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# The Chinese Electricity Access Model for Rural Electrification

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## Abstract

The economic and infrastructural disparities between the rural and urban communities of most developing countries in general and in terms of energy access in particular are quite glaring. China presents a good example of a developing country that has successfully embarked on rural electrification and energy projects over the last few decades and achieved a great feat of almost 100% electrification rate (IEA 2009). The purpose of this paper is to find out how China has achieved this feat; how China's rural energy projects were financed and whether China provides lessons for other countries to follow.

The above questions are examined through an extensive literature review and the paper finds that unlike many other countries following the top-down approach to rural electrification, China has preferred to use a phased development through a bottom-up approach where local resources, and village level development and empowerment played an important role. While the state provided the overall guidance and financial support, the integrated rural development approach has produced local-level solutions that are subsequently integrated to produce an alternative development pathway. Strong government commitment, active local participation, technological flexibility and diversity, strong emphasis on rural development through agricultural and industrial activities and an emphasis on capacity building and training have also played an important role in the success. However, despite achieving the universal access objective, China still faces a number of issues related to rural electricity use, especially in terms of regional use patterns, long-term sustainability of supply and commercial operation of the systems. The Chinese model could serve as an inspiration for other developing countries trying to ensure universal electricity access.

Keywords: China, rural electrification, financing, lessons

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## Introduction

It is now widely recognised in the development policy circle that access to clean energies is a prerequisite to economic development of developing countries. With more than 1.3 billion people (i.e. about 19% of the global population) without access to electricity in 2009 (IEA, 2011), the scale of the problem cannot be over-emphasised. Interestingly, the most populous country in the world, China, has achieved a very impressive record in providing electricity, with only 8 million population (or about 0.6% of its population) lacking the facility at present. Our curiosity about this extra-ordinary performance led us to inquire more about the Chinese experience to see how China managed such an impressive feat and whether other countries can also benefit from its experience. This is the main purpose of this paper.

This paper specifically asks three questions:

a) What is the Chinese model for electricity access and how it managed to provide access to all of its population despite being a very large and populous country?
b) How did China finance its rural electrification programme?
c) What are the critical success factors behind the Chinese success, and what lessons others can learn from the Chinese experience?

The paper tries to answer these questions through a thorough literature review. We recognise that our dependence on the literature alone introduces a number of challenges. First, we have only considered works published in the English language and did not review any literature written in Chinese. Second, we have taken the reported information as accurate and we did not try to ascertain the veracity of the reported information through independent surveys or other means. Researchers working on China face the information issue due to language barrier and strong regulatory control over the information generation and dissemination processes. This is a problem for many studies and ours is not immune to it. Yet, it needs to be recognised that the accuracy of our analysis and results is conditional on the veracity of information we have used from the available information sources. Third, the possibility of finding contradictory or conflicting information in the available literature cannot be overruled. Where such issues have arisen, we have compared more than one source of information to arrive at our view. A few China energy specialists have also reviewed the earlier drafts as internal reviewers, which we believe has mitigated some of the above risks arising from information issues.

The paper is organised as follows: the second section presents a review of the status of electrification in China. This historical development is divided into three phases to capture the politico-socio-economic changes in the country. It also presents the technological choices and organisational arrangements. The third section discusses how China financed its rural electrification over the past five decades. The fourth section then identifies the critical success factors and lessons for others, while some concluding remarks are given in the last section.

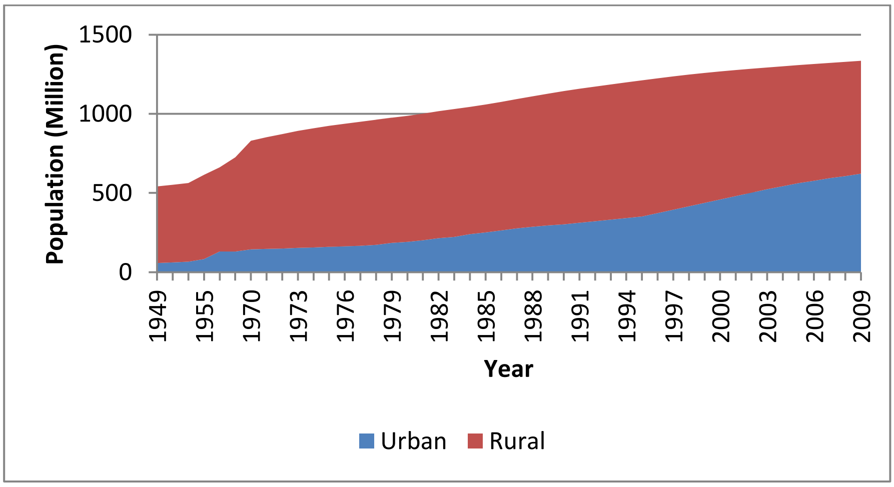
## 2.0 Review of rural electrification status and process in China

To answer the first question (i.e. how China provided electricity access to its billion-plus population?), we review the status of electrification and the electrification process in the country since 1949. This stylised historical review is aimed at capturing the evolution, identifying the technical choices, and highlighting the organisational arrangements and policies used.

### 2.1 Status

China, with a surface area of 9.6 million square metres, is the fourth largest country in the world area-wise (after Russia, Canada and the USA) but is the most populous country with a population of 1.33 billion in 2009 (China Statistical Yearbook 2010). Although the majority of its population still lives in rural areas, the country has seen a rapid growth in urban population in recent times (see Fig. 1). In 1949, 89% of its population lived in rural areas. The share of rural population fell to about 81% in 1980 but since then, the share of rural population registered a 10% reduction in every decade to reach just above 53% in 2009 (China Statistical Yearbook 2010). This structural change is even more impressive as this happened when the population increased from 541 million in 1949 to 1.33 billion in 2009.

Fig. 1: Rural and urban population in China



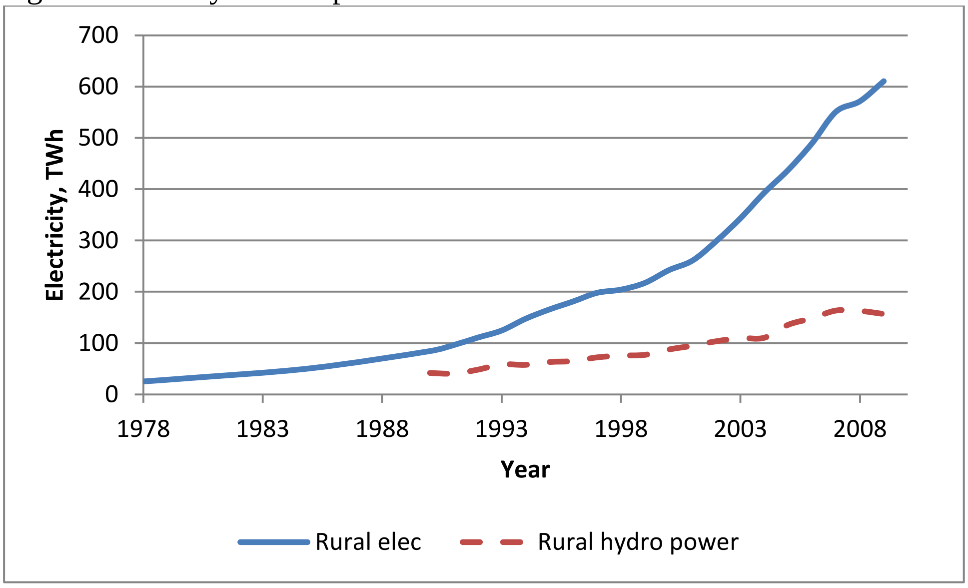

Data source: China Statistical Yearbook 2010.

