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Clean cookstoves and clean cooking solutions — Field testing methods for cookstoves

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National foreword

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First edition
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Clean cookstoves and clean cooking solutions — Field testing methods for cookstoves

Fourneaux et foyers de cuisson propres — Méthodes d'essai sur site des fourneaux

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 285, *Clean cookstoves and clean cooking solutions*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

Field measurements of cooking systems are essential for providing metrics for impact evaluation and performance evaluation. Elements of the cooking system include cooking practice, fuel type, fuel quality, cooking device (cookstove) characteristics, and environmental conditions. Each can affect performance. Field tests provide measurements that capture elements of the system that are not able to be reproduced in a laboratory setting. The performance metrics in this document are considered more representative of cooking system performance than those described in ISO 19867-1. However, field testing results are generally only applicable to the study region. Guidelines for determining social impacts on individuals and communities from the cooking system are the subject of ISO/TR 19915[1].

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Clean cookstoves and clean cooking solutions — Field testing methods for cookstoves

1 Scope

This document provides field testing methods to evaluate cooking system performance in real-world conditions.

This document is intended to:

a) Provide quantitative and qualitative measurements of cooking system performance. Requirements and guidance are provided for evaluation of usage, usability, fuel consumption, energy consumption, power, emissions, safety, and durability. These measurements include uncontrolled and controlled cooking tests.

b) Provide guidance for measurements of household air pollution and personal exposure to $PM_{2,5}$ and CO.

c) Provide guidance for field assessments that compare cooking system performance metrics either to defined performance levels or to a counterfactual scenario that enables assessment of whether the new cooking system is improved compared to what would have been observed without the implementation of a new cooking system.

d) Provide guidance for prioritizing measurements that balance comprehensiveness and feasibility.

The parts of the cooking system include the cookstove, cooking vessel, fuel, user practice, and additional cooking devices (such as pot skirts and retained heat cookers). Several measurements in this document are presented as measurements of "cookstoves" or "cooking devices" for simplicity, but are intended to be interpreted as measurements of cooking systems. Some measurements (usage, kitchen energy consumption, and pollutant exposure) pertain to household-level cooking systems that include all cookstoves, cooking devices, fuels, and user practices in a household. Cooking systems can also include other aspects of the cooking environment (such as ventilation when measuring exposure).

This document is applicable to cookstoves used primarily for cooking or water heating in domestic, small-scale enterprise and in institutional applications, typically with firepower less than 20 kW and cooking vessel volume less than 150 l. The provisions of this document are applicable to solar cookers. This document does not cover electric stoves or cookstoves used primarily for space heating. Although some parts of this document can be applicable to electric stoves (usage, usability, safety, durability, cooking power, and household energy consumption), specific considerations required for testing electric stoves are not provided.

This document is intended for manufacturers, implementing organizations, researchers, governments, or other entities that need to evaluate cooking system performance in the field.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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*

ASAE S580.1, *Testing and reporting solar cooker performance*

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3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 Cooking system

3.1.1
cooking device
apparatus used for cooking (by heating)

Note 1 to entry: Cooking devices include such items as *cookstoves* (3.1.4), pot skirts, *cooking vessels* (3.1.3), and retained heat cookers.

3.1.2
cooking system
combination of *cookstove* (3.1.4), fuel, cooking equipment, cooking environment (including ventilation) and cooking practice

3.1.3
cooking vessel
pot or container in which food or water is heated and prepared

3.1.4
cookstove
device primarily employed for the cooking of food, but which can also be employed for space or water heating, or other purposes

3.1.5
improved cookstove
cookstove (3.1.4) proposed for a geographic region or *target community* (3.2.7), which has been shown to outperform a *baseline* (3.2.2) with respect to primary criteria that can include *emission factors* (3.4.5), *fuel consumption* (3.3.3), *thermal efficiency* (3.3.12), *durability* (3.5.2) and/or *safety* (3.5.7)

3.1.6
solar cookstove
solar cooker
device that delivers useful cooking heat from thermal energy received from the sun

3.1.7
traditional cookstove
type of *cookstove* (3.1.4) or three-stone open fire that has been in long existence in a region and has been established from generation to generation

3.2 Adoption

3.2.1
adoption
condition in which a user employs an *improved cookstove* (3.1.5) regularly and maintains it

3.2.2
baseline
status of a market, community, or *cooking system* (3.1.2) prior to intervention, determined by measurements and metadata

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3.2.3
displacement
replacement of a *cookstove* (3.1.4) for major tasks with a different technology that is more efficient, safer, and/or produces fewer harmful emissions

3.2.4
initial acceptance
regular use of *improved cookstove* (3.1.5) by household when it is acquired

3.2.5
cookstove stacking
continued household use of one or more traditional biomass-burning *cookstoves* (3.1.4) in addition to *adoption* (3.2.1) of an *improved cookstove* (3.1.5) for some cooking tasks

3.2.6
sustained adoption
state in which there has been *adoption* (3.2.1) for an extended period of time

Note 1 to entry: The length of time for an *improved cookstove* (3.1.5) to be considered adopted is location and stove specific, but should be defined by the users' reliance on the stove, integration into regular cooking behaviour, and frequent use of the improved cookstove, as well as repair and/or replacement of the improved cookstove when it breaks or wears out.

3.2.7
target community
social group that regularly employs *cookstoves* (3.1.4) and has expressed a willingness to consider the use of *improved cookstoves* (3.1.5)

3.2.8
usability
extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use

[SOURCE: ISO 9241-210:2010, 2.13]

3.2.9
usage
action, amount, or mode of using a cooking device; often a quantitative measure of time that a *cookstove* (3.1.4) is used

3.3 Fuel consumption

3.3.1
as fired
condition of a fuel immediately before testing in a *cookstove* (3.1.4)

3.3.2
burn sequence
combustion of fuel in a *cookstove* (3.1.4) from ignition to an end point defined in a specified protocol

3.3.3
fuel consumed
mass of *raw fuel* (3.3.9) fed, see *fuel fed* (3.3.5), minus mass of *residual fuel* (3.3.10), if applicable, during a defined *burn sequence* (3.3.2)

Note 1 to entry: It is expressed in kilogrammes (kg).

Note 2 to entry: For applicability of *residual fuel* (3.3.10), see details in testing protocol.

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3.3.4
fuel energy used
product of the *heating value* (3.3.6) of the *raw fuel* (3.3.9) and its mass as fired, less the product of the heating value of the *residual fuel* (3.3.10), if applicable, and its mass

3.3.5
fuel fed
fuel supplied to a *cookstove* (3.1.4) during the course of the *burn sequence* (3.3.2)

3.3.6
heating value
energy per unit mass released in the complete combustion of a sample of fuel

Note 1 to entry: The heating value shall be stated as either *higher heating value* (3.3.7) or *lower heating value* (3.3.8).

3.3.7
higher heating value
measured value of the energy of combustion of a fuel burned in oxygen in a bomb calorimeter under such conditions that all the water of the reaction products is in the form of liquid water at 15 °C, $MJ.kg^{-1}$

3.3.8
lower heating value
calculated value of the energy of combustion of a fuel burned in oxygen in a combustion bomb under such conditions that all the water of the reaction products remain as water vapour at 150 °C, $MJ.kg^{-1}$

Note 1 to entry: The *heating value* (3.3.6) at constant pressure is generally used when calculating lower heating value.

