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Assessment of Electric and traditional Open- Fire Stoves Utilization to Reduce Environmental Impacts and Energy Conservation in the Case of South Gondar

Addisu Worku Bezabih

Debre Tabor University, Department of Electrical and Computer Engineering, Debre Tabor, Ethiopia

Abstract

To assess the possibility of biomass based injera backing and mirt stove to contribute the reduction of environmental issues such as indoor air pollution and energy conservation. Environmental degradation is a global problem, but it must be dealt with onseveral different scales: local, regional, national and international.The predominant use of conventional biomass fuels, combined with the use of inefficient technologies, is leading to environmental deterioration and the prevalence of health problems caused by indoor air pollution. The levels of these pollutants in the kitchen were measured using carbon monoxide data loggers. According to the conclusions of this investigation, installing a Mirt burner in the kitchen. Carbon monoxide and particulate matter levels were reduced by 88.8% and 17.3%, respectively, when the analysis was done over an 8-hour period. The 15-minute maximum exhibited a similar trend, with carbon monoxide levels of 91.5 percent and particulate matter levels of 19.3 percent. The mean pollutant concentration during baking time is the most essential measure to compare these stoves. In comparison to athree stone fire system, the result suggests that it might reach a particular fuel consumption of 45 percent.

Key words: *1.* energy conservation *2.* carbon monoxide (CO) *3.* particulate matter (PM), Mirt stove *4.* three stone fire *5.* Fuel efficiency *6.* Human health *7.* South Gondar

1. Introduction

Ethiopia, as one of Sub-Saharan Africa's least developed countries, faces a serious domestic energy crisis. The country's domestic energy challenge is expressed, among other things, by the country's relatively low per capita energy consumption and the prevalence of traditional biomass fuel use. According to the Mengistu, M. G., Simane, B.,

Eshete, G., &Workneh, T. S. (2015). Electricity is arguably the most versatile of fuels, capable of providing a wide range of energy services, from running electronics to providing light, motive power, and heat, typically as efficiently as or more conveniently than other fuels, with very low environmental and human health impacts at the end-use level.Nowadays, climate change is one of the most important global issues to the international community. And nearly thirty kinds of greenhouse gases have been found in the atmosphere, of which the carbon dioxide plays a crucial roleWu, W., Ma, X., Zhang, Y., Li, W., & Wang, Y. (2020). Our health is influenced by the environment in a variety of ways. Environmental risks have been proved to have a major impact on human health, either directly by exposing humans to toxic agents or indirectly by affecting life-sustaining ecosystems. Although the specific involvement of environmental variables in the development of mortality and disease is unknown, the World Health Organization (WHO, 2009) estimates that environmental factors cause thirteen million deaths each yearTyagi, S., Garg, N., &Paudel, R. (2014). Cooking is a major source of indoor particulate matter (PM)Zheng, S., Wang, M., Wang, S., Tao, Y., & Shang, K. (2013).The World Health Organization argues that 18% of global carbon dioxide (CO2) emissions are attributed to energy and to the fuel used by the residential sectorNathaniel, S. P., &Iheonu, C. O. (2019).

Worldwide, approximately 2.8 billion individuals—almost 41% households—use solid fuels for heating and cooking purposes Bonjour, S., Adair-Rohani, H., Wolf, J., Bruce, N. G., Mehta, S., Prüss-Ustün, A., ... & Smith, K. R. (2013).Biomass fuels account for more than half of total energy consumption in many developing countries, and up to 95 percent of total energy consumption in some of the world's poorest countries. It accounts for more than 90% of overall energy use in Ethiopia. For developing countries like Ethiopia, where people rely mostly on biomass fuels like wood, charcoal, and agricultural leftovers, technological advancements in energy efficiency are crucial. One of the outcomes of these efforts in the country is the invention of the ‘Mirt' biomass Injera stove Mengistu, M. G., Simane, B., Eshete, G., &Workneh, T. S. (2015).

