FACTORS THAT INFLUENCE HOUSEHOLD SOLID FUEL USE AND SUCCESSFUL FUEL TRANSITION IN THE GLOBAL SOUTH

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I. AN IMPORTANT GLOBAL HEALTH INEQUITY: EXPOSURE TO AIR POLLUTION FROM HOUSEHOLD SOLID FUEL DEPENDENCE

Solid fuels, such as coal, wood, and peat, remain dominant energy sources for many households in low- and middle-income countries (LMICs).[1] This presents a significant global health equity challenge because solid fuel use at the household level exposes some 3 billion people worldwide to significantly elevated levels of indoor air pollution.[2] Exposure to indoor air pollution—toxic particles, gasses, and carbon dioxide from burning solid fuels—contributes to 2.6 million premature deaths annually, primarily those of women and children.[3] In addition to the impact on human health, reliance on firewood produces multiple indirect effects: it contributes to deforestation, which in turn increases the risk of flooding and landslides, and accelerates climate change.

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Despite well-known human and environmental hazards associated with solid fuel usage, household transition to cleaner energy sources remains a challenge.[4] Until recently, no existing studies offered a systematic assessment of the factors associated with fuel transitions across LMICs. Other unaddressed aspects of solid fuel transitions include the determinants of continued use of cleaner fuels after transitioning to them, and analysis of sizeable variation in solid fuel use that can occur in countries with modest overall dependence on solid fuels.

It is critical to identify and understand the complex drivers of solid fuel use so that the development of policy to address solid fuel dependence can be grounded in empirical evidence. In turn, the implementation of such policies is critical because without substantial policy change, the total number of people relying on solid fuels globally is forecast to remain largely unchanged by 2030.[5]

The above research gaps were addressed in two recently-published research articles: "Country-level analysis of household fuel transitions," and "Household dependence on solid cooking fuels in Peru: An analysis of environmental and socioeconomic conditions."[6] Both papers were co-authored by an interdisciplinary team of University at Buffalo researchers affiliated with the Community for Global Health Equity.

II. PRACTICAL TAKEAWAYS: MULTIPLE UPSTREAM FACTORS DRIVE SOLID FUEL USE BY HOUSEHOLDS

Drawing from a dataset composed of household use of solid fuel for cooking, socioeconomic and demographic variables, energy production data and political variables from a number of sources, the authors' work suggests that solid fuel transition depends on multiple upstream determinants. Statistical tests indicate that a given country's socio-political context, population, economic development, and energy production are factors that influence solid fuel dependence and movement to cleaner alternatives.

Specifically, the team identified the following determinants of continued solid fuel use at the country level:

Poverty. The authors' findings underscore poverty as a critical determinant of solid fuel use. This is consistent with previous studies in which there is a lag between electrification and subsequent transition to cleaner cooking fuels at the country level, even though solid fuel transition and electrification are tied to the same factors: GDP, education, and aggregate household income.[7]

Fluctuating household income. Cleaner fuel choices require investments such as reusable gas cylinders. For those with fluctuating household income, this sort of investment is not feasible, particularly when households can obtain a small quantity of cheap or free solid fuel on a daily basis.

Population size and density. The authors' findings indicate that an average, large-population country has greater solid fuel use than an average, small-population country in their dataset. Further, an LMIC with greater population density has greater solid fuel use than an LMIC with a lower population density.

Greater rural population share. The author's findings support previous research in which the urban/rural divide in solid fuel use has been noted: over 95% rural households use solid fuel in LMICs, compared to as few as 5% urban households.[8,9]

Income inequality. While a lesser factor than GDP per capita, the authors find that a country's distribution of wealth has a significant impact on solid fuel use.
Charcoal production within the country. In-country production of charcoal is a reliable predictor of household solid fuel dependence.

Conversely, the data revealed the following determinants of decreased solid fuel use, and a likely shift to cleaner alternatives at the country level:

Higher GDP per capita. Citing previous research, the authors note that adoption of cleaner fuels in the Global South is not widespread until a country achieves approximately $12,000 in per capita GDP.[10] However, even when countries have not attained this threshold but have established substantial natural gas production, they are less dependent on solid fuels at the household level. This suggests that domestic production as well as availability of cleaner fuels can offset lower per capita GDP.

