KITCHEN PERFORMANCE TEST
UPDATE TO INCLUDE SENSOR-BASED METHODS

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I. KPT CORE CONCEPTS

The core concepts of the KPT are as follow:

The KPT is an uncontrolled test, taking place in the kitchen of actual households from the project targeted area. These households are instructed not to change their habits in any ways and to keep cooking as they would usually do, using the same stoves and same fuels.

The KPT includes every fuel type used by the households. Even if the project assesses the impact of a firewood stove for instance, all the fuel used by the household should still be measured. For instance, in complex cooking energy systems with stove and fuel stacking, the introduction of an efficient firewood stove may very well induce a switch form charcoal to firewood and reduce the household charcoal consumption.

The KPT has wide boundaries and includes all thermal energy used by the household. Cooking for people and animals, space heating, bath water warming, boiling drinking water are all activities that are included. There are synergies between these different uses of thermal energy, and an intervention that makes cooking more efficient (ie: channel a higher proportion of fuel energy toward cooking) might also impact other aspect of the household energy system. By including all thermal energy consumption at the household level, we ensure that these potential ripple effects are also captured.

Because of the core principles of the KPT described above, this test is the best suited to assess an interventions real life impact in terms of fuel consumption. Its main strengths are:

- fuel consumption is measured directly, both with and without the intervention, without the need to makes assumptions on stove thermal efficiency, stove usage intensity or conservation of useful energy level for instance.
- KPT allow to seamlessly assess very complex energy systems.
- thanks to its uncontrolled nature, real cooks, stoves and fuels are used to carry out a large variety of cooking tasks. That ensures that fuel consumptions measured are representative of local cooking practices.

However, despite its significant strengths, the current '*analog'* version of the KPT protocol has also its limitations.

- **Very labor intensive**: fuel stock needs to be measured every 24h by an enumerator. Typically, a team of 2 enumerators will only be able to carry out the KPT in 5 to 6 households per week.

- **Intrusive**: the daily visits are quite intrusive, there is a risk that households modify their behavior (Hawthorne effect) because of them. For example, they may start to use the project stove more during the KPT than before or after it.

- **Requires enough fuel for the duration of the KPT**. In households with a large enough stock of fuel available, the KPT can be carried out smoothly. But in households buying their fuel every day just before cooking, KPTs become very difficult to implement. The cook must either wait for the enumerators to come back and weigh the fuel before being able to use it (which is a major complication for them) or they will just use it before it is weighed and therefore invalidate the KPT data for that household.

- Alternatively, a supply of fuel can be provided to the household, however this may distort their practices. Providing fuel to households for the KPT has been prohibited in the ISO field testing standard[1] but the KPT protocol v4.0 has not yet been updated to reflect this.

- **No ways to detect non-compliance**: the households are trusted to only use the fuel that was set apart and pre-weighed. If they do not comply (use other/unweighed fuel source or give away some of the fuel set aside for instance), the KPT will overestimate or underestimate their actual consumption.

Furthermore, because of the logistical difficulties and high training requirements and workload, the 'analog' KPT is very resource intensive (time, money, expertise) and is often implemented infrequently and with a small sample size.

i. Advances with a 'Digital' KPT

However, there has been significant development in stove use monitors and datalogging scales since the 2018 revision of the KPT protocol. These new tools have now been extensively tested[2],[3],[4],[5]. and address most of the 'analog' KPT limitations listed above.

- **Higher measurement frequency**: datalogging scales take a measurement every minute (instead of every 24h with analog KPT). That allow newly purchased/collected fuel to be measured right away and used shortly after.

- **Less labor intensive and intrusive**: the sensors are deployed at the beginning of the measurement period and collected at the end of it, there are no

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[1] ISO 19869 Clean cookstoves and clean cooking solutions — Field testing methods for cookstoves, paragraph 7.7.1

[2] Monitoring impacts of clean cookstoves and fuels with the Fuel Use Electronic Logger (FUEL): Results of pilot testing, 2019, Energy for Sustainable Development, Jennifer Ventrella, Nordica A. MacCarty

[3] Techno-Economic Comparison Of The Fuel Sensor And Kitchen Performance Test To Quantify Household Fuel Consumption With Multiple Cookstoves And Fuels, 2020, Development Engineering, Jennifer Ventrella, Olivier Lefebvre, Nordica A. MacCarty

