EnDev's proxy-indicator approach
for assessing the quality of a

Cooking Energy System

energising
development

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Deutsche Gesellschaft für
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Registered offices: Bonn and Eschborn, Germany
P.O. Box 5180
65726 Eschborn, Germany
T +49 61 96 79-0
F +49 61 96 79-11 15
E info@giz.de
I www.giz.de

Contact:

Energising Development
Verena Brinkmann, and
Dr. Christoph Messinger

T +49 6196 79-6179
F +49 6196 79-806179
E endev@giz.de
I www.endev.info

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Overview and context

A. Context

EnDev's mission is to facilitate new and sustainable access to modern energy to poor households, social institutions and productive uses of energy. However, in the field of cooking energy, 'new access' is not feasible as practically everyone uses some sort of cooking fuel and device for processing of the food already. Instead, **EnDev promotes a 'better level of cooking energy quality'** with its project intervention.

Initially, the yardstick was a 40% reduction of specific fuel consumption between the baseline and the promoted new cookstove (Controlled Cooking Test). This indicator derives from the times where deforestation and poverty reduction were the main drivers for promoting improved cookstoves (ICS).

Contextualising the performance assessment of stoves

In the last 20 years, the ambition and justification for **promoting ICS** has changed significantly. Currently, there are **two main drivers** in the sector: the **Health Agenda** (GACC, "Cooking should not kill") and the **Climate Agenda**. The requirements for defining what a 'better cooking energy quality' is have become very complex and linked to larger concepts.

EnDev is engaged in various international processes that are currently underway for defining the quality of cookstoves or access to cooking energy (development of IWA; ISO TC 285; ESMAP GTF etc.). However, most of these efforts rely on the application of lab tests for measuring key performance indicators. While lab testing has a central role in the development of a technology, there are serious limitations for its application in the assessment of cooking energy quality in the field.

For its own reporting on the **quality of cooking energy** facilitated by its interventions, EnDev is developing its own assessment concept based on proxy indicators which can be easily verified in the field. The so-called **Cooking Energy System (CES)** comprises two parts. One part assesses the "quality" of a cooking energy system from the perspective of the user. The second part, which has not yet been developed, will focus on the climate relevance of cooking.

The methodology is still under development. EnDev tested a first version in some country projects and discussed the concept with more than 20 of its cookstove programmes globally. Based on their feedback, this improved version was developed and will now undergo field-testing. In parallel, researchers will use existing and new field data to verify some of the proxy indicators used in this system. By the end of 2017, the version 2.0 shall be ready for application in the field.

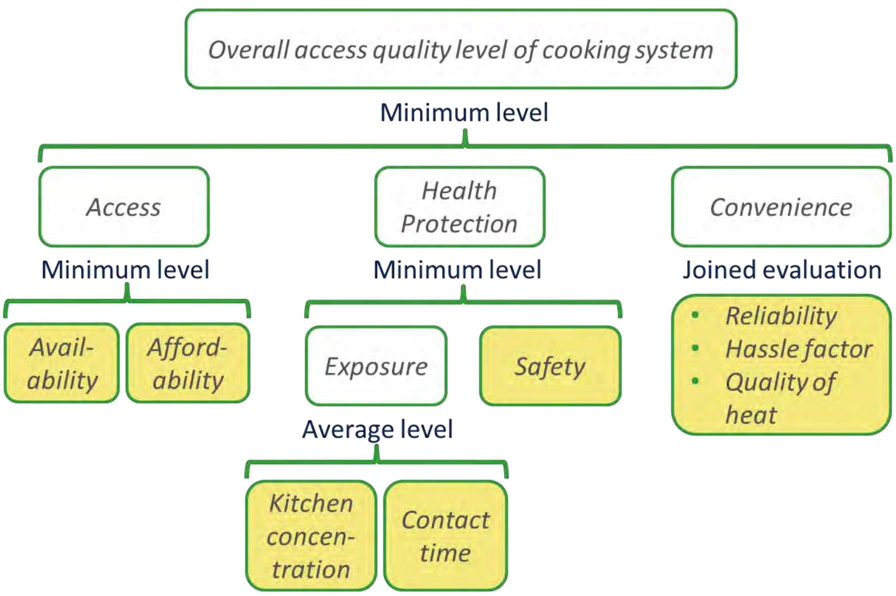
B. Structure of the Cooking Energy System

The primary **purpose of a cooking system** is to facilitate the **transformation of food items into meals**. It is not a dedicated health care device, nor a climate-saviour.

The first part of the assessment tool is structured according to the **key interests of the user** (defined based on EnDev field staff knowledge from the past 10 years).

The chore interest of a household in the use of a cooking energy system is to prepare all the required meals at the desired time, in the desired quantity and the preferred quality. In scientific terms, this interest refers to the accessibility of the required fuel in its availability in the living space of the household and the affordability for the household economy.

Households are risk aware to a different extent. While safety concerns are more common, the knowledge of the threat of being exposed to a harmful level of emissions is only partially available.



In contrast, the user-friendliness of a cooking system is an instant observation and concern. If a stove-fuel system frequently fails to heat the food, or it is very complicated or cumbersome to use, or if the quality of the heat does not permit to prepare important types of daily meals, households will not appreciate it regardless of how smoke-free or climate friendly it is.

C. How the Cooking Energy System deals with stacking

Stove and fuel stacking is a global phenomenon in kitchens. It is an expression of comfort, resilience and diversity of food. The absence of stacking might even serve as a poverty indicator rather than as an indicator for successful transformation to 'modern cooking'. Hence stacking should rather be used as an opportunity than considered as an obstacle to success.

However, stacking makes assessing the impact of a promoted stove-fuel system on the overall quality of the cooking energy situation of a household rather complex:

1. If households use the EnDev intervention stove for 70% or more of their total daily cooking time, the use of the other stoves does not contribute significantly to the overall quality of the cooking energy system of the household.
2. If households use the EnDev intervention stove for less than 70% of their total daily cooking time, the quality of the other stove-fuel systems needs to be considered, too. This implies evaluating all stove-fuel systems used in the household with the same methodology as the intervention stove and compare their CES ranking. If the household uses stove-fuel systems with lower CES ratings for at least 30% of its total daily cooking time, it does not benefit sufficient from the better quality of the promoted technology. Therefore, the overall CES ranking will be reduced by one level.

Stove stacking: How to assess stacking?

a) Which are the main meals of the day?
b) Which of the stoves and fuels available in the household are commonly used in the preparation of these meals?
c) How long is each of the stoves used on average for the preparation of meals?

	Intervention stove	Other CES used in households			
meal	**CES 1**	**CES 2**	**CES 3**	**CES 4**	**total**
breakfast	[minutes]	[minutes]	[minutes]	[minutes]	
lunch	[minutes]	[minutes]	[minutes]	[minutes]	
dinner	[minutes]	[minutes]	[minutes]	[minutes]	
	% CES 1	% CES 2	% CES 3	% CES 4	Total daily cooking time [minutes]
		of total daily cooking time			

Source of information:

- Random sample field survey with observations in situ (project measures the time of each stove use)
- Random sample field survey (or RBF verification) in situ with interview of stove users
- Estimation by EnDev field staff

Assessment done at household level. For each CES geographic area, an average for the stacking is used.

D. Level of accurateness in the CES assessment

EnDev does not strive for perfect data quality as in academic research. The approach entails a process that starts with informed guesses of EnDev's field staff, followed by a constant process of small field surveys in the EnDev intervention zones to replace estimations by measurements. Sample sizes and sampling procedures will not always satisfy scientific requirements. EnDev aims at improving its understanding gradually and increase the reliability of its findings, without overstretching its budget on monitoring and the engagement of its field staff.

Indicators of the CES

E. Accessibility of the energy source

Accessibility of energy source
- **Availability** of energy source
- **Affordability** using the energy source


The cost of the stove and its availability on the market are factors for the decision to buy the stove. However, EnDev assess the situation after the household has already bought the stove. Therefore, EnDev focusses on the **availability and affordability of the fuel** needed for cooking.

E.1 Availability of energy source

The availability of fuel can be seasonal for various reasons.

- Firewood collection areas get flooded in the rainy season;
- Government imports of LPG stop because the required foreign exchange become scarce some months after the end of the seasonal export of cash crops (e.g. tobacco).

In cases of seasonal un-availability, the duration of availability forms the base for the classification.

However, the fuel can also be available 12 months per year but during some months not available in the required quantity, leading to omission of certain energy-intensive foods or even the reduction of the number of meals prepared per day. Possible reasons are:

- A cold season can reduce the level of biogas production;
- Governments restrict access to a subsidy-controlled fuel (e.g. LPG, kerosene) if funds do not permit to provide full fuel supply.

In these cases, the classification is based on the months in which availability of fuel is enough for all cooking tasks.

How does the CES differentiate the quality levels of availability?

Level	In situations where fuel is only sometimes available (and sometimes not)	In situations where fuel is always available, but sometimes not enough* (e.g. biogas)
5	12 months available and always enough for all cooking needs	
4	12 months available, at least for 9 month enough for all cooking needs	
3	< 12 months available	< 9 months enough for all cooking needs
2	< 9 months available	< 6 months enough for all cooking needs
1	< 6 months available	< 3 months enough for all cooking needs
0	< 3 months available	Never enough for all cooking needs

* Fuel is not enough =
a) at least one meal per day could not be prepared because of fuel shortage
and/or
b) commonly prepared energy intensive foods would be avoided (e.g. beans)

Special cases to be regulated

1. Some stoves are specified as working with different fuels (e.g. firewood and charcoal)

   If these fuels are fully exchangeable (you can use either of the two), it is sufficient if one of the fuels is available at a time. You can still cook.
   Only if neither of the fuels is available, the month counts for "fuel not available".

   If one of these fuels is obligatory (e.g. wood) while the other is just complementary for parallel use (e.g. in some cases dung is used supplementary to fuelwood, but would not burn for it alone), the availability of the obligatory fuel (here: firewood) would be the limiting factor for the assessment of fuel availability.

2. Sometimes fuel is not acquired every month, but private bulk stocks are always sufficient throughout the year.

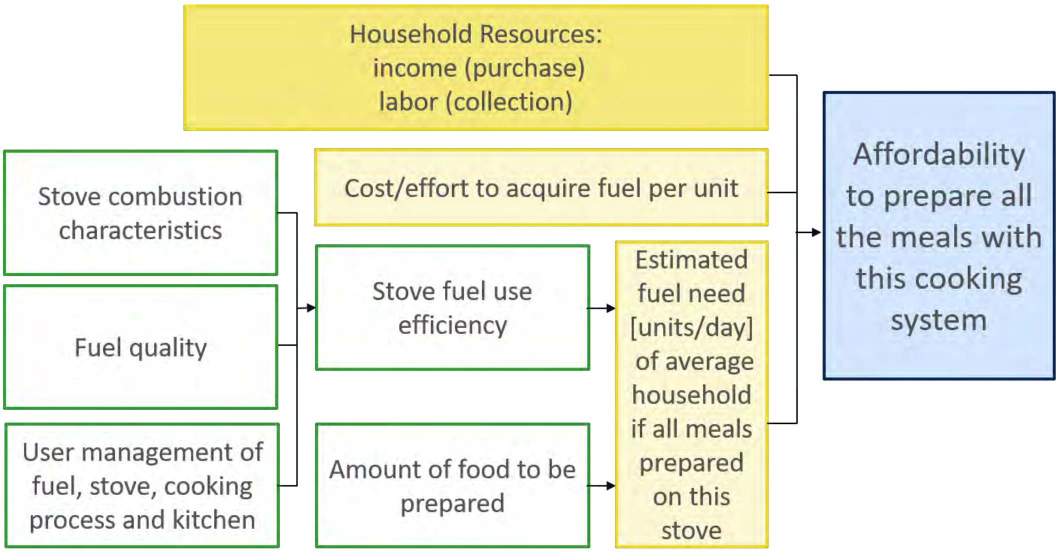
   Example:
   You cannot collect firewood in the 5 months of rainy season due to flooding of the area. However, during rainy season every household uses firewood from large piles stocked in their barns. Is availability in this case 7 month or 12 months?

   a) If bulk collection is a common practice in the respective geographic area to overcome acute non-availability of fuel for collection or purchase, the assessment of the "fuel availability" can ignore the temporary in-availability (based on the availability of private stocks).
   b) However, if these private stocks of fuel are commonly insufficient to cover all of the availability gap (e.g. it only lasts for 3 out of 5 months, after that people have to use a different cooking system), then the assessment of "fuel availability" should reflect this deficiency (in this example, 2 months would be counted as "fuel not available")

E.2 Affordability of energy source

How to measure affordability?

Affordability is an evaluation of the relationship between the overall cost or effort to acquire the required fuel for domestic cooking vis-à-vis the income or labour resources of the household.



The affordability to prepare all the meals with the cooking system is based on the comparison between the household resources (labour, money) and the cost or effort to acquire the required quantity of fuel for cooking. Many factors influence the affordability.

If fuel is collected, the effort of collecting the fuel for domestic cooking is compared with the overall labour resources of the household. If fuel is purchased, the cost of buying the needed amount of fuel for domestic cooking is compared with the financial resources of the household.

While it would be nice to evaluate all influencing factors (stove efficiency, fuel quality, user management, food requirements) separately and then aggregate their results, this would make the research very complex. EnDev therefore rather decided to base the assessment preferably on actual measurements of consumption (similar to KPT). If that is not feasible, results from the Controlled Cooking Test (CCT) or household interviews can allow for rough estimations.

E.2.1 How to consider the stacking in the assessment of affordability

In reality, it is not so easy to calculate the affordability. Most households use some sort of stacking of stoves and even stacking of fuel for cooking. However, if EnDev based the calculation on the actual consumption of the intervention stove (and leave out the fuel consumed by other stoves in the stacking system) the result would be strongly influenced by the stacking level and not meaningful for assessing the affordability.

One option would be to assess the cost and/or effort to acquire all fuels used by the different stove-fuel systems in the actual household. The combined costs or efforts are compared with the household resources. Depending on the stacking situation, this could become quite a complex calculation. Furthermore, the measurement of LPG consumption per meal or per day is practically not feasible as the decrease of weight of the fuel container is too small.

