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FRACTION OF NON-RENEWABLE BIOMASS IN EMISSION CREDITING IN CLEAN AND EFFICIENT COOKING PROJECTS

A REVIEW OF CONCEPTS, RULES, AND CHALLENGES

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List of Acronyms and abbreviations

AFOLU	Agriculture, Forestry and Land Use
AMS	Approved Methodology for Small Scale Projects
CDM	Clean Development Mechanism
CERs	Certified Emission Reductions
CH_4	methane
CMP	Conference of the Parties (to the Kyoto Protocol)
CPA	Component Project Activity
CO_2e	carbon dioxide equivalent
DNA	Designated National Authority
DRB	demonstrably renewable biomass
EF	emission factor
ER	emission reductions
ESMAP	Energy Sector Management Assistance Program
FAO	Food and Agriculture Organization
fNRB	fraction of Non-Renewable Biomass
FDF	Forest Degradation by Fuelwood tool
GHGs	greenhouse gases
GS	Gold Standard
H	total annual woodfuel consumption
ha	hectare
HAP	household air pollution
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
$ktCO_2e$	kiloton(s) of carbon dioxide equivalent
LDCs	Least Developed Countries
MAI	mean annual increment
MoFuSS	Modeling Fuelwood Sustainability Scenarios
MT	megaton

NCV	net calorific value
NDC	Nationally Determined Contribution
PDD	Project Design Document
PM	particulate matter
PoA	Program of Activities
RB	renewable biomass
SIDS	Small Island Developing States
SSC WG	Small-Scale Working Group
t	ton(s) / tonne(s)
tCO_2e	tonne(s) of carbon dioxide equivalent
TPDDTEC	Technologies and Practices to Displace Decentralized Thermal Energy Consumption
UNFCCC	United Nations Framework Convention on Climate Change
VCS	Verified Carbon Standard
VCU	Verified Carbon Unit
VERs	Verified Emission Reductions
WISDOM	Woodfuel Integrated Supply/Demand Overview Mapping
yr.	year

Executive Summary

For several decades, international donors, researchers, and grassroots organizations have tried to address the health and environmental effects of cooking and heating with woodfuel, charcoal, and other solid fuels, but success has been elusive, so financing transitions to clean and efficient cooking has been a major challenge. Monetized climate benefits such as carbon offsets have the potential to bring outside investment to clean and efficient cooking interventions, which reduce emissions by reducing or displacing nonrenewable biomass . A key parameter—the fraction of nonrenewable biomass (fNRB)—is required to estimate the magnitude of offsets.

As with any activities that generate emission reductions (ERs), detailed carbon-offset methodologies are used to define how to quantify and verify ERs from clean and efficient cooking interventions for use in voluntary and compliance markets. This report is designed to help carbon financiers and investors make sense of the methodologies that have been developed for clean and efficient cooking interventions. The methodologies all follow the same general processes but differ in some important details, including how they address fNRB.

Accurately estimating fNRB is difficult because it requires accurate assessments of woodfuel consumption and woody biomass growth rates in areas where projects are being implemented, which are often remote, rural, and marginalized. In an ideal world, current information about place-specific woodfuel consumption, biomass stocks, tree growth, and accessibility would be readily available. This would make it easy to estimate and periodically update fNRB values anywhere people rely heavily on woodfuel and charcoal. Unfortunately, these data are difficult to obtain. For many countries, the only information about woodfuel consumption comes from country-level estimates from international organizations such as the Food and Agriculture Organization (FAO) and the International Energy Agency (IEA), but these are rarely grounded in empirical data. Some countries periodically conduct household surveys, which are preferable, but most censuses and demographic surveys ask about the primary type of cooking fuel used without gathering information about the quantity consumed. Even when surveys try to quantify consumption, the data are difficult to interpret because woodfuel quantities are not standardized; people collect woodfuel by headloads or oxcarts, and charcoal is sold by sacks, buckets, or tins. Translating into kilos often relies on guesswork by survey enumerators. Finally, some studies visit households over several days and weigh daily fuel consumption, but these types of assessments are invasive, costly, and time consuming and typically cover only small populations.

Obtaining accurate information about reliable biomass supply is also challenging. Although forest-cover data are readily available from easily accessible remote-sensing data such as Landsat and related analyses, date on woody biomass stock and growth rates are less accessible. This is particularly true in woodland-mosaic landscapes, tropical dry forests, and trees growing outside forests, which are the most important sources of woodfuel and charcoal in the global south.

To ease the burden on project developers, offset methodologies allow them to use simplifying assumptions and/or default values for critical parameters under certain conditions. Although these are not necessarily accurate representations of field data, they are supposed to be conservative, which means that, if they are incorrect, they err on the side of *underestimating* rather than *overestimating* ERs. Carbon offset methodologies have been developed to address these data challenges. They were first introduced in the Kyoto Protocol's Clean Development Mechanism (CDM) and by Gold Standard (GS) in 2008. Since then, these methodologies have undergone many revisions. Versions that were in place during the peak of the CDM and voluntary market activity period relied heavily on assumptions about demonstrably renewable biomass" (DRB) that allowed assumptions and/or default values that were generous rather than conservative. **For many registered projects, this resulted in fNRB values and emission reduction claims that were very likely overestimates, a fact documented in several peer-reviewed publications**. In response, CDM methodologies were revised again in an attempt to rein in unrealistic fNRB estimates.

Other tools have been developed to examine woodfuel sustainability independently of carbon offset methodologies. Spatial models using remotely sensed data and geographic information systems have been used to map woodfuel and charcoal demand, woody biomass growth rates, and accessibility based on topography, infrastructure, and legal barriers. Modeling tools such as Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) and Modeling Fuelwood Sustainability Scenarios (MoFuSS) have brought more-quantitative approaches to fNRB analyses. Comparisons of outputs from these models and fNRB values that registered CDM, GS, and Verified Carbon Standard projects claim reveal that project values are systematically high. Given that the spatial models use more rigorous methods with biomass stock and growth maps based on empirical measurements, it is likely that the models are closer approximations of actual woodfuel supply-and-demand imbalances. The regulatory community has recognized this by making 30 percent the new (optional) default fNRB value for all CDM projects instead of individual default value for only a list of countries. This was derived from a 2015 pan-tropical WISDOM study of woodfuel sustainability and is substantially lower than previous defaults permitted under the United Nations Framework Convention on Climate Change. In addition to this new conservative default option, a new methodological tool introduced for the CDM resembles the approach that the models have taken, albeit without the spatially explicit component that makes them most realistic.

Despite these developments, spatial models generate many of the same difficulties that project developers face when they estimate fNRB using offset methodologies. A model is only as reliable as the information modelers put into it, and the data modelers require are often difficult to find or do not exist, so they also use default values and simplifying assumptions. In addition, WISDOM and MoFuSS are complex and accessible only to people with knowledge of geographic information systems or advanced programming.

In short, there are no simple solutions to assessing fNRB. Methodologies that are overly simple have not been sufficiently conservative, whereas modeling approaches that resulted in less conservative and potentially more accurate estimates are data-intensive, complex, and highly technical. Although recent changes to methodologies are moving in the right direction, there is still some potential for confusion and for outcomes that are not sufficiently conservative. In response, this report makes several recommendations to investors and regulators. We suggest that investors approach carbon offsets from clean and efficient cooking projects fully aware of the factors examined in this report. They should keep in mind that ERs depend almost entirely on the magnitude of fNRB and that project developers have not been conservative with their fNRB estimates. Investors should therefore question project developers in detail and be skeptical of fNRB values that seem too high.

We recommend that carbon market regulators consider developing subnational fNRB default values similar to those developed in the 2015 pan-tropical WISDOM analysis. Given that this will take time and money, the countries selected could be prioritized based on several criteria such as woodfuel "hotspots" or high disease burden from exposure to household air pollution. These subnational values would then be updated periodically to ensure that they remain valid.

1. Introduction

For the past several decades, international donors, researchers, and grassroots organizations have made an effort to address the health and environmental effects of cooking and heating with woodfuel, charcoal, and other solid fuels. Poor rural and urban communities throughout the global south are the hardest hit by these effects (Smith et al. 2014), yet they typically cannot afford cleaner alternatives (Masera et al. 2015). At the same time, attracting sufficient financing for clean and efficient cooking interventions has been challenging. An alternative mechanism that could supplement public and international concessional finance is results-based carbon financing.

Monetized climate benefits, measured as certified or verified emission reductions (CERs or VERs), have been introduced to improve the financial viability of clean and efficient cooking interventions. As with other activities that generate carbon offsets, crediting methodologies have been developed that define specific protocols for quantifying emissions from baseline and intervention technologies. These methodologies help ensure that emission reductions (ERs) are valid.

There are several clean and efficient cooking crediting methodologies. They differ in certain details but also share a number of characteristics. For example, each methodology requires project developers to:

1) Estimate fuel consumption from the existing baseline technology and from alternative or project technologies

1) Assign emission factors (EFs) to each fuel and estimate ERs by accounting for changes in fuel consumption and associated emissions

2) Estimate the fraction of firewood and charcoal that is harvested unsustainably, a factor called fraction of non-renewable biomass (fNRB)

fNRB forms the basis of all or most carbon offsets from clean and efficient cooking projects. By introducing more efficient cooking devices or alternative fuels, the clean cooking interventions seek to reduce or displace reliance on unsustainable biomass. This report reviews the methodologies used to estimate carbon ERs from these types of projects, with a focus on estimating fNRB. Through a literature review and expert interviews, we aimed to provide institutional carbon offset buyers with a comprehensive overview of fNRB assessments and suggest some improvements to current approaches.

2. fNRB in theory

Woody biomass is considered renewable if it is managed in a way that does not involve the long-term loss of biomass carbon stocks. In contrast, biomass is considered nonrenewable if its extraction results in a loss of biomass and carbon stocks over time.

On nearly every kind of terrain, we can find some amount of woody biomass. A hectare of tropical forest can support hundreds of tons of biomass, whereas a hectare of grassland may support only a few hundred kilograms. Regardless of the magnitude, wherever a stock of biomass exists, there is also a definable growth rate, often called an annual increment. Harvesting woody biomass by lopping branches or cutting trees may or may not be sustainable. How do we know this? One of the determining factors of sustainability is whether the rate of extraction is less or greater than the annual increment. If extraction exceeds the annual increment, then woody biomass stocks decline, and harvesting is unsustainable. In the context of carbon offsets, the quantity harvested in excess of the annual increment is called the nonrenewable biomass (NRB), and the ratio of NRB to total harvest is fNRB.

Although relatively simple in theory, determining fNRB in practice is difficult. The key concepts underlying fNRB, such as annual increment and sustainable yield, are borrowed from silviculture. In silviculture, forest stands are well bounded and consist of large tracts of land planted with a single species. The land is not subject to other high-impact uses such as crop cultivation or intensive grazing, and forest managers tend to follow formal plans that include periodic pruning, thinning, harvesting, and replanting. In such situations, annual increments and sustainable yields are relatively easy to define.

