MAKING RENEWABLE ENERGY A SUCCESS IN BANGLADESH: GETTING THE BUSINESS MODEL RIGHT

Peter Marro and Natalie Bertsch

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ABSTRACT

This paper analyzes the success of the solar home system program in Bangladesh, which today provides clean, reliable electricity to more than 16 million people in off-grid areas. It describes the impact and benefits of the program; various components of the adopted technology, warranties, and disposal aspects; and highlights the price fluctuations of its components in the global market. The report outlines how the program's business model was the main success factor for its immense scalability. The final section looks at the business model of the program, its current challenges, and other renewable energy applications.

ABBREVIATIONS

AC	–	alternating current
ADB	–	Asian Development Bank
CFL	–	compact fluorescent lamp
DC	–	direct current
GIZ	–	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Development Cooperation)
IDCOL	–	Infrastructure Development Company Limited
LED	–	light-emitting diode
NGO	–	nongovernment organization
PV	–	photovoltaic
REB	–	Rural Electrification Board
SHS	–	solar home system

CURRENCY EQUIVALENTS

(as of 2 December 2015)

Currency Unit	–	taka (Tk)
Tk1.00	=	79.00
$1.00	=	Tk0.0127

EXECUTIVE SUMMARY

This paper examines various success factors that have made Bangladesh home to one of the largest off-grid solar energy programs in the world. Close to 75% of Bangladeshis in rural areas have no electricity in their homes, forcing these villagers to complete their work during daylight. In the dark, they depend on kerosene lamps, which provide poor illumination and produce emissions that cause respiratory illnesses and carry high risks of fire accidents. Solar home systems (SHSs), however, have enabled this population to have access to electric lighting. Today, children can study in the night, shop owners can extend the opening hours of their businesses, and mobile phones can be charged at any time.

In Bangladesh, SHS installation has been driven by the Infrastructure Development Company Limited (IDCOL), a state-owned infrastructure financing company, with technical and financial support from various development partners including the Asian Development Bank (ADB). Since 2002, IDCOL's SHS program has connected more than 3.5 million households, or roughly 16 million persons, in off-grid areas to energy. Under its Public–Private Infrastructure Development Facility 1 and 2, ADB has supported the installation of over 370,000 SHSs, thereby helping poor households save kerosene costs of over $600 million and reduce carbon dioxide emissions by 1.7 million tons over the 20-year SHS life cycle. This paper also examines solar technology and its components, and highlights some factors, such as parts disposal to be undertaken in an environmentally friendly manner, that will become pressing issues in the near future.

A key element of the IDCOL program's success is IDCOL's innovative, partially subsidized SHS delivery and financing scheme. IDCOL works with over 50 participating nongovernment organizations, known as partner organizations, that sell, install, and maintain the SHSs. IDCOL provides direct subsidies that encourage reductions in SHS prices to customers, as well as support for microcredit financing, which makes the price of SHSs affordable. At the core is a strong partnership between IDCOL and its participating organizations in terms of specifically defined responsibilities, a system of checks and balances, smart incentives, and trust.

The program is successful because participating organizations have such an extensive presence in rural areas. They not only extend microcredit to the buyers of the SHSs, but also provide the full range of after-sales services—including guaranteeing the performance of the SHS. Their technicians—often women—install the SHSs and perform any required maintenance, free of charge. If something fails, a replacement can be easily obtained.

This paper also provides an overview of some of the other renewable energy applications that receive funding from IDCOL such as biomass installations, commercial and domestic biogas-based power plants, solar irrigation pumps, and solar minigrids. Some of these applications face substantial barriers which hinder the deployment of these technologies on a much larger scale. It is crucial, therefore, to identify the right business model to ensure the scalability of these applications.

1. INTRODUCTION

1. Although the energy needs of rural Bangladeshis are modest, energy is essential to the country's development. Reliable electricity is needed to power market stalls, cafés, rice mills, saw mills, tailoring shops, and grocery stores for extended opening hours. Children need adequate light to study in the evenings, and schools need energy to teach the information technology skills mandated in the national high school curriculum. Community health centers need refrigerators to store vaccines and other medications. Mobile phones keep villagers in touch with market prices for their products and with relatives working in the cities or overseas.

2. However, 75% of rural Bangladeshis have no electricity in their homes—the grid does not extend to the remote villages where they live. In fact, in most cases, the power lines will not reach them in the foreseeable future. These villagers thus try to do most of their work during daylight hours and in the evenings, depending on kerosene lamps that provide poor illumination and produce emissions that cause respiratory and eye problems.

3. Solar technology is an effective, environmentally sound way to provide the majority with electricity. As such, one of the world's most successful solar energy programs has been working in Bangladesh for the last 13 years to do just that—over 3.5 million solar home systems (SHSs) have been installed in the country's rural villages since 2002—benefitting over 16 million Bangladeshis.

4. This report provides an overview of SHSs in Bangladesh, highlights the factors that have contributed to their success, explains the positive effects that SHS installations have had on the lives of millions, and describes how the Asian Development Bank (ADB) has contributed.

2. SOLAR HOME SYSTEM DISSEMINATION IN BANGLADESH

5. SHSs were introduced in Bangladesh in 1997 when the state-owned Rural Electrification Board (REB) implemented a pilot project for the electrification of 850 households in a remote river island in Narsingdi District. This project used a fee-for-service model, under which the SHSs belonged to the REB, while the users had to pay an initial security deposit and fixed monthly tariffs for the use of the system. As the users were not the system owners, the REB was responsible for the installation, maintenance, repair, and replacement of the SHS components. Appliances, such as lamps and televisions, however, belonged to the users.

6. The project proved the technical feasibility and socioeconomic acceptability of SHSs in rural areas of Bangladesh, and the experience was useful in the design of later SHS programs. Another program using a fee-for-service model—funded by the Government of Bangladesh without any commitments from development partners—started in 2002. The Diffusion of Renewable Energy Technologies Program focused on remote locations of selected districts with a final target of 6,000 disseminated SHSs. However, only 605 SHSs were installed by April 2006 when the program ended.

7. Despite the relatively slow growth of these initial initiatives, nongovernment organizations (NGOs) developed their own SHS dissemination programs. The first commercial activities with SHSs were initiated by Grameen Shakti in 1997, following the cash-sale and credit-sale models.

8. Only once IDCOL and its development partners joined forces, the SHS program became a success. Development partners began SHS promotion in Bangladesh with the Rural Electrification and Renewable Energy Development Project, which was jointly financed by the German Development Cooperation (GIZ), Global Environment Facility, International Development Association, and Kreditanstalt für Wiederaufbau (KfW). The project, which started in June 2003, had six components, two of which focused on helping establish a commercial framework for the off-grid lighting market by supporting the REB and Infrastructure Development Company Limited (IDCOL). The REB component was aimed at developing a fee-for-service program for 14,000 off-grid households, while the IDCOL component was designed to provide the company with project development support and financing to offer loans and grants for renewable energy development. This component also aimed to provide SHSs to 50,000 households by 2008 through a microfinance-based, direct-sales program. The project was extended several times, its investment increasing from $191.00 million to $492.98 million. By 2012, it had financed 1.23 million SHSs in Bangladesh.[1] Development partners jointly provided additional financing under follow-on projects to increase the number of installed SHS to 3.5 million by the end of 2014.

3. INFRASTRUCTURE DEVELOPMENT COMPANY LIMITED'S SOLAR HOME SYSTEM PROGRAM

9. IDCOL is the largest financier of private sector infrastructure projects in Bangladesh, with the ability to catalyze international long-term local and foreign currency funding and international know-how for infrastructure projects and renewable energy interventions. Incorporated on 14 May 1997 as a 100% state-owned public limited company under the Companies Act (1994), IDCOL was set up with World Bank assistance under the Private Sector Infrastructure Development Project.[2] The company is owned by the Ministry of Finance and is governed by an independent board of directors drawn from the government and the private sector.

10. IDCOL's initial function was to administer the Private Sector Infrastructure Development Fund set up under the World Bank-led Private Sector Infrastructure Development Project and to onlend funds to eligible privately sponsored infrastructure projects. IDCOL acted as the fund manager, while the subprojects were financed from a special fund established for this purpose. IDCOL was paid up-front, and the monitoring fees and the principal and interest repayments were directly funded out of government repayment accounts. Since 2005, IDCOL has widened its operations and started financing from its balance sheet after the government injected further equity capital into the company.

11. The company had an initial 5-year target of financing 50,000 SHSs under the Rural Electrification and Renewable Energy Development Project, achieved in August 2005, 3 years ahead of the target date and $2 million below estimated costs. This program has since grown to become the market leader in the renewable energy sector in Bangladesh and is supported by ADB, Department for International Development of the United Kingdom, GIZ, Global Environment Facility, Global Partnership on Output-Based Aid (a multidonor trust fund), Islamic Development Bank, Japan

[1] Independent Evaluation Group, World Bank. 2014. *Project Performance Assessment Report: Rural Electrification and Renewable Energy Development Project, Power Sector Development Technical Assistance Project, and Power Sector Development Policy Credit.* http://ieg.worldbank.org/Data/reports/Bangladesh_RuralElecrificationRenewables_PowerSectorTA_PowerDPC_PPAR_885460PPAR0P070Codisclosed060240140_0.pdf

[2] World Bank. 1997. *Private Sector Infrastructure Development Project*. Washington, DC.