The other option is to use the information of the stacking assessment (percentage of cooking time), combine it with an assessment of fuel consumption and calculate the hypothetical daily fuel consumption if 100% of the cooking time is done with the intervention stove. This is not 100% correct as stoves have different power outputs which further affects the cooking time needed. Nevertheless, it is a good rough estimation of the effect if all cooking was done with the intervention stove on the affordability of the cooking system.

The problem of stacking in this assessment: Households use different levels of stove and fuel stacking. Example: **Stove A** and Firewood = **system to be assessed**

	Stove A	Stove B	Stove C	Cooking time
Breakfast	not used	20 minutes 200 g LPG	Not used	20 minutes
Lunch	90 minutes 3,5 kg wood	Not used	30 minutes 700 g charcoal	120 minutes
Dinner	60 minutes 2 kg wood	Not used	20 minutes 500 g charcoal	80 minutes
% daily cooking time	150 min. = 68%	9%	23%	220 minutes
Actual wood use	5,5kg wood	If all cooking time would have been done with stove A on this day, the wood consumption would have been 8,1 kg (assuming that all stoves have the same power output		
Hypothetical daily wood use if 100% cooking time done with stove A	(5,5kg*100)/68= 8,1kg			

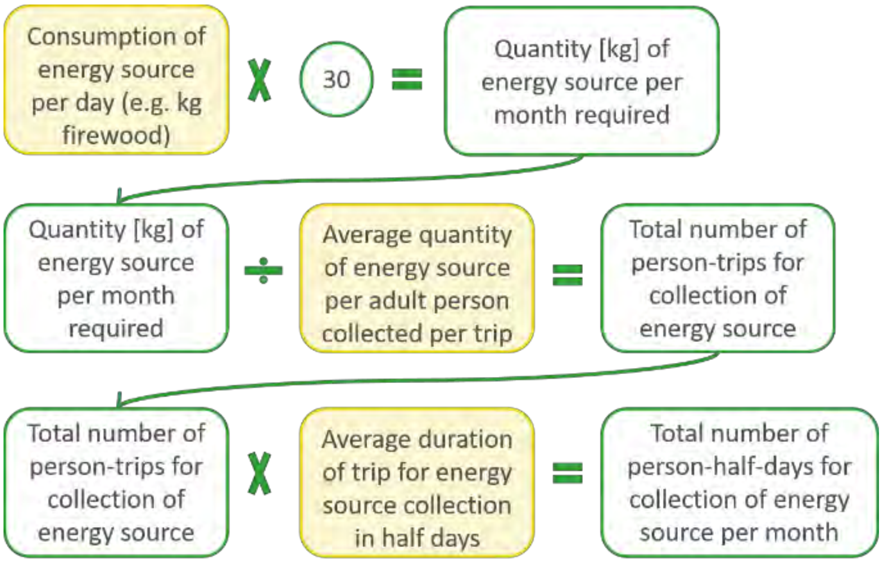
Stacking and fuel use will be assessed in a selected number of households (smaller sample) for each project intervention zone. A process tool for CES will be developed.

E.2.2 How to measure affordability if the energy source is collected

The assessment and evaluation of labour effort for the collection of the needed fuel is more difficult in practice than generally assumed. The indirect assessment based on the influencing factors of collection time (distance to fuel source, type of landscape, type of fuel, means of transportation, and transport-capacity per person) is too complex.

However, the direct assessment is not that easy either. Interviews on collection times should rather focus on “person-half-days” (morning/afternoon = approx. 4 hours each) as smallest unit of measurement “hours or minutes” do not play an important role in the real life of many target communities. Instead of interviews, direct observations of collection times and the weighing of fuel loads are useful methodologies.

Example of how to assess the required labour for the collection of the monthly fuelwood demand in case no direct data collection has been done



In the absence of a field study, EnDev can roughly estimate the labour requirements using the above concept. Once EnDev knows the daily energy source requirement, it can calculate the monthly amount by multiplying by 30. EnDev estimates or measures the weight of the quantity of fuel an adult person can transport on a single trip. This gives EnDev the total number of trips per month. By estimating the duration of a collection trip, EnDev has a rough estimation of the total number of person-half-days for the collection of the energy source per month.

How to deal with child labour observation when assessing fuel collection efforts

Children participate often in fuel collection trips. However, EnDev is a programme contracted by governments. It therefore shall not promote or recognise child labour as a labour resource of a household.

- For the calculation of the labour resource of a household, EnDev only considers "adult labour (AL)" as a resource. Commonly the age limit is 18 years.
- For the assessment of the actual labour invested in fuel collection, the time children spend in fuel collection substitutes working time of their parents. Thus, EnDev needs to translate their collection efforts into the time an adult would have used to collect the same amount of fuel.
- *Example:*
  If a child collects 50% of the amount of wood in a half day compared to an adult, this means 2 half days of a child = 1 half day of an adult.

How to determine the monthly adult labour resource of the households

In a field survey, the AL is assessed directly. However, EnDev needs to generalise the information at an aggregated level, as it does not report on individual households but on the level of intervention zones.

For the following, EnDev distinguishes between small households (1-5 people) and middle and large households (>5 people). Depending on the average household size of an intervention zone, the AL resources of the table above shall be used in case there are no field data available yet.

How to determine the monthly adult labour (AL) resource of the household (# of person-half-days per month)

Category	Household size	Assumed Adult labor [AL]	Standardized labor half days per month [1 AL = 60 halfdays (HD) per month]
Small households	1	1	60
	2-5	2	120
Middle and large households	6-8	3	180
	9-10	4	240
	>10	5	300

- 30 working days per month as this is domestic work
- This table only considers Adult Labour
- HD = half day of work = morning or afternoon = app. 4h

These are default values to be used when working with averages.
However, in field assessments, the actual value of AL should be assessed.

Affordability ranking based on percentage of disposable adult labour (AL)

EnDev is applying the same benchmarks (percentages) for affordability in case of fuel collection or purchase. There is a stricter set of benchmarks for resource-poor households compared to the medium and resource-rich households. This means that for a resource-poor household, the fraction of the resource invested into fuel access is more critical than for a resource-rich household.

Small households

	Fraction of labor resource [%]	HH with 1 AL	HH with 2 AL
5	<= 0,5	<= 0,5 HD	<= 1 HD
4	> 0,5	> 0,5 HD	> 1 HD
3	> 1,25	> 1 HD	> 2 HD
2	> 2,5	> 2 HD	> 3 HD
1	> 5	> 3 HD	> 6 HD
0	> 10	> 6 HD	> 12 HD

Medium and large households

	Fraction of labor ressource [%]	HH with 3 AL	HH with 4 AL	HH with 5 AL
5	<= 1	<=2 HD	<= 3 HD	<= 4 HD
4	> 1	> 2 HD	> 3 HD	> 4 HD
3	> 2,5	> 5 HD	> 6 HD	> 8 HD
2	> 5	> 9 HD	> 12 HD	> 15 HD
1	> 10	> 18 HD	> 24 HD	> 30 HD
0	> 20	> 36 HD	> 48 HD	> 60 HD

- Same percentages applied as in the table for commercial access
- For the better applicability, the number of halfdays in the table are mostly rounded
- HD = half day of work = morning or afternoon

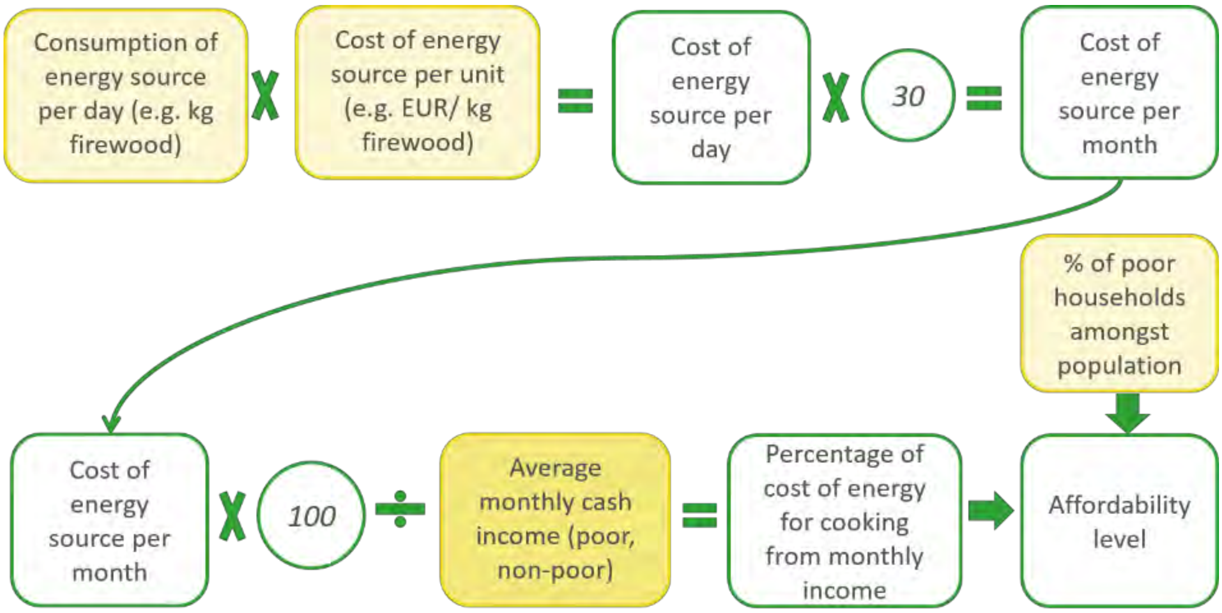
Special cases in fuel collection:

- If fuel is collected in bulk (for storage), divide the number of person-half days of collection by the number of months the stock will last for cooking;
- If fuel collection is part of a regular trip for field work (or other regular activities), only the time for assembling the wood is counted, not the time of coming and going;
- If fuel is also collected for productive uses or selling, only consider the amount used for domestic cooking;

- If fuel collection times are different between seasons, assess the collection time of both seasons. Take the value of the longer season. If the shorter season is > 3 months, modify the value of the longer season 1 up or 1 down in the direction of the level of the shorter season;
  Example:
  Dry season affordability level 2, 60% of the time
  Rainy season affordability level 4, 40% of the time
  Reported: affordability level 3
- If dung is collected from the fields to be fed into the biogas digester, it also has to be prepared before being filled in. Only the time of collection is considered here, not the preparation time;
- The different quality of wood or charcoal and their impact on the affordability of fuel access will not be considered (too detailed);
- If collection is partially done during field work trips and partially done with specific trips, calculate the person-half-days of both shares of the collection approaches and add them up.
  Example:
  1. *collection during field work trips: 10 HD/month*
  2. *collection on specific collection trips: 20 HD/month*
  3. *Total: 30 HD per month invested into collection of firewood*

E.2.3 How to measure affordability if the energy source is purchased

Key factor Ib: Affordability using the energy source



Similar to fuel collection, the starting point is the amount of fuel (number of units) required for cooking per month. Information about fuel costs (EUR per unit) allow calculating the fuel costs per day, which easily can be translated into monthly fuel costs. Observations or interviews are alternative options to obtain this information.

EnDev uses government statistics on average disposable income of poor and middle to better off households in order to calculate the percentage of fuel costs on the overall monthly disposable income. In some context, it might be feasible to collect information about income directly, but that is generally not recommended unless it is obvious that official statistics do not represent well the situation in EnDev target groups.

level		Low income households	Middle and high income hh
5	Very Good	< 0,5% of income	< 1 % of income
4	Good	0,5 - < 1,25% of income	1 - < 2,5% of income
3	Sufficient	1,25 - < 2,5% of income	2,5 - < 5% of income
2	Limited	2,5 - < 5% of income	5 - < 10 % of income
1	Deficiant	5% - < 10% of income	10% - < 20% of income
O	Highly deficient	10% or more of income	20% or more of income

For households with more income, even a higher percentage of fuel cost from their monthly cash (compared to poor households) is still acceptable if the energy service is much better.

Project staff indicates the percentage of poor households amongst the population for each intervention zone (government statistics, reports, estimations etc).

Special cases:

1. If the purchase of fuel (particularly the industrial fuels like LPG) regularly requires a significant amount of time (e.g. at least 1 person spends half a day travelling to the next distribution point) and these are special trips for this purpose, the affordability level shall be reduced by 1 level;
2. It was suggested to include the investment cost of the stove divided by its average life span in months in the assessment of affordability. However, this can only be done if fuel access is commercial. As it cannot be translated into person-half-days of collection time, EnDev is not able to consider this point for areas with fuel collection. Therefore this point is not considered;
3. If fuel prices vary throughout the year, use the average fuel price.

Special cases to be regulated

If the same fuel is collected and purchased during the year:

a) Determine the number of months which are predominantly collection (e.g. 7) and predominantly purchased (e.g. 5)
b) Evaluate affordability level for both forms of access (e.g. level 2 for collection and level 4 for purchase)
c) Calculate the overall affordability level.

Form of access	# of months	Level of access		Calculation	
collection	7	2	X	14	+
purchase	5	4	X	20	
		Total level-point per year		34	/12
		Rounded average affordability level		3 (2,8)	

This assessment is done at household level. Use the average level of the sampled households to determine the level of a CES geographic area.

If the same stove is used with two different fuels during the year (e.g. firewood and charcoal):

a) Determine the number of months which are predominantly fuel A (e.g. 8) and predominantly fuel B (e.g. 4)
b) Evaluate affordability level for both fuels (e.g. level 1 for fuel A and level 4 for fuel B)
c) Calculate the overall affordability level.

Form of access	# of months	Level of access	Calculation
Fuel A	8	1	8
Fuel B	4	4	16
		Total level-point per year	24
		Rounded average affordability level	2

This assessment is done at household level. Use the average level of the sampled households to determine the level of a CES geographic area.

F. Health protection

F.1 Exposure

1. Direct exposure measurement (in situ):

Good for case studies and to verify proxies, but not feasible for monitoring or regular surveys.

Photo: SNV Cambodia

There are different possibilities for how to assess exposure. The most accurate methodology is the in situ measurement, the direct exposure measurement on the body of the cook. This is a good approach for case studies and to verify proxy indicators, but not feasible for regular surveys. Data collection and processing take a lot of time and the process is very costly.

