Lessons Learned in Small-Scale Renewable Energy Dissemination

A Comparison of China and Thailand

National Renewable Energy Laboratory

Prepared by Debra Lew

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Introduction

In the last two decades, governments, multi- and bi-lateral organizations, and non-governmental organizations throughout the world have tried to disseminate small-scale renewable energy technologies as an alternative to grid connection in rural areas. However, despite the large number and extensive history of *individual*, "one-off" projects, the international community is only beginning to understand how to *sustainably* disseminate these technologies. There are success stories in Kenya, for example, where 80,000-100,000 small solar systems have been commercially disseminated through the private sector, or in Mexico, where some 40,000 solar home systems (SHS) have been installed as part of a government-subsidized program. In this report, we examine the dissemination of small-scale renewable energy technologies in Thailand and China and discuss the lessons learned.

In commercial or near-commercial dissemination of household-scale renewable energy systems, China has been perhaps the most successful in the world. They have disseminated about 150,000 small wind turbines, 60,000 micro-hydro units, 5.4 million biogas digesters, tens of thousands of solar home systems, over 120 million improved biomass cookstoves, and 3 million square meters equivalent to 1.5 million typically sized panels) of solar water heaters. All of this has been accomplished through minimal subsidies, a decentralized network infrastructure, and extensive training and marketing.

Thailand has been very successful in deploying photovoltaic systems for battery charging and water pumping in its rural areas. As a result of three government programs, Thailand now has more photovoltaic battery charging stations (over 1000 installations) and probably more PV water pumping stations than any other country. Their extensive dissemination activities now service much of the rural, unelectrified population.

The Thai and Chinese approaches to disseminating small-scale renewable energy systems have been very different, and tailored to the unique conditions of their countries. Thailand's small unelectrified population and relative wealth has resulted in a heavily subsidized, government-driven program approach. China's large unelectrified population, limited financial resources, and industrial capabilities have led to a market-based, government-enabled approach. In both countries, the role of entrepreneurs or local government agencies to push dissemination and drive the programs has been essential.

Thailand

There are approximately 66,000 villages in Thailand. Despite a successful and effective grid-extension program, 1-2% of the population is too remote or otherwise unable to be grid-connected. Two government agencies run photovoltaic battery charging station (PV BCS) programs to provide electricity services to these villages: the Public Works Department (PWD) and the Department of Energy Development and Promotion (DEDP). Additionally, PWD has a PV water pumping program. Figure 1 shows the cumulative installations of PV BCS through both agencies over the last decade.

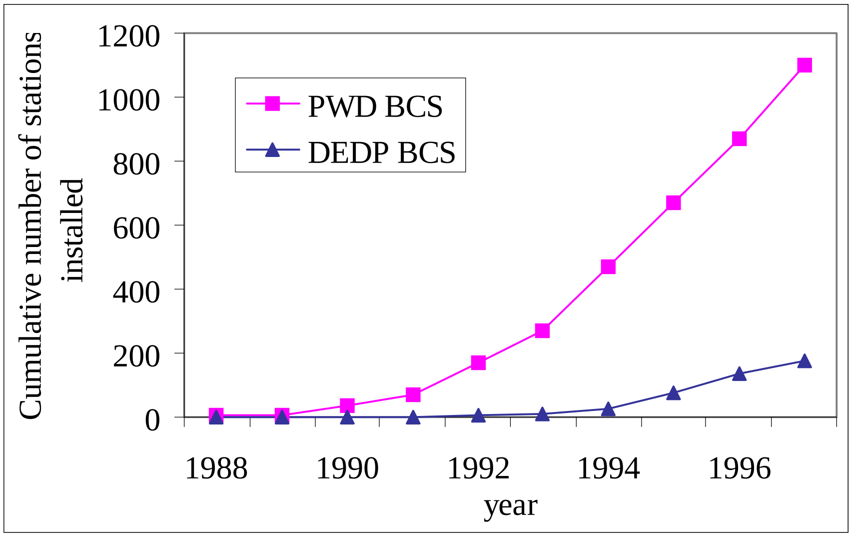

Figure 1. Cumulative installations of photovoltaic battery charging stations in Thailand[1]. The squares represent 3 kW installations by DEDP; the triangles represent 795 W installations by PWD.

Solartron

Khun Wandee Khunchornyakong, managing director of Solartron, Inc., is the main driving force behind Thailand's PV BCS dissemination programs[2]. She was introduced to PV technology in 1981, and decided to market this technology in Thailand, where the solar insolation remains relatively high year-round. Initially, Solartron targeted Bangkok customers, but they soon found that the urban market was largely limited to research and education applications.

In 1985, Khun Wandee turned to the rural areas, where the PV technology would be able to fulfill electrification needs for villages that were not yet grid-connected. Solartron hired technicians, bought trucks, visited villages that were easily accessible, and demonstrated applications that would be desirable in rural areas: water pumping and TV. However, despite great interest in the SHS, the villagers had on hand only a fraction of the 10,000 Baht (US$400) cost of the systems. Khun Wandee tried to obtain PV loans for the villagers from local banks, but while the Agricultural Bank was willing to loan for this technology, the villagers had no collateral: they had already given their land deeds as collateral for fertilizer and other loans.

Solartron decided to provide the financing themselves through a leasing program. The arrangement consisted of down payments of 1000 Baht, with the remainder paid monthly over

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[1] Amnuay Thongsathitya, "The Application of Photovoltaic Use in Thailand", *Investigating Directions and Procedures to Support Photovoltaic Application and Policy Formulation in Thailand*, Phuket, Thailand, 10-12 May 1997.
Sophon Phan-i-nakul, "Photovoltaic Program of the Thai Public Works Department", Public Works Department, Thailand, 1997.

[2] Wandee Kungchornyakong, "PV Project Development: Approaching Grassroot Groups to Policy Makers for 15 Years", *Institutional Cooperation for Solar Energy in the Mekong Riparian Countries*, Hanoi, Vietnam, 11-16 May 1998.

the next two years. One hundred 50 W systems were distributed with this payment scheme. Solartron opened a temporary office in Nakhon Ratchasima, the nearest city, and sent a salesman to collect the fees every month. However, it was difficult to collect the monthly payments: the salesman might be forced to go out to the rice fields to find the farmers or to return when the farmers had enough money. The company spent more money trying to collect the fees than the fees were worth. It was also difficult to deal with nonpayment: Solartron staff found it nearly impossible to remove PV systems from the homes of impoverished villagers, for whom the energy services were so important. They ultimately gave away many of the leased systems to the villagers.

