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Abstract

Presently India is facing the twin challenge of energy universalization as well as emission reduction. Nearly 0.4 billion people in India– mostly residing in rural areas– do not have access to electricity and more than 0.8 billion people do not use modern cooking fuels. Provision of energy services however needs to take into account the global temperatures rise, which if to be limited to 2°C more from its pre-industrial value, Green House Gas (GHG) emissions must be halved by 2050 from its 1990 level. Energy infrastructure plays a key role to meet this dual challenge of universalization of energy services and reduction of energy-induced emissions. Assessing India's infrastructure, this study presents the high humane (Energy universalization) and low carbon scenarios and discusses investment needs, financing mechanisms and the key policy issues.

Keywords:

Energy climate nexus, Energy universalization, Infrastructure Investments, Financing mechanisms, Energy efficiency.

JEL Code:

P28, Q41, Q42, Q48

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Abstract

Presently India is facing the twin challenge of energy universalization as well as emission reduction. Nearly 0.4 billion people in India– mostly residing in rural areas– do not have access to electricity and more than 0.8 billion people do not use modern cooking fuels. Provision of energy services however needs to take into account the global temperatures rise, which if to be limited to 2°C more from its pre-industrial value, Green House Gas (GHG) emissions must be halved by 2050 from its 1990 level. Energy infrastructure plays a key role to meet this dual challenge of universalization of energy services and reduction of energy-induced emissions. Assessing India's infrastructure, this study presents the high humane (Energy universalization) and low carbon scenarios and discusses investment needs, financing mechanisms and the key policy issues.

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1. Introduction

Asia is driving the world energy markets, largely propelled by demand in China and India. As per International Energy Agency (IEA, 2008) estimates, the world energy consumption will increase by 45% in 2030 from its 2006 level, and India will account for 13.5% of that growth. India's high energy demand is driven by its high growth path.[1] India is also characterized by a large populace who is deprived of modern energy services; 45% rural households and 7.8% urban households do not have access to electricity and 90% rural households and 33% of urban households do not use clean cooking fuel (NSSO, 2007). To attain energy universalization and sustain growth, India needs to step up its energy use. However, like other developing countries, India is constrained by the environmental consequences of energy use.[2] Energy, which accounts for about 60% of Green House Gas (GHG) emissions, has a strong linkage with climate. Globally, since the beginning of industrial revolution, there has been an increase of 30% Carbon Dioxide (CO_2), 15% Nitrous Oxide (N_2O) and 145% methane (CH_4) (Environment Canada, 1999). To limit the global temperature to 2°C more from its pre-industrial value, the global GHG emissions must be halved by 2050 from its 1990 level (EU, 2008). India's heavy reliance on coal, which is relatively unclean compared to other fossil fuels,[3] and very low share in zero-carbon fuels (only 1%) made energy related CO_2 emission more profound. Additionally, the biomass consumption, which satisfies 72% of the domestic energy and 90% of all rural energy needs in India (TERI, 2006), contributes to climate change through its black carbon emission.

Appropriate energy infrastructure is the answer to India's twin challenge of energy universalization and climate mitigation.[4] Provision of secure, adequate, low-cost energy of quality and convenience in an environmentally benign manner is core to energy infrastructure.

[1] India's average annual GDP growth rate for current decade is 7.2% and it is expected to maintain high growth rate in the next two decades.

[2] The biggest dilemma the developing countries face is on the prioritization of energy-goals. On one hand, these countries, with per capita energy consumption and CO_2 emission of one-sixth of those of the industrialized world, are not primarily responsible for climate deterioration, but on the other hand they are the most vulnerable to climate change impacts because they have fewer resources to adapt – socially, technologically and financially (UNFCCC, 2007). Also, in developing countries, climate change issue is not a priority concern compared with problems of poverty, natural resource management, energy and livelihood needs (Reddy and Assenza, 2009).

[3] In 2005, among fossil fuels, coal accounted for less than 57% of energy needs, whereas its CO_2 share is more than 67% (IEA, 2007).

[4] Energy infrastructure means the infrastructures associated with energy system from cradle to grave; i.e. from extraction to end use and disposal.

Energy infrastructure influences choice of fuels, efficiency of use, choice of end use devices, and conservation practices. These are critical aspects of the India's energy future considering the challenges to universalize energy services and at the same time cut down on emissions.

After introducing the relevance of energy infrastructure this study presents the energy demand outlook under low carbon scenario vis-à-vis baseline. The low carbon scenario is characterized by increased use of renewables through solar, wind, geothermal, biomass and hydro – which will reduce fossil-fuel demand. Another important shift will be more usage of nuclear energy. Also, use of efficient and clean end use devices in all the sectors will multiply savings. Then the study presents the high humane scenario, which corresponds to energy univrsalization for domestic sector – i.e. providing all households with electricity for lighting and LPG and biogas for cooking. The study will also identify the actors and analyse their roles in achieving the low carbon energy infrastructure goals. The financial model to attain the required infrastructure investment will be outlined with emphasis on barriers and drivers. The study concludes with discussion on key policy issues.

2. Energy Infrastructure

Energy infrastructure stands for infrastructures associated with all energy related processes; i.e. extraction, generation, processing and distribution. Depending upon the stage of energy system, energy infrastructure can be primarily classified into following categories: infrastructure required for (i) exploration, development and extraction of energy sources (example: mining infrastructure, dams) (ii) transportation of raw natural resources to the generation unit (example: coal carrying trains) (iii) transformation of energy that turn raw material into useful energy products (example: power plants, oil refining units) (iv) transmission and distribution of energy to consumers (example: network of pipes for oil and natural gas, electricity transmission lines). Also storage of energy products and transportation network for waste disposal are part of energy infrastructure. Certain infrastructure like ocean tankers, oil and gas pipelines and specialized trucks for oil and refined products, such as LPG, gasoline and fuel oil are *exclusive* infrastructure for energy system, whereas for other infrastructures like the waterways, highways, and railroads are *inclusive* to goods and services other than energy. Again, energy infrastructure can be classified as (i) *standing* type (example: power plant, hydro-electric dam) (ii) *locomoting* type (example: pipelines, transmission lines, locomotives).

