International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 4 Issue 9, September-2015

Perspectives and Projections Based on the Current Indian Energy Scenario

Trina Som[1], Rahul Pathak[2]

[1]Department of Electrical Engineering, JSSATEN, UPTU University, C-20/1, Sector 62, Noida, 201301, India
[2]Department of Electrical & Electronics Engineering, NIEC, IP University, FC- 26,Shastri Park, New Delhi, 110053, India

Abstract: The centralized power delivery schemes incur high amount of transmission losses, heavy maintenance, and installation and protection costs. Thus the concept of delivering power only through centralized delivery schemes to remote customers is considered to be techno-economically and techno-environmentally unviable for the 21st century and partial or total replacement by a decentralized power delivery systems has been predicted in the recent literature. Unlike the conventional grid, the resources required for decentralized power delivery, known as distributed energy resources (DERs) are gaining fast attention due to their sustainability towards environment and flexibility of siting. Even though the technological advantages of DERs are apparent, in order to make the microgrid concept economically viable to the consumers, a standardized and competitive price structure has to be established in the electricity market. In this study, the economical and environmental cost of generating electricity by conventional and non-conventional energy is ascertained through analysis of recent time trends and inferences are drawn on the future role of non-conventional and renewable resources and decentralized power delivery systems in the Indian energy scenario.

Keywords: DERs, Economy, Renewable, Environment, Micro grid, Time, India.

1. Introduction

A relative study of both conventional and non-conventional energy sources based power delivery systems over past several years has been dealt with. According to previous records, it has been known that about 54% of the total installed electric generation capacity is based on coal [1]. Further, an addition of coal based power production of about 67% of the total installed capacity has been made during the 11th five year plan period (i.e. from 2007 to 2012). Apart from electric power production, about 53% of commercial energy during 2008 to 2009 was also met up from the coal. Thus almost about 70% of the total installed capacity in India is coal based. [1]. Moreover, most of the thermal power plants in India is mainly coal and lignite based, so lignite production is equally necessary as that of coal [2].
However, the shift in paradigm of electrical technology from conventional to non-conventional type can be analyzed through various aspects, which has been arranged in following sections, in the time based stud Among these sections, the first three sections pertain to the economics of conventional energy resources and discuss the recent time-based evolution of the costs of thermal coal, conventional power plant-setup and labor costs and conventional electricity pricing, respectively. The fourth section brings in an environmental perspective by discussing the concept of carbon credit tax and performing related calculations. The sixth section discusses non-conventional power plant set-up costs and non-conventional electricity pricing. In the last section, a predictive conclusion is arrived at.

2. Coal Cost

In developing countries, such as India, the growth in economy remains highly dependent on amount of energy consumption. Consequently production of electric power always played a crucial role in socio-economic development of the country. India has a long history of electric power generation following from huge load demand. The first hydroelectric power plant was set up in India at the foot-hills of Darjeeling having an altitude of 3600 ft or 1100 m. This oldest hydel-power delivery system was named as Sidrapong Hydel Power Station [3]. Asia's oldest thermal power plant was developed in 1952 at Bokaro under India's first multipurpose river valley project [4]. Since then, the supply of electricity has been mainly based on coal power. About 51.7% of total power in India is produced from coal as energy resource, and around 35% is produced from both imported and produced mineral oil, while the rest is generated from other resources [5]. The

economic reforms of 1990s leading to globalization of the Indian economy form an important land-mark in coal-based power. With a coal-based power generating capacity of about 70% of total installed capacity [6], government of India initiated certain economic reforms in 1991.With the aim of reducing prices, the principle of economic globalization started encouraging imports and exports [7] in 1993 by opening of coal sectors to private investment without any restriction. Ministry of Coal has fixed different polices and strategies though sanction of important high valued projects in respect to the assessment and development of coal along with lignite reserves. These policies also deal with many related issues. Central government and public sector undertakings such as Coal India limited (CIL), Nevyeli Lignite Corporation (NLC) limited and Singareni Collieries Company limited (SCCL) [1] have started implementing the above mentioned key features or policies. Further, Government of India has undertaken a joint sector with Government of Andhra Pradesh with an investment share of capital about 51:49 respectively [1] to follow the strategies. Despite the strategies and policies adopted by several sectors in India with increase in the electric power consumption the demand for coal also increased to a large level during years [5]. The coal consumption by power utilities has been noted around 199.6 million tons (Mt) in 1996 to 97, while the consumptions have been found to increase to around 250 Mt in 2000/01[6].

Currently, this situation has resulted in a demand–supply gap of around 85 million tons [2]. The authors [2] also predicted the increment in demand-supply gap to nearly 140 million tons by 2017. Consequently to meet this increasing demand supply gap, India also started importing coals from other countries. Presently, India imports about 85 million tons of coal, which includes about 50% for generation of electricity in thermal power plants. The rest amount is however used in different industrial purpose as well as coking coal. Australia, Indonesia, New Zealand and South Africa are the main countries from which thermal coal is imported by India in present scenario [1]. The dearth of coal as a resource for electric power production has also encompassed many other countries. This gives rise to import thermal coal from international market. Hardening in coal price has been concomitant with a huge growth in ocean carriage charges. Subsequently many consumers have already started investing for fair coal charges in conventional coal exporting countries while many others are exploring new coal deposits in other countries. This resulted in an unstable variation of coal prices, which are assumed to be in uncontrolled state until and unless an increment in productions of coal and suitable developments related to the infra-structure does not occur in the coal exporting countries.