Finally, Khun Wandee decided to take a different tack. The Thai government had a mandate to provide basic infrastructural services to the rural people. Khun Wandee drew up petitions which asked the government leaders for PV systems for electricity and water services. Solartron went out to the villages again and had the villagers sign the petitions, which were then brought to a Member of Parliament from Nakhon Ratchasima, General Chatichai Choonhavan[3]. In return for votes from the rural people, Khun Wandee asked the General for donations for PV systems. He was convinced and bought 100 modules.

Simultaneously, Khun Wandee's petition expanded her program to the national level and thousands of letters flooded into the government, requesting PV water pumping stations and PV BCS. While political will was being cultivated, it wasn't clear which government agency would be most appropriate for implementation. The Provincial Electricity Authority (PEA), the distribution utility serving all areas outside of Bangkok, wasn't interested in PV, because it was purchasing subsidized electricity from the generation utility. The Director-General of the National Energy Agency (later to become DEDP) was interested in using PV for water pumping, but in the end it was the PWD which was most amenable to PV and ready to take a proactive role.

It took three years for the government to allocate the budgets but in 1988, Solartron and the PWD were able to secure 600,000 Baht and establish 5 PV BCS as a pilot project. Evaluation of the pilots took place in 1989 and the dissemination phase of the program began in 1990. Later studies showing that PV lighting was a major factor in declining birth rates in the villages helped to persuade the government to continue these programs.

Installed PV capacity in Thailand reached 3.4 MW in 1998. The PV water pumping stations and PV BCS are responsible for 2/3 of this capacity[4]. The PV BCS alone make up nearly half of the total installed PV capacity in Thailand Solartron, with a production capacity of 2 MW/year, is the largest of the three local companies which assemble modules and integrate systems. There is not yet PV cell manufacturing in Thailand, but the government is currently funding the development of an amorphous silicon PV cell manufacturing facility.

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[3] General Chatichai was elected the Prime Minister of Thailand in 1988.

[4] Other applications of PV in Thailand include communications, grid-connected PV rooftops, hybrids, individual home systems, and education.

PWD PV Battery Charging Station Program

The PWD estimates that there remain about 3000 villages in extremely remote areas, for which grid connection is not viable[5]. The PWD sees solar PV systems as a possible approach to supplying small-scale energy for lighting, TV, and water pumping. PWD, a technical department under the Ministry of Interior, has been responsible for rural development activities such as road-building and drilling water wells. PWD has a mandate to provide basic rural infrastructure to improve the living standard of rural people.

Persistent droughts at the end of the 1980's especially affected the rural people and resulted in migration to Bangkok and other big cities. The King of Thailand asked all government agencies to mobilize resources to alleviate immediate hardship and to find sustainable water supplies for rural areas. PWD responded to this request by beginning two national rural service programs using PV: the water pumping and BCS applications. Each year PV water pumping and BCS were to be installed in 50-100 villages. The PV BCS program were to be implemented during the Sixth (1987-1991), Seventh (1992-1996) and Eighth (1997-2001) National Plans.

Already, PWD has installed over a thousand of the PV BCS throughout the country, especially in the northern region. The systems are installed by PWD and then turned over to the village to operate and maintain. The village determines how the station will be run, how much will be charged, and how the income will be spent. The village also must maintain and repair the systems by themselves. Because there is little or no follow-up, some systems still exist in villages which were later grid-connected and some systems are no longer performing optimally.

Due to the 1997 economic crisis, PWD's budget for the PV BCS has been decreased by an estimated 40%. This affects installations from 1998 on.

DEDP PV Battery Charging Station Program

DEDP estimates that of the 6,000 villages which had not been electrified by 1996, 5,500 were to be electrified by the Provincial Electricity Authority (PEA) through conventional and non-conventional means: grid-connection, diesel mini-grids, wind/diesel hybrids and PV/diesel hybrids. They see the remaining 500 villages as opportunities for PV BCS.

The DEDP PV BCS program is modeled on a 4 kW PV BCS demonstration project, jointly implemented in 1992 by DEDP and the Japanese New Energy and Industrial Development Organization (NEDO). In this project - "Demonstrative Research for Photovoltaic Power Generation Systems in Thailand" - a 4 kW PV BCS and a larger PV village system of 40 kW were installed.

The 4 kW PV BCS was installed in a village of 147 households (about 500 people) in Kanchanaburi Province, about 250 km northeast of Bangkok. The village is located inside a national park. Despite nearby high-voltage transmission lines from a hydro power plant, the village had not been electrified because grid connections are forbidden within the park. The PV BCS was installed in April of 1993, and is still operational. The village was divided into ten groups, each with a leader. A project management committee, consisting of a chairperson, vice-

[5] There does not appear to be coordination between these plans and PEA's electrification program.

chairperson, the ten group leaders, and a DEDP technician, was established. The committee is responsible for overseeing the system, setting charging fees, and allocating funds. The group leaders are responsible for hooking up the batteries and day to day operations and maintenance.

Charging of the batteries occurs on a rigid schedule. Each group can charge their batteries every ten days and every household is allowed only one battery. NEDO provides maintenance and checks up on the system every 4-5 months.

As a result of the success of this PV BCS demonstration, DEDP used it as a model for their PV BCS Program which began in 1995. The program's goal is to provide basic electricity services, for some of the poorest, most remote villages. This program will benefit 24,000 households in 300 villages over 5 years. This program is in conjunction with the King's decree that for the 50^{th} anniversary of his ascension to the throne (1996), all villagers will have access to 50 W of electricity.

The DEDP program learned from lessons in the NEDO demonstration project and incorporated improved and less expensive technologies into their designs. The charge controllers and inverters are locally made and can be easily serviced through universities and DEDP. DEDP has six Regional Energy Centers throughout the country which implement and service the program as part of their assistance activities in rural energy development.

Unfortunately, due to the 1997 economic crisis, new installations have been halted. DEDP continues to provide limited service to existing stations, however.

