IRADe-PR-42(2014)

# *Economy Wide Model for Low Carbon Strategy*

**Under Planning Commission's Scheme of Supporting Socio Economic Research (SER)**

**Submitted by**

**Integrated Research & Action for Development**

**4th April 2014**

Integrated Research and Action for Development
IRADe

The research report has been prepared by Integrated Research and Action for Development (IRADe) with the funding support from the Planning Commission of India, Government of India. The views and results expressed in the report are wholly of the IRADe team. Inputs from the report were incorporated in various chapters of the "The Final Report of the Expert Group on Low Carbon Strategies for Inclusive Growth" by the Planning Commission of India, Government of India published in 2014.

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# Economy Wide Model for Low Carbon Strategy

## 1. Objective

The study intends to find out what would be the consequence for growth and poverty in India of a carbon emission reduction strategy that is consistent with inclusive growth. Specifically, it examines the likely loss in growth of national income and increase in the incidence of poverty due to various policies to reduce $CO_2$ emissions in future. We also attempt to estimate the incremental costs of abating $CO_2$ emissions and quantify the additional inflows of foreign finances, which will compensate the welfare losses incurred for abatement.

Specifically, the study answers questions like –

1. What will be India’s emissions profiles in 2020 and 2030 given the desire for faster and more inclusive economic growth and expected population growth?

2. How will India achieve reductions in carbon intensities?

3. What technology changes are needed in Energy, Power, Transport and commercial Buildings?

4. What would be the impact on rural and urban poor of such policies?

5. India needs to increase energy access to 600 million people and improve well-being of millions of persons. How can that be achieved and what would be CO2 implications?

6. How would household electricity consumption growth in future when energy efficient appliances are available?

Section 2 presents results of analysis of policies to pursue low carbon strategy for inclusive growth to find answers to questions 1 to 5 above.

Section 3 addresses question 6 above.

# 2. A Model for Low Carbon Strategy for Inclusive Growth

## 2.1 Why a Macro Model?

Many measures to reduce emission intensities, impact on the economy in a variety of ways. Additional investment may be required that reduces investment available for other sectors. More energy efficient processes can increase profitability of such processes and the structure of the economy may change. It is even conceivable that energy efficiency improvement may make the economy more productive, increase its growth rate and lead to larger consumption of energy (MoEF, 2009). Thus it is important to assess the macro-economic and inter sectoral implications of different measures to reduce emission intensities to ensure that the low carbon strategy suggested is consistent. Models that assess economy energy interaction in the literature can be classified as bottom-up, top-down and integrated. The bottom-up models bring technological knowledge and specificity. However, often techno-economic evaluations are incomplete and overtly optimistic in that the policy and institutional obstacles are not fully accounted for. Top-down models bring macro-consistency but simplify the sectoral details by judgments and assumptions. Among them are econometric models which use reduced form equations and the implied policies behind them remaining unclear. Another approach of top-down modeling is the computable general equilibrium (CGE) approach where a sequence of single period equilibrium is worked out. An activity analysis approach permits macro-consistency, dynamic behavior, new and specific technological options, and resource limitations and thus limits substitution. It can constitute a truly integrated top-down- model. At the national level, computable general equilibrium models, which incorporate behavior of individual agents in response to endogenous prices, have been used for development policy analysis (Adelman & Robinson, 1978, Narayana et al., 1991). These are either static models (Bergman, 1990) that give a snap shot for the target year or the dynamic ones (Jorgenson and Wilcoxen, 1990) that give trajectories of the growth path, the latter are useful for analyzing the effects of adopting alternative market-based policy instruments.

A few modeling studies have explored India's technology options. Shukla (1996) uses two models, the bottom-up MARKAL (Bergel et al, 1987) which is an energy system model suitable for techno-economic analysis given exogenously specified sectoral growth rates and the top-down SGM with endogenous macro variables such as growth rate. The Indian component of SGM has been used to explore $CO_2$ policy options for India (Shukla, 1996 and Fisher-Vander et al, 1997). Gupta and Hall (1996) have tried to use a simple econometric macro-model as a top-down model to integrate technological options identified by techno-economic assessment of various technical options for carbon abatement. Weyant and Parikh (2004) analyzed how various global models have projected India's emissions. Murthy et. al (1997a, b) made a study of interactions among production, energy demand and $CO_2$ emissions for the Indian economy using input-output (I-O) table for 1989-90 and projected emissions for 2004-05. Parikh et. al (2009) have estimated CO2 emissions for India by major sectors for the year 2003-04 (2008) based on a Social Accounting Matrix (SAM), which incorporates the input-output flows for that year. MOEF (2009) report develops energy models for India using three diff approaches and presents similar looking GHG profiles for India up to 2030. In this report we use the IRADe energy economy model in activity analysis framework for India by using the Social Accounting Matrix (SAM) for 2007-08 by Pradhan, Saluja and Sharma (2013).

The IRADe activity model was first developed under the project "Developing a CGE model with Activity Analysis for climate policies in India" funded **by the Ministry of environment and forests, Government of India during 2006-2009.** The results from the model developed in the study were used by the Ministry in the report "India's GHG Emissions profile – Results of five climate modeling studies" in 2009 http://moef.nic.in/downloads/home/GHG-report.pdf. The model was used to project India's CO2 emissions up to 2030. The model gave for the first time impact on poverty and also the result that it is possible to reduce Carbon emission intensity declines by 20% by 2025. The impact of increase in Autonomous Energy efficiency (AEEI), carbon tax and TFPG on GHG emissions up to 2030 was analyzed.

Subsequently, the model was further modified to project India's energy pathways up to 2050. This was done with the support of the **Technology, Information Forecasting and Assessment Council, DST, GOI and in research collaboration with IIASA, Austria in 2010-2012.** Availability of energy resources within the country and from outside was factored in to the model to make the model results more realistic. The projection of commodity wise consumer demand, which was the major USP of the IRADe model, was further improved by expanding the number of expenditure classes from 5 to 10 each in Rural and urban areas. The model provided the transitions required in the power sector and associated costs and GDP loses to achieve current targets of the

NAPCC and MNRE and also in the case of a adopting carbon cuts in the power sector that is consistent with achieving 2 degree global temperature reduction target.

**the World Wildlife federation (WWF) India in a conglomeration of partners further supported a research study in 2012-2014 to use the model to analyze sustainable development pathways for India.** The model was extended to incorporate development parameter like life expectancy of male & female, infant mortality rate, mean years of schooling, access to sanitation, access to clean water, access to electricity and access to clean cooking fuel. The model incorporated higher expenditures on education and health and cash transfers to achieve faster eradication of poverty, and attaining higher levels of development while still adhering to a stringent low carbon pathway.

**In 2011, the centennial group supported IRADe in a study to analyze the role of Agriculture in helping India achieve double digit growth**. The IRADe activity model was modified to include many detailed sectors of agriculture and also incorporate rural and urban migration and fall in urban and rural income parity to make very concrete forecast of india's food demand and the change in composition of this. The impact of urbanization on growth and demand composition in general and food demand in particular was analyzed.

**In 2012, The South-South North university South Africa, supported a study analyze Poverty alleviating Mitigation actions (PAMA).** The model was used analyze PAMAs. The study analyzed the impact of developmental measures on emissions and mitigation actions on poverty and growth.

## 2.2 The Model and its Appropriateness

A multi sectoral, inter-temporal, activity analysis model that is bottom-up in the sense that it includes different technological options and top-down in that it covers the whole economy is used (Parikh J and Ghosh P, 2009). The model has endogenous income distribution with 10 consumer expenditure classes in rural and urban areas each. The demand functions of each of these 20 consumer classes are determined based on an empirically estimated non-linear demand system (Swamy, G., Binswanger, H.P., 1983 and Parikh K. et al, 2014) from which linear expenditure systems (LES) are estimated for each class as a local approximation of the underlying demand system. An LES ensures that the expenditure of a consumer on different goods and services add up to her total expenditure (Stone, R., 1954). The differentiation of consumers in 20 classes helps in assessing inclusiveness of a strategy. There are 25 sectors. Output of a sector can be produced by more than one production activity. Thus we have 13 activities to produce electricity. The model is solved simultaneously for a number of periods with the objective of maximizing present discounted value of private consumption. The model is solved using the GAMS programme (Brooke, A., Kendrick, D. and A. Meerhaus, 1998). Detailed technical description of the model is given in an appendix.

### 2.3 The Scenarios

Though we look at the results up to 2030-31 only, the model scenarios are run for 37 years from 2007-08 to 2037-38 to minimize the impact of terminal period. The two main scenarios for policy analysis are:

BIG – Baseline, Inclusive Growth. This scenario incorporates policies in the context of the 12th five year plan for inclusive growth and serves as the reference scenario.

LCIG – Low Carbon, Inclusive Growth – This incorporates various policies and activities for reducing emission intensity.

In addition one other scenario is constructed to get insights in to the cost of low carbon measures. This is:
CLCIG – Compensated low carbon inclusive growth scenario where additional foreign inflows ensure that the level of GDP is the same as in the BIG scenario, to separate the impact of different policies from that of changes in output and consumption levels in LCIG.
The motivations and specific details of the scenarios are described below.

#### 2.3.1 BIG – Baseline Inclusive Growth

India's Twelfth Five Year Plan (2012-2017) aims for "Faster and More Inclusive Sustainable Growth". Inclusion was also the objective of the 11th plan. Inclusion is sought to be achieved by a number of measures and the plan lists a number of target indicators. See Box 2.1 below.

**Box 2.1 Target Indicators of the 12th Plan**

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**Health**

10. Reduce IMR to 25 and MMR to 1 per 1,000 live births, and improve Child Sex Ratio (0–6 years) to 950 by the end of the Twelfth Five Year Plan.

11. Reduce Total Fertility Rate to 2.1 by the end of Twelfth Five Year Plan.

12. Reduce under-nutrition among children aged 0–3 years to half of the NFHS-3 levels by the end of Twelfth Five Year Plan.

**Infrastructure, Including Rural Infrastructure**

13. Increase investment in infrastructure as a per-centage of GDP to 9 per cent by the end of Twelfth Five Year Plan.

14. Increase the Gross Irrigated Area from 90 mil- lion hectare to 103 million hectare by the end of Twelfth Five Year Plan.

15. Provide electricity to all villages and reduce AT&C losses to 20 per cent by the end of Twelfth Five Year Plan.

16. Connect all villages with all-weather roads by the end of Twelfth Five Year Plan.

17. Upgrade national and state highways to the minimum two-lane standard by the end of Twelfth Five Year Plan.

18. Complete Eastern and Western Dedicated Freight Corridors by the end of Twelfth Five Year Plan.

19. Increase rural tile-density to 70 per cent by the end of Twelfth Five Year Plan.

20. Ensure 50 per cent of rural population has access to 40 lpcd piped drinking water supply, and 50 per cent *gram panchayat*s achieve Nirmal Gram Status by the end of Twelfth Five Year Plan.

**Environment and Sustainability**

21. Increase green cover (as measured by satellite imagery) by 1 million hectare every year during the Twelfth Five Year Plan.

22. Add 30,000 MW of renewable energy capacity in the Twelfth Plan.

23. Reduce emission intensity of GDP in line with the target of 20 per cent to 25 per cent reduction over 2005 levels by 2020.

**Service Delivery**

Provide access to banking services to 90 per cent Indian households by the end of Twelfth Five Year Plan.

Major subsidies and welfare related beneficiary payments to be shifted to adirect cash transfer by the end of the Twelfth Plan, using the Aadhar platform with linked bank accounts.

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These are sought to be achieved by a variety of measures.

Short-term measures entailing income transfer through subsidized consumption goods and an employment guarantee.

Medium-term measures promoting education, skill formation and rural infrastructure of power and roads. Primary enrolment is now nearly 100 per cent. Educational participation is increasing at all levels. Today there are some 17 million students enrolled in tertiary education. To build on these, additional measures will be required.

The following specific measures are introduced in the scenario:

**Income Transfer**: To substantially reduce poverty cash transfer is provided. An amount of Rs 1000 per person per year at 2007-08 prices is given as cash transfer to 10 % of the people beginning 2013. The amount is increased to Rs 1500 in 2015 and to Rs 2000 in 2017. The coverage of rural population also increases to 60% of the rural population in 2015 and 70% in 2017. In the urban areas the coverage increases to 20% in 2015 and to 50% in 2017. From 2017 onwards the amount transferred is increased by 2 % per year and covers bottom 50% of urban population and 70% of rural population. This includes the income provided by programmes such as MGNREG programme.

**Housing**: The objective is to provide every person with a pucca house by 2030. This is accomplished by stepping up Indira Awas Yojana and Rajiv Awas Yojana and is reflected in the scenario by increased government demand for construction from 2011 to 2025 when an additional 0.7 million houses for the poor are built. The houses are given free to the poor households.

**Drinking Water**: It is assumed that the existing government programme will provide clean drinking water to all by the end of 12$^{th}$ plan (2016-17).

**Sanitation**: Increased education of women and growing demand for sanitation will lead to elimination of open defecation by the end of 13$^{th}$ plan (2021-22).

**Education and Health**: Government expenditure on education and health is increased by an amount that corresponds to 4 % of GDP in 2013. The expenditure stays at that level of GDP after that.

**Electricity**: All households consume 1 kWhr per day of electricity by 2013. The deficit from the households' normal consumption is made up by the government.

**Cooking gas**: The poor households' expenditure on energy is supplemented by government so that they can have 6 cylinders of LPG per year from the year 2013. The supply of LPG increases correspondingly.

**Growth**: Real GDP growth of 7 % is realized from 2007 to 2030.

The improvements in health, education access to water and sanitation will result in lower IMR and fertility. Also since this is a national level model regional and social group specific measures are not introduced. However these do not require additional resources but modification in governance measures and would not have any macro-economic consequences.

Apart from these measures of inclusion, other assumptions for the BIG scenario are as follows: "Autonomous" Energy Efficiency Improvement (AEEI): AEEI rate of 0.5 % per year has been stipulated for energy inputs of coal, petroleum products, natural gas and electricity in to production activities. These reflect efficiency improvement observed over the past without specific low carbon policies. These are autonomous to that extent. It is assumed that improvement up to 0.5% per year have payback period of less than one year and so no additional investment during the year is needed.

Total Factor Productivity Growth (TFPG) is stipulated at 1% for agricultural sectors and 1.5% for non-agricultural sectors which are historically observed values. Since capital is the only factor in the model TFPG reduces capital output ratios.

No carbon emission constraints or specific measures to reduce emission intensity are introduced in this scenario. These are introduced in the LCIG scenario.

### 2.3.2 LCIG Scenario

The measures introduced are as follows:

The rate of autonomous energy efficiency improvement (AEEI) in production activities is assumed to increase to 1.5 per cent per year from 2015. However, in the case of power sector, lower rates of AEEI have been taken to reflect the technological limits for coal, natural gas and petroleum products required as inputs for generation. AEEI in power sector is assumed to be 1 percent. AEEI for electricity used in the power sector is taken as 0.5 percent, which reflects reduction in T&D losses from 20 percent to 10 percent, and also reduction in auxiliary consumption. One may note that in the Model, the power sector is vertically integrated and includes generation, transmission and distribution facilities. Efficiency improvements beyond 0.5 percent per year will require upfront investment, for which the payback period is assumed to be six years at a discount rate of 4 per cent.

Many power generation technologies that do not emit $CO_2$ are introduced. These include solar photovoltaics (PV), solar concentrated solar power (CSP) and wind, all with and without storage, and biomass based power generation plants.

Hydro and nuclear power development is accelerated.

The share of generation by conventional coal plants in the total coal based power generation is restricted to increase by only 1.6 percent per year from 2015 onwards. Additional generation from coal plants takes place from the new super critical plants with 20 percent higher fuel efficiency and 25 percent higher capital costs.

Total factor productivity growth rates for all sectors are same in both BIG and LCIG scenarios. However to provide for falling costs of renewables like wind and solar, higher TFPG rates are assumed for renewable power generation technologies up to 2025. After 2025 the TFPG rates for renewable are also the same as for other non agricultural sectors.

A minimum penetration rate for renewable power[1] is prescribed so that the share of renewables in total generation increases from around 7 percent at the end of the Eleventh Plan (2012) to 18 percent by 2030. The total share of non-fossil fuel based power increases from around 20 percent in 2012 to 33 percent by 2030. *To put it simply, one-third of the total power generation by 2030 becomes fossil free.*

For the transport sector, some of the options assessed are the following:

i. The share of railways in freight movement is stipulated to increase by 2.5 percent per year, from around one-third in the year 2011 to almost half by the year 2030.

ii. Fleet efficiency norms on motorized vehicles double fuel efficiency by the year 2030.

iii. Greater use of public and non-motorized transport by households is introduced by changing demand system parameters to reduce marginal budget shares for petroleum products by 0.2 per cent per year beginning 2015.

iv. The use of electricity and natural gas will substitute petroleum products as alternative fuels in transport sector. This is stipulated by reducing petroleum products inputs in the transport sector by 1.5 percent per year, and replacing them by increasing inputs of natural gas and electricity in the ratio 60:40 percent respectively beginning 2015.

To reflect the use of energy-efficient appliances, the marginal demand for electricity by households is assumed to fall by 2.0 per cent per year from 2015, thereby reducing overall, by 30 percent, by the year 2030.

An alternative service activity is introduced to reflect higher energy efficiency of commercial buildings, but with higher initial cost. The share of this activity is specified to increase from 1 percent to at least 3.4 percent by the year 2030 to reflect projections for the compliance of Energy Conservation Building Code (ECBC). To reflect energy savings from ECBC compliant public buildings, government consumption of energy is reduced appropriately.

Higher AEEI rate of 1.5 percent is assumed for the industrial sector based on various industry studies and the on-going 'perform, achieve and trade (PAT)' scheme, as estimated in Chapter 5.

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[1] Excludes hydro-power as per the existing Government of India practice.

Finally, to reflect the National Mission for Green India that aims to increase green cover in India by 5 million hectares, and improve the quality of forest on another 5 million hectares by 2020, $CO_2$ sequestration rates have been increased from around 185 million tonnes of $CO_2$ per year in 2011 to 270 MT of $CO_2$ per year by 2030.

## 2.4 Results

### The Macro Economic Characteristics of the Scenarios

The growth rates of GDP, private (household) consumption and their levels are shown in table 2.1. Figures 2.1 and 2.2 show the paths of GDP and per capita consumption in the scenarios.

**Table 2.1 Macro Characteristics of BIG and LCIG in Constant 2007-08 prices**

| | | | | Growth Rate (%) | |
|---|---|---|---|---|---|
| | 2007 | 2020 | 2030 | 2007-20 | 2020-30 |
| **BIG** | | | | | |
| GDP (Billions) | 48330 | 121083 | 230550 | 7.32 | 6.65 |
| Consumption (Rs/capita/year) | 21787 | 41641 | 78804 | 5.11 | 6.59 |
| **LCIG** | | | | | |
| GDP (Billions) | 48330 | 119731 | 222729 | 7.23 | 6.40 |
| Consumption (Rs/capita/year) | 21787 | 41201 | 77972 | 5.02 | 6.59 |

### Wellbeing

Since inclusive growth is the non-negotiable objective of India’s development, BIG has included many policies to raise wellbeing and the levels of well-being indicators are worth examining. These are given in table 2.2 for both BIG and LCIG.

**Table 2.2 Wellbeing Indicators**

| | BIG | | | LCIG | |
|---|---|---|---|---|---|
| Indicator | 2007 | 2020 | 2030 | 2020 | 2030 |
| Poverty | 250 | 51 | 8 | 55 | 8 |
| IMR | 60.66 | 27.57 | 14.79 | 27.57 | 14.79 |
| MYS | 4.4* | 6.3 | 8.7 | 6.3 | 8.7 |

| | | | | | |
|---|---|---|---|---|---|
| LEB male | 61.63 | 68.08 | 71.07 | 68.08 | 71.07 |
| LEB Female | 63.43 | 70.34 | 73.53 | 70.34 | 73 |

(Poverty – Millions of persons below poverty line; IMR – Infant Mortality Rate per 1000 live births; MYS – Mean Years of Schooling, LEB – Life Expectancy at Birth in years.)

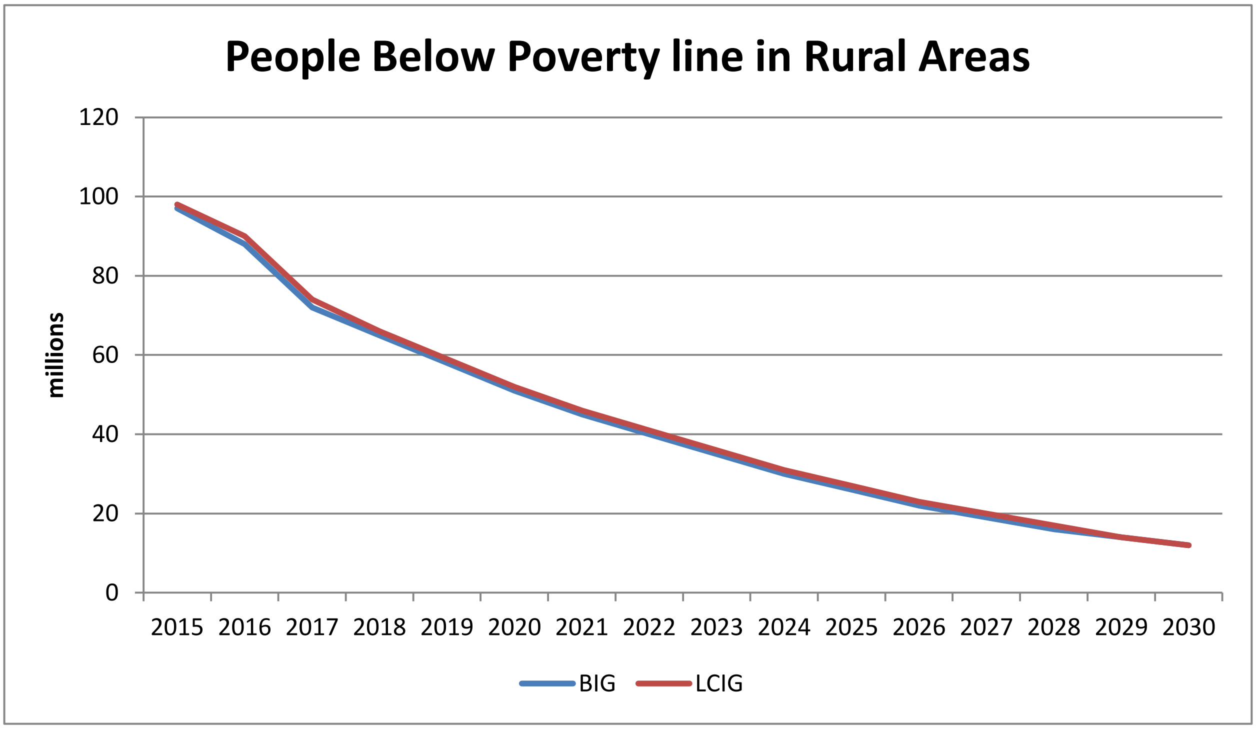



**Figure 2.3: Millions of persons below poverty line in Rural India**

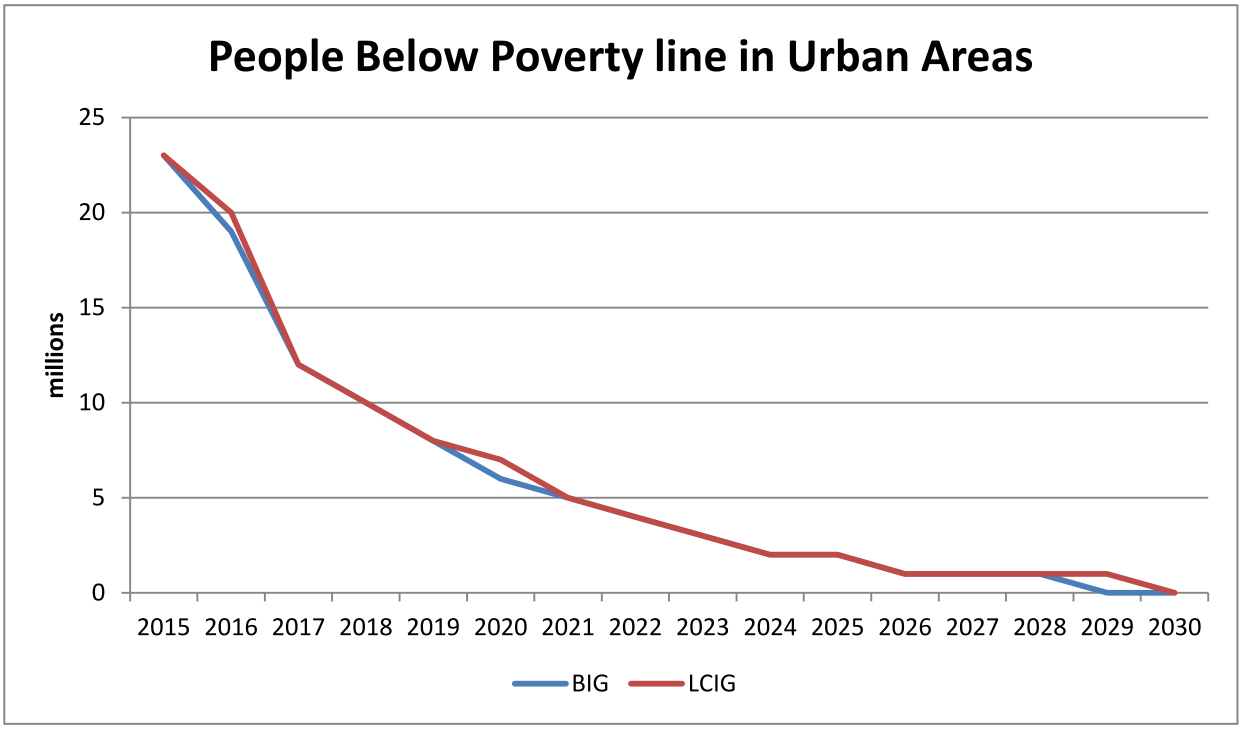



**Figure 2.4: Millions of persons below poverty line in Urban India**

Figures 2.3 and 2.4 show how the number of persons below poverty line changes over time in different scenarios. We see a fall in poverty since 2015 when the scheme of direct cash transfer is introduced. By 2030 poverty is virtually eliminated in both rural and urban areas in the BIG scenario. Since the government without any additional taxes finances the income transfer, the available resource for investment goes down. However in 2030 there is not much difference in the poverty rates. The lower growth rate and lower per capita consumption results in higher poverty in the early years.

