


A comprehensive, multi-dimensional energy index for India

April 2014

Prayas (Energy Group)

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About Prayas

Prayas (Initiatives in Health, Energy, Learning and Parenthood) is a non-governmental, non-profit organization based in Pune, India. Members of Prayas are professionals working to protect and promote the public interest in general, and interests of the disadvantaged sections of the society, in particular. The Prayas (Energy Group) works on theoretical, conceptual regulatory and policy issues in the energy and electricity sectors. Our activities cover research and intervention in policy and regulatory areas, as well as training, awareness, and support to civil society groups. Prayas (Energy Group) has contributed in the energy sector policy development as part of several official committees constituted by Ministries and Planning Commission. Prayas is registered as SIRO (Scientific and Industrial Research Organization) with Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India.

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Executive Summary

Energy is understood to be a key input to socio-economic development as it can play a critical role in enhancing productivity and reducing drudgery. This is particularly true for countries like India, whose development levels and per-capita energy consumption are low. Hence, it is important to holistically and objectively understand and assess the country's energy sector to identify its strengths and weaknesses so that policies and interventions can be appropriately prioritized to further the country's development.

In this report, we develop a comprehensive methodology, called the *energy sector assessment index*, to objectively and holistically assess the Indian energy sector. The proposed index is comprehensive because it not only considers the energy sector by itself but also considers the relationship and impacts of the energy sector on other related aspects such as society, environment and the economy. In order to be able to assess the energy sector and its impacts on these related aspects, the index has been designed to be *multi-dimensional* in nature – i.e. it is not a single value or number, but a collection of scores, each representing one aspect.

The proposed index has five dimensions representing the five aspects of the energy sector and its impacts:

1. The demand dimension assesses the productive role played by energy as a development input in peoples' lives, by considering measures such as access to modern energy, and usage of modern energy in households, agricultural and non-agricultural enterprises, and communities.
2. The supply dimension assesses the country's efforts at managing its energy supplies to meet the demand for energy and looks at elements such as India's import exposure, import diversity and domestic energy project management.
3. The social dimension looks at how well the country deals with the social impacts of the energy sector. This dimension looks at the country's record in rehabilitating and resettling those displaced by energy projects, the human development levels in the vicinity of energy projects and inequality in consumption of modern energy.
4. The environmental dimension assesses the effectiveness of the country's environmental management regime with respect to the energy sector and looks at air and water pollution near energy projects as well as GHG emissions from the energy sector.
5. The economic dimension assesses how efficiently the country uses energy and the financial implications of the energy sector on the economy. It considers aspects such as energy intensity, the role of energy imports in the country's trade deficit and the role played by energy subsidies.

Over all, the index consists of over 30 *indicators* to which values are assigned. These values are converted into scores in the 0-100 range, and based on these, the various dimensions are scored. We have applied the proposed methodology and computed India's energy sector assessment index for 2011-12. This assessment throws up some interesting insights.

1. Popular discourse suggests that the most pressing problems with the Indian energy sector are an inability to attract investments (mainly due to the pricing structure), delays in granting clearances and the financial implications of increasing energy imports. While these are indeed issues of concern, they only focus on the supply side. In contrast, our analysis shows that the supply dimension is actually the strongest dimension in the Indian energy sector with a score of 69, while the demand dimension scores the worst with just 40. The environmental, economic and social dimensions also do not fare very well with scores of just 43, 45 and 51 respectively.
2. The demand dimension scores only 40 because of high levels of energy poverty in the country even 65 years after independence, with about 40 crore citizens without access to electricity and 80 crore citizens without access to modern fuels for cooking. The low score of this dimension can also be attributed to the fact that energy is used sparingly in enterprises to improve productivity and communities to provide better services, perhaps because it is either unaffordable or not reliably available or both.

3. The low scores on environmental and social dimensions result from serious failures in managing the socio-environmental impacts of energy projects such as limiting or mitigating the environmental damage of energy projects and resettling and rehabilitating those displaced by energy projects. This is reflected in scores of 0 for water pollution, 30 for air pollution, and 26 for providing people with alternative livelihoods upon displacement due to an energy project.
4. The combination of these factors perhaps explains why there is increasing resistance to energy projects, as it seems citizens most affected by energy projects more often than not face the negative impacts of energy projects but do not enjoy the benefits that come from energy.
5. India also scores poorly on the economic dimension with a score of just 28 in managing the financial impacts of the energy sector, primarily due to its poor showing on energy subsidies and growing energy imports. The latter in particular is likely to become a serious issue in the coming years as India develops and demand for energy increases rapidly.

Thus, contrary to popular discourse, our analysis suggests that, in addition to the issue of growing imports and better targeting of subsidies, India needs to focus much more on the demand, environmental and social dimensions of the energy sector than it currently does. This will ensure that energy truly becomes a tool to enhance human development.

Ideally, the index should be computed on a periodic basis to regularly assess the energy sector and identify its strengths, weaknesses and trends, so that policy formulation can be informed accordingly. However, one big potential obstacle to such regular assessment could be the difficulty of obtaining some kinds of data, particularly related to the socio-environmental dimensions. The assessment for 2011-12 was also made with considerable difficulty and by using suitable proxies where data could not be obtained. This suggests that there is a need to improve data collection and publication mechanisms, particularly with respect to socio-environmental aspects of energy.

We hope that the proposed index will be used to continually assess the country's energy sector and understand its strengths and weaknesses, and the insights gained from its application to 2011-12 will help to bring demand, social and environmental issues into greater prominence. The proposed methodology may also be relevant and applicable to other developing countries.

■

1 Introduction

Energy supply and access is one of the key drivers of social and economic development as it can play a critical role in enhancing productivity and reducing drudgery (AGECC, 2010, p. 3; GoI, 2006, p. 1). This is particularly true for a country such as India, as evidence suggests that there is a strong correlation between a small increase in per-capita energy consumption and significant improvements in human development levels for countries at India's development level (Figure 1).

A comprehensive and objective understanding of India's energy sector is necessary in order to evaluate its performance with regard to driving social and economic development of the country. Such an understanding can help to identify the strengths and weaknesses of the country's energy sector, and thus identify areas for intervention and prioritization. In particular, such an assessment may help to identify some issues that have not gained sufficient attention or highlight some interesting linkages between energy and development that may otherwise be missed. An objective assessment can also form a basis for informed policy discourse to prioritize among different possibilities. Performing such an assessment on a regular basis will be even more useful as it can also help understand the evolution of the sector and its impact on society and development. Understanding such trends can perhaps help in early identification of policy options to address some trends. This report develops a methodology, called an *energy sector assessment index*, for such a comprehensive and objective assessment of India's energy sector and applies it to evaluate the Indian energy sector in 2011-12.

The Indian energy sector is characterised by various specific problems such as poor household access to modern fuels, increasing import dependence, limited domestic fossil fuel resources and high socio-environmental impacts. Therefore, a comprehensive approach for India would need to be *multi-dimensional* in nature. In this report, we review the existing literature on energy sector assessment and develop a multi-dimensional energy sector assessment index for India. A detailed framework or methodology to compute the energy sector assessment index is then presented, by identifying various indicators corresponding to each dimension. The index is then computed for India's energy sector for 2011-12, and analysed to identify its strengths and weaknesses. Ideally, to achieve maximum benefits, this index should be used on a regular basis to assess the energy sector, so that one can identify interesting trends in the sector and take action as required. It is hoped that the findings of this assessment, and the weaknesses identified therein, will help initiate a policy discourse on priority areas to be tackled through interventions. The proposed index may also be adapted to usefully assess the energy sectors of other developing nations.

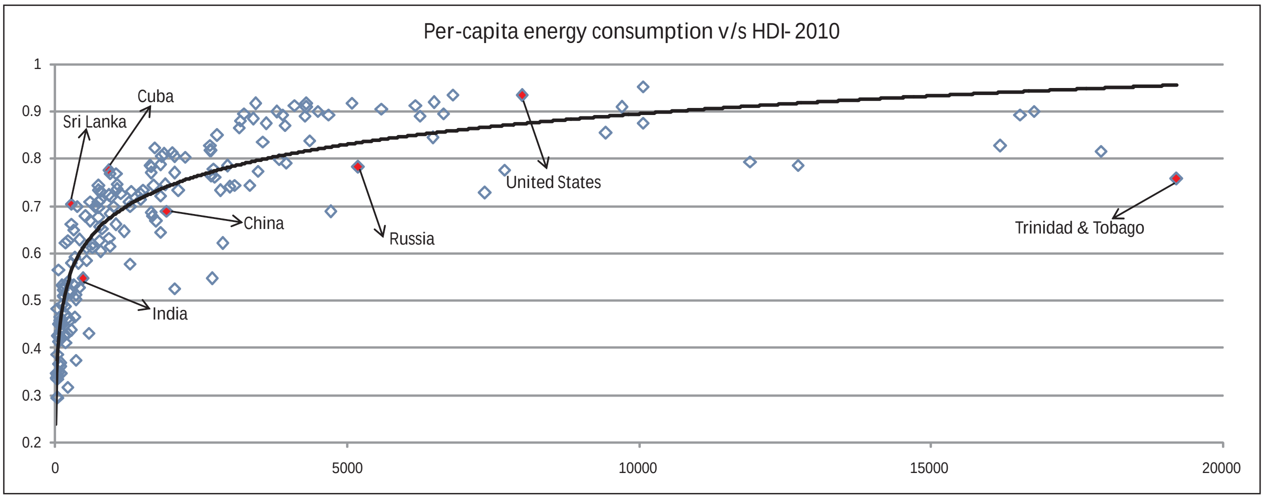

Figure 1: HDI levels and per-capita primary energy consumption[1]

1 Based on (U.S. DoE, 2013) and (United Nations, 2010, pp. 143–146)

2 Literature on energy sector assessment

With few exceptions, most of the literature to assess a country's energy sector is typically framed in the context of energy security and its assessment.

Two recent reports assess various aspects of the energy sector for some countries with the objective of an international comparison. The Global Energy Architecture Performance Index Report (EAPI) – 2014, by Accenture and the World Economic Forum (WEF) tracks the performance of 124 nations across three objectives: economic growth and development, environmental sustainability, and energy access and security (WEF, 2014). Each objective is measured through indicators such as energy efficiency, import dependence, emissions, level of access, distortion in energy pricing, and share of low carbon sources in the energy mix. The Poor People's Energy Outlook (PPEO) – 2013 by Practical Action introduces the Energy Access Ecosystem Index, which focuses on availability of energy for community services (health, education, public infrastructure and institutions), and specifically looks at Rwanda, Bangladesh and Bolivia (Practical Action, 2013). It uses nine indicators that include provision of access, a transparent, participatory and accountable decision making process, provision of public finance, and involvement of private sector.

The bulk of the literature on energy sector assessment focuses on energy security, which in turn is defined by and large as the adequate and reliable supply of energy at stable and affordable prices(Calder, 2008; Cohen, Joutz, & Loungani, 2011).Some of the literature tries to link the idea of enhancing energy security with combating climate change (Parikh & Parikh, 2011; N. Singh, 2012). This approach is more prevalent in nations like Germany and Japan which are heavily dependent on imports for their energy needs while also consciously trying to address the climate change threat (Duffield, 2009; Valentine, 2011).

There are many frameworks and methodologies for evaluating and comparing energy security across nations, such as (Cohen et al., 2011; Institute for 21st Century Energy, 2012; Sovacool, Mukherjee, Drupady, & D'Agostino, 2011; WEF, 2014).(Cohen et al., 2011) focuses exclusively on import diversification. The International Index of Energy Security Risk – 2012 from the Institute for 21st Century Energy uses 28 indicators under eight categories such as fuel imports, intensity of energy use and the efficiency of electricity and transportation sectors for an international comparison (Institute for 21st Century Energy, 2012, pp. 73–84). (Sovacool et al., 2011) evaluates energy security for 18 nations using 20 metrics that include issues of regulation and governance, technology development and efficiency, in addition to availability, affordability, and environmental sustainability.

One thread of the literature on energy security focuses on issues of institutions and governance, particularly related to energy diplomacy, availability of finance, lock-in and path dependence on technology, or the kind of prioritization seen for certain energy sources over others (Duffield, 2009; Vivoda, 2012). Some other aspects of energy security such as issues of equity and energy access for citizens, or the relationship between energy security and the economy, are relatively less studied (Hildyard, Lohmann, & Sexton, 2012; Sreenivas & Dixit, 2012).

Our interest is to develop a comprehensive assessment framework suitable to the Indian energy sector, going beyond the notions traditionally associated with energy security. In particular, we wish to capture issues specific to India, such as energy poverty, inequity and socio-environmental impacts of energy production, distribution and consumption in our assessment (Census, 2011a; Fernandes, 2007; Greenpeace India, 2011; MoSPI, 2013), while building on relevant aspects considered by many others. Moreover, our focus is on assessing the Indian energy sector and not an international comparison. This requires the development of a custom approach to assess the Indian energy sector, as none of the available methodologies can be directly used to meet our needs.

3 Multi-dimensional approach to assessing the Indian energy sector

We propose that a *multi-dimensional* approach is required to assess the Indian energy sector, if it has to be comprehensive and cover the various aspects relating energy to society and development. The spirit of this multi-dimensional approach is similar to the co-benefits approach for a climate change policy proposed in (Dubash, Raghunandan, Sant, & Sreenivas, 2013).

We propose an index consisting of the five dimensions, namely demand, supply, social, environmental and economic dimensions. This is because the effectiveness of energy as a developmental input can only be assessed by looking at its demand or consumption patterns; meeting such demand requires supplies to be secured and planned for; and energy production, distribution and consumption have social, environmental and economic impacts. These dimensions are described briefly below, and are further broken down into relevant sub-dimensions and specific indicators in the next section.

1. Demand dimension: Usage of modern energy is a key driver of human development (AGECC, 2010, p. 3; Practical Action, 2013, p. x). Hence, it is important for the assessment index to look at the demand or consumption of energy by considering issues such as access levels of Indian people to modern sources of energy, as well as its productive usage in households, communities and enterprises.
2. Supply dimension: Affordable and reliable supply of energy to the country is obviously an important aspect of the energy sector and energy security. This is consistent with the definition of energy security as defined in the Planning Commission's Integrated Energy Policy (IEP) document which states "*We are energy secure when we can supply lifeline energy to all our citizens irrespective of their ability to pay for it as well as meet their effective demand for safe and convenient energy to satisfy their various needs at competitive prices, at all times and with a prescribed confidence level considering shocks and disruptions that can be reasonably expected.*" (GoI, 2006, p. 54).

   Hence, it is necessary to have a supply dimension to the energy sector assessment index.
3. Social dimension: Setting up energy projects typically requires large amounts of land and other resources such as water. This can lead to social distress in the immediate vicinity of energy projects, particularly in a densely populated country as India. If energy is viewed as a key input to development, it is important to assess how well the country is managing this social distress and whether citizens in the vicinity of energy projects enjoy a good standard of life (Fernandes, 2007; Sharma & Singh, 2009). Hence, though these aspects are typically not considered in other literature, we believe it is necessary to have such a dimension in the assessment index.
4. Environmental dimension: Energy production, distribution and consumption can lead to air and water pollution, which can have a negative impact on people's lives if they are not controlled or limited. Energy consumption also emits climate-change inducing greenhouse gases. Therefore, it is important to understand how well the country manages its environment in the context of the energy sector. This aspect is also captured by many others (Institute for 21st Century Energy, 2012, p. 82; Sovacool et al., 2011; Vivoda, 2010; WEF, 2014, p. 14).
5. Economic dimension: Supplying energy reliably and affordably could have some economic impacts due to the necessity of importing energy, providing subsidies as well as the efficiency of the energy system (Institute for 21st Century Energy, 2012, p. 80; WEF, 2014, p. 14).This dimension captures such impacts of the energy sector on the country's economy.

