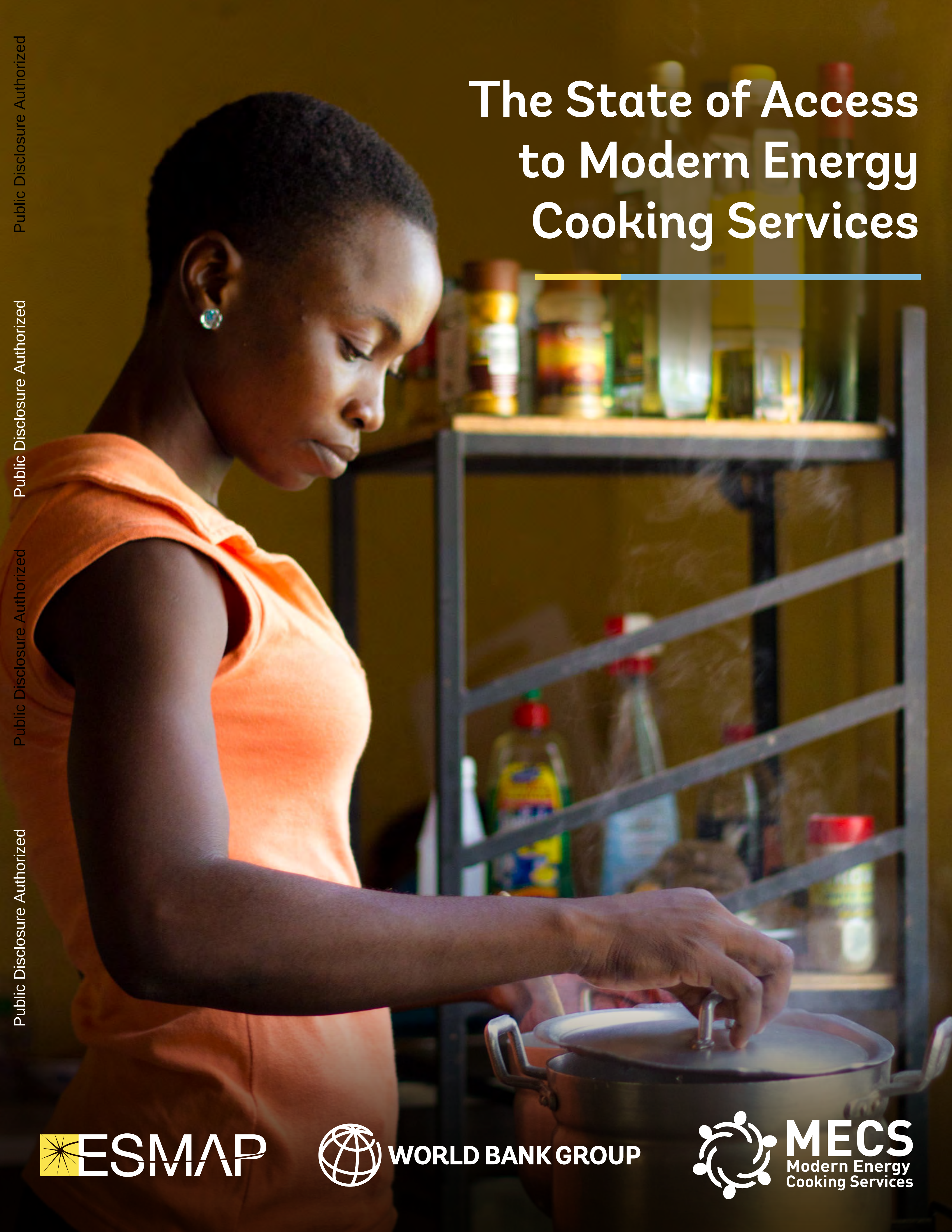

The State of Access to Modern Energy Cooking Services

ESMAP

WORLD BANK GROUP

MECS
Modern Energy
Cooking Services

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ABOUT ESMAP

The Energy Sector Management Assistance Program (ESMAP) is a partnership between the World Bank and development partners and private nonprofit organizations that helps low- and middle-income countries reduce poverty and boost growth through sustainable energy solutions. ESMAP's analytical and advisory services are fully integrated within the World Bank's country financing and policy dialogue in the energy sector. Through the World Bank Group (WBG), ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG 7) to ensure access to affordable, reliable, sustainable, and modern energy for all. It helps to shape WBG strategies and programs to achieve International Development Association (IDA) policy commitments and the WBG Climate Change Action Plan targets.

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This report is dedicated to the work and memory of Kirk R. Smith. He was a pioneer in the field of environmental health, household air pollution, and clean cooking. Through his commitment, Professor Smith raised this field to the global agenda, sparking action and inspiring countless researchers, policy makers, and practitioners.

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The State of Access to Modern Energy Cooking Services is a product of the research efforts implemented under the Modern Energy Cooking Services (MECS) Program, a five-year initiative funded by UK Aid of the Foreign, Commonwealth and Development Office (FCDO) and led by Loughborough University and the World Bank's Energy Sector Management Assistance Program (ESMAP). The MECS Program aims to accelerate the global transition from traditional biomass-based cooking to modern-energy cooking solutions. Following on the 2015 report, *The State of the Global Clean and Improved Cooking Sector,* led by ESMAP and the Clean Cooking Alliance [formerly Global Alliance for Clean Cookstoves], this second global report, also led by ESMAP, in collaboration with Loughborough University and the Clean Cooking Alliance, presents newly compiled evidence and insights to guide continued sector progress toward achieving the UN Sustainable Development Goal (SDG) Target 7.1 for 2030.

This report was prepared under the overall guidance of ESMAP's Program Manager, Rohit Khanna. The project team was led by Yabei Zhang and comprised Laurent Durix, Alisha Pinto, Caroline Adongo Ochieng, Jingyi Wu, and Yuhan Wang from ESMAP, Ed Brown and Simon Batchelor from Loughborough University, and Peter George and Donee Alexander from the Clean Cooking Alliance. Dalberg Advisors (www.dalberg.com) acted as the consultants for the report. The Dalberg team was led by Oren Ahoobim, Michael Tsan, and Marcos Paya and comprised Pooja Singhi and Scott Fanuzzi, with external consultant support from Brady Seals, Manuel Oviedo, and Jesse Lichtenstein.

The report relied on input from a wide cross-section of World Bank staff, as well as numerous industry experts, manufacturers, distributors, policy makers, and nongovernmental organizations. This input included interviews with a broad range of global players in the clean and improved cooking sector and across the modern energy spectrum. The project team extends special thanks to the following individuals for their valuable review and technical inputs: Shrikant Avi, Kip Patrick, and Amy Todd (Clean Cooking Alliance); Christine Eibs-Singer and Olivia Coldrey (Sustainable Energy for All); Kimball Chen and Alex Evans (Global LPG Partnership); Elisa Puzzolo (University of Liverpool); Frank van der Vleuten (Netherlands Ministry of Foreign Affairs); Marcel Alers (United Nations Development Programme); Minoru Takada (United Nations Department of Economic and Social Affairs); Marcel Raats and Bianca van der Kroon (Netherlands Enterprise Agency); Sheila Oparaocha (ENERGIA/Hivos); Nathalie Laure Roebbel, Heather Adair-Rohani, and Jessica Lewis (World Health Organization); and Seraphine Haeussling, Sandra Cavalieri, and Yekbun Gurgoz (Climate and Clean Air Coalition).

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ABBREVIATIONS

ALRI	acute lower respiratory infections
ARI	acute respiratory infections
BC	black carbon
CCA	Clean Cooking Alliance
CCAC	Climate and Clean Air Coalition
COPD	chronic obstructive pulmonary disease
DfID	See FCDO
DHS	Demographic and Health Survey
efNRB	expected fraction of non-renewable biomass
EPC	electric pressure cooker
ESMAP	Energy Sector Management Assistance Program
FCDO	Foreign, Commonwealth and Development Office (merged Foreign and Commonwealth Office and Department for International Development [DfID])
GBD	Global Burden of Disease
GBV	gender-based violence
GCF	Green Climate Fund
GOGLA	Global Off-Grid Lighting Association
HAP	household air pollution
HEPA	Health and Energy Platform of Action
HLPF	High-Level Political Forum
ICS	improved cookstove
IEA	International Energy Agency
IoT	Internet of Things
ISO	International Organization for Standardization
LNG	liquefied natural gas
LPG	liquefied petroleum gas
M&E	monitoring and evaluation
MECS	Modern Energy Cooking Services
MICS	Multi-Indicator Cluster Survey
MTF	Multi-Tier Framework
PAYGo	pay-as-you-go
PM	particulate matter
R&D	research and development
RBF	results-based financing
SDG	Sustainable Development Goal
SEforALL	Sustainable Energy for All
SHS	solar home system

CLARIFICATION OF KEY TERMS

Clean cooking solutions—Fuel-stove combinations that achieve emissions performance measurements of Tier 4 or higher following ISO/TR 19867-3:2018 Voluntary Performance Targets (VPTs), which refer to the World Health Organization's 2014 guidelines for indoor air quality.

Modern Energy Cooking Services (MECS)—Refers to a household context that has met the standards of Tier 4 or higher across all six measurement attributes of the Multi-Tier Framework: convenience, (fuel) availability (a proxy for reliability), safety, affordability, efficiency, and exposure (a proxy for health related to exposure to pollutants from cooking activities).

Multi-Tier Framework (MTF) for cooking—Multidimensional, tiered approach to measuring household access to cooking solutions across six technical and contextual attributes with detailed indicators and six thresholds of access, ranging from Tier 0 (no access) to Tier 5 (full access). The aggregate MTF tier is the lowest tier rating across the six attributes (Annex 1).

Improved cooking services —Refers to a household context that has met at least Tier 2 standards of the MTF across all six measurement attributes but not all for Tier 4 or higher. Household contexts with a status of MTF Tier 2 or Tier 3 are considered in **Transition.**

EXECUTIVE SUMMARY

How we guide progress toward achieving access to modern-energy cooking solutions for all is more critical than ever before. To date, measurements of access have focused primarily on fuel penetration, overlooking many of the contextual factors that shape users' adoption of stoves and fuels. Over the past decade, much attention has focused on expanding access to "clean" cooking solutions, defined by the technical attributes of combustion and heat-transfer efficiency and emissions. However, the 2020 *Tracking SDG 7: The Energy Progress Report* finds that the annual increase in access to clean cooking fuels and technologies between 2010 and 2018 averaged just 0.8 percentage points. In Sub-Saharan Africa, population growth outpaced the annual growth in access. Most progress was in urban areas, with rural areas continuing to fall behind. Clearly, without a more complete understanding of the local context of cooking—including users' cooking experience, their physical cooking environment, and the markets and energy ecosystems in which they live—the uptake and sustained use of the stove technology-and-fuel solutions available today will remain limited.

Not progressing beyond the status quo is costing the world more than US$2 trillion each year. The recent outbreak of the coronavirus disease (COVID-19) underscores the interlinkages between traditional cooking, gender, health, and the environment. Exposure to air pollution is a known risk factor for underlying chronic diseases that are predictive of the severity and outcome for COVID-19 patients. This linkage suggests a heightened risk for women across all age groups who cook using traditional technologies and fuels. Because the UN Sustainable Development Goals (SDGs) are cross-cutting, slow progress in meeting the 2030 SDG 7.1 target—ensuring universal access to affordable, reliable, and modern energy services—hinders progress toward meeting the SDG targets for health, gender equality, and climate, among others. Women and children account for most of the estimated 4 million premature deaths that occur each year from household air pollution (HAP) linked to cooking with traditional stoves and fuels.[1] The health-impact portion alone is estimated at US$1.4 trillion per year. Women bear a disproportionate share of the cost of inaction in the form of poor health and safety, as well as lost productivity, which is estimated at US$0.8 trillion annually. In addition, cooking with high-emissions stove technologies with fuels sourced from non-renewable biomass contributes to environmental degradation and adverse climate impacts, estimated at US$0.2 trillion per year.

FROM BINARY TO CONTEXTUAL ACCESS MEASUREMENT

To date, the Sustainable Development Goal (SDG) 7.1.2 indicator, access to clean fuels and technologies for cooking, has been measured using a proxy of whether households cook primarily with "clean" fuels. While this binary approach has remained the official method for tracking SDG 7 and is also used in this report to estimate the cost of inaction (chapter 2), the growing consensus among practitioners is that measurement of access should reflect a continuum of improvement that focuses not only on fuels but also other attributes of the cooking system that reflect the user's context and cooking experience. The approach of the International Organization for Standardization (ISO), for example, goes beyond the efficiency and emissions attributes of the World Health Organization's guidelines for indoor air quality,[2] providing guidelines for cookstove safety and durability. While an important step forward, the ISO approach is technocentric and does not integrate the cookstove user's experience. Yet, users' needs and preferences, along with their context while cooking, can have a large impact on cookstove uptake and should therefore be integrated into the design of cooking interventions.

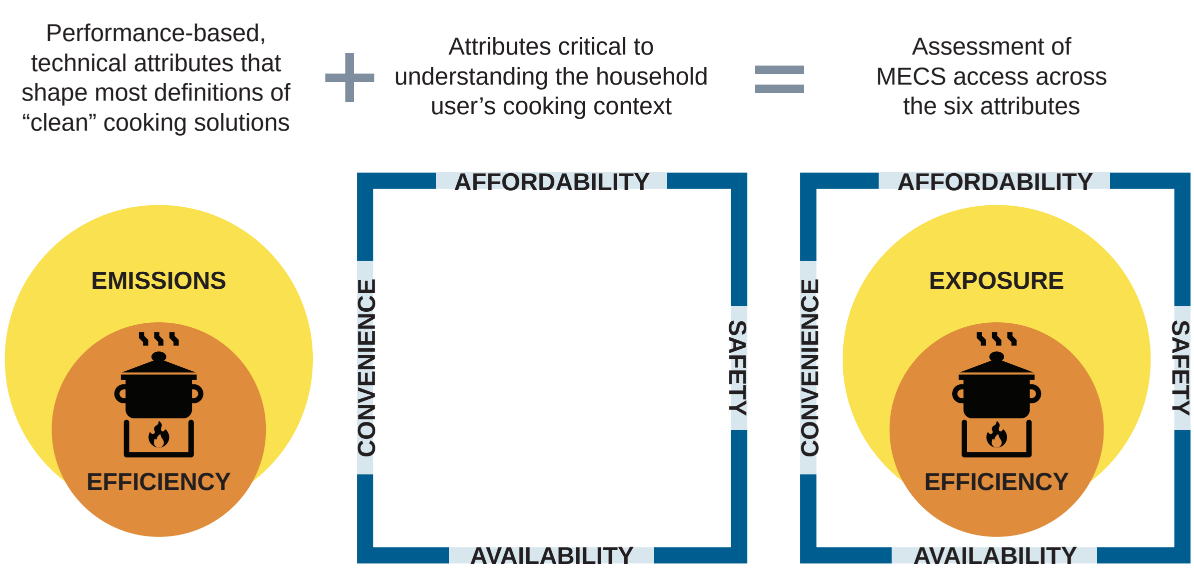
Accelerating progress requires rethinking how households access modern cooking energy so that solutions are better aligned with users' priorities. To break the impasse, the World Bank's Energy Sector Management Assistance Program (ESMAP), in collaboration with Loughborough University and in consultation with multiple development partners, including the Clean Cooking Alliance (CCA), has developed and applied a comprehensive way of measuring progress toward access to modern cooking energy for all. Its broadened, contextual definition of access, termed *Modern Energy Cooking Services (MECS),* draws on the approach of the World Bank's Multi-Tier Framework (MTF) for cooking, which offers a formal tool for integrating holistic criteria on users' needs and preferences into the measurement of access (figure ES.1).

The MTF captures detailed, indicator-level data for tracking stepwise progress across tiers of access. This information encompasses various individual and multiple cooking solutions (i.e., "stacking"), user behavior, and cooking-environment conditions, as well as convenience and safety aspects. Based on the MTF's multidimensionality, a household that meets the standards of Tier 4 or higher across all six measurement attributes can be considered to have gained access to MECS, while one that scores at least Tier 2 but not Tier 4 or higher across all six attributes is considered in transition, with access to improved cooking services (box ES.1).

The framework allows for disaggregate and aggregate analyses that can yield detailed information about various parameters and indexes that facilitate comparison over time and across geographic areas. Thus, it not only enables tracking of progress toward access to MECS to complement the current approach of tracking SDG 7.1.2.[3] It also provides sufficient detail for understanding contextual household-level impact and setting sectorwide aspirations.

Utilizing these analytical tools, this report presents newly compiled evidence and in-depth insights. These can contribute to better-informed sector decision-making and the design and delivery of more effective solutions that accelerate progress toward meeting the aspirations of the SDG 7.1 target.

FIGURE ES.1 Holistic Criteria to Measure Access to Modern Energy Cooking Services



Note: "Exposure" considers the contextual factors of ventilation and contact time, in addition to the technical attribute of "emissions."

BOX ES.1 Key Definitions for Measuring Access

Modern Energy Cooking Services (MECS)—Refers to a household context that has met the standards of Tier 4 or higher across all six measurement attributes of the Multi-Tier Framework (MTF) (figure BES.1.1):

Exposure Personal exposure to pollutants, which depends on both stove emissions and ventilation (higher tiers indicate lower exposure)

Efficiency Combination of combustion and heat-transfer efficiency

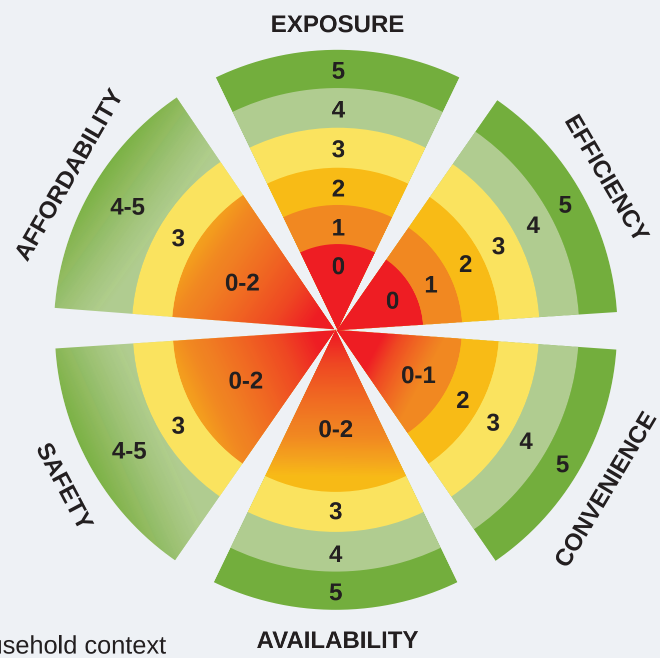
Convenience Time spent collecting/purchasing fuel and preparing the stove

Safety Severity of injuries caused by the stove over the past year

Affordability Share of household budget spent on fuel (higher tiers indicate lower share of spending)

Availability Readiness of the fuel when needed by the user

FIGURE BES.1.1 MTF Attributes, Showing Tiered Progress toward MECS Access



Improved Cooking Services Refers to a household context that has met at least the Tier 2 standards of the MTF across all six measurement attributes but not all for Tier 4 or higher (figure BES.1.1). Household contexts with a status of MTF Tier 2 or Tier 3 are considered in **Transition.**

Source: World Bank.

Note: Each attribute is scored across six tiers (0–5), and the tiers are measured using one or more indicators, each spanning a lower and upper threshold.

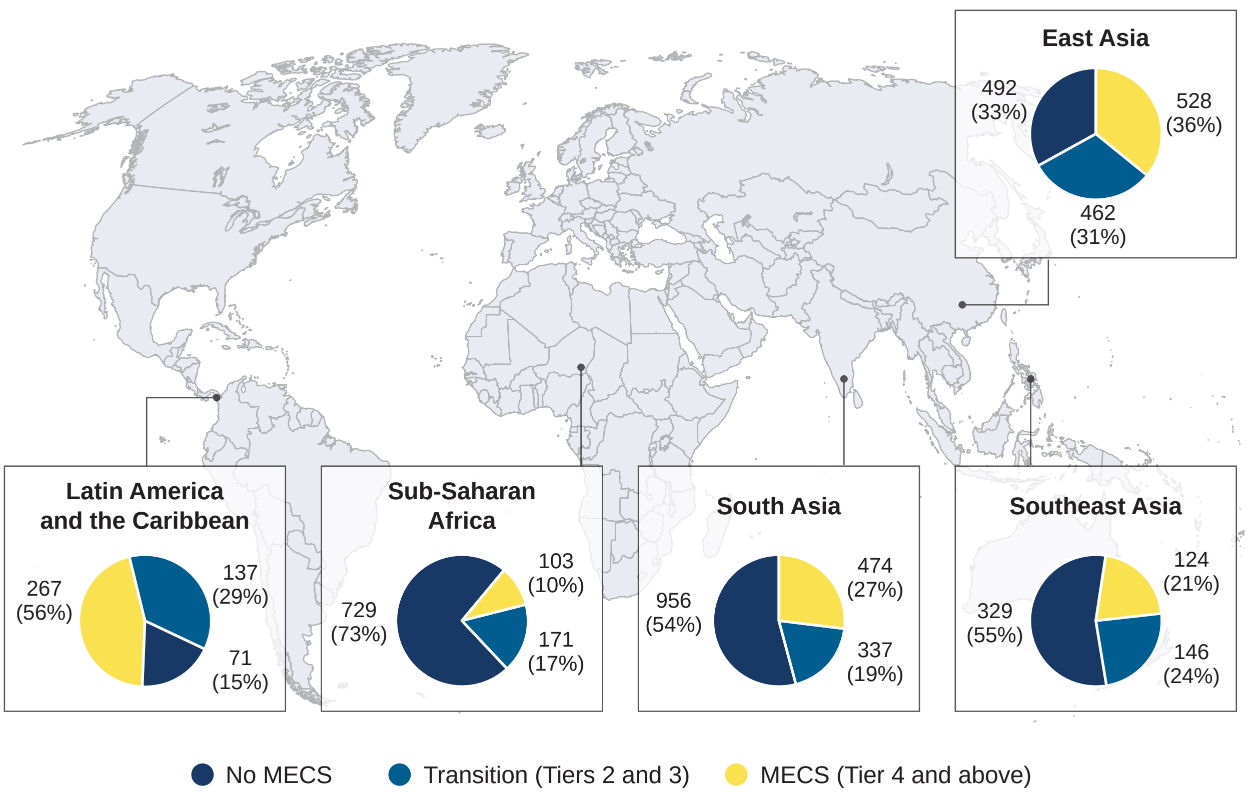
WHAT HAVE WE LEARNED?

Using the MECS definition and a more detailed, household-level dataset, this report estimates for the first time that 4 billion people are without access to MECS. Based on a 71-country sample of 5.3 billion people representing 90 percent of lower- and lower-middle-income countries, this report finds that some 4 billion people—about half of the global population—lack the ability to cook efficiently, cleanly, conveniently, reliably, safely, and affordably. Sub-Saharan Africa has the smallest share of people with access to MECS, at 10 percent, while Latin America and the Caribbean and East Asia have the highest shares, at 56 percent and 36 percent, respectively (figure ES.2).

Among those without access to MECS in the study sample, 1.25 billion are considered in transition, while the rest face significant access barriers (figure ES.2). Households in transition are defined as those that currently meet at least the Tier 2 MTF standards across all six measurement attributes, but not all for Tier 4 or higher. Deploying targeted investments and support to those in transition could jump-start progress across this spectrum of access and lead more quickly and effectively toward the achievement of access to MECS by 2030.

FIGURE ES.2 Population Access to MECS, by Developing Region

Millions of people and tier %
N = 71 countries



Sources: World Bank MTF country datasets, Demographic and Health Surveys (DHSs), Multi-Indicator Cluster Surveys (MICSs), and Task Team analysis.

New in-depth datasets from the MTF household surveys and multi-country studies, including attitudinal questions, allow sector stakeholders to dig deeper into the "hows" and "whys" of adoption of modern cooking services. In-depth data makes it possible to understand stacking behavior (i.e., use of multiple stoves and fuels in the same household) and thus be able to distinguish between the negative trend of "dirty" stacking with polluting, traditional stoves and fuels and the high potential of "clean" stacking. Even in countries where clean-fuel penetration is relatively strong, affordability and availability factors may drive users, particularly in rural areas, toward less clean, secondary solutions. In Nepal, for example, this report finds that 58 percent of rural households that use liquefied petroleum gas (LPG) as their primary cooking fuel supplement its use with a traditional stove. In rural Myanmar, up to 57 percent of rural electricity users stack with three-stone fires. That said, clean-stacking behavior, which occurs when traditional stove users try modern fuels, can potentially yield positive near- and longer-term results. Specifically, stacking with cleaner stove-fuel combinations—even for such small cooking tasks as boiling water for tea or refrying—represents less use of a lower-tier alternative. And experimentation with lower-emissions solutions may facilitate learning and increase the likelihood of adoption over the longer term.

Obstacles to Progress

This report finds that progress toward universal access to MECS has been hindered by a lack of interventions and solutions that are fully responsive to the underlying needs of lower-income and rural households. In many countries, this situation is driven by a combination of higher up-front capital costs, low household awareness, and low availability of fuels, owing, in part, to underdeveloped infrastructure. While the number of households accessing such fuels as LPG and electricity has grown over the past decade, the absolute number of people cooking with wood fuels, charcoal, and coal has also increased. This is due, in part, to access interventions not keeping pace with population growth in communities that primarily use biomass and charcoal in traditional stoves that burn fuels inefficiently. While the use of wood as a primary fuel has declined significantly, it remains a major source of household energy across the world (35 percent in this 71-country sample). Most clean-fuel gains can be attributed to large, government-driven fuel transition programs, but the continued availability, perceived affordability, and accessibility of biomass fuels exacerbates the access challenge. Even in rapidly urbanizing settings, users continue to make behavioral trade-offs with their time, health, and safety in order to use the accessible and affordable traditional cooking alternatives.

Slow progress also reflects the fact that the cooking ecosystem—for both supply and demand generation—is complex and fragmented. Based on the Clean Cooking Alliance (CCA) database, the number of fully-dedicated, active manufacturers and distributors in the cooking-operations chain across the world totals 400–500, with approximately 10 percent of enterprises collectively responsible for upwards of 40 percent of stove sales. Across the cooking space, it is difficult to find businesses that have reached volumes that enable economies of scale. In Sub-Saharan Africa, for example, only 15 alternative biofuel businesses (e.g., ethanol and pellets)—less than 18 percent of the estimated active number—consistently supply more than 5,000 households with cooking fuel; just 7 businesses (less than 8 percent) reach over 20,000 households, while only 1 claims to reach more than 100,000 customers on a regular basis (2017 figures). Across other cooking-solution categories, only a handful of players have successfully cracked the 200,000 stove mark, largely as a result of integrating production (e.g., through an owned factory). A variety of demand-stimulation interventions continues to drive the uptake of clean cooking solutions. However there remains a dearth of knowledge and a lack of consensus on what behavior-change approaches can spur adoption of clean cooking solutions once the supply-side challenges are tackled.

Lack of an enabling environment—along with the absence of "champions" and intergovernmental coordination—has also hindered progress. For example, for cooking industry suppliers looking to achieve greater penetration of clean fuels and high-efficiency, low-emissions technologies, the fiscal and trade environment is a significant, ongoing obstacle. High taxes and misaligned tariff codes, in particular, are hindering industry growth and dampening product adoption. In the early stages of market development when local supply is inadequate, poorly calibrated tax and tariff regimes make it especially difficult to import fuel-production equipment, quality stoves and components, and clean fuels. In many contexts, LPG is stored as a liquid, but taxed as a gas, which limits the opportunity for more efficient global value chains and impedes players from adequately storing and reliably supplying fuel. In addition, clean biofuels like ethanol and formally distributed pellets and briquettes nearly always face sales taxes (i.e., value-added tax) and, in many cases, high levels of import duty. For example, in many African countries, denatured ethanol faces duties in a range of 5–25 percent.

Moreover, the lack of coordination within and between institutions in country contexts has stymied cooking interventions from becoming high-impact policy priorities. Multiple countries in Sub-Saharan Africa—where financing could potentially have the greatest impact—have seen financing commitments more than halved. This challenge is exacerbated by the cross-cutting nature of cooking policy and interventions; that is, truly holistic solutions require the participation of stakeholders across multiple sectors, ranging from energy, health, climate, industry, and finance to rural and urban development, gender, and social protection, among others. In addition, many countries are still without clear access targets for cooking. While governments may include accelerating access to modern cooking energy in their policy agendas, they often lack the required institutional leadership and incentives for making major progress. Furthermore, a lack of integrated energy planning often isolates electrification programs from cooking policies and interventions.

Encouraging Trends

Accounting for and leveraging the "bright spots" identified in this report are urgently needed to overcome the slow and, in some regions, stagnant progress to date. Positive trends include greater penetration of clean fuels and clean stacking patterns. Within this report's 71-country study sample, electricity accounts for 10 percent of the global share of cooking fuels, while LPG, natural gas, and biogas comprise another 37 percent. These gains for clean fuels have come at the expense of coal and kerosene, which have seen relative declines. Increasing levels of urbanization and generationally-linked behavior change (a younger demographic showing higher preference for clean cooking solutions) are likely to accelerate the use of both primary and secondary clean fuels within households, which can facilitate the transition away from harmful and gradually price-uncompetitive options, such as charcoal. Urban households across income quintiles are facing higher charcoal prices, while the affordability of LPG, electricity, ethanol, and biomass pellets is improving. New business models, including decentralized ethanol distribution, pay-as-you-go (PAYGo) models for LPG distribution, and microcredit, have seen growing success, particularly in urban and peri-urban settings; these are opening up channels for increased accessibility, reliability, and affordability of MECS.

In addition, greater institutionalization development in the cooking space and a growing commitment to increasing sector financing are encouraging trends for expanding MECS access. The progression of sector dialogue since the establishment of the SDGs points to a space where donors, development partners, policy makers, and enterprises, among many players, are brought closer together with a more consistent focus on outcomes (figure ES.3).

Among the players long involved in funding cooking interventions, financial resources are moving in the direction of access to MECS. High-profile, results-based financing (RBF) programs include the World Bank's recently announced US$500 million Clean Cooking Fund, housed under the Energy Sector Management Assistance Program (ESMAP). The Clean Cooking Fund will offer RBF grants, primarily at national and subnational scale, to help countries incentivize the private sector to deliver MECS. The World Bank's Carbon Initiative for Development (Ci-Dev) Facility and the Netherlands Enterprise Agency's RVO SDG 7 Partnership Facility also aim to attract private-sector financing to deliver MECS or improved cooking services. In the United Kingdom, the Foreign, Commonwealth and Development Office's MECS Challenge Fund supports

FIGURE ES.3 Key Sectorwide Milestones, 2014–19

August 2014
The first WHO conference on Health and Climate closely integrates two critical global issues and narratives.

May 2015
ESMAP and the CCA publish the report, *The State of the Global Clean and Improved Cooking Sector.*

July 2015
The World Bank and SEforALL conceptualize a new Multi-Tier Framework for defining and measuring access to energy, including a multi-attribute matrix for measuring access to cooking solutions.

September 2015
UN Sustainable Development Goal 7 calls for access to affordable, reliable, sustainable, and modern energy for all.

June 2018
The ISO publishes the International Standard on clean cookstoves and clean cooking solutions.

April 2019
The five-year, Department for International Development (DfID)–funded Modern Energy Cooking Services (MECS) Program is launched.[a]

May 2019
Launching of the Health and Energy Platform of Action at the 72nd World Health Assembly strengthens cooperation between the health and energy sectors.

September 2019
The World Bank's Clean Cooking Fund is launched during the high-level event on the energy transition track of the UN Climate Action Summit.

November 2019
The Clean Cooking Forum in Nairobi brings together donors, development partners, enterprises, researchers, and policy makers to chart a course for the sector.

Source: World Bank.

a. On September 2, 2020, the Department for International Development (DfID), which functioned as a ministerial department since May 1997, merged with the Foreign and Commonwealth Office to create the Foreign, Commonwealth and Development Office (FCDO).

early-stage research to stimulate innovation in modern-energy cooking technologies and systems, as well as the advancement of technology-based cooking-energy products, processes, and services in low-income countries. The Clean Cooking Alliance's Cooking Industry Catalyst program provides seed funding and capacity building to increase the pipeline of investment-ready companies that design, manufacture, and sell clean cooking solutions in developing countries around the world. Beyond the traditional cooking space, but critical to accelerating modern energy uptake, the consolidation and expansion of funds focused on climate-change mitigation and renewable-energy access, including the Green Climate Fund and the Africa Climate Change Fund, among many others, can help open new avenues for better integration of cooking objectives within broader energy policy. The potential for integration also exists within governments and with donors allocating resources to health, gender-equality, and social-protection interventions.

Need for Least-Cost, Best-Fit Approach to Accelerate MECS Access

A more in-depth, user-centered understanding of cooking contexts, underpinned by recent structural advances and technology innovations, should inform a least-cost, best-fit approach. National roadmaps for MECS access should reflect transition pathways based on users' needs and local market realities. A more detailed understanding of households' local cooking context (e.g., fuel-and-stove usage and spending/purchasing patterns, product functionality, and cooking location, among other factors) must be used to inform the development of services and infrastructure that help accelerate progress toward MECS access.

This means using granular household cooking data as an input for broader, national-level energy decision-making—a process that capitalizes on energy-system investments, incentives for clean energy consumption, and trade and energy investment policies that best leverage national comparative advantages. In geographies where broad-based electrification programs are already under way, this may mean accelerating the transition to electric cooking. In the context of enhanced LPG access, it may mean a push toward efficient gas cooking. In still other settings, where incentives for producing and distributing ethanol or highly efficient gasification technologies are in place, it may mean spurring alternative biofuel use. In short, a least-cost, best-fit approach can best address the urgent challenge of achieving access to MECS as 2030 quickly approaches.

With this more complete understanding of cookstove users comes a recognition of the inherent and potential limits of purely market-based solutions. While private sector–driven innovation should be encouraged, taken alone, current stove and fuel services, which remain subscale and underfinanced, will not ensure universal access to MECS by 2030. Most businesses in the space remain unprofitable and have yet to reach scale. An analysis of the current industrial stove market, limited to those supplying clean stove-and-fuel combinations, reveals that the cooking space currently features approximately 50 consistently profitable and stable, cooking-focused businesses or approximately 10 percent of the total formalized industry. In addition, total financing levels remain critically low. Investors and funders have been unwilling to provide a critical mass of capital to the modern-energy sector owing, at least in part, to the perceived riskiness of these enterprises. Grant volumes are small, and a critical share of the non-grant financing in the cooking space is poorly adapted to the volumes or financial structures needed by businesses in the sector. Moreover, innovative financing instruments (e.g., carbon finance) fail to reach their beneficiaries at the right time.

Despite these industry challenges, advances in technology and commercial innovation have made sector scalability and growth a potential reality. Recent advances across a range of technologies, aided by the introduction of new payment and financing approaches, are helping to make MECS more affordable for many more households. While not exhaustive, pellet-gasifier stoves, electric pressure cookers, and bottled ethanol are all examples of important innovations in making MECS increasingly accessible. Equally significant, such business models as PAYGo for LPG and biogas/gasification, microfinancing for LPG, and distribution partnerships/bundling with off-grid solar companies are transforming the way that end-user consumers are progressing toward MECS access.

Given the nascent state of market-based solutions, steep affordability gaps, and high negative externalities associated with limited access to MECS, a good case can be made for public support to underserved populations. A combination of enabling policies, including results-based incentives and targeted infrastructure investments (notably in the generation, transmission, and distribution of clean energy), will prove essential for accelerating access to MECS, particularly in rural settings, as nascent product and fuel markets develop. These should be supplemented by expansive behavior-change campaigns that take a systemwide approach to MECS adoption and adherence (e.g., by underscoring the benefits of improved ventilation and the lifetime value and impact of using highly efficient stove-and-fuel combinations). Ultimately, public support, in the form of policies, incentives including direct subsidies, and infrastructure investments, can pave the way for market-based approaches where access gaps are largest and market failures are most acute.

MOVING THE SECTOR FORWARD

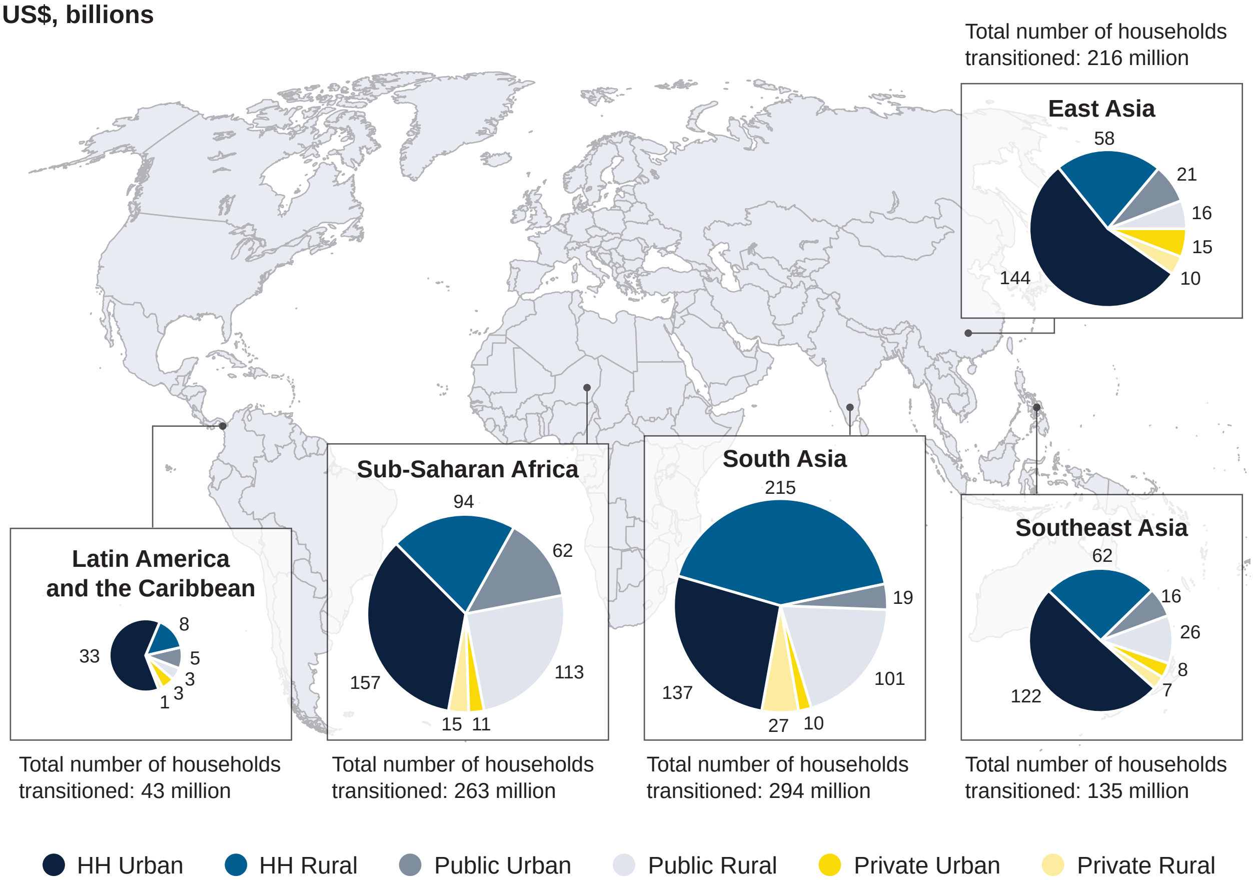
Without evolving beyond the status quo, the goal of universal access to MECS will remain out of reach for 4.5 billion people by 2030. Based exclusively on expected population growth and urbanization over the next decade, a majority of the populations in Sub-Saharan Africa, South Asia, and Southeast Asia would be expected to remain below Tier 2 in 2030. In Sub-Saharan Africa, for example, this would amount to nearly 400 million more people without access to improved or modern cooking solutions. This disappointing potential reality not only points to the size of the 2030 access challenge; it also underscores the need to intentionally mobilize solutions at significant scale.

Transitioning to Greater Access

This analysis estimates the total cost of transitioning to universal MECS access by 2030 at approximately US$1.5 trillion, or US$148–156 billion annually over the next 10 years. This analysis, the MECS Scenario, builds on a 2030 forecast and segmentation of the population not expected to reach MTF Tier 4 or higher, based on current policies. Achieving universal access implies a significant transformation of the current energy systems to meet the requirements needed to lift all households currently at Tiers 0–3 to at least Tier 4. Of this cost, it is expected that approximately 26 percent (US$39 billion per year) will be shouldered by governments and development partners, in part, to ensure that affordability criteria are met; 7 percent (US$11 billion per year) by the private sector to cover the installation of downstream infrastructure essential to the functioning of modern-energy cooking markets; and the remaining 67 percent (US$103 billion per year) by households' direct contributions for stoves and fuels (figure ES.4). As large as the required investment commitment appears, the avoided cost of inaction for health, gender, and climate/environment is 16 times greater over the same 10-year period.

FIGURE ES.4 MECS Scenario: Total Cost to Transition over 10 Years, Disaggregated by Region, Locality, and Contributor

US$, billions



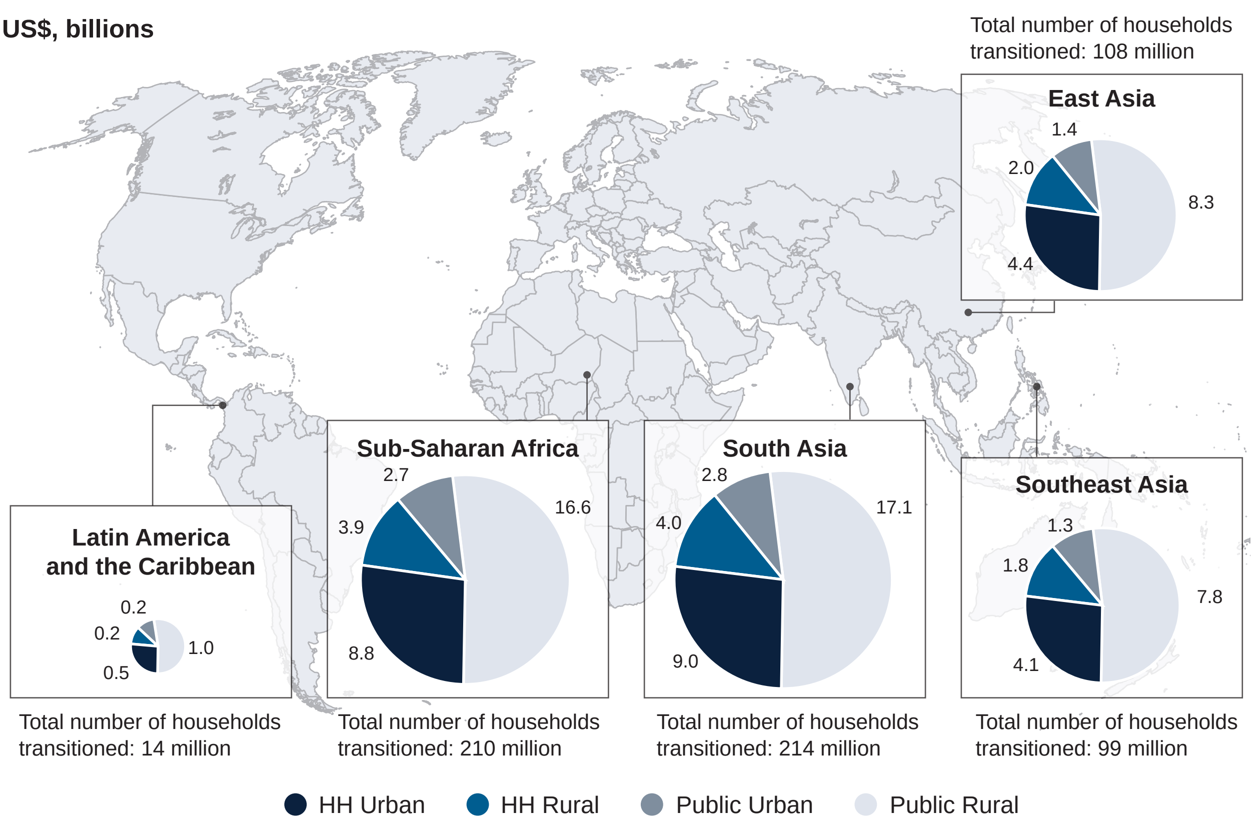
Sources: ESMAP access to MECS costing model; World Bank MTF data; Task Team fuel-mix database.

Note: The sizes of the pies represent the respective regional contributions to the total transition cost. HH = household contributions, Public = government and development-partner contributions, and Private = private-sector contributions.

A more pragmatic, though less ambitious, scenario considers universal access to improved cooking solutions by 2030, at an estimated total cost of approximately US$100 billion. This alternative Improved Cooking Scenario uses similar assumptions as the MECS Scenario for population growth and urbanization, but focuses costing on only a Tier 2 + 3 migration using improved cookstoves; that is, the cost of transitioning all households expected to fall into Tiers 0 or 1 to at least Tier 2 (the lowest transition tier). At a much lower cost than the MECS Scenario, the Improved Cooking Scenario raises the baseline for future Tier 4 (and higher) transitions, putting into play a sufficiently disruptive technology that can eliminate the most polluting and unhealthy cooking solutions. Its aim is to migrate millions of lowest-access households along a continuum of access—giving priority to supporting the poor with much less public-funding commitment to ensure no one is left behind. From a regional standpoint, the majority of expenditure for the Improved Cooking Scenario, like the MECS Scenario, would be concentrated in the Sub-Saharan Africa and South Asia regions, which feature large rural populations (figure ES.5). Of the US$10 billion in annual cost, the public sector would invest US$6 billion per year, with households contributing the other US$4 billion.

Any future pathway to universal access to MECS will require strong collaboration between public and private sectors in order to develop robust modern-energy markets for households. While both scenarios account for high levels of public-sector commitment (potentially with donor support), especially in the lowest-income countries, a significant share of the MECS reality will depend on private-sector investment. This is notably the case for the core capital infrastructure necessary to get the supply chains up and running for clean cooking fuels.

FIGURE ES.5 Improved Cooking Scenario: Total Cost to Transition over 10 Years, Disaggregated by Region, Locality, and Contributor



Sources: ESMAP access to MECS costing model; World Bank MTF data; Task Team fuel-mix database.

Note: The sizes of the pies represent the respective regional contributions to the total transition cost. HH = household contributions and Public = government and development-partner contributions.