Both of these PV BCS programs are completely subsidized by the national government. The capital subsidy includes the PV modules, chargers, balance of system, installation, initial set of batteries and basic training. In the DEDP program, follow-up maintenance is provided and training is more extensive. Villagers are also given charge indicators which allow them to determine when the battery should be recharged. The stations are run by committees with fixed rules; and the charging fees are deposited into village bank accounts. The PWD program turns the stations over to the villages as infrastructure projects in a more laissez-faire fashion, and leaves the villages to organize themselves and operate the station.

Despite the similar nature of the two programs, the two government agencies do not collaborate on technical designs, program implementation or even site planning. As a result, some villages have one PV BCS from each agency.

The Future of PV for rural Thailand

The 1997 economic crisis has suspended or decreased the activities of many government-subsidized programs. Rural electrification programs are no exception. Because commercial markets for PV rural electrification have not been developed, there are now few new installations. In existing installations where demand has grown, there are no mechanisms to overcome the significant cost barriers to increase the site capacity. The shrinking government budgets may now be forcing policy-makers to turn to new market-based approaches with less dependence upon government support.

For example, at the Ban Huay Ta village in Uttaradit Province, increasing incomes and a productive use weaving program set up by the Queen has led to a demand for a higher level of electricity service. The village already has one DEDP and one PWD PV BCS, but the villagers would like to be able to power fans and refrigerators. The PV BCS operator has surveyed the village and finds that about 45 households in the community would like to purchase a SHS, and that their annual incomes are approximately 7,000-10,000 Baht (about $175-250 in 1998). However, because the two existing PV BCS in the village are virtually free (charging fees are 40-60 Baht/battery/year or $1-1.50/battery/year), the typical 4800 Baht/year ($120/year) payments for a SHS may seem prohibitively expensive. The PV BCS operator has investigated costs and thinks he (and other villagers) would need a 50% subsidy in order to afford a SHS.

One option currently being investigated for this and other villages is the establishment of a rural energy service company (RESCO) which sells energy *services*, as opposed to PV panels, to households[6]. In this setup, the RESCO would own, operate and maintain the solar home systems and the households would agree to pay monthly fees based upon their energy consumption. This RESCO concept eliminates the problems of broken or poorly maintained components and gives the customers what they really want: electricity (not PV panels). In Kiribati, this service approach has proven to provide much higher customer satisfaction than the conventional PV sales approach[7].

China

There are some 100 million people in rural China who lack access to electricity. The combination of dispersed rural populations, expensive grid extension, and low energy consumption in rural areas means that distributed small-scale systems may be the best way to electrify the farmers and herdsmen. China's goal is to provide electricity access to 95% of the farmers by the year 2000. To do this, the national and provincial governments have implemented a number of programs to electrify rural areas with renewable energy. Many of these programs are largely commercial or near-commercial. For example, the micro-hydro turbines, some of the wind turbines and many of the solar home systems are sold without any end-user subsidy.

[6] Anil Cabraal, Mac Cosgrove-Davies, and Loretta Schaeffer, *Best Practices for Photovoltaic Household Electrification Programs: Lessons from Experiences in Selected Countries*, World Bank Technical Paper Number 324, World Bank, Washington DC, 1996.

[7] Terubentau Akura, “Compare Sales Approach and Energy Service Company Approach for PV in Kiribati for the Past 15 Years”, *Institutional Cooperation for Solar Energy in the Mekong Riparian Countries*, Hanoi, Vietnam, 11-16 May 1998.

In this report, we detail the dissemination of solar home systems and small wind turbines for rural electrification in two provinces. We present the work of one Gansu province entrepreneur, who has taken a market-based approach to dissemination, and the program of the Inner Mongolian government, which is a government-enabled, market-based approach.

Solar Home Systems in Gansu Province

Gansu is one of the poorest provinces in China. It is located in the northwest, and separates the central, densely populated areas of China from the remote deserts, mountains and plateaus of the west. Average annual household (one household contains approximately four people) incomes range from 2200 to 4500 Yuan (~$265-542). The Gansu utility reports that in 1996, 696,718 households in 1946 villages and 26 townships lacked grid access, although local estimates of the number of unelectrified households are up to 1 million.

In this region, it is estimated that some 10,000 solar home systems (SHS) have been sold to rural customers. Although there have been credit and subsidy programs by the Solar Electric Light Fund (SELF) and the US National Renewable Energy Laboratory (NREL), most of the systems have been sold commercially as cash sales.

Gansu PV Company is a large, regional PV systems integrator and distributor. We will detail lessons learned from their history of trial and error with subsidies, credit, and village power projects. Their experience has led them to sell small individual systems at full cost as cash sales.

Large versus individual energy systems

In 1986, Kyocera donated a 10 kW PV system to the Gansu government. It was installed for rural electrification in a remote part of Gansu province. The villagers were instructed to use their lights and their TV or cassette player for only four hours per day. However, in practice one household might leave their lights on for six or eight hours, complaining that their neighbors had left their lights on for longer than four hours the night before. In response, another household would leave their lights on all night. This mismanagement of loads eventually led to system failure after 4 years of service. After this difficult experience, no one else wanted the system, so it was eventually moved to an experimental center. This problem recurred in Linjou county, Tibet, where a 1.4 kW PV system was set up for rural electrification. This system was functional for only 6 months, and failed for similar reasons. In this village, households damaged the system by leaving their lights on 24 hours a day.

Some systems integrators have turned to individual meters to overcome problems with energy wastage. However, meters for each household are expensive. Instead, Gansu PV Company decided to focus on individual systems for the additional reason that individual systems are more easily affordable and can be commercially purchased. They began with 100W systems, but finding that these were still too expensive for the rural areas, they decreased the system size first to 50 W, then to 36 W, and finally to 20 W and below[8]. They found that the 20 W size is quite suitable, because it is affordable and people will conserve energy if necessary. In addition, the higher cost of larger systems requires subsidies, but the very small systems could be bought on a purely commercial basis. Gansu PV Company typically sells 16W, 18W, and 20W systems.

[8] The 20 W and below size range is also found to be the most popular size range in Kenya, with one vendor estimating 1998 sales to be over 20,000 systems.