These five dimensions, namely the demand and supply of energy, as well as its social, environmental and economic impacts, together give a comprehensive understanding of the country's energy sector and how it impacts citizen's lives both positively and negatively. Hence, these dimensions together constitute the multi-dimensional energy sector assessment index for India.

4 Assessing the various dimensions of the energy sector

Each of the five dimensions identified above are further expanded into a hierarchy as described below. The bottom-most elements in the hierarchy, which would have measurable values, are called *indicators*. Appendix I presents the complete hierarchy of the five dimensions, sub-dimensions and indicators. Some choices of sub-dimensions and indicators have also been dictated by pragmatic considerations such as availability of data.

4.1 Demand dimension

This dimension looks at the extent to which Indian citizens have access to modern energy sources for basic services, and the extent to which energy enables people to lead dignified and productive lives through its usage in houses, enterprises and communities (Practical Action, 2010, 2012, 2013). It is also in tune with the definition of energy security given in the IEP, which stresses on meeting "*effective demand*" (GoI, 2006, p. 54). This dimension is measured through two aspects:

1) "Household access to modern energy" looks at household access to modern energy for basic energy services. This aspect only accounts for basic access and not quality of access/supply, and has been considered by many others due to its close relation with social and economic development (Sovacool et al., 2011; Vivoda, 2010; WEF, 2014, p. 14). It is measured using two indicators:

a) "Access to modern energy for cooking / heating" looks at the share of Indian households using modern energy sources[2] for cooking and heating purposes.

b) "Access to electricity for lighting" looks at the share of Indian households using electricity as primary source of lighting.

For both indicators, a higher share leads to a higher score.

2) "Productive welfare impacts" assesses how modern energy is contributing to improving productivity and quality of life of Indian citizens. This sub-dimension also indirectly measures affordability, reliability and general quality of energy supply, as the extent of its usage indicates its affordability and reliability. This aspect is measured as follows:

a) "Productive impact on households" looks at the ownership of assets consuming modern energy at the household level:

i) "Ownership of appliances" is calculated as the share of Indian households owning either a television set or a refrigerator or both. Ownership of such appliances is considered as a proxy for better quality of life and reduced drudgery.

ii) "Access to motorized transport" is calculated as the share of Indian households having access to either public (bus or rail-based) or private transport (ownership of either two-wheeler or four-wheeler), as access to motorized mobility is an important aspect of quality of life in the modern age.

b) "Productive impact on enterprises" looks at the usage of modern energy in rural enterprises – both agricultural and non-agricultural, as it indicates the availability and affordability of such energy to enhance productivity and reduce drudgery at workplace. We focus on rural enterprises as urban enterprises by and large have access to modern energy. It is measured through two indicators:

i) "Use of modern energy in agriculture" is calculated as the share of land area of marginal and small farms that are irrigated using modern sources of energy (diesel/electricity). This indicator is important as more than half the Indian population is directly or indirectly dependent on agriculture (Census, 2011b, pp. 76, 80). For reasons of data unavailability and simplicity, other forms of modern energy used in agriculture such as tractors, harvesters etc. are currently not considered.

ii) "Use of modern energy in rural non-agricultural enterprises" is calculated as the share of rural non-

2 Modern energy for cooking/heating is defined as one among LPG (liquefied petroleum gas), PNG (piped natural gas), electricity or biogas. Though electricity may perhaps be an inefficient source for heating applications, its convenience and absence of negative health impacts at usage lead to its being considered here. Its inefficiency would result in lower scores for other indicators such as Conversion and delivery efficiency and Primary energy intensity. Biomass-based fuels, coal and kerosene are considered non-modern energy sources. Biomass is considered a problem because of its negative impacts on people's lives due to indoor pollution, health impacts and time spent in fetching the fuel, and its inefficiency in conventional stoves. Improved biomass cook-stoves may partially address this problem but do not appear to have been successful in practice (Sinha, 2002).

agricultural enterprises using modern sources of energy (diesel/electricity) for purposes other than heating/lighting at the workplace, as it indicates the extent to which modern energy forms help to improve productivity and promote livelihoods.

c) "Productive impact on communities" measures the positive impacts energy supply can have on communities, as energy is an important input to services such as health, education etc. (Practical Action, 2013). It is measured through the following indicators:

i) "Use of electricity in health centres" is calculated as the percentage of primary health centres having access to regular power supply. This indicator helps capture the positive impact of such regular supply on child births, refrigeration of vaccines, storage of drugs and blood, and comfort of patients and doctors.

ii) "Use of electricity in schools" is calculated as the percentage of primary schools having access to regular power supply. This indicator helps capture the positive impact that electricity brings in terms of illumination, comfort and the potential to have computers, laboratories and libraries in schools.

In all these cases, the score awarded is proportional to the respective shares.

4.2 Supply dimension

Traditional energy security literature that focuses on this aspect looks at two issues – reducing import dependence for energy requirements, and proper management of risks associated with energy supply from domestic and international sources (Cohen et al., 2011; Yergin, 2006). On the same lines, we assess how well the country manages its risks of energy supply, both through imports and domestic sources. These are further described below.

4.2.1 Imports

Assessing the country's management of energy imports is essentially about two aspects.

1) "Import risk exposure" accounts for the extent of risk associated with energy supply from overseas, such as geopolitical and price risks associated with dependence on energy imports. This is effectively captured for a nation by its net dependence on energy imports (Institute for 21st Century Energy, 2012, p. 79; Vivoda, 2010; WEF, 2014, p. 14). Hence, this risk is captured through a single indicator "Net energy import exposure", defined as the share of quantity of net energy imports (energy exports deducted from gross energy imports) in India's net energy supply[3]. A higher import exposure leads to a lower score.

2) "Import risk management" assesses the extent to which mitigation measures have been taken to manage these risks. This is effectively captured through a single indicator – "Import source diversity" which measures the extent to which India has diversified its gross energy imports (primary energy, petroleum products and electricity) as such diversification reduces the risks attached to energy imports (Cohen et al., 2011; Duffield, 2009; Yergin, 2006).

We measure the extent of source diversification (both the number of sources and how imports are distributed among the various sources) using the Herfindahl-Hirschman Index (HHI)[4]. The lower the HHI value, the higher the score.

4.2.2 Domestic Sources

Assessing domestic energy supply consists of measuring how well India is managing its energy resources and projects, and the extent to which it is dependent on depletable resources. These aspects are captured as follows:

1) "Domestic resource management" focuses on how well India is doing in managing its domestic energy supply in terms of planning and execution. This is captured through two indicators:"Target achievement– production" and "Target achievement – generation". Together, these two indicators look at India's performance both in the production of primary energy (coal, oil, gas) and in the generation of electricity. These are measured as percentages of actual production and generation against corresponding targets set in five-year plans, with a greater percentage resulting in a better score. This indicator helps assess energy

3 We consider net imports – i.e. exports subtracted from imports – of primary energy (crude oil, LNG and coal), electricity and petroleum products. We take the liberty of combining these forms of energy for simplicity, since there is very little energy loss in refining crude oil to petroleum products and India's current electricity imports are very small and consist only of hydro-electricity, where primary and final energy may be considered the same. This will need to be revisited if India begins to import a significant quantity of other forms of electricity.

4 See http://en.wikipedia.org/wiki/Herfindahl_index for more information.

generation processes and how realistic energy targets for plan periods are. They also indicate whether there have been delays in actual implementation of energy projects. Some other authors do focus on this aspect though they do not attempt to measure it (Institute for 21st Century Energy, 2012; B. K. Singh, 2010).

2) "Domestic resource sustainability" assesses the long-term sustainability of the country's energy sector by considering the extent to which India is dependent on non-depletable energy resources. It is calculated as the share of India's net primary energy supply met through non-depleting or renewable resources such as biomass[5],wind, solar and small hydropower (less than 25 MW)[6]. Domestic resource endowment is not factored into this score as it is intended to assess the sustainability of the Indian energy sector for the long-term, irrespective of India's resource endowment (over which it has no control). A higher share results in a higher score.

4.3 Social dimension

This dimension focuses on two aspects: one, how energy projects have impacted people's lives and livelihoods directly and indirectly, and two, the level of inequity with regard to modern energy consumption in India. These are captured using the following sub-dimensions and indicators:

1) "Compensatory rehabilitation and resettlement" looks at whether people who have been displaced by energy projects have been suitably compensated, resettled and rehabilitated. Energy projects require large amounts of land, which often leads to large-scale displacement, loss of livelihood, loss of access to natural resources and breakup of the community (Desai, Jain, Pandey, Srikant, & Trivedi, 2007; Fernandes, 2007; Sharma & Singh, 2009). The extent to which these impacts have been addressed by the country, are assessed using the following indicators:

a) "Monetary one-time compensation" is the share of households who have been given a monetary compensation for losing their lands or associated livelihoods to energy projects.

b) "Alternative livelihood opportunity" is the share of displaced households who have been provided with either a job, monetary annuity, or an alternative livelihood opportunity (such as re-skilling, shops, or land for agrarian or other economic activities). This is in addition to the one-time monetary compensation provided for loss of land and/or livelihood, since provision of alternative livelihood opportunity to those affected by projects is also necessary to ensure sustainable and just development (Fernandes, 2007; Sharma & Singh, 2009).

c) "Rehabilitation and resettlement (R&R)" is calculated as the percentage of affected households who have been resettled with good houses[7] and provided access to amenities such as clean water, health centres, schools and all-weather roads.

Certain other impacts, such as the impact of energy-related activities on the quantity and quality of ground or surface water, are not measured in this index though they may be important for some kinds of energy projects such as coal mining (Greenpeace India, 2011). This is primarily due to lack of availability of such data.

In each of the above cases, the higher the share, the higher is the score.

2) "Human development levels in the vicinity of energy projects" is used to measure the impact of energy projects on human lives in their vicinity, where vicinity is defined as the tehsil in which the project is located. This is measured using the Multi-dimensional Poverty Index (MPI) defined by the United Nations (United Nations, 2010, pp. 221–222). MPI values for those living in the vicinity of energy projects and for the country as a whole are converted to non-poverty or non-deprivation scores by subtracting them from 1. The ratio of the non-poverty values in the vicinity of energy projects to the non-poverty value for the country is calculated, with a higher ratio resulting in a higher score.

MPI values in the vicinity of energy projects are compared to Indian MPI values (rather than against a global normative benchmark) as the intent is to assess

5 We assume that biomass use is sustainable (i.e. not over-harvested) and hence non-depleting. This assumption is by and large valid currently. However, in future, if there is reason to believe that this is not so, then this indicator would have to be revisited.

6 Definition of renewable power in India includes hydropower plants with a capacity of 25 MW or less (MNRE, 2011).

7 "Good" houses refer to houses with roofs made of tiles, burnt brick, stone, slate or concrete.

how well the tehsils in which energy projects are located are doing in comparison to the country.

3) "Inequality" looks at the inequality in energy consumption across Indian households[8]. High levels of inequality indicate imbalanced development across the diverse socio-economic strata of the country, which is undesirable. This is measured using two indicators:

a) "Inequality in consumption of modern energy for cooking/heating" is calculated as the Gini coefficient[9] of consumption of modern energy for cooking/heating in Indian households.

b) "Inequality in consumption of electricity" is calculated as the Gini coefficient of consumption of electricity in Indian households.

In these cases, the score awarded is inversely proportional to the respective Gini coefficients.

4.4 Environmental dimension

This dimension focuses on how energy sector activities impact both the local and global environment. As discussed earlier, this aspect of the energy system has received considerable attention in literature (Institute for 21st Century Energy, 2012, p. 82; Sovacool et al., 2011; WEF, 2014, p. 14). Local pollution focuses on two forms of pollution caused by energy projects: air and water, since high pollution levels have a disabling effect on peoples' lives. Global pollution considers greenhouse gas (GHG) emissions from the energy sector. These have been captured in this index through the following indicators:

1) "Local air pollution" is measured for three kinds of pollutants: sulphur dioxide (SO_2), nitrogen oxides (NO_X) and respirable suspended particulate matter (RSPM). For each pollutant, concentration values are obtained for a sample set of energy projects. The highest ratio of the concentration for each pollutant to the stipulated norm is considered, as it depicts the weakest link (among the sampled projects) to clean air quality. Note that air quality norms for different types of energy projects are different. Hence, ratios of concentrations to norms are compared rather than concentrations themselves. Higher ratios result in lower scores.

Air pollution caused by energy consumption – particularly pollution from the transport sector in urban areas – has not been considered. This is because it is difficult to find good source apportionment studies for urban air pollution that can isolate the impacts of energy use. Similarly, while indoor air pollution from biomass is a critically important health issue, the objective of this indicator is to capture ambient (rather than indoor) air pollution levels due to the energy sector. Poor access to clean energy sources resulting in such pollution would result in low scores under the demand dimension and also a low score on the economic dimension as biomass is a very inefficient source of energy.

2) "Water pollution" is measured as the concentration of total suspended solids (TSS)[10] present in the water discharge from a sample set of energy projects. As with air pollution, the highest ratio of the concentration of TSS in the water discharge to the stipulated norm is considered, with higher ratios resulting in lower scores.

3) "Per-capita GHG emissions from the energy sector" are considered as the energy sector is a major contributor to climate change. GHG emissions from energy sector include all emissions from production, conversion, distribution and consumption of energy. Higher emissions would result in a lower score.

4.5 Economic dimension

This dimension focuses on the Indian economy's efficiency of energy use and the financial impact of ensuring adequate and reliable energy supplies. We focus on this dimension in the light of the importance of energy sector for the larger economy (Institute for 21st Century Energy, 2012, pp. 80–81; WEF, 2014, p. 14). We capture these aspects through the following:

4.5.1 Efficiency of energy use

Efficiency of energy use estimates the efficiency of energy conversion and consumption. Inefficiencies on these parameters could point to room for improvement whereby the same amount of primary energy can result in greater final energy or economic output. This is represented through two indicators:

8 One approach could have been to adjust other indicators (such as access or energy use indicators) for inequality. However, we choose to keep inequality as a separate indicator because we believe it is important to explicitly highlight the extent of inequality in energy consumption.

9 See http://en.wikipedia.org/wiki/Gini_coefficient for more on Gini coefficient.

10 Other kinds of pollutants, such as metals, were not considered for pragmatic reasons of data unavailability.

1) "Primary energy intensity of the economy" is calculated as India's primary energy consumption per unit of India's Gross Domestic Product (GDP), with a lower intensity leading to a higher score as it indicates a higher efficiency in translating energy consumption to economic output.

2) "Conversion and delivery efficiency" is calculated as the ratio of final energy to primary commercial energy, indicating the efficiency of the energy conversion and distribution processes used. A higher ratio results in a higher score as it indicates lesser losses in conversion, transmission and distribution.