China has a long experience of rural electrification and has been successful in providing access to 900 million people over a period of 50 years (Peng and Pan, 2006). But the success in rural electrification started since 1979 when the economic reform began from rural areas. Rural China accounted for only 0.66% of national electricity consumption until 1957 but the level increased to 13.31% by 1978 (Yang, 2003). More than 50% of the farmers did not have access to electricity at that time and the per capita energy consumption in rural areas was one-fifth of that of the urban areas (Zheng et al, 2002). But the country recorded a rapid growth in electricity use in rural areas since then and the share of rural electricity consumption increased to 31.55% by 1987. The country achieved a tremendous success in ensuring electricity access to 95.5% of households by 1997 (Yang 2003). According to IEA (2011), about 8 million people lacked electricity China by 2009, while the latest statistics from the National Energy Administration suggest that 2 million households still lack access –

this represents a population of 9 to 10 million. The government intends to use off-grid and decentralized options to electrify the remaining areas by 2020.

Figure 2 presents the growth in rural electricity use in China, which clearly indicates an exponential growth, with rapid progress in the new millennium. To put the information in perspective, the annual electricity consumption in the UK is typically about 400 TWh. Rural China consumed about 1.5 times of this volume in 2007. Surely, the challenge and scale is very different in China.

Fig. 2: Electricity consumption in rural China



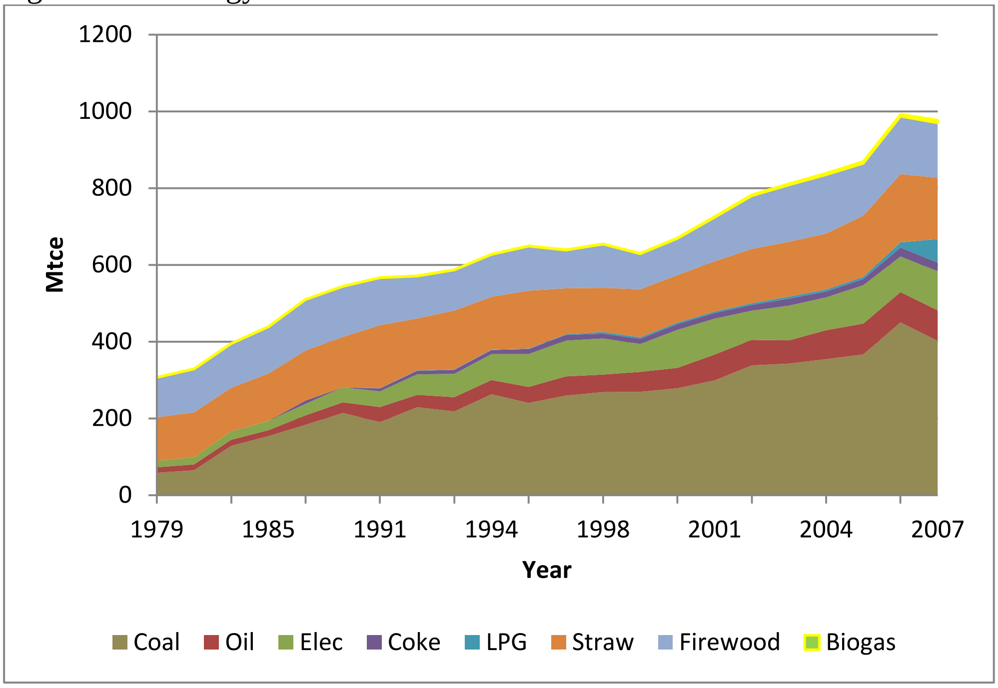

Source: China Statistical Yearbook, 2010

Although we focus on electricity here, it must be noted that electricity still plays a minor role in rural China and accounts for about 10% of all energy consumption. The rest is provided by coal, oil and non-commercial energies[1]. An exponential growth can be seen in the overall rural energy use as well (see Fig. 3), with coal and non-commercial energies supplying 41% and 31% respectively in 2007[2]. Moreover, there is significant spatial variation in electricity use – especially between the northern and southern regions (Zhang, et al, 2009a). In per capita terms, rural energy consumption is almost one half of the national average but the accelerated growth rate of rural energy consumption points towards a possibility of role reversal in the future (Yang et al, 2010). However, we do not focus on these aspects here.

[1] See Luo (2004) for a general discussion on rural energy in China.

[2] See Zhang et al (2009b), which provides the data for the period between 1979 and 2007. This is a good source of information on rural energy in China.

Fig. 3: Rural energy trend in China




Note: Biogas appears just as a line due to its relatively small volume.

Source: Zhang et al. (2009b).

## 2.2 Review of the Chinese rural electrification process

Since the People's Republic of China was founded in 1949, China has witnessed major developments in its economic and social policies. Over the past six decades, the government gradually moved from a centrally controlled economy to a more market-oriented one. The Chinese energy policy was no exception – the country has seen major institutional changes in her energy policy over the same period (Peng and Pan, 2006). Three distinctive phases which have shaped China's rural electrification policies over time can be identified: a) the Maoist era of central planning (1949-1977); b) the era of market reform (1978-1997); and c) a subsequent move towards a dynamic market economy from 1997 till date (Peng and Pan, 2006). Each phase influenced the rural electrification process in certain ways, which are discussed below.

### *2.2.1 The Maoist era of central planning (1949 to 1977)*

Prior to 1949, electricity consumption in rural China was low with a per capita consumption of 0.05 kWh and representing only 0.58 percent of the total national consumption (Peng and Pan, 2006, Ming, 2003). This period was characterised by strict central planning where a comprehensive framework following the Soviet Union's command system of government was adopted. China was mostly isolated from the rest of the world during this period. Energy sector development was under strict state control and the commercial energy supply to rural areas was not a priority (Pan, 2002).

During the first Plan period, China imported technology from the Soviet Union, when the country had limited technical capacities, financial resources and management skills. The institutional structure during this period was such that provincial and local governments were in charge of the management of power projects. Although new power supply projects were established during this period, there was limited attention to rural areas. Consequently, the rural share increased marginally to 0.66% of the national electricity consumption by 1957 (Ming, 2003). Biomass-based energy was the main fuel used in rural households during this period (Zheng et al, 2002). However, during the first plan period China completed its rural land reform process by confiscating land from landlords and redistributing the same to landless peasants. The rural living condition was constrained by limited economic activity and shortage of essential supplies such as food, commercial energy and water.

The Communist Party under Mao Zedong launched the Great Leap Forward in 1958 to transform the economy through rapid development of the agricultural and industrial sectors. But the programme was abandoned in 1961 amidst widespread famine, starvation and economic recession. The movement was enormously disruptive for the country and its energy sector, with coal industry being hardly hit (Arruda and Li, 2003). The strategy for economic development was then adjusted towards agriculture as the foundation of development, and industrialisation as the leading activity. The "dual track" policy was however biased towards industrialisation at the cost of agriculture and the peasants (Long et al., 2009). The Cultural Revolution in 1966 again disrupted the economic development, and the social upheaval further isolated the country from the rest of the world. Low agricultural productivity and the existence of "price scissors" – low prices for agricultural outputs and high prices for industrial products – meant that the rural farmers were poor and there was a striking urban-rural income disparity. The rural population had no option but to work in the agricultural collectives and the agricultural stagnation affected the country for about two decades (Long et al., 2009).

As the country became politically isolated, the economic policy during this period aimed for self-reliance through "self-construction, self-management and self-consumption" [Pan, 2002, Zhang and Heller, 2004), where local resources, technologies and state-controlled management played an important role. Rural electricity supply received attention during this period for irrigation, water conservation and drainage to support agricultural development. Strong emphasis was laid on small hydropower wherever possible, funded and managed mostly by rural residents and collectives with some support from the state. According to Pan et al. (2006), 1000 small hydropower stations were built by the end of 1959, with an installed capacity of 150 MW. Hydropower stations operated on a single unit basis at this time and electricity was transmitted at low voltage to local communities (Pan et al., 2006).

