Energy Access: Country Perspectives

Ashish Gupta, Associate Fellow, Observer Research Foundation, India

Akhilesh Sati, Programme Manager, Observer Research Foundation, India

Louise Scholtz, Manager, Special Projects, Living Planet Unit, WWF, South Africa

Igor Makarov, Associate Professor, National Research University - Higher School of Economics, Russia

Zhongyi Yin, SRF & Executive VP, China Institute of Reform & Development, China

Introduction

The global discourse on universal energy access became part of the mainstream development agenda only about a decade ago. The beginning was probably made when world leaders adopted eight millennium development goals (MDGs) at the United Nations (UN) headquarters in New York in 2000.[1] Though universal access to energy was not among the eight goals chosen, it is reasonable to assume that there was implicit understanding that without universal access to modern energy services it would not be possible to achieve most of the MDGs. A 2005 report by the UN observed that lack of access to modern energy would limit ability to achieve the MDGs.[2]

The 12th International Energy Forum (IEF) Ministerial in Cancun in 2010 called for the international community to set up a ninth goal, specifically related to energy to consolidate the evident link between modern energy services and development goals.[3] In its annual outlook report of 2010,[4] the International Energy Agency (IEA), the energy think tank of the Organisation for Economic Co-operation and Development (OECD) nations, expressed 'alarm' over the lack of access to modern lighting and cooking energy services for billions of people around the world.

This sense of alarm over lack of access to modern energy services led to a number of global initiatives to increase energy access. The UN declared 2012 as the international year of sustainable energy for all with the goal of achieving universal access to energy for all (SE4ALL) by 2030.[5] In 2013, a UN high-level panel of eminent persons recommended that universal access to modern energy services be included in the post-2015 development agenda.[6]

Despite these initiatives, the provision of universal access to energy remains a challenge. This paper aims to examine initiatives for universal energy access in four BRICS nations and identify country-specific challenges, with a view to promoting knowledge sharing among emerging and developing countries.

Global Energy Access Status

In 2010, there were about 1.4 billion people (20 percent of the global population) who lacked access to electricity and 2.7 billion people (40 percent of the global population) who lacked access to modern cooking fuels.[7] In 2013, the number of people without access to electricity had marginally come down to 18 percent of the global population and those without access to modern cooking fuels to 38 percent.[8] Though this is a sign of progress, the pace of progress is unlikely to deliver universal energy access by 2035.

Projections based on policies currently in place show that by 2035 sub-Saharan Africa and developing Asia, which currently account for over 95 percent of the global total of people without access to modern energy services, will continue to have a significant share of their populations without such access.[9] At present, India has the largest number of people without access to modern energy services in terms of absolute numbers, but the number in sub-Saharan Africa is expected to increase in future and the region is expected to overtake India on this parameter.

The provision of universal access to energy is expected to make only a small impact on global energy demand and consequently, will not contribute significantly to carbon emissions. The additional electricity demand for universal access is estimated to be about 120 mtoe which is just one percent of the total primary energy demand. For cooking, the additional demand in the form of bottled liquid petroleum gas (LPG) is expected to be about 0.82 mbpd which is about a hundredth of global oil demand. The additional carbon dioxide (CO_2) emission is expected to be less than 0.7 percent of total emissions.[10]

Energy Access in India

Surveys conducted by the Indian government reveal that over 300 million people or 25 percent of the population lacked access to electricity, and over 800 million or 66 percent of the population lacked access to modern cooking fuels in India in 2011.[11] These are striking figures when compared to levels of energy access in other BRICS nations which have achieved near universal electricity access. However, when compared to the energy access status in India about six decades ago, these figures convey significant progress.

India's Electrification Programmes since Independence

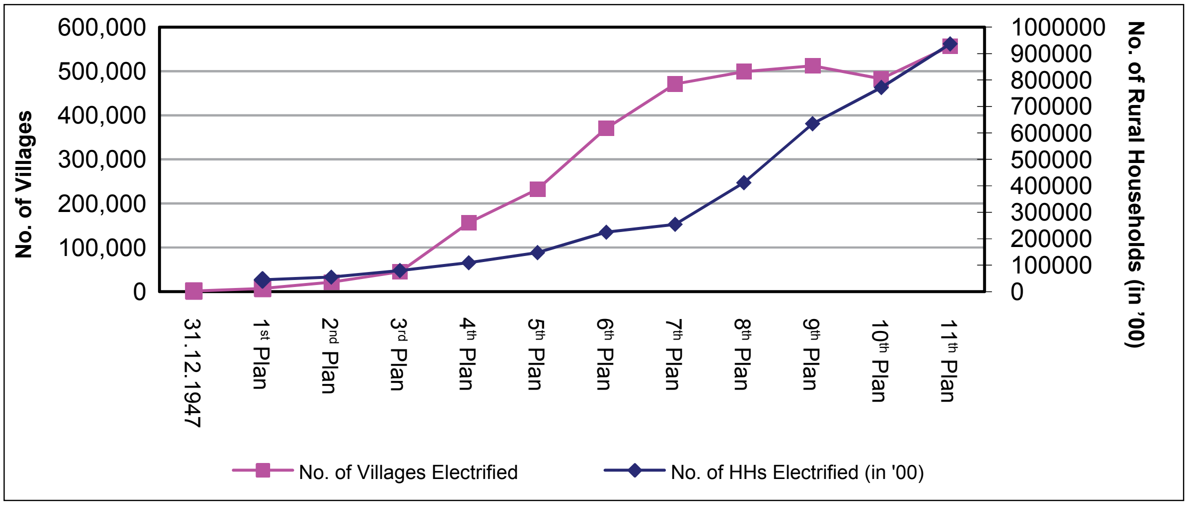
When India became independent in 1947, more than 90 percent of households lacked access to electricity. Increasing electricity supply was part of India's programme for nation-building. Between 1947 and 2011, electricity supply increased by over 20,000 percent and village electrification by 35,000 percent. However, household electrification increased only by 2,000 percent. This confirms one of Nobel Laureate Amartya Sen's key insights that increase in aggregate supply does not automatically translate into access at the individual level. Interventions are necessary to increase access. But even in this regard it is hard to find fault with the government's efforts.