3.3.9
raw fuel
mass of the unburned fuel supplied to a *cookstove* (3.1.4) during the course of the *burn sequence* (3.3.2)

3.3.10
residual fuel
material that has a usable energy content that remains after a *burn sequence* (3.3.2) is completed

3.3.11
specific fuel consumption
amount of *fuel consumed* (3.3.3), on a mass or energy basis, per mass of food cooked

3.3.12
thermal efficiency
ratio of *useful energy delivered* (3.3.13) to *fuel energy used* (3.3.4)

3.3.13
useful energy delivered
energy transferred to the contents of a *cooking vessel* (3.1.3), including the sensible heat that raises the temperature of the contents of the cooking vessel and the latent heat of evaporation of water from the cooking vessel

3.4 Emissions

3.4.1
black carbon
particulate carbonaceous material containing mostly carbon by mass and measured by its high absorption of visible light

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3.4.2
carbon emission ratio
ratio of a pollutant concentration to total carbon concentration

Note 1 to entry: Total carbon includes the CO_2, CO, CH_4, non-methane hydrocarbons, and PM.

3.4.3
carbon monoxide
toxic gas formed during the incomplete combustion of carbonaceous material

3.4.4
elemental carbon
particulate carbonaceous material emitted during combustion that demonstrates a refractory nature according to a defined thermal-optical protocol

3.4.5
emission factor
ratio of the mass of a pollutant emitted to a defined measure that quantifies the activity emitting the pollutant

3.4.6
emission rate
ER
mass of an air pollutant emitted per unit time, reported in units such as mg/h or g/s

3.4.7
fuel-based emission factor
EF_{mass}
mass of pollutant per mass of *fuel consumed* (3.3.3)

3.4.8
fuel energy-based emission factor
EF_{energy}
mass of pollutant per MJ of heat from the fuel

3.4.9
household air pollution
presence of air pollutants including solid particles or gases in air in both indoor and outdoor environments of living spaces

3.4.10
modified combustion efficiency
MCE
proxy for true combustion efficiency calculated as molar CO_2 over the sum of molar CO_2 and CO

3.4.11
organic carbon
carbonaceous material emitted during combustion in which the carbon is chemically bonded to hydrogen and possibly also oxygen, nitrogen, sulphur, or other elements

3.4.12
partial capture method
emission sampling method in which part of the exhaust plume is captured and a continuous sample is collected

3.4.13
particulate matter
PM
solids and liquids of a sufficiently small size to be suspended in air

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3.4.14
$PM_{2,5}$
fine *particulate matter* (3.4.13) such that the aerodynamic equivalent diameter of the particles is less than or equal to 2,5 µm

3.4.15
pyranometer
instrument used for measuring global (all-sky) solar radiation

3.4.16
total capture method
emission sampling method in which all of the exhaust plume is captured and a continuous sample is collected

3.5 Safety and durability

3.5.1
acute hazard
hazard (3.5.3) that has immediate or short-term negative consequences

3.5.2
durability
ability of a *cookstove* (3.1.4) to continue to be operated for an extended period safely and with minimal loss of performance under conditions typical of those found in the *target community* (3.2.7)

3.5.3
hazard
potential source of harm

[SOURCE: ISO 7176-14:2008, 3.13]

3.5.4
kitchen
location where food is prepared and cooked

Note 1 to entry: The kitchen may be located indoors or outdoors.

3.5.5
likelihood of hazard
probability of occurrence of a *hazard* (3.5.3)

3.5.6
risk
product of the severity of the consequences of a *hazard* (3.5.3) and the likelihood that the hazard will occur

3.5.7
safety
ability of a *cookstove* (3.1.4) to be operated at an acceptable level of risk of harm

3.5.8
serious hazard
hazard (3.5.3) associated with outcomes that, if present, would lead to severe consequences, such as death or severe injury

4 Symbols, abbreviated terms, and units

NOTE Following ISO convention, decimal comma and thousand spacer in strings of numbers are used in this document.

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Symbol/ Abbreviated term	Definition/ Meaning
BC	black carbon
C	carbon
C_{C}	total carbon concentration, g/m^3
C_{CO}	average CO concentration (background subtracted), g/m^3
$C_{CO,ppm}$	average CO concentration (background subtracted), ppm
$C_{CO,ppm,bkg}$	average background CO concentration, ppm
$C_{CO,ppm,bkg,realtime}$	real-time CO background data series, ppm
$C_{CO,ppm,postbkg}$	post-test background period average CO concentration, ppm
$C_{CO,ppm,prebkg}$	pre-test background period average CO concentration, ppm
$C_{CO,ppm,realtime}$	real-time CO data series, ppm
$C_{CO,ppm,realtime,n}$	measured CO concentration at time point index n, ppm
$C_{CO,ppm,test}$	test period average CO concentration, ppm
C_{CO2}	average CO_2 concentration (background subtracted), g/m^3
$C_{CO2,ppm}$	average CO_2 concentration (background subtracted), ppm
$C_{CO2,ppm,bkg}$	background CO_2 concentration, ppm
$C_{CO2,ppm,postbkg}$	post-test background period average CO_2 concentration, ppm
$C_{CO2,ppm,prebkg}$	pre-test background period average CO_2 concentration, ppm
$C_{CO2,ppm,realtime,n}$	measured CO_2 concentration at time point *n*, ppm
$C_{CO2,ppm,test}$	test period average CO_2 concentration, ppm
CCT	controlled cooking test
$C_{EC(or\ OC)}$	EC or OC concentration (background subtracted), mg/m^3
$C_{EC(or\ OC),back}$	EC or OC concentration measured by backup quartz filter, mg/m^3
$C_{EC(or\ OC),bkg}$	EC or OC background concentration, mg/m^3
$C_{EC(or\ OC),prim}$	EC or OC concentration measured by primary quartz filter, mg/m^3
$C_{EC(or\ OC),sample}$	EC or OC sample concentration, mg/m^3
$CFrac_{eff}$	effective fuel carbon fraction, g/g
$CFrac_{fuel,af}$	as-fired fuel carbon fraction, g/g
CO	carbon monoxide
CO_2	carbon dioxide
CoV	coefficient of variation; standard deviation/mean
$c_{p,p}$	specific heat of cooking vessel material, J/gK
$c_{p,w}$	specific heat of water, 4,186 J/g/K
C_{PM}	average PM concentration (background subtracted), mg/m^3
$C_{PM,bkg}$	average background PM concentration, mg/m^3
$C_{PM,sample}$	average PM concentration, mg/m^3
CSM	continuous stove monitor
D_{back}	backup quartz filter spot diameter, cm
D_{prim}	primary quartz filter spot diameter, cm
DTT	dithiothreitol
EC	elemental carbon
E_{cons}	energy consumed in past 24 h, MJ
$EF_{CO,energy}$	fuel energy based CO emission factor, g/MJ
$EF_{CO,mass}$	fuel mass based CO emission factor, g/kg
NOTE ppm = parts per million.	