The promotion of hydropower continued in the 1960s and early 1970s, to support agriculture. However, realising the importance of electricity for rural development, there was a shift in the policy in the 1960s. The central government decided to expand the central grid alongside the local networks in rural areas. Funds for such network extensions were provided in the national plan and the central government decided to adopt an equal share arrangement for investments.

Non-state sector small coal mines were also promoted as a biomass conservation effort in rural areas. Upon issuance of a government directive in 1957, small coal mines started to emerge in rural areas and the production trebled between 1957 and 1960 (from 6.49 Mt in 1957 to 21. 95 Mt in 1960) and quadrupled between 1960 and 1965 (to reach 95.32 Mt in 1965)[Pan, 2002]. However, state sector coal mining in general was hard hit during the Great Leap Forward and the Cultural Revolution, and the strained Sino-Soviet relations in the 1960s. This caused energy shortages during the period (Arruda and Li, 2003).

This era equally witnessed recurring changes in the bureaucratic structures of the government as a result of restructuring of various ministries and government agencies, and lacked a comprehensive long term strategic energy plan (Zhao, 2001). The Ministry of Fuels and Power (MFP), which was hitherto saddled with the sole responsibility of managing all the production of all types of fuel with limited results, had to be unbundled into different new ministries, due to increased demand for energy in the country. This led to the creation of the Ministry of Petroleum Industry (MPI), Ministry of Coal Industry (MCI) and the Ministry of Electric Power (MEP). The early 1960s equally witnessed more institutional changes, with more powers and management responsibilities being vested in the county level agencies, especially with the management of small hydrothermal energy systems and other types of power networks in the rural areas, making them the basic units of the rural electrification drive of China. This led to a comprehensive vertically integrated power network in China that spans from the central government, through regions and provinces to the local authorities and counties by late 1970s (Peng and Pan, 2006).

Notable achievements were recorded during this period in terms of rural electrification, as electricity access to rural China increased to 61% by the year 1978. Per capita electricity consumption increased to 32 kWh in 1978[3] but the share of electricity in overall rural energy consumption was just 5% due to high reliance on traditional fuel wood energies in rural areas (Zhang et al, 2009).

Although, the share of rural energy consumption in this era increased to 13.31% towards the end of the 1970s (Yang, 2003), half of the farmers in the rural areas still lacked access to electricity, and only accounted for a fifth of the per capita energy consumption of China compared to the urban areas (Zhang et al. 2002). The shortage of electricity supply was a common feature and the over-reliance on firewood led to deforestation and local environmental problems in rural areas (Zhang et al., 2009b). Wang and Feng (2001) indicate that the policy of self-reliance of this period that meant limited commercial energy supply led to over-dependence on local resources but inefficient technologies, limited local resources,

[3] This is calculated from the data obtained from China Statistical Yearbook 2010.

and high population pressure meant that local supplies were often inadequate, and this resulted in energy shortages.

### 2.2.2 The Era of market reform (1978-1997)

The Open Door economic policy was adopted in 1978 and the economic reforms embarked upon by the Chinese government led to a rapid growth in the nation’s economy. During this period, the rural economy moved away from subsistence agriculture to more “commercialised and industrialised” economy. The Township and Village Enterprises (TVE) led this economic transformation in rural areas, and became a vital source of employment, revenue creation and poverty alleviation. Hitherto agricultural labourers in rural areas now moved to TVEs, which resulted in an increase in the household income. The demand for electricity and other commercial energies increased consequently (Wang and Feng, 2001). Growing income in rural areas also led to increasing demand for appliances, which led to a transition to commercial energies in rural areas (Jiang and O’Neill. 2004)). Better availability of electricity in the 1990s was also another factor behind higher electrical appliance demand in rural areas (Wang and Feng, 2001).

A series of rural energy policy announcements were made in the early 1980s to move towards an integrated energy strategy and rural energy management. In the 1980s, four rural energy technologies, namely small hydropower, biogas units, improved biomass stoves and firewood forest plantations were pursued individually (Catania, 1999). The focus shifted to re-forestation, conservation of coal and firewood through better technology use, and expansion of biogas development alongside small hydropower development (Zhang et al., 2009b). At the same time, pilot projects were initiated in 12 counties to develop integrated rural energy construction projects. Based on the successful trial in these counties, the government decided to diffuse integrated systems in all rural areas in the 8$^{th}$ five year plan (1991-95) (Catania, 1999). Another pilot project development during this period was the State Council approval for 100 rural hydro counties. These counties aimed at rural electrification through development of small hydropower plants. They achieved this target in 1995 (Pan, 2002).

Thus, at the end of the 1980s, 78% of people living in the rural areas had access to electricity. This tremendous progress in terms of rural electrification can be attributed to the new wave of thinking and enterprise reforms carried out in China during this era, which was based on the decentralization of operations and devolution of powers amongst component units of government to fast-track the electrification process. Electricity availability increased as a result – investments went to both hydro and non-hydro sources of power (see also section 2.3 below). In fact, by 1990, the contribution of the local governments to total investments in power projects rose from 1% in 1983 to a 17% in 1990 (Zhao, 2001). More revenues accrued to the local governments due to special taxes imposed on power development in 1988, and a major portion of this revenue was invested in small power plants of 10 MW, light industries, real estate and processing industries, all of which raked in high short term profits (Zhao, 2001).

However, there was energy supply capacity shortage, which triggered another institutional restructuring to increase energy supply capacity, while minimising the demand for energy through efficient use of energy and reducing its intensity (Zhao, 2001). These reforms, which basically involved the transition from a centrally planned system to a more devolved one, were targeted at the rural areas towards giving the counties and local authorities more autonomy in investment decisions making. Thus, funding for capital projects from higher government agencies to county and local governments increased during the late 1970s (Peng and Pan, 2006). Increased use of coal and non-commercial energies between 1979 and 1995 led to environmental degradation. Deforestation resulted due to land clearing for agricultural expansion, timber production and failed industrial movements (Chen et al., 2006).

The progress towards the rural electrification for all was intensified and almost achieved during this period, and by 1997, 97% of rural Chinese households were provided with electricity. The development of rural water systems and renewable energies also got a boost during this era as the central government promoted and supported its drive. Per capita electricity consumption increased to 235.2 kWh in 1997, representing a seven fold increase in use level compared to that in 1978[4]. The share of electricity in the overall energy consumption increased to 11.5% (Zhang et al, 2009), but this was due to a significant increase in electricity use for residential use and that for productive purposes. The share of electricity use for productive purposes reduced to 62% in 1999 from 81% in 1980, but still the volume was significantly higher (Zhang et al, 2009b). Wang and Feng (2001) argue that three factors contributed to a low share of electricity in the overall energy mix: a) high electricity price for rural consumers due to high level of power loss in the old power network; b) the long-standing supply shortage; and c) the policy bias towards urban consumers who received higher priority in supply. Low voltage and outdated network in the rural areas was responsible for 20-30% line losses compared to 8-9% losses on the national level (Wang et al., 2006). The reconstruction of rural power system was undertaken during this period to reduce power transportation losses. The "pilot counties" provided encouraging results where losses reduced significantly (Wang and Feng, 2001).

