



BURNING OPPORTUNITY:

Clean Household Energy for Health, Sustainable Development, and Wellbeing of Women and Children

BURNING OPPORTUNITY:

Clean Household Energy
for Health, Sustainable
Development, and Wellbeing of
Women and Children

WHO Library Cataloguing-in-Publication Data

Burning opportunity: clean household energy for health, sustainable development, and wellbeing of women and children.

1.Air Pollution, Indoor. 2.Environmental Exposure. 3.Household Products – adverse effects. 4.Conservation of Natural Resources 5.Women 6.Child. I.World Health Organization.

ISBN 978 92 4 156523 3

(NLM classification: WA 754)

© **World Health Organization 2016**

All rights reserved. Publications of the World Health Organization are available on the WHO web site (www.who.int) or can be purchased from WHO Press, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland (tel.: +41 22 791 3264; fax: +41 22 791 4857; e-mail: bookorders@who.int).

Requests for permission to reproduce or translate WHO publications –whether for sale or for non-commercial distribution– should be addressed to WHO Press through the WHO website (www.who.int/about/licensing/copyright_form/en/index.html).

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by the World Health Organization in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

All reasonable precautions have been taken by the World Health Organization to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall the World Health Organization be liable for damages arising from its use.

Cover photo: SEWA, the Self Employed Women's Association, helps women learn to build and repair solar lanterns in areas where no electricity exists, India (Credit: Annie Griffiths/National Geographic Creative/Corbis)

Design and layout: Paprika

Printed in Luxembourg

Contents

Acknowledgements	v
Abbreviations	vi
Foreword.....	vii
Executive summary	viii
1. A health crisis.....	ix
2. Gender inequities in energy use and fuel gathering	ix
3. Energy access is key to sustainable development	x
4. Limited access to clean energy.....	x
5. Widespread use of polluting kerosene	x
6. Data gaps hinder progress	xi
7. The need for a gender-responsive research agenda	xi
8. WHO leadership.....	xii
9. Climate benefits of clean household air	xiii
10. Accelerating action.....	xiii
1 Introduction: a global health crisis in the home.....	3
The energy–gender–health nexus.....	3
Energy access: a global development imperative and opportunity.....	4
WHO’s agenda to accelerate action for clean air	7
Purpose of report: informing action	8
2 The health impacts of household air pollution.....	15
How household air pollution damages human health.....	15
Disease burden in numbers.....	16
Labored breaths.....	18
Conclusions	19
3 A global snapshot of energy access	25
The clean cooking roster	25
The messy, complex reality of fuel stacking.....	26
What drives sustained adoption and use?.....	28
Household energy analyses	29
Cooking energy use – analyses.....	30
Heating energy use – analyses.....	45
Lighting energy use – analyses.....	50
WHO’s agenda to accelerate action for clean air	59
4 The heavy burdens of household energy.....	63
Gender roles and fuel collection.....	63
Fuel collection by children – analysis	66
Proportion of children collecting wood or water	66
How much time is lost to wood and water collection?	67

5 The climate benefits of clean household energy	73
The climate impacts of household air pollution	73
Clean energy and climate resilience	77
6 The opportunity.....	81
Key conclusions.....	81
The way forward.....	84
The role of WHO and its international partners.....	85
A call to action.....	89
Annex 1: WHO regions.....	91
Annex 2: Additional notes on methodology.....	93
Cooking fuel analysis	93
Global aggregate analysis of clean and polluting cooking fuels.....	93
Regional analysis of individual cooking fuels	94
Lighting analysis.....	94
Heating analysis.....	94
Methodology for analysis of firewood or water collection time	94
Annex 3: Summary of recommendations from WHO guidelines for indoor air quality: household fuel combustion (2014)	96
Specific recommendations	96
Implementation of the guidelines	99
Annex 4: country data for household cooking fuels.....	100
Annex 5: country-level data on household heating.....	105
Annex 6: country-level data on household lighting.....	106
Annex 7: country-level data on wood and water gathering.....	108
References.....	110

Acknowledgements

The main contributors to this report were Heather Adair-Rohani (World Health Organization, WHO), Jessica Lewis (WHO Consultant), Jonathan Mingle (WHO Consultant), and Sophie Gummy (WHO). Project oversight was provided by Maria Neira (WHO) and Carlos Dora (WHO). Significant peer review and additional technical contributions were provided by Verena Brinkman (EnDev, Deutsche Gesellschaft für Internationale Zusammenarbeit, GIZ), Nigel Bruce (University of Liverpool), Marie-Noel Brune Drisse (WHO), Ariel Charney (WHO Consultant), Joy Clancy (University of Twente, Energia), Dan Dorner (International Energy Agency), Rachael Freeth (Department for International Development, United Kingdom), Carsten Hellpap (EnDev, GIZ), Marlis Kees (GIZ), Vanessa Lopes Janik (Energy Sector Management Assistance Program), Helen Patech (United States Agency for International Development), Marit Viktoria Pettersen (Ministry of Foreign Affairs, Government of Norway), Annette Prüss-Ustün (WHO), Elisa Puzzolo (Global LPG Partnership, University of Liverpool), Jennifer Rasanathan (WHO Consultant), Ivan Vera (UN Department of Economic and Social Affairs), Joanna Vogel (WHO), Adrian Whiteman (International Renewable Energy Agency), Blake Zachary (ICF International) and Tony Zhang (WHO Intern).

This document draws upon the discussion at an international meeting of experts: *Meeting on Indicators for Household Energy Use, Gender and Health*, hosted by the World Health Organization in October 2015. We would like to acknowledge the contributions made by representatives from the Centers for Disease Control and Prevention; Energia; International Center for Research on Women; George Washington University; Ghana Health Services; Global Alliance for Clean Cookstoves; Global LPG Partnership; ICF International; Integrated Public Use Microdata Series, International; Inter-American Development Bank; International Institute for Applied Systems Analysis; International Union for Conservation of Nature; John Hopkins University; National Institutes of Health; National Statistical Offices of Botswana, India, Philippines, and United Republic of Tanzania; Pan American Health Organization; Self-Employed Women's Association, India; UNEP; UNICEF; University of Liverpool; and the World Bank.

This material has been funded by UKaid from the Government of the United Kingdom of Great Britain and Northern Ireland; however, the views expressed do not necessarily reflect the official policies of the UK Government.

The document was copy-edited by Susan Kaplan.

Abbreviations

ABPP	Africa Biogas Partnership Programme
ALRI	acute lower respiratory infection
AFR	African Region
AMR	Region of the Americas
BSP	Biogas Sector Partnership
CCAC	Climate and Clean Air Coalition
COPD	chronic obstructive pulmonary disease
DFID	Department for International Development
DHS	Demographic and Health Surveys (USAID)
EMR	Eastern Mediterranean Region
EUR	European Region
GACC	Global Alliance for Clean Cookstoves
GAPPD	Global Action Plan for the Prevention and Control of Pneumonia and Diarrhoea
GNI	gross national income
GTF	Global Tracking Framework
HAP	household air pollution
HFC	hydrofluorocarbon
IARC	International Agency for Research on Cancer
IAEG	Intra-Agency Expert Group
IAQ	indoor air quality
IEA	International Energy Agency
IFC	International Finance Corporation
IPUMS	Integrated Public Use Microdata Series
ISO	International Organization for Standardization
LMICs	low- and middle-income countries
LPG	liquefied petroleum gas
LSMS	Living Standard and Measurement Survey (World Bank)
MDG	Millennium Development Goal
MICS	Multi-Cluster Indicator Survey (UNICEF)
NCD	noncommunicable diseases
PM	particulate matter
PNG	piped natural gas
RCT	randomized controlled trial
SDG	Sustainable Development Goal
SEAR	South-East Asia Region
SE4All	Sustainable Energy For All Initiative
SLCP	short lived climate pollutant
SSA	sub-Saharan Africa
SE4ALL	Sustainable Energy for All
UN	United Nations
UNICEF	United Nations Children's Fund
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
VOC	volatile organic compound
WHA	World Health Assembly
WHO	World Health Organization
WHS	World Health Survey
WPR	Western Pacific Region

Foreword

Today, more than 3 billion people worldwide rely on polluting energy sources such as wood, dung and charcoal for cooking. Almost 1 billion rely on kerosene lamps and other polluting devices to light their homes.

The health implications of this are terrible. Women inhale thick smoke for hours on end as they prepare meals for their families and tend fires to keep the home warm. Children, the elderly and other vulnerable people also suffer disproportionately because, like women, they spend more time in the home than men. In 2012, more than 60% of all premature deaths from household air pollution were among women and children.

It is imperative these people have the opportunity to replace polluting fuels with clean sources of household energy. Not only will this benefit their health, it will also advance sustainable development and reduce the emission of climate-affecting greenhouse gases.

Unfortunately, progress towards this goal is currently far too slow. As this report highlights, the use of polluting fuels and inefficient energy devices in the home is actually more widespread than previously estimated, with even greater health impacts. For the first time, the authors take account of the health risks from the use of kerosene, which is a highly polluting fuel.

They also present new data on the time-consuming and back-breaking work required to gather fuel. Most of it is performed by women and children, who in the process are exposed to the risk of injury and violence. Girls in households that cook with polluting fuels were found to spend 18 hours a week on average gathering fuel compared to five hours a week in those that use clean fuels – time that could be spent in education or at play.

The health inequities that result from household air pollution are stark and tragic. It causes almost half a million of women's deaths each year from chronic obstructive pulmonary disease, while many more die from other noncommunicable diseases related to household smoke. Half a million children under five die each year from pneumonia caused by exposure to household air pollution. These women and children are killed by the everyday act of breathing, in what should be the "safety" of their own homes.

These facts are a call to action for the global community, because household air pollution signals a missed opportunity on a vast scale – an enormous amount of human potential lost to illness, injury, drudgery and premature death. By replacing polluting fuels with clean sources of energy in their homes, people can lead more healthy, productive lives. Clean fuels will allow them to meet their basic needs of cooking, heating and lighting, while also creating and maintaining a safe living environment.

Sustainable Development Goal 7 calls for universal access to "affordable, reliable, sustainable and modern energy" by 2030, ending energy poverty that prevents almost half of humanity from reaching its full potential. By expanding access to clean household energy, at affordable prices, the global community can improve the health and well-being of billions. In parallel this will advance the sustainable development agenda by creating healthy urban environments, fighting climate change and enabling equity and gender equality.

To achieve these ends we need more comprehensive data on heating, lighting and other energy uses, and more gender-sensitive surveys and programme design to better understand how women and girls are affected. We need better insights into why people decide to use different types of household energy, and how access to clean energy can benefit all members of the household. Dramatically increased investment and strategic cooperation across sectors are required to make clean fuels more available and to make existing fuels cleaner (such as wood, charcoal and other biomass).

The global community has the power to rid the world of household air pollution, accelerate progress across the entire sustainable development agenda and lift a terrible burden from millions of marginalized people. A burning opportunity now exists to extend access to clean sources of energy to every person on the planet. We should waste no time, and spare no effort, in seizing it.



Flavia Bustreo

Dr. Flavia Bustreo
Assistant Director-General
Family, Women's and Children's Health
World Health Organization

EXECUTIVE SUMMARY

There is a global consensus and an ever-growing body of evidence that expanding access to clean household energy for cooking, heating and lighting is key to achieving a range of global priorities, such as improving health, gender equality, equitable economic development and environmental protection. In September 2015, Member States of the United Nations (UN) adopted the Sustainable Development Goals (SDGs), including Goal 7, which seeks to “ensure access to affordable, reliable, sustainable and modern energy for all” by 2030 and would be measured as the percentage of the population relying primarily on clean fuels and technology.

This and other important developments, such as the UN Secretary-General’s Sustainable Energy for All (SE4All) campaign show that prospects have never been brighter

for cleaning up air in and around the home, throughout the world.

However, success is not guaranteed. The new analyses stemming from the WHO Household energy database demonstrate that progress towards the goal of universal access remains far too slow: more than three billion people still rely on polluting, inefficient energy systems to meet their daily cooking needs. And too many depend on polluting fuels and devices for heating and lighting.

These key findings, which are described below, lead to an urgent, inescapable conclusion: the global community must redouble its efforts to expand and accelerate access to clean energy. In so doing, we have an unprecedented opportunity to eliminate an enormous health burden that currently weighs down nearly half the world, especially its women and children, and thereby free up a vast amount of human potential.



*A young girl carries a load of biomass in Gatlang, Nepal.
Credit: Practical Action/Nigel Bruce*

1. A HEALTH CRISIS

Household air pollution (HAP) is driving a global health emergency.

Household air pollution is the single most important environmental health risk factor worldwide. Based on estimates of solid fuel use for cooking in 2012, exposure to HAP causes 4.3 million premature deaths each year. Of those deaths, 3.8 million are caused by noncommunicable diseases (NCDs): HAP is estimated to cause 25% of all deaths from stroke, 15% of deaths from ischaemic heart disease, 17% of deaths from lung cancer, and more than 33% of all deaths from chronic obstructive pulmonary disease in low- and middle-income countries (LMICs). HAP exposure is responsible for close to one quarter of the disease burden from cataract, the leading cause of blindness in LMICs.

Women and children are at a particularly high risk of disease from exposure to HAP. Sixty percent of all premature deaths attributed to household air pollution occur in women and children. Women experience higher personal exposure levels than men, owing to their greater involvement in daily cooking and other domestic activities. The single biggest killer of children aged under five years worldwide is pneumonia. This disease cuts short almost a million young lives each year. More than 50% of those pneumonia deaths are caused by exposure to HAP.

HAP has other important impacts on disease and disability. Emerging evidence links exposure to HAP with risk for other adverse health outcomes, such as low birth weight and stillbirths, cervical cancer, tuberculosis, asthma, ear and upper respiratory infections, and with nasopharyngeal and laryngeal cancers.

Improving health in urban environments depends in part on addressing pollution from household fuel burning. In India, for example, new research estimates that almost 30% of outdoor air pollution is from household sources.

Globally, household energy is an important source of outdoor air pollution as well. HAP from cooking is responsible for 12% of global ambient fine particulate matter pollution (PM_{2.5}), and is estimated to cause some 500 000 of the 3.9 million premature deaths each year attributable to outdoor air pollution. Clean household energy is therefore important for reducing the heavy burden of disease from outdoor air pollution as well.

2. GENDER INEQUITIES IN ENERGY USE AND FUEL GATHERING

Women and girls are the primary procurers and users of household energy services, and bear the largest share of the health and other burdens associated with reliance on polluting and inefficient energy systems. Owing to the considerable amount of time spent in proximity to polluting combustion sources, women and children are at particularly high risk of disease from exposure to HAP. Dependence on polluting fuel and technology combinations can also lead to other negative health impacts that disproportionately affect women and children, particularly girls. These include burns, injuries, poisonings, cataracts, chronic headaches and many other adverse outcomes. Women and girls are the primary gatherers of fuel for cooking in most LMICs. They face safety risks associated with fuel collection and preparation, and significant constraints on their available time for education, rest and productive activities for income generation.

New analyses find that reliance on polluting fuels and technologies is associated with significant drudgery and time loss for children – especially girls. Data on wood and water gathering from 30 countries show that both boys and girls in clean fuel-using households spent less time gathering wood or water than those from homes cooking mainly with polluting fuels. Girls living in households that cook mainly with polluting fuels bear the greatest time-loss burden collecting wood or water. Analysis of surveys from a range of African countries shows that in households that primarily cook with polluting fuels, there are high rates – above 70% – of children collecting wood or water. Both boys and girls spend a substantial amount of time in this task – but girls are more likely to gather fuel than boys, and girls spend more time collecting wood or water than boys do. In most of the countries reviewed, children of both sexes who collect wood or water spend at least 15 hours a week on these tasks, and in some countries they spend more than 30 hours per week.



Children show off solar powered lanterns that they use at night when they do their homework for school in Tondo, Manila.
Credit: Corbis/Sherbien Dacalanio/Demotix

3. ENERGY ACCESS IS KEY TO SUSTAINABLE DEVELOPMENT

Expanding access to clean cooking, heating and lighting unlocks progress across the entire sustainable development agenda. Closing the energy access gap is now a firmly fixed priority on the global sustainable development agenda. Accelerating access to clean energy presents an enormous opportunity to make progress toward several SDGs, and exploit the synergies currently offered by initiatives that encompass energy, gender, health and climate change, including SE4All, the Global Alliance for Clean Cookstoves (GACC) and the Climate and Clean Air Coalition (CCAC).

SDG 7 sets an ambitious target for ensuring universal access to clean household energy by 2030. The 2030 Agenda for Sustainable Development reflects new understanding and emerging consensus that household energy is not only the province of environment and energy ministries, but a central concern in almost every facet of human development, from health (SDG 3) to sustainable urban environments (SDG 11) to gender equality (SDG 5) to climate action (SDG 13).

4. LIMITED ACCESS TO CLEAN ENERGY

WHO's new focus on tracking use of "polluting" and "clean" fuels and technologies enables more complete estimates of the health and other impacts of household energy use. In light of the new WHO *Indoor air quality guidelines: household fuel combustion*, WHO has transitioned to a new indicator, tracking the use of "clean" and "polluting" fuels and technologies for cooking, heating and lighting.



Clean and polluting fuels and technologies are often 'stacked' for daily cooking activities, as in this home, where a traditional stove and LPG stove are both in use.
Credit: Jessica Lewis

The focus of the previous household energy indicator and reporting was on "solid" fuels used as the primary cooking fuel, as a practical surrogate for dirty fuels used in the home. The new indicator – used to track progress towards SDG 7 – is based on scientific evidence of the health risks associated with the full range of household energy end-uses beyond cooking, including space heating and lighting.

This indicator captures the health impacts of kerosene use, and of fuel-stove stacking – the use of multiple fuels and devices in parallel for different purposes. Its focus on polluting fuel and technology combinations will enable a more complete and accurate understanding of the scope of the health challenge posed by HAP. It also facilitates identification of specific opportunities for displacing polluting cooking, lighting and heating systems and mitigating their health impacts.

According to new analysis of data from the WHO Global Household Energy database, around 3.1 billion people in LMICs rely on polluting fuels and technologies for cooking. More than 50% of households in all 128 LMICs surveyed use biomass as their primary cooking fuel. These analyses demonstrate that significant differences in energy use patterns exist among the different regions, and between urban and rural areas around the world. According to the new analysis, over 20% of urban households surveyed rely primarily on polluting fuels and technologies, while the ratio is reversed in rural areas, where around 80% rely on polluting fuels and technologies. Survey estimates from 18 countries in the WHO African Region show that more than 95% of all households rely primarily on biomass for cooking. In south-east Asia, biomass is the most common primary fuel used by households for cooking (62%), followed by gaseous fuels (32%). These statistics can inform specific tailored policies at the regional, country, and subnational level to reduce dependence on polluting cooking systems.

There is a severe lack of data on heating fuel use. Fewer than 40 surveys provide reliable data on primary heating fuels; only 14 were conducted in LMICs. The available data show, however, that there are several countries in different parts of the world where kerosene, a polluting fuel, is an important source of energy for space heating.

5. WIDESPREAD USE OF POLLUTING KEROSENE

Kerosene is a polluting fuel: WHO recommends that governments and practitioners immediately stop promoting its household use. New WHO guidelines provide the first definitive guidance

on what counts as “clean” household energy. In November 2014, WHO issued the first-ever health-based normative guidance for household fuel combustion. The WHO *Indoor air quality guidelines: household fuel combustion* include emissions rate targets for fuel and stove combinations that can be considered clean for health, and recommendations against the use of unprocessed coal and discouraging the use of kerosene as household fuels.

Based on extensive evidence reviews, the guidelines are intended to help policy-makers accelerate access to clean fuels and technologies, and advance optimal interim technologies such as efficient biomass-burning stoves. The indoor air quality (IAQ) guidelines are an important tool for planning effective energy, development and public health policy, as they steer stakeholders away from polluting fuels, such as kerosene and unprocessed coal, and towards solutions that are truly clean and beneficial for health.

New analyses show that kerosene is still widely used for lighting in most LMICs, and in certain countries it is also an important polluting heating and cooking fuel. About one third of households in LMICs depend on polluting fuels (mostly kerosene) for lighting. In the WHO African Region, based on the latest survey data (which cover 71% of the population), 53% of households use kerosene and oil lamps as their primary lighting source. In the South-East Asia Region – where 79% of the population was covered by the surveys analysed – 32% of households rely on kerosene and oil lamps as their primary lighting source. India has more people using kerosene for lighting than the nine next highest kerosene-using countries combined, at almost 400 million people.

The reclassification of kerosene as a polluting fuel changes our understanding of access to clean energy dramatically in some countries.

For example, new analysis shows that over 80% of households in Djibouti use kerosene as their primary source of energy for cooking. Under the previous indicator, Djibouti seemed close to achieving universal access to modern energy. This new assessment shows that the country has much further to go before all of its citizens have access to truly clean energy – and thereby, access to clean air.

New estimates of the burden of disease from kerosene use in the household – based on assessments of the relative risks and exposures associated with its use – will be produced as part of WHO’s burden of disease estimates.

Recent reports demonstrate that solar lighting systems and solar lanterns are being more widely disseminated in many LMICs. However, there are few data available on their durability and sustained

use, or on whether these technologies are being used alongside other polluting lighting sources.

6. DATA GAPS HINDER PROGRESS

Data collection efforts must be improved to inform effective, targeted interventions. Significant data gaps impede global progress towards cleaning up air in and around the home, especially in LMICs. A lack of detailed data – on heating and lighting energy use, on gender roles and decision-making within the household, and on the gender-related determinants of health inequities – makes it impossible to properly target the use of finite resources to reduce health risks and end energy poverty. These data gaps must be quickly addressed. More coordinated action is needed to develop, harmonize and deploy better survey instruments and indicators.

Harmonized questions on household surveys are urgently needed in order to gain a more complete understanding of the range of health, development, and environmental consequences of household energy use, and to enable the comparison and validation of data across countries. Survey instruments must also be enhanced to capture more detailed information on energy use for heating and lighting, as well as on fuel stacking practices and intra-household decision-making.

More research is needed into the adoption and sustained use of energy interventions, including user preferences, behaviour change and complex factors of decision-making.

Substantial benefits for climate and the environment could be obtained through improving access to clean household energy. Rigorous monitoring and evaluation is essential to track the adoption of those interventions that are effective for improving health – and to identify areas that need more focused efforts. The same holds true for verifying the potential economic benefits and climate benefits of clean household energy fuels and technologies. International collaboration between WHO, SE4ALL partners, UNICEF Multiple Indicator Cluster Surveys, USAID Demographic and Health Surveys and national statistical offices play an important role in tracking progress toward clean energy.

7. THE NEED FOR A GENDER-RESPONSIVE RESEARCH AGENDA

Critical data are missing on the gender dynamics of household energy use and the gender determinants of related health risks.



Women gather to bake bread in a dung-fired oven in front of a home in Zaskar, India.
Credit: Jonathan Mingle

Gender roles are major determinants of decision-making about energy in the household.

Adoption and sustained use of clean energy solutions hinge on a better understanding of these intra-household dynamics, and of sex-specific impacts and opportunities related to involvement in the energy value chain.

Universal energy access cannot be achieved without more gender-responsive programmes and policies – which in turn require better data collection and targeted indicators. To address the crisis of HAP, programmes and policies must explicitly take into account the gender dynamics influencing household decision-making, energy acquisition and use, and livelihoods. To inform successful interventions, we need a more robust understanding of the interests and involvement of both women *and* men when it comes to energy.

The relative power of women and men in household decision-making is a critical and often overlooked factor in the adoption and sustained use of clean fuels and technologies. Many household energy programmes, surveys, and research studies have historically been blind to the critical importance of gender roles, both within the household and within societies. Women are typically the primary acquirers and users of energy in the home, and are the ones who would benefit most from switching to cleaner fuels for cooking and other uses in the home.

The relative lack of empirical evidence on gender, household energy use and health impacts, has impeded the development and implementation of policies and interventions to promote clean and safe household energy. Policy-makers, health planners and those in charge of public health programming need relevant data to characterize the disparities in health status between and among populations of women and

men. Gender statistics reflect questions, problems and concerns related to specific issues that affect one sex more than the other or which stem from gender relations. Even when health data are disaggregated by sex, many indicators do not reflect the complex interconnections between gender as a health determinant and the resulting health inequities among and between women and men. A critical first step in ameliorating gender-based health inequities is to measure those differences and their determinants with gender-sensitive indicators, to provide a better understanding of the complex interconnections between gender and household energy.

