Duke
NICHOLAS INSTITUTE
for ENERGY, ENVIRONMENT
& SUSTAINABILITY

Duke
JAMES E. ROGERS
ENERGY ACCESS PROJECT

Taxes and Subsidies and the Transition to Clean Cooking

A Review of Relevant Theoretical and Empirical Insights

Ipsita Das, Marc Jeuland, Victoria Plutshack, and Jiahui Zong

Taxes and Subsidies and the Transition to Clean Cooking
A Review of Relevant Theoretical and Empirical Insights

CONTENTS

Executive Summary 1

Acronyms 11

Introduction 12

Theoretical Principles applied to Environmental Health Technology Taxation/Subsidization 14

Review of Empirical Evidence on the Effectiveness of Subsidies, Taxes, and Duties on Improved and Clean Cooking Solutions 25

Case Study: Nepal 40

Summary and Conclusions 53

References 56

Appendix A: Selection from Nepal's Ministry of Population and Environment, Renewable Energy Subsidy Policy, 2073 BS (Government of Nepal 2016) 65

Appendix B: Summary of Literature 67

Summary

United Nations Sustainable Development Goal (SDG) 7.1 sets a target of ensuring universal access to affordable, reliable, and modern energy services by 2030. Unfortunately, many low- and middle-income countries (LMICs) are well off course to meet this target, especially with respect to access to clean cooking energy.

Though many challenges impede progress toward use of modern and sustainable energy for cooking purposes, cost barriers are perhaps most significant. Against this backdrop, this report discusses the role of subsidy and tax policies—levied on both the supply and demand side of this market—in affecting progress toward universal access to clean cooking in LMICs. Moreover, we aim to combat a common myth among those opposing subsidies for clean cooking: we show that a "fear of spoiling the market" with such incentives finds little empirical support in the literature. Based on the latest empirical evidence and theory, this report offers recommendations to policy makers, in additional to a case study on clean cooking transitions in Nepal.

EXECUTIVE SUMMARY

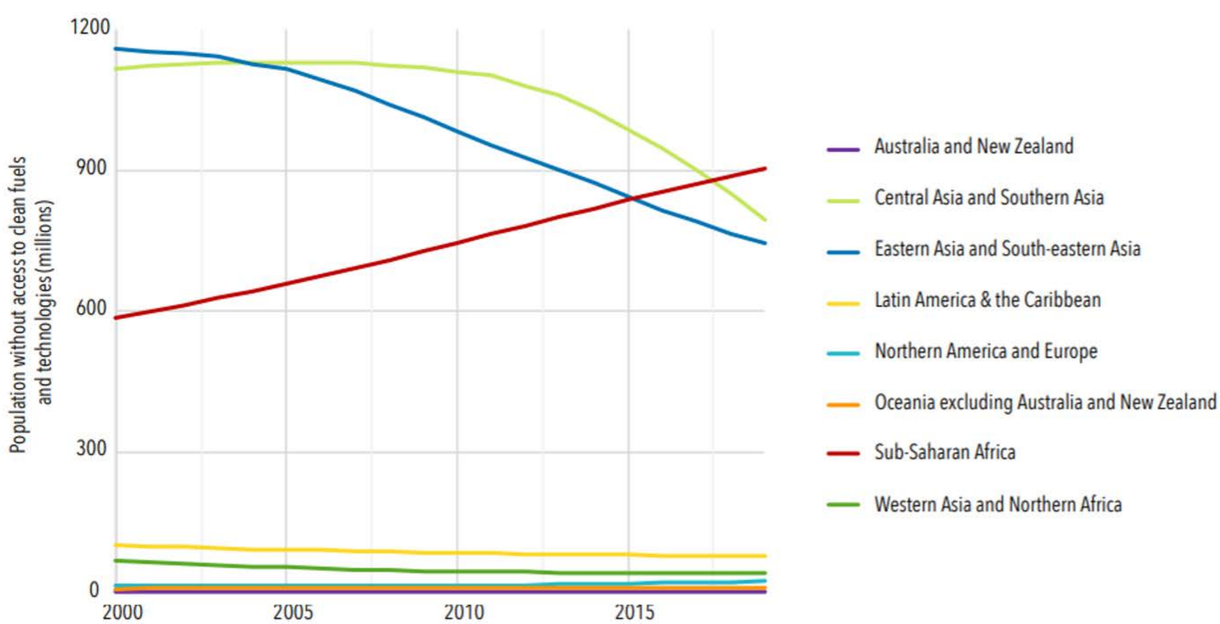
Introduction

Cooking with biomass fuels in inefficient stoves degrades the environment, increases the global burden of disease, and perpetuates energy poverty (Jeuland et al. 2018). Despite clear evidence of these harms, however, progress in achieving large-scale adoption and use of clean and so-called improved technologies—particularly among the poor rural households who arguably need them most—has been slow. United Nations Sustainable Development Goal (SDG) 7.1 sets a target of ensuring universal access to affordable, reliable and modern energy services by 2030. Unfortunately, many low- and middle-income countries (LMICs) are well off course to meet this target, especially with respect to access to clean cooking energy (Figure 1).

The progress of cooking transitions is too often impeded by a set of affordability, technology, supply chain, and policy barriers that render persistent and durable adoption of improved solutions challenging for much of the energy poor.

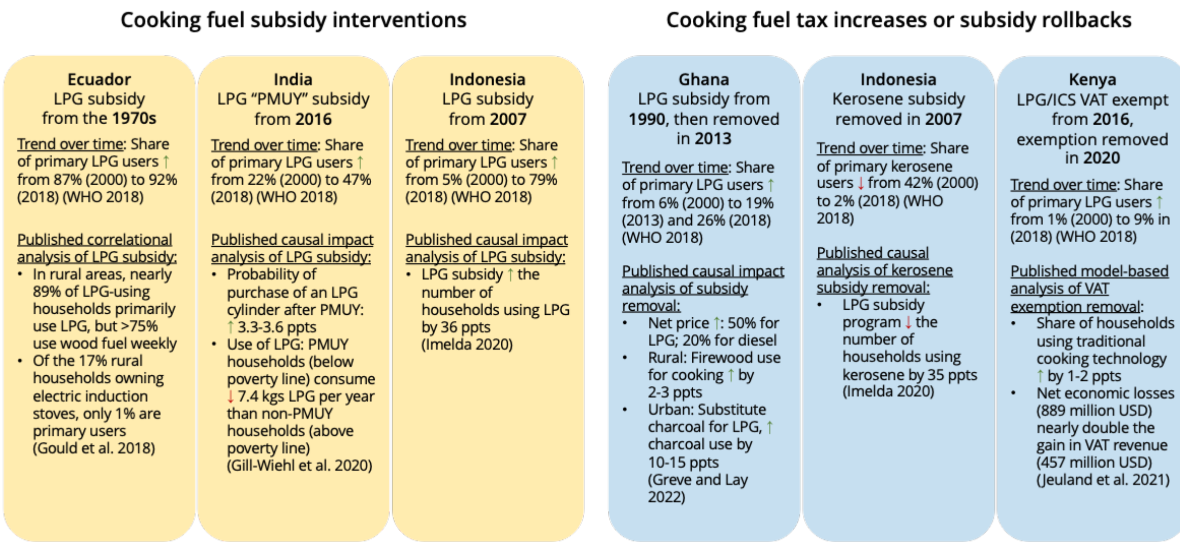
Against this backdrop, many governments intervene in markets for fuels and cooking technologies by implementing subsidies and taxes (Figure 2 highlights prominent examples). The rationale for and experiences with these exemptions and subsidies highlights a contradiction between economic efficiency and fiscal objectives: on the one hand, exemptions and subsidies are efficient and socially beneficial because they spur adoption of clean technology and thereby reduce negative pollution externalities; on the other hand, they increase the strain on already limited public budgets.

Figure 1. Access deficits by region (population without access to clean cooking fuels and technologies), 2010–2019



Source: IEA et al. (2021); WHO (2021)

Figure 2. Summary of main effects estimated or predicted from national-level programs



Source: Gill-Wiehl et al. 2020
Abbreviations: LPG: liquefied petroleum gas, PMUY: Pradhan Mantri Ujjwala Yojana, ppts: percentage points, ppts: percentage points, and ICS: improved cookstoves.

This report offers first a summary of salient considerations from tax theory, as they relate to goods such as cleaner cooking technologies and fuels. Second, it provides a comprehensive review of experiences with the use of price instruments to influence uptake of cleaner cooking technologies, as well as other similar quasi-public goods.[1] The review also considers the distributional consequences of such policies, as well as practical difficulties and common fears policy makers or donors have about pricing instruments. The report then presents a case study analysis aimed at identifying the potential of leveraging such solutions in Nepal, informed by a review of policy documents and drawing on consultations with key country stakeholders. The closing section offers a set of general and Nepal-specific recommendations for policy.

Salient Considerations from Tax Theory

There are two main arguments for price interventions aimed at altering households' use of improved efficiency cooking stoves and clean fuels. The first is based on enhanced economic efficiency and internalizing externalities,[2] and the second on the need to overcome significant affordability challenges that reduce willingness to pay for clean solutions, especially among the poor.

More efficient taxes and subsidies are those (a) levied on goods with relatively inelastic supply and demand, (b) supported by a broad base and levied at lower rates, (c) having stable rates over time,

[1] Quasi-public goods are goods that generate both private and public (spillover) benefits, and whose provision is often supported by government or policy intervention to achieve a more efficient level of societal uptake.

[2] Externalities are impacts not directly felt by consumers of the polluting cooking services, and in this setting come in the form of negative health (illness and mortality related to respiratory and cardiovascular illnesses, among others) and environmental (local deforestation, regional air quality degradation, and global climate forcing) spillovers.

and (d) that keep or bring the market closer to the socially optimal equilibrium, where marginal benefit equals marginal cost.

Applied to the cooking energy use problem, the latter principle is especially important and highlights that economic efficiency would be enhanced by making the use of polluting traditional stoves and fuels more expensive by using a tax. This is because traditional cooking generates substantial negative externalities in the form of health and environmental harm, such that private use of such technologies is above the social optimum. Globally, most such technologies are not purchased, however, because traditional fuels are often collected from the environment (as for firewood), and traditional stoves are constructed with households' own labor. Even when polluting stoves and fuels are purchased, those transactions tend to occur in the informal and untaxed sector of the economy. These facts render implementation of a tax (to raise prices of polluting solutions) impractical, but they also provide a strong policy rationale for subsidization of more efficient stoves and combustion of clean fuels (to reduce their prices) as a second-best option, because households' use of improved options in turn generates positive externalities for society. Indeed, taxes and duties on improved and clean cooking technologies, whether locally produced or imported, are doubly damaging, because they shift an already inefficient market—where there is too little adoption of improved technology—to even greater levels of inefficiency.

Economic modeling has established that these externalities and inefficiencies are typically quite large, depending on the nature of the technologies involved, even for cooking using fossil fuels such as liquefied petroleum gas (LPG) (Jeuland et al. 2018; Jeuland and Pattanayak 2012).[3] Subsidies help internalize the large positive externalities of technology adoption, and are thus efficiency-improving for a broad range of these and similar technologies. For example, mosquito control or bed nets to avert malaria (Brown and Kramer 2018), water treatment and sanitation (Ashraf et al. 2013; Blum et al. 2014; Guiteras et al. 2015), vaccines (Cook et al. 2009), and many others.

Adoption of improved solutions is particularly low because demand is typically very price elastic, especially among the poor.[4] Much of LMIC households' price sensitivity can be explained by tight liquidity constraints (Bensch et al. 2015; Berkouwer and Dean 2019), fears about the appropriateness or durability of improved technology (Brown et al. 2013), and low prioritization of mitigating health risks (Mobarak et al. 2012). Moreover, intrahousehold dynamics and low bargaining power for those benefiting within households may inefficiently depress adoption (Simon et al. 2014; Krishnapriya 2016). Financing of stoves and free trials with unknown technology therefore boost uptake (Beltramo et al. 2015; Levine et al. 2018). Notably, demand is price elastic and subject to liquidity and bargaining constraints for many similar environmental health goods, including water treatment, insecticide-treated bed nets, sanitation, vaccines, and health treatments (Bhattacharya et al. 2013; Null et al. 2012; Guiteras et al. 2015; Lucas et al. 2007; Garn et al. 2017). Referring to tax and subsidy theory principles, inefficiencies are largest

[3] This is because such fuels burn so much more efficiently than biomass. Biomass burning generates climate-forcing emissions of black carbon and other pollutants, and biomass harvesting is not fully sustainable in most countries, such that it contributes to forest degradation and net CO_2 emissions.

[4] The price elasticity of demand for a good is a measure of the responsiveness of quantity demanded by consumers to changes in the price of that good. Elastic demand is a term used when the percent change in quantity is greater than the percent change in price, while inelastic demand indicates the opposite. Supply of a good can similarly be price elastic or price inelastic.

when the market in question is characterized by more elastic supply and demand curves, and large externalities.

Of course, the substantial price sensitivity of demand for clean cooking solutions is also a reflection of the second rationale for price intervention, which is to improve affordability for the poor.

Empirical Evidence on Demand for Improved Environmental Health Technologies

Numerous reviews of the drivers of adoption of improved cookstoves (ICSs) or modern fuels have identified a common set of determinants: low cost of solutions, availability or prices of alternatives (e.g., firewood), higher income and education, urbanization and connectedness, efficient and equitable subsidies that benefit the poor, positive learning from neighbors and peers, financing or access to credit, greater economic empowerment (especially among women), and more future-oriented or health-risk reducing preferences (Puzzolo et al. 2016; Puzzolo et al. 2019; Lewis and Pattanayak 2012; Masera et al. 2000; Bonan et al. 2017). These reviews highlight the critical role of subsidies to mitigate a set of factors such as liquidity and credit constraints, intrafamily inequities, present bias (i.e., a focus on the short term), and externalities and peer effects that manifest in inefficiently low rates of community adoption.

Many have also argued for the importance of government support for suppliers (Sovacool 2016). Indeed, the private sector and even government-supported utilities have often failed to invest in rural markets because of the high cost and risks associated with reaching scattered and low-consuming customers (Bazilian et al. 2010; Joffe and Jones 2003).

General Evidence on Pricing Policies and Environmental Health Technology Adoption

Rigorous evidence on the impacts of subsidies for clean stoves and fuels from large-scale programs is growing but remains limited. Long-term evidence comes from Indonesia's kerosene-to-LPG conversion program, which featured subsidization of LPG coinciding with a phasing out of kerosene subsidies (Andadari et al. 2014). Research has also discussed national government subsidy efforts to subsidize LPG in Ecuador, Indonesia, and Peru (Gould et al. 2018; Pollard et al. 2018; Thoday et al. 2018). Such evidence is complemented by that from subsidy removal or phase-out experiences; for example, the removal of fuel subsidies in Ghana (Greve and Lay 2022) and reimposition of value-added tax (VAT) on ICS and LPG fuel in Kenya (Jeuland et al. 2021).

The experimental and quasi-experimental literature offers particularly valuable information on the causal impacts of subsidies. Evidence from rural India, for example, shows that ICS uptake and use is strongly responsive to subsidies that support combined supply chain development and lower end user prices, plus low-cost financing (Pattanayak et al. 2019). Free trials and time payments (making payments over four weeks) were found to enhance adoption among charcoal users in rural Uganda (Levine et al. 2018). Free distribution, or use of subsidies larger than what is socially optimal in the short term, may even be efficient in the long term when learning is important, as demonstrated from experiences with insecticide-treated bed nets (Bhattacharya et al. 2013). Positive information spillovers on neighboring households' demand have also been observed for sanitation (Dickinson and Pattanayak 2009; Guiteras et al. 2015; Deutschmann 2021; Kresch et al. 2020).

Importantly, even subsidized clean fuel transitions may increase household energy expenses, as people switch from noncommercial fuels that can be gathered from the environment to commercial fuels that must be purchased, or switch from purchasing less expensive to more expensive fuels (Jeuland et al. 2018). A range of studies show that exclusive use of clean technology generally remains elusive and reliance on traditional polluting technology persists, even when subsidies are generous (Gould et al. 2018; Pollard et al. 2018; Thoday et al. 2018).

A common concern with subsidies for clean stoves and fuels is that they mainly benefit higher-income populations. Many therefore argue that better targeting of subsidies to the poor is needed, sometimes called smart subsidies. Such subsidies would need to simultaneously address factors that inhibit adoption, leverage local market distribution channels, and avoid creating dependence (Simon et al. 2014). Unfortunately, operational guidance on designing smart subsidies, backed by solid empirical research, remains scarce. Empirical evidence for targeting of energy subsidies, meanwhile, is largely focused on electricity, where targeting is typically poor (Komives et al. 2005). Some sectors and interventions—for example, for bed nets and water treatment (Cohen et al. 2015; Dupas et al. 2016; Dizon-Ross et al. 2017)—have experienced more success with targeting.

Subsidies are typically insufficient on their own; complementary policies are also important. The successful Indonesian kerosene-to-LPG conversion program, for example, had the strong support of the central government, involved an able implementing partner, and engaged heavily with existing fuel distributors to ensure market access (Budya and Arofat 2011). India's ongoing LPG subsidization program, Pradhan Mantri Ujjwala Yojana (PMUY), similarly benefits from strong political backing. PMUY moreover is designed to limit consumption of subsidized cylinders while minimizing market distortions via direct reimbursement to consumers following purchases, which discourages black market development and quality deterioration. Information technology limits duplication and improves targeting, and promotion campaigns have used social pressure to encourage the wealthy to give up their subsidies.

With LPG and electricity, it is typically necessary to improve the fuel distribution network and, when relevant, to incorporate direct delivery of stoves and fuels to overcome inconvenience and reliability concerns (Pollard et al. 2018). In the broader environmental health context, triggering changes in cultural norms that affect technology adoption requires social pressure, as well as increased accessibility to materials and technical knowledge about solutions (Pattanayak et al. 2009; Orgill-Meyer et al. 2019). Moreover, implementer identity and local knowledge have been shown to have major implications for demand for a range of other technologies, such as improved cookstoves, agricultural productivity improvements, latrines, health products, and more general development efforts. Finally, prior experience with other interventions—especially negative experience—may have negative spillovers for new promotion initiatives.

Distributional Aspects of Subsidy Programs

Finally, despite the clearly positive impacts of subsidies on increased adoption and use of improved cooking technology, a key problem with energy subsidies is their tendency to be inequitable (IMF 2013; Troncoso and da Silva 2017). Demand for new technology among the poor is highly elastic, such that subsidy incidence on the poor is typically low. In contrast, demand for clean fuels among higher income households is highly inelastic, such that subsidy incidence for this group is high. The result is that these latter, wealthier households capture a large share of energy subsidy benefits.

Consistent with these ideas, Andadari et al. (2014) noted that the groups that benefitted the most from LPG subsidies in Indonesia were medium- and high-income households, while in India, though the current LPG program (PMUY) is meant to reach the poor, targeting the poorest and most marginalized households has remained a challenge (Tripathi et al. 2015). Gill-Wiehl et al. (2020) argue that subsidy levels should be increased for poorer households to support greater consumption of clean cooking fuel. Evidence from China similarly points to the exclusion of poor and lower-income households from the biogas subsidy scheme (Zuzhang 2013).

Equity challenges appear in other technology adoption situations in low-income countries; however, the relative incidence of benefits of subsidies vary substantially across technologies and service provision modalities. As noted previously, high-income consumers tend to receive an unbalanced share of subsidies delivered through increasing block tariffs commonly touted as “pro poor” in water and electricity provision, compared to low-income residential customers. In contrast, targeted subsidies were highly beneficial for encouraging adoption and improved outcomes among below-poverty-line households adopting latrines (Pattanayak et al. 2009). A cost-effective strategy for long-term sanitation change would appear to earmark short-term discounts for the poorest households, with regular reinforcement.

Nepal Case Study

Nepal today has clear opportunities to accelerate progress towards greater use of improved (and largely renewable) cooking technologies, including biogas, improved cookstoves, LPG, and especially electric induction stoves. From 2000 to 2018, the percentage of households primarily using polluting cooking fuels decreased from 93% to 71%. Reductions were larger in urban areas (from 78% to 40%), though that progress slowed considerably during the past decade, in part caused by urbanization as rural, primarily biomass-using households moved to towns and cities. The country is anticipating an oversupply of hydroelectric power in the near future and is actively seeking to decarbonize its clean cooking sector. However, with 17.4% of Nepal’s population defined as poor, affordability is a key constraint to adopting improved technology and increased use of commercial fuels (UNICEF 2021). Nepal’s 2020 Second Nationally Determined Contributions aims to achieve a 23% reduction in climate-forcing emissions from cooking, but 71% of the population still primarily use polluting cooking fuels (Government of Nepal 2020b).

To support clean cooking goals, the government of Nepal has already implemented tax reductions on electric cooking products and subsidies for a range of cleaner cooking technologies. Yet, given the need to accelerate the cooking transition and to achieve progress across multiple technologies simultaneously—including traditional cooking to simple ICS, biogas and LPG, and LPG to electric cookstoves—additional fiscal policies appear necessary.

Affordability is a key constraint impeding adoption of improved technologies, and subsidizing desirable technologies such as ICS, biogas, LPG, and electric cookstoves could play a role in speeding up several cooking transitions. Two key fiscal policy options for improving affordability are (1) reducing taxes and (2) increasing subsidies on desirable stove types and fuels. In terms of taxes, the government of Nepal's 2021 budget made significant cuts to customs and excise duties on a range of electric cooking appliances, intending to reduce costs for importers and lower prices for consumers as part of its goal to promote electric cooking.

Many cleaner cooking technologies are already subsidized by federal or local governments (see Appendices for Renewable Energy Subsidy Policy 2073 BS), including biogas, ICS, and rocket stoves. Nepal's Alternative Energy Promotion Centre (AEPC) subsidizes ICS, but the number of stoves covered depends on annual budget constraints, which impedes more rapid expansion of coverage. LPG is also subsidized by the Nepal Oil Corporation to support a transition from traditional cookstoves to LPG. Unfortunately, the resulting artificially low prices of LPG create a barrier to the adoption of electric cooking in urban areas, which would better align with national energy assets and climate mitigation objectives (Poudel 2020). It is difficult to target LPG subsidies in a way that benefits lower income households while offering a more cost-reflective price to wealthier, urban households and promoting a shift to induction cooking.

While several electric cooking programs offer subsidies to private sector companies to promote its adoption, there is widespread perception that electric cooking is for wealthier, urban households. To make electric cooking more appealing than LPG, Nepal's Electricity Regulatory Commission has subsidized electricity in their latest tariff regime, including waiving fees for low-consuming customers (42% of customers) and lowering tariffs for all other customers (Shrestha 2021b). However, lowering tariffs will reduce revenue for the Nepal Electricity Authority, and an increase in consumption for cooking is expected to increase peak load during evening hours, which may impact reliability if the national grid cannot manage the load.

While fiscal policies can draw on federal and local government budgets, finance may also be available from multilateral development banks or climate funds. The government of Nepal has ongoing Clean Development Mechanism (CDM) funds for biogas, ICS, and micro-hydro to replace kerosene, and is looking to support more electric cooking projects. AEPC is the lead partner on the $49.2 million Green Climate Fund project, "Mitigating GHG emission through modern, efficient and climate friendly clean cooking solutions (CCS)," which aims to reach 500,000 households with domestic biogas and Tier 3+ ICS and electric cooking (GCF 2021). In addition to project-level finance, consumer financing could improve the affordability of cleaner cooking solutions. In Nepal, microfinance institution (MFI) networks are extensive and meet monthly with consumers, which makes them ideal partners to promote ICS and electric cooking. However, they typically provide financing only for more expensive products.

Policy Recommendations (General and Specific to Nepal)

Better leveraging of incentives is sorely needed to accelerate progress towards cleaner cooking, and to allow capturing of the myriad social benefits associated with that objective. We close with a set of general and Nepal-specific recommendations related to subsidies and taxes in the cooking energy sector. The recommendations are based on theoretical arguments and empirical evidence from experiences with taxes and subsidies on clean cooking and related quasi-public goods. The Nepal recommendations are more specific, given the more specific contextualization that is possible given that country's realities.

Table 1. Policy recommendations regarding use of price instruments in the clean cooking sector

Recommendation	General	Nepal
Taxes	1. Taxes and other levies on clean and improved cooking solutions should be eliminated wherever progress is lagging behind SDG 7 goals. Such taxes raise limited revenue but are extraordinarily inefficient.	1. Several taxes on improved cooking products should be reduced (e.g., VAT exemptions, lower taxes on imports and key raw materials, maintenance of 1% duty, or removal of taxes on electric stoves altogether).
Subsidies, general	2a. Clean cooking solutions should be more aggressively and generally subsidized across LMIC contexts to achieve greater adoption and affordability. Such instruments are efficient, even after accounting for leakage.	2a. Subsidy programs for ICS should be expanded. Subsidies should be available to all eligible customers, not just a budget-constrained target number.
	2b. More holistic consideration of the technologies and fuels that should be subsidized based on local constraints and realities is needed. LPG subsidies are common, but disproportionately benefit high-income urban households. Improving the progressivity of electricity tariffs is an urgent issue, while subsidies for cheap efficient biomass solutions that work would benefit the rural poor.	2b. The viability and impacts of reduced electricity tariff rates should be explored for low-usage customers in order to promote electric cooking. Reduced tariffs may be supportive of clean cooking, but they may be poorly targeted (to consumers who do not need them or going to other, less socially beneficial uses of electricity).