2. Model based calculated EXPOSURE (based on lab test results):

requires emission data and kitchen information to configure the variables.

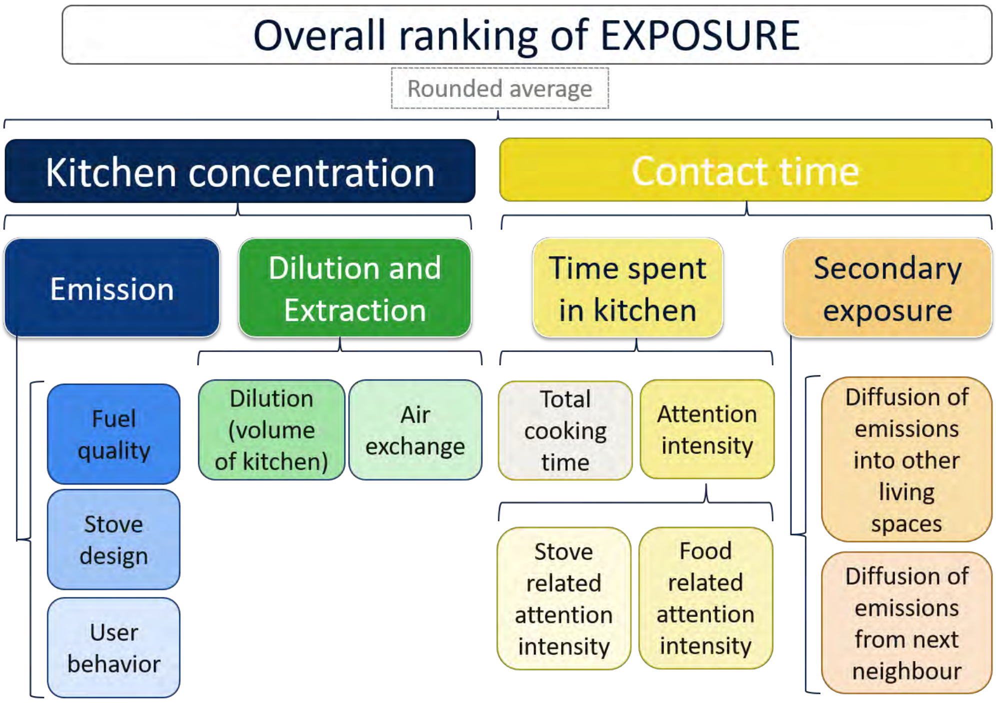
A cheaper method is the calculation of exposure based on mathematic models using lab test results of stove emission as an information base. Kitchen information is either set on default values or adapted based on field information to extrapolate an exposure level based on lab test results. This approach is under development by several actors. It is not as costly as the direct measurement. Research still has to verify the validity of the approach.

3. EXPOSURE assessment by proxy indicators (in situ):

Allows field based verification in monitoring and surveys. However, proxies need to be verified at some stage with calculations or measurements.

Proxy indicators do not suggest, unlike the model tool, that the results are accurate. They do not deliver a figure of exposure level. It is a classification by comparing different real life situations in the sense of “contributing more or less to exposure”. By including a broad variety of factors, the overall assessment still represents a comprehensive picture of exposure. Research still has to verify the validity of the approach.

The same broad set of factors needs to be considered whether you want to approximate or model exposure levels. The type of data and the method of aggregation is different though.



As an exemption, EnDev defines that if the emission is at the best level (level 5) there are no harmful level of emissions. In this particular case, the other key dimensions of “dilution and extraction” and “time spent in kitchen” are not applicable. However, the secondary exposure deriving from the neighbouring compound may still influence exposure levels.

F.2 Kitchen Concentration

The emissions coming from the stove and their dilution and extraction from the kitchen structure influence the concentration of harmful emissions in the kitchen.

F.2.1 Emissions

Mainly three factors influence the emission level of a stove-fuel system: the fuel quality, the stove design, and the behaviour of the stove and fuel user.

How to grade fuel quality as a factor for emission

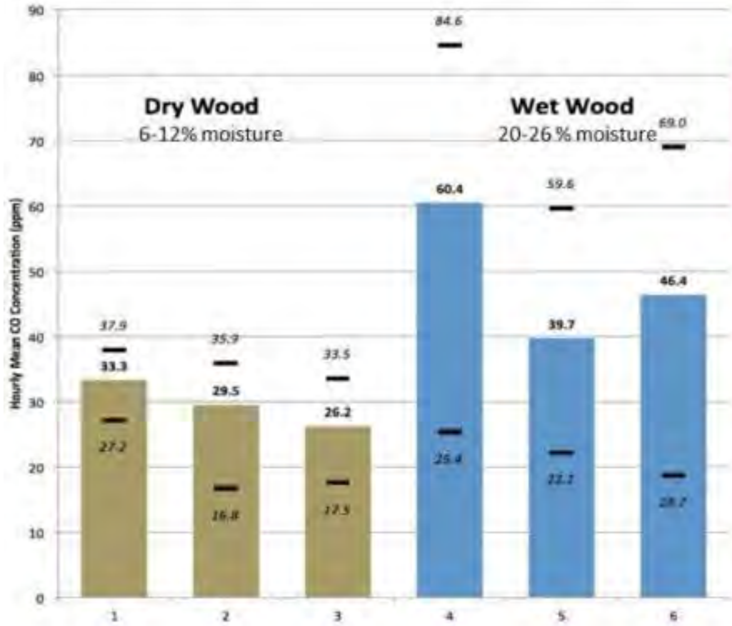
For biomass fuels, the moisture content of the fuel and the regularity of its shape are the main factors influencing the emission level. For simplification, EnDev attributes the highest level of cleanliness to electricity, LPG and biogas with no level of differentiation. For other fuels such as mineral coal, kerosene and paraffin, it is not yet clear how to define fuel quality in terms of the factor contributing to emissions.

Fuel quality as factor for emission

Fuel	Assumptions on fuel-related factors that could enhance emissions when using this fuel	Level range
Dung, Leaves, twigs	Generally inhomogeneous fuels • Moisture content	0-1
Firewood	• Moisture content • thickness of the wood, oily content	0-3
Charcoal	• Moisture content • Level of carbonization	0-3
Rice husks, Pellets, Briquettes	Homogeneous fuels, regular spaces for air • Moisture content	0-4
Mineral coal	to be determined	tbd
Kerosene, Paraffin	Generally mix of different length of molecules • Cleanliness of fuel	tbd
LPG, Biogas, Electricity	No impurities of fuel expected which could enhance emissions of CO or PM in the kitchen	5

The moisture level is the most significant factor for emissions of biomass fuels. The moisture reduces the burning temperature (as the evaporation of the water cools down the flames). This results in incomplete combustion, which is the main source for the emission of CO and PM.

Impact of fuel moisture on air quality using a 3-stone fire



Evidence emerges that the drying wood might have a bigger impact on air quality than the type of stove technology.

Source: Whelan/Peterson/Ruth: Kitchen 2.-0 – Design Guidance for Healthier Cooking Environments (ETHOS 2013)[51]

How to evaluate biomass fuel moisture in the field?

There are moisture meters for the field and bomb calorimeters for the lab. However, EnDev looks for proxy indicators that can be used in the field. The key question is: why should a biomass fuel be wet when used in the stove? Some biomass fuels are wet after production (e.g. firewood, dung) while other biomass fuels are dry after production (e.g. charcoal). This condition might have already changed until the fuel has either been collected or purchased by the end user. Firewood could dry out or charcoal could be exposed to rain. However, the actual important question is how the household treats the fuel before using it. Is the fuel stored at a dry place? Is the fuel sundried before using it in the stove? These are the two guiding questions.

Dung leaves and twigs contain a lot of moisture in fresh condition. Even in dry condition, they will still result in higher emission levels because of their inhomogeneous shape and quality.

Firewood and charcoal emit far less CO and PM when used in dry condition. However, rosin containing firewood and incomplete carbonised charcoal show higher emission levels.

Rice husks, pellets and briquettes have a far more regular shape than firewood or charcoal. In dry condition, they have a lower emission level compared to charcoal and firewood.

Grading of biomass fuel quality

Fuel	Description of level	Level
Dung, Leaves, Twigs	Fuel 12 month sundried or from dry storage (humidity low)	1
	Fuel < 12 month sundried or from dry storage (humidity low)	0
Firewood, Charcoal	Fuel 12 month sundried or from dry storage (humidity low)	3
	Fuel < 12 month sundried or from dry storage (humidity low)	2
	Fuel < 9 month sundried or from dry storage (humidity low)	1
	Fuel < 6 month sundried or from dry storage (humidity low)	0
	If firewood is commonly very oily / has a lot of rosin (=smoke when burning), reduce the level determined for moisture by 1 level	
	If charcoal is mostly incomplete carbonized (=smoke when burning), reduce the level determined for moisture by 1 level	
Rice husks, Pellets and Briquettes	Fuel 12 month sundried or from dry storage (humidity low)	4
	Fuel < 12 month sundried or from dry storage (humidity low)	3
	Fuel < 9 month sundried or from dry storage (humidity low)	2
	Fuel < 6 month sundried or from dry storage (humidity low)	1
	Fuel < 3 month sundried or from dry storage (humidity low)	0

How to grade stove design as a factor for emission

CO and PM emissions are the result of uncompleted burning of the fuel. The factors contributing to the level of combustion are commonly:

Factor	Explanation of the impact on emissions
Temperature	the higher the temperature in the combustion chamber, … …the better the combustion of the fuel
Time	the more time the fuel has to combust in the stove, … …the less is left uncomplete combusted
Turbulence	the more the fuel(-gases) are mixed with (hot) oxygen, … …the better the combustion

Stoves with design features that increase the temperature, time and turbulence in the combustion chamber tend to have lower emission of CO and PM than other stoves. These design features will be different for different fuel types.

Please note that the following is not about fuel use or energy efficiency, nor any other stove quality features except for the likeliness of a stove to produce CO and PM when combusting the designated fuel.

Stove design as factor for emission

Stoves by fuel type	Assumptions on stove design-related factors that could enhance emissions when using this fuel	Level range
Firewood, Dung, Twigs, Leafs	• Heat in the combustion chamber: Insulation • Surface area of fuel to burn: Shelf • Mixing of woodgas and oxygen: height of combustion chamber, secondary air • Extraction of emissions: chimney	0-4
Charcoal	• Heat in the combustion chamber: Insulation • Mixing of combustion gas with oxygen: secondary air	1-4
Rice husks, Pellets and Briquettes	Natural draft gasifier (only pellets and briquettes): mixing of gas less efficient, more vulnerable for flame going out	3
	Forced air : better mixing of gas, less vulnerable for flame being blown out	4
Mineral coal	tbd	tbd
Kerosene, Paraffin	• Wick stoves • Pressure stoves	tbd
LPG, Biogas, Electricity	No information available for design features taking impact on emissions	5

Grading stoves for emission: Dung, leaf, twigs and firewood burning stoves

Key factors for the complete combustion of non-carbonised biomass fuel are

- heat in the combustion chamber (insulation),
- the surface area of the fuel to burn (shelf),
- the mixing of the woodgas and oxygen (height of combustion chamber, secondary air) and
- the use of a chimney to transport emissions out of the kitchen.

EnDev differentiates between five levels of stove designs (level 0 to 4) in respect to the likeliness of producing harmful emissions.

Grading stoves for emissions: Dung, leafs, twigs and firewood burning stoves: Level 0

#	Stove type	Design feature
0	3 stone fire, tripod, flat mud ring	a) (mostly) low combustion temperature as fire is exposed to cold wind and heat is lost to ambiance; pot often sits in the flames (cooling) b) Low time to combust fuel gas as pot is sitting in the flames c) Fuel rests on the ground being cooled and less access to oxygen








Grading stoves for emissions: Dung, leafs, twigs and firewood burning stoves: Level 1

#	Stove type	Design feature
1	Conventional ICS	a) Higher combustion temperature due to enclosed combustion chamber an sometime insulation b) Position of pot raised above the fire allowing more time for combustion c) Fuel still rests on the ground being cooled and less access to oxygen (No improvement over level 0)




Grading stoves for emissions: Dung, leafs, twigs and firewood burning stoves: Level 2

#	Stove type	Design feature
2	ICS with chimney	See level 2, but a chimney is taking most of the emissions outside kitchen
	Rocket stoves (RS) with conventional materials for insulation	a) Insulation of the combustion chamber is keeping fire hot b) High internal chimney (combustion chamber) is promoting the mixing of combustion gases with hot oxygen; c) Fuel is resting on shelf (or hanging in air) promoting higher fuel temperature and more mixing for combustion gas with oxygen

Level two includes (a) normal ICS with a chimney and (b) Rocket stoves built with conventional (high mass) materials for insulation.

Grading stoves for emissions: Dung, leafs, twigs and firewood burning stoves: Level 3

#	Stove type	Design feature
3	RS with high insulation	As above, but temperatures are higher due to application of very effective insulation materials
	RS with chimney (not well sealed)	Chimney is taking some emissions out, but significant emissions still enter the kitchen


Level three considers (a) high mass rocket stoves with not well sealed chimneys and (b) Rocket stoves with high quality insulation (low mass) without chimney.

Grading stoves for emissions: Dung, leafs, twigs and firewood burning stoves: Level 4

#	Stove type	Design feature
4	RS with chimney (well sealed)	Chimney is taking out most of the emissions
	RS - gasifier	See level 3, but staged combustion with secondary air
	Batch feed gasifier	Staged combustion: hot secondary combustion of gasses


Level 4 is the highest level assigned to non-carbonised biomass burning stoves. This level is selected for (a) rocket stoves with conventional high mass material and well-sealed chimney, (b) Rocket stove gasifier with secondary air system and (c) gasifier stoves if used with small pieces of wood.

