



News & Highlights

Gas Versus Biomass Cooking—Landmark Trial Yields Unexpected Results

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William Checkley, professor of medicine and a pulmonary and critical care specialist at Johns Hopkins University (Baltimore, MD, USA) has seen kitchens with stalactites. But not the kind found in caves. “You walk in, and the smoke is everywhere,” said Checkley. “It is difficult to breathe—you cough, your eyes burn.” Layers of soot from cookfires cover the walls and, in some extreme cases, form stalactites that hang from the ceiling.

Over the past 15 years, Checkley has visited such kitchens in households around the world that cook on traditional stoves that burn biomass (Fig. 1), typically wood, dung, crop waste, and coal and charcoal. Roughly a third of the world’s humans cooks this way, creating household air pollution (HAP) [1], a health issue that is Checkley’s particular area of expertise.

To the surprise of many, however, the landmark randomized controlled trial (RCT) that Checkley co-leads, the Household Air Pollution Intervention Network (HAPIN) trial, has failed to show the health benefits expected from a widely adopted intervention—swapping households’ biomass stoves for cleaner-burning liquified petroleum gas (LPG) stoves [2]. Published from 2022 to 2024 in several *New England Journal of Medicine* reports, the trial’s primary results were solidly inconclusive [2–5]. Although households cooking with LPG cut residents’ average daily fine particulate exposure from roughly 100 to 35 $\mu\text{g}\cdot\text{m}^{-3}$ [4], a World Health Organization (WHO) intermediate air quality target [6], no significant health improvements were observed. “All the health outcomes where we thought we could make a difference, they were all a ‘no,’” Checkley said.

Regardless, experts say alternatives like gas stoves, electricity mini-grids, and standalone solar-powered appliances are still needed for rural people in low- and middle-income communities without access to clean cooking—or reliable energy in general—for reasons that include, but go well beyond, health. Burning organic matter emits smoke, particulate matter, carbon monoxide, and nitrogen dioxide, and these can accumulate to dangerous levels in enclosed spaces [7]. In biomass-burning kitchens, average concentrations of fine particulates over 24 h can top 1000 $\mu\text{g}\cdot\text{m}^{-3}$, Checkley said, “several-fold higher than even really bad days of ambient air pollution.” Exposure, especially chronic exposure, to such air pollutants raises the risk of pneumonia, tuberculosis, lung disease, lung cancer, cardiovascular disease, and low birth weight, all of which contribute to millions of premature deaths each year [2,3]. The health impacts are most pronounced in rural areas in poor and middle-income countries, particularly in Africa, where

four-fifths of people cook with biomass [1]. Women—usually the primary home cooks—and children are most affected [1]; studies have suggested that roughly half of child pneumonia deaths are linked to air pollution, mostly from indoor exposure [8].

On its face, it seems self-evident that switching to stoves fueled with LPG, which burns far more cleanly than biomass, would improve health [1]. LPG’s portability also suits rural areas where electricity is unavailable or insufficient. “It comes in a 20 kg cylinder that you can move around easily, whether you carry it or put it on a bicycle or motorcycle or get somebody to deliver it,” Checkley said. Many countries, including India and Indonesia, have already taken steps to expand access to LPG [9]. Globally, 70% of new access to cleaner cooking from 2010 to 2023 occurred through a switch to LPG [1].

The HAPIN trial sought to quantify the health impacts of this switch. Funded by the US National Institutes of Health and the Bill & Melinda Gates Foundation, the trial, begun in 2017, enrolled 3200 poor households in Guatemala, India, Peru, and Rwanda. The households were randomly assigned, half to receive LPG stoves and half to continue cooking with biomass. Researchers recorded outcomes over 18 months, focusing on women’s blood pressure and birth weights (800 babies were born during the study), pneumonia incidence, and stunting in children [2].



Fig. 1. A man in Indian-controlled Kashmir cooks on a traditional biomass-burning stove, while a gas burner rests on the floor to the right. Even when in possession of both types of stoves, many people continue to cook with biomass, often because liquified petroleum gas (LPG) is expensive, inaccessible, or culturally unfamiliar. Credit: Ankur Panchbudhe/Wikimedia (CC BY-SA 2.0).

