

Health & Environmental Benefits of Solar Microgrids to Expand Electricity Access in Developing Economies

A Bangladesh Case Study

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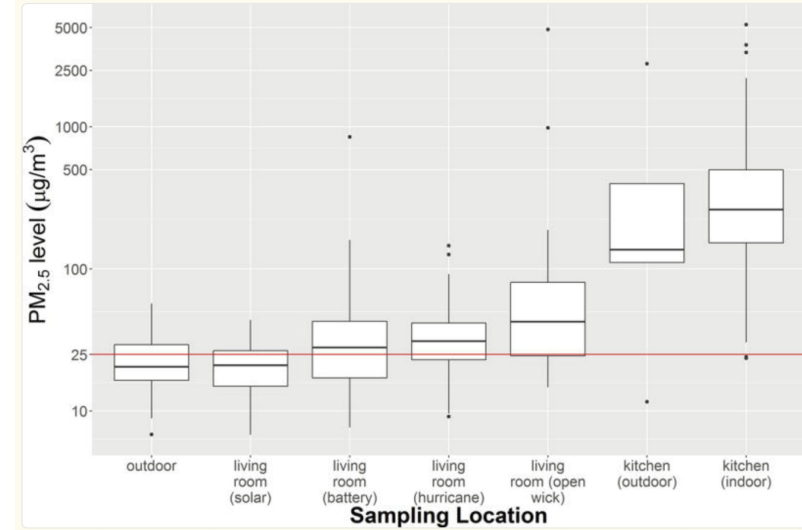
Background: Why not Traditional Grids?

- Immense human development gains from electricity access
 - Lighting - kerosene substitute, indoor air quality and education
 - Refrigeration - food and vaccine preservation
 - Cell Phone Charging, Radio, Television - communication, financial and information services
 - Higher Incomes - reducing energy costs, enabling non-farm activities, productivity benefits
 - Methodological Challenges (Torero 2015); selection & placement bias of grids, research subjects
- Challenges for traditional grid expansion
 - Characterized by:
 - high upfront capital investments
 - Long payback periods / time horizons
 - Lack of WTP for grid services in rural areas
 - Sometimes: engineering, governance challenges; energy theft and underinvestment

Theory of Pollutant: Kerosene

- Primarily used in lamps for poor-quality household lighting in rural areas - sometimes heaters, generators
- Combustion emits $\text{PM}_{2.5}$, CO , SO_2 , NO_x , Formaldehyde, PAHs. Research on lighting focuses on indoor $\text{PM}_{2.5}$ (Lam et al. 2013)
- (Barron & Torrero 2014): 63% reductions in air pollution, 37-44% reductions in child respiratory infections via kerosene substitution
- 2.5 kg/L CO_2 emissions; global stock pollutant

FIGURE 2. Fine particulate matter levels by location.



(Mujanja et al. 2018): Nonrandom sample of off-grid households in Uganda

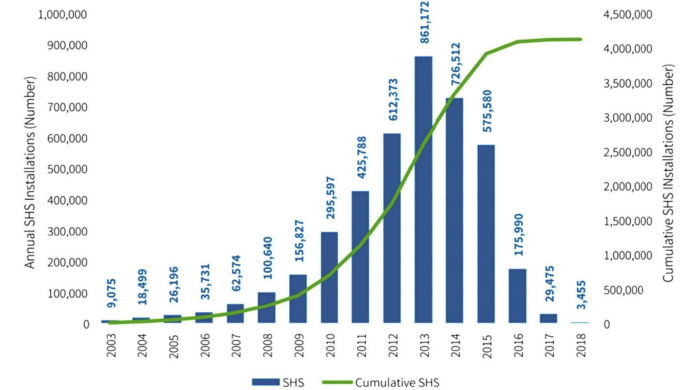
Policy Goal: Restrict Kerosene Consumption to Efficient Level

- Example Options:
 - *Cap-and-trade kerosene emissions permits to efficient quantity*
 - *Tax health and climate externality of kerosene consumption*
 - *Collect and disseminate information on kerosene consumption and air quality impacts*
 - *Emissions standards for kerosene lighting, generators, heaters*
 - **Subsidies for solar microgrids**
- Evaluation Criteria
 - Efficiency
 - **Equity (regulating kerosene consumption directly makes the poor poorer)**
 - Cost-effectiveness
 - Dynamic Efficiency
 - **Information Requirements, Enforceability (especially difficult in rural areas)**