Energy infrastructure positively affects the economy of a country. Literatures say energy infrastructure though alone is not expected to precipitate economic growth and reduce poverty; the availability of modern energy together with other enabling factors can accelerate economic welfare (ESMAP, 2000; ADB, 2005). Energy infrastructure is highly capital-intensive and not always affordable by every country. For instance, though having gas reserves, the projects could not be realized in developing economies as the countries could not afford expensive infrastructure involving foreign exchange (ESMAP, 2003). Also, the importance of energy infrastructure stems from its complexity, and interlinking nature. Any inadequacy or incompleteness in infrastructure at any stage of energy system makes the final users deprived from the service. India's electricity in rural area is an example in this regard, where the absence of electric connection to households deprives people from electricity for lighting and other appliance use. Though close to 80% of the Indian villages are electrified (as on March 2006); only 55% of the rural households have electricity connections (CEA, 2006, NSSO, 2007). The current energy infrastructure in India is grossly inadequate from both energy universalization and low carbon point of views. It necessitates immediate attention not only to add new infrastructure but also to modernize and improve the systems for brining about efficiency in production, processing, transmission and distribution and reduce the gap between supply and demand. Financing of energy infrastructure remains a major concern as experience shows that finance from traditional sources of funding would be insufficient to meet the demand and there would be need for innovative options such as carbon finance, fossil fuel subsidy re-orientation, streamlined Global Environment Facility (GEF) and Clean Development Mechanism (CDM) funds.

3. Energy demand Outlook

Table 1 gives the energy consumption in India met by different primary energy sources (Planning Commission, 2008). In the last four and half decades, the PEC (primary energy consumption) has increased that many times with a CAGR (compound annual growth rate) of 3.4%. The increase in population in the same time period is 2.5 times indicating 1.8 times increase in per capita energy consumption. Among different energy sources, coal will grow with a CAGR of 3.9%, whereas the same for oil is 6.2%. Natural gas is relatively new entrant in the fossil fuel market and it has experienced a CAGR of 13.1% since 1980. The increase in natural gas consumption can be attributed to the deregulation of the power sectors in India which led to increased competition between coal and natural gas. Though the share of coal has been progressively decreasing over the years, it continues to be the dominant fuel in the total energy use in the country, because of its stable price and large availability.[5] In terms of reserve to production (R/P) ratio,[6] coal has 114 years, whereas those of oil and gas are 21 and 36 years respectively. The share of oil has remained around one-third of commercial fuel since 1970; however the share of natural gas increased from mere 1% in 1970-71 to 8.8% in 2006-07. The share of hydro has peaked in 1980s and now is on the decline. Nuclear energy, on the contrary, steadily increasing its share and emerging as an alternative to fossil fuels. Between 1990–91 and 2006–07, PCE registered a CAGR of 3.8%, whereas the commercial energy consumption grew at 4.9% suggesting a decline in growth rate of non commercial energy sources.[7] This indicates a gradual shift towards commercial fuels, particularly in urban areas.

Table 1: Primary energy demand in India (MTOE)

Type of carrier	1960-61	1970-71	1980-81	1990-91	2000-01	2006-07	2011-12[#]
Coal[*]	35.7 (79.9)	37.3 (62.3)	58.2 (60.2)	97.7 (55.9)	138.0 (49.1)	208.7 (53.3)	283 (51.8)
Oil[*]	8.3 (18.6)	19.1 (32.0)	32.3 (33.4)	57.8 (33.1)	107.0 (38.1)	132.8 (33.9)	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)	34.6 (8.8)	48 (8.8)
Hydro[*]	0.7 (1.5)	2.2 (3.6)	4.0 (4.1)	6.2 (3.6)	6.4 (2.3)	9.8 (2.5)	12 (2.2)
Nuclear[*]	0.0 (0.0)	0.6 (1.1)	0.8 (0.8)	1.6 (0.9)	4.41 (1.6)	4.86 (1.2)	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)	391.5 (72.6)	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)	147.6 (27.4)	169 (23.6)
Total	117.2	147.1	208.3	303.2	432.8	539.1	715

[#] Projected requirement at the end of the Eleventh Plan as per the Integrated Energy Policy Report (IEPR) report

[*] The number in the bracket shows the percentage with respect to total commercial fuels

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Source: Planning Commission (2008)

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[5] India has 7.1 % of the world coal reserves, the corresponding figure for oil and gas is only 0.5% and 0.6% (BP, 2009).

[6] R/P is the ratio of the amount of a resource known to be economically recoverable (proven reserves) to the amount of resource used in one year at the current rate. This indicator is too simplistic as future production is likely to change and there is uncertainty with reserve estimates.

[7] Non-commercial energy resources include traditional fuels such as fuel wood, cow dung and crop residue.

3.1 Future Energy Scenario – *Baseline versus Low carbon*

The two scenarios presented here are *baseline* (no specific policies to reduce demand; coincides with the 'reference scenario' of IEA), and *low carbon future* (efficiency improvements, fuel switching, innovative financing for infrastructure development, implementation of energy policies of the government, etc., coincides with the APS i.e. alternative policy scenario of IEA).[8] Table 2 gives the projected energy demand met through different carriers and CO_2 emissions thereof for these scenarios. In the baseline scenario the coal will progressively increase its share in total demand from 38.7% in 2005 to 47.7% in 2030. Coal is predominantly used in power generation accounting 70% share. If abundance and indigenous production favor coal, its high ash content and CO_2 emission act to its disadvantage. Oil and natural gas also follow their respective trend. In the absence of any radical policy disfavoring fossil fuels; these fuels together dominate the energy scene accounting for more than 80% of energy demand in 2030. The demand for other renewables (biomass, hydro, etc.) is likely to be relatively flat. Nuclear power is clearly an option though plant location and waste management are issues that restrict its growth.

In the low carbon scenario, nuclear, hydro, biomass and other renewables increase their share in the total energy demand. Among fossil fuels, coal loses its share by almost 10 percentage points. The increase in coal demand halved compared to baseline. This saving is explained by lower electricity-demand growth, fuel-switching and higher power generation efficiency due to clean coal technologies (CCTs).[9] Natural gas increases its share being the cleanest fossil fuel.[10] Oil tends to maintain its share because of lack of alternative to oil as transportation fuel. Both nuclear and hydro record increased share under low carbon scenario, however their use is limited because of the socio-environmental concern surrounding nuclear waste disposal and displacement due to large dams. The increase share in biomass and waste in low carbon scenario suggests increased production of bio-power and energy from industrial and municipal waste. [11]

[8] The baseline scenario assumes that demographic growth, economic parameters and energy prices would continue to influence the patterns of demand and supply as per the trend. The low carbon scenario considers climate-change concerns and environmental sustainability and encompasses policies and practices, which include efficiency and emission standardization, use of alternative fuels and clean technologies, demand side managements.