Priority Actions for the Sector

Charting a course to meet the aspirations of SDG 7.1 will prove challenging; but targeted actions that expand MECS access can guide the sector forward. Driving progress forward requires mobilizing financial and analytical resources to improve the overall cooking ecosystem, as well as innovative technologies and partnerships. In particular, the sector needs to adopt several priority actions:

- **Create high-profile coalitions of political leaders to prioritize MECS access in global and national arenas.** The United Nations' Health and Energy Platform of Action (HEPA); the proposed High-Level Coalition of Leaders for Clean Cooking, Energy and Health; and other coalitions are critical for raising the stakes for implementing measures to achieve SDG 7.1 and affirming cooking as an essential component of energy policy. Such coalitions generate the political will and incentives needed to embed cooking within cross-cutting, national policy making and create a context for countries in transition to learn from each other and ensure coordinated action.

- **Formalize cooking energy demand in national energy planning and development of strategies for achieving universal access.** Such energy planning and strategy development require expanded implementation of the MTF and other national household-level surveys, combined with the sharing of lessons and insights through open-data platforms and consultation with a full range of stakeholders, to undertake more evidence-based decision-making, with households as the key unit of analysis. The transition pathways of national roadmaps to universal access should be guided by a least-cost, best-fit strategy that reflects diverse users' needs, local market conditions, and national comparative advantages on energy resources.

- **Dramatically scale up public and private financing for MECS.** To reach universal access to MECS, investment needs to be scaled up from the tens of millions to tens of billions, along with dedicated policies. Such investment includes not only the initial capital costs of stoves and deposit/connection fees, but also the energy infrastructure costs and additional subsidies required to make the clean-fuel costs affordable to the poorest consumers. Large-scale grant resources for MECS are particularly needed to scale up the availability, diversity, and volume of capital in the sector, as well as stimulate product and business-model innovations. Integrating the envisioned progress toward universal access to MECS with that of electrification as part of energy-access efforts is also critical to underpinning the scale and impact of allocated public resources and private-sector capital.

NOTES

1. One should note that deaths attributable to household air pollution (HAP) are greater among males than females because the underlying burden of disease is higher for men; see World Health Organization (WHO), *Guidelines for Indoor Air Quality: Household Fuel Combustion* (Geneva: World Health Organization, 2014).

2. World Health Organization (WHO), *Guidelines for Indoor Air Quality: Household Fuel Combustion* (Geneva: World Health Organization, 2014).

3. International Energy Agency, International Renewable Energy Agency, United Nations Statistics Division, World Bank Group, World Health Organization (IEA, IRENA, UNSD, WBG, WHO), *Tracking SDG 7: The Energy Progress Report* (Washington, DC: World Bank Group, 2018, 2019, 2020).

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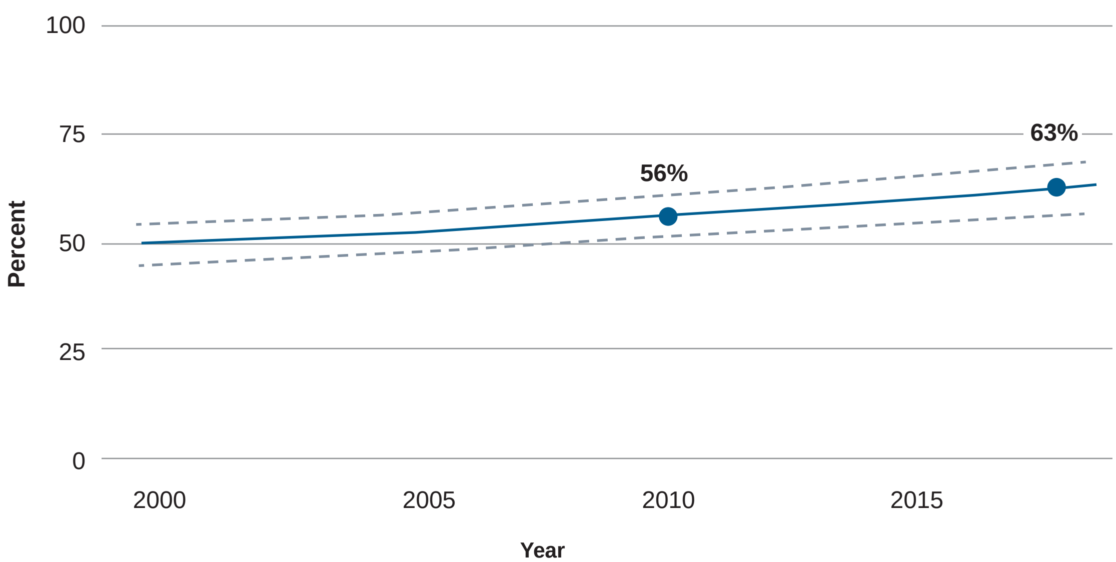
CHAPTER 1

INTRODUCTION

UNDERSTANDING COOKING AS A KEY COMPONENT OF MODERN ENERGY SERVICES

By current estimates, the world remains far off track to meet the UN Sustainable Development Goal (SDG) 7.1 target—ensure access to affordable, reliable, sustainable and modern energy for all.[1] In 2018, 63 percent of the global population had access to clean cooking fuels and technologies—currently tracked as the percentage of the population that primarily uses clean fuels for cooking. The global population without access was 2.8 billion. At this rate, universal access will fall short of the SDG target by nearly 30 percent (figure 1.1).

FIGURE 1.1 Global Population with Access to Clean Fuels and Technologies for Cooking (SDG 7.1.2)



Source: IEA et al. 2020.

To date, progress toward the SDG 7.1 target for access to clean cooking solutions has been uneven. Most of the progress has been achieved in Asia. In Sub-Saharan Africa, the access rate has not kept pace with population growth; in fact, between 2010 and 2018, the number of people without access rose from 750 million to 890 million.

Uneven progress on access has gone hand-in-hand with a lack of financial capital that is fully committed, at scale, to addressing the challenge. According to calculations of Sustainable Energy for All (SEforALL) for high-impact countries,[2] funding commitments for residential clean cooking have decreased, falling from nearly US$120 million to US$32 million in the last two years of commitment tracking (SEforALL 2019).

Improving and expanding access to cooking seldom takes top political priority, despite the high social and economic opportunity costs of inaction (chapter 2). To date, policies, cross-sectoral plans, and public investments have struggled to catalyze large amounts of private financing (Yumkella 2019). This challenge is exacerbated by the cross-cutting interests that cooking presents and the inherent relevance of cooking to a multitude of sectoral and thematic bodies that may be part of the political process. Stakeholders tend to differ in their prioritizations of the health, environment, and gender impacts of cooking (e.g., placing a higher premium on the health impacts and isolating environmental effects by focusing [for instance] on clean-burning fossil fuels) (Quinn et al. 2018). Differences in prioritization have allowed for the emergence of thematic financing (e.g., climate finance or gender-lens investing). This has raised the relevance of cooking for investors and funders with a narrow allocation focus, but has also risked missing out on building synergies between cross-cutting themes.[3,4] Alignment at the highest levels of decision-making both within and between countries has proven consistently difficult. The limited integration of cooking policies with broader plans for expanding energy access has resulted in missed opportunities for programs and investments.

Inadequacy of a Binary Perspective

The ways in which access drivers and barriers have been framed, measured, and addressed have contributed to the slow pace of progress. Historically, access to cooking energy has often been equated with the use of nonsolid fuels as the primary cooking energy source. The analysis and framing of cooking access indicators and data have referred to binary categorizations, such as “clean” and “polluting” or “solid” and “nonsolid” solutions (box 1.1).

Using this binary metric for the primary cooking fuel has proven inadequate for assessing household energy use. It presumes that all nonsolid fuels are clean and efficient and that all solid fuels are harmful, ignoring underlying scientific evidence regarding interlinkages between cooking emissions, indoor air quality, and health risks. It also overlooks aspects of convenience, including the time and effort involved in collecting and preparing cooking fuels, as well as considerations of safety and fuel availability and affordability.

Cooking is not a binary activity, even at the household level. An important challenge in measuring access to cooking solutions is the phenomenon of “stacking,” which involves the parallel use of multiple cooking fuels and stoves in the same household. Households that have already adopted modern fuels commonly practice stove and fuel stacking to meet sociocultural considerations and minimize risks (e.g., when the availability of a primary or preferred fuel is unreliable) (chapter 3, box 3.2). Access to cooking solutions is also affected by variations in the types and quality of the fuel used, variations in cooking practices, proper use of equipment, and kitchen size and degree of ventilation. In short, access to energy for cooking refers to the usability of cooking solutions in the context of these various attributes, with the end user’s cooking experience at the center.

Emphasis on binary definitions to promote clean primary cooking fuels has sometimes overlooked effective and sustainable, improved cooking solutions that fit local contexts. This situation has prevented the implementation and promotion of such localized solutions at scale. In turn, it has hindered a broad range of sector players from gaining in-depth knowledge of and insights into the local roots of the access challenge.

A range of ideological considerations in the cooking space has also been framed in binary terms, at times foreclosing the possibility of aligned, collective actions. For example, should country programs focus only on technologies that provide high impacts but are currently costly and difficult to disseminate to most households at large scale (i.e., highest-tier stove-plus-fuel combinations)? Or should such programs include improved, low-cost stoves that may provide only marginal reductions in adverse health and environmental impacts but are likely to reach many? Health and environmental impacts have also been framed as a trade-off, at least in the near term. While an exclusive focus on renewable solutions may allow the cooking space to move away from dependence on fossil fuels, it risks omitting high-impact, low-emissions solutions like LPG or

BOX 1.1 "Clean" Cooking in Data Collection

Introducing "clean" into the cooking lexicon was an important step-change. Data collection using "clean" as a proxy for health has been utilized to monitor the health impacts of clean cooking transitions with respect to Sustainable Development Goal (SDG) 3.9.1. This has held energy policies and programs more accountable for their impacts and led to greater dialogue and collaboration between the energy and health sectors.

However, the definitions of "clean" have not found common ground. *Tracking SDG 7: The Energy Progress Report* defines clean fuels and technologies as "electricity, LPG, natural gas, biogas, solar, and alcohol fuels" (IEA et al. 2020). But clean fuels can also be defined as fuels that do not cause household air pollution (HAP) in homes (CCA 2011). Processed biomass (e.g., wood pellets) has shown promise as a clean fuel when burned in a highly efficient stove,[a] under correct user operation, and with a sufficiently low pellet moisture content (Champion and Grieshop 2019; Jagger et al. 2019). The Regulatory Indicators for Sustainable Energy (RISE) policy report defines clean cooking solutions as "the combination of stove technologies and fuels that have higher efficiency and/or produce lower particulate and carbon emissions levels than the current baseline in a given country" (Foster et al. 2018). Unlike the definition in *Tracking SDG 7*, the RISE report definition also considers improvements in efficiency for cooking solutions that use solid fuels.

A definition that depends primarily or exclusively on technology metrics, including the tiered (0–5) standards of the International Organization for Standardization (ISO) for measuring thermal efficiency and emissions, among other stove performance factors, does not contain valuable additional details on how and why a technology may be used.[b]

Source: World Bank.

a. The majority of combustion evidence for pellet gasification has been generated in controlled, laboratory-based conditions.

b. The ISO is an international standards-setting body composed of representatives from various national standards organizations.

electricity (through fossil fuel–powered grids), whose rapid uptake has shown significant aggregate health and climate benefits. Similarly, focusing on a subset of potential users might achieve faster near-term progress but isolate the remaining population. Alternatively, shifting an entire population to modern energy services may be more broadly impactful but less immediately feasible. Finally, total dependence on either private-sector investors or government decision-makers to shape the market for cooking solutions may be at odds with the nascent state of the sector since emerging technologies and business models benefit from both investor support and large-scale, public-procurement and nurturing policies.

Such trade-offs have often forced debates in which sector stakeholders take sides and fail to seize the potential for greater coordination, particularly when faced with scarce resources. Binary frameworks have fed into the creation of a "siloed" cooking sector, obscuring the fact that cooking is an integral element of the broader energy space. Until recently, the cooking sector remained largely "invisible" to investors. Despite the urgent need to address this cross-cutting issue, clean-cooking interventions still struggle to reach scale.

Accelerating the Access Transition

Acknowledging the essential relationship between cooking and modern energy services can open the door for greater leveraging of capital and greater pooling of risk. Irrespective of context, decision-making requires a step-change in discourse beyond current narratives that isolate thematic areas of impact. Shared accountability across sectors can provide greater incentives to simultaneously address the health, climate, and gender impacts of cooking. The cooking and public-health sectors provide one such successful example. Their integrated efforts and resources to reduce the disease burden associated with HAP has created a common platform to ensure the complementarity and synergy of approaches needed to accelerate the transition to modern energy access.

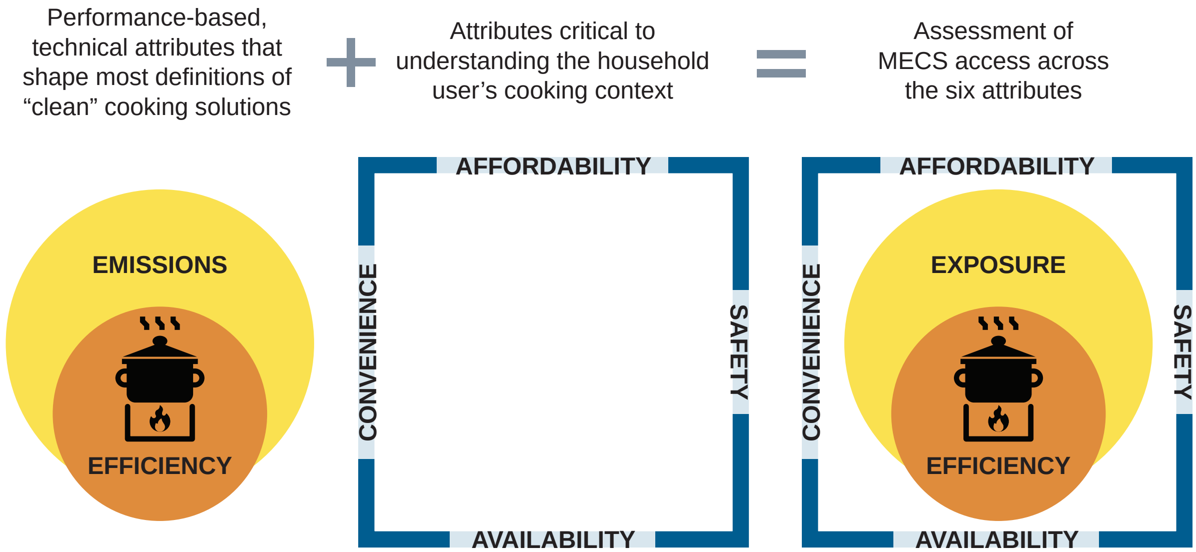
Today more than ever, the cooking-sector narrative must expand to account for the multiplicity of factors that shape a household's unique cooking context. Beyond the stove and fuel technologies at hand, many contextual factors contribute to the household cooking experience, including human behavior (e.g., who cooks; what is cooked; and how, for how long, and how often it is cooked), housing conditions (e.g., kitchen location, arrangement and size of rooms, construction materials, and quality of ventilation), and other types of energy demand that may equally contribute to HAP (e.g., lighting, space heating, and water heating). Other dimensions of household choice, adoption, and adherence—including economic conditions (e.g., income/affordability and proximity to fuel markets)—must also be captured.

A more complete and rigorous, multidimensional perspective is needed to drive progress. As the world progresses toward affordable, reliable, sustainable, and modern energy for all, fuel and technology choices and transition pathways will vary by country context. A more comprehensive approach to decision-making and investments is needed to guide the transition pathways of national roadmaps through advancing localized solutions informed by a more granular understanding of users' needs and preferences. This calls for a significant expansion in the collection and analysis of in-depth household-level data to inform program and policy design, track progress, and measure impacts.

REPORT PURPOSE AND METHODOLOGY

The main objective of this report is to inform better sector decision-making to guide progress toward the SDG 7.1 target by providing a new analytical framework with more data, evidence, and insights, as well as a pathway forward. The key part of the analytical framework is the introduction of the term "Modern Energy Cooking Services (MECS)," which, drawing on the World Bank's Multi-Tier Framework (MTF), considers the broader contexts in which people cook. MECS is defined by six technical and contextual attributes that consider users' cooking experience, environment, and the market and energy ecosystems in which they live: (i) exposure, (ii) efficiency, (iii) convenience, (iv) safety, (v) affordability, and (vi) fuel availability (figure 1.2).

FIGURE 1.2 Holistic Criteria to Measure Access to Modern Energy Cooking Services



Source: World Bank.

Note: "Exposure" considers contextual factors of ventilation and contact time in addition to the technical attribute of "emissions."

These six attributes are integrated into the MTF to capture detailed, indicator-level data for tracking stepwise progress across tiers of access.[5] Each attribute is scored across six tiers (Tiers 0–5), and these tiers are measured using one or more indicators, each spanning a lower and upper threshold (see Annex 1 for detailed metrics). A household scoring Tier 4 or higher across all six attributes can be considered to have gained access to MECS, while one that scores at least Tier 2 but not Tier 4 for all six attributes is considered in transition (box 1.2). This comprehensive way of measuring progress toward MECS access was developed by the World Bank's Energy Sector Management Assistance Program (ESMAP), in collaboration with Loughborough University and in consultation with multiple development partners, including the Clean Cooking Alliance (CCA).

The analyses informing this report make the case for multidimensionality as a more complete and rigorous perspective from which to drive progress toward access to modern cooking. The analyses rely on the most up-to-date evidence documenting the health, environment, and gender impacts of MECS access. They combine the recently collected household data from multiple MTF datasets that together paint a nuanced picture of end-user demand (box 1.3). They also draw on a tailored enterprise survey that highlights critical barriers and opportunities from the standpoint of today's suppliers of the world's fuels and cookstoves.

BOX 1.2 Key Definitions for Measuring Access

Modern Energy Cooking Services (MECS)—Refers to a household context that has met the standards of Tier 4 or higher or above across all six measurement attributes of the Multi-Tier Framework (MTF) (figure B1.2.1):

Exposure Personal exposure to pollutants, which depends on both stove emissions and ventilation (higher tiers indicate lower exposure)

Efficiency Combination of combustion and heat-transfer efficiency

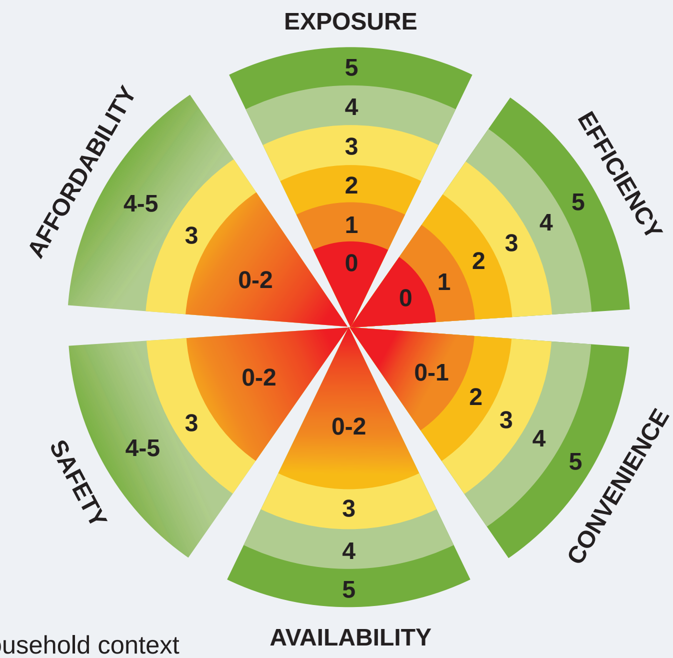
Convenience Time spent collecting/purchasing fuel and preparing the stove

Safety Severity of injuries caused by the stove over the past year

Affordability Share of household budget spent on fuel (higher tiers indicate lower share of spending)

Availability Readiness of the fuel when needed by the user

FIGURE B1.2.1 MTF Attributes, Showing Tiered Progress toward MECS Access



Improved Cooking Services Refers to a household context that has met at least the Tier 2 standards of the MTF across all six measurement attributes but not all for Tier 4 or higher (figure B1.2.1). Household contexts with a status of MTF Tier 2 or Tier 3 are considered in **Transition**.

Source: World Bank.

Note: Annex 1 provides detailed metrics.

The report's multi-pronged research approach utilizes primary data from household and enterprise surveys and key stakeholder interviews, as well as secondary data sources. Specifically, it incorporates the review of more than 100 secondary sources; analysis of primary data in dozens of existing market and household surveys, including the recent Clean Cooking Alliance (CCA) Industry Snapshot reports and partner surveys; publicly available databases of product-testing results; impact evaluation data from large regional and national programs; and interviews with more than 50 key global sector participants, including academic researchers, product designers, manufacturers, distributors, financiers, program managers, and policy makers. Secondary sources include a systematic review report of 160 studies that have been transparently collated, coded, configured, and reviewed by a wide range of stakeholders and experts to minimize bias in the way the evidence was identified and selected.

BOX 1.3 Multi-Tier Framework for Cooking at a Glance

The Multi-Tier Framework for Cooking (MTF) is part of a global initiative to collect household-level data on energy access for cooking and electrification. Since its development in 2015, the MTF has been rolled out through nationally representative household surveys in 16 countries: Bangladesh, Cambodia, Democratic Republic of Congo, Ethiopia, Honduras, Kenya, Liberia, Madagascar, Myanmar, Nepal, Niger, Nigeria, Rwanda, São Tomé and Príncipe, Zambia, and Uganda. Further rollout is planned for Burkina Faso, Burundi, Cameroon, Malawi, Sierra Leone, and Zimbabwe.

The World Bank and the World Health Organization are developing a guidebook for policy makers to track SDG 7.1 that includes MTF attributes. These guidelines provide a questionnaire module and steps to calculate indicators. The guidebook and planned follow-up capacity-building activities aim to support the integration and mainstreaming of such data-collection efforts in national household surveys and country statistics systems to track annual progress.

Source: World Bank.

The report also acknowledges that the definitions of problems and solutions will vary immensely by user context. The design of products and interventions that seek to increase access of the poorest wood-collecting rural populations will differ dramatically from those focused on maximizing the partial access of third- or second-quintile urban households (figure A.1). As a result, the report seeks to highlight data and analysis that shine a light on these diverse contexts, eventually arguing that fuel and/or stove transition programs, even if managed centrally, should be localized based on a community's needs and energy ecosystem realities.

Data collection efforts have included the development and updating of global databases on historical fuel mix, energy expenditures, and impact data (e.g., World Bank health impact definitions and additional environmental and gender variables from a literature review). In-depth household data analysis leans on the World Bank's MTF country databases. Supply-side analyses piggybacked on an enterprise survey purpose-built for this report, as well as an in-depth review of the CCA's partner database. The report was also informed by a global stocktaking of national and regional cooking initiatives with which to assess the enabling environments for MECS across the globe.

The information provided in this report constitutes a best-effort attempt to harmonize data sources to offer a comprehensive picture of the overall sector landscape, with the caveat that definitional and data-quality challenges may impact its ultimate precision. Data have generally been interpreted conservatively, and key assumptions are tracked throughout the report's notes and supporting data. Ultimately, the report should be taken as a core source for sector analysis, and the updating of data should continue as the modern energy space evolves.

REPORT STRUCTURE

This report is divided into seven chapters. Chapter 2 highlights the main evidence on the development impacts from maintaining the status quo and the cost of inaction. Chapter 3 presents the state of global access and demand, while Chapter 4 reviews the global supply landscape. Chapter 5 assesses the enabling environment for cooking. Chapter 6 offers key insights and cost estimates for guiding the transition pathway toward universal access to MECS. Finally, Chapter 7 outlines priority actions and recommendations to accelerate sector progress.

ANNEX 1. MEASURING MECS ACCESS USING THE MULTI-TIER FRAMEWORK

As part of a global initiative launched in 2015 to collect household-level data on energy access for cooking and electrification, the Multi-Tier Framework (MTF) for cooking has been developed and continuously refined through consultation with partners and feedback from field surveys. The MTF for cooking includes six attributes: (i) exposure, (ii) efficiency, (iii) convenience, (iv) safety, (v) affordability, and (vi) fuel availability. To measure progress, each attribute has six tiers, ranging from 0 to 5. The MTF provides a comprehensive tool to capture information on access to cooking energy, encompassing user behavior, cooking conditions, and the use of multiple cooking solutions, as well as convenience and safety aspects. It allows for disaggregate, as well as aggregate, analysis to yield detailed information on various parameters and indexes that facilitate comparison over time and across geographic areas.

Attribute Measurement and Scoring

Exposure: The health impacts from household air pollution (HAP) linked to traditional cooking activities have been a key driver of promoting clean and efficient cooking. $PM_{2.5}$ and carbon monoxide (CO) emissions are considered key marker pollutants for exposure to HAP. According to the World Health Organization (WHO) guidelines for indoor air quality, the average annual $PM_{2.5}$ concentration should be lower than 10 µg per m^3, and the 24-hour exposure to CO concentration should be less than 7 µg per m^3 (WHO 2014). Direct exposure measurement on the body of the cook would be the most accurate method to measure exposure to pollutants, yet this process is quite costly and impractical to implement in large-scale household surveys. Exposure is currently formulated using the recently published ISO/TR 19867-3 Voluntary Performance Targets (VPTs) for cookstoves, based on laboratory testing (2018), hereafter referred to as ISO 2018. The key parameters that determine the cooking-exposure tiers are stove/fuel emission factor, ventilation level, and contact time. As a protective approach, the MTF follows the ISO 2018's assumption that the contact time or time spent in the cooking area is equivalent to 24 hours per day. The emission factor for the stove/fuel should be estimated using existing lab tests from the country, following ISO 19867-1 harmonized laboratory-testing protocols. In cases where lab testing for the stove/fuel emission factor is unavailable, the MTF uses a series of proxy questions to estimate the stove/fuel emission factor. For ventilation level, following the approach used in ISO 2018, the MTF uses proxy questions to estimate three ventilation scenarios: (i) high, (ii) average/default, and (iii) low. Based on the estimated ventilation level, the estimated stove/fuel emission factors are adjusted into performance tiers, following ISO 2018 guidance. This attribute also accounts for the use of multiple stoves or stove stacking.

Efficiency: The MTF follows the cookstove efficiency tiers in ISO 2018. The cookstove efficiency should be estimated using existing lab tests from the country, following ISO 19867-1 harmonized laboratory-testing protocols. In cases where lab testing for the cookstove efficiency is unavailable, the MTF uses a series of proxy questions to estimate it.

Convenience: In the MTF, convenience is proxied by the amount of time necessary to collect the fuel and prepare the stove for cooking. It is a key consideration from the user's perspective and has high gender impacts.

Safety: The degree of safety risk can vary by type of cookstove and fuel used. Risks may include exposure to hot surfaces, fire, or potential for fuel splatter. In the MTF, reported incidences of past injury and/or fire are used to proxy safety.

Affordability: Cooking is a required activity in a household; therefore, households will allocate whatever share of their household income (expenditure) is necessary to meet basic cooking requirements. The affordability of a given cooking solution should be considered when assessing household access to cooking solutions; if a large share of household income (expenditure) is required for cooking fuel, then other elements of cooking solutions (e.g., safety, health, and convenience) may be constrained. To determine affordability, the MTF utilizes a levelized cost-of-cooking solution as a share of household expenditures.

Availability: A given fuel's availability can affect the regularity of its use. Constraints to availability can come in the form of seasonality, especially for types of solid fuels (e.g., wood); market supply shortages (e.g., LPG cylinders); or limited, grid-connected electricity supply (e.g., manifested in blackouts). Shortages in fuel availability can cause households to resort to using inferior, secondary fuel types. The MTF uses the household's reporting on primary fuel availability for the previous 12 months.

For each of the six attributes described above, a household is assigned a score. These six scores are then aggregated into a single household score by assigning the lowest tier rating across the six attributes. Tier 5 represents households with the cleanest, safest, most reliable, and most efficient cooking solutions (table A.1).

TABLE A.1 Tiered Structure of the MTF for Cooking

Attribute	*Measurement indicators*	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Exposure	ISO's voluntary performance targets on emissions-default ventilation $PM_{2.5}$ (mg/MJd) CO (g/MJd)	> 1030 > 18.3	≤ 1030 ≤ 18.3	≤ 481 ≤ 11.5	≤ 218 ≤ 7.2	≤ 62 ≤ 4.4	≤ 5 ≤ 3.0
	High ventilation $PM_{2.5}$ (mg/MJd) CO (g/MJd)	> 1489 > 26.9	≤ 1489 ≤ 26.9	≤ 733 ≤ 16.0	≤ 321 ≤ 10.3	≤ 92 ≤ 6.2	≤ 7 ≤ 4.4
	Low ventilation $PM_{2.5}$ (mg/MJd) CO (g/MJd)	> 550 > 9.9	≤ 550 ≤ 9.9	≤ 252 ≤ 5.5	≤ 115 ≤ 3.7	≤32 ≤ 2.2	≤ 2 ≤ 1.4
Efficiency	Stove efficiency, using ISO's voluntary performance targets (%)	<10	≥ 10	≥ 20	≥ 30	≥ 40	≥ 50
Convenience	Fuel acquisition and preparation time (hours/week)	≥ 7		< 7	< 3	< 1.5	< 0.5
	Stove preparation time (minutes/meal)	≥ 10			<10	< 5	< 2
Safety	Severity of accidents caused by the stove over the past year	Serious			Minor	None	
Affordability	Fuel cost as a share of household expenditure (%)	≥ 10			< 10	< 5	
Availability	Ready availability of primary fuel when needed (% of the year)	≤ 80			> 80	> 90	100

Source: World Bank.

Applying MTF to Measure MECS Access

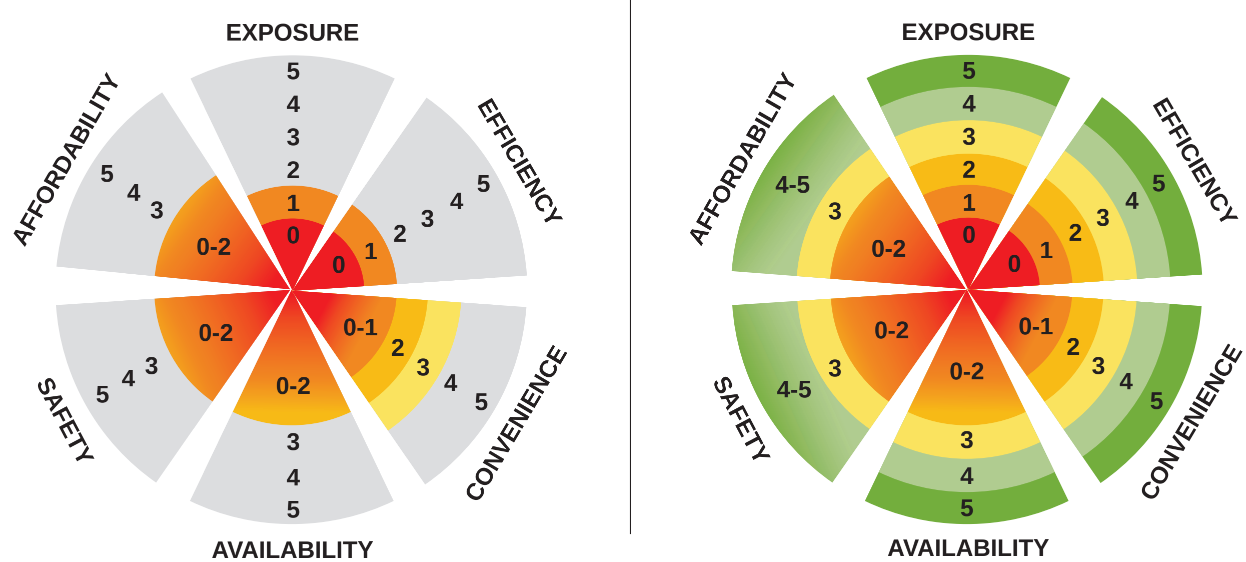
No one attribute can convey the complete story of how effectively a household's cooking needs are met. The reality is that a combination of technological, sociocultural, and market factors drive a household's unique cooking context. Technological factors include emissions (key determinant for exposure), efficiency, and safety. Sociocultural factors also include exposure (given that ventilation of the cooking space within or outside the house largely affects this attribute) and safety, as well as convenience. Market-driven factors include affordability, availability, and convenience.

Using the MTF, Modern Energy Cooking Services (MECS) refers to a household context that has met the Tier 4 standards or above across all six measurement attributes. Figure A.1 compares two illustrative examples of household cooking contexts: one that uses a traditional stove, mainly with purchased biomass (figure A.1a) and another that relies on a grid-powered electric stove (figure A.1b). The stove of the biomass-reliant household is inefficient and unsafe, emits a substantial amount of particulate matter within a poorly ventilated cooking location, is relatively expensive to use, and has a somewhat inconvenient fuel source (i.e., the access point for charcoal is relatively far away). Because this household scores Tiers 0–3 across the six attributes of the MTF, it cannot be considered to have gained access to MECS. By contrast, the highly efficient electric cookstove used by the household with relatively reliable electricity and affordable tariffs crosses at least the Tier 4 threshold across all six attributes and thus meets the MECS criteria.

FIGURE A.1 Illustrative Examples of Aspirational Cooking Contexts

a. Household using mainly readily-available, purchased biomass with a traditional stove

b. Household using cheap, relatively-reliable grid power, with a high-performing electric cookstove



Source: World Bank.

Given the multiple tiers of the framework, "access" to MECS should be understood as the process through which a household progresses across tiers of access to eventually reach Tier 4 or above. One should note that households that meet at least the Tier 2 MTF standards across all six attributes, but not all for Tier 4 or higher, are considered households in transition, with access to improved cooking services. This distinction is critical, given that the modern energy needs of a Tier 2 or Tier 3 household close to crossing the MECS access bar are likely to differ significantly from those of a household that scores Tier 1 across most attributes. Understanding the factors that determine the degrees of access will prove essential to effective household energy interventions.

Strengths and Limitations of the Multi-Tier Framework

Multidimensionality can allow sector players to keep track of sector progress using household-level data and enable aggregation of households across geographic, social, economic, and gender categories. The six-attribute MTF incorporates a broad set of data and encourages granular data collection through the World Bank's MTF household surveys, making it particularly useful on three fronts: (i) mainstreaming new data-collection approaches for SDG 7.1; (ii) understanding contextual, household-level impacts; and (iii) setting sectorwide aspirations for moving toward MECS or other measures of "good" cooking practices.

The MTF can help mainstream new and complementary data-collection approaches for meeting the SDG 7.1 target. The development of measurable indicators across attributes (some more granular and specific than others) and the current ability to field multiple MTF surveys across 16 countries make it possible today to measure progress toward SDG 7.1 in ways that bring household needs to the fore. As more country surveys are completed, sector players will gain a holistic perspective of multinational progress based on systematic comparisons of survey results. Moreover, the ability of the MTF team and its survey fielding partners to continuously enhance the quality of data collection (e.g., by improving and/or adding survey questions and developing increasingly effective approaches for adjusting to local nuances) will provide the sector progressively higher-quality data.

The framework can also be used to elevate contextual household-level impacts. The MTF and its underlying data sources capture and allow for new types of analyses of household data. For example, the incorporation of questions within MTF surveys that measure stove-stacking behavior (i.e., the use of multiple stoves and fuels in the same household) can give sector players a better view of the efficacy of specific stove or fuel programs and campaigns. The collection of data on electricity access and use (through a parallel electricity questionnaire), in combination with data on cooking fuel-plus-technology access and use, allows for the unique assessment of household energy consumption and expenditure, as well as the measurement of correlations between improvements in grid access and adoption of or adherence to electric cooking products and services, among many other analyses.

Using the MTF, sectorwide aspirations can be set for moving toward "modern" or other measures of "good." By moving beyond binary measurements and instead considering a wide range of factors related to cooking, the sector can now set goals and assess progress for each of the framework's six attributes. This can allow the sector to measure progress using underlying indicators and indicator-level thresholds. In addition, by considering multiple attributes explicitly, sector actors can more transparently evaluate real (and perceived) trade-offs across the attributes. For example, some stove or fuel technologies may score favorably on metrics of affordability or exposure but less favorably in terms of convenience or availability.

While the MTF gives the sector a more nuanced and contextual understanding of household cooking activity and behavior, some caveats apply. The framework's emphasis on the household as the ultimate unit of analysis gives target framework audiences an ability to score households (and populations, once aggregated) on critical energy-usage criteria. But aggregated assessments must also account for other critical macro variables that the MTF does not explicitly include—notably, variables that capture climate effects, macroeconomic impacts, and intervention costs. As a result, the framework should not be positioned as a catchall instrument on which donors and policy makers should rely exclusively for the design of complete interventions or policies.

The framework should not be employed as a comparative performance tool for assessing and classifying specific technologies and fuels, given that its household-unit emphasis balances assessments of what type of fuel or technology is used with how it is used. This forces the framework to strike a careful balance. On the one hand, it should consider improvement in energy and cooking access as a continuum of increasing levels of energy attributes across technologies and service-quality levels. On the other hand, it must remain technology and fuel neutral. This is rooted in the reality that no one fuel or technology is best-positioned for use in all contexts: Differences in the localized structure of energy supply chains—and above all—variations in household behaviors and needs must inform least-cost, best-fit solutions, with the framework as a guiding input. This approach allows households, as well as countries, to move up the tiers of access by closely incorporating local conditions.

Intended Audience and Use

The MTF is particularly relevant for research and monitoring. Given that the framework goes hand-in-hand with a range of in-depth household surveys, it should fundamentally act as a tool for research and analysis. It should help to inform, alongside other sources, the design of specific programming. It can help stove and fuel program designers identify the contextual needs that an intervention can address, such as reducing affordability constraints (e.g., by introducing lower-priced alternatives or deploying a subsidy) or improving safety practices among a specific population subgroup, among other examples. Importantly, it does so by setting up a more holistic set of trade-offs on how to improve a population's access across tiers. For example, if a household is using a highly efficient technology in a low-emissions environment, interventions may focus less on driving changes in the cooking solution employed and more on improving the household's accessibility, affordability, convenience, or safety attributes if progress across tiers is more limited in that context.

On the back of its underlying household data, the MTF can serve as a monitoring tool—that is, by setting the high-level parameters across which progress can be assessed. This is particularly relevant for interventions that seek to drive improvements across tiers, such as a results-based financing (RBF) program designed to move a population from a Tier 3 to a Tier 4 or Tier 5 modern-energy cooking context.

Additional primary research methods can complement and enhance the MTF findings. The framework is underpinned by contextual information on the "what," "where," and "how" of cooking and not by in-depth behavioral insights into the "why" of cooking. Thus, additional primary research methods, such as human-centered design, can help unpack why a specific household might prefer to trade greater affordability for greater convenience factors or why the primary cook selects her or his secondary fuel for specific occasions. Stove performance and usability tests can add rich supplementary insights into the ways in which households use products versus how products are designed and intended for use.

In short, the MTF can play a critical role in advancing the research baseline for access to modern cooking energy. Its wealth of underlying data makes it a multifaceted input, though not a catchall mechanism, for program design and monitoring.

NOTES

1. In SDG 7, “modern energy” refers to electricity and clean cooking.
2. High-impact countries include Afghanistan, Bangladesh, China, Democratic People’s Republic of Korea, Democratic Republic of the Congo, Ethiopia, India, Indonesia, Kenya, Madagascar, Mozambique, Myanmar, Nepal, Nigeria, Pakistan, Philippines, Sudan, Tanzania, Uganda, and Vietnam.
3. Nuances also exist between individual and aggregate impacts. For example, household use of electricity for cooking may provide localized benefits; however, at an aggregate level, the impact may be quite negative if a national power grid is powered by burning large amounts of coal or oil.
4. Task Team interviews report that energy policy choices are spread, rather than integrated, across the SDGs (notably, for goals 3, 5, 7, 13, and 15), which makes coordination and shared dialogue difficult. Moreover, neither energy development nor health communities are particularly accustomed to addressing issues at the household level, which creates challenges in finding a common unit of analysis.
5. The MTF’s multidimensional design contributes to monitoring incremental, attribute-specific progress toward achieving the SDG 7.1 target. Since its initial development in 2015, the MTF has evolved to include more detailed indicators and tier thresholds (Annex 1, table A.1).

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CHAPTER 2

DEVELOPMENT IMPACTS

THE COST OF INACTION

Without meeting the clean cooking target under Sustainable Development Goal 7 (SDG 7.1.2), the cost of inaction—driven by negative externalities for health, gender, and climate—would total US$2.4 trillion per year. The health-impact portion alone is estimated at US$1.4 trillion per year. This figure results from quantifying the deaths and disability-adjusted life years (DALYs) linked to household air pollution (HAP) produced by stoves and fuels. The gender cost, estimated at US$0.8 trillion annually, assumes that women may spend up to six hours per day performing cooking-related tasks, including fuel collection, cooking, and stove cleaning. Finally, the climate-impact cost is estimated at US$0.2 trillion per year (table 2.1).

TABLE 2.1 Annual Cost of Inaction, by Externality

Externality	Cost of Inaction (US$, trillions/year)
Health	1.4
Gender	0.8
Climate	0.2
Total	**2.4**

Source: World Bank.

Note: See Annex 2 for cost calculations.

These alarmingly high figures are conservative estimates, suggesting the adverse development impacts resulting from households' ongoing use of polluting stove technologies and cooking fuels (table 2.2). The DALYs included in the health-impact calculation account for morbidity, but do not assume productivity losses due to ill health, which would likely raise the final value. In the gender calculation, the cost of women's time is set relatively low, at US$0.54 per hour. Even so, the value of women's time spent on cooking-related tasks and drudgery skyrockets. The dollar value of the climate impact is driven, in part, by carbon prices and estimates of the social cost of carbon, which many in academic and policy communities perceive as being set too low (Annex 2). These and other negative impacts underscore the urgent need to move households without Modern Energy Cooking Services (MECS) up the tiers of access.

TABLE 2.2 Adverse Impacts of Non-Clean Cooking, by Externality

Externality	Main impacts
Health	• Broad range of health conditions associated with household air pollution (HAP), including chronic respiratory disease, acute lower respiratory infections (ALRI), lung cancer, stroke, and cardiovascular disease • Burns suffered by household members cooking with traditional fuels and appliances • Chronic and acute physical ailments that can occur during fuel collection
Gender	• Disproportionate effects on women and young girls: ◦ Health conditions associated with HAP ◦ Burns from cooking with traditional fuels and appliances ◦ Physical ailments, injury, and gender-based violence (GBV) associated with fuelwood collection ◦ Time poverty (from cooking, fuel collection, and drudgery), resulting in less time for leisure and opportunities for market employment, with potential risk of lowered household status
Other social effects	• Avoidable spending on fuel due to reliance on inefficient fuel-stove combinations • Lost opportunities for income generation due to time spent cooking • Reduced access to education due to impaired child health and time spent on fuel collection • Poorer nutrition due to partly prepared food or reduced food budgets • Increased poverty due to diversion of scarce resources to pay for fuel • Negative aesthetic effects (e.g., poor lighting and soot-darkened home environment)
Climate	• Greenhouse gas (GHG) emissions due to the use of inefficient fuel production and consumption • Catalytic warming effects of black carbon (BC) emissions
Environment	• Forest degradation and deforestation due to fuel collection and production • Foregone agricultural productivity due to habitat degradation and combustion of dung as fuel
Employment	• Risk of displacement of existing economic activities for poor rural and urban households in the woodfuel value chain[a]

Source: World Bank.

a. However, switching to modern energy cooking solutions brings rewards in the form of broader macroeconomic potential, particularly in the creation of local jobs.

The costs of inaction for health, gender, and climate/environment vary widely by region: East Asia has the highest overall cost (US$943.8 billion) and Latin America the Caribbean the lowest (US$86.8 billion). For health, East Asia and Latin America and the Caribbean also report the highest and lowest respective costs of inaction. The high health cost for East Asia (US$729.4 billion) is driven by the morbidity costs, which for that region alone account for nearly half of the opportunity cost for global health. Latin America and the Caribbean's low health cost (US$21 billion) can likely be explained by that region's high penetration of liquefied petroleum gas (LPG). The highest costs of inaction for both gender and climate/environment are reported in South Asia (US$321.9 billion and US$66.6 billion, respectively), followed by Sub-Saharan Africa (US$186.2 billion and US$47.5 billion, respectively). Despite the considerably high health impact from non-clean cooking in Sub-Saharan Africa, the estimated cost is relatively low (US$96.3 billion), owing to low values of gross domestic product (GDP) per capita, which factor directly into the costing methodology (table 2.3). Annex 2 provides an in-depth methodological overview.

TABLE 2.3 Cost of Inaction by Region

Externality	Cost (US$, billions/year)				
	Sub-Saharan Africa	Latin America and the Caribbean	East Asia	Southeast Asia	South Asia
Health	96.3	21	729.4	174.1	423.5
Gender	186.2	59.8	178.9	89.2	321.9
Climate and Environment	47.5	5.9	35.5	15.4	66.6

Sources: Institute for Health Metrics and Evaluation (IHME) Global Burden of Disease (GBD) Project; HEI 2019; HEI Household Air Pollution Working Group 2018; World Bank/Dalberg Results-Based Financing (RBF) Model; Task Team fuel database.

Note: The primary drivers of regional variations in the cost of inaction are population size and values of gross domestic product (GDP) per capita, which are incorporated into World Bank externality costing methodologies for health calculations (Enriquez, Larsen, and Sánchez-Triana 2018).

HEALTH

Household air pollution (HAP) is associated with approximately 4 million premature deaths each year (WHO 2014). HAP resulting from the inefficient use of biomass, charcoal, coal, and kerosene for cooking has been linked to premature deaths and multiple illnesses, notably acute lower respiratory infections (ALRI), lung cancer, chronic obstructive pulmonary disease (COPD), stroke, and ischaemic heart disease (Cohen et al. 2017; GBD 2016 Risk Factors Collaborators 2017; WHO 2014, 2018). Exposure to HAP nearly doubles the risk of childhood pneumonia and is responsible for 45 percent of all pneumonia deaths in children under five years of age (WHO 2014). Emerging evidence shows that HAP is also a risk factor for cataracts, the leading cause of blindness in lower-middle-income countries, and low birth weight (Quinn et al. 2018; WHO 2014, 2016).

However, it is a near certainty that HAP mortality and morbidity data have historically underestimated the full health impacts of household cooking with unprocessed fuels and low-quality stoves. The estimates exclude a number of compelling, currently understudied epidemiological associations with other respiratory outcomes, such as asthma and tuberculosis; childhood nutritional deficiencies, including anemia and stunted growth; cognitive impairment in youth and the elderly; and various forms of cancer (e.g., cervical, nasopharyngeal, and laryngeal) (Pope et al. 2010; Sumpter and Chandramohan 2013; WHO 2016).[1] The health-impact estimates also exclude more prosaic discomforts and physical injuries associated with cooking-related HAP, such as headaches and eye irritation, which are nearly universally reported in surveys of households that cook with biomass fuels on traditional stoves (Matinga 2010; WHO 2016).