4.5.2 Financial impacts

This sub-dimension looks at the financial impacts of the energy system on the country's economy. It is captured through two indicators:

1) "Impact on trade deficit" measures the contribution of India's energy imports to its trade deficit. It is calculated as net energy import costs as a percentage of the country's trade deficit, with a higher percentage receiving a lower score. Trade deficit, rather than total export revenues, is considered because it is the deficit that could have major macro-economic impacts (e.g. on exchange rates and India's macro-economic stability), rather than the costs of imports or revenue earned from exports.

2) "Impact of energy subsidies" looks at the subsidy burden of energy on the economy. Some energy subsidies need to be provided in a country like India in order to increase access to modern energy[11]. This imposes some cost on the economy, which is measured as the value of energy subsidies as a percentage of GDP – with a higher subsidy share receiving a lower score.

Definition and calculation of energy subsidies is a contentious issue. For example, there are multiple opinions about whether petroleum "under-recoveries" are subsidies or not (IISD & TERI, 2012; Sethi, 2010). Others believe that subsidies should not be restricted to explicit subsidies, but should also include implicit subsidies such as tax holidays or incentives such as cheap land, water or tax concessions (Singhvi, 2012; Srivastava & Bhujanga Rao, 2002). However, it is generally accepted that very high subsidies, particularly those not targeted at the poor, are harmful to the economy. The definition of subsidies used by us and scoring based on it is discussed further in Section 6. Note that the positive effects of such subsidies – to the extent achieved – will result in higher scores for other indicators such as access and productive usage of modern energy. The following table presents a summary of the five dimensions described above and their key elements. The detailed list of dimensions, sub-dimensions and indicators is given in Appendix I.

Dimension	Sub-dimension	Key elements/indicators
Demand dimension	Household access to modern energy	Access to modern energy for cooking/heating
		Access to electricity for lighting
	Productive welfare impacts	Productive impacts on households
		Productive impacts on enterprises
		Productive impacts on communities
Supply dimension	Imports	Import risk exposure
		Import risk management
	Domestic Sources	Domestic resource management
		Domestic resource sustainability
Social dimension	Compensatory rehabilitation and resettlement	Monetary one-time compensation
		Alternative livelihood opportunity
		Rehabilitation and resettlement (R&R)
	Human development levels in the vicinity of energy projects	
	Inequality	Inequality in consumption of modern energy for cooking/heating
		Inequality in consumption of electricity
Environmental dimension	Local air pollution	SO_2 concentration
		NO_x concentration
		RSPM concentration
	Water pollution	TSS concentration
	Per-capita GHG emissions from the energy sector	
Economic dimension	Efficiency of energy use	Primary energy intensity of the economy
		Conversion and delivery efficiency
	Financial impacts	Impact on trade deficit
		Impact of energy subsidies

11 This is not to claim that all energy subsidies in India are well-directed and targeted at the deserving.

5 Scoring, Normalization and Weightage

5.1 Scoring methodology

The previous section described the dimensions and their components proposed to comprehensively assess India's energy sector. In order to arrive at the energy sector assessment index, each level is scored between 0 and 100, with 0 representing the worst and 100 representing the best possible score.

The scores of the bottom-most indicators in the hierarchy are obtained by normalizing the indicator values to the 0-100 range. The final scores for all the five dimensions (demand, supply, social, environmental and economic), are computed bottom-up with scores for higher levels in the hierarchy being weighted sums of scores at the lower levels. The scores of the five dimensions are not further combined into a single final score as we believe all these five dimensions are independent facets of the energy sector and should be distinguished as such. This is also what makes the proposed index '*multi-dimensional*', as the final energy sector assessment index is a set of five numbers rather than just a single number. This multi-dimensional energy sector assessment index can be depicted as a 'radar diagram' or 'spider diagram' for easier comprehension. Individual dimension scores may also be depicted through such diagrams to further expose the breakup of the particular dimension, and identify strengths and weaknesses within a dimension.

5.1.1 Normalization of values

Appendix II presents how indicator values are normalized to arrive at scores in the 0-100 range. In this section, we briefly describe the overall approach used and some indicators whose normalization needs further elaboration.

Indicators are assessed against global maxima-minima benchmarks to the extent possible, i.e. where credible and acceptable benchmarks are available. In such cases, values equal to or worse than the global minimum are scored 0, values equal to or better than the global maximum are scored 100 and values in between are scored by linear interpolation. For example, indicators that are measured as percentages or as a ratio between 0 and 1, are easily converted to a 0-100 range through simple scaling. Thus, for air and water pollution indicators, a ratio (of the pollution value to the permissible norm) of 0 is scored 100 while a ratio of 1 or more is scored 0. Indicators of inequality and HHI are scored similarly. The reverse (ratio of 0 scored as 0 while ratio of 1 or more scored as 100) is done for indicators on human development levels in vicinity of energy projects.

For three indicators, it is difficult to decide global normative benchmarks to represent 0 and 100. These are primary energy intensity of the economy, impact of energy subsidies and per-capita GHG emissions from the energy sector. Hence, these indicators are scored based on an international comparison[12] against the corresponding values for the set of "major economies", which is defined as the set of G-20 nations[13]. In such cases, the indicator is scored based on India's rank among the G-20 nations with the top-most rank getting a score of 100, the bottom-most rank getting a score of 0, and ranks in between being linearly interpolated to arrive at a score.

5.2 Weighting of scores

Weights for the indicators and sub-dimensions were decided using a modified version of Analytical Hierarchy Process (AHP) method, which involves pair-wise prioritization of indicators and sub-dimensions (Nathan & Reddy, 2011). For simplicity, we have given equal priority to all elements at the same level of the hierarchy in most cases. The few exceptions made are described below:

- In the demand dimension, productive welfare impacts

12 Some of these indicators are admittedly difficult to compare across nations. For example, energy intensity is also a function of the structure of the country's economy and different countries may have different economic structures. Similarly, different poverty levels in different countries could lead to differing need for subsidies. However, for simplicity, we use the proposed international comparison for these indicators.

13 G-20 consists of Australia, Canada, Saudi Arabia, United States, India, Russia, South Africa, Turkey, Argentina, Brazil, Mexico, France, Germany, Italy, United Kingdom, China, Indonesia, Japan, South Korea and the European Union (Source: http://www.g20.org/about_g20/g20_members). In this framework, we do not consider the European Union as the other 19 members include 4 major European Union economies, and together, these 19 economies account for around 62% of the world's population, 76% of its annual primary energy consumption and 73% of its GDP (constant 2005 US$PPP) (U.S. DoE, 2013; WB, 2012).

have been given a greater weight (66.67%) compared to basic household access to modern energy (33.33%), because productive welfare impacts on households, enterprises and communities have a greater beneficial impact on society and economy than mere basic access to modern sources of energy, particularly in rural areas (Cabraal, Barnes, & Agarwal, 2005; IEA, 2010).

- Among the productive impacts on communities, energy has a greater enabling role to play on health services rather than education (Cabraal et al., 2005; Nussbaumer, 2012). Hence, use of modern energy in health services has been given a greater weightage (66.67%) compared to education (33.33%).
- In the case of measuring the MPI values for the nation as well as in the vicinity of energy projects, the weights proposed are the same as those used in the United Nations' Human Development Reports (United Nations, 2010, pp. 221–222).

Appendix I gives the complete list of the weights given to all sub-dimensions and indicators within each dimension.

6 Discussion of proposed index

The objective of the proposed index is to help in getting a broad understanding of the strengths and weaknesses of India's energy sector, and identify areas of improvement. In particular, the scoring system is not intended to help in making fine judgements based on small differences in scores. Thus, it cannot be used to conclude that a score of, say, 70 for some indicator or sub-dimension is better than a score of 68, while it would be correct to conclude that a score of 70 is a good score while a score of, say 40, is not so good.

Since global benchmarks have been used to assess the impact of energy subsidies on the economy, a uniform definition of energy subsidies applicable to multiple countries is required. Therefore, as a pragmatic choice, we use the definition of post-tax energy subsidies as defined by the International Monetary Fund (IMF), which includes the difference between the benchmark price[14] and actual consumer price for coal, petroleum products, natural gas and electricity[15] (IMF, 2013, p. 6), even though such a definition may not be acceptable to all.

The proposed index tries to assess how well the country mitigates the impacts associated with human displacement arising out of energy projects. However, some impacts, such as loss of agricultural productivity (due to fall in water tables, reduced soil fertility or increased competition for water use), psychological or traumatic impacts of displacement and forced migration, and impacts due to inadequate or improperly designed or implemented compensatory R&R packages, have not been captured in the index, mainly due to lack of data availability. The impacts on morbidity and health issues have been captured only indirectly through air and water pollution.

The proposed index does not include certain indicators or elements that others have considered. These are discussed below.

Some energy security literature considers use of diplomatic initiatives in securing energy supply through pipelines, bilateral energy deals and/or the acquisition of energy assets abroad (Dadwal, 2012; Leung, 2011). However, there is no consensus that such initiatives indeed help in securing energy supply, particularly through blockage of supply routes or threat to supply infrastructure (Leung, 2011; Mahalingam, 2013). Hence, this aspect has not been included in our index.

Some energy sector assessment frameworks measure the capacity, transparency and effectiveness of energy sector institutions (Sovacool et al., 2011; Vivoda, 2010). While these aspects are indeed important, our index does not include them, as the index is intended to represent the performance of the energy sector at a point in time. Current policies and institutional structures which would impact future energy sector performance are not relevant to the current score, while past policies and institutional governance structures would have impacted some aspect of the current energy sector's performance. Hence, leaving these elements out of the proposed index is consistent with the objective of the index.

Our assessment index does not capture the adequacy of India's energy infrastructure. However, this aspect is captured partially through indicators such as use of modern energy in households, enterprises and communities, net energy import exposure and India's target achievement, which together represent India's energy demand which has been met and energy that has been supplied.

An indicator which looked at delays in commissioning of energy projects was considered as part of domestic supply management, but discarded as the impacts of such delays were already captured in indicators measuring target achievements for energy production and generation.

As described in Section 5.2, we have given equal weights to most indicators and sub-dimensions in our index with a few exceptions. It is possible that others may want to assign different importance to the various elements of the index or focus on specific aspects of it. Thus, an analyst focusing on pollution impacts of the

14 The benchmark price is the international price of the good, appropriately adjusted for transportation and distribution costs (IMF, 2013, p. 7).

15 It is not clear how this definition addresses issues such as targeting and delivery of subsidies, cross-subsidies, and distortionary taxes, as acknowledged in the report. However, the definition is still useful for two reasons in addition to providing a uniform way of measuring subsidies across nations – one, it captures implicit subsidies such as tax breaks to a certain extent; two, it also considers some environmental externalities, such as GHG emissions and local pollution to some extent.

energy sector may wish to give it more importance compared to GHG emissions, while another analyst focusing on financial impacts of energy sector may wish to choose a different set of weights within the economic dimension. The proposed index allows for such customization of weights to suit a particular purpose, as long as the reasoning behind a particular choice of weights is transparent and explicit.

Finally, it is pertinent to note that we have used a linear scoring method as described in Section 5.1, where scores of higher levels in the hierarchy are computed as simple weighted sums of lower levels. While some other index calculation frameworks propose other models, such as the geometric mean used in Human Development Index (HDI) calculations (United Nations, 2010, pp. 216–217) and the Displaced Ideal (DI) technique suggested by (Nathan & Reddy, 2011), many energy sector assessment frameworks use the simple linear scale (Institute for 21st Century Energy, 2012; Sovacool et al., 2011)[16]. Hence, we also use the simple linear approach.

16 The recently formulated MPI measurement by the United Nations also uses a simple linear combination (United Nations, 2010, pp. 221–222).

7 Assessing India's energy sector for 2011-12

Based on the methodology described above, we computed India's energy sector assessment index for 2011-12. Appendix III presents the values of all indicators and corresponding scores on a 0-100 range, while Appendix IV presents the scores for the hierarchies of all dimensions. In this section, we describe the various data sources used for the assessment and some adjustments that had to be made to the methodology.

7.1 Data sources for the assessment

To the extent possible, data from Government agencies such as the Central Electricity Authority (CEA), Coal Controllers' Organization (CCO) and Ministry of Petroleum & Natural Gas (MoPNG) have been used (CCO, 2012; CEA, 2012b; MoPNG, 2013, p. 10). Other Government sources such as the working group reports of energy-related ministries have also been used (MoC, 2011, p. 20; MoPNG, 2006, p. 82). Data from the Export-Import Data Bank of the Department of Commerce and Economic Survey of India is used to assess the financial impact of energy imports (Dept. of Commerce, 2012; MoF, 2013, p. A–76). International data has been obtained from sources such as the World Bank, IMF, US Department of Energy and World Resources Institute (IMF, 2013, pp. 57–61; U.S. DoE, 2013; WB, 2012; WRI, 2013).

Some of the socio-economic data has been taken from sources such as National Sample Survey Organization (NSSO) reports and Census 2011 by the Government of India (Census, 2011a; MoSPI, 2013). Other Government reports, such as Economic Census and District Level Health Survey III have also been used to get some socio-economic data (IIPS, 2010, p. 220; MoSPI, 2001, 2008).

Data related to air and water pollution have been obtained from responses to applications under the Right to Information (RTI) Act. Initially, RTI applications were sent to 12 state pollution control boards (SPCBs), seeking information about air and water pollution levels near 23 energy-related projects spread across coal mines, coal-based power plants and gas-based power plants. We only received responses with useful information from nine SPCBs, with some of them not sharing data citing reasons such as unavailability of data though such data is expected to be submitted to them under Section 14 of Environment (Protection) Rules, 1986[17]. We have tried to supplement the information obtained from SPCBs by information obtained through further RTI queries to some publicly owned energy projects and information from websites of some SPCBs. The scores for air and water pollution have been computed based only on the information obtained through the above means. A detailed list of projects from which information was sought, replies were obtained, pollution norms for these projects, and the pollution values reported, are given in Appendix V.

Exact data sources used for all indicators have been listed in Appendix III.

7.2 Methodological adjustments

The methodology used to compute India's energy sector assessment index for 2011-12 is slightly different from the methodology presented above. These adjustments were necessary mostly due to unavailability of required data, as explained below.

a) Compensatory R&R

This was the toughest category of indicators to obtain data for. Very little official data is available regarding compensation and R&R of families or people affected by energy projects at an all-India level. There is some project-specific data available through research papers, though not for 2011-12. The literature surveyed by us is briefly presented below.

(Mathur, 2008) informs us that 6 crore people have been displaced by all developmental projects in India. (Fernandes, 2007) presents figures on how Coal India provided jobs to about 36% of those displaced by its mining projects during 1981-85, but this share reduced to around 10% in the 1990s on account of mechanization of mining processes.

A few papers focus on the different and varied impacts of energy projects on the displaced such as loss of livelihoods, gender relations, health of women and children, cultural impacts and mental trauma (Baxi, 2008; Dewan, 2008; Hemadri, Mander, & Nagaraj, 2000; Padel & Das, 2008). They also stress the necessity

17 Though technically possible, it was not practically feasible to pursue these cases through appeals and so on.

of energy projects to improve the lives of displaced through suitable compensation and R&R packages.