**Why is GDP Lower in LCIG?**

The cumulated investments in the economy from 2007-08 are shown in figure 2.5. It is seen that cumulated investments in BIG is slightly lower than LCIG.

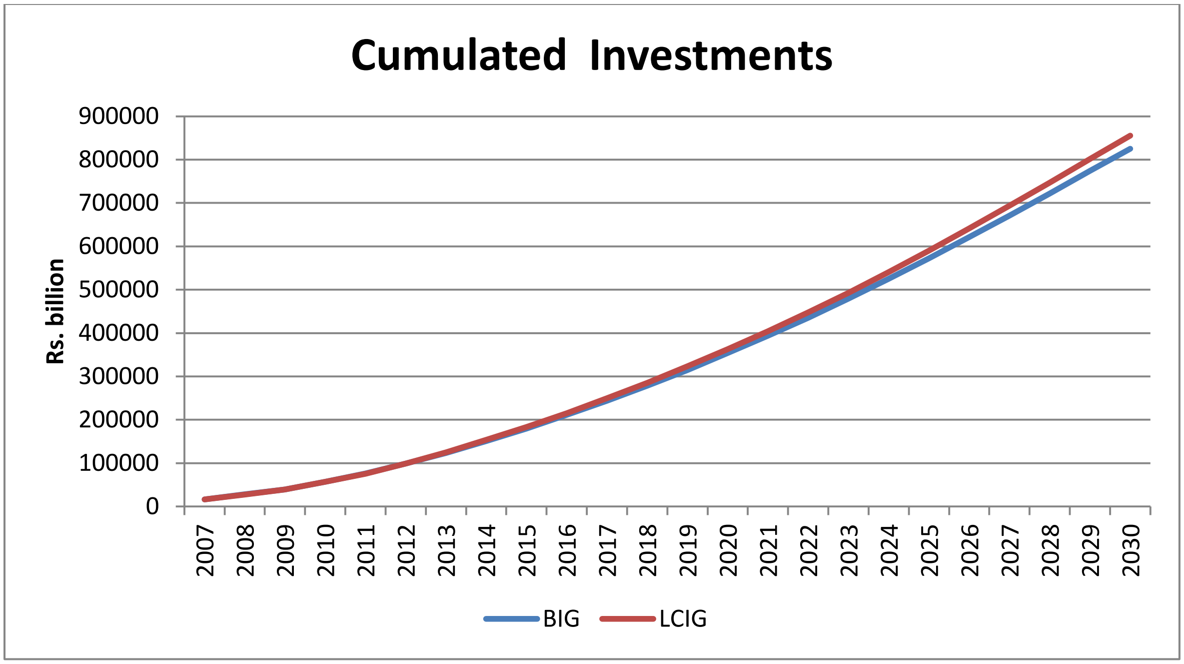



**Figure 2.5: Cumulated Investments in BIG and LCIG at Constant Prices**

In figure 2.6 it is seen that LCIG requires over the years 44 per cent higher investment in the energy sector. Thus even though total investment increases only slightly between the two scenarios, GDP is lower in LCIG because more investment goes for the substantially more expensive renewable sources of electricity and less is available for other sectors.

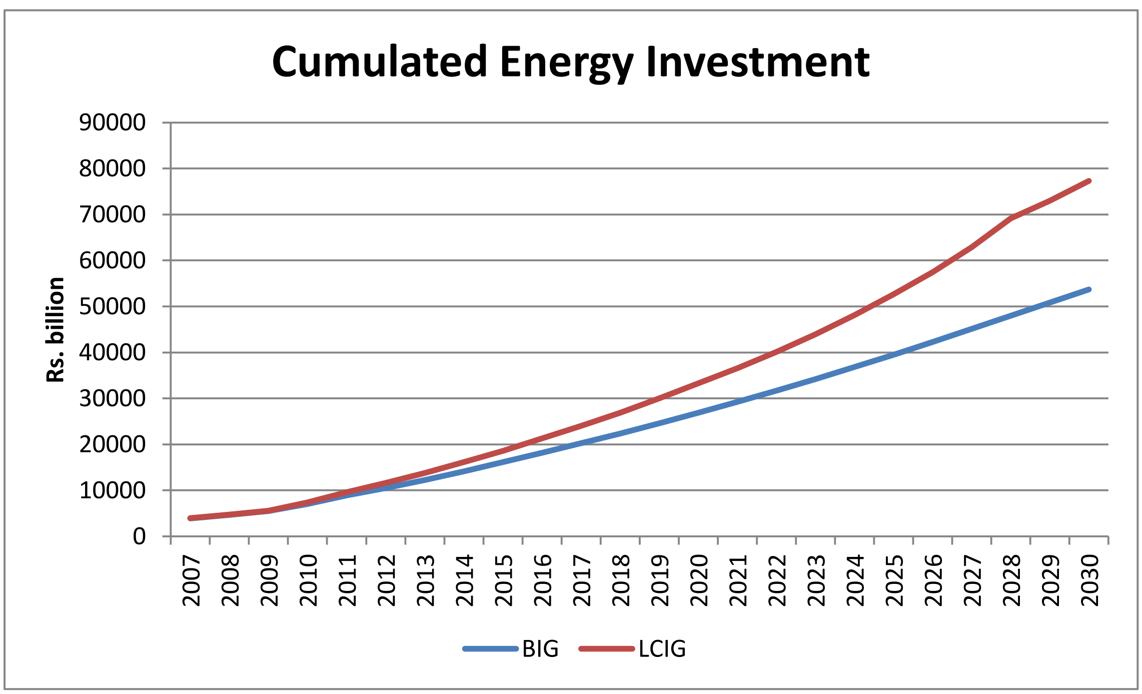


**Figure 2.6: Cumulated Energy Sector Investment in constant prices**

It is worth noting that even though the total energy supply is lower in LCIG compared to BIG electricity generation is higher in LCIG, This is due to additional demand generating from higher railway demand due to shift in freight from road to rail and from increased used of electricity based transportation. The investments are larger in LCIG than in BIG. This is because more expensive technologies of power generation are used in the LCIG. This is seen in figures 2.7 and 2.8.

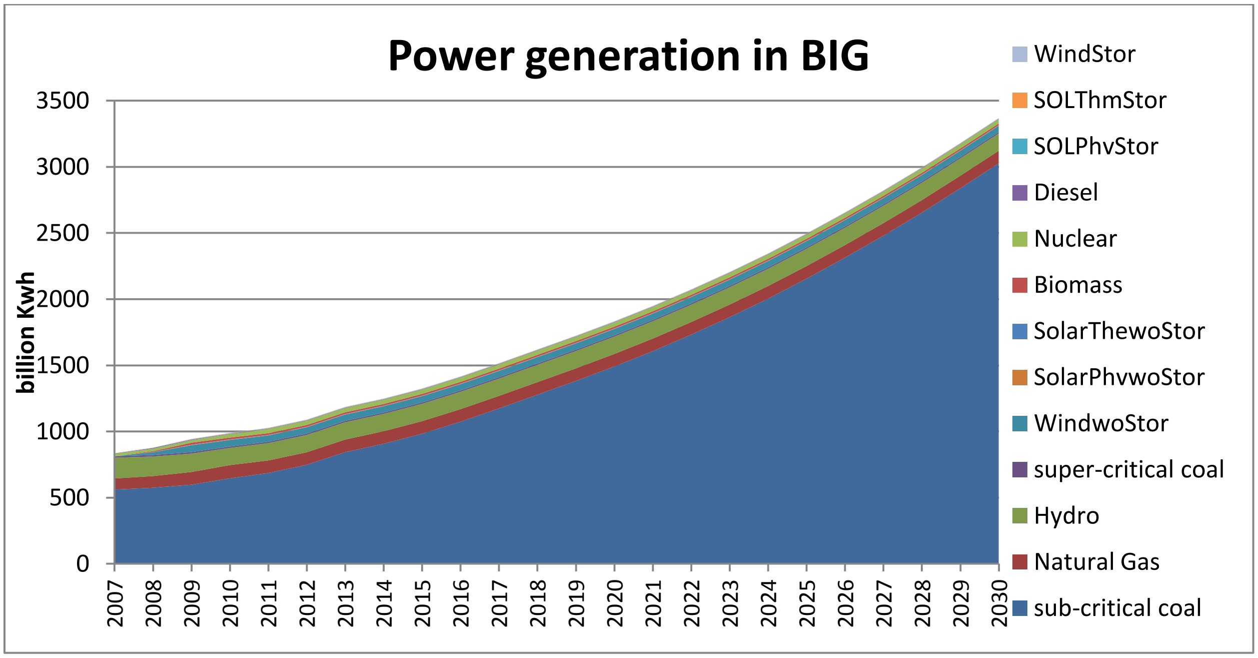



**Figure 2.7: Power Generation in BIG**

BIG relies largely on subcritical coal. Out of a total generation of 3,371 billion units (BU) in 2030 in the BIG scenario, sub-critical coal provides 3,028 BU; whereas in the LCIG scenario, both sub-critical and super-critical coal plants provide only 2,200 BU. On the other hand, non-carbon sources provide 234 BU in BIG and 1134 BU in LCIG **which is 1/3 of total power generation from non fossil fuel sources**. The source wise installed capacities are given in the figure 2.7a below. The comparison of installed capacities between the two scenarios shows a complete swith over to super critical technology in case of coal and very high increase in installed capacities for wind without storage and solar without storage.

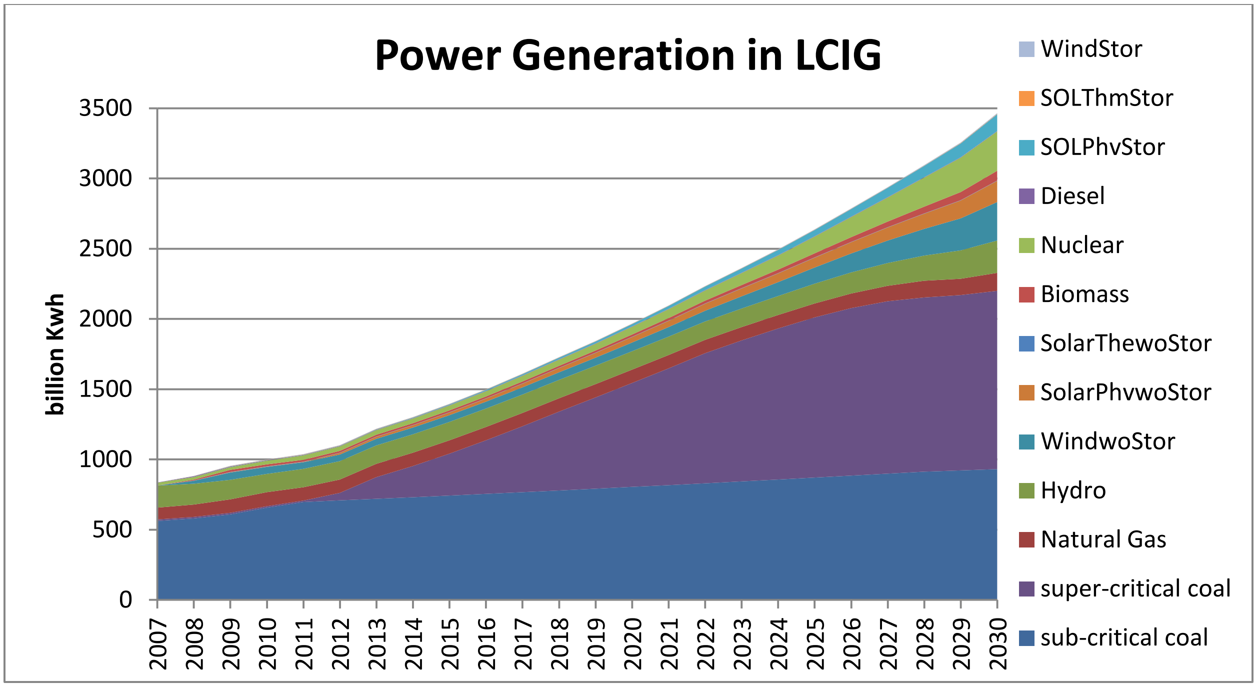



**Figure 2.8: Power generation in LCIG**

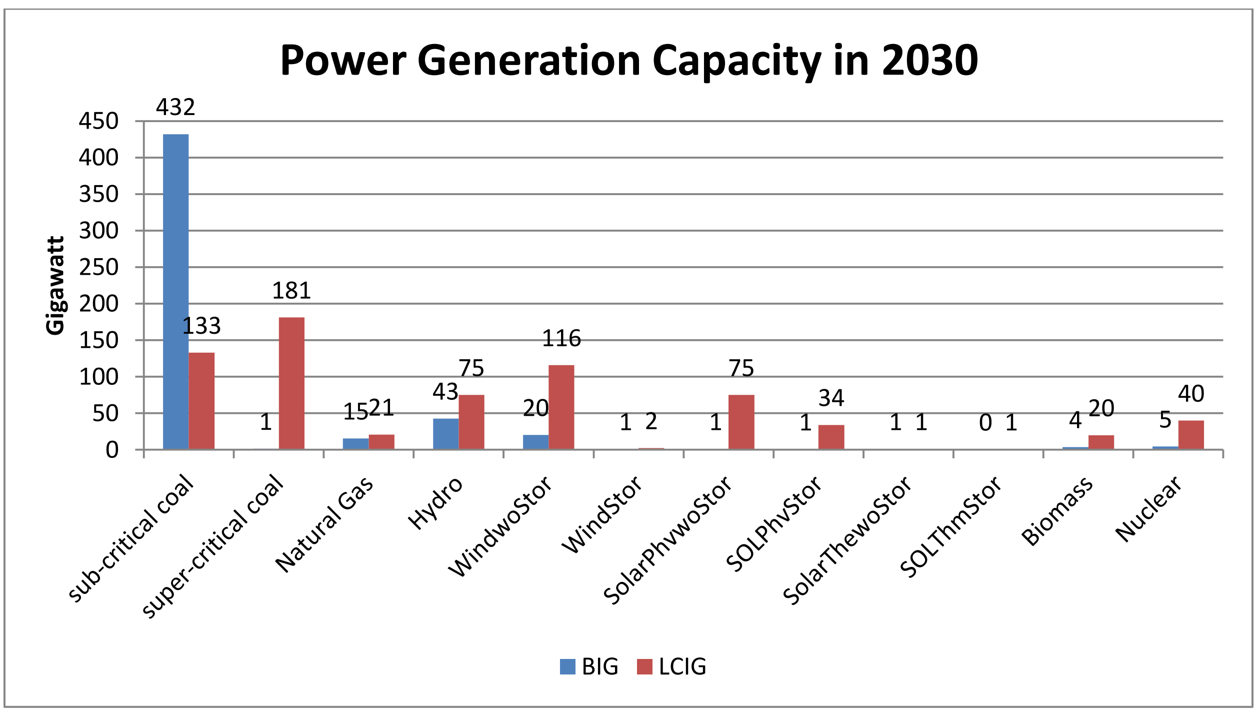



**Figure 2.7a: source wise power generation capacities in 2030 (GW)**

Since the load factor of solar and wind plants are much lower than thermal plants, the installed capcities of solar and wind are much larger than what the levels of generation might indicate. These are shown in figure 2.8b. While solar and wind provide in the LCIG scenario, 48 BU out of 3466 BU in 2030 amounting to 1.4 %, their capacites are 227 Gigawatt (GW) out of 698 GW, which amounts to 32.5 per cent.

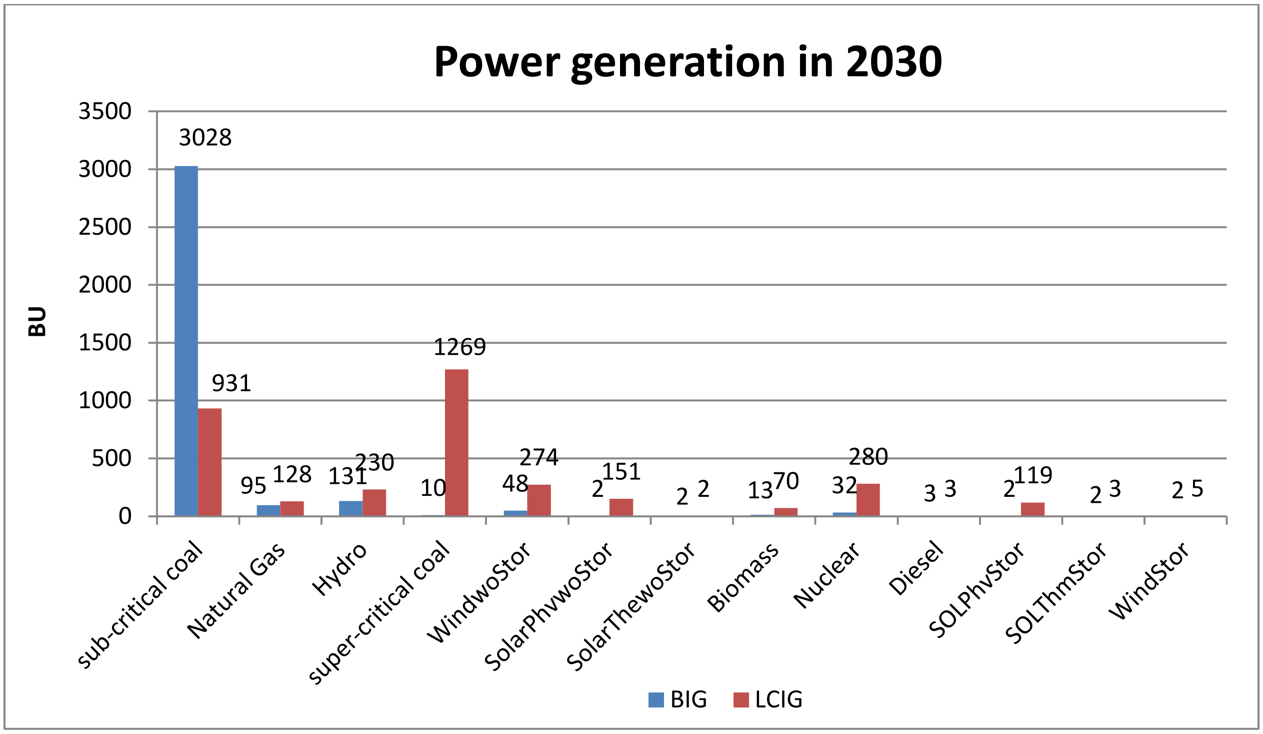



**Figure 2.8b: source wise contribution of total power generation (BU)**

**Total Energy Mix**

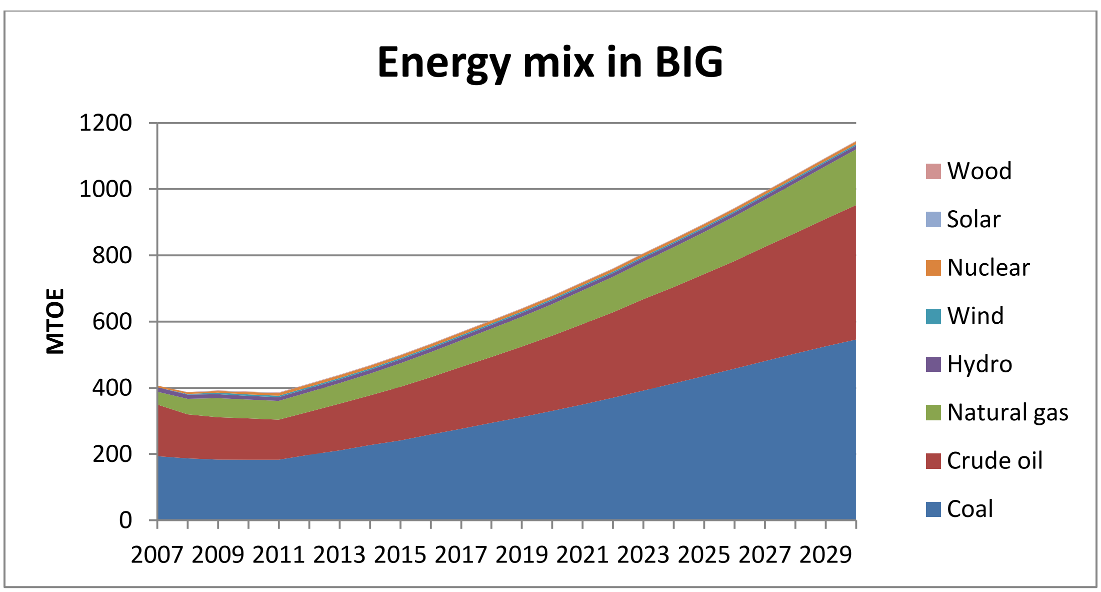



**Figure 2.7b: Energy mix in BIG**

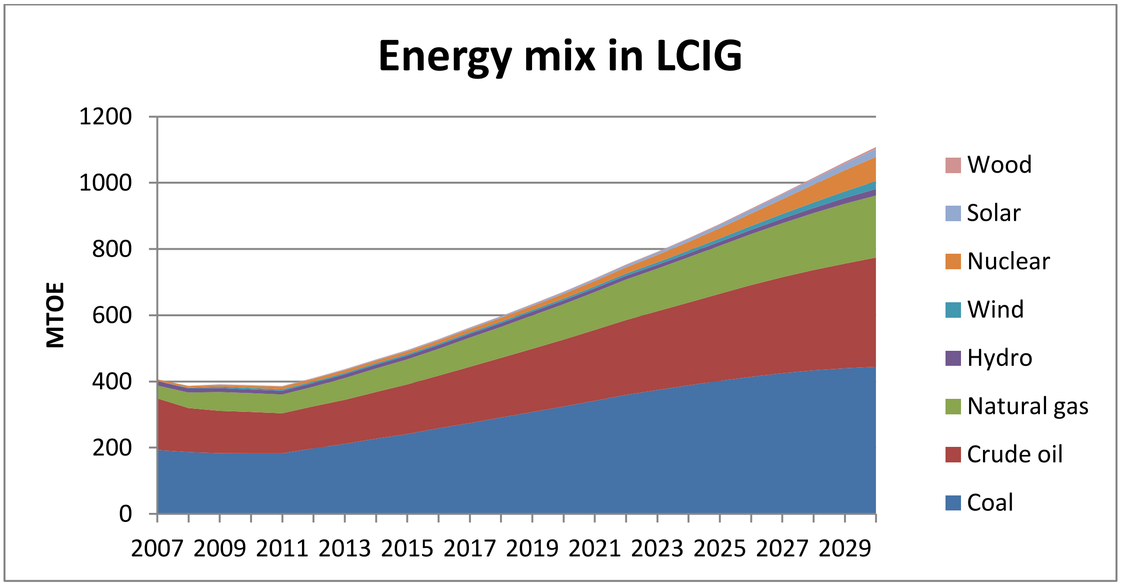



**Figure 2.8b: Energy mix in LCIG**

There is an equivalent shift in the total energy mix between the two scenarios. It can be seen from Figure 2.7b and 2.8b above that the total energy requirment rises from 407 mtoe in 2007 to 1,146 mtoe in the BIG scenario and 1,108 mtoe in the LCIG scenario. While the difference in total energy requirment is moderate, the energy mix changes significantly. Demand for coal in 2030 reduces from 1,568 mt in the BIG to 1,278 mt in the LCIG scenario, and demand for crude oil reduces from 406 mt to 330 mt between the two scenarios, while demand for natural gas rises from 187 bcm in the BIG to 208 bcm in the LCIG scenario. This is shown in the Figure 2.9 below. The demands for Coal and Crude Oil fall by 20 percent, demand for natural gas rises by 11 percent, while the supply of non-fossil energy increases six fold.

