WP-2014-043

INDIA'S ENERGY SYSTEM TRANSITION-SURVIVAL OF THE GREENEST

B. Sudhakara Reddy

Indira Gandhi Institute of Development Research, Mumbai
October 2014
http://www.igidr.ac.in/pdf/publication/WP-2014-043.pdf

INDIA'S ENERGY SYSTEM TRANSITION-SURVIVAL OF THE GREENEST

B. Sudhakara Reddy

Indira Gandhi Institute of Development Research (IGIDR)

General Arun Kumar Vaidya Marg

Goregaon (E), Mumbai- 400065, INDIA

Email(corresponding author): sreddy@igidr.ac.in

Abstract

The transition to a clean and green energy system is an economic and social transformation that is exciting as well as challenging. The world today faces a formidable challenge in transforming its economy from being driven primarily by fossil fuels, which are non-renewable and a major source of global pollution, to becoming an economy that can function effectively using renewable energy sources and by achieving high energy efficiency levels. In the present study, a green economy scenario is developed for India using a bottom-up approach. The results show that significant resource savings can be achieved by 2030 through the introduction of energy-efficient and green technologies. The building of a green energy economy can also serve another purpose: to develop new 'pathways out of poverty' by creating more than 10 million jobs and thus raise the standard of living of low-income people. The differences between the baseline and green energy scenarios are not so much the consequence of the diffusion of various technologies. It is the result of the active roles of different actors and the drivers that become dominant.

Keywords: : Emissions, Green energy, Fossil fuels, Green Jobs, Scenario

JEL Code: P28, Q41, Q42, Q48

INDIA'S ENERGY SYSTEM TRANSITION—SURVIVAL OF THE GREENEST

B. Sudhakara Reddy

Indira Gandhi Institute of Development Research
Goregaon (E), Mumbai 400 065, INDIA
Tel: 022 2841 6526, Fax: 022 2841 6399; email: sreddy@igidr.ac.in

Abstract

The transition to a clean and green energy system is an economic and social transformation that is exciting as well as challenging. The world today faces a formidable challenge in transforming its economy from being driven primarily by fossil fuels, which are non-renewable and a major source of global pollution, to becoming an economy that can function effectively using renewable energy sources and by achieving high energy efficiency levels. In the present study, a green economy scenario is developed for India using a bottom-up approach. The results show that significant resource savings can be achieved by 2030 through the introduction of energy-efficient and green technologies. The building of a green energy economy can also serve another purpose: to develop new 'pathways out of poverty' by creating more than 10 million jobs and thus raise the standard of living of low-income people. The differences between the baseline and green energy scenarios are not so much the consequence of the diffusion of various technologies. It is the result of the active roles of different actors and the drivers that become dominant.

JEL CODE:

P28, Q41, Q42, Q48

Key words: Emissions, Green energy, Fossil fuels, Green Jobs, Scenario

1.INTRODUCTION

In modern economy, energy is fundamental to virtually every product and service in use. It has been developed on the dependence of abundant and easy-to-transform polluting fossil fuels. The insatiable hunger for energy among emerging economies like India and China has resulted in a dismal air quality across the countries and is a constant reminder of their reliance on fossil fuels (Ahn S and Graczyk D, 2012). On one hand, increase in population and income levels combined with increased per capita energy consumption requires energy production to keep pace with economic growth, and on the other, the impact of fossil fuel use on environmental degradation is enormous (Reddy and Balachandra, 2003). The conflicting policy objectives of protecting the environment while increasing economic growth and employment has resulted in this paradox. Hence, it is important to decouple economic growth from environmental degeneration. From the perspective of energy security, dependence on fossil fuels carries a risk premiums linked to energy supply, economic risk, environmental impact and geopolitical instability. The need for abundant energy sources that do not pollute environment while ensuring energy security is one of the greatest technological challenges of the 21st century. Hence, the search for green energy involving affordable, low-carbon, and renewable energies has become global priority (UNEP, 2011).

The approaches to green economy include increasing device efficiency, fuel switching (from non-renewable to renewable energy), and decreasing energy intensity of the industrial processes and transportation modes. Various studies suggest (Pollin, 2009, UNEP, 2011, Kejun, 2011) that transitioning to a green economy has economic and social benefits from the perspectives of the government and the society. From the government perspective, this results in significant resource savings, reforming existing polices, designing new incentives to consumers, strengthening market infrastructure and market-based mechanisms, and redirecting public investment. From the society perspective, this provides an opportunity for savings in energy use, reduced health costs and increased employment opportunities.

For a successful design of a green strategy, we have to find out the main causes of the problem. It may be market failure or the limited capacities of the governments to intervene in market activities. There is a possibility that human behaviour might inhibit the penetration of green technologies. Deficits in traditional command and control measures may hinder the innovative processes. Also, interaction between political and broader societal forces is not taking place to bring about necessary changes. But the key factor is the lack of integration of 'technological systems' with 'institutional systems' along with "sustainable socio-economic" systems. Such transitions will be greatly influenced by policies and regulatory frameworks within the policy-making process (Anon, 2014).

This paper explores a transition to a sustainable energy system using the socio-economic-technical scenario method (Elzen *et al*, 2002, Sudhakara Reddy and Balachandra, 2003, UENP, 2011). This approach takes into account the multifaceted nature of transitions which not only require the development and use of new technologies, but also of changes in user behaviour, policy and regulation.

The scenarios that are developed are: baseline business as usual (BAU) as well as green energy (GE). The purpose is to illustrate, by example, how a country can try to green its economy and what are its advantages in terms of resource savings and job creation. We have analysed various technology shifts (e.g., inefficient to efficient), carrier shifts (e.g., fossil fuels to renewable resources) and modal shifts (e.g., personal transport to public transport). Our scenarios are, to a great extent, based on the existing technologies. The results indicate a very high demand for renewables, mainly solar, in the future. The proposed measures used in the scenario substantially reduce dependency on fossil fuels by 2030. The challenges to this path lie in socio-economic-political domains. Attention should be focussed on energy types, technologies, policy approaches and most importantly the societal dimension, that is, how a society adopts a new energy system. In this perspective, this study bears importance as it considers major energy sources, the key variables, which influence the energy demand and develops a green energy scenario targeting high growth, efficient resource system and low-carbon economy.

2.INDIA'S ENERGY TRAJECTORY

A combination of rising incomes and population growth fuels energy use. In India, between 1960 and 2010, the primary energy consumption has increased six-fold from 117 to 715 MTOE while the non-commercial energy just doubled. Coal is the major energy source and has provided 80% of the total primary energy use in 1960 but only 51.8% in 2010. The consumption grew most quickly in the oil and natural gas sectors, with an increase of about 4.2 and 3.6% respectively. The increase in other renewable sources like solar, wind, small hydro, hydrogen, geothermal forms is just about 1% per annum. The share of non-commercial energy in total had decreased from 63.5 to 31.6% (Planning Commission, 2012). The challenge is therefore to focus on the transition towards increase in renewable base of the energy system. Table 1 provides the energy demand met by different energy sources. It shows how the per capita energy use and carbon emissions between 1960 and 2010, which have increased from 0.26 to 0.59 TOE and 0.07 to 0.45 tons, respectively. Even though energy consumption has increased six-fold, the increase in per capita use has only doubled largely because of the shift from inefficient to efficient devices/carriers. The increased energy use has resulted in a large increase in CO_2 emissions. In general, there exists a strong relationship between per-capita income and emissions per capita. For this reason, countries with large economies tend to be the largest emitting nations. This is due to higher rates of consumption and more energy-intensive lifestyles. In case of India, due to low per-capita income, India's per-capita emissions are relatively lower when compared with other developing economies. However, due to its large population, the total emissions are high.

The capacity of power plant generation in 2010 was 174.5 GW and produced 964 GWh of electricity. Thermal power plants accounted for over 60% of the installed capacity and over 75% of the energy mix. During peak hours, lack of continuous power supply forced industries to opt for decentralised cogeneration of heat and power using precious petroleum products. Nearly 15% of the existing coal power plant capacity was built prior to 1980 and will be 50 years or older by the year 2030. An additional 27% of capacity was built after 1990s and will be 40 years or older by 2030. Currently over 275 generating units are operating in India (Anon 2013).