Although conventional wisdom and experience from other areas indicates that 16-20W systems may be too small or outgrown too quickly, Gansu PV Company has not found this to be a serious problem. The solar insolation is quite high, ranging from 4 to 6 kWh/m^2/day in the province. They have focused on designing high-efficiency electronics and lamps. The systems are designed to power one TV and two lights for up to three cloudy days in a row. One user reported that during the past winter, he was reliably powering one TV, three lights and occasionally charging his son's battery! In addition, as the user's demand increases and the user's demand outgrows his system size, Gansu PV Company provides a trade-up policy, described below.

Working out the technical bugs

Gansu PV Company gives small payments to some end-users and local "technicians" to work part time or on occasion for Gansu PV to provide technical service. The local technicians are trained for 1-2 weeks by the company and have very basic technical skills. They fix systems, help to sell systems, and log problems.

Through this continuous monitoring of system performance, Gansu PV Company has been able to solve recurring technical problems. About three years ago, their main system failures were due to the batteries, controllers and lamps. Through trial and error they have found good, local batteries. They now estimate a typical battery lifetime of five years and lifetimes of up to eight years under careful operation. Controllers are now manufactured by Gansu PV Company with high quality elements that are bought directly from specific factories. Originally, the lamps, including the energy saving lamps, suffered extremely short lifetimes of two weeks. They discovered high-frequency transients in the waveform which caused these early failures and refined the circuitry so that they are now able to use standard fluorescent lamps which are available in most local town centers.

No capital subsidies

Subsidies for capital equipment purchases are often used to make systems more affordable for rural poor. However, Gansu PV Company's experiences show that such capital subsidies may not reach the target groups and may also lead to corruption. Implementing a subsidy program adds an extra layer of administration and middlemen, who may take money from both ends of the market chain. For example, the middleman might charge the user a fee for selling him a subsidized system; and the middleman might charge the funding agency a fee for distributing and marketing the systems. The subsidies themselves provide a financial cushion that allows the middleman to undercut market prices and still make a healthy profit.

In addition, the subsidies often led to corruption. In one instance, the middleman switched out the expensive imported equipment for cheaper, local components and passed them off as foreign equipment. It is likely that the original imported equipment was sold off at a profit by the middleman. Subsidized systems were often earmarked for politically powerful people. In one village, they found that the village leader owned three of the subsidized systems, despite the project's limitation of one system per household.

Finally, Gansu PV Company found that the use of subsidies distorts the playing field and hurts local suppliers who are not part of the subsidy program and who cannot compete with the subsidized systems.

Credit doesn't work in this region

Many multilateral, international and non-governmental organizations are promoting credit schemes to make the systems more affordable for users. However, Gansu PV Company found that the people in their region lacked an understanding of credit. There is no law in China which allows creditors to collect money which they have loaned. Because Gansu PV Company had no legal right to collect money for systems which are bought on credit, their collection rate was abysmal in the first year of their credit program. It may also be that rural villagers are so accustomed to hand-outs from the government, that they assume that the solar home systems are or should be free.

Trade-up program

As a way to deal with the affordability, finance and demand growth issues, Gansu PV Company turned instead to a trade-up mechanism. In this way, households start with the smallest system that they can afford. As they save up more money and as their energy demand grows, they can trade in the smaller system for a larger system. This concept requires that the product quality be high. As Gansu PV Company says, "you can cheat people once, but not three or four times." This is the third year of the trade-up program and a significant percentage of their customers have engaged in trading their systems in for larger ones.

Marketing

Gansu PV Company believes that advertising and word of mouth are essential to their business. They advertise on the radio, hand out flyers along the roadsides, and use their part-time workers to help spread the word. Gansu PV Company believes that advertising is so important to commercial dissemination that they recommend that potential international donors fund marketing activities rather than direct equipment subsidies[9].

[9] There are other examples of the power of marketing in renewables and energy efficiency. The Thai demand side management (DSM) program has been quite successful also because of the extensive marketing. Much of the $15.5m GEF loan to program is for marketing and EGAT has the largest nationwide TV advertising account, most of which is for DSM. In Greece, a government-driven solar water heater program was started by several years of capital equipment subsidies, but grew most rapidly when the government replaced the capital subsidies with subsidized advertising on television during evening hours. Sales reportedly rose 50% per year during the two years of this advertising campaign.

Gansu PV Company's success appears to be a function of their persistence, adaptation and innovation. Adaptation to local conditions is essential, because even mechanisms, such as credit, which are widely and successfully used around the world[10], may not be applicable for all cultures or regions. Gansu PV Company's trade-up system demonstrates the need for developers and suppliers to be flexible and innovative.

Small-scale wind power in Inner Mongolia

One of the big successes in deployment of household renewable energy systems is the dissemination of small wind turbines in China. The Chinese have a long history of using wind energy, beginning with the use of windmills for pumping water 2000 years ago. By 1959, there were 200,000 canvas windmills pumping water, mostly in north Jiangsu province. In the 1950's the Chinese government began research on wind electricity generation and by the 1970's they were able to begin a campaign to electrify rural areas with small-scale distributed renewable sources, including wind and photovoltaics.

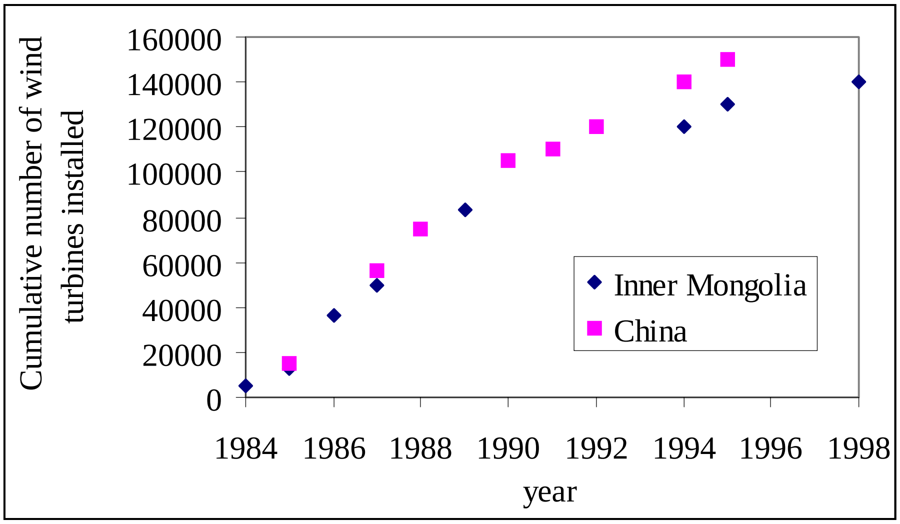


Figure 2. Cumulative number of installations of small-scale wind turbines (typically 50-300 W) for rural electrification in Inner Mongolia and China.