Hence, in response to huge power demand, a change in normal trade pattern occurred pertaining to an upward trend in coal prices. Again as India is a developing country, so the change in trade pattern affects geopolitical disquiets which consequently leads to coal security problems. This price instability due to scarcities of coal, and lack in infrastructure to move coal to and from the ports, highly affected the energy security, economics, and geopolitics of India. This made an end to the existence of a well-developed open market. This again may lead in introducing equity investments for future coal mines in dealing and sourcing coals from different countries, as an urgent requisite. Since 2003 to 2005 the instability in coal price has been noticed at large and is found to be almost doubled within a year. The typical rise as reported [8] was from a value of about $30/ton in May 2003 to a value of $70/ton in 2004. Finally the increasing trend in the price of non-coking coal reached at around $100/ton in 2007. Thus the shortage of non-coking coal causes dependence for the coal on different developed countries, resulting in the price inflation. So, with increase in electric power demand, the pattern of interdependency also increases. A typical picture for this incremental trend in importing non-cocking coal has been depicted by the authors in [8].USA, Canada, and Mozambique are rated as the fastest emerging sources to supply coal. In focus to total global reserve of coal, the international market today is limited to about 700 MT/year [2]. Thus, despite the anticipated growth in power demand, the same is unlikely to be met through increase in import volumes of coal.

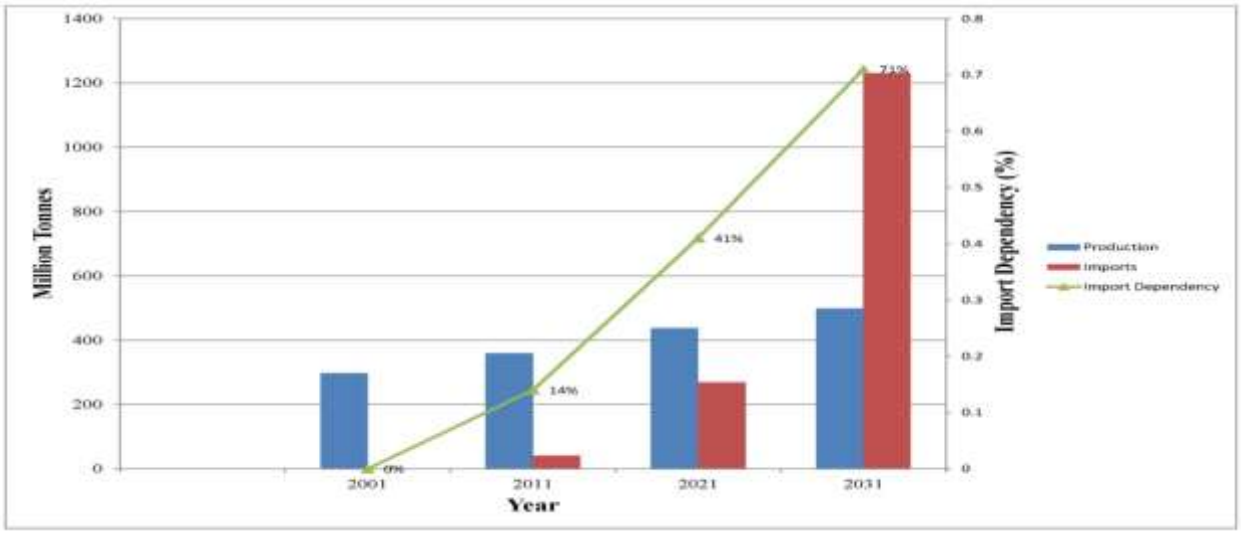

Figure 1: Trend of Interdependency of Indian Coal

Moreover, coal prices are dictated by wide range of factors like political dispute within the global international relationships leading to trade embargos, exchange rate of currencies, international oil prices, and productivity rate of coal mines and depletion of resources. These all lead to price fluctuation in coal price [23],[28] . For India which is vying for energy security and sustainability, there are serious apprehensions on role of coal for energy requirement in future.

Figure 2: Coal prices over the years

In focus to the non-desirable emission of carbon and particulate matters, the quality of coal used in thermal power plants is of high concern. As an outcome, along with the production volume of non-coking coal, the quality of coal also plays a vital role in electric power production. Due to increased carbon-dioxide emissions from conventional thermal power plant certain undesirable effects are caused resulting to a global change in climatic conditions. In consideration to this scenario, supercritical steam parameters have been adopted by many Ultra Mega Power Plants, especially in developed countries. Recently the countries like India and China mainly face a huge power demand with increasing growth rates. However, the governments of countries in the developing world, have attempted to introduce the usage of coal with subcritical steam parameters in the electric power producing plant, which has undesirable from both emissions and efficiency point of view. Heavily coal dependent countries having huge amount of coal consumptions consequently faces another price hike for enhancing the quality of coal production.

In context of improving the quality of non-coking coal different washing procedures have been mentioned in [2] with intent to reduce the content of ash from an inferior grade coal. The procedure has achieved an ash reduction to 34% through a single target washery model. It has also been noted that the introduction of the washery system can reduce the emissions of suspended particulate matter (SPM) and CO_2 by approximately of about 42,000 and 100,000 tons, respectively, as compared to projected "business as usual" levels in 2006-07. A 40% increase in costs has found to take place over the baseline cost for the coal handling process [2]. Thus the coal treatment process becomes economically unfit.

3. Conventional Power Plant Set-Up and Labor Cost

The real gross domestic product (GDP) growth of any country has a close relation with the electric power production [1]. For developing countries like India, China, the high growth of GDP derives from three factors, viz consumption, investment, and government spending. For India, the predicted average annual increment rate of GDP is 4.1% between the years 1985 and 2030 [7]. The fall in GDP growth rate is mainly due to shortage in supply of labor, which was mainly due to the slowdown in the growth of population as shown in table 1 below [7].