Some papers focus on R&R of those displaced by specific energy projects in India. (Sharma & Singh, 2009) looks at R&R for those displaced by energy projects in Singrauli district of Madhya Pradesh as on December 2009, and states that about 36% of the displaced families were provided alternative livelihoods, while about 55% were provided resettlement plots for housing. (Desai et al., 2007) compares the livelihoods, amenities and basic services (provision of water, public health care facility and school) before and after displacement of those displaced by the Indira Sagar project and living in 5 Government-resettled sites as on November-December 2006.

Given the scarcity of data, the following adjustments were made to the scoring methodology:

• The indicator for one-time monetary compensation was not used since no data was available for it at all. The weights of the other two indicators (alternative livelihood opportunities and R&R) were accordingly changed to 50% each.

• The scores for R&R were calculated based on the data from the Indira Sagar project as provided in (Desai et al., 2007) since it provided all the data components in the index except access to all-weather roads. The indicator for all-weather roads was accordingly removed, and the other four indicators (availability of good houses, access to schools, health care and water supply) were weighted equally (25% each).

• The indicator on alternative livelihood opportunity was scored based on the average of the two energy projects – Singrauli and Indira Sagar – for which data was available with us (Desai et al., 2007; Sharma & Singh, 2009).

b) Access to motorized transport

In our proposed index, we look at the access of India's population to motorized transport – both public and private – as a productive impact at the household level. However, since data is not available on the share (%) of Indian population/households having access to public motorized transport, we only consider the share (%) of Indian households having access to private motorized transport (two-wheeler or four-wheeler).

This has two implications. First, considering only access to private motorized transport is likely to significantly underestimate the share of the population with access to motorized transport, since a large percentage of india's population is likely to use public transport. Second, using access to private motorized transport is anomalous to the extent that, in the proposed methodology, greater access to private motorized transport will actually improve the score for this indicator though it is widely understood that there is a negative correlation between the use of private motorized transport and energy security (GoI, 2011).

However, this indicator is only intended to measure access to motorized transport. Hence, we use access to private motorized transport as a proxy indicator though it under-estimates the real access figure. The negative impacts related to higher use of personal motorized transport will be captured in other indicators, such as net energy import exposure, domestic resource sustainability and energy intensity.

c) Human development levels in vicinity of energy projects

The index proposes to calculate human development levels in the vicinity of energy projects (i.e. tehsils in which the project is located) using the MPI approach (United Nations, 2010, pp. 221–222). However, tehsil-level data is not available to calculate MPI[18]. Therefore, we have used eight alternative indicators and combined their values to assess human development levels in the vicinity of energy projects. These are: good houses (i.e. houses with roofs made from tiles, burnt brick, stone, slate or concrete), water availability within premises, sanitation facility within premises, access to electricity for lighting, access to clean fuels (LPG/PNG/electricity/biogas) for cooking, access to private motorized transport (two wheeler)[19], ownership of electronic assets (landline/mobile phone, television), and availing banking services. It would have been good to consider elements such as access to schools and healthcare in the human development levels near energy projects but such information was not available at the tehsil level.

18 In particular, data on health and education indicators is not available at the tehsil level.

19 We consider access to private motorized transport for the same reason given earlier regarding the indicator about access to motorized transport. We only consider ownership of two-wheelers since there is no tehsil-level data available on ownership of two-wheelers and four-wheelers separately.

For each energy project in the chosen sample, the ratio of the percentage of households with a particular amenity, service or appliance (e.g. good house or sanitation or banking services) at the tehsil level to the percentage of households for the same indicator at the national level is calculated. The ratios for each amenity or service or appliance are then combined for each energy project using weights as described below. Of the eight indicators used to measure human development levels, five (access to good quality housing, modern energy for cooking and lighting, water and sanitation within premises) are given greater and equal weights (15% each) while the remaining 25% is equally divided among the other three indicators (availing banking services and ownership of household assets and personal motorized transport). This is done since the former set represents more “fundamental” developmental needs (United Nations, 2010, pp. 221–222).

The lowest score among the scores thus computed for the sample set of energy projects is chosen as the score for this indicator, as it represents the weakest link in terms of providing better development to those in the vicinity of energy projects. Appendix V gives more details in this regard.

d) Inequality in consumption of modern energy

The quantity of household consumption of modern energy sources (LPG/PNG/electricity/biogas) specifically for cooking/heating is not available. Hence, for simplicity, we use the Gini coefficient of LPG consumption across households as a proxy for inequality in consumption of modern energy for cooking or heating, since it is by far the most dominant of the modern fuels used for cooking/heating (Census, 2011a).

e) Use of modern energy in agriculture

The index proposes to calculate this indicator as the share of land area of marginal and small farms that are irrigated using modern sources of energy (diesel/electricity). However, this data is not available for India. Hence, a proxy of the number of pumps using diesel or electricity per marginal or small farm that is either un-irrigated or is irrigated by either wells or tube-wells[20] is used. This data is collected in the Agriculture Census conducted by the Ministry of Agriculture. However, since this data is not available for 2011-12, it has been estimated based on extrapolation from three previous Agriculture Census of 1995-96, 2000-01 and 2005-06 (DAC, 2011).

f) Use of modern energy in rural non-farm enterprises

The number of rural non-farm enterprises using modern energy was obtained from the Economic Census conducted by the Ministry of Statistics and Programme Implementation (MoSPI). However, since this data is not available for 2011-12, this indicator was extrapolated from the previous two Economic Censuses for 1998-99 and 2004-05 (MoSPI, 2001, 2008).

g) Per-capita energy emissions from the energy sector

Data on total and per-capita energy emissions from the energy sector is not available for either India or the other G-20 nations for 2011-12. Since this data is available for the period 2005-2009 (WRI, 2013), during which India consistently ranks the lowest in terms of her per-capita GHG energy-related emissions, we used the same to obtain India’s score for 2011-12.

h) Use of electricity in health centres (PHCs)

Data on primary health centres with regular power supply is not available for 2011-12. So, data for this indicator from District Level Health Surveys (DLHS) III of 2007-08[21] is used as a proxy (IIPS, 2010).

i) Use of electricity in schools

Data on schools with regular power supply is not available, so we modified this indicator to look at the share (%) of schools having an electricity connection, for which data was available in District Information System for Education Survey (2011-12) (NUEPA, 2012).

20 We understand that there is some usage of electric or diesel pumps to pump water from canals to areas far away or higher than the canal, and that there is usage of electric or diesel pumps to support water markets. However, our assessment does not consider these due to lack of availability of data.

21 Previous DLHS surveys cannot be used to extrapolate the value for 2011-12, as the previous surveys did not ask about regular power supply to PHCs.

8 India's energy sector assessment index in 2011-12

We first present the scores revealed by the energy sector assessment index and discuss its implications in the subsequent sections.

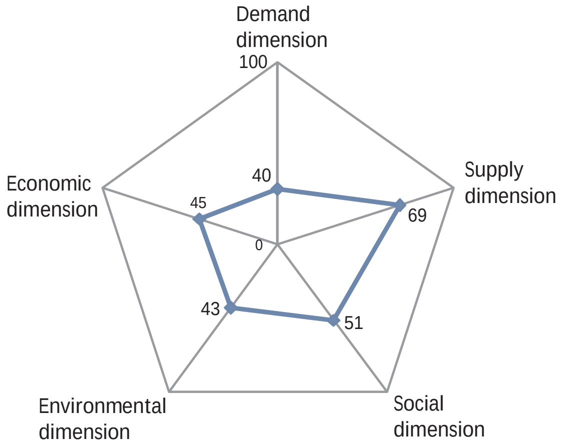

Figure 2: India's energy sector assessment index scores

Figure 2 shows the energy sector assessment index scores for India on all the five proposed dimensions in the form of a radar diagram[22]. India performs well on the supply dimension (69), followed by average scores on the social (51), economic (45), environmental (43) and demand dimensions (40). Detailed scores of all the indicators and sub-dimensions are given in Appendix IV.

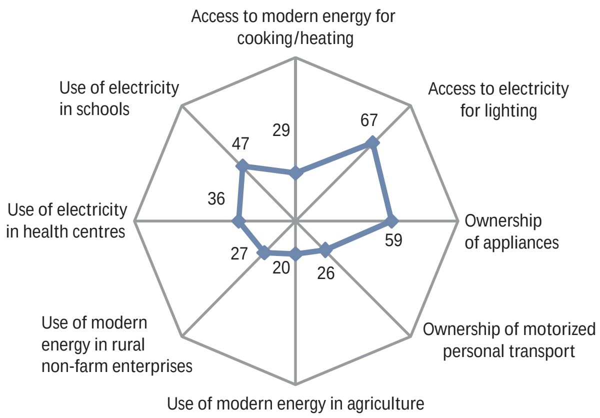

Figure 3: India's scores on demand dimension

Figure 3 shows the scores for indicators on the demand dimension of the index. This dimension has the worst score among all dimensions. While India scores well (60-100) on access to electricity for lighting (67), its score is average (40-60) on ownership of appliances (59) and use of electricity in schools (47). All the other scores are poor (0-40): use of modern energy in agriculture (20), access to motorized transport (26), use of modern energy in rural non-farm enterprises (27), access to modern energy for cooking/heating (30) and use of electricity in health centres (36).

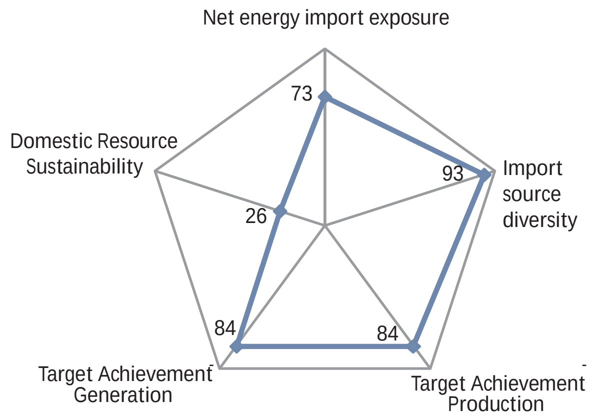

Figure 4: India's scores on supply dimension

Figure 4 depicts India's scores on the supply dimension of the index. This dimension has the best score among the dimensions as India scores quite well on four of the five indicators: import source diversity (93), target achievement (84 each for production and generation) and net energy import exposure (73). On the other hand, the score is poor for domestic resource sustainability (26).

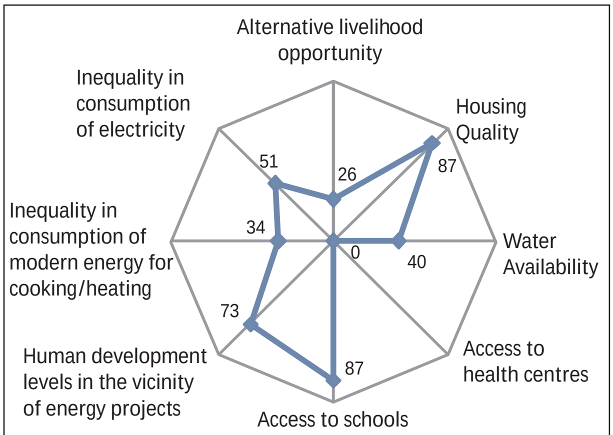

Figure 5: India's scores on social dimension

India's scores on the social dimension of the index are shown in Figure 5. There is substantial variation in scores of the various indicators in this dimension with some good scores, some average scores and some poor scores. Scores are good on three indicators: housing

22 The radar diagram is merely used as a visual aid. No importance should be attached to the order of the various points in the radar diagram – which can change its shape and enclosed area.

quality and access to schools for the displaced (both 87 each) and human development levels in vicinity of energy projects (73). However, the performance is average with regard to indicators on inequality in consumption of electricity (51) and poor-to-average on water availability to those displaced by energy projects (40). The scores are poor for the indicators of inequality in consumption of modern energy for cooking/heating (34) and providing alternative livelihood opportunities to those displaced by energy projects (26). The performance is abysmal with regard to access to health centres for those displaced by energy projects (0).

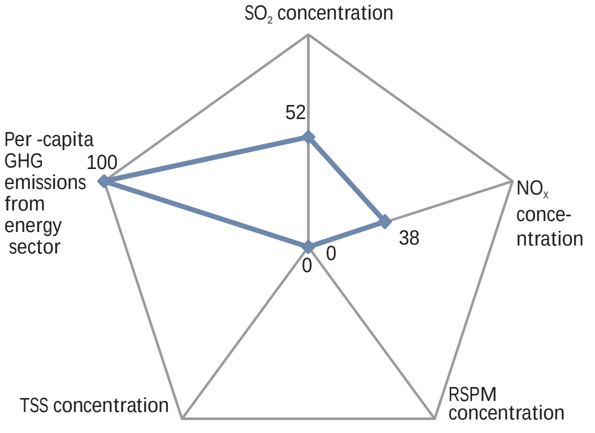

Figure 6: India's scores on environmental dimension

Figure 6 shows India's scores on environmental dimension indicators. Again, there is a huge variation in the scores of these indicators. While India scores a perfect 100 on per-capita GHG emissions from the energy sector, it scores an abysmal 0 on both RSPM concentration in air and TSS concentration in water. The performance is average for SO_2 concentration (52) and poor-to-average for NO_x concentration (38).

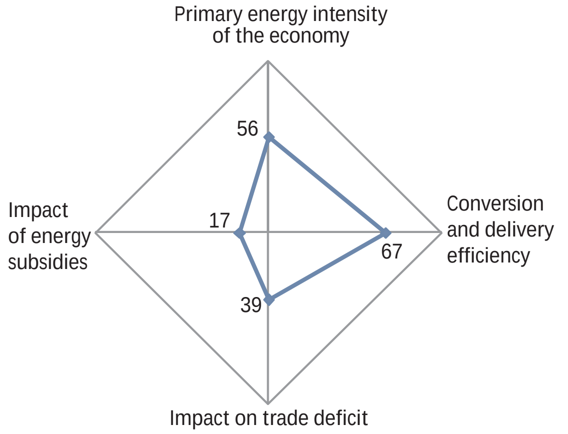

Figure 7: India's scores on the economic dimension

Figure 7 shows India's scores on indicators for the economic dimension of the index. The scores are good for conversion and delivery efficiency (67), average for primary energy intensity (56) and poor-to-average with scores of 39 for the energy sector's impact on trade deficit and a very poor 17 regarding the financial impact of energy subsidies.

We now discuss the robustness of the scores and analyse the strengths and weaknesses of India's energy sector based on the above scores.

9 Robustness and analysis of the scores

9.1 Robustness of the scores

Given that the choice of weights may be considered somewhat subjective, we performed a sensitivity analysis to assess the variation in dimension or sub-dimension scores to varying weights. The sensitivity analysis was performed by varying the relative importance of elements in the hierarchy by up to 30% (or even 50% in some cases) from what was proposed, and analysing the variation in the score for all elements above it in the hierarchy. The analysis showed that the proposed methodology was robust, since even such a reasonably large change in weights only changed the dimension-level scores by less than 5%. As a result, one may claim that the scores obtained are not sensitive to the choice of weights made in the proposed index.

