ESMAP Energy Sector Management Assistance Program

Ci-Dev CARBON INITIATIVE FOR DEVELOPMENT

THE WORLD BANK IBRD • IDA | WORLD BANK GROUP

June 2020

Quantifying and Measuring Climate, Health and Gender Co-Benefits from Clean Cooking Interventions

Methodologies Review

ABOUT ESMAP

The Energy Sector Management Assistance Program (ESMAP) is a partnership between the World Bank and 18 partners to help 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 (SDG7) to ensure access to affordable, reliable, sustainable and modern energy for all. It helps to shape WBG strategies and programs to achieve the WBG Climate Change Action Plan targets. https://esmap.org

1818 H Street NW | Washington DC 20433
Telephone: +1-202-473-1000 | www.worldbank.org

Attribution—Energy Sector Management Assistance Program (ESMAP). 2020. *Quantifying and Measuring Climate, Health, and Gender Co-Benefits from Clean Cooking Interventions: Methodologies Review*. Washington, DC: World Bank.

Front Cover Photo Credit: ©Charlotte Pert / Hivos.

TABLE OF CONTENTS

List of Figures

List of Tables

ACKNOWLEDGMENTS

This report documents the findings from the first phase of methodologies review of the Field Study on Quantifying and Measuring Climate, Health, and Gender Co-Benefits from Clean Cooking Interventions. This field study is an activity implemented under the programmatic Advisory Services and Analytics for the Energy Sector Management Assistance Program (ESMAP) Efficient Clean Cooking and Heating Program (P156948). The objective of this study is to review existing methodologies and field experience, and then design and conduct a field study to quantify and measure all three co-benefits—black carbon, health, and gender—from selected clean cooking intervention(s).

The field study is being managed by a cross-sectoral World Bank team led by Yabei Zhang (Energy) and Zijun Li (Climate) and includes Tamer Samah Rabie (Health), Kathleen G. Beegle (Gender), Inka Ivette Schomer (Gender), Stephen Geoffrey Dorey (Health), Matthew David King (Climate), Caroline Ochieng (Energy), and Alisha Noella Pinto (Energy). This report was prepared by a consortium of consultants led by Berkeley Air Monitoring Group, under overall guidance of the World Bank team. The leading authors of the report are Vikash Talyan (Gold Standard), Sumi Mehta (Vital Strategies), and Joni Seager (Bentley University). The associated authors are Dana Charron, Samantha Delapena, Kirstie Jagoe, Michael Johnson, David Pennise (Berkeley Air Monitoring Group), and Abhishek Goyal (Gold Standard).

The report was also benefited from the review inputs of Women Organizing for Change in Agriculture and Natural Resource Management (WOCAN), UN Climate and Clean Air Coalition, and C-Quest Capital. Contributors included Jeanette Gurung (WOCAN), Sophie Bonnard, Nathan Borgfordparnell, Seraphine Haeussling, and Yekbun Gurgoz (CACC), and Ken Newcombe (CQC). Jonathan Davidar provided light copyediting, Jingyi Wu designed the cover, and Heather Austin served as the Production Editor.

The work was jointly funded by the Energy Sector Management Assistance Program (ESMAP) and Carbon Initiative for Development (Ci-Dev) at Climate Change Group.

ABBREVIATIONS

ADALYs	averted disability-adjusted life years
BC	black carbon
CDM	Clean Development Mechanism
CO_2	carbon dioxide
DHS	Demographic and Health Surveys
ECCH	efficient, clean cooking and heating
ESMAP	Energy Sector Management Assistance Program
GHG	greenhouse gas
GS	Gold Standard
GWP	global warming potential
HAPIT	Household Air Pollution Intervention Tool
ICRW	International Centre for Research on Women
IPCC	Intergovernmental Panel on Climate Change
MRV	monitoring, reporting, and verification
OC	organic carbon
PM	particulate matter
$PM_{2.5}$, PM_{10}	particulate matter less than 25 or 10 micrometers in diameter, respectively
RBF	results-based financing
RMNCAH	Reproductive, Maternal, Newborn, Child, and Adolescent Health
SLCP	short-lived climate pollutants
SDG	Sustainable Development Goal
UN	United Nations
WEAI	Women's Empowerment in Agriculture Index
WHO	World Health Organization
WOCAN	Women Organizing for Change in Agriculture and Natural Resource Management

All currency is in United States dollars (US$, USD), unless otherwise indicated.

1| CLEAN COOKING INTERVENTIONS

Worldwide, 3 billion people rely on solid fuels such as wood or coal for cooking and heating. This can result in severe health, environmental, and climate impacts. According to the World Health Organization (WHO 2014b), household air pollution from cooking kills between 3 and 4 million people every year, more than malaria and tuberculosis combined. It causes cardiovascular and respiratory disease in millions more. WHO has declared air pollution, measured using $PM_{2.5}$ concentrations as an indicator, the most important global environmental health risk (WHO 2016), and household air pollution is a leading source of global $PM_{2.5}$ emissions. Women and children are disproportionally affected, as they spend the most time in proximity to stoves and bear much of the burden of cooking, as well as collecting firewood or other traditional fuels.

Incomplete combustion of fossil fuels and biomass emits several different climate-heating particles. The most important is black carbon (BC), a component of particulate matter (PM) air pollution and a significant human-caused contributor to global warming. In low- and middle-income countries, residential heating and cooking practices with solid fuel such as coal and biomass (i.e., plant and animal material, including dung) are important sources of BC emissions. As a result of open biomass burning and residential solid fuel combustion, Asia, Africa, and Latin America contribute approximately 88 percent of global BC emissions (CCAC 2019). The sources of BC are also sources of other components of $PM_{2.5}$.[1]

Improving global cooking conditions is a primary focus of Sustainable Development Goal (SDG) 7, which aims to "ensure access to affordable, reliable, sustainable, and modern energy for all." Compared to other SDG 7 targets, however, there has been little progress in expanding access to modern cooking and heating technologies. Nearly 3 billion people still lack modern cooking and heating resources. Not only is this detrimental to them, it compromises the achievement of other SDGs (ESMAP 2019). To increase access to efficient, clean cooking and heating (ECCH) solutions on a large scale, an estimated US$4.4 billion is needed annually (Angelou et al. 2013).[2] Innovative ways for bridging this investment gap are needed if SDG 7 is to be achieved.

ECCH programs have the potential to leverage increased public sector support, because they offer public goods in terms of climate mitigation, public health, improved livelihood, and gender equality. Public sector support, however, must mobilize private sector investment to reach the scale needed for universal access to ECCH solutions. An approach in which the public sector uses resources to pay for verified climate, health, and gender co-benefit results could potentially incentivize private sector action; public support could be linked to and drive increases in private investment. Success with this approach was observed with climate impacts when the market for averted greenhouse gas emissions was at its peak (Putti et al. 2015).[3] Critical features that underpinned the mobilization of carbon financing include: (i) the development of widely agreed upon methodologies for determining the quantity of avoided CO_2-

---

1 $PM_{2.5}$ is particulate matter less than 2.5 micrometers in diameter. $PM_{2.5}$ is small enough to be deposited deep in the lungs. There is strong and compelling toxicological and epidemiological evidence of its health impacts. https://www.who.int/airpollution/household/guidelines/Review_4.pdf?ua=1

2 According to the SE4ALL Global Tracking Report (World Bank 2015), the investment needed to achieve universal access to modern cooking (not including heating) by 2030 is about US$4.4 billion annually. In 2012, investment was just US$0.1 billion.

3 Clean development mechanism, gold standard, and verified carbon standard (VCS) methodologies are widely accepted and used. A total of US$162 million from the sale of carbon offsets was mobilized for the efficient cooking sector in the voluntary carbon markets (Gold Standard and VCS) from 2007 to 2014.

equivalent emissions resulting from an intervention; (ii) credible, independent, third-party verification of results; and (iii) clear demand and a price signals for verified results (through a strong market price).

The World Bank has used results-based financing (RBF) widely in the health and climate impact sector. Borrowing from this experience, the World Bank works to support approaches in which impact-driven funds could be deployed to pay for verified climate, health, and gender impacts from ECCH interventions. If such funds could be unlocked, they could serve as an innovative way to: (i) attract other funds that target public good benefits for climate, health, and gender; (ii) develop the market for ECCH by catalyzing private investment, innovation, and risk taking; and (iii), over time, mainstream approaches to quantify the benefits of ECCH into national policies and budgetary allocations. This type of RBF approach builds on recent progress in developing methodologies to measure health, gender, and expanded climate (black carbon) benefits (Table 1.1).

TABLE 1.1: CO-BENEFIT QUANTIFICATION METHODOLOGIES

IMPACT	METHODOLOGY
Climate (BC)	• Quantification of climate-related emission reductions of BC and co-emitted species due to replacement of inefficient cookstoves with improved cookstoves (hereafter referred to as "BC methodology"; Gold Standard 2017)
Health	• Methodology to Estimate and Verify Averted Mortality and Disability Adjusted Life Years (ADALYs) from Cleaner Household Air (Gold Standard 2017) • W+ health method: Women Organizing for Change in Agriculture and Natural Resource Management (WOCAN)/ W+ Standard™
Gender	• Gender Equality Guidelines and Requirements (Gold Standard 2018) • W+ methods: WOCAN and W+ Standard™

Source: Authors.

Most of these methodologies, while promising, have yet to be validated in real-world settings, particularly when used in an integrated fashion to measure multiple co-benefits. Needed are field data and experience that could lead to improved definition and standardization. We need to better understand the strengths and limitations of existing methodologies, as well as their application in RBF-based approaches. This study reviews these methodologies to determine their potential to be components in a field study that will measure their effectiveness. The long-term goal is to develop methodologies that will support the effective implementation of clean cooking interventions and the estimation of their climate, health, and gender co-benefits.

1.1. METHODOLOGY REVIEW APPROACH

This project builds on the field experience and data that quantify climate, health, and gender co-benefits from clean cooking interventions. The aim is to produce findings and recommendations that will be useful in designing and conducting a field study to quantify and measure the co-benefits from selected interventions. The field study will then need to document how the recommended methods can be combined and applied affordably in low- and middle-income countries to generate robust results.

It is important to note that although some headway has been made to develop methodologies that evaluate these co-benefits, they have not been widely applied in different contexts and geographies. In addition, there has not yet been a rigorous evaluation for efficiencies that can derive from combining them to support scaling. Consequentially, the first step of the project is to thoroughly review existing co-benefit quantification methodologies and field experiences. That review and its findings have been documented in this report.

The review assesses the effectiveness—or ineffectiveness—of the co-benefit methodologies, measurement approaches, and tools as used in the field. It asks, in this sense, if they are effective and how they can be further developed. The aim is to locate and rectify weaknesses in the existing methodologies themselves rather than identifying new ones.

Corresponding to this objective, the review consistently follows a four-step approach across the next chapters:

1. Select methodologies for review
2. Identify their strengths and weakness
3. Assess them against the evaluation criteria
4. Make recommendations

The sections that follow outline the properties of each of these steps.

Selecting Methodologies for Review

In step 1, the methodologies were identified through a literature review that included the following:

- Existing methodologies developed by recognized organizations: Gold Standard, Women Organizing for Change in Agriculture and Natural Resource Management (WOCAN), and others
- Reports and publications generated using these methodologies
- Lessons learned from case studies and published field studies
- Methodological approaches and tools that are being used in the context of results-based financing (RBF) schemes by the World Bank, US Agency for International Development (USAID), Food and Agriculture Organization (FAO), and similar organizations

Step 1 resulted in shortlist of methodologies and tools to be assessed in detail (Table 1.2). They are addressed in the impact sections of the report.

Identification of Strengths and Weakness

The short-listed methodologies, tools, and monitoring approaches were evaluated for strengths and weaknesses. It was essential that they present a robust quantification approach to estimating the desired outcome and that they provide a monitoring, reporting, and verification (MRV) protocol to verify the performance of efficient, clean cooking and heating (ECCH) interventions.

Evidence from published literature and pilot field studies supported the assessment of the methodologies, where possible.

The outcome of step 2 is the identification of gaps and limitations of selected methodologies.

Assessment Against the Evaluation Criteria

In step 3, the chosen methodologies and approaches were assessed with the criteria listed in Table 1.3.

Recommendations

The analysis in the previous sections underlines the rich diversity of existing methodologies. A detailed balancing exercise, involving an evaluation of their objectives and their alignment with the aims of each study will be necessary for the final step of our approach, focusing on recommendations. Step 4, in this way, draws recommendations for strengthening existing methodologies, and addresses any deficiencies with alternative and supplementary approaches. The recommendations are made with the goal of harmonizing methods for quantifying and measuring climate, health, and gender co-benefits. When possible, this overview recommends alternative measures, at least when remedying deficiencies is impossible or very costly

TABLE 1.2: LIST OF CO-BENEFITS METHODOLOGIES SELECTED FOR REVIEW

IMPACT	METHODOLOGY AND SOURCE
Climate Impact (black carbon)	• Quantification of climate-related emission reductions of black carbon (BC) and co-emitted species after replacing inefficient cookstoves with improved efficiency cookstoves (hereafter, BC methodology; Gold Standard 2017) • Woodsmoke Reduction GHG quantification methodology (California Air Resources Board 2019) • Black Carbon Methodology for the Logistics Sector Climate and Clean Air Coalition (CCAC 2018) • Reducing Black Carbon Emissions from Diesel Vehicles: Impacts, Control Strategies, and Cost-Benefit Analysis (Minjares, Wagner, and Akbar 2014) • Greenhouse Gases (GHGs) quantification methodologies by Clean Development Mechanism (CDM) and Gold Standard (GS)
Health	• Methodology for ADALYs from Cleaner Household Air (Gold Standard 2017) • W+ health method (WOCAN W+ Standard™) • Measurement of direct health outcomes and/or changes in health-seeking behavior (health care facility–based measures), multiple sources • Measures consistent with health sector and/or health systems performance, such as accessing health services Reproductive, Maternal, Newborn, Child, and Adolescent Health (RMNCAH) initiatives • Reductions in personal exposure to $PM_{2.5}$ (Institute for Health Metrics and Evaluation Comparative Risk Assessment) • Self-reported health indicators and outcomes based on validated questions (e.g., Demographic and Health Surveys cross-sectional epidemiologic studies)
Gender	• W+ methods (WOCAN/ W+ Standard™) • Gender Equality Requirements and Guidelines (Gold Standard 2018) • Social Measurement Impact System for cookstove and/or fuel value chains (Clean Cooking Alliance and the International Centre on the Research for Women (ICRW) 2016) • Women's Empowerment in Agriculture Index (WEAI 2012, 2020)

Source: Authors.

TABLE 1.3: PRESELECTED EVALUATION CRITERIA

CRITERIA	PURPOSE
Cost Effectiveness	While the chosen methodologies and approaches will be robust and have environmental integrity embedded in their design, profitability for practitioners and users will be essential to their usefulness. Among others, the key determining factors of their cost-effectiveness include: (i) monitoring requirements, such as field or lab-based testing, surveys, and minimum sample size, and (ii) enabling infrastructure, including any needed monitoring expertise, availability of testing facilities across geographies, monitoring equipment costs, and other resources.
Scalability	Methodologies and approaches will be assessed for their potential to help projects and programs scale-up effectively.
Replicability	The reference methodologies and approaches should be replicable. Projects in different geographies, of different scales, and using a range of ECCH interventions should all be able to use these methodologies.
Robustness	The methodologies and approaches will be assessed for robustness for quantification and verification of the impact and whether they have been developed in consultation with a wide variety of stakeholders, including subject experts.
Compatibility	Ideally, application of the methodology should be compatible with methods for verifying other impacts.
Operational Feasibility	The operational feasibility of bringing the methodologies and approaches up to scale will be assessed.

Source: Authors.

.

2 | CLIMATE IMPACTS

Burned fossil fuels emit long-lived greenhouse gases, such as carbon dioxide (CO_2) and methane, and short-lived climate pollutants (SLCPs), such as black carbon (BC). BC is associated with the melting of polar ice and glaciers, as well as with negative health impacts, such as stroke, hypertension, asthma, chronic obstructive pulmonary disease, bronchitis, and a variety of cancers. It also affects food security through disruptions in weather patterns caused by climate change.

SLCPs have a larger impact than CO_2 on global temperatures and the climate system over short periods. BC may be responsible for close to 20 percent of the planet's warming (World Bank and CCAC 2015), making it the second highest contributor to climate change. Estimates show that household energy is the single largest controllable source of BC globally. It accounts for up to 58 percent of emissions caused by human activities (IIASA 2017). Despite mitigation opportunities, BC has not been the focus of results-based financing (RBF) mechanisms, partly because the Kyoto Protocol does not include it.[4]

Clean cooking, heating, and lighting technologies can reduce the emission of SLCPs, including BC. RBF mechanisms can help this mitigation effort and are aligned with the Paris Agreement and two targets of Sustainable Development Goal (SDG) 13, Climate Action:

> **SDG Target 13.A:** Implement the commitment undertaken by developed-country parties to the UNFCCC to a goal of mobilizing jointly $100 billion USD annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible.
>
> **SDG Target 13.B:** Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing states, including focusing on women, youth, and local and marginalized communities.

2.1. SELECTION OF THE METHODOLOGIES FOR REVIEW

Carbon finance investment can fund projects not otherwise economically viable. At the same time, it can stimulate the development and adoption of technology by creating incentives to reduce greenhouse gas (GHG) emissions. To accurately measure and certify a project's GHG emission reductions, an intervention must follow a robust GHG quantification and monitoring methodology.

This review builds on the experience of monetizing climate benefits through carbon markets. The study's overall objective is to design a harmonized approach for quantification of climate, health, and gender co-benefits of clean cooking initiatives.

Carbon finance methodologies for mitigating long-term climate impacts have been more thoroughly developed and applied than those for SLCPs, and an overview of these methodologies follows. The objective of the overview is to understand the eligibility requirements and data collection efforts of carbon finance methodologies and look for potential synergies in the carbon market infrastructure. The

---

4 The six mainstream greenhouse gases known as Kyoto Gases are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6). See United Nations Climate Change, "Kyoto Protocol—Targets for the First Commitment Period," https://unfccc.int/process-and-meetings/the-kyoto-protocol/what-is-the-kyoto-protocol/kyoto-protocol-targets-for-the-first-commitment-period.

Gold Standard BC methodology and other methodologies developed to quantify BC emissions for clean cooking and transportation are reviewed. These others were reviewed mainly to understand fundamental approaches and principles followed for BC emissions quantification and to assess standardized quantification and monitoring approaches across sectors. This work could strengthen our recommendations.

Greenhouse Gas Quantification Methodologies

Currently, carbon market standards—Clean Development Mechanism (CDM) and Gold Standard (GS)—use widely accepted GHG quantification and monitoring methodologies for clean cooking projects. CDM and GS methodologies present quantification approaches to measure GHG emission reductions compared to the status quo or an appropriate counterfactual baseline scenario for the project activity. The methodologies rely on one of three standard protocols used to estimate the difference in fuel consumption of a baseline cooking method versus an intervention stove:

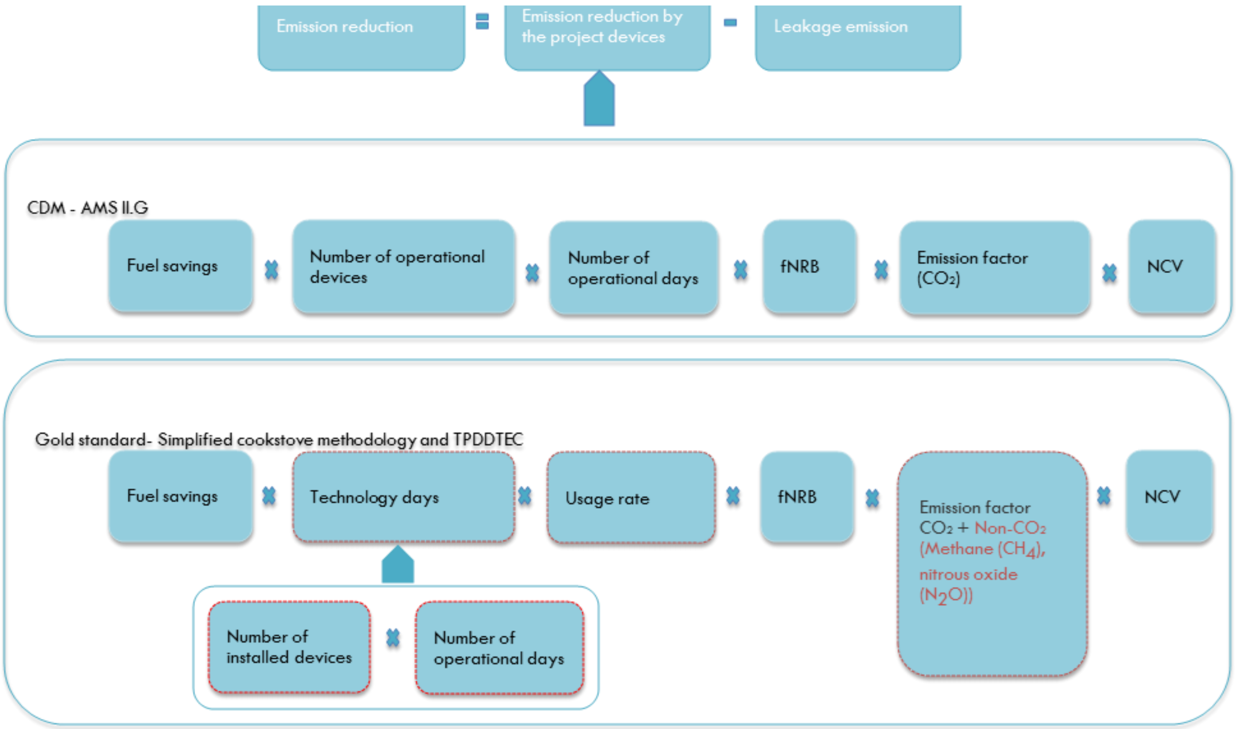
- **Water Boiling Test**: a stove is put through a standardized operational cycle simulating boiling and simmering water.
- **Controlled Cooking Test**: a typical meal for the given population is prepared by local cooks.
- **Kitchen Performance Test** (KPT): each fuel type used in a household is weighed over consecutive days in homes conducting their normal activities.

Each of these protocols requires additional input parameters to estimate fuel savings. A summary of different methods, corresponding requirements, and the ways in which values for these parameters are estimated in provided in Appendix A. The fuel savings are then combined with default emission factors from the Intergovernmental Panel on Climate Change (IPCC) and fraction of nonrenewable biomass values[5] to estimate the GHG emission. Other parameters such as the usage rate of the stoves and/or fuels, stove stacking, and leakage are also accounted for.

The GHG quantification approaches and monitoring requirements vary significantly, considering their applicability, project scale, and other key factors, but the key monitoring requirements are more or less similar across the methodologies. A snapshot of the GHG quantification and monitoring methodology is depicted in Figure 2.1.

[5] The fraction of nonrenewable biomass (fNRB), is the fraction of woody biomass saved by a project activity that can be established as nonrenewable biomass, has a direct impact on GHGs emission reductions therefore its assessment is of significant importance

FIGURE 2.1: OVERVIEW OF GREENHOUSE GAS QUANTIFICATION AND MONITORING METHODOLOGIES



CDM methodology AMS-II g = [Energy efficiency measures in thermal applications of non-renewable biomass](); fNRB = fraction of nonrenewable biomass; NCV = Net Calorific Value; TPDDTEC = technologies and practices to displace decentralized thermal energy consumption.
Source: Gold Standard 2016.

Gold Standard Black Carbon Methodology

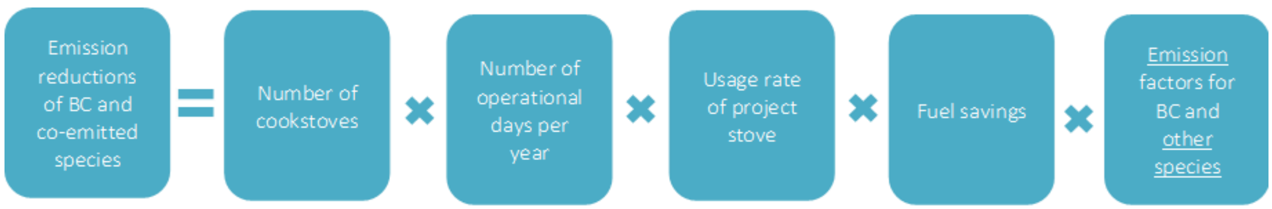
The Gold Standard Methodology: Quantification of Climate-Related Emission Reductions of Black Carbon and Co-Emitted Species Due to the Replacement of Less Efficient Cookstoves with Improved Efficiency Cookstoves was first released in 2015. It provides approaches to quantify and monitor emission reductions of BC and other short-lived climate pollutants, achieved by projects focused on improved cookstove technologies or clean burning fuels—accounting for net reduction in the SLCPs.[6] This methodology is meant to be applied as an add-on methodology to the GHG quantification methodology (Technologies and Practices to Displace Decentralized Thermal Energy Consumption [TPDDTEC]).

The approaches for measuring fuel consumption and other input parameters to quantify the performance of the project stoves can be applied for the accounting of both the BC and GHG. This allows

6 In Gold Standard black carbon methodology, SLCPs include compounds such as BC, methane (CH4), tropospheric ozone (O3), and many hydrofluorocarbons (HFCs). These compounds have short lifetimes in the atmosphere compared to long-lived GHGs. Although their concentrations or loadings can be elevated by human-related activities and emissions, these compounds do not accumulate in the atmosphere over decade to century time scales and longer, and so their effects on climate are shorter lived, predominantly in days to decades following their emission. Cookstoves fueled by solid fuels are one of the key contributors to SLCPs such as BC, CH4, and ozone (O3) precursors like carbon monoxide (CO) and volatile organic compounds (VOCs). These are compounds exert positive radiative forcing.

carbon project developers to quantify, monitor, and verify the BC emission reductions in a harmonized and cost-effective manner. The methodology provides approaches to quantify the emissions of SLCPs, including BC, organic carbon (OC), and other associated short-lived forcing pollutants. The emission reductions of BC and co-emitted species[7] are quantified by comparing the project and baseline scenarios; BC is quantified by combining the fuel savings, emission factors for pollutants, and other input parameters (see Figure 2.2).

FIGURE 2.2: QUANTIFICATION APPROACH FOR BLACK CARBON AND CO-EMITTED SPECIES



Source: https://globalgoals.goldstandard.org/407-ee-ics-technologies-and-practices-to-displace-decentrilized-thermal-energy-tpddtec-consumption/

The quantity of fuel saved is estimated by applying the KPT at both baseline and after the intervention. The emission factors for BC (gram per kilogram of fuel) and other species are determined in a laboratory or field setting using a representative cooking situation for both pre- and postimplementation of interventions. BC emissions have been historically difficult to measure in the field and are relatively intensive and costly compared to other types of stove performance testing in homes (Garland et al. 2017). On other hand, the laboratory-based emission factors may differ significantly from those determined through field measurements. The methodology allows for the use of BC emissions measured in laboratory settings, with the BC emission factors adjusted for bias in laboratory versus field measurements. The adjustment factors are determined with parallel testing of project and baseline technology in both the lab and the field by measuring particulate matter in the plume of the stoves and determining whether the ratio of BC to OC is larger or smaller than that from the laboratory tests. If the ratios being applied from laboratory testing are not conservative (e.g., the field measurements show a lower ratio of BC for the project stove), the emission factors must be adjusted such that the ratios match that measured in the field.