Grading charcoal burning stoves for emissions

#	Stove type	Design feature
0	Traditional charcoal stoves	a) Low combustion temperature due to single wall, no/poor insulation, a lot of cold excess primary air because of too many openings; b) Temperatures mostly too low to burn off the CO (< 600 °C) c) Pot sits mostly on the charcoal (no space for burning of CO, pot cools charcoal/combustion gasses)
1	old generation ICS	a) Access of primary air is more controlled than above; b) Temperatures a little bit higher, but rarely reaching 600 °C c) Pot sits mostly on the charcoal (no space for burning of CO, pot cools charcoal/combustion gasses)
2	Conventional ICS	a) Insulation of the combustion chamber is keeping fire hot and protecting against too much cold excess air b) Temperatures sometimes above 600°C, but not for most of the time; c) Pot rests keep pot above charcoal
3	Advanced insulation charcoal stoves	Advanced insulation materials applied to keep temp above 600°C most of the time
4	Advanced secondary air charcoal stoves	Air insulated stove, but pre heated secondary air is mixed with combustion gasses below the pot to burn off CO

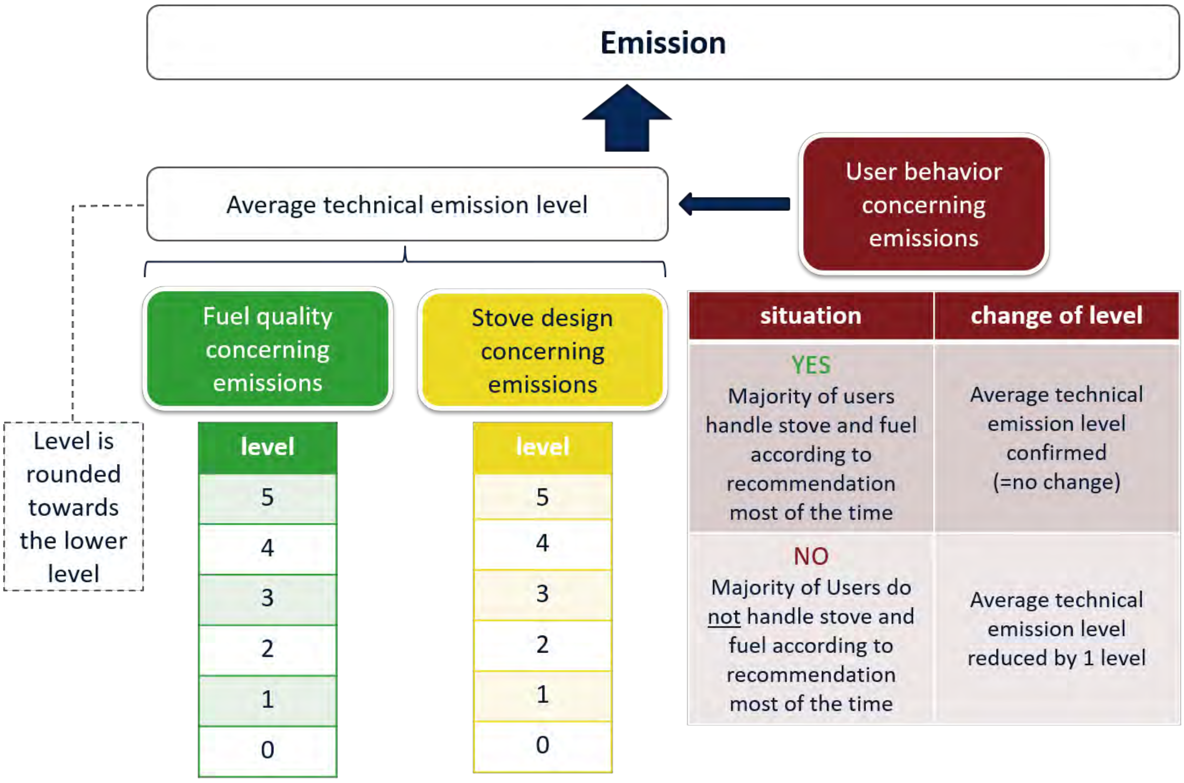
How to grade “user behaviour” as factor for emissions

There are many ways for the user to cause higher emissions when utilising the stove. However, EnDev needs to focus on the major factors and calculate the average user behaviour of an intervention zone.

“Does the majority of the users apply the below mentioned recommendations for the handling of the stove and fuel-system in the respective area most of the time?” (Yes/No)

Stove- and fuel type	Assumptions on handling-related factors that could reduce emissions when using this stove and fuel
Firewood, Dung, Twigs, Leafs	• Not overloading combustion chamber with fuel • Removing ash from combustion chamber to allow for air • Cleaning chimney according to recommendation
Charcoal	• Lighting stove outside the kitchen
Pellets	• Avoid filling broken pellets and dust in the combustion chamber

How to calculate the overall emission level?



The average of fuel quality and stove design is rounded down towards the lower level. If most of the time the majority of the users in the intervention zone are handling the fuel and the stove according to recommendations, this level is confirmed. In case of common mistakes in user behaviour, the average technical emission level is reduced by one level.

F.2.2 Dilution and extraction

The emissions of a stove-fuel system enter a kitchen (unless taken out by a chimney). They mix with the ambient air and (partially) leave the kitchen depending on the air exchange rate. To approximate the kitchen concentration, we estimate the "dilution of emission in the kitchen" and the "extraction of emissions from the kitchen".

Dilution of emissions in the kitchen

Level	Volume [m³]
5	Open air
4	>40
3	>20
2	>10
1	>5
0	<=5

30m³ = Level 3

Emissions of a stove mix with the ambient air in the kitchen. The larger the kitchen, the lower the concentration of the emissions in the kitchen. In many calculation models, the „standard kitchen volume" is set at 30m³. However, out in the field, the volumes differ a lot from very small kitchens to open air cooking.

For the purpose of this assessment, the 30m³ kitchen is set in the middle of the kitchen volume calibration. The volume doubles each level.

How to assess the volume of a rectangular kitchen

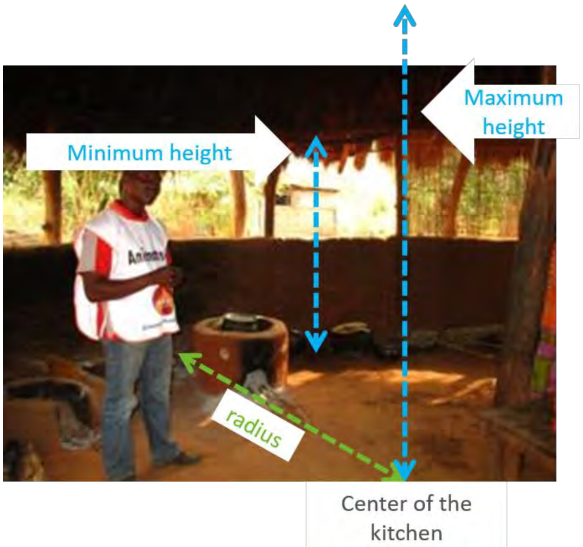
- Average height: there is often an inclination of the roof. Measure the highest and the lowest kitchen height and use the **average**.
- Measure the width and the depth of the kitchen floor.

Examples:

Level	Bench-mark [m³]	Volume [m³]	Width [m]	Depth [m]	Average height [m]
Formular: Volume = Width*Depth*Height					
5	Open air				
4	>40	50	5	5	2
3	>20	30	5	3	2
2	>10	15	3	2,5	2
1	>5	7,5	2,5	1,5	2
0	<=5	3	1,0	1,5	2

How to assess the volume of a round kitchen

- Average height: there is often an inclination of the roof. Measure the highest and the lowest kitchen height and use the **average**.
- Measure the radius of the floor (= diameter/2).



Examples:

Level	Bench-mark [m³]	Volume [m³]	Radius [m]	Average height [m³]
Formular: Volume = π * r² * h; π=3,14				
5	Open air			
4	> 40	51	2,85	2
3	> 20	30,4	2,2	2
2	> 10	15,1	1,55	2
1	> 5	7,6	1,1	2
0	<= 5	3,1	0,7	2

Air exchange in the kitchen

Air exchange is based on the permeability of the kitchen structure for air:

- To the top (= roof)
- To the side (= walls)
- And in some countries even to the bottom (=floor); however, not considered in this assessment.

This permeability can be limited by:

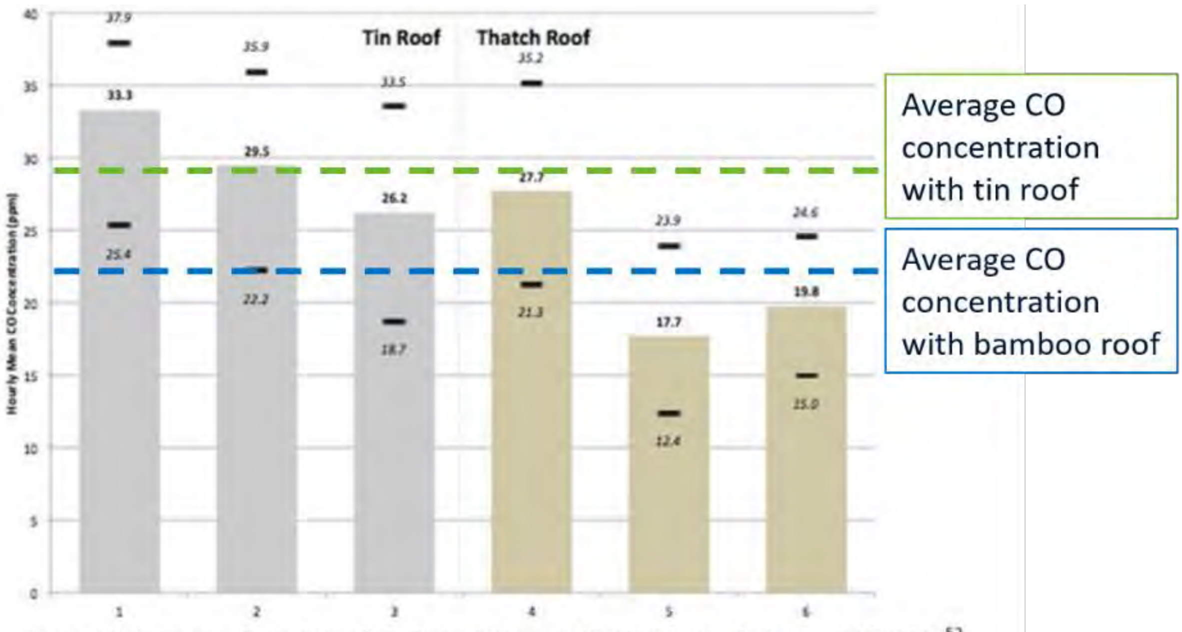
- The availability of a structure (level of confinement)
- The material of the structure (permeability for air)
- The availability and location of air outlets

Hoods are an active smoke remover for the room and part of this assessment. Chimneys however, are part of the stove and have already been mentioned in the emission section.

The availability of a structure and air outlets are natural aspects of this assessment. Research has shown that different types of construction materials also influence the amount of emissions that exit the kitchen structure.

Whelan/Peterson/Ruth have shown in a presentation at the ETHOS conference in January 2013, that a kitchen with a thatched roof had a lower concentration of CO than the same scenario with a tin roof.

Impact of roofing material on air quality using a 3-stone fire



Source: Whelan/Peterson/Ruth: Kitchen 2.-0 – Design Guidance for Healthier Cooking Environments (ETHOS 2013)[52]

For assessing the permeability of the kitchen structure, EnDev developed a point system.
EnDev evaluates the roof, the walls and the ventilation structure separately.
The number of points accumulated in the three categories define the overall level for air exchange.

Aspect	Points
Roof	0-3
Walls	0-5
Ventilation structure	0-5
total	**0-13**

Level	Points
5	11-13
4	8-10
3	6-7
2	4-5
1	2-3
0	0-1

Assessment of the roof

Points	Roof structure	Roofing materials
3		Open air
2	Fully enclosed	Permeable (see through at some places)
1	Fully enclosed	Permeable (bamboo, grass…)
0	Fully enclosed	Solid roof (iron sheet, tiles, concrete etc.)

0 = Solid roof

1 = permeable

Foto: Fresh Air Uganda

2 = permeable, but „see through“

3 = open air cooking

For the assessment of the roof, EnDev distinguishes between **open air cooking** and **cooking under a roof**. However, the permeability of the roof depends on the roofing material.

- Solid roofs made from iron sheet, tiles, concrete etc. block the air exchange largely.
- Thatched roofs out of bamboo, grass and other materials allow at least some level of air exchange even if they are rather compact.
- If you can see the sky through the roof at least at some places, there is even more air exchange possible.
- The best air exchange occurs when there is no roof at all.

When assessing the walls, EnDev combines different levels of presence of the structure, and different levels of permeability of materials.

- The lowest level is a kitchen with solid walls all around, made from bricks, concrete, mud etc.
- If the same fully enclosed kitchen is built from permeable materials such as bamboo, grass, wooden sticks/planks or other, it is considered it one level better.
- If you can see in the same fully enclosed kitchen at least in some places the outside through the kitchen walls, the air exchange is improved.
- A semi-enclosed kitchen lacks at least one wall in the kitchen structure. Here, the building material does no longer play a role, as the ventilation is much better than in the previous cases.
- Partial kitchens have maximum one wall going to the roof (though other walls can still be there as long as they are below head height of the cook). Here the cross ventilation is stronger, providing better air exchange.
- The best ventilated cooking place is the open-air kitchen.

Assessment of the walls

Points	Wall structure	Wall materials
5		Open air
4	Partial (maximal 1 wall to the roof)	Any material
3	Semi-closed (at least 1 wall is missing)	Any material
2	Fully enclosed	Permeable (see through at some places)
1	Fully enclosed	Permeable (bamboo, grass, wooden planks…)
O	Fully enclosed	Solid walls (concrete, bricks, Mud)

Examples for assessment of the walls

0 = fully enclosed, Solid walls

1 = fully enclosed, permable walls

2 = fully enclosed, see through in some paces

3 = semi enclosed, at least 1 wall missing

4 = partial, max 1 wall to the roof

5 = open air cooking

Openings in the wall can facilitate the exchange of air to the outside of the kitchen, hence reducing the kitchen concentration of emissions. There are different factors influencing the extent to which these openings effectively influence the kitchen concentration.