[4] Use of an integrated suite of sensors to simultaneously monitor fuel consumption, air quality, and adoption provides important insights and validates impact metrics for household stoves, 2022, Development Engineering, Heather Miller, Janam Shrestha, Olivier Lefebvre, Nordica A. MacCarty

[5] Saving time and reducing smoke: A sensor-based performance assessment of a forced-draft "Jet-Flame" cooking system in Malawi, 2024, Energy for Sustainable Development, Nordica A. MacCarty, Grant Ross, Olivier Lefebvre, Alena Morris

needs for intermediary visits other than to check-in. That reduces considerably the labor intensiveness and intrusiveness of the KPT.

- **Detect non-compliance**: Usage/temperature sensors on the stoves allow to check that fuel consumption is associated with cooking. Non-compliance can be detected during data analysis and flagged data can be excluded from the measurements.

- **Detect Hawthorne effect**: Sensors measure the usage intensity of the project stove during KPT. That value can be compared to long term measurement carried outside of the KPT to detect Hawthorne effect and correct for it.

- **Auditable**: Measurement of fuel consumption can be easily be audited afterwards by investigating the logs of the fuel weight measurement.

Because sensor-based KPTs are less labor intensive and faster to implement than analog KPTs, they may be carried out more frequently and with larger samples. We will refer to sensor-based KPT as *digital* KPT in the rest of this document. It is important to note that both analog and digital versions of the KPT are fully aligned with the core concepts of the KPT.

II. KPT BOUNDARIES

All the fuel consumption for thermal energy should be accounted for at the household level (indoor or outdoor). That includes:

- Cooking for the member of the households or for guests.
- Heating the house during the coldest months of the year
- Warming water for bathing
- Boiling drinking water
- Preparation of food for animals
- Other energy usage to create heat

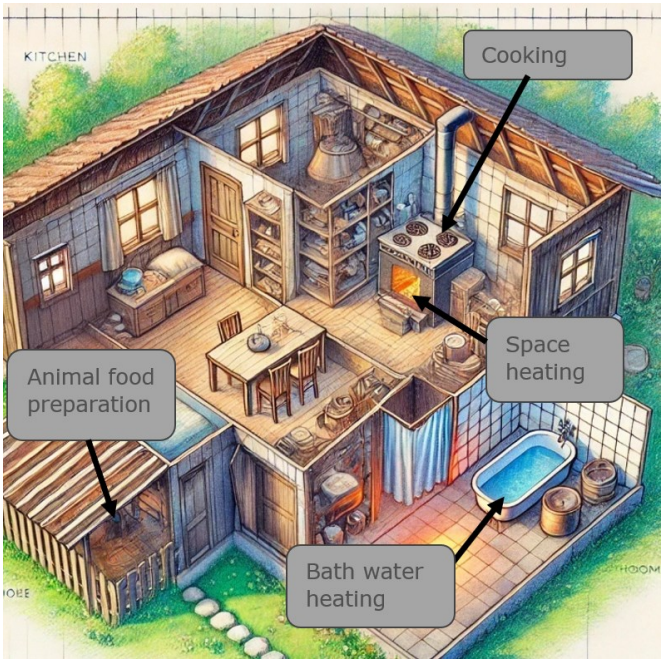

Figure 1: KPT bundaries (Credit : Dall-E 2024)

Electric appliances used for thermal energy for cooking or space heating should be included but other usage like electricity consumption for lighting, watching television, keeping food cold are outside of the boundaries of KPT.

III. HOUSEHOLD ELIGIBILITY CRITERIA

i. Screening for adherence to Baseline and Project Scenarios defined in the monitoring plan

Before inclusion of a household into the KPT study, a set of questions should be used to determine in which scenario the household should be categorized in. This is a key step and should be taken to properly characterize this. For instance, the project target domestic use of the stove, there should a set of questions designed to understand if there are any commercial cooking activities done on the stoves present in the households. A small street food business will have a large impact of fuel consumption but might not be immediately obvious. The eligibility questionnaire should be designed to probe these key aspects with more depth to ensure that there is no misclassification of household into the wrong scenario.

ii. Inclusion of days with no cooking

Once a household is selected, great effort should be taken to include this household in the study. For instance, if the household is traveling and not present then it should be kept in the study and its fuel consumption be noted as zero. Indeed, this consumption will be extrapolated to larger period and if households not present are systematically excluded then the fuel consumption of the group of interest will be overestimated.