Recommendation	General	Nepal
Subsidies, leveraging lessons from prior experiences	3. Service coverage for the poor has been expanded with more success in many other sectors, and these experiences should inform cooking energy subsidy program design. In particular, subsidies for bed nets have been shown to be especially efficiency-improving in the long term, where learning and positive spillovers are important. Relevant options for boosting adoption by the poor are guaranteed access (e.g., distributing locally accepted ICS free of charge), reducing the cost of clean fuel with generous and well-targeted discounts, and use of demand-revealing “ordeal” mechanisms to allocate benefits, rather than payment in cash.	3. The government of Nepal should leverage lessons from subsidy programs for electric cooking, which focus on private sector support, to determine whether this approach is effective enough, or whether other types of subsidies (e.g., targeted tariff support, demand-side subsidies) are necessary to boost electric cooking.
Subsidies, targeting	4. Given that resources for subsidization are scarce, better targeting of subsidies is needed. Low-income households are most price-sensitive and most likely to heavily rely on traditional technology. In some cases, targeting can be geographic, or may use means testing and systems such as the Aadhar in India.	4. Targeting subsidies to customers most in need is urgent. Such targeting could be categorical, based on household characteristics, or means-tested (based on household income). LPG subsidies deserve a critical look; they have proven valuable in shifting households away from traditional stoves but may undermine electric cooking.
Subsidies, capacity to use electric cooking		5. Subsidizing household wiring would support electric cooking and help target subsidies to lower-income households. A key challenge in Nepal is that many household electricity connections are currently unsuitable for electric cooking.

Recommendation	General	Nepal
Financing	5. Where subsidies prove overly challenging for budgetary or political reasons, financing support is sorely needed to ease liquidity constraints. Such policies are relatively low in cost and can largely be implemented by MFIs and the private sector but need to be regulated to ensure loan terms are reasonable for the poor. Financing can also support durable goods and appliance acquisition (such as electric cooking technology).	6. Partnering with MFIs to provide financing for a bundle that includes an induction stove and basic utensils would help ease households liquidity constraints where standard subsidies are infeasible. The loan terms of such financing arrangements must be made favorable to actually reach the poor.
Complementary policy	6a. Subsidies alone will be insufficient to achieve clean cooking goals, so complementary interventions must also be prioritized. This would include investing in improved distribution infrastructure (for LPG and electricity), incorporating market development and direct delivery to users, empowering women both as suppliers and as primary consumers of technology, and awareness-raising or education campaigns. 6b. Draw on experiences from related sectors (e.g., electricity, health-improving goods, sanitation, water treatment) where service coverage for the poor has been expanded with more success than for cooking energy access.	7a. Nepal critically needs investment in transmission and distribution of electricity. Electric cooking requires reliable access to electricity during peak cooking hours. This is likely to be especially challenging in rural areas, absent substantial off-grid solar or micro-hydro expansion. 7b. Many beneficiaries are not fully cognizant of the costs of traditional cooking. Information campaigns to help raise awareness and skills in repair or servicing are essential. 7c. Coordinated promotion of electric cooking appliances and transmission and distribution investment is essential to ensure that infrastructure upgrades precede electric cooking promotion activities. 7d. Training (especially women) in after-sales service is vital. Electric cooking transitions with women involved in the supply chain are more sustainable. 7e. Investing in local research and development and manufacturing to address both supply and affordability issues. 7f. A time-of-use tariff could be trialed as a solution to shift evening load and better manage demand.

ACRONYMS

DWL: Deadweight loss

ICS: Improved cookstoves

ITN: Insecticide-treated mosquito nets

LMIC: Low- and middle-income country

LPG: Liquefied petroleum gas

MB: Marginal benefit

MC: Marginal cost

MPB: Marginal private benefit

MPC: Marginal private cost

MSB: Marginal social benefit

MSC: Marginal social cost

NGO: Non-governmental organization

PMUY: Pradhan Mantri Ujjwala Yojana

SDG: Sustainable Development Goal

VAT: Value-added tax

1 INTRODUCTION

Cooking with biomass fuels in inefficient stoves degrades the environment, increases the global burden of disease, and perpetuates energy poverty (Sagar 2005; Anenberg et al. 2013; Bailis et al. 2014; Bruce et al. 2000; Dherani et al. 2008; Ezzati and Kammen 2002). Despite clear evidence on these negative impacts, however, progress in achieving large-scale adoption and use of clean and so-called improved technologies—particularly among the poor rural households who arguably need them most—has been slow.[5] Indeed, the progress of cooking transitions is too often impeded by a set of affordability, technology, supply chain, and policy barriers that render persistent and durable adoption of improved solutions challenging for the majority of the energy poor.

As of 2019, 2.6 billion people, or nearly one-third of the global population, still relied on dangerous or polluting energy technologies and fuels for cooking. Moreover, population growth over the 2010–2018 period essentially offset the modest (approximately 1 percentage point per year) gains in access to clean cooking fuels and technologies (IEA et al. 2021). While gains in Asia (1.6 percentage points per year in East and Southeast Asia, and 1.5 percentage points per year in South Asia) were somewhat higher and outpaced population growth, the sub-Saharan Africa region only saw access increases of 0.4 percentage points per year, and the absolute number of people without access grew by 140 million people (IEA et al. 2021) (Figure 1).

Against this backdrop, many governments intervene in markets for fuels and cooking technologies by implementing subsidies and taxes. In Kenya, for example, an abrupt reimposition of the value-added tax (VAT), following a period of VAT exemption for clean cooking solutions in response to fiscal challenges imposed by the COVID-19 pandemic, has been particularly controversial considering its projected impact on slowing progress on United Nations Sustainable Development Goal (SDG) 7. Other countries (e.g., Indonesia, India, and Ecuador) have instituted generous and targeted subsidies for clean cooking solutions in recent years and have seen accelerated progress in adoption of these beneficial social goods. The rationale for and experiences with these exemptions and subsidies highlights the contradiction between economic efficiency and fiscal objectives: on the one hand, exemptions and subsidies are efficiency-improving and socially beneficial because they spur adoption of clean technology and thereby reduce negative pollution externalities; on the other hand, they increase the strain on already limited public budgets.

The main objectives of this study are to:

(1) Undertake a literature review to document global best practices on taxation for social goods and growing sectors, like clean cooking and broader energy access, and review the impact of tax changes on clean cooking and other social goods in other countries.

(2) Engage stakeholders, via semi-structured consultative interviews conducted virtually, to determine the scope of potential solutions that would accelerate the transition to clean cooking in Nepal, especially as it pertains to electric cooking.

(3) Develop policy briefs based on the findings that outline recommendations both specific to Nepal and for a global audience.

[5] Here we refer to clean technologies as those which are clean from a household air pollution perspective, such as LPG, electric, or very efficient biomass-burning stoves. In contrast, the term *improved* refers to more efficient biomass-burning stoves that may or may not sufficiently reduce emissions to provide health benefits.

This report, which is complemented by a separate analysis specific to the VAT reform in Kenya (Jeuland et al. 2021), comprises:

(1) A summary of salient considerations from tax theory, as they relate to goods such as cleaner cooking technologies and fuels.

(2) A comprehensive review of real-world experiences on the effects of pricing instruments on the demand for cooking technologies, the course of cooking transitions, and the impacts of such transitions.

(3) A case study aimed at identifying potential solutions and pricing policies for Nepal, informed by a review of relevant policy documents and a set of consultations with key stakeholders in Nepal.

Two accompanying policy briefs are expected, the first focusing on theory and global lessons on tax and subsidy policy for this sector, and the second on the Nepal case in particular. Findings from the work are expected to help the Clean Cooking Alliance engage strategically on tax and subsidy issues affecting clean cooking, drawing on best practices and experiences in other sectors with much longer histories with such policy instruments.

In the next section, we aim to provide a simple and accessible primer that reviews the principles behind socially efficient taxes and subsidies and relate them to examples in the real world. We explain that the imposition of taxes and subsidies on clean cooking technologies and fuels will mediate prices according to the relative elasticities of supply and demand. We note the implications that these changes have for efficiency and for the distribution of costs (or benefits) to different parties of taxes (or subsidies). In discussing this theory, we derive a set of key generalized implications.

In section 3, we then turn to relevant empirical evidence on the demand for improved cookstoves (ICS) and fuels: results from various large-scale and research studies focused on the effects of prices, taxes, and subsidies in the sector. We show, based on evidence from prior research, for example, that the demand for household energy sources overall is highly inelastic, since households need energy to meet their needs. Yet the demand for cleaner alternatives is typically highly price elastic, because households have ready substitutes in nonclean options such as firewood, charcoal, and kerosene. And while the availability of such substitutes is also mediated by urbanization and access to biomass, consumers of clean fuels will only bear a portion of the additional cost from taxes (or capture only partial benefits from subsidies) in the short term, with suppliers of clean fuels and stoves bearing the rest. This shared incidence from taxes and subsidies in turn affects employment and growth of the clean cooking sector, with implications for the long term (Fullerton and Metcalf 2002). Furthermore, another downside of a tax on clean fuels is that it lowers their consumption, which is already undervalued relative to polluting fuels. Standard public economics principles presented in section 2 argue that the more appropriate instruments to use to achieve social efficiency would be a Pigouvian tax[6] on polluting fuels such as kerosene or

[6] A Pigouvian tax (named after the economist Arthur Pigou) is a tax assessed against private individuals or businesses for engaging in activities that create adverse side effects, or negative externalities, for society. This tax is meant to fully redistribute the cost of the negative externality back to the party responsible for it.

charcoal (Tietenberg and Lewis 2018) or a subsidy on clean technologies, both of which move the market equilibrium closer to the social optimum, albeit with somewhat different effects.

The empirical section also includes a discussion of distributional considerations that complements the theoretical points first presented in section 2. Still, in section 3, we consider complementarities between pricing and other policies, to the extent that evidence on such complementarities exists. We focus on other supporting policies that help to reach those often left behind by energy transitions but that bear the costs of energy poverty, such as women and the rural poor.

Section 4 then presents the case study from Nepal. We draw on a set of consultations with stakeholders in Nepal—policy makers within the government, key parties involved in the supply chain for various fuels, and representatives from academia and civil society—to identify and comment on potential pricing policies for that context. These consultations were meant to shed light on the feasibility of different types of taxes and subsidies in Nepal; the types of solutions that should be supported, given government priorities and objectives (e.g., preference for promotion of electric cooking); and any implementation or fiscal challenges that might arise for specific policies over the short and long term.

Finally, section 5 synthesizes the theory and empirical evidence and comments on the general relevance of the Nepal case study.

2 THEORETICAL PRINCIPLES APPLIED TO ENVIRONMENTAL HEALTH TECHNOLOGY TAXATION/SUBSIDIZATION

There are two general topics from public finance theory that apply to the levying of taxes and subsidies on environmental health technologies. The first concerns the economic efficiency of such instruments, and the second has to do with their distributional implications, in terms of who pays or benefits from such instruments. We discuss each of these two topics in the following sections.

2.1 Tax/Subsidy Efficiency

The first important consideration regarding taxes and subsidies on environmental health improving technologies relates to their economic efficiency. According to the basic theory of public finance, the efficiency of taxes (and subsidies) is determined by the following key principles:

- Principle 1: The elasticities (or relative *price sensitivity*) of supply and demand for the good: more efficient taxes and subsidies are those levied on goods with relatively inelastic (or *price insensitive*) supply and demand.
- Principle 2: The breadth of the base of taxation: more efficient taxes and subsidies are those with lower rates and a broad base across many goods and market actors, rather than a narrow base targeting specific items with correspondingly higher rates to raise equivalent revenue.

- Principle 3: The stability of taxes over time: more efficient taxes and subsidies have stable average rates over time, rather than alternating between low and high rates.

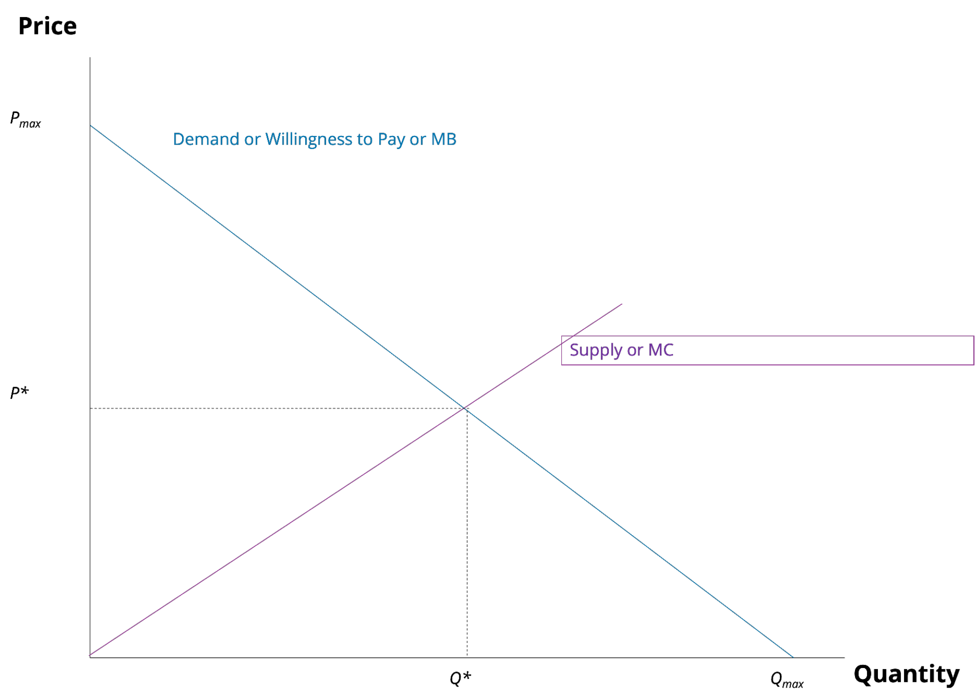
- Principle 4: The nature of existing distortions that have already moved markets away from socially efficient consumption: more efficient taxes and subsidies are those that keep or bring the market closer to the socially optimal equilibrium.

2.1.1 Principle 1: More Efficient Taxes and Subsidies are Those Levied on Goods with Relatively Inelastic Supply and Demand

Markets are efficient at allocating goods and services to those who desire them, defined as private willingness to pay that exceeds the cost of producing the same goods. In well-functioning markets, the quantity produced is set such that the willingness to pay for the last unit purchased (or the marginal benefit [MB] in equilibrium) is just equal to the cost of producing it (the marginal cost [MC] in equilibrium). This follows from the fact that the willingness to pay or marginal benefit curve is downward sloping and the marginal cost curve is upward sloping (Figure 3). The efficient equilibrium for the private market is thus where MB = MC and is depicted as the locus of P^* and Q^*.

Marginal benefit decreases in quantity because the most valuable units are snapped up first by consumers. This reflects the diminishing marginal utility of consumption, whereby the most valuable units are obtained first. Meanwhile, marginal cost increases in quantity because it (usually) becomes increasingly difficult to produce more of a particular good, because of the

Figure 3. Supply and demand curves in a typical market for a good or service



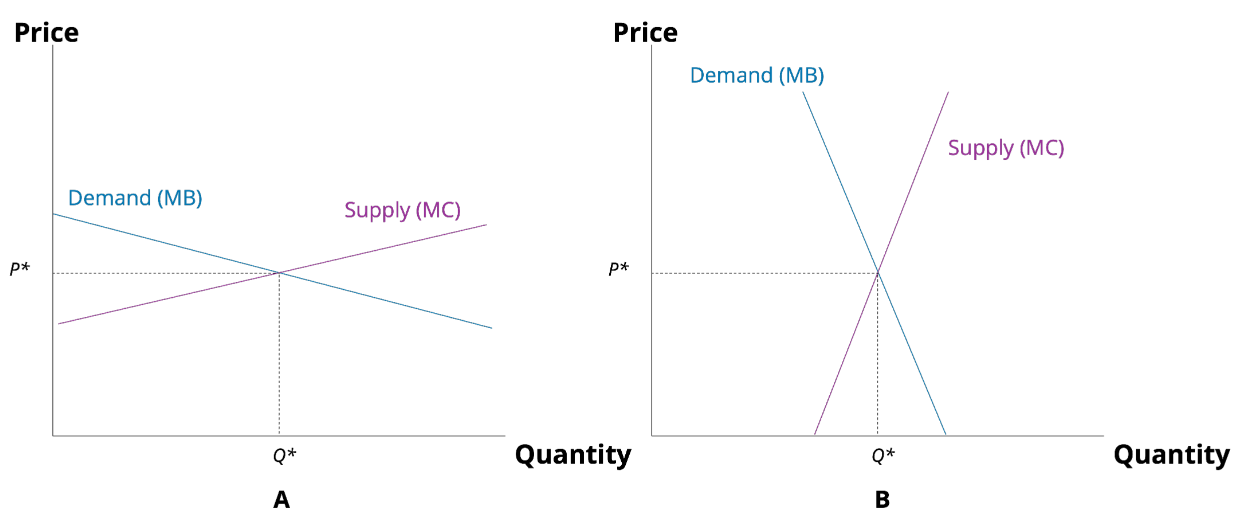
diminishing marginal productivity of inputs used in that production. In other words, producers of a good begin by producing the units that are cheapest to make, but progressively find it more expensive to obtain raw materials, labor, land, and capital as more and more units of the good are produced.[7]

The efficient equilibrium is where MB = MC, because consumption beyond the point Q^* where this equality holds, at $Q > Q^*$, entails lower benefits than the cost of production, and consumption below that point, at $Q < Q^*$, entails higher benefits than the cost of production. At nonefficient levels of consumption, there will be some loss of welfare caused by these divergences. Specifically, when consumption is too low, the loss of welfare will be equal to the triangular area lying between the MB curve and the MC curve up to Q^*. Additional consumption would deliver positive net benefits that equal the MB minus the MC of production, up to the point Q* where MB = MC. Similarly, when consumption is above Q^*, the loss of welfare will be equal to the triangular area lying between the MC curve and the MB curve. There, excess consumption beyond Q^* implies negative net benefits that are equal to MB minus the MC of production, which now exceeds MB.

Turning to the rationale for principle 1, then, it is helpful to begin with definitions. Inelastic supply and demand curves are those for goods where the quantity supplied or demanded tends to be relatively insensitive to price changes (Figure 4). In contrast, elastic supply and demand curves are those for goods where the quantity supplied or demanded is highly sensitive to such price changes.

Given this, by using demand and supply diagrams with different elasticities one can observe why a tax or subsidy in a market with relatively inelastic supply and demand curves will tend to be

Figure 4. Relatively (A) elastic and (B) inelastic supply and demand curves in a typical market for a good or service



[7] A notable exception to this upward sloping supply curve occurs in markets with natural monopolies, where there are large economies of scale associated with increasing production. This is generally not the case for household environmental health–improving technologies, but markets for clean fuels such as electricity and LPG are important exceptions. We comment on implications under principle 4.

more efficient than one in a market with relatively elastic supply and demand curves. In Figure 6, the effect of a tax on suppliers of the good raises the cost of production.[8]

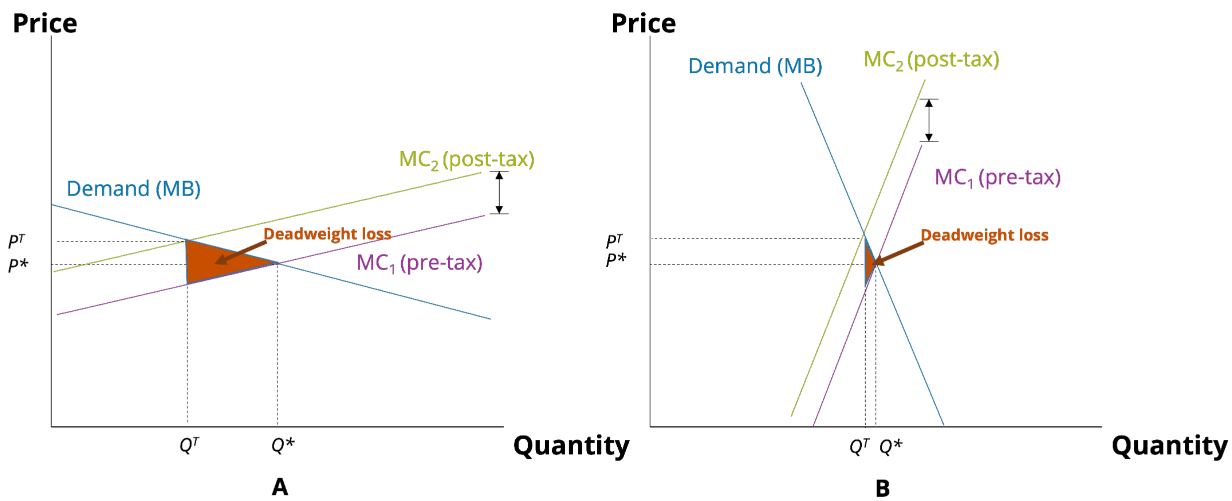
In a market with relatively elastic supply and demand curves, this tax leads to a new post-tax equilibrium at a much lower quantity *QT* (Figure 5A), whereas the shift in quantity in the market with inelastic supply and demand is much smaller (Figure 5B). As a result, the effect on quantities consumed in the latter inelastic market is much smaller. In other words, fewer efficient trades where marginal benefits exceed pretax marginal costs are eliminated in this inelastic market. The efficiency implications are captured by the deadweight loss (DWL), which is the area pertaining to these forgone, efficient trades. Accordingly, even though the vertical base (parallel to the price axis) of the DWL triangle is equivalent to *PT* – *P** in both cases, the horizontal length of the triangle *Q** – *QT* is much smaller in second market, and the efficiency loss is therefore smaller as well.

The same basic logic applies for subsidies, though these would result in a downward shift in the supply curve rather than an upward shift (or analogously, to a shift up in the demand curve). Given such a subsidy, the quantity traded in equilibrium would increase relatively more for the market with elastic supply and demand than in the one with inelastic supply and demand. As a result, the DWL would again be larger in the former market, though it would be oriented in the opposing direction.

2.1.1.1 Practical Implications

- In well-functioning markets with no externalities or other distortions, taxes levied for

Figure 5. The effect of a tax on producers in the markets for a good or service with relatively (A) elastic and (B) inelastic supply and demand curves



Note: The tax increase is equivalent in magnitude in both panels (as shown by the vertical black double arrow).

[8] The same tax could, of course, be levied on consumers instead, which would result in a downward shift in the demand or marginal benefit curve, since buyers would derive lower benefit from consumption because of the need to pay the tax alongside consumption.

revenue-raising purposes are more efficient when they are applied to goods and services for which demand and supply are relatively more inelastic.

- In the long term, since supply curves tend to be fairly elastic (inputs can be readily reallocated to generate products that face lower tax burdens), the relative elasticity of demand will often be most important for determining efficiency. Basic necessities such as food staples tend to have more inelastic demand, whereas lifestyle-improving luxury goods are more elastically demanded.

- Analogously, subsidies will be most efficient when they are applied to goods with inelastic supply and demand and, in the long term, especially when applied to basic necessities.

- In markets with significant nonpriced externalities (e.g., many environmental health-improving goods such as cooking stoves and fuels), however, this logic will not always apply, as explained further in following sections.

2.1.2 Principle 2: More Efficient Taxes and Subsidies are Those with a Broad Base and Lower Rates

The next principle for efficient taxes and subsidies holds that it is better to apply lower rates, on average, on a broad base of goods and services than to impose higher rates on a few goods while keeping others exempt or untargeted. The rationale for this principle is illustrated in Figure 6. In Figure 6A, the tax is applied on only one of the two goods (good 1), while in Figure 6B it is applied to both good 1 and good 2. As a result, the magnitude of the tax on good 1 in Figure 6A must be at least twice as large as the taxes on each good in Figure 6B to generate a comparable amount of revenue.

