Section 1 - The Local Solutions Proposed for Climate Action and Development

1.1. Improved Cookstoves for Firewood and Charcoal by ENDA - INFORSE West Africa

Description of the solution

An improved cook stove (ICS) is a food cooking device built to use wood energy or charcoal just like the traditional open stoves and fires, but more economical in wood energy and less polluting. Its thermal efficiency is much higher than that of the traditional fireplace[1].

In Senegal as in other parts of the developing world, there are different types of improved stoves. They vary in form and size. Among the most popular and well known that consume less charcoal or firewood than traditional stoves, there are: the Jambar stove, the Sakkanal stove, the banco stove, as well as larger institutional stoves. The Jambar stove, also known as the Kenya Ceramic Jiko (KCJ), will be considered hereby as the standard improved stove.

The metal-ceramic Jambar improved cookstove consists of a metal fireplace with a ceramic part inside that allows it to conserve heat as much as possible. This stove is manufactured in workshops and has an energy efficiency of about 30 to 50% higher than the traditional stoves. It has a lifespan of 3 to 5 years (IFDD)[2].

What the solution provides?

Improved cook stoves offer reduced use of wood or charcoal. Being thermally and ecologically more efficient than the traditional cook stoves, they allow a significant saving of wood energy, with the consequence of preserving woodlands. The improved cook stoves make it possible to reduce the consumption of domestic cooking fuels, to contribute to the reduction of expenses related to the purchase of the fuels, and the improvement of sanitary conditions during the cooking of food (less smoke). It improves the quality of the air inside homes, and reduces the time spent collecting wood, for those who collect it themselves.

Why is it successful, from a user-perspective

The use of improved cookstoves brings great satisfaction to consumers. Improved cookstoves are convenient, make it easier to cook food, adapt to cooking habits and save money. Indeed, according to testimonies, expenses of 4000 CFA Franc every 7 days to ensure the supply of butane gas are reduced to only 6000 FCFA (9 euros) (a bag of charcoal) for a month. The use of Jambar stove saves 10,000 FCFA (15 euros) each month compared with LPG. Compared with

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[1] Kitoto, Patrick Arnold Ombiono .- Facteurs d'adoption des foyers améliorés en milieux urbains sahéliens camerounais / *Adoption factors of improved stoves in Cameroon urban Sahelian environment* https://doi.org/10.4000/developpementdurable.12182

[2] https://ifdd.francophonie.org/media/docs/publications/519_Fi_foyers_ameliores_7.pdf

traditional stoves, the savings is around 6000 FCFA (9 euros) each month Financial profit is the first motivation for users[3].

Energy savings or energy production

The energy efficiency of the Jambar cookstove is around 30 to 50% compared to the traditional one.

Climate effects

In terms of the environment and climate, the activities have generated the following results:

1. A reduction in CO_2 emissions of approximately 86,000 tons each year (for a total of around 40,000 stoves/year);
2. Protection of 2,800 hectares of forest each year (uncleared area);
3. An annual saving of approximately 57,000 tons of firewood[4].

Costs and time to construct

In a workshop with a dozen staff, production can reach 50 units of ICS per day, or 250 per 5-day week.

Prices for different sizes :

Jeeg (4 to 7 kg pots) : 6,000 CFA Franc (9 euros) to 8,000 CFA Franc (12 euros)
Jaabot (7 - 10 kg pots) : 7,000 CFA Franc (10 euros) to 9,000 CFA Franc (14 euros)
Jongoma (10 - 15kg pots) : 10,000 CFA Franc (15 euros) – 15,000 CFA Franc (23 euros)

Lifetime

The estimated lifespan of Jambar cookstoves is 3 to 5 years.

What policies and strategies helped the success?

The dissemination of improved cookstoves through the 'FASEN' project in Senegal was done through the consideration of the multidimensional aspect of the problem of improved cookstoves within the framework of a market approach.

These dimensions include:

- Technical: to put on the market a proven, efficient technology at an affordable price obeying well-regulated and modernized standards and manufacturing methods.
- Social and cultural: implementation of innovative systems taking advantage of traditional networks of savings and credit, formal and informal trade.
- Ecological, by campaigning for the use of improved stoves.

[3] PERACOD.- Vulgarisation des foyers améliorés au Sénégal : Les acquis du projet FASEN du PERACOD. La vulgarisation des Foyers améliorés au Sénégal.
[4] PERACOD, Idem.Senegal

- Economic, with the creation of jobs and income, providing affordable and reliable equipment.
- Politics, by basing the problem on socio-economic development policy.

The strategy was based on the establishment of organizational systems adapted to the different levels: macro and micro. The macro-organizational level is the political dimension. Several ministries, in charge of issues related to energy, environment, women, etc. are involved through capacity building to ensure the sustainability of actions. This involvement took into account the areas of competence of the structures concerned: supply of raw materials (energy and environment), household production (trade), marketing (research, control of standards and micro-finance) and finally consumption (ministry in charge of crafts).

The micro-organizational level concerns the operational level. It focuses on the technical, economic, environmental and social dimensions. The project was based on the dissemination of improved stoves adapted to the environment (rural and urban) and at socially acceptable prices. This strategy allows each stakeholder in the sector, from the producer to the consumer through the distributor, to find an economic and social interest in getting involved. The sustainability of the sector is based on the economic benefits that each actor can derive.

How widespread is it, where is it popular

The following results were obtained (estimates):

- 200,000 (Senegal) improved stoves released from 2007 to April 2012 (for a total of around 40,000 stoves/year).
- ~57,000 tons of firewood saved each year.
- ~2 million € saved by households each year.
- More than 81 blacksmiths and 40 distributors (women's promotion groups, shops, associations).
- 11 ceramics production centres, 5 of which are managed by men and 6 by women.

Example, description

There are two models of the Jambar ICS, one uses charcoal as fuel and the other uses wood-fuel. The most adopted is the first one that uses charcoal. Its hourglass shape is made of metal in the exterior and ceramic in the internal liner. This ceramic liner has a hole in its base to let ash fall through and be collected in a box located at the bottom of the stove.

Features and components:-

- Metal lining: a mild steel sheet.
- Ceramic insert with a grid at the base with small holes, the number of which varies according to the size of the stove.
- Kettle supports made of mild steel bars on which the kettle rests.
- Insulating bonding material between the metal sheet and the ceramic insert obtained from several mixtures of materials to prevent cracking during use[5].

The following artisans are needed to manufacture :

- Ceramists potters: they provide the ceramic inserts necessary for the production of the stoves
- Blacksmiths / metal welders: produce the different models of stoves.

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[5] PERACOD.- Fiche technique de fabrication des foyers améliorés « Jambar » à bois et charbon de bois. https://energypedia.info/images/4/44/GUIDE_DE_FABRICATION_DU_FOYER_AMELIORE_JAMBAR.pdf

Examples, links

Ciza, Angélique Neema; Ngezirabona, Stany Vwima; Mardochée Ngandu; Mubasi, Clérisse Casinga.- Etude comparative de performance d'utilisation des foyers améliorés et leurs effets sur les niveaux de vie des ménages de Bukavu

https://doi.org/10.4000/vertigo.24496

Improved Cook Stoves, https://www.ctc-n.org/technologies/improved-cook-stoves

Kitoto, Patrick Arnold Ombiono .- Facteurs d'adoption des foyers améliorés en milieux urbains sahéliens camerounais/

Adoption factors of improved stoves in Cameroon urban Sahelian environment

https://doi.org/10.4000/developpementdurable.12182

PERACOD. Vulgarisation des foyers améliorés au Sénégal: Les acquis du projet FASEN du PERACOD. https://d-nb.info/1127680684/34

PERACOD. Fiche technique de fabrication des foyers améliorés « Jambar » à bois et charbon de bois.
https://energypedia.info/images/4/44/GUIDE_DE_FABRICATION_DU_FOYER_AMELIORE_JAMBAR.pdf

1.2. High-efficiency Improved Cookstoves for Firewood by TaTEDO - INFORSE East Africa

Description of the solution

Cooking on traditional biomass stoves is mostly related to very low levels of energy efficiency. The most basic type of cooking with biomass is the so-called "three-stone fire", which is made by arranging three stones in such a way that it is possible to place a pot for cooking above it. Although this type of biomass cooking is most inefficient and bears serious risks to human health and the environment, it has been around for thousands of years and is still the most prevalent way of cooking in the world. About 1.5 billion people in the world use traditional stoves for cooking (and heating)[6]. Many efforts have been made in order to improve the energy efficiency and reduce risks for human beings and to the environment related to cooking using a traditional stove. These efforts have resulted in a large number of improved cooking stoves (ICS) which vary in design, performance and costs. Improved stoves come in different forms and sizes, can be designed and built in various ways, depending on the local conditions. Especially in developing countries, stoves occupy a central place in the health, environmental, economic and social domains of life. By improving the efficiency of wood burning stoves, the amount of toxic smoke produced can be reduced and health risks to the family be minimised. In view of these and other concerns, a good cooking stove is defined as one that meets technical, scientific and safety standards, and has high combustion quality, technical efficiency, minimal smoke emission, ergonomics and structural stability.

What the solution provides?

Compared to a basic three-stone fire with 10-15% thermal efficiency, improved cooking stoves can easily halve the fuel requirements of the cooking process achieved by providing an insulated combustion chamber, improving the air supply, and other measures. New designs of improved cooking stoves can reach efficiencies over 50%, being four times as efficient as the three-stone fire. If a chimney is added to an indoor biomass stove, indoor air pollution drops to almost zero[7]. One of the new, efficient cooking stoves is the SeTa-IIFC firewood stove designed by the Tanzanian company, SEECO for institutions as well as for small and medium enterprises (SMEs) such as schools, colleges, prisons, hotels, restaurants, and any other mass cooking places.

[6] Improved Cook Stoves, https://www.ctc-n.org/technologies/improved-cook-stoves

[7] Test Results of Cook Stove Performance", Partnership for Clean Indoor Air, 2012. See Appendix C for the University of California Berkeley (UCB) Water Boiling Test (WBT) protocols.

Why is it successful, from a user-perspective?

SETA-IIFC succeeds because the stoves have high efficiency due to good design for heat transfer, increased surface area for heat exchange, high efficiency of the combustion chamber for reduction of harmful emissions and heat loss by application of ceramic fibre blanket to areas where heat exchange takes place. According to evidence from stove users, the SETA-IIFC has the ability to save more than 70 % of fuel. For example, Mnolela Secondary school in Lindi Region (Tanzania), before it started using SETA-IIFC, required about 430 pieces of firewood each day for preparation of students' meals. Switching to the SETA-IIFC dropped that amount to 57 pieces per day. It means that if trees of 16 inches' diameter at breast height (DBH) are harvested for firewood, this one institution reduces forest-harvesting from 2 trees to 0.25 trees per day.

Energy savings or energy production

A three-stone fire, thermal efficiency is stated to be as low as 10 to 15%[8]. In other words, 85 to 90% of the energy content in the wood is lost as heat to the environment outside the cooking pot. The thermal efficiency of different improved stoves (of the rocket stove types) varies between 23 and 54%. The SETA institutional cook stove manufactured by SEECO with rocket stove features has a thermal efficiency of 54.8 %, which means it has the ability to reduce fuel consumption by around ¾ (75%) compared to three-stone fireplaces with efficiencies 10-15%. The reduction of fuel consumption also implies that the stove contributes to a reduction of the institution's cooking-energy budgets, allowing less time to be spent in cooking and contributing to environmental conservation.

Climate Effects

Improved stoves use less firewood and produce less smoke, and they have been touted as a way to reduce greenhouse gas emissions and health effects from indoor air pollution, as well as to improve forest conservation[9]. The emissions from stoves are dependent on various parameters involved in the combustion process, such as the type of fuel, the type and design of the stove and the operating conditions. Therefore, it is not possible to set a definitive value. The SeTA Improved Institutional Stove contributes to forest conservation. It reduces greenhouse-gas emissions, since the amount of firewood used for cooking is reduced. If the wood used is the result of deforestation and other cutting of trees without replanting, each reduced kg of wood reduces CO_2 emissions with 0,39 kg CO_2/kWh wood, equal to around 1.2 kg CO_2/kg wood. For a larger school that uses 1 ton of firewood per day, 200 days per year of unsustainable firewood, the four times improvement with change to a high-efficient stove from cooking on three stove fires will save ¾ of 1.2 tons = 900 kg CO_2/day, equal to 180 tons CO_2/year. If only half the used wood is unsustainable, reductions with the high-efficiency stove will be "only" 90 tons CO_2/year in this example. If it is possible to reduce wood use to the volume that it is possible to grow sustainably, it can make the fuel use at the school sustainable. In addition to CO_2, the improved stoves also reduce emission of black carbon that is also a driver of climate change.

Costs and time to construct

[8] What users can save with energy-efficient stoves and ovens, Microsoft Word - Appliance__Residential_CookingStoves__User_Savings__20140220__8.doc (bigee.net)

[9] https://openknowledge.worldbank.org/handle/10986/29972

The SeTA-IIFC is available in different sizes. According to the SEECO company price list of 2020, the stove of 25 liters costs TSh 1,200,000 (USD 550), the 50 liters stove is TSh 1,600,000 (USD 730), a stove of 100 litres costs TSh 2,300,000 (USD 1045), and a stove of 200 liters costs TSh 3,500,000 (USD 1,600). The prices also include a stainless-steel pot. The fabrication of SeTA-IIFC stove and its pot takes about 5 days. Installation of the chimney outside the roof normally takes two hours.

Lifetime

The durability of SeTA-IIFC is more than 10 years.

What policies and strategies helped the success?

Globally 2.8 billion people do not have access to clean cooking fuels and technologies, according to the 2020 *Tracking Sustainable Development Goal (SDG) 7: The Energy Progress Report.* The world falls short on its progress towards the Sustainable Development Goal 7, achieving universal access to affordable, reliable, and modern energy services. Globally, clean cooking is increasingly viewed as an urgent development issue with significant benefits for public health, gender equality, the local environment, and the global climate.

The Tanzania national Energy policy emphasises the promotion of efficient biomass energy conversion technologies to save resources; reduce deforestation and minimise threats of climate change. The Tanzania Biomass Energy Strategy (BEST) and SE4All Action Agenda support the production, business, and utilization of efficient biomass stoves.

There have been a number of small projects on improved cook stoves initiated by the government through ministries (e.g., Vice President's Office) and agencies (such as Rural Energy Agency) supporting the private sector to disseminate ICS in specific areas in the country.

- Also, carbon financing and social subsidies have helped to enhance incentives to adopt.
- In 2015 Kenya enacted the Energy (Improved Biomass Cookstoves) Regulations
- Development of standards - for instance the Tanzania Bureau of Standards (TBS) has developed a standard for only charcoal stove (TZS 473:2010) but due to the informality of the sector there is no enforcement mechanism on the products and in the interim, there is no mechanism or framework in place to protect customers from sub-standard cookstoves in the market.

How widespread is it, where it is popular?

Of the more than 2.85 billion people who rely primarily on solid fuels globally, less than one-third use improved cookstoves. In sub-Saharan Africa and Asia, the lack of access to clean cookstoves is especially acute.

Problems and Challenges

It requires a special pot, which means the pot has to be fabricated together with the stove. The bottom of the stainless-steel pot has to be 3 mm thick to ensure its longevity.

1.3. High-efficiency Electric Pressure Cookers (EPC, E-cookers) by TaTEDO - INFORSE East Africa

Description of the solution

Pressure cookers existed first as a stove-top version that required manual monitoring of pressure. A pressure cooker works on a simple principle: steam pressure. Electric pressure cookers arose to help streamline and simplify the process. They have digital or analogue timer controls and are generally easy to use. The quick cooking time and ability to electronically set time also increase their consumer appeal. In addition, the cooker is a closed system which helps retain moisture, nutrients and flavor.

Additionally, well-insulated electric pressure cookers are more energy efficient than stove top or oven cooking. The insulation prevents energy from being lost in the cooking process. Every pressure cooker model is different. Older, less insulated models tend to use more energy than newer models. An upgrade to a newer energy-efficient model can save you money. In addition to energy efficiency, the biggest advantage of an electric pressure cooker is its features. You can schedule your cooking with the in-built timer. They come with safety features too to protect you from explosions. Some of these features are pressure sensors and warning for high temperatures with the help of temperature sensors. Unfortunately, not all pressure cooker models are energy efficient. Thoroughly check the manufacturer's description before buying a pressure cooker.