It is all known that the increase in greenhouse gases in the atmosphere can lead to global warming and climate change. The source of greenhouse gases in our atmosphere are mainly water vapor, carbon dioxide, nitrous oxide, ozone, and methaneRamanathan, V., & Feng, Y. (2009) andSt. Louis, V. L., Kelly, C. A., Duchemin, É., Rudd, J. W., & Rosenberg, D. M. (2000). The most crucial area in Ethiopia, according to ESD, is improving household cooking efficiency. Lakech (‘excellent', ‘good') improved charcoal stove may be built in 1991 based on this fact. Commercial manufacture of Lakech (improved charcoal burner) began in early 1992 in Addis Ababa, according to the ESD report. Millions of these enhanced stoves have been sold to far, saving approximately 25% on charcoal when compared to regular burners Barbieri, J., Riva, F., & Colombo, E. (2017). Hundreds of hectares of ecologically and economically important dry land forest in Ethiopia have been saved as a result of this. Each Lakech stove saves 75 kg of charcoal per household per year on average. However, burning wood causes a slew of problems

that are cause for considerable concern. The widespread use of old fuels, combined with inefficient technology, is leading to environmental degradation and the prevalence of health concerns caused by indoor air pollutionWassie, Y. T., &Adaramola, M. S. (2021).

Economic growth and investments in health care and renewable energy projects will allow them to take use of their enormous renewable energy resources, enhance citizens' health, and combat climate changeOyedepo, S. O. (2012). More commerce and more renewable energy usage lower carbon emissions, implying that both are effective measures for combating global warmingJebli, M. B., Youssef, S. B., & Ozturk, I. (2016). Human life depends on the availability of energy. Food preparation and preservation, access to water, agricultural production, health care, education, job development, climate change, and environmental sustainability are all influenced by it Oh, S. H., Legros, M., Kiener, D., &Dehm, G. (2009).

1.1 Environmental Impacts

Environmental issues, such as potential benefits such as avoided greenhouse gas emissions, regional, local, and indoor air pollution, potential costs such as the impacts of power lines on animal populations, and considerations such as compliance with local and international regulations and protocols, as well as grid interconnection operation coordination to maximize environmental benefits.Harvesting and burning are the two most significant environmental impacts of the domestic fuel cycle. Fuel harvesting in rural areas of developing countries has been widely reported to cause deforestation. However, in many parts of the world, extensive investigations have rarely found examples where fuel consumption is a substantial source of deforestation. Nonetheless, this is not the case in Ethiopia. According to the study, the large reliance on fuel wood, combined with its poor and unsustainable consumption, has resulted in massive deforestation and environmental degradation. The Ethiopian Environmental Protection Authority (1998) recognized that increased demand for fuel wood and charcoal, among other things, is one of the principal causes of forest loss in the country. As stated in this document, existing Acacia woods in the dry plains are being drained at an alarming rate for fuel wood, particularly in the area along the lower Awash Valley. Over 2 billion people are affected by global fuel shortages Witt, M. B. (2005). Forests in developing countries are fast dwindling, according to this analysis, and the forest-to-people ratio is less than half of what it was in 1960. A study of 15 emerging countries conducted in 1989 revealed a massive demand for fuel wood. According to Witt, M. B. (2005), 669,000 hectares of forest are required each year. However, only roughly 63,000 hectares were replanted, which is less than 10% of the total need.

1.2 Health Impacts

The physical shape and pollutant content of fuels are the two factors that most influence the quality of pollutant emissions produced when they are burned. It is often difficult to

appropriately premix solid fuels with air in small-scale devices such as domestic stoves to ensure good combustion. As a result, while most biomass fuels contain few toxic toxins, they are frequently burned inefficiently in residential stoves, resulting in a wide spectrum of health-damaging chemicals. As much as one-fifth of the carbon in the fuel is redirected to incomplete combustion products. Biomass-dependent households typically utilize the fuel indoors, in open flames or poorly operating stoves, with inadequate smoke venting WHO, (2000). Small particles, carbon monoxide, nitrogen dioxide, formaldehyde, and carcinogenic compounds such as benzo[a]pyrene and benzene are all present in biomass fuel smoke, which is hazardous to one's health.Indoor air pollution levels in these households are exceedingly high, many times the WHO standards, according to studies from Asia, Africa, and the Americas (Table 1). PM10 levels in biomass-using homes in Africa, Asia, and Latin America typically range from 300 to 3000 micrograms per cubic meter (g/m3) over a 24-hour period.