[9] CCTs involve beneficiating coal and efficiency improvement of the existing plants and using advanced technologies which include Combined Heat and Power Plant (CHP), Fluidized Bed Combustion (FBC), Integrated Gassification Combined Cycle (IGCC) and Pressurized Fluidized Bed Combustion (PFBC).

[10] Out of coal, oil and natural gas, natural gas has minimum CO_2 emission per unit combustion.

[11] This does not indicate increased use of fuel wood and dung cake as cooking fuel because these fuels get partially substituted as the availability and affordability of modern fuels improve in rural areas and among the urban poor.

The other renewable energies experience the highest growth rate and get a share close to 2% of total energy by 2030, much higher than the meager 0.7% share under baseline. Among the renewable sources, wind registers a significant growth with its share of electricity generation rising from just under 1% to 2.5% (IEA, 2007).

Table 2: Energy demand, and CO_2 emission under Baseline and Low carbon scenarios

Source	2005	Baseline Scenario		Low carbon Scenario		Saving	
		2020	2030	2020	2030	2020	2030
Total primary energy demand (MTOE)							
Coal	208 (38.7)	427 (45.1)	620 (47.7)	330 (39.3)	411 (38.0)	97	209
Oil	129 (24.0)	235 (24.8)	328 (25.3)	206 (24.5)	272 (25.1)	29	56
Gas	29 (5.4)	63 (6.7)	93 (7.2)	61 (7.3)	89 (8.2)	2	4
Nuclear	5 (0.9)	22 (2.3)	33 (2.5)	28 (3.3)	47 (4.3)	-7	-14
Hydro	9 (1.7)	16 (1.7)	22 (1.7)	22 (2.6)	32 (3.0)	-6	-10
Biomass and waste	158 (29.4)	179 (18.9)	194 (14.9)	182 (21.7)	211 (19.5)	-4	-17
Other renewables	1 (0.2)	6 (0.6)	9 (0.7)	11 (1.3)	21 (1.9)	-5	-12
TOTAL	537	946	1299	840	1082	106	217
CO_2 emissions (Mt)							
Coal	774 (67.5)	1579 (68.4)	2284 (68.9)	1227 (65.4)	1544 (63.9)	351	740
Oil	312 (27.2)	593 (25.7)	829 (25.0)	517 (27.6)	678 (28.1)	76	151
Gas	62 (5.4)	136 (5.9)	201 (6.1)	132 (7.0)	193 (8.0)	4	8
TOTAL	1147	2307	3314	1876	2415	431	899

Source: IEA (2007)

[Note: number in parenthesis gives the share in the total]

Table 2 also gives savings under low carbon scenario vis-à-vis baseline. In 2030, the annual energy saving turns out to be 207 MTOE i.e. one-sixth of the total energy demand. It is worth noting here that reduction in the low carbon scenario does not mean cut down on energy services, rather it indicates fuel substitution and efficient use of fuel. The monetary benefit can be from both the saving through energy bill and Certified Emission Reductions (CERs) obtained for 900 Mt CO_2 emission reduction, which together can be Rs 3.15 Trillion in 2030.[12,13]

[12] As per United Nations Framework Convention on Climate Change (UNFCCC, 1992), India can implement Clean Development Mechanism (CDM) and generate CERs which can be credited to her emission target.

3.2 Energy for "high humane" Scenario

This scenario presents the case of energy universalization for residential sector. In a recent work Reddy et al (2009) has developed a scheme for provision of modern energy services (gaseous fuels, such as liquefied petroleum gas (LPG) and biogas for cooking and electricity for lighting) to all Indian households (Table 3). The strategy developed was to include households deprived of modern energy services in a phase wise manner for every five-year period into the universalization program to attain energy for all by 2030. The regions where there is no access to LPG and electricity, the services are provided through renewable energy technologies (RETs) such as biogas for cooking, and electricity generated through micro-hydro, solar PV or biomass combustion/gasifier for lighting. For the regions, where modern services available, the proposed scheme followed a judicious mix of the centralized and decentralized options.

Table 3: Energy Universalization Schedule

Year	Rural		Urban	
	Target for provision of services (percent)			
	Cooking	Lighting	Cooking	Lighting
2010-11 to 2015-16	35	80	85	100
2015-16 to 2020-21	60	90	95	100
2020-21 to 2025-26	90	100	100	100
2025-26 to 2030-31	100	100	100	100
	Share of LPG and biogas for the households			
	LPG	Biogas	LPG*	Biogas
2010-11 to 2015-16	50	50	90	10
2015-16 to 2020-21	40	60	85	15
2020-21 to 2030-31	30	70	85	15
	Share of Centralized and options for the households			
	Centralized^	Decentralized#	Centralized	Decentralized
2010-11 to 2030-31	90	10	100	0

* LPG for urban area is indicative here, there can be other modern cooking gas services like piped natural gas (PNG).

^ Centralised power corresponds to conventional electricity based on thermal, hydro and nuclear.

Decentralised power corresponds to electricity obtained form biomass, solar, wind and micro-hydro.

Source: Reddy et al (2009)

[13] The assumption for monetary equivalence of 1 unit (1KWh) energy is 1 Re and 1 t CO_2 is 700 Rs.

The authors have estimated the incremental annual energy requirements for universalization of household cooking and lighting services (Table 4). The CO_2 emission reduction shows the additional emission in case of no universalization program. The reduction is expected to increase during the plan periods and reaching a peak of 158.5mt by 2025-26 and subsequently declining as the targets become closer. Cumulatively, the CO_2 reduction potential of this programme is approximately 2,300mt in the coming two decades. Again, in terms of CER saving, this is equivalent to cumulative saving of Rs 1.61 Trillion by 2030.

Table 4: Energy need and CO_2 reduction

Items	Target years											
	2015-16			2020-21			2025-26			2030-31		
	R	U	T	R	U	T	R	U	T	R	U	T
Annual energy requirements for cooking (PJ)	160.9	75.7	236.6	226.6	83.4	310.0	298.4	83.8	382.6	130.0	75.3	205.2
Annual energy requirements for lighting (GWh)	766	645	141	759	667	1426	791	789	1580	539	903	1442
Annual CO_2 Emissions Reduction in Cooking (mt)	71.9	21.8	93.7	101.3	24.7	126.0	133.6	24.8	158.4	58.1	22.3	80.4
Annual CO_2 Emissions Reduction in Cooking (mt)	0.09	0	0.09	0.09	0	0.09	0.09	0	0.09	0.06	0	0.06
Total annual CO_2 Emissions Reduction	93.82			126.06			158.49			80.43		

R=Rural, U=Urban, T=Total

Source: Reddy et al (2009)

4. Energy infrastructure and investment needs

4.1 Capacity Development and Import Needs

The total demand and domestic production of different fossil fuels and electricity generation in the low carbon scenario is presented in Table 5. The difference gives the import. The coal production is likely to increase by 70% in 2030 over its level in 2005, mainly driven by the power demand. The increasing import of coal necessitates improvement of import infrastructure. Also, imports of thermal coal will put competitive pressure on the domestic coal industry to be more efficient (Planning Commission, 2006 and Chikkatur, 2008), hence modernization of plants get triggered.

