ENERGY
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Technical Guide: Clean Cooking

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Figure 1. Credit: Centre for Research in Energy and Energy Conservation (CREEC), 2022

Cooking is an activity that brings families together and has immense cultural and social significance around the world. However, the use of solid fuels such as wood and coal in traditional stoves typically results in indoor air pollution which can contribute to various health conditions such as respiratory illnesses and heart problems. Globally, indoor air pollution causes more than three million premature deaths every year, including over 200,000 deaths of children under the age of five. Women and children are disproportionately affected due to higher levels of exposure inside the home and spending significant parts of their day collecting the fuel needed to cook a meal.

In addition to health impacts, cooking with biomass can release harmful emissions that contribute to global warming and contribute to environmental degradation through the use of unsustainable biomass sources. Cooking with traditional stoves is also time-consuming and wood fuel collection can expose women and girls to security risks. Therefore, the use of clean cooking solutions represents a multi-pronged solution which has the potential to reduce negative health impacts, mitigate climate change, create livelihood opportunities, reduce the risks and drudgery of fuel collection and can lower household expenditure on fuel.

Despite tremendous efforts by public and private actors, access to clean cooking fuel and technologies has continued to be an issue in many parts of the world. Currently, approximately 2.6 billion people still rely on polluting traditional fuels and technologies to cook food. Furthermore, about 4 billion people still lack access to modern energy cooking services which are clean, efficient, convenient, safe, reliable, and affordable[1]. Providing clean cooking solutions to households is critical to achieving global climate and sustainable development goals, including SDG7 which sets the target of ensuring access to affordable, reliable, sustainable and modern energy for all.

Key challenges the sector is facing include the following three areas:

- **Supply**: The lack of a stable supply of clean, affordable, and culturally acceptable solutions is a major impediment to the adoption of clean cooking by households, particularly in rural areas and fragile settings.

[1] For more about the definition of modern energy cooking services, visit https://www.esmap.org/ESMAP_Clean_Cooking_Fund_Program_Profile#:~:text=Furthermore%2C%20about%204%20billion%20people,safe%2C%20reliable%2C%20and%20affordable.

- **Demand**: Lack of knowledge and understanding of the economic, social, and health benefits of clean cooking serve as a barrier to the adoption of clean household energy. This, coupled with the higher upfront cost of clean cooking solutions and competing priorities for taking credit, means solutions are percieved as unaffordable for many people. This can be complicated by the dynamics of household decision-making and the value that is placed on the task of preparing and cooking meals.
- **Enabling environment**: A lack of policies focused on clean cooking paired with the under-allocation of financial resources are critical challenges to facilitating the cross-sectoral collaboration needed to scale up clean cooking.

This guide provides an introduction to different cooking solutions emerging in the clean cooking sector as well as an overview of financing options for companies and end users. Finally, it is important to acknowledge that 'clean cooking' is a term often used somewhat loosely. Whilst specific definitions exist for improved, clean and modern cooking solutions, the sector, and those working in it, often use the term more broadly to encompass any of the different categories and the topic itself more generally. This guide outlines the specific definitions of clean cooking below as these are important when it comes to comparing different types of solutions and their impacts.

Improved cooking solutions

Cooking solutions are commonly called “improved” if they are more efficient, release fewer emissions or are safer than traditional cookstoves or three-stone fires. In order to be able to compare different types of improved cooking solutions, the International Organization for Standardization (ISO) has developed several publications including a standard on laboratory testing covering performance, safety, and durability (ISO 19867-1) and a technical report on voluntary performance targets for cookstoves (ISO/TR 19867-3). This technical report provides a tiered benchmarking scale to rate lab-tested cookstoves. There are five indicators covered by the targets: thermal efficiency, fine particulate matter emissions (PM2.5), carbon monoxide emissions, safety and durability. For each indicator, lab test results are rated by six tiers: Tier 0 being the lowest performing to Tier 5 the highest performing. Tier 0 typically represents the performance of open fires and the simplest cookstoves. Clean cooking solutions are generally those that can achieve Tier 4 or above on emission indicators.