Table 1: Energy demand (MTOE), GDP and carbon emissions (1960-2010)

Type of carrier	1960–61	1970–71	1980–81	1990–91	2000–01	2011–12
Coal*	35.7 (79.9)	37.3 (62.3)	58.2 (60.2)	97.7 (55.9)	138.0 (49.1)	283 (51.8)
Oil*	8.3 (18.6)	19.1 (32.0)	32.3 (33.4)	57.8 (33.1)	107.0 (38.1)	186 (34.1)
Natural gas*	0.0 (0.0)	0.6 (1.0)	1.41 (1.5)	11.5 (6.6)	25.1 (8.9)	48 (8.8)
Hydro*	0.7 (1.5)	2.2 (3.6)	4.0 (4.1)	6.2 (3.6)	6.4 (2.3)	12 (2.2)
Nuclear*	0.0 (0.0)	0.6 (1.1)	0.8 (0.8)	1.6 (0.9)	4.41 (1.6)	17 (3.1)
Total Commercial	42.8 (36.5)	60.3 (41.0)	99.8 (47.9)	181.1 (59.7)	296.1 (68.4)	546 (76.4)
Non-Commercial	74.4 (63.5)	86.7 (59.0)	108.5 (52.1)	122.1 (40.3)	136.7 (31.6)	169 (23.6)
Total	117.2	147.1	208.3	303.2	432.8	715
GDP/cap (US$)	220	250	295	400	590	1050
Energy consumption/ cap(TOE)	0.267	0.268	0.305	0.358	0.420	0.591
Carbon emissions (tons/cap) *	0.07	0.1	0.14	0.22	0.31	0.45

* Boden, et al, 2011; Source: Anon, 2012.

3. THE IMPORTANCE OF ENERGY TRANSITION

In the 21st century, India faces twin challenges, one of expanding opportunities for a growing population and another of reducing import dependence of petroleum products. At the same time, carbon emission reduction is also a challenge. Even though significant technology innovations to replace the existing fossil-fuel-based technologies with renewables are available, we have not succeeded in this endeavour. This is because we fail to understand the nature of the energy system. To achieve the transitions to green energy we should not only invest in new technologies but also change user practices, policy, infrastructure and institutions accordingly.

3.1 The relevance of fuel poverty

Energy is essential for everyday living and to get work done. The quality of life depends on the quality and quantity of energy used. Generally, poor people use traditional biofuels such as fuelwood using devices, whose efficiencies are as low as 10%. These fuels for poor are inefficient, expensive (in terms of useful energy) and hazardous to health. The poor spend a far greater proportion of their income on energy (15–30%) than the wealthy (3–6%). Even as recently as 2012, nearly 75% of rural households and half of the urban households in India have used bio-fuels. It is an important consideration while examining the impacts of shifting to energy-efficient technologies and devices, which assist the fuel-poor through investments in these initiatives.

3.2 Worker intensity

In general, any investment in the economy will create jobs (direct and indirect) depending on the labour intensity in the sector. In the case of energy, traditional energy extraction and power generation are capital intensive (a high proportion of the total cost is attributed to fossil fuel inputs) (Anon, 2009). The renewable energy as well as energy efficiency are labour intensive (Anon, 2010) which benefit countries like India which has the largest youth population in the world with around 66 per cent of the total population under the age of 35. At present, a significant share of youth is either unemployed or employed with low salaries in informal sector (Mitra and Verick, 2013. Therefore, a shift to renewable energy system provides opportunities for this young people as they enter the labour market.

3.3 Reduction of energy dependence

Increased energy efficiency and the shift from non-renewables to renewables can contribute to sustainable development by stimulating economic growth. Studies suggest that many countries with lower energy intensities (consumption per unit of economic output) show higher rates of economic growth than their competitors (Pollin et al, 2009, UNEP, 2011). Also an economy which makes efficient use of resources will grow more rapidly than one which is wasting the resources through inefficient use. At the same time, the power generation through renewable is labor-intensive which means it creates more jobs per rupee invested than power generation from conventional resources like coal and gas. Also since renewable are indigenous resources, they reduce import dependency thus providing energy security.

3.4 Environmental Considerations

In general, environmental benefit is not a factor in consumer decisions in fuel choice. However, many low-carbon energy systems provide benefits in cost, productivity, and in the quality of service provided (Kats, 2003). Hence, policy action is needed to accelerate energy transitions. If a decision to shift to a low-carbon energy system is based solely on environmental criteria, then policy action would be the only way to enact such a transition.

To pave the way for a sustainable energy system innovations or transition to green economy should not only involve new technologies but also in user practices, policy, infrastructure and institutions. This means that there is a change in the socio-technical nature of the system resulting in an integrated system of technologies and social practices along with institutional changes. Traditional approaches exploring transitions has not paid any attention to the interaction between technology and society and neglect the role of actors (Reddy and Srinivas, 2009, Delucchi and Jacobson 2010; Teske et al. 2010; Deng et al. 2011; Jeffries 2011). To rectify this we need new and innovative approaches keeping in mind the socio-economic-technical nature of the system that will assist policy makers to design strategies to achieve a green economy.

For the present study, we develop two contrasting scenarios that describe possible transitions towards a green economy. For each scenario a combination of specific interventions are chosen to explore the implications on the future of economy and environment. These scenarios—baseline and green economy—provide the changing energy mix under the current policy framework and a new policy paradigm, respectively. For any case study it is necessary to take into account a business as usual case (BAU). This scenario reflects existing policies and measures to increase the diffusion of energy-efficient and renewable energy technologies. The alternative scenario, viz., green economy scenario, differs from BAU in terms of device efficiency, fuel shifts and technological shifts.

4. SCENARIO DEVELOPMENT

4.1 The Model

To set a scenario, identifying the drivers is the pre-condition of scenario analysis. The drivers play an important role in affecting the society, economy, technologies, and environment. These include macro-economic factors (GDP, energy intensity of consumption, etc.), demographic factors (population, rate of urbanisation, etc.) and technological factors (device efficiency, appliance stock, etc.). The factors considered here are not exhaustive but are considered important from the Indian perspective.

The model developed in this paper is an integrated energy–engineering–environmental–economic system model (Reddy and Balachandra, 2003). Unlike other economic models that have been used previously, this is a bottom-up approach which covers all sectors of the energy economy and all energy carriers. The growth rate of each carrier can be expressed by key demographic, macroeconomic, supply, and demand factors as follows[1],

$$d_i = f(g, p, u, s_i, e_i, t_i, i_i, v_i, m_i, n_i, o_i) \quad (1)$$

where, d_i = Demand growth rate for energy carrier i (%), g = GDP growth rate (%), p = Population growth rate (%), u = Rate of urbanization (%), s_i = Rate of change in demand for energy carrier i due to fuel shift (%), e_i = Rate of change in energy efficiency during generation for energy carrier i (%), t_i = Rate of change in T&D efficiency of energy carrier i (%), i_i = Rate of change in energy efficiency of industry using energy carrier i (%), v_i = Rate of change in vehicle stock using energy carrier i (%), m_i = Rate of change in demand of energy carrier i due to mode shift (%), n_i = Rate of change in appliance stock using energy carrier i (%), o_i = Rate of change in efficiency of appliances using energy carrier i (%). The formulation of transition pathways follows an approach based on various elements which include: (i) characteristics of existing energy regime; (ii) technologies, activities and services; and (iii) specific gaps at various levels. The main features of the model are shown in Figure 1. The assumptions for forecasting energy demand, savings, investment and emissions are given in Appendix1.

The model calculates the likely energy demand for different energy sources and GHG emissions based on which we obtain GDP and carbon intensities. For the household sector, the main input variables are the growth rates of population and households, the estimated fuel/carrier shifts, device efficiency, the rate of change in appliance stock and the level of urbanization. For the industrial sector, the variables are energy intensity and the value of output. The variables used in the transportation sector include mode of transport, technological efficiency and the type of fuel used. Since power generation is a key sector with respect to renewable energy use, we have used various types of technology and energy sources, including capacity factor, capital and O&M cost, employment, and emissions. Using the information, two scenarios are developed for the analysis.

[1] Note that we have not considered the price variables as the same have already been accounted for fuel quantity shifts. Also, the international price of oil is assumed to be the same under both scenarios as also that there is no specific price administration by government under GE.