Table1.Health affecting limits according to WHO's Exposure Guidelines

Product	Concentration	Time limit
Carbon monoxide	100 mg/m3	15 min
	60 mg/m3	30 min
	30 mg/m3	1 hour
	10 mg/m3	8 hours
Formaldehyde	100 µg/m3	30 min
Lead	1 µg/m3	1 year
Nitrogen dioxide	400 µg/m3	1 hour
	150 µg/m3	24 hours
Ozone	200 µg/m3	1 hour
	120 µg/m3	8 hours
Sulfur dioxide	500 µg/m3	10 min
	350 µg/m3	1 hour
	125 µg/m3	24 hours
Suspended particles	100 mg/m3	24 hours
Benzene	60 mg/m3	1 year

Source: Usinger 1996

As previously stated, wood-burning stoves are responsible for a large portion of indoor air pollution. Incomplete burning of wood releases fine particles and carbon monoxide, which cause acute respiratory diseases, ear and eye issues, dyspnea, chest pains, migraines, disorientation, and other symptoms, many of which affect women and children Witt, M. B. (2005).The most extensively used measure of the health danger of indoor air pollution is small particles with a diameter of up to 10 microns (pm10). Fine particles having a diameter of up to 2.5 microns (pm2.5) can penetrate deep into the lungs and have the most health-damaging potential. These particles have been shown to

promote inflammation of the airways and lungs, as well as hinder the immunological response WHO, (2006). Inhaling indoor smoke increases the risk of pneumonia and other lower respiratory tract infections in children under the age of five.

Because biomass will continue to dominate energy consumption in developing nations for the foreseeable future, more efficient and cleaner biomass technologies are critical for reducing poverty, creating jobs, and expanding rural markets IEA, (2002). Women and people in the middle- and lower-income sectors of society are the main benefactors of improved stoves.Adoption of better stoves can have substantial economic and environmental consequences for communities Barnes, Douglas F., Keith Openshaw, Kirk R. Smith and Robert Vander Plas, (1994). It can also improve food safety and nutrition by increasing the number of hot meals taken per day Alemayehu, Y. A. (2015). In fact, it has been recognized that a conflict exists between high efficiency and low emissions. This often yields an overall efficiency but increased emissions. It is therefore vital to measure stove emissions and not to assume that a high efficiency stove will have low emissions. The procedures and equipment used for monitoring are determined by the analysis and monitoring conditions. Only in circumstances where the findings clearly exceed or go below the limitations can simple measurement methods be used. The goal of this study was to see if the biomass-based Injera baking stove (Mirt stove) could help with environmental Sheehan, J., Aden, A., Paustian, K., Killian, K., Brenner, J., Walsh, M., & Nelson, R. (2003). The concentration of gaseous pollutants can be determined in one of two ways: first using reacting chemicals or using catalytical opto-electronic sensors. Chemical sensors, such as test tubes, contain chemical reagents that react with airborne contaminants and seconda distinct reagent is required for each pollutant

The HOBO CO logger, which was used in this research, is an example of such a method. Sensors are used to determine the amount of pollution in the air. The measured value is displayed on a digital readout. The equipment in this technology transfer. Our health is influenced by the environment in a variety of ways. Environmental risks have been proved to have a major impact on human health, either directly by exposing humans to toxic agents or indirectly by affecting life-sustaining ecosystems. Although the precise role of environmental factors in the development of death and disease cannot be determined, the World Health Organization (WHO) estimates that thirteen million deaths are caused by preventable environmental factors each yearLandrigan, P. J., Espina, C., &Neira, M. (2011).Environmental degradation poses a significant threat to human health worldwide. Climate change and other atmospheric changes, land use changes and soil degradation, freshwater depletion and contamination, and biodiversity loss are four major areas of global environmental change that all pose significant dangers to human health, albeit partially or entirely unknown McMichael, A. J., & McMichael, T. (1993).

2. Materials and Methods

2.1 Study area

In order to analyze the stove's influence on reducing indoor air pollution and conserving energyMasera, O., Edwards, R., Arnez, C. A., Berrueta, V., Johnson, M., Bracho, L. R., ... & Smith, K. R. (2007).Instead, it was conducted as an experimental type study at a specific location. The experiment took place in South Gondar, Ethiopia. The study site is located in the South Gondar Debre Tabor city. For this project, a temporary shade was built on the GTZ-SUN Energy office site in Bahir Dar city to simulate a regular kitchen. Three of the kitchen's walls were made of canvas. The kitchen's fourth wall is a concrete wall that was built to act as a fence. The kitchen's roof is made of corrugated iron sheet. The kitchen is estimated to be roughly $32m^3$ in size. Although we tried to make the shadow as realistic as possible.For the stoves, bricks were used to create a platform that was 10 cm off the ground. Both stoves were installed in the same spot. The instruments were kept in the same area when using the Mirt stove and anthree stone fire.