Although the central government provided research and development of wind technology, they played a relatively minor role in this success story of small-scale wind turbine dissemination. Local governments in some rural, windy provinces - Xinjiang and Qinghai, for example - have only been mildly successful in disseminating small-scale wind turbines. It is the local government of Inner Mongolia that has had the most aggressive policy of wind power expansion and this is reflected in the tremendous number of wind systems installed in this region. Figure 2 shows that over 80% of the small-scale turbines in China are located in Inner Mongolia.

[10] The Grameen Bank has been one of most successful micro-lending institutions for the poor. Their housing loans are most widely known but they also lend for micro-enterprise and small-scale renewable energy systems. Projects by Solar Power & Light Company in Sri Lanka and by the Solar Electric Light Fund/Vietnam's Women Union in Vietnam are other examples of successful use of credit to make solar home systems affordable for rural people.

Inner Mongolia is an autonomous region in northern China, bordering Mongolia. Inner Mongolia has about 1/8 of the total area of China, but less than 2% of the total population. Most of the land is grassland, and many of the rural people are herdsmen and farmers. Average per capita annual incomes are about 2000 Yuan ($240), which is fairly rich for a rural, unelectrified population in an underdeveloped province. This is 2-3 times higher than Gansu province, and may account for the proliferation of small-scale energy systems. It is estimated that there remain 300,000 households in 1100 villages and 198 townships that currently lack electricity[11].

Policy and Planned Development

In 1980, Inner Mongolia's Science and Technology Commission made renewable energy development and utilization a priority program. They emphasized local development and implementation of this program with these guidelines:

- The primary objective of new energy development and utilization is to solve the energy problems of remote areas, and the top priority is to develop small-scale wind turbines, PV cells, and balance of system components for stand-alone applications.
- The basic principles of new energy R&D are "reliable to use, convenient to maintain, and affordable to herders".
- Small-scale products and energy use for daily life are the main focus, and the needs of production and daily life should be integrated.
- Local people should be in charge, with the state providing appropriate support.

The local government integrated the research, production and outreach components of their program into a single continuous system. In 1984, the New Energy Office was established to manage the renewable energy work. This agency set policies for renewable energy development, conducted near- and long-term planning for renewable energy, and coordinated activities in research, production and dissemination.

In the 1990's Inner Mongolia began collaborations with international partners to advance their technologies, especially in hybrid and centralized systems. Utility-scale wind farms and other renewable energy technologies also became more widespread during this time. The long-term goals for the region are to disseminate a total of 150,000 small wind turbines, 150 kW of PV, and 150,000 m^2 of passive solar buildings by the year 2000. By 2010, electrification of remote areas in the region is planned to exceed 50%[12].

Wind Turbine Technology Development

The State government assisted wind power development by supporting R&D and preferential loans for manufacturers under the Sixth, Seventh, and Eighth Five-Year Plans. The local Inner Mongolian government has long viewed wind power as an exploitable energy source, boost to the local economy and solution to rural electrification. They had a heavy hand in promoting the technology, to the point of specifying production output and price of the wind turbines. For example, to their specification, in 1985, Shangdu Livestock Machinery Works produced 4400 turbines, which were sold at an average of 518 Yuan/turbine, at a 23% profit.

[11] John Byrne, Bo Shen and William Wallace, "The economics of sustainable energy for rural development: A study of renewable energy in rural China," *Energy Policy*, Vol 26, No. 1, pp. 45-54, 1998.
[12] Lin Li, "The Development and Utilization of New Energy Sources in the Inner Mongolia Autonomous Region: Review and Outlook", *Inner Mongolia Science, Technology and Economy*, No. 4, pp 27-30, 1997.

The Shangdu Livestock Machinery Works began cooperation with many research institutions and universities in 1975 to develop wind electric generators. They acquired technology from the SVIAB Company in Sweden in 1988 and have been improving the technology and simplifying the structures over the years. Today they produce the largest number of wind turbines in China.

The small Chinese wind turbines have been designed to perform well at the low wind speeds found at the typical hub height of less than 10 m. Figure 3 compares the power curves of the Chinese turbines with those of similarly sized turbines from abroad, showing that the Chinese turbines begin producing power near their rated power output at much lower wind speeds than typical small turbines from the US and Germany.

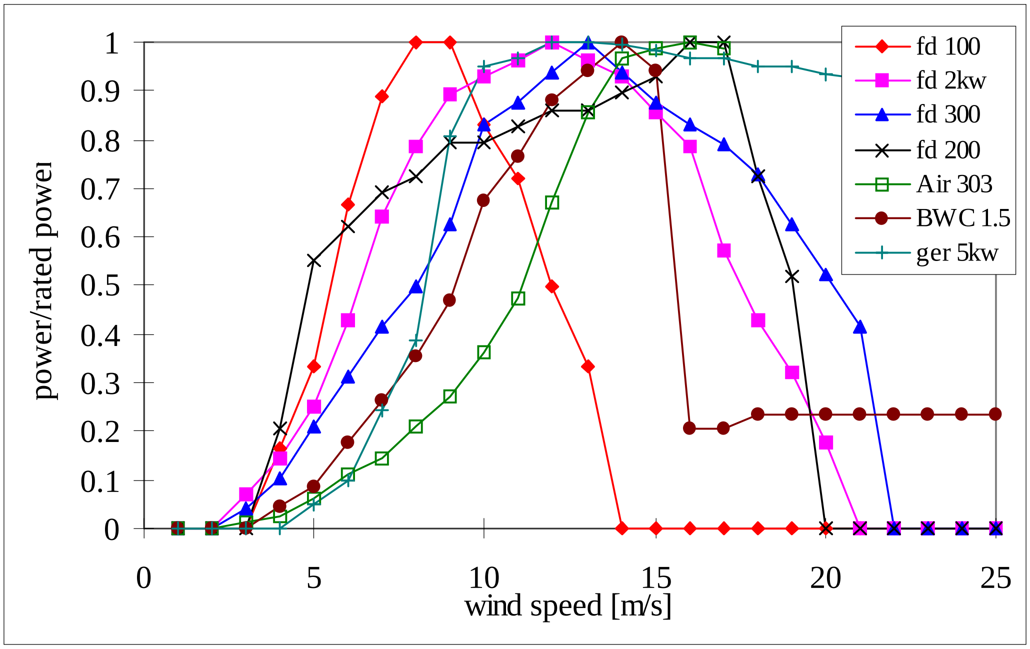


Figure 3. Comparison of scaled power curves from small wind turbines manufactured in China, US and Germany.