8. WHO LEADERSHIP

The health sector has an important role to play at multiple levels in the fight to reduce HAP. Building on the work of WHO for over a decade, there is an enormous opportunity waiting to be seized to improve public health around the globe, through the development of comprehensive action plans to tackle HAP at the national level. National governments can reduce the burden of NCDs and childhood pneumonia in their populations by formulating and implementing detailed plans and policies for taking action to clean up household air. Promising models and pilot efforts should be identified for testing and scaling up. Country-level strategies will need to take stock of the emerging evidence on effective interventions, local circumstances, including strengths of institutions and service capacity, as well as opportunities for finance, and delivery mechanisms. WHO provides global tracking of household energy use (i.e. for cooking, heating and lighting) and its health impacts through the WHO Household energy database and the Global Health Observatory. WHO will continue to expand its own efforts to engage the health sector, support planning and programme delivery at the national level, and promote research to address critical data gaps. WHO is increasingly focusing on working with country-level agencies on developing and providing specific tools to support their development of national action plans to address the HAP crisis.

WHO regional offices, such as South-East Asia, have already adopted a resolution to intervene to reduce indoor air pollution as part of their strategy to prevent NCDs. Actors working to reduce NCDs should engage much more actively in efforts to reduce HAP through clean household energy interventions, in view of the substantial impact of air pollution on NCDs and of the high levels of exposure to air pollution in the home. Child survival and other objectives of the Global Strategy for Women's, Children's and Adolescent's Health, launched by the UN Secretary-General and

world leaders, alongside the SDGs in 2015, can be advanced through targeted action to improve household energy, which has the potential to substantially reduce the number of pneumonia deaths and help prevent close to half of the one million annual deaths from chronic obstructive pulmonary disease in women caused by HAP. Targeting household energy is a key element of the Global Strategy for Women's, Children's and Adolescent's Health 2016–2030.

9. CLIMATE BENEFITS OF CLEAN HOUSEHOLD AIR

Reducing HAP offers an unparalleled opportunity to realize climate and health co-benefits. Household fuel combustion is a significant source of both greenhouse gases and short-lived climate pollutants such as black carbon.

Household combustion is estimated to produce 25% of global emissions of black carbon, which is the second largest contributor to climate change after carbon dioxide (CO₂), and disrupts regional environmental systems critical to human welfare. As the most strongly light-absorbing component of particulate matter, black carbon absorbs a million times more energy per unit mass than CO₂ – but it exerts its impact over a much shorter period.



A woman spreads dung to dry for fuel in the shadow of glacier-covered peaks of the Khumbu Valley, Nepal.
Credit: Jonathan Mingle

Although black carbon is a significant contributor to global climate change, its impacts are especially magnified on a regional scale, in areas close to the source of emissions. Because of black carbon's short lifespan in the atmosphere (of the order of days to weeks), reducing its emissions can lead to immediate slowing of warming.

Eighty-four per cent of all black carbon emissions from household combustion come from developing countries. Within Asia and Africa, residential solid fuel use accounts for 60–80% of total black carbon emissions. Particulate emissions from kerosene are almost 100% black carbon. Kerosene burned for lighting is the source of 270 000 tonnes of black carbon per year, contributing the warming equivalent of 240 million tonnes of CO₂.

Accelerating access to clean energy for cooking, heating and lighting can have an immediate beneficial impact in reducing local warming and avert a significant amount of atmospheric warming in the next few decades, as well as protecting vulnerable systems such as the Arctic and high mountain glaciers.

10. ACCELERATING ACTION

Encouraging progress is being made, but the current global transition from polluting to clean household energy use is proceeding too slowly. To date, international and national policies, programmes and targeted interventions have advanced solutions, but have failed to substantially alter long-term trends. Too many people in LMICs continue to lack access to affordable, life-saving clean energy systems.

Several decades of research, national stove programmes and international initiatives have yet to lead to a significant reduction in the population depending on polluting fuels and technologies to meet their daily energy needs. Roughly the same number of people today cook with polluting energy systems as did 30 years ago. Population growth has outstripped incremental progress in increasing access to clean, modern energy systems. If current trends continue, the total number of people relying on polluting cooking energy will remain roughly the same in 2030 as it is today. The World Bank projects that by 2030, only 72% of the global population will have access to modern energy services for clean cooking – well short of the universal target by 2030.¹

¹ International Energy Agency (IEA) and the World Bank (2015). Sustainable Energy for All 2015 – Progress toward sustainable energy (June). Washington (DC): World Bank. doi: 10.1596/978-1-4648-0690-2.

The global community must redouble its efforts, and accelerate the pace of its response to this crisis. The level of historical investment in technology development for clean delivery of household energy services is a pittance compared to the estimated value of their potential benefits. Dramatically expanded investment, research and development are needed to develop breakthrough innovations in clean household cooking, heating and lighting.

To achieve the SDG 7 target of universal access by 2030, two parallel efforts should be continued and accelerated. One is the ongoing project of making energy solutions that are clean for health at the point-of-use – gas, electricity, biogas, and others – more widely available, especially among the poor in the developing world.

The other is the task of creating the next generation of efficient stoves that can cleanly burn biomass fuels – fuels that are already widely available in many parts of the world. Supporting research and development of such innovative, low-emissions technologies to provide household energy services should be a top priority for the global development agenda.

Without increased ambition and investment, more effective targeted policies and interventions, and a greater sense of urgency, the global community will miss the target of universal access by 2030. And with it, we will miss an enormous opportunity to improve human health, slow down climate change and lift some of the heaviest burdens from the most vulnerable among us.



*A girl in Mombasa, Kenya with the solar lantern that lets her study at night.
Credit: Corbis/Andrew Aitchison/In Pictures*



Solar panels catch the sun to power homes in Hyderabad, Pakistan.
Credit: Corbis/Rajput Yasir/Demotix



*Doratea, 5, does her homework as her lunch, consisting of corn tortillas, is toasted on an open flame on the outskirts of Chiquimula, Guatemala.
Credit: REUTERS/Daniel LeClair*

01

INTRODUCTION: A GLOBAL HEALTH CRISIS IN THE HOME

“ More than half of all households in low- and middle-income countries rely on polluting energy to meet their daily cooking needs. ”

1 INTRODUCTION: A GLOBAL HEALTH CRISIS IN THE HOME

A hot meal. A warm room. Light by which to read or work at night.

These needs are universal. For about half of humanity, meeting them requires paying a monthly bill, and simply flipping a switch or turning a knob. Modern fuels and technologies – such as gas and electric stoves, heaters and lights – free these people to turn their own energy to other productive pursuits.

But for the other half, meeting those daily needs demands far more effort, expense and exposure to risk – especially for women and girls, who are the primary users of household energy around the world. The heat that cooks their rice or warms their room comes from burning wood hauled from kilometres away, or coal purchased with scarce income. The light cast by their simple lamps is often fuelled by kerosene, which can be costly and dangerous to handle.

And for these three billion people, all this burning can turn the home – which ought to be a place of safety and refuge – into one of the most health-damaging environments.

Combustion of fuels like biomass, coal, and kerosene in traditional stoves, open fires, and wick lamps can produce large quantities of dangerous pollutants, from carbon monoxide to particulate matter to volatile organic compounds. In dwellings with poor ventilation, emissions of fine particulate matter and other pollutants can reach 100 times the levels recommended as safe by WHO guidelines.

This household air pollution (HAP) is the single largest environmental risk factor for health worldwide: it caused 4.3 million premature deaths in 2012.

This global crisis is the tragic consequence of acts of survival performed in hundreds of millions of homes around the world every day. The health risks of HAP are determined by, and are themselves perpetuators of, poverty. The vast majority of these preventable deaths occur in low- and middle-income countries (LMICs), in households that lack access to clean alternatives or the resources to purchase them.

The energy-gender-health nexus

The heaviest burdens of this widespread dependence on polluting and inefficient energy fall on women and children, as they are the ones who spend the most time in and around the home, breathing in smoke from these inefficient fires.

Women and children accounted for over 60% of all premature deaths from HAP in 2012. For women in LMICs, HAP is the single leading cause of noncommunicable diseases (NCDs) like stroke, chronic obstructive pulmonary disease (COPD), lung cancer and heart disease. HAP causes over half of all pneumonia deaths in children under the age of 5 years. Children are also frequent victims of burns and poisonings from accidents involving kerosene stoves and lamps.

Gender roles in the household – including who does the cooking and other domestic work, who works outside the home, who makes decisions about buying fuels and appliances, and other differences in behaviours between men and women – are major determinants of relative health risks (WHO 2015a). Of all risk factors for human health analysed in the most recent Global Burden of Disease study, HAP was the second-largest overall for women and girls. In sub-Saharan Africa, HAP exposure was the single greatest health risk for women and girls. For men worldwide, HAP was the fifth biggest risk factor, after tobacco smoking, alcohol use and high blood pressure (Lim et al., 2012).

Reliance on polluting and inefficient energy systems imposes other heavy burdens too. In many parts of the world, people depend on fuel that they can gather freely, for use in traditional stoves and open fires. And in many – although not all – societies, traditional gender norms often assign the tasks of collecting and preparing this fuel to women and girls. In many places, boys are expected to earn income in the future, justifying the time investment in their education. Consequently, girls must stay at home, and are tasked with hauling water and wood.

Fuel collection entails much physical effort, and exposes women and girls to a host of risks. Those who carry wood in large bundles on their backs or heads over a lifetime can develop spinal conditions and chronic

headaches. Out in the forest or on back roads, they are susceptible to injuries, animal attacks and threats of physical and sexual violence.

These tasks carry an enormous time cost. One recent study across 22 African countries found that women and girls spend an average of two hours each day just collecting fuel (Kammila et al., 2014). The never-ending job of feeding the stove prevents many girls from attending school, and keeps many women from pursuing opportunities to improve their livelihoods in ways that could help raise themselves and their families out of poverty. The daily tedium of collecting, processing and then using these fuels in inefficient devices also robs women and girls of time to spend in rest, socializing or simple leisure – a profound benefit of modern energy sources like gas and electricity that is often taken for granted by the half of the world that uses them.

Many aspects of the serious health and other impacts on women and girls – who are, in most LMICs, the primary providers and users of energy in the household – are not extensively studied. If these impacts are not adequately measured, interventions designed to alleviate them are less likely to be properly targeted and monitored to maximize health and other benefits. Indeed, some studies have suggested that the “slow transition to modern energy services in some regions is,

in part, intertwined with a failure to address the gender dimensions of energy poverty” (Pachauri & Rao, 2013). Closing the energy access gap hinges in large part on filling these data gaps. An urgent priority is improving and expanding the evidence base on gender roles and the gender-specific impacts related to energy use in the household. Enhanced data collection efforts will inform the development of better targeted, more effective interventions and programmes to reduce reliance on polluting, inefficient fuels and technologies, and thereby advance human development on almost every front.

Energy access: a global development imperative and opportunity

In 2016, with so many people leading lives of unprecedented comfort and opportunity, it is remarkable that more than three billion people still face an impossible choice: breathe easy, or live without hot meals, warmth and light.

Millions die each year from exposure to HAP – but it is just as true to say that their deaths are caused by energy poverty. Most of the people relying on these polluting fuels and technologies live in poor, rural



WOMEN AND CHILDREN

accounted for over 60% of all premature deaths from HAP in 2012.



A girl covers cow dung patties with hay to store them for cooking fuel on the outskirts of Lahore, Pakistan.
Credit: REUTERS/Mohsin Raza

households in the developing world. They use these fuels because they lack access to clean, affordable, convenient alternatives such as electricity, gas, biogas and other low-emission fuels and devices.

Because merely venting smoke outdoors can still expose certain populations to significant levels of pollution, what is needed most are clean solutions at the point-of-use. Improving combustion efficiency reduces the amount of pollution emitted from a cooking, heating or lighting fire, and can therefore reduce the exposure to HAP. Technologies that provide essential energy services without any combustion at all – such as solar-powered light-emitting diode (LED) lanterns for lighting – are the safest of all.

Given a choice, those who depend on polluting energy sources would make the switch to clean fuels and technologies, much as residents of today's developed countries traded coal stoves for gas burners, and oil lamps and candles for electricity and light bulbs, almost a century ago. But, to date, policies, programmes and targeted interventions have largely failed to make these life-saving technologies more widely available, accessible and affordable in many LMICs.

This can, and must, change. This report arrives at a moment of unprecedented awareness of the role of household energy in enabling and contributing to all facets of human development. The fact that some 3 billion people still burn fuels the way humans

did many thousands of years ago is increasingly and rightly regarded as unacceptable – and a fundamental impediment to humanity's shared aspirations for progress and equitable development.

Closing the energy access gap is now a firmly fixed priority on the global sustainable development agenda – as two recent actions amply demonstrate. In a galvanizing, unprecedented step in May 2015, the World Health Assembly unanimously adopted a resolution on air pollution and health, calling for increased cross-sectoral cooperation and the integration of health concerns into national, regional and local air pollution-related policies. And in September 2015, Member States of the United Nations (UN) adopted the Sustainable Development Goals (SDGs), including Goal 7, which seeks to “ensure access to affordable, reliable, sustainable and modern energy for all” by 2030.

There has recently been a surge in momentum towards achieving this ambitious goal. Several global initiatives are pursuing targets for expanding clean energy use in households. WHO and the United Nations Children's Fund (UNICEF)'s Global Action Plan for the Prevention and Control of Pneumonia and Diarrhoea (GAPPD) aims to save up to 2 million children every year from deaths caused by those two diseases, and includes a core focus on improving indoor air quality. The Global Alliance for Clean Cookstoves (GACC), launched in 2011 by the United Nations Foundation, is helping to build a market ecosystem to deliver clean cooking solutions to 100 million households by 2020 (Cordes, 2011).



Girls gather around the tank of a household biogas system used for cooking in rural Nepal.
Credit: WHO/Heather Adair-Rohani



A girl with a new solar light distributed by SolarAid in East Africa.
Credit: Ashden Awards

One of the three core goals of the Sustainable Energy for All (SE4All) initiative – a multi-stakeholder partnership between governments, the private sector and civil

society, co-chaired by the Secretary-General of the UN and the World Bank – is focused on achieving universal access to modern energy services for cooking, heating, lighting and other end uses. SE4All facilitates the sharing of best practices, scaling up of private investment, and transparent tracking of progress towards universal access to clean energy. Its Global Tracking Framework (GTF) uses a multi-tiered approach to describe different levels of access to energy, and helps diagnose and inform interventions to move people up the “ladder” of those tiers. In October 2013, SE4All and the World Liquid Petroleum Gas Association announced a joint goal of transitioning one billion people from traditional fuels to liquefied petroleum gas (LPG).

These strategic partnerships and investments reflect a new understanding of energy as a “nexus” issue, strongly interconnected with other global priorities such as health, gender equality, equitable economic development and environmental protection. Indeed, extending access to clean energy offers an unprecedented opportunity to unlock progress on multiple elements of the 2030 Agenda for Sustainable Development, including poverty alleviation (SDG 1), improved health and well-being (SDG 3), gender equality (SDG 5), good livelihoods and economic opportunity (SDG 8), sustainable urban environments (SDG 11), climate action (SDG 13) and more (Figure 1).

Figure 1. Household energy connects many Sustainable Development Goals.



Meanwhile, the past few years have witnessed a surge in innovation in the household energy sector, in terms of technology, financing and business models. In sub-Saharan Africa, solar lanterns and home lighting systems are spreading rapidly, displacing dangerous kerosene lamps. From Kenya to Nepal, emerging entrepreneurs and partnerships are developing and disseminating affordable clean energy solutions, based on a more nuanced understanding of the preferences, needs and aspirations of their intended users.

Given all these developments, the prospects have never been brighter for cleaning up indoor air around the world. However, as the analyses in this report demonstrate, progress still remains too slow to achieve universal access by 2030. This leads to one inescapable conclusion: we must leverage all of this momentum and this moment, and redouble our efforts to expand and accelerate access to clean energy. By doing so, we have an unprecedented opportunity to eliminate an enormous health burden that currently weighs down nearly half the world, and thereby free up a vast amount of human energy and potential.

WHO's agenda to accelerate action for clean air

Mainstreaming household energy and air quality into the global public health agenda

WHO is advancing awareness of reducing HAP as a core preventive public health measure on multiple fronts, including various global forums addressing maternal and child health issues.

A focus on HAP is an important component of the action plan for the control of noncommunicable diseases (NCDs) in the WHO South-East Asia Region, where NCDs are the leading cause of death. The action plan target is a 50% reduction in the proportion of households where solid fuel is used as the primary energy source for cooking. WHO is providing technical support and research for evaluating interventions aimed at reducing HAP, and facilitating sharing of best practices among the Region's Member States. Reducing HAP is also a key element of the Every Woman, Every Child campaign launched by UN Secretary-General Ban Ki-moon in 2010, which aims to intensify international and national action to alleviate the health risks for women and children around the world. Its goals include reducing by one third premature mortality from NCDs in women, children and adolescents by 2030. Improving indoor air quality is also one of the five key strategies for preventing pneumonia in children laid out in the Integrated Global Action Plan

for the Prevention and Control of Pneumonia and Diarrhoea (GAPPD). The GAPPD provides a roadmap for national governments and their partners to plan and implement integrated approaches for the prevention and control of pneumonia and diarrhoea. One of the GAPPD's goals is to reduce the incidence of severe pneumonia by 75% in children less than 5 years of age compared to 2010 levels, by 2025. Multiple studies suggest that steep reductions in HAP can significantly reduce the risk of severe pneumonia.

WHO is integrating resources for promoting clean household energy into global child health initiatives and decision-support tools for use by Member States' health ministries and other organizations. WHO is also working with partners at country-level survey agencies, as well as administrators of global household surveys such as MICS, Living Standards Measurement Studies and DHS, to develop, field test and refine new questions about household energy use. To date, inconsistencies in the design of questions and responses used in various surveys have hampered coordinated monitoring of progress towards energy access, and comparison of data across countries. Using harmonized indicators and questions on national and international household surveys will enable a more complete understanding of the range of health, development and environmental consequences of household energy use. As women and girls bear most of the burden of relying on polluting fuels, and are the primary users of household energy, there is an especially urgent need to collect more gender-relevant information.

In order to develop and refine indicators and survey questions along these lines, in October 2015 WHO convened a meeting of experts in data collection on household energy, survey design and implementation, gender indicators, health and livelihood impacts, representatives from statistical bureaus in various countries, and representatives from the World Bank, the Global Alliance for Clean Cookstoves and other international institutions. Valuable progress was made towards developing a detailed set of harmonized indicators and survey questions on household energy use and health impacts. In the wake of the meeting, field testing of recommended survey questions is being conducted in several countries, including Ghana and Belize. WHO is also supporting efforts to build the capacity of local researchers and public health practitioners to measure exposure and health outcomes, and assess the efficacy of various interventions. This will inform the finalization of questions and modules for use in relevant national and global household surveys, and possibly in other monitoring efforts, including the Global Tracking Framework of the SE4ALL initiative. These updated survey tools will

reflect the new SDG indicator's focus on "clean fuels and technologies", and help capture a more complete picture of different energy activities in the household.

Purpose of report: informing action

This report addresses some key questions:

- What do we know about the current state of access to clean and polluting fuels and energy devices in households in the developing world?
- What do we know about the specific health and other impacts of reliance on clean and polluting fuels, respectively, for women and children?
- Where are the data gaps? What are the areas –

such as fuel use for space heating or time spent collecting fuel – where better empirical evidence is needed?

- How can we collect more accurate, detailed, useful data to inform policies and interventions to work towards achieving universal access to clean, safe, modern energy by 2030?

Drawing on the most up-to-date data from the WHO Global Household energy database and nationally representative surveys, this report offers a snapshot of the current energy access situation in LMICs. Whereas previous analyses have focused almost exclusively on "solid fuel" use for cooking, this report includes a comprehensive analysis of access to energy, fuels and technologies for cooking, heating and lighting (see Box 1).



An Afghan girl carries home a new gas stove.
Credit: REUTERS/Fayaz Kabli

BOX 1 – Benchmarks for better burning

New indicators to track clean energy progress

To effectively track progress in improving health and reducing poverty, indicators that help us make meaningful and accurate measurements and estimates are essential. So how should we measure progress toward the universal clean energy access target of SDG 7?

During the Millennium Development Goal era, the household energy indicator used in large-scale surveys and monitoring efforts was “percentage of population with primary reliance on solid fuels for cooking”. Since most demographic surveys include some questions on “primary” fuels used, this was a practical proxy on which to base estimates of the health risks of exposure to HAP. But new evidence has demonstrated the serious limits of this indicator. Measuring use of “solid fuels” for cooking alone does not capture the full range of health and other impacts from polluting household energy sources, nor does it allow for new innovations in efficient biomass-burning technologies to be considered as a healthy household energy solution.

In October 2015, the International Working Group of the SDG Intra-Agency Expert Group (IAEG) recommended a new indicator to track progress towards SDG 7 – “percentage of population with primary reliance on clean fuels and technologies at the household level” where “clean” is defined by the recommendations included in the *WHO Guidelines for indoor air quality: household fuel combustion* (See Box 2). Following the IAEG review, which includes the recommended disaggregation of all indicators (by sex, rural/urban, and other categories), the indicator will be submitted to the UN Statistical Division for final approval in March 2016. WHO has accordingly transitioned to using the categories of “clean” and “polluting” fuels and technologies in its monitoring and reporting of rates of energy access, in addition to its regular reporting on the percentage of the population primarily relying on solid fuels.

This new indicator expands the end uses considered beyond cooking to include heating and lighting – both significant sources of HAP. It focuses on fuel–technology combinations, since real combustion performance and emissions depend on the interaction of fuel and device,

not just on the particular fuel used. For example, burning a “modern” fuel like liquefied petroleum gas in the wrong stove can produce significant amounts of pollution. Likewise, processed biomass fuels like pellets and briquettes can burn relatively cleanly in stoves designed for their use, but burn incompletely in traditional stoves.

It also reflects new understanding of the health risks associated with the use of kerosene, a nonsolid but nevertheless polluting fuel. And it enables tracking of intermediate progress in the development and adoption of transitional technologies such as high-efficiency biomass cookstoves, which – if demonstrably clean – can improve health outcomes while using a potentially renewable energy resource.

As a binary indicator, this indicator remains an imperfect proxy – a useful but inherently limited tool. Like most indicators, it represents a compromise, balancing the imperative of capturing more detailed information on the full range of energy end uses in the household, with more pragmatic considerations, such as the feasibility of conducting surveys and eliciting reliable information from respondents about their everyday use of different fuels and devices. Indeed, use of the word “primary” itself is a compromise, as “secondary” fuels and technologies can be major sources of pollution. There are other drawbacks too. This indicator cannot yield information about the gendered nature of the impacts and decision-making related to household energy use. It cannot capture trends in sustained adoption or detailed information about the availability, affordability and reliability of various technologies and fuels in different settings. Other indicators and survey modules must be developed and used to track these other critical aspects of household energy use.

Despite these limitations, the new benchmarks represent a significant step forward, reflecting the new understanding that focusing on fuels for cooking alone is inadequate to generate an accurate picture of all the burning that takes place in and around the home, of the resulting pollution and exposures, and of the health consequences for billions of people.

Building on WHO’s recently issued *Indoor air quality guidelines: household fuel combustion* (see Box 2), this report also presents and summarizes new aggregated data on the health impacts of exposure to HAP, as well as other risks associated with the use of polluting sources of energy in the home, such as those related to fuel collection. It highlights the gaps in our understanding of the implications of household

energy use for the health and livelihoods of women and girls, and identifies areas that are systematically under-measured and under-represented in the design, implementation and monitoring of energy access interventions. It also suggests ways to address these gaps, through improved data collection to inform effective policies at the global, national, and subnational levels.

The report also summarizes evidence of the climate impacts of HAP, and the opportunities for realizing health and climate co-benefits through expanding access to clean energy. Finally, the report notes the need for improved, harmonized survey methodology to measure and track progress towards goals, and reviews and recommends changes in related

indicators for tracking progress on SDGs for energy, gender and health.

In summary, this report sheds new light on where and how progress is being made, and where, as a global community, we are falling short of the effort and investment required to provide clean energy to all by 2030.



Women in Zaskar, India comb the mountainsides for yak, cow and sheep dung to use as fuel for cooking and heating.
Credit: Jonathan Mingle

BOX 2 – WHO guidelines for indoor air quality: household fuel combustion

New standards for clean burning in the home

For decades, household energy experts, researchers and policy-makers focused on developing and disseminating so-called “improved” stoves to deliver health and environmental benefits. But what does “improved” mean? “Improved” relative to what, and based on what criteria? And how low do reductions in pollution from stoves and other devices need to go to achieve meaningful health benefits?

A lack of clarity on these questions, borne of a lack of standard protocols for cookstoves and other household energy devices, has frustrated efforts to promote solutions that achieve measurable improvements in health. Cleaning up indoor air is impossible without a clear definition of what is “clean” at point-of-use.