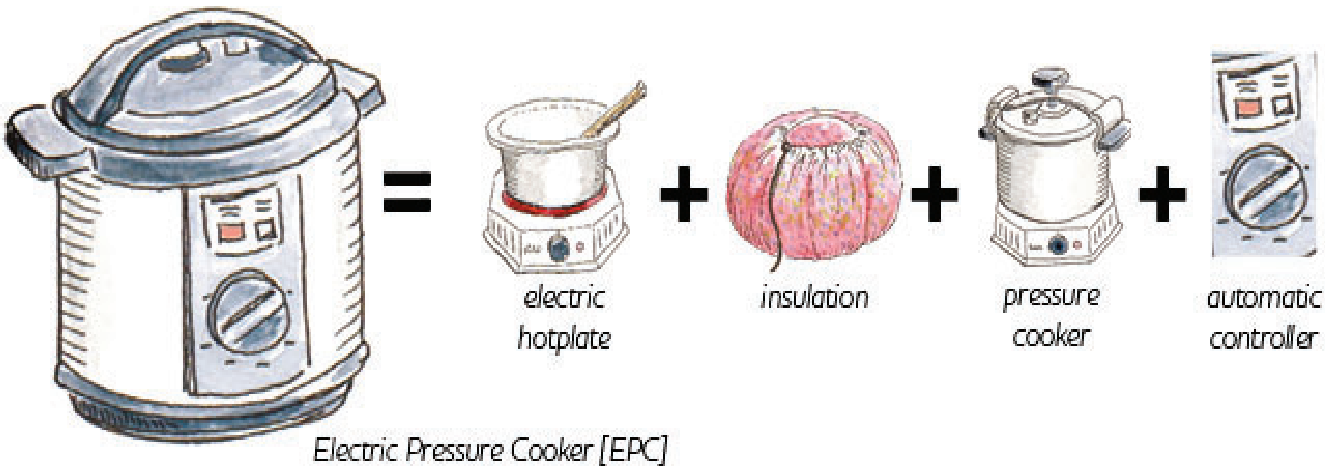


Fig 1: Fundamental components of Electric Pressure Cooker

What the solution provides?

It's a genuinely useful device that can save you both time and money in the kitchen. Pressure cookers speed cooking in two ways. First, the higher heat inside the pot cooks food faster than you can with ordinary boiling water or steam, often reducing cooking times to ⅓. Second, the high pressure forces the moisture into the food, so it heats through quickly. Pressure cooking has other advantages, too. The high-pressure cooking preserves the flavor of food in a way that ordinary steaming can't. And the high temperatures inside the pressure cooker can even allow some food types to brown and caramelize, producing rich, complex flavors that you normally can't get when cooking with water. A pressure cooker doesn't just save you time in the kitchen; it also saves you money. Cooking with a pressure cooker saves energy and opens up a whole new range of cheaper food options for busy cooks. Because pressure cookers cook faster, it also uses less energy.

Why is it successful, from a user perspective?

The pressure cooker is highly efficient — it uses far less energy than many other appliances, since it cooks so quickly and leverages the pressure powers of steam. A pressure cooker cook food about 30 percent faster than conventional methods like steaming, boiling, and braising using the same power. According to the American Council for an Energy-Efficient Economy, pressure cookers also use 50 to 75 percent less energy due to shorter cooking times than normal electric cooking. Pressure-cooked foods retain more vitamins (except vitamin C) and minerals (as well as flavor) than boiled foods because there is less water into which nutrients can dissolve.

Energy savings or energy production

Pressure cookers use less electricity than other electric cooking appliances, more energy efficient than ovens or stoves, pressure cookers are more versatile and cook more efficiently—especially today's versions. Pressure cookers cut energy use in two ways. First, they cook food faster than a slow cooker because they can slash cooking time by 70%. Secondly, they are well insulated, retaining heat that is transferred to cooking so you don't waste energy radiating heat into your kitchen. So, you don't have to turn on the fan or air conditioning. You save energy this way too! Compared to other cooking methods with the same power, pressure cookers are 2-10 times faster. They save energy instead, cutting down electricity costs. However, it depends on what kind of pressure cooker you have and how often you use it. On average, it can use 700 to 1,000 watts of electricity. For example, if you use it for around 3 hours a day, your pressure cooker might use 700 watts. It varies from home to home. By cooking using a pressure cooker, you can save 65 to 70 percent of energy.

The cost saving depends on the price of the electricity. In Tanzania, cooking using the EPC was approximately 7 times cheaper than kerosene, 10 times cheaper than LPG, and 13 times cheaper than charcoal for boiling heavy foods, based on 2020 market prices of the electricity. The device also limits the temperature of the food inside during cooking: when a specific temperature (typically 130'C) is reached, the heating element automatically turns off. Because it is insulated, it maintains that optimal cooking temperature while reducing cooking time to 60%.

Table 1: Daily, Monthly, Annual Costs per Person of Cooking within a Mini-grid Context

Appliance Type	Daily Cost Range per Person, in EUR	Monthly Cost Range per Person, in EUR	Annual Cost Range per Person, in EUR
Electric Hot Plate (2000W)	0.127 – 0.211	3.81 – 6.33	46.25 – 77.09
Induction Hot Plate (1500W)	0.106 – 0.176	3.18 – 5.28	38.54 – 64.24
Slow Cooker (190W)	0.038 – 0.063	1.14 – 1.89	13.73 – 22.88
Pressure Cooker (700W)	0.023 – 0.039	0.69 – 1.17	8.55 - 14.26

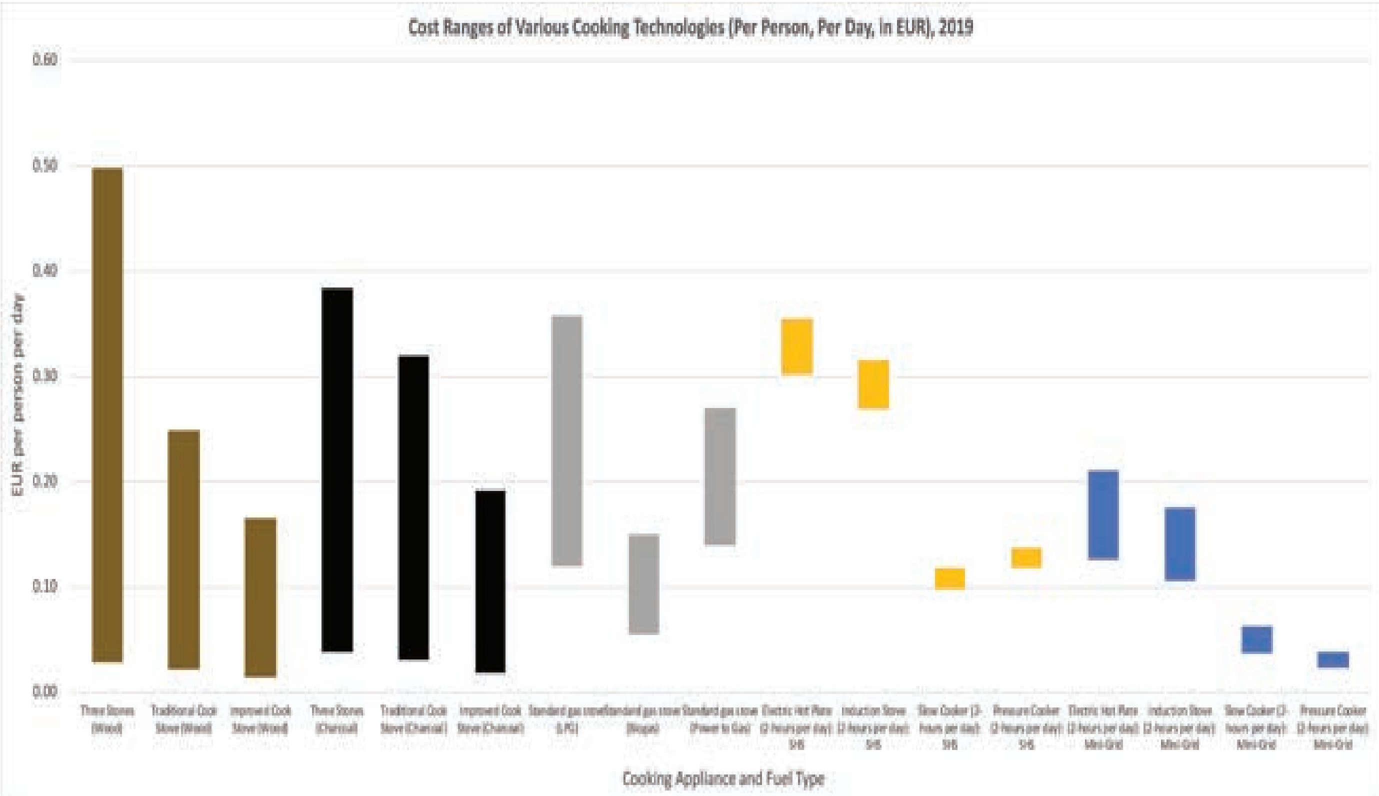
Cost range of **EUR 0.53/kWh to EUR 0.88/kWh** (USD $0.60 - $1.00/kWh; see RMI 2018) is assumed.

Table 2: Daily, Monthly, Annual Costs per Household (average of 5 people) of Cooking within a Grid Context in Tanzania using Pressure Cooker

Appliance Type	Daily Cost Range per Person, in Tsh	Monthly Cost Range per Person, in Tsh	Annual Cost Range per Person, in Tsh
Pressure Cooker (1000W)	200 – 700	6,000 – 21,000	73,200 – 256,200

Cost range of **Tsh 100/kWh to Tsh 350/kWh** (USD $0.04 - $0.15/kWh) is assumed.

Figure 2: Cost Ranges of Various Cooking Technologies (Per Person, Per Day in Tanzania, in EUR), 2019



Legend:

h	= Firewood		= Charcoal		= Gas-based Fuels		= SHS (Electric)		= Mini-grids (Electric)

Sources: Authors' elaboration, based partly on RMI 2018; BNEF 2018; Leach and Oduro, 2015; Goodwin et al. 2014; GACC 2015; Adkins 2010; Smith et al. 2013; FNR 2016.

Table 3: Electricity Consumption of Sample Cookware

Electricity Consumption of Sample Cookware Bringing 1.5 Litres of Water to a Boil (energy savings for pressure cookers are even greater when actually cooking food)	
Cookware	**Energy Use in Watt-hours (Wh)**
Pressure Cooker	60
Warped Bottom Pot	290
Flat Bottom Pot	190

Source: https://fastcooking.ca/pressure_cookers/energy_savings_pressure_cooker.php

Climate effects

Electric pressure cooking provides a wide range of benefits, from reducing carbon emissions and personal exposure to harmful pollutants to lowering the burden of disease associated with household air pollution.

The reduction of energy consumed by using an automatic electric pressure cooker also results in less greenhouse gas emissions from the power plant used to generate the electricity for your electric stove and also lesser smoggy air, depending on power sources of the country.

Electric Pressure Cookers generate less heat, cook your meal quickly and you also don't have to turn on your fan or air conditioning. This reduces pressure on your air conditioner as the amount of heat generated now is far less than before. Normally an air conditioner consumes one unit of energy to remove three units of heat from your home or apartment which is not very efficient. Thus, using an electric pressure cooker can result in a decrease in your electricity bill by reducing the amount of time your air conditioning is on.

Electric Pressure Cookers save forests by providing an alternative clean cooking solution and avoid emissions from combustion of biomass. Exposure to household air pollution from burning wood, charcoal, coal and kerosene is a leading risk factor for diseases. Furthermore, emissions from household cooking are a significant source of ambient air pollution and a contributor to climate change.

Researchers have found that the contribution of indoor emission to atmospheric air pollution is 37%. And almost 90% of that comes from the kitchen. 90% of 37% is 33.3% and it is the contribution from the kitchen.

The new generation pressure cookers help cut pollution and minimise the greenhouse gas emissions from your gas stove, and reduce electric power consumption when using electric stoves, and that means electric plants use less energy to generate power.

If around 4.5 billion people or close to 1 billion houses start cooking their food in pressure cookers, they will be saving huge amounts of fuel and ultimately the emission of greenhouse gases would be cut down by 21.64%.
https://www.linkedin.com/pulse/use-pressure-cooker-everyone-can-offset-global-warming-rajan-pandey.

Costs and time to construct

There are many online resources providing reviews and recipes for all the main brands of electric pressure cookers available. Prices of models range from $50 to $100. Market prices in Tanzania range from Tsh 180,000 to 250,000 (USD 77 to 107) for good quality EPCs with capacities of 4- to 6 liters. EPCs are manufactured in factories and special engineering knowledge is required. Training is required to be able to provide after-sale services.

Lifetime

For most regular users who maintain it properly, it will last for more than five years before replacement.
Most of the EPCs for residential use come with a 1 year to two years warranty; it is very common for EPC to last anything from 2 – 5 years. This shows that the product is expected to last at least that time of the warranty. In some cases, they can last longer if they are properly cared for and certain parts replaced.

For instance, the manufacturers of Instant Pot say that it can withstand more than 100,000 uses. This also extends to individuals who use the instant pot several times a day. Although it is dependent on the maintenance culture of the user, proper cleaning after each use is ideal. The one component that a manufacturer specifies a long-life span for, is the heating element. The silicone ring that surrounds the lid and ensures it is closed is also a part that is expected to last. However, assuming regular usage, it should take a user two to three years before it needs to be replaced. The piece of the EPC that goes through the most wear and tear is the ring, which has a lifespan of 1 to 2 years. Since the delicate parts stand the test of time, through a few replacements, a pot that is properly cared for will last. The stainless-steel pot can withstand minor scratches over a long time.

Problem and challenges

Uses only one type of pot. Not suitable for some fried foods like nyama choma, chapati, and deep frying. If you want crispy fried chicken, then the EPC is not the right cooking appliance because it makes food moist and tender but not crispy.
EPC looks complicated at first.

What policies and strategies helped the success?

Modern Energy Cooking Services (MECS), the UK clean cooking funded programme. Modern Energy Cooking Services (MECS) is a five-year programme funded by UK Aid. The Modern Energy Cooking Services (MECS) programme aims to break out of this "business-as-usual" cycle by investigating how to rapidly accelerate a transition from biomass to genuinely 'clean' cooking on a global scale. Awareness raising campaigns are critically important to raise demand for the EPCs.

How widespread is it, where is it popular?

EPC are widespread all over the world and most popular in Netherlands, India, Asia,

Examples, links

SESCOM electric pressure cooker is among the best EPCs, for more information visit
https://storage.googleapis.com/e4a-website-assets/2020-Global-LEAP-EPC-Buyers-Guide.pdf
and https://sescom.co.tz/products

1.4. Efficient Charcoal Making by TaTEDO and Uganda Coalition for Sustainable Development (UCSD) - INFORSE East Africa

Description of the solution

Charcoal is produced from wood and other biomass types in a process called carbonisation. Carbonisation is the method of burning wood or other biomass in the absence of air after which it breaks down into liquids, gases and charcoal. In many towns in Africa, charcoal is the dominant cooking fuel, making it an important form of energy.

Charcoal is made using charcoal kilns or retort technologies. The most common type of kiln used in charcoal production in Tanzania and many other countries is the traditional (basic) earth mound kiln (BEK) with varying degrees of efficiency. The efficiency of the kiln depends on the construction of the kiln (arrangement of the fuel etc.), moisture content of wood and the monitoring of the carbonization process. There are also other different kiln technologies for production of charcoal, they include: Earth pits (low efficiency), improved Earth mound kilns (medium efficiency), Half orange brick kilns (better efficiency) and metal kilns (better efficiency). Retorts are used for carbonizing residues from Agro processing or sawmill residues, generally with good efficiency.

The Basic Earth Mound Kiln (BEK) is one of the oldest and most commonly used kilns in Tanzania and East Africa. BEK has average efficiency of 8-15%, so only 8-15% of the energy in the used wood is retained in the produced charcoal and wastage is 85%. Carbonization time is eight days, during which the kiln requires continuous attention, and cooling time is 24-48 hours on average. The quality of charcoal produced is rather low. The Improved Basic Earth Mound Kiln (IBEK) has efficiency up to 25% and carbonization takes only four days, cooling takes 24 hours, and the quality of charcoal produced is relatively high.

What the solution provides?

IBEK has an efficiency of about 20-25%. It requires half the time required by the traditional BEK to produce charcoal. IBEK yields large pieces of charcoal with no leftovers, requires only 4.5 kg of wood per 1kg of charcoal, and raises the calorific value of produced fuel to more than 31kJ/kg. For traditional EMK, in contrast, 7 kg of wood are required to produce 1 kg of low-quality charcoal of calorific value of 26kJ/kg.

Why is it successful, from a user-perspective?

Normally, most people prefer to use technologies which they are familiar with rather than new technologies. The Basic Earth Mound Kiln (BEK) has been selected for improvement so that it can be adapted to the improved basic earth mound kiln (IBEK). This is because this kiln is very popular in Tanzania since it is commonly used by most charcoal producers. Charcoal producers prefer to use IBEK because when compared, the quality of charcoal made from a traditional kiln and from the IBEK are significantly different in terms of time of carbonization and weight of charcoal. IBEK uses a relatively smaller quantity of wood, and less carbonization time (hence, less monitoring time) to produce charcoal in the same quantity as the traditional method. Moreover, the IBEK yields large pieces of charcoal with no leftovers.