The methodology also allows for direct field-based measurements of emission factors (needing a minimum of 20 samples) and must meet minimum precision level requirement to apply mean emission factor values. This allows for the calculation of BC emission reductions based on the estimated mean

---

7 The incomplete combustion of solid fuels also releases other pollutants, such as OC, nitrogen oxides (NOx) and sulfate—creating sulfur dioxide (SO2)—along with BC (Bond et al. 2013). Although the methodology conservatively attributes cooling effect to the organic carbon (OC), recent research suggests that the brown carbon component of OC emissions mitigates the potential cooling effect of total OC emissions from cookstove activities (Bahadhur et al. 2012; Feng, Ramanathan, and Kotamarthi 2013; Saleh et al., 2014). The sulfate species exert cooling effect, while NOx leads to a net cooling effect on the lower atmosphere and surface. The net climate impacts of cooking-related aerosol emissions, however, are uncertain, although likely warming (Bond et al. 2007; Koch et al. 2007; Lacey and Henze 2015), but likely to be lower than the effect of BC alone. Replacement of traditional cookstoves with alternative technologies thus has the potential to provide considerable climate and health benefits by reducing emissions and human exposures (Kodros et al. 2015; Grieshop et al. 2009, Roshan, Kevin, and Grieshop 2017). Note that the BC methodology accounts and presents only the quantification approach for BC and co-emitted species, which includes OC, CO, VOCs, and sulfur species.

emission factors. One can use the mean values only if the test results satisfy the 90/30 rule, that is, the endpoints of the 90 percent confidence interval lie within +/- 30 percent of the estimated mean. Other performance parameters such as number of operational days, number of cookstoves, usage rates, and leakage are monitored following the TPDDTEC methodology.

The methodology provides net SLCPs reduction in BC equivalent (grams per kilogram of fuel) terms.[8] All species are converted to BC equivalent using the ratio of the global warming potential of the co-emitted species to the global warming potential of BC for the 20-year time horizon to estimate the net emission reductions in SLCPs. This way, the methodology accounts for the warming and cooling nature of different SLCPs. Since OC has a cooling effect, the net short-term climate impacts are a function of both the magnitude and the ratio of BC and OC emissions and could be negative that is, have a cooling effect. As mentioned, the methodology also calls for measuring the BC and OC ratios (based on kitchen concentrations), which serves as a check that the in-field aerosols are not more warming than estimated.

To the best of our knowledge, Gold Standard methodology is the first publicly available BC accounting methodology for clean cookstoves that quantifies the net climate impacts based on field measurement of BC and co-emitted species emissions. In parallel to ongoing research in this area, several efforts have been made to develop methodologies for different mitigation action types. Most notable methodologies are the California Air Resources Board (CARB) Methodology and Black Carbon Methodology for the Logistics Sector. These methodologies, described in the following subsections, have many principles in common with Gold Standard methodology.

Woodsmoke Reduction Greenhouse Gas Quantification Methodology

The California Air Resources Board[9] woodsmoke reduction program developed the Woodsmoke Reduction Quantification Methodology to help households replace an uncertified wood stove, wood insert, or fireplace with a cleaner burning and more efficient device. The California Air Resources Board developed the Woodsmoke Reduction GHG Calculator Tool, which provides guidance for estimating the GHG emission reductions and selected pollutant emissions co-benefits, including BC and $PM_{2.5}$ emission reductions.[10]

Like GHGs and other pollutant emissions, the BC emission reductions (pounds per stove) from the qualifying projects are calculated as the difference between the baseline and project scenarios using default emission factors for BC emissions. The calculator determines the default emission factors for BC based on fuel consumption values, project technology usage rates, the $PM_{2.5}$ emission factor, and BC

8 The BC equivalent conversion factor for an emitted species x is a ratio of the global warming potential (GWP) of that species to the GWP of BC for the 20-year time horizon as calculated by the IPCC on a global basis. The global IPCC values are provided in the methodology. The project developer can apply the regional GWP values or sector-specific GWP values for BC and co-emitted species. The regional (country or group of countries) GWP values must be derived from peer-reviewed publications. The regional values will be subject to further review and approval from Gold Standard. The approved regional values can be applied for subsequent projects developed in the same region and for the same sector.

9 California Climate Investments is a statewide initiative that puts billions of cap-and-trade dollars to work facilitating GHG emission reductions, strengthening the economy. and improving public health and the environment, particularly in disadvantaged communities. The cap-and-trade program also creates a financial incentive for industries to invest in clean technologies and develop innovative ways to reduce pollution.

10The Woodsmoke Reduction Program was established to promote the voluntary replacement of old wood-burning stoves with cleaner and more efficient alternatives. The replacement devices emit less greenhouse gas (GHG) and other air pollutants including, $PM_{2.5}$ and BC. The program offers incentives toward the purchase and installation of the qualifying device. See California Air Resources Board, "Woodsmoke Reduction Program," https://ww3.arb.ca.gov/planning/sip/woodsmoke/reduction_program.htm.

emission fraction of $PM_{2.5}$.[11] The PM_{10} emission factor is considered as the basis for these estimates, with a set of standard ratios to convert PM_{10} to $PM_{2.5}$ then $PM_{2.5}$ to BC emissions for different technologies. The PM_{10} emission factors, $PM_{2.5}$, and BC standard ratios are sourced from the US Environmental Protection Agency emission inventory and are adjusted, applying relevant standard ratios for California. Further details are provided in the Woodsmoke Reduction Program Quantification Methodology[12] and the accompanying tool.

Black Carbon Methodology for the Transport Sector

In the recent past, similar efforts have been made to develop BC quantification methodology for the transport sector. For example, Black Carbon Methodology for the Logistics Sector was developed to better track and report BC emissions from freight movement emissions over time (Smart Freight Centre 2017). This voluntary methodology uses a bottom-up approach based on fuel consumption. BC emissions are estimated based on a measure of actual or estimated freight activity (ton-kilometer, kilometer, or liter fuel) multiplied by a standard emission factor (BC per ton-kilometer, kilometer, or liter fuel). The BC emission factors (gram per kilogram of fuel) are sourced from published reports and national inventories, or $PM_{2.5}$ emission factors are converted to BC using conversion factors applicable to different modes, vehicle types, and fuels.

The methodology presents a tiered approach following IPCC's tiered emissions calculations approach. Three levels of calculation can be undertaken, depending on the information available. Tier 1 represents the simplest approach using the most default data, whereas Tiers 2 and 3 (defined as silver and gold, respectively) demand increasingly detailed data. The World Bank followed a similar approach for quantifying transport-related BC emissions in the report on Diesel Black Carbon Emission and Impacts on Climate and Health (Minjares, Wagner, and Akbar 2014). The report presented estimated BC emissions using a bottom-up approach, based on the amount of fuel combusted and an assumed ratio of BC to $PM_{2.5}$.

In principle, these methodologies apply similar approaches to estimating BC emission reduction, including:

- Fuel quantification, either measured or estimated, based on assumptions for the representative case
- BC default or measured emissions factors for the intervention technology and fuel
- Other input parameters that influence the performance of the intervention technology, such as usage rate

Methodology Selected for Further Assessment

Of the methodologies presented above, the Gold Standard BC methodology has been chosen for further assessment:

11 For firewood, $PM_{2.5}$ is used as proxy indicator of BC and organic carbon emissions as $PM_{2.5}$ emission agrees well with the sum of organic matter and BC emissions.

12 The California Air Resources Board (CARB) is responsible for providing guidance on estimating the GHG emission reductions and co-benefits from projects receiving money from the Greenhouse Gas Reduction Fund. This guidance includes quantification methodologies, co-benefit assessment methodologies, and benefit calculator tools. See the Woodsmoke Reduction Program Qunatification Methodology, https://ww2.arb.ca.gov/resources/documents/cci-quantification-benefits-and-reporting-materials?corr.

- It presents quantification and monitoring approaches for BC and other associated SLCPs to quantify the net climate impact of improved cookstove projects. This more inclusive approach is critical, given that some co-emitted species such as OC produce a cooling effect and need to be considered when characterizing the net impact.
- It applies a harmonized monitoring, verification, and reporting approach, which allows easy integration with carbon offset methodologies in a cost-effective manner.
- It provides a verifiable outcome as "BC equivalent," which represents the net reductions in emissions of BC and co-emitted pollutants.
- It allows opportunity for BC equivalent emission reductions to be converted into the net climate impact of SLCPs from intervention technology. Therefore, the methodology outcome can then be used for RBF schemes to drive investment into much-needed climate and development initiatives.

Lessons from the other methodologies, however, are still considered in the final recommendations.

2.2. Identification of Strengths, Gaps, and Limitations

Gold Standard BC methodology was reviewed to determine whether it will be used to estimate the performance of improved cookstove projects for RBF. To serve this purpose, the methodology must include the following:

- Be applicable to proposed project and across technologies and fuel types
- Follow uniform quantification approaches applicable across geographies
- Apply existing and proven quantification and monitoring approaches
- Apply project-level data, where available and appropriate
- Result in conservative estimates that are well supported by the empirical literature

Applicability: Technology and Fuel

The BC methodology is applicable to projects expected to reduce emissions of BC and co-emitted species, primarily from lower levels of fuel consumption and/or changes in emission factors (gram per kilogram of fuel) that can be achieved through an intervention technology and/or fuel. The methodology is to be used in conjunction with the most widely applied carbon methodologies for household cooking practices. The BC methodology covers a variety of technologies and practices used in residential and nondomestic premises such as institutional, industrial, or commercial facilities.[13] Due to a wide scope of application, the methodology can be applied to different technologies and cooking practices across geographies.

The methodology can also be applied to projects that involve shifting from nonrenewable fuels to green charcoal, plant oil, renewable biomass briquettes, and so forth. To safeguard against the potential risks of fuel switching, such as a negative impact on household air quality or non-renewability of project fuel, the methodology applies a set of established requirements of carbon methodologies. For example,

13 Technologies include the introduction of improved biomass or fossil fuel cookstoves, ovens, and dryers; space and water heaters (solar and otherwise); heat retention cookers; solar cookers; biodigesters; safe water supply and treatment technologies that displace the boiling of water; thermal insulation in cold climates, and so forth. Practices include the improved application of such technologies, a shift from non-renewable to renewable fuel (for example, a shift to plant oil–fired stoves), humidity control through improved storage and drying of fuels, and so forth.

adequate evidence must be supplied to demonstrate that indoor air pollution is not negatively impacted by the fuel switch compared to the baseline.

To apply the BC methodology, the intervention cookstoves must meet the minimum International Workshop Agreement Tier 3 performance criteria for total emissions.[14] The minimum performance benchmark has its advantages and disadvantages. Requiring that the intervention must meet Tier 3 performance criteria will ensure that the intervention technology is well designed to achieve meaningful emission reductions under real-world conditions, but, it likely means that a large number of existing new stoves will not qualify, thereby limiting options.

If an intervention technology fails to meet the performance criteria during the crediting period,[15] the project would not be eligible for claiming BC and co-emitted species emission-reduction benefits.

Applicability: Stacking, Double Counting, and Emission Reduction Ownership

Stove stacking, or mixed use of multiple stoves and fuels, is observed almost universally. The carbon methodologies address this issue using different approaches, such as adjusting corresponding emissions for parallel use of the baseline stove. From a carbon accounting point of view, these approaches are considered effective to an extent, although avoiding stacking altogether would most likely lead to greater reductions in BC and $PM_{2.5}$ emissions.

The methodology considers stove stacking and requires that studies include an incentive that encourages displacement of the baseline stove. Intervention technologies must be monitored over time, and the approach must be adjusted if significant displacement is not observed. The continuous monitoring of stove stacking presents opportunities: first to understand the extent to which the baseline technology is still used after the intervention technology is introduced, and second, to improve the improved-stove design if the technology is not widely accepted by the community.

As an added complexity, however, reduction of BC is also a factor in improving air quality, which has correlations to health. The methodology does not address this connection, although Gold Standard follows a conservative approach and includes safeguards against potential double claiming of impacts in its guidelines.

Black Carbon Emission Quantification

The methodology follows standard governing principles for quantification and monitoring of BC emission reductions similar to the widely recognized carbon methodologies. As previously discussed, the BC methodology requires project information on key activity data, such as number of stoves, operational days, usage rate, fuel consumption, and BC and co-emitted species emissions factors to monitor and quantify the reductions. Information on input parameters, except BC emission factors, is

---

14 International Workshop Agreement (IWA) provided a framework for rating cookstoves against tiers of performance for a series of performance indicators including: Fuel Use (efficiency), Emissions (carbon monoxide and particulate matter 2.5), Indoor Emissions (carbon monoxide and $PM_{2.5}$), and Safety. The latest version of the BC methodology refers to IWA, which should be updated in line with the new ISO standard 19867-1:2018. This ISO standard presents five voluntary performance indicators covered by the targets: thermal efficiency, fine PM emissions, carbon monoxide emissions, safety, and durability. See ISO, "ISO 19867-1:2018 Clean Cookstoves and Clean Cooking Solutions—Harmonized Laboratory Test Protocols—Part 1: Standard Test Sequence for EMISSIONS And Performance, Safety and Durability," https://www.iso.org/standard/66519.html.

15 The period in which verified and certified emission reductions attributable to a project activity, can result in the issuance of certified emission reductions. "

the same as required for carbon accounting, and the user can capitalize on ongoing data collection and verification efforts.

The net emission reductions of SLCPs is a distinguishing feature of BC methodology. Incomplete combustion of fuels releases BC and co-emitted species, which are involved in several atmospheric physical and chemical processes that lead to both warming and cooling of the atmosphere. The co-emitted species, primarily OC and sulfur, can influence the direction (net cooling or warming) and magnitude of the net climate impact of SLCPs. Recent research suggests understanding net climate impacts requires accounting for the contributions of species co-emitted with BC. Although accounting for climate impact by co-emitted species entails significant uncertainty, ignoring these effects may convey a mistaken impression about the magnitude or even the direction of the net climate impact of BC. Unlike other methodologies, which account only for BC emissions, the Gold Standard BC methodology follows a conservative approach and quantifies the net emission reductions considering the warming and cooling nature of SLCPs emitted during fuel combustion.

To quantify and standardize the net outcome of interventions, the methodology follows an innovative approach in that it quantifies the impact in BC equivalent (gram per kilogram of fuel) terms. This has two benefits. First, it allows for the accounting of both the warming and cooling nature of BC and co-emitted species and estimates the outcome as net reduction by converting emissions of different gases to a common unit.[16] Second, it provides an option to consider local and/or regional climate impact rather than the global average to estimate the net reduction.[17]

Monitoring Requirements

In addition to key performance variables required for carbon accounting, the BC methodology requires monitoring of the BC and co-emitted emission factors (gram per kilogram of fuel) to quantify the net emission reduction. The methodology follows industry standards and protocol, widely followed in the cooking sector, and provides key guidance for monitoring. For example, it recommends sample-based, emission-factor monitoring approaches to keep the methodology requirements realistic for real world application and at the same time ensure that the results are statistically sound, where feasible, using the technically sound proxy indicators such as the $PM_{2.5}$ emission factor.

As mentioned in the overview, the methodology allows one to monitor emission factors for BC (grams per kilogram of fuel) and other species in both laboratory and field testing. This holds for a representative cooking situation for both pre- and postimplementation of an intervention technology. When laboratory-based emission factors are applied, the methodology requires application of adjustment factors to account for bias between stove testing in a laboratory versus in the field, moisture variance in the biomass, and fuel types. Like other sectors, the cooking technology, fuel type, amount of fuel consumed, and end-use practice are key factors that influence the BC and co-emitted species emissions in a real work context.

---

16 For example, tCO2eq for GHGs

17 BC is not well mixed in the atmosphere because of its short lifetime and climate-forcing mechanisms that differ from GHGs. Thus, regional changes and impacts on climate variables other than temperature differentiate BC from how most GHGs affect climate. The climate forcing per emission depends on the region (and timing) of emissions. Thus, the summed climate forcing of all species for a source category emitting in a particular region (or season) may have a different magnitude than the global average, or even a different sign. Although BC methodology recommends global mean GWP values for net reduction, it recognizes the fact that globally averaged forcing does not reflect the potentially strong regional climate impacts of SLCPs. Forcing that appears small in the global average might be significant over a smaller area and near 0 over the rest of the globe.

The methodology tries to adopt a balanced approach to achieve accuracy in measurement, while also being practical for conducting measurements in the field. A key concern is the cost of the project and availability of requisite infrastructure such as technical capacity, access to laboratories, and related factors.

Challenges and limitations with meeting the monitoring requirements of BC methodology include the following:

- The methodology requires sample-based monitoring of emission ratios in households. The monitoring effort for determining these ratios is significant. Presently, there is a lack of skill and infrastructure for conducting the testing to determine these emission factors on a global scale. This poses a challenge to implementing projects applying this methodology at scale.
- As learned from experience in carbon markets, a programmatic framework can help achieve scale, while keeping the impact real. A similar approach for BC quantification is needed in the scope of this methodology. Such an approach can allow for exemptions in cases where homogeneity—reduced monitoring effort or use of default emission factor values appropriately corrected for associated assumptions and uncertainty—can be demonstrated.

2.3 Assessment Against the Evaluation Criteria

Table 2.1 summarizes the BC methodology assessment against the preselected evaluation criteria.

Alternative Methodological Approaches

The most relevant requirement of the BC methodology is determining the emissions factors of BC and co-emitted species in pre- and postintervention scenarios. Currently, field-based emissions testing is the primary requirement, with the possibility of laboratory-based emission factors, adjusting the results for bias. The methodology also calls for measuring the BC/OC ratios (based on kitchen concentrations), which serves as a check that in-field aerosols are not more warming than estimated.

A default emission factor-based approach could be considered as an alternative to field testing. At the time of the methodology's development, there was somewhat limited data available on BC and OC emission factors for the variety of stove and fuel combinations commonly disseminated by project developers. Since its publication, the BC methodology has not been applied in a project seeking Gold Standard certification, but several peer-reviewed research articles have reported field-based emissions of BC and OC. These publications present data on the most frequently implemented fuel and stove combinations in several geographies (see Appendix D). A review and synthesis of the data in these publications could provide a set of default emission factors for a range of technologies. Such an approach could substantially reduce the resource burden for project developers, while still potentially providing reasonable estimates of BC and OC emissions.

TABLE 2.1: ASSESSMENT OF BLACK CARBON METHODOLOGY AGAINST THE PRESELECTED CRITERIA

CRITERIA	PURPOSE	ASSESSMENT
Cost-Effectiveness	Cost is impacted by monitoring requirements such as field versus lab-based testing, surveys, and minimum sample size as well as by enabling infrastructure, including monitoring expertise required, availability of testing facilities across geographies, monitoring equipment costs, and other resources	The methodology monitoring requirements can be categorized as (i) key performance parameters overlapping with carbon accounting methodology and (ii) monitoring of emission factors for BC, OC, and other co-emitted species. The alignment with carbon accounting methodology for overlapping performance parameters ensures robustness and cost-effectiveness. For BC, OC and co-emitted species emission factors, monitoring requirements involve laboratory and/or field testing to determine the baseline and project emission factors. Such extensive monitoring involves costs for hiring experts as well as procuring equipment, the availability of which can be limited and expensive. As reported by the project developers and other stakeholders involved in carbon finance projects, the lack of financial incentives in lieu of verified BC outcomes has been a barrier for methodology adoption in the past and makes it difficult to assess the cost-effectiveness at large. A firm commitment to purchase verified results would provide much-needed certainty for project developers and help invest in and expand the scope of monitoring. As experienced in carbon market, investment could lead to the building of requisite monitoring infrastructure over time across geographies, which likely would bring down the cost. In the meantime, a simplified approach such as application of representative default emission factors from peer-reviewed published field studies,[a] where available, with conservative adjustments can be applied.
Scalability	Methodologies and frameworks will be assessed for their potential to enable projects to grow effectively.	In the carbon market, the Program of Activities[b] approach has achieved tremendous success for scaling the implementation of distributed technology such as cookstoves and water filters across geographies. Similar to carbon accounting methodologies, the BC methodology can be adopted at scale across geographies. The methodology, however, requires measurement of context-specific BC emission factors due to the fact that BC emission has associated uncertainties, such as localized versus global impact, due to fuel and technology type and other factors that can influence the outcome. This fact may limit its potential for scaling up. A programmatic approach with safeguards can help implementation at scale. In such case, selection of emission factors, for example, literature-based default values for BC and OC emission factors based on representative fuel mix/technology and geography will be critical to facilitate the implementation at scale.
Replicability	The reference methodologies and approaches should enable replicability. Projects in different geographies and of different scales, and those using a range of stoves and fuels, should all be able to use these methodologies.	The BC methodology follows a uniform quantification approach applicable across geographies, technologies, and scale. Ensuring representativeness and accounting for uncertainty in a transparent and robust manner, however, will be the key to successful application at scale.

CRITERIA	PURPOSE	ASSESSMENT
Robustness	The methodologies will be assessed for robustness for quantification and verification of the impact and also whether they have been developed in consultation with a wide variety of stakeholders, including subject experts.	The BC methodology was developed following similar standards and levels of scrutiny used for carbon accounting methodology. For example, the BC methodology was developed under the guidance of subject matter experts, informed by the latest science, and adopted after two rounds of stakeholder consultations. The methodology relies on same monitoring, reporting, and verification (MRV) infrastructure used in carbon accounting and hence is expected to achieve a high level of robustness.
Compatibility	Ideally, application of the methodology should be compatible with methods to be used for verifying other impacts.	The BC methodology is aligned with carbon methodology with regard to quantification as well as MRV of outcomes and therefore is compatible with GHG climate impacts methodology. It should be noted, however, that the outcome is quantified as a net reduction in $BC_{equivalent}$ gram per kilogram of fuel, which is different from carbon methodology, $tCO2_{equivalent}$. As discussed, the primary reason for avoiding such conversion at the methodology level is the uncertainty around and lack of a commonly agreed metric for estimating the climate impact of SLCPs. Having said that, the end-user and outcome funder can agree on a common metric to convert the BC emission reduction outcome to $tCO2_{equivalent}$ following IPCC or peer-reviewed regional global warming potential values.
Operational Feasibility	Assessing operational feasibility when bringing the methodology to scale will consider aspects of the cost-effectiveness, complexity, and robustness of the methods.	As discussed, the methodology presents a cost-effective and robust framework for quantification and MRV of BC emissions. Measuring BC, OC, and other co-emitted species requires an enabling environment, including clear price signals and requisite monitoring infrastructure.

a. Appendix E presents an overview of recently published BC and OC emission factors.
b. A voluntary coordinated action by a private or public entity which coordinates and implements any policy/measure or stated goal (i.e. incentive schemes and voluntary programs), which leads to anthropogenic GHG emission reductions or net anthropogenic GHG removals by sinks that are additional to any that would occur in the absence of the PoA. https://cdm.unfccc.int/newsroom/factsheets/docs/glos_CDM.pdf
Source: Authors.

2.4 RECOMMENDATIONS

Previous sections of this chapter highlighted that the pathway to achieving methodological resilience passes from recognizing the limits of existing approaches and striking a balance with their individual advantages. Avoiding double counting, overcoming material constraints of finance and availability of resources are key factors to consider when selecting a methodological outlook. Balancing across these considerations, we can summarize the basic messages of this chapter's analysis into the following recommendations:

- **Consider BC impacts in tandem with existing climate finance opportunities**, such as the carbon market. The cookstove methodologies that are commonly used in carbon markets and the Gold Standard averted disability-adjusted life years (ADALYs) methodology have overlapping MRV requirements and approaches. These include fuel-use assessment, usage monitoring, field surveys, field tests, and so forth. These overlaps provide an opportunity to harmonize monitoring requirements and approaches for BC and other co-benefits in a cost-effective manner.
- **Continue to employ the BC methodology as a focal point to quantify and monitor net reductions in emissions**. Existing analysis has demonstrated that BC represents a robust approach that has been effectively used and it follows a uniform quantification approach applicable across geographies, technologies, and scale. Ensuring representativeness and accounting for uncertainty in a transparent and robust manner, however, will be the key to successful application at scale.
- **Use the default emissions' factors for BC and OC (based on existing literature) to set the basic properties**. The default values represent the best option since there is limited globally available expertise and facilities to field test per the BC methodology. Factor selection can rely on fuel, technology, and geography. At the same time, the Gold Standard approach needs to be refined further, while using the default values can alleviate resource barriers.
- **Use the Gold Standard BC methodology to avoid double counting of BC effects.** As analyzed, BC is associated with the melting of polar ice and glaciers and with negative health impacts, such as stroke, hypertension, asthma, chronic obstructive pulmonary disease, bronchitis, and a variety of cancers. It also affects food security through disruptions in weather patterns caused by climate change. At the same time, it also has negative effects on the environment and human health. The Gold Standard BC Methodology accounts for additional environmental impacts but does not include quantification of health benefits. It thus avoids the risk of double counting when incorporating both the BC and health methodologies.

3 | HEALTH IMPACTS

The clean cooking sector was originally conceived to provide more efficient innovations needed to address concerns about environmental degradation from the use of traditional stoves and unprocessed fuels. The evidence linking household air pollution with major public health impacts, however, spurred interest in ensuring that clean cooking would also be able to deliver health benefits. There have been major research and implementation efforts to demonstrate how smoke reduction can improve the health of household members—especially women and children, who spend the greatest time in proximity to cooking fires and subsequently experience the greatest exposure.

The health benefits of clean household energy are dependent on achieving substantial and sustained reductions in exposure to air pollution, measured using fine particulate matter ($PM_{2.5}$) as an indicator. We also know that maximum health benefits can be achieved only when air quality matches World Health Organization (WHO 2014a) health-based guideline levels. Health benefits are likely to be maximized through: (i) sustained, near exclusive use of clean fuels; (ii) when competing sources of air pollution are carefully mitigated; and (iii) with community-level uptake and use of clean fuels.

One of the challenges of valuing the health benefits of cookstove technologies has been the discomfort around quantifying health improvements at air quality levels far exceeding health-based guidelines for air pollution, particularly given what is known about the tendency for households to 'stack' or use multiple cooking systems (Ruiz-Mercado and Masero 2015). Now that there are opportunities to bring truly clean cooking technologies to scale, there is added incentive to assess health benefits.

In addition, as the carbon markets have continued to evolve over time, the ability to make a verifiable public health impact could unlock an additional source of funding for project developers, particularly if certified outcomes can contribute toward attainment of the Sustainable Development Goals (SDGs) for health. One example can be found in the target of SDG 3, Good Health and Well-Being, to "ensure healthy lives and promote well-being for all at all ages." The following are specifically relevant:

> **SDG Target 3.9:** Substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination
>
> **SDG Indicator 3.9.1:** Mortality rate attributed to household and ambient air pollution.