In BAU scenario it is assumed that there are no major changes in the country's energy profile (i.e., electricity supply is still dominated by coal-based generation, the transport sector remains mainly dependent on oil, and the households continue to depend on biomass-based fuels, particularly in rural areas). In this scenario, no additional public policies are considered that would encourage the use of alternative energy sources and energy efficiency interventions. The GE scenario assumes that significant policy focus will be on achieving green energy future through policies such as structural reform away from energy intensive industries; the dissemination of currently available energy efficient and renewable energy technologies and the diversification of the electricity generation mix. This path evolves as specific energy technologies serve specific demands (e.g., biogas for power generation in hilly regions) and the policy shift to public transport away from personal transport. These measures would reflect a shift towards efficient and clean production in the industrial sector, renewable energy for power generation and standards that would encourage a public focus on energy efficiency in the residential and commercial sectors. This results in (i) significant employment creation, (ii) an energy efficient economy, (iii) reduction in import dependence, (iv) low carbon profile in line with international obligations, and (v) a 'green' economy.

To segregate green energy considerations, the demographic and macroeconomic factors have been assumed to hold good for both baseline and green economy (GE) scenarios. Each of these is considered for 2010, 2020 and 2030. There are no calculations between these points. The data presented in figures are generally made as area diagrams for easy comprehension. In the diagrams a straight line connects the different decades, while in fact the process described and anticipated in the scenario takes place mostly at the end or the beginning of the period. It should be borne in mind that when interpreting the diagrams, the gradient in the line between 2010 and 2020 does not account for the actual situation in the preceding years. Considering the growth we observe a shift from this trend to a slight increase to decrease in energy use (while maintaining the levels of services constant).

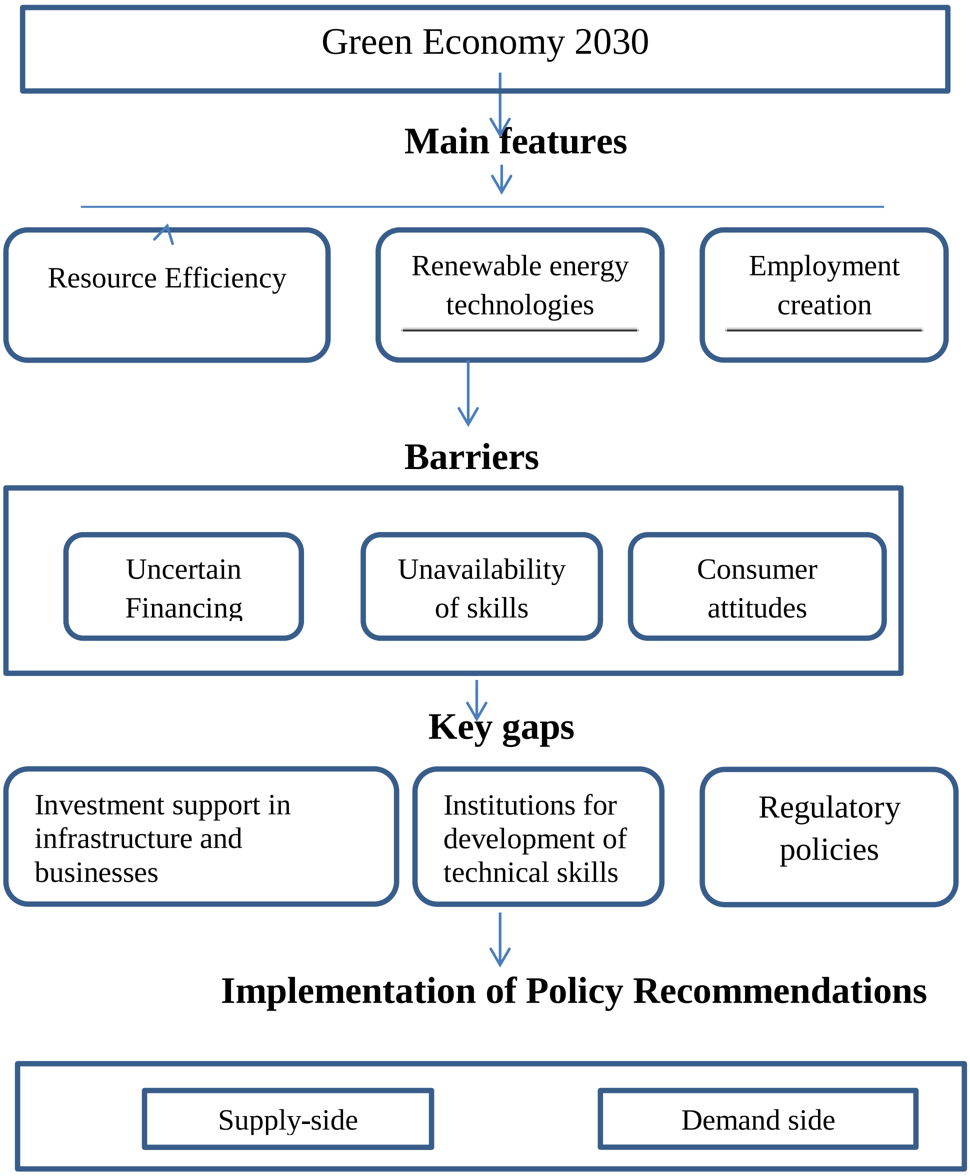

Figure 1: Green economy—Bottom-up approach

4. 2 Scenario Projections

4.2.1 Energy demand

The baseline scenario assumes that the current trends (energy use, efficiency levels, etc.) will continue in future. India's population is projected to grow by 23% during 2010 –2030, reaching 1.47 billion. The real GDP, as per the model, is projected to grow by 6.5% per year on average between 2010 and 2030 reaching US$5.1 trillion $3,586 per capita (base year 2010). Due to increase in population and GDP, the primary energy demand will double in two decades reaching 1,397 MTOE in 2030 with the share of fossil fuels remaining around 80%. Among the fossil fuels, a reduction in coal demand and a corresponding increase in oil and gas demand is seen. The increase in energy use corresponds to an increase in energy intensity (TOE/US $ of GDP) from 0.019 to 0.036. With a large population base and higher income, there will be an increase in resource use which will result in increased waste generation. As a consequence, the carbon emissions are projected to increase by 2.5 times from 2010 reaching 3,440 million tonnes with per capita emissions of 2.2 tons/annum. However, the carbon intensity (tons per US$ of GDP) decreases from 0.96 to 0.67.

The projected trends in BAU scenario for resource use and emissions will have significant negative consequences on society, economy and environment. To reverse this trend, green growth is necessary, but it is generally perceived to be an impediment for economic development. However, we feel that it is necessary to decouple energy use from economic growth. Countries like Japan have achieved significant economic growth without increasing energy use. The green growth scenario can provide the context to understand the impact of large-scale shifts in technology, demographics, and/or policy. With focus on green technologies, energy efficiency and public transport, energy demand and carbon emissions will be reduced significantly. As per the model, the results for GE scenario, energy use will reach 1079 MTOE by 2030, a saving of about 30% over BAU. However, no significant difference is seen in energy demand between the 2010 and 2020, because alternative energy technologies such as renewables can be cost-effective in the long run. Therefore, much of the demand reduction occurs after 2020. Coal beneficiation and combined cycle power plants are the new strategies for an efficient power generation regime. Significant investments in power plant modernisation, and reduction in T& D losses will improve power supply. The penetration rate of renewable energy resources will reduce the total primary energy demand by 23% under GE. Expansion of public transportation network (rail and bus) and improvements in energy efficiency (e.g. households, industrial and commercial sectors), the increased use of renewable energy and waste will result in reduced demand to the tune of 318 MTOE. The volume of energy-related CO_2 emissions decline to 2,218 Mt in 2030 from 3440 under the BAU scenario and the per capita emissions will reduce by about 35% (from 2.22 to 1.45) under the GE scenario. The reduction in fossil fuel demand and focus on clean energy will reduce the energy intensity to 0.21 (TOE/US$ of GDP) and carbon intensity to 0.42 (ton/US$ of GDP) under the GE scenario.