In contrast, the landscapes exploited for woodfuel are usually not under formal management. They are often forest mosaics (irregular stands of trees intermixed with crops and grazing lands) that consist of a wide range of tree species of varying age and grow through a range of different mechanisms, including natural seed dispersal, root sprouting, coppicing, and intentional planting.

In addition, although people often picture woodfuel being extracted mainly from forests, woodfuel and charcoal are extracted from many types of land cover other than forests, including agricultural lands, live fences, home gardens, and roadside commons. The areas that are accessed for woodfuel may not have well-defined boundaries and could be subject to multiple activities, ranging from permanent agriculture to shifting cultivation and livestock raising. There may be periodic fires to clear undergrowth or prepare new fields for planting. Some areas may host large populations of grazing or browsing wildlife. Furthermore, woodfuel production may be integrated into land management. For example, when trees are cleared to create space for crop cultivation or grazing, they can be converted to charcoal to create an additional revenue stream. Simultaneously, previously cropped fields may be allowed to lie fallow for several years, allowing woody biomass to accumulate and create a future revenue stream.

Calculating fNRB values also depends on the scale and boundaries of the system under consideration. When wood harvesting is undertaken purely for subsistence purposes, and each individual family meets just its own demand, the effects are highly localized, and it becomes fairly easy to draw boundaries around an intervention. In contrast, where consumers rely on markets for their woodfuel, it is much more difficult to define boundaries.

All these factors complicate assessment of fNRB and sustainable yields. Rather than being fixed numbers to be balanced, they are moving targets that evolve as land use and land cover change. Forest management policies directly affect how fNRB values are determined, which requires consistent accounting and reporting of biomass resources, but to incorporate fNRB values into carbon offset projects, project stakeholders need a simple but conservative method of estimating fNRB that maintains environmental integrity without burdening project developers excessively. Carbon offset methodologies for clean and efficient cooking projects have existed for more than a decade, but there is still a lack of operational solutions that balance environmental needs with the practical constraints that project developers and their developing-country hosts face. Below we review the existing methodologies and suggest some ways to improve on them.

3. Clean-Cooking Crediting under Various Carbon Offset Schemes

Carbon offsets are generally divided into compliance and voluntary markets. Both include some kinds of clean and efficient cooking offset projects. The Clean Development Mechanism (CDM) framework is the only program that currently issues offsets from developing countries for use in compliance markets.[1] Of voluntary offset programs, Gold Standard (GS) and Verified Carbon Standard (VCS) issue offsets for clean and efficient cooking projects.

Of the three carbon offset schemes, GS has registered the largest number of clean and efficient cooking projects and issued the largest volume of credits. CDM[2] is second and VCS third (figure 1).

Figure 1. Cookstove Programs Under Each Registry

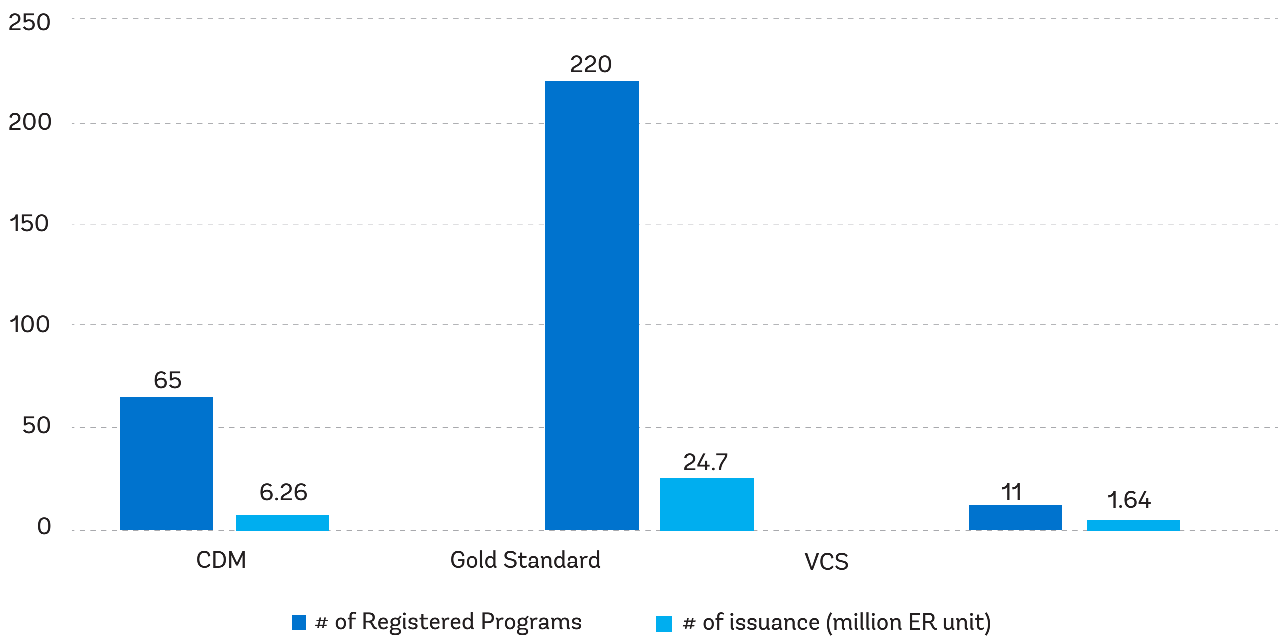


Figure 1 illustrates the number of programs and projects registered or certified under each platform, as well as the number of ERs issued. The details are delineated below.

1 The California Air Resources Board offers compliance offset certification, but it focuses on a limited range of interventions in North America.

2 This report considers only programs of activities (PoAs). Individual activities were initially introduced in 2010 but were gradually phased out as the program-of-activities approach gained traction with project developers. The total issuance from all individual cookstove projects amounts to only 0.6 million CERs.

CDM: Of 327 registered programs of activities, 65 are cookstove programs—the most popular type—followed by solar photovoltaic (n=49) and run-of-the-river hydropower (n=28). In all, 29 cookstove programs of activities (45 percent of total registered) have achieved issuance totaling 6.26 million CERs (UNEP–DTU CDM database). The second-largest issuance is from methane avoidance from domestic manure (6.09 million CERs), followed by lighting projects (2.94 million CERs).

GS: 220 cookstove projects are certified under GS projects, accounting for 29 percent of total registered GS projects; 24.7million VERs[3] have been issued for cookstove projects.

VCS: Eleven cookstove projects have been registered under VCS's 1.64 million verified carbon units.[4]

3 As per the GS Project Registry, available at https://registry.goldstandard.org/projects?q=&page=1 (as of December 1, 2019).
4 VCS Database https://www.vcsprojectdatabase.org/#/vcs (as of December 1, 2019).

Methodologies and ER calculations

As with all types of ER offsets, clean and efficient cooking projects require a well-defined methodology that specifies eligible technologies and defines procedures to quantify and validate ERs created when technology is deployed. Approaches to measuring ERs have evolved. The United Nations Framework Convention on Climate Change (UNFCCC) initially introduced the concepts of renewable biomass (RB) and nonrenewable biomass (NRB) in 2006 (CDM Executive Board 2006). RB refers to biomass that is grown in a sustainable manner not involving long-term losses of carbon stocks. NRB refers to extraction of biomass that is not sustainable and carbon stocks on the land area that decrease over time. In 2008, these concepts were formalized in the first cookstove-related methodologies for the CDM, but the details in the early versions of these methodologies were vague and difficult to operationalize.

In 2011, in response to calls for a simpler, more standardized approach, UNFCCC initiated a process of public input into two methodological approaches (UNFCCC 2011). One approach focused on mean annual increment (MAI), which is a long-term average of the annual increment concept introduced in the previous section. The second approach proposed using a spatial model called the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) (Drigo, Masera, and Trossero 2002). The MAI approach was simpler and was eventually incorporated into the CDM methodologies. MAI is also a critical parameter in the WISDOM model, but WISDOM requires many other inputs to simulate woodfuel supply and demand. We explain each approach in greater detail below.

All methodologies follow a similar approach by first defining a **baseline scenario** that quantifies fuel consumption and then estimating the fraction of consumption that is nonrenewable. They then define a **project scenario** that estimates fuel consumption after deployment of an alternative technology or fuel. The methodologies then estimate the emissions associated with each scenario and define ERs as the difference between the two. All approaches follow this basic concept, although the methodologies differ in certain details, as explained below. Of the several methodologies developed under the CDM, two in particular cover the majority of NRB projects—Approved Methodology for Small-Scale Projects (AMS) I.E and AMS II.G.[5]

- **AMS I.E** applies to deployment of cooking devices that use renewable fuels such as biogas, ethanol, and solar, thereby displacing NRB (UNFCCC 2019a). This methodology was first approved in 2008 and has undergone many revisions. The latest revision, Version 10.0, went into effect in November 2019.[6]

- **AMS II.G** applies to deployment of efficient wood or charcoal that still relies on NRB but reduces its consumption by introducing more-efficient devices (UNFCCC 2019b). Like AMS I.E, this also dates to 2008 and has been revised many times. The latest revision is Version 11.0, which also went into effect in November 2019.[7]

GS allows project developers to use CDM methodology or methodologies GS itself has developed.

5 Other CDM methodologies applicable to NRB activities include AMS-I.C, AMS-III.R, and AMS-III.AV. These are used infrequently and in combination with I.E and/or II.G. For a fuller discussion, see Bailis et al. (2017).
6 See https://cdm.unfccc.int/methodologies/DB/XA6RFKB3QM9T8S6ELI0V4P8SY8RR2U for a review of version histories.
7 See https://cdm.unfccc.int/methodologies/DB/ZI2M2X5P7ZLRGFO37YBVDYOW62UHQP for a review of version histories.

- **Technologies and Practices to Displace Decentralized Thermal Energy Consumption** (TPDDTEC) applies to deployment of technologies and practices that reduce or displace emissions from thermal energy consumption of households and nondomestic premises. TPDDTEC was first released in 2011 and has undergone several revisions. The most recent is Version 3.1, released in August 2017 (GS 2017a).

- **Simplified Methodology for Efficient Cookstoves**, released in 2013, is designed specifically for micro-scale activities that generate reductions of no more than 10 kt of carbon dioxide (CO_2) equivalent per year (GS 2013).

VCS does not have its own cookstove project methodology but allows project developers to use approved CDM methodologies.