In addition to lab testing, researchers have increasingly shown that real world market testing is important to understand the performance of cooking solutions. Meals are not made by solely boiling water, and so Controlled Cooking Tests, which seek to cook culturally acceptable food in a replicable, measured way, and Kitchen Performance Tests, show how ‘real world’ cooks respond to different cooking solutions. Since many of the barriers to improved cookstoves have been socio-economic, going beyond lab testing is now seen as the norm.

More recently the World Bank has produced the Multi-Tier Framework (MTF) which takes into account the context in which the stove is being used, in addition to its performance. The MTF collects and analyses data on several parameters relating to cooking solutions, including exposure, efficiency, convenience, safety, affordability, and fuel availability. Each attribute has six tiers, ranging from 0 to 5 for measuring progress. Improved cooking services refers to a household context that has met at least Tier 2 standards of the MTF across all six measurement attributes, but with at least one attribute not meeting Tier 4. These cooking solutions might include natural draft improved biomass stoves. Modern energy cooking services refers to a household context that meets the standard of Tier 4 or higher across all six attributes of the Multi-Tier Framework (MTF). These cooking solutions may include LPG, solar, electric, biogas, ethanol, and some processed biomass pellet cooking solutions.

Technology options

Challenges with traditional cooking methods include the supply of the fuel (primarily unsustainable biomass usage), inefficient combustion, health risks from smoke and other emissions released during cooking, and poor safety and quality standards. However, there is also a lack of knowledge and understanding amongst consumers of the pros and cons of improved and modern cooking solutions.

Several improved and modern cooking solutions exist which range from improving the efficiency of the current cooking process to replacing it with alternative technologies and fuels.

Biomass-based cooking solutions

Energy efficiency describes the amount of heat transferred into the pot in relation to the overall fuel used by the stove within a defined task. When burning biomass, a higher efficiency can be achieved by:

- Better combustion of the fuel by providing an insulated combustion chamber around and above the fire and/or better draw of combustion air, which leads to a better mixing of gases, flame, and air.
- Maximising the transfer of heat from the combustion of the flame and the hot gases to the cooking pot.
- Minimising loss of heat to the surroundings.

Several different designs have been developed, using wood, charcoal or briquettes, with different levels of efficiency. Increased efficiency results in less fuel being burned for the same amount of heat and hence saves the end-user money on fuel costs and reduces fuel collection. Some of these stoves are made using local artisan techniques whilst others are made in industrial factories. Examples of companies manufacturing and distributing improved biomass cookstoves include BURN, Biolite and Greenway.

Over the past decade, a number of companies have coupled manufactured biomass pellets with cleaner, more efficient, fan-driven, gasifier stoves (often through a 'tool and fuel' business model). This results in high quality combustion and such stoves have the ability to meet clean and modern cooking standards. Examples of companies distributing pellet fuels coupled with gasifier stoves include Emerging Cooking Solutions and African Clean Energy.

Biogas

Biogas is produced by the anaerobic digestion of organic materials such as manure, sewage sludge, organic waste from households, industry waste, crop residues and energy crops. It is composed mainly of methane (40-70%) and carbon dioxide (30-60%). In any digester, the organic material is mixed with water to create the right environment for bacteria to decompose it. The biogas accumulates at the top of the tank, where it is collected and taken by pipe to the user. The remaining slurry has to be removed regularly from the tank and can be used as an agricultural fertilizer.

Biogas production for domestic cooking depends on the availability of an affordable, appropriate digester at a suitable scale for domestic use as well as the availability of sufficient feedstock (organic waste). As such, they are well suited to rural households that keep livestock that produce manure that can be collected. Food waste can also be used as a feedstock on a smaller scale. Biogas digesters can be at the scale of an individual household or at community scale, with the gas distributed by pipes to individual households. They are sensitive to temperature, and in colder climates can stop working for part of the year. Biogas can also be used in institutions where food or human waste can be collected or in industries that have organic waste. When used in schools, for example, the absence of the children during school holidays can create problems and specific user factors such as these should be considered when assessing the appropriateness of the technology.

