Unit Economics Framework and Analysis for the Clean Cooking Sector

Final Report 2024

CLEAN COOKING ALLIANCE

Acknowledgments

Report Commissioner

The Clean Cooking Alliance works with a global network of partners to build an inclusive industry that makes clean cooking accessible to the three billion people who live each day without it. Established in 2010, CCA is driving consumer demand, mobilizing investment to build a pipeline of scalable businesses, and fostering an enabling environment that allows the sector to thrive. Clean cooking transforms lives by improving health, protecting the climate and the environment, empowering women, and helping consumers save time and money. The production of this report was led by Lindsay Umalla with oversight from Feisal Hussain and review by Ronan Ferguson.

Report authors

Greencroft Economics is a boutique economic consultancy founded in 2019 to advise public and private sector clients on sustainable and inclusive socioeconomic development in emerging economies. Its core focus is on the role of access to basic services, infrastructure, and global value chains as drivers of economic activity while creating opportunities for vulnerable communities. Its work bridges the gap between economic theory and practical application to provide clients with actionable insights founded on rigorous analytics. The lead authors of this report are Ed Day (Greencroft Economics, UK), Iwona Bisaga (Independent Consultant, Rwanda), Stephen Nash (Kuungana Advisory, UK), Femi Eludoyin (Kuungana Advisory, UK).

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Cover photo: Folklore/Clean Cooking Alliance

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Abbreviations

Abbrev.	Full Description
CCA	Clean Cooking Alliance
CIF	cost, insurance, and freight
CSR	corporate social responsibility
DRC	Democratic Republic of Congo
EoS	economies of scale
EPC	electric pressure cooker
ESMAP	Energy Sector Management Assistance Program
EUEI	European Union Energy Initiative
FMO	Dutch Entrepreneurial Development Bank
FOB	free on board
GNI	gross national income
ICS	improved cookstove
IEP	integrated energy planning
ILO	International Labour Organization

Abbrev.	Full Description
ISO	International Organization for Standardization
KPIs	key performance indicators
LPG	liquefied petroleum gas
MECS	modern energy cooking services
MRV	Measurement, reporting, and verification
MTF	Multi-Tier Framework
PAYGo	pay-as-you-go
RBF	results-based finance
SDG	Sustainable Development Goals
SEforAll	Sustainable Energy for All
SSA	sub-Saharan Africa
VAT	value-added tax
VCM	voluntary carbon market
WHO	World Health Organization

Unit Economics Framework and Analysis for the Clean Cooking Sector

Executive Summary

Scope of this report

A substantial increase is needed in mobilizing public and private sector capital if all people worldwide are to gain access to clean, sustainable, and modern cooking technologies. To unlock the necessary investment capital, the value of clean cooking must be better articulated, transaction costs reduced, and participating actors across the ecosystem supported to capitalize on commercial and impact opportunities, while ensuring no one is left behind.

This report sets out the evidence on key unit economics drivers for the clean cooking sector. It explores the differences in unit economics across three illustrative clean cooking archetypes and across nine priority country contexts. It is accompanied by an interactive unit economics toolkit in Excel that helps users explore the key drivers of unit cost and revenue evolution based on a wide range of user-defined inputs.

The aim is to provide a first step toward standardization around the unit economics in the sector. Standardization is important to reduce transaction costs and frictions of assessing clean cooking ventures on a case-by-case basis — albeit acknowledging that a one-size-fits-all approach would not work given the complex range of technologies and business models in the sector.

It is the first toolkit of its kind to build in explicit relationships between key cost drivers and how unit costs evolve with scale. For example, cost drivers such as population density and infrastructure quality are modeled with assumptions on how they influence the unit cost of downstream distribution activities. This offers insights in this report on how different cost types evolve as market penetration increases and offers users of the toolkit an information base built on published third-party data.

Outcome markets are changing the nature of the clean cooking market and its key unit cost and revenue centers. Monetizing the value of noncustomer sales such as carbon credits and other outcomes such as health or gender is already causing significant changes to the unit economics across the value chain, and this trend is expected to strengthen in the coming years.

Achieving scale upstream can deliver several unit cost benefits

Upstream manufacturing offers the highest potential for improved unit economics as companies scale up. Cost efficiencies can most consistently be achieved in upscaling and standardizing production, also assuring a high and standardized quality. However, this may need to be weighed against managing the risk of downstream cost escalation, which may be avoided by localization of production closer to demand centers.

Product diversification upstream will be necessary to meet the needs of different customer segments, reflecting relatively higher and lower ability to pay. To achieve sustainable unit economics, companies will need to transition to an increasing share of products that can support a reasonable margin and deliver a rate of return to investors.

Downstream distribution faces several risks likely to degrade unit economics

In some countries there is a large potential addressable market that could sustain viable unit economics in at least some customer segments. Densely populated urban areas are likely to have pockets of customers with high enough ability to pay to support the commercial unit prices. Fuel and tool business models have the added attraction of generating repeat sales that can help cover the cost of downstream distribution infrastructure. Companies can serve these customers without needing large per unit subsidies, with the right balance of early-stage grant support and catalytic finance to overcome short-term business constraints and de-risk initial scaleup of operations.

Achieving sufficient scale to drive the economies of scale in upstream production may mean serving beyond these core markets — with a risk of downstream cost escalation. The marginal cost of downstream distribution is estimated to be up to five times as expensive in deep rural areas as in central urban locations. For many country markets, distributing clean cooking technologies beyond the first million or so currently unconnected customers is likely to drive a deterioration in downstream unit costs.

Meanwhile, ability to pay is also likely to deteriorate for the same customer segments that are expensive to serve. Remote rural households are likely to have lower disposable income, and they may also be less willing to pay where free or cheap substitutes such as firewood are available.

This increasing unit cost to serve alongside declining unit revenue potential means there are large customer segments that will not be reached by commercial business models alone. There will be a need for subsidies, either by companies cross-subsidizing using revenue generated from other customers or carbon credit sales, or by public subsidies. Probably both.

Achieving scale in rural areas will need various forms of catalytic finance. Servicing the most isolated and poorest households will require concessional finance (i.e., a significant commitment from subsidy providers), alongside mobilizing carbon revenue and other forms of outcome finance. If carbon revenue could be directed to those who would otherwise be unable to afford a clean cooking product, access to 30% of households currently lacking access clean or modern cooking solutions could be accelerated.

Consumer financing may help bridge the affordability gap by allowing customers to spread payments, but it will not be a panacea. Offering payment over time in installments or through PAYGo technologies also increases operational risk to recover payments, and it increases total cost to serve by at least 30% — a substantial increase for populations with low ability to pay.

Carbon and other outcome markets could change the nature of clean cooking unit economics

Carbon revenues could play a key role in supporting downstream costs of distribution and retail by providing repeat revenue generation from customers. For carbon markets to fulfil their potential, industrywide norms will need to be established and respected to ensure an efficient and fair use of revenue generated. One of the initiatives supporting such developments is the Responsible Carbon Finance initiative led by the Clean Cooking Alliance (CCA) and carried out through four working groups covering integrity and coherence, fair pricing and revenue sharing, additionality and complementarity, and market access and competition.[1]

[1] https://cleancooking.org/industry-development/innovative-finance/responsible-carbon-finance-working-groups/

Intended Audience

Program designers	The principal audience for this toolkit is the designers, funders, and implementers of programs seeking to catalyze clean cooking market development. The insights are intended to help identify points in the value chain that are likely to need different forms of short- and long-term concessional finance and to help provide a pathway to longer-term commercial sustainability through a structured analysis of how unit costs and unit revenue evolve over time.
Ventures	Clean cooking ventures may also find value in the tool to explore how their addressable market may evolve and to identify and describe to investors how their approach overcomes market challenges. Over time, there may also be the potential to structure anonymized data collection around a common unit economics framework, which would allow for industrywide intelligence and benchmarking to be carried out.
Financiers	For investors and lenders, this report provides information on where there is the most potential for commercial returns and how the role of outcome-based finance may be changing the fundamental unit economics of clean cooking ventures.
Partners	For other partners working in the industry, this report provides an accessible entry point to understand the core features of the clean cooking sector and the businesses operating in it.

1. Introduction

1.1. Objectives and context of this report

Overview

The objective of this study is to improve the understanding of unit economics in the clean cooking sector. Commissioned by the Clean Cooking Alliance (CCA) and carried out between September 2022 and July 2023, this report feeds into CCA's programmatic workstreams and contributes to the literature supporting program design and a broader understanding of the evolution of sector-wide and venture-level unit economics.

Better understanding unit economics is essential if clean cooking ventures are to crowd in the investment volume and type required to achieve scale. Investment will need to rise by several orders of magnitude from the record-breaking US$ 200 million in 2022 if the SDG 7 objective of affordable clean and modern energy for all is to be realized. Understanding the unit economics of different types of clean cooking businesses is essential to understanding what type of concessional finance is needed for companies to grow, when and how they can represent attractive commercial investment opportunities, and which parts of the clean cooking customer base and supply chain will need some form of subsidies. It is also a prerequisite for structuring how carbon revenue is raised and deployed, when government or development partner support will be needed, and where commercial capital can be leveraged with an expectation of a return on investment.

This report represents the first step in developing a structured framework for the unit economics across the sector. The overarching structure is important as there is a high degree of variation in both how clean cooking ventures are structured and how stakeholders across the sector consider unit economics. The analysis looks at the clean cooking sector as a whole and takes a countrywide view of how the unit economics on the demand side (unit revenue) and supply side (unit costs) may evolve with scale and increased market penetration. It proposes a degree of standardization in the structure of how unit economics can be assessed at the sector-wide level.

Given the complexity of the clean cooking technology and business model space, this report also breaks out variations in unit economics by technology and business models. With significant variation across technologies and business models, there can be no one-size-fits-all approach to assessing the unit economics at the venture level. This report seeks to disaggregate where possible how key unit economics features change across technologies and business models.

Three clean cooking company archetypes are used throughout to illustrate variations of the unit economics of different cooking businesses. To break through the complexity of the product and business model space, three illustrative archetypes are used. The wide product and business model landscape of clean cooking ventures is summarized in Section The Core Elements of Clean Cooking Unit Economics, with the three archetypes set up in Section Clean Cooking Unit Economics Archetypes. The variations in the cost and revenue structures of each archetype and across different country contexts are then explored in Sections Clean Cooking Unit Economics Archetypes through What is Needed to Drive Improved Unit Economics and Increase Flows of Finance.

The report is accompanied by a toolkit to improve information sharing and provide an accessible resource with some built-in data and analytics. The toolkit includes a range of default data that can pre-populate estimates of demand and supply curves across nine illustrative country markets for a limited number of clean cooking technology and business model combinations. It is not a detailed due diligence tool but may provide a starting point to explore how unit revenues and costs are likely to evolve in each country, with flexible input assumptions on such matters as payment modalities, cost structure, and customers' ability to pay.

Approach and sources used

First, we carried out a literature review and an initial set of key expert interviews. To frame the unit economics challenge for the clean cooking sector, we reviewed nascent but growing literature relating to the economics of clean cooking business models and held initial conversations with development partners and industry stakeholders at the Clean Cooking Forum in Ghana in October 2022.

A company survey was rolled out to clean cooking ventures, and responses were collected between December 2022 and March 2023. The survey gathered data on sales volumes of different stove and fuel technologies and business models as well as data on the breakdown of the cost structures and cost drivers behind the delivery of these units to market. Around 30 responses were received, although many were only partially complete, underlining the challenges around data availability and clarity of understanding of unit economics that will need to be addressed if transparency around the economics of clean cooking ventures is to be improved.

Secondary data is used to provide benchmarks for key cost drivers and to explore how key cost centers may differ across countries and archetypes. The data is used both to provide contextual information as processed data and to help calibrate the unit economics toolkit (see Annex 1).

To support the data collected from industry and secondary data sources, we carried out 15 semi-structured interviews with investors. These discussions explored key barriers to commercial financing and tested hypotheses around the structure of the economics framework and toolkit.

Three venture-level case studies are used to provide a practical example relating to each of the three archetypes. Given the relative paucity of detailed costing and revenue data to work with, BURN, and PowerUP, and BioMassters generously helped us complete a description of their unit economics journey to date.

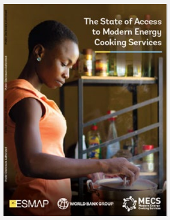
1.2. Building on the existing unit economics literature

Understanding of the core economics of clean cooking businesses is limited. A recent literature review undertaken for the FMO concluded that *"rigorous evidence on the effectiveness of different business and financing models is limited,"* with information on *"production, distribution, and marketing models ... particularly sparse"."*[2]

Nonetheless, there is a growing body of evidence on the importance of unit economics for clean cooking ventures, which this report contributes to. While there is no standardized industrywide

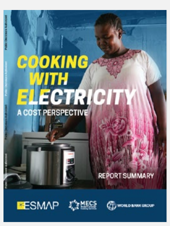
[2] FMO (2021). "Clean Cookstoves: Impact and Determinants of Adoption and Market Success." Link

approach to assessing the unit costs, unit revenue-generating potential, or overall financial structure of clean cooking ventures, a range of informative reports and toolkits released in the past few years contains useful elements of unit economic analysis. These include:

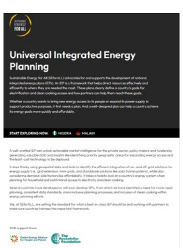


The State of Access to Modern Energy Cooking Services report (2020),[3] which, based on the analysis of data from the Multi-Tier Framework (MTF) household surveys, proposes transition pathways modeled for two 2030 universal access scenarios: access to modern cooking solutions (all households at Tiers 4 or above) and access to improved cooking solutions (households in Tiers 0 and 1 move to Tiers 2 and 3).

The ESMAP and MECS Clean Cooking Planning Tool (live tool),[4] which builds on the above report and offers a scenario-based tool to demonstrate the estimated clean cooking sector costs and public co-benefits of transitioning urban and rural populations to modern and improved cooking energy services by 2030.



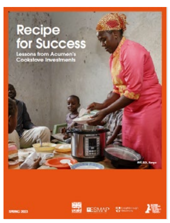
ESMAP's Cooking with Electricity: A Cost Perspective (2020),[5] which provides a series of case studies demonstrating the competitiveness of cooking with electricity in both grid and off-grid settings. The report highlights that innovative financing and delivery models will be critical in making electric cooking appliances affordable. This can be enabled by the private sector (solar companies, mini-grid operators) as well as utilities adopting the technology as part of the services they offer to customers.



SEforALL's Integrated Energy Planning Tools (IEPs), which include clean cooking modules (live tools). For example, SEforALL collaborated with the Government of Nigeria to launch an updated IEP for Nigeria, which contains an assessment of the costs of provision of different stove and fuel combinations, including a countrywide assessment of fuel usage and fuel costs for LPG, electric cooking, and biogas.[6] A similar tool has been launched in Malawi and two more tools are under development in Rwanda and in Madagascar.[7]

3 ESMAP (2020). "The State of Access to Modern Energy Cooking Services." Link
4 https://energydata.info/cleancooking/planningtool/
5 ESMAP (2020). "Cooking with Electricity: A Cost Perspective." Link
6 https://nigeria-iep.sdg7energyplanning.org/
7 https://malawi-iep.sdg7energyplanning.org/

The Clean Cooking Alliance's 'Strengthening Supply Chains' (2018) developed a market replication tool to assess economic viability of wood fuel providers.[8] The interactive tool allows users to provide detailed inputs on the drivers of fuel supply costs and revenue from a number of market segments. The investment and operating costs across the supply of feedstock, production, distribution, and retail make up the cost stack, and inputs around sales, customer retention, fuel consumption, and stove lifetimes are used to assess revenue from households, schools, and other customer groups. Company profitability is then assessed with outputs on a number of financial performance indicators.



Acumen's lessons learned from its five clean cooking investments (2023),[9] spanning the need for clean cookstove companies selling good-quality, affordable products; raising awareness of the benefits of shifting to modern energy cooking solutions; benefits of working in partnerships for last-mile distribution; the important role carbon finance has been playing in transforming the sector, making products more affordable and boosting companies' profitability prospects; and the need for committed teams with a strong moral compass given the challenges of the clean cooking sector.

The European Union Energy Initiative Partnership Dialogue Facility (EUEI PDF) Building Energy Access Markets report (2015),[10] which explored value chains for clean cookstoves as part of the development of a framework for analyzing energy market systems. The report highlights key stages of the value chain for improved biomass stoves and for LPG fuel and stove markets and the different types of business models that exist.

FMO's review of impact and determinants of success in clean cooking markets (2021),[11] which looks at what policy, market, and household characteristics affect the success of clean cooking businesses. It also provides estimates of the impact that the adoption of efficient cookstoves has on health, economic, and environmental outcomes.

[8] https://cleancooking.org/reports-and-tools/strengthening-supply-chains-a-handbook-for-cooking-fuel-enterprises/
[9] Acumen (2023). "Recipe for Success: Lessons from Acumen's Cookstove Investments." Link
[10] EUEI PDF (2015). "Building Energy Access Markets: A value chain analysis of key energy market systems." Link
[11] FMO (2021). "Clean Cookstoves: Impact and Determinants of Adoption and Market Success." Link

1.3. Structure of this report

The remainder of this report is structured as follows:

- **Section 2: The Importance of Unit Economics** explains the importance of unit economics to support growth of the clean cooking sector.
- **Section 3: The Core Elements of Clean Cooking Unit Economics** describes the diverse product and business models that serve the clean cooking market and notes the implications for unit economics analysis.
- **Section 4: Clean Cooking Unit Economics Archetypes** proposes three illustrative archetypes to represent clean cooking unit economics and presents three company case studies.
- **Section 5: Clean Cooking — Economies of Scale** maps the clean cooking value chain to potential economies and diseconomies of scale.
- **Section 6: Unit Economics — Quantitative Insights** presents quantitative insights and provides some illustrative examples of how clean cooking unit economics is likely to vary within and across archetypes in different country contexts.
- **Section 7: What is Needed to Drive Improved Unit Economics and Increase Flows of Finance** summarizes the lessons learned on unit economics from the literature and from engagement with companies and investors.
- **Section 8: Conclusion** summarizes key conclusions drawn from this review of existing literature, engagement with companies and investors, and the quantitative analysis.
- **Section 9: Setting Up a Longer-term Unit Economics Agenda** proposes priorities for an ongoing agenda of work on unit economics.

2. The Importance of Unit Economics

2.1. The need to improve the unit economics of clean cooking businesses

There are still 2.3 billion people worldwide without access to clean cooking technologies.[12] Nearly one-third of people across the globe rely on rudimentary cooking stoves and fuels, burning coal, firewood, or animal dung. Bringing clean cooking to these people is central to a modern and sustainable energy transition, as well as to poverty reduction, health, gender equality, and other elements of the sustainable development agenda.[13]

The transition to universal access to modern, clean cooking by 2030 would cost around US$ 150 billion per year.[14] This represents the cost of adoption of modern and clean cooking technologies and for the most part represents direct contributions from households purchasing clean and modern cooking tools and fuels. However, it also includes US$ 39 billion from the public sector to ensure that clean and modern cooking solutions are accessible and affordable to the poorest and US$ 11 billion from the private sector to develop the downstream infrastructure and supply chains needed to reach customers.

While financing has increased year-on-year, surpassing US$ 200 million in 2022, it still falls far short of what is needed.[15] Investment is on the rise, however still far short of the estimated US$ 4.5 billion estimated annual investment need.[16]

This investment capital is heavily concentrated in just a few clean cooking companies. In 2020, seven ventures raised more than 90% of tracked investment. Four of these companies were also present among the eight companies that received 90% of the capital raised in 2019.[17] While this is an encouraging sign that some companies are repeatedly raising investment capital successfully, it also shows the investment-raising challenge facing many other companies in the sector.

Given the breadth and complexity of the clean cooking sector, it is clear that more companies will need to attract more capital for the sector to scale. The market has a wide range of technologies and business models and given the complexity of making sure much-needed products reach end users in a range of contexts across sub-Saharan Africa and Asia, the sector will need a competitive landscape that is more diverse than a "big seven." The sector will need to ensure that the companies already successfully raising capital continue to expand and achieve long-term commercial sustainability, and that more companies are supported, especially at an early stage in their growth, to access the finance they need.

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[12] WHO Global Health Observatory (2022). "Population with Primary Reliance on Polluting Fuels and Technologies for Cooking." Link
[13] IEA (July 2023). "A Vision for Clean Cooking Access for All." Link
[14] ESMAP (2020). "The State of Access to Modern Energy Cooking Services." Link
[15] CCA (2023). "Clean Cooking Alliance 2022 Annual Report." Link
[16] SEforAll (2021). "Energizing Finance: Understanding the Landscape 2021." Link
[17] Clean Cooking Alliance (2022). "Clean Cooking Industry Snapshot — Third Edition." Link

Improving the understanding of what drives successful unit economics will be essential for clean cooking ventures to achieve profitability and attract investment at scale. Of 27 enterprises surveyed in 2020, only nine reported positive net profit numbers each of the three previous years.[18] Meanwhile, Acumen's US$ 6 million invested in clean cooking companies has borne fruit, with a multiple on invested capital (MOIC) three times as high as Acumen's portfolio average.[19] What is less clear to date is what drives more or less favorable unit economics across clean cooking technologies, business models, and market contexts. Building further evidence and tools that can provide a shared understanding of how to assess, measure, and compare unit economics across the clean cooking sector will be a key to successfully attracting investment.