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Symbol/ Abbreviated term	Definition/ Meaning
$EF_{CO2,energy}$	fuel energy based CO_2 emission factor, g/MJ
$EF_{CO2,mass}$	fuel mass based CO_2 emission factor, g/kg
$EF_{EC(or\ OC),energy}$	fuel energy based EC or OC emission factor, mg/MJ
$EF_{EC(or\ OC),mass}$	fuel mass based EC or OC emission factor, mg/kg
$EF_{PM,energy}$	fuel energy based PM emission factor, mg/MJ
$EF_{PM,mass}$	fuel mass based PM emission factor, mg/kg
E_{fuel}	energy consumed, MJ
EHV	effective fuel heating value, MJ/kg
E_{percap}	daily per capita energy consumed for a fuel type, MJ
ER_{CO}	average emission rate CO, g/min
ER_{CO2}	average emission rate CO_2, g/min
$ER_{EC(or\ OC)}$	average emission rate EC (or OC), mg/min
ER_{PM}	average emission rate PM, mg/min
ERC_{CO}	CO carbon emission ratio, g/g
ERC_{CO2}	CO_2 carbon emission ratio, g/g
$ERC_{EC(or\ OC)}$	EC or OC carbon emission ratio, mg/g
ERC_{PM}	PM carbon emission ratio, mg/g
E_{tot}	total daily energy consumed for all fuel types, MJ
$E_{totpercap}$	total daily per capita energy consumed for all fuel types, MJ
FEPX	field emissions protocol
g	gram
H	hydrogen
HAP	household air pollution
HEPA	high-efficiency particulate arrestance
IQR	interquartile range
kg	kilogram
kJ	kilojoule
KPT	kitchen performance test
kW	kilowatt
l	litre
LHV	lower heating value, MJ/kg
LHV_{af}	lower heating value, as fired, MJ/kg
LOD	limit of detection
LOQ	limit of quantification
LPG	liquefied petroleum gas
MCE	modified combustion efficiency
mg	milligram
min	minute
MJ	megajoule
$m_{EC(or\ OC),back}$	EC or OC mass density on backup quartz filter, mg/cm^2
$m_{EC(or\ OC),prim}$	EC or OC mass density on primary quartz filter, mg/cm^2
$M_{EC(or\ OC),back}$	EC or OC mass on backup quartz filter, mg
$M_{EC(or\ OC),prim}$	EC or OC mass on primary quartz filter, mg
NOTE ppm = parts per million.	

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Symbol/ Abbreviated term	Definition/ Meaning
M_{col}	new fuel mass collected in past 24 h, kg
M_{cons}	fuel mass consumed in past 24 h, kg
M_f	final mass of fuel, kg
M_{food}	mass of food cooked, kg
M_{fuel}	total mass of fuel consumed, kg
M_i	initial mass of fuel, kg
M_{lid}	mass of cooking vessel lid, g
M_{percap}	per capita fuel mass consumed, kg
M_{PM}	artefact-corrected PM mass on filter, mg
$M_{PM,filter}$	mass of PM collected on filter, mg
$M_{PM,filter,blank}$	average mass of PM collected on blank filters, mg
$M_{PM,filter,f}$	final PM filter mass, mg
$M_{PM,filter,i}$	initial PM filter mass, mg
M_{pot}	mass of cooking vessel, g
M_{prev}	fuel mass stock of the previous day, kg
M_{rem}	fuel mass remaining from the previous day's stock, kg
M_{stock}	mass of fuel stock, kg
MW_x	molecular weight of species x, g/mol
$n(x)$	data series point index for time x
N	nitrogen
OC	organic carbon
Pa	pascal
PAH	polycyclic aromatic hydrocarbon
P_{ave}	average firepower, W
P_{cook}	cooking power, W
P_{post}	post-test ambient pressure, Pa
P_{pre}	pre-test ambient pressure, Pa
P_{std}	standard pressure, 101 325 Pa
PE	personal exposure
PM	particulate matter
PM_{bkg}	average background PM magnitude from real-time sensor, arbitrary units
$PM_{postbkg}$	post-test background period average PM magnitude, arbitrary units
PM_{prebkg}	pre-test background period average PM magnitude, arbitrary units
$PM_{realtime}$	real-time PM data series, arbitrary units
$PM_{realtime,n}$	measured PM magnitude at time point n, arbitrary units
PM_{test}	test period average PM magnitude from real-time sensor, arbitrary units
$PM_{2,5}$	particulate matter with an aerodynamic diameter ≤ 2,5µm
PTFE	polytetrafluoroethylene
Q_{filter}	average volumetric flow across filter (standard conditions), l/min
$Q_{filter,post}$	post-test volumetric flow across filter (actual conditions), l/min
$Q_{filter,post,std}$	post-test volumetric flow across filter (standard conditions), l/min
$Q_{filter,pre}$	pre-test volumetric flow across filter (actual conditions), l/min
$Q_{filter,pre,std}$	pre-test volumetric flow across filter (standard conditions), l/min
NOTE ppm = parts per million.	

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Symbol/ Abbreviated term	Definition/ Meaning
Q_{prim}	average volumetric flow through primary quartz filter (standard conditions), l/min
$Q_{prim,post}$	post-test volumetric flow through primary quartz filter (actual conditions), l/min
$Q_{prim,pre}$	pre-test volumetric flow through primary quartz filter (actual conditions), l/min
$Q_{prim,post,std}$	post-test volumetric flow through primary quartz filter (standard conditions), l/min
$Q_{prim,pre,std}$	pre-test volumetric flow through primary quartz filter (standard conditions), l/min
QFF	quartz fibre filter
R	ideal gas constant, 8,314 J/mol/K
RH	relative humidity
ROS	reactive oxygen species
s	second
SC_{energy}	specific energy consumption, MJ/kg
TCTT	time to complete tasks test
t	time between initial and final water temperatures for the cooking power test, s
$t_{postbkg,end}$	post-test background period end time, hh:mm:ss
$t_{postbkg,start}$	post-test background period start time, hh:mm:ss
$t_{prebkg,end}$	pre-test background period end time, hh:mm:ss
$t_{prebkg,start}$	pre-test background period start time, hh:mm:ss
t_{start}	start time of cooking power test, hh:mm:ss
t_{stop}	stop time of cooking power test, hh:mm:ss
t_{test}	test time length, min
$t_{test,end}$	test period start time, hh:mm:ss
$t_{test,start}$	test period start time, hh:mm:ss
T_{post}	post-test ambient temperature, K
T_{pre}	pre-test ambient temperature, K
T_{std}	standard temperature, 293,15 K
T_1	initial water temperature of cooking power test, °C;
T_2	final water temperature of cooking power test, °C;
UCT	uncontrolled cooking test
V_{back}	volume of air sampled through the backup quartz filter, m^3
V_{filter}	volume of air collected by the PM filter, m^3
V_{prim}	volume of air sampled through the primary quartz filter, m^3
VOC	volatile organic carbon
$w_{c,db}$	moisture content, dry basis, %
$w_{c,wb}$	moisture content, wet basis, %
°C	degrees Celsius
Δ	change
Δt_{burn}	burn sequence time for average firepower test, s
NOTE ppm = parts per million.	

5 Field study development

5.1 General

The purpose of this clause is to provide requirements and guidance for field studies intended to determine performance metrics of cooking systems. It links study design considerations to the metrics

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and guidance provided in this document. Requirements are given for conducting a performance assessment.

Appropriate study design is critical for effective use of resources and ensuring research questions are answered. However, study design depends on numerous technical and practical considerations that can vary immensely across studies. This clause cannot practically address all potential considerations and solutions, but instead provides a framework for determining performance metrics to be measured and a testing strategy. Additional information for developing cooking system field studies is provided in Reference [2], including qualitative thinking tools, considerations and trade-offs, and example surveys for field studies of cookstove programs. In certain cases, specialist knowledge can be necessary to ensure appropriate and statistically valid study design.

The following clauses in this document provide methods for evaluating elements of cooking system field performance. Table 1 identifies common questions driving cooking system field evaluation. The second column of Table 1 refers to relevant metrics in Table 2 for addressing the specified question.

Table 1 — Field research question and suggested metrics for measurement

Field research question	Relevant metric number(s) in Table 2
How is the cookstove performing in terms of energy and fuel consumption?	Fuel use: 13 Power: 28 to 31
What are the potential hazards to health?	Emissions and usage: 15 to 27, and 2 to 9 Household air pollution and personal exposure: 35 and 36
How much is the cookstove influencing climate?	Emissions: 15 to 27
Is the cookstove likely to be used?	Usability: 12
How does the cookstove design relate to usage?	Usability: 12
How much is the cookstove being used?	Usage: 2 to 7
How is the cookstove changing time use patterns?	Usage: 9 to 11
How safe is the cookstove?	Safety: 32
How durable is the cookstove?	Durability: 33 and 34

5.2 Selection of testing strategy

5.2.1 General

Due to the time and resources required for conducting field tests, only cooking systems with reasonable potential for good performance and adoption rates in the targeted communities should be considered for the most rigorous testing. This subclause describes discrete evaluation levels to guide the user of this document to the appropriate measurement method and study design for the cooking system assessment. These evaluation levels are also reflected in Table 2 to guide the user toward the appropriate metric or metrics to measure.