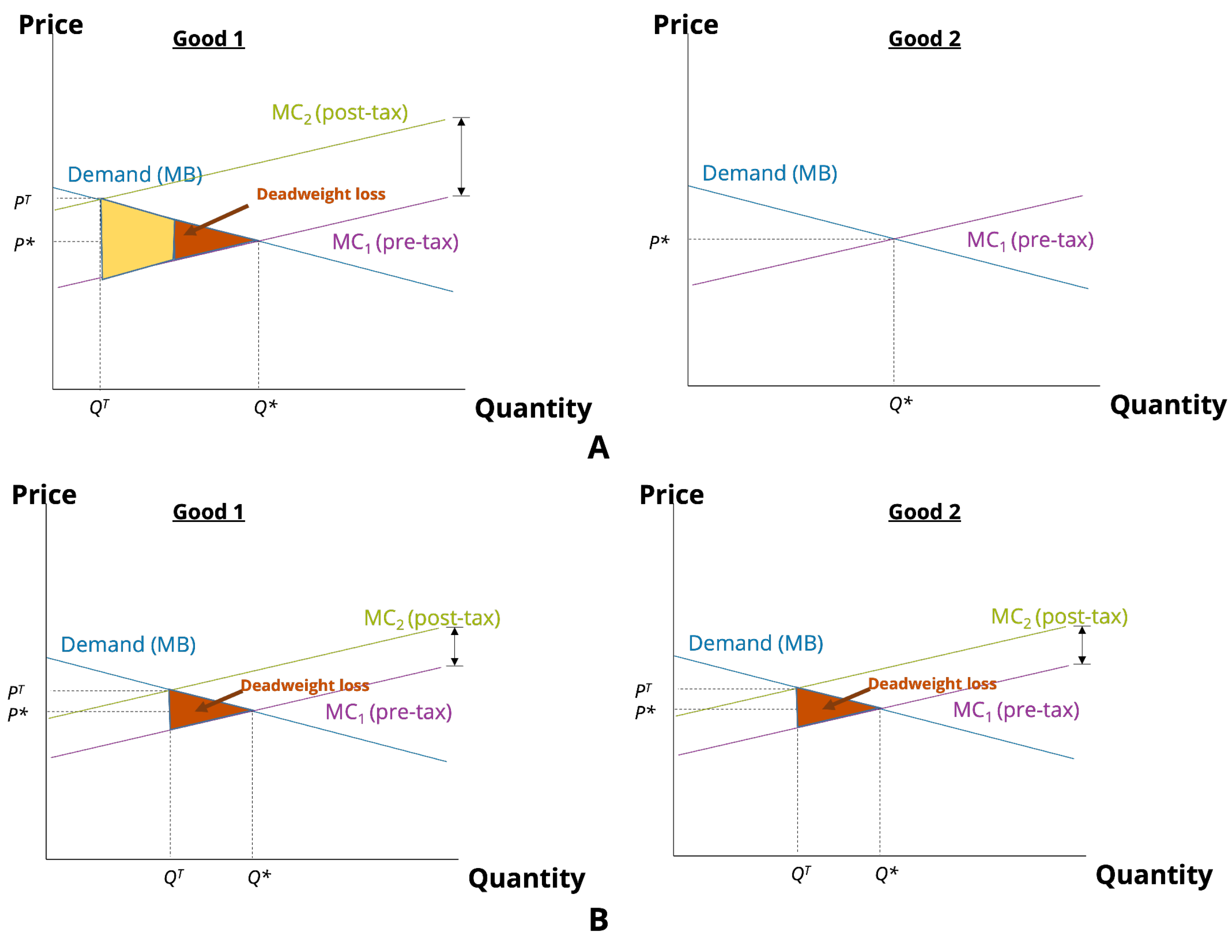
Examining the size of the DWL (or efficiency loss) triangles, though, we observe that the additional DWL (a trapezoidal area shown in lighter brown) that results from doubling the tax on good 1 in Figure 6A is considerably larger than the DWL (dark brown triangle) newly created in the market for good 1 from the compensatory increase in revenue in Figure 6B. This is because the increase in the tax on good 1 moves the market ever further away from the efficient equilibrium where MB = MC, and every additional transaction lost in that movement is increasingly costly (because of the greater difference between the MB that is lost and the MC that it costs to produce the affected units of the good). The illustrative example actually understates the extent of this inefficiency, because the revenue collected is also shrinking because of a lower quantity of transactions. Thus, a revenue neutral change would actually require an even greater increase (more than doubling) of the tax rate on good 1 in Figure 6A.

2.1.2.1 Practical Implications

- This principle of broad-based taxation implies that broadly applied taxes, such as the VAT, tend to be more efficient than taxes required to generate equivalent revenue that are only targeted at specific markets or sectors. The latter imply highly asymmetric rates across goods, and therefore usually result in larger efficiency losses. Note that this is the basis for the typical argument against giving some goods (e.g., clean cookstoves and fuels) special VAT exemptions.

- Combined with the first principle discussed in principle 1, however, there is an efficiency

Figure 6. The effect of a tax on producers in the markets for (A) only one of two goods and services with similar demand and supply, versus (B) both goods



Note: The overall tax increase is equivalent in magnitude in both cases (as shown by the sum of the vertical black double arrows across both markets).

case for somewhat differentiated rates across goods with more (lower rates) or less (higher rates) elastic supply and demand and, in the long term, especially regarding the relative elasticity of demand.

2.1.3 Principle 3: More Efficient Taxes and Subsidies Have Stable Average Rates Over Time

Principle 3 follows from essentially the same logic as that undergirding principle 2. To see this, consider a simple case of taxes fluctuating over time between high and zero levels, where the high rates are established to meet short-term revenue needs or objectives, but then reduced when those needs become less urgent. This is similar to the case displayed in Figure 6, only good 1 is now taxed in year 1 and good 2 is taxed in year 2. Imposing high rates according to short-term needs in only one year is equivalent to maintaining a narrow base as in Figure 6A, while keeping rates lower overall is equivalent to maintaining a broad base across years as in Figure 6B. The efficiency losses from the former revenue strategy will be larger. One can think of fluctuating subsidy policies to meet specific short-term adoption targets in a similar way: it will be economically more efficient to maintain steady, lower subsidy supports than to alternate between high and low or no subsidies to meet the same goals.

2.1.3.1 Practical Implications

- This principle of stable tax rates over time again supports broadly applied taxes such as the VAT, which tend to be more efficient than revenue-equivalent taxes levied only during times of fiscal strain, which would tend to require highly asymmetric rates over time. Conversely, subsidies (or tax exemptions) that support policy goals such as clean cooking are better when maintained at modest levels over time, rather than implemented in interrupted fashion at higher levels.
- This principle also aligns with better management of policy risks, since constantly adjusting tax policy is politically contentious. It also increases certainty among private companies supplying goods and services to the economy.

2.1.4 Principle 4: More Efficient Taxes and Subsidies are Those that Keep or Bring the Market Closer to The Socially Optimal Equilibrium, Where Marginal Benefit Equals Marginal Cost

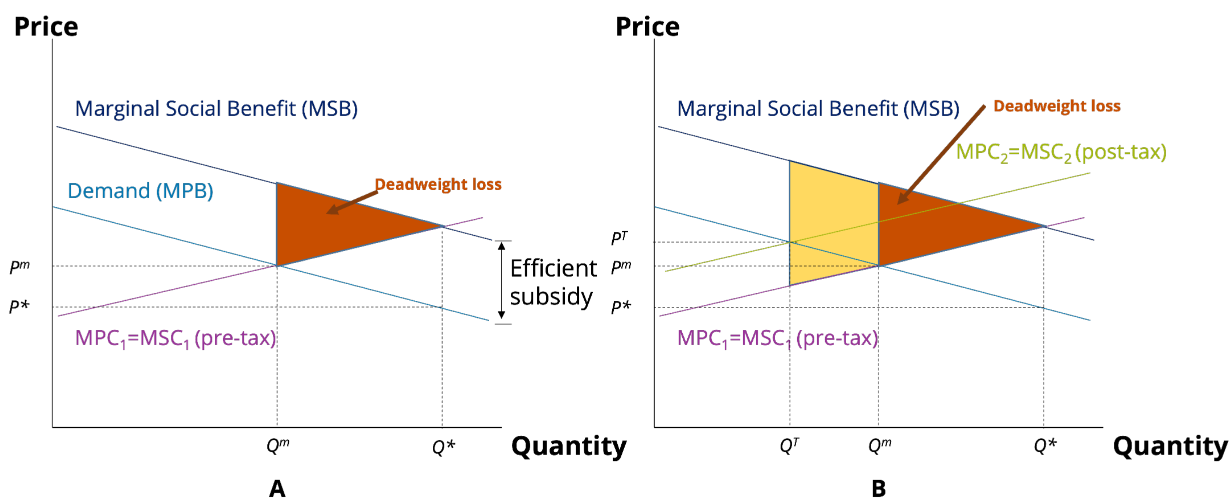
The final principle of efficient taxes and subsidies also follows from the others, and is of vital importance for environmental health–improving technologies such as cleaner stoves and fuels. Specifically, consider two cases: one where the quantity being consumed in a market is already considerably too low and one where that quantity is at or near the socially efficient equilibrium. Because the incremental loss of efficiency, or marginal DWL, associated with tax increases as the quantity equilibrium in the market diverges from the socially optimal quantity, it follows that taxes levied on goods in the former market will be less efficient than taxes on goods in the latter. Similarly, new subsidies applied to goods for which the presubsidy equilibrium is well above the socially efficient equilibrium will tend to be less efficient than those where that equilibrium is at or near the efficient equilibrium.

What does this principle imply? We begin with the situation with no unpriced externalities, that is, where the market naturally delivers an efficient outcome. First, imagine that a tax already exists on one particular good (good A), but that additional revenues are needed. The government could increase taxes on good A or could impose a new levy on a different good B. This is similar to the situation shown in moving from Figure 6A (with an already-imposed tax and some DWL, shown in brown) to Figure 6A (increased tax on good A and very large additional DWL, equal to brown and yellow areas combined) or Figure 6B (new tax on good B with smaller DWL). Because the market for good A starts further from the efficient equilibrium, adding to the tax on that good is particularly costly in displacing trades that are beneficial, as in where MB exceeds MC.

A second and more nuanced interpretation is also possible. Many goods and services of different types—and environmental health-improving technologies in particular—are offered in markets where the conventional market equilibria are privately, but not socially efficient. To see this, we must introduce the idea of the marginal social cost (MSC) and marginal social benefit (MSB) curves, which are different from the marginal private cost (MPC) and marginal private benefit (MPB) curves that we have so far considered. Specifically, MPC and MPB curves represent only the costs and benefits to producers and purchasers engaged directly in the market, while MSC and MSB curves include spillovers that affect the rest of society and that are not borne by those directly participating in the market. Another word for such spillovers is externalities, which can be positive or negative. For example, use of a household cooking fuel such as LPG or electricity provides certain benefits to society above and beyond those experienced by the users of those fuels. Such benefits include reductions in ambient air pollution levels that improve other households' health, reduced deforestation or forest degradation resulting from lower biomass harvesting, and, in some cases, reduced climate-forcing emissions. On the other hand, there may be social costs associated with use of these fuels that are also not considered by their producers. For example, depending on the energy generation mix in a country, electricity and LPG fuel production and the manufacture of commercial cookstoves may increase emissions. In general, environmental health-improving technologies' defining characteristic is that they provide substantially higher MSB compared to MPB because of the factors discussed previously, whereas MSC and MPC tend to not deviate much from one another.

We show the implications of this divergence of MPB and MSB in Figure 7. The starting point in Figure 7A is a market without taxes, where the market equilibrium Q_m is determined by the intersection of the MPB and MPC curves. However, this market delivers positive consumption spillovers as represented by the higher MSB curve. As a result, MSB is substantially above MPC

Figure 7. (A) The loss of efficiency in a typical market for a good with positive consumption externalities, such as use of an environmental health–improving technology and (B) what happens when such goods are taxed, rather than subsidized, resulting in a substantial increase in DWL



Note: The efficient policy is to subsidize such goods to achieve Q^* and eliminate DWL.

at Q_m, which is the market equilibrium.[9] Thus, these socially efficient outcome is where MSB = MPC, at Q^*. To achieve this level of consumption, the price faced by consumers would have to be P^*, which can only be realized if a subsidy representing the difference between the MPC and MSB at Q^* is delivered to sufficiently lower the price on each purchased unit.

Figure 7B then shows the additional efficiency cost of putting a tax on a good with such positive externalities. Because the effect of this tax is to raise the price of the good in the market to PT, this shifts the market even further from the socially efficient equilibrium than before, with particularly large costs in terms of incremental DWL added (now a trapezoidal light brown area added to the original dark brown triangle). This is a manifestation of principle 4: because the market in question began with quantities consumed below the efficient equilibrium, an additional tax on the good is particularly costly. This is the problem with a VAT levied on clean cooking technology—it moves the market toward an equilibrium that is even lower than the already inefficiently low market outcome. However, if the good providing this spillover were supported by a countervailing subsidy, a general tax that affected that good as well as others would be less problematic.

An additional manifestation of this principle is in markets with monopolies, which occur when there are large economies of scale or when there is market power created through other means. Such markets also tend to underproduce relative to the market equilibrium, as producers restrict quantities sold to inflate prices and gain profits. In such markets, where prices are already too high relative to the efficient outcome, taxation is again particularly costly because it elevates prices even further and suppresses consumption of the good. This is relevant for fuels such as LPG and electricity that tend to be provided through utility- or state-run natural monopolies.

2.1.4.1 Practical Implications

- Taxes (e.g., excise or VAT taxes) levied on goods where quantities are consumed at levels below the social optimum (e.g., goods that deliver positive spillovers, such as environmental health technologies) are costly, while equivalent taxes levied on goods where quantities are consumed at levels above the social optimum (e.g., goods that deliver negative spillovers, such as pollution) tend to be efficient.
- Subsidies applied to goods where quantities are consumed at levels below the social optimum are efficient, while equivalent subsidies applied to goods where quantities are consumed at levels above the social optimum tend to be particularly costly.
- Goods with positive social spillovers should be subsidized and be exempt from instruments like the VAT to achieve socially efficient outcomes.

2.2 Tax Incidence

The second key dimension of tax or subsidy policy relates to tax incidence, namely, the issue of which parties bear the costs or obtain the benefits of those policies. Tax incidence therefore concerns who really pays (or captures) these costs (or benefits). Such distributional considerations may in some instances push against arguments for efficient tax and subsidy policy.

[9] This is the market equilibrium because consumers individually compare their MPB to the market price and will not consume the good beyond the point where MPB is less than that price, as determined by the MPC of production.

A common misconception among non-economists is that the statutory or legal burden of taxation determines who really pays these costs. For example, when a sales tax of 10% is applied to purchases consumers make in shops, many assume that these consumers bear the full increment of 10% of the original cost. Conversely, if subsidies or rebates are given to consumers that reduce the prices they pay relative to normal sales prices, the statutory benefit would appear to favor the consumers.

The problem with this logic is that the prices that consumers see in the market are themselves influenced by both supply and demand. So, if consumers respond to a tax by purchasing less of a good that is taxed, this suggests the presence of a new equilibrium in the market where they buy less of the good. They will buy from the cheapest producers, and the most expensive producers of the good will exit the market.

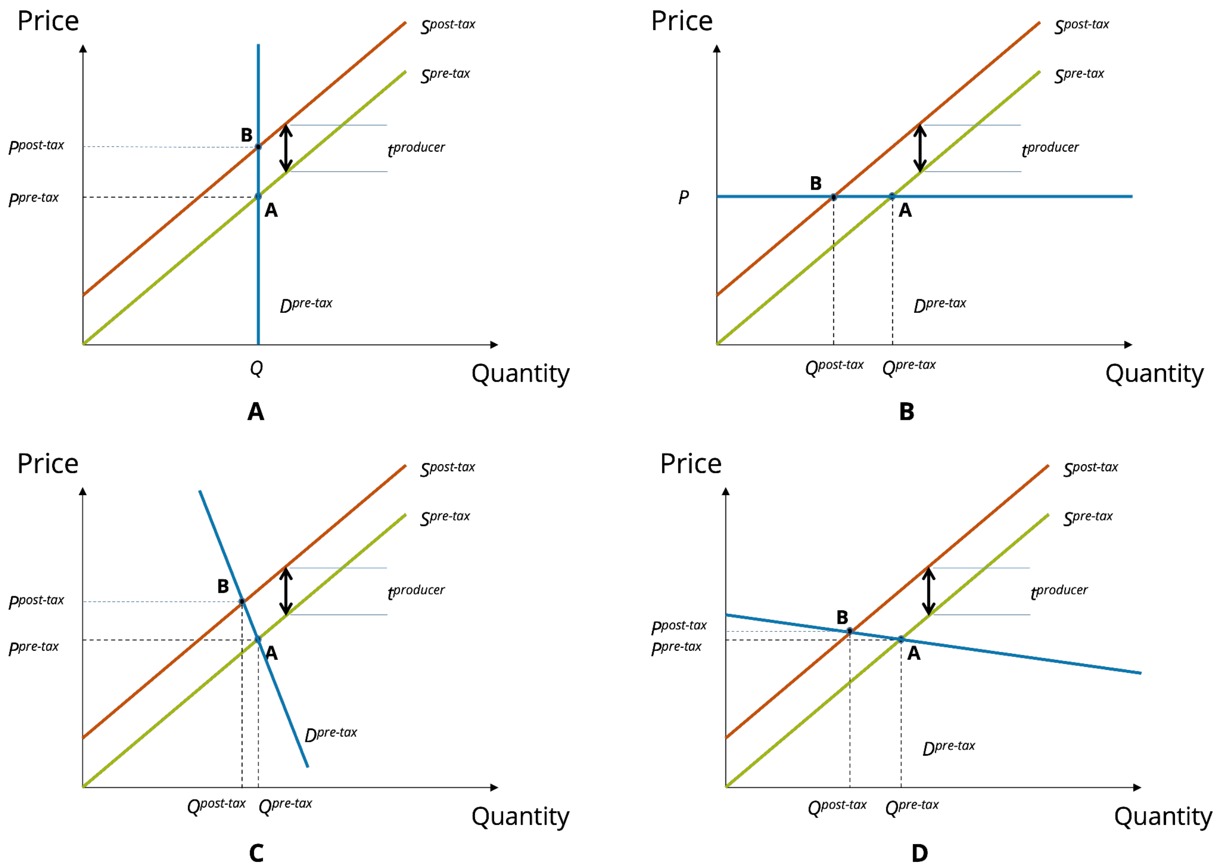
At the new and lower quantity traded in the taxed market, the pretax marginal cost of production in equilibrium will be lower, such that the 10% tax rate will only result in a net price increase (and burden on consumers) that is therefore somewhat lower than 10%. Producers will bear the balance of the cost because they will lose revenue and will sell lower quantities of the good at lower, pretax prices.

What determines the magnitude of this "somewhat lower" price increase? In general, the party with relatively inelastic supply or demand will bear a larger proportion of the costs (or capture more of the benefits) of taxes (or subsidies) and, conversely, the parties with relatively more elastic supply or demand will bear less of these costs (or capture lower benefits). To see this, we show four cases in Figure 8, where the statutory burden is always imposed on producers. This is reflected in the upward shift in the supply curve because the cost of production of every unit of the good increases by the tax amount $t_{producer,}$ which is the amount that producers would newly transfer to the government for each unit that is produced.

In Figure 8, the elasticity of the supply curve is held constant, while that of the demand curve is varied to demonstrate the impact of relative changes in the latter. Even though the statutory burden is imposed on suppliers, when demand is perfectly inelastic—as in Figure 8A—the tax leads to a price increase in the market for the good that is exactly equivalent to the tax increase. In this case, with perfectly inelastic demand, consumers are willing to pay any price to obtain quantity *Q* of the good. As a result, producers respond by charging a higher price $P_{post\text{-}tax}$ that entirely offsets the additional amount that they must now transfer to the government. This is a case of complete pass-through of the tax to consumers. The inelastic party (consumers) bears the full cost. In Figure 8B, the opposite case is shown, with perfectly elastic demand. In this case, consumers are not willing to pay anything more than *P*, so producers' only option to break even is to reduce the quantity sold in the market, given the higher costs now imposed on them. Maintaining the original level of production would lead them to have higher costs than the maximum price *P* that they could charge. There is zero pass-through in this case.

Finally, Figures 8C and 8D show demand curves that are relatively less and more elastic than the supply curves. In Figure 8C, where demand is relatively inelastic compared to supply, most of the cost is passed on to consumers in the form of higher prices ($P_{post\text{-}tax}$ is substantially higher than

Figure 8. Four cases demonstrating (A) perfectly inelastic demand, (B) perfectly elastic demand, (C) relatively inelastic demand, and (D) relatively elastic demand



Note: The elasticity of supply is held constant.

P_{pretax}, by almost the amount $t_{producer}$), whereas Figure 8D, with relatively elastic demand compared to supply, is a case where most of the cost is borne by producers who must therefore reduce production more substantially ($P_{post\text{-}tax}$ is not much higher than P_{pretax} and does not approach the amount $t_{producer}$).

The lesson of this analysis is that the relative elasticity of supply and demand will matter greatly in determining who bears the costs of taxes (or analogously, who benefits from subsidies). Generally speaking, and as discussed in the next section on empirical evidence, the poor who are most affected by environmental health burdens in low- and middle-income countries (LMICs) tend to have relatively elastic demand for environmental health–improving goods versus relatively inelastic demand for basic necessities like food, housing, and clothing. This is not always true, of course, and relative elasticities depend a great deal on available alternatives (e.g., where biomass is plentiful and harvested from the environment rather than purchased, elasticities for clean fuels will be higher). Accordingly, even relatively low taxes or modest subsidies can lead to substantial reductions (or increases) in the quantity of purchases of these health-improving goods. At the same time, producers will tend to bear most of the private short-term harms (or capture private short-term benefits) from use of these instruments.[10] In the long term, supply is relatively elastic, however, because producers will tend to reduce or increase participation in the market such that few of these costs (or rents) remain, at a lower (or higher) quantity equilibrium.

2.2.1 Practical Implications

- The distributional consequences of taxes and subsidies are important concerns because it is especially important to try to avoid imposing high cost burdens on the poor. Because basic necessities tend to have relatively inelastic demand, the poor will be hit especially hard by taxes on them, but conversely will especially benefit when such goods are subsidized.
- The poor will tend to benefit less (at least directly) when subsidies are applied to goods with relatively elastic demand, but the fact that environmental-health technologies deliver positive spillovers some of the non–pro-poor concerns about such policies. Moreover, because the burden of pollution from traditional cooking tends to fall disproportionately on the poor, the positive spillovers from such subsidies will tend to be progressive.

3 REVIEW OF EMPIRICAL EVIDENCE ON THE EFFECTIVENESS OF SUBSIDIES, TAXES, AND DUTIES ON IMPROVED AND CLEAN COOKING SOLUTIONS

In this section we describe literature that is relevant to understanding the impacts of various price instruments or policies that affect progress toward cleaner cooking. Building on the theory in the previous section, but with reference to findings from applied research, our discussion begins with a brief description of the rationale for subsidies of cleaner technologies and fuels. We then provide a review of the empirical evidence on the demand for ICS and cooking fuels, because understanding demand—the relationship between prices and consumers' adoption of various stoves and fuels—is critical to understanding of the impacts of price instruments. Next, findings from various research studies on the effects of prices, taxes, and subsidies in the clean cooking sector are described, many of which pertain to relatively small-scale studies that experimentally manipulate prices to better understand their implications for technology adoption, and the eventual impacts of that adoption. Given that subsidy and tax interventions in the real world often occur in tandem with other policy changes, we then further examine the evidence on potentially complementary policies as well as implementation details, before discussing in greater detail distributional considerations that relate to the theory principles presented in Section 2. Throughout this section, we first cover evidence pertaining to improved cooking stoves and clean fuels before discussing related to other similar social goods, namely, environmental health technologies.[11]

[10] Recall that private costs and benefits are not equivalent to social costs and benefits. As such, quantity changes must be kept in mind for goods, such as environmental health–improving technologies, that provide disproportionately high social benefits under increased consumption. This relates to the prior discussion of efficiency.

[11] We use the term *social good* to refer to quasipublic goods that have important social benefits that extend beyond those accruing to the private individuals or households that adopt them; in other words, goods that deliver positive consumption externalities.