- Size of the opening (larger openings allow more air per time to pass). As a pragmatic indicator the size of a head of an adult person has been chosen as a benchmark;
- Location of the opening – its height in the room: smoke (PM) first accumulates under the roof of the kitchen. The closer an opening is to the roof, the more effectively it will remove the smoke from the kitchen. However, field tests carried out in EnDev projects have shown that CO mainly accumulates on ground level. This leads to the assumption that openings closer to the ground are more effective to reduce the CO concentration in the kitchen. Therefore, the ranking of the ventilation structures has to be differentiated by the type of emissions. Hence,

the assessment of the ventilation structure is different for mainly PM emitting stove/fuel systems (e.g. firewood stoves) and mainly CO emitting stove/fuelsystems (e.g. charcoal stoves).

There is one factor not yet considered in this assessment, though it might be included in a later edition of this methodology:

- Orientation of the openings: If windows or ventilation slots are in the opposite wall of the door (and the door is open during cooking), the ventilation effect is much higher than if they are on the same side as the door.

If ventilation structures are closable, like doors and windows, the user behaviour needs to be considered in the assessment. A closed door or window does not provide any air exchange. If households do not open a window when cooking, the window is just a part of the wall and does not provide ventilation effects.

Please observe if there are obstructions that inhibit the opening of windows. Observe the soot at the walls (if available) to see if there is evidence that smoke has passed the window frame.

Assessment of ventilation structure

Points	Ventilation structures	
	For mainly PM emmitting stove/fuel systems (e.g. firewood stoves)	For mainly CO emitting stove/fuel systems (e.g. charcoal stoves)
5	Open air	
4	Significant openings in the roof or at the highest point of the room Or: a hood is used to extract the smoke	Significant openings below the height of the door
3	Significant openings above the height of the door	Small openings below the height of the door
2	Significant openings below the height of the door	Significant openings above the height of the door
1	Small openings below the height of the door	Significant openings in the roof or at the highest point of the room Or: a hood is used to extract the smoke
O	No opening except for the door	

Significant openings = at least the full size of a head of an adult person

Example for assessment of ventilation structure

0 = no opening except door — *worst - best* — *5 = open air cooking*

Example for assessment of ventilation structure

small openings below height of door

significant openings below height of door

Example for assessment of ventilation structure

Overall ranking for Dilution and Extraction

Average level

Dilution (Kitchen volume) level	Air exchange level
5	5
4	4
3	3
2	2
1	1
0	0

If average is between levels, the level is rounded towards the level of the air exchange

The average level for dilution and air exchange is rounded down to the level of the air exchange, as this is the more dominant factor of the kitchen concentration. For better illustration, EnDev applied the concept on three examples:

Example 1

Dilution: 1
Air exchange: 0
Overall level: 0

Level	Volume [m³]	Width [m]	Depth [m]	Average height [m]
Formular: Volume = Width*Depth*Height				
<1	9,66	2,3	2	2,1

Dimensions	Points	Justification
roof	0	Roof is solid (tiles)
wall	0	Wall is solid
ventilation	0	Significant opening at highest point of the room
overall	0	

Dilution

Level	Volume [m³]
5	Open air
4	>40
3	>20
2	>10
1	>5
0	<=5

Air exchange

Level	Points
5	13-11
4	8-10
3	6-7
2	4-5
1	2-3
0	0-1

Example 2

Dilution: 3
Air exchange: 3
Overall level: 3

Level	Volume [m³]	Width [m]	Depth [m]	Average height [m]
Formular: Volume = Width*Depth*Height				
3	25	5	2	2,5

Dimensions	Points	Justification
roof	2	Roof is permeable, and you can see through it
wall	1	Permeable, but no „see through"
ventilation	4	Significant opening at highest point of the room
overall	7	

Dilution

Level	Volume [m³]
5	Open air
4	>40
3	>20
2	>10
1	>5
0	<=5

Air exchange

Level	Points
5	13-11
4	8-10
3	6-7
2	4-5
1	2-3
0	0-1

Example 3

Dilution: 3
Air exchange: 4
Overall level: 4

Level	Volume [m³]	Width [m]	Depth [m]	Average height [m]
Formular: Volume = Width*Depth*Height				
3	22,5	3	3	2,5

Dimensions	Points	Justification
roof	0	Roof is solid
wall	4	Partial enclosed, just 1 wall
ventilation	4	Significant opening at highest point of the room
overall	8	

Dilution

Level	Volume [m³]
5	Open air
4	>40
3	>20
2	>10
1	>5
0	<=5

Air exchange

Level	Points
5	13-11
4	8-10
3	6-7
2	4-5
1	2-3
0	0-1

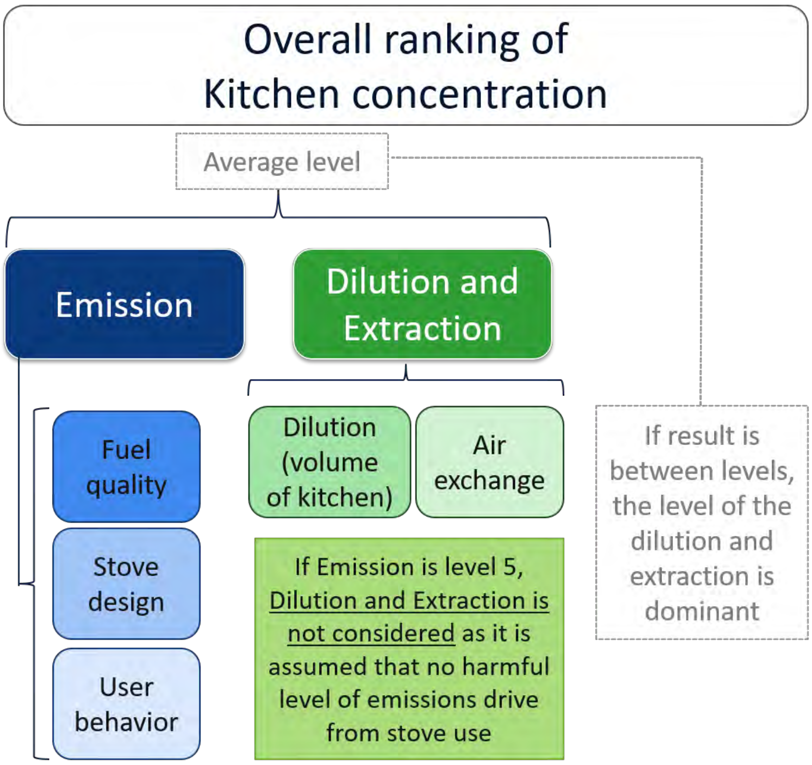
How to consider stacking of cooking places?

In some countries, households use different places for cooking during the year, which is considered stacking of cooking places. There is seasonal stacking between dry season (open air) and rainy season (under a shelter). Another form is daytime stacking, e.g. between breakfast (inside), lunch (outside) and dinner (again inside).

- If seasonal stacking and daytime stacking is observed, the assessment is done for the most used kitchen (= most frequently used/longest cooking time spent).
- If secondary system is used more than 30% of all cooking time a year, then the secondary kitchen has to be evaluated the same way as the primary kitchen.
- If the levels for the secondary kitchen are lower than those of the primary kitchen, the result of the primary kitchen is reduced by one level.

There is also a stove-related stacking of cooking places, as a “dirty stove” might only be used outside (3-stone fire), while the “clean stove” (charcoal stove, LPG, biogas) is used inside. However, in the EnDev context one specific stove for the CES assessment (e.g. intervention stove) is selected and the assessment is done in respect to the cooking places for this specific stove and its fuel.

F.2.3 Overall ranking of kitchen concentration

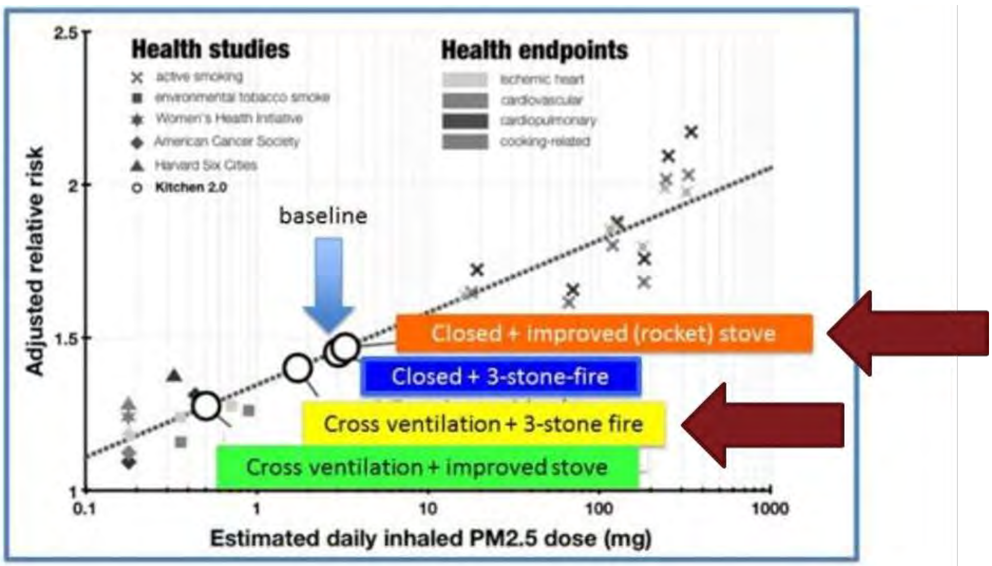


The average CES level of “Emission” and “Dilution and Extraction” is the measure for the kitchen concentration. “Dilution and Extraction” is the dominant factor, which means that the average is rounded down to that factor in case it is between two levels.

Why not using the “lower tier” approach?

Whelan/Ruth/Maggio et al. 2013 showed that ventilation might have a stronger impact on exposure than the emission from the stove.

Impact of ventilation combined with improved cookstove

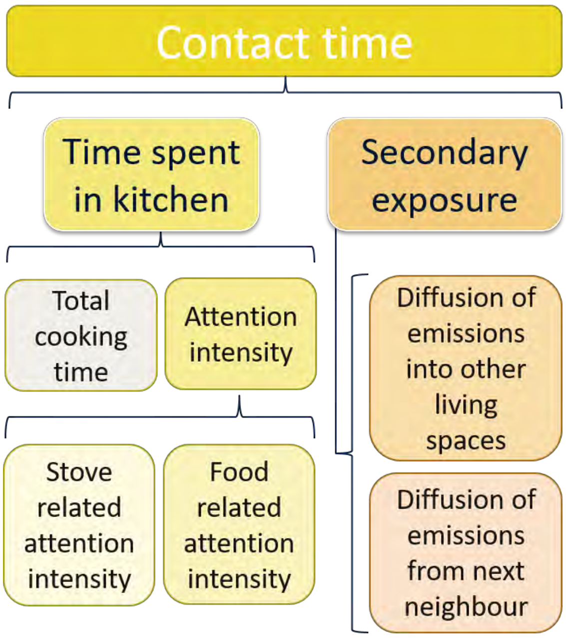


Adapted from Whelan, Ruth, Maggio e al: Kitchen 2.-0 – Design Guidance for Healthier Cooking Environments, International Journal for Service Learning in Engineering Special Edition, pp. 151–169, Fall 2013

If we use the „lowest tier“ approach with the levels of “Dilution & Extraction” and “Emission”, we cannot show that a 3-stone fire in a ventilated place might lead to less exposure than an improved stove in an enclosed kitchen.

Generating the average level of “Dilution & Extraction” and “Emission” as an estimation of kitchen concentration allows acknowledging situations with “higher emitting stove systems” in “better ventilated cooking environments”.

F.3 Contact time



Household members inhale emissions resulting from cooking both inside the kitchen and outside.

F.3.1 Time spent in the kitchen

The total cooking time is a proxy for the potential duration of exposure of the cook in the kitchen. The attention intensity expresses the special behaviour of the cook during the cooking process. The attention intensity of the cooking process limits the ability of the cook to walk away from the kitchen. Meals vary in their attention requirements as well as different stove types.

Total daily cooking time

At first glance, it seems to be evident. The longer the preparation of meals takes the more emissions a cook inhales. Thus, adding up all daily cooking time gives us a good approximation for this effect.

However, this is only true if cooks only use one stove at a time and food items are prepared one after the other all with the same stove.

From the stacking assessment, we know that many households are using different stoves either in alteration or in parallel during the cooking process.

We do not want to evaluate the effect of stacking (use of different stoves) but the overall daily time a cook stands in the kitchen

Main meals of the day	Intervention stove (wood)	LPG	Baseline (wood)	Total time of use on average day
Breakfast	0	15	0	15
Lunch	90	0	60	150
Dinner	60	0	0	60
Stacking	150 minutes = 66%	15 min. = 7%	60 minutes = 27%	225 minutes = 100%

- We need to assess cooking time as if there was no stacking, otherwise we just evaluate the stacking
- Total (daily) cooking time = sum of duration of cooking tasks (in this example 225 minutes)
- Parallel cooking is summed up as it increases the exposure

This 'total daily cooking time' simulates that all cooking would be done with the same stove – simplifying that all stoves have the same cooking times).

In this assessment, EnDev is not interested in stacking. EnDev wants an approximation of the exposure to emissions according to the duration of the cooking time. Therefore some simplifications are applied:

- All stoves of the stacking mix are treated as if they were intervention stoves;
- Parallel cooking on two flames increases the emissions in the kitchen. However, it is too complicated at this time to develop a methodology for parallel cooking. Instead, we add the individual cooking times for each stove together as if the cook is preparing everything on a single stove one after the other.

level	minutes	hours
5	< 90	<1,5
4	<180	<3,0
3	<270	<4,5
2	<360	<6,0
1	<450	<7,5
0	>=450	>=7,5

The total cooking time in this case is the sum of the duration of all cooking tasks and evaluated based on the table to the left.

This proxy-indicator generalises several factors in a very rough way. However, the alternatives are currently so detailed and complex that they do not seem feasible.

In a future edition of the CES EnDev will have to improve this section based on better knowledge.

Stove related attention intensity

The stove design influences the necessity of the cook to remain close to the stove.

This can be influenced by several factors:

- The fuel supply requires a continues manual feeding
- The performance requires frequent tending of the fire
- The stove is vulnerable to external impacts that can lead to a discontinuation of the combustion process.