Table 5: Energy Demand and Production in Low Carbon scenario

Production	Unit	2005*			2020			2030		
		T	P	I	T	P	I	T	P	I
Coal	Mt	298	262	36	473	366	107	590	443	147
Oil	(mb/d)	2.71	0.81	1.9	4.10	0.70	3.4	5.44	0.54	4.9
Gas	BCM	35.3	29.3	6	73.3	46.6	27	105.7	49.7	56
Electricity generation	TWh	699			1582			2305		

T=Total demand, P=Production capacity, I=Imports

*For oil the values are given for year 2006.

The supply of petroleum products depends on the availability of crude oil and refining capacity. In India, the total production capacity in 2006 is 0.81 million barrels per day. By 2030, the production capacity progressively declines by one-third in 2030 due to relatively low R/P ratio for oil. The high oil demand is going to be satisfied with imports, which cannot be substituted under low carbon scenario (the import shares in oil in baseline and low carbon scenario are 92 and 90% respectively). With increasing import, new refinery additions will struggle to keep pace with demand growth in the future. Moreover, saving in oil demand in low carbon scenario (17% in 2030) partly comes from modal shift and fuel mix. Modal shift reduces the demand for two-wheelers and cars. Hence, from infrastructure point of view, the development of rapid mass transit system (RPTS) has to be high on agenda. The fuel mix in transportation is on account of ethanol and biodiesel blending in petrol and diesel respectively. Ethanol production requires processing of molasses and biodiesel requires increased cultivation of jatropha. Natural gas share increases from 5% in 2005 to 8% in 2030 in low carbon scenario on account higher use in power generation for its high quality, convenience of use and environmental benefits. For this the production, transmission and distribution networks will have to be considerably expanded. By 2030, natural gas production will increase by 70% from its level in 2005, whereas the import increases manifold during the same period with a compound annual growth rate of 9.3%. The gross electricity generation in India is at 700TWh in 2005, which will reach 2305TWh by the year 2030, an increase of nearly 3.3 folds (IEA, 2007).[14]

[14] For electricity generation imports are not considered, though India has already started importing power from Bhutan and has plans to increase the power import network. However the same forms a minute share in total consumption (0.3% in 2004) in India (UNDP, 2007).

Energy infrastructure is particularly important not only because of the varied geography of the country, but also the large distances between import locations and demand centers. As India will be importing more crude oil, coal, and natural gas in the future, it will need improved pipelines and ports, which are already struggling to cope with current volumes and additional imports will impose further strain (USAID, 2009).

4.2 Investment

Table 6 gives the investment needs in low carbon scenario under different heads for the period of 2010-2030.[15] The investment for coal is Rs 1588 billion which includes mining and port development, with former having almost 95% share.[16] In mining, there needs to be a tradeoff between opencast and underground types of mining as the former more productive yet is damaging to environment and leads to displacement of villages at times. The investment in coal does not look as an attractive option due to restricted market,[17] regulated price and lack of commercial discipline. In low carbon scenario the investment in coal is less by 35% compared to baseline. This is primarily because of pro-policies for renewable energy and nuclear power.

Table 6: Investments needs (Rs billion) under major heads in Low Carbon Scenario for the period 2010-2030

Type/Heads	Mining	Exploration and development	Refinery	Generation	Transmission and distribution	Liquefaction	Port development	Total*
Coal	1505 (94.8)						83 (5.2)	1588 (3.2)
Oil		1526 (22.0)	5410 (78.0)					6936 (13.8)
Natural gas		1369 (51.0)			1060 (39.5)	255 (9.5)		2684 (5.4)
Electricity				19454 (53.2)	17135 (46.8)			36589 (73.0)
Demand side								2319 (4.6)
Total								50116

* The values in parenthesis for this column give the share of investment of each type; the values in parenthesis for other columns give the share of investment of each head for a particular type.

[15] The amount is calculated by using investment value for alternative policy scenario of IEA for the period 2006 to 2030 (IEA, 2007), and assuming the investments for 2006-2009 are 50% met. For conversion from dollar to rupees Reserve Bank of India (RBI) reference data for 1st Jan 2010 as 1USD=46.68Rs has been used (RBI, 2010).
[16] The investments in thermal based power generation are included under electricity head.
[17] The restricted market is due to presence of only a few buyers and sellers, which gives rise to prevalence of monopsony and monopoly effect respectively.

On account of large share of imports, refinery turns out to be the major head accounting for more than three-fourths of total investment by 2030, which is around Rs 6936 billion, which is 90% of the baseline investment. The reduced investment in low carbon scenario is due to fall in volume of oil required on account of fuel mix, modal shift and improvement in technology and standards. In case of natural gas, investment remains same under both the scenarios. Investment is required both for developing upstream capacities and transmission and distribution (T&D) infrastructure. The large share of T&D is because of the fact that most of this gas has to be imported involving long distances pipelines. Approximately one-tenth of the investment goes under liquefaction and regasification purpose.

The cost of generating electricity include: (i) capital expenditure, i.e. the initial level of investment required to engineer, procure and construct the plant, (ii) fixed costs of operation and maintenance, e.g. staff salaries, insurance, rates and other costs; (iii) variable costs which include cost of fuel consumed in generating electricity and other operation and maintenance costs. The other costs include: power grid of long-distance transmission lines that move electricity from one region to other, as well as the local distribution lines that carry electricity to consumers. Powered plants require a dependable transportation infrastructure to deliver the fuels necessary for the production of electricity. A transportation network for waste disposal is also necessary for power plants that create by products. The targets for electricity generation in India under low carbon scenario would see the installed capacity of electricity having an additional 331GW during 2006-2030, which is 45GW less than the baseline (IEA, 2007). The investments required to install this additional capacity would be Rs 36589 billion accounting for 73% of the total investment. It is worth noting that investment in power generation is more in low carbon scenario compared to baseline because of the investments needed for modernizing power plants and developing generation units based on renewable sources. The wind power capacity increases from 4 to 46GW in 2005-2030 under low carbon scenario. Similarly, biomass based and solar power develops during this period to attain generation capacity of 12 GW and 9 GW respectively. The T&D investment, which forms 46% share in total electricity investment, registers a decline by 23% compared to baseline. The reduction in T&D investment is due to partial substitution of conventional fossil fuel based power generation with decentralized power generation through renewable sources.

