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Household Energy Usage, Indoor Air Pollution, and Health

Sarah L. Hemstock[1], Mark Charlesworth[1] and Ranjila Devi Singh[2]
[1]Bishop Grosseteste University, Lincoln, UK
[2]Faculty of Science, Technology & Environment, The University of the South Pacific, Suva, Fiji Islands

Synonyms

Cooksmoke; Eco-feminism; Solid fuel local pollution

Definitions

Bioenergy Solid biomass used primarily for domestic uses (heating, cooking) and industrial applications (heat and power), for both small- and large-scale uses; biofuels refer to liquid biofuels (biodiesel and bioethanol) used primarily in road transport (Rosillo-Calle et al. 2015).

Biomass A biological material, living or dead, but excludes that which has become fossilized or mineralized. Biomass energy is a renewable energy resource which includes all plant matter (trees, shrubs, crops, forest and crop residues, etc.) and animal dung which has potential as a source of energy.

Household energy usage It is here intended to convey the energy directly used within a dwelling and any directly associated activities, e.g., outdoor cooking or in outbuildings. The principle concern here is with domestic energy services – energy used for preparing sustenance (food and drink), space heating, and lighting. It is recognized that households may use energy for other purposes and are typically dependent on energy used by those who provide the household with services – e.g., municipalities. For the purposes of this chapter, the focus for household energy use will be on domestic energy services provided by direct combustion of fuels such as biomass to meet household energy needs for cooking, space heating, and lighting.

Improved cookstove A cooking stove that is more efficient and emits less indoor air pollution or is safer than a traditional cook stoves or three-stone-fires. For this chapter,

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improved cookstoves are burning either firewood, charcoal, agriculture residues, or dung. There are literally thousands of different designs of improved cookstoves, they can be portable or fixed – installed in a kitchen; they can be made of a range of different materials, e.g., metal (including roofing iron), cement, or clay/mud; with or without a chimney; and they can have a range of different sizes.

Indoor air “Air within a building occupied for a period of at least one hour, by people of varying states of health” (WHO 2005, p. 6); biomass which is burned for cooking, heating and lighting homes is recognized as the major source of indoor air pollution (WHO 2005).

Indoor air pollution An atmospheric condition in which certain substrates (e.g., gasses, aerosols, particulates) are present in a form and concentration that can produce undesirable effects on people and their environment. For the purposes of this chapter, in considering indoor air pollution it is recognized that there are sources of air pollution in dwellings other than those generated by combustion for sustenance and lighting – for example, formaldehyde and volatile organic compounds (cf. OECD 2003); nonetheless focus will be on the use of bioenergy for cooking, heating, and lighting as the most essential and significant cause of health concerns from indoor air pollution (WHO 2018).

Woodfuels All types of bioenergy derived directly and indirectly from trees and shrubs grown in forest and nonforest lands. Woodfuels also include biomass derived from silvicultural activities (thinning, pruning, etc.) and harvesting and logging (tops, roots, branches, etc.), as well as industrial by-products derived from primary and secondary forest industries that are used as fuel. They also include woodfuel derived from ad hoc forest energy plantations. Woodfuels are composed of four main types of commodities: fuelwood (or firewood), charcoal, black liquor, and other (Rosillo-Calle et al. 2015).

Introduction

It seems likely that households have used energy for cooking for as long as there have been households. Globally, until the industrial revolution, this would have been principally woodfuel, agricultural waste (e.g., straw), dried dung, and charcoal, with some regions relying on coal and peat. Archaeological evidence suggests the use of oil lamps for lighting appears to also stretch towards the beginnings of households, with ceramic decorated lamps dating from a few thousand years BC (Cam 2014).

Today, although difficult to estimate because traditional biomass energy use (for cooking and heating) is not accurately captured in energy statistics, bioenergy sources currently supply around 10–13% (1365 to 1775 million tons of oil equivalent annually) of the world’s primary energy making biomass the world’s fourth largest energy source (Hemstock and Singh 2015; International Energy Agency 2017). Around 70% (955 to 1242 million tons of oil equivalent annually) of this bioenergy use is in developing countries. It is used in the form of traditional woodfuel (fuelwood and charcoal), agricultural residues, and dung to provide domestic energy services, mostly for cooking, by burning on open fires in 41% (Bonjour et al. 2013) of households in the world. These energy sources, along with coal and peat in some areas, are often inefficiently used and can be environmentally detrimental. They are deleterious to health when used traditionally and in inefficient domestic appliances in poorly ventilated cooking areas. Gender is also an issue as women are usually customarily responsible for cooking, meaning that women and children are at greater risk of exposure to high levels of indoor air pollution. In some least developed countries and in lower income households of developed countries, biomass provides more than 90% of total energy consumption for the populations who live in rural areas (Hemstock and Singh 2015).