In November 2014, WHO issued its first ever *Guidelines for indoor air quality: household fuel*

combustion. Based on exhaustive evidence reviews of the health impacts of HAP, these guidelines specify absolute and interim targets for emissions rates for carbon monoxide and fine particulate matter from household fuels and energy devices. They also include recommendations against the use of unprocessed coal for cooking and heating, and against the use of kerosene. These fuels are simply too dirty and dangerous to burn. WHO recommends that governments and practitioners immediately stop promoting their use.

The WHO IAQ guidelines for household fuel combustion provide the technical basis for developing a common terminology for describing and communicating the performance of “clean” cooking and other energy systems – a critical step for improving the performance of currently available technologies.

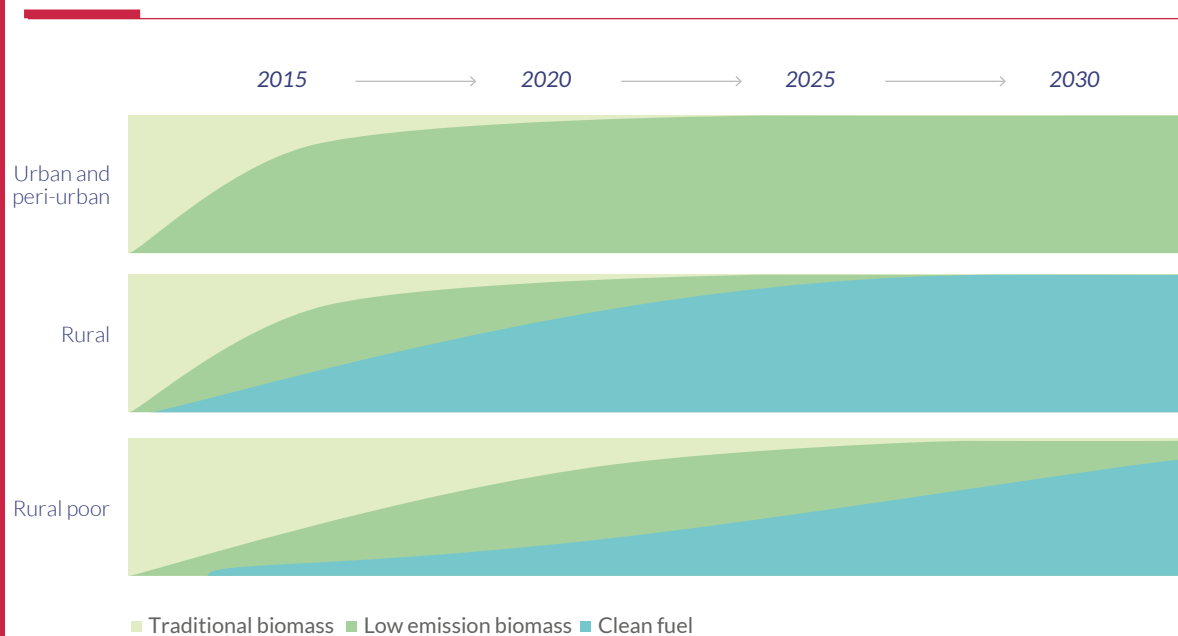


*Cornmeal cooks for breakfast in La Loma, in the eastern Seibo province, Dominican Republic.
Credit: REUTERS/Ricardo Rojas*

The guidelines also offer intermediate targets that recognize the challenge, in many settings, of making the “leap”, all at once, from polluting to clean fuels and technologies. Better biomass-burning stoves – while not yet able to deliver emissions reductions

in line with WHO-recommended limits– can be an important step towards cleaning up indoor air. These targets accordingly offer a benchmark by which to measure incremental progress towards healthy, clean household environments (Figure 2).

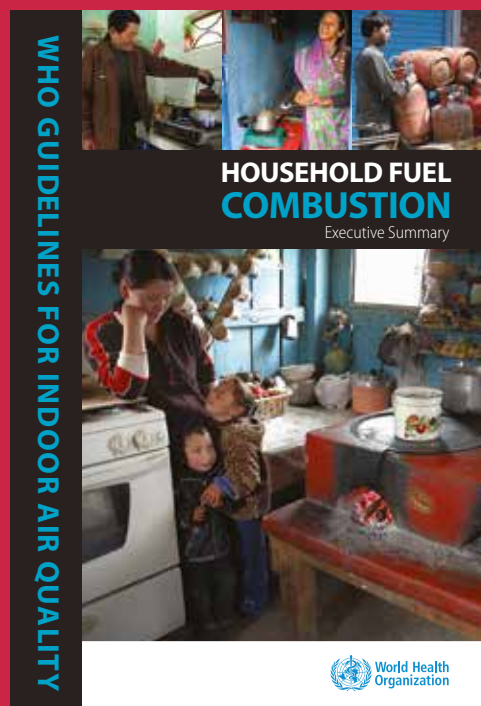
Figure 2. Hypothetical scenarios for rates of transition from traditional biomass use to low-emissions biomass and clean fuels across different groups



Note: This figure shows the anticipated role for low-emission biomass stoves in rural areas before a transition to clean fuels.

An “improved” stove may perform better in terms of fuel efficiency over the baseline of a traditional stove, but it may not produce low enough emissions at point-of-use to result in meaningful health benefits. So what is the difference between an “improved” stove and a “clean” stove? Quite simply, any device – whether it uses a more modern fuel such as gas or electricity, or a forced-draft stove that burns biomass – is considered “clean” if its emissions are in line with the WHO guidelines (See Annex 3).

Putting these new guidelines into practice will require increasing the capacity of local and regional testing centres to evaluate stove performance under various “real world” conditions. In partnership with the Global Alliance for Clean Cookstoves and other institutions, new testing and knowledge centres have been established from Ghana to Nepal. WHO is also providing technical support to country-level health ministries and other agencies in conducting research and needs assessments, evaluating interventions and designing policies to expand access to clean energy solutions that meet these air quality guidelines.





*A girl cooks dinner for her family by candlelight in a makeshift shelter in Palo Leyte, Philippines.
Credit: REUTERS/Athit Perawongmetha*

A man wearing a dark cap and a light-colored shirt is working in a kitchen. He is looking down at a counter where there are various items, including a white box. The background is dimly lit, showing shelves with jars and other kitchen items. A large white box is overlaid on the image, containing the number '02' and the title 'THE HEALTH IMPACTS OF HOUSEHOLD AIR POLLUTION'.

02

.....

**THE HEALTH
IMPACTS OF
HOUSEHOLD AIR
POLLUTION**

“ Household air pollution is an emergency demanding urgent, coordinated action on multiple levels: hearth, home, country and planet. ”

2 THE HEALTH IMPACTS OF HOUSEHOLD AIR POLLUTION

The human health toll of HAP is, by any measure or comparison, staggering. It is a global disaster unfolding quietly, on a daily basis, around the globe.

How household air pollution damages human health



A woman, who is the primary cook in her household, takes a spirometry test to measure her lung function in a clinic in Odisha, India.

Credit: Jessica Lewis

Fine particles, carbon monoxide, methane, carcinogenic polyaromatic hydrocarbons (PAH), volatile organic compounds (and many other substances) can all be found streaming out of a hearth fire or stove, in different quantities. And all are toxic to human beings in different ways, and to varying degrees.

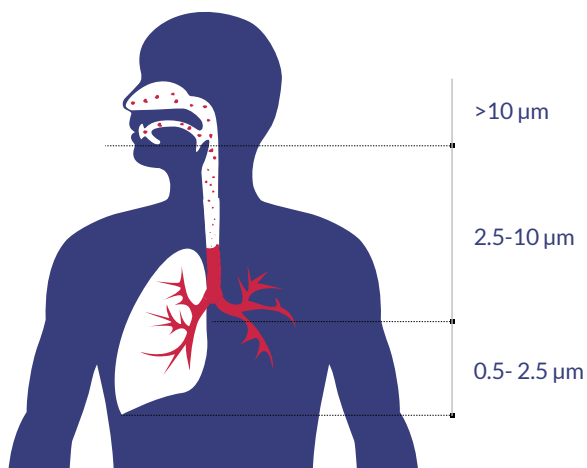
Of these, the pollutant most commonly and robustly associated with health impacts is particulate matter (PM). Although it is difficult to identify the precise mechanisms by which PM damages human health, numerous studies have demonstrated a direct relationship between exposure to PM and adverse outcomes such as inflammation and oxidative stress.

Generally, the smaller the particle, the more dangerous it is. Coarser particles (such as dust or pollen) tend to be captured in the nasal cavity, upper airways or thoracic cavity. Smaller-diameter particles (PM_{2.5} or smaller) can reach deeper into the smaller airways of the body and deposit on the alveoli – the tiny sacs in the lungs where oxygen exchanges with carbon dioxide in the blood (Figure 3). (The burden of disease estimates are based on the exposure–response functions for exposure to PM_{2.5}, or particulate matter less than 2.5 microns in diameter.) There is less conclusive evidence about the impacts of ultrafine particles (one micron in diameter or less), but their ability to penetrate into tissues and organs suggests they are likely to pose an even greater risk of systemic health impacts. In addition to particle size, chemical composition, concentration and surface area are also important factors.

Black carbon is a fine particulate produced by household fuel combustion. Some recent studies suggest that it may also be a better indicator than PM_{2.5} of the entire bundle of toxic particles emitted from an inefficient fire. Several health studies have found that black carbon is associated with a 7–10-times higher risk per microgram per cubic metre than PM_{2.5} (Kinney, 2015). More research is needed, but some studies suggest that black carbon is a better indicator of cardiovascular effects than other forms of PM. One possible reason may be that black carbon rarely travels alone: other toxic chemicals can “piggyback” on it. (See Climate Benefits section for a discussion of black carbon’s climate impacts.)

Because HAP is a complex, ever-changing stew of particles, gases and other chemical compounds, it is difficult to differentiate and pinpoint the precise impacts of individual constituents. The specific ways in which pollutants produced by household combustion affect specific systems in the body demand much further study. Short-term exposure to high levels of pollution probably results in different adverse outcomes than long-term, chronic exposure to low concentrations. But regardless of the uncertainty surrounding specific mechanisms, there is robust epidemiological evidence that exposure to HAP is a significant health risk, in both the near and the long term.

Figure 3. Smaller PM particles penetrate deeper into the lungs



SMOKY HOMES

Household air pollution threatens the most vulnerable



GENDER

Gender roles and gender-specific behaviours are a determinant of health risks worldwide

Disease burden in numbers

According to the most recent burden of disease estimates by WHO, HAP from cooking is responsible for 4.3 million premature deaths each year (WHO, 2016) – equivalent to 7.7% of global mortality, which is more than the toll from malaria, tuberculosis and HIV/AIDS combined (Figure 4). Measured in years of healthy life lost attributable to it, HAP is the single most important environmental health risk factor worldwide, more important even than lack of access to clean water and sanitation. These terrible distinctions make HAP perhaps the most overlooked, widespread health risk of our time.

HAP from cooking causes one quarter of all global deaths from stroke, 17% of adult lung cancer deaths, and 15% of deaths from ischaemic heart disease. It is also responsible for almost one third of all deaths from chronic obstructive pulmonary disease (COPD) in LMICs. All told, it is responsible for 3.8 million premature deaths annually from NCDs (including stroke, ischaemic heart disease, COPD and lung cancer). HAP is likely to be the most important cause of COPD in non-smokers.



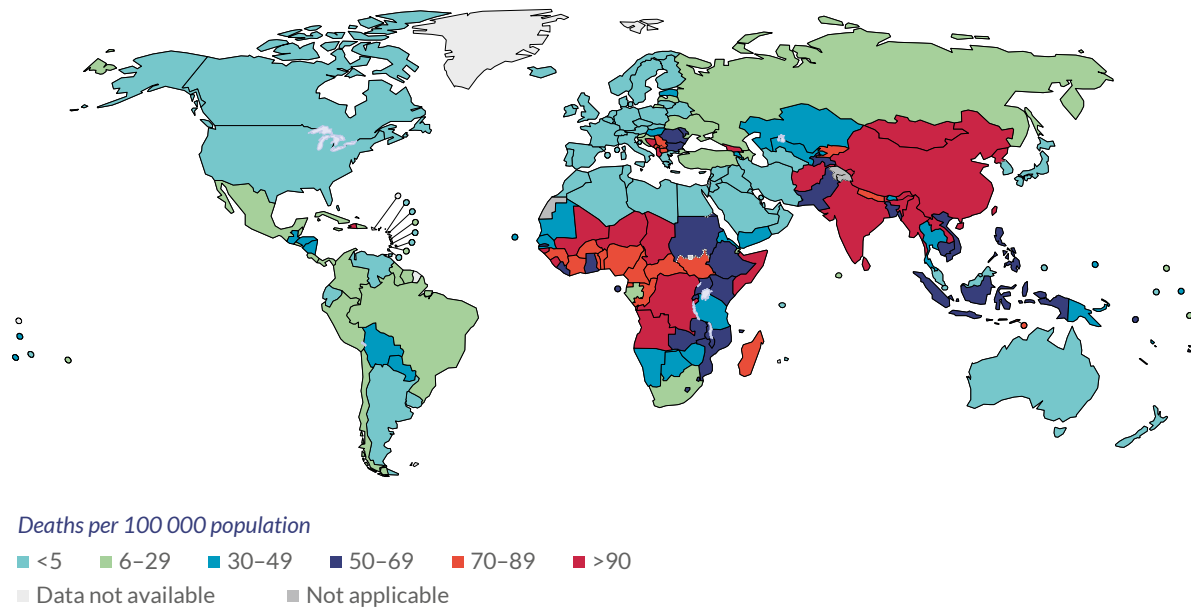
HEALTH TOLL

HAP is responsible for 3.8 million premature deaths annually from NCDs



A child, displaced by fighting in the Democratic Republic of Congo, sits in front of a three-stone fire fed by twigs, in a border area of Uganda. Credit: REUTERS/James Akana

Figure 4. Map of deaths per 100,000 population, per year, attributable to HAP from polluting cooking energy use in 2012



There is emerging, but still tentative evidence that HAP increases the risk of other important health problems, such as asthma, ear and upper respiratory infections, tuberculosis, nasopharyngeal and laryngeal cancers, cervical cancer, low birthweight and stillbirths. A number of epidemiological studies offer strong evidence that HAP is associated with cataract formation – which is the main cause of blindness in adults in developing countries (Bruce & Smith, 2014).

This immense burden of disease is not distributed evenly across countries, within countries, or even within households. These health risks are strongly correlated with poverty. For cooking, low-income households tend to depend on solid fuels that can be freely gathered. Most of the premature deaths occur in the “hotspots” of south-east Asia (1.69 million), the western Pacific (1.62 million) and Africa (600 000) (WHO, 2016). India is the country that bears the heaviest burden in absolute terms: almost 800 million people depend on polluting cooking systems, leading to 1.3 million premature deaths from HAP each year.



A displaced Congolese mother prepares a meal at a border transit camp for refugees in Uganda. Credit: REUTERS/Peter Andrews

BOX 3 – From household to outdoor air pollution – and back again

HAP is a major source of outdoor air pollution, as it escapes through chimneys and openings in the building envelope. Depending on factors such as weather and topography, background levels of pollution contributed by other sources, and the density of the population exposed, this indoor smoke can degrade outdoor air quality to unsafe levels. About 12% of global ambient fine particulate matter (PM_{2.5}) comes from cooking with solid fuels (Smith et al., 2014). HAP is estimated to cause some 500 000 of the 3.9 million premature deaths each year attributable to outdoor air pollution (WHO, 2012). (This is just for cooking; the mortality figures would be higher if heating and lighting were included.)

This close linkage between household and outdoor air pollution is one reason why there are limits to the benefits of stove hoods, chimneys and other improved ventilation strategies to move combustion products outside. Ambient air pollution cycles back inside and reduces indoor air quality, as air constantly

flows in and out of the house, through open windows, doors and other gaps. Clean household combustion is therefore a critical but much-overlooked solution to the outdoor pollution crisis.



Smoke rises from fires in the courtyard and kitchen of this home in Odisha, India.

Credit: Jessica Lewis

In most countries, the majority of people using polluting fuels live in rural areas where access to clean alternatives is limited. Within those households, women and children have the highest relative risk of exposure to dangerous pollutants. HAP is the second most important health risk factor for women and girls globally, and is responsible for more than half of the deaths from pneumonia in children under five years old.

Labored breaths

How household air pollution threatens the most vulnerable



Children with respiratory diseases receive treatment at a hospital in Hangzhou, Zhejiang province, China. Credit: REUTERS/China Daily.

For millions of children, exposure to household air pollution (HAP) turns what should be a place of refuge – hearth and home – into one of the most dangerous realms they enter. The single biggest killer of children aged under five years worldwide is pneumonia. This disease cuts short almost a million young lives each year, accounting for 15% of all under-5 child mortality. More than half of those pneumonia deaths are caused by exposure to HAP.

Children spend much of their time in and around the home, and thus have high levels of exposure to fine particles and other products of incomplete combustion (Box 7). It is a terrible, tragic irony: as parents care for their children, keeping them close while they perform routine tasks like cooking, they are also exposing them to deadly risks (Box 4). More than half a million young lives each year are snuffed out by the very same fires lit to sustain them and brighten their days.

Children are particularly sensitive to adverse exposures. Even for those who avoid or survive respiratory illnesses, early exposure to HAP can affect them for the rest of their lives, compromising lung structure and function. Although the lungs go through dramatic changes during the embryonic and fetal stages, this growth and maturation continues after birth until late adolescence. A baby has about 10 million alveoli; at the age of 8 years, a child has 300 million alveoli. Repeated infections and adverse exposures may cause lung alterations later in life (WHO, 2006). Evidence is not conclusive, but some empirical studies suggest that early exposure to HAP might affect children's cognitive development too.

Some children are vulnerable to the household smoke breathed by their mothers even before they are born. There is a need for further research on the links between HAP exposure and adverse pregnancy outcomes, but emerging, and in some cases strong, evidence from epidemiological studies suggests that exposure to HAP contributes to low birthweight, stunting and preterm births. Exposure to toxic pollutants during critical periods of lung development in utero and during early childhood may have effects that would not be observed with exposure later in life. HAP exposure may combine with other exposures that may have similar effects, like moulds or mycotoxins (Dietert et al., 2000).

Although further study is needed of the linkages between exposure to different types and levels of pollution and specific adverse health outcomes, it is clear that clean air in and around the home is essential for the health and well-being of children. If interventions that lower pollution levels to meet WHO IAQ guidelines are widely and rapidly disseminated, the risk of outcomes like low birthweight and acute lower respiratory infection (ALRI) can be substantially reduced (Bruce et al., 2013). Polluting energy exacts a terrible toll on the most vulnerable, but switching to cleaner alternatives can protect them and provide them with a strong start in life.

Box 4 – Gender, childcare and HAP

Cultural attitudes towards gender can strongly influence exposure to HAP and associated health impacts. Citing a study from Gambia (Armstrong & Campbell, 1991) and one from India (Mishra et al., 2000), Margaret Matinga compared divergent outcomes largely driven by different prevalent cultural norms in those two societies around gender roles and childcare:

“(Armstrong & Campbell’s study) found that the risk of pneumonia had an increased association with smoke exposure in girls, but not in boys. This was because girls were kept in kitchen environs with their

mothers until an older age than were boys. They also found that children strapped on their mothers’ backs during cooking were six times more likely to develop Acute Respiratory Infections (ARI) than unexposed children. Strapping children on the back is a common way of carrying them, so that a woman or a young girl can look after the child while working. In India, (Mishra et al., 2001) found that the incidence of fuel-related ARI was higher among boys than among girls. Here, the keeping of boys in the kitchen until a later age was linked to Indian parents’ social preference for male children which results in mothers allocating longer care times to male children.” (Matinga, 2010)

Conclusions

These numbers should shock us all. And yet the number of people who rely on polluting cooking systems to meet their basic needs has not changed appreciably in over three decades. The global community has not treated this problem with an urgency commensurate with its impact. Reducing HAP has not been a global priority until relatively recently.

Why has this crisis largely been overlooked? Perhaps because it is a slow-motion catastrophe: breathing smoke can take years to manifest as an illness. Perhaps because it has the greatest impacts on affects the most marginalized – the rural poor, especially women and children (See Box 6). Perhaps because smoke has long

been such a familiar sign of the warm hearth, regarded as a by-product of survival, a necessary evil.

The evidence clearly shows that HAP is no mere nuisance, but a grave threat to health and well-being, and a serious impediment to equitable global development. The lack of access to clean, affordable alternatives to polluting fuels and technologies consigns billions to daily levels of exposure to smoke in their own homes that would cause most people in the developed world to rush out of the room and call the fire department.

As shocking as these statistics are, being shocked is not enough. HAP is an emergency demanding similarly urgent, coordinated action on multiple levels: hearth, home, country and planet.

BOX 5: Reducing HAP for healthy and sustainable urban environments

Clean household air is key to SDG 11

Reliance on polluting energy systems is not a phenomenon limited to rural areas. HAP is a problem in many urban areas as well. In fact, the goal of creating safe, resilient and sustainable cities (SDG 11) cannot be achieved without addressing the risks posed by HAP.

Although vehicles and industry are the predominant sources of air pollution in most cities, HAP is often a significant contributor. A recent analysis estimates that, across India, household energy consumption contributes 29.6% of ambient $PM_{2.5}$ concentrations and accounts for up to 72 000 of the premature deaths attributed to outdoor air pollution. Many residents of India's capital burn wood, waste or other solid fuels to stay warm in winter; some continue to use these fuels for cooking too. In densely populated South Delhi, the contribution of HAP to outdoor $PM_{2.5}$ is actually higher than the national average, and space heating accounts for two thirds of total household $PM_{2.5}$ emissions (Guttikunda, 2016). In certain parts of Ulaanbaatar, Mongolia, migrants from rural areas live in *ger*, the tents that serve as their homes on the steppe. Ulaanbaatar's average yearly $PM_{2.5}$ concentrations

are at least seven times WHO standards. During Mongolia's harsh winter, many households burn coal or wood for heating (Guttikunda et al., 2013). The resulting smoke contributes to sharp seasonal spikes in the city's outdoor air pollution – which is why a World Bank project is currently helping residents in the outlying *ger* districts of Ulaanbaatar to switch to cleaner-burning stoves and fuels.



A woman cooks on an improvised stove as a train passes through an informal settlement in Dhaka, Bangladesh.
Credit: REUTERS/Andrew Biraj



A woman cooks for her family in Najaf, south of Baghdad, Iraq.
Credit: REUTERS/Alaa Al-Marjani

BOX 6 – The gendered nature of household energy and health

“Gender” is often mistakenly conflated with “having to do with women”. The term “gender” refers to a social construct, one that varies according to different norms and values in different cultures, and which encompasses expected and socially sanctioned roles and behaviours of men and women. As such, gender issues impact both women and men, throughout their lifetimes, and influence their respective opportunities, entitlements and roles in society.

Although women and girls tend to bear most of the health burdens of unclean energy use in the household – and stand to gain the most from access to clean energy – a gender-sensitive approach to the problem means developing a richer understanding of how women, men, girls and boys make decisions about and use household energy.

Gender-responsive programming means going beyond merely counting the number of women participating in a project, or disaggregating household data by sex. It means developing strategies and solutions based on a deeper understanding of the gendered nature of the health burdens linked to household energy use, from the laboured breaths of someone suffering from COPD, to the headaches of a woman who “headloads” 20 kg of wood for her family every day in rural Kenya. The respective and relative social, cultural and historical roles of women and men affect these health outcomes in profound ways, even though they are little studied (Matinga, 2010).

Gender roles and gender-specific behaviours are a determinant of health risks worldwide. To take just one example, men in developing countries tend to work more outside the home than women do; the proportion of the total disease burden attributable to occupational risk factors – injuries that happen on the job or at the workplace – is 18.5 times higher for men than women (Lim et al., 2012). Meanwhile, because women and girls tend to spend the most time working around the home, they suffer from higher exposure to the smoke produced by burning household fuels, and have a higher relative risk for illnesses such as COPD, stroke and respiratory illness.

Gender-sensitive indicators highlight the different status and roles of women and men, which accordingly impact decision-making, health risks and health outcomes. Such indicators can help us capture and track gender-related changes in household energy use and impacts over time. They can also help us focus more precisely on

important areas such as time use, access to information or financing, monthly expenditures by women and men, domestic unpaid care work, labour participation in the formal energy sector, and others.

The lack of empirical evidence and data on gender and household energy presents challenges for the development and implementation of evidence-based, gender-responsive policies and interventions to promote clean and safe household energy. Even when health data are disaggregated by sex, many indicators fail to reflect the complex interconnections between gender as a health determinant and the resulting health inequities among and between women and men. A critical first step in ameliorating gender-based health inequities is to identify, measure and monitor them, and their determinants, with gender-sensitive indicators.