India's 1st Plan document (1951-56) lamented that "only one in 200 villages was electrified and that just 3 percent of the population in six large towns consumed over 56 percent of the utility electricity." The 2nd Plan document (1956-61) had some concrete observations on how to improve access to electricity. It estimated that the cost of extending electricity supply to villages at INR 60,000-70,000 per village amounted to a total capital outlay of about INR 3,000 crore for complete electrification of villages. Towards this end, the Plan document earmarked a sum of INR 75 crore for electrification of small towns and villages. This was in addition to the sum of INR 20 crore allotted for expansion of power to small towns to facilitate employment generation in the first and second plan periods. The 3rd Plan (1961-66) observed that there was a 200 percent increase in the number of villages electrified and provided an allocation of INR 105 crore for rural electrification. Noting a 175 percent increase in village electrification and a 100 percent increase in energising irrigation pump sets in the preceding decade, the 4th Plan (1969-74) increased the outlay for rural electrification to over INR 400 crore.

Village electrification increased by over 200 percent in the 4th and 5th plan periods and most of the credit was given to the Minimum Needs Programme initiated in the 5th plan. The 6th Plan (1979-84) allocated INR 1,576 crore for rural electrification, which included INR 285 crore for Special Project Agriculture to be implemented by the Rural Energy Corporation (REC). The 7th plan (1984-89) introduced an Integrated Rural Energy Plan, which proposed that a basket of solutions such as rural electrification, use of petroleum products and fuel-wood, along with renewable energy sources, must be pursued towards the ultimate goal of 100 percent rural electrification. The diversification strategy based on the use of local resources and fuels reduced the allocation for rural electrification to about INR 47 crore (6.8 million euros) which was only three percent of the allocation in the previous plan period. Between the 4th and the 7th plan, rural electrification rates increased dramatically but faltered when the budget was reduced on account of the strategy of diversification of fuel sources (Figure 1).

The 8th (1992-97) and 9th (1997-02) plan outlays for rural electrification were INR 4,000 crore and INR 7,000 crore respectively. The 10th Plan (2002-07) was quite significant in terms of

Figure 1: Progress of Electrification Programmes, 1947-2012



Source: Authors' calculations from various documents of Planning Commission and Ministry of Power.

rural electrification, as it contained a detailed investigation of rural electrification programmes. It acknowledged that while 86 percent of villages in India were claimed to have been electrified, less than 30 percent of the households had electricity connections and that electricity had played no role in generating economic activity in the 'electrified' villages. The Plan document emphasised the need for revising the definition of electrification, which stated that "a village was deemed electrified if electricity was used in the inhabited locality within the revenue boundary of the village for any purpose whatsoever".

It also recommended coordination of multiple rural electrification and energy access programmes such as the Pradhan Mantri Gram Yojana, the Minimum Needs Programme for Rural Electrification, the MP Local Area Development Scheme, the Jawahar Gram Siddhi Yojana, the Kutir Jyoti Programme, Programmes of the Rural Electrification Corporation (REC) and decentralised Renewable Energy Programmes of the Ministry of New & Renewable Energy under the Integrated Rural Energy Programme with a plan outlay of about INR 178 crore (26 million euros). The document also mentioned an outlay of INR 1,600 crore (233 million euros) towards non-conventional energy sources but did not clarify whether this was for rural renewable energy sources.

The Rajiv Gandhi Grameen Vidyudikaran Yojana (RGGVY), a scheme launched in 2005 with the aim of providing universal access to electricity in five years, incorporated all the other schemes for rural electrification and was the primary thrust in the 11th Plan (2007-12). The basic provisions of the scheme were a 90 percent grant from the Central Government and 10 percent loan to the State Governments from the REC for provision of universal access to electricity as per the revised definition of electrification. The total cost of projects sanctioned under the RGGVY during the 10th and 11th Plans is estimated to be about INR 33,000 crore (4.8 billion euros). The cost estimate for the scheme during the 12th Plan is estimated to be about INR 50,000 crore (7.3 billion euros). It has been almost eight years since the RGGVY began but not all villages are yet electrified and not all households have access to electricity.

Challenges in India's Rural Electrification Programmes

The first challenge in India's publicly funded grid-based electrification programmes is that it is not economically sustainable. The programmes make ever-growing demands on dwindling public resources and raise little or no revenue. One of the reasons for the inadequacy of the RGGVY scheme is that it is entirely based on subsidies with no scope for raising revenue. No doubt, with an average rural household's consumption being less than 0.5 Kwh a day, and household density in villages being low, talk of raising revenue is meaningless. Even if there is enthusiasm for economic activity, the single phase connections provided under the RGGVY cannot facilitate any. And without economic activity there is little or no opportunity for raising revenue. The success of rural electrification programmes between 1970 and 1990 was primarily due to the fact that they energised pump sets that increased rural incomes through increased agricultural production, and consequently provided revenue returns for electricity distribution companies.

Second, there is the well-known challenge of cost, both in erecting infrastructure and in supplying electricity. This is not a challenge unique to India, but overall costs do appear to be relatively high in India. This is a significant challenge as there are many competing demands on India's scarce public resources which underwrite electrification programmes. Even in 1955, the cost of providing grid-based electricity to a village was as high as INR 60,000-70,000. The current estimate is as high as INR 1 million. This is much higher than the cost of electrification per village in Brazil, estimated at INR 200,000. As per the latest data (March 2013), there were about 33,180 villages in India yet to be electrified. At INR 1 million per village this works out to more than INR 33 billion (483 million euros).

When it comes to supplying electricity, the challenge is even bigger. Almost all of India's state-owned distribution companies have illiquid balance sheets; many continue to accumulate losses. The accumulated debt of power distribution companies is estimated at INR 179,000 crore (26 billion euros) without subsidies and INR 80,000 crore if subsidies are taken into account (11 billion euros). This is roughly one to two percent of India's GDP. These loss-making utilities have no incentive to supply electricity to rural households, especially when the cost of doing so is as high as INR 91/Kwh in some villages.[12] The average loss per unit of electricity supplied to rural areas in India is estimated at INR 3.9/Kwh; this is almost twice the average purchase cost of electricity.[13]

Even if these financial challenges are overcome, there are social challenges to be addressed if the goal of universal access to electricity is to be achieved. Studies have found that rich households appropriate most of the benefits of subsidised rural electrification programmes.[14] One study revealed that the lowest income groups derived no electrification benefits in terms of increases in household expenditure. In terms of income, the positive percentage impact was seen to be 46 percent for richer households compared to 26 percent for poorer households.[15] It has also been found that spatial segregation between upper and lower caste households in villages affects access to electricity. Upper caste settlements, which command social and economic power, corner electricity infrastructure and assets and restrict its access to lower caste settlements. In response the government has redefined an electrified village as one in which at least 10 percent of lower caste households are electrified.[16]

There are other problems that rural electrification schemes have not considered. For example, it is very likely that the pace at which people are moving towards electricity and economic activity (to towns or cities) is faster than that at which electricity and economic activity are moving towards people through these schemes. If this is true, physical infrastructure erected at huge cost in rural areas will become redundant.