A common issue affecting biomass, solid fossil fuel, and oil use for domestic energy services is that the products of combustion (smoke) are harmful to health if inhaled in substantial amounts over long periods of time, often leading to a range of illnesses such as pneumonia and significant impacts on increasing rates of mortality (WHO 2018; cf. Poddar and Chakrabarti 2016).

Tragically, indoor air pollution is a key causal factor child pneumonia – a leading cause of death in children under five in many least developed countries, accounting for the deaths of around half a million children under the age of 5 years annually (Mortimer et al. 2017). This is clearly contrary to SDG3 Good Health and Wellbeing (UN 2015). Issues surrounding indoor air pollution and health are also directly linked to SDG7: Affordable and Clean Energy, which is related to fuel and technology choices available for domestic energy services, which are in turn linked to SDGs 1, 2, 4–6, and 8–13.

Prospects for Improving Outcomes

Sustainable Development Goals have been set, but how are we planning to achieve these in terms of past efforts to improve health outcomes by reducing people's reliance on traditional domestic bioenergy services? In 2006, the International Energy Agency estimated that in rural areas of developing countries around 2.5 billion people were reliant on biomass (woodfuel, agricultural waste, and animal dung) to provide domestic energy services for cooking and that this service alone accounted for over 90% of household energy consumption. The International Energy Agency (2006) report also predicted that by 2030, 2.7 billion people (one third of the global population) would still be reliant of biomass energy for basic household energy services if no specific action was taken to address this situation. At that time, the UN Millennium Project (UN 2005; UN Millennium Project 2005, p. 30) set development goals and target indicators related to energy for cooking recommended "enabling the use of modern fuels for 50% of those who at present use traditional biomass for cooking. In addition, support (a) efforts to develop and adopt the use of improved cookstoves, (b) measures to reduce the adverse health impacts from cooking with biomass, and (c) measures to increase sustainable biomass production."

Based on International Energy Agency (2006) figures, the United Nations Millennium Project recommendation (UN 2005) of reducing the number of households reliant on traditional biomass for cooking by 50% by 2015 would have involved switching 1.3 billion people to other fuels and technologies for domestic energy services. The United Nations Millennium Project (2005) recommendations were not achieved, and the worst-case International Energy Agency (2006) scenario of 2.7 billion people being reliant on biomass energy for cooking by 2030 was actually a reality by 2015. This is truly a disastrous situation, compounded by our increasing knowledge of the adverse effects of indoor air pollution on health. For example, in 2005 there were 2.5 billion people reliant on traditional bioenergy and around 1.3 million people annually – mostly women and children since they spend most time indoors – were thought to die prematurely due to exposure to indoor air pollution (International Energy Agency 2006). However, knowledge and information relating to health implications and links to wellbeing of indoor air pollution estimates suggest that in 2010, continued exposure to polluted indoor environments is linked with in excess of 3.5 million (uncertainty interval: 2.7, 4.5 million) premature deaths each year and 4.3% of global disability adjusted life years (Lim et al. 2012). By 2015, 2.7 million people were reliant on traditional biomass, (International Energy Agency 2017).

Lessons learnt

Firstly, it must be recognized that there are two complementary approaches that can improve outcomes for reducing the impacts of indoor air pollution:

1. Promoting more efficient and sustainable use of traditional biomass
2. Encouraging people to switch to modern cooking fuels and technologies

The fuel switch and/or technology choice made depends on local circumstances and considerations such as per capita income and the availability of a sustainable biomass/fuel supply (International Energy Agency 2006).