WHO is coordinating an effort to refine and harmonize survey questions, in order to better capture a range of critically important gender-specific information. These include the health impacts of HAP exposure; time use related to gathering and preparing fuel; other health impacts including burns, musculoskeletal injury and poisonings; perceptions of safety and risk of violence associated with fuel collection; purchasing decision-making and other roles within the household; livelihoods, quality of jobs and income generated from involvement in the energy value chain; access to credit and financing for clean energy; and awareness of, access to, and satisfaction with various fuels and energy technologies.

Building this evidence base, and mainstreaming gender-responsive actions into energy programme design and monitoring, will improve the lives of all – women, men, girls and boys.



*A woman prepares cow dung cakes to be used as cooking fuel in a village on the outskirts of Chandigarh, India.
Credit: REUTERS/Ajay Verma.*

BOX 7 – Putting solutions to the test

Randomized trials inform targeted interventions for child health



*A woman in rural Guatemala cooks with an improved wood cookstove equipped with a chimney.
Credit: WHO/Heather Adair-Rohani*

The Randomized Exposure Study of Pollution Indoors and Respiratory Effects (RESPIRE) study was the first randomized controlled trial (RCT) ever to investigate the health effects of cooking interventions. It focused on children in rural homes in the highlands of Guatemala. Half of the more than 500 homes that participated received an improved *plancha* stove with a chimney, while the other half continued to cook with wood on open fires. Researchers tracked the children in the households for 18 months, and found that those in the households with improved *plancha* stoves were exposed to 50% less smoke on average (Smith et al., 2011). But the results for health were mixed: there was no statistically significant reduction in incidence of pneumonia in children up to 18 months of age. There was, however, a significant reduction of one third in the number of physician-diagnosed cases of severe pneumonia. The findings, while not conclusive, suggest that much cleaner-burning stoves may be required to make substantial reductions in the incidence of childhood pneumonia.

An ongoing trial in the Brong-Ahafo region of central Ghana is investigating that very question. Researchers from Columbia University and the Kintampo Health Research Centre have launched a five-year study, the first of its kind in Africa, called the Ghana Randomized Air Pollution and Health Study. They are following more than 1000 pregnant women, assigning each of their households to a control group or to one of two different intervention groups, one of which will receive LPG fuel and stoves, while another will receive the BioLite Home Stove, a new, forced-draft efficient biomass stove. The study will track birthweight and physician-assessed severe pneumonia incidence within the first year of life (Jack et al., 2015).

Other RCTs are ongoing in Nepal and Malawi, assessing whether households with advanced biomass cookstoves have a lower incidence of ALRI and pneumonia, respectively. An RCT being conducted in Nigeria is providing intervention households with bioethanol stoves and gathering data on adverse pregnancy outcomes (GACC, 2014).

Which interventions are clean enough to achieve measurable benefits for the health of mothers and children? Which distribution strategies are most effective? Is providing access to clean fuels and technologies in a given household sufficient to improve the health of children, or must all of its neighbouring households make the switch, too, to meaningfully reduce exposure to HAP?

Carefully designed studies such as these studies will shed light on some possible answers, helping government health officials weigh up whether to include clean cooking systems in the standard prenatal care package for women of childbearing age in low-income countries.



A family eats dinner in a home newly illuminated by solar-powered lights, in the village of Meerwada, Madhya Pradesh, India. Credit: REUTERS/Adnan Abidi

03

A GLOBAL SNAPSHOT OF ENERGY ACCESS

“ Universal energy access cannot be achieved without more gender-responsive programmes and policies – which in turn require better data collection and indicators. ”

3 A GLOBAL SNAPSHOT OF ENERGY ACCESS

How many devices do you use to cook your food and make hot drinks every day? If you stop to count them all, you may be surprised at the variety and amount. Because we eat a wide range of foods, and cook in so many different ways, we typically use a suite of devices tailored to specific tasks. This is as true in the rural households of the developing world as it is in the kitchens of developed countries.

The clean cooking roster



A woman prepares a meal on an electric cookstove in Northern India. Credit: Jessica Lewis

What counts as a “clean” stove or cooking system?



At point-of-use, one of the cleanest fuels in terms of exposure to health-damaging pollutants is **electricity**, whether used to power standard stovetops, specific-use devices such as rice cookers, or induction cookers. When properly used and maintained, **liquefied petroleum gas (LPG)** and **piped natural gas (PNG)** stoves also produce very low levels of emissions of particulate and other by-products of incomplete combustion. Stoves that use **alcohol fuels** and **solar cookers** are also clean for health.



Biogas is a promising alternative that burns as cleanly as LPG and PNG but, as a renewable fuel, has no negative climate impacts. Household biogas systems turn organic material from livestock manure, human waste, or crop residues and food waste into methane and other combustible gases through anaerobic digestion. This gas is then piped into the house and used for cooking, lighting or powering an electric generator. The remaining slurry is a valuable fertilizer that many families sell for income or use on their own agricultural fields. Biogas systems can also improve hygiene and sanitation in homes, by collecting animal and human waste in one location and reducing exposure to harmful pathogens, which get broken down by anaerobic digestion. Biogas has some disadvantages: it requires sustained maintenance, and a reliable supply of waste and water.



Solar cooking devices – including panel, box and parabolic cookers – directly convert the sun’s energy into useful heat. They produce no harmful emissions, and cost nothing to operate, but they tend to require longer cooking times and greater adjustment in user behaviour, and they can only be used during times and seasons when there is adequate sunshine. Hence they can be an appropriate, clean complement to a household cooking system.



Biomass-burning stoves that meet WHO guidelines for emissions rates are still not widely available. New forced-draft biomass stoves offer potential for meaningful fuel savings – an important consideration for many household cooks – as well as reductions in pollution exposures relative to traditional stoves or open fires. Currently, emissions from these stoves are not as clean as those from LPG or electric cooking, and field-based measurements of real-world usage show higher rates of PM_{2.5} and other emissions than in laboratory tests. But further innovation, research and investment may indeed produce affordable biomass stoves that meet the IAQ guidelines.

Given the diversity of cooking practices and preferences across cultural and economic contexts, there is no one-size-fits-all answer. All of these solutions – LPG, PNG, electricity, biogas, solar energy and more efficient biomass devices – have roles to play in the effort to achieve universal access to clean cooking energy by 2030. New definitions, measurement tools and test protocols for establishing what is “clean” for health will make it possible to track progress towards this goal, and to ensure that better burning actually translates to better health outcomes for billions of people (see Box 8).

The messy, complex reality of fuel stacking

Understanding how people really use energy in the home

Researchers describe this parallel use of multiple types of fuel and technologies in a single household as “fuel-stove stacking”.

The old model to describe the household transition to modern fuels was of an “energy ladder” that people climb linearly as their incomes rise, swapping a traditional stove completely for a new gas one, for example. But the “stacking” model offers a much more realistic picture of how people actually use energy in their homes (Figure 5). Even after gaining access to LPG, members of a household might continue to cook or heat their home with an open fire or with a traditional wood-burning stove. Or they may continue to use kerosene lamps in certain rooms to supplement electric lights, even after being connected to the grid.



COOKING

Less than half of households in LMIC primarily cook with clean fuels



A worker fashions the body of an electric cooking device out of clay in Bhaktapur, Nepal. Demand for electric cookers has risen in the midst of fuel shortages in Nepal.

Credit: REUTERS/Navesh Chitrakar

Figure 5. An example of the household energy fuel progression from polluting to cleaner energy sources, showing household fuels typically used for cooking, heating and lighting at low-, middle-, and high-income levels^a

Energy service	Developing country households		
	Lower-income	Middle-income	Higher-income
Cooking	<p>WOOD AGRICULTURAL RESIDUES COAL DUNG</p>	<p>WOOD AGRICULTURAL RESIDUES COAL LPG/NATURAL GAS KEROSENE BIOGAS SOLAR</p>	<p>LPG/NATURAL GAS SOLAR ELECTRICITY PELLETS BIOGAS</p>
Lighting	<p>OPEN FIRE CANDLES KEROSENE</p>	<p>ELECTRICITY BIOGAS SOLAR KEROSENE BATTERIES/TORCH</p>	<p>BIOGAS LPG/NATURAL GAS ELECTRICITY SOLAR</p>
Heating	<p>WOOD AGRICULTURAL RESIDUES DUNG COAL KEROSENE</p>	<p>WOOD AGRICULTURAL RESIDUES COAL KEROSENE LPG/NATURAL GAS</p>	<p>WOOD COAL KEROSENE ELECTRICITY OIL PELLETS LPG/NATURAL GAS</p>

^aAs countries transition to higher income levels, households transition to cleaner cooking, lighting and heating energy sources.

Source: Adapted from Sovacool (2012).

There are many reasons why people stack fuels and devices. A given stove may have some benefits for the user – convenience, reliability, affordability – but still not meet all of the user’s preferences. For instance, a cook may decide to continue using her inefficient older stove because her pots do not fit on a new “improved” one. A family that cooks with gas may keep a solid fuel stove in operation, as a backup in case the supply of LPG is disrupted. In some colder areas, traditional stoves may be kept in use for heating, even though LPG is used for cooking. And in many places, such as in parts of rural China, people may cook their own meals with gas or electricity but still use open fires and simple stoves to prepare feed for their animals.

If a household adopts one clean fuel–device combination, it does not necessarily mean that the air in that home will be cleaner – or will become clean enough to significantly improve the occupants’ health. Serious health risks can persist even if a household uses a clean fuel like gas for its primary cooking needs. If an inefficient stove or device is used alongside a newly adopted clean one, pollution levels inside the home may remain dangerously high, and the intended health benefits may not be realized.

This is why some researchers emphasize that the “dis-adoption” of old stoves is even more important than the adoption of new, more efficient ones (Barrett, 2015). To meet WHO IAQ emissions limits, the use of three-

stone fires or simple charcoal stoves for cooking must be virtually eliminated (Johnson & Chiang, 2015).

Programmes and interventions must be based on an understanding of the whole range of cooking, heating and lighting devices that people actually use in the household. Surveys need to be refined and improved to capture the complex reality of stacking. There are relatively few studies that examine how fuel stacking patterns change over time. This data gap creates a risk of missing trends with critical implications for exposure to HAP and health outcomes. For example, one study found that between 1987 and 2010 in India, fuel stacking for lighting decreased, but increased for cooking – meaning that increasing access to LPG did not replace traditional biomass use (Cheng & Urpelainen, 2014).

Fuel stacking is one major reason why the transition to exclusive use of clean energy at the household level is a complex challenge. A failure to understand users’ actual needs and preferences can limit the efficacy of interventions to improve health in the household. Some researchers therefore advocate a “portfolio” approach to substituting clean for polluting energy technologies, tailoring a suite of options to meet users’ preferences and needs in specific cultural, geographical and economic contexts (Ruiz-Mercado & Masera, 2015). In order to develop strategies that improve health in a durable, meaningful way, it is essential to measure and take into account the full range of energy tasks and end

uses – and then design programmes and interventions based on that textured understanding of how people really use energy in their homes.



Stove stacking (use of LPG stove, electric stove, a kerosene lamp, and a traditional mud chulha stove in parallel) in Uttarakhand, India. Credit: Jessica Lewis

What drives sustained adoption and use?

The mere presence of a clean energy device in a household cannot ensure health benefits. It must actually be *used*, regularly and properly, to make a difference for health.

This may seem like an obvious point, but many well intentioned stove programmes and household energy interventions have failed to produce anticipated health and environmental benefits because the technology did not meet the users' needs and expectations – and therefore it was not kept in use for a sustained period.

This problem has particularly plagued efforts to design and disseminate better-burning biomass stoves in rural areas of low-income countries. In the wake of India's national improved stove programme in the 1980s and 1990s, for example, follow-up visits to many homes found that newly distributed stoves had fallen into disuse. Lessons from other past efforts to disseminate "improved" stoves likewise show that the sustained adoption and use aspects of fuel stacking are complex (Hanna et al., 2012). Cost and household income are important considerations, but there are many other factors involved, from personal eating habits, to availability of freely gathered fuel, to the perceived fuel savings of the stove or even safety risks from cleaner alternatives like LPG (Rehfuess et al., 2013).

People with limited resources engage in elaborate decision-making calculations when it comes to new purchases. The stakes of making the wrong choice are much higher for the poor, given that the share of income they spend on energy is much higher.

So how can sustained use of truly clean energy solutions be encouraged? Those working to develop and disseminate household energy interventions and programmes must take into account how the intended users employ different fuel–technology pairings to

meet their various needs, and perform specific tasks. The relative advantages of each energy system – in terms of cleanliness, convenience, durability, ease of use and fuel processing, availability of fuel, affordability and cultural appropriateness, to name but a few factors – must be carefully weighed up and considered.

How fast can it cook a meal? Does it require chopping wood into small pieces, or otherwise preparing the fuel? Does it reduce smoke? Does it save fuel? Will it make the home cleaner or reduce the soot that builds up on pots? How much does it cost to purchase? If the stove breaks, how easy and how costly is it to get it fixed? How far must one travel to replace the stove or have it repaired? Does the household have enough livestock to sustain a biogas system? What kinds of dishes are being made on the stove, and how robust must it be to withstand vigorous stirring? Is there an aspirational quality to the device? What design elements help determine whether new fuels and devices will be used properly, and for a sustained period of time? Who makes the decision to purchase a new stove or lighting system in a household?



A woman cooks on a LPG stove in Dujana village on the outskirts of New Delhi, India. Credit: REUTERS/Anindito Mukherjee

Burning is a complicated business. Cooking rhythms and fuels used can shift from season to season, week to week, and even from hour to hour. In the winter, a stove might be kept going all day for space heating. How people actually use energy in their homes is therefore not easy to measure. But it is essential that these measurements are made, in order to understand how interventions perform in actual kitchens, and to verify that they reduce pollution as intended (Ruiz-Mercado et al., 2011). Developing accurate estimates of pollution exposure demands a textured understanding of the complex interactions between people and fuel, food and hearth, temperature and appetites. New sensor-based tools, for example, enable continuous, objective monitoring of how people use the different energy systems (Ruiz-Mercado et al., 2013). Combined with the data yielded by expanded and improved survey instruments, and observational studies, these new tools can help provide a much richer, more realistic picture of how, and for how long, people adopt and use fuels and devices for cooking, heating and lighting.



A boy waits to fill jerrycans with kerosene in Jakarta, Indonesia in 2007, at the start of the Indonesian government's program to shift over 50 million households from kerosene to LPG for cooking. Credit: REUTERS/Supri

Household energy analyses

How many people rely on clean fuels to meet their daily needs for cooking, heating and lighting? How many use polluting fuels? What fuels and devices do people in cities mostly use? What do those in rural areas depend on? How has access to clean fuels and devices expanded over time? In what parts of the world do these life-saving solutions remain out of reach of the people who need them most?

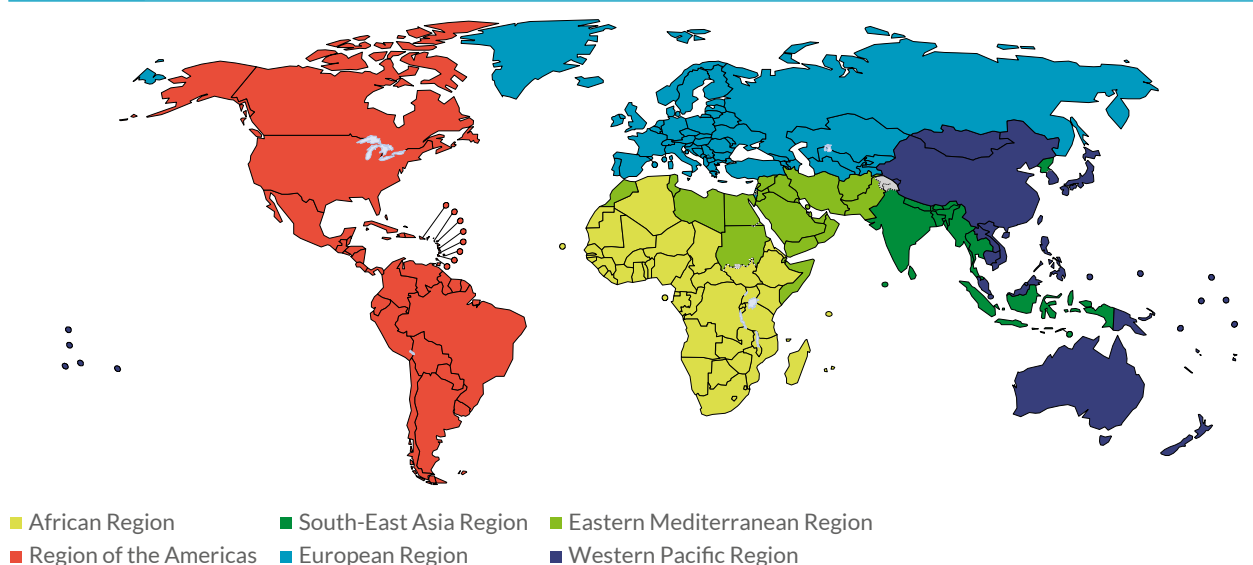
Some answers to these critical questions can be found in the WHO global household energy database. This database compiles nationally representative data on household energy use (i.e. cooking, heating and lighting fuels, stoves, time spent collecting fuel, and incidence of acute lower respiratory infection for 157 countries. The database is regularly updated with new data from national censuses and large-scale household surveys (such as UNICEF's Multiple Cluster Indicator Survey (MICS), the World Bank's

Living Standard and Measurement Survey and USAID's Demographic and Health Surveys) and is being used to inform the SE4All GTF, to monitor progress towards the achievement of SDG 7, as well as to create burden of disease estimates and support national-level policy planning and monitoring.

The following sections use both survey data and statistical modelling estimates to provide a preliminary analysis of the new indicator of "percentage of population with primary reliance on clean fuels and technologies at the household level". This indicator was given initial approval in October 2015 by the member states of the Inter-Agency Expert Group (IAEG) on Sustainable Development Goal Indicators to track progress towards SDG 7. The categories of "clean" and "polluting" fuels and technologies, as defined by the emission rate target and fuel use recommendations within the WHO IAQ guidelines on household fuel combustion replace the previous focus on "solid fuels" (see Boxes 1 and 2). This represents a significant step forward in generating a more accurate and complete understanding of the health-related risks of household energy use worldwide and provides the impetus for collection of more comprehensive data on household energy use and its health impacts.

Owing to constraints and inconsistencies in the currently available data on technologies and devices used in the home for cooking, heating and lighting, this analysis focuses solely on the primary fuels for the different end-uses (cooking, heating and lighting). When possible, these are disaggregated by urban and rural areas. For cooking and lighting, national-level statistics are complemented by WHO regional averages where there were sufficient data available (see Figure 6 for a map of the WHO regions). Further information about the methods used for the analysis is provided in the relevant sections.

Figure 6. WHO Member States divided into six regional groups, 2015^a



^a See Annex Table A1.18 for a list of countries in each WHO region.

BOX 8 – New global standards for clean cooking solutions



*A woman cooks on a gas stove in her home in Kuala Lumpur, Malaysia.
Credit: REUTERS/Samsul Said*

Acknowledging that shifting to exclusive use of clean household energy will take years if not decades in some settings, recommendation 2 of the IAQ guidelines is designed to guide policy during this transition. It advises prioritizing fuels and technologies that offer substantial health benefits in the interim. For instance, the performance of new biomass burning stoves should be measured in the laboratory and in the home, to ensure they achieve meaningful reductions in emissions of harmful pollutants. The IAQ guidelines include interim emissions rate targets for carbon monoxide and PM_{2.5} that reflect the reality that, in some low-income households, baseline levels of pollution are very high, and meeting the guideline recommendations in the near-term might not be feasible.

These standards will ensure that near-term opportunities for improving health, and lowering

the risks and costs associated with inefficient consumption of traditional fuels, are not overlooked. In settings where the infrastructure for distributing LPG and supplying electricity is not yet in place – especially rural areas that lie well beyond existing supply chains and grid networks – people will continue to burn the fuel they can most easily access and afford (Foell et al., 2011). Efforts to extend access to gas, electricity and associated cooking devices, such as through the Global LPG Partnership, should be accelerated – while entrepreneurs and researchers should continue to work in parallel to create truly clean biomass stoves, and build the sustainable supply chains to make them widely available.

The International Organization for Standardization (ISO) is currently developing the first-ever global standards for clean cooking solutions. When completed, they are likely to provide a voluntary framework for rating cookstoves against five tiers of performance for a series of indicators, including fuel use, emissions indoor and overall, and safety. These tiers are being informed by the WHO guidelines emissions rate targets and recommendations for pollutant concentrations. The Global Alliance for Clean Cookstoves, meanwhile, maintains a “clean cooking catalog” (GACC 2016) that documents the testing results of many different stoves and fuels. It is updated regularly with results submitted by institutions from around the world. Together with the ongoing ISO process, this catalogue offers an important resource for identifying and monitoring technologies that can truly be considered clean.

Cooking energy use – analyses

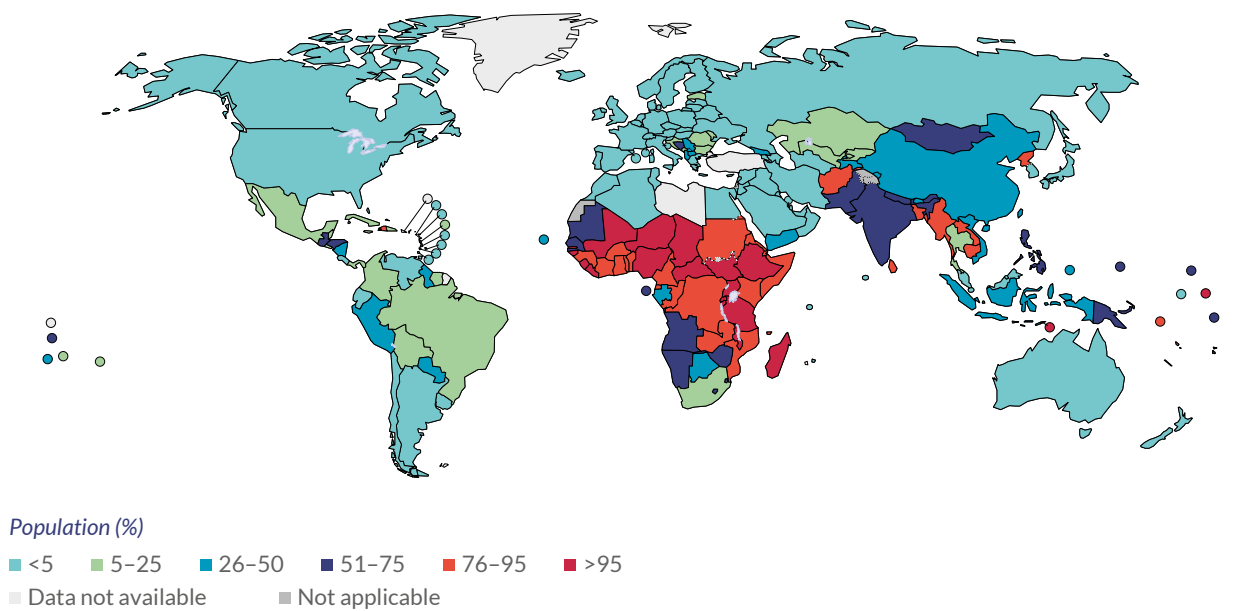


Worldwide, 2.9 billion people are estimated to rely primarily on solid fuels for their cooking needs. Using the new SDG indicator categories of “polluting” and “clean” fuels, the scope of the challenge is revealed to be even greater: more than three billion people in LMICs rely primarily on polluting fuels and technologies for cooking (Figure 7).



*A woman prepares lunch for children at a camp for displaced people in eastern Uganda.
Credit: REUTERS/Euan Denholm*

Figure 7. Global polluting fuel use in 2014 (for low- and middle-income WHO Member States)



These categories reflect the recommendations in the most recent WHO IAQ guidelines (see Box 2). Polluting fuels include biomass (wood, dung, crop residues and charcoal), coal (including coal dust and lignite) and kerosene. Clean fuels include electricity, LPG, piped natural gas (PNG), biogas, solar and alcohol fuels.

The majority of the population in LMICs relies primarily on clean fuels, but that does not imply that these individuals have no exposure to HAP (Tables 1 and 2; Figures 8 and 9). The well-documented reality of fuel stacking in many households suggests that

many continue to use polluting fuels as a secondary or supplementary energy source for cooking.

Almost 3.1 billion people, or just over half (53%) of the population in LMICs cook with polluting fuels; this is 43% of the global population (including high-income countries) (Figure 8). Reliance mainly on polluting cooking fuels varies widely from region to region: the African Region, the South-East Asia Region and the Western Pacific Region have by far the highest proportions of households primarily using polluting fuels for cooking (Figure 9, Table 2).



