Towards safe drinking water and clean cooking for all

*Isha Ray, Kirk R Smith**

The public health community has tried for decades to show, through evidence-based research, that safe water, sanitation, and hygiene (WASH) and clean cooking fuels that reduce household air pollution are essential to safeguard health and save lives in low-income and middle-income countries. In the past 40 decades, there have been many innovations in the development of low-cost and efficacious technologies for WASH and household air pollution, but many of these technologies have been associated with disappointing health outcomes, often because low-income households have either not adopted, or inconsistently adopted, these technologies. In this Viewpoint, we argue that public health researchers (ourselves included) have had an oversimplified understanding of poverty; our work has not focused on insights into the lived experience of poverty, with its uncertainties, stresses from constant scarcity, and attendant fears. Such insights are central to understanding why technologies for safe water or clean cooking are unused by so many households that could benefit from them. We argue that, rather than improved versions of household-scale delivery models, transformative investments in safe water and clean cooking for all require utility-scale service models. Until then, research should focus on interim safe water and clean cooking options that are directed towards the utility-scale service model.

Lancet Glob Health 2021; 9: e361–65

Published Online January 11, 2021 https://doi.org/10.1016/S2214-109X(20)30476-9

Energy and Resources Group (Prof I Ray PhD) **and School of Public Health** (Prof K R Smith PhD)**, University of California, Berkeley, Berkeley, CA, USA**

*Prof Smith died in June, 2020

Correspondence to: Prof Isha Ray, Energy and Resources Group, University of California, Berkeley, Berkeley, CA 94720, USA **isharay@berkeley.edu**

Introduction

Universal access to safe water and clean cooking remains an elusive goal of sustainable development. Global public health research is strewn with examples of low-cost safe water devices that are unused, or of improved cookstoves that have been forgotten about. Active debates exist on why so many households in low-income and middle-income countries (LMICs) do not use simple, low-cost measures that could improve their quality of life. Even when households adopt these measures, correct and consistent use is frequently not practised; water filters are not replaced, chlorine is not replenished, or traditional, solid-fuel stove use continues alongside cleaner-burning, more efficient stoves.[1–3] Epidemiological models suggest that high and sustained adherence to improved technologies is needed to reach measurable health benefits.[4,5] However, meticulously designed studies concerning domestic water and energy have been unable to reach high enough levels of habitual use in LMICs.[6–8] Furthermore, several safe water treatments and improved solid-fuel cookstoves, even when correctly used, do not meet the minimum WHO standards consistent with human health.[9,10]

The collective cost of these unsuccessful attempts has been enormous: globally, 0·8–1·8 million deaths annually are attributed to unsafe water, sanitation, and hygiene (WASH),[11] and household air pollution from cooking with solid fuels leads to 1·6–3·8 million deaths annually.[11] Children younger than 5 years are the most vulnerable group with respect to microbial contamination from inadequate WASH, which is the most common form of water contamination in low-resource settings. Household air pollution affects women more than men because they are the primary cooks in most households. Women are also affected by inadequate access to safe water, because women are usually expected to collect water and be responsible for its management. Therefore, investing in safe WASH and cleaner cooking fuels could be transformative for public health and also for gender equality.

A considerable body of research exists on the possible reasons for the low uptake of cheap safe water and clean cooking technologies in LMIC households.[12] For decades, studies have shown disappointing (null) results regarding the health effects of these devices.[6,13,14] Researchers have provided efficacious technologies for free to encourage their use and have devised educational and social marketing campaigns to increase awareness of the value of clean water and clean indoor air, often to little avail.[15–17] Researchers and non-governmental organisations have developed strategies to promote behavioural change and have applied peer-pressure tactics and nudges to increase the uptake of health products, with mixed effects.[18–21]

In this Viewpoint, we argue that public health researchers, ourselves included, have not internalised the everyday complexity of poverty. The Viewpoint is based on our own decades of field research, and on insights from development economics, cognitive science, and anthropology, for a deeper understanding of the lived experience of poverty. First, these insights are central to understanding why so many available technologies for safe water or cooking are unused by so many households. Second, these insights show that transformative investments in providing universal access to safe water and clean cooking require a utility-scale delivery model rather than improved versions of household-scale models. Third, these insights suggest that strategies to change behaviour that focus on individuals, although necessary, might not alleviate the financial and cognitive stressors that keep the adoption and use of safe water and clean cooking low. Finally, these insights imply that the provision of utility-scale services is not just best practice—the WASH policy sector has already accepted this idea[22]—but that this method is possibly the only delivery model for universal access to clean water and clean energy, as called for in the Sustainable Development Goals.

