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Renewable energy policies and household solid fuel dependence☆

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ABSTRACT

What effects do domestic and international policies have on household solid fuel consumption? Previous studies analyze some of the policies that national governments and international organizations have implemented to reduce solid fuel dependence, but these studies tend to examine one policy and/or one country at a time. In contrast, this article seeks to provide a more systematic analysis of whether and to what extent domestic and international policies can encourage transition to less polluting fuels. Using data on the proportion of population using solid cooking fuels, and domestic and international programs promoting renewable energy, we evaluate the association between renewable energy policies and household solid fuel dependence. Our statistical tests show that such policies, regardless of their domestic or international origins, matter in explaining the level of solid fuel dependence. As the number of domestic policies increases, the share of population using solid fuels tends to decline. International efforts to promote renewable energy are also linked to reduced solid fuel dependence in countries where such international programs are implemented.

1. Introduction

Indoor air pollution driven by solid fuel consumption remains a significant health hazard in many parts of the world. In 2017, as much as 47 percent of global population, residing predominantly in South and East Asia, and sub-Saharan Africa, experienced regular exposure to household air pollution as a result of their dependence on solid fuels (Health Effects Institute 2019: 8). These regions, consequently, bear the brunt of health damage caused by exposure to indoor air pollution. Whereas globally just 21 age-standardized deaths per 100,000 people could be attributed to this type of air pollution in 2017, in low-income regions of the world the toll was significantly higher – 96 age-standardized deaths per 100,000 people. The highest values of this standardized indicator were calculated for the Central African Republic (153) and Papua New Guinea (219), according to the State of Global Air 2019 database.

Solid fuel consumption also generates broader environmental costs, such as deforestation, soil erosion and biodiversity loss. For instance, Stevenson (1989) links rapid deforestation in Haiti to firewood and charcoal production and consumption. Moreover, Barlow et al. (2016) find that economic activities in tropical forests can lead to a significant loss of conservation value, even if such activities do not always result in substantial deforestation. Household solid fuel use also contributes to global climate change: for instance, Bond et al. (2013) report that solid fuel burning accounts for 60–80 percent of Asian and African emissions of black carbon, which is second only to carbon dioxide in its contribution to global climate warming.

One of the important drivers of transition to less polluting fuels is government policies. As our literature review in the next section suggests, previous research has examined extensively the implementation and success of government programs promoting electrification and the use of gas, including liquified petroleum gas (LPG). While traditional propane is a clean-burning fuel, there is a growing interest in using renewable propane, i.e., bio-LPG, which relies on production sources such as vegetable and animal oils. Previous studies find that national governments and international organizations have deployed a broad range of policies to facilitate transition from solid fuel to modern energy sources. Such policies include subsidies, price controls, distribution of cleaner stoves and cooking fuels. However, one of the key limitations of the existing research is its focus on one policy and/or one country at a

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time, which hampers comparisons in examining impacts of different approaches and the importance of country context for fuel transition.

In addition, measures seeking to encourage households to switch from traditional fuels to cleaner alternatives can be viewed as part of broader national (or domestic) and international strategies to transition to clean energy derived from renewable sources. Renewable energy has multiple energy sources such as natural energy fluxes of the sun, the wind, gravity, photosynthesis, and geothermal heat (Moomaw 2008), while oil, coal, and natural gas are non-renewable energy sources (Baul et al., 2018). Consider the magnitude of such renewable energy efforts, relative to more narrow programs to phase out solid cooking fuels, in the case of the World Bank, one of the largest international development agencies. According to the 2021 annual report on progress towards Sustainable Development Goal (SDG) 7, the World Bank's new initiative, the Clean Cooking Fund, is expected to provide $500 million in project funding to accelerate progress toward universal access to clean cooking between 2019 and 2030 (IEA, IRENA, UNSD, World Bank, WHO, 2021). The scale of this program and its potential impact stand in stark contrast to the World Bank's existing renewable energy portfolio, which totaled $22 billion between 2000 and 2017 (IEG, 2020). Therefore, it is important to understand whether these large-scale programs can help to accelerate transition to cleaner household fuels.

To date, there are few, if any, systematic studies on the effect of programs promoting renewable energy on solid fuel dependence. This article aims to fill this gap and contribute to our understanding of the impact of such energy policies on households' transition to cleaner energy sources. Furthermore, we differentiate energy programs by origin (domestic vs. international), policy instrument (e.g., economic or regulatory instruments), and policy target (e.g., solar or wind energy) to compare their impacts on solid fuel use. We show that domestic and international renewable energy policies are statistically significant determinants of households' solid fuel dependence. While both types of policies are associated with reduced solid fuel use, international efforts appear to have a more enduring influence on clean fuel transition than domestic policies. Our analysis also shows that economic instruments, regulatory instruments, and voluntary approaches are policies that can succeed in incentivizing household fuel transition, but there is no evidence that other policy instruments (i.e., information and education policies, policy support, and R&D and deployment measures) can have a similar effect. Voluntary approaches are defined as "agreements on environment performance negotiated with industry and public programs in which firms can volunteer to participate" (OECD, 2000; OECD, 2003). For instance, Environment Canada, which is the main federal environmental agency, and Ontario's Ministry of the Environment negotiated the Accelerated Reduction/Elimination of Toxics program and the Environmental Management Agreement with the steel company Dofasco Inc in 1997 (OECD 2003, 28-29). These negotiations helped the federal and provincial governments to involve Dofasco in their efforts to protect the natural environment by advancing the prevention and abatement of releases from Dofasco's steel manufacturing facility in Hamilton, Ontario. Finally, we identify national programs in wind, bioenergy, and geothermal sectors as promising policy targets with regard to reductions in solid fuel dependence.

2. Existing research on determinants of solid fuel use

Where does energy consumed by households come from? What is the impact of using different types of energy on human health and natural environment? The 2021 annual report on progress towards SDG 7 – affordable and clean energy – shows that, as of 2019, 759 million people still lack access to electricity and 2.6 billion people depend on traditional cooking technologies and fuels (IEA et al., 2021). Some estimates are more pessimistic: Ayaburi et al. (2020) calculate that 3.5 billion people do not have reliable access to electricity. Even though modern fuels, including LPG and electricity, are more sustainable and efficient than traditional alternatives, households in lower-income countries remain heavily dependent on solid fuels. In particular, households' solid fuel use shows little or no change over time in sub-Saharan Africa, the Western Pacific and South-East Asia, especially rural China (McLean et al., 2019b; WHO, 2013).