A small-scale biogas system for household use will typically consist of the following components:

- Collection space: raw, liquid, slurry, semi-solid and solid animal, human or agricultural waste.
- Anaerobic digester.
- Slurry storage.
- Gas handling: piping, gas pump or blower, gas meter, pressure regulator and condensate drain(s).
- End-use device: cooker, boiler and/or lighting equipment.

Challenges with biogas systems for household use include the upfront investment needed for the technology, and user labour for correct feeding of the system and regular removal of the slurry. There have been several examples of underperforming biogas projects in the past and the provision of adequate and regular maintenance

and aftersales services is critical to keep systems operational.

Particularly in Asian countries such as Nepal, large government-backed development programmes have supported the sector. In Africa, the African Biodigester Component (ABC) aims to build off previous programmes and support the growth and sustainability of the commercial biogas sector in five sub-Saharan African countries.

Prefabricated biogas systems with standardised components have been developed by a number of companies, some of which are testing the integration of Pay-As-You-Go (PAYGO) technologies. BBOXX, for example, piloted a project in Rwanda where it teamed up with a local biogas technology provider and applied its solar PV-based PAYGO technology to offer an affordable package to the end-user. Sistema.bio from Mexico has successfully attracted funding to expand its prefabricated biogas technology into Africa and Asia with financing plans for customers. ATEC International have integrated PAYGO technology into their 'plug and play' biodigesters sold in Cambodia.

LPG

Traditionally, LPG is distributed in metal cylinders ranging in size from 3kg to 45kg (and larger for commercial use) with upfront payments for the cylinder and the subsequent refills. In urban areas, where charcoal prices are high, cooking with LPG can be cost-competitive and even cheaper in terms of ongoing fuel costs. However, the higher upfront cost for the cylinder and cooking appliances is often a key barrier to access. To overcome this, several companies have developed models to allow households to pay for these upfront costs over time. KopaGas in Tanzania, for example, is addressing this issue through PAYG technology that it leases to its customers. These kits consist of an LPG cylinder, an LPG stove, and a proprietary smart meter that allows for prepayment of small quantities of gas. The meter collects fuel consumption and payment data, and once the credit balance is depleted, the meter locks automatically and can only be unlocked by topping up via mobile money.

Volatility in global energy markets has impacted on LPG prices in recent years, with consumers experiencing several price hikes. This price volatility and the lack of control over large regional price differentials can adversely affect adoption and sustained use of this fuel. Limited bulk storage capacity, sufficient number of cylinders and investments in distribution infrastructure have also hampered uptake. In rural areas, the availability of LPG is often a barrier to uptake and concerns around the safety of LPG also persist for some potential customers. Storage and bottling facilities, jetties, off-taking port infrastructure, adequate roads, and alternative distribution models, such as cylinder reticulation, are also needed to increase the availability of LPG. Governments have a key role to play in the uptake of LPG and several countries, such as Ghana, have developed ambitious targets and promotion programmes. Regulation, legislation and standardisation are key factors in creating an enabling environment and various institutional arrangements are needed to coordinate this and address issues of price volatility and ensuring adequate LPG imports.

Ethanol

Another fuel benefiting from companies taking a “tool and fuel” approach is ethanol. There are a number of players procuring and distributing bottled ethanol (in liquid or gel form) including Green Energy Biofuels in Nigeria, Novogaz in Haiti, and Consumers Choice Limited in Tanzania.