Affordability on US$2 per person per day

Many technologies that provide safe water and stoves that burn cleaner fuels have been labelled as low cost when they are not particularly affordable for many households. In the literature, the upfront costs of durable systems, such as ceramic filters or improved stoves, have been calculated, but the costs of operation, refills, education, and unpaid family labour have not always been accounted for.[23,24] The role of household income (or of who controls it) has been neglected in the calculation of affordability, other than suggestions of generic thresholds;[25,26] the meaning of low cost, with consideration of the need for other non-discretionary expenses (eg, food), has not been defined. The literature has rarely extended beyond economic indicators to understand what feels affordable. Perhaps most importantly, research regarding safe water and clean energy has not focused on what money management looks like for a household in which members live off $2 per person per day.

Financial stress for people in poverty

People who are poor do not simply have less money; they are also engaged in the constant management of meagre cash flows. Collins and colleagues[27] showed that a person who earns $2 per day does not have a steady income: they can have days when they earn $1 or $3. Thus, the family will have to continually make tradeoffs among their basic needs. For example, they will have daily budgets for food and potentially small debts to neighbours or local storekeepers, or they might have given small loans out to help people who have helped them in the past. The family might even be trying to save some of their income for emergencies somewhere safe from theft or temptation. Banerjee and Duflo[28] have suggested that "they [people who are poor] have to be sophisticated economists just to survive". The constant juggling of financial costs takes up substantial time and effort, and the less income one has, the more one is forced to juggle.[28] In these circumstances, it could seem unnecessary to purchase a health product at a certain cost when the benefits of this product might be uncertain and not immediate; not everyone who drinks untreated water becomes sick. For durable products, such as ceramic water filters or liquefied petroleum gas cylinders, which many households like using, the costs can be prohibitive.[16,29] Buying these products with even a generous loan can feel risky. Yet on some days, perhaps on a day that has brought in $3, it might be hard to resist a toy for a grandchild, or some nail varnish for a daughter, even if these cost more than a bottle of liquid chlorine. The best designed social marketing campaigns and behaviour change efforts cannot alter these realities.

Cognitive stress for people in poverty

Poverty imposes what Mullainathan and Shafir[30] call a bandwidth tax; poverty uses up cognitive capacity with constant worries about how to manage with small and uncertain cash flows, often earned through multiple small and uncertain jobs. Ethnographic studies of mental health in Bangladesh have named this chinta rōg, or the worry disease.[31] People who are poor report that they worry about their children, the onset of a health emergency, and their permanent states of exhaustion. They also worry about their tenuous access to water and sanitation. When people are consumed with their immediate circumstances, their own future needs, such as long-term health or financial stability, can lose salience.[30] Saving little by little towards a future expense, such as a cylinder refill for a liquefied petroleum gas-fuelled stove, can fall outside of their available bandwidth. Understanding what living in constant scarcity can do to cognitive capacity is foundational to understanding what is and is not possible by way of safe water and clean energy uptake for people who live in such circumstances. To our knowledge, no study of the barriers to adoption of, or non-compliance with, safe water and clean energy approaches has factored in the bandwidth tax associated with poverty. Behaviour change is hard, researchers often say, after a set of null results. But behaviour change is especially hard for families in poverty, for whom everything is hard.

Safe water and clean energy: a product or a service?

The bandwidth tax associated with poverty means that, if the use of safe water and cooking with clean fuels are to become scaled up and habitual, they need to be made affordable but also easy to use. In nudge-theory terms, the default option has to be made the health-promoting option.[18] Thus, the delivery model for safe water and fuel needs to mimic a utility service. When water is chlorinated and piped into the premises, it is easy to use as long as the bills are affordable.[32] Additionally, when gas cylinders are subsidised and refills are delivered to the home, the fuel is easy to use as long as the charges are affordable.[6,33] However, the easier option with many technology choices on today's market is to continue conventional practices, because these practices are already habits and are often free. Adding chlorine to a bucket of water, agitating the water, and waiting before use is not particularly easy compared with the use of untreated water. Additionally, instead of switching to the use of only stoves that burn cleaner fuels, stacking an improved wood stove with the older unimproved stove makes cooking easier. The use of improved technologies is also more likely if there are immediate rewards—eg, people like to use liquefied petroleum gas-fuelled stoves mainly because these stoves are fast and convenient.[33] By contrast, improved biomass-burning stoves, despite aggressive promotion, are often unused.