Traditional fuel usage presents a significant environmental hazard for human health (Rahut et al., 2017). Cooking with solid fuels generates significant indoor air pollution, which increases a number of health risks, including child mortality and respiratory diseases (Bruce et al., 2000; Ezzati and Kammen, 2002; Gall et al., 2013). Household air pollution from burning solid cooking fuels adversely impacts about 3 billion people worldwide and results in approximately 3.5 million premature deaths and 77 million patients annually (WHO, 2018; Rajkumar et al., 2019; Admasie et al., 2019; Osano et al., 2020). Women and children are particularly vulnerable, as their level and duration of exposure are greater, and existing research shows a direct association between hours of use and health damage (Arlington et al., 2019; Tamire et al., 2019; Liu et al., 2020). Solid fuel use not only contributes to adverse health outcomes, but also harms childhood learning and development in lower-income countries. For instance, children in households dependent on solid fuel had lower IQ than those in families with LPG access (Brabhukumr et al., 2020). Similarly, children exposed to indoor air pollution associated with solid fuel use show worse performance on early childhood development indicators (Nazif-Muñoz et al., 2020). Adverse impacts of solid fuel dependence are evident not only in young children, but also middle-aged and elderly people, whose cognitive abilities and mathematical reasoning deteriorates as air pollution resulting from solid fuel consumption grows (Qiu et al., 2019). Therefore, transition to cleaner energy sources is required to reduce indoor air pollution, thereby producing substantial health and other benefits for vulnerable groups, such as women and children (Meng et al., 2019). Existing research indicates that, when low or lower-middle-income countries (LMICs) transition away from solid fuels toward LPG and electricity in the process of urbanization and economic development, these changes in household energy sources produce measurable health benefits (Maji and Kandlikar, 2020).

What explains cross-country variation and temporal shifts in households' use of solid fuels? Previous studies have identified a number of determinants of solid fuel consumption (e.g., McLean et al., 2019b). For instance, in contrast to urban populations, rural residents in LMICs typically depend on firewood, dung and charcoal to satisfy their cooking and heating needs. The utilization of solid fuel in rural areas is higher than in urban areas due to differences in household incomes and fuel prices (Osano et al., 2020; McLean et al., 2019a). However, results from a study conducted in rural areas of India and Ethiopia question the relationship between household income and the use of solid fuels: the top income quartile in rural areas shows preference for solid fuels as an energy source (Sehjpal et al., 2014; Guta, 2014). Therefore, despite a general shift from traditional energy sources (e.g., coal and firewood) to modern fuels (e.g., electricity and LPG) as a consequence of growing household incomes, a mixed fuel choice pattern can sometimes emerge, depending on preferences and needs (Barnes et al., 2005; DeFries and Pandey, 2010; Wolf et al., 2017; Ravindra et al., 2019). In other words, economic development and income growth alone may not always reduce solid fuel dependence, because accessibility, reliability, and cultural factors can serve as important drivers of fuel choices. These factors can be countered by governments, which may encourage the fuel transition process by implementing policies to promote and incentivize adoption of less polluting energy sources. Such policies may include regulatory and monetary incentives, or investments in awareness and information dissemination campaigns, such as education programs (Pachauri and Jiang, 2008; Muller and Yan, 2018; Rahut et al., 2019).

A broad range of national-level economic programs seeks to encourage adoption of cleaner stoves and cooking fuels in different regions of the world. For instance, national governments can design domestic energy policies offering economic incentives, such as subsidies, to encourage transition away from solid fuels. Households may resist switching to cleaner energy sources because cleaner fuels are usually more expensive and require a significant change in habits (Troncoso and Soares da Silva 2017, 189). Hence, adoption of cleaner fuel alternatives may depend on economic assistance to offset their costs and lower opportunity costs from avoiding solid fuels (Slaski and Thurber, 2009).

Empirical studies have analyzed such domestic economic programs encouraging fuel transition, and explained their adoption in a variety of countries located in different regions of the world. Subsidies and grant programs for low-income households made LPG and electricity more accessible as energy sources in Argentina, Brazil, Mexico, Indonesia, Thailand and Ghana, to list just a few examples (Troncoso and Soares da Silva, 2017; Smith et al., 2005; Coelho and Goldemberg, 2013; Kojima, 2011; Septin et al., 2019; Hanung & Muhammad, 2011; Edgar et al., 2014). Another economic measure that national governments commonly implement is distribution of free or low-priced stoves and LPG cylinders, which lower households' costs of transition from traditional energy sources to cleaner substitutes. Existing research details such policies implemented by governments of Ecuador, Indonesia, and Mexico, among others (Troncoso and Soares da Silva, 2017; Troncoso et al., 2019; Araujo, 2015; El Universo, 2017; Septin et al., 2019).

Governments can also enact a set of regulatory policies to expand clean fuel use. Such policies not only reduce costs of clean fuels, but also increase costs of traditional fuels, thereby affecting households' energy choices. Besides providing incentives or subsidies, tradable permits and carbon taxes are popular measures that governments adopt to promote renewable energy. The regulatory framework is at least as important as subsidies in the case of renewable energy. One of the regulatory policies takes the form of feed-in tariffs, which set a price that is guaranteed over a certain period of time, so that power producers can rely on this price when they sell renewably generated electricity to the grid. Another type of a regulatory policy is quota obligations: governments set standards requiring a minimum percentage of energy sold or capacity installed to be derived from renewable energy sources. Feed-in tariff regulations have been introduced in at least 50 countries, including most European Union member states, which have also implemented quota policies at the national level (Tükenmez and Demireli, 2012).

Consumers are more likely to continue using traditional fuels rather than switch to cleaner alternatives when they do not have sufficient information about clean fuels. Also, when consumers are not aware of exact costs and benefits of different energy types, they may be reluctant to abandon traditional cooking stoves and fuels. Governments can address these knowledge gaps by providing relevant information and educating the public (Kandpal and Broman, 2014). Jennings (2009) finds that educational programs can be effective in informing the general public about renewable energy. This suggests that governments can implement educational policies with the goal of influencing consumers' attitudes and preferences to make clean energy options more acceptable to the public.

Various policies aiming to reduce solid fuel consumption have been executed at the international level as well. One example of such an international-level effort is a program linked to the Central American Integration System (Sistema de la Integración Centroamericana, SICA), which aimed to promote clean energy. SICA placed a high priority on transition to modern cooking fuels in Central America as part of its Sustainable Energy Strategy for 2020, with the goal of reducing firewood consumption through distribution of one million cleaner cooking stoves (SICA, 2009). In connection to this initiative, Nicaragua and Guatemala eliminated regulations on all petroleum fuel prices. Guatemala taxes LPG, but Nicaragua does not subsidize or impose a tax on LPG. Honduras provides a small amount of subsidy on LPG and implements regulations on retail and wholesale prices of oil products in accordance with import parity criteria (WB-ESMAP, 2010).

Some of these international programs are supported by non-governmental organizations (NGOs), which seek to coordinate international efforts to promote the use of clean energy. One such NGO is the Clean Cooking Alliance: its goal is to support development of clean cooking solutions and make clean cooking stoves and fuels accessible as widely as possible. Given the recognition that cooking with solid fuels causes household air pollution and significant environmental and health burdens (Chafe et al., 2013), the Clean Cooking Alliance attempts to replace existing cooking techniques with improved alternatives, reducing pollution from traditional energy sources (Rosenthal et al., 2017). Unlike national governments, international NGOs cannot enforce policies. Thus, they focus on programs that either provide information about clean fuels, raise public awareness of harms associated with solid fuels, provide funding for research and development, or encourage consumers to switch to less polluting cooking alternatives (e.g., by distributing cleaner stoves free of charge).