A woman tends her cooking fire.
Credit: Ajay Pillarisetti

Box 9 – Safety and household energy



Residents of a slum in Dhaka, Bangladesh try to put out a fire - started by a cooking oven - that killed a child and destroyed hundreds of homes. Credit: REUTERS/Andrew Biraj

While they may substantially reduce the risks of exposure to HAP, not all clean household energy solutions are equally safe when it comes to use and handling. Certain fuels and technologies pose safety risks that are important to consider.

LPG cylinders, bottles and valves can sometimes fail, resulting in leaks. Explosions, although rare, can occur, and are a concern commonly expressed by users in surveys. Both distributors and users of LPG must be properly trained to handle it safely. Pipes in natural gas and biogas delivery systems can also corrode or fail, causing leakage of harmful gases. Relatively few studies have examined the safety risks of LPG, PNG or biogas.

Kerosene has its own unique safety concerns. Kerosene is frequently sold in old soda or water bottles in many parts of the developing world, contributing to unintended ingestion and poisonings of children. Burns, scalds and house fires caused by tipped-over kerosene lamps and heaters are sadly common. (Over 95% of deaths from burns occur in LMICs.) Burns and scalds are, of course, common injuries associated with use of solid fuels and traditional stoves, as well.

Registries are being developed to better monitor the incidence and cause of burns. Safety is a core consideration in the ongoing development of the ISO standards for clean cooking (see Box 8). Alcohol-fuelled stoves have a much lower risk of leaks, explosions or burns. Solar cookers pose very few safety risks.

Table 1. Population coverage of the WHO Global Household energy database for cooking fuel use by low- and middle-income countries (LMICs) in 2014

WHO regions	Population of LMICs	LMICs with survey data (%)	No. of LMICs with survey data
AFR	963 265 031	100	46
AMR	525 235 457	100	24
EMR	573 448 114	99	14
EUR	186 687 966	71	18
SEAR	1 906 087 231	100	11
WPR	1 633 441 197	100	21
Global population	5 788 164 996	98	134

AFR, WHO African Region; AMR, WHO Region of the Americas; EMR, WHO Eastern Mediterranean Region; EUR, WHO European Region; SEAR, WHO South-East Asia Region; WPR, WHO Western Pacific Region.

Notes: Countries with survey data that were analysed for this report are only WHO Member States. Surveys were used only if they were conducted after the year 2000, are nationally representative, and contained disaggregated cooking fuel categories (for additional details, please see Annex 2. Population numbers from UNDESA 2014 (<http://esa.un.org/unpd/wup/CD-ROM/>). Designation of LMICs from World Bank (2015), which categorizes high-income countries as those with gross national income per capita of US\$ 12 746 or more. Equatorial Guinea was reclassified as an LMIC owing to its high use of polluting fuels.

Source: WHO Household energy database, 2016

Table 2. Estimates of global population relying on polluting fuels for cooking, with 95% confidence intervals

WHO region	Population using polluting fuels (%)	Population exposed, millions
	(95% CI)	(95% CI)
AFR	84 (87–81)	809 (835–784)
AMR	16 (21–10)	82 (113–52.1)
EMR	31 (35–28)	179 (200–159)
EUR	13 (16–0.01)	23 (29.6–17.0)
SEAR	65 (0.73–0.56)	1230 (1400–1070)
WPR	44 (0.52–0.36)	718 (852–583)
World	43 (0.46–0.40)	3048 (3280–2830)

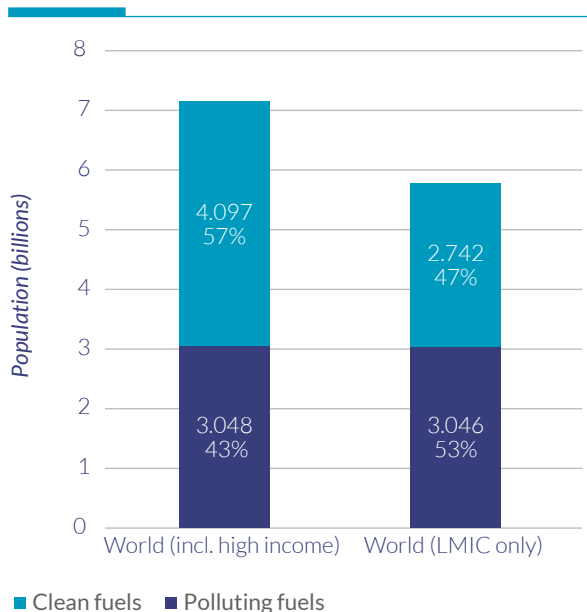
AFR, WHO African Region; AMR, WHO Region of the Americas; EMR, WHO Eastern Mediterranean Region; EUR, WHO European Region; SEAR, WHO South-East Asia Region; WPR, WHO Western Pacific Region.

CI, confidence intervals.

Note: Estimates are provided for WHO member states with available survey data. Regional fractions using polluting fuels vary, with the most intensive use being in the African and South-East Asia regions.

Source: WHO Household energy database, 2016

Figure 8. Total population relying primarily on polluting and clean fuels for cooking in 2014



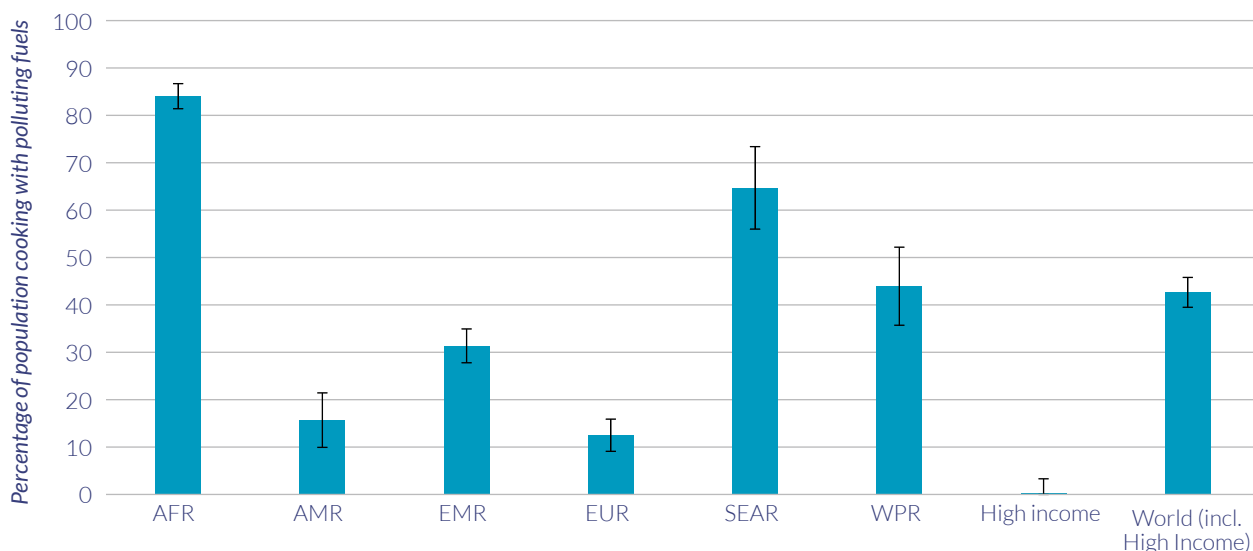
Notes: The left bar shows the entire world population including high-income countries, 43% of which cook primarily with polluting fuels; the right bar shows only the LMIC population, 53% of which cooks with polluting fuels. These estimates are derived using a multilevel nonparametric model based on data from the WHO Household energy database (see Annex 2 for methodology). Polluting fuels include biomass fuels (such as wood, charcoal, or agricultural waste and dung), kerosene and coal. Population numbers do not include Libya and Turkey for which no data were available

Source: WHO Household energy database, 2016



A woman cooks with a stove fueled by biogas generated from the dung she gathers from her buffaloes in India.
Credit: Jessica Lewis

Figure 9. Proportion of the population, by WHO region, mainly relying on polluting fuels for cooking^a



AFR, WHO African Region; AMR, WHO Region of the Americas; EMR, WHO Eastern Mediterranean Region; EUR, WHO European Region; SEAR, WHO South-East Asia Region; WPR, WHO Western Pacific Region.

^a Error bars indicate 95% confidence intervals.

Note: There is significant regional variation ranging from just over 10% reliance on polluting fuels in the European Region to over 80% in the African Region. These estimates are derived using a multilevel nonparametric model based on data from the WHO Household energy database (see Annex 2 for methodology). Polluting fuels include biomass fuels (such as wood, charcoal, or agricultural waste and dung), kerosene and coal. Data are available for all WHO Member States except Libya and Turkey.

Source: WHO Household energy database, 2016

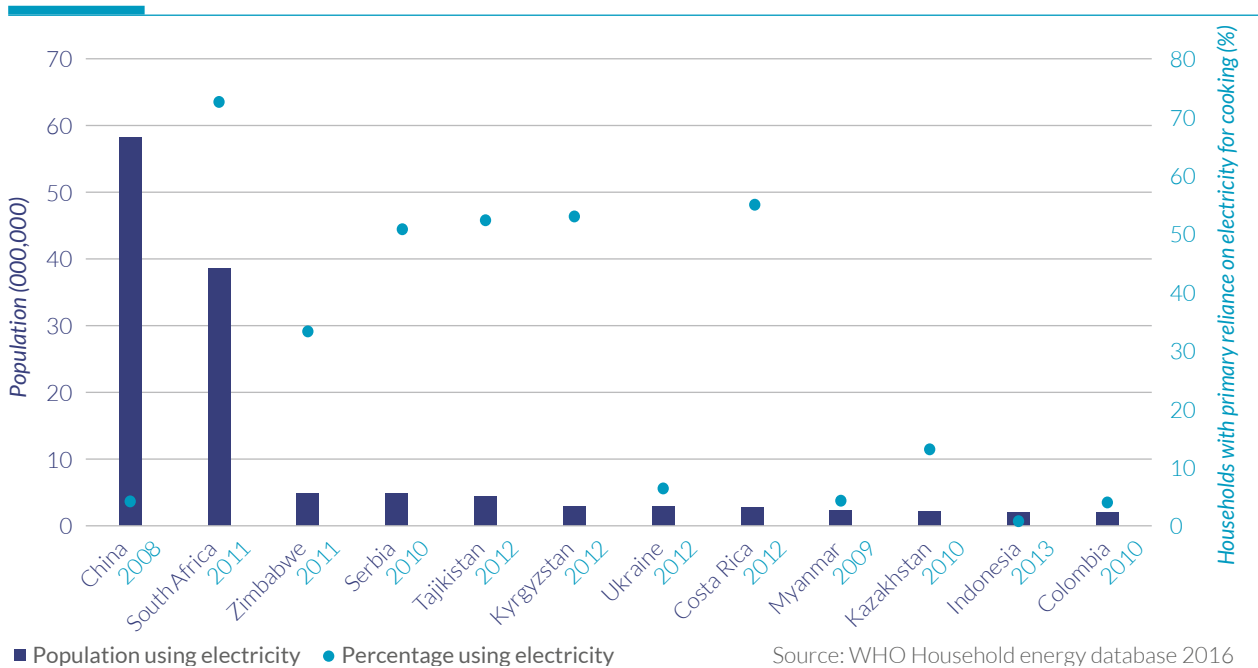
Highlighting the penetration of clean fuels in LMICs

From all available global data (on LMICs), China and South Africa have the highest number of people who report mainly cooking with electricity, followed by Zimbabwe (Figure 10). However, when looking at the proportion of households that mainly cook using electricity, a different story emerges: only around 5% of households in China primarily cook with electricity. Only eight LMICs report that the majority of their households use mainly electricity for cooking.

Almost 700 million households in China report primarily cooking with gas, almost double the number of gas users in any other country (Figure 11). Over 100 million households have transitioned to cooking with gas in India, Brazil as well as Indonesia. Several other countries have very high fractions (over 99%) of the population mainly cooking with gas, including Egypt, Jordan, Tunisia and Turkmenistan.

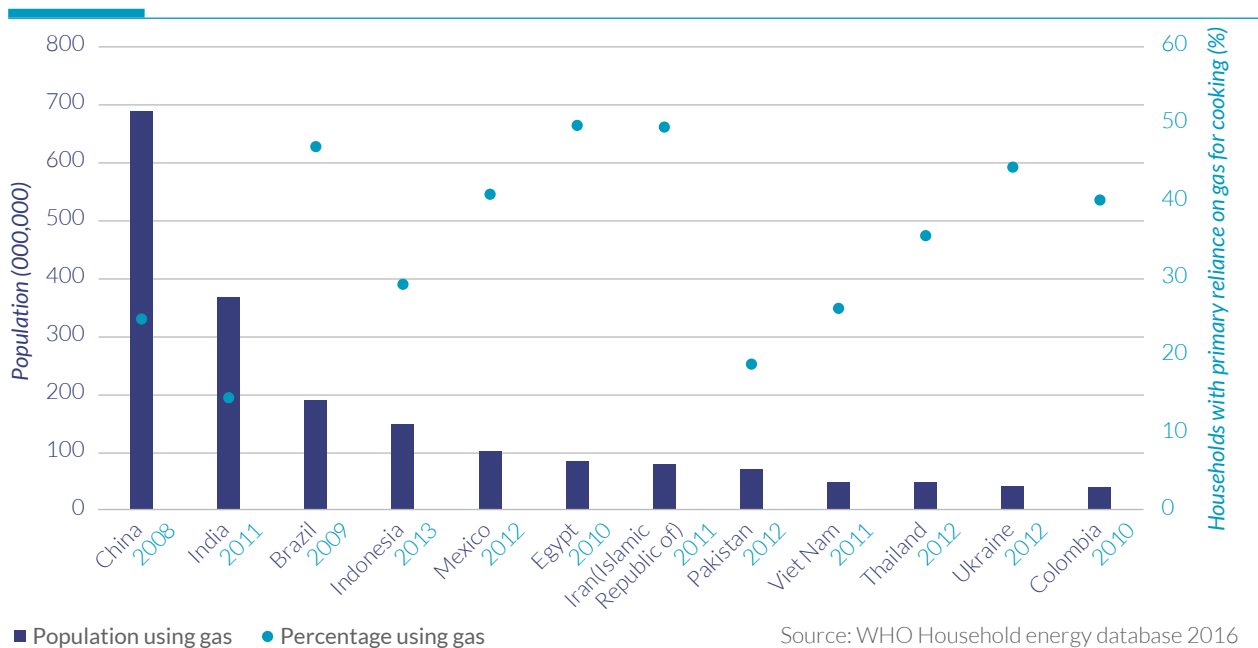
Unsurprisingly, in China and India significantly higher proportions of the populations rely on polluting fuels than in other countries (Figure 12), although this accounts for a much lower proportion of their respective total populations than in many other countries.

Figure 10. Top 10 countries by population mainly using electricity for cooking



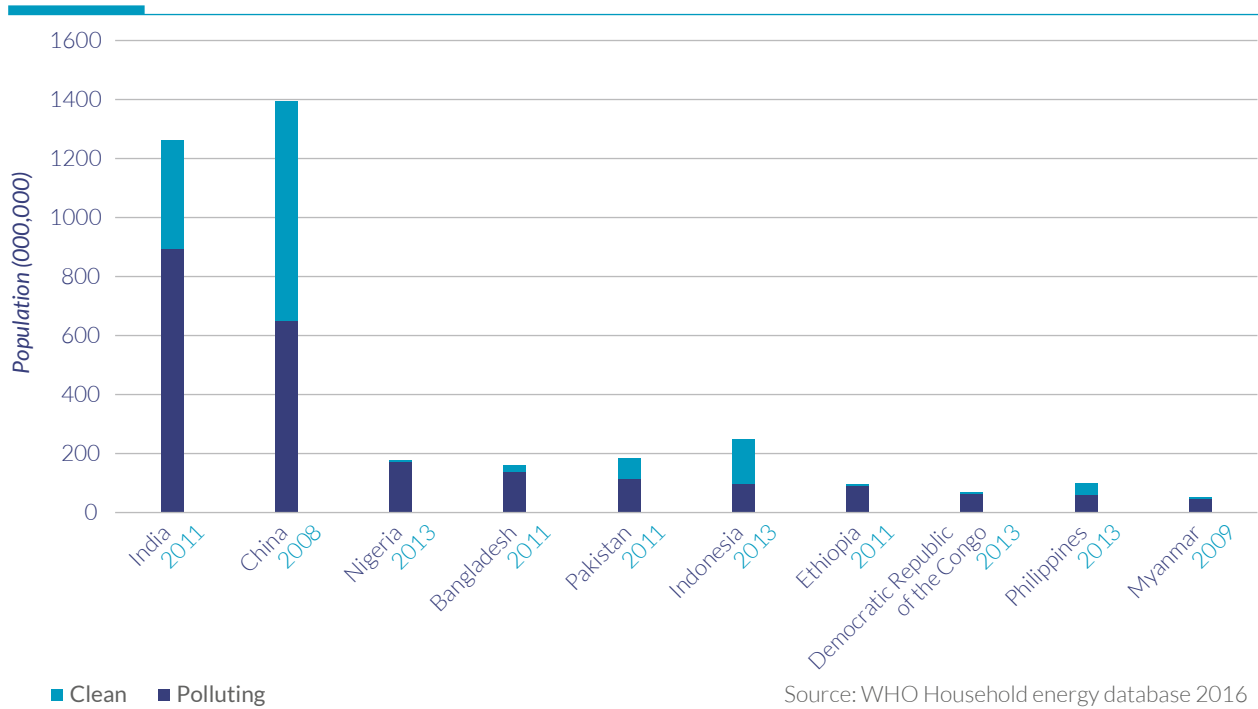
Note: The figure shows high absolute populations cooking mainly with electricity, although in some countries, like China, the proportion can be quite low.

Figure 11. Top 10 countries by population using gas as primary cooking fuel



Note: The figure shows the large populations cooking with gas in China and India, although the proportion of the population varies significantly between these countries.

Figure 12. Top 10 populations using polluting fuels as primary energy source for cooking, based on most recently available national survey data



Urban and rural differences

The majority of the LMIC households surveyed rely on polluting fuels for cooking however these overall trends fail to tell the whole story. There are significant differences in energy use patterns between urban and rural areas. More than 75% of urban households surveyed rely primarily on clean fuels (Figure 13), ratio is reversed in rural areas, where more than 75% rely on polluting cooking fuels.

In every region of the world, a significantly higher fraction of rural households than urban households report cooking with polluting fuels (Figure 14). For example, in the Western Pacific Region 82% of

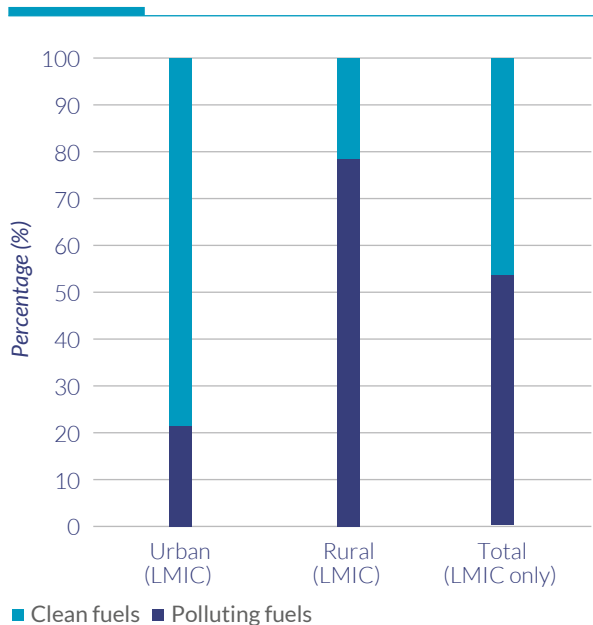
rural households cook with polluting fuels, whereas only 13% of urban households mainly rely on these fuels.

Even though polluting fuel use is lower in urban than rural areas, it accounts for a significant fraction of fuel use in several regions. Among rural households in the African Region, just 2% and 3% of households report using electricity and gas, respectively, as their primary cooking fuel; 91% use biomass. However, in the urban areas of the African and South-East Asia regions, especially, biomass is still widely used (in 53% and 25% of households, respectively) (Table 3).



A woman gathers charcoal into sacks at a village about 30 km south of South Sudan's capital Juba.
Credit: REUTERS/Andreea Campeanu

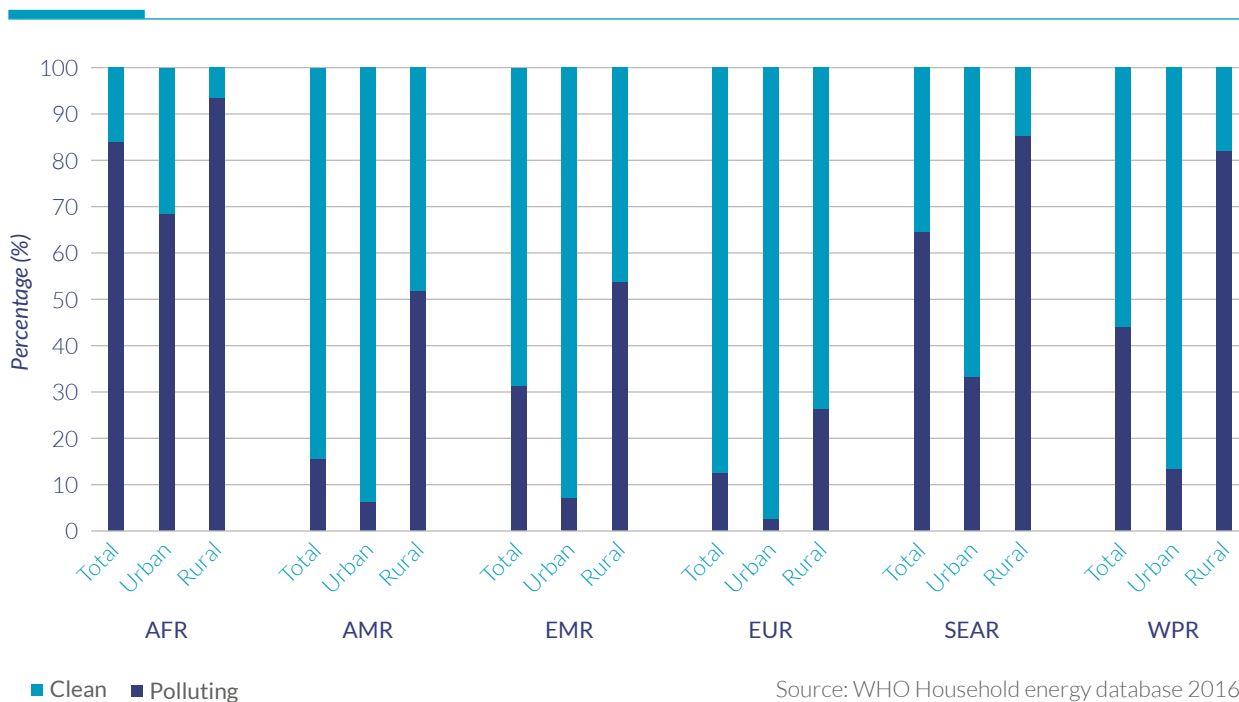
Figure 13. Percentage of population in urban and rural areas of LMICs with primary reliance on polluting and clean fuels and technologies for cooking



Improved stoves that cook, heat water and warm homes in Northern Pakistan. Credit: Aga Khan Planning and Building Service (AKPBS) project, Ashden Awards.

Source: WHO Household energy database 2016

Figure 14. Percentage of population using polluting and clean fuels by WHO region disaggregated by urban/rural, population weighted using modelled regional estimates



Source: WHO Household energy database 2016

Note: This figure shows rural areas have a higher proportion of households cooking with polluting fuels.

Table 3. Primary reliance on cooking fuel disaggregated by individual fuel type^a

WHO Region	Electricity (%)	Gas (%)	Kerosene (%)	Coal (%)	Biomass (%)	Other (%)	No. of LMICs with survey data (and total)
African Region	6	9	6	<1	77	2	46 (out of 46)
Urban	11	19	14	<1	53	2	46
Rural	2	3	2	<1	91	1	46
Region of the Americas	2	80	<1	<1	17	1	22 (out of 24)
Urban	2	91	<1	<1	6	1	21
Rural	1	47	<1	<1	51	1	21
Eastern Mediterranean Region	<1	64	<1	<1	34	<1	13 (out of 15)
Urban	<1	90	<1	<1	9	<1	13
Rural	<1	43	1	<1	55	<1	13
European Region	13	70	<1	<1	12	<1	17 (out of 19)
Urban	15	81	<1	<1	3	<1	17
Rural	11	58	<1	<1	23	<1	17
South-East Asia Region	<1	32	3	2	62	<1	11 (out of 11)
Urban	<1	63	7	3	25	1	11
Rural	<1	14	1	<1	83	<1	11
Western Pacific Region	4	49	<1	4	43	<1	18 (out of 21)
Urban	3	88	<1	6	3	<1	13
Rural	5	12	<1	2	81	<1	13

^a See Annex 2 for additional details on methodology.