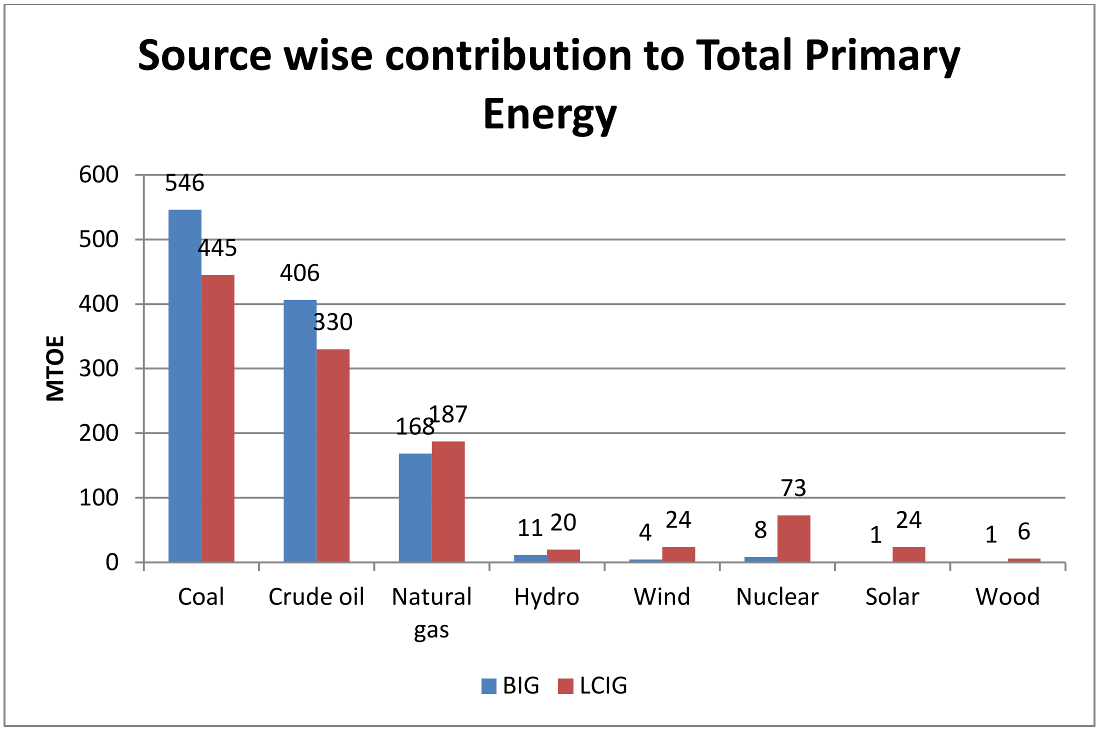



**Figure 2.9: source wise contribution of total primary energy**

## $CO_2$ Emissions

The IRADe model considers only CO2 emissions. The other Non GHG emissions are not considered in the model. The Total CO2 emissions reduce significantly in the LCIG as compared to the BIG scenario. Figure 2.10 shows how they change over time and across scenarios. The total CO2 emissions are expected to reach a level of 5,271 million tonnes by 2030 in the BIG, but could be lowered to 3,830 million tonnes by pursuit of low carbon strategies in the LCIG scenario. The per capita emissions are expected to be 3.6 MT (see fig 2.10) of CO2 by 2030 in the BIG, but could be reduced to 2.6 MT of CO2 in the LCIG scenario

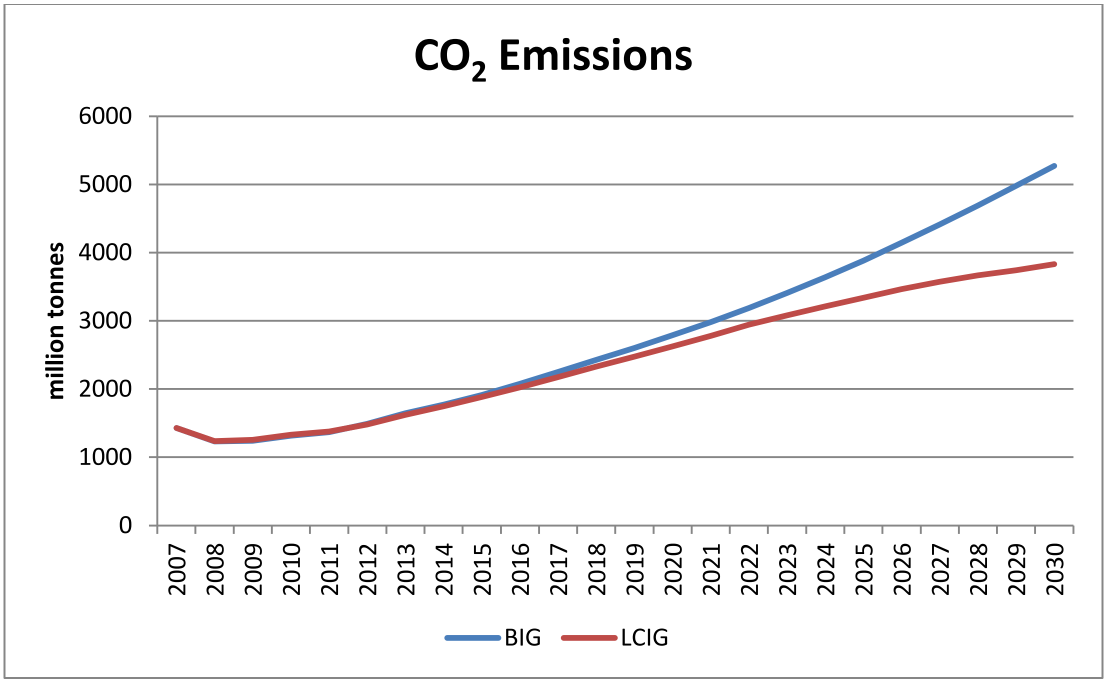



**Figure 2.10: Total CO2 emissions in million tonnes**

In the BIG scenario, the emissions intensity falls from 0.43 kg of CO2/ $ GDP 2007-PPP, in 2007, to 0.33 kg of CO2 / $ GDP 2007-PPP by 2030. This is a reduction of 22 per cent over the 2007 levels. In the LCIG scenario, low carbon measures further reduce it to 0.25 kg of CO2 / $ GDP 2007-PPP by 2030. This is a cumulative reduction of 42 percent over the 2007 levels in the LCIG scenario, nearly twice as much as that in the BIG scenario. These are summarized in table 2.3

**Table 2.3 Emission Intensity in kg of co2 / $ GDP (PPP 2005)**

| | Years | | Percentage Reduction |
|---|---|---|---|
| | 2007 | 2030 | 2007 to 2030 |
| BIG | 0.43 | 0.33 | 22 |
| LCIG | 0.43 | 0.247 | 42 |

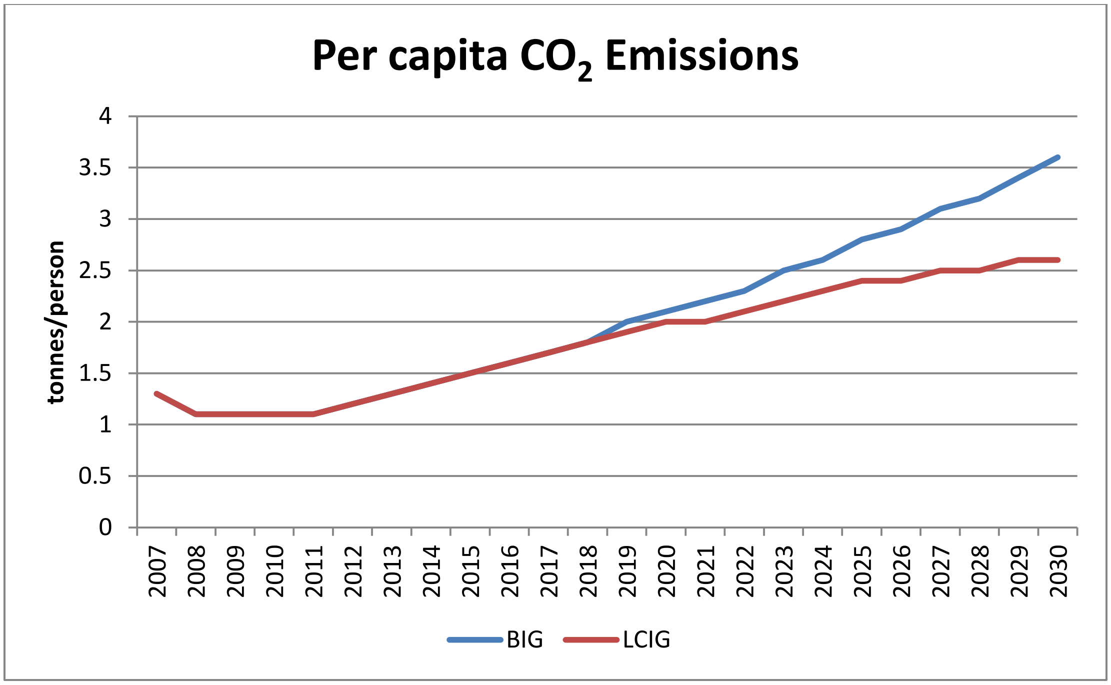



**Figure 2.11: Per Capita CO2 emissions in tonnes/person/year**

**Factors Contributing to Emission Reduction**

The emission intensity reduction is realized through three measures; reduction in GDP, reduction in energy intensity of GDP through demand side management and emission intensity of energy through introduction of low carbon energy sources. The energy intensity of GDP falls from 0.121 kgoe /$ GDP 2007-PPP, in 2007, to 0.071 kgoe/ $ GDP 2007-PPP, in 2030 in both the scenarios. The reason why the LCIG energy intensity not lower, is that in LCIG, the GDP itself is lower, and there are modal shifts in different sectors.

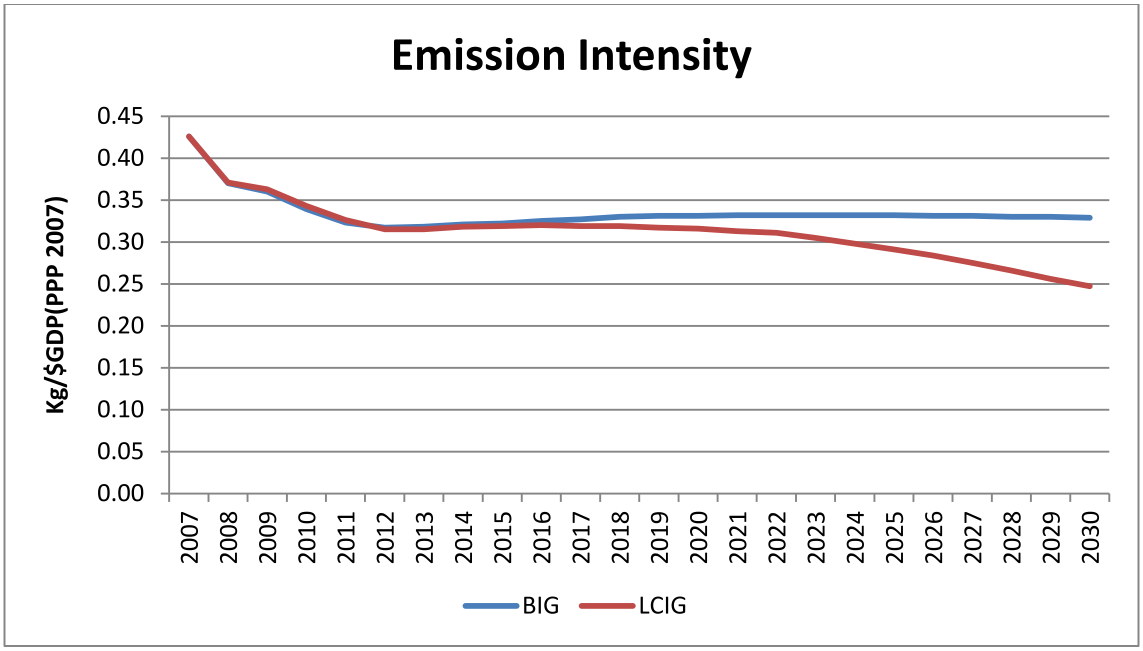



**Figure 2.12: The Emissions' Intensity in kg of CO2/ $ of GDP (PPP 2005)**

A decomposition analysis shows in figure 2.12 the contributions in reducing CO2 emissions of the three factors, reduction in GDP, energy intensity and emission intensity of energy.

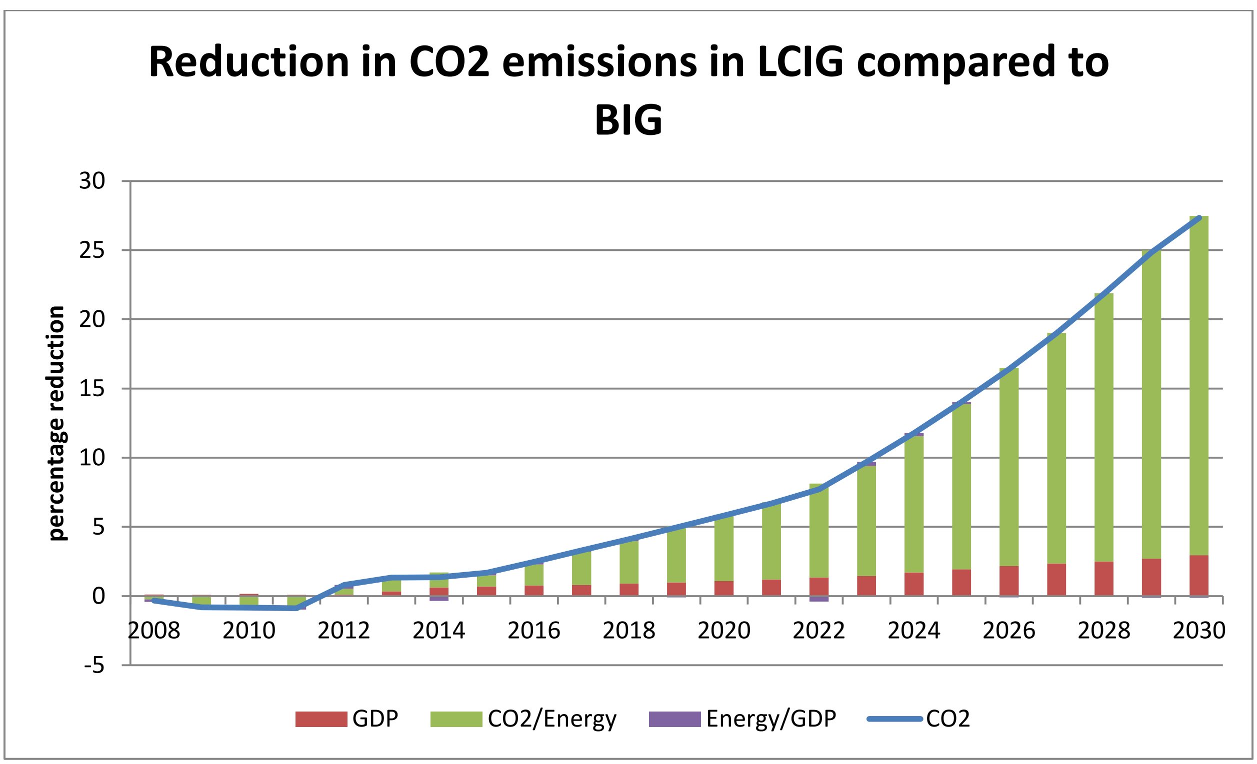



**Figure 2.12: Contributions to CO2 Reductions by the Three Factors**

This decomposition has been attempted in a manner similar to a typical growth accounting exercise in the economic literature. It can be seen that even though total emissions in the LCIG scenario are 27 percent lower than in the BIG scenario in 2030, only 3 percent of it comes from reduced GDP, none from energy intensity of GDP and the remaining entire 24 percent comes from change in the supply mix (CO2/energy).

The impact of specific low carbon measures has to be separated from the impact of lower GDP. Table 2.5 below gives flows of energy sources in 2030 for important sectors and the contribution of different low carbon measures to the overall emission reduction between the two scenarios:

**Contributions of Different Measures**

The impact of specific low carbon policy has to be separated from the impact of lower GDP. To do so, we have developed one more scenario, CLCIG scenario, where additional foreign inflows ensure that the level of household consumption is the same as in the BIG scenario. The CLCIG scenario gives the same path of consumption as shown in table 2.1 for BIG. The additional inflows of foreign capital required are shown in Table 2.4.

**Table 2.4a: Additional Cost to the economy due to GDP loss**

| Total GDP Cost in 2011-12 Prices | | | | |
|---|---|---|---|---|
| Year | GDPloss | Cumulated GDPloss | Cumulated GDPloss ($) | cumulated discounted loss |
| 2011 | 80 | 80 | 2 | 2 |
| 2012 | 105 | 185 | 4 | 4 |
| 2013 | 346 | 531 | 11 | 10 |
| 2014 | 668 | 1199 | 25 | 22 |
| 2015 | 792 | 1991 | 42 | 36 |
| 2016 | 948 | 2939 | 61 | 50 |
| 2017 | 1098 | 4037 | 84 | 67 |
| 2018 | 1305 | 5342 | 111 | 85 |
| 2019 | 1544 | 6886 | 144 | 105 |
| 2020 | 1825 | 8712 | 182 | 128 |
| 2021 | 2157 | 10869 | 227 | 153 |
| 2022 | 2560 | 13428 | 280 | 182 |
| 2023 | 2992 | 16420 | 343 | 214 |
| 2024 | 3808 | 20228 | 422 | 254 |
| 2025 | 4691 | 24920 | 520 | 300 |

| | | | | |
|---|---|---|---|---|
| 2026 | 5663 | 30583 | 638 | 354 |
| 2027 | 6635 | 37218 | 777 | 415 |
| 2028 | 7645 | 44863 | 936 | 481 |
| 2029 | 8980 | 53843 | 1124 | 555 |
| 2030 | 10558 | 64402 | 1344 | 638 |
| | | | | |
| **Market exchange rate 2011-12 47.9229** | | | | |

## Table 2.4b: Additional Cost to the economy due to investment in Low carbon technologies and measures

| Total Investment Cost in 2011-12 prices | | | | |
|---|---|---|---|---|
| Year | Cost increase | Cumulated Costincrease | cumulated Costincrease ($) | cumulated discounted cost increse |
| 2011 | 472 | 472 | 10 | 10 |
| 2012 | 729 | 1202 | 25 | 24 |
| 2013 | 849 | 2051 | 43 | 40 |
| 2014 | 885 | 2935 | 61 | 54 |
| 2015 | 1001 | 3936 | 82 | 70 |
| 2016 | 1115 | 5051 | 105 | 87 |
| 2017 | 1232 | 6283 | 131 | 104 |
| 2018 | 1375 | 7659 | 160 | 121 |
| 2019 | 1522 | 9180 | 192 | 140 |
| 2020 | 1704 | 10885 | 227 | 160 |
| 2021 | 1606 | 12491 | 261 | 176 |
| 2022 | 1887 | 14378 | 300 | 195 |
| 2023 | 2294 | 16672 | 348 | 217 |
| 2024 | 2646 | 19318 | 403 | 242 |
| 2025 | 3020 | 22338 | 466 | 269 |
| 2026 | 3464 | 25802 | 538 | 299 |
| 2027 | 4150 | 29952 | 625 | 334 |
| 2028 | 5244 | 35196 | 734 | 377 |
| 2029 | 2068 | 37264 | 778 | 384 |
| 2030 | 2693 | 39958 | 834 | 396 |
| | | | | |
| **Market exchange rate 2011-12 47.9229** | | | | |

As a percentage of GDP, LCIG scenario requires an additional energy investment worth 1.5 percent of GDP, over and above the BIG scenario. The calculations are reported in table 2,4 a and b above. This amounts to a total of 834 Billion US Dollars at 2011 prices. This diverts resources from other needs and may not possible to sustain if the growth is not fast enough. The total GDP loss caused by the additional energy investment in the LCIG scenario has been quantified at 1,344 Billion US Dollars at 2011 prices, which amounts to an output loss of 3 percent over the BIG scenario. International help, in both finance and technology, would therefore be critical to support this effort.