2.2 Data Collection and processing

The UCB Particle Monitor was used to measure the amount of suspended particulate matter (University of California, Berkeley). The HOBO Carbon Monoxide Data Logger was used to measure carbon monoxide levels Singh, A., Tuladhar, B., Bajracharya, K., &Pillarisetti, A. (2012). Data from the UCB and HOBO monitors was obtained using the protocols listed in the annexes. All of the data obtained on the data collection page was entered into Excel spreadsheets. The most recent version of the program was used in this inquiry. The software is divided into two parts. The first component of the software is the UCB PM Browser, and the second is an excel spreadsheet Chowdhury, Z., Le, L. T., Al Masud, A., Chang, K. C., Alauddin, M., Hossain, M., ... &Hopke, P. K. (2012).

2.3 Statistical Analysis

Despite the fact that this study's primary goal was to examine the Mirt stove, the statistical analysis of the two most critical indicators to consider when analyzing stove efficiency was conducted using SPSS statistical software and a Microsoft Excel spreadsheet. To examine stove efficiency, the t-test was utilized as a statistical tool.

4. Results and Discussion

Cook stove emissions are frequently analyzed for carbon monoxide (CO) and suspended particulates. The following is the medical rationale for choosing these contaminants: Carbon monoxide is a dependable indicator of danger Lam, N. L., Smith, K. R., Gauthier, A., & Bates, M. N. (2012). In the characterization of a stove, further descriptive data is required. An 8-hour average was used to calculate the time required for the smoke to completely dissipate.The 15-minute maximum and the 95th percentile are two further parameters to consider when comparing stoves that are operating at their worst. As a result, a flurry of studies has been conducted to investigate the health risks caused by climate change.

4.1 The average pollutant concentrations

The average carbon monoxide and particulate matter concentrations in the Mirt stove and three stone fire conditions, respectively, are depicted in Figures 1 and 2. One-way analysis of variance was used to compare these results in Table 2. The concentrations of carbon monoxide differed in a statistically significant way.

Table 2. shows the average pollutant concentrations during an eight-hour period for each stove type.

	Stove type	Three stone fire	Mirt	F
8-hour CO concentration (ppm)	Means	25.10	2.80	34.27
	Standard dev.	12.37	2.55	
8-hour PM concentration (mg/m3)	Means	0.32	0.26	0.39
	Standard dev.	0.18	0.23	

When compared to athree stone fire system, these data reveal that Mirt stoves can reduce carbon monoxide emissions by 88.8% and particulate matter concentrations by 17.3%.The pollutant concentration levels in this study varied greatly throughout an eight-hour period Hanna, R., Duflo, E., & Greenstone, M. (2016). During the 8-hour period, CO concentration had average coefficients of variation (defined as the ratio of standard deviation to the mean; a measure of data variability relative to its mean) of 0.91 and 0.49, respectively, for Mirt and three stone fire stoves.For the same time period, the coefficients of variation of particulate matter for Mirt stove and three stone firestoves are 0.88 and 0.56, respectively. This means that each CO measurement measured deviates from the mean by almost 91% and 49% of the means of the Mirt stove and three stone fire respectively. In the case of the Mirt stove, the most variation is found. This demonstrates that the Mirt stove's burning process was not consistent. This could be due to poor fire management or stove operation management. If the stove is not used properly, it may emit more pollutants than anthree stone fire system. In two

of the tests, for example, a similar situation was seenLiyew, K. W., Habtu, N. G., Louvet, Y., Guta, D. D., & Jordan, U. (2021).

As shown in figure 1, the bulk of the carbon monoxide measurements for Mirt stove are in the 0 to 10 ppm range. Maximum values ranging from 20 to 40 ppm were found more frequently in the case of athree stone fire. The frequency distribution of mean particle matter shows little variance. With the highest frequency, values ranging from 0.2 to 0.3 were reported in both stove scenariosMahata, K. S., Panday, A. K., Rupakheti, M., Singh, A., Naja, M., & Lawrence, M. G. (2017).