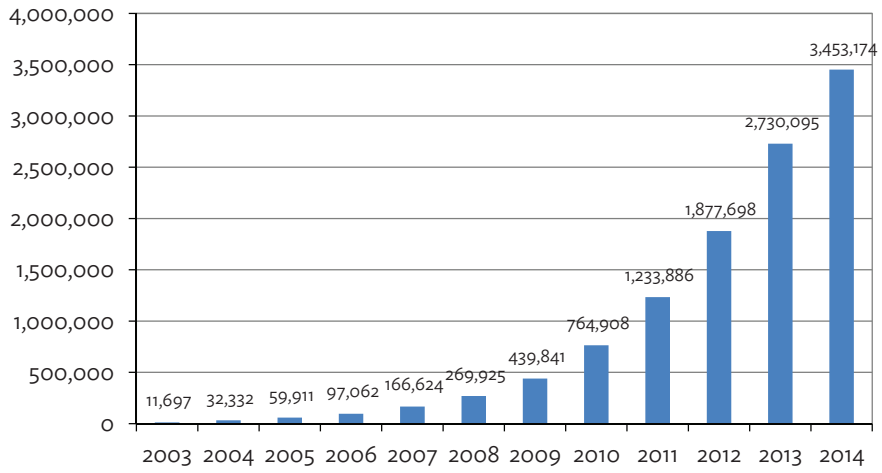
International Cooperation Agency, KfW, SNV, United States Agency for International Development, and World Bank.

12. IDCOL has been promoting SHSs through its network of participating organizations, which are implementing the program by selling SHSs on microfinance-based credit, as well as installing, distributing, and maintaining the systems. The company provides wholesale financing to participating organizations for relending, and closely monitors program administration.

3.1 Outcomes

13. Today, Bangladesh has one of the most successful renewable energy programs in the world. As of December 2014, IDCOL provided loans and grants totaling about $594 million for the installation of 3.5 million SHSs generating clean electricity equivalent to about 141 megawatts. The program has changed the lives of over 16 million people living in off-grid areas, primarily in rural regions. This is equivalent to about 10% of the overall population of Bangladesh and is the largest off-grid solar program in the world.[3] The program is also saving about 200,000 tons of fossil fuel per year and has created jobs for over 75,000 people. By 2018, the program intends to install 6 million SHSs across the entire country.

Figure 1: Solar Home System Installation Numbers, 2003–2014



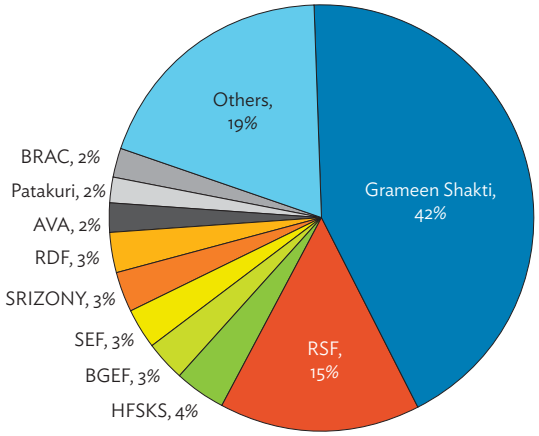
Source: IDCOL.

14. The program has succeeded in achieving rapidly growing penetration rates of SHSs in all parts of rural Bangladesh, even though households pay almost the full cost of their SHSs using a microcredit loan facility. Participating organizations report an average loan collection rate of 96%, and IDCOL has not experienced any defaults among the participating organizations servicing their debt.

[3] There are probably more than 10 million SHSs worldwide in use. Apart from over 3.5 million homes that have been supplied through the IDCOL program in Bangladesh, the World Bank's Renewable Energy Development Program has supplied over 400,000 systems to rural areas in the People's Republic of China as well as about 350,000 installations in Kenya, which is the largest market for SHSs in Africa. Despite its large size and huge demand for electricity, India installed only 1 million SHSs in 2011, a number which is expected to grow to 3 million–4 million by the end of 2015.

15. The dominant participating organization is Grameen Shakti, which has a market share of roughly 42% of all installations. Grameen Shakti is a member of the Grameen family of organizations, which includes Grameen Bank, the country's most extensive microcredit network and resource base. The second largest participating organization, the Rural Services Foundation, accounts for about 15% of all installations.

Figure 2: Distribution of Solar Home Systems by Participating Organizations January 2015



BGEF = Bright Green Energy Foundation, HFSKS = Hilful Fuzul Samaj Kallyan Sangstha, RDF = Resource Development Foundation, RSF = Rural Services Foundation.
Source: IDCOL.

16. Other than its SHS program, IDCOL is also involved in a number of other renewable energy initiatives using various technologies and applications (Table 1).[4]

Table 1: Renewable Energy Initiatives Supported by the Infrastructure Development Company Limited

Program	Target	Achievements as of December 2014
Solar Home System	6 million systems by 2018	3,500,000
Domestic Biogas	100,000 biogas plants by 2020	36,000
Solar Irrigation	1,550 solar agricultural pumps by 2017	124
Solar Minigrid	50 solar minigrids by 2017	4
Solar-Powered Telecom Base Transceiver Stations	As per demand	138
Biogas-based Electricity	130 biogas-based power plants by 2017	5
Improved Cooking Stove	1 million cooking stoves by 2018	Recently launched

Source: IDCOL.

[4] This report focuses primarily on SHSs. Some other renewable energy initiatives, such as solar minigrids, base transceiver stations, and improved cooking stoves, are not covered as they have been recently introduced in Bangladesh, and the accumulated experience and knowledge are still too limited.

3.2 ADB Involvement

17. Since 2008, the ADB-financed Public–Private Infrastructure Development Facility has supported the IDCOL program to increase electricity access in rural Bangladesh. Through the facility, ADB provided a loan of $33 million from the Asian Development Fund to finance IDCOL's SHS program. In addition, a $2 million grant from the Asian Clean Energy Fund under the Clean Energy Financing Partnership Facility[5] provided buy-down grants of $25 per individual SHS installation, which were equally applied to all systems sold at any time. Given the success of IDCOL's refinancing program, it was decided in 2010 to increase the SHS component under the Public–Private Infrastructure Development Facility to $78 million.

18. ADB has thus supported the installation of 330,362 SHSs through the Asian Development Fund loan and 80,000 SHSs through the grant. Assuming that each SHS saves about $5.70 per month or $68.50 per year of kerosene and reduces carbon dioxide emissions by 188 kilograms annually, it is expected that ADB will help households save $562.2 million and reduce carbon dioxide emissions by 1.54 million tons over the 20-year SHS life cycle.

19. A follow-on Asian Development Fund loan of $10 million under the Second Public–Private infrastructure Development Facility was approved in October 2013. This is expected to fund 42,355 SHSs, leading to $58 million in kerosene savings and a reduction of 159,255 tons of carbon dioxide emissions over the 20-year SHS life cycle.

3.3 Economic Benefits

20. Environmentally friendly and modern energy technologies are essential to economic, environmental, and social development—the three pillars of sustainable development. Making these technologies affordable and accessible for people at the bottom of the income pyramid provides enormous potential to stimulate inclusive and sustainable growth for developing countries such as Bangladesh.

21. **General economic benefits.** Although kerosene lamps, candles, and battery-run torches are relatively expensive and inefficient, they are the most used light sources in the rural areas of Bangladesh. As a consequence, lower-income households pay relatively high amount per month for poor lighting services, as a fraction of their income.[6] SHSs have the potential to help reduce some of the expenditures incurred for lighting, and information and communication technologies (e.g., mobile phone charging and the use of radios and televisions) and can therefore ease stretched households' budget.

22. Beyond this savings potential, SHSs provide additonal economical benefits to consumers in off-grid areas. Improved lighting conditions enable students to study longer during the night and provide shop owners with increased income-generating activities after dark. The use of mobile phones and radios improves access to information about market opportunities and prices, increases the impact of education, helps social cohesion, and assists in emergency situations, all of which can all enhance economic growth and reduce risks to which poor households are particularly vulnerable.

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[5] Established by the Government of Japan.

[6] The expenditures for kerosene account as much as 10% of poor households' overall spending, so the economic benefits that are derived from solar lighting systems are significant.

23. **Economic impacts for micro, small, and medium-sized enterprises.** SHSs also offer significant economic benefits for micro, small, and medium-sized enterprises, which can be broadly divided into two categories: (i) after-sales services offered by these enterprises, and (ii) the purchase and use of SHSs to improve their business prospects. The impact of SHSs on companies located in rural areas of Bangladesh can be observed on many levels. For instance, food stalls are able to stay open late, and operators of mobile phone booths can serve more clients in the evening, thereby increasing their income.

24. The IDCOL program has also had a significant impact on generating local jobs in manufacturing and after-sales services, and in training local technicians. Except for the photovoltaic (PV) panel, all other SHS components are produced domestically which provides employment for technicians and for many—mainly female—workers in factories, located in rural and urban centers that produce charge controllers and solar lamps. Grameen Shakti alone reports that a total of 46 Grameen technology centers have been set up for local manufacturing of SHS components, thus creating a green industry and jobs. Close to 17,000 technicians have been trained, 1,000 of whom are women. The Rural Services Foundation also provides training on the basic maintenance and safety of SHSs—representatives take solar demonstration kits around villages to show people the benefits of owning SHSs.

3.4 Social Benefits

25. **Health and safety benefits.** In Bangladesh, poor households without access to electricity use mostly kerosene-based lamps and lighting devices, which pose serious health and safety hazards, along with their broader contribution to global warming. Kerosene lamps are one of the major sources of household air pollution in Bangladesh, emitting black carbon which can cause chronic pulmonary diseases and other respiratory problems. Typically, women and children are most exposed to the kerosene vapors, as they spend a substantial portion of their time inside the house. It is estimated that nearly 2 million children are killed in developing nations each year because of acute respiratory infections like influenza and pneumonia. In fact, over 32,000 Bangladeshi children under 5 years old have died as a result of indoor pollution.[7]

26. The use of kerosene lamps indoors also carries a high risk of fire accidents. It is estimated that over 95% of fatal fire-related burns occur in low- and middle-income countries.[8] The ongoing nationwide dissemination of SHSs among low-income households in Bangladesh will therefore make a valuable contribution to improved health and safety conditions among the most vulnerable groups within the country.