The three evaluation levels of cooking system assessment are as follows and are described in 5.2.2 to 5.2.4.

1) **Preliminary assessment**: If no previous and/or relevant testing of a cooking system has been conducted, and performance is unknown, a preliminary assessment of the cookstove should be completed. This preliminary assessment includes measurements, observations, and surveys of usability, usage, safety, and durability. See 5.2.2 for more information on preliminary assessments.

2) **Performance assessment**: The performance assessment includes measurements, observations, and surveys of usage, fuel consumption, emissions, safety, and durability, and shall be employed to

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evaluate cooking systems that have undergone a preliminary assessment (5.2.2). See 5.2.3 for more information on performance assessments.

3) **Outcomes assessment**: The outcomes assessment can be conducted to determine a change in metrics, such as emissions or household air pollution (HAP), due to use of the improved cooking system (i.e. compared to a baseline cooking system). See 5.2.4 for more information on outcomes assessments.

The metrics measured and the clauses in which to find guidance on these measurements are shown in Table 2.

Table 2 — Field-based metrics of cooking system measurements

Metric #	Metric name	Units	Clause	Preliminary assessment	Performance assessment	Outcomes assessment
1	Laboratory test results	several	5	optional	N/A	N/A
2	Average cooking events per day on a specific cooking device	events/ day	6	optional	required	N/A
3	Average cooking events per day on all cookstoves in a household	events/ day	6	optional	required	N/A
4	Average cooking duration per day on a specific cooking device	h/day	6	optional	required	N/A
5	Average cooking duration per day on all cookstoves in a household	h/day	6	optional	required	N/A
6	Displacement: fraction of cooking events on a specific cooking device	events/ events	6	optional	required	N/A
7	Displacement: fraction of cooking duration on a specific cooking device	h/h	6	optional	required	N/A
8	Number of stacked cooking devices		6	optional	required	N/A
9	Changes in cooking time	min/day	6	optional	optional	N/A
10	Changes in total cooking-related time	min/day/ household member	6	optional	optional	N/A
11	Changes in time-use patterns	qualitative	6	optional	optional	N/A
12	Usability assessment	qualitative	6	optional	optional	N/A
13	Percent difference specific energy consumption	% diff (MJ/kg)	7	N/A	required	N/A
14	Percentage difference of household energy consumption	% diff (MJ/ person/day)	7	N/A	N/A	optional
15	Modified combustion efficiency	mol/mol	8	N/A	required	optional
16	CO emission rate	g/min	8	N/A	required	optional
17	CO fuel energy-based emission factor	g/MJ	8	N/A	required	optional
18	CO fuel-based emission factor	g/kg	8	N/A	required	optional
19	$PM_{2,5}$ emission rate	g/min	8	N/A	required	optional
20	$PM_{2,5}$ fuel energy-based emission factor	g/MJ	8	N/A	required	optional
21	$PM_{2,5}$ fuel-based emission factor	g/kg	8	N/A	required	optional
22	OC emission rate	g/min	8	N/A	optional	optional
23	OC fuel energy-based emission factor	g/MJ	8	N/A	optional	optional

N/A Not applicable.

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Table 2 *(continued)*

Metric #	Metric name	Units	Clause	Preliminary assessment	Performance assessment	Outcomes assessment
24	OC fuel-based emission factor	g/kg	8	N/A	optional	optional
25	EC emission rate	g/min	8	N/A	optional	optional
26	EC fuel energy-based emission factor	g/MJ	8	N/A	optional	optional
27	EC fuel-based emission factor	g/kg	8	N/A	optional	optional
28	Cooking power	W	9	N/A	optional	N/A
29	Average firepower	W	9	N/A	optional	N/A
30	Cooking power for solar cook-stoves	W	9	N/A	required	N/A
31	Cooking efficiency for solar cookstoves	—	9	N/A	required	N/A
32	Safety assessment report	qualitative	10	optional	required	N/A
33	Fraction of non-functional stoves	—	11	optional	required	N/A
34	Fraction of stoves with particu-lar failure	—	11	optional	required	N/A
35	$PM_{2,5}$ concentration 24 h average	$\mu g/m^3$	12	N/A	N/A	optional
36	CO concentration 24 h average	$\mu g/m^3$	12	N/A	N/A	optional
N/A Not applicable.						

5.2.2 Preliminary assessment

If no previous and/or relevant testing of a cooking system has been conducted, and performance is unknown, a preliminary assessment of the cooking system should be completed. The preliminary assessment includes qualitative and quantitative measurements within the study region, as well as any existing laboratory test results. The preliminary assessment can be used to assess adoption and basic performance of a cooking technology and should be conducted before either a performance assessment or an outcomes assessment.

5.2.2.1 Laboratory tests

Laboratory tests (see ISO 19867-1) are highly recommended to be conducted in conjunction with the preliminary assessment and before a performance assessment. Cooking systems that do not perform well under relatively ideal operating conditions of controlled laboratory testing are generally not expected to perform well under normal uncontrolled conditions in homes. Results of laboratory tests can be assessed using the thresholds defined in ISO/TR 19867-3[3].

5.2.2.2 Usage

Adoption and displacement measurements should be sensor-based by using continuous stove monitors (CSMs).

Displacement is a useful way to understand rates of use and adoption by determining the fraction of total cooking duration or events per day on an improved cookstove calculated by measuring cooking duration on all household cookstoves. Displacement can be calculated over a 24 h period and/or over a longer-term period (e.g. 1 year).

Optionally, observations and surveys may also be used to complement CSMs and determine changes in time use patterns (see 6.3.3).

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5.2.2.3 Usability

Information on usability measurement methods is provided in 6.4.

Studies to establish levels of usability should be carried out in target communities where a cookstove type has not been previously tested. Culturally compatible and preferred cookstoves may be identified from a pool of those cookstoves meeting performance-related criteria, or cookstove designs may be created or adapted with these factors in mind. The evaluation of usability can be used to determine if certain cookstoves (and cooking systems) meet the cooking requirements of the target population in ways that provide benefits to the cooks and their families.

Usability metrics may include:

a) fuel cost and convenience: the expense and effort required to obtain and prepare fuel;

b) cooking performance: cooking speed, control, and versatility;

c) operability: ease of operation, ease of learning, and error-tolerance;

d) maintenance: expense and effort required for short- and long-term maintenance;

e) comfort: perceived comfort and aesthetic considerations; and

f) location-specific needs, including secondary uses besides cooking.

5.2.3 Performance assessment

The performance assessment produces quantitative performance metrics for a cooking system of interest that can be compared to existing performance results from comparable measurement methods in publications and resources such as Reference [4]. PM and CO emission rates and fuel-based emission factors can be compared to metrics reported in laboratory tests defined in ISO 19867-1.

Required and optional metrics for a performance assessment and the associated measurement methods are referenced in Table 2. The required metrics for the performance assessment assess fuel consumption, emissions, cooking system usage/adoption, durability, and safety (shown along with optional metrics in Table 2). Requirements shall include all required metrics to claim compliance with this document's performance assessment. Multiple metrics can be measured simultaneously during a performance assessment campaign.

The testing guidance presented in this document may also be used to assess a more limited list of metrics without claiming to have completed a performance assessment in accordance with this document. If baseline data from the study region of interest exists for a given metric, then a performance assessment for this metric can be appropriate for use in comparison against existing baseline data. Comparisons to test results published in the literature and in Reference [4] should only be considered meaningful if data are collected using the protocols described in this document and if sufficient detail regarding the test conditions [e.g. fuel type(s) used, fuel moisture content] is available.