The basic equations to estimate ERs that the current CDM and GS methodologies use are as follows:

AMS I.E – used if NRB is displaced by devices using renewable fuels other than woodfuels

$$ER_y = BE_y - PE_y - LE_y = \left(B_y f_{NRB,y} NCV_{biomass} EF_{projected\_fossil\ fuel}\right) - PE_y - LE_y \qquad (1)$$

AMS II.G – used if NRB is displaced by more efficient woodfuel devices

$$ER_y = \sum_{i,j} ER_{y,i,j} - LE_y = \sum_{i,j}\left(B_{y,i,j} N_{y,i,j} \mu_y f_{NRB,y} NCV_{biomass} EF_{projected\_fossil\ fuel}\right) - LE_y \qquad (2)$$

GS V3.1 – used if baseline fuel and EFs are the same as project fuel and EFs

$$ER_y = \sum_{b,p}\left(N_{p,y} U_{p,y} P_{p,b,y} NCV_{b,fuel}\left(f_{NRB,b,y} EF_{b,fuel,CO2} + EF_{b,fuel,nonCO2}\right)\right) - \sum LE_{p,y} \qquad (3)$$

GS V3.1 – used if baseline and project fuel or EFs are different

$$ER_y = \sum_{b,p} N_{p,y} U_{p,y}\left(f_{NRB,b,y} ER_{b,p,y,CO2} + ER_{b,p,y,nonCO2}\right) - \sum LE_{p,y} \qquad (4)$$

where:

ER_y =	emission reductions in year y
BE_y =	baseline emissions in year y, defined in AMS I.E by the right-hand side of Eq. 1
PE_y =	project emissions in year y, defined by the UNFCCC (2017) TOOL16
B_y =	baseline wood consumption (AMS I.E)
$B_{y,i,j}$ =	quantity of woody biomass saved by cookstove device of type-i and batch-j in year y (AMS II.G)
μ_y =	adjustment to account for continued use of preproject devices in year y
b and p =	indices for baseline and project scenarios in GS projects
fNRB =	the fraction of NRB

NCV = net calorific value of each fuel indicated by a subscript

$\mathbf{EF}_{\mathbf{projected\_fossil\ fuel}}$ = emission factor used for substitution of NRB in CDM projects. This is typically a weighted average of Intergovernmental Panel on Climate Change (IPCC) default emission factors of LPG ad kerosene, which are fossil fuels considered to be the most likely fuels used by similar consumers in the absence of woody biomass. IPCC default values are 71.5 tCO_2/TJ for Kerosene and 63.0 tCO_2/TJ for LPG

$\mathbf{N}_{\mathbf{p,y}}$ = number of project technology-days in year y

$\mathbf{U}_{\mathbf{p,y}}$ = technology usage in project scenario in year y based on observed adoption/rejection rates

$\mathbf{P}_{\mathbf{p,b,y}}$ = fuel savings for each individual technology of project p resulting from the displacement of baseline technology b in year y

$\mathbf{EF}_{\mathbf{b,fuel,CO2}}$ = CO_2 emission factor for fuel that is substituted or reduced

$\mathbf{EF}_{\mathbf{b,fuel,nonCO2}}$ = non-CO_2 emission factor for fuel that is substituted or reduced

$\mathbf{ER}_{\mathbf{b,p,CO2}}$ = CO_2 emission reductions resulting when an individual project technology p displaces baseline technology b in year y, measured in tCO_2/day

$\mathbf{ER}_{\mathbf{b,p,non\text{-}CO2}}$ = non-CO_2 emission reductions resulting when an individual project technology p displaces baseline technology b in year y, measured in tCO_2e/day

$\mathbf{LE}_{\mathbf{y}}$ and $\mathbf{LE}_{\mathbf{p,y}}$ = leakage emissions in year-y[8]

The critical elements of each ER equation include:

- Reduction or displacement of the baseline woodfuel. This is explicitly shown as By in Eq. 1, $B_{y,i,j}$ in Eq. 2, and $P_{p,b,y}$ in Eq. 3 and is implicitly embedded as ERs in Eq. 4.
- EFs: the quantity of pollution emitted when a unit of fuel is burned. As with the previous term, EFs are explicitly included in Eqs. 1-3 but embedded as a component of the ER terms in Eq. 4.
- f_{NRB}

The methods and assumptions used to estimate each variable contribute to uncertainty in calculating ERs. One analysis that examined the contributions of each variable to the overall uncertainty in carbon ERs found that fNRB accounted for nearly half of the uncertainty. Fuel consumption and EFs each contributed roughly one-quarter (Johnson, Edwards, and Masera 2010). fNRB is the primary focus of the remainder of this report.

8 Leakage is defined as emissions that occur outside the boundary of the project as a result of project activity.

4. Current AND PAST methods used to determine FNRB

Since the advent of clean and efficient cooking projects, fNRB has been defined in different ways. Both CDM methodologies rely on a methodological tool developed specifically for this purpose. Called TOOL30, it was originally used in 2017 and was updated in 2019 (UNFCCC 2019c). TOOL30 offers project developers several options. First, it allows a global default value of 30 percent. This is based on a pan-tropical geographic information systems–based study of woodfuel sustainability using the WISDOM approach (Bailis et al. 2015). The study estimated that 27 percent to 34 percent of the global woodfuel harvest was unsustainable; the UNFCCC chose the middle of this range. This default value is much lower than used in the majority of projects that have been registered through CDM and GS (Bailis et al. 2017). The WISDOM methodology, and reasons for the divergence between registered projects and WISDOM estimates are explored in box 4.1.

Box 4.1: Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM): Uses and Limitations

Rudi Drigo, a consultant for the Food and Agriculture Organization (FAO), developed the WISDOM method in 2002 (Drigo, Masera, and Trossero 2002). The method uses geographic information systems data to identify imbalances between woodfuel demand and supply at different geographic scales. This information can be used to estimate nonrenewable biomass (NRB) and other aspects of woodfuel sustainability—such as identifying locations at risk of woodfuel-driven degradation or locations with a surplus of woody biomass—that could supply high-demand areas. More than 30 WISDOM case studies have been conducted, including a pan-tropical geographic information systems–based study of woodfuel sustainability (Bailis et al. 2015). Other studies have covered individual countries, regional groupings such as East Africa, subnational units, and cities. The sources of information required for a WISDOM analysis vary with the scale of the study but usually include:

- Woody biomass supply data in the form of land use or land cover maps, biomass or carbon stock maps, or forest inventories and biomass growth rates or mean annual increments specific to particular types of land cover
- Woodfuel demand data taken from national censuses or surveys
- Accessibility data based on maps of populated areas, roads, protected areas, and other factors that affect the ease or difficulty with which people can access places where trees grow

Several sources of uncertainty affect the accuracy of WISDOM analyses.

Demand: It is difficult to obtain data about how much woodfuel is consumed. Freely available data from international sources such as FAO and the International Energy Agency are ultimately guesses. National data are preferable, but nationally representative surveys such as censuses and demographic surveys typically ask about primary cooking fuel but not about the quantity consumed. Surveys that ask questions about quantity, such as the World Bank Energy Sector Management Assistance Program's recent multitier framework surveys, do not collect easily interpreted data. Difficulties arise because quantities of woodfuel consumed are neither standardized nor measured precisely because people collect woodfuel by the headload or oxcart, not by the kilo. Similarly, charcoal is sold in sacks, buckets, and tins. Converting from locally relevant units into kilos often relies on guesswork by survey enumerators. Some studies visit households over several days and weigh daily fuel consumption, but these types of assessments are invasive, costly, and time consuming and typically cover small populations (Bailis et al. 2018). Commercial and industrial sectors can be major sources of woodfuel demand, but data about these sectors are even more difficult to obtain than household data.

Supply: There is uncertainty regarding biomass supply because there is a lack of accurate data about growth rates in many land use and land cover categories. Although forest cover data are readily available from easily accessible remote-sensing data collections such as the Landsat Program and other related analyses,[a] data on woody biomass stock and growth rates are less accessible. This is particularly true in woodland-mosaic landscapes, tropical dry forests, and trees growing outside forests, which are the most important sources of woodfuel and charcoal in the global south. WISDOM assigns stocks and growth rates to specific land cover types on the basis of secondary data that may not be accurate for the particular site(s) where project activities are taking place.

Other types of remote-sensing data can provide even deeper insights into woodfuel sustainability. For example, Ryan, Berry, and Joshi (2014), using satellite-based radar images coupled with direct ground observations to estimate the causes of deforestation and degradation in a charcoal-producing area of western Mozambique, found that, between 2007 and 2010, a 7,500-km^2 region lost woody biomass at a rate of nearly 3 percent per year. Charcoal would have been the easy scapegoat, but the study estimated that smallholder agriculture was responsible for nearly half of the losses, with logging and construction activities accounting for more than 30 percent. Charcoal was responsible for less than 20 percent.

Role of other Land use change drivers: One reason that high fraction of NRB (fNRB) values were perpetuated over a decade of Clean Development Mechanism and Gold Standard projects is that many regions with high rates of woodfuel consumption also have high rates of deforestation, making it easy to lay the blame on woodfuel users and charcoal producers. Nevertheless, as in any natural-human interactive system, spatial correlation and proximity do not necessarily mean direct causation. There are many drivers of forest loss and degradation. Most often, demand for agricultural and grazing land is the main cause of long-term forest loss (Ryan, Berry and Joshi 2014; Hosonuma et al. 2012; Geist and Lambin 2002). If woodfuel extraction is occurring in the same place, it is likely to contribute, but apportioning blame accurately among different drivers is difficult and requires close study of the characteristics and dynamics of each location.

Modeling efforts beyond WISDOM

Taking inspiration from WISDOM, another modeling approach has emerged that may also be helpful for researchers and practitioners concerned with fNRB. Researchers at the National Autonomous University of Mexico developed Modeling Fuelwood Sustainability Scenarios (MoFuSS) in the early 2010s. Like WISDOM, MoFuSS uses geo-spatial mapsof woody biomass supply and demand to quantify nonrenewable woodfuel extraction, but MoFuSS differs from WISDOM in that it has a dynamic, temporal component. Rather than considering supply and demand in a snapshot, as WISDOM does, MoFuSS simulates supply and demand dynamics over an extended period. It accounts for biomass regrowth, population growth, and other drivers of land use and land cover change. It also incorporates uncertainty into key parameters. A web-based version is being developed that will enable users to access key woodfuel parameters, including fNRB, for any area of interest in select countries.

[a] For an example of such data collections, see World Resources Institute (2020).

If they choose, project developers can estimate fNRB for their specific project location(s) using TOOL30 instead of the 30 percent default value. The tool defines fNRB as a ratio of NRB to the sum of NRB and RB:

$$f_{NRB} = \frac{NRB}{NRB+RB} \tag{5}$$

In this form, NRB is defined as the difference between total woodfuel consumption (H) and RB:

$$NRB = H - RB \tag{6}$$

H can be determined through official statistics, reports, and peer-reviewed studies or by multiplying the number of woodfuel consumers in the country or region by some estimate of their consumption.