3.1 The Rationale for Subsidies Supporting Clean Stoves and Fuels—And Other Social Goods

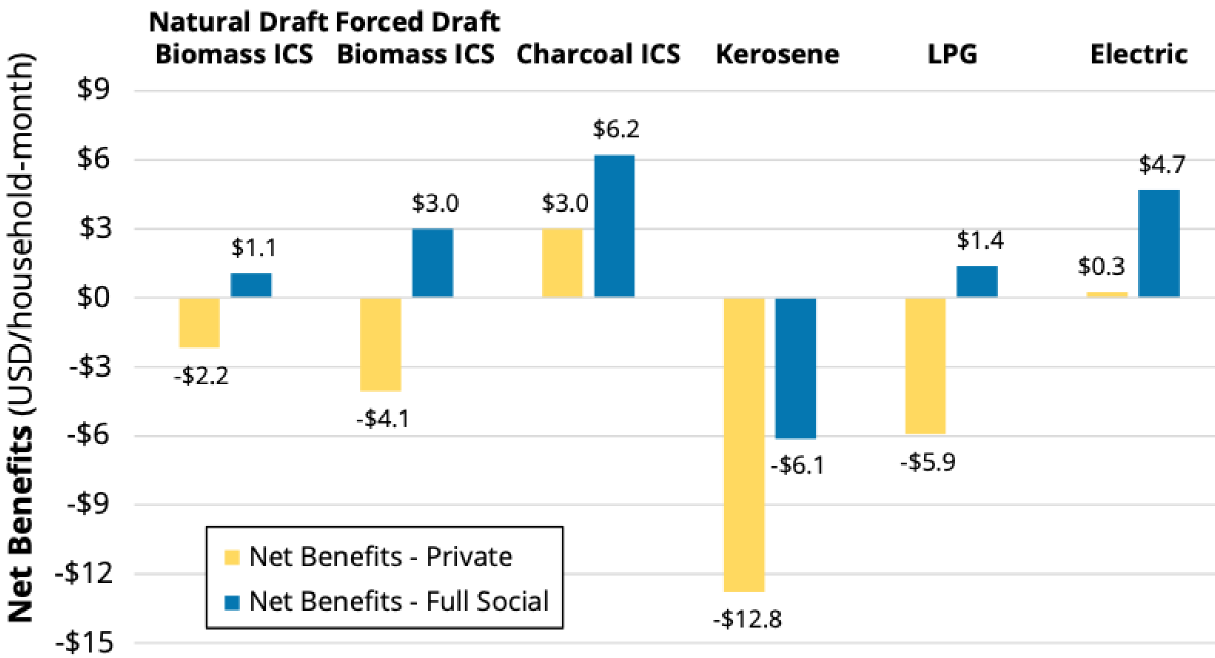
Drawing on the theory presented in the prior section, the primary economic motivation for using subsidies—and for limiting taxes—on improved cooking technologies and clean fuels is that consumption of these goods generates substantial positive externalities or spillovers. Recall principle 4, which states that more efficient taxes and subsidies are those that keep or bring the market closer to the socially optimal equilibrium, where marginal benefit equals marginal cost. In the positive consumption externality case, the market equilibrium where marginal private benefit equals marginal cost will underprovide. Subsidies therefore efficiently increase adoption, while taxes are particularly costly in generating even larger deviations from the social optimum. Alternatively, governments could tax polluting fuels and technologies to align the marginal social benefit of polluting technology use—which lies below the marginal private benefit caused by negative spillovers in this case—with marginal cost. But taxing traditional cooking technology and solid fuels is generally impractical. Traditional stoves are often provided by the informal sector or self-built (Khandelwal et al. 2017); biomass fuels are often collected from the environment rather than purchased, especially in rural areas (Bensch et al. 2021; Bailis et al. 2014); and charcoal and other polluting fuels are also collected or sold by the informal sector (Neufeldt et al. 2015). At the very least, economic theory very clearly supports minimizing taxes and duties on improved technology and clean fuels and reducing the burdens of licensing requirements and hurdles (Lambe et al. 2015).

Several studies in the applied literature have attempted to calculate the extent of these externalities and what they might imply for efficient pricing. Specifically, economists have used cost-benefit accounting to demonstrate the substantial gap between the private benefits of shifting to cleaner options (to users of traditional technology) and the social benefits that include health and environmental spillovers (Jeuland et al. 2018; Jeuland and Pattanayak 2012).[12] Figure 9 presents a comparison of typical levels of private versus social costs and benefits for a common set of technology transitions. While social net benefits are positive for all transitions except traditional firewood to kerosene, private benefits that do not include positive environmental and health spillovers are generally negative or near zero because of the high costs of cleaner technologies. Such calculations demonstrate that externalities are responsible for substantial deviations from the socially efficient level of clean cooking technology use in situations where private behavior and markets are left alone.

Similar modeling also shows the particularly high costs of taxes on clean cooking products; for example, a recent and socially costly policy change that rolled back VAT exemptions in Kenya (Jeuland et al. 2021). Lack of subsidization leads to market equilibria characterized by underprovision and underadoption of improved technology, and taxes on improved cooking technology make this divergence even worse. The magnitude of the divergence between private and social benefits is not the only notable feature of these analyses, however. In fact, in a large variety of contexts (though not all), such calculations show that the private benefits of adopting

[12] In the broader environmental health literature, this argument also appears and has been made to support the case for long-term subsidies of health-improving technologies, such as those that reduce infectious and parasitic diseases, and deliver “large positive treatment externalities” (Kremer and Miguel 2007).

Figure 9. Private and social net benefits of household transitions from traditional firewood to various improved cookstoves (ICSs) and commercial fuels, in USD/household-month, with base case (average) parameter assumptions

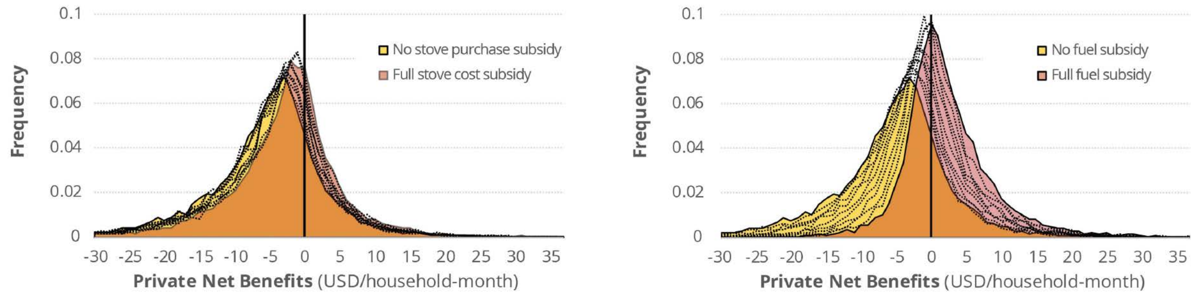


Source: Jeuland et al. (2018)
Note: The charcoal ICS transition is slightly different as it shows a shift from traditional charcoal cooking.

clean technology alone will be less than their private costs, even with fairly generous subsidies (see Figure 10 for the shift in net benefits of transitioning from firewood to LPG with increasing stove and fuel subsidies).

Adding to this simple accounting perspective, there is much discussion in the literature about whether households and individuals even correctly account for the private benefits from clean fuel use. Among the key issues, mitigating health risks may be a particularly low priority for households, compared to other development needs (Mobarak et al. 2012). An especially acute short-term focus or extremely tight liquidity constraints may also contribute, since these would both limit households' ability to make investments that pay off even over relatively short periods of time (Berkouwer and Dean 2019; Bensch et al. 2015). The latter would likely be reflected in a great degree of price sensitivity (or high price elasticities) of demand among low-income households, who are especially cash-constrained. Finally, intrahousehold dynamics and low bargaining power for those benefiting within households may also inefficiently depress adoption rates (Simon et al. 2014; Krishnapriya 2016), while risk aversion often limits households' willingness to pay for new and unfamiliar technology (Brown et al. 2013). Unsurprisingly, these various demand-suppressing factors tend to be especially strong among low-income households. Thus, subsidies can be justified not just by the desire to improve economic efficiency, but also for

Figure 10. Private net benefits of household transitions from traditional firewood to LPG as a function of stove (left panel) and fuel (right panel) subsidies, in USD/household-month



Source: Jeuland et al. (2018)
Notes: Results are for 10,000 simulations with plausible "developing country" assumptions. Thin lines refer to the family of distributions generated by increasing the subsidy fraction by 10% at a time, up to 100%.

distributional reasons, as a means to ensure that the poorest households gain access to welfare-improving technology.

International institutions and LMIC governments often articulate a rationale for subsidizing clean fuels or stoves that is reflective and consistent of their high positive social net benefits, consistent with the applied cost-benefit modeling described previously. For example, a public health and development perspective is well-represented by the World Health Organization, which has long argued that cookstove subsidies are relatively inexpensive when compared to the development benefits these provide (WHO 2006). National government justifications, however, also emphasize fiscal, distributional, and other considerations. The goal of Indonesia's LPG subsidy program, for instance, in addition to promoting a switch to clean fuel and delivering associated benefits, was primarily framed as one that would allow simultaneous reduction of kerosene subsidies, which were a major budgetary burden to the government at the time (Thoday et al. 2018). In Ecuador, LPG subsidization started in the early 1970s as part of a wider set of social support reforms (Gould et al. 2018). In 2014, however, the Ecuadorian government introduced the Program for Energy Efficiency in Induction Cooking and Water Heating with Electricity in Substitution of LPG in the Residential Sector to reduce fossil fuel consumption through gradual reduction of residential LPG use, and introduce electric cooking supported by renewable generation and subsidies for purchasing induction stoves (Figari and Gomez 2015).[13] In Nepal, the government has expressed commitment to electric cooking as a strategy to promote clean energy transition and capture myriad benefits, reduce dependence on (and trade imbalances caused by) LPG imports from India, all while pivoting to exploitation of the renewable hydropower potential in Nepal and meeting climate goals (Government of Nepal 2021a).

[13] The program deploys numerous economic incentives to promote technology transition. First, induction cookers and other equipment can be purchased with "long-term and low interest loans for users … payable in up to six years through monthly energy bills with an interest of 7%" and installation kits can be installed at no cost. The program also provided 80 free kilowatt hours monthly until 2018, after which the charge was set to $0.4 per kW-hr, 55% less than the regular price. Price instruments to discourage LPG, meanwhile, included higher importation tax for stoves (Figari and Gomez 2015).

In closing this section, it is also worth noting some of the views that subsidies are not needed in this sector. An important set of objections relates to the perspective that direct subsidies are easily captured by consumers who do not really need them (i.e., who would otherwise adopt clean technology anyway), or by rent-seeking individuals who use them to increase profits or surplus without substantively improving outcomes. In economics literature, this latter issue is often called leakage, denoting that the purported subsidy benefits are not actually realized. Another issue has to do with the political challenge of removing such support once it is in place, which relates to the idea that subsidy supports unhelpfully create an “entitlement effect” that “anchors” beneficiaries around subsidized price levels (Barnes et al. 1994; Dupas 2014). We engage with these objections and discuss them in light of existing empirical evidence in following sections.

3.2 Empirical Evidence on the Demand for Improved Environmental Health Technologies

There is rich literature on the drivers of adoption of improved cookstoves and clean fuels nested within broader literature on environmental health and energy technology adoption. We therefore briefly review relevant results from key analyses or systematic reviews. Considering general energy transitions, Leach (1992) conducted one of the first cross-country regression analyses aiming to identify the factors related to household substitution of traditional biomass fuels with modern energy sources, using data from 40 low-income countries. That analysis suggested that urbanization and income were more important determinants of transition than fuel prices and proposed that this result reflected availability and liquidity constraints that limit uptake of modern fuel-using appliances and the fuels (LPG especially) themselves. Leach further suggested that policies should target (a) improved supply of modern fuels via investment in transport and storage infrastructure, increased availability of fuel cylinders, and incentives to improve distribution; and (b) reduced cost or subsidies for equipment and smaller fuel containers, to address cash availability constraints. Others have noted the importance of government support for suppliers while highlighting that fuel pricing matters quite a bit when consumer behavior must shift; for example, in China for higher-efficiency stoves (Sovacool 2016). Indeed, the private sector and even government-supported utilities have often failed to invest in rural markets because of the high cost and risks associated with reaching scattered and low-consuming customers (Bazilian et al. 2010; Joffe and Jones 2003).

Several reviews or critical appraisals have focused specifically on the drivers of adoption of improved cookstoves or modern fuels (Puzzolo et al. 2016; Puzzolo et al. 2019; Lewis and Pattanayak 2012; Masera et al. 2000; Bonan et al. 2017). Though each of these offer somewhat different perspectives, they highlight a set of common determinants: low cost of solutions, availability or prices of alternatives (e.g., firewood), higher income and education, urbanization and connectedness, efficient and equitable subsidies that benefit the poor, learning from neighbors and peers, financing or access to credit, greater economic empowerment (especially among women), and more future-oriented or health-risk reducing preferences. Masera et al. (2000) emphasize the gradual nature of the cooking energy transition, while Lewis and Pattanayak (2012) discuss aspects that have received less attention, such as the role of social marketing and behavior change campaign design elements that are most effective. Bonan et al. (2017) additionally highlight studies that focus on households’ diverse preferences, given the various attributes of cooking technology (e.g., cost, smoke, fuel efficiency and requirements, and aspects related to taste, convenience, and technology durability or versatility). Perhaps because such aspects are difficult to study quantitatively, relatively few reviews address supply-side and institutional barriers and enablers; Lewis and Pattanayak (2012) and Puzzolo et al. (2016) are notable exceptions that highlight the importance of standards, effective implementation, and supply chain development.

Uncertainty about the value of new and untested options implies that demand for shifting from one technology to another, also known as the extensive margin (e.g., switching stove or fuel types, changing water sources, adopting new forms of water treatment) is often highly price elastic (Mobarak et al. 2012; Null et al. 2012). There is evidence from urban Ethiopia that charcoal demand has the highest own-price elasticity, and has high cross-price elasticities with firewood (Kebede et al. 2002). Evidence from India suggests that, because of cross-price elasticities, fuel subsidies would be less likely to reduce demand for polluting fuels like coal and firewood, and that improved LPG availability and awareness of household harms from solid fuels would be needed to increase demand (Gupta and Köhlin 2006). Another study from India finds that both rural and urban households respond to higher firewood prices, and that households respond by either switching to inferior fuels, continuing with firewood if alternative fuels are more expensive, or by reducing firewood consumption (Gundimeda and Köhlin 2008). Irfan et al. (2018) find that in Pakistan, demand for all fuels (firewood, crop residue, animal dung, kerosene, LPG) except natural gas is price inelastic and that all fuel expenditure elasticities are positive (meaning that expenditures increase with higher prices, given the relative lack of a demand response). From analysis of provincial-level data from rural China between 2003–2012, Teng et al. (2019) find that demand for coal among rural households has become more price elastic over time, and that the income elasticity of demand is negative (meaning that coal-based energy is an inferior good).

In addition, moving households along the intensive margin to greater or lesser use of a particular improved technology, once they have come to appreciate their value, is relatively price inelastic. In these and other reviews, the role of substantial subsidies and price decreases is thus highlighted as critical to mitigate a set of factors, such as liquidity and credit constraints, present bias (i.e., a focus on the short term), lack of information and awareness, and peer effects that manifest in low rates of community adoption. Reducing prices is especially important when the returns to adoption appear uncertain; Dupas (2011) provides a valuable and relevant general review. Externalities (both in terms of effects on the local disease environment and in terms of social networks' knowledge spillovers), intrafamily inequities (women and children may benefit most from improved environmental health technology, but women may lack access to resources and agency), and institutional failures are other reasons for reducing prices and making such solutions more affordable (Null et al. 2012). Indeed, deviations away from the socially efficient uptake of household environmental health technologies are often particularly costly because of this high price elasticity of demand.

3.3 General Evidence on Pricing Policies that Affect Environmental Health Technologies

3.3.1 Improved Cooking Stoves and Clean Fuels

As discussed previously, the general consensus among economists and policy makers is that environmental health–improving technology should be subsidized and not taxed; as such, most empirical evidence is related to the latter pricing policy rather than the former. Rigorous evidence on the impacts of subsidies for clean stoves and fuels from large-scale programs is growing but remains limited (Figure 2 summarizes results from several notable country experiences). Some of the most long-term evidence comes from an analysis of Indonesia's kerosene-to-LPG conversion program, which featured subsidization of LPG coinciding with a phasing out of kerosene subsidies. Andadari et al. (2014) found that though the program did not considerably reduce the number of households classified as energy poor (households that spend more than 10% of their income on energy expenditures), it did effectively end extreme energy poverty.[14] Research has also discussed national government subsidy efforts to subsidize LPG in Ecuador, Indonesia, and Peru (Gould et al. 2018; Pollard et al. 2018; Thoday et al. 2018). Indonesia has seen large shifts toward LPG adoption, with more than 57 million LPG start-up kits distributed as of 2015 (Thoday et al. 2018). In rural Ecuador, many households have moved toward the primary use of clean fuels. In Peru, LPG use has risen sharply, especially among households with electricity access, who have been targeted most aggressively resulting from an approach centered on private sector distribution.

Such evidence on the impacts of subsidies for clean cooking fuels is also complemented by that from subsidy removal or phase-out experiences. Quasi-experimental evidence from Ghana, for example, shows that the removal of fuel subsidies led some households to slide back into use of polluting cooking options (Greve and Lay 2022). That country's fossil fuel reform in 2013 resulted in a 50% price increase for LPG and a 20% price increase for diesel, which in turn caused rural households to increase firewood use for cooking purposes by 2 to 3 percentage points, and led urban households to substitute charcoal for LPG, increasing charcoal consumption by 10 to 15 percentage points at the intensive margin (or extent of use of charcoal). The authors found that most urban households reduced their LPG consumption despite LPG expenditure increased because of the higher prices. This suggests a somewhat inelastic price response that nonetheless threatens the substantial progress made in the country toward the use of modern energy sources for cooking. More recently, Jeuland et al. (2021) used primary data on fuel demand to develop model-based predictions that show similar slowing of progress towards achievement of cleaner cooking goals in Kenya, following the reimposition of a VAT on manufactured stoves and on LPG fuel.

One problem with examining correlations between advances toward clean cooking targets and the institution (or rollback) of subsidy programs to support them is that confounding factors other than the subsidies may also explain the observed results. The experimental and quasi-experimental literature therefore offers particularly valuable complementary information on the causal impacts of subsidies, as well as particular subsidy designs, though such evaluations are

[14] The *extreme energy poor* were defined as households spending more than 10% of their income on energy expenditures and whose useful energy consumption was below 580 kWh.

typically undertaken for initiatives that are relatively limited in scale. Experimental evidence from rural India, for example, shows that ICS uptake and continued use is strongly responsive to subsidies that support combined supply chain development and lower end-user prices, plus low-cost financing (Pattanayak et al. 2019), consistent with the evidence in support of a high price elasticity discussed previously. Moreover, a combination of free trials and time payments coupled with an opportunity to return ICS if they are deemed unsatisfactory was found to ease households' liquidity constraints and enhance adoption among charcoal users in rural Uganda (Levine et al. 2018). In Cambodia, delayed rebates conditioned on continued use of technology promoted use of clean technology among households that persisted well beyond the short-term purchasing period (Usmani et al. 2017). An additional study from Senegal finds that personalized door-to-door sales are a key determinant of rural Senegalese households' willingness to pay and purchase ICS (Bensch and Peters 2016). These findings suggest that subsidies aimed at reducing liquidity constraints, plus supply chain development and enabling convenient delivery, may be particularly vital and is consistent with the evidence from India by Pattanayak et al. (2019).

Importantly, though, clean fuel transitions (to LPG and electric stoves) may lead to increases in household energy expenses as people switch from non-commercial fuels that can be gathered from the environment to commercial fuels that must be purchased, or switch to more expensive fuels (Jeuland et al. 2018). Even switching from one clean fuel to another can be expensive for households. Martínez et al. (2017), for example, find that households in Ecuador that switch to induction cooking from LPG face 2.4 times higher energy expenses relative to their historical LPG expenses. However, energy expenses for LPG would greatly exceed electricity expenses if subsidies were eliminated, which points to the importance of rationalizing policies across different clean fuels to also meet environmental objectives.

In addition, a range of studies show that exclusive use of clean technology generally remains elusive and reliance on traditional polluting technology persists, even when subsidies are generous (Gould et al. 2018; Pollard et al. 2018; Thoday et al. 2018). For example, 89% of LPG-using households in rural Ecuador primarily use that fuel, but more than 75% of households still use wood fuel at least once per week. Further, among the 17% households who own induction stoves in the country, only 1% use these as their primary cooking device (Gould et al. 2018). In Peru, over 95% of households in targeted areas continue to use biomass fuels (Pollard et al. 2018). To be sure, fuel and stove stacking, or the use of traditional and clean cooking devices, is common in LMICs for various reasons that extend well beyond costs.[15] These include supply chain constraints of clean technology (Puzzolo et al. 2019), household preferences for cooking with traditional technologies (McCarron et al. 2020; Puzzolo et al. 2016; Rehfuess et al. 2014), households optimizing across many nonhealth dimensions, and other factors. In Mexico, in areas where the government even provides free LPG stoves and cylinders, households continue to use firewood for other, nonmonetary reasons (Troncoso et al. 2019). Fuel stacking is also prevalent

[15] Complementary evidence from Ecuador supports the interpretation that fuel stacking is ubiquitous. Primary users of LPG continue to experience average and short-term $PM_{2.5}$ exposure that is above the World Health Organization interim-I guideline (Gould et al. 2020). Simon et al. (2014) argues, partly based on such evidence, that the case for subsidizing clean cookstoves on efficiency grounds is thus unclear, because they may not sufficiently move behavior to generate health spillovers. However, this argument ignores environmental spillovers, which tend to be more clearly and linearly related to increased use of clean technology.

among rural households with biogas plants in Kenya, Uganda and Tanzania (Clemens et al. 2018); there are no ongoing fuel costs associated with operation of such technology. Yet costs nonetheless remain critical: in Indonesia, fuel stacking of clean fuels with biomass increased as kerosene subsidies were removed and households switched to higher consumption of more expensive LPG and electricity, largely for affordability reasons (Andadari et al. 2014). More recently, in India, the Pradhan Mantri Ujjwala Yojana (PMUY) scheme increased the probability of eligible below-poverty-line households obtaining an LPG connection by 3–4 percentage points (Gill-Wiehl et al. 2020). They also found that PMUY households consume 7.4 kg less LPG than non-PMUY (above-poverty-line) households, despite the roughly 30% fuel subsidy the former households receive. Consistent with this, Kar et al. (2020) found that only a small percentage (7%) of PMUY beneficiaries purchase five or more cylinders per year, which would be enough to meet about half of the typical rural family's cooking requirements. Those authors argue that larger subsidies are needed to encourage the transition.[16]

A significant and common concern with subsidies for clean stoves and fuels is that they mainly benefit higher-income populations, who have relatively inelastic demand for improved stoves and clean fuels than the poor. Reflecting our theoretical discussion of tax and subsidy incidence in section 2 and one of the significant objections to subsidies covered in section 3.1, then, these higher-income groups disproportionately capture the benefits of subsidy. Many also argue that enhanced targeting of subsidies specifically to the poor, sometimes called smart subsidies, is the policy that is really needed to move the needle on clean cooking technology adoption. Such subsidies would especially need to address factors that inhibit improved and clean cooking adoption, circumvent dependence on subsidies, and leverage local market distribution channels (Simon et al. 2014). For example, drawing on experiences in Latin America, Troncoso and da Silva (2017) argue for better targeting of subsidies to the poor who are most price-sensitive. Zuzhang (2013) similarly argues for targeted biogas grants to rural low-income households in China, while Lambe et al. (2015) argue for better targeting of subsidies for low-income households in sub-Saharan Africa. Finally, Kuehl et al. (2021) suggest pro-poor targeting in Indonesia, and provide some specific recommendations on how to support differential targeting: (a) enhanced data collection to identify disparities in LPG access and (b) engagement with political and influential groups to better communicate objectives and benefits to target beneficiaries.

Unfortunately, operational guidance on designing such smart subsidies, backed by solid empirical research, is relatively scarce. Empirical evidence for targeting of energy subsidies, meanwhile, is largely focused on electricity, as discussed in following sections, and is negative on the ability to effectively tailor energy subsidies in this manner.

3.3.2 Other Environmental Health Technologies

Still in the energy domain, there is large, multicountry empirical literature on the role of prices and subsidies in the electricity sector. Electricity subsidies are common and often criticized for their distortionary (e.g., costly in efficiency terms) dimensions, but panel data analysis from 63 developed countries and LMICs covering the years 1982–2009 shows no consistent pattern

[16] Kar et al. (2020) also find that only 45% of wealthier non-PMUY beneficiaries use five or more cylinders per year, confirming other previously discussed results that show fuel stacking is not solely about lack of affordability.

regarding the impact of electricity sector reforms on residential and industrial price-cost margins or cross-subsidy levels (Erdogdu 2011). That study identified power consumption, income level, and context-specific features as determinants of electricity price-cost margins and cross-subsidy levels, which suggests that successful reform in one country may not deliver similar results elsewhere. Two frequently used mitigation policy options in the power sector in China are renewable electricity subsidies and carbon pricing (Yin et al. 2018).

The broader literature on subsidization of environmental health interventions offers many useful and relevant results. Subsidies are generally proposed as efficiency improving for a broad range of such technologies: mosquito control or bed nets (to avert malaria), water treatment, sanitation, vaccines, and many others. Brown and Kramer (2018) show that efficient subsidies for indoor residual spraying in Uganda even exceed the cost of providing that service (~$0.8–$1.7 per household per month) and argue that such generous subsidies could decrease cases of malaria between 19%–25%, depending on the type of insecticide used and the spraying frequency. Price subsidies, rather than information provision, are typically needed to increase adoption of household water treatment and sanitation. This positive impact of subsidies has been found in studies from a wide range of contexts: in rural Zambia (Ashraf et al. 2013), rural Kenya (Blum et al. 2014), rural Bangladesh (Guiteras et al. 2015), rural India (Pattanayak et al. 2009), and urban Senegal (Lipscomb and Schechter 2018), as well as in a meta-analysis that identifies subsidies as among the most effective interventions for sanitation (Garn et al. 2017). Additionally, in the Blum et al. (2014) study from Kenya, households that were expected to benefit the most from point-of-use treatment for household drinking water (i.e., those with young children) were not more likely to purchase the product at higher prices.