27. **Improved educational opportunities.** As kerosene lamps do not provide sufficient lighting conditions for evening activities, such as studying and reading, there is a direct impact on the literacy and school performance of students due to limited studying hours. One case study from the World Bank, based on data from Bangladesh, confirmed the positive correlation of access to electricity by households to educational enrollment ratios.[9]

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[7] World Health Organization. 2007. *Indoor Air Pollution: National Burden of Disease Estimates.* http://www.who.int/indoorair/publications/nationalburden/en/

[8] World Health Organization. Violence and Injury Prevention: Burns. http://www.who.int/violence_injury_prevention/other_injury/burns/en/

[9] S. R. Khandker, D. F. Barnes, and H. A. Samad. 2009. Welfare Impacts of Rural Electrification: A Case Study from Bangladesh. *World Bank Policy Research Working Paper Series.* No. 4,859. Washington, DC.

28. Another study carried out by the Energy Sector Management Assistance Programme in 2003 to measure the social benefits of improving educational opportunities and conditions in monetary terms estimated that there is a potential return of $80–$150 per month and per rural household from access to modern energy sources.[10] Since SHSs are a relatively low-cost option for improved lighting, their introduction and countrywide dissemination can offer significant opportunities to improve studying conditions to many students in lower-income households and can thereby help enhance educational performance in developing countries.

29. **Gender aspects.** The burden of providing supplies for kerosene lamps is the responsibility of women in most developing countries, which can add substantially to the workload of women in rural areas, where these supplies are not always available in villages. SHSs can therefore substantially lessen the workload of women, particularly in low-income households, by reducing or eliminating the time it takes to procure these lighting supplies.

3.5 Environmental benefits

30. The use of lighting devices, which are based on fossil fuel, is the primary source of greenhouse gas emissions related to lighting in developing countries. According to a report from the International Association for Energy-Efficient Lighting, 244 million tons of carbon dioxide are emitted each year through the use of fuel-run lighting devices like kerosene lamps, oil lamps, gas lamps, and candles.[11] Finding alternative clean lighting solutions that are affordable and use of simple technologies for low-income households are therefore important entry points for the reduction of global greenhouse gas emissions. SHSs provide relatively low-cost opportunities for emerging economies with large rural populations, like Bangladesh, to pursue low-carbon development paths without compromising the goal of continuous improvements of living conditions.

31. A 2012 survey by the Bangladesh Institute of Development Studies and World Bank estimated the reduction in carbon dioxide emissions from kerosene replacement due to SHS adoption to be approximately 5.5 kilograms per month per household.[12] This translates to more than 500,000 tons in avoided carbon dioxide emissions each year for all SHS households in Bangladesh. Considering that only about 10% of people in off-grid areas have adopted SHSs, the potential for even greater reductions is considerable.

4. SOLAR HOME SYSTEM TECHNOLOGY

4.1 Components

32. SHSs are small PV systems that offer a convenient supply of electricity for lighting and running small appliances for about 3–5 hours per day. Typically, an SHS consists of a small solar PV panel, charge controller, battery, and wires and connected switches.

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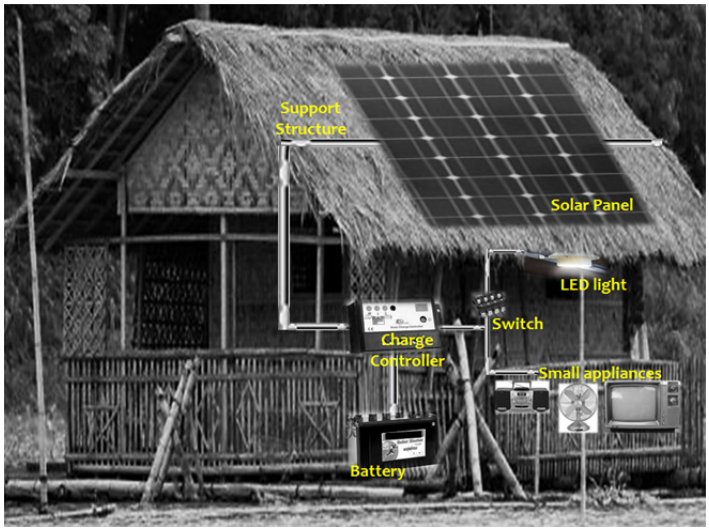
[10] Energy Sector Management Assistance Programme. 2003. *Household Energy Use in Developing Countries: A Multicountry Study*. Technical Report. Washington, DC.

[11] E. Mills. 2002. *The $230-Billion Global Lighting Energy Bill.*http://evanmills.lbl.gov/pubs/pdf/global_lighting_energy.pdf

[12] Bangladesh Institute of Development Studies and World Bank. 2012. *Household Survey Data on Impact Evaluation of Solar Home Systems in Bangladesh.* Dhaka.

33. The core component of the SHS is the PV solar panel which converts sunlight into electricity. The battery stores the energy for use at night or during cloudy weather. The charge controller is a device that manages the electric flow through the system and protects the battery from damage. It alerts the user as soon as the battery needs charging or when the module is not working properly. Wires and connected switches (through universal outlets) distribute the electricity within the system and to the load, such as lights or electrical appliances. Typical SHSs operate at 12-volt direct current (DC) and use compact fluorescent lamps (CFLs) or light-emitting diode (LED) lights and small appliances to make the best use of the provided power.

Figure 3: Components of a Solar Home System



LED = light-emitting diode.
Source: ADB.

34. SHSs are primarily meant to be used by low- and middle-income households, as well as micro and small enterprises, in off-grid rural locations to run simple household appliances such as televisions, radios, fans, a few light bulbs, and chargers for mobile phones. They do not allow for more energy-intensive uses such as cooking, water heating, or industrial use, so it should not be thought of a full solution to energy access. SHSs typically have capacities of 20 watt-peak–130 watt-peak. While the 50 watt-peak models represent the most sales, the smaller 20-watt-peak systems are becoming increasingly popular due to the advancements of new LED technology that consumes much less energy to produce the same amount of lumen.[13]

[13] Lumens measure the amount of light produced, and watts measure the amount of energy required to light products. The more lumens in a light bulb, the brighter the light will be.

35. Table 2 provides an overview of the appliances, operating time, and retail price of various SHS configurations.

Table 2: Popular Solar Home System Configurations

Capacity	Appliances	Duration of Operation	Retail Price ($)
20 watt-peak	3-watt LED lamp: 2 Mobile phone charger: 1	4–5 hours	140
50 watt-peak	3-watt LED lamp: 5 LED color television: 1 Mobile phone charger: 1	4–5 hours	350
85 watt-peak	3-watt LED lamp: 7 LED color television: 1 Mobile phone charger: 1 12-watt direct-current desk fan: 1	4–5 hours	480

LED = light-emitting diode.
Source: IDCOL.

36. Depending on their size and purchase modality, prices of SHSs are $80–$590. Local prices depend on factors such as duties, taxes, and subsidies; scale of manufacturing and assembly processes; scale and cost of marketing and after-sales services such as servicing and repairs; degree of competition; capacity utilization in the manufacturing process; and cost of funds for working capital and capital costs. In the case of Bangladesh, all components—with the exception of the solar cells—are produced by local manufacturers.

4.2 Solar Panels

37. Solar panels, which are the heart of an SHS, are made of wafers or cells of semiconductor material that use sunlight and the PV effect[14] to generate electricity. Three different types of cell technologies—solar cells made of monocrystalline silicon, polycrystalline silicon, and thin-film materials—represent different energy-conversion efficiencies and manufacturing techniques that have tried to reduce the cost of PV-generated electricity, which has been progressing since the 1970s.

38. A solar panel is made up of numerous series and parallel combinations of identical individual cells to generate a desired power output. A power rating in watts is assigned to the panels based on the maximum electricity that can be produced under ideal sunshine and temperature conditions. This rating helps determine how many panels are needed (attached together in solar arrays) to meet the demand in terms of electrical load. There is a direct relationship between output power and solar panel cost—the solar panel accounts for roughly 27% of the total cost of an SHS.

39. **Warranty and disposal.** The PV modules carry a 20-year warranty that guarantees that the units produce at least 80% of their rated power. There is a concern that improper disposal of PV panels could become a problem when the PV panels start to reach the end of their useful lifespan of 20 years.

[14] The PV effect is the creation of voltage or electric current in a material upon exposure to light and is a physical and chemical phenomenon.

Since the program started in 2003, with the majority of the SHSs being installed after 2008, this issue needs to be addressed in the next few years.

40. The first-generation crystalline-silicon PV panels experienced lead leaching, while the second generation of thin-film panels suffered from cadmium leaching. Furthermore, hazardous materials, such as glass and aluminum (common components in most PV panels), can result in various types of health and environmental risks. An appropriate mechanism must be established, therefore, for the safe disposal of solar panels to ensure the sustainability of the program. Since Bangaldesh does not presently have any recycling facilities for PV panels, IDCOL has appointed a consultancy firm to develop a policy framework and the requisite infrastructure to ensure the safe disposal of PV panels.

41. **Global industry.** Over the last 10 years, the global solar industry has been growing at approximately 70% annually. Even in the recession year of 2009 and the recovery year of 2010, the industry grew at an astonishing rate of 172%. It was difficult to keep up with demand. As a result, companies that were able to dramatically increase capacity gained market share. No one wanted to be left out, so every company added capacity as fast as possible while assuming that the industry growth would continue in the foreseeable future. In 2010, industry analysts started to warn that too much capacity was being brought on line. As the market was growing at double forecasted growth rates, there seemed to be ample absorption capacity.