### 2.2.3 Era of dynamic market economy from 1998 till date

During this period, the Chinese government focused on achieving some fundamental objectives which includes; reforming the management system of rural electricity, harmonising electricity tariffs of rural and urban consumers, implementing the renovation program of rural electricity, separating the commercial arm of energy agencies from the policy and regulatory arms, as well as to centralize government's control on the sector. Based on a State Council decision to upgrade rural electricity networks, an allocation of RMB 180 billion (equivalent to about 18 billion British pound) was made from treasury bonds. This project led to tangible benefits through a significant reduction in transportation losses (from 25% to 12%), which also helped in reducing the rural electricity tariffs (Pan, 2002). Simultaneously, China also undertook an ambitious plan to electrify remote areas in a phased manner through the Brightness programme, Township programme and then Village

[4] Based on China Statistical Yearbook 2010 data.

Electrification programme. A brief description of the Brightness Programme and Township Electrification Programme can be found in Box 1 below.

Box 1: Renewable energy-based rural electrification programmes in China

Here we present a brief account of two main programmes, namely the Brightness programme and the Township Electrification programme.

The Brightness Programme

The Brightness electrification program was introduced in 1996 with an objective of providing electricity to 23 million people in remote areas by 2010[5]. Its strategy is to use renewable energies like wind or solar in meeting its objective. Pilot projects were launched in 2000 in three western provinces (Inner Mongolia, Tibet and Gansu) to test the programme and better understand any issues related to the successful implementation of the programme. The pilot projects successfully installed 5515 SHS, 518 wind/ solar hybrid systems and 5 solar/ hybrid power stations at a cost of 40 million RMB (around USD 50 million) (Shyu, 2010). The pilot projects provided important insights related to service networks, financing mechanism, training needs, and manufacturing needs.

The Township Electrification programme

As a scaling-up effort of the pilot projects, a new programme was launched in 2002 called the Township Electrification Programme to extend electricity access to 1013 non-electrified townships in 11 western provinces (Shyu, 2010). This is now regarded as the largest renewable electricity supply programme in the world. The RNB 4.7 billion programme (IEA 2010) totally funded by the Chinese government aimed at supplying renewable energy-based electricity to power businesses and homes with sufficient capacity to supply basic needs such as public facilities, lighting and entertainment. The programme relied on system integrators who designed, procured and installed the systems while the service companies were responsible for operating and maintaining the systems. Thirteen system integrators were chosen through a competitive bidding process and by 2005 when the programme was implemented, more than 840,000 people were supplied with electricity.

[5] National Renewable energy laboratory: Renewable energy in China, Brightness Rural electrification program found at http://www.nrel.gov/docs/fy04osti/35790.pdf

The present era (1998 till date) ushered in another wave of restructuring and re-organisation of various government agencies and departments. This led to the merging of some government organisations which were hitherto perceived as duplicating responsibilities, and downsizing/rightsizing the number of government workers in such agencies in order to become more efficient (IEA, 2000).

As a result of the aforementioned efforts, coupled with the modernization of rural infrastructural facilities and the harmonization of the rural/urban consumers tariff and grid Network, electricity in the rural areas of China became efficient in supply, as access rose to 99% during this era, while urban China achieved a 100% electrification rate in 2009 (IEA, 2009). Consequently, the rural electrification efforts have slowed down now (IEA, 2010). Between 1997 and 2007, the electricity consumption in rural areas trebled and electricity consumption per capita increased to 856.3 kWh in 2009[6]. The share of productive use of electricity marginally increased to 65% in 2007, while the rest was used in households (Zhang et al, 2009b). However, the rural electricity consumption per capita in 2008 is just 30% of China's average electricity consumption. This suggests that the rural electricity market has not reached its saturation level and further development will take place in the future.

Three periods discussed above can be seen as three phases of electrification of rural China (Wang and Feng, 2001). The first period marked by severe shortage of supply restricted household use of electricity mainly to lighting. The second period saw a rapid expansion of electricity system that allowed widespread use for irrigation as well as for lighting and other household uses (e.g. TV, fans). The third phase has further expanded electricity use to Town and Village Enterprises. Electricity is also being used in highly energy intensive appliances (such as air-conditioning, washing machines, refrigerators, etc.) in rural areas and the appliance holding has rapidly increased. For example, the refrigerator ownership per 100 households increased from 1.22 in 1990 to 37.11 in 2009, while the air conditioner ownership increased from zero in 1990 to 12.23 in 2009.[7] The trend of urban living in rural areas is perhaps catching up.

### 2.3 Technology choice for rural electrification in China

China, unlike many other developing countries, has relied on multi-resources, multi-distribution channels for its rural energy supply (Catania, 1999). For electricity supply, both grid extension and off-grid options have been used, which are discussed below.

#### 2.3.1 Grid-based electricity supply in rural areas

Unlike most developing countries where the grid extension has been the preferred mode of electrification, China has experimented with alternative strategies. Pan et al. (2006) report that rural electrification relied on three modes of delivery: local grid-based, central-grid based and a hybrid system of local and centralised grids. Local grids played an important role in areas with large hydro potential where county water bureaus or small hydropower companies are responsible for electricity supply. However, the dominant mode of supply

[6] This is calculated from the China Statistical Yearbook 2010 data.

[77] Based on China Statistical Yearbook 2010 data.

remains the extension of central grid (about 2/3rd of the counties relied on this as per Pan et al. (2006)) but due to high cost of transmission and high losses of this mode, rural consumers either face shortages or are unable to afford electricity from the grid. This has also prevented the development of local resources in these areas. The third mode (i.e. a hybrid system) is used in areas where hydropower is inadequately available to meet local demand. ESMAP (2000) noted that the delegation of electricity provision to local power companies in the first instance and then integration of the local grids to the central system has allowed the Chinese system to accomplish a higher rate of access.

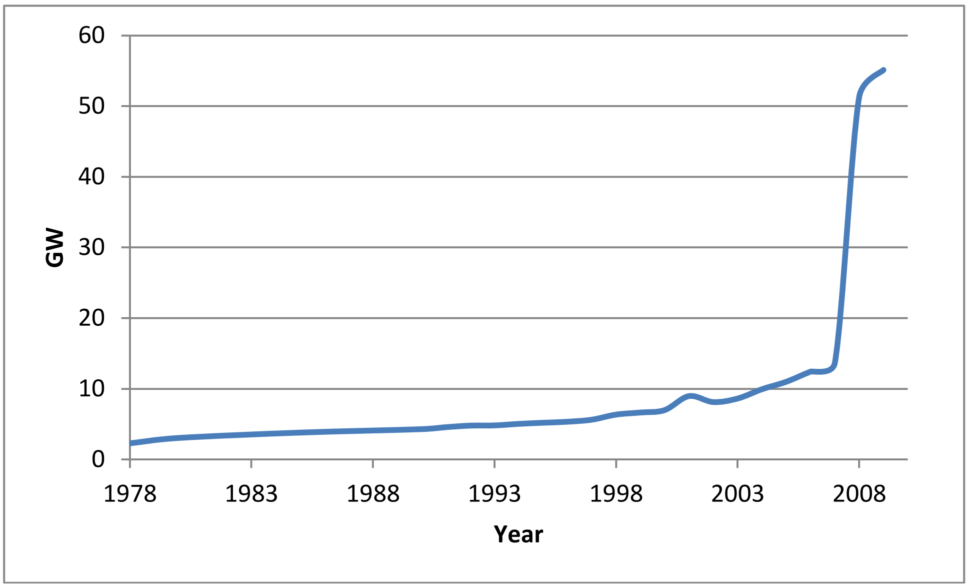
The Chinese strategy for rural electricity supply has focused on a number of energy sources:

a) **Small hydro power**[8] – Hydropower has played an important role in the electrification of rural China since the first phase of its development (i.e. in the central plan period). The self-reliance policy during the central planning period and the policy of empowerment of rural population through utilisation of local resources in the reform era stressed on small hydropower development. Small hydro power (SHP) served multiple purposes – produced electricity, provided irrigation water and supplied drinking water in rural areas. It also offered environmental benefits through reduced firewood dependence. Small hydropower incentives in terms of reduced VAT rate and state investment funds were provided to make this a success. This helped resolve the power supply problem in many areas and small hydropower accounts for more than one-half of the local generating capacity (Pan et al., 2006). The growth in hydro capacity for rural energy supply is presented in Fig. 4.[9] The rapid growth in this area can be attributed to, among others, a decentralised approach, reliance on special policies and strategies, manufacturing capabilities, and a close co-ordination with rural electrification programmes (Hicks, 2004). However, SHP was not always the cheapest option because of high initial cost for small plants, subsidised supply of other energies, and high per kWh cost due to limited electricity supply due to hydrological factors (Hicks, 2004).