The push for decentralised renewable energy solutions such as solar and biomass is generally seen as the answer to high-cost grid-based systems. Though this appears to be a perfectly rational option, especially in the light of carbon emissions and financial resource constraints, it has not been as successful as one would presume. There are some success stories of innovative business models, but very few have proved to be financially self-sustaining. Anecdotal evidence suggests that the rural poor prefer high quality grid-based electricity rather than complex and intermittent renewable electricity technologies that are thrust upon them.[17]

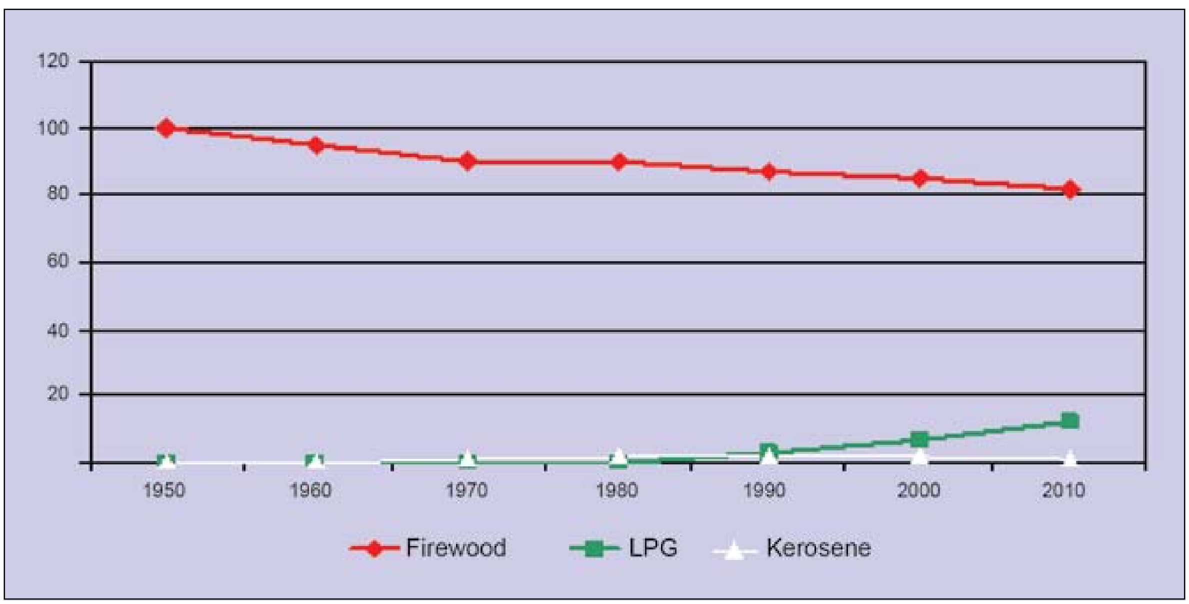
This suggests that energy choices of the rural poor are influenced by energy options available to the affluent urban population and not by arguments of economic rationality or environmental sustainability. As most of the increase in electricity access in developing Asia is attributed to grid-based solutions, there is a need to review energy access programmes based on renewable energy.[18]

Access to Modern Cooking Fuels

The concern over access to modern cooking fuels such as bottled LPG is less than three decades old. Until the late 1980s, most government reports on energy projected an increase in demand for firewood, which remained the primary fuel used for cooking even in urban households until the late 1970s.[19] Following the stabilisation of oil prices after the oil embargoes of the 1970s, kerosene stoves and bottled LPG were introduced in the market. Consequently, urban households rapidly shifted away from firewood use in their kitchens. Between 1970 and 2011 kerosene use increased by 150 percent and LPG use by 8,000 percent – albeit from a small base.

Despite this dramatic increase in the supply of petroleum-based fuels for cooking, more than 70 percent of households in India continued to use biomass (twigs, firewood and dried animal dung) as fuel for cooking even in 2011 (Figure 2). Biomass used for cooking accounts for over 26 percent of India's total primary energy consumption – which is