Economic incentives and subsidies for sustainable energy. Approximately half of the countries in the authors' dataset offered no clean energy incentives. Of those that did, they offered an average of 3 incentive programs per year. Peru provided the greatest number of economic incentives for clean energy programs (13 in 2012). The authors use this variable as a proxy for governmental efforts to promote transition to cleaner household fuels, finding that as governments offer a greater number of economic incentive programs, solid fuel dependence decreases substantially.
Natural gas and electricity production within the country. The authors find that the domestic production of cleaner fuels can offset a relatively low per capita GDP.

PRACTICAL TAKEAWAYS: **THE CASE OF PERU**

It is important to note that LMICs are not internally homogeneous in terms of their solid fuel use and related characteristics, including natural and built environments and population distribution. Noting this, the authors turned to Peru, which has low dependence on solid cooking fuels overall, but displays a striking level of variation in solid fuel use across regions.[11] Their findings reveal that a combination of external and household factors explain regional variation in solid fuel use.

<u>Solid fuel use within Peru is associated with:</u>

Higher elevation, cooler air temperatures, and forest cover. Consistent with prior research, the authors find that households at higher elevation and those where firewood is plentiful prefer to use firewood for cooking.[12]

Indigenous communities. Existing research shows that areas with higher concentrations of indigenous groups demonstrate greater solid fuel dependence, and that this dependence cannot be explained by climate, poverty, or literacy. This association may be attributed to large families, and thus, more people available to gather fuel; the cultural value of traditional stoves and fuel choices, and insufficient information in indigenous languages to explain the costs, benefits, and safe use of cleaner fuels.[13]

Female employment as domestic workers. The authors find that while the employment of women in professional and skilled manual occupations has reduced solid fuel dependence, the inverse is true of women employed in the domestic workforce: this occupation type is linked with greater solid fuel dependence. Other occupations do not yield statistically significant links to fuel choices.

<u>Cleaner fuel use within Peru is associated with:</u>

Female education. The authors find a significant association between women's literacy and lower solid fuel dependence, consistent with a prior finding that higher levels of women's education are linked to increased usage of liquefied petroleum gas stoves.[14]

Proximity to the country capital. The authors find that the area around Lima has less solid fuel consumption than elsewhere in the country. Electricity access. While previous studies suggest that households in Peru prefer not to use electricity for cooking, the authors find that i mproved electricity access reduces solid fuel use.

III. POLICY TAKEAWAYS

1. The authors' findings indicate that the following factors are associated with lasting transition to cleaner fuels at the country level: government provision of economic incentives to promote fuel transition, higher per capita GDP, and domestic clean energy production. Further, income inequality, poverty, fluctuating household income, domestic charcoal production, and larger numbers of rural residents are associated with greater solid fuel use.

2. These factors can be used as potential levers by LMIC governments that must address a number of urgent country-level challenges and cannot afford costly initiatives like country-wide electrification. For example, policies that enhance girls' access to education and develop worker skills result in increased household income, as well as a reduction in solid fuel dependence.

3. Sustainable energy policies and economic incentives are the most direct means of encouraging fuel transition.

4. Aggregate data can mask significant disparities in fuel dependence in different regions of a given country. It is important to examine regional differences and tailor domestic policies accordingly.

FOOTNOTES

1. Globally, the number households that rely primarily on solid fuels for cooking fuel declined from 62% in 1980 to 41% in 2010; however, 71% of households in Africa and 61% of households in Southeast Asia remained dependent on solid fuels for cooking in 2010. Bonjour, S, Adair-Rohani, H, Wolf, J, Bruce, N, Mehta, S, Prüss-Ustün, A, Lahiff, M, Rehfuess, E, Mishra, V and Smith, K. (2013) Solid Fuel Use for Household Cooking: Country and Regional Estimates for 1980–2010. Environmental Health Perspectives, 121, 784.

2. WHO (2013) Population using solid fuels (estimates): Data by country. Global health observatory data repository. World Health Organization. Available online: http://apps.who.int/gho/data/node.main.135

3. Global Burden of Disease Collaborative Network (2017). Global Burden of Disease Study 2016 (GBD 2016) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME). Available from: http://ghdx.healthdata.org/gbd-results-tool

4. Though once considered to be crucial in reducing indoor air pollution, improvements in cook stove technology seem to offer only modest benefits. More contemporary research has concluded that household transition from solid fuel to cleaner choices is a more promising direction. Puzzolo, E., & Pope, D. (2017). Clean fuels for cooking in developing countries. Reference Module in Earth Systems and Environmental Sciences.