Table 2.5 gives flows of energy sources for 2030 for important sectors and their decomposition into impact of various measures. The difference between IG and CLCIG is considered due to policy measures and the difference between LCIG and CLCIG is ascribed due to lower GDP. *It may be emphasized that these attributions are approximate as the sectoral structure of the economy in LCIG and CLCIG are somewhat different and some of the change ascribed to lower growth may be due to this change in structure.*

**Table 2.5: Low Carbon Measures and Reduction in Energy Use in Important Sectors in 2030**

(a) Electricity (bkWh)

| | Availability | Transport | Household | Government | Industry | Other services |
|---|---|---|---|---|---|---|
| BIG | 4079 | 70 | 526 | 312 | 1688 | 782 |
| LCIG | 3661 | 64 | 391 | 271 | 1363 | 580 |
| CLCIG | 3952 | 71 | 449 | 271 | 1434 | 635 |
| | | | | | | |
| % reduction in LCIG over IG | | | | | | |
| Efficient appliance | 0.03 | | 0.31 | | | |
| Electric Transport | | -0.97 | -0.06 | -0.05 | | |
| vehicular efficiency | | | | | | |
| Road to rail | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| ECBC Compliant buildings | | | | 0.18 | | 0.19 |
| PAT+ Autonomous efficiency | | 0.94 | | | 0.04 | |
| Growth | 0.07 | 0.11 | 0.01 | | 0.15 | 0.07 |
| Total | 0.10 | 0.09 | 0.26 | 0.13 | 0.19 | 0.26 |
| (b) Petroleum products (MT) | | | | | | |
| | Availability | Transport | Household | Government | Industr y | services |
| BIG | 424 | 133 | 140 | 17 | 81 | 164 |
| LCIG | 301 | 60 | 127 | 13 | 62 | 84 |
| CLCIG | 333 | 67 | 145 | 13 | 64 | 93 |
| | | | | | | |
| % reduction in LCIG over IG | | | | | | |
| Efficiency | 0.22 | | | | | 0.43 |
| fuel substitution by gas and electricity | | 0.07 | 0.03 | 0.13 | | |
| vehicular efficiency | | 0.42 | 0.05 | 0.12 | | |
| Road to rail | | | | | | |
| ECBC Compliant | | | | | | |
| PAT | | | | | 0.04 | |
| Growth | 0.07 | 0.06 | 0.01 | | 0.20 | 0.06 |
| Total | 0.29 | 0.55 | 0.10 | 0.25 | 0.23 | 0.49 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| (c) Coal (MT) | | | | | | |
| | Availability | Transport | Household | Government | *Industry | services |
| BIG | 2789 | | 15 | 11 | 2742 | 19 |
| LCIG | 1980 | | 13 | 11 | 1940 | 14 |
| CLCIG | 2043 | | 15 | 11 | 2001 | 15 |
| | | | | | | |
| % reduction in LCIG over IG | | | | | | |
| Efficiency | 0.27 | | 0.00 | 0.00 | 0.27 | 0.20 |
| fuel substitution | | | | | | |
| vehicular efficiency | | | | | | |
| Road to rail | | | | | | |
| ECBC Compliant | | | | | | |
| PAT | | | | | | |
| Growth | 0.02 | | 0.13 | 0.00 | 0.02 | 0.05 |
| Total | 0.29 | | 0.13 | 0.00 | 0.29 | 0.25 |

*Industry coal reduction includes the reduction of coal due to substitution by renewables and shift to super critical coal

| (d) Natural gas (bcm) | | | | | | |
|---|---|---|---|---|---|---|
| | Availability | Transport | Household | Government | *Industry | services |
| BIG | 277 | 0.0 | 0.2 | 7.3 | 197.1 | 72.1 |
| LCIG | 169 | 39.5 | 22.0 | 9.1 | 146.7 | 97.2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| CLCIG | 241 | 44.2 | 25.3 | 9.1 | 154.8 | 110.4 |
| | | | | | | |
| % reduction in LCIG over IG | | | | | | |
| Efficiency | 0.13 | | | | 0.04 | 0.04 |
| Gas Transportation | | -44.29 | -106.49 | -1.41 | | |
| vehicular efficiency | | -0.04 | 0.00 | 1.15 | | |
| Road to rail | | | | | | |
| ECBC Compliant | | | | | | |
| PAT | | | | | | |
| Growth# | 0.26 | 4.88 | 1.49 | 0.00 | 0.22 | -0.38 |
| Total | 0.39 | -39.45 | -105.00 | -0.26 | 0.26 | -0.35 |

*Industry coal reduction includes the reduction of Gas due to substitution by renewables

# For Transport the number reported is absolute number

An analysis of the table 2.5 shows the following:

- The total electricity consumption increases by 95 bkWh in LCIG compared to BIG in 2030. Power demand decreases by 92 bkwh is due to lower GDP. The total consumption of petroleum products falls by 94 mt of which 26 mt is due to lower GDP, that of coal by 376 mt of which 126 mt is due to lower GDP, and that of natural gas increases by 29 bcm.
- Household consumption of electricity in LCIG falls by 91 bkWh in 2030, which is a reduction of 20 percent. Of this 26 percent is due to energy efficient appliances, and less than 1 percent due to reduction in GDP and an increase of 6 percent due to electric vehicles.
- Government consumption of electricity falls by 36 bkWh, which is 13 percent of consumption in BIG. This is due to 12.58 percent reduction due to ECBC compliant buildings and 0.5 percent increase due to electric vehicles.

- ECBC compliant commercial buildings provide a reduction of 97 bkWh in 2030 which is 14 percent of consumption in BIG.
- Energy efficiency in industry including power generation, due to the PAT scheme reduces electricity demand by 48 bkWh, coal demand by 248 mt, petroleum products' demand by 3 mt and natural gas by 6 bcm.
- Transport vehicles efficiency improvement leads to a reduction of 30 mt of consumption of petroleum products; whereas fuel substitution of petroleum products by natural gas and electricity, and reduced demand by households for motorized transport together reduce consumption of petroleum products by 40 mt; and increase consumption of electricity by 48 bkWh and of natural gas by 67 bcm.

The analysis above shows the importance of looking at various low carbon measures in an integrated way in a macro model framework. The interactions of various policy measures and feedback are significant.

## 2.5 Conclusion

Inclusiveness remains unchanged between the two scenarios while the low carbon strategies span the vector space between them. Both scenarios BIG and LCIG equally improve the wellbeing indicators in 2030. The endpoint scenarios are summarized below:

1. **Baseline, Inclusive Growth (BIG):** An average 7 percent GDP growth is sustained up to 2030. Rural poverty is expected to fall below 10 percent, while urban poverty will be completely eliminated. The aggregate $CO_2$ emissions are expected to rise from 1,429 MT in 2007 to 5,271 MT in 2030 and per capita emissions are expected to rise from 1.3 tonnes of $CO_2$ per year to 3.6 tonnes of $CO_2$ per year by 2030. The total energy demand is expected to rise from 400 Mtoe in 2007 to 1146 Mtoe in 2030, while the power demand is expected to increase from 837 Billion Units in 2007 to 3371 Billion Units in 2030. The total demand for fossil fuels is expected to be 1568 MT of coal, 406 MT of crude oil and 187 bcm of natural gas in 2030, which is a significant increase as compared to 556 MT of coal, 156 MT of crude oil and 43 bcm of natural gas in 2007. Emissions intensity in terms of kg $CO_2$ $ per GDP (2005 PPP) comes down from 0.43 in 2007 to 0.33 in 2030, a reduction of 22 percent over 2007 levels.

2. **Low Carbon, Inclusive Growth (LCIG):** Although the average long term GDP growth is only marginally lower at 6.9 percent, low carbon strategies require an additional investment worth 834 billion US dollars at 2011 prices. Cumulative investment in rupee value in the energy sector between 2007 and 2030 is 44 percent higher in the LCIG scenario as compared to the BIG scenario. A finance of this magnitude would be difficult to mobilize, particularly if the high growth is not sustained in the long run, and adequate assistance in the form of international finance and technology is not forthcoming. Outcomes, which measure inclusion and wellbeing, remain the same as in the BIG scenario, while the total CO2 emissions now increase much more moderately to 3,830 MT and per capita emissions to 2.6 tonnes by the year 2030. The decline in emissions intensity of GDP nearly doubles to 42 percent, over 2007 levels, by 2030. An accounting exercise shows that out of this total reduction, 3 percent comes from GDP, 10 percent from energy efficiency and 29 percent from shift to energy sources which emit less carbon. The total energy demand, in 2030, will be lower at 1,108 Mtoe, while the power demand would still rise to 3,466 Billon Units due to improved access and modal shifts. About one-third of power supply would be fossil free and aggregate demand of fossil fuels would be much lower at 1,278 MT of coal, 330 MT of crude oil and 208 bcm of natural gas.

# 3. Projecting Electricity Consumption by Households Appliances

## 3.1 Objective:

This study is intended to project the number of appliances of different star ratings that will be possessed by the households of different expenditure classes for the year 2021 and 2031. The study estimates the energy savings from labeling of appliances assuming that consumers will buy energy efficient appliance that are economically justified at a discount rate of 10 per cent for the for top 5 classes and 20 per cent for the relatively poorer bottom 5 classes.

## 3.2 Projecting Appliances

With economic development consumption of energy increases as households buy and use more appliances. Household appliances consume substantial amount of electricity. Higher income group possesses more appliances and more energy intensive appliances and consumption of electricity increases. The National Sample survey is a quinquennial survey of consumer expenditure. The 66$^{th}$ round data (year 2009-10) gives the number of households possessing an appliance per 1000 households for the year 2009-10. Population is divided into 10 decile classes of monthly per capita consumer expenditure (MPCE). The survey generates estimates of average households of MPCE and its distribution over households and persons and also its break up by commodity group at all India and State/UT level, and also for different socio economic groups. These indicators are highly significant to measure the level of living of people.. However, here we have taken 12 items of household appliances and durable goods that are possessed by rural and urban households according to their MPCE decile class for all India level in the year 2009-10. Total estimated households in rural and urban areas in 2009-10 were 163 million and 68 million respectively. Thus each decile class represents 16.3 million and 6.8 million households in rural and urban areas respectively.

Data are given below **in Table 3.1** for rural and in **Table 3.2** for urban households.

**Table 3.1: Number of Rural households possessing household appliances and durable goods. Per 1000 no. of households.**

| | MPCE decile class | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Items | 0-537 | 537-631 | 631-718 | 718-804 | 804-895 | 895-1001 | 1001-1133 | 1133-1322 | 1322-1653 | 1653-More | All | Number of households possessing the appliances (Million) |
| MPCE (Rs) | 452.98 | 584.4 | 675.35 | 760.79 | 848.07 | 944.35 | 1062.9 | 1220.6 | 1470.33 | 2517 | 1054 | |
| Music System | 183 | 220 | 253 | 269 | 283 | 270 | 287 | 279 | 275 | 291 | 265 | 43.10 |
| Television | 94 | 160 | 235 | 294 | 353 | 398 | 471 | 565 | 612 | 702 | 417 | 67.82 |
| Electric Fan | 205 | 289 | 357 | 440 | 511 | 550 | 629 | 684 | 737 | 825 | 552 | 89.78 |
| Sewing Machine | 21 | 33 | 47 | 62 | 69 | 96 | 120 | 140 | 162 | 237 | 109 | 17.73 |
| Washing Machine | 0 | 1 | 2 | 1 | 2 | 5 | 5 | 10 | 22 | 90 | 18 | 2.93 |
| Refrigerator | 1 | 3 | 4 | 7 | 12 | 25 | 34 | 72 | 122 | 292 | 71 | 11.55 |
| Water purifier | 1 | 1 | 3 | 4 | 5 | 10 | 13 | 19 | 34 | 60 | 18 | 2.93 |
| Pc/Laptop incl .software | 3 | 1 | 1 | 1 | 1 | 3 | 2 | 6 | 7 | 47 | 9 | 1.46 |
| Mobile phone handset | 167 | 245 | 336 | 382 | 475 | 516 | 582 | 628 | 683 | 764 | 506 | 82.30 |
| Motor cycle scooter | 7 | 22 | 28 | 50 | 64 | 104 | 126 | 188 | 256 | 363 | 139 | 22.61 |
| Motor car, jeep | 1 | 3 | 0 | 2 | 4 | 3 | 5 | 10 | 16 | 66 | 14 | 2.28 |

**Source:** Tabulation from NSSO 66th Round Consumption Expenditure, 2009-10, Ministry of Statistics and Programme Implementation (MOSPI), GoI.

In the NSS data air conditioners and coolers are combined. Energy consumption is very different for these two. Thus, in order to obtain estimates of only Air Conditioners, we use data from NCAER survey which is available by quintile groups. These are given in Table 1.1.

**Table 3.1.1: Number of Rural households possessing Air Conditioner per 1000 no. of households**

| MPCE(Rs) | 519 | 718 | 896 | 1142 | 1994 |
|---|---|---|---|---|---|
| Air Conditioner | 0 | 1 | 1 | 2 | 10 |

Source: National Council of Applied Economic Research 2011, New Delhi

Table 3.1 show the number of possessing an appliance per 1000 households in each decile and Table 3.1.1 gives data for only AC by quintile class of MPCE in rural areas.

**Table 3.2: Urban households possessing household appliances and durable goods Per 1000 no. of households.**

| MPCE decile class | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Items** | 0-733 | 733-926 | 926-1101 | 1101-1293 | 1293-1502 | 1502-1773 | 1773-2097 | 2097-2603 | 2603-3665 | 3665-More | All | **Number of households possessing the appliances (Million)** |
| **MPCE (RS)** | 599.27 | 831 | 1011.8 | 1196.08 | 1398 | 1633.42 | 1931 | 2329.9 | 3050.69 | 5863.25 | 1856 | |
| **Music System** | 158 | 169 | 177 | 197 | 219 | 225 | 235 | 251 | 282 | 312 | 233 | 15.88 |
| **Television** | 429 | 597 | 691 | 768 | 830 | 827 | 823 | 818 | 839 | 778 | 758 | 51.67 |
| **Electric Fan** | 664 | 822 | 831 | 902 | 922 | 938 | 946 | 943 | 966 | 970 | 906 | 61.76 |
| **Sewing Machine** | 99 | 136 | 157 | 207 | 227 | 234 | 247 | 248 | 277 | 239 | 217 | 14.79 |
| **Washing Machine** | 5 | 13 | 23 | 50 | 99 | 119 | 177 | 259 | 389 | 495 | 199 | 13.57 |
| **Refrigerator** | 24 | 70 | 114 | 218 | 328 | 359 | 450 | 537 | 664 | 658 | 390 | 26.59 |
| **Water purifier** | 8 | 16 | 32 | 44 | 71 | 101 | 125 | 151 | 256 | 410 | 149 | 10.16 |
| **Pc/Laptop incl. software** | 1 | 2 | 7 | 12 | 25 | 31 | 60 | 91 | 173 | 354 | 99 | 6.75 |
| **Mobile phone handset** | 378 | 576 | 672 | 754 | 827 | 839 | 835 | 886 | 902 | 910 | 787 | 53.65 |
| **Motor cycle scooter** | 32 | 88 | 127 | 201 | 302 | 330 | 400 | 452 | 551 | 477 | 330 | 22.50 |
| **Motor car, jeep** | 1 | 2 | 5 | 10 | 13 | 22 | 29 | 48 | 104 | 255 | 65 | 4.43 |

Source**:** Tabulation from NSSO 66th Round Consumption Expenditure, 2009-10, Ministry of Statistics and Programme Implementation (MOSPI), GoI.

**Table 3.2.1: Number of Urban households possessing Air Conditioner per 1000 no. of households.**

| **MPCE(Rs)** | 715 | 1104 | 1516 | 2130 | 4457 |
|---|---|---|---|---|---|
| **Air Conditioner** | 1 | 3 | 4 | 13 | 120 |

**Source**: National Council of Applied Economic Research 2011, New Delhi

Table 3.2 show the number of possessing an appliance per 1000 households in each decile and Table 3.2.1 gives data for only AC by quintile class of MPCE in urban areas.

The NSS survey does not collect data on how many units of the appliance are possessed by households possessing the appliance. We have assumed that in the first few deciles each household has only one units of the appliance where as on average the higher deciles would have more units for some appliances. The assumed number of units of an appliance per an appliance owning household is given in table 3 and table 4 for rural and urban households in year 2009-10.

**Table. 3.3 Assumed number of unit of each appliance possessed by rural households possessing the appliance**

| CL | Music system | Television | Electric Fan | Air Conditioner, Cooler | Sewing Machine | Washing Machine | Refrigerator | Water purifier | Pc/Laptop incl. software | Mobile phone handset | Motor cycle e scooter | Motor car , jeep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RH1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **RH2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **RH3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **RH4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Rh5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **RH6** | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 |
| **RH7** | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 |
| **RH8** | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 |
| **RH9** | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 |
| **RH10** | 1 | 1 | 3 | 1 | 1 | 1 | 2 | 1 | 1 | 3 | 2 | 2 |

Source**:** IRADe Calculation

**Table 3.4 Assumed number of unit of each appliance possessed by urban households possessing the appliance**

| CL | Music system | Television | Electric Fan | Air Conditioner, Cooler | Sewing Machine | Washing Machine | Refrigerator | Water purifier | Pc/Laptop incl. software | Mobile phone handset | Motor cycle scooter | Motor car, jeep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **UH1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **UH2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **UH3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **UH4** | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **UH5** | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **UH6** | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 |
| **UH7** | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 |
| **UH8** | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 |
| **UH9** | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 |
| **UH10** | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 |

**Source:** IRADe Calculation

Based on this the stock of appliances in the rural and urban households in 2009-10 is worked out and is given in **Table 3.5** The projections are more or less consistent as compared to the NCAER data for the year 2010-11. In fact the data in tables 3 and 4 were selected to get estimates which match the NCAER estimates of stock of various appliances with households.

**Table: 3.5: Estimated number of appliances possessed by households in 2009-10 in Rural and Urban areas (in Million)**

| Appliances | Rural | Urban |
|---|---|---|
| **Music system** | 43 | 21 |
| **Television** | 63 | 67 |
| **Electric Fan** | 166 | 151 |
| **Air Conditioner, Cooler** | 7 | 13 |
| **Sewing Machine** | 16 | 14 |
| **Washing Machine** | 2 | 11 |
| **Refrigerator** | 14 | 44 |
| **Water purifier** | 2 | 8 |
| **Pc/Laptop incl.software** | 1 | 5 |
| **Mobile phone handset** | 153 | 106 |
| **Motor cycle scooter** | 26 | 20 |
| **Motor car, jeep** | 3 | 5 |

Source: NSSO 66th round (2009-10)

In order to project the number of appliances in the future we use the expenditure class wise projection of the population by the IRADe's multi sectoral inter-temporal model. The model has endogenous income distribution with 10 rural and 10 urban consumer expenditure classes. These are given in **Table 3.6** below. Total rural and urban populations were prescribed exogenously based on Registrar General's projections.

**Table 3.6: Projected population proportions in the different expenditure classes by their monthly per capita consumption expenditure (MPCE) in Rs for rural India.**

| Class | MPCE (Rs) (2021) | Population Proportion 2021 | MPCE (Rs) (2031) | Population Proportion 2031 |
|---|---|---|---|---|
| **RH1** | 324 | 0.005 | 588 | 0.001 |
| **RH2** | 559 | 0.031 | 588 | 0.003 |
| **RH3** | 1073 | 0.192 | 1125 | 0.042 |
| **RH4** | 1652 | 0.148 | 1668 | 0.058 |
| **Rh5** | 2141 | 0.129 | 2154 | 0.072 |
| **RH6** | 2936 | 0.218 | 2990 | 0.186 |
| **RH7** | 4130 | 0.119 | 4168 | 0.161 |
| **RH8** | 5408 | 0.072 | 5448 | 0.141 |
| **RH9** | 7032 | 0.047 | 7094 | 0.131 |
| **RH10** | 11225 | 0.038 | 12958 | 0.205 |

Source: IRADe Calculation

**Table 3.7 Projected population proportions in the different expenditure classes by their monthly per capita consumption expenditure (MPCE) in Rs for urban India**

| CL | MPCE(2021) | Population proportion (2021) | MPCE(2031) | Population proportion 2031 |
|---|---|---|---|---|
| **UH1** | 378 | 0.013 | 735 | 0.002 |
| **UH2** | 812 | 0.06 | 833 | 0.015 |
| **UH3** | 2051 | 0.272 | 2158 | 0.126 |
| **UH4** | 3779 | 0.153 | 3811 | 0.108 |
| **UH5** | 5266 | 0.111 | 5289 | 0.098 |
| **UH6** | 7411 | 0.143 | 7478 | 0.158 |
| **UH7** | 10454 | 0.082 | 10502 | 0.113 |
| **UH8** | 13905 | 0.062 | 13968 | 0.103 |
| **UH9** | 17822 | 0.033 | 17865 | 0.065 |
| **UH10** | 33947 | 0.072 | 40184 | 0.212 |

Source: IRADe Calculation

We have plotted possession of appliance data against MPCE. Since MPCE will increase substantially in the future, the 2009-10 NSS data has to be extended. Figures R-1 to R-12 and U-1 to U-12 show the graphs for different appliances. The projections are made on heuristic considerations based on what seemed reasonable. Figures R show the data for rural households and figures U for urban households.