Since 1990, the German technical aid agency GTZ has sponsored a project in Inner Mongolia to transfer technology of small-scale wind turbines and electronics for hybrid systems. They have successfully transferred the know-how for production of their equipment to the joint venture Hua De New Technology Company, who now replicates and sells the equipment. To go the next and very challenging step of transferring a deeper understanding of the design such that the local company could improve upon and modify the original design would require much more training of and experience by the joint venture[13].

Hybrid Systems

The systems used in Inner Mongolia, although widely disseminated, suffer from low winds during the summer. The power of the wind increases as the cube of the wind speed, so that the

[13] Hubert Klapheck, FGU Consulting, personal communication, 21 April 1998.

power available in the high wind months of winter can be 3-4 times greater than that in the low wind months of summer. Since the *solar* resource peaks during the summer, the addition of PV provides a means for electricity production year-round.

The second major problem with wind-only systems is that they are typically used with automotive lead-acid batteries. These batteries are designed for continuous charge, for low depth of discharge and for providing a large amount of power over a very short period of time. However, in use with wind electric chargers, the batteries are discontinuously charged and are severely discharged over a long period of time. In this mode of use, the batteries only last 1-2 years, and thus comprise a significant expense. Rising battery costs further aggravate this problem. In comparison, when used in solar chargers, these batteries typically have lifetimes of 5-6 years.

The Chinese herdsmen have already recognized the limitations of the wind-only systems and the advantages of hybrid wind/PV systems and have begun adding photovoltaic panels to their wind systems. The relatively high cost of PV is currently the greatest obstacle to their widespread use. The local government has begun collaborations with the US, Germany and the UNDP to study the design and application of hybrid systems in the region.

Infrastructure

The central and local governments have established an extensive network of rural and new energy offices which disseminate information and provide technical training and service at the county level. These offices have been instrumental in deployment of the small-scale renewable energy technologies.

The Ministry of Agriculture established the management system of rural energy offices in 1979. These rural energy offices now exist in 1800 of the 2200 rural counties in China. The original programs of the early 1980's focused on single technologies such as improved biomass cookstoves, biogas digesters and small hydropower. In 1983, they began a pilot project for integrated rural energy development in six counties. The success of the pilot led them to expand it to twelve counties during 1986-90 and then into the "One hundred counties" program during 1991-95. These integrated rural energy development programs focused on the interdependence of the energy and environmental sectors as well as social, economic and environmental development[14].

In addition to the central government's rural energy offices, the local Inner Mongolian government has set up new energy service stations in over 60 of their region's 88 counties. These provide information and subsidies specifically for renewable energy systems. Their technical and training sites provide additional technical support.

Subsidies

In 1986, the Inner Mongolian government began offering a subsidy of 200 Yuan ($24) per turbine (or PV panel) and 50 Yuan ($6) per battery for components manufactured in Inner Mongolia. The process for obtaining the subsidy was quite simple: the herdsmen went to their

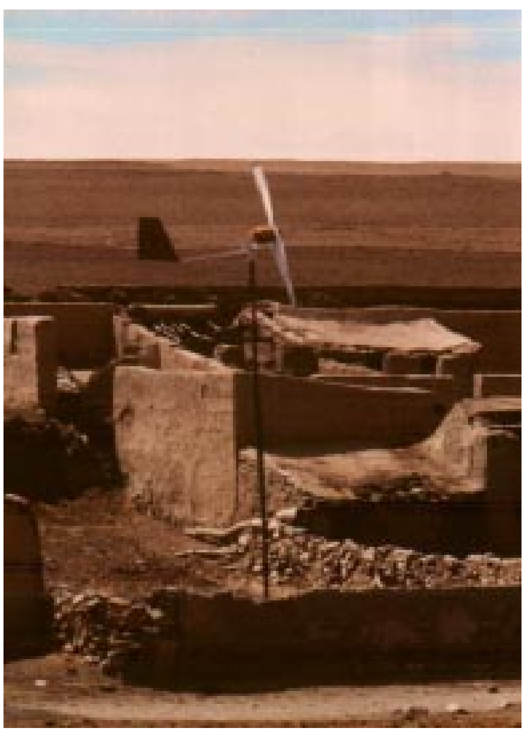
[14] Deng Keyun, Gu Shuhua and Liu Wenqiang, "Rural energy development in China", *Energy for Sustainable Development*, Vol, 3, No. 3, September 1996.

local new energy office and obtained a coupon which they brought to the Inner Mongolian turbine manufacturer of their choice. This helped to build up the local industry. The local government and utility each provided 5 million Yuan annually for these programs. Currently, subsidies are about 100 Yuan per 100 W rated capacity for the wind turbine and they do not apply for batteries. This program was completely driven by the local government until 1990, when the central government began contributing about one-third of the wind power subsidies.

There has been little experience with financing of systems. While there is now a revolving credit program underway, nearly all installations to date have been cash sales. The relative wealthiness of the rural population and the relative inexpensiveness of the locally manufactured equipment has made the systems affordable for the users. However, in order for the dissemination program to reach less affluent segments of the population, financing may become an important component of future programs.

Domestic industry

These programs have been successful in creating a domestic industry of wind turbine manufacturers. Today, China produces more turbines than any other country through its 42 local manufacturers. These are mostly 100 W units used in single households, although 300 W units have now become very popular. Shangdu Livestock Machinery Works reports production growth of about 58% per year to about 10,000 units in 1996[15]. In 1996, total annual production in China was estimated at 20,000 units. China also exports these turbines to various Asian countries including Mongolia, Malaysia, Vietnam, Pakistan, Sri Lanka, and Japan. In addition to creating a manufacturing industry, over 10,000 people were trained for construction, installation or maintenance of turbines.