Ethanol can be produced from a range of renewable feedstocks, most commonly as by-products from the sugar industry, and also cassava, sorghum and maize. Availability of the fuel, particularly locally, can be a bottleneck, especially where there are other demands for ethanol such as from the transport industry. In some cases, distributors have to import ethanol fuel to ensure the availability of supply. Setting up last-mile distribution infrastructure to ensure the fuel is available at a convenient location for customers also requires investment. The company, Koko Networks, is implementing innovative solutions to bottlenecks in the supply chain of ethanol. Via automatic payment and dispensing machines, similar to financial automatic teller machines ("ATM"s), customers are able to refill their stove canister with ethanol using mobile money. Currently active in Kenya, Koko intends to spread to other countries in the region. As with LPG, governments play a key role in the uptake of ethanol fuel in terms of policy, taxation and regulation and support to develop local ethanol production industries.

Solar cookers

Solar cookers are an inexpensive way of using thermal energy from the sun to cook. Different types of solar cookers exist, including the solar box cooker which has insulated sides and bottom to retain the heat. It typically cooks food at temperatures between 90°C (194°F) and 200°C (392°F), can often accommodate multiple pots, and usually takes between one and three hours to cook various foods. Parabolic solar cookers are able to reach higher temperatures than wood fuel and perform more like a traditional stovetop. As such, they require more attention while cooking to avoid burning the food, and must be turned periodically to follow the sun depending on cooking time.

The uptake of solar cookers in households to replace the use of wood and wood-derived products for cooking has been limited. The main reasons are the fact that using a solar cooker will typically mean a change in cooking patterns, as a solar cooker works optimally during the middle of the day, which is traditionally not the time for cooking. Furthermore, not all types of food can be prepared using a solar cooker, while the co-benefits of other cooking methods, like heating the house, do not exist. There has been exploration of thermal storage for evening cooking, such as sun buckets, to overcome some of these limitations.

In institutions that habitually prepare lunches, like schools, prisons and hospitals, as well as in refugee camps, uptake has been more successful. Commercial applications of solar cookers are limited, but there are examples of solar parabolic ovens for bakeries in Lesotho and Namibia.

Electric cooking

Another approach is to use electricity for cooking (also known as e-cooking). Cooking with electricity is often perceived as unreliable, expensive, and inconvenient, but new research and advances in technology are making it an attractive and affordable option for many households. The Modern Energy Cooking Services (MECS) programme has been promoting the uptake of electric cooking as a way to bring together cooking and electrification agendas, leveraging additional investment and partnerships through this imperative.

Several different appliances exist for cooking with electricity such as kettles, electric ovens, air fryers, induction and infrared hobs, and electric pressure cookers (EPCs). EPCs in particular are highly energy efficient with the ability to cook quickly with low levels of power, making them cost effective for meals which normally require long cooking times. However, while users find their automatic controls very convenient, such appliances often require some change in cooking habits. Multiple appliances may be needed to provide all types of cooking. As with other clean cooking options, their cost is higher than traditional biomass stoves and may require end-user financing mechanisms to support uptake. In some countries, the supply of electric cooking appliances is still limited.

Electric cooking is a viable option for people with connections to national grid networks who continue to cook with biomass fuels. Electricity tariffs are well-regulated and tend to be relatively stable. Trials are being conducted to test e-cooking with mini-grids and even solar home systems. In the past, special low wattage electrical cookers have been developed for micro-hydro based mini-grids in Nepal. With the current developments in solar PV mini-grids, renewed interest has taken momentum around this technology, especially with the reduced cost of solar PV. Product suppliers include, Electrocook, Power Up and Sunspot. Pesitho, a Danish company, has developed a home cooking unit powered by solar energy that is being used in refugee camps in Uganda. A number of recent calls for proposals for electric cooking solutions, may bring more players into this market. This includes calls for electric cooking solutions in sub-Saharan Africa (Engie), for solar based induction cooking solutions for India (Energy Efficiency Services Limited) and for piloting of EPCs in Uganda (UMEME).

