comment

A pro-health cookstove strategy to advance energy, social and ecological justice

A pro-health fuels and stoves agenda based on the World Health Organization standards can realign lagging progress toward meeting the United Nations Sustainable Development Goal 7's call for universal energy and clean cooking access by 2030, combat the household energy crisis, and promote health and social justice.

Annelise Gill-Wiehl and Daniel M. Kammen

The global community is not on track to meet the United Nations Sustainable Development Goal 7 (SDG7), which calls for the adoption and continued use of clean-burning stoves by the 2.6 billion people worldwide currently relying on solid, smoky fuels[1]. Globally, 2.3 million untimely deaths are attributed annually to household air pollution from unclean stoves[2]. In 2019, household air pollution was a top-ten contributor to global total disability adjusted life years (DALYs), resulting in 230 million DALYs (3.6%; 95% uncertainty interval: 2.7, 4.6)[2]. These risks are higher for women, children, and low–middle income countries[2,3]. Limiting particulate (notably particulate matter ($PM_{2.5}$)) and carbon monoxide (CO) emissions from cooking fuels and stoves is necessary to prevent cancer, chronic obstructive pulmonary disease, respiratory infections, ischemic heart disease, and stroke[2].

Cooking fuels and stove technologies have diverse designs, carbon footprints, and, most importantly, implications for users' health (Table 1). Prominent multi-lateral institutions have generally followed a largely unwritten rule of fuel neutrality in which they hesitate to advocate for specific fuels or stoves. The differing features of stoves encouraged innovation, but it slowed the scale-up of viable solutions needed to meet the on-going health and energy crisis.

Fuel neutrality has led to a diversity of fuel and stove approaches, well intentioned support of unclean stoves by national governments, companies, and non-governmental organizations alike, and lack of a unified effort and progress toward SDG7 for cooking by 2030.

Ultimately, decentralized efforts[4] and a lack of focus on local context and stove training[5] have hindered clarity on the affordability and performance metrics of fuels and stoves[6]. Compared to steady, significant improvements and scaling of solar photovoltaics, wind, and batteries, there have not been comparable gains from experience (that is, learning curves) for cooking technologies[7]. Research, innovation, and progress on fuels and stoves now allow the global community to identify and explicitly pursue 'pro-health' (that is, clean by WHO health standards) stoves and fuels.

Identifying pro-health stoves and fuels

The WHO defines a clean stove as one that meets Tier 4–5 for $PM_{2.5}$ and Tier 5 for CO, according to the International Organization for Standardization (ISO) 19867-3 Voluntary Performance Targets (VPTs), which range from Tier 0 to 5 as measured by laboratory testing (Table 2). Diverse stove designs emerged as researchers evaluated the health implications of different fuels and stoves[8,9]. Evaluating and comparing fuels and stoves is crucial as decades of empirical evidence suggest that households will utilize (or stack) multiple fuels[10]. Due to inevitable stacking and the fact that no one fuel alone is likely to scale fast enough to reach universal access by 2030, the sector needs to offer a suite of pro-health fuels to ensure a clean stack.

Fortunately, data on stove and fuel combinations now definitively identifies truly pro-health fuels and stoves, worthy of funding and scaling. These include: liquefied petroleum gas (LPG), ethanol, biogas/bio-compressed natural gas (bio-CNG), natural 'fossil' gas (NG), electricity, and biomass pellets in two advanced gasifiers, (that is, the Mimi Moto[9] and the SupaMoto[11]). All other improved biomass stoves currently available are unclean (that is, Tiers 1–3), not reducing the emissions to safe levels for human health.

LPG is a crucial clean transitional cooking fuel as it is an unavoidable by-product of oil and fossil gas production, representing ~11% of oil and gas production[12]. The International Energy Agency (IEA) models that in order to reach net-zero emissions (NZE) by 2050, 25% of individuals will gain access to modern cooking fuel by 2030 through LPG (ref. [13]) — echoing Dr Kirk Smith's clarion call that LPG could be a sustainable cooking option for the rural poor[14].

