Experiences and Lessons from China's Success in Providing Electricity for All *

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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.

Keywords: Electricity for all; Energy access; China; Experiences and lessons

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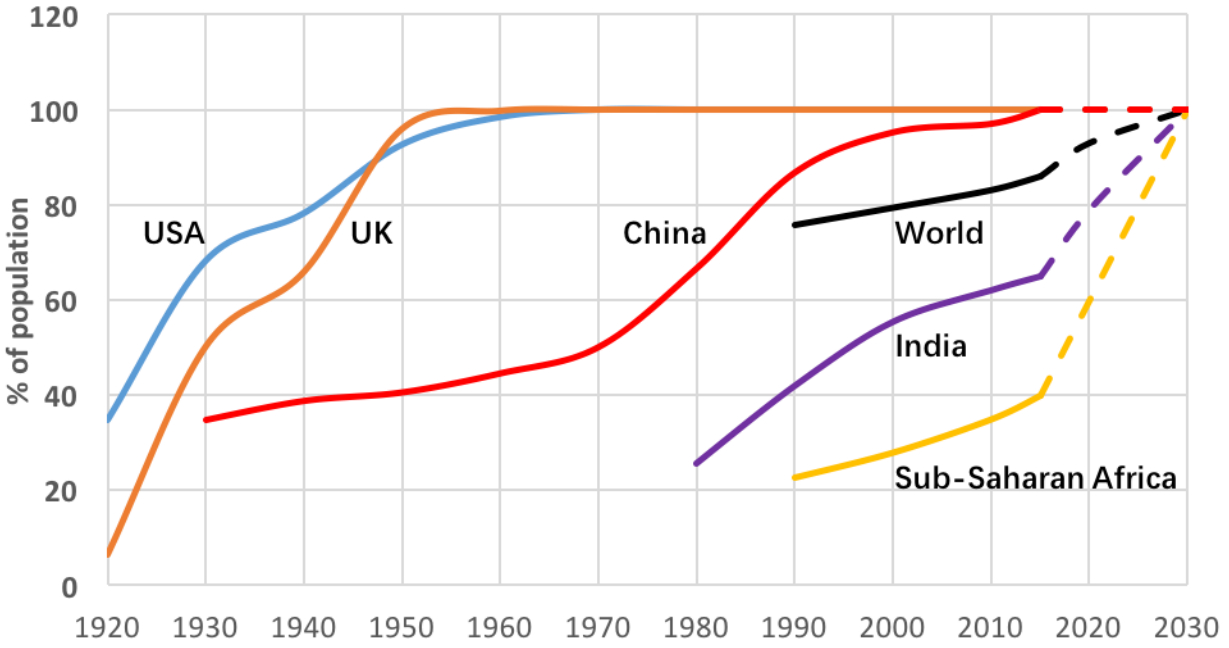
1 Introduction

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 (Figure 1) [4]. 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 [5]. 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 [3, 14]. 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 [12].



Note: Solid lines are historical data; dotted lines are projections consistent with the SE4All goal of complete electrification by 2030. Sources: IIASA [4] (USA, UK, India) and World Bank Data [13].

Figure 1: The many paths for full access to electricity

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 [2, 6, 11].

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 percent of the population [2]. 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 [10]. 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 [10]. 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 electricity supply to the last 2.73 million people [8]. 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 [13].

