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Current Status of Design, Adoption and Dissemination of Biomass Cookstove in Ethiopia

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Abstract

Domestic air pollution produced using inefficient, unclean solid-fuel cookstoves is a leading risk factor for illness and death worldwide. Despite this fact, the energy sector of Ethiopia as of any other developing countries is largely relying on traditional biomass as energy source. In addition to the indoor pollution and risk associated with it, GHG emission, Deforestation and degradation of forests, are a results of the same problem. Problem generated from the unavailability of the clean cooking source like the lack of good health, death, being socially inactive participant etc. mainly affected women, girls and children. Work on the Improved cookstoves started in Ethiopia in1990 by Ethiopian government jointly with NGOs especially GT. From the starting day on the country produce five basic kinds of improved cool stove, namely MIrt, Gounziye, Lakech, Tikikil and IRS. Evaluating by going through different articles listed in the reference; in relation to the design future, the adoption and the distribution figure and other aspects of the stoves; it seems the countries ambition and efforts are lost somewhere. Since related to the given problem to resolve, that is providing / indicating /adopting /distributing of clean, safe house hold biomass stove, still the problem largely existed.

Reviewing the design of the cookstoves available in the country, the type is classified in to traditional (three stone, Metal charcoal stove), simple non-traditional (Gunziye, Mirt), and for improved cookstove (Rocket) the classification is done based on the Berkeley Air. Except the rocket and Tikikil cookstoves, all other stoves do not meet the ISO standard and listed as tier-0 and are regarded as unsafe and inefficient. The adoption and the dissemination of these cookstoves are still not high enough to resolve the situation.

Keyword: Biomass cookstoves, Design, Adoption, dissemination, improved cookstoves, non-traditional cookstove.

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1. INTRODUCTION

The world is worrying about the climate change and the sustainable supply of energy. International initiatives such as Sustainable Energy for All (SE4ALL), the United Nations Framework Convention on Climate Change (UNFCC) and the Paris Agreement pursue efforts to limit the world's rise in average temperature, to achieve universal access to sustainable energy, and double the share of renewable energy in the global energy mix by 2030 [1].

Cooking demands a huge amount of energy, every person needs food to sustain their lives. The vast majority of main foods, 95% [4,], need cooking before they can be eaten and most people cook 2-3 times per day, every day. Cooking energy accounts for about 90% of all household energy consumption in developing countries [4, 12].

Worldwide, Nearly half of the world population- about 2.96 billion people in the developing world do not have access to energy infrastructure and depend on unclean, polluting, open fires and inefficient fuels to cook their food. Especially; in sub-Saharan Africa and Asia, the lack of access to clean cooking is desperate, with a third of the urban population and the vast majority of the rural poor using cooking fuels like wood, charcoal, crop residues or dung coal, and kerosene. Besides being highly inefficient these traditional, open-fire cooking methods produce toxic particulates and gases that cause household air pollution [4, 10].

This practice can lead to indoor air pollution levels that are 20 to 100 times greater than the World Health Organization's (WHO) air quality guidelines and release greenhouse gases and black carbon into the environment [4,]. Indoor air pollution resulted from inefficient burning of biomass in inefficient cookstoves is responsible for the death of 4.2 million people in 2018 all over the world. This figure is much greater than the death registered from the combined three killer diseases reported in the same year (Malaria, HIV, and TB, which is 3.7million) [4-6, 16]. Open fires and undeveloped cookstoves may also increase pressures on local environmental resources (e.g. forests, habitat) and contribute to climate change at regional and global levels [2-8].

Weighing the impacts across the gender and age groups; women, girls, and children are excessively affected by the health and economic impacts of cooking with polluting, open fires and inefficient fuels []. Lack of access to cooking fuel forces women and children to spend many hours gathering fuel - up to 5 hours per day- or spend significant household income purchasing fuel [,23]. In some cases, women provide 91% of households' total efforts in collecting fuel and water, and women have an average working day of 11-14 hours, compared to 10 hours on average for men [23, 54, and 55].

In general; the technical inefficient of the cooking stoves used in many developing country like Ethiopia; make the women and children inactive participant in activities, which results in poverty alleviation and capacity building of the women and the childlike spend more time with their children, incline to other responsibilities, improving existing economic opportunities, pursuing income-generating or educational opportunities and leisure activities and rest [12, 36]. After looking; the negative impact of the traditional Biomass cooking practices; in the 1970s and afterward the impacts are broadly exposed and considered as the "other energy crisis" [16, 36].

These days, the patterns of household energy use and local fuel collection linked to poor health and local environmental pressure are well documented by most policymakers. The main sticking point is how to develop effective policies and programs to address the problem.

Despite massive efforts aimed at substitution of the open fire system and electrification, the number of people relying on biomass is decreasing only slightly. It is estimated that by 2030, 2.52 billion people will still use the unclean cooking system with biomass as a main resource [4, 48-54].

Eagle-eyed on the Ethiopian situation; the major source of energy is biomass, which accounts for 91% of energy consumed [4]. And biomass consumption accounts for over 98% of total domestic supply. As per different studies; like The World Development Indicators [3] and several other studies [6-8] show that the national energy balance is of the country is dominated by firewood, crop residues, and dung. Due to the rise of the fuel consumption and the inefficiency usage of the biomass; the CO_2 emission per capital of Ethiopian is increases from 0.05 metric tons in 1999 to 0.16 metric tons in 2018, at an average rate of 7.20% per annum [12, 48-54].

Different factors influence the pollutant emissions from the combustion process such as fuel property, stove design and fire management. Generally, it is understood that improved stoves with relatively high burning efficiency could result in the alleviated air pollution, lower fuel and energy consumption, free women time and benefits for human health etc.

In Ethiopia; in the last several decades, several regional or national programs have been deployed by the local government to work on improved biomass cookstove design, adoption and distribution. But the efforts has not resulted in much progress toward cleaner and more efficient cookstoves as the rest of the world ; However it has been an ongoing challenge to develop high-performing, high-quality products that also satisfy user preferences and are affordable in developing countries [9,11].

2. LITERATURE REVIEWS

2.1 Literature Search and Keywords

Table 1: Search Terms

Type	Interest	Programs
Cookstove/ Improved cookstove / wood burning	Adoption/distribution	Ethiopian energy/environment/resource/
Cookstove/ Improved cookstove in Ethiopia	design	National Improved Stove Program
High efficient low emission Stove biomass stove	Design/ type/dissemination	National traditional cookstoves
biomass/ biogas fuel wood/ firewood coal	Resource	Indoor pollution and problem in the country
Charcoal	Household	
High efficient low emission stove	Design/ type/dissemination	

Using search terms and keywords listed above; research papers and different documents are reviewed and investigated in-depth. The main documents screened are show in the reference.

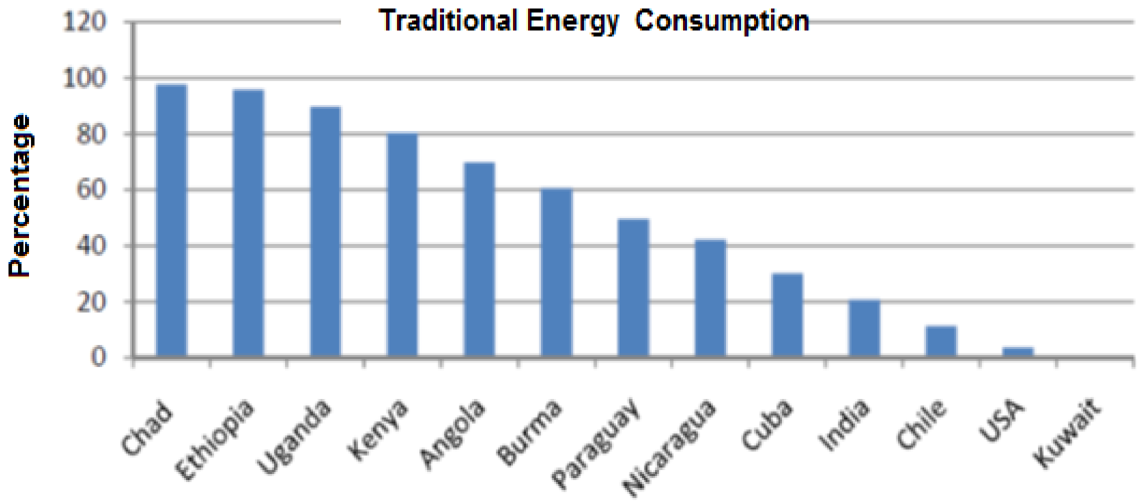
2.2 Background of Energy Situation in Ethiopia

In any country, the availability of energy plays a major role in the development process and livelihood improvement. Insufficient supply of power is considered as the main issue for economic and social development [8]. Access to modern energy supports both income generation activities and the national development agenda through improving education, reducing indoor air pollution, and ensuring environmental sustainability. The Ethiopian energy sector tested by the dual challenges of inadequate access to modern energy and heavy dependence on traditional biomass energy sources to cover the growing demand of the country [8-10].

Except for petroleum, which is wholly imported, Ethiopia is endowed with substantial energy resources for that include biomass, natural gas, hydro power, wind, solar, geothermal, coal and other energy sources. The main issues are the availability, the relative cost of these energies, the sustainability and the environmental acceptability when harnessed for different purposes [13].

Power generation for the electric grid in Ethiopia currently depends almost entirely on hydropower. The primary source of energy in Ethiopia is biomass, which a coconut for 95% of the energy consumed [4], which means Ethiopia is the third largest user in the world of traditional biofuels for household energy use, next to Chad and Eritrea (see figure-1). Petroleum supplies about 7% of total primary energy and electricity account for only 2% of total energy use [8]. 98 % the total domestic energy supply is covered by biomass. The World Development Indicators [3] and many other studies [6-8] show that the national energy balance is dominated by a heavy reliance on firewood, crop residues, and dung.

Figure 1: Traditional Bioenergy Consumption in Percentage vs. Selected Countries.



Source: NationMaster.com, 2010.

According to the joined report from five SDG 7 custodian agencies, the energy progress report of 2019, indicted that Ethiopia is one of the 20 countries with the largest access deficit for electricity and with the largest clean cooking access deficit over the 2010-2017 tracking period. In other words; 58 million people out of the total population in Ethiopian have no access to electricity. There are stark differences in the rate of electricity access in urban and rural areas (see Figure-2 & table-2). In urban areas, 87% of the population has access to electricity [14, 19], while in rural areas electricity access remains extremely low at about 5% [3]. Eighty-three percent of the population resides in rural areas, largely relying on traditional biomass energy sources for cooking and heating. Electricity is mostly used by urban households and small industry [8, 14, and 19].