There is hesitancy to introduce a fossil fuel, such as LPG, because of its greenhouse gas (GHG) emissions. Analytically, this hesitancy is misguided; LPG is less GHG intensive than Tier 0–3 cookstoves under most contexts, and the IEA finds that a switch to LPG leads to net reductions in GHG emissions[13]. Further, reducing 1.9–2.3% of global GHG emissions[15] should not be prioritized over severe health outcomes, particularly for women. To cite global decarbonization as a reason to deny low-income households pro-health stoves is a form of energy, carbon, gender, and social justice discrimination.

To meet NZE by 2050, global oil and gas production must fall by 55% and 75% (and eventually by 100%), respectively[13]. Thus, the global community is simultaneously planning to rely on LPG for cooking, yet reduce its supply and thus increase its cost[13]. Beyond 2030, the IEA find that LPG must be increasingly decarbonized, that is, replaced by bio-LPG sourced from municipal solid waste and other renewable feedstocks. The Global LPG Partnership has identified pilot sites in Kenya, Ghana, and Rwanda. Pilot identification is an insufficient start if bio-LPG is expected to fully replace standard LPG after 2030, even though it can use the same LPG distribution infrastructure[16]. In addition to LPG, the global community must prepare a range of clean fuels and stoves.

A diverse set of companies are expanding the use of emerging Tier 4+ biomass pellet gasifiers across Kenya, Rwanda, Mozambique, Malawi, and Zambia[9]. Ethanol/bio-ethanol, sourced from wood, sugar cane, and so on, is another pro-health option and has had some success at the pilot or small scale in Ethiopia, Kenya, Nigeria, and Mozambique (see for example[17,18]). Additionally, biogas, bio-CNG, and natural gas are also pro-health fuel and stove options that have been deployed through the Africa Biogas Partnership in Kenya, Tanzania, and Uganda as well

Table 1 | Description of improved fuel and stove technologies

Fuel	Description	Associated stoves	Pro-health stove and fuel combination?
Biomass pellets	Processed firewood (apply high pressure and compact non-carbonized agricultural waste)	Biomass pellet gasifiers	Yes; using a WHO Tier 4+ gasifier
Electricity	Electricity from utility-scale, mini-grid, or local generation (DG renewable) without air quality impacts	Electric stove connected to the national grid, mini-grid, or standalone solar power	Yes
Ethanol from sugarcane/wood	A liquid fuel produced from the distillation of wood or agricultural products	Metal liquid fuel stove	Yes
Improved charcoal	A product of carbonizing firewood (or burning firewood without access to oxygen inside a kiln or earthen mound)	Improved charcoal stoves	No
Improved firewood	Unprocessed, solid wood, typically collected for free, but occasionally sold in towns or peri-urban areas	Improved firewood stoves	No
Natural gas/biogas/bio-compressed natural gas	Natural gas is primarily methane gas, sourced from fossil, non-renewable sources. Alternatively, biogas is produced through anerobic digestion of organic wastes (animal, human, kitchen or crop wastes). The biogas can then be further processed to be stored at high pressure to produce compressed natural gas.	Gas stove	Yes
Liquefied petroleum gas (LPG) (derived from natural gas or oil) or bio-LPG	A by-product of natural gas or crude oil extraction, while bio-LPG is sourced from municipal solid waste and other renewable feedstocks that produce bio-sourced butane and propane.	LPG stove	Yes

We include the most common stove and fuel combinations, and exclude solar ovens, dimethyl ether LPG, and briquettes.

as programmes in India, Rwanda, Nepal, Pakistan, and China (see for example refs. [19,20]). Despite high upfront costs, biogas can provide a decentralized pro-health stove for rural populations. There are also already commercial plants for bio-CNG (that is, processed biogas), which can use the same municipal solid waste and other renewable feedstocks, in both high- and low-income countries, suggesting its viability to scale[21]. The IEA recommends that 55% of the population gain access to modern energy by 2030 through modern biomass (pellets), biogas, or ethanol[13].