The serious health impacts of HAP could extend beyond those that have been researched and evaluated. The available clinical data to date suggests that cardiovascular disease, diabetes, chronic respiratory illness, and hypertension—conditions all strongly associated with exposure to HAP—are also risk factors for the coronavirus disease (COVID-19). Should COVID-19 take hold in countries with high population exposure to air pollutants linked to the use of traditional cooking fuels and stoves, one could expect an exacerbation of its impact (box 2.1).

BOX 2.1 COVID-19 and Air Pollution–Related Impacts

The World Health Organization (WHO) declared the global outbreak of the coronavirus disease (COVID-19) a pandemic in March 2020. As of July/August 2020, the virus had reached all continents, with the United States, Brazil, and India affected the most. The number of cases has been growing rapidly in many developing-country regions that form the focus of this report (e.g., Sub-Saharan Africa, South Asia, and Central America).

In the already affected countries, the speed of propagation and the related death toll are strongly influenced by age and underlying health status, the ability of instituting and maintaining good hygiene practices and social distancing, the availability of widespread testing, and the capacity of public-health systems to safely take in a sudden influx of patients. All of these factors are a cause for serious concern in countries with an already high disease burden, low infrastructure capacity, and cultural and socioeconomic conditions that make it impossible or ineffective to implement the full set of required response measures.

A few preliminary studies in this still developing crisis have directly linked COVID-19 and air pollution, although the mechanism of effect is less clear. It can nonetheless be expected that people with serious underlying health conditions caused by air pollution will be more likely to develop a severe form of the disease and less likely to recover from it. The focus of these early studies is outdoor air pollution. But household air pollution (HAP) could worsen the impact for households that rely on traditional stoves and fuels, particularly the primary cooks who have historical and repeated exposure to high concentrations of pollutants. Reducing exposure to air pollution often realizes immediate health benefits.

Source: World Bank.

Additional under-appreciated health consequences of reliance on traditional biomass and kerosene stoves include injuries from firewood collection and cooking burns. Though limited in scope, evidence from multiple countries suggests that household members involved in fuelwood collection suffer from a range of maladies, including cuts, broken bones, skin irritations, infections, and bites (WHO 2016).[2] Headloading and transport of heavy firewood bundles, in particular, can contribute to fatigue; headaches; chest, joint, waist, and chronic back pain; and spinal injury. Although robust data on such conditions is limited, large proportions of populations in the developing world regularly engage in firewood collection, which translates into a large disease burden and thus an important area of concern. Cooking with traditional (paraffin) kerosene stoves also contributes to burns and reportedly accounts for a significant percentage of the 300,000 global deaths attributed to burns each year (CCA 2011). In addition, childhood poisoning from kerosene storage is a major health risk in some settings (Dayasiri, Jayamanne, and Jayasinghe 2017).

Recent studies of national stove-and-fuel transition and distribution programs have highlighted the transformative health benefits of switching to cleaner cooking solutions. In China, for example, Zhao et al. (2018) report that switching to clean stoves reduced exposure to both ambient pollution and HAP by 47 percent over a 10-year period (2005–15), corresponding to an estimated 0.4 million averted premature deaths per year. That study also notes the even greater public-health benefits that could be achieved by switching to cleaner cooking and heating fuels (Zhao et al. 2018). Results of a recent study in Rwanda, which included household purchases of sustainably-produced biomass pellets and leasing of micro-gasification cookstoves with lab-verified emissions reductions, reported significant health improvements for primary cooks, including reductions in systolic blood pressure and self-reported shortness of breath (Jagger et al. 2019).

The cleanest cooking solutions can reduce HAP to levels that approach the guidelines of the World Health Organization (WHO), but achieving these benefits under real-world conditions is difficult. Few of the improved or clean-cooking solutions on the market today can address the most pertinent health concerns of reliance on traditional stoves and fuels. The reason is that the exposure-response curve for such conditions as childhood pneumonia has been shown to be non-linear. This means, for example, that a 50 percent reduction in exposure would not halve the health risk. Rather, exposure reductions of up to 90 percent may be required to realize improved health outcomes. The WHO's indoor-air-quality guidelines for household fuel combustion are formulated on this basis. However, the exposure-response relationship for other conditions, such as cancer, are linear, meaning that any reduction in exposure can accrue some health benefits, as shown in retrospective cohort studies on fuel and stove transitions in China (Chapman et al. 2005; Lan et al. 2008; Shen et al. 2009).

Of the available solutions, the cleanest from a health perspective are also the most difficult to adopt because they involve a change in both fuel and technology. They include liquefied petroleum gas (LPG), electricity, best-in-class fan gasifiers (under conditions of correct user operation and low pellet-moisture content), biogas digesters, and solar cookers. Correctly used, these solutions can realize HAP reductions exceeding 90 percent. Among them, solar, electricity, and LPG provide the cleanest cooking experience as they are not associated with any emissions of particulate matter (PM) or other pollutants of health concern at point of use. Biogas and ethanol fuels can achieve HAP reductions of 80–90 percent, which is also possible with best-in-class gasifiers (high-efficiency, pellet-fed forced draft stoves). At the lower tiers of cleanliness are rocket stoves and other manufactured cookstoves, with a 60 percent HAP reduction, and basic efficient wood and charcoal stoves, with a 30 percent reduction (Putti et al. 2015).[3]

Factors beyond stove efficiency—such as fuel characteristics and user behavior—must be closely accounted for in health considerations. For example, stoves that burn wood, other unprocessed biomass, and charcoal have significant ranges of performance. These depend on characteristics of the fuels being burned (e.g., size and moisture content) that can be altered by user behavior (e.g., through processing or drying), resulting in higher or lower emissions. The use of efficiently-combusting processed wood pellets would, for example, result in lower emissions, even with the same base stove technology. It is likely that real-world reductions in exposure are significantly lower because of the multiple fuel-and-stove practices of most households or user alterations and customization of the technologies to suit certain meal preparations.

Other sources of pollution present in the household and community may also pose important health risks. For example, lighting with kerosene or using a three-stone fire for space heating may contribute to shaping the overall emissions profile and health impact (CCAC 2014; Tedsen, Eberle, and Zelljadt 2013). In homes that have transitioned to clean fuels, background levels of ambient air pollution (e.g., from neighbors cooking outdoors with inefficient technologies) can lead to indoor concentrations above WHO air-quality guidelines (Larsen and Pierre 2017). This is particularly the case in more densely populated areas like slums and other settings where homes tend to cluster. Failing to account for such sources of pollution can lead to incorrectly attributing the impact of clean cooking interventions.

GENDER

It is well-known that women throughout the developing world are disproportionately affected by the adverse impacts of traditional biomass cooking. Owing to gender and sociocultural norms, women in many developing countries have primary responsibility for household cooking (including food preparation and post-meal cleanup), relying on polluting stoves and fuels, as well as fuelwood collection and fuel processing (e.g., drying and cutting). This means that women in such countries bear a disproportionate share of the negative health risks from HAP, as well as the time poverty associated with traditional household cooking, leading to opportunity costs (i.e., less time for education, rest and leisure, and income-generating activities). Young children, who tend to stay close to their mothers indoors, also suffer a disproportionate share of the negative health risks. And children born to such mothers may suffer from low birth weight and stunting. In addition, many children, particularly girls, may not attend school in order to help their mothers with fuelwood collection and food preparation.

Evidence from various countries shows that, compared to men, women are exposed to significantly higher levels of PM emissions. South Asia studies, for example, indicate that women's level of $PM_{2.5}$ emissions exposure can reach twice that of men's; in Kenya, it is up to four times greater (Balakrishnan et al. 2004; Dasgupta et al. 2004; Ezzati, Saleh, and Kammen 2000; Smith et al. 2007). It is unclear whether higher exposure necessarily translates into more adverse health outcomes since men's exposure levels also exceed safe minimum levels significantly and are often exacerbated by a higher underlying burden of disease (HEI Household Air Pollution Working Group 2018), among other considerations. That said, the differential impact of PM exposure for women, particularly manifested in the form of lung cancer and COPD, is highly likely.

Beyond women's disproportionate health burden, evidence shows that risks of physical injury and violence associated with women's involvement in fuel collection are endemic. Women and girls must often walk long distances to obtain cooking fuel, and, as a result, face increased risk of physical and sexual violence. According to the United Nations High Commissioner for Refugees (UNHCR), 42 percent of households in Chad reported incidents of gender-based violence (GBV) during firewood collection over a six-month period in 2014. Such risks are particularly high for refugee women and female children, who are more vulnerable to sexual violence because of their low status in host communities and the resulting daily need to leave their camps (often during predawn hours) in search of wood (Clancy et al. 2011).

Time spent on fuelwood collection can contribute significantly to women's time poverty; but the gender differential varies across countries and regions. Household time-use surveys show that women spend significantly more time on fuelwood collection than do men. However, the gender differential varies by cultural norms (e.g., with respect to hard physical labor and the acceptability of women's work outside the home). Across most of Sub-Saharan Africa and in parts of China, women are the primary fuelwood collectors. However, in Madagascar and the Tigray region of Ethiopia, as well as parts of Southeast Asia and much of Central America, men have the main responsibility for this task.[4] In various other countries, including India, fuelwood collection is a joint family responsibility, with parity between men and women in time expended on such tasks (Cooke, Köhlin, and Hyde 2008; Köhlin, Pattanayak, and Wilfong 2011).

Women's aggregate time loss from fuelwood collection and cooking averages about 5 hours per day. The aggregate time loss across fuel collection, cooking with traditional biomass cookstoves, and related fuel-preparation and food-processing activities translates into 2–8 hours of effort per day or about 5 hours a day on average.[5] In Uganda, for example, women (age 15 and older) spend an average of 3.8 hours per day cooking, while girls spend close to 30 minutes per day. By contrast, men and boys are virtually uninvolved in cooking. Likewise, female household members in Uganda spend 3.4 hours a week acquiring cooking fuels and preparing foods—7.5 times more than do men.

Gender factors related to household decision-making are still insufficiently embedded in cooking-program considerations, but insights from new MTF data are encouraging. Survey instruments must be enhanced to capture more and better sex-disaggregated data on energy use, intra-household decision-making, and stove-stacking practices. The Multi-Tier Framework (MTF) household questionnaires offer a promising path forward by allowing for insights on intra-household decision-making power regarding the purchase of a cookstove. Data disaggregated by gender of household member is also available and can be compared to decision-making on purchase of a solar device (box 2.2).

BOX 2.2 Unexpected Insights on Gender and Stove Purchasing Power in Uganda

Preliminary results from Multi-Tier Framework (MTF) household questionnaires in Uganda show that women are more likely to decide on purchasing a cookstove rather than a solar device. About 1 out of every 3 women surveyed reported being the decision-maker for purchase of a cookstove, versus 1 out of 5 who decided on the purchase of a solar device. Interestingly, female-headed households in the top four income quartiles were less likely than male-headed households to primarily use a highly-inefficient and high-exposure, three-stone stove.

Source: World Bank MTF data.

CLIMATE

Large-scale consumption of fuels like wood and charcoal produces greenhouse gas (GHG) emissions that contribute to global warming. GHG emissions from non-renewable woodfuels for cooking amount to a gigaton of carbon dioxide (CO_2) per year—about 1.9–2.3 percent of global emissions (Bailis et al. 2015). At the low end of the range, these CO_2 emissions are on par with the 2010 carbon footprint of an industrialized country like the United Kingdom and, at the top of the range, approach those of Japan.[6] Uncertainty about the precise GHG figure stems from the fact that CO_2 emitted from the combustion of renewably harvested wood is re-absorbed during biomass regrowth and therefore does not qualify as a climate-forcing emission. The renewability level of woodfuels is an area of ongoing debate and research, with analysis commissioned by the Clean Cooking Alliance (CCA) suggesting that a substantial share of cooking woodfuel is not harvested sustainably (Bailis et al. 2015).

Black carbon (BC) and other particles of incomplete combustion from cooking with non-clean fuels play a more important role than CO_2 in anthropogenic global warming. The burning of residential solid fuels accounts for up to 58 percent of global BC emissions (CCAC 2019). Reducing BC emissions from traditional stoves and three-stone fires could act as a near-term lever to address global warming and the health benefits of their removal from household environments (Grieshop, Marshall, and Khandikar 2011; US EPA 2011). While CO_2 remains in the atmosphere for decades, BC particles have an atmospheric lifetime of only 8–10 days (Bond et al. 2013); thus, reducing BC emissions theoretically leads to relatively rapid, global cooling.

It is most likely that the short-term, local climatic effects of BC emissions, including those from traditional biomass cooking, are harmful. BC emissions have been shown to influence regional precipitation and temperature patterns by diminishing albedo cooling effects and accelerating glacial melting, contributing to anthropogenic changes in monsoon circulation and the retreat of mountain glaciers in South Asia (Praveen et al. 2012). Recent research undertaken by the International Centre for Integrated Mountain Development (ICIMOD) reveals that, even if dramatic curtailing of carbon emissions succeeds in limiting global warming to 1.5°C objectives, 36 percent of the glaciers along the Hindu Kush Himalaya range will have disappeared by 2100 (Bolt et al. 2019). Through such local climate impacts, BC can also have significant negative effects on agricultural production, most directly for mountain cash crops, such as coffee and tea. The impacts of such effects may be important, but have not yet been analyzed. According to the scientific advisory panel of the Climate and Clean Air Coalition (CCAC), household emissions could be reduced by 60 percent by improving traditional biomass cooking and heating stoves, converting to LPG, and eliminating the use of coal stoves and kerosene wick lamps.

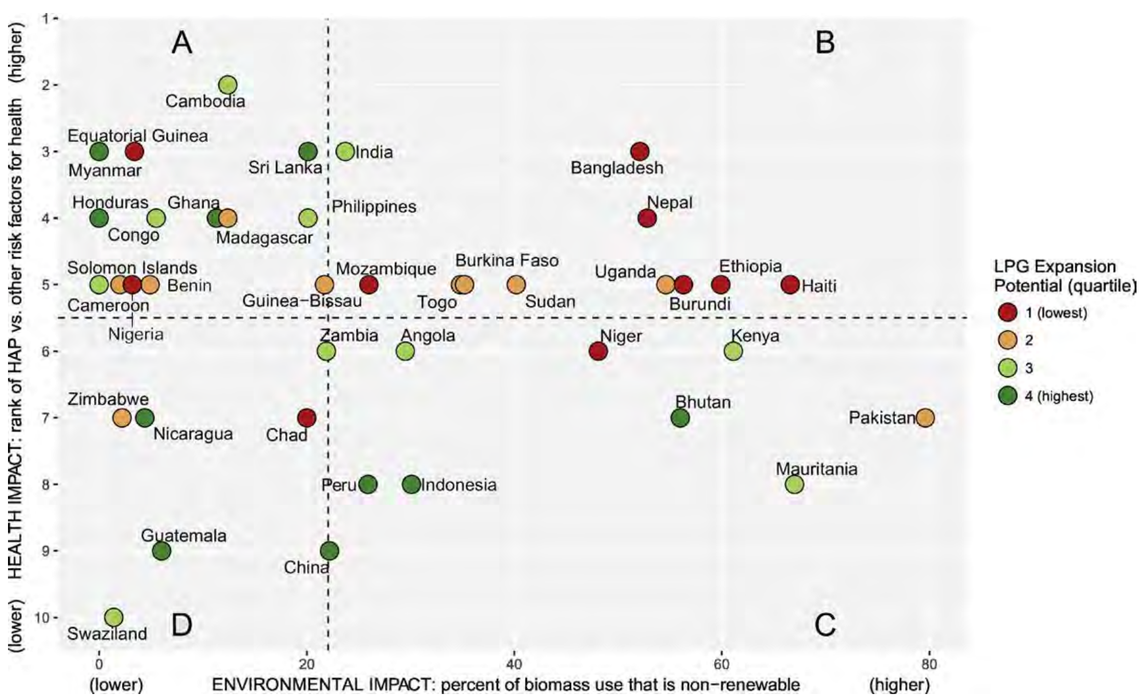
ENVIRONMENT

Biomass cooking is a contributing factor to forest degradation and localized deforestation. The current consensus view is that the primary causes of deforestation are land clearing for agriculture, exploitation of wood for lumber and road building, commercial and residential development, and other permanent land uses rather than the collection of firewood for energy (EC 2010; Hiemstra-van der Horst 2008; UCS 2011; World

Bank 2011). Some analysts suggest that charcoal may be a significant new driver of degradation,[7] as well as localized deforestation in Africa, Asia, Central America, and the Caribbean; however, most experts characterize charcoal production as just one forest-degradation factor among many. New research highlights that non-renewable biomass harvesting—which characterizes about one-third of the woodfuel harvest—can result in forest degradation (Ahrends et al. 2010; Hosonuma et al. 2012; Masera et al. 2015; Quinn et al. 2018). Indeed, on the African continent, wood collection and the charcoal supply chain are the principal drivers of regional forest degradation, jointly accounting for 48 percent (Hosonuma et al. 2012).

Given the multiplicity of negative environmental impacts, environmental benefits are more difficult to realize. The "greenest" solutions at the point of fuel consumption are renewable technologies using electricity generated from solar, hydropower, or wind; biogas; and sustainable ethanol; followed by advanced biomass gasifiers. The net climatic impact of clean cooking more broadly is complicated by the fact that solutions like LPG-reliant stoves or stoves that depend on electricity generated from coal or diesel are often directly linked to unsustainable and carbon-intensive, fossil-fuel extraction. However, LPG fuel use has been shown to produce net positive environmental payoffs, especially when displacing non-renewable biomass (Singh, Pachauri, and Zerriffi 2017). The environmental benefits of intermediate improved cookstove (ICS) technologies, such as rocket stoves, a technology family on which a substantial range of access programming relies today, are often undermined by their net BC emissions.[8] In the case of ICS, all else being equal, the most extensive environmental benefits are possible with those solutions that use sustainable processed fuels, such as crop-waste briquettes and pellets.

FIGURE 2.1 Rank of HAP-Related Disease Burden at the National Scale versus Expected Fraction of Non-Renewable Biomass for 40 countries



Source: Rosenthal et al. 2018.

Note: Health impact is the national rank of HAP relative to other risk factors (GBD 2013 Risk Factors Collaborators 2015); the expected fraction of non-renewable biomass (efNRB) is a measure of, among other things, unsustainable fuel use (Bailis et al. 2015). Countries in the upper-right quadrant are those for which HAP is among the greatest risk factors for disease and that have the most unsustainable supply of wood for cooking.

Looking ahead, fuel policy decision-makers should take an increasingly holistic view when accounting for environmental impacts. Specifically, climate and health benefits should be put side-by-side and accounted for within the fuel-consumption realities (i.e., one of multiple least-cost, best-fit factors of each market). Figure 2.1 illustrates how boosting the penetration and uptake of fuels like LPG may be less impactful in contexts where wood is consumed sustainably and HAP health impacts are low; enabling LPG penetration may make more sense in geographies with a high share of non-renewable biomass where LPG expansion is high.

EMPLOYMENT

The economic impact of biomass fuel use is not unequivocally negative because the woodfuel value chain employs millions of poor rural and urban households. While highly negative from the standpoint of energy poverty, dependence on fuels like biomass has positive impacts in terms of rural livelihoods and urban employment for tens of millions of small-scale wood collectors, charcoal producers, transporters, and last-mile retailers around the globe. The World Bank estimates that the Sub-Saharan Africa charcoal sector alone employs 7 million people, with aggregate employment expected to reach 12 million people by 2030 (World Bank 2011).

Clean cooking solutions carry both risks and rewards in terms of broader macroeconomic potential, particularly in terms of local job creation. While introducing alternatives to the traditional use of biomass runs the risk of substantial disruption up front—creating winners and losers, particularly when displacing long-established charcoal value chains—the employment impacts of modern fuels (e.g., LPG, electricity, and clean-combustion biofuels) can be positive once transition costs are absorbed. For electricity and LPG, capital infrastructure projects—notably focused on grid or pipeline extension or fuel-storage facilities—create job surges during construction periods and improve local economic environments. Specifically, rural-electrification initiatives have been shown to augment female labor supply, driven by such factors as increased home-business activities (Dinkleman 2011; Peters and Sievert 2015). Among alternative biofuels, ethanol exhibits high employment potential, given that value chains depend on feedstock cultivation, a labor-intensive sector that, if scaled, could potentially employ millions of small landholders (Kappen et al. 2017; Thurlow 2010). Moreover, Task Team interviews show that decentralized ethanol production via micro-distilleries can help establish vibrant local economies. In addition, pellet and briquette value chains depend on collected biomass or waste feedstock, a by-product of existing agriculture value chains or waste collection.

CONCLUDING REMARKS

Modern-energy cooking solutions can lessen much of the harm caused by dependence on wood, coal, and other non-clean fuels. Relatively strong evidence from the field suggests that fuelwood expenditures and time poverty are the harmful effects most easily addressed from a cost-benefit perspective (CCA 2017; World Bank 2018). Cooking-fuel expenditures and fuel-collection times can, in theory, be eliminated via renewable cooking solutions (e.g., biogas and solar) or significantly reduced through use of the most thermally-efficient improved cookstoves (ICSs), which require fewer trips to fuel-collection points. Impact evaluations suggest that fuelwood-expenditure savings of 60–80 percent (or reductions in collection time, albeit at a lag versus the reduction in fuel use) are feasible based on such technologies as biogas digesters and built-in, multi-pot chimney rocket stoves with a high thermal efficiency, which are most likely to minimize baseline technology use.[9] Clean fuels (e.g., LPG, electricity, renewable biofuel, and biogas) and select advanced ICSs can generate substantial household time savings by reducing total cooking time by as much as half and minimizing time loss and safety risks from fuelwood collection in many areas.

However, impact mitigation will require more than a "silver bullet." Across transition pathways and the design of interventions, it is critical to understand the fuel-and-stove payment dynamics. For example, one must understand whether a household pays for its cooking fuel or collects it freely from the surrounding environment. In communities with a high rate of fuelwood collection, behavior-change campaigns may need to make an argument for the trade-offs between free fuelwood and the value of collectors' safety and time. The livelihood impact of transitioning to clean or improved cooking stoves is likely net positive in terms of the number and quality of jobs created, but the precise impact will vary by geography and should be managed carefully to ensure sensitivity to potential near-term displacement of jobs in woodfuel value chains. Environmental benefits are more difficult to achieve than economic ones and are highly variable, based on the specific features of the cookstove and how it is used. Positive health impacts are the most difficult to achieve and can only be realized in cases where the most efficient and lowest-emitting cooking solutions displace daily use of traditional cooking technologies.

ANNEX 2. METHODOLOGICAL NOTE: CALCULATING THE COST OF INACTION

The cost-of-inaction estimates presented in this report rely on three separate calculations, all seeking to unitize the annual dollar value of sustaining the status quo (i.e., continuing to cook with the latest available global fuel mix). These estimates cover health (the costs of morbidity and mortality), gender (the costs of fuel collection, cooking, and stove cleaning), and climate (the social cost of carbon).

Health

The health calculation understands the cost of morbidity as the cost of one year of life lost to disability, including work absenteeism and medical treatment, resulting from household air pollution (HAP) and the cost of mortality as the cost of a life lost due to HAP. The calculation for health costs follows a top-down methodology. It uses the region-specific values for deaths and disability-adjusted life years (DALYs) due to HAP,[10] which are multiplied by a region-specific gross domestic product (GDP) per-capita figure. Each region's lowest national GDP per-capita figure is used to ensure a conservative estimate.[11] Finally, this value is multiplied by a cost multiple specific to DALYs or deaths: DALYs are estimated at 5 times GDP per capita, while the cost of mortality or the cost of one death due to HAP is estimated at 70 times GDP per capita.[12]

Gender

The gender calculation, as well as the climate calculation below, follows a bottom-up approach. A factor multiple for time spent on fuel collection, cooking, and stove cleaning is applied to each country's primary-fuel proportion,[13] using fuel-mix data; each factor multiple varies by primary fuel and all add up to a number of hours per year. This value is then multiplied by the cost of a woman's time, which is set at a conservative estimate of US$0.54 per hour.[14]

Climate

The climate calculation relies on the application of a fixed carbon cost to a global estimate of the carbon footprint of the current global cooking-fuel mix. The social cost of carbon, also described as the "present value of all future damages to the global society of one additional metric ton of carbon dioxide (CO_2)–equivalent greenhouse gasses emitted today" (Howard and Sylvan 2015), is set at US$45.92.[15] This cost value is sourced from the United States Government Interagency Working Group and the New York University (NYU) School of Law.[16] This cost value is then multiplied by a volume value—an estimate of the carbon footprint of the current global cooking-fuel mix (tons of CO_2 per year)—which is calculated using a bottom-up analysis: Each country's proportion of cooking fuel[17] is multiplied by a factor-specific multiple to understand the tons of CO_2 per year resulting from yearly fuel usage (in kilograms), the total Kyoto emissions rate with fraction of non-renewable biomass (fNRB), total CO_2 emissions for production, and total black carbon (BC) emissions. When added together, these values produce a total estimate of emitted CO_2.[18]

NOTES

1. Conditions linked to HAP but not extensively quantified in the current Global Burden of Disease (GBD) data include tuberculosis (Sumpter and Chandramohan 2013); childhood nutritional deficiencies, including anemia and stunted growth (Mishra and Retherford 2007); blindness (Siddiqui, Lee, and Gold 2005; West et al. 2013); asthma (Schei et al. 2004); depression in women of child-bearing age (Banerjee et al. 2012); cognitive impairment in the young and old (Perera et al. 2013; Suglia et al. 2008; Weuve et al. 2012); upper respiratory, digestive, and cervical cancers (Bhargava et al. 2004; Reid, Ghazarian, and DeMarini 2012); exacerbation of the effects of HIV/AIDS (Fullerton, Bruce, and Gordon 2008); and bacterial meningitis.

2. See also Ezzati and Kammen (2002), Odoi-Agyarko (2009), and Wickramasinghe 2003.

3. See International Organization for Standardization (ISO) standards for clean cooking and stoves.

4. Geographies with near parity in fuelwood collection include India, Mongolia, and Papua New Guinea; in such countries as Guatemala, Honduras, Indonesia, Lao PDR, and Nicaragua, men are the primary fuelwood collectors (Cooke, Köhlin, and Hyde 2008; Köhlin, Pattanayak, and Wilfong 2011).

5. Past Task Team reviews have suggested 0.5–5 hours for fuel collection (about 2 hours on average) and 1.3–5 hours for cooking and food preparation (2.5–3 hours on average), based on gender-disaggregated data for a dozen developing countries; see also Putti et al. (2015).

6. Assumes total global greenhouse gas (GHG) emissions of 34 billion tons of CO_2 (2011 figure), based on Olivier et al. (2011).

7. Degradation is defined as the direct human-induced reduction in forest carbon stocks from the natural carbon carrying capacity of forest ecosystems without a net reduction of forest area (TNC 2009).

8. A number of common rocket stove models more than double BC emissions for each kilogram of fuel burned, cancelling out the emissions-abatement effects of improved fuel efficiency (BAMG 2011).

9. Savings reported from the field for rocket stoves are 45–65 percent (with the high end of the range representing chimney rocket stoves) and 60–80 percent from biogas-digester interventions.

10. This top-down calculation uses the estimates of the Health Effects Institute (HEI 2019), with data from the Institute for Health Metrics and Evaluation (IHME)–coordinated Global Burden of Disease (GBD) Study 2017 (HEI Household Air Pollution Working Group 2018).

11. Benchmarks include Burundi for Sub-Saharan Africa, Haiti for Latin America and the Caribbean, Nepal for South Asia, Cambodia for Southeast Asia, and Mongolia for East Asia.

12. These cost multiples are aligned with those described in the World Bank's methodology for DALYs

and deaths; see Enriquez, Larsen, and Sánchez-Triana (2018) and the World Bank's GDP per-capita calculations (World Bank 2019).

13. Representative of 71 countries (see chapter 3 for details).
14. Sources are the World Bank/Dalberg Results-Based Financing (RBF) Model for time multiples and the Dalberg Impact Model for cost multiples.
15. US$37 (2007 value) adjusted for inflation to 2019 value; sourced from Howard and Sylvan (2015).
16. See note 15.
17. Representative of 71 countries (see chapter 3 for details).
18. Factor multiples are sourced from the World Bank/Dalberg RBF Model.

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SAFUNA

CHAPTER 3

UNDERSTANDING THE STATE OF ACCESS AND DEMAND

ACCESS SHARES AND OPPORTUNITIES

Analysis of new datasets allows this report to put forward an initial, comprehensive estimate of access to Modern Energy Cooking Services (MECS).[1] Benefitting from a granular, fuel-specific dataset that captures nuances between rural and urban fuel use, the compilation of national-level primary fuel data allows this report to present an updated view of fuel consumption over time and by locality.[2] The dataset comprises a 71-country sample,[3] totaling 5.3 billion people that represent approximately 90 percent of the population in all middle-income, lower-middle-income, and lower-income countries—about 70 percent of the world's 7.8 billion people (2020 figure).[4]

The report calculates shares of MECS access across the countries included in its cooking dataset. It does so by matching the access archetypes of users for a range of primary fuels (across multiple countries with granular Multi-Tier Framework [MTF] data) to the populations using these same primary fuels in countries where data from demographic and health surveys are available. The 71 countries encompass most of Sub-Saharan Africa, East Asia, and Southeast Asia, and the most populous regions of Latin America and the Caribbean. However, some portion of the population in every country—including higher-income countries—does not meet the Tier 4 criteria for one or more of the MECS attributes; therefore the calculated number of people without access can be interpreted as conservative (Annex 3).

Of the 5.3 billion people that comprise the sample, approximately 4 billion do not truly have access to MECS (figure 3.1). Thirty-eight percent of urban households in the sample meet all access criteria, compared to just 12 percent of rural households. The 4 billion figure can serve as a starting point for further refinement as more countries field MTF household surveys that more accurately calculate MECS access.

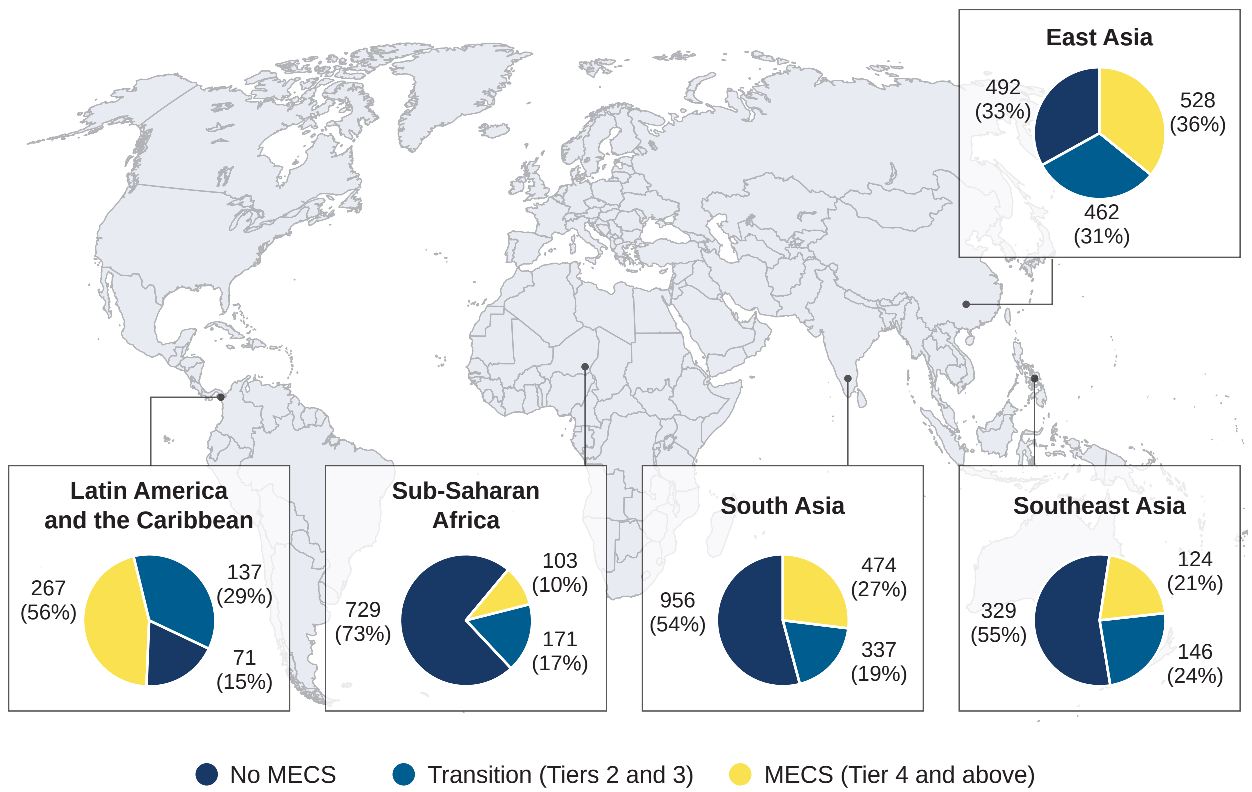
Sub-Saharan Africa has the smallest share of the population with access to MECS, at 10 percent, while Latin America and the Caribbean and East Asia have the highest shares, at 56 percent and 36 percent, respectively (figure 3.1). In East Asia, the share of the urban population with access is more than five times that of the rural population; thus, urban access in East Asia drives up the regional score and more than compensates for low rural access. The region's high share of urban access can be explained, in large part, by the significant increase in China's populations using natural gas and electricity in recent years. Myanmar and Nepal have achieved strong fuel transitions in urban environments and therefore see relatively high levels of access. Meanwhile, the fuel mix for nearly two-thirds of the Sub-Saharan Africa countries included in the sample is similar to that of Nigeria or Rwanda—mostly wood as the primary fuel and 5 percent or less penetration of MECS in both urban and rural areas.

Of the 4 billion people without MECS access, approximately 1.25 billion are considered in transition; focusing on this subset could help accelerate access gains. Targeted interventions that focus on moving transition-tier populations up to Tier 4 (i.e., by improving the affordability of stoves with a Tier 4 [or higher]

FIGURE 3.1 **Population Access to MECS, by Developing Region**

Millions of people and tier %

N = 71 countries



Sources: World Bank MTF country datasets, Demographic and Health Surveys (DHSs), Multi-Indicator Cluster Surveys (MICSs), and Task Team analysis.

efficiency level), could bring a greater share of the global population into the fold of MECS. East Asia and Latin America and the Caribbean have the largest transition populations as a share of all households, at 31 percent and 29 percent, respectively, while Sub-Saharan Africa has the smallest, at 17 percent.

Non-accessing segments are predominantly rural, transition populations skew slightly more urban, and MECS-accessing segments are predominantly urban. Extremes arise in Sub-Saharan Africa and South Asia, where rural segments below Tier 2 are disproportionately large compared to the sample average. In Latin America and the Caribbean, by contrast, the largest regional segment—nearly half of all households—consists of urban users that meet the criteria of Tier 4 or higher (table 3.1); that region also has the highest transition-population opportunity.

Sharp social and economic transformations over the next decade will likely shift these access patterns substantially, growing the size of the transition populations. Most notably, high urbanization rates will concentrate populations in denser city environments, impacting the distributional economics of fuels and stoves and setting the scene for fuel-utility models that focus not only on price but also meeting user needs linked to convenience and accessibility. According to research by the Center for Strategic and International Studies, in Sub-Saharan Africa alone, urban areas currently contain 472 million people, and this figure is set to double over the next 25 years. This trend may eventually help to improve the marginal cost of electrification, with more households closer to grid coverage. However, ready access to modern fuels like electricity (especially if

TABLE 3.1 **MECS Access Rates, by Region and Locality**

% population
N = 71 countries

Region	No MECS (< Tier 2)		Transition (Tiers 2 and 3)		MECS (Tier 4 +)	
	Rural	Urban	Rural	Urban	Rural	Urban
Latin America and the Caribbean	9	6	5	24	7	49
Sub-Saharan Africa	53	20	6	11	2	8
South Asia	47	7	10	9	10	17
Southeast Asia	42	13	9	16	4	17
East Asia	22	11	10	21	8	28

Sources: World Bank MTF country datasets, DHSs, MICSs, and Task Team analysis.

power comes from renewable generation) will require overcoming prohibitively high connection costs, even for households within reach of the grid.

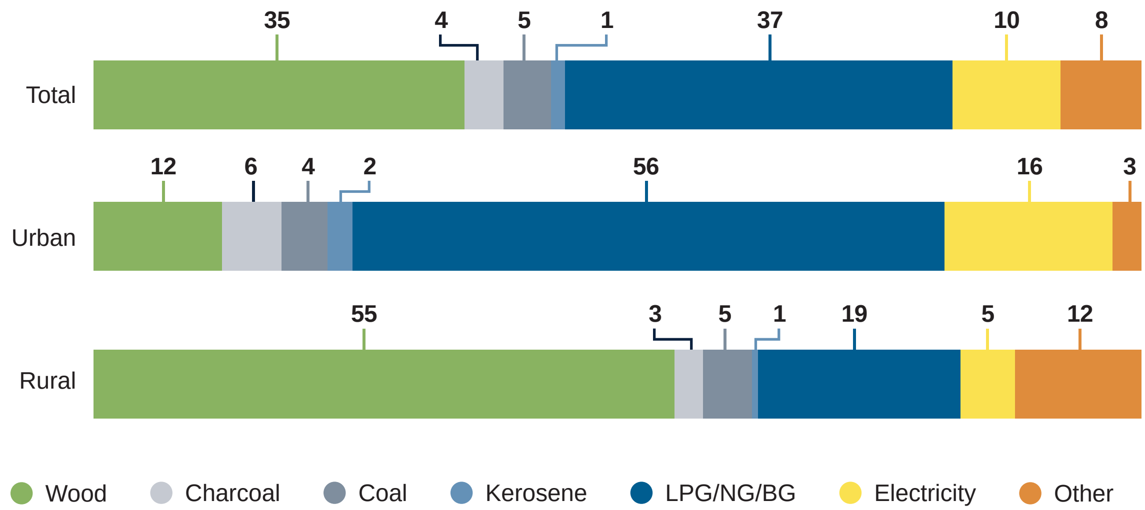
MAPPING TRENDS IN PRIMARY FUEL USE

Understanding what fuel types households adopt can provide insights on affordability, convenience, and other key attributes that shape the cooking context. The set of additional analyses performed on the granular 71-country database shows that the world is split in its use of primary cooking fuels. Results of the analysis reveal that just over half of the sample cooks with such fuels as wood, charcoal, coal, and kerosene. The other half cooks with fuels that allow households to meet Tier 4 (or higher) exposure criteria, under conditions of adequate ventilation and with advanced stove technology. This split varies across localities since cleaner fuels are more prevalent in urban settings (figure 3.2).

Over the last decade, the number of households with access to clean fuels has increased in absolute terms, as has the number of those cooking with less clean fuels. Significant population growth in communities that primarily use biomass and charcoal in inefficient stove-fuel combinations accounts, in large part, for this finding. In addition, notable gains in liquefied petroleum gas/natural gas/biogas (LPG/NG/BG) and electricity, whose respective shares of the global fuel mix total 37 percent and 10 percent, have come at the expense of coal and kerosene, which have seen relative declines.[5] While wood has seen a significant drop in use as a primary fuel, it remains a major source of household energy across the world, representing 35 percent of the sample (figure 3.2).

FIGURE 3.2 **Global Primary Fuel Mix for Cooking**

% global population



Sources: DHSs, MICSs, and Task Team analysis.

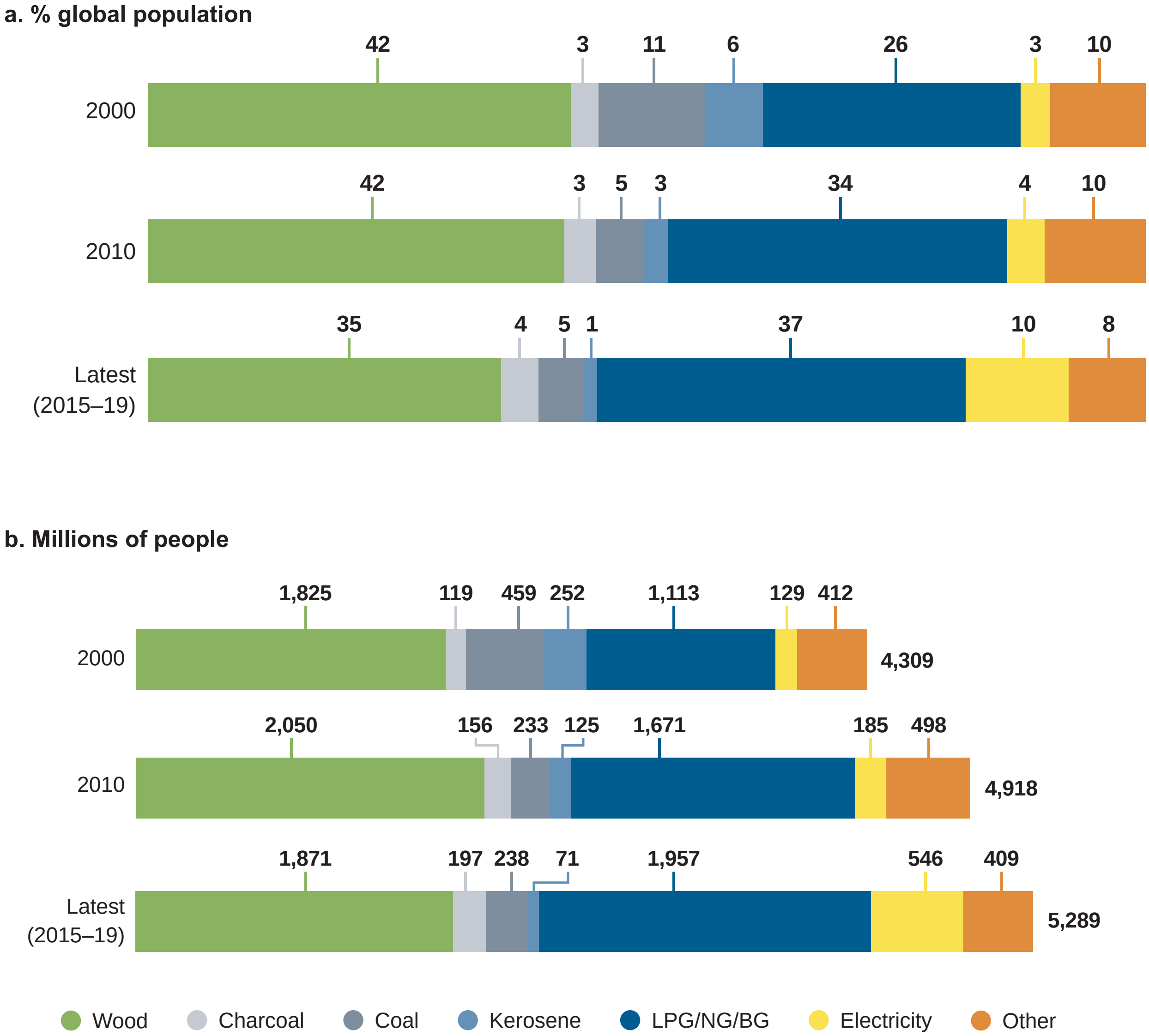
Note: Data is from the 71-country study conducted in 2019 or otherwise the most recently available data.

United Nations urbanization and population data were used to extrapolate fuel-mix percentages for the urban, rural, and total global populations. For China (in the absence of publicly-available data), the data reflect internal scenarios of a fuel transition away from coal and wood and toward natural gas and electricity. In the legend, "LPG/NG/BG" indicates the sum of liquefied petroleum gas, natural gas, and biogas, and "Other" primarily includes dung, crop waste, and other fuels.

Both access levels and gains in access over the past decade vary considerably by region. Not surprisingly, the share of the population without access is highest in Sub-Saharan Africa and lowest in Latin America and the Caribbean. At the same time, adoption of LPG/NG/BG and electricity—the primary energy sources for most households that access MECS—has increased as an aggregate share of the global fuel mix from 38 percent to 47 percent (figure 3.3a), representing 2.5 billion people in the sample (figure 3.3b). Large LPG-using populations are found in Southeast Asia and Latin America and the Caribbean (figure 3.4a), but are less common in rural South Asia and East Asia, with relatively little used in Sub-Saharan Africa (figure 3.4b). Large-scale, clean-fuel transition programs in such countries as China, India, and Indonesia, have had a major effect on the overall fuel mix in both South Asia and East Asia. By contrast, Sub-Saharan Africa has seen absolute increases in the use of biomass, driven by population growth.

FIGURE 3.3 Evolution of Primary Fuel Mix for Cooking

N = 71



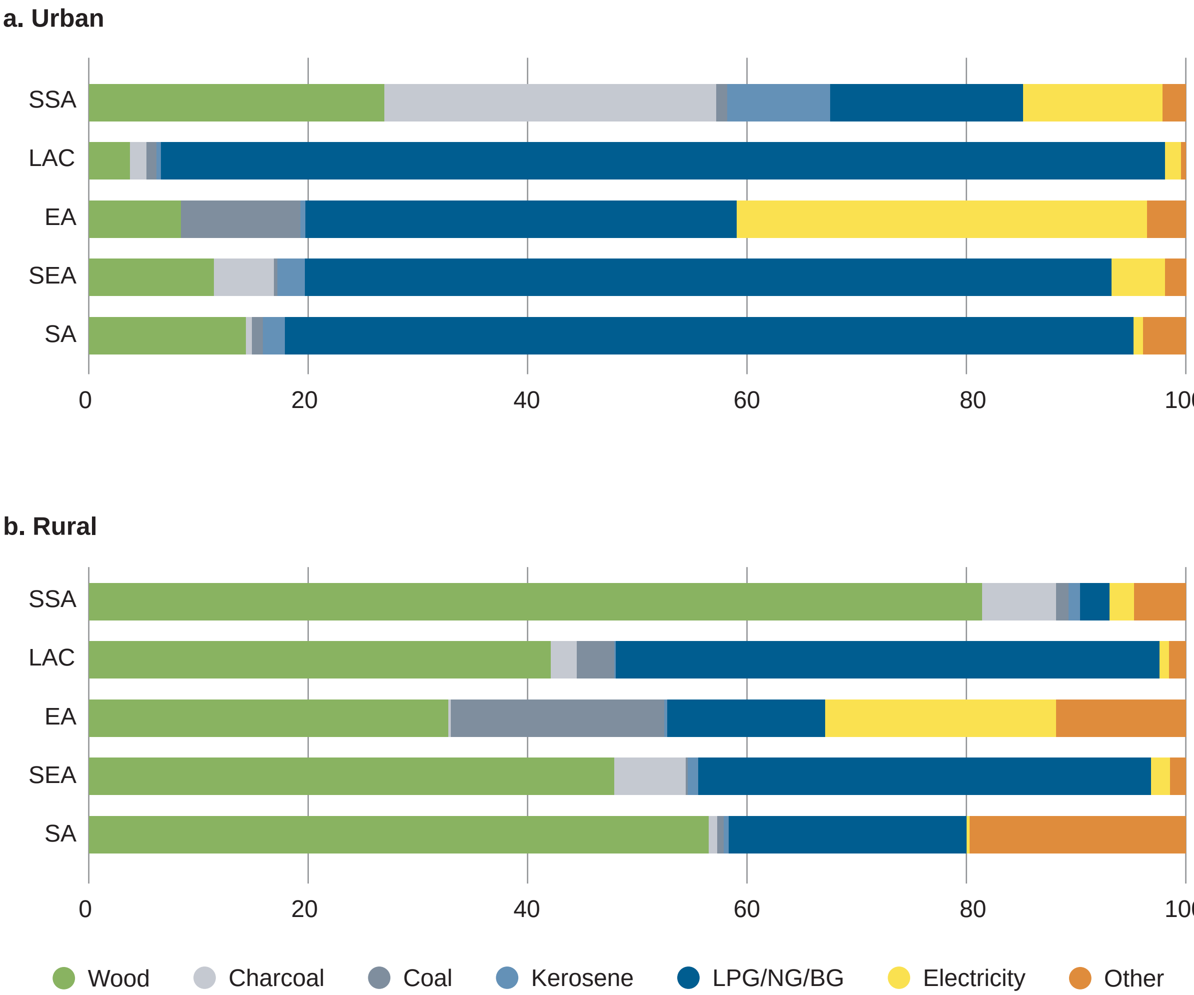
Sources: DHSs, MICSs, and Task Team analysis.