Adverse health effects of solid fuel consumption attract the attention of international development and health agencies and motivate them to formulate and implement clean energy policies at the international level. Specifically, the World Health Organization (WHO) identified solid fuel dependence as a public health hazard that requires urgent action (Liao et al., 2019; Troncoso et al., 2019). The WHO's involvement encourages domestic governments to implement policies that offer subsidies for LPG use or promote adoption of induction stoves (Gould et al., 2018). In one of the WHO regions, the Pan American Health Organization (PAHO) seeks to provide technical assistance and advocacy to increase the pace of clean energy transition (Pan American Health Organization. 2018). PAHO also supports countries' progress toward achieving the Sustainable Development Goals (SDGs), and provides member governments with evidence of possible impacts of various energy policies and programs on health outcomes (Haby et al. 2016). One of the SDGs is particularly relevant in this regard: SDG7 focuses on clean and accessible energy. This SDG emphasizes the importance of providing affordable and clean energy sources, and the influence of clean energy on local communities and global climate (Hillerbrand, 2018).

In sum, there is a well-documented range of policies implemented at the national and international levels aiming to promote transition from solid fuels to modern energy sources. Yet, research measuring effects of various policies on the pace of fuel transition tends to have a single-policy and/or single-country focus, which limits scholars' ability to assess overall impacts of efforts to promote fuel transition. Moreover, policies narrowly targeting households' solid fuel consumption are a relatively small subset of clean energy policies adopted and implemented by governments and international organizations. Therefore, this article broadens the scope of investigation to include all policies that aim to reduce dependence on polluting fuels and increase the use of clean, sustainable energy from a variety of sources, such as solar, wind, hydropower, bioenergy, geothermal, and ocean.

3. Research Methods

To evaluate the role of national and international policies on household transition to cleaner cooking fuels, we construct a dataset, using four sources of data. First, we obtain solid fuel data from the State of Global Air 2019 Database (Health Effects Institute 2019; https://www.stateofglobalair.org/data/#/air/plot). Second, the International Energy Agency's Policies and Measures Database (https://www.iea.org/policies/about) provides information for one of our key explanatory variables – *Domestic policy (count)*. Third, AidData.org (http://dashboard.aiddata.org/) is the data source for *International policy (count)*, another key explanatory variable. Finally, we extract data for all control variables from the World Bank's Word Development Indicators dataset (https://databank.worldbank.org/home). We summarize all variables in Table A1 of the Appendix. The unit of analysis is country-year.

3.1. Dependent variable: solid fuel dependence

To construct our dependent variable, we use the State of Global Air 2019 Database. The data on the proportion of population using solid fuels are available for all countries in 5-year increments for the period between 1990 and 2010, and then annually until 2017. With this spatial and temporal coverage, we have 2338 country-year observations. To improve our coverage, we use linear interpolation to fill in missing values prior to 2010. As a result, our sample size increases to 5939 country-year observations.

Fig. 1 illustrates temporal changes in solid fuel dependence at the aggregate level. The average value of the variable shows a substantial decline: from 46.3 percent in 1990 to 32.4 percent in 2017 (panel (a) of Fig. 1). At the same time, the median has decreased even more dramatically: from 39 to 13.5 percent during the period under study (panel (b) of Fig. 1). Countries with maximum values of solid fuel dependence (100 percent of the population relies on solid fuels for cooking) are located in Africa: Central African Republic, Democratic Republic of the Congo, Burundi, Rwanda, Somalia and South Sudan. All of these countries showed improvement in solid fuel dependence towards the end of the period under study, but such changes are extremely small. For instance, the 2017 value for Burundi, Rwanda and South Sudan is 99 percent. The lowest levels of solid fuel dependence are observed in advanced economies, such as the U.S., Japan and Canada (0.17, 0.11, and 0.08 percent, respectively, in 2017), as well as countries with significant natural gas deposits, such as Qatar and Russia (0.02 and 0.18 percent, respectively, in 2017).

3.2. Main explanatory variables: domestic and international policies

3.2.1. Domestic policy (count)

We use information from the International Energy Agency's Policies and Measures Database to count the number of renewable and clean energy policies deployed at the national level in each of the countries included in our dataset. For time coverage, we restrict our focus to the years, for which we have data on solid fuel dependence (i.e., 1990–2017). We create a count measure that adds up the number of active policies in a given year. When a government terminates or replaces a policy, it does not contribute to our count measure afterwards. 60% of country-year observations have no domestic renewable energy policies associated with them. China leads the world with the highest number of such policies – all implemented in recent years. Although the country lagged behind many others in the adoption of such policies (for instance, Germany's first policy in our dataset dates back to 1990), from the year when China's first policies were recorded (2006) until the end of the coverage period of the dataset (2017), China was able to reach the maximum policy count value in the dataset (i.e., 66).

For additional analyses, which aim to tease out more nuanced effects of different types of domestic policies, as well as policies with various targets, we construct additional measures of domestic policies. The source of information is the same IEA database as for the aggregate count measure. First, we identify distinct types of policies and count the number of individual policies within each type. The IEA database collects information on the following six policy types: economic instruments (such as feed-in tariffs, tax relief, grants, subsidies, or loans); information and education; policy support (mainly institutional development and strategic planning); regulatory instruments (such as codes and standards); R&D and deployment (such as funding for research and demonstration projects); and voluntary approaches. Second, policies can vary by the type of energy generation that they seek to promote. Therefore, we use the IEA database to construct policy count measures for the following policy targets: solar, wind, hydropower, bioenergy, geothermal, ocean, and multiple energy sources. Bioenergy projects, for instance, can facilitate transition away from solid fuels to biogas, which can lead to improvements in indoor air quality (Semple et al. 2014; Abadi et al. 2017). In our dataset, the use of economic instruments is the most common policy type (with the mean value of 1.5), while voluntary approaches constitute the least common type (the mean of 0.09). Among policy targets, the most popular policies target multiple clean energy sources (the mean of 1.95), while policies targeting ocean-generated energy are the least common (the mean of 0.11).

3.2.2. International policy (count)

Our data source for this measure is the project-level database compiled by AidData.org. We extract information for all aid recipients, from all donors, for all years starting in 1990, with one restriction: included aid projects provide support for clean energy programs in recipient countries. The maximum number of such projects was recorded in China in 2013, when the country secured loans, grants and other forms of international assistance (from bilateral and multilateral sources) for 134 renewable energy initiatives.

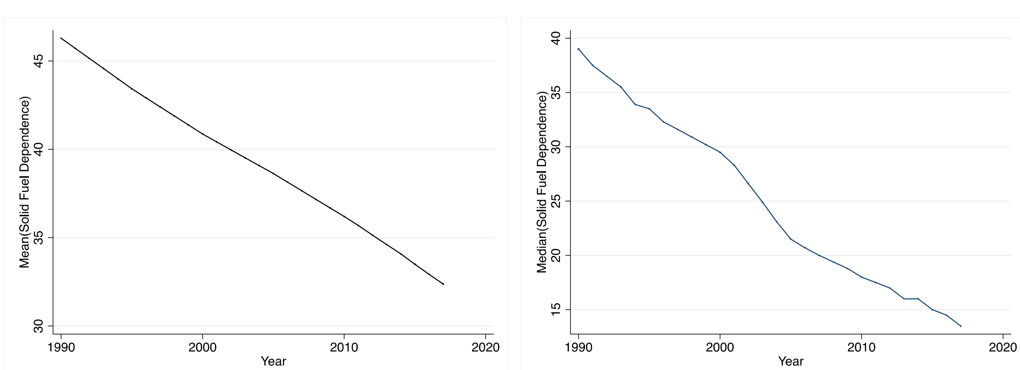
3.3. Control variables

3.3.1. GDPPC (logged)

To account for the effect of economic development levels on cooking fuels, we include per capita GDP (in constant 2010 USD; logged). Countries in our dataset display a substantial amount of variation in their development levels. The richest country is Luxembourg, with GDP per capita of $111,968 (in 2007). On the other end of the spectrum, the least affluent country is Ethiopia in 1992, with per capita GDP of just $164.

