1.1 Introduction:

Energy plays a vital role in the process of economic development. The functioning of any economy, activity, system, sector, region, and organization depends on the availability and access to energy. The every stage of modern life requires access to appropriate energy. The producers and consumers also require energy to undertake economic activities (Cengiz, Nisa, & Burhan, 2005). One of the key-resources of economic development is energy. Energy should be available continuously and in adequate quantity. Energy accelerates economic development (Helcio & Luiz, 2012). The modern world economy invariably depends upon energy. It is a vital input in the production of goods and services which have an economic value all over the world (Saba & Shahid, 2017).

The economic growth of a country depends upon the availability of energy. The lack of adequate supply of energy can retard the economic progress of a country. Energy is directly correlated with the economic growth. Energy is also directly correlated with the size of per capita income and per capita consumption. Energy is one of the components of infrastructure. The growth of the industrial sector depends on energy. The functioning of an economy also depends on energy. It is a vital and critical factor in agriculture. The development of transport, commerce, trade and household sector, etc. also depend on the adequate supply of energy (Bilikisu & Shuaibu, 2017). All activities starting from consumption to production depend on energy. Energy plays a vital role even in the human development (Premakumara, 2012).

One of the essential parts of the economic development is energy development. Energy is an important factor in the economic development. The economic development depends upon the adequate provision of energy services. But, energy is also a scarce factor. The policy recommendations and institutional reforms are needed for energy development (Michael & Barbora, 2003). Energy drives economy. Energy security is as important as national security. Energy security has become a non-military component of the national security (Cooley, 2011). Energy availability, energy affordability and energy accessibility determine energy consumption at the household level. The development of the household sector depends on the adequate supply of energy services (Ganesan & Vishnu, 2014).
Energy services have to be provided for the all-round human development in any country (Reddy, 2003). The socio-economic development and energy availability are strongly correlated. The availability and supply of energy determine the pace of economic progress (Ajayi & Ajanaku, 2009). Economic growth results in increasing energy use.

The growing demand for energy and not a corresponding increase in energy supply would make country to import energy (Anjali & Shahid, 2017). Economic growth depends upon the availability of energy. Scarcity of energy obstructs economic development. Energy is also a factor of production. There is casual relationship between energy and economic growth. Production is a function of labour, capital and energy. The elasticity of substitution between energy and capital is very low (Stern, 2010).

Industrial sector plays a predominant role in the economic development of a country. Agriculture plays a crucial role in the initial stages of economic development, as it contributes more national income to the country. Once the agricultural sector sustains, it would promote the growth of the industrial sector by supplying raw materials required by the industries. In the second phase of economic development, industrial sector leads the process of economic development as a major contributor of income to the country by producing final commodities to the economy. The industrial sector does promote the growth of tertiary and agricultural sectors. Therefore, the overall development of the economy invariably depends upon the industrial sector. Therefore there is significant and positive correlation between the industrial sector and the economic development (Sutikno & Muhammad, 2015). The growth of the industrial sector depends upon many factors. They are: state of technology, efficiency of labour, demand for the products, policy of the government, availability of raw materials, availability of credit, infrastructure, transport and communication and energy. There is a causal relationship among these variables (Jiangyong & Zhigang, 2009).

There is no unanimity among the economists about considering energy as a factor of production. There are two divergent arguments among the economists. The first argument is energy has significant impact on the production. The other inputs such as labour, capital cannot be used without energy. The production cannot take
place without energy. The production in turn will result in development (Asafu-Adjaye, 2000). The other argument is energy is not at all a factor of production. The cost on energy in the total cost of production is very negligible and insignificant. Therefore, energy does not play a significant role in the process of development (Cheng, 1995).

Energy efficiency determines the level of profitability, productivity, etc. in the production unit. Energy efficiency means using less amount of energy to produce the same level of output. Energy efficiency has implications on the environment (Murray, 1996). Energy efficiency is a modern approach developed in the recent past. Energy efficiency is a modern approach for using energy resources economically (Wilson & Cosmos, 2013). Energy production, energy extraction, energy use, etc. have impact on the environment. Energy efficiency measures reduce emission level. Sustainable development will take place only if poverty is tackled and environment is protected and preserved (Kaygusuz, 2011). Energy, being a factor of production has too many implications. It acts an input in the industrial sector. It has significant association with production, productivity and environment. Energy has a significant impact on the economic development. Energy and GDP are correlated (Premakumara, GS, 2015).