Energy savings or energy production

The conversion of wood to charcoal plays a small but crucial role in the charcoal value chain. In most instances, charcoal production takes place using traditional BEK or pit kilns, where wood is cut and stacked before being covered in earth and carbonized.

In most instances traditional kilns are used resulting in low conversion efficiencies of around 8 percent to 12 percent. Table 1 summarizes kiln technologies and their associated conversion factors and emission rates. It clearly shows that significant efficiency gains can be achieved by applying improved kiln technologies and that this aspect needs to be considered for designing appropriate policies for sustainable charcoal utilization.

In recognition of these potential challenges, there is an increasing body of experience in Tanzania (and other east African countries) relating to promoting low-cost improvements to the traditional earth kiln design. The Tanzania Traditional Energy Development and Environmental Organization (TaTEDO) has pioneered this approach with a range of simple adaptations to traditional designs that can achieve significant savings at a low cost. These include the introduction of a chimney, as well as ensuring that wood used in the kiln is adequately dried and cut into approximately similar sizes. Semi-industrial and industrial kilns (Table 1) have met with some success, but only under intensive production systems (such as in a plantation setting or with significant external investments by a private sector enterprise dedicated exclusively to charcoal production).

Table 1: Efficiency of Alternative Kiln Technologies

Characteristics	Traditional Phase	Transition Phase	Semi-Industrial Phase	Industrial Phase
Conversion Technology	Traditional Kilns 	Improved Kilns 	Semi-industrial Kilns 	Industrial Kilns 
Efficiency	8-12%	12-18%	18-24%	>24%
Emissions (in g per kg charcoal produced	CO_2: 450 - 550 CH_4: ~700 CO: 450 - 650	→	→	CO_2: ~400 CH_4: ~50 CO: ~160

Source: Sepp (2008b) in World Bank 2009

Climate effects

Each ton of charcoal produced and consumed in Tanzania using traditional methods generates nine tons of CO_2 emissions; IBEK reduces emissions considerably. With the increase in efficiency from around 12% to around 24%, emissions are reduced from around 9 kg CO_2/kg charcoal (2.4 kg/kWh) to around 1.2 kg CO_2/kWh charcoal. If the wood used is from deforestation or other not replanted trees, the total emissions contribute to climate change. For more sustainable wood sources, a smaller part of the CO_2 emissions contributes to climate change.

The IBEK is designed such that the chimney plays an important role in reducing air pollution by serving as a smoke filter. It works well, reducing the emission of harmful volatile substances into the atmosphere by as much as 75 %. Of these, both methane (CH_4) and black carbon contribute to global warming.

Costs and time to construct

Construction cost depends on the type of the kiln. IBEK is a temporary structure; the size of the kiln varies from a few cubic meters' capacity to over 100 cubic meters. One iron sheet to make the chimney is required, the price ranges from TSh 15,000 to 18,000 (USD 6.50 to 7.75). Another cost in time, effort, labour, to construct, to load, to monitor, and to clear away the kiln. Given the reductions in number of days required for carbonization and in the amount of wood needed, the IBEK is a vast improvement over the traditional BEK in terms of labour costs.

One corrugated-iron sheet is needed to make a chimney. Wood, grasses, and soil, all locally available, complete the building materials. The IBEK requires little capital investment once one possesses the necessary common hand tools.

Lifetime

In IBEK, carbonization takes four days and cooling takes 24 hours, then off-loading follows. IBEK is a temporary structure, as the kiln is offloaded, mark the end of the structure. However, it should be noted that the iron sheet can be used for more than three to five times depending on thickness of the sheet used and size of the kiln constructed.

What policies and strategies helped the success?

The Tanzania Forest Act (2002), Charcoal Regulations (2006), and Guidelines for Sustainable Harvesting and Trade in Forest Produce (2007) provide the legal basis for the production and trade of charcoal. The Charcoal Regulations and the Guidelines for Sustainable Harvesting require the establishment of a harvesting committee at the district level. This committee includes participation by village representatives for areas where charcoal production is occurring.

How widespread is it, where it is popular

The IBEK design is applied in Tanzania's coastal and southern areas, mainly used in Kilosa in the Morogoro region, Tanzania.

Problems and challenges

More time is consumed while preparing and organizing wood in the kiln to minimize void space. A large amount of small pieces of wood is required to make the apron. More grasses are required, as the more efficient design requires the entire piles of wood to be covered completely. Higher material costs, increased labor input, but also lack of knowledge all represent disincentives for charcoal burners to adapt improved technologies in situations where they are not rewarded with increased prices.

1.5. Briquettes from Biomass/Agri Waste and Charcoal Dust by ENDA - INFORSE West Africa and REDES - INFORSE Latin America

Description of the solution

Briquettes are blocks of combustion materials made of biomass, charcoal dust, etc. and obtained by die-casting and used instead of charcoal or wood-fuel. Charcoal briquettes are inexpensive solid fuels made from the charred biomass or charcoal dust[10]. They are obtained by compacting these biomass residues into a single solid block.

There are two types of briquettes on the market:

1. Non-carbonised briquettes. These are produced from non-carbonised waste such as sawdust, paper and cardboard waste, waste from the wood products industry, etc.;
2. Carbonised briquettes. They are made from waste that has undergone carbonisation such as powdered charcoal or by carbonising uncarbonised briquettes, invasive plants; residues from the processing of agricultural products – such as coffee husks, coconut shells, croton shells, shells, acacia bark residues, maize cobs, bagasse, groundnut husks, rice husks; as well as agricultural residues from the harvesting of maize, leaves, grasses, stalks and straw from agriculture (if not needed for soil improvement).

In African countries, thousands of tons of biomass residues are produced every year as a result of logging, farming, etc. and their use is generally not profitable. The transport and handling of charcoal, which is the main source of domestic energy in many towns, also produces a large quantity of residues in the form of dust that cannot be used for briquettes. In general, in each bag of charcoal, there is about 5 to 10% of dust depending on the weight. This huge amount of biomass residues and unused charcoal dust can be utilised, turning it into briquettes.

What the solution provides?

The use of charcoal dust for the production of briquettes avoids the waste of resources and protects the environment. The use of briquettes has ecological, economic and societal advantages. Economically, it seems to be more affordable than charcoal, since a kilo is sold at 150 CFA francs

[10] CARNAJE, Naomi P et al.- Development and characterisation of charcoal briquettes from water hyacinth (*Eichhornia crassipes*)-molasses blend https://doi.org/10.1371/journal.pone.0207135

(0.25 USD) as against 300 CFA francs for charcoal (0.5 USD)[11]. Ecologically and environmentally, the recycling of the charcoal dust avoids pollution and congestion with piles of charcoal dust in sales outlets or on landfill sites. Finally, from a societal point of view, just like charcoal, the use of briquettes respects culinary habits, emits less smoke and does not blacken pots.

In Africa, the production and sale of briquettes provide income generation opportunities for entrepreneurs in the cooking and heating fuel supply market. Moreover, the production of biomass briquettes fits perfectly with waste management in the context of a circular economy[12].

Why is it successful, from a user-perspective?

The success of briquettes is due to their lower cost than charcoal (see above). Moreover, briquettes do not pollute and do not upset culinary habits. In addition, the use of fuel briquettes means less firewood to collect and less charcoal to buy; this saves time and money. Fewer trees will be cut down, which will help save the forests.

New employment can be made by selling dust for briquette making or by making and selling fuel briquettes yourself. Briquettes mean less rubbish on the streets and in dumpsites, which improves hygiene in the places where charcoal is sold.

Energy savings - up to 25% saving on charcoal cost. Not all residues will give briquettes of the same calorific value: briquettes produced from banana and cassava peels give a long and brisk cooking time whereas briquettes produced from paper and cereal stalks give less heat than charcoal.

In order to optimise the use of briquettes, specific stoves can be developed or improved cookstoves can be used. The specific stoves are more efficient than conventional stoves, generate less smoke, which has positive impacts on women's health, and the cooking time is reduced.

Climate effects

Using briquettes means less firewood to collect and less charcoal to buy. More importantly, fewer trees will be cut down, which will help to save the forests.

Costs and time to construct

To make briquettes, there are various types of pressings that can be used: manual or motorised screw pressing, manual piston or motorised pressing and lever pressing. The cost and construction time vary according to the pressings or briquette machines.

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[11] NEBEDAY.- Bio charbon : Fabriquer des briquettes de charbon à partir de déchets agricoles carbonisés. https://wiki.lowtechlab.org/wiki/Bio_Charbon

[12] RAMSEY, Deanna.- Cinq choses à connaitre les briquettes de biomasse et la bioénergie durable en Afrique. https://forestsnews.cifor.org/72699/cinq-choses-a-connaitre-sur-les-briquettes-de-biomasse-et-la-bioenergie-durable-en-afrique?fnl=

What policies and strategies helped the success?

Business opportunities along the briquette value chain can help promote the successful adoption of briquettes:

- Collection and sale of raw materials to producers
- Production and wholesale of briquettes
- Purchase of briquettes from producers
- Retail or packaging of briquettes for the general public / supermarkets
- Production and sale of briquettes
- Production and sale of stoves
- Organisation of training courses on briquette production for people interested in interested in briquette production[13]

Examples, links

LA GUILDE.- Le Charbon vert, espoirs et réalités d'une alternative énergétique séduisante: Etude réalisée par Mathilde Laval
https://mediatheque.agencemicroprojets.org/wp-content/uploads/Le-charbon-vert-espoirs-et-r%C3%A9alit%C3%A9s-dune-alternative-%C3%A9nerg%C3%A9tique-s%C3%A9duisante1.pdf

Practical Action.- La fabrication des briquettes: fiche descriptive
La fabrication des briquettes - Practical Answers (practicalaction.org)

[13] Practical Action.- La fabrication des briquettes: fiche descriptive

1.6. Biogas, Household Scale by INSEDA - INFORSE South Asia

Grameen Bandhu Biogas Plants

Description of the Solution Development:

The design framework for building a fixed dome biogas models using Bamboo Reinforced Cement Mortar (BRCM) was conceived in early 1993 by Dr Raymond Myles, the actual experimentation could only be initiated towards the mid of 1993 after collecting all the available information and details on civil construction based on BRCM.

Bamboo is preferred as construction material as it is widely grown the world over and the properties of bamboo as a building (civil construction) material are well documented.

Few crucial aspects related to the implementation of the biogas programme which needed to be looked into were:

- The Reinforced Cement Concrete (RCC) slab of the Outlet Displacement Chamber (ODC) was designed to be an integral part of Deenbandhu Biogas plant, however, in several cases, the ODC was not covered and posed a threat of accidents as small animals and children could fall inside the plant..
- Women masons trained in construction could not be involved at a large-scale construction of DBP in rural India because of:
    i. the socio-cultural reasons for not employing trained women masons in rural areas.
    ii. the reason that the trained women masons could not travel to distant places and stay for longer duration in the field due to family pressure.
    iii. difficulty in supervising men involved in construction..
    iv. additional drudgery as women masons had to perform their daily household chores along with masonry job.

Keeping the above in mind, the first prototype model of the new biogas plant was conceived by Dr. Raymond Myles and was built in March 1994. As about 45% of the cost of building this new model is the wages of labourers, therefore the designer gave the name “**Grameen Bandhu”** (friend of the rural people) plant.

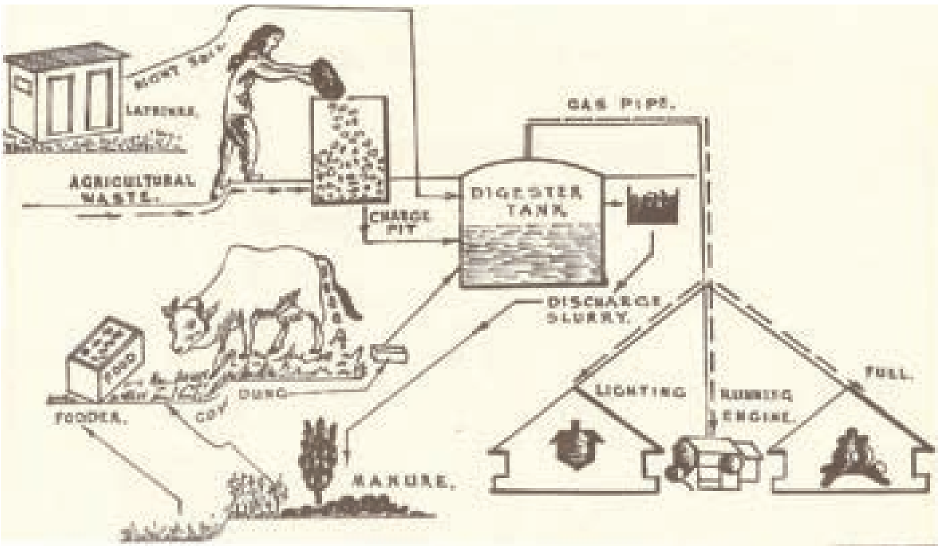
A few family size plants of Grameen Bandhu plant (GBP) model are in operation for over one decade now and have been found to be working satisfactorily as a simple semi-continuous hydraulic digester biogas plant.

In this design, a large ellipsoidal shaped structure, called the “Main Unit of the Plant” (MUP) is woven with bamboo strips in two segments which are joined tightly using binding wires. The “MUP” of the Grameen Bandhu plant (GBP) is made by joining these two bamboo baskets (each of which is segment of different spheres of two different diameters) at their open ends to form an ellipsoidal shaped structure.

The diameters of these two baskets-like structures at their peripherals (i.e. at their open-ended bases) are the same; therefore, they will perfectly match each other). When joined at their junction and properly tied using binding wire, the shape of MUP thus formed would look almost like an oval shaped football. However, only the top structure of the entire composite bamboo structure, placed inside the plant pit can be seen from outside, thus from outside the MUP would look like a hemi-spherical basket shaped shell structure.

Joining two fabricated or prefabricated woven bamboo shells in the shape of two baskets makes the Main Unit of the Plant (MUP) of GBP model. One of them, which comprise the bottom segment of the MUP, is shallower and looks like a big dish. The bottom segment (which constitutes the lower portion of the digester or fermentation chamber) also acts as the base of the MUP of GBP model and rests on the surface of the foundation of the appropriate size plant pit, as per the dimensional drawing. The bottom segment once cast becomes an integral part of the foundation of MUP and along with it also acts as the load bearing structure of the unit; as well as carries the weight of slurry inside the plant. Whereas the ‘top segment’ is a larger hemi-spherical shaped bamboo shell.

The structure, which looks like a very big and deeper basket, and is placed inverted on top of the dished shaped (looks like a shallow basket) bottom bamboo structure. The cement mortar in the appropriate ratios, is used for casting (both from outside and inside) the woven bamboo surface of the MUP. Two coats of plasters follow this, on the outer and inner cast surfaces, to form a continuous BRCM structure for MUP. In the same manner other components, sub-components and minor components of the GBP model are made of BRCM structures, as described in detail in the GBP manual.



The Grameen Bandhu plant (GBP) being made of Bamboo Reinforced Cement Mortar (BRCM), has substantial advantages especially for building it in remote and other areas where quality bricks, stones etc. are not easily available but bamboo is either available or its cultivation can be easily promoted. As the bamboo reinforced structures can be either fabricated or prefabricated at any place, the rural women, landless peasants, unemployed rural youth and other marginalized sections of the rural community can be trained to fabricate these woven structures from bamboo strips. This activity would promote regular income generating activities & opportunity of self-employment on a massive scale in rural areas.

Practical Pictorial Field Guide on Grameen Bandhu Biogas Plant

What the solution provides?

- Biogas Production Technology is an environmentally sound and Eco-friendly technology and a Carbon Neutral System. Biogas provides a smokeless, high efficiency fuel for domestic purposes (cooking and lighting), as well as heating and power generation at the village level.
- Biogas is a clean fuel and keeps, kitchen, household and the surroundings clean.
- The manure (slurry) from the biogas plant has higher nutritive value as compared to that of conventional Farmyard Manure (FYM) produced from the same amount of dung.
- Reduces environmental pollution and improves public health by preventing flies and mosquitoes which otherwise breed on the fresh dung heaps, especially during rainy seasons and also prevents foul odours as decomposition in open areas is avoided.
- Digested slurry can be applied directly along with the irrigation water to the crops and tree plantation to reduce nutrients lost from the slurry.
- Digested slurry is good for backyard horticulture and kitchen gardens and helps supply of nutrition from fresh fruits and vegetables to the families with additional income from sale of surplus.
- Biogas plants save time in cooking, cleaning utensils and reducing drudgery of women and girl children in fuelwood collection.
- Biogas is a very safe fuel for rural homes as it cannot explode easily due to presence of 35-40% CO_2 (Carbon dioxide) in the biogas mixture.