Policy: Bangladesh Solar Home Systems Program, 2003-2021

- Collaboration between the World Bank and Bangladeshi government to meet 2020 goal of universal electricity access despite slow grid connections
- Subsidized and expanded access to very small-scale solar-battery installations in rural areas
- Cumulative investment of USD \$1.1 billion, serving (peak) 20 million people, avg. cost \$266 / household
- Cut tariffs on solar panel imports

Figure 1. IDCOL SHS Program: Annual and Cumulative SHS Sales

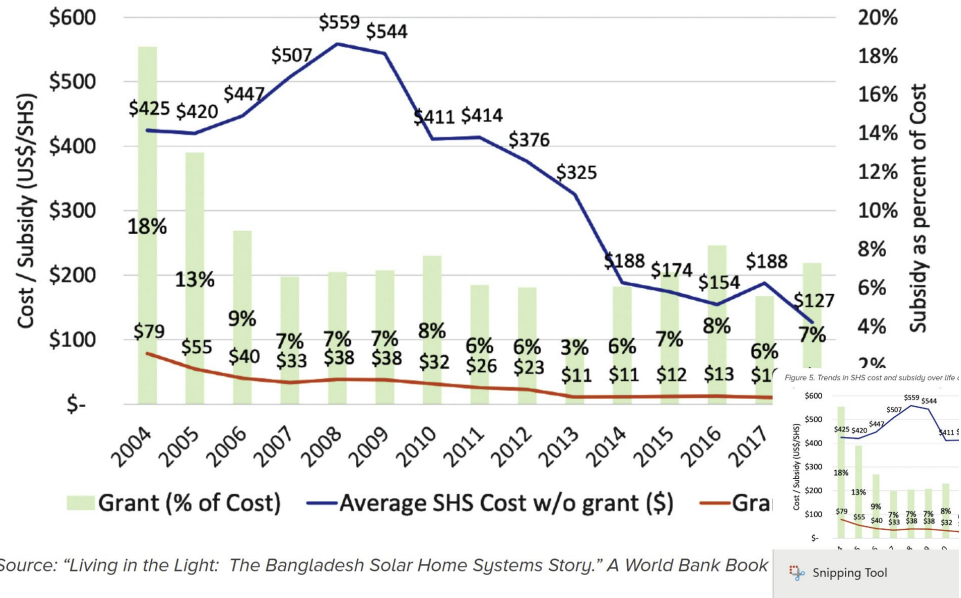


Source: "Living in the Light: The Bangladesh Solar Home Systems Story," A World Bank Book Publication.

Efficiency: Excellent

- At its face, sounds like a bald-faced government intervention in a free market
- However, the market for rural electricity services was already terribly inefficient
- Actual subsidy as a small share of system costs → most program dollars go towards making rural electricity services market more efficient

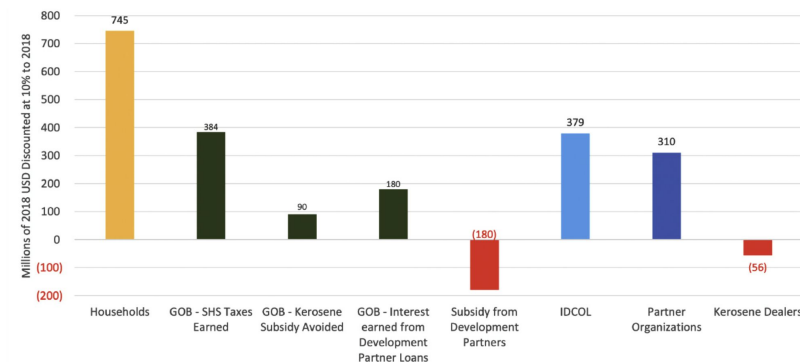
Figure 5. Trends in SHS cost and subsidy over life of program



(Cost-)Effectiveness: Excellent...

- (Halder 2016) case study finds most of these systems have favorable PBP, NPV, IRR
- Most program value accumulated to households
- Payback installments routinely less than kerosene purchases
- Utility of SHS *artificially shortened* by owners switching to grid connection: see shortcomings

Figure 7. Present Value of Benefits from SHS Program



Source: Bangladesh Subsidy Lab Webinar, October 2021

Table 4. Findings of financial analysis of case studies.

