

Review

Experiences and lessons from China's success in providing electricity for all

Gang He^{a,*}, David G. Victor^{b,c}^a Department of Technology and Society, College of Applied and Engineering Sciences, Stony Brook University, Stony Brook, NY 11794, USA^b School of Global Policy and Strategy, University of California, San Diego, La Jolla, CA 92093, USA^c The Brookings Institution, 1775 Massachusetts Ave, NW, Washington DC 20036, USA

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ABSTRACT

In 2015 China provided access to electricity to its entire population—the first of the large emerging and developing countries to achieve that landmark goal that most advanced industrialized countries met decades earlier. We found some key experiences and lessons to be learned from China's successful program to provide electricity for all. Substantial funding from the central government, delivered by mechanisms sensitive to local provincial needs, were essential to success. Also vital was use of off-grid solar home systems for the most remote users for whom grid connection would be quite costly.

1. Introduction

Energy, electricity in particular, is vital for development. The industrialized countries largely achieved full access to electricity for their populations between the 1950s and the 1970s, but developing countries are understandably still lagging behind (Fig. 1) (GEA, 2012). In total, today 1.2 billion people still lack “electricity access”—meaning the ability to obtain electricity at the household level—and another roughly 1.5 billion people have unreliable service (IEA, 2015). Without fixing the access problem many other elements that are essential to human development—such as providing modern public health services and access to information and narrowing the digital divide—are more daunting to solve (Cameron et al., 2016; World Bank, 2016). For these reasons there have been many initiatives—such as the United Nations' “Sustainable Energy for All (SE4All)”, the World Bank's “Lighting Africa” and the Clean Energy Ministerial (CEM) Global Lighting and Energy Access Partnership, aimed at providing ubiquitous electric power service (United Nations, 2012).

These efforts stand to learn a lot from China, which in 2015 became the first large emerging economy to achieve full electricity access. Indeed, China's success in providing electricity to 900 million people between 1949 and today stands out as, numerically, the most impressive achievement in the history of electrification (Bhattacharyya and Ohiare, 2012; Luo and Guo, 2013; Pereira et al., 2011).

While every country is different, success in China offers insights and warning signs for the ambitious global effort to provide reliable electric power service promptly to the entire human population. First, the Chinese experience suggests that the state is indispensable. Full electricity access required central government leadership, funding and

support—in China, about 20% to 80% of the total cost depending on the local conditions—but that state intervention was effective only when coordinated with local authorities and providers for implementation. Second, unlike in the advanced industrialized countries whose electrification programs were achieved nearly completely through grid extensions, it is now possible to use off-grid systems effectively. Most of China's electrification happened by extending the grid, but when the country made its last big push to providing electricity to a few million of the most remote populations it relied on off grid systems for about half the effort—notably with small solar photovoltaic (PV) systems. Third, the Chinese experience reinforces what has been known for a long time in other settings—electrification yields empowerment, economic growth, improved public health, and other benefits.

China has addressed rural electrification on two distinct waves of effort. The first, which was synonymous with economic development of the country, ran through the late 1990s and resulted in China enabling electricity service to 97% of the population (Bhattacharyya and Ohiare, 2012). About four-fifths of the rural population gained access through extension of the power grid while the rest were electrified by interconnecting small hydro and small (< 50 MW) coal-fired plants into local and regional grids (Peng and Pan, 2006). The second front of effort, to provide electricity for the last 3%, was much harder and offers perhaps the lessons of greatest relevance to other countries that are struggling to sending electricity to remote, poor populations. In this end game for remote rural electrification China made notably advances by extending and renovating rural grids (Peng and Pan, 2006). But grid extensions could not reach everyone in a cost-effective manner, which is why in 2012, the central government released its *Electricity for all three-year action plan (2013–2015)* that outlined a plan to assure

* Corresponding author.

E-mail address: gang.he@stonybrook.edu (G. He).

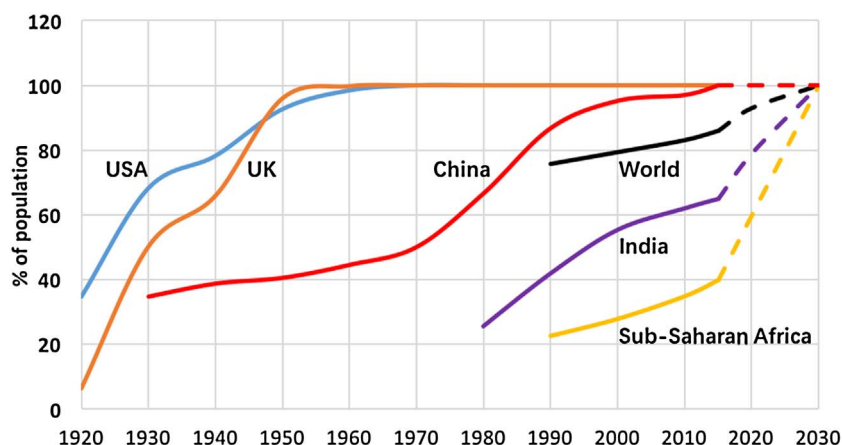


Fig. 1. The many paths for full access to electricity. Solid lines are historical data; dotted lines are projections consistent with the SE4All goal of complete electrification by 2030. Sources: IIASA(GEA, 2012) (USA, UK, India) and World Bank Data (World Bank, 2015).