Secondly, the complementary approaches outlined above rely absolutely on financing – the availability of cash at the household level to pay for new equipment and/or fuel switching. It is apparent that the failure of the United Nations Millennium Project (UN 2005) to reduce the number of households reliant on traditional biomass for cooking by 50% by 2015 was mainly due to a lack of financing for this initiative. The means of achieving the complementary approaches (re efficient technology choices and alternative fuels and technologies) were technically available and achievable, but were out of reach of biofuel dependent households due to affordability. Additionally, the International Energy Agency (2005) predicted that in order to achieve a 50% reduction as per the UN Millennium Project target, providing LPG (liquefied petroleum gas) stoves and cylinders, for example, would cost at most US$1.5 billion per year to 2015. This appears to be an underestimate of annual costs when considering replacing "free" traditional biomass at the household level, based on a household LPG consumption costing around US$250 per year; costs would more likely be in the region of US$5 billion annually – and that would only provide one year's worth of fuel for each household over the period from 2005 to 2015. It also seems reasonable to assume that the poorest people, more than 1 billion of whom were living on less than US$1 per day, would have means to pay for either kerosene or LPG – even if financing for the stoves, heating and lighting apparatus that use these fuels were available. Despite these shortcomings, LPG was the favored technology of the UN Millennium Project, this is because LPG burns clean, appliances are more efficient than traditional stoves so cooking time is reduced, and, most importantly, substantially reducing indoor air pollution by between 51% and 80% for particulate matter and 74–81% for carbon monoxide (Bates 2005). From surveying the current literature, it would seem that the focus of achieving relevant SDGs has again given emphasis to LPG. This is despite failings reaching MDG targets and recognition that poverty and supply chain issues are major barriers to LPG adoption for domestic energy services in least developed countries. Additionally, the start-up cost (purchase of cooker/burner, cylinder, regulator, and hose) for using LPG for cooking is still too high for the majority of low-income households in developing countries such as India (D'Sa and Murthy 2004; Goswami et al. 2017). On top of that, there are limited distribution networks, which means that getting to a place where an LPG tank can be collected and exchanged is an additional household expense (D'Sa and Murthy 2004). However, in support of achieving the SDGs, we now have the Global LPG Partnership (GLPGP). This is an UN-backed, nonprofit Public-Private Partnership formed in 2012, under the UN Sustainable Energy for All initiative. The purpose of GLPGP is "to aggregate and deploy needed global resources to help developing countries transition large populations rapidly and sustainably to liquefied petroleum gas (LPG) for cooking" (GLPGP 2012). So, at least here, with the creation of the GLPGP, the development initiative "fail-repeat-fail again" paradigm outlined by Easterly (2007) of *let's do everything exactly the same and hope that it turns out better* is not being followed *exactly*. It is clear that there are many barriers to overcome – the main one being that people in poverty cannot afford LPG, so the bottom line here is: lift people out of poverty or buy the LPG for them. If the GLPGP are unable to accomplish either of those pre-requisites, then they are unlikely to achieve their mission of "Lifting One Billion People from Energy Poverty" (GLPGP 2012). Let us not also forget that LPG is a fossil fuel and its use does have adverse effects on the environment, not least in terms of greenhouse gas emissions that contribute to climate change impacts. Although LPG has a comparatively lower ratio of carbon to hydrogen when compared to other hydrocarbon fuels, for example, it has only 50% of the carbon footprint of coal, it does not really deserve the clean-green fuel tag it has gained internationally.

By contrast, in many low-income communities in developing countries, the replacement of kerosene and oil lamps by efficient electric lamps powered by renewables such and photovoltaics with battery storage is underway and already relatively successful, cost effective for communities and achievable by commercial means with minimal governmental intervention (Roche and Blanchard 2018).

However, not all domestic energy services can be met by small-scale solar photovoltaics. The situation for preparing sustenance is much more complicated and in many cases more acute. The reasons for this are that if cooking needs cannot be met from agricultural waste and dried dung then firewood will typically be sought; however, in many locations firewood has increasingly limited availability caused by and leading to deforestation, making free collection of firewood more difficult and encouraging commercial extraction and distribution (cf. Chikulo 2014, 5965). Chikulo (2014) also points to the possibility of increased incomes allowing the growth of other options for cooking such as kerosene and electricity; however, with over 1.2 billion people still having no access to electricity, for many areas of the world grid supplied electricity is likely to be many years away if it ever occurs (Ahlborg and Hammar 2014). In these cases at least, intermediate technologies should be considered:

- More efficient cookstoves, that both reduce fuel use and reduce indoor air pollution, are one possibility that has been deployed in numerous forms in a variety of locations. Success has been mixed for a range of reasons such as robustness, ease of maintenance, and cultural acceptability. For example, Goswami et al. (2017) suggest that involving local tradespersons and civil society – typically local religious organizations – may be key in effective deployment of improved cookstoves. This current study has estimated that to achieve a 50% replacement of traditional biomass by improved cookstoves by 2030 would cost in the region of US$1.2 billion annually. Additionally, it should be noted that, for the past four decades, efforts to reduce indoor air pollution have focused on the distribution of a variety of improved cookstoves – where *improved* usually means that various individuals and agencies have been improving the *efficiency* of cookstoves while keeping their fingers crossed for a corresponding decrease in emissions. Therefore, despite the promotion and dissemination of millions of improved cookstoves throughout developing countries, the issues of reliance on biomass energy for domestic energy services and its associated indoor air pollution continue to persist. This lack of success is due to numerous reasons, comprising lack of awareness of the issues, a focus on improving efficiency rather than reducing emissions, and a lack of affordable stoves and fuels that decrease exposures substantially (Williams et al. 2015), along with a lack of exposure-response data (Williams et al. 2015). Recognizing the extent of this problem, the UN Foundation Global Alliance for Clean Cookstoves was launched in 2014. Bruce et al. (2015) asserted that planning must account for the fact that the 2.7–2.8 billion people relying on solid fuels are also the world's poorest, and moreover that experience has shown that securing technology adoption and lasting use of clean and efficient stoves and fuels can be very challenging, for reasons that involve a wide range of factors. Of significant note is that no solid fuel cookstove, improved or otherwise, has been assessed as meeting all WHO indoor air quality guidelines (WHO 2014).
- Solar cookers score highly on emissions reduction, but work only intermittently and can only be effective if their technology matches or can

match the culinary habits and social/cultural demands of the users; however, harmful side effects need to be considered, such as reduced insect repellent effects from less smoke in the household. A project introducing improved cookstoves and solar cookers to households in the Peruvian Andes leads to the loss of essential clothing and bedding due to an increase in insect activity. To achieve a 50% replacement of traditional biomass by solar cookers by 2030 would cost in the region of US$1.9 billion annually.

- A more flexible and arguably more robust alternative is biogas production and use, which more readily allows cooking at a time to suit users and can be used for lighting, electricity production, and space heating. Biogas production still needs sufficient suitable organic matter and sufficient skills to use and maintain the equipment safely (Hemstock 2008). To achieve a 50% replacement of traditional biomass by household biogas (e.g., a 6 cubic meter plastic floating dome digester) by 2030 would cost in the region of US$7.7 billion annually. Biogas is a renewable energy source which is more or less environmentally benign and has the added advantage that the digestate/process slurry can be used as a fertilizer for agricultural crops/family gardens. The potential for household biogas digesters is enormous. Additionally, biogas reduces $PM_{2.5}$. In Buysman's (2015) comparative study of households in Cambodia with and without biogas for cooking, households with biogas showed a reduction of around 36% in exposure and 88% in kitchen concentrations; CO levels are also much lower.

For all these technologies, harmful side effects from changes of cooking processes need to be considered alongside social and cultural considerations related to issues such as solar cooker use and biogas substrate collection and use. Improved cookstoves may not be accepted by households unless they are compatible with traditional pots and pans and cultural practices linked to the preparation of traditional foods. Since women are most likely to be using cookstoves, it is essential that they should be at the center of any cookstove/fuel switching program from the outset. Additionally, women should be in control of implementation of activities within the household, such as installing stoves, as well as be trained on correct operation and maintenance.

Since developing countries have up to 90% dependence on bioenergy for domestic energy services and have the highest impacts of indoor air pollution, the WHO indoor air quality guidelines (WHO 2014) are designed around their specific needs. The guidelines acknowledge the challenges likely to be faced in implementing activities to reduce impacts of indoor air pollution and provide detailed information on cookstove performance and potential health risks (Amegah and Jaakkolab 2016). Much of the research carried out on indoor air pollution thus far tends to examine just a few impacting factors. Implementation of the WHO (2014) guidelines will require detailed research at local levels to improve understanding of the complexities of indoor air pollution and bioenergy use.