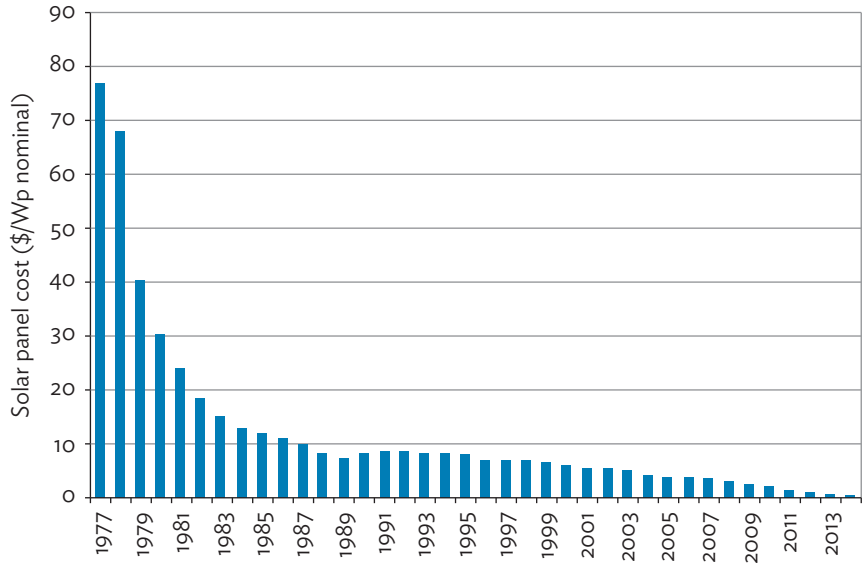
42. In early 2011, however, capacity additions finally began to exceed the demand. Prices of crystalline-silicon solar cells began to drop, as companies, especially second- and third-tier producers, fought to reduce inventories that were piling up. Although the industry continued to grow at a 40% rate, there was so much inventory by the middle of the year that all prices—modules, cells, wafers, and polysilicon—tumbled almost uncontrollably. For example, wafer prices dropped about 70%, solar cells dropped about 60%, and modules dropped about 50%. A paper published by Greentech Media Research estimated that 31 gigawatts of crystalline solar cells were produced, and about 25 gigawatts were sold, leaving 6 gigawatts of excess crystalline inventory.[15] Because of this glut, many smaller producers simply suspended manufacturing operations, and one major company, Q-Cells of Germany, filed for bankruptcy.

43. Hardest hit were the polysilicon suppliers.[16] Prices dropped from about $80 per kilogram at the beginning of 2011 to $20–$25 per kilogram towards the end of 2011, about a 70% drop. In 2007 and 2008, there was a worldwide polysilicon shortage, and polysilicon prices increased to about $400 per kilogram. Suppliers made a lot of money and added massive capacity, so there was a huge polysilicon capacity overhang, estimated at 40 gigawatts. In 2011, the raw material, polysilicon, which makes up a significant part of the total cost, dropped dramatically.

44. Most analysts believe solar cell and module capacity will be reasonably in line during 2015, but the polysilicon glut may take several years to work off. Due to the falling prices while unit shipments increased, almost all of the companies in the solar industry were unprofitable from 2011 to 2013.

[15] Four Peaks Technologies. Solar Markets. http://solarcellcentral.com/markets_page.html
[16] *Ibid.*

Figure 4: Solar Panel Price History, 1977–2013



Wp = watt-peak.
Source: Bloomberg (New Energy Finance).

4.3 Battery

45. Almost all solar electrical applications use lead-acid battery chemistry to store energy.[17] This is due to the battery's storage capacity–cost ratio, its wide availability, technical simplicity, and support infrastructure. A lead-acid battery is an electrochemical device that stores chemical energy and releases it as electrical energy upon demand. When a battery is connected to an external load, such as light, chemical energy is converted to electrical energy, and direct current (DC) flows through the circuit.

46. The batteries have storage capacities of 55 ampere-hours–130 ampere-hours. They differ in detailed construction from standard lead-acid car batteries, because PV batteries must withstand daily deep discharge cycles that could rapidly reduce the lifetime and storage capacity of a car battery. For this reason, most batteries used in the IDCOL program have tubular plates, which enable significant removal and replacement of lead during the discharge and recharge process, and allow for regular discharge of up to 80% of their capacity. They also have a large reservoir of electrolytes to reduce the frequency of topping up. Other benefits are much higher charging efficiencies and low rates of self-discharge. The battery cost is roughly 40% of the total equipment cost of an SHS.

47. **Warranty and disposal.** Generally, the warranty for a lead-acid battery under the IDCOL program is 5 years, but the life expectancy may differ from the warranty period due to different usage pattern or other operational issues. Batteries from Rahimafrooz, the largest manufacturer in the IDCOL program, are designed to last 8–10 years with proper care and maintenance. Rahimafrooz repairs batteries free of charge in most cases. So far, more than 3,300 batteries have been repaired

[17] J.Chow. 2010. *Assessment of Solar Home System for Isolated Rural Communities in Vanuatu Using Project Lifecycle/Sustainability Framework*. Houghton, Michigan: Michigan Technological University. p. 6.

although some of them were not under warranty. Rahimafrooz buys batteries back for recycling at the end of their service life, paying the users Tk300–Tk500, depending on their conditions.

48. All 17 battery companies operating in Bangladesh have completed the ISO Environmental Management Standard 14001:2004 and Occupational Health Safety Standard 18001:2007 certification processes. Out of these 17 battery suppliers, only three have their own recycling plants, while the rest have entered into arrangements with the existing three recycling plants to use their facilities. Only the recyclers have proper effluent treatment and air treatment facilities, as no policies or legal framework is currently in place to require them to do so. Given the growth of the IDCOL program, it is expected that the existing recycling capacity will become inadequate in the near future, which will force all existing manufacturers to have their own recycling plants.

49. Improper disposal and recycling of lead-acid storage batteries can cause sulfate contamination in groundwater, soil, and the human body. Lead sulfate is a water-soluble substance that can contaminate the groundwater, severely affect hydrogen in the soil damaging crops, kill fish, and cause skin damage to those who are in physical contact with contaminated water. Acute lead poisoning can occur when people are directly exposed to a large amount of lead through inhaling dust, fumes, or vapors dispersed in the air.[18] Chronic poisoning from absorbing low amounts of lead over long periods of time is a much more common and pervasive problem. Lead can enter the body through the lungs or the mouth and, over a long period, can penetrate in bones. Health risks include impaired physical growth, kidney damage, mental retardation, and, in extreme cases, death. Lead poisoning also can lead to fatigue, headaches, aching bones and muscles, memory loss, loss of appetite, and sleep disturbances.

50. Every 6 months, IDCOL monitors the environment, health, and safety compliance of the battery-recycling plants in Bangladesh. Furthermore, IDCOL arranges quarterly awareness-raising trainings with battery manufacturers and recyclers on the importance of environment, health, and safety compliance. Any issues related to battery recycling are discussed with the participating organizations, battery manufacturers, and recyclers in a quarterly compliance meeting during which they also must present quarterly compliance reports.

51. Since November 2012, IDCOL has inspected 47,679 warranty-expired batteries which represents 11% of total warranty-expired batteries. About 4% of these units have been replaced. About 90% were found to be fully operational and supply adequate electricity, while 6% of batteries were partly functional.

52. Through the introduction of IDCOL's recycling initiative, it is hoped that Bangladesh will not face the same problems of improper battery disposal procedures as in the People's Republic of China and India where they have become major sources of pollution.[19]

4.4 Loads, Compact Fluorescent Lamps, and Light-Emitting Diode Lights

53. Loads are electrical appliances that draw power from the battery, either directly or indirectly.[20] Typical home electrical appliances are alternating current (AC)-powered. To be able to use AC-powered appliances with an SHS, an AC/DC power inverter is required. The inverter itself acts as a

[18] M. Asaduzzaman et al. 2013. *Power from the Sun: An Evaluation of Institutional Effectiveness and Impact of Solar Home Systems in Bangladesh*. Dhaka: Bangladesh Institute of Development Studies. p. 108.

[19] P. Gottesfeld and C. R. Cherry. 2011. Lead Emissions from Solar Photovoltaic Energy Systems in China and India. *Energy Policy*. 39. pp. 4,939–4,946.

[20] Footnote 17, pp. 6–7.

load because of parasitic power draw (i.e., stand-by power consumption) and conversion-efficiency loss. All AC-powered appliances connect to the inverter, which gets its power from the battery. In many SHSs, however, an inverter is not included due to cost and system-abuse concerns. Therefore, technically modified DC-powered appliances, such as CFLs and LED lights, small radios, and small televisions, are connected directly to the 12-volt DC SHS circuit. It is cost-effective and efficient to deploy DC-only SHSs due to the typical low power requirements of DC appliances, and it also simplifies the system design.

54. Given the high price of AC/DC inverters for SHSs, only DC systems have gained popularity under the IDCOL program. Today, most appliances are insensitive to DC or AC connections. Therefore, it is less likely that all systems need inverters. New technologies currently under development increase the prospect for innovative DC-powered appliances, such as refrigerators.

55. **Warranty and disposal.** IDCOL requires 3-year warranties for LED lamps and 1-year warranties for CFLs. Because conventional CFL bulbs contain substantial levels of mercury, there is a risk of environmental and health hazards due to improper disposal of CFL bulbs. A national disposal policy framework and guidelines are currently being developed to ensure safe collection and disposal with the help of an international consultant hired by IDCOL. Presently, there are not enough facilities in Bangladesh to properly dispose CFL bulbs. It is hoped that—as an outcome of the report prepared by IDCOL—the government will introduce a legal framework and requirements for safe disposal. The gradual move to LED lights will also decrease these risks, as LED lamps contain less hazardous materials.

4.5 Charge Controller

56. The primary function of the charge controller is to maintain battery health by preventing battery overcharge by the solar panels and full discharge by the loads, as either condition will lead to severely reduced battery lifespans. Charge controllers come in all sizes, and have various protection and monitoring features. The selection depends on the size of installed solar panels and the complexity of loads and future expansion possibilities. Different charging and maintenance algorithms are employed, depending on the state and the type of the battery. Suitably designed charge controllers have many electrical protection features that are beneficial in SHSs, such as reverse polarity; short circuiting; over-current, low-voltage disconnect; and tropicalization of circuit boards.