It is important to keep in mind that the households are not always present and cooking every single day and every single meal. It is expected to see days where no cooking happens or where only one meal is cooked. Again, if these days were to be excluded, then the measured average would be biased and would overestimate the average fuel consumption.

iii. Inclusion of project households

Project households are households who own the cooking technology promoted by the project. Before the KPT is started in the household, there should be confirmation that the household still owns their project technology (Ownership Rate). If the technology has been given away, resold or discarded then the project household is not eligible.

This Ownership Rate is an important metric that must be established prior or right before the project KPT. Project KPT should be carried out only in households who still own their project technology. However, usage is not a factor in determining their eligibility and low usage, or no usage, is not a ground for excluding a household from the KPT.

IV. KPT PROCESS OVERVIEW

The overall process is slightly different if the KPT is based on an analog or digital method. We detail here both approaches separately.

- **Analog method**[6]

    1. Define a testing period of at least 3 consecutive days.
    2. Explain to family members the purpose of the test, and arrange to measure their fuel consumption at a roughly the same time each day. Stress to household members that their cooking practices should remain as close to normal as possible for the duration of the test. Record the weight and moisture content of the initial stock of solid fuels. If liquid and/or gaseous fuels are used, also record the initial stock of fuel and ask the family to keep newly acquired fuel separate from the fuel you have already measured.
    3. Ask the family to define an inventory area to store the fuel during the test. If the family is going to collect or purchase solid fuel during the days of the test, ask them to keep newly collected or purchased solid fuel separate from fuel that has already been tested for moisture and weighed. If necessary, provide containers to help the family keep newly gathered fuel separate from fuel that is already measured.
    4. Visit each household at roughly the same time each day, without being intrusive. With each daily visit, record the number of people that ate their meals in the household since your last visit. As this number can vary from one day to the next, try to avoid using an average value. Record the gender and age of each person. This information is used to calculate the number of *standard adults* served (see section V.ii below). Record fuel consumption by weighing the remaining wood. Record the weight and moisture content of newly collected fuel before it is added to the family's stock.
    5. At the end of the measurement period, thank the household for their cooperation, and provide them with the form of compensation considered appropriate by the project implementers (as discussed above).

- **Digital method**

    1. Define a testing period of at least 3 consecutive days.
    2. Explain to family members the purpose of the test. Stress to household members that their cooking practices should remain as close to normal as possible for the duration of the test.
    3. Record the moisture content of the initial stock of solid fuels.
    4. Record the number of meals prepared during the last 24h. For each of these meals, record the age/gender of each person presents. This information will be useful to calculate the number of *standard adults* (see section V.ii).
    5. Place the datalogging scales in the kitchen per the guidelines from section VI.ii below. One scale should be deployed for each fuel type

[6] This paragraph is largely adapted from the KPT v4.0 document (page 14 and 15) available here: https://cleancooking.org/binary-data/DOCUMENT/file/000/000/604-1.pdf

used in the household. Once the scales are in place with the empty fuel holder, start them so that they tare themselves. The fuel may now be added to the scales.

6. Deploy a Continuous Monitoring System (CMS also called Stove Use Monitor) sensor on the project stove and potentially all the other stoves (if using the optional non-compliance detection method described in section VII.ii.b)
7. Explain to the household what practices they should follow during the duration of the KPT (see section VI.i)
8. Come back to the household at the end of the KPT and download the data from the datalogging scales and CMS. After the download is complete, the fuel may be removed from the scales
9. Take a measurement of moisture content of each fuel type and record the gender and age of each person that ate each of the meal prepared the day before. This information is used to calculate the number of standard adults served (see section V.ii below).
10. Thank the household for their cooperation, and provide them with the form of compensation considered appropriate by the project implementers (as discussed above).

Guidelines for selecting days of the KPT

When deciding on the schedule for the KPT implementation, please consider during which days of the week the measurement will be done. There are likely days where the consumption is different (weekend, market day, etc…). In order to limit bias from these, please ensure these good practices are followed:

Option 1: carry out the KPT for 7 consecutive days in each household.