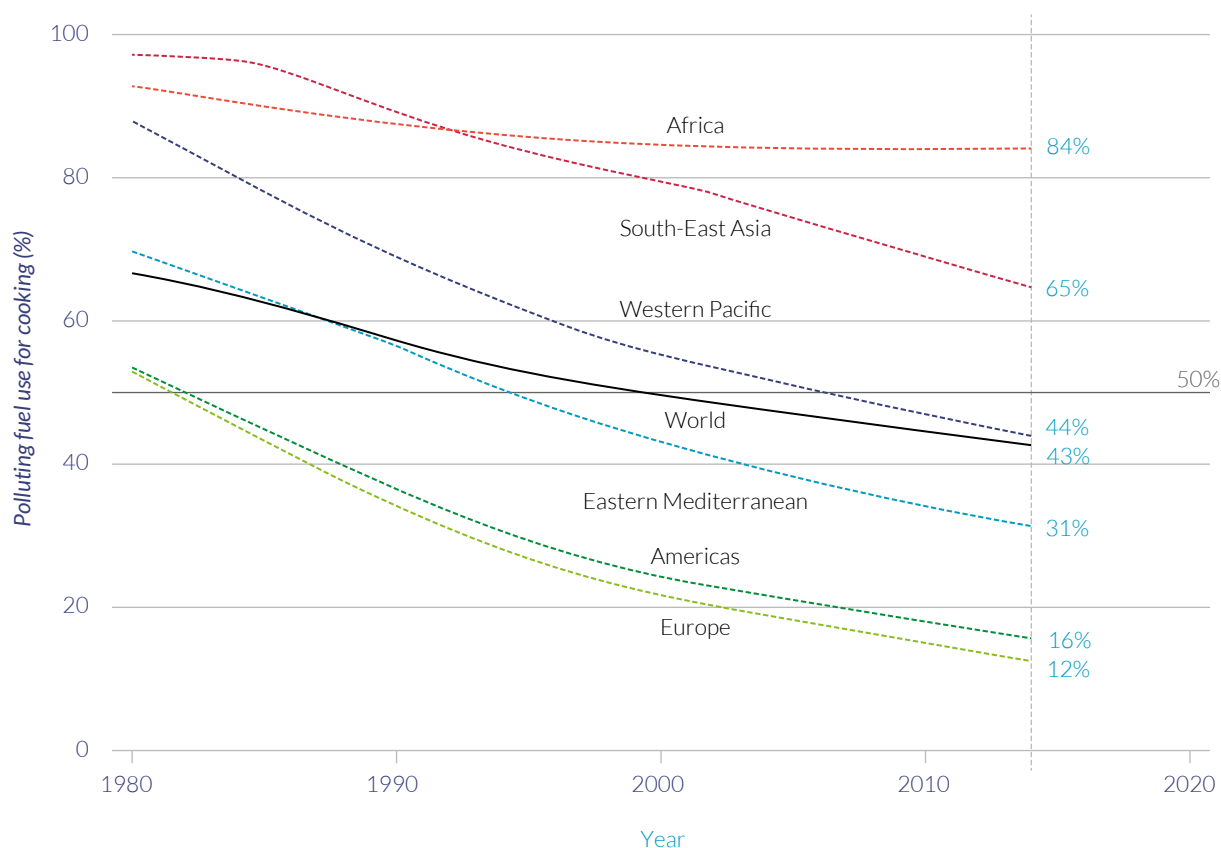
Source: WHO Household energy database, 2016

Regional trends

Primary global reliance on polluting fuels for cooking has decreased to varying degrees in all WHO regions over the past several decades (Figure 15). Recent regional estimates for 2014 show the WHO African Region (84%) as having the highest percentage of the population with primary reliance of polluting fuels for cooking, followed by the South-East Asian Region (65%), the Western Pacific Region (44%), and the Eastern Mediterranean Region (31%). Both the Americas and European Regions both show the lowest proportions of polluting cooking fuel use in 2014, with regional averages of 16% and 12% respectively.

Percentages fail to capture the whole story. Looking at the total number of people relying on polluting fuels for cooking, the South East Asia Region reports the highest number of people exposed to HAP from cooking, with over 1.2 billion people mainly using polluting fuels for cooking, followed by the African Region with over 800 million people and the Western Pacific Region with almost 720 million people mainly using polluting fuels for cooking. Estimates for the WHO Region are significantly lower with the estimates from the Eastern Mediterranean showing around 180 million people cooking with polluting fuels, the Americas and the European Regions both showing less than 100 million people.

Figure 15. WHO regional trends for the percentage of the population mainly cooking with polluting fuels in LMICs, 1980–2014



Source: WHO Household energy database 2016

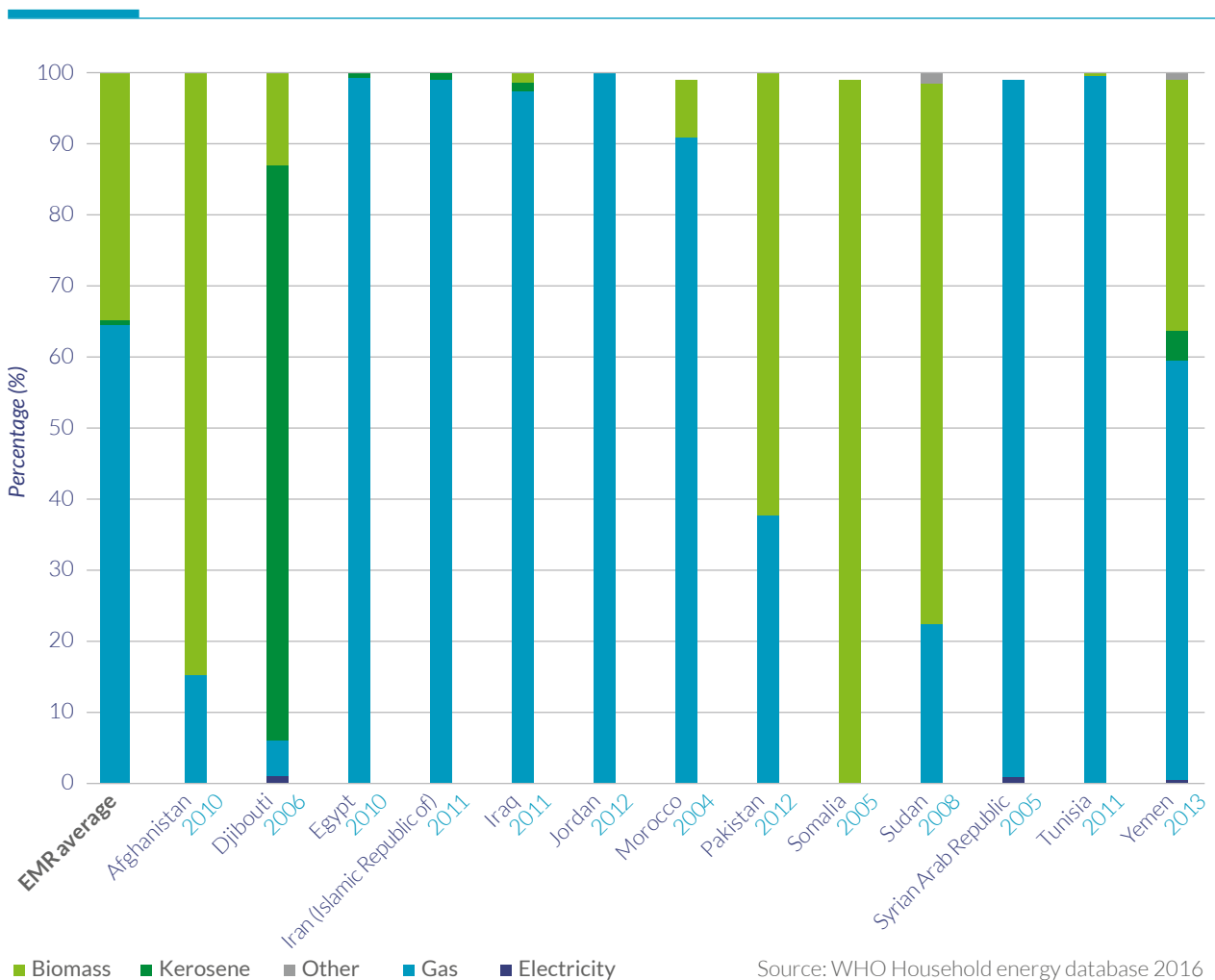
Differences in regional and national cooking energy usage

The countries making up the different WHO regions are extremely diverse in terms of cultural practices, socioeconomic conditions and available resources – all of which can directly influence households’ choices of cooking fuels and technologies. Therefore, looking only at regional averages of the sources of energy for cooking fails to capture the dynamic range

of cooking energy choices worldwide. The following sections offer a more in-depth analysis of the fuel and technology choices at both a regional and a national level.

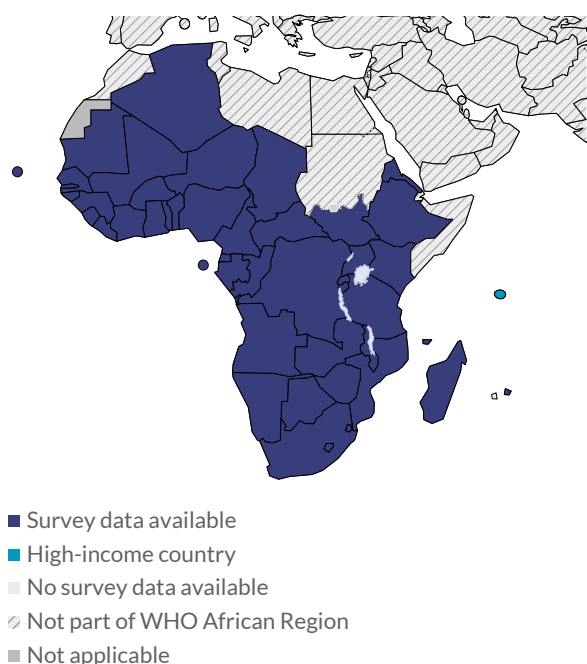
For example, around 65% of households in the Eastern Mediterranean Region primarily cook with clean fuels. However, a close look at the cooking fuels reported by the countries in this Region reveals substantial heterogeneity of polluting and clean fuel use by countries (Figure 16).

Figure 16. Regional averages of individual cooking fuels in the WHO Eastern Mediterranean Region (left bar) paired with data on fuel used for cooking by country in the Region



Source: WHO Household energy database 2016

Figure 17. African Region



Recent data were available from every country in the African Region (Figure 17). With 6% of its population mainly using electricity for cooking, the African Region ranks second after the WHO European Region in terms of cooking with electricity. However this average is strongly influenced by just six countries in the Region: Botswana, Namibia, Swaziland, South Africa, Zambia and Zimbabwe. The most recent surveys in these six countries show that more than 10%, or in the case of South Africa more than 70%, of households rely primarily on electricity for cooking. In most other countries of the African Region, the use of electricity is much less – 25 of the Region’s countries report that less than 0.1% of households use mainly electricity for cooking.

Biomass fuels are by far the most commonly used primary cooking fuel in the Region. Survey estimates from 18 countries in the African Region show that 95% or more of households rely primarily on biomass for cooking. Charcoal is a far more important part of the biomass fuel mix in this Region, especially in its urban areas, than in other WHO regions. Compared to other regions (where charcoal use is more scarce), the collection of data on charcoal use in the African Region was far more systematic, and was included in almost every recent national survey, allowing for a more refined regional analysis separating charcoal from other biomass fuels. The results show that, on average, close to 15% of households in the African Region mainly use charcoal for cooking, accounting for almost one quarter of urban households, and for a smaller fraction of rural households.

The use of gas, mostly LPG, for cooking is common in a few African countries. Algeria and Mauritius show an almost complete transition to LPG, with 98% or more of their populations using gas for cooking. Cabo Verde and Gabon follow, with over 70% of households using gas. Botswana has the next largest proportion, with around 43% of the population reporting relying primarily on gas for cooking. However, the large majority of countries in the Region (i.e. 30) report that 10% or less of households rely primarily on gas with 13 of these 30 countries, reporting that less than 0.1% of households use mainly gas for cooking.

Kerosene is an important contributor to the fuel mix in a few of the Region’s countries. Surveys from three African countries (i.e. Equatorial Guinea, Eritrea and Nigeria) show between one quarter and one third of households use kerosene as their main cooking fuel. The large majority of countries, however, report little or no kerosene use for cooking, with 30 countries reporting that less than 1% of households cook primarily with kerosene.

Coal is not very commonly used in the African Region. Only three of its countries report that about 1% of households use coal for cooking. The other 43 countries in the Region report that less than 0.5% of households use coal, and the vast majority of these countries report no coal use at all.

Figure 18. Region of the Americas

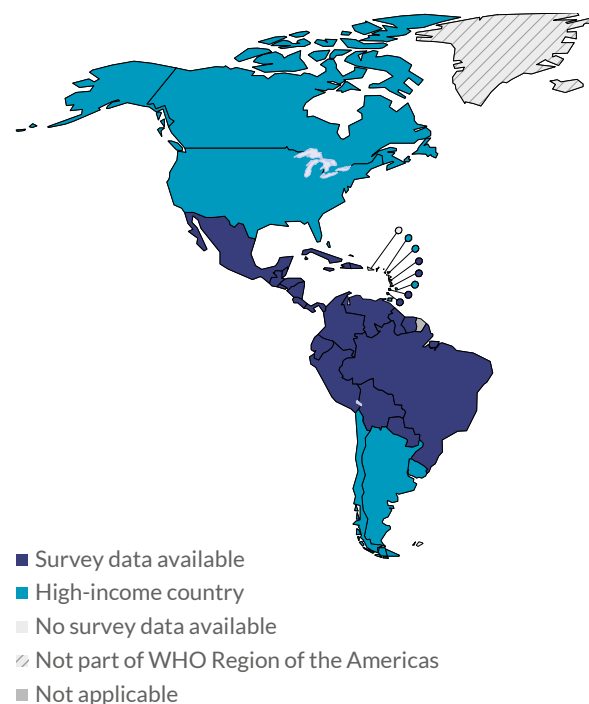
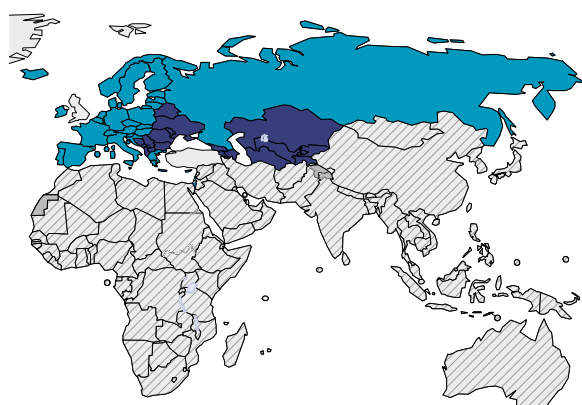


Figure 20. European Region



- Survey data available
- High-income country
- No survey data available
- ▨ Not part of WHO European Region
- Not applicable

The sources of energy for cooking vary significantly in the European Region (Figure 20). Gas, followed by electricity and biomass are the leading sources of cooking energy. A large majority of homes (i.e. 70%) in both rural and urban areas of the European Region use mainly gas for cooking. Armenia, Belarus, the Republic of Moldova and Turkmenistan all report that 90% or more of households mainly use gas, with Turkmenistan showing almost universal (i.e. 99%) usage of gas for cooking.

Electricity is used by around 13% of the Region's homes overall with similar levels of usage in both urban (i.e. 15%) and rural areas (i.e. 11%). Montenegro shows the highest electricity usage with two thirds of the population cooking with electricity. Over half of the households in the former Yugoslav Republic of Macedonia, Kyrgyzstan, Tajikistan and Serbia also cook mainly with electricity.

On average, a little over 10% of households in the European Region rely primarily on biomass fuels for cooking. Biomass is most commonly used in Bosnia and Herzegovina (69%), and Georgia (54%). About one third of households in the Republic of Albania, the former Yugoslav Republic of Macedonia, Serbia and Tajikistan mainly use biomass for cooking.

Striking differences exist in biomass use between urban and rural areas of the European Region. Almost one quarter of all LMIC households in rural areas mainly use biomass for cooking, whereas only around 3% of homes in urban areas do so. Georgia, for example, reports that almost 90% of its rural households and only 18% of the urban population in 2005 used mainly biomass for cooking.

Like the Region of the Americas, very little cooking with coal or kerosene is reported in the European Region. Only Kazakhstan and Montenegro report that 5% or less of their population use coal for cooking. The former Yugoslav Republic of Macedonia, which reports that 9% of the population cooks with kerosene, is the only LMIC country in the Region to report any use of kerosene.

Figure 21. South-East Asia Region



- Survey data available
- High-income country
- No survey data available
- ▨ Not part of WHO South-East Asia Region
- Not applicable

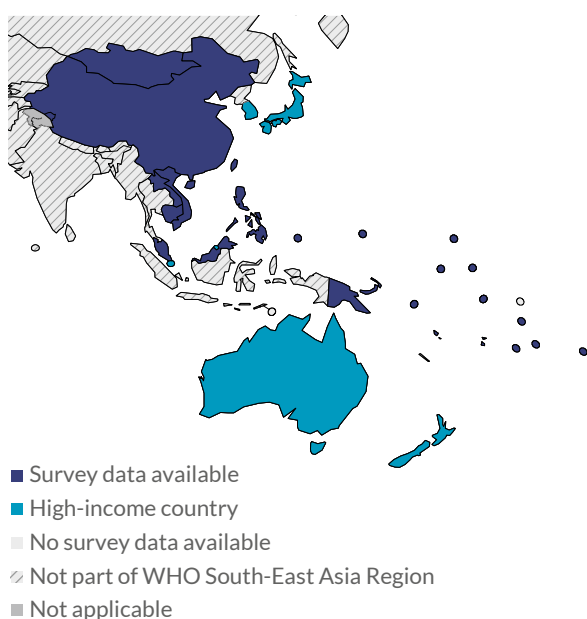
Biomass and gas are the two main cooking fuels used in the South-East Asia Region (Figure 21).

A population-weighted average of the recent country surveys shows biomass as the most common primary fuel used by households for cooking (62%), followed by gaseous fuels (32%), and kerosene (3%). Coal makes a small contribution to the regional fuel mix, being the main cooking fuel in only around 2% of households, and electricity makes an even smaller contribution, being used in less than 1% of all households.

Four countries in the South-East Asia Region (i.e. Bangladesh, Myanmar, Sri Lanka and Timor-Leste) report that more than 80% of households rely mainly on biomass for cooking, whereas Nepal and India report biomass use in 74% and 66% of households, respectively. Primary reliance on biomass fuels is more common in rural areas than in urban areas. Over 80% of rural households use mainly biomass, compared to only one quarter of urban homes.

The Maldives has the largest fraction of the population (90% of households) relying on gas for cooking in this Region.

Figure 22. Western Pacific Region



Two cooking energy sources, biomass and gaseous fuels, account for over 90% of households' choices of cooking fuels in the Western Pacific Region (Figure 22). Coal and electricity account for a small (i.e. 4%) but significant proportion of the Region's cooking energy mix (see Box 10). In countries in the Western Pacific Region, the use of gas for cooking is much more common in urban areas (i.e. 88%) than in rural areas (i.e. 12%). In contrast, biomass is most commonly used in rural areas of the Region's countries, where a population-weighted regional average of 13 countries shows that 81% of rural homes cook with biomass, compared to only 3% in urban areas.

Owing to the substantial variation in population size of the Region's countries, regional averages fail to capture the variations in cooking energy choices between countries. For example, in four countries (i.e. Niue, Mongolia, Cook Islands and Marshall Islands), from 20% to over 50% of households

primarily use electricity for cooking. Likewise several island states of the Western Pacific Region (i.e. Fiji, Marshall Islands and Tuvalu) report that between one quarter and one half of households mainly use kerosene for cooking.

Around 90 to 95% of households in Cambodia, Lao People's Democratic Republic, Solomon Islands, and Vanuatu cook mainly using biomass. Only four countries in the Western Pacific Region for which data are available report any coal use: Mongolia, China, Viet Nam and Lao People's Democratic Republic. Mongolia reports a much larger fraction than any other country with one fifth of households cooking with coal, whereas the other countries report that coal is used for cooking in $\leq 5\%$ of households. Owing to China's substantial population size, however, the 5% of households using coal amounts to 70 million people, which is more than the total population of all the Region's island states, Cambodia, Mongolia and Lao People's Democratic Republic combined.

Conclusions

More than 50% of households in all 128 countries surveyed use biomass as their primary cooking fuel. These analyses demonstrate the significant differences in energy use patterns between regions, countries and urban and rural areas around the world. According to the new analysis, over 75% of urban households surveyed rely primarily on clean fuels and technologies, while the ratio is reversed in rural areas, where more than 80% rely on polluting fuels and technologies. Survey estimates from 18 countries in the African Region show that more than 95% of all households rely primarily on biomass for cooking. In the South-East Asian Region, biomass is the most common primary fuel used by households for cooking (62%), followed by gaseous fuels (32%), and kerosene (3%). These statistics can inform specific tailored policies at the regional, country, and subnational levels to reduce dependence on polluting cooking systems.

Heating energy use – analyses



In many places, when winter arrives – or even just when the sun goes down – lighting a fire to stay warm is a matter not only of comfort, but of survival. Heating is an essential energy service for people of all ages, but it is especially important for the health of infants, children, the elderly and those who are ill. Even though it is such a fundamental need for so many, space heating is a largely overlooked source of HAP and health risk. Effective household energy interventions must take the whole picture into account – and heating is a critical component of many households' energy needs.

Even if a household has shifted to cooking primarily with gas, electricity or biogas, indoor air quality may not necessarily improve enough to yield meaningful health benefits. Those systems may not provide sufficient radiant heat to keep a living space warm on a cold winter night. Likewise, the improved insulation of a cleaner biomass stove might lead to better combustion, but more energy put into the pot means less energy available to warm the living space (and a closed firebox also reduces light from the flames to illuminate the home).

In other words, a stove that is efficient for cooking may not be very efficient for heating, so a household with a clean cooking system may continue to rely on burning polluting fuels on open fires or in traditional stoves for heating. And its inhabitants will continue to face serious health risks as a result.

For instance, many households in high-altitude regions, from Bhutan to northern Pakistan, use LPG for cooking and fast-boiling tea, but also continue to burn dung or wood to heat their homes through the long, cold Himalayan winter. In cold regions, the same stoves

that are used for cooking are frequently also used for space heating. This dual use – with pots simmering all day on the stove, which itself is fed regularly throughout the day – makes it difficult to quantify how much fuel is burned for heating relative to other end uses. This, in turn, makes it hard to determine how much the fuel used for heating contributes to HAP and other health risks.

Developing a clean-burning dual-use stove that satisfies both cooking and heating needs is a technical challenge. Indeed, relatively few stove programmes and design efforts have attempted to develop advanced dual-use devices, especially for use in high-altitude settings where fuel is scarce, air is thin, and the demand for space heating remains high all year round. Some research institutions, for example, are currently developing prototype stoves that use stored solar thermal energy for a variety of cooking tasks and space heating, but this is an area that requires further experimentation and innovation.

Central heating systems fuelled by gas or electricity are clean point-of-use solutions that effectively move the combustion off-site, but may not always be feasible in rural or remote settings. Expanding access to LPG for use in gas space heaters and to biomass pellet heating stoves can reduce exposure to HAP from traditional heating stoves and open fires. In certain climates, passive solar heating techniques – such as Trombe walls, attached greenhouses, and direct gain systems – can be appropriate strategies to reduce demand for space heating and the associated combustion of solid fuels like wood, dung or coal. Improvements in the building's thermal envelope, through increased insulation and reducing unintended air leaks, can reduce loss of heat to the outdoors, but care must be taken to maintain adequate introduction of fresh air and ventilation.



*A woman warms her hands over the stove in her home outside of Moscow, Russia.
Credit: REUTERS/Sergei Karpukhin*

BOX 10 – The dangers of unprocessed coal

The WHO IAQ guidelines for household combustion include a recommendation that unprocessed coal should not be used as a household fuel. Most households in LMICs burning coal for cooking and heating use a raw, unprocessed form, which has not been treated by chemical, physical or other means to remove contaminants. It can therefore contain toxic elements such as arsenic, lead, fluorine, selenium and mercury. Burning this coal does not destroy these dangerous substances; instead it makes them airborne, increasing the risk of a variety of additional adverse health effects like fluorosis. Indoor emissions from coal combustion have been determined by the International Agency for Research on Cancer (IARC) to be a Group 1 carcinogen.