The typical vaccine policy in LMICs advocates for giving vaccines to targeted populations free of charge, but the efficiency costs and public financing burden of free distribution can be large, depending on the disease and scale of the program. Leveraging empirical data from Kolkata, India, and information about how the herd protection externality varies as a function of vaccination coverage for the case of cholera, Cook et al. (2009) calculate the optimal subsidy level and determine that selling vaccines at full marginal cost is preferable to giving them away.

Free distribution, or use of subsidies larger than what is socially optimal in the short term, may be efficient in the long term when learning is important, however. The case of insecticide-treated bed nets for malaria prevention is a good illustration of this idea. Combining experimental data with GPS-based location information in Kenya, Bhattacharya et al. (2013) show that use of insecticide-treated mosquito nets (ITNs) by individual households increases with neighborhood subsidy rates, and that lack of accounting for these spillovers leads to overestimation of ITN use at low subsidy rates and underestimation of ITN use at high subsidy rates. There is evidence of similar positive spillovers on neighboring households' demand for sanitation from several studies (Dickinson and Pattanayak 2009; Guiteras et al. 2015; Deutschmann 2021; Kresch et al. 2020). In a two-stage randomized pricing experiment with Olyset antimalarial bed nets in Kenya, Dupas (2014) found an increase in short-run adoption rates among subsidy recipients and their neighbors and positive impacts on longer-term willingness to pay following positive learning about the technology. Importantly, the latter study also found no evidence of anchoring or an entitlement effect (that would lower willingness to pay) from prior free provision.[17] This latter result is consistent with evidence that free distribution of ICS in rural Senegal, employed to spur initial adoption of an unknown technology, does not reduce later willingness to pay (Bensch and Peters 2020). Additional evidence of positive long-term impacts on demand following subsidy provision can be found for urban latrine desludging services (Deutschmann 2021). Garn et al. (2017) present somewhat contrary evidence from the sanitation purview in their meta-analysis, which finds that communities' prior sanitation subsidy experience negatively contributes to responses to other, nonsubsidy interventions. Similarly, Fischer et al. (2019) suggest a negative effect of free provision on the purchase of three health products (a branded pain killer, a deworming drug, and a treatment for childhood diarrhea), though they note that this might be due to consumers' overly optimistic beliefs about product effectiveness.

As with stove and fuel subsidies, targeting is also typically not well-implemented for utility-provided electricity and water services. Working with data from 45 subsidy programs and 27 electrical utilities, and 32 programs from 13 water utilities across regions, Komives et al. (2005) found that most utilities use quantity-based subsidies that typically fail to reach the poor. Many poor households are entirely left out of subsidy programs because of their lack of connections to these types of services, and poor households capture only half as much subsidy value as they would if there were random distribution of cash subsidies across the whole population. The authors recommend guaranteeing utility service coverage for the poor by (a) reducing the service cost through efficiency improvements in operating and capital expenditures and by improving revenue collection, (b) regular billing and removal of minimum consumption requirements and fixed charges, and (c) easing legal restrictions that restrict expansion of services to the poor. Meanwhile, the very generous electricity subsidies prevailing in the Indian agricultural sector primarily benefit large and medium farmers, because poor farmers in backward areas are less likely to have agricultural electricity connections and also use less electricity on their smaller plots (Jain 2006).

In contrast to energy subsidies, some sectors and interventions have experienced substantial success with targeting, though some leakage is typically unavoidable. For example, Dizon-Ross et al. (2017) found that approximately 80% of those eligible for targeted bed net subsidies (those most vulnerable to malaria—pregnant women and their unborn children) effectively received the subsidy in Ghana, Kenya, and Uganda, but that 15% of subsidies went to those who should have been ineligible. Combining this subsidy program with other efforts to improve the performance of distribution agents, such as audit threats, increased bonus pay, and changes in stock size did not improve targeting, however. Targeting can also be attempted by instituting ordeal mechanisms. For example, Dupas et al. (2016) tested a redemption mechanism that provided free chlorine solution for water treatment that required use of vouchers at specific distribution centers. Compared to a free distribution program with chlorine delivery, this allocation mechanism decreased the amount of chlorine procured (i.e., take-up of the health product)

[17] The idea that free provision will spoil the market for improved technology is a common complaint voiced by both donors and implementers, but evidence for such an effect remains limited. Lack of understanding of selection—whereby free provision enables adoption by all households, not just those with high demand—likely explains the persistence of this idea. Related to this evidence on ITNs, Khatib et al. (2008) found that free ITN distribution in rural Tanzania only affected the ITN market temporarily.

dramatically (by 60 percentage points), suggesting that target beneficiaries also respond to time costs. Moreover, compared to households in the free home distribution group, households in the voucher treatment group did not use substantially more water treatment, suggesting that this allocation scheme does not better target those with higher demand for water quality. In the same Kenyan geographic area, Cohen et al. (2015) found that, contingent on having fever, households were willing to pay the effort costs of visiting a local drug shop to redeem a voucher for highly subsidized antimalarial medication, demonstrating that these beneficiaries have demand but struggle to afford unsubsidized products.

3.4 Complementary Interventions and Implementation Details

3.4.1 Improved Cooking Stoves and Clean Fuels

While the previous discussion refers to the general impacts of fuel subsidy programs on choices to adopt new technologies, existing program experiences offer a host of other lessons related to specific implementation aspects and complementarities. Most of the time, subsidy programs or policies are only one part of a portfolio of government interventions designed to foster increased use of modern cooking technologies. For example, subsidies for LPG were only one of several factors responsible for the successful kerosene-to-LPG conversion program that began in 2007 in Indonesia. First, the strong role of prominent central government officials and relevant ministries was essential (Budya and Arofat 2011). Second, an able implementing partner was needed to serve as an intermediary between the government, beneficiaries, and other relevant sector stakeholders. Third, complementary policies gradually impeded market accessibility and price advantages (including existing subsidies) of polluting fuels.[18] Fourth, engaging with and empowering existing fuel distributors to promote the new technology and market new fuels (especially those with strong interests in the fuels being phased out) was important (Budya and Arofat 2011). Strategies such as free initial starter packs including a stove and a cylinder of clean fuel were deployed to help spur adoption and acceptance of new technology, especially among the poorest consumer segments (Budya and Arofat 2011).

Mittal et al. (2017) comment on several important lessons from India's recent LPG subsidization program, PMUY. Noting that its scale makes PMUY the world's largest cash transfer program, several of its features have enhanced its success, including strong political backing and clear communication of program objectives. In addition, the design of PMUY limits consumption of subsidized cylinders while eliminating distortions of market prices (via direct reimbursement to consumers following their purchases), which effectively discourages development of a black market that might in turn compromise product quality. Third, a complementary information campaign has used social pressure to encourage the wealthy to withdraw from receipt of LPG subsidies. Finally, the program relies on information technology that limits duplication, improves subsidy targeting, and expands access to clean cooking among beneficiaries.

As reviewed, substantial empirical work finds that consumer price remains among the most important determinants of the extent of transition to cleaner technology (Kar et al. 2020; Raha et al. 2014; Troncoso and da Silva 2017). Other factors are also critical, however, including

[18] Of course, this is more difficult when the fuels being replaced are collected from the environment, as is the case for firewood, crop residues, or dung.

contextual aspects like seasonality (Kar et al. 2020), features such as delivery and convenience of fuels and technology (Sharma et al. 2019), and target beneficiary characteristics such as education, household size, and income (Andadari et al. 2014). Through in-depth interviews with households served by Peru's LPG promotion program, Pollard et al. (2018) document problems related to the difficulty of enrollment and access to LPG distribution points. The previously mentioned Pattanayak et al. (2019) study in northern India similarly indicates how critical a well-designed package focused on supply chain development and household technology demonstration and behavior change communication is for success in remote rural areas, as well as the role of trust and experience with local implementing partners (Usmani et al. 2018). On the other hand, behavior change communication alone appears to have minimal influence on the willingness to pay for, and adoption of, ICS (Beltramo et al. 2015). This latter point raises a more general one: overly simple "silver bullet" interventions that rely on a single policy lever are rarely sufficient to foster large-scale transitions in the household energy domain.

Taking LPG as an example, it will clearly be necessary to first improve the fuel distribution network and, typically, to incorporate direct delivery to users to address convenience and reliability concerns (Pollard et al. 2018). Second, increasing the value of LPG vouchers to cover the full monthly cost of one or two LPG cylinders is essential to address lack of affordability among the poor. Finally, behavior change communication strategies can help support LPG adoption and abandonment of biomass fuels, where cultural barriers and traditional norms about cooking persist.

3.4.2 Other Environmental Health Technologies

Complementarities between and across policies are also noted in the broader literature on environmental health technology adoption. Household demand and use of latrines, for example, is strongly influenced by cultural norms and attitudes about privacy and dignity, the approach used to trigger changes in those norms (through social pressure and peer monitoring), and the accessibility of materials and technical knowledge about solutions (Pattanayak et al. 2009; Orgill-Meyer et al. 2019). Hulland et al. (2015) also found that frequency of personal contact with a health promoter, accountability, advertisements, and group meetings are key determinants of the sustainability of latrine programs.

Other aspects of distribution also matter, as evidenced in a field experiment conducted in rural Uganda (Fischer et al. 2019). These authors found that for three health products (Panadol, a branded pain killer version well-known to consumers; Elyzole, a deworming drug somewhat known by consumers; and Zinkid, a treatment for childhood diarrhea hardly known by consumers), take-up was higher among those offered the products for free, compared to those offered the products for sale, as expected. But households were also more likely to purchase Zinkid when it was sold by a nongovernmental organization (NGO) than by a for-profit company. Purchase rates 10 weeks after free distribution declined for Panadol and Elyzole, perhaps because of negative experience with those products, but did not vary by seller type, while demand for a newly introduced, different product called Aquasafe (a home water purifier) was higher when the seller was a not-for-profit organization. Implementer identity and local experience has been shown to have important implications for demand for a range of other technologies: Improved cookstoves, as noted previously (Usmani et al. 2018); agricultural productivity improvements

(BenYishay and Mobarak 2019); latrines (Cameron et al. 2019); health products (Fischer et al. 2019); and more general development efforts (Vivalt 2020). Finally, prior experience with other interventions—especially negative experience—may have negative spillovers for new promotion initiatives. This was the case of demand for clean cooking technology (induction stoves) that followed latrine promotion in Orissa, India, at least among men, whose preferences for such technologies are less clear (Krishnapriya et al. 2021).

3.5 Distributional Aspects of Subsidy Programs

3.5.1 Improved Cooking Stoves and Clean Fuels

Despite the clearly positive impacts of subsidies on increased adoption and use of improved cooking technology, a key problem with energy subsidies, also closely related to the challenge of targeting them to the poor, is their tendency to be inequitable, as they often mainly benefit upper-income households (IMF 2013; Troncoso and da Silva 2017). The International Monetary Fund has argued that "on average, the richest 20 percent of households in low- and middle-income countries capture six times more in total fuel product subsidies (43 percent) than the poorest 20 percent of households (7 percent)" (IMF 2013). This regressive dimension is largely caused by the nature of demand for clean technology, discussed previously, and the theoretical points about incidence presented in section 2.1. Specifically, demand for new technology among the poor is highly elastic, such that subsidy incidence on the poor is low. In contrast, demand for clean fuels among higher income households that tend to have already partially made the transition to clean fuels is highly inelastic, such that subsidy incidence for this group is high. The result is that these latter, wealthier households capture a large share of energy subsidy benefits.

Turning to cooking subsidy programs specifically, and consistent with these ideas, Andadari et al. (2014) noted that the groups that benefitted the most from LPG subsidies in Indonesia were medium- and high-income households living in suburban areas. Similarly, in India, though the current LPG program is meant to reach the poor, targeting to the poorest and most marginalized households has remained a challenge (Tripathi et al. 2015). While the PMUY has a positive effect on obtaining LPG connections, it appears to have only limited effects on overall LPG consumption, which points to the need for more generous and targeted fuel refill subsidies for below-poverty-line households (Gill-Wiehl et al. 2020). Evidence from China similarly points to the exclusion of poor and lower-income households from the biogas subsidy scheme (Zuzhang 2013). To be sure, the poorest households may find improved solutions unaffordable even when these are highly subsidized, lack access to other essential inputs such as livestock needed for biogas production, lack knowledge of the benefits of improved technology, or have greater distrust of the various institutions delivering such interventions. As energy price increases raise the costs of many of households' basic needs (cooking, heating, lighting, transport, and higher prices for energy-intensive goods and services), it is important for policy makers to consider broader social safety nets (e.g., cash transfer programs) that protect the less-well-off from energy-related costs, or that allow them to avoid backsliding toward cheaper polluting alternatives (IMF 2013).

Of course, subsidies whose direct financial benefits are disproportionately captured by richer households nonetheless also benefit poor households indirectly, insofar as these lead to lower household air pollution contaminating ambient air or reduce climate change pressures. The former externality may be particularly meaningful in some settings, while the latter will typically be very modest, given the small marginal contribution of household air pollution to climate change.

3.5.2 Other Environmental Health Technologies

Similar equity considerations appear in many technology adoption situations in low-income countries; however, the relative benefits of subsidies vary substantial across technologies and service provision modalities. As noted previously, high-income consumers tend to receive an unbalanced share of subsidies delivered through increasing block tariffs commonly touted as “pro poor” in water and electricity provision, compared to low-income residential customers. In Nairobi, Kenya, for example, those in the lowest wealth quintile receive only 15% of the total subsidies delivered to households in the study sample, while households in the highest wealth quintile capture 30% of the total subsidies (Fuente et al. 2016). These authors argue for delivering subsidies for connections (targeting the extensive, rather than intensive, margin) and deploying means-tested approaches (i.e., subsidies wherein households must meet an income or wealth criteria). Khatib et al. (2008), on the other hand, find that the sale of ITNs at market prices leads to low adoption among the poor, but such differences are not observed with voucher-subsidized and freely distributed ITNs in Tanzania.

Subsidies in some cases can compromise the integrity of implementation of promotion efforts. For example, Dizon-Ross et al. (2017) found, counterintuitively, that combining subsidy vouchers with the standard bed net distribution program in Ghana, Kenya, and Uganda actually lowered coverage among eligible participants. They provide two potential explanations for this result. First, in the areas around the voucher clinics, a lower percentage of people (and especially women) were aware of the bed net distribution program, suggesting that vouchers may crowd out marketing effort by promoters. Second, the voucher system may have reduced the distributing health workers’ independence and confidence; several clinics declined to implement the combined program because of its greater complexity, in contrast to the lack of refusals among the standard distribution clinics.

Subsidies have in several studies been found to be highly beneficial for encouraging adoption and improved outcomes among the poor. In rural India, subsidies helped below-poverty-line households adopt latrines, whereas for above-poverty-line households, subsidies were not as required and a “shaming” strategy was sufficient (Pattanayak et al. 2009). Deutschmann (2021) argues that a cost-effective strategy for long-term sanitation change would be earmarked short-term discounts for the poorest households, with regular reinforcement. Nonetheless, it is generally difficult and uncommon for studies to disaggregate outcomes. A recent systematic review of interventions promoting uptake of water, sanitation, and hygiene improvements noted an uptick in the number of studies focusing on outcomes among women and children, but sex-disaggregated outcomes remain rare, and other vulnerable populations (e.g., people living with disabilities) are even less studied (Chirgwin et al. 2021).

4 CASE STUDY: NEPAL

4.1 Clean Cooking Transitions in Nepal

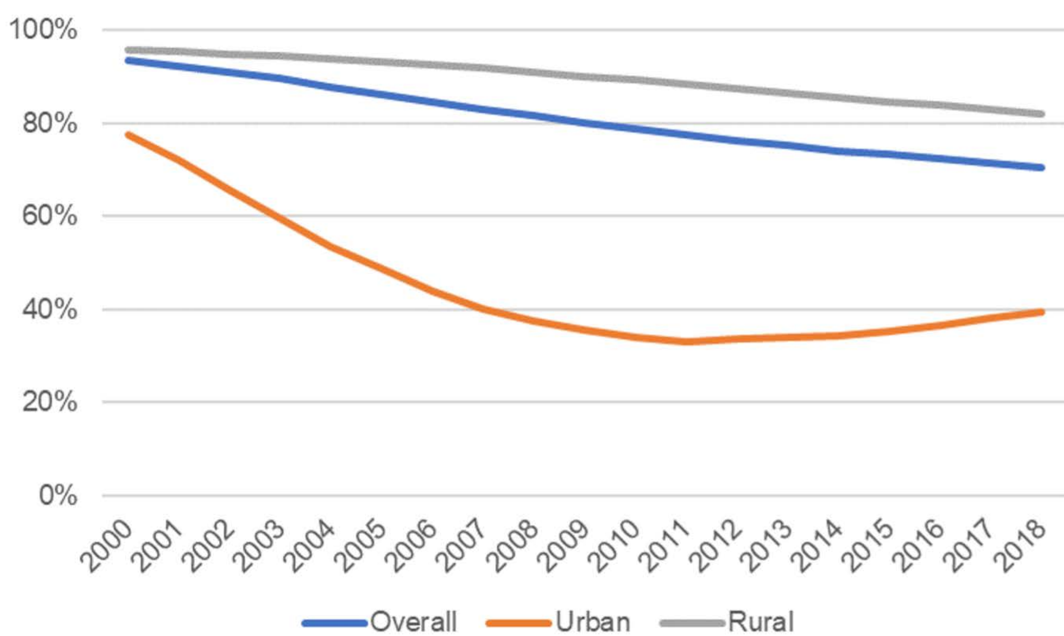
In Nepal, the percentage of households primarily using polluting cooking fuels decreased from 93% to 71% between 2000 and 2018. Reductions were larger (from 78% to 40%) in urban areas, though that progress slowed considerably during the past decade, partly caused by urbanization as rural, primarily biomass-using households moved to towns and cities (Figure 11). To address the persistent high rates of polluting fuel use and low rates of improved cookstove adoption, the government of Nepal has taken measures to support cleaner cooking transitions.

This case study relies on a set of consultations with stakeholders in Nepal to identify and comment on potential pricing policies to address cleaner cooking transitions, including interviews with policy makers within the government, key parties involved in the supply chain for various fuels, and representatives from academia and civil society.

4.1.1 The Government of Nepal's Clean Cooking Ambitions

According to the Biomass Energy Strategy 2017, the government of Nepal aims to ensure the availability of modern clean energy in all the households using solid biomass by 2030 (Government of Nepal 2017). Adding more specific targets to those ambitions, Nepal's 2020 Second Nationally Determined Contributions (NDCs) outline a set of ambitious targets that would achieve a 23% reduction in climate-forcing emissions from cooking:

Figure 11. Percentage of households using polluting cooking fuels as their primary cooking source in Nepal, 2010–2018



Source: WHO (2021)

- By 2030, ensure 25% of households use electric stoves as their primary mode of cooking.
- By 2025, install 500,000 ICSs, specifically in rural areas.
- By 2025, install an additional 200,000 household biogas plants and 500 large-scale biogas plants (institutional/industrial/municipal/community) (Government of Nepal 2020b).

Previous policies have acknowledged the need for promoting clean cooking but avoided such specific targets. Nepal's National REDD+ Strategy (Government of Nepal 2018) does not explicitly mention improved cooking, for example, although action 8.2 mentions "providing input on technology and subsidies [for] equipment for energy production to increase access to sustainable, affordable and reliable energy (Objective 3)" (Government of Nepal 2018). Nepal's climate policy meanwhile mandates that "technologies be developed for reduction of black carbon and greenhouse gas emissions induced by water, land, and air pollution" (Government of Nepal 2020a). Finally, the 2018 white paper by Nepal's Ministry of Energy, Water Resources and Irrigation (MoEWRI) specified only that the AEPC, as part of their work on clean energy, would promote biogas, improved cooking stoves, bio-briquette, and gasifiers to help reduce environmental pollution and aid the efficient use of energy in rural areas (Pun 2018).

To reach the ambitions of clean cooking for all and the second NDCs, the government of Nepal must oversee two critical transitions: from LPG to electric cooking in urban areas, and a different shift from traditional cookstoves to ICS in rural regions.

4.1.2 Transition 1: LPG to Electric Cooking

In 2015–2016, a nearly six-month blockade along the Nepal–India border cut supply chains and created a fuel crisis that highlighted Nepal's reliance on foreign fossil fuels for daily energy needs (Acharya et al. 2015). As access to LPG dried up, people in Nepal switched to firewood or bought electric induction stoves to cook, which in turn caused power shortages as underprepared distribution systems had to manage cooking loads during periods of peak electricity demand. That experience created the perception that electric cooking is unreliable, but the rapidity of households' behavioral responses also convinced national-level policy makers that a switch to electric cooking was possible and desirable.

Prior cost-benefit policy analysis focused on the Kathmandu Valley has shown that transitions from firewood and LPG to electricity generate the highest social net benefits (Das and Jeuland 2021). Moreover, further supporting of a transition from firewood to LPG in this setting requires LPG subsidization, which creates a substantial public financing burden and primarily benefits wealthier household who have already adopted LPG. Another theoretically efficient approach would be a firewood ban, but such a policy has unknown enforcement costs, would be politically challenging, and may not succeed considering persistent stove and fuel stacking in the region. To ease the public financing burden, pricing policies that combine stove or appliance subsidies for electric cooking devices and efficient biomass ICS with financing options would be simplest. Electricity tariffs should also be studied carefully given their important implications for adoption of electric cooking by the poor.

While that analysis was focused on the Kathmandu Valley, we expect similar patterns across Nepal for similar cooking transitions. The main difference is in the different starting points across different regions and across urban and rural areas, because of the varying appropriateness of clean fuel alternatives arising from the variance in the feasibility of supply. For example, efficient biomass solutions and biogas remain highly relevant in rural Nepal, where electricity access is still not universal and electricity reliability remains problematic. LPG may be most appropriate as a clean fuel alternative in areas that the grid has not reached and off-grid electricity generation cannot be sustained. An important point to note is that while transitions to electricity appear encouraging in Kathmandu Valley, and primary clean cooking fuel use is high in urban Nepal at 60% (WHO 2021), behavior change communication campaigns would be required to inform households of the benefits of electric cooking, given the existing low penetration and use of electric cooking appliances.

The other key factor driving the current policy focus on electric cooking is the sharp increase in hydropower generation that is expected to be realized in the coming years. Nepal aims to produce 10,000 MW of power by 2026 and has around 4,000 MW already scheduled to come online, compared to current peak demand of 1,550 MW (Shrestha 2021c). While Nepal plans to export much of the new supply to India, it is also hoping to increase domestic consumption, to improve revenues for the Nepal Electricity Authority (NEA) as well as to increase quality of life. Electric cooking is a key aspect of that strategy of increasing domestic consumption, because it would allow achievement of NDC targets while also improving health- and gender-related outcomes (Government of Nepal 2021a).

Experience globally suggests that a large effort will be needed to promote the adoption of electric cooking, however. As of 2020, only around 6% of households used electric induction stoves at all in Nepal (Government of Nepal 2021a). In 2021, MoEWRI released the Assessment of Electric Cooking Targets for Nepal's 2020 Nationally Determined Contributions that outlines several major initiatives to promote electric cooking, including a Green Climate Fund project on the acceleration of cooking solutions through modern, climate-friendly, and efficient clean cooking solution and a proposed World Bank project on electric cooking (Government of Nepal 2021a).

Several other institutions are also involved in spurring an electric cooking transition. The NEA, the national utility, manages transmission and distribution infrastructure at the national level, while Community Rural Electrification Entities act as local utilities in many rural areas. The NEA has been upgrading national infrastructure in part to support the transition to greater cooking loads in urban areas. The AEPC promotes micro-hydro and rural electrification efforts and has a clean cooking mandate that supports deployment of subsidies to promote a range of improved cooking solutions. The Electricity Regulatory Commission (ERC) sets the national tariff structure and has recently reduced tariffs for low-electricity users to promote electric cooking.

NGOs, multilateral development funds, and ministries have worked together over the past few years to promote electric cooking. One key initiative is the Improving Access to Modern Energy Services in Nepal project, led by the MoEWRI under the auspices of Deutsche Gesellschaft für Internationale Zusammenarbeit Energising Development (GIZ EnDev) and in partnership with AEPC, SNV, and Practical Action (GIZ 2022). One component of this project is a results-based financing program for clean cookstoves that supports market development by offering a fixed 20% subsidy, delivered to retailers, per cookstove sold. The aim is to incentivize cookstove providers to move into less profitable markets or reduce appliance prices for consumers. Initially this project exclusively worked with biomass ICSs, but as of 2019, it was expanded to include a pilot with 500 electric cookstoves. The latter experience is now being scaled up.