Table 2: Energy demand and CO_2 emission under BAU and GE scenarios

Source	2010	Baseline Scenario		GE Scenario		Saving (MTOE)	
		2020	2030	2020	2030	2020	2030
Share of primary energy demand (%)							
Coal	41.2	42.7	41.4	40.8	35.4	70	192
Oil	24.2	25.6	27.7	22.8	19.7	59	178
Gas	6.6	9.7	11.0	9.8	11.8	11	25
Nuclear	0.8	1.4	2.3	1.6	2.2		
Hydro	1.9	2.0	1.9	2.0	2.0		
Renewables	25.3	18.6	15.8	22.9	29.8	-16	-88
TOTAL (MTOE)	621	996	1397	893	1079	103	318
Energy use/cap (TOE)	0.59	0.75	1.05	0.67	0.71	125	307
Energy intensity (TOE/US$ of GDP)	0.019	0.028	0.036	0.19	0.21		
CO_2 emissions (%)							
Coal	67.9	65.3	61.9	63.4	63.40	252	679
Oil	25.9	27.0	28.4	28.7	24.2	51	208
Gas	6.2	7.7	9.7	7.7	12.4	19	96
TOTAL (Mt)	1403	2440	3440	2113	2218	327	1222
Emissions/cap (tons)	1.10	1.84	2.22	1.5	1.45		
Emission intensity (ton/US$ of GDP)	0.96	0.89	0.67	0.77	0.42		

For power generation, significant investments in green energy technologies will increase the penetration rate of renewables to 45% of total installed capacity by 2030, compared to 18% under BAU and 10% in 2010. Out of the total installed capacity of 448 GW, the share of various renewables by 2030 are: 21.2% (hydro), 4.62% (biomass/waste), 10.77% (wind), and 17.85% (solar). As a result, these renewable sources of energy will account for about 34% of total electricity generation while that of fossil fuels, coal in particular, will decline to 44% compared to 60% in BAU scenario. The efforts to diffuse green-energy technologies will increase the share of renewable power generation to 23.3% in 2020 and 33.87% in 2030 in GE scenario. Even though their share of installed capacity is high (30.41% and 44.8% by 2020 and 2030, respectively), due to the low plant load factors, the power generation is relatively low when compared with fossil fuel power plants.

Table 3: Trends in BAU and GE scenarios in the electricity sector

	Installed capacity (GW) share (%)					Power generation (TWh) share (%)				
	BAU			GE		BAU			GE	
Source	2010	2020	2030	2020	2030	2010	2020	2030	2020	2030
Coal	52.81	52.26	51.48	44.31	32.37	63.08	62.04	59.73	54.35	43.92
NG	10.11	11.29	14.12	9.23	8.93	11.27	12.51	15.29	10.57	11.31
Hydro	21.35	16.77	13.67	12.92	10.04	15.3	11.95	9.51	9.51	8.18
Nuclear	2.70	2.58	2.73	1.85	2.01	3.22	3.06	3.17	2.26	2.73
Small hydro	0.67	4.84	6.38	9.85	11.16	0.43	3.06	3.95	6.44	8.08
Biomass	0.84	1.94	2.28	4.62	5.58	1.01	2.3	2.64	5.66	7.57
Wind	6.74	5.81	6.38	10.77	12.05	4.3	3.68	3.95	7.05	8.72
Solar PV	1.12	1.29	1.37	3.69	10.04	0.45	0.51	0.53	1.51	4.54
Solar thermal	1.69	1.61	2.28	4.62	7.81	0.94	0.90	1.23	2.64	4.95
Total (GW)	182	310	439	325	448	980	1715	2486	1586	2082
Renewables (%)	11.29	14.00	17.55	30.41	44.8	7.12	10.44	12.3	23.3	33.87

4.3 GE Scenario—Impacts

4.3.1: Resource savings: Energy production from domestic sources in 2010 was 428 MTOE or 69% of the total. With increase in commercial energy, particularly oil, it is not feasible to match supply with demand. India's dependence on energy imports is expected to reach 50% by 2030 according to BAU scenario. In 2009-10, the country imported 133 million tonnes of oil which amounts to 80% of its domestic crude oil consumption and 23% of its coal imports. According to IEA (2012) the import of oil will reach 90% and that of coal by 50% by 2030. The average real price of coal is expected to increase from $65/ton in 2010 to $100/ton by 2020 and $110/ton by 2030. In case of oil, the average price increase will be from $455/ton in 2010 to $700/ton by 2020 and $770 by 2030. As per BAU scenario, the total import bill will amount to US$ 334 billion by 2030 (at 2010/11 prices), but as per the GE scenario, it would be US$ 194.2 billion, a saving of about US$ 140 billion. The energy savings and shift to green economy would result in money saved on energy in 2030 by as much as US$ 140 billion annually, depending on the price of coal, oil and gas. The savings of US$ 140 billion has significant beneficial effects to the economy as a whole, which we are not presenting here. Such large savings indicate that investing in green energy protect the economy from economic risks associated with over-dependence on imported fuels thus providing energy security for the country.

Table 4: Resource demand and Import bill

Energy source	Units	BAU			GE		Savings/year	
		2010	2020	2030	2020	2030	2020	2030
Coal	Mt.	461.1	834.0	1108.7	726.0	711.3		
	Imports (%)	23.0	35.0	50.0				
	Imports (Mt)	106.1	291.9	554.3	254.2	355.5	37.7	198.8
	Price ($/ton)	65.0	100.0	110.0				
	Import bill ($ billion)	6.89	29.19	60.98	25.42	39.11	3.8	21.9
Oil	Mt.	166.0	255.0	373.0	202.0	209.0		
	Imports (%)	80.0	85.0	90.0				
	Imports (Mt.)	132.8	216.8	335.7	171.9	187.7	44.9	148.0
	Price ($/ton)	455.0	700.0	770.0				
	Import bill ($ billion)	60.42	151.73	258.49	120.3	144.5	31.4	114.0
Gas	bcm	26.5	51.5	91.2	41.2	66.2		
	Imports (%)	18.0	35.0	53.0				
	Imports (bcm)	4.8	18.0	48.4	14.4	35.1	3.6	13.2
	Price ($/bcm)	0.2	0.2	0.3	0.2	0.3		
	Import bill (billion $)	0.95	4.33	14.51	2.88	10.54	1.4	4.0
Total import bill (billion US $)		68.3	185.2	334	148.6	194.2	36.6	139.8

Ref: Anon, 2012

4.3.2 Employment Road map for 2030: The general assumption of a green economy is that the energy and resource savings comes at a financial cost. However, a number of studies (Greenpeace International, 2009, Kammen et al, 2013) suggest that the green economy is dependent on the efficient use of energy and power generation through renewables and provides significant economic benefits through new job creation[2]. Compared with fossil fuels, power generation through green technologies is labour intensive and creates more jobs per given amount of investment. Fossil fuel-power generation requires significant amount of investments on acquiring machines, land (either on- or offshore) and energy itself relative to clean power generation.

Jobs are of three types; direct, indirect and induced. A direct job is related to installation, construction, operation and maintenance of the plant and relevant works on site. They comprise contractors, construction workers, executives, and plant operators (among others) working on the construction/operations of the power plant. An indirect job is related to the manufacture of the components of the installation (off site). Construction and O & M jobs are inherently different: construction jobs are assumed to be temporary jobs associated with the initial investment and installation of a given plant, while O&M jobs are spread across the entire lifetime of the plant. Indirect job creation is across a range of sectors, including extraction, manufacturing, utilities, transport, and administrative and professional

[2] A green job pertains to a work in agriculture, manufacturing, research and development, administrative, and service activities that contribute substantially to preserving or restoring environmental quality.

occupations. Induced jobs are those created or supported by the spending of the workers with direct and indirect jobs such as accountants, office clerks, human resource managers, cashiers, and retail sales people.

Information on employment generation in the power sector and in particular, the renewable sector, is patchy and disaggregated. Data for coal is readily available and employment factors other than for coal are derived from various sources and are adjusted using regional multipliers to allow for the fact that economic activities in developing countries are generally more labour intensive (Rutovitz and Atherton, 2009, IRENA, 2013, Anon, 2009). Only direct employment in development, construction, manufacturing, operations and maintenance are included while in transmission and distribution it is not. During 2010, 80% of the total jobs are in renewable energy sector which reaches 87.82% by 2030 under the BAU scenario and 97% under the GE scenario. In 2020, GE will generate about 1.75 million additional jobs compared to the BAU scenario. The gap between the two scenarios widens in 2030. Table 5 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030.