Demand side investment is the most critical component under low carbon scenario. These investments include advanced technologies to promote energy efficiency and fuel shifts. For industrial sector, this includes energy efficiency improvement in the 15 energy intensive industries identified under Electricity Act, 2001 (MoP, 2009). In transportation front, heavy investment is needed in develop urban rail services and rapid transit bus system and infrastructure to enhance use of alternative fuels like Compressed Natural Gas (CNG) and biofuels. The infrastructure investment for residential sector includes energy efficient commercial and large residential buildings, and the infrastructure to promote energy efficient appliances like improved cooking stoves, efficient lighting devices like CFL (Compact Fluorescent Lamps) and solar water heaters. It is worth noting that the demand side investments are difficult to be realized in Indian context because of large pay back period due to heavy subsidization of fossil fuels, and in turn electricity. Nevertheless these infrastructural investments form the cornerstone to the goal of low carbon.

The low carbon scenario requires total energy infrastructure investments amounting to Rs 50.3 trillion in the period 2010-2030.[18] This investment is 6.25% less than corresponding figure under baseline scenario. In fact, the supply side investment is 10.56% less in low carbon scenario; however the same has been offset due to increase in demand side investment to improve efficiency of utilization, which amounts 4.5% of investments.

5. Energy Infrastructure Policy Strategies

The energy infrastructure sector has been characterised by large economies of scale which has resulted in huge investment requirements, particularly in large capacity required in fossil fuels and electric power sector. The funding of such a large lumpy investment has become a major problem for many developing countries including India. The “failure” of the public institutions has made the multilateral institutions such as Word Bank to believe that the energy sector needed to be reformed to attract large scale private capital. The current renewed interest in energy infrastructure financing stems in part from the recognition that the earlier approach of government driven investment has largely failed and the private sector is uninterested or unwilling to invest in many of the bigger projects, except in a few countries. There is also

[18] Same as footnote 15.

recognition that development will not occur without adequate access to modern energy services and there is a need to try and test innovative approaches.

5.1 Reducing inefficiencies in Energy Chain

5.1.1 Generation and Transmission

The core of the energy infrastructure issues lies with the inadequacies leading to inefficient generation, transmission and utilization of energy. If energy is produced inefficiently, transmitted with leaks, and used incompletely then the objective of low carbon and universal access will remain far from achieved. Both standing and locomoting types of energy infrastructure can have in built inefficiencies which must be identified and minimized. First and foremost concern here is the efficiency of plants and machineries which convert the natural resources (Primary energy) to useful energy products (Final energy).[19] The coal fired power plants is an example in this regard. The average thermal efficiency of coal fired power plants in India is 27%, whereas for OECD countries it is 37%. Given the fact that 70% of India's power is from on coal fired power plants and coal is going to dominate the future energy scene (Mishra, 2004, IEA, 2007), effort to remove the efficiency gap would relax the supply constraint to a great extent. Investment in infrastructure related to plant modernization and developing world class infrastructure for new plants can only give the due value the fuels deserve.

The energy loss during transmission is like carrying water in a leaking pot, which makes the vessel half empty by the time it reaches its destination. The high transmission and distribution (T&D) losses in power system is a case in point. India with T&D loss at 28.65% (CEA, 2008) is one among the highest losers in the world. T&D loss for developed countries is at 7-8%. Considering the Indian condition of remote rural areas and system configuration a reasonable permissible T&D loss could be 10-15% (Kumar and Chandra, 2008). So, the T&D loss in India can be brought down by 15 percentage points. Table 7 gives the State wise deficit and loss.[20]

[19] Final Energy (FE) is the energy associated with the final form of energy carriers after the technical conversion from their primary form. Energy in primary form is the one associated with the raw materials prior to any technical conversion. This energy is known as Primary Energy (PE). PE signifies energy repository whereas FE signifies energy availability.
[20] The list includes all major states and Delhi, the capital state. Major state definition follows the convention of NSSO (2007), which refers to States of India which had a population of 20 million or more as per Census 2001. Together, these states account for 95% of the total population, and 88% of total installation capacity.

Bihar tops the list with T&D loss above alarmingly high at 50%. It is followed by Orissa and Madhya Pradesh with losses around 40%. In general the northern States have recorded a T&D loss higher than national average whereas the southern region has registered lower loss. The high T&D loss seems unacceptable given the high overall requirement deficit (9.9%) and peak demand deficit (16.6%). The T&D losses can be attributed to high voltage network losses, defective meters, and theft.[21] Because of the shortage of funds, T&D loss investment gets low priority than generation. However, the T&D loss coupled with absence of accounting in certain cases, are the reasons behind tremendous financial loss of SEBs and distribution companies.

Table 7: Capacity, Deficit and T&D Losses for Indian States

State	Installed Capacity	Requirement Surplus/Deficit* (%)	Peak Surplus/ Deficit* (%)	T&D Loss^ (%)
Bihar	1969.99	-13.3	-32.0	50.67
Orissa	4050.66	-1.8	-7.5	40.86
Madhya Pradesh	7751.87	-14.1	-10.6	39.24
Rajasthan	6242.85	-3.1	-12.7	35.60
Assam	955.3	-8.4	-9.7	33.69
Uttar Pradesh	9277.66	-18.0	-22.8	33.49
Haryana	4590.29	-12.6	-2.7	33.35
Delhi	3689.34	-0.6	-1.1	33.00
Chhattisgarh	3103.25	-4.8	-0.6	31.71
Maharashtra	19582.8	-18.3	-26.4	31.64
Punjab	6530.01	-8.4	-15.4	26.61
Jharkhand	2152.57	-13.3	-9.0	26.21
Karnataka	8876.92	-2.7	-15.4	25.91
Gujarat	11051.99	-16.2	-26.7	24.87
West Bengal	7431.69	-3.9	-5.6	23.64
Tamil Nadu	13563.41	-2.8	-15.9	19.54
Kerala	3495.15	-2.4	-6.4	19.11
Andhra Pradesh	11866.81	-4.1	-8.8	18.65
All-India	143061.01	-9.9	-16.6	28.65

* The figures correspond to power supply position during 2007-08. Deficit has been expressed with negative sign.