2.2. Current approaches to assessing clean cooking unit economics

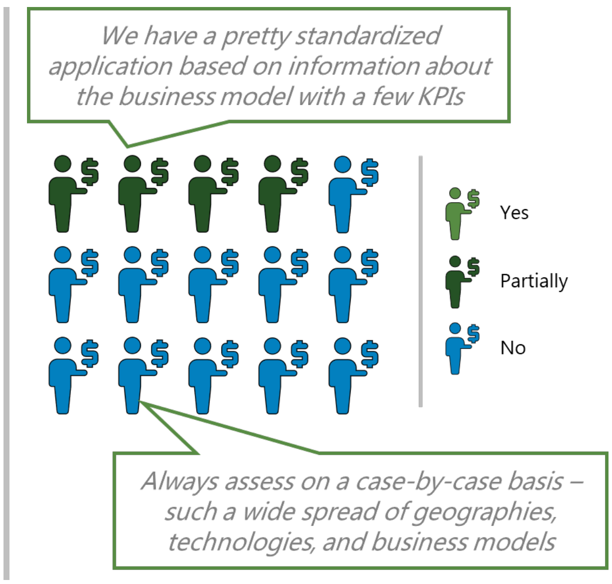
There is an absence of standardized tools to shed light on the unit economics of clean cooking ventures, reflecting the challenges of standardization but also underlining the potential value where standardization could be achieved. No financiers are operating at sufficient scale and with sufficient depth of experience in the sector to have developed sophisticated toolkits to assess potential investment opportunities. The result is that investments are assessed on a case-by-case basis, which makes transactions relatively cumbersome and expensive. On the one hand, this is reflective of the wide variety of business models (Section 3) and the difficulty of applying a single standardized lens. On the other hand, there are common types of information that almost all investors look for and where there may be opportunities for a standardized toolkit to provide initial insights without replacing the need for subsequent detailed due diligence.

Most financiers do not apply a standard unit economics or financial analysis. Of the 15 investors interviewed, none used a detailed unit economics framework and only four set out a relatively standardized approach based around a few key performance indicators (KPIs).

In practice, assessments are made on a case-by-case basis. Given the differences across technologies, business models, and country contexts, all investors evaluate the business model on its individual merits based on its own specific context, with discretion applied even where KPIs are used.

Only a few financiers have a wide enough portfolio to standardize their approach. The lack of standardization in approach is largely driven by limited experience working with clean cooking

Figure 1: Standardized way to assess clean cooking unit economics?



Source: Interviews with 15 investors

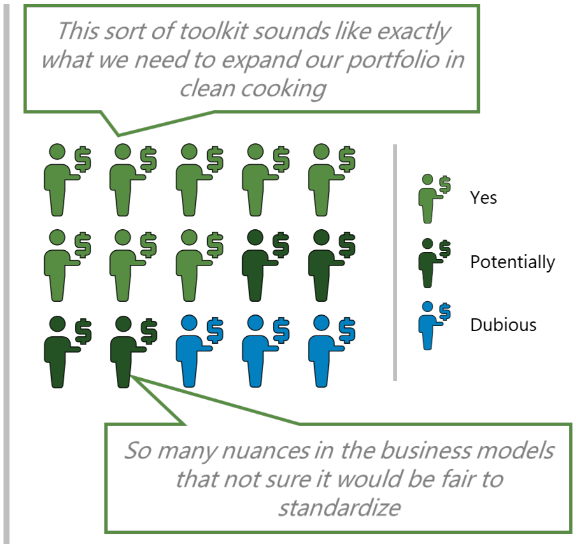
[18] ESMAP (2020). "The State of Access to Modern Energy Cooking Services." Link
[19] Acumen (2023). "Recipe for Success: Lessons from Acumen's Cookstove Investments." Link

companies and by insufficient data to attempt to benchmark companies.

There would be high value in some standardization to support unit economics assessments. Being able to quickly understand and compare businesses would be a major advantage, especially for relatively smaller investors. A standardized framework could help orient more detailed due diligence by providing an early flag to key business risks that would need to be further investigated.

There may also be factors that all financiers analyze, where a standardized approach data could help. For example, some standard metrics of addressable market could be helpful, rather than each investor doing their own analysis and potentially duplicating effort. Similarly, while the details of operating costs will vary by business, something that helps set out how and why unit costs are likely to change would be useful to compare against company business plans.

Figure 2: Would a standardized framework be helpful?



Source: Interviews with 15 investors

Key features of any such framework are flexibility to circumstances and adaptability over time. Where a company is on its growth trajectory matters, and applying a framework that reflects maturity is important for financiers and companies alike. A standardized unit economics framework would be of most value for relatively young ventures or investors that do not yet have sophisticated in-house financial and economic models.

Differences across business models make standardized unit economics challenging. A manufacturer of electric stoves and an improved cookstove and fuel provider face dissimilar challenges. Their cost and revenue structures will be significantly different, complicating direct comparisons with other businesses. Where consumer financing is provided, cost and revenue centers become more complex and challenging to compare. Even where the same metrics can be used, companies may record and report these metrics in different ways, making benchmarking difficult.

2.3. Overcoming unit economics barriers to help raise capital

Smaller companies find it particularly difficult to attract the financing they need. The shortfall of finance for early-stage growth companies and poorly targeted public finance for innovation and risk mitigation for later-stage investors has been exacerbated by limited data and knowledge, concentrated among a small number of specialized funders.[20]

Complexity can be overwhelming, and a unit economics will need to cut through this to provide pragmatic and meaningful insights. The unit economics framework and toolkit developed in this

[20] Coldrey, O., Lant, P., & Ashworth, P. (2023). "Elucidating Finance Gaps through the Clean Cooking Value Chain." Link

assignment provides a simplified framework applied to three illustrative archetypes. The toolkit itself allows users to define and calibrate their own cost and revenue parameters, but this is not necessary to provide initial analysis of unit cost evolution, revenue potential, and how the addressable market is likely to evolve as companies scale up.

Unlocking increased investment will need more than just an improved understanding of unit economics. With better understanding of unit economics, private and public finance flows can be better targeted and risk-informed. For example, improving the unit economics of clean cooking could support improved models of concessional finance to de-risk investment, more private capital channeled to climate solutions,[21] and a better understanding of the role of nature-based solutions to support the transition to clean and modern energy for cooking.[22]

[21] IEA, IRENA, UNSD, World Bank, & WHO (2023). "Tracking SDG 7: The Energy Progress Report." Link
[22] Clean Cooking Alliance (2022). "Accelerating clean cooking as a nature-based climate solution." Link

3. The Core Elements of Clean Cooking Unit Economics

3.1. Key dimensions of clean cooking unit economics

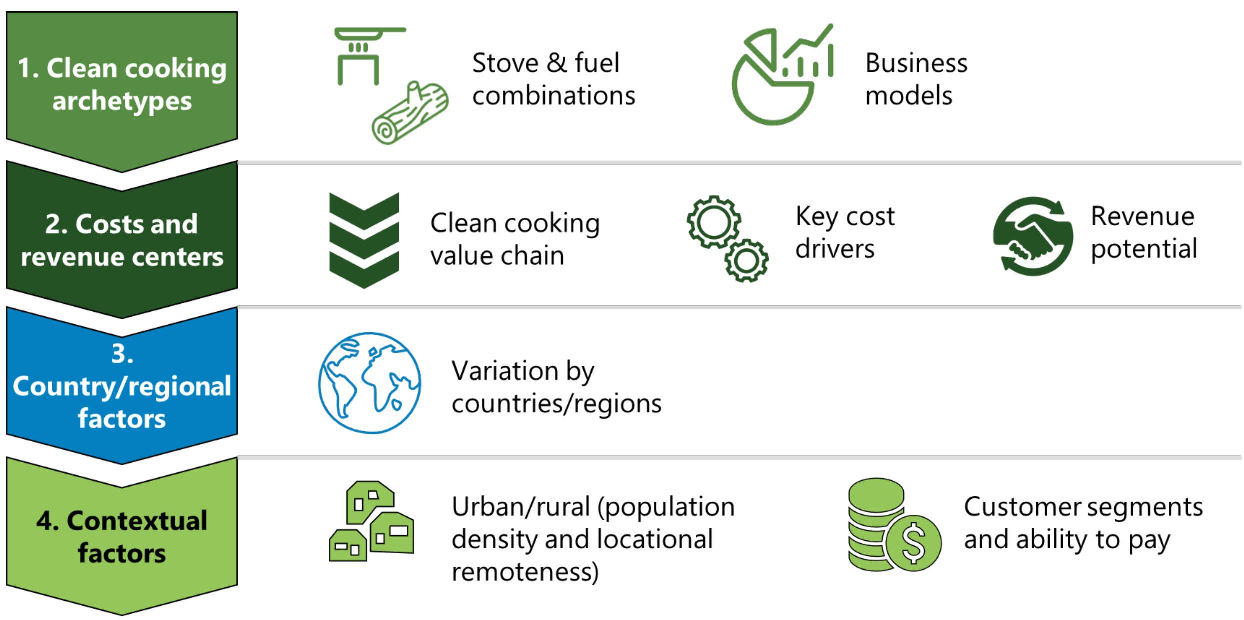
The first element of the unit economics framework is the technology. Different stoves and fuels of course come at varying cost to serve, reflected through different end user prices and different addressable markets.

Equally important is the business model used to reach customers. Whether a venture serves the full value chain from manufacturing through to end user sales and services or whether it focuses on part of that value chain will affect the type of metrics that best represents the economics of that business.

Regional and contextual factors can drive decisive variations in unit economics. Unit cost evolution can vary significantly depending on regional and contextual factors such as remoteness and population density or the ability of different target customer segments to pay.

The result is a vast and complex variation in how clean cooking businesses serve markets. As described in the subsections below, there are at least seven fuel types, over 500 stove types, several different points across the value chain where companies may operate, significantly different inter-country variation, and intra-country variation particularly across urban and rural areas. In practice, this means hundreds of different technology <> business model <> market combinations, each of which will have slightly (or highly) different unit economics.

Figure 3: Key dimensions for the unit economics framework



Source: Greencroft Economics

3.2. The clean cooking technology space

The landscape of clean cooking solutions spans improved cookstoves (ICS) through to advanced modern energy cooking solutions. At the entry level, improved cookstoves provide energy-efficient combustion of biomass fuels such as firewood and charcoal, or improved fuel technologies such as pellets or briquettes. Moving further up the energy access ladder,[23] more advanced cooking technologies include one- or two-burner stoves that use liquid or gas fuels such as kerosene, or cleaner fuels such as bioethanol, LPG, and biogas. There is also a growing market for electric cookstoves, potentially powered by solar or connected to the grid, such as hot plates or coil stoves, electric induction stoves, electric pressure cookers (EPCs), and rice cookers.

Within the ICS category, the range of stoves is very diverse, with two broad categories:

- **Fuel-efficient stoves**, such as rocket stoves, improve heat transfer and reduce fuel consumption. They are typically made from clay, brick, metal, or other locally available material.
- **Advanced combustion stoves** increase airflow to boost combustion efficiency and reduce fuel consumption and emissions. Examples are fan-powered and gasifier stoves.

This product space is vast and diverse with over 500 products registered in CCA's Clean Cooking Catalog.[24] The product space is ever evolving, and there is a great diversity in how technologies are adapted to different countries and cooking habits.

Two overarching categories of "clean" and "modern" are used across the industry, as described in the bullets below. Technologies such as EPCs, LPG, ethanol, and biogas and selected ICS stoves such as the Mimi Moto stove are "modern" according to the MTF and "clean" according to the WHO standards.

- **The World Health Organization provides a categorization of "clean" cookstoves.**[25] Cooking technologies are typically categorized as "clean" if they meet Tier 4 or Tier 5 of the ISO 19867-3 voluntary performance targets (VPT) for PM2.5 emissions, while Tier 3 is categorized as "transitional," and Tier 1 – 3 stoves as "polluting".
- **The World Bank's Multi-Tier Framework (MTF) categorizes "modern" cooking solutions.**[26] A household is considered to have access to modern energy cooking services if it scores Tier 4 or higher on all six cooking system attributes: cooking efficiency, exposure to pollutants, convenience in terms of usage and preparation time, availability of fuel when needed, safety, and affordability.

[23] https://ourworldindata.org/energy-ladder
[24] http://catalog.cleancookstoves.org/
[25] https://www.who.int/tools/clean-household-energy-solutions-toolkit/module-7-defining-clean
[26] WB Brief (September 24, 2020). "Multi-Tier Framework for Cooking: A Comprehensive Assessment Method to Measure Access to Modern Energy Cooking Services." link

3.3. Business models to reach end users

Clean cooking providers offer their customers a range of business models to buy access to goods. Some of the most common business models for the provision of clean cookstoves and fuels according to the product offering, payment modality, and sales channels are described below. Ventures may deploy multiple combinations of these, adapted to what is best suited for different product-customer market segments.

Product offering

Many cooking providers offer their customers a single product type, especially when establishing their brand. This could be companies selling only a single cookstove or a limited range of them, such as the upstream manufacturing approach of Mimi Moto or EPC providers such as PowerUP. Other companies offer several types of stove but concentrate on development of a core type of product.

The single product offering is equally, if not even more, prevalent on the fuel side. BioMassters, KOKO Networks, and Circle Gas are heavily focused on the provision of a single fuel type (biomass pellets, bioethanol, and LPG, respectively), albeit with some variants in how customers access these technologies and if stoves are offered.

A core distinguishing feature of these business models is repeat versus one-time sales. The fuel and tool business model provides a way for single-sale stoves to be deployed as part of a customer relationship that offers repeat revenue-generating potential to cover the cost of that stove alongside ongoing fuel consumption.

Alternatively, companies may offer multiple product lines. This could be multiple cooking tools or fuels, or cross-selling a range of noncooking-related goods and services such as household appliances or financial and insurance services and the like. This sort of product diversification has been a major part of the trends in the off-grid solar sector, but less so (to date) in the clean cooking sector.

Across all product offerings, customer retention is an important consideration. Companies based on repeat sales need to retain customers and ensure stove or fuel usage is at a sufficient volume to cover costs. Customer satisfaction is also important for single-product sales as it can help companies reach more customers through recommendations.[27] The potential to generate carbon revenue or other outcome-based revenue based on stove usage means retaining customers is essential,[28] while for asset finance business models customer retention is essential for continued asset repayments. Where providers are accessing results-based finance (RBF), they may also need to demonstrate ongoing usage of systems deployed. In the context of clean cooking, the concept of customer retention is complex; it means keeping customers and making repeat sales and also achieving sales volumes at a level that is sub-commercial for the clean cooking company.

Stove (and fuel) technologies that include accurate usage monitoring can support improved business information and open additional revenue streams, but they come at a cost. Digital measurement, reporting, and verification (MRV) provides valuable information on consumption patterns and

[27] CCA (2021). "Financing Growth in the Clean Cookstoves and Fuels Market: An Analysis and Recommendations." Link
[28] WB Blog (January 13, 2023). "Balancing opportunity and risk: Harnessing carbon markets to expand clean cooking." Link

preferences, which can help improve products, identify target customer segments, and enhance customer retention (see below). Digital MRV can also provide the information to underpin the sale of other outcomes such as carbon, or potentially health, gender, and others. However, these technologies add to the upfront cost of the system and to ongoing costs to run systems that analyze the data. The cost can be much higher if digital monitoring solutions are not available.[29]

By payment modality

The most straightforward payment modality is cash up-front. Cash sales are attractive for a range of reasons. For companies, they are straightforward and avoid the costs of implementing more complex payment modalities. They also are lower risk, so companies do not have to manage late or nonpayment. From the customer's perspective, the price is lower, albeit it has to be paid upfront, creating a liquidity challenge. The downside is that access to more expensive, higher-tier systems may be limited to large segments of the population because of their cost.

Alternatively, payments may be spread over time using an installment plan or PAYGo technology. These are typically used for higher-tier cooking solutions, as the cost of implementing the payment modality may be prohibitive for lower-value units. With PAYGo, customers make gradual payments as they use their system over an agreed repayment period, often with the system activated only once (e.g. digital, mobile) payment has been made. Installment-based models offer repayment plans for cookstoves over a specified period of time, regardless of usage.

Sales channel/value chain structure

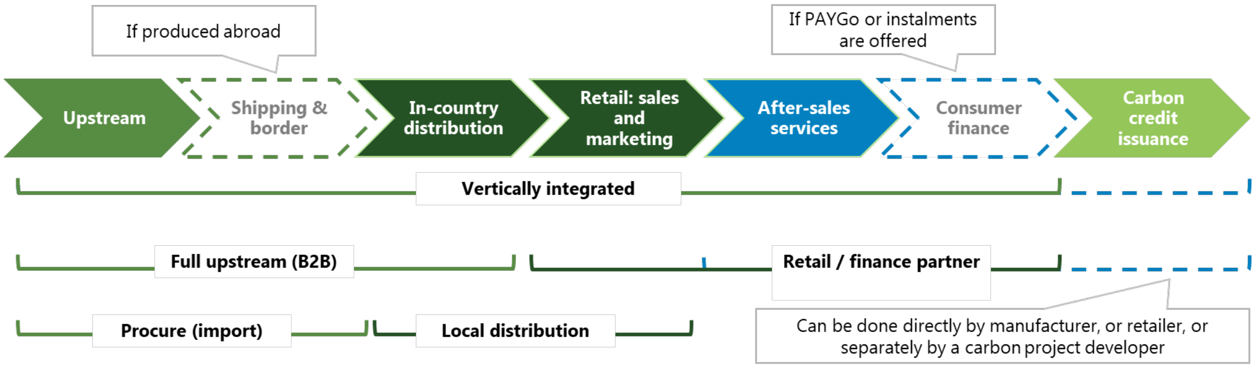
A fully vertically integrated cookstove provider goes from stove (or fuel) manufacturing (or procurement) through to the customer (B2C). Upstream there is a range of options from in-house manufacturing to procurement of components for assembly to procurement of full kits. The B2C component means servicing the full value chain through to the end user, either by retail points or a direct door-to-door customer service.

A common alternative, at least for cookstove sellers, is sales through retail partners (B2B). The cost of establishing a wide-reaching distribution network can be high, and it might not be commercially viable with a single- or limited-product offering. Partnership with dedicated last-mile distributors can be attractive where they can serve different products to different customers within their distribution radius and generate repeat sales interactions.

The business model is at least as important for how unit economics is likely to evolve as the underlying technology. Where in the value chain companies operate, and how they interact with their customers, is likely to be more determinant in driving potential economies of scale, and business risks, than the differences in technologies per se.

[29] MECS and E4I (2021). "Clean Cooking: Results-Based Financing as a Potential Scale-Up Tool for the Sector." Link

Figure 4: Overview of the clean cooking value chain



Source: Greencroft Economics

4. Clean Cooking Unit Economics Archetypes

4.1. Three representative clean cooking unit economics archetypes

To draw out key features of the unit economics of clean cooking ventures, we considered three stylized archetypes. These were selected to provide a representation of some of the most common business models in the sector and to bring out variations in the unit economics across each archetype. They are not intended to be comprehensive — other archetypes could be envisaged — nor are they mutually exclusive (i.e., elements of Archetype 3 could be combined with elements of Archetype 1). They are used as illustrative examples only.

Archetype 1: Improved cookstove production. ICS can be produced in a range of manufacturing contexts, depending on the business model.

- **Imported:** Manufactured offshore, for example, in China, often outsourced and contracted to a service provider, and then imported. An example is the Mimi Moto Tier 4 stove, designed in the Netherlands, mass manufactured in China, and distributed across sub-Saharan Africa and Asia.
- **Large-scale local:** Scalable production facilities at one or more centralized locations within the country served and local onward distribution. An example is BURN's production facilities in East Africa. BURN plans to extend manufacturing and assembly to West Africa.
- **Artisanal:** Production facilities are close to the core market, typically one or more small-scale production facilities within a geographic market. An example is the Save80 stove manufactured by ENEDOM in Rwanda and the ICS manufactured by the CEPROSOPE workshop in DRC, supported by EnDev.

Archetype 2: Modern cooking technology — asset finance. Higher-tier stoves such as electric pressure cookers or induction stoves are increasingly offered with some form of consumer asset finance to spread the cost. This can be done in one of two ways:

- Pay-as-you-go (PAYGo), with access to the system contingent on payments.
- Payment on installments, with a defined repayment plan for the asset that does not depend on its usage.

These higher-tier stoves can, of course, also be sold for cash and are commonly available in supermarkets or electrical goods outlets. Examples include ATEC in Bangladesh and Cambodia and PowerUP in East Africa.

Archetype 3: Captive fuel distribution. Some ventures service a repeat customer base by providing clean cooking fuels. This may also be done in combination with the two stove-focused archetypes above, or indeed variants on these where the stove is provided at a discount and the costs recovered through fuel sales. The defining feature of this archetype is the repeat product sale, which is typically done in one of two ways:

- **Retail points,** where fuel is distributed close to a retail outlet in proximity to demand centers and customers come to collect or refill fuel. An example is KOKO Network's retail points for bioethanol refills, or BioMassters, which sells its locally manufactured pellets through local outlets and a network of agents in Rwanda and exports them to other markets, such as Kenya and DRC.
- **Last-mile, door-to-door,** or at least scalable production facilities in a single location within a country and onward distribution nationwide. An example is Circle Gas servicing customers with LPG canister refills and replacements.

4.2. The core unit economics of each archetype

Archetype 1: Improved cookstove distribution

The upstream manufacturing of ICS is likely to generate high economies of scale. Standardization of production at scale allows for the cost per unit to reduce while maintaining a high level of quality in the production process. This is especially the case when more production is centralized — i.e., the scaling up of production at a large offsite factory is likely to generate the most economies of scale, followed by large-scale production facilities within the national or regional market where customers are based. Artisanal production located near customers is less likely to generate significant economies of scale — and indeed may have diseconomies of scale if it means setting up (and managing) multiple points of production.