- The smokeless kitchen helps prevent eye and lung disease among women and children who are normally in the kitchen when food is cooked on firewood and dung cake.
- Manure prepared from digested biogas slurry has humus in addition to all the nutrients and trace elements that enrich and regenerate the soil thus contributing to better quality of crops and sustainable crop yields.
- Application of manure from biogas plants increases the water holding capacity of the soil, which makes it easily available to plants.
- The application of biogas manure changes texture and structure of the soil and makes it porous for better aeration, thus contributing to better crop yields.
- Biogas slurry can be used for seed treatment and is found to result in better germination.
- Biogas slurry can be used in the intensive composite pisciculture to give better returns to the farmers.
- The dried slurry can be used as feed for poultry and pigs.

Why is it successful, from a user-perspective?
The Grameen Bandhu plant (GBP) is simple to operate & handle by any plant owner or his/her family in rural areas. Being a simple technology based on the principle of a fixed dome rural household semi-continuous hydraulic digester biogas plants, which are very common in India e.g., Janata & Deenbandhu models, the maintenance and daily care needs to be done in the same way, which can be easily managed by the rural housewife or even the teenage children by devoting only 15 to 30 minutes each day.

Energy production
A 2 cubic meter (daily gas production) biogas plant fed daily with 50 kg cattle manure mixed with 50 liter of water produces enough gas for cooking for a family size of 6-8 persons.

Climate effects
Grameen Bandhu biogas plant would save approximately 4 tons of CO_2 equivalent/ year.

Costs and Size
A 2 cubic meter biogas plant which produces enough gas for cooking for a family size of 6-8 persons, and would cost about INR 40,000 to 45,000 (440-500 EUR)

Lifetime: If properly maintained, life could go easy to 25 to 30 years.

Examples, Links:
Grameen Bandhu Biogas Plant in the Catalogue of Local Solutions Eco-Village Development:
https://inforse.org/evd/presentation/present_solution.php?id=80
https://www.inseda.org/assets/documents/Grameen-BandhuBiogas-plant-A-Pictorial-Field-Guide.pdf

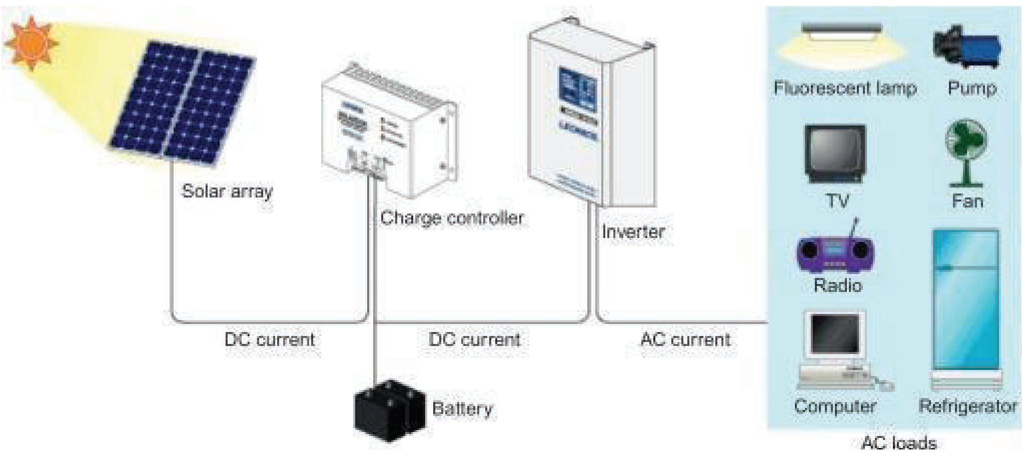
1.7. Solar Home Systems by INSEDA - INFORSE South Asia

Description of the solution

Solar home systems (SHS) are stand-alone photovoltaic systems that offer a cost-effective mode of supplying amenity power for lighting and appliances to remote off-grid households. In rural areas that are not connected to the grid, SHS can be used to meet a household's energy demand fulfilling basic electric needs. Globally SHS provides power to hundreds of thousands of households in remote locations where electrification by the grid is not feasible. SHS usually operate at a rated voltage of 12 V direct current (DC) and provide power for low power DC appliances such as lights, radios and small TVs for about three to five hours a day. Furthermore, power conditioners/ inverters can be used to change 12/ 24 V power to 240VAC power for larger appliances. SHS are best used with efficient appliances to limit the size of the photovoltaic array.

A SHS typically includes one or more PV modules consisting of solar cells, a charge controller which distributes power and protects the batteries and appliances from damage and at least one battery to store energy for use when the sun is not shining.

What the solution provides?



A solar home system provides electric energy to fulfil the power requirements of a home. It is capable of providing AC power as traditionally all homes use AC power to operate lighting systems, gadgets, appliances and equipment such as computers, refrigerators, mixers, fans, air conditioners, TVs and music systems.

Why is it successful, from a user-perspective

They contribute to the improvement of the standard of living by:

- reducing indoor air pollution and therefore improving health as they replace kerosene lamps,
- providing lighting for home study,
- giving the possibility of working at night and
- facilitating the access to information and communication (radio, TV, mobile phone charging).

Stand-alone photovoltaic systems can also be used to provide electricity for health stations to operate lamps during night and a refrigerator for vaccines and medicines to better serve the community.

Energy savings or energy production
Solar home systems are available 100 W to 10 kW systems.

Climate effects

SHS avoids greenhouse gas emissions by reducing the use of conventional energy resources like kerosene, gas or dry cell batteries or replacing diesel generators for electricity generation.

Costs and time to construct

The benchmark cost of a typical 1 kW off-grid system generating 4-5 kWh/day of electric power can vary between Rs 1 lakh and 1.25 lakh INR (1000 - 1400 EUR).

An off-grid home solar system is an excellent cost-saving feature when planned properly and is capable of paying back the initial investment within the first 5 years of operation through savings in electricity bill.

Price List of Off-Grid Solar System in India 2022

Off-Grid Solar Model (kW)	Selling Price	Price Per Watt
1kW Solar System Price	Rs. 71,442	Rs. 71.442
2kW Solar System Price	Rs. 1,70,774	Rs. 85.38
3kW Solar System Price	Rs. 2,11,313	Rs. 70.44
5kW Solar System Price	Rs. 3,59,011	Rs. 71.81
6kW Solar System Price	Rs. 4,45,256	Rs. 74.20
7.5kW Solar System Price	Rs. 5,15,574	Rs. 68.74
10kW Solar System Price	Rs. 6,23,101	Rs. 62.32

(71,441 INR is equal to around 850 US$)

Lifetime

Solar panel systems are extremely durable and require little to no maintenance over their productive lifetime, which can span 25 years or more. Solar systems are also extremely easy to maintain. The main maintenance that these panels require is an occasional dusting to remove dirt, leaves, or any other fragments. One can always call a professional, to clean these panels once in a while. Batteries have typical lifetimes of 5 years and charge controllers can live 20 years, if they are not overheated.

What policies and strategies helped the success?

Clean Energy Cess in India, 2010

The Clean Energy Cess was introduced to levy the amount of INR 50 (0.60 USD) to every tonne of coal used in the country. The Cess created the National Clean Energy Fund (NCEF) that aims to fund clean energy projects. It provides up to 40 per cent of the total costs of renewable energy projects through the Indian Renewable Energy Development Agency (IREDA). The Cess has now grown to INR 400 (5 USD) per tonne of coal used.

Joint Liability Group (JLG) for off-grid installations

The purpose of Joint Liability Group (JLG) is to augment flow of credit to tenant farmers cultivating land either as oral lessees or sharecroppers and small farmers who do not have proper title of their land holding through formation and financing of JLGs and to extend collateral free loans to target clients through JLG mechanism. By synthesising business and social potential, a small group of 4–10 local entrepreneurs as JLG can help in making loans available for micro-grid installations.

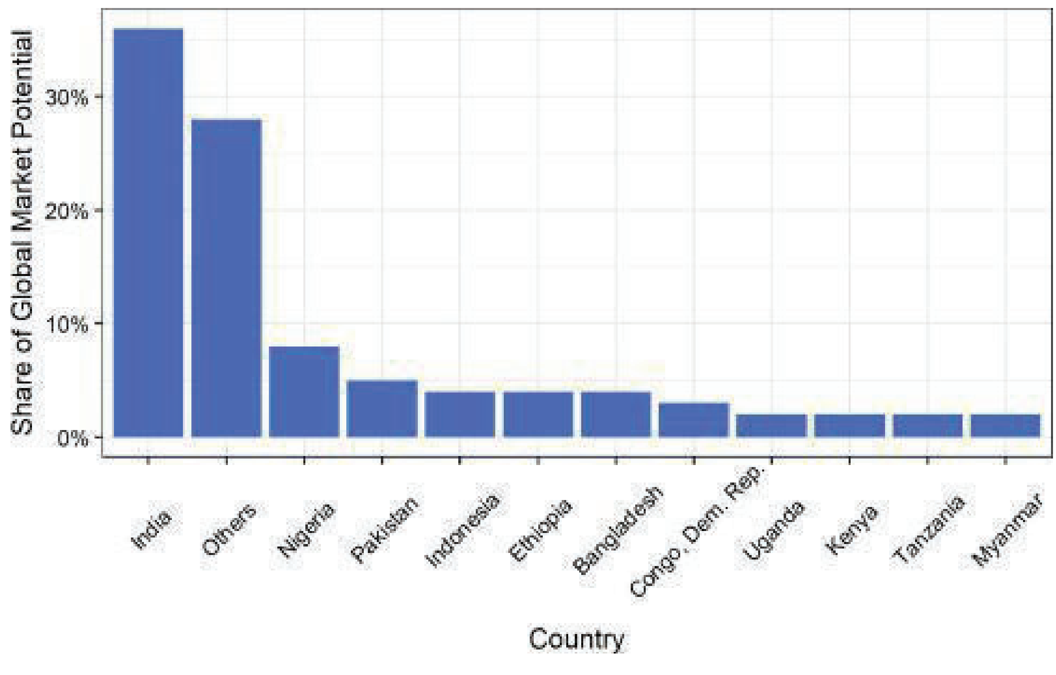
Central Financial Assistance (CFA) from Ministry of New and Renewable Energy (MNRE) for grid connected rooftop solar projects in the residential sector in India (as percentage of benchmark cost or cost discovered through competitive process whichever is lower).

Type of residential sector	CFA
Residential sector (maximum up to 3 kW capacity)	40 % of benchmark cost**
Residential sector (above 3 kW capacity and up to 10 kW capacity)*	40 % up to 3 KW Plus 20% for RTS system above 3 kW and up to 10 kW
Group Housing Societies/Residential Welfare Associations (GHS/RWA) etc. for common facilities up to 500 kWp (@ 10 kWp per house), with the upper limit being inclusive of individual rooftop plants already installed by individual residents in that GHS/RWA at the time of installation of Roof Top Solar System (RTS) for common activity.	20 %

** The residential sector users may install RTS plant of even higher capacity as provisioned by respective State electricity regulations; however, the CFA will be limited up to 10 kWp capacity of RTS plant.*
*** Benchmark cost may be different in General Category States/UTs and Special Category States/UTs i.e., North Eastern States including Sikkim, Uttarakhand, Himachal Pradesh, Jammu & Kashmir, Lakshadweep, and Andaman & Nicobar Islands. CFA shall be on benchmark cost of MNRE for the state/ UT or lowest of the costs discovered in the tenders for that state/ UT, whichever is lower*

How widespread is it, where it is popular

Currently, SHS business models have reached somewhere on the order of 2–4 million households (or 10–20 million citizens worldwide) with more installations in Bangladesh than in any other country.



When pico-solar products are added, over 300 million citizens worldwide have benefited from solar-powered lighting and electrification solutions. And yet, with an estimated global total of 1.1 billion without access, there is still much work to be done.

The IEA estimates in its new policy scenario that under the expansion at current pace still more than 600 million people (or roughly 130 million households) will lack electricity access in 2030. This is despite average investments of 24 billion USD per year into energy access or roughly 1.5% of the global annual energy investment (IEA and World Bank, 2017).

Problems and challenges

More expensive due to additional battery cost. The cost of solar PV is usually a cost effective way to supply smaller quantities of electricity needed. Although the cost of solar PV electricity has been significantly decreasing, further decreasing is still necessary in order for this technology to be affordable to everyone.

Solar PV has challenges regarding the uncertainty of how much of the sun's rays it would receive, as weather can change from time to time. This can prove difficult in determining how much energy to store for future use. Sunlight is clearly unavailable during night hours while there is still demand for electricity. In addition, peak radiation availability may not match with the demand for peak electricity. A mechanism for effective energy storage is needed for this reason.

Location can be an issue. The availability of solar radiation can vary depending on location. Some places such as Southwest, have significantly more solar radiation than other locations. This would mean that solar energy generation of a specific system is dependent on the locations where the systems are installed.

Low quality products have been a big problem in several countries, where vendors sell PV panels and equipment with very short lifetime (below one year). This has given SHS a bad reputation in some countries, including some African countries. Quality control and standards as well as enforcement is needed to cope with this.

Examples, description

Case Study from Fosera - How Teddy's Tailoring Business Was Re-ignited by Solar Lighting, provided by Fosera's partner in Zambia VITALITE.

After more than two decades spent building up a loyal customer base, Teddy Hangandu, a tailor in Lusaka's Luangwa Compound, found himself falling into a slump. If you are living in a house without power, work comes to a standstill once the sun goes down. But Teddy's clientele wants their clothing when they want it, sunup or sundown.
With this in mind, Teddy tried using paraffin lamps at nighttime, but this ended up costing him K50 (about 2.80$) a week on fuel.

These lamps also pose serious hazards:

- The paraffin lamps give off poisonous fumes that badly affect the respiratory system.
- Paraffin is highly flammable, and if knocked over, the lamp can cause serious house fires.
- Impure paraffin has been known to explode without warning.

Aware of these dangers and unhappy about spending money on fuel instead of more valuable activities, Teddy vented his frustrations to a friend. Luckily, his friend, a VITALITE customer, introduced him to the **Lighting Plus Solar Kit** – a product that is particularly adapted to the needs of people with limited or no access to grid electricity in Zambia.

The Lighting Plus Kit, built on a Pay-As-You-Go basis, comes with three lamps that last six to eight hours when fully charged and three years warranty. Because of these extended hours, Teddy went from serving 10 to 15 customers a week to a booming business with 20 to 30 customers a week. He no longer turns away last minute clients and has increased his turnover.

Outside the long-term positive impact on the environment, the **FOSERA** solar system has helped Teddy save money. The increase in sales means he can better support and provide for his two orphaned grandchildren.

His advice for small business owners still reliant on candles and paraffin lamps is to make that switch to solar. He is no longer pressured to turn away clients or only work in daylight hours. He no longer worries that a clumsy grandchild might knock over an oil lamp and burn the house down. More importantly, the solar PV system will continue to save him money in the future.

Sharing SHS Electricity, Bangladesh

Grameen Shakti (INFORSE member in Bangladesh) partnering with ME SOLshare, was the winner of “Powering The Future We Want” initiative of United Nations Department of Economic and Social Affairs (UN DESA) in 2017, awarded to implement the project titled “Smart Peer-to-Peer Solar Grids for Rural Electrification & Empowerment”. The project was developing a sustainable business model for peer-to-peer energy trading solar system by establishing 100 SMART grids in villages (15000 beneficiaries). Under this project, bi-directional energy meters are installed both in houses with SHS and without SHS, interconnected to create a decentralized, low voltage grid. These meters enabled the households to sell or purchase electricity through peer-to-peer solar energy trading facilities, backed by mobile wallets. The households which generate excess electricity can sell in the grid and make money. Also, the houses which require electricity can purchase it from the grid without expending on the upfront cost of an entire solar system. The entire operation is monitored and managed by a back office connected through a Wi-Fi tower.