Table 1: Labor Cost Trend [4]

Year	Labor Supply	Percent at Work	Annual Wage (in Rs)	Average Annual Wage Growth Rate (%)
1985		67.3	59.43	
1990	4.16	70.9	66.82	2.37%
1995	4.15	74.7	76.31	2.69%
2000	2.77	78.8	89.93	3.34%
2005	2.18	81.9	103.93	2.94%
2010	1.93	84	116.86	2.37%
2015	1.91	85.4	128.19	1.87%
2020	1.92	86.4	138.12	1.50%
2025	1.69	87.1	147.96	1.39%
2030	1.46	87.7	158.91	1.44%

In order to gather more labor power a labor force participation was introduce in 1985 which predicts an increment of the labor supply from 67% (in 1985) to 87% in 2030. The data in the above table depicts a rate of growth in the labor supply of about 1.46% per year by the year during 2030; while this rate was much larger of about 4.16% per year in 1990. Another reason behind this shortage in percent at work is the age factor of the population. However, it has been inferred from the data in table 1, that the average annual growth of population is 1.6% while this rate of growth in supply of labor was observed to be 2.5% [7]. Consequently, with deficiency of labor supply the labor cost increases. For the same amount of job to be done the capital/labor ratio will subsequently increase. This decrease in the labor growth resulted in an increase of labor cost from Rs 22,821 per worker to Rs 72,132 per worker [7]. Apart from the enhancement in daily or monthly wages of labor, the economy of the country is also affected only through production in demand for goods and services. The lack of significant growth in the labor force will translate to a lack of investment in the conventional power sector, according to the authors of [7].

4. Conventional Electricity Price

A major portion of electric power in India is generated by the thermal power plants. Again the governing fuel for the thermal power plant is coal. As per records of Government of India in the years 2011 and 2012, about 83 percent of installed generation capacity is based on thermal power [10]. Hence, the unavailability of coal leading to expensive coal cost, as mentioned earlier in section 1, will obviously have some effects on the electricity price. The pricing structure of electricity in India is generally developed on an incremental block tariff composition which includes marginal increment in the electricity price in proportion to the amount consumed. Depending on extremities and duration for different seasonal conditions different states of India generally have different conventional electricity price. As the electricity charges changes with amount of electric power consumed, so the electricity price also varies between huge industrial consumers and low rural consumers. A trend in this regard has been presented by the authors in [29] as shown on Figure 3. Further, increase in cost of supply of electricity has been presented in figure 4.[24]

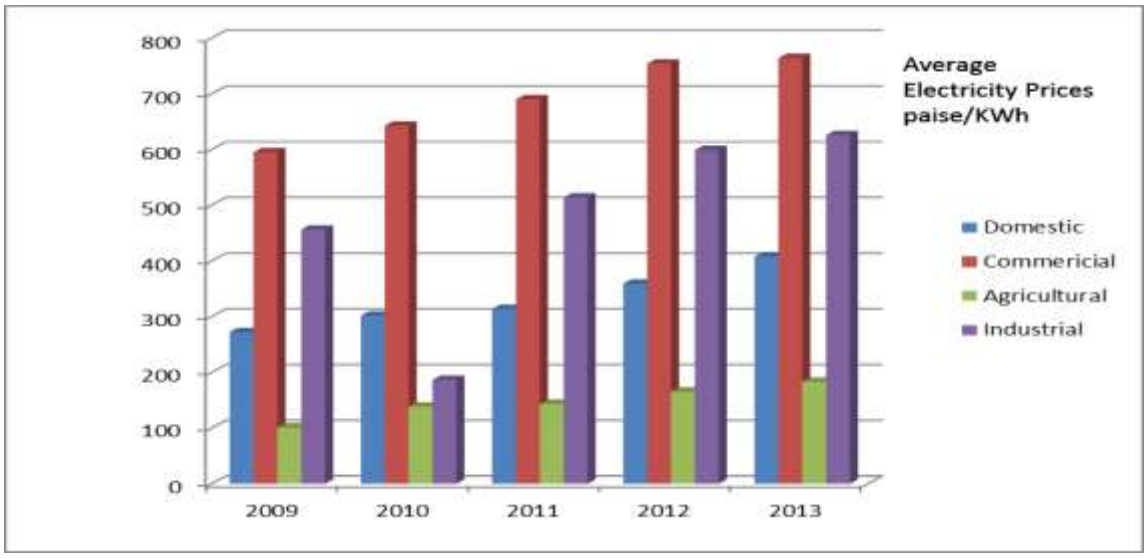

Figure 3: Average Electricity Price for Different Categories of Users over Past Year