3.1 Selection of Methodologies for Review

Despite interest over the past several years in quantifying health benefits, approaches tailored for the clean cooking sector are still in a relatively nascent stage of development. Not a great deal of information publicly available and there is a lack of applied examples, limiting the ability to fully evaluate some approaches. With this in mind, the literature review that initially focused on proven examples from within the clean cooking sector expanded to include a wider set of methodologies being applied by the broader health sector. While these may not be a perfect fit, their review does demonstrate the extent to which other methodologies may or may not be further refined for future application and use, as well as the extent to which they are likely to be considered comparable with other more widely accepted approaches used in the health sector. In particular, the review was conducted to assess the extent to which changes in specific measures of health (symptoms, indicators, and/or outcomes) may be quantified as part of an integrated approach. Thus, the following were reviewed:

- Existing methodologies developed by standard bodies such as Gold Standard and Women Organizing for Change in Agriculture and Natural Resource Management (WOCAN)
- Reports generated using these methodologies, where available
- Recent reviews of results-based financing (RBF) schemes applied in the health sector
- Approaches being used to quantify household energy-related health impacts via household surveys, such as those used in epidemiologic studies

Gold Standard Health Impacts Methodology: ADALYs

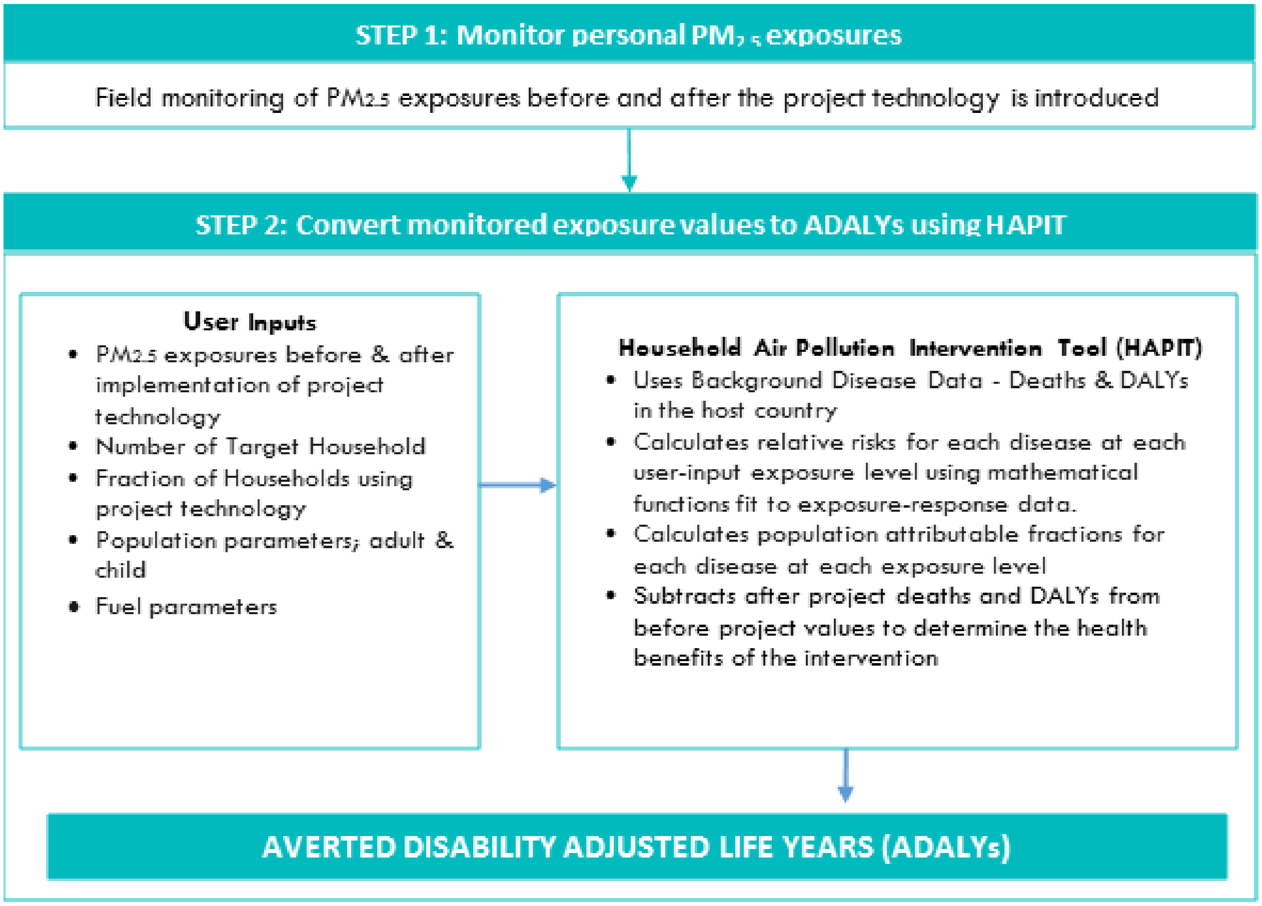
The averted disability-adjusted life years (ADALYs) is an approach intended to demonstrate a "direct and verified" impact on the health of vulnerable communities. The approach was developed to enable a quantification of the SDG Targets 3.9 and 3.91. This methodology is, to the best of our knowledge, the first publicly available, transparent, and certified methodology developed to quantify the health benefits of clean cooking interventions. The ADALY methodology is more informative than a focus on exposure reduction alone, in that it allows for a more comparable comparison of potential benefits expected. In brief, it focuses on quantifying reductions in personal exposure to air pollution and linking these exposures to ADALYs. These are a measure of overall disease burden, expressed as the number of years lost due to ill health, disability, or early death. Expected health benefits of interventions are modeled using the Household Air Pollution Intervention Tool (HAPIT), which is periodically updated to ensure consistency with the health evidence, assumptions, and data used to estimate the global burden of disease from household air pollution (Figure 3.1). The approach is able to estimate benefits based on quantitative measures of consistency and intensity of use, competing sources of air pollution, and local characteristics influencing exposures of household members. These modeled benefits offer the important ability to extrapolate benefits, so that the expected impacts of successful implementation on a larger population scale can also be calculated.

Key assumptions underlying the suitable application of the HAPIT model are as follows (Pillarisetti, Mehta, and Smith 2016):

- Change in personal exposures of the cook adequately indicates a change in exposure to other household members adjusted by the default relationship between women's and child exposures (HAPIT Version 3.0).[18]
- Measurements of changes over a few months adequately indicate changes over years if the intervention cooking technology continues to be used and maintained, that is, seasonal and secular variations do not alter the basic conclusions.
- Different dissemination approaches during the planned large-scale intervention will not result in significantly different performance and usage, compared to what is observed during the validation study.
- The international $PM_{2.5}$ exposure-response relationships integrated in HAPIT adequately reflect health impacts for the risk of the five diseases estimated.
- Underlying national background demographic and disease patterns are consistent with the dissemination region and will remain relatively constant over the evaluation period.

18 HAPIT estimates health changes due to interventions designed to lower exposures to the household air pollution of household members currently using unclean fuels (wood, dung, coal, kerosene, and others). These interventions could be due to cleaner burning stoves, cleaner fuels, providing chimneys or other ventilation changes, movement of the traditional hearth to a different location, motivating changes in behavior, or a combination of the above. See "HAPIT 3.1.1," database, https://householdenergy.shinyapps.io/hapit3/

FIGURE 3.1: THE BUILDING BLOCKS OF THE ADALYS METHODOLOGY



Source: Gold Standard 2017b.

With regard to monitoring requirements, the ADALYs methodology has significant overlap with carbon accounting methodology TPDDTEC for parameters such as technology, usage rate, cooking practices, and household characteristics. The methodology has not yet formally applied to be registered with Gold Standard.

W+ Standard™ Health Impact Methodology

WOCAN developed a health methodology as part of its W+ Standard™, a women-specific standard intended to measure the benefits of women's empowerment (see further details in Chapter 4). Health is one of six critical domains essential for women's empowerment measured using W+ methods: Time Savings, Income and Assets, Health, Leadership, Education and Knowledge, and Food Security (Figure 3.2).

FIGURE 3.2: WOCAN'S W+ STANDARD™ WOMEN'S EMPOWERMENT DOMAINS

Source: WOCAN 2019.

The W+ Standard™ health methodology focuses on evaluating the improvement to overall health of women. Since the methodology is explicitly focused on women's health, health benefits to other household members are not quantified. This obviously limits the ability to measure children's health benefits; WOCAN notes that additional measurable improvements could potentially be quantified for infant mortality, vaccine, and other local disease rates, but these are outside of the scope of the existing methodology.

The methodology is used to quantify self-reported improvements in health, using IH units (see the equation that follows), which are denominated in terms of monetary value or the number of beneficiaries. Health improvements are calculated by comparing women's self-reported health improvements between stove-and-fuel technology user and nonuser households, after adjusting for existing health conditions, any negative health impacts due to project implementation, and time when the project was not operating.

Health problems associated with both indoor (household) and outdoor air pollution are quantified by comparing technology users and nonusers in the same community and calibrated on a per-person basis. Similarly, health problems due to a range of other causes, including sanitation, sexual violence, malaria, tuberculosis, work-life-balance, and maternal reproductive health, are also quantified on the basis of the questionnaire. Each category of health is coded according to specifications in the survey. For example, in the case of air pollution, coding ranges from 0 to 2 (with 2 being the best health) based on answers to two questions concerning air quality. The scores for each category, that is, the improvements over several health domains, are then combined into the overall IH units as follows:

$$\mathbf{IH = Wc,n,p * Pperf,c,p * [\ sum\ (A + B + C + D + E + F + G + H + I + J) - sum\ (K + L)].}$$

The terms are as follows:

IH = Health improvements for women during project operation
Wc,n,p = Number of women users
Pperf,c,p = Project performance

A = State of general health when project is operating as designed
B = Health problems due to indoor and outdoor air pollution
C = Health problems due to water quality
D = Health problems due to hazardous materials
E = Health problems due to sanitation
F = Maternal and reproductive health services for women
G = Incidence of sexually transmitted infections and related health services
H = Incidence of malaria and tuberculosis and related treatment and prevention
I = Incidence of physical and sexual violence
J = Work-life balance, social connection, and well-being
K = Existing health conditions
L = Negative health impacts as a result of project

A few aspects of the methodology remain challenging to evaluate. They include the following:

- It was challenging to fully evaluate the reliability and the comparability with which health problems are being self-evaluated.
- It is unclear, particularly for the air pollution–related problems, how accurate and/or verifiable self-reported health assessments would be.
- It is not evident that the scores for the diverse range of health problems assessed can be simply added up to a clearly interpretable unit.
- Survey design must be compliant with Clean Development Mechanism methodology, but this does not necessarily ensure that there would be adequate power to detect a difference in perceived benefits to health.

Based on a review of the projects that have applied the W+ Standard™, to date, none of the household energy-focused projects have included a focus on air pollution–related health benefits. Future opportunities where the methodology can be applied will shed light on the practical application and interpretation of results.

Public Health Sector Methodologies

This section summarizes quantification approaches commonly taken in the public health sector. The *Results-based Financing Indicator Compendium for RMNCAH Initiatives*[19] has compiled an illustrative list of indicators used by the public health sector to incentivize health care provider performance. These are based on manuals published by WHO, as well as case studies conducted by the World Bank, and reflect consistency in the health sector on indicators to be used for RBF. The compendium has organized indicators into four categories of measurable results:

1. Structural
2. Quality of services
3. Service use and intervention coverage
4. Health outcomes and impact

19 For more detailed information, see a literature review of relevant materials (Craig 2017): Evaluation Research on Results-Based Financing: An Annotated Bibliography of Health Science Literature on RBF Indicators for Reproductive, Maternal, Newborn, Child, and Adolescent Health.

TABLE 3.1: APPLICATION OF METHODOLOGIES IN EFFICIENT CLEAN COOKING AND HEATING INTERVENTIONS

APPLICATION METHODOLOGY FRAMEWORK	EXAMPLE OF APPLICATION	CURRENT OR POTENTIAL APPLICATION FOR ECCH INTERVENTIONS	EXAMPLE OF APPLICATION FOR ECCH INTERVENTIONS
Methodology for Averted Mortality and Disability Adjusted Life Years (ADALYs) from Cleaner Household Air–Gold Standard	Averted illness and death attributed to reduced air pollution exposure	Current	Lao PDR project
W+ Health Method	One project on food, fuel, and livelihoods includes focus on health benefits of no pesticide, clean water (nothing on air pollution)	Potential	Self-reported general health and problems due to air pollution (indoor and outdoor)
Reductions in Personal Exposure to $PM_{2.5}$	Health impact assessments for air pollution	Potential	Reductions in personal exposure to $PM_{2.5}$
Measures Consistent with Health Sector and Health Systems Performance	Increased use and quality of health services received	Potential	N/A: Measures are too distal from intervention
Measurement of Change in Health Expenses	Water and sanitation interventions	Potential	Reduced household energy-related health expenditures
Measurement of Direct Health Outcomes or Changes in Health-Seeking Behavior (health care facility-based measures)	Number of children immunized; number of women receiving antenatal care visits	Potential	Reduced visits to health care facility for respiratory illness; improved lung function
Self-reported Health Indicators and Outcomes (based on validated questions, e.g., DHS)	Reduced diarrheal disease associated with improved water and sanitation	Potential	Reduced respiratory illness in young children

Note: RBF = results-based financing; DHS = Demographic and Health Surveys (https://dhsprogram.com/data/).
Source: Authors.

The latter two are most directly relevant to the clean cooking sector.

The service use and intervention coverage collection includes indicators that track the number of people using a service and proportions of people who need a service and are using it. Illustrative indicators include the following:

- Antenatal care coverage: at least four visits (percent)
- Births attended by skilled health personnel
- Children with diarrhea receiving oral rehydration solution
- Immunization coverage rate by vaccine for each vaccine in the national schedule
- Intermittent preventive therapy for malaria during pregnancy

- Percent of girls vaccinated with three doses of human papillomavirus vaccine by age 15 years
- Percent of infants of human immunodeficiency virus (HIV) positive mothers receiving antiretroviral medicines for prevention of mother-to-child transmission at birth
- Percent of pregnant women who were counseled and tested for HIV and know their results
- Percent of women who received at least two doses of tetanus-toxoid vaccine in their last pregnancy
- Percent of service delivery points providing youth-friendly services
- Postpartum care coverage
- Service utilization
- Use of specified sexual and reproductive health services by young people
- Vitamin A supplementation coverage

The health outcomes and impact collection includes indicators that monitor change in the health status of an individual, group, or population attributable to a planned intervention or series of interventions, regardless of whether such an intervention was intended to change health status. This collection includes measures of morbidity and mortality. The indicators include the following:

- Adolescent fertility rate
- Case fatality rate for diarrhea
- Case fatality rate for pneumonia
- Caesarean sections as a percent of all births
- Children under 5 years who are underweight
- Children under 5 years who are overweight
- Children under 5 years who are stunted
- Children under 5 years who are wasted
- Facility neonatal mortality rate
- Fatality rate among hospitalized children under 5 years of age
- Hospital admission rates
- Incidence of low birth weight among newborns
- Institutional maternal mortality ratio
- Intrapartum or fresh stillbirth rate
- Percent of infected infants born to HIV-infected mothers
- Perioperative mortality rate

The ADALYs approach aspires to fit in the fourth category of measurable benefits, namely health outcomes and impact. At the same time, as the quantified indicator quantifies a change (ideally, a reduction) in exposure, it seems that the approach may actually be most consistent with the third category, service usage and intervention coverage.

Insights from the Field: The Lao People's Democratic Republic

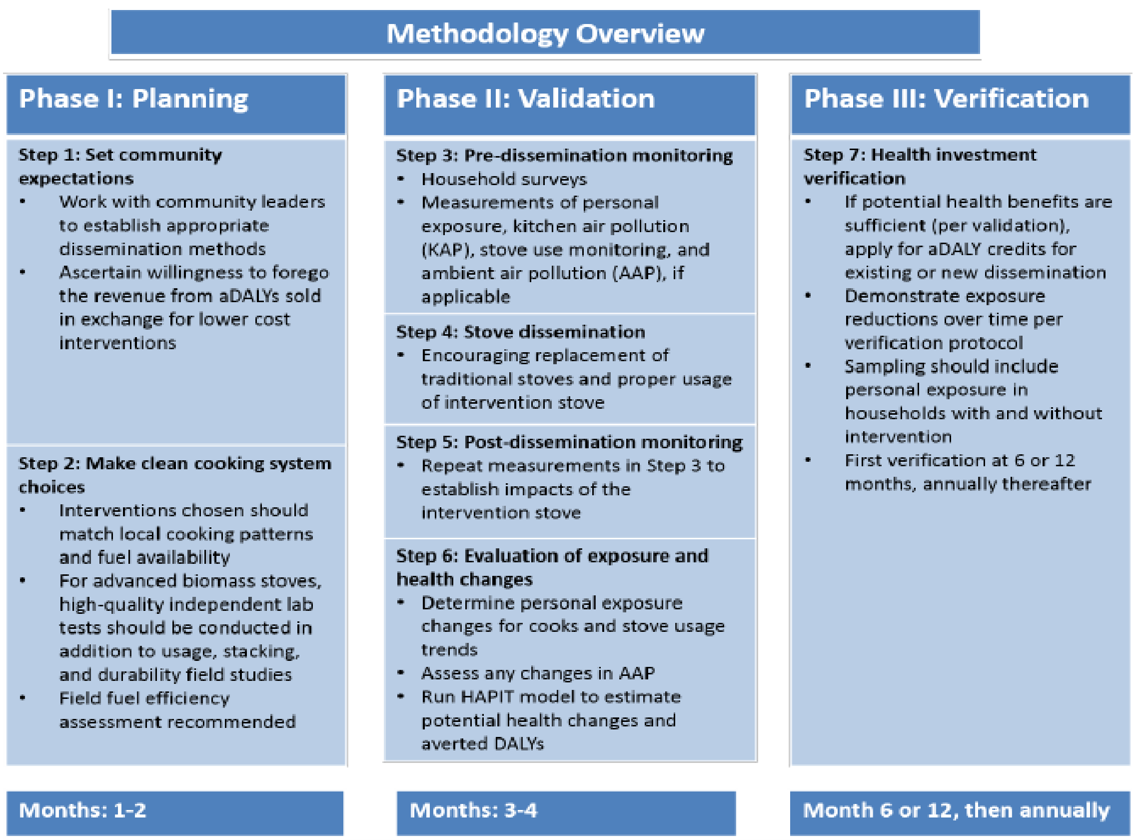
Much of the development and refinement of the ADALYs methodology was informed by the World Banks's field experience in Lao PDR led by colleagues from UC Berkeley and Berkeley Air Monitoring Group in 2015.

Their recommendations were categorized in a three-phased approach:

1. **Program planning:** This includes setting community expectations and obtaining stakeholder support for the program, with particular focus on the distribution of the resulting revenue between developers and communities.

2. **Validation study:** This entails validation study requirements, in which specific air pollution, demographic, and programmatic data are collected from the field and subsequently used to model changes in health due to the intervention in terms of ADALYs. In particular, recommendations for this phase focused on how best to establish what changes in air pollution exposure occur in households with the intervention technology compared to those with the old cooking system, and then how to convert these changes in air pollution exposures to health impacts using the web-based HAPIT. HAPIT enables the use of the best available health effects studies worldwide and methods from the Global Burden of Disease, giving further credibility to expected benefits from the public health perspective.
3. **Annual ADALY verification:** This summarizes recommended components for a final verification phase, during which field checks are performed to confirm that the validation study results continue to apply. Figure 3.3 summarizes recommendations by phase.

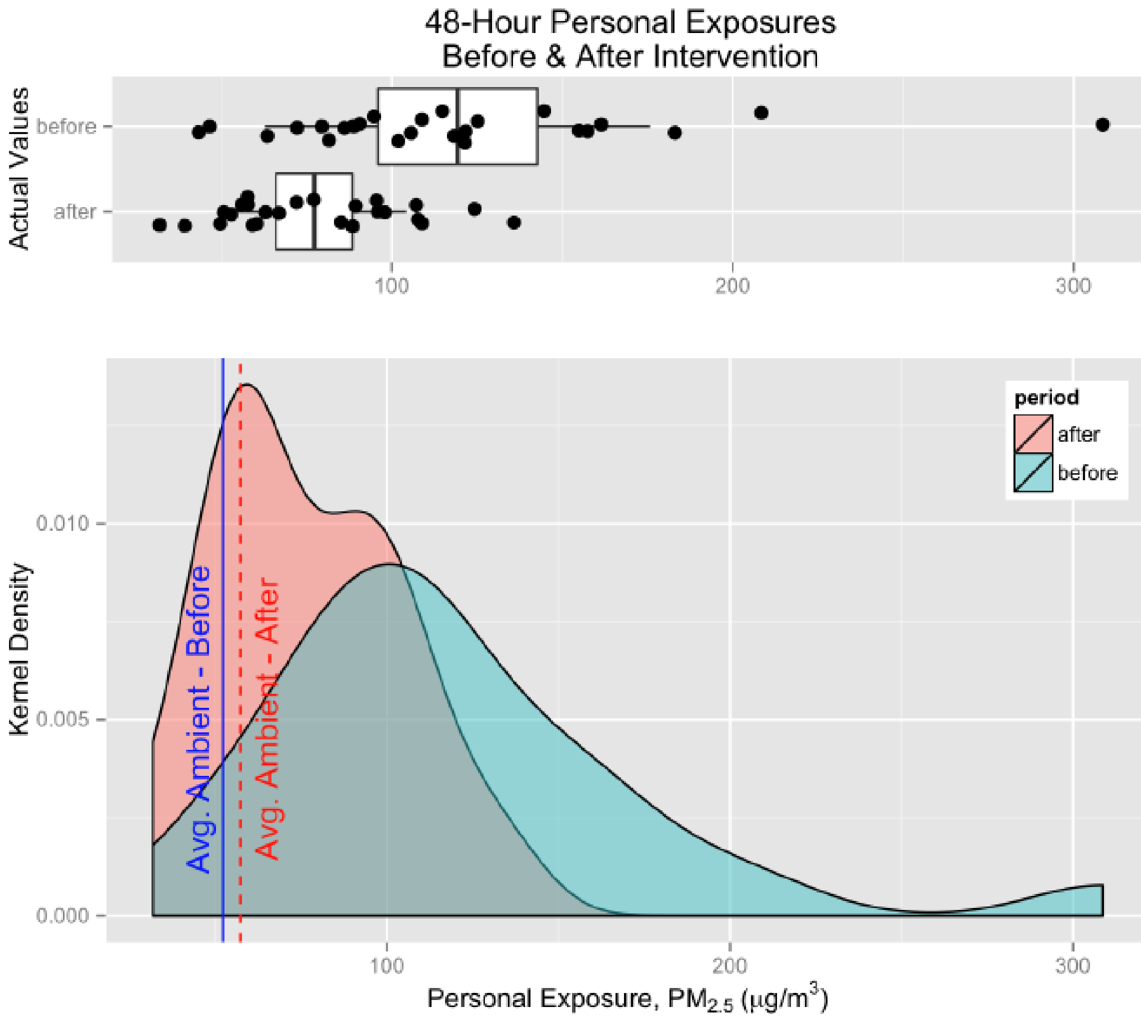
FIGURE 3.3: SUMMARY OF RECOMMENDATIONS BY PHASE, LAO PDR CASE STUDY



Source: Smith K.R et al 2015.

In addition, a huge contribution of this work was the demonstration, under real-world settings, of how measurements of personal exposure before and after the intervention could be made practically and then applied to estimate the expected changes in exposure associated with the intervention at the population level (Figure 3.4).

FIGURE 3.4: PERSONAL EXPOSURE AND AVERAGE AMBIENT MEASUREMENT RESULTS, LAO PDR CASE STUDY



Source: Smith K.R et al 2015.

3.2 IDENTIFICATION OF STRENGTHS, GAPS, AND LIMITATIONS

Table 3.2 summarizes the strengths and weaknesses of the reviewed methodologies.

TABLE 3.2: ASSESSMENT OF HEALTH METHODOLOGY AGAINST THE PRESELECTED CRITERIA

CRITERIA	PURPOSE	ADALYS METHODOLOGY	PERSONAL EXPOSURE TO $PM_{2.5}$	MEASURES CONSISTENT WITH HEALTH SECTOR & HEALTH SYSTEMS PERFORMANCE	MEASUREMENT OF CHANGE IN HEALTH EXPENSES	MEASUREMENT OF DIRECT HEALTH OUTCOMES & CHANGES	SELF-REPORTED HEALTH INDICATORS & OUTCOMES
Cost Effectiveness	While the methodologies or approaches shortlisted will be robust and have environmental integrity embedded in their design, their profitability for practitioners and users will be essential. Among others, the key determining factors include monitoring requirements such as field or lab-based testing, surveys, minimum sample size, enabling infrastructure including monitoring expertise, availability of testing facilities across geographies, monitoring-equipment costs, and other resources.	Requires pre- and post-intervention field measurement of personal exposure to $PM_{2.5}$ and stove usage measurement. Although the monitoring requirements enhance the robustness of the methodology, they are resource intensive. Further, there is a lack of requisite enabling infrastructure such as monitoring expertise, availability of testing facilities across geographies, and the cost of monitoring equipment.	Similar to the ADALYs methodology, monitoring of reductions in personal exposure to $PM_{2.5}$ is a resource-intensive method.	Depends on the current capacity of the health system and can be cost-prohibitive (Castilia 2015)	Inexpensive on a per household basis	Outcomes include hospital respiratory admissions, changes in average blood pressure, and changes in health-seeking behavior (health care facility-based measures) (IOD Parc 2018). This approach depends on the current capacity of the health system.	Self-reported health indicators and outcomes based on validated questions (Castilia 2015); this approach is inexpensive on a per household basis.
Scalability	Methodologies and approaches will be assessed for their potential to grow projects effectively.	Yes, this methodology can be explicitly developed to scale.	No, it is too resource intensive to be conducted at scale.	Yes, although the relevance of scalable measures is a bigger challenge	Yes, would be more robust if conducted at scale	Yes, would be more robust if conducted at scale	Yes, would be more robust if conducted at scale

CRITERIA	PURPOSE	ADALYS METHODOLOGY	PERSONAL EXPOSURE TO $PM_{2.5}$	MEASURES CONSISTENT WITH HEALTH SECTOR & HEALTH SYSTEMS PERFORMANCE	MEASUREMENT OF CHANGE IN HEALTH EXPENSES	MEASUREMENT OF DIRECT HEALTH OUTCOMES & CHANGES	SELF-REPORTED HEALTH INDICATORS & OUTCOMES
Replicability	The reference methodologies and approaches should enable replicability. Projects in different geographies, of different scales, and using a range of ECCH interventions should all be able to use these methodologies.	Yes	Yes, if resource limitations are overcome, exposure reduction is a common metric.	Possibly. There are context-specific considerations.	No. There are context-specific considerations.	Yes	No. Too many factors can influence reporting bias, including competing risk factors and perceptions.
Robustness	The methodologies will be assessed for robustness for quantification and verification of the impact and also whether they have been developed in consultation with a wide variety of stakeholders, including subject experts.	Yes	Yes	No	No	No	No
Compatibility	Ideally, application of the methodology should be compatible with methods used for verifying other impacts.	Yes	No	No	No	No	No

CRITERIA	PURPOSE	ADALYS METHODOLOGY	PERSONAL EXPOSURE TO $PM_{2.5}$	MEASURES CONSISTENT WITH HEALTH SECTOR & HEALTH SYSTEMS PERFORMANCE	MEASUREMENT OF CHANGE IN HEALTH EXPENSES	MEASUREMENT OF DIRECT HEALTH OUTCOMES & CHANGES	SELF-REPORTED HEALTH INDICATORS & OUTCOMES
Operational Feasibility	Assessment of the operational feasibility when bringing up to scale: This will consider aspects of the cost-effectiveness, complexity, and robustness of the methods.	This is the best option at present, as it integrates exposure indicators with the most comprehensive epidemiologic evidence.	It is the most accurate indicator of risk but is difficult to align with conventional outcomes familiar to health sector.	Not relevant to this sector	Given sampling considerations, this is feasible only at an extremely large scale (several thousand households).	Given sampling considerations, this is feasible only at an extremely large scale (several thousand households). Different indicators may work over different time horizons, making measurement of impact more challenging.	Unreliable measures lead to difficult-to-interpret results. Results are highly influenced by external factors that are difficult to predict and quantify.

Source: Authors.

