. Producer gas

Figure 3-8: Assembly of pipes between scrubber/juicer and blower for tar removal

1. Producer gas before tar removal
2. Producer gas after tar removal
3. Blower
4. Tar
5. Collection in pan of juicer

Figure 3-9: Parts of scrubber and picture of inside story for tar removal

3.4.2 Experiment by Non Throated Gasifier-Biomass Gasification

Procedure: Corncobs are cut into small pieces to fill the flask bottle. Furnace has controlled environment to gasify the material as shown in Figure 3-10. Temperature is programmed to 700 C for complete conversion of corncobs. At about 300 °C, pyrolysis occurs. At 700° C, material was gasified into combustible gases. Then producer gas is tested by Gas chromatography to know composition of combustible gases.

Figure 3-10: Non throated Gasifier

3.4.3 Solar/Natural Gas Water Heating System

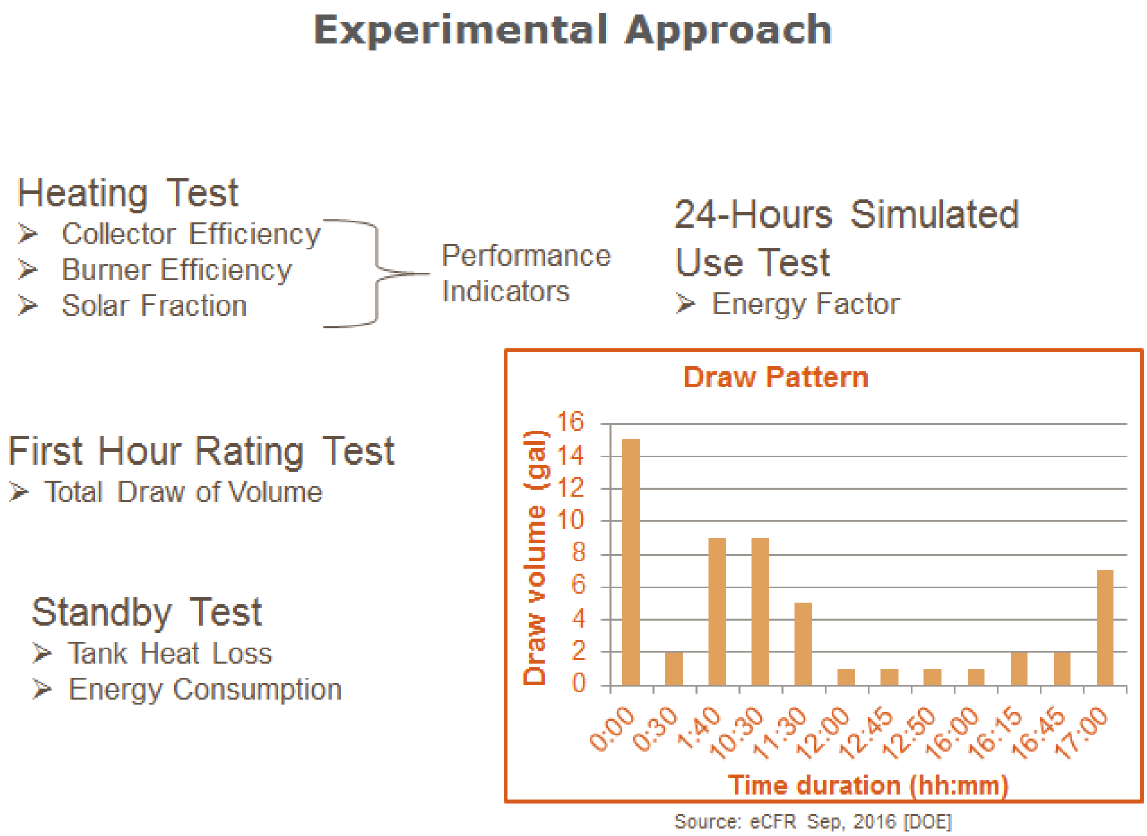


Figure 3-11: Draw Pattern in 24-Hours Simulated Use Test

Experiments are conducted for the energy usage and efficiency calculation of a residential water heater following the test conditions recommended by the DOE. There are different factors to determine the energy performance of domestic water heaters. The present test procedure is the e-CFR (Code of Federal Regulation) Appendix E to Subpart B of Part 430 of September 23, 2016. The objective is to find the load dependent efficiency of the given water heater in three different modes of operation; gas, solar and hybrid mode (solar+gas).

To ensure the performance of any residential heater there are following three parameter defined by the DOE standards. This includes; the first-hour rating test, Recovery efficiency test and Energy factor test . Test conditions are followed as given in Table 6.

Table 6: Highlights the testing condition recommended by DOE.

Supply water temperature	58 ± 2ºF
Ambient dry bulb temperature	67.5 ± 2.5ºF
Average storage tank temperature	135 ± 5ºF
Water flow rate	3 ± 0.25gpm

3.4.4 24-Hour Simulated Use Test

This test is significant to determine the system recovery efficiency and energy factor based on the heat delivered to the storage tank and total energy consumption including auxiliary power. During this experiment the water heater is tested under the following draw patterns as shown in Figure 3. This criterion is set by the department of energy in e-CFR, Sep 23, 2016. For our system we have selected the "medium-usage draw pattern" divided into 12 draw at non-uniform interval with total discharge volume of 55gal/day.
Procedure.

- Fill the storage tank with fresh water and turn on the gas burner.
- Launch the Hoboware pro at specific interval to record data.
- Set the cut-out temperature (135±5ºF) using a labeled nob on the gas control unit (placing at position between B&C).
- When the system is fully recovered, start the test at specified hour by withdrawing volume according to a draw pattern as shown in Figure 3 [eCFR Sep, 2016], using water profile simulator facility.
- At the completion of 24 hours, stop the system and read data using Hoboware.
- Record the total volume delivered, temperature, gas flow and export to excel file.

Performance Analysis

Recovery Efficiency: The recovery efficiency during 24-hour simulated use test for a gas heater can be measured as follow;

$$\eta_r = \frac{M_1 C_{p1}(\bar{T}_{del,1} - \bar{T}_{in,1})}{Q_r} + \frac{V_{st}\rho_2 C_{p2}(\bar{T}_{max,1} - \bar{T}_0)}{Q_r} \qquad M_1 = V_1\rho_1$$

V1 is the total volume of hot water removed during 24-hour simulated use test; ρ1 is the density of hot water; Cp1 is the specific heat capacity of water at average outlet and inlet tank temperature measured during 24-hour simulated use test; T ̅_(del,1) is the average outlet temperature of water; T ̅_(in,1) is the average inlet temperature of water; Vst is the storage tank volume. Cp2 and ρ2 are the water density and specific heat capacity, respectively at average tank temperature after cut-out at the end of 24-hour simulated use test; T ̅_(max,1) is the maximum mean temperature after cut-out following 24-hour simulated use test; T ̅_0 is the maximum mean tank temperature before starting the 24-hours simulated use test; Qr is the total energy supplied by gas burner starting form cut-out tank temperature prior to test and cut-out tank temperature during first recovery at the end of 24-hour simulated use test.

Energy Factor

Energy Factor is the total energy content of (cut-out temp-58ºF) rise in delivered hot water for total energy consumption during 24 hours.

$$\text{Energy Delivered} = \frac{55\,\frac{gal}{day} * 1\,\frac{Btu}{lbºF} * 77ºF * 8.36\,\frac{lb}{gal} * 365\,\frac{days}{year}}{100{,}000\,\frac{Btu}{therm}}$$

Summary

For power era, biomass gasification is an ecologically inviting and capable innovation, and furthermore can add to the moderation of environmental change issues. Coordinate burning of fossil fills is in charge of the expansion in a dangerous atmospheric devation and atmosphere changes on this planet. Maker gas from biomass gasifier can be utilized as a part of generators after gas refinement. An approach was proposed to expel tar from syngas in light of a strategy for radial constrain.

Tar expulsion from syngas is constantly costly and relentless to be acknowledged by the end clients basic or privately planned gasifiers. Costly gasification frameworks are never invited by ranchers particularly in the creating nations. Here, an imaginative and financially savvy approach is acquainted with use biomass for vitality purposes at field for help of ranchers and contribute decidedly towards administration of environmental change dangers.

This progression may advance biomass gasification at mechanical/agribusiness segment; esteem expansion of syngas should be talked about with conceivable arrangements concentrating on cost adequacy and productivity. So as to meet vitality and condition challenges, industry is searching for a supportable outline and techniques to fathom the continuing test of tar expulsion.