Case Studies	Capacity (Wp)		NPV (BDT)		
		Payback period (Years)	8%	12%	IRR (%)
Case 1	42	9.56	-11,347	-12,985	-
Case 2	42	16.58	-22,976	-22,271	-
Case 3	20	2.37	30,784	19,568	37.7
Case 4	42	7.55	-4243	-8019	5.3
Case 5	20	1.86	53,252	38,371	222
Case 6	42	4.36	14,156	8601	29.45
Case 7	30	1.97	42,198	30,612	75.2
Case 8	20	1.13	43,169	31,589	87.97
Case 9	42	5.26	5508	2049	15.9
Case 10	42	5.63	5513	2043	15.64

(Halder 2016)

Equity: Mixed, Passing

- World Bank study of adoption finds significant relationships in adoption for:
 - Head of household education
 - Primary education access
 - Land and non-land wealth
 - Gender of head of household
 - Women *more* likely to adopt
 - Potentially due to female staff at partner NGOs, or more directly motivated by indoor lighting/air quality
 - Lands subject to riverine erosion and flooding

(Samad et al. 2013)

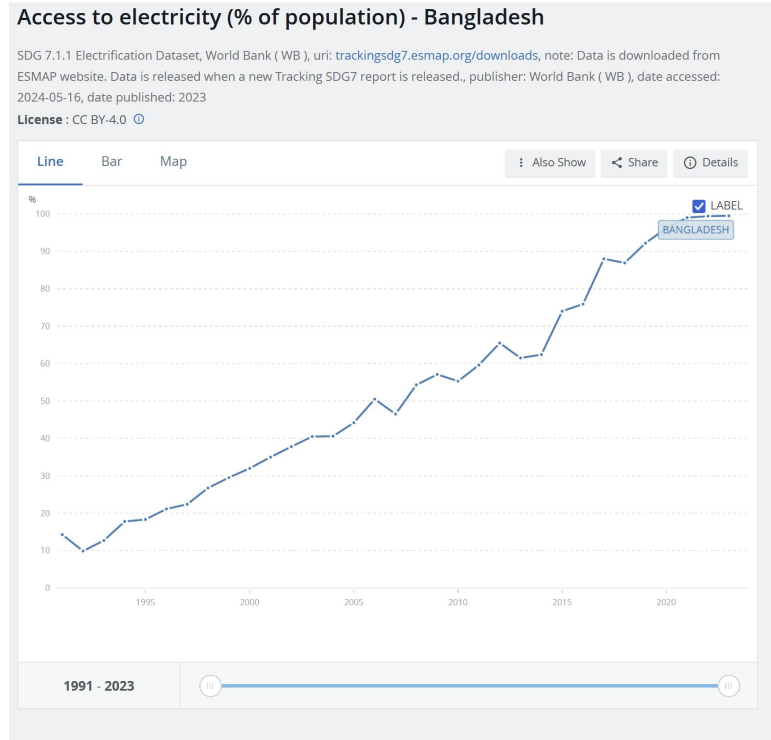
Table 7. Determinants of HH adoption of solar home system

(N=4,000)

Explanatory variables	Probit estimates	Logit estimates
Sex of HH head (1=Male, 0=Female)	-0.023** (-2.81)	-0.023** (-2.74)
Age of HH head (years)	-0.0006** (-3.22)	-0.0006** (-2.87)
Max. education of HH adult males (years)	0.002** (4.06)	0.002** (3.65)
Max. education of HH adult females (years)	0.002** (3.37)	0.002** (3.18)
Log HH land asset (decimals)	0.006** (2.71)	0.006** (2.62)
Log HH non-land asset ('000 Tk.)	0.011** (5.08)	0.011** (4.78)
Village price of fuel wood (Tk./kg)	0.0004 (0.09)	0.0004 (0.08)
Village price of dung (Tk./kg)	0.005 (0.46)	0.005 (0.46)
Village price of kerosene (Tk./liter)	-0.006 (-1.58)	-0.005 (-1.55)
Log price of solar home system (Tk./Wp)†	-0.130** (-2.49)	-0.203** (-2.37)
Village has primary schools (1=Yes, 0=No)	0.047** (2.28)	0.053** (2.22)
Village has secondary schools (1=Yes, 0=No)	0.009 (0.71)	0.011 (0.92)
Village is in <i>char</i> land (1=Yes, 0=No)	0.052** (3.04)	0.051** (3.01)
Village is in a land subject to river erosion (1=Yes, 0=No)	0.047** (2.42)	0.046** (2.32)
Village has paved roads (1=Yes, 0=No)	-0.010 (-0.65)	-0.013 (-0.81)
Village has Grameen Bank (1=Yes, 0=No)	-0.015 (-1.01)	-0.011 (-0.76)
Village has BRAC (1=Yes, 0=No)	0.038** (2.06)	0.036* (1.80)
Village has NGOs (1=Yes, 0=No)	0.021 (1.02)	0.020 (0.88)
Pseudo R ²	0.206	0.208