Figure 2: Progress in Use of Modern Cooking Fuels, 1947-2012



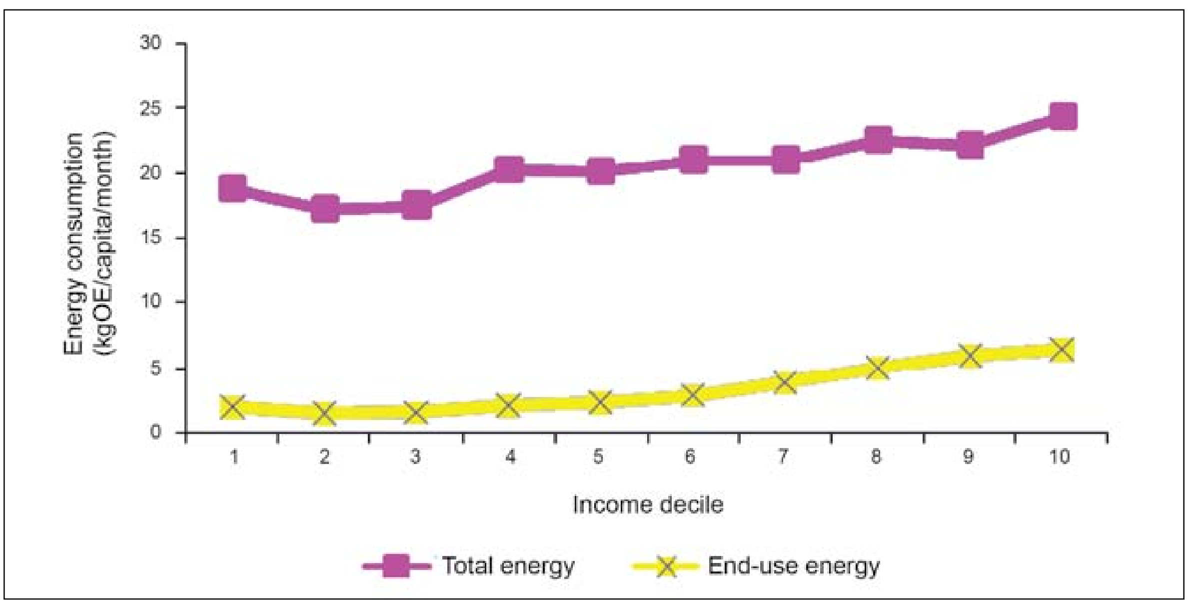
Source: Census of India reports

more than the India's consumption of oil at 24 percent. In energy equivalent terms, the energy supplied by firewood, twigs and animal dung in India at 135 mtoe is more than the entire energy consumption of Australia at 123 mtoe. What this piece of data conceals is the tragic fact that the energy spent by millions of women and children in collecting biomass to burn in their stoves is not counted or even acknowledged in India's energy balance sheet.

To obtain one unit of useful heat energy to cook a meal, millions of women and children, at the bottom of the income pyramid, have to collect and carry firewood and dung with six to seven units of energy because five units of energy is 'wasted' by the inefficient open cook stoves that they use (Figures 3 and 4). The next best use of their labour (the opportunity cost in economic terms) is almost 'nothing' because they are largely illiterate and have no special skills. This is a wealth-destroying system because the net energy gain (energy obtained for cooking minus the total energy content in biomass plus human energy spent collecting/processing biomass) is negative.

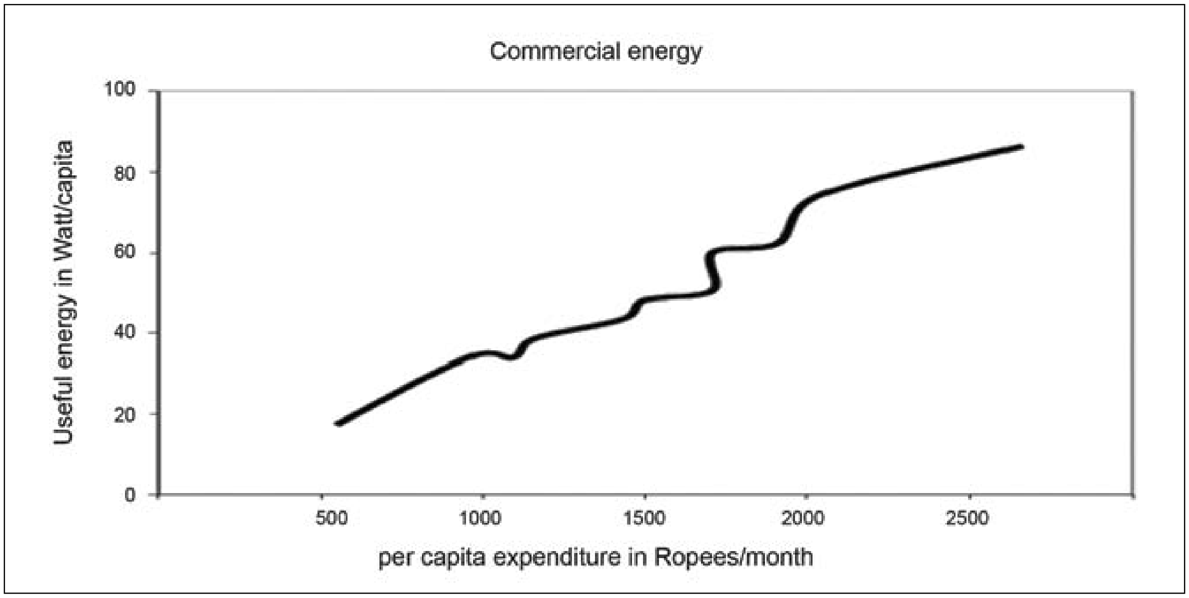
As illustrated in the charts above, rural households have to collect ('consume') more energy than their wealthier counterparts in urban areas because over 80 percent of total energy collected by rural households is dissipated or wasted. In other words, the effective cost of energy used in most of the rural households is much higher than that in households which use modern cooking fuels such as natural gas, because their energy cost includes the transaction cost of gathering the fuel as well as the energy that is wasted in inefficient cooking stoves. For the nation as a whole, the opportunity cost of collecting and using firewood has been estimated to be more than $6 billion/year even if the wage rate is assumed to be just $1.33/day/person. While the cheapest, cleanest and the most efficient forms of cooking fuel such as LPG, natural gas and electricity are used by the richest households, the dirtiest, most inefficient and most expensive cooking fuels are used by the

Figure 3: Useful Energy Obtained by Households using Biomass



Source: Shahidur R. Khandker, Douglas F. Barnes, Hussain A. Samad (2010): "Energy Poverty in Rural and Urban India."

Figure 4: Useful Energy Obtained by Households using Modern Fuels



Source: Shahidur R. Khandker, Douglas F. Barnes, Hussain A. Samad (2010): "Energy Poverty in Rural and Urban India."