RB is estimated using theoretical concepts discussed in the introduction to this report. Specifically,

$$RB = \sum_i MAI_{forest,i}\left(F_{forest,i} - P_{forest}\right) + \sum_i MAI_{other,i}\left(F_{other,i} - P_{other}\right) \tag{7}$$

where:

$MAI_{forest,i}$ = Mean annual increment of woody biomass growth per hectare in category i of forest areas

$F_{forest,i}$ = extent of forest in category i

P_{forest} = extent of nonaccessible areas, such as protected areas where wood extraction is prohibited, or geographically remote forest areas that are unlikely to be exploited for fuel

$F_{other,i}$ = extent of wooded areas in other land-cover categories i

P_{other} = extent of nonaccessible wooded areas in other land-cover categories, such as protected areas where wood extraction is prohibited, or geographically remote forest areas that are unlikely to be exploited for fuel

TOOL30 is an improvement over earlier CDM methodologies. Before 2017, CDM methodologies used a concept of demonstrably renewable biomass (DRB). DRB can be defined by one of several conditions, but rather than leading to conservative estimates of ERs, the steps used to define DRB resulted in unrealistically high values of fNRB (box 4.2).

Box 4.2: Definitions of Demonstrably Renewable Biomass (DRB) Used in Clean Development Mechanism (CDM) Methodologies Before 2017

Until the introduction of TOOL30, CDM projects defined nonrenewable biomass (NRB) as any woodfuel consumption that was not demonstrably renewable. Biomass was considered demonstrably renewable if any of the following criteria held:

1. The biomass originated from land defined as forests[a] and

a. the land area remained a forest; and

b. sustainable management practices were undertaken on these land areas to ensure, in particular, that the level of carbon stocks on them did not systematically and persistently decrease over time (carbon stocks may temporarily decrease owing to harvesting); and

c. all relevant national or regional forestry and nature conservation regulations were complied with.

2. The biomass was woody biomass and originates from croplands or grasslands where

a. the land area remained cropland or grasslands or reverted to forest; and

b. sustainable management practices were undertaken on these land areas to ensure in particular that the level of carbon stocks on these land areas did not systematically decrease over time (carbon stocks may temporarily decrease due to harvesting); and

c. national and regional forestry, agricultural, and nature conservation regulations were complied with.

3. The biomass was nonwoody biomass and originated from cropland or grasslands where

a. the land area remained cropland or grasslands or reverted to forest; and

b. sustainable management practices were undertaken on these land areas to ensure in particular that the level of carbon stocks on them did not systematically and persistently decrease over time (carbon stocks may temporarily decrease because of harvesting); and

c. any national or regional forestry, agricultural, and nature conservation regulations were complied with.

4. The biomass was a biomass residue, and the use of that biomass residue in the project activity did not involve a decrease of carbon pools—in particular dead wood, litter, or soil organic carbon—on the land areas where the biomass residues originated from.

5. The biomass was the nonfossil fraction of industrial or municipal waste.

Once DRB is identified, NRB is defined as any wood not designated as DRB, but realizing that this method of defining DRB may not be sufficiently conservative, the methodologies include additional considerations; specifically, in addition to not satisfying the conditions of DRB, NRB should demonstrate two of these three trends:

- Time or distance required to gather woodfuel is increasing
- Prices are increasing
- Biomass is declining in quality

Although these indicators may reflect scarcity, it may not be that unsustainable wood harvesting is the cause of that scarcity. Urbanization, crop expansion, and grazing pressure are all recognized drivers of land-cover change that reduce access to woodfuels, increase collection times, raise prices, or cause people to opt for lower-quality fuels. In addition, price trends could simply reflect inflation. For example, in Kenya, the nominal price of a 4-kg tin of charcoal tripled between 2005 and 2015 but was nearly constant in real terms.

Finally, the way DRB was defined resulted in no middle ground. Wood harvested from areas that were not considered demonstrably renewable were assumed to have no regenerative capacity. This overstated land degradation and contributed to very high estimates of fraction of NRB in CDM projects registered before 2017.

[a] Forest definitions as countries establish in accordance with UNFCCC decisions 11/CP.7 and 19/CP.9 should apply.

Before the introduction of TOOL30, CDM methodologies provided country-level fNRB default values that were applicable in least-developed countries (LDCs), small island developing states (SIDSs), and other countries with few projects (CDM 2012). Fifty-eight countries have their country-specific default value approved. The defaults were determined using a formula similar to the one in Eq. 6 but assuming that RB can originate only from protected forest areas. This approach equates sustainable management with national parks, game reserves, wilderness areas, and other legally established protected areas, implicitly assuming that land without such designations cannot be sustainably managed. The median default estimate of fNRB was 88 percent. As with most estimates based on DRB, the UNFCCC's approach to determining defaults resulted in high fNRB estimates; most exceeded 88 percent (more details in appendix A). This is may be unrealistic because it is far higher than estimates from spatial models. Moreover, fNRB values approaching 90 percent indicate rapid destruction of all accessible biomass. Although some areas in these countries may be heavily deforested, none of the countries have been completely denuded of trees (boxes 4.3 and 4.4).

Box 4.3: United Nations Framework Convention on Climate Change (UNFCCC) Defaults Used Before TOOL30

In 2012, UNFCCC ruled that project proponents have an option to use country-specific default values for least-developed countries, small island developing states, and a select number of other countries that had a limited number of Clean Development Mechanism (CDM) projects (table B3.1). Default values were published for 58 countries and were valid for 5 years. The estimates relied on a simplified application of the demonstrably renewable biomass (DRB) approach, in which DRB was limited to biomass from protected forest areas. This fails to reflect biomass from unprotected forest and other land areas, from which the vast bulk of woodfuels is obtained. Default values are shown in table B3.1.

Table B4.3.1: Default Values of Fraction of Nonrenewable Biomass (fNRB)

Country	National Default fNRB value	Country	National Default fNRB value
Angola	97%	Jamaica	65%
Antigua and Barbuda	85%	Lao People's Democratic Republic	87%
Bahamas	85%	Lesotho	98%
Bahrain	100%	Liberia	97%
Bangladesh	83%	Madagascar	72%
Barbados	96%	Malawi	81%
Belize	88%	Maldives	85%
Benin	81%	Mali	73%
Bhutan	40%	Mauritania	85%
Burkina Faso	90%	Mauritius	100%
Burundi	77%	Mozambique	91%
Cambodia	76%	Myanmar	95%
Cape Verde	89%	Nepal	86%
Chad	92%	Niger	82%
Comoros	100%	Papua New Guinea	99%
Cuba	40%	Rwanda	98%
Djibouti	100%	Saint Lucia	96%
Dominican Republic	85%	Samoa	85%
DR Congo	90%	Senegal	85%
Equatorial Guinea	68%	Sierra Leone	95%
Eritrea	97%	Singapore	85%
Ethiopia	88%	Sudan	81%
Fiji	90%	Suriname	87%
Gambia	91%	Togo	97%
Grenada	88%	Trinidad and Tobago	85%
Guinea	96%	Uganda	82%
Guinea-Bissau	85%	UR Tanzania	96%
Guyana	85%	Yemen	94%
Haiti	96%	Zambia	81%

Of the 59 default values published, country-level designated national authorities endorsed 34, and many were used for registering in CDM and Gold Standard projects, although by the end of 2019, 32 default values had expired. The remainder will become invalid in 2020, and no designated national authority has indicated an intention to renew its country's default value. The introduction of TOOL30 appears to have replaced these less-conservative defaults for future project development.

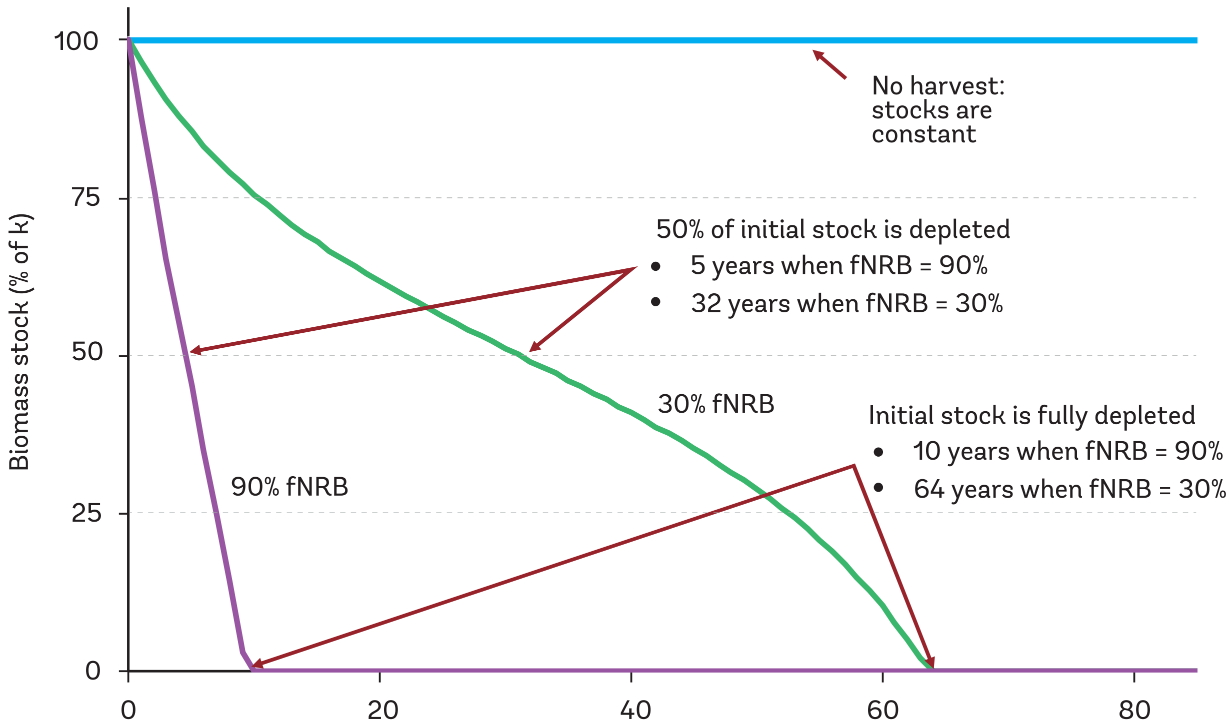
Box 4.4: Examining Different Values of Fraction of Nonrenewable Biomass (fNRB)

Above-ground biomass can be modeled using a relatively simple logistic equation that simulates growth up to a maximum value. In its simplest form, the equation is defined using two key parameters:

- K = carrying capacity, which is the maximum amount of biomass than can be supported
- r_{max} = maximum rate of growth (slope of logistic curve at its inflection point)

Figure B4.4.1 presents a simple nonrenewable biomass (NRB) model that shows three hypothetical scenarios. We start with a mature stand of trees in which biomass is equal to 100 percent of K. In scenario 1 (blue line), nothing is harvested, and stocks remain fixed. This would continue until some natural disturbance (e.g., fire or storm) caused a loss of biomass. In scenarios 2 and 3 (green and purple lines), wood is removed each year. In our model, the harvest exceeds the mean annual increment (MAI), and the stock decreases. In both cases, the remaining trees continue to grow, and some new seeds sprout so that wood accumulates as well, but total woodfuel consumption exceeds MAI, so losses exceed gains, and stocks decline. In scenario 2, we set the harvesting rate at 1.4*MAI (fNRB = 30 percent), and in scenario 3, we set it to 10*MAI (fNRB = 90 percent). Both result in long-term reduction of biomass but over much different time frames. With an fNRB of 30 percent (the TOOL30 default value), biomass stocks are reduced by half after 32 years and completely depleted after 64 years. With an fNRB of 90 percent (a common value in registered projects and among United Nations Framework Convention on Climate Change defaults –box 3), biomass stocks are reduced by half after just 5 years and completely depleted after 10 years. If fNRB were 90 percent on a national scale, there would be very little standing biomass in any of the affected countries. Although biomass can be scarce, none of the countries listed in box 2 is completely devoid of trees. In summary, for most countries, an fNRB of 90 percent is probably not realistic.