9.2 Weaknesses of India's energy sector

9.2.1 Energy: not enabling enough, but disabling plenty

A score of just 40 for the demand dimension suggests that energy and its consumption has not played a sufficiently enabling role in helping Indians lead productive lives. This is reinforced by the following:

1. About one-third of India's population (40 crore, well over the population of US) lack access to electricity[23]. More than two-thirds (80 crore, comparable to all of Europe) lack access to clean cooking fuels (Census, 2011a). This situation persists though it is more than 65 years since India achieved independence, about 30 years since India began its first 'clean cook stoves' program (Sinha, 2002), and 2 years beyond the deadline of 2012 for universal electricity access as promised in 2005 (MoP, 2005).

2. These low levels of access are reflected in poor scores not just on access indicators, but also in the poor score on inequality in consumption of modern energy for cooking/heating. It also suggests that there is a huge unmet latent demand for energy services.

3. Modern energy has also not been adopted sufficiently in either agricultural or non-agricultural enterprises. As a result, it has not contributed sufficiently to productivity improvement in these crucial sectors. This is in contrast to somewhat better scores of modern energy usage in households (particularly on appliance ownership) and communities.

While the scores on the demand dimension suggest that energy has not enabled people to lead productive lives, the scores on both social and environmental dimensions indicate that energy related projects have actually played a disabling role in people's lives as the ill-effects of energy generation, transmission and consumption have not been mitigated, as illustrated by the following:

1. Poor scores of 30 on air pollution (with 0 on RSPM concentration) and 0 on water pollution indicate abysmal enforcement of pollution norms and poor management of environmental pollution caused by energy sector activities. This is consistent with the findings of a study by Yale University which found that India ranked near the bottom (155 out of 178) in the 2014 Environmental Performance Index (EPI) (Hsu, Emerson, Johnson, Levy, Malik, Schwartz, Sherbinin, & Jaiteh, 2014).

2. India's score on providing compensatory R&R for those affected by energy projects is a modest 40, indicating that those displaced by energy projects often receive a raw deal. This is indicated by the poor score on provision of alternative livelihoods (26), abysmal score of 0 on providing access to health centres, and a modest score of 40 on providing access to drinking water for those displaced by energy projects.

This also perhaps explains why energy projects, particularly large ones, frequently face strong grass-roots resistance – as those affected by such projects seem to enjoy few of the benefits arising from such projects but suffer significantly in the bargain (Prayas Energy Group, 2012). One hopes that the recently enacted "The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013" will facilitate a change for the better in this aspect (MoRD, 2013).

9.2.2 Economic dimension – poor ability to manage financial impacts

India scores poorly (28) on managing the financial impacts of the energy sector. The poor score on the

23 In this context, the seemingly high score of 67 for access to electricity is deceptive.

impact of India's energy imports on its trade deficit is likely due to a combination of factors such as India's poor fossil-fuel resource base, inability to optimally exploit domestic resources (both conventional and renewable) and lack of sufficient attention to improving energy efficiency.

With regard to energy subsidies (where we use an international comparison), the only two nations among the G-20 group with greater subsidies as a share of their GDP than India are Russia and Saudi Arabia, both energy-rich nations. Therefore, there is a need to address this issue through better targeting of subsidies, improved management of domestic resources and improved efficiency of energy use.

9.2.3 Other weaknesses

India scores poorly on domestic resource sustainability, though in this respect India is perhaps not very different from other countries which are also heavily dependent (as of now) on non-renewable fossil fuels for energy. In India's case, sustainable domestic resources are of two types: renewable sources used for power generation, and biomass, currently used mainly for household purposes. The latter – by far the larger part of sustainable resources used – has ill effects such as indoor air pollution and associated health impacts due to the way it is used. While it is heartening that over the years, the share of biomass for household use has gradually reduced and the share of renewable sources for power generation has increased, there is clearly a long way to go on this aspect (CEA, 2012a; GoI, 2006, p. 52; MoSPI, 2012, p. 67).

A major difficulty during the calculation of the index scores was the sheer paucity or difficulty of obtaining some important data, particularly for indicators related to the socio-environmental dimensions. Data about pollution, displacement and aspects of compensatory R&R are either completely non-existent, difficult to obtain or patchily available. Data about displacement and compensatory R&R does not seem to be collected systematically at all. Data regarding pollution is expected to be collected and submitted to State pollution control boards according to Section 14 of Environment (Protection) Rules, 1986 (MoEF, 1986), but this data was still difficult to get. It was also not easy to obtain data related to the positive impacts of the modern energy use on communities, as it does not seem be collected regularly. This aspect needs to be looked at and improved, if objective assessments of the energy sector are to be done. As described in Section 7.2, our computation of the index has tried to use the best available data.

9.3 Strengths of India's energy sector: a deeper look

Two indicators where India genuinely appears to be doing quite well are on diversifying energy imports[24] and conversion and delivery efficiency. In fact, India's score of 67 on conversion and delivery efficiency is not far behind the US (73%), which is the best performing among the G-20 nations. However, a deeper analysis shows that there may be hidden concerns in other areas where India scores well in the assessment.

The only indicator on which India scores a perfect 100 is related to per-capita GHG emissions from energy, as its per-capita GHG emissions are lower than other G-20 nations. India's per-capita GHG emissions from the energy sector in 2009 were 1.43 tCO_2-eq/capita (tonnes of carbon dioxide-equivalent per capita) compared to a range of 1.91 to 19.32 tCO_2-eq /capita for G-20 nations (WRI, 2013). However, this is essentially because of India's very low per-capita energy consumption: India's per-capita annual primary commercial energy consumption was only 470 kgoe in 2010, compared to an average of 2332 kgoe for the G-20 nations (U.S. DoE, 2013). As can be inferred from Figure 1, such low per-capita energy consumption correlates with poor development levels and needs to increase if India has to develop further. India's low per-capita consumption of modern energy also probably contributes to the good scores for primary energy intensity and energy import exposure.

The score for human development levels in the immediate vicinity of energy projects is a reasonably good 73. However, a deeper analysis reveals some concerns here too. Firstly, given that average human development levels of India are not high[25] and the score of 73 roughly implies that development in the vicinity of energy projects is about 73% of Indian development levels, it does not indicate a high quality

24 Note that we consider all Organization of Petroleum Exporting Countries (OPEC) as different in our calculation though some consider them as one block (Gupta, 2008).

25 India's HDI is 0.554 and it ranks 136 out of 186 nations as per United Nations Human Development Report 2013 (United Nations, 2013, p. 146).

of life. Moreover, given the problems with compensatory R&R discussed above, it is very likely that this score is because the worst affected due to such energy projects had migrated elsewhere in search of better lives while those who in-migrated (officials and those working in these projects) were likely to be more educated and have access to a better quality of life – without which they are unlikely to have voluntarily migrated there.

The high scores attained on target achievement indicators (production and generation) can also be misleading. The score represents the percentage of the target that was achieved, as this was the simplest objective measure possible. Given this measure, though a performance of achieving (say) only 50% of the target should be considered extremely poor and probably derail the economy, it would still receive an average score of 50. The attained scores of 80-85% suggest either an exaggerated expectation in setting the original plan target (thereby indicating poor planning) or a poor performance in achieving these targets[26].

India scores well (73) on net energy import exposure but this also needs to be treated with caution. This is because, though India scores well on this indicator it scores poorly (39) on the related indicator of the financial impacts of such imports. Moreover, our energy sector assessment index presents a snapshot of the energy sector at one point of time, and indicators with seemingly good scores may actually show a negative trend over time. This is true of net energy import exposure as India's energy imports have been steadily growing leading to concerns about increasing trade deficits (CCO, 2012, p. 7.5; MoF, 2013, p. A–77; MoPNG, 2013, p. 10), and they are projected to increase further in the 12th five year plan (GoI, 2012, pp. 165–166, 175).

That energy import exposure could become a serious concern in the future is also indicated by the India Energy Security Scenarios (IESS) 2047 tool (GoI, 2014), which suggests that India's energy import exposure would be as high as 31% in 2047 in the 'Best Possible Energy Security Pathway for Determined Effort'; even in the most energy-secure pathway ('Maximum Energy Security Pathway') which requires 'heroic efforts', India would be required to import more energy in 2047 than its entire energy consumption in 2011-12. Therefore, this is an issue that India needs to pay serious attention to, in the coming years.

This also highlights the importance of periodically assessing the country's energy sector by applying this index to help identify such trends early so that corrective actions can be taken. However, it should be noted that such periodic assessments are extremely difficult to do with the current levels of data availability and frequencies of data collection. In the absence of such data, proxies and/or interpolations or extrapolations would have to be used to estimate values for some indicators. This further highlights the importance of robust and frequent data collection and publication mechanisms, to support an objective assessment of the country's energy sector.

26 In addition, some part of the targets achieved may be because projects previously delayed have now have been commissioned!

10 Concluding remarks

We propose a comprehensive index to assess India's energy sector which goes beyond just looking at the supply dimension and also looks at demand, social, environmental and economic dimensions. We believe such an index is essential to holistically understand the energy sector and its impacts on society and environment, and inform policies and interventions which can be directed at those aspects that need most attention. Such a framework should be periodically applied to assess the country's energy sector as it can help to identify negative trends early and trigger policy discourse to address them.

As a first step, we have applied the framework to assess India's energy sector in 2011-12. This reveals many serious concerns:

1. The most glaring weaknesses relate to the demand and socio-economic dimensions of India's energy sector.

a. Too many Indians still do not have access to modern energy for cooking/heating or lighting even 65 years after independence. Modern energy is also not used by most rural farm or non-farm enterprises to enhance their productivity, indicating poor quality of supply and/or unaffordability of energy. There is also substantial inequality with regard to consumption of modern energy in households, particularly with respect to cooking or heating.

b. India is very poor in its environmental management regime with air and water pollution levels at many energy projects above the prescribed norms, particularly with regard to RSPM and TSS concentration levels.

c. Available data suggests a very poor record at providing alternative livelihoods to citizens displaced by energy projects, and a poor record of resettlement post-displacement, particularly with respect to access to water and health facilities. This combination of reasons perhaps explains the increasing resistance to energy projects in the country, as those affected by energy projects neither enjoy the benefits of such energy projects nor do they seem to be compensated or rehabilitated sufficiently.

2. India is also poor in managing the financial impacts of its energy sector, due to increasing energy imports and poorly managed subsidies. The effect of increasing imports is only likely to increase unless serious measures are taken (GoI, 2012, pp. 165–166, 175, 2014).

3. Finally, there are serious shortcomings in data availability, particularly with respect to demand and socio-environmental aspects of energy. Such lack of data makes it difficult to objectively assess the sector's strengths and weaknesses[27], and therefore indicates a serious shortcoming.

Current discourse suggests that the issues needing most attention in the Indian energy sector are energy pricing, which is said to discourage investments, and highly cumbersome processes for statutory clearances (Jagran, 2014; PTI, 2013). While these issues may indeed deserve attention, they focus only on the supply side. Our comprehensive and multi-dimensional analysis shows that India actually fares relatively better on the supply dimension, while it faces its greatest challenges on the demand and socio-environmental dimensions – on which there is little attention. Perhaps the key finding of this assessment is that these demand and socio-environmental issues need as much or more attention compared to supply side issues.

Finally, while this index has been developed with the Indian context in mind, it could perhaps also be used in other developing countries with some adaptation, as they are likely to face similar challenges.

27 Our assessment is based on 'best guess' estimates for some indicators as indicated in Section 7.2.

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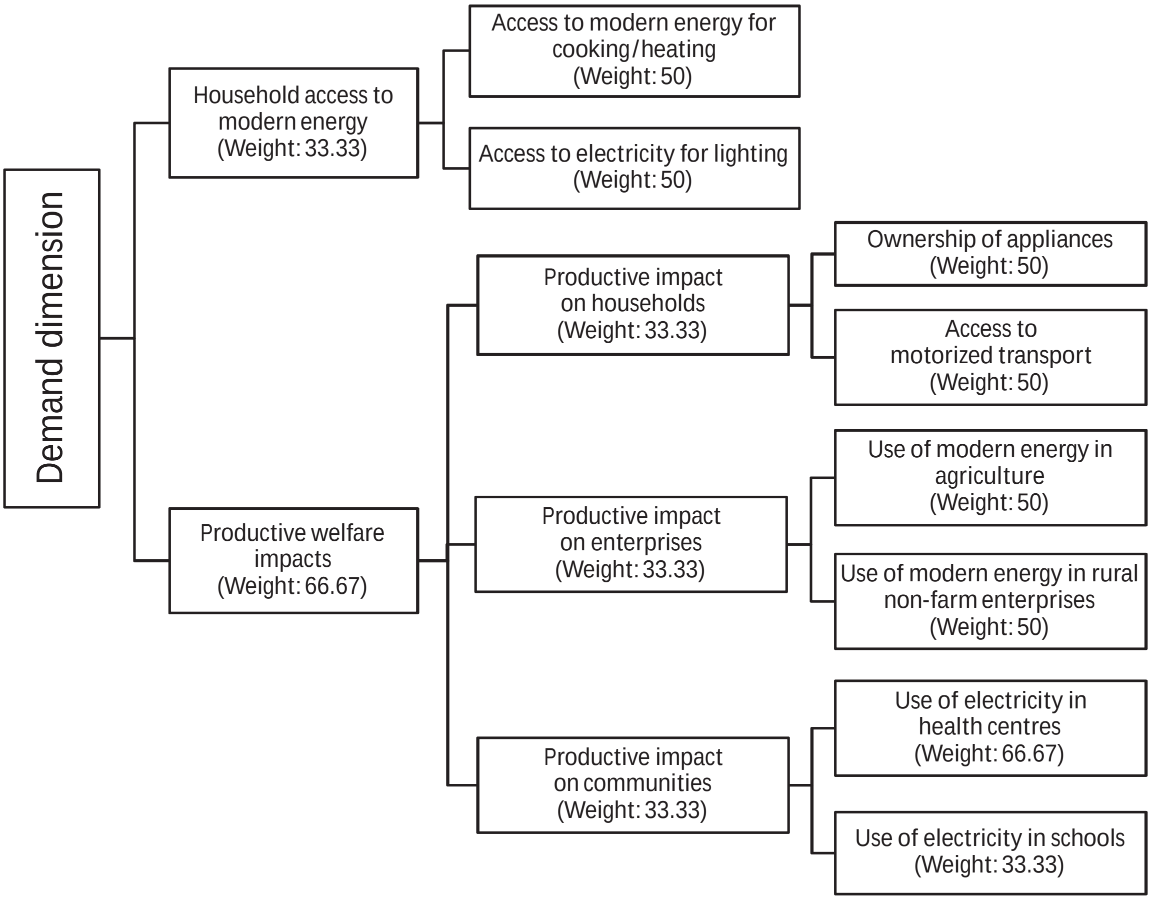
12 Appendix I: Energy Sector Assessment Index Hierarchy

The following diagrams present the entire energy sector assessment index hierarchy, and also indicate the weights assigned to each element. The final indicators, to which values and scores are assigned, are indicated in bold.