3.3.2. GDP growth

In addition to the level of economic development, the pace of its change may influence households' choice of solid fuels for cooking. Hence, we control for the country-level annual percentage growth rate of GDP. Equatorial Guinea displayed the maximum rate of growth in the dataset: 150 percent in 1997, following the 1995 oil discovery in the country. The most substantial economic contraction during the period



(a) (b)

Fig. 1. Temporal patterns of change in solid fuel dependence.

was recorded in Iraq: in 1991, the Iraqi economy shrunk by 64 percent as a result of a drop in oil prices and a slumping global economy.

3.3.3. Total employment ratio

This indicator is a share of employed population, aged 15 and older, based on the International Labor Organization estimates. Greater employment rates increase resources that households can allocate towards more expensive cleaner cooking fuels. Alternatively, households with greater resources may choose to burn more fuel overall, including solid fuels. The minimum value of the total employment ratio in our dataset is 26.3 percent, corresponding to Samoa in 2016. The highest employment ratio was recorded in Rwanda in 1991: 89 percent.

3.3.4. Rural population

We control for the size of each country's rural population, as a share of overall population, to account for urbanization and its potential effect on solid fuel dependence. Infrastructure development is often more difficult in sprawling rural areas, which can result in greater resilience of cooking practices that rely on solid fuels. While the population of the average country in our dataset is more urban than rural (the mean value of *Rural population* equals 44 percent), there is significant variation in urbanization patterns. Two countries have only urban population, corresponding to the minimum value of 0 for the *Rural population* variable in our dataset: Singapore and Kuwait. The maximum value of this variable (95 percent) represents Rwanda in 1990.

3.3.5. Population density (logged)

An important constraint on governments' ability to deliver cleaner fuels to individual households is the population density. Often, the most remote parts of a country are least likely to be connected to the national infrastructure providing access to gas and electricity. This, in turn, may force the population of these remote areas to rely on solid fuels to satisfy their household energy needs. Our population density measure, which captures the number of people per square kilometer of a country's land area (logged), gauges the severity of this constraint. The country with the lowest population density in our dataset is Mongolia: in 1990, it recorded just 1.4 residents per square kilometer of its territory. On the other end of the population density spectrum is Singapore: 7,916 people reside on each square kilometer of its land area, which represents the maximum value in the dataset.

3.3.6. Forest area

Easy availability of wood can incentivize households' greater reliance on solid cooking fuels, such as firewood and charcoal. To gauge how abundant forestry resources are in a given country, we rely on the indicator of forest area as a ratio of overall territorial size. Suriname is the most forest-rich country in our dataset, with forest coverage of over 98 percent of its territory (the maximum is 99 percent in 1990). The lowest value of this variable corresponds to Qatar: throughout the entire period under study, its forest cover is zero percent.

3.3.7. Electricity access

Households without electricity access may have little choice but to use solid cooking fuels. Therefore, expanded electricity delivery infrastructure should be positively correlated with reduced solid fuel dependence. Our models control for this potential effect by including the share of population with electricity access as an independent variable. A large number of countries located in different parts of the world have provided electricity access to 100 percent of their populations, including North America (e.g., the U.S. and Canada), Europe (e.g., Germany and France), Asia (e.g., Japan and South Korea), and the Middle East (e.g., Qatar and the UAE). The country with the most limited electricity access is Rwanda: in 1993 and 1994, it could only provide electricity to 0.01 percent of its population (the minimum value in our dataset).

3.4. Model specifications

Given that our dependent variable is the proportion of a country's population dependent on solid fuels in a given year, we specify and estimate linear models. These models include fixed effects to control for time-invariant unobserved country characteristics that can display correlation with the observed regressors. In addition, our specifications incorporate the lagged dependent variable and cubic polynomial approximation (i.e., *Time*, *Time squared*, and *Time cubed*). First, we include the lagged dependent variable as a regressor because we are interested in modeling changes in solid fuel dependence levels. Moreover, we expect that the current level of solid fuel use should depend significantly on the past level because adjustments to new energy sources cannot happen very quickly. Second, we use cubic polynomial approximation to control for temporal dependence. We follow the approach discussed in Carter and Signorino (2010): cubic polynomial approximation is an easier and more efficient way to model time dependence compared with alternatives such as time dummies, splines, or auto-smoothing procedures. Finally, we use logged values for highly skewed variables such as *Population density* and *GDPPC* to improve linearity between these variables and solid fuel dependence.

4. Empirical Results

To investigate the association between renewable energy policies and household solid fuel dependence, we conduct several statistical analyses. These tests yield findings that are consistent with the expectation that domestic and international policies can encourage transition from traditional energy sources to cleaner alternatives, such as solar energy or biofuels. Table 1 reports our main results, which are based on estimates from four fixed-effects linear models. We also show results from disaggregated models that include individual policy types and specific targets of domestic renewable energy policies in Tables 2 and 3, respectively. Overall, our empirical evidence suggests that a country's level of household consumption of solid cooking fuels declines as the number of renewable energy policies implemented in the country increases. Both domestic and international policies have a negative and statistically significant association with solid fuel dependence. This suggests that countries' efforts to reduce household use of polluting fuels can benefit from a broad range of renewable energy projects.

As Models 1, 3, and 4 in Table 1 show, the number of domestic policies, *Domestic policy (count)*, implemented in a given country is significantly and negatively associated with the dependent variable. In other words, when a government adopts more renewable energy policies, the share of the country's population using solid cooking fuels decreases. When we include one- and two-year lags of the domestic policy variable in Model 4 to investigate more lasting effects of such policies, coefficients on these regressors fail to reach statistical significance at conventional levels. We also find that the use of solid fuel in a given country declines as the number of international programs implemented in the country increases (Models 2, 3, and 4 of Table 1). This implies that international support for renewable energy adoption may expand clean energy options for households. When our model specification includes one- and two-year lags of international-level policies (Model 4), the two-year lagged regressor, *International policy (count; 2Y lagged)*, is significantly and negatively associated with the use of solid fuels. This implies that effects of international projects on energy transition may endure beyond their implementation year. In sum, our results indicate that policies initiated at the national and international levels to promote renewable energy may contribute to households' transition to cleaner cooking fuels.

Table 1 also shows that several control variables have statistically significant relationships with household solid fuel consumption. The share of a country's population that uses solid fuels tends to decrease when the country's economic performance – measured as GDP per capita and the rate of economic growth – improves. In addition, solid

Table 1
Renewable energy policies and solid fuel use.