Figure B4.4.1: Nonrenewable Biomass Model



TOOL30 is inherently more conservative than previous UNFCCC fNRB methodologies. The default option is lower than previous defaults. For project developers who do not use the default value, TOOL30 includes clear guidance about sources of data (e.g., FAO 2006), UNFCCC defaults (IPCC 2006), and government statistics for MAI. Similarly, data sources, survey methods, and default values are specified for developers to determine biomass demand. Although UNFCCC (2012) has developed some guidance, project developers still face challenges if they implement their own surveys rather than use default values. Household survey methods such as random sampling and data entry, cleaning, and analysis require specialized training. Challenges also arise if developers opt to use official data. These sources tend to be highly aggregated and may not reflect the situation in the project area.

Since November 2017, when TOOL30 was approved, only eight registered programs of activities have adopted the tool, and just one has elected to use the conservative default value of 30 percent. The remaining programs of activities arrived at fNRB values that range from 82 percent to 97 percent, which are much higher than WISDOM-derived values.

Current GS methodologies propose multiple ways to estimate fNRB. For example, the simplified methodology allows developers to use the UNFCCC default values or the methods designed for TPDDTEC (GS 2013). TPDDTEC offers project developers several options (GS 2017a), including

- A method based on DRB that is similar to the pre-TOOL30 CDM methodologies
- A **quantitative approach** that relies on biomass supply and growth in the collection area and is similar to the methods defined in the UNFCCC TOOL30. Specifically, it requires project developers to
  - specify the geographic area(s) used to supply woody biomass to the project population
  - determine the average rate of biomass regeneration in the area(s) by consulting credible sources, field surveys, or both. (This is MAI).

    - define NRB in the area(s) as NRB = H – MAI (similar to TOOL30 Eq. 6)
- A **qualitative approach** that incorporates available satellite imagery, field surveys, literature reviews, and expert consultations, leading to an acceptable conservative estimate (GS 2017a).

Furthermore, to reduce the workload of project developers in Latin America, GS has approved default fNRB values for five Latin American countries: Peru, Bolivia, Columbia, Honduras, and Guatemala (GS 2016). The method GS used follows the same DRB approach that UNFCCC used for its LDC and SIDS defaults (box 4.2), which assumed that only protected areas could produce DRB. As a result, the fNRB estimates, which range from 48 percent to 82 percent, correlate very closely with the ratio of each country's protected forest area to total forest area. As with other default values, these are substantially higher than values derived from the pan-tropical WISDOM analysis, which ranged from 10 percent to 64 percent for those countries, depending on specific assumptions

After the methodology undergoing a number of revisions, project developers have four alternative approaches to estimating fNRB in GS and CDM projects:

1) A conservative global default of 30 percent (CDM)
2) A set of nonconservative default values applicable only in LDCs, SIDs, and a few other countries
3) A set of qualitative steps and expert consultations (applicable to GS projects only)
4) A set of similar approaches applicable to GS and CDM projects but that require project developers to go the extra step of not only identifying the areas used for woodfuel production, but also quantifying biomass growth rates and withdrawals from those areas

Faced with the choice of a global default value of fNRB that is easy to apply but much lower than the fNRB estimates that have been claimed in registered projects, a vague set of time-intensive qualitative steps, and a fairly complicated quantitative process, it would be easy to imagine that project developers are frustrated, but working with a range of imperfect but largely acceptable methodologies, project developers have managed to select methods that result in fNRB estimates that maximize carbon revenues, and there is some evidence that registered projects have used fNRB estimates that are unrealistically high (box 4.4) (GS 2017a).

Although the quantitative approaches defined in TOOL30 and TPDDTEC have the potential to provide more accurate estimates of fNRB, project developers who employ these approaches still need to overcome the challenges associated with determining biomass stocks and growth rates in dynamic, multifunctional landscapes (described in the Introduction). These approaches are similar in theory to the WISDOM approach, which provides a conservative global estimate of 30 percent, although WISDOM is a spatially explicit method that is more useful for its site-specific estimates than for the global average that if offers. Appendix B summarizes the main methods that have been introduced to estimate fNRB, including WISDOM, and one other model that has also played a prominent role in analyzing renewable and nonrenewable woodfuel.

Other Carbon Offset Programs

Verified Carbon Standard

Nine clean and efficient cooking projects are registered in the VCS. These projects all follow some version of the UNFCCC-approved methodologies, but unlike CDM and GS, details about ER calculations are not publicly available, so it is not possible to review them. One VCS project in Malawi uses an fNRB value of 90 percent, which is higher than the CDM default of 81 percent (Verra 2015). Although the fNRB calculation is not detailed in their VCS documentation, the same project is registered as a program of activities in the CDM, and there, the fNRB estimation is described in the design document.

American Carbon Registry

The American Carbon Registry (2013) published its own methodology for clean and efficient cooking projects in 2013. The methodology is based on an earlier version of AMS.II.G but with two modifications: first, they use EFs for woodfuel and charcoal rather than for fossil fuels; and second, they introduced an adjustment factor for actual harvested biomass to account for the below-ground biomass and a portion of the above-ground biomass that is not typically removed. No projects in the American Carbon Registry use this methodology.

Agriculture, Forestry, and Land Use carbon calculator

The Forest Degradation by Fuelwood tool, which is part of the U.S. Agency for International Development Agriculture, Forestry, and Land Use carbon calculator, provides a quantitative method to estimate forest degradation from land management activities, including woodfuel extraction (Winrock International 2014). Winrock International developed it in 2014 as an extension of the pan-tropical WISDOM study that was underway at the time. Rudi Drigo, WISDOM's primary developer, conducted the majority of the analysis. It provides default values for fNRB for most tropical and subtropical countries at subnational levels. It extends the pan-tropical assessment published in 2015 by distinguishing fNRB for urban and rural areas. fNRB can be calculated by applying weights for urban and rural households. Although it was developed to calculate ERs, project developers have not adopted it for use in compliance or voluntary carbon projects.

5. Policy Implications of fNRB for Carbon Finance

Despite widespread recognition that meeting global targets for access to clean and efficient cooking options will require investment into the billions of dollars, finance flowing to the sector has been limited (Clean Cooking Alliance 2019). Nevertheless, carbon finance is a vital source of financing for the sector. In the 12 years since the introduction of the first carbon offset methodologies, it has enabled distribution of millions of stoves around the world, but to access this stream of finance, project developers need to have a credible estimate of fNRB. The majority of fNRB estimates used in registered projects have been excessively high, which maximizes revenue but also risks undermining the validity of the offsets issued and creates unrealistic expectations about the degree to which clean and efficient cooking options can reduce deforestation and degradation.

fNRB directly affects project revenues. In deciding on an fNRB methodology, project developers choose between developing their own assessment, which may be costly and technically complex, and using a default value, which frequently oversimplifies the realities on the ground but adds little cost to project development. The choice is easy when default values are high, as with the UNFCCC LDC and SIDS values (box 4.2) and with some current GS Latin America options, but with the introduction of UNFCCC TOOL30, the default option for compliance markets has fallen to 30 percent, roughly one-third of the average fNRB claimed in earlier projects. Lowering fNRB from 90 percent to 30 percent cuts potential revenue and creates an incentive for project developers to develop their own estimates of fNRB rather than use defaults.

The pan-tropical WISDOM assessment demonstrated that fNRB is spatially variable (Bailis et al. 2015). Having a national default value may be meaningful for country comparisons but is not very useful for estimating the effect of interventions that are introduced heterogeneously, although generating subnational fNRB estimations requires subnational data, which can be difficult and costly to obtain. This leads to a tension between selecting nationally aggregated data (which may not be appropriate to the specific locations where projects are being implemented) versus investing in costlier subnational assessments versus opting for TOOL30's low default valu versus opting out of the CDM entirely and choosing TPDDTEC, which still allows an imprecise qualitative approach combined with a quantitative approach using the flawed concept of DRB.

6. Recommendations and Conclusions

When they are implemented well, clean and efficient cooking projects can bring a range of co-benefits in addition to ERs, but they are more complex than some other carbon offset activities. To address these complexities, this report presents two sets of recommendations. One set consists of important takeaway messages for the report's primary audience: potential investors in carbon offsets. The second set of recommendations is directed at carbon market regulators and other decision makers in this space.

First, we recommend that investors approach carbon offsets from clean and efficient cooking projects fully aware of the issues examined in this report. As shown in Eqs. 1-4, ERs depend on the magnitude of fNRB, which is difficult to estimate accurately. This presents a serious challenge to project developers and investors. There is no perfect solution, and project developers must find the right balance between accuracy, cost, and complexity, although there is evidence that many of the registered CDM and GS projects from the past decade have not been conservative with their fNRB estimates. To avoid overestimates, investors should question project developers in detail and be skeptical of high fNRB estimates. They should also scrutinize project documents closely to ensure that the data sources they use are credible and inquire about other drivers of deforestation in the project area(s).

Second, for carbon market regulators and other decision makers, we recommend that a set of subnational fNRB default values similar to those developed using the 2015 pan-tropical WISDOM analysis be developed (Bailis et al. 2015). This could be developed on a country-by-country basis using a process of stakeholder consultation to ensure that the best available data are used. Given that this will take time and money, countries could be prioritized based on several criteria. For example, Bailis and colleagues (2015) identified area where the woodfuel use is highly unsustainable (woodfuel "hotspots,") as well as countries where the disease burden from exposure to household air pollution is especially high. This includes a mix of countries that have developed more carbon finance programs than an average country such as Kenya and India, and others that have not generated much project activity, such as Togo, Benin, Gambia, and other smaller African countries. As with previous national default values, these subnational values should be updated periodically to ensure that they remain current and valid. WISDOM or MoFuSS (box 4.2) would be ideal tools for determining these default values. The costs of developing and maintaining a database of subnational fNRB defaults could be supported by large institutional buyers of CERs or VERs or by placing a small levy on other project streams, something that was done in the CDM to support project development in LDCs.