There is a positive relationship between energy use, size of the firm, amount of investment, scale of operations, state of technology, energy price, etc. There is an inverse relationship between energy use and energy price. The energy efficiency has a positive impact on the economic and industrial development. However, the relationship of energy efficiency in the industrial development is subjective and not directly related with the amount of energy consumed in production. As a matter of fact, energy efficiency has been estimated based on energy intensity of production. Therefore, energy efficiency is the ratio of between amount of energy used and quantity of output produced. However, energy efficiency is relative and is determined by a number of factors which have to be examined empirically. Energy efficiency has unique importance in determining productivity and environmental sustainability. Therefore, examining energy efficiency in general and particularly in small scale industries is necessary and meaningful. Accordingly, the present study has been chosen for research to address the above said issues.
1.2 Research Gap:

The researcher has reviewed a good number of previous literatures on energy policies, energy efficiency, energy and environment, energy intensity, energy security, energy and sustainable development, energy and economic development, energy and industrial development. A considerable amount of research has been carried out in the field of energy. It has been found from the reviews that energy is a critical input in the process of development. Energy plays a vital role in the development of industrial sector. Energy security is a multi-dimensional concept. Energy also plays a crucial role in the sustainable development. Energy and economic activities are related to each other. There is a positive correlation between economic growth and demand for energy. The demand for energy increases as a country attains a higher level of economic development. Energy has both forward and backward linkages. The adoption of energy efficiency reduces Co\textsubscript{2} emissions. It has also been found from the reviews that different countries have adopted different policies in their energy sector. The most of the countries across the globe have not considered energy efficiency issues in the formation of general policies for economic development. At the same time, energy policies have focussed only on increasing the availability of energy sources. Energy policies have given importance to energy efficiency very recently. The energy relation with economic development is an important area of research and most of the previous works on energy have studied the role of energy in economic development.

The estimation of the causality of economic growth on energy consumption was started in the early 70’s. The most of the early research works on causation of economic growth and energy consumption have confirmed causation by using unidirectional Granger-Causality. In the late 90’s, scholars have employed Engel-Granger Models to estimate the causation of electricity and energy on economic growth. Meanwhile, the Johansen co-integration techniques have also been employed to estimate the long-run relationship between energy consumption and economic growth. However, a few scholars have identified the long-run relationship between energy and economic development. Some research studies have established the bi-directional relationship between energy consumption and economic growth. The estimation of multi-dimensional relationship has also proved the role of energy in the
overall economic development. The increased pollution and environmental implications have also been analysed in many previous research studies.

A few research studies have also developed the methods to measure the energy efficiency and security. As a matter fact, studies on energy were country specific and sector specific. However, there is no specific methodology used to measure the energy efficiency in general and energy efficiency in the industrial sector in particular by using frontier analysis. There are no studies which have attempted to measure energy efficiency in the industrial sector by using unit level data particularly in Mysore District of Karnataka. Accordingly, the present study will fill this gap.

1.3 Statement of the Problem:

It has been found from the review of literature that there is a positive correlation between energy and economic development. Energy is the most important input in the industrial development. The present study will establish the long-run relationship between energy and economic development, and also establish the relationship between energy and industrial development at country level. To analyse the relationship the study uses different energy sources, like, oil, coal, electricity and gas along with industrial income and income of the country. Once, the relationship has been established, and then the study will examine the impact of energy efficiency and energy consumption on economic and industrial development.

At the unit level, the study will analyse the inputs usage and income of small scale industries in Mysore. The major focus of the study is to estimate the energy efficiency in small scale industries. Accordingly, the study will estimate the energy efficiency of small scale industries in Mysore by using deterministic input oriented frontier model. Accordingly, the present study entitled “An Economic Analysis of Energy Efficiency in Selected Small Scale Industries: With Special Reference to Mysore” is a new attempt in this direction.

1.4 Objectives of the Study:
The objectives of the study are:

- To establish the relationship between energy and economic development.
- To establish the relationship between energy and industrial development.
To examine the impact of energy consumption and efficiency on economic and industrial development of India.