Finally, there have been significant, but still insufficient efforts to support cooking with electricity. Electric cooking, particularly solar electric, is increasingly cost competitive with firewood and charcoal[22] and could find a new avenue of support in this transition. The global community is, however, far from providing reliable electricity that households could exclusively or even primarily use for cooking. Further investment in electric cooking is needed by 2050 to meet the IEA's recommendation that 55% of the population in developing economies would use primarily electricity for cooking[13]. The sector could leverage the simultaneously expanding electricity infrastructure (for example, Kenya, India, Nepal) for cooking as well.

Pro-health affordability and preference

Simply identifying pro-health fuels and technologies will not guarantee universal access, particularly given the barriers of affordability and user preference[23,24]. We must ensure that pro-health fuels and stoves are affordable at the household level through the market or subsidies. Pro-health stoves and fuels must be affordable for households to use consistently and exclusively to realize their health benefits.

User preference is extremely important for stove adoption and continued use; the literature has seen low rates of adoption and use among both unclean Tier 1–3 and pro-health Tier 4+ stoves[5,25]. Users will and even want to adopt and use Tier 4+ options, if affordable and functional[26]. The high rates of LPG exclusive use and dirty stove abandonment in the Household Air Pollution Intervention Network Trial[26] and a comprehensive review of the literature reveals that user preference and ultimate use are largely a function of affordability and stove functionality, not necessarily culture[24,26].

Pro-health does not conflict with climate

The literature emphasizes climate implications of access to improved cooking solutions. Yet, domestic cooking only contributes 1.9–2.3% of GHG emissions, even when including black carbon emissions[15], while industry and on-road transport remain the largest offenders[14,27]. However, all stoves and fuels above Tier 4 provide emission reductions[28].

Numerous comprehensive ISO lifecycle analyses (LCAs), covering the feedstock production, processing, distribution, and point of use emissions of different cooking fuels[12,28–30], found that pro-health fuels and stoves have a limited carbon dioxide impact, particularly compared to charcoal and firewood[28]. Modelling as early as 2005[31] has shown that even large transitions to fossil fuels for cooking leads to net reduction in GHGs.

We reductively evaluate criteria for health, affordability, and climate based on the most recent literature (Fig. 1). The research reveals that health standards — the most pressing implication of unclean cooking — limit the viable fuel and stove options. Simultaneously, households will only be able to adopt and use pro-health stoves if they are affordable. These standards of pro-health and affordability must be prioritized, especially as all improved stoves and fuels provide emission reductions.

A call to focus on pro-health cooking

Investment and infrastructure for nascent pro-health options such as Tier 4+ gasifier, ethanol, and biogas stoves are less developed

Table 2 | ISO voluntary performance targets for cookstoves

Tier	Thermal efficiency (%)	CO (g/$MJ_{delivered}$)	$PM_{2.5}$ ($mg/MJ_{delivered}$)	Safety (score)	Durability (score)
5	≥50	≤3	≤5	≥95	≤10
4	≥40	≤4.4	≤62	≥86	≤15
3	≥30	≤7.2	≤218	≥77	≤20
2	≥20	≤11.5	≤481	≥68	≤25
1	≥10	≤18.3	≤1,030	≥60	≤35
0	≥10	>18.3	>1,030	≥60	>35

The WHO outlines that health benefits occur for fuel and stove combinations that meet Tier 5 for carbon monoxide (CO) and Tier 4 for particulate matter ($PM_{2.5}$). Table data based on ref. [38].