**Figure R-1: Television**

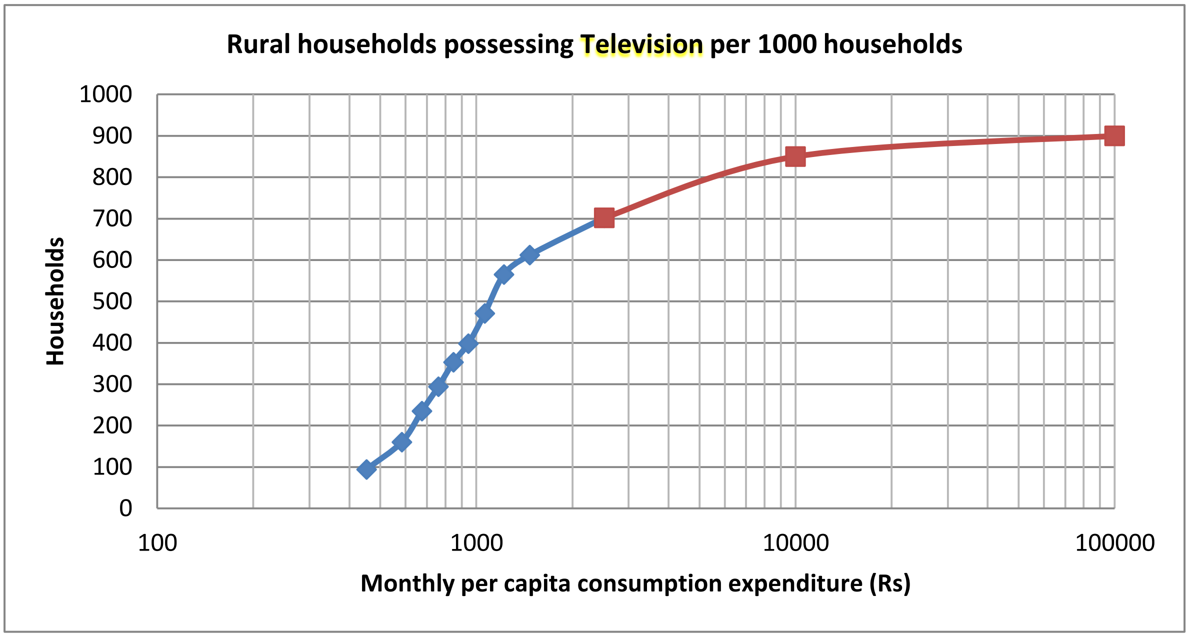



**Figure R-2: Music System**

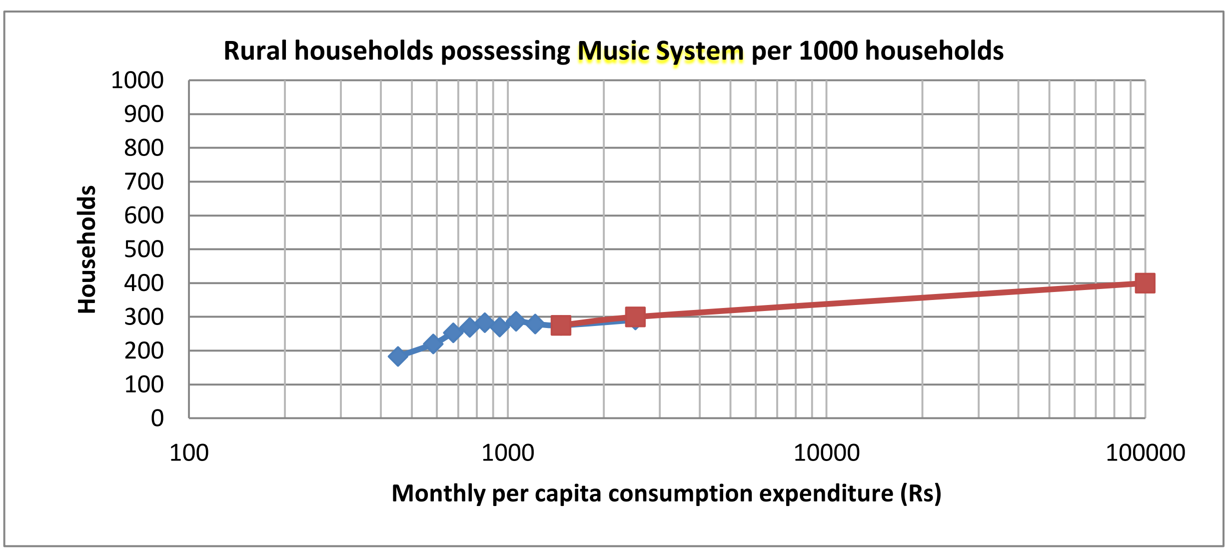


**Figure R-3: Sewing Machine**

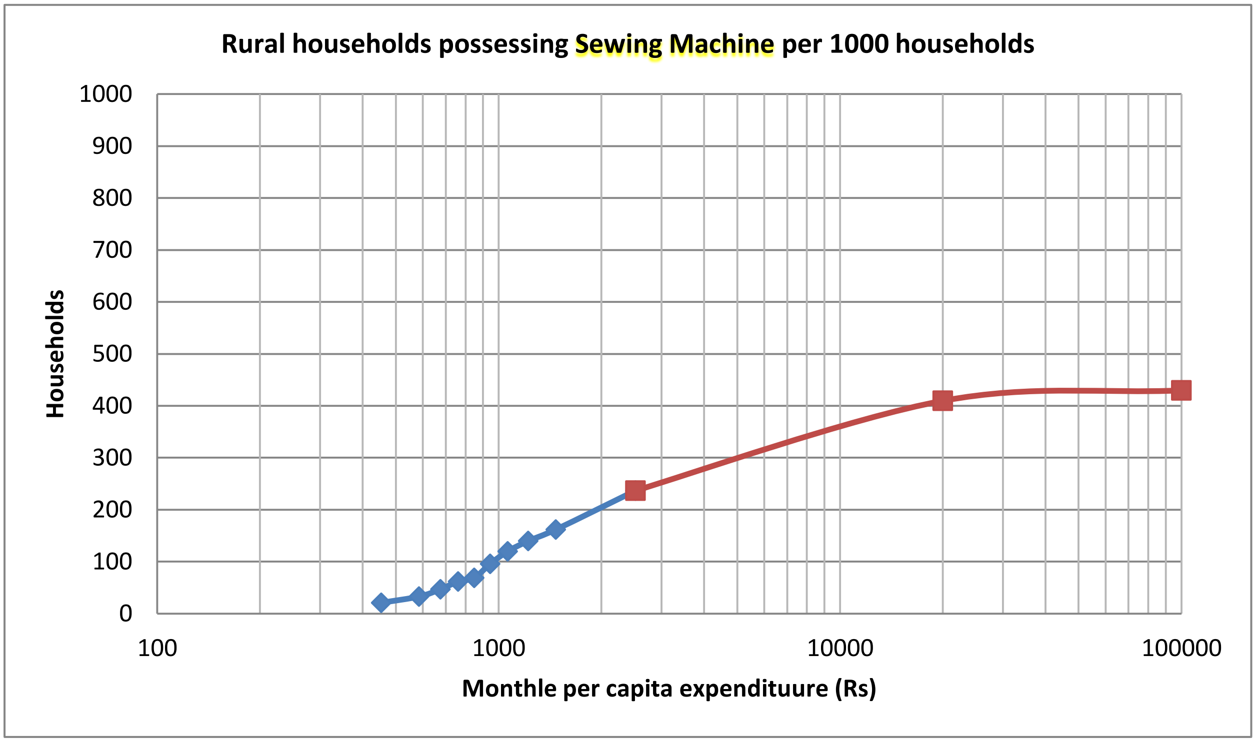



**Figure R-4: Washing Machine**

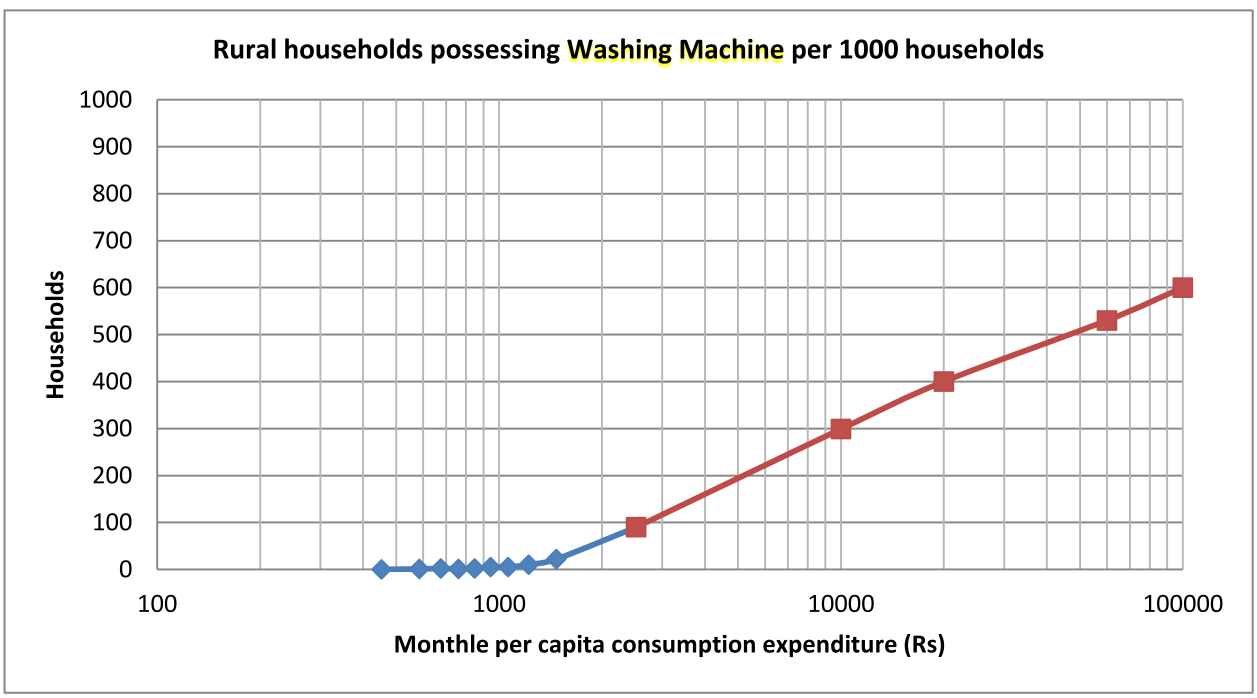


**Figure R-5: Water Purifier**

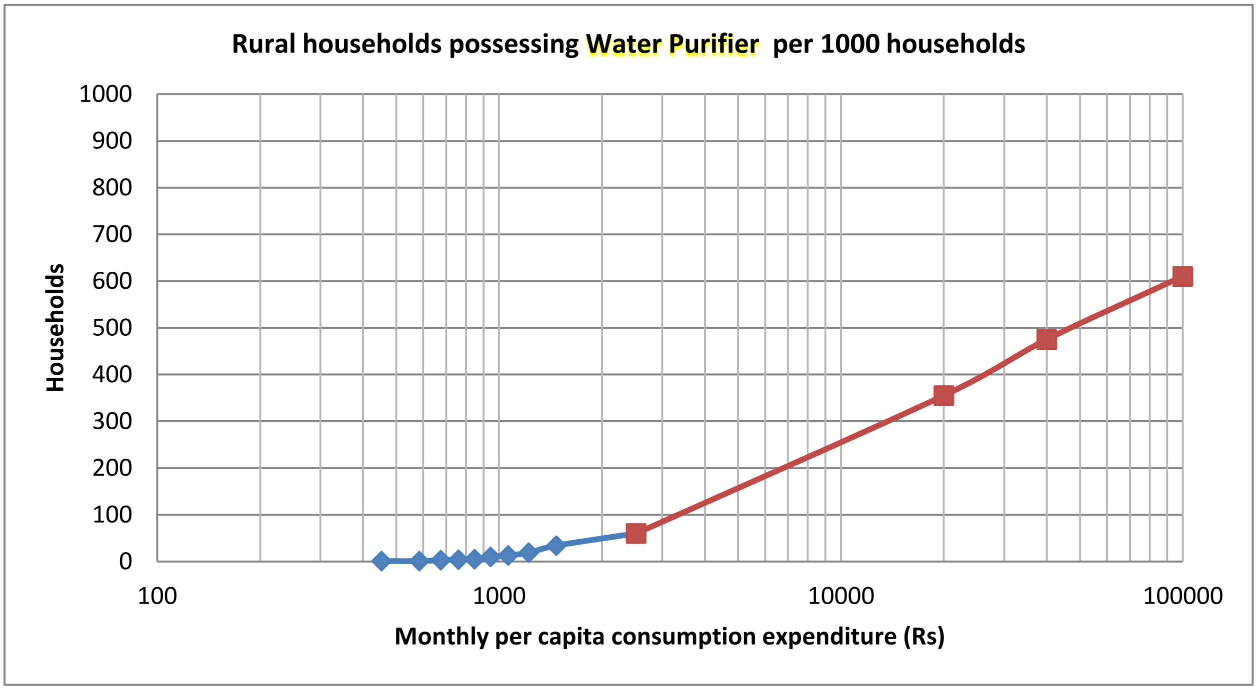



**Figure R-6: Motor Cycle Scooter**

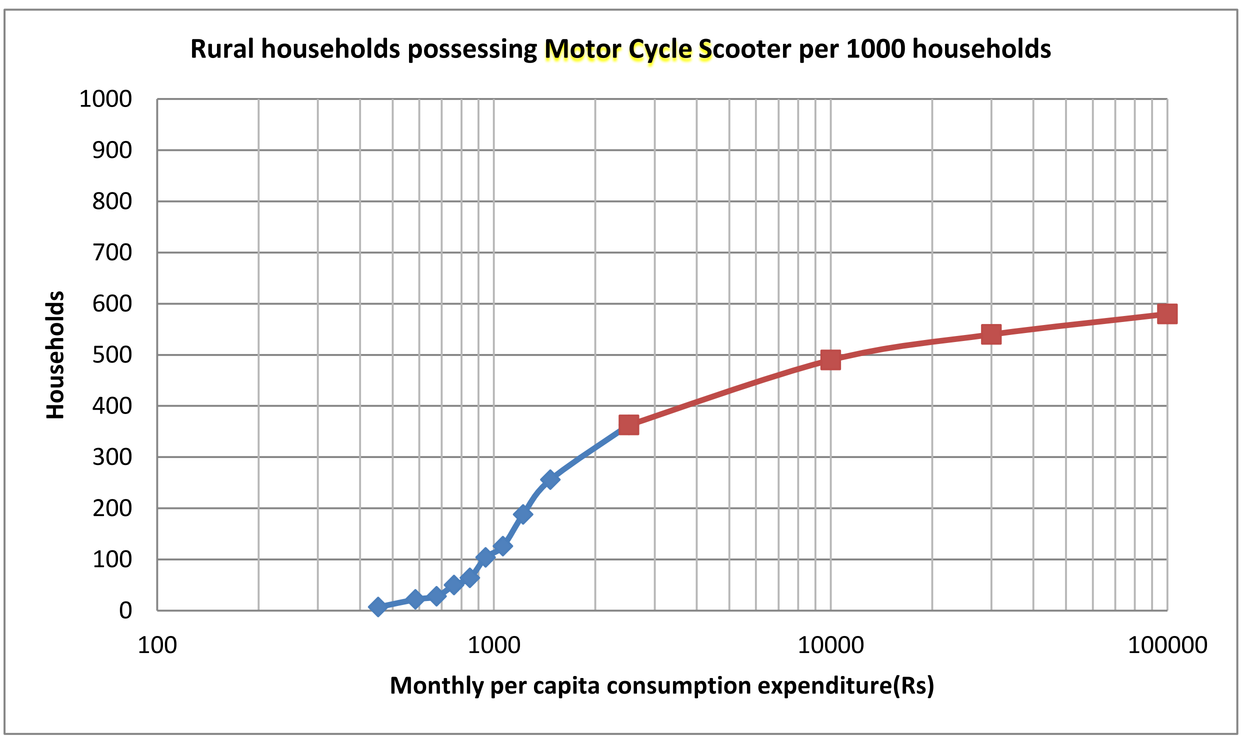


**Figure R-7: Mobile Phone**

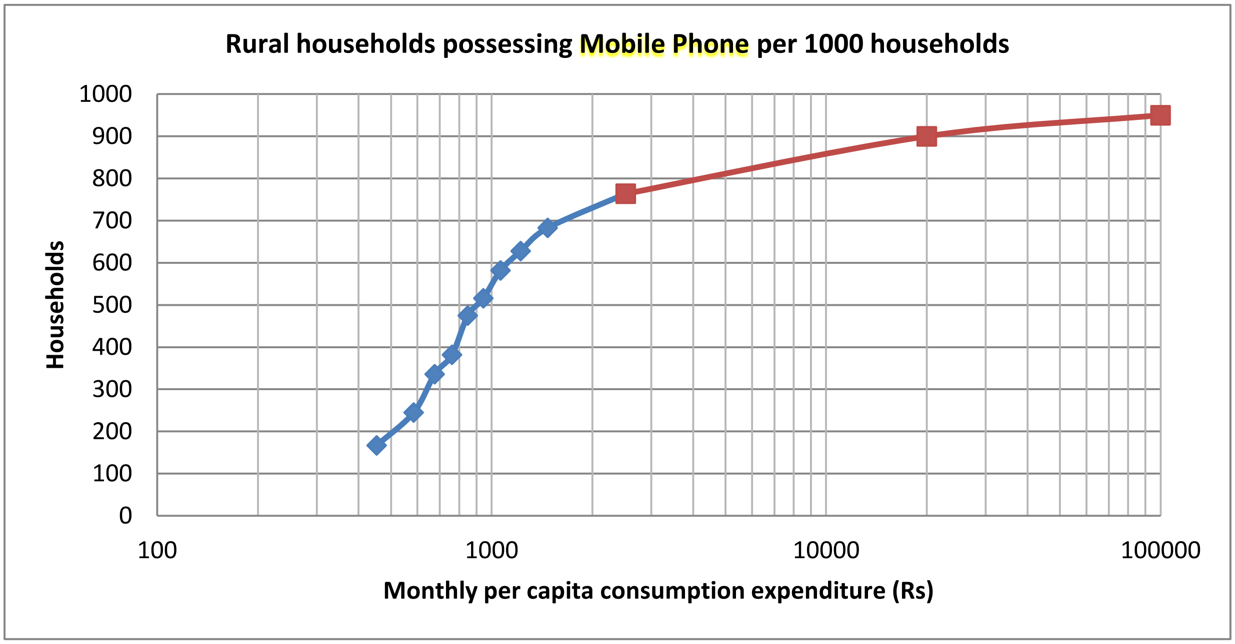



**Figure R-8: Refrigerator**

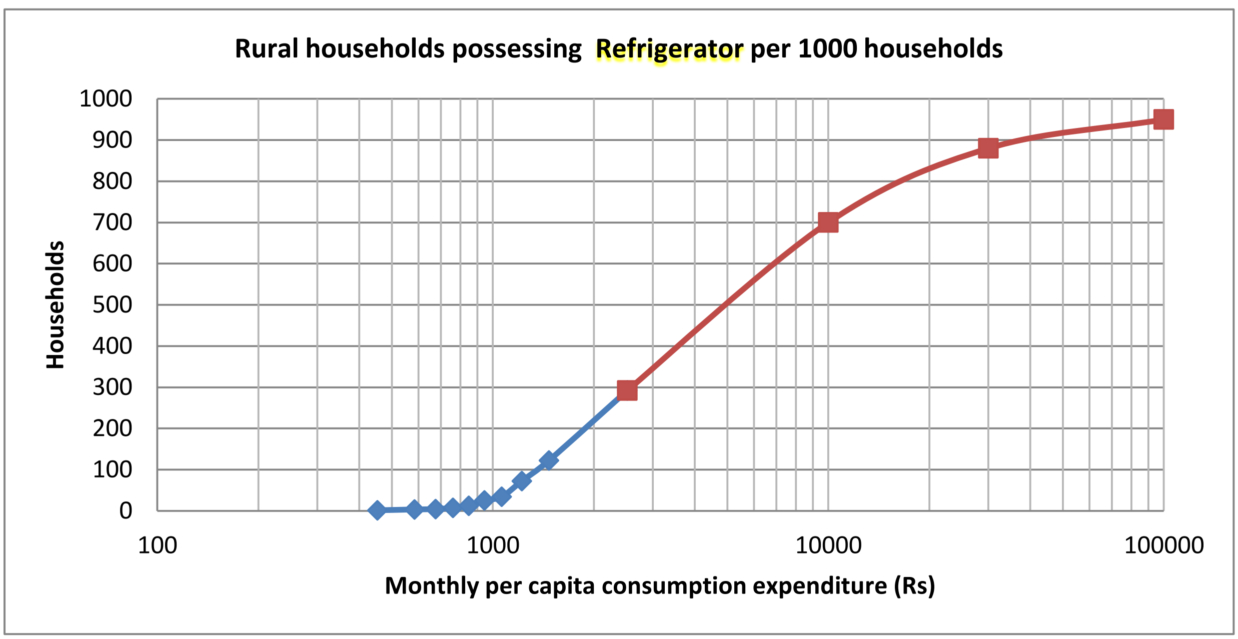


**Figure R-9: Electric Fan**

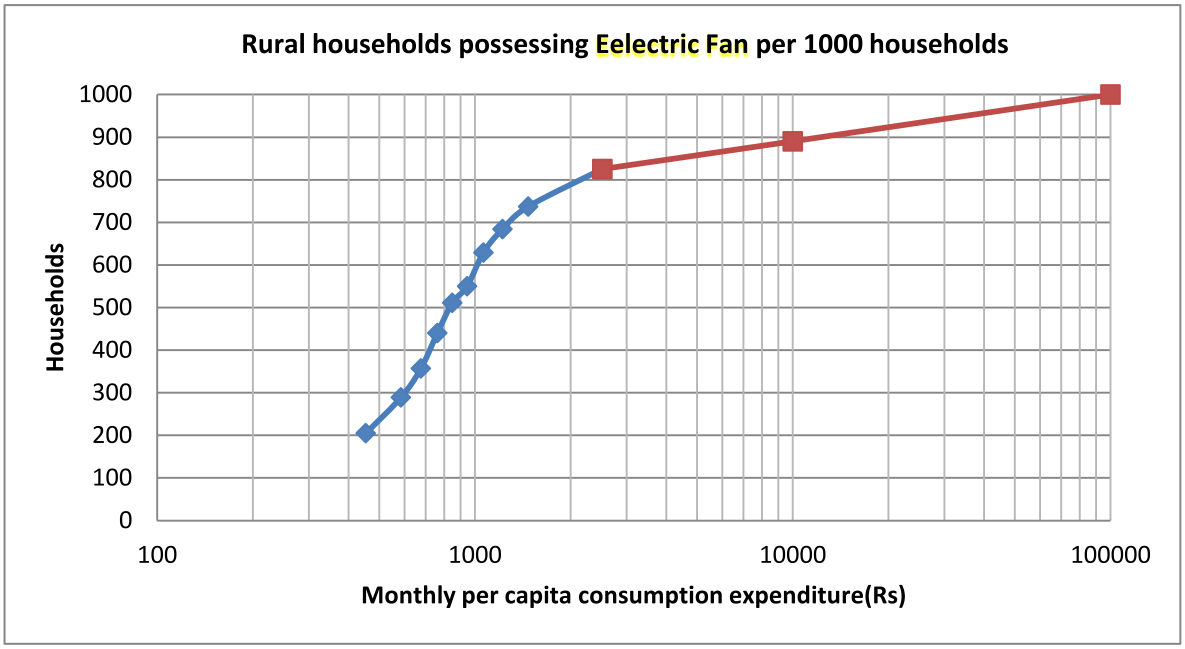



**Figure R-10: Air Conditioner**

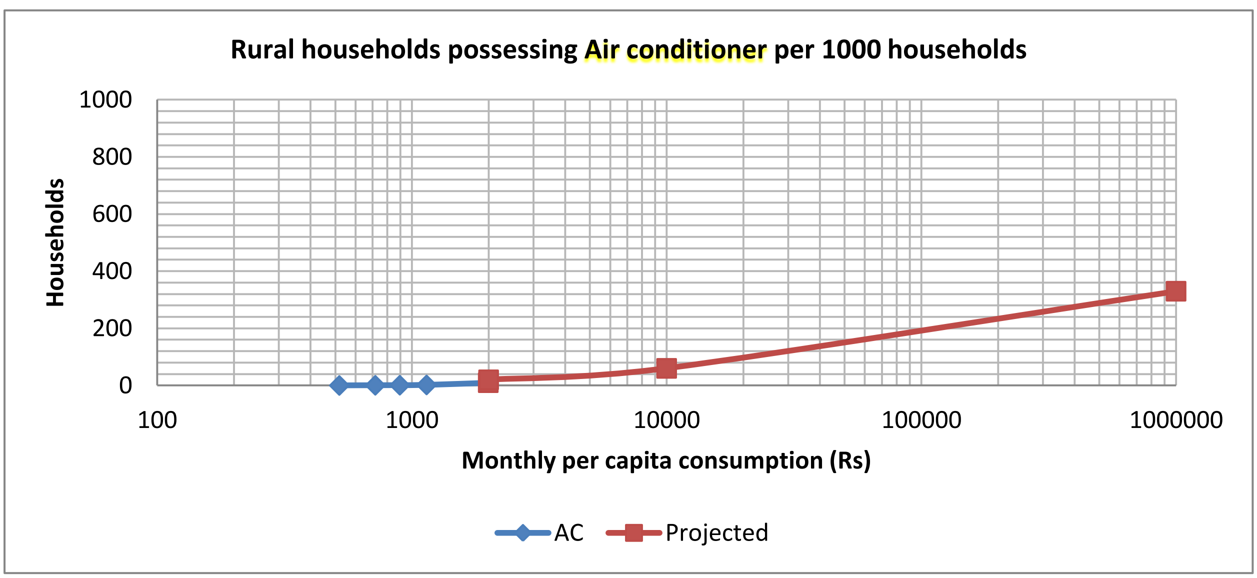


**Figure R-11: PC/Laptop**

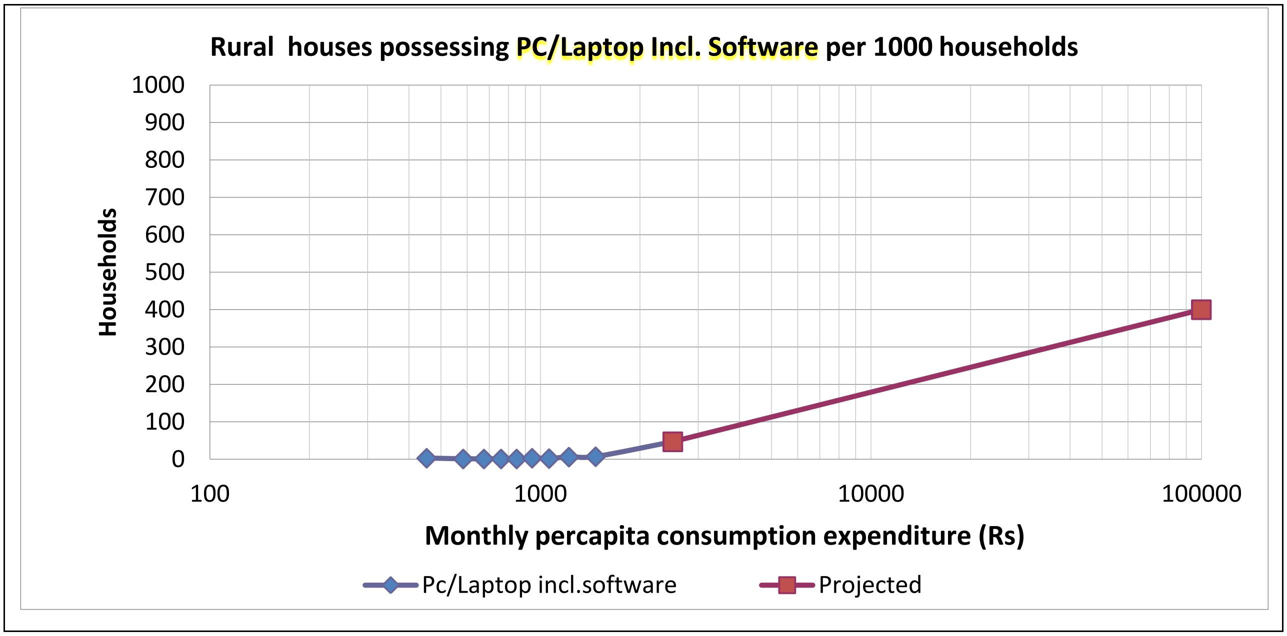
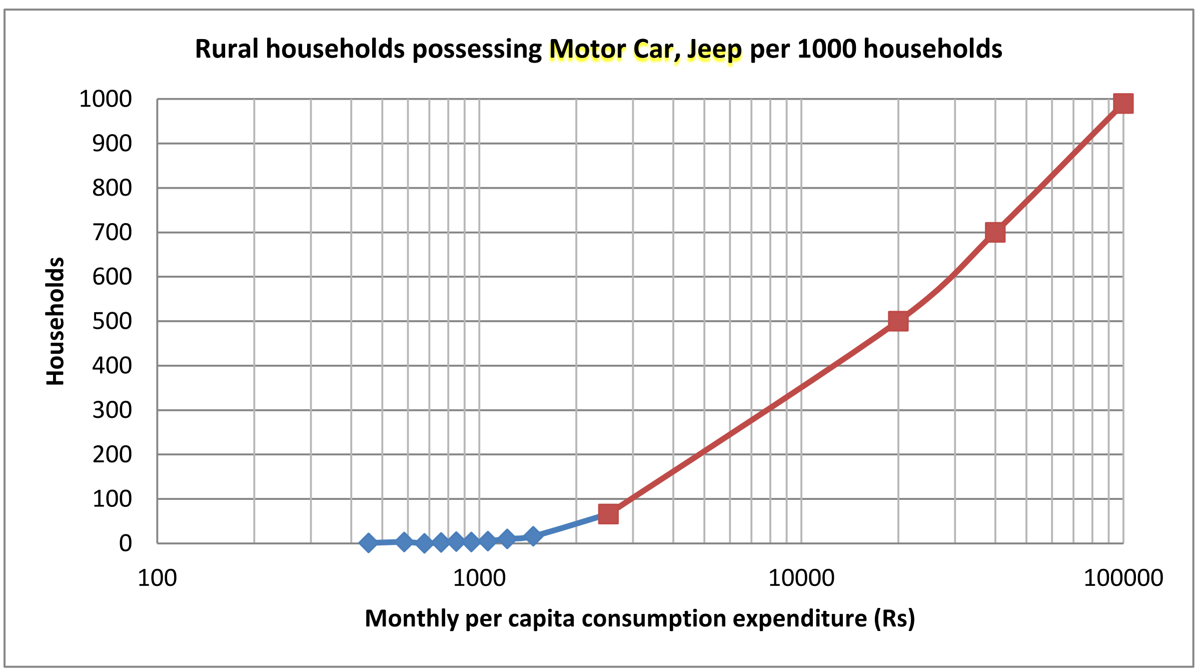



**Figure R-12: Motor Car, Jeep**




Data source has taken from NSSO 66th Round Consumption Expenditure, 2009-10, Ministry of Statistics and Programme Implementation (MOSPI, GOI).