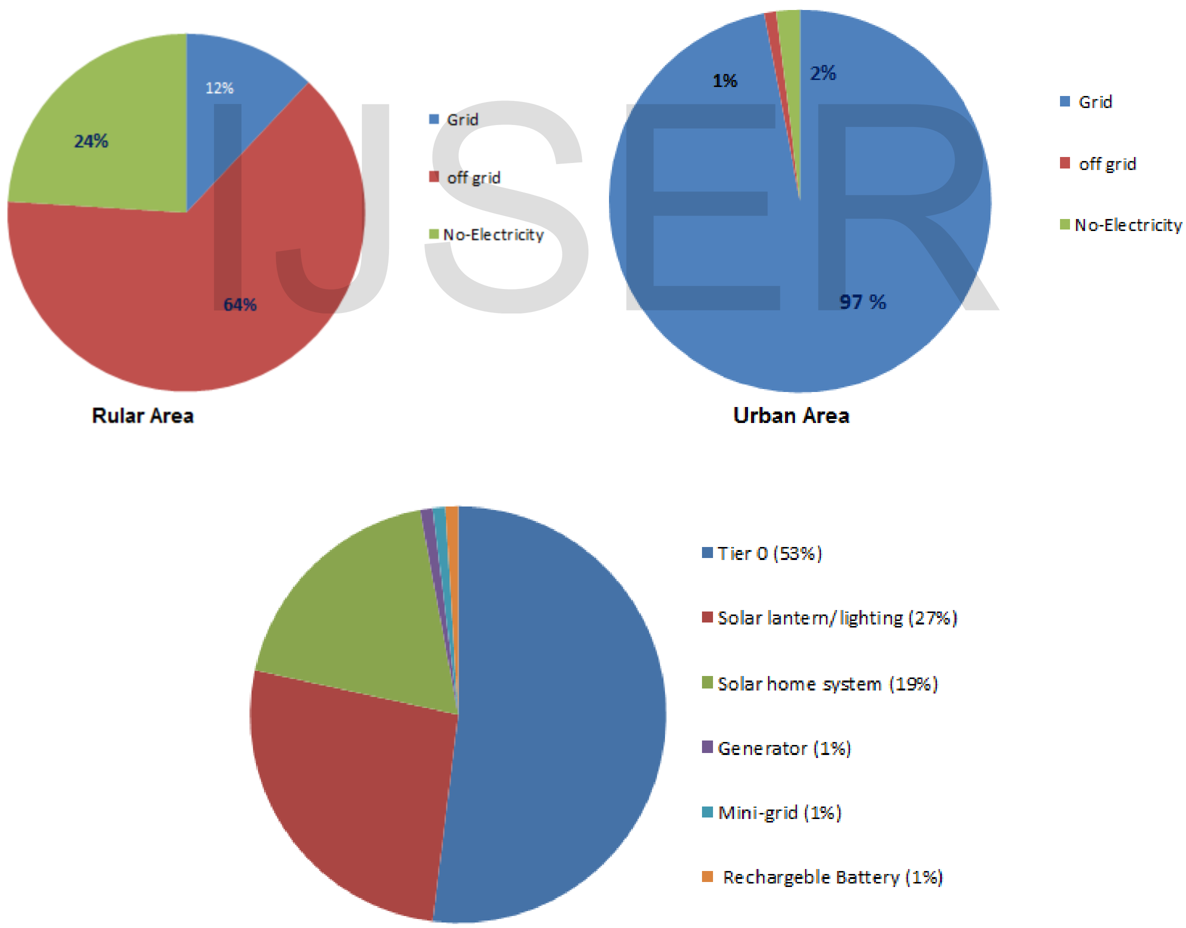
Off-grid electrification solutions that provide Tier 1+ access, including mini-grids, generators, off-grid solar products, and rechargeable batteries, served 14% of the combined population of Ethiopia, in 2017 [4]. within the last 2-3 years, the role of off-grid energy solutions is also become crucial element in power supply, solar lantern or solar lighting systems which deliver elementary lighting services along with mobile charging and radio are the most predominant off-grid energy solutions in Ethiopia. But this account currently only about 11.3% of Ethiopian households (See figure-2) [4].

Table 2: Source and Type of Energy Used By Urban and Rural Households.

Type of fuel	Percentage of households [%]			
	Country level	Rural	Small town (urban)	Large town urban
Collected firewood	61.5	77.2	34.6	14
Purchased firewood	12.1	3.2	46.7	33
Charcoal	5.2	0.5	6.4	21.7
Crop residue/leaves	6.8	8.9	0.7	1.3
Dung/manure	6.6	8.2	2.1	2
Electricity	5.2	0.1	4.5	23.3
None	0.9	0.3	2.3	2.8
Other	1.8	1.7	2.7	1.9

Source: CSA and World Bank 2017.

Figure 2: Type of electricity used in Ethiopia, portion of total and along the rural/urban. 2017



Source/extracted: MTF, World Bank

2.3 Biomass resource in Ethiopia

In short; an Organic plant or animal materials that are used to generate energy is called Biomass. Biomass is basically generated by a well-known process called photosynthesis; the leaves of the plants absorb the sun's energy in which carbon dioxide and water are converted into stored energy.

Biomass can be purposely grown energy crops or residues from agriculture, harvests from forest (in the form of firewood, charcoal, residues), crop residue, energy crops, animal manure, collected residues from agro-industrial and food manufacturing sector, community solid wastes, and other biological resources. Basing the characteristics of the biomass resources; the resources might be directly employed for basic energy needs like firewood, charcoal, dung cake, in turn to be incinerated and generate energy or transformed into invaluable renewable energies like Biogas, biofuel, bioelectricity, hydrogen energy, etc. for household as well as industrial and transportation sectors .

Biomass was the oldest form of fuel used in the history of humankind and is also the fuel which was the mainstay of the global fuel economy till the middle of the 18th century [20, 13]. It accounts for 35% of primary energy consumption in developing countries [23], constituting about 14% of the world's total primary energy consumption and is only organic petroleum substitute that is renewable [14]. All over the world, biomass is used to address a variety of energy demands, including generating electricity, heating homes, fueling vehicles and providing process heat for industrial facilities [23]. Studies indicate that biomass resources offer renewable energies that can play a pivotal role in the current global strategies for reducing greenhouse gas emissions by partially replacing fossil fuels [19-2, 32].

2.3.1 Solid Biomass Resource in Ethiopia

Ethiopia demands biomass for fuel, with per capita consumption of around 0.9 tons per year, is doubles that of the sustainable annual yield [3-7]. Mainly biomass fuels are used *Mitad* baking for baking of traditional food like *enjera, ambasha, kocho*, etc. and for other cooking activities in the kitchen (*Wot, coffee*, etc.). The source for solid biomass can be solely divided into cattle dugs, agricultural residues and woody biomass that are found from big threes.

2.3.2 Cattle Dung

Ethiopia has a large livestock population. The country's livestock population according to the 2016/2017 survey was 59.5 million (Ethiopia Central Statistical Agency [CSA] 2017). Around 700 kilograms (kg) of dry dung can be obtained per animal per year (Bond and Templeton 2011). Cattle are mostly range-fed, and around 40 percent of the produced dung is not accessible for collection. Around 22.8 million tons of dung was used in Ethiopia in 2013 for energy purposes [8, 10].

2.3.3 Agricultural Residues

Agricultural residues are important as a source of biomass intended for fuel (Table-3). The utilization rate of agricultural residues is low and accounts for only 30 percent [21-24].

Total potential supply of residues has been estimated to be 22.4 million tons per year of which 10.3 million are used as fuel in 2014 [21-24].

Table: 3. Types of Agricultural residues available in the country

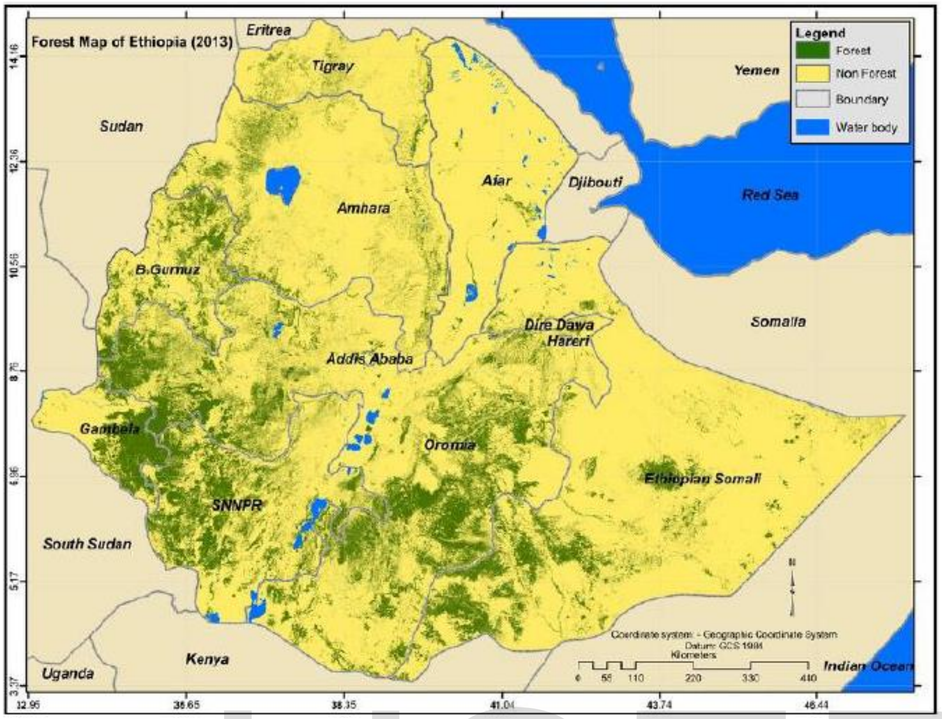
Type of crop	Residue	Land cover (1 000 ha)	2014/2015 Production (1 000 tons)	Residue-to-production ratio	Quantity of residue (1 000 tons)
Teff	Chaff	3 017.5	4 420.6	9	39 785.4
Wheat	Chaff	1 605.8	3 930.1	1.75	6 877.7
Maize	Stalk	2 027.19	6 497.5	2.11	13 709.7
Pulses	Chaff	1 732.6	2 820.8	1.89	5 331.3
Sugarcane leaf	Leaf	30.1	1 513.4	0.298	451.0
Sorghum	Stalk	1 678.4	3 720.8	2.23	8 297.4
Barley	Chaff	1 020.4	1 210.2	1.76	2 130.0
Vegetables residue		171.4	714.8	0.42	300.2
Sugarcane bagasse	Bagasse	30.1	1 513.4	0.36	544.8
Rice	Chaff	34.8	90.3	1.72	155.3
Coffee	Husk	598.4	372	2.11	784.9
Grass	Stalk/ Chaff	707			
P. Julifloa and other invasive bush	Biomass	502 400	21		21
Forest residue	Biomass	180 000			105
Cattle dung	Dung				23

2.3.4 Woody Biomass

According to the U.N. FAO, 11.2% or about 12,296,000 ha of Ethiopia land is forested, and 511,000 ha of is planted forest. Amente et al. (2016) asserting it to be more than 15 percent by adopting a new definition of forests. Ethiopian forest contains woody biomass of 219 million metric tons of carbon in living forest biomass. Seeing a Change in Forest Cover; bin the years between 1990 and 2010, Ethiopia lost an average of 140,900 ha or 0.93% forest coverage per year [].

Totally, between 1990 and 2010, Ethiopia lost 18.6% of its forest cover or around 2,818,000 ha. Woody biomass is the most important biomass fuel in Ethiopia; it provides an estimated 68 percent of the total biomass demand that is nearly 95 percent of the nation's energy supply [21-24]. Here; only 34 % of Wood fuel is manufactured legally and sustainably from natural high forests and woodlands, a small volume of wood waste and a negligible amount from imports. The remainder, around 66 percent, is unsustainably sourced from natural high forests and woodlands [21-24].