3.3 RECOMMENDATIONS

The following recommendations are based on the review of the ADALY approach—considering implementation experience to date—the W+ approach, potential approaches commonly taken in the public health sector, and potential approaches considered by the household energy sector:

- Experiences in the water, hygiene, and sanitation sectors, where information on reduced diarrheal disease is the parallel to reduced child respiratory illness in the clean household energy sector, have demonstrated repeatedly the limits of self-reported information on health outcomes and indicators. Information on self-reported measures are easy to collect using validated questions via routine household surveys. Despite that, they are subject to recall bias and are often inaccurate. In addition, in the short term, external factors that can be difficult to predict or quantify can heavily influence the reliability of these measures.
- Measures of changes in expenditure on health would be subject to the same limitations, with the added bias resulting from implicit assumptions on how household energy practices have affected health.
- Parties that are interested in demonstrating health benefits, particularly clean cooking advocacy and implementing organizations, should take into account that they will not be able to accurately measure direct indicators and/or outcomes in these settings. There is often a misperception, particularly outside of the health community, that shifting to a cleaner cooking technology will result in measurable changes to key health indicators in the short term. Desired changes could include improvements in lung function or blood pressure, or changes in the incidence of air pollution-related illness. Unless researchers carefully design health evaluation studies with the primary aim of assessing these changes, however, these perceived benefits are unlikely to be observed.[20] Moreover, as with the self-reported measures, in the short term, background disease rates, especially for respiratory illness, can be quite variable and influenced by other factors unrelated to household energy. These fluctuations could cause misleading results that would likely reduce the ability to measure health benefits and jeopardize the ability to demonstrate project impacts.
- Other RFBs for health commonly use measurement of direct health indicators at health care facilities, such as the number of children immunized. The ability to accurately measure these indicators, however, is dependent on the current capacity of the local health system. In addition, detecting changes in health would require larger sample sizes at scale—likely orders of magnitude larger than any of the household energy projects are likely to be. Different indicators would be appropriate over different times, further limiting the ability to quantify a comprehensive set of impacts. Compatibility that may result from measuring other impacts would also be compromised.
- Given that monitoring exposure is one of the costlier and resource-intensive methodological components, we recommend looking at new efforts to estimate exposures based on more simplified or indirect (proxy) measures. These include models developed by Berkeley Air with

---

20 Even with carefully designed epidemiologic studies, large numbers of households are needed to detect effects. Moreover, in the absence of a truly clean intervention, intended effects may not be observed. For example, a randomized control trial of improved biomass stoves in Malawi enrolled over 8,000 household, but was unable to observe effects on child pneumonia (Mortimer et al. 2016). A more recent trial, currently under way and focused on evaluating the use of LPG, a far cleaner cooking fuel, across four countries (Emory 2016). While this trial is designed to maximize reductions in exposure to household air pollution, given prevalence of child pneumonia and other key health outcomes, over 3,200 households have been enrolled to ensure sufficient power.

support from the World Bank and the Clean Cooking Alliance, as well as by investigators of the Household Air Pollution and Health (HAPIN) trial. Evaluate those new efforts, when available, to determine their accuracy, the implied uncertainty they would produce, as well as their feasibility for application.

- One simple option would be to have $PM_{2.5}$ exposure reductions be the outcome metric, rather than ADALYs. This approach would potentially provide a more readily understood impact, without the assumptions built into HAPIT. Conversely, such an approach would account for neither the differential health benefits achieved across different segments of the exposure-response relationship nor background health data. It would also not be possible to combine this metric with health benefits accrued from other reductions in environmental health risks, such as access to clean water.
- The ADALY approach is likely more informative, as it allows for a better comparison of potential benefits expected with the exposure reductions observed.
- As the ADALYs approach relies on what some may feel is a leap of faith from exposure reductions to health benefits, include an additional indicator to align with indicators related to service use and/or intervention coverage. Information on usage is already being collected to calculate the ADALYs.
- Adopt technology usage measurements as an indicator. This may be measured with thermal sensors, such as stove-use monitors, or by quantifying fuel use at the household level. Stove usage is relatively less resource intensive to assess than other parameters. At the same time, usage alone should not be considered sufficient to demonstrate health benefits. The reason is that health gains require significant measurable changes in exposure.

Much more detailed discussion of the strengths and limitations of approaches used more broadly by the health sector can be found in Castilia (2015) and IOD Parc (2018)—two recent reviews of RBF for health.

4 | GENDER IMPACTS

Lack of access to modern energy affects the health of women and girls and influences how they use their time and other resources. Rural women and children often spend long hours gathering fuel in sometimes dangerous situations. In resource-poor urban and peri-urban communities, fuel purchases have a severe impact on household economics and on women's lives. Women play a crucial role in the adoption of cleaner, modern household solutions because of their responsibility for managing domestic energy and cooking. Less time spent collecting fuel and cooking may benefit women in several ways: they could spend more time with their children, pursue income-generating or educational opportunities, and increase healthful leisure activities and rest. These can contribute to poverty alleviation and enhanced well-being. Unpaid work, including collecting fuel and cooking, is a major cause of gender inequality, which is the target of Sustainable Development Goal (SDG) 5.

Co-benefits from efficient, clean cooking and heating (ECCH) interventions could advance SDG 5: Gender Equality through the following targets:

> **SDG Target 5.4:** Recognize and value unpaid care and domestic work through the provision of public services, infrastructure and social protection policies and the promotion of shared responsibility in the household and the family as nationally appropriate
>
> **SDG Target 5.B:** Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women

The prevailing view in both clean energy and gender sectors is that ECCH programs offer public goods in climate mitigation, public health, and improved livelihood and gender equality. However, the mechanisms by which ECCH, particularly a cleaner cookstove, might improve "gender equality" are largely undetermined and untested. Public policy demand for field-tested gender assessments of all kinds of clean energy is increasing rapidly. For example, the government of Kenya (2019) just released an ambitious Gender Energy Policy. It includes commitments to develop gender-disaggregated energy databases and to have a comprehensive assessment of all clean energy and clean cooking technologies by 2023.

The purpose of the gender element of this review is to improve the evidence base on whether household-level adoption of cleaner cookstoves provides gender co-benefits. More specifically, can adoption of cleaner cookstoves help improve gender equality and/or enhance women's empowerment? Following Kabeer (2018), the foundational "theory of change" is an understanding that particular interventions, such as cookstoves, have the potential to improve women's livelihoods in a way that not only enhances women's practical capacity to look after themselves and their families but can also provide a strategic pathway for change in other spheres of their lives. This could occur in two spheres:

- **Human** (labor, time, knowledge, "soft" and "hard" skills and information, building confidence)
- **Material** (financial services, income, productive assets of various kinds) **or social** (access to those in power, connections with others)

Empowerment in either of these spheres is a function of the agency women acquire over different aspects of their lives.

4.1. Selection of Methodologies and Tools for Review

This review provides assessment, critiques, and analyses of related methodology and field studies. It draws from all the major gender-focused methodological models, frameworks, and indices available. It also includes an in-depth review of a subset of illustrative field studies that provide insight into field monitoring of gender impacts and point to best practices. The selected studies have a primary gender co-benefit focus and include those identified by the World Bank team to be of particular interest. All discussions are supported with evidence from peer-reviewed literature (Table 4.1). Appendix B includes snapshots of the guidance that can be drawn from these sources.

TABLE 4.1: LITERATURE REVIEWED ON GENDER IMPACTS

METHODOLOGY	METHODOLOGY TYPE	ASSESSMENT APPROACH
Women Organizing for Change in Agriculture and Natural Resource Management (WOCAN)/ W+ methods	Framework & Measurement	Survey algorithm to convert measured results and outcomes to women's empowerment "credits" Requirements and guidelines to enable the design of project-specific monitoring and a quantification approach for gender claims
Gold Standard Gender Equality Requirements and Guidelines	Framework	Survey and other methods Requirements and guidelines to enable the design of project-specific monitoring and a quantification approach for gender claims
Clean Cooking Alliance and International Centre for Research on Women (ICRW) Social Measurement Impact System	Measurement & Framework	Survey by phone and/or in person Customized survey templates for both cookstove and fuel value chain and end users
The Women's Empowerment in Agriculture Index (WEAI)	Measurement index	Survey and provision for time diary
Impacts and Effects of Improved Wood Burning Stoves on Time Use and Quality: An Experimental Study in Rural Kenya. Baseline Results: Final (Clean Cooking Alliance and Berkeley Air 2019)[a] ***Effects on Gender-Related Outcomes after the Introduction of Improved Cookstoves in Rural Zambia*** (C-Quest Capital and Berkeley Air Monitoring Group 2020) ***Lao PDR Clean Cookstove Initiative*** (World Bank 2018) ***Gender and Livelihoods Impacts of Clean Cookstoves in South Asia*** (Practical Action and Clean Cooking Alliance 2015)	Project-specific (field studies)	Multiple methods, including survey, focus group discussions (FGDs), stove-use monitoring, and photo elicitation

[a] Additional reference: Jagoe, K., Rossanese, M., Charron, D., Rouse, J., Waweru, F., Waruguru, M., Delapena, S., Piedrahita, R., Livingston, K., & Ipe, J. 2020. Sharing the burden: Shifts in family time use, agency and gender dynamics after introduction of new cookstoves in rural Kenya. Energy Research & Social Science, 64, 101413. https://doi.org/10.1016/j.erss.2019.101413
Source: Authors.

Women Organizing for Change in Agriculture and Natural Resource Management (WOCAN)/ W+ Standard™ Methodologies

The W+ Standard™ is the first women-specific standard to provide a metric and framework with indicators to systematically and comparatively measure results of development projects, of almost any type, in terms of whether those projects enhance gender equality and women's empowerment. It was created to provide project developers with a clear framework to improve their project design, measure, and report on progress on women's empowerment, and translate this progress into a financial value through the monetization of W+ units (www.wplus.org/projects/). Women's empowerment ~~are~~ is measured in six domains: time savings, income and assets, health, leadership, education and knowledge, and food security (Table 4.2).

TABLE 4.2: THE DOMAINS OF EMPOWERMENT AND W+ STANDARD™ METHODS

DOMAIN	SCOPE OF W+ METHOD™
Time Savings	The time method enables project developers to document the increase in women's discretionary time, by measuring shifts in the use of time away from lower-value activities and toward higher-value activities. Representative samples of time-use survey results from users are compared with results from nonusers from the same or a comparable community.
Income and Assets	The income and assets method assesses measurable and verifiable improvements in access to resources and control of earned assets by women in project communities. Income and asset increases are determined by comparing representative samples of survey results from users against the baseline.
Health	The health method enables project developers to evaluate how the project has improved the overall health of women. Representative samples of health survey results from users are compared with results from nonusers from the same or a comparable community.
Education and Knowledge	The education and knowledge method enables project developers to evaluate how projects have helped increase women's knowledge and skills, as well as the transmittal of those to others in the community. Knowledge increases are determined by comparing the baseline results with the measurement results generated a period determined by the project.
Leadership	The leadership method enables project developers to evaluate how projects result in increased decision-making roles for women, in the context of the project itself or in households and communities. Baseline survey results are compared with results generated after aa period determined by the project.
Food Security	The food security method enables project developers to evaluate how the project has decreased the quantity and quality of food insecurity in households

Source: WOCAN https://www.wplus.org/w-domains.

The W+ Standard™ provides methods in each domain to measure and quantify projects' outcomes on women's lives, as summarized in Table 4.2. Each method provides project organizers with baseline survey-based methodologies, templates, and guidelines to assess progress in gender equality and enhanced empowerment achieved through their project. Questionnaires are available for proponents that have registered projects with the W+ Standard™ (https://www.wplus.org/w-domains).

This methodology also provides an algorithm to measure the impact of an observed result, such as increased food security, on women's empowerment. If these results are certified by independent auditors, the W+ Standard™ provides an algorithmic method to convert the empowerment results into W+ credits that can be sold globally to investors, companies, and individuals. At least 20 percent of the money received from W+ Standard™ unit sales is returned directly to women's groups in the communities that hosted the projects.

WOCAN currently (2019) has nine W+ Standard™ projects certified or in process of being certified (www.wplus.org/projects).

Of the four certified and completed W+ Standard™ projects, only two involved improved cookstove interventions, and both of those measured primarily the time domains.

There is not yet a completed W+ Standard™ cookstove project that directly measures any of the health empowerment domains. Two current projects, however, are measuring health benefits in biomass and corporate social responsibility contexts.

Gold Standard Gender Equality Requirements and Guidelines

The Gold Standard Gender Equality Requirements and Guidelines were released in 2018. This standard presents requirements and guidelines for gender certifications at two levels:

1. **Gender-Sensitive Requirements (mandatory)** ensure that all projects conduct gender safeguards assessment, including reducing risks, minimizing harm, and recognizing gender differences and gender-sensitive stakeholder consultations. If those requirements are met, the project can claim to be gender sensitive.
2. **Gender-Responsive Guidelines (optional)** outline the requirements for projects seeking performance level certification to claim Gold Standard Certified SDG Impacts under SDG 5.

Performance-level certification is for projects undertaking actions to intentionally address gender gaps and contribute to gender equality and women's empowerment. It requires the project to do the following four activities:

1. Conduct deeper gender analysis
2. Establish gender-targeted project goals and actions
3. Identify project-specific gender indicators[21] and monitoring parameters to measure change
4. Monitor project performance against the established baseline

The guidelines outline an approach to identify the context-specific gender issues and factors that contribute to gender inequalities in the targeted population. The gender analysis leads to establishing the project baseline and identification of project-relevant SDG targets.

Projects then select the relevant action(s) to close the gender gaps and identify corresponding gender indicators. The project designs the monitoring plan by selecting indicators to measure performance and track progress toward equality enabled by the project, as reflected in chosen indicator. The guidelines provide references to help identify monitoring indicators.

21 Gender indicators are established to measure and compare the situation of women and men over time. Gender indicators can refer to quantitative indicators (based on statistics broken down by sex) or to qualitative indicators (based on women's and men's experiences, attitudes, opinions, and feelings).

The guidelines group the gender goals under economic and social empowerment categories (Table 4.3), potential corresponding project actions, and examples of gender indicators. The project developer can also propose indicators.

TABLE 4.3: GOALS AND POTENTIAL ACTIONS—GOLD STANDARD GENDER EQUALITY REQUIREMENTS AND GUIDELINES

GOALS	PROJECT ACTIONS
Economic Empowerment Goals	
Income and Expenditures	Closing gender gaps in earnings and income-generation opportunities
Economic Assets	Closing gender gaps in asset access, ownership, and control Absolute increase in women's relative control and ownership of an asset
Quality Employment	Closing gender gaps in labor market segregation and paid and unpaid employment
Education	Closing literacy gap between boys and girls and creating parity in enrolment rates in primary, secondary, and tertiary education
Social Empowerment Goals	
Individual and Community Empowerment (incl. meaningful participation and leadership and stronger social networks and agency)	Closing gender gaps in women and men's participation and leadership and access to networks Closing gender gaps in leadership positions and decision-making at the individual, household, community, and political levels
Applied Skills and Training	Closing gender gaps and ending stereotypes in women's and men's access to applied skills and training
Secure Access to Health, Reproductive Health, and Health Rights	Closing gender gaps in accessing health services and entitlements, expressed as a ratio
Access to Infrastructure Services and Technologies	Closing gender gaps in access to infrastructure services
Rest and Leisure	Closing gender gaps in women and men's unpaid time poverty and labor burden

Source: Gold Standard 2018.

While all projects certified as Gold Standard for the SDGs must meet the Gender-Sensitive Requirements for project design, the Lango Safe Water project is the only project, to date (2019), that has applied the full Gender-Responsive Guidelines.[22] The project involves rehabilitation of boreholes to provide clean water access to the local communities in northern Uganda. The project monitored the gender outcomes and has verified positive gender benefits under three domains:

1. Rest and leisure time poverty
2. Leadership (individual and community empowerment)

22 Gender- Responsive Guidelines are accessible at: https://www.goldstandard.org/blog-item/first-ever-gold-standard-certified-%E2%80%9Cgender-responsive%E2%80%9D-project

3. Safety (exposure to gender-based violence during water collection)

Clean Cooking Alliance Social Measurement Impact System

In 2016, Clean Cooking Alliance and ICRW released a comprehensive toolkit to enable enterprises promoting cleaner cookstoves and fuels to measure how their products empower women and create social change.

The Social Impact Measurement System is divided in two main pathways through which the cookstoves and fuels sector creates social impacts.[23] The first focuses on how involvement in clean and/or efficient cookstoves and fuels value chains can expand livelihood opportunities for women and men. There is a special emphasis on how the involvement of women can enhance their social and economic empowerment. The second identifies how adoption of clean and/or efficient cookstoves and fuels can translate into improvements in women's social and economic well-being, as well as that of their households.

The measurement system follows a survey-based approach to measure livelihoods, social and economic empowerment, and household social and economic well-being impacts (Table 4.4). The survey template lists social impact indicators customized to each target group. The user group survey includes monitoring indicators for key impact areas such as livelihoods, adoption, time use, drudgery and safety and health, and household finances. Change is measured by comparing baseline and follow-up survey outcomes of the indicators.

A recent application of the framework was presented by ICRW (2018). The study assessed the social impacts of a cookstove program in Rwanda's Kigeme refugee camp. Participants reported reduced cooking time, fewer burns, less coughing and eye irritation, and feelings of improved safety. Customers also reported a decrease in drudgery, measured as the amount of effort to perform cooking-related tasks. The cost of fuel was reported as the main barrier.

The Women's Empowerment in Agriculture Index

The Women's Empowerment in Agriculture Index (WEAI; http://weai.ifpri.info/) was developed in 2012 as a tool to reflect changes in women's empowerment that might result from the United States government's Feed the Future Initiative, which commissioned WEAI's development. WEAI has also been used extensively since 2012, however, by a variety of organizations to assess empowerment and gender parity in agriculture and to identify areas in which empowerment needs to be strengthened.

WEAI is a survey-based index designed to measure the empowerment, agency, and inclusion of women relative to men in the agricultural sector at an aggregated country or regional level. It is based on individual-level data collected by interviewing men and women in the same households.

23 Social impact is defined as "the positive and negative consequences of any actions on the well-being of an individual, his/her family, or his/her community. In relation to cookstoves and/or fuels, social impact consists of the ways in which participation in clean and/or efficient cooking value chains and the use of clean and/or efficient cookstoves and fuels alter or affect the ways in which people live."

TABLE 4.4: IMPACT DOMAIN AND IMPACT AREAS FROM THE CLEAN COOKING ALLIANCE AND ICRW FRAMEWORK

TARGET STAKEHOLDER	ORGANIZATION	EMPLOYEE OR ENTREPRENEUR	USER
Impact Domain	**Economic Well-Being**	**Women's Social and Economic Empowerment**	**Household Social and Economic Well-Being**
Impact Areas **(Indicators are provided for each impact area)**	Employment	Employment	Household economic stability
	Income	Income	Usage and adoption, and cooking time
	Technical and business skills	Technical and business skills	Cooking: dynamics, drudgery, and safety and health
	Business and social networks	Business and social networks	Household fuel expenditure, time use, drudgery, and safety and protection
	Expanded access to and use of capital or credit	Expanded access and capital or credit	Income earned through productive use of the clean and/or efficient cookstove and fuel
		Agency	Status

Source: Adapted from Clean Cooking Alliance 2016 and ICRW 2016.

TABLE 4.5: THE DOMAINS AND INDICATORS IN WEAI AND A-WEAI

	ORIGINAL WEAI	A-WEAI
Domains	**Indicators** (10)	**Indicators** (6)
Production Decisions about agricultural production	Input in productive decisions	Input in productive decisions
	Autonomy in production	
Resources Access and decision-making power over productive resources	Ownership of assets	Ownership of assets
	Purchase, sale, or transfer of assets	
	Access to and decisions on credit	Access to and decisions on credit
Income Control over use of income	Control over use of income	Control over use of income
Leadership Leadership in the community	Group membership	Group membership
	Speaking in public	
Time Time use for productive and domestic tasks and satisfaction with the available time for leisure activities	Workload	Workload
	Leisure	

Source: WEAI 2020.

Its five domains of measurement are agricultural production, resources, income, leadership, and time. They comprise 10 indicators (see Table 4.5). WEAI was revised to shorten the interview and to modify questions difficult to implement in the field, while maintaining cross-cultural applicability. The streamlined version, known as Abbreviated WEAI (A-WEAI), retains the five domains of empowerment but consists of only six composite indicators, with weights for each indicator adjusted accordingly.[24]

The output of the index is a measure of empowerment that shows how many domains women can be empowered in. The index represents a snapshot, but if done sequentially, it can track progress over time (Alkire et al. 2013; WEAI 2020).

WEAI has 12 projects in its project subindex, none of which directly involves EECH, that deploy a standard survey that includes probes for women's "decision-making" capacity.

Insights from the Field

Time Use Study in Kenya, Clean Cooking Alliance and Berkeley Air Monitoring Group

This 2019 project aimed to identify and understand fluctuations in time-use patterns and changes in the quality of time for women in 55 households in rural Kenya after a switch in cooking technologies. To fully understand and quantify the impact of the new technology along all the potential causal pathways, an in-depth exploration was implemented. It uses an explanatory sequential mixed-method design to first collect quantitative data, including survey and stove-use monitoring, and then apply qualitative research methods to explore and interpret them. Key findings included the following:

- Women reported spending just over an hour less per day cooking at the endline survey compared to baseline.
- Stove-use monitor data showed a consistent but not exclusive use of the new stove.
- Participants reported time spent collecting fuel almost halved 10 weeks after receiving the stove.
- Participants reported a partial shift in cooking to teenage children and husbands.
- When their time was saved, the majority of the participants reported that they used this for economically productive tasks.
- Impacts on time quantity and quality are possible without complete displacement of traditional cooking technology.

Effects on gender-related outcomes after the introduction of improved cookstoves in rural Zambia, C-Quest Capital and Berkeley Air Monitoring Group

The aim of this 2020 study was to measure and understand any changes in time-use patterns and perceived levels of drudgery after the installation of a TLC-CQC stove in 75 rural Zambian households. While the focus was on the main cook, the study design also allowed for the exploration of effects and changes in all household members.

24 The project-level Women's Empowerment in Agriculture Index (pro-WEAI) is a new tool that builds on WEAI to meet projects' impact assessment need to measure women's empowerment. The pro-WEAI version uses A-WEAI and adds specialized project-relevant modules, designed and tested by the WEAI team, as well as an enhanced livestock module and an add-on module specific to nutrition and health projects. Pro-WEAI is still undergoing pilot testing. See IFPRI, "pro-WEAI," http://weai.ifpri.info/versions/pro-weai/.

The exploration and measure of drudgery applied multiple questions that probed about perceived hard work, levels of effort, and enjoyment, together with an all-encompassing question about any task that was "very hard work, either physically or mentally, was time consuming, repetitive, AND unavoidable." This technique aimed to identify cross-cutting, recurring themes that would illustrate the drudgerous tasks.

Key results include the following:

- Data showed evidence of a significant reduction in the self-reported time spent cooking, cleaning the kitchen area, and collecting and preparing fuelwood.
- Participants described multiple pathways through which the TLC-CQC stove saved varying amounts of time, including the ability to simultaneously cook two dishes, faster cooking of food, and a shift of cooking responsibilities to other household members.
- The main cook was the person who was mostly responsible for the collection of fuelwood in all households, meaning she experienced most of the time burden from these activities and, consequently, the time savings from the new technology.
- Most women reported they used saved time resting and sleeping. Very few women reported using extra time in extra income-generating activities.
- The majority of women believed they had drudgerous activities in their everyday life. The most frequently reported tasks at baseline were working on the land and fuelwood collection. Fuelwood collection was seen as drudgerous by nearly 40 percent of the participants before the introduction of the TLC-CQC stove, falling to less than 5 percent afterward. Although not frequently cited as a drudgerous task at baseline, cooking was not viewed as drudgerous by any participants after installation of the stove, and was, in fact, the activity people reported enjoying most at both baseline and follow up.
- Even with the time saved from collecting fuelwood, the women still spent a considerable amount of time engaged in tasks perceived as drudgerous. These drudgerous hours were mostly spent tending the field and gardens.

Overall, the purpose of the study was to create a Sustainable Development Verified Impact Standard (SDVista) methodology in partnership with Verra. It would quantify and sell forward time savings to provide funds to support women in reaching a higher and sustainable level of prosperity resulting from productive use of time saved. This methodology concept has been approved by Verra, and the full methodology is currently under development.

Lao PDR Improved Cookstove Initiative, World Bank

This World Bank initiative was launched with support from the Energy Sector Management Assistance Program (ESMAP), which has now transitioned to investment-project financing. It introduced new cookstoves to replace charcoal and wood-burning cooking fires in three Laotian provinces.

The team conducted a gender and consumer acceptance survey at baseline and postintervention to measure gender outcomes and consumer acceptance of the adoption of the Tier 4 stoves. The survey was conducted in partnership with the Poverty Reduction Fund and World Food Program in villages in Houaphan province and schools in Nalae district of Luang Namtha province. The evaluation sought insights into the daily lives of household members and school cooks who received and used the cookstove. How much time did they save? What activities replaced time previously spent cooking and collecting fuel? How was family health affected? What other changes occurred in family life?

A baseline survey was conducted November 7–11, 2017, with 40 households in Houaphan and 10 households and 50 school cooks in Nalae. An endline survey took place March 19–23, 2018, in Nalae and April 26–28, 2018, in Houaphan.[25] The results of the study are summarized in Appendix B.4 and illustrate time savings, reduction in drudgery, and so forth.

Gender and Livelihoods Impacts of Clean Cookstoves in South Asia, Practical Action and Clean Cooking Alliance

This 2015 study aimed to measure the gender impacts of clean cooking solutions as well as women's involvement in improved cookstove market systems in Bangladesh, India, and Nepal. Focusing primarily on biomass cookstoves, surveys, focus group discussions, key informant interviews, and workshops were used to collect data.

The results showed the uptake of improved cookstoves contributed to fuel savings and the reduction of household air pollution. This resulted in a reduction of drudgery through reduced fuel collection, as well as time saving and health improvements.

Time savings allowed for increased involvement in social and family activities. Due to the reduced drudgery and time saving, women reported needing less support from their children for household chores and fuel collection. Cooks with the improved cookstove were more likely to send their children to school than those with traditional cookstoves.

4.2. Identification of Strengths, Gaps, and Limitations

The methodologies and framework models were fundamentally structured around two core elements: (i) impact domains defining women's empowerment and gender equality and (ii) a range of indicators to monitor the results and measure the outcome of actions. In the following section, we first discuss the domains of empowerment and gender equality covered by the different methodologies. This is followed by indicators in the context of clean and improved cooking interventions.

Domains of Empowerment and Gender Equality

Despite the breadth of conceptual thinking about empowerment, households, cookstoves, and gender inequality, we are still in the preliminary phase of developing robust toolkits to measure gender co-benefits of ECCH interventions beyond the survey method.

- **WOCAN and Clean Cooking Alliance, with ICRW**, have impressive, conceptually developed frameworks for measuring empowerment across several domains, primarily through survey techniques and an algorithm (the W+ Standard™) for turning findings of empowerment or livelihood improvement into monetized W+ Standard™ credits, based on living-wage metrics. The full methodology, however, has not yet been used in any improved cookstove project. Though not required, W+ Standard™ credits can be stacked onto carbon credits generated

25 Details are featured here https://www.worldbank.org/en/news/feature/2018/04/20/clean-cookstove-innovative-financing-lao-pdr-project-promise-results-women-climate (World Bank 2018) and in the video https://www.youtube.com/watch?v=fnfhhaM9txo&feature=youtu.be.

through carbon standards, including the Clean Development Mechanism and other Voluntary Carbon Standards. WOCAN has a relationship with Verra that allows for a streamlined approach to simultaneously measure women's empowerment and carbon emissions reductions. This results in W+ Standard™ labeled "verified carbon units."
- **WEAI** is not attempting to develop an overall empowerment measurement toolkit beyond what is needed to develop its hallmark index. Its main methods involve surveys and are designed to yield a "scored" index of equality to inequality.
- **Gold Standard** presents a framework approach broadly applicable in the context of climate projects issuing carbon credits. Similar to other frameworks, it is designed around a range of economic and social empowerment goals.