Table 5: Employment potential-Direct

Technology	Installed capacity (MW)	Employment Jobs (2010) (millions)	Job intensity (No. of jobs/MW)	BAU		GE		Additional employment (million)			
								BAU		GE	
				2020	2030	2020	2030	2020	2030	2020	2030
PV	2000	0.016	8.2	0.03	0.05	0.098	0.37	0.017	0.033	0.082	0.353
Solar thermal	2800	0.015	5.40	0.03	0.054	0.081	0.19	0.012	0.039	0.066	0.174
SWH	3.24	0.032	0.01	0.05	0.10	0.15	0.30	0.018	0.068	0.118	0.268
Wind	12300	0.055	4.50	0.08	0.126	0.158	0.243	0.026	0.071	0.102	0.188
Biomass (**)	2300	0.013	5.70	0.03	0.057	0.086	0.143	0.021	0.044	0.072	0.129
Biogas (million)	4.1	0.820	0.20	1.20	1.60	2.00	4.00	0.380	0.780	1.180	3.180
Small hydro	2760	0.010	3.62	0.05	0.101	0.054	0.181	0.044	0.091	0.044	0.171
Coal	98100	0.1324	1.35	0.22	0.305	0.194	0.196	0.086	0.173	0.062	0.063
Gas	18600	0.017	0.94	0.03	0.058	0.028	0.038	0.015	0.041	0.011	0.020
Hydro	38200	0.080	2.09	0.11	0.125	0.088	0.094	0.029	0.046	0.008	0.014
Nuclear	4800	0.008	1.60	0.01	0.019	0.010	0.014	0.005	0.012	0.002	0.007
Total	181867	1.199		1.85	2.60	2.95	5.77	0.65	1.40	1.75	4.57
Total renewable	22167	0.962		1.479	2.088	2.627	5.425	0.517	1.126	1.665	4.463
% of total	12.19	80.20		79.86	80.43	89.14	94.07	79.23	80.62	95.28	97.71

Note: (*) Weighted by capacity factor; Units of SWH in million m^2 and biogas (no. of plants)
(*) Nuclear includes oil and diesel jobs
This does not include power system T&D, coal and oil extraction.
(**) includes cogeneration
Sources: (i) MNRE Achievements as on 30.06.2010—http://www.mnre.gov.in/)
(ii) IREANA; (iii) Green Peace; (iii) www.indiapowerjobs.com; Director General (Employment & Training)

From the perspective of RE technologies, non-grid biomass use accounts for the largest share with 4 million employed persons. With the exception of biogas, each of the other RE technologies can contribute over 100'000 jobs. The most important RE techno logy (other than biogas) in terms of employment is solar power, where solar thermal and solar water-heating systems are responsible for employment of 0.76 million persons. Wind technology follows with 0.243 million and hydro power (large and small) with 0.275 million persons employed (Table 5). Appendix 3 provide information on the type of jobs provided by the green economy in renewable energy sector.

Table 6 provides information on job years, jobs/MW and jobs/GWh generated. To compare power generation with various technologies we have calculated lifetime average employment per unit of energy (jobyears/GWh). Employment factors such as construction and installation (job-years/MWp) are averaged over plant lifetime to obtain average employment (jobs/MWp) which is added to the O&M factor. Finally, considering the capacity factor, we have calculated employment/unit of energy generated (job-years/GWh). It is difficult to assess employment factors for energy efficiency since the sector is diverse. Overall, PV is expected to create the largest number of jobs per GWh. However, the technology that has the highest employment-enhancing potential is bioenergy that will take the lead. Biogas produces the highest number of jobs (mainly operation and maintenance) per unit of output. The direct job creation ranges between 1.25 and 3.4 jobs per GWh for RE, whereas for conventional power generation it is between 0.27 and 0.8.

Table 6: Employment creation estimates through various power generation technologies

Energy technology	capacity factor (%)	Life (years)	Jobs/MWp		Jobs/MWa			Job years/GWh			Total (Dire
			CIM	O&M	CIM	O&M	Total	CIM	O&M	F, E & P	Jobs/
PV	0.25	30	1.28	0.79	5.12	3.16	8.28	0.58	0.36	0	
Solar thermal	0.35	30	0.6	1.30	1.71	3.71	5.429	0.20	0.42	0	
SWH		20	0.018	0.010	0.01	0.003	0.009	0.00	0.0004	0	
Wind	0.4	30	0.8	1.00	2.00	2.50	4.500	0.23	0.29		
Biomass	0.75	45	0.58	3.65	0.77	4.87	5.640	0.09	0.56	0.01	
Biogas		20									
Small hydro	0.4	40	0.2	1.45	0.50	3.63	4.125	0.06	0.41	0	
Coal	0.75	40	0.3	0.65	0.40	0.87	1.267	0.05	0.10	0.06	
Gas	0.7	40	0.03	0.63	0.04	0.90	0.943	0.00	0.10	0.02	
Hydro	0.45	40	0.21	0.73	0.47	1.62	2.089	0.05	0.19	0	
Nuclear	0.75	40	0.5	0.70	0.67	0.93	1.600	0.08	0.11	0.01	
EE		20									

Note: CP = Capacity factor
CIM = Construction, installation, and manufacturing O &M = Operation and Maintenance; FE and P = Fuel extraction and process
jobs/MWp (peak MW), MWa (average MW)
For solar water heater, the values are per sq.m and for bio gas the numbers are per plant.

For the present study, an employment factor of job creation per GWh saved is provided. We have added indirect and induced employment factors to arrive at the total number. Table 6 clearly points to the way that countries like India with high solar exposure would favour the technology with high job potential. Solar, wind and biomass offer strong job creation prospects depending only on local resources. Investing in solar installations offers 20% more jobs than wind (0.57) and four times more than coal (0.24). It appears that investment in energy efficiency has strong employment impacts since such investment creates 90% more jobs per unit of energy saved/produced.

It is important to compare options based on the generation of power. If generation costs vary significantly across technologies, then it is appropriate to normalise the job-creation estimates on the basis of rupees. Cost-based estimates of job creation in column (3) are obtained by dividing the number in column (2) by that in column (4). Thus, column (3) shows job creation per million rupees spent on using the capacity of a particular energy type. The job-creation estimates of all RE technologies are more than twice that of fossil-fuel-based power generation. Table 7 provides data comparing the green energy and fossil fuel investments in terms of the numbers of jobs they create with long-term employment opportunities.

The data indicate that green energy investments create 0.2 jobs per one million rupee investment versus fossil-fuel investments with 0.02 jobs. Most of the jobs in the RE sector are of low level relative to the fossil-fuel power generation which benefits the local population immensely. This shows that there will be ten times more jobs per Rs. million investment and those that benefit through decent employment opportunities are from the lower strata of the society with meagre incomes. In fossil-fuel-based power generation about 15% jobs are at low level where as they are more than 50% in renewable energy-based power generation.

When we consider for the differences in relative job creation for a given amount of spending, three factors seem to play a role. They include the relative labour intensity, local context and the type of job. In terms of labour intensity, RE power generation involves a significant share of capital on hiring workers, as opposed to spending on materials, land, resource and transportation. A significant amount of money spent on an RE project remains within the local community as opposed to that spent for outside supplies. If a given amount of spending is used to pay people lower average wages, it means that this given spending level can create more jobs.

Table 7: Cost and level of employment in GE economy

	Jobs/MW/ life time	Cost/MW (Rs.million)	Jobs/ Rs. million of investment	Level of employment (%)					
				Executive (PG and above)	Skilled			Graduates	Labo urers
					High level	Middle level	Low level		
					Engg.	ITI			
Coal	1.16	55	0.02	3	25	45	15	10	2
Gas	0.81	60	0.01	3	25	45	15	10	2
Hydro	1.2	100	0.01	3	20	40	25	10	2
Nuclear	1.67	65	0.03	5	30	30	10	20	5
EE (GWh saved)	0.3	3	0.10	3	30	40	10	15	2
PV	8.2	80	0.1	2	8	30	40	12	8
Solar thermal	5.4	80	0.08	3	10	40	30	10	7
SWH (per sq.m)	0.002	0.008	0.24	2	3	20	60	10	5
Wind	3.9	60	0.08	2	10	30	40	12	6
Biomass	5.7	50	0.11	1	4	30	55	4	6
Biogas (per plant)	0.02	0.02	1.0	2	1	5	75	5	12
Small hydro	3.62	60	0.06	2	12	40	30	10	6
RE average (%)				2.1	9.8	34.4	37.5	9.8	6.5

Appendix 1 gives a detailed break-up of the employment benefits that modern energy services offer.