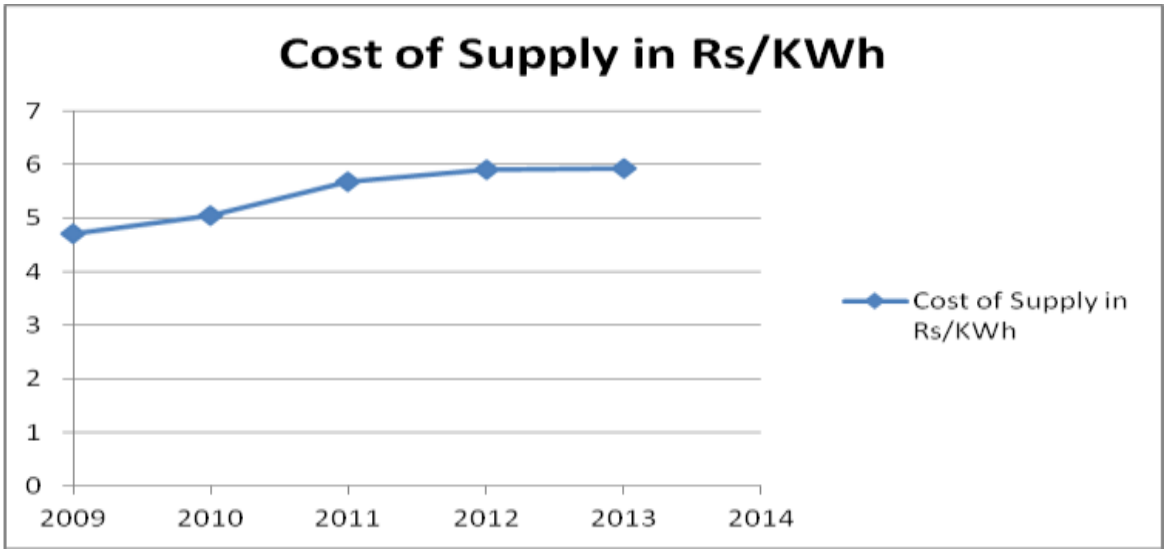

Figure 4: Trend of cost of supply of electricity from conventional sources.

5. Carbon Credit Tax

Carbon credit is basically defined as authority or right to emit a certain amount of carbon dioxide by any power producing plant. To diminish the concentration of greenhouse gases, both national and international countries have made attempt in restricting an equivalent amount of emitted carbon. According to the Indian module of their second generation model (SGM), the authors in [7] analyzed the emissions performance on the basis of three levels of stabilizing emissions. To drive the industrial and commercial processes in the direction of low emissions or less carbon intensive approaches, the carbon market policies generate credits on the green house gas (GHG) emission or equivalent amount of carbon emission. Moreover in focus to greater market orientation toward public distribution system more enhanced economic reforms have also started. Moreover, the impact of rapid economic development on environment resulted in placing a certain amount of charges on carbon or green house gas emission. Energy and carbon emission trends have been depicted **[27]** in the table 2, as shown below;

Table 2: Carbon Emission Trend from Conventional Power Plant

Years	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Energy Generation (GWh)	350407.40	374511.62	386677.11	401948.34	414059.39	444455.41	476992.47	508963.24	533113.44
Total Carbon Emission(kg/ kWh)	0.92	0.92	0.94	0.93	0.91	0.94	0.95	0.95	0.94

The results pointed an increase in power consumption occurred about 2 times, while that of carbon emission is around three times. Almost a six-fold increase in carbon emission has been predicted by the authors [11] from 1985 to 2025. As per recent records [12] the annual total amount of carbon emitted by India is about 1875.5 Mton. Further, according to [13] the total amount energy produced per year in India is about 600 Billion kWhr. The percent of carbon emitted from conventional power producing schemes is about 88.8; while that produced from non-conventional source constitute 11.2 % [14]. The European Commission has adopted several structural measures to make the carbon credit market more competitive [9]. The amount of carbon emitted per kWhr during the years as shown in table 2 [27] is about 0.95kg Therefore, the amount of carbon emitted in tonnes/kWhr can be calculate as

$$CO_2(tons)/kWhr = 0.95 \times .001102 = 0.00104$$

Further, the total energy generated per year as observed from table 2, is about 533113.44 GWh; i.e. 533113 $*10^6$ kWh. Therefore, the total CO_2 emitted over a year results to

$$CO_2(\text{tons}) = 533113 \times .00104 \times 10^6 = 554.4375 \times 10^6$$

Thus a carbon credit is valued at 10 €/ton, as of April 2013. The conversation factor results in Rs 700/ton. The carbon credit tax for 4.97ton/ kWhr of CO_2 emission in an Indian scenario becomes around Rs 3478/kWh.

The carbon credit tax for 0.728/kWh (700*0.00104) of CO_2 emission in an Indian scenario becomes = Rs 388106.25 $*10^6$(700*554.4375*10^6). Consequently a huge amount of annual carbon credit occurs.

Moreover, apart from the cost the results of this analysis show that coal is taking a heavy toll on human life across large parts of the country. Estimated annual health impacts and health costs due to PM pollution from coal-fi red power plants in India, 2011-12 is shown below in the table 3[30].

Table 3: Health Impacts and cost due to Carbon Emission

Effect	Heath Impact	Health Cost (Cores in rupees)
Total premature mortality	80,000 to 115,000	16,000-23,000
Child mortality (under 5)	10,000	2100
Respiratory symptoms	625 million	6200
Chronic bronchitis	170,000	900
Chest discomforts	8.4 million	170
Asthma attacks	20.9 million	2100
Emergency room visits	900,000	320
Restricted activity days	160 million	8000

Hence, a thrust of developing more renewable energy has taken a toll over recent years.

6. NON-CONVENTIONAL POWER PLANT SET-UP COST

Over past several years, electric power consumption as well as demand for electricity has increased. Graphical information in this regard has been presented by the authors of [29] in figure 5.