Option 2: carry out the KPT only during week days. Per the previous version of the KPT, this is assumed that fuel consumption is lower during week days and that would lead to a conservative fuel savings measurement.

Option 3: The KPT may be carried out during week day and/or weekend in households. The number of week day and weekend days sampled for the group should be representative of the week (5 week-days for 2 weekend-days). Deviation from the 5/2 ratio are acceptable if an analysis of fuel consumption shows that the result is conservative.

The same option must be chosen for both Baseline Field Test (Baseline KPT or BFT) and Project Field Test (Project KPT or PFT).

V. MEASUREMENT METHOD AND EQUIPMENT NEEDED FOR KPT

i. Moisture

The applicable moisture measurement method depends on the type of fuel. For some fuel types, using default moisture level is allowed.

Fuel type	Moisture meter	Kiln	Alcohol meter	Default Value
Firewood	X	X		
Agricultural residue		X		X
Charcoal		X		X
Pellets		X		X
Briquettes		X		X
Ethanol			X	

- **Moisture meter**[7] (with or without pin): these devices use conductivity or capacitance to determine the moisture present in the wood. Please choose 3 different pieces of wood that are representative of the whole bundle and take a measurement of 3 different locations for each piece. If the moisture meter has different calibration for different wood type (hard wood/soft wood for instance), make sure to use the right settings there. Moisture Content may be expressed in dry-basis or in wet-basis, that information must be documented. The calibration of the meter must also be checked before and after the measurement campaign (most meters offer a self-calibration check).

- **Kiln**[8]**:** please follow these steps to measure the moisture content:
  - collect a small sample of fuel (around 20g) in each household.
  - Place the sample in an airtight bag for transport.
  - Measure a quantity of 5g (+/- 1g) for each household and pooled them together.
  - Measure the mass of this pooled sample using a balance with resolution of 1g or better.
  - Place the sample in a temperature-controlled kiln set to 95C for at least 6h, and continue to dry and weigh every few hours until the mass of the sample stops dropping.
  - Measure the mass of the dried sample using a balance with a resolution of 1g or better.
  - Calculate the moisture content of the fuel using the following formula:

    $$MC_{wet-basis} = \frac{Mass_{wet} - Mass_{dry}}{Mass_{wet}}$$

[7] More details is available in: ISO 19869 Clean cookstoves and clean cooking solutions — Field testing methods for cookstoves paragraph 7.4.1

[8] More details is available in: ISO 19869 Clean cookstoves and clean cooking solutions — Field testing methods for cookstoves, paragraph 7.4.2

- **Default Value**: a default moisture content (wet-basis) of 10% may be used for the fuel where this method is allowed.
- **Alcohol meter**: if the ethanol is sourced from a controlled supply chain and its energy content is tightly controlled, then this method is not required. When ethanol is bought on the open market, from unknow sources, the concentration of alcohol should be measured (using a density-based alcohol meter for instance) and recorded so that NCV of the fuel can be calculated properly.

ii. Standard adult meal

The table below allows to normalize the number of people present at each meal and to express it as a standard portion. The "Standard adult"[9] equivalence factors is defined in terms of gender and age.

Gender and age	Fraction of standard adult
Child: 0-14 years	0.5
Female: over 14 years	0.8
Male: 15-59 years	1.0
Male: over 59 years	0.8

iii. Fuel mass

- Solid biomass fuel (firewood, charcoal, agricultural residue, dung, briquettes, pellet, coal, etc.)

    - Manual scales

    The weight of the fuel must be measured using a hanging scale with a resolution of at least 20g and a capacity greater than 20kg. The weight of the fuel holder must be subtracted from the total weight measured. The stock of fuel must be weighed in as few batches as possible to limit compounding the measurement error from the scale.

    - Data-logging scale

    The solid biomass fuel must be placed in an appropriate fuel holder below a hanging scale. Each fuel type must be placed in a different scale. The datalogging scale used must have a resolution of 1g or lower and a

[9] From Guidelines for Woodfuel Surveys, for F.A.O. by Keith Openshaw cited in (Joseph, 1990)

capacity greater than 20kg. The scales must be set to record a measurement every 1 minutes or more frequently.

