WORKING DRAFT

What lessons have we learnt from the adoption of LPG, PNG, and electricity for clean cooking?

LPG: Liquefied Petroleum Gas, PNG: Piped Natural Gas, e-cooking: use of electricity to cook

Authors
Vijay Modi* (Columbia University), Abhishek Kar (CEEW), Nishant Narayan (SEforALL)
Sebastian Rodriguez (Circle Gas), * send comments: modi@columbia.edu

Executive summary

1. While SDG 7 aims to ensure that universal access to clean cooking by 2030, many countries in sub-Saharan Africa face an acute challenge, as according to the IEA, 29 countries of the region have clean cooking access rates below 20% (in 2022) and the region continues to see an increase in the number of people without access to clean cooking since tracking started, reaching around 900 million. IEA estimates nearly half million deaths annually of women and children due to the use of primitive stoves.
2. We narrowly address LPG, PNG[1], and e-cooking as modern cooking options here.
    a. Piped natural gas is the lowest cost fuel especially in settings where the gas can be distributed from a trunk pipeline to the consumer through a city gas distribution network cost-effectively without liquifying it first. The fuel is clean burning and easy to use- but the upfront distribution infrastructure cost is viable only in dense urban settings (India is a good example) and in specific geographies close to gas resources (e.g. coastal East Africa with sources in Tanzania, Mozambique).
    b. In that sense PNG is not unlike electricity- except investments in distribution of electricity have already been made for some of those that currently rely on biomass or will be made since universal electricity access is equally a goal. Electrification efforts could dovetail with "integrated energy planning" approaches that ensure that e-cooking is also an appealing option. The delivered prices of electricity are however three to five times higher today. This has limited e-cooking adoption except in places with ample low-cost hydropower and low tariffs (e.g. Ethiopia). There is a desire to understand how higher electricity consumption coupled with tariff structures can be leveraged to lower the cost of delivered electricity.
    c. LPG avoids both the distribution infrastructure of PNG and is generally lower in delivered cost than electricity. After firewood and charcoal it is the most adopted clean fuel in sub-Saharan Africa and can be made available in small

[1] At the outset, it is crucial to differentiate between LPG, a mixture of liquified propane and butane that is primarily distributed to the consumer in cylinders. Unlike natural gas, Propane and Butane can be modestly pressurized to convert to liquid form, and the liquid can then be placed in a cylinder. Natural gas or Methane needs very high pressures in industrial facilities and specialized vessels/ships for transport as LNG (liquified natural gas). Moving natural gas in pipelines is feasible at modest pressures- and such transport is carried out in many parts of the world and hence the term Piped Natural Gas or PNG. City gas distribution (CGD) systems have been deployed in urban settings even when the gas use at households is primarily for cooking.

towns and peri-urban settings, just as easily in urban settings. These settings may not have the initial density of users that say countries in Asia have enjoyed. The portability and divisibility of LPG allows one to gradually increase its use starting with the most desirable tasks first.

3. Fuel stacking- a term to describe the use of multiple different fuels, stoves, devices depending upon specific cooking tasks. Even limited use of clean commercial fuels or electricity is a very desirable entry point that leverages familiarity gained in the process as means accelerate adoption towards exclusive use of clean fuels. Beyond health and environment, evidence of use of clean commercial fuels shows the convenience, utility, efficiency, and aspirational benefits of these fuels.
4. This note does not address the potential of bio-derived fuels such as ethanol or biogas. Creating affordable supply at scale of biomass derived liquid and gaseous fuels will be specific to agroecology, population density, land-use modalities and in case of biogas also on livestock ownership. Here, leveraging nature-based solutions for feedstock, links to agriculture, process heat needs, animal husbandry, forestry, local economy, and/or import substitution will be place-specific. The absence of bio-derived fuels from this brief should not be taken as a lack of their importance.
5. It is crucial to acknowledge that there will be continued use of biomass and hence efficient improved cookstoves will be important, especially in rural settings. Income constrained rural households are likely to use gathered biomass when possible.
6. With commercial clean fuels, the first costs of accessing a stove, cooking appliance, a cylinder or fuel canister, are frequently a barrier but this initial cost burden is a manageable barrier to overcome as seen with prior experiences.
7. The larger challenge is to drive higher adoption through lowering the recurrent costs associated with commercial fuels and electricity. There are successful examples how this was done through policy, investments in infrastructure, incentives, tariffs, and digitization. Measures that can lower recurrent costs through infrastructure and digitization without subsidizing the fuel itself, are probably the most urgent interventions that can increase adoption after addressing first costs. Otherwise, the vicious cycle of high recurrent costs will suppress demand, and suppressed demand will in turn lead to even lower investment in supply chains.
8. Initially measures to drive adoption may succeed in urban settings where a) there is constrained access to free or low-cost biomass, leading to purchased fuelwood or charcoal, b) consumers are more likely to value time and convenience, c) living quarters are smaller not allow open fires and d) consumers may have higher disposable incomes. At the same time there are supply side advantages- urban settings are amenable to lower cost distribution of fuel by cylinder/cannister (e.g. LPG, Ethanol), by pipe (e.g. PNG), or by a reliable safe grid network (e.g. electricity).
9. LPG and PNG are fossil fuels. But it is worth noting that even if one billion people use these fuels for cooking- the GHG emissions would be about the same as those from natural gas use in the state of New York. This highlights the fact that compared to the use of fossil fuels in the global north, clean cooking needs are miniscule.
10. While nearly 900 million lack access to clean cooking, only 600 million lack access to electricity. Closing the electricity access gap can be an opportunistic entry point towards leapfrogging or towards longer-term use of electricity for cooking as is being envisioned in the global North.