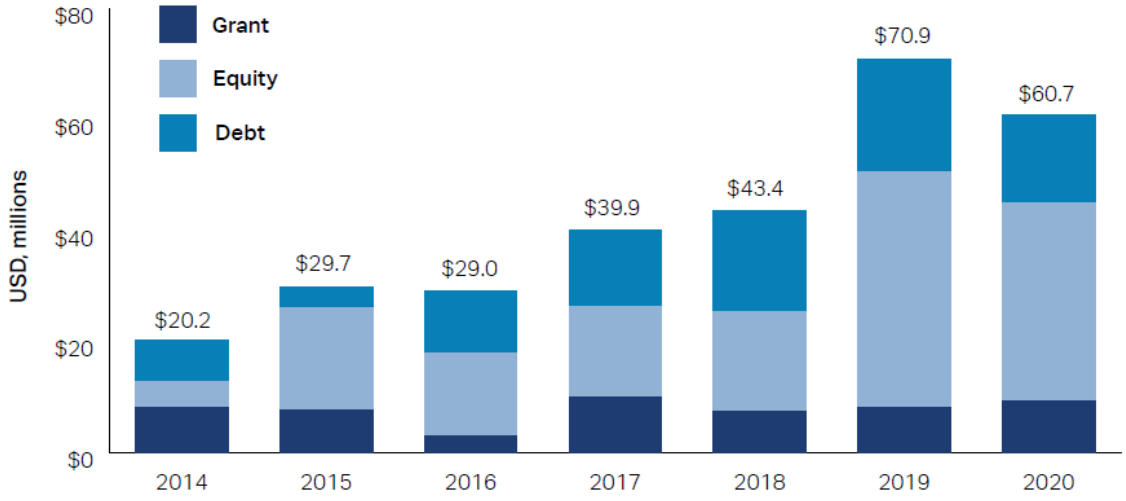
Financing clean cooking

Investment trends

According to the Clean Cooking Alliance (CCA), investment in clean cooking companies in 2020 was in the tens of millions of dollars with USD $61 million of investment into 32 companies tracked by CCA. Data shows that between 2014 and 2020, investment reaching clean cooking companies grew at a compound annual growth rate

of 20%. Nevertheless, it still falls below the USD $4.5 billion required annually for universal access by 2030 and is significantly less than the amounts invested in improving access to electricity. Investment and revenue also remain concentrated in a small number of companies: in 2020 just seven companies raised more than 90% of investment in the sector. Whilst biomass cookstoves were dominant in terms of market revenue share reported to CCA, in more recent years financing volumes have increased significantly with a much larger share being taken by Modern Energy Cooking.

Recent years have also seen increased amounts of equity investment into the sector (USD $3.3 million per company in 2020) and carbon credits playing an increasingly important role in companies' revenue. Revenue from carbon credits increased 21-fold from the USD $500,000 tracked by CCA in 2017 to over USD $11 million in 2020 and this revenue is expected to increase in the coming years. In 2022, the Africa Carbon Markets Initiative (ACMI) was launched with the aim of expanding Africa's participation in voluntary carbon markets. This includes increasing the production of African carbon credits, ensuring that carbon credit revenues are transparent and equitable, and creating jobs through carbon markets. Carbon revenue can provide additional funds to companies, can be used to lower the cost of the solution to end-users or can be shared with distributors and retailers to incentivise sales. Most importantly, carbon credits can be structured innovatively to leverage more finance into the clean and modern energy cooking sector.



Source: Clean Cooking Alliance. (N=92 for 2014–16, N=51 for 2017–19, N=63 for 2020). The data rely on self-reporting by the companies. N relates to the number of companies that answered the three Industry Snapshot surveys (2014–16, 2017–19, and 2020); not all these companies raised investment each year.

Figure 2. Capital raised by clean cooking companies tracked by CCA. Graphic taken directly from 2022 Clean Cooking Industry Snapshot, published by the Clean Cooking Alliance.