Fig. 4: Rural hydro capacity (GW)

[8] The definition of small hydropower (SHP) has evolved over time – in the 1950s, stations below 500 kW were considered as SHP. In the 1960s, the size increased to up to 3 MW. The size was increased to 12 MW then and now up to 25 MW stations are included as SHP (Hicks, 2004). This adds to the data consistency issue as well.

[9] A sharp increase in capacity is shown in the diagram since 2007. IEA (2010) also confirms the overall capacity at 51 GW. This change may be due to a change in the definition that increased the size of hydro plants to 50 MW from 25 MW used earlier.




Source: Chinese Statistical Yearbook, 2010.

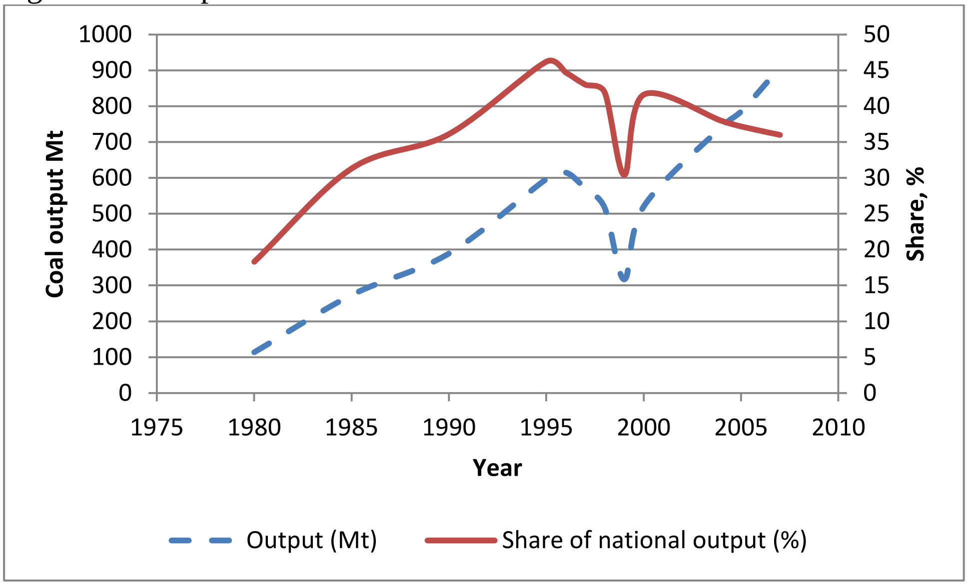
b) **Small coal mine development** - Because of widespread availability of coal, China followed a policy of small, local mine development policy with an objective of reducing rural poverty. Small-scale coal mines are found in all provinces of China and these were developed since 1950s but the big push came after the economic reform when the demand for coal increased. The average output of these mines can be as low as 4000 tonnes per year to 25,000 tonne per year, while the largest ones can produce as much as 100,000 tonnes per year (Andrews-Speed et al., 2003). These mines were promoted in the 1980s to avert the severe energy crisis China was facing in the period of economic reform. They were owned by provincial government in general and were a major source of employment (Andrews-Speed et al., 2003). These mines enjoyed a number of cost advantages (Zhu and Cherni, 2009) – their cost of production was low as they extracted coal from shallow seams; they paid low wages to miners; they were subjected to less tax payments and social burdens; and they hardly invested on safety and environmental protection. Zhang et al (2009b) suggest that in 1996, there were 73,000 Township coal mines in the country that employed 20 million people. The price liberalisation of coal also gave a further boost to these mines and by 1995, they produced about 45% of the national output (see Fig. 5). But recently, the government has imposed a ban on these mines to reduce safety hazards and environmental degradation. Even then, 13,900 non-state mines were operating in 2007 and produced 908 Mt of coal, which represented 36% of national coal output (Zhang et al, 2009b).

c) **Development of modern renewable energies**: This is a new initiative to use modern renewable energies like wind and solar power. Although these energies have been emphasised since 1990s, serious efforts have been made in the new millennium to promote modern renewable energies such as solar PV, and wind. China relied on three specific approaches – small- and micro-hydro was used where hydro potential exists; mini-grids and village networks using renewable energies were developed in areas with "clustered households and township infrastructure" (Zhang and Kumar, 2011). In remote areas, off-grid technology options were used.

It must be mentioned here that biomass plays an important role in rural energy supply in China but instead of traditional burning, bio-gasification has been promoted widely in the

1980s, making China the world leader in biogas production (Zhang et al 2002). As biogas is mainly used for heating and cooking, it is not considered here.

Fig. 5: Coal output from small rural mines in China




Data source: Zhang et al (2009b).

### 2.3.2 Off-grid or decentralised electricity supply

Although the main emphasis was on grid-based electrification, China has also undertaken a number of off-grid initiatives to provide electricity access, especially in remote locations where grid extension is difficult. Zhang and Kumar (2011) indicate that the cost of grid extension in western or north-western China has been reported to range between $5000 and $12,750 per kilometre, making the option uneconomic. Therefore, to reach the population in these areas, China has initially launched the Brightness Programme in 1996, which was then scaled-up to include 1065 townships in 12 provinces under the name of Township Electrification Programme. In addition, various bilaterally and multi-laterally assisted programmes were also undertaken (See Shyu, 2010 for more details) to promote rural energy supply through renewable energies.

Stand alone systems have been mainly used in remote areas of North and Northwest China and include provinces such as Gansu, Inner Mongolia, Qinghai and Xinjiang. Photovoltaic systems are being used in these areas since mid-1990s. Three different types of supply mechanisms of PV exist in these areas: 1) Distribution companies that procure major components from manufacturers directly; 2) Small assembly shops selling directly to installers, and 3) Retailers directly selling to end users (ESMAP 2000, p. 27).

Initially state enterprises were involved in the business and systems were sold with a large subsidy component. However, the subsidies were removed or reduced and many small companies have entered the market to sell the products on a commercial basis.

Wallace and Tsuo (1997) report the PV-based electrification initiatives undertaken in co-operation with US Department of Energy in western China. They report that in 1995, the PV installed capacity in China was 6.6 MWp, 65% of which was for telecommunication applications, 16% for household electrification, 11% for agricultural and industrial applications while remaining 8% was for consumer applications.

In Inner Mongolia Autonomous Region (IMAR) small wind generators (100 to 300W) have been used in more 120,000 households for providing electricity by 1994. Similarly, more than 7000 small PV systems have been installed within that period. Wallace and Tsuo (1997) report the result of the levelised cost study undertaken for the region by CEEP (University of Delaware) and indicate that the cost of small wind-based electricity was lower than PV/ Wind hybrid systems and much lower than that supplied from the gasoline generator sets. A similar analysis is reported by Byrne et al (1998) but indicates that the PV-Wind systems represent a cost-effective option for the IMAR region.