In this Viewpoint we argue in favour of the utility-scale service model, whether systems are centralised, small-grid, or hybrid,[34] because safe water or clean fuel for cooking for people who are poor are too often treated as

products when they should be treated as services. Even piped-in water might not be safe, and treatment in research as well as practice is regularly left to the household.[14,35] However, household product models are not scaling up for people who are most in need. This is not because low-income households are unwilling to take personal responsibility for their health, but because "people's ability to take personal responsibility is shaped by their circumstances."[36] The research community cannot expect more education and creative behaviour change methods to scale up current technologies of access, because these efforts will have limited impact given the circumstances of people in poverty. Rather, clean water and energy services should be designed and delivered such that exercising personal responsibility requires less effort and thought. This method of delivering clean water and energy is, after all, the default option for people in high-income countries and, increasingly, for people who are better off in low-income countries.

We are not making the ethical point that people who are poor should not be stuck with poor choices.[3] We are making a pragmatic argument, drawing on decades of well intentioned efforts to get clean technologies adopted and used at scale. We also argue for the need to reduce, rather than add to, the bandwidth tax that people who are poor contend with daily, based on insights from cognitive science. Research with a primary focus on household behaviours implicitly attributes low take-up or inconsistent use of clean water and clean cooking to the non-compliance of households.

The role of the state

How does an LMIC implement water and energy deliveries through a utility-based service or an otherwise regulated service model? The utility-scale service model is expensive, whether it is centralised or decentralised, and is conventionally considered too expensive for low-income communities. For this reason, research regarding safe water and energy has focused on point-of-use or point-of-collection models of provision that are not on a utility scale, and which are often conveyed as short-term measures with no discussion of when long-term measures will be implemented. From the perspective of social cost–benefit analysis, the conventional understanding should be questioned: the costs of waterborne and respiratory diseases to health are high, and disproportionately borne by those who can least afford to pay.[3] Additionally, it might be more rational to pay for reliable and convenient water and energy systems that people will use than to spend money (and engineering talent) on systems that few people use and benefit from. The debate here is about who pays and how they pay. Do the costs have to be recovered through user charges (which is the case with most household devices) or does the state (ie, the taxpayer) help to subsidise the cost of clean water and clean cooking for low-income communities?

State-subsidised programmes have been established to provide at-scale access to clean water and energy in some LMICs. An example includes China's rural clean cookstove project (the National Improved Stoves Programme); this programme enabled the delivery of improved stoves to 100 million households, with a coordinated effort by multiple ministries, county and village officials, and rural energy companies.[37] Furthermore, India's Ujjwala programme to replace 50 million biomass-fuelled stoves with liquefied petroleum gas-fuelled stoves has worked through government channels to provide subsidised stoves, subsidised refills, and free home deliveries for families living below the poverty line. Even then, unaffordability has been a barrier.[38] Regarding clean water, the government of China has invested heavily in centralised as well as village-based utilities, such that more than 400 million people gained access to piped (but not always treated) water between 2000 and 2017.[39] Public utilities in LMICs have been accused of inefficiencies, corruption, and not benefiting people with low incomes. During the early 2000s, however, utility-based reforms that have been supported by the governments in Kampala (Uganda) and Hubli-Dharwad (India) have increased the reliability and quality of water supply for thousands of households in each city,[40,41] and, in India's case, water availability was also increased.[33] Low lifeline rates enabled expansion in both cases, as subsidised rates have done for urban populations living in poverty elsewhere. Low-income countries, like low-income households, have many competing needs and few available resources, necessitating hard tradeoffs. However, we argue that even low-income countries should invest more generously, with international assistance when needed, in their water and domestic energy services if universal access is the aim. The if is important. States can be incompetent, or even venal, and the health of their citizens on low incomes might not be their primary concern. However, no country in history has delivered at-scale access to clean water or energy without the state having a central role in implementation and regulation, although not necessarily in direct service provision. If, instead, we see a rolling back of state support for utilities in low-income communities, we run the risk of "sharply regressive" outcomes for safe water, clean cooking, gender equality, and public health.[42]