Stove design as factor for attention time

Stoves by fuel type	Assumptions on stove & fuel-related factors that could enhance attention time of the cook in the kitchen	Level range
Continuous feed stove for wood, dung, twigs etc.	• energy content of fuel • Size of combustion chamber	0-3
Charcoal stoves	• Batch feed: low attention required • Time to time shaking off the ash from the coal	3
Natural draft gasifier	Natural draft gasifier: batch feed, once it is lid attention only required in case flame has been blown out	3
Gasifiers with forced air	Forced air : like natural draft gasifier, but less vulnerable for fire blown out	4
Mineral coal	tbd	tbd
Kerosene, Paraffin	tbd	tbd
Stove for gas and Electricity	No real attention requirement because of the stove system	5

Continuous feed stoves for un-carbonised biomass require a lot of manual fuel feeding. Unfortunately, the more fuel-use-efficient firewood is, the higher the attention intensity of the stoves tend to be.

Grading "continuous feed stoves" for contact time

#	Stove type	Desgin feature
3	3 stone fire, tripod, mud ring	if used with thicker pieces of wood (>5cm), attention interval > 10 minutes; Otherwise use level 2
2	Conventional ICS	medium size combustion chamber allows thicker wood or more sticks to be entered, attention interval < 10 minutes
	3 stone fire, tripod, mud ring	
1	Rocket stoves for firewood	small combustion chamber requires firewood feeding < 5 minutes
	All stoves using twigs, leafs or dung	Low energy content of fuel requires constant attention to maintain the fire
0	Natural draft gasifier for rice husks	Container for husks, but constant knocking on the stove required to keep the fuel dropping into the combustion chamber

The "walk away test" is a good approximation for this indicator:

- If a cook can walk away from the stove for more than 10 minutes without an interruption of the fire, EnDev considers it level 3.
- If a cook can walk away from the stove for 5 minutes or more without an interruption of the fire, EnDev considers it level 2.
- If a cook can walk away from the stove but only less than 5 minutes, EnDev considers it level 1.
- If a cook cannot walk away at all from the stove, EnDev considers it level 0.

However, if there is no opportunity for implementing the "walk away test", please use the description of the stove types instead.

Food related attention intensity

The meals prepared for day-to-day cooking vary in their requirement of attention by the cook. They also differ in their preparation time on the fire. To be able to categorise them in a simplified manner, the meals are structured in a cross table.

The matrix is designed to differentiate between various cooking tasks by their likeliness to force the cook to remain close to the stove:

- The longer the cooking task takes, the more likely the cook is exposed to emissions.
- The less a cook can walk away from the pot during cooking, the more she or he is exposed to emissions.
- The black numbers in the boxes represent the CES level attributed to this specific food attention intensity.

Food preparation time matrix (levels of attention intensity)

Attention Intensity				
	High (no walk away)	2	1	0
	Medium (< 5 min. walk away)	4	3	2
	Low (> 5 min. walk away)	5	4	3
		Short (< =30 minutes)	Medium (> 30 minutes)	Long > 60 minutes
		Preparation time		

Less contact time

Less contact time

Inspired by Ilse Ruiz-Mercado and Omar Masera, 2015, figure 8

This is a simplification as cooks prepare rather a menu than individual dishes, so over time we should further develop this proxy indicator for assessing different daily menus rather than dishes.

For the evaluation of the matrix, you follow the subsequent steps:

1. List all meals prepared during a normal week (from morning to evening, 7 days).
2. Enter all parts of the meals in this table. If there are repetitions, note the number of the events for each food in this week.
3. In each box, multiply the number of cooking events recorded with the level of intensity allocated to this box.
4. Sum up all the sub-totals and divide the result by the number of events. This leads to the average level of food related attention intensity.

Example: cooking task of one week prepared with a specific stove and fuel system

Attention Intensity						
High (no walk away)	2	2 X meat frying **4**	1	1 x tortilla **1**	0	1 x barbeque **0**
Medium (< 5 min. walk away)	4	3 x Egg frying **12**	3	3 x soup 7 X souce **30**	2	5 x bread baking **10**
Low (> 5 min. walk away)	5	7 x Tea **35**	4	5 X rice boiling 2 x potato boiling **28**	3	2 X beans **6**
	Short (< =30 minutes)		Medium (> 30 minutes)		Long > 60 minutes	
	Preparation time					

- Total number of events = 2+1+1+3+3+7+5+7+5+2+2 = 38 events
- Total points = 4+1+0+12+30+10+35+28+6 = 126 points
- Average points per cooking event: 3.3
- Round figure for level of food related attention intensity = here: level 3

F.3.2 Secondary exposure

Even when being outside the kitchen, household members may inhale emissions from cooking. Smoke extracted from their own kitchen dilutes the ambient air of other living spaces.

However, even if the actual household under investigation is cooking clean, a nearby neighbour might be extracting his smoke into the ambient air of the sampled household.

Diffusion of emissions into other living spaces

The amount of emissions that could pollute the ambient air of the household members is influenced by nature (structure) and location (distance from main living space) of the kitchen.

EnDev distinguishes between following cooking places:

- **Under the roof of the main living house:** if the household cooks under the roof of the main living house, emissions are likely to pass into the living space area, leading to exposure of all household members. Internal structures can reduce this effect.
- **In a separate kitchen house:** A separate enclosed kitchen may not be good for the cook. However, as the emissions stay in the kitchen to a large extent, it also means that the secondary exposure is less than in more ventilated kitchens.
- **Outside open air cooking:** While open air cooking reduces the exposure for the cook, the diluted emissions are transported to other living spaces.

level	Inside the main house	Open air kitchen or hangar	Enclosed kitchen
5	All cooking done on stoves with CES emission level 4 or 5		>= 5m from house
4	All cooking done on a well sealed chimney stove in seperated kitchen under the same roof	>= 5m from main house	< 5m from house
3	All cooking done on a well sealed chimney stove in main room	< 5m from main house but not infront of entrance	n.a.
2	All cooking done in a kitchen fully seperated from the main house	Directly in front of main entrance, but no roof	n.a.
1	All cooking done in a kitchen not fully seperated from the rest of the house	Directly in front of main entrance, and roof connected to the main house	n.a.
0	All cooking done in the central living room	n.a.	n.a.

In a later edition of the CES, EnDev will provide examples of these cooking places.

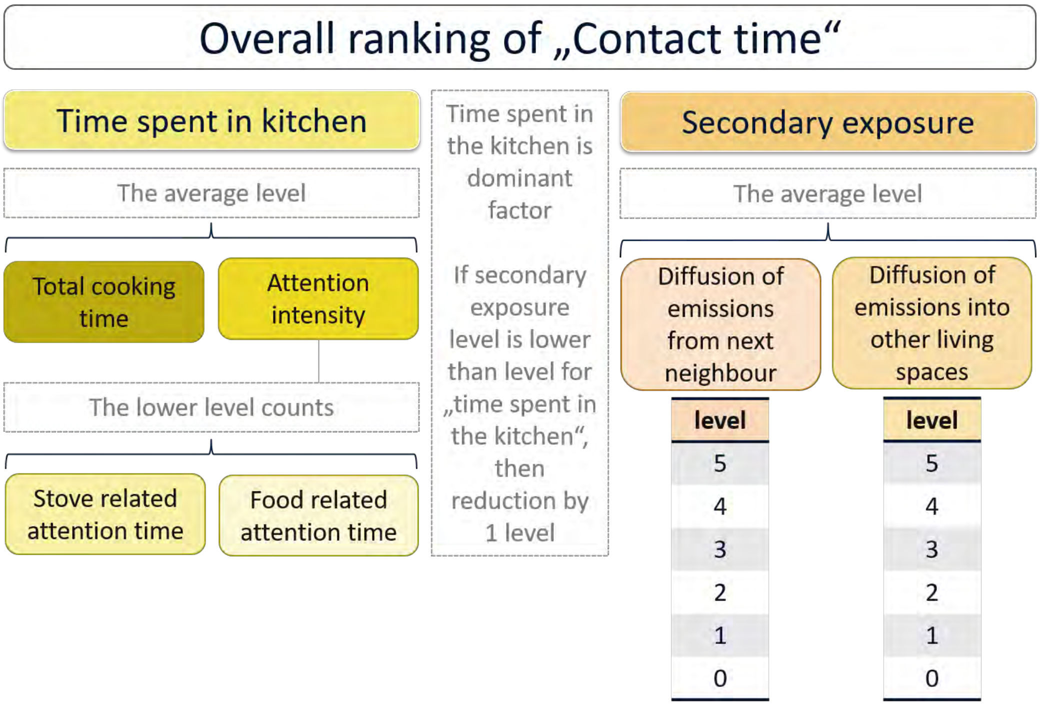
Secondary exposure from next neighbour cooking

The quality of the ambient air of a household is not entirely determined by the cooking situation of the household itself. Exposure to emission can also derive from cooking processes in the neighbourhood.

It is not feasible for EnDev to do ambient air quality measurements during this CES assessment process. Nor is it feasible to assess an entire community based on the CES methodology. Therefore, the smell of a fire is used as a rough proxy indicator for the PM concentration in the air.

	Survey household smells fire of their neighbour…	
Level	Category	Explanation
5	Rarely or never	Less than once a month
4	Sometimes, in a specific season	At least once a month, but not all year long
3	Often, in a specific season	At least once a week, but not all year long
2	Sometimes, all year long	At least once a month, all year long
1	Often, all year long	At least once a week, all year long
0	Always	Every day, all year long

F.3.3 Overall ranking of “contact time”



- The CES level for secondary exposure is determined by the rounded average level of the two proxy-indicators.
- Secondary exposure is far less important for the contact time compared to the time the cook spends in the kitchen. Therefore, the overall result for “contact time” is taken from the “time spent in kitchen”.
- If the “secondary exposure” is ranked at lower than the “time spent in the kitchen”, the level for the overall ranking of “contact time” is reduced by one level.

F.4 Safety of stove use

Accidents during cooking can result in illnesses and even deaths. This is not restricted to biomass-using stoves but applies to all stove-fuel systems. The Global Alliance for Clean Cookstoves developed a safety test for stoves burning solid biomass. For other stove-fuel systems, we still lack a methodology.

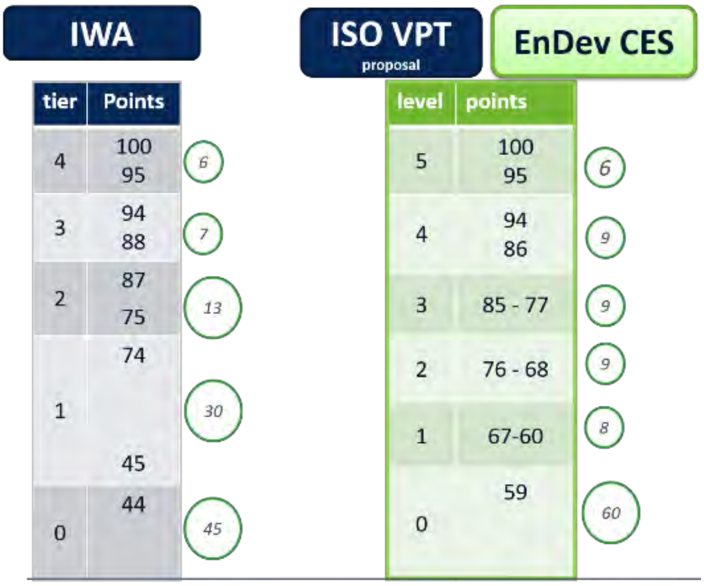
GACC safety test – not for all stoves yet

Stoves by fuel type	Overview on stove & fuel-related factors that could enhance safety problems	Level range
Solid biomass	GACC safety test, EnDev grading system	0-5
Mineral coal	tbd	tbd
Kerosene, Paraffin	Stoves with wick	0-1
	Stoves with pressurized tanks	tbd
LPG	• Quality and maintenance of LPG equipment • Users knowledge on correct application of LPG	0-5
biogas	Tbd.	5
Stove for Electricity	• Danger of electric chock • Hot surfaces	5 (unless observations)

Safety grading has so far not been done for all stove and fuel systems.

EnDev applies the GACC safety test for all promoted biomass cookstoves. However, the evaluation of the result differs from the tiers of the GACC system. In line with the ISO TC 285 Voluntary Performance Targets (to be published in the near future), EnDev distinguishes between six levels (level 0 to 5) with a more evenly distribution of the points regarding the levels 1-4.

Grading of safety test results



Safety also has a cultural dimension. Some technologies may appear safe from a researcher's perspective, but households experience burns or cuts in their day-to-day life. However, the contrary may also be the case. EnDev will develop the methodology for the assessment of this dimension in the near future.

There are also a number of biomass cookstoves from other sources in the field, which no one ever tested for safety. For this purpose, EnDev developed a "virtual safety test" as a proxy indicator (see below). It shall not replace the official safety test, but act as an onsite help for the enumerators.

The basis is the concept of the GACC safety test and its dimensions:

1. Sharp edges and points
2. Cookstove tipping

3. Containment of fuel
4. Obstructions near cooking surface
5. Surface temperature
6. Heat transfer to the environment
7. Handle Temperature
8. Chimney shielding
9. Flames surrounding cookpot
10. Flames exiting fuel chamber, canister, or pipes

As in the GACC safety test, all 10 dimensions are assessed (ranking 1-4), processed with the respective weighting factor and become part of the overall sum of the total safety score. The only difference is the methodology used to determine the ranking 1-4.