Wang (1998) reported that remote areas of North and Northwest were the target regions for SHS installation. China imported production lines from USA, Canada and other countries since 1983 and by 1996, China had a PV manufacturing capacity of 5 MW per year. 30,000 households installed the systems. The government provided subsidies but this accounted for only 5 to 150 of the costs. Only those with a high income level could afford to own a SHS with the subsidy. Moreover, as the users are less knowledgeable and less educated, the systems were operated and maintained poorly, limiting the life of the systems and producing poor experience.

The size of the PV systems used in these areas is generally small: 10 to 20- watt systems were used for catering to the lighting needs and powering television or a radio-cassette player. Only a few larger systems were used of 50-75 watt size. However, the consumers were not always happy with the system performance and servicing of the systems. In recent times, the average size of the modules has increased: according to World Bank (2009), between 2002 and 2007, the average size has increased from 20 Wp to 45Wp.

A recent report, World Bank (2009) provides further details about the renewable energy development in China. It claims that more than two million people in western China are receiving electricity through PV systems. Between 2002 and 2007, companies have reported a total sale of more than 0.5 million PV systems with an aggregate capacity of 11.5 MWp. Four provinces account for the majority of these sales: Tibet, Qinghai, Sichuan and Xinjiang. The annual sales and PV system costs are indicated in table 1.

Table 1: Annual PV sales and costs in China

| Year | Sales | | PV system costs | |
|---|---|---|---|---|
| | Annual (MWp) | Cumulative (MWp) | Per year (million US$) | Cumulative (million US$) |
| 2002 | 0.80 | 0.80 | 6.6 | 6.6 |
| 2003 | 0.90 | 1.70 | 7.5 | 14.1 |
| 2004 | 1.73 | 3.43 | 14.3 | 28.4 |
| 2005 | 2.68 | 6.11 | 22.2 | 50.6 |
| 2006 | 2.45 | 8.57 | 20.3 | 70.9 |
| 2007 | 2.50 | 11.07 | 20.7 | 91.6 |

Source: World Bank (2009).

China is the world's third largest producer of PV modules with a production capacity of 2800 MWp in 2007 systems. The unit price of a 20Wp system has declined in dollar terms to $9/ Wp in 2007 from $16/ Wp before the project.

The renewable energy-based electrification raised a number of issues (Zhang and Kumar, 2011):

a) first, the inability of the present system to support power needs other than basic lighting and telecommunication. Other productive uses of electricity that will bring income generating opportunities cannot be supported by the present system and therefore larger systems will be needed to maintain this. There are also concerns about future demand growth and the ability of the system to meet the demand in the long-term;
b) second, instead of optimising the use of local energy sources to meet the demand, a fixed configuration was used, which neglected the appropriate use of local resources.
c) Third, weak quality management systems led to poor system performances, including black outs. Poor production quality management as well as lack of commissioning checks and supervision has affected the performance of renewable energy systems. The problem worsens when the above is coupled with the neglect of proper operation and maintenance at the village level.
d) Fourth, the "confused ownership" of the systems, especially those funded through grants or donor support, hindered proper management and operation of the systems.

e) Finally, there are tariff related issues as well. The tariff-setting process and its collection are haphazard, and the tariff is often inadequate to meet the expenses. There are also issues related to the availability and flow of subsidies.

Byrne et al. (2007) suggested that the removal of such barriers will require a "multidimensional response, including policy and institutional reform, market development, new financing initiatives and a concerted outreach and training effort."

## 2.4 Organisational arrangements for and governance of rural electrification in China

As indicated above, the organisational arrangement for rural electrification has changed significantly over the past fifty years[10]. Yet, the country still follows three levels of management – central government, provincial government and county or village level committees. At the Central level, traditionally a multitude of organisations have played a role but the Ministry of Agriculture and the State Planning Commission (or its new avatar National Development and Reform Commission, NDRC) have always played an important role. In general, all programmes require NDRC approval. The provincial level management caters to the province level efforts but also supports the county level management in achieving the central government objectives. The county level management is responsible for the local-level decision-making about financing, resource mobilisation and operation of the systems (Catania, 1999).

However, during the first period of rural electrification, there was no national entity responsible for rural electricity system management or development (Pan, 2002). The role of local government was strengthened in the era of reform, when the central government transferred the responsibility of rural electrification to local governments. However, the tariff-setting power was still with the central government and in the mid-1980s, a policy of dual tariff system was introduced whereby old plants get old tariff while new plants are allowed new tariff (Pan, 2002). This was done to encourage new investment in the sector. Management through the decentralised local governments was a main driving force behind the success of rural electrification in China (Pan et al., 2006). Each county created a rural electrification leading group led by the local chief administrative officer (county governor) to take important decisions on rural electrification investments and operation. However, the distinction between the utility function and the local governance function was non-existent, which in turn led to performance-related issues subsequently.

Due to the clash of interests and power tussles between the central government and local governments experienced towards the end of the 1980s and early 1990s which posed a great threat to the rural electrification drive of China, the central government took over some responsibilities and powers hitherto devolved to the local governments during the transition era 1980 to 1992. The period 1993 to 1998 ushered in another wave to institutional restructuring towards re-positioning the central government to effectively control the production and consumption of energy in the nation's economy. Here, the Ministry of Energy was broken up, and in its place, the State Economic and Trade Commission (SETC) was established, while the State Planning Commission (SPC), currently the State Development Planning Commission (SDPC), and Ministry of Coal Industry and Ministry of Electric

[10] See Zhao (2001) for a detailed account of the organisational changes in the energy sector.

Industry (MEI) were re-established (Zhao, 2001). Though existing Ministries and Government Corporation were equally expanded and strengthened during this era, and controls over investments, consolidated by the central government, there was the challenge of effective coordination of these agencies and duplicity of policy implementation, which triggered criticisms amongst energy experts in China.

The re-organisation and reform of rural electrification in the third phase tried to address this issue by separating the responsibilities and introducing service or utility companies in rural areas. This commercialisation process has helped improve the performance of the sector significantly, by removing inefficiencies and bringing role clarity. However, issues related to asset ownership cropped up, as the collective assets held by the counties had to be transferred to companies that may be privatised in due course.

In the case of decentralized electrification, the project implementation is done through competitive bidding. State companies, private entities and former state companies as well as start-ups participate in these activities. The National Energy Administration (NEA) normally deals with the planning related to rural electrification.

## 3.0 Financing of rural electrification in China

This section aims to answer the second question related to financing of rural electrification in China. We cover all three phases of the electrification process below, although more information is available on recent efforts.

Rural electrification projects in China are usually not financed by market mechanisms; rather, they are financed by government or with the help of international funding. The Chinese government has over the years provided specific low interest loans for rural energy development. For example, loans granted for the execution of large and medium biogas projects, wind and solar projects by the government all have interest rates which are almost half the interest rates obtainable on similar projects at a commercial rate. Although, the commercial banks are seen to be largely involved in providing private sector lending to the Chinese public, they have not been very active in providing finance to rural energy projects. The reason for this is the high risk and low profit margins that may be associated with these energy loans. With a developed rural banking infrastructure, the links between these banks and the rural energy renewable sector in supporting some of these rural projects is still weak.

### 3.1 Financing of rural electrification in the Maoist era

During this phase of centrally planned economic development, China faced severe financial constraints due to its isolation from the rest of the world. The self-reliant policy left the burden on the local communities and governments to fund any investments, with limited or no central government support in most cases. Local communities also provided labour or in-kind support but the asset ownership rested with the local governments (Pan et al., 2006).

In the 1960s, the government adopted an equal share policy where the central government and the lower level governments will take equal shares in hydropower development. Generally the village communities provided the labour while money came from the government. The return on the investments were re-invested in the sector itself, thereby allowing further expansion of the system. Moreover, during this decade, the central plan allocated funds for developing rural grids to improve safety and reliability of the system. This was the first significant state investment in rural electricity infrastructure, which subsequently set in competition between large state grids and local grids.