It is worth being clear that the use of biomass both as woodfuel and biogas for subsistence is a different category to the use of biofuels for transport by citizens of wealthy countries, e.g., the use of biofuels mandated by the EU which evidence suggests is leading to issues such as widespread deforestation through plantations of crops to feed the perceived reductions in CO2 reductions (e.g., Helliwell and Tomei 2017). Similarly distinctions of justice should be drawn between luxury biomass cooking, i.e., barbeques by wealthy citizens and subsistence sustenance. Of the 2.5 billion people reliant on biomass energy today the food versus fuel ecosystem services dilemma is a daily reality.

Impacts of Indoor Air Pollution

It is worth noting that indoor air pollution is not measured directly by any national health survey. Global exposure estimates tend to be based on the type of fuel use as a proxy indicator for indoor air pollution (Smith et al. 2014). This represents a large knowledge gap, and the effects of indoor air pollution have been underestimated in the past and are possibly still underestimated for at least the most vulnerable communities. The accuracy of monitoring indoor air pollution must be improved in the future in order to identify and target interventions to those who are most at risk. This could be achieved by using low-cost particulate matter monitors since particulate matter of less than 2.5 μm in diameter ($PM_{2.5}$) is a standard indicator of air pollution. Additionally, the first international standard for laboratory testing of cookstoves was recently published by the International Organization for Standardization (ISO). The WHO IT-1 guideline value for $PM_{2.5}$ is 35 μg/m^3; and the 24-hr average guideline for CO is 7 mg/m3 (WHO 2014).

Clark et al. (2013) carried out a systematic review of indoor air pollution literature where sampling for PM2.5 had occurred. Clark et al. (2013) reported that they found very high baseline average kitchen levels of $PM_{2.5}$, ranging from several hundred to several thousand μg/m^3. Bruce et al. (2015) noted that reducing indoor air pollution using available interventions, such as improved cookstoves, could improve health outcomes by 20–50%, even though interventions would still lead to $PM_{2.5}$ values higher than the WTO IT-1 guideline. Although a broad overgeneralization, in effect, this would mean that if all of the 2.7 billion people currently reliant on bioenergy had access to a current interventions such as an improved cookstove, the current health impacts of indoor air pollution would only improve by 20–50%. However, this overgeneralization does not appear to have a positive spin when it comes to improving observed health outcomes of reducing indoor air pollution by using improved cookstoves. Mortimer et al. (2017) interpretation of a three-year cluster randomized control trial was a sobering "We found no evidence that an intervention comprising cleaner burning biomass-fuelled cookstoves reduced the risk of pneumonia in young children in rural Malawi. Effective strategies to reduce the adverse health effects of household air pollution are needed." It is clear that a radical approach is required that encompasses reductions in PM and CO, improves energy efficiency, is relatively low cost, and has zero carbon emissions. Historically, improved cookstoves are not up to the task – could it be time to focus on biogas?

Health and Wellbeing

Specifically, indoor air pollution exposure has causal impacts on cardiovascular diseases, lung cancer, chronic obstructive pulmonary disease, acute lower respiratory infections and chronic bronchitis, cataract (McCracken et al. 2012; Mortimer et al. 2017; Smith et al. 2014), neonatal mortality, low birth weight, and stillbirth (Amegah et al. 2014; Epstein et al. 2013). Other adverse health outcomes linked with indoor air pollution include pharyngeal and laryngeal cancer, otitis media, asthma, tuberculosis, and nutritional deficit (Amegah and Jaakkolab 2016).

This study estimates that there are around 600,000 average human lifespans of time and effort given over every year to collecting and preparing woodfuel, residues, and dung, as well as environmental sustainability issues associated with traditional biomass use. Additionally, during collection of woodfuel, deleterious impacts on health and wellbeing include assault of women and girls, prolonged contact with disease vectors (e.g., mosquitoes), wild animals, and snakes, which increase the probability of infection, poisoning, and injury. Other negative impacts include school absenteeism and health issues such as musculoskeletal injuries from carrying large bundles of firewood on the head and back for long distances (Oluwole et al. 2012).

Gender

To expand on the relationship between energy for cooking that uses firewood, crop waste, and dung and SDG5 "Gender Equality," the following is vital to be aware of the fact that the collection and preparation of biomass for use as fuel for subsistence rural households in most parts of the world falls to women and children (International Energy Agency 2017; Muller and Yan 2018). This fact alone has many consequences.