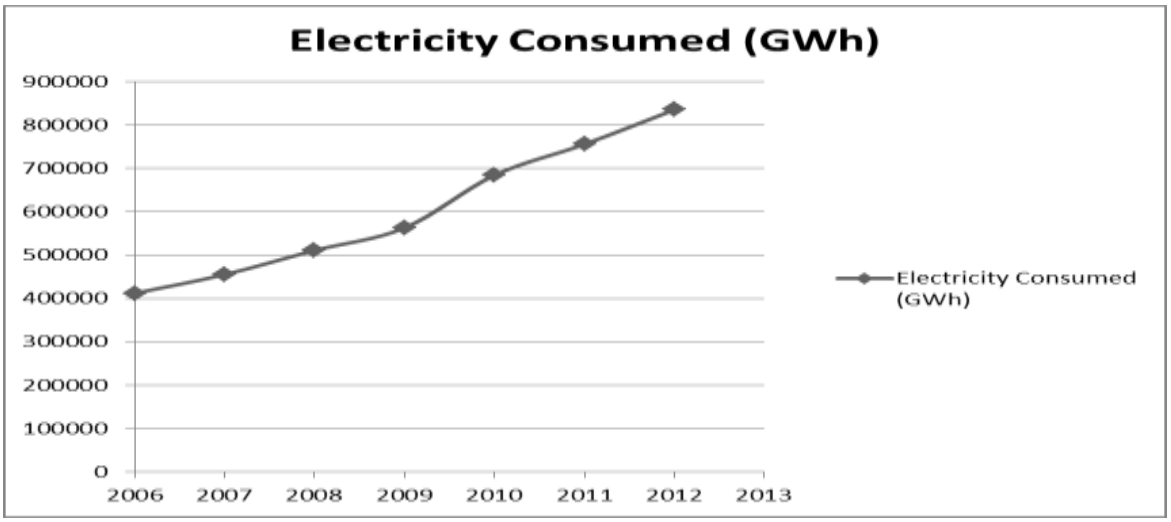

Figure 5. Trend in Electric Consumption in India

With the growing consumption of electric power and simultaneous scarcity of high-grade coal used by conventional power grid, the demand-supply gap has increased resulting in continuous inflation with time and the trends has been envisaged to remain same as mentioned in earlier sections. Beside the increasing trend of electricity price, India is having a national average energy shortage of about 10% [16]. This shortage of power delivery varies from 3% to 21% in different states. Thus power generation from non-conventional energy resources have started to emerge, in consideration of the above mentioned adverse effects. Although some of these emerging technologies may not be currently cost competitive with respect to that of conventional fuels, but renewable energy sources find its importance due to various other aspects. These aspects include rural electrification i.e. electric power production in those areas where conventional electricity supply is not feasible; and the undesirable environmental issues caused due to the usage of conventional fuels. However, considering the key factor, i.e. the shortage of power supply in Indian scenario the non-conventional energy delivering systems have fast gained importance. Besides, delivering the shortage of conventional power supply, renewable energy sources have been widely accepted for enhancing the energy security issues. The Ministry of Non Conventional Energy Sources (MNES) introduced several policies and programmes in support of promoting renewable energy technologies. These non-conventional or renewable energy options include, solar power, wind power, ocean thermal energy, bio-mass, wave energy, geo-thermal and tidal power. Through these promotional policies non-conventional energy sources achieved considerable progress and developed a good potential in India. Installed and possible renewable energy generation technologies in India, as recorded on 31.03.2013 have been presented in table 4 below [29]

Table 4: Renewable energy based installed capacity

Renewable energy sources	Potential (MW)	Installed Capacity (MW)
Wind	49130	19051.46
Small Hydro	19750	3632.25
Biomass	17538	3601.03
Bagasse-based cogeneration in sugar mills	500	89.68

Despite the fact that renewable power generation technologies have been adopted, the installed capacity of renewable-energy-based electricity systems in India is about 28,067 MW among a the total installed capacity of about 2,66,644 MW as on 31.03.2013 [29]. Thus it can be concluded that the utilization of renewable energy for electricity generation has remained insignificant with respect to the overall power generation scenario in India.

Though the renewable or non-conventional power resources have proved to be better in terms of delivering clean power, but the pricing of power generated from renewable energy sources continues to be the most serious issue. In focus to this key factor various policies have been implemented to overcome this issue in India, which can be explained as follows [16];

- The Ministry of Non Conventional Energy Sources (MNES) prepared and introduced policy guidelines in 1993 which included certain factors, viz, accelerated depreciation, concessions regarding the banking, controlling third party sale with others, thereby encouraging the power generation from non-conventional as well as renewable energy sources.

- In recognition to the importance of different renewable and non-conventional based power delivery systems, Ministry of Power introduced The Electricity Act in June 2003 (EA 03) and notified the National Electricity Policy with some added factors to be followed. These factors or rules were operated on the agreement with National Electricity Policy. Calculation of tariff was made under mandatory consideration to set a certain percentage of quotas for renewable energy among the total consumption of electricity in the area having license for distributed generation.

The results from the above-mentioned promotional policies are evident in the growth in installed renewable capacity as depicted in fig. 6 below [25-26]