This is not to necessarily say that the more manufacturing is centralized, the more cost-effective it is. The more decentralized production is, the more the business may be able to avoid other costs in other cost centers. For example, having national production can avoid some or all of shipping and border costs, while artisanal production may mean avoiding in-land distribution.

The most challenging cost center for this business model is likely to be in setting up last-mile distribution networks. For what are likely to be relatively low-price products, the cost of setting up a retail network to reach door-to-door distribution is likely to be expensive on a per-unit basis. For this reason, many ICS stove producers work through B2B sales to retail partners. However, the possibility of generating carbon revenue may be changing this approach because, as described above, this can generate the sorts of economies of scale that could make the unit economics of maintaining the last-mile customer relationship worthwhile.

An example of the economics for this type of archetype is set out in Box 1, for BURN.

Archetype 2: Modern cooking technology — asset finance

The production of higher-tier modern cooking technologies is likely to be offsite with economies of scale in production. Even more so than for ICS described in Archetype 1 above, there are likely to be substantial economies of scale in offsite production, which can be maximized by serving multiple offtake (country) markets. Products will need to be high quality and commoditized, with mass production raising precision and quality control and bearing down on unit costs.

Given offsite production, shipping and border costs will be important drivers of final end user pricing. The ability to achieve supply chain efficiencies in shipping and warehousing will depend on reaching a minimum scale, while engagement will be needed with national governments to advocate for border process and tax reductions where possible and appropriate.

The fundamental difference for Archetype 2 is the offering of PAYGo or installment-based payments. This adds the cost of hardware (and firmware/software), and also adds cost for provision of consumer finance, resulting in working capital requirements, late payment, and default risk. There may also be an increase in after-sales servicing to meet enhanced warranty requirements.

For electric cookers, the unit price of grid-tied electricity will be a major determinant of success. Electric cookers will need to be able to compete on price with alternatives such as charcoal and kerosene. Working with electricity regulators and policymakers to advocate for reduced tariffs on electric cooking, as has been done in Kenya and Uganda, may help.[30]

Carbon revenue is likely to be an essential part of this archetype. The ability to monitor usage and generate credits based on actual usage adds a not insignificant cost to the hardware, but once companies reach scale the generation of carbon revenue can be expected to largely outweigh this cost. This revenue can help incentivize usage by subsidizing the cost of electricity,[31] which in turn can incentivize users to continue to make their PAYGo or installment plan payments.

An example of the economics for this type of archetype is set out in Box 2, for PowerUP.

Archetype 3: Captive fuel distribution

Fuel distribution models are heavily dependent on managing costs in the distribution and retail cost centers. While upstream costs may still represent a significant share of the final end user price, these are less directly within the control of the provider (as they are, for example, for wholesale LPG, local feedstock for pellet production, and other expenses).

A key cost determinant will be whether companies deliver door to door or through retail networks. A blended approach will likely be needed depending on the product<>customer segment, with a distribution center combined with retail door to door, or to retail points very close to end users more feasible in high-density urban areas.

An example of the economics for this type of archetype is set out in Box 3, for BioMassters.

[30] See, for example, Electricity Regulatory Authority of Uganda December 27, 2021), "Energy Minister Launches Reviewed Electricity Tariff Structure." Link
[31] See, for example, the ATEC and MECS pilot where users "earn" as they use their electric cooking technology: Link

4.3. Summarizing the unit economics by archetype

Figure 5: Overview of unit economics differences across clean cooking archetypes

	Archetype 1: Improved cookstove distribution	Archetype 2: Modern cookstove asset finance	Archetype 3: Captive fuel distribution
Payment type	Bought cash upfront	Paid over 12–18 months	Payment on per-usage basis
Technologies (illustrative)	Biomass ICS	Electric pressure cooker	LPG
Variants	(1) Imported (2) Locally manufactured in a factory (3) Local artisanal production	(1) PAYGo (2) Carbon revenue to subsidize/remove customer repayments	(1) Distribution through local retail points (2) Last-mile distribution to point of sale
Economies of scale	High potential EoS in manufacturing. Risk of diseconomies of scale in expanding distribution to hardest-to-reach areas, possibly mitigated by B2B sales.	High EoS in manufacturing, especially if serving multiple country markets. Diseconomies of scale in distribution, possible mitigated by B2B partnerships	EoS in acquiring critical mass of customers around distribution hubs. High diseconomies of scale in low population density (nonurban) areas
Key costs/risks to manage	Cost escalation as downstream reaches further into rural areas.	No or late customer finance-related costs to escalate rapidly. Need to monitor usage and understanding customer behaviors/technology stacking.	Risk of customer churn (lack of retention) or stacking as dependent on achieving sustainable repeat sales volumes. Risk target market quickly limited by low ability to pay and high cost to serve outside core urban markets.

Source: Greencroft Economics

Box 1: BURN's unit economics journey

Company profile

BURN is a Kenya-based cookstove company with direct carbon projects in nine countries across sub-Saharan Africa and retail partnerships in many more. BURN raised US$ 37 million of carbon financing in 2022, in addition to investment over the past decade from Acumen, Yunus Social Business, and Spark+, among others.

BURN has sold over 3 million stoves and affected over 15 million lives. Since launching in 2013, BURN's production facilities have reached a capacity of 400,000 stoves per month. Access to these stoves delivers a wide range of social, environmental, and economic impacts, estimated at US$ 590 million worth of savings on fuel expenditure, saving around 8 million tonnes of wood, and avoiding 14 million tonnes of carbon dioxide emissions.[32]

BURN offers products for customers on all steps of the energy ladder. BURN caters to multiple market segments, from rural households that traditionally cook on open fires to urban business owners with grid connectivity. The product range stretches from firewood and charcoal improved cookstoves to electric pressure cookers and induction stoves.

The unit economics challenge

Establishing a strong brand and ensuring quality have been fundamental to BURN's business model. BURN's biomass stoves are independently verified as Tier 5 for thermal efficiency[33] and Tier 4 for indoor air pollution (PM2.5[34] and CO[35]). In August 2022, BURN's production facilities were awarded ISO 9001:2015 certification, a significant milestone in the development of a high-quality product meeting robust international standards.

Nonetheless, many households that most need an improved cookstove are unable to pay for it. Despite an estimated return on investment of 295% for households purchasing a US$ 40 BURN cookstove, willingness to pay is only US$ 12.[36] Introducing new product lines to serve customer segments with limited ability to pay can be challenging. At first this resulted in negative margins on sales, as prices had to be kept as low as the market could bear[37] until the brand was well established. BURN has worked with microfinance institutions and grant funding to expand access.

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32 From BURN website, accessed May 2023. https://www.burnstoves.com/
33 Both wood and charcoal stoves (CREEC 2020, 2022).
34 Charcoal stove, KIRDI 2020.
35 Wood stove, CREEC 2022.
36 Berkouwer, S., & Dean, J. (2022). http://www.susannaberkouwer.com/files/theme/BerkouwerJMP.pdf
37 Acumen (2023). "Recipe for Success: Lessons from Acumen's Cookstove Investments." Link

I used to spend US$ 1.20 to buy charcoal to cook lunch and supper with a traditional stove, but since I started using the Jikokoa, I now spend only US$ 0.40. With my Jikokoa savings, I am able to pay school fees for my child."

[Alice Wanjiku, Kiambu, Kenya]

BURN's unit economics journey

BURN manufactures in two production facilities in Nairobi. Manufacturing in Africa, close to the end market, makes the product responsive to customer feedback and shortens the logistics chain to make it more cost-effective.

Economies of scale have helped bring down cost per unit. BURN has transitioned from low volumes to a large-scale manufacturing operation. Increased volume brings efficiencies through reductions in changeovers and allows a sharpened focus on repeat manufacturing process, which are both cost-effective and high quality. Continuing to improve production processes at scale can reduce waste and deliver cost, such as reducing scrap by increasing sheet metal yield. Scale has helped secure better prices of raw materials, working with multiple input suppliers. Scale also allows for optimization of shipping and logistics.

The COVID-19 pandemic significantly affected unit economics. Transporting raw materials from Asia to Africa increased 600% year on year, and material and commodity prices rose 40%–60%. Most of those dynamics have since been reversed, with supply chain costs stabilizing around pre-pandemic levels.

The unit economics vary by country depending on the complexity of shipping and logistics. Shipping around the Cape of Good Hope from East to West Africa is expensive, and landed costs are affected by local customs and import duties. In addition, last-mile distribution to remote areas can be an expensive logistical challenge.

Carbon revenue has already been a game-changer for expanding access to BURN's stoves and enabling a focus on business-to-consumer (B2C) sales. For example, for the Kuniokoa woodstove,[38] carbon revenue has helped lower prices by 30%–80%; without that revenue, this product would likely not be able to reach market at scale.[39] The requirements for monitoring and evaluating high-integrity carbon projects also means BURN sales are increasingly B2C.

[38] https://burndesignlab.org/projects/kuniokoa
[39] Acumen (2023). "Recipe for Success: Lessons from Acumen's Cookstove Investments." Link

BURN — looking to the future

Unit economics are driven by scale of production, which is ultimately driven by the demand for stoves. BURN has secured grants and investment for capital investment that have been essential to its expansion to date. Given much of the customer base's low ability to pay, a greater global commitment to clean cooking will be needed to support investment in production and distribution and to bridge the affordability gap.

Looking ahead, BURN is launching new production facilities and new modern cooking product lines. This autumn, BURN will launch manufacturing and assembly facilities in West Africa, which will reduce shipping time and landed cost. BURN will also roll out electric cooking products stoves across six countries with high grid access and affordable electricity.

Box 2: PowerUP's unit economics journey

Company profile

PowerUP is a Uganda-based electric pressure cooker (EPC) provider, supplying electric cooking appliances with integrated digital usage monitoring. The company has been operating since 2021, focused on clean-technology product development to source appropriate products for customers in low-income contexts. Initially established in Uganda, PowerUP also supplies stoves across multiple East African markets.

The offering combines the provision of upstream manufacturing of the EPC kit and downstream digital measurement, reporting, and verification (MRV). This can enable PAYGo integration for retailers; detailed usage monitoring and customer information collection; and MRV for carbon credit generation based on actual usage.

The unit economics of EPC production and trading

Scale is essential to delivering attractive unit economics for an upstream supplier of EPCs. The gains that can be made from reaching scale in production facilities in China are substantial. Much of this stems from negotiating power in the procurement of components, and the difference between working in the low thousands of units and over 50,000 or 100,000 units is enormous. Not only does scale help bring down the factory production cost per unit, but it also helps rationalize supply chains, shipping, and inventory management. Crucially, reaching scale also means providers can leverage bargaining power to both bring costs down and ensure high quality assurance.

There is significant potential for economies of scale at this point in the value chain — almost all the cost centers related to upstream manufacturing improve with scale.

"There are no diseconomies of scale for us: materials and electronics go down in price with volume. There's also supply chain efficiency — getting to scale allows us to have more control of the cost and more negotiating power. On top of it, we can create different procedures on the manufacturing lines for efficiencies and cutting cost."

[Kato Kibuka, CEO & Co-Founder, PowerUP]

Reaching scale can also mean improvements in quality and reliability. Quality is essential for a product that has significant customization and enhancement to enable digital monitoring, data collection, and remote activation. Reaching sufficient scale in bulk orders from production lines helps drive down costs while driving up quality as more investment can be made to customize the production and testing processes.

At the other end of the product journey, there are significant economies of scale in delivering carbon credit projects. The cost of setting up a carbon credit program can be high for small providers: the cost of registration with a verified carbon crediting agency such as Gold Standard and the cost of consultant experts to lead this process. At larger scale spanning multiple geographies, it becomes more feasible to bring carbon project development in-house, which is far more cost-effective per carbon credit. PowerUP is overcoming this barrier by offering small players access to its carbon program to speed up their entry in the electric cooking space.

Carbon revenue is key to underpinning PowerUP's business model and unit economics. The carbon revenue can be used in a range of ways, such as sharing those revenue streams with retail partners or reducing the upfront price of the EPCs to retail partners. The key balance to be struck is reducing prices enough so as to generate a large enough demand among end users while not reducing too much so as not to undermine commercial sustainability.

Given the price sensitivity of the market, sharing carbon revenue is essential to reaching scale. Even though the ongoing costs of electric cooking is low, the cost of acquiring electric stoves is more than other traditional cooking technologies. Carbon revenue offers a way of reducing PowerUP's price to distributors, with a requirement that these price reductions are passed on to customers to help reach a wider customer base.

Experience in carbon markets for higher-tier cooking solutions is limited, and a broader evidence base will need to be built. For businesses relying to some extent on carbon to scale, the industry will need more information on both the volumes of credits that can reliably be taken to market and the price of credits. Then a "gain-share" arrangement including a per-unit subsidy can be calibrated that supports both commercial sustainability and reduced pricing to increase market penetration.

Grants and concessional capital will be needed to support pilots and de-risk investment. Given that this is the first time complex, usage-monitoring technologies are being deployed to generate high-integrity carbon credits, there is uncertainty about how carbon credit volumes and prices will evolve. As data flows back and companies and investors have more confidence on volume and price of credits, there can start to be more certainty for distributors and for financiers. Key metrics that will need to be tracked are:

- **Churn:** How many customers continue to use a technology after adoption?
- **Usage:** How much stove stacking is present and how frequently and for how long do customers use their modern cooking technology?

Both of these matter in terms of potential to reliably generate carbon credits and their associated revenue streams.

As PowerUP is a business-to-business (B2B) seller to distributors, retailers need to have a firm handle on the economics of serving customers. For example, border processes and taxes can drive substantial variation in end user prices. When it comes to distribution, factors like population density become a major unit cost driver. Attractive commercial markets are often urban areas or a mini-grid site, where there is a captive customer base. There is also the cost of electricity, as adoption and usage depend on being cheaper than the baseline alternative. Other factors may include quality of infrastructure access and creditworthiness if distributors are offering stoves on PAYGo terms.

PowerUP — looking to the future

PowerUP's goal is to transition 1% of African households to electric cooking in the next five years. It is still only the very early stages of scaling electric cooking products in low-income markets. More innovations will be needed in the products, business model, and carbon cycle to optimize the unit economics for better affordability. Scale has a large role to play; reaching distribution channels in multiple country markets is key to increase volume and impact. This may mean working with different distribution partners in different markets, with the essential attribute being the ability to deploy systems and manage customer relationships to ensure carbon revenue can be effectively recovered.

Box 3: BioMassters' unit economics journey

Company profile

BioMassters is a Rwandan pellet-producing clean cooking company serving more than 2,500 customers. BioMassters produces pellets in a local production facility in Rubavu, using locally sourced feedstock from wood waste. The pellets are used in Tier 4 pellet gasifier stoves, which BioMassters imports and provides for customers through sale or consumer financing options.

Pellet production and consumption reduces the unit input of wood by several orders of magnitude. In terms of unit volumes of inputs needed, 8 kilograms of wood is needed to produce 1 kg of charcoal, while just 1.5 kg of wood or sawdust is needed to produce 1 kg of pellets. As for usage, pellet gasification stoves have twice the thermal efficiency of traditional charcoal stoves, more than compensating for the difference in calorific value. So for the same cooking output, a pellet stove needs around 90% less wood than a charcoal stove.

Three BioMassters' projects digging into their unit economics

BioMassters has undertaken, with support from CCA, several unit economics studies to guide its business model development and expansion strategy.

"These very tailored feasibility studies have helped BioMassters to look at our business structure at commercial scale, the importance of pricing feedstock correctly, and the financial viability of increasing factory pellet production capacity."

[Claudia Muench, CEO & Co-Founder, BioMassters]

First, BioMassters looked into the core unit economics of the business. A three-day workshop with consultant TIL Ventures explored how the business model will need to adapt and identified risks to get to breakeven and achieve full scale of operations.

A second project investigated local biomass supply options. Working with UNIQUE, BioMassters explored local biomass supply to inform its upstream feedstock sourcing strategy. BioMassters had already partnered with the Rwandan forestry firm SEAL and as a result of the study also made plans to source from smallholder forestry cooperatives.

Finally, BioMassters' pellet production scenarios were modeled from a unit cost perspective. FutureMetrics helped undertake a financial analysis of pellet production plans and how a range of parameters and sensitivities may affect unit production costs.

Key insights from the unit economics assessments

BioMassters has doubled down on its core offering of pellet supply and split out its stove offering into a separate product line. The price of stoves and fuels, which had originally been sold as a bundle, are now itemized separately. Stoves are available either cash upfront or on a lease-to-own payment plan, and customers can now buy as much fuel as they want as long as they keep making their monthly stove repayments. This approach opens the market to different customer segments with variable usage patterns and provides more transparency regarding business unit profitability.

Through the upstream supply analysis, BioMassters has built a strategy to sustainably source local biomass. This includes a standard moisture level requirement with biomass suppliers so that seasonal weather changes do not bear on the cost paid per tonne of dry input. BioMassters has also improved its decision-making for where, when, and how to cost-effectively process raw biomass before conversion into pellets and is training local partners to improve biomass yields.

The pellet manufacturing financial modeling resulted in an increase in the price per kilogram of pellets, while in the longer term, economies of scale should bring costs down. The financial modeling reassessed short-term pricing to a level that improves margins while competing with local charcoal vendors. Over the medium term, the modeling shows a clear potential for unit cost reductions as production facilities expand. As a result, BioMassters is exploring options to expand production capacity at its current facilities or build additional production facilities or both.

BioMassters — looking to the future

BioMassters is seeking to grow its customer base and expand its reach. BioMassters already sells pellets to customers in Kenya and the DRC and is on track to reach the maximum production of 10 tonnes per day, serving approximately 10,000 customers.

Carbon credit revenue is also expected to play a significant role in driving affordability for customers and boosting the company's bottom line. BioMassters is working with FairClimateFund to develop a MECD Gold Standard carbon methodology that generates carbon credits based on usage. The credits will be sold on the voluntary carbon market, and 25% of revenue will be shared directly with end users as a reward on their mobile money account for every 100 kg of pellet fuel purchased. The revenue will also support BioMassters' product maintenance for customers and will help bring down financing costs for stoves paid over time.

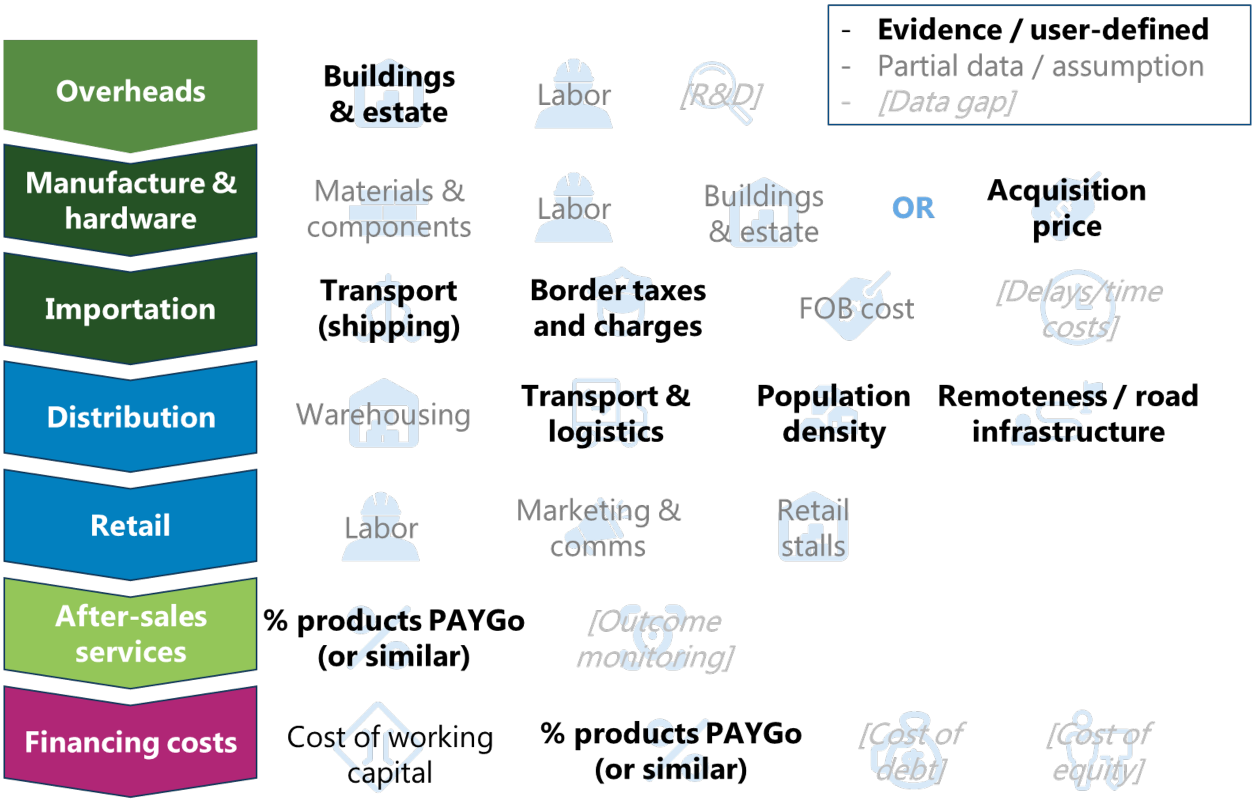
All of this raises exciting potential and plans for expansion in the future. Around 93% of the Rwandan population still cooks with traditional biomass, including more than half a million urban households. BioMassters is pressing forward to plan pellet factories in different parts of the country so that feedstock can be sourced locally and the final product sold locally, creating green jobs and contributing to the circular economy.