The negative results “really challenge the existing notion of the impact of household air pollution, though it merits further systematic investigation as it is difficult to control for multiple competing factors in households,” said Praveen Kumar, an associate professor at the Boston College School of Social Work (Chestnut Hill, MA, USA). Kumar was not involved in the trial but has collaborated with Checkley and other HAPIN investigators on related HAP research.

What might explain the unexpected results? Perhaps, Checkley said, households must abandon biomass before pregnancy, not during it, to improve the health of newborns and young children. And maybe too many other factors affect poor families’ health for clean cooking alone to have an impact.

It could also be that LPG may not be clean enough—cooking with it still emits nitrogen dioxide and particulates [4,7,10]. Regarding this point, Tangchun Wu, professor of environmental health and dean of Tongji Medical College at Huazhong University of Science and Technology (Wuhan, China), called out the need for adequate ventilation: “Even if switching to LPG is effective, it is still necessary to improve ventilation to achieve optimal health benefits.” Indeed, research performed by Wu and colleagues has shown that using a range hood during gas cooking can cut average kitchen concentrations of fine particulates by more than 80%, with electric stoves cleaner still [10]. Wu further noted that especially for biomass cooking, improving ventilation “offers a highly economical and effective intervention, requiring minimal behavioral change and low cost.”

In any case, the HAPIN trial is not the final word. Although it represents one of only a few RCTs comparing the health outcomes of people cooking with gas versus solid fuels, and despite other studies having reported similarly negative results [11,12], dozens of observational studies collectively have associated gas cooking with lower risks of lung disease and adverse birth outcomes compared to biomass cooking [13]. Two studies conducted by Wu and colleagues also showed a lower risk of mortality [14,15]—up to 60% lower five years after replacing solid fuel with gas or electricity [14].

“There definitely should be more resources allocated towards LPG use for poorer households,” said Kumar, especially given the obstacles faced by many who could benefit. Compared to freely gathered biomass fuels, LPG is expensive, with its fluctuating price and high import cost [1,9]. Government assistance often falls short, Checkley said: Families in Peru, for example, can apply for a subsidized half-tank of LPG each month, but most need two full tanks [16]. In India, logistic difficulties, delivery costs, and low demand make it difficult for LPG suppliers to serve rural areas [17]. “Families still burn biomass due to convenience and the cost of LPG—economics is the main concern,” said Hai Zhang, a professor of industrial engineering at Tsinghua University (Beijing, China). Zhang, whose research focuses on combustion science, expressed concern about interpreting the HAPIN results too literally. He said the transition from biomass to LPG 25 years ago brought cleaner cooking and improved quality of life to his hometown in southern China.

In some areas, other energy sources may make more sense than LPG as a cleaner alternative to biomass. “There is no one-size-fits-all solution for different households, different communities, and different countries,” said Kumar. He said economic conditions in southern India, for instance, may make the recurring, fluctuating cost of LPG more affordable than in sub-Saharan Africa where abundant sunny weather likely makes solar the best option.

The price of photovoltaic panels, produced largely in China, has decreased by 90% in the last decade [18], making solar a more viable proposition for the 680 million people without access to electricity globally, particularly in sub-Saharan Africa [19,20]. Compared to other power sources, solar is also quick to deploy

and highly customizable. “It is very modular—easy to plug in a bit more every year,” said Tobias Schmidt, professor of energy and technology policy at Federal Institute of Technology (Zurich, Switzerland). “That is extremely powerful. You do not want to overinvest in infrastructure that goes unused.”

Two oft-mentioned options for bringing solar to unelectrified regions are solar mini-grids—local-scale electric grids typically owned by private companies (Fig. 2 [18])—and standalone solar-powered appliances, both studied by Schmidt from a policy and economics perspective. The technologies bypass central grids, which in many low-income nations do not reach rural areas, cannot shoulder much new demand, and typically experience long and frequent power outages [1,9,18].