Links:

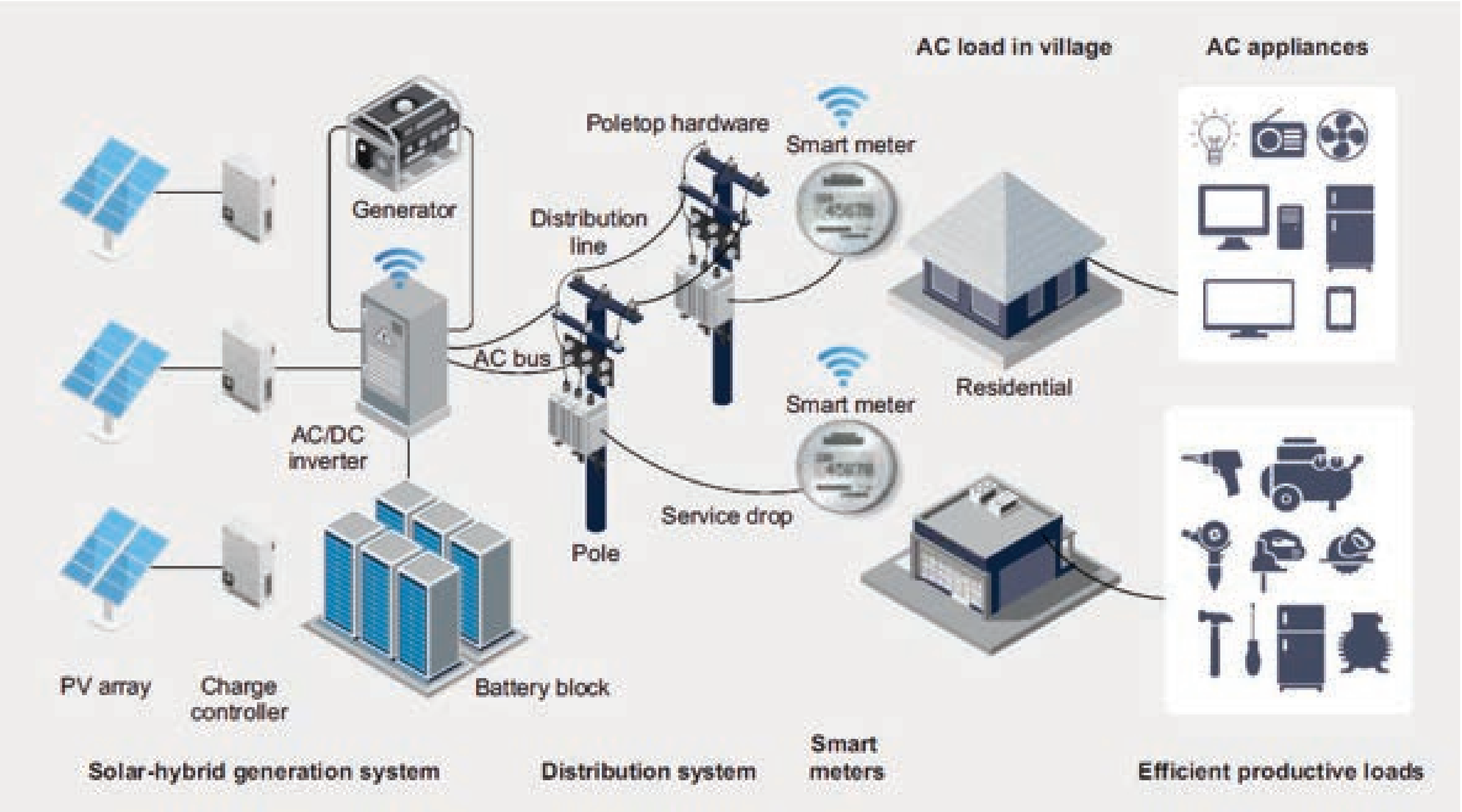
https://www.gshakti.org/pdfs/downloads/GS_Consultancy%20_%20Knowledge.pdf
https://poweringthefuture.un.org/recipients/2017/grameenshaktiandmesolshare.html

1.8. Mini-grids by REDES - INFORSE Latin America

Description of the solution

A typical third-generation mini grid consists of a hybrid generation system that includes solar panels, windmills or other renewable electricity sources, batteries, charge controllers, inverters, and may have diesel backup generators. It could be connected to a bigger grid at the time of installation or in the future. These mini grids typically use smart, remotely controlled electricity meters that allow customers to prepay for their electricity, for example in a pay-as-you-go (PAYG) model. They use remote monitoring systems to manage the status of the system in real time from a distance. They have also integrated partnership programs throughout the lifecycle of the mini grid that stimulate the local economic development of their clients and do this in collaboration with suppliers of energy-efficient appliances as well as microfinance providers. Research shows that the uptimes of third-generation mini grids often exceed 97 percent—less than 2 weeks of scheduled maintenance per year. This performance is significantly better than previous generations of mini grids and most utilities across Sub-Saharan Africa.

The combination of falling costs, new technologies, and favorable enabling environments has made third-generation mini grids an option to connect 490 million people, complementing grid extension and solar home systems to reach universal electrification by 2030.At the same time community energy systems within bigger already established grids are using similar Technologies taking advantage of distributed energy schemes and participatory policies holding the potential of serving an even greater population in urban and peri urban media.



What the solution provides.

Mini grids can be a low-cost and timely solution to supply electricity to people in areas that the main grid is unlikely to reach or deliver reliable electricity services in the medium term (five to ten years). In such regions, mini grids have an edge over main-grid expansion/ reinforcement in several ways.

Mini grids can be deployed more rapidly than the main grid. Their planning and implementation are more conducive to spontaneous entrepreneurial development, while grid expansion involves several institutions (ministries, utilities, rural electrification agencies) in a longer and more complex series of steps.

Mini grids are now more than ever price-competitive against traditional sources of off-grid energy (diesel self-generation, kerosene, and dry cell batteries) thanks to the significant improvements in the cost and performance of renewable and storage technologies, coupled with innovative business models. The latest generation of low-cost, rapidly deployable "solar hybrid" mini grids source their energy from solar photovoltaic (PV) systems coupled with battery storage and diesel backup. They make use of smart in-home meters and offer convenient payment options, such as mobile money.

Why is it successful, from a user-perspective?

High efficiency for lighting, fridges, TV, computers, and other information and telecommunication (ITC) equipment can be provided by relatively small appliances but still bigger than for solar home systems (SHS)*. Efficient productive loads can be added for AC or DC appliances (see graph) due to the increase in available power with considerable positive impact on job generation at a much lower cost.

Mini grids can access private financing and operate without subsidies when the regulatory framework allows them to charge full cost-recovery tariffs. Even at cost-recovery levels, users can save money in comparison with traditional sources of energy. For example, mini grids could save Nigeria's off-grid and underserved consumers up to $2.4 billion annually on diesel self-generation (REA 2017: 7).

Policymakers may view investing in mini grids as a waste of resources in the longer term if they are meant to be replaced by a cheaper, more cost-efficient main grid. But the arrival/reinforcement of the main grid does not necessarily mean that the investment in mini grids would be wasted. Indeed, mini grids' generation and distribution assets can be reused in an integrated system, either separately or together. Solar hybrid and small hydro mini grid systems can improve the stability and quality of the main grid by providing backup and frequency stability; and they can do so without significantly lowering efficiency, since their levelized costs are close to those of larger solar PV and hydro plants that would be built as independent power producers. Reusing mini grids' generation and distribution assets can enable developing countries to shape their power system into a centralized grid that integrates fractal systems.

Climate effects

The climate effects are dependent on the emission profile of the local power production and the extent of the substitution of diesel for the gensets and combustion of other fuels, e.g. GPL, kerosene etc.

What policies and strategies helped the success?

Information campaigns can help final users understand how much money they can save. Defining clear technical standards and commercial options for integration can address key concerns of mini grid developers and entice them to invest.

What happens when the main grid arrives is a major concern for mini grid developers. Investors face two risks: The first is that their assets will be stranded. This can occur when the main grid builds over the mini grid, pulling customers to the cheaper or better service the main grid offers. The second risk is expropriation of assets, which occurs if the utility or the government takes over the mini grid assets without adequate compensation. Governments that are serious about increasing electricity access will want to mitigate these risks to foster mini grid investments and hasten electrification.

Two sets of actions can reassure potential mini grid investors. The first set would define clear technical standards for mini grids, enabling them to connect to the main grid. The second would establish clear rules on commercial options available to mini grids when the main grid arrives. The two sets are intertwined, so they need to be dealt with together.

Setting clear technical standards is key to allowing future connection of mini grids to the main grid at minimal cost. Setting main-grid standards and granting a right to connect, subject to compliance with standards, may be useful where the main grid is likely to expand soon; light standards may be enough where the main grid is likely to expand later.

Technical standards for connection with the main grid should cover the following aspects:
- Equipment (distribution network poles, conductors, and insulators) that ensures the network can handle the quantities of electricity that flow when energized by the main grid

- Generation synchronization, to ensure the safe and reliable operation of the grid when connected to the mini grid generator.
- Interoperability, which refers to the capability of two or more networks, systems, devices, or components to interact, communicate, and exchange information securely and effectively.

Guaranteeing mini grids, the right to connect, subject to compliance with standards, can further reassure investors. Without a legal requirement, the operator of the main grid may be tempted to exert discretionary power and reject the connection of a mini grid.

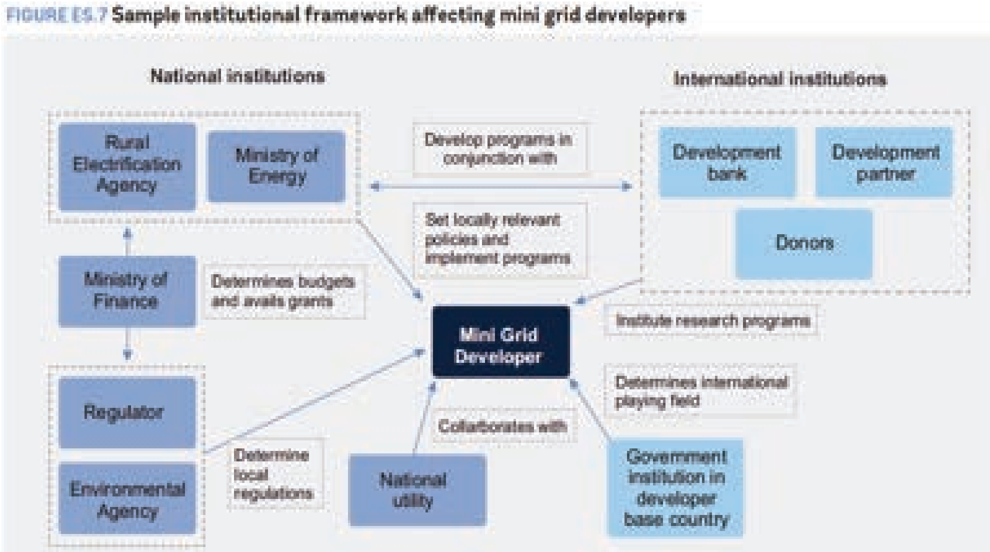
Setting grid-compatible or main-grid standards can be useful when the grid is expected to be expanded within the lifetime of a mini grid's assets. At that point, a mini grid operator may well not have received the required return. Having the option to connect to the main grid may allow a mini grid operator to earn the expected revenue, preserving the value of the investment.

Grid-compatible or main-grid standards enable mini grids to integrate without jeopardizing the safety, stability, and reliability of the power system. Mandatory standards guarantee the stability of the power system and ensure higher equipment quality and safety. But stability of the power system can be preserved even with optional standards, while offering flexibility to mini grid operators. Operators can choose either to follow the standards to guarantee later connection or not to do so and risk being denied the right to connect if they are unable to upgrade their infrastructure when the main grid arrives.

Grid-compatible or main-grid standards entail relatively high costs both for developers and governments for several reasons:
- Equipment that meets these standards is typically more expensive. For example, in Bangladesh one developer reported that compliance with pole standards accounted for 25 percent of the total mini grid's capital expenditure, compared with 5 percent for an unregulated project in Nigeria. Grid-compatible or main-grid standards may also prevent innovation that could decrease costs.
- Governments may need to provide subsidies to cover the added costs and attract investments in communities where incomes are too low to charge a cost-recovery tariff. Subsidies can help users in the transition period. e.g., by providing Lifeline tariffs to avoid harming the poor.
- Designing and enforcing grid-compatible standards requires significant human resources from governments. For example, in Cambodia the regulator advises developers on how to build mini grid systems so that they can integrate with the main grid later (Tenenbaum 2018: 30).

A lighter approach to setting standards may be appropriate for areas where grid expansion is expected to occur *after* developers and investors have recouped their investments. A lighter approach includes options that range from safety standards only (and no technical standards), or technical standards specific to mini grids.

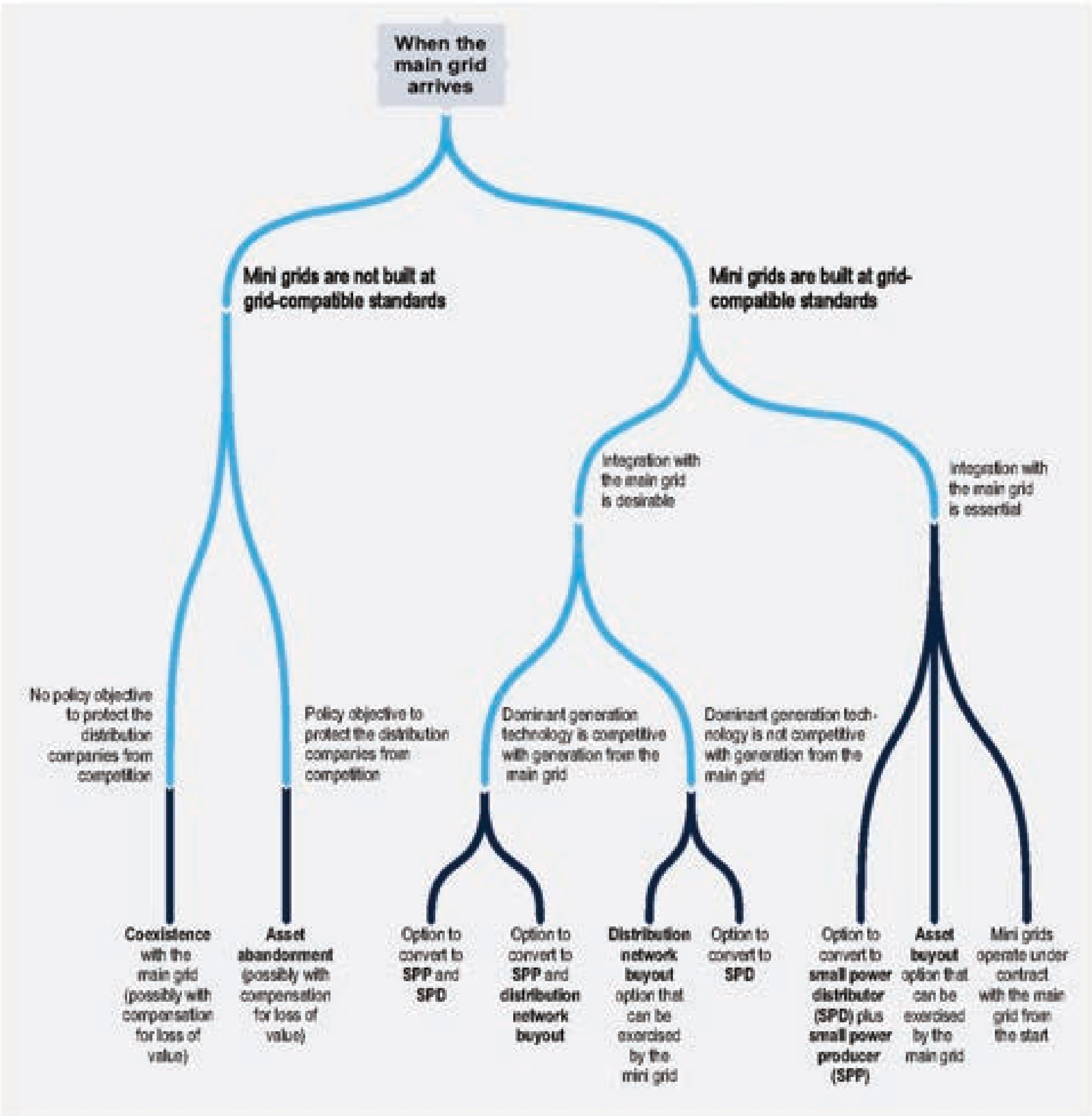
FIGURE ES.7 **Sample institutional framework affecting mini grid developers**



Setting lighter standards can save resources for both developers and governments:

- This option gives developers more flexibility to design mini grids with their target market and local conditions in mind—and it encourages innovation. For example, developers might design their mini grids to operate on direct current, which is cheaper than operating on alternating current.
- Governments may save on subsidies. No subsidy is generally required when there are no technical standards; safety standards require minimal subsidies. A lighter approach may foster the development of mini grids in communities where subsidies are limited, and where the ability to pay for the desired service level rules out the use of technology compatible with the main grid.

Decision tree for determining what happens to mini grids when the main grid arrives



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Cost Analysis of mini-grids

TABLE ES.5 Current and projected tariffs, costs, and profits of mini grid operators, 2019 and 2030

Item	2019	2030
Average tariff/kWh	0.45	0.26
Cost of service/kWh	0.43	0.21
Profit on mini grids deployed this year (millions of US$)	28	608
Cumulative profit on all mini grids deployed (millions of US$)	153	3,343

Source: ESMAP analysis.
Note: kWh = kilowatt-hour.