5.DISCUSSION

5.1 Investment for transition

There is growing consensus that a transition from fossil fuel-based energy system to the one with renewable energy is essential and should begin immediately. This is because investment decisions made today could bind the economy on a particular path for the next several decades and a reversal will be expensive. As presented here, the GE scenario assumes increased investments over the period 2015–2030 which are significantly higher than business-as-usual scenario. These include (i) modernisation of power plants, (ii) efficient power grid of long-distance transmission lines and local distribution lines, (iii) power development of units based on renewable sources, (iv) efficiency improvements in the household and industrial sectors, and (v) increasing investments in public transport. These additional investments increase resource efficiency and reduce carbon intensity while creating jobs and stimulating economic growth. Among renewable energy resources, wind (onshore and offshore), solar photovoltaic (PV) and solar thermal electricity generation, biofuels (ethanol), biogas, mini hydro and waste to heat are the most mature renewable energy generating technologies. We have provided investment allocation by the government in realising the required targets. The investment provides a reflection on the reasonability of the scenario rather than financial feasibility. The policy instruments required to provide financing and incentivise to promote the necessary measures and investments are a crucial aspect here.

The resources required to finance the transition to the green economy have been subject to widely diverging estimates. Here, we concentrate more on the broader allocation for various categories. Over half of the estimated needs come from the government. This includes the financing of access to modern energy services for the poor. It is essential that priority is given to public sector infrastructure investments that are critical to the transition to the green economy, in particular, shifting the focus from private to public transportation systems and efficient electricity grids (Table 8).

Table 8: Investment allocation across various sectors

Sector	Share of GDP to be spent	Target
Energy supply	*0.05*	Increase the efficiency of existing power generation
	0.15	Increase the penetration of renewable energy in power generation and primary energy consumption up to 30%
	0.1	Increase the efficiency of transportation and distribution
Energy demand	0.1	Provide gaseous fuels for cooking and electricity for lighting for all households
Industry	0.06	Increase energy efficiency levels of industrial processes and devices (motors, boilers, etc.)
Transport	0.16	Expand public transport network and non-motorised transport
Waste	0.1	Reducing 70% of waste that goes to landfill through proper implementation of 3Rs
Skill development	0.01	Nearly five million job creation which requires skill development

It is natural to expect that the promotion of renewable energy will reduce fossil-fuel consumption, in particular oil and gas and hence the import dependence. However, concern lingers whether the much-needed investment comes from the private sector for such aspects as R&D, technology development, and supply push mechanism. The government should take policy measures with targeted financial provisions to boost green energy technology diffusion. Presently, there is Clean Energy Fund with a tax of US$1 per tonne of coal to be used to fund research and innovative projects in green technologies. In addition, two schemes, viz., Renewable Energy Certificate and Renewable Purchase Obligation, were launched resulting in increase in investment of 25% in 2012 (a total of US$ 4.5 billion). However, investors are likely to focus on short-term gains (where there are clear and immediate paybacks) instead of long-term returns. This is because of the heavy focus on economic growth, which depends on the critical role of fossil fuels for power generation. At the same time, energy security is likely to be dominant consideration for policymakers (Venugopal and Srivastava, 2013). This has implications for the level of support that will be provided to green technologies.

5.2 Commercialisation of Innovative Technologies

The energy-efficient and renewable energy technologies will take two to three decades for diffusion to dominate the market. To diffuse quickly, the green technologies need a bundle of desirable attributes which include: (i) *Technological Dynamism:* continued innovation, so costs fall/quality rises, and (ii) *Innovative Complementarities:* users improve own technologies and find new uses. Also, technology developers should ensure that the technology (i) should be competitively priced, and (ii) should have appropriate carbon price. Technologies typically follow a common commercialisation development path with the following stages: (1) feasibility analysis, (2) research and development, (3) system demonstration, and (4) commercial deployment and scaling-up. These activities require large capital requirements and also involve high risks (technology performance and market dynamics are high). The government should encourage innovation and provide the supply of ready capital. There is a need to provide low-cost capital for these development stages and also loan guarantees that result in the commercialisation of new and innovative renewable energy technologies.

The tendency among policy makers is to view renewable energy sources as oddities because most of the technologies may not appear to be cost effective. The role of the government is to design policies which help scaling up the new technologies and encourage entrepreneurial culture to generate new ideas for the mass market. Unfortunately, the share of government spending on research in the renewable energy sector is just 1% of the total R&D. The investment in RE in India is about $3.8 billion with wind energy getting an investment of US$ 2.3 billion, followed by $400 million each for solar, biomass and waste -to –energy (Anon, 2010). Biofuels seem to be a well-established source of RE but has been slowed down by rising food prices. A robust and sustainable green economy will not be possible without the availability of funds both from private and public sectors to support investments in green services, technologies and infrastructure. For the technology to successfully penetrate there is a need to change the consumer behaviour appropriately.

5.3 Green jobs[3] and social inclusion

The employment qualification for the majority of people in India is high school degree or less, and green economy can use such people or those even with lesser education. It provides opportunities for low-grade jobs and help earn better wages and improve living conditions over time. Also, the renewable energy sector generates more jobs per million rupee investment and per megawatt of power in the construction, manufacturing and installation sectors, as compared to power generation through coal and natural gas. This is because green energy investments have labour-intensive character.

Also, in green economy, the economic activities take place in and around rural areas or small towns and activities such as construction of bio-gas plant or installing solar water-heating systems give boost to the local economy by creating jobs. By raising employment levels, clean-energy investments provide new opportunities to previously unemployed workers, which raises their productivity levels. At the same time, green economy investments create new opportunities for underemployed workers. This indicates that green-energy investments raise economy-wide labour productivity substantially by providing millions of people with new opportunities to become productive workers. At the same time, industries with a high percentage of low-income workers are better placed to achieve decent earnings which in turn increase activities in construction, manufacturing, employment services (temporary employment agencies), health services, public administration, social services, transportation and utilities, and wholesale trade.

Providing modern energy services through renewable energy resources (biogas for cooking and decentralised power for lighting) to rural households increases rural growth and livelihoods, and provides employment avenues. These services provide employment to the target communities, particularly the poor, marginalised, landless rural labour and other weaker sections of the population. Construction of biogas plant involves local labour, in the form of skilled (local artisans), semi-skilled and unskilled labour, who generally work as daily wage earners. It also generates employment and self-employment to trained local people in providing post-plant implementation services to the entrepreneurs who build biogas plants.

[3] A green job is a work in activities that contribute(s) substantially to preserving environmental quality. It includes jobs that reduce energy and material consumption through efficiency strategies, de-carbonise the economy and minimise the generation of waste and pollution.

In India, the rate of unemployment is generally lower than other developed countries, but its type is at the low end, that of wage labourer. The unemployment rate particularly in the age group of 15–24 is around 10% (NSSO, 2012). Almost half of the rural youth are on casual employment and hence are not regularly employed. Those who drop out of the school early join as casual labourers since many of them may not possess the necessary skills and experience required for regular wage jobs. This shows the mismatch between skill demand and supply. The green economy to be successful, it is important to increase quality of education and skill levels amongst the youth to benefit from this unique opportunity.

During 2010–11, there were 190 million people in the age group of 15–24 of which 18% are unemployed or under-employed (Mitra and Verick, 2013). If we increase labour intensity through green-energy investments—if we generate about 0.2 jobs per Rs. one million investments versus about 0.02 jobs through fossil-fuel spending—then we can reduce unemployment rate significantly through shifting spending toward green energy.

5.4 Green technologies—Skill development

5.4.1 Assessing the needs: For a successful development of green economy, the supply of skills is crucial. However, predicting long term skills supply, particularly in renewable energy industry, is really a challenge. This is because of uncertainty about the nature and scale of future demand since current demand from employers is poorly articulated (Levy, 2010). However, one can provide an intelligent guess. Manufacturing sector is highly relevant to renewable energy activities and technical skills are likely to be of significant relevance for this sector. In addition, science and engineering skills have been identified as of relevance for energy efficiency and renewable energy sectors. For a long-term perspective, skills development policies need to focus on early identification of skills to avoid future bottlenecks. The government should also focus on coordinating skills policies with national strategies on technology, trade, rural development and the environment to anticipate the sources of economic and employment growth and better prepare young people and the workforce for various activities across these sectors.