To analyse the input usage and income in small scale industries in Mysore.

To analyse the efficient energy practices in small scale industries in Mysore.

To measure energy efficiency in small scale industries in Mysore.

1.5 Hypotheses of the Study:

The following hypotheses have been set for the present study:

- The long-run stable relationship has been established between energy and economic development of India.
- The short-run disturbances are temporary and it helps in maintaining long-run relationship between energy and industrial development.
- The economic development of India has been jointly determined by energy consumption and energy efficiency.
- The industrial development of India has been jointly determined by energy consumption and energy efficiency.
- The lower energy efficiency has resulted in lower technical efficiencies of small scale industries in Mysore.
- The plastic firms have more slacks in their production process compared to the intermediate and the manufacturing firms.

1.6 Research Methodology:

The present research work is exploratory, critical and analytical in nature. The qualitative, descriptive, econometric tools and inferential methods have been used to fulfil the objectives of the study. The study has used both the primary and the secondary data to analyse the role of energy on Gross Domestic Product (GDP) and also to analyse the impact of energy efficiency on the GDP and the industrial sector in India. The study has also estimated the energy efficiency of small scale industries.

1.6.1 Data and Scope of the Study:

The study has conducted at two levels: at the macro level in India and at the unit level in Mysore. Accordingly, the study has used secondary data to address the issues at macro level in India. The study has also used primary data to address the
issues at unit level in Mysore. India is one of the leading economies of the world and demand for energy has been steadily increasing in India and it will have the effect on economic and industrial development of India. Therefore, India has been considered for the study. At the same time, comparable energy data are only at the national level particularly in relation to industrial development. Hence, the study has conducted at national level.

The major focus of the study is to estimate the energy efficiency in small scale industries. Mysore is the second industrial hub of Karnataka after Bengaluru. There are wide ranges of opportunities for the growth of industries in Mysore. Energy and energy efficiency play a crucial role in the development of industries in Mysore. Therefore, there is a need to understand the level of energy efficiency in the small scale industries for the efficient and faster growth of industries in Mysore. Accordingly, Mysore has been chosen for the present study.

1.6.2 Period:

To study the macro level issues, the secondary data have been used for the period from 1972 to 2016. The primary survey was conducted during 2016-17 in Mysore.

1.6.3 Sources of Secondary Data:


1.6.4 Sample Design:

The primary data have been collected by using schedules pertaining to inputs usage, output and energy efficiency in small scale industries in Mysore. The following sample design has been used to collect the primary data. From each industry type 30 firms have been taken for study, which is statistically the large sample and any statistical technique can be applied.
1.6.5 The Analysis of Data:

The trends in GDP, industrial income, electricity, oil, coal, gas, energy efficiency in the economy and energy efficiency in the industrial income have been presented through graphs. The growth rates have been computed for all parameters, for identifying their direction and the rate of change in them. The growth is estimated in terms of Compound Annual Growth Rate (CAGR). The CAGR has been computed by using log linear exponential functions. The stationarity of all parameters was checked by conducting Phillips-Perron test. It has been found from the unit root analysis that most of the time series used in the present analysis are non-stationary and they remember the short run shocks forever. Therefore, all the parameters have been transferred to their respective level of integrated order wherever necessary for further analysis. An attempt has been made to estimate the long-run relationship of GDP with energy sources. An effort has also been made to estimate the long-run relationship of industrial income with energy sources. The non-stationarity time series data have been used for co-integration analysis. The Johansen co-integration tests have been conducted for finding out the long-run relationship of GDP with electricity,
oil, coal and gas. The Johansen co-integration tests have also been used for estimating the long-run relationship of industrial income with electricity, oil, coal and gas.

The Vector Error Correction Models (VECMs) have been used to test short term disturbances in the long-run relationships between the variables. The VECMs have also been used to find out the variable which causes short term disturbances and restores the long-run relationship with the other. The VECMs have been used for GDP with energy parameters such as electricity, petrol, coal and gas. The VECMs have also been used for industrial income with petrol, coal and gas.