This ESMAP study should be revised since costs of PV, batteries and inverters have reduced more than expected. The World Bank considers 15 000 U$ per system a reasonable threshold for mini-grids in Latin America, but the ESMAP study (see box above; Mini-grid evolution in a snapshot) arrives at much lower figures: 4000 U$ 2019, 3000 U$ 2030. Community energy based in renewables is providing final users within the grids with even lower upfront costs.

TABLE ES.4 Cost benchmarks and price projections for mini grid components[9]

Component	Unit	Percent of total capital cost	Median cost in ESMAP survey	Minimum cost in ESMAP survey	Mainstream industry benchmark in 2010	Mainstream industry benchmark in 2018 (percent change from 2010)	Cost estimate by 2020	Cost estimate by 2030 (percent change from 2018
PV module	$/kWp	11%	690	497	1,589	230 (–85%)	220	140 (–39%)
PV inverter	$/kWp	5%	264	176	320	115 (–64%)	80	58 (–50%)
Battery	$/kWh	15%	214	126	—	147 (n.a.)	127	118 (–20%)
Battery (Li-ion)	$/kWh	15%	598	461	1,160	176 (–85%)	139	62 (–64%)
Battery inverter	$/kVA	9%	649	311	565	203 (–64%)	142	102 (–50%)
Smart meters	$/client	4%	83	50	106	40 (–62%)	35	30 (–25%)

Sources: ESMAP analysis; Bloomberg New Energy Finance databases; Fu and others 2017. Full references are provided in Chapter 3 of the book.

Note: Median, minimum, and 2010 benchmark data are expressed in inflation-adjusted dollars. Future prices are as reported by the source. — = not available; kVA = kilovolt-ampere; kWp = kilowatts-peak; n.a. = not applicable; PV = photovoltaic.

How widespread is it, where is it popular?

According to the latest ***Tracking SDG7: The Energy Progress Report*****, progress toward achieving universal access to electricity has been promising** (World Bank and others 2019). In 2017, the global electrification rate reached 89 percent, with the number of people without access dropping to around 840 million—compared with around 1 billion people in 2016 and 1.2 billion in 2010. Despite this progress, under current policies, an estimated 650 million people—or 8 percent of the global population—will still lack access to electricity in 2030; 9 out of 10 of them will be in Sub-Saharan Africa.

Reaching the remaining unserved people, including those connected to frail and overburdened urban grids, as well as displaced people and those in hard-to-reach locations, will require strong policies, increased private financing, and comprehensive electrification planning. *Tracking SDG7: The Energy Progress Report* shows that countries with a comprehensive approach to planning—which consists of main grid extensions, mini grids, and solar home systems—have achieved the fastest results in electricity access (World Bank and others 2019). Countries with the fastest gains in electrification between 2010 and 2018 include Bangladesh, Cambodia, India, Kenya, Myanmar, Nepal, Rwanda, and Tanzania.

Compared with the main grid and solar home systems, mini grids are a more viable solution for off-grid areas with high population density and demand. Extending the main grid to serve remote communities consuming a limited number of kilowatt-hours (kWh) per month is prohibitively costly in most cases. Meanwhile, solar home systems are ideal for areas with low population density and low demand. Mini grids are generally the most economically viable option for servicing areas that are too expensive for the main grid to reach in a timely manner but have high enough demand and population density to support commercial viability.

At the same time, mini grids have grown from a niche solution to being deployed widely. The World Bank's Energy Sector Management Assistance Program (ESMAP) has developed a database of more than 26,000 installed and planned mini grid projects around the world. Globally, at least 19,000 mini grids are already installed in 134 countries and territories, representing a total investment of $28 billion, providing electricity to around 47 million people. Most of these mini grids are diesel-fueled, followed by hydro-powered and solar-hybrid systems. Between 2014 and 2018, twice as many solar-hybrid mini grids were built compared with the period between 2009 and 2013. In Africa and South Asia only, however, the investment figure drops to $5 billion for 11,000 mini grids covering 31 million people. Another 7,500+ mini grids are planned to go online over the next couple of years, mostly in Africa, connecting more than 27 million people for an investment cost of $12 billion. These planned systems show a significant shift from diesel to solar-hybrid systems using the latest technologies.

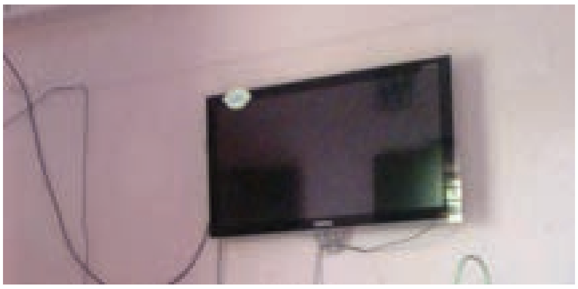
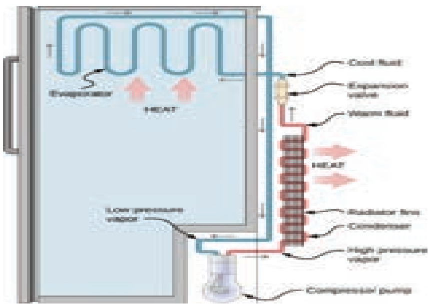
Asia has the most mini grids installed, but Africa has the largest share of planned mini grids. The ESMAP database of mini grid projects around the world indicates that Asia—including South Asia, East Asia, and the Pacific—has a combined total of more than 16,000 installed mini grids, representing 85 percent of the global total. The majority (61 percent) of the installed mini grids in Asia are in just three countries: Afghanistan (4,980), Myanmar (3,988), and India (2,800). Estimates show, however, that mini grid deployment will grow predominantly in Africa. Currently, more than 4,000 mini grids are being planned for development in Africa, representing more than half (54 percent) of the total 7,507 planned mini grids globally. More than half of the planned mini grids in Africa will be developed in Senegal (1,217) and Nigeria (879).

Sources:
Mini Grids For Half A Billion People: Market Outlook And Handbook For Decision Makers, ESMAP, The World Bank, September 2022.
https://www.esmap.org/sites/default/files/esmap-files/Mini%20Grids%20for%20Half%20a%20Billion%20People%20-%20OKR%20Download%20Version_compressed_MKA.pdf
Tracking SDG7, The Energy Progress Report 2022, ESMAP, The World Bank.
https://trackingsdg7.esmap.org/data/files/download-documents/sdg7-report2022-full_report.pdf
Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers, ESMAP, The World Bank, 2019.
https://openknowledge.worldbank.org/bitstreams/f3815820-92b6-5807-8e9f-d0bd98732b5a/download

1.9. Efficient Light and Electricity Use by INFORSE Secretariat

Gunnar Boye Olesen, INFORSE - Secretariat: Training material for advocacy for local sustainable energy solutions

Description of the solution: Efficiency Use of Electricity
Electric appliances have become much more efficient over the latest two-three decades. The development of efficient lamps is probably the most remarkable development, but energy efficiency is not limited to that. The most important electricity saving solutions are

 Wikimedia, photo by Geoffrey.landis	Lamps, where there is an increase in efficiency from incandescent lamps to LED of a factor 10. The increase in efficiency of good LEDs over halogen lamps is around 7 times and over fluorescent lamps around two times. In many countries, the inefficient incandescent and halogen lamps are still on the market.
 Wikimiedia, photo by Superbmust	Modern TV's and computers are now over 10 times as efficient as 20 years ago, but some of the less efficient types are still on the markets[14]
 Wikimedia, Illustration by DigitalNet99	Good refrigerators and freezers are around 5 times as efficient as 20 years ago. Today, the best models on the market are three times more efficient than the less efficient ones.[15]

[14] According to Topten.eu a 32" (81 cm TV) can consume only 24 kWh/year, if used 1000 hours/year. On the EU market are TV's with twice the consumption, while consumption over 240 kWh/year was normal before 2010 according to https://www.aceee.org/files/proceedings/2012/data/papers/0193-000292.pdf

[15] A high-efficient fridge uses 65-75 kWh/year (250 ltr) and a high-efficient fridge-freezer uses 110-120 kWh/year (250 ltr. fridge + 100 ltr freezer) according to topten.eu. On the EU market are fridges with three times this consumption. Before 2005, consumption above 600 kWh/year normal for a fridge according to https://www.osti.gov/servlets/purl/971432

 Wkimedia, photo: VEM motors GmbH	Pumps and electric motors can be used much more efficiently, when they are equipped with variable speed drives and controls that limit speed, adapting the speed to the needs.
 Photo: TaTEDO, Tanzania	High-efficient e-cookers are twice as efficient as cooking with normal electric stoves, and more if they are used in pressure cooking mode (see description of e-cookers).
 Photo: Wikimedia, en.wikipedia.org/wiki/User:Firstfreddy	Standby consumption. Older chargers and some equipment use a lot of power, when not in use, but the demand has been much reduced for new chargers. for an old charger, the consumption can be as much as 40 kWh/year, while for new chargers it is just 1 kWh/year[16].

What the solution provides?

In general, the efficient lamps and equipment make it possible to provide the electricity services for households and businesses with much less power than with the traditional, inefficient types. With the high efficiency, electricity for light, TV, computers, and other information and telecommunication (ITC) equipment can be provided by relatively small solar home systems (SHS), at least in tropical and subtropical areas (see description of SHS). Focusing of lamps: good LED lamps can both provide light with very little power demand and with much longer

[16] Modern small power supplies, such as mobile phone chargers use just 0.1 Watt in standby, which is equivalent to just below 1 kWh for a year. Chargers from before 2010 can use as much as 5 Watt, equal to 40 kWh/year, if left in the plug.

lifetime than incandescent lamps. LEDs are made for all voltages, both for low volt power systems for small solar home systems and for mains power.

Why is it successful, from a user-perspective?

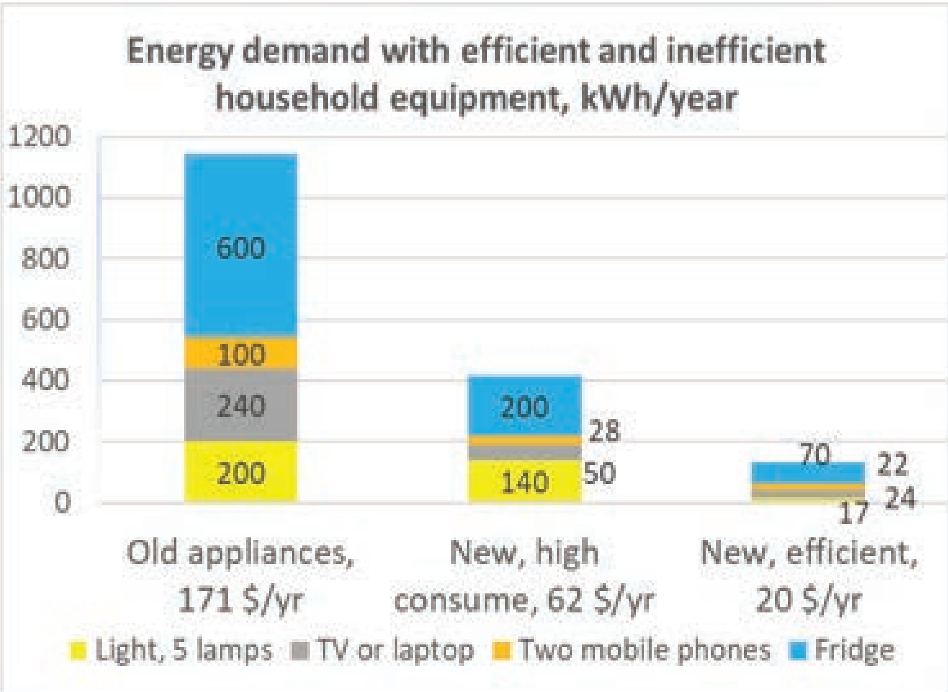
It is possible to light a house with minimal power, for instance 5 lamps for a household can together use just 17 Watt and per year 17 kWh while giving the same light as 5 incandescent lamps that use 200 Watt together and per year consume 200 kWh[17]. This saving will for instance save a household consumer in India 14 US$/year and in Uganda 35 US$/year with 2021 electricity prices[18]

The LED lamps have normal lifetimes of 15-50 years, if used 3 hours/day, opposite to incandescent lamps that have normal lifetimes of just one year. Thus, the user can benefit from them for a long time. It is also possible to have other power consumption with small energy consumption. In some countries with lifeline tariffs, where the first consumed kWh is cheaper (as South Africa, Tanzania, Uganda), it is possible to limit consumption to the cheaper power.

Energy savings or energy production

Savings with efficient lamps: The energy savings for an efficient LED that replaces a 40 Watt incandescent, used 3 hours per day is:

- Compared to a incandescent lamp it saves 92%, equal to 37 kWh/year
- Compared to a halogen lamp it saves 90% equal to 32 kWh/year
- Compared to a compact fluorescent lamp (CFL) it saves 60% equal to 5 kWh/year
- Compared to less efficient LEDs it saves 50% equal to 4 kWh/year[19]



[17] This example is based on replacing 40 watt incandescent lamps with a light of 470 lumen each with Philips MASTER Value LED bulb E27 A60 3.4W 927 matt

[18] With household electricity prices in June 2021 of 7.6 US-cent/kWh in India and 19.2 US cent/kWh i Uganda according to https://www.globalpetrolprices.com/Uganda/electricity_prices/

[19] The efficiency in light in lumen per watt of electric power are in this example: incandescent: 11.8 lm/W, halogen lamp 13.2 lm/w, CFL 53 lm/W, low efficiency LED 67 lm/W, Philips MASTER value LED 138 lm/W. All lamps in this example are available on the Danish market

Savings for a household: Hereby an example for a family with a basic set of modern electric appliances, showing how the power consumption can differ with different efficiencies of appliances.

Electricity in a household, data for above graph	Old appliances*	New, high consuming	New, efficient	
Light, 5 lamps	200	140	17	kWh/year
Fridge, 160 ltr.no freezer	600	200	70	kWh/year
TV or laptop	240	50	24	kWh/year
Two mobile phones	100	28	22	kWh/year
Total	1140	418	133	kWh/year
Costs/year	171	63	20	US$/yr @ 0.15 $/kWh

*** Including old chargers for mobile phones and laptops**

Climate effects

The climate effects are dependent on the sources of power production. In India with mainly coal power, each efficiency LED that replaces a 40 W incandescent lamp saves 34 kg CO_2/year, while in countries with a large proportion of renewable energy in power production, as Brazil and Uganda, the electricity savings reduce CO_2 emissions by 5 kg CO_2/year or less[20]. In the above example for a household, the CO_2 emissions can be reduced 120 kg/year with average electricity production in India.

Costs and time to construct

The LED lamp prices depend on the light they produce. For a LED that replaces a 40 W incandescent, the price can vary between 1 and 5 US$, depending on the shop, but also how efficient it is and the light it gives. Other appliances vary in price, but the extra price for the efficient equipment may not be much.

Lifetime

With normal use, 3 hours a day, the lifetime is normally above 15 years. Warranty for many lLED lamps is 5 years. In general, efficient appliances have the same lifetime as inefficient ones.

What policies and strategies helped the success?

Ban of incandescent lamps in several countries, including all the EU countries in Europe, has been the most important policy to drive the development.

Energy labelling of lamps has been an important policy to speed up the uptake of the most efficient types of lamps. Information campaigns can help people understand how they can save energy and how much they can save. Subsidies can help people buy new, efficient equipment,

[20] CO_2 emissions per kWh power consumed in India is around 0.93 kg according to https://www3.epa.gov/ttnchie1/conference/ei20/session5/mmittal.pdf, while in Brazil it is around 0,15 kg CO_2 according to https://link.springer.com/article/10.1007/s11356-021-14097-w. In Uganda it is lower, but it varies a lot with river flows to hydro power that determines the need for fossil fuel based power.

but it only saves electricity, if the old equipment is discarded. Lifeline tariffs can make the user's electricity savings pay better without harming the poor. Quality control is important to avoid counterfeit products and wrong labelling of products to make them appear energy efficient. Quality control is also important to ensure the long lifetime of products.

How widespread is it, where it is popular?

LED lamps are widespread all over the world, and in many countries, it is the most popular type of lamp. For energy efficient appliances, they are widely available in Europe, and in many countries around the world.

Problems and challenges

LED's can be ruined if there is an unstable power supply with periods of longer spikes with too high voltage.
The light spectrum of a LED lamp is not homogenous as it is for sunlight and for light from incandescent lamps. The best LED has a light spectrum better than 90% similar to a homogenous spectrum. This is specified with a RA number above 90. For cheaper LED, the light spectrum is less homogenous and the RA is 80 or even lower.
While state of the art LED has an efficiency of above 130 lm/W, older models have efficiencies well below 100 lm/W.