Another initiative, the Nepal Renewable Energy Programme (NREP), is a joint program between UK Aid Direct and the government of Nepal. Its main goal is to promote private involvement in the renewable energy sector, while (1) leaving no one behind in terms of energy access and (2) working on the commercialization of renewable energies. The program aims to mobilize investment to support private sector development of sustainable systems, deploying viability gap funding—capital provided to make an unprofitable project viable—to projects that offer the greatest outputs with the least amount of additional funding. They work on a variety of technologies, with one focus area as electric cooking, with a number of promising projects being proposed.

These initiatives notwithstanding, the widespread adoption of electric cooking faces many notable challenges:

- **Electricity constraints.** Electric cooking requires reliable access to electricity at affordable prices during peak cooking hours. In the near term, electricity supply is expected to be greater than demand during peak hours. Yet Nepal's electricity generation is primarily dependent on hydropower, such that supply varies considerably over the year, leading to deficits particularly during drier periods. Even if supply were better secured, electricity access in Nepal hovers just below 90%, with lower rates of access in rural areas (The World Bank 2020). This precludes very rural areas from using electric cooking, absent significant expansion of off-grid solar. Additionally, national grid infrastructure needs to be upgraded to improve transmission and distribution lines and substation infrastructure. At the household level, most have a 5 ampere connection, but electric cooking generally requires a 10 ampere connection. Household wiring throughout the country will therefore need to be upgraded.
- **Unattractive design.** Induction stoves are typically available in two configurations: one hob or two hobs. Stakeholders regularly noted that this is inconvenient for Nepalese cuisine, which includes multiple dishes prepared for a single meal, and may be one cause of energy stacking in kitchens. Additionally, induction stoves require flat-bottomed cooking equipment, whereas most homes currently rely on circular bowls and utensils for cooking.
- **Poor appliance supply.** For those households who wish to purchase an electric cookstove or rice cooker, there are limited available options in urban areas. In rural areas, it is challenging even to find induction stoves because retailers do not stock them. Stakeholders recognized that this is a demand issue, but also pointed to the need to import stoves because they are not currently manufactured in Nepal. This raises prices and limits distribution.
- **Low awareness.** Although much was made of the initial uptick in induction stove ownership after the 2015 blockade, awareness of electric cooking remains limited.

Knowledge about the varied benefits of clean cooking remains low, as does knowledge of how to repair or service stoves, as well as knowledge of the full costs of electric cooking. Although households may be able to see the sticker price of the stove, there is a perception and fear among consumers that electricity costs are high.

- **LPG subsidy.** The Government of Nepal currently subsidizes LPG for households as an alternative to dirtier fuels, such as biomass. Thus, most stakeholders consulted for this report noted that for electric cooking to compete, electric cookstoves would also need to be subsidized to be competitive with subsidized LPG. Although almost all stakeholders consulted recommended the removal of LPG subsidies, a few noted that such a change would be politically challenging and would have to be implemented very carefully to minimize damage to households who currently depend on the LPG subsidy.
- **Affordability.** While there was a consensus that electric cookstoves were reasonably affordable for urban households, it was acknowledged that rural households may struggle to afford them, and that the upfront cost of a cookstove (of about 4500 Nepalese rupees [NPR] ($61 USD) for basic models) may limit adoption. Some stakeholders noted that MFIs have been working to provide financing for electric cookstoves, and that they might be able to bundle a loan for appliances and the new utensils required by electric cooking. Finally, ongoing electricity usage costs present a real challenge for adoption, in part because customers are uncertain what the impact of regular electric cooking may be on electricity bills. In August, the ERC announced that customers using less than 20 units of electricity a month would only have to pay a nominal 30 NPR service charge, in part to encourage the electricity use among lower-income households (Shrestha 2021a). Future tariff structures remain under discussion, but the ERC expressed a commitment to decreasing tariffs for low-electricity users as part of an effort to encourage electric cooking.

4.1.3 Transition 2: Traditional Cooking Practices to Improved Cookstoves

While much of the recent attention has been devoted to electric cooking, the reality is that in many regions, especially remote and rural areas, ICS are likely to remain the more immediately relevant technology. Nearly 75% of Nepalis use traditional energy (firewood, dung, and so on) for cooking, which has serious health impacts and entails significant fuel collection burdens (Pun 2018). For consumers in rural areas, lack of electricity access or poor electricity reliability means that a shift to electric cooking is not currently feasible. The government of Nepal has implemented a number of subsidy schemes targeting ICS over the past decade, discussed as follows. While current international partnerships focus on electric cooking, some were initiated as biomass ICS programs. For instance, the GIZ EnDev Improving Access to Modern Energy services in Nepal project initially focused on supporting ICS distributors through its results-based finance (RBF) scheme, targeting 10,000 households with ICS (GIZ 2022).

Despite these efforts, the transition to ICS has been hampered by several challenges:

- **Poor supply.** Private sector ICS distributors are disinclined to extend their market into rural areas because demand is low and costs increase when they work in remote markets. This was the logic behind the GIZ EnDev ICS RBF program, which tried to incentivize distributors to supply rural markets by giving them a direct subsidy per cookstove sold. However, there was the impression that without that subsidy, which was originally scheduled to close out at the end of 2021, suppliers would abandon those markets.

- **Low awareness.** Stakeholders noted that awareness is still low about the health impacts of traditional cooking and the potential benefits of ICS. This burden also impedes a transition to clean cooking.
- **Affordability.** Given that this transition is expected to be more prevalent in rural or remote areas, where poverty levels are higher, stakeholders consulted generally believed that financial assistance would be required (or ICS prices lowered) for consumers to pay for ICS. Some noted that MFIs are already doing this work and that since they are in close, regular contact with communities, they are also key actors in spreading awareness about ICS. Others believed that larger subsidies were going to be required to see large-scale adoption of ICS in rural areas.

4.2 The Government of Nepal's Policies on Subsidies, Taxes, and Duties on Improved and Clean Cooking Solutions

To address affordability thus far, the government of Nepal has introduced federal subsidies for cleaner cooking technologies and a reduced duty on imported electric cooking equipment. The subsidy for domestic biogas ranges from 16,000 to 35,000 NPR depending on the size of the biogas plant and geographic region within Nepal. For domestic renewable energy technologies, including biogas, metallic ICS, and metallic rocket stoves, "the per unit cost price [is] determined for the suppliers every fiscal year depending on demand of district and geographic region. Users … receive subsidy from recognized company on the basis of the determined per unit cost price" and not exceeding the amount mentioned in the Renewable Energy Subsidy Policy of 2016 (Government of Nepal 2016). There are additional policies to support socioeconomic groups requiring further subsidy, including an additional 1,000 NPR per metallic ICS per household for targeted groups, such as women-headed households with dependents, households in areas affected by earthquake, or indigenous groups (Government of Nepal 2016).

In the most recent budget, the government of Nepal announced several new initiatives specific to clean cooking:

- A reduction of customs duties on rice cookers from 15% to 10%
- A reduction in customs duties for induction cookers to 1%
- The abolishment of excise duties on rice cookers and induction stoves, among other electrical appliances, which had previously been 5%
- A 20% discount on cooking gas (among other products deemed necessary) sold by Food Management and Trading Company Limited during the COVID-19 lockdown period (Government of Nepal 2021b, Nepali Times 2021, Prasain 2021).

It is worth noting that, since Nepal adopted its new constitution in 2015, its devolved governance structure means that many aspects of energy policy are now under the jurisdiction of provincial and local governments. The Ministry of Energy focuses on national energy policy and planning, the AEPC provides a national-level subsidy for specific energy technologies, and local governments also have their own additional subsidy schemes. This requires coordination across multiple levels of government.

4.3 Policy Options: Tax and Duty

Two key fiscal policy options for improving the affordability of electric cookstoves are cutting (a) import duties or (b) excise duties. Most stakeholders were broadly supportive of the recent cuts mentioned in section 4.2, although this came through more clearly in government interviews. These stakeholders believed that the decrease in taxes would lower the cost of the stove to distributors who, in turn, would lower prices facing consumers.

However, some civil society organizations, foundations, and development banks felt there were limits to the efficacy of this approach. One stakeholder noted that, despite the expectation that prices would be reduced, this has not happened because complications from COVID-19 have increased manufacturing and transport costs, essentially canceling out the tax decreases. Another argument was that the tax cut is relatively small, and thus will not make a large difference in the price seen by consumers. Finally, since taxes are announced annually, this year's tax cut may not influence supply in the long term, as there has been no indication that this is a longer-term change to duties.

4.4 Policy Options: Subsidy

4.4.1 Subsidizing Electric Cookstoves

Stakeholders did not agree on the use of direct subsidies for electric cookstoves. For electric cooking, the upfront affordability of induction cookstoves was not seen as a major barrier by nearly all stakeholders. This is because the expectation was that wealthier, urban populations would be the primary users of these stoves, since electricity reliability would preclude widespread near-term adoption in rural areas. However, as reliability improves and the government of Nepal pushes for increased use of electric cooking appliances, the price of induction stoves will become an issue for poorer and more rural populations.

Government actors and multilateral development banks were more supportive of subsidies, although they noted that these must be well-targeted. There is a belief, specifically among government stakeholders, that providing a subsidy or rebate for electric cookstoves would encourage additional investment from customers, once they can see its benefits. Additionally, providing a government subsidy can aid and simplify enforcement of product standards and quality assurances, since the government only provides subsidies to specific technologies. Since subsidizing energy technology is now the purview of local governments, and these governments have limited budgets, it becomes more important to target limited subsidies to those customers that truly need it. But finely tuned targeting raises administrative costs. It was also noted that subsidizing induction cookstoves would be most effective if the government also phased out LPG or kerosene-based cooking subsidies.

However, many stakeholders who had been involved in the active implementation of cookstove projects were also disappointed by the lack of targeting. Government subsidies are typically available for a set number of cookstoves—whether it is 100 or 10,000—on a first-come, first-served basis, and program implementers noted that this then constrained the market size for the year. This was because few customers would accept to pay full price for the 101st stove but would rather wait until the subsidy was made available again in the following year. Even government actors noted that, in practice, subsidies are often captured by wealthier households, who have a higher level of awareness of programs and are best able to take advantage when they first appear.

Other stakeholders more focused on private-sector development felt that subsidies disturbed the market in other ways. Multiple stakeholders believed that subsidizing a product reduced feelings of ownership and decreased use. While this perception is generally misplaced, as discussed in the previous section, it is nonetheless common among implementers. There was also the belief that subsidizing stoves directly did not support the growth of the electric cookstove ecosystem—distributors, retailers, and post-sales service providers—and therefore was only sustainable so long as subsidies continued to be available. Furthermore, more than one implementer noted that even delivering the subsidies to the vendor, instead of the consumer, did not lead to lower product prices and did not improve targeting to the rural poor.

In terms of the practicality of implementation, although local governments have the power to enact subsidy programs, the federal government can still play a strong role. The AEPC can still promote subsidies through joint subsidy programs, as shown by the example of a forthcoming call to local governments. In this call, local governments interested in promoting cookstoves are asked to provide 60% of the subsidy with the federal government providing the remaining 40%, but local governments must apply to participate. A similar program exists for Tier-4 ICS, in which 80% of the subsidy is provided by the federal government and 20% by the local government. This requires coordination with local governments, who are also being lobbied by many of the civil society stakeholders to promote different cooking policies, including for the distribution of free electric cookstoves or free utensils with electric cookstoves.

4.4.2 Subsidizing Electricity Use

Additionally, subsidizing electricity use through a range of potential tariff structures could be used to encourage the adoption—and use—of electric cooking. The largest discussion of this topic was with the recently established ERC, who believed that removing or lowering tariffs for low-income consumers would increase electricity use in general and the adoption of electric cooking in particular.

In the past, as electricity supply was insufficient, the tariff structure was not designed to increase consumption. However, this year's new tariff proposal aims specifically to increase household consumption through the following approach (Shrestha 2021b):

- Customers consuming up to 20 units with 5 ampere meters (42% of customers) will have their fee waived and only need to pay a service charge of 30 NPR
- Customers using 150-250 units a month will have their tariff lowered from 10 NPR per unit to 9.50 NPR
- Customers consuming over 400 units per month will have their tariff lowered from 12 NPR to 11 NPR per unit

Program Spotlight: Improving Access to Modern Energy Services in Nepal

Project agency: EnDev Nepal
Lead executing agency: Ministry of Water and Irrigation
Overall term: 2009 to 2021

EnDev's program sought to address the multiple interrelated challenges of electricity and clean cooking access in Nepal, including connecting houses to the national grid, promoting off-grid connections, and supporting the clean cooking sector. In 2015, EnDev partnered with Practical Action and SNV on a results-based finance program that targeted 10,000 households with improved cookstoves. EnDev and partners also recently conducted a 500-household pilot of the program for induction cookstoves.

The program targeted market development by offering a subsidy per cookstove to private sector players, to encourage them to move into new areas, improve marketing and reduce prices. The subsidy started at 75% before dropping to 60%, then 40% in subsequent years. The goal was to exit with 0%, but the subsidy remained at 40% because the private sector was not confident they could sell to rural consumers without incentives. They were further limited by the federal government's subsidy of 50% because they did not want to offer subsidies far below the government subsidy.

As of 2019, 175,000 people were reached by energy-efficient stoves through the program, but there were some challenges to its success (GIZ 2022). While partners found that the private sector became more confident in the product, fewer private sector companies moved into rural areas than anticipated. Although the goal was partly to reduce the end-user price of the stoves, subsidies did not necessarily help reduce the price. The disbursement of the subsidy meant high transaction costs for the private sector, who embedded that price in their product, so prices remained high. Partners found that information about subsidies reached well-educated consumers but not lower-income households. The program's success was also impacted by other local government subsidy programs that sold the stove at a lower price.

One of the stated goals of the household tariff changes is to increase the use of electric cooking. Other stakeholders were broadly supportive of this tariff approach, which some thought had the potential to make electric cooking cost competitive with LPG. Notably, government stakeholders recognized that electric cooking required 60–90 units per month at minimum and felt that the small shift in the tariff rate was currently insufficient to encourage electric cooking.

Of course, the downside of lowering tariffs is reduced revenue for the NEA. The new tariff structure is expected to reduce revenues for the utility by close to one billion NPR. In the past, domestic consumers were cross-subsidized by industrial consumers to support rural electrification. The ERC has indicated that they may use the industrial tariff to cross-subsidize the household tariff going forward, but there is discussion about what the correct approach is to support the NEA while also promoting electricity use. Absent solutions, reduced revenue and financial viability of the utility would jeopardize its ability to provide reliable service.

In addition to reducing NEA revenues, an increase in consumption for cooking is expected to increase peak load during evening hours. Going forward, a number of stakeholders from government and civil society, including the ERC and AEPC, thought that a time-of-use tariff for households might address this issue by either increasing the tariff during peak hours or decreasing the tariff in the early evening to shift some load forward in time. Others believed that the strong cultural component of cooking would make that demand relatively inelastic, and that little behavior change would result.

4.4.3 Subsidizing Household Wiring

Finally, a few stakeholders also mentioned the need for household wiring and how subsidizing household wiring could be a way to better target subsidies to low-income houses. Although around 70% of households in Nepal are wired for 5 amperes, regular use of an induction cookstove requires upgrading to anywhere between 10 to 50 amperes. Currently, individual households would be responsible for upgrading their wiring, which is a barrier to the adoption of electric cooking. One stakeholder was already advocating for local governments to subsidize household wiring as a way of better targeting subsidies while also supporting electric cooking.

4.5 Policy Options: Finance

While fiscal policies can draw on federal and local government budgets, finance may also be available from multilateral development banks or climate funds. However, there was some concern from multilateral development banks that providing loans with concessional terms to government partners, like AEPC, is not translating to customers, since government institutions extend the credit through local banks who add additional charges until the interest rate is comparable with standard commercial terms. Another stakeholder noted that the shift to a federal republic has been expensive, and that the government may have to look to outside financing until the economy improves, which could include additional climate finance.

The government of Nepal is already tapping into climate finance to support the distribution of cookstoves, and there is broad consensus among actors that carbon finance could be further leveraged to support this transition. Nepal was one of the first countries to undertake a CDM project for clean cookstoves, and there are ongoing and potential carbon projects on cooking. AEPC is the lead partner on the $49.2 million Green Climate Fund Project "Mitigating GHG emission through modern, efficient and climate friendly clean cooking solutions (CCS)," which aims to reach 500,000 households (GCF 2021). Meanwhile, the Asian Development Bank and the Climate Investment Fund are already working together to strengthen Nepal's transmission and distribution lines. In terms of future opportunities, the Ministry of Forestry and Environment is looking to potential electric cooking projects for the CDM.

However, a common refrain was that carbon finance does not reach remote villages, who manage small micro-hydro installations for electricity generation or small biogas plants for cooking. This is because accessing carbon finance is time and logistically intensive and so must come through a facilitating agency, either a development partner or an international NGO. However, many stakeholders feel that international NGOs typically work in Nepal like consulting agencies and do not do enough to promote the capacity of local communities or consumers. Some stakeholders wonder how benefits can effectively be transferred to households. Ensuring sustainable use of products is an ongoing challenge for many carbon finance initiatives. It was also noted that the AEPC's CDM funds for biogas, ICS and micro-hydro to replace kerosene have yet to be fully used, in great part because of bureaucratic hurdles. On a practical level, stakeholders noted the need for a clear gold standard methodology for electric cooking, so that carbon finance could go to such projects more easily.

In addition to project-level finance, almost all stakeholders highlighted the role that MFIs had to play in improving affordability. In Nepal, MFI networks are extensive, and one stakeholder noted that 3 million households are borrowing from them. Since MFIs meet monthly with consumers, their platforms could be used to promote electric cooking, integrated with product demonstrations, allowing customers to see and test new products, and linking consumers to reliable service providers for post-sales servicing.

However, awareness of the potential of electric cooking among MFIs remains low and, in general, consumer financing is missing for electric products. MFIs are generally not interested in providing finance for products that cost less than 30,000 NPR, and a bundle of an induction stove with induction-friendly utensils might only be priced at 9,000 NPR. Nevertheless, stakeholders believed that such a bundle would be very popular.

4.6 Key Policy Recommendations

The following are the key policy recommendations for improving the adoption of electric cooking among the stakeholders.

4.6.1 Taxes

(1) **Several taxes on improved cooking products should be reduced**. Lowering tax exposure in the sector would help improve the affordability of stoves. In addition to continuing with reduced import taxes, cooking products could be made VAT-exempt (decreasing the rate from 13% to 0%). One stakeholder suggested an accelerated depreciation rate for importers who wish to import a large number of stoves, to encourage bulk purchases and improve supply, but other incentives might be more appropriate. Import taxes could be abolished completely for electric stoves, although the current 1% tax is set to enable the government of Nepal to track the number of products being imported. Finally, taxes on raw materials for biomass stoves should be reduced. To support the import of stoves, the Nepali government could announce a longer-term budgetary commitment to retaining low taxes on these products, although it retains the prerogative to adjust taxes on an annual basis.

4.6.2 Subsidies

(2a) **Subsidy programs for ICS should be expanded**. One major criticism of current ICS subsidy programs is that they do not target low-income households and are disproportionately captured by wealthier households better able to access program information. Government subsidies are also typically available only for a set number of cookstoves on a first-come, first-served basis, which acts as an artificial cap to the market that favors more informed and higher income consumers. In order to avoid this situation, subsidies should be better funded and should be extended to all eligible customers (see also a related recommendation for better targeting that follows). The AEPC has trialed bulk procurement of cooking technologies, then provided these to target groups with a higher subsidy (90% for ICS, 80% for electric cooking), which is a model that could be expanded.

(2b) **The viability and impacts of reduced electricity tariff rates should be explored for low-usage customers to promote electric cooking.** Reduced tariffs may be supportive of clean cooking, but they may be poorly targeted (to consumers who do not need them or by going to other, less socially beneficial uses of electricity). Tariff reductions for low-usage customers in the latest tariff regime are sufficient for encouraging lighting, but houses regularly cooking with an induction stove or with one than one appliance will quickly overcome the low-usage tariff threshold. Future rate adjustments should focus on raising that threshold or lowering the regular residential tariff rates, if these are found to encourage electric cooking.

(3) **The government of Nepal should leverage lessons from subsidy programs for electric cooking**. Current programs supporting electric cooking—EnDev's program and NREP—focus on subsidizing the private sector to expand into new markets and offer lower prices to consumers, rather than offering an end-user subsidy. The aim is to improve the market for electric cooking, from distribution to after-sales servicing, by supporting private sector development, with the understanding that affordability is not the major constraint for wealthier, urban electric cooking customers. As these programs are expanded, they will offer insights into whether this approach is effective enough to support access goals, and on whether other types of subsidies (e.g., targeted electricity tariff support, demand-side subsidies) are necessary to boost electric cooking.

(4) **Targeting subsidies to customers most in need is urgent.** The goal should be to target subsidies to customers most in need, possibly using categorical approaches such as targeting by education, household size, or the presence of young children. Alternatively, the government could use means testing with household income as the eligibility criterion. LPG subsidies deserve a close and critical look; these subsidies have proven valuable for promoting the shift from traditional cookstoves to LPG but may also undermine the adoption of electric cooking, which is typically unsubsidized. While increases in LPG prices have led to recent protests, there is political support for reducing LPG subsidies. The state-owned Nepal Oil Corporation loses 511.88 NPR per LPG cylinder, which is cross-subsidized by other products, such as petrol and aviation fuel, and MoEWRI sees this as an opportunity to shift support to electric cooking (Samiti 2021, Poudel 2020).

(5) **Subsidizing household wiring would support electric cooking and help target subsidies to lower-income households.** A key challenge in Nepal is that many household electricity connections are currently unsuitable for electric cooking. Subsidizing household wiring could be a way to better target electric cooking subsidies than an end-user subsidy. Currently, individual households are responsible for upgrading their wiring, which is a major barrier to the adoption of electric cooking. Wealthier households are likely to have already improved their wiring to use other appliances; targeting a subsidy for upgrading household wiring would therefore

support adoption without distorting the market.

4.6.3 Financing

(6) Partnering with MFIs to provide financing would help ease households liquidity constraints where standard subsidies are infeasible. Although MFIs typically work with more expensive products, they have the potential to expand the awareness and distribution of a range of cleaner cooking technologies. For electric cooking, MFIs could provide financing for a bundle that includes an induction stove alongside the basic utensils needed to use it, which would be especially popular if the loan term were 12–18 months with 0% equated monthly installment. Both the Foreign, Commonwealth, and Development Office–funded Nepal Renewable Energy Program and NGO Practical Action are partnering with MFIs to encourage them to create new loan products. Supporting this effort could unlock key consumer finance.

4.6.4 Other Efforts to Support Electric Cooking

The government of Nepal has indicated its strong support for electric cooking, both to improve domestic energy security and to use its anticipated new electricity supply. Supporting electric cooking will require additional environmental support beyond fiscal policies.

(7a) Nepal critically needs investment in the transmission and distribution of electricity. Electric cooking requires reliable access to electricity at affordable prices during peak cooking hours. In the near term, electricity supply is expected to be greater than demand during peak hours, but electricity access is still low in rural areas and reliability is expected to be a challenge as demand increases. This precludes very rural areas from using electric cooking, absent significant expansion of off-grid solar or micro-hydro. National grid infrastructure needs to be upgraded to improve transmission and distribution lines and substation infrastructure.

(7b) Many beneficiaries are not fully cognizant of the costs of traditional cooking. Knowledge about the varied benefits of clean cooking remains low, as does knowledge of how to repair or service stoves and of the full costs of different cooking alternatives. Local governments and community organizations are best placed to conduct awareness-raising campaigns around electric cooking.

(7c) Coordinated promotion of electric cooking appliances and T&D investment is essential. Electric cooking can only be used where electricity supply and distribution is reliable. Currently, the AEPC expects penetration of electric cooking to remain below 25%, but as that number increases, so will the need for coordination. Federal and local government agencies must coordinate awareness-raising campaigns in specific regions only after infrastructure improvements have been made.

(7d) Training (especially for women) in after-sales service is vital. There is little after-sales service available for electric cooking and there must be additional support for training. There is an opportunity to incorporate women into the supply chain, as they are the primary users of induction cookstoves. Some civil society organizations have begun to arrange such training, but wider training and support will be required.

(7e) **Investing in local research and development and manufacturing to address both supply and affordability issues.** For households who wish to purchase an electric cookstove or rice cooker, there are limited options available in urban areas and even fewer in rural areas, where retailers are unlikely to stock them. Stakeholders pointed out that importing stoves increased their price and limited their availability. While the government of Nepal has not supplied direct financial investment to private partners to date, the AEPC is supportive of providing financial support for infrastructure and linking private sector partners to finance. Investments in research and development and manufacturing within Nepal could address both supply and affordability issues.