The methodological models make provisions for an assessment of empowerment and gender equality outcomes. To date, these provisions have not yet yielded a robust evidentiary base on these relationships. Potential reasons for this include the following:

- There are many aspects of empowerment that are difficult, if not impossible, to measure. Empowerment is as much an intrinsically self-reflective condition as an extrinsically measurable characteristic.
- Evidence of empowerment or improved gender equality typically take longer to emerge than the time frame of any single field study.
- All the gender empowerment co-benefit methodological toolkits have been developed relatively recently (since 2012) and have not yet been thoroughly field-tested.

The empowerment domains in the context of ECCH are discussed in the following sections.

Time as lever for empowerment

Time saved is a "result" metric, not an impact measure. The empirical measurement of time-use patterns and time saved *in itself* is not necessarily meaningful in terms of inferring livelihood improvements or enhanced gender equality. There are many reasons why time saved may not necessarily lead to women's empowerment or to any meaningful livelihood improvement:

- The time saved by new cookstoves is often quite minor, in some cases only minutes a day (Samad and Portale 2019).
- Time shifting and task expansion can result in "more work fills the vacuum."
- There is significant evidence that "labor-saving" devices do not always save time.

Nonetheless, time savings may be an enabler of equality and empowerment enhancement. Most of the literature examining the intersection between cookstoves and gender assumes, and in a few cases provides evidence, that the time saved by using an improved cookstove provides a pathway to enable gender empowerment and equity. The shared wisdom is that women use the time saved via cleaner cookstoves in activities that exemplify and yield enhanced empowerment. These activities include leisure, taking advantage of new capacity-building opportunities (for example, literacy classes), networking and socializing, and taking advantage of income generating opportunities.

The scholarly and practitioner literature on empowerment relations of cookstoves offers a cautionary note: "Obviously, there are limits to the breadth of transformation that can be expected from a single, small-scale intervention like the introduction of cookstoves" (Lehmann 2019) and, "Stoves are not techno-superheroes; cooking with better stoves will not enable poor women to resolve the structural causes of poverty, violence or climate change" (Abdelnour 2015). Project developers and implementers should be wary of the tendency to overreach in attributing women's empowerment benefits to ECCH interventions.

Empowerment and equality indicators embedded in time-use and allocation measures

While the theoretical framework for this review positions time saving primarily as a leveraging, strategic pathway toward other metrics of empowerment, time saving in itself *may* have embedded empowerment effects.

Understanding women's satisfaction with time (use, allocation, and sufficiency) brings an empowerment dimension into time measurement. WEAI, for example, specifically measures "satisfaction with time available for leisure" as one empowerment measure. The survey asks respondents if they are subjectively satisfied with their available time for leisure activities such as visiting neighbors, watching TV, listening to the radio, seeing movies, or doing sports. The United Nations Department of Economic and Social Affairs similarly emphasizes the importance of understanding women and men's satisfaction with their time and their agency over it. The existing survey-based evidence on how time saved is redeployed by women, however, or by "the household" is currently inconclusive (World Bank personal communications).

Changes in gender relations may turn up as a quantitative indicator through survey tools that measure whether men do more cooking with new improved cookstoves. Several studies, including the Clean Cooking Alliance and Berkeley Air Monitoring Group (2019) work from Kenya, suggest that this may be the case. This may not always represent an *improvement* in gender relations, however, if it represents male authority supplanting women's authority in their traditional domain. Nonetheless, it may signify a new loosening of gender norms. See Appendix C for further discussion on this topic.

Income and assets and empowerment

The prevailing perception in the empirical literature is that women are typically disadvantaged in market-based activities because of the large time burden of having to undertake both formal work and domestic duties (Lawson 2007, 2012; Mukuna 2015). Understanding whether time saved by adopting improved cookstoves can and does translate into improved economic opportunities for women is of compelling interest. All methodological model toolkits include improvements in economic status, income, or assets as possible empowerment domains.

There is considerable doubt, however, about the assumption that increased economic activity can be equated to gender equality. In fact, it has been shown that higher levels of economic development do not automatically lead to a more equal redistribution of unpaid care work between women and men, due to the persistence of restrictive gender norms that place the responsibility for domestic work and childcare on women. Indeed, adding formal economic opportunities into the mix for women may in fact add to their time poverty (Ferrant and Thim 2019).

Systematic and robust measurement of this domain is challenging and costly because income improvements typically manifest over a relatively long time and are best measured by a before-and-after analysis with a control group to allow for extrinsic influences. Nonetheless, it is possible to explore, using a qualitative survey and focus group discussions for impressions of whether the adoption of the new cookstove might have improved the women's economic status.

Leadership

Women are still widely underrepresented in decision-making at all levels: in the household, in businesses, and in the public sphere. Addressing these inequities is one way of formalizing the goal of gender equality. In the WOCAN and WEAI models, improvements in leadership empowerment, as a result of a project intervention, do not necessarily suggest that women pursue formal positions of leadership. Leadership empowerment is more typically manifested in "coming into agency" or "finding your voice" or through informal leadership roles around community organizing or mentoring. For example, the WEAI template for developing an empowerment index through a case study in Uganda probes for responses to questions such as "Do you feel comfortable speaking up in public to help decide on infrastructure (like small wells, roads, water supplies) to be built in your community?" and "Do you feel comfortable speaking up in public to protest the misbehavior of authorities or elected officials?"

Education and knowledge

Plausibly, increased time and improved health could open opportunities for women and girls to pursue education, literacy, and knowledge-enhancement opportunities. The key question, however, is whether cleaner cooking projects have resulted in women's increased knowledge and skills, as well as the transmittal of women's knowledge and skills to others in the community. Increases in education and knowledge need not be identified as formal education opportunities. As WOCAN advises, this can be measured by increased knowledge and skills gained from extension services about agriculture, forest management, livestock, renewable energy, sanitation, and health. Other skills include those of basic reading and writing, numeracy, business management, computer and global positioning system use, and communication. Local initiatives to share knowledge, skills, and information, invitations to participate in training and education opportunities, and exposure visits to observe successful initiatives in other communities, especially those run by women, can provide strong incentives and positive examples.

Access to formal education for girls is a subset of this domain. Since girls are often the primary fuelwood collectors, reduction in time spent in this task, hypothetically, could open up opportunities for them to attend school. Some evidence already points to this result (EnDev 2016; Ndiritu and Nyangena 2011; Practical Action 2015; Waris and Antahal 2014).

Systematic measurement of this domain remains challenging. The literature suggests that availability of time may be only one factor—and perhaps not the primary one—in whether girls are allowed to attend school. Changes in education and knowledge is also a complex indicator to monitor, requiring specialists in the educational field. Further, improvements typically manifest over a longer time and require careful recognition and allowance for multiple potential confounders.

Food security

Food security is critical for women's attainment of economic, social, and health improvements. Women are often responsible for ensuring that their families are fed, yet they themselves may go without adequate nutrition. Effective probing for food security happens best in the confines of an agricultural survey. WOCAN (2019) recommends types of projects that can typically apply the food security method, including aspects such as:

- Food security and nutrition projects
- Women's social and economic empowerment projects that increase women's income and assets
- Capacity-building activities that increase food and nutrition knowledge of women
- Food support programs

Reduction in violence

While there is a general association with the threat of sexual violence and fuelwood collection, particularly if women and girls have to travel to remote areas to collect wood, there is almost no empirical evidence about this link. Women and girls are at threat of sexual violence no matter where they are, and there's limited evidence that the threat is heightened by fuelwood collection. While there has been some suggestion that improved cookstoves, by reducing the need for women to collect wood, thus reduce their exposure to this threat, there is very little evidence to prove or disprove this assumed association. A survey of the literature by the Global Alliance for Clean Cookstoves (2016) found that this association is understudied, difficult to study, and that existing research does not consider potential unintended consequences of reducing firewood collection trips. Another study found no impact evaluations that tested these gender-based violence issues and improved cookstove interventions (Arango et al. 2014).

A dedicated longitudinal study across several geographies would be needed to make any headway on establishing or disproving links between cookstove interventions and reductions in gender-based violence.

Indicators for the Measurement of Gender Co-Benefits of Improved Cookstove Interventions

Time savings from the adoption of improved cookstoves is seen as a strategic pathway that may help women tap resources, enhance capabilities, and develop agency over their lives. These may catalyze further empowerment outcomes.

Measuring changes in time-use patterns

The most clearly anticipated, identified, and documented gender co-benefit from improved cookstove interventions is time savings (Table 4.6). Time use is the core indicator used to measure the socioeconomic ripple effects of improved cookstoves (e.g., Jeuland 2015; Mukuna and Shisanya 2015). All of the core sources and models and the methodologies previously listed position time savings as a primary metric.

The key reasons why time is such a frequently measured indicator include the following:

- Given the burdens of time poverty on women (disussed below), and the extraordinarily high health, well-being, and economic costs of household air pollution, these are the domains in which new improved cookstove interventions are most likely to make rapidly evident and substantially positive benefits.
- Time is the indicator most easily measurable with quantitative methods alone or with mixed qualitative and quantitative methods.
- In the theory of change framework, the cookstove is an “index intervention” that produces time savings, which in turn, may enable and catalyze women’s empowerment and gender equality.

Time burden and time poverty

A considerable research establishes that particularly in poor, rural, agricultural, and biomass-fuel-dependent contexts (but arguably everywhere in the world), women work a “double day” and carry disproportionate time burdens of unpaid work. The overburdening of time is increasingly referred to as *time poverty*. It is widely considered to be an anchor that prevents women from engaging in income-generating activities, having appropriate leisure and rest, and developing self-agency. It also constrains their participation in civil, economic, social, and political spheres and corrodes their ability to seek employment and income, thereby increasing the risk of economic disempowerment (ADB 2015; Chopra and Zambelli 2017; Eyben and Fontana 2011; Klugman and Tyson 2016; Lawson 2012; Seager 2018; UN General Assembly 2019; UN Women 2016, 2019; Zacharias, Antonopoulos, and Masterson 2012).

TABLE 4.6: TIME BENEFITS IN RELATION TO IMPROVED COOKSTOVE INTERVENTIONS

Primary Benefit	**Time saved** Time allocation in relation to cooking and cookstoves and, thus, the potential for time savings, occurs along a spectrum that includes the following: • Fuel procurement • Preparing fuel for use in cooking • Cooking and tending the stove • Cleaning up after cooking • Maintaining the cooking and fuel device(s)
Associated Benefits	**Drudgery relief** **Time poverty relief**

Source: Authors.

Possible gender co-benefit synergies: Time savings combined with improved health

Given that women are typically the primary caretakers of family well-being, improving the health of other household members may reduce women's responsibilities and multiply time savings. The time burden associated with women's household responsibilities is, in itself, a health risk. In these circumstances, women sleep fewer hours than their male counterparts and experience more interrupted sleep (ADB 2015; Seager 2018; UN Women 2019). There is increasing medical evidence of the ill-effects produced by poor, limited, and disrupted sleep. Thus, time savings can synergistically magnify the health benefits derived from the pollution and exposure reduction benefits of ECCH interventions. To this extent, health and gender co-benefits are intertwined. Improved health intersects with gender benefits as a potential multiplier. Healthier women are more able to participate in activities and take advantage of opportunities that may lead to greater empowerment or gender equality.

Tools used to measure time

The meta-literature on measuring time use in the household context, is well established (Ferrant and Thim 2019; Lawson 2012; Seymore, Malapit, and Quisumbing 2017; UN DESA 2015). Lessons and best practices derived from these sources are incorporated throughout the following sections.

A growing literature examines, on both theoretical and case-study bases, the contributions of improved cookstoves to time savings for the primary cook and fuel procurer. Time allocation in relation to cooking and cookstoves, and thus the potential for time savings, can occur along a spectrum, as described in Table 4.6. Most gender-related cookstove methodologies measure the following four aspects of time:

1. The amount of time spent cooking and engaged in cooking-related tasks
2. The allocation and use of time among various household duties
3. Any change in time (usually presumed to be savings) that can be attributed to ECCH interventions—reduced drudgery is also often assessed, with mixed results, as will be described below
4. Satisfaction with time—an important empowerment benefit that is often incorporated into surveys

Although the evidence remains limited, more recent studies (Clean Cooking Alliance and Berkeley Air Kenya 2019; CQC and Berkeley Air Zambia 2020) have explored the ways in which "saved time" is redeployed or valued by households and by women themselves. Because of the multidimensional nature of time use, allocation, and potential savings—all experienced both quantitatively and qualitatively—effective measurement of time in relation to cookstove interventions requires a mixed

TABLE 4.7: ESTABLISHED METHODOLOGIES FOR MEASURING TIME USE, ALLOCATION, AND SAVINGS RELATED TO CLEAN AND/OR IMPROVED COOKSTOVE ADOPTION

METHOD	PURPOSE AND APPROACH	EXAMPLES OF USES	PROS AND CONS
Focus group discussions and semi-structured interviews	These are typically designed as a series of questions about whether the new cookstove has shifted time allocations for the primary cook and fuel procurer or for other members in the household. Interviews also probe for activities the respondent has undertaken with any extra time.	• World Bank Lao PDR, endline survey • W+ Standard™ • Clean Cooking Alliance and Berkeley Air (2019), Kenya • CQC and Berkeley Air (2020), Zambia • Cundale et al. (2017)	• Self-reporting on time use and task allocation is subject to distortions of memory and bias. This effect can be muted by using complementary quantitative techniques, including stove-use monitors. • Results can be captured quantitatively and qualitatively. • Can be flexible and adjusted to interview circumstances. • Can capture the nuances of self-identification of drudgery. • Can capture aspects such as satisfaction with time.
Capturing activity-specific time: Stylized surveys and time diaries	Stylized questions focus on a specific activity, asking respondents how much time they spent on that activity over a given period. For example, "How much time did you spend milking cows in the past 7 days?" (Martinez 2017). Time diaries ask respondents to recall all of their activities in a given period, such as the previous 24 hours. The WEAI index employs a variety of stylized survey tools, using a detailed 24-hour time allocation module. Respondents are asked to recall the time spent on primary and secondary activities during the previous 24 hours.	• WEAI (diary captures time in 15-minute intervals) • Lesotho Time Budget Study (Lawson 2007) pictorial survey assist • Clean Cooking Alliance and Berkeley Air (2019), Kenya • Masuda et al. (2014), Ethiopia	• Little standardization in developing and administering these tools (Seymour 2017) • Pictorial aids can be deployed in low literacy and low numeracy settings (Masuda et al. 2014). • 24-hour recall time diaries are subject to memory distortions and lapses. • Deploying predetermined time use time use and activity categories can confine results. • Respondents often find stylized survey questions more difficult to answer because they have to recall activities over a longer period. For instance, time spent farming can be difficult to remember because it is a commonplace activity that does not always follow a set schedule (Martinez 2017; Seymour 2017). • Unless complemented by subjective, qualitative reporting, this provides insight into functional time allocation only, with no dimension of time satisfaction or the personal effect of time use.
Time-tracking devices: Mobile phone trackers, and so forth	A pictorial smartphone app that prompts users to enter a real-time snapshot of their activities at specified times of the day, or a tracker device. This data collection method was used to record effects of agricultural mechanization on time use in smallholder farming households in Zambia. To best of our knowledge it has not be used in a cookstove project.	• Daum, Capezzone, and Birner (2019)	• Pictorial real-time activity tracking eliminates recall bias. • Pictorial tracking does not require numeracy or literacy. • Expensive and not suited for all field conditions. • Some respondents may not be comfortable using such advanced technological tools. • This is still a novel approach but results from the Zambia study show substantial bias in estimated time spent working when compared to estimates from typical survey recall methods. Overall, the validation study showed data collected via the app

METHOD	PURPOSE AND APPROACH	EXAMPLES OF USES	PROS AND CONS
			was high quality, had lower recall and social desirability bias, and was a low burden for the participants.
Stove-use monitoring	Sensor-based stove-use monitors can be placed on or near stoves to objectively measure the time a stove is alight. This allows for the tracking of frequency and duration of stove-use events for all household cooking devices.	• Clean Cooking Alliance and Berkeley Air (2019), Kenya • Pillarisetti (2014) • Ruiz-Mercado et al. (2011)	The sensors provide objective measurement of stove use which is often affected by social desirability bias in survey responses (Thomas et al. 2013). The sensors, however, cannot differentiate between active cooking and the stove burning unattended, nor can it identify who is engaged in the cooking tasks. The method is relatively expensive and requires expertise to analyze results.
Shadowing	An enumerator shadows a small subsample of respondents and records real-time activities and time use. The purpose is direct observation of daily activities. Time coverage can be continuous or random.	More common in ethnographic studies than time-specific studies. • UN DESA (2015)	• High cost in terms of needed survey support and enumerator commitment. • Can be intrusive to the respondent. • Captures real-time time allocations to specific tasks without the distortion of later recall. • Has not been tested thoroughly in time studies, due to operational constraints (including above). • Unless complemented by subjective and qualitative probing, this method provides insight only into functional time allocation but not time satisfaction or the personal effect of such time use.

Source: Authors.

methods approach. The primary methodologies for measuring time allocation, use, and savings are detailed in Table 4.7.

Measuring changes in perceived levels of drudgery

The notion of drudgery is challenging to define and measure, particularly if framed by people from outside the study community. On initial review, much of women's unpaid work falls into a reasonable common understanding of drudgery—long hours of work that are physically or emotionally depleting, repetitive, socially undervalued, time-consuming, and unavoidable (Chopra and Zambelli 2017; C-Quest Capital and Berkeley Air 2019). However, this conventional wisdom of drudgery, extrinsically defined, might be wrong or situationally wrong. Drudgery can only really be defined intrinsically, by the person experiencing it, and it may vary from individual to individual: "For an individual, the same activity may be regarded as work or as leisure depending on the context. Likewise, an activity may be viewed one way by the individual and another by the researcher. For example, an individual may see baking as a leisure activity while the researcher may view it as a productive work activity" (UN DESA 2015).

With increasing attention being paid to the complexity of drudgery, the evidence suggests that collecting fuel may not be considered, by most women, as the most onerous or least desirable of their unpaid labor activities. Water collecting or farming are frequently reported as the most drudgerous household tasks (Clancy et al. 2012; Clean Cooking Alliance and Berkeley Air 2019; Jagoe et al. 2020; Pachauri and Rao 2013; see Appendix C.)

The Clean Cooking Alliance and Berkeley Air (2019) Kenya study found that a key differentiator between hard work and drudgery appears to be the extent to which a task brings pride, such as in a clean home, a well-dressed family, or an accomplishment, such as growing food to feed the family or sell to the community. One effort to develop a drudgery index (Wankhade 2016) has not been picked up elsewhere. Quantitative methods have limited utility in capturing the qualitative and experiential nature of drudgery, which is always best defined by the individual doing the work.

In the realm of cookstoves, fuelwood collecting is typically defined (extrinsically) as drudgerous. There are many aspects of this task that point to this interpretation including the weight of the wood, the distance to collecting areas, often difficult terrain, and the repetitive need. Collecting fuelwood, however, may not represent unmitigated hardship. One recent study measured the considerable ethno-botany skills and the traditional ecological knowledge that women and girls in Kenya developed in the course of fuelwood collecting (Tian 2017). Shifts in fuel sources, and especially the marketization of fuel, may lead to loss of valuable local ecological knowledge (Reyes-Garcia et al. 2005). There is also evidence that women derive group solidarity and friendship benefits from having the opportunity to be with other women and away from the scrutiny and policing of men (Khandelwal et al. 2017). The finding that arduous or undesirable work can intensify tendencies toward solidarity and gender-based bonding is supported by the broader literature on drudgerous work, which has mostly been studied through men's work in socially stigmatized occupations such as slaughterhouse labor or sewerage work (Simpson, Hughes, and Slutskaya 2016; Slutskaya et al. 2016).

If group solidarity, in itself, is reported as a source of social empowerment, then collecting fuelwood, might, counter-intuitively, be a source of empowerment. Drudgery relief through reducing or eliminating the need for fuelwood collection might have the unintended consequence of social loss for women for whom cooking-related activities will be shrunk to the household level.

In view of the challenges described, at best, drudgery should be measured intrinsically and qualitatively (Table 4.8).

TABLE 4.8: METHODOLOGIES FOR MEASURING DRUDGERY RELIEF

METHOD	PURPOSE AND APPROACH	EXAMPLES OF USES	PROS AND CONS
Focus Group Discussions and Semi-Structured Interviews	Survey questions are designed to elicit views on tasks that are drudgerous, and on any changes in the nature of or time commitments to those tasks related to improved cookstoves	• W+ Standard™ • Clean Cooking Alliance and Berkeley Air (2019), Kenya • CQC and Berkeley Air (2020), Zambia • Clean Cooking Alliance and ICRW (2018), Rwanda	As discussed above, defining drudgery can pose a significant challenge

Source: Authors.

4.3 Assessment Against Selection Criteria

All of the primary methodological models on gender co-benefits reviewed here (W+ Standard™, WEAI, Clean Cooking Alliance and ICRW, Gold Standard, and related field studies), deploy mixed-method surveys as their foundation, but they were designed with different objectives. For example, the W+ Standard™ methods and Gold Standard framework are designed to enable project developers to monitor and independent auditors to verify the gender outcome(s), primarily for monetization as a market commodity similar to carbon offsets. Whereas the Clean Cooking Alliance and ICRW measurement system was designed for organizations involved in improved cookstove and fuel value chains to quantify the social and economic benefits they create for both their employees-entrepreneurs and users of their products. Organizations can also use this social impact data to better understand the needs and preferences of their customers to improve their marketing. The WEAI approach is distinct from the other approaches in that it aims to create an aggregated overall index at regional or national scales.

Given that all of these methodologies deploy mixed-method approaches and have virtually no distinctions for field applications, the methodologies are assessed only against the evaluation criteria for an RBF-based application, similar to carbon offset schemes (Table 4.9). It should be noted that at the time of review, there were a limited number of studies where these methodologies had been applied on the ground.

Constraining factors when measuring gender outcomes

Many of the pathways to empowerment and gender equality through ECCH interventions, fully emerge only over a considerably long-time frame, if at all. For example, it is unlikely that shifts in empowerment and equality, in terms of increased income or increased leadership roles, would happen in a year. Some gender equality and empowerment trends *may* be evidenced in a one-year timeframe, but a longer longitudinal study, following new adopters over two or three years, would provide more certain evidence of sustained and attributable shifts.

Best practice principles for consideration during study design

Overall, the design of a study to measure the gender co-benefits of a cookstove program should draw on the core methodological sources, as discussed, and must be adapted to local context and cultures.

TABLE 4.9: ASSESSMENT OF GENDER CO-BENEFITS METHODOLOGY AGAINST THE PRESELECTED CRITERIA

CRITERIA	PURPOSE	ASSESSMENT			
		W+ Standard™	**Gold Standard Gender Requirements and Guidelines**	**Clean Cooking Alliance & ICRW Social Impact Measurement Tool**	**WEAI**
Cost Effectiveness	Cost is affected by monitoring requirements such as field and lab-based testing, surveys, minimum sample size, enabling infrastructure (including monitoring expertise required), availability of testing facilities across geographies, monitoring equipment costs, and other resources.	W+ Standard™ has the most comprehensive set of methods to measure gender outcomes across six domains: time savings, income and assets, health, education and knowledge, leadership, and food security. Monitoring requirements and level of expertise required to design a project that employs these methods has not yet been determined.	Gold Standard requirements present a broader framework, which needs context-specific assessment of gender issues, selection of gender goals, project actions, indicators, and gender disaggregated data collection on relevant monitoring parameters. The framework follows a robust approach to project design and development of a monitoring framework that ensures the environmental integrity. This methodology requires subject matter expertise to design and audit. For example, gender experts must be part of the audit team, to verify the gender claims of the project, thus adding additional cost to the user and project developer.	The Clean Cooking Alliance and ICRW measurement system is most comprehensive and tailor made for clean and/or efficient cookstoves and fuel value chains. The measurement systems present a robust monitoring tool, provide a customized survey template, and also provide a guidebook with details such as recommendation for sample sizes, monitoring, frequency, and protocols on administering surveys. Thus, they can be adapted as per the user's needs. Given that this is a measurements system, the project-level application under an RBF scheme might need further alignment with other co-benefit methodologies.	
Scalability	Methodologies will be assessed for their potential to enable projects to grow effectively.	W+ Standard™ methods can be applied to climate-impact projects and implementation at scale. Due to similarities with the carbon accounting	Similar to W+ Standard™ methods, the framework is designed to include gender aspects in climate impact projects.	The Clean Cooking Alliance measurement system can be applied across geographies.	The WEAI index approach is designed for national and regional reporting. A new version, pro-WEAI, is being

CRITERIA	PURPOSE	ASSESSMENT			
		methodologies and the review of registered ECCH projects, the W+ Standard™ methods appear to be a good fit to apply at scale across geographies. This allows flexibility in application with other carbon methodologies. Further, W+ Standard™ units can be “stacked” onto carbon reduction units. For example, the W+ Standard™ can be applied as a label to “voluntary carbon units” through streamlined templates that have combined the processes for measurement and verification.	The framework presents flexibility to apply with other carbon accounting and co-benefit methodologies, including the W+ Standard™ and Clean Cooking Alliance measurement system, thus broadening its adaptation and applicability. Following the recommendations of this study, a customized approach can be designed for ECCH interventions and applied to similar interventions across geographies.		designed and tested for project-level assessment.
Replicability	The reference methodologies should enable replicability. Projects in different geographies, of different scales, and using a range of ECCH interventions should all be able to use these methodologies.	As mentioned, due to similarities with carbon accounting methodologies and review of registered ECCH projects, the W+ Standard™ method can be replicated across geographies.	The framework requires context-specific assessment of gender issues, but its application follows a uniform assessment approach, replicable across geographies and at scales similar to carbon accounting methodologies.	The Clean Cooking Alliance and ICRW measurement system is customized to ECCH interventions and supply chains and can be applied across the range of interventions.	
Robustness	The methodologies will be assessed for robustness in quantification and verification of the impact and also whether they have been developed in consultation with a wide	WOCAN project reports and validation from independent auditors can be found here (https://www.wplus.org/projects/). They establish the basis for robust impact verification.	The framework follows a robust approach established under the carbon mechanism, project-specific baseline assessment, and third-party validation and verification of outcomes.		