The major focus of the present work is to estimate and analyse energy efficiency. Accordingly, the energy efficiency in the economy and also in the industrial sector has been estimated for each of the energy source. Energy efficiency in the economy is computed dividing GDP by total energy consumption in the economy. Energy efficiency in the industrial sector is computed, dividing industrial income by the total energy consumption in the industrial sector. The graphs have been drawn to present the estimated energy efficiency of the economy and also of the industrial sector. The growth rates of energy efficiency in the economy and also in the industrial sector have been estimated by using log linear exponential function which gives CAGR.

One of the objectives of the study is to estimate the impact of each of the energy sources and their efficiency on the economic and industrial development. Accordingly, impact models have been constructed to estimate the impact of total energy consumption and energy efficiency on the economic and industrial development in India.

**Model 1:**

The impact models have been constructed to estimate the impact of total electricity consumption and total electricity efficiency on the economic development of India.

\[ Y_t = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t} + e_t \]

In the above model, \( Y_t \) represents GDP, \( X_1 \) Represents total electricity consumption, and \( X_2 \) Represents total electricity efficiency.
\[ \Delta \Delta \text{gdp}_t = \alpha + \beta_1 \Delta \Delta X_{1t} + \beta_2 \Delta \Delta X_{2t} + e_t \]

**Model 2:**

The impact model has been constructed to estimate the impact of industrial electricity consumption and industrial electricity efficiency on the industrial development in India.

\[ Y_t = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t} + e_t \]

In the above model, \( Y_t \) represents industrial income, \( X_1 \) represents industrial electricity consumption, and \( X_2 \) represents industrial electricity efficiency.

\[ \Delta Y_t = \alpha + \beta_1 \Delta X_{1t} + \beta_2 \Delta X_{2t} + e_t \]

**Model 3:**

The impact model has been constructed to estimate the impact of total petrol consumption and total petrol efficiency on GDP in India.

\[ Y_t = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t} + e_t \]

In the above model, \( Y_t \) represents GDP in India, \( X_1 \) represents total petrol consumption, and \( X_2 \) represents total petrol efficiency.

\[ \Delta \Delta \text{gdp}_t = \alpha + \beta_1 \Delta X_{1t} + \beta_2 \Delta X_{2t} + e_t \]

**Model 4:**

The impact model has been constructed to estimate the impact of industrial petrol consumption and industrial petrol efficiency on industrial income in India.

\[ Y_t = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t} + e_t \]

In the above model, \( Y_t \) represents industrial income, \( X_1 \) represents industrial petrol efficiency, and \( X_2 \) represents industrial petrol efficiency.

\[ \Delta Y_t = \alpha + \beta_1 \Delta X_{1t} + \beta_1 \Delta X_{2t} + e_t \]
**Model 5:**

The impact model has been constructed to estimate the impact of total coal consumption and total coal efficiency on GDP in India.

\[ Y_t = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t} + e_t \]

In the above model, \( Y_t \) represents GDP in India, \( X_{1t} \) represents total coal consumption, and \( X_{2t} \) represents total coal efficiency.

\[ \Delta \Delta \text{gdp}_t = \alpha + \beta_1 \Delta X_{1t} + \beta_2 \Delta X_{2t} + e_t \]

**Model 6:**

The impact model has been constructed to estimate the impact of industrial coal consumption and industrial coal efficiency on industrial income in India.

\[ Y_t = \alpha + \beta_1 X_{1t} + \beta_1 X_{2t} + e_t \]

In the above model, \( Y_t \) represents industrial income, \( X_1 \) represents industrial coal consumption, and \( X_2 \) represents industrial coal efficiency.

\[ \Delta Y_t = \alpha + \beta_1 \Delta X_{1t} + \beta_2 \Delta X_{2t} + e_t \]

**Model 7:**

The impact model has been constructed to estimate the impact of total gas consumption and total gas efficiency on GDP in India.

\[ Y_t = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t} + e_t \]

In the above model, \( Y_t \) represents GDP, \( X_{1t} \) total gas consumption, and \( X_{2t} \) total gas efficiency.

\[ \Delta \Delta \text{gdp}_t = \alpha + \beta_1 \Delta X_{1t} + \beta_2 X_{2t} + e_t \]

**Model 8:**

The impact model has been constructed to estimate the impact of industrial gas consumption and industrial gas efficiency on industrial income in India.