electricity supply to the last 2.73 million people (NEA, 2015). Success on this last front is what has allowed China to declare full electrification in 2015; China has notorious problems in the reliability of its statistics, there are numerous sources of corroborating information to confirm that this achievement is genuine (World Bank, 2015).

2. Lessons learned from China's final push

What can the rest of the world learn? We suggest three lessons from China's final, successful effort to electrify.

2.1. First, coordination between central and local governments and other stakeholders is essential

As in many countries, the central government has made electrification a priority but that government, acting alone, could not implement the needed investments nor manage these highly decentralized infrastructures. In China, that challenge was addressed by the central government leading and investing with extensive local coordination for implementation. Provincial governments offered information about local conditions and coordinated project implementation; some ran experiments to test different ideas and technologies since the best strategies for ubiquitous electrification were hardly obvious (NEA, 2013). For example, they obtained detailed information about which households lacked electricity as well as local environmental and socioeconomic conditions essential to selecting the right technologies.

The central government also sat at the center of vital cost sharing schemes. For example, during 2013–2015 the central government allocated 24.8 billion RMB (~4 billion USD, all conversions are based on historical exchange rate) investment for grid extension and small off-grid solar photovoltaic (PV) systems. Of that total, roughly 60% (14.6 billion RMB) actually came from the central budget while the rest was mainly provided by state owned power enterprises and local governments. Central and local governments also experimented with ways to rely on private firms to fund and implement PV projects. That revenue sharing approach varied with the province. For example, the central government paid a larger share (80%) of the investment in Xizang (Tibet) where economic status is the poorest among those focus areas and sensitivities around the success of development projects was particularly high (Fig. 2).

It is widely known within the debate over how to assure electricity to the entire global population that governance must be shared between central, regional and local authorities. What's important to learn from the Chinese approach is the indispensable role of reliable funding—in China's case, from the center although in other countries different governing authorities may prove more reliable—along with the importance of guided experimentation and learning.

2.2. Second, selection of appropriate technologies to fit local situation and demand

In the final push (2013–2015) roughly half of the electrification occurred through grid extension while the other half deployed off-grid solar PV. Grid connection offered more reliable service, but for the most remote users this option has proved expensive and less flexible. Through experimentation the central government and agencies responsible for electrification learned that grid connection costs could be as high as 100,000 RMB (~16,000USD) per household, depending on the distance to the nearest substation or connection and the local situation for grid expansion. Distributed solar PV at 0.5–1 kW per household offered better system reliability, but those micro-grid systems were also costly—averaging 9000–20,000 RMB (~1400–3200 USD) per household. Individual solar PV at 0.3–0.4 kW per household was the cheapest option, averaging cost 7500–11,200 RMB (~1200–1800 USD) per household. As a rule of thumb, where local households were highly dispersed—less than 20 households per square kilometer—individual solar PV was preferred (NEA, 2013). Providing such households with grid service—via grid extension or through micro-grids—was prohibitive as it was costly to assure power quality and voltage support on such thin networks. Yet households prefer grid service—absent considerations of cost—because it is easier to scale power demand and grids are thought to be more reliable. This suggests that connection of the most remote households involves major tradeoffs between power quality, level of supply and cost. Continued improvement in remote off-grid systems may lessen those tradeoffs to some degree—allowing for greater power service at higher quality (Alstone et al., 2015).

In other countries, a central challenge for off-grid systems has been ongoing maintenance costs. China addressed that problem by covering them with the nation-wide renewable energy fund that collected from all electric bills at 1.5 cents RMB per kWh and raised to 1.9 cents RMB per kWh in 2016 to match the fund gap created by soaring renewable generation. In areas that were prohibitive to serve with any system—grid extension or off-grid—the government actually moved people to more hospitable geography.

2.3. Third, embedding electrification into overall social economic development

As in the U.S. and other mature industrialized countries that made electrification a national mission, China's electrification was embedded in the country's poverty eradication strategy, mainly through the "Infrastructure to Every Village Project" which provides power, roads, water, drinking water, phone, cable, and internet to the rural area. Electrification is used to facilitate rural economic development and raise the income of rural population, which in return promotes the use

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