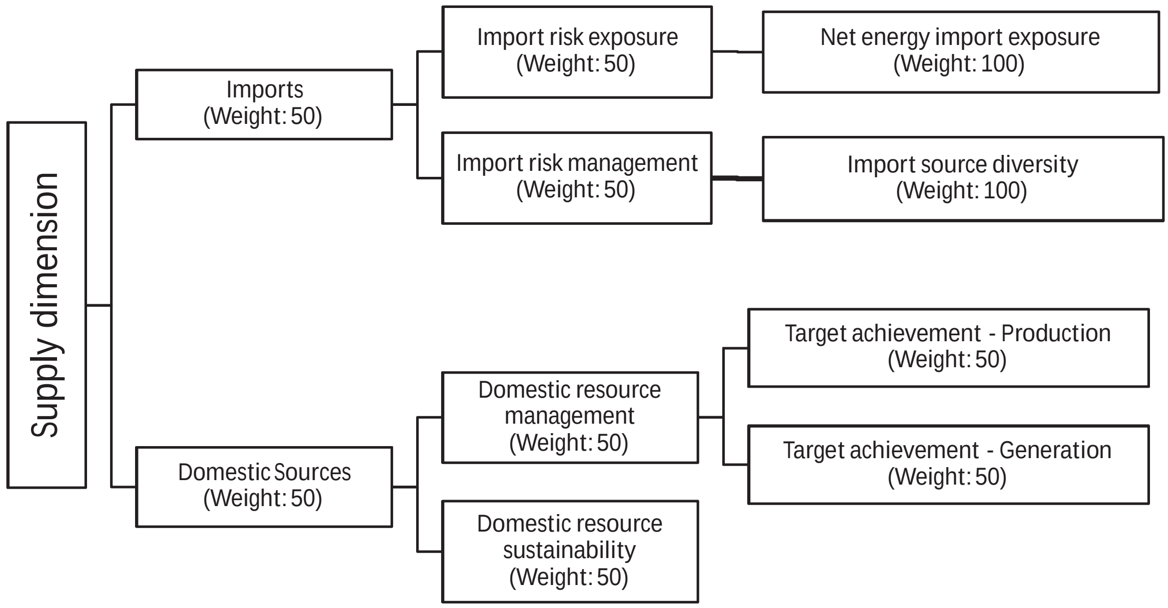
Some of the indicators shown here had to be changed when the index value was computed for 2011-12. These changes are also listed in the following sections, and justifications for these changes are given in Section 7.2.

12.1 Demand dimension

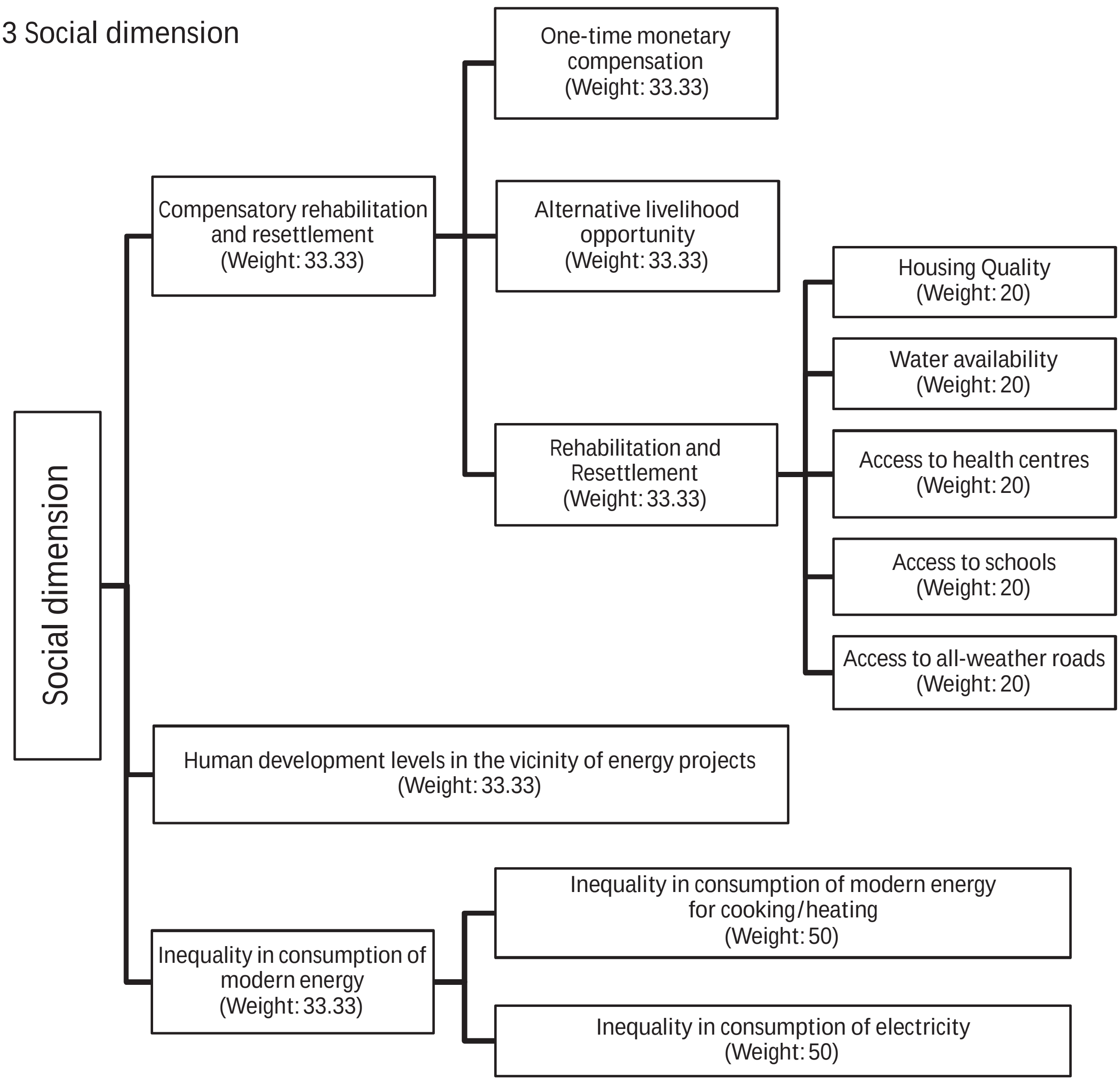


Proposed indicator	Changed indicator
Access to motorized transport (public or private)	Access to private motorized transport (ownership of two-wheelers or four-wheelers) used as a proxy
Use of modern energy in agriculture (Land area of marginal/small farms irrigated using modern energy sources)	Number of pumps using diesel/electricity per marginal/small farm that is un-irrigated or irrigated by wells/tube-wells, extrapolated from three previous Agricultural Census
Use of modern energy in rural non-farm enterprises	Extrapolated from previous two economic census of 1998-99 and 2004-05
Use of electricity in health centres (regular power supply)	Data from DLHS III of 2007-08 is used as a proxy
Use of electricity in schools (regular power supply)	Percentage of schools having electricity connection

12.2 Supply dimension

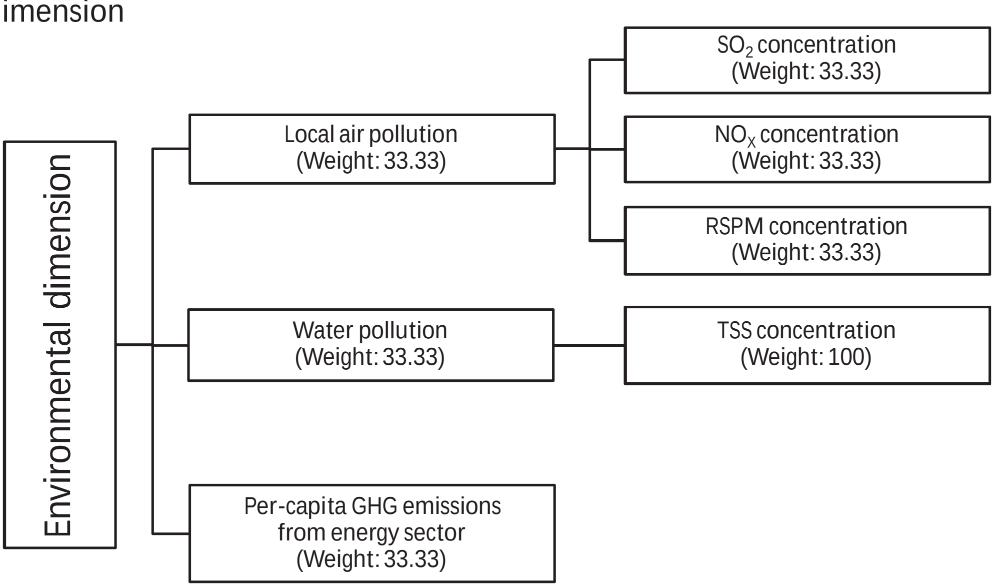


12.3 Social dimension



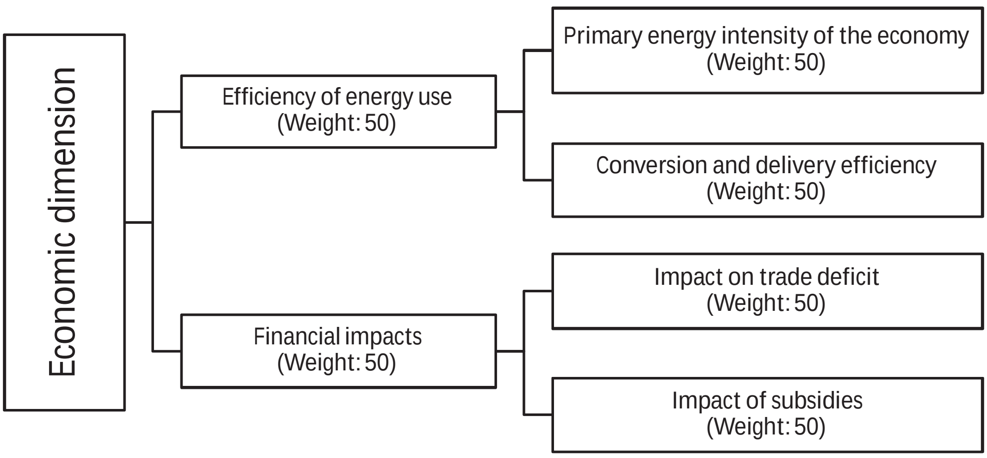
Proposed indicator	Changed indicator
Monetary one-time compensation	Dropped and weights adjusted
Alternative livelihood opportunity	Data from two energy projects - Singrauli and Indira Sagar - considered and averaged
Rehabilitation and resettlement	Data from one project (Indira Sagar) used
Human development levels in the vicinity of energy projects	Alternative indicators used – see Section 7.2 and appendix V for details
Inequality in consumption of modern energy for cooking/heating	Consumption of LPG used as a proxy

12.4 Environmental dimension

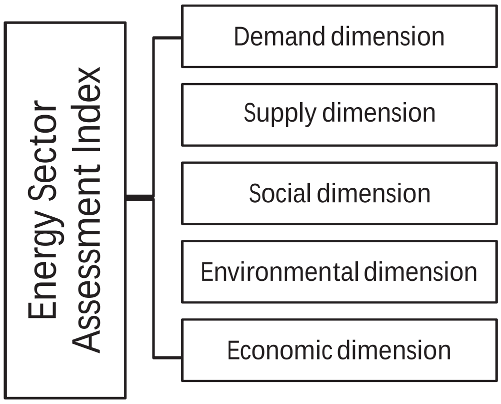


Proposed indicator	Changed indicator
Per-capita GHG emissions from the energy sector	Based on values for 2005-2009

12.5 Economic dimension



12.6 Energy sector assessment index



13 Appendix II: Calculation and normalization of indicator values

The calculation of values for each indicator in the energy sector assessment index and normalization of that value to a score in the 0-100 scale is described below.

13.1 Demand dimension

Indicator	Value	Normalization
Access to modern energy for cooking/heating	% of households using LPG/PNG/ electricity/biogas for cooking/heating	Score is same as the share, scaled up to 100.
Access to electricity for lighting	% of households using electricity as primary source of lighting	Score is same as the share, scaled up to 100.
Ownership of appliances	% of households with at least one television or refrigerator or both	Score is same as the share, scaled up to 100.
Access to motorized transport	% of households having access to motorized transport (public – bus/rail and private – two-wheeler or four-wheeler)	Score is same as the share, scaled up to 100.
Use of modern energy in agriculture	% of total area under small and marginal farms irrigated using diesel or electricity	Score is same as the share, scaled up to 100.
Use of modern energy in rural non-farm enterprises	% of rural non-farm enterprises using diesel or electricity	Score is same as the share, scaled up to 100.
Use of electricity in health centres	% of primary health centres (PHCs) having access to regular power supply	Score is same as the share, scaled up to 100.
Use of electricity in schools	% of schools having access to regular power supply	Score is same as the share, scaled up to 100.

13.2 Supply dimension

Indicator	Value	Normalization
Net energy import exposure	Net energy imports as share (%) of net energy supply	Score is same as the share, scaled up to 100.
Import source diversity	HHI (Herfindahl-Hirschman index) for India's gross energy imports in terms of MTOE	HHI value of 1 is given a score of 0;HHI value of 0 is given a score of 100; intermediate values are scored linearly in between.
Target achievement – Production	Actual production of primary energy (coal, oil and gas) as % of target[28]	Score is same as the share, scaled up to 100.
Target achievement – Generation	Actual generation of electricity as % of target	Score is same as the share, scaled up to 100.
Domestic resource sustainability	Share (%) of renewables[29] in net primary energy supply	Score is same as the share, scaled up to 100.

28 Targets for both production and generation as set in Five Year Plan documents/Working Group reports.
29 Renewables include small hydro (less than 25 MW capacity), wind, solar and biomass.

13.3 Social dimension

Indicator	Value	Normalization
Monetary one-time compensation	% of households impacted by energy projects who have been provided one-time monetary compensation	Score is same as the share, scaled up to 100.
Alternative livelihood opportunity	% of households impacted by energy projects, who have been provided with at least one among the following three: a job, alternative land or annuity	Score is same as the share, scaled up to 100.
Housing Quality	% of households impacted by energy projects who have been provided with 'good houses'[30].	Score is same as the share, scaled up to 100.
Water Availability	% of households impacted by energy projects who have been provided houses having access to clean water within the premises	Score is same as the share, scaled up to 100.
Access to health centres	% of households impacted by energy projects who have access to primary health centres (PHCs) in their new settlements	Score is same as the share, scaled up to 100.
Access to schools	% of households impacted by energy projects who have been provided access to schools in their new settlements	Score is same as the share, scaled up to 100.
Access to all-weather roads	% of households impacted by energy projects who have been provided access to all-weather roads in their new settlements	Score is same as the share, scaled up to 100.
Human development levels in the vicinity of energy projects	Lowest ratio of non-deprivation (MPI subtracted from 1) at tehsil level to non-deprivation at the national level for a sample set of energy projects	A ratio of 1 or more is scored as 100 while a ratio of 0 is scored as 0, with linear scoring for ratios in between.
Inequality in consumption of modern energy for cooking/heating	Gini coefficient of household consumption of LPG/PNG/electricity/biogas for cooking/heating	The inverse of the Gini coefficient of consumption of clean fuels for cooking scaled to 100[31].
Inequality in consumption of electricity	Gini coefficient of household consumption of electricity	The inverse of the Gini coefficient of electricity consumption scaled to 100.