Collecting cooking fuels such as firewood is typically time consuming, meaning that activities such as schooling for children, and time for agricultural and other work that can lead to an income is then limited – often significantly (IEA 2017; Chikulo 2014). For women and girls, the activity presents significant risks of harm such as sexual assault. The related processes for collecting water for drinking, cooking, and washing also presents similar consequences.

Traditional forms of bioenergy (fuelwood, agricultural residues, and dung) are viewed as a "free" resource for many of the people reliant on them. However, there is a large human cost, this study estimates around 600,000 average human lifespans of time and effort is spent every year collecting and preparing woodfuel, residues, and dung. These lifespans relate largely to women and girls as they are the people participating in this activity.

It is also typical that the use of the fuel when indoors and with stoves that produce significant quantities of smoke is also the principle responsibility of women and children meaning that they tend to suffer the ill health consequences of such activity more than men (IEA 2017; see Pandey et al. 2017 for some technical details). Around 1.6 billion women and children die each year because of this exposure (UN 2005).

Household Energy Use and Natural Resource Management

Much literature on the subject of biomass energy indicates that women are the primary users of biomass energy (IEA 2017; Joon et al. 2009; Malhotra et al. 2004; Pandey et al. 2017). This is also true of households in Piliura and Tassiriki villages in Vanuatu where woodfuel is the main source of energy for cooking and in 78% of the households surveyed, cooking was done by women. Hence, any initiative to change the sources of energy or type of stove for household cooking should be directed at women and done in collaboration with them. Women are responsible for household energy and any benefits will be directly felt by them. The two projects in India, National Project on Biogas Development and the National Programme on Improved Chulhas were directly targeted at women, were successful in projects conserving fuelwood, reducing kitchen smoke levels, improving health and sanitation, and reducing women's labor from fuelwood collection (Malhotra et al. 2004).

Using results from a household survey of conducted in Piliura (82% of households) and Tassiriki (57% of households) villages in Vanuatu as an example of how household energy use is managed in a developing country rural community; it can be seen that there are tangible and complex links with household income and energy choices, and natural resource management. Analysis reveals that the household income and source of energy for household lighting in both villages is largely determined and managed by men. Males manage the household income for the majority of the households surveyed (64%). Males mostly do decision making around household income use in rural areas. The selection of fuel type has implications for woodfuel use, indoor air pollution, and climate change mitigation, illustrating the importance of understanding gendered divisions of labor and power relations for sustainable resource management. Vanuatu survey results showed that purchase of household electrical appliances will also be determined by males as they dominate management of household income. Only in 19% of the households surveyed the household income is managed by females, in 13% by both males and females, and in 3% by the whole family.

Solar power is the dominant source of lighting in Piliura and Tassiriki Villages and was used by 50% of the respondents. This is followed by kerosene lamp (38%), then candles (9%), and diesel generator (3%). All the households with solar power have bought their own solar panels and solar lamps. They have also paid for the installation. The cost of a solar system (inclusive of installation) varies between US$556 to US$1668 depending on the household requirements. For the respondents, the average diesel generator cost for a week was US$17 and average kerosene cost for a week was US$5 for lighting. Solar power is a renewable and a sustainable source of lighting, while kerosene and diesel are nonrenewable ultimately unsustainable. Lighting in households surveyed was mainly managed by males (74%), in 18% by females, 4% by the family and 4% stated not much lighting was used. According to the results of this research, there is difference along gender lines in the management of lighting for the households that is males dominate the management of household lighting. Women's opportunities with regard to decision making in the households are generally limited and this also applies to household energy. Decision-making in terms of the type, time invested, and use of lighting is determined by men.

For the households that use open fire, 94% of them were located inside while 6% were outside. Woodfuel is the main source of energy used for cooking on indoor stoves, with associated indoor air pollution issues. Additionally, Joon et al. (2009) show that children under 5 years and elders may remain indoors and be exposed to similar health impacts as those cooking. For the households surveyed, the source of energy for cooking was managed by 66.7% of females and 33.3% of males. Even though 78.2% of females did household cooking, only 66.7% managed the source of energy for cooking.