Fuel specific lessons are:

11. **LPG:** The retail premium for LPG in many countries of Sub-Saharan Africa is high. These countries are smaller in population, sometimes land-locked, and can lack bulk cross-border movement infrastructure. Addressing these issues alone could possibly halve the retail premium (price above wholesale) in LPG from $1.50/kg to $0.75/kg. Policies and investments in port, and storage infrastructure, improved distribution logistics, digitization to allow targeting, pay-as-you-go, can lead to supply-chain efficiencies and economies of scale. Such measures, coupled with regional co-operation can lower retail fuel costs. There is likely differentiated role of public investments in port and storage facilities, nationwide digital payment models to unlock private investments in cylinder filling/distribution and use of digitization in logistics and payments. For many consumers, LPG is an aspirational fuel, perhaps due to familiarity, convenience, and portability of the fuel- thus obviating the need for pipe or wire to the consumer.
12. India has gained considerable experience and lessons from promoting LPG as a clean fuel. Initially the LPG fuel was subsidized and while subsidy was intended for household use, there was unintended diversion of fuel to commercial users as well. Affordability and availability of the fuel generally restricted use to urban consumers. The cost to state exchequer a decade ago reached as high as $7B in one year. This burden was dramatically lowered using direct transfers to households purchasing LPG, as opposed to providing the subsidy to the fuel distributor. More recently the primary focus of the Government of India has been on programmatically lowering/eliminating the upfront costs of the stove and the cylinder, also providing LPG fuel for the first cylinder free of cost, along with a modest subsidy for recurrent use (about $3 to $4 per cylinder at today's exchange rates)- but only for targeted below poverty line consumers. Over the last eight years this approach has led to an additional 100 Million households using LPG (beyond the nearly 200 Million households already using the fuel in India). Note that these additional households were lower-income households for whom even the first cost was a very significant barrier. When this barrier was removed, most poorer households (except 12% who never purchased fuel again) started to use LPG for some tasks (fuel-stacking), with LPG utilization being about a third to a fourth of what it would otherwise be for exclusive LPG use. Considering this partial use of LPG by the additional 100 Million households, the cost to the state exchequer of this program is about $12 per beneficiary household or about $1/capita if one takes the entire national population as the normalizing basis.
13. An open question here is the extent to which the use of LPG would have reduced if the recurrent cost of fuel was not subsidized. One estimate is that if fuel cost to consumer increased from $10 to $14 per cylinder, then the annual use might have reduced from three-four cylinders per year to a range of two-three cylinders assuming cash outlay towards LPG remains the same. An approach that does not subsidize the fuel itself has some attractive features- it does not impose a fuel subsidy burden on the state exchequer. It would also free up public resources towards investments in infrastructure and digitization- thus lowering retail costs.
14. A direct-to-consumer payment ecosystem is essential (there are other co-benefits) if one wishes to provide targeted upfront-cost incentives or wishes to implement innovative pay-as-you-go models to lower lumpy payments or implement some form

of carbon credits tied to use of the fuel. Introducing smaller cylinder sizes (e.g. Senegal) is also a route to increase adoption.