\[ Y_t = \alpha + \beta_1 X_1 + \beta_2 X_2 + e_t \]
In the above model;

\[ Y_t \] Represents industrial income,

\[ X_1 \] Represents industrial gas consumption, and

\[ X_2 \] Represents industrial gas efficiency.

\[ \Delta Y_t = \alpha + \beta_1 \Delta X_{1t} + \beta_2 \Delta X_{2t} + e_t \]

One of the objectives of the study is to estimate energy efficiency in small scale industries in Mysore based on the field study. Accordingly, the idea of estimation of energy efficiency has been extended by analysing production patterns of selected small scale industries in Mysore. A survey was carried out to collect the data on various parameters pertaining to the nature of the firm, factors of production, cost, income, profit, etc. Three different types of small scale industries in the study area were surveyed namely plastic, intermediate (spare parts, components, ancillary parts) and final product manufacturing industries. The primary data from 30 enterprises in each category and 90 enterprises were surveyed. The information was obtained from the entrepreneurs or the management personnel.

The chi-square tests for equal distribution and also for association have been used for presenting and analysing the general information of the small scale industries in the study area. The t-tests, ANOVA and Duncan tests were also conducted to compare means of parametric variables among plastic, intermediate and manufacturing industries.

One of the objectives of the study is to analyse energy efficiency in small scale industries in the study area. Accordingly, the Technical Efficiencies of small scale industries in the study area was estimated. The input oriented Data Envelopment Analysis (DEA) has been applied to measure Technical Efficiencies of Decision Making Units (DMUs) in the study area. The DEA has identified the frontier firms. The frontier firms are those firms which are the most efficient in using and converting inputs into output. The efficiency is measured on a scale of 0 to 1. 1 shows the unit is relatively efficient in using and converting inputs into output. The value less than 1 indicates the unit is inefficient in using and converting inputs into output. The efficiency score of a unit varies from firm to firm depending upon inputs used. The efficiency score of a DMU is always relative. A unit’s efficiency is related to its radial distance from the efficient or efficiency frontier. Radial measure is the ratio of the
distance from the origin to the inefficient unit, over the distance from the origin to the composite unit on the efficient frontier. Slacks were also calculated by using a multi-stage method. Slacks represent the under production of output or over use of input. Slacks show the improvements needed to make an inefficient firm to efficient firm by making the best use of inputs.

The Technical Efficiencies of plastic, intermediate and manufacturing firms have been estimated by using DEA. The firm by firm results of all 90 firms have been obtained. The efficiencies of energy, labour, capital and materials of plastic, intermediate and manufacturing firms have also been estimated by using DEA. The standard deviation for average technical efficiency has been calculated. The average technical efficiency minus one standard deviation has been treated as the benchmark for identifying the most inefficient firms among the inefficient firms. Accordingly, the firms less than average technical efficiency minus one standard deviation, have been treated as technically the most inefficient firms. The peer, average and inefficient or lagging firms have been identified. Radials and Slacks of each input used in the plastic, intermediate and manufacturing firms have also been calculated and analysed.

1.7 Chapter Scheme:

**Chapter I: Introduction**

The first chapter deals with introduction, research gap, statement of the problem, objectives of the study, hypotheses, methodology used for the study, sample design, research period and the chapter scheme. This chapter has provided the basis for other chapters of the study.

**Chapter II: Review of Literature**

The second chapter deals with review of literature. In this chapter, a brief review of research studies conducted by the individual researcher scholars and the research institutions on energy security, energy intensity, energy policy and programmes, energy practice, energy management, energy and economic development, energy and industrial development, methods used for measuring energy efficiency, energy and environmental issues, eco-efficiency and sustainability and barriers for energy efficiency measures have been analysed.

The third chapter deals with the empirical estimation of energy efficiency and long-run relationship of energy with economy and industry.

Chapter IV: Estimation of Energy efficiency in Small Scale Industries – A Field Study Analysis

The fourth chapter deals with the estimation of energy efficiency in small scale industries in Mysore.

Chapter V: Research Findings, Suggestions and Conclusion

The fifth chapter deals with the research findings, suggestions and conclusion.
REFERENCES