If no safety test available: the virtual safety test

#	Safety feature	ranking				Weight	Score
		1	2	3	4	factor	Total
1	Sharp edges and points					1,5	
2	Cookstove tipping					3	
3	Containement of fuel					2,5	
4	Obstructions near cooking surface					2	
5	Surface temperature A: child height (< 90 cm) B: above child height (> 90 cm)					2	
6	Heat transfer to the environment A: Floor B: Wall					2,5	
7	Handle temperature					2	
8	Chimney shielding					2,5	
9	Flames surrounding pot					3	
10	Flames exiting fuel chamber, canister, or pipes					4	

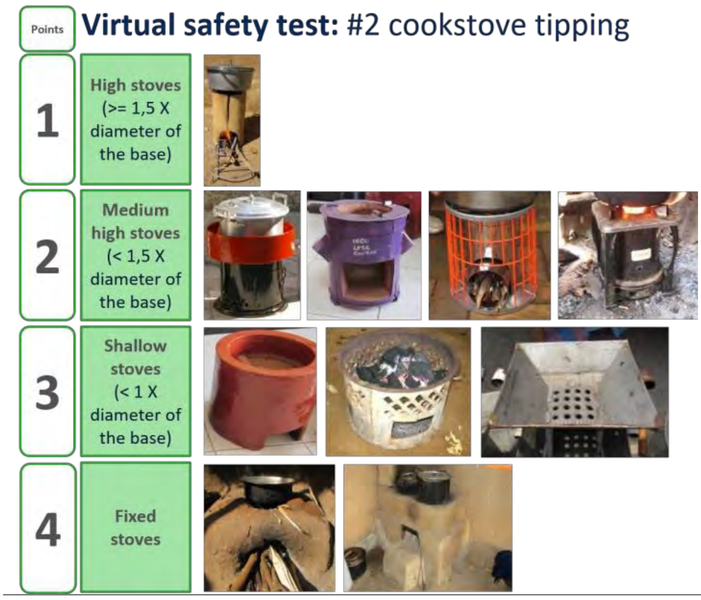
Select ranking and multiply

To be done for each of the features

The EnDev proxy indicator uses a visual inspection of the stove.

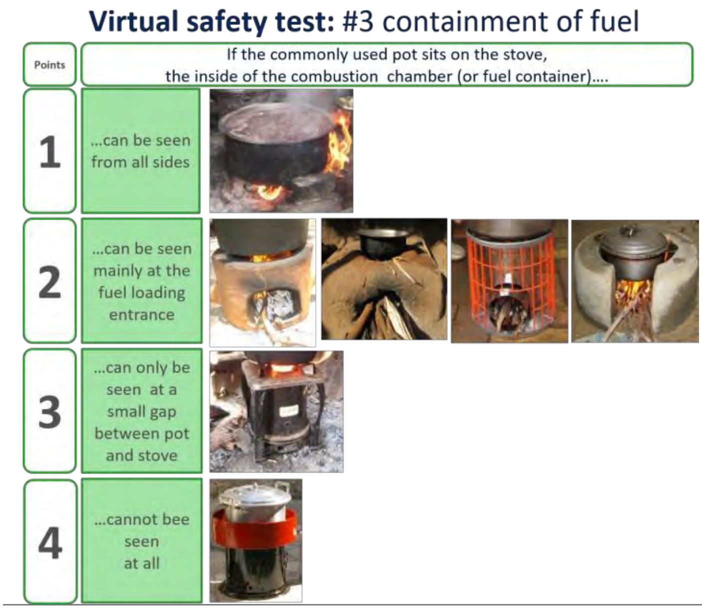
1. Rough artisanal stoves out of metal tend to have sharp edges and points.
2. More elaborated artisanal stoves tend to be smoother and a coat of paint may do the rest.
3. Quality control of industrial products may prevent the appearance of sharp edges.
4. Stoves out of mud, clay and brick normally do not have sharp edges and points.

However, if feasible the stove should be inspected physically to verify these assumptions.

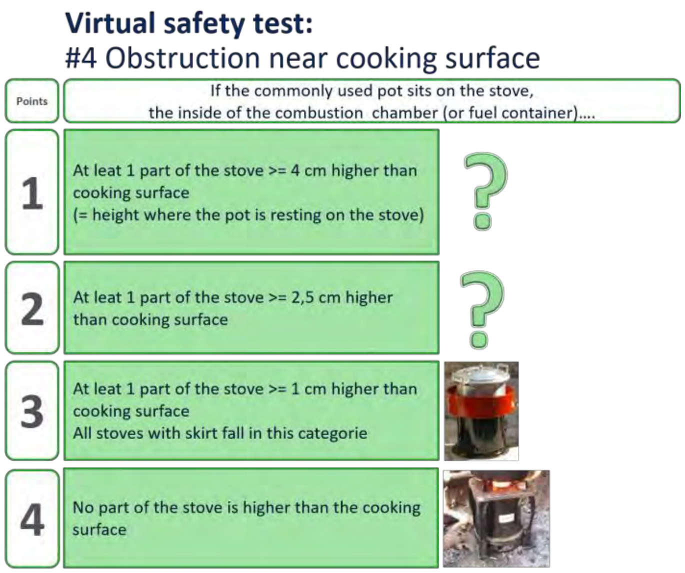


The height in relation to the diameter of the base is quite a good proxy for the tipping of the cookstove (provided the weight is evenly distributed).

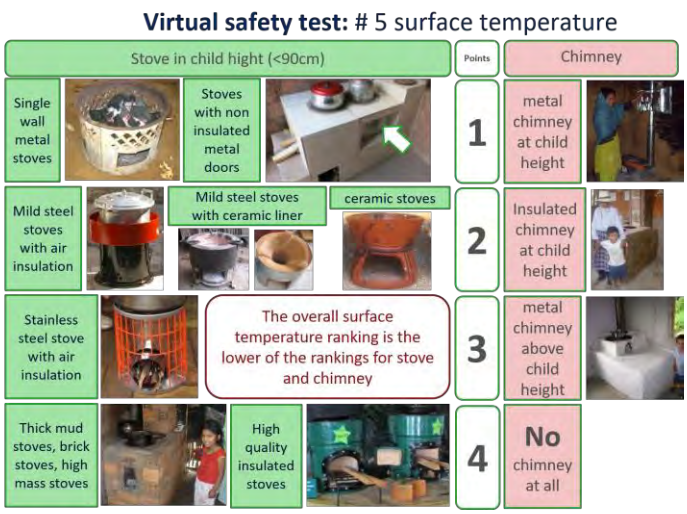
1. If the stove is significantly higher than wide, the likeliness to tip over is high.
2. Stoves that are slightly higher than wide are likely to tip over, but not that much.
3. Shallow stoves are wider than they are high. It would take a lot to make them tip.
4. Fixed stoves are by definition not able to tip over.



1. If the combustion chamber can be seen from all sides, it is a very unsafe stove.
2. If the inside of the combustion chamber can be seen mainly through the loading entrance of the fuel, there is a chance that fuel can exit here.
3. If the combustion chamber can only be seen through a small gap between the stove and the pot, it is still quite well-protected.
4. If the commonly used cooking pot is placed on the stove, the inside of the combustion chamber or fuel container should not be seen at all. This would ensure that (burning) fuel cannot exit the combustion chamber.



EnDev is not aware of any stove which does have any obstructions near the cooking surface other than a skirt.



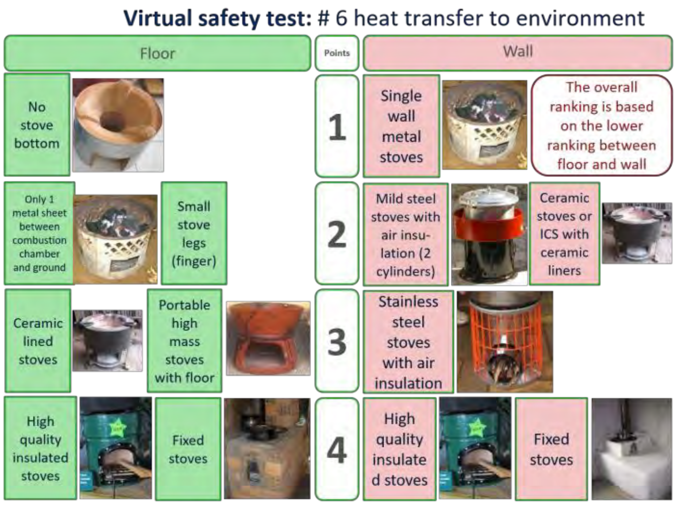
This is a double indicator for the stove (left) and the chimney (right). The lower rank of the two sides decides about the overall ranking.

Stove in child height:

1. Single metal sheets at the combustion chamber become extremely hot.
2. If the metal sheet is insulated with air or ceramic, or if it is a ceramic stove, the temperature tends to be lower.
3. Stainless steel reflects heat to the inside of the stove, reducing the outside temperature compared to the mild steel versions.
4. Thick, massive stoves or high quality insulated stoves will emit low temperatures.

Chimney in child height:

1. The worst situation is a metal chimney directly at child height.
2. If the chimney is at child height, at least an insulation should offer some protection
3. If the chimney is above child height (>90cm), it is less likely that they will burn their fingers.
4. The lowest risk to burn the fingers on a chimney is when there is no chimney.



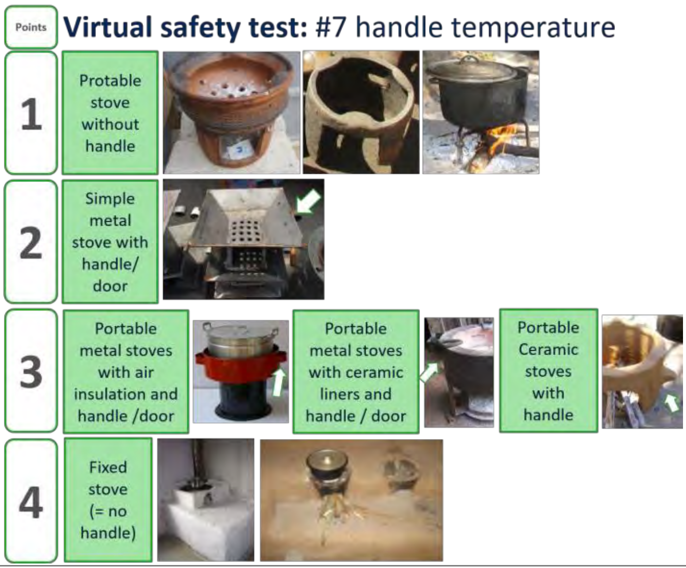
This is again a double proxy indicator, measuring the heat transfer to the floor and the wall of the stove.

Heat transfer to the floor:

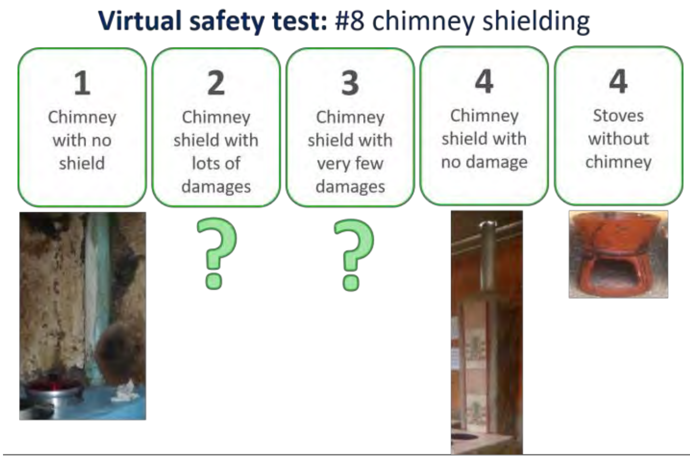
1. A stove without bottom is the worst case.
2. A stove with a single metal sheet to the ground is a little bit better.
3. A stove with a solid base of normal material transfers less heat.
4. A fixed stove or a high insulated stove is the best case for heat transfer to the ground

Heat transfer through the wall:

1. A single metal sheet transfers the most heat
2. An insulation with air or ceramic is a bit better
3. A stainless steel air insulated stove reflects more heat to the inside and is cooler at the outside
4. A high quality insulation of a massive fixed stove have the lowest heat transfer to the ambient air.



1. A portable stove without a handle makes the user touch the hot stove body. This is the worst case.
2. If the handle is attached to a stove with no insulation, it is extremely hot.
3. A handle on a stove with insulation will not be as hot, as the insulation will prevent the outer shell of the stove to heat up.
4. A fixed stove does not require a handle. Hence, there is no chance that a user can burn his hands on a handle.



A stove without a chimney or a fully shielded chimney (up to the roof) are the best protection.

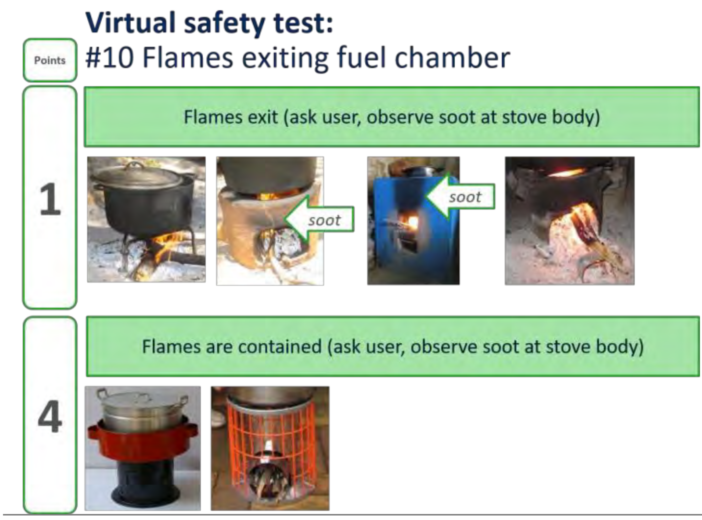
If the protection shows different grades of damages, the ranking is reduced. A chimney without shield is the lowest grade.

If flames surround the cooking pot, the risk of burns on the hand is high.

There are different options how to assess this aspect:

- Observing the soot on the cooking pots after cooking (before cleaning);
- Asking the cooks
- Assessing by stove type (least preferred option)

1. If flames or soot cover the full cooking pot including handles, the likeliness of burns is very high
2. If most of the pot is black but the soot does not reach the handles, there is still a chance to lift the pot without burns.
3. If the soot is only found at the bottom 4 cm of the cooking pot, a few flames are protruding from the combustion chamber.
4. If there is no soot at all on the cooking pot after cooking, no flames are protruding from the combustion chamber.



The last question concerns the possibility that flames could exit the fuel chamber through the fuel entrance.

There are only two options: yes or no.

The information can be obtained by the user and through observations.

In some countries, national government bodies released safety standards that are different to the IWA/GACC safety test.

- If the test is the same but the points are evaluated differently, please use the EnDev grading system for reporting in the CES.
- If it is a different type of safety test, please consult with EnDev headquarters .