Companies in East Africa (either headquartered or with substantial operations there) in particular have seen increased interest by investors in recent years. A combination of enabling policies by East African governments, a well-established charcoal market, product category awareness and demand for clean cooking solutions as a result of past development programmes have helped to set this trend. Dependence on charcoal in urban and peri-urban areas has built demand for biomass cookstoves, and generally shaped consumer dynamics with regards to cooking fuel expenditures.

Multilateral Development Banks (MDBs) and other large Development Finance Institutions (DFIs) have tended to neglect the cooking sector in their mainstream operations, as cookstove projects did not correspond with the larger investment profiles they normally target. However, electric and other forms of modern cooking are increasingly providing an opportunity for the larger DFIs to incorporate clean cooking into their strategies. The emergence of electric cooking also brings opportunities to merge the clean cooking and electrification agenda and bring in new players such as utility and off-grid solar companies which may open up more funding opportunities and mean funding previously available to electrification can now be leveraged for clean cooking.

Several new business models have also emerged recently. In particular, enterprises selling stoves *and* associated fuels (the so-called "tool and fuel" business models) have attracted increased visibility and investment in the past several years. This category of business model benefits from enhanced consumer data, a stronger customer feedback loop, a regular revenue stream from fuel sales, and the ability to reduce the upfront cost of stoves. In the past, this model has been particularly applied to gasifier stoves bundled with biomass pellet fuel. For these companies, challenges faced may not be primarily related to the stoves, but rather to being able to demonstrate the financial viability of pellet production and distribution and having the timelines and capital required to reach sufficient scale for this.

Smart data, through which companies can remotely collect data on fuel usage and payment is also increasingly being collected by companies through PAYGO and remote monitoring technology. This is creating new opportunities for the cost-effective provision of impact funding by donors and private investors, due to the opportunity to measure and report impacts more efficiently and accurately. In October 2021, the Gold Standard approved a new methodology to quantify greenhouse gas impacts from metered cooking devices by directly measuring the amount of energy or fuel used in a project scenario.

There is a public benefit to clean cooking through the form of improved health and environmental impacts, that has typically not been articulated or recognised by many public institutions, hampering the flow of public financing. The collection of smart data on clean cooking usage is also being used to reduce the cost of company reporting and streamline impact measurements in areas such as health, gender, livelihoods and environment. This in turn can open up new funding possibilities where these impacts can be monetised through instruments such as Development Impact Bonds (DIB) and some early pilots have begun.

End-user financing

One of the challenges with improved and modern forms of cooking is their higher upfront cost to the end users, compared to traditional cooking methods, which means consumer financing can play a role in making these products more affordable. Currently two main approaches are taken:

1. Companies create inhouse payment plans that offer customers the option to pay over time. These can be through instalment payment plans or through the use of PAYGO technology which aligns payments with customer usage.
2. Companies partner with finance providers such as MFI or SACCOS who offer credit and associated payment plans for the products.

In the past, there has been a limited number of partnerships with finance providers, given that many of them view the loan size needed for clean cooking solutions as too small to justify the administrative costs and most domestic cooking solutions are non-revenue generating. However, clean cooking solutions such as biogas or institutional stoves, with a higher price tag, have seen more uptake from interested financiers. Inhouse payment plans come with challenges for the companies as they must develop their own credit processes, manage associated cashflows and divert time into credit management and follow up.

Many PAYG models rely on the ability to remotely control the operation of the stove and thereby turn the stove or fuel 'on or off' based on payments made. Examples of such models include for gasifier stoves by remotely controlling the built-in electrical fan that is essential for the proper operation of the stoves. Smart metering technology on LPG gas cylinders has also enabled this payment model because the gas can be switched on and off according to payments made. Several solar home system companies have also expanded into the provision of clean cookstoves as products added to their solar offering, maintaining the ability to turn off the solar home system based on repayment for additional products. The uptake in electric cooking also opens up opportunities for on-bill financing of e-cooking appliances through payments made to local utility companies.