5.4.2 New skills for new jobs: Despite high unemployment rate, Indian companies are finding it difficult to source people with the required skills that a modern manufacturer needs. Much needs to be done to help companies get the skilled workers they need. The skills that need include: highly skilled (engineering graduates), intermediate-skilled (energy auditor, insulation worker, electrician, solar photovoltaic installer and sheet metal worker), and low-skilled (refuse/recycling collector). Many of the skill gaps overlap across different industries with common areas being; oral communication, team working, customer handling and technical or job specific skills. It is important to note that skill shortage is mainly due to the unwillingness of young people willing to take up these jobs. It is difficult to attract young talent to practical, manual work which is generally termed as ‘dirty job” with poor working conditions and low pay. Other reasons include lack of adequate training and irrelevant course material. Iimproved productivity of enterprises and improved worker employability can be achieved by (i) matching demand and supply of skills: Information on present skills demand and supply needs to be made available through labour-market information systems and employment and career services; (b) helping workers and enterprises adjust to change: ease the transition of workers and enterprises from declining or low-productivity activities and sectors into growing and higher-productivity activities and sectors. (c) skill upgradation: reskilling, upgrading and lifelong learning support workers in maintaining their employability and enterprises in adjusting and remaining competitive;

5.4.3 Curriculum development: The industrial training institutes in India should be encouraged to trains students in green skills by revising the existing curricula, qualification standards and training programmes. The training can be a multi-skilled training or even diploma level so that they can get employed in any setting[4]. This way, modern concepts will spread easily. The government should bear not only their expenses for training and hostel expenses, but also compensate them for the loss of livelihood during the period. Employers and training providers need to work on a long-term partnership to bring about these changes. However, in countries like India such active labor market policies are a challenge since the information gathering capacity is low, the training opportunities are limited and the trainers are almost non-existent in the green sectors (such as wind turbine installation and efficient building construction). For effective and efficient labour market and skill development policies, there is a need to collaborate between educational institutions, government and private sector– at the enterprise, industry and sector level (ILO, 2011). There is also a need to include ‘green’ skills across all of the training institutes. This would help meet the needs of various power generating companies.

[4] Carrier in US has experimented with this and was successful. Years ago Dubai and middle east countries preferred multi-skilled South Koreans to anybody else as they fit like jokers in playing card game

5.4.4 Revamping of ITIs: The setting up of the Industrial Training Institutes (ITI) by the government of India was to meet the need for skilled labour in the manufacturing and services sectors. However, the ITIs are unable to match the expectations of the industry and hardly any attempt has been made to understand the level of skill the industry needs. Presently, there are 11,000 ITIs (20% government and 80% private) with a seating capacity of about 1.5 million. A total revamp of the skill development of youth is needed with a focus on providing placement in tune with the demands of employers. Focus also should be on skill upgradation, quality and quantity of infrastructure, relevance of the courses and skill training.

There is also a need for the collaboration between government authorities and business houses to develop industry-endorsed training programms that give graduates nationally recognised technological skills and provides skilled employees with a diploma certificate. Developed with industry input and support, these programs can give students an education that they can take with them wherever the job market leads them to. Secondly, there is need to create a nationwide, online skill database that would link students, colleges and employers. Both small and large companies would be encouraged to register on the site, listing the types of skills they need and, where appropriate, the partnership training they offer or are willing to offer through the local colleges. Colleges, meanwhile, would register the courses they offer and the areas in which they would be interested in partnering with businesses. Owned by the government and supported by subscription fees to participating companies this database could substantially ease the process of forming public–private skill partnerships and develop millions of skilled workers[5].

6.CONCLUSIONS

With increasing energy security challenges and decreasing natural resource base, India needs an aggressive policy agenda to promote green technologies that are effective in building a clean-energy path as rapidly as possible while developing significant employment opportunities. Based on the results of this study, an alternative GE scenario emerges which recognises the value of natural resources, increases job potential, reduces import dependence, increases growth and builds local economies. For example, the use of coal and oil is

[5] It can be further simplified using IT.

estimated to decrease by 15, and 30 per cent, respectively relative to BAU by 2030, with clear benefits for the productivity of various sectors and avoid negative consequences arising from their depletion. Through the substitution of traditional energy resources with low-carbon alternatives, CO_2 emissions will be considerably lower than BAU over the next 15 years. We have examined the effect measuress on job creation and economic growth which effectively operate as a complementary set of policy initiatives that could produce about 10 million job opportunities over the next 15 years. The employment growth involves a combination of clean-energy investments—building retrofits, public transportation, and constructing a smart grid, as well as promoting renewable energy sources such as wind, solar, and biomass power—and will generate roughly five times more jobs than an equivalent amount of money invested on conventional fossil fuels.

The green economy results in the protection of natural resources benefiting the individual and society as well as the global stakeholders. For example, global stakeholders benefit from the reduced carbon emissions, while local people benefit from employment opportunities and improved services. From a social cost-benefit perspective, the benefits outweigh the costs. However, to attain a green economy the appropriate policy package should be in place which will be critical in determining the kind of investments that will be needed and the incidence of costs and benefits, i.e., who will pay and how much. There is a need for greater emphasis on engaging stakeholders, at all levels. These results provide a basis for policy discussions on investments, policies and incentives to be put in place by national and local governments.

References

Ahn S and Graczyk D, 2012, Understanding Energy Challenges in India: Policies, Players and Issues, International Energy Agency, France

Anon, 2009, Opportunities for Employment Generation and Training requirement for Skilled Manpower, Presentation at the International Conclave on Key Inputs for Accelerated Power Generation, New Delhi.

Anon, 2009, Working for the climate: Renewable Energy and the Green Job [R]Evolution, Report on Global Job scenario, Green Peace.

Development of Indian Power Sector for 12th Plan, National Power Training Institute, Faridabad.

Anon, 2010, Human resource development strategies for Indian Renewable Energy Sector, Ministry of New and Renewable Sources of Energy, Government of India.

Anon, 2011, Census of India. 2011, Distribution of households by source of lighting. Government of India, New Delhi.

Anon, 2013, Growth of electricity sector in India (1947-2013), Central Electricity Authority, Government of India, New Delhi.

Anon, 2012, BP Energy Outlook *2030*, London.

Anon, 2013, Employment effects of selected scenarios from the Energy roadmap 2050, Final report for the European Commission, Warwick Institute for Employment Research, Cambridge, UK.

Anon, 2014, Long-Term Energy and Development Pathways For India, Report prepared by the Indo-German Centre for Sustainability, IIT Madras.

Balachandra P, Nathan H S K and Sudhakara Reddy B, 2010, Commercialisation of Sustainable Energy Technologies, *Renewable Energy*, Vol 35, pp 1842-1851.

Boden, T.A., G. Marland and R.J. Andres, 2011, Global, Regional, and National Fossil-Fuel CO_2 Emissions, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A

Carragher V, McLoughlin P J and Kenny P, The Job Creation Prospects of Renewable and Sustainable Energy Technologies, available at http://tea.ie/wp-content/uploads/2013/07/Carragher-et-al-2013.pdf

CEA, 2012, Central Electricity Authority: *Annual Report: 2007-08*, Ministry of Power, Govt. of India.

Comings T, Fields S, Takahashi K and Keith G, 2014, Employment Effects of Clean Energy Investments in Montana, Synapse, Cambridge, Massachusetts.

Elzen B, Geels F W, and Hofman P S, 2002, Sociotechnical Scenarios: Development and evaluation of a new methodology to explore transitions towards a sustainable energy supply, University of Twente: Centre for Studies of Science, Technology and Society, Enschede.

IEA, 2012, World Energy Outlook 2010, China and India insights, OECD/IEA, Paris, France.

IRENA, 2013, Renewable Energy and Jobs, International Renewable Energy Agency, Abu Dhabi.

Jay Rutovitz, Alison Atherton, 2009, Energy Sector Jobs To 2030: A Global Analysis, Institute for Sustainable Futures

Kammen D M, Kapadia K and Fripp M, 2013, Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?, Report of the Renewable and Appropriate energy laboratory , Energy and Resources Group, Goldman School of Public Policy, Berkeley, CA, United States.

Kejun J, 2011, Potential, Secure, Low Carbon Growth Pathways for the Chinese Economy, Working paper, Energy Research Institute, Beijing, China

Levy C, 2010, A 2020 Low Carbon Economy, The Work foundation.

Mathias G, Erik S, Peter S and Lars Z, 2009, Energy Scenario for Sweden 2050, Report prepared for Swedish environmental research institute.