Note: Data is for 2019 or otherwise the latest available, fuel-mix data from the DHSs, MICSs, or country-level energy-census data collected mainly between 2012 and 2019. United Nations urbanization and population data were used to extrapolate fuel-mix percentages to the urban, rural, and total global populations. For China (in the absence of publicly-available data), data reflect internal scenarios of a fuel transition away from coal and wood and toward natural gas and electricity. In the legend, "Other" includes ethanol, pellets, dung, crop waste, and other fuels, which are inconsistently categorized in national datasets and energy-census data.

FIGURE 3.4 **Global Primary Fuel Mix for Cooking, by Region**

% global population

N = 71 countries



Sources: DHSs, MICSs, and Task Team analysis.

Note: Data is for 2019 or otherwise the latest available, fuel-mix data from the DHSs, MICSs, or country-level energy-census data collected mainly between 2012 and 2019. United Nations urbanization and population data were used to extrapolate fuel-mix percentages to the urban, rural, and total global populations. For China (in the absence of publicly-available data), data reflect internal scenarios of a fuel transition away from coal and wood and toward natural gas and electricity. In the legend, “Other” includes ethanol, pellets, dung, crop waste, and other fuels, which are inconsistently categorized in national datasets and energy-census data. SSA = Sub-Saharan Africa, LAC = Latin America and the Caribbean, EA = East Asia, SEA = Southeast Asia, and SA = South Asia.

ASSESSING STACKING BEHAVIOR

Despite modestly encouraging trends in the uptake of clean fuels, stacking—the use of multiple stove-and-fuel combinations within the same household—persists in many developing countries. This report finds that the practice of stacking is more prevalent among higher-income quintiles in urban areas, notwithstanding considerable inter-country variations (figure 3.5). Stacking is particularly acute in countries with higher urban and peri-urban populations and among households whose primary fuel is not wood. Households in urban settings that practice stacking tend to do so with the next-cleaner fuel. In Nigeria, for example, urban populations that stack with charcoal tend to use wood as their primary fuel, while those that stack with kerosene or paraffin mainly use charcoal. In urban Myanmar, 85 percent of households that stack with charcoal use purchased wood as their primary fuel. The World Bank MTF data show that urban stacking patterns differ markedly by country. For example, only 15 percent of urban households in Nepal practice stacking, compared to 80 percent in Cambodia. Such dramatic differences have important implications for developing policies and behavior-change campaigns.

FIGURE 3.5 Comparison of Stacking Behavior for Selected Countries

a. Urban areas (%)

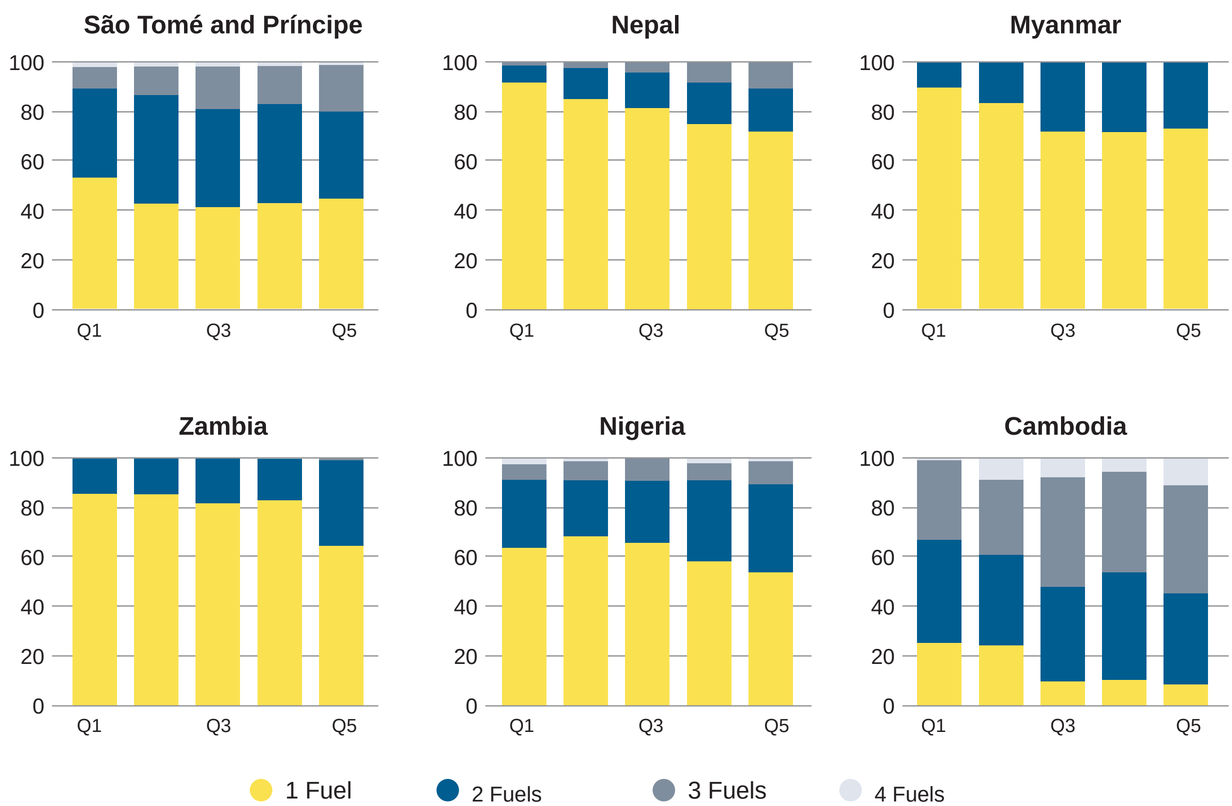
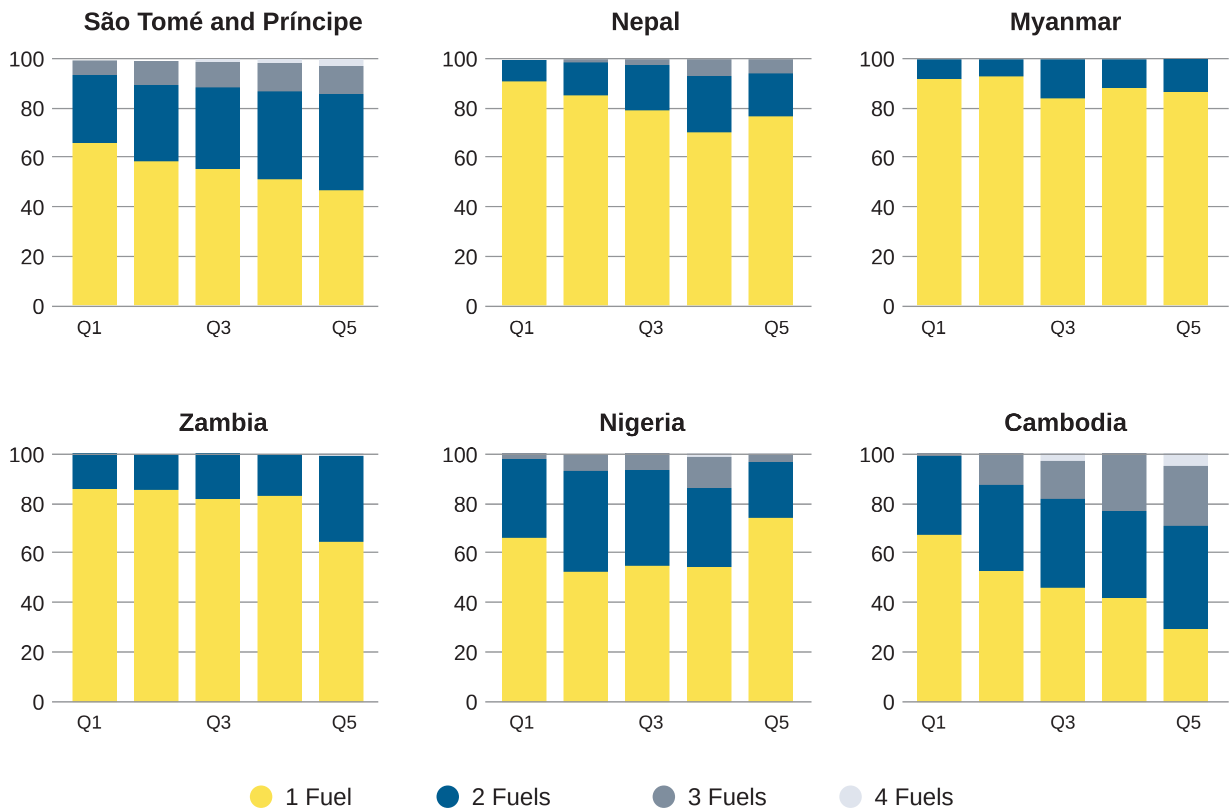


FIGURE 3.5 ***Continued***

b. Rural areas (%)

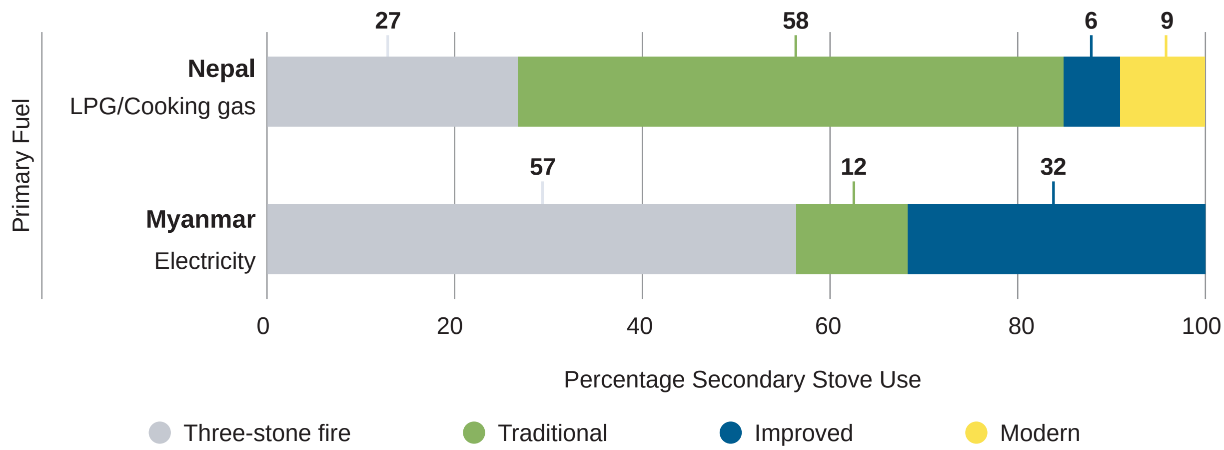


Source: World Bank MTF country datasets.

Note: Income quintiles range from lowest (Q1) to highest (Q5).

A key challenge today is how to limit stacking with less clean traditional fuels and stoves by households that have already become primary users of clean cooking solutions. In many countries where stacking is the norm, substantial progress has been made in the penetration of clean primary fuels. However, many primary users of clean stoves and fuels persist in high-frequency, secondary use of traditional fuels (e.g., wood and charcoal) and stoves (e.g., three-stone fires, fireside cookers and wood ovens, charcoal stoves, and charcoal barrels). A recent study in Kenya, for example, reveals that households that are primary LPG users consume 42 percent as much charcoal as households that are primary charcoal users (Republic of Kenya, Ministry of Energy 2019). In Nepal, 58 percent of rural households that are primary LPG users and also stack do so with a traditional stove. Similarly, in Myanmar, up to 57 percent of primary electricity users in rural areas that also stack use a three-stone fire (figure 3.6). This so-called "dirty" stacking behavior—the use of non-clean fuels for stacking by populations that are primary users of clean fuels—also extends to urban settings (e.g., Nepal). In Ecuador, which has already accomplished a substantial shift to clean cooking solutions, supplemental wood use for cooking is quite prevalent (box 3.1). These examples underscore the importance of contextual and behavior-change factors outside the "clean" versus "non-clean" fuel-access dichotomy that influence users' cooking choices and preferences (e.g., reliable availability of fuels and affordability). They also highlight the reality that many households that have met the threshold for primary clean-fuel access continue to face substantial exposure to household air pollution (HAP) linked to their secondary use of traditional stoves and fuels.

FIGURE 3.6 Secondary Stove Stacking in Rural Households of Nepal and Myanmar



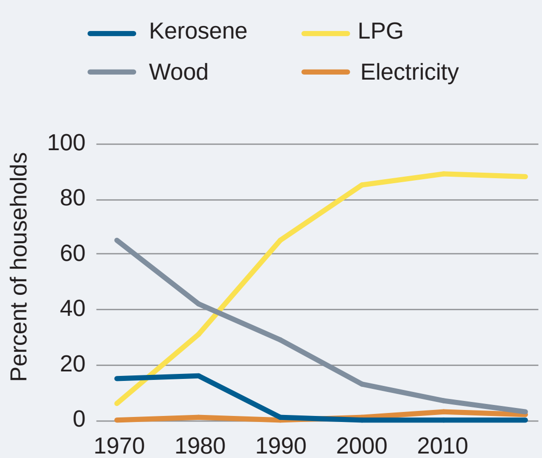
Source: World Bank MTF country datasets.

Note: Fuel-stacking households are those that use two or more fuels. In the legend, "Three-Stone Fire" refers to open-fire stoves; "Traditional" includes fixed/self-made stoves, traditional metal stoves, and self-built/traditional stoves; "Improved" includes rocket stoves (chimney, fan, and grate), ceramic stoves, ceramic stoves in metal bucket, and locally-manufactured kerosene stoves; and "Modern" includes biogas stoves, electric/induction/rice cookers, LPG/natural-gas stoves, and electric stoves.

BOX 3.1 Prevalence of Secondary Stacking: Example of Ecuador

Despite Ecuador's decades-long fuel transition program, stacking persists today. Between 1974 and 2016, the country shifted substantially away from wood toward liquefied petroleum gas (LPG) as its primary cooking fuel (figure B3.1.1). Even so, 44 percent of households that mainly use LPG for cooking continue to supplement its use with wood at least once a day (table B3.1.1).

FIGURE B3.1.1 Primary Cooking Fuel, 1974–2016



Source: Gould et al. 2018.

TABLE B3.1.1 Persistence of Secondary Wood for Cooking in LPG-Using Households

Frequency of fuel use	LPG (%)	Wood (%)
Multiple times a day	99	29
Once a day	0	15
1–6 times per week	1	34
Less than once a week	0	22

Note: Represents 51 percent of total sample.

BOX 3.2 End-User Perspectives on Stacking: Qualitative Study Findings from Kenya

A recent in-depth, qualitative study in Kenya reveals that cookstove stacking is the norm. Supported by the European Union/Irish Research Council (EU/IRC) and the World Bank's Energy Sector Management Assistance Program (ESMAP), the study interviewed 71 rural and urban households. More than 80 percent of those interviewed reporting stacking as a regular practice. This finding is consistent with the Multi-Tier Framework (MTF) national survey, where a majority of respondents reported frequent use of more than one stove type.

The qualitative study's participants cited practical limitations associated with the primary stoves and time costs as the major reasons for stacking. They reported the inability of any single cooking device (traditional or improved) to fulfill all stove applications in the household. Secondary stoves were reported to serve important basic functions, such as providing a fallback stove when the primary one cannot meet key functionalities or when fuel is unavailable. They also reported time savings from being able to prepare multiple meals simultaneously. Other less dominant and highly divergent reasons for stacking included preference for preparing some meals on particular cookstoves.

Designing a cookstove that responds to variations in individual tastes and preferences, which are transient by nature, would be challenging. However, harmonized solutions can be applied to meet the shared practical challenges of cooking one meal at a time and boiling functions that require large-sized pots that do not fit on modern cookstoves.

Based on these findings, the study recommends the following:

- **Change the narrative on stacking** from that of attenuating benefits of cookstove programs to being an essential element in the stove transition process. This study finds that stacking can enable households to sample and aspire to modern cooking, as well as keep them on the modern-energy transition pathway by overcoming the bottlenecks of newly adopted solutions.
- **Make stacking part of stove-promotion efforts by offering a suite of clean stacking options** to add to existing stoves. Many of the secondary functions that necessitate stacking with traditional stoves, such as water heating and slow-cooking meals, could be substituted with pressure cookers, water heaters, and other more efficient appliances that can be powered by grid or off-grid electricity.
- **Standardize the number of stove burners to a minimum of two,** and use this standard as part of behavior-change campaigns and stove demonstrations.
- **Capture data on secondary cookstoves** as part of national surveys. This qualitative study finds that, even among rural fuelwood users, stacking is common, with an additional three stones (for a total of six stones) or inefficient charcoal stoves serving secondary functions. This type of information is lost in surveys that utilize binary indicators of energy access.

Source: Ochieng et al. (Submitted).

“Clean” stacking behavior—the use of clean fuels for stacking by households that primarily use non-clean primary fuels—can yield positive near- and longer-term impacts. Each cooking task undertaken using a clean stove-fuel combination—even for such small tasks as boiling water for tea or refrying food—represents less use of a non-clean cooking solution. Moreover, stove-fuel product experimentation by those who primarily use biomass fuels on a traditional stove may facilitate greater adoption of clean fuels and thus gradually lower household exposure over time.

Stacking behavior has important implications for policies and campaigns promoting the adoption and use of high-efficiency, low-emissions stove-and-fuel combinations. Findings from a recent qualitative study on stacking in Kenya suggest the need to change the narrative on stacking from one of weakening the benefits of cookstove programs to being an essential element in the stove transition process. Clean stacking can enable households to aspire to modern cooking solutions and overcome the bottlenecks of newly adopted solutions. The study recommends integrating clean stacking into stove-promotion efforts and highlights the need for national surveys to capture data on household use of secondary fuels and stoves (box 3.2).

ASSESSING ADOPTION FACTORS

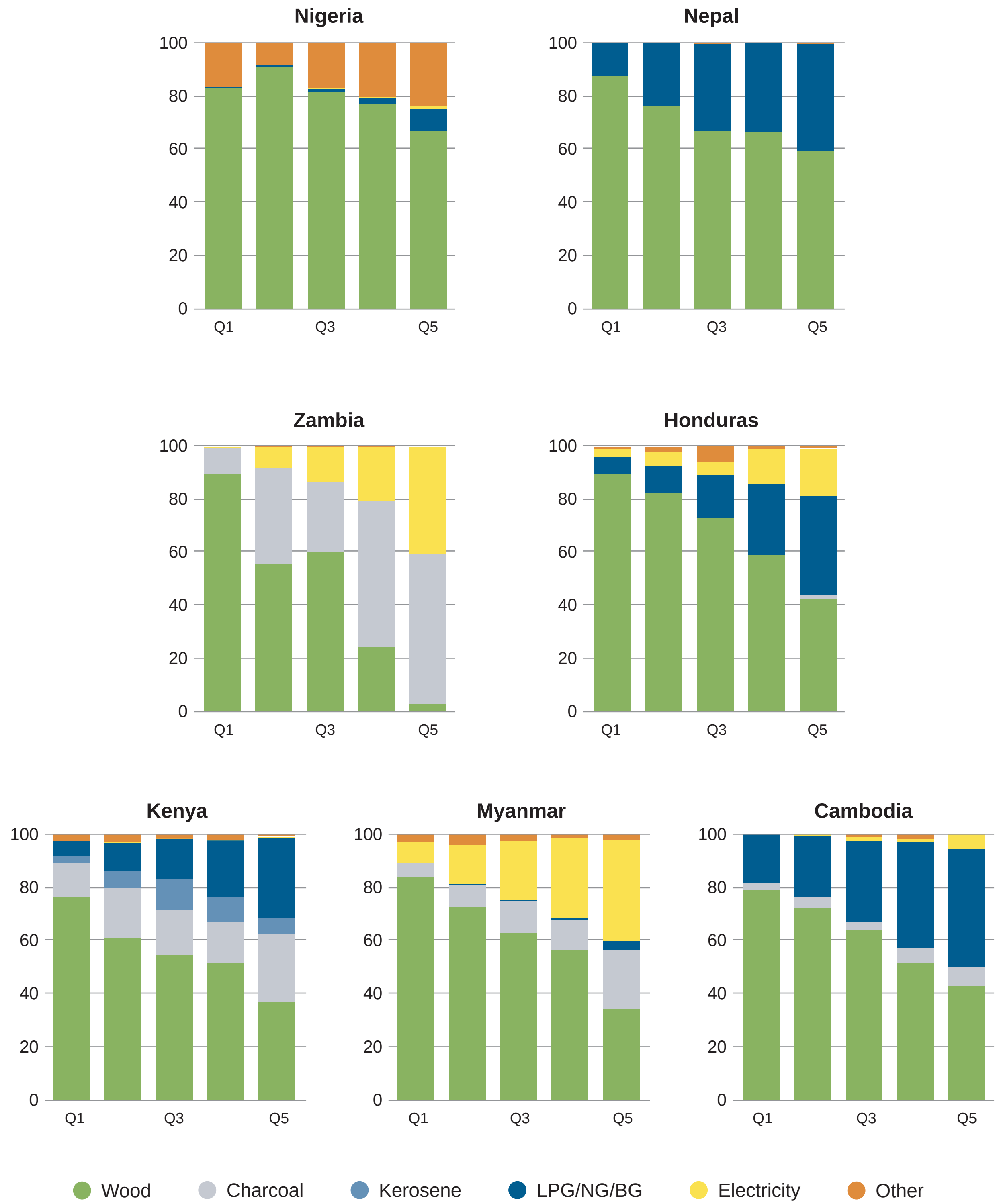
MECS adoption depends on a range factors that are market-specific and culturally-determined. As important as it may be to highlight the nuances of primary fuel-use patterns, a range of additional contextual factors beyond the fuels and technologies used contribute to enabling or hindering the adoption of MECS. Affordability is an essential determinant of a household’s access to MECS, while convenience, availability, and safety also play a critical role in determining whether and how people adopt a clean stove-fuel combination and the extent to which they adhere to it. While the weight carried by each of these attributes may differ and be driven by a variety of factors unique to each country context, a comparative assessment of each helps to shed light on trends common to most households accessing MECS.

Affordability

Income remains a fundamental driver of fuel and stove demand, with the lowest quintiles most dependent on the historically most affordable fuels—primarily wood and charcoal. Among the countries analyzed, clean fuels mainly tend to penetrate the uppermost quintiles. However, markets that feature substantial, long-standing fuel subsidies and national programs that impact end-user prices (e.g., electricity in Myanmar and LPG in Cambodia and Nepal) allow for more widespread adoption of primary clean fuels (figure 3.7).

FIGURE 3.7 **Primary Fuels for Selected Countries, by Income Quintile**

%

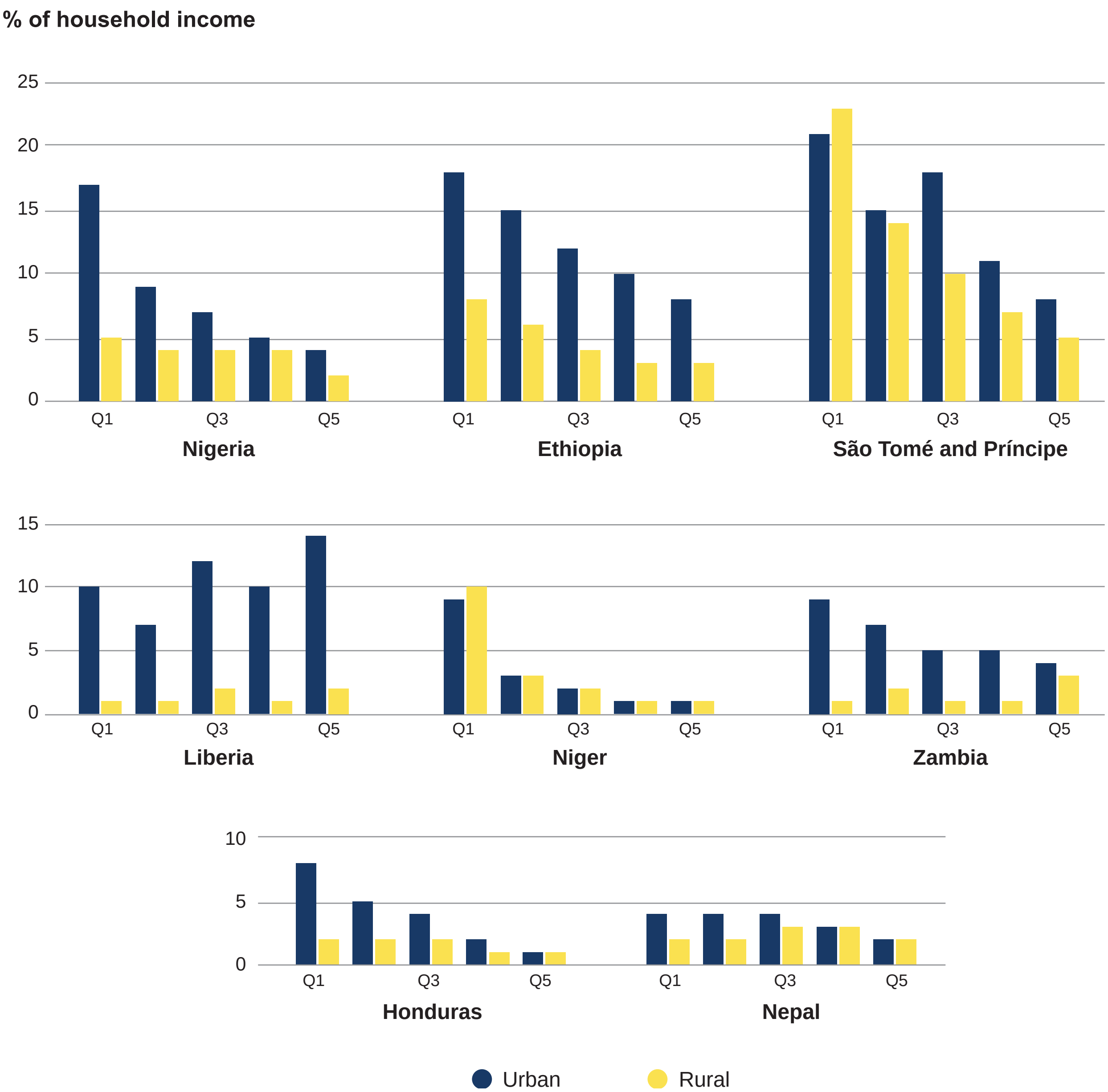


Source: World Bank MTF country datasets.

Note: Income quintiles range from lowest (Q1) to highest (Q5).

Affordability remains a disproportionate barrier to access for lower-income quintiles. When looking primarily at the relative share of income spent on fuel, higher-income quintiles are more likely than lower-income quintiles to afford access to MECS. This trend even occurs in countries with subsidy and direct-provision programs. Compared to urban users, rural users tend to spend less on fuel owing, in large part, to the prevalence of wood that can be freely collected. In urban settings, where households are less likely to have access to readily available, free fuel sources, a larger proportion of their income must be allocated to cooking energy (figure 3.8).

FIGURE 3.8 Rural and Urban Fuel Expenditure for Selected Countries, by Income Quintile



Source: World Bank MTF country datasets.

Note: Quintiles are determined by expenditure (a proxy for income).

The affordability challenge is especially problematic where the high up-front costs of appliances and fuels severely limit the potential for the bottom half of the market. The costs range from US$50–100 for LPG and electric stove kits and US$75–100 for biomass fan gasifier stoves to US$500–1500 for biogas. Stove enterprise interviews and analogous data from the World Bank and International Finance Corporation (IFC)–supported Lighting Africa program suggest that consumers are willing to spend the equivalent of 1–2 months of fuel expenditures on an improved appliance. With this as an assumption, stoves in the US$30–100 price range are affordable only to the highest income segment of bottom-of-pyramid consumers (i.e., those that earn more than US$1,500 per capita annually), equivalent to approximately 34 percent of the global population. Historical purchasing behavior also shows the importance of this constraint. New business models explore how this constraint is being addressed by challenging the need to charge high up-front prices (chapter 4).

Today, few developing-world consumers have spent more than US$15 on their primary cookstoves. Adoption of an intermediate improved cookstove solution in the US$15–30 price range implies a significant re-allocation of budget priorities for an average household. The challenge is even greater for LPG stove appliances and biomass fan gasifiers, whose average prices are in a range of US$50–100. Despite their promise, financing options for last-mile consumers lag in most places. For example, in Kenya, research indicates that the vast majority of both urban and rural households pay for stoves up front (Republic of Kenya, Ministry of Energy 2019).

The affordability facet of the access challenge must account for the range of factors that shape users' purchasing decisions. Affordability should not be reduced exclusively to a proportion of household expenditure. It must also account for such factors as barriers in awareness, availability, forms of finance, and financial flows. Absolute income factors may be more likely to take a central role if the purchase is in the form of a large capital expenditure or a lump-sum bulk refill of a gas bottle. But with most fuel purchases taking place at regular intervals (daily, weekly, or monthly), unitary transactions are likely closer indicators of fuel choice.

Freely collected fuelwood for cooking is affordable on a daily cost-of-fuel basis only if users' perceptions factor out risks to their safety, health, and economic potential. That roughly half of Sub-Saharan Africa's population depends on free fuelwood for cooking is a well-assessed example (Kappen et al. 2017). However, in contexts where users are more aware of the physical harm and opportunity costs of drudgery and smoke, households may put a higher premium on convenience and availability and begin using cooking-utility models that break down expenditure economics to the unit of the meal or week (e.g., PayGo Energy in Kenya). Uptake of such models has been driven by enterprises' better understanding of the localized trade-offs that, when addressed, help households progress through the MECS tiers (chapter 4).

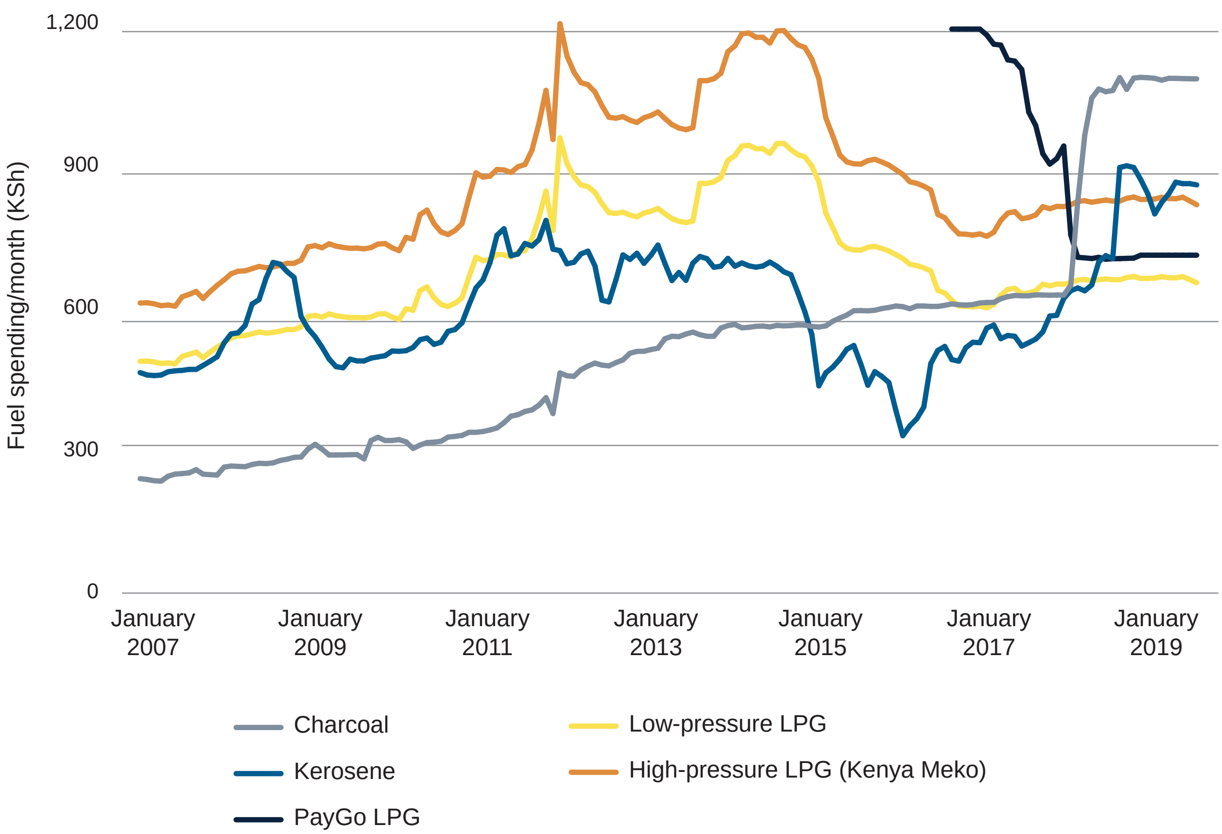
While it is difficult to compete with the unit economics of households that do not pay for fuel, the remaining and more immediate addressable market of fuel payers is large and growing. Solutions that require the up-front purchase of a stove, combined with ongoing fuel costs, will struggle to convert primarily rural households that rely on free biomass collection. Extensive business-model innovation and/or substantial subsidies may switch wood collectors to cleaner fuels, but the likely (and most immediately addressable) market for clean cooking companies consists of people who currently pay for wood and charcoal. Because wood buyers already face moderate economic pressure from fuel costs, they are often more willing to consider trading up. A surprising number of wood buyers—roughly half of the total, particularly in Sub-Saharan Africa and parts of Asia—are located in urban and peri-urban areas. This means that, in theory, they have greater physical access to distributors of cleaner stoves and fuels. In Sub-Saharan Africa, the one-third of the population that pays for charcoal and wood alone comprises a market estimated at US$12 billion annually; this market is on track to double in size due, in part, to rising household incomes, urbanization, and population growth (chapter 4).

This growth in market potential comes at a time when cleaner fuels like LPG are becoming increasingly price-competitive against staple urban primary fuels like charcoal and kerosene. To take Kenya as an example, the price of LPG has oscillated over the last decade.[6] Nevertheless, its price has decreased dramatically since 2014 owing, in large part, to the cheaper supply of imported LPG. Since 2018, the price of charcoal has doubled due to a ban on logging for charcoal, and prices for kerosene have increased since the imposition of a fuel tax. The introduction of pay-as-you-go (PAYGo) LPG has made the monthly consumer cost of gas lower than nearly all other cooking fuels (figure 3.9). Under these assumptions, gas remains the most affordable fuel on a monthly basis. However, because it has not been widely available for purchase in small quantities, the majority of people who spend more per meal on purchasing non-clean fuels do not access it.

Improvements in the affordability of clean fuels are not limited to LPG. Alternative biofuels like carbonized briquettes and pellets may not be affordable to the poorest segments of the population that rely on free wood. However, they have been shown to be a competitive fuel for charcoal users and, in many instances, LPG users, as demonstrated by First Energy's Oorja household customer base for pellet fuels in India during an earlier phase of that business.[7] The analysis below compares average urban and peri-urban household expenditures

FIGURE 3.9 Monthly Fuel Expenditure in Kenya for Selected Fuels

Kenyan Shillings (KSh)



Source: Kenyan Bureau of Statistics (analysis by PayGo Energy).

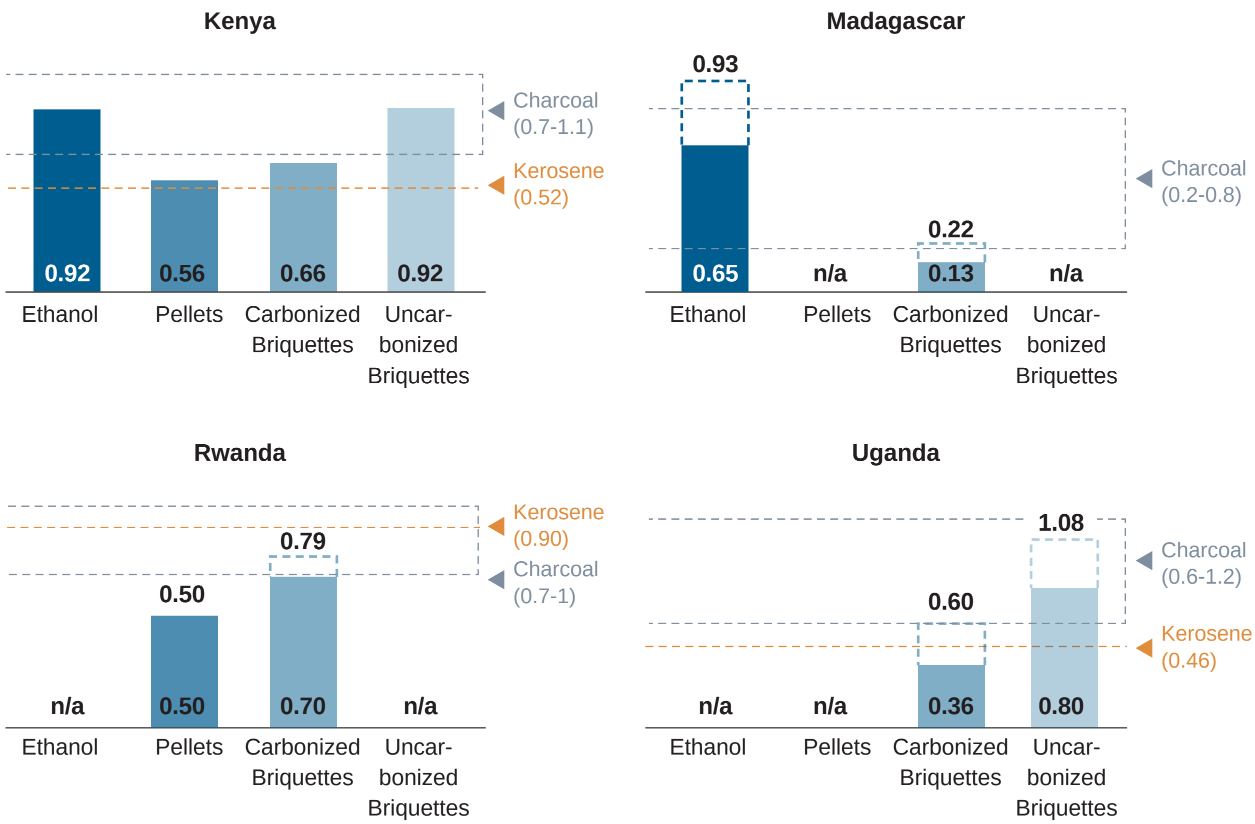
Note: For each fuel, the monthly expenditure is based on equivalent energy needs for PayGo Energy customer consumption of 4 kg LPG.

on biofuels to that required for charcoal and kerosene across several East African markets (figure 3.10). While these numbers should be viewed only as directional or indicative, they nonetheless yield several interesting findings. First, pellets and carbonized briquettes are cheaper than charcoal and kerosene in some countries. Second, charcoal can vary significantly in price, even within a country. Third, within the comparison set, ethanol remains the most expensive alternative biofuel at face value and has historically struggled to compete in price with charcoal and kerosene.

The increased and sustained affordability of alternative biofuels will depend on further improvements in technology and enabling factors like taxes and duties. Alternative fuel producers of ethanol or pellets looking to compete on price must first overcome critical capital-expenditure barriers and ensure that user populations are effectively acclimated to the use of new fuel-stove combinations (Jagger et al. 2019). The affordability of pellet cooking is promising, but depends on the business model design and performance of the specific gasifier stove being used (Kappen et al. 2017; Patel and Nyangena 2016). For example, the combination of Inyenyeri pellets and high-efficiency Mimi Moto stoves distributed by the company allows households to reduce their cooking-energy expenditures by 30 percent compared to the cost of charcoal

FIGURE 3.10 Household Biofuel Costs (Average), Indexed to Fuel Needed, for Selected Countries (2015–16)

US$ per day



Sources: Task Team analysis based on World Bank/ PfI data, self-reported fuel distributor data, and fuel prices available in the press; Kappen et al. 2017.

Note: This analysis is based on data collected for the World Bank in Q1 2015–Q1 2016 and augmented by self-reported fuel-price data by biofuel producers and distributors. Actual fuel expenditures for common fuel-stove combinations are used and, where possible, levelized for the expenditures required to cook 2.5 meals a day for a household of five.

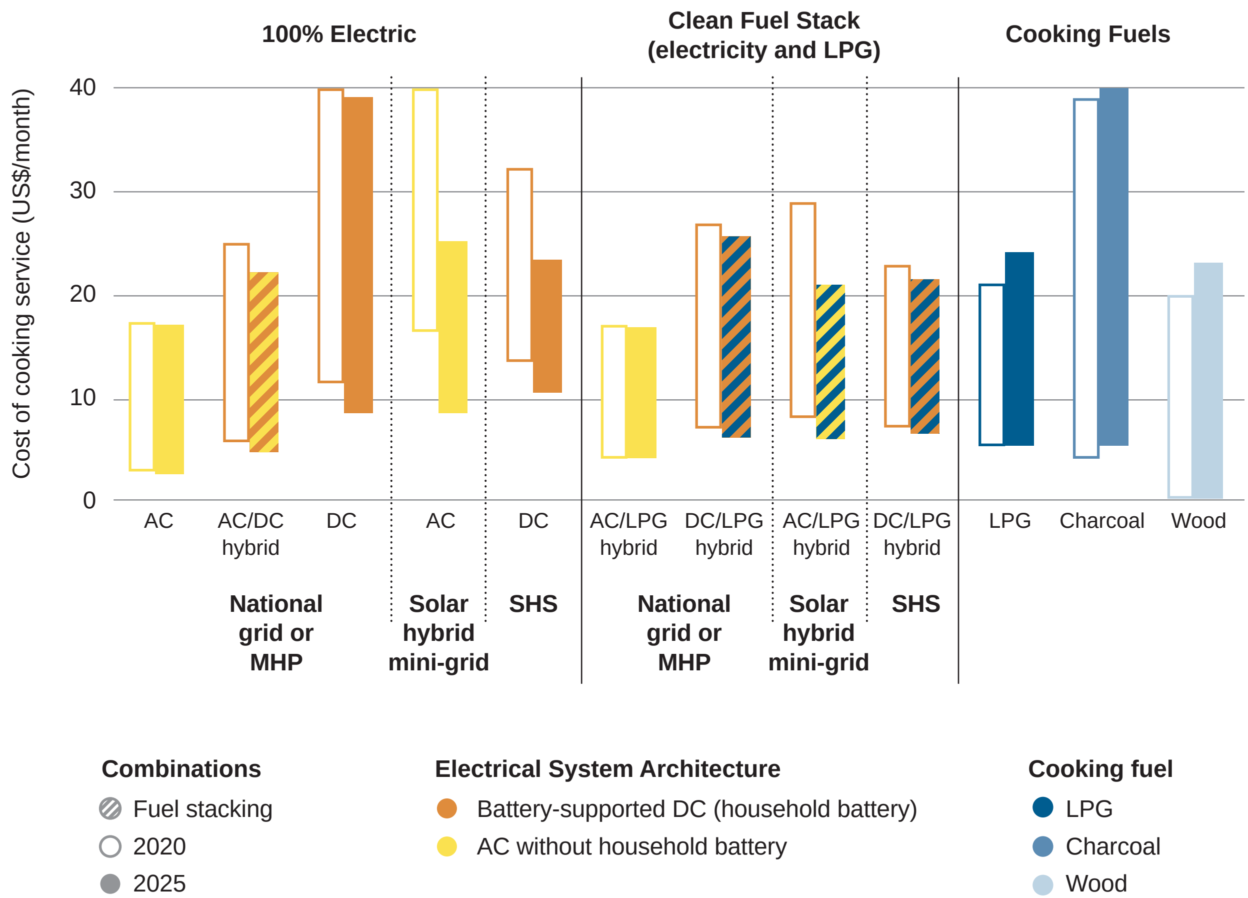
cooking in urban Gisenyi, Rwanda (Kappen et al. 2017; Task Team interviews). While ethanol fuel cooking in Sub-Saharan Africa has historically remained uncompetitive in price, policy changes and business-model development could change this (Kappen et al. 2017). If ethanol's taxes and duties were equalized relative to other fuels, ethanol cooking could be on par with or even 10–30 percent cheaper than charcoal cooking, while still allowing for profitable deployment (Kappen et al. 2017). Furthermore, ethanol's pricing challenges also result from early-stage, and often inefficient, sourcing and distribution. Business-model streamlining by organizations like KOKO Networks, POET, FUNRECO, MEC, and Safi International hold the promise of improving the price competitiveness of ethanol versus charcoal in Sub-Saharan Africa (Kappen et al. 2017; Task Team interviews).

In addition to LPG and alternative biofuels, new research suggests that electricity could become a more affordable cooking solution than charcoal in the near future (ESMAP 2020). Researchers have modeled the cost of cooking with electricity compared to other baseline fuels, as well as stacking scenarios. The outlook for eCooking at a global level is attained by comparing the range of costs of the eCooking technologies explored in this report with those of the most widely used cooking fuels (figure 3.11). The results show that alternating-current (AC) eCooking on national grids and micro-hydropower are already cost-effective for many people today, while battery-supported, direct-current (DC) eCooking and solar-hybrid mini-grids open up in 2025. However, clean fuel stacks with LPG can make all of these technologies cost-effective today. Where technically possible, cooking with AC grid electricity can be the cheapest option for many people, at US$3–17 per month. Supporting 50 percent of cooking loads with a battery increases the cost of cooking to US$5–22 per month in 2025, which is still competitive with the monthly costs of LPG (US$6–24), charcoal (US$5–41), and firewood (US$0–23) in 2025. Supporting 100 percent of the cooking loads increases the cost substantially (to US$8–39 per month); however, this monthly cost may still be competitive in contexts with low tariffs and energy demand. By 2025, the cost of cooking with both AC appliances connected to solar-hybrid mini-grids, at US$8–25 per month, and DC-appliances powered by solar home systems (SHSs), at US$11–24 per month, become competitive. However, LPG can play an important role as a transition fuel, as a clean fuel stack of electricity, and as a way to make battery-supported eCooking cost-competitive for some today (US$6–29 per month).