	(1) Domestic policy	(2) International policy	(3) Domestic & International	(4) Domestic & International (with lags)
Domestic policy (count)	−0.0085***		−0.0084***	−0.0217**
	(0.0023)		(0.0023)	(0.0093)
Domestic policy (count; 1Y lagged)				0.0127
				(0.0140)
Domestic policy (count; 2Y lagged)				0.0040
				(0.0102)
International policy (count)		−0.0047***	−0.0046***	−0.0042***
		(0.0016)	(0.0016)	(0.0016)
International policy (count; 1Y lagged)				−0.0017
				(0.0016)
International policy (count; 2Y lagged)				−0.0061***
				(0.0017)
GDPPC (logged)	−0.4575***	−0.4482***	−0.4509***	−0.4239***
	(0.0522)	(0.0516)	(0.0522)	(0.0526)
GDP growth	−0.0040***	−0.0036***	−0.0040***	−0.0040***
	(0.0013)	(0.0013)	(0.0013)	(0.0013)
Total employment ratio	0.0141***	0.0149***	0.0138***	0.0131***
	(0.0028)	(0.0028)	(0.0028)	(0.0028)
Rural population	0.0020	0.0035	0.0017	0.0012
	(0.0035)	(0.0034)	(0.0035)	(0.0035)
Population density (logged)	−0.2119**	−0.1882**	−0.2042**	−0.1672**
	(0.0848)	(0.0833)	(0.0848)	(0.0852)
Forest area	0.0110***	0.0100***	0.0109***	0.0109***
	(0.0037)	(0.0037)	(0.0037)	(0.0037)
Electricity access	−0.0080***	−0.0072***	−0.0079***	−0.0076***
	(0.0013)	(0.0013)	(0.0013)	(0.0013)
Lagged solid fuel use	0.9779***	0.9787***	0.9778***	0.9771***
	(0.0019)	(0.0018)	(0.1883)	(0.1893)
Time	0.0679***	0.0606***	0.0621***	0.0535***
	(0.0152)	(0.0153)	(0.0153)	(0.0155)
Time squared	−0.0020*	−0.0016	−0.0015	−0.0009
	(0.0010)	(0.0010)	(0.0010)	(0.0011)
Time cubed	0.0000	0.0000	0.0000	−0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Constant	3.8532***	3.5369***	3.8216***	3.5647***
	(0.6743)	(0.6700)	(0.6737)	(0.6757)
N	3,710	3,736	3,710	3,709
R^2: overall	0.9994	0.9995	0.9995	0.9995
R^2: within	0.9940	0.9942	0.9940	0.9940
R^2: between	0.9996	0.9996	0.9996	0.9996
Log-likelihood	−1698.8077	−1712.2700	−1694.4513	−1684.6379

Fixed-effects linear models. Standard errors in parentheses. Control variables lagged by one year. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

fuel dependence declines when a country's population density and electricity access increase. In contrast, urbanization rates – measured as the share of rural population – do not have a statistically significant association with solid fuel consumption, while an increase in forest area in a country has a positive, statistically significant relationship with solid fuel dependence. Finally, patterns of solid fuel use demonstrate substantial path dependence: the coefficient on *Lagged solid fuel use* is positive and statistically significant across all specifications.

We conducted robustness checks by adding a measure of renewable energy investment divided by GDP as a control in all models in Table 1. Our main results remain unaffected, while the coefficient on the investment variable is negative but not statistically significant. The appendix provides a table showing results of these robustness checks.

Next, we use the estimates from Model 3 of Table 1 to calculate predicted solid fuel dependence in two countries. We select two countries in Africa, and look at their predicted values of solid fuel use in 2017. One country is Algeria (a low dependence case) and the other is Niger (a high dependence case). The countries share a border, which means that they have some common geographical/regional characteristics; at the same time, they are on the opposite ends of the solid fuel dependence spectrum. Predicted values can help us to assess the predictive power of our statistical models. First, we set all explanatory variables that reach statistical significance in Model 3 to values for the Algeria-2017 observation. The predicted level of solid fuel use for this country-year observation equals 0.75, and the 95% confidence interval is (0.26; 1.23). The observed value of Algeria's solid fuel use in 2017 is 0.32, which is well within the confidence interval. Second, we re-set all values of explanatory variables to those of Niger in 2017. Niger's predicted level of solid fuel use is 98.63, while the 95% confidence interval is (97.91; 99.34). The observed value of Niger's solid fuel dependence in 2017 equals 98, which falls within the confidence interval. These illustrations suggest that our statistical analysis relies on a model that generates fairly accurate predictions of observed levels of solid fuel dependence.

Statistical tests summarized in Table 2 rely on disaggregated data on types of domestic renewable energy policies to examine their relationship with household solid fuel use. While *International policy (count)* remains unchanged in these models, *Domestic policy (count)* is now replaced with variables that focus on individual policy types: i.e., *Economic instruments, Information and education, Policy support, Regulatory instruments, R&D and deployment*, and *Voluntary approaches*. Table 2 reports estimates from fixed-effects linear models. Among six national-level policy types, *Economic instruments, Voluntary approaches*, and *Regulatory instruments* have a statistically significant (at 0.05 for the first two policy types, and at 0.1 for *Regulatory instruments*), negative association with solid fuel dependence.

Interpretation of the coefficients is straightforward because we estimate linear models. For example, for every additional voluntary program launched in a country, the proportion of households that rely on solid fuels decreases, on average, by 0.05% per year. This implies that

Table 2
Types of domestic renewable energy policies and solid fuel use.

	(1) Economic instruments	(2) Information & education	(3) Policy support	(4) Regulatory instruments	(5) R&D & deployment	(6) Voluntary approaches
International policy (count)	−0.005**	−0.005**	−0.005**	−0.005**	−0.005**	−0.005**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Economic instruments	−0.007***					
	(0.003)					
Information & education		0.005				
		(0.004)				
Policy support			0.001			
			(0.005)			
Regulatory instruments				−0.008*		
				(0.005)		
R&D & deployment					−0.003	
					(0.003)	
Voluntary approaches						−0.050***
						(0.011)
GDPPC (logged)	−0.467***	−0.469***	−0.469***	−0.469***	−0.472***	−0.480***
	(0.065)	(0.065)	(0.065)	(0.065)	(0.065)	(0.065)
GDP growth	−0.004***	−0.004***	−0.004***	−0.004***	−0.004***	−0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Total employment ratio	0.015***	0.014***	0.014***	0.014***	0.014***	0.014***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Rural population	0.003	0.004	0.004	0.004	0.004	0.003
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Population density (logged)	−0.198**	−0.155**	−0.153*	−0.180**	−0.163**	−0.170**
	(0.078)	(0.076)	(0.080)	(0.079)	(0.077)	(0.076)
Forest area	0.010**	0.011**	0.011**	0.011**	0.011**	0.011**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Electricity access	−0.007***	−0.007***	−0.007***	−0.007***	−0.007***	−0.007***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Lagged solid fuel use	0.9781***	0.9773***	0.9774***	0.9778***	0.9776***	0.9779***
	(0.318)	(0.322)	(0.318)	(0.317)	(0.322)	(0.322)
Time	0.062***	0.061***	0.062***	0.062***	0.062***	0.063***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
Time squared	−0.002	−0.002*	−0.002*	−0.002	−0.002	−0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Time cubed	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	4.730***	4.397***	4.487***	4.578***	4.617***	4.839***
	(0.813)	(0.799)	(0.821)	(0.809)	(0.816)	(0.808)
N	3,710	3,710	3,710	3,710	3,710	3,710
R^2: overall	0.9995	0.9995	0.9995	0.9995	0.9995	0.9995
R^2: within	0.9940	0.9940	0.9940	0.9940	0.9940	0.9940
R^2: between	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996
Log−likelihood	−1697.592	−1700.924	−1701.070	−1699.488	−1700.906	−1697.937

