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Studies on the impact of energy quality on human development index

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ABSTRACT

Bio-mass is one of the most dependable energy resources in the rural areas of the developing world. The energy quality and emission intensity of bio-mass is varying from species to species and also on the processing techniques. As the effective energy output and emission intensity have direct influences on health, education and income generation, these become the major input for human development index (HDI). Long term field studies were conducted in a couple of rural areas of different geographical locations to quantify the impact of the energy quality on the HDI value. Results of such studies indicated that geographical locations and the available infrastructure therein have distinct role in providing access to superior resources. Further studies indicated that switching over from kerosene lamp to solar photovoltaic (PV) lighting systems and plugging into charcoal fuel from raw bio-mass have opened up multiple avenues of opportunities and development for the villagers. Adaptability of these resources made significant positive contributions on ecology, economy, and empowerment. It was further found that the use of locally available good quality energy resources enhanced the HDI value by more than 16–18% from its initial figure.

1. Introduction

Quality of any resource is an important aspect from its acceptability standpoint and energy quality of the available resources is of no exception. The quality of energy resources is measured in terms of delivering usable energy output and effective emission intensity level. Experiences indicated that use of the quality energy resources can deliver a range of benefits to the economy and society [1,2]. From the usability point of view, the rural people in India are more inclined to use bagasse than that of other bio-mass as quantity of heat generation from bagasse is more than that of other bio-mass with low emission intensity. However, access to this superior bio-mass imposes a barrier in its use.

As the effective energy output and emission intensity have influences both on the economy as well as on society, thus, there need to be well-addressed these issues for the benefit of all users and suppliers. However, since the impact of energy qualities at regional and national economies remain largely overlooked and inadequately addressed, this particular research area is still very much unexplored. Moreover, the merit on the use of energy quality was not considered due to availability and acceptability standpoints. Other related benefits and welfare gains from the use of quality energy resources were not addressed in the literature [3–5].

In the use of effective energy products and services, the researchers [1] provided more concentrations on the energy efficiency in the demand side as well as supply side to find out the energy conservation potential of the energy conversion gadgets. However, very little work is reported on the impact of use of good quality of resources in conservation measures and their impact on ecology and empowerment [2–5]. Thus, there exists a knowledge gap in terms of the impact of quality of energy resource usage in various sectors of society and economy. The possible philosophy behind this may be:

- Energy efficiency was given a priority in the industrial sectors as these are consuming bulk energy than the domestic sectors.
- Some efforts were given to introduce the good quality of resources in domestic sectors of urban areas but very little have reached the rural areas, though the developing world has more than 70% of its total population still living in the villages. As a result the real impact on use of quality of resource remains unexplored.

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- People those are living in the rural areas in the developing world have limited awareness about quality of fuel they used and its effective impact on health and economy.
- Rural households have limited access to the supply market where benefits of using efficient energy conversion devices is recognized.

In order to quantify the energy flow in meeting the demand of the society, it may be necessary to conduct surveys in the societal sectors where human activities are the major consumers of energy. It has been reported that on an average the human body needs about 2000 kilo Calories (kCal) or 2.36 kilo Watt hour (kWh) per person per day for sustaining itself [6]. In the developed countries, per capita energy consumption is about 229,000 kCal or 266 kWh per day [7] and this value is much higher than that consumed by people of the developing world. If one looks from Carnot principle of operation on the conversion process of primary/crude resources into the secondary/usable ones, it appears that the system rejects wastes during the conversion process and these are imposing additional loads on the environment. The waste load from the manmade systems affects the earth and her eco-systems negatively and hence, raises the question of environmental sustainability. Thus, from sustainable development perspectives, the methodologies for reduction of waste load either at source or at sinks require to be addressed on an urgent basis.

Recent studies indicated that about 314 million people live in USA, 1.36 billion live in China and 1.24 billion of people are living in India [8]. Out of the total global population, about 1.6 billion people are living without access to electricity and approximately 3.5 billion people are using fuel wood, charcoal, agriculture and animal wastes as their principal source of energy [9]. As the people in the developing world are striving to improve their standard of living, they will have to consume more energy compared to what they are doing in the present. Indeed, as China has brought 400 million people in its own country out of poverty over the last 30 years [10], it has come with a commensurate increase of 11,000 kWh per capita per year i.e. 30.14 kWh per capita per day, which is about 320% increase in primary energy consumption. This increase in energy consumption has contributed to additional load of greenhouses gasses (GHGs) to the tune of 3.1 Tons per capita per year of CO_2 to the atmosphere over the same time period.