(7f) **A time-of-use tariff could be trialed as a solution to shift evening load and better manage demand.** If electric cooking does increase, this will cause peak loads to increase during evening hours. A time-of-use tariff for households might address this issue by increasing the tariff during peak hours or decreasing the tariff in the early evening to shift some load to earlier in the day.

5 SUMMARY AND CONCLUSIONS

5.1 Review

As of 2019, 2.6 billion people, or nearly one-third of the global population still relied on dangerous or polluting energy technologies and fuels for cooking. Despite clear evidence of the varied and severe negative impacts of such technologies, progress in achieving adoption and use of improved alternatives—particularly among the poor rural households who arguably need them most—remains remarkably slow in many parts of the world. The socially beneficial cooking transition is too often impeded by a set of affordability, technology, supply chain, and policy barriers that render persistent and durable adoption of improved solutions challenging for much of the globe.

Despite this, many governments intervene in markets for fuels and cooking technologies by implementing subsidies and taxes that are not always supportive of economic development. For example, in response to the fiscal challenges of the COVID019 pandemic, Kenya reimposed a VAT on clean cooking technologies, which will slow progress and impose steep costs on society. On the other hand, some countries (e.g., Indonesia, India, and Ecuador) have instituted generous and targeted subsidies for clean cooking solutions and seen accelerated progress in adoption of these technologies. These exemptions and subsidies highlight the contradiction between economic efficiency and fiscal objectives: on the one hand, exemptions and subsidies are efficiency-improving and socially beneficial because they spur adoption of clean technology and thereby reduce negative pollution externalities; on the other hand, they increase the strain on already limited public budgets.

This report—which is complemented by a separate analysis specific to the VAT reform in Kenya (Jeuland et al 2021)—presented:

- A summary of salient considerations from tax theory, as they relate to goods such as cleaner cooking technologies and fuels.

- A comprehensive review of real-world experiences on the effects of pricing instruments on the demand for cooking technologies, the course of cooking transitions, and the impacts of such transitions.
- A case study aimed at identifying potential solutions and pricing policies for Nepal, informed by a review of relevant policy documents and a set of consultations with key stakeholders in Nepal.

We began with an accessible primer that reviewed the principles behind socially efficient taxes and subsidies and related them to examples in the real world. We explained that the imposition of taxes and subsidies on clean cooking technologies and fuels will mediate prices according to the relative elasticities of supply and demand and noted the implications that these changes have for efficiency and for the distribution of costs (or benefits) to different parties of taxes (or subsidies). In discussing this theory, we noted the strong economic (efficiency) rationale for subsidies of clean cooking technology, given its positive externalities.

In section 3, we then discussed relevant empirical evidence on the demand for ICSs and fuels, as well as results from various large-scale and research studies focused on the effects of prices, taxes, and subsidies in the sector. We showed, based on evidence from prior research, that the demand for household energy sources overall tends to be inelastic because households need energy to meet their needs. Yet, the demand for cleaner alternatives is typically highly price elastic because households have ready substitutes in nonclean options such as firewood, charcoal, and kerosene. The empirical section also includes a discussion of distributional and affordability considerations that complemented the theoretical points first presented in section 2. Finally, we discussed complementarities between pricing and other policies, and the fact that price instruments alone will typically be insufficient to achieve clean cooking goals.

Section 4 then presented a case study from Nepal. Drawing on policy documents and a set of consultations with stakeholders in Nepal—policy makers within the government, key parties involved in the supply chain for various fuels, and representatives from academia and civil society—we identified and commented on existing and potential pricing policies for that context. A notable aspect of this case is the need to carefully reconsider (or at least better target) the existing LPG subsidy, if a transition towards renewable electricity-based induction and appliance-facilitated cooking is to be appropriately supported. In addition, subsidies supporting improved biomass options remain necessary to meet the needs of the rural poor.

5.2 General Recommendations

We close with a set of general recommendations that emerge from this study (a concise summary along with Nepal-case recommendations appears in Table 1). Given the theoretical explanation and empirical evidence on taxes and subsidies on clean cooking, we recommend:

(1) **Wherever access to modern cooking energy services remains well short of universal, remove taxes and other levies on all clean and improved cooking solutions.** These taxes generally produce limited revenue, while greatly impeding progress toward achieving SDG 7 and capturing its many social benefits.

(2) **Much more aggressive subsidization of clean cooking solutions across LMIC contexts to achieve greater adoption of these socially beneficial solutions and enhance economic efficiency and affordability.** Cost-benefit analysis shows that large and generous subsidies consistently increase social net benefits relative to market provision, even accounting for leakage.

(3) **Given that resources for subsidization are scarce, better target low-income households who are most price-sensitive and most likely to heavily rely on traditional technology.** In some cases, such targeting can be geographic, or via means testing and systems such as the Aadhar system in India.

(4) **More holistic consideration of the technologies and fuels that should benefit from subsidization, based on local constraints and realities.** LPG subsidies are most common in the sector, but tend to disproportionately benefit high-income, urban households. Among clean fuels, progress on electrification makes electric cooking increasingly viable, especially when supported by renewable energy, and where reliability has been prioritized. This highlights the urgency of improving the progressivity of electricity tariffs. Finally, many energy poor households, especially in rural and remote areas, need cheaper efficient biomass solutions that are well-adapted to their cooking needs.

(5) **Where subsidies prove overly challenging for budgetary or political reasons, employ financing support to ease liquidity constraints.** Such policies are relatively low in cost and can largely be implemented by MFIs and the private sector but need to be regulated to ensure loan terms are reasonable for the poor. Financing can also support durable goods and appliance acquisition (such as electric cooking technology).

(6a) **Supplement subsidies with related complementary interventions, such as investing in improved distribution infrastructure (for LPG and electricity), incorporating market development and direct delivery to users, empowering women both as suppliers and as primary consumers of technology, and awareness-raising or education campaigns.**

(6b) **Draw on experiences from related sectors (e.g., electricity, health-improving goods, sanitation, water treatment) where service coverage for the poor has been expanded with more success than for cooking energy access.** Subsidies for such goods have been shown to generally be efficiency-improving, particularly in the long-term where learning and positive spillovers are important. Some of the most relevant strategies for boosting adoption of clean cooking services by the poor are guaranteed access (e.g., distributing locally accepted ICS free of charge), reducing the cost of clean fuel with generous and well-targeted discounts, and use of demand-revealing "ordeal" mechanisms to allocate benefits, rather than payment in cash.

REFERENCES

Acharya, M., S. Phuyal and S. Dhakal. 2015. "Nepal Blockade: Six Ways it Affects the Country." *BBC*. https://www.bbc.com/news/world-asia-35041366.

Andadari, R. K., P. Mulder, and P. Rietveld. 2014. "Energy Poverty Reduction by Fuel Switching. Impact Evaluation of the LPG Conversion Program in Indonesia." *Energy Policy* 66:436–49. doi:10.1016/j.enpol.2013.11.021.

Anenberg, S. C., K. Balakrishnan, J. Jetter, O. Masera, S. Mehta, J. Moss, and V. Ramanathan. 2013. "Cleaner Cooking Solutions to Achieve Health, Climate, and Economic Cobenefits." *Environmental Science & Technology* 47 (9):3944–52. doi:10.1021/es304942e.

Ashraf, N., B. K. Jack, and E. Kamenica. 2013. "Information and Subsidies: Complements or Substitutes?" *Journal of Economic Behavior & Organization* 88:133–9. doi:10.1016/j.jebo.2012.12.031.

Bailis, R., R. Drigo, A. Ghilardi, and O. Masera. 2014. "The Carbon Footprint of Traditional Woodfuels." *Nature Climate Change* 5: 266–72. doi:10.1038/nclimate2491.

Barnes, D. F., K. Openshaw, K. R. Smith, and R. Van der Plas. 1994. "What Makes People Cook with Improved Biomass Stoves?" World Bank Technical Paper 242. Washington, D.C.: The World Bank.

Bazilian, M., A. Sagar, R. Detchon, and K. Yumkella. 2010. "More Heat and Light." *Energy Policy* 38(10):5409–12. doi:10.1016/j.enpol.2010.06.007

Beltramo, T., G. Blalock, D. I. Levine, and A. M. Simons. 2015. "The Effect of Marketing Messages and Payment Over Time on Willingness to Pay for Fuel-Efficient Cookstoves." *Journal of Economic Behavior & Organization* 118:333–45. doi:10.1016/j.jebo.2015.04.025.

Bensch, G., M. Grimm, and J. Peters. 2015. "Why do Households Forego High Returns from Technology Adoption? Evidence from Improved Cooking Stoves in Burkina Faso." *Journal of Economic Behavior & Organization* 116:187–205. doi:10.1016/j.jebo.2015.04.023.

Bensch, G., M. Jeuland, and J. Peters. 2021. "Efficient Biomass Cooking in Africa for Climate Change Mitigation and Development." *One Earth* 4(6):879–90. doi:10.1016/j.oneear.2021.05.015.

Bensch, G., and J. Peters. 2016. "Enablers of Strong Cookstove Sales Through a Purchase Offer Approach in Rural Senegal: An Explorative Analysis." Ruhr Economic Papers 650. Bochum, Germany: RWI Leibniz-Institut für Wirtschaftsforschung, Ruhr-University Bochum, TU Dortmund University, University of Duisburg-Essen.

Bensch, G., and J. Peters. 2020. "One-Off Subsidies and Long-Run Adoption—Experimental Evidence on Improved Cooking Stoves in Senegal." *American Journal of Agricultural Economics* 102 (1):72–90. doi:10.1093/ajae/aaz023.

BenYishay, A., and A. M. Mobarak. 2019. "Social Learning and Incentives for Experimentation and Communication." *The Review of Economic Studies* 86(3):976–1009. doi:10.1093/restud/rdy039.

Berkouwer, S. B., and J. T. Dean. 2019. "Credit and Attention in the Adoption of Profitable Energy Efficient Technologies in Kenya." E-47415-KEN-2. London: International Growth Centre. https://escholarship.org/uc/item/8g698115.

Bhattacharya, D., P. Dupas, and S. Kanaya. 2013. Estimating the Impact of Means-Tested Subsidies under Treatment Externalities with Application to Anti-Malarial Bednets.

National Bureau of Economic Research Working Paper 18833. Cambridge, MA: National Bureau of Economic Research. doi:10.3386/w18833.

Blum, A. G., C. Null, and V. Hoffmann. 2014. "Marketing Household Water Treatment: Willingness to Pay Results From an Experiment in Rural Kenya." *Water* 6(7):1873–86. doi:10.3390/w6071873.

Bonan, J., S. Pareglio, and M. Tavoni. 2017. "Access to Modern Energy: A Review of Barriers, Drivers and Impacts." *Environment and Development Economics* 22(5):491–516. doi:10.1017/S1355770X17000201.

Brown, J. K., T. V. Zelenska, and M. A. Mobarak. 2013. Barriers to Adoption of Products and Technologies that Aid Risk Management in Developing Countries. *World Development Report Background Papers*. Washington, DC: World Bank. http://hdl.handle.net/10986/16365.

Brown, Z. S., and R. A. Kramer. 2018. "Preference Heterogeneity in the Structural Estimation of Efficient Pigovian Incentives for Insecticide Spraying to Reduce Malaria." *Environmental and Resource Economics* 70(1):169–90. doi:10.1007/s10640-017-0115-x.

Bruce, N., R. Perez-Padilla, and R. Albalak. 2000. "Indoor Air Pollution in Developing Countries: A Major Environmental and Public Health Challenge." *Bulletin of the World Health Organization* 78(9):1078–92. PMID:11019457.

Budya, H., and M. Y. Arofat. 2011. "Providing Cleaner Energy Access in Indonesia Through the Megaproject of Kerosene Conversion to LPG." *Energy Policy* 39(12):7575–86. doi:10.1016/j.enpol.2011.02.061.

Cameron, L., S. Olivia, and M. Shah. 2019. "Scaling up Sanitation: Evidence From an Rct in Indonesia." *Journal of Development Economics* 138:1–16. doi:10.1016/j.jdeveco.2018.12.001.

Chirgwin, H., S. Cairncross, D. Zehra, and H. Sharma Waddington. 2021. "Interventions Promoting Uptake of Water, Sanitation and Hygiene (WASH) Technologies In Low- and Middle- Income Countries: An Evidence and Gap Map of Effectiveness Studies." *Campbell Systematic Reviews* 17(4):e1194. doi:10.1002/cl2.1194.

Clemens, H., R. Bailis, A. Nyambane, and V. Ndung'u. 2018. "Africa Biogas Partnership Program: A Review of Clean Cooking Implementation Through Market Development in East Africa." *Energy for Sustainable Development* 46:23–31. doi:10.1016/j.esd.2018.05.012.

Cohen, J., P. Dupas, and S. Schaner. 2015. "Price Subsidies, Diagnostic Tests, and Targeting of Malaria Treatment: Evidence From a Randomized Controlled Trial." *American Economic Review* 105(2):609–45. doi:10.1257/aer.20130267.

Cook, J., M. Jeuland, B. Maskery, D. Lauria, D. Sur, J. Clemens, and D. Whittington. 2009. "Using Private Demand Studies to Calculate Socially Optimal Vaccine Subsidies in Developing Countries." *Journal of Policy Analysis and Management* 28 (1):6–28. doi:10.1002/pam.20401.

Deutschmann, J. W. 2021. Subsidies and the sustainability of technology adoption: Evidence from the sanitation services market in Dakar. Working Paper. https://jwdeutschmann.com/Papers/Deutschmann_Subsidies_20211130.pdf

Dherani, M., D. Pope, M. Mascarenhas, K. R. Smith, M. Weber, and N. Bruce. 2008. "Indoor Air Pollution From Unprocessed Solid Fuel Use and Pneumonia Risk in Children Aged Under Five Years: A Systematic Review and Meta-Analysis." *Bulletin of the World Health Organization* 86(5):390–8. doi:10.2471/blt.07.044529.

Dickinson, K., and S. K. Pattanayak. 2009. "Open Sky Latrines: Social Reinforcing in the Case of a (Very) Impure Public Good." *Duke University*. https://www.researchgate.net/publication/242175759_Open_sky_latrines_Social_reinforcing_in_the_case_of_a_very_impure_public_good

Dizon-Ross, R., P. Dupas, and J. Robinson. 2017. "Governance and the effectiveness of public health subsidies: Evidence from Ghana, Kenya and Uganda." *Journal of Public Economics* 156:150–69. doi:10.1016/j.jpubeco.2017.09.005.

Dupas, P. 2011. "Health behavior in Developing Countries." *Annual Review of Economics* 3(1):425–49. doi:10.1146/annurev-economics-111809-125029.

Dupas, P. 2014. "Short-Run Subsidies and Long-Run Adoption of New Health Products: Evidence From a Field Experiment." *Econometrica* 82 (1):197–228. doi:10.3982/ECTA9508.

Dupas, P., V. Hoffmann, M. Kremer, and A. Peterson Zwane. 2016. "Targeting Health Subsidies Through a Nonprice Mechanism: A Randomized Controlled Trial in Kenya." *Science* 353(6302):889–95. doi:10.1126/science.aaf68.

Erdogdu, E. 2011. "The Impact of Power Market Reforms on Electricity Price-Cost Margins and Cross-Subsidy Levels: A Cross Country Panel Data Analysis." *Energy Policy* 39(3):1080–92. doi:10.1016/j.enpol.2010.11.023.

Ezzati, M., and D. M. Kammen. 2002. "Household Energy, Indoor Air Pollution, and Health in Developing Countries: Knowledge Base for Effective Interventions." *Annual Review of Energy and the Environment* 27(1):233–70. doi:10.1146/annurev.energy.27.122001.083440.

Figari, A., and X. Gomez. 2015. *Promoting Induction Cooking in Ecuador*. International Partnership on Mitigation and MRV. https://api.knack.com/v1/applications/5b23f04fd240aa37e01fa362/download/asset/5c9392a9fc8c902edf363b17/20142013inductioncooking_ecuador.pdf.

Fischer, G., D. Karlan, M. McConnell, and P. Raffler. 2019. "Short-Term Subsidies and Seller Type: A Health Products Experiment in Uganda." *Journal of Development Economics* 137:110–24. doi:10.1016/j.jdeveco.2018.07.013.

Fullerton, D., and G. E Metcalf. 2002. "Tax Incidence." In *Handbook of Public Economics*, vol. 4, edited by A. J. Auerbach and M. Feldstein, 1787–872. Amsterdam: Elsevier.

Gakii Gatua, J., M. Ikiara, J. Kabubo-Mariara, M. Mwaura, and D. Whittington. 2016. "Water and Sanitation Service Delivery, Pricing, and the Poor: An Empirical Estimate of Subsidy Incidence in Nairobi, Kenya." *Water Resources Research*, 52(6): 4845–62. doi: 10.1002/2015WR018375.

Garn, J. V., G. D. Sclar, M. C. Freeman, G. Penakalapati, K. T. Alexander, P. Brooks, E. A. Rehfuess, S. Boisson, K. O. Medlicott, and T. F. Clasen. 2017. "The Impact of Sanitation Interventions on Latrine Coverage and Latrine Use: A Systematic Review and Meta-Analysis." *International Journal of Hygiene and Environmental Health* 220(2):329–40. doi:10.1016/j.ijheh.2016.10.001.

GCF. 2021. FP172: Mitigating GHG Emission through Modern, Efficient and Climate-Friendly Clean Cooking Solutions (CCS). Incheon, Korea: Green Climate Fund. https://www.greenclimate.fund/project/fp172.

Gill-Wiehl, A., T. Brown, and K. R. Smith. 2020. "LPG for Free? A Difference-in-Differences approach to analyze effect on adoption of India's PMUY LPG program." Preprint. Berkeley, CA: University of California, Berkeley. doi: https://doi.org/10.21203/rs.3.rs-58247/v1.

GIZ. 2022. Improving Access to Modern Energy Services in Nepal. Bonn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH. https://www.giz.de/en/worldwide/17859.html.

Government of Nepal. 2016. Renewable Energy Subsidy Policy, 2073 BS. Kathmandu: Government of Nepal. https://www.aepc.gov.np/uploads/docs/2018-06-19_RE%20Subsidy%20Policy,%202073%20(English).pdf

Government of Nepal. 2017. Biomass Energy Strategy 2017. Kathmandu: Government of Nepal, Ministry of Population and Environment. https://www.aepc.gov.np/uploads/docs/2018-07-29_Biomass%20Energy%20Strategy%202073%20BS%20(2017)%20English.pdf.

Government of Nepal. 2018. Nepal National REDD+ Strategy. Kathmandu: Government of Nepal. https://www.forestcarbonpartnership.org/system/files/documents/Nepal%20National%20REDD%2B%20Strategy.pdf

Government of Nepal. 2020a. National Climate Policy 2019. Kathmandu: Government of Nepal. https://leap.unep.org/countries/np/national-legislation/national-climate-change-policy-2076-2019

Government of Nepal. 2020b. Second Nationally Determined Contribution (NDC). Kathmandu, Nepal: Government of Nepal. https://unfccc.int/sites/default/files/NDC/2022-06/Second%20Nationally%20Determined%20Contribution%20%28NDC%29%20-%202020.pdf.

Government of Nepal. 2021a. Assessment of Electric Cooking Targets for Nepal's 2020 Nationally Determined Contributions (NDC). Kathmandu: Government of Nepal. https://www.mofe.gov.np/uploads/documents/e-cooking-assmntndc-20201623998059pdf-3367-307-1658827919.pdf.Government of Nepal. 2021b. Public Announcement of Income-Expenditure Details of Fiscal Year 2021/22. Kathmandu: Government of Nepal.

Gould, C. F., S. Schlesinger, A. Ochoa Toasa, M. Thurber, W. F. Waters, J. P. Graham, and D. W. Jack. 2018. "Government Policy, Clean Fuel Access, and Persistent Fuel Stacking in Ecuador." *Energy for Sustainable Development* 46:111–22. doi:10.1016/j.esd.2018.05.009.

Gould, C. F., S. B. Schlesinger, E. Molina, M. L. Bejarano, A. Valarezo, and D. W. Jack. 2020. "Long-Standing LPG Subsidies, Cooking Fuel Stacking, and Personal Exposure to Air Pollution in Rural and Peri-Urban Ecuador." *Journal of Exposure Science & Environmental Epidemiology* 30(4):707–20. doi:10.1038/s41370-020-0231-5.

Greve, H., and J. Lay. 2022. "Stepping Down the Ladder: The Unintended Impacts of Fossil Fuel Subsidy Removal in a Developing Country." *Journal of the Association of Environmental and Resource Economics* (forthcoming). https://www.journals.uchicago.edu/doi/pdf/10.1086/721375..

Guiteras, R., J. Levinsohn, and A. Mushfiq Mobarak. 2015. "Encouraging Sanitation Investment in the Developing World: A Cluster-Randomized Trial." *Science* 348(6237):903–6. doi:10.1126/science.aaa0491.

Gundimeda, H., and G. Köhlin. 2008. "Fuel Demand Elasticities for Energy and Environmental Policies: Indian Sample Survey Evidence." *Energy Economics* 30(2):517–46. doi:10.1016/j.eneco.2006.10.014.

Gupta, G., and G. Köhlin. 2006. "Preferences for Domestic Fuel: Analysis With Socio-Economic Factors and Rankings in Kolkata, India." *Ecological Economics* 57(1):107–21. doi:10.1016/j.ecolecon.2005.03.010.

IEA, IRENA, UNSD, World Bank, and WHO. 2021. *Tracking SDG 7: The Energy Progress Report 2021*. Washington, DC: The World Bank. https://www.irena.org/publications/2021/Jun/Tracking-SDG-7-2021.

Imelda, I. (2020). "Cooking that Kills: Cleaner Energy Access, Indoor Air Pollution and Health." *Journal of Development Economics* 147: 102548. https://doi.org/10.1016/j.jdeveco.2020.102548.

IMF. 2013. *Energy Subsidy Reform: Lessons and Implications*. Washington, D.C.: International Monetary Fund. https://www.imf.org/en/Publications/Policy-Papers/Issues/2016/12/31/Energy-Subsidy-Reform-Lessons-and-Implications-PP4741.

Irfan, M., M. P. Cameron, and G. Hassan. 2018. "Household energy elasticities and policy implications for Pakistan." *Energy Policy* 113:633–42. doi:10.1016/j.enpol.2017.11.041.

Jain, V. 2006. "Political Economy of the Electricity Subsidy: Evidence from Punjab." *Economic and Political Weekly*, 4072–80. https://www.jstor.org/stable/4418730.

Jeuland, M., I. Das, V. Plutshack, M. Barasa, D. Wanjohi, T. Shikorire, J. Muchiri, M. Maina, and R. Gichuhi. 2021. *Value-Added Tax on Cleaner Cooking Solutions in Kenya*. Report to the Clean Cooking Alliance. Durham, NC: Duke University. https://energyaccess.duke.edu/publication/analysis-of-the-implications-of-the-value-added-tax-on-clean-cooking-in-kenya/,

Jeuland, A. A., and S. K. Pattanayak. 2012. "Benefits and Costs of Improved Cookstoves: Assessing the Implications of Variability in Health, Forest and Climate Impacts." *PloS One* 7(2):e30338. doi:10.1371/journal.pone.0030338.

Jeuland, M., J.-S. Tan Soo, and D. Shindell. 2018. "The Need for Policies to Reduce the Costs of Cleaner Cooking in Low Income Settings: Implications From Systematic Analysis of Costs and Benefits." *Energy Policy* 121:275–85. doi:10.1016/j.enpol.2018.06.031.

Joffe, S., and S. Jones. 2003. *Stimulating Private Investment and Market Development for Agriculture: New Approaches and Experience*. Oxford,UK: Oxford Policy Management.

Kar, A., S. Pachauri, R. Bailis, and H. Zerriffi. 2020. "Capital Cost Subsidies Through India's Ujjwala Cooking Gas Programme Promote Rapid Adoption of Liquefied Petroleum Gas but not Regular Use." *Nature Energy* 5 (2):125–6. doi:10.1038/s41560-019-0536-6.

Karanja, A., and A. Gasparatos. 2019. "Adoption and Impacts of Clean Bioenergy Cookstoves in Kenya." *Renewable and Sustainable Energy Reviews* 102 (2019): 285–306. doi:10.1016/j.rser.2018.12.006.

Kebede, B., A. Bekele, and E. Kedir. 2002. "Can the Urban Poor Afford Modern Energy? The Case of Ethiopia." *Energy Policy* 30(11–12):1029–45. doi:10.1016/S0301-4215(02)00056-3.

Khandelwal, M., M. E. Hill Jr., P. Greenough, J. Anthony, M. Quill, M. Linderman, and H. S. Udaykumar. 2017. "Why Have Improved Cook-Stove Initiatives in India Failed?" *World Development* 92:13–27. doi:10.1016/j.worlddev.2016.11.006.