In addition, designated national authorities within countries hosting clean and efficient cooking projects could take the initiative to develop a set of subnational fNRB default values. This too has costs, but the international community could support them, with provisions to conduct and continuously update their own estimations. This would also build local capacity in advanced spatial modeling, which could then be applied more broadly.

Finally, CDM and GS should acknowledge that carbon offsets that clean and efficient cooking projects generate are inherently tied to avoided deforestation and degradation. CERs and VERs exist, fully or in part, because project activities are leading to lower rates of deforestation and degradation. This linkage was not taken into consideration during development of the first CDM methodologies,[9] but it needs to be highlighted because it would help people better understand the science underlying the methodologies. It would also encourage project developers and other

9 Avoided deforestation and degradation. It was eventually included in the climate regime through reducing emissions from deforestation and forest degradation in developing countries, and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries, but this was an entirely different process and is not open to tradable offsets.

stakeholders to ensure that they have sufficient knowledge and training to gather and interpret the necessary data.

Despite uncertainties about CDM and its transfer to a new mechanism, there will be demand for ERs from clean and efficient cooking projects and thus a need to deepen understanding and lessen uncertainties surrounding use of fNRB values. To accomplish this, project developers and researchers will need reliable data for biomass demand and supply at scales that are relevant for different types of projects and programs of activity. Ensuring that enough reliable data are available and accessible will be challenging, particularly for LDCs, which have not benefited from much project activity, yet it is urgent not only that forest practitioners address deforestation and forest degradation, but also, in the climate context, that all countries in the Paris Agreement, who are expected to meet their nationally determined contribution target beyond 2020, do the same.

Despite the efforts of UNFCCC, more is needed to ensure environmental integrity of ERs from clean and efficient cooking interventions. Adding clarity will enhance buyers' confidence and facilitate much needed financial flows into the clean-cooking sector. Of the approaches reviewed in this report, WISDOM and similar models such as MoFuSS stand out as sensible approaches for examining woodfuel sustainability and for estimating fNRB at different scales. They allow for a transparent and systematic process using the best available data to estimate fNRB on subnational, national, or regional scales. Combined with stakeholder consultations and periodic updates, these models have the capability to build some consensus around woodfuel sustainability and appropriate interventions.

Challenges will remain. Outputs are only as reliable as the input data. Models invariably require assumptions or simplifications that often do not fully reflect real-world conditions. Complexity and costs are also concerns. The models require some expertise to understand and run, expertise that may be beyond the capacity of project developers implementing small or mid-size projects. Field surveys are also costly, and they face regulatory uncertainty if they fail to meet the requirements of project validators, designated national authorities, or UNFCCC itself.

Appendix A. Supplemental Data

Project design document (PDD) fraction of nonrenewable biomass (fNRB) values compared with Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) values for groups of projects

Figures B.1, B.2, B.3, and B.4 were developed based on the information in the supplementary data of the paper (GS 2016)

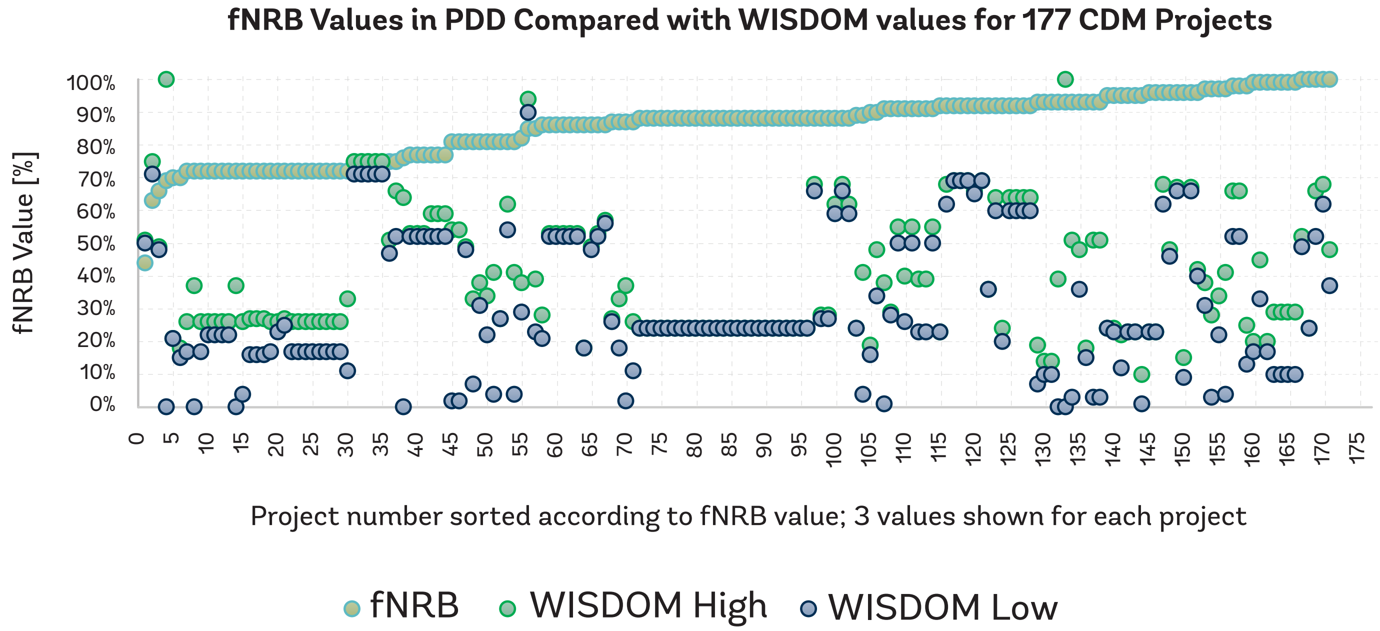


Figure B.1: Comparison of project design document fraction of nonrenewable biomass (fNRB) values and Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) High and Low for Clean Development Mechanism

For each of 177 Clean Development Mechanism (CDM) projects spread along the horizontal axis, the fraction of nonrenewable biomass (fNRB) value and the values for the WISDOM high and low estimates are plotted. There is essentially no overlap between these two approaches. Some of the WISDOM pairs overlap (indicating low uncertainty).

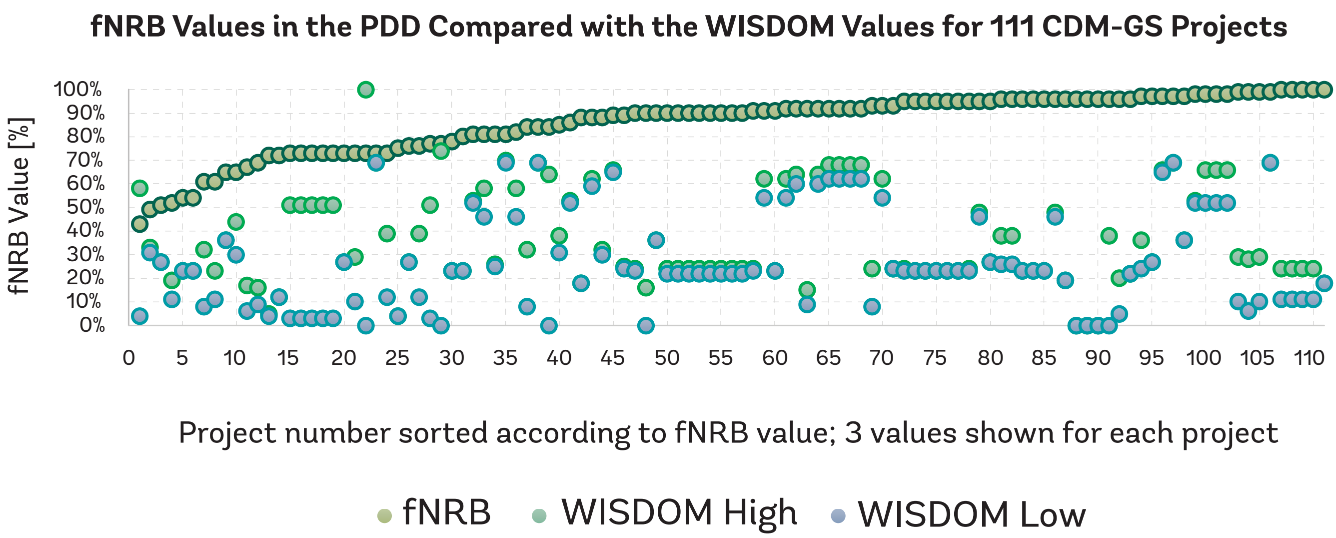


Figure B.2: Comparison of Project Design Document Fraction of Nonrenewable Biomass (fNRB) Values and Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) High and Low for Gold Standard (2008)

Again, there is little agreement between the fNRB values in the PDD, even when the WISDOM value range is very small.

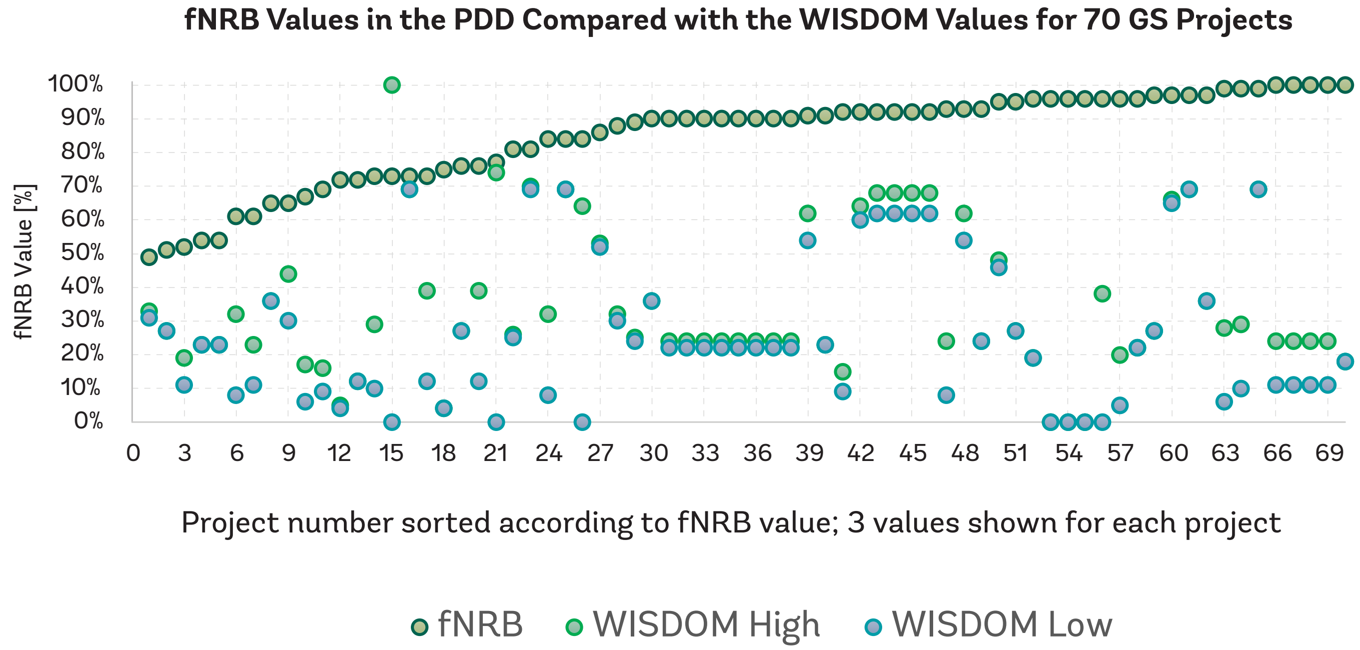


Figure B.3: Comparison of Project Design Document Fraction of Nonrenewable Biomass (fNRB) Values and Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) High and Low for Gold Standard (2013)

With the GS projects, there is little agreement between the methods in all cases. Most WISDOM estimates do not have a small range, meaning that they are quite uncertain. Only one WISDOM range encompasses a PDD value, and that WISDOM range is 0 percent to 100 percent.