57. **Warranty.** The charge controllers have an expected 5-year life cycle and carry a 3-year warranty. Until 2006, Rahimafrooz maintained a 2% emergency stock of charge controllers that were free to consumers, so that replacements could be provided rapidly. Since then, the emergency stock has been reduced to only 1%, as the charge controllers have proved to be very reliable.

4.6 New Developments in Technology

58. The advancements of new LED technology has helped design small SHSs between 10 watts and 20 watts that cost on average $200 and can power two to four lights and charge a mobile phone. Public response to these small SHSs was positive so that IDCOL agreed to include these systems in its program.

59. An even smaller solar system, known as a pico PV solar lantern, is currently being developed to meet the basic lighting needs of the poorest households. These lanterns, with panel sizes of less than 10 watt-peak, use efficient LED technology to ensure maximum light output from a small amount of energy. Lithium-based batteries with a capacity to run the light at full power for 12 hours make these

products environmentally friendly and reliable in the rainy season, where light levels can remain low for several days. With a capacity of at least 200 lumen per system, the lanterns can light a small hut much more comfortably and efficiently than traditional kerosene lanterns. The aim is to hold the cost of these new solar lanterns below the amount that a household could potentially save in 2 years by not using kerosene lamps. Some estimates suggest that 1–2 million of these lanterns could be installed in Bangladesh by 2015. This would require a steep change in production rates and some careful planning to manage the pace of installation and maintenance.

5. BUSINESS MODEL

60. This section provides an overview of the business model of the IDCOL program and analyzes its various success factors, enabling it to reach over 16 million people in off-grid areas—a scale unprecedented by other countries. While the SHS technology is widely available, few countries were able to scale up the SHS distribution in a manner to connect a substantial part of the rural population to electricity. The program is a success story because it managed to get the SHS business model right. At the core is a strong partnership between IDCOL and its participating organizations in terms of specifically defined responsibilities, a system of checks and balances, smart incentives, and trust.

61. IDCOL, as the implementing agency, provides refinancing and recruits participating organizatons, which select subproject areas and potential consumers, extend loans, install the systems, monitor their performance, and provide maintenance and technical support. This arrangement allows IDCOL to benefit from a grassroots network, which is vital for introducing efficient technology to underdeveloped rural areas and encouraging community participation.

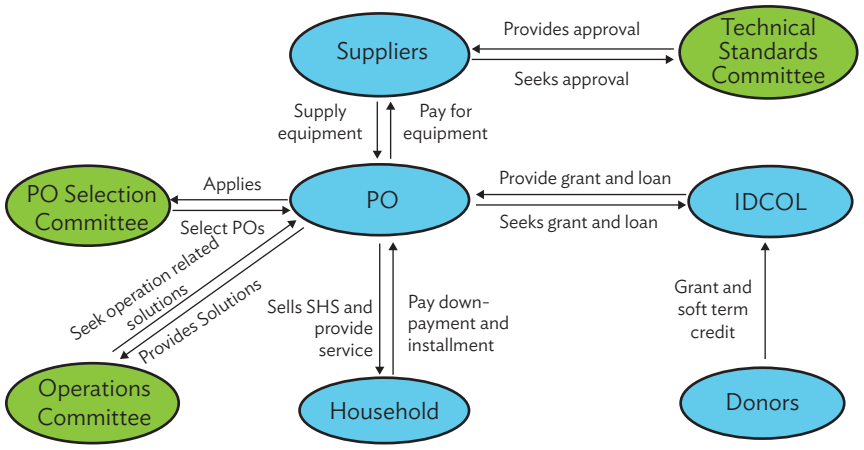
62. IDCOL's Participating Organization Selection Committee[21] screens organizations against clear eligibility criteria for inclusion in the program. Prior to installation, IDCOL's Technical Standards Committee, which meets monthly, approves the suppliers and SHS equipment.[22] The participating organizations obtain the SHSs from equipment suppliers, in compliance with the technical standards set by the Technical Standards Committee, which also reviews product credentials and approves and certifies eligible equipment.

[21] The Participating Organization Selection Committee is composed of senior representatives from the government, NGOs and academia such as the Bangladesh Institute of Development Studies; Economic Relations Division, Ministry of Finance; NGO Affairs Bureau; and Palli Karma-Sahayak Foundation.

[22] The Technical Standards Committee comprises senior representatives of the Local Government Engineering Department, Power Cell (technical arm of the Power Division), a private technical university, a public technical university, REB, and the University of Dhaka.

63. The program structure is shown below.

Figure 5: Participating Organization Selection Committee



IDCOL = Infrastructure Development Company Limited, PO = participating organization, SHS = solar home system.
Source: IDCOL.

64. IDCOL verifies the financial claims of participating organizations and makes payments within 21 days of claims.

65. IDCOL's Operations Committee[23] is responsible for the implementation and oversight of the program. In addition to providing refinancing and grants to participating organizations, IDCOL also carries out training and awareness-raising activities for its staff, the participating organizations, and SHS consumers. Training activities include areas such as SHS installation, maintenance and troubleshooting, and market development. An important aspect of IDCOL's awareness-raising activities is the preparation and distribution of marketing materials to increase the awareness and use of SHSs among rural households. IDCOL also maintains a call center to handle queries and complaints.

66. **Product.** Given the specific client base in remote areas, including some of the poorest segments of the population, the program includes three salient features: (i) the high quality and reliability of all technical components, (ii) a buy-back policy for any reason including dissatisfaction and financial difficulties, and (iii) stable pricing. The price of an SHS has approximately remained the same through the program (2002–2014), and thus has become less expensive in real terms.

67. **Corporate governance and staffing.** IDCOL is a fully state-owned corporation. Half of the board of directors are civil servants (at the secretary level) from various relevant ministries, while the other half are independent directors from the private sector. Although it has a mandate guided by Bangladesh's economic and developmental policies, IDCOL is free from political interference in its operations and lending decisions. As a company, IDCOL is in a position to pay competitive salaries that—in combination with its purposeful work and mandate—enables it to retain committed and

[23] Members of the Operations Committee include IDCOL staff members and participating organization representatives. The chief executive officer of IDCOL chairs the committee.

competent staff in management and at the project level. As of December 2014, IDCOL had 180 staff members exclusively working on its various renewable energy initiatives, including SHSs.

68. **Participating organizations.** The IDCOL program uses participating organizations that are primarily NGOs and microfinance institutions with established presence and high credibility in Bangladesh to operate as SHS vendors, although there are also some private companies. NGOs and microfinance institutions acting as participating organizations are regulated by the Microcredit Regulatory Authority of Bangladesh. The number of participating organizations has substantially grown over the last 13 years from 5 in 2002 to 56 as of September 2015. Overall, the program runs across 5,732 branches of the different participating organizations and employs 33,627 staff members.

69. **Partnerships.** A memorandum of understanding between IDCOL and participating organizations is signed to define respective obligations and responsibilities (Table 3).

Table 3: Overview of Respective Responsibilities Regarding Solar Home Systems

Item	IDCOL	Participating Organization
Overall program management	Determines eligibility of participating organizations in the program.	Enters into an agreement with IDCOL.
Logistics support	Each participating organization is given a computer for efficient documentation related to SHS installation. They are provided with toolboxes, demonstration kits, hydrometers, and battery chargers to render better services to consumers. IDCOL shoulders the major share of costs. Further logistic support is provided if and when necessary.	Sources, procures, and installs the SHSs throughout the country.
Financing	Provides 70%–80% financing to participating organizations.	Extends credit to consumers and receives refinance from IDCOL.
Quality control	Sets standards, monitors at the field level, and organizes technical audits by a third party.	Ensures quality during procurement, and monitors at the field level.
Procurement	Accredits suppliers.	Purchases SHSs and on-sells them to its clients.
Training	Pays up to 75% of training cost of participating organization staff.	Pays minimum of 25% of training cost.
Warranty and after-sales service	Runs a call center (1 person).	Conducts extensive after-sales services.
Audit	Appoints independent organizations to conduct commercial and technical audits. The objective of the commercial audit is to ensure that households' downpayments are accounted for properly and that participating organizations are utilizing the grants and refinancing for their intended purposes only. A technical audit is conducted to ensure that only approved equipment by the technical standards commission is used under the program. Representatives of the suppliers accompany the technical audit team.	Facilitates the audit by making its staff and equipment available for the auditors.

IDCOL = Infrastructure Development Company Limited, SHS = solar home system.
Sources: ADB and IDCOL.

70. IDCOL and participating organization representatives openly discuss in monthly meetings any issues that may have arisen and regularly review and update program business procedures to reflect new approaches and solutions.

5.1 Supply and Value-Chain Analysis

71. IDCOL's Technical Standards Committee vets acceptable international and local suppliers in line with technical specifications provided by IDCOL management who then further vet the suppliers with regard to their ability to supply the required volume. Suppliers must have a representative office in Bangladesh. Thus, although Bangladesh depends on importing solar panels, the program has also fostered an increased presence of domestic manufacturers of SHS components.

72. **Solar panels.** A participating organization can choose from a list of 94 IDCOL-approved solar panel suppliers, mostly from the People's Republic of China. The main criteria for the approval are the technical specifications established by the Technical Standards Committee, including warranty periods and volume capacity. IDCOL technical inspectors check the quality of all imported panels as part of their general inspections. Participating organizations generally order a 3-month stock of panel supplies. In the beginning of the program, four to five partner organizations ordered panels together to achieve price discounts and address inventory storage constraints. This is no longer necessary as the order volumes have grown significantly. All solar panels are imported tax-free.

73. Numerous local and foreign manufacturers are involved in providing SHS components of varying qualities in Bangladesh.[24] As the pace of SHS installations has accelerated, concerns about quality and system efficiency have increased. Standards testing for quality is needed to increase the SHS life cycle, reduce environmental damage from improperly discarded components, and increase the feasibility of a future scaled-up program. Recent efforts by IDCOL to work with the Bangladesh University of Engineering and Technology for establishing a PV-testing facility in Bangladesh is a step in the right direction. The facility is expected to be in operation by end of 2015.