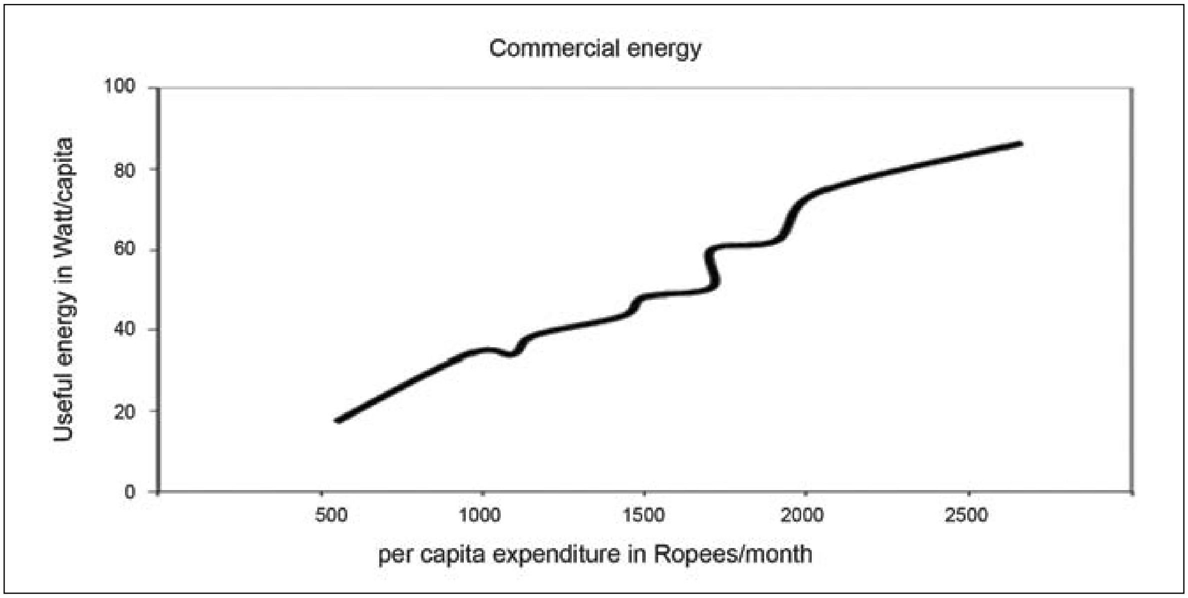
poorest households. As a result, poor households spend a higher share of their income on inefficient, polluting, high transaction cost energy than wealthier households and this deprives them of consuming other basic goods. This poses a significant challenge to India's inclusive development agenda.

There is a significant development gap between households with access to commercial forms of energy (LPG, Kerosene, etc) and those without access. Figures 5 and 6 show that households with access to commercial energy forms such as kerosene and LPG consume more energy compared to households without access to commercial energy forms, even when they belong to the same income group. This implies that access to commercial energy forms increases consumption of energy and consequently increases quality of life in the household. The government has intervened in the market to increase access to liquid fuels but these interventions have not achieved the desired outcomes.

In contrast to the electricity sector where government intervention to increase access has focused on investment in infrastructure, intervention in the petroleum sector has taken the form of price subsidies. The prices of fuels such as kerosene and LPG, supposedly used by poor and middle class households, do not recover cost of service; the difference is made up for by government subsidies. However, a number of studies have revealed that a large share of the subsidised fuel is appropriated by richer urban households.

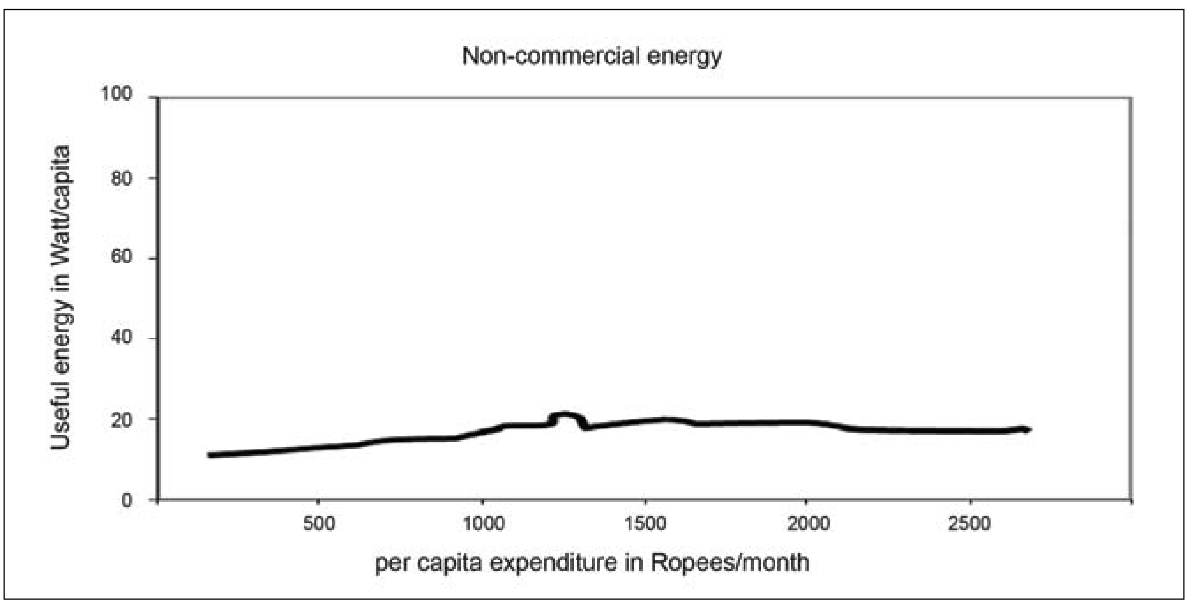
Studies have also revealed that about 37 percent of subsidised kerosene intended for poor rural households is diverted for adulterating diesel or resold in the open market.[20] National surveys have revealed that less than 10 percent of households use LPG and most of these households are affluent ones in urban areas. The government is aware of these leakages in its subsidy schemes and is experimenting with alternative options such as direct transfer of subsidy in the form of cash.

Figure 5: Change in Commercial Energy Use with Income



Source: S. Pachauri, A. Mueller, A. Kemmler and D. Spreng (2004): "On Measuring Energy Poverty in Indian Households"

Figure 6: Change in Non-commercial Energy Use with Income



Source: S. Pachauri, A. Mueller, A. Kemmler and D. Spreng (2004): "On Measuring Energy Poverty in Indian Households"

Most analyses misinterpret the question of energy access in India as a problem of supply scarcity. Under the 'scarcity' framing, energy supplies are seen to be dwindling with little left for Indian consumers. Policy suggestions advise India to scrounge for energy from every source, every corner of the world. This is an attractive framing as it facilitates the transfer of disproportionate sums of money to state and private players who are supposedly in the business of securing energy for India. But as Prof. Amartya Sen has pointed out in his Nobel Prize winning work, physical availability of any vital resource, be it food or energy, is less important than broad purchasing power to obtain it.

As pointed out by Arvind Subramanian, India already has an informal 'right to subsidised energy' policy under which the price of energy sources and energy forms such as electricity are 'subsidised'.[21] The right to 'subsidised' energy has distorted the energy market to such an extent that it has become a barrier to investment in the energy sector. But the term 'right to subsidised energy' needs to be qualified. The so-called subsidy on energy is in reality a complex mix of cross subsidies that do not actually reduce the price of energy relative to other consumption goods for the average energy consumer. Apart from the fact that the average Indian pays one of the highest prices for energy (petroleum and electricity) in purchasing power parity terms,[22] he/she also pays a higher share of wages to purchase a unit of energy compared to people in comparable countries such as Pakistan.[23] Further, the energy system that delivers the 'right to subsidised energy' has a carefully crafted system of leaks that allows unintended beneficiaries to appropriate energy.