5. IEA (International Energy Agency)(2001) "Energy for all. Financing access for the poor." World Energy Outlook: Special Report. https://www.iea.org/media/weowebsite/energydevelopment/presentation_oslo_oct11.pdf

6. McLean, E, Bagchi-Sen, S, Atkinson, J, Ravenscroft, J, Hewner, S, Schindel, A. (2019) Country-level analysis of household fuel transitions." World Development 114 267-280, and McLean, E, Bagchi-Sen, S, Atkinson, J, and Schindel, A. (2019) Household dependence on solid cooking fuels in Peru: An analysis of environmental and socioeconomic conditions." Global Environmental Change 58 101961.

7. (Behera, Jeetendra, & Ali, 2015; Davis, 1998; Heltberg,2003, 2005; Khandker, Barnes, & Samad, 2012; Nansaior, AranPatanothai, Rambo, & Simaraks, 2011; Rao & Reddy, 2007; USAID, 2005).

8. Puzolo, E, Pope, D, Stanistreet, D., Rehfuess, E, & Bruce, N. (2016) Clean fuels for resource-poor settings: A systematic review of barriers and enablers to adoption and sustained use. Environmental Research, 146, 218-234.

9. See Alem, Beyene, Kohlin & Mekonnen, 2016; UNDP/WHO, 2009.

10. World Bank and International Energy Agency (2017). Sustainable energy for all global tracking framework – summary. The authors note that there are outliers: countries with nearly 90% cleaner cooking fuel access, though their per capita GDP is below $12,000: Guyana, Dominican Republic, Ukraine, Armenia, Azerbaijan, Morocco, Egypt, Jordan, Turkmenistan, and Maldives.

11. McLean, E, Bagchi-Sen, S, Atkinson, J, and Schindel, A. (2019) Household dependence on solid cooking fuels in Peru: An analysis of environmental and socioeconomic conditions." Global Environmental Change 58 101961

12. Córdova-Aguilar, 1992;Gubler, 2017;Rhodes et al., 2014.

13. Ekouevi, K., Tuntivate, V., 2012. Household Energy Access for Cooking and Heating: Lessons Learned and the Way Forward. The World Bank; Freire, G., Schwartz Orellana, S.D., Zumaeta Aurazo, M., Costa, D.C., Lundvall, J.M.,Viveros Mendoza, M.C., et al. (2015). Indigenous Latin America in the Twenty-first Century: the First Decade (98544). Retrieved from http://documents.worldbank.org/curated/en/145891467991974540/Indigenous-Latin-America-in-the-twenty-first-century-the-first-decade; Heltberg, R., 2004. Fuel switching: evidence from eight developing countries. Energy Econ. 26 (5), 869–887; Rao, M.N., Reddy, B.S., 2007. Variations in energy use by Indian households: an analysis of micro level data. Energy 32 (2), 143–153; Rhodes, E.L., Dreibelbis, R., Klasen, E.M., Naithani, N., Baliddawa, J., Menya, D., et al.,2014. Behavioral attitudes and preferences in cooking practices with traditional open-fire stoves in Peru, Nepal, and Kenya: implications for improved cook stove interventions. Int. J. Environ. Res. Public Health 11 (10), 10310–10326. https://doi.org/10.3390/ijerph11101031; Malakar, Y., 2018. Studying household decision-making context and cooking fuel transition in rural India. Energy Sustain. Dev. 43, 68–74; Edwards, J.H., Langpap, C., 2005. Startup costs and the decision to switch from firewood to gas fuel. Land Econ. 81 (4), 570–586; Pollard, S.L., Williams, K.N., O'Brien, C.J., Winiker, A., Puzzolo, E., Kephart, J.L., et al.,2018. An evaluation of the Fondo de Inclusión Social Energético program to promote access to liquefied petroleum gas in Peru. Energy Sustain. Dev. 46, 82–93. https://doi.org/10.1016/j.esd.2018.06.001.

14. Muneer, S.E.T., 2003. Adoption of biomass improved cook stoves in a patriarchal society :an example from Sudan. Sci. Total Environ. 307 (1–3), 259–266.

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