^ The figures correspond to 2006-07 (provisional)

Source: CEA (2008)

[21] Literature show the actual losses are more, however the same is under reported to cover up high technical loss and commercial loss (theft).

5.1.2 Energy End Use

The inefficiency in the utilization refers to the conversion inefficiency of final energy to useful energy.[22] Though these inefficiencies are associated with the devices and equipments, in most of the cases poor infrastructure turns out to be the root cause. In India, a relatively large share of industrial output comes from small-scale operations, often located in inner-city slums. Slums not only suffer from civic infrastructure issues like roads, water and electricity, but also house industries which use inefficient technologies and practices breaching environmental norms. In a recent study on Indian manufacturing sector, Ray (2009) concludes infrastructural solutions to energy inefficiencies in cement and paper industry. A transportation infrastructure built to make use more slag in the cement industry and waste paper in paper industry can drastically improve the efficiencies. Similar instance of misuse of energy occur when a high-end energy like electricity is used for low-end purpose like water heating. One kg of coal available in nature loses 87.2% of its energy as it goes through various process of transformation to reach as electricity to the consumers.[23] So energy efficient end use, we need to have policies for demotion of geysers and promotion of solar water heaters in domestic and commercial sector.

5.1.3 The Final Connection

One of the failures in energy infrastructure management in India has been the ‘final connection’. The typical characteristics of any energy infrastructure program results in lower energy bills for future at the expense of higher initial funding, which act as bottleneck to full realization of the potential. Rural electrification program is a case in point. The whole effort to make electricity available to rural households goes in vain as the final electricity connection to the household is not provided. This forces the rural households to rely on inefficient fuel like kerosene for lighting, which in turn defeats the subsidization purpose of kerosene (Mishra et al, 2005). Kerosene is subsidized as cooking fuel, but finally used as lighting and adulterate petrol; and households continue dependency on fuel wood and dung cake (Gangopadhyay, et al, 2005, NACER, 2005). Adulterate petrol adds to the air pollution.

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[22] Useful Energy (UE) is the portion of Final Energy (FE) which after being converted in energy device is actually available for any use. The useful energy is calculated by taking the efficiency of utilization of the energy device like cooking stove or an electric appliance.

[23] This figure is calculated by assuming efficiencies of mining, transportation, power plant conversion, and transmission as 60, 95, 30 and 75% respectively.

5.2 Role of Actors

5.2.1 Structure of the Market

Energy markets in India are vertically integrated utilities which facilitate centralized decision making process. Historically, supply– both the generation and transmission– of electricity, oil and gas have been dominated by the public utilities within a regulated price regime. In recent years, it was recognized that private ownership may provide efficiency premiums over government owned systems and hence, India opened up its energy markets to competition. Presently there are a number of private companies that compete with the government owned utilities in power generation as well as the import and supply of oil and gas and supply to large customers and distribution companies. Also, most of the non-conventional energy production and distribution is by regional private players. However, for safety and security nuclear energy production is completely in the hands of the government.

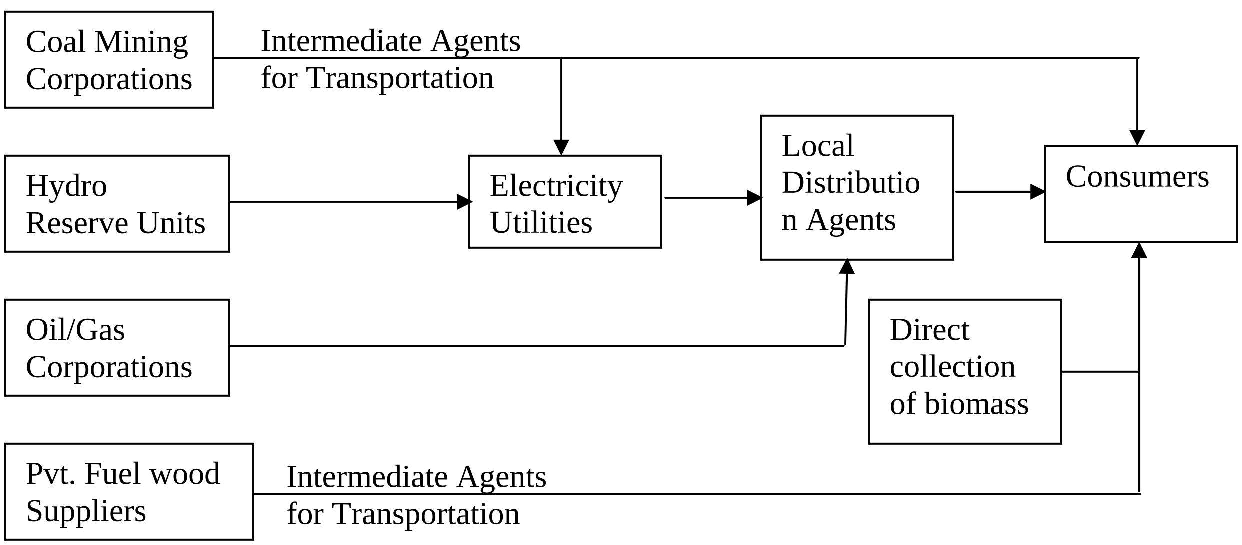

Figure 1: Existing Energy Market Structure

Different actors who have stake in provision of energy services are: utilities, planners, financial institutions, power companies, and consumers. The roles and coordination of actors describes the socio-technical structure of the market.

5.2.2 Role of Actors in Energy Infrastructure Financing

There is a growing recognition that the usual investment decisions such as payback period, rate of return on investment, net present value, etc, do not account adequately in infrastructure financing. In conventional financing, there are only two main participants, that is, the government and the private player. In the emerging energy markets, there are many actors such as the utilities, state agencies, financial institutions, consumers, market institutions, international organizations, etc. who play important roles. These can be classified broadly into, 'meta', 'macro', meso, and 'micro' levels. At the "meta" level are the international financial institutions which provide financial as well information inputs. At the macro level there are 'high-level' institutions (state/market/civil society) that determine the setting under which the lower levels have to operate (financial, information, training, support by specialists, etc). At the meso level, there are organisations such as energy development agencies (EDAs), energy service companies (ESCs), private entrepreneurs, etc. At the micro level, organizations such as individuals (through domestic savings) operate. Institutions at each level carry out a project at its own level and work within existing 'external constraints' given by 'higher-level' institutions. Fig.1 outlines the roles of actors at different level in promoting energy infrastructure for universal access and low carbon future.