CRITERIA	PURPOSE	ASSESSMENT		
	variety of stakeholders, including subject experts.			
Compatibility	Ideally, application of the methodology should be compatible with methods to be used for verifying other impacts.	The W+ Standard™ is a broad framework that can be aligned and stacked with carbon and other co-benefit methodologies. The framework presents flexibility to design project-specific quantification, monitoring, verification, and reporting.	The Gold Standard requirements and guidelines are a broad framework that can be aligned with carbon and other co-benefit methodology. The framework presents flexibility to design project-specific quantification, monitoring, verification and reporting approaches and is, therefore, compatible with GHG climate impacts methodology.	Unlike other quantification methodologies, Clean Cooking Alliance and ICRW is an independent measurement system, which needs further alignment with other methodologies.
Operational feasibility	Assessment of the operational feasibility, when bringing up to scale. This will consider aspects of the cost-effectiveness, complexity, and robustness of the methods.	WOCAN provides rigorous but project-flexible guidelines and program validation frameworks that could be applied across scale.	The Gold Standard Gender Requirements and Guidelines present a robust framework to quantify and verify gender impacts of climate-impact projects. The framework presents flexibility to design interventions specific to the monitoring, reporting, and verification (MRV) approach, as per the developer's needs. The MRV methodologies, including monitoring indicators from literature, W+ Standard™ methods, Clean Cooking Alliance and ICRW measurements system, and other relevant protocols can be adopted to design cost-effective, simplified MRV protocol for ECCH interventions using this framework.	The Clean Cooking Alliance and ICRW measurement system is a comprehensive and tailor-made MRV tool for ECCH interventions. To apply it at scale in a cost-effective manner, further alignment with other co-benefits methodologies is required.

Sourcce: Authors.

Appendix B provides examples of good practices in specific survey approaches. These can be adapted to meet the aim of most studies.

Several key broad principles should be considered during study design and planning:

- Use available resources, such as the WEAI enumerators' manual, that provide comprehensive guidelines about how to capture diverse positionalities of adults in the same household, since it is now well established that "head of household" is not a useful survey category.
- Ensure same-sex pairings for the interviewee to feel most comfortable
- Probe for intrahousehold gender relations in terms of financial control and decision-making, as this information is crucial for understanding the patterns of cookstove adoption. Whose idea was it to buy the new stove? Was there was resistance to the idea? Who in the household has the resources and authority to buy the stove on his or her own?
- Interview men with a script that closely mirrors the women's interview.
- Start a men-only focus group. Men and women should not share the same focus group.
- Be attentive to subtle bias by not making the following assumptions:
    - **Having an improved stove is intrinsically good.** The efficiency, effectiveness, and modernity of improved cookstoves are not going to produce meaningful benefits if users aren't satisfied with them.
    - **Overall, the new cookstove has brought positive changes into daily lives.** Do not lead the interviewee with presumptive questions.
    - **Improved cookstoves are essentially empowering.** Time saved in cooking may not be the most important domain for relief of drudgery or overall time poverty. Other tasks such as water collection and domestic animal management may be more onerous. Always incorporate questions to explore for shifts in time use in the household.
- To the extent possible, develop a demographically diverse sample of households. Several studies find that female-headed households are the most likely adopters of new cookstoves, as are households with larger numbers of young children. Further, women who are part of social groups are more likely to own an improved cookstove. Households of marginalized groups (class, ethnicity, and indigeneity) are less likely to adopt clean cookstoves (Jeuland et al. 2015; Lewis and Pattanayak 2012).
- Be particularly attentive to female-headed households, as these women heads tend to be uniquely time poor and unable to shift responsibilities to other (male) adults.
- Surveys and focus group discussions (FGDs) should focus, not only on the perceived advantages of new cookstoves, but also on perceptions of traditional cooking approaches. For example, a recent northern Indian study (Jeuland et al. 2015) included survey questions on the awareness of the impacts of traditional stoves in terms of health, local forests and environment, and air quality and climate change. This study found that interest in cleaner stoves was higher in households with an awareness of the negative impacts of traditional stoves.
- WOCAN requires a "do no harm" assessment for each certified project, which is defined as not less than 97 percent of both women and men reporting that the project has not caused any unwelcome and nonremunerated increase of time spent on either productive on reproductive activities (on daily activities, excluding leisure time). This is a principle that should be incorporated into all field projects.

4.4 RECOMMENDATIONS

The analysis of the previous sections has focused on the basic properties of the prevailing methodological outlooks. While each outlook has its merits, there are individual limitations which make necessary the employment of a mixed method approach, relying on several qualitative and quantitative tools. Some of the key determinants while shaping the core methodological choices of research in this field are the resources available—including operational constraints—the level of comfort of respondents in using technology, as well as the need to apply a tool in different geographies. Balancing across these considerations, the following recommendations emerge:

- For tools and methods to measure *time allocation*, *use,* and *savings,* include:
    - FGDs and semi-structured interviews with participants using traditional cooking methods, as well as those with the ECCH intervention
    - Time trackers in a sample subset, using mobile phones to identify real-time activities
    - Stove-use monitors to identify the actual time the stove is burning, although this approach does not indicate who is doing the cooking (this can also be used as a ground-truth mechanism to compare with self-reports on time spent cooking.)
- Conduct the FGD, semi-structured interviews, and time tracking with both men and women from the same households to explore and understand intrahousehold time-use patterns in baseline and intervention situations.
- Implement these tools and approaches to allow for the collection of time-metric evidence relevant to as many dimensions of time as possible for men *and* for women, including the following metrics
    - Time-use patterns
    - Intrahousehold allocation of time
    - Satisfaction with how time is used
    - Ways in which the ECCH intervention has or has not changed the nature, quantity, and time-consuming character of cooking-related tasks, including cleaning the kitchen area, fuel procurement and processing, and actively tending the stove
    - Quality of cooking time
    - Required changes (if any) to the kitchen physical infrastructure to accommodate the new stove and the implications for time and space use
    - Shifts in participation in cooking-related tasks as well as fuel procurement and processing since introduction of the ECCH
- For tools and methods to assess *empowerment- and equality-related* outcomes and impacts, include FGDs and semi-structured interviews to gather quantitative and qualitative evidence. The implementation of these approaches will enable the collection of the following metrics:
    - Gender relations in the household (generally, and specifically related to cooking, stove use, and fuel procurement and processing)
    - Satisfaction with time
    - Agency and autonomous decision-making
    - Self-definitions of empowerment

The metrics should be cross tabulated with health findings and self-reported health perceptions.

5 | PROPOSAL FOR CO-BENEFITS QUANTIFICATION APPROACH

The co-benefits methodologies are designed to stand alone[26] and can quantify a given benefit independently, but there are synergies across the methodologies. These can be leveraged to decrease field costs and required resources. Table 5.1 summarizes the parameters and tools used in the respective methodologies to highlight where these synergies can be leveraged and where specific components of the data collection need to be applied individually. A detailed overview of monitoring requirements is presented in the Table 5.2.

TABLE 5.1: KEY MONITORING REQUIREMENTS ACROSS CO-BENEFIT METHODOLOGIES

BENEFIT	SURVEY	FOCUS GROUP DISCUSSION	EXPOSURE MEASUREMENTS	HOUSEHOLD AIR POLLUTION MEASUREMENTS	STOVE-USE MEASUREMENTS	PROGRAM DATA OR DESK RESEARCH
Gender	X	X			X	X
Health	X		X	X	X	X
Black Carbon				X		X

Source: Authors.

The Table 5.2 illustrates the efficiencies that can be gained by conducting surveys for health and gender methodologies in a combined effort. This would leverage training activities and visits to households. The household air pollution measurements conducted for the health methodology can be used to estimate the ratio of black carbon (BC) to organic carbon, for the BC methodology. Stove-use estimates are also required for the gender and health methodologies, although these can be done via survey or direct measurement with monitors. All the methods also require inputs at the program level, such as the number of homes and duration of project.

The data collected using a harmonized approach could be a useful source of information to measure access to modern energy cooking services with the Multi-Tier Framework (MTF) for Measuring Energy Access (https://www.esmap.org/node/55526). MTF accounts for six attributes—cooking exposure, efficient heat, convenience, cookstove safety, affordability, and fuel availability—to measure access to cooking. It provides a comprehensive tool to capture information about access to energy for cooking, encompassing various cooking solutions, user behavior, cooking conditions, and use of multiple cooking solutions, as well as convenience and safety aspects. It is recommended that the MTF questionnaire be used to leverage the synergies.

---

26 The black carbon methodology is designed to be applied as an add-on to that for quantifying CO2equivalent reductions.

TABLE 5.2: MONITORING REQUIREMENTS ACROSS CO-BENEFIT METHODOLOGIES

MONITORING PARAMETER	MONITORING METHOD	GHGS	BLACK CARBON	HEALTH	GENDER
Project Database					
Total Sales Record		Yes	Yes	Yes	Yes
Household Baseline and Project Survey					
Family Details **(gender-disaggregated data: number of family members, gender, age group, etc.)**	Survey	Yes (partially)	Yes (partially)	Yes	Yes
Kitchen Characteristics **(indoor or outdoor, ventilated, etc.)**	Survey	Yes	Yes	Yes	Yes
Fuel Collection **(time, purchase, collection type, etc.)**	Survey	Yes	Yes	--	Yes
Project and Baseline Technology Type and Features	Survey	Yes	Yes	Yes	Yes
Seasonal Variation	Survey and observations	Yes	Yes	Yes	Yes
Number of Children Per Household Under 5 Years of Age	Survey	--	--	Yes	Yes
Time: Allocation, Use, Savings, and Satisfaction for Cook and Other Household Members	Focus group discussion, semi-structured surveys, and time trackers	--	--	--	Yes
Women's Perceived Agency and Empowerment	--	--	--	--	Yes
Fuel Characteristics and Fuel Consumption					
Fuel Type(s)	Default, measurement, and survey	Yes	Yes	Yes	Yes
Stove Efficiency*	Measurement	Yes	--	Yes	--
Baseline Fuel Consumption	Default, measurement, and survey	Yes	Yes	--	--
Project Fuel Consumption	Default, measurement, and survey	Yes	Yes	--	--
Fraction of Nonrenewable Biomass **(fNRB)**	Measurement	Yes	--	--	--
International Workshop Agreement Rating of Stove	--	--	Yes	Yes	Yes
Stove-Use Monitoring					

MONITORING PARAMETER	MONITORING METHOD	GHGS	BLACK CARBON	HEALTH	GENDER
Usage Monitoring	Survey and stove-use monitors	Yes	Yes	Yes	Yes
Exposure Measurement					
Baseline Personal Exposure	Field measurement	--	--	Yes	--
Project Personal Exposure	Field measurement	--	--	Yes	--
Household Air Pollution					
Black Carbon and Co-Emitted Species	Measurement and default	--	Yes	--	--
CO**	Measurement	--	Yes	Yes	--
$PM_{2.5}$ Concentration	Measurement	--	Yes	Yes	--

**Some GHG methodologies use stove efficiency as an eligibility criteria and for estimation of fuel consumption and savings.*
***CO monitoring is required in certain cases: for example, a project involving a charcoal cookstove.*
Source: Adapted from Gold Standard 2016.

APPENDIX A | FUEL-SAVING ESTIMATION METHODS

Greenhouse gas methodologies follow fuel-consumption methods to estimate savings, as presented in Table A.1.

Table A.1: Summary of Fuel-Saving Methods

METHOD	INPUT PARAMETER REQUIRED	METHOD	SOURCE OF INFORMATION OR HOW GATHERED
Thermal energy output	Number of hours of utilization	Monitoring	Survey
	Rated thermal capacity of project device	Measurement	Manufacturer specification
	Efficiency of the baseline devices	Default	Three-stone fire or conventional device, not charcoal stove
			Other device
		Measurement	
	Efficiency of the project device	Measurement	Certificate by national standard body or appropriate certifying body, or Manufacturer specification, or Sample test
Water-boiling test	Baseline fuel consumption	Default	0.5 tonnes per capita per year
		Survey	Following sampling and surveys for Clean Development Mechanism project activities and program of activities
		Historical	Literature or published reports relevant to project boundary
	Efficiency of the baseline devices	Default	Three-stone fire or conventional device, not charcoal stove
			Other device
		Measurement	Efficiency tests
	Efficiency of the project device	Measurement	Certificate by national standard body or appropriate certifying body. or Manufacturer specification, or Sample test
	Project fuel consumption	Survey	Sample surveys based solely on questionnaires or interviews
		Measurement	Measurement campaigns at representative households
Kitchen performance test (KPT)	Baseline fuel consumption	Default	0.5 tonnes per capita per year
		Measurement	Baseline KPT
	Project fuel consumption	Measurement	Project KPT
Controlled-cooking test (CCT)	Specific fuel consumption or fuel consumption rate of the baseline stove	Measurement	Controlled cooking test following CCT protocol
	Specific fuel consumption or fuel consumption rate of the project stove	Measurement	Controlled cooking test following CCT protocol

Source: Adapted from Gold Standard 2016.

APPENDIX B | EXAMPLES OF CONTRIBUTIONS OF THE CORE METHODOLOGICAL TOOLS AND APPROACHES

B.1 WOMEN'S EMPOWERMENT IN AGRICULTURE INDEX

Women's Empowerment in Agriculture Index (WEAI) is not cookstove focused. It is an *agricultural work and empowerment* methodology to produce an aggregated, ranked index of women's agricultural empowerment. It focuses on time allocation rather than changes in time resulting from technological interventions. The primary quantitative instrument is a time-diary recall exercise: respondents did not keep diaries, but survey interviewers use grids of preprinted activities and time intervals, asking the respondent what activities they pursued over what time intervals. This is a WEAI-developed variant on a Lesotho time budget survey (Lawson 2007).

In WEAI, two factors of time are measured: the *allocation* of time to productive and domestic tasks (hours and minutes per day) and *satisfaction with the available time* for leisure activities. The first indicator is derived from a detailed 24-hour time allocation module based on the Lesotho Time Budget Study (Lawson 2007). Respondents are asked to recall the time spent on primary and secondary activities the previous 24 hours. "Hours worked" are defined as the sum of the time reported in work-related tasks as the primary activity plus 50 percent of the time reported as spent in work-related tasks as the secondary activity. The individual is considered to have excessive workloads and time demands if he or she worked more than 10.5 hours in the previous 24 hours. The other time indicator asks whether the individual is subjectively satisfied with his or her available time for leisure activities like visiting neighbors, watching TV, listening to radio, seeing movies, or doing sports (Alkire et al. 2013).

WEAI relies on a combination of quantitative information collection as well as qualitative and subjective assessments about the nature of perceived "empowerment." The strength of WEAI, and its relevance for this study, is in foregrounding satisfaction with time, especially for leisure. This is an important and often overlooked element of quality of life and gender equality. The complete methodological toolkit for enacting WEAI is available on the index's website (http://weai.ifpri.info/weai-resource-center/guides-and-instruments/).

B.2 CLEAN COOKING ALLIANCE

The Clean Cooking Alliance advises measuring "empowerment" as part of the social impact of clean cooking interventions with metrics that cover a combination of (i) perceptions of self-efficacy, in other words, beliefs in one's own capabilities (agency); (ii) perceptions as to whether one possesses the necessary skills and/or resources needed to act on those beliefs (skills and resources); and (iii) self-reported participation in decision-making (achievements). In addition to these domains of empowerment, we also suggest measuring changes in social status, as this captures whether respondents feel that shifts in their skills, beliefs, and/or role in decision-making have changed the way that they are viewed in their families and communities.

B.3 W+ Time Methods

Women Organizing for Change in Agriculture and Natural Resource Management (WOCAN) provides detailed templates and guidelines for assessing the measurement of results and outcomes for each of their identified domains. For example, the W+ time domain methodology identifies the indicators of change (noting that they are not exhaustive:

- Reduced drudgery (immediate outcome)
- Increased discretionary time (immediate outcome)
- Increased sharing—men take on work that is normally considered that of women (intermediate outcome)
- Increased perception of well-being (intermediate outcome)

The guidelines identify specific dimensions of "improved family dynamics" (as a correlate of improved gender equality) that projects should probe. Sample questions for discussion in focus groups include the following:

- Do you believe that your family well-being is improved?
- How would you define injustice? Give examples.
- Do you believe the time saved from introduction of biogas has somehow contributed to reduction of injustice? And if so, how? And if not, why?

B.4 World Bank Lao PDR Study

The Lao PDR Clean Cookstove Initiative team conducted a gender and consumer acceptance survey at baseline and postintervention to measure gender outcomes and consumer acceptance of the adoption of Tier 4 stoves. The survey work was conducted in partnership with the Poverty Reduction Fund and the World Food Program in villages in Houaphan province and schools in Nalae district of Luang Namtha province. This evaluation sought insights into the daily lives of household members and school cooks who received and used the cookstove. How much time did they save? What activities replaced time previously spent cooking and collecting fuel? How was family health affected? What other changes occurred in family life?

A baseline survey was conducted November 7–11, 2017, with 40 households in Houaphan province, and 10 households and 50 school cooks in Nalae, Luang Namtha province. An endline survey took place March 19–23, 2018, in Nalae[27] and April 26–28, 2018, in Houaphan.

Households in Houaphan and Nalae: Key Findings

At baseline, 82 percent of the main cooks at home cooked three times a day: at 5/6am, 11am/12pm, and 5pm/6pm. At endline, 60 percent reported having cooked three times a day, with some having increased to four times a day.

27 Two school cooks were no longer in the area and could not be interviewed for the endline survey.

- *Time and allocation of saved time:* When the head, spouse, and/or main cook were asked if they had saved time on cooking since getting the stove, 100 percent said yes. This gained "free" time was reported to be allocated to other domestic work (44 percent of heads and 39 percent of spouses) and leisure (28 percent of heads and 20 percent of spouses). Among spouses, 42 percent reported using their "free" time for weaving, farming, feeding livestock, and other nondomestic activities.[28]
- *Cooking practices:* 42 percent of cooks reported cooking in a closed room inside the house, 36 percent outside the house, and 12 percent in a courtyard. The main stove used at home at baseline was the traditional cookstove followed by open, three-stone fire. At endline, 94 percent reported using the Tier 4 stove as the primary stove. In households, the main cook usually cooks three times a day. A statistically significant reduction in cooking time was observed at every meal: 31 minutes less while cooking breakfast, 25 minutes less while cooking lunch, and 30 minutes less while cooking dinner, with a total of 86 minutes of time saving reported daily. Cooks reported doing secondary activities while cooking, such as cleaning house, washing dishes, and feeding animals. Seventy percent reported a shift in who helps with cooking-related activities at home, with 71 percent saying at least one male household member now helps.
- *Drudgery:* Cooks were shown a picture representing drudgery while cooking from a scale of 1 to 5, where 1 is the less effort and 5 the most effort incurred in cooking practices. Cooks reported an average of 4.4 before using the Tier 4 stove and an average of 1.3 after using the new stove, indicating a significant reduction of drudgery.
- *Health:* The introduction of the stove showed positive impacts for women's health. At baseline, heads of household reported chronic headaches (18 percent), eye irritation (25 percent), nose and throat irritation (36 percent), and coughing and sneezing (39 percent). Spouses reported the same: chronic headaches (30 percent), eye irritation (28 percent), nose and throat irritation (22 percent), and coughing and sneezing (35 percent). At endline, both head and spouses reported fewer headaches, reduced eye irritation, reduced coughing and sneezing, and reduced chest pains and shortness of breath. When the main cooks in the households were asked what health benefits they had noticed after using the stove, they all reported some form of benefit. Qualitative responses collated included: "better health," "breathing well," "no eye irritation," "feel healthier," "no headache," and "no cough".
- *Stove feedback:* Respondents reported that the new stove made the cooking process shorter, did not emit smoke, and had an easily controlled fire. They reported liking the taste of food cooked on the stove, and 100 percent of respondents reported they would recommend the stove to family and friends. Cooks also perceived that time spent collecting fuel, mostly by women, was reduced because of pellet distribution.
- *Training and usability:* Among cooks, 94 percent said the training provided was clear and sufficient, but some said they needed more information about stove maintenance. When asked how many meals it took for them to feel comforTable cooking with the Tier 4 stove, 46 percent said three meals and 24 percent said one meal.
- *Willingness to pay and income generation:* At baseline, both head and spouses reported a willingness to pay between US$10 and US$30 for a stove, and at endline this shifted to US$30 to US$60. Ninety-four percent of respondents said they would be interested in gathering raw material for pellets.

28 Only 25 percent of heads reported using their free time in nondomestic activities.

School Cooks in Nalae, Luang Namtha: Key Findings

At endline, 96 percent of school cooks reported that the school received the Tier 4 stove over three weeks prior to survey, and in 78 percent of cases school cooks used the stove both at school and at home (they were encouraged to take the stove at home in the evening).

- *Time and allocation of saved time:* When asked if they felt they saved time on cooking activities since the school received the stove, 100 percent said they saved time at school and 90 percent indicated they save time at home (conditional on using the stove at home). The perception was that the most time saved was at home. Respondents reported using their gained "free" time for mostly leisure activities (40 percent) and doing other domestic work (31 percent).
- *Cooking practices:* The school cooking frequency varied. Some cooks would cook once a month, once a week, or sometimes daily, as the schedule varies per school and per the WFP-supported school feeding programs. At baseline, the main stove used at school was the open fire, three-stone method, and at endline it was the Tier 4 stove. The school cooks prepare lunch for students once a day, starting around 8 am, and get help from other school cooks to cut and wash vegetables. There is a statistically significant reduction in cooking time of 25 minutes for every school meal: 16 minutes reduction boiling water, 21 minutes reduction preparing sticky rice, 18 minutes reduction preparing fish, and 21 minutes reduction in preparing lentils.
- *Time and allocation of saved time at home:* On a typical day with the Tier 4 stove at home, 38 percent reported using it to cook three times and 27 percent twice a day. There is a statistically significant reduction in cooking time for every meal: 20 minutes less while cooking breakfast, 14 minutes less while cooking lunch, and 20 minutes less while cooking dinner, with a total of 54 minutes of time saved daily. Ninety-one percent of school cooks reported (in terms of stove use and time savings at home) doing some domestic work (cleaning, washing clothes, and taking care of kids) while cooking and 35 percent reported to see a shift with who helps with cooking related activities at home (with 69 percent reporting at least one man now helping).
- *Drudgery:* Cooks were shown a picture representing drudgery while cooking with a scale of 1 to 5, where 1 is the less effort and 5 the most effort incurred in cooking practices. School cooks reported an average of 3.8 before using the Tier 4 stove and an average of 1.4 after using the new stove at school, indicating a significant reduction of drudgery.
- *Health:* The introduction of the stove showed positive impacts in terms of women's health, as well. For example, at baseline, school cooks reported chronic headaches (46 percent), coughing and sneezing (36 percent), chest pains (20 percent), and shortness of breath (10 percent). At endline, they experienced fewer headaches (7 percent), less coughing and sneezing (23 percent), and reduced chest pain (4 percent) and shortness of breath (2 percent), although they still suffer these conditions to some extent. When the main cooks were asked what health benefits they had noticed after using the stove, they all reported some form of benefit: responses collated included "feel better because there is no smoke" and "no eyes and nose irritation."
- *Stove feedback:* All respondents said the new stove reduced cooking time, did not emit smoke, was easy to control. They also liked the taste of the food and the look of the stove. Ninety-eight percent reported they would recommend the stove to family and friends. Cooks also perceived that time spent collecting fuel, mostly for women, was reduced because of pellet distribution.
- *Training and usability:* Eighty-one percent of cooks thought the training provided was clear and sufficient, although some suggested they would need more information about stove maintenance, more frequent training, and access to material that shows usage instructions. When asked how many

meals it took to feel comforTable cooking with the Tier 4 stove, 40 percent said three meals, 23 percent said two meals, and 17 percent said one meal.

- *Willingness to pay and income generation:* At baseline, school cooks reported willingness to pay up to US$10 for a stove. At endline, 40 percent reported the same amount, while 40 percent were willing to pay US$10–30. Ninety-two percent of respondents said they would be interested in gathering raw material for pellet production.

B.5 C-Quest Capital and Berkeley Air Monitoring Group: Zambia

The C-Quest and Berkeley Air Zambia project (2019) provides an example of survey designs that probe for possible "impact pathways" of improved cookstoves on time poverty and drudgery (see Table B.1).

Table B.1: Impact Pathways for the Purchase of Improved Cooking Devices on Time Poverty

POSSIBLE PATHWAYS TO IMPACT ON TIME POVERTY	NOTES
Reducing the time required to collect fuelwood	Impacts will be seen only in populations that collect significant amounts of their cooking fuel from beyond their immediate plot of land. People also often leave the house to do more than one activity, such as collect water, socialize, obtain food, and so forth, so it can sometimes be difficult to isolate and quantify the change in fuel collection time. If the fuel is collected infrequently (less than monthly) and in very large amounts, it is challenging to measure the impacts the cookstove might have on fuel collection time.
Reducing the time spent preparing fuelwood	It is often assumed that a more efficient wood-burning stove will require less wood and therefore less time will be spent on cutting and preparing the fuel. Some new technology, however, requires much smaller pieces of wood than open fires, and so an increase in time spent preparing wood for the cookstove might be seen.
Reducing the time it takes to cook	It is assumed that the new stove has a proven ability to cook a standard meal quicker than the traditional or baseline option, at least in a controlled setting. The effect of a new technology or fuel on time spent cooking can be distorted by people wanting to cook more or longer because the stove is comfortable or because it is more fuel-efficient and thus more affordable.
Reducing the time required to actively tend the stove	This assumes the new device and fuel is safer than the baseline alternative, and so the cook feels happier to walk away from it. Conversely, time tending the stove sometimes increases if the "improved" biomass stoves requires smaller pieces of wood and therefore more frequent feeding of fuel into the combustion chamber.

POSSIBLE PATHWAYS TO IMPACT ON TIME POVERTY	NOTES
Reducing the time to clean the kitchen and pots	If there is to be an impact from reduced time spent cleaning the kitchen, the majority of cooking needs to be conducted indoors. Cleaning of pots alone might not be a sufficiently significant time burden to have an impact on net time available, but it can have a more qualitative impact on reducing drudgery.
Increasing the time that the cook can spend with family and friends, which improves time quality	A cleaner cookstove can create an environment conducive to the family being near the cook as she prepares meals, increasing social interaction and reducing isolation. A safer stove allows the cook to care for her children while cooking without fear of injury.
Reducing physical effort, which reduces fatigue and promotes a sense of wellness	Reducing physical effort may a extend woman's energy for other activities, even if the time itself doesn't change.

Source: C-Quest and Berkeley Air 2019.

B.6 Clean Cooking Alliance and Berkeley Air Monitoring Group Kenya: Measuring Time-Use Patterns

The User Social Impact Survey (USIS) (developed by Clean Cooking Alliance and ICRW) was central to the design of the time-use patterns tool that Berkeley Air Monitoring Group developed and deployed in its Kenya study (Clean Cooking Alliance and Berkeley Air 2019). The study drew heavily on the approach to understand cooking habits, alternative time uses, effort diagrams (rolling a boulder up a hill), and questions about income-generation from use cookstoves.

Some questions and sections were heavily adapted, such as the "Usage Adoption and Cooking Time" section. Reasons given by the Berkeley Air team for this adaptation was the following:

> The fuel/stove profile in our population is simpler than the one the tool fits; we are not focusing on other seasons so heavily; and we felt we did not need to disaggregate cooking tasks in as much detail to achieve our study aims. Thus, our final section on cooking habits and time use is an adapted and simplified version of the tool.
>
> Although the focus of the USIS overlapped with the aims of the time-use questionnaire, certain areas were covered in more detail than we felt necessary (including: health and safety, detail on other seasons, purchase of fuels, and customer satisfaction). Some others were not covered in sufficient detail. In particular, we wanted to dig deeper into respondents' perception and impact of time use, drudgery and family relationships, which required further questions.

Surveys incorporated direct questions on time-agency and empowerment, such as the following:

- "Assuming you had more time, do you think anything/anyone would stop you from spending your time in this way?"
- Before we finish, I'd like to ask you about the idea of 'empowerment' and what it means to you. What would you say the word means?

- What would an empowered woman look like in this community?
- Do you think the women in community are empowered? If not, what do you think stops them from becoming so?"