Table 1: Active support programmes for clean cooking	
Programme	**Main activities**
Clean Cooking Alliance	The Alliance provides support for research, capacity building, training, entrepreneur support, in-country alliances and other initiatives that help advance and catalyse the clean cookstoves and fuels sector. This includes specific grant windows and the Cooking Industry Catalyst (CIC) which includes enterprise funding and technical assistance programmes.
EEP Africa	EEP provides grants, repayable grants and technical assistance for innovative businesses in the renewable energy sector in 15 countries in Southern and East Africa. It targets all renewable energy technologies, but has in the past supported substantial numbers of clean cooking initiatives including, BURN Manufacturing, Emerging Cooking Solutions, Inyenyeri and ACE.
Clean Cooking Fund (CCF)	A World Bank ESMAP fund that provides financial and technical support, primarily through results-based funding grants, to help countries incentivise the private sector to deliver modern cooking services. It will also establish a global platform for knowledge, innovation, and policy coordination. The first project under the fund is the Energy Access Quality Improvement Project (EAQIP) in Rwanda, which expands access to clean cooking to 500,000 households through an RBF mechanism. Other countries in the pipeline include Uganda, Burundi, Ghana, Myanmar, Niger and Mozambique.
Spark + Africa Fund	Spark + is an impact investment fund for financing clean cooking solutions in Africa with a target fund size of US$ 70 million. Spark+ will invest in early-growth stage companies with scalable business models across the value chains of LPG, ethanol, biomass, biogas, and electric appliances and fuels. It prioritizes innovative technology enabled solutions which overcome affordability barriers, enable economies of scale, and build long-term customer relationships, and maximize social and environmental impacts in doing so.
AECF	AECF are implementing the Tanzania Clean Cooking Programme a US$3.75 million three-year project that aims to catalyse the clean cooking sector through enhanced private sector participation. The project will provide matching grant financing and technical assistance to small and growing businesses working in clean cooking. AECF have also supported clean cooking companies through their Renewable Energy and Adaptation to Climate Technologies (REACT) portfolio.
MECS Challenge Funds	The MECS Challenge Fund provides early-stage research funding to stimulate innovations in modern energy cooking technology and systems and support the advancement of technology-based cooking energy products, processes and services in low- and middle-income countries. The Challenge Fund is run as a series of competitions, each with their own focus and objectives.
Modern Cooking Facility for Africa	The Modern Cooking Facility for Africa is a financing programme supporting scale-up of clean cooking solutions in six sub-Saharan African countries: Democratic Republic of the Congo, Kenya, Mozambique, Tanzania, Zambia and Zimbabwe. The aim of the programme is to provide over 3 million people in Africa with access to clean, modern and affordable cooking solutions by the end of 2027.
African Biodigester Component (ABC)	ABC is a 5-year programme, running until December 2025. The programme aims to create sustainable biodigester markets in 5 countries: Burkina Faso, Kenya, Mali, Niger and Uganda.

Industry associations

The Clean Cooking Alliance (CCA) works with a global network of partners to build an inclusive industry that makes clean cooking accessible to the three billion people without it. The Alliance's work is built around three core pillars:

- Driving consumer demand for cleaner, more modern stoves and fuels by supporting behaviour change and awareness-raising interventions.
- Mobilising investment to build a pipeline of scalable businesses capable of delivering affordable, appropriate, high-quality clean cooking products.
- Fostering an enabling environment for industry growth by advocating for effective and predictable policies, providing trusted, relevant data, and serving as the convener and champion of the clean cooking sector.

CCA have also spurred the creation of several country and regional level associations such as the Clean Cooking Association of Kenya and the West African Clean Cooking Alliance. These communities of practice provide a platform for a range of stakeholders to share information and to influence government policy.

Solar Cookers International (SCI) improves human and environmental health by supporting the expansion of effective, carbon-free solar cooking in world regions of greatest need. SCI leads through advocacy, research, and strengthening the capacity of the global solar cooking movement.

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