Map 1: Forest cover of Ethiopia



Source: National REDD+ Secretariat, MEFCC 2018

The biomass demands for fuel, with per capita consumption of around 0.9 tons per year, is double that of the sustainable annual yield. The forest sector review (MEFCC 2017) indicates that the volume of sustainable yields of branches, twigs, and leaves from the high forest is 3.4 million m^3, woodland 3.3 million m^3 and shrub land 2.0 million m^3.

Data from FAO (2018) indicate that the annual fuel wood (including wood for charcoal production) and charcoal production of Ethiopia were around 109,389,000 m^3 and 4,317,000 Mt, respectively. Biomass of numerous sizes and shapes, containing fine biomass, has been used. The fine biomass may be raw biomass or residue dust from charcoal making. Previously; the fine biomass was left at production sites or dumped as waste. However, as population pressure increased, the rise in the demand for fuel was tremendous. As a result, the fine biomass was found to be useful either as fuel directly or after compaction through traditional or industrial means [21-24].

2.4 **Biomass cookstoves**

2.4.1 **Biomass cookstoves design**

All over the world, to resolve the energy crises and the problem unclean energy resource, the design of biomass cookstove have been vigorous treated for decades and have showed in much development toward cleaner and more efficient cookstoves. However it has been an ongoing challenge to develop high-performing, high-quality products that also satisfy user preferences and are affordable in most developing countries [27, 28, and 36].

It is needed to follow the three major considerations while designing a cookstove: technical, social and economic. Social considerations depend upon prevailing cultural and local needs and constraints, and are a pre- requisite for long-term adoption of a cookstove by the society. Technical considerations are high efficiency, low emission, user's safety, durability, weight or easiness for handling, attractiveness etc. must be considered. The above criteria need also to look the cost of the production, cost unit sales, or affordability and cost of maintenance [30, 35].

Countrywide wise; designing any product requires prioritizing the most important features and knowing when compromises can be made since; the designing of cooksstoves has been involving lots of parties with different objectives (see figure-3 and 16) [30]. For example, a user may prioritize a fast igniting stove that saves time and fuel, an agent and or an NGO may aim to distribute stoves or fuels that offer health and livelihood benefits, a national government may support efficient cookstoves to achieve reductions of greenhouse gases and manufacturers aim to make a stove as inexpensively as possible to be competitive in the market. While it is challenging to meet the needs of every stakeholder, a successful product will incorporate multiple design ingredients listed in the figure below [30, 35].

To meet the demand of individual party's interest; in the design phase it is demanded to include a range of stakeholders (e.g., community members, users, entrepreneurs, government officials). This process of co-creation ensures that everyone with an interest in the solution can include their needs and ideas and contribute to a successful solution.

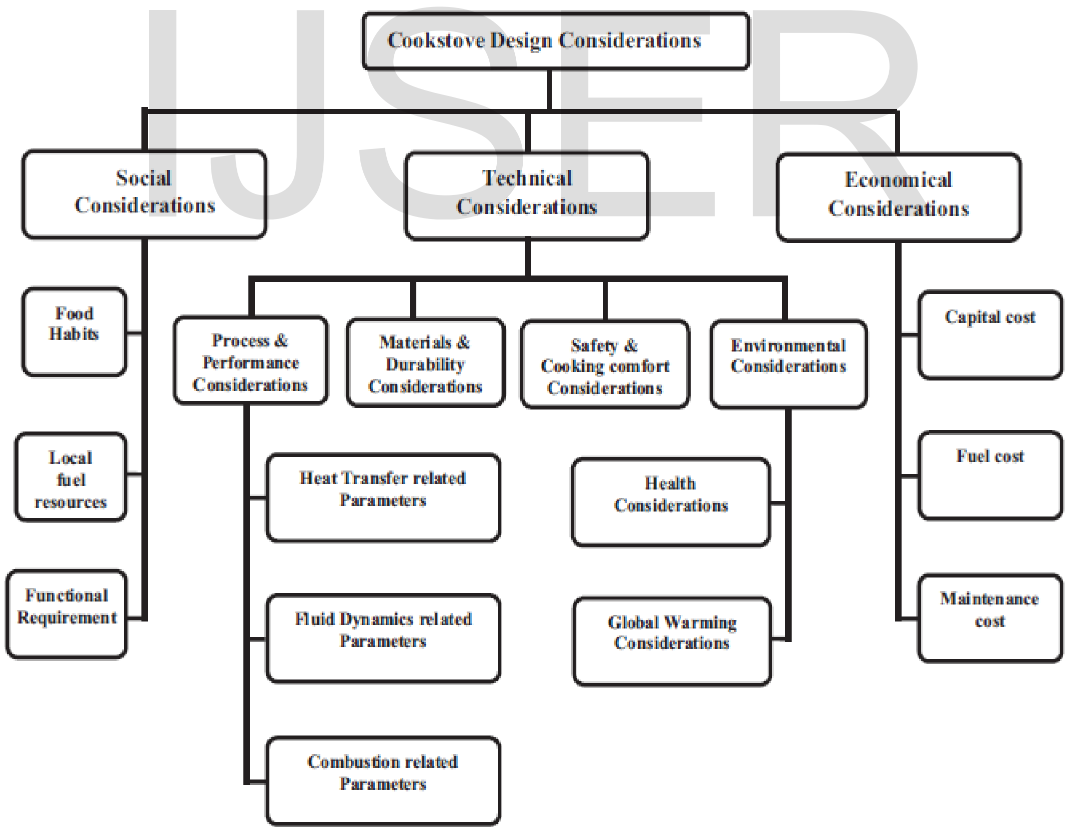


Figure 3: Ingredients for Cookstove Design [30, 35].

The types of materials used for the manufacturing and insulation purpose of the biomass cookstove have an impact on the design item performance; therefore the designing of the cookstove need an intensive look through on the material lists available for this purpose (see figure 3 and figure: 1 –Appendex-1 for the types of materials used for the construction of biomass cookstove with their advantage and dis advantage) [28, 29, 31, 35, 39].

2.4.2 Performance evaluation of the cookstoves

To evaluate the performance of the cookstoves; the International Workshop Agreement (IWA) 12 based on ISO norms have been approved as a guiding principle to categorize the performance of stoves and laid out framework for evaluating cook stove performance. The rating system will define tiers of performance in the areas of fuel efficiency, emissions of fine particulate matter (PM 2.5) and carbon monoxide (CO), indoor emissions (particulate matter 2.5 and carbon monoxide), and safety. Each area will be ranked separately (ISO 2012).

The standards are based on "Tiers of Performance", which provide a map towards increasing performance, from traditional open fire stoves (Tier 0) to aspirational goals for meeting ambitious health and/or environmental targets (Tier 4), Table shows a summary of tier category based on performance of stoves.

. Table 4: IWA 12 Tier Categorization Based on Performance 0f Stoves (ISO 2012).

	Emissions				Efficiency / Fuel use		Indoor Emissions		Safety
	High Power CO		Lower Power PM		High Power	Lower Power			
	(g/MJ$_d$)	(mg/MJ$_d$)	(g/min/L)	(mg/min/L)	Thermal Efficiency (%)	Specific Consumption (MJ/min/L)	CO (g/min)	PM (mg/min)	
Tier 0	>16	>979	>0.20	>8	<15	>0.050	>0.97	> 40	< 45
Tier 1	≤ 16	≤ 979	< 0.20	≤ 8	≥ 15	≤ 0.050	≤ 0.97	≤ 40	≥ 45
Tier 2	≤ 11	≤ 386	≤ 0.13	≤ 4	≥ 25	≤ 0.039	≤ 0.62	≤ 17	≥ 75
Tier 3	≤ 9	≤ 168	≤ 0.10	≤ 2	≥ 35	≤ 0.028	≤ 0.49	≤ 8	≥ 88
Tier 4	≤ 8	≤ 41	≤ 0.09	≤ 1	≥ 45	≤ 0.017	< 0.42	≤ 2	≥ 95

2.4.3 Biomass Combustion

To get the useful heat energy from solid biomass; it has to undergo combustion. In traditional term; combustion of Solid biomass is a process in which the fuel is burnt with the oxygen from the air at a temperature sustainable for the release heat in burners. The process of combustion is a complex interaction of physical and chemical processes that are basically affected by the physic-chemical properties of the fuel to name a few: size, shape, density, moisture content, fixed carbon content, volatile matter, etc. and quantity, mode of air supply and the conditions of the surroundings , temperature, wind, humidity and soon [29,30].

To design a better biomass cook stove, it is mandatory to know the combustion process and the system including the combustion process. The cooking system includes the cookstove, fuel, cooking vessel or, user, and kitchen. All these have an influence and impacts that a cookstove has on the user and environment.

Complete combustion occurs when the amount of oxygen and mixing of fuel and oxygen is sufficient to completely convert all of the fuel to heat, carbon dioxide (CO_2), and water vapor (H_2O) (Equation 1). Incomplete combustion occurs when the amount of oxygen and mixing is insufficient, resulting in partial conversion of the fuel and emission of products of incomplete combustion (PICs, e.g., carbon monoxide, particulate matter, methane, other hydrocarbons), many of which are associated with health and climate risks (Equation 2). The combustion zone is the high-temperature region containing burning fuel and gases in the flame. Fuel-rich combustion occurs when the amount of air is insufficient to combust all of the fuel in an area of the combustor. Fuel-lean combustion occurs when more air than needed for complete combustion is present. Solid-fuel cookstoves typically operate fuel lean overall, but local fuel-rich regions are still present within the combustion zone.

Fuel + O_2 heat + CO_2 + H_2O
Fuel + O_2 heat + CO_2 + H_2O + PICs

When solid biomasses are burned, there are various simultaneous processes. First, gases with other names like: volatile gases, pyrolysis gas, fuel gas, combustible gases are released when the fuel heats up. Then the generated gases react with oxygen and ignite to form the flame, which is visible part of the fire. Hot combustion products also referred to as emissions and exhaust gases are released from the flame.

Heat produced in the flame is transferred back to the fuel, which releases more volatile matter and continues the process. After all of the volatile matter is released from the fuel, charcoal remains and reacts with oxygen to produce more heat and combustion products. Flame temperatures can surpass 2000°C, depending and configuration of the stove design, moisture content of the fuel, amount of air supply, characteristics of the fuel, heating etc. [27-36].

2.4. 4. Classification of Biomass cookstoves

Cookstoves can generally be classified and identified based on the level of applied engineering knowledge, material of construction, type of draft used, combustion, intended use (for domestic or communal purposes), functionality, presence of chimney, portability and type of feedstock used [27,28]. Figure shows a diagrammatic representation of biomass cookstoves classification. The cookstoves can also be classified in to two: traditional biomass cookstove, simple non-traditional and improved cookstove (ICS).

Traditional stoves are created over thousands of years, and have been developed according to local culture and food practices. The stoves are least costly, and the users are familiar with their operation; and hence are widely accepted in society.

Defining an improved stove, The "Improved Cookstove" is a cookstove designed using certain scientific principles, to assist better combustion and heat transfer, for improving emissions and efficiency performance; it may also utilize modern construction. Observing the world; traditional cookstoves can range from three-stone open fires to substantial brick-and mortar models and ones with chimneys. An improved stove is designed to improve energy efficiency, lower biomass consumption, reduce pollutant and particulate emission, reduce space consumption, eliminate risks related with cooking, etc. (see figure 3.).