A research agenda towards the utility-scale service model

Extending community-scale or municipal-scale utilities where they do not exist could take years or even decades in the countries with the lowest incomes. Interim steps towards clean water and clean energy are therefore necessary. We contend that water and energy research should focus on interim solutions on the pathway towards a utility-scale service model, as opposed to solutions that could crowd out the potential of this model. Productive directions might include designing

For **global data on household water services** see https://washdata.org/data/household

and evaluating cost-efficient delivery mechanisms for the distribution of liquefied petroleum gas,[43] reliable electricity services through regulated mini-grids, rural piped water systems fitted with automatic chlorinators,[44] or staffed kiosks dispensing treated water into homes via flexible pipes.[22]

We suggest several approaches for public health and related research on interim options. Consistent use, water quality or household air pollution, and health and economic effects of local utility-style delivery systems for water or cooking fuels should be evaluated. A range of service models should be piloted and evaluated, especially in rural areas where utilities are unwilling to expand.[45] The social determinants of health-seeking behaviours associated with different delivery mechanisms, different user costs, and different subsidy regimes need to be better understood and informed by daily spending and daily stresses in underserved communities. The non-conventional health outcomes of easier access to safe water and clean fuels, such as increased mental capacity or fewer everyday hassles, should be operationalised and counted. Feasible financing mechanisms for cost recovery, including cross-subsidisation, have to be designed and their effects need to be evaluated; LMICs often provide free primary education and free immunisations, but targeted subsidies for water disinfection or cooking fuels are still a topic of active debates. These interventions could have important health impacts and will need innovative approaches for evaluation when random assignments to the so-called treatment are not viable. However, achieving measurable health impacts also depends on reducing the faecal contamination in the environment in LMICs (which safe water alone cannot do),[14,35] and on reducing household air pollution to concentrations that are deemed suitable for human health (which clean cooking alone might not deliver).[46]

Utility services might not be feasible in all terrains or for sparse populations, and pro-poor utility regulation is a major administrative challenge.[47] Treated water or liquefied petroleum gas cylinders can be delivered to the home or the compound under these circumstances; with price breaks and quality regulations, this type of delivery service could become an add-on to a utility-based service model, as opposed to alternative approaches to a functioning utility. By contrast, technologies led by demand, such as cleaner solid-fuel cookstoves, packaged water, or household disinfectants, that might not be affordable for all, or that do not relieve the cognitive overload of individuals with low incomes, are not on the pathway towards reliable utility-based services.[48,49] Prepaid water ATMs are spreading quickly in low-income communities; however, unless these are accompanied by low lifeline rates and realistic consumption allowances, they cannot provide universal and reliable access. We conclude that sustained research that factors in decision making under scarcity,[30] infrastructure design, public finance, and public health will be needed to, eventually, take water and domestic energy access in the direction of utility-scale provision.

Conclusions

This Viewpoint was started before the COVID-19 pandemic. Since then, the morbidity and mortality occurring as a result of poverty, crowded living conditions, the scarcity of water for handwashing, and household air pollution from cooking with solid fuels under shelter-in-place rules have further exposed inequalities between, and within, high-income countries and low-income countries. Our conclusion that a well supported service model is the only way to provide safe and affordable water, and to provide clean cooking fuels, for all seems even more pertinent. It is not easy, cheap, or fast to design, finance, and evaluate reliable and regulated utilities for low-income citizens. However, universal access to water and energy have never been historically possible without utility services.

Contributors
IR and KRS planned and designed the Viewpoint. IR wrote the Viewpoint.

Declaration of interests
We declare no competing interests.

Acknowledgments
KRS and IR planned this Viewpoint together. They discussed the content and agreed IR would write the first draft. IR sent him the draft on June 10, 2020. KRS died unexpectedly on June 15, 2020. His path-breaking research and passionate advocacy did much to accomplish the better world he so wanted to see. Although he ultimately could not comment on the full draft, this paper is a joint endeavour and IR presents it in his memory. IR would also like to thank Alasdair Cohen and Jessica Goddard for their valuable comments on an earlier draft.