In 1993, it was estimated that of all wind turbines in Inner Mongolia, 85% were in good condition and 78% were in operation. This is remarkable in light of the fact that these wind turbines have reported lifetimes of 10-12 years, and that parts of the turbines are often of poor quality (especially the blades, which must be replaced every 5-7 years). More recent anecdotal evidence suggests that this is an overestimate and that many turbines are now inoperational[16]. However, no survey has been done to ascertain the performance of these turbines.

By 1995, there were about 150,000 small turbines in rural China, providing electricity for lighting, radios, televisions and small appliances. Today, approximately 140,000 small wind turbines (and about 10,000 PV systems) are located in Inner Mongolia, and about half a million people receive electricity from

[15] Yang Bing, *Small Scale Wind Energy Systems*, March 1997.
[16] Personal communications from program managers at the Chinese Academy of Sciences, with the US DOE/China collaboration and with the GTZ/China collaboration.

these small wind or solar systems[17]. These small turbines contribute over 17 MW to installed capacity.

The Chinese small wind story is one of excellent policy and planning, well-established infrastructure, development of domestic industry, and a target population which could afford the systems. Minimal subsidies were used to stimulate both the industry and sales, but it is likely that the dissemination has been mostly to the wealthier households. However, the resulting development of a domestic industry has been that low-cost turbines are now widely available and come closer to the reach of the middle-class households.

Lessons Learned

Subsidies – Degrees of market distortion

Various kinds of subsidies and various levels of subsidization have been used in Thailand and China. In this section, we examine some of the end-user subsidies and the degree to which the subsidies distort the markets.

Subsidies from in-country

In Thailand, the traditional government-subsidized approach has resulted in renewable energy programs which subsidize renewable energy technologies by 50-100%. In addition to the 100% subsidies on PV BCS through the DEDP and PWD programs, there are 50% subsidies on PV through a proposed PEA program and 30-40% subsidies on solar water heaters through a National Energy Policy Office program.

The large market distortions may make it difficult to move to a market-based dissemination program. The Ban Huay Ta villagers interest in moving to a higher level of electricity service may be thwarted due to the fact that their current costs in the subsidized BCS are only 1% of the costs of commercial SHS.

Another factor which may make the cost of a SHS less attractive in rural electrification is that the distribution utilities' rural electricity prices are cross-subsidized by urban electricity prices. Because of the subsidies for rural users on both sides of the SHS market, completely commercial dissemination of SHS faces large barriers.

Subsidies from multilateral institutions

The international development world is fraught with the misuse of subsidies in the form of grants and loans which distort the market. The more benign of these is the multilateral development bank (MDB) loans, which sometimes compete with private investors by lending money for projects which are easily financed in commercial markets[18]. The 6% interest rates offered by the World Bank, for example, are far below commercial rates and thus far more attractive to developers.

[17] Long Zequiang, *Small Scale Wind Energy Systems*, December 1996.
Ma Shenghong, Hua De New Technology Company, personal communication, 31 May 1998.
[18] *Asian Wall Street Journal*, "The World Bank is Edging Out Lenders in China", by Craig Smith, p 1, June 11, 1998.

In some cases the MDB's are even at odds with each other. A recent Asian Development Bank study of optimal financing for a 1.8 GW power plant in Shanghai recommended a bid invitation to private investors. However, when Shanghai checked with the World Bank, which was willing to finance the loan, the competitive bidding option became uncompetitive.

Subsidies from bilateral donors

Subsidies from bilateral donors may provide an even greater market distortion than the MDB's in that they subsidize the technologies from one country only, in a move to take over market share from competing suppliers of other countries.

Recently, new bilateral subsidy programs for renewable energy technologies have been proposed. These include the soft loans for utility-scale wind turbines in China as well as subsidies for PV solar home systems (SHS) in several Asian countries.

Soft loans for wind turbines

DANIDA recently announced their most favorable soft loans to date for China: $150M over 3 years for wind turbines at zero interest over ten years. It is estimated that 90% of wind power installations in China were funded through concessional finance. While the Chinese argue that there is limited capital available in-country, the availability of concessional finance means that the only development which occurs in China will be that which has access to concessional finance. Other bilateral aid agencies have provided concessional loans in an effort to compete in the subsidized loan market to promote their own countries' technologies. Since not all concessional terms are equal, those countries with the most favorable loan terms will be the ones who will be able to sell turbines in China.

By making soft loans available, foreign governments have destroyed any hope of commercial wind markets and privately financed wind development in China for the near term. In the 1995 Beijing International Conference on Wind Energy, one of the largest Danish wind turbine manufacturers noted that the fledgling commercial market which had existed prior to the concessional finance programs had vanished. As a result, no turbines had been sold on commercial terms in China in 1994[19]. It is generally agreed that when the current round of soft loans run out, the Chinese will wait again for more of the same. The availability or even possibility of subsidized loans has reduced the Chinese willingness to pay full cost for commercial machines. Unfortunately, the Chinese do not have domestic production of large turbines, so this means that wind power development will be stalled.

Subsidized solar home systems

The markets for SHS are rapidly expanding throughout the developing world, with new suppliers and developers being established. In an effort to develop PV markets, the Dutch government has proposed donor aid to subsidize their SHS in the Philippines, China and Sri Lanka. In addition to distortion of local markets, there is concern that this aid may hurt local distributors and dealers and, in the case of China, local PV manufacturers.

[19] Hans Buus, "Large Scale Wind Power Plants in China," *Beijing International Conference on Wind Energy*, Beijing, 9-13 May 1995.

In Sri Lanka, the Dutch government is offering 35% subsidies for their SHS to local distributors. While this program may initially seem enticing, due to the large subsidies and numbers of systems involved (about 30,000 are eventually planned), it may distort future markets by eroding the willingness of later end-users to pay full price for systems after the subsidies end. In practical terms, the local distributors have no choice but to join the program, if they want to compete in what will be a subsidized and distorted market.

In the Philippines, local developers and systems integrators have been cultivating local commercial markets for SHS for several years. Their largest project to date is about 1000 systems. The Dutch aid would subsidize 15,000 SHS to the Philippines government for rural areas. There is great concern that the donor aid may harm the fledgling commercial markets and create subsidy dependencies.

In China, the World Bank has been packaging a 200,000 SHS project for rural areas in five remote provinces. If the proposed Dutch aid for SHS in one of these provinces is implemented, then the World Bank will be forced to pull their project out of this province because they will not be able to compete with the large proposed subsidies of the donor aid program[20].