5.2.4 Outcomes assessment

5.2.4.1 General

NOTE 1 This subclause provides guidance, rather than prescriptive direction, on procedures for assessing outcomes, and does not address all ethical and practical considerations of sample selection and study design.

The outcomes assessment evaluates the effect of the improved cooking system compared to a baseline cooking system. Thus, during an outcomes assessment, the baseline cooking system performance should be measured in addition to the improved cooking system performance.

NOTE 2 A cooking system can exhibit improved performance and yet not reduce levels of pollution to which a resident is exposed. For example, the stove might not be used regularly or could be moved into a less-ventilated cooking area.

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Outcomes assessment addresses the question of whether a household cooking system yields improved performance and/or associated outcomes in the target community. Performance and/or outcome metrics can be measured using the study design elements presented in this clause. Refer to Table 2 for a list of the metrics that may be measured under the outcomes assessment study design framework.

5.2.4.2 General design issues

The outcomes assessment requires larger sample sizes or longer monitoring periods than the performance assessment, since both the improved and original cookstove systems are measured. This expansion can be achieved using a cross-sectional study design (greater sample size), described in 5.2.4.3.3.1, or a before-and-after/longitudinal study design (longer monitoring time), described in 5.2.4.3.3.2. The metrics included in the outcomes assessment may include emissions and fuel use, and can also include HAP and/or personal exposure (other potential metrics are shown in Table 2). Metrics listed as outcome metrics in Table 2 are measurements that require a comparative baseline measurement to contextualize the improved stove measurements. Multiple metrics can be measured simultaneously during an outcomes assessment campaign.

5.2.4.3 Study design options

5.2.4.3.1 General

There are several types of program evaluations that may be used as a framework for study design to answer outcomes assessment research questions. Each study design has advantages and disadvantages that should be considered in the planning of the study.

NOTE A common hypothesis for a outcomes-with-performance-metrics study takes the form of 'cooking system X uses less fuel than cooking system Y' or, for an outcomes-with-outcome-metrics study, 'a home with cooking system X has lower household air pollution than one with cooking system Y'. Cooking system X in these examples is typically some sort of improved cooking system and cooking system Y is typically an original cooking system.

5.2.4.3.2 Experimental study design

For an experimental study, randomization of study subjects into control and treatment groups is recommended.

NOTE 1 In randomized experiments, study subjects (or groups) are randomly assigned to a group that receives the program intervention (study or treatment group) or a comparison group that does not receive the intervention (control or non-treatment group). Data for each group are collected before and after the intervention. At the end of the experiment, differences between the intervention and comparison groups can be attributed to the effect of the intervention, if the sample is sufficiently large.

NOTE 2 Randomization, if the sample size is large enough, ensures that the intervention and comparison groups are equivalent with respect to all factors other than whether they received the intervention. The comparison group serves as the 'counterfactual' of what would have happened in the absence of the program—a key requirement in determining whether a program caused an outcome.

NOTE 3 Randomized experiments, also called experimental design, are the most rigorous evaluation design. Although considered the 'gold standard', randomized experiments often are not feasible in real-world scenarios. For more information on experimental, or randomized, studies, as well as other study design options, see Reference [5].

5.2.4.3.3 Observational study design

Observational study designs that do not alter the natural pattern of use and measure what is occurring naturally should be used.

NOTE Observational studies are generally more feasible in a real-world setting than experimental study designs. The two simplest and most commonly used observational study designs in cooking system trials are cross-sectional and before-and-after/longitudinal studies.

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5.2.4.3.3.1 Cross-sectional study (independent samples)

In a cross-sectional study, a sample group of households using improved cookstoves are compared with a sample group of households not using the improved cookstoves, and outcomes are compared across these two groups. The cross-sectional measurement comparison is done on a population level rather than an individual level, which introduces variability and hence requires a larger sample size when implementing a cross-sectional outcomes assessment.

Theoretically, the main difference between the original and improved cooking system(s) measurement groups is the presence or absence of the improved cooking system. However, it can be difficult to ensure that this is the only meaningful difference between the two groups. Careful consideration should be made when selecting participants so that the two groups are well matched in demographic, socio-economic, behavioural, fuel availability, cooking behaviour, cooking location, family size, and other factors that may be specific to the study location, such as commercial cooking, smoking, or animal feed cooking.

These factors are especially important when implementing cross-sectional outcomes assessments as there can be important differences that influence the uptake of new cookstoves and also the reporting of outcomes. The factors should first be assessed with a survey prior to participant selection to understand which factors in the study region might influence uptake and outcomes. These factors need to be well matched or measured between the study groups.

Alternatively, randomized assignment to the original or improved cooking system for the study period can account for some differences. This similarity between the groups should be verified with a comparison between the two study groups and considered in the analysis of the results.

Cross-sectional measurements should be collected during the same time period for the independent study groups, so they are not influenced by temporal factors, such as seasonality or food/fuel availability. However, as the cookstove use and outcomes are measured at the same point in time, it will not necessarily be clear whether the cookstove use influenced the outcomes or vice versa (correlation does not imply causation).

5.2.4.3.3.2 Before-and-after/longitudinal study (paired samples)

In a before-and-after study, the samples for the original and improved cooking systems are collected from the same cooks or households. The sampling is conducted at two different time points, first with the original cooking system, and then after the introduction of the improved cooking system. An adjustment period of at least one month should be planned between 'before' cooking system distribution measurements and the follow-up 'after' cooking system measurements, to allow the users of the improved cooking system to become accustomed to their new technology. Since the monitoring periods are separated in time, temporal changes between the monitoring periods can influence the measurements. Changes such as fuel quality or moisture content, fuel and food availability, and participant schedules can have effects on measurements.

Before-and-after studies can also employ a 'control group', which does not receive the improved cooking system, in order to account for temporal changes observed by the improved cooking system study part. Use of a control group leads to a more robust study design and necessitates a larger sample size and more resources. If the improved cooking system demonstrates favourable performance in the field test, it is advisable to provide equal opportunity for households in the control group to obtain the improved cooking system at the end of the study period. Situations where improved cooking systems are made available in a phased approach can create a natural control group for this purpose.

5.2.4.3.4 Benefits and challenges of cross-sectional vs. before-and-after studies

The benefits and challenges of cross-sectional studies in comparison to before-and-after studies are presented in Table 3.

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Table 3 — Benefits and challenges of study design approaches

Cross-sectional		Before-and-after	
Benefits	**Challenges**	**Benefits**	**Challenges**
— Requires least amount of planning — Can be conducted during a single field campaign without requiring a follow-up of study households at a later time	— Requires larger sample sizes — Improved cooking system users and original cooking system users should be carefully matched	— Smaller samples sizes possible — Samples from improved and original cooking systems are directly comparable	— Greater burden on participants due to the multiple visits required — Possible changes between the before-and-after monitoring (i.e. seasons) can affect measurements

There are many study design options for different research needs. If more complex study design options are required, such as randomized control trials, researchers should consult with a study design expert.

5.3 Sample selection guidance

5.3.1 General

The aim of a field study is to measure a subset of homes that represent the general study population and yield the same results as that the entire region of interest would yield if the full set of homes within the region was sampled. Guidelines for sampling are available from Reference [6], which outlines the various considerations for sample design and provides a sample size calculator.

Additional methods and considerations for sample selection are provided in Reference [2].

5.3.2 Efficacy versus effectiveness

For intervention studies, whether randomized or observational, it is important to define whether the study is an effectiveness trial (uncontrolled, i.e. measuring the performance or outcome of an intervention under real-world conditions) or an efficacy trial (controlled, i.e. measuring performance or outcome under near-ideal circumstances). This determination will frame the study and guide how participants are requested to participate. Some considerations are presented in Table 4.