- Biogas or piped LNG

For these fuels, the recommended method is to use a gas meter designed for the specific gas being measured. The meters must be calibrated at least once per year using a method approved by national or ISO standard.

- Ethanol/Kerosene/LPG

Liquid fuels mass may be measured separately or along with the stove when it is more practical. When measuring the fuel along with the stove, make sure the initial and subsequent measurement are done with same part of the stove. For example, some stoves have detachable pot rests, the measurements should be done consistently with the pot rest for all of them or without the pot rest for all of them.

Given the high energy density of these fuels and high efficiency of the stoves using them, it is expected to see smaller mass reduction for these fuels. For these reasons, a manual scale with a resolution of 20g or better must be used and measurement may only be done only on the first and last day of KPT for each household[10].

- Electricity

Electricity meter must be placed on each cooking electric appliance included in the KPT boundary. The total energy consumption (expressed in kWh) must be recorded every 24h for analog KPT or at the end of the measurement period for digital KPTs.

A note about scale calibration

All the scales (whether manual or data-logging) must be calibrated before and after the KPT measurement campaign using reference weight (accurate to 0.05% of nominal weight[11])

Before the KPT, the scale must be calibrated to within 1% of the reference weight. At the end of the campaign, if the deviation from reference weight is less than 5%, the data may be used as is. If the deviation is greater than 5%, then the data must be corrected to address the drift in the scale sensitivity. One acceptable method to correct for drift would be to assume it occurred linearly with time during the KPT.

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[10] Daily measurement for these fuel types may be below the limit of detection of the scales, that is why doing only a measurement at the beginning and at the end is permitted rather than the 24h period (analog KPT) or 1 minute period (digital KPT) typically required.

[11] Class M3 or better per the IOLM recommendation R 111 classification

VI. HOUSEHOLD AND FIELD TEAM TRAINING

i. Household Training

Explaining clearly to the cooks the expected practices during the KPT is important so that good data is collected.

For a **digital KPT**, the 5 main recommendations are as follow:

1. **Only use fuel from the holder in your own household**. The fuel taken from the holder should only be used for the household energy needs (for instance, the fuel from the holder should not be resold or given to another household).

2. **Ensure all fuel used in your household was first placed in the holder.** Household energy needs should be met only with fuel from the holder (for instance, do not take fuel from outside the holder to cook).

3. **Wait until holder is empty or nearly empty to refill**. Rather than refilling often, it is better to wait until the fuel holder is empty to refill it with fuel.

4. **Wait at least 5 minutes after refilling before using the fuel.** After refilling the fuel holder, the household should wait for at least 5 minutes before taking some fuel away from it.

5. **Do not replace leftover fuel at the end of a cooking event** back into the holder. Keep it instead by the stove so that this fuel maybe reused for the next cooking event.

These explanations should be provided to all the cooks who typically prepare meals in the household. If some of them are absent, please request the cooks that heard the explanations share them with the other people doing some cooking in the household.

After the enumerator explained the expected behavior during KPT, they should ask the cook to re-explain with their own words to make sure they understood the KPT guidelines. It is important to spend enough time to ensure that these guidelines are clear and well understood by the cooks.

For an **analog KPT**, the main recommendations are as follow:

1. Only use the fuel that was set aside by the enumerator when cooking (do not cook with fuel that is not coming from the stack that was set aside and weighted by the enumerator)
2. Only use the fuel that was set aside by the enumerator for the household's thermal energy needs (do not use this fuel other purposes like giving it away or selling it for instance).
3. If you buy more fuel, do not use it quite yet. Please set it aside and wait for the enumerator to come back. Once the enumerator has weighed it, then the fuel may be used.

ii. Field Team training

a. Good practice for deployment of data-logging scales

- **Location:** The location where the datalogging scales are deployed is important. To minimize risks of non-compliance, the scales should be deployed in a location that is convenient for the cook. Ideally, it should be **close to the stove** and **not in the way of household members**. To ensure that accurate measurements are done, the scale and fuel holder should be hanging freely and not touch any walls or objects.

When hanging the scales from the ceiling, care should be taken to choose a **beam that is strong enough** to carry the weight of the fuel that will be placed in the holder.