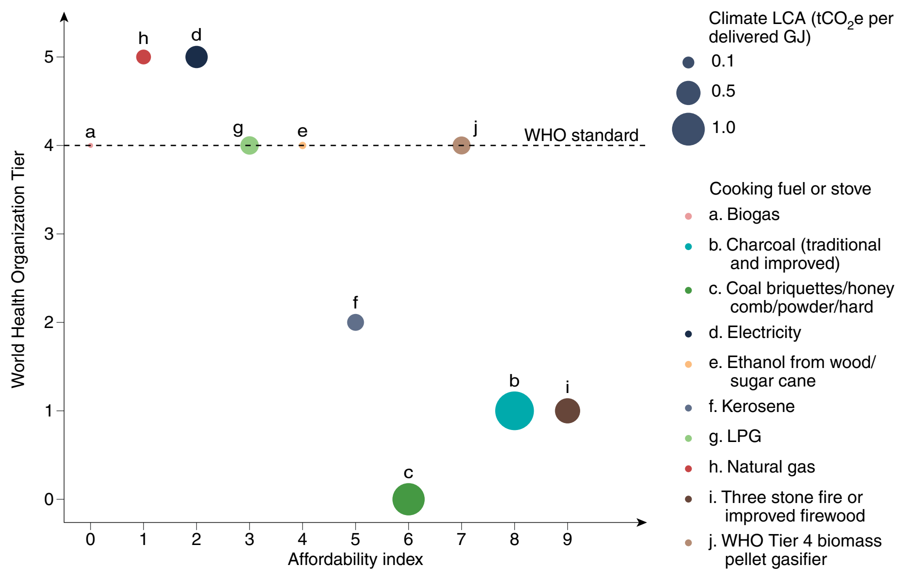

Fig. 1 | Metrics of cooking fuels and stoves across health, affordability and climate. This scatter plot maps select stoves and fuels according to their World Health Organization's Health Tier and an index indicating increasing affordability. The size of the bubble indicates the fuel's average climate lifecycle analysis (LCA) in tons of carbon dioxide equivalent per delivered gigajoule. The WHO Health Tier is derived directly from ISO VPT testing. After completing a comprehensive review of affordability in the literature, we built the affordability index, specifically for this Comment, using the sources cited in that review, considering stove cost, recurring fuel costs, size of purchasable quantities, and so on[23] (see ref. [37] for a full explanation). Finally, we averaged the carbon dioxide equivalent per gigajoule of delivered energy from various LCA studies that evaluated the feedstock production, processing, distribution, and point of use of different cooking fuels[12,28–30]. We note that the position of these stove and fuel metrics may change depending on country, context, and time. Renewable energy costs (for example, solar and bio-CNG) and embedded carbon are rapidly improving.

than that of LPG[25,32] and have thus prohibited their scalability[18,21]. New research stresses that this investment must address supply needs of pro-health fuels, which differ for each fuel, but span feedstock supply availability, feedstock price variability, safety, accessibility and last-mile distribution, scale-up potential, convertible currency, and foreign exchange[25,32].

The Energy Sector Management Assistance Program (ESMAP) estimates that an annual US$150 billion per year is needed to provide universal access to pro-health Modern Energy Cooking Services[6]. ESMAP and Sustainable Energy for All project a range of US$4.5 to US$10 billion per year to provide improved, but unclean cooking[6,33]. However, the health costs of unclean cooking are the largest associated cost at US$1.4 trillion per year[6]. Thus, funding improved but unclean stoves do not as effectively affect that global cost.

The Voluntary Carbon Market (VCM) is already a critical source of investment and funding for the cookstove sector, having issued roughly 44 million credits (~US$440 million) to cookstove projects as of December 2021[34]. However, of those 630 projects, only 27 even mention a pro-health stove or fuel[34].

The VCM could instead only fund pro-health projects that simultaneously reduce carbon emissions, instead of Tier 1–3 stoves whose distribution does not contribute to SDG7. Energy, social, and ecological justice demand that we prioritize the health needs of those cooking daily over an open fire, rather than those wanting to buy cheap carbon credits to justify continued GHG emissions.

It's time to explicitly choose pro-health

With under eight years remaining to meet SDG7, we must abandon fuel neutrality and make informed, drastic fuel and stove decisions. The WHO's approach 'to support the use of the cleanest possible option in each setting'[35] and the CCA's approach to 'gradually drive solutions and markets toward advanced and clean options'[36] will not achieve SDG7.

Multilaterals, countries, and the VCM must acknowledge the research findings that now clarify the health, economic, and climate implications of different stoves and fuels to inform which stoves and fuels they fund and make affordable.

Failure to meet SDG7 hinders energy, social and gender justice. Climate change is often cited as a primary argument for expanding modern cooking access[15], yet the lack of progress toward SDG7 signals that dialogue over carbon net-zero targets is largely about the industrialized nations. Development goals as pledges are left in name only.

We have reached the point where it is time to exclusively coalesce around and fund pro-health stoves and fuels. ❐

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