The Chinese government formulated some policies during the 1970s such as the rural electrical irrigation and agricultural production programme, electricity revenue for electricity policy geared towards hydroelectric power projects, as well as national subsidies at 20 percent of the cost of construction, but, investments in rural energy projects during this era were solely carried out by counties and local communities without much support from the central government. The asset ownership rule was clarified in 1973 – investor is allowed to own and operate the asset. This policy encouraged investors to invest in hydro projects (Pan et al., 2006).

### 3.2 Financing of rural electrification in the reform era

The source of funding changed during this period when more government funds were allocated to rural electrification. The government arranged funds from the Agricultural Bank of China for rural grid construction and transformation. In addition, grants, loans, in-kind contribution are also available. In 1987, the government created a special interest-bearing loan for rural electrification which was used for large biogas plants, solar thermal and small-scale wind projects. The interest was 50% subsidized by the commercial bank.

But the decentralized electrification was either fully financed by the central government or through a cost-sharing scheme where the provincial government contributes a share. The Township Electrification Programme which supported off-grid electrification in 11 provinces was a joint financing scheme where the share of central contribution was determined by the level of socio-economic development. In certain provinces, 100% central contribution was available (e.g. Tibet).

However, this era also witnessed some challenges as local authorities invested only a fraction of revenues on energy projects and looked up to the central government for financial assistance and credit towards bridging the gap in energy supply. This period also witnessed various energy fees and taxes on industries, as well as increased the rents on land and other services. These led to frictions and clashes of interests between the central government and the local authorities. More so, there was an increase in the financial deficit of the central government due to the rising tax regimes imposed by the local governments, which led to a reduction in the central government's control of resources, further deepening the friction and power tussle between the federal government and the component units.

### 3.3 Financing in recent times

In the third phase, the government invested heavily in improving the network system and also to provide access in the remote areas. The government invested RMB 230 billion (or equivalent to £23 billion) in the Rural Power Grid Restructuring project between 1998 and 2003 (Wang et al, 2006). 20% of the investment came from the central government while the rest came from the preferential loans from development banks and locally matched finance (Wang et al., 2006).

An investment of RMB 9.88 billion (or equivalent to £1 billion) went into the Brightness Program, whereas RMB 4.7 billion (or £.5 billion) was invested in the Township Electrification program (Wang et al., 2006). RMB 2.96 billion (or £0.3 billion) came from the central government while the rest came from local governments (Wang et al., 2006).

Clearly, the state participation has played a vital role in extending the electricity access in China, although community contribution in the process was crucial as well.

## 4.0 Critical success factors of China's electrification and lessons for others

This section answers the third question and is organised in two parts. The first part identifies the critical success factors of Chinese electrification and is followed by a discussion on lessons for other developing countries.

### 4.1 Critical success factors

China's success in providing electricity access to its entire population remains one of the inspirational stories for the rest of the world trying to achieve the same feat. A number of critical success factors can be identified from the Chinese experience and are discussed below.

a) **Bottom-up approach to electrification** – Unlike other developing countries that followed a top-down approach to electrification, China has relied on a bottom-up approach, where the local level administration and participation was responsible for the local solution. The approach allowed flexibility and was anchored in self-reliance. Although it may be argued that this started not as a deliberate policy innovation as such in a politically isolated country in its initial days but as a desperate, last resort option of some sort, the credit still goes to the country for retaining this decentralised approach in an otherwise planned, command-oriented economy. This is echoed in IEA (2010) which attributes the success of electrification to the pragmatic approach which allowed local level administrative responsibility of the projects while retaining the overall programme planning at the central level. Government's commitment to the programme was crucial for its success.

b) **Phased approach to development** – Alongside the decentralised approach to electrification, China also recognised that the rural electricity systems are essentially different from the urban ones due to the difference in demand patterns. Consequently, the establishment of local grids at the village or community level initially followed by an upgrading of the system to link to the regional or national network proved to be a pragmatic approach. This placed the onus of initial demand creation on the local communities and because of the "self-reliant" supply policy, they were also required to develop a suitable system. The expansion and upgrading of the system at a later date proved less challenging due to better financial and economic standing of the country.

c) **Early recognition of rural electrification-rural development link** – While most other countries have taken up electrification as a social policy objective of the government, China recognised that rural electrification and rural energy supply is closely linked to rural economic development. Its focus on agricultural development in the planned economy phase and on TVE in the reform era clearly highlights this recognition. World Bank (1996) attributes the success to rural development initiatives that have transformed the rural economy and thereby increased rural income greatly. Yang (2003) and Peng and Pan (2006) also suggest that the decentralised, local level management of rural electrification initiatives and the emphasis on rural development through agricultural activities, town and village enterprises and poverty reduction programmes were also responsible for the success of the country. Dollar (2008) pointed out that with sustained economic growth China has been successful in reducing its poverty from over 60% in 1978 to 7% in 2007. He attributes this to a liberalised agricultural sector, existence of a vibrant private sector, and infrastructure pricing based on cost –recovery principles. China Statistical Yearbook (2010) indicates that in 2009, only 3.3% of the rural population had an annual income per person less than 1000 Yuan (or £100 per capita income per year) while in 1990 the share was 82.3% in 1990. About 53% of the rural population had a yearly income between 1000 and 5000 Yuan per person (or between £100 and £500) in 2007 while the rest (about 44%) had an income above 5000 Yuan per person per year (or above £500). This shows the change in the economic conditions of the rural habitants. As a consequence, the holding pattern of durable goods has changed dramatically. For example, in 1990, air conditioner was not at all used in the rural areas but in 2009, 12.2 units of air conditioners are found in every 100 households. Similarly, the number of washing machines and refrigerators has multiplied manifolds: in 1990, only 9.1 and 1.2 units respectively of washing machines and refrigerators were found in every 100 households while in 2009, the number has increased to 53.1 and 37.1 respectively (China Statistical Yearbook 2010).

d) **Organisational arrangements** – The hierarchical organisational arrangement with devolved powers and responsibilities at the lowest level and the central administration setting the overall programme objectives have also helped in implementing the programmes successfully.

e) **Pilot projects and capacity building** – China used pilot projects to gain vital information before implementing it on a large scale. This small-scale experimentation has allowed programme adjustments and helped the country to direct resources where necessary. In addition, the emphasis on training and capacity building, standardisation and dissemination has helped in spreading the knowledge widely across the country. The development of a cadre of skilled technicians and project staff and the performance improvement through feedback loops were also essential factors.

f) **Technological flexibility** – Because of emphasis on local resource utilisation, China allowed selection of locally-relevant energy sources and as a consequence allowed technological diversities to co-exist. Although the main emphasis was on small hydropower and coal initially, there was never a "single solution fits all" approach. Technological flexibility has also allowed local resource utilization and avoided highest cost options for difficult locations. The sense of local ownership has also ensured success of projects in remote areas.

g) **Local manufacturing base** – China's strong manufacturing strength has also helped in reaching the rural areas. The country has developed a strong manufacturing capacity in hydropower equipment, biogas and even in modern renewable energies. Continued growth in demand and consequent exploitation of scale and scope economies have resulted in lower supply costs, making supply more affordable. Moreover, local supply also reduced external dependence and project completion time.

h) **Funding arrangements -** Peng and Pan (2006) argue that funds for rural electrification flowed from central and local governments and even local residents participated in providing funds. Strong state support and the ability to engage the local communities to the creation of local infrastructure have surely contributed to the success. Dollar (2008) indicates that although the state invested in creating the infrastructure, the pricing system ensured almost full cost recovery, which in turn allowed future sustainability of the system. He points out that increased private participation also supported this growth and in fact, cost recovery allowed domestic private sector to achieve a significantly better financial result. In fact, China has avoided the trap of high electricity subsidy syndrome noticed in many South Asian countries.

i) **Policy influence** - Yang (2003), and Zhang and Heller (2004) suggest that the central government policies played an important role in promoting rural electrification. This is evident from the review of the electrification process presented above.