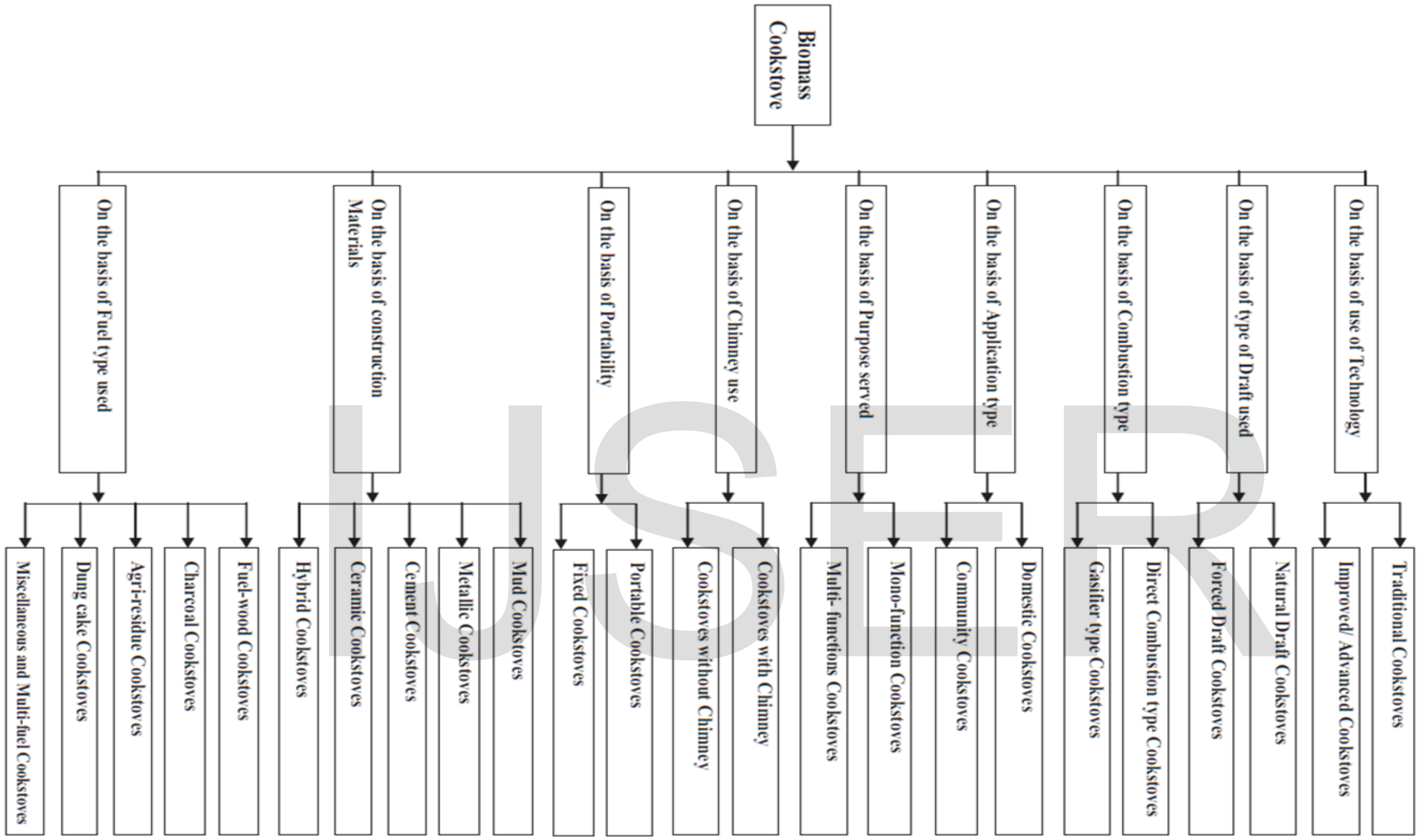


Fig. 4 Classification of biomass cookstoves [30].

To clarify figure-3

Batch-operated refers to stoves that are operated on a single load of fuel at a time.
Continuously fed stove it is demanded to feed the fuel continually till the cooking process end.
Rocket/side-fed stove demand a continual feeding of wood sticks or biomass residues that are through the side of the stove; usually resting on a grate so that ash and charcoal can settle below. Air is natural or by forced-draft.
Gasifier stoves use preprocessed fuel like pellet or briquette or any other densified biomass. This fuels are batch or continuously to the stove. Combustion occurs in two zones — the pyrolysis zone where fuel is heated to produce combustible gases, and the combustion zone where pyrolysis gases are mixed with air and combusted to produce heat.
Charcoal stoves are batch-operated and fueled with charcoal or carbonized biomass, which is produced through pyrolysis to remove volatile matter leaving mostly carbon.
Forced-draft / fan stoves have air that is forced into the stove using a fan or blower to enhance turbulence and promote cleaner combustion.

4. Types of Biomass cookstove available in Ethiopia

4.1 Traditional cookstoves

4.1.1 Three Stone Biomass Cookstove

In the classification of traditional in Ethiopia, a three-stone open cookstove is used with wood, and a stove made of sheet metal that is used for charcoal is highly recognized.

Worldwide, 2.9 millions of people still depend on highly inefficient three-stone fires for their cooking needs. The method is most common used for cooking in developing countries [48, 49]. Fire is usually shielded or surrounded by "three or more stones, bricks, mounds of mud, or lumps of other incombustible material". For short, such fires are called "three-stone" fires. The three-stone fire is the cheapest stove to produce, requiring only three suitable stones of the same height on which a cooking pot can be balanced over a fire. These three-stone fires have continued to be in use for cooking and heating purposes, mainly due to their simplicity. They are easy to build, support a range of fuels and can be adapted to different cooking habits quite easily.

In Ethiopia, the vast majority of rural people who are dependent on traditional fuels use primitive and inefficient technologies, use open fire stove used to put the "Mitad" or the cooking pot. It is open except the spaces occupied by the stones. This kind of traditional house hold stove widely used throughout the country.

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Figure 5: Three Stone Biomass cookstove.

Source: Global Alliance for Clean Cookstoves

Open three-stone stoves dissipate most of the heat into the surroundings without any significant recovery. Most sources cite the fuel-efficiency of traditional stoves as five to ten percent [2, 6]. Since nearly three billion people in the world use traditional stoves for cooking purposes, efforts to improve the efficiency of such stoves have been increasingly popular. The traditional open-fire cookstove can be improved easily to a closed stove with either cement or clay enclosure and is 25 to 50 per cent more energy efficient, with less smoke and less carbon monoxide emission [48-55].

4.1.2 The Traditional Metal Charcoal Stove

Figure 6: The traditional Metal Charcoal Stove

Source: Mamuye et al. 2017.

The traditional metal charcoal stove has been used in the country for the purpose of cooking using charcoal-figure-6. It needs 700 grams (g) of charcoal to meet the daily cooking energy demand of an average household. That is double in amount comparing with the improved charcoals stoves available in the market currently.

4.2. Simple Non- Traditional Cookstoves

Simple non-traditional are defined as stoves which have some type of design intended to increase combustion or fuel efficiency but do not fit into the other stove classes; for example, stoves constructed with simple, non-rocket style ceramic or mud combustion chambers [23,24].

Improving the traditional cookstoves of Ethiopia Injera baking started in the government institution in the 1970s [32]. The work started by improving the enclosed injera baking stoves used in selected regions of the country and then testing and improving it to obtain Mirt and later on Gonzie stove. Such kinds of design stoves were basically used in some parts of Ethiopia but the construction materials differ [31-33]. The task of improving from the traditional to relatively improved stove is done only by changing the construction material form Mud to concrete and providing chimney on the top for the withdrawal of smoke.

The local technological development of cookstove is a contribution of various stakeholders: government, multi-lateral institutions, academia and research institutions and innovation funds supporting private companies [31-33].

4.2.1 Gounzie Stove

Figure 7: Gounziye Stove

The Ethiopian Rural Energy Development and Promotion Center develop Gonzie stove in 1994, which serve as cooking and baking to make available affordable fuel saving stoves to the rural areas [31]. Gonzie stove is made with mold but with no groves rather each closing another component. Thus the Gonzie has a maximum diameter, to the size of the mold, does not have a minimum diameter.

The Gonzie multi-purpose stove attains an efficiency of 23%. It has fuel saving potential of 54% for baking, 42% for cooking compared with traditional practices [4, 31].

4.2.2 Mirt stove

Mirt is enclosed stove produced with mortar – a mixture of river sand with cement and has an average lifespan of five years. The stove is designed by the former Ethiopian Energy studies and Research center of the Ministry of Mines and Energy. Mirt' stove is native to Ethiopia and improvement is only made to make it energy efficient. And it is also used to cook and boil food while taking without the use of additional fuel [].

Figure 8: Injera Cooking and pouring with Mirt Stove

Source:ethiopiaethos.files.wordpress.com/2010/06/comp5.jpg. , energypedia.info/wiki/Baking_with_Improved_Ovens

The stove has six parts. Four arcs which fit together to form the circular combustion chamber & two-U-shapes that form circular pot rest. The four arcs of the combustion champers enable the stoves to avoid cracks due to thermal stresses & also help to handle & transport the stove easily. The U-shape part is used for pot rest & chimney purposes. The components of Mirt stove energy saving stove mold are side mold, exit smock mold, wood intern mold and mold for dish.

Mirt consumed 67.15% of the wood consumed by traditional stove. Mirt burned only 84.40% of the amount of wood consumed by Gonzie stove. (Amare, et al.2015). The length of time the stoves gave energy sufficient to bake additional 'Injera' is around 1.63 times the length of traditional stove burned; Mirt gave a burning time of 0.08 times longer than Gonzie.

It is also possible to extract charcoal from mirt, this impossible from the traditional stove for Injera baking. The weight of charcoal extracted from Mirt stove was averagely higher than that of Gonzie. Open fire or local stove damage to what would have been saved as a by-product (charcoal) to be used for stew and coffee making.

4.3. Improved Cookstove in Ethiopia

The improved cookstove development started in the government institution in the 1970s [31-35]. The work started by improving the enclosed injera baking stoves used in selected regions of the country and then testing and improving it to obtain Mirt and later on Gonzie stove. The major stoves developed for pot-sized stoves (non-baking cookstoves) were Tikikil and Laketch stove. Laketch was massively distributed throughout the country [31]. The local technological development of cookstoves is a contribution of various stakeholders: government, multilateral institutions, academia, and research institutions and innovation funds supporting private companies [32].

The cookstoves can be generally categorized as those for injera baking (Mirt and Gonzye stoves), and those for pot-size general cooking (mainly Tikikil). Typical charcoal cookstoves include Merchaye, Lakech, and traditional metal stoves. They are also categorized as charcoal stoves (i.e. Lakech and Mirchaye) and wood/raw biomass (Tikikil and all injera baking) according to the fuel they use. Out of the improved stoves implemented from 2005 to 2017, 27 percent were closed mud stoves, 21 percent Mirt stoves, 14 percent Lakech, 6 percent Tikikil, 6 percent other stoves [33].

4.3.1 Lakech and Mirchaye stove

Lakech stove was adopted from the Kenyan Ceramic Jocko (KCJ), by the EREDPC of the Ministry of Mines & Energy in 1990 under the Cooking Efficiency Improvement & New Fuels Marketing Project. The stove was optimized by thinning the metal cladding of KCJ to suit with the Ethiopian cooking habits & reduces construction cost. It has the form double conic fitted with ceramic liner above its waist. A half liner combined with the bell-bottom shape provides stability to the stove, with lower cost and low weight as compared to full liners [6].