B.7 UN DESA–Recommended Survey Instruments to Capture the Subjectivity of Time

Sample questions from the UN Department of Economic and Social Affairs appear in Figure B.1

Figure B.1: Questions about Different Kinds of Subjective Experiences

In the list below we ask some questions about how you experienced the activities you have described in your diary.

Please indicate if you recognize any of the experiences we ask about. And if so, also indicate with a letter in the diary to which activities this applies.

	Question		
A	Have you reported any activities that you would not have done had you not been obliged or forced to?	☐ YES → ☐ NO ↓	Indicate with the letter A in the diary which activities this applies to
B	Have you reported any activities that you would rather not have done had it not been necessary in order to fulfill daily tasks?	☐ YES → ☐ NO ↓	Indicate with the letter B in the diary which activities this applies to
C	Have you reported any activities that you could not skip without a feeling of bad conscience?	☐ YES → ☐ NO ↓	Indicate with the letter C in the diary which activities this applies to
D	Have you reported any activities that you just did because there was nothing else to do?	☐ YES → ☐ NO ↓	Indicate with the letter D in the diary which activities this applies to
E	Did any of the activities you have reported lead to new social contacts or to better contact with people you already know?	☐ YES → ☐ NO ↓	Indicate with the letter E in the diary which activities this applies to
F	Did any of the activities you have reported improve your health or sense of well-being?	☐ YES → ☐ NO ↓	Indicate with the letter F in the diary which activities this applies to
G	Did any of the activities you have reported leave you with a feeling of personal growth?	☐ YES → ☐ NO ↓	Indicate with the letter G in the diary which activities this applies to

Source: UNDESA 2015.

APPENDIX C | EMERGING RESEARCH—PROBLEMATICS AND CAUTIONARY NOTES

The possibility of monetizing gender credits alongside carbon credits appears to have heightened interest in developing field projects that examine the gender dimensions of cookstoves. The most energetic and emerging research in the field, however, raises critical questions about the underlying principles.

C.1 Problem Definition: Are Cookstoves High-Priority Needs for Women?

As the benefits of improved cookstoves (ICs) are increasingly emphasized and monetized as "public goods" (climate change mitigation, lower rates of deforestation, and so forth), there is increasing pressure on women to want ICs. Many field assessments of cooking preferences in the context of the actual or posited availability of new, clean(er) cookstoves, however, find strong attachment to traditional methods and stoves. Few studies establish that women actually *want* new cookstoves (Jeuland et al. 2015). Indeed, some women may see a loss to their autonomy if ICs mean giving up, sharing, or redistributing "their" space (material and metaphorical space) (Ferrant and Thim 2019). Most evidence suggests that the cookstove "problem" is one defined exogenously—and perhaps inappropriately transferred as a responsibility of women to solve (Abdelnour 2015; Khandelwal et al. 2017; Pachauri and Rao 2013).

- Pachauri and Rowe (2013) note the following: "The disadvantages of an absence of modern energy services for women are well understood. Women spend more time and energy on unpaid care tasks, domestic, and farm work than do men, they forego opportunities to engage in income-generating or livelihood enhancing activities and leisure, and they damage their health. . . . Improving access to modern energy is thus seen as a potential means of improving welfare and mitigating these adverse impacts. Yet compelling empirical evidence on the benefits to women of transitioning to modern energy services remains weak. . . . [I]n Bangladesh, although most (94 percent) of surveyed women believed indoor smoke to be harmful, the majority (>66 percent) believed it to be less harmful than polluted water or spoiled food. Further, Miller and Mobarak . . . also show that women decision-makers are more reluctant (due to liquidity constraints, they hypothesize) than men to pay a price for improved stoves, despite expressing a greater preference than men for efficient and less polluting stoves. Similarly, women may spend more time collecting water than firewood, which raises questions about how much women value the time gained from shifting to modern fuels. . . . [I]n households in India, according to the India Human Development Survey, regardless of the type of stove used, most women spend close to or more than double the time collecting water as they do collecting biomass."
- Clancy et al. (2012) state: "Fuelwood collection might not always be the most onerous task for women". A study in the resource-deficit Chiduku Communal Area in eastern Zimbabwe in the early 1990s (where there was no electricity and kerosene was expensive) showed that women spent 4.1 hours a week on fuelwood collection and 10.3 hours on water collection. Women provide 91 percent of the household's total effort in providing both of these household needs."
- Khandelwal et al. 2017 note the following: "In India, [IC] adoption is limited despite massive promotion over many decades. Existing research suggests that many rural women in India do not want improved stoves, and those who do face obstacles to adoption. We step back from the many

good case studies to examine the broader story of improved cookstoves (ICs) in India. . . . Rather than assuming a priori that traditional stoves require replacement, we ask why Indian cookstoves have been a magnet for so much attention, why adoptions rates have remained low, and what lessons might be learned from a broad, multi-disciplinary perspective. . . . Our 'big picture' review shows that the Indian *chulha*, for all its problems, is a remarkably successful technology which also satisfies several important household needs. Hence, targeting this device for obsolescence has profound implications that cannot be reduced to energy consumption or environmental hazards. Rural women do not prioritize ICs, but addressing their priorities requires either capital-intensive investment or challenging powerful institutions. In contrast, IC interventions are relatively cheap, decentralized, mechanical and seemingly apolitical, hence their popularity in development programs. Our review of *chulha* research leads us to reject both the optimism of development planners who frame such problems as technical and the antagonistic pessimism of their critics. Searching for a middle ground requires stepping back from the dogma of efforts to improve biomass cookstoves."

C.2 Technology in Itself has Limited Capacity to Change Gender Norms (or not necessarily for the better)

There is a paradox of labor-saving devices that don't save time**.**

Some of the earliest empirical assessments of the putative "time-saving" attributes of new household technologies were conducted in rich-world, Western contexts. Joann Vanek, a founding innovator in bringing gender statistics into United Nations work, produced in 1974 a startlingly counter-intuitive analysis that the introduction of much-heralded "labor-saving" household appliances in the United States did not actually save women's household labor time (Vanek 1974). Tracking time use coincident with the mass commodification and widespread introduction of household technology (for example, washing machines, electric vacuum cleaners) into American homes between 1920 and 1970 did not reduce the time women spent in housework for full-time homemakers; only for wage-employed women was some reduction found. While there have been findings that contradict Vanek's foundational work, much of the literature replicates this finding (for example, Cowan 1983, Bittman, Rice, and Wajcman 2004).

One can explain the findings in various ways. For example, according to "expectation inflation," if a housewife *can* do laundry every day, it becomes a new standard for cleanliness and housekeeping diligence. In "demand expansion" and "time shifting," scenarios, the intervention might save time in one task, but aggregate time spent in housework remains relatively constant. Time is redistributed among tasks, or even shifted to new tasks. While food preparation time declined, for example, in Vanek's study, time spent in childcare, shopping, and household management expanded substantially.

If there are no structural changes in gender relations, introducing "improved' domestic appliances" can deepen women's domesticity, not expand their civic engagement. Saving time, in itself, does not shift gender norms and may do little to empower women, understood as the "process by which those who have been denied the ability to make strategic life choices acquire such an ability" (Lehmann 2019).

- Thomas and Zmroczek (1985) noted: "The claim that technology has 'liberated' or can liberate women from the home is even more problematic. What is meant by 'liberation' in this context? It appears to mean freedom from the burden of household work commonly borne by women, but it does not appear to challenge the assumption that this work is primarily women's responsibility."

- Bittman, Rice, and Wajcam (2004) state the following: "The analysis of this data shows that domestic technology rarely reduces women's unpaid working time, and even, paradoxically, produces some increases in domestic labour. The domestic division of labour by gender remains remarkably resistant to technological innovation."
- Ferrant and Thim (2019) note: "Higher levels of economic development do not automatically lead to a more equal redistribution of unpaid care work between women and men, due to the persistence of restrictive gender norms which place the responsibility for domestic work and child care on women. . . . [E]ncouraging men's involvement in unpaid care work also requires working with women and girls, to create space for men and boys in a traditionally feminine space. Women and girls may be reluctant to have men and boys engage in housework, for fear of losing the limited responsibility they have in the home. Women and girls can also internalise gender stereotypes on which tasks are socially accepTable for women or men, making them resistant to change. Thus, as Hopem's experience shows, real redistribution of domestic responsibilities requires rethinking restrictive gender roles by and for both women and men."

C.3 Opportunism Instrumentalism and Shifting Responsibilities to the Poor

Monetizing women's labor and time savings, especially as related to carbon credits and markets, can appear to be opportunistic and not driven by authentic interest in women's empowerment.

- Abdelnour (2015) notes the following: "Using the empowerment of women as a pretext and marketing/advocacy platform, the promotion of improved cookstoves inadvertently transfers the responsibility for resolving complex problems into the households of the global poor. For instance, in addition to sexual violence, improved cookstove promoters suggest that through more efficient cooking, poor women are empowered to address complex problems such as deforestation and climate change. Such ignores the fact that poor women and inefficient cooking are neither at the root causes of, nor the major contributors to these problems. It also negates the momentous role of global industry (including extractive industries, large-scale logging, livestock production, and transportation) as well as the consumption patterns of the haves (especially in the West) in creating and maintaining these problems. Moreover, efforts to carbon-certify stove initiatives will place poor women and girls in a position where they unknowingly, and through sheer necessity, serve to subsidize the polluting activities of global industry. The promise of carbon finance should not be taken as a simple 'win– win' strategy. Mobilizing poor women in deeply unequal neoliberal structures raises ethical questions for donors, humanitarian intermediaries, and household energy market actors."
- Wang and Corson (2015) state: "We highlight the role of women's labor in creating the initial carbon emissions reductions, which then become tradable virtual commodities through a series of studies to measure and verify the associated carbon savings, as well as the signing of a contract that transfers the property rights to the verified savings from the stove user to an international nonprofit carbon credit developer. We argue that, while introducing some improvements in cooking time, smoke level, and labor, the improved cookstove carbon offset ultimately constitutes a gendered, ongoing accumulation by decarbonization that, by securing the means of future wealth that could be generated from the project for investors in the Global North, marginalizes rural Kenyan women."
- Listo (2018) notes: "The discourse [on energy poverty] instrumentalises women and gender for particular energy interventions, and does so at the expense of gender equality outcomes."

There are considerable concerns about positioning a technological innovation as a solution to complex social problems. Not unrelatedly, there is considerable concern about the ethics of placing responsibility for saving the environment and mitigating climate change on the shoulders of poor women:

- Abdelnour (2015) argues: "...It is not enough to simply market stoves through abstract or theoretical propositions that convey the lives of poor women through generalized, simplified, and disingenuous narratives. Stoves are not techno-superheroes; cooking with better stoves will not enable poor women to resolve the structural causes of poverty, violence or climate change."
- Westholm (2017) observes: "[REDD+] can be seen as a transfer of responsibilities for environmental protection and reproduction. The direction of this transfer—from North to South, and from rich to poor—is an effect of the rationality of economic efficiency, where emissions reductions and mitigation actions are to be implemented where they are constructed as cheapest, based on the logic of opportunity costs… The commodification of carbon credits is an important factor facilitating this transfer of responsibilities. Further, these transfers are mediated by international institutions working on REDD+, as well as governmental actors and NGOs implementing national and local REDD+ projects. Arora-Jonsson et al…. identify a new kind of 'global' citizenship where the new responsibilities for care and reproduction of the global environmental commons are transferred to poor people in the South, but without being matched by corresponding rights."
- Lehmann (2019) notes: "Charismatic carbon projects are becoming increasingly popular in the voluntary carbon market. These are carbon offset projects that lend themselves to telling stories about the livelihood benefits they provide for poor people in the Global South in addition to carbon emission savings... [S]uch projects are less transformative than they pretend to be—especially as they fortify ascribed gender roles…marketing these projects as a contribution to women's empowerment means to 'co-opt feminist discourses, and analytical tools and concepts, namely gender and empowerment, in ways that distort their political implication… The introduction of improved cookstoves then appears to be a technical intervention at the expense of an emphasis on the need for more integrated interventions… Obviously, there are limits to the breadth of transformation that can be expected from a single, small-scale intervention like the introduction of cookstoves. However, if the introduction of new cookstoves was publicly framed as a process that may open up spaces to contest gendered norms of care work and local labor markets structures, this would anchor empowerment agendas much more firmly in public perceptions."

APPENDIX D | SUMMARY OF BLACK CARBON AND ORGANIC CARBON EMISSION FACTORS

Black carbon (BC) and organic carbon (OC) emission factors for different stove classes are summarized in Tables D.1 and Table D.2. The stove class definitions are based on stove design:

- **Simple**: improved cookstove stoves, including locally manufactured stove with material such as metal, ceramics, and so forth
- **Rocket**: efficient small combustion stove
- **Advanced**: forced and natural draft stoves that use wood or pellets, liquefied petroleum gas (LPG), or biogas as fuel

Each stove is categorized by stove class and fuel type with which the stoves were tested in field and lab. The number of monitoring events refers to the total number of field tests conducted for a particular stove and fuel type in different countries. The emission factors are compiled to demonstrate the variation in emissions due to fuel type, stove technology, and geography. Further assessment considering the intervention stove, fuel, and locality is recommended. A methodology requirement is recommended to establish the default factors.

Table D.1: Black Carbon and Organic Carbon Emission Factor in Field Setting

TEST TYPE	FIELD TEST	BC (G/KG FUEL)			OC (G/KG FUEL)		
Stove Class and Country or Economy	Number of Monitoring Events	Mean	Max	Min	Mean	Max	Min
Advanced Biomass	**464**	**0.77**	**0.07**	**1.51**	**3.60**	**16.20**	**0.30**
China	11	1.24	1.20	1.20	2.60	2.60	2.60
Cambodia	22	1.50	1.50	1.50	2.00	2.00	2.00
Honduras	5	0.51	0.51	0.51	0.68	0.68	0.68
India	188	0.73	0.50	1.00	2.10	4.30	1.20
Malawi	35	1.03	0.50	1.51	1.30	2.43	0.53
Rwanda	59	0.07	0.07	0.07	0.30	0.30	0.30
Tibet	34	0.80	0.70	0.90	12.35	16.20	8.50
Uganda	32	1.00	1.00	1.00	6.50	6.50	6.50
Vietnam	78	0.50	0.10	0.90	8.75	12.70	4.80
Advanced Charcoal	**71**	**0.37**	**0.13**	**0.70**	**2.26**	**3.90**	**0.49**
Kenya	60	0.28	0.28	0.28	3.90	3.90	3.90
Uganda	11	0.70	0.70	0.70	2.40	2.40	2.40
Advanced Coal	**7**	**0.69**	**0.05**	**1.33**	**20.21**	**40.02**	**0.39**

China	7	0.69	0.05	1.33	20.21	40.02	0.39
Biogas	**57**				**0.11**	**0.11**	**0.11**
Nepal	57				0.11	0.11	0.11
LPG	**6**	**0.01**	**0.01**	**0.01**	**0.27**	**0.27**	**0.27**
Nepal	6	0.01	0.01	0.01	0.27	0.27	0.27
Rocket	**167**	**1.17**	**0.01**	**2.28**	**4.76**	**17.11**	**0.05**
China	26	1.61	0.93	2.28	13.20	17.11	9.28
India	92	1.40	1.35	1.50	3.45	4.15	5.09
Malawi	3	0.73	0.73	0.73	0.51	0.51	0.51
Rwanda	16	0.21	0.21	0.21	3.62	3.62	3.62
Uganda	30	2.00	2.00	2.00	6.50	6.50	6.50
Simple Biomass	**124**	**1.58**	**0.30**	**9.67**	**3.20**	**7.60**	**0.60**
China	43	3.06	0.43	9.67	2.98	6.76	1.14
Honduras	6	1.81	0.52	3.10	2.08	2.46	1.70
India	1	0.30	0.30	0.30	0.60	0.60	0.60
Malawi	1	0.35	0.35	0.35	1.07	1.07	1.07
Nepal	14	0.84	0.80	0.88	3.55	3.70	3.40
Uganda	24	0.80	0.80	0.80	4.20	4.20	4.20
Vietnam	35	0.80	0.80	0.80	6.25	7.60	4.90
Simple Charcoal	**120**	**0.25**	**0.03**	**0.52**	**1.59**	**4.40**	**0.18**
Benin	54	0.37	0.25	0.49	1.44	1.90	0.97
Kenya	47	0.44	0.44	0.44	4.40	4.40	4.40
Uganda	19	0.51	0.50	0.52	3.05	3.20	2.90
Simple Coal	**2**	**0.23**	**0.23**	**0.23**			
China	2	0.23	0.23	0.23			
Three-Stone Fire	**332**	**1.23**	**0.30**	**4.40**	**4.84**	**31.60**	**0.30**
China	1	0.47	0.47	0.47	1.78	1.78	1.78
Cambodia	21	2.50	2.50	2.50	2.90	2.90	2.90
Honduras	12	1.50	1.50	1.50	4.00	4.00	4.00
India	126	1.13	0.90	1.65	4.63	6.40	2.87
Malawi	16	0.94	0.94	0.94	3.06	3.06	3.06
Mexico	21	1.98	0.43	4.40	1.45	2.26	0.30

Nepal	64	0.99	0.68	1.58	3.03	3.30	2.77
Rwanda	16	2.09	2.09	2.09	7.05	7.05	7.05
Tibet	14	0.30	0.30	0.30	31.60	31.60	31.60
Uganda	20	0.60	0.60	0.60	5.50	5.50	5.50

Note: g/kg = grams per kilogram.
Source: Authors.

Table D.2: Black Carbon and Organic Carbon Emission Factor in Laboratory

TEST TYPE	LAB TEST	BC (G/KG FUEL)			OC (G/KG FUEL)		
Stove Class	Number of Monitoring Events	Mean	Max	Min	Mean	Max	Min
Advanced Biomass	24	0.52	0.06	1.50	0.36	0.61	0.15
Advanced Coal	3	0.32	0.02	0.48	4.39	10.74	0.05
Rocket	2	0.84	0.52	1.16	0.49	0.76	0.22
Simple Biomass	18	1.30	1.30	1.30	1.40	1.40	1.40
Simple Charcoal	1	0.20	0.20	0.20	0.81	0.81	0.81
Simple Coal	3	3.30	1.64	4.79	2.72	4.04	1.21
Three-Stone Fire	29	0.96	0.70	1.30	2.03	3.98	0.07

Note: g/kg = grams per kilogram.
Source: Authors.

The list of research publications reviewed to compile the emission factors is provided in the appendix E bibliography.

Appendix D Bibliography

Baqir, M., Bharti, S. K., Kothari, R., and Singh, R. P. “Assessment of an Energy-Efficient Metal Chulha for Solid Biomass Fuel and Evaluation of Its Performance.” *International Journal of Environmental Science and Technology* (2018). https://doi.org/10.1007/s13762-018-2028-9.

Bilsback, K. R., Eilenberg, S. R., Good, N., Heck, L., Johnson, M., Kodros, J. K., Lipsky, E. M., L’Orange, C., Pierce, J. R., Robinson, A. L., Subramanian, R., Tryner, J., Wilson, A., and Volckens, J. “The Firepower Sweep Test: A Novel Approach to Cookstove Laboratory Testing.” *Indoor Air* 28, no. 6 (2018): 936–949. https://doi.org/10.1111/ina.12497.

Champion, W. M., and Grieshop, A. P. “Pellet-Fed Gasifier Stoves Approach Gas-Stove Like Performance during in-Home Use in Rwanda.” *Environmental Science and Technology* 53 no. 11 (2019): 6570–6579. https://doi.org/10.1021/acs.est.9b00009.

Edwards, R., Princevac, M., Weltman, R., Ghasemian, M., Arora, N. K., and Bond, T. “Modeling Emission Rates and Exposures from Outdoor Cooking.” *Atmospheric Environment* 164 (2017): 50–60. https://doi.org/10.1016/j.atmosenv.2017.05.029.

Eilenberg, S. R., Bilsback, K. R., Johnson, M., Kodros, J. K., Lipsky, E. M., Naluwagga, A., Fedak, K. M., Benka-Coker, M., Reynolds, B., Peel, J., Clark, M., Shan, M., Sambandam, S., L’Orange, C., Pierce, J. R., Subramanian, R., Volckens, J., and Robinson, A. L. “Field Measurements of Solid-Fuel Cookstove Emissions from Uncontrolled Cooking in China, Honduras, Uganda, and India.” *Atmospheric Environment* 190 (2018): 116–125. https://doi.org/10.1016/j.atmosenv.2018.06.041.

Fachinger, F., Drewnick, F., Gieré, R., and Borrmann, S. “How the User Can Influence Particulate Emissions from Residential Wood and Pellet Stoves: Emission Factors for Different Fuels and Burning Conditions.” *Atmospheric Environment* 158 (2017): 216–226. https://doi.org/10.1016/j.atmosenv.2017.03.027.

Fleming, L. T., Weltman, R., Yadav, A., Edwards, R. D., Arora, N. K., Pillarisetti, A., Meinardi, S., Smith, K. R., Blake, D. R., and Nizkorodov, S. A. “Emissions from Village Cookstoves in Haryana, India and Their Potential Impacts on Air Quality.” *Atmospheric Chemistry and Physics Discussions* (2018): 1–21. https://doi.org/10.5194/acp-2018-487.

Garland, C., Delapena, S., Prasad, R., L’Orange, C., Alexander, D., and Johnson, M. “Black Carbon Cookstove Emissions: A Field Assessment of 19 Stove/Fuel Combinations.” *Atmospheric Environment* 169, supp. C (2017): 140–149. https://doi.org/10.1016/j.atmosenv.2017.08.040.

Grieshop, A. P., Jain, G., Sethuraman, K., and Marshall, J. D. “Emission Factors of Health- and Climate-Relevant Pollutants Measured in Home during a Carbon-Finance-Approved Cookstove Intervention in Rural India.” *GeoHealth* 1 no. 5 (2017): 2017GH000066.

Jimenez, J., Farias, O., Quiroz, R., and Yañez, J. “Emission Factors of Particulate Matter, Polycyclic Aromatic Hydrocarbons, and Levoglucosan from Wood Combustion in South-Central Chile.” *Journal of the Air and Waste Management Association* 67, no. 7 (2017): 806–813. https://doi.org/10.1080/10962247.2017.1295114.

Johnson, M. A., Garland, C. R., Jagoe, K., Edwards, R., Ndemere, J., Weyant, C., Patel, A., Kithinji, J., Wasirwa, E., Nguyen, T., Khoi, D. D., Kay, E., Scott, P., Nguyen, R., Yagnaraman, M., Mitchell, J., Derby, E., Chiang, R. A., and Pennise, D. “In-Home Emissions Performance of Cookstoves in Asia and Africa.” *Atmosphere* 10, no. 5 (2019): https://doi.org/10.3390/atmos10050290.

Liu, Y., Zhang, Y., Li, C., Bai, Y., Zhang, D., Xue, C., and Liu, G. “Air Pollutant Emissions and Mitigation Potential through the Adoption of Semi-Coke Coals and Improved Heating Stoves: Field Evaluation of a Pilot Intervention Program in Rural China.” *Environmental Pollution* 240 (2018): 661–669. https://doi.org/10.1016/j.envpol.2018.04.110.

Medina, P., Berrueta, V., Martínez, M., Ruiz, V., Edwards, R. D., and Masera, O.” Comparative Performance of Five Mexican Plancha-Type Cookstoves Using Water Boiling Tests.” *Development Engineering* 2 (2017): 20–28. https://doi.org/10.1016/j.deveng.2016.06.001.

Medina, P., Berrueta, V., Martínez, M., Ruiz, V., Ruiz-Mercado, I., and Masera, O. R. “Closing the Gap between Lab and Field Cookstove Tests: Benefits of Multi-Pot and Sequencing Cooking Tasks through Controlled Burning Cycles.” *Energy for Sustainable Development* 41 (2017): 106–111. https://doi.org/10.1016/j.esd.2017.08.009.

Pandey, A., Patel, S., Pervez, S., Tiwari, S., Yadama, G., Chow, J. C., Watson, J. G., Biswas, P., and Chakrabarty, R. K. “Aerosol Emissions Factors from Traditional Biomass Cookstoves in India: Insights from Field Measurements." *Atmospheric Chemistry and Physics* 17, no. 22 (2017): 13721–13729. https://doi.org/10.5194/acp-17-13721-2017.

Rapp, V. H., Caubel, J. J., Wilson, D. L., and Gadgil, A. J. "Reducing Ultrafine Particle Emissions Using Air Injection in Wood-Burning Cookstoves." *Environmental Science and Technology* 50, no. 15 (2016): 8368–8374. https://doi.org/10.1021/acs.est.6b01333.

Ruiz, V., and Masera, O. "Estimating Kitchen $PM_{2.5}$ and CO Concentrations out of Stove Emissions: The Case of Mexican Plancha-type Stoves." Laboratorio de Innovación y Evaluación de Estufas de Biomasa, Universidad Nacional Autónoma de México (2018). http://cleancookstoves.org/resources/543.html.

Ruiz-García, V. M., Edwards, R. D., Ghasemian, M., Berrueta, V. M., Princevac, M., Vázquez, J. C., Johnson, M., and Masera, O. R. "Fugitive Emissions and Health Implications of Plancha-Type Stoves." *Environmental Science and Technology* 52, no. 18 (2018): 10848–10855. https://doi.org/10.1021/acs.est.8b01704.

Saliba, G., Subramanian, R., Bilsback, K., L'Orange, C., Volckens, J., Johnson, M., and Robinson, A. L. "Aerosol Optical Properties and Climate Implications of Emissions from Traditional and Improved Cookstoves." *Environmental Science and Technology* 52, no. 22 (2018), 13647–13656. https://doi.org/10.1021/acs.est.8b05434.

Shen, G. "Changes from Traditional Solid Fuels to Clean Household Energies—Opportunities in Emission Reduction of Primary $PM_{2.5}$ from Residential Cookstoves in China." *Biomass and Bioenergy* 86 (2016): 28–35. https://doi.org/10.1016/j.biombioe.2016.01.004.

Shen, G., Hays, M. D., Smith, K. R., Williams, C., Faircloth, J. W., and Jetter, J. J. "Evaluating the Performance of Household Liquefied Petroleum Gas Cookstoves." *Environmental Science and Technology* 52, no. 2 (2018): 904–915. https://doi.org/10.1021/acs.est.7b05155.

Stockwell, C. E., Christian, T. J., Goetz, J. D., Jayarathne, T., Bhave, P. V., Praveen, P. S., Adhikari, S., Maharjan, R., DeCarlo, P. F., Stone, E. A., Saikawa, E., Blake, D. R., Simpson, I. J., Yokelson, R. J., and Panday, A. K. "Nepal Ambient Monitoring and Source Testing Experiment (NAMaSTE): Emissions of Trace Gases and Light-Absorbing Carbon from Wood and Dung Cooking Fires, Garbage and Crop Residue Burning, Brick Kilns, and Other Sources." *Atmospheric Chemistry and Physics* 16, no. 17 (2016): 11043–11081. https://doi.org/10.5194/acp-16-11043-2016.

Sun, J., Zhi, G., Jin, W., Chen, Y., Shen, G., Tian, C., Zhang, Y., Zong, Z., Cheng, M., Zhang, X., Zhang, Y., Liu, C., Lu, J., Wang, H., Xiang, J., Tong, L., and Zhang, X. "Emission Factors of Organic Carbon and Elemental Carbon for Residential Coal and Biomass Fuels in China—A New Database for 39 Fuel-Stove Combinations." *Atmospheric Environment* 190 (2018): 241–248. https://doi.org/10.1016/j.atmosenv.2018.07.032.