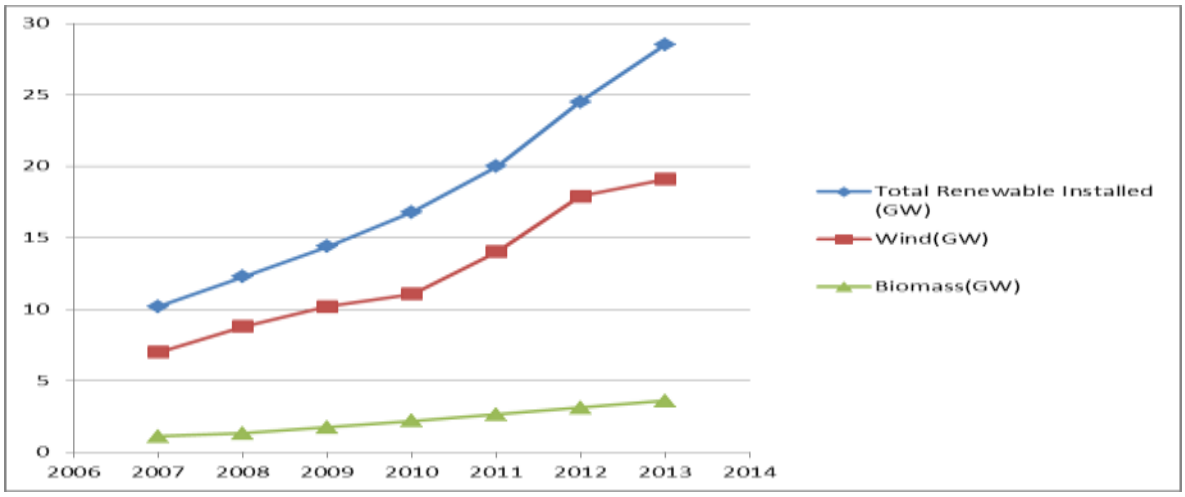

Figure 6: Renewable installed capacity (GW) trend

The rules or policies relating to the installation of renewable energy resources set forth by governmental attempts of popularizing distributed generation generally differ from country to country, but still they comprise some common features [18]. These features are as follows;

- Feed-in Tariffs: The phrase feed-in tariff is generally defined as the minimum guaranteed price per unit of delivered electricity which has to be paid to the producer, as decided and approved by the regulator [19]. Generally, the tariffs for non-conventional energy resources have a value as a premium in addition to market electricity prices. However, regulatory measures have been taken through usage of policy instrument for the promotion of renewable electricity production. These applied regulatory rules enforce an obligation on electricity utilities to pay a price as specified by the government for the non-conventional or renewable energy power consisting independent producers. The level of the tariff is commonly set for a number of years, in focus to secure the income of investors for a considerable part of the project lifetime.
- Renewable Portfolio Standards (RPS) and Renewable Energy Credits (RECs): The dominant features of the policy instrument in determining the pricing of renewable energy power, has been mentioned in the above point. In this context, the best practices followed in the international level in terms of demand or supply of renewable electricity and Feed-In-Tariffs are noted. Many different adaptations have been taken on electricity generation or on the installed capacity of renewable electricity plants and several other instruments are also applied in this regard. For example the German federal government, as well as the state and district governments, has placed a number of measures for promoting renewable sources of energy [17].Unlike conventional power pricing, where the pricing

laws are first established and the market determines capacity and generation; the adopted quota policy works differently. The working principle of quota is based on a mandatory minimum share of capacity or generation of electricity that should come from renewable sources. According to the mandatory target set by the government, the market determines the price.

- Tendering Schemes: The tendering schemes or methods are generally decided and set up by the regulators, through which an amount of capacity or share of total electricity can be achieved, with a focus to maximum price per kWh [19]. On the basis of the calculated shares and prices, the project developers then submit price bids for an agreement. These are generally country specific.
- Other incentive mechanisms: Beside, the regulatory policies determining the tariffs, quotas and tendering methods, Government has also taken some other additional initiatives to support the development of renewable energy technologies. Secondly, attention have been paid over the financial issues by including investment tax credit, loan guarantees, low interest loans, production tax credit, and investment subsidies. However, the new legislation on renewable energy builds upon the "Act on the Sale of Electricity to the Grid" passed in the German Parliament in 1990, as a proposal with many better features [18].

7. NON-CONVENTIONAL ELECTRICITY PRICING

Though the non-conventional power delivery systems, utilizing different renewable and non-conventional energy resources, have gained increasing attention from 1994 onwards as shown in fig 6; but the pricing has always been a critical issue. According to the policy guidelines prepared by The Ministry of Non-Conventional Energy Sources (MNES), which helped in the promotion of power generation from renewable energy sources in India, different states have adopted the MNES guidelines to varying degree. As the climatic and political factors are different for different states so several modifications in the state level policies are made. These modifications sometimes may causes an adverse effect by weakening the rules and regulations of MNES, and may sometime provide additional benefits to renewable energy sources.

In focus to an improved operation of power sector entities in the country, it is necessary to create a favorable environment for investments in the area of non-conventional electricity. These favorable features of the policy guideline includes purchase of electricity at Rs 2.25 per kWh with 5% annual increase, over the base rate fixed by MNES in 1993; concessions regarding banking by allowing 100% accelerated depreciation. The above MNES instruction was valid for a period of 10 years from 1993 [16]. After that, in focus to create a complete legislation policy major administrative actions, legislative changes, and policy measures have been taken. As a result, the Electricity Act, 2003 (EA 03) has been enacted in consideration to provide renewed force in coordinating and developing the power sector in India. This act has been developed by the central government in consultation with the State Governments. The new policy endorsed consists of the following features:

- Preparation of proper tariff policy by the Central Government in collaboration with the authority for development of the power system, which operates through optimal utilization of resources such as coal, natural oils, hydro-electric and renewable energy resources, should be made.
- Strengthening the laws relating to generation, transmission, and distribution
- Taking proper measures in developing the entire electricity industry
- Proper trading and usage of electricity
- Supply of electricity to all areas along with the protections on consumer interest
- Guaranteeing visible policies regarding financial support
- Endorsing a competition in the industry
- The central Government in consultation with State Governments should sanction stand-alone power delivery systems for rural areas, as a national policy [20].
- Suitable measures for connecting stand-alone distributed electricity generation with the grid should be taken.
- Proper specification regarding the purchase of electricity from such non-conventional sources, as a percentage of the total consumption of electricity in the area of a distribution licensee should be mentioned.