Table 4 — Examples of factors to consider for effectiveness versus efficacy trials

Study development consideration	Training on use of an improved cooking system during cooking system dissemination	Participant instruction for personal exposure or household air pollution study	Will improved cooking systems be repaired or replaced for free during study period?
Effectiveness (real world)	Training should mirror the expectation for training in the scaled-up cooking system program	Participants should be instructed to cook as they wish with no specifications on which cooking systems to use during measurement period	Repair and replacement should mirror what the scaled-up program for the improved cooking system will employ
Efficacy (idealized)	Training should be as extensive as possible to ensure participant is fully clear on operation of the improved cooking system	Participants should be encouraged to use only the improved cooking system and discontinue use of the original cooking system	Cooking systems should be repaired and replaced as soon as needed in order to have the greatest number of optimally working cooking systems during the study

For more information on effectiveness versus efficacy trials, see Reference [7].

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5.3.3 Uncontrolled cooking test (UCT)

An uncontrolled cooking test is a set of measurements performed when the meal is not constrained, and cooks are free to prepare what they want, how they want, using whatever cooking implements and fuels they choose. The UCT can be employed for the measurement of any cooking system, either original or improved. The UCT is applicable for measuring usage, power, and emissions.

5.3.4 Representative site selection

Selection of the study site is generally dictated by the focus area of the implementing organization. Assuming there is flexibility within the project area, several considerations can help guide the selection of the specific communities to ensure a successful field campaign.

5.3.4.1 Generalizability

Selection bias occurs when the participants selected do not represent the target population. When determining a study sample, researchers should consider the target demographic for the given study cooking system and should ensure the recruited participants match the target demographic based on key descriptors. Depending on the indicator measured, these factors can include socioeconomic status, primary fuel type, kitchen characteristics, family size, cooking practices, and original cooking system type. However, there are always potential influencing factors that cannot be predicted or measured, so within these constraints, randomization should be used.

5.3.4.2 Identifying representative communities

Cooking systems should be tested in communities that are representative of the cooking and fuel use practices of the potential customer/users, considering socio-economic and agro-climatic traits. Local cuisine, fuel types/mixing, and other energy demands, such as heating, should be carefully considered to ensure that the measurements are taken in communities that typify the larger geographic region and the location where the cooking system program will be scaled up. The samples should be selected from households that represent the potential customers/users, with care taken to represent the relevant socio-economic and agro-climatic conditions. If large and distinct differences in these conditions exist within a given region, then sampling across these conditions will be necessary to provide representative performance estimates.

5.3.4.3 Obtaining data on representative practices

If information on the cooking and fuel use practices to guide the study site designation is not formally available through prior surveys or census data such as Reference [4], it can often be provided by local partners or contacts with knowledge of the target area.

5.3.4.4 Representative household selection

Within each of the sampling approaches, selection criteria can further guide recruitment of households. Selection criteria are designed to identify study participants that are representative of the target population of interest and have the necessary characteristics to answer the research question. Participant selection criteria will vary depending on the performance or outcome metric measured. Exclusion and inclusion criteria are specified during study design to decide who will take part in the study. In selecting representative samples, the factors mentioned in 5.2.4.3.3 are unlikely to be matched.

NOTE Reference [2] provides an example of a short selection criteria survey used in the field to screen potential participants for an uncontrolled cooking test.

5.4 Selection of representative sampling times

Selection of representative sampling days is particularly important because it is usually impractical to randomize the sampling days across seasons. There can also be specific days or times when

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sampling is not representative due to factors such as cultural events and household work schedules (e.g. harvest times).

5.4.1 Seasonal

There are likely to be seasonal differences in emissions. If a before-and-after study design is carried out with the baseline and follow-up data collection periods occurring in different seasons, there is a risk that the results will be confounded by seasonal changes in cooking and fuel use behaviour. Although some of the confounding effects of seasonal behaviour can be explored and controlled for, if possible, the before-and-after sections of the study should be conducted in the same season.

5.4.2 Events

Consultation with the local team should be carried out to identify any religious or cultural festivals/events occurring during the proposed study timeline in the target population. These events can often cause the communities to be unavailable to participate in the study or can influence them to cook in ways that are not reflective of normal behaviour. Such events can also limit the availability of the field staff.

5.4.3 Harvest

If conducting the study in an agricultural community, care should be taken to ensure that the harvest and/or planting season will not complicate sampling due to participants' time demands. The influx of migrant workers and use of harvest-specific crop residues for cooking can also alter the normal cooking patterns and performance.

5.4.4 Weather constraints

In geographical areas with extreme climatic seasons, possible constraints imposed by the weather should to be considered. For example, physical access to the study site can be limited during the rainy season.

5.5 Sample size

Sample sizes should be determined following the guidelines in Reference [6].

When determining the difference in performance between an improved and an original cooking system, the sample size or number of tests required to support or refute a hypothesis is a function of the expected variability in the measurements and the expected or desired difference in performance of the improved and original cooking systems. Any study reliant on repeated measures is at risk of participant fatigue or drop out. Fatigue and dropout occur when participants begin a study but are unable or unwilling to participate in follow-up visits. It is often advised to oversize a study to mitigate the impacts of participant dropout by approximately 10 %.

Key sample size concepts and conventions can be found in Reference [2].

NOTE Cross-sectional studies necessitate more samples because the comparison is between two independent groups, which results in more variability. A before-and-after study, in contrast, directly compares the results of a paired sample, which reduces the variability.

Tables 3 and 4 in Reference [2] provide a guide for determining sample sizes for a field study. The tables assume the standard conventions: p-value of 0,05, power of 80 %, and a two-tailed statistical test. Given the assumed conventions, the remaining factors to consider are study design, expected/desired difference in the means, and expected variability.

EXAMPLE If the detectable difference for the performance metric of interest is targeted to be 40 % and a CoV of 60 % is expected, then the researcher would need 36 test samples in each group for cross-sectional study, or 18 in a before/after study (sampled once with the original cooking system and once with the improved cooking system). Adding an additional 10 % for potential drop-out would yield 40 test samples in the cross-sectional study or 20 in a before-and after study. For a study in which the outcomes relate to health or the sample is clustered, a larger sample is likely to be needed.

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With large detectable differences and small CoV, it is theoretically possible to measure statistically significant differences with very small sample sizes; however, sample sizes less than 15 for uncontrolled field testing should be avoided to maintain a reasonable level of confidence in the results.

5.6 Field technician capacities

Field technicians should have experience with instrument handling and following protocols. Collecting quality data will be aided by having conscientious, well-trained, independent, and motivated field staff. The technicians should be sensitive to local cultures and customs and be able to communicate fluently, preferably in the same language as the participants. These individuals should not have any vested interested in the outcome of the study, nor be supervised by personnel responsible for the promotion of any fuel or technology.

In-field responsibilities include correctly completing consent forms; filling out survey forms legibly, completely, and consistently; and setting up/running the test equipment according to set protocols. The team should pay close attention while taking detailed notes during tests.

Post-field procedures can include downloading data from instrumentation, calibrating and cleaning instruments, gathering supplies for the following day, and possibly data entry, depending on the arrangement with the field supervisor and project manager.

5.7 Measurement statistics

5.7.1 General

All aggregated measurements should be reported as a sample mean or proportions, median, standard deviation, and CoV. Confidence intervals should also be included.

Further information on statistical analysis can be found in Reference [8].

5.7.2 Reporting guidelines

Written consent of the cook should be obtained for all test methods and metrics in this document along with photographs and records of test conditions.