74. Because of their cheaper cost, together with the lack of knowledge and understanding by consumers, PV modules with poorer-quality standards and efficiency levels are increasingly becoming attractive to Bangladeshi retail customers outside the IDCOL program. It is therefore crucial that the Technical Standards Committee develops and enforces standards that require local assemblers to improve their products.

75. **Bulbs.** 57 local LED lamp suppliers supply their products to the program. The lamps are assembled in Bangladesh. The program started initially with CFLs and slowly switched to LED lights. Initially, the participating organizations offered both options, CFLs and LED lights, since there was insufficient quantity of suppliers offering high-quality LED lights at affordable price levels. All SHSs are now being sold with LED lights, and no CFL or fluorescent tubes are being promoted in the program.

76. **Control chargers.** At present, 53 charge-controller local suppliers are enlisted under the program. Initially, IDCOL provided stickers with the telephone number of the IDCOL call center to consumers when they purchased SHSs. The idea was that consumers would place them on the control chargers where they would be visible to anyone who needed help with an SHS component. However, IDCOL discovered that the stickers quickly disappeared and/or were misused for other purposes.

[24] S. Khandker, et al. 2014. *Surge in Solar-Powered Homes: Experience in Off-Grid Rural Bangladesh*. Washington, DC: World Bank. p. 83.

IDCOL discussed the issue with the control charger suppliers, and they changed the form of the control charger, enabling them to imprint the call center number on the component itself.

77. **Solar panel assembly.** The program has also created a supply of domestic solar panel assembly companies. To date, there are 9 solar panel assembly companies in Bangladesh, and 25% of panels were assembled locally in 2014. Many of them employ women.

78. **Batteries.** All batteries are sourced locally. IDCOL has approved 17 out of the 30–40 battery suppliers in the country. When the program started, there were only 3 suppliers in Bangladesh, but the demand for SHSs has fostered the entry of new battery producers into the market. As an example, Rahimafrooz, one of the largest local battery suppliers in Bangladesh, has doubled its capacity to meet the demand, creating many job opportunities for poor women. Despite increasing competition, however, the price of batteries has gone up, mainly due to higher raw material prices for lead.

5.2 Sales Distribution System

79. SHSs are sold through the extensive local branch network of participating organizations. In most villages, several participating organizations offer SHSs from the same or different suppliers, thereby competing for customers. The 5,732 branches publish price lists and share them with microfinance institutions and consumers. Because the program leverages an existing distribution network, overhead costs are reduced, and a wide client base is reached.

5.3 Warranties, After-Sales Services, and Recycling

80. IDCOL and participating organizations jointly provide important warranty and technical services for consumers. If a consumer experiences technical difficulties, several options are available: (i) return the SHS for a discounted refund from the participating organization, (ii) exchange one of the components in line with the respective warranty guarantee, or (iii) have the component repaired free of charge within the warranty period.

81. If the issue cannot be resolved by the participating organization's local branch, then the consumer can contact the IDCOL call center whose number, as mentioned previously, is imprinted on the control charger. IDCOL employs one staff member exclusively dedicated to the call center who receives approximately 600 calls per month. In addition, IDCOL employs 124 technical inspectors with the objective to test every SHS at least once in its life cycle. The technical inspectors check whether the household is in an off-grid area, verify that the participating organization has used certified products, and ascertains whether an installation is consistent with technical requirements and is fully operational. It also follows up with the participating organizations and consumers, and randomly visits systems to ensure that the issues are resolved.

82. Technical problems generally include shading on panels, problems with charge controllers, inaccurate panel angles, voltage drops of more than 3% at load due to long cables, and overload. As IDCOL asks all participating organizations to address all issues recorded at the call center, subsidies and refinancing amounts are not released until participating organizations have fixed the problem.

83. In response to the potential environmental and health hazards associated with improper battery disposal procedures, policy guidelines on the disposal of batteries with expired warranty were instituted by IDCOL. Based on these guidelines, participating organizations are required to set up a system for collecting expired batteries and handing them over to the manufacturers and/or recyclers.

The policy further outlines the battery recycling process, requires the batteries to be manufactured in an environmentally safe manner, and stipulates that consumers have to sell their expired batteries exclusively to participating organizations.

84. In 2008, IDCOL facilitated a buy-back agreement between the battery manufacturers and participating organizations, under which participating organizations are responsible for notifying consumers 3 months before the expiry of the warranty date and advising them to replace the batteries. Consumers can continue using existing batteries after warranty expiration if units are found to be working. Otherwise, participating organization representatives must collect malfunctioning batteries and transport them safely to the regional offices of battery manufacturers. Manufacturers are then responsible for collecting the units from these offices and transporting them to sites where the batteries will be recycled or disposed in an environmentally friendly manner. IDCOL pays up to $10 for each returned battery with an expired warranty[25] as an incentive to the battery recyclers and to the participating organizations.[26]

85. If a participating organization extends a loan facility for selling a new battery in place of a warranty-expired battery, then it will receive up to 100% of the loan amount (up to $100) in new financing from IDCOL. IDCOL also introduced financial incentives for consumers to return expired batteries to participating organizations and not to backyard smelters. This is done through a 24% rebate of the new battery price as salvage value when they return old batteries.

5.4 Financing

86. A vital factor contributing to the success of the IDCOL program is its microcredit financing model. To make the systems affordable, IDCOL requires a consumer to make a 10% downpayment to a participating organization and spread the installment payments, at a flat 6%–9% interest rate over 5–7 years. Once the downpayment is received, the participating organization enters into a sales and/or lease agreement for microcredit lending with the consumer, the provisions of which are approved by IDCOL. The participating organization also can make a sales agreement with suppliers to obtain SHSs, components, and accessories (e.g., bulbs, cables, power outlets) on credit.

87. Participating organizations can obtain new financing of the credit extended to consumers through soft loans from IDCOL at interest rates of 6%–9% per year on reducing the balance method for a tenor of 5–7 years for 70%–80% of the credit extended to consumers, thereby benefiting from the lower interest rate and longer repayment period. The microfinance rates offered are much cheaper compared to the average microfinance interest rate in Bangladesh as a result of the stiff competition among SHS providers and IDCOL's regulatory role to control the prices and financial terms of the program.

[25] Up to a total of 200,000 batteries are recycled each year.

[26] About 6 liters–7 liters of sulfuric acid and 4 kilograms of lead are required for a 30-ampere-hour solar battery. Roughly 50% of the sulfuric acid and 60%–70% of lead can be extracted from the expired battery.

88. Table 4 provides an overview of the main lending terms of the IDCOL program and its successive evolution toward semi-commercial credit.

Table 4: Evolution from Concessional to Semi-Commercial Credit

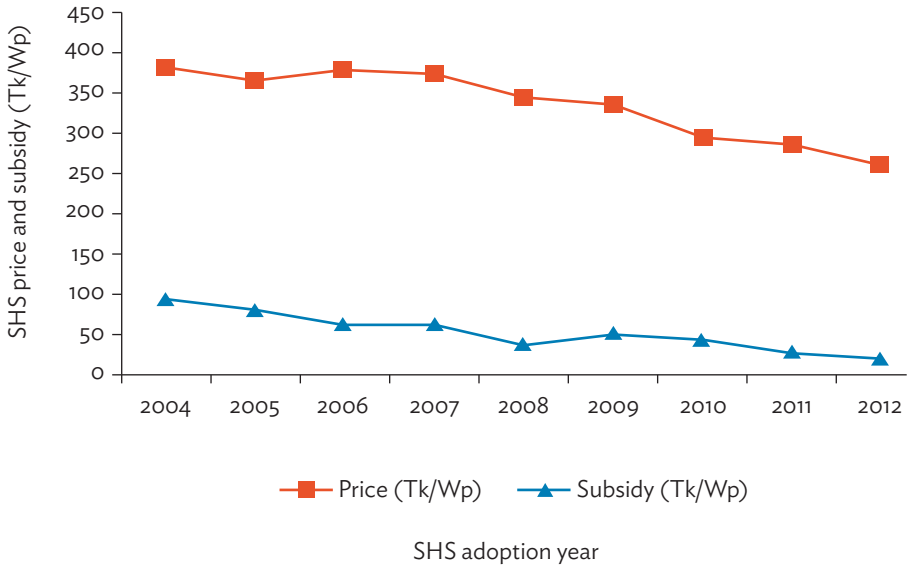
Item	2003–2008	2009	2010	2011	2012	2013 onward
Loan tenor (years)	10	6–10	6–8	6–8	5–7	5–7
Interest rate	6%	6%–8%	6%–8%	6%–8%	6%–9%	6%–9%
Loan portion refinanced	80%	80%	80%	80%	70%–80%	70%–80%

Source: IDCOL.

89. To make SHSs even more affordable, in 2003, IDCOL developed an innovative, partially subsidized delivery scheme within an institutional framework. Two types of grants are provided: (i) buy-down grants to reduce household-level costs and to promote systems in remote areas, and (ii) institutional development grants to build capacity of smaller participating organizations.

90. As seen in Figure 6, the grant amount per solar panel unit has declined over time. Nevertheless, the subsidy was critical in providing a financial incentive to participating organizations for marketing the various configurations of SHS, particularly in encouraging smaller NGOs to enter the market and thereby increase supply and market demand. The growing competition among participating organizations as well as higher demand from the market reduced the price of SHSs, thereby offsetting the drop in subsidies.