5. Clean Cooking — Economies of Scale

5.1. Cost and revenue centers

The unit cost analysis is structured around the key steps in the clean cooking value chain. The cost per unit is estimated from the bottom up, based on an estimated allocation of costs to each cost center and the relationship between each cost center and key cost drivers (Figure 6). The functional form between the cost drivers and the cost centers and the relative importance of different cost centers vary across different archetypes and country contexts.

Figure 6: Clean cooking unit economics framework — cost centers and cost drivers



Source: Greencroft Economics

5.2. Economies and diseconomies of scale in the clean cooking value chain

The core feature of unit economics is how costs are likely to evolve as sales volumes increase. There will be fixed and semi-fixed capital costs associated with establishing and rolling out a new business, plus fixed overhead costs. As sales increase, the importance of these cost lines will typically decline. Other cost centers will increase in importance the deeper the market is penetrated.

Overheads and upstream capital and fixed costs are cost centers where economies of scale may typically be expected — at least initially. The cost of setting up a company requires a significant effort in product (and service) development, research and innovation, and pilots. These costs then do not increase as sales volumes increase, so the larger unit volume reached, the more these initial fixed costs can be spread. For upstream production, particularly of stoves, the higher the production volume the greater the possibility for supply chain efficiencies and standardization of manufacturing at high volumes, which is likely to drive the cost per unit down.

Even overheads and upstream may eventually hit an inflexion point and see diseconomies of scale. This happens in mature industries where marginal costs (i.e., the cost for each additional unit) start to rise, as increasing production means adding less efficient production units or extra layers of quality control and management. Clean cooking companies are unlikely to be reaching this sort of scale to encounter diseconomies of scale in the near term.

Shipping and border processes will benefit from some, but relatively limited, economies of scale. As volumes increase, larger containers can be used and filled and supply chain logistics optimized. However, these are likely to be relatively small, as to a large extent shipping, and even more so border costs such as import duties, are variable and will increase proportionately with unit volumes.

Increasing distribution within an existing network may deliver economies of scale, while expanding to new locations is likely to encounter diseconomies of scale. Around an existing warehouse, the more customers that can be serviced, the lower the unit cost — i.e., the higher the economies of scale. For distribution to a core urban customer segment, the more customers acquired, the lower the unit cost. However, the rollout of the distribution network to new areas is likely to become increasingly expensive and give rise to diseconomies of scale, especially as companies are likely to first serve the customers who require the lowest cost to reach.

Retail and sales are likely to generate economies of scale initially, then diseconomies of scale. The initial costs of customer acquisition and marketing are fixed or semi-fixed in the sense that they rely on gaining a critical mass of clients and achieving brand awareness. The unit cost initially decreases as a company scales. However, this reaches an inflexion point when acquiring customers in more remote regions, which need increased effort on awareness and sensitization.

After-sales services are likely to scale roughly proportionately to customers served. They may share the scaling attributes described for retail, although this will also depend on the approach; for example, if customers bring products for repairs versus products are collected, repaired, and returned. It is also worth noting that the period immediately following customer acquisition is critical for longer-term customer retention, so the costs in the first few months of the customer journey are likely to be relatively higher cost than in subsequent months.

Putting in place a carbon credit project is likely to have high economies of scale. The initial cost may be high — requiring either recruitment of a dedicated team to run this process, or the use of specialist consultants. For smaller companies, the best route to carbon markets may be through carbon project developers, which also comes at a cost. However, as companies scale, it becomes increasingly viable to bring the carbon project in-house or indeed to continue to use external project developers but with a larger “gain share” negotiated. To a large extent the costs of putting in place a carbon program are fixed, with almost no variable costs as scale increases. So the larger the units involved, the lower the cost per unit that sits in this cost center.

Figure 7: Potential for economies of scale across the clean cooking value chain

High economies of scale | Low economies of scale | High diseconomies of scale | Low diseconomies of scale

Overheads		Mostly fixed and semi-fixed costs, which can be spread over larger unit volumes. Some management increases with scale.
Upstream		High EoS once scaleup to high 10,000s. Production can be both cheaper and higher quality when negotiating sufficient volume at production facilities and can generate supply chain efficiencies. Small risk of diseconomies of scale once expanding beyond a certain size, as facilities may become less cost-effective than the first (optimal) site(s) selected.
Shipping & border processes		Some EoS in bulk transportation, such as by filling containers and negotiating bulk transport deals. But EoS flattens quickly and has limited overall impact on total unit costs.
In-land distribution		Initial EoS in core distribution market, as the larger the customer base around a distribution network, the more units these costs can be spread over. However, rapidly rising costs are incurred if extending to new geographies in settings that are hard to reach.
Retail (sales and marketing)		High EoS for initial brand establishment, followed by diseconomies as cost of active sales to more remote customers rise. Some companies have invested heavily in establishing brand presence early on and, once established, reduced these costs to drive positive unit economics.
After-sales services		In general, after-sales services will need to scale up to match sales volumes. There may be some economies of scale through efficient workforce management, but they are unlikely to be significant.
Consumer financing costs		Providing consumer finance is a relatively high-touch engagement for all new customers onboarded. Where digital technologies are deployed, this could represent a high upfront cost that can then be spread over additional units sold. However, even where this happens, scaling up to serve more customers typically means serving less creditworthy customers, increasing risk and therefore costs.

Carbon credit accreditation and projects		High economies of scale cost center. The cost of putting in place a carbon crediting program is high, but then very low marginal cost for additional credits is generated. There are also costs added to stove and fuel technologies that can be significant, although these decline with unit volume as per upstream above.

Source: Greencroft Economics

5.3. Introducing the clean cooking unit economics toolkit

The unit economics toolkit has been developed to provide insights on the unit economics of clean cooking ventures. It is illustrative and presents some of the key drivers in the unit economics within archetypes, across contexts, and across the three archetypes. It estimates how costs across the value chain may evolve as companies scale. Building on the insights on economies and diseconomies of scale presented in Section 5.2 and the variation across the three clean cooking archetypes introduced in Section Clean Cooking Unit Economics Archetypes, the toolkit presents the key differences in the unit cost structure and unit revenue generation across the three archetypes.

Secondary data is used generously throughout. While the clean cooking sector is still relatively young, there is very limited data from within the industry itself that can be used to calibrate unit economics analysis. To bridge this data shortcoming, secondary data sources are used throughout this section, for example, to present summary statistics on key cost drivers such as population density and infrastructure quality and to posit an illustrative functional relationship between these cost drivers and their impact on unit economics.

Cross-country variation is presented to show differences within archetypes. Nine priority countries were selected and tracked throughout to illustrate the importance of regional and contextual factors: Democratic Republic of Congo (DRC), Ethiopia, Kenya, Malawi, Nigeria, Rwanda, Tanzania, Uganda, and Zambia.

Toolkit caveats and limitations

The toolkit has been developed as a user input-based analytical tool. Based on a few user inputs, it calculates a few standardized outputs to help understand the possible evolution of costs, based on the business attributes selected, and the potential of different sources of revenue to contribute to recovery of these costs.

It is not a predictive tool and is not intended to replace company-specific models and plans. It does not use any company data directly. This is both to preserve the confidentiality of information provided by industry players and to recognize that each company will approach its offering in a different way. The tool should not be interpreted as predicting the costs of any particular business, but rather to highlight likely drivers of unit cost decreases or increases as well as the gap between costs and revenue and how this gap may evolve over time.

Unit costs presented are full commercial prices, excluding corporate finance. The costs, and end user prices, presented do not account for grant financing anywhere in the value chain. They represent a “what if” scenario where companies deliver products at cost, with no subsidy and no concessional finance. This means the prices discussed are likely to be significantly higher than what is observed on the market, where a significant volume of grant finance is embedded in end user prices. At the same time, they do not explicitly build in corporate finance and a return to equity shareholders or lenders, nor profits that can be reinvested to further grow the business.

6. Unit Economics — Quantitative Insights

6.1. Clean cooking unit economics across archetypes

Archetype 1: Improved cookstove distribution: cash sales

The following assumptions are used to provide an illustrative worked example:

- An FOB cost of US$ 30 per stove.
- Selling 50,000 stoves annually in a densely populated urban region of Kenya.
- All sales are cash-based.
- Stove lifetime?

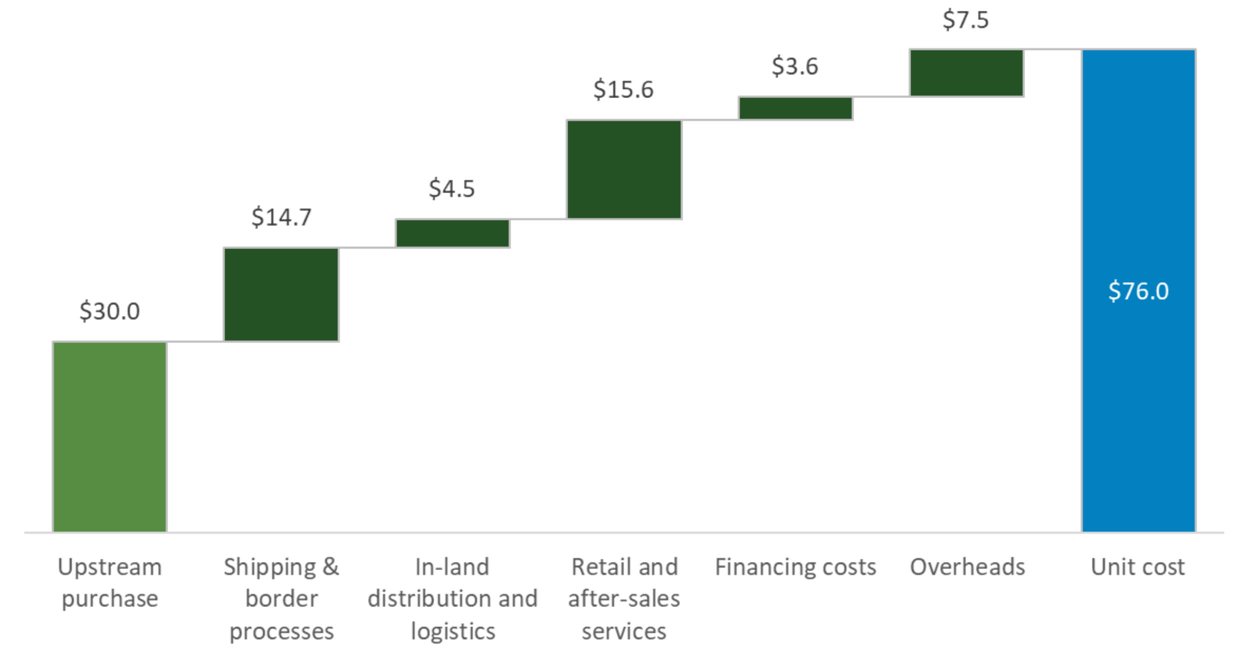
A fully vertical integrated B2C model could raise the total cost to serve from US$ 30 pre-import to US$ 76. Retail and after-sales services add the largest cost for this business model, with the focus on B2C sales. The cost of in-land distribution and logistics is small as this illustration assumes urban sales. How this cost changes with increasing rural sales is explored in Sections 6.2 and 6.3.

Localization may help avoid the costs sitting in the middle parts of the value chain, which represent almost 50% of unit costs. One of the key trade-offs for ICS is the decision to import products, mass produce and distribute nationally, or produce on a small scale near offtake markets. As shown in Section 3.1, there is a significant concentration in costs across the downstream distribution parts of the value chain. Local mass production would avoid costs associated with shipping and border processes, while local, unmechanized (e.g., artisanal) production may also avoid a significant part of the distribution- and retail-related costs.

However, the benefits of localization need to be weighed against the efficiency and economies of scale of offsite production. Economies of scale start to show up at production of over 100,000 stoves per year, and this can be a major contributor to bringing down the upstream costs. Furthermore, production offsite may mean more access to cheaper inputs and materials than fully localized production can achieve. Especially for businesses with a high growth prospect and potential to deploy units across multiple geographic markets, the benefits of centralized production may outweigh the savings achieved from localized production near to end consumers.

One of the keys to unlocking this business model is the ability of usage monitoring technologies to offer PAYGo functionality and to access carbon revenue. Spreading payments through PAYGo or other asset or consumer finance structures can help open up a larger customer base. Usage monitoring may also mean companies can generate high-integrity carbon credits, which can command a good and stable price on voluntary carbon markets. However, it should be noted that usage monitoring adds an upfront cost to each unit (stove) and ongoing servicing, maintenance, and analysis costs to collect and interpret the data.

Figure 8: Cost breakdown for biomass stove distributor (US$)



Source: Clean cooking unit economics toolkit

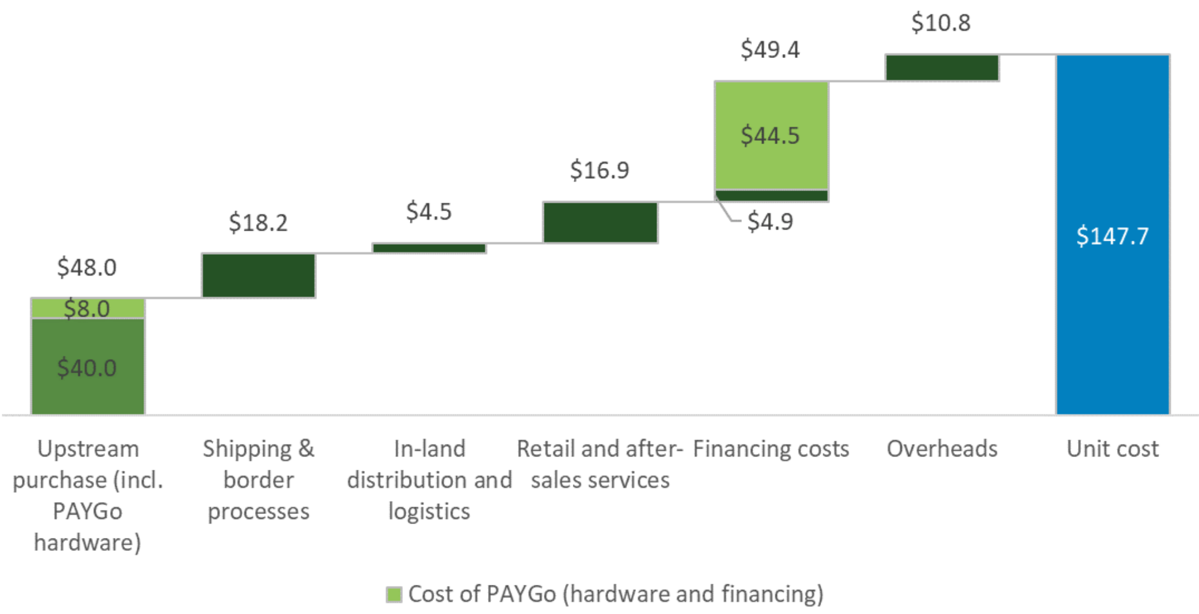
Archetype 2: Modern cooking technology — asset finance

The following assumptions are used as an illustrative example:

- An FOB cost of US$ 40 per stove.
- All sales are PAYGo, with an upfront payment of 20% with the remainder reimbursed over 18 months.
- 10% write-offs and 30% late repayment (average 12 months' delay), and a 30% cost of working capital.
- Selling 50,000 stoves annually in a densely populated urban region of Kenya.
- Stove lifetime? Stove recollection rates?

The cost of financing receivables adds US$ 45, a significant wedge amounting to 30% of the price. The full vertical service provision of an EPC stove, including B2C distribution, after-sales services, and consumer finance, raises the cost per unit to US$ 148, compared to US$ 98 with payment upfront. It is nonetheless worth noting that servicing a full B2C value chain in this way is likely to result in a much higher cost per unit than would be achieved through, for example, stocking stoves in supermarkets or other retail outlets.

Figure 9: Impact of PAYGo on EPC stove cost (US$)



Source: Clean cooking unit economics toolkit

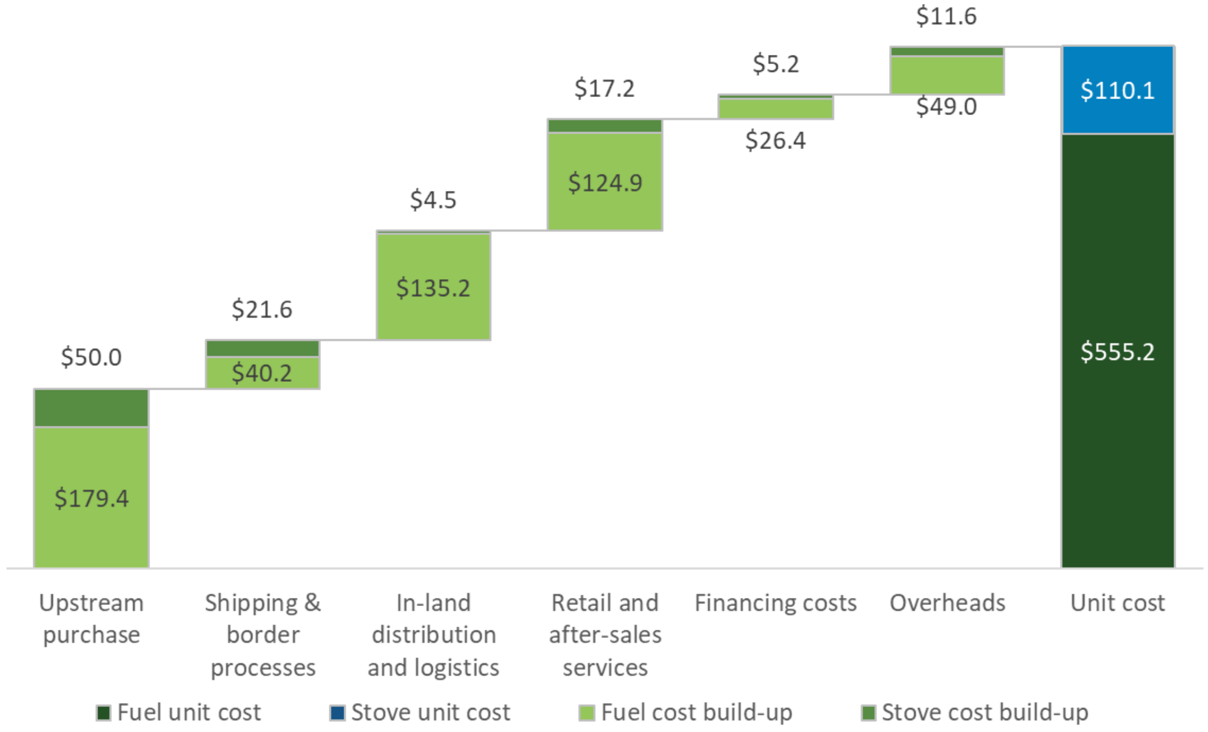
Archetype 3: Captive fuel distribution

The final archetype is a tool and fuel model, illustrated by LPG distribution with the following assumptions:

- An FOB cost of a two-burner stove of US$ 50.
- Selling 50,000 stoves and 7,800 tonnes of fuel annually in a densely populated urban region of Kenya.
- Average household monthly fuel consumption of 13 kg.
- 36-month stove lifetime.

For this tool and fuel archetype, the cost of repeat fuel sales accounts for around 83% of total costs. In this example, the cost output from the toolkit for LPG fuel import and distribution is US$ 1,278 per tonne. Most of these costs sit in upstream fuel cost, in-land distribution and logistics, and retail and after-sales services (Figure 10), with unique drivers of cost such as bulk storage. Under the stove assumptions outlined above, fuel costs account for a considerable share of the costs compared to stove costs.

Figure 10: Captive LPG fuel business — stove and fuel cost (US$ per stove)



Source: Clean cooking unit economics toolkit

Clean cooking cost structure comparison by archetype

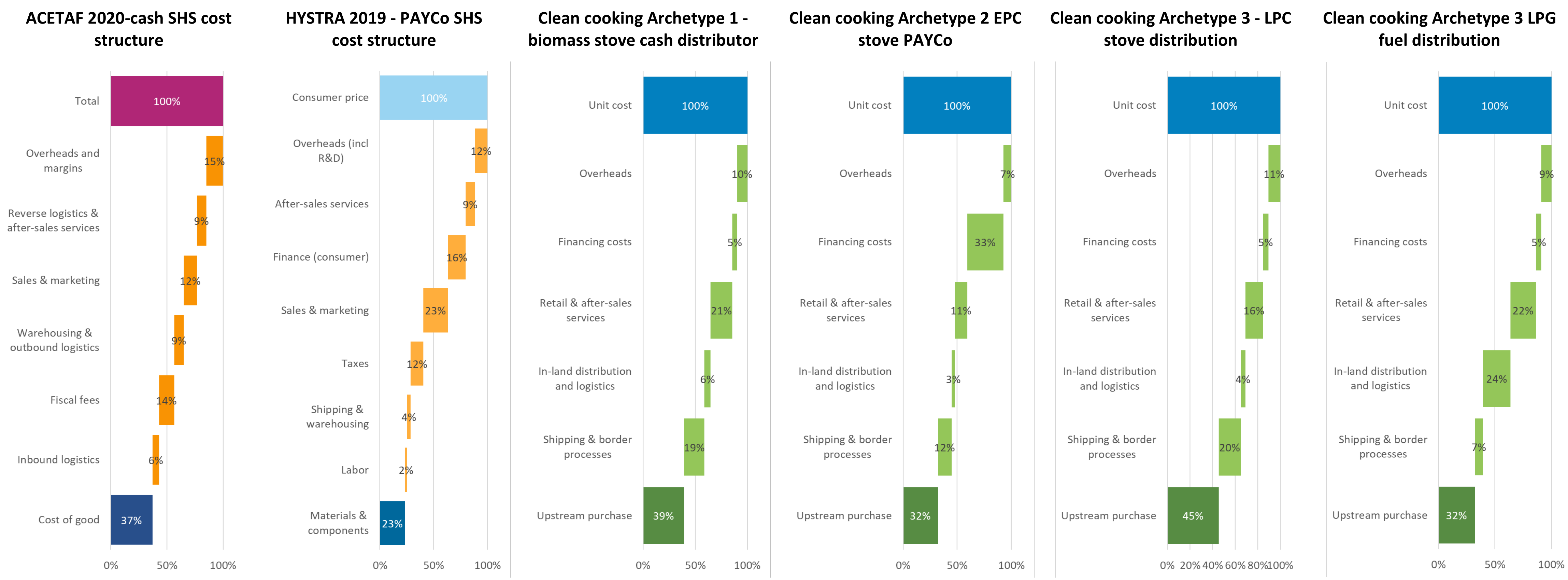
The cost structure for the three archetypes shows significant variation across cost centers. The concentration of costs for improved biomass stove distribution (Archetype 1) sits in upstream manufacturing, a substantial portion in border processes, and then a large share relating to in-land distribution, retail, and after-sales services.