Dynamic Efficiency: Excellent

- Micro:
 - Successfully incentivizes substitution for kerosene, cutting consumption by $\frac{1}{2}$ to $\frac{2}{3}$ (Samad et al. 2013) (Uddin et al. 2023)
 - Uddin also finds about a $\frac{1}{2}$ boost to years of schooling, but stronger effect for boys
- Macro:
 - Supported investments in domestic manufacturing and assembly of solar cells, LEDs, and batteries (GOGLA)



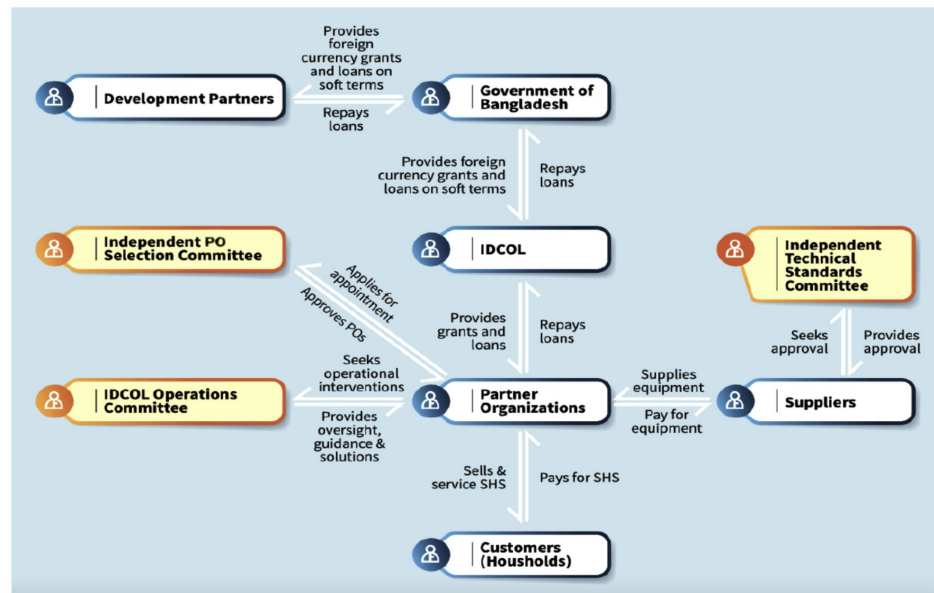
Source:

<https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=BD>

Informational Needs, Enforceability: Excellent

- Avoids the trappings of a bureaucratic, government-led effort or a command-and-control boondoggle
- Decentralized actors still technically and socially accountable to ultimate stakeholders
- Favorable development loan rates successfully passed on to households

Figure 2. IDCOL SHS Program: Implementation Model



Source: "Living in the Light: The Bangladesh Solar Home Systems Story." A World Bank Book Publication.

Shortcomings:

- Lack of policy certainty and unity: as the government pushed several electrification initiatives, grid interconnections accelerated; demand for the program fell in late 2010s
- Dependence on existing network of NGOs, microfinance institutions
- Equity issues

Recommendations:

- Much more to learn from this program than to avoid from it
- **Coordinate central grid expansion with off-grid access initiatives, or risk stranded assets**
- Lowering trade barriers for goods lowers program costs
- Efforts to mitigate urban-rural inequalities should account for intra-rural inequalities
- Strict maintenance of technical standards to keep public trust

Open Questions

While it's easy to say central grid expansion should've been coordinated with off-grid developments, what might this have looked like? More broadly, how can developing economies balance grid-expansion and off-grid solutions when promoting electricity access?

Most of Bangladesh's central electricity supply is now from natural gas combustion. Is achieving universal grid access a step forward or a step backwards in the energy transition?

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