30 'Good houses' here refers to houses with roofs made from slate, stone, burnt brick, concrete or tiles (both man-made and machine-made)

31 Thus, perfect equality Gini score of 0 is scored as 100 and perfect inequality Gini score of 1 is scored as 0.

13.4 Environmental dimension

Indicator	Value	Normalization
SO_2 concentration	Highest ratio of ambient SO_2 concentration in the vicinity of a sample set of energy projects to permissible norms for that project	A ratio of 1 or more is scored 0, ratio of 0 is scored 100, and values in between are scored linearly.
NO_x concentration	Highest ratio of ambient NO_x concentration in the vicinity of a sample set of energy projects to permissible norms for that project	NO_x concentration is scored similar to SO_2 concentration.
RSPM concentration	Highest ratio of ambient RSPM concentration in the vicinity of a sample set of energy projects to permissible norms for that project	RSPM concentration is scored similar to SO_2 concentration.
TSS concentration	Highest ratio of TSS concentration in the water discharge of a sample set of energy projects to permissible norms for that project	TSS concentration is scored similar to SO_2 concentration.
Per-capita GHG Emissions from energy sector	Per-capita GHG emissions of Indian energy sector	Scored based on India's rank in comparison with major economies

13.5 Economic dimension

Indicator	Value	Normalization
Primary energy intensity of the economy	Ratio of net primary energy consumption to total GDP (US$ PPP)	Scored based on India's rank in comparison with major economies
Conversion and delivery efficiency	Final energy consumption as share (%) of net primary energy supply	Score is same as the share, scaled up to 100.
Impact on trade deficit	Net energy import costs as share (%) of trade deficit	Inverse of the value (i.e. 1 minus the value) scaled to 100
Impact of energy subsidies	Energy subsidies[32] as % of GDP	Scored based on India's rank in comparison with major economies

32 Energy subsidy is defined as the difference in actual and benchmark prices of fossil fuels and electricity as defined by (IMF 2013, p.7).

14 Appendix III: Values and scores of various indicators for 2011-12

This section lists the values and scores for all indicators when the index was computed for India for 2011-12. The indicators, values and scores listed here include any changes to the proposed methodology as described in Section 7.2 and Appendix I.

14.1 Demand dimension

Indicator	Value	Unit	Worst Value	Best Value	India's Score
Access to modern energy for cooking/ heating	29.06	%	0%	100%	29.06
Access to electricity for lighting	67.25	%	0%	100%	67.25
Ownership of appliances	59.20	%	0%	100%	59.20
Access to motorized transport	25.73	%	0%	100%	25.73
Use of modern energy in agriculture	0.2032	Pumps per farm holding	0	1	20.32
Use of modern energy in rural non-farm enterprises	27.38	%	0%	100%	27.38
Use of electricity in health centres	35.70	%	0%	100%	35.70
Use of electricity in schools	47.11	%	0%	100%	47.11

Data sources: (Census, 2011a; DAC, 2011; IIPS, 2010, p. 220; MoSPI, 2001, 2008, 2013; NUEPA, 2012, p. 67)

14.2 Supply dimension

Indicator	Value	Unit	Worst Value	Best Value	India's Score
Net energy import exposure	27.16	%	100%	0%	72.84
Import source diversity	0.07	-	1.00	0.00	93.16
Target achievement – Production	84.17	%	0%	100%	84.17
Target achievement – Generation	83.93	%	0%	100%	83.93
Domestic resource sustainability	26.40	%	0%	100%	26.40

Data sources: (CCO, 2012, p. 1.17; CEA, 2012a, 2012b; Dept. of Commerce, 2012; GoI, 2012, p. 137; MoC, 2011, p. 20; MoPNG, 2006, p. 82, 2013, p. 10; MoSPI, 2012, p. 61)

14.3 Social dimension

Indicator	Value	Unit	Worst Value	Best Value	India's Score
Alternative livelihood opportunity	25.99	%	0%	100%	25.99
Housing Quality	86.70	%	0%	100%	86.70
Water Availability	40	%	0%	100%	40
Access to health centres	0	%	0%	100%	0
Access to schools	86.67	%	0%	100%	86.67
Human development levels in the vicinity of energy projects	72.60 (Singrauli)	-	0	100	72.60
Inequality in consumption of modern energy for cooking/heating	0.663	-	1.00	0.00	33.70
Inequality in consumption of electricity	0.493	-	1.00	0.00	50.70

Data sources: (Census, 2011a; Desai et al., 2007; MoSPI, 2013; Sharma & Singh, 2009)

33 See Appendix V for details

14.4 Environmental dimension

Indicator	Value	Unit	Worst Value	Best Value	India's Score
SO_2 concentration	0.48 (Ghuggus)	-	1	0	51.67
NO_x concentration	0.63(Chandrapur)	-	1	0	37.50
RSPM concentration	2.66 (Chandrapur)	-	1	0	0
TSS concentration	6.26 (Jharia)	-	1	0	0
Per-capita GHG Emissions from energy sector	1.43	tCO_2-eq per capita	19.32 (Australia)	1.91 (Brazil)	100

Data sources: (MPCB, 2013; WRI, 2013),and responses to RTI applications– see Appendix V for more details

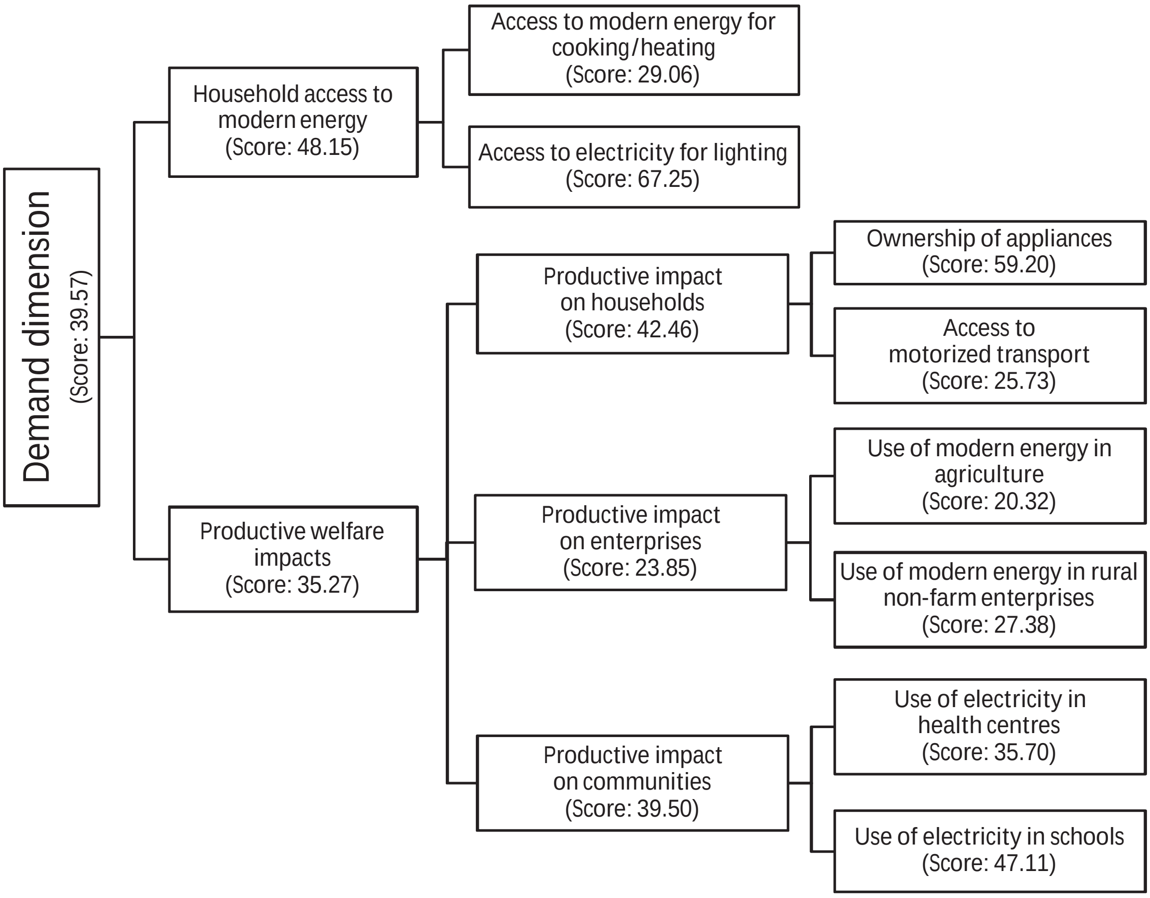
14.5 Economic dimension

Indicator	Value	Unit	Worst Value	Best Value	India's Score
Primary energy intensity of the economy	5860.36 (Ranked 9th)	BTU/ US$PPP	14543.83 (Russia)	4173.54 (United Kingdom)	55.56
Conversion and delivery efficiency	67.38	%	0%	100%	67.38
Impact on trade deficit	60.77	%	100%	0%	39.23
Impact of energy subsidies	4.46 (Ranked 16th)	%	16.71 % (Saudi Arabia)	0.17% (France)	16.67

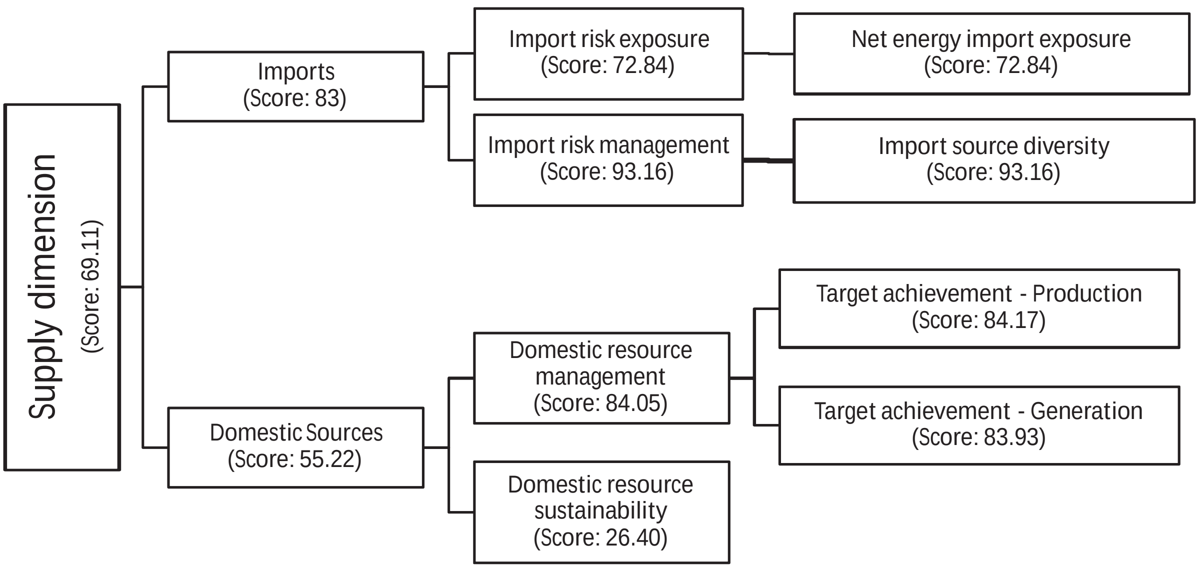
Data sources: (CCO, 2012, p. 4.37; CEA, 2012b; Dept. of Commerce, 2012; EC, 2013; IMF, 2013, pp. 57–61; MoF, 2013, p. A–76; MoPNG, 2013, p. 10; U.S. DoE, 2013)