15. International LPG prices do fluctuate with oil/natural prices. Shipping costs can also introduce fluctuations in landed wholesale prices. Alleviating these fluctuations can help maintain adoption levels but this could come at high cost to the state exchequer and risks the political economy of removing subsidies when fuel prices to come down.

16. **Piped Natural Gas:** Countries in Sub-Saharan Africa with natural gas reserves and production could leverage the lower cost of natural gas (closer to $5/MMBtu near production facilities) compared to LPG (equivalent to $10/MMBtu when at $0.50/kg). Natural gas could be delivered as PNG to consumers in dense metro areas. There is a clear affordability and user convenience win with PNG, if one can ensure cost-effective deployment capex of the city-scale infrastructure. India has already reached 15 million households and is targeting 125 million households for PNG in the next ten years. Upfront investment capex of PNG delivery infrastructure if treated as a long-term low-interest loan can be below $2/month for countries such as Mozambique, Tanzania, and their immediate neighbors. When considered volumetrically there is plenty of natural gas to meet cooking needs. While the global north due to its high gas use and hence emissions, is trying to reduce and eventually eliminate gas use, the question is whether one can leverage the low cost of the fuel to help those in the global south. To be sure, volumetrically, the current gas consumption of New York State in the U.S. is about the same as the cooking fuel needs for one billion people in the world. Note that household cooking requires a miniscule amount of energy when compared to the gas demands from industry and heating buildings in the colder climates of the global north.

17. **E-cooking**. It is worth noting that even in low electricity access countries, rural households are more likely to have access to electricity than to LPG or PNG. However, the electrical power requirements for such cooking is high, in kWs (kiloWatts), nearly ten times the peak power use of those with first access to grid electricity. Hence one needs to ensure that the poor and vulnerable can also access to safe reliable power, housing/wiring quality behind the meter or supply-side reliability in front of the meter.
18. Use of electricity for specific cooking tasks (e.g. kettles, microwave, toasters, rice cooker or an electric pressure cooker) is already popular in the global north even when the primary cooking fuel might be natural gas or propane or LPG. We observe evidence of electric cooking (we include heating and boiling water as cooking tasks for brevity), albeit as a small fraction of the fuel stack, even in urban informal settlements in Kampala and Nairobi where both home wiring and supply quality were a challenge. MECS has championed the benefits of electric cooking, leveraging additional efficiency gains through use of electric pressure cookers.
19. Note that within the limits of use where lifeline tariffs are available, the cost of electricity can be half to a third of the cost of LPG fuel. But lifeline tariffs are currently available only for a fraction of desired cooking requirements. Just like fuel staking with LPG, closing the electricity access gap in Sub-Saharan Africa could allow e-cooking as part of the mix if one can leverage appropriate tariffs for some initial block of lifeline consumption.

20. There are those that live in urban informal settlements that have electricity access and many of them face challenges of reliability and quality of electric supply or lack safe inside wiring. Existing connection quality, earthing, circuit breakers, protection, ready-boards and inside wiring may be adequate only for low power services such as lighting and solid-state electronics. Yet it is this group that also spends considerable sums on a host of other alternatives- including wood and charcoal. While those in informal settlements may face the additional barrier from the lack of formal tenancy rights-measures to move this demographic to clean cooking can be viable since they would be substituting existing expenses on low quality biomass, provided suitable housing tenure and utility-directed measures can be adopted.

The overarching message is clear: a concerted effort from governments, the private sector, and international organizations is essential to make clean cooking accessible and affordable, thereby achieving significant health and environmental benefits on a global scale.

Acknowledgements: Some of the lessons here emerged from a South-South learning event on the sidelines of a meeting on April 22, 2024, facilitated by the OPEC Fund, SEforALL, UNIDO, MECS and Dr. Kandeh Yumkella of Sierra Leone. Vijay Modi acknowledges the support of the Columbia World Projects and the Rockefeller Foundation through the e-Guide effort.

Abhishek Kar of CEEW, Sebastian Rodriguez of Circlegas both have deep experience with LPG in India and East Africa respectively. Nishant Narayan from SEforALL brought to bear his knowledge and links to Integrated Energy Planning. I shared my own experience with Piped Natural Gas from working in Gujarat, India. We quickly put together this short piece. Supplementary material will be posted at qsel.columbia.edu.