Figure 9: Charcoal improved cookstoves

Source: Mamuye et al. 2017.

Materials needed to produce the stove are metal, clay, cement, sand, and water. Metal and clay are the main raw materials to supply the stove. All the joints in casing are either riveted/ folded and no welding, soldering or brazing is required. The recommended thickness of sheet steel for the casing is between 0.5 – 0.8mm. It uses charcoal or briquette as fuel which is continuously fed into the upper part of stove. Charcoal stoves are the most widely used for "Wat" cooking, water boiling, coffee making, and other related activities in urban and semi-urban areas of Ethiopia. The use of these stoves increases with the rapid growth of the urban population of the country.

4.3.2 **Tikikil stove**

The Tikikil stove is an improved, portable household, wood-fuelled cooking stove of the „rocket stove" design. Tikikil stove is used for cooking. It uses firewood as fuel which is continuously fed into the combustion chamber. Scrap galvanized sheet metal is made into the cladding while the ceramic liner is made of clay mixture [27]. The Tikikil Stove saves up to 50% of fuel compared to the three-stone open fire; its thermal efficiency is around 28% [21-23].

The stove is Tier 2 with the Thermal efficiency of the stove is 26% [25].

Figure 10: Tikikil stove and A Girl cooking watt with the

Source: GIZ/EnDev Ethiopia 2015 and MEFCC and SNV 2018.

4.3.3 Institutional Rocket Stove (IRS)

A Rocket stove is presented by ease of construction and simplicity of building materials. It is mainly designed to accept small-diameter fuel such as twigs or small branches and yield high combustion efficiency and directing the resultant heat most. The Institutional Rocket Stove (IRS) is a portable stove used for larger-scale cooking in institutions. The stove can potentially save to 70% of fuel compared to the three-stone fire with a thermal efficiency of 40-50%. The

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stove is commonly available in third world countries. In Ethiopia; GIZ-ECO in collaboration with stove producers has been disseminating the stove. Components of IRS are: Fuel magazine: Into which the unburned fuel is placed and from where it feeds into the combustion chamber.

Combustion chamber/Internal chimney: At the top of the fuel magazine where the wood is burned. Internal chimneys are mere extensions of the combustion chamber and should be constructed from a bigger tin can to piping and supply the desired draft to keep up the hearth. The top of the combustion chamber/chimney function the support for the cooking area. Some Rocket stove designs have chimneys in a separate location to the combustion chamber.
Chimneys: Located above the combustion chamber or to one side or is often a part of the hood extraction system.

Figure 11: The women cooking Watt with IRS

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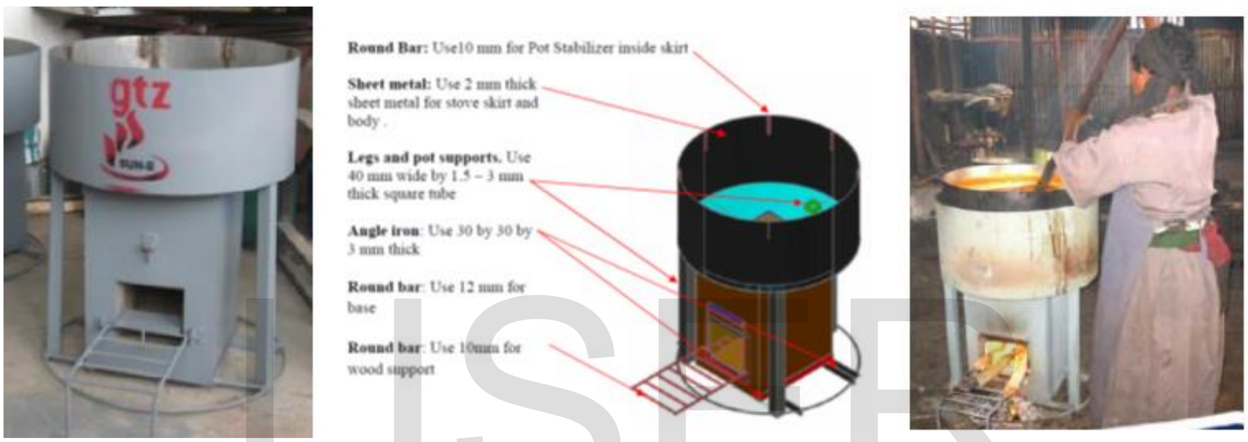

Source: GIZ/EnDev Ethiopia 2015

Heat exchanger: To transfer the warmth to where it's needed, i.e. the cooking pot. From the chimney the heat passes into a suitable heat exchanger to ensure the efficient use of the generated heat. For cooking purposes the design keeps the cooking vessel in touch with the hearth over the biggest portion possible area by use of a pot skirt to make a narrow channel which forces hot air and gas to flow along the bottom and sides of the cooking vessel. The pot is typically encompassed by a fixed or adjustable pot skirt. The pot skirt functions as a shield to force the emission gases to pass close to the container holding the food. The gap between the skirt and therefore the pot is additionally referred to as the pot gap

4.3.4 Ezy Stove

Ezy Stove, A wood-burning stove with a unique design, allows wood to burn more efficiently while producing less smoke. It is a batch loaded rocket stove designed for household level use The stove is distributed Ethiopia, Ghana, India, Kenya, Malawi, Mexico, Nicaragua, Nigeria, Papua New Guinea, Rwanda, Solomon Islands, United States, Burkina Faso, Sierra Leone, Uganda, and Zambia. The stove is locally manufactured in Mekele.

These fuel efficient stoves still use wood, but can cut the amount of wood that is used for cooking by 40-50%, as well as cut greenhouse gases released into the atmosphere quantifiable to one metric ton of CO_2.

Figure 12: A-Ezy Stove, B-C traditional coffee making with Ezy Stove

(A) (B) (C)

Source: http://www.makingmebrave.com/blog-posts/why-mekelle.

4.4 The Performance of Ethiopian Improved and Non-Traditional Cookstove Design

Berkeley Air data is provides the means for easily comparing and mapping stove performance against standards or benchmarks. It is easy and possible to roughly access the design efficiency and performance of Ethiopian cookstoves - (tradition, simple Non-traditional and improved biomass ones) basing Berkeley Air data.

4.4.1 Biomass Type vs. MCE and PM

From the graph below A; t is indicated that thee biomass type used largely affected the combustion efficiency (MCE) and the generated particulate matter (PM). In Ethiopians biomass cookstoves, it is used mostly dung, crop residually and wood that have a higher capability of generating PM emission.

4.4.2 Emission Generation vs. Cookstove Design

The graphs B, C and D show a general trend of increasing emissions performance from traditional wood stoves, to simple traditional and plancha stoves, then rocket stoves, and finally well performing fan/gasified stoves approaching the emissions performance of gas/liquid fuelled stoves.

As we see above; Ethiopian cookstoves are most of them traditional and simple nontraditional. But in the country we also have types of rocket cookstove (institutional, Tikikil and ezy cookstoves). The improved charcoal that is Lakech is the best performing cookstove of the country with Tier-2, next the rocket cookstoves with Tier-1. The other is ranged an unclean, Tier-0 cookstove and treated as a stove that create pollution and need great improvement work [40].

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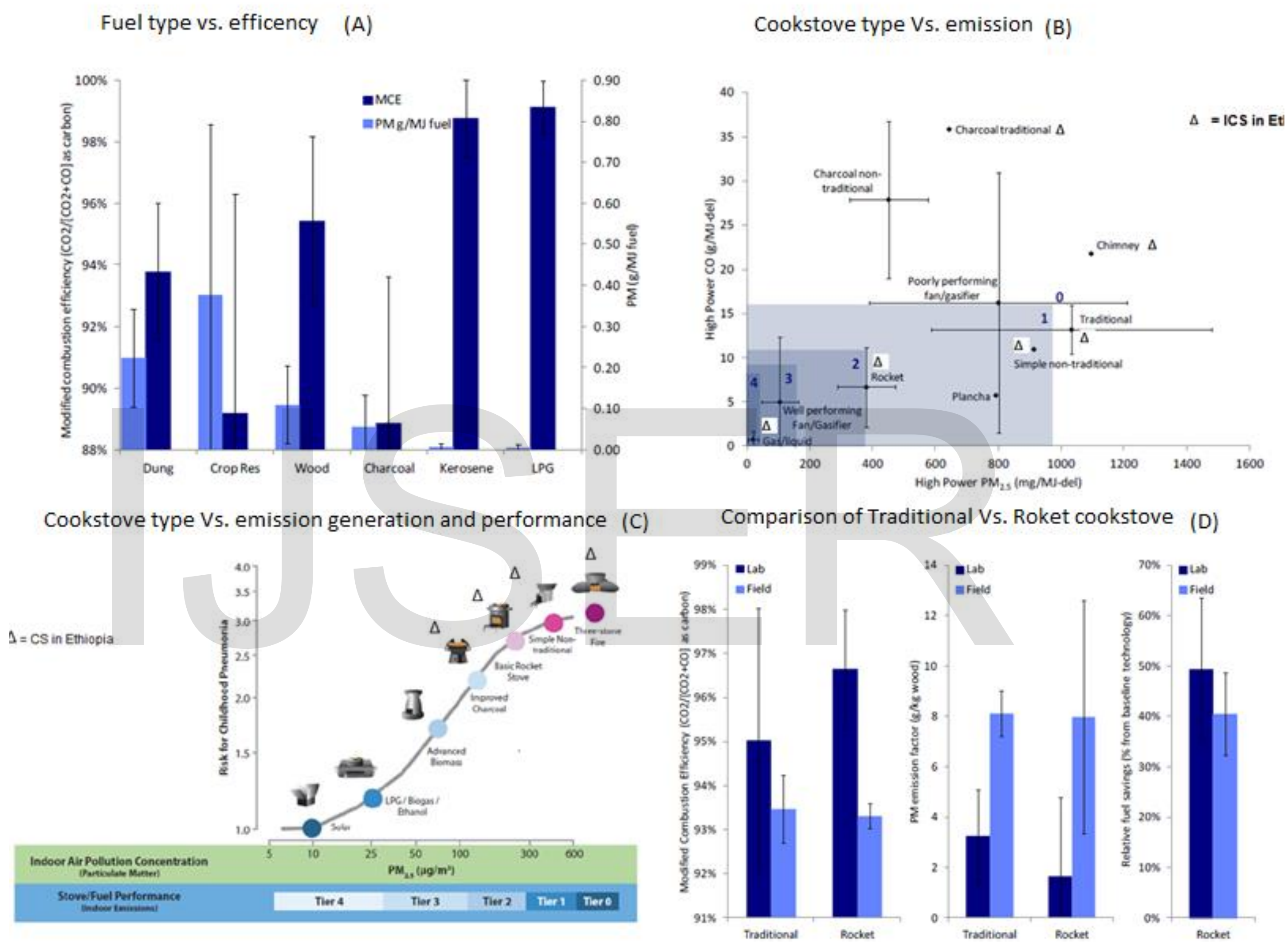

Figure 13: The emissions, performance of different cookstove investigating by Berkeley air, the comparison is tried to be made with Ethiopian stove.