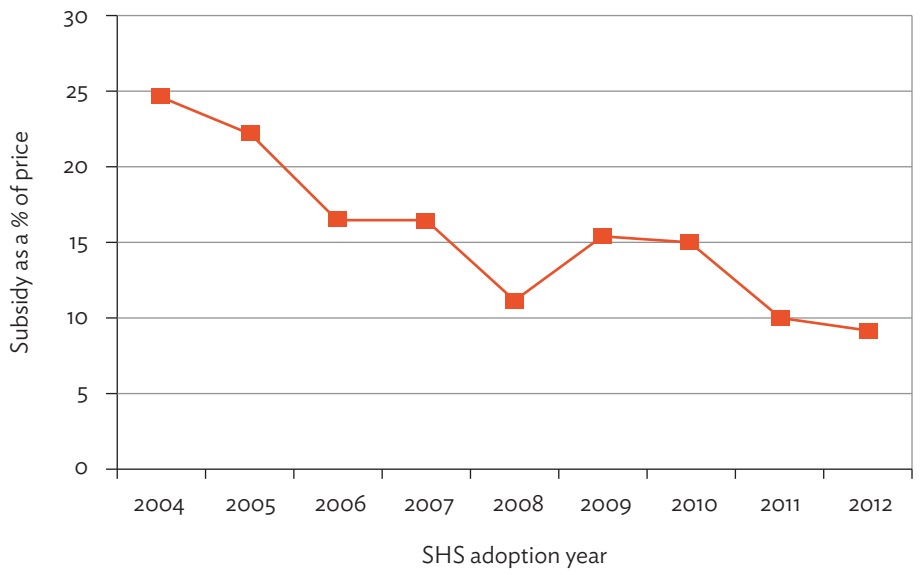
Figure 6: Evolution of Solar Home System Price and Subsidy Element



SHS = solar home system, Tk = Taka, Wp = watt-peak.
Source: IDCOL.

91. In fact, as Figure 7 shows, the subsidy was about 25% of the SHS price in 2004, dropping to less than 10% by 2012. Interestingly, despite the decline in subsidy and price support by IDCOL and its development partners, the demand for SHSs continued to increase, in part, because of a steeper decline in the prices of solar units due to technological advances and economies of scale in production over time.

Figure 7: Subsidy as Percentage of Solar Home System Unit Price



SHS = solar home system.
Source: IDCOL.

92. Since the program provides a fixed level of subsidy (currently $20) for all sizes of SHSs, smaller systems—which are typically more affordable to the poorest—receive a higher percentage of subsidies compared to larger systems. To encourage a transition toward a commercially oriented SHS market in the country, the subsidy elements, as well as the concessional rates of IDCOL's refinancing program, are gradually being reduced (Table 5). In any case, the subsidy is small compared to the subsidies on grid extensions and the SHS programs in other countries.

Table 5: Phased-out Subsidies per Unit

	2003–2004	2004–2005	2006–2007	2008–2009	2010–2011	2012–2013	2013–2014
Capital buy-down grant	$70	$55	$40	$40	$25	$25	$20
Institutional development grant	$20	$15	$10	$5	$3	$0	$0

[a] For smaller units only (i.e., less than or equal to 30 watt-peak capacity).
Source: IDCOL.

93. One of the lessons learned from the use of grants is that while income data on consumers are not collected, anecdotal evidence suggests that the relatively better-off in rural areas were the first consumers and, hence benefitted from the highest subsidies. A solution may be to favor subsidies to specifically targeted smaller systems usually selected by the relatively poorer populations.

5.5 Marketing

94. IDCOL has launched several marketing campaigns, including advertisements in print media and on billboards. IDCOL has also developed and distributed publicity materials to raise awareness and popularize the use of SHSs in different parts of the country. Posters, leaflets, and t-shirts have been distributed to participating organizations for wider publicity of solar energy. Television and radio spots have also aired. The marketing efforts highlight the benefits of SHSs, quality and sustainability of the product, financial return in the long run, and availability of microfinance credit.

95. In addition, participating organizations are marketing the program through their extensive network of microfinance members. Word-of-mouth referrals of prospective consumers have been successful given that Bangladesh is one of the most densely populated countries in the world.

5.6 Key Success Factors

96. The key success factors of the IDCOL program can be summarized as follows:.

(i) **IDCOL demonstrates effectiveness, ownership, and technical expertise.** IDCOL manages the program professionally with great dedication and guidance from a strong, private sector-oriented management team and board.

(ii) **Strong partnerships among IDCOL and participating organizations and shared risks and responsibilities.** Regular proactive dialogue between the partners ensures a constant improvement and adoption of the program's business procedures.

(iii) **Participating organizations leverage their existing microfinance branch network for sales distribution.** The program uses existing NGO and/or microfinance institution operators with an established presence and high credibility in rural Bangladesh to operate as SHS vendors.

(iv) **Reliability and maintenance services are emphasized.** The program emphasizes after-sales service. Observing the reliability of quality of these services convinced late adopters from often poorer families to acquire a SHS.

(v) **Overcome the affordability barrier.** A combination of subsidies and consumer credits (financed by development partners including ADB) from participating organizations has helped in this endeavor by providing long-term access to finance households and capital buy-down grants.

(vi) **Sustained technical assistance from development partners.** Various technical assistance initiatives from development partners have helped IDCOL manage the rapid rollout and quality of the program.

6. KEY CHALLENGES AND WAY FORWARD

6.1 The Future

97. Despite the enormous growth in SHS adoption by off-grid rural households in Bangladesh, there is ample room for further SHS expansion, and demand is not expected to diminish soon. Although market growth is difficult to predict, it is safe to assume that it may reach 6–7 million SHSs by 2018. Market growth will likely come from (i) increased outreach of the program to consumers in off-grid areas, (ii) existing consumer upgrading to bigger and/or more efficient systems, and (iii) new consumers in grid areas using SHSs during times of brownouts and blackouts in the country.

98. The greatest concern for participating organizations has been the entry of unregulated commercial providers of lower-quality SHSs and components, putting pressure on prices. New strategies are needed to compete with these new entrants. For instance, some participating organizations provide SHSs at the same prices as unregulated commercial providers operating outside the IDCOL program in the event of full up-front payment by the consumer.

6.2 Renewable Energy Market beyond Solar Home Systems[27]

99. IDCOL is also involved in the financing of renewable energy applications other than SHSs, such as biomass installations, commercial and domestic biogas-based power plants, solar irrigation pumps, solar minigrids, wind energy, and small hydropower projects, which are developed by the private sector, NGOs, and various communities. There is significant potential to deploy these technologies on a much larger scale. Some of the generic barriers identified are (i) lack of workable financing models that can finance renewable energy projects in a commercial and sustainable manner, (ii) inability to identify technologies suitable to Bangladesh's context, and (iii) inadequate needs assessments.

6.2.1 Solar Irrigation Pumps

100. According to statistics from the Power Division of the Ministry of Power, Energy and Mineral Resources, nearly 309,000 grid electricity connections for irrigation pumps were provided in Bangladesh as of 2013.[28] There were an estimated 1.475 million irrigation pumps in Bangladesh, which means that more than 79% of irrigation pumps in Bangladesh are off-grid.

101. These 309,000 grid-connected irrigation pumps consumed 1,519 megawatts of power in the summer season of 2012–2013, up from 1,260 megawatts in 2008–2009. The Power Division estimated that these irrigation pumps will have a combined demand of 1,700 megawatts of power in 2015.

102. Although the power utilities try to provide a reliable power supply during the day to agricultural regions in the dry season, the power supply can be unreliable. Additionally, power supply to on-grid irrigation pumps during summer months result in power shortages for others, such as domestic and industrial consumers, necessitating load shedding. Hence, the power utility companies in Bangladesh want to reduce electricity demand from irrigation pumps and are working to move this demand to off-peak hours. Off-grid irrigation pumps primarily use diesel, and, according to the Bangladesh Petroleum

[27] This section is based on an ADB staff consultant's report under project SC-103039 BAN: Renewable Energy Program for IDCOL.

[28] Power Division. http://www.powerdivision.gov.bd/

Corporation, they consumed 984,936 metric tons of diesel in 2012–2013, up from 651,073 metric tons in 2003–2004. This consumption accounts for nearly one-third of the total diesel consumption in Bangladesh, which is a significant expense for the economy considering the fact that Bangladesh imports all of its fuel requirements.

103. The use of solar irrigation pumps has therefore high potential in Bangladesh due to (i) abundant solar radiation, (ii) irrigation-based agriculture (63% of the country's agricultural land is irrigated), (iii) insufficient and unreliable grid electricity, (iv) the large number of existing off-grid irrigation pumps, (iv) high consumption of diesel fuel for water pumping combined with rising diesel prices and soaring diesel subsidies, (v) good groundwater resources with low water heads, (vi) small holdings of agricultural land, and (vi) carbon emission reduction potential.

104. **Barriers.** There are several barriers and issues with the solar irrigation pump business and implementation model: (i) the program has only just begun, as solar irrigation pumps were introduced in Bangladesh in 2009; (ii) high equipment costs, ranging from $32,000 to $45,000;[29] (iii) financial viability issues given the seasonality of irrigation requirements and low revenue generation; (iv) technical design and equipment capacity issues resulting from lack of available information on soil quality and water requirement estimations; (v) high collateral and equity contribution requirements from participating organizations; (vi) limited control over equipment purchases; (vii) lack of technical know-how and capacity of participating organizations in ordering the right specifications from suppliers; (viii) limited number of experienced solar irrigation pump experts in the country; (ix) need for streamlined IDCOL processes and documentation checklists; (x) lack of diesel generators as back-up solutions; (xi) water-intense farming techniques that require large, expensive systems; (xii) lack of community ownership and social issues; and (xiii) slow increases in agricultural yield that negatively impact the capacity to pay off farmers.

105. **Changes to the IDCOL financial package.** In response to initial low interest from participating organizations to borrow from IDCOL under its solar irrigation pumps program, IDCOL has taken several measures to make it more attractive. For example, when the program was first launched, the financing structure had a debt–equity–subsidy ratio of 40%:30%:30%, but based on feedback from participating organizations on their difficulty in arranging equity and financial viability of solar irrigation pumps at the 30% subsidy level, the structure changed its debt–equity–subsidy ratio to 40%:20%:40%. IDCOL is currently contemplating increasing the subsidy element to 50% and reducing equity to 15%.