To prevent risks of damaging the scales, they should not be deployed outside without a roof above to **protect them from the rain.**

Compressive scales (used to measure LPG canisters) should be placed under the LPG canister at their usual location provided that the **ground is hard, flat and level**. If these conditions are not met, then a hard plank of wood or sheet of metal should be placed under the scale so that all four feet are touching the flat surface and the scale is level.

- **Fill the holder before leaving:** Before leaving the household, the fuel holder should be filled up by the enumerator so that it is easy for the cook to get started.
- **Local fuel holder:** Fuel holder should be adapted to the fuel that will be used. For firewood, an open design makes it easier to place and remove the fuel from the holder. For charcoal or pellets, a sturdy bag attached to one handle is the most convenient.
- **Secure holder to the scale:** The fuel holder should be securely attached to the scale so that it may not be removed from it for the duration of the KPT. A small padlock is a good way to ensure that the

cooks will take the fuel form the holder but not remove the holder itself.

b. Good practice for deployment of stove use monitors (CMS)

CMS general deployment guidelines

- Proper temperature range

The sensors should be deployed in such a way that the temperature measured by the sensor is high enough to be easily detected as a cooking event, but not so hot that the sensor (or its probe) lifespan is reduced by excessive heat.

To find the proper location, a pilot in a few households might be useful. We recommend to deploy several sensors on the same stove at different location. After a week or two of use, the temperature data is then analyzed to determine what is the most suitable location. Once the location is determined, it must remain fixed to ensure consistency.

- Out of the way of the cook

The CMS should be placed in a way that will not prevent or hinder the use of the stove. Whenever possible, the sensor should be placed on the back of the stove or inside of it.

- Do not restrict the mobility of the stove

For mobile stoves, the CMS must be placed on the stove itself so that the stove may be used indoor or outdoor without restriction.

- Outdoor use

The CMS deployed by the project must be waterproof so that it may withstand rain if the stove is left outdoor.

CMS attachment methods

- Drill and self-taping screw

A battery-powered portable electric drill and self-tapping screw may be used to secure the sensors to a wide array of stoves. For metallic stove, sheet metal screws are the most appropriate (M4 diameter, 30-40mm length). Drilling a smaller pilot hole first will help install the screw more easily.

For mud or earth stoves, a long wood screw may be used (M4 diameter, 100mm length).

- Rivets

For a more secure installation, pop rivet may be used instead of self-tapping screws. Handheld mechanical tools to install rivets are quite inexpensive and will work well to install smaller quantities of rivets.

For larger deployments, pneumatic tools might be more appropriate but would probably require an installation of the sensors on the stove before they are deployed in the households.

In both cases, a hole must be drilled in the stove before the installation of the rivet.

- High temperature adhesive (epoxy putty or silicon sealant)

For more expensive stoves where drilling is not a good option, high temperature epoxy putty or quick cure silicone sealant might be used.

Epoxy putty will make a stronger bond and is preferred for longer duration deployment. It might leave some residue after removal though and might be more difficult to find locally.

A local solution that is good enough for shorter term deployment is high-temperature one-component quick-cure RTV[12] silicone sealant.

In both cases, surface preparation is key to ensure that the adhesive will form a good bond. First clean the surface with an Iso Propyl Alcohol wipe or with local denatured alcohol. Regular dish washing soap may also be used but it important to rinse and dry well. Once the surface is clean of dirt and grease, the adhesive can be applied. The stove should not be hot during application.

[12] Room Temperature Vulcanization

- Stakes

For open fire that are monitored by InfraRed sensors, heavy duty tent stakes maybe used to anchor the sensor in the ground by the fire. The stake should be firmly hammered into the ground at a distance of 20-30 cm from the fire.

- Metallic wires or hose clamp

If drilling the stove is not an option or its surface is too hot or otherwise not appropriate for adhesive, then using metallic wire to secure it around the stove might be a good alternative. This solution will work for short term deployment but should not be considered a suitable method for permanent installation.

c. Good practices for fuel management during analog KPTs

For analog KPT, where the fuel is manually weighed every 24h, place the fuel in an inventory area designated by the household for convenience. The location must clean and dry and, if possible, close to the cooking area to limit undue burden on the cook.