Coal burning for household space heating is a major public health problem in China. A recent

study examining the region of north China where the government provided free coal for winter heating between 1950 and 1980 found that levels of particulate matter were 55% higher than levels reported south of the Huai River. There was an associated increase in cardiorespiratory deaths; on average, lives of residents of northern China were 5.5 years shorter than those living in southern China (Chen et al., 2013). Despite its widespread use in China and elsewhere as a heating fuel, there are limited data available to estimate the population at risk from use of coal for heating, as most of the data relating to household coal use are for cooking. To gain a fuller understanding of the health risks from household coal burning around the world, it is essential that household surveys include more questions about fuel use for space heating.



*Women laborers rest as they watch a boy play with their tools at a coal yard in the western city of Ahmedabad, India.
Credit: REUTERS/Amit Dave*

A dearth of data on heating in LMICs

Historically, the overwhelming focus of demographic household surveys has been on measuring fuel use for cooking. Epidemiological studies of HAP have also primarily focused on measuring exposure during cooking activities. There are very few comprehensive studies or reliable sources of data on energy use for space heating.

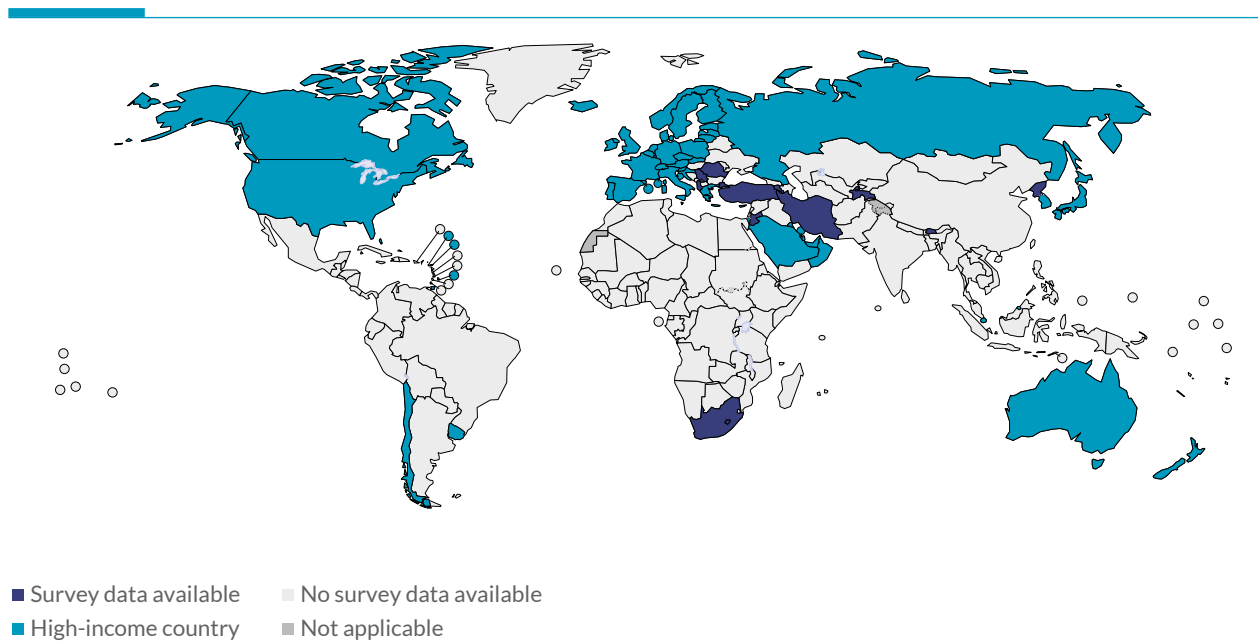


Children warm themselves around a fire in a metal barrel in eastern Ghouta near Damascus, Syria.
Credit: REUTERS/Mohammed Abdullah

A global estimate of current household fuel use for space heating is therefore not feasible. The following analyses are country-level estimates of averages for primary fuel use for space heating. Statistics on space heating with solid fuels reported in national surveys are typically for either biomass (e.g. wood, dung, grass) or coal.

A comprehensive search for recent national-level surveys found fewer than 40 surveys with data on primary heating fuel, representing 13 LMICs (Figure 23). This reveals the critical need for enhanced and expanded efforts to collect information on the range of fuels being used for space heating. In many warmer countries, where heating is not a significant end use, this will of course not be applicable. But for most countries, a more detailed understanding of the range of fuels being used to stay warm – often in parallel with modern fuels – is essential to informing policies and programmes to reduce the health risks associated with burning polluting fuels for heating.

Figure 23. LMICs with available data from national surveys on primary heating fuel use



^a This map shows the paucity of nationally representative data on heating fuels currently available and the limited geographical areas with data.

For this analysis, clean fuels include central heating, electricity, fuel oil, natural gas, LPG and solar systems. Polluting fuels include kerosene, coal, firewood, dung, and grass or crop waste (see Box 11).

Electricity, natural gas, and central heating systems are the most commonly reported clean energy sources for space heating at point-of-use. Firewood,

followed by kerosene and coal, are the most commonly reported polluting energy sources used for space heating.

Four of the 14 countries with data primarily reported using clean fuels for heating (>50%), including Turkey, Armenia, the Islamic Republic of Iran and South Africa. The penetration of clean fuels and technologies within

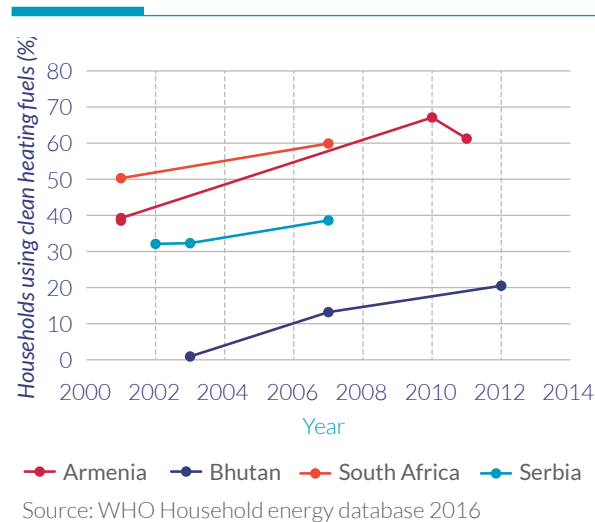
these four countries varies substantially. Turkey reported a universal reliance on clean energy (i.e. 100%) for space heating in 2011, whereas in Armenia, the Islamic Republic of Iran and South Africa, the choice of fuels and technologies for space heating is more varied. For example, a survey from Armenia in 2011 revealed that around 60% of households use clean energy for space heating, with the rest using polluting sources, particularly firewood. Likewise, two surveys from South Africa in 2007 showed that between 55% and 60% of households mainly used clean fuels for space heating, whereas around 40% of the population used polluting fuels, such as firewood (~20%), kerosene (~12%) and coal (~4%).

Unlike other countries, Bhutan and the Democratic People's Republic of Korea showed a heavy reliance on coal for space heating. Kerosene also serves as an important fuel for heating in some countries like Jordan and Lesotho, where, in the most recent survey, 64% and 34% of households respectively, reported kerosene as their primary heating energy source.

In the six countries where data heating were available over multiple years, each country revealed a slow but steady increase in the use of clean energy for heating. Armenia showed the most marked increase in reliance on clean energy for heating. In just one decade, the share of households using clean energy for space heating in Armenia grew from 40% in 2001 to 61% in 2011, a net increase of 21% (Figure 24).

Although few countries have national survey data on space heating, the country-level data on space heating that are available show that a substantial proportion of households use polluting fuels and technologies for space heating. The lessons are twofold. There is an urgent need for more comprehensive data collection on space heating. And, more importantly, heating in the home is a critical but often overlooked risk for health.

Figure 24. Primary use of clean household heating fuels in a selection of countries with multiple years of data available^a



^a Survey data show a generally increasing trend in use of clean fuels for heating over time.



A family gathers around a *sagarh*, a traditional heater, in Uttarakhand, India.
Credit: Jessica Lewis



Sixty-six-year-old Sofya Mozol carries a log as her son Nikolai waits with a saw as they pile firewood in the small village of Kozlevschina in Belarus.
Credit: REUTERS

BOX 11 – Curtailing kerosene

A household fuel that is not solid – but not clean either

If the electricity goes off in your home, what do you use for light?

For most people in the developed world, the answer – for a short time until their utility restores power – is a battery-powered torch. But for most of the 1.3 billion who live without electricity every day, the answer is kerosene. Kerosene (also known as paraffin) has been commonly used as a lighting fuel since the mid-nineteenth century. At that time, whale oil was the fuel of choice for illuminating homes. Then along came kerosene – a cheap, widely available by-product of petroleum distillation. It soon became the dominant lighting fuel.

But within half a century, most households in today's high-income countries had transitioned away from kerosene to electric lighting. In the developing world, however, many households still burn kerosene – typically in simple wick lamps, made of a bit of cloth in a container – for lighting. Almost one third of households in India, for example, use kerosene as their primary lighting fuel. (See analysis below)

It is also a common fuel for cooking, used in wick or pressurized stoves. In cold mountain regions, including those in higher income countries such as Chile and Japan, kerosene is an important heating fuel. And on cold nights, kerosene is a source of warmth in countries of the Eastern Mediterranean Region, such as Jordan.



A boy buys kerosene from a vendor in the Kibera slum in Nairobi, Kenya.

Credit: REUTERS/Thomas Mukoya.

Kerosene used to be lumped in with LPG, biogas, and electricity as a “modern” fuel. It was certainly an improvement over whale oil. But despite its continued widespread use, kerosene can no longer be considered a “clean” fuel. The fourth recommendation of the WHO IAQ guidelines for household fuel combustion discourages the use of kerosene for any household purpose. (see Annex 3)

Studies that have measured emission rates and pollutant concentrations in households using kerosene find pollution levels that are consistent with substantially increased risks of adverse health outcomes. One recent study conducted in the city of Bhaktapur, Nepal found that children in households where kerosene was used for cooking had a significantly higher risk of acute lower respiratory infection (ALRI) than those living in homes where electricity is used (Bates et al., 2013). A systematic review found that levels of PM_{2.5} emissions from wick-type kerosene lamps exceed WHO guidelines, and that use of kerosene was associated with elevated risk of cancer, respiratory infections, asthma, tuberculosis, cataract, adverse pregnancy outcomes and ALRI in children (Lam et al., 2012b). This evidence was one of the primary reasons for the shift away from reporting on “solid” fuel use, to a new indicator focused on “polluting” versus “clean” fuels (see Box 1).

Kerosene use can also lead to poisonings, injuries and house fires. Millions of people suffer burns from using kerosene lamps every year. Unintended ingestion of kerosene is one of the most common causes of child poisoning worldwide, particularly in LMICs. These risks are well-documented and yet also likely to be underestimated, as many injuries go unreported (Mills, 2016).

Kerosene use poses dangers far beyond the boundaries of the home or village. Particulate matter emitted by burning kerosene is almost pure black carbon, a form of fine particulate pollution that is the second biggest contributor to global warming after carbon dioxide. As a fossil fuel, kerosene also produces carbon dioxide when combusted. As a source of serious health risks, and of both short-lived and long-lived climate pollutants (including 6% of global black carbon emissions), kerosene is a ripe candidate for rapid replacement.



A woman uses a kerosene stove to prepare a meal in Dar es Salaam, Tanzania.

Credit: REUTERS/Sala Lewis

Lighting energy use – analyses



Lighting is a basic need. When the sun goes down, every household needs light to perform simple tasks or engage in simple pleasures, such as cooking or reading.

Lighting enables businesses to stay open after dark, increasing productivity and income. Better lighting in the home helps prevent accidents, and enables children to study and learn in the evening. In community settings and refugee camps, streetlights improve safety and give people a sense of security.

Soon after Thomas Edison invented the electric light bulb in 1879, with the goal of rendering gas and oil lamps obsolete, he predicted, “We will make electric light so cheap that only the wealthy can afford to burn candles.” Affordable, accessible electricity has indeed transformed the way many people light their homes: in the developed world today, lighting is fuelled almost exclusively by electricity.

But Edison’s goal has not been fully realized. That light has still not reached a huge proportion of those alive today, more than 130 years later. At least 1.3 billion people – one sixth of humanity – still lack access to electricity. To light their homes, they rely on kerosene lamps and, to a lesser extent, other polluting sources such as biomass and candles.

Many more households are connected to the grid but have only sporadic, unreliable access to electricity. The mere presence of a connection does not ensure that a household uses “clean” energy for lighting, or that associated health risks are therefore reduced. Concerns about affordability or other factors mean these households may still use kerosene for light when the power cuts out, or in other rooms or spaces without an electric light.

Global lighting trends are characterized by deep inequity: those without access to electricity spend up to

1000 times more per unit of light than those who have a reliable electricity supply. The poor spend far more, as a proportion of their income, on light of far lower quality, than the rest – totalling around US\$ 40 billion per year worldwide (Mills 2005).

There are serious health consequences of this lighting gap. While much of the focus in the global development community is on the importance of extending electricity access for economic productivity, there are substantial health and environmental benefits to be realized from transitioning households to electric lighting and other clean lighting fuels.

Analysis of survey data on lighting in LMICs

An analysis of WHO’s lighting database reveals that much work remains to be done before Edison’s prophecy comes true. The database includes lighting survey data from 58 countries (Table 4). These limited data highlight the need to expand collection of data on lighting fuel use. Owing to the limited data coverage, we do not present global lighting trends. Details on specific lighting fuels used are presented only for those WHO regions that have lighting survey data representing at least 50% of the regional population (African Region, Eastern Mediterranean Region and South-East Asia Region).

Household lighting sources at point of use that are considered clean include electricity (grid and generator), LPG, PNG, solar and battery-powered lights or devices. Polluting lighting sources include biomass (firewood, grass and dung), candles, kerosene and oil lamps (WHO, 2014a). Oil lamps were categorized as a polluting fuel in this analysis because, in the LMICs, oil lamps are similar in efficiency or are fuelled in similar ways to kerosene lamps. However, the collection of more precisely categorized lighting data in future surveys would facilitate more accurate analysis of clean and polluting lighting fuels.



A woman stands in her shack in the state of Guarico, Venezuela. Her mud hut still has a black stain on the wall from the kerosene lamp she used for twenty years, but she proudly stands beneath a ceiling light bulb - a sign she finally has power.

Credit: REUTERS/Francesco Spotorno (VENEZUELA)

Table 4. Population coverage of surveys with lighting data in the WHO Household energy database

	Population from countries with lighting data (thousands)	No. of countries	Percentage of population in LMICs covered (%)
AFRO	675 823	25	70
AMR	61 315	10	12
EMR	377 848	7	66
EUR	6 169	2	3
SEAR	1 476 247	5	77
WPR	210 079	9	13
Total	2 807 480	58	49

AFR, WHO African Region; AMR, WHO Region of the Americas; EMR, WHO Eastern Mediterranean Region; EUR, WHO European Region; SEAR, WHO South-East Asia Region; WPR, WHO Western Pacific Region.

Notes: Countries with survey data that were analysed for this report are only WHO Member States. Surveys were used only if they were conducted after the year 2000, are nationally representative, and contained disaggregated cooking fuel categories (for additional details, please see Annexes 2 and 6.. Population numbers from UNDESA 2014 (<http://esa.un.org/unpd/wup/CD-ROM/>). Designation of LMICs from World Bank (2015), which categorizes high-income countries as those with gross national income per capita of US\$ 12 746 or more. Equatorial Guinea was reclassified as an LMIC owing to its high use of polluting fuels.

Source: WHO Household energy database, 2016

A look at lighting data

Looking at the countries with survey data, the main sources of energy for lighting are electricity followed by kerosene (see Box 12). As already mentioned, kerosene has recently been classified as a polluting

household fuel with significant adverse health impacts, but it remains widely used as a household lighting fuel (see Box 11). Primary reliance on polluting lighting fuels is particularly marked in sub-Saharan Africa and South-East Asia (Figure 25).



*A girl studies by kerosene lamp due to a power cut-off in the remote village of Lingsey, India.
Credit: REUTERS/Rupak De Chowdhuri*

BOX 12 – Lighting the way

A range of new ventures are supplanting kerosene with solar-powered light

The new WHO recommendation discouraging the use of kerosene coincides fortuitously with a number of promising market-based efforts to reach households that still rely on this polluting fuel. Clean alternatives to kerosene lamps have never been more accessible or reliable.

Solar-powered home lighting systems are becoming increasingly affordable for low-income households. New LED lamps are much more energy efficient, and provide much higher quality light, than kerosene lamps. Supply chains and retail sales operations for these clean alternatives are rapidly expanding throughout markets such as East Africa and India, home to many of the 1.3 billion without electricity.

Public-private partnerships are working to lower costs for consumers even more quickly. The joint International Finance Corporation (IFC)-World Bank Lighting Africa programme aims to bring clean off-grid lighting and energy products to 250 million Africans by 2030. The “Energy Africa” campaign launched in October 2015 by the United Kingdom’s Department for International Development (DFID) is working to expand the market for household solar systems and devices, rallying donor support and helping to remove policy and regulatory barriers to investment in Africa’s household energy sector.

Meanwhile, a host of new start-ups are trying to sell clean energy products and services, promising better quality light and reduced expenses to customers who still rely on dangerous kerosene. Companies such as Off Grid Electric in the United Republic of Tanzania are capitalizing on the widespread use of mobile phones to offer customers “pay as you go” financing options, which lower the upfront costs of these products for the rural and urban poor alike, and lets customers divert the money they spend on kerosene each month to micro-payments that incrementally pay off the cost of the solar system, instead. Through a partnership with the government, the company plans to provide power to one million homes in the United Republic of Tanzania by 2017.

Many governments subsidize kerosene; this remains a huge obstacle to creating incentives for the use of alternatives. More research and targeted interventions are needed to address kerosene use for cooking and heating. But if the early strides made by these new entrepreneurial approaches, creative financing models, and cross-sectoral partnerships are sustained and accelerated, then kerosene, just like whale oil before it, may soon become a hallmark of a bygone era – and not a moment too soon for the billions exposed to the risks of its continued use.



A man in rural Guangxi Province, China, uses a light and a cooking stove that are both fueled by biogas from his household’s digester.

Credit: Corbis/Andrew Rowat

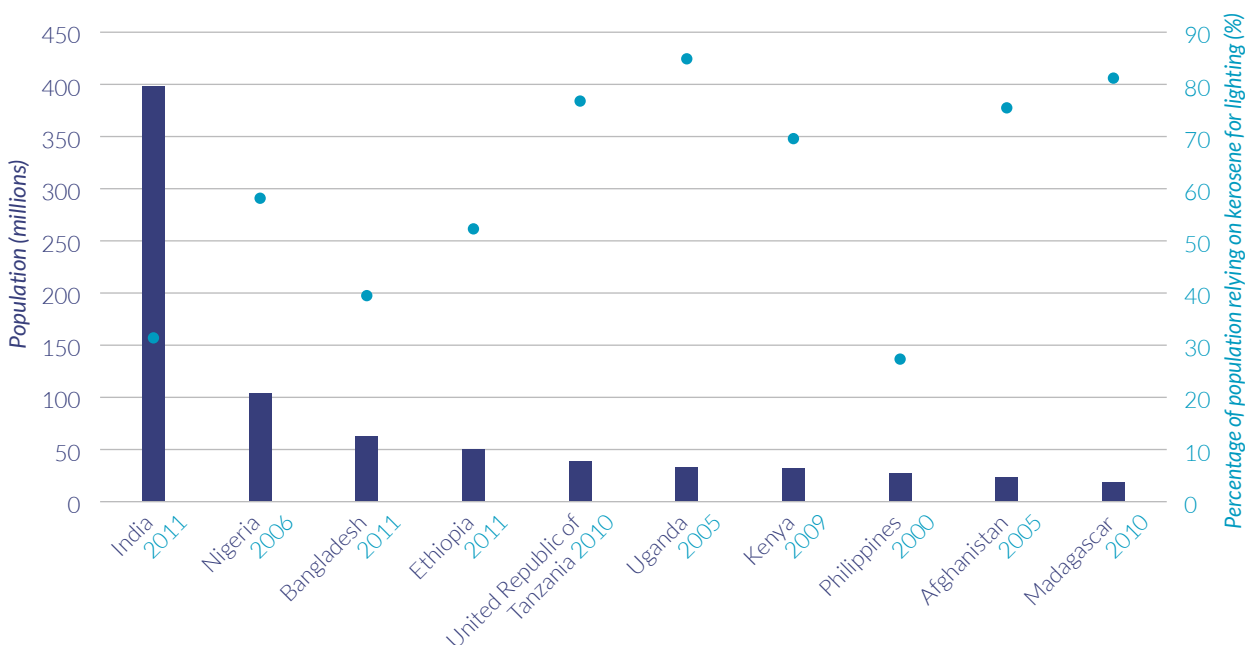
Of countries with lighting data, the most recent surveys from Madagascar (2010), Sierra Leone (2007) and Uganda (2005) all report that more than three quarters of their populations rely primarily on kerosene or oil lamps for lighting. In India, 400 million people, or 31% of households, still mainly use kerosene for lighting, representing the largest absolute kerosene-using population of all 57 countries included in the WHO Household energy database (Figure 25).

It should be noted that some more recent survey data suggest that clean lighting fuels are rapidly displacing kerosene in some countries, especially in sub-Saharan Africa (see Box 12). In the past few years, there has been a marked rise in sales of solar lanterns and in the installation of solar home lighting systems in Malawi and Rwanda, for instance (Rwanda Fourth Household Living Conditions Survey, 2014). These fast-moving trends are not always reflected in the most recently available, comprehensive surveys.

However, there are encouraging signs that the transition to clean lighting is accelerating in certain

parts of the world, displacing the use of polluting candles, kerosene and wood.

Figure 25. Top 10 LMICs by population relying on kerosene as primary lighting fuel (total)



Source: WHO Household energy database 2016

In the WHO African Region, the majority of households use polluting fuels as their primary lighting fuel (49% use kerosene or oil-lamps), although a substantial and growing fraction (41%) use electricity to light their homes (see Table 5 and Figure 26). In Madagascar, Sierra Leone and Uganda

more than 80% of households rely on kerosene as the primary lighting fuel. Around 3% of households in the African Region report that they use “candles”, another polluting source of energy for lighting. Likewise “straw” or “grass” is used in a small fraction of the households of Malawi and South Sudan.



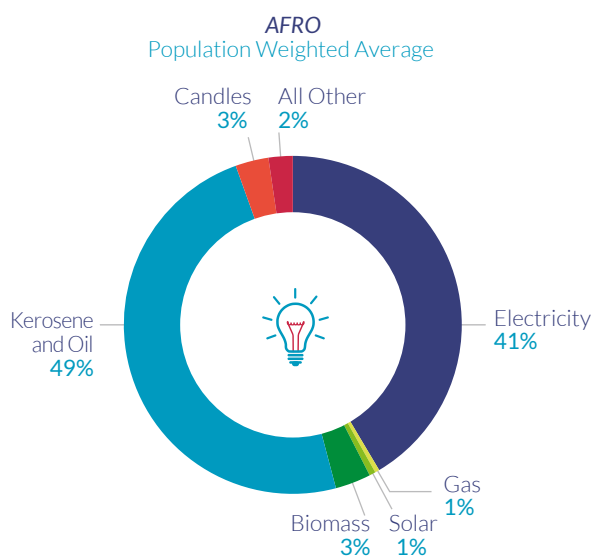
A Surinamese woman uses a solar lamp to illuminate her kitchen in the village of Botopasi, along the upper Suriname River in district Sipaliwini. Credit: REUTERS/Ranu Abhelakh

Table 5. Fuels used as primary lighting source by households in WHO African Region (25 countries included)

	Population weighted average (%)	Median (%)	Range (%)
Electricity	41	42	2.6–91.83
Gas	0	0	0–1.1245
Solar	1	0	0–3.4
Biomass	3	0	0–50
Kerosene and oil	49	36	0.65–85.75
Candles	3	3	0–65.7
All others	2	1	0–27

Source: WHO Household energy database, 2016

Figure 26. Fuels used as primary lighting source by households in WHO African Region (25 countries included)



Source: WHO Household energy database, 2016

In the Eastern Mediterranean Region and the South-East Asia Region, the two other regions with sufficient data to derive regional averages, the majority of households (86% and 66% respectively) report mainly using electricity for lighting (Tables 6 and 7; Figures 27 and 28). Looking only at population-weighted regional averages, however, can be misleading, as they hide the inherent intra-regional variation. For example, the main lighting sources of Afghanistan are substantially different from those of Tunisia, although both countries are in the Eastern Mediterranean Region. In Afghanistan, over three quarters of households rely primarily on polluting fuels for lighting, whereas in Tunisia, the entire population reports mainly using clean energy, such as electricity, for lighting. Similar differences between countries are seen in the South-East Asia Region. For example, 40% of households in Bangladesh rely on polluting fuels for lighting, compared to only 9% of households in Bhutan.