Khatib, R. A., G. F. Killeen, S. M. K. Abdulla, E. Kahigwa, P. D. McElroy, R. P. M. Gerrets, H. Mshinda, A. Mwita, and S. P. Kachur. 2008. "Markets, Voucher Subsidies and Free Nets Combine to Achieve High Bed Net Coverage in Rural Tanzania." *Malaria Journal* 7(1):1–9. doi:10.1186/1475-2875-7-98.

Kremer, M., and E. Miguel. 2007. "The Illusion of Sustainability." *The Quarterly Journal of Economics* 122(3):1007–65. doi:10.1162/qjec.122.3.1007.

Kresch, E. P., M. Lipscomb, and L. Schechter. 2020. "Externalities and Spillovers from Sanitation and Waste Management in Urban and Rural Neighborhoods." *Applied Economic Perspectives and Policy* 42(3):395–420. doi:10.1093/aepp/ppz024.

Krishnapriya, P. P. 2016. "Effects of Information on Energy Related Choices." Working Paper. https://www.isid.ac.in/~epu/acegd2016/papers/PPKrishnapriya.pdf

Krishnapriya, P. P., M. Jeuland, J. Orgill-Meyer, and S. K. Pattanayak. 2021. "Gendered Demand for Environmental Health: Evidence of Complementarities from Stove Auctions in India." *Working Paper*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4216609.

Kuehl, J., M. Maulidia, K. Bajaj, and S. Boelts. 2021. *LPG Subsidy Reform in Indonesia: Lessons Learned from International Experience*. Winnipeg, Manitoba: International Institute for Sustainable Development. https://www.iisd.org/system/files/2021-05/lpg-subsidy-reform-indonesia.pdf.

Lambe, F., M. Jürisoo, H. Wanjiru, and J. Senyagwa. 2015. Bringing Clean, Safe, Affordable Cooking Energy to Households across Africa: An Agenda for Action. New Climate Economy working paper, based on a background paper to the Africa Progress Panel 2015 report *Power, People, Planet: Seizing Africa's Energy and Climate Opportunities*. Stockholm: Stockholm Environment Institute. http://www.sei-international.org/publications?pid=2841.

Leach, G. 1992. "The Energy Transition." *Energy Policy* 20(2):116–23. doi:10.1016/0301-4215(92)90105-B.

Levine, D. I., T. Beltramo, G. Blalock, C. Cotterman, and A. M. Simons. 2018. "What Impedes Efficient Adoption of Products? Evidence From Randomized Sales Offers for Fuel-Efficient Cookstoves in Uganda." *Journal of the European Economic Association* 16(6):1850–80. doi:10.1093/jeea/jvx051.

Lewis, J. J., and S. K. Pattanayak. 2012. "Who Adopts Improved Fuels and Cookstoves? A Systematic Review." *Environmental Health Perspectives* 120(5):637–45. doi:10.1289/ehp.1104194.

Lipscomb, M., and L. Schechter. 2018. "Subsidies Versus Mental Accounting Nudges: Harnessing Mobile Payment Systems to Improve Sanitation." *Journal of Development Economics* 135:235–54. doi:10.1016/j.jdeveco.2018.07.007.

Lucas, M. E. S., M. Jeuland, J. Deen, N. Lazaro, M. MacMahon, A. Nyamete, A. Barreto, L. von Seidlein, A. Cumbane, and F. F. Songane. 2007. "Private Demand for Cholera Vaccines in Beira, Mozambique." *Vaccine* 25(14):2599–609. doi:10.1016/j.vaccine.2006.12.027.

Martínez, J., J. Martí-Herrero, S. Villacís, A. J. Riofrio, and D. Vaca. 2017. "Analysis Of Energy, CO_2 Emissions and Economy of the Technological Migration for Clean Cooking in Ecuador." *Energy Policy* 107:182–7. doi:10.1016/j.enpol.2017.04.033.

Masera, O. R., B. D. Saatkamp, and D. M. Kammen. 2000. "From Linear Fuel Switching To Multiple Cooking Strategies: A Critique and Alternative to The Energy Ladder Model." *World Development* 28(12):2083–103. doi:10.1016/S0305-750X(00)00076-0.

McCarron, A., I. Uny, L. Caes, S. E. Lucas, S. Semple, J. Ardrey, and H. Price. 2020. "Solid Fuel Users' Perceptions of Household Solid Fuel Use in Low- and Middle-Income Countries: A Scoping Review." *Environment International* 143:105991. doi:10.1016/j.envint.2020.105991.

Mittal, N., A. Mukherjee, and A. Gelb. 2017. *Fuel Subsidy Reform in Developing Countries: Direct Benefit Transfer of LPG Cooking Gas Subsidy in India*. Washington, D.C.: Center for Global Development. https://www.cgdev.org/publication/fuel-subsidy-reform-developing-countries-india.

Mobarak, A. Mushfiq, P. Dwivedi, R. Bailis, L. Hildemann, and G. Miller. 2012. "Low Demand for Nontraditional Cookstove Technologies." *Proceedings of the National Academy of Sciences* 109(27):10815–20. doi:10.1073/pnas.1115571109.

Nepali Times. 2021. "New Nepal Budget Sparks Electric Comeback" *Nepali Times* May 30, 2021. https://www.nepalitimes.com/latest/new-nepal-budget-sparks-electric-comeback/.

Neufeldt, H., J. Fuller, and K. Langford. 2015. *From Transition Fuel to Viable Energy Source: Improving Sustainability in the Sub-Saharan Charcoal Sector*. Nairobi: World Agroforestry Centre. http://apps.worldagroforestry.org/downloads/Publications/PDFS/WP15011.pdf

Null, C., M. Kremer, E. Miguel, J. Garcia Hombrados, R. Meeks, and A. Peterson Zwane. 2012. *Willingness to Pay for Cleaner Water in Less Developed Countries: Systematic Review of Experimental Evidence*. 3ie Systematic Review 06. Delhi: The International Initiative for Impact Evaluation (3iE). https://3ieimpact.org/sites/default/files/2017-11/sr006.pdf.

Orgill-Meyer, J., S. K. Pattanayak, N. Chindarkar, K. L. Dickinson, U. Panda, S. Rai, B. Sahoo, A. Singha, and M. Jeuland. 2019. "Long-Term Impact of a Community-Led Sanitation Campaign in India, 2005–2016." *Bulletin of the World Health Organization* 97(8):523. doi:10.2471/BLT.18.221572.

Pattanayak, S. K., M. Jeuland, J. J. Lewis, F. Usmani, N. Brooks, V. Bhojvaid, A. Kar, L. Lipinski, L. Morrison, and O. Patange. 2019. "Experimental Evidence on Promotion of Electric and Improved Biomass Cookstoves." *Proceedings of the National Academy of Sciences* 116 (27):13282–7. doi:10.1073/pnas.1808827116.

Pattanayak, S. K., J.-C. Yang, K. L. Dickinson, C. Poulos, S. R. Patil, R. K. Mallick, J. L. Blitstein, and P. Praharaj. 2009. "Shame or Subsidy Revisited: Social Mobilization for Sanitation in Orissa, India." *Bulletin of the World Health Organization* 87:580–7. doi:10.2471/BLT.08.057422.

Pollard, S. L., K. N. Williams, C. J. O'Brien, A. Winiker, E. Puzzolo, J. L. Kephart, M. Fandiño-Del-Rio, C. Tarazona-Meza, M. R. Grigsby, and M. Chiang. 2018. "An Evaluation of The Fondo de Inclusión Social Energético Program to Promote Access to Liquefied Petroleum Gas in Peru." *Energy for Sustainable Development* 46:82–93. doi:10.1016/j.esd.2018.06.001.

Poudel, U. 2020. Govt Preparing to Remove LPG Subsidies. *The Himalayan Times*. https://thehimalayantimes.com/business/govt-preparing-to-remove-lpg-subsidies.

Prasain, K. 2021. " Duty cuts expected to boost sales of home appliances." *The Kathmandu Post*, June 4, 2021. https://tkpo.st/3pt9XYl.

Pun, B. 2018. *Present Situation and Future Roadmap of Energy, Water Resources and Irrigation Sector*. Kathmandu, Nepal: Government of Nepal, Energy, Water Resources and Irrigation Ministry. https://cip.nea.org.np/wp-content/uploads/2020/09/KMS-6-white-paper-on-energy-water-resources-and-irrigation-sector.pdf.

Puzzolo, E., H. Zerriffi, E. Carter, H. Clemens, H. Stokes, P. Jagger, J. Rosenthal, and H. Petach. 2019. "Supply Considerations for Scaling up Clean Cooking Fuels for Household Energy in Low- and Middle- Income Countries." *GeoHealth* 3(12):370–90. doi:10.1029/2019GH000208.

Puzzolo, E., D. Pope, D. Stanistreet, E. A. Rehfuess, and N. G. Bruce. 2016. "Clean Fuels for Resource-Poor Settings: A Systematic Review of Barriers and Enablers to

Adoption and Sustained Use." *Environmental Research* 146:218–34. doi:10.1016/j.envres.2016.01.002.

Raha, D., P. Mahanta, and M. L. Clarke. 2014. "The Implementation of Decentralised Biogas Plants in Assam, NE India: The Impact and Effectiveness of the National Biogas and Manure Management Programme." *Energy Policy* 68:80–91. doi:10.1016/j.enpol.2013.12.048.

Rehfuess, E. A., E. Puzzolo, D. Stanistreet, D. Pope, and N. G. Bruce. 2014. "Enablers and Barriers to Large-Scale Uptake of Improved Solid Fuel Stoves: A Systematic Review." *Environmental Health Perspectives* 122 (2):120–30. doi:10.1289/ehp.1306639.

Sagar, A. D. 2005. "Alleviating Energy Poverty for the World's Poor." *Energy Policy* 33 (11):1367–72. doi:10.1016/j.enpol.2004.01.001.

Samiti, R. S.. 2021. "NOC's Likely to Go Up." *The Himalayan Times*. https://thehimalayantimes.com/nepal/nocs-loss-likely-to-go-up.

Sharma, A., J. Parikh, and C. Singh. 2019. "Transition to LPG for Cooking: A Case Study from Two States of India." *Energy for Sustainable Development* 51:63–72. doi:10.1016/j.esd.2019.06.001.

Shrestha, P. M. 2021a. "Government announces electricity tariff waiver as Ghising takes charge." *The Kathmandu Post.* https://kathmandupost.com/national/2021/08/12/government-announces-electricity-tariff-waiver-as-ghising-takes-charge.

Shrestha, P. M. 2021b. "Nepal wants people to use more electricity to prevent wastage. *The Kathmandu Post*. https://kathmandupost.com/national/2021/10/29/nepal-wants-people-to-use-more-electricity-to-prevent-wastage.

Shrestha, P. M. 2021c. "Once Power-Starved, Nepal now Aims to Export Electricity." *The Kathmandu Post*. https://kathmandupost.com/money/2021/08/10/once-power-starved-nepal-now-aims-to-export-electricity.

Simon, G. L., R. Bailis, J. Baumgartner, J. Hyman, and A. Laurent. 2014. "Current Debates and Future Research Needs in the Clean Cookstove Sector." *Energy for Sustainable Development* 20:49–57. doi:10.1016/j.esd.2014.02.006.

Singh, O. P., R. Singh, and M. K. Singh. 2014. "Impact of Farm Sector Electricity Subsidy on Water Use Efficiency and Water Productivity in India." *Indian Journal of Agricultural Economics* 69(902-2016-68336): 404–13. https://ideas.repec.org/a/ags/inijae/229844.html.

Sovacool, B. K. 2016. "How Long Will it Take? Conceptualizing the Temporal Dynamics of Energy Transitions." *Energy Research & Social Science* 13:202–15. doi:10.1016/j.erss.2015.12.020.

Teng, M., P. J. Burke, and H. Liao. 2019. "The Demand for Coal Among China's Rural Households: Estimates of Price and Income Elasticities." *Energy Economics* 80:928–36. doi:10.1016/j.eneco.2019.03.005.

Thoday, K., P. Benjamin, M. Gan, and E. Puzzolo. 2018. "The Mega Conversion Program from Kerosene to LPG in Indonesia: Lessons Learned and Recommendations for Future Clean Cooking Energy Expansion." *Energy for Sustainable Development* 46:71–81. doi:10.1016/j.esd.2018.05.011.

Tietenberg, T. H., and L. Lewis. 2018. *Environmental and Natural Resource Economics*, 11th edition. Abington-on-Thames, UK: Routledge.

Tripathi, A., A. D. Sagar, and K. R. Smith. 2015. "Promoting Clean and Affordable Cooking: Smarter Subsidies for LPG." *Economic and Political Weekly* 50(48):81–84. https://www.jstor.org/stable/44002904.

Troncoso, K., and A. Soares da Silva. 2017. "LPG Fuel Subsidies in Latin America and the Use of Solid Fuels to Cook." *Energy Policy* 107:188–96. doi:10.1016/j.enpol.2017.04.046.

Troncoso, K., P. Segurado, M. Aguilar, and A. Soares da Silva. 2019. "Adoption of LPG for Cooking in Two Rural Communities of Chiapas, Mexico." *Energy Policy* 133:110925. doi:10.1016/j.enpol.2019.110925.

Tsai, F.-J., M. Wu, and C.-P. Lin. 2020. "Does a Free-Trial Approach Increase Purchase and Use of a Household Water Treatment and Safe Storage Product in Rural Haiti?" *The American Journal of Tropical Medicine and Hygiene* 102(3): 518. doi:10.4269/ajtmh.19-0606.

UNICEF. 2021. Nepal Multidimensional Poverty Index 2021: Report: Analysis towards action. Sept. https://www.unicef.org/nepal/reports/nepal-multidimensional-poverty-index-2021-report#:~:text=In%202019%2C%2017.4%20percent%20of,schooling%2C%20assets%2C%20and%20nutrition.

Usmani, F., M. Jeuland, and S. K. Pattanayak. 2018. "NGOs and the Effectiveness of Interventions." WIDER Working Paper 2018/59. Helsinki: UNU-WIDER. doi:10.35188/UNU-WIDER/2018/501-5.

Usmani, F., J. Steele, and M. Jeuland. 2017. "Can Economic Incentives Enhance Adoption and Use of a Household Energy Technology? Evidence from a Pilot Study in Cambodia." *Environmental Research Letters* 12(3):035009. doi:10.1088/1748-9326/aa6008.

Vivalt, E. 2020. "How Much Can we Generalize from Impact Evaluations?" *Journal of the European Economic Association* 18(6):3045–89. doi:10.1093/jeea/jvaa019.

WHO. 2006. *Fuel for Life: Household Energy and Health*. Geneva: World Health Organization. https://www.who.int/publications/i/item/9789241563161.

WHO. 2018. *Household Energy Database*. Geneva, Switzerland: World Health Organization. https://www.who.int/data/gho/data/themes/air-pollution/who-household-energy-db.

WHO. 2021. *Database: Cooking Fuels and Technologies (By Specific Fuel Category)*. Geneva, Switzerland: World Health Organization. https://www.who.int/data/gho/data/themes/air-pollution/cooking-fuel-and-technology-database-by-fuel-category.

The World Bank. 2020. "Access to Electricity (% of Population)—Nepal." World Bank Global Electrification Database from *Tracking SDG 7: The Energy Progress Report*. Washington, D.C.: IEA, IRENA, UNSD, the World Bank, and WHO.

Yin, G., L. Zhou, M. Duan, W. He, and P. Zhang. 2018. "Impacts of Carbon Pricing and Renewable Electricity Subsidy on Direct Cost of Electricity Generation: A Case Study of China's Provincial Power Sector." *Journal of Cleaner Production* 205:375–87. doi:10.1016/j.jclepro.2018.09.108.

Zuzhang, X. 2013. *Domestic Biogas in a Changing China: Can Biogas Still Meet the Energy Needs of China's Rural Households*. London: International Institute for Environment and Development. https://www.iied.org/sites/default/files/pdfs/migrate/16553IIED.pdf.

APPENDIX A: SELECTION FROM NEPAL'S MINISTRY OF POPULATION AND ENVIRONMENT, RENEWABLE ENERGY SUBSIDY POLICY, 2073 BS (GOVERNMENT OF NEPAL 2016)

Subsidy amount for biomass energy systems or technologies will be as follows:

11.6.1. No direct subsidy will be provided for the promotion of household mud improved cooking stoves. However, local bodies are encouraged to provide financial support to install mud ICS to targeted beneficiaries like women-led households with dependent children, earthquake victims, endangered indigenous community identified by Government of Nepal.

11.6.2. Maximum subsidy amount of up to 50% but not exceeding Rs. 3,000 and Rs. 4,000 per stove per household for metallic improved cooking stove of one or two pot hole and three pot hole types respectively will be provided in areas above the altitude of 1,500 m for cooking and space heating. For these stoves, additional subsidy amount of Rs. 1,000 and Rs. 500 per stove per household will be provided for Category "A" and "B" VDCs listed in Annex-1.

11.6.3. Maximum subsidy amount of up to 50% of the stove cost but not exceeding Rs. 20,000 per stove will be provided for metallic improved cooking stove to be installed in institutions like public school, public hospital/health post, police and army barracks, religious places and orphanage homes for cooking and space heating purposes.

11.6.4. Maximum subsidy amount of up to 50% of the stove cost but not exceeding Rs. 3,000 will be provided for one or two pot hole with full or partial metal body portable/rocket cookstoves in rural and peri-urban areas.

11.6.5. Maximum subsidy amount of up to 50% of the stove cost but not exceeding Rs. 4,000 will be provided for one or two pot hole with full or partial metal body gasifier system 12 household cookstoves in rural and peri-urban areas.

11.6.6. Maximum subsidy amount of up to 50% of the plant cost but not exceeding Rs. 150,000 will be provided to metallic gasifier plant for thermal applications for agroprocessing by small, medium and cottage enterprises.

11.6.7. Additional subsidy amount of Rs. 1,000 per stove per household will be provided for the metallic improved cookstoves to the "targeted beneficiary groups".

11.6.8. Subsidy for biomass electrification projects above 5 kW up to 100 kWp in areas not connected through national grid or other sources, depending on the choice of the project developer to opt for subsidy on the basis of actual power generation or actual energy consumption, will be as follows:

Subsidy Category	Subsidy Amount in NPR		
	Category A Regions	Category B Regions	Category C Regions
Subsidy on the Basis of Project			
Distribution, per household	32,000	30,000	28,000
Generation, per kW	125,000	110,000	100,000
But, the maximum subsidy amount per kW for generation and distribution will not exceed NPR 445,000, NPR 410,000, and NPR 380,000 for Category A, Category B, and Category C regions, respectively. Distribution subsidy will be provided to a maximum of 10 households per kW.			
Subsidy on the basis of energy consumption			
Energy consumption, kWh	50%	50%	50%
Subsidy for energy consumption will be paid over a period of five years only after electricity generation based on actual energy consumption.			

APPENDIX B: SUMMARY OF LITERATURE

Table B.1. Summary of Literature

Authors	Year of Publication	Study Location	Domain	Price Instrument
Andadari et al.	2014	Indonesia	Clean cookstoves	Subsidies
Ashraf et al.	2013	Zambia	Water treatment	Subsidies
BenYishay et al.	2017	Cambodia	Sanitation	Microfinance
Bhattacharya et al.	2013	Kenya	Insecticide-treated bed nets	Subsidies
Blum et al.	2014	Kenya	Water treatment	Subsidies
Brown and Kramer	2018	Uganda	Insecticide spraying for mosquito control	Subsidies
Budya and Arofat	2011	Indonesia	Clean cookstoves	Taxes and subsidies
Cameron et al.	2016	South Asia	Clean cookstoves	Subsidies
Chirgwin et al.	2021	Global	WASH interventions	Subsidies and finance (and other)
Clemens et al.	2018	East Africa	Clean cookstoves	Taxes
Cook et al.	2009	India	Vaccines	Subsidies
Deutschmann	2021	Senegal	Sanitation	Time-limited subsidies
Dizon-Ross et al.	2017	Ghana, Kenya, and Uganda	Vaccines	Subsidies
Dupas	2014	Kenya	Insecticide-treated bed nets	Subsidies
Dupas et al.	2016	Kenya	Vaccines	Subsidies
Erdogdu	2011	Global	Electricity	Subsidies
Fischer et al.	2019	Uganda	Vaccines	Subsidies
Gakii Gatua et al.	2016	Kenya	Water and sanitation	Subsidies
Garn et al.	2017	Global	Sanitation	Subsidies (and other)
Gould et al.	2018	Ecuador	Clean cookstoves	Subsidies
Gould et al.	2020	Ecuador	Clean cookstoves	Subsidies
Guiteras et al.	2015	Bangladesh	Sanitation	Subsidies
Jain	2006	India	Electricity	Subsidies

Authors	Year of Publication	Study Location	Domain	Price Instrument
Jeuland et al.	2018	Global	Improved cookstoves	Subsidies
Kar et al.	2020	India	Clean cookstoves	Subsidies
Karanja and Gasparatos	2019	Kenya	Clean cookstoves	Taxes and subsidies
Khatib et al.	2008	Tanzania	Insecticide-treated bed nets	Subsidies
Komives et al.	2005	Global	Electricity and water treatment	Subsidies
Kuehl et al.	2021	Indonesia	Clean cookstoves	Subsidies
Lambe et al.	2015	Sub-Saharan Africa	Clean cookstoves	Taxes and subsidies
Martínez et al.	2017	Ecuador	Clean cookstoves	Subsidies
Lipscomb and Schechter	2018	Senegal	Sanitation	Subsidies
Mittal et al.	2017	India	Clean cookstoves	Subsidies
Null et al.	2012	Global	Clean water	Subsidies
Pattanayak et al.	2009	India	Sanitation	Subsidies
Pattanayak et al.	2019	India	Improved cookstoves	Subsidies
Pollard et al.	2018	Peru	Clean cookstoves	Subsidies
Puzzolo et al.	2016	Africa, Asia, and Latin America	Clean cookstoves	Taxes and subsidies
Raha et al.	2014	India	Clean cookstoves	Subsidies
Sharma et al.	2019	India	Clean cookstoves	Subsidies
Sharma et al.	2021	India	Clean cookstoves	Subsidies
Simon et al.	2014	Low- and middle-income countries	Clean cookstoves	Subsidies
Singh et al.	2014	India	Electricity and water treatment	Subsidies
Thoday et al.	2018	Indonesia	Clean cookstoves	Subsidies
Tripathi et al.	2015	India	Clean cookstoves	Subsidies
Troncoso and da Silva	2017	Latin America	Clean cookstoves	Subsidies
Troncoso et al.	2019	Mexico	Clean cookstoves	Subsidies

Authors	Year of Publication	Study Location	Domain	Price Instrument
Tsai et al.	2020	Haiti	Water treatment	Time-limited subsidies (free trials)
Usmani et al.	2017	Cambodia	Improved cookstoves	Subsidies
Yin et al.	2018	China	Electricity	Subsidies
Zuzhang	2013	China	Clean cookstoves	Subsidies

Author Affiliations

Ipsita Das, Sanford School of Public Policy and James E. Rogers Energy Access Project, Duke University
Marc Jeuland, Sanford School of Public Policy, Duke Global Health Institute, and James E. Rogers Energy Access Project, Duke University
Victoria Plutshack, James E. Rogers Energy Access Project, Duke University
Jiahui Zong, Sanford School of Public Policy, Duke University

Citation

Das, Ipsita, Marc Jeuland, Victoria Plutshack, and Jiahui Zong. 2022. "Taxes and subsidies and the transition to clean cooking: A review of relevant theoretical and empirical insights." NI Report 22-07. Durham, NC: Duke University. https://energyaccess.duke.edu/publication/taxes-and-subsidies-report/.

Acknowledgments

We thank the Clean Cooking Alliance for funding the project that led to this report and its accompanying policy brief. The brief can be found at: https://energyaccess.duke.edu/publication/the-role-of-taxes-and-subsidies-in-the-clean-cooking-transition-a-review-of-relevant-theoretical-and-empirical-insights/.

Publication Number: NI R 22-07

Nicholas Institute for Energy, Environment & Sustainability

The Nicholas Institute for Energy, Environment & Sustainability advances Duke University's efforts to build a more sustainable world, working closely with Duke schools and other units. The Nicholas Institute develops transformative educational experiences; galvanizes and conducts impactful research; and engages with key decision makers at the global, national, state, and local levels. The Nicholas Institute's team of economists, scientists, lawyers, and policy experts has developed a strong reputation for delivering timely, credible analysis and for convening decision makers to advance actionable solutions to pressing energy and environmental challenges.

Contact

Nicholas Institute
Duke University
P.O. Box 90335
Durham, NC 27708

1201 Pennsylvania
Avenue NW
Suite 500
Washington, DC 20004

919.613.8709
nicholasinstitute@duke.edu