If necessary, provide containers to help separate the fuel that is already measured from the other fuel present in the household. If the quantity of fuel available in the household is not enough for the duration of the KPT, designed a second area where they should store the newly purchased fuel while they wait for the enumerator to come back before using it.

To prevent risk of bias, no external fuel may be provided to the households for the KPT. All the fuel needed for the KPT must be procured by the household itself as it would normally.

VII. DATA PROCESSING GUIDELINES

These guidelines are not prescriptive per say but these good practices were developed over several large-scale deployment and provide good results. Deviation from the processing method described below should be thoroughly justified and the steps applied should be explained in details.

i. Datalogging scales

The data collected from logging scale can be processed using the 3 easy steps:

- **5 minutes running median pass** to remove short spikes. A short window running median pass will remove short spikes that may be recorded when fuel is loaded or unloaded from the scale.
- **Remove last 10 minutes** in case fuel was removed before downloading data. Recommended practice for the enumerators is to download the data first and then to remove the fuel from the holder. However, it may happen that the fuel was removed from the holder before the data was downloaded. To prevent overestimating fuel consumption in these cases, we recommend to systematically discard the last 10 minutes of data from the file before processing it.
- **Use a 20g threshold** to remove slow variation due to temperature sensitivity or creep. Fuel consumption is then calculated by looking at sudden drop in weight. There will be slow change in fuel weight from the load cell sensitivity to temperature or from the creep. We suggest to use a small weight change threshold of 20g for instance to filter out these slow changes and to only capture weight decrease due to removal of fuel from the holder.

ii. Stove Use Monitor

There has been a lot of work done on processing temperature trace to detect cooking events. We are not going to repeat it here but focus instead and how to use cooking event data in conjunction with data logging scale within the framework of digital KPT: SUMs placed on the stoves maybe used during KPT to detect Hawthorne effect and non-compliance.

a. Hawthorne effect

The KPT last for a short duration during which a large number of sensors are deployed in the household. In households who own a project stove, there is a risk that the cook increase usage of the project during this period because they feel observed (Hawthorne effect).

To measure this effect, we recommend to record project stove use during KPT and outside of it. Indeed, while it is easy to increase one's project stove for a few days during the KPT, regular pattern will prevail during longer duration monitoring of the project stove with SUMs only.

We then recommend to discount fuel savings derived from KPT based on the measure Hawthorne effect. For instance, if the project stove was 2 times per day during KPT in average but only 1.5 times per days during long term monitoring, then the fuel savings should be discounted by (2-1.5)/2=25%.

b. Non-compliance detection

Analog KPT relies on self-reported declaration of non-compliance from the cooks. With a digital KPT, in addition to the self-reported method, we can also use sensor data to detect instance where stove usage and fuel consumption are not matching.

- **Map fuel/stove**: The first step is to map stove to the fuel they are using. There might be multiple stoves using the same fuel type and potentially stove that can accommodate multiple fuel types.
- **Identify fuel use events**: associate each fuel use event to its corresponding timestamps
- **Identify stove use events**: associate each stove use event to its corresponding initial and final timestamps
- Match fuel use events and stove use event:
  - for each fuel events, associate it to a cooking event within 30 minutes
  - check what percentage of fuel use event have no matching stove events (orphan fuel events)
  - check what percentage of stove use event have no associated fuel use events (orphan stove events)

Limitation of sensor-based non-compliance detection:

- this approach requires that all the stoves in the households are equipped with CMS. If some stoves are not equipped, that might trigger some false-positive orphan fuel events or some orphan stove events might go unnoticed.
- fuel leftover from the previous cooking event might be enough for a second cooking event.

This approach is useful to detect household with strong non-compliance issues where fuel consumption would be severely under or over estimated.

As a first approach to this issue, we suggest to remove household whit more than 25% of orphan fuel or stove events

More advanced non-compliance detection methods are currently being developed and tested. For instance, a more fine-grained approach could be to look at each 24h period and to remove only the ones where non-compliance is detected. Another approach to detect abnormal fuel consumption is to look at specific fuel consumption per minute of cooking.

In the meantime, first order approaches like the one described above improves upon current requirements from analog KPTs (which is based on cooks self-reporting noncompliance).