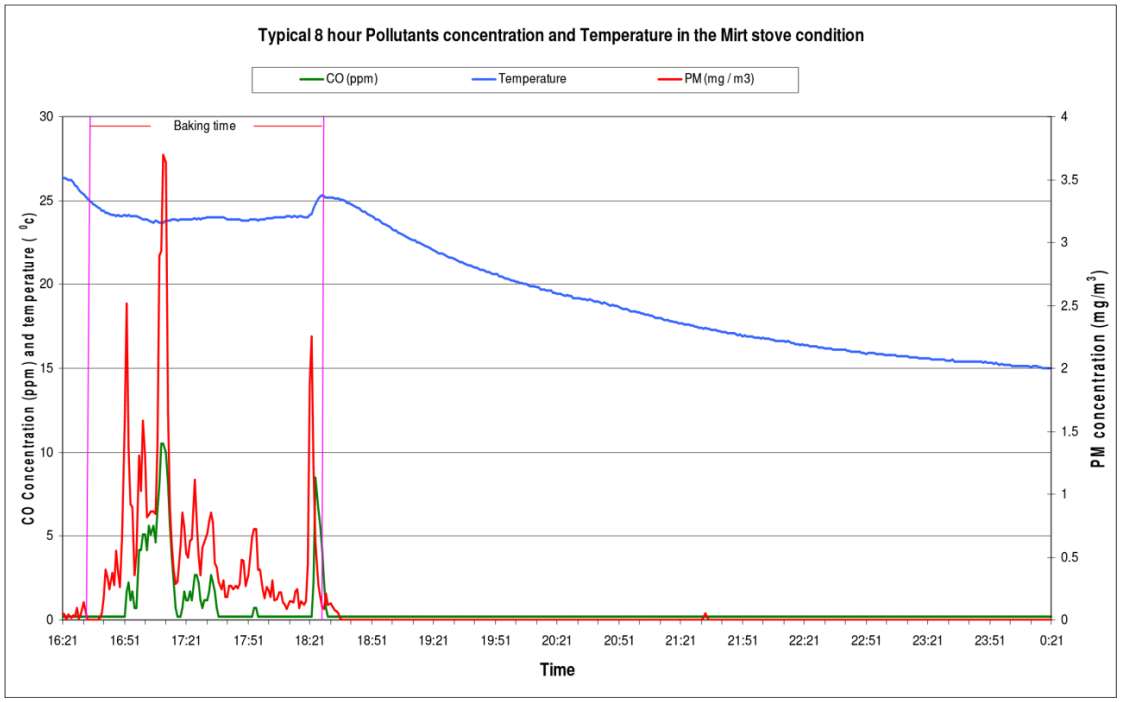


Figure 1: Data from an 8-hour monitoring test showing CO (ppm), PM (mg/m3), and temperature (0°C) in Mirt stove conditions.