In agreement with Section 3 of the EA 03, the tariff policy referred to MOP notification No.23/2/2005-R&R (Vol. III) dated January 6, 2006 towards a betterment in electricity price with regard to non-conventional energy generation [16]. The features of this advanced policy are:

- Depending on the region specific energy resources and its impact on retail tariffs, section 86(1) (e) of the Act decides a suitable charge to get a minimum percentage for purchase of non-conventional electrical energy.

- Through competitive bidding process within suppliers offering energy from same type of non-conventional source, Distribution Licensees for future requirements can be obtained as prescribed by Section 63 of the Act.
- Certain rules for pricing of non-conventional power should be arranged by Central commissions within three months.

The policies adapted for calculating electricity prices for different types of non-conventional power plants are as follows:

- Site selection is almost free for wind power, but however auctions for the sites to set up wind power plant can be held
- Tariff order for wind power for different states can easily be issued by state electricity regulatory commission (SERCs)
- On the basis of operating performance on different places different tariff value can be calculated
- The factors that can be taken account in this calculation are initial capital, Operation and Maintenance (O&M) expenses, Return on Equity (RoE), the capacity utilization factor (CUF). CUF is a measure of actually used installed productive capacity in terms of economy and management.
- An incentive of 80% of accelerated depreciation benefit available for generating wind power can be utilized by the investors in reducing the tax liability [5].
- The tariffs for small hydro plant are calculated by considering the topology and the available resource.
- The costs for run off the river (ROR) and the canal-based systems are evaluated on the basis of different technology required.
- The royalty charges for small hydro are also been decided to be paid by license holding distributor system.

Pricing of non-conventional energy resources based power delivery system generally depends on the size, i.e. installed capacity and type of resources used. Moreover many auxiliary equipments or devices utilized for structuring different non-conventional plants makes the variation of cost between the same power generating technologies. However, the pricing trend of non-conventional power systems has been shown in the table 4 below [21];

Table 5: Trend of Non-Convention Electricity Price

Years	Cost of Non-Conventional Power (Rs/W)				
	Solar Power	Fuel-Cell Power	Bio-mass Power	Wind Power	Battery Energy Storage System
1995	313	-	-		
1997	361	-	23.8		
1999	325	-	-		
2000	264	-	-		
2001	-	-	30	45	
2002					16.225
2003	264	-	-		
2004	195	1.41	-		
2005	-	-	36	50	
2006					4.3
2007	-	-	45.9		2.36
2008	-	-	-		2.065
2009					1.77
2010					1.18
2011	-	-	49		0.885
2012	222	-	-	70	
2013	140	1.25	23.8		

A detailed study regarding the trends of the above mentioned factors in the scenario of energy economy has been presented in [16]. The average cost of supply per unit of electricity sold has been progressively increasing over the years. The cost of

supply has increased to Rs 5.70 per kWh sold in 2011-12 from Rs 2.63 per kWh sold in 1998-99, implying an annual growth rate of 6.1 per cent. Moreover, there has been 26% rise in the unit cost of supply from period of 2009-10 to 2013-14.Further non-linear growth is stated and predicted by authors of [5]. Again, figure 5 from [15],[29] depicts the growing trends in electricity power consumption; where it has been observed that consumption increased to 8,52,900 GWh in 2012-13 from 4,11,887 GWh during 2005-06. There was increase of 8.62% in consumption from 2011-12 (7,85,193 GWh) to 2012-13 (8,52,400 GWh) .An extrapolation of the results leads about to a large increase of power consumption around 2030.

Again, from figure 6**,** the renewable installed power capacity has been observed to increase from year 2007 to 2013.There has been 18.4% growth in renewable power from 10.2 GW in 2007 to 28.5 GW in 2013.Wind power has been lead player in renewable energy sector, however during last ten years, lots of energy has been put in harnessing of solar power. The solar capacity has increased from mere 2.5 MW in 2010 to 1759 MW in year 2012.National Solar Mission has set up target to achieve 22,000 MW by the year 2022[24]. Thus, it can be stated that the non-conventional power systems will depict a growth with a faster rate than the linear trend in the next 10 to 20 years. The trends of non-conventional pricing resulted in a reduction of 53% in solar price within 13 years, while this shrink in fuel cell power is about 12.8% in last 9 years. Further, works have been done in regard for cost evaluation of customer based autonomous power delivery system utilizing different renewable generations, in an Indian scenario[21] The study in an Indian scenario showed that the renewable energy resources are strong candidate for different autonomous and rural electrification programs in the developing countries like India.[22] With proper utilization of different renewable and non-conventional sources, the electricity price may reduce to affordable range with respect to total sum of conventional electric price and carbon tax, in another 15 to 20 years.

CONCLUSION

It may therefore be inferred that the costs relating to set-up, operating cost and electricity price of conventional energy resources are facing an increasing trend due to various factors. On the other hand, the renewable resources along with their inherent positive impact on environmental and source conservation issues may even be found to be cost effective. Hence it can be predicted that within another 15 to 30 years, the share of renewable or non-conventional energy delivery systems will rise to become comparable to that of conventional power systems.