References

1 Amrose S, Burt Z, Ray I. Safe drinking water for low-income regions. *Annu Rev Environ Resour* 2015; **40:** 203–31.
2 Ruiz-Mercado I, Masera O, Zamora H, Smith KR. Adoption and sustained use of improved cookstoves. *Energy Policy* 2011; **39:** 7557–66.
3 Clasen T, Smith KR. Let the "A" in WASH stand for air: integrating research and interventions to improve household air pollution (HAP) and water, sanitation and hygiene (WaSH) in low-income settings. *Environ Health Perspect* 2019; **127:** 25001.
4 Brown J, Clasen T. High adherence is necessary to realize health gains from water quality interventions. *PLoS One* 2012; **7:** e36735.
5 Enger KS, Nelson KL, Rose JB, Eisenberg JNS. The joint effects of efficacy and compliance: a study of household water treatment effectiveness against childhood diarrhea. *Water Res* 2013; **47:** 1181–90.
6 Smith KR, Sagar A. Making the clean available: escaping India's chulha trap. *Energy Policy* 2014; **75:** 410–14.
7 Reygadas F, Gruber JS, Dreizler L, Nelson KL, Ray I. Measuring user compliance and cost-effectiveness of safe drinking water programs: a cluster-randomized study of household ultraviolet disinfection in rural Mexico. *Am J Trop Med Hyg* 2018; **98:** 824–34.
8 Parvez SM, Azad R, Rahman M, et al. Achieving optimal technology and behavioral uptake of single and combined interventions of water, sanitation hygiene and nutrition, in an efficacy trial (WASH benefits) in rural Bangladesh. *Trials* 2018; **19:** 358.
9 Champion WM, Grieshop AP. Pellet-fed gasifier stoves approach gas-stove like performance during in-home use in Rwanda. *Environ Sci Technol* 2019; **53:** 6570–79.
10 Roden CA, Bond TC, Conway S, Pinel AB, MacCarty N, Still D. Laboratory and field investigations of particulate and carbon monoxide emissions from traditional and improved cookstoves. *Atmos Environ* 2009; **43:** 1170–81.

11 Landrigan PJ, Fuller R, Acosta NJR, et al. The *Lancet* Commission on pollution and health. *Lancet* 2018; **391:** 462–512.

12 Figueroa ME, Kincaid DL. Social, cultural and behavioral correlates of household water treatment and storage. Baltimore, MD: Johns Hopkins Bloomberg School of Public Health and USAID, 2010.

13 Schmidt W-P, Cairncross S. Household water treatment in poor populations: is there enough evidence for scaling up now? *Environ Sci Technol* 2009; **43:** 986–92.

14 Pickering AJ, Null C, Winch PJ, et al. The WASH Benefits and SHINE trials: interpretation of WASH intervention effects on linear growth and diarrhoea. *Lancet Glob Health* 2019; **7:** e1139–46.

15 Luoto J, Najnin N, Mahmud M, et al. What point-of-use water treatment products do consumers use? Evidence from a randomized controlled trial among the urban poor in Bangladesh. *PLoS One* 2011; **6:** e26132.

16 Burt Z, Njee RM, Mbatia Y, et al. User preferences and willingness to pay for safe drinking water: experimental evidence from rural Tanzania. *Soc Sci Med* 2017; **173:** 63–71.

17 Kirby MA, Nagel CL, Rosa G, et al. Effects of a large-scale distribution of water filters and natural draft rocket-style cookstoves on diarrhea and acute respiratory infection: a cluster-randomized controlled trial in western province, Rwanda. *PLoS Med* 2019; **16:** e1002812.

18 Thaler RH, Sunstein CR. Nudge: improving decisions about health, wealth and happiness. New York, NY: Penguin Group, 2009.

19 Mosler H-J. A systematic approach to behavior change interventions for the water and sanitation sector in developing countries: a conceptual model, a review, and a guideline. *Int J Environ Health Res* 2012; **22:** 431–49.

20 Guiteras RP, Levine DI, Luby SP, Polley TH, Khatun-e-Jannat K, Unicomb L. Disgust, shame, and soapy water: tests of novel interventions to promote safe water and hygiene. *J Assoc Environ Resour Econ* 2016; **3:** 321–59.

21 Kar A, Zerriffi H. From cookstove acquisition to cookstove transition: framing the behavioral aspects of cookstove interventions. *Energy Res Soc Sci* 2018; **42:** 23–33.

22 WSUP. The urban water supply guide: service delivery options for low-income communities. 2014. https://www.wsup.com/insights/the-urban-water-supply-guide-service-delivery-options-for-low-income-communities (accessed Dec 2, 2020).

23 Smith KR. What's cooking? A brief update. *Energy Sustain Dev* 2010; **14:** 251–52.

24 Fonseca C, Franceys R, Batchelor C, et al. Life-cycle costs approach: WASHCost Briefing Note 1. 2011. https://www.ircwash.org/sites/default/files/Fonseca-2010-Life.pdf (accessed Dec 2, 2020).