All this does not mean that the objective of providing energy access to all must be abandoned. Experiments with new and innovative ways of providing energy access must continue until the optimal solution is found.

Energy Access in South Africa

In 1994, the democratically elected South African government came to power and created a constitution which is world renowned for its all-inclusive description of human rights. One of those rights is access to electricity. The new dispensation inherited a grossly inequitable electricity system which it tackled with an electrification programme, aimed to achieve universal access to electricity by 2014. The programme has been fairly successful with access to electricity increasing from 35 percent of all households in 1990 to 84 percent of households in 2011, according to StatsSA2012.[24]

Although published data on the state of electrification varies from source to source,[25] the general consensus is that about a quarter of South African households still do not have access to electricity. This number can be further contested because connected households do not necessarily have the means to buy electricity. This raises the question of whether South Africa's current way of delivering electricity is contributing to inequality of access to electricity.

Almost 47 percent of South Africans are poor, defined as living in a household with less than R800 per month.[26] If a suburban household were to use 700 kWh, the cost of electricity would make up a small percentage of their income which is generally between R 10,000 - R 15,000. The cost of 500 kWh to a township household would take up 23 percent of income, which is generally derived from social grants and pensions. Consequently, low income households either under consume electricity or cannot pay their electricity accounts.[27] As a result, many homes are illegally connected to the grid.

History of Electrification in the New Regime

With the end of apartheid, the new administration was constitutionally obliged to implement universal access to electricity for disadvantaged citizens. From 1994 to 2000, new policies were drafted and institutional reforms carried out in the electricity sector that would see electrification levels increase from about 35 percent to 71 percent. The state electricity utility Eskom was responsible for financing the programmes from 1991-2001.[28] The Energy White Paper, 1998, asserted policy direction to establish a National Electrification Programme and in 2002, the Integrated National Electrification Programme (INEP) was created.

In 2005, INEP's planning, funding and coordination was housed into the Department of Energy and Minerals (now the Department of Energy).[29] About 190,000 new connections were auctioned annually, but each year the number of new households that came online was between 320,000 and 350,000. Thus delivery was below growth.[30] The required funding allocation from 2007 to 2011 was about 50 percent less than what was required to address the backlog.[31]

The inefficient administration of the INEP programme negatively impacted its delivery, with the serious lack of technical and managerial skills within municipalities cited as the major barrier to its success.[32] When the government realised that the poor could not afford electricity, it introduced Free Basic Electricity (FBE) in 2004. This was the government's response to energy access for the energy poor. Poor households pay a nominal fee for connection, and receive 50 kWh per month paid for by the exchequer.

State of Energy Access

While the South African government wrestles with its electrification system, many citizens continue to live in energy poverty and rely on 'dirty energy' fuels for their energy needs. Coal, wood, paraffin stoves and candles all pose significant health and safety risks – such as fires and respiratory illnesses. These are also used in households that are connected to the grid but cannot afford the cost of electricity beyond the 50 kWh provided free by the state. A study revealed that households spent about R120 per month on electricity and an additional R60 on other fuels.[33] Access to electricity would address various issues, such as creating adequate lighting and more time to study at night, preventing women and girl children from spending up to two hours a day collecting fuel, making streets are safer to walk in at night and providing households with additional energy for other productive uses.[34]

Free Basic Electricity

To a large extent, FBE fails to deliver equitable access to electricity. For most poor people, the biggest barrier to electricity access is the high connection fee. Pre-paid metering had been introduced to reduce the cost of billing and meter readings, as well as assisting the poor to not exceed affordable costs.[35] Although this has addressed the issue of massive debt to municipalities, which were not able to pay for their energy purchases owing to under-recoveries, it still did not change the fact that electricity remains unaffordable for a large number of citizens.

FBE is purported to provide enough electricity for the poor, "suitable for basic lighting, TV, and radio, basic ironing and basic cooking" (DME 2003b: section 3.5), but the reality is that a small refrigerator alone used for just six hours a day would use up all the FBE allotted for a month and a hotplate used for two hours a day would use far more than the daily FBE amount.[36]

The system of accessing FBE is also complicated and time-consuming. The poor have to first prove that they are in a condition of poverty and get registered as indigent – in 2007 only 47,000 were registered. Once registered, they have to agree to have a pre-paid meter installed in their home and only then are they eligible for FBE. The meter installed is only a 10 amp supply which trips when several appliances are used at once, leading to frequent outages and disconnections.[37] Forty eight percent of municipalities have no maintenance plans for their distribution networks, or knowledge of power quality and performance issues.[38] Half the municipalities do not have contingency plans for dealing with power cuts nor do they conduct maintenance checks.[39] This is in spite of the fact that municipalities make an average 10-15 percent surplus from their electricity distribution and retail activities.[40]

As the poor have incremental access to money, electricity is bought incrementally at vending stores. This requires multiple visits and often long queues, posing risks to safety. In the Tshwane municipality, for instance, customers have a cap of 150 kWh on electricity purchases. This is instituted to make customers pay for other services and to prevent the illegal sale of electricity.[41] That municipalities have to resort to this type of disincentive is indicative of a system that is not working for the poor. Further, the capping of the amount of energy that people can buy can be seen as an infringement of human rights. Highlighting this systemic inequity is the fact that mining and manufacturing companies are charged about half the tariffs that domestic customers are.[42]

In conclusion, the amount of electricity provided in the FBE falls short of the definition of universal access, which is generally accepted as energy for cooking, lighting, heating and potentially a cell phone charger or a TV. The inability of the poor to supplement FBE with additional energy purchases, and the need to resort to paraffin, coal and candles, points to deeply embedded socio-economic inequity. Similarly, a quarter of households remain unconnected to the grid, which indicates a structural dysfunction within government, ultimately precluding the goal of universal energy access.