Fixed-effects linear models. Standard errors in parentheses. Control variables lagged by one year. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

governments' economic and regulatory policies, as well as voluntary programs, such as the Tunisian Solar Plan, which was based on partnership between the public and private sectors, can contribute to energy transition at the household level, thereby reducing the proportion of population that uses solid cooking fuels. We also find that voluntary approaches are the most effective policy instrument compared to the other two policies that have statistically significant effects on solid fuel use. For example, one unit increase in voluntary programs is estimated to reduce solid fuel dependence 7–8 times more than adoption of additional economic and regulatory instruments. However, remaining policy type variables, i.e., *Information and education, Policy support*, and *R&D and deployment,* fail to yield statistically significant results. At the same time, the coefficient on *International policy (count)* remains consistently negative and statistically significant across all models in Table 2. Results for control variables remain essentially unchanged in all model specifications.

The third set of results, shown in Table 3, examines variation in domestic policy targeting and associated changes in household solid fuel use. Given that clean energy generation can depend on different energy sources, i.e., *Solar*, *Wind*, *Hydropower*, *Bioenergy*, *Geothermal*, *Ocean*, as well as a combination of sources, some policy targets may offer more sizeable benefits for the process of household transition from solid fuels to cleaner alternatives. As in Tables 1 and 2, we report estimates based on fixed-effects linear models. Our specifications with individual policy targets yield negative and statistically significant results in the wind and bioenergy models (the coefficients on the *Wind* and *Bioenergy* variables are significant at 0.05), and in the geothermal model (the coefficient on the *Geothermal* variable is significant at 0.1). For example, a national policy targeting energy sources such as wind and geothermal would reduce the proportion of households dependent on solid cooking fuels by 0.01–0.02% per year. These findings show that, when a growing number of domestic policies focus on wind, bioenergy, and geothermal sectors, household consumption of solid fuels declines. Our result for international policies remains unaffected, as we replace the aggregate domestic policy variable with individual policy target measures: international support for renewable energy is associated with reduced solid fuel use, and the relationship remains significant at the 0.05 level. Finally, control variables yield results that are largely similar to those reported in Table 1.

5. Conclusions

In this article we show that, regardless of their domestic or international origins, renewable energy policies matter as drivers of households' switch from more polluting and harmful solid fuels to cleaner cooking options. The number of implemented domestic policies is

Table 3
Targets of domestic renewable energy policies and solid fuel use.

	(1) Solar	(2) Multiple	(3) Wind	(4) Hydro	(5) Bio	(6) Geo	(7) Ocean
International policy (count)	−0.005**	−0.005**	−0.005**	−0.005**	−0.005**	−0.005**	−0.005**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Solar	−0.002						
	(0.006)						
Multiple resources		0.001					
		(0.002)					
Wind			−0.012**				
			(0.006)				
Hydropower				−0.012			
				(0.014)			
Bioenergy					−0.008**		
					(0.004)		
Geothermal						−0.016*	
						(0.009)	
Ocean							0.006
							(0.004)
GDPPC (logged)	−0.468***	−0.469***	−0.470***	−0.464***	−0.470***	−0.471***	−0.468***
	(0.065)	(0.065)	(0.065)	(0.063)	(0.065)	(0.065)	(0.065)
GDP growth	−0.004***	−0.004***	−0.004***	−0.004***	−0.004***	−0.004***	−0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Total employment ratio	0.014***	0.014***	0.014***	0.014***	0.014***	0.014***	0.014***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Rural population	0.004	0.004	0.004	0.004	0.004	0.003	0.004
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Population density (logged)	−0.159**	−0.150*	−0.176**	−0.162**	−0.186**	−0.175**	−0.154**
	(0.076)	(0.080)	(0.077)	(0.077)	(0.079)	(0.078)	(0.076)
Forest area	0.011**	0.011**	0.011**	0.011**	0.010**	0.011**	0.011**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Electricity access	−0.007***	−0.007***	−0.007***	−0.007***	−0.007***	−0.007***	−0.007***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Lagged solid fuel use	0.9776***	0.9773***	0.9779***	0.9777***	0.9779***	0.9779***	0.9774***
	(0.323)	(0.320)	(0.323)	(0.316)	(0.320)	(0.321)	(0.321)
Time	0.062***	0.062***	0.062***	0.062***	0.061***	0.062***	0.062***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
Time squared	−0.002*	−0.002*	−0.002	−0.002*	−0.001	−0.002	−0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Time cubed	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	4.509***	4.459***	4.609***	4.468***	4.688***	4.629***	4.474***
	(0.803)	(0.828)	(0.805)	(0.790)	(0.814)	(0.815)	(0.804)
N	3,710	3,710	3,710	3,710	3,710	3,710	3,710
R^2: overall	0.9995	0.9995	0.9995	0.9995	0.9995	0.9995	0.9995
R^2: within	0.9940	0.9940	0.9940	0.9940	0.9940	0.9940	0.9940
R^2: between	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996
Log−likelihood	−1701.029	−1701.053	−1700.046	−1700.725	−1699.512	−1700.223	−1700.971

Fixed-effects linear models. Standard errors in parentheses. Control variables lagged by one year. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

associated with a reduced share of population using solid fuels. International efforts have a similar impact: as the number of international clean energy programs increases, solid fuel dependence tends to decline. Moreover, these international projects have more enduring effects as a driver of transition to cleaner energy, compared to domestic policies. We also disaggregate types of national-level renewable energy policies to evaluate which policy instruments are associated with the beneficial effects identified at the aggregate level. Our results identify economic instruments, voluntary approaches, and regulatory instruments as statistically significant determinants of the fuel transition process, while the remaining three policy instruments (i.e., information and education policies, policy support, and R&D and deployment measures) did not appear to have any effect on household fuel transition. Finally, we disaggregate policy targets to capture governments' efforts to promote various sources of renewable energy. Findings from policy target models suggest that households' solid fuel dependence decreases when national policies focus on wind, bioenergy, and geothermal sectors, while other sectors (i.e., solar, hydropower, and ocean) may not have a similar effect.

Our results have important policy implications. Countries' efforts to reduce households' dependence on solid cooking fuels can be expanded and strengthened through linkages to national and international renewable energy programs. The reach and effectiveness of programs that focus only on promotion of cleaner cooking fuels and technologies tend to be low due to limited resources available for such programs (see, for instance, Thakur, van Schayck, and Boudewijns, 2019). Instead, a broader approach to clean energy transition that incorporates the goal of expanded use of cleaner cooking fuels may offer a more promising solution for this urgent environmental health issue. Renewable energy policies can encourage greater investment from both public and private sources, thereby making transition to cleaner fuels more affordable for households. It is important for governments and international development agencies to focus their programs on the most promising policy targets and choose policy instruments that are associated with clean fuel adoption at the household level. For instance, national governments may be able to accelerate clean fuel transition by adopting a combination of policies that offer economic incentives for clean energy use and specify regulations and rules to disincentivize the use of solid fuels, while also encouraging voluntary private and/or public programs that make clean fuels more accessible and acceptable for the general public.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gloenvcha.2021.102408.