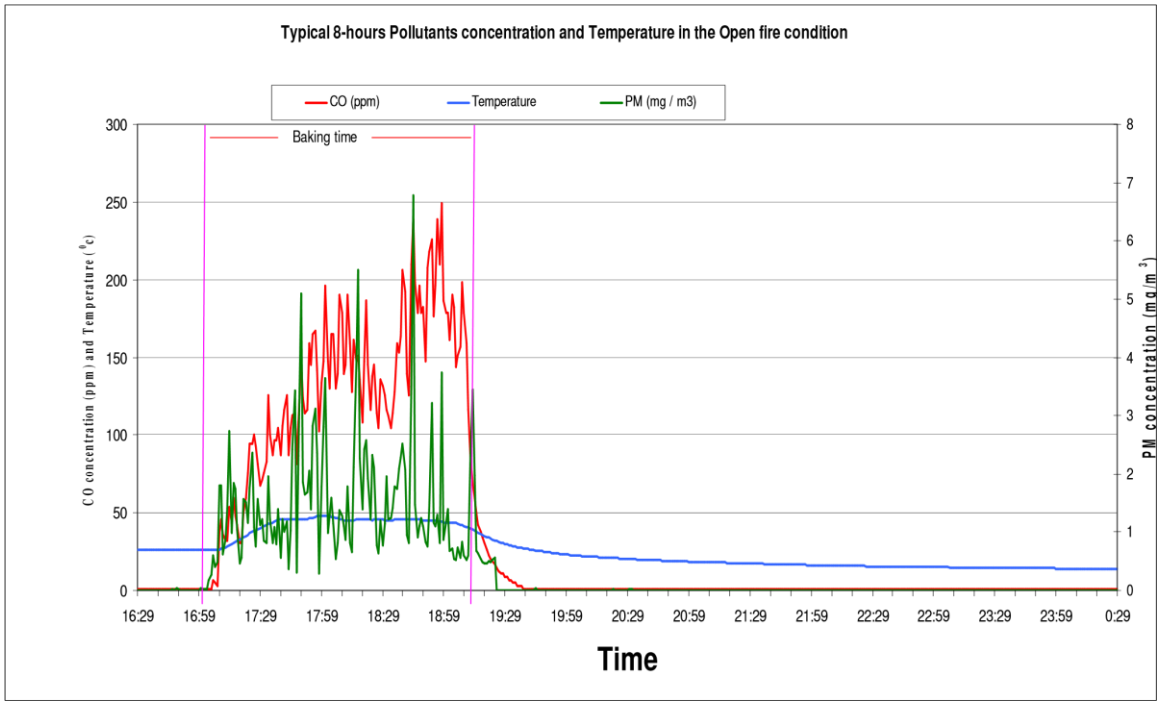
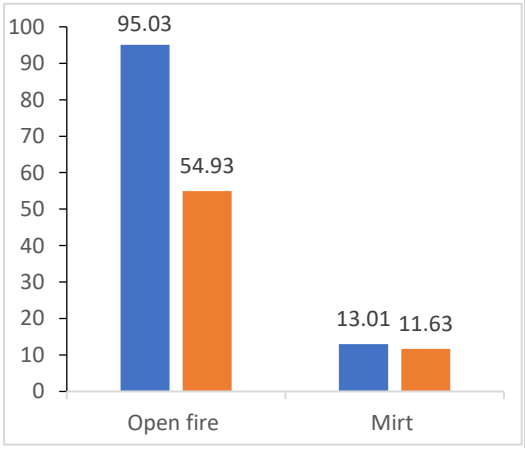


Figure 2: CO (ppm), PM (mg/m3), and temperature (0°C) in athree stone fire setting from an 8-hour monitoring test.

Pollutant concentrations in the kitchen last longer while using athree stone fire than when using a Mirt stove. The time it takes for pollutants to decompose appears to be proportional to the number of pollutants produced during the baking process. It is commonly known that in the kitchen, particulate matter is generated by more than just fuel combustion. As a result, we track the amount of PM before and after the event Christian, T. J., Yokelson, R. J., Cárdenas, B., Molina, L. T., Engling, G., & Hsu, S. C. (2010) and Negash, D., Abegaz, A., & Smith, J. U. (2021).



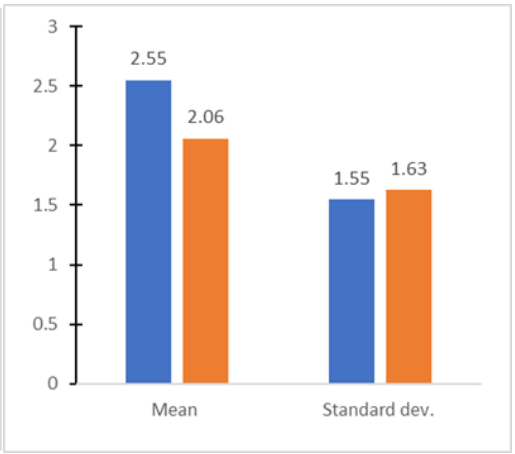
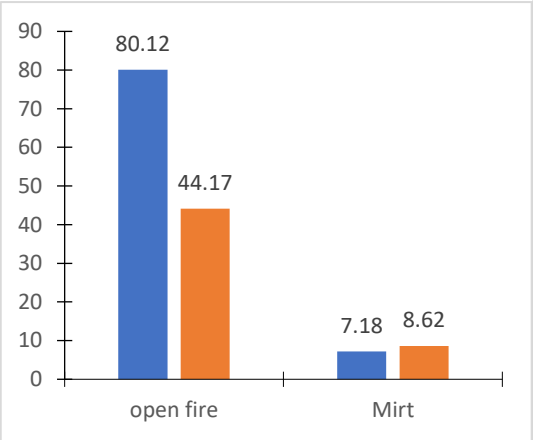