Drawing on prior analysis of Kenya, Madagascar, Rwanda, and Uganda, cooking with AC would consistently undercut kerosene and charcoal, and a 50/50 AC-DC combination would actively compete with traditional fuel prices (ESMAP 2020; Kappen et al. 2017). However, it is important to note that this model does not account for the cost of building a grid where one does not exist or a household's initial grid connection.

Beyond demonstrating the improved unit economic viability of clean fuels, these trends in affordability all point to how much enabling-environment factors, which vary considerably by country, can drive fuel prices and thus impact household access. In some countries, the price of woodfuel and charcoal is driven upwards by policy-linked shortages (e.g., charcoal production and distribution bans in select countries in Africa), as well as scarcity (Kappen et al. 2017). Meanwhile, some countries have regulations that penalize alternative fuels or favor traditional ones (e.g., kerosene subsidies, unregulated charcoal industries, and ethanol taxes and duties) (Kappen et al. 2017). Electricity policy—through retail tariff and subsidy design, connection incentives, and other measures—can be a key driver of uptake.

FIGURE 3.11 **Comparison across System Architectures Using Aggregated Data from All Case Studies**



Source: ESMAP 2020.

Note: For all system architectures, the cost of cooking service is calculated over a five-year financing period. The range on each bar represents two sensitivities: (i) energy demand and (ii) grid tariff or solar resource. The ranges for energy demand are derived from the range of median values from the four country cooking-diary studies for 100 percent eCooking: 0.87–2.06 kWh per household per day. The ratios of energy demand for cooking fuels, electricity calculated from the cooking diaries, were used to model demand for LPG (2:1), charcoal (10:1), and firewood (10:1). Grid-connected system architectures use a tariff range encompassing 90 percent of Sub-Saharan African utilities from the Africa Renewable Energy and Access Program (AFREA) (Kojima and Trimble 2016): US$0.04–$0.25 per kWh. National grid and mini-/micro-hydropower (MHP) are grouped together as the tariff ranges are nearly identical (US$0.05–$0.25 per kWh for MHP) (SKAT 2019). Solar-hybrid, mini-grid system architectures use a current tariff range of US$0.55–$0.85 per kWh and a 2025 range of US$0.25–$0.38 per kWh. The solar resource range is the average range of monthly solar irradiation in the least sunny months in each of the four case-study countries, at 3.68–4.30 kWh per kW_{peak}. Batteries are LiFePO4, sized to meet 100 percent and 50 percent of daily cooking loads, at 1–3 kWh and 0.34–0.98 kWh, respectively. For PV, the respective ranges are 300–700 W for 100 percent daily cooking load and 100–200 W for 50 percent.

Convenience, Availability, and Safety

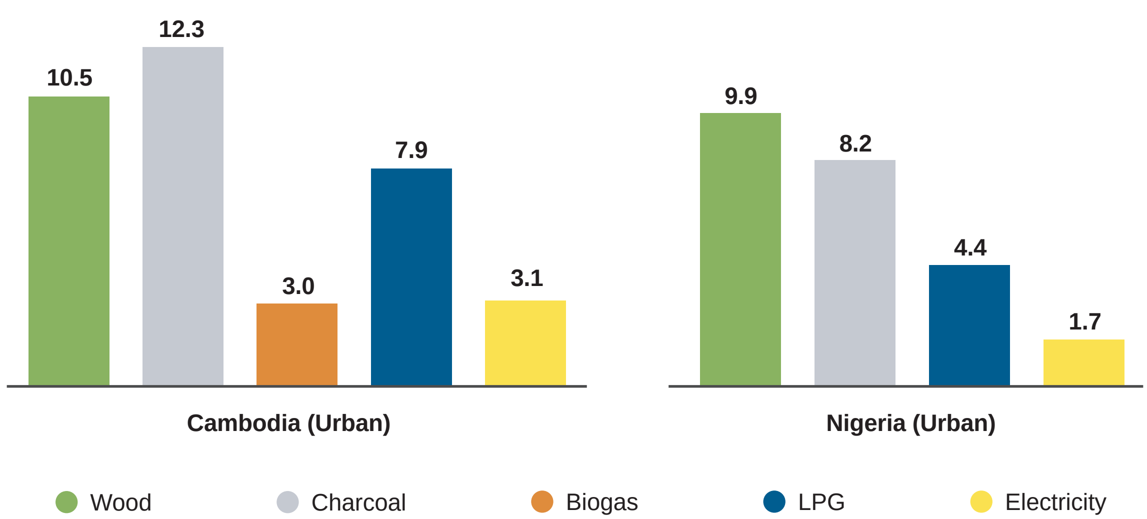
Convenience factors, measured primarily by the time taken to collect and cook, vary dramatically by fuel; yet MTF data demonstrate that this variation is relatively consistent across countries and localities. Average stove preparation time for users of electricity, LPG, and biogas fuels is generally lower than for charcoal or wood users, especially in urban settings (figure 3.12). Stove preparation time is the principal reason why most households using improved stoves (e.g., top-lit updraft stoves) that gasify biomass fail to meet the criteria of MECS. Cooking time also plays a part in explaining why primary electricity and LPG users are more likely than primary wood users to meet criteria for MECS access. For example, in Honduras, Nepal, and Zambia, primary electricity users spend, on average, at least 43 minutes less time cooking than primary wood users. In Nepal, this discrepancy increases to an average of 85 minutes. These factors link back closely to the concept of multidimensionality in the cooking space—less cooking time, in some cases, may equate to less energy consumed, which, in turn, may equate to lower average expenditure and higher affordability.

Convenience factors are critical enough determinants of household fuel used that they are being priced into how fuel is distributed and sold. Fuel players like KOKO Networks, a Kenya-based fuel and technology player, have used embedded technology to understand how convenience factors can impact purchasing decisions. KOKO is mainstreaming liquid bio-ethanol cooking fuel as a fast, safe, and affordable alternative to traditionally higher-emissions cooking fuels, such as charcoal. Furthermore, the use of smart metering across cooking fuel-and-technology combinations, including on-grid and off-grid electricity provision, is beginning to create rich datasets that can further fuel providers' understanding of customers' time of use and convenience patterns to improve product design and service-model delivery (figure 3.13).

Availability factors can be key drivers of fuel-stacking behavior, particularly when accounting for seasonality and supply-chain volatility. For example, a localized study in Mexico finds that, in some contexts, stove stacking using fuelwood is driven by seasonal LPG shortages (Ruiz-Mercado and Masera 2015). Results of this study reinforce the importance of accounting for availability factors in understanding a household's energy use, even if a household's primary fuel source is a clean cooking solution.

FIGURE 3.12 Stove Preparation Time by Fuel in Urban Settings of Two Countries

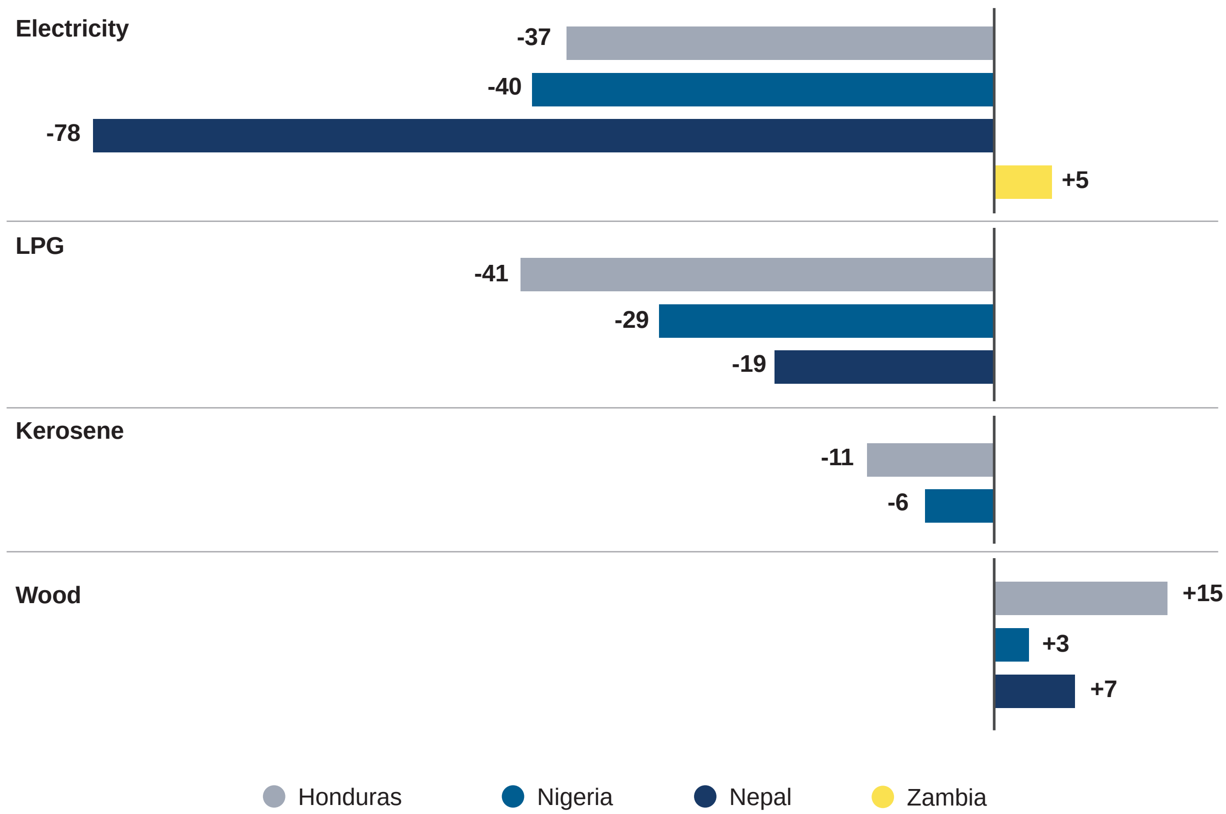
Average number of minutes per meal



Source: World Bank MTF country datasets.

FIGURE 3.13 **Difference in Cooking Time by Fuel versus Average Time across All Fuels for Selected Countries**

Minutes per day by primary fuel users



Source: World Bank MTF country datasets.

Safety factors also play into whether a household meets MECS access criteria. While fuels like LPG have often faced uptake challenges due to perceptions of safety risks (e.g., cylinder bursting, gas leakage, or fear of explosion or fire) (Dalaba et al. 2018), selected country data indicate that the use of LPG, as well as electricity and other clean fuels, has generally resulted in a lower incidence of serious impacts (e.g., physical injury, illness, or death), as well as less-serious ones (e.g., fires without injury, itchy/watery eyes, or light coughing). MTF household data analysis from Cambodia and Nigeria highlight that approximately 2–4 percent of primary LPG-using households, on average, report either serious or minor injuries, compared to an average of 7–14 percent of households using mainly charcoal or wood. These ranges are still relatively high, however, and will likely need to be reduced in order to drive greater adoption.

CONCLUDING REMARKS

Ensuring greater demand for MECS will require services, products, and interventions that are better adapted to underlying household needs. This means overcoming the long-standing barriers of high up-front capital costs, low levels of public awareness, and low availability. Continued price support, outcome-based incentives, and effective enabling environments are needed to ensure base affordability of fuel, successful market entry of cost-effective stoves, and the spread and consolidation of cooking utility models. The shifting demographic realities of denser urban environments must also be taken into account. In urban contexts, access to financial services tailored to household energy use is growing, and physical access to clean technology can be made easier.

In countries where the clean-fuel transition has been achieved but stacking persists, new messaging around product value and aspiration can help households stay on the modern-energy transition pathway. Many of the secondary functions that necessitate stacking could be substituted with more efficient appliances powered by grid or off-grid electricity. Enabling the provision of such products and services will require that national surveys capture data on secondary stoves and fuels in order to expand and sharpen the multidimensional evidence base on user needs. It also calls for broader implementation of MTF household surveys, Demographic and Health Surveys (DHSs), and other sufficiently rigorous instruments that embed user attributes, along with conducting complementary behavioral-adoption studies.

ANNEX 3. METHODOLOGICAL NOTE: ESTIMATING POPULATION WITHOUT MECS ACCESS

This report's analysis utilizes a three-step filtering exercise to project the global population without access to modern energy cooking services (MECS), as defined in chapter 1.

Three-Step Process

Step 1 utilizes the World Bank's recent Multi-Tier Framework (MTF) data for a selected set of archetype countries to calculate the "archetype ratio"—the proportion of each primary-fuel population in rural and urban settings that fully meets the MECS criteria (i.e., Tier 4 threshold or above across all six measurement attributes of the MTF).[8]

Next, Step 2 uses the MTF and global fuel-mix data to identify an MTF country archetype for each country included in the global fuel-mix database.[9] Archetype identification is based on similarities in fuel mix, income level, region, fuel affordability, urbanization, electrification, and other factors, resulting in the matching of 66 other Demographic and Health Survey (DHS) dataset countries with respective MTF archetypes.

Finally, Step 3 applies the archetype ratios from Step 1 to the urban and rural primary-fuel population of each matched global fuel-mix country identified in Step 2.

Key Assumptions and Baseline Inputs

The analysis assumes that the share of urban and rural populations without access to MECS in archetype countries resembles that of matched countries. It also assumes that fuel mix—namely, the most common primary fuels—is the most important criterion for determining whether the shares of MECS are comparable between countries. It relies on population numbers from the latest available DHSs, Multiple Indicator Cluster Surveys (MICSs), and/or fuel census data, and uses United Nations estimates for total population and urban population figures.

The same methodology is applied to determine the size of transition populations (i.e., populations meeting the MTF's Tier 2 or Tier 3 access threshold, albeit with a transition-specific archetype ratio, determined in Step 1.

NOTES

1. Earlier estimates of the world's population without access to "clean" cooking fuels and technologies have been helpful in making clear the enormous scale of the problem; 2.8 billion has been the latest estimate from the *Tracking SDG 7* progress report (IEA et al. 2020).
2. Including Demographic and Health Surveys (DHSs), Multi-Indicator Cluster Surveys (MICSs), and national energy censuses.
3. The 71 countries are as follows: Afghanistan, Angola, Bangladesh, Benin, Botswana, Brazil, Burkina Faso, Burundi, Cambodia, Cameroon, Cape Verde, Central African Republic, Chad, China, Colombia, Comoros, Congo, Democratic Republic of the Congo, Côte d'Ivoire, Ecuador, El Salvador, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guatemala, Guinea, Guinea-Bissau, Haiti, Honduras, India, Indonesia, Kenya, Lao PDR, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mexico, Mongolia, Mozambique, Myanmar, Namibia, Nepal, Niger, Nigeria, North Korea, Pakistan, Papua New Guinea, Paraguay, Peru, Philippines, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sri Lanka, Sudan, Swaziland, Tanzania, Thailand, Togo, Uganda, Vietnam, Zambia, and Zimbabwe.
4. In Putti et al. 2015, the fuel mix analysis included data from 82 developing countries with a combined population of 4.9 billion that also represented 70 percent of the world's population at that time.
5. Since 2000, kerosene declined from 6 percent to 1 percent.
6. Assumes average consumption of PayGo Energy customers (4 kg per month) as the baseline consumption figure, and compares the energy demand for Meko (high-pressure LPG), charcoal, kerosene, PayGo metered gas, and low-pressure LPG cooking appliance (four-burner stove), based on the energy efficiency of the stove and amount of energy produced during consumption. Estimates the household energy expenditure based on the amount of energy required per household; underestimates the kilograms of charcoal used, given the inability to switch a charcoal stove on and off.
7. See case study and analysis of First Energy's Oorja business in Thurber et al. (2014).
8. The MTF market archetypes included Myanmar, Nepal, Nigeria, Rwanda, and Zambia.
9. Representative of 71 countries, as discussed in this chapter.

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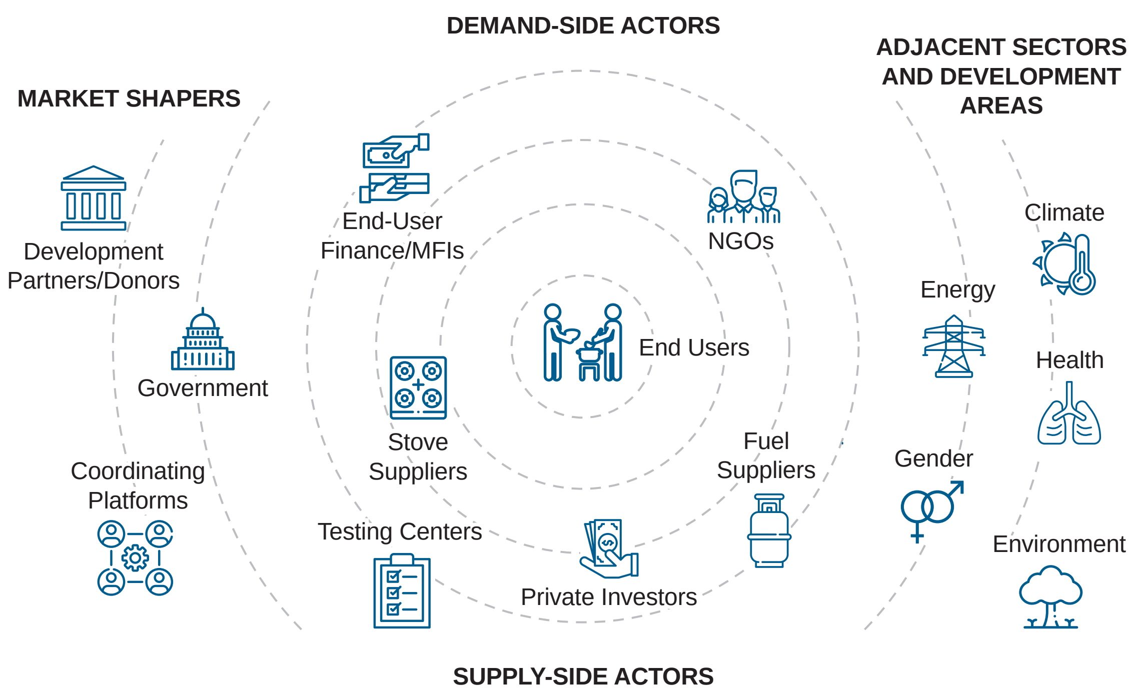
CHAPTER 4

UNDERSTANDING THE SUPPLY LANDSCAPE

THE EVOLVING ECOSYSTEM

A diverse variety of organizations and institutions are shaping and growing the MECS space. This evolving ecosystem consists of nine major categories of players: (i) development partners and donors, (ii) government agencies and programs, (iii) nongovernmental organizations (NGOs), (iv) end-user finance providers, (v) private investors, (vi) research and testing centers, (vii) fuel and stove suppliers, (viii) adjacent energy-services players, and (ix) coordinating platforms (figure 4.1).

FIGURE 4.1 **Main Players across the Cooking Ecosystem**



Source: World Bank.

Note: Fuel suppliers include designers, manufacturers, distributors, and retailers.

Market shapers include development partners and donors, as well as government agencies. Development partners and donors support both market development in weak or non-existing markets and national-level change. These activities include, among others, the funding of large-scale stove and/or fuel transition programs (e.g., through direct distribution or campaigns) and the creation of new financing incentives (e.g., through results-based financing [RBF] and the provision of challenge funding to spur product and service innovation). **Government agencies and programs** implement policies that enable sector growth. For example, they enable importation of clean fuels and stoves and spurring of their local production. They also manage subsidies for fuel and stove distribution and support market transformation through fiscal, tax, and trade policies, as well as spearheading business-environment improvements. In addition, they are the principal actors in awareness creation and demand generation through campaigns and incentives. More broadly, government decision-makers can promote holistic modern-energy access through their capacity to coordinate cooking and electrification expansion.

Key demand- and supply-side actors include NGOs, microfinance institutions (MFIs), private investors, research and testing centers, and fuel and stove suppliers. NGOs support commercialization and market sustainability through program design and implementation (e.g., commercial training, end-user education, and dissemination of stoves and fuels, whether through direct distribution or donation). **End-user finance** providers include MFIs, savings and credit cooperative organizations (SACCOs), and commercial banks, among others. **Private investors,** which supply commercial financing for MECS, include carbon-finance firms, commercial banks, social-impact investors, and private-equity firms. Investors like Acumen have been offering financing to players like BURN Manufacturing, KopaGas, Greenway Grameen, and Biolite to improve the distribution viability of enterprises and the affordability of end-user products. **Research and testing centers** innovate new designs, test stoves in the laboratory and field, conduct market studies, and undertake monitoring and evaluation (M&E) programs. **Fuel and stove suppliers** develop new stove designs, produce and distribute fuels and stoves, and provide after-sales service for the products they sell. Increasingly, suppliers are diversifying their range of products and services, thereby creating opportunities for new commercial/operational partnerships with **adjacent energy-services players,** including off-grid/last-mile distributors and on-grid power utilities, among many others.

International platforms and coalitions sit at the nexus of this ecosystem. These platforms coordinate diverse actors in joint advocacy and resource mobilization, and also aggregate and disseminate technical knowledge and standards. They may be specific to a fuel or technology, such as the Global LPG Partnership, or to a sector, such as the Clean Cooking Alliance (CCA), which ensures sectorwide coordination among stakeholders to drive collaboration and alignment toward shared goals. The CCA has recently initiated a sectorwide strategy process (the Clean Cooking Sector Strategy) that aims to be a living and dynamic effort designed to build on existing efforts, catalyze a systems-level transition to clean cooking, and evolve with the sector. Other platforms, such as the Health and Energy Platform of Action (HEPA), bring in technical expertise and high-level dialogue across traditionally siloed sectors. The HEPA has proposed to set up the High-Level Coalition of Leaders for Clean Cooking, Energy and Health, which aims to demonstrate the global leadership in advocacy and action required to create political momentum, drive practical solutions, spur investments, and mobilize public support and multi-stakeholder engagements for clean cooking.

Institutional and methodological advances over the past five years have brought about a positive evolution in the context of modern energy supply. In July 2015, the World Bank and Sustainable Energy for All (SEforALL) conceptualized the Multi-Tier Framework (MTF) for defining and measuring access to energy, including a multi-tier matrix for measuring access to cooking solutions. Later that year, UN Sustainable Development Goal 7 (SDG 7) explicitly called for access to affordable, reliable, sustainable, and modern energy for all. That same year, the World Bank's Energy Sector Management Assistance Program (ESMAP) launched its Efficient, Clean Cooking and Heating (ECCH) Program—a cross-sectoral initiative to support the integration of clean cooking in the World Bank's investment lending portfolio and also work with partners to generate knowledge and raise awareness. In January 2018, the World Bank published the results of MTF surveys for Cambodia, Ethiopia, and Rwanda. Six months later, the International Organization for Standardization (ISO) published the first set of globally-harmonized international standards for clean cookstoves and clean cooking solutions. 2019 saw an acceleration in activity. Highlights included launching of the HEPA in May, followed by SEforALL's Clean Cooking charrette in June; in September, UK Aid announced a £40 million commitment for development of the MECS Program,[1] and the World Bank launched the Clean Cooking Fund during the UN Climate Action Summit. Two months later, the Clean Cooking Forum in Nairobi convened actors working to accelerate the production, deployment, and use of more efficient MECS. The forum introduced a range of large-scale global commitments and began evolving the narrative of the cooking space toward one more focused on driving scale in the sector (i.e., demanding larger funding pools and advocating for the need to accelerate business growth, among other factors) (figure 4.2).

In addition to greater sector coordination and cohesion, the development of methods to measure the health, gender, and climate benefits of MECS has advanced significantly (Gold Standard 2017 a, b, and c; WOCAN 2014). Currently, the World Bank is conducting a study to review, refine, and field-test methodologies that quantify and measure the co-benefits of health, gender, and climate (including black carbon [BC]) from clean-cooking interventions. The goal is to apply such methodologies through RBF mechanisms to monetize these co-benefits, attract potential impact donors, and thus incentivize the private sector to invest and deliver these co-benefits.

FIGURE 4.2 Key Sectorwide Milestones, 2014–19

August 2014
The first WHO conference on Health and Climate closely integrates two critical global issues and narratives.

May 2015
ESMAP and the CCA publish the report, *The State of the Global Clean and Improved Cooking Sector.*

July 2015
The World Bank and SEforALL conceptualize a new Multi-Tier Framework for defining and measuring access to energy, including a multi-attribute matrix for measuring access to cooking solutions.

September 2015
UN Sustainable Development Goal 7 calls for access to affordable, reliable, sustainable, and modern energy for all.

June 2018
The ISO publishes the International Standard on clean cookstoves and clean cooking solutions.

April 2019
The five-year, Department for International Development (DfID)–funded Modern Energy Cooking Services (MECS) Program is launched.[a]

May 2019
Launching of the Health and Energy Platform of Action at the 72nd World Health Assembly strengthens cooperation between the health and energy sectors.

September 2019
The World Bank's Clean Cooking Fund is launched during the high-level event on the energy transition track of the UN Climate Action Summit.

November 2019
The Clean Cooking Forum in Nairobi brings together donors, development partners, enterprises, researchers, and policy makers to chart a course for the sector.

Source: World Bank.

a. On September 2, 2020, the Department for International Development (DfID), which functioned as a ministerial department since May 1997, merged with the Foreign and Commonwealth Office to create the Foreign, Commonwealth and Development Office (FCDO).

THE MECS SUPPLY CHAIN

While nascent, subscale, and underfinanced, the MECS supply chain has seen significant progress in recent years. Product and business-model innovations are making it increasingly more affordable, convenient, and safe to cook with increasingly available fuel-and-stove combinations that are efficient and expose users to far fewer harmful by-products.

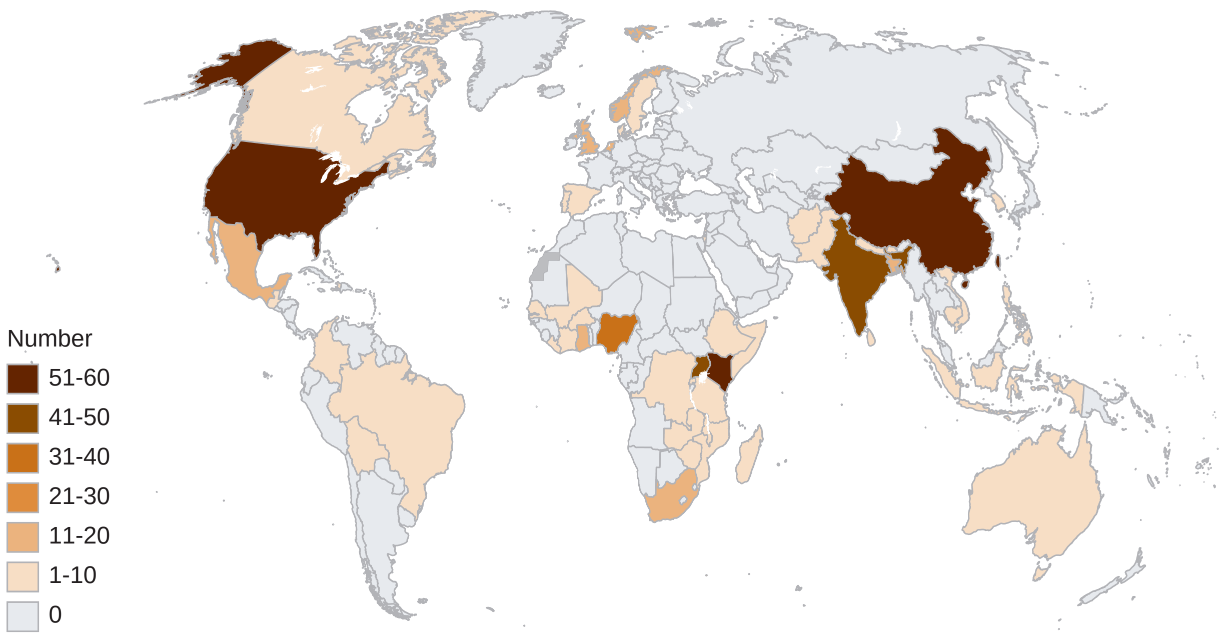
The global supply chain comprises mainly cooking service providers,[2] as well as broader energy-infrastructure players, including electric utilities and other fuel distributors. Tracking by the CCA partner database shows that the formalized stove-player landscape comprises approximately 450–500 fully dedicated manufacturers and distributors. The headquarters of most companies active in design and manufacturing are concentrated in China, India, Kenya, the United Kingdom, the United States, and several Nordic countries (figure 4.3a). However, the most active companies operate across Sub-Saharan Africa and Asia—with concentrations of activity in East and Central Africa, India, and Nigeria (figure 4.3b). Approximately one-third of the enterprises tracked by the CCA operate in fuel/technology categories used by stoves that typically earn exposure ratings of Tier 4 or higher.

The geographical distribution of cooking enterprises and organizations varies by the cooking services provided. NGOs and community organizations play a vital role in stove and fuel distribution. While enterprises for LPG (figure 4.4a) and solar cooking (figure 4.4b) are relatively widespread, pellet and briquette players tend to be concentrated in East Africa and South Asia (figure 4.4c). Ethanol players, while few in number, are most heavily concentrated in East and Southeast Africa and Brazil (figure 4.4d).

FIGURE 4.3 Maps of Cooking Stove and Fuel Suppliers

a. Designers and Manufacturers, by Headquarters Country

N = 450



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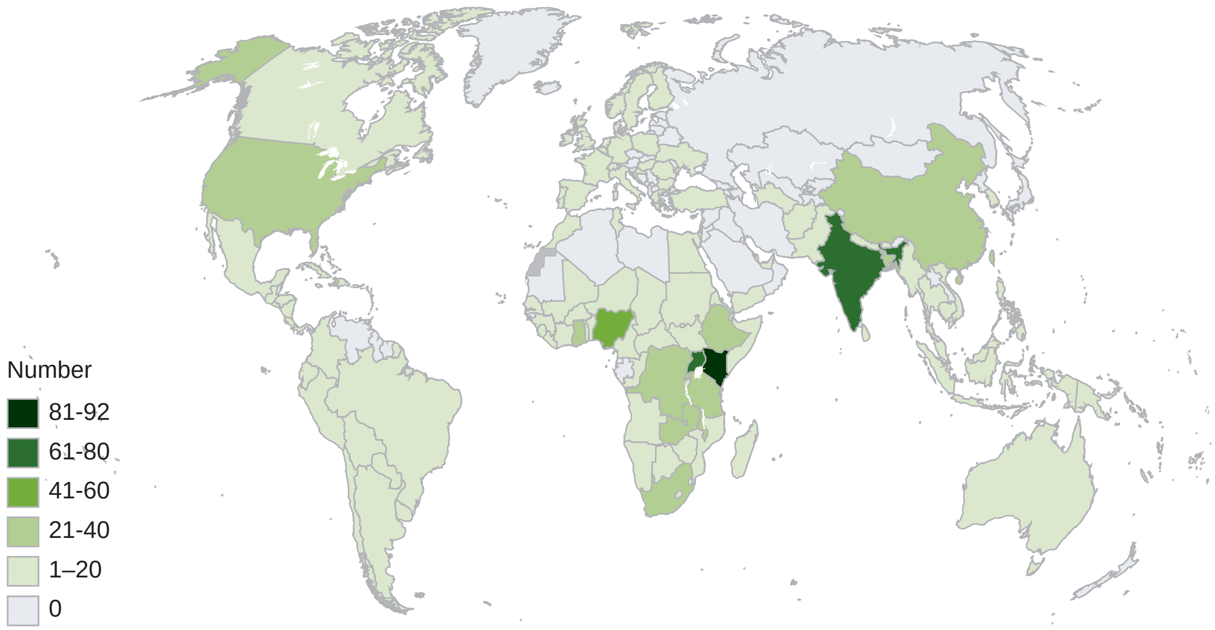
b. Distributors and Retailers, by Countries of Operation

N = 450



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Sources: Clean Cooking Alliance partner database; Task Team analysis.

FIGURE 4.4 Maps of Cooking-Fuel Players, by Countries of Operation

a. LPG

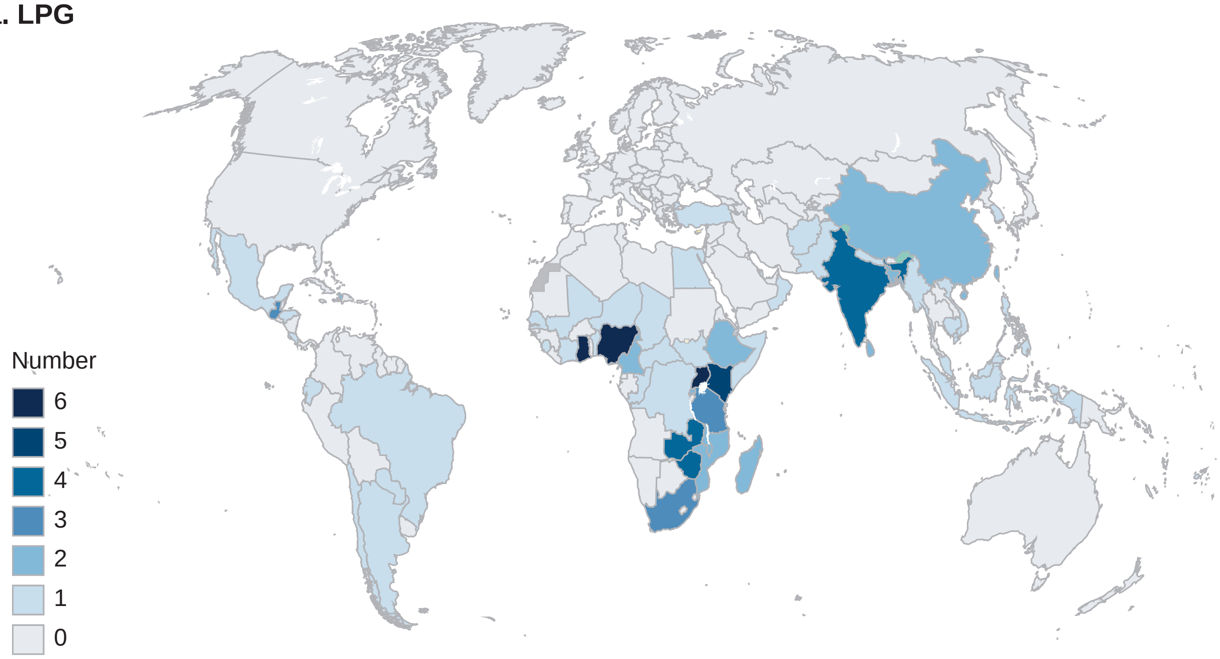

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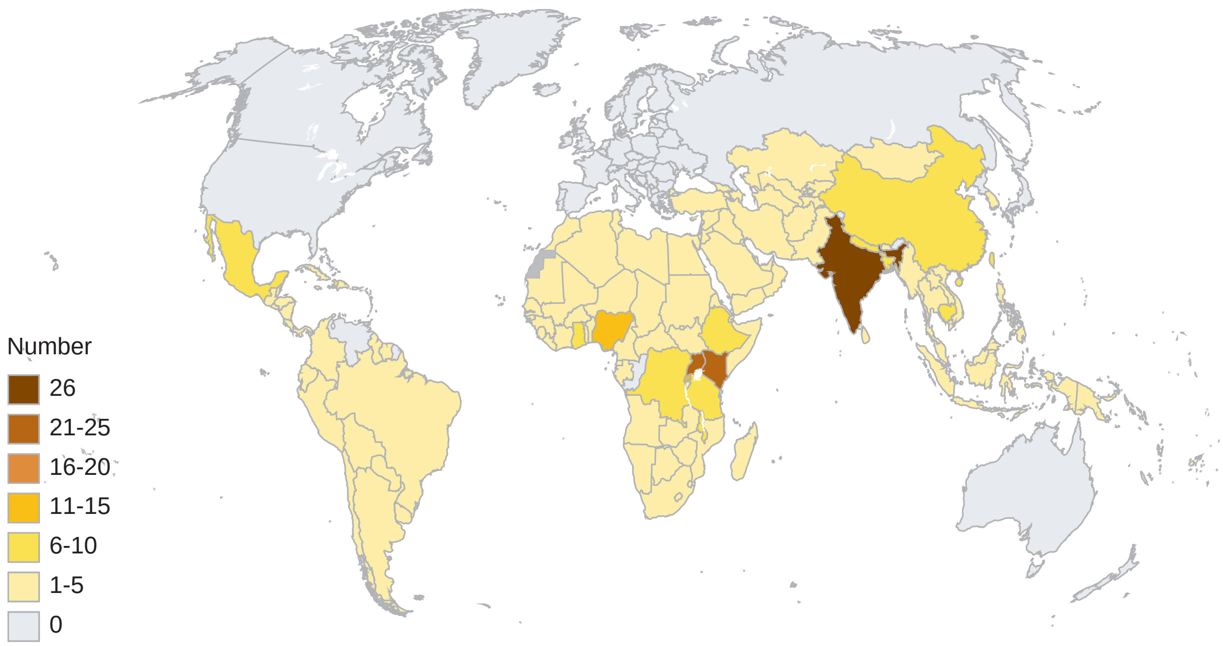
FIGURE 4.4 *Continued*

b. Solar



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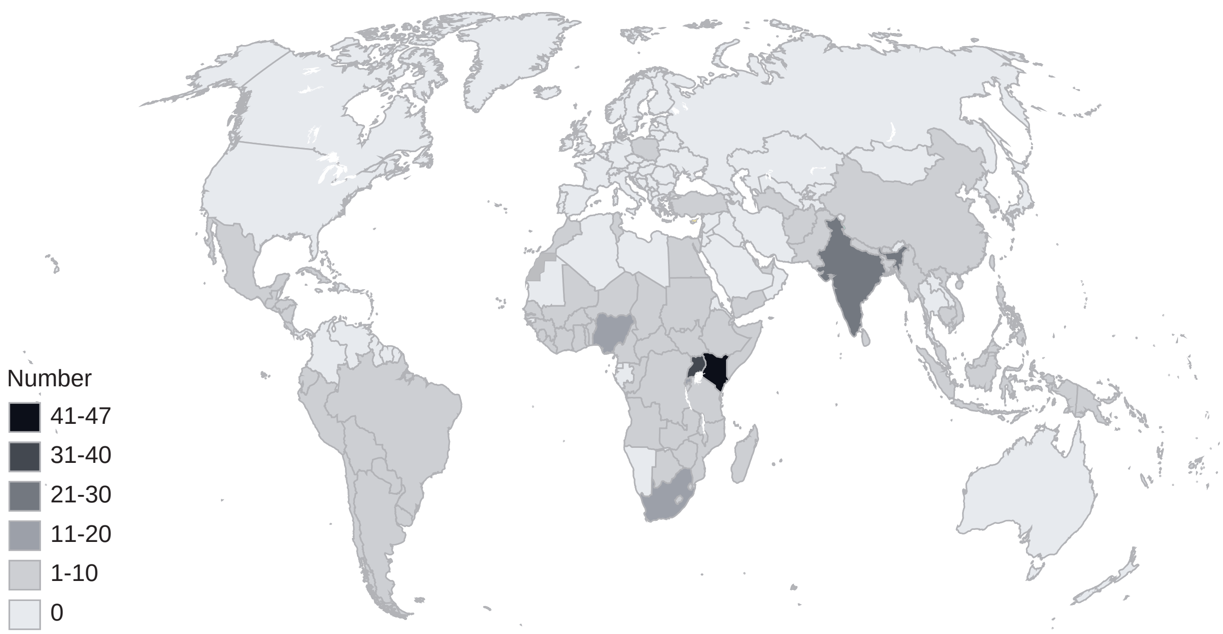
c. Pellets and Briquettes



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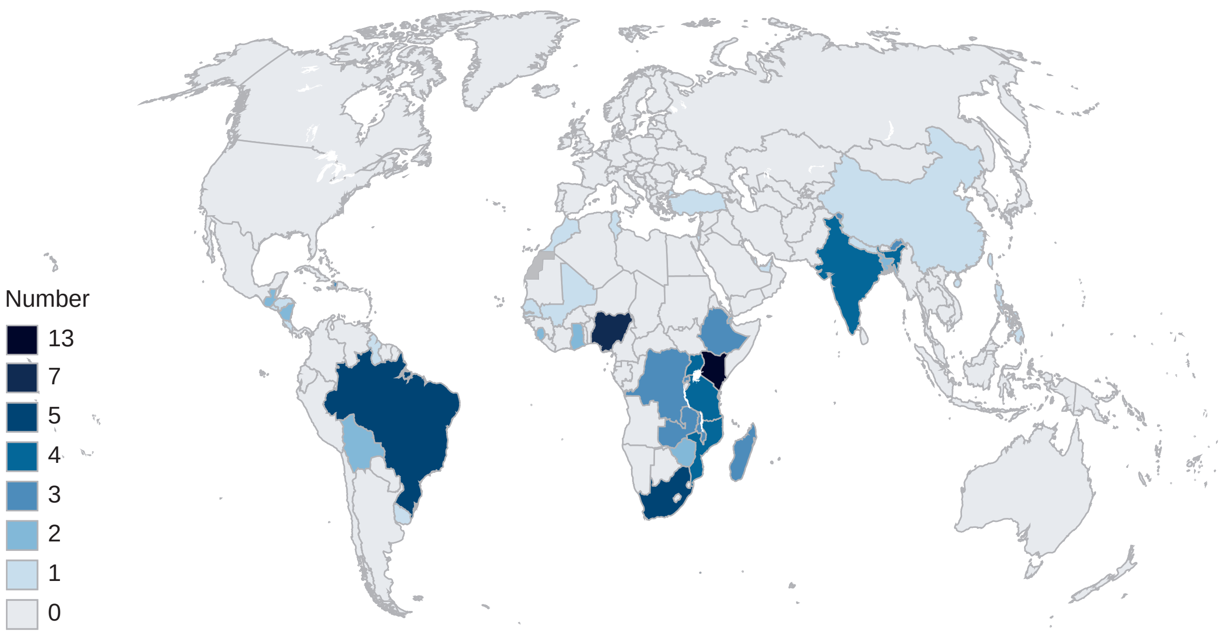
d. Ethanol



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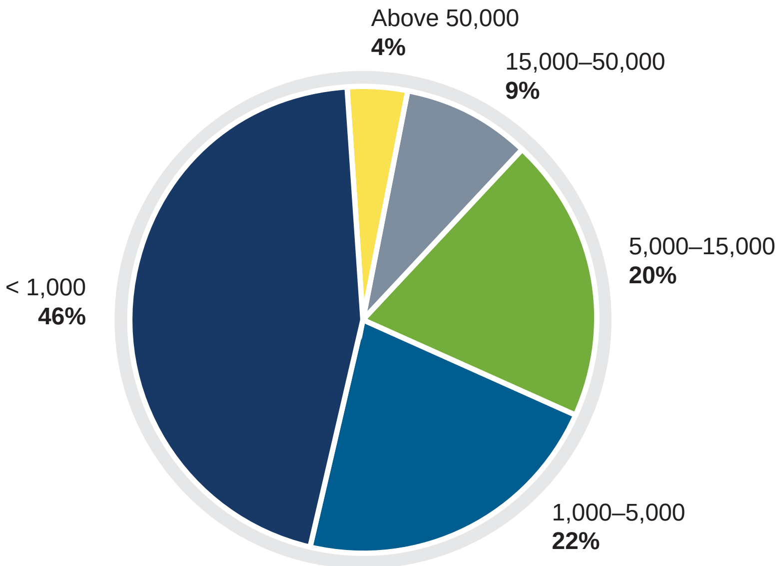
Sources: Clean Cooking Alliance partner database; Task Team analysis.

The formal industrialized and semi-industrialized stove sector is fragmented, and it is difficult to find businesses that have reached meaningful volumes. The enterprise survey conducted as part of this report shows that nearly half of the enterprises have annual stove sales of less than 1,000, while only 4 percent have surpassed 50,000 (figure 4.5). Across the cooking space, it is difficult to find businesses that have reached meaningful volumes. In Sub-Saharan Africa, for example, only 15 alternative fuel businesses (less than 18 percent of estimated biofuel businesses) were consistently supplying more than 5,000 households with cooking fuel in 2017; just 7 (less than 8 percent) had reached more than 20,000 households, and only 1 claimed to have reached over 100,000 customers on a regular basis (Kappen et al. 2017). The Biofuel Enterprises Database for Sub-Saharan Africa reveals that most of the region's larger biofuel players in terms of household reach focus on ethanol and ethanol-gel distribution. Across other cooking fuel-plus-technology combinations, only a handful of players has successfully cracked the 200,000 stove mark, largely as a result of integrating production (e.g., through an owned factory).

FIGURE 4.5 Annual Sales of Industrially and Semi-Industrially Produced Stoves, by Manufacturer

Number of units

N = 45



Sources: 2019 ESMAP/CCA/Loughborough University (LU) Enterprise Survey; Task Team analysis.

INDUSTRY ECONOMICS

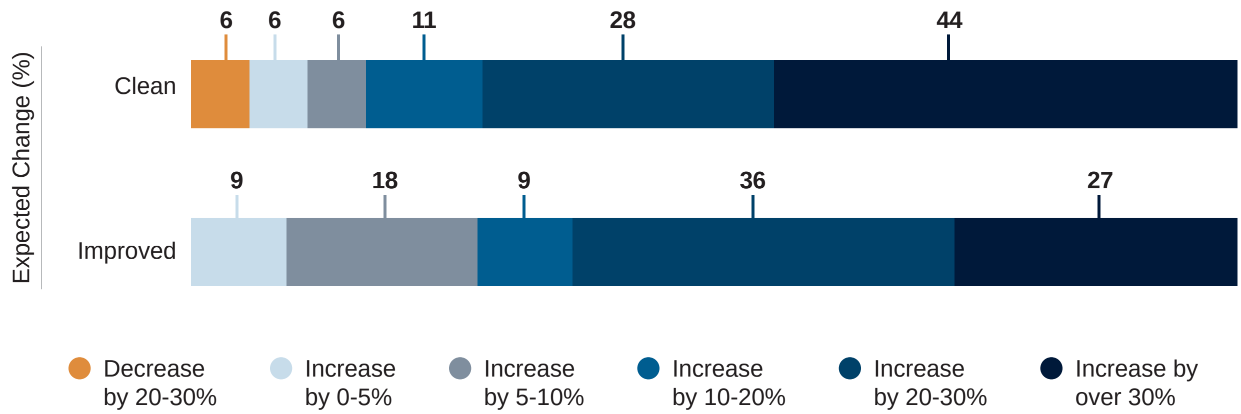
Given the nascent state of the majority of private enterprises in the cooking space, most fuel and stove businesses are searching for a path leading to consistent profitability. While a few subsector leaders have begun to show relatively healthy revenue growth, the majority of the cooking-sector actors surveyed remain unprofitable and have yet to reach scale. Of the 27 surveyed enterprises that reported reliable revenue and operating-cost numbers for 2016–19, only 9 reported greater than zero net-profit numbers for 2016, 2017, and 2018.