**Figure U-1: Music System**

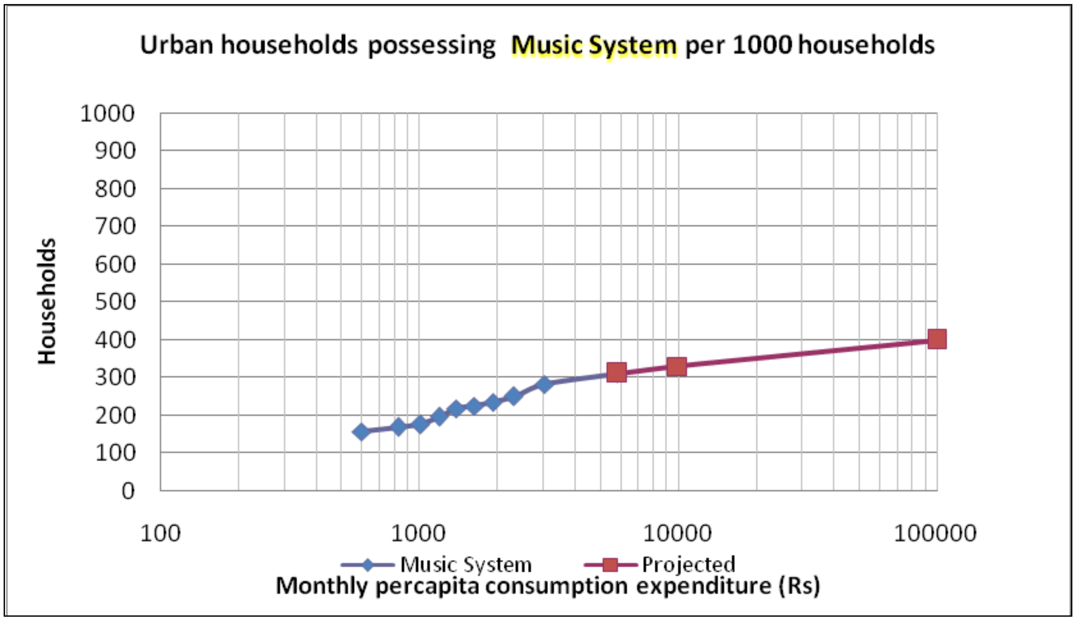



**Figure U-2: Washing Machine**

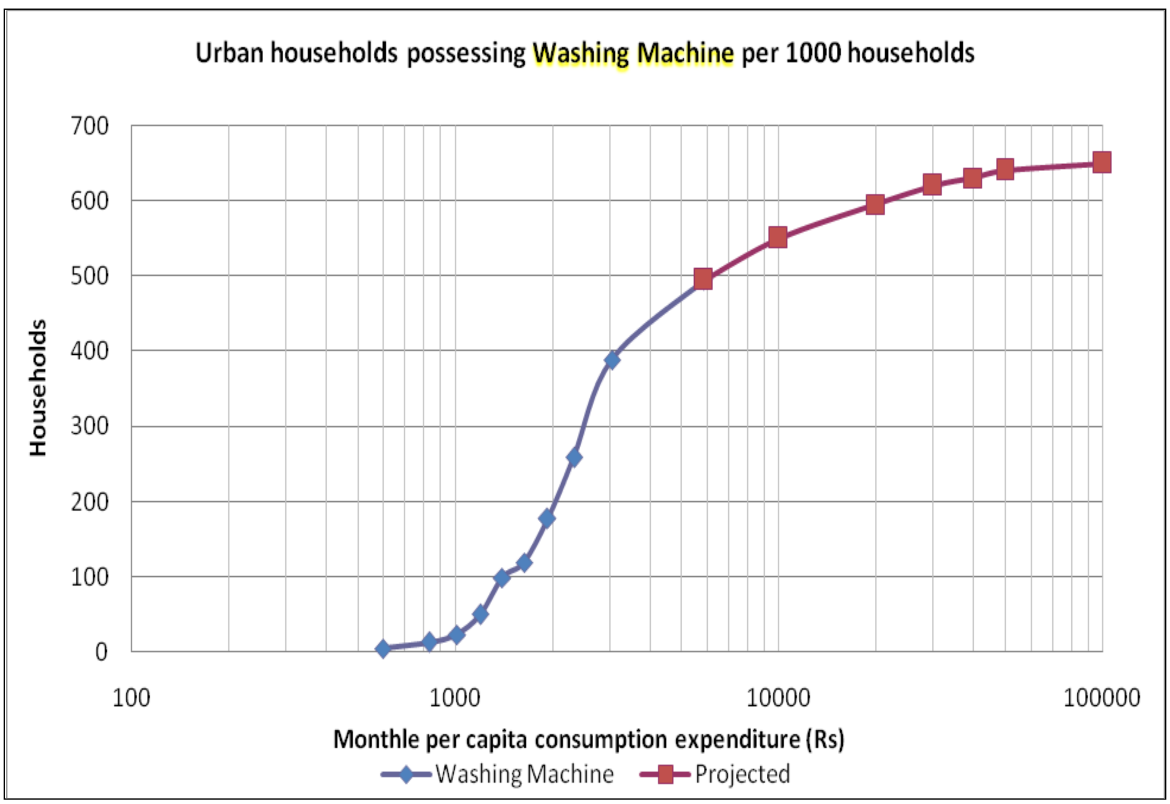


**Figure U-3: Air Conditioner**

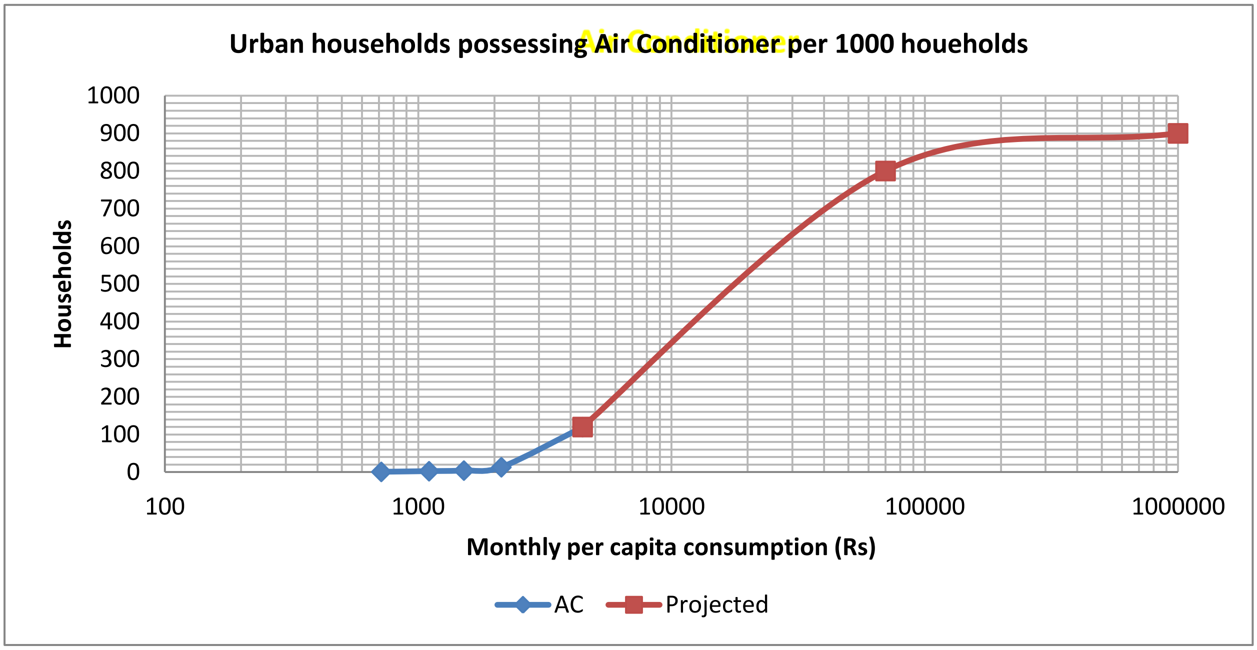



**Figure U-4: Water Purifier**

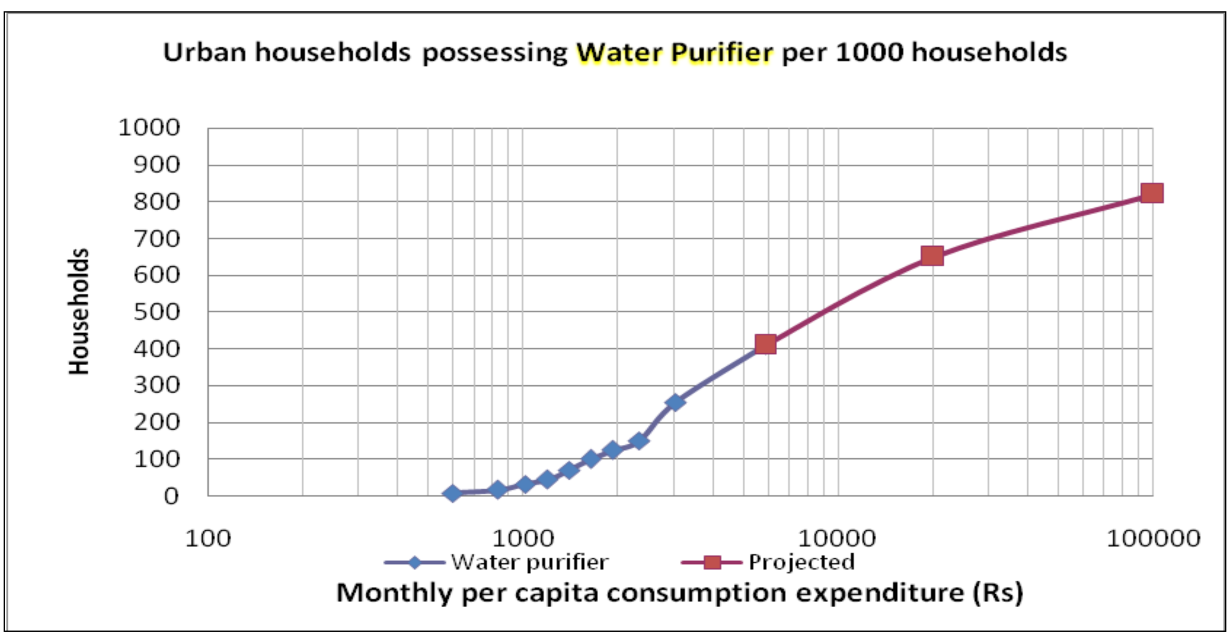


**Figure U-5: Mobile Phone Handset**

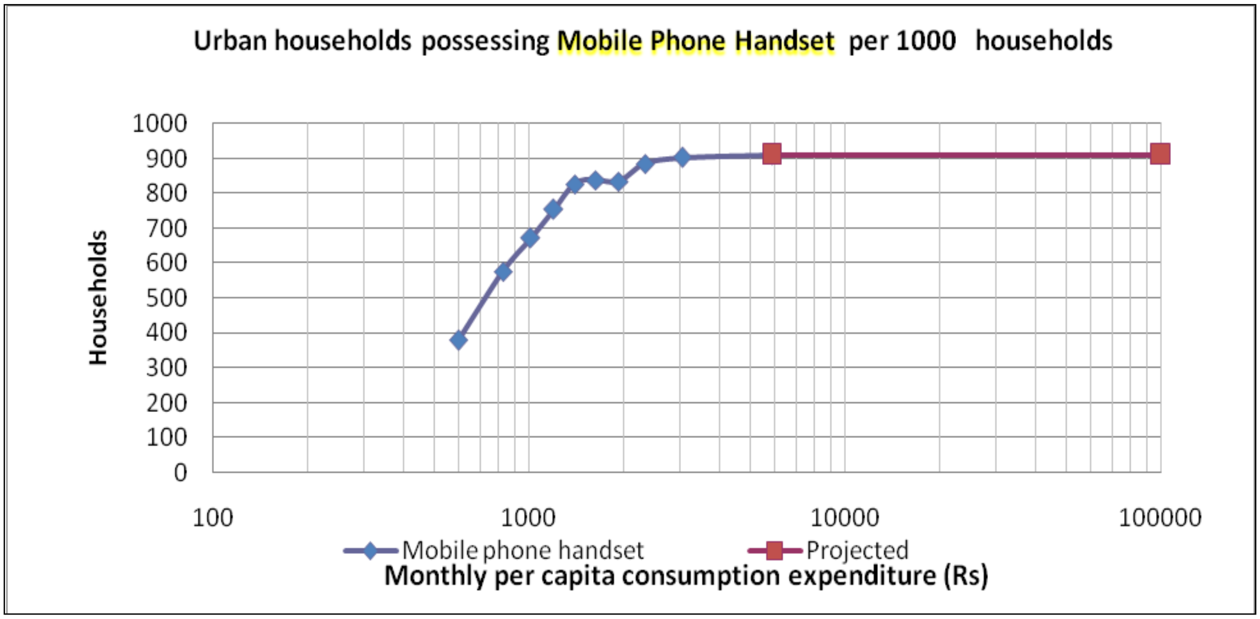



**Figure U-6: Motor Car, Jeep**

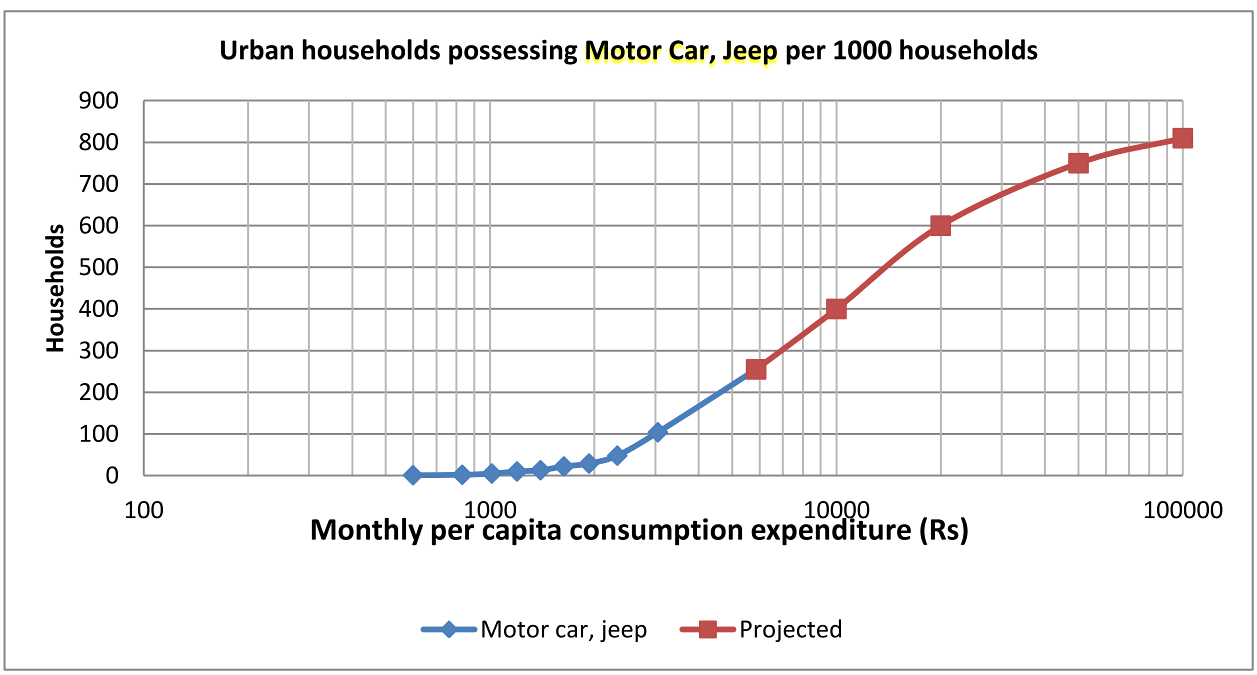


**Figure U-7: Television**

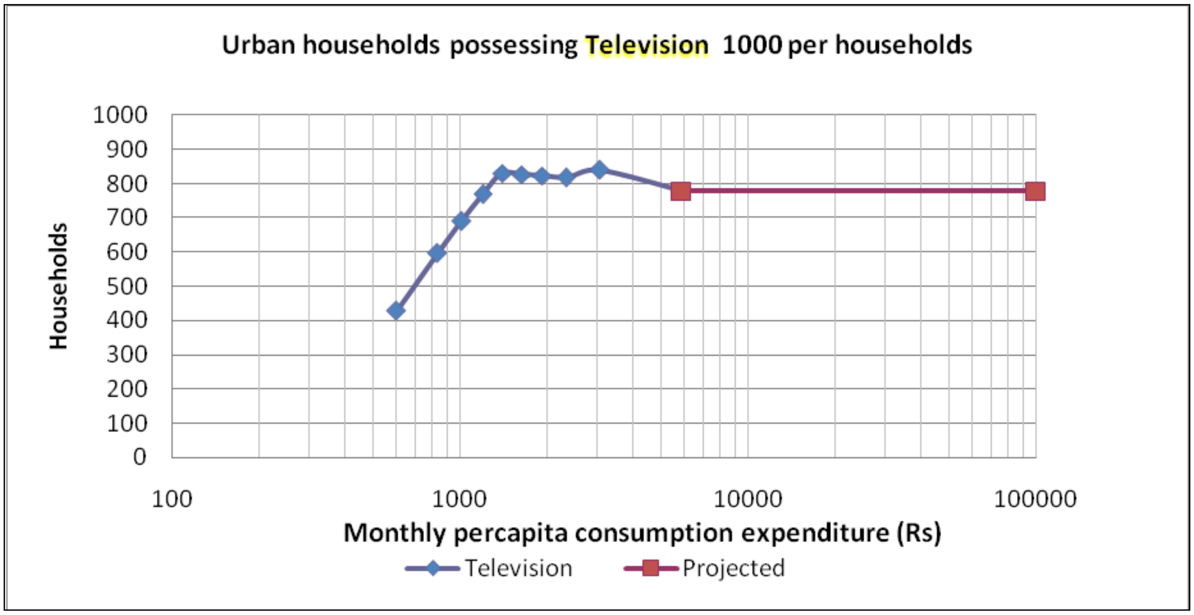



**Figure U-8: Electric Fan**

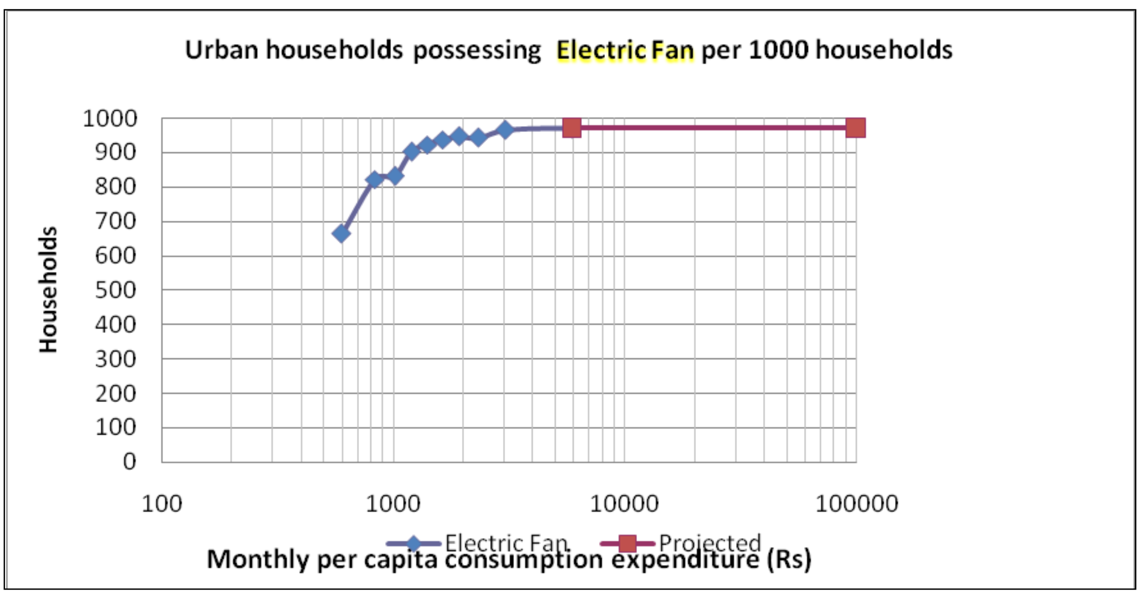


**Figure U-9: Sewing Machine**

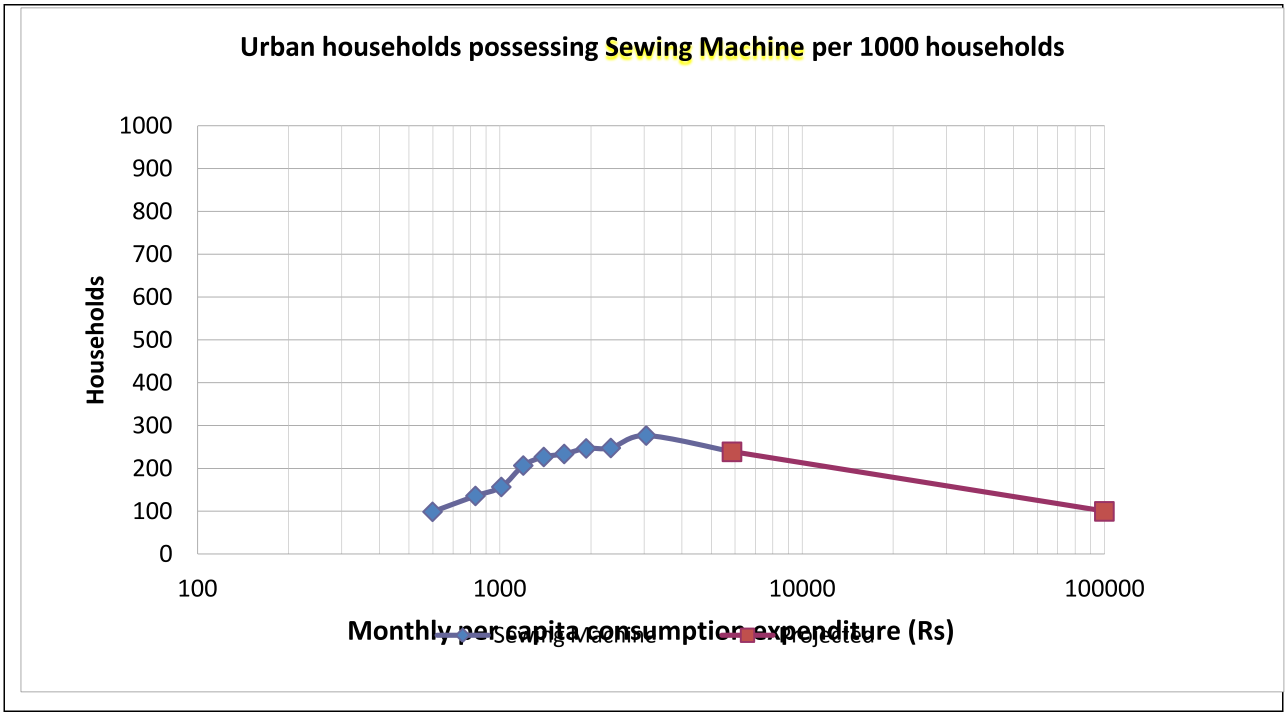



**Figure U-10: Refrigerator**

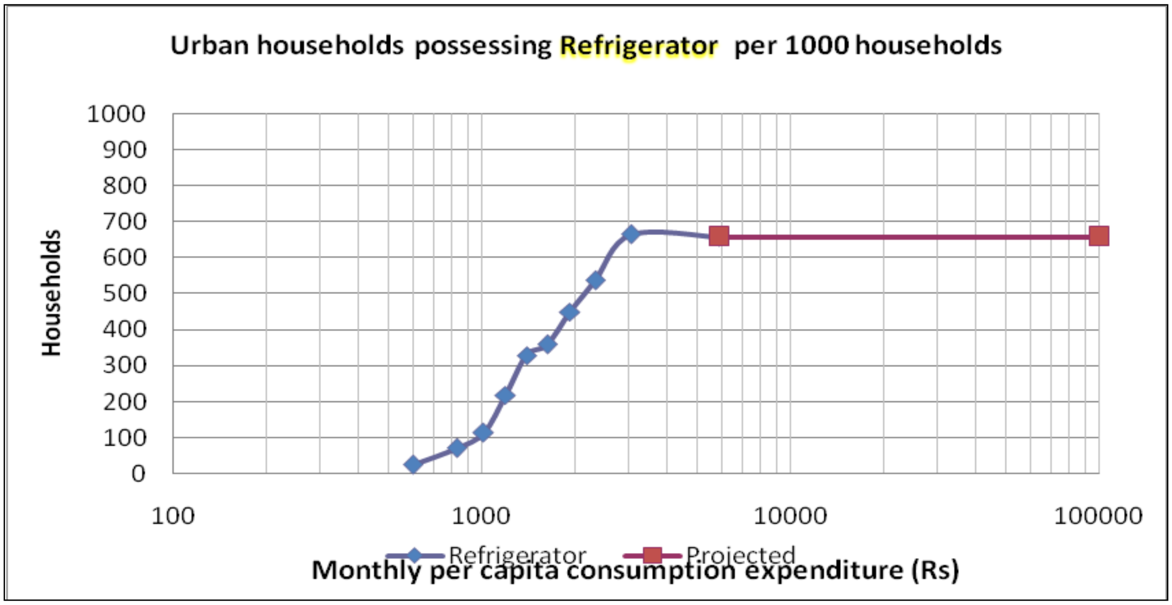



**Figure U-11: PC/Laptop**

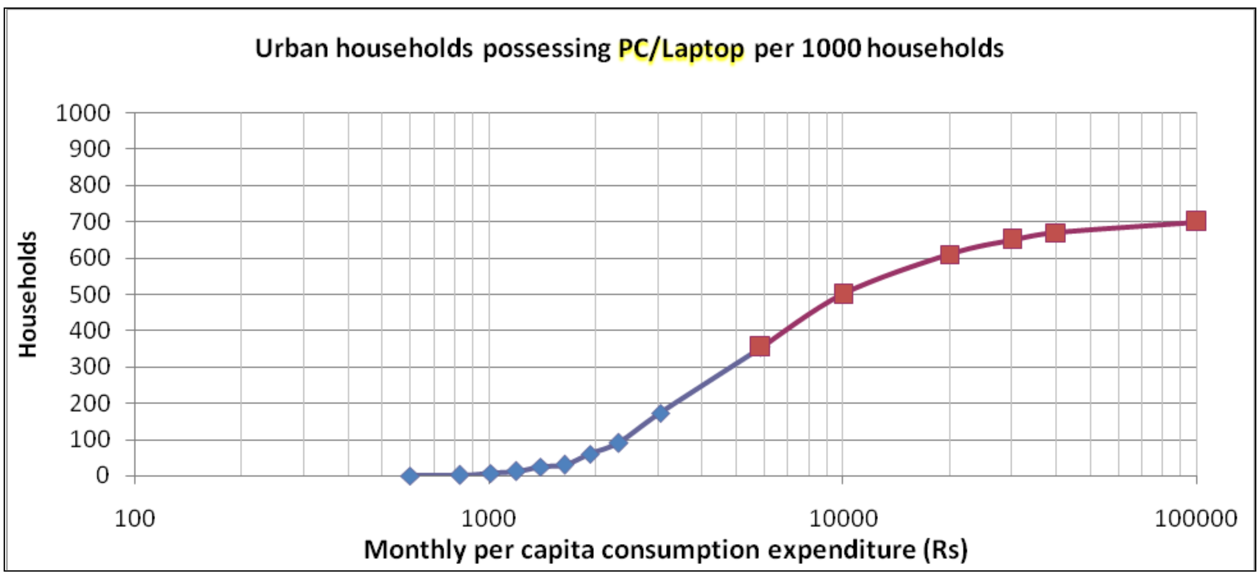
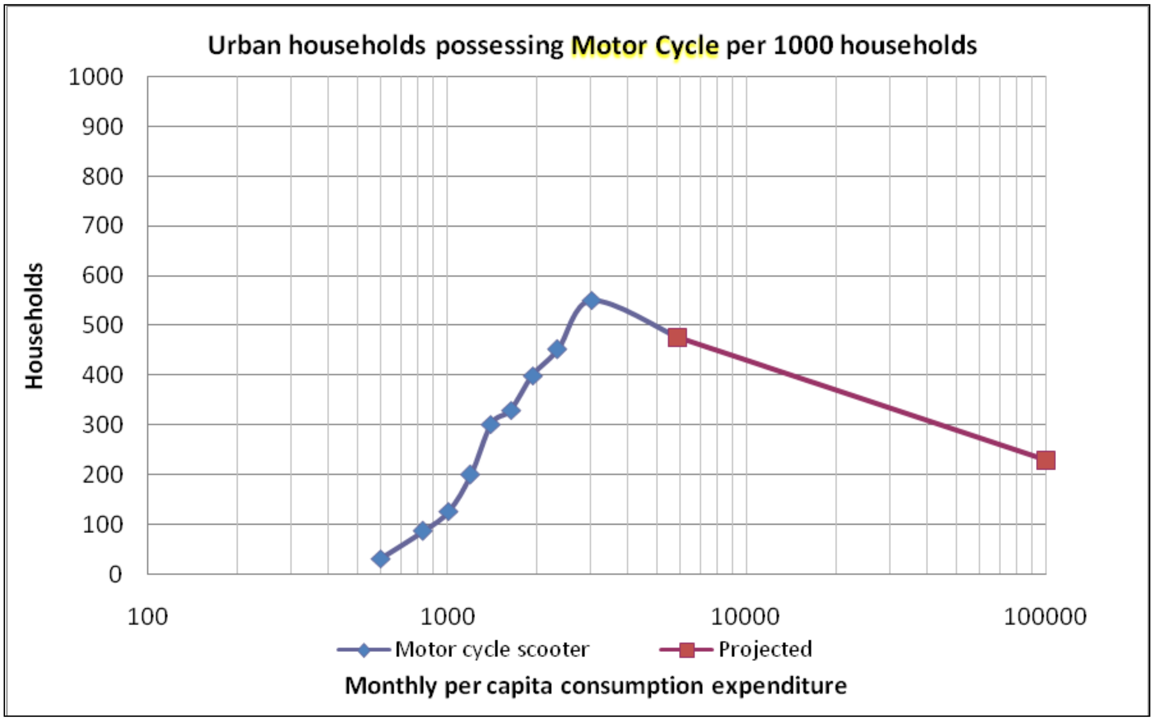



**Figure U-12: Motor Cycle**




We have projected total number of households possessing appliances per thousand households for the expenditure classes of the IRADe model based on these graphs. Numbers of households possessing various appliances out of 1000 households are shown in Table 7.

**Table 3.8: Number of households possessing the appliances out of 1000 households**

| Cl | Music system | Television | Sewing Machine | Washing Machine | Water purifier | Refrigerator | Electric Fan | Air Conditioner, Cooler | Mobile phone hand set | Pc/Laptop incl software | Motor cycle scooter | Motor car, jeep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RH1** | 183 | 94 | 21 | 0 | 1 | 1 | 205 | 6 | 167 | 3 | 7 | 1 |
| **RH2** | 220 | 160 | 33 | 1 | 1 | 3 | 289 | 15 | 245 | 1 | 22 | 3 |
| **RH3** | 253 | 235 | 47 | 2 | 3 | 4 | 357 | 12 | 336 | 1 | 28 | 0 |
| **RH4** | 269 | 294 | 62 | 1 | 4 | 7 | 440 | 19 | 382 | 1 | 50 | 2 |
| **RH5** | 283 | 353 | 69 | 2 | 5 | 12 | 511 | 30 | 475 | 1 | 64 | 4 |
| **RH6** | 270 | 398 | 96 | 5 | 10 | 25 | 550 | 31 | 516 | 3 | 104 | 3 |
| **RH7** | 287 | 471 | 120 | 5 | 13 | 34 | 629 | 36 | 582 | 2 | 126 | 5 |
| **RH8** | 279 | 565 | 140 | 10 | 19 | 72 | 684 | 52 | 628 | 6 | 188 | 10 |
| **RH9** | 275 | 612 | 162 | 22 | 34 | 122 | 737 | 79 | 683 | 7 | 256 | 16 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RH10** | 291 | 702 | 237 | 90 | 60 | 292 | 825 | 152 | 764 | 47 | 363 | 66 |
| | | | | | | | | | | | | |
| **UH1** | 158 | 429 | 99 | 5 | 8 | 24 | 664 | 42 | 378 | 1 | 32 | 1 |
| **UH2** | 169 | 597 | 136 | 13 | 16 | 70 | 822 | 73 | 576 | 2 | 88 | 2 |
| **UH3** | 177 | 691 | 157 | 23 | 32 | 114 | 831 | 96 | 672 | 7 | 127 | 5 |
| **UH4** | 197 | 768 | 207 | 50 | 44 | 218 | 902 | 143 | 754 | 12 | 201 | 10 |
| **UH5** | 219 | 830 | 227 | 99 | 71 | 328 | 922 | 178 | 827 | 25 | 302 | 13 |
| **UH6** | 225 | 827 | 234 | 119 | 101 | 359 | 938 | 190 | 839 | 31 | 330 | 22 |
| **UH7** | 235 | 823 | 247 | 177 | 125 | 450 | 946 | 208 | 835 | 60 | 400 | 29 |
| **UH8** | 251 | 818 | 248 | 259 | 151 | 537 | 943 | 236 | 886 | 91 | 452 | 48 |
| **UH9** | 282 | 839 | 277 | 389 | 256 | 664 | 966 | 295 | 902 | 173 | 551 | 104 |
| **UH10** | 312 | 778 | 239 | 495 | 410 | 658 | 970 | 433 | 910 | 354 | 477 | 255 |

Source: NSSO 66th round (2009-10)

We also assume the units of each appliance possessed by rural households possessing the appliance by their expenditure class. These are shown in **Table 8** for rural and urban households.

**Table: 3.9 Number of operating units at a time for rural and urban for 2021 and 2031**

| CL | Music System | Tv | Refrigerator | Washing machine | sewing machine | Electric Fan | AC | Water purifier | Pc/laptop incl software | Mobile phone | Motor Cycle/ scooter | Motor car, jeep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RH1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **RH2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **RH3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **RH4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 |
| **Rh5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 |
| **RH6** | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 4 | 1 | 1 |
| **RH7** | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 4 | 1 | 1 |
| **RH8** | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 4 | 1 | 1 |
| **RH9** | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 4 | 1 | 1 |
| **RH10** | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 4 | 1 | 2 |

| CL | Music System | TV | Refrigerator | Washing machine | sewing machine | Electric Fan | AC/cooler | Water purifier | Pc/laptop incl software | Mobile phone | Motorcycle/ scooter | Motor car, jeep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **UH1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **UH2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **UH3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **UH4** | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 |
| **UH5** | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 |
| **UH6** | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 3 | 1 | 1 |
| **UH7** | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 2 | 3 | 1 | 2 |