Figure 3. The max. CO concentrations in 15 minutes Figure 4. The max. PM concentrations in 15 minutes

In the experiments we ran with the three stone fire, the average CO content (95 ppm) was close to the WHO 15-minute exposure maximum limit (100 ppm) to avoid severe poisoning. The result of the Mirt stove tests (13 ppm) is far lower than this. The average CO concentration during three stone fire baking (80 ppm) is significantly greater than the WHO limit for 1-hour CO exposure (30 ppm). From figure3 and 4. (7 ppm) is extremely low in the Mirt stove condition.



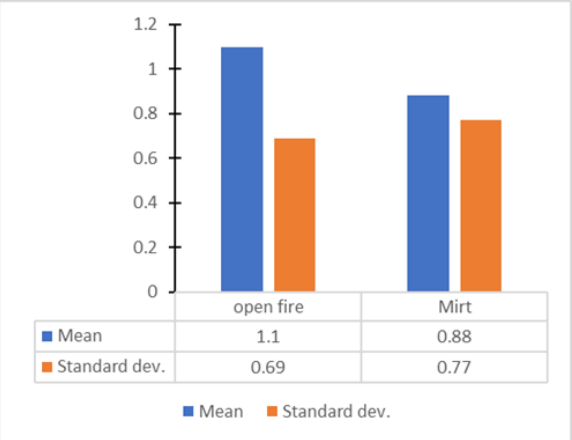
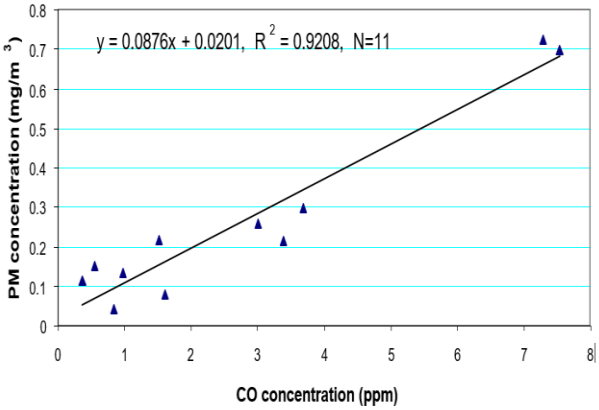


Figure 5. The average CO conc. during the baking process.Figure6.The average PM conc. the baking process.

As shown in table 6, the average CO concentration in athree stone fire system is 80.1 ppm, while it is 7.2 ppm in a Mirt stove setting during baking. In this case, the CO level from the Mirt stove may be reduced by 91%. Although the two stove conditions have a slight difference in PM concentration (19.3 percent) (figure.5 and 6).The correlation coefficient in four of the Mirt stove tests and two of the three stone fire tests was between 0.55 and 0.72. These results are close to those published by Naeher, L.P., K. R. Smith, B.P. Leaderer, L. Neufeld and D.T. Mage, (2001). From athree stone fire kitchen (R2 = 0.5) and (R2 = 0.14 – 0.91) Ezzati, Majid and Daniel M. Kammen, (2002).The cause of the fluctuation could be anything. One source of diversity is the nature of the contaminants. Particulate emissions are affected by a variety of factors, including the type of appliance used, the chimney, the fuel used, and the firing behavior. Another reason could be pollution sources. Residential biomass combustion produces two types of primary particlesZhao, Y., & Zhao, B. (2018, October).



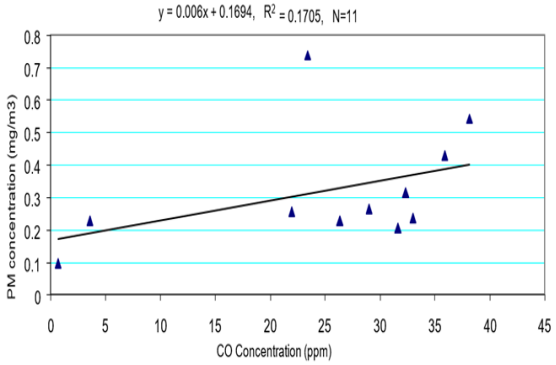


Figure 7. PM and CO Mirt stoveFigure 8. PM and CO of three stone fire.