When reporting aggregated data, measures of spread (such as the range, interquartile range, variance, and standard deviation) should be reported to help contextualize test results and to help others when designing similar studies. One way to characterize uncertainty is to report the 95 % confidence interval, which indicates that in repeated identical experiments, there is a 95 % probability that the confidence interval will include the true mean value.

For more information on statistical analysis for calculating uncertainty and variability of a data set, see Reference [8].

5.7.3 Mitigating bias and managing uncertainty

Mitigating bias and managing measurement uncertainty are critical for controlling the quality of the data collected during a field measurement campaign. Systematic bias can be minimized with good quality assurance and quality control practices. See Reference [2] for more information. See Annex C for guidelines on reporting measurement uncertainty.

6 Usage and usability

6.1 General

Cookstove use and adoption rates, which relate to the potential impact of a cooking system, can be assessed through usage measurements. The cookstove user's cooking needs and attitudes towards

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a cookstove, which may impact usage decisions, can be understood by the assessment of cookstove usability.

An example cookstove usage and usability survey can be found in Reference [2].

6.2 Sample selection and timing

Guidelines for sample selection are provided in 5.3 and contain provisions for selecting a representative sample of households in a target community. Additional considerations important in study design for cookstove usage measurements can be found in 5.2. These considerations include determining relevant baseline use and time required to adjust to an improved cookstove, which need to be determined before representative measurements can be taken.

6.3 Cookstove usage

Intended outcomes of an improved cooking device can only be realized if it is used. Usage measurements include how much and how often a cooking device is used, as well as savings in time use attributed to a cooking device. This subclause describes sensor, observation, interview, and survey-based usage measurements.

6.3.1 Usage reporting metrics

The quantitative measurement of changes in time use due to a new cooking system relative to the old cooking system does not necessarily provide a complete picture of the impact on time use. Qualitative investigations of the changes in time use patterns for all household members are also recommended, as tasks may shift from one family member to another or take place simultaneously after the introduction of a new cooking system. Similarly, perceptions of drudgery and quality of time may also evolve.

Reporting metrics for cooking events in usage studies can be used to assess changes in time use due to a new cooking system compared to the original cooking system. These metrics include:

a) changes in time use, measured relative to time to complete a standard cooking task;

b) changes in time use of other activities related to cooking, such as

   1) fuel gathering (walking, chopping, carrying);

   2) fuel preparation (chopping, splitting, stacking);

   3) food preparation (peeling, chopping, grinding, mixing);

   4) fire tending (fanning, blowing, adding fuel);

   5) fire starting (lighting, adjusting, maintenance);

   6) food tending (mixing, stirring, flipping); and

   7) clean-up (extinguishing fire, removing ashes, washing pots); and

c) total changes in time use, measured as the sum of the time savings for the cooking task and all other related activities.

The following reporting metrics are determined by using continuous stove monitors as described in 6.3.3.3:

— average cooking events per day on a specific cooking device;

— average cooking events per day on all cooking devices in a household;

— average cooking duration per day on a specific cooking device;

— average cooking duration per day on all cooking devices in a household;

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— displacement as a fraction of cooking events on a specific cooking device;

— displacement as a fraction of cooking duration on a specific cooking device; and

— number of stacked cooking devices.

NOTE Displacement is a useful way to understand rates of use and adoption by determining the fraction of total cooking duration or events per day on an improved cookstove calculated by measuring cooking on all cooking devices in a household including both improved and traditional cooking devices.

6.3.2 Usage claims

6.3.2.1 Performance assessment

To claim compliance with this document's performance assessment, requirements for usage shall use sensor-based measurements. The measurement period shall last one month or more. The sample of households shall be determined following the provisions of Clause 5, with a minimum sample size of 20 households if the sample guidelines result in a lower sample size.

NOTE Studies have shown that self-reported cookstove usage is not correlated with sensor-based measures of cookstove usage (see References [12] and [10]).

6.3.2.2 Sustained adoption

Claims regarding sustained adoption should be based on long-term sensor-based monitoring in order to track how usage has changed over time (see References [9] and [10] for more information). To achieve an accurate understanding of sustained adoption, measurements should be made over 8 months or more[11]. Daily measurements of all cooking events should be taken by placing sensors on the cookstove to continuously monitor for the duration of 8 to 9 months. This length of time might not reflect seasonal variation. Sensors should be used to calculate average daily usage per month, and data should be plotted on a histogram to assess how usage has changed over time.

6.3.2.3 Changes in time use

While it is possible to make claims of cooking time savings of one cooking system relative to another using the approach described in 6.3.3.2, claims based on this methodology should be presented very specifically in relation to technology and fuels only. Any claims of outcomes for users based on time-related metrics should focus on labour time and reflect a more nuanced investigation. Such claims should take into consideration the ways in which changes in cooking technology, fuel, or practices (alone or in combination) affect household time use, whether through time savings, increased time expenditures, or balance-neutral transference of time among activities and/or household members, as well as changes in the user's perceptions of the changes in time use, such as the increase or decrease of perceived drudgery.

6.3.3 Measurement methods

6.3.3.1 General

Measurement methods can be observational, interview, and/or sensor-based (see Reference [2]).

6.3.3.1.1 Observational-based usage measurements

Observational-based methods include local observation during individual cooking events, allowing for notes to be taken regarding cooking time, exposure time, tending time, and clean up time associated with a specific event.

Observational forms reduce recall bias by the participant and allow the surveyor to make objective observations of use. Quick observations can include spot-checking cookstove presence, absence, or

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condition. Observations of all cookstoves in the home are recommended. Structured observations may be used in which certain key behaviours are counted.

EXAMPLE The inspector might count the number of times the stove was relit during a cooking event or the number of refuellings.

These methods can facilitate collecting observational data efficiently across larger samples sizes. These approaches also provide insights into how intensively the cook participates in the cooking across the duration of the event.

Longer-term observations can include physically observing behaviours associated with cooking by keeping a record of activities performed by the cook before, during, and after cooking times. When conducting this type of observation, it is important to limit intrusiveness to avoid observational bias (i.e. changes in behaviour due to the researcher's presence).

In some cases, longer-term observations can be partially automated using time-lapse video cameras to record cooking behaviours (i.e. 'video ethnography'). Informed consent of the cook and family members will be necessary for such studies, and these studies should be approved by an ethics review committee.

6.3.3.1.2 Interview/survey-based usage measurements

Interview and survey methods rely on recall by the participant on typical behaviour patterns. These methods yield information on subject demographics, characteristics, and factors associated with cookstove use behaviour.

Interview-based usage measurement can be conducted using questionnaires designed to investigate usage patterns, cookstove and fuel preferences, effects on use due to seasonal or other external factors, and drivers for adoption. Questionnaires should be piloted before use to ensure cultural appropriateness and clarity of the questions. Surveyors should be trained in the use of the surveys before administering them.

An example cookstove usage and usability survey can be found in Reference [2].

NOTE There are disadvantages to interview and survey methods. Responses do not necessary reflect reality, but instead an interviewee might try to satisfy the interviewer's expectations. Imperfect human recall can also lead to errors in responses. This effect increases with the time gap between an event and the interview.

6.3.3.1.3 Sensor-based usage measurements

Sensor-based methods allow direct, objective measures of cookstove heat output using temperature as a proxy for cooking. These methods can be used to measure use across many households using multiple cookstoves. Sensor-based methods cannot necessarily distinguish between cooking time, energy output time, heating time, and other associated applications that increase the temperature of cookstoves without necessarily increasing the cooking time. Sensor-based methods can be used to quantify sustained use over time. Study design for sensor-based methods can vary.

6.3.3.1.4 Combining measurement approaches

Sensors and survey forms can be used independently or together. Combining the methods can allow contextual information from surveys to inform sensor-based measurements.