REFERENCES

[1] World Energy Council, Indian Member Committee. India Energy Book 2012. http://indiaenergycongress.in/iec2012/ieb2012/ieb2012.pdf
[2] Mathur,R., Chand,S.,Tezuka, T. Optimal use of coal for power generation in India. Energy policy, 31(4), 319-331, 2003.
[3] Khurana,S., Kumar, A. Small Hydro Power-A review. Int. J. Therm. Technol, 1(1), 107-110, 2011.
[4] Wikipedia contributors. Bokaro (Thermal) http://en.wikipedia.org/wiki/Bokaro_%28Thermal%29
[5] Banerjee, R. Clean Technology Landscape in India. http:// www. me.iitb.ac. in/~rangan /professional _activity/Clean Tech08. pdf
[6] The Energy Research Institute. Energy Data Directory and Yearbook (TEDDY). Tata Energy Research Institute, New Delhi, India. 2001–2002.
[7] Fisher-Vanden, K.,Shukla,P. R., Edmonds, J. A., Kim, S. H., & Pitcher, H. M. Carbon taxes and India. Energy Economics, 19(3), 289-325, 1997.
[8] The Energy Research Institute. Energy Data Directory and Yearbook (TEDDY) Tata Energy Research Institute, New Delhi, India. 2007–2010.
[9] Oster,S., Davis,A. The Wall Street Journal. China Spurs Coal-Price Surge. http://online.wsj.com/article/SB120275985736359763.html
[10] Indian Power market team. Indian Power Market: Electricity prices in different states of India http://www.indianpowermarket.com/2012/09/electricity-prices-in-different-states.html
[11] J.Sathaye.,Ketoff, K. CO_2 Emission from Major Developing Countries: Better Understanding the role of Energy in Long Term, Energy Journal, Vol 12, pp 161-196. 1991.
[12] Wikipedia contributors. List of countries by greenhouse gas emissions. http://en.wikipedia.org/wiki/List_of_countries_by_greenhouse_gas_emissions
[13] Barrientos, M.,Soria,C. India Electricity Consumption. http://www.indexmundi. com/india/ electricity_consumption.html
[14] Prabhu,R. India's Installed Power Generation Capacity touches 2,10,544 MW, http://www. renewindians.com/ 2012 /12/Renewable-energy-contribution-in-india.html
[15] The Energy Research Institute. TERI report on Pricing of power from Non-Conventional Sources. http://cercind.gov.in/09012008/Pricing%20methodology%20for%20renewables-%20Final-13%20March.pdf
[16] Audinet, P. Electricity prices in India. Energy Prices and Taxes. 2nd Quarter. 2002
[17] Banerjee, R. Comparison of options for distributed generation in India. Energy Policy, 34(1), 101-111, 2006.
[18] Abeberese, A.B. Electricity Cost and Firm Performance: Evidence from India. http://www.dartmouth.edu/~neudc2012/docs/paper_292.pdf

[19] Bhattacharya, S., Patel, U. R. The Power Sector in India: An Inquiry into the Efficacy of the Reform Process. In India Policy Forum, Global Economy and Development Program, The Brookings Institution. Vol. 4, No. 1, pp. 211-283,2007.
[20] https://www1.eere.energy.gov/hydrogenandfuelcells/accomplishments.html
[21] WWF-India and TERI. A study report, 100% renewable power by 2050 for India. http://awsassets.wwfindia.org/downloads/the_energy_report_india.pdf
[22] Som,T., Chakraborty,N.Studies on Economic Feasibility of an Autonomous Power Delivery System Utilizing Alternative Hybrid Distributed Energy Resources, IEEE Transactions on Power Systems, Volume 27, Issue 1, pp. 172-181, January 2014.
[23] Mimuroto, Yoshimitsu. An analysis of steaming coal price trends-Factors behind price fluctuations and outlook. Energy in Japan 162, pp. 26-35. 2000.
[24] Power & Energy Division. Planning commission, Government of India. Annual report on the working of state power utilities and electricity departments. Feb2014. http://planningcommission.nic.in
[25] Renewable energy policy framework for 21st century (REN 21), 10 years of renewable energy progress http://www.ren21.net/Portals/0/documents/REN21_10yr.pdf
[26] Earnst & Young India and CII. A Study Report, Renewable energy the next wave,http://www.cii.in/webcms/Upload/renewableenergythenextwave.pdf
[27] Mittal,M., Sharma, C., Singh, R. Estimates of emissions from coal fired thermal power plants in India. International Emission Inventory Conference. 2012.
[28] World bank quarterly report, Commodity Market Outlook, Jan 2015.
[29] Government of India, Energy statics 2014, Twenty first issue. http://www.mospi.nic.in/mospi_new/upload/Energy_stats_2014.pdf
[30] Guttikunda, Sarath, K., Jawahar, P. Atmospheric emissions and pollution from the coal-fired thermal power plants in India. Atmospheric Environment 92,449-460, 2014.

About Authors

Trina Som was born in Kharagpur, India, on October 8, 1982. She received her M.S. degree in Power engineering in 2008 and her PhD degree in 2013 from Jadavpur University, Kolkata, India. At present, she is Assistant Professor in Department of Electrical Engineering at JSSATEN, UP Tech University Noida, India. Her Research areas include Economical and operational viability of Renewable energy, Power systems, Soft computing techniques and Optimization algorithms. She can be mailed at : trinasom@gmail.com

Rahul Pathak was born in Varanasi, India, on 11 September 1985.India.He received his B.E degree in electrical engineering in 2007 and M.E degree in control system in 2010 from B.I.T Mesra, Ranchi, India. At present he is Assistant Professor in Department of Electrical & Electronics Engineering at N.I.E.C, Indrapastha University, New Delhi, India. His area of interest includes Renewable Energy, Soft Computing Techniques and System Biology. He can be mailed at: mailrahulpathak@gmail.com