This also reflects the cost centers where there may be the highest opportunities and risks.

- For upstream manufacturing, economies of scale can significantly lower costs.
- For border processes, working with national policymakers to provide preferential tariff and importation processes can drive a significant difference in making products affordable and expanding their reach.
- For downstream distribution and retail, localization may help (although traded off against upstream cost efficiencies), while partnerships with last-mile distributors may help bring some of those costs under control.

For Archetype 2 (asset financed stoves), financing costs make a major difference. The working capital required to service receivables in the PAYGo business increases financing costs to represent 33% of unit costs.

Figure 11: Comparison of cost structures across off-grid energy business models



Source: Greencroft Economics, based on Greencroft analysis, and (1) ACE TAF (2020). "Understanding the Impact of Distribution Costs on Uptake of OGS Products in Select SSA Countries"; (2) Hystra (2019). "Pricing Quality: Cost Drivers and Value-add in the Off-grid Solar Sector"

6.2. Clean cooking unit economics across countries

This subsection presents quantitative indicators across nine priority countries to tease out how regional factors affect the unit economics of clean cooking. The countries were selected following consultations with program managers as high priorities to support clean cooking market development in coming years and to represent a range of different contexts.

Within archetype there is significant variation in the relative weight of cost centers depending on the country context. In this section we explore differences in cost drivers across the nine priority African markets — Democratic Republic of Congo, Ethiopia, Kenya, Malawi, Nigeria, Rwanda, Tanzania, Uganda, and Zambia — mostly using Archetype 1 to illustrate the impact of contextual factors on unit costs. The following subsections discuss variation within each cost center (Figure 12).

Shipping and border processes add a significant, but highly variable, wedge to unit costs. This is driven almost entirely by different border tariff regimes.

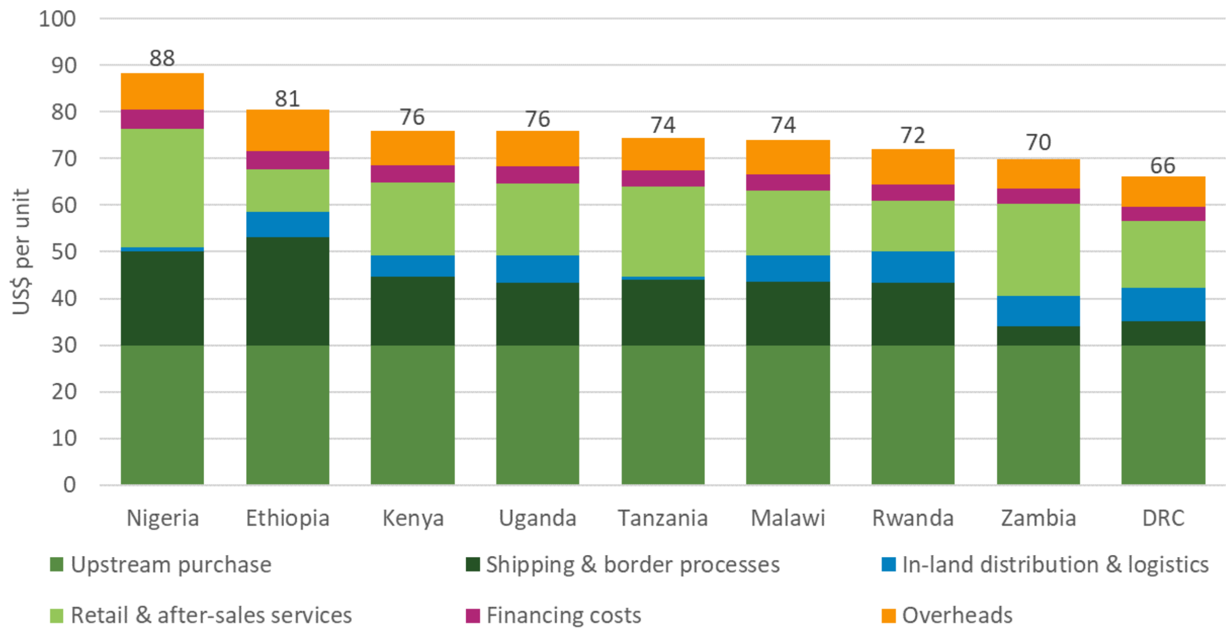
Distribution and retail and after-sales services account for just under 30% of costs, with some large variation across countries. These differences are driven to a large extent by labor costs, as retail and after-sales services are highly dependent on human capital.

It is also worth noting that unit costs will evolve very differently in each country context. As discussed in Section 6.2.3, expansion to serve increasingly remote rural areas can be expected to significantly increase costs to serve per unit, due to higher supply chain logistics costs and lower population density.

When serving rural areas, distribution, retail, and after-sales services increase to account for over 50% of costs, and as high as 75% (Figure 13). Zambia goes from being the least costly to serve in the context of urban areas to the costliest to serve in the rural context. Drivers of these cost increases are discussed in Section 6.2.3.

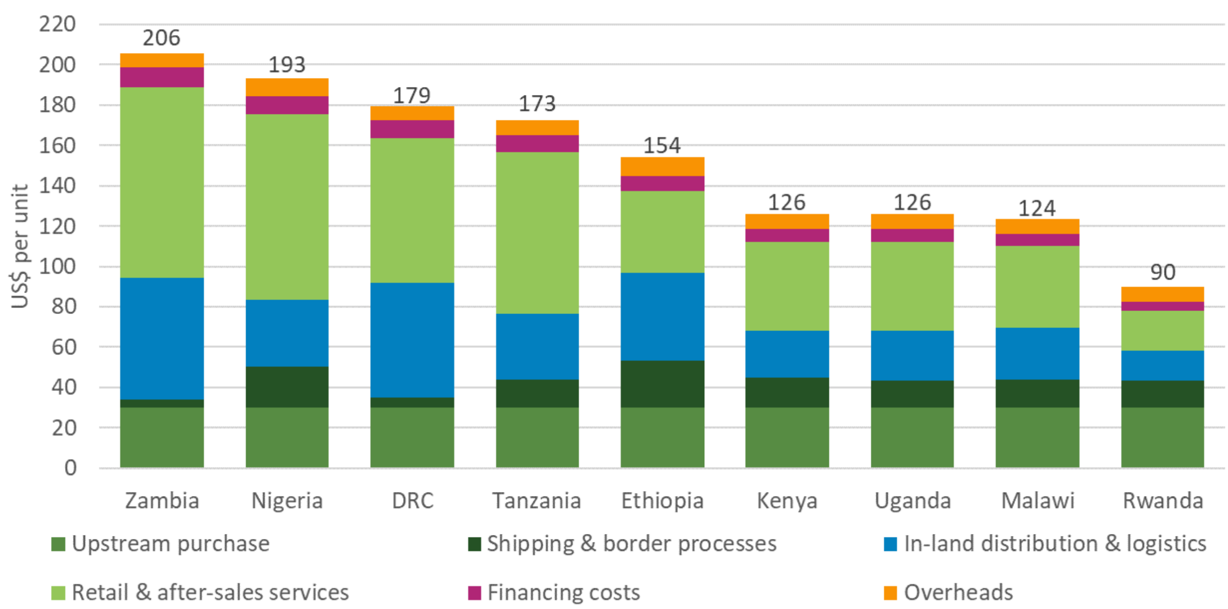
Production costs are likely to have significant variation if production is carried out locally. However, there is very limited information from the industry to estimate or predict these cost variations. For the purposes of the illustrative analysis below, each country market starts with a US$ 30 stove, pre-importation. Localization of production could avoid much of the downstream costs discussed below, although that would need to be weighed against the potential increase in production costs.

Figure 12: Unit costs for imported ICS distribution — urban areas



Source: Clean cooking unit economics toolkit

Figure 13: Unit costs for imported ICS distribution — rural areas



Source: Clean cooking unit economics toolkit

Shipping and border processes

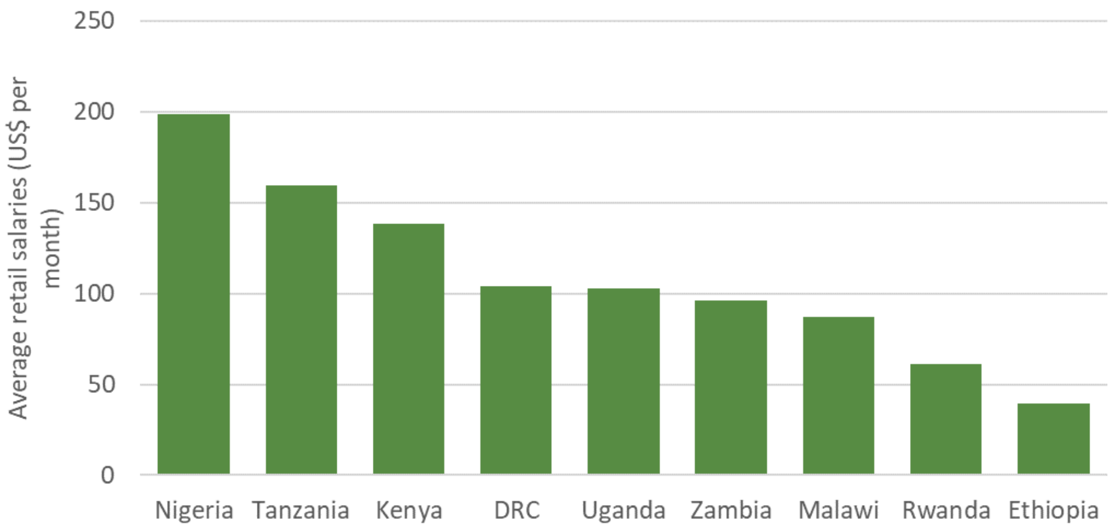
Sea freight costs can represent a significant cost driver for lower-value products, although with relatively limited country variation. For a Tier 2 improved biomass cookstove at a relatively low FOB cost of US$ 5, shipping may double the cost. For larger value units, the cost of shipping tends to be proportionately less important. In terms of regional variation, the big difference would be shipping to West Africa, while the east coast ports tend to have a similar cost. More important is variation in discharge handling costs and time delays for clearing containers, although their overall impact on unit cost tends to be small less than 2%.

Border tariffs present a significant cost for the biomass stove importer. In Ethiopia, Malawi, and other countries with higher tariff regimes, import duty and value-added tax (VAT) combined add around US$ 20 to a stove with an upstream FOB cost of US$ 30. In Zambia and elsewhere with lower tax exemption regimes, the savings on the total cost per unit are significant.

Retail and after-sales services

Retail and after-sales services are mainly driven by salary costs. Salary costs have an important impact on downstream costs, and they vary significantly from country to country (Figure 14). For example, retail labor costs in Ethiopia contribute just US$ 5 of the US$ 76 cost of the stove, while in Nigeria retail labor costs account for US$ 23 of the US $101 unit cost.

Figure 14: Country comparison of average salaries for retail employees



Source: ILO Labor Statistics

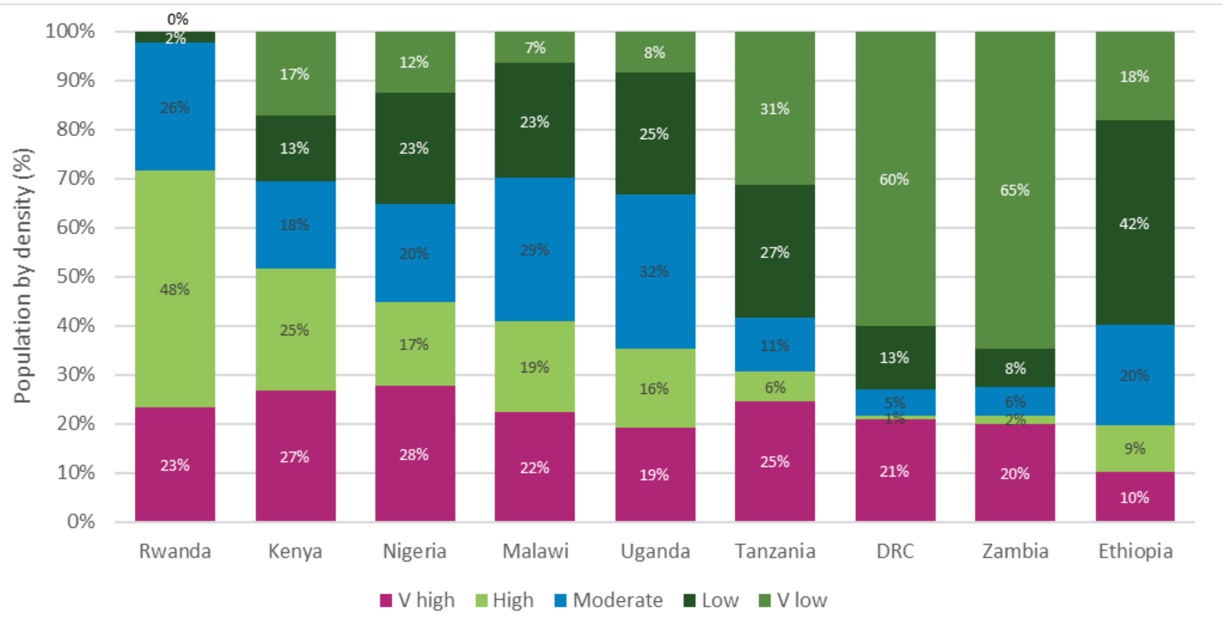
Inventory stocking and retail outlets can also add an important stack to cost per unit. The cost of retail space is an important driver of costs, particularly in Nigeria, where average rental rates for retail spaces are around double the average in sub-Saharan Africa. Because of high labor and space costs in Nigeria, the retail and after-sales services cost center in Nigeria represents around 40% of the cost of a unit for urban sales.

In-land distribution and logistics

In-land transportation adds a cost layer for delivery from port arrival to distribution centers, although this does not appear to be a major cost adder. The cost of trucking from port to primary commercial city drives some variation in distribution and logistics costs. Trucking containers of products to landlocked countries from the nearest seaport often entail lengthy routes, for example, along East Africa's Northern Corridor (1,700 km long) from the port of Mombasa through Kenya to Uganda, Rwanda, Burundi, and eastern DRC. This overland transportation could add US$ 6 to the cost of a US$ 30 FOB biomass cookstove,[40] although a recent study found limited impact on overall pricing and affordability.[41]

Population density is a crucial cost driver for downstream distribution, especially when expanding into rural areas, with large variation within and between countries. To serve the last mile requires retail hubs being at an accessible distance for end users or agents making visits to customers. The cost of acquiring and maintaining customers is lower the closer customers are to one another. As shown in Figure 15, population density varies significantly across countries, with 71% of Rwandans living in high-density towns or villages, compared to around 20% of households in DRC, Ethiopia, and Zambia.

Figure 15: Population density distribution



Source: Greencroft Economics analysis

A high share of Ethiopia's population lives in low-density regions. Around 21 million Ethiopians live in regions where population density is at least 500 people per square kilometer, 20 million live in regions

40 On the basis of a full container load (FCL).

41 ACE TAF (2020). "Understanding the Impact of Distribution Costs on Uptake of OGS Products in Select SSA Countries." Link

with less than 100 people per square kilometer, and 46 million live in locations with less than 250 people per square kilometer.

Rwanda, meanwhile, may have more homogeneity in distribution costs. Of a total population of around 13 million, over 9 million live in regions where density is over 500 people per square kilometer, and only 300,000 people live in regions where density drops below 250 people per square kilometer.

Different distribution business models will be needed to adapt to different customer segments. In Kenya, Nigeria, and Rwanda, for example, where there is a large addressable market in relatively densely populated areas, clean cooking companies may be able to achieve scale through existing retail networks. In DRC, Ethiopia, and Zambia, meanwhile, the majority of the population lives in relatively sparsely populated areas, and reaching all — or even a significant share — of these populations cost-effectively may be more challenging and require partnerships.

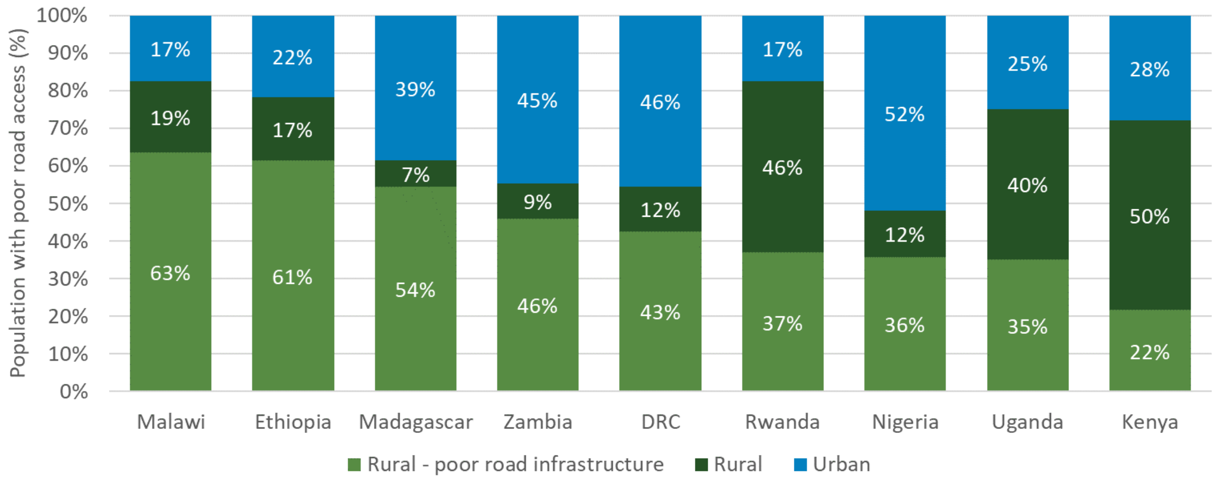
Undertaking retail services in rural areas will also be affected by the quality of physical infrastructure such as road access. Poor access to all-season roads makes it more costly to acquire and maintain customers. Analysis from the off-grid solar sector suggests that poor rural infrastructure can add 20%–50% to the cost of a product.[42]

Kenya and Uganda have large rural populations but relatively good physical infrastructure to reach these rural residents. In Kenya, 72% of the population lives in rural areas, and in Uganda, it's 75%, but the majority of those communities live within 2 km of an all-season road. Similarly, while Rwanda's population is predominantly rural at 83% of the population, the majority of these communities also have relatively good all-season road access.

Zambia and Nigeria are more urbanized, but the infrastructure serving their sizable rural populations is relatively weaker. In Zambia, urban dwellers account for 45% of the population, and in Nigeria, it's 52%, but the rural population is almost entirely situated more than 2 km from an all-season road. Malawi, like Rwanda, has a highly rural population (83%), but unlike Rwanda most of its population is remote from all-season roads.

[42] Dalberg Advisors (2018). "Off-Grid Solar Market Trends Report." Link

Figure 16: Country comparison of population with limited road access



Source: Greencroft Economics analysis of Rural Access Index data[43]
Note: No RAI data for DRC, so has been proxied with low quality road access, compatible to e.g. Ethiopia, Malawi, Nigeria.

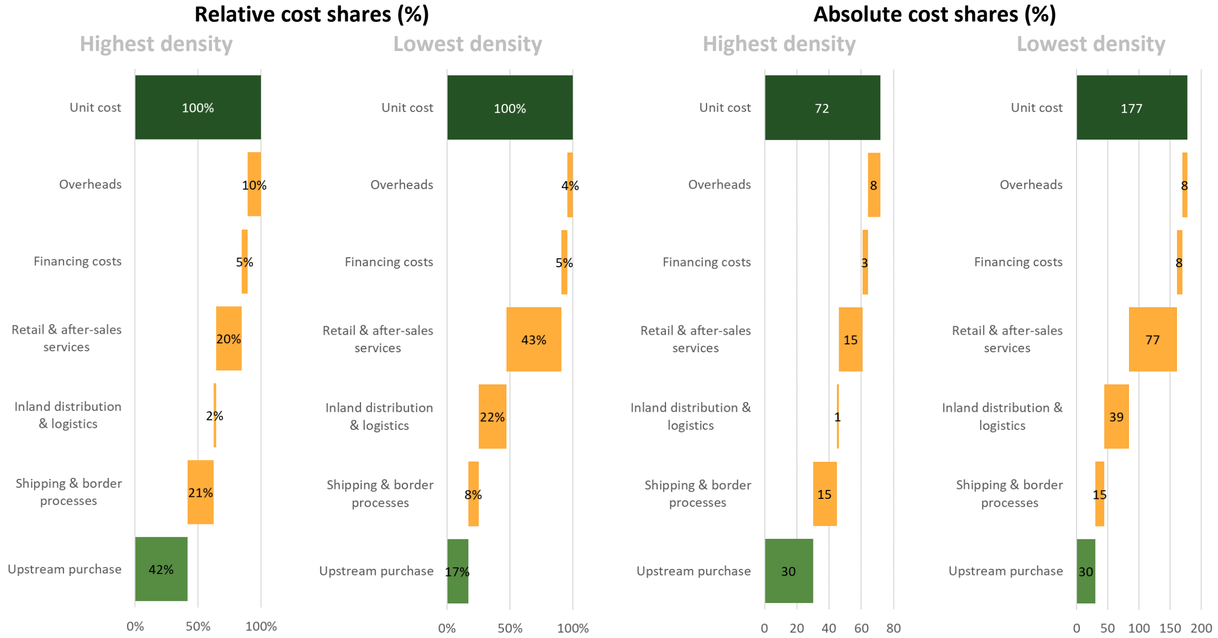
The cost of serving the most remote rural populations could increase distribution cost per unit by a factor of five. With a similar multiplier for retail, sales, and after-sales services in deep rural areas, the viability gap of serving deep rural customers can quickly become prohibitive if there is no subsidy such as grants, RBF, or some form of carbon revenue allocations.