Easy accesses to energy resources have several constraints like availability, accessibility, affordability and adoptability [11]. Each of the above constraints is composed of several matrices. Overcoming these constraints enables energy security in a particular region and ultimately influences the development strategy. Although the level of energy consumption is widely considered to be indicative of the scale of development, but its larger impact is perhaps yet to be well-comprehended. . This is evident in the Gross Domestic Product (GDP) of a nation being its development index, while also being a function of its total energy consumption. Globally, fossil fuel is the majority of the primary energy resources and as GDP is correlated with energy consumption pattern; this means that GDP is also correlated to CO_2 emission. Thus, GDP as the only indicator of development is providing a distorted picture in totality. A comparatively better and more holistic measure, although still not perfect, is the Human Development Index (HDI).

The HDI is a pseudo quantitative measure that was first proposed in 1990 [12]. The HDI quantifies human development by considering school enrollment and literacy rates as a measure of education level, life expectancy as a measure of health care level, and per capita GDP based on purchasing power parity as a measure of material wealth level. The HDI is an average of three component indices: the education level index (EL_I), life expectancy index (LE_I) and per capita gross domestic product index based on purchasing power parity i.e. income level index (IL_I) [13]. Thus, HDI is represented mathematically as,

$$\mathrm{HDI} = \frac{EL_I + LE_I + IL_I}{3} \tag{1}$$

Each of these components in Equation (1) is depending on energy flow pattern in the national systems.

In addition to these, the geographical locations of the habitat site and the available infrastructure are also the predominating factor in influencing HDI level as these are affecting the ability in getting access to the opportunities. Availing of opportunities also depends on the health conditions and the education level. Thus, to study the influence of energy resources on HDI, the following aspects need to be analyzed:

i Opportunity in accessing the energy resources quantified in terms of opportunity cost (OC) and ii. Impact of emission on human health in terms of health cost. Energy quality is an integral parameter in these two items.

Thus, it is essential to address the opportunity cost and health cost of energy products and services, which are directly related to the use of quality energy resources. In order to examine the influences on use of energy quality, studies were conducted in two different locations where one group of household is using the quality fuel like charcoal for meeting thermal demand and solar PV operated lamp for meeting the lighting demand while the other group is using the raw bio-mass for meeting thermal demand and kerosene operated lamp for meeting the lighting demand. Long term studies were conducted in these zones in evaluating all the individual indices that control the effective HDI value. As energy is the key parameter in influencing the indices, knowledge on energy usage pattern is essential and this is discussed in the sections below.

1.1. Energy security and development

Access to the energy resources is under the control of three components and these are i. Availability, share of domestic production and amount of import, ii. Affordability, energy subsidy per capita and iii. Acceptability, in terms of energy quality and emission intensity. Indeed, any disruption on access into the resources is measured in terms of its security. However, full understanding of energy security lies within the other parameters like accessibility, affordability and acceptability. According to theory if the supply of a particular form of energy get struck for any reason, and it is possible to instantaneously substitute it with another form of energy without putting any additional cost, there would really be no threat to security of any kind.

From uninterrupted supply consideration, the power systems required to be planned in such a way that they have the spinning reserve, which means that if a particular power station failed or shut down suddenly, there is an enough capacity available in the systems itself to manage the failure or to immediately bring on line another standby source of supply to meet the demand such that there is no disruption of any kind and no economic loss is involved. Hence there is no threat to security in supply. The energy security aspects are interrelated with, i. International Competition, ii. Wars and Conflicts, and iii. Security mistakes.

In order to take necessary measures on the security elements, the researchers advocate for putting thrusts on: i. certainty in supply in terms of enhancement of the most economical mode, ii. reduction in consumption by improvements in energy efficiency in all sectors, iii. substitutions of import by using available local