Rural Access to Electricity in China

Before the founding of the People's Republic of China, rural electric power consumption was only 20 million kWh or 0.58 percent of the total national consumption. In the 1950s, rural power consumption grew at a steady rate, but total rural consumption remained small because of the small base. The period between 1960 and 1970 saw China's rural power consumption growing at an average annual rate of 34 percent, much higher than the growth rate of total national power consumption. In the 1980s and 1990s, rural power demand continued to grow rapidly. In 1978, the percentage of towns, villages and rural households that had access to electricity were respectively 86.83 percent, 61.05 percent and 93.3 percent, while by 2000, these percentages rose to 98.45 percent, 98.23 percent and 98.03 percent.

According to statistics issued by the State Grid Corporation of China, national power development programmes such as rural power grid renovation and universal access to electricity have greatly improved access to electricity in rural and remote areas. Between 2003 and 2011, the grid power transformation capacity, electricity sales and power consumption per capita at and below the county level grew 2.1 times, 1.9 times and 2.3 times respectively. Importantly, consumption of electricity at and below the county level grew more rapidly than in cities, and rural electricity consumption grew more rapidly than in county-level cities.

For some years, the price of electricity in rural areas remained higher than in urban areas because the cost of power supply was much higher in the former, due to the high cost of maintaining the grid and low electricity load factor in rural areas. In order to reduce the price of electricity in rural areas, the rural electricity administration system was reformed and the rural power grid was renovated. Now, in most regions of China, rural and urban residents pay the same price for electricity.

Development of Smart Power Grids in China

In China, a smart power grid is defined as a new model of power grid that includes various kinds of power generation equipment, power transmission and distribution networks, electric equipment and energy storage equipment along with the physical power grid. This is the basis by which the physical power grid is integrated with modern transducing and measuring technology, network technology, information communication technology, automation technology, intelligence control technology and so on. These technologies can monitor, control and accommodate the state of all the equipment of the power grid and can systematically and comprehensively optimise and balance the whole grid (achieving a balance between power generation, power transmission and distribution, and power use). A smart grid thus makes the electric power system clean, efficient, secure and reliable.

Accordingly, China's State Power Grid Corporation's goals for building a nationally unified smart power grid were adopted in the 12th Five-Year Programme (2011-2015) on National Economic and Social Development. Further, goals and policy measures for speeding up the construction of a nationally unified power grid system have been specified in the "12th Five-Year Programme (2011-2015) on National Energy Science and Technology Development" as well as in the "12th Five-Year Programme (2011-2015) on Projects of Industrialising Key Smart Power Grid Technologies."

By now, marked progress has been made in the construction of smart power grids – represented by the Strong Smart Grid being built by China's State Power Grid Corporation – as well as in technology research and development and in the demonstration of new technologies. Key smart power grid equipment such as intelligent switches, composite apparatus and Optical Fibre Composite Low-Voltage Cable has been successfully developed. The construction of the comprehensive demonstration project of smart grid, the wind and solar power storage and transmission demonstration project in the Sino-Singapore Tianjin Eco-city, the Baoqing Lithium Battery Energy Storage Power Station Pilot Project, and the Pilot Project of Wind Power Prediction and Operation Control for Large-Scaled Wind Farms in Shenzhen have all begun. Smart grid industry clusters such as the Central Plains Electronics Valley in Henan Province, the Jiangsu Provincial Smart Grid Research and Industrial Base, and the Smart Grid Industrial Park in Yangzhou have already taken shape.

According to the China's State Power Grid Corporation's plan, the construction of a nationally unified ultra-high voltage power grid made up of two vertical lines and two horizontal lines will be finished by 2015. The construction of a nationally unified ultra-high voltage power grid made up of three vertical lines and three horizontal lines will be through by 2017, while the construction of a nationally unified ultra-high voltage power grid made up of five vertical lines and five horizontal lines will be done by 2020. In addition, a project of 27 UHV DC transmission lines will also be completed by then. All these will lay a solid foundation for developing a nationally unified smart grid.

Structure and Trend of Rural Cooking Energy

At present, rural cooking energy in China is mainly firewood (crop stalks and fuel wood), coal, liquefied gas/natural gas, electricity, biogas and solar energy. In 1996, 94.55 percent of rural households used firewood and coal as cooking energy and 5.07 percent used liquefied gas/natural gas for cooking purposes. By 2010, the percentage of rural households using firewood and coal as cooking energy fell to 48 percent, and the percentage of rural households using liquefied gas/natural gas as cooking energy increased to 22 percent. Meanwhile, 24 percent of rural households started to use biogas as cooking energy, six percent started to use electricity and one percent started to use solar energy.

Drivers for these changes in the structure of rural cooking energy in China include supportive policies, technological advancement and the increasing income of rural households. The Chinese government has been supporting and encouraging rural households to use clean and renewable energy such as solar energy through subsidies. Technological advancements have created favourable conditions for biogas and solar energy to become stable and sustainable clean energy sources for rural areas. It has become possible for biomass solid fuel to be mass produced.

According to the goal of energy innovation set by the Chinese government, "the percentage of rural households using clean and renewable energy by 2020 should surpass 70 percent," so it is anticipated that even more remarkable changes in the structure of rural cooking energy will take place. By then, it is expected that the percentage of rural households still using firewood and coal as cooking energy will fall from 48 percent in 2010 to 5.49 percent; the percentage of rural households using liquefied gas/natural gas as cooking energy will rise from 22 percent in 2010 to 24.5 percent; the percentage of rural households using biogas as cooking energy will rise from 24 percent in 2010 to 39.95 percent; the percentage of rural households using electricity as cooking energy will rise from 6 percent in 2010 to 10.07 percent; and the percentage of rural households using solar energy as cooking energy will rise from one percent in 2010 to 6.67 percent.

Development of Biomass Energy in Rural China

In 2006, "Several Opinions on Advancing the Construction of Socialist New Countryside" by the Communist Party of China's (CPC) Central Committee proposed to speed up rural energy development, actively spread biomass energy technology in suitable areas, substantially increase investment in rural biogas development and take advantage of biogas as a driver to promote renovation of rural household pigsties (and sheepcotes, lairs, stables) as well as of rural household toilets and kitchens. In 2012, the 18th National Congress of the CPC called for advancing the revolution of energy production and consumption as well as creating innovations in energy supply.