References

Abadi, N., Gebrehiwot, K., Techane, A., Nerea, H., 2017. Links between biogas technology adoption and health status of households in rural Tigray, Northern Ethiopia. Energy Policy 101, 284–292.

Admasie, A., Kumie, A., Worku, A., Tsehayu, W., 2019. Household fine particulate matter (PM2.5) concentrations from cooking fuels: the case in an urban setting, Wolaita Sodo, Ethiopia. Air Qual. Atmos. Health 12 (6), 755–763.

Araujo, A., 2015. USD 50 por chatarrizar la cocina de gas [50 USD to scrap gas stoves]. El Comercio Available online: http://www.elcomercio.com/actualidad/programa-chatarrizar-cocina-gas.html.

Arlington, L., Patel, A.B., Simmons, E., Kurhe, K., Prakash, A., Rao, S.R., Hibberd, P.L., Dunea, D., 2019. Duration of solid fuel cookstove use is associated with increased risk of acute lower respiratory infection among children under six months in rural central India. PLoS ONE 14 (10), e0224374.

Ayaburi, J., Bazilian, M., Kincer, J., Moss, T., 2020. Measuring "Reasonably Reliable" access to electricity services. Electricity J. 33 (7), 106828. https://doi.org/10.1016/j.tej.2020.106828.

Barlow, J., Lennox, G.D., Ferreira, J., Berenguer, E., Lees, A.C., Nally, R.M., Thomson, J. R., Ferraz, S.F.d.B., Louzada, J., Oliveira, V.H.F., Parry, L., Ribeiro de Castro Solar, R., Vieira, I.C.G., Aragão, L.E.O.C., Begotti, R.A., Braga, R.F., Cardoso, T.M., de Oliveira, R.C., Souza Jr, C.M., Moura, N.G., Nunes, S.S., Siqueira, J.V., Pardini, R., Silveira, J.M., Vaz-de-Mello, F.Z., Veiga, R.C.S., Venturieri, A., Gardner, T.A., 2016. Anthropogenic disturbance in tropical forests can double biodiversity loss from deforestation. Nature 535 (7610), 144–147.

Barnes, D.F., Krutilla, K., Hyde, W., 2005. The Urban Energy Transition: Energy, Poverty, the Environment. World Bank, Washington, D. C.

Baul, T.K., Datta, D., Alam, A., 2018. A comparative study on household level energy consumption and related emissions from renewable (Biomass) and non-renewable energy sources in Bangladesh. Energy Policy 114, 598–608.

Bond, T.C., et al., 2013. Bounding the role of black carbon in the climate system: a scientific assessment. J. Geophys. Res. Atmos. 118, 5380–5552.

Brabhukumr, A., Malhi, P., Ravindra, K., Lakshmi, P.V.M., 2020. Exposure to household air pollution during first 3 years of life and IQ level among 6-8-year-old children in India – A cross-sectional study. Sci. Total Environ. 709, 135110. https://doi.org/10.1016/j.scitotenv.2019.135110.

Bruce, N., Perez-Padilla, R., Albalak, R., 2000. Indoor air pollution in developing countries: a major environmental and public health challenge. Bull. World Health Organ. 78, 1078–1092.

Carter, D.B., Signorino, C.S., 2010. Back to the future: modeling time dependence in binary data. Polit. Anal. 18 (3), 271–292.

Chafe, Z., Brauer, M., Klimont, Z., Van Dingenen, R., Mehta, S., Rao, S., 2013. Household cooking with solid fuels contributes to ambient PM2.5 air pollution and the burden of disease. Environ. Health Perspect. 122 (12), 1314–1320.

Coelho, S.T., Goldemberg, J., 2013. Energy access: lessons learned in Brazil and perspectives for replication in other developing countries. Energy Policy 61, 1088–1096.

DeFries, R., Pandey, D., 2010. Urbanization, the energy ladder and forest transitions in India's emerging economy. Land Use Policy 27 (2), 130–138.

Edgar, C., Sarah H., John C., Abdel-Rahmen, L., & Luca, T. 2014. "Estimating the impact on poverty of Ghana's fuel subsidy reform and a mitigating response." PEP working paper series 2014-02, 1-33.

El Universo, 2017. Medardo Cadena: Hay que revisar subsidio eléctrico [Medardo Cadena: There is a need for electricity subsidy reform]. El Universo. Available online: https://www.eluniverso.com/noticias/2017/10/15/nota/6430621/hay-que-revisar-subsidio-electrico.

Ezzati, M., Kammen, D.M., 2002. The health impacts of exposure to indoor air pollution from solid fuels in developing countries: knowledge, gaps, and data needs. Environ. Health Perspect. 110 (11), 1057–1068.

Gall, E.T., Carter, E.M., Matt Earnest, C., Stephens, B., 2013. Indoor air pollution in developing countries: research and implementation needs for improvements in global public health. Am. J. Public Health 103 (4), e67–e72.

Gould, C.F., Schlesinger, S., Ochoa Toasa, A., Thurber, M., Waters, W.F., Graham, J.P., Jack, D.W., 2018. Government policy, clean fuel access, and persistent fuel stacking in Ecuador. Energy Sustain. Devel. 46, 111–122.

Guta, D.D., 2014. Effect of fuelwood scarcity and socio-economic factors on household bio-based energy use and energy substitution in rural Ethiopia. Energy Policy 75, 217–227.

Haby, M.M., Chapman, E., Clark, R., Galvão, L.A.C., 2016. Energy interventions that facilitate sustainable development and impact health: an overview of systematic reviews. Rev. Panamer. Salud Pública 39, 200–207.

Hanung, B., Muhammad, A., 2011. Providing cleaner energy access in Indonesia through the megaproject of kerosene conversion to LPG. Energy Policy 39 (12), 7575–7586.

Health Effects Institute. 2019. State of Global Air 2019. Data source: Global Burden of Disease Study 2017. Institute for Health Metrics and Evaluation, 2018.

Hillerbrand, R., 2018. Why affordable clean energy is not enough. a capability perspective on the sustainable development goals. Sustainability 10 (2485), 1–14.

IEA, IRENA, UNSD, World Bank, WHO. 2021. Tracking SDG 7: The Energy Progress Report. World Bank, Washington DC.

IEG, 2020. Renewable Energy: Evaluation of the World Bank Group's Support for Electricity Supply from Renewable Energy Resources, 2000–2017. World Bank, Washington DC.

Jennings, P., 2009. New directions in renewable energy education. Renew. Energy 34 (2), 435–439.

Kandpal, T.C., Broman, L., 2014. Renewable energy education: a global status review. Renew. Sustain. Energy Rev. 34, 300–324.

Kojima, M., 2011. The Role of Liquefied Petroleum Gas in Reducing Energy Poverty. World Bank, Washington, D. C.

Liao, H.a., Tang, X., Wei, Y.-M., 2019. Solid fuel use in rural China and in health effects. Renew. Sustain. Energy Rev. 60, 900–908.

Liu, T., Song, Y., Chen, R.u., Zheng, R., Wang, S., Li, L., 2020. Solid fuel use for heating and risks of breast and cervical cancer mortality in China. Environ. Res. 186, 109578. https://doi.org/10.1016/j.envres.2020.109578.