As stated in many of the documents, utilizing CO as an indication of suspended particulate matter is problematic from an exposure assessment standpoint (fig. 7 and 8).

4.2 Efficiency of Mirt stove

An average home saving 570 kg of fuel wood per year by using an improved Mirt burner for Injera making. The buyer of the stove has a payback period of about 2-3 months, while the stove has an average lifespan of about 4-5 years and an efficiency of more than 33% Workneh,(2005).

Table 3. The three pairs of backings were tested for stove efficiency.

1. CCT results: Mirt	**Test 1**	**Test 2**	**Test 3**	**Mean**	**St. Dev**
Cooked food total weight(g)	10060	10190		10125	91.9
Remaining charcoal weight(g)	490	710		600	155.6
Consumption of equivalent dry wood(g)	5473	5722		5597	176.5
Fuel consumption by kind(g/kg)	544	562		553	12.4
Total backing time (min)	134	137		136	78.2
2. CCT results: Three stone fire					
Total weight of food cooked (g)	10500	10580	10610	10563	56.9
Weight of char remaining (g)	740	640	670	683	51.3
Equivalent dry wood consumed (g)	10091	9906	10700	10233	415.5
Specific fuel consumption (g/kg)	961	936	1009	969	36.7
Total backing time (min)	107	108	115	110	4.4
Three stone fire vs. Mirt Stove comparison		**t-test**		**Sig @ 95%**	
Fuel consumption by kind(g/kg)		-18.60		Yes	

Backing time in total(min)	0.56	No

4.3 Efficiency of renewable energy

The average monthly household energy use in Ethiopia is roughly 120.7 kwh, and the greenhouse gas emissions entered above are 0.086 metric tons of carbon dioxide equivalent.

Table 4. Greenhouse gas and CO_2 emission in electricity uses.

Greenhouse gas emission from electricity	
Passenger vehicle driven for one year	0.019
Miles driven by average passenger vehicle	215
CO2 Emission	
Gallons of gasoline consumed	9.6
Gallons of diesel consumed	8.4
Pounds of coal burned	94.5
Homes energy use for one year	0.01
Number of smart phones charged	10405

Indeed, economic growth needs energy (fossil or renewable) that has an immediate impact on CO_2 emissions. Our long-run parameter estimates show that per capita GDP has a positive impact on per capita carbon dioxide emissions Ben Jebli and Ben Youssef (2015). These traditional stoves or fires are characterized by low efficiency that results in inefficient use of scarce fuel-wood supplies Anozie, A. N., Bakare, A. R., Sonibare, J. A., &Oyebisi, T. O. (2007). Electricity is usually regarded as the cleanest domestic fuel Howells, M. I., Alfstad, T., Victor, D. G., Goldstein, G., &Remme, U. (2005). Moreover, the use of renewable energy sources is serving to lessen emissions of carbon dioxide, nitrogen dioxides, and particulate matters, which can ultimately decrease the mortality rate and extend the life expectancy in Ethiopia.

5. Conclusion

Greenhouse gas emissions are increasing, posing a major threat to the environment and human health. We advise these countries to pursue economic growth while also investing in health care and renewable energy projects, which will allow them to take use of their enormous renewable energy resources while also improving the health of their citizens and combating climate change. Furthermore, encouraging developing countries to embrace clean technologies has proven to be a smart policy for improving health and reducing carbon emissions in the fight against global warming. the average CO concentration in athree stone fire system is 80.1 ppm, while it is 7.2 ppm in a Mirt stove setting during baking. In this case, the CO level from the Mirt stove may be reduced by 91%. Although the two stove conditions have a slight difference in PM concentration (19.3 percent). Understanding the projected effects of climate change on

human welfare is essential for identifying the best strategy for dealing with the growing greenhouse effect. CO monitoring will continue to be a valuable tool for grading homes depending on their emission levels. Because the episodic nature of indoor smoke necessitates small-scale monitoring technology, such as the one used here CO's value as a technique for determining scattered particulate matter exposure is limited. Consequently, any exposure assessment should analyze scattered particle matter using techniques designed for this purpose. As a result, it's apparent that utilizing a Mirt stove throughout the baking process lowers CO levels.To those in charge of energy policy, "energy security" has always meant ensuring access to oil and other fossil fuels.

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