The use of biomass energy in China began with rural households. Efforts of quite a few decades in China have reaped preliminary results - the government has been subsidising construction of rural household biomass digesters. The number of rural household biogas digesters increased from 18.06 million in 2005 to 40 million in 2012, and their annual output of biogas grew from 7.06 bcm in 2005 to 14 bcm in 2010. From 2005 to 2009, the number of livestock and poultry breeding farm biogas digesters increased from 3,556 to 536,354, and their annual output of biogas grew from 230 mcm to 765 mcm. In addition, the number of biomass tanks reached more than 1,500 in 2010, whose average capacity is 31 mcm each.

Subsidies for Developing Renewable Energy

Subsidies for developing renewable energy mainly cover four items: rural household biogas digesters, livestock and poultry breeding community biogas projects and biogas projects for a number of rural households, large/medium-sized livestock and poultry farm biogas projects, and rural biogas service outlets. The subsidy standards are as follows:

Rural household biogas project: A rural household biogas project includes building a biogas digester and renovating the kitchen, the toilet and the pigsty/sheepfold/pen/stable. The total cost of this kind of project is about 4,000 RMB, which is shared by the central government, the local government and the rural household. The central government provides 1,200 to 1,500 RMB (1,500 RMB for households in the western region), the provincial government 1,000 RMB, the county government another 1,000 RMB and the household pays 500 to 800 RMB (500 RMB for households in the western region).

Livestock and poultry breeding community biogas projects, and biogas projects for a number of rural households: A livestock and poultry breeding community biogas project refers to one that designates a zone for all livestock and poultry breeding of different households in a village. In this zone, livestock manure and waste water are collected and utilised to produce and supply biogas for a community of 50 rural households. The project includes a methane fermentation pool and facilities for pre-treatment of raw materials, biogas supply facilities and biogas manure utilisation.

The central government's subsidy to each household for a livestock and poultry breeding community biogas project, and biogas project using livestock and poultry manure, is up to 120 percent of the amount for each rural household biogas project (1,200 RMB/1,500 RMB X number of households X 120 percent). The central government's subsidy to each household joining a biogas project for a number of rural households by using straw as raw material is up to 150 percent of the amount given for each rural household biogas project (1,200 RMB/1,500 RMB X number of households X 150 percent).

Large and medium-sized biogas projects in livestock and poultry farms: The central government subsidises each pigsty with more than 3,000 pigs, each cattle farm with more than 200 milk cows and each beef cattle farm that annually produces 500 cattle to build a biogas project. To qualify for the subsidy, these livestock farms must be independent legal entities, well operated and capable of sharing the required part of the total investment. Usually, the central government's subsidy is about 25 percent of the total investment up to one million RMB. The provincial government is required to subsidise another 25 percent and the municipal/county government another 20 percent.

Rural energy service system and its service outlets: Each county-level service station of the rural energy service system in the central region can get a subsidy of 150,000 RMB from the central government, and one in the western region of 200,000 RMB. A village/town service outlet in the central region can get a subsidy of 35,000 RMB from the central government, while one in the western region can get 45,000 RMB.

Energy Access in Russia

Though nearly everyone in Russia has access to energy resources and there is practically no energy poverty in the country, structural problems in several areas impede provision of energy. The Russian power market is officially divided into three groups: Price zones, non-price zones and isolated areas (see Figure 1).

Price zones include the European zone, the Urals and Siberian zone. They are the core of the Russian United Energy System. The wholesale electricity market, with a large number of competing providers, works here. Prices are therefore not regulated. The competition among providers and their ability to substitute one another in case of an emergency ensure stability of supply and a relatively low level of electricity tariffs.

Non-price zones are also included in the United Energy System, but climatic conditions and large distances between consumers make competition among providers impossible. Prices are therefore regulated by the state in these areas. Tariffs are determined every year by the Federal Tariff Service on the basis of complicated calculations of production and transportation costs. The state's intervention ensures relatively low tariffs. At the same time, the absence of market competition results in a lack of stimuli to modernise energy infrastructure.

Isolated areas experience the largest problems in terms of stability of access to energy resources. These areas are sparsely populated and represent a small portion of Russian energy market (only 9.4 GW of capacity[43]) but cover a huge area –

Figure 1: Zones of the Russian Power Market

Source: Kristiansen T. The Russian Power Market // The International Association of Energy Economics Energy Forum, No. 1, 2011.

about one-third of the territory of Russia. They are not included in the United Energy System and there is no wholesale electricity market here. Moreover, most of these areas have no local energy resources. Fossil fuels are provided for their needs from the other regions on the eve of every cold season. It is done through the so-called "North delivery" – the regular large-scale provision of oil products, coal and fresh food products to the distant territories of the northeast subsidised by the state. The absence of market forces and the lack of local energy resources, combined with bad infrastructure and long distances, impose various risks on access to electricity in isolated areas.

First, electricity tariffs are much higher in the isolated territories than in the other areas. For example, in Magadan Oblast the simple electricity tariff for households using gas stoves amounts to 4.85 rubles/kWh. For reference, in Moscow Oblast (the richest part of Russia) tariffs do not exceed 3.8 rubles/kWh, and in Volgograd Oblast (the Volga region), the maximum is 2.53 rubles/kWh.[44] Average wages in northeastern Russia are higher than in other parts of the country because of an additional allowance for working in severe climatic conditions and the region's remoteness from economically developed areas. However, there are some for whom energy bills represent a heavy burden, including those indigenous to the region.

Secondly, infrastructure and facilities in isolated areas are extremely outmoded. Breakdowns happen very often and there is no backup. Blackouts in Sakhalin Oblast, Kamchatkakrai, Magadan Oblast' and other isolated areas have become regular occurences for the local population. Another factor that increases the possibility of breakdowns is the unstable climate, characterised by frequent cyclones from the ocean.

Thirdly, there is an additional risk for isolated regions due to poor logistics and dangers of interruptions in the "North delivery." For many settlements, cargos are delivered by rivers or roads that are passable for only some weeks in a year. In case of bad weather or an accident, cargos sometimes can not be delivered, which forces local authorities to declare a state of emergency and claim special federal support.

The problems of access to energy resources in isolated regions can be mitigated in a number of ways. The government plans to build new power lines, implement renewable energy and develop transport infrastructure within the parameters of the Energy Strategy of Russia up to 2030 (2009),[45] the State Programme of Social and Economic Development of the Far East and Baikal region (2013),[46] and the Strategy of Development of Arctic Zone and Ensuring of National Security up to 2020 (2013).[47]

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