The cooking space has some 50 viable businesses that can play a pivotal role in improving products and services; but enterprises remain broadly optimistic about growth. If extrapolated to the current size of the industrial stove market and limited to those supplying clean fuel-and-stove combinations, the cooking space currently has approximately 50 viable businesses that can improve the supply side of the market. Nevertheless, the overwhelming majority of entities consulted expect revenue increases in the next year. Revenue increases of 20 percent or higher are expected by providers of both clean and improved cooking solutions, at 72 percent and 63 percent, respectively (figure 4.6).

Enterprises generally expect revenue growth to exceed that of operating cost. The delta between expected growth in revenue and cost growth is generally higher for enterprises supplying MECS compared to those operating with improved stoves and fuels (i.e., 10 percent versus 7.5 percent). Ethanol/alcohol players

FIGURE 4.6 Expected Revenue Change, by Stove-Enterprise Type

N = 29



Sources: 2019 ESMAP/CCA/LU Enterprise Survey; Task Team analysis.

Note: In this specific analysis, “Clean” indicates enterprises whose primary stock-keeping unit (SKU) is designed for the use of LPG, electricity, biogas, ethanol/alcohol, and solar and biomass stoves with an International Workshop Agreement (IWA) indoor-emissions rating of 3 or greater or with ventilation systems/forced-draft gasifiers; “Improved” refers to enterprises whose stoves do not meet these criteria.

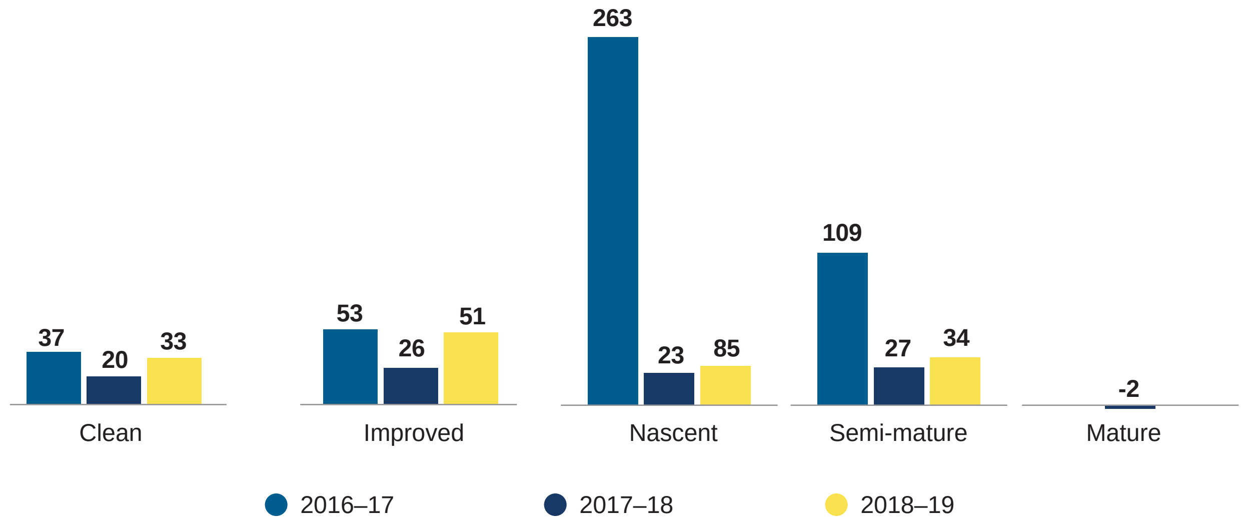
forecast the most promising potential for gross profitability, as do enterprises whose stoves combust processed and unprocessed biomass fuels, referred to as “multiple-biomass” players.

The distribution of companies’ operating costs, which varies considerably, is based on enterprise size, business model, and primary-fuel product.[3] A limited cut of data isolating for fully vertically-integrated stove manufacturers reveals that the upstream costs of sourcing and manufacturing are 9 percentage points higher for smaller enterprises, compared to medium-sized or large companies (i.e., 51 percent versus 42 percent). Conversely, the costs of operations (e.g., salaries, taxes, and marketing) are 7 percentage points higher for larger companies, compared to smaller ones (i.e., 28 percent versus 21 percent). Cost structures vary significantly between players offering improved and clean cooking services. Players that work primarily with charcoal (only), wood,[4] and biogas face the highest upstream costs, while pellet, ethanol, and solar players face greater downstream expenses. For example, ethanol players face high regulatory costs in key markets that tax alcohol, while solar-cooking players spend substantially on user acquisition and partnership development.[5]

Mature enterprises and those supplying clean technologies have a demonstrated ability to keep cost growth consistently low or minimize spikes in year-over-year expenditure. Clean cooking enterprises have showcased lower average shifts in operating costs compared to peers in improved product categories. Less mature enterprises have exhibited larger spikes, especially in 2016–17 (figure 4.7). More established enterprises have demonstrated greater cost control, with minimal change (-2–0 percent) over the last three years of operation. The higher cost structure of less mature enterprises may be driven by the expense inherent in transforming unconnected, unbanked households into a new user base.

FIGURE 4.7 Growth Rates of Year-over-Year Operating Costs, by Enterprise Type

%
N = 23 (clean/improved)
N = 22 (nascent/semi-mature/mature)



Sources: 2019 ESMAP/CCA/LU Enterprise Survey; Task Team analysis.

Note: In this specific analysis, "Clean" refers to enterprises whose primary stock-keeping unit (SKU) is designed for the use of LPG, electricity, biogas, ethanol/alcohol, and solar and biomass stoves with an International Workshop Agreement (IWA) indoor-emissions rating of 3 or greater or with ventilation systems/forced-draft gasifiers; "Improved" refers to enterprises whose stoves do not meet these criteria. "Nascent" refers to enterprises formed after 2015; "Semi-mature" indicates enterprises formed between 2010 and 2015, and "Mature" indicates those formed before 2010.

Operating costs can also be highly subject to external volatility—notably, to shifts in the regulatory environment for stove and fuel entities. In contexts like China, externally-driven market transformations have reorganized the operational status quo for domestic industry players (box 4.1).

Stove players continue to experiment with distribution and production models in order to bring down operating costs and reach scale more effectively. Among the stove-only and stove-plus-fuel enterprises surveyed, players that outsourced distribution achieved 50 percent higher gross margins than those that relied entirely on in-house distribution (-17 percent gross margins). While this range reflects the experiences of a select sample of players, it nevertheless highlights the significant variation in unit economics within the sector, as well as the substantial costs associated with the sell-in to sell-through stages of the value chain, at 15–50 percent of operating costs.

BOX 4.1 China's Stove Market Transformation

In 2017, the Chinese government launched a plan to move the country away from coal-intensive household cooking and heating toward gas and electric cooking appliances, while increasing the government's role as a central procurer of stove technology. Since then, coal stove companies have seen a dramatic decline in volume, falling roughly 30 percent in 2017–18, followed by a drop of about another 30 percent the next year (2018–19).

These reductions have been driven mainly by the exit of a large number of enterprises from the cooking space, given the difficulties of meeting higher-quality emissions and efficiency standards and government procurement protocols. The government's shift pushed many entities to either diversify into parallel production sectors with less stringent regulations or cease operation, given the high capital costs required to invest in new production facilities and technology.

While the medium-term effects of this regulatory overhaul are yet to be seen, it is clear that, for the entities that have remained active in the sector, government policy has fundamentally changed operating economics, as follows:

- Production costs have increased by about 10 percent in order to meet higher production standards.
- Sales costs have increased by about 5 percent as sales staff have dedicated more time to bidding for government programs.
- Finance costs have increased, given the need of enterprises to seek a greater amount of outside financial leverage (e.g., paperwork delays due to increased government procurement have created pressing cash-flow challenges).
- Marketing costs have decreased significantly as companies have turned away from consumer markets to focus on government procurement (i.e., "one" customer rather than "many").

Source: Task Team interviews with Chinese stove industry.

Within the production node, cooking businesses have taken various, often market-specific paths to reach growth and increased scalability, with no "go-to" models of success to date. BURN Manufacturing, for example, has integrated production into its own facilities, and has achieved significant traction in its home market of Kenya. Players like Mimi Moto, which have cemented outsourced production agreements with Chinese manufacturers, have also been able to reach substantial volumes. Both models highlight that the familiar dichotomy between integration and outsourcing no longer describes companies in a global context where trade facilitation, tariffs, and tax environments are highly variable over the long run (box 4.2).

BOX 4.2 Greenway Grameen's Journey to Scalability

Greenway Grameen, an Indian manufacturer of biomass stoves that produces more than 200,000 units per year, has undertaken several strategic steps to increase its scalability:

1. **Built an "anchor-partner" distribution network.** The selection of a shortlist of distributors—each with a strong, focused regional presence—has allowed Greenway to maximize market access and minimize transaction costs (e.g., having to handle a long tail of distribution partnerships).

2. **Pursued growth capital to overhaul production capacity.** Greenway raised financing to invest in a proprietary production facility. This action has dramatically reduced the high variation in product quality that resulted from the manufacturer's previous dependence on a range of vendors, and has significantly raised stove margins.

3. **Evolved from a stove to a credit company.** Greenway now provides credit lines to cookstove users, who are primarily women. This builds the credit histories of previously unbanked consumers, and creates a strong business case for linking consumers to financial institutions and financial technology providers, allowing the manufacturer to recover the high up-front cost of user acquisition.

Source: Task Team interviews.

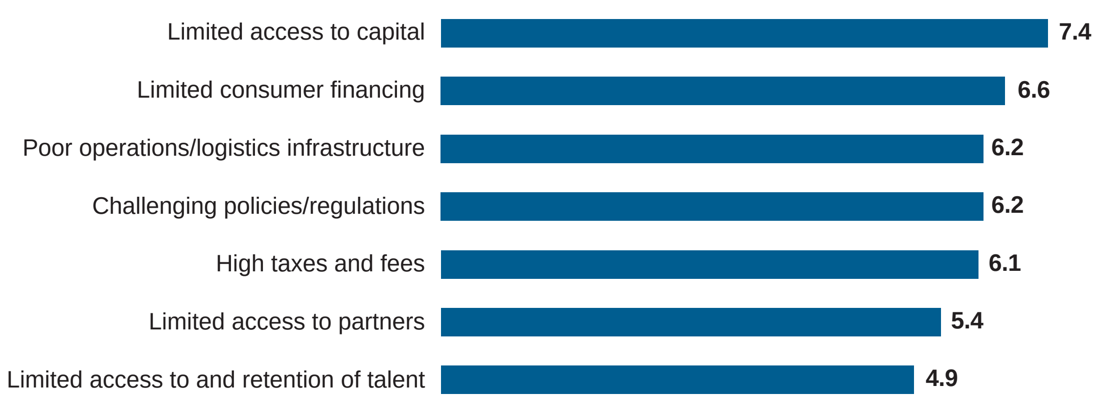
OVERCOMING BARRIERS TO ACCESS

For private stove and fuel enterprises, the most critical barrier to scaling up is the inability to access capital. This barrier is closely followed by end users' inability to attain suitable consumer financing, among other constraints (figure 4.8).

FIGURE 4.8 Ranking of Biggest Barriers to Scale

Weighted rank score

N = 56



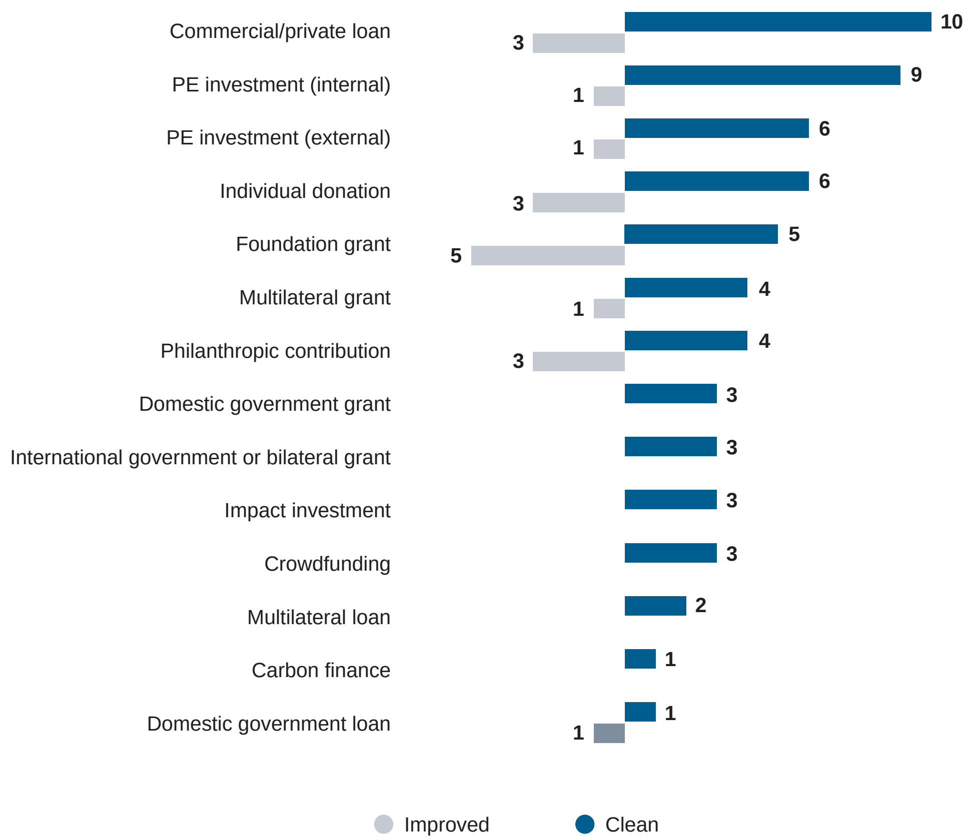
Sources: 2019 ESMAP/CCA/LU Enterprise Survey; Task Team analysis.

Note: Non-categorized or incomplete answers were excluded from the scoring.

Entities supplying clean cooking services have been able to source more capital from a more diverse set of investors than have players that supply improved cooking services. This is true of investment flows destined specifically for commercial enterprises.[6] Players in improved cooking services, on the other hand, have had to depend primarily on philanthropic support (figure 4.9). This may be driven by their target beneficiaries, who often are part of lowest-income cooking campaigns and tend to receive improved cookstoves rather than more advanced, clean technology.

FIGURE 4.9 Frequency of Past Financing Sources for Stove Enterprises, by Type

N = 39



Sources: 2019 ESMAP/CCA/LU Enterprise Survey; Task Team analysis.

Note: In this specific analysis, “Clean” refers to enterprises whose primary stock-keeping unit (SKU) is designed for the use of LPG, electricity, biogas, ethanol/alcohol, and solar and biomass stoves with an International Workshop Agreement (IWA) indoor-emissions rating of 3 or greater or with ventilation systems/forced-draft gasifiers; “Improved” refers to enterprises whose stoves do not meet these criteria.

BOX 4.3 Insights on Energy-Access Financing Needs amid the COVID-19 Crisis

New grant instruments that would complement concessional loan relief funds in the pipeline are urgently needed to assist the off-grid energy sector in navigating the COVID-19 crisis. This key finding is reported by the Energising Development (EnDev)–led Energy Access Industry Barometer—an inclusive, global survey of 613 companies across 44 countries in the off-grid market segments of improved and clean cooking solutions, mini-grids, solar home systems, and appliances/productive use. Conducted from June 29 to July 21, 2020, the survey underscores the impact that the COVID-19 crisis is having on the sector. Seventy percent of respondents report at least a significant disruption to their businesses, with low demand generation, cash flow problems, and low customer sales. From a regional perspective, East Africa has experienced the greatest impact, with 35 percent of businesses moved into hibernation mode. Overall, only about 30 percent of the companies surveyed have received assistance from central, state, provincial, and local government authorities.

Despite these hardships, the crisis has been a strong driver of business creativity and innovation, stakeholder commitment and flexibility, customers' continued prioritization of energy-access investments and payments, and increasing recognition of energy access as an essential service by governments and other stakeholders. Effective response-and-recovery strategies must focus on comprehensive and flexible support that is timely and fast, as well as appropriate to meeting the range of diverse sector needs. Smaller enterprises, particularly distributors, for which the impact of the COVID-19 crisis has been more severe, urgently require grant funding and COVID-19 relief funds to cover operational costs. More than half of the companies surveyed will need less than US$50,000 to survive the next six months, while nearly one-third will require only US$10,000, meaning that US$2 million can save 200 companies.

Source: EnDev 2020.

Financing instruments have also evolved in recent years—grant capital's share of overall financing is shrinking while corporate equity is playing a greater role. In 2016, 74 percent of financial instruments dedicated to residential clean cooking were in the form of grant capital (SEforALL 2019). By 2017, grants represented only about 38 percent (US$12.2 million) of disbursements, while corporate equity accounted for 44 percent (US$14 million) of financial instruments, followed by corporate debt (US$3.7 million) and project debt (US$2.1 million).

This shift signals greater participation by private investors, though grant capital should continue to play a pivotal role as cooking enterprises continue to innovate and find pathways to scale. In absolute terms, current grant funding remains insufficient and, in the eyes of both manufacturers and investors, needs to be scaled up further to drive sector progress. The sector's need for grant financing is becoming even more critical as the COVID-19 crisis develops (box 4.3). Grant financing also needs to be better coordinated and targeted to help address key risks that prevent follow-on investment; that is, the concentration of funding around a "donor darling" enterprise.

Drivers of the Financing Challenge

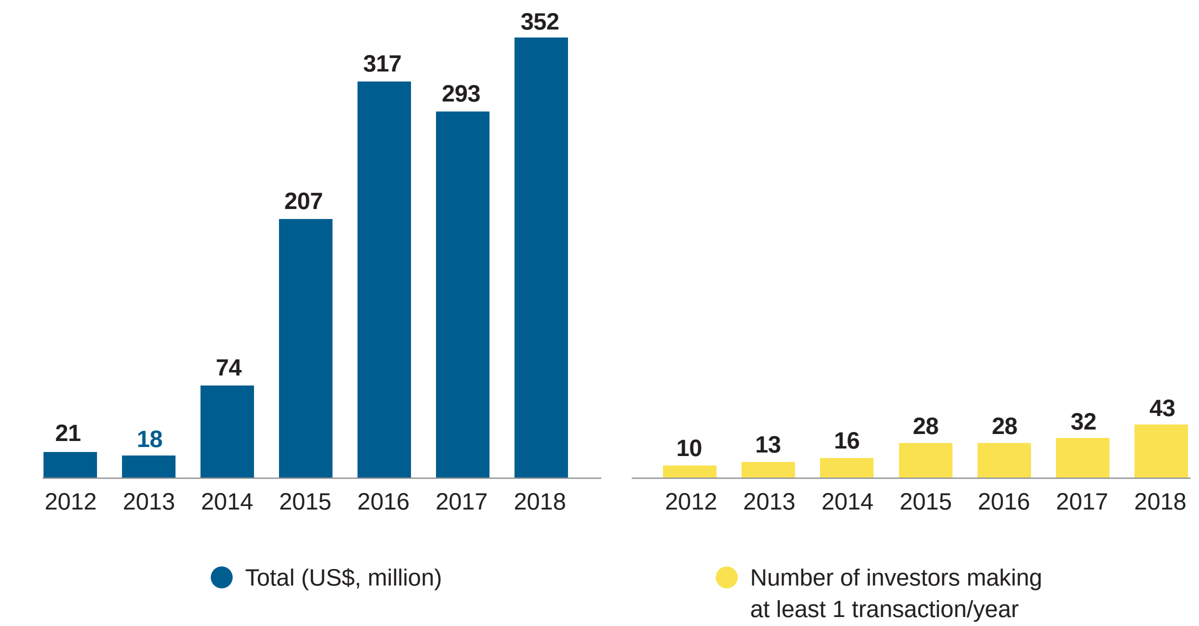
Investors and funders have been unwilling to provide a critical mass of financing to the modern-energy sector at least, in part, because of the enterprises' perceived riskiness. Absolute financing levels remain extremely low. Because few cooking enterprises have cracked the double challenge of profitability and scale, immediately investable models for traditional funders are relatively few. At the same time, business models are evolving too quickly for investors and lenders to suitably assess risk, creating a significant challenge for funders to keep pace with the "dynamism of the sector, its players, its evolving regulations, [and] its unsolved debates."[7] Also, the cooking space in and of itself tackles complex problematics that do not always have an obvious runway to commercial return—notably, the need to acquire customers who currently do not pay for their fuel. Given these layers of uncertainty, risk aversion has driven existing investors toward familiar investees rather than high-potential new ventures. As one stove manufacturer remarked in a Task Team interview: "Money isn't getting to the people who need it; those that raised 10 million a few years ago can raise 15 [million] now, but the clean cooking sector [can't raise these same amounts]."[8]

While much work is needed to improve investors' risk appetite, challenges regarding the shape and form of financing remain. Specifically, the structures of non-grant financing modalities do not yet align with the needs of sector players, and emerging and innovative instruments are not reaching the right beneficiaries at the right time. Investment in the modern-energy cooking space must account for the relative nascence of stove and fuel enterprises, few of which have become profitable. "Since we only provide debt products," explained one development finance institution (DFI) official during a Task Team interview, "it still often seems that we are trying to square the circle. What companies need is equity or a very alternative debt structure." The solution need not be complex. As another DFI official remarked, "The cooking sector may not be ready for some fancy financing model." Simple instruments that provide near-term capital in a timely fashion are in short supply and badly needed. Distributors and end users alike suffer from delays in receiving capital up front. In another interview with the Task Team, a stove manufacturer explained, "This is particularly the case with carbon credits, which we receive with a one-to-two-year lag."

Today, the cooking sector can be viewed as a still immature, but high-potential, component of the broader modern energy space. Over the past decade, the sector has seen significant risk dilution. Indeed, from an institutional perspective, players like the International Finance Corporation (IFC) and the World Bank–supported Lighting Global program have set a good example of playing a catalytic role in reducing first-mover risk and mobilizing private-sector investment through market intelligence, quality assurance, business support services, and consumer education. Industry associations like the Global Off-Grid Lighting Association (GOGLA), the convener and partnership platform of the off-grid solar energy industry, have been essential to capturing market intelligence and disseminating industry trends, which have allowed investors to mobilize at higher frequencies and bigger volumes (figure 4.10, box 4.4).[9]

The perceived risk of the cooking sector would likely differ substantially if cooking investments were better integrated into large urban investments and broader energy policy. The scale of capital deployed to grid extension programs, as well as to the improvement of electricity networks in dense city environments, tends to dwarf the investment traditionally allocated to cooking programming. The case of Kenya Power, however, provides an alternative model: cooking loads are becoming better integrated into the utility's capacity planning, and electric cooking appliances are included in product portfolios. This type of bundling diversifies the risk attached to a single product model and creates greater potential for scale economies of distribution. Engaging with utilities and energy-distribution networks will prove even more critical where power access is handled closely by local entities.[10] In such cases, understanding localized user needs and trade-offs will prove particularly important for accelerating gains in access to MECS.

FIGURE 4.10 Total Investment in the Off-Grid Solar Sector



Source: Global Off-Grid Lighting Association (GOGLA) investment data.

Enablers of Greater Flows of Financing

Enterprises that provide clean cooking solutions and are moving toward scale are at last finding traction with financiers, which should mark the start of greater investment flows. Larger and faster-growing MECS entities receive bigger ticket sizes. In 2019, 36 percent of “clean” enterprises, compared to 7 percent of improved stove-and-fuel players, raised more than US$250,000 (figure 4.11).

Over the next 12–18 months, enterprise demand for capital will continue to grow at a range of ticket sizes. It is expected that two-thirds of all small-sized enterprises will require financing. Of those, 27 percent will require under US$50,000. At the same time, a greater number of medium- and large-sized companies are looking for larger infusions. Over the past 12 months, four-fifths of such enterprises received financing. Over the next 12–18 months, approximately 86 percent of large entities expect to require more than US$500,000 in investment (figure 4.12).

Various financing instruments are being piloted and deployed across the cooking space to spur enterprise growth and introduce new leverage for private capital. Such investors as the BIX Fund are using debt, equity, and/or mezzanine capital in new and varied ways. The Spark+ Development Fund will provide debt and quasi-equity across the entire ecosystem throughout Sub-Saharan Africa. Recipients will include stove manufacturers, vertically-integrated fuel players, and distribution/financing companies (e.g., off-grid solar providers and microfinance institutions [MFIs]). The fund will comprise three tranches: (i) senior debt (provided by commercial investors, including pension funds, insurance companies, family offices, and development finance institutions [DFIs]), (ii) equity (provided by DFIs and impact investors), and (iii) first loss (concessional capital provided by impact investors and non-grant donor facilities). The BIX Fund, meanwhile, provides debt to companies with fixed carbon offtakes and other results-based financing (RBF) contracts. The Netherlands Development Finance Company (FMO), Calvert, Anthos, and the International Finance Corporation (IFC) provide the financing.

BOX 4.4 Meeting the Financing Challenge for Off-Grid Solar Energy

In October 2019, Unlocking Solar Capital Africa, a flagship investment conference supported by Solarplaza and the Global Off-Grid Lighting Association (GOGLA), convened decision-makers in Dakar to address the financing challenges faced by on- and off-grid solar project developers in Africa. Below are key lessons that emerged from the off-grid sessions:

- **Good unit economics.** Recent industry failures have led investors to focus more on business-model performance and sustainability. Companies will need to control their unit cost economics as the basis for future profitability; their responses on how to do this differ markedly.
- **The right kind of debt.** There is more debt available, which in itself is good news. However, loan terms matter, and many companies cannot yet benefit from this trend. In particular, local-currency financing remains evasive and expensive. Local financiers and other debt providers will need better data and indicators to allow them to assess and compare company performance transparently.
- **Initiatives to help starter companies and African entrepreneurs.** Attracting equity investments remains a significant challenge, especially for starter entrepreneurs and African-owned companies. New players will need to demonstrate that they add value and impact—which they can do, for example, by focusing on productive-use technologies powered by off-grid solar power.

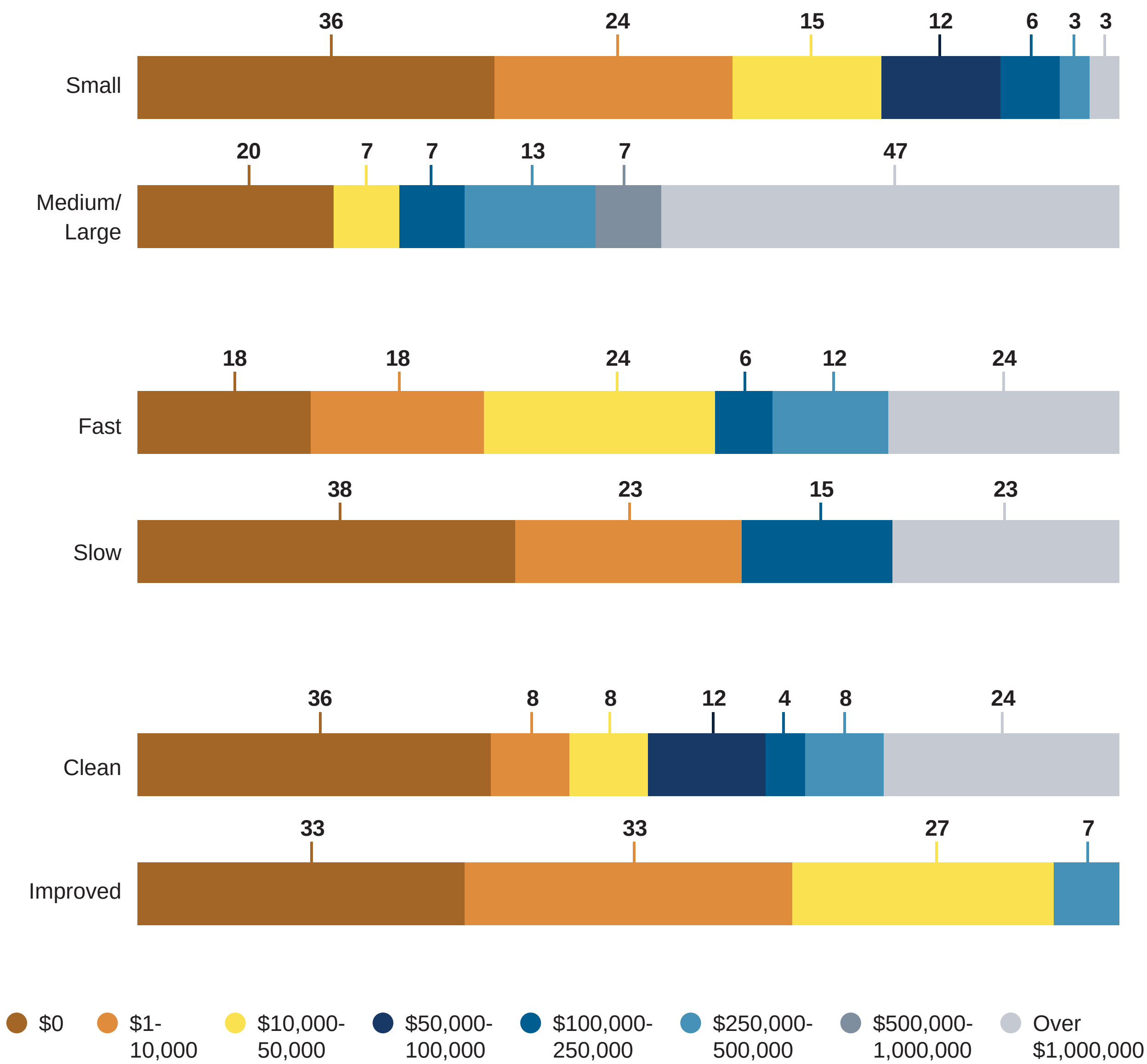
  GOGLA members announced exciting findings and initiatives designed to help local and fledgling companies. For example, Catalyst Off-Grid Advisors and Open Capital Advisors announced the launching of VentureBuilder, a new approach to support African off-grid solar companies; the initiative is supported by the DOEN Foundation, Shell Foundation, Facebook, and the United States Agency for International Development (USAID). Acumen presented its report on exits in the off-grid solar industry. More exits within the sector will allow early-stage investors to recycle their capital into pioneering off-grid companies.
- **Entry of large players and competition dynamics.** In recent months, the off-grid sector has seen a larger number of strategic investors in the space, including ENGIE, EDF, Total, Shell, Mitsubishi, and Marubeni. It is too early to say how this will affect the market, but a change in competition dynamics is likely as these multinationals bring cheaper capital to their investees, as well as more operational discipline and rigor.
- **Partnering with public funding.** Off-grid solar is now firmly on the radar of governments and multilateral development banks. Several countries are reviewing how they can deploy public funding in innovative ways to stimulate faster market growth or a deeper reach (e.g., the World Bank–funded Regional Off-Grid Electrification Project [ROGEP], which involves 19 West African countries). Growing government interest, however, might also lead to an increased push for regulation. Outcomes will vary significantly by country.[a] It will be all the more important for the industry to continue conversations with governments and development partners in the Community of Champions format or at future global off-grid solar forums.

Source: GOGLA 2019.

a. See, for example, the new country market briefings from USAID.

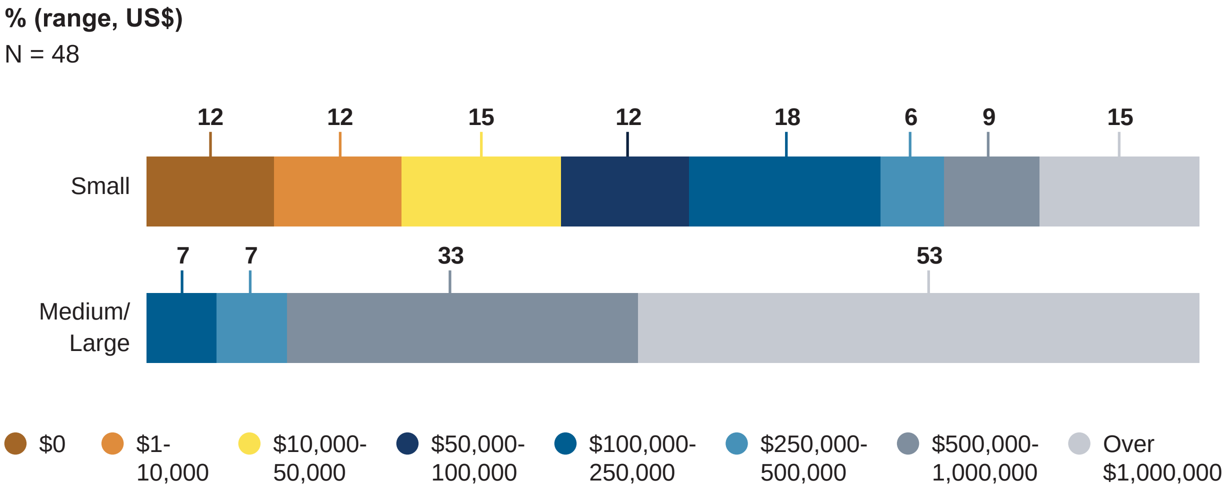
FIGURE 4.11 Capital Raised in the Last Year, by Enterprise Type

% (range, US$)
N = 48 (small or medium/large enterprise)
N = 30 (fast or slow growth rate)
N = 40 (clean or improved enterprise)



Sources: 2019 ESMAP/CCA/LU Enterprise Survey; Task Team analysis.

FIGURE 4.12 **Expected Future Financing Needs, by Enterprise Size**



Sources: 2019 ESMAP/CCA/LU Enterprise Survey; Task Team analysis.

A select number of grants for pilots and research and development (R&D), along with a wider range of high-profile RBF programs, are sparking MECS growth and innovation. The MECS Program, funded by UK Aid of the Foreign, Commonwealth and Development Office (FCDO), provides grants for innovation in electricity- and LPG-based cooking technology and products. Power Africa, funded by USAID, also offers grants to renewable-energy and energy-efficiency projects, including cooking innovations.[11] Various energy funds, including the Africa Enterprise Challenge Fund (AECF) and the Energy and Environment Partnership (EEP) Trust Fund, among others, provide grants for pilot programs in specific countries. High-profile RBF programs include the World Bank's US$500 million Clean Cooking Fund, housed under the Energy Sector Management Assistance Program (ESMAP). The Clean Cooking Fund offers results-based grants, primarily at the national and subnational scale, to help countries incentivize the private sector to deliver MECS (box 4.5). In parallel, Energising Development (EnDev) RBF country programs have provided a multitude of grants.[12] EnDev projects involve a variety of energy-related technologies, including cookstoves, mini-grids, and grid connections. The Netherlands Directorate General of International Cooperation (DGIS), BMZ, and others provide financial support. FCDO, the UK's Department for Business, Energy and Industrial Strategy (BEIS), the Government of Sweden, and the Swiss Climate Cent Foundation are funding the World Bank's Carbon Initiative for Development (Ci-Dev) Facility, a multi-country RBF program supporting 12 projects that aim to improve Sub-Saharan Africa's energy access through the acquisition of carbon credits. The RVO SDG 7 Facility, supported by the Directorate-General for International Cooperation (DGIS), focuses on results-based funding for projects that advance SDG 7 through renewable-energy access in the following countries: Bangladesh, Burkina Faso, Chad, Ethiopia, Gambia, India, Kenya, Mali, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sudan and/or South Sudan, Tanzania, and Uganda. Finally, the World Bank–financed Kenya Off-Grid Solar Access Project (KOSAP), a flagship initiative of the Government of Kenya's Ministry of Energy, has integrated an RBF program for clean cooking into its off-grid energy program.

BOX 4.5 Shifting the Investment Paradigm for Large-Scale Impact: The World Bank's Clean Cooking Fund

At the September 2019 UN Climate Summit, the World Bank Group (WBG) announced its plans to establish the US$500 million Clean Cooking Fund to galvanize political commitment and investment to achieve universal access to modern energy cooking services (MECS) by 2030. Hosted by the World Bank's Energy Sector Management Assistance Program (ESMAP), with initial funding from the governments of Denmark, the Netherlands, and Norway, the Fund's main objectives are as follows:

- Co-finance and leverage concessional finance from the WBG and other Multilateral Development Banks (MDBs) and attract private-sector investments to the clean cooking sector.
- Catalyze technology and business innovations by generating additional revenue sources and incentives for businesses across MECS value chains.
- Link incentive payments with verified results at the output, outcome, and impact levels to promote MECS access for last-mile customers and contribute to better health, gender equity, and environmental sustainability.

Source: World Bank.

New non-financing enablers are also being introduced to make new and private investment go farther. The Clean Cooking Alliance (CCA) recently launched its Venture Catalyst program, which provides venture-level technical assistance and grants in order to increase the pipeline of investible companies with scalable business models. The program provides businesses with technical assistance on investment readiness, capital raising, market expansion, sales and marketing, supply-chain management, impact assessment, and product R&D. It also includes supplementary grants in alignment with and linked to advisory support. These grants may focus on R&D/innovation, investment readiness, and operational-growth and other key initiatives for which grant funding is justified to accelerate growth. Grants are not to be used to fill fundamental viability gaps in a company's business model or unit economics. In parallel, the CCA's Market Catalyst program focuses on building the modern-energy cooking ecosystem. The program offers advisory support and direct engagement with investors, policy makers, and market development organizations (e.g., other grant makers and consultants), as well as support on pipeline sourcing, due diligence, strategy development, and implementation. This program also conducts policy research, including studies of regulatory decision-making tools and models. It pursues market research and uses tools related to consumer economics and dynamics; market sizing; technologies, products, and services; business models and commercial strategies; pipeline and investment opportunities; and investor and funding databases. Finally, it works toward profile-building to "grow the pie" with impact investors and energy-access players (central planners and adjacent sectors), among others. In addition to the CCA's Catalyst initiatives, other enabling programs include EnDev's provision of business development services (BDS) to small companies producing biomass stoves, biogas systems, and briquettes, which are funded by the DGIS, BMZ, and others; the Global LPG's advocacy and technical-assistance grants for LPG partnerships, funded by various bilateral donors; development NGOs (e.g., SNV and Practical Action) that provide advocacy and BDS for small-scale solutions with foundation and bilateral donor funding; GET.invest Finance Catalyst's technical-assistance program for renewable-energy projects; and Power Africa's technical assistance for electricity and LPG projects, funded by USAID.

OPPORTUNITIES FOR ACCELERATED SCALE

Recent advances in technology and commercial innovation are making scalability and growth a potential reality. Despite challenging product and enterprise economics and limited financing, technological advances are making MECS more affordable for many more households, aided by the introduction of new payment and financing approaches (Annex 4). While not exhaustive, pellet-gasifier stoves, electric pressure cookers (EPCs), and bottled ethanol are innovations that are increasing MECS accessibility for households. Gasifier stoves that use pellets instead of raw biomass can lower emissions and allow for more efficient combustion, and the economics of pellet production are encouraging. The affordability argument for EPC eCooking appliances is promising, and grid-powered EPCs have already taken root in many markets of Asia. Bottling of ethanol using an itemized approach can reduce company costs and user prices, achieve scale, and realize safety and environmental benefits. Equally significant, innovative business models are transforming the ways in which end-user customers access cleaner and more energy-efficient cooking solutions. For example, embedding PAYGo and the Internet of Things (IoT) into LPG cooking solutions can overcome supply-chain inefficiencies. Various companies in Sub-Saharan Africa (e.g., Kenya, Rwanda, and Tanzania) now have PAYGo offerings in the cooking space. Bundling cooking with other modern-energy products and services can help cooking enterprises to capitalize on existing distribution networks, potentially increase revenues, and spread risk.

All of these examples underscore the reality that greater access to MECS requires supply-side solutions that put the user at the center as part of an innovative fuel-utility model. Whether restocking on pellets, walking to a nearby "fuel ATM," or purchasing a stove at the same time as a home solar panel, households are set to have greater agency with products that creatively overcome affordability challenges and energy market failures. The promise of these models is strong, but a long road lies ahead for capitalizing on this potential.

CONCLUDING REMARKS

This chapter has mapped the supply side of the cooking space through analysis of in-depth player databases (e.g., the Clean Cooking Alliance [CCA] partner database), historical CCA surveys and market assessments, and a tailored enterprise survey of 70 respondents spanning all sizes and subsectors of the cooking fuel and stove spaces. Pulling from dozens of interviews with entrepreneurs, investors, and market facilitators, the findings show that the immediate supply of MECS is still marked by nascent cooking businesses that are relatively small in scale and, in many cases, unprofitable. Altering this state of affairs is critical to improving access. It requires understanding the nuances of the global supply network, as well as unpacking the commercial and financial challenges faced across multiple operating models for stoves and fuels. The next step will require elevating key breakthroughs that are redefining scale in the cooking and broader energy space (Annex 4). It means learning from scalable success stories and highlighting the multiple new levers—whether financing, enterprise support and acceleration, or business-model integration—that are poised to transform the cooking space in the years to come.

ANNEX 4. DEEP-DIVE CASE STUDIES

This annex presents five deep-dive case studies on promising supply-side solutions for overcoming the affordability challenges of access to Modern Energy Cooking Services (MECS) and energy market failures. The case studies focus on three new technologies for increasing household affordability—pellet-gasifier stoves, electric pressure cookers (EPCs), and itemized bottling of ethanol—as well as two innovative business models for increasing accessibility—pay-as-you-go (PAYGo) for liquefied petroleum gas (LPG) and biogas/gasification and distribution partnerships/bundling with off-grid solar companies.

Pellet-Gasifier Stoves

Pellet gasifier stoves use a non-combustive technology that relies on heat, steam, and oxygen to convert biomass pellets into energy for cooking (EERE 2019). Pellets are biomass compressed into pieces of similar size, shape, and moisture content; the homogenous nature of the pellets—as opposed to gasifiers that use raw biomass as inputs—is a crucial factor in lowering emissions, while the reduced moisture content allows for highly efficient combustion (Champion and Grieshop 2019).

Inyenyeri, a Rwandan company self-described as a “triple-bottom-line cooking power utility,” illustrates the potential of the “cooking-as-a-service” business model, underpinned by fuel pellets.[13] Under this model, customers receive free Mimi Moto stoves and technical support, and pay the company monthly for the provision of pellets (EEP 2016). Another company, African Clean Energy, sells the ACE 1, a solar-biomass hybrid that uses one LiFePO4 (lithium iron phosphate) battery to power a ventilator, facilitating the highly efficient combustion of pellets.[14] Its users also have access to solar electricity for mobile charging and lighting.

Pellet production stands out as a potentially cost-effective way to bring people closer to modern cooking than the approach historically taken by developed countries (i.e., oil fuel).[15] The economics of pellet production are encouraging: The total cost of goods sold for pellets is about US$110 per ton, which can easily compete with Rwanda’s expensive charcoal while offering cleaner and more convenient cooking experiences.

Despite this promise, the ability of firms to scale up production remains an uncertainty.[16] Studies focused on Central Africa, as documented by Jagger et al. (2019) and Puzzolo et al. (2019), point to the still limited range of companies that have been able to comprehensively achieve strong productive returns, source inputs sustainably and profitably, and create vibrant local economies. These entities also face challenges in maintaining pelletizing equipment and ensuring the energy-intensive drying of wet pellets, as well as ensuring stable pellet production over time. Meeting these challenges must occur in parallel with the growth of other clean solutions like LPG, whose returns on scaled infrastructure have been proven (GLPGP 2019).

Looking forward, research and development (R&D) is a continuing priority, even for cleaner stove-and-fuel solutions like pellet gasifier stoves.[17] Thermal efficiency today tops out at about 46–48 percent, but, according to Task Team interviews, experts believe a thermal efficiency of 60 percent is possible. The investment needed to improve gasifier stoves pales in comparison to the current investment in, for example, natural-gas stove improvement. As one Task Team interviewee pointed out, “The best stove in the world today is the Mimi Moto, which was designed by a 22-year-old student in a garage.” Although the stove itself may perform well, the pellet moisture content and performance under humid and wet-season conditions will strongly affect household use. Additional in-depth research should focus on the emissions profile of pellet stoves and personal exposure of stove users. Pellet gasifiers have been shown to emit lower levels of $PM_{2.5}$ compared to traditional biomass stoves (with performance varying based on the pellet moisture content and user operations) (Champion and Grieshop 2019; Tryner, Volckens, and Marchese 2018). However, Task Team interviews indicate that it is possible that pellet gasifiers release other harmful emissions (e.g., ultrafine emissions). In addition, $PM_{2.5}$ personal-exposure studies have not yet been published to verify that pellets burned in Mimi Moto stoves under field conditions meet or approach the World Health Organization’s guidelines for indoor air quality (WHO 2014).

Electric Pressure Cookers and eCooking

Electric pressure cookers (EPCs) are electricity-powered, airtight pots that seal in steam during cooking, increasing the pressure and therefore the maximum temperature of liquids within the pot. The higher temperatures and pressurized steam that infuses the food allow for much shorter cooking times. Various foods can be cooked in a pressure cooker, including meals traditionally prepared in “long boilers, medium boilers/fryers, and quick fryers” (ESMAP 2020). A new generation of high-efficiency, eCooking appliances, now available, can drastically lower costs by reducing the amount of electricity required to cook (Couture and Jacobs 2019; Leary et al. 2019; Zubi et al. 2017). Field trials with 80 households show that energy-efficient, eCooking appliances, notably EPCs, are highly attractive to consumers and can substantially lower the cost of eCooking by reducing energy demand.

The technology's affordability argument is also encouraging: eCooking directly with alternating-current (AC) grid electricity is already cheaper than cooking with charcoal in some urban centers where charcoal costs more than US$0.40 per kg and electricity tariffs are below US$0.35 per kWh (ESMAP 2020). Battery-supported eCooking is already cost-effective for charcoal users in urban centers with electricity tariffs below US$0.15 per kWh. By 2025, expected increases in charcoal prices and declining costs of battery-supported solutions suggest that the cost of eCooking will become comparable to that of cooking with charcoal and kerosene in many weak-grid and off-grid contexts.

Most critically, eCooking appliances have already taken root in many markets that are key to future progress toward meeting Sustainable Development Goal 7 (SDG 7). In Asia, 1.6 million people pay up-front prices of US$50 for a grid-powered EPC used to cook some of their meals; meters track electricity consumption, and customers pay their bills at utility shops. Task Team interviewees report that, in 2018, 7,100 EPCs were sold in Kenya. Although the majority of these purchases occurred among households in higher-income quintiles, they shine a light on the possibility of using a market foothold—even if an aspirational product—to capture a larger base.