Berkeley Air is currently a member of the U.S. Technical Advisory Group for ISO/TC 285 for Clean Cookstoves and Clean Cooking Solutions.

5. Problem Related with Unclean Biomass Cookstove

Energy use by humans for life support is one of the principal activities, which necessarily interferes with natural environment in various ways at different places and time. At it is well known; human being basically dependent on the environment for the basic need -food, clothing, water, shelter and energy. People in developing country relatively have crude, low technologies in extracting these resources and have not yet developed efficient technologies to convert the resources into more efficient and productive ways. Therefore; they tend to be more extreme and direct dependent on their natural resources than developed countries. However, what matters is not the use of its natural resource, it is the unbalanced and excessive use of the resource base with very low efficient in extraction also as use or intake of energy from its source.

5.1 Indoor Pollution and Health Problems

Many studies across the world have relate indoor air pollution to sicknesses like acute lower respiratory infection (currently the leading cause of death among children less than 5 years), chronic obstructive disease, lower birth weights, and higher risk of tuberculosis see figure ..[6]. Although many sources of indoor air pollution exist, studies conducted by the World Health Organization (WHO) have identified coal and biomasses burning for heating and cooking are the leading contributor to indoor air pollution in the rural households of developing countries [6, 40,41].

Women and youngsters in developing countries are exposed every day to pollution from indoor cooking smoke, within the sort of small particulates, up to twenty times above the utmost recommended levels of the WHO and other environmental agencies round the world (WHO 2005). Smoke from cooking fuels is estimated to account for nearly 4.2 million deaths, more than 99 percent of which occur in developing countries []. The figure indicated make indoor air pollution the number one killer in the world even with higher figure than the three disease combined (HIV, Malaria and TB-),which is 3.7 million death [12].

That means; a significant percentage of the annual burden of disease is caused by cooking smoke. Because mothers and their young children are the most household members who regularly breathe such cooking smoke, they're disproportionately suffering from the related health issues. Strong evidence supports the causal linkages between biomass combustion emissions and acute respiratory tract infection (ARI) among Children [12, 16] and Children are especially susceptible indeed.

In Ethiopia also; air pollution is the single largest environmental risk factor for premature death and household air pollution due to burning of solid fuels is responsible for over 65 000 premature deaths and more than 3.1 million disability-adjusted life–years per year [23]. The deaths attributed to household air pollution are due mainly to lower respiratory tract infections (36, 144 cases in 2016), with the greatest impact in the first 6 days of life [12, 16,]. In 2016, air pollution was the most important environmental risk factor for chronic respiratory and cardiovascular diseases, stroke and pneumonia (figure-14.).

5.2 Environment and Climate Change

The greenhouse emission burden, forests and woodlands are degraded where biomass is harvested in more than natural yields. This degradation reduces the potential of forests to soak up CO_2 thus contributing to net emission of

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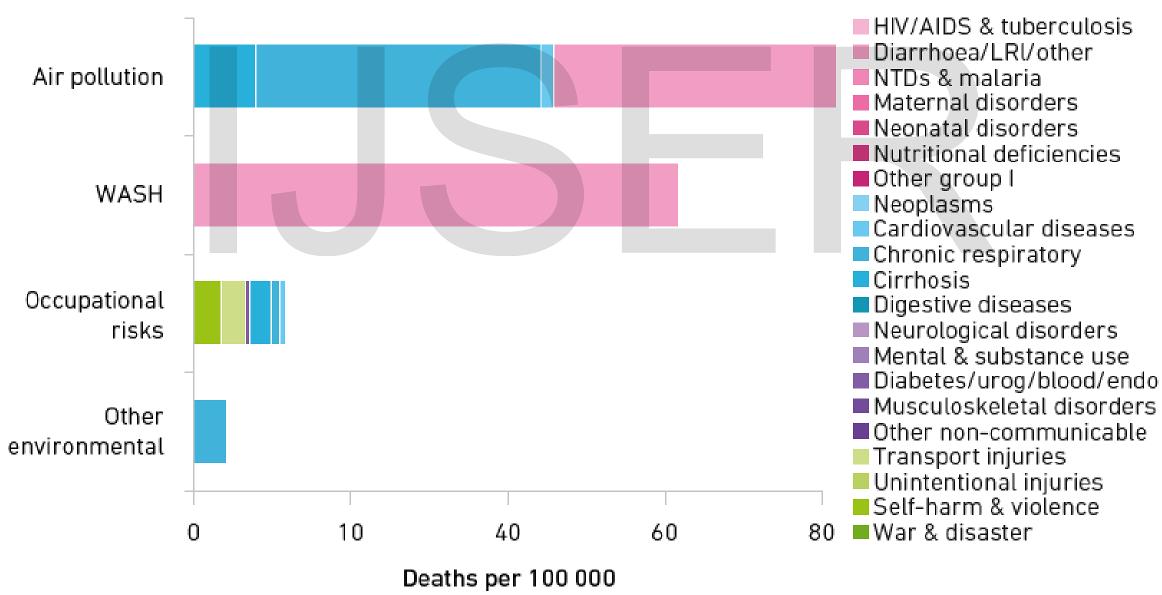
CO2 to the atmosphere. The Nature Conservancy estimates that communities that cook over open fires generate 25% of the global CO_2 emissions [48]. See box-1

Since; biomass has important benefit in the overall energy balance; its inefficient use in developing countries has been linked to a number of adverse environmental effects like excessive deforestation at local, regional and national scales, and decline in crop yields in addition to indoor air pollution and [16, 40, 48]. Thus, the high and direct dependence on biomass energy coupled with low efficiency in its end use at household level, mainly for cooking on open fire, are contributing to unnecessary high level of biomass resource extraction and consumption.

This great dependence on biomass is believed to have led chronic depletion of forest resource, there by resulting in declining in welfare of households, a reduction in agricultural productivity, and environmental degradation.

The figure 15 below illustrated the percentage of land covered by the forest in Ethiopia verses year. Due to the huge demand of the biomass and inefficient utilization; currently In many localities and places in Ethiopia, people are now left with no choice but use animal dung and crop residue as their main sources of energy, which constitutes a significant of the total energy supply of the country [49].

Figure 14: Environmental risk factors for death in Ethiopia, 2016

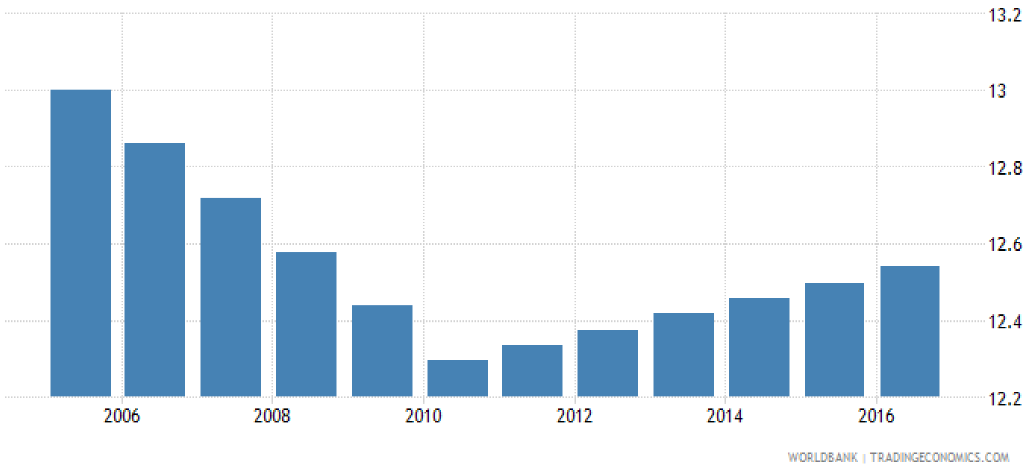


5.3 Gender and Household Labor

Biomass fuel is usually collected from the local environment, most frequently by women. This time consuming activity diverts time from productive and family activities. During a typical week, family members spend a considerable amount of time collecting fuel, whether from common village land or farmer's fields.

In Ethiopia the time spent collecting fuel per day is considerable for both rural and urban areas. It is estimated that 41% of in rural area spent more than 2 hours collecting fire wood and this figure is 23% for urban regions. The fuel collection burden, endured by women, is significant with significant impact on loss of productive and home sustaining potential. In addition to this biomass fuel collection often demands walking long distances carrying heavy head loads unsafely.

Figure 15: Tendency of Forest Coverage in Ethiopia in the Period between 2006 And 2016

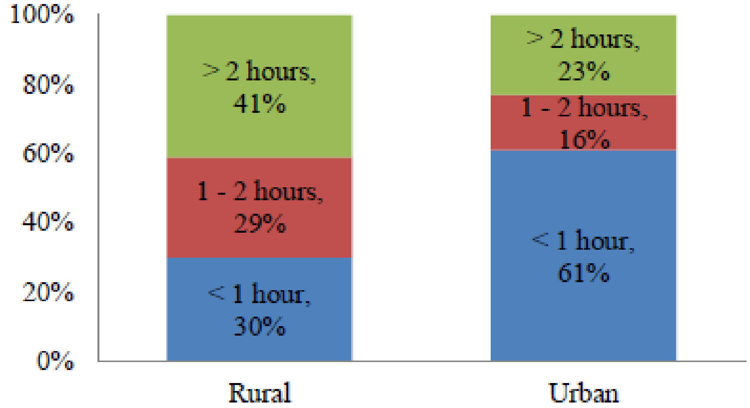


Box: 1. biomass cookstoves and Black carbon emission Source: Ramanathan and Carmichael

Black carbon

Smoke from biomass cooking emits both black carbon (BC), which is largely elemental carbon, and organic carbon (OC), where carbon is combined with other elements, such as oxygen and hydrogen. BC and OC are referred to as aerosols (fine particles suspended in the atmosphere), and have a significant impact on climate. BC absorbs sunlight, and has a significant net warming effect, while OC reflects sunlight back into space and has a cooling effect on the atmosphere. Both BC and OC are the components of soot, a carbonaceous substance generally defined by its means of production, incomplete combustion, rather than by its chemical or physical properties. The aerosol emissions from biomass cookstoves consist of both BC and OC; hence they combine warming and cooling agents (these are accounted for separately from GHGs, such as CO2). Moreover, aerosols interact with clouds and affect the climate in ways that are not yet fully understood. While the emissions characteristics of biomass burning in cookstoves are considered critical for climate science, there is surprisingly little concrete scientific data on such key factors as the ratio of OC to BC. This ratio is critical for calculating the effect of household biomass combustion in global climate models. As a result, there is still significant uncertainty about whether BC emission from use of biomass in cook stoves has a net warming effect on climate globally.

Figure 16: Collection times for households collecting fuel wood



Source: CSA (2013) Ethiopia Time Use Survey 2013.