106. To remedy these constraints, it is proposed to (i) redistribute risks among all stakeholders, including the possibility of securing small equity contributions from farmers and/or entering into long-term water purchase agreements with them; (ii) modify the IDCOL financial package to ensure financial viability to participating organizations by considering subsidies as a viability gap funding (but limited at 50% subsidy) instead of a fixed subsidy at 40%; (iii) set up a credit risk guarantee fund to reduce the collateral requirements; (iv) reconsider the participating organization–supplier relationship modules to reduce the upfront costs of solar irrigation pumps; (v) explore other solar irrigation pump business and implementation models, including a community-based model to help redistribute risk;

[29] Solar irrigation pump systems that have been installed under the IDCOL program (typically solar PV panels of 5–7 kilowatts operating 3.5–5.0-kilowatt water pumps) cost $32,000–$45,000. Despite the subsidy provided by IDCOL, participating organizations need to provide an equity of $6,400–$9,000 and also borrow $12,800–$18,000 from IDCOL by providing full collateral for every installation. Thus, the participating organizations' initial investment cost is still high, as most are NGOs. In comparison, a standard diesel generator-based shallow tube-well system for individual farms costs $640–$1,000 in initial investment.

(vi) create a financial package for solar irrigation pumps installed on individual farms to tap the market segment of smaller installations; and (vii) provide technical assistance to participating organizations, IDCOL, and farmers. IDCOL is also considering an ownership model in which farmers become owners of pumps after paying off installments. For this, IDCOL is encouraging smaller-capacity pumps that are affordable to farmers. ADB is currently exploring providing assistance on structuring and financing the credit risk guarantee facility.

107. **Changes to the IDCOL business model.** IDCOL has recently introduced a number of new measures to remove some of the administrative burdens and to cut down processing time. These initiatives push IDCOL to (i) process loan applications more quickly than the usual 3–4-month lead time, (ii) approve individual loans by an internal IDCOL committee that does not require approval from the IDCOL board, (iii) consider loan applications from entities that are currently not on its participating organization accreditation list, and (iv) reduce its collateral requirements for the loan portion from 100% to 50% for participating organizations with which it has strong existing credit relationships and history.

108. Despite these improved incentives, proposals from participating organizations for loan applications are slow despite renewed interest from the market. If the current pace of loan uptake continues, then IDCOL will find it difficult to reach its target of financing and installing 1,550 solar irrigation pumps in the country by 2017.

6.2.2 Biogas Digesters

109. Biogas digesters are important for rural and off-grid areas of Bangladesh, given the limited access to energy in these areas and local availability of large amounts of biowaste such as cow dung, chicken litter, and other animal waste. Biogas digesters are one of the oldest renewable energy technologies in the world, and the first biogas digester in Bangladesh is said to have been installed in the early 1970s. Having identified the large potential in the country, IDCOL initiated its National Domestic Biogas and Manure Program in 2006. Domestic biogas digesters of capacity less than 4.8 cubic meters of biogas output, used primarily for generating cooking gas in rural households, have been financed and installed under this program for over 31,000 households as of the end of 2013. Several development partners have channeled funds to the program as well.

110. Bangladesh also has several medium- to large-sized dairy, poultry, and goat farms, which use diesel generators as backups during load shedding. They can, however, use the waste generated in their farms to generate electricity by setting up commercial biogas units. It is estimated that about 500–600 commercial biogas units are currently operational in the country. The operational cost reduction (mainly from reduced diesel consumption) and environmental benefits of such systems are substantial.

111. IDCOL's target is to finance and install at least 130 commercial biogas digester systems by 2017 with an average generator capacity of 50 kilowatts. So far, IDCOL has financed 5 commercial biogas plants (all for poultry farms), with three of these being small capacity (i.e., a generator capacity of 5 kilowatts), one medium (i.e., 50 kilowatts), and one large (i.e., 400 kilowatts).

112. **Changes to the IDCOL business model.** To scale up the financing and deployment of both domestic and commercial biogas digesters, IDCOL has taken a number of steps, such as increasing the subsidy amount for domestic biogas units from Tk9,000 to Tk13,500 and organizing awareness-raising campaigns and workshops for poultry and dairy farm owners and managers.

113. **Barriers.** Barriers to the large-scale deployment of commercial biogas digester include (i) slow progress by participating organizations to identify and install domestic biogas projects; (ii) slow market adoption, as the alternative (wood and straw) is more cost-effective, although causes health and environmental hazards; (iii) lack of technical service providers for commercial biogas installations; (iv) limited availability of working capital for technical service providers; (v) limited number of biogas technology experts in IDCOL; (vi) lack of awareness on benefits of biogas technology; and (vii) lack of risk mitigation planning.

114. **Proposed initiatives.** To address these constraints, it is proposed to (i) provide technical assistance to biogas digester suppliers to install newer technologies and increase trained manpower capacity, (ii) encourage participating organizations to install a combination of biogas and SHSs, (iii) set up a revolving supplier credit facility for commercial biogas technical service providers, (iv) revise the financial structure of IDCOL's proposition to 80:20 debt–equity ratio, (v) insure against risks such as avian flu, (vi) provide technical assistance to IDCOL, and (vii) increase awareness about the program.

115. Proposals from participating organizations and/or technical service providers and uptake of its loans for biogas digesters are slower than anticipated. If the current pace of loan uptake continues, then IDCOL will find it difficult to reach its 2017 target.

6.2.3 Biomass

116. A large amount of biomass waste is available in Bangladesh, primarily as agricultural residue such as rice husk and rice straw, jute stick, and residue from other cereals such as wheat. In addition, wood waste, dry leaves, and other dry biomass waste are also available. Biomass from crop residue, animal waste, and wood waste is the primary source of traditional energy for heating and cooking purposes in rural households, with inefficient burning of biomass fuel in open fires and traditional cookstoves accounting for over 60% of the overall primary energy use in the country.

117. Biomass gasifier technology offers an efficient, clean method of generating heat and electricity from biomass waste. In Bangladesh, biomass gasifier technology is new, with the country's first biomass gasifier unit for generating electricity having been set up less than 5 years ago. There are no local suppliers of biomass gasifier technology in Bangladesh, and all equipment is currently being imported mainly from the People's Republic of China and India.

118. **Benefits.** The benefits of biomass gasifiers are (i) generation of gas and/or electricity from biomass waste, (ii) generation of highly profitable by-products such as silica, (iii) replacement of existing diesel generators that are expensive to operate, (iv) effective alternative to grid electricity, (v) environment-friendly solutions that lead to efficient utilization of biomass waste, and (vi) proven technology in some countries.

119. **Risks.** Technology risks exist due to its novelty in Bangladesh. Additionally, biomass waste in rural areas that is energy-dense, such as rice husk, already has several competing uses such as rice parboiling in rice mills, household cooking, and warm beds for chickens in poultry farms. Hence, securing a long-term, reliable supply of biomass waste as feedstock to biomass gasifiers is a major challenge. Globally, the most important reason for failure of biomass gasifier plants is the lack of feedstock and, with competing uses for biomass waste in Bangladesh, IDCOL needs to conduct a detailed resource availability and feedstock risk assessment before making bigger financial commitments for large-scale deployment of biomass gasifier technology.

120. The biomass gasifier is a relatively new technology and there is limited awareness, understanding, and expertise of the technology in the country, which severely limits the number of project proposals that IDCOL receives for financing. Further, there are feedstock risks regarding the long-term sustainability of supply given competing use; a lack of local suppliers or technical service providers; limited use of captive biomass gasifiers in rice mills due to low-cost incentives; a limited number of biomass gasifier technology experts in IDCOL; lack of awareness on the benefits of biomass gasifier technology; and a lack of risk mitigation planning.

121. **Recommendations.** To address these issues, an in-depth technology, market, and risk assessment of biomass gasifiers in Bangladesh should be conducted. If the outcome of the market and risk assessment exercise is positive, then the recommendations for IDCOL to further develop this market will be (similar to those for commercial biogas program) to create a local supplier development program, set up a revolving supplier credit facility for biomass gasifier technical suppliers, ensure an appropriate financial structure and insurance for biomass gasifier installations, provide technical assistance and capacity building support to IDCOL, and conduct awareness-raising campaigns.

122. Despite its benefits, IDCOL has only financed 2 biomass gasifiers in the country. The first project, a 250-kilowatt plant in Gazipur, was installed mainly to supply electricity for lighting and other applications of the local community. The other project is a Grameenphone telecommunications tower.

7. CONCLUSION

123. The IDCOL SHS program in Bangladesh is one of the largest programs in the world, connecting more than 3.5 million households, or roughly 16 million citizens, in off-grid areas to reliable and clean energy. There are many benefits associated with the program, including electricity for personal use, as well as improved business and education activities; health and safety benefits, in particular, for women; and reduced carbon emissions.

124. This report suggests that the scale and success of the program was achieved by getting the business model right. A strong partnership and ownership among IDCOL—as the creator and regulator of the overall program—and the implementing participating organizations was the core to its successful rollout. In addition, an existing distribution network, reliable after-sales services, and availability of long-term microfinance loans at affordable rates and grant financing by development partners are important factors. Going forward, one important challenge for the program is its commercialization without compromising quality standards and ensuring consumer protection. Regarding other renewable energy applications, such as biogas digesters and solar irrigation pumps, it is essential to get the business model right in order to ensure scalability.

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Making Renewable Energy a Success in Bangladesh

Getting the Business Model Right

This paper analyzes the success of the solar home system program in Bangladesh, which today provides clean, reliable electricity to more than 16 million people in off-grid areas. It describes the impact and benefits of the program; various components of the adopted technology, warranties, and disposal aspects; and highlights the price fluctuations of its components in the global market. The report outlines how the program's business model was the main success factor for its immense scalability. The final section looks at the business model of the program, its current challenges, and other renewable energy applications.

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