Chapter 4

Results &Discussions

4.1 Feedstock Selection

Results:
Table 7: Proximate analysis for Pakistani Corncobs samples and similar work of other researchers for different biomass samples.

Fuel	Volatile-matter %	Fixed-Carbon %	Ash%	Heating-value(MJ/kg)	Ref.
Bagasse	83.2	10.6	5.35	17.8	[14]
Rice Hull	62.95	13.49	18.15	14.8	[16]
Corncob	83.5	15.5	1.0	17.9	[15]
Corncob	60.04	29.85	6.61	17.41	P.S

Table 8: Ultimate analysis for Pakistani Corncobs samples and similar work of other researchers for different biomass samples.

Fuels	C	H	S	Oxygen*	Ref.
Baggasse	49.8	6	.17	40.2	[17]
Rice Hull	37.8	5.2	.61	27.6	[15]
Corn Cobs	45.0	5.8	N/A	48.5	P.S

*Oxygen by difference

Table 9: Composition (weight %) of biomass fuels reported in the literature.

Fuels	Cellolose %	Hemicellulose %	Lignin %	Ref.
Baggasse	46.6	25.2	20.7	[18]
Rice Hull	35	19	20	[19]
Corncobs	41.27	46.0	7.40	[20]

Discussion:
TG estimations are generally used to decide; the composition investigation, impact of responsive environments, warm dependable qualities, and oxidation secure qualities and deterioration energy of material.
Transformation prepare has three occasions: first occasion is drying and second occasion is devocalization and third occasion is coke change. Dormant climate is accommodated initial two occasions and oxidizing condition for the third stage. Current studies were in good results with results of other researcher data as given in Table 7, Table 8 and Table 9.
It was concluded that thermal destruction of all materials in biomass samples create more easily. The higher substance of hemicellulose and cellulose accelerate the devolatization which thus contribute in development of burnable gasses and light hints of substantial hydrocarbons.

4.2 Key Design Parameters of Biomass Gasifier

Results

	Parameters	Range	Conversion Efficiency%
This Study	Throat Diameter	8.6 cm	74.4
	Throat Angle	48°	74.4
Toni Anukam et al.,(2014)	Throat Diameter	10 cm	65
		30 cm	62
		50 cm	58
	Throat Angle	25°	65
		40°	62
		90°	57

Figure 4-1: Conversion Process & effects of TD and TA on Efficiency

Discussion:
Diverse reviews have uncovered that throat width significantly affects transformation effectiveness. As revealed, the littler the throat width more noteworthy will be the transformation proficiency. The reverse impact was additionally seen in some detailed information that bigger distance across of throat gave better change proficiency. With the progression of time change proficiency may increment or diminished. For this situation throat distance across is variable; in the event of little breadths it demonstrates high gasification rate and shallow gas speed as upheld by [21]. The ideal estimation of throat distance across can be balanced by gas speed and prerequisite as in Figure. Time is on x-pivot and transformation effectiveness is on y-hub and throat slant is 48°. Because of disparate impacts of gasifier, throat slant was taken little. As in announced information, when throat slant was vast, gasifier indicated disparate impacts, temperature and rate of gasification response turned out to be less. With littler throat edge it demonstrated high temperature and high rate of response and thus transformation productivity. Comparison was done in Figure 4-1.

4.3 Biomass Gasification

Results

Table 10: Experimental Data-Composition of Producer Gas from Corncobs and comparison with reported data of various fuels using Downdraft technology.

Fuel	Volume Percentage of Combustible Gases only.			Calorific Value (MJ/m^3)	Ref.
	CO	H_2	CH_4		[22]
Charcoal	28-31	5-10	1-2	4.6-5.6	[22]
Wood with moisture (12-20%)	17-22	16-20	10-15	5-5.84.5	[22]
Wheat straw pellets	14-17	17-19	11-14	4.5	[22]
Coconut Husks	16-20	17-19.5	10-15	5.8	[22]
Coconut Shells	19-24	10-15	11-15	7.2	[22]
Pressed Sugarcane	15-18	15-18	12-14	5.3	[22]
Corncobs	17.6	14.5	4.4	5.2	**P.S**

Rice hulls pelleted	16.1	9.6		3.25	[22]
Cotton Stalks cubed	15.7	11.7		4.32	[22]

Volume of Producer Gas = Gas velocity× Area of Pipe ×Time

Conversion Efficiency= [(HVgas×2.5÷HVfuel) ×100%]

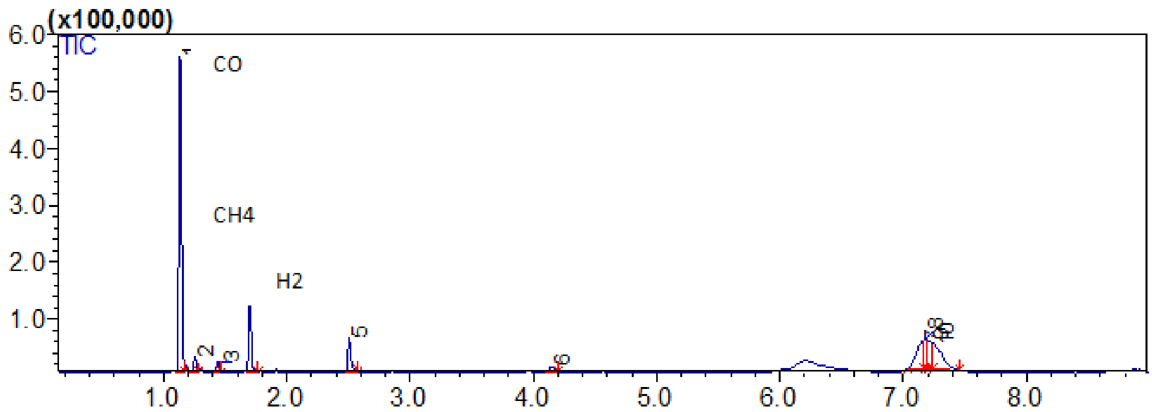


Figure 4-2: Results of Volume Percentage of Combustible Gases only using non – throated type gasifier

Qualitative Table

Print Edit View Similarity Search

Peak#	Ret.Time	Start Tm	End Tm	m/	Area	Area	Height	Height%	A/	Mar	Name
1	1.132	1.100	1.170	TI	849407	44.89	551985	54.45	1.		
2	1.255	1.210	1.285	TI	32041	1.69	25998	2.56	1.	V	
3	1.437	1.415	1.470	TI	28625	1.51	18375	1.81	1.		
4	1.699	1.675	1.765	TI	206650	10.92	150311	14.82	1.		
5	2.505	2.475	2.580	TI	107487	5.68	60270	5.94	1.		
6	4.141	4.110	4.200	TI	28156	1.49	9889	0.98	2.		
7	7.150	7.040	7.165	TI	192648	10.18	48689	4.80	3.		
8	7.183	7.165	7.195	TI	94672	5.00	54448	5.37	1.	V	
9	7.215	7.195	7.235	TI	116126	6.14	51199	5.05	2.	V	
10	7.260	7.235	7.455	TI	236603	12.50	42812	4.22	5.	V	

Figure 4-3: Composition% of Combustible & noncombustible gases

Table 11: Volume Percentage of Combustible Gases only.

Fuel	Volume Percentage of Combustible Gases only.			Calorific Value of gas(MJ/kg)
	CO	H_2	CH_4	
Corncobs	54.45	14.8	2.56	9.32

Discussion:

This analysis provided information that 17.6% CO, 14.5% H_2, 4.4% CH_4 and % of other gases. Energy conversion efficiency of corncobs based gasifier was found as 74.7% and temperature in gasification process was 700 °C for this case. This experimental data can validate simulation data by other researchers for locally fabricated gasifiers. Heating Value of gas was 5.2 MJ/m^3. Also, in another experiment biomass gasification was done at 700° C and gas analysis was done by GC as shown in Figure 4-2. This analysis provided information that 54.45% CO, 14.82% H_2, 2.56% CH_4 and 28.17% other heavy hydrocarbons. Energy conversion efficiency of corncobs based gasifier was found as 53%. Experimental Data-Composition of Producer Gas from Corncobs and comparison with reported data of various fuels using Downdraft technology is given in Table 11.

Figure 4-2 and Figure 4-3 showed composition % of combustible gases.