| **UH8** | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 2 | 3 | 1 | 2 |
| **UH9** | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 2 | 3 | 1 | 2 |
| **UH10** | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 2 | 3 | 1 | 2 |

Using Table 3.7, 3.8 and 3.9 we have projected total number of appliances possessed by the households by their expenditure class in the year 2021 and 2031. These are shown in **Table 3.10.**

**Table 3.10: Total number of appliances possessed by households (in Millions) in the year 2021 and 2031.**

| | 2021 | | 2031 | |
|---|---|---|---|---|
| **Appliances** | **Top 5 Expenditure Classes** | **Bottom 5 Expenditure Classes** | **Top 5 Expenditure Classes** | **Bottom 5 Expenditure Classes** |
| **Music System** | 39 | 38 | 69 | 19 |
| **Television** | 96 | 96 | 169 | 51 |
| **Refrigerator** | 58 | 39 | 113 | 22 |
| **Washing machine** | 31 | 16 | 64 | 13 |
| **Sewing machine** | 37 | 30 | 64 | 15 |
| **Electric fan** | 248 | 131 | 489 | 80 |
| **Air conditioner** | 18 | 3 | 42 | 3 |
| **Water Purifier** | 25 | 14 | 51 | 10 |
| **Pc/laptop incl software** | 42 | 11 | 57 | 7 |
| **Mobile phone** | 389 | 180 | 558 | 81 |
| **Motor Cycle, scooter** | 54 | 40 | 84 | 12 |
| **Motor, car, jeep** | 48 | 7 | 119 | 5 |

**Source**: IRADe Calculation

## 3.3 Spread of Labeled Appliances:

BEE started appliance labeling programme five years ago. Every year an independent evaluation is carried out which assesses the penetration of starred products. Using the data from the evaluations downloaded from BEE website, penetrations of different starred products are worked out. These data are shown in the **Table 3.11** to **3.17** and **Figure 1** to **7**

### Table 3.11 Total BEE labeled sold Refrigerator

| Category | Cost | Approx. Energy Saving (Compared to lowest Star Category) (kwh/product/yr) | 2007-2008 | 2008-2009 | 2009-2010 | 2010-2011 | 2011-2012 |
|---|---|---|---|---|---|---|---|
| **1 star** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **2 star** | 9000 | 205.97 | 1741 | 4659 | 0 | 0 | 2222 |
| **3 star** | 10500 | 282.69 | 23573 | 604046 | 183157 | 165798 | 980965 |
| **4 star** | 13000 | 352.18 | 92229 | 3646241 | 764594 | 313908 | 1833661 |
| **5 star** | 16000 | 410.87 | 3980 | 58955 | 647051 | 649291 | 3676576 |
| **Total** | | | **121523** | **4313901** | **1594802** | **1128997** | **6493424** |

Source**:** National Productivity Council Bureau of Energy Efficiency for the year 2009 to 2012

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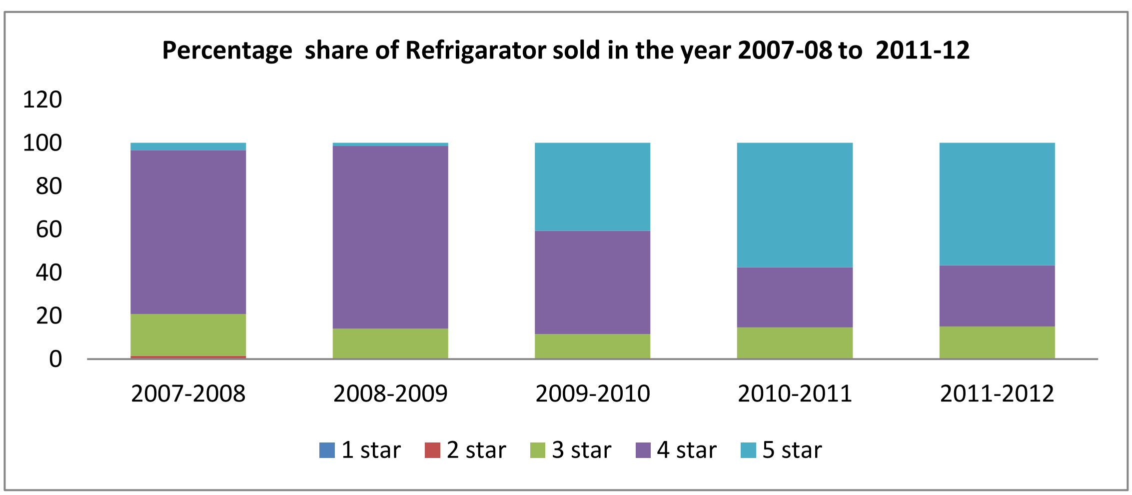


**Figure1: Percentage share of refrigerator sold in the year 2007-08 to 2011-12**

## Table 3.12 Total BEE labeled ACs sold

| Star Rating Category | Cost | | Approx. Energy Saving (Compared to Non Star Category) (kwh/product/year) | Year | | | | |
|---|---|---|---|---|---|---|---|---|
| | Window | Split | | 2007-2008 | 2008-2009 | 2009-2010 | 2010-2011 | 2011-2012 |
| **1 Star** | 18190 | 23000 | 259.54 | 52218 | 34988 | 361703 | 265387 | 50636 |
| **2 Star** | 19000 | 26000 | 415.32 | 227468 | 370531 | 871288 | 1263155 | 1034072 |
| **3 Star** | 24990 | 29000 | 566.94 | 10683 | 162848 | 692482 | 993836 | 1177119 |
| **4 Star** | 27000 | 31500 | 688.16 | 11191 | 21823 | 70496 | 114280 | 75477 |
| **5 Star** | 30000 | 33500 | 787.37 | 3640 | 5937 | 236634 | 486332 | 632846 |
| **Total** | | | | **305200** | **656127** | **2232603** | **3122990** | **2970150** |

Source: National Productivity Council Bureau of Energy Efficiency for the year 2009 to 2012.

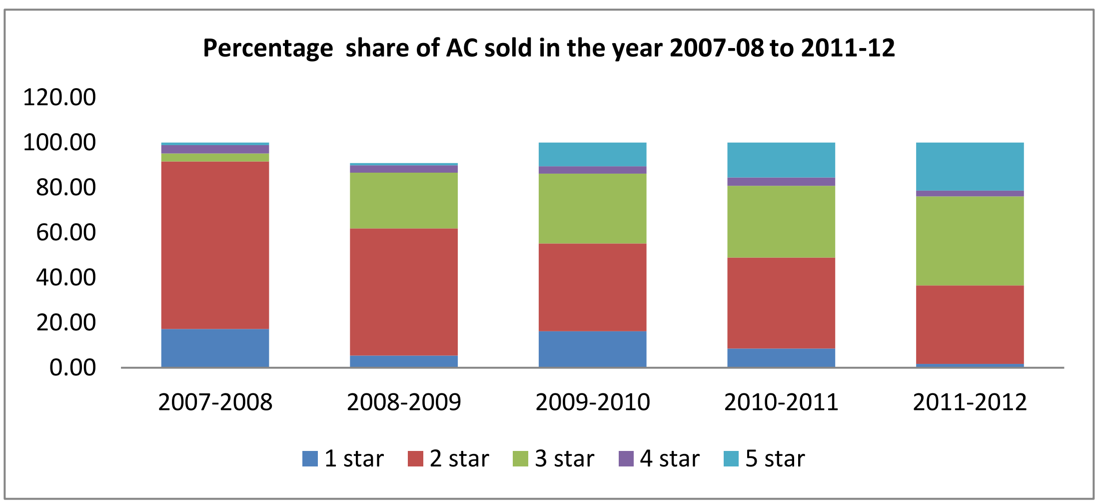


**Figure 2: Percentage share of AC sold in the year 2007-08 to 2011-12**

### Table 3.13 Total BEE labeled Transformers sold

| Category | Cost | Approx. Energy Saving (Compared to Non Star Category) (kwh/product/year) | 2008-2009 | 2009-2010 | 2010-2011 | 2011-2012 |
|---|---|---|---|---|---|---|
| **1 star** | 55000 | 0 | 0 | 0 | 19499 | 5673 |
| **2 star** | 80000 | 2275 | 200 | 0 | 0 | 21 |
| **3 star** | 90000 | 4300 | 298 | 16338 | 38422 | 67958 |
| **4 star** | 108000 | 5959 | 24 | 35274 | 26791 | 11846 |
| **5 star** | 100000 | 7550 | 0 | 0 | 482 | 6864 |
| **Total** | | | **522** | **51612** | **85194** | **92362** |

**Source**: National Productivity Council Bureau of Energy Efficiency for the year 2009 to 2012

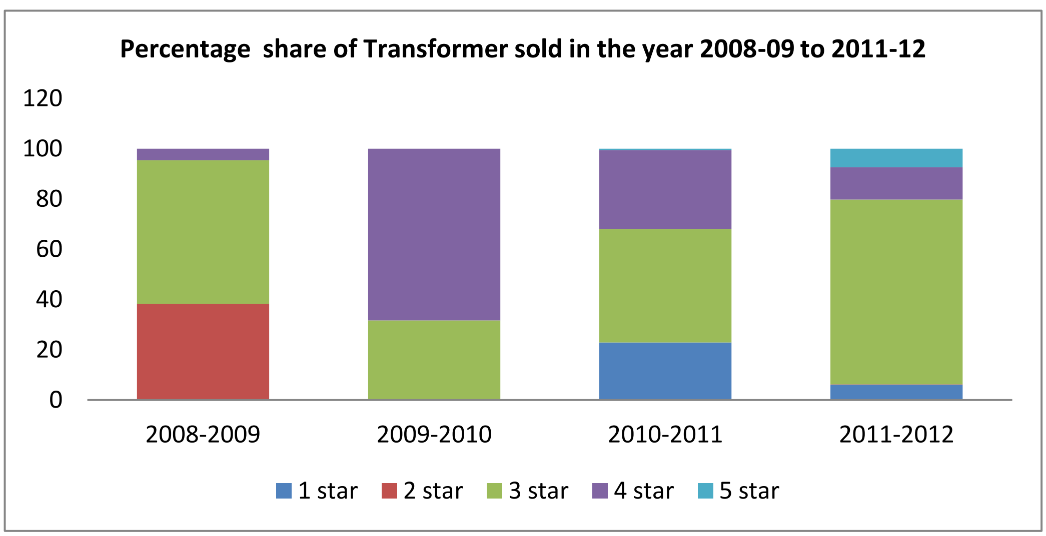


**Figure 3: Percentage share of Transformer sold in the year 2008-09 to 2011-12**

### Table 3.14 Total BEE labeled sold Fluorescent Tube Light

| Category | Cost | Approx. Energy Saving (w.r.t lowest star) (kwh/product/yr) | 2008-2009 | 2009-2010 | 2010-2011 | 2011-2012 |
|---|---|---|---|---|---|---|
| **1 star** | 0 | 0 | 34988 | 361703 | 0 | 0 |
| **2 star** | 41 | 20 | 370531 | 871288 | 99835 | 6880007 |
| **3 star** | 45 | 32 | 162848 | 692482 | 11369843 | 108556352 |
| **4 star** | 75 | 40 | 21823 | 70496 | 0 | 204347 |
| **5 star** | 80 | 48 | 5937 | 236634 | 1150154 | 1415602 |
| **Total** | | | **656127** | **2232603** | **12619832** | **117056308** |