For energy efficient appliances, they are working similar to inefficient ones, no specific problems..

Example, description
A good examples of a modern LED lamp is the Philips LED Lamp (Dimmable) bulb E27 5.9 Watt, Colour 822-927 matt. It has a high efficiency of 135 lm/W, a good colour rendering with CR(RA)-number of 90, cost around 3.5 € + VAT (a cheaper version with CR number of 80 and only 110 lm/W cost around 2.2 € + VAT) .

Example:
www.lighting.philips.co.uk/consumer/p/led-lamp--dimmable-/8719514323858/specifications

1.10. Electric Two-Wheelers (Bicycles, Scooters) by TaTEDO and UCSD - INFORSE East Africa

Description of the solution

Electric bicycles (e-bike) are very similar to regular bicycles, but with an electric motor. The only significant difference in appearance is the inclusion of the electrical drive system. This includes a motor, a battery, and sometimes a display screen. It makes it much easier to bicycle, in particular uphill. E-bikes use rechargeable batteries that can travel up to 25 to 45 km/h and can drive 40-80 km between charging, depending on battery size and how much you let the motor work for you.

E-scooter and e-motorcycles are like normal scooters and motorcycles, just driven with an electric motor and a battery instead of a petrol tank . They have the same speed as petrol versions, faster acceleration and can drive 50-200 km between charging depending on battery size.

E-Scooters / E-Motorcycles

Description of the solution

E-scooters/motorcycles use electricity to run. They have rechargeable batteries to store the electric energy and propel the two-wheeler. A two-wheeler that uses only electricity to run is called the E-2-wheeler, E-scooter, or E-Motorcycle. Instead of an internal combustion engine (ICE), an e-scooter gets its power from an electric motor.

There are more riding modes such as Eco, Power, and Sport for different types of performances. The battery range differs depending on the riding mode. For example, your e-scooter will go more miles in the Eco mode than the Sport mode. However, Eco mode will restrict the speed, while Sport mode will deliver maximum speed but lower mileage. The performance of an e-scooter mainly depends upon the power (wattage) rating of the electric motor. According to the industry experts, for better performance & carrying two passengers needs at least a 200 - 250 W electric motor, but some have over 10 kW motors.

Picture: Ampere Magnus Ex, E-scooter with 2.1 kW motor, see information below

What the solution provides?

In several East African countries two-wheelers dominate the fleet. In Uganda two wheelers make up for 46 per cent of the vehicle fleet. In Kigali, Rwanda, motorcycles are more than half of all vehicles on the road. In Kenya, motorcycles are set to more than triple to five million this decade compared with 2018. Motorcycles and utility vehicles of all types are also the fastest-growing segment of the African automotive market, transition to zero emissions technology can provide considerable benefits.

Why is it successful, from a user-perspective

The first factor to become apparent when jumping on an e-motorcycle/e-scooter is the noise and vibration, or more, the lack of it, when compared with a petrol-powered equivalent which makes for a smoother and more comfortable ride. Electric motorcycles are also exceptionally simple to operate. Just power it on, twist the throttle and you're moving. With an e-motorcycle, you can reach top speeds without any shifting or other complications that come with manual transmissions on petrol motorcycles. This makes them easier to ride, especially for beginners.

Energy savings or energy production

Removing the need for fuel dramatically reduces the cost of running. Charging e-motorcycle batteries usually costs considerably less than the use of gasoline. Further to this, there are fewer additional running costs such as servicing requirements for oil changes, ignition & clutch parts that petrol-powered two wheelers need that an electric powered one doesn't. The main additional costs on top of charging are for e-scooters battery replacement. Battery lifetime typically range from 3 to 10 years with regular use of the scooter.

Expanding market

UNEP, 2021 estimated 270 million motorcycles were on the road worldwide, a number expected to swell to 400 million by 2050. Running on fossil fuels, emissions from these vehicles drive climate change and are hazardous to people. UNEP's ground-breaking Emob calculator reveals that a global shift to electric motorcycles could prevent 11 billion tons of carbon dioxide emissions, more than double the annual energy-related emissions in the United States of America. It would also save global motorcycle owners a combined US$ 350 billion by 2050, largely because electric vehicles are cheaper to fuel and maintain.

While electric motorcycles do produce CO_2 emissions in countries where the electricity is predominantly produced by fossil fuel combustion, even then electric motorcycles still produce much less CO_2 emission per mile than gasoline driven ones. They're also more environmentally friendly than electric cars because of the smaller size and lower electricity demand.

Costs

In Kenya, e-scooters and e-motorcycles range between KSh 75,000 to KSh 1,000,000 (USD 500-7,000) depending on power capacity and brand. While you'll likely find a petrol-driven motorcycle cheaper than most electric ones, electric motorcycles are more cost-effective in the long run. Over the lifetime of the vehicle, these savings can be significant. While replacing the battery is expensive, electric motorcycles have effectively less maintenance than petrol driven ones. No engine oil or filters to change, and it doesn't have parts exposed to high temperatures that may get damaged easily.

Lifetime

The average lifespan of an electric motorbike is around 8-10 years. Generally, the average lifespan of an electric motorcycle battery ranges from **3 to 10 years**, but some batteries can last even longer with proper care. Overcharging or fully de-charging the battery reduces battery lifetime considerably. While charging the motorbike, make sure to not use a cheap quality charger to prevent your battery from any short circuit. Battery chargers also play a vital role in the lifespan of electric motorbike batteries because any faultiness in the charger can destroy the battery permanently.

If you charge your motorbike battery overnight, you should go with a charger, which has an auto cut-off feature. You can use an auto voltage regulator charger, which manages the voltage irregularity giving your battery a constant and stable charging.

How widespread is it, where it is popular

The electric scooters and motorcycles market was valued at USD 2 billion globally in 2020, and it is anticipated to reach USD 3.5 billion by 2026," according to a study by Mordor Intelligence. The electric motorcycle market is seeing considerable growth due to increased interest and need for sustainable, environmentally friendly transportation coupled with favourable government initiatives. As fuel prices continue to rise, riders are also benefiting from the lower costs of using electricity than petrol fuel.

E-motorcycles/e-scooters are popular in many countries in Asia including China, India and in East African countries.

Problems and challenges

Despite the environmental benefits and cost savings, there are some obstacles which hinder the spread of electric motorcycles, including higher upfront costs than petrol driven scooters, charging times, lack of infrastructure, low awareness and understanding, and limited battery range.

While charging times are improving, it often takes at least six hours to fully charge a battery. With quick chargers and sufficient mains power, charging times can be shorter, but it still takes longer to fully charge a battery compared with filling a fuel tank.

Examples of e-scooters, e-motorcycles

Ninebot Q80c is an electric scooter that can go up to 115 km with a maximum speed of 45 km/h, price (2023) KSh 74528 (USD 513).

Ampere Magnus Ex is an electric scooter that can go up to 121 km/charge with a maximum speed of 50 mph (80 km/h), price (2023) 132,600 KSh (USD 912).

TVS X is an electric motorcycle than can go up to 140 km/charge with a maximum speed of 105 km/h, price (2023) 424,864 KSh (USD 2923).

E-Bicycles

What the solution provides?

The e-bike is one of the most environmentally friendly means of transportation. It makes you mobile in a sustainable way - flexible, emission-free, quiet and climate-friendly. E-bikes use a motor to assist the movement of the pedals, making riding the bicycle less taxing. The motor only assists when you pedal. You can ride electric bikes like a normal bicycle. The ability to ride it like a regular bike often saves riders when their bikes run out of battery power.

Photos by https://www.zigwheels.com

Norwegian researchers found electric bikes place less stress on the heart when compared to riding a regular bike. (see the paper)

Why is it successful, from a user-perspective

E-bikes are more efficient and less expensive than cars for short-to-medium-distance travel. An e-bike is often faster for urban trips, and the cost per mile is negligible compared to running a car. Importantly, cycling is non-polluting, so it is better for the environment.

You can charge your electric bicycle from a normal socket which costs pennies, unlike fuel which costs pounds.

An electric bike allows you to relax as you enjoy the natural surroundings, something you are likely to miss when driving a car because of the speed of the ride or the routes used.

Energy savings or energy production

Charging the battery is affordable. You can go 1000 miles for about USD 6. A single charge costs a few pennies. You will invest about USD 4 a month for charging, which comes to about USD50 per year for an e-bike..

Costs

The most common e-bikes in the market today range from USD 400 to USD 2000. Electric bikes are primarily expensive because they feature costly components, including a motor, controller, and rechargeable battery.

The e-bike market was valued at USD 27.22 billion in 2021, and it is expected to reach USD 54.48 billion by 2027, registering a CAGR of 12.26% during the forecast period (2022-2027).

Lifetime

On average, e-bikes last around 10 years. That number can be higher or lower depending on the type of bike and how you use it. If you are conscientious about caring for your e-bike, it can last well over a decade. However, various parts like motors and chains will need to be periodically replaced even with proper care. Batteries typically last 3-5 years, depending on use.

How widespread is it, where it is popular

E-bikes are popular in North America (United States, Canada, Rest of North America), Europe (Germany, United Kingdom, France, Italy, Rest of Europe), Asia-Pacific (China, Japan, India, South Korea, Rest of Asia-Pacific), Rest of the World (South America, Middle-East and Africa). E-scooters are gradually increasing popularity around the globe, including South Asia and several African countries.

Problems and challenges

While e-bikes are efficient in manoeuvring traffic, they cannot be used for specific situations. Because of the restricted speed limit, e-bikes can only cover a short range, similar to other bi-cycles. For this reason, they are only useful in urban settings and other places, where distances are relatively short. There are special models for rural areas. The fact that you have to charge the battery after every 20-40 miles or so means you need a place where you can easily access electricity.

You can use your electric bike to commute to work if you are living in the same town where you work. If you forget to charge your battery at home, you can charge it in the office or use the pedals.

E-bikes are made to be assisted by the driver, so you will not have a completely relaxing ride.

Bicycles need to be taken care of in order to last a long time. Apart from general upkeep such as greasing the chains, some services can be more expensive, such as replacing motors, batteries and controllers. A good charge controller is important for long battery life.

Example, description

A good example of e-bike is the Superdelite mountain which is specifically made for long off-road trips. 1,125 Wh of fully integrated power is effectively transferred to all terrains, whether you're riding up high mountains or steep trails.

All Two-wheelers

Climate and air pollution

Development of low-carbon transportation is a key element of climate action, since the transportation sector is estimated by the Intergovernmental Panel on Climate Change (IPCC) to generate 23% of global energy-related greenhouse gas emissions. By 2050 it is likely to reach one-third, when the global number of passenger cars is projected to more than double.

Consequently, promotion of public transportation and electric mobility is identified as crucial points in the combat against climate change.

E two-wheelers are invariably more eco-friendly than petrol-powered ones. This is not only a benefit for the climate. The lack of exhaust fumes and odour make for a fresh and pleasant riding experience, particularly when manoeuvring through traffic at low speeds or standing still. Electric motorcycle riders don’t emit any exhaust fumes that contribute to air pollution. Removing gasoline, oil and combustion from the equation makes electric motorcycles a much more environmentally friendly choice for riders. By using electric instead of petrol or diesel motorcycles, we not only benefit ourselves, we also benefit the community as EV's reduce our collective carbon footprint as well as noise and air pollution.

What policies and strategies helped the success?

UNEP’s Electric Mobility (eMob) Programme promotes the transition of low-income countries to zero emission vehicles. The UNEP e-Mobility programme is the only global programme that supports electric mobility for developing and transitional countries. It supports over 50 countries and cities to introduce electric buses, cars and two- and three-wheelers.

Some countries have pioneered a range of incentives to encourage e-mobility. See an overview below in the chapter on policies for two-wheelers

Scaling up the transition to electric mobility will require investments in battery charging infrastructure. In many countries, including Kenya, the electric power generation capacity is sufficient to support the charging infrastructure for e two-wheelers. However, while demand for motorcycles is high, particularly in rural areas, distribution networks are inadequate. However, this challenge may be tackled by using solar energy, setting up charging stations, and consulting boda-boda operators

1.11. Electric Three-Wheelers/Local Transport by INSEDA - INFORSE South Asia

E-Rickshaw

Description of the solution

Electric rickshaws (also known as electric tuk-tuks or e-rickshaws or toto or e-tricycles have become more popular in some cities since 2008 as an alternative to auto rickshaws and pulled rickshaws. This popularity is due to their lower fuel cost and ease of use compared to human-pulled rickshaws. They are being widely accepted as an alternative to petrol/diesel/CNG auto rickshaws. They are three-wheelers powered by an electric motor ranging from 650 to 1400 Watts. They are mostly manufactured in India and China. Battery-run rickshaws could be a low-emitter complementary transport for the low-income people, who suffer most from a lack of transport facility, if introduced in a systematic manner according to experts.

What the solution provides?

The e-rickshaws do not use petrol or diesel and use chargeable batteries instead, the travel costs are low, efficient and affordable for all sections of the society. These E-Rickshaws are more comfortable to drive when compared with the arduous task of manually pulled rickshaws. The e-rickshaws provide last mile connectivity at an affordable price. These are mostly used by travellers where other options like petrol or CNG auto-rickshaws are not viable for economic reasons.

Why is it successful, from a user-perspective?

The major growth drivers behind this tremendous growth are socio-economic and environmental benefits, along with the supportive government policy landscape:

Socio-economic benefits: The upfront cost of e-rickshaw is quite low compared to its counterpart ICE-based auto-rickshaw. The initial cost of e-rickshaw is Rs 0.6-1.1 lakh (700 - 1300 USD), whereas the cost of ICE-based auto-rickshaw Rs 1.5-3 lakh. Similarly, the running cost for an e-rickshaw is only Rs 0.4 (0,5 US cent) a kilometre as compared to Rs 2.1-2.5 a km for the ICE-based rickshaws. The maintenance issues related to e-rickshaws are less, which saves maintenance cost. E-rickshaws provide better employment opportunities to cycle-rickshaw drivers whose business is swiftly vanishing.

Supportive policy / mission / scheme: In India, continuous support has come through National Electric Mobility Mission, 2013; National Urban Livelihood Mission 2013, Pradhan Mantri Mudra Yojna, 2015; Smart City Mission, 2015; Faster Adaptation of Manufacturing of Electric Vehicles (FAME I and II), state's electric vehicle policy in the form of loans, regulatory framework and direct subsidies.

Energy savings or energy production

Average mileage of three wheelers is around 35 to 40 km per litre running on petrol or CNG which is around 25 to 30 ml of petrol per km costing around 2.1 to 2.5 Rs per km per person. The three wheelers (generally called autos) usually carry only one passenger and are not economical for short distances and therefore are not available for passengers who have to travel one or two kilometres. On the other hand, E rickshaws carry 4 to 6 passengers with the running cost of only Rs 0.4 a kilometre amounting to less than Rs. 0.1 per passenger per person.

Climate effects

E-rickshaws help mitigate air and noise pollution. At least 1,036.6 tonnes of CO_2 emissions can be mitigated a day (378,357 tonne CO_2 annually) if compressed natural gas auto are replaced by e-rickshaws.

Costs and time to construct

The initial cost of e-rickshaw is Rs 0.6-1.1 lakh (620 to 1320 USD). However, new models launched by renowned companies like Mahindra E-Alfa mini 4 seater costs Rs. 1.26 Lakhs (1514 USD) in India.

Lifetime

The life of these electric rickshaws is barely 1-1.5 years whilst batteries may need replacement every 6 months.

What policies and strategies helped the success?

More than anywhere else in India, green license plates – indicating the vehicle is powered by a rechargeable battery, not an internal combustion engine – are prominent in Delhi. To some extent, this has been enabled by the state government's concerted efforts to complement national policies that encourage adoption of EVs. India launched Faster Adoption and Manufacturing of E-Vehicle schemes in April 2015 and April 2019 to subsidise EVs, but their budgets have been under-utilized. So, with a growing ecosystem of manufacturers, the Delhi government's revised EV policy has focused on generating demand and providing subsidies, especially to borrowers looking to buy two- and three-wheelers, with a goal that one in four of all new vehicle registrations in 2024 would be for an EV.

The typical price for an electric three-wheeler from renowned companies starts around Rs 1.26 lakh (1514 USD), with more expensive models offered by automakers like Mahindra and Piaggio priced around Rs 1.7 lakh or higher. For an average driver, even the models at the bottom of the range would require him to pay around four months' earnings towards the cost of the vehicle.

For registered drivers, the Delhi government's financial incentives include a Rs 30,000 (360 USD) purchase incentive and 5% interest subvention on loans for the purchase of an e-rickshaw, and a waiver of road tax and registration fees. These drivers also receive Rs 7,500 (90 USD) for scrapping and deregistering old rickshaws with internal combustion engines to limit the number of old, polluting models on the roads and prevent informal operation of rickshaws.

How widespread is it, where it is popular?