Innovative delivery and financing models will be needed to support the extended rollout of eCooking. Even where it is cost-competitive, challenges remain, especially if energy storage is required. In markets that do not require energy storage, supply chains are emerging but are not yet strong. Although private-sector, retail supply of EPCs is increasing in Asia, it is not yet common in Sub-Saharan Africa (IMARC Group 2019), where localized supply chains (e.g., for retail, repair, and auxiliary equipment) are not yet in place and consumer awareness remains low. Basic consumer-finance packages need to be extended to include such devices as EPCs. Behavior change (adapting cooking practices to task-specific, energy-efficient appliances) will also be required. The uptake of eCooking will depend substantially on the willingness of the private sector (particularly solar companies, mini-grid operators, and utilities) to adopt the technology as part of a suite of services they offer their customers. Utilities with excess generating capacity, for example, could stimulate demand by developing an on-bill financing mechanism for EPCs and supporting women entrepreneurs to sign up new customers by running cooking demonstrations in their homes. Grant funding could support initial feasibility studies and piloting, with access to finance facilitating the scaling up of promising solutions.

Itemized Ethanol

At present, ethanol is a seldom-used cooking fuel in many lower- and middle-income countries. Across Sub-Saharan Africa, less than 6 million liters per year are sold for cooking purposes (2017 figure). This number is low not only in absolute terms but also in relation to the number of ethanol stoves that have been distributed (70,000–80,000). However, ethanol remains a promising commercial and impact opportunity, given its unique production attributes.

Ethanol can be bottled and distributed following either a bulk or itemized model. In the bulk model, ethanol is packaged into plastic disposable bottles in a large, centrally-located facility and transported across the market via trucks. Small shops sell ethanol bottles to consumers, who pour it from the bottle into their stoves (and then discard the bottle). In the itemized model, small retrofitted fuel tankers transport ethanol in bulk to dedicated tanks at petrol stations. Fuel ATMs inside shops dispense ethanol into reusable containers, for which users pay digitally.

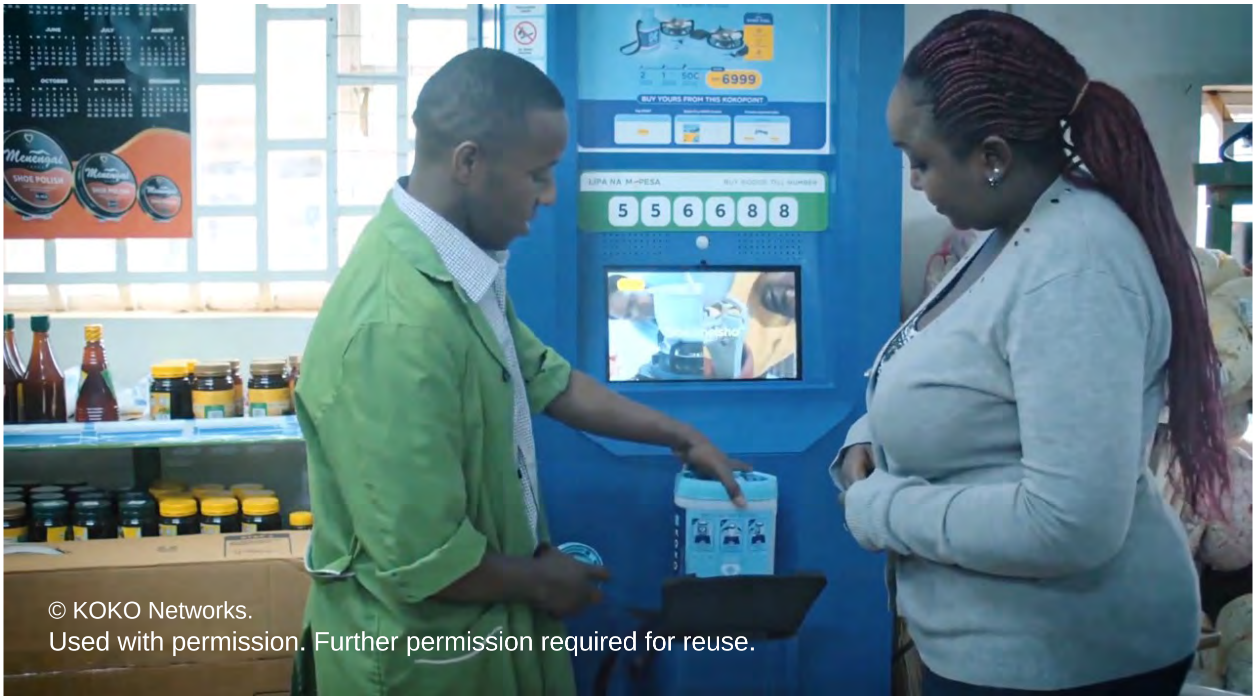
This approach has most prominently been adopted by KOKO Networks in Nairobi. KOKO's distribution coverage has shown notable growth in greater Nairobi via a dense network of "KOKOpoints"—fuel ATMs located inside neighborhood stores across the city, each communicating in real-time with the entity's cloud-based platform. KOKO also employs analytics, pulled from the data generated by smart canisters, to understand consumer behavior and measure purchasing patterns based on the distance between point-of-fuel use and the fuel distribution point. CEO Greg Murray says, "Cooking fuel is like Coca Cola in that access to a staple fuel should be defined as less than 500 m or less than 5 minutes from home. Our smart canisters show that consumption drops as people move farther away from access points."

This experience has produced insights that directly impact KOKO's distribution and pricing strategy. In urban settings, KOKO prices its fuel to match consumer demand: On average, consumers are willing to spend roughly an additional US$0.10 per liter in order not to walk more than 5 minutes. Recognizing that network coverage is critical for the uptake of cooking solutions, KOKO Networks has expanded to approximately 700 KOKOpoints in Nairobi. As the company looks toward peri-urban and increasingly rural settings, it expects to prioritize and cluster its points of sale in order to maximize reaching households for which KOKOpoints are currently least convenient—specifically, by locating refueling points on arterial roads at junctures near M-Pesa agents and other last-mile distributors. Building on its success in Nairobi, KOKO is now creating a consumer/retail platform that includes a radio station, coupons for KOKO stores, and WiFi in KOKO stores.

The itemized-bottling approach represents an innovative way to reduce company costs and user prices, achieve scale, and realize other environmental and safety benefits. Itemized bottling can deliver ethanol at scale to customers at a price that is approximately 40 percent lower than that using a centralized approach. Leveraging existing downstream infrastructure, such as local commercial retail, can cut bulk-storage and transport costs by about 90 percent, while technology-enabled distribution can reduce combined distribution and retail costs by roughly 45 percent.

Embedding PAYGo and IoT into LPG Cooking Solutions

A pay-as-you-go (PAYGo) model allows customers to pay for cooking solutions in small amounts as needed (e.g., a week's worth of fuel instead of a whole cylinder). Some companies amortize the stove cost into regular fuel payments, reducing the affordability barrier of the up-front stove cost. For many household and company end users, this option is more attractive than microfinance, which can be time-consuming and involve difficult collateral demands. By comparison, PAYGo accounts, in many cases, can be up and running within a much shorter time frame.



PAYGo usually builds on the penetration of mobile money and cell phones—and, more recently, the Internet of Things (IoT) technology, which directly connects appliances to the Internet, facilitating real-time measurements of fuel usage and accommodating smaller refills at lower prices. PAYGo for cooking builds off the established track record of PAYGo for off-grid solar energy. For example, M-KOPA, a solar home system (SHS) company based in Nairobi, has deployed PAYGo to reach 3 million people with 750,000 units across Kenya, Tanzania, and Uganda.

The following companies in Sub-Saharan Africa now have PAYGo offerings in the cooking space:

- **PayGo Energy,** a Kenya-operating enterprise launched in 2015, recognized how supply-chain inefficiency was hindering the uptake of LPG for cooking fuel and encouraging illegal refilling of cylinders. In response, PayGo Energy digitized its supply chain and incorporated PAYGo technology, with the goal of providing LPG as a service.

  In a pilot program comprising 300 homes in Nairobi, customers signed up with PayGo Energy and provided an initial payment of US$50 (half of which they were allowed to pay in increments over a 6–10 week period). The enterprise installed cylinders equipped with smart meters in customers' homes, which closely tracked their LPG consumption. Customers purchased small amounts of fuel with mobile money, and, with the power of IoT, their cylinders immediately dispensed the amount purchased. Over the course of the pilot, customers paid, on average, US$1.85 per kg of LPG. The smart meters informed LPG distributors and retailers when their customers' cylinders were nearly out of fuel so that they could replace them in a timely fashion.

  The pilot has shown promising results. The company retained 91 percent of customers and 98 percent of cylinders over a year's time. The LPG-as-a-service approach appears to have enabled the spread of LPG cooking as 86 percent of customers had never used LPG before. In addition, PayGo Energy found that customers purchased larger amounts of LPG as the pilot continued, possibly suggesting that they were progressively stacking less with other fuels over time.

- In 2018, **Envirofit**, a global energy and cooking company, started its own PAYGo LPG solution in Nairobi (SmartGas) using gas cylinders enabled with Envirofit's SmartMeters. Like PayGo Energy, Envirofit underwent a long process of research and development (R&D) before launching its meter technology. Mobile money is an important enabler for Envirofit, which, in part, explains its launch in Kenya, where 96 percent of households outside Nairobi have at least one M-Pesa account. In some cases, Envirofit cross-sells LPG stoves to SmartGas customers, who have the choice to buy an Envirofit stove at full price, buy an Envirofit stove with consumer financing, or use another stove. Safety concerns constitute a key obstacle to LPG uptake and usage; as such, Envirofit employees carry out a nine-point safety check during service provision and instruct people on how to safely use their cooking solution. In the coming years, Envirofit hopes to scale its SmartGas offering, notably through its specially-designed SmartMeter hardware and software, which adapt to other LPG cylinders and country contexts.

- In Tanzania, **KopaGas** offers PAYGo LPG, enabled by money services and smart meters. In 2015–17, GSMA funded a KopaGas pilot comprising 148 households and 2 small-scale food stands, the results of which were encouraging for gender inclusion, affordability, and LPG expansion. Women accounted for 98 percent of customers. Most customers spent US$2.92 less per week on cooking, and nearly two-thirds had not previously used LPG for cooking. By late 2018, KopaGas had reached more than 500 customers. By 2021, it expects to have reached 200,000 customers in Dar es Salaam and Zanzibar. Among other organizations, Acumen and the Clean Cooking Alliance (through the Cooking Industry Catalyst program) are providing funding and support.

In markets where people are already familiar with the idea of installment payments, PAYGo cooking solutions do not represent a significant constraint to the uptake of modern cooking solutions. In practice, this has meant that markets with high mobile-money penetration (e.g., Kenya, Rwanda, and Tanzania) have been relatively friendly to PAYGo offerings; for example, PayGo Energy, KopaGas, and BBOXX started in these markets. The IoT component of PAYGo solutions allows companies to get to know their customers and thus better serve them. Innovative smart meters monitor how much fuel households use and when they tend to use it. The meters send data back to the company, which can better forecast the fuel needed at a given time. With a detailed understanding of when and where to expect demand, the companies can tailor and target their supply-chain operations. Improved fuel-use measurement can help reduce operational inefficiencies, reduce costs (e.g., for fuel storage and distribution throughout the supply chain), and mitigate negative impacts or risks (e.g., limiting the potential for fuel shortages). Most critically, smart meters can help expand and improve grid extension, particularly in urban settings, and thus proactively integrate the traditional cooking reality with the modern energy space.

Bundling with other Modern-Energy Products and Services

Manufacturers and commercial distributors are increasingly focused on bundling and diversification of product offerings. In recent years, stove manufacturers have begun producing or adding cleaner fuels to their product mix and bundling in other product types (e.g., solar home systems [SHSs] or household appliances). At the same time, established commercial distributors, particularly in the off-grid lighting sectors, have diversified their portfolios with cookstove and fuel products.

Bundling represents a valuable opportunity for cooking enterprises to capitalize on existing distribution networks, many of which include off-grid and/or last-mile distribution (CCA 2018). This reduces customer acquisition costs, improving sales agents' productivity as they cross-sell and/or up-sell (Winrock International and USAID 2017). Thus, bundling can potentially increase revenues and spread risk among multiple business lines. The Task Team interviews indicate that the following companies, among others, have taken a range of approaches to bundling cooking and energy products and services:

- **Greenway Grameen,** a biomass stove manufacturer, provides credit lines to its stove customers (building their credit histories) and then connects them to other financing products via partnerships with microfinance institutions (MFIs).

- **BBOXX,** an energy company with activities across West, Central, and East Africa, began operations strictly as a provider of off-grid solar solutions to rural homes. Through its customer interactions, BBOXX observed that households with television sets were still cooking with three-stone fires. A Task Team interviewee recalls, “This was contrary to our vision to unlock potential through access to energy. If you want to solve SDG 7, electricity is only one part of it, and clean cooking is the other.” BBOXX subsequently began offering PAYGo cooking products and has now placed its cooking technologies in 100 households in Kigali. The company aims to become a next-generation utility by leveraging its trusted, long-standing relationships with customers to cross-sell additional products and services.

- **Biolite,** a stove producer based in the United States with operations across Africa, recently diversified into off-grid solar products. In 2018, it signed a technology integration agreement with Angaza (an SaaS company specializing in PAYGo), whereby Biolite was allowed to embed Angaza’s technology into its product (Biolite 2018). This partnership has made it possible for Biolite’s distribution partners to sell solar solutions to off-grid homes four times faster (Biolite 2018). Biolite’s home solar product, launched in 2017, is itself a bundled product, incorporating a motion-detector light and a radio/mp3 player.

- **M-KOPA** cross-sells home-related offerings (e.g., lights, cookstoves, smart phones, and water tanks) to households that have satisfactorily paid off their off-grid solar solutions (M-KOPA 2016). It also offers PAYGo consumer financing for these additional products. Among the products offered, the company claims that “locally-manufactured, clean-burning, sustainable-fuel-using” cookstoves have been the most popular (M-KOPA 2016).

Bundling has so far proved popular. The ESMAP/CCA/LU Enterprise Survey conducted as part of this report found that more than half of respondents manufacture, distribute, and/or sell technologies beyond stoves and fuels. Most commonly, these enterprises bundle with solar products, although non-cooking (e.g., heaters) and cooking (e.g., electric pressure cookers [EPCs]) appliances are also cross-sold by multiple stove-and-fuel enterprises. Companies that bundle tend to be those that face relatively smaller financing challenges (e.g., larger companies that are established in other sectors, have other funding sources, have proven their business model, or have leeway for a research and development [R&D] budget). As one executive interviewed by the Task Team explained, “As a growth-stage company, we have just closed our Series D funding round. We have been able to use this funding to develop our new scalable cooking product, which requires a significant development budget.” Task Team interviews indicate that, for these companies, lessons learned from other business lines can be applied to cooking and vice versa. Translatable lessons from BBOXX’s solar business, for example, include IT systems, the PAYGo business model, and PAYGo market-attractiveness scoring.

A fundamental barrier to expanding these types of cross-sector bundles is the difficulty of incentivizing companies in other sectors to enter the cooking market, where achieving scale has historically been perceived as challenging. As one executive of an off-grid solar company also active in the cooking ecosystem explained to the Task Team, “The reason we are scaling is because of our lighting business—we do not harbor any illusions about our ability to scale a business on the back of cooking.” Nevertheless, the drive to bundle may well originate with players in the cooking sector rather than actors in adjacent ones. The ESMAP/CCA/LU Enterprise Survey found that more than 70 percent of cooking enterprises (33 out of 46 respondents) reported an interest in pursuing technological integration and/or distribution partnerships with companies traditionally adjacent to the cooking sector (e.g., off-grid solar companies and last-mile, multi-product distributors).

NOTES

1. The MECS Program focuses on essential research and sector-building activities.
2. Service providers include fuel and stove producers and manufacturers, distributors, and retailers.
3. Based on the results of the 2019 ESMAP/CCA/LU Enterprise Survey (16-company sample) and Task Team analysis.
4. Stoves are mainly designed for wood only; multiple-biomass companies have greater flexibility in terms of biomass fuel consumed.
5. LPG companies were not included in this sample, given the absence of fully vertically-integrated respondents; however, non-vertically integrated LPG respondents reported that about 40 percent of costs were concentrated in upstream sourcing, with a 10–20 percent spread across the other cost categories (i.e., manufacturing, distribution, sales, storage, and company operations).
6. One should note that large, international public financing is often earmarked for national stove or fuel programs.
7. Task team interviews.
8. The perception of high risk may be rooted in the concept of a “siloed” cooking sector” (chapter 1).
9. Task team interviews.
10. In Nepal, for example, distribution has taken place through cooperatives; in South Africa, it has occurred through municipalities.
11. See also the Power Africa Off-Grid Project (PAOP).
12. As of May 2018, EnDev had supported 17 projects with RBF across 14 countries in Africa, Asia, and Latin America and the Caribbean.
13. Inyenyeri did not achieve its ambition since it was unable to raise the required funding to become self-sustaining; thus, the company ceased operations in April 2020.
14. Other sourced biomass can be used, albeit less efficiently.
15. Task Team interviews.
16. See note 13.
17. See note 15.

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CHAPTER 5

THE ENABLING ENVIRONMENT

OVERVIEW

A global patchwork of national, regional, and global stove and fuel programs and policies work to bridge the gap between supply of and demand for modern energy cooking services (MECS). In recent years, large public spending and donor-facilitated financial support have enabled accelerated growth in access to modern primary fuels in such countries as China, India, Indonesia, and Cambodia. New laws and regulations that facilitate the import, production, and supply-chain improvements of MECS have also played a critical role. At the same time, results-based financing (RBF) and other innovative, financial-incentive structures are pushing the next generation of enabling-environment interventions to focus on efficacy, accountability, and measurable outcomes.

But large-scale and innovative interventions in cooking have not been without setbacks and costly lessons. Implementation challenges in stove and fuel distribution have, at times, led to unwelcome outcomes; these include limited technology adherence and persistent dirty-stacking behavior on the part of users (chapter 3), as well as the inability of companies and organizations to continue programming without extended subsidies. Many intervention designs have failed to sufficiently account for the many nuances of household use, instead prioritizing selected attributes of access at the expense of the total access picture (e.g., overemphasis on improving fuel affordability without addressing market challenges in order to make the fuel readily available year-round).

NATIONAL PROGRAM EXPERIENCE

Scale and Focus

Today, the greatest concentration of cooking initiatives is in Sub-Saharan Africa, while the best-funded initiatives are found in Asia. This report's Task Team analysis shows that the global enabling environment for cooking comprises more than 90 global, regional, and national initiatives (World Bank 2019a). Sub-Saharan Africa alone is home to more than 24 national programs, followed by approximately 18 in South, Southeast, and Central Asia. Recent examples in China (box 5.1), Bangladesh (box 5.2), and India (box 5.3) provide useful lessons on the implementation and impact of large-scale programming.

BOX 5.1 China: Hebei Air Pollution Prevention and Control Program

Hebei Province encompasses 8 of China's 10 most polluted cities (World Atlas 2018). The region's heavy smog and poor air-quality composite index scores, as well as its historical failure to meet emissions standards, have attracted government and international attention (Reuters 2019). In response, the World Bank in June 2016 approved US$500 million in loan funding for the Hebei Air Pollution Prevention and Control Program Project to reduce emissions of specific air pollutants in key sectors of Hebei Province (World Bank 2019b).

Among a large set of interventions, the project included a US$80 million clean-stove component, which used a results-based financing (RBF) approach to link disbursement of funds with the verified number of eligible clean stoves deployed to replace traditional coal-fired or biomass-burning stoves. Through the project, Hebei Province helped more than 1.2 million households replace coal stoves with gas and electric heating appliances, exceeding the set target of 800,000 stoves.

However, program implementation was not without its challenges. For example, in January 2018, the government had to pause the program because natural-gas shortages threatened industrial operations in the region and meant that some houses lacked winter heat. This issue, reported to have resulted from poor communication between governments and gas producers, was later resolved.

From 2013 to 2017, Hebei Province reported a 40 percent average annual reduction in ambient concentrations of $PM_{2.5}$ (Huang 2019). In fact, the $PM_{2.5}$ concentration reported by the Hebei Ecology and Environment Bureau in May 2019, at 33 µg per m^3, was the first time the province had met the 35 µg per m^3 standard (Reuters 2019). Contributing to this reduction in $PM_{2.5}$ concentration was the program's clean-stove component, which helped reduce total $PM_{2.5}$ emissions by 5,000 tons, exceeding the original target by 3,700 tons (World Bank 2019b; Zhao et al. 2019).

Source: World Bank.

BOX 5.2 Bangladesh: Improved Cookstoves Program

In Bangladesh, exposure to household air pollution (HAP) results in nearly 107,000 deaths every year, mostly among women and children (World Bank 2018). The high mortality rate can be explained, in part, by the fact that nearly half of Bangladeshi households use wood as their primary cooking fuel (UNEP 2019).

In response, Bangladesh's Infrastructure Development Company Limited (IDCOL) developed the Improved Cook Stoves (ICS) program in partnership with the World Bank (World Bank 2018). Additionally, the International Development Association (IDA) and Green Climate Fund (GCF) each contributed US$20 million for the program's second phase (GCF 2018).[a] The ICS program is a component of the World Bank's Second Rural Electrification and Renewable Energy Development (RERED II) Project for Bangladesh, whose broader objective is increasing energy access in rural areas through the use of renewable sources and more efficient energy consumption (GCF 2018; World Bank 2019c).

The ICS program installs improved cookstoves in Bangladeshi households, aiming to reach 4 million households by the end of 2021 (World Bank 2018). To increase uptake, the program employs women to implement awareness-raising campaigns involving village meetings, rural folk songs and product displays, and exhibitions (World Bank 2018). In addition, it incentivizes the local development of cookstoves that suit customers' preferences by funding partner organizations based on their sales performance (World Bank 2018).

By early 2019, the ICS program had installed 1.7 million improved cookstoves in households and reduced greenhouse gas (GHG) emissions by 3 million metric tons of CO_2 equivalent (MT CO_2e).[b] This resulted in emissions reductions of 90 percent for carbon monoxide (CO) and more than 20 percent for $PM_{2.5}$ (World Bank 2018). Beyond the climate impact, the program has also had gender and economic benefits: more than 3,000 direct and indirect jobs created for women, a 58 percent reduction in firewood use, and monthly household savings of more than BDT 375.84 per stove (World Bank 2018).

Source: World Bank 2019c.

a. The GCF's involvement indicates recognition of the program's large-scale climate impact.
b. By the end of 2021, it is expected that the project will have reduced GHG emissions by a total of 10.5 million MT CO_2e.

BOX 5.3 India: National Biomass Cookstoves Initiative

An estimated 160 million households in India rely on traditional biomass cookstoves, the use of which adversely affects the health of household members, particularly women and children (Venkataraman et al. 2010). In response, the Government of India's Ministry of New and Renewable Energy (MNRE) launched the National Biomass Cookstoves Initiative (NBCI) in December 2009. This initiative aimed to develop an improved cookstove (i.e., an efficient, cost-effective, durable, and easy-to-use stove) and install 2.75 million units over a five-year period (2012–17). The NBCI built on the results of the National Program on Improved Chulhas (1964–2002), which had deployed more than 12 million units.

To meet its objectives, the NBCI focused on research and development (R&D), awareness raising, and cookstoves deployment. Planned activities included support for stove-testing centers and revision of testing protocols and standards, pilot-scale demonstration projects, public-awareness and marketing campaigns, and dissemination of cooking applications. Implementation of these activities entailed numerous partnerships between the MNRE and public- and private-sector actors.

Because the results of the NBCI have not been widely published, it is difficult to assess its impact. However, a follow-on initiative—the Unnat Chulha Abhiyan Program—was launched in June 2014 with the stated objective of developing and deploying biomass cookstoves *(unnat chulhas)* throughout the country. According to the MNRE's Press Information Bureau, the program had, by March 2018, disseminated roughly 36,900 family-type and 850 community-type cookstoves.[a]

Source: World Bank.

a. Clean Cooking Alliance (CCA) partner database (Phoenix Udhyog Pvt. Ltd.).

Highly-funded initiatives are not as prevalent outside of Asia, but certain programs are noteworthy. For example, in Haiti, Global Affairs Canada is funding an ongoing US$20 million cookstove and fuel program. In Africa, Kenya is implementing a US$150 million World Bank–funded program focused on off-grid solar with a US$8 million cooking component. In addition, about US$10 million has been invested in Madagascar for an ethanol cooking program involving carbon credits, and Senegal's national program has mobilized more than US$19 million for household energy. Most well-funded initiatives have been supported by a multilateral entity that has led the financial mobilization, with governments often taking on an implementing role, sometimes supported by a nongovernmental organization (NGO) or bilateral organization.

Recent national-program experience suggests that nearly all clean fuel and stove programs involve some form of performance-based incentive or subsidy. The scale of these subsidies varies. For example, Ecuador and Indonesia built widespread subsidy programs at the national level, while India utilized technology and various campaigns to implement a more targeted subsidy for a subset of the population. Subsidies continue as a defining feature of national programs across a range of stoves and technologies. For example, Bangladesh, Honduras, Mexico, Myanmar, and Nepal all offer subsidies for improved biomass cookstoves. Nepal and Rwanda provide biogas subsidies, and Tanzania has a subsidy program for ethanol cookstoves. In Ecuador, subsides for electric stoves have been utilized at a national scale, while subsidization of LPG stoves, cylinders, and fuel has been widely used in Brazil, India, Indonesia, and Peru, and more recently in Cameroon. The sector also has examples of subsidies shifting through stages in the value chain (Asante et al. 2018). Deciding on the type of subsidy to implement will influence various factors of program implementation. Yet subsidy incentives alone may not suffice to encourage the sustained uptake of fuels: Successful subsidized switching has often gone hand-in-hand with awareness-raising campaigns and other incentives.

Programs and policies are increasingly shifting their focus to "clean" fuel solutions, using LPG, electricity, and ethanol. Members of the health community—primarily those focused on household air pollution (HAP)—have been vocal proponents of making a sectoral switch to cleaner fuels, guided by the principle of "making the clean available instead of making the available clean" (Rosenthal et al. 2018). The World Health Organization (WHO) has also endorsed a shift in focus from traditional biomass to higher-tier solutions (Rosenthal et al. 2018). The initiatives launched more recently have acknowledged this advocacy by placing greater emphasis on promoting cleaner fuels and higher-tier stoves. These initiatives have also evolved from traditional, direct-provision models toward greater technical cooperation, deeper capacity building, and more widespread use of innovative finance. For example, in 2017, the Global LPG Partnership launched the Bottled Gas for Better Life program, through which governments and their local partners utilize microfinance schemes to enable consumers to adopt LPG products. The program was launched in Cameroon and is currently being rolled out in Ghana and Kenya. In Indonesia, an at-scale program, initiated in 2007, focused on transitioning households from kerosene to LPG (box 5.4). Various other at-scale programs, including the one in Ecuador (box 5.5), focus on transitioning households from LPG to electric cooking.

Other countries are experimenting with broader modern cooking programs aimed at promoting a "cleaner" alternative to any number of traditional fuel-and-stove choices. Ethiopia's 2017 Electrification Program aims to provide electricity, via both grid connections and off-grid solutions, to more than a million households. This could enable the transition to electric stove cooking from a range of alternatives. In Tanzania, the United Nations Industrial Development Organization (UNIDO) launched a five-year program in 2018 to provide ethanol for cookstoves for half a million households while rapidly growing related local industries. The program aims to replicate this clean-fuel model in 20 additional countries where UNIDO believes it can have the greatest impact (UNIDO 2019).

BOX 5.4 Kerosene-to-LPG Conversion in Indonesia

The Indonesian government's Kerosene-to-LPG Conversion Program, initiated in 2007, aims to transition 50 million homes from kerosene to LPG cooking. As of 2017, the program had reached 60 million households, thereby reducing the fiscal burden of hefty kerosene subsidies (Smith and Jain 2019). Analysis of the program shows that the government was able to realize substantial economies of scale for distribution and provision, primarily through major investment in LPG-specific infrastructure (Thoday et al. 2018). Even so, the program falls short of capturing all segments of the population, particularly rural end users. While switching the subsidy from kerosene to LPG has realized significant fiscal efficiencies, the subsidy cost continues to rise due to rising energy demands.

Source: World Bank.

BOX 5.5 Ecuador's Transition from LPG to Electric Cooking

Approximately 90 percent of Ecuador's population cooks with liquefied petroleum gas (LPG) as a result of the Government of Ecuador's heavily subsidized LPG program (Gould et al. 2018). As of 2017, the program cost the government nearly 1 percent of its total annual gross domestic product (GDP). In an effort to reduce LPG subsidies and take advantage of hydropower, the government launched a national initiative in 2009 to transition 3.5 million households to induction electric stoves.

Progress has been slower than expected. The initial target date for transitioning the households was pushed back five years (from 2018 to 2023). Analysis of the program indicates that households were unwilling to transition to electricity when the price was higher than the subsidized LPG price (Gould et al. 2018). While government credits help reduce the up-front purchase barrier of electric stoves, increasingly targeted, needs-based subsidies may better address program challenges in the future.

Source: World Bank.

Even when a country successfully implements a nationwide fuel-switching program, additional initiatives may become necessary to transition households to even cleaner energy solutions. Nearly all countries with large-scale programs, such as China and India, have already implemented more than one type of fuel switching (e.g., from biomass or kerosene to LPG, followed by LPG to electricity). The deployment of cleaner fuel transitions in recent years has allowed administrations and funding partners to build on past progress (Smith and Jain 2019).

Transformative Trends

National cooking programs are also being shaped by transformative trends in the broader modern energy space. Beyond evolving in their breadth and scope, large-scale programs are being influenced by a growing standardization of stove performance. In addition, today's better understanding of the potential impacts from carbon-finance programs, as well as capacity-building needs, provides an opportunity for taking actions to accelerate the transition to MECS.

The ISO tiers for stove performance now provide clearer benchmarks and guidelines, and these measurements are being integrated into the stove choices that programs promote. For example, the newly launched Lao PDR Clean Cook Stove Initiative,[1] which focuses on distributing 50,000 forced-air gasifier stoves in multiple districts, aims to enhance the energy efficiency of stoves while also ensuring that all units meet the ISO tier 4 ratings (World Bank 2019d). Another recently launched initiative is the stove component of the Kenya Off-Grid Solar Access Project (KOSAP) (Republic of Kenya, Ministry of Energy 2019). In order to be included in the program, stoves must meet an efficiency threshold of tier 2 for wood or tier 3 for charcoal. Through an open-call and field-testing process, only 11 out of more than 20 stoves submitted were chosen for the program's first phase (World Bank 2019e).

In addition to these initiatives, researchers are developing new methods for measuring program co-benefits to help inform the shift to cleaner fuels (Rosenthal et al. 2018). This type of analysis can be critical to convincing governments of the potential climate, health, and gender co-benefits from supporting MECS transitions. However, despite their global introduction, standards have not yet been adopted locally or widely enforced (e.g., by government ministries or national regulators). This situation limits the potential for full deployment of global, regional, and multi-country programs that rely on performance- or outcome-based metrics.

Broader uptake in carbon finance is accompanied by a recognized need to refine such mechanisms. Subsequent to defining the Clean Development Mechanism (CDM) in the Kyoto Protocol in 2007, Malawi, Peru, and Sudan quickly launched national programs that utilized carbon finance to fund stove programs. Carbon mechanisms have featured in programs promoting multiple technology and fuel sources (e.g., cookstoves, ethanol, and biogas), as well as improved fuel efficiency as a means of reducing deforestation (e.g., Peru). However, some of the stove technologies featured have also led to increased emissions of short-lived climate pollutants (SLCPs), which are not accounted for in the Kyoto Protocol. Thus, refining these mechanisms is needed to accelerate the transition to MECS (CCAC 2019).

Interest in household energy products, including cookstoves, is growing, particularly in the voluntary credit market (Karhunmaa 2016). Also, the increasing visibility of project co-benefits—including better health outcomes and sustainable markets—is significant, as carbon buyers typically pay more for projects with clearly positive knock-on effects. Although the number of household energy projects in carbon-project portfolios has increased, these projects account for only a small percentage of programs. And although carbon markets have been depressed in recent years, cookstove distribution is still a primary transaction type (Hamrick and Gallant 2017).

Recognition of the need to focus on coordinated capacity building and technical assistance is growing. The coordination of national programs through an umbrella organization can facilitate the transfer of knowledge and technical capacity. One such example is the Africa Biogas Partnership Program (ABPP). Founded in 2009 by the Netherlands Development Organisation (SNV), the ABPP aims to disseminate domestic biodigesters to local commercial industries and spur their development (Clemens et al. 2018). Under this umbrella program, SNV launched the first African national program in Rwanda and subsequently in Kenya, Tanzania, and Uganda.

Subsectors within the broader household-energy space have also started to consolidate capacity-building efforts. For example, the Global LPG Partnership, formed in 2012 under the SEforALL initiative, is mandated to provide eight African countries and regional partners capacity building and other assistance.[2] The public sector, in particular, is well suited to such activities. The GIZ, a long-standing supporter of the sector, has suggested that public-sector funding be directed toward capacity building, awareness raising, technology development, and research on scaling mechanisms—arguing that these elements seldom occur naturally, often requiring external participation or impetus (Kees and Feldman 2011). Yet far more must be done to build local capacity and technical expertise. A 2018 review of SDG 7 progress highlights the heightened need for technical cooperation, enabling frameworks, technical know-how and transfer, and staff training (UN DSDG 2018).

THE ROLE OF RESULTS-BASED FINANCING

Results-based financing (RBF) can incentivize cooking enterprises to achieve specific outcomes for health, gender equality, climate action, and more. Market forces are important for driving sector growth, but may not be optimal for desired development aims, particularly for the lowest-income and most marginalized populations. RBF also allows donors to more actively engage with enterprises in capacity building and technical assistance, as well as more closely monitor the outcomes of their programs (Zhang et al. 2018).

Through a multi-donor, energy-access partnership, the World Bank and Energising Development (EnDev) have been the most active RBF players in the cooking space.[3] Using RBF instruments, the World Bank has helped private companies enter clean stoves markets in numerous countries, including Bangladesh, China, Kenya, Lao PDR, Madagascar, Mongolia, Rwanda, and Uganda, among others. In Indonesia, an RBF pilot project provided 10 private-sector suppliers incentives to distribute 10,000 clean cookstoves. The Lao PDR Clean Cook Stove Initiative uses an RBF approach to promote the uptake of the most advanced, “super-clean” gasifier stoves that meet WHO guidelines for indoor air quality (World Bank 2017). EnDev has also been active in the space, particularly through a four-year, US$50 million RBF energy-access facility implemented across Africa (Benin, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Tanzania, and Uganda), Asia (Bangladesh, Cambodia, Lao PDR, Nepal, and Vietnam) and South America (Peru). This facility has spanned a wide range of cooking-related technologies (e.g., gasifiers and other cookstoves, domestic biogas, grid connections, and solar) and RBF modalities (e.g., advanced market commitments, auctions, output-based aid, conditional cash transfers, vouchers, credits, and inducement prizes).

To date, RBF programs have primarily focused on access to lower-tier stoves, though some movement toward promoting cleaner stoves has been witnessed in recent years. Task Team interviews confirm that the lower-tier approach has prioritized reaching larger populations more economically—driving improvements on thermal efficiency for climate benefits—rather than achieving the health impacts generally ensured through the use of Tier 4 (or higher) technology with a focus on low emissions. Some RBF interventions have also focused on market development through the alleviation of distribution bottlenecks. As the sector moves increasingly toward MECS, it will be critical that RBF follow suit.

Global experience indicates that, when implemented well, RBF can move the clean-cooking sector forward, but, as Task Team interviews confirm, it is not a “silver bullet.” The most critical lessons to date from RBF deployment are as follows:

- *Enterprise capacity constraints can present a significant operational challenge.* An overwhelming number of players engaged in the sector do not have the capacity to measure reporting streams or meet RBF requirements. Task Team interviews show that they may lack bank accounts, technical acumen for data collection, and basic financial literacy.[4] The interviews also confirm that technical assistance and support—tailored to enterprise needs—can help build business development skills, increase comfort with data-collection systems, and spread market insights. The World Bank has noted that institutional strengthening, capacity building, and awareness-raising campaigns are integral to the success of its RBF projects across countries (Zhang et al. 2018).

- *Payments and incentives must be appropriately balanced.* That is, too little payment up front can make the risk too high, but too much may decrease players’ incentives to meet expected results (Zhang et al. 2018).

- *Market incentives do not always take root initially.* It takes time for the private sector—especially risk-averse, small- and medium-sized enterprises (SMEs)—to respond to market incentives. For example, in the first year of the World Bank’s Indonesia pilot program, transactions were quite limited because market aggregators were still familiarizing themselves with the RBF mechanism and market (Zhang et al. 2018).

- *Instrument design must be flexible and adjustable to reflect changing market conditions.* For example, at the outset of the Indonesia pilot program, the World Bank team recognized the risk aversion of market aggregators. For this reason, a third stage of incentives was added to the design for stove stocking, with a one-off bonus for the first 300 stoves in stock (Zhang et al. 2018).

- *RBF can benefit from complementary financing sources, including early-stage, high-risk capital.* There are two main reasons. First, most donors or investors still perceive RBF instruments as too risky. Second, given the up-front challenges associated with a fundamental rethinking of business and product offerings, RBF seems better suited to an extension of business as usual;[5] however, an RBF intervention could help de-risk the sector or a specific market for follow-on commercial financiers interested in funding modern cooking solutions other than through grants.

- *Enabling environmental conditions can largely determine the success of an RBF intervention.* Task Team interviews with stakeholders suggest that regulations and fiscal policy can prevent RBF from sustainably increasing the uptake of clean stoves and fuels. In Uganda, for example, RBF interventions have struggled because of the high value-added-tax (VAT) rate. One interviewee noted, “We would never make real investments in that market on the back of the RBF because we know the minute the RBF ended the unit economics [would] no longer make sense because of the regulatory environment.”

Looking ahead, applying the Multi-Tier Framework (MTF) to RBF could allow for a more multidimensional perspective on what constitutes results—as opposed to a singular outcome focus (e.g., employment or gender). Furthermore, the surveys and data collection that inform the MTF could allow for better-designed, localized RBF interventions.[6]

CALL FOR A STEP-CHANGE IN PROGRAM DESIGN AND MEASUREMENT

The evidence base shows that many transition interventions in modern cooking energy have lacked sufficiently rigorous measurement, including the integration of counterfactuals, and evaluation protocols. This finding resulted from an in-depth, systematic literature review recently undertaken by a World Bank team. However, detailed analysis of the relatively small number of sufficiently robust studies yielded important insights (box 5.6).

BOX 5.6 Key Insights on MECS Transition: Drivers and Barriers

In 2019–20, the World Bank’s Energy Sector Management Assistance Program (ESMAP) commissioned a systematic evidence evaluation on modern-energy transition drivers and barriers with reference to cooking in low- and middle-income countries. More than 800 articles from a wide range of sources covering the energy and related sectors were assessed. Of the 160 studies eligible for review and with lower risk of bias, 116 reported some information related to program success, measures of outcomes, or documented evidence of factors that could be considered transition drivers or barriers.The evaluation framework was taken from eight domain areas previously highlighted in the literature as necessary for successful at-scale transitions (Bruce et al. 2006; Puzzolo et al. 2013, 2016; Stanistreet et al. 2014), along with relevant ones on poverty and gender. Despite the small number of studies (86) that reported data most relevant to the review question, the study yielded a robust assemblage of research, which provides key insights on understanding transition drivers and barriers.

Financial incentives. Government-backed subsidies can be a key driver of fuel transitions and LPG uptake, particularly in dwellings otherwise dependent on cheaper fuel sources (e.g., kerosene) or free fuels (e.g., firewood). Subsidies helped ensure distribution of the cleaner fuels, while their removal negatively impacted the uptake of improved cookstoves and alternative fuels. Higher levels of household income encouraged MECS adoption. Structured financial mechanisms addressing liquidity constraints were cited as drivers of adopting improved cookstoves and alternative fuels because high prices and the substantial, required down payments put a range of new technologies beyond reach of the poorest households in many communities.

Access to fuel and appropriate technology. Ease of access to clean energy sources was a driving factor, with poor uptake where distribution channels were not well developed. Ease in accessing plentiful, traditional biomass was a barrier to transitioning to MECS, adhering to the transition energy, and using clean energy sources exclusively. Ease of technology use was a motivator for uptake, while technological unfamiliarity was a key barrier. Durability and reliability of the new technology were important drivers of uptake, while technology breakdown led to discontinued use.

Influence of gender. Women's participation in awareness raising and marketing through women's groups whose members have greater financial independence were important factors for adopting improved cookstoves. Male influence on adoption was unclear, with at least some evidence of an overall negative effect.

Role of information and communication. Networks and communication channels (e.g., person-to-person knowledge transfer and social media) played a strong role in encouraging adoption, as did community mobilization and the presence of community leaders or volunteers willing to demonstrate new products and ideas. Communication did not encourage adoption in cases where it only involved people who did not inspire trust or engage users in the design of messaging.

Evidence gaps. Urban settings featured a clear gap in understanding MECS transitions. Select characteristics (e.g., a young demographic and higher level of education) encourage MECS adoption, while their counterparts often negate it. The growing trend of rapid urbanization among youth presents an opportunity to understand their behavior and explore whether their experiences with modern cooking energy can be harnessed to influence families they have left in rural areas.

Multiple-objectives programs dealt mostly with health improvements and cost savings. Health benefits appear to have limited marketing appeal and are less prioritized. Time savings, a commonly-cited driver of uptake and sustained use, has been less studied. Thus, further studies on time savings as a driver, including intra-household time allocation, are needed.

Evidence map. The evidence base includes the first-ever interactive geo-map produced by studies in the field of modern cooking energy. The map has been designed to allow for additions over time and can be accessed at https://energydata.info/apps.

Source: World Bank.

Note: Systematic evidence evaluations (whether reviews or maps) are synthesis methods that aim to provide an accurate description of the evidence base relating to a policy-relevant question. They collate, code, and configure all available evidence relevant to the question using pre-defined methods, agreed on and reviewed by a wide range of stakeholders and experts, to minimize bias in the way the evidence is identified and selected. A descriptive overview of the evidence base is developed, which can help policy makers and practitioners identify key trends and knowledge gaps in research.

The analysis identified instances of success among programs, particularly those that accounted for local contexts to support transitions linked to outcomes, both objective and perceived. From these 160 studies, successful program examples included those focused on delivery of technology support, collaborative knowledge exchange with users, government-backed cleaner-fuel subsidies for users, and fuel distribution. The dearth of literature and research anchored in practical application limits the extent to which the effects of subsidy design can be determined. Many past transition programs have outlasted single administrations and have continued to adapt, through expanding or contracting in scope and ambition, with changes in governments. Programs that have embedded results measurement and monitoring and evaluation (M&E) (e.g., RBF mechanisms) can help hold public financing more accountable and also track the leverage of private financing.

NEED FOR ENABLING POLICIES AND POLITICAL WILL

The fiscal and trade environment is a significant, ongoing obstacle for cooking-industry suppliers looking to achieve greater penetration of clean fuels and high-efficiency, low-emissions technologies. High taxes and misaligned tariff codes, in particular, hinder industry growth and dampen end-user adoption. Poorly calibrated tax and tariff regimes make it difficult to import fuel-production equipment, quality stoves and components, or clean fuels themselves when local supply is inadequate, as is almost invariably the case in the early stages of market development. LPG, for example, faces significant misalignment of tariff codes with its product category. The fuel is stored as a liquid but is sometimes taxed as a gas. This limits the opportunity for more efficient global LPG value chains, and impedes players from adequately storing—and thus reliably supplying—the fuel.

Clean biofuels, in particular, have faced strong external volatility, which has impacted subsector growth. Fuels like ethanol and formally-distributed pellets and briquettes nearly invariably face VATs and, in many cases, high levels of import duty. In many African countries, denatured ethanol faces duties in a range of 5–25 percent. In such markets as Cameroon and Uganda, combined duties and taxes on biofuel stoves have approached 50 percent; this has effectively deterred companies from attempting to enter these markets owing to the need to test them before scaling up. Import duties are even more common for un-denatured ethanol, which is often categorized as beverage alcohol. This is a challenge for biofuel distributors who intend to manage a quality-controlled, denaturation/coloring/ bottling process in the target country. Ethanol is further subject to domestic alcohol excise taxes, some dating to colonial times, in a range of 20–100 percent per liter. Some taxes fail to differentiate between beverage and technical alcohol (96 percent +) suitable for household cooking fuel, which put the fuel at a clear disadvantage relative to its substitutes. Rare examples of positive progress on fuel taxes and duties include Kenya's recent tax and duty holiday for technical ethanol, driven by its recognition of ethanol's potential as a clean fuel for household cooking.

In addition, the absence of comprehensive legal frameworks for clean fuel-plus-technology combinations continue to hinder sector development. For briquettes and pellets, in particular, the lack of policies regulating illegal charcoal and firewood industries poses a severe problem for sustaining demand. Other concerns relate to quality control. Country-level policies and regulations rarely include quality standards for the common categories of biofuels and new international standards (e.g., the ASTM E0350 standard for ethanol). The lack of enforced standards for fuel production can dampen demand. In the case of ethanol, for example, impurities in its distillation and watering-down process result in quality variations of the cooking fuel, which can significantly impact consumers' cooking experience. Poor regulation also contributes to already-present safety concerns. Perverse incentives built into existing subsidy schemes (e.g., subsidies for less clean fuel alternatives like kerosene) create a higher barrier for displacement.

CONCLUDING REMARKS

All sector actors can contribute significantly by advocating for and supporting the development and implementation of harmonized enabling policies and driving political will at the highest levels of government. Donors and development finance institutions (DFIs), in particular, can support market development in multiple important ways. These include designing clean-cooking policy roadmaps for governments; pushing for reduction in taxes and tariffs on clean stoves, production equipment, and fuel imports; and championing the elimination of subsidies for alternatives like kerosene. They can also contribute by pooling resources for at-scale behavior-change campaigns and engaging with efforts to develop and harmonize quality standards, particularly for emergent clean solutions like biofuels. In addition, they can advocate for the formalization (and taxation) of the charcoal and firewood fuel sectors, as well as the elimination of specific licensing regulations that restrict technology transfer. These measures should be undertaken in a coordinated manner across the multiple decision-making bodies that can critically move the needle in the direction of truly modern cooking contexts; that is, by working with ministries of energy, health, environment, finance, and infrastructure, among others. Given the cross-cutting nature of cooking interventions and the intersectionality of cooking impacts, building committed, senior-level alignment will prove a prerequisite to greater and better investment in solutions.