EXAMPLE 1 An observation of a broken cookstove explains why a sensor-based measurement yields a "no-use" status.

EXAMPLE 2 A completed questionnaire reveals that the festival season is responsible for the higher than normal sensor-based usage measurements, which show cooking for 6 h per day for 3 days in a row.

Reference [2] compares the data measured by observational, interview, and sensor-based methods and also discusses their associated protocols, data analyses, and limitations. It is recommended that interviews or surveys be completed as close to the event as possible.

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6.3.3.2 Observation, interview, and survey-based time measurements

Time measurements are listed in 6.3.1 and can be separated into cooking time and labour time.

6.3.3.2.1 Potential constraints of observational and interview measurements

The use of observational methods can require significant time investment by observers to obtain appropriate sample sizes.

These data can also be subject to biases such as the Hawthorne effect, whereby study participants change their behaviour due to the presence of an observer.

EXAMPLE Study subjects might use the improved stove for a larger portion of cooking than they normally would or might load fuel in a manner that more closely follows the training they received than they would when not under observation.

Similarly, interview methods are subject to recall bias by the participant.

6.3.3.2.2 Cooking time

Cooking time refers to the total time spent cooking a dish; it is the time difference between the finishing time and the starting time of cooking (in minutes), which is referenced within the CCT protocol[13]. Cooking time can be measured by sensor-based, observational, or interview methods (see 6.3.3.1).

Observational methods allow for single events to be observed.

Interview methods can also be used to investigate cooking time for different tasks on different cookstoves.

6.3.3.2.3 Labour time

Labour time includes cooking-related times that are not measures of the actual cooking period. These time periods consist of:

a) fuel gathering (walking, chopping, carrying);

b) equipment maintenance (axe sharpening, knife sharpening, fixing);

c) fuel preparation (chopping, splitting, stacking);

d) food preparation (peeling, chopping, grinding, mixing);

e) fire starting (lighting, adjusting, maintenance);

f) fire tending (fanning, blowing, adding fuel);

g) food tending (mixing, stirring, flipping); and

h) clean-up (extinguishing fire, removing ashes, washing pots).

Observations allow for records to be kept regarding cooking-related behaviours, such as gathering and preparing fuel, preparing food, starting a fire, cookstove tending time, and clean up after cooking that cannot be captured by sensor-based methods.

Interview methods can also be used to investigate the cooking-related behaviours listed above.

6.3.3.2.4 Time to complete tasks

For a time to complete tasks test (TCTT), the time to prepare a controlled meal should be monitored for the traditional cookstove and improved cookstove of interest. The full cycle of food and fuel preparation, cookstove lighting, cooking, and any cookstove cleaning tasks should be recorded during a timed event for each cookstove. A minimum of three traditional cookstove events and three improved cookstove

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events should be conducted on the same meal type that is applicable to the local context. Multiple meal types can be chosen, as needed in the local context. Refer to ISO/TR 19915[1], for more context and qualitative guidelines. See also the CCT protocol[13].

6.3.3.3 Continuous (cook)stove monitoring (CSM) measurement method

6.3.3.3.1 General

A number of commercially available continuous stove monitors (CSMs) can be purchased, which log temperature data or other indicators of cookstove use. Deciding which one works best for a given project depends on the cookstove type, budget, and study design, with respect to the availability of appropriate data analysis alternatives. The main components to consider when selecting among device options are memory and battery life of the device, cost, data processing and analysing, and size/placement requirements. Each cookstove use monitor will come with more explicit instructions for use, which are not covered in this document. A comparison of several cookstove use monitors can be found in Reference [2]. Accuracy of CSM devices vary, but the accuracy of cookstove usage measurements (in hours per day) is more strongly affected by other factors such as CSM placement and the algorithm used to translate raw CSM output to hours of usage.

Calibration of the algorithm for the sensor to translate temperature into cooking duration shall be performed before sensors are used to compare usage across different stoves.

NOTE For sensor-based methods, it is important to understand how the cookstoves are used. Fuel left in the cookstove to burn out after cooking is done can lead to a misinterpretation of 'hot cookstove' time as 'cooking' time.

6.3.3.3.2 Piloting placement of temperature sensors

Protocol for CSM placements varies with choice of device for the study. Placement of the sensors should be piloted with all cookstove types seen in the field to decide on a standardized placement protocol for each cookstove type that will yield strong signals and will not break sensors from frequent overheating and burn out. Potential places suitable for CSM placement can be determined using a data logging thermocouple with a real-time screen interface.

While the cookstove is in use, a location should be identified that shows a strong heat signal but not higher than that for which the CSM is rated. After identification of this location, the CSMs should be placed according to the user guide and data should be logged over at least 24 h in a home that is using the cookstove. The data should then be assessed to determine if the signal is both clear and safe for the CSM's temperature threshold. For some CSMs, insulation, such as high temperature silicone, can be added to protect the CSM from high heat.

6.3.3.3.3 Installing CSMs during a study

Once a standard location for CSM placement has been determined for all cookstoves, CSMs should be placed in homes. If displacement metrics are intended to be reported, CSMs should be placed on all cookstoves in homes. Those cookstoves may include traditional cookstoves, advanced cookstoves, gas cookstoves, electric cookstoves, electric rice cookers, or electric kettles.

Manufacturers' usage guides should be followed when handling CSMs. Additionally, CSM placement should not be in direct sunlight, and should not interfere with participants' normal activities. Participants should be informed of the purpose of the CSMs and should be instructed not to tamper with CSMs.

When installing CSMs, surveyors shall fill out a tracking form for each house that documents the location of all CSMs. The placement of each CSM shall be documented with a photograph that includes a visible ID number for each cookstove. Reference [2] provides an example of a tracking form. Using identifiers such as label stickers or barcodes will help to track CSMs in the field when handling many sensors for many households.

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When using temperature-based CSMs, additional CSMs shall be deployed to measure ambient temperature. Ambient CSMs shall be located out of direct sunlight. A minimum of three ambient CSMs shall be used within a sample region.

6.3.3.3.4 Analysing CSM data

A standardised algorithm shall be used to determine the time periods when each stove is being used and the daily stove usage (in hours per day) from the raw CSM data. For temperature-based CSMs, ambient temperature data series shall be subtracted from stove CSM data series. Output data from CSM analysis software should be inspected for erroneous results and cross-checked against a subset of observational data.

Cookstove stacking is determined by identifying all cooking devices that are used in a household. Cooking devices that are not used (determined by analysing CSM data) shall not be counted.

6.3.3.3.5 CSM usage reporting

A usage reporting template should include:

a) average and standard deviation of:

   1) average cooking events per day on a specific cooking device,

   2) average cooking events per day on all cooking devices in a household,

   3) average cooking duration per day on a specific cooking device,

   4) average cooking duration per day on all cooking devices in a household,

   5) displacement as a fraction of cooking events on a specific cooking device,

   6) displacement as a fraction of cooking duration on a specific cooking device, and

   7) average number of stacked cooking devices per household; and

b) description of:

   1) sample location,

   2) household sample size,

   3) cooking devices measured and frequency of use of each cooking device,

   4) CSM type and features, and

   5) algorithm and/or software used to analyse raw CSM data.

6.4 Cookstove usability

Usability measures the degree to which a cooking system is able to meet the needs of a cook in a given context and can be understood in terms of effectiveness, efficiency, and user satisfaction. The usability of a cookstove can depend on each end user; therefore, measurements should be taken across diverse ranges of target populations. Usability criteria include:

a) fuel cost and convenience: the expense and effort required to obtain and prepare fuel;

b) cooking performance: cooking speed, control, and versatility;

c) operability: ease of operation, ease of learning, and error-tolerance;

d) maintenance: expense and effort required for short- and long-term maintenance;

e) comfort: perceived comfort and aesthetic considerations; and

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