25 Hutton G. Global costs and benefits of reaching universal coverage of sanitation and drinking-water supply. *J Water Health* 2013; **11:** 1–12.

26 Nussbaumer P, Bazilian M, Modi V. Measuring energy poverty: focusing on what matters. *Renew Sustain Energy Rev* 2012; **16:** 231–43.

27 Collins D, Morduch J, Rutherford S, Ruthven O. Portfolios of the Poor: how the world's poor live on $2 a day. Princeton, NJ: Princeton University Press, 2009.

28 Banerjee AV, Duflo E. Poor Economics. New York, NY: Public Affairs, 2011.

29 Gould CF, Urpelainen J. LPG as a clean cooking fuel: adoption, use, and impact in rural India. *Energy Policy* 2018; **122:** 395–408.

30 Mullainathan S, Shafir E. Scarcity: why having too little means so much. New York, NY: Picador, 2013.

31 Selim N. Cultural dimensions of depression in Bangladesh: a qualitative study in two villages of Matlab. *J Health Popul Nutr* 2010; **28:** 95–106.

32 Burt Z, Ercümen A, Billava N, Ray I. From intermittent to continuous service: costs, benefits, equity and sustainability of water system reforms in Hubli-Dharwad, India. *World Dev* 2018; **109:** 121–33.

33 Lewis JL, Bhojvaid V, Brooks N, et al. Piloting improved cookstoves in India. *J Health Commun* 2015; **20** (suppl 1)**:** 28–42.

34 Hoffmann S, Feldmann U, Bach PM, et al. A research agenda for the future of urban water management: exploring the potential of nongrid, small-grid and hybrid systems. *Environ Sci Technol* 2020; **54:** 5312–22.

35 Cumming O, Arnold BF, Ban R, et al. The implications of three major new trials for the effect of water, sanitation and hygiene on childhood diarrhea and stunting: a consensus statement. *BMC Med* 2019; **17:** 173.

36 Marmot M. The health gap: the challenge of an unequal world. London: Bloomsbury, 2015.

37 Sinton J, Smith KR, Peabody JW, Liu Y, Gan Q. An assessment of programs to promote improved household stoves in China. *Energy Sustain Dev* 2004; **8:** 33–52.

38 Kar A, Pachauri S, Bailis R, Zerriffi H. Using sales data to assess cooking gas adoption and the impact of India's Ujjwala programme in rural Karnataka. *Nat Energy* 2019; **4:** 806–14.

39 Li H, Cohen A, Li Z, Zhang M. The impacts of socioeconomic development on rural drinking water safety in China: a provincial-level comparative analysis. *Sustainability* 2019; **11:** 85.

40 Berg SV, Mugisha S. Pro-poor water service strategies in developing countries: promoting justice in Uganda's urban project. *Water Policy* 2010; **12:** 589–601.

41 Kumpel E, Nelson KL. Comparing microbial water quality in an intermittent and continuous piped water supply. *Water Res* 2013; **47:** 5176–88.

42 Marmot M. Society and the slow burn of inequality. *Lancet* 2020; **395:** 1413–14.

43 Kimemia D, Annegarn H. Domestic LPG interventions in South Africa: challenges and lessons. *Energy Policy* 2016; **93:** 150–56.

44 Crider Y, Sainju S, Shrestha R, et al. System-level automatic chlorination in community-managed water systems. 2019 https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/schwerpunkte/WST/REACH/automatic_chlorination.pdf (accessed Dec 2, 2020).

45 Moriarty P, Smits S, Butterworth J, Franceys R. Trends in rural water supply: towards a service delivery approach. *Water Altern* 2013; **6:** 329–49.

46 Katz J, Tielsch JM, Khatry SK, et al. Impact of improved biomass and liquid petroleum gas stoves on birth outcomes in rural Nepal: results of 2 randomized trials. *Glob Health Sci Pract* 2020; **8:** 372–82.

47 Gerlach E, Franceys R. Regulating water services for all in developing economies. *World Dev* 2010; **38:** 1229–40.

48 Bailis R, Cowan A, Berrueta V, Masera O. Arresting the killer in the kitchen: the promises and pitfalls of commercializing improved cookstoves. *World Dev* 2009; **37:** 1694–705.

49 Cohen A, Ray I. The global risks of increasing reliance on bottled water. *Nat Sustain* 2018; **1:** 327–29.