The number of mini-grids in sub-Saharan Africa increased from around 500 in 2010 to more than 3000 in 2023 [20]. By 2030, the technology is projected—perhaps optimistically—to provide cheaper energy than utilities for more than 60% of Africans, reaching as low as 20 USD·(kW·h)⁻¹ (about 10 USD per month for each household) [20]. Some mini-grid companies offer differently priced payment plans based on how much electricity users consume, creating more affordable options [18]. Schmidt said mini-grids work well in places with sound governance—to ensure the mini-grid is maintained and its electricity distributed fairly—and reliable, high-volume demand, which lowers the cost for users and reduces risk for providers. Examples might include a large bazaar or a dense city with an insufficient central grid.

Mini-grids have some disadvantages. Wherever people tend to use electricity at the same times of day, as in many rural areas, any grid (central or mini) becomes less efficient, Schmidt said. And private mini-grid companies can clash with governments. This was the case for Husk Power Systems (Fort Collins, CO, USA), which sold its assets in Tanzania after the government demanded it sell electricity at the same price as the state-subsidized electric utility, leaving thousands without power [18]. “I have seen few mini-grids that operate for their full technical lifetime,” Schmidt said, often due to governance issues. “There is a role for mini-grids, but it is a niche.”

Schmidt said he favors standalone systems, which power appliances like stoves, refrigerators, ice machines, and pumps with dedicated solar panels that are typically owned by households or businesses (Fig. 3). Coupled with mechanisms to boost affordability—for instance, one where a user gradually pays off the cost of a system as they use it—such systems provide not just electricity,



Fig. 2. A solar mini-grid in Bayelsa, Nigeria. In total, sub-Saharan Africa has increased its number of mini-grids roughly six-fold since 2010, reaching more than 3000 in 2023. Major organizations including the World Bank have dedicated billions of dollars to the development of mini-grids on the continent [18]. Credit: Repumped/Wikimedia (CC BY-SA 4.0).



Fig. 3. A solar panel powers a water pump on a farm in Rwanda. Standalone solar systems, often sold with appliances attached, offer practical services as well as electricity to power them, allowing users to bypass many of the bureaucratic hurdles associated with accessing electricity from central or mini-grids. Credit: Churchill Agutu, with permission (courtesy of Tobias Schmidt).

Schmidt said, but also appliances that support the livelihoods of farmers, fishermen, and shopkeepers. “Energy is not an end in itself; it is a means,” he said.

But persuading people to give up biomass cooking may not be easy. In many cases, after obtaining a cleaner stove, “poor households will use traditional stoves for daily cooking and fancy, cleaner stoves for special occasions,” Kumar said. In addition, male heads of household often consider cleaner cooking a low-priority expense [1], even when LPG is affordable and accessible, he added. For this and other cultural reasons, education will likely be important for prompting a switch from biomass. In the Cardiopulmonary Outcomes and Household Air Pollution (CHAP) [21] and HAPIN trials, “we had to convince people that cooking with LPG was a good idea,” Checkley said. Some study subjects worried that LPG would mean giving up perceived attributes of biomass cooking, like its smoky flavors. “It was debunked once people got a taste,” Checkley said.

Even without certainty about health benefits, promoting sustainable environmental and climate goals provide good reasons to eliminate biomass burning. Demand for firewood and charcoal each year clears an Ireland-sized area of forest, largely in Africa [1]. While solar is likely the most climate-friendly option, even replacing all biomass with LPG would still slash the planet-warming emissions biomass fuels generate through burning and deforestation by the net equivalent of 1.5 Gt of CO₂, roughly the emissions from all planes and ships in 2022 [1,22].

There are also social impacts to consider. Gathering biomass fuels can consume 1.5 h or more daily that might otherwise go towards education or income-earning [1]. “These activities take up a lot of time, which has economic implications,” Kumar said, particularly for women, to whom these tasks typically fall. “Energy poverty and income poverty are linked. If you release households from energy poverty, you are reducing income poverty as well.”

The HAPIN researchers will continue monitoring children in the trial until age nine in Peru [23] and age five in Guatemala, India, and Rwanda to see if health differences might emerge over a longer period [2]. Although he cautioned against making such claims for health benefits from switching to LPG, at least based on the current HAPIN trial results, Checkley said it was not until the Clean Air Act in the United States that pollution decreased and health benefits were seen. “That says if you improve air quality, down the line, you will see improvements in health.”

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