Recommendations for Household Energy Use and Indoor Air Pollution in Relation to the Relevant SDGs

SDG3: Ensure healthy lives and promote well-being for all at all ages

– Fully implement the WHO indoor air quality guidelines (WHO 2014). This will require more than household changes to fuel and cooking technology. For example, for Cambodia, Buysman (2015) showed that levels of household air pollutants may be attributable to ambient air pollution. The study concludes that: “biogas can help address household air pollution, but that the current scale and the focus on clean energy for cooking alone is not sufficient to bring the overall levels of $PM_{2.5}$ near the WHO guidelines. Tackling this requires a community based approach that focusses on clean energy, addresses the ubiquitous problem of the inefficient burning of household and garden waste, and the clearing of agricultural land by burning the crop waste.”
– Behavioral changes, such as not carrying children while cooking or taking them into the kitchen or smoky areas, could reduce childhood household air pollution exposure significantly. Other changes, such as cooking outdoors, keeping the kitchen well ventilated while cooking (e.g., opening the kitchen door), reducing time spent near the fire/in the kitchen, could also have a significant impact on exposure to indoor air pollution. To enable behavioral change, a wide awareness campaign is required which could be facilitated through child health clinics, religious centers, community health workers, midwives, women's group meetings, etc.
– Building standards concerning ventilation (windows, doors, chimneys, outdoor kitchens, etc.) also assist with reducing indoor air pollution. Unfortunately, since traditional bioenergy is used in the poorest households, many of which are built as informal settlements (especially in urban areas), building standards or codes are pretty much irrelevant. In these situations, education and information dissemination are really the most effective approach to ensuring housing improvements for improved health in informal settlements. However, historically, education and information dissemination has not been successful. Some authors, such as Amegah and Jaakkolab (2016), see the key to the success of improved housing for health improvements is enforcement of building standards, but recognize that in developing countries “enforcing building standards is also a major challenge, as construction is often informal without plans and permits. Building inspectorate departments need to be better

resourced, to enable them carry out their functions efficiently." However, state provision of social housing that is decent, available to those most in need, and built in line with national building codes may be the only way to address this impasse.

– Formal education will bring a sustainable element to behavioral change. In order to educate health and community workers about indoor air pollution and behavioral change, teaching resources and information could be embedded into vocational qualifications such as those developed for Pacific regional certificate level qualifications on Resilience (Climate Change and Health stream) and Sustainable Energy. These were developed under the European Union Pacific Technical Vocational Education and Training Project on Sustainable Energy and Climate Change Adaptation (Hemstock et al. 2018; Havea et al. 2018).

SDG6: Ensure availability and sustainable management of water and sanitation for all

– Promote household and community biogas digesters. These are extremely cheap and effective solutions to sanitation requirements and provide benefits such as reduced water use, energy, and fertilizer.

SDG7: Ensure access to affordable, reliable, sustainable, and modern energy for all

– Greater involvement of academia linked with the private sector in order to enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency, and advanced and cleaner fossil-fuel technology. The human aspects of technology adoption and uptake should also be researched.
– Do not focus on LPG or improved cookstoves.
– Focus on biogas as this has been shown to produce significant reductions in PM and CO, improves energy efficiency, is relatively low cost, and, for the most part, has zero carbon emissions.

SDG11: Make cities and human settlements inclusive, safe, resilient, and sustainable

– Biogas is again the answer here since it is capable of reducing the adverse per capita environmental impact of cities, improving air quality and waste management.
– Building standards.
– Social housing that complies with building standards.

SDG12: Ensure sustainable consumption and production patterns

– Biogas, from a household scale and up, reduces waste generation by recycling organic waste into energy and fertilizer. It is an ingenious system.
– Looking at natural resource management and related gender issues could support more sustainable patterns of consumption and production.

SDG13: Take urgent action to combat climate change and its impacts

– Use the Green Climate Fund to support renewable energy technology up-take in developing countries.

SDG15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

– Use more efficient cookstoves.
– Move away from charcoal production for cooking fuel.
– Promote renewable energy technologies such as biogas.

Cross-References

- ▶ Hazardous Chemicals and Air, Water and Soil Pollution and Contamination
- ▶ Health Promotion in the Implementation of SDG
- ▶ Health Risks in the Way of Sustainable Development
- ▶ Public Health and Sustainability
- ▶ Public Health
- ▶ Resilient Communities and Cities: Strategies to Foster Sustainable Development
- ▶ SDG3 Good Health and Well-Being: Integration and Connection with other SDGs
- ▶ Sustainable Diets
- ▶ Systems of Equity: Achieving Health and Wellbeing for Rural Communities
- ▶ Urban Development and Health

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