There are ways in which host countries can avoid these problems. Host governments can channel all aid through their own rural electrification/renewable energy programs or agencies, such as the MDB funding through the Indian Renewable Energy Development Agency. Or they can carefully segment the population and target various aid programs based on geography or affordability, such as Indonesia's handling of German, Australian, and World Bank aid. Since bilateral aid subsidies have proven to be so powerful and since governments have been so aggressive about using them, it is imperative that both government recipients and donors alike be educated about the need to create sustainable, commercial markets and the long-lasting havoc that market distortions can wreak in the marketplace.

Market-based versus government-driven dissemination

Many Asian developing countries are interested in using small-scale renewable energy technologies to provide basic electricity services for rural people. However, most governments are not familiar with the latest methods in market-based dissemination that have resulted from the lessons learned in government-driven dissemination. Many of the newest ideas of market-based dissemination, such as rural energy service companies or elimination of end-user subsidies, are only beginning to be discussed in Asia. Therefore, many governments still opt for the traditional government-driven and government-subsidized approach.

In the industrialized countries, however, the current conventional wisdom is to move away from traditional government-driven dissemination and to pursue a market-based approach. This is in line with worldwide trends towards privatization of many government operations and competition in sectors such as telecommunications and power. One of the reasons why the development community has come to this conclusion is that government and international aid is limited and only the private sector can source the levels of funding that will be necessary to provide electricity services to the some 2 billion people still unserved. Perhaps a more important

[20] Thomas Reindl, "Private Sector Initiatives to Commercialize Photovoltaics without subsidies", *Institutional Cooperation for Solar Energy in the Mekong Riparian Countries*, Hanoi, Vietnam, 11-16 May 1998.

reason is that the private sector typically provides services more cost-effectively and more efficiently than the government.

Today competitive, commercial markets are viewed as the most reliable and cost-effective structures for sustainable dissemination of new technologies. Subsidies come and go as political will changes. Government funding dries up during economic hard times. The challenge is to create these competitive, commercial markets for renewable energy technologies in developing countries.

However, it is hard to ignore the success of Thailand in its government-driven dissemination of over 1000 PV BCS. For nearly a decade, Thailand has been able to provide electricity services to a growing number of rural villagers at practically zero cost to the end-user. Can these successes be applied elsewhere?

Thailand is a unique case in the developing world. It is a relatively rich country which has graduated from many donor aid programs. A small fraction of their petrol tax is deposited into the Energy Conservation (ENCON) Fund, which is then allocated towards energy efficiency and renewable energy programs. Before the 1997 currency devaluation, the ENCON Fund totaled $600M. The government is committed to energy efficiency and renewable energy; and environmental protection and indigenous energy use are high priorities for the country. In addition, approximately 98-99% of the population is grid-connected. Thailand therefore finds itself in the unique position of being able to afford and having the political will to completely subsidize electricity services for their unelectrified population.

However, the economic and currency crisis of 1997 has had huge repercussions on Thailand's programs. DEDP has completely halted installations of PV BCS and only limited funding is available to ensure that existing stations remain operational. PWD's installations of PV BCS and water pumping stations have declined substantially. Some of the ENCON Fund was diverted towards non-energy government needs and at one point during the economic crisis, the government was seriously considering usurping the Fund to make up for budget shortfalls during the economic crisis.

With current funding limitations and increased electricity demand in many villages which would require much more money than is currently spent per villager, Thailand may now need to move to a more market-based approach in order to meet the needs of the rural populations.

The commercialization and government-enabled market-based approaches of China may be better suited as a model for other developing countries. Indeed, China is similar to much of developing world in that a large percentage of their population (about 10% or some 100 million people) lacks electricity access. Like most other developing countries, China doesn't have enough money to completely subsidize electricity services for all of their unelectrified population.

However, China is unique in that it has a relatively mature small-scale renewable energy industry. This, combined with a huge demand for decentralized energy systems, has conspired to drive prices down. China is one of the few developing countries that manufacture PV systems from cells to modules to solar home systems; they have mature wind turbine, micro-hydro and solar water heater industries with an extensive local manufacturing base. The high demand and resulting large production scales means that prices are among the cheapest in the world, per kW or per kWh. Their technologies have a reputation for inferior quality, however, and thus China is not able to export their products to many parts of Asia, notably Southeast Asia.

New projects in China may help to accelerate current efforts. The World Bank is starting work in China that may accelerate the development of SHS use. The United Nations Development Program is starting a project to transform the renewable energy market into a demand-driven market, to attract investors by offering business opportunities, and to coordinate the local industry by creating renewable energy industry associations.

Conclusions

In conclusion, both Thailand and China have been successful in disseminating large numbers of small-scale renewable energy technologies to provide electricity in rural areas. They have utilized very different strategies in approaching the problem: the Thai government has directly disseminated the technologies in fully subsidized programs and the Chinese government has provided infrastructural, technical, and financial support so that local industries could disseminate the technologies. Despite Thailand's successes, the recent economic crisis has had huge repercussions on their programs, revealing their current dissemination strategy to be unsustainable. New market-based approaches with less dependence upon government support may be useful in filling the gap caused by shrinking government programs. It is hoped that the near-commercial renewable energy markets in China are independent enough of government budgets to suffer fewer repercussions than those in Thailand, if the Asian economic crisis should spread to China. The World Bank, UNDP and GEF are also implementing projects to support and expand market development in China.

In addition to the sustainability issues, it is not recommended that other developing countries adopt Thailand's model because the conditions which made Thailand's strategy successful – relatively large government funds and relatively small unelectrified population – are not found in most developing countries. Few developing countries are rich enough to be able to subsidize electrification for all of their remote, rural areas.

Finally, the development of sustainable markets for dissemination is generally hindered by end-user subsidies which tend to distort markets and often result in a boom-and-bust dissemination pattern. The long-lasting effects of these distortions are often underestimated by the governments and institutions who provide the subsidies. Some of the most flagrant abuses of subsidies have been the recent efforts of bilateral aid agencies to expand export markets for their countries under the guise of development aid. Education for both donors and recipients alike about the long-term effects of these subsidies is essential if governments are to craft policy for sustainable dissemination of renewable energy technologies.