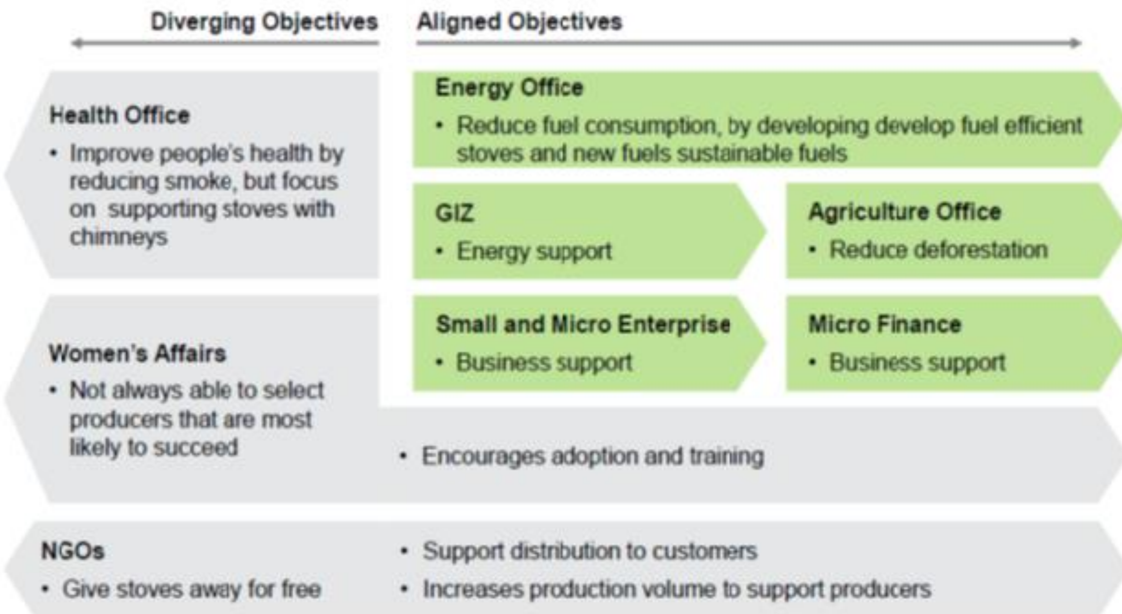
6. Distribution and Adoption of Improved Biomass Cookstove

6.1 Adoption and Distribution Data

Since the development of biomass cookstove started in the government institution; responsibility for the dissemination of appropriate energy technologies was also by the government in the same year 1970s. Among institutions that contributed to the development of biomass cookstoves in Ethiopia the government took the prime initiative followed by multi-lateral cooperation, and more recently the academic and research institutions. Currently; improved cook stove are disseminated by various initiatives such as the Gaia project [22] and a CDM project implemented by World Vision along with the Gesellschaft für Internationale Zusammenarbeit (GIZ). By the mentioned organization and Ethiopian government; various types of improved biomass cook stoves have been delivered in both urban and rural Ethiopia. As summarized in the graph below; there are multiple organizations supporting the cookstove development and market, each with different objectives and approaches that are not always aligned.

The biomass cook stoves which are currently promoted through multi-lateral collaborates- GIZ-ECO are the Mirt, Tikikil–pot sized stove, and Institutional Rocket Stoves (IRS). GIZ-ECO in collaboration with stove producers has been disseminating the three stoves. Mirt is distributed by private businesses in urban and semi-urban areas where as Tikikil was mainly distributed through humanitarian organization to highly vulnerable settlements such as refugee camps and communities in highly degraded areas. Institutional rocket stove (IRS) is disseminated in restaurants, prisons and university cafeterias in the country World Vision Ethiopia is another actor which has been working in the cookstove sector in collaboration with GIZ-ECO to disseminate biomass stoves to rural areas taking the combined emission saving to be considered for carbon saving projects such as voluntary market and CDM outlets. SNV using the National Biogas Programmed of Ethiopia (NBPE) support a researcher to design injera baking biogas stove bringing a result which could further be refined to obtain a wide spread use of the stove [36].

Figure: 17. Organization concerned for the adoption and distribution of improved biomass cookstoves.



Several institutions including the Alternative Energy Development and Promotion Directorate of MoWIE, GIZ-ECO, SNV, research & academic institutions are working on development and promotion of both clean and fuel efficient cookstoves in Ethiopia (see figure-17).

Table 5: Distribution of improved cookstoves by Ethiopian government and GIZ

Region	2011	2012	2013	2014	2015	2016	2017	Sum
Oromiya	529 744	613 245	1 491 263	892 861	886 082	685 259	707 139	5 805 593
Amhara	598 747	419 831	80 769	93 583	104 879	255 256	205 736	1 758 801
SNNPR	106 366	124 616	122 374	135 457	80 485	133 439	124 401	827 138
Tigrai	16 488	34 420	0	82 605	103 789	140 517	130 413	508 232
Benshangul-Gumaz	5 685	2 895	2 971	4 170	2 809	7 993	10 615	37 138
Dire Dawa	800	4654			538	3 200	13 741	22 933
Somale	113	35				1 500	1 500	3 148
Afar						1 523	3 500	5 023
Harari						4 682	600	5 282
Gambela						424		424
Addis Ababa	60 885	199 147	182 498	383 183	223 470	373 149	296 500	1 718 832
GIZ		85 585	124 325	95 661	112 377			417 948
Total	1 318 828	1 484 428	2 004 200	1 687 520	1 514 429	1 606 942	1 494 145	11 110 492

Source: data found from Water, Irrigation and Energy 2018

6.2 Factors affecting improved cookstove adoption and distribution

There are various challenges and variables are likely to affect the speed of adoption of new technologies, as not everyone in developing countries is willing to pay for or want to use the improved cookstove technologies [55-62]. For example, household perceptions related to biomass fuel availability, information related to trends in the price of biomass fuels, as well as information related to the technology. Though; East African is hub for the event and marketing of improved cook stoves since the 1980s; there are differences in the rates of uptake of stoves between the countries. Kenya is the number one country that is called for best adoption and distribution of the technology [57]. Slaski and Thurber (2009) stated that the determinant of adoption of a new technology is inherent incentive or motivation because of human beings by nature resistant which is connected with the perceived value of the new product or service. In general; a variety of subjective and objective factors affecting the uptake and sustainable use of improved cookstove in a given country, one of these might be technology characteristics, policy and standards, market development, financial and Subsidy, awareness and perception, and the support and emphasis from the local government, the publicity, after-sale service and so on. The slow rate of adopting the improved technology in Ethiopian also believed basically form the limitation of the technology related to safety of handling the stove (hotness of external surface problem), durability, and improper installation and insufficient production of the stove or in availability of the ICS in the local market and the cost of the product [56]. The main factors that hinder the diffusion of the improved cookstove to every household are:-

1. Unclear regulatory responsibility and Lack of coordination from responsible parties
2. Insufficient market development and Inadequate Infrastructure for the distribution
3. Education or knowledge, lack of awareness and perception by individually household members.
4. Age, gender, marital status, Family size and Cultural factors
5. Household characteristics
6. Price of the product, Unaffordability and Source of fuel-wood

6.3 Unclear regulatory responsibility and Lack of coordination

Regulatory (policy, licenses, quality, standards, etc.) and rural energy development activities relevant to household energy aren't clearly designated per se. Institutional infrastructure, from federal to woreda level, would have the benefit of sustained capacity-building to enhance planning, programming and implementation. Government stakeholder consultations showed that the responsibility for household energy is spread among many ministries, such as the Ministry of Water, Irrigation and Electricity (electricity, biogas, solar, technology development and promotion), the Ministry of Mines, Petroleum and Natural Gas (biofuel) and the Ministry of Environment, Forestry and Climate Change (national improved cooking stove programmer) and other organization shown in the figure above. For example, weak links between the Ministry of Water, Irrigation and Electricity and the Ministry of Agriculture and Natural Resources has limited cooperation on promotion of biogas as a clean fuel Such “soloed” responsibility and lack of coordination are obstacles to designing a coherent strategy to reach Government policy goals, such as the targets for emission reductions in the climate-resilient green economy.

6.4 Insufficient market development and Inadequate Infrastructure

The market has not developed sufficiently to support private sector enterprise. Entrepreneurship has not been encouraged, and there has been little return on investments in new ideas and technologies [55-62]. There is no a clear cut integration and interaction between different parties involved in the duty.

The availability of clean fuels is limited by poor market development, limited distribution networks and relatively small-scale production facilities. Small- and medium-sized enterprises working on clean cooking solutions have limited access to investment capital for their businesses, and they operate with low profit margins [55-62].

Inadequate Infrastructure for distribution poses a barrier for the use and adoption of improved cookstove just like any other renewable energy resource and technologies in the country [55-62].

6.5 Education, Knowledge and perception

It is obvious, the knowledge and awareness of the characteristics of cleaner fuels and perception of environmental protection and energy-saving affect the adoption behavior. A field study from, Warkaw.L 2015, in rural area of shoa Oromiya region, indicated that about half the household studied has no asses to the knowledge about improved cookstove; despite the survey result also show among who were aware households about the advantages of improved stove only 32.0 percent of households were adopted; generally indicated that limited knowledge or information about cleaner stoves is a crucial barrier in the deployment and sustainable use of the things.

Education level is a crucial factor affecting the knowledge and perception, a review by Lewis and Pattanayak (2012) indicated that education is positively and statistically significant factors that determine the adoption of improved cookstoves across. Educated potential customers are more likely to bear in mind of the advantages of improved cookstoves as compared to uneducated or less educated customers (Inayat, 2011; Menon &, Thandapani, 2011; Adrianzen, 2009). Studies reviewed generally , people with relatively high education levels like better to use cleaner high-quality fuels, and reduce the consumption of traditional solid fuels and understood the extent of the danger using unsafe traditional cooking methods [55-62].

Generally; If Households lack adequate information on the negative health outcomes related to inefficient combustion of solid fuels; it'll impede the expansion of market demand for improved also as clean cooking stoves. It means; in Ethiopian Improving household awareness and adoption of unpolluted energy would require clear messages and capacity-building work [].

6.6 Age, gender, marital status, Family size and Cultural factors

The family size, age, and gender of a member within the family also have direct or indirect impacts on the ICS adoption. From the review by Lewis and Pattanayak (2012), and work from Dawit (2008) and Puzzolo et al (2013) it's understood; the old prefer preferable to use traditional solid fuels and the young tend to adopt the ICS easily. When it's explore for the marital status; a single woman means in female-headed household research found it's more likely to adopt improved cookstoves as compared to married women male-headed counterparts (Damte & Koch, 2011; Inayat, 2011; Adrianzen, 2009). This might be related with the explanation that in male leading family, economical decisions are made by the male but the cooking tasks and also the negative impact related with its carried by the ladies and the children (see graph below); therefore it's not sensed enough by the husband to adopt the technology.

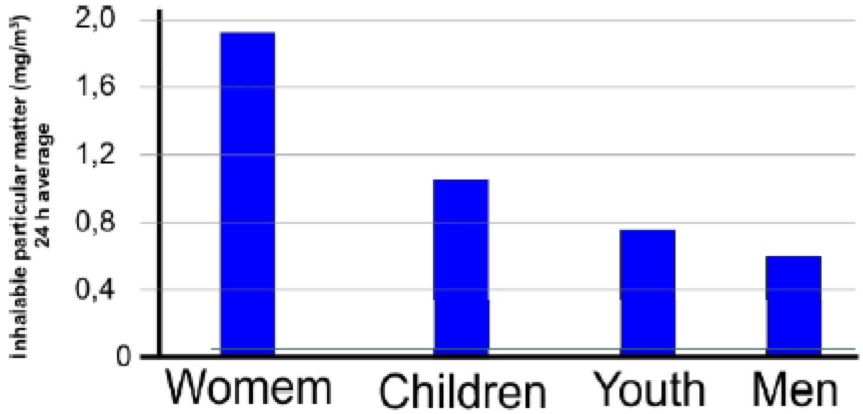


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Figure 18: Pollution effects from smoke particles on users of traditional cook stoves and load of the effect with respect to family member.