However, China still faces a number of problems despite achieving 100% electrification. Gao and Luo (2009) indicate that the investment in transmission and distribution networks lagged behind that for power plants, which created network inefficiencies and bottlenecks, especially when the rural demand is growing fast. Moreover, the regional imbalances in terms of electricity use and access continue. Zhang et al (2009) reported that the asset ownership has not been clarified in many cases and although the Provincial Power Grid Company is investing heavily in the county-level grids, issues such as responsibilities and right, asset cross-over, profitability of assets, property right, liabilities for loans, etc. still continue to bother the system. Evidently, the path dependence and lock-in effects are important to consider so that a proper transition can be easily made.

Rapid electrification has led to tariff inconsistency, overlapping responsibilities, and poor technical quality of supply. For Brightness Programme/ Township Programme, the use of inappropriate materials/ designs has resulted in a high rate of system malfunctions. For Township programme, issues like transfer of ownership, management and maintenance of systems, financial support for the long-term and tariff in the future etc. are not clear. Similarly, as small capacities suitable for limited level of applications are used, the long-term needs are unlikely to be satisfied. Because some technologies were never deployed in a large scale, their long-term future is unknown (IEA, 2010). Further, the subsidised systems have not always benefited the poor who cannot afford the services and who could not replace the capital assets at the end of life (Mohanty, 2010). The increase in demand is putting pressure on subsidies and there is no mechanism for determining the real cost of off-grid electrification.

Simultaneously, despite its reliance on a bottom-up approach to development, it is not really evident that the Chinese electrification programme has achieved local resource integration for power generation in an effective way. Although the focus has been on hydropower, coal and biogas development traditionally and of late on modern renewable energies (such as wind and PV), there is no evidence to show that the electrification programmes really considered the resource potentials and opted for the most economic options. In fact, in the early days the focus on self-reliance actually led to de-forestation due to over-exploitation of biomass resources. There is still potential for an integrated rural energy development to ensure long-term security and sustainability of supply.

## 4.2 Lessons for others

Clearly, China's success in providing electricity access to its population is an inspiration for all other developing countries that are trying to achieve universal electrification. A number of lessons can be learnt from the Chinese experience and are summarised below:

a) **Strong commitment** – Any ambitious programme requires a strong government and stakeholder commitment. The key success factor in the Chinese case was the strong central government commitment to rural electrification. The Central support was essential for developing programmes, providing directions and for funding. Surely a strong political power system in China helped such a strong control over the programmes, which may be difficult to replicate in more democratic systems, although examples of strong policy-making systems exist in other political systems.
b) **Active local participation**: Rural energy and electricity supply requires active local involvement and participation. Programmes are likely to work better when there is

strong state support in terms of finances and design, but are implemented through local buy-in and participation. This however requires a strong local level governance mechanism that has close links with other levels of the governance. The Chinese experience shows that local level systems can be created through local contributions and support.

c) **Multiple solutions**: As each rural area has its own specific characteristics in terms resources, economic activities, geography, etc., one solution does not fit all. Although grid extension has been the most common approach in China to ensure electricity access, the reliance on multiple technologies and multiple systems simultaneously has proved to be effective. The use of local level grids initially to provide supply by using locally available resources and then building a network of local to regional to national grid can be an alternative approach to electrification compared to the standard approach of heavy reliance of extending the grid alone.

d) **Rural development**: Electricity or energy provision cannot be divorced from the rural development agenda. The development of agriculture and TVE confirms that only when rural population has access to economic activities to earn a decent living, rural electrification succeeds. The rejoins the issue of proper selection and clustering of activities in each area or community considering its specific characteristics.

e) **Local capacity building** – Success also depends on learning from the small scale experiments (pilot projects) and learning from others. Simultaneously, training and capacity building for designing, operating and maintaining systems is essential. Even a village-level project remains technically demanding and without proper training and capacity building, such systems cannot be effectively run. Moreover, standardisation of systems and enforcement of quality and safety aspects are crucial for a reliable and safe supply.

f) **Consideration for environmental issues** – The Chinese example also suggests that local environmental issues related to rural electricity development cannot be neglected. Although China promoted small hydro power, yet unplanned development of this resource can have significant environmental impacts. Similarly, small-scale coal mining has damaged the environment and is responsible for fire and flooding hazards. It is appropriate to consider these issues at the time of planning and development.

## Conclusions

The Chinese model of electricity access provision is a pragmatic approach that has evolved over the past sixty years as it passed through the command-and-control era to a more market-oriented economy. Obviously, the strategy required several adaptations and adjustments - starting from a locally-developed, locally managed programme using local resources the strategy moved to a combination of central grid extension and use of local grids and finally to off-grid solutions, with strong state support. But it appears that the approach has clearly tried to make best use of available resources and opportunities, keeping the constraints in mind within which the country had to operate at different phases of its development. Thus, the self-reliance approach of the Maoist era with an emphasis on the mobilisation of local level resources for electricity supply mainly for agricultural purposes, or the dual approach of grid expansion coupled with local grid based supply in the reform era was trying to find local answers to the problem that suits the local context. But a strong commitment of the central government and its financial support, especially in the later halves of the development, has produced the result.

At the same time, a better articulation of the electricity access issue with rural development firstly through a link with agriculture and subsequently through the TVE was a key to the success as well. While other countries have struggled to achieve this balance, China has succeeded in doing so effectively, and often without introducing distorted incentives such as heavy reliance on subsidies. Additionally, the idea of developing local grids first and then attempting an integration worked well, as it allowed demand creation using appropriate small-scale systems, which could be either upgraded or connected together to form a regional network. Although the issues of non-standard supply, weak networks and high power losses emerged as a consequence, the benefits of the phased approach to development appear to have exceeded the costs, because of rapid reduction in the number of people without electricity. While further work is required to ascertain whether the Chinese model can be replicated elsewhere or not, it surely serves as an inspiration for the rest of the world. Surely, all developing countries can learn lessons from the Chinese example.

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# OASYS South Asia project

The Off-grid Access Systems for South Asia (or OASYS South Asia) is a research project funded by the Engineering and Physical Sciences Research Council of UK and the Department for International Development, UK. This research is investigating off-grid electrification in South Asia from a multi-dimensional perspective, considering techno-economic, governance, socio-political and environmental dimensions. A consortium of universities and research institutes led by De Montfort University (originally by University of Dundee until end of August 2012) is carrying out this research. The partner teams include Edinburgh Napier University, University of Manchester, the Energy and Resources Institute (TERI) and TERI University (India).

The project has carried out a detailed review of status of off-grid electrification in the region and around the world. It has also considered the financial challenges, participatory models and governance issues. Based on these, an edited book titled "Rural Electrification through Decentralised Off-grid Systems in Developing Countries" was published in 2013 (Springer-Verlag, UK). As opposed to individual systems for off-grid electrification, such as solar home systems, the research under this project is focusing on enabling income generating activities through electrification and accordingly, investing decentralised mini-grids as a solution. Various local level solutions for the region have been looked into, including husk-based power, micro-hydro, solar PV-based mini-grids and hybrid systems. The project is also carrying out demonstration projects using alternative business models (community-based, private led and local government led) and technologies to develop a better understanding of the challenges. It is also looking at replication and scale-up challenges and options and will provide policy recommendations based on the research.

More details about the project and its outputs can be obtained from www.oasyssouthasia.dmu.ac.uk or by contacting the principal investigator Prof. Subhes Bhattacharyya (subhesb@dmu.ac.uk).

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