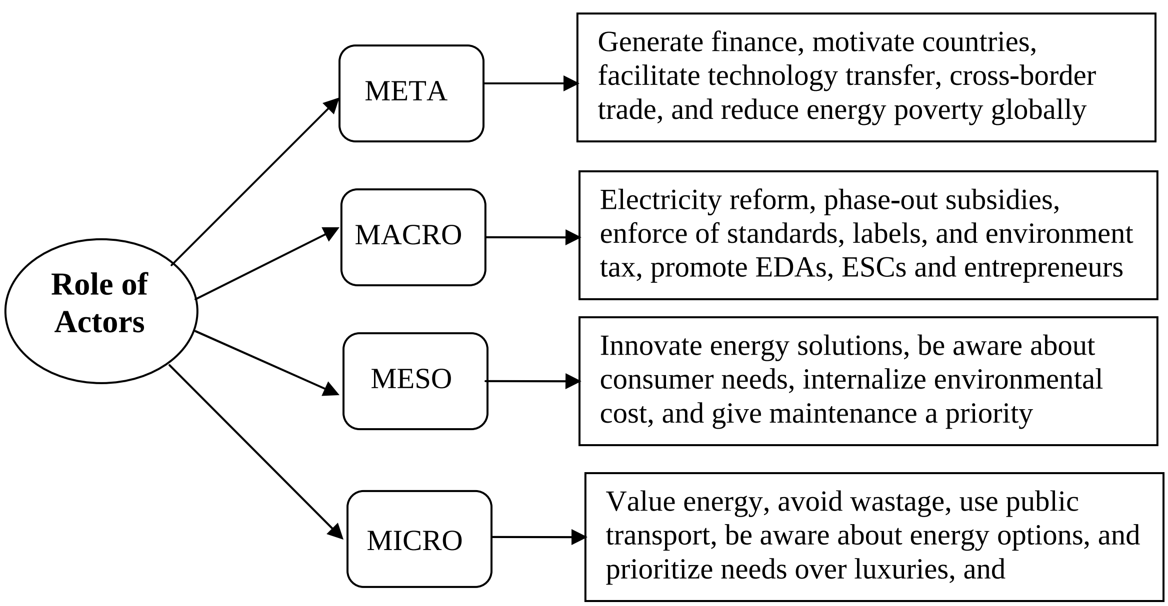

Fig 2: Role of actors

5. 3 Financing Mechanisms

5.3.1 Public vs Private

For many years energy infrastructure was funded almost exclusively by the public sector, and many projects were designed and implemented by multilateral institutions without significant private participation. Because of non participation of the sustainable and renewable Energy Technologies (SETs and RETs) also suffered as the objective of such programs were one time demonstration, not commercialization (Balachandra et al, 2010). Presently, there is an increasing involvement of cooperative arrangements between governments, multilateral institutions and private investors. A stage may come in future where the involvement of private sector is full and the role of governments and multilateral institutions is reduced to a minimal level.

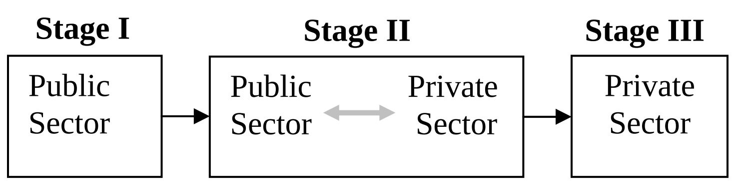

Fig 3: Public Private Partnership Evolution

Such an approach to succeed a systemic competitiveness is essential.[24] Infrastructure Financial Corporation (IFC) of India is a case in point. IFC, established by the Government of India, plays a catalytic role in building world-class infrastructure. It raises funds from both domestic as well as external markets on the strength of government guarantees, which will be extended as necessary. In the first year of its operation, a guarantee limit of Rs.10000 has been specified by the government. It is expected to provide the much needed long-term debt for financing projects. Such public-private partnerships (PPPs) are flexible, and are project specific tailor-made solutions. Hence, it is difficult to evaluate the exact instruments and identify the conditions for success. Finally it is believed that if a dialogue between different parties could be organized before actually implementing PPP projects in the infrastructure sector, the chances of success would be enhanced.

[24] Systemic competitiveness refers to the set of intertwined aspects of the socio-economy that combine in order to determine the success for a particular project. The use of systemic competitiveness terminology is useful in clarifying the roles played by government, the private sector and other institutions. It is also useful in identifying success factors of particular actions (constructing a power plant, developing rail and road network, etc.) and factors necessary to attract more funding.

5.3.2 Low Carbon Finance

Environmental Finance Programmes (EFP) are also like the Public Private Partnership model, which provides creative approaches to funding infrastructure projects that benefit environmental activities. Environmental Strategy and Policy underscore the positive linkages between the environment and sustainable development. These linkages often involve not just commodity and resources markets, but also financial markets and innovative sources of finance. Two key linkages are "carbon finance" and the Global Environment Facility. These linkages operate not just to increase financial flows but also to stimulate innovation in the use of natural resources (Peszko and Zylicz, 1998). However, adequate investments are not occurring at the rate originally hoped. This is due to a weak policy framework and limited availability of affordable investment capital, and lack of information and skills in enterprises and financial institutions to develop and implement projects. The most important needs are to strengthen the demand for better environmental performance by subjecting enterprises to budgetary, policy and other incentives which promote the efficient use of resources and to pursue effective environmental compliance.

5.3.3 Financing for Energy Efficiency

Investment in energy efficiency (EE) is hard to track in its entirety as efficiency improvements can be done at different levels – generation, transmission and distribution (T&D) and end use devices. Investments come into EE projects particularly to smart/grid distribution and power storage and also in the establishment of energy service companies (ESCOs). Financing through commercial banks remains difficult in many cases because energy efficiency (EE) investments often do not meet the standard investment criteria, such as collateral requirements. However, a growing number of specialized financing sources for energy efficiency are presently available particularly through Clean Development Mechanisms (CDM). Though different sources have their own set of priorities and criteria used to select projects for investment, all of the sources have one thing in common; that is they want to invest in projects that will generate enough EE savings cash flow to repay their investment. As more and more EE projects prove themselves, both the fund seekers and investors will gain confidence and the financing environment will improve.