Taking Archetype 1 as an example, unit costs would increase substantially to serve the most remote rural customers. As shown in Figure 17, the cost for each additional unit sale to the most remote rural populations is much higher — increasing almost threefold from US$ 72 to US$ 177— than serving urban markets. This is due to the increased cost of customer acquisition and maintenance (retail and after-sales services) as well as the higher logistics cost of serving that customer base. It should be noted that this is to illustrate the extreme end of the cost curve, and it represents the most expensive customer to reach. This is driven by a significant increase in the share of costs for in-land distribution and logistics, which rise from 2% to 22%, with a similar increase for retail and after-sales services.

Customer retention can be a significant long-term cost, which is balanced against an acceptable level of client turnover. As discussed in Section 0, across all product offerings and business models, retaining customers is as important as acquiring customers in the first place. How much this contributes to retail and after-sales services will depend significantly on the business model — and there will be a trade-off between how much is spent here versus accepting some level of customer turnover.

[43] The Rural Access Index is not regularly updated. Data years vary across countries.

Figure 17: Marginal cost of stove sale in highest density urban vs. most remote rural



Source: Clean cooking unit economics toolkit

6.3. Clean cooking viability gap

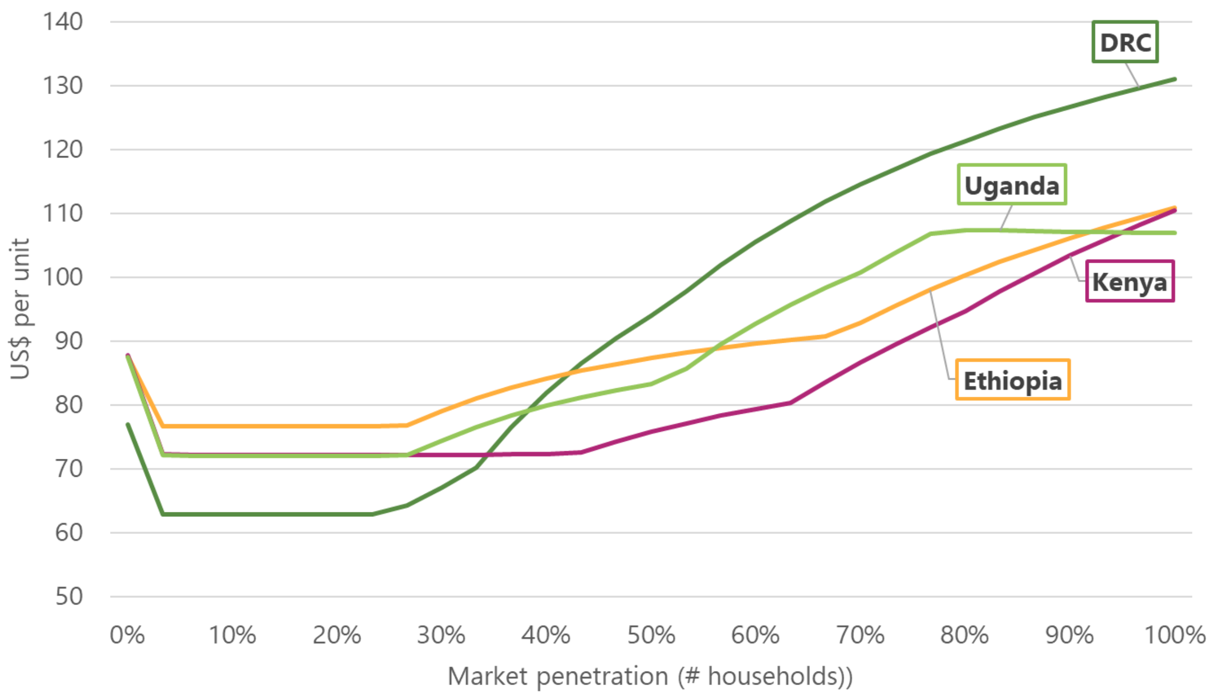
Stylized supply (cost) curves

Increasing sales volumes is likely to reduce cost per unit at least initially, due to supply chain efficiencies and upstream economies of scale. To take the example of Archetype 1, a biomass ICS importer, the benefit from economies of scale increasing sales volumes from 5,000 stoves to 100,000 could deliver unit cost savings of around 20% depending on the country. This is across the full value chain, with the economies of scale concentrated in upstream manufacturing.

For some countries, economies of scale may persist even at high rates of penetration. This is represented by the initially declining, and then increasing, marginal cost curves shown in Figure 18. In this example, the unit cost of stoves sales in DRC, Ethiopia, Kenya and Uganda, economies of scale prevail up to serving 30% of the potential addressable market – and given the number of households lacking access to clean cooking technologies this equates to a market size of at least 3 million households in each of these countries. Beyond that 30% penetration, downstream cost drivers overbear the potential upstream economies of scale, and unit costs begin to rise.

In some countries unit cost escalation may happen much quicker – at lower levels of market penetration and sales volumes. For example, in Malawi, Rwanda and Zambia, which have relatively smaller populations, downstream cost drivers may start to push costs up after just a few hundred thousands sales have been made. In the case of Rwanda this increase in unit costs will plateau relatively quickly given even in rural areas population density remains high, whereas in Zambia the risk of unit cost escalation is much more significant.

Figure 18: Impact of increasing sales on unit cost with constraints on the addressable market



Source: Clean cooking unit economics toolkit

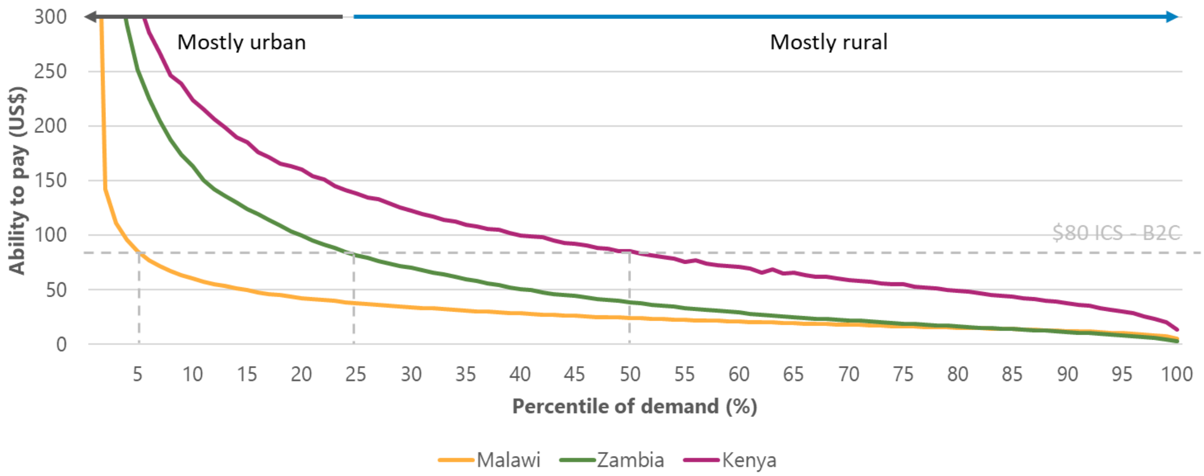
Ability to pay

The ability to pay for clean cooking technologies is likely to be very limited outside of urban regions.[44] There are likely to be relatively high ability-to-pay customer segments – concentrated in urban areas. However, moving out into the populations where the clean cooking access gap is heavily concentrated — that is, into increasingly remote rural regions — the ability to pay is likely to fall sharply. In these locations the ability to pay commercial prices will be extremely limited, as illustrated for Malawi, Zambia, and Kenya in Figure 19. While this crude analysis suggests half of Kenyan households could afford a Tier 3 ICS at a retail price of US$ 80, the same price point would be affordable for just 25% of Zambian households and 5% of Malawian households.

This lower ability-to-pay population is likely to be highly correlated with the higher cost-to-serve customers shown in Figure 18 above. Each additional unit of sales will become increasingly costly to distribute — both in terms of acquiring and retaining customers — especially moving into increasingly remote rural regions. At the same time, the revenue-generating potential from households is likely to be declining, as these customer segments have less ability to pay. So as clean cooking ventures scale beyond their best commercial product<>customer segments, the unit economics are likely to deteriorate on both the cost and the revenue sides, and there will be customer segments that at least in the short to medium term will need a form of long-term subsidy.

[44] A description of the illustrative demand curves described in this section is provided in Annex 1, A.4.

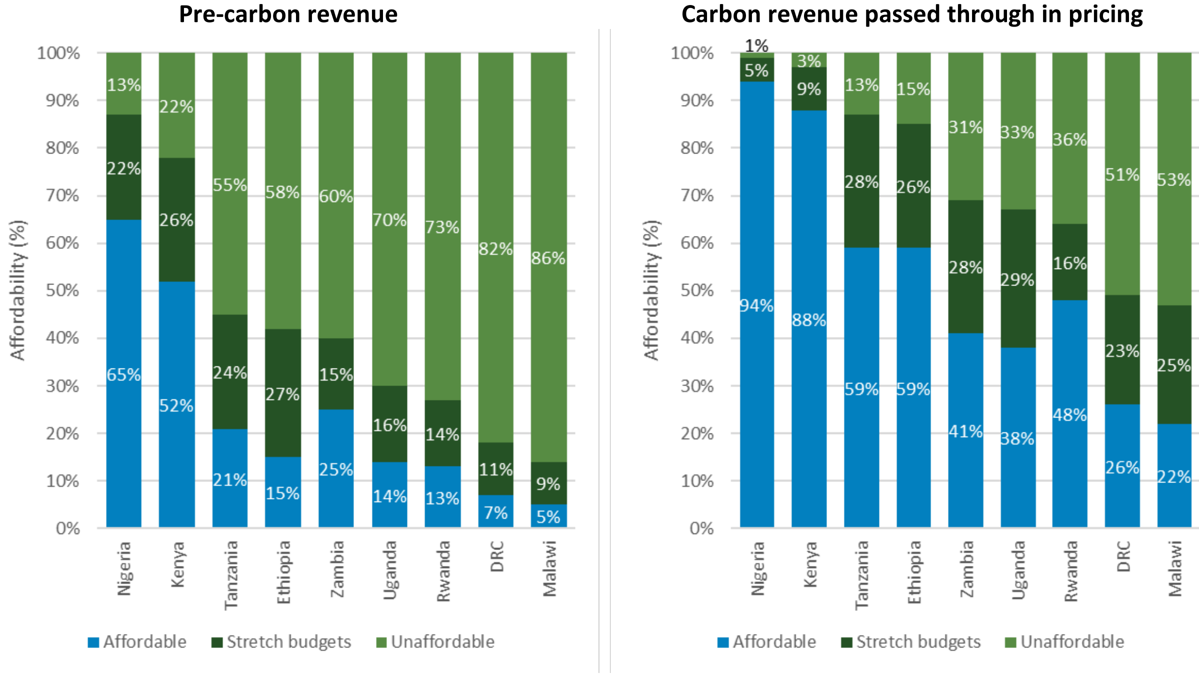
Figure 19: Illustrative ability to pay curves



Source: Clean cooking unit economics toolkit

To bridge this viability gap, other forms of revenue and subsidies will need to be mobilized. Figure 20 shows the impact on affordability where the retail price of US$ 80 could be reduced by 50%. This is in line with the potential order of magnitude of pricing reductions reported by providers accessing carbon revenue, although the industry is still at an early stage in terms of evidence for the magnitude of potential carbon credit volumes and pricing. Alternatively, the 50% price reduction could represent grant and concessional finance passed through to end users. Taking Zambia as an example, while only 25% of households could afford an US$ 80 ICS (and an additional 15% if they stretch their household budgets further), this increases to 41% (plus 28% if stretching their budgets) of households where prices can be brought down to US$ 40.

Figure 20: Proportion of the population that can afford clean cooking technology



Source: Greencroft Economics analysis

7. What is Needed to Drive Improved Unit Economics and Increase Flows of Finance

This section provides further insights from the literature and our engagement with financiers. It then summarizes lessons learned on how unit economics can be improved and what will be needed to increase flows of finance to support growth of ventures.

7.1. Unit economics structure and variation

Sales of stoves and fuel represent the largest source of revenue, although these receipts have declined in recent years. Product sales accounted for around 90% of industry revenue generated in 2017, at just shy of US$ 40 million. By 2020, this declined year on year in both relative terms (down to 70%) and absolute terms (down to under US$ 30 million).[45]

At the same time, revenue generated from carbon markets is growing fast. Carbon market revenue has increased from just 1% of clean cooking company revenue in 2017 to 29% by 2020.[46] Total carbon revenue generated between 2013 to 2022 is estimated at US$ 60 million to US$ 150 million, with annual revenue flows reaching just over US$ 35 million in 2020.[47]

A third stream of revenue may be available from the sale of other outcomes, but this remains incidental for now. The sector's inaugural Clean Impact Bond launched by Sistema.bio in 2022 for the first time explicitly monetizes outcomes for health and gender.[48] However, there is no at-scale market for the trading of such outcomes, and it may take many years until sufficient demand (i.e., organizations prepared to pay at high enough volume for such outcomes) makes a real difference to the unit economics of clean cooking providers.

Various studies point to substantial variation in the cost structure of clean cooking technologies. The costs of improved biomass cookstove providers are often concentrated upstream (stove manufacture), while fuel producers of pellets or ethanol have a far greater concentration of their activities and costs in downstream expenses. Similarly, solar cooking has a significant concentration of costs in customer acquisition and business partnership development, while in general tool and fuel business models incur ongoing costs to deliver fuel to customers.[49]

Comparing unit costs is complicated, as archetypes provide different services and may be stacked alongside one another. Households often use multiple cookstoves and fuels, which can reduce the revenue-generating potential of each unit, as households optimize the choice of the technology they use depending on the type of meal being cooked, the price of fuel, and other factors. As an example, projections suggest that by 2025 electric cooking could be cost-effective compared to traditional biomass or charcoal.[50] However, there are challenges associated with such issues as grid reliability and

[45] CCA (2022). "2022 Clean Cooking Industry Snapshot — Third Edition." Link
[46] CCA (2022). "2022 Clean Cooking Industry Snapshot — Third Edition." Link
[47] Climate Focus (April 2023). "The Role of Voluntary Carbon Markets in Clean Cooking." Link
[48] IFC (2022). "Clean Impact Bond: Mobilizing Finance for Clean Cooking." Link
[49] See discussion, for example, in ESMAP (2020). "The State of Access to Modern Energy Cooking Services." Link
[50] For more information, see, for example, ESMAP (2020). "Cooking with Electricity: A Cost Perspective." Link

battery storage that may mean in practice multiple cooking technologies are used, which affects the cost-effectiveness and unit economics (revenue and costs) of deploying modern cooking solutions.

7.2. Upstream manufacturing and import procedures

Upstream and manufacturing costs have been shown to deliver economies of scale. As a share of total cost per stove, the cost of upstream and manufacturing account tends to fall as companies scale, from 51% of total costs for small vertically integrated companies down to 42% for larger companies. [51] Among Acumen's investments, biomass companies became profitable only after stove sales exceeded 100,000 per year.[52]

To build positive unit economics, companies must deliver high-margin products. [53] While cash sales of low-cost units play an important role in establishing operations for a new business, higher margin (i.e., typically higher cost and higher value-add) products deliver sustainable commercial margins. This can be achieved either through business models such as PAYGo for stove sales, product diversification, or repeat sales of fuels that can build in a margin over time. Acumen's clean cooking portfolio highlights a transition to the sale of higher-margin products as essential to achieving sustainable unit economics, alongside subsidies. For example, Greenway revenue jumped 92% from 2018 to 2019, while costs increased by only 42%, driven in part by a huge increase in the share of sales of Greenway's largest stove.[54]

Nonetheless, the ability to generate high unit price sales can be challenging when potential customers have a limited ability to pay. Despite studies estimating a very high internal financial return on adopting clean cookstoves, actual ability and willingness to pay often remain low (see Box 1 for an example from BURN).

Some of the most significant upstream cost centers are highly vulnerable to external market conditions. LPG providers' cost to serve is highly dependent on the raw commodity price, while importers of higher-tier stoves made in China will be dependent on material input prices and negotiations with upstream providers.

Providers need to focus on getting the core product to market. Most clean cooking stove sales are improved biomass cookstoves, and some of the largest and most capitalized clean cooking producers have focused on ICS to build their customer base. This may represent a similar trajectory to that seen in the off-grid solar market, where cash sales of lanterns were a forerunner to building a market for larger systems often offered on PAYGo. Focusing on identifying the right core product<>customer market segment and successfully building sufficient sales volume are essential before product diversification can be rolled out.

It can take years for ventures to reach positive unit economics, so they will need patient investors. Given the significant costs of product development and the need to build customer awareness and activate demand, providers are likely to have negative cashflows in early years. BioLite and BURN earned

[51] ESMAP (2020). "The State of Access to Modern Energy Cooking Services." Link
[52] Acumen (2023). "Recipe for Success: Lessons from Acumen's Cookstove Investments." Link
[53] Ibid.
[54] Ibid.

negative gross margins on early versions of their products, reflecting the need to sell at a price the market would bear in terms of ability to pay when serving the bottom of the pyramid and willingness to pay for a new product while marketing and brand presence are being established (see Box 1).

7.3. Downstream distribution and customer service

The middle and end of the value chain — distribution and retail — have not seen the same unit cost reductions with scale. Larger companies have a higher proportion of costs in downstream operating cost centers.[55] Indeed, companies that have outsourced the middle part of the value chain — distribution — tend to have higher gross margins. Several of Acumen's investees set out to sell B2C, but *"all saw some pivot to strategic partnerships,"* with most sales being B2B.[56]

Controlling downstream costs during expansion is essential, and localization may help achieve this. *"The narrow margins of cookstove sales provide no room for error."*[57] Localization can help by, among other things, reducing costs, however, as noted in Section 0, localization may also increase other costs, such as reducing cost efficiencies and economies of scale that can be driven by larger-scale production.

The drive for rapid growth can risk downstream unit cost escalation. A key lesson from the off-grid solar sector is that companies may *"rack up exorbitant operating costs to expand at all costs with unprofitable unit economics,"* with the result that lower-income customer segments suffer first as companies seek to reduce losses. [58] There may be a risk of chasing positive unit economics through growth, with downstream unit costs rising and unit revenue not increasing in line.

Investors are wary of business models that rely on a vertically integrated single-product offering, especially in rural areas. Working in partnership with last-mile distributors can be more cost-effective for a company than establishing its own distribution channels. This, however, requires companies to be able to manage partnerships effectively and comes with its own set of hurdles given the challenges faced by last-mile distributors, including access to finance and consumer financing.[59]

Partnerships may provide an attractive alternative route to market than providing a full B2C vertically integrated service. With limited ability to pay in rural customer segments, selling a single, one-time sale product can be make delivering positive unit economics challenging. An alternative may be to leverage partnerships with distributors, retailers, and consumer financers, which already have both the retail network and the experience of selling to the target customer base. These last-mile distributors may also be able to deploy adapted financing products for their consumers; 78% of the Global Distributors Collective's members provide some form of consumer finance.[60]

[55] ESMAP (2020). "The State of Access to Modern Energy Cooking Services." Link
[56] Acumen (2023). "Recipe for Success: Lessons from Acumen's Cookstove Investments." Link
[57] Acumen (2023). "Recipe for Success: Lessons from Acumen's Cookstove Investments." Link
[58] Acumen (2019). "Lighting the Way: Roadmap to Exits in Off-Grid Energy ."" Link
[59] https://infohub.practicalaction.org/bitstream/handle/11283/622892/GDC%20State%20of%20the%20sector%20update%202022.pdf?sequence=1&isAllowed=y
[60] GDC (August 2022). "LMD-MFI partnerships to deliver beneficial products to last mile households." Link

The off-grid solar sector's path to profitability (P2P) toolkit[61] identified several factors that put upward pressure on unit costs as distribution networks expand. These include: [62]

- **Smaller operating units**, which deliver lower economies of scale and may potentially result in diseconomies of scale as the larger a company grows, the smaller its operating units become and unit costs will tend to increase.
- **High-touch customer acquisition**, with greater investment needed in marketing and sales networks to drive adoption.
- **High-touch customer service**, facing lower penetration and adoption of digital payment technologies, the further companies expand into poorer rural areas, the more cash handling is required, and more intensive follow-up on monthly payments and the like.