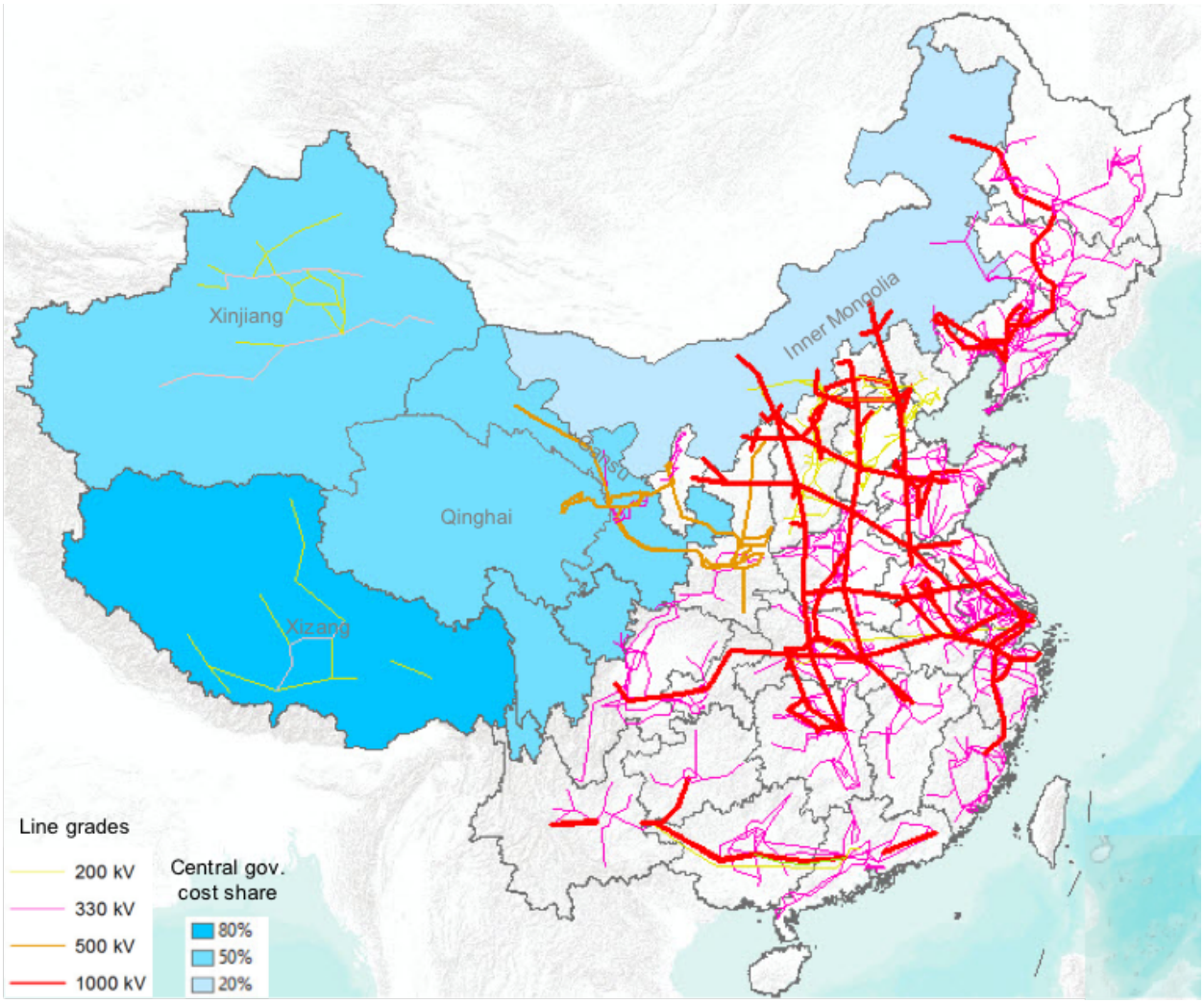
2 Lessons learned from China's final push

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

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 [7]. 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 percent) 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.



Note: Western provinces generally have the weakest grid systems (200kV and above lines shown in the figure) and have been the focus of final electrification because they have large scattered rural populations and high levels of povertyfor these reasons, they have also attracted the largest share of central government funding (shading).

Figure 2: The Geography of China's bulk grid and electrification

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.

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 0.5-1kW per household offered better system reliability, but those micro-grid systems were also costly–averaging 9,000-20,000 RMB (˜1,400-3,200 USD) per household. Individual solar PV at 0.3-0.4kW per household was the cheapest option, averaging cost 7,500-11,200 RMB (˜1,200-1,800 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 [9]. 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 [1].

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.

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 of electricity and attracts more investments to rural electrification. The feedback loops between electricity access, consumption and economic development would enable sustainable electricity supply in those areas, rather than purely subsidized by government programs. That process takes time, in part because it requires changes in human perception and behavior, and can be accelerated with information technologies and policy instruments [1]. China's "home appliances to the countryside" program provides subsidy to the rural residents to buy appliances such as TVs, washing machines, and mobile phones–just as the electrification programs in the US included subsidy to buy power-consuming appliances of the day.

3 Conclusion

Of course, there is much about China that is different from other countries. China's authoritative central government can mobilize large amounts of capital in ways that other countries probably can't. And the powerful state can align the state-owned power enterprises and local governments for a final push, less authoritative governments will find those tasks more

difficult. Moving people from isolated locations–for example–is not an option that all governments have and raises a host of important questions about justice and the ability of peoples to adapt to new locales.

It doesn't mean China achieves electricity-for-all without any problems. Central and local government's interests do not always align with each other, the information asymmetry and principal-agent problem might lead to subsidy fraud and other implementation challenges. Some locations might lose electricity access due to technological or maintenance failures. The subsidized appliance may not get used as the electricity quality is too low or electricity price is too high for some households. Those risks are along the development and can only be addressed in the development by improved transparency, continuous monitoring and updating of the program.

Even as it is important to be mindful of the differences and potential risks, China's achievement nonetheless offers important lessons as other countries aim to electrify. One is the role of funding, which is indispensable. A second important lesson is about the shifting role for the grid. Grid extension is likely to provide the backbone for electricity access, but new technologies are rapidly making off-grid systems more viable. Continued improvement in these technologies–such as cheaper batteries and better systems integration–could continue to shift the balance of economic merit away from the grid to off-grid solutions.

Providing electricity for all the world's poorest is an ambitious goal. Careful planning and coordination between different stakeholders–within countries–is needed to align the desired investment, human resources, and action plans. Integrating electricity access to local economic development will help to ensure more sustainable electrification–one of the key lessons from electrification of the advanced industrialized nations and a lesson that China's experience reinforces.

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