A woman works with a solar-powered sewing machine in Nieuw Aurora village in Suriname.
Credit: REUTERS/Ranu Abelakh

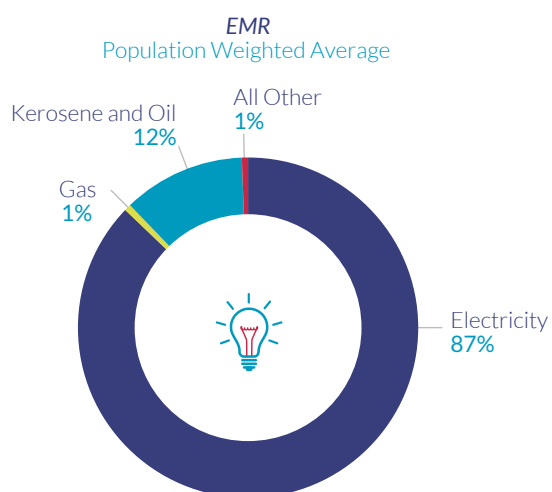
Table 6. Fuels used as primary lighting source by households in WHO Eastern Mediterranean Region (seven countries included)

	Population- weighted average (%)	Median (%)	Range (%)
Electricity	87	98	18.2–99.53
Gas	1	0	0–3.8
Solar	0	0	0–0.54
Biomass	0	0	0–0.52
Kerosene and oil	12	1	0.31–75.5
Candles	0	0	0–0.9
All other	1	0	0.06–4.01

Note: See Annex 2: methodology.

Source: WHO Household energy database, 2016

Figure 27. Fuels used as primary lighting source by households in WHO Eastern Mediterranean Region (seven countries included)



Source: WHO Household energy database, 2016



An Afghan woman and her child use a kerosene light.
Credit: Peter Turnley/Corbis

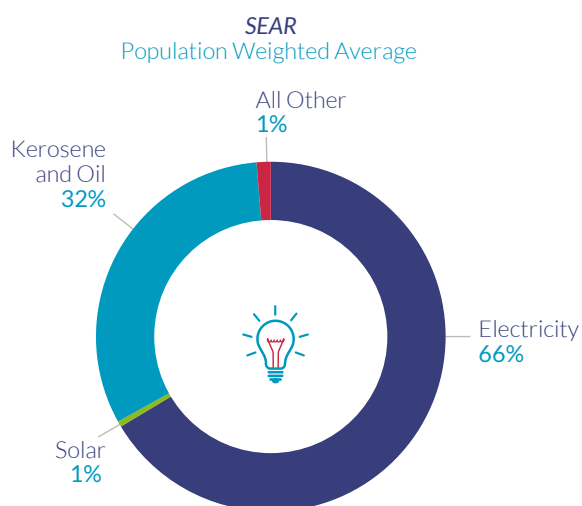
Table 7. Fuels used as primary lighting source by households in WHO South-East Asia Region (five countries included)

	Population- weighted average (%)	Median (%)	Range (%)
Electricity	66	67	57–88
Gas	0	0	0–0.3
Solar	1	2	0–7
Biomass	0	0	–
Kerosene and oil	32	18	8–40
Candles	0	0	0–0.2
All other	1	1	0–7

Note: See Annex 2: methodology.

Source: WHO Household energy database, 2016

Figure 28. Fuels used as primary lighting source by households in WHO South-East Asia Region (five countries represented)



Source: WHO Household energy database, 2016

For the Region of the Americas, the European Region and the Western Pacific Region, for which data are more limited, we do see some general trends when looking at national-level estimates. In the European Region, for which there are recent data for two of its LMICs, Albania and Armenia, both countries report almost complete reliance on clean energy sources for lighting (99% and 98%, respectively). Similar trends can be seen in the Region of the Americas, where eight of the 10 countries for which data are available report that 80% or more of households primarily



A man rents gasoline lanterns from his shop in Karachi. Credit: REUTERS/Akhtar Soomro

use clean sources of lighting. In the Western Pacific Region, all but two of the eight countries with lighting data report that two thirds or more of households use clean sources of energy for lighting, whereas the neighbouring Western Pacific Region countries, the Solomon Islands and Vanuatu, each report that a large proportion of households use polluting fuels for lighting (76% and 62% respectively). (Further national-level data for each of the regions can be found in Annex 6.)

BOX 13 – Voices from Uttar Pradesh: the many benefits of clean lighting

The people of the small village of Kaharan Purwa, in the state of Uttar Pradesh in north India, understand the dangers of kerosene all too well. “One of my customers, his whole house burned down, because of the kerosene lamp,” says the village shopkeeper. “In many places, children are burned by them.” Ramesh, a tenth-class student, says, “Before when I tried to read, smoke from the lamp would get in my eyes.” Now, thanks to the solar home systems installed by a new company, Mera Gao Power, he studies in the smoke-free glow of LED lamps. On his fingers, he ticks off the benefits of these simple systems, which include a cell-phone charger, and cost less per month than a typical household’s spending on kerosene. “First, we save money. Second, we save our houses and children – safety. Third, we can study. In the wet season, the flame is moving in lamp, but with light, no problem.” In the neighbouring village of Bhitauli, Betti Devi, a young mother, says she no longer uses five litres of kerosene

every month – an important savings on her family’s meagre farming income. But even more important is that “the children can study.” “It’s easier to prepare food,” she adds. “We are saved from smoke.” Her neighbour, village headman Krishna Kumar, agrees: “Before with kerosene burning, the house was always black. Now there is less smoke and soot. We like that there is less smoke now, and seven hours of light each day.” Other villagers point out a range of other benefits. They can now see dangerous snakes that like to coil and lurk in the dark corners of their kitchens. The light deters thieves who might come in the night to steal their grain. “People come and sit and talk because of the light”, says a shopkeeper. “The tailor is sitting up late, working. The doctor is looking at patients at night.” The light has brought people together.

Adapted from Fire and ice: soot, solidarity and survival on the roof of the world (Mingle, 2015).



The Energy and Resources Institute (TERI) provides rural Indian household with electric lights charged by solar-powered PV stations as part of their “Lighting a Billion Lives” initiative.
Credit: TERI

Closing the energy and ambition gap

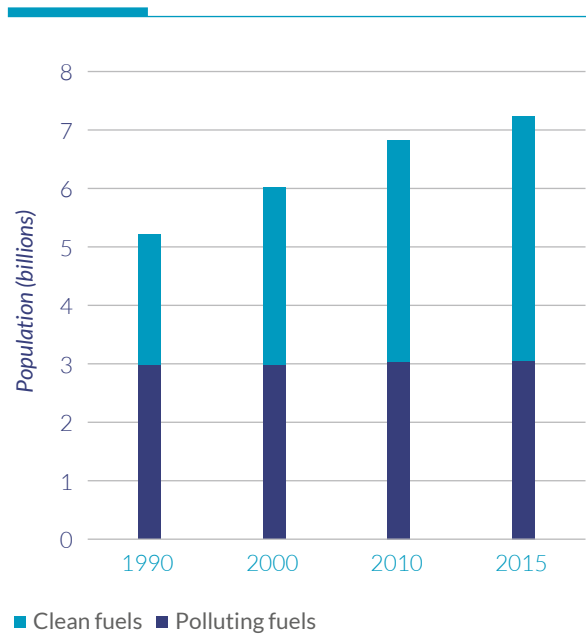
The data tell a sobering story: progress towards achieving universal access to clean energy remains much too slow (see Box 19).

In 2016, roughly as many people depend on polluting energy systems for cooking as did three decades ago (Figure 29). More than half of all households in LMICs rely on polluting energy to meet their daily cooking needs. The number of households using solid fuels for cooking nearly doubled in Africa between 1980 and 2010 (Bonjour et al., 2013).

The vast majority of people who lack access to clean, modern energy for cooking live in rural areas of the African, South-East Asia and Western Pacific Regions. In the African Region, more than half of households primarily use kerosene and other polluting fuels for lighting. About a third of people in India depend on kerosene to light their homes. Population growth has outstripped the modest rate at which access to clean energy has expanded in these regions.

This presents an enormous challenge for the global community. If current trends continue, the world will fall far short of achieving the goal of universal access to clean energy by 2030.

Figure 29. Global population relying on clean and polluting fuels from 1980 to 2014



Source: WHO Household energy database 2016

This plateau in the share of households using clean energy must be bent quickly into a sharply rising curve (see Box 14). Without a swift redoubling of effort – including expanded research into impacts and solutions, greater financial investment and more innovative financing mechanisms, and more effective policies – the absolute number of people bearing the heavy burdens of reliance on polluting, inefficient household energy will only increase in the coming decades.

BOX 14 – The investment gap and the cost of inaction



Estimates from the International Energy Agency (IEA)'s World Energy Outlook (WEO) 2014 suggest that a US\$ 45 billion investment will be needed annually up to 2030, to meet the universal access target for electricity. That is a fivefold increase over the amount invested in 2010, which was US\$ 9 billion (IEA, 2014). To achieve universal access to “modern” cooking solutions, investment will need to increase from US\$ 0.1 billion invested in 2010 to US\$ 4.4 billion annually until 2030 – a 44-fold increase. About US\$ 0.6 billion per year is needed for investment in clean cooking solutions such as LPG stoves, cleaner biomass stoves and biogas systems (IEA and World Bank, 2015).

These are not trivial sums. But the cost of inaction is much, much higher. An analysis conducted for the Intergovernmental Panel on Climate Change's

report *Climate change 2014: impacts, adaptation, and vulnerability* estimated that the total economic cost of the lost years of healthy life due to particulate pollution worldwide – both household and outdoor combined – in 2010 was US\$ 1.9 trillion (US). Another modelling study by UNEP in 2011 found that enacting a suite of 16 measures to reduce methane and black carbon measures would avoid 2.4 million premature deaths each year, most of them from exposure to emissions from biofuel combustion in households. The value of those avoided deaths would be over US\$ 5 trillion (UNEP/WMO, 2011). These estimates do not include the value of avoided climate impacts or avoided crop losses. When these and other environmental and economic impacts are taken into account, reducing household air pollution emerges as one of the most cost-effective strategies for jointly improving health and slowing climate change.

WHO's agenda to accelerate action for clean air

Mainstreaming household energy and air quality into the global public health agenda

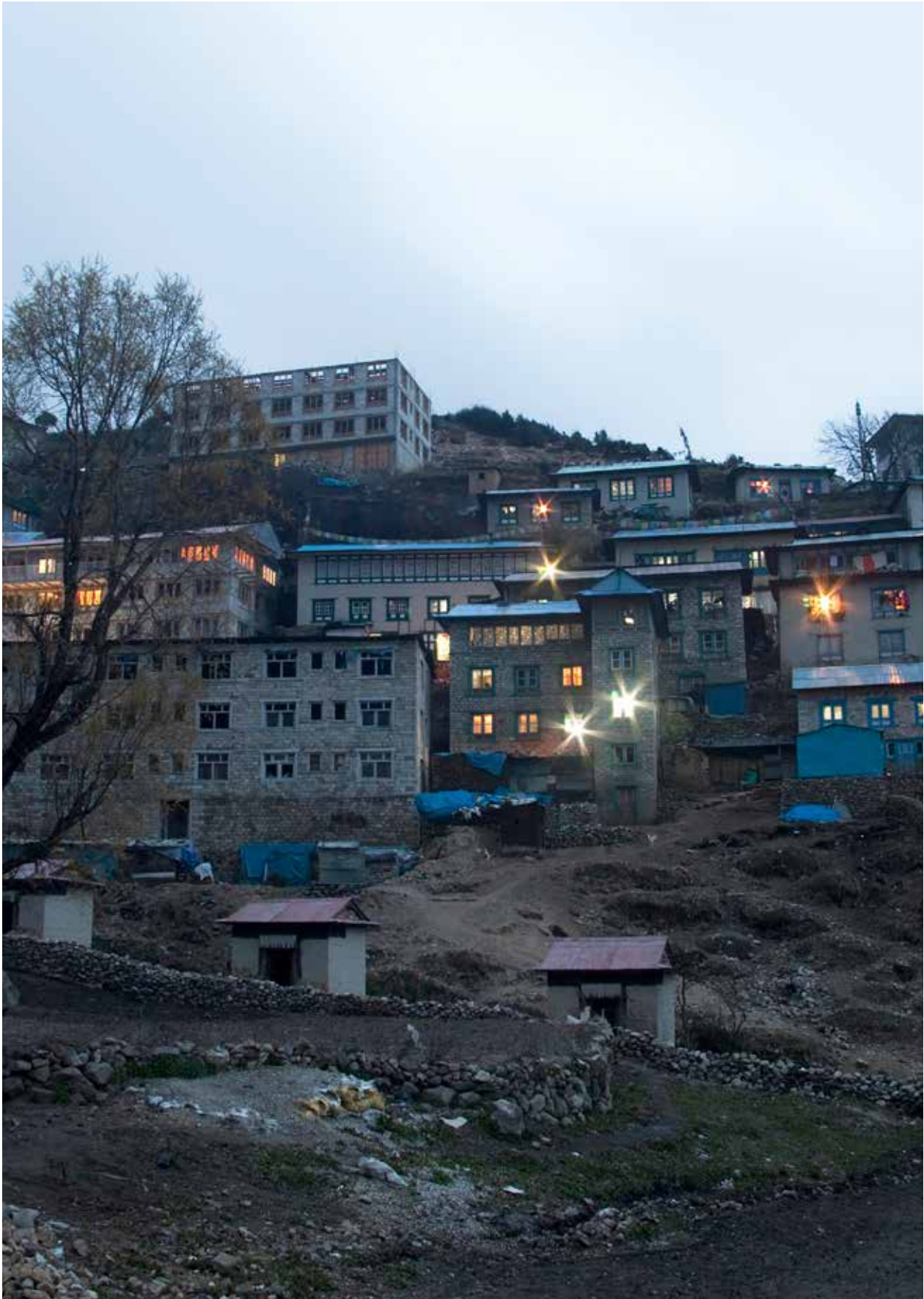
WHO is advancing awareness of reducing HAP as a core preventive public health measure on multiple fronts, including various global forums addressing maternal and child health issues.

A focus on HAP is an important component of the action plan for the control of noncommunicable diseases (NCDs) in the WHO South-East Asia Region, where NCDs are the leading cause of death. The action plan target is a 50% reduction in the proportion of households where solid fuel is used as the primary energy source for cooking. WHO is providing technical support and research for evaluating interventions aimed at reducing HAP, and facilitating sharing of best practices among the Region's Member States. Reducing HAP is also a key element of the Every Woman, Every Child campaign launched by UN Secretary-General Ban Ki-moon in 2010, which aims to intensify international and national action to alleviate the health risks for women and children around the world. Its goals include reducing by one third premature mortality from NCDs in women, children and adolescents by 2030. Improving indoor air quality is also one of the five key strategies for preventing pneumonia in children laid out in the Integrated Global Action Plan for the Prevention and Control of Pneumonia and Diarrhoea (GAPPD). The GAPPD provides a roadmap for national governments and their partners to plan and implement integrated approaches for the prevention and control of pneumonia and diarrhoea. One of the GAPPD's goals is to reduce the incidence of severe pneumonia by 75% in children less than five years of age compared to 2010 levels, by 2025. Multiple studies suggest that steep reductions in HAP can significantly reduce the risk of severe pneumonia.

WHO is integrating resources for promoting clean household energy into global child health initiatives and decision-support tools for use by Member

States' health ministries and other organizations. WHO is also working with partners at country-level survey agencies, as well as administrators of global household surveys such as MICS, Living Standards Measurement Studies and DHS, to develop, field test and refine new questions about household energy use. To date, inconsistencies in the design of questions and responses used in various surveys have hampered coordinated monitoring of progress towards energy access, and comparison of data across countries. Using harmonized indicators and questions on national and international household surveys will enable a more complete understanding of the range of health, development and environmental consequences of household energy use. As women and girls bear most of the burden of relying on polluting fuels, and are the primary users of household energy, there is an especially urgent need to collect more gender-relevant information.

In order to develop and refine indicators and survey questions along these lines, in October 2015 WHO convened a meeting of experts in data collection on household energy, survey design and implementation, gender indicators, health and livelihood impacts, representatives from statistical bureaus in various countries, and representatives from the World Bank, the Global Alliance for Clean Cookstoves and other international institutions. Valuable progress was made towards developing a detailed set of harmonized indicators and survey questions on household energy use and health impacts. In the wake of the meeting, field testing of recommended survey questions is being conducted in Ghana and Peru. WHO is also supporting efforts to build the capacity of local researchers and public health practitioners to measure exposure and health outcomes, and assess the efficacy of various interventions. This will inform the finalization of questions and modules for use in relevant national and global household surveys, and possibly in other monitoring efforts, including the Global Tracking Framework of the SE4ALL initiative. These updated survey tools will reflect the new SDG indicator's focus on "clean fuels and technologies", and help capture a more complete picture of different energy activities in the household.



Light bulbs illuminate the Himalayan village of Namche Bazar, Nepal. Light bulbs replaced kerosene lamps when Namche got electricity from a hydroelectric plant.
Credit: REUTERS/Laurence Tan



A woman carries wood to use for cooking in her home in a slum in Islamabad, Pakistan. Credit: REUTERS/A. Ali



04

.....

**THE HEAVY
BURDENS OF
HOUSEHOLD
ENERGY**

“ The heaviest burdens of widespread dependence on polluting and inefficient energy fall on women and children. ”

4 THE HEAVY BURDENS OF HOUSEHOLD ENERGY

Gender roles and fuel collection

If you rise at dawn on a dry season day, and go out to the road leading west from the town of Birendranagar, Nepal, you are likely to find a parade of hunched figures, slowly approaching in the half light. As they come nearer, you will see they carry towering bundles of wood on their backs, secured by lines around their foreheads. And as they draw still closer, you will hear their voices, see their faces, and you will realize they are all women.

These women have already spent many hours in the forest, on this and prior visits, cutting and stacking wood. Now they are hauling it back to use for cooking in their homes, or to sell in the market to earn income for their families.

The types of fuel may vary, but a scene quite similar to this one plays out every day, from Botswana to Myanmar and beyond. As in Nepal, so in much of the world, fuel collection is typically considered women's work. The gender dynamics of household energy use vary from place to place, but they tend to be driven both by deep-seated cultural norms and economic factors (see Box 15). In Ghana, national surveys find that women spend three times as many hours per week collecting wood as men do, and they spend more than 10 times as many hours cooking (FAO, 2012). From Senegal to the United Republic of Tanzania, surveys show that women in most, if not all, African countries do the bulk of fuel wood collection for use in the home. (In many urban areas of the developing world, men collect wood to sell for profit, or are employed as porters of charcoal and fuel wood; very few studies have examined the health and safety risks they face.) In rural areas of Guatemala, collecting wood is almost exclusively considered women's work (Rath, 2005). But even in urban areas – where there is more access to LPG and electricity – female-headed households are significantly more likely to use wood than those headed by males (Heltberg, 2003). That is because women-headed households generally have fewer financial resources, and are more sensitive to the price of modern fuels, than male-headed ones.

There are some exceptions. For example, as new analysis has found, boys in Haiti spend more time in wood

gathering than girls. One interpretation of this finding may be that boys are sent out to gather fuel, to protect girls in settings where security is a major concern.

Women and girls often carry loads of wood, dung and other fuels, which can weigh 40 kg or more, on their backs or heads. They are responsible for harvesting, bundling, chopping, storing and burning them. Common sense suggests that the cumulative physical strain of performing these tasks, day after day, year after year, is considerable. But there are few empirical studies on the injuries and types of chronic discomfort – muscle strains, spinal injuries, headaches, bone fractures, back aches, rheumatism and complications of pregnancy, to name but a few – that women incur in the process of procuring wood and other polluting fuels.

Reliance on polluting fuels imposes other heavy costs on women and girls: it robs them of their time. This is an aspect of energy poverty that is nearly universal, and almost as nearly universally overlooked. There are relatively few empirical studies of the time cost and drudgery involved in fuel collection and preparation by women and girls, but those few that exist paint a picture of unrelenting tedium, strain and risk. The Self-Employed Women's Association in India conducted a recent survey of its members, and found that women in rural Gujarat spend as much as 40% of their waking time collecting fuel or cooking (World LP Gas Association, 2014). One survey of more than 700 rural households in Himachal Pradesh in northern India found that women walked an average of two kilometres to collect wood. Finding, harvesting, and transporting fuel to keep hearth fires burning took each household an average of 40 hours per month. Procuring LPG was almost exclusively done by men, while women were mostly responsible for gathering wood, dung and crop residues (Parikh, 2011).

Broadly speaking, the impacts of energy collection have received much less attention from researchers and policy-makers than the impacts of energy use. Formal economic indicators mostly fail to capture the value of domestic work performed by women in the developing world. This constitutes a significant "blind spot", with important consequences for planning effective interventions: if something is not measured, it is less likely to be addressed in public health programmes and policies. Without a large evidence base to motivate

action, other health priorities will of course eclipse what may be a large, but uncertain, burden.

But even as more research into the linkages between health impacts and fuel collection proceeds, action need not wait. After all, the burdens of inefficient home energy are plain to see for anyone who goes to watch the women walking with their heavy loads at dawn back into Birendranagar. But the avenues for transforming energy from a burden to an opportunity, for those determined women and their families, are increasingly coming into focus. Rapidly transitioning to clean energy systems in the home will largely help alleviate these real and heavy burdens, however “hidden” they may be today from official measures.



A girl carries a LPG cylinder as she follows her mother in Kabul, Afghanistan.

Credit: REUTERS/Adnan Abidi



TIME LOST

Girls in households that cook with polluting fuels spent up to 35 hours a week collecting wood and water



Women carry wood for their stoves in La Fuente, Guatemala.

Credit: REUTERS/Daniel LeClair

BOX 15 – Gender, energy and decision-making

How gender roles influence household energy choices

Why hasn't there been more widespread adoption of cleaner fuels and technologies in recent decades? One part of the answer is surely that many household energy programmes (and surveys and studies as well) have historically been blind to gender roles within the household, and within societies.

The relative power of women and men in household decision-making is a crucial and often overlooked factor in the adoption and sustained use of clean fuels and technologies. In many cultures and countries, men and women often make different choices about energy, and use energy in different ways. In most societies, men have more control than women over household budgets, and therefore more influence over the decision to purchase a new stove or device. Meanwhile, women are typically the primary gatherers and users of energy in the home, and the ones who would benefit most from switching to cleaner cooking, heating and lighting systems. But if women lack decision-making authority within the household, their preferences for healthier options may be trumped by men's concerns about costs.

One study in Bangladesh found that men generally placed more value on fuel savings and associated costs, while women were more likely to acknowledge the value of the health benefits of a more efficient stove – leading to lower adoption rates of health-improving stoves (Miller & Mobarak, 2013). Another

study, in Ethiopia, found a correlation between higher rates of adoption of electric cookstoves with higher education levels of women in the household (and with the number of educated household members overall) (Alem et al., 2013). This suggests that education may lend more status in decision-making, and more educated women may have more negotiating power within the household. Other studies have found that households with women who have their own source of income or savings are also more likely to purchase cleaner cooking devices (Puzzolo et al., 2014).

Efforts to make the cleanest cooking, heating or lighting solutions more widely available and affordable will not necessarily close the energy access gap, if those who control the finances do not assign or acknowledge the value of their benefits for other members of the household. (The same holds true for women in high-income households who employ someone else to do the cooking, and who therefore may not prioritize investing in clean cooking.)

To successfully address the health crisis of HAP, programmes and policies must explicitly account for this and other important gender dynamics. And to inform such policies and successful interventions, we need a much more robust understanding of the varied interests and involvement of both women *and* men when it comes to energy use.



A man watches his stove light, fueled by his household biogas system, which runs on cow manure. Guazapa, El Salvador. Credit: REUTERS/Luis Galdamez

Fuel collection by children – analysis

So just how much time do households spend collecting fuel? How much does it vary between countries? Is there an unequal fuel collection burden for girls compared to boys?

Data from national surveys shed a little light, as they generally ask a few questions on the amount of time spent gathering wood for household uses. The most widely available questions are from child labour modules on the USAID DHS and UNICEF MICS, which include questions assessing whether wood or water was collected in the past week, and if so, how much time was spent on this task (in hours) over the past week. Although these questions do not exclusively focus on wood collection, they serve as practical surrogates to estimate the prevalence of fuel collection by children, and children's time lost to fuel collection. To better understand the degree to which the household cooking fuel type relates to drudgery and time loss, the data on fuel collection are disaggregated by households that mainly cook with clean and polluting cooking systems (including wood).

Considering available data from these sources collected since 2010, the African Region has the most data available on wood and water collection (for 16 countries), followed by the Region of the Americas (5 countries), the European Region (four countries), the Eastern and Mediterranean Region, Western Pacific Region (two countries each) and South-East Asian Region (one country). Data presented here

for the ten countries show the highest proportion of girls and boys collecting wood or water. Data for all