Thompson, R. J., Li, J., Weyant, C. L., Edwards, R., Lan, Q., Rothman, N., Hu, W., Dang, J., Dang, A., Smith, K. R., and Bond, T. C. "Field Emission Measurements of Solid Fuel Stoves in Yunnan, China Demonstrate Dominant Causes of Uncertainty in Household Emission Inventories." *Environmental Science and Technology* 53, no. 6 (2019): 3323–3330. https://doi.org/10.1021/acs.est.8b07040.

Tryner, J., Volckens, J., and Marchese, A. J. "Effects of Operational Mode on Particle Size and Number Emissions from a Biomass Gasifier Cookstove." *Aerosol Science and Technology* 52, no. 1 (2018): 87–97. https://doi.org/10.1080/02786826.2017.1380779.

Venturini, E., Vassura, I., Agostini, F., Pizzi, A., Toscano, G., and Passarini, F. “Effect of Fuel Quality Classes on the Emissions of a Residential Wood Pellet Stove.” *Fuel* 211 (2018): 269–277. https://doi.org/10.1016/j.fuel.2017.09.017.

Wathore, R., Mortimer, K., and Grieshop, A. P. “In-Use Emissions and Estimated Impacts of Traditional, Natural- and Forced-Draft Cookstoves in Rural Malawi.” *Environmental Science and Technology* 51, no. 3 (2017): 1929–1938. https://doi.org/10.1021/acs.est.6b05557.

Weyant, C. L., Chen, P., Vaidya, A., Li, C., Zhang, Q., Thompson, R., Ellis, J., Chen, Y., Kang, S., Shrestha, G. R., Yagnaraman, M., Arineitwe, J., Edwards, R., and Bond, T. C. “Emission Measurements from Traditional Biomass Cookstoves in South Asia and Tibet.” *Environmental Science and Technology* 53, no. 6 (2019: 3306–3314. https://doi.org/10.1021/acs.est.8b05199.

Weyant, C. L., Thompson, R., Lam, N. L., Upadhyay, B., Shrestha, P., Maharjan, S., Rai, K., Adhikari, C., Fox, M. C., and Pokhrel, A. “In-Field Emission Measurements from Biogas and Liquified Petroleum Gas (LPG) Stoves.” *Atmosphere* 10, no. 12 (2019): 729. https://doi.org/10.3390/atmos10120729.

REFERENCES

Abdelnour, S. 2015. “The Cookstove–Rape Prevention Myth and the Limits of Techno-Saviorism.” In *Sustainable Access to Energy in the Global South: Essential Technologies and Implementation Approaches*, edited by Silvia Hostettler, Ashok Gadgil, and Eileen Hazboun, 205–215. Cham, Switzerland, Springer International.

Asian Development Bank(ADB). 2015. *Desk Review of Women’s Time Poverty and Infrastructure in Asia and the Pacifi*c. Mandaluyong City, Philippines: Asian Development Bank.

Alkire, S., R. Meinzen-Dick, A. Peterman, A. Quisumbing, G. Seymour, and A. Vaz. 2013. “The Women’s Empowerment in Agriculture Index.” *World Development* 52: 71–91.

Angelou, Nicolina, Gabriella Elizondo Azuela, Sudeshna Ghosh Bannerjee; Mikul Bhatia, Irina Bushueva, Javier Gustavo Inon, Ivan Jaques Goldenberg, Elisa Portale, and Ashok Sarkar. 2013. *Global Tracking Framework: Sustainable Energy for All.* Washington, DC : World Bank. http://documents.worldbank.org/curated/en/603241469672143906/Global-tracking-framework.

Arango, D., M. Morton, F. Gennari, S. Kiplesund, and M. Ellsburg. 2014. “Interventions to Prevent or Reduce Violence against Women and Girls: A Systematic Review of Reviews.” *Women’s Voice and Agency* Series 10, World Bank, Washington, DC.

Bahadur, R., P.S. Praveen, Y. Xu, and V. Ramanathan. 2012. “Solar Absorption by Elemental and Brown Carbon Determined from Spectral Observations.” *Proceedings of the National Academy of Sciences* 109 (43): 17366–17371. https://doi.org/10.1073/pnas.1205910109.

Bittman, M., J. M. Rice, and J. Wajcman. 2004. “Appliances and Their Impact: The Ownership of Domestic Technology and Time Spent on Household Work.” *British Journal of Sociology* 55 (3): 401–423.

Bond, T. C., E. Bhardwaj, R. Dong, R. Jogani, S. Jung, C. Roden, D. G. Streets, and N. M. Trautmann. 2007. “Historical Emissions of Black and Organic Carbon Aerosol from Energy-Related Combustion, 1850–2000.” *Global Biogeochemical Cycles* 21 (2). https://doi.org/10.1029/2006GB002840.

Bond T. C., S. J. Doherty, D. W. Fahey, P. M. Forster. T. Berntsen, B. J. DeAngelo, M. G. Flanner, S. Ghan, B. Kärcher, D. Koch, et al. 2013. “Bounding the Role of Black Carbon in the Climate System: A Scientific Assessment.” *Journal of Geophysical Research Atmospheres* 118 (11): 5380–5552. https://doi.org/10.1002/jgrd.50171.

California Air Resources Board (CARB). 2019. Woodsmoke Reduction Program. https://ww3.arb.ca.gov/planning/sip/woodsmoke/reduction_program.htm

Castilia (Strategic Advisors). 2015. *Review of Results-Based Financing Schemes in WASH: A report to the Bill and Melinda Gates Foundation*. Seattle: WA: Bill and Melinda Gates Foundation. https://www.rbfhealth.org/resource/review-results-based-financing-schemes-wash-report-bill-and-melinda-gates-foundation

Clean Cooking Alliance and Berkeley Air. 2019. *Impacts and Effects of Improved Wood Burning Stoves on Time Use and Quality: An Experimental Study in Rural Kenya. Baseline Results: Final.* Accessed at: https://www.cleancookingalliance.org/resources/560.html

Clean Cooking Alliance and International Centre on the Research for Women (ICRW). 2016. *Measuring Social Impact in the Clean and Efficient Cooking Sector: A How-To Guide*. Washington, DC: Clean Cooking Alliance and ICRW. https://www.cleancookingalliance.org/about/news/10-28-2016-measuring-social-impact-in-the-clean-cooking-sector

———. 2018.*Inyenyeri Clean Cooking Pilot in Kigeme Refugee Camp: Social Impact Assessment*, 2018. Washington, DC: Clean Cooking Alliance and ICRW. https://www.cleancookingalliance.org/resources/552.html.

Climate and Clean Air Coalition (CCAC). 2018. *2018 Annual Science Update—Black Carbon Briefing Report*. Paris: United Nations CCAC. https://www.ccacoalition.org/en/resources/2018-annual-science-update-black-carbon-briefing-report.

———. 2019. "Black Carbon." Paris: United Nations CCAC. https://www.ccacoalition.org/en/slcps/black-carbon.

Chopra, Deepa, and Elena Zambelli. 2017. *No Time to Rest: Women's Lived Experiences of Balancing Paid Work and Unpaid Care Work*. Global Synthesis Report for Women's Economic Empowerment Policy and Programming. Brighton, UK: Institute of Development Studies.

Clancy, J. S., T. Winther, M. N. Matinga, and S. Oparaocha. 2012. "Gender Equity in Access to and Benefits from Modern Energy and Improved Energy Technologies." World Development Report background paper. New York: ETC/ENERGIA in association Nord/Sør-konsulentene.

Cowan, R. S. 1983. *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave*. New York: Basic Books.

C-Quest Capital and Berkeley Air Monitoring Group. 2019. *Drudgery and Time-use Patterns: Zambia*.

———. 2020. *Impacts and Effects on Gender-Related Outcomes and Sustainable Cooking Fuel Supply after the Introduction of Improved Cookstoves in Rural Zambia*.

Craig, L. 2017. *Evaluation Research on Results-Based Financing: An Annotated Bibliography of Health Science Literature on RBF Indicators for Reproductive, Maternal, Newborn, Child, and Adolescent Health.* New Orleans, LA: Tulane University, Measure Evaluation.

Cundale, K., R. Thomas, J. K. Malava, D. Havens, K. Mortimer, and L. Conteh, L. 2017. "A Health Intervention or a Kitchen Appliance? Household Costs and Benefits of a Cleaner Burning Biomass-Fueled Cookstove in Malawi." *Social Science and Medicine* 183: 1–10.

Daum, Thomas, Filippo Capezzone, and Regina Birner. 2019. "Of Trackers and Tractors. Using a Smartphone App and Compositional Data Analysis to Explore the Link between Mechanization and Intra-Household Allocation of Time in Zambia." ZEF-Discussion Papers on Development Policy 278. https://ssrn.com/abstract=3387859.

Emory. 2016. "NIH awards $30M to Emory, Johns Hopkins, Colorado State for Household Air Pollution Study." Press release. Atlanta, GA: Woodruff Health Sciences Center, Emory University. http://news.emory.edu/stories/2016/10/tom_clasen_air_pollution_study/.

EnDev. 2016. *Empowring People: Report on Impacts*. Eschborn, Germany: GIZ. https://endev.info/images/1/1e/EnDev_Impact_Report_2016.pdf.

ESMAP (Energy Sector Management Assistance Program). 2019. *Tracking SDG 7: The Energy Progress Report*. Washington, DC: World Bank ESMAP. https://trackingsdg7.esmap.org/.

Eyben, R., and M. Fontana. 2011. *Caring for Well-being, Full Report*. Brighton, UK: IDS.

Feng, Y., V. Ramanathan, and V. R. Kotamarthi. 2013. "Brown Carbon: A Significant Atmospheric Absorber of Solar Radiation?" Atmospheric Chemistry and Physics 13: 8607–8621. https://doi.org/10.5194/acp-13-8607-2013

Ferrant, G., and A. Thim .2019. "Measuring Women's Economic Empowerment: Time-use data and Gender Inequality." *OECD Development Policy Papers* 16, Paris: OECD Publishing. https://doi.org/10.1787/02e538fc-en.

Garland, C., Delapena, S., Prasad, R., L'Orange, C., Alexander, D., and Johnson, M. 2017. "Black Carbon Cookstove Emissions: A Field Assessment of 19 Stove/Fuel Combinations." *Atmospheric Environment*, 169(Supplement C), 140–149.

Global Alliance for Clean Cookstoves. 2016. *Gender-Based Violence in Humanitarian Settings: Cookstoves and Fuels*. https://www.cleancookingalliance.org/resources/478.html

Gold Standard. 2016. Gold Standard Improved Cookstove Methodologies Guidebook - GS Simplified, AMS II.G and TPDDTEC 07.07.2016 Version 1.0. http://www.goldstandard.org/sites/default/files/documents/ics_methodology_guidebook_v1.pdf.

———. 2017a. Quantification of climate related emission reductions of Black Carbon and Co-emitted Species due to the replacement of less efficient cookstoves with improved efficiency cookstoves. https://globalgoals.goldstandard.org/412-ics-slcp-black-carbon-and-co-emitted-species-due-to-the-replacement-of-less-efficient-cookstoves-with-improved-efficiency-cookstoves/

———. 2017b. Methodology to Estimate and Verify Averted Mortality and Disability Adjusted Life Years (ADALYs) from Cleaner Household Air. https://globalgoals.goldstandard.org/411-hi-ics-adalys-support-for-methodology-to-estimate-and-verify-adalys-from-cleaner-household-air/

———. 2018. Gender Equality Guidelines and Requirements. https://globalgoals.goldstandard.org/104-par-gender-equality-requirements-and-guidelines/

Government of Kenya, 2019. "Gender Policy." Nairobi: Department of Energy. http://energy.go.ke/wp-content/uploads/2019/10/Gender-Policy-in-Energy.pdf.

Grieshop, A. P., C. C. O. Reynolds, M. Kandlikar, and H. A. Dowlatabadi. 2009. "Black-Carbon Mitigation Wedge." *Nature Geoscience* 2: 533–534. https://doi.org/10.1038/ngeo595.

IIASA GAINS. 2017. *Residential Heating with Wood and Coal: Health Impacts and policy options in Europe and North America*. Eighth Environment for Europe Ministerial Conference, 2016, Batuma, Georgia. https://www.unece.org/fileadmin/DAM/env/documents/2016/ece/ece.batumi.conf.2016.5.e.pdf

IOD Parc. 2018. *Health Results Innovation Trust Fund, Mid-term Review, 2018*. Sheffield, UK: IOD Parc. https://www.rbfhealth.org/sites/rbf/files/HRITF%20MTR%20Final%2004042018.pdf.

International Centre on the Research for Women (ICRW). 2016.

International Food Policy Research Institute. 2012. *Women's Empowerment in Agriculture Index*. Washington DC. http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/126937/filename/127148.pdf.

Jagoe, K., Rossanese, M., Charron, D., Rouse, J., Waweru, F., Waruguru, M., Delapena, S., Piedrahita, R., Livingston, K., & Ipe, J. 2020. Sharing the burden: Shifts in family time use, agency and gender dynamics after introduction of new cookstoves in rural Kenya. Energy Research & Social Science, 64, 101413. https://doi.org/10.1016/j.erss.2019.101413

Jeuland, M. A., V. Bhojvaid, A. Kar, J. J. Lewis, O. Patange, S. K. Pattanayak, N. Ramanathan, I. H. Rehman, J. S. Tan Soo, and V. Ramanathan. 2015. "Preferences for Improved Cook Stoves: Evidence from Rural Villages in North India," *Energy Economics* 52 (PB): 287–298.

Kabeer, Naila. 2018. "Gender, Livelihood Capabilities and Women's Economic Empowerment: Reviewing Evidence over the Life Course." GAGE Working Paper. Overseas Development Institute, UK. https://www.gage.odi.org/publications/gender-livelihood-capabilities.

Khandelwal, Meena & Hill, Matthew E. & Greenough, Paul & Anthony, Jerry & Quill, Misha & Linderman, Marc & Udaykumar, H.S. 2017. "Why Have Improved Cook-Stove Initiatives in India Failed?," World Development, Elsevier, vol. 92(C), pages 13-27. https://www.sciencedirect.com/science/article/abs/pii/S0305750X15309566

Klugman, J., and L. Tyson. 2016. *Leave No One Behind: A Call to Action for Gender Equality and Women's Economic Empowerment*, Report of the UN Secretary-General's High-Level Panel on Women's Economic Empowerment. New York: United Nations. www.womenseconomicempowerment.org/assets/reports/UNWomen%20Full%20Report.pdf

Koch, D., T. C. Bond, D. Streets, N. Unger, and G. R. van der Werf. 2007. "Global Impacts of Aerosols from Particular Source Regions and Sectors." *Journal of Geophysical Research Atmospheres* 112 (D2). https://doi.org/10.1029/2005JD007024

Kodros, J. K., C. E. Scott, S. C. Farina, Y. H. Lee, C. L'Orange, J. Volckens, and J. R. Pierce. 2015. "Uncertainties in Global Aerosols and Climate Effects due to Biofuel Emissions." *Atmospheric Chemistry and Physics* 15 (15): 8577–8596. https://doi.org/10.5194/acp-15-8577-2015.

Lacey, F., and D. Henze. 2015. "Global Climate Impacts of Country-Level Primary Carbonaceous Aerosol from Solid-Fuel Cookstove Emissions." *Environmental Research Letters* 10(11). https://iopscience.iop.org/article/10.1088/1748-9326/10/11/114003 .

Lawson, D. 2007. A Gendered Analysis of 'Time Poverty'–The Importance of Infrastructure. Global Poverty Research Group. https://ora.ox.ac.uk/objects/uuid:21eea8b3-c18c-4af9-aadf-fc6c44555c76/download_file?file_format=pdf&safe_filename=gprg-wps-078.pdf&type_of_work=Working+paper

Lawson, D. 2012. "A Gendered Analysis of Time Poverty: The Importance of Infrastructure." Global Poverty Research Group Working Paper GPRG-WPS-078. London: Economic and Social Research Council.

Lehmann, I., 2019. "When Cultural Political Economy Meets 'Charismatic Carbon' Marketing: A Gender-Sensitive View on the Limitations of Gold Standard Cookstove Offset Projects." *Energy Research and Social Science* 55: 146–154.

Lewis, Jessica J., and Subhrendu K. Pattanayak. 2012. "Who Adopts Improved Fuels and Cookstoves? A Systematic Review." *Environmental Health Perspectives* 120 (5): 637–645.

Listo, R. 2018. "Gender Myths in Energy Poverty Literature. A Critical Discourse Analysis." *Energy Research and Social Science*. 38: 9–18.

Martinez, E. 2017. *Counting the Hours: The Challenges of Measuring Time Use*. Washington, DC: CGIAR. http://a4nh.cgiar.org/2017/08/30/counting-the-hours-the-challenges-of-measuring-time-use/

Masuda, Y. J., L. Fortmann, M. K. Gugerty, M. Smith-Nilson, and J. Cook. 2014. "Pictorial Approaches for Measuring Time Use in Rural Ethiopia." *Social Indices Research* 115 (1): 467–482. doi:10.1007/s11205-012-9995-x.

Minjares, Ray, David Vance Wagner, and Sameer Akbar. 2014. *Reducing Black Carbon Emissions from Diesel Vehicles: Impacts, Control Strategies, and Cost-Benefit Analysis*. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/329901468151500078/pdf/864850WP00PUBL0l0report002April2014.pdf

Mortimer, Kevin, Chifundo B. Ndamala, Andrew W, Naunje, Jullita Malava, Cynthia Katundu, William Weston, Deborah Havens, Daniel Pope, Nigel G. Bruce, Moff at Nyirenda, Duolao Wang, Amelia Crampin, Jonathan Grigg, John Balmes, and Stephen B Gordon. 2016. "A Cleaner Burning Biomass-Fuelled Cookstove Intervention to Prevent Pneumonia in Children under 5 Years Old in Rural Malawi (the Cooking and Pneumonia Study): A Cluster Randomized Controlled Trial." *Lancet* 389: 167 –175. https://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(16)32507-7.pdf

Mukuna, E., and A. Shisanya. 2015. *Milestones in Green Transition and Climate Compatible Development in Eastern and Southern Africa*. Oxford, UK: African Books Collective.

Ndiritu, S. W., and W. Nyangena. 2011. "Environmental Goods Collection and Children's Schooling: Evidence from Kenya." *Regional Environmental Change* 11 (3): 531–542.

Pachauri, S., and N. D. Rao. 2013. "Gender Impacts and Determinants of Energy Poverty: Are We Asking the Right Questions?" *Current Opinion in Environmental Sustainability* 5(2), 205–215.

Pillarisetti, A., S. Mehta, and K. Smith. 2016. "HAPIT, the Household Air Pollution Intervention Tool, to Evaluate the Health Benefits and Cost-Effectiveness of Clean Cooking Interventions." In *Broken*

Pumps and Promises: Incentivizing Impact in Environmental Health, edited by E. Thomas, 147–169. Cham, Switzerland: Springer International.

Pillarisetti, A., M. Vaswani, D. Jack, K. Balakrishnan, M. N. Bates, N. K. Arora, and K. R. Smith. 2014. "Patterns of Stove Usage after Introduction of an Advanced Cookstove: The Long-Term Application of Household Sensors." *Environmental Science and Technology* 48(24): 14525–14533. https://doi.org/10.1021/es504624c.

Practical Action. 2015. *Gender and Livelihood Impacts of Clean Cookstoves in South Asia*. Washington, DC: Clean Cooking Alliance, Global Alliance for Clean Cookstoves. https://policy.practicalaction.org/resources/publications/item/gender-and-livelihoods-impacts-of-clean-cookstoves-in-south-asia-full-report.

Putti, Venkata Ramana; Michael Tsan, Sumi Mehta, and Srilata Kammila,. 2015. "The State of the Global Clean and Improved Cooking Sector." ESMAP Technical Paper 007/15. Washington, DC: World Bank. http://hdl.handle.net/10986/21878.

Reyes-Garcia, V., V. Vadez, E. Byron, L. Apaza, W. Leonard, E. Perez, and D. Wilkie. 2005. "Market Economy and the Loss of Folk Knowledge of Plant Uses: Estimates from the Tsimane" of the Bolivian Amazon." *Current Anthropology* 46: 651–6. https://doi.org/10.1086/432777.

Roshan, W., M. Kevin, and A. P. Grieshop. 2017. "In-Use Emissions and Estimated Impacts of Traditional, Natural- and Forced-Draft Cookstoves in Rural Malawi." *Environmental Science and Technology* 51 (3): 1929–1938. https://doi.org/10.1021/acs.est.6b0555 .

Ruiz-Mercado I, Masera O. 2015. "Patterns of stove use in the context of fuel-device stacking: rationale and implications." *Ecohealth* 12(1):42-56. doi:10.1007/s10393-015-1009-4

Ruiz-Mercado, I., O. Masera, H. Zamora, and K. R. Smith. 2011. "Adoption and Sustained Use of Improved Cookstoves." *Energy Policy* 39 (12): 7557–7566. https://doi.org/10.1016/j.enpol.2011.03.028

Saleh, R., E. E. Robinson, D.S. Tkacik, A. T. Ahern, S. Liu, A. C. Aiken, R. C. Sullivan, A. A. Presto, M. K. Dubey, R. J. Yokelson, et al. 2014. "Brownness of Organics in Aerosols from Biomass Burning Linked to Their Black Carbon Content." *Nature Geoscience* 7: 647–650. https://doi.org/10.1038/ngeo2220.

Samad, Hussain A., and Elisa Portale. 2019. "Have Improved Cookstoves Benefitted Rural Kenyans? Findings from the EnDev Initiative." *Livewire Knowledge Note Series* 102. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/772731563431443718/Have-Improved-Cookstoves-Benefitted-Rural-Kenyans-Findings-from-the-EnDev-Initiative.

Seager, Joni. 2018. *The Women's Atlas*. London: Myriad/New Internationalist.

Seymour, Greg, Hazel Malapit, and Agnes Quisumbing. 2017. *Measuring Time Use in Development Settings.* Washington, DC: World Bank. http://pubdocs.worldbank.org/en/108361466185527591/Greg-Seymour.pdf

Simpson, R., J. Hughes, and N. Slutskaya. 2016. *Gender, Class and Occupation: Working Class Men Doing Dirty Work*. London: Palgrave Macmillan.

Slutskaya, N., R. Simpson, J. Hughes, A. Simpson, and S. Uygur. 2016. "Masculinity and Class in the Context of Dirty Work." *Gender, Work and Organization* 23 (2): 165–182.

Smith K. R., M. Jerrett, H. R. Anderson, R. T. Burnett, V. Stone, R. Derwent, R. W. Atkinson, A. Cohen, S. B. Shonkoff, D. Krewski, C. A. Pope, M. J. Thun, and G. Thurston. 2009. "Public Health Benefits of Strategies to Reduce Greenhouse-Gas Emissions: Health Implications of Short-Lived Greenhouse Pollutants." *Lancet* 374 (9707): 2091–2103. doi:10.1016/S0140-6736(09)61716-5.

Smith KR, Pillarisetti A, Hill LD, Charron D, Delapena S, Garland C, Pennise D. 2015, December. Proposed Methodology: Quantification of a saleable health product (aDALYs) from household cooking interventions, Household Energy, Climate, and Health Research Group (University of California) and Berkeley Air Monitoring Group, Berkeley, CA, for the World Bank.

Smart Freight Centre. 2017. *Black Carbon Methodology for the Logistics Sector*. New York: United Nations Global Green Freight Project. https://www.ccacoalition.org/en/resources/black-carbon-methodology-logistics-sector

Thomas, E. A., C. K. Barstow, G. Abadie Rosa, F. Majorin, and T. F. Clasen. 2013. "Use of Remotely Reporting Electronic Sensors for Assessing Use of Water Filters and Cookstoves in Rwanda." *Environmental Science and Technology* 47 (23): 13602–13610. https://doi.org/10.1021/es403412x.

Thomas, G., and C. Zmroczek. 1985. "Household Technology: The 'Liberation' of Women from the Home?" In Family and Economy in Modern Society, edited by P. Close and R. Collins, 101–128. London: Palgrave Macmillan.

Tian, X. 2017. "Ethnobotanical Knowledge Acquisition during Daily Chores: The Firewood Collection of Pastoral Maasai girls in Southern Kenya." *Journal of Ethnobiology and Ethnomedicine* 13 (1). doi:10.1186/s13002-016-0131-x.

UN DESA (UN Department of Economic and Social Affairs). 2015. *Guide to Producing Statistics on Time Use: Measuring Paid and Unpaid Work.* New York: UN DESA. https://unstats.un.org/unsd/publication/seriesf/seriesf_93e.pdf

UN General Assembly. 2019. *Why Addressing Women's Income and Time Poverty Matters for Sustainable Development*. World Survey on the Role of Women in Development Report of the Secretary-General. New York: United Nations. https://undocs.org/en/A/74/111

UN Women. 2016. "Redistributing Unpaid Care and Sustaining Quality Care Services: A Prerequisite for Gender Equality." *Policy Brief* No. 5, UN Women, New York.

UN Women. 2019. *Progress of the World's Women, 2019-2020*. New York: UN Women.

Vanek, J., 1974. "Time Spent in Housework." *Scientific American* 231 (5): 116–121.

Wang, Y., and C. Corson. 2015. "The Making of A 'Charismatic' Carbon Credit: Clean Cookstoves and 'Uncooperative' Women in Western Kenya." *Environment and Planning A: Economy and Space* 47 (10): 2064–2079. https://doi.org/10.1068/a130233p.

Wankhade, P. P., Mankar, D. M., Kale, N. M., & Shambharkar, Y. B. 2016. "Drudgery Perceived by Women Labourers in Farm Operations." *Indian Research Journal of Extension Education* 15 (3): 85–90.

Waris, V. S., and P. C. Antahal. 2014. "Fuelwood Scarcity, Poverty, and Women: Some Perspectives." *IOSR Journal of Humanities and Social Science* 19 (8): 21–33.

WEAI (Women's Empowerment in Agriculture Index). 2020. *WEAI Resource Center*. Washington, DC: IFPRI.

Westholm, Lisa. 2017. "Gender Perspectives on REDD+ and Global Climate Policy" (doctoral dissertation, Swedish University of Agricultural Sciences, Uppsala).

WOCAN. 2019. "W+ Standard™." San Francisco, CA: WOCAN. https://www.wplus.org/

World Health Organization (WHO). 2014a. "Guidelines for Indoor Air Quality—Household Fuel Combustion." Geneva: WHO. https://www.who.int/airpollution/guidelines/en/.

———. 2014b. *Household Air Pollution and Health—Key Facts Geneva*. WHO. http://www.who.int/mediacentre/factsheets/fs292/en/

———. 2016. *Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease.* Geneva: WHO. http://apps.who.int/iris/bitstream/handle/10665/250141/9789241511353-eng.pdf?sequence=1

World Bank. 2015. *Sustainable Energy for All 2015: Progress Toward Sustainable Energy*. Washington, DC: World Bank. http://hdl.handle.net/10986/22148.

———. 2018. "Super-Clean Cookstove, Innovative Financing in Lao PDR Project Promise Results for Women and Climate." Washington, DC: World Bank.

https://www.worldbank.org/en/news/feature/2018/04/20/clean-cookstove-innovative-financing-lao-pdr-project-promise-results-women-climate

World Bank and CCAC (Climate and Clean Air Coalition). 2015. *Black Carbon Finance Study Group Report*. Washington, DC. World Bank. https://ccacoalition.org/en/resources/black-carbon-finance-study-group-report.

Zacharias, A., R. Antonopoulos, and T. Masterson. 2010. *Why Time Deficits Matter: Implications for the Measurement of Poverty*. New York: United Nations Development Programme and Levy Economics Institute of Bard College.