Electric rickshaws are most popular in Asia, especially in China, India, Bangladesh and Nepal. The low-cost Chinese models were the first electric rickshaws to become popular in those countries. China, Japan, India, and European countries (Switzerland, France, Germany) have researched and developed electric tricycles for commercial transport and are attempting to capture the growing market in Asia.

Problems and challenges

Slow moving speed of e-rickshaws is a challenge outside city centres. Lack of parking space and haphazard halting on roads creates traffic jams in already congested areas such as metro stations and bus stops. Components are imported from outside as few countries produce some key components. Then the vehicles are assembled in India. These are usually non-standardised and assembled in local workshops without complying with standards. Unorganised players sell e-rickshaws. The e-rickshaws sold by the unorganised sector are of poor quality and operate on lead-acid batteries that need to be changed after every six to eight months.

The replacement cost per battery is Rs 25,000-Rs 28,000. The lead-acid batteries usually weigh close to 80 kilograms, which reduces vehicle mileage. As the battery cannot be refurbished, an e-rickshaw owner typically returns the battery to the vendor after its lifetime.

Used batteries are too often disposed of carelessly, harming the environment. The Union government discontinued subsidies for lead acid-based e-rickshaws from October 2019 in FAME I.

Example, description

Long before the Government of India announced its intention to have an all-electric fleet by 2030; three three-wheeled retrofitted battery rickshaw was taking the Indian cities by storm. In 2016, in Delhi alone, the number of electric rickshaws on the roads was over 1,00,000. India has always been home to the largest market for three wheelers and similar modes, as they provide a much needed solution for motorized mobility, which is affordable and frequently available.

Initially launched in Delhi during early 2010 with an objective to eventually phase out manual cycle rickshaws, the e-rickshaws presented themselves as an affordable and clean mode of mobility that had the immense potential of bridging the gap of first and last mile connectivity. In Delhi, these battery-fitted three-wheelers were able to provide the much needed first and last mile access to Delhi Metro, which received a mixed response; while it was welcomed by the passengers, the lack of regulation triggered concern for the authorities. The e-rickshaws were also spreading to other Indian cities such as Lucknow, Amritsar, Ahmedabad, Kochi, etc. In case of cities like Gaya and Jamshedpur, the e-rickshaws provided a para-transit solution for connecting remote villages to cities. The spread and acceptance of the electric rickshaws became inevitable. Also in Bangladesh,the electric three-wheelers have become popular for local, rural transport.

While e-rickshaws' growth was sporadic, there wasn't any clear regulatory framework for the registration of these vehicles. In wake of the exponential growth and problems such as congestion, the Government of India amended the Motor Vehicles Act (MVA) in December 2015 and defined e-rickshaws and e-carts. Following the amendment, authorities of Delhi, Gujarat, and Pondicherry came up with procedures to regularize these vehicles.

In spite of being surrounded by an array of controversies such as fatal accidents caused at unauthorized charging stations and road accidents, e-rickshaws have witnessed an unrestricted growth on Indian streets. The lack of regulation coupled with their sporadic expansion has come to symbolize the yawning cracks in the country's rigid regulatory framework that seem to create more problems than they fix. These vehicles are widely noted for carrying more than the prescribed number of passengers i.e., 4 and the components installed in the vehicle aren't verified. Agencies like ICAT and ARAI do control the approval of assembly lines and vehicle design permits; however, due to lack of control on conformity of production, sub-standard components continue to be used widely by manufacturers. Moreover, these vehicles run on batteries that in turn put extra strain on the overtaxed electricity grid. An average electric rickshaw takes up to 7-7.5 kWh of electricity, which is charged domestically or in some cases electricity is consumed through unregistered and illegal power connections. The power distribution companies incur losses of almost 20 lakhs per day in Delhi alone from illegal power connections.

1.12. Solar Dryers by INSEDA - INFORSE South Asia

Description of the solution

Solar drying is one of the most efficient and cost-effective, renewable, and sustainable technologies to conserve agricultural products. Reducing the existing high rates of global food loss and waste, including post-harvest loss, along the various production and supply chains, will play a key role in tackling the problem of food insecurity. In less developed countries, most losses mainly occur early in the value chain, especially in post-harvest handling and processing. The use of appropriate drying technologies can potentially enable small-scale producers to significantly reduce post-harvest losses, improve the quality of food, and generate income and employment opportunities.

A reduction of the moisture content prevents the risk of microorganism growth, minimizes many of the moisture-intermediated, deteriorative reactions such as enzymatic reactions, non-enzymatic browning, and oxidation of lipids and pigments, and substantially reduces weight and volume.

The open-air sun drying process greatly relies on ambient conditions and is very prone to contamination by dust, rain, wind, pests, and rodents, leading to low-quality products and a loss of farmers' income. The solar dryers are faster, more efficient, and more hygienic, resulting in lower crop losses relative to the traditional open-air sun drying. During the solar drying process, the moisture in raw agricultural materials is removed by conduction, convection, and radiation modes of heat transfers. The solar radiation passes through a transparent sheet and is retained as heat in a drying chamber or solar collector at a temperature of 30–60 °C. Thermal energy is then transferred through hot air that is led into the chamber by fans run by a solar PV panel.

Solar dryers cabinet can be made from wood, metal or bamboo. The cover can be made from net, glas or transparent polyethylene folia. The models are often equipped with a small solar-cell powered ventilator to increase efficiency. The bamboo made model has an advantage that it is lighter and inexpensive when bamboo is available (see case as example).

Solar dryers: Cabinet model from wood and glas (CRT, Nepal), cabinet from metal and glas (AIWC, India), Poly-Tunnel model from Bamboo, (INSEDA, India), and semi-industrial models (PHilMech) in the Philippines, and ESFRITA & TaTEDO in Tanzania.

There are also semi industrial models like the Philippines Center for Post-harvest Development and Mechanization (PHilMech) (www.philmech.gov.ph) modified the tunnel dryer model, which originated from the UHOH, Germany, to the Multi-Commodity Solar Tunnel Dryer

(MCSTD). This version comprises a heat collector, drying chamber, and fan/blower with a capacity of 250 kg. The heat collector and drying chamber are covered with a UV-stabilized polyethylene plastic sheet and mounted in metal frames with an inverted V shape. An axial fan with an electric motor is used to force air into the heat collector, increasing the drying air temperature to 45–60 °C.

What the solution provides?

Solar dryers are used for different crops in different countries. For example, they are commercially used for drying fish, meat, tomato, coffee, mango, medicinal plants, macadamia nuts, and rice crackers in Thailand and other countries. In India, solar dryers can be used for fruit, vegetables, medicinal plants, fish, and marine products. In China, it is used to dry corn, vegetables, fruits, and Chinese herbal medicines etc.

Why is it successful, from a user-perspective

People can earn extra income by drying some produce and selling it later. Bari and Papad (spiced dried products from certain types of pulses etc have lots of demand by Indian families) can be made and sold in the market.

The use of solar dryers enables small-scale producers to reduce post-harvest losses in a cost-effective and energy-efficient manner, improve the quality of food, and generate additional income and employment opportunities.

Energy savings or energy production

Fossil fuels and electricity are widely used as energy sources in most drying systems which results in high operational costs and environmental problems by increasing greenhouse gas (GHG) emissions. As a result, some food producers have shifted towards clean energy-based technologies such as solar and thermal energy in both direct and indirect forms (Eswara and Ramakrishnarao, 2013). Eltawil et al. (2018) suggested that the energy usage of the solar dryer could be computed using indicators such as embodied energy, time to energy payback, CO_2 emission, and carbon mitigation. Liu et al. (2015) indicate that the power consumption of the fan in the forced ventilation greenhouse dryer accounts for 5% of the total energy. The fan can be driven by local solar PV, see INFORSE-EVD Database. Solar dryer typically reduces CO_2 emissions by 1.4-3 tons per year when solar drying replaces electric or fossil-fuelled dryers.
https://www.inforse.org/doc/Pub_EVD_White_Paper_Climate_Mitigation_Adaptation_2018.pdf

Climate effects

Solar drying can also reduce climate change. If solar drying replaces commercial drying with gas, electricity, or coal, the CO_2 emissions of fossil fuel burning are avoided as often electricity is made with coal burning at power plants, which gives substantial CO_2 emissions.

With climate change, the untimely rains can destroy the harvest and therefore drying in safe condition to preserve the produce becomes necessary. In this way solar dryers are also contributing to climate adaptation.

Climate change can have negative impacts on food quality, physical availability and economic access to food. In other words, it affects nutrition and food security of vulnerable people. In this context, food dehydration technologies assist in preserving nutrition quality and improving shelf life of fruits and vegetables etc. The food thus preserved could be used during drought and flood conditions. The larger stock of food also helps adapt to volatile food prices during climate induced disasters and become a reliable source of nutritious food.

Costs and time to construct

A simple low cost family size dryer developed and promoted by INSEDA could cost INR 8000 to 9000 (US$ 100 to 113) depending upon cost of materials, size and specification of construction of the solar dryer. The dryer can be constructed in 5 days which includes arranging for materials like bamboo, UV sheets etc. The tunnel dryer with 3 trays of 2-3 m^2 each has drying capacity around 18 kg/day of fresh fruit. If it is used half the year (i.e., 180 days/year) for various fruits, replacing drying with fossil fuel, it will dry around 3 tons of fresh fruit annually.

Lifetime

Average useful working life of a low cost family size dryer developed and promoted by INSEDA is around 5 years.

How widespread is it, where it is popular

The solar dryers are successfully demonstrated in Asian countries like India, Thailand, China, Philippines, Indonesia, and are picking up in Sub Saharan Africa such as Burkina Faso, Kenya, Uganda, and DR Congo. Open sun drying is also being practised in all these countries.

Some of the benefits of solar drying of agricultural and horticultural crops, spices and herbs and medicinal plants are given below because of which solar dryer are becoming popular:

- Farmers can get some cash value for the dried products when sold during lean period as huge quantities of food items go to waste during peak production while there is no food available during lean period.
- Drying food items (raw or cooked) in the solar dryer is fast compared to open sun drying.
- Solar dried food items are hygienic as they are covered with glass or polythene sheet, the food items are not contaminated with dust insects or bird droppings.
- Drying process does not require an external source of energy.
- Problem of food items eaten by birds is eliminated.
- It requires very low repair and maintenance.
- Household solar dryers are portable so can be carried to different places when required.
- Solar dryers can be used for various income generating activities like making spices, pickels, Baries (Baries are spicy, sun-dried dumplings made of grounded pulses and spices used in many Indian dishes) etc.

What policies and strategies helped the success?

India: The key factor for the success of the solar dryer in India has been the presence of a favorable enabling policy environment. In 2010, the Jawaharlal Nehru National Solar Mission (JNSSM), also known as the National Solar Mission, was launched by the Government of India and State governments to promote solar power.
During the second phase (2014–2022), the scaling of solar energy in the country has been promoted. Under this policy, a 30% subsidy is provided for the installation of solar-energy-driven equipment. In some States, such as Tamilnadu, the subsidy for setting up solar dryers was up to 50%.

China: To support the use of solar thermal energy in the country, Ruicheng et al. (2014) and Shuiying et al. (2011) report that China will (1) establish development goals and formulate a "Renewable Energy Law"; (2) carry out research on near (2020), mid-term (2030), and long-term (2050) energy strategies for the systematic and integrated development of solar energy, which will focus on market, technologies, industry, and policies; and (3) put forward various economic incentives such as providing financial assistance through investment subsidies as well as product and consumer subsidies for the solar industry.

The Philippines: Among various agricultural products, rice is one of the major crops in the Phillipines (United Nations Development Programme (UNDP), 2018). Post-production losses of rice in the country occur mainly in handling and drying (Food and Agriculture Organization (FAO), 2017). A tunnel dryer for drying paddy rice was tested at the International Rice Research Institute (IRRI) in the Philippines in 1989 by the University of Hohenheim (UHOH) (Djokoto et al., 1989). Thereafter, the Inflatable Solar Dryer (ISD) or Solar Bubble Dryer (SBD), which is an innovative, low-cost technology, was developed at the UHOH, IRRI, and GrainPro Inc (www.grainpro.com). The Republic Act (RA) 9513 or the Renewable Energy Act of 2008 was established to accelerate exploration and the development of the country's renewable energy resources, such as biomass, solar, wind, hydro, and geothermal power, and the ocean (Philippine Institute for Development Studies (PIDS), 2017).

Situation in Africa:
Solar drying technology presents great potential as an eco-friendly method to reduce post-harvest losses in low and middle-income countries. However, the adoption of the solar dryer technologies, particularly in sub-Saharan African (SSA) countries, is facing several challenges, such as high costs compared to income levels, lack of information, technology and financing, poor institutional and legal framework, and inadequate regulations and legislation on renewable energy (Karekezi and Kithyoma, 2002; Tchanche et al., 2009). Therefore, to scale up solar drying, governments should support renewable energy policies and encourage the use of solar technologies at both individual and industrial scales; cooperatives should be created at multilateral levels, such as farmers, government bodies, private organizations, and NGOs; solar dryers should be designed based on practical experience, local climate, and economic conditions. For example, low-cost and simple dryers should be disseminated to rural areas targeting small- and micro-enterprises and households. Training of users on solar drying for each crop should be provided; and national media networks should be generated in raising awareness of dryer applications to speed up the adoption of the technology.

Burkina Faso: The utilization of a PV-driven system to run the fans for active solar dryers in Burkina Faso can provide affordable electricity and support a sustainable energy generation system. However, the system application still faces many challenges, such as theft, poor access to standards and certifications, as well as incompetent technicians for installation and maintenance (Ramde et al., 2009). On the other hand, the current costs of solar components, such as a PV-panel, solar charge controller, and a battery, are still beyond the investment capability of rural customers (Ramde et al., 2009; Bensch et al., 2018) Nevertheless, this financial issue could be resolved through a solar microcredit program that could cover 40–50% of the investment costs (Holt, 2016). In Burkina Faso, high demand for active dryers integrated with a PV-driven system has been identified to dry fruits and vegetables at both cooperative and individual levels (Nonclercq et al., 2009; Boroze et al., 2014). To ensure a successful implementation in the country, a comprehensive data mapping of the solar radiation, testing facilities, standard protocols, production of local solar components, development of an efficient drying operation, as well as a promotion of tax incentives, should be established (Ramde et al., 2009).

Kenya: For many years, projects on solar drying have been conducted under Kenyan conditions researching the application of various dryer types for different commodities such as maize or fish, e.g., Othieno (1987), Thoruwa et al. (1996), Kituu et al. (2010), and Ronoh et al. (2010). Also, combined drying techniques with an additional desiccant have been developed (Thoruwa et al., 2000).
DR Congo: A low cost and locally made greenhouse dryer has been introduced by IITA as an alternative method to improve the quantity and quality of dried products. With the application of a solar dryer, for example, the cassava community processing center, which is managed by the youth and a women's group in Katana, Eastern DR Congo, recorded a significant increase in production of high-quality cassava flour and other derived products as well as improved income.

Problems and challenges of solar dryers
There is a need for a space to keep the dryer safe during rains. It cannot usually be used during the rainy season as there are chances of developing fungus if drying is too slow. The cost and technical knowhow are also challenges associated with Solar dryers. Apart from this, there can be a challenge of creating markets for solar dried products.

Examples, description

Bamboo Solar Poly Tunnel Dryer innovated and promoted by INSEDA in India can be either made for individual households or as a community solar dryer or for commercial purpose. The dryer is made from bamboo and UV stabilized transparent polyethylene (poly) sheets for harnessing energy from the sun for drying fruits, vegetables, spices and herbs in a clean hygienic way, retaining the natural colour and taste of these items, which can be stored for a longer time. This solar poly tunnel dryer has been designed and developed by the Secretary General and Chief Executive, INSEDA, for both hilly and plain areas of the country. Its size is 1.60-meter length x 1.00-meter width x 1.00-meter height (or 5 feet Length x 3-feet width, 3-feet height). The size can be increased based on the requirement and quantity of fruits and vegetables etc., for drying. To improve its efficiency, this solar dryer has been provided with two small exhaust fans which are operated by a 10-watt solar panel during the day. The dryer is successfully used in Ranichauri, a small town in Himalayan region of Northern India.

Solar dyer examples from the database of Local Solutions in South Asia:
- Poly Tunnel Solar Dryer from bamboo by INSEDA, India: inforse.org/evd/presentation/present_solution.php?id=59
- Cabinet Solar Dyer by AIWC, India: inforse.org/evd/presentation/present_solution.php?id=135
- Cabinet solar dryer by CRT, Nepal inforse.org/evd/presentation/present_solution.php?id=104

Solar dryers in Tanzania, Uganda, and Kenya, from the catalogue of local sustainable solutions in east Africa: https://localsolutions.inforse.org/pages/Solar-drying.php