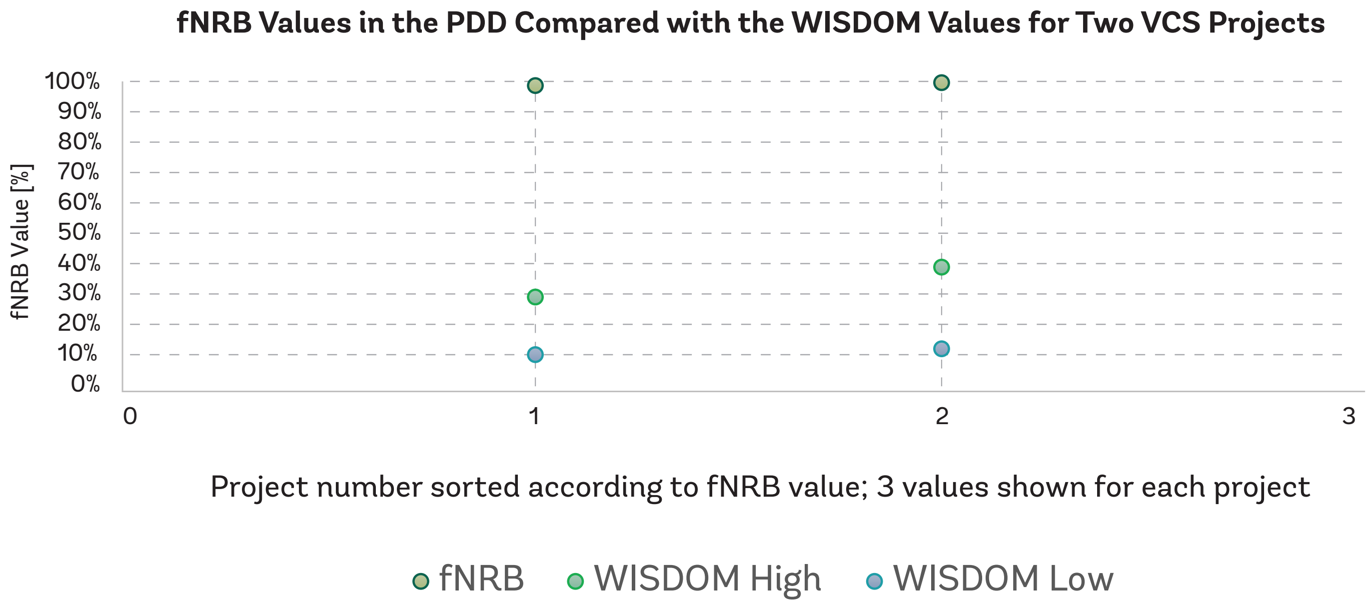


Figure B.4: Comparison of Project Design Document Fraction of Nonrenewable Biomass (fNRB) Values and Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) High and Low for Verified Carbon Standard

The WISDOM estimates are less than half of the values that appear in the PDD.

Appendix B. Summary of Methodologies for Determining Fraction of Nonrenewable Biomass (fNRB)

Methodology	Description	Approach to fNRB	Number of active projects or component project activities[a]
Clean Development Mechanism			
AMS-I.E: User switches from NRB for thermal applications	Designed for projects in which devices using renewable fuels other than woodfuels displace NRB. Version 10.0 went into effect in November 2019.	I.E and II.G use the same approach to determine fNRB. Previous versions required project participants to define DRB (box 4.2), which was relatively simple but led to overestimations. Default values were available for least-developed countries and small island developing states, which were also overestimations (box 4.3). Current version uses TOOL30, which is more conservative than the DRB approach. TOOL30 includes a default fNRB value of 30 percent, which is much lower than previous defaults. If the default is not used, fNRB is defined on the basis of wood harvest and MAIs specific to land cover categories. It is likely that this approach results in more accurate estimates of fNRB, but calculations are data intensive, which could be difficult for some project developers.	103
AMS-II.G: Energy efficiency measures in thermal applications of NRB	Designed for projects in which more efficient woodfuel devices displace NRB. The latest revision is Version 11.0, which went into effect in November 2019.		335
Gold standard			
TPDDTEC: Thermal energy production with or without electricity	Used for projects deploying technologies and practices that reduce emissions from household cooking. The current version, 3.1, was released in August 2017.	Allows multiple options for fNRB: 1. Something similar to DRB from pre-TOOL30 AMS-I.E and II.G 2. A quantitative approach similar TOOL30 3. A qualitative approach that is relatively vague and poorly defined 4. National-scale default values for select countries	220
Simplified Methodology for Efficient Cookstoves	Designed specifically for micro-scale activities generating less than 10 kt of carbon dioxide equivalent per year	Suggests same approach as TPDDTEC or United Nations Framework Convention on Climate Change defaults.	N/A
Other approaches involving modeling work			
WISDOM and **MoFuSS**	Both are spatial models with location specific information of woody biomass. WISDOM uses ARC-GIS, which is commercial software. MoFuSS uses DINAMICA-EGO and other freely available programs.	Both models use spatial maps of biomass demand, supply, and accessibility to estimate fNRB. WISDOM creates a snapshot for a single year. MoFuSS is dynamic and simulates an extended period. Both have advantages over other fNRB methodologies because they create more realistic estimates, but they are data-intensive and require more technical capacity.	NA

Note: AMS, Approved Methodology for Small-Scale Projects; NRB, nonrenewable biomass; DRB, demonstrably renewable biomass; WISDOM, Woodfuel Integrated Supply/Demand Overview Mapping; MoFuSS, Modeling Fuelwood Sustainability Scenarios; TPDDTEC, Technologies and Practices to Displace Decentralized Thermal Energy Consumption; N/A, not available.

a For the Clean Development Mechanism, entries include projects that are registered or at validation. Some projects use more than one methodology, so this includes some double counting.

Appendix C. Review of Real Cases in Carbon Crediting Schemes

To illustrate how these concepts have been operationalized in real cases in different countries, we present examples from Bolivia, Kenya, and India. These case studies are drawn from published reports, project documents, and regulatory reports.

Bolivia

Gold Standard (GS) published a default value for Bolivia in 2016 . The resulting fraction of nonrenewable biomass (fNRB) value is almost identical to CDM despite the updated input data (e.g., GS adopted the Food and Agriculture Organization (FAO) Global Forest Resources Assessment 2015, Country Report for Bolivia) (FAO 2015). The calculation method and results are presented below.

NRB = R-DRB

fNRB = [(F x GR + ΔF) – (PA x GR)]/[((F x GR + ΔF) – (PA x GR)) + (PA x GR)]

where

F =	extent of forest (hectares)
GR =	growth rate of biomass (tons/hectare per year)
PA =	protected areas, extent of forest (hectares)
ΔF =	annual loss of extent of forest (tons/year)
DRB =	demonstrably renewable biomass. The unit for DRB and NRB is tons/year.
MAI =	mean annual increment (tons/year)
R =	total annual biomass removal (tons/year)
NRB =	nonrenewable biomass
fNRB =	fraction of nonrenewable biomass

Given the data source for the fNRB calculation under the Clean Development Mechanism (CDM), the report analyzes only the two GS exercises (calculated as 82.6 percent and 80.5 percent, respectively). The values differ because each was calculated from a different set of FAO data: the 82.6 percent value from 2010 data and the 80.5 percent value from 2015 data.

The creator of an fNRB value is free to choose from a variety of FAO sources, and within each project cases, there are different ways to obtain values. ΔF can be determined in several ways. Using the 2010 data, change in mass was calculated based on annual change in carbon stock (–24,000 tons) divided by the fractional carbon content of biomass (0.47) and multiplied by 1,000, yielding a loss of 51,063,829.8 tons.

Table C.1: Parameter Values for Bolivia According to Various Methodologies

Parameter	Clean Development Mechanism 2012	Gold Standard 2012 (a)	Gold Standard 2016 (b)
Extent of forest (hectares)	57,196,000	51,654,945	54,764,000
Growth rate of biomass (tons/hectare per year)	5	5.28	5.28
Protected areas, extent of forest (hectares)	10,680,000	10,680,182	10,680,000
Annual loss of extent of forest (tons/year)	48,000,000	51,063,800	46,700
Demonstrably renewable biomass	53,934,000	56,391,414	56,370,802
Mean annual increment (tons/year)	288,839,800	272,738,110	289,053,428
Total annual biomass removal (tons/year)	336,839.800	323,801,910	289,100,128
Nonrenewable biomass	282,905,800	267,410,496	232,729,326
Fraction of nonrenewable biomass, %	84	82.6	80.5

Kenya

Kenya was covered in the 2012 CDM national default value exercise. The values used were recorded in appendix 2 of annex 22 of the CDM Executive Board's meeting 67[10] and are presented in the middle column of table C.2. Later that year, the designated national authority approved a proposed national default value, and the (very similar) values used for that registration are shown in the third column of table C.2. The source for the CDM default calculation from 2012 to 2017 is the CDM Small Scale Working Group 37th Meeting Report, annex 14.[11]

Table C.2: Parameter Values for Kenya According to Clean Development Mechanism Methods, 2012

Parameter	Executive Board 67, annex 22	Calculation by Kenya
Extent of forest (hectares)	3,467,000	N/A
Growth rate of biomass (tons/hectare per year)	2.10	N/A
Protected areas, extent of forest (hectares)	520,050	N/A
Annual loss of extent of forest (tons/year)	6,000,000	N/A
Demonstrably renewable biomass	1,092,105	1,092,755
Mean annual increment (tons/year)	7,280,700	N/A
Total annual biomass removal (tons/year)	13,280,700	N/A
Nonrenewable biomass	12,188,595	12,192,279
Fraction of nonrenewable biomass, %	92	92