Similarly, P2P identifies factors that may tend to reduce unit revenue, including: [63]

- **Limited addressable market/geographic reach** — The reachable market for customers who can afford energy access technologies may be small, limiting the ability to continue to generate the same revenue per unit as companies scale up.
- **Low unit sizes and price points** — Often to build a new market, ability and willingness to pay is low, resulting in a high share of lower-capacity products that are at low price points and cannot generate sustainable margins for companies.
- **Low consumption/usage** — Even once systems are adopted on a PAYGo basis, usage of these systems has often been substantially lower than expected especially when serving an increasingly poor customer base as companies scale up. This delays or just reduces revenue generated per unit.
- **Slow adoption rates** — Scaling up unit volumes is challenging and takes time, and in a reflection of the increased cost of customer acquisition mentioned above, revenue growth can be slower than hoped for.

7.4. The role of carbon revenue

Carbon revenue fundamentally changes the unit economics of downstream activities. Companies can generate significant revenue from the sale of a second product (emissions reductions), contingent on customers continuing to use their clean cooking technology, which incentivizes a closer relationship with customers and may support B2C business models (as described in Box 1 and Box 2).

Growth in carbon revenue for clean cooking providers has been driven both by a volume effect and a price effect. Cookstove activities yielded an average carbon credit price of US$ 7.50 between 2013 and 2022, compared to a cross-sector average of US$ 5 over the same period.[64] There has also been an expansion in the number of companies generating carbon credits, as well as the volume of credits being

[61] Note that the path to profitability toolkit was developed for the off-grid solar sector looking specifically at a single technology and business model: solar home systems sold on pay-as-you-go. This approach would likely be far more complex if applied to the clean cooking sector, given the much wider diversity of technologies and business models.
[62] EEP Africa (2020). "Path to Profitability Webinar: EEP Africa and IFC Lighting Global." Link
[63] EEP Africa (2020). "Path to Profitability Webinar: EEP Africa and IFC Lighting Global." Link
[64] Climate Focus (April 2023). "The Role of Voluntary Carbon Markets in Clean Cooking." Link

generated. However, the track record of consistently generating stable revenue from carbon markets is still relatively limited, particularly for modern energy cooking solutions.

Scale is essential to access carbon markets and generate carbon revenue. Improved cookstove providers need to reach around 100,000 units per year to companies for development of carbon projects to be viable.[65] It will be significantly more expensive on a per unit basis to generate sales at small scale, needing dedicated carbon consultant expertise or working through intermediaries, than bringing these services in-house. In-house services are feasible only at larger scale (see Box 2).

Lenders see carbon as a significant boost to financing opportunities. This is particularly the case where an emissions reduction purchase agreement (ERPA) provides pricing and offtake certainty, so the only risk is the ability of the business to deploy the systems and ensure verifiable ongoing usage. For equity investors there is less certainty on the role of carbon markets; long-term valuation is what matters and that depends on the long-term value of carbon markets, which has historically been volatile. There have been numerous high-profile news articles questioning the value of credits traded on voluntary carbon markets, and after a spike in 2022 there has been a fall in prices observed in 2023.[66]

There is no consensus on how carbon revenue should be shared across the value chain and end users. While two of the 15 investors interviewed had a clear expectation of what companies should do with carbon revenue, most were not yet advanced enough in their understanding to be able to take a firm position. To support enhanced commercial viability and end user impact, there cannot be a one-size-fits-all approach for the use of carbon revenue. It may be feasible and desirable for a high share of carbon revenue to be passed on to customers for some technologies where the gap between commercial pricing and ability to pay is relatively smaller. For higher-tier, modern energy cooking solutions, it may be that companies need this revenue to reach breakeven, in which case it may be optimal for companies to maintain carbon revenue to remain solvent and continue to serve their customers. Several financiers expressed support for the idea of a best-practice guide to be developed and adopted as an industrywide standard — with work underway by CCA's Responsible Carbon Finance Working Group.[67]

7.5. Monetizing other outcomes to improve unit economics

The impact of access to clean cooking is well established. Clean cooking technologies can deliver energy expenditure savings, enhance economic well-being in local communities, improve health by reducing indoor air pollution, reduce damage to local environments, and deliver time savings that can be used for income generation, leisure, or other activities.

These impacts are often absent from market transactions and do not appear in commercial unit costs or revenue. Even fuel savings may not be fully represented in market transactions, where firewood can be freely collected. In this case, the internal financial rate of return for households is suppressed, and willingness to pay for technologies that reduce fuel usage consumption, or require a shift to more efficient but payable fuels, will be limited.

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[65] Acumen (2023). "Recipe for Success: Lessons from Acumen's Cookstove Investments." Link
[66] World Bank (2023) "State and Trends of Carbon Pricing 2023", Link
[67] CCA (2023). Responsible Carbon Finance Working Group. Link.

An example of this sort of missing or undervalued market is time savings. In contexts where household members have relatively high time availability and are un- or underemployed, time savings may not convert into higher willingness or ability to pay. While a recent study found time savings of 7.7 hours per week on cooking-related tasks perceived as drudgery, these did not *"consistently translate into … increased time spent on productive activities or rest and leisure."* [68]

Other benefits may be less tangible or far-off and therefore not taken into account in market transactions. Households may not be fully aware of the long-term health benefits of cleaner cooking, or they may be unable to place a monetary value on these benefits. Even with "perfect information," there may be a timing challenge, with the costs faced now while the health benefits are spread over many years. In a poverty setting, opting to incur costs today for potential benefits far into the future is not an easy decision. A summary of the types of co-benefits delivered by access to clean cooking technologies, and why they are not valued in market transactions, is provided in Figure 21.

Creating markets to price these other outcomes may develop in the future, but such initiatives are very nascent at present. The first clean impact bond in the sector leverages results-based finance for delivery of emissions reductions, while also explicitly monetizing health improvements and gender impacts.[69] However, the pool of funders to pay for such outcomes is very limited, and if this approach is to make a real difference to the unit economics of clean cooking ventures, the amount of funding for such initiatives would need to scale up significantly.

Figure 21: Access to clean cooking — potential unit values and missing markets

Clean cooking benefit	Unit value	Market failures
Reduced fuel consumption	US$ X times tonnes of wood fuel purchases reduced	**Missing market:** In many rural markets, wood and biomass fuels are freely collected and there is no financial cost of high fuel consumption. This means households do not have an internal incentive to reduce consumption, which will have negative local and global environmental consequences (discussed below).
Reducing carbon dioxide emissions	US$ X for tonne of CO_2 emissions avoided	**External market:** Households do not directly benefit in full from the global benefits of reduced emissions reductions. Global voluntary carbon markets (VCMs) allow trading of carbon emissions reductions, but this requires cooking companies to sell a second type of product (carbon credits). **Suppressed value:** The value of clean cooking credits on VCMs has averaged US$ 7.50 over the past decade; this is far below estimates of the social cost of carbon, which is at

[68] ESMAP (2023). "Building Evidence to Unlock Impact Finance: A Field Assessment of Clean Cooking Co-Benefits for Climate, Health, and Gender." Link
[69] IFC (2023). "Clean Impact Bond: Mobilizing Finance for Clean Cooking." Link

Clean cooking benefit	Unit value	Market failures
		least US$ 50 per tonne, and many countries now value over US$ 100 per tonne.
Improved air quality (health)	US$ X for improvement in "disability adjusted life years"	**Information asymmetry:** Understanding the long-term impact on human health is complex and likely not internalized by household decision-makers. **Timing:** Benefits are spread over the long term and do not yield a direct revenue stream, while households incur costs now.
Reduced local environmental degradation	US$ X per hectare deforestation, biodiversity, and the like	**Missing market:** Local environment is a public good, and while communities as a whole benefit, individual households do not incur costs from local deforestation for firewood.
Time savings (1)	US$ X income per hour saved	**Suppressed value:** Where unemployment or underemployment is high, time savings may not deliver additional income generation. So paying for a technology that increases already relatively abundant free time does not deliver any financial resources to help affordability.
Time savings (2)	X minutes' time saving for women	**Suppressed value:** As per above, this is not to say this is a fair reflection of the value of these time savings, but that it is not represented in market transactions. There is also some evidence that time spent on fuel collection and cooking reinforces links to the community and that this time can represent a value in itself.[70]

Source: Greencroft Economics

7.6. What is needed to increase financing flows

Sales of lower-value units through B2B and B2C cash sales will be important to scale up, but companies will also need to transition to higher-margin products. Cash sales are essential to building a customer base, getting basic products to market and learning about customer needs, and building a strong balance sheet.[71] However, once brands are established and the market begins to mature, companies need to make the transition to higher-value stove sales or repeat sales of fuels, which can deliver a sustainable commercial margin. Product diversification may also play a role to capitalize on the cost of establishing downstream distribution networks with an adapted product offering to generate

[70] See, for example, FMO (2021). "Clean Cookstoves: Impact and Determinants of Adoption and Market Success." Link
[71] See more discussion, for example, in Greencroft Economics (April 2022). "FMO's Contribution to the Off-Grid Electricity Sector Review 2014–2020." Link

different sales adapted to each customer segment and multiple-product sales to the same customer segment.

There is a fundamental viability gap in terms of affordability compared to pricing. The successful ventures in the clean cooking sector have relied heavily on a range of grant funding and concessional financing to support them across the length of their journey. This has typically been in the form of grant funding for product development, research and development, and piloting, through to concessional finance and some continued grant funding to support achieving scale and targeting populations with a low ability to pay.

There will be a significant need for funding in the form of subsidies for the unit economics to stack up and provide universal access to clean cooking technologies. Of the total expenditure required to reach all households with clean cooking technologies, 67% is expected to be contributed by end users (households), with 26% needed from some form of public funding. [72] In sub-Saharan Africa, subsidy will continue to be an essential part of building markets for modern (higher-tier) cookstoves, and even for charcoal and improved biomass cookstoves. Carbon may make a major contribution to reducing the need for subsidies, but it will not overlap entirely with the subsidies needed to reach the populations that are the poorest and most in need.

The influx of revenue generation from carbon credits could support improved unit economics for households to access clean cooking technologies. Carbon revenue could be used in a range of ways: from pass-through to households either as cash payments or price reductions; cross subsidies to reduce pricing for relatively poorer customers, as, for example, is often baked into grid-based tariff arrangements; for companies to improve commercial viability; and for governments, also including emissions reductions as part of nationally determined contributions.

Mobilizing additional revenue streams is likely to be a part of a successful commercial strategy. Generating revenue from multiple product sources, leveraging at least partially the same cost base, is clearly likely to improve unit economics. This could be from multiple product sources, repeat sales, or potentially from the sale of a broader range of outcomes such as carbon emissions reductions or the other outcomes described in Section 7.5 if these can be monetized and are not already valued or double counted within the carbon credit co-benefits.

Finally, a key point raised repeatedly by financiers was the equal importance of good governance, alongside unit economic type financial indicators. This entails the policies of investees around customer protection and safeguarding, especially when complex business models are involved that require warranty and after-sales service for the technology, data protection and privacy where usage data is monitored, and responsible consumer finance where this is offered.

[72] ESMAP (2020). "The State of Access to Modern Energy Cooking Services." Link

8. Conclusion

8.1. Key conclusions

- **The clean cooking sector is still at a relatively young stage of commercial maturity, and patient finance will be needed.** Few ventures are showing stable year-on-year profit and are accessing commercial capital. While some companies reach hundreds of thousands of customers per year, most remain on a small scale and are seeking a path to growth. The sector will need a combination of successful companies continuing to scale and a sufficiently diverse ecosystem to continue to drive innovation, competition, and a range of solutions to meet the needs of different market and customer contexts.
- **Upstream manufacturing can generate significant economies of scale.** Achieving scale in manufacturing facilities is a key lever to bring down unit costs. Until companies can achieve sufficient scale, grant finance has a huge role to play in supporting product development and piloting to de-risk companies trying to take new products to market.
- **Multi-country operations can be an effective route to achieving scale.** To achieve scale, B2B or B2C sales across multiple geographic markets may be needed. This allows serving the most viable customer segments in each market — that is, those with the highest ability to pay and the lowest cost to serve — to attain a sufficient scale of operations. Doing this means businesses will need support in managing the transition from focusing on product development to running a multinational sales operation.
- **For downstream activities, unit costs may quickly encounter upward pressure.** For higher value-add units, this is because the addressable market may shrink quickly and a large-scale viable customer market may require presence in multiple jurisdictions. For lower cost units, this is because the costs of moving along a demand curve that becomes increasingly rural is highly likely to significantly increase the cost to serve. Results-based finance can help incentivize expansion into these customer segments that are harder to serve. There will also a need for longer-term pricing support through the sale of carbon credits or other outcomes and subsidies.
- **Fuel sales support repeat sales to customers, which can help cover downstream costs.** Where stoves are also offered, repeat fuel sales offer a way to spread the upfront cost of the stove. One of the major challenges for fuel-based models is to overcome ability to pay (income) and willingness to pay (unit cost compared to substitutes). This has typically limited the scaleup of cleaner fuels into rural markets, where firewood can often be collected freely or cheaply or where charcoal is easily accessible, convenient, and relatively cheap.
- **Carbon revenue will play an important role in accelerating access and could support a transition to higher-tier systems.** Carbon credit programs can provide a much-needed boost to companies' revenue, at least a portion of which may be used to cross-subsidize relatively poorer customers who would otherwise not be commercially viable to serve. While there can be a risk of "lock-in" associated with long-term carbon contracts, it may be possible to design responsible carbon markets value technologies, including some higher-tier stoves, that have a larger impact on emissions reductions. This may support not only increased access but also a transition to increasingly high-quality access.
- **The sector will need a substantial volume of subsidies to serve customers who are the poorest and most in need.** While carbon may play a role in cross-subsidizing units for these populations,

the volume of carbon finance per unit will not be enough on its own to ensure all households can afford modern cookstoves and fuel, nor are they necessarily adapted to reach the poorest customer segments. Subsidies will be needed; providers will not be able to serve the world's poorest population on purely commercial terms.

8.2. The role of finance to support each archetype

A combination of catalytic finance and longer-term subsidy support will be needed. Catalytic finance — that is, time-delimited financial instruments designed to overcome short-term barriers such as, but not limited to, results-based finance — will be needed to support companies to move along their path to commercial viability. This will also support ventures in a transition to longer-term sustainable corporate finance (i.e., forms of debt and equity on commercial terms). Longer-term subsidies will also be needed for two reasons: to realize the SDG 7 ambition to reach all to bridge a fundamental gap in the ability to pay, and to value outcomes delivered that are not represented in market transactions.

Across all three clean cooking archetypes are common financing needs:

- **Developing bridge finance to provide a route to carbon revenue and ensure high-integrity carbon credits.** Catalytic financiers should support ventures early in their growth path to access carbon revenue, initially through carbon project developers/aggregators, then once companies can show a credible route to scale, bringing these functions in-house. Concessional funding may then be phased back as carbon revenue can back commercial lending.
- **Establishing a community of outcome funders to set up markets for other nonmonetized outcomes.** These markets will be dependent on grant finance and corporate CSR funding. The amount of this type of funding is not yet at the volumes needed to make a significant dent on the US$ 150 billion needed per year for adoption of clean cooking technologies.
- **Creating short- and long-term catalysts for downstream activities reaching deep rural regions.** Downstream last-mile distribution will remain commercially challenging for clean cooking products to reach the poorest and most remote customer segments. Time-limited RBF can help overcome upfront constraints of expanding into new areas, while longer-term pricing support will be needed to bridge fundamental affordability gaps.

Some of the bottlenecks and catalytic financing priorities vary by archetype:

Archetype 1: Improved cookstove production

- Catalytic finance to bridge the gap between product development and deployment, which can take years to generate revenue at scale.
- Once the market is established, inventory and working capital finance to support scaleup, which can then deliver upstream economies of scale.
- B2B partnerships and a combination of RBF and longer-term pricing support to expand distribution to the hardest-to-reach customer segments.
- For producers and distributors reaching sufficient scale, support development of carbon projects to unlock carbon revenue, helping to overcome initial financial and skills gaps to then to unlock revenue at low marginal cost per unit.

Archetype 2: Modern cooking technology — asset finance

- Concessional finance to support the development of an ecosystem of carbon project developers, aggregators, and traders, to provide a means for clean cooking providers to benefit from carbon revenue from an early stage of growth.
- Bridging loans or concessional finance to enable development of in-house carbon projects once providers start to achieve sufficient scale.
- Concessional consumer finance, or de-risking mechanisms such as partial guarantees, can help manage the costs of offering asset financing to customers with no or limited credit history. These may be channeled through consumer financing partners such as microfinance institutions and Village Savings and Loan Associations.
- RBF to encourage distributors to expand into new areas where ability to pay is lower and the cost to serve is higher.
- Short-term pricing support to embed behavioral change by encouraging adoption and sustained use by new adopters.
- Longer-term pricing support to ensure a level playing field with dirtier conventional cooking fuels.

Archetype 3: Captive fuel distribution

Innovation grants for product development especially for smart metering, usage monitoring, and payment systems.

RBF to expand rollout beyond urban areas, to cover one-off fixed costs of establishing new distribution networks such as capital expenditure for distribution facilities and marketing costs to establish brand awareness and acquire a critical mass of customers.

Longer-term subsidies, potentially using carbon or other outcome revenue, with conditionality around channeling these subsidies to cover the higher operating costs outside urban areas.

Longer-term subsidies, as above, to bridge the remaining affordability gap, potentially building in explicit cross-subsidization of customers with a lower ability to pay.

9. Setting Up a Longer-term Unit Economics Agenda

The clean cooking sector is at a relatively early stage of its unit economics journey. The industry will need to work together to improve unit economics and share insights for the good of all — end users, providers, and financiers. Four priority areas are identified for further work:

Short-term priority	**Conduct deep dives with individual ventures.** Getting under the skin of unit economics can clearly add a lot of value, both to companies as described in the three boxes in this report, and for investors. In the short term, work to challenge, unpick, and improve the unit economics and path to profitability of high-potential ventures should be the highest priority for development partners. This could also contribute to an ability over several years to begin to draw common lessons learned on the path to commercial sustainability and to benchmarking.
Short- term priority	**Develop detailed unit economics profiles of high-priority archetypes.** This report has looked across the industry and provided some high-level insights into how the unit economics differs across different types of clean cooking companies and their operating contexts. Deeper dives should be carried out at the archetype level, deepening analysis of a representative clean cooking company across a subset of high-priority technologies and business models, and country contexts. For example, electric cooking, LPG or bioethanol fuel-based models, or biomass improved cookstove production. These studies should focus on how costs and revenue will evolve as companies within each archetype achieve scale and what key country factors will drive differences in costs and revenue generation.
Medium-term priority	**Improve data collection, sharing, and transparency.** There is a trade-off between the benefits of sharing information and establishing industrywide knowledge from which all can benefit and revealing commercially confidential information. The sector as a whole will benefit from more and better information on unit cost trajectories. In the coming years more information will need to be shared through anonymized platforms that can generate industrywide analytics and benchmarks. This will require a concerted effort from all in the sector, including companies, program managers, and development partners.
Long-term priority	**Develop and track high-level benchmarks.** Very limited data is available — and certainly not on a comparable basis — to assess how the unit economics of different types of companies evolve over time. This could and should be collected by investors and development partners to provide actual data on where economies of scale can be realized and their order of magnitude. Similarly, more data should be collected on where there are risks of diseconomies of scale and the conditions where costs are likely to increase in different contexts.

Collecting the data needed to provide industrywide benchmarks is likely to require several more years of experience and continued work with clean cooking ventures and investors.

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Annex 1 — Toolkit — Technical Guide

A.1. Purpose of the unit economics toolkit

The unit economics toolkit is user-oriented and intended to help stakeholders analyze the unit economics of clean cooking archetypes. It can support companies to understand the potential for, and barriers to, achieving profitability and can support investors to compare companies. It also provides an accessible entry to get a quick understanding of the basic economics of clean cooking ventures.

The principal audience for the toolkit is RBF/subsidy program designers and implementing partners. The intention is to support the design and implementation of financial and nonfinancial support programs to help clean cooking companies increase their reach into target populations.

Figure 22: Potential use of the unit economics toolkit

For results-based finance design:
(1) Standardized benchmark of the "viability" gap of select technologies in different markets
(2) Flexible user-friendly tool to calibrate potential subsidy interventions to bridge the viability gap

For clean cooking companies:
(1) Define key drivers for clean cooking archetypes and business models
(2) Identify barriers to – and opportunities to reach – sustainable profitability

For investors:
(1) A simple tool to provide a standardized estimate of unit costs and revenue potential
(2) Tool to compare clean cooking company cost and revenue performance

For wider partners in the clean cooking sector:
Knowledge sharing and communication on the structure of clean cooking stove & fuel technologies and business models, providing an entry point to help unpick a complex industry and support entry of new funding and implementing partners

Source: Greencroft Economics

The toolkit has been designed to provide a careful balance between flexibility and robustness:

Flexibility. It can be deployed to support a range of nuanced clean cooking business models and technologies. Many of the inputs to the toolkit can be changed by users, tailored to reflect business-specific context or more up-to-date information.

Evidence-based. It builds in second-party datasets and assumptions to provide pre-loaded insights, based on data analysis and assumptions informed by the stakeholder engagement and company data collected as part of this assignment.

Pragmatic. The toolkit does not attempt to predict the unit economics of a particular clean cooking venture's commercial journey. Nor does it represent a prescriptive requirement on how companies should record or account for their data. Rather, it provides a pragmatic bird's-eye view of some of the key elements that will affect a company's path to profitability and helps identify risks and opportunities to unit cost evolution.