In addition, the investigate study by [60] also showed that the female is more willing to alter to the cleaner high-quality fuels as compared with the male. to examine the cultural effect here on the adoption; In many settings of our country, women don't have the income to get a replacement stove and believe their husbands, who could also be immune to purchasing a replacement appliance, albeit their wives are convinced of its benefits.

Different studies [55-62] revealed a statistically direct correlation between improved cookstoves adoption and enormous family size. These authors claim that households with larger family size consume larger fuel wood as compared to households' smaller family size that ends up in influencing larger family size households to economize fuel wood usage and therefore the likelihood of finding an informed person within the larger family is quite that of the smaller ones

6.7 House structure and area

Puzzolo et al (2013) found constituency among research results that having a separate kitchen may be a positive and statistically significant factor in determining a household's improved cookstoves adoption decision. Previous studies found a separate kitchen houses mutually significant factor that features a positive effect on a household's improved cookstoves adoption decision [55-62]. These works investigated the direct correlation between the separate kitchen and improved cookstoves adoption. Based on the prevailing literature, having a separate kitchen is predicted to possess a positive effect on households' Mirt stove adoption decisions within the study areas. Households with kitchen are expected to be found more likely Mirt stove adopters with the idea that since Mirt stove is larger in size and technically fixed in nature, additional space is required [60].

6.8 Price, Unaffordability and Source of Fuel-wood

Lack of money may be a major constraint. In rural areas, where the majority of the population lives, firewood is perceived as a "free" commodity, despite the time required to gather it. The study by Levine et al (2013) found that the lack of the poor to pay the value of improved cookstoves is one among the important barriers of adoption decision. And also the systematic review of Puzzolo et al (2013) found constituency among research results that higher socioeconomic status may be a positive and significant factor in determining a household's improved cookstoves adoption decision. Geary et al (2012) found that the free availability of fuel-wood one among the factors that cause the choice to not adopt improved cookstoves. Source of fuel-wood is that the determinant factor of improved cookstoves adoption decisions (Inayat, 2011). The investigation found that households not collecting wood for free of charge were found more likely to adopt improved cookstoves. A study by Pine et al (2011) also found that access to the open forest is found to be negatively correlated and statistically significant with the probability of improved cookstoves adoption decision. It is Investigated a direct correlation between lack of access to open forest and improved cookstoves adoption and the other way around. supported this empirical evidence, one can hypothesize that households that get fuel-wood with the charge to be found more Mirt stove adopters as compared to households that obtain fuel-wood for free of charge within the study area [59]. It's assumed that for households that get wood for free of charge, fuel-wood saving or efficient use of wood might not be their concern while fuel-saving the priority for people who buy wood.

7. CONCLUSION AND RECOMMENDATION

The limitation of using the unclean biomass cookstove is enormous; the problem is happing all over the world. The indoor air pollution, the death, the sickness, the greenhouse gas emission, the deforestation and land degradation, the incapability of the girls and the women being socially actives are the major problem listed all over the literature.

The mentioned problems are basically affecting the developing countries, which do not have a clean cooking access and a better technological advancement to resolve the root cause of the problem easily.

Like any other developing country, Ethiopia is also facing the problems regarding the situation massively. Per year in the county; thousands of premature death are registered, millions of sickness and illness are reported, woman's' and youngster waste their time collecting fire wood more than an hour, drought resulted from land degradation is also a major problem.

To thinking about the condition, working on it and stopping those problems seems quite a huge breath taking, because; the people in Ethiopian are entirely dependent on nature for their existence.

To reduce and resolve the problem, globally; it has been worked for the past decades because the condition with the unclean cookstove is creating a death far more than, the deaths frightened like HIV. All over the globe; Works on the design and adaptation and distribution of the improved clean house cooking stoves are done.

Our Government with different organization also initiated with great ambition and has been involved to resolve the problem lately; in the country since 1995. But it appears that the efforts are found not good enough to go even an inch in the field of designing an improve biomass cookstove.

The researches, the reviewed articles generated from different peoples indicated that the design aspects of the improved cooks stove for ijera making (Mirt, Gounzye for Injera baking) are not suitable to be adopted as expected he country. The pointed out reasons are:

1. They consume relatively larger area of kitchen floor.
2. They are balk in size and difficult to be handled by women's.
3. They are not advocated enough to be accustomed.

4. The price of the material is unaffordable and
5. They are not available in most of the local market of rural areas.

The performances of these stoves are also classified as Tier-0 that means; the stoves are not suitable for the energy efficient cooking and regarded as unsafe that generate pollutant and cause indoor pollution. In addition to these facts, injeral baking consume a huge amount of energy in the house hold energy demand. Therefore efforts are demanded to improve Injera baking stove (Mitads).

The most adopted and distributed the improved cookstove of Ethiopia is Lakech. Lakech has a better performance and relatively less pollution generation. But when we see the market areas for cook stoves; it is easily screened both the traditional and improved cookstove together (see figure). This indicates that the traditional charcoal cookstove has still market. The reasons for the persistence of demand for the unimproved cookstove might be (as per the review research).

1. The price of the improved cookstove is much higher than the traditional
2. The price of the traditional cookstove is much much lower than the improved one.
3. The improved cook stove production and distribution is not enough
4. Awareness about the difference cookstove is not created enough
5. The obtainability of biomass might not as such hard enough to worry to switch the stove

Seeing these, Works should be done to create awareness on people about the problem related with the use of the traditional cookstove and even it might need to ban the production of such kind of cookstoves in the country. And also the manufacturing of the improved charcoal stove should done hostilely by the small and micro-sized business sectors in collaboration with the responsible parties to resolve the basic problem of availability of the stove in the market and cost. In turn this effort will creates job opportunity.

Even if the rocket type cookstove- Tikkile, Ezy and IRS have a good performance than Mirt and Gonziye; their distribution are limited to specific tasks and location.

Different types of improved cookstoves are also seen in different refugee camp (see Appendex-2), but their design is not copied or knowledge related with it is not transferred enough to local people to adopt the technology and to improve the existing Ethiopian cookstoves.

Generally; in these aspect every one – the educated, - the delegated, - the responsible, the involved, the participated, the rich, -the expert and ever one is expected to work hard to resolve the problem related with unclean cookstove situation of the country.

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Appendix -1

Table: MATERIAL OPTIONS AND THEIR ADVANTAGES AND DISADVANTAGES

Lists of several types of materials that can be considered for use in a biomass cook stove, advantages and disadvantages, and possible stove components. This is not a complete list of available materials, but meant to provide a starting point for exploring possibilities

MATERIAL	ADVANTAGES	DISADVANTAGES	STOVE COMPONENTS
Ceramics			
Clay brick (common)	Low cost Widely available High service and melting temperature Low thermal expansion Can be cast into different shapes	Low strength Density varies depending on type Thermal conductivity varies depending on type Difficult to determine type/ quality of clay Long drying and curing time (2-3 weeks) Requires controlled firing at high temperature	Combustion chamber/ refractory liner
Cement	Moderate cost Widely available Can be reinforced w/ aggregate or steel wire to provide strength Can be cast into different shapes Low thermal expansion	High density High thermal conductivity Long drying and curing time (3-7 days) High environmental impact	Binding additive in insulating mixture
Refractory cement	Moderate cost High durability Resistance to high temperature	High density High thermal mass	Cast combustion chamber
Metals			
Aluminum	Easy to machine or form Low density Moderate strength Reflective foil can be used for radiative insulation	High cost Very high conductivity Low availability Low service and melting temperature	Radiative insulation

MATERIAL	ADVANTAGES	DISADVANTAGES	STOVE COMPONENTS
Cast iron	High strength High service and melting temperature Can be cast into different shapes	High cost Very high conductivity Low availability of scrap iron Melting and casting is difficult	Cone deck and pot supports Grate
FeCrAl alloy steel	High service and melting temperature Good corrosion resistance Moderately easy to form	High cost Low availability Very high conductivity	Combustion chamber/ liner
Mild steel	Low cost Widely available	Low service and melting temperature Poor corrosion resistance	External component (door, handles, legs,etc)
Minerals			
Calcium silicate	Low density Very low thermal conductivity	High cost Not widely available Low strength Aerosol dust is harmful if inhaled	Insulation layer
Ceramic fiber	Low density Very low thermal conductivity	High cost Not widely available Very low strength Exposed fibers irritate skin Aerosol fibers are harmful if inhaled	Insulation layer
Vermiculite	Low density Very low thermal conductivity Produced from common laminar magnesium-aluminum-iron silicates (e.g., mica) Can be mixed w/ binder and cast	Moderate cost Not widely available Low strength Natural deposits can include harmful minerals (e.g., asbestos) Granular material- needs to be contained or cast w/ a binder	Insulation layer

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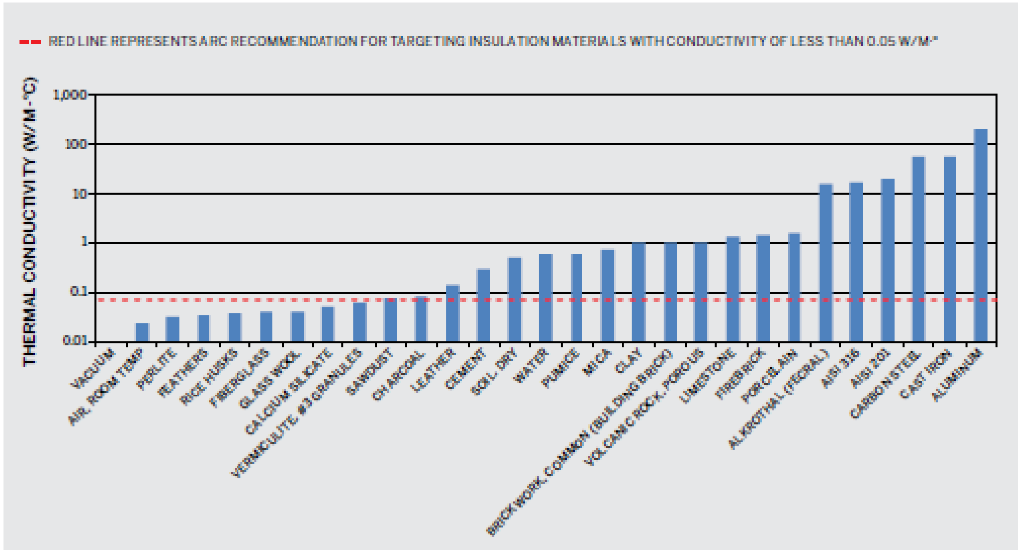
FIGURE THERMAL CONDUCTIVITIES OF COMMON COOKSTOVE MATERIALS.



Appendex-2

West Guji (Oromia Region) and Gadeo Zones (Southern Nations, Nationalities, and Peoples' Region provided by IOM in 2019

Reference. https://ethiopia.iom.int/iom-starts-providing-energy-efficient-cooking-stoves-6500-internally-displaced-households-and-host

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The Berkley stove

Finnish Turbo Stoves

Distributed by UNHCR in Burumino refugee camp in Dollo Ado, Ethiopia

https://blumont.org/innovation/fuel-efficient-stoves-an-introduction