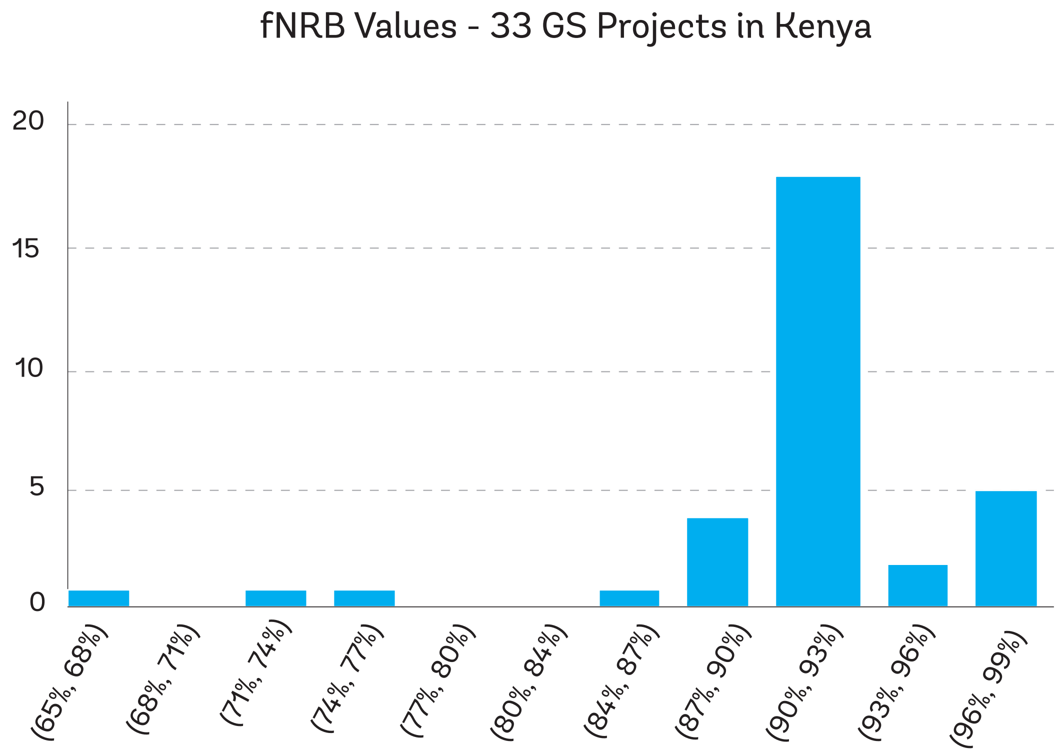
Note: N/A, not available.

Values for Kenya Using GS Methods

GS lists 36 projects registered in Kenya, of which 33 had certified emission reductions issued. The range **of fNRB value o** is 65 percent to 99 percent, the average is 90 percent, and the mode is 92 percent. Excluding the outlier (65 percent) brings the average to 91.2 percent.

10 https://cdm.unfccc.int/Reference/Notes/meth/meth_note12.pdf
11 https://cdm.unfccc.int/Panels/ssc_wg/meetings/037/ssc_37_an14.pdf.

Figure C.1: Fraction of Nonrenewable Biomass Values for Gold Standard Projects in Kenya[[Again, remove figure caption embedded in figure]



fNRB Values for Kenya Using Woodfuel Integrated Supply/Demand Overview Mapping Methods

A 2015 fNRB Assessment for Kenya (Drigo et al. 2015) that offers a high-resolution data set for each of 47 counties in the country provides a detailed analysis that shows that different assumptions and rules about fuels—for example, about how to classify harvested fuel, what biomass is considered “cooking fuel,” and how to categorize industrial wood waste—can lead to very different fNRB values. The considerations that make the most significant difference are:

- Whether biomass cut from land cleared for new farmland (and other land use changes) is available to be used as woodfuel. The CDM method assumes that it is. Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) provides values with and without land clearing

- Whether the entire supply of fuel should be provided by wood and not low-quality biomass alternatives that also could be used. The idea is that, if the whole harvest really were taken by chopping trees, the nonrenewable fraction would be higher

Four parameters are presented under two scenarios (table C.3). Scenario A considers that all cooking fuel should be wood, in which case the shortfall is 41 percent of the harvest. Scenario B considers cooking fuel as including marginal fuels, in which case the shortage is 38 percent of the harvest. When land clearing provides the cooking fuel, the values for Scenario A and B drop to 31 percent and 35 percent.

Table C.3: Four Combinations for Kenya Using the Woodfuel Integrated Supply/Demand Overview Mapping Method

Parameter	Scenario A: Only from trees		Scenario B: From all biomass	
	Land clearing excluded	Land clearing included	Land clearing excluded	Land clearing included
Demonstrably renewable biomass	15,899,760	15,332,641	17,602,985	17,108,394
Total annual biomass removal (tons/year)	27,078,760	24,848,641	27,072,985	24,878,394
Nonrenewable biomass	11,179,000	9,516,000	9,470,000	7,770,000
Fraction of nonrenewable biomass, %	41.3	38.3	35.0	31.2

Because of the different definitions of what constitutes removal of fuel, total annual biomass removal is not the same in each scenario. The project developer would have to decide which definition to use. Table C.4 shows the resulting four fNRB values and the assumptions that yielded them.

Table C.4: Woodfuel Integrated Supply/Demand Overview Mapping National Values of Fraction of Nonrenewable Biomass, Kenya, Various Scenarios

Use of biomass from cleared land	All fuel comes from trees	Fuel also includes marginal biomass
	%	
Not used as cooking fuel	41.3	38.3
Always used as cooking fuel	35.0	31.2

All these values are less than half of the CDM national default value or the average value applied in the 33 GS projects.

fNRB values for Kenya were 91.8 percent according to GS,[12] 92.0 percent according to CDM,[13] and 38 percent to 41 percent according to WISDOM.[14]

The most recently registered program of activities in Kenya, the KOKO Kenya – Ethanol Cookstoves Program,[15] adopted TOOL30, but upon further examination, the default value for Kenya under CDM was adopted, even though it had expired by the time of the program of activities validation. The program of activities further refers to "the latest Climate Change Action Plan 2018-2022, published by Kenyan DNA [designated national authority]-Ministry of Environment and Forestry, reports. Moreover, it was further confirmed by the DNA representative that the DNA considers the same value as applicable in context of woody biomass consumed in Kenya."[16] Although there are concerns raised about whether the approach strictly follows the requirements of the tool, it validated and approved the program of activities.

12 https://impact.sustain-cert.com/document_files/3182.
13 https://cdm.unfccc.int/Panels/ssc_wg/meetings/037/ssc_37_an14.pdf.
14 https://iopscience.iop.org/1748-9326/12/11/115002/media/ERL_12_11_115002_suppdata.pdf.
15 https://cdm.unfccc.int/ProgrammeOfActivities/poa_db/V2SD6ZA4EG57KXMIF9BNJORYWHQ1LT/view.
16 "Validation report of KoKo Kenya - Ethanol Cookstoves Program". Available at https://cdm.unfccc.int/ProgrammeOfActivities/poa_db/V2SD6ZA4EG57KXMIF9BNJORYWHQ1LT/view

India (Madhya Pradesh State)

We compare fNRB calculated for a GS project with the pan-tropical WISDOM assessment mentioned previously. India does not have a national default value under CDM or GS.

GS Project: Household Biogas Plants Installed in Rural Areas of Madhya Pradesh, India (GS project reference Number: 7510)

Project developers in the State of Madhya Pradesh, India, used the CDM methodology from AMS I.E to calculate emission reductions (Eq. 1) and used the approach from TOOL30 to define fNRB (Eq. 5) (GS 2017):

As TOOL30 allows, the project developers used official statistics from the 2011 Forest Survey of India report (2011) to estimate annual wood consumption of approximately 93 million tons per year. To determine renewable biomass, they used equation above, which accounts for wood collected from forest and nonforest areas, although the project design document (PDD) includes only data for forest areas that the Indian Forest Service has defined. Data in the PDD indicate that the state's forest cover is 8.7 million hectares, or approximately 28 percent of the total state area. The PDD also claims that mean annual increment (MAI) in this forest area is 0.5 tons per hectare per year, which is quite low. The default guidelines of the Intergovernmental Panel on Climate Change for MAI in dry forests or shrubland areas of Asia is 2 to 10 times as large as this. The source given for the data used in the PDD is a broken weblink.[17] In addition, the PDD ignores trees outside forest areas, which can be a significant source of woodfuel, particularly in areas with limited forest cover. Ignoring trees outside of forest areas and using a low value for MAI results in renewable biomass of just 4.4 megatons per year. These estimates of annual wood consumption and renewable biomass result in an fNRB of 95 percent.

An fNRB of 95 percent should result in a dramatic reduction in tree cover within a very short period (box 4.4), but according to the Indian Forest Service, between 2017 and 2019, Madhya Pradesh observed an increase in forest and tree cover (Forest Survey of India 2017; 2019), indicating that the PDD overestimated fNRB. A review of 17 other GS projects in the state showed similar results, with fNRB estimates ranging from 46 percent to 100 percent.

Comparison with WISDOM

In the pan-tropical WISDOM assessment, researchers estimated that fRNB falls between 12 percent and 24 percent (Bailis et al. 2015). The reason for the large difference between the GS PDDs and WISDOM is that the latter accounts for all accessible biomass in the state and uses spatially-dependent biome-specific MAI estimates rather than a single low value, so overall supply is larger. In addition, the PDD uses a much higher-value wood harvest than the WISDOM assessment. The PDD claims to have used the 2011 Forest Survey of India Report (2011), but the wood harvest data for Madhya Pradesh in that report do not agree with the values in the PDD (table C.5).

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17 http://www.moef.nic.in/sites/default/files/Pacific.pdf.

Table C.5: Woodfuel consumption estimates for Madhya Pradesh

Source	Value (megatons/year)	Reference
Woodfuel Integrated Supply/Demand Overview Mapping Assessment	19-21	UNFCCC 2019
Project Design Document for Gold Standard 7510		Drigo, Masera, and Trossero 2002
Domestic woodfuel	20.9	
Nonfuel consumption	71.9	
Total	92.7	
2011 Forest Survey of India Report		Ryan, Berry, and Joshi 2014
Domestic woodfuel	13.7	
Nonfuel consumption	17.9[a]	
Total	32.6	

Note: [a] The Forest Survey of India report gives woodfuel data in cubic meters. In the present report, this was converted to tons using a ratio of 0.6 t/m_3

Because of this, the sources of data used in the PDD and the application of the formula specified in the methodology can both be called into question. Combined, they resulted in a high value of fNRB that very probably overestimates the emission reductions that the project achieved.

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