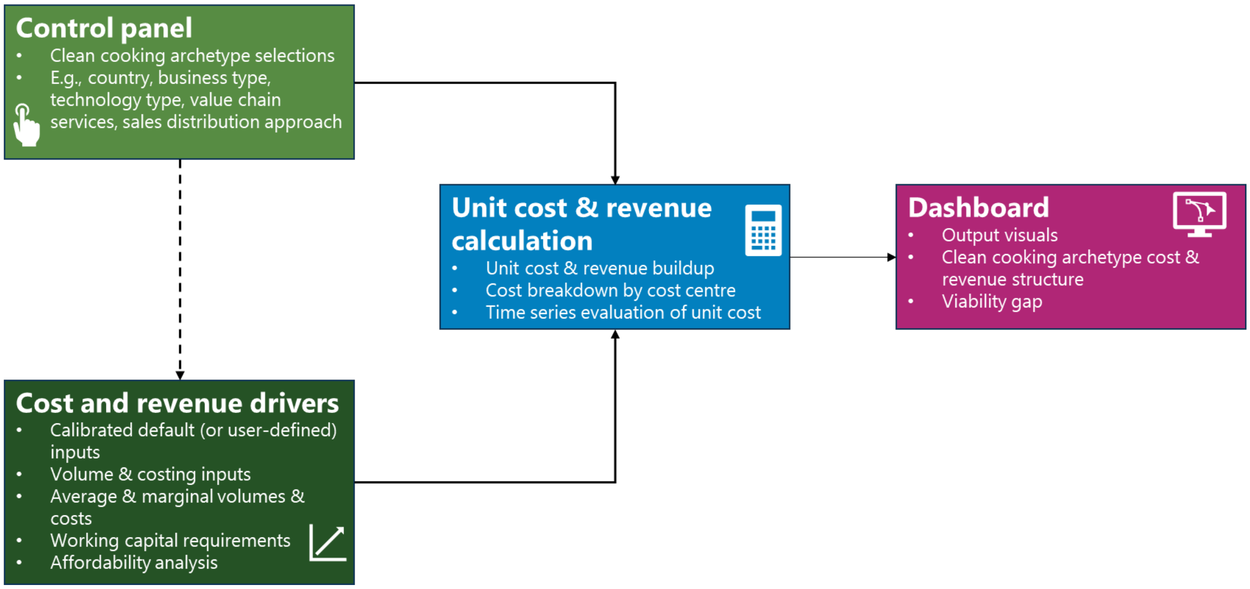
Figure 23: What the unit economics toolkit is and is not

What the unit economics toolkit ***is***:	What the unit economics toolkit ***is not***:
✓ A framework to structure, build evidence around, and provide an external benchmark of unit cost structures	✗ A full representation of the complexities and nuances of a specific business in a specific market context
✓ A simple quantitative tool, that draws on built-in data and a user-friendly interface to represent a range of clean cooking archetypes	✗ A precise estimation of exactly what costs should be in all conceivable circumstances for all conceivable technologies
✓ A flexible toolkit to support design of RBF and other financing facilities to bridge the gap between unit costs, and viable unit revenue	✗ A top-down requirement imposed on companies/investors
✓ Anonymized and confidential; calibrated to provide an industry benchmark and allow users to input bespoke data/selections	✗ A new and complicated accounting standard for all companies in the sector

Source: Greencroft Economics

A.2 Overview of structure and limitations

Figure 24: Logical flow of clean cooking unit economics toolkit



Source: Greencroft Economics

The toolkit is populated with inputs from third-party industry data and publicly available datasets. These have been used alongside assumptions informed by responses to the clean cooking unit economics survey that were collected between December 2022 and March 2023. However, the number and depth of responses was limited, and the depth of data available from the industry at present does not allow for a detailed disaggregation of the cost drivers of different technologies and business models in different country contexts.

The toolkit is intended to represent an illustrative notional company for each archetype — not a detailed due diligence of a specific company's context. It is adaptable to different country contexts. It should not be used to inform investment decisions in a specific venture, rather as a high-level benchmark of the economics of clean cooking companies in different contexts.

Mandatory and optional inputs

Depending on user selections on business models, some inputs are mandatory for unit cost calculations to be complete. These have been indicated as mandatory inputs to be populated in the control panel, with error messages included if a user-selection is required or if users make inconsistent selections.

The toolkit uses conditional formatting to grey-out selections that do not have to be made, depending on selections made elsewhere, and includes red error message tags if a user needs to update a selection before running the toolkit.

Some inputs are either optional or require data depending on the technology/fuel selected. These have been indicated on the control sheet and require the user to provide inputs on the detailed parameters sheet.

Before viewing the updated results on the dashboard, users should re-run the embedded macro by pressing the button at the top of the Control tab, as some calculations feeding into the model outputs are only updated when this macro is run.

Defining the urban-rural sales split

The toolkit disaggregates company operations between urban and rural areas to account for the difference in cost to serve populations in rural areas. This functionality is relevant when using the toolkit to compare the impact of sales expansion on unit costs.

The toolkit gives the user the option to:

- Calculated rural sales based on maxing out urban sales first in a given market context. This default setting assesses the limits of economies of scale and the diseconomies of scale as unit sales scale up.
- Alternatively the user can define the mix of sales to urban and rural areas. In this case the mix of urban and rural sales remains fixed as market penetration increases, so unit costs related to population density and remoteness do not change with scale.

The toolkit offers the user the opportunity to select the sales distribution approach. Within urban and rural areas, customers are distributed depending on the level of population density. Lower density populations are more costly to serve, which the toolkit accounts for. This selection gives the user the option to:

- Have all sales in urban or rural areas distributed across all density buckets of that region (urban or rural), or
- Have sales begin in the most densely populated segment of a region (urban or rural) and expand to lower density segments as default customer thresholds are reached.

This functionality is relevant particularly when comparing the impact of sales expansion. Some companies choose to start by serving areas that are easiest to reach, while other companies adopt a wider geographical coverage from the outset.

Average and marginal inputs

The model uses average and marginal cost drivers to calculate average and marginal unit costs. For some of the default inputs for which data is available, marginal cost driver inputs vary depending on volume variables (e.g., sales and distance). This allows the benefits of economies of scale at given inflexion points to flow through unit cost calculations.

However, user inputs on marginal values for cost drivers will not vary by volume and will impact only the estimate of marginal unit cost. Average unit cost will not be affected, as is the case with some of the default inputs.

A.3 Unit costs by cost center

Upstream costs

Stove technology cost is a user-defined upstream cost center. Default inputs are informed by secondary data (see tables below) to provide reasonable estimates for each technology type. However, upstream costs will vary depending on stove type, so users should input their own cost data estimates using selections on the detailed parameters tab.

For fuels, the upstream purchase cost center is relevant only for LPG. This is taken as the CIF. The default assumption in the toolkit is that the business models for all other fuels are based on local production, although a purchase price can also be inputted in lieu of a production cost. This assumption can be overridden by the user on the detailed parameters tab, as described further below.

Figure 25: Cost drivers of upstream purchase cost center

Cost driver	Description	Unit	Technology relevance	Use in cost buildup	Disaggregation	Source(s)
FOB cost per unit	Importing product cost prior to shipping	US$ per unit	Stoves	Direct cost	Technology	Financing appliances for end-users 2021, MECS; Scaling LPG for cooking in developing markets: insights from Tanzania 2019, CCA
CIF per unit	Importing product cost including cost of shipping	US$ per unit	Fuels (LPG)	Direct cost	Single input	ICE futures 2023

Source: Greencroft Economics

Shipping and transportation

The toolkit takes into account a range of transportation cost drivers across the value chain:

Shipping to port: The cost from port of departure to arrival at port of destination for imported products, calculated using shipping distances for typical routes. Users may select from pre-loaded product origins and destinations, such as Mombasa for Uganda or Lagos for Nigeria.

Trucking to centralized stocking warehouse: Overland transport is assumed to be carried out by trucks. Unit costs are estimated by container, with users able to select their own unit cost inputs for transportation. The default approach in the toolkit is to transport from a port to a centralized warehouse in the commercial city of each country, such as Kampala for Uganda, or Lagos for Nigeria. Users may amend the distances to centralized warehouse and unit warehousing costs.

Trucking from centralized warehouse to distribution center: This reflects the logistics for rural operations, with default distance and costs pre-loaded for each country, such as to the Nakasongola region in Uganda or to a secondary town like Kaduna in Nigeria. These costs sit in the in-land distribution cost center and activate only for rural sales.

Distribution from the distribution center to retail point: The final transportation step is transporting from warehouse to retail point. Distribution to retail points (stores or households) is captured from both the centralized warehouse for urban customers and from distribution centers for rural customers. Default inputs are used for distribution radius around warehouses, but users may tailor these toolkit inputs.

Shipping & border processes

Default inputs are in the model for shipping costs. This was informed by data from searates.com and includes the cost of shipping by volume and by distance, plus destination port handling costs. Costs are related to transportation via a 20-foot container for stoves.

The toolkit is populated with data on maritime distances between a wide range of international ports of origin and arrival in the focus countries. Shipping distances are used in model calculations depending on the country focus and import origin selections made by the user. User input is required to indicate the shipping size of the technology.

Border tariffs have been populated in the model based on general treatment of product imports. In practice, the tax rates experienced by companies may differ depending on trade agreements.

Figure 26: Cost drivers of shipping and border processes cost center

Cost driver	Description	Unit	Technology relevance	Use in unit cost buildup	Disaggregation	Source(s)
Shipping cost per cubic meter	Cost of ocean freight per km per cubic meter	US$ per km per cubic meter	Stoves	Calculation of shipping cost per unit	Single input	Informed by searates.com
Stove shipping size	Product shipping size	Cubic meters per unit	Stoves	Calculation of shipping cost per unit	Single input	Informed by Clean Cooking Catalog

Cost driver	Description	Unit	Technology relevance	Use in unit cost buildup	Disaggregation	Source(s)
Shipping distance	Bilateral maritime distances between port of origin and destination ports in the focus countries	km	Stoves	Calculation of shipping cost per unit	By country	CERDI-seadistance database 2016
Port discharge handling cost	Cost of cargo handling at destination port	US$	Stove	Calculation of discharge handling cost per unit	By country	Informed by searates.com
Border tariffs	Country rates for import duty, VAT, and other border tariffs	% CIF or other calculation basis	Stove, fuels (LPG)	% CIF or other calculation basis	By country	Descartes CustomsInfo database www.customsinfo.com/trade-gov/

Source: Greencroft Economics

In-country manufacturing/assembly/production

Default inputs are in the toolkit for labor costs based on ILO data. Costs are on an hourly basis and differ across countries.

Labor volume requirements differ depending on factors such as the archetype and number of sales. Where data is available, the toolkit accounts for the economies of scale with default inputs for labor hours depending on number of sales. Limited data on labor requirements across clean cooking archetypes means this has been done for a limited number of archetypes.

The toolkit contains default inputs for space cost. These are space rental rates, which differ depending on the country selected. As with other inputs, users are able to override these inputs with their own data.

Space area requirements also differ depending on archetype and scale of operations and is another area where economies of scale can be realized. Limited data means this primarily requires user input. Manufacturing hardware and operational costs also require user data.

Figure 27: Cost drivers of in-country manufacturing/assembly/production cost center

Cost driver	Description	Unit	Use in unit cost buildup	Disaggregation	Source(s)
Labor cost	Manufacturing/ production labor cost per hour	US$ per hour	Calculation of labor cost per unit	By country	ILO Labor Statistics
Labor volume	Manufacturing/ production labor hours required per unit sold	Hours per unit	Calculation of labor cost per unit	Calculated based on sales volume – stoves Single input – Biomass pellet fuel User input required for other fuels	Informed by industry data
Space cost	Industrial stock rental rates per sq.m per month	US$ per sq.m per month	Calculation of space cost per unit	By country	CBRE Excellerate Research
Space area	Space requirement per unit	Sq.m per unit	Calculation of space cost per unit	Single input – biomass pellet fuel User input required for other technologies and fuels	Informed by industry data
Product manu-facturing/ production cost	Operational cost per unit sold (excluding labor)	US$ per unit	Calculation of manufacturing / production cost per unit	For biomass pellet fuel – calculated based on sales volume. User input (US$ per unit) required for all other technologies	Informed by industry data
Hardware costs	Manufacturing/ production hardware depreciation cost per unit sold	US$ per unit	Direct cost	User input required	N/A

Source: Greencroft Economics

In-land distribution and logistics

Warehousing area requirements are calculated based on sales volumes and shipping sizes. Default data for warehousing costs have been included in the toolkit. These can be overridden by user inputs.

The cost of bulk storage is specific to LPG distribution only. The model calculates this cost using estimates of the proportion of storage costs in total cost from secondary data to calculate a cost per unit of fuel. The user is able to update this cost with a US$ per unit value in the detailed parameters sheet of the toolkit.

Trucking costs have been populated in the toolkit. For stoves, trucking costs vary depending on the distance to be transported, accounting for economies of scale in unit cost after a threshold distance. The toolkit is also populated with a default input for LPG tanker trucking. Inputs for trucking costs for other fuels will require user inputs.

Assumptions have been made regarding trucking distances and distribution radius for the purpose of this report. Users can tailor the inputs to match their specific context.

Figure 28: Cost drivers of in-land distribution and logistics cost center

Cost driver	Description	Unit	Technology relevance	Use in unit cost buildup	Disaggregation	Source(s)
Space cost	Industrial stock rental rates per sq.m per month	US$ per sq.m per month	Stove, fuels	Calculation of space cost per unit	By country	CBRE Excellerate Research
Space area	Warehousing space requirement per unit	Sq.m per unit	Stove, fuels	Calculation of space cost per unit	Calculated based on sales volume	N/A
Storage cost	Bulk storage costs for fuel imports	% of total cost	Fuels (LPG)	Calculation of storage cost per unit	Single input	Assumption informed by GLPGP Kenya Market Assessment 2013, Dalberg. Link
Cargo trucking cost	Trucking cost by cargo	US$ per km per unit	Stove	Calculation of land transport cost	Calculated based on distance travel	Informed by searates.com

Cost driver	Description	Unit	Technology relevance	Use in unit cost buildup	Disaggregation	Source(s)
Tanker trucking cost	Trucking cost by tanker	US$ per km per tonne	Fuel	Calculation of land transport costs	Single input (LPG) User input required for other fuels	Informed by Ihemtuge and Aimikhe 2020. Link
Trucking distance – port to urban	Trucking distance from port to urban centralized warehouse	km	Stove, fuels	Calculation of land transport cost	By country	N/A
Trucking distance – urban to rural	Trucking distance from centralized to distributed warehouse	km	Stove, fuels	Calculation of land transport cost	By country	N/A
Distribution radius	Distribution radius from warehouse to retail stalls	km	Stove, fuels	Calculation of distribution cost	Population density	Assumption

Source: Greencroft Economics

Population density and rural infrastructure cost-drivers

A population density distribution is built into the model based on UN gridded population of the world data. This is then used to allocate, on a 1km square grid basis, population into density according to population density buckets, as set out in Figure 28 below. The extent of the drivers in the right hand side column can be modified by users on the ‘Detailed Parameters’ tab.

Rural road access is captured using data from the Rural Access Index, available in different years for different countries and in some cases relatively dated. It provides an estimate for the share of the rural population living more than 2km from an all-season road. The default cost uprating is set to 20% of total (pre-consumer finance) costs, and this can be modified on the ‘Detailed Parameters’ tab.

Figure 29: Population density categories and cost drivers

Category	Population density per sq km	Multiplier on downstream cost-drivers
Extremely high density	More than 1,000 people per sq. km	n/a
High density	More than 500 people per sq. km	n/a
Moderate density	More than 250 people per sq. km	100%
Low density	More than 100 people per sq. km	200%
Extremely low density	Less than 100 people per sq. km	300%

Source: Greencroft Economics

Retail and after-sales services

The toolkit has been populated with default inputs for labor and space costs and volumes in retail as in the manufacturing cost center. Labor and space costs populated are specific to the retail sector across countries, although data is limited on costs outside of major cities. It is assumed that volume requirements are more similar in retail for stove sales, so estimates are applied to all stove archetypes. Default data is provided for volume requirements for LPG. Other fuels will require user inputs.

Default data is provided for marketing and communication costs based on limited data availability. User input is recommended given this cost is unique to specific business strategies, and is an important cost driver for early-stage businesses.

Figure 30: Cost drivers of retail and after-sales services center

Cost driver	Description	Unit	Use in unit cost buildup	Disaggregation	Source(s)
Labor cost	Retail labor cost per hour	US$ per hour	Calculation of labor cost per unit	By country	ILO Labor Statistics
Labor volume	Retail labor hours required per unit sold	Hours per unit	Calculation of labor cost per unit	Calculated based on sales volume — stoves and LPG User input required for other fuels	Informed by industry data
Space cost	Office stock rental rates per sq.m per month	US$ per sq.m per month	Calculation of space cost per unit	By country	CBRE Excellerate Research
Space area	Space requirement per worker	Sq.m per worker	Calculation of space cost per unit	As with labor volume	CBRE Excellerate Research
Marketing and comms	Marketing and communications cost per unit sales	% of total cost	Calculation of marketing and communications cost per unit	Single input – stoves, other fuels Single input – LPG	Assumption informed by Hystra Pricing Quality 2019; GLPGP Kenya Market Assessment 2013, Dalberg. Link

Source: Greencroft Economics

Carbon transaction costs

The cost of setting up a carbon finance program needs to be defined by users. There is space for both the upfront costs of setting up a carbon project and the ongoing running costs.

Financing costs

The toolkit estimates financing costs based on a set of user inputs. Calculations consider the cost of a working capital facility for inventory and receivables (where relevant) and the cost of bad debt from consumer finance offerings.

Figure 31: Cost drivers of company and consumer finance

Cost driver	Description	Unit	Technology relevance	Use in unit cost buildup	Disaggregation	Source(s)
Cost of working capital	Nominal interest rate for working capital loans	% of cost	Stove, fuel	Calculation of cost of working capital per unit	User input	N/A
Bad debts loss rate	Proportion of PAYGo sales write-offs	% of PAYGo sales	Stove	Calculation of cost of bad debt per unit	User input	N/A
Late repayment	Proportion of PAYGo sales repaid late	% of PAYGo sales	Stove	Calculation of cost of working capital per unit	User input	N/A
Average length of late repayment	Average number of months repayments overdue	Months	Stove	Calculation of cost of working capital per unit	User input	N/A
Inventory months	Average number of months inventory held before sold	Months	Stove, fuel	Calculation of cost of working capital per unit	User input	N/A

Source: Greencroft Economics

Overheads

The toolkit has been populated with default values for overheads as a proportion of unit cost. Overheads includes labor and space costs, but also the cost of R&D, which tends to be company-specific. The cost of overheads as a proportion of total costs is assumed to fall gradually once a scale of around 100,000 in annual sales is achieved.

Figure 32: Cost drivers of overheads cost center

Cost driver	Description	Unit	Technology relevance	Use in unit cost buildup	Disaggregation	Source(s)
Overheads	Overheads cost per unit	US$ per unit	Stove, fuel	Proportion of unit cost	N/A	N/A

Source: Greencroft Economics

A.4 Revenue-generating potential

The toolkit includes a default demand curve built based on modeled ability to pay. This is built up to provide a distribution across the household market per country, adapted for different customer segments in each country.

To build a proxy demand curve, consumption expenditure patterns are combined with income per capita. The default illustrative demand curves are built up using consumption expenditure distributions from PovcalNet to define the shape of the curve and the most recent GNI per capita data to define the overall level of ability to pay. Adjustments are made for average household size.

Note that the demand curve considers only the ability, not the willingness, to pay. Ability to pay is determined by disposable income, while willingness to pay would reflect consumer *preferences* and would be affected by the availability and price of alternatives, such as cheaply collected or freely accessible firewood, and any other cooking technologies available in the local market other than the archetype selected in the toolkit. There is no information included in the toolkit on the availability or pricing of such alternatives.

Users may override the default. To do this, a user needs to define the ability to pay per month for its customer base, by decile (each 10^{th} percentile).

The core assumptions and steps in the ability to pay analysis are:

- The amount of monthly expenditure that can be allocated to paying for cooking technologies is 5%–8% per month. This is based on previous reviews of energy access expenditure thresholds (see, for example, the Off-Grid Solar Market Trends Report 2022), adjusted down slightly to reflect that clean cooking is just one part of energy access, alongside expenditure on electricity access.
- For stove systems where the full price is paid upfront, it is assumed that customers save up to three months of disposable income that can be allocated to energy access.
- For monthly payments, i.e., for consumer or asset finance stove sales and for fuel, the 3% and 8% thresholds are used.

Figure 33: Data used in ability to pay assessment

Indicator	Description	Unit	Source(s)
GNI per capita	Used to set the average ability to pay, to calibrate the level of the demand curve	US$ per person	World Development Indicators, GNI per capita
Consumption expenditure	Used to set the shape of the demand curve, for each point in the percentile distribution from 1 to 100	US$ per person	PovcalNet consumption expenditure distributions
Household size	Used to convert ability to pay per person into household units	# people per household	United Nations Population Division 2022

Source: Greencroft Economics

A second source of revenue captured in the toolkit is from the sale of credits in carbon markets. The tool allows users to input a carbon price and a volume of carbon credits generated per unit, with defaults in the toolkit based on industry averages. Note that the toolkit does not predict prices, nor credits generated per unit, for different technology types.

The toolkit does not estimate the value of other impacts that access to clean cooking technologies can deliver. The evidence in the sector is at a very early stage, and experience in pricing these outcomes is very limited. This could be added to future versions of a unit economics toolkit, as more information becomes available about the potential volume and pricing of these outcome markets.

About Greencroft Economics

Greencroft Economics is a boutique economic consultancy, founded in 2019, to advise public and private sector clients on sustainable development in emerging economies.

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