4.4 Tar Removal Mechanism

Result

Comparison of measured tar levels from different biomass gasifier design are mentioned in such a way that in fixed bed gasifier its minimum value is 0.04 g/Nm^3 and maximum value is 6.0 g/Nm^3. For updraft biomass gasifier its minimum value is 1 g/Nm^3 and maximum value is 150 g/Nm^3 [23]. Tar tolerances for end use device and tar removal mechanism are given by Table 12 and Table 13 respectively. Flame quality comparison is given in Figure 21.

Table 12: Producer gas quality is necessary and average tolerable values of impurities for currently available engines.

Dust	<50mg/m3 gas
Tars	<500mg/m3 gas
Acids	<50mg/m3 (measured as acetic acid)

Table 13 : Reported methods for tar removal mechanism.

Methods	Technique Used	Details
Mechanical method	Usage of mechanical device or equipment	Cyclone, rotary partial separator, fabric filter, ceramic filter, activated carbon adsorber, sand bed filter Electrostatic precipitator, wet cyclone, wet scrubber
Self modification method	Alteration in gasifier design and operational variables	Appropriate operating parameters like temperature, pressure, equivalence ratio, gasifying media, biomass types along with gasifier design are selected
Thermal cracking	Application of high temperature with residence time	Maximum tar destruction was found at 1250 °C and 0.5 s
Catalytic cracking	Usage of appropriate catalyst	Tar cracking catalysts are divided into 5 major groups, namely Ni-based, non-Ni-based, alkali metal-based, acid catalysts, basic catalysts and activated carbon-based catalysts

Figure 4-4: Difference b/w flame qualities before and after tar removal.

Discussion:

While comparing the proposed device for tar removal with present and past technologies, it can be concluded that the proposed device is user friendly option with good efficiency and less cost. It can be used without any reluctance and miscellaneous issues therefore can be recommended as sustainable device with no environmental concerns. There will be no issue of availability and operational hazards of innovative scrubber at lab scale to separate tar from syngas for safely end use. This proposed device can accomplish our needs to improve gas quality at small scale proving maximum feasibility leading to be a best option as compared to above mentioned techniques and scrubbers. It was observed that tar removes maximally from this scrubber that can compete other techniques for tar removal in sense of efficiency and cost. In concerned work, it was observed that pure syngas shows a high quality blue flame Figure 4-4. Before connection of scrubber with blower from where syngas out, it was observed that gas was impure with bad quality flame as shown in Fig 4-4. It is preferable on other devices as it is not so much expensive and gives efficient performance for removal of tar at lab scale. Biomass utilization and contribution of biomass in resolving issues of energy shortfall will increase the market of existing machine i.e. juicer. Figure 4-4 shows flames quality before and after removal of tar content through introduced scrubber. For effectiveness of introduced scrubber it can be said that it is preferable at lab scale experiments but similar design is recommended for large scale applications as tar removal

Scrubber should work for at least six hours continually for rural electrification. This option with high power electric motor and by optimum material selection can be implemented at large scale successfully. Above mentioned tar removal scrubber at lab scale performs well and it is a good option economically and also with respect to tar removal efficiency. At lab scale it can be replaced easily after passing its life time as innovation leads to far-reaching conclusions.

4.4.1 Recommendations for tar removal from producer gas

An innovative approach is recommended by using a home electric appliance for removing tar from syngas that gives better result in terms of efficiency and cost (unpublished data).Removal of tar from syngas also mitigates climate change issue by utilizing innovative approach in terms of sustainable device that is easily approachable and user friendly. A home electric appliance is used as scrubber to remove tar from syngas that is a juicer of specifications (National juicer: 220V-50Hz, 250W) and working principle is based on centrifugal force. This juicer was equipped with 0.5 HP, 1725 RPM electric motor. When it is compared for tar removal to present and past technologies it proves as a user friendly option with good efficiency and less cost. It can be used without any reluctance and miscellaneous issues therefore can be recommended as sustainable device with no environment concerns. There will be no issue of availability and operational hazards of innovative scrubber at lab scale to separate tar from syngas for safely end use. This existing device can accomplish needs to improve gas quality at small scale proving maximum feasibility so considered as best option as compared to above mentioned techniques and scrubbers. Syngas is cleaned from tar by using above mentioned home appliance as scrubber that can be used at small scale directly. It was observed that tar removes maximally from this scrubber that can compete with other techniques of tar removal in the sense of efficiency and cost. In concerned work it was observed pure syngas shows a high quality blue flame. Design on industrial level can be suggested as shown in Figure 4-5.

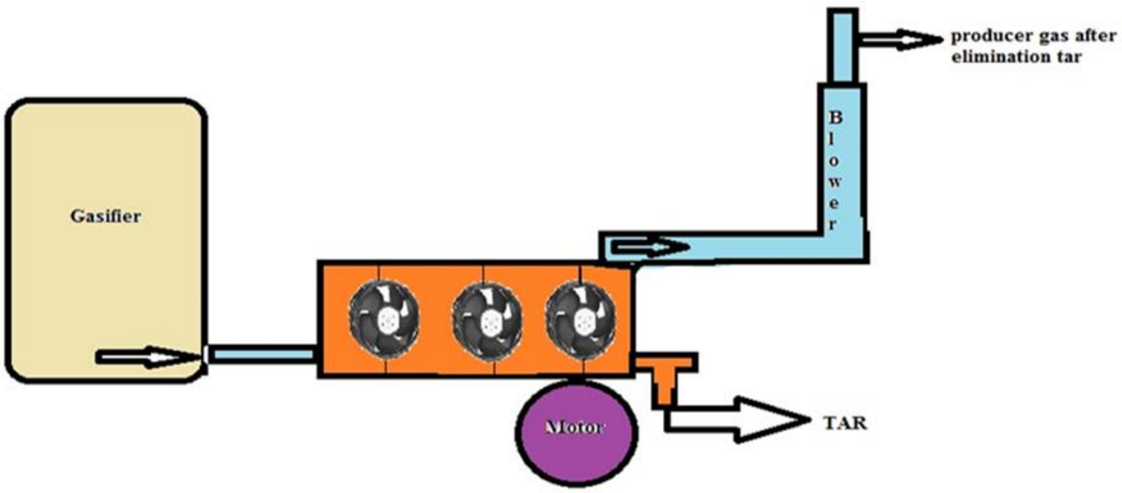
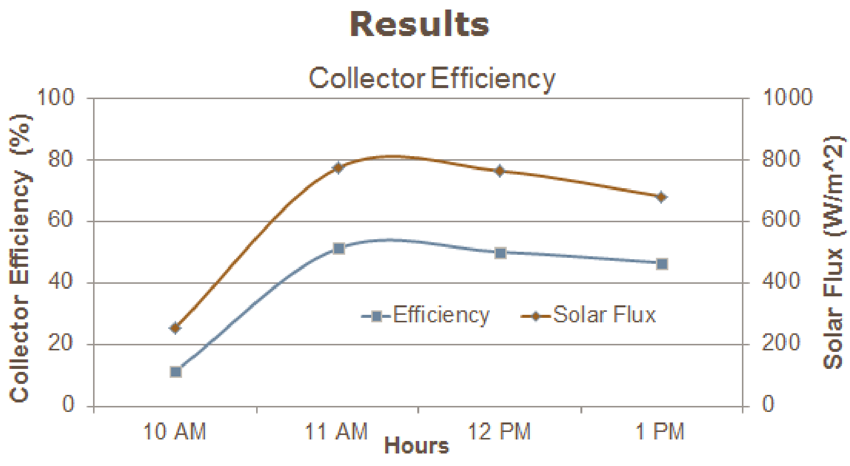


Figure 4-5: Proposed Model for Tar Removal

Proposed Model: Maker gas from biomass gasifier will go into tar expulsion scrubber containing turning wheels working at 1500-1700 RPM. An electric home apparatus can be utilized at lab scale chipping away at outward standard so this proposed display with radiating rule can be introduced everywhere scale. Gas containing with tar when goes into proposed scrubber, tar will stick at wheels that will pivot with appended engine at previously mentioned RPM. Maker gas has some temperature that will soften tar from turning haggles a descending approach to tar accumulation outside scrubber. Some effect partition and also radial constrain will clean maker gas from tar. Blower will suck the maker gas outside from top of scrubber and furthermore make negative weight in biomass gasifier.