5.3.4 Financing for Universalisation of Modern Energy Services

Micro financing for projects for Universalisation of Modern energy services through energy efficiency and renewable energy technology is less risky. For example, small-scale water power, or micro-hydro (with capacity less than 100kW), can be a particularly attractive option for electrification in many rural areas. The International Technology Development Group (ITDG) has developed micro-hydro schemes with the involvement of communities in countries like Kenya, Nepal, Peru and Sri Lanka (ITDG, 2010). The Inter-American Development Bank supported the project through a *revolving fund* where pay-back of an original loan is used to provide funding for further micro-hydro plants. Three major factors contribute to the success of such projects: (i) participation of the beneficiaries in project planning and implementation, (ii) development of a local manufacturing base to produce low-cost equipment, (iii) capacity building at the community level to enable the replication of the technology.

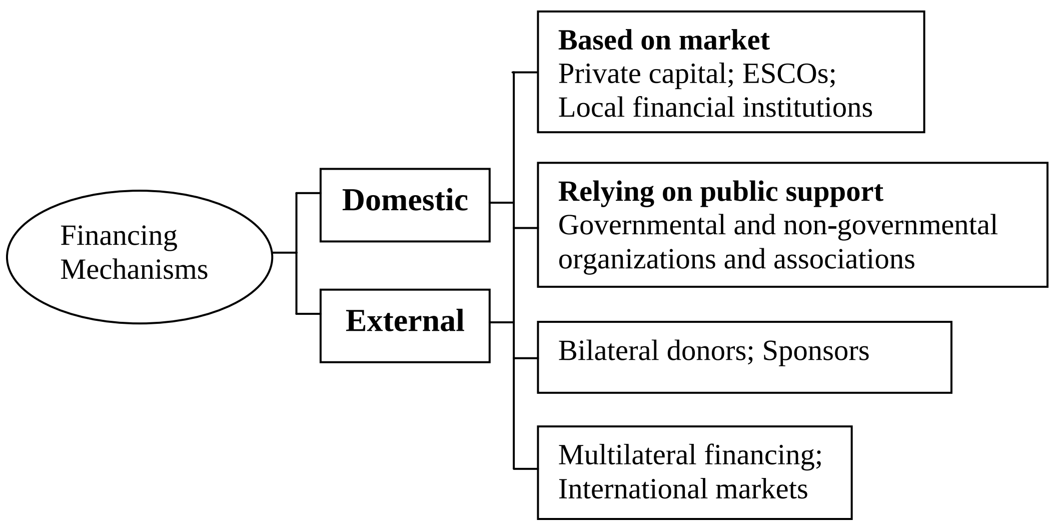

Fig 4 Financing mechanism for Energy Efficiency and Universalisation of modern energy services

5.3.5 Build, operate and transfer (BOT) arrangements

There is a method which allows less restricted or unrestricted investment in new power assets, the independent power project. According to this method, a foreign company builds a power unit and operates the unit for an agreed-upon number of years before transferring ownership to the host country. This investment arrangement is commonly referred to as a build, operate, transfer agreement, or BOT. In several nations, rate reform has also played a critical role in encouraging such non-utility electric power investments. In several cases privatization has involved foreign utilities purchasing one or more utilities in other countries. Some privatization efforts have involved consortiums of foreign and domestic companies. Joint ventures with host nation companies have been another avenue of privatization. In some cases, foreign companies or investors have purchased shares in newly privatized electric utilities. In a few cases, recently privatized companies have acquired ownership interests in other recently privatized companies (EIA, 1996).

5.3.6 Regional special purpose vehicle (SPV)

Another instrument that is gaining popularity is the Special Purpose Vehicle (SPV) for project financing. As the name itself indicates, an SPV is a legal entity created by a sponsor by transferring assets to it, to carry out a specific purpose. It has no other purpose other than that for which it is created. The rules governing an SPV are set in advance and built into its activities. An SPV is a form of securitization, which offers higher quality assets to investors by virtue of the fact that the structures insulate investors from the bankruptcy risk of the sponsor or the originator (RBI, 1999). One advantage of this approach, particularly in the energy sector, is the limited exposure to financing a viability gap as most energy projects carry high economic returns. However, pricing of energy products such as electricity, gas and fuel oil could become a social issue particularly when the global prices of fuel oil are high. Countries are required to put in place transparent rules and regulations under which the pricing of such products are undertaken to avoid social unrest without compromising the operational viability of energy sector projects.

6. Conclusions

Investment in energy infrastructure is the need of the hour to save climate and reduce poverty. This investment will expand energy supply capacity and replace the existing and future supply facilities that will be exhausted or become obsolete in near future. The total investment is around Rs 50 trillion for the next two decades. This investment is required to expand the supply capacity and to replace existing and future supply facilities that will be exhausted or become obsolete during this period. The electricity sector dominates the investment picture: power generation, transmission and distribution absorbing almost three fourths of the total energy investment. This share is over 80% if investment in the fuel chain to meet power-station fuel requirements is included. Renewables will capture a significant share in new power plants. 4.5% investment is needed to align the demand towards the more energy efficient solutions.

The study has investigated different ways of mobilising the investment required for energy sector to transform the energy resources into available supplies and usable energy carriers. This also depends on the ability of the energy sector to compete with other sectors of the economy for capital. The issues to be considered while discussing financing for energy infrastructure are (i) safeguarding debt sustainability of the country; (ii) need to manage socio-environmental impacts (iii) the ability to provide energy services and achieve the Million Development Goals (MDGs); (iv) the importance of regional integration in the promotion of cross-border trade; (v) the need to mainstream energy policies into national development strategies and address the issues of inadequate budget allocations to the energy sector; and (vi) the need for a comprehensive approach to the building of human capital. Unless these issues are addressed in an integrated and effective way the prevailing inadequacies are expected to continue even in the future.

Security of energy infrastructure is important since it is vulnerable to physical disruption that could threaten its safety. Disruptions could come from natural events, like earthquakes, or could come from accidents. In addition, a nation’s transportation and power infrastructures have grown increasingly complex and inter-dependent. Consequently, any disruption in one sector can have significant consequences for other sectors. The growing reliance on computer technologies, automated monitoring and control systems, and electronic commerce makes the system more efficient and vibrant, but also requires a greater level of diligence and use of safeguards.

Energy infrastructure is the key to meet the challenge of energy universalization and climate change mitigation. Infrastructure can be sustained to remain effective if the leaks in the energy system are identified and minimized. All the stakeholders in the system, the government, international institutions, industries, business associations, civil society, and consumers have responsibility in this regard. A high humane and low carbon energy infrastructure satisfies the three principal goals of energy policy: improved economic efficiency, more environmental protection, and greater security.

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