Chapter 1

Introduction

1.1. Background and research motivation

India is a developing country with more than 1.27 billion people and accounting for more than 17% of world’s population. The continuously rising India’s population has boosted the primary energy consumption and forced to increase the energy generation capacity. The energy demand in India is increasing at a rapid pace, in fact, it is growing exponentially. In recent years availability of power in India has both increased and improved but demand has consistently surpassed supply and substantial energy and peak shortages prevailed in previous few years. Shortage of power or energy is not the only issue but its spread is also matter of concern. Energy security is of utmost importance and is one of the most important inputs for the development and economic growth [Katuwal and Bohara, 2009; Mulder and Tembe, 2008; Mahapatra and Dasappa, 2012]. Economic growth or development is determined by per capita energy consumption. India’s per capita energy consumption is 540 (kg of oil equivalent), which is very
low as compared to the worldwide average of 1803 kg of oil equivalent [International Energy Agency, 2010]. A developing country like India, economic development is being hindered as a result of energy scarcity. So, it should be necessary to provide energy access to entire Indian population for economic growth.

India is the fourth largest energy consumer and fifth largest electricity producer in the world [U.S. Energy Information Administration]. The per capita electricity consumption in India is about 879 kWh/year, which is continuously rising, however it is far less than the world average of around 2,600 kWh/year [Energy statistic. New Delhi, 2013]. The country has the power generation capacity of 223,625 MW in addition to 34,444 MW of captive power [Central Electricity Authority, Government of India]. In spite of this generation, 289 million people in India still have no access to electricity [World Energy Outlook, 2011]. Like in any typical developing country, about 70% of India's population currently lives in rural areas but a large proportion of the population (nearly one-quarter of the population) living in rural and remote area does not have access to modern forms of energy. More than 80,000 villages are currently facing a shortage or lack of electricity [Vadirajacharya and Katti, 2012], due to inherent problems of location, large transmission losses and high cost of grid extension [Sinha and Kandpal, 1991; Chaurey et al., 2004; Bhattacharyya, 2006]. Many villages which are connected to grid system the electrical supply is found intermittent and unreliable. The electrification in poor rural area is characterized with many challenging factors such as low load factors, low access rate and high upfront equipment cost resulting in to higher unit cost of electricity [Urmee et al., 2009; Haanyika, 2008; Rahmana et al., 2013].

The alternative for rural and remote area electrification is the introduction of decentralized electricity production. Off-grid electrification can provide a more reliable supply and has a great potential to supply power to remote and rural areas [Nouni et al., 2008; Sharma, 2007; Banerjee, 2006]. The various technological option suited for distributed generation projects are SPV (solar photo voltaic), Internal Combustion based engines (conventional on residual fuel operated/gas based), biomass based engines, independent generators, mini/micro hydro turbine, etc. [Hiremath et al., 2009]. Out of these options, the gas engine coupled with biomass gasifier is a proven technology and can be economically used for decentralized power generation in the remote areas distant from the grid [Banerjee, 2006; Buragohain et al., 2010; Ravindranath, 1993; Tripathi et al., 1997; Martínez et al., 2012]. An exhaustive research work is reported on the gasification of wood, fuel cane bagasse, olive industry wastes, oil palm waste, hazelnut,
sugarcane leaf, rice husk, paper industry wastes, cashew nut shells and MSW (municipal solid waste) in downdraft gasifier. Most of the earlier reported work on gasification revolved around the use of wood, agriculture waste, charcoal, sugarcane bagasse, rice husk, etc. However, their seasonal/limited availability and land requirement for their production coupled with other competing use has forced the attention of development of technologies for the use of other comparable gasifier fuels.

Coal is the fossil fuel that has been considered as a promising fuel since long. Oil was substituted by coal during the 1970/80s oil crises [Aigner et al., 2011]. The reservoir of coal in the world is large as compared to oil and gas [Taba et al., 2012]. Coal as a fossil fuel, is widely used for electricity generation in most of countries due to its common availability and cost effectiveness [Rizkiana et al., 2014]. The coal is primary energy source for many countries and currently caters to about 41.3% and 28.8% of the world’s total electricity generation and primary energy supply respectively [International Energy Agency, 2013]. In India, coal is a primary source of energy and coal represents 56% of total installed capacity and 71% of total generated electricity. With the continuously rising world’s energy demand, coal will play a key role as an energy source to meet that demand in the future [Yuehong et al., 2006]. While there is increasing pressure to adopt non-fossil fuel electricity generating technologies, the abundant reserves and low cost of coal makes it the preferred energy source to meet increasing demands for the foreseeable future. However, the use of coal faces several challenges such as handling of ash, solids, pollutant emissions, etc. and thus it is considered as dirty energy source [Goyal et al., 2010]. The combustion of coal results into hazardous substances such as particulate matter, CO₂, SOx and NOx, which subsequently cause climate change, air pollution, ozone depletion and acid rain [Demirbas, 2003]. Thus, it is necessary to employ the technology for reducing the gaseous emissions from coal.