McCarthy R, Yang C, and Ogden J, 2012, California Baseline Energy Demands to 2050 for Advanced Energy Pathways, Institute of Transportation Studies, University of California, Davis.

Mitra A and Verick S, 2013, Youth employment and unemployment: An Indian perspective, International Labour Organization, South Asia and Country Office for India. - New Delhi: ILO.

NSSO (National Sample Survey Organisation), 2011, Results of the National Sample Survey, 66th Round, NSSO, New Delhi.

Planning Commission, 2012, *Eleventh Five-Year Plan, 2007-12, Agriculture, Rural Development, Industry, Services and Physical Infrastructure*, Vol. III, Planning Commission, Govt. of India, New Delhi.

PMEAC, 2010, Prime Minister's Economic Advisory Council: *Review of the Economy 2009-10*, Govt. of India.

Pollin R, Wicks-Lim J and Garrett-Peltier H, 2009, Green Prosperity: How Clean-Energy Policies Can Fight Poverty and Raise Living Standards in the United States?, University of Massachusetts, Amherst.

Rutovitz J and Atherton A, 2009, Energy Sector Jobs To 2030: A Global Analysis

Report for Green Peace International, Institute for Sustainable Futures, University of Technology, Sydney.

Sarewitz, D. (2000). Science and Environmental Policy: An Excess of Objectivity. Columbia University, Center for Science, Policy, and Outcomes

Sudhakara Reddy B, and Srinivas T, 2009, Energy Use in Indian Household Sector—An Actor-Oriented Approach, *Energy-The International Journal*, 2009, 34 (6).

Sudhakara Reddy B and Nathan H S K, Emerging Energy insecurity—the Indian Dimension, 2010, India Development Report, Oxford University Press, New Delhi.

Sudhakara Reddy B and Ray B, 2010, Decomposition of energy consumption and energy

intensity in Indian manufacturing industries, *Energy for a Sustainable World*, 14, pp 35-47.
Sudhakara Reddy B and Ray B, 2011, Understanding industrial energy use: Physical energy intensity changes in Indian manufacturing sector, Energy Policy 39: 7234–7243.
Sudhakara Reddy, Balachandra P and Nathan H S K, 2009, Universalization of access to modern energy services in Indian households—Economic and policy analysis, *Energy Policy*, 37 (11), pp: 4645-4657.
Sudhakara Reddy B, 2014, Mainstreaming Energy Access*:* An economic and policy framework *(*Paper submitted *to Energy Policy).*
Sudhakara Reddy B and Balachandra P, 2003, Integrated Energy-Environment-Policy Analysis, *Utilities Policy* Vol 11, No 2 pp 59-73.
TERI, 2012, The Energy and Resource Institute (TERI) Energy Data Directory and Year Book (TEDDY) 2009/10, TERI Press, New Delhi.
UN, 2010, United Nations: *World Urbanization Prospects: The 2007 Revision*, Online Database. <http://esa.un.org/unup> (accessed 26.02. 10).
UNEP, 2011, Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication—A Synthesis for Policy Makers, www.unep.org/greeneconomy
Wei M, Patadia S, and Kammen D M, 2010, Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?, Energy Policy, 38, 919–931
UNEP, 2011a, Global Trends in Renewable Energy Investment, United Nations Environment Programme, Frankfurt School, Frankfurt.
UNEP, 2011b, Modelling global green investment scenarios: Supporting the transition to a global green economy, United Nations Environment Programme.
Venugopal S and Srivastava A, 2013, Reading resources on using public climate finance to leverage private capital, WRI WORKING PAPER.
World Bank, 2008, Residential consumption of electricity in India: Documentation of data and methodology, Back ground paper, The World Bank.

Appendix 1: Scenario Assumptions

Time		BAU		GE	
		2010–20	2020–30	2010–20	2020-30
GDP		7.2	5.8	8.7	7.3
Population		1.1	1.0	1.1	1.0
Urbanisation		2.4	2.6	2.4	2.6
Power plant efficiency (%)		32	33	37	39
T&D losses (%)	25	20	18	20	18
Rate of growth of Vehicle stock(*)		6.5	2.9	6.5	2.9
Energy intensity (PJ/Mt) (**)	21	18	15	12	8
Device efficiency in HH sector (%)					
Cooking (biofuels)	12	20	25	30	35
Lighting (electricity)	8	20	25	30	40
Energy intensity of passenger transport (kgoe/km)	0.6	0.5	0.4	0.4	0.3

*Note: (*) Only bulbs, TV, refrigerator, washing machine, micro wave, geyser, fan and AC are considered; R*ef: World Bank, 2008.

(**) Only five types of industries are considered: Iron and steel, aluminium, textiles, cement, and paper. Ref: Reddy and Ray, 2011.

Appendix 2 : Employment benefits due to decentralised power/energy generation

Type of Job	Biogas plant	Small hydro power	Small Wind	Solar lighting – Solar lighting (decentralized)		Total
No of units	2486833	6219	373	75000 (*)	200000 (*)	
Capacity (MW)						
Blacksmiths	8290					8290
Masonary	4145	21			200	4366
Entrepreneurs	2486833	6219	373		500	2493925
Plumber	16580				700	17280
Plant operator	2486833	6219	373			2493425
Technician	2486833	6219	373			2493425
Biomass collector cum storekeeper	2486833					2486833
Customer care, sales, cum accountant	2486833	6219	373			2493425
Engineer		124				124
Local supplier, manufacturer				200		200
Street lighting maintenance				500		500
Others (equipment manufacturer, local dealer, etc.)	2920	250	180			3350
TOTAL	12466097	25271	1672	700	1400	12511810

(*) Panels (**) Street Lighting (Nos.)

Assumptions:

1. Each community biogas plant, would provide at least five people full-time employment opportunities: One entrepreneur, one plant operator, one technician/electrician, one biomass collector cum storekeeper, one customer care executive-cum-accountant.
2. Assume 1 engineer per 50 plants
3. For construction of biogas plant, the program would demand the service of one blacksmith per 10 plants, one masonry per 20 plants and one plumber per 5 plants per year
4. Assuming 30 years of work life, we can work out the number of masonries, blacksmiths, and plumbers required for the purpose
5. Assuming 15 jobs per MW as local dealers, equipment manufacturers, agri-processing industries (reference bio power employment Austria 19 jobs/MW)

(Ref: bio-power: http://www.biogasin.org/files/pdf/Highlights_of_socio-economic%20issues.pdf

6. Full employment can be assumed for one hydraulic engineer per 50 plants.
7. Assuming 10 jobs per MW as local dealers, equipment manufacturers, agro-processing industries.
8. Each wind power plant, would provide at least four people full time employment opportunities: One entrepreneur, one plant operator, one technician/electrician, one customer care executive-cum-accountant.
9. For manufacture, component supply, wind farm development, installation and indirect employment at wind power plant, the programme would generate 12 jobs per MW (ref: India wind power outlook) in terms of manufacturing, installation, component supply, wind farm development.
10. Assuming one job for 1000 lighting systems in terms of supply
11. Assuming one maintenance person per street lighting in 50 villages
12. Assuming jobs@MW = 15 (Reference)
13. Assuming jobs@MW = 30 (ref: Rajasthan Project)
14. Assuming jobs@MW = 2 (ref: mospi)
15. Assumed one-half of the loss case, as students might use lamp now

Appendix 3: Green investments and jobs

Major area	Representative jobs
Biogas plants	Electricians, welders, metal fabricators, engine assemblers, construction equipment operators, insulation workers, contractors
Mass transit/freight rail	Civil engineers, rail track layers, electricians, welders, metal fabricators, engine assemblers, bus drivers, dispatchers, locomotive engineers, railroad conductors
Smart grid	Computer software engineers, electrical engineers, electrical equipment assemblers, electrical equipment technicians, construction laborers, operating engineers, electrical power line installers and repairers.
Wind power	Iron and steel workers, sheet metal workers, machinists, electrical equipment assemblers, construction equipment operators, truck drivers, industrial production managers, production supervisors, environmental engineers,
Solar power	Electrical engineers, electricians, mechanics, welders, metal fabricators, electrical equipment assemblers, construction equipment operators, installation helpers, laborers, construction managers
Biofuels	Chemical engineers, chemists, chemical equipment operators, chemical technicians, machine operators, agricultural workers, truck drivers, farm product purchasers, agricultural and forestry supervisors
Energy efficiency	Electricians, retrofitting persons, insulators, dispatchers