15 Appendix IV: India's energy sector assessment scores for 2011-12

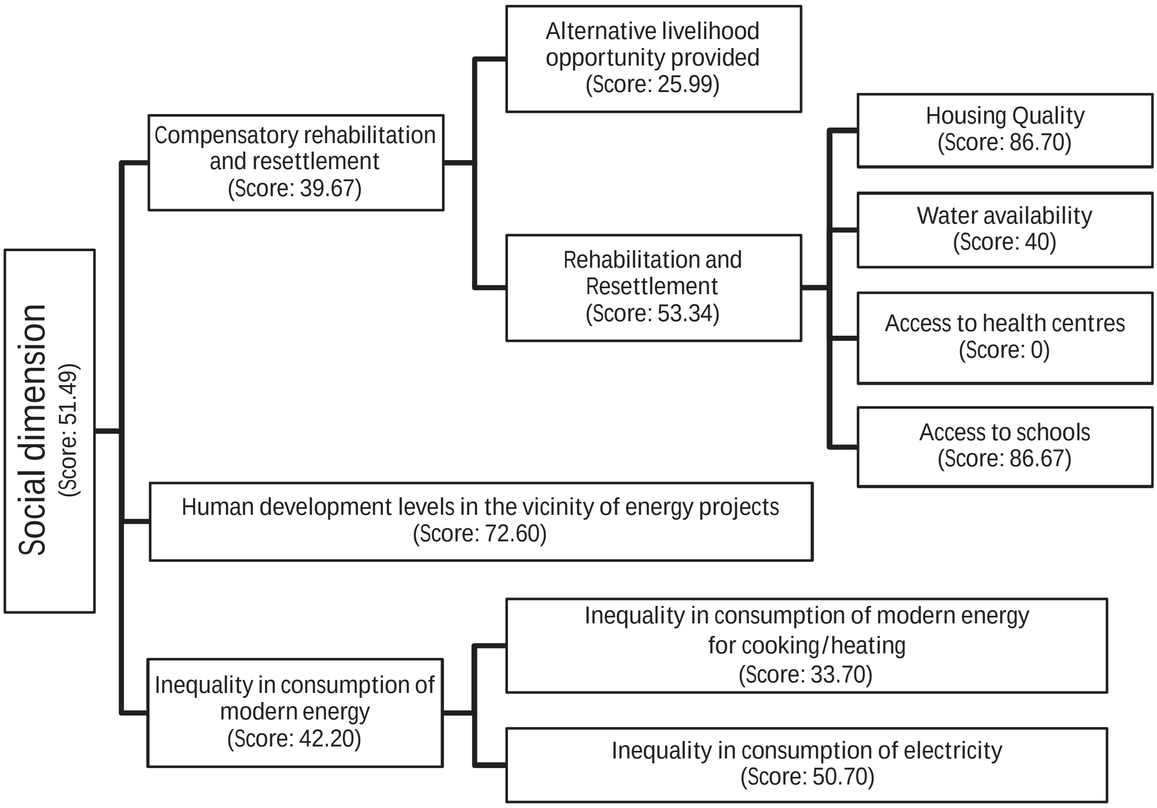
15.1 Demand dimension



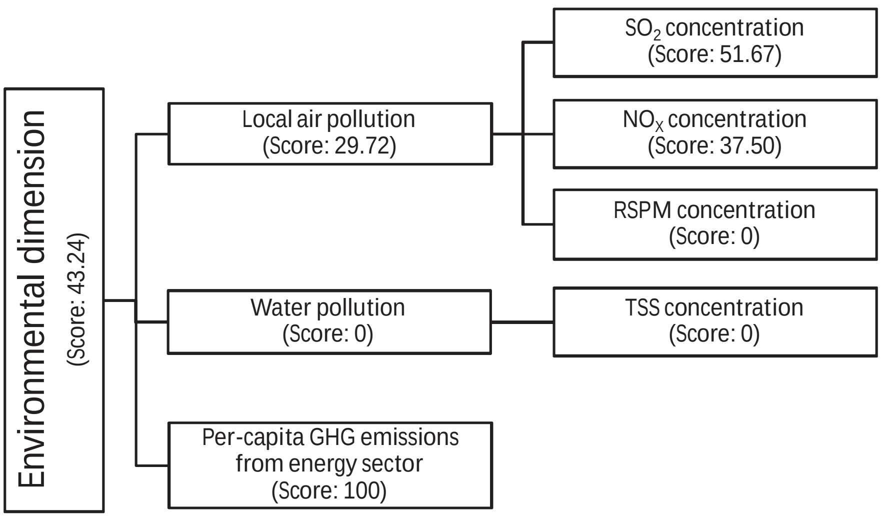
15.2 Supply dimension



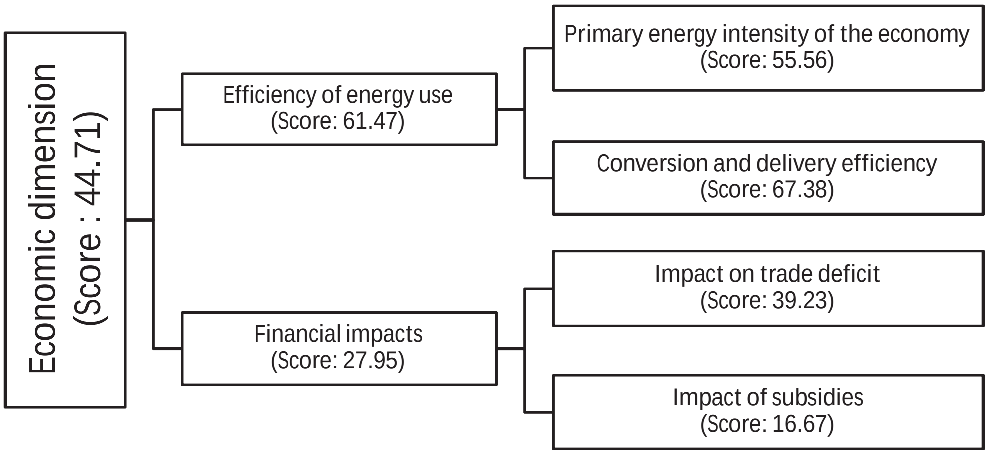
15.3 Social dimension



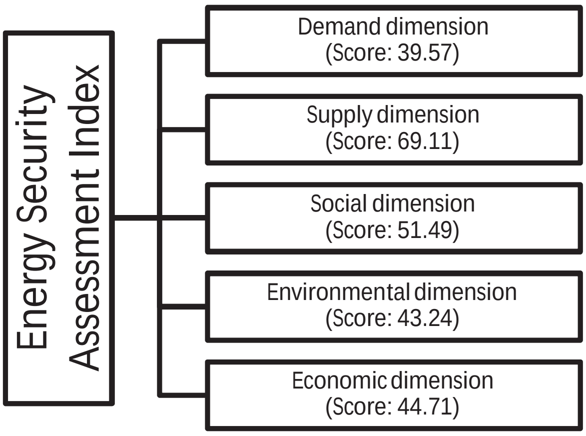
15.4 Environmental dimension



15.5 Economic dimension



15.6 Energy sector assessment index



16 Appendix V: Pollution and human development levels

16.1 Pollution

We looked only at thermal power plants (coal and gas-fired) and coal mines to score air and water pollution, since it is these projects which would cause the most pollution. We sought information from twenty-three projects through RTI applications. The applications sought air and water pollution levels near these plants at various times of the day over four days for each project.

16.1.1 List of projects we sought data from

The list of the 23 projects (along with their location: district and state) from which we sought data is as follows:

a) Coal-based power projects:

1) Chandrapur Super Thermal Power Station (MAHAGENCO), Chandrapur District, Maharashtra
2) Korba Super Thermal Power Station (NTPC), Korba District, Chhattisgarh
3) Mundra Thermal Power Station (Adani Power), Kutchh District, Gujarat
4) Raichur Thermal Power Station (KPCL), Raichur District, Karnataka
5) Raigarh Thermal Power Station (Jindal), Raigarh District, Chhattisgarh
6) Jharsuguda Power Plant (Sterlite), Jharsuguda District, Odisha
7) Suratgarh Super Thermal Power Station (RVUNL), Sri Ganganagar District, Rajasthan
8) Talcher Super Thermal Power Station (NTPC Talcher Kaniha), Angul District, Odisha
9) Vindhyachal Thermal Power Station (NTPC), Singrauli District, Madhya Pradesh

b) Gas-based power projects:

1) Dadri Gas Power Plant (NTPC), Gautambudhnagar District, Uttar Pradesh
2) Dhoulpur CCPP (RVUNL), Dhoulpur District, Rajasthan
3) Kawas Thermal Power Station (NTPC), Surat District, Gujarat
4) Pragati – III CCPP (PPCL), Bawana, Delhi
5) Ratnagiri Gas Power Plant (RGPPL), Ratnagiri District, Maharashtra

c) Coalfields:

1) Godavari Valley Coalfield (SCCL), Andhra Pradesh
2) Mand-Raigarh Coalfield (SECL), Chhattisgarh
3) Tatapani-Ramkola Coalfield (SECL), Chhattisgarh
4) Raniganj Coalfield (BCCL), Jharkhand
5) Jharia Coalfield (BCCL), Jharkhand
6) Ib Valley Coalfield (MCL), Odisha
7) Talcher Coalfield (MCL), Odisha
8) Raniganj Coalfield (ECL), West Bengal
9) Birbhum Coalfield (ECL), West Bengal

16.1.2 List of projects from which we obtained data:

The following is the list of projects from which we obtained useful data[34]:

a) Coal-based power projects:

1) Chandrapur Super Thermal Power Station (MAHAGENCO), Chandrapur District, Maharashtra
2) Korba Super Thermal Power Station (NTPC), Korba District, Chhattisgarh
3) Vindhyachal Thermal Power Station (NTPC), Singrauli District, Madhya Pradesh
4) Raichur Thermal Power Station (KPCL), Raichur District, Karnataka
5) Talcher Super Thermal Power Station (NTPC Talcher Kaniha), Angul District, Odisha

b) Gas-based power projects:

1) Ratnagiri Gas Power Plant (RGPPL), Ratnagiri District, Maharashtra
2) Dadri Gas Power Plant (NTPC), Gautambudhnagar District, Uttar Pradesh
3) Pragati - III CCPP (PPCL), Bawana, Delhi

c) Coal Mines:

1) Godavari Coalfield (SCCL), Andhra Pradesh
2) Jharia Coalfield (BCCL), Jharkhand

We did not get any useful information from the other projects.

16.1.3 Air and Water Pollution values

The table below gives the worst values of the air and water pollution indicators for the above-mentioned projects, obtained through RTI applications filed with the respective State Pollution Control Boards or power producing companies regarding data for coal-based/gas-based power projects.

Project Name	SO_2 emissions ($\mu g/m^3$)	NO_x emissions ($\mu g/m^3$)	RSPM ($\mu g/m^3$)	TSS (mg/l)
Ratnagiri	37.45	21.41	78.98	37.39
Dadri	15.00	14.00	107.00	63.65
Pragati Gas	4.90	33.10	0.00	36.00
Chandrapur	32.00	50.00	266.00	N.A.
Korba	12.90	20.30	91.00	N.A.
Vindhyachal	23.30	26.60	115.90	168.00
Raichur	6.00	8.00	80.00	206.00
NTPC Talcher	21.70	32.05	54.00	78.00
Norms	80.00	80.00	100.00	100.00

In addition, we also took data on ambient air quality from the Ghuggus air monitoring station of Maharashtra Pollution Control Board, located in Chandrapur District, Maharashtra, which has coal fields and power plants nearby. The table below provides the worst performance of the above-mentioned coalfields and of the Ghuggus monitoring station on the air and water pollution indicators based on responses to RTI applications filed with the respective State Pollution Control Boards (SPCBs) for coal mines, and the website of Maharashtra Pollution Control Board for Ghuggus.

34 SPCBs were willing to share data for Mundra thermal power station, Dhoulpur CCPP and NTPC Kawas power station, but required some payment for copying and providing the information. We did not pursue them for lack of time. The Tatapani-Ramkola coalfield was not functional when we sought information.

Project Name	SO_2 emissions (µg/m^3)	NO_x emissions (µg/m^3)	RSPM (µg/m^3)	TSS (mg/l)
Godavari coalfield	17.00	23.00	318.00	56.00
Norms for Godavari coalfield	120.00	120.00	300.00	100.00
Jharia coalfield	31.80	36.10	493.05	626
Norms for Jharia coalfield	120.00	120.00	250.00	100.00
Maharashtra Pollution Control Board (Ghuggus)	58.00	66.00	410.00	N.A.
Norms	120.00	120.00	250.00	N.A.

The norms for air and water pollution are as given under the Environment Protection Act (1986 and subsequent amendments) for these indicators in the vicinity of energy projects, and also given on the website of Central Pollution Control Board[35].

As per the ratios, the worst project for each of the four indicators considered by us, along with the ratio, is as follows:

- SO_2 concentration: Ghuggus, with a ratio of 0.48.
- NO_x concentration: Chandrapur Super Thermal Power Station, with a ratio of 0.63.
- RSPM concentration: Chandrapur Super Thermal Power Station, with a ratio of 2.66.
- TSS concentration: Jharia coalfields, with a ratio of 6.26.

16.2 Human development levels in vicinity of energy projects

For measuring human development levels, we chose the following set of energy projects to approximately represent the various sources of energy in the country:

1. Godavari coalfield, located in Ramagundam Tehsil of Karimnagar District, Andhra Pradesh
2. Sardar Sarovar dam project (hydro-electric project) located in Nandod Tehsil of Narmada District, Gujarat
3. Raichur Thermal Power Station (coal-power plant), located in Raichur Tehsil of Raichur District, Karnataka
4. Vindhyachal Thermal Power Station (coal-power plant) and Northern Coalfields Limited (coal mining), located in Singrauli Tehsil of Singrauli District, Madhya Pradesh
5. Tarapur Atomic Power Station (nuclear power plant) located in Polsar Tehsil of Thane District, Maharashtra
6. NTPC Kaniha Plant (coal-fired plant) and Mahanadi Coalfields Limited (MCL) (coal mining), located in Kaniha and Talcher Tehsils, Angul District, Odisha
7. NTPC Dadri Plant (gas-fired plant) located in Dadri Tehsil, Gautambudhnagar District, Uttar Pradesh

35 Obtained from http://cpcb.nic.in/Industry_Specific_Standards.php

The table below gives the values of different indicators near the above-mentioned energy projects as well as for all of India.

Parameter	Ramagundam	Nandod	Raichur	Singrauli	Polsar	Kaniha + Talcher	Dadri	India
Housing Quality	40.37%	64.53%	49.62%	75.02%	50.58%	53.55%	89.53%	66.90%
Water Availability	65.99%	46.63%	32.55%	31.35%	57.84%	30.39%	86.83%	46.60%
Usage of electricity for lighting	96.07%	87.09%	92.41%	41.21%	83.19%	62.64%	90.00%	67.30%
Access to in-house sanitation	75.14%	32.23%	33.88%	21.73%	60.65%	27.56%	85.64%	46.90%
Usage of modern cooking fuels	61.83%	22.46%	25.48%	19.82%	54.52%	14.16%	73.45%	28.70%
Ownership of television	81.38%	45.70%	69.27%	46.35%	70.24%	46.06%	90.23%	63.20%
Ownership of landline / mobile phone	74.97%	40.01%	56.26%	26.24%	55.63%	37.62%	78.32%	47.20%
Ownership of personal motorized transport	33.45%	23.50%	27.02%	22.98%	22.80%	28.24%	39.62%	21.00%
Availing Banking services	67.10%	51.28%	49.16%	51.50%	62.01%	55.87%	75.61%	58.70%

This results in the following scores on human development levels:

Parameter	Ramagundam	Nandod	Raichur	Singrauli	Polsar	Kaniha + Talcher	Dadri
Housing quality	60.34	96.46	74.16	100.00	75.61	80.05	100.00
Water availability	100.00	100.00	69.84	67.26	100.00	65.22	100.00
Lighting	100.00	100.00	100.00	61.24	100.00	93.08	100.00
Sanitation	100.00	68.73	72.23	46.33	100.00	58.76	100.00
Cooking	100.00	78.26	88.78	69.07	100.00	49.34	100.00
Electric appliances	100.00	78.53	100.00	64.46	100.00	76.28	100.00
Telephone/mobile phone	100.00	72.31	100.00	73.33	100.00	72.87	100.00
Television	100.00	84.76	100.00	55.59	100.00	79.69	100.00
Transport ownership	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Availing banking services	100.00	87.35	83.75	87.73	100.00	95.18	100.00
Weighted average score	94.05	88.67	84.40	72.60	96.34	74.59	100.00

Based on the above scores, it can be seen that the worst performer with regard to human development levels in the vicinity of energy projects is Singrauli, with a score of 72.60.

Table of Abbreviations

AHP	Analytical Hierarchy Process
CEA	Central Electricity Authority
CCO	Coal Controllers' Organization
DI	Displaced Ideal
EAPI	Energy Architecture Performance Index
EPI	Environmental Performance Index
GHG	Greenhouse Gas
GDP	Gross Domestic Product
HHI	Herfindahl-Hirschman Index
HDI	Human Development Index
IESS	India Energy Security Scenarios
IEP	Integrated Energy Policy
IMF	International Monetary Fund
LPG	Liquefied Petroleum Gas
MoSPI	Ministry of Statistics and Programme Implementation
MPI	Multi-dimensional Poverty Index
NSSO	National Sample Survey Organization
OPEC	Organization of Petroleum Exporting Countries
PNG	Piped Natural Gas
PPEO	Poor People's Energy Outlook
R&R	Rehabilitation and Resettlement
RSPM	Respirable Suspended Particulate Matter
RTI	Right to Information
SPCB	State Pollution Control Board
TSS	Total Suspended Solids
WEF	World Economic Forum

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3 Role Of Thermal Power Plants And Coal Mining In Local Area Development And Addressing Regional Imbalance: Conditions And Processes

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http://prayaspune.org/peg/publications/item/74.html

Energy is a key input for the socio-economic development of a country, particularly for countries like India. Hence, it is important to holistically and objectively understand and assess the country's energy sector, so that policies and interventions can be appropriately prioritized to further the country's development. This report develops a comprehensive energy sector assessment index for such an assessment of India's energy sector, by considering not only energy demand and supply but also the relationship and impacts of the energy sector on society, environment and the economy. The index should be periodically computed to understand the energy sector and trends within it. As a beginning, this report presents the energy sector assessment index for India for 2011-12. This assessment throws up some interesting insights.

Popular discourse suggests that the most pressing problems faced by India's energy sector are an inability to attract investments due to the pricing and subsidy structure, delays in granting clearances and the financial implications of increasing energy imports. While these may indeed be issues of concern, they only focus on the supply side. In contrast, our analysis shows that the supply dimension is the strongest dimension of the Indian energy sector with a score of 69, while the demand dimension scores the worst with just 40. The environmental, economic and social dimensions also do not fare very well with scores of just 43, 45 and 51 respectively. This perhaps explains the increasing resistance to energy projects, as it seems citizens most affected by these projects more often than not face the negative impacts of energy projects but do not enjoy their benefits. Therefore, there is a great need to focus on the demand and socio-environmental side of the energy sector in addition to the commonly understood issues listed above, if energy is to truly act as an input to human development.

प्रयास

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