**Source**: National Productivity Council Bureau of Energy Efficiency for the year 2009 to 2012

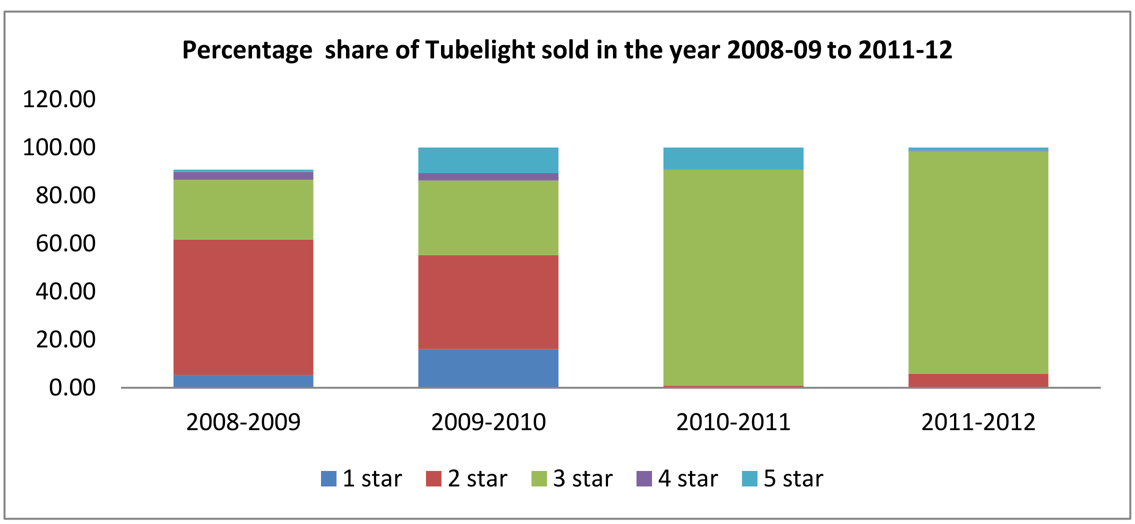


**Figure 4: Percentage share of Tube light sold in the year 2008-09 to 2011-12**

## Table 3.15 Total BEE labeled sold Colour Television

| Star Rating Category | Cost | | Approx. Energy Saving (Compared to lowest Star Category) (kwh/product/yr) | Year | | |
|---|---|---|---|---|---|---|
| | CRT | LCD | | 2009-2010 | 2010-2011 | 2011-2012 |
| **1 Star** | 7800 | 16500 | 0 | 0 | 0 | 0 |
| **2 Star** | 8200 | 17000 | 21.5 | 0 | 0 | 0 |
| **3 Star** | 8500 | 17500 | 35.81 | 320765 | 557413 | 514203 |
| **4 Star** | 10000 | 18500 | 70.51 | 719919 | 1449183 | 2205241 |
| **5 Star** | 13500 | 23000 | 117.72 | 723165 | 888355 | 485315 |
| **Total** | | | | **1763849** | **2894951** | **3204759** |

**Source**: National Productivity Council Bureau of Energy Efficiency for the year 2009 to 2012.

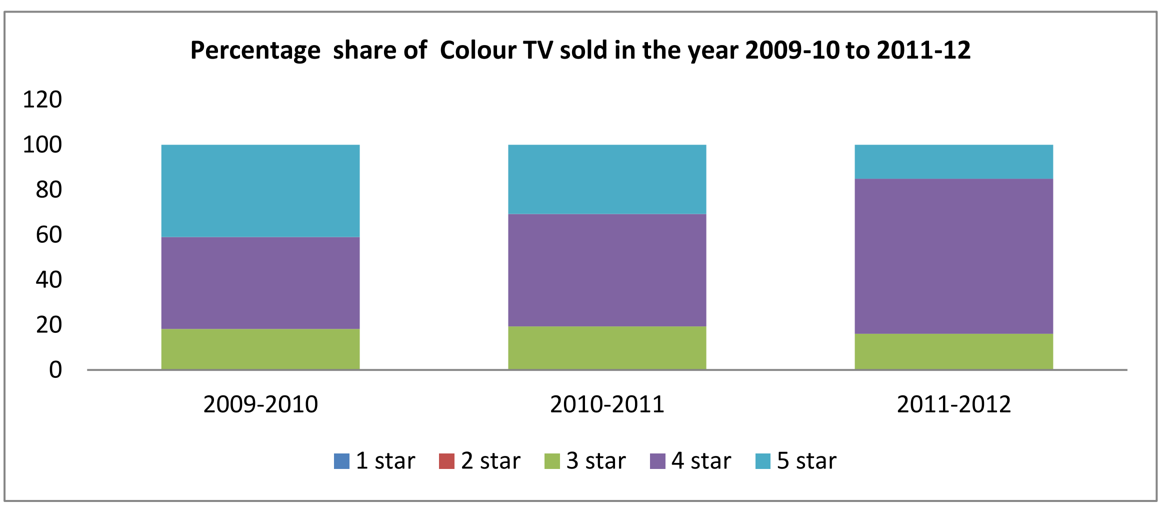


**Figure 5: Percentage share of TV sold in the year 2009-10 to 2011-12**

### Table 3.16 Total BEE labeled Ceiling Fans

| Category | Cost | Approx. Energy Saving (Compared to lowest Star Category) (kwh/product/yr) | 2009-2010 | 2010-2011 | 2011-2012 |
|---|---|---|---|---|---|
| **1 star** | 0 | 0 | 0 | 0 | 0 |
| **2 star** | 0 | 6.7 | 0 | 0 | 0 |
| **3 star** | 1300 | 12.88 | 64531 | 31578 | 6224 |
| **4 star** | 1900 | 25.41 | 29290 | 17346 | 10909 |
| **5 star** | 2100 | 48.33 | 159245 | 448581 | 527502 |
| **Total** | | | **253066** | **497505** | **544635** |

Source: National Productivity Council Bureau of Energy Efficiency for the year 2009 to 2012.

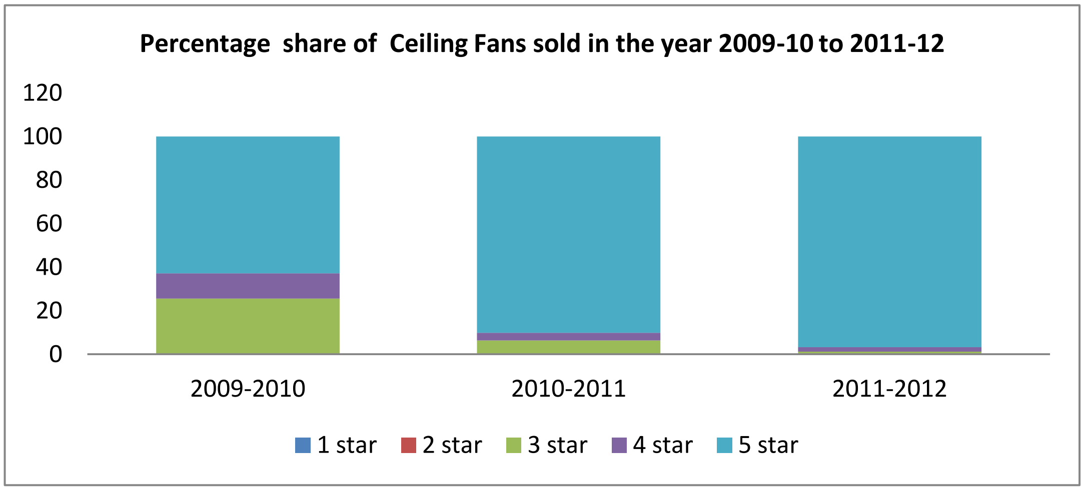


**Figure 6: Percentage share of Ceiling Fan sold in the year 2009-10 to 2011-12**

**Table 3.17 Total BEE labeled Water Heaters**

| Category | Cost | Approx. Energy Saving (Compared to lowest Star Category) (kwh/product/yr) | 2009-2010 | 2010-2011 | 2011-2012 |
|---|---|---|---|---|---|
| **1 star** | 5000 | 0 | 1280 | 14756 | 9909 |
| **2 star** | 5500 | 55.85 | 10189 | 93861 | 49579 |
| **3 star** | 6500 | 89.05 | 2666 | 29197 | 30249 |
| **4 star** | 7500 | 129.9 | 140041 | 381653 | 486981 |
| **5 star** | 8500 | 152.99 | 45638 | 193213 | 384302 |
| **Total** | | | **199814** | **712680** | **961020** |

Source: National Productivity Council Bureau of Energy Efficiency for the year 2009 to 2012

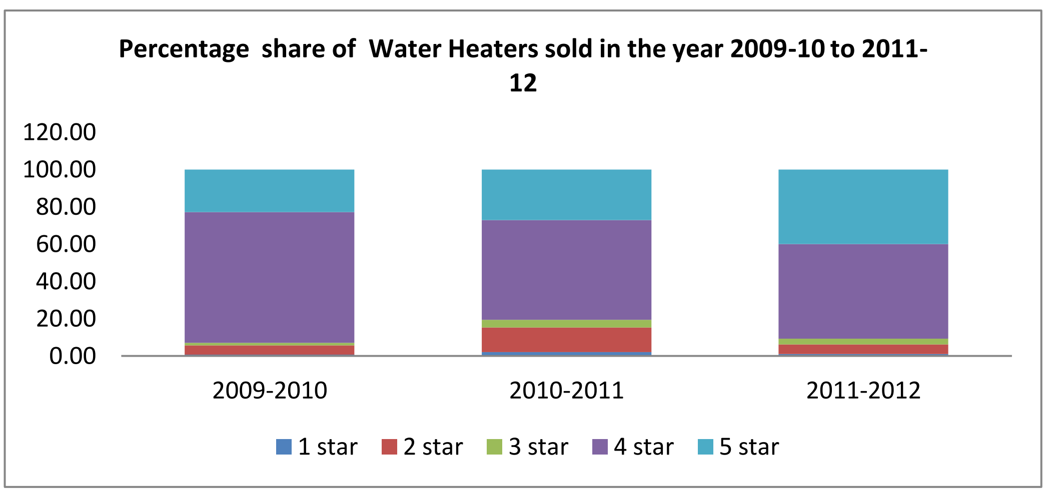


**Figure 7: Percentage share of Water Heaters sold in the year 2009-10 to 2011-12**

## 3.4 Estimation of Energy Saving From Labeling of Appliances

Here we have done the energy saving analysis of households' starred appliances. We have taken 7 major power consuming appliances. These are: AC, refrigerator, frost free refrigerator, tube light, colors television, ceiling fans and Geyser. We have calculated the present discounted value of electricity savings using discount rates of 10 per cent and 20 per cent over the life of the appliance. The savings will depend on the price of electricity. Here we have taken electricity tariff at Rs 4/kwhr and Rs 6/kwhr. The two tables, A.9 and A.10, illustrate when the PDV of savings exceeds the initial cost difference. The 'tick mark' shows where cost saving is greater than initial cost difference.

**Economics of star labeled appliances**

**Table 3.18 Present discounted value at discount rate 10% > Initial cost difference**

| | | Rs 4/ kwhr | | | Rs 6/ kwhr | | |
|---|---|---|---|---|---|---|---|
| **Appliances** | **Base Rating** | **Life of appliances in years** | | | **Life of appliances in years** | | |
| **Air conditioner** | **1*** | **5** | **7** | **10** | **5** | **7** | **10** |
| **2*** | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **3*** | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| **4*** | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| **5*** | | | | ✓ | ✓ | ✓ | ✓ |
| **Refrigerator** | **2*** | | | | | | |
| **3*** | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| **4*** | | | | | | ✓ | ✓ |
| **5*** | | | | | | | ✓ |
| **Colour Televisions** | **2*** | | | | | | |
| **3*** | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| **4*** | | | | | | ✓ | ✓ |
| **5*** | | | | | | | |
| **Ceiling Fans** | **1*** | | | | | | |
| **2*** | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **3*** | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| **4*** | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| **5*** | | | | ✓ | | | |

Source: IRADe Calculation

**Economics of star labeled appliances**

**Table 3.19 Present discounted value at discount rate 20% > Initial Difference**

| | | Rs 4/ kwhr | | | Rs 6/ kwhr | | |
|---|---|---|---|---|---|---|---|
| Appliances | Base Rating | Life of appliances in years | | | Life of appliances in years | | |
| Air conditioner | 1* | 5 | 7 | 10 | 5 | 7 | 10 |
| 2* | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 3* | | | | ✓ | ✓ | ✓ | ✓ |
| 4* | | | | ✓ | ✓ | ✓ | ✓ |
| 5* | | | | ✓ | ✓ | ✓ | ✓ |
| Refrigerator | 2* | | | | | | |
| 3* | | | | ✓ | ✓ | ✓ | ✓ |
| 4* | | | | | | | ✓ |
| 5* | | | | | | | |
| Colour Televisions | 2* | | | | | | |
| 3* | | | | | ✓ | ✓ | ✓ |
| 4* | | | | | | | |
| 5* | | | | | | | |
| Ceiling Fans | 1* | | | | | | |
| 2* | | | | | | | |
| 3* | | | | | | | |
| 4* | | | | | | | |
| 5* | | | | | | | |

Source: IRADe Calculation

We assume that the richer top 5 classes will have a discount rate of 10 per cent and the poorer bottom 5 classes have a discount rate of 20 per cent. Based on this the star rated appliance bought by each class is worked out and shown in **Table A11 and Table A12.** Here we have taken electricity tariff at Rs 4/kwhr for bottom 5 classes and Rs 6/kwhr for top 5 classes.

**Table 3.20 Appliances for which present discounted value at discount rate 10% > Initial cost difference for top 5 classes**

| | Classes | Rs 6/Kwhr | | |
|---|---|---|---|---|
| | Top 5 Expenditure classes | Life of appliances in year | | |
| **Appliances** | | **5** | **7** | **10** |
| **Air condition** | | 5* | 5* | 5* |
| **Refrigerators** | | 3* | 4* | 5* |
| **Frost Free Refrigerators** | | 5* | 5* | 5* |
| **Fluorescent Tube Lights** | | 5* | 5* | 5* |
| **Colour Televisions** | | 3* | 4* | 4* |
| **Ceiling Fans** | | 4* | 4* | 4* |
| **Geyser** | | 5* | 5* | 5* |

**Source**: IRADe Calculation

Table A.12 shows that bottom 5 expenditure classes will have a discount rate of 20 per cent and consumption of electricity at Rs 4 per hour.

**Table 3.21 Present discount value at discounted rate 20% > Initial cost difference for bottom 5 classes**

| | Classes | Rs 4/Kwhr | | |
|---|---|---|---|---|
| | Bottom 5 Expenditure classes | Life of appliances in year | | |
| **Appliances** | | **5** | **7** | **10** |
| **Air condition** | | **2*** | **2*** | **5*** |
| **Refrigerators** | | | | 3* |
| **Frost Free Refrigerators** | | 3* | 3* | 4* |
| **Fluorescent Tube Lights** | | 5* | 5* | 5* |
| **Colour Televisions** | | | | |
| **Ceiling Fans** | | | | |
| **Geyser** | | 2* | 3* | 4* |

Source: IRADe Calculation

Energy savings are worked out for bottom 5 classes and top 5 classes as follows in the year 2021 and 2031 at Rs 4 per kWh and Rs 6 per kWh respectively.

### Table 3.22 Energy saving by economical star rated appliances

**Energy Saving by Appliances in 2021**

| **Households** | **Appliance** | **total no operated Millions** | **Life in years** | **Star rated** | **Energy saving (kwh/product/year)** | **Energy saving by star rated appliances (million kwh)** | **Energy used by non rated appliance (Million kWh)** | **Energy saved (per cent)** |
|---|---|---|---|---|---|---|---|---|
| Bottom 5 | AC | 3 | 7 | 2* | 415 | 1348 | 8444 | 16 |
| | Refrigerator | 39 | 10 | 3* | 283 | 11082 | 28194 | 39 |
| | Colour Tv | 96 | 7 | 0 | 0 | 0 | 3822 | 0 |
| | Ceiling Fans | 131 | 10 | 0 | 0 | 0 | 30579 | 0 |
| | | | | | | | | |
| Top 5 | AC | 18 | 10 | 3* | 567 | 10382 | 47357 | 22 |
| | Refrigerator | 58 | 10 | 5* | 411 | 23835 | 41755 | 57 |
| | Colour Tv | 96 | 7 | 4* | 71 | 6784 | 38222 | 18 |
| | Ceiling Fans | 248 | 10 | 4* | 25 | 6192 | 57956 | 11 |
| All | | | | | | **59569** | **290730** | **20** |

Source: Irade Calculation

### Table 3.23 Energy saving by economical star rated appliances

**Energy Saving by Appliances in 2031**

| Households | Appliance | total no operated Millions | Life in years | Star rated | Energy saving (kwh/product/year) | Energy saving by star rated appliances (million kwh) | Energy used by non rated appliance (Million kWh) | Energy saved (per cent) |
|---|---|---|---|---|---|---|---|---|
| Bottom 5 | AC | 3 | 7 | 2* | 415 | 4150 | 7856 | 53 |
| | Refrigerator | 22 | 10 | 3* | 283 | 70092 | 15820 | 443 |
| | Colour Tv | 51 | 7 | 0 | 0 | 0 | 20467 | 0 |
| | Ceiling Fans | 80 | 10 | 0 | 0 | 0 | 18679 | 0 |
| | | | | | | | | |
| Top 5 | AC | 42 | 10 | 3* | 567 | 23592 | 108182 | 22 |
| | Refrigerator | 113 | 10 | 5* | 411 | 46591 | 81619 | 57 |
| | Colour Tv | 169 | 7 | 4* | 71 | 11977 | 67477 | 18 |
| | Ceiling Fans | 489 | 10 | 4* | 25 | 12217 | 114352 | 11 |
| All | | | | | | **168619** | **395306** | **43** |

Source: Irade Calculation

### 3.5 Conclusion

This study has emphasized on cost benefit analysis of star rated appliances for top 5 and bottom 5 classes. Here we have taken NSSO 66th round class wise expenditure data for the year 2009-10. A rising trend has been observed from poorer class to richer class in possession of appliances. However, NSSO data has been extended and based on this extension we have done the projections and plotted graphs on each of the appliances for rural and urban households. We have projected the estimated number of appliances possessed by households for the year 2021 and 2031. We have taken star rated products and sales data on refrigerator, frost free refrigerators, colour televisions, air conditioner, ceiling fan and geyser from National Productivity Council evaluations of Bureau of Energy Efficiency programme for the year 2009 to 2012 and their capital cost and energy savings for each star rated appliances. This data depicts that capital cost and energy savings of high star rated appliances are higher than low star rated appliances. In addition, we have done cost savings analysis over the capital cost difference and computed present discounted value using 10 per cent and 20 per cent discount rates of electricity consumption at Rs 4 per hour and Rs. 6 per hour. Here, we assumed that the top 5 classes have 10 per cent discount rate and they pay Rs. 6 per kWh for electricity consumption while the bottom 5 classes have 20 per cent discount rate and pay Rs. 4 per kWh for electricity consumption at.

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## Annexure: Model description

The following equations are introduced in the model as constraints.

Constraint equation

$$C_{iht} = c_{iho} + \beta_{ih}(E_{ht} - \sum_i c_{iho}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where,

$C_{iht}$ = per capita consumption of the $i^{th}$ commodity by the $h^{th}$ household group in $t^{th}$ time period,

$c_{ih0}$ =minimum per capita consumption of the $i^{th}$ commodity by the $h^{th}$ household,

$\beta_{ih}$ = share of $i^{th}$ commodity in total per capita consumption of the $h^{th}$ household and

$E_{ht}$ = Total per capita consumption expenditure of the $h^{th}$ household.

As incomes rise, per capita consumption increases, which results in people moving from lower expenditure classes to higher classes. Such changes would impact the demand structure of the economy. The model has an endogenous income distribution, separately for rural and urban areas, to incorporate the change in the number of people in different classes over the period of time (2005-2050). The linear expenditure system (LES) and endogenous income distribution together provide a dynamically changing commodity-wise non-linear demand structure of the economy. The original input–output table consisting of 115 sectors was aggregated to 25 commodities, being produced by 38 production activities. The model considers one commodity being produced by each production activity, except electricity. For example, to produce power, the model employs renewables (wind, solar thermal, solar photovoltaic, wood gasification) and nuclear-based technologies. Assumptions on nuclear are based on plants that are already present or are in the process of construction. No further policies on nuclear are assumed, apart from the traditional technologies of thermal, hydro and gas, similar to those assumed in the IEP (2006) model. Coal, crude, natural gas and electricity are energy inputs into the model. The model ensures equilibrium between demand and supply in the optimal path for each commodity.

Demand and supply equilibrium equation

$$C_{it} + G_{it} + I_{it} + IO_{it} + E_{it} \leq Y_{it} + M_{it} \ \ldots \ (2)$$

Private consumption demand + government consumption demand+ investment demand + intermediate input demand+ export demand = domestic production + imports

Government consumption ($G_{i,t}$) is exogenous and specified to grow at a growth rate of 7 per cent. (The government's tax collections and revenue are not modelled explicitly but accounted for implicitly.)

Intermediate demand ($IO_{i,t}$) is determined endogenously by the input–output coefficients. Total private consumption ($C_{i,t}$) is obtained from the LES demand function and endogenous income distribution. Exports ($E_{i,t}$) and imports ($M_{i,t}$) are determined endogenously from trade-side equations of balance of payments and other constraints.

Domestic availability of commodities is assumed to come from domestic output ($Y_{i,t}$) and imports ($M_{i,t}$). Domestic production is constrained by capacity constraint, i.e., the maximum output that can be produced at the given capital stock.

Capacity constraint

$$(X_{j,t} - X_{j,t-1}) \leq (K_{j,t} - K_{j,t-1}) / ICOR_j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

(Incremental output is related to incremental capital.)

Where,

$X_{j,t}$ = domestic output of the $j^{th}$ sector at time t,

$K_{j,t}$ = capital of the $j^{th}$ sector at time t and

$ICOR_j$=incremental capital output ratio of the $j^{th}$ sector, which is exogenously specified in the model.

Capital stock in sector j depends upon the rate of depreciation, and investment and is modelled using the following relation.

Capital stock equation

$$K_{j,t} = DEL(J) * K_{j,t-1} + I_{j,t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

Where *DEL(J)* is the rate of depreciation in sector j, which is exogenous, and $I_{j,t}$ is the investment in sector j.

Aggregate investment demand is assumed to depend on aggregate domestic investible resources (domestic savings determined by the marginal savings rate) and foreign investments available. Investment goods, which reflect the structure of capital goods in the sectors, are identified separately and are allocated to different sectors as fixed proportions ($P_{i,j}$) of the total investment ($I_{i,j}$) in each sector.

Investment equations

$$\sum_i Z_{it} \leq Z_o + S*(VA_t - VA_0) + (FT_t - FT_0) \quad \text{………….. (5)}$$

$$\sum (P_{i,j} * I_{j,t}) \leq Z_{i,t} \quad \text{……………………………….......... (6)}$$

$$FT_t = (a - b*t)*VA_t \quad \text{………………………………….. (7)}$$

Where,

$Z_{i,t}$ = investment demand of commodity i at time t,

$VA_t$ = value added at time t,

$FT_t$ = foreign investment at time t,

S = exogenously specified maximum marginal savings ratio,

$Z_0$= investment in the base year (2004-05) and

$P_{i,j}$ and a and b are pre-specified constants.

Trade is endogenous to the model. Foreign capital inflow (*FT*) is a changing proportion of value added. Though exports and imports are endogenous to the model, upper and lower limits are exogenously specified on the growth rate of exports and imports. The model has a balance of payment constraint for exports and imports so that they grow in a realistic manner.

Balance of payment equations

$$\sum_i (M_{i,t} * MTT_i) = \sum_i E_{i,t} + FT_t \quad \text{…………… (8)}$$

$$M_{i,t} \geq (1 + MGRU_i) * M_{i,t-1} \quad \text{………………………. (9)}$$

$$M_{i,t} \leq (1 + MGRL_i) * M_{i,t-1} \quad \text{…………………………. (10)}$$

$$E_{i,t} \leq (1 + EXGRU_i) * E_{i,t-1} \quad \text{…………………… …… (11)}$$

Where,

$MTT_i$= trade and transport margins for commodity i,

$MGRU_i$ and $MGRL_i$=upper and lower bounds for imports growth rates of commodity i and

$EXGRU_i$=upper bound for exports growth rate of commodity i.

Equations (7) to (11) form the complete specifications of the trade-side of the model.

Equations (1) to (11) form a set of constraints, based on economic criteria, for the model solution to be meaningful.