4.5 Solar/Natural Gas Hybrid Water Heating System



Natural Gas

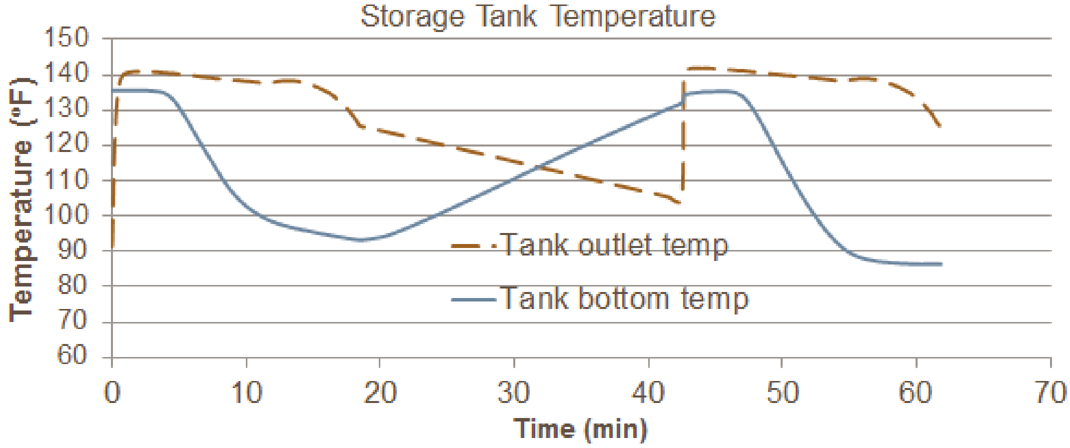
Gas supply rating (Btu/hr)	68338.98
Gas Burner Efficiency (%)	70± 2

Hybrid

Gas supply rating (Btu/hr)	68478.26
Solar Supply (Btu/hr)	3270.82
Solar Fraction (%)	7.63± 3

Figure 4-5: Heating modes Results.

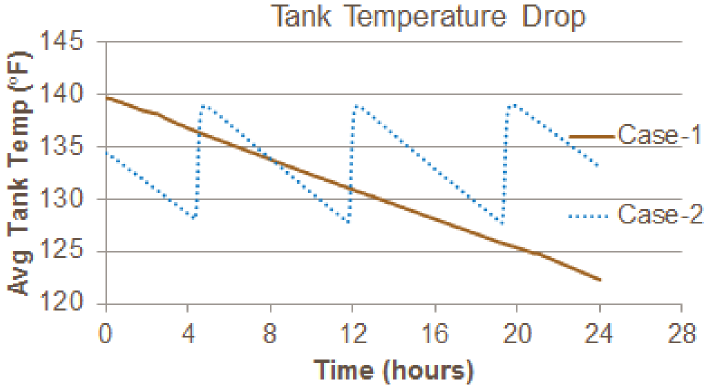
FHR-Test



	Draw_1	Recovery_1	Draw_2	Total Draw
Duration (min)	18.5	23.00	19.17	60.7
Vol of hot Water (gal)	67	-	66	133

Figure 4-6: FHR Test Results

Standby Test



Case-1

Temp Drop = 0.72 °F/hr
Heat loss = 450 Btu/hr

Case-2

Energy Consumption
1312.5 Btu/hr

24-Hours Simulated Use Test

Energy Deliver per year (therms)	Q_{daily}	124.97
Yearly consumption (therms)	Qr	247.60
Energy Factor	EF	0.52

Figure 4-7: Standby Test Results

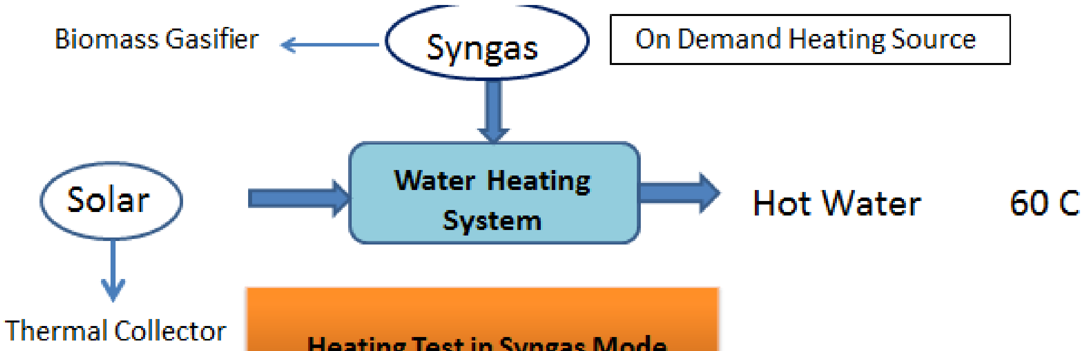
Table 14: Tabulated results for 24-hours simulated use test during combine heating process.

Sr.No	Parameters	Symbol	value
1	Mass Removed (lb.)	M1	459.80
15	Energy Deliver per year (therms)	Q_{daily}	124.97
16	Energy Consumption per year (therms)	Qr	247.60
17	Energy Factor	EF	0.52

Discussion:

As shown in Table 5a, for a given draw pattern, the recovery efficiency and energy factor were determined. Instead of initiating the draw at 12:00 am, the draw pattern was modified by shifting to 7:00 pm (5 hours early) in order to conduct test during working hours as shown in Figure 4-5. The objective of this test is to measure the water heater performance over a long period of time representing an actual house hold hot water usage. The resulting recovery efficiency and energy factor were calculated as shown in Figure 4-6. Throughout this test the tank temperature remain quite high, resulting high heat losses and lower the system performance. Both the outlet and inlet average temperature were little higher then desired. Time duration for power consumption was measure only when the burner turned on. The gas burner running time was 56 minutes during 24 hours test. The energy deliver in the form of drawn hot water was 34485 Btu and the energy lowered of the storage tank was 2395 Btu. The total blower fan power consumption was considered 200 W. Energy delivered per year were 125therms for total consumption of 247 therms. This resulted, the recovery efficiency and energy factor 47% and 0.5, respectively as shown in Figure 4-7. Due to selection of medium draw pattern, the performance parameters were found quite lower than expected. The recovery efficiency is supposed to be measured based on the resulted data from first draw and recovery at the start of 24-hours simulated use test. But such calculation was impossible due to the late response of the gas burner. Therefore it is highly recommended to repeat this test for high-usage draw pattern in future. Purposed calculation using syngas are in Figure 4-8.

4.6 Proposed Water Heating System



Biomass Gasification	
Combustible gas volume m^3	**36.5**
Total time (mins)	120
Total time(hours)	2
HV of Syngas (MJ/m^3)	5.2

Heating Test in Syngas Mode	
Heating time(mins)	**25**
Volume flow of Syngas(ft^3)	257.797
HV(Btu/ft^3)	139.563
Energy Supplied(Btu)	35978.92
Power(Btu/hr.) (kW)	89947.3 26
Energy stored in water tank(Btu)	16970.8
Gas Supply Efficiency= 47%	

24-hour simulated use test	
Yearly Consumption Therms/year.	**131.35**
Energy Delivered Therms/year.	129.2
Energy Factor	0.9

Figure 4-8: Proposed Calculations.

Summary

Current studies wer in good agreement with results of other reported data. For locally fabricated downdraft biomass gasifier, present modification in throat diameter (8.6 cm) and throat inclination (48°) of downdraft biomass gasifier provides high yield of gas; 1kg of biomass gives 2.5m3 of producer. This analysis provided information that 17.6% CO, 14.5% H_2, 4.4% CH_4 and % of other gases. Energy conversion efficiency of corncobs based gasifier was found as 74.7% and temperature in gasification process was 700 °C for this case. This experimental data can validate simulation data by other researchers for locally fabricated gasifiers. Heating Value of gas was 5.2 MJ/m^3. Also, in another experiment biomass gasification was done at 700° C and gas analysis was done by GC. This analysis provided information that 54.45% CO, 14.82% H_2, 2.56% CH_4 and 28.17% other heavy hydrocarbons. Energy conversion efficiency of corncobs based gasifier was found as 53%. The proposed technique can add value to the syngas from simply designed gasifiers by removing the tar. Here, an innovative approach is presented to remove tar maximally using home electric appliance at small scale which can be up graded for larger scales. At small scale flame quality comparison was done with and without electric appliance scrubber. A high blue quality flame was found with electric appliance scrubber that is indication for removal of tar. Hybrid Solar/Natural Gas water heating system at domestic level provides 120 therms/yr. natural gas savings. The gas burner firing efficiency was found to be very consistent and recorded about 70±2% for different storage tank temperatures. The energy factor which reflects the overall performance of the system was founded 0.52. The total annual delivered energy and consumption was 125therms and 247therms, respectively. Therefore, by including solar part minimum of 125 therms of natural gas are saved. It is useful to recommend syngas as replacement of natural gas for water heating purpose at domestic level to save conventional fuels.

According to NW natural the energy saving potential is less. There is need to increase energy saving potential. Domestic water heating can be done on solar/syngas as by using hybrid technology solar/natural gas 120 therms/yr. of natural gas is saved. For family of four members 200 therms/yr. energy is needed to warm up water at residential level. Natural gas can be saved more when we will replace it by syngas from biomass gasification technology. This would be a best solution to meet challenges in energy sector of Pakistan. Also, this technology will play a role in mitigation of climate change issues. Long run of technology will save more money than you pay. It's a good source to reduce electricity bills for water heating .In this way, a cost effective and efficient technology will come into development.

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Conclusion and Recommendations

Conclusion

In the event that product buildup or biomass is accessible in adequate sum with no risk to backwoods and creature sustain, gasifier can fill in as a possibility for vitality supply in remote zones. This innovation is decentralized vitality change framework which works monetarily notwithstanding for little scale. Blended with air, the maker gas can be utilized as a part of gas motors with little adjustment or in burners. This innovation is useful for adjustment particularly for towns as biomass is in abundance amount. The Corn pith must utilized with no earlier preparing. It is less expensive than coal and charcoal and gives practically rise to volume of gas when contrasted with different powers.

Recommendations

Further research is still needed for suitable collection of biomass resources in the mills for commercialization of biomass gasification technology. Biomass gasification has been proved as an applicable way for production of renewable hydrogen that is advantageous to develop a highly effective clean way for large scale hydrogen production and has less dependency on insecure fossil energy sources. This syngas can be used in fuel cells (syngas fed microbial fuel cell) as further application of syngas utilization to enhance commercialization and also to overcome energy crisis to raise economy of Pakistan. Solar/Syngas hybrid technology is recommended for water heating at domestic level.
Data should be statistically analyzed for further research in this area.

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Annexure-B

Biomass gasification with solutions for elimination of tar from producer gas

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b) Faculty at Agriculture University Faisalabad.

Abstract
Energy crisis in Pakistan stimulate sustainable solutions like biomass gasification technology for power generation purposes. For power generation, biomass gasification is an environmentally friendly and proficient technology that can contributes to the mitigation of climate change issues. In industrial and agricultural areas, biomass gasification can be used as a tool to produce electricity at industrial level as a substitute of conventional fuels. Tar removal from producer gas is considered as big challenge in biomass utilization for power generation purposes through gasification. Many scrubbers have been developed for tar removal from syngas before syngas utilization as a fuel to run generators. In this review, solutions for elimination of tar from producer gas are given with their limitations and future solution for tar elimination is recommended with its proficiency and cost-effectiveness. To promote biomass gasification at industrial/agriculture sector, value addition of syngas needs to be discussed with possible solutions focusing on cost effectiveness and efficiency. In order to meet energy and environment challenges, industry is looking for a sustainable design and methods to solve the enduring challenge of tar removal in both manners of cost effectiveness and efficiency.

Key words
Biomass, electricity, scrubber, tar, syngas

1 Introduction

Biomass is plant derived organic matter and before utilizing of biomass proximate and ultimate analysis is done to check quality of biomass and mass concentrations of elements respectively. Proximate analysis is important for checking quality of biomass and ultimate analysis gives mass concentrations of elements and is important for heat balance [1]. Pakistan is an agricultural country and has maximal potential of crop residues [2]. Corncobs can be used as they have fewer prices, low ash content and do not create slag. In some biomasses, corn cobs have good calorific value that is enough to produce optimum yield of producer gas. Corncobs are preferred over wheat straw and rice husk because they both are also used in other fields for example as fodder and in Paper industry. Therefore, production and utilization do not have balance between them [3]. In fact many of biomasses other than corncobs have good calorific value but it is not necessary that they would be good in other proximate properties (ash content, moisture content, volatile matter etc.). Pretreatment (drying, size reduction, pelleting and briquetting) is necessary when some of properties not hold in utilizing biomass in thermochemical conversion [4]. Corncobs are proved to be used without any pretreatment that ultimately saves cost and makes this gasification technology more economical [5]. Proximate and ultimate analysis can be done for corncobs as biomass that are shown in table 1, table 2:

Table 1 [6], [7].

FUEL	VM%	FC%	ASH	HHV (MJ/kg)
Corncobs (Punjab, Pakistan)	60.04 83.5	29.85 15.5	6.61 1	16.41 17.9

Table 2 [8]

Fuel	C	H	S	O
Corncobs(Punjab, Pakistan)	45	5.8	N/A	48.5

Table 1 shows proximate analysis of corncobs and this can be done by using TGA 701.
Table 2 shows mass concentrations of elements in corncobs and this can be done by CHNS test (True spec) elemental analyzer. Biomass utilization plays best role in Pakistan's energy market as Pakistan is an agricultural country. In Fig 1 various energy markets or fields are shown.

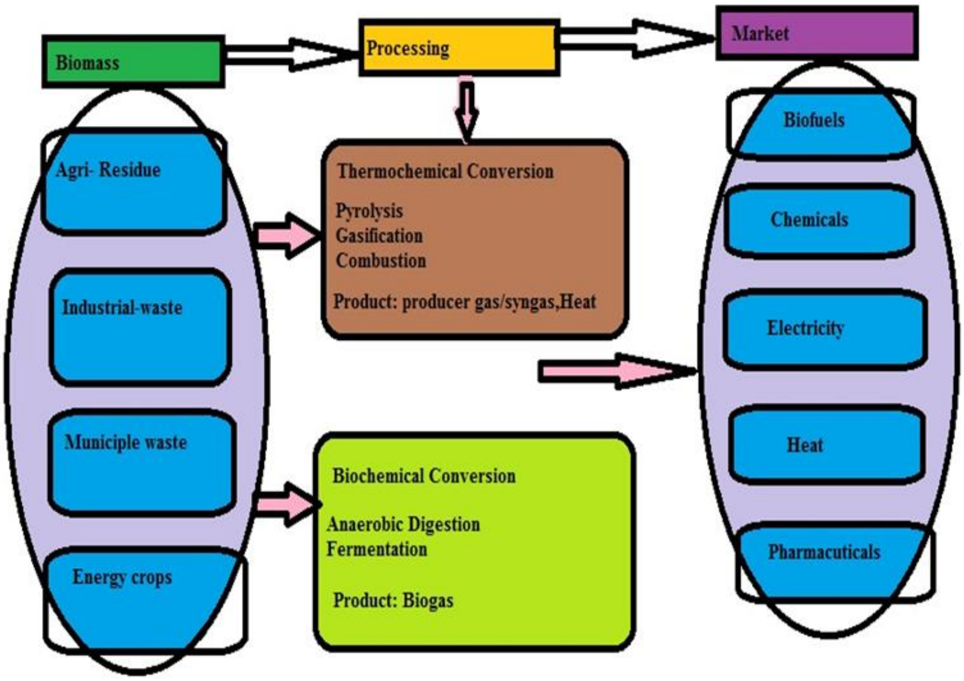

Fig 1.

2 Biomass gasification and its purpose

Biomass gasification is thermochemical conversion method in which carbonaceous solid fuel is converted into gaseous fuel in controlled manner of air. UNIDO promotes biomass gasification by introducing power plants of megawatts in Pakistan to raise economy of Pakistan and also to overcome energy shortfall. UNIDO enhances industrialization process in sustainable way to promote biomass gasification in Pakistan. Temperature and conversion technology matter a lot to get premium product and chemical composition through gasification and biomass affects the efficiency of process. Three demonstration projects are in Kamoki, Jhelum, Thatta, which will generate electrical power in megawatts from biomass gasification [9].

A process in a controlled environment and partial combustion of biomass occurs; it results in production of a mixture of gas known as “Producer gas”. The name of such process is Biomass gasification. It is process in which carbonaceous solid biomass fuel is converted to gaseous gas which is combustible as well. Biomass gasification involves a sequence of thermo chemical reactions(pyrolysis process, oxidation reactions and reduction reactions) [10].Energy obtain through sun and wind is renewable energy and these are most popular sources of getting energy. As compare to this form of energy biomass energy is most renewable form of energy production and it is also oldest method to obtain energy [11]. Recent literature shows that electricity obtains through process of biomass rather than through the Sun or through wind source. Sustainable, low-carbon biomass can provide a significant fraction of the new renewable energy we need to reduce our emissions of heat-trapping gases like carbon dioxide to levels that scientists say will avoid the worst impacts of global warming [12]. Purification is needed in combustion process but in gasification process, non-ash fraction of biomass into syngas is primary objective. We do not need purification as we get cleaner products in this process. The purpose of gasification technology is to get fuel rich gas often in this process tar production thus takes place [13]. In conversion process high need is required for getting fuel for transportation and biomass potential is for making chemical production and for electricity use. In gasification technology, controlled emissions and commercially useful products are found. When these parameters are being modified we can enhance on industrial level production of gasification process. Improvement in fixed bed gasifiers and in cooling and cleaning of gas system can perform good role to improve the performance of overall biomass gasification system [14]. Fixed bed gasifiers have a simple construction and operation at high conversion of carbon and long residence time. Removal of tar is a major problem, while recent progress in thermal and catalytic conversion of tar has given reliable options [15]. For average strength of small-scale heat and power applications, fixed bed gasifiers are reliable options. The gas cleaning and cooling system normally consists of filtration through dry filters, cyclones and wet scrubbers. For the production of high quality product gas, the usage of dual fluidized bed gasifiers is credible. By burning the remaining char with air gasification as circulating fluidized bed is used.[16],[17].

Pressurized fluidized bed gasification may play a good role in improvement of gasification technology. FBC systems involve essentially two major groups, atmospheric systems (FBC) and pressurized systems (PFBC), and two sub groups, bubbling (BFB) and circulating fluidized bed (CFB) [18]. For the gas turbine, the PFBC burns the char for the production of steam and to heat air that is needed to do combustion. Heat is recovered from the gas turbine exhaust in order to produce steam, which is used to run a conventional steam turbine, resulting in a higher overall efficiency for the combined cycle power output [19]. Treatment of flue gas can play a viable role to obtain optimum results or efficient performance of technology by improving quality of product [20]. Removal of tar and dust and other particulates from synthetic gas is called treatment of flue gas to protect the environment from harmful substances. Selective catalytic reduction process is required for this purpose [21]. Gas engines usage for power applications should be necessary in this process to get splendid results. Gas turbines usage for power applications are so necessary and gas turbines are used for large scale power generation and deliver 600 MW or more from a 400 MW gas turbine coupled to a 200 MW steam turbine in a co - generating installation [22]. For bringing power to remote sites such as oil and gas fields and installations are such generation used for electricity emergency (base load) and possible for the major electricity grids in many applications e.g. peak shaving to supply emergency peak power. Presence of heat recovery system in industry for electricity generation and building of CHP (combined heat and power) system instead of internal combustion engine system is needed as heat recovery is important part to increase the efficiency of overall system [23].

Four types of reactors are (up draft, down draft, fluidized bed, fixed bed, draft cross) used in this technology for gasification purpose having the following advantages and disadvantages [24] .
Some improvements in the system are needed e.g. automated feeding system should be available otherwise process becomes tedious. Due to depleted efficiency of energy conversion, gasifier system modifications are required and they should be carefully done. Accuracy in measurements and collection of data should exist to accomplish this gasification technology effectively. Usage of sensitive gas chromatogram for composition of gas and analytical methods should be done. Additional costs of heat sales that minimize the production cost should available. Therefore, such steps should be taken out to get optimum conclusion [25].

In the drying process, biomass fuels contain usually humidity in the range of 10 to 35 percent to minimize additional cost of drying and to get more conversion efficiency. If the temperature provided to biomass exceeds above 100 ° C, steam generation takes place. After drying for biomass is heated, it runs through in pyrolysis stage. Pyrolysis is defined as a process in which the thermal decomposition of fuels used in biomass when oxygen is absent. Biomass decomposes in different forms such as coal which is solid, liquid tar and gases. The products produced in this process are dependent on different factors such as temperature, pressure, residence time and heat loss.

In oxidation zone, air is introduced in a gasifier and oxidation takes place at about 700-1400°C, the solid carbonized fuel reacts with oxygen in the air producing carbon dioxide, and releasing heat [26]. Gasification Process can be viewed in Fig 2.

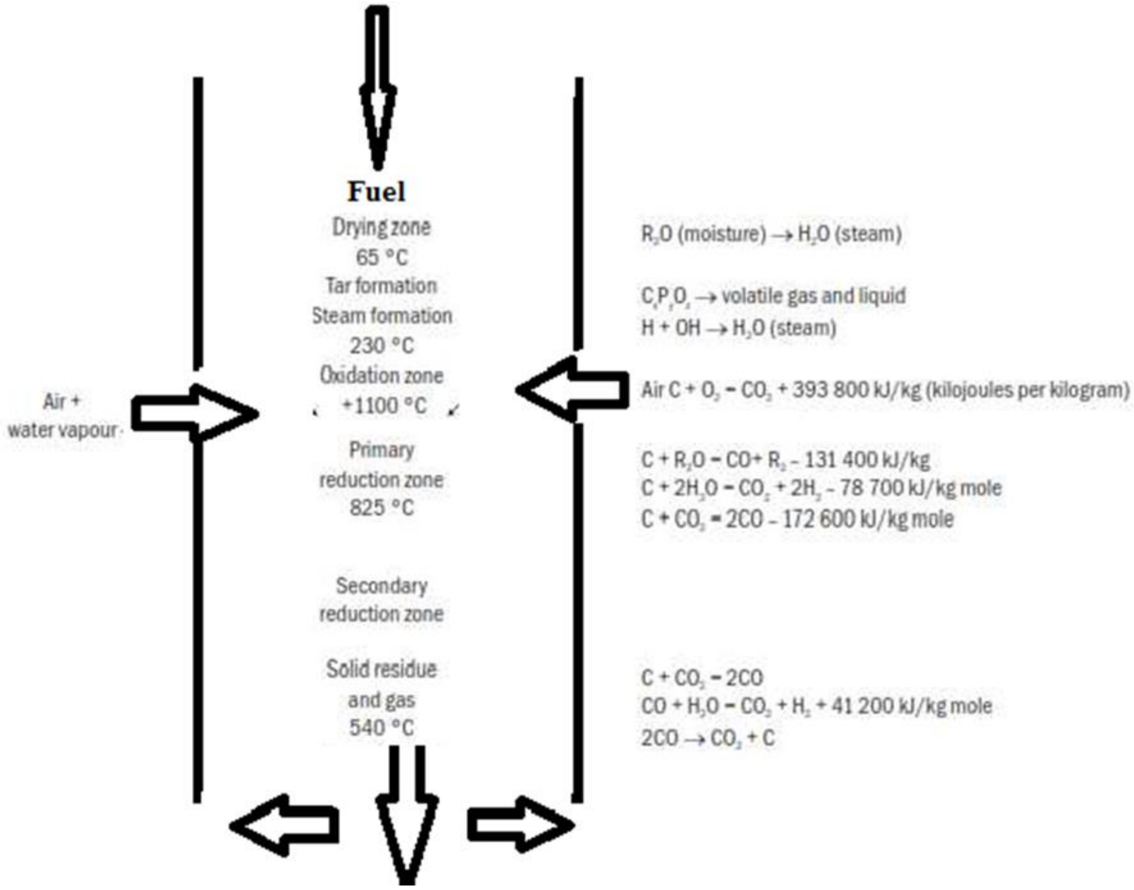

Fig 2.

$C + O_2$	→	CO_2	(-1, 72,600 J/mole)
$CH_4 + H_2O$	→	$CO + 3H_2$	(-2, 06,400 J/mole)
$CO + H_2O$	→	$CO2 + H_2$	(-1, 31,400 J/mole)
$C + ½ O_2$	→	CO	(Exothermic)
$C + 2H_2$	→	CH_4	(+75,000 J/mole)
$C + H_2O$	→	$CO + H_2$	(Endothermic)
$C + CO_2$	→	$2CO$	(Endothermic)
$CO + 3H_2$	→	$CH_4 + H_2O$	(Endothermic)

2.1 Biomass gasifiers and their use

For biomass gasification, biomass gasifiers are designed in which a series of thermochemical reactions take place to produce syngas [27]. Downdraft biomass gasifier is good on the basis of less environment problems by less tar production and also good economically [28]. Poorly designed gasifiers give high tar that creates issues in power generation process by clogging engine. Producer gas along with tar content creates issues in its proper utilization. Gasifier population is mentioned in Table 3 and gasifier sizes for application ranges are mentioned in Table 4.

Table 3 [29]

Downdraft	75%
Fluidized bed	20%
Updraft	2.5%
Other Designs	2.5%

Table 4 [30]

Gasifier Design	Application Range
Downdraft	For < 5MW
Updraft	5MW-50MW
Bubbling fluidized bed	5MW - <100MW
Circulating fluidized bed	10MW - <1000MW
Pressurized fluidized bed	100MW-1000MW

2.2 Biomass gasifier applications (CHP system)

Combined heat and power systems are preferred to achieve high efficiency from biomass gasification process in terms of heat and power. Small and large levels systems are proposed and they are shown in Fig 3 and Fig 4 respectively.

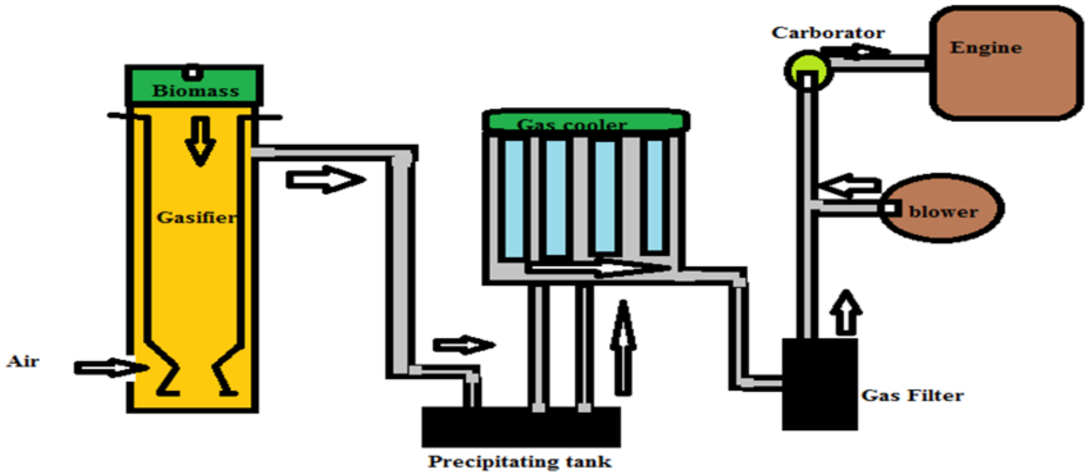

Fig 3.

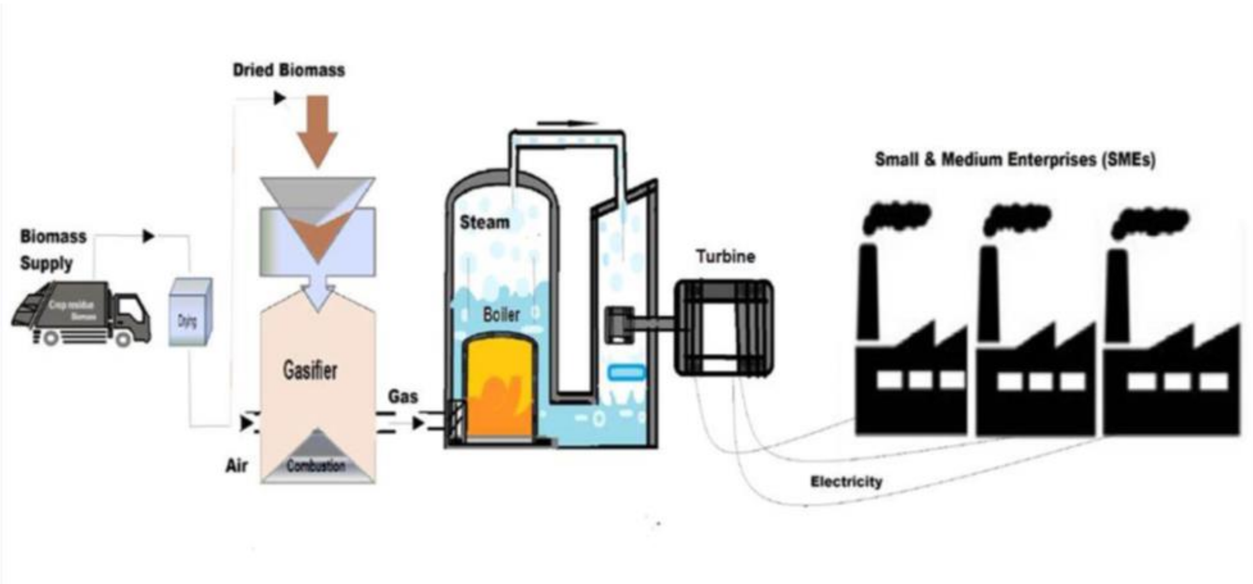

Fig 4.

3 Tar and its classification

Tar is overwhelming hydrocarbon and is made out of different substantial mixes. Tars can be separated into various classes relying upon their sub-atomic weight. There are five classes: GC imperceptible, heterocyclic aromatics, light aromatics, light PAH mixes and substantial PAH mixes [27]. In gas quality necessity control generators require <100 mg/Nm3 tar content [15]. An adjusted tar division framework is presented by [31].In this framework tars are isolated as essential, optional or tertiary subsequently of research finished up on responses of warm splitting in the gas shape. Essential tars are specified by cellulose inferred yields (laevoglucose and furfurals), lignin determined methoxyphenols and practically equivalent to hemicellulose determined yields.

Phenolic and olefins are ordinarily named as auxiliary tars. Tertiary tars are grouped into two more classes; alkyl tertiary items that include methyl subordinates of aromatics (toluene, indene and methyl naphthalene) and consolidated tertiary items (benzene and naphthalene) [32] [33].

3.1 Tar level in gasifiers and producer gas quality

Examination of measured tar levels from various biomass gasifier configuration are specified in a manner that in settled bed gasifier its base esteem is 0.04 g/Nm^3 and most extreme esteem is 6.0 g/Nm^3 [20] . For updraft biomass gasifier its base esteem is 1 g/Nm^3 and greatest esteem is 150 g/Nm^3 [13]. Tar resiliences for end utilize gadget is given by [34].producer gas quality is fundamental and normal bearable estimations of contaminations for at present accessible motors are appeared in Table 5.

Table 5 [35]

Dust	<50mg/m^3 gas
Tars	<500mg/m^3 gas
Acids	<50mg/m^3 (measured as acetic acid)

3.2 Tar removal advancements

The present tar evacuation headways are orchestrated into five strategies [22].

System techniques including scrubber, channel, twister and electrostatic precipitators are fundamentally used to catch particles. Be that as it may, these frameworks are genuinely costly, create a great deal of tainted water and furthermore vitality in the tar is lost. Turning molecule separator (RPS) was utilized as a part of Energy research Center of the Netherlands (ECN) to evacuate tar despite the fact that it was not palatable [36],[37].The self-change system relies on upon improving the working parameters that are temperature, correspondence extent, biomass sort, weight, gasifying medium and living arrangement time with a particular extreme objective to let down the tar content [16],[17]. Yet, this won't be the concerned circumstance in this paper. Warm breaking requires elevated temperature so still it is not appropriate financially at small level gasifier [36],[38],[39].In any case, small scale settled bed gasifiers have a syngas temperature in the scope of 500 to 1000C and tar fixation lower than 1000 mg/Nm3 [21],[40],[41]. Sand bed channels are less easy to understand and have tar detachment 70%. Sand bed channel has the least capital speculation. A water extinguish will be utilized as a part of this case before the sand bed channel to cool the gas and make up for the remaining evacuation proficiency [22]. This is more than the 90% evacuation necessity for an IC engine application so cyclone and sand bed channel ought to need to utilize together to finish this interest of gas quality to engine. It will ultimately resolve issues of efficiency but create issues economically, therefore a need exist to introduce a device and method that should be cost effective as well as efficient.

Major techniques used in tar cleaning are thermal cracking, catalytic cracking and physical removal of tar. Numerous a times, mix of all techniques are used for cleaning of producer gas for collection, identification and quantification of tars in producer gas obtained from biomass [22].

Physical process assume an exceptionally practical part for the effective usage at business size of gasification as they make the nuts and bolts for evacuating crude gasifier sullied particulates, including tar [42].The exhibit examination demonstrates that a 90% molecule expulsion is less demanding to accomplish than a 90% tar evacuation. With the exception of the reactant tar wafers, none of the gas cleaning frameworks tried so far can securely meet a tar detachment surpassing 90% and thus new thoughts for tar evacuation are required [31]. High molecule gathering efficiencies are normal for dry gas cleaning frameworks, for example, elite texture channels and the rotational molecule separator. For both, the tar diminishment is littler than in wet gas cleaning frameworks and consequently an extra tar lessening is required. A tar gathering in the scope of no less than 70% can be normal with extra tar adsorbers in light of actuated carbon. The sand bed channel and the wash tower have as of now been effectively tried in settled bed biomass gasifiers coupled to IC motors [15].

3.3 Limitations of tar removal techniques

Advantages and disadvantages of tar taking care of strategies are said in [34] . Warm devastation does not require impetuses that are expensive but rather require high temperature. Tars cause fast impetus deactivation, so impetuses should be supplanted or recovered regularly; this can be costly. Tar reuse and ignition for process warm has issue that warming estimation of tar + roast is more prominent than process warm required for gasifiers ,along these lines warm vitality is squandered by blazing the greater part of the tar + scorch. Different utilizations (for instance, isolating single ring aromatics for use in making sweet-smelling polymers, for example, plastics and filaments requires an abnormal state of preparing to isolate the tar into its parts .Since gasification ruins a large number of the sweet-smelling rings in the biomass, it is not a decent strategy if the last objective is to create chemicals; pyrolysis or liquefaction ought to be utilized rather [18].

4 Efficiency and cost comparison

Expected particle and tar separation and investment cost of the gas cleaning for a 300 kW fixed bed biomass gasifier including waste treatment is given in [31],[43]. It proves that Fabric filter/tar adsorbers are best option if you want to get high tar separation (%) [39],[44]. Some of technologies are labeled in table 6.

Table 6 [32], [31]

Tar separation techniques	Tar removal %	Cost (kECU) (Capital investment)
Cooling towers	10-25	125
Venturi	50-90	40
Absorption /adsorption on solids	50	N/A
RPS	0-60	49
ESP	30-70	N/A
Thermal & catalytic cracking	90	N/A
Ceramic fabrics	0-50	78

5 Solutions for reducing tar production

5.1 Modification in throated downdraft biomass gasifier and impact on conversion efficiency

It can be done to get high conversion efficiency and good calorific value of syngas. The recommended method to fabricate a downdraft biomass gasifier is to fix their throat diameter small and throat inclination standard value according to hearth load perception. According to throat diameter we can evaluate number of nozzles [14],[45],[46]. Small throat diameters are used to get high gasification rate that will give rise to superficial gas velocity and hence volume of gas. Throat inclination is important because if it is large then due to divergent effects of gasifier temperature becomes less that will enhance rate of reaction and hence conversion efficiency.

High temperature exists when its value is small that will ultimately reduce tar content because gas has to pass through hot bed of char. Nozzles are responsible of supplying air so they are selected, designed and fixed carefully as they impact on production rate of gas [47],[5].

5.2 Biomass fuel processing and impact on conversion efficiency

For downdraft gasifier, biomass fuel should be treated before usage [5]. Densified material is needed in biomass gasifiers for biomass gasification because fluffy material creates flow problems and excessive pressure drop. Drying, size reductioning, pelletizing and briquetting are good options for prepared material to use in biomass gasifier. Moisture is one factor as biomass moisture content is the quantity of water present in the biomass. The moisture content impacts on the value of biomass as a fuel. It is significant as biomass material have large range content of moisture (wet basis), ranging from less than 10% for grain straw up to 50 to 70% for the forest residues [26]. Moisture content affects conversion efficiency; therefore it should be minimized by utilizing dryers. If moisture content is less, CO production is high while H2 production is less and vice versa. Size of biomass fuel is according to size of biomass gasifier hopper. If small gasifiers are made at lab scale, size reductioning is done.

6 Recommendations for tar removal from producer gas

An innovative approach is recommended by using a home electric appliance for removing tar from syngas that gives better result in terms of efficiency and cost (unpublished data).

Removal of tar from syngas also mitigates climate change issue by utilizing innovative approach in terms of sustainable device that is easily approachable and user friendly. A home electric appliance is used as scrubber to remove tar from syngas that is a juicer of specifications (National juicer: 220V-50Hz, 250W) and working principle is based on centrifugal force. This juicer was equipped with 0.5 HP, 1725 RPM electric motor. When it is compared for tar removal to present and past technologies it proves as a user friendly option with good efficiency and less cost. It can be used without any reluctance and miscellaneous issues therefore can be recommended as sustainable device with no environment concerns. There will be no issue of availability and operational hazards of innovative scrubber at lab scale to separate tar from syngas for safely end use. This existing device can accomplish needs to improve gas quality at small scale proving maximum feasibility so considered as best option as compared to above mentioned techniques and scrubbers. Syngas is cleaned from tar by using above mentioned home appliance as scrubber that can be used at small scale directly. It was observed that tar removes maximally from this scrubber that can compete with other techniques of tar removal in the sense of efficiency and cost. In concerned work it was observed pure syngas shows a high quality blue flame. Design on industrial level can be suggested as shown in Fig 5.

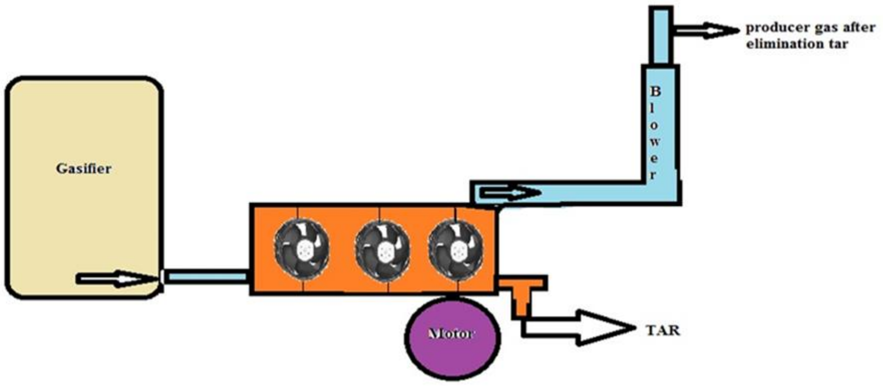

Fig 5.

Proposed Model:

Maker gas from biomass gasifier will go into tar evacuation scrubber containing turning wheels working at 1500-1700 RPM. An electric home machine can be utilized at lab scale chipping away at outward guideline so this proposed demonstrate with diffusive rule can be displayed everywhere scale. Gas containing with tar when goes into proposed scrubber, tar will stick at wheels that will turn with joined engine at previously mentioned RPM. Maker gas has some temperature that will dissolve tar from turning haggles a descending approach to tar gathering outside scrubber. Some effect partition and in addition diffusive drive will clean maker gas from tar. Blower will suck the maker gas outside from top of scrubber and furthermore make negative weight in biomass gasifier.

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8 Conclusions

Further research is still needed for suitable collection of biomass resources in the mills for commercialization of biomass gasification technology. Biomass gasification has been proved as an applicable way for production of renewable hydrogen that is advantageous to develop a highly effective clean way for large scale hydrogen production and has less dependency on insecure fossil energy sources. This syngas can be used in fuel cells (syngas fed microbial fuel cell) as further application of syngas utilization to enhance commercialization and also to overcome energy crisis to raise economy of Pakistan. For removal of tar from syngas, reported data cannot meet the industry needs in terms of cost, proficiency and environment considerations. An innovative approach is recommended by using a home electric appliance for removing tar from syngas that gives better result in terms of efficiency and cost .Removal of tar from syngas also mitigates climate change issue by utilizing innovative approach in terms of sustainable device that is easily approachable and user friendly. Electric home appliance equipped with centrifugal principle works efficiently to remove water droplets, tar and smoke particles. Efficient system can also be designed at large scale with spinning wheel at 1500-1700 rpm. Introduction of Mechanical/Electrical system to remove tar can replace existing scrubbers (wet/dry scrubbers) with respect to cost-effectiveness & efficiency.

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