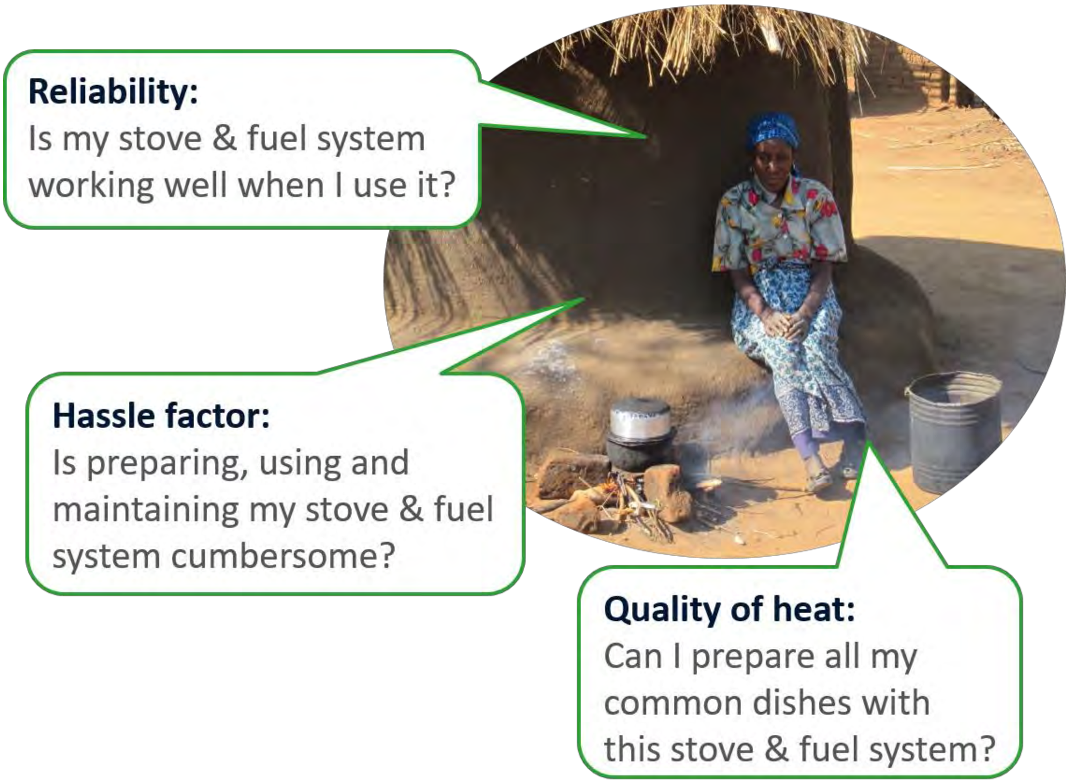
How safe is LPG?

LPG is commonly portrayed as the "clean and safe" fuel. First, it is necessary to differentiate "LPG" by the devices used to store and burn LPG. Some LPG stoves are used with small tin containers. These tin containers are not supposed to be refilled, but in real life refilling is a common practice (e.g. in Cambodia). There are frequent accidents with these refill containers. Hence, the safety of this system is considered level 0.

The large LPG bottles with solid containers tend to be of a much better safety and should be set at level 5 in general.

However, even for this type of LPG burning, sometimes accidents occur. Enumerators should ask during the survey about incidents on safety of LPG and note down the feedback. If there are reports about accidents in the intervention zone, the safety level of LPG in these bottles is reduced to level 3.

G. Convenience of stove use



Convenience is difficult to measure in "minutes" or "centimeter". Convenience is a perception of a user on a new device compared with the baseline device used so far. Convenience can comprise many different issues. However, for the purpose of the CES assessment EnDev selected the criteria: reliability, hassle factor and the quality of heat.

G.1 Reliability

Households like to know if the stove-fuel system works well when it is used.

Difficulties to ignite the stove/light the fire:

- The combustion chamber of some stoves is too small for a user to comfortably reach the fuel with a match in order to light the fire.
- Other stoves require a tricky pre-heating procedure that fails at times.

Difficulties to maintain the fire:

- Some stoves are vulnerable to external factors such as wind. If the flame can be extinguished at any time, it is an inconvenience as the cook needs to remain near the stove for re-ignition of the fire.

Frequent non-functioning of the system reduces the convenience of the system.

Reliability

criteria	factor	scores	
Reliability	Difficulties to ignite the stove / light the fire	2	Less than baseline (or no problem)
		1	Equal to baseline
		0	More than baseline
	Difficulties to maintain the fire (cook needs to observe fire all the time to prevent flames from going off)	2	Better than baseline (or no problem)
		1	Equal to baseline
		0	Worse than baseline

Reliability if applied for baseline stove

criteria	factor	scores	
Reliability	Difficulties to ignite the stove / light the fire	2	no problem
		1	At least some times a problem
		0	n.a.
	Difficulties to maintain the fire (cook needs to observe fire all the time to prevent flames from going off)	2	no problem
		1	At least some times a problem
		0	n.a.

The reliability of an intervention stove (or any other new stove) is compared to the most common baseline stove of the intervention zone.

- EnDev rates it 0 points if the new stove is less reliable than the baseline stove.
- EnDev rates it 1 point if the new stove is equally good as the baseline stove.
- EnDev rates it 2 points if the new stove is better than the baseline stove.

Note: if both stoves (baseline and intervention) have no problems, 2 points are rewarded.

In some cases, the baseline stove itself needs to be assessed. The upper table does not apply, as the baseline stove cannot be compared with itself. For this situation, the lower table was developed. If at least sometimes there are problems with the ignition of the fire or the maintenance of the fire, EnDev allocates 1 point to the baseline stove. If there are no problems, EnDev allocates 2 points each.

G.2 Hassle factors

Handling a stove includes activities before lighting the fire, during as well as after the cooking process.

Before cooking:

- Cooks need to prepare the fuel (like splitting, drying or cutting)
- The time needed for lighting the stove until it is ready to use for cooking.

During cooking:

- Time required to prepare the common dishes

After cooking:

- Cleaning soot from the cooking pot
- Maintenance of the stove

All these factors differ from one stove-fuel system to another.

Phase	criteria	scores	
Before cooking	Time/effort to prepare the fuel (e.g. splitting, drying, cutting…) compared to baseline stove	2	Less than baseline
		1	Equal to baseline
		0	More than baseline
	Time to light/ignite the stove compared to baseline stove (from ‘setting fire’ to ‘pot on’)	2	Faster than baseline
		1	Equally fast
		0	Slower than baseline
During cooking	Time/effort to prepare traditional meals compared to baseline stove	2	Less than baseline
		1	Equal to baseline
		0	More than baseline
After the end of cooking	Cleaning soot from cooking pot	2	‘No soot’ or ‘no cleaning practice’
		1	‘little soot’ or ‘rarely cleaning practice’
		0	‘a lot of soot’ or ‘daily cleaning practice’
	Time/effort to maintain the stove according to recommendation of the producer compared to baseline stove	2	Less than baseline (or no maintenance)
		1	Equal to baseline
		0	More than baseline

The users compare the intervention stove with the baseline stove.

For the assessment of the baseline stove, EnDev provides the following table.

Hassle factors if baseline stoves are assessed

Phase	criteria	scores	
Before cooking	Time/effort to prepare the fuel (e.g. splitting, drying, cutting…) compared to baseline stove	2	No need
		1	At least sometimes done
		0	n.a.
	Time to light/ignite the stove compared to baseline stove (from ‘setting fire’ to ‘pot on’)	2	n.a.
		1	For all baseline stoves
		0	n.a.
During cooking	Time/effort to prepare traditional meals compared to baseline stove	2	n.a.
		1	For all baseline stoves
		0	n.a.
After the end of cooking	Cleaning soot from cooking pot	2	‘No soot’ or ‘no cleaning practice’
		1	‘little soot’ or ‘rarely cleaning practice’
		0	‘a lot of soot’ or ‘daily cleaning practice’
	Time/effort to maintain the stove according to recommendation of the producer compared to baseline stove	2	no maintenance
		1	At least some maintenance done
		0	n.a.

G.3 Quality of heat

The purpose of a cookstove is to prepare meals as desired by the user. The ability of a cookstove to prepare a range of common meals is a crucial requirement of convenience.

However, there are specialised devices that are designed to prepare a very specific type of traditional meal, e.g. injera baking stoves or baking ovens. No one can blame them for not performing other tasks like roasting peanuts or frying meat. In these cases, the baseline stove should be used for the same purpose. This means a traditional injera stove must be compared with an improved injera stove, and a traditional baking oven with an improved baking oven.

Quality of heat

Phase	criteria	scores	
Quality of heat	Range of common meals that can be prepared with stove	2	More than baseline stove (or all common meals)
		1	Equal to baseline stove
		0	Less than baseline stove

Quality of heat if applied for baseline stoves

Phase	criteria	scores	
Quality of heat	Range of common meals that can be prepared with stove	2	all common meals
		1	At least some common meals **can not** be prepared
		0	n.a.

G.4 Overall ranking of convenience

level	Sum of scores
5	15-16
4	12-14
3	9-11
2	6-8
1	3-5
0	0-2

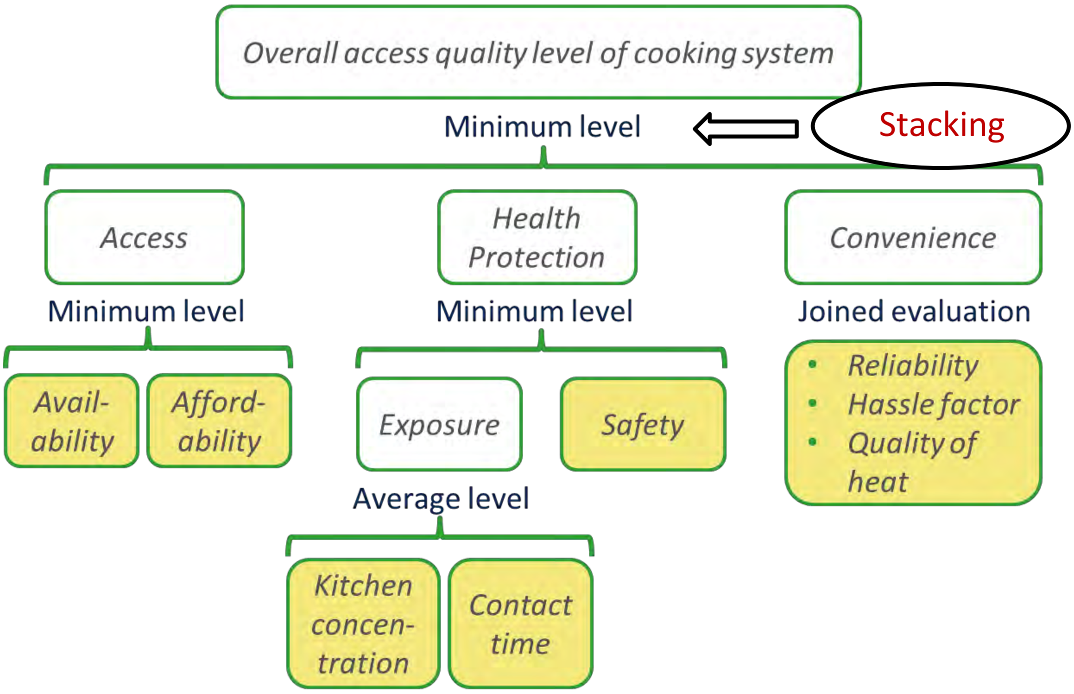
All eight criteria are evaluated separately.

The scores of the eight criteria are added up.

The sum is compared with the evaluation table on the left.

Summary and way forward

H. Overview of the Cooking Energy System



The CES assessment concept comprises three main dimensions and many influencing factors.

We can use this CES assessment concept for various purposes:

- **Baseline study before the start of an intervention:** It helps EnDev find out what the weak points in the current cooking situation are. EnDev can target its intervention concept better and improve the weak areas in order to reach a higher overall level. A chain is just as strong as its weakest link. Let us find out what it is.
- **Case study for the sampling in a scientific research:** Scientific studies on impacts can use this approach to stratify the households and select cases to be examined in more detail (e.g. for exposure and concentration measurements). This can help verify the proxy indicators of the CES over time.
- **EnDev reporting on impact levels:** In the previous two cases, the emphasis lies on the differences of the CES between households within a community or village. For EnDev reporting, we are looking at the similarities. The outcome monitoring of EnDev provides information on sales of each stove type per intervention zone. With the CES, EnDev will further be able to identify the average CES quality level achieved for households using a specific intervention stove per intervention zone. Thus, being able to determine with which quality of access the in these zones have been provided. This requires condensing the diverse CES results of several interviewed households, which use a specific intervention stove in an intervention zone into one CES level that is then applied for all owners of this intervention stove in this area. This is done partially by taking the averages, and partially by looking for the most common case. It will remain a gross generalisation across a diverse reality, but so far it is the best effort of capturing this diversity into one figure.

I. Data collection for CES

EnDev prepares app-based data collection tools for the CES. In order to prevent overloading the households with interview questions, there will be four different tools for different data requirements.

1. Regional data that can be collected by project staff (e.g. fuel prices)
2. Stove specific data that can be collected by project staff (e.g. safety test information)
3. A general household interview covering questions without measurement (e.g. ventilation situation)
4. An intensive household survey (one week with a small sample of households selected using the outcome of the general household survey) to assess the stacking (KPT-like process), the food related cooking intensity, the total cooking time, the daily fuel use etc.

By distributing the information requirements on several research tools, the general household survey is not as demanding.

An excel tool will be developed to process the data collected with the surveys through the EnDev Surveys tool.

Abbreviations

AL	Adult labour
CCT	Controlled Cooking Test
CES	Cooking Energy System
CO	Carbon monoxide
GACC	Global Alliance for Clean Cookstoves
ICS	Improves cookstove
IWA	Inbternational workshop agreement
KPT	Kitchen performance test
PM	Particulate matter

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Internationale Zusammenarbeit (GIZ) GmbH
Registered offices Bonn and Eschborn, Germany

Dag-Hammarskjöld-Weg 1-5
65760 Eschborn, Germany
E endev@giz.de
I www.endev.info