NOTES

1. The Lao PDR Clean Cook Stove Initiative is one of the first national programs to explicitly promote a pellet stove.
2. See also LPG planning documents completed for Cameron, Ghana, and Kenya.
3. Task Team interviews.
4. Lack of financial literacy disproportionately affects women.
5. See note 3.
6. See note 3.

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CHAPTER 6

TRANSITIONING TO GREATER ACCESS

SCALE OF THE CHALLENGE

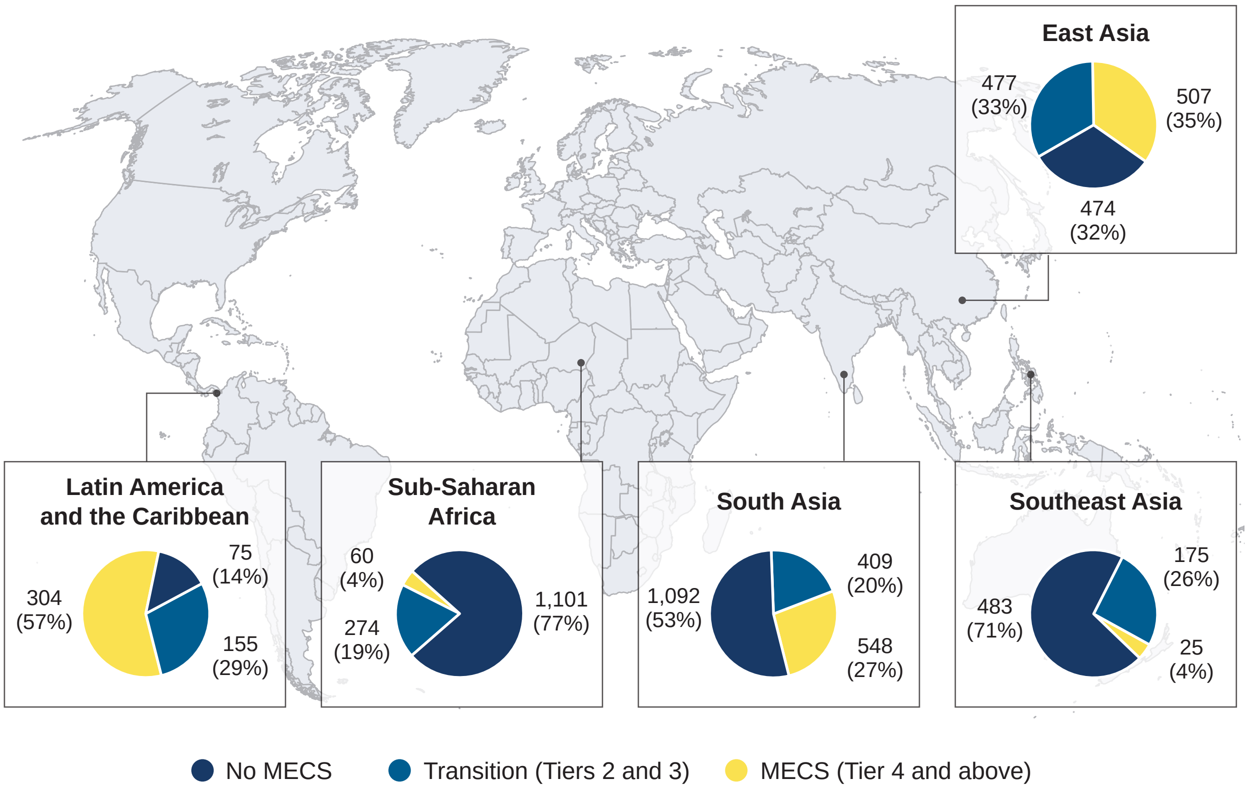
Without evolving beyond the status quo, the goal of universal access to modern energy cooking services (MECS) will remain out of reach for 4.5 billion people by 2030. Based exclusively on expected population growth and urbanization over the next decade, a majority of the populations in Sub-Saharan Africa, South Asia, and Southeast Asia would be expected to remain below Tier 2 of the Multi-Tier Framework (MTF) for cooking in 2030. Given its current high rates of urbanization, Latin America and the Caribbean would remain at a relatively strong MECS access level of 57 percent,[1] followed by East Asia at 35 percent, South Asia at 27 percent, and Sub-Saharan Africa and Southeast Asia at just 4 percent each. The populations in transition (i.e., those that meet MTF thresholds for Tiers 2 and 3) would be expected to expand to nearly 1.5 billion, with 477 million people found in East Asia, followed by South Asia (409 million), and Sub-Saharan Africa (274 million) and relatively fewer in Southeast Asia (175 million) and Latin America and the Caribbean (155 million) (figure 6.1).

This disappointing potential reality not only points to the size of the 2030 access challenge; it also underscores the need to intentionally mobilize solutions at significant scale. If business as usual continues, one could expect uneven progress, with demographic trends in some regions even driving an increase in sub-Tier 2 populations in absolute terms; in Sub-Saharan Africa, for example, this increase would amount to nearly 400 million more people without access to improved or modern-energy cooking solutions.

A universal transition to MECS should follow a least-cost, best-fit approach that reflects local users' needs and local market conditions. The reality is that no "silver-bullet" approach is available to move all underserved populations to accessing Tier 4 or higher cooking services. Instead, granular household cooking data should be used as an input for broader national-level energy decision-making—a process that capitalizes on energy-system investments and policies and best leverages national comparative advantages. In some geographies, this may mean accelerating the transition to electric cooking if broad-based electrification programs are under way. In other geographies, it may mean a push toward efficient gas cooking in the context of enhanced access to liquefied petroleum gas (LPG), or even toward spurring alternative biofuel use in settings where incentives are in place for production and distribution of ethanol or highly efficient biomass gasification technologies. A least-cost, best-fit approach to fuel and stove deployment can address the affordability, convenience, and reliability challenges more effectively and pragmatically as the year 2030 quickly approaches.

FIGURE 6.1 MECS Access in 2030 under a Natural Evolution Forecast

Millions of people



Sources: ESMAP access to MECS costing model; World Bank MTF data; Task Team fuel-mix database.

New analysis performed as part of this report seeks to quantify the cost of achieving universal access to MECS by 2030. This analysis, the MECS Scenario, takes a least-cost, best-fit approach to quantify global transition costs. It builds on a 2030 forecast and segmentation of the population not expected to reach MTF Tier 4 or higher, based on current policies, practices, and natural evolution of population growth and urbanization. It models a series of transition costs benchmarked against recent modern-energy transitions, and applies them to specific population segments at the country level, controlling for their starting access tier, primary fuel, and locality (urban versus rural, based on differentiated energy diets).

Transition costs differ according the type of modern-energy transition each country is expected to undertake between 2020 and 2030 (e.g., to LPG, electric cooking, ethanol, biogas, pellet gasification, or a combination thereof). All pathways assume a two-burner stove for achieving the transition in order to fully displace alternative technologies that could be used for “dirty” stacking (chapter 3). Determining the countries’ projected pathways is based on a review of their respective governments’ policy commitments for meeting the Sustainable Development Goal (SDG) 7.1 target, modern-energy forecasts (e.g., by the International Energy Agency [IEA] and the International Renewable Energy Agency [IRENA]), and consideration of their installed energy infrastructure. This, in turn, determines the specific costs applied to each country’s population to be transitioned. The analysis also makes specific assumptions about contributions to the cost of transition—notably, that public actors (governments and development partners) will play a role in ensuring that no household exceeds the 5 percent threshold for cooking energy expenditure through targeted subsidies or conditional cash transfers for fuel payment.

This report also recognizes that achieving a truly universal transition, whereby all households meet at least Tier 4 status over a 10-year time frame, may be exceedingly optimistic. For this reason, a second modeling exercise, the Improved Cooking Scenario, was conducted. This alternative forecast uses similar assumptions for population growth and urbanization, but focuses costing on only a Tier 2 + 3 migration using improved cookstoves; that is, the cost of transitioning all households expected to fall into Tiers 0 or 1 to Tier 2 (the lowest transition tier). Rather than cost out a large-scale transition requiring significant stove, fuel, and infrastructure investments, this scenario quantifies the cost of ensuring minimum access to a Tier 2 standard cookstove during a fixed transition period. Each household is assumed to have access to a two-burner improved cookstove or two stand-alone, single-burner improved cookstoves to fully displace Tier 0 or Tier 1 cooking technologies.[2]

SCENARIOS FOR ACHIEVING TRANSITION BY 2030

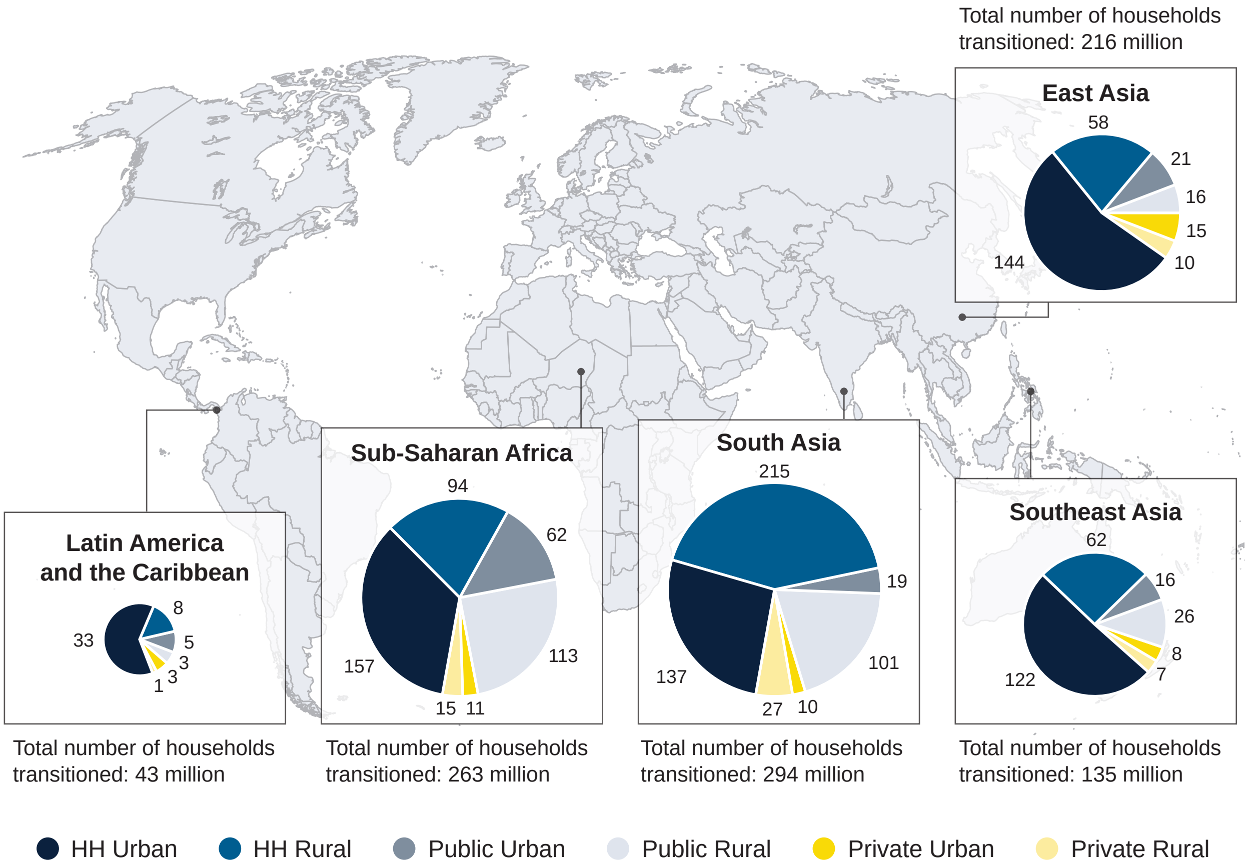
MECS Scenario

This study estimates the total cost of transitioning to universal access to MECS by 2030 at approximately US$1.5 trillion or US$148–156 billion per year over the next 10 years. Achieving universal access implies a significant transformation of the current energy systems to meet the requirements needed to lift all households currently at Tiers 0–3 to Tier 4. Of this cost, it is expected that approximately 26 percent (US$39 billion per year) will be shouldered by governments and development partners, in part, to ensure that the MTF's affordability criteria are met. It is expected that the private sector will allocate 7 percent (US$11 billion per year), focused exclusively on installation of downstream infrastructure essential to the functioning of modern-energy cooking markets. The other 67 percent (US$103 billion per year) will consist of households' direct contributions for stoves and fuels (figure 6.2).

Given the varied pace of population growth and urbanization across the world, the allocation of transition investment is also expected to vary markedly by region. The largest investments are expected in Sub-Saharan Africa and South Asia, where at least US$175 billion and US$120 billion in respective public investments will be needed over a 10-year period. As in all other world regions, households will be major contributors. However, in Sub-Saharan Africa, where most households, particularly in rural areas, are not expected to meet minimum affordability criteria,[3] the ratio of public-to-household spending will be higher. In South Asia, by contrast, households will be expected to shoulder a larger proportion of the cost, even in rural contexts where the transitioning population is largest (figure 6.2).

FIGURE 6.2 MECS Scenario: Total Cost to Transition over 10 Years, Disaggregated by Region, Locality, and Contributor

US$, billions



Sources: ESMAP access to MECS costing model; World Bank MTF data; Task Team fuel-mix database.

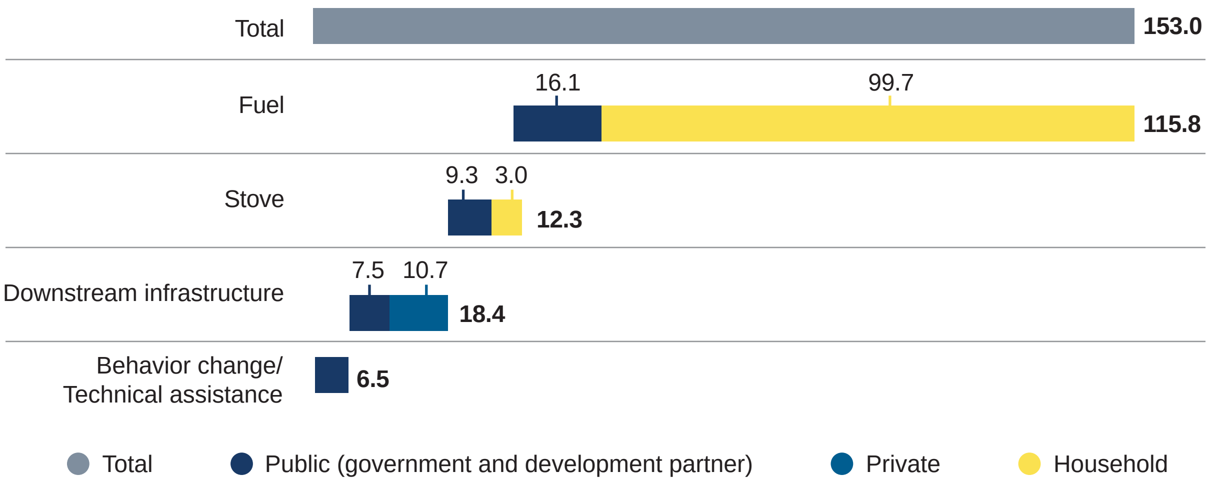
Note: The sizes of the pies represent the respective regional contributions to the total transition cost. HH = household contributions, Public = government and development-partner contributions, and Private = private-sector contributions.

Costs are expected to be driven primarily by fuel-expenditures support, particularly among rural populations that are starting from lower average levels of access (Tiers 0–1). Stoves and downstream infrastructure are key expenses, accounting for approximately 8 percent and 12 percent of costs, respectively (figure 6.3).[4] These shares are disproportionately higher for populations below the Tier 2 transition threshold. Because households in many rural settings opt for freely collected wood, crop waste, or dung, switching fuels will require significant financial incentives and support while maintaining affordability, in addition to targeted messaging and marketing. Financing such significant costs related to what are effectively subsidies for clean fuel may prove challenging. Effectively designed transition programs (e.g., using results-based financing [RBF] mechanisms) may prove more cost-effective, as well as more politically feasible.

Costs are also expected to vary by the fuel transition undertaken. Using a standardized household cooking-energy diet (differentiated between urban and rural households), the universal-access scenario relies on a bottom-up costing of five possible transitions for households to access MECS (figure 6.4).

FIGURE 6.3 MECS Scenario: Average Annual Cost of Transitioning Households over 10 years, Disaggregated by Expenditure Type

US$, billions/year

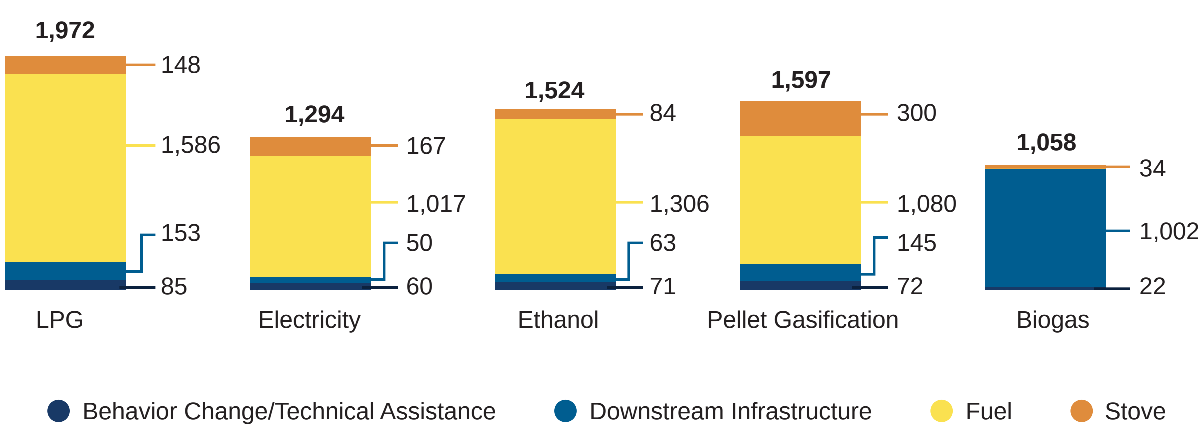


Sources: ESMAP access to MECS costing model; World Bank MTF data; Task Team fuel-mix database.

Note: Downstream infrastructure includes biodigester costs unique to biogas transitions; some of these costs are covered by the contributions of public-sector actors.

FIGURE 6.4 MECS Scenario: Cost Breakdown for One Household to Transition over 10 Years, by Transition Type

US$

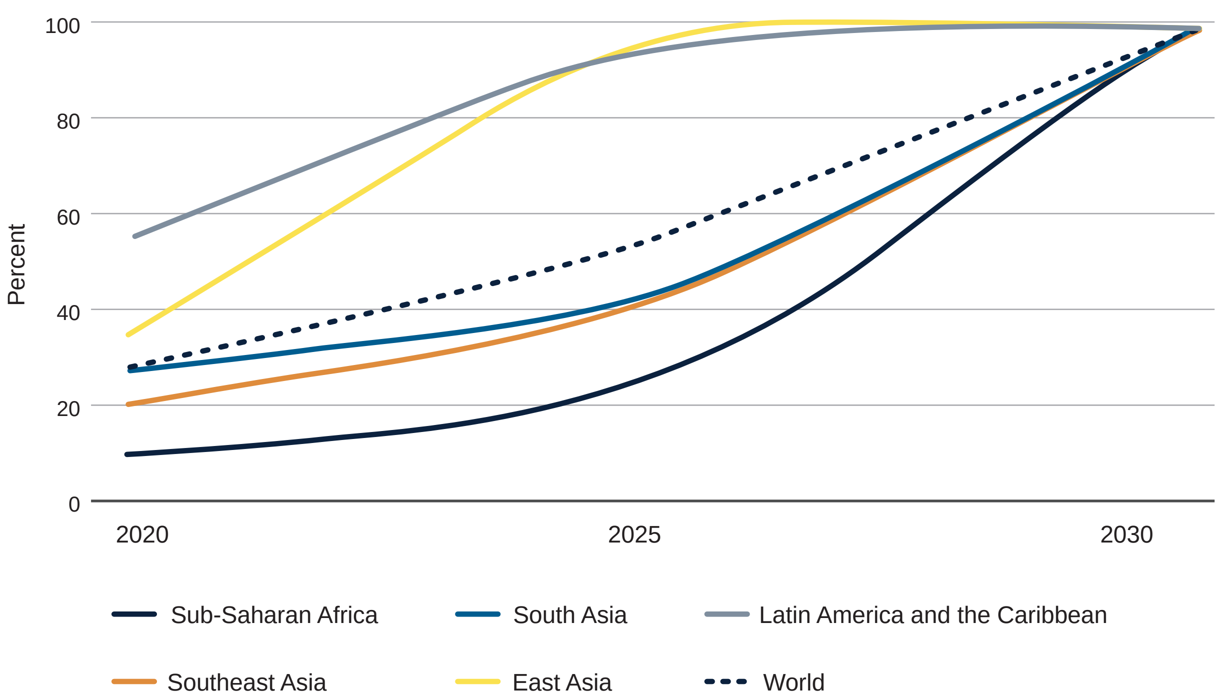


Sources: ESMAP access to MECS costing model; World Bank MTF data; Task Team fuel-mix database.

Note: Costs are indicative of a rural household below Tier 3 status. Stove and fuel costs are benchmarked against January 2020 nonsubsidized market prices. It is assumed that the downstream infrastructure costs of fuel generation/production and transmission/distribution are factored into the retail price; some transitions assume multiple replacements over the 10-year period.

Regions' access rates over the coming decade will also vary, given their differences in starting conditions, local market contexts, and relative speed of transition. This new analysis considers various factors that will likely shape rates of regional access, and models an expected transition scenario for 2020–30 (figure 6.5). It assumes that populations already at Tier 2 or Tier 3 will take a shorter amount of time to transition to Tier 4 (or higher), compared to sub-Tier 2 populations. It also assumes that upper-middle-income countries are better positioned than lower-income or lower-middle-income countries to accelerate the time required to transition. Such regions as Latin America and the Caribbean and East Asia would be expected to transition more quickly, given their relatively higher Tier 3 and Tier 4 (or higher) shares in 2020, their high urbanization rates, and strong existing modern-energy infrastructure (table 6.1). Conversely, Sub-Saharan Africa, Southeast Asia, and South Asia would be expected to require a longer period of time within the 10-year horizon to fully transition, given their need to displace existing primary fuels (in most cases, by pricing them out through price supports for clean fuels) and alter household cooking behaviors in order to completely transform energy markets.

FIGURE 6.5 MECS Scenario: Regional Access Rates over 10 Years



Sources: ESMAP access to MECS costing model; World Bank MTF data; Task Team fuel-mix database.

TABLE 6.1 MECS Scenario: Cumulative Share of Households Fully Transitioned by 2030, by Locality

% urban and rural

Region	Urban			Rural		
	2020	2025	2030	2020	2025	2030
South Asia	51	70	100	15	30	100
Sub-Saharan Africa	21	41	100	3	13	100
East Asia	46	98	100	20	96	100
Southeast Asia	37	54	100	7	29	100
Latin America and the Caribbean	62	98	100	34	92	100

Sources: ESMAP access to MECS costing model; World Bank MTF data; Task Team fuel-mix database.

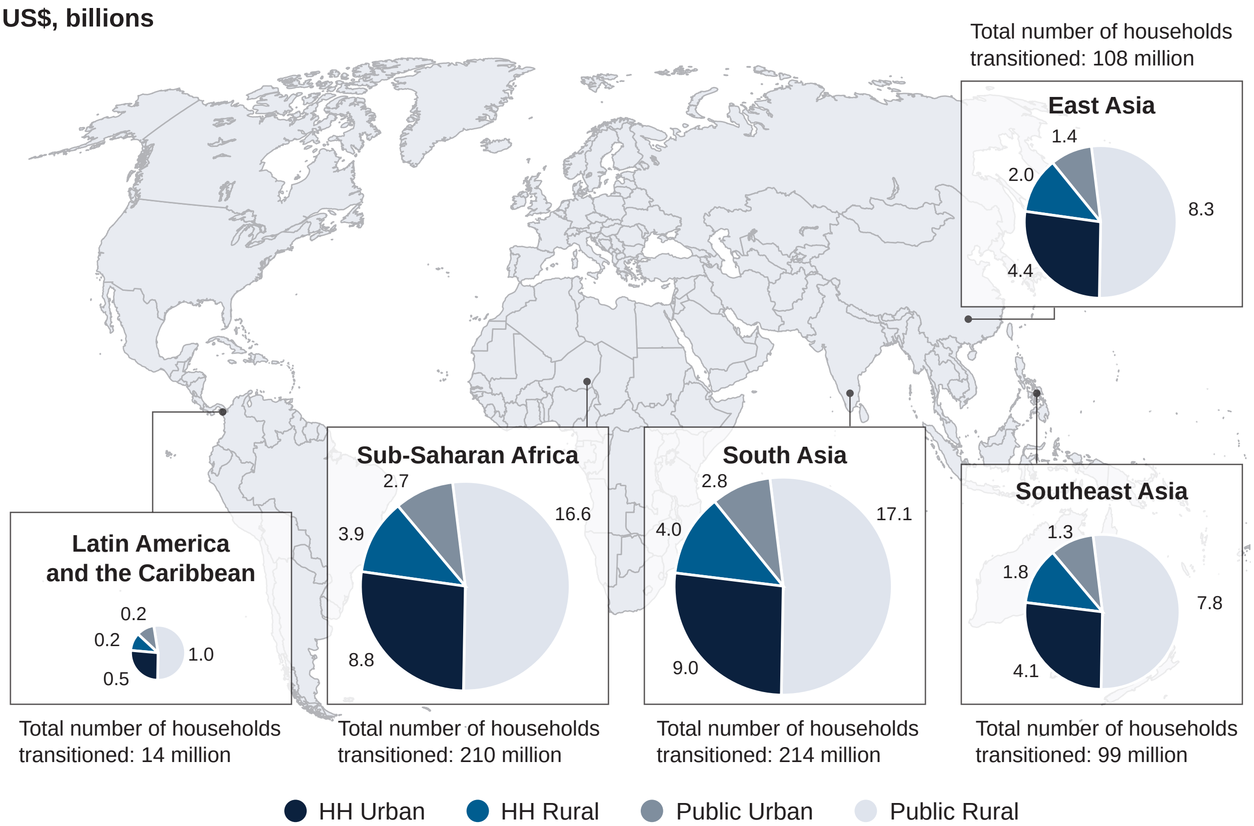
Improved Cooking Scenario

A more pragmatic, though less ambitious, scenario, considers a 2030 transition of all populations to at least Tier 2 access, at an estimated total cost of approximately US$100 billion. This Improved Cooking Scenario assumes a more limited fiscal outlook, whereby investment allocations target only basic cooking-technology improvements (e.g., improved cookstoves [ICS]) and the lowest-accessing populations (Tiers 0–1). It assumes a full displacement of Tiers 0 and 1 cooking technologies by providing households a double-burner cooking setup (either two single-burner stoves or one double-burner stove). Households would undergo a gradual displacement process over 10 years, with three full stove replacements during that period. The transition assumes no fuel costs--it does not force a fuel switch, meaning that households would continue to cook with such fuels as wood and other biomass--or downstream infrastructure costs.

Over the next 10 years, the expected annual cost would average about US$9.8 billion, including US$6.3 billion for transitioning rural populations to Tier 2 access and US$3.5 billion for urban transitions. From a regional standpoint, the majority of expenditure for the Improved Cooking Scenario, like the MECS Scenario, would be concentrated in the Sub-Saharan Africa and South Asia regions, which feature large rural populations (figure 6.6).

Approximately 61 percent of this expenditure would fall to public actors (governments and development partners), with households contributing the remaining share in the absence of extensive consumer financing. A wealth of evidence highlights the challenges of making ICS sufficiently affordable and appealing in order for households to be willing to make a bulk payment (FAO 2013; Hanna, Duflo, and Greenstone 2016; McNulty, Nielsen, and Zeller 2017; Mobarak et al. 2012; Rosenbaum, Derby, and Dutta 2015; Sagbo 2014). Mobilizing donor and government resources will prove critical to reducing up-front stove costs and thus paving the way to this potential reality. Extensive donor activity is already under way in the ICS space—notably the work being undertaken by Energising Development (EnDev)—with an increasing number of planned future initiatives using RBF as a vehicle for driving greater volumes of capital and enhanced performance and measurement of outcomes. The World Bank–supported Bangladesh Improved Cookstoves Program has helped to install more than 1.7 million improved cookstoves in households. Initially focused on Tier 2 cooking technologies, that program has now advanced to Tiers 3 and 4 cooking technologies.

FIGURE 6.6 **Improved Cooking Scenario: Total Cost to Transition over 10 Years, Disaggregated by Region, Locality, and Contributor**



Sources: ESMAP access to MECS costing model; World Bank MTF data; Task Team fuel-mix database.

Note: The sizes of the pies represent the respective regional contributions to the total transition cost. HH = household contributions and Public = government and development-partner contributions.

Achieving this scenario within these cost bands also depends on a high enough household contribution, particularly in urban settings, which can be driven by fuel savings (figure 6.6). The model that underpins the scenario assumes indicative costs for a rural household below Tier 2 status to transition over 10 years at US$152 (US$145 for stove costs, benchmarked against January 2020 market prices, and US$7 for behavior change/technical assistance). It assumes that urban households will require lower levels of price support for stoves relative to rural households (approximately 20 percent versus about 80 percent). This difference is driven by stronger perceived and materialized savings on fuel expenditure, which, as illustrated by recent randomized field experiments in Kenya, can amount to a 300 percent average annual rate of return on the stove investment (approximately US$120 per year or one month's income) (Berkouwer and Dean 2019). A household's willingness to purchase a stove can potentially double in the presence of effective credit solutions, which can also play a role in closing the energy-efficiency gap of the stove's use once in the household (Berkouwer and Dean 2019).

Funders of the Improved Cooking Scenario could enhance the pathway's cost efficiency by driving innovation in product research and development (R&D) and deploying effective technical assistance. Beyond communicating the value of adopting and adhering to ICS, scaled-up adoption could be accelerated through disruptive production techniques or innovative input alternatives, which could help bring down the marginal cost of each stove deployed. Examples like those of Greenway Grameen's factory scale-up, detailed in chapter 4, or the mass-produced ICS taking place in China using repurposed assembly facilities (e.g., Mimi Moto stoves on a deep-fryer production line) could be models to follow. In addition to upstream improvements, investing in behavior-change activities much farther downstream could also play a role in lowering costs.[5] For example, effective stove-use training could extend the life of the stove and potentially reduce the frequency of replacement. Also, targeted messaging could facilitate a quicker displacement of baseline technologies, thereby reducing the duration of the intervention.

The Improved Cooking Scenario should be considered a pragmatic, albeit partial, step in the direction of universal access. At a much lower cost than the MECS Scenario, though with a potentially much lower impact, this scenario raises the baseline for future Tier 4 (and higher) transitions, putting into play a sufficiently disruptive technology that can challenge the chronic use of highly polluting, unhealthy solutions like three-stone fires. This scenario is limited in that it neither seeks to motivate a fuel switch nor lay the ground for fuel-utility models or more advanced IoT innovations. However, it is an intent to migrate millions of lowest-access households along a continuum of access—giving priority to supporting the poor with much less public-funding commitment to ensure no one is left behind. As such, it can eliminate the most rudimentary cooking solutions and pave the way for accessing MECS.

KEY CONSIDERATIONS FOR AT-SCALE IMPLEMENTATION

Any future pathway to universal access to MECS will require strong collaboration between public and private sectors in order to develop robust modern-energy markets for households. While the two scenarios described above account for high levels of public-sector commitment (potentially with donor support), especially in the lowest-income countries, a significant share of the MECS reality will depend on private-sector investment. This is notably the case for the core capital infrastructure necessary to get the supply chains up and running for clean cooking fuels. In the case of an LPG transition, this implies investing in new bottling plants. In the case of an ethanol transition, it means stronger supply (e.g., increasing dedicated storage and upgrades to allow for bulk handling) and distribution networks (e.g., new retail dispensers, small and bulk trucks, and smart depots in fuel stations). Similarly, any future scenario that involves electric cooking will require close coordination between initiatives for cooking, lighting, and heating that tap into new electric-power generation.

Downstream service collaboration should also force a consideration of whether upstream and midstream energy infrastructure is currently fit for purpose for a planet fully transitioned to MECS. If one were to consider the additional upstream and midstream investment necessary to supply the energy necessary under a universal-access scenario, the cost to transition would increase by another US$800 billion over 10 years; of this amount, approximately US$550 billion would be needed for production and generation of clean fuels and US$250 billion for their transmission and/or distribution. Of the global total, approximately US$320 billion would fall to Sub-Saharan Africa, US$200 billion to South Asia, US$120 billion each to East Asia and Southeast Asia, and the remainder to Latin America and the Caribbean. The scale of these tallies reinforces the notion that the traditional cooking sector cannot drive progress alone. Integrated energy planning—at both national and global scale—will prove more necessary than ever. At a national level, integrated planning is needed to create higher returns on investment in household energy infrastructure, and, at a global level, to maximize the shape and flow of energy supply chains.

As large as the required investment commitment appears, the cost of inaction is much greater. As noted in chapter 2, the health, gender, and climate/environment opportunity costs of not transitioning total US$2.4 trillion per year, which is 16 times the cost of an ambitious, universal transition over a 10-year period. This cost-effectiveness differential should inform the need to allocate a much more significant volume of funding and investment to the access challenge than ever before.

ANNEX 6. METHODOLOGICAL NOTE: MODELING TRANSITION COSTS

This report relied on a custom-cost modeling exercise, which was performed for two scenarios: The MECS Scenario (an ambitious, universal-access scenario) and the Improved Cooking Scenario (a more pragmatic, transition-oriented scenario). Under the MECS Scenario, the global population accesses the Tier 4 (or higher) level of the Multi-Tier Framework (MTF) for cooking, while under the alternative Improved Cooking Scenario, it transitions from below Tier 2 access to at least universal Tier 2 access.

Data Sources

A wide range of data sources were used for this modeling exercise. They included in-depth data on modern energy use from the World Bank's Multi-Tier Framework (MTF) household surveys in six "archetype" countries (Cambodia, Myanmar, Nepal, Nigeria, Rwanda, and Zambia). Global fuel-mix data was compiled from Demographic and Health Surveys (DHSs), Multi-Indicator Cluster Surveys (MICSs), and national energy censuses. The report used the World Bank's country-level historical data for gross national income (GNI) per capita (1960–2018) and electricity access (1960–2017). Additional World Bank data sources included its List of Economies, covering country-level information on income group and country lending category (IDA/IBRD/Blend); Energy Consumption, covering per-country household-level information on annual energy-use expenditure; and Population, covering historical and projected country-level information (1960–2030) by total, urban, and rural populations. For household size and composition data, the report used United Nations historical and current country-level data.

The MECS Scenario

The modeling exercise for the MECS Scenario follows three broad steps: (i) sizing the number of households to transition by 2030 (i.e., the volume to solve for), (ii) assigning a type of transition pathway that each country will follow, and (iii) applying a set of costs to transition (i.e., the price of transitioning, applied in a weighted proportion to each country in the model's sample set).

The first step sizes the number of households/people to transition by 2030, employing the same methodology used for the 2020 estimates (Annex 3). Instead of using baseline 2020 population figures, the model uses 2030 estimates that account for population growth and urbanization. This results in projected 2030 primary-fuel populations for each country in the model sample, nuanced by urban and rural localities. For these primary-fuel populations, the model determines what share of each population is not expected to have access to MECS in 2030, using 2020 archetype ratios. This essentially becomes the value to solve for.

The second step assigns an energy transition pathway for each of the countries included in the sample. The transition pathway refers to the energy model through which a country aims to achieve universal access by 2030 (using liquefied petroleum gas [LPG]/liquefied natural gas [LNG], electricity, ethanol, pellet gasification, biogas, or a combination thereof). For each country in the sample, this pathway was identified through a review of diverse literature covering planned and potential fuel transitions (e.g., as determined by national energy strategies and/or International Energy Agency [IEA] estimates). Most countries in the sample are expected to undertake a mixed transition pathway to 2030, dominated by a primary fuel (e.g., 80 percent of a country transitions to LPG, and the remaining 20 percent transitions using ethanol and electricity). However, several countries in the sample lack a clear pathway forward due to limited data/justification for determining it. For these, the model runs a sub-scenario–based forecast composed of five separate costing scenarios—each being a 100 percent transition to LPG/LNG, electricity, ethanol, pellet gasification, or biogas. For a base-case calculation, the average cost of these five scenarios is taken as the transition cost of each country for which this exercise was undertaken. For a low case and high case, the least and most expensive of these transitions is taken, respectively.

The third step determines the actual transition costs referred to in the second step. A bottom-up total cost of transition per household is determined for each of the LPG/LNG, electricity, ethanol, pellet gasification, and biogas transitions, estimated at a duration of 10 years for full displacement of non-clean fuels and stove technologies (with the exception of households already at Tier 3 or those in upper-middle-income countries who are expected to require fewer years [e.g., 5] to transition). Bottom-up total transition costs comprise costs for stoves, fuel, downstream infrastructure, and behavior change/technical assistance. The values for fuel consumed vary by urban and rural contexts and reflect unitized caloric values per person, validated through expert interviews. Fuel prices reflect market values as of January 2020, while stove prices reflect retail (nonsubsidized) prices. Both fuel and stove prices for each transition include benchmarks, from which an average is taken. These costs are validated against the costs of recent fuel transitions in developing markets.

Multiplying the number of households per country (Step 1) by the weighted cost to transition (Step 3), following the transition pathway determined for that specific country (Step 2) for the population of every country in the model's data sample yields a total global figure of the cost to transition the world's population over a maximum of 10 years.

The Improved Cooking Scenario

The costing exercise for the Improved Cooking Scenario follows the same logic as Step 1 in the MECS Scenario but is applied to fewer segments of the population (i.e., only those beginning at below Tier 2 access). Rather than undertaking a full fuel-switching transition, the scenario assumes a much more simplified transition, whereby the household accesses an improved cooking technology (i.e., ICS matching at least Tier 2 emissions and efficiency standards). This transition assumes that 10 years (with multiple stove replacements) are required to achieve full displacement of basic cooking technologies and practices.

NOTES

1. Given Latin America and the Caribbean's high urbanization rates at present, this level of access is relatively unchanged from its 2020 level.
2. Annex 6 provides details on the cost-quantification approaches used in the modeling exercise for the MECS Scenario and the Improved Cooking Scenario.
3. Households fall into energy poverty since their cooking-fuel expenditure exceeds 5 percent.
4. Total expenditure includes approximately US$6.5 billion per year allocated to behavior change and technical assistance.
5. Estimated at 5 percent of stove costs in this scenario.

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CHAPTER 7

RECOMMENDATIONS

Charting a course to meet the aspirations of SDG 7.1 will prove challenging; but targeted actions that expand MECS access can guide the sector forward. Driving progress forward requires mobilizing financial and analytical resources to improve the overall cooking ecosystem, as well as innovative technologies and partnerships. In particular, the sector needs to adopt several priority actions. These, in turn, should be tailored as recommendations at the level of key stakeholders, including donors and development partners, national governments, and private investors and entrepreneurs.

PRIORITY ACTIONS FOR THE SECTOR

- **Create high-profile coalitions of political leaders to prioritize MECS access in global and national arenas.** The United Nations' Health and Energy Platform of Action (HEPA); the proposed High-Level Coalition of Leaders for Clean Cooking, Energy and Health; and other coalitions are critical for raising the stakes for implementing measures to achieve SDG 7.1 and affirming cooking as an essential component of energy policy. Such coalitions generate the political will and incentives needed to embed cooking within cross-cutting, national policy making and create a context for countries in transition to learn from each other and ensure coordinated action.

- **Formalize cooking energy demand in national energy planning and development of strategies for achieving universal access.** Such energy planning and strategy development require expanded implementation of the Multi-Tier Framework (MTF) and other national household-level surveys, combined with the sharing of lessons and insights through open-data platforms and consultation with a full range of stakeholders, to undertake more evidence-based decision-making, with households as the key unit of analysis. The transition pathways of national roadmaps to universal access should be guided by a least-cost, best-fit strategy that reflects diverse users' needs, local market conditions, and national comparative advantages on energy resources.

- **Dramatically scale up public and private financing for MECS.** To reach universal access to MECS, investment needs to be scaled up from the tens of millions to tens of billions, along with dedicated policies. Such investment includes not only the initial capital costs of stoves and deposit/connection fees, but also the energy infrastructure costs and additional subsidies required to make the clean-fuel costs affordable to the poorest consumers. Large-scale grant resources for MECS are particularly needed to scale up the availability, diversity, and volume of capital in the sector, as well as stimulate product and business-model innovations. Integrating the envisioned progress toward universal access to MECS with that of electrification as part of energy-access efforts is also critical to underpinning the scale and impact of allocated public resources and private-sector capital.

RECOMMENDATIONS FOR KEY STAKEHOLDERS

National Governments

- **Put into play national policies and strategies that prioritize cooking and embed political priorities for the sector within broader energy decision-making.** This includes making MECS access a political prerogative through developing national roadmaps for cooking, ensuring high-level political involvement in MECS initiatives, and building coalitions of domestic political interests relevant to advancing MECS access. It also includes embedding commitments in the broader national 2030 agenda and building the technical capabilities and awareness of senior decision-makers around the positive socioeconomic and environmental returns of improving MECS access. Common to all of these actions is the need to increase intersectoral and intergovernmental coordination between domestic political actors.

- **Develop and enforce regulations and standards that promote market development for clean cooking solutions.** This includes the review of existing regulations that hinder clean-cooking market development (e.g., reassessing the macroeconomic impact of taxing clean fuels and stoves and checking that tariff codes align with product categories to ensure a level playing field for meeting supply and demand more efficiently). It also includes driving national standardization that sets the baseline for quality and performance, especially ahead of deploying outcomes-based funding commitments. Governments should play a role in localizing international standards through close coordination with international standards-setters, strong domestic monitoring and enforcement, and engaging critical players, where needed, to strengthen capabilities.

- **Deploy infrastructure and programming investments that reflect the country's comparative advantages for energy supply and greatest requirements for generating demand.** This means prioritizing the country's best-positioned clean-cooking infrastructure and closely integrating household cooking needs into generation and distribution projects, which can leverage financing and make more capital available for expanded MECS access; this includes leveraging individual countries' energy resources where appropriate (e.g., good solar irradiation as a foundation for solar powered e-cooking). It also means re-assessing the role of large-scale fuel subsidies and considering the potential for results-based incentives that focus on sustained product uptake and behavior change. National programs that leverage an outcome mentality, including the close measurement and evaluation of impact or the effective pricing of carbon abatements, are more likely to align with the priorities of funders and donors driving large-sale capital into the cooking space.

Donors and Development Partners

- **Grow the sector further through the development and dissemination of high-quality public goods.** Donors and development partners, including research institutions, are best placed to invest in data, tools, open-source technologies, and platforms that can spur innovation, knowledge sharing, and learning. These efforts may include (i) financing MTF and other national household-level surveys to build demand-side contextual baseline data, analyze key barriers, and track progress and trends; (ii) consolidating supply-side information through a clean-cooking product database or marketplace with pricing, performance, and potential consumer feedback; (iii) developing a clean-cooking planning tool, possibly similar to the geospatial planning tool for electrification, building on the Costing Model for MECS Access developed for this study; (iv) supporting open-source technologies development, innovation, and knowledge sharing and transfer; and (v) fostering the global rollout of awareness campaigns to drive organic demand.

- **Encourage national governments to review their enabling environments for modern cooking solutions.** Donor and development institutions are well-positioned to share best global practices with policy makers seeking to alter and/or evolve the fiscal, trade, and investment policies that shape a country's energy mix. They should support least-cost, best-fit solutions that spur demand (e.g., a national clean cooking program made cost-effective through trade-enabled energy imports or local generation with targeted subsidies for low-income households to access clean cooking solutions) and drive supply (e.g., a fiscal environment conducive to low-cost domestic manufacturing or importing of clean stoves and fuels).

- **Dramatically expand the availability of grant resources to monetize public benefits and catalyze private investments.** The cooking sector is known for its high impacts on health, gender, environment, and climate. However, these public impacts are not internalized by end users and suppliers. As a result, clean cooking businesses often struggle to compete with low-cost (or no-cost) traditional cooking solutions and attract commercial financing to reach scale. Grant financing can play a catalytic role to (i) correct a temporary market failure by monetizing full co-benefits of access to MECS not currently priced in by the market, (ii) subsidize market actors' costs to build customer awareness and market adoption, and (iii) improve the viability of clean cooking businesses to attract private-sector financing. The World Bank's Clean Cooking Fund will support the establishment of an impact bond market to monetize the health, gender, and climate co-benefits from access to MECS, with the aim of bringing in a broad range of capital to the sector.

Private Investors and Entrepreneurs

- **Drive targeted seed and growth capital toward supply-side innovators and first-movers, particularly those advancing a cooking-utility model that considers household needs holistically.** Private investors should direct their limited resources toward proven, high-impact models (e.g., clean-cooking enterprises at or close to scale that have a demonstrated ability to build cross-sector partnerships with a pathway to commercial return on investment). They can do this by buying into the knowledge base generated on the back of grant funding, which is essential to product and business-model innovation. Investors should request close reporting by their investees to build the evidence base, which is key to de-risking future investments in the sector, thereby reducing many of the information asymmetries that hinder participation in early-stage cooking ventures. Investors can also play an essential role in growing the financing "pie" in the cooking space—primarily through tapping into the broader modern-energy ecosystem and leveraging existing distribution networks by other energy players (e.g., utilities and off-grid solar companies). This approach could potentially lower the marginal cost of access. Key to this ambition is remaining wary of excessive concentration, where only established players are able to obtain cooking-directed financing.

- **Seek blended finance commitments from donors and development institutions to help maximize the leverage available for investing in emerging and best-in-class business models.** Philanthropic funding, in particular, can play a critical role in providing (i) guaranteed payments based on verified impacts/public goods from delivering MECS to improve bankability of clean cooking projects, (ii) risk-sharing mechanisms (e.g., first-loss loans or guarantees) to attract more investors, and (iii) technical assistance grants to build capacity and lower transaction costs. This targeted financial participation can gradually begin to crowd in greater volumes of private capital, similar to the market development efforts in the off-grid lighting sector.

- **Push for user-centered innovation and focus on long-term business sustainability.** The massive challenges now faced by the cooking sector also offer tremendous opportunities for innovative entrepreneurs to drive the cooking ecosystem. It is essential that entrepreneurs who aim to become MECS providers build "sticky" customer relationships, meaning that product design, financing arrangements, and service delivery should center on users' cooking contexts and preferences (e.g., cleanliness, efficiency, convenience, safety, reliability, and affordability, as captured in the MECS attributes). Entrepreneurs who can advance in user-centered innovation and demonstrate long-term business sustainability and scalability will be more likely to attract investments and drive the sector changes.

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