Maji, P., Kandlikar, M., 2020. Quantifying the air quality, climate and equity implications of India's household energy transition. Energy Sustain. Devel. 55, 37–47.

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

McLean, E.V., Bagchi-Sen, S., Atkinson, J.D., Ravenscroft, J., Hewner, S., Schindel, A., 2019b. Country-level analysis of household fuel transitions. World Devel. 114, 267–280.

Meng, W., Zhong, Q., Chen, Y., Shen, H., Yun, X., Smith, K.R., Li, B., Liu, J., Wang, X., Ma, J., Cheng, H., Zeng, E.Y., Guan, D., Russell, A.G., Tao, S., 2019. Energy and air pollution benefits of household fuel policies in northern China. PNAS 116 (34), 16773–16780.

Moomaw. 2008. "Renewable Energy and Climate Change An Overview." IPCC Scoping meeting on renewable energy sources In: Proceedings of Lubeck Meeting, 20-25 January, 4.

Muller, C., Yan, H., 2018. Household fuel use in developing countries: review of theory and evidence. Energy Econ. 70, 429–439.

Nazif-Muñoz, José.I., Spengler, J.D., Arku, R.E., Oulhote, Y., 2020. Solid fuel use and early child development disparities in Ghana: analyses by gender and urbanicity. J. Exposure Sci. Environ. Epidemiol. 30 (4), 698–706.

OECD. 2000. Voluntary Approaches for Environmental Policy: An Assessment, OECD Publishing, Paris, https://doi.org/10.1787/9789264180260-en.

OECD. 2003. Voluntary Approaches for Environmental Policy: Effectiveness, Efficiency and Usage in Policy Mixes, OECD Publishing, Paris, https://doi.org/10.1787/9789264101784-en.

Osano, A., Maghanga, J., Munyeza, C.F., Chaka, B., Olal, W., Forbes, P.B.C., 2020. Insights into household fuel use in Kenyan communities". Sustain. Cities Soc. 55, 102039. https://doi.org/10.1016/j.scs.2020.102039.

Pachauri, S., Jiang, L., 2008. The household energy transition in India and China. Energy Policy 36 (11), 4022–4035.

Pan American Health Organization. 2018. "Workshop report: toward the elimination of the use of solid fuels and kerosene in urban homes in the Americas." 11-14 Sep 2018, Mexico City, Mexico. Executive summary. https://www.paho.org/hq/index.php?option=com_docman&view=download&slug=workshop-toward-the-elimination-of-the-use-of-solid-fuels-and-kerosene-in-urban-homes-in-the-americas&Itemid= (Accessed date: 09 November 2020).

Qiu, Y., Yang, F.-A., Lai, W., 2019. The impact of indoor air pollution on health outcomes and cognitive abilities: empirical evidence from China. Populat. Environ. 40 (4), 388–410.

Rahut, D.B., Ali, A., Behera, B., 2017. Domestic use of dirty energy and its effects on human health: empirical evidence from Bhutan. Int. J. Sustain. Energy 36 (10), 983–993.

Rahut, D.B., Ali, A., Mottaleb, K.A., Aryal, J.P., 2019. Wealth, education and cooking-fuel choices among rural households in Pakistan. Energy Strategy Rev. 24, 236–243.

Rajkumar, S., Young, B.N., Clark, M.L., Benka-Coker, M.L., Bachand, A.M., Brook, R.D., Nelson, T.L., Volckens, J., Reynolds, S.J., L'Orange, C., Good, N., Koehler, K., Africano, S., Osorto Pinel, A.B., Peel, J.L., 2019. Household air pollution from biomass-burning cookstoves and metabolic syndrome, blood lipid concentrations, and waist circumference in Honduran women: a cross-sectional study. Environ. Res. 170, 46–55.

Ravindra, K., Kaur-Sidhu, M., Mor, S., John, S., 2019. Trend in household energy consumption pattern in India: a case study on the influence of socio-cultural factors for the choice of clean fuel use. J. Clean. Product. 213, 1024–1034.

Rosenthal, J., Quinn, A., Grieshop, A.P., Phillarisetti, A., Glass, R.I., 2017. Clean cooking and the SDGs: integrated analytical approaches to guide energy interventions for health and environment goals. Energy Sustain. Devel. 42, 152–159.

Sehjpal, R., Ramji, A., Soni, A., Kumar, A., 2014. Going beyond incomes: Dimensions of cooking energy transitions in rural India. Energy 68, 470–477.

Semple, S., Apsley, A., Wushishi, A., Smith, J., 2014. Commentary: switching to biogas – What effect could it have on indoor air quality and human health? Biomass Bioenergy 70, 125–129.

Septin, A., Rosie, D., Steven, E., 2019. A successful fuel transition? Regulatory instruments, markets, and social acceptance in the adoption of modern LPG cooking devices in Indonesia. Energy Res. Soc. Sci. 58, 1–10.
SICA, 2009. Sustainable Energy Strategy for Central America 2020. CEPAL, SG-SICA, Central American Integration System.
Slaski, X., & Thurber, M. C. 2009. "Three key obstacles to cookstove adoption (And How to Overcome Them)." Global Village Energy Partnership International, December, 37-40.
Smith, K.R., Rogers, J., Cowlin, S.C., 2005. Household Fuels and Ill-Health in Developing Countries: What Improvements can be Brought by LP Gas? Environmental Health Sciences, School of Public Health University of California, Berkeley.
Stevenson, G., 1989. The production, distribution, and consumption of fuelwood in Haiti. J. Devel. Areas 24 (1), 59–76.
Tamire, M., Addissie, A., Kumie, A., Husmark, E., Skovbjerg, S., Andersson, R., Lärstad, M., 2019. Respiratory symptoms and lung function among ethiopian women in relation to household fuel use. Int. J. Environ. Res. Public Health 17 (1), 41.
Thakur, M., van Schayck, C.P., Boudewijns, E.A., 2019. Improved cookstoves in low-resource settings: a spur to successful implementation strategies. NPJ Primary Care Respiratory Med. 29 (1), 36.
Troncoso, K., Segurado, P., Aguilar, M., Soares da Silva, A., 2019. Adoption of LPG for cooking in two rural communities of Chiapas, Mexico. Energy Policy 133, 1–10.
Troncoso, K., Soares da Silva, A., 2017. LPG fuel subsidies in Latin America and the use of solid fuels to cook. Energy Policy 107, 188–196.
Tükenmez, M., Demireli, E., 2012. Renewable energy policy in Turkey with the new legal regulations. Renew. Energy 39 (1), 1–9.
WB-ESMAP, 2010. Central America Regional Programmatic Study for the Energy Sector: General Issues and Options. World Bank, Washington, D. C.
WHO. 2013. Population using solid fuels (estimates): Data by country. Global health observatory data repository. World Health Organization. Available online: http://apps.who.int/gho/data/node.main.
WHO, 2018. Household air pollution and health. World Health Organization. Available online: http://www.who.int/en/news-room/fact-sheets/detail/household-air-pollution-and-health.
Wolf, J., Mäusezahl, D., Verastegui, H., Hartinger, S.M., 2017. Adoption of clean cookstoves after improved solid fuel stove programme exposure: a cross-sectional study in three Peruvian Andean regions. Int. J. Environ. Res. Public Health 14 (7), 745.