Total world coal resources, all categories combined, may come to about 891.531 billion tonnes [BP Statistical, 2014]. Although coal deposits are widely distributed, 72.4% percent of the world’s recoverable reserves are located in five countries: the United States (26.6 %), Russia (17.6 %), China (12.8 %), Australia (8.6 %) and India (6.8 %) [BP Statistical, 2014]. Lignite is a kind of coal and that has been longest in use. A lignite recoverable reserve in world is 201 billion tonnes. So, lignite represents 22.54% of world coal reserves. Lignite, often referred to as brown coal, is a soft brown fuel with characteristics that put it somewhere between coal and peat. Lignite is brownish-black in color, porous, light in weight and has a carbon content of
around 30%, a high moisture content (Approximately 25%) and an ash content ranging from 6% to 19% [Gujarat mineral development corporation ltd.]. The heat content of lignite ranges from 10 to 20 MJ/kg on a moist, mineral-matter-free basis. Most lignites are geologically young, generally having formed during the Cenozoic and Mesozoic eras (approximately 2 to 250 million years ago). Many lignite beds lie close to the surface and are of great thickness, sometimes greater than 30 m (about 100 feet); they are easily worked, and the cost of production is low. Lignite proven and total reserves in the India are approximately 6.18 and 41.96 billion tonnes respectively [Energy statistic. New Delhi, 2013]. Occurrence of lignite in India is confined to states of Tamilnadu, Gujarat, Rajasthan, Pondicherry, Jammu & Kashmir and Kerala. In Gujarat, proven and total recoverable reserves of lignite is around 1.28 and 2.72 billion tonnes respectively [Energy statistic. New Delhi, 2013]. So, an ample amount of lignite is available in India in general and in Gujarat in particular.

1.2. Scope of work

Due to low energy density, lignite is inefficient to transport and is not traded extensively on the world market compared with high grade coals. Lignite fired power plants generate electricity at lower prices than other fuels because of their low mining and minimal transportation costs. As lignite has a higher moisture content and lower heating value, the overall efficiency of plants operating on lignite is lower. Carbon dioxide emissions from traditional lignite-fired plants are generally much higher per megawatt generated than other coal plants. Slagging and fouling problems are very common in case of lignite fired boiler [Pipatmanomai et al., 2009]. Lignite fired power plants also require typical environmental controls to avoid environmental damage due to the major air pollutants. The challenge in the future is to enhance both the efficiency and environmental acceptability of lignite use by adopting clean coal technologies. One important lignite utilization process in the suite of clean coal technologies is lignite gasification. In lignite gasification, lignite is converted into gaseous fuel used to power a turbine or engine and thereby to generate electricity. In this process, the emission of environmental pollutants such as CO₂, NOx, SOx and particulates are significantly reduced. Lignite gasification could be an attractive alternative for power generation as it offers higher efficiency and improved environmental performance than conventional power generation technology. The various problems associated
with lignite combustion could be overcome by gasifying lignite in to producer gas in gasifier. The gases after scrubbing, so produced could be utilized for running internal combustion engine or gas turbine for power generation. The remote regions of India face severe shortage of power. Few of them are even not grid connected. In such cases, a stand-alone small capacity downdraft gasifier could be installed to produce gaseous fuel (producer gas) by gasifying lignite. Producer gas may be used as a fuel in internal combustion gas engine or gas turbine for electricity generation in villages.

Lignite is high ash content fuel, which may make operational difficulties of gasifier as it leads to occurrence of clinkering and slagging. The co-gasification of lignite having high ash content with biomass is a promising and potential resolving technology. Woody biomass in form of agricultural residue and forest residue is easily available in the remote regions and may be collected at fairly low cost. Woody biomass have favorable properties for gasification i.e. low ash content, low moisture content, higher volatile matter. The addition of wood waste to lignite in appropriate proportion can adjust the ash content of the mixtures and mixing wood waste with lignite could offset the adverse effects of ash and sulfur in lignite, making lignite gasification more feasible.

#### 1.3. Objectives of the work

In light of the above discussions, the following objectives are laid down for the present study.

A. To study and investigate the feasibility of the lignite as a fuel for pilot-scale (10 kWe) downdraft type fixed bed gasifier and to evaluate the effect of the particle size on gasifier performance.

B. To study the co-gasification of lignite and wood waste.

C. To develop an equilibrium model and validate through experimental work.
1.4. Organization of the thesis

The thesis brings out the study of the lignite as a fuel for downdraft gasifier along with the influence of the particle size on performance of downdraft gasifier. Thesis also covered the co-gasification study of lignite and wood waste and modeling work.

Chapter 2 presents the literature review of gasification process. It includes different gasification techniques with coal and biomass as a fuel. Different types of gasifiers are discussed and their performance is compared in this chapter. Effect of various parameters on gas yield and performance of gasifier is also discussed. This chapter also includes the effect of particle size of fuel on performance of gasifier.

The description of the experimental set-up and procedure for the experiments carried out are presented in Chapter 3. The design of pilot-scale (10 kWe) fixed bed downdraft gasifier for lignite fuel is also presented in this chapter.

Chapter 4 deals with the experimental studies. Detail experiments conducted to evaluate the effect of lignite particle size on gasifier performance is presented in this chapter. The evaluation of gasifier performance based on the specific gas yield, cold gas efficiency, fuel consumption rate, gas composition and temperature profile in various zone is discussed in this chapter.

Co-gasification study of lignite and wood waste is presented in Chapter 5. This chapter also includes the gasifier performance on co-gasification of lignite and wood waste.

A thermodynamic equilibrium model is developed to determine the producer gas composition, LHV and cold gas efficiency based on ultimate analysis of lignite and wood waste for downdraft gasifier and same is presented in Chapter 6.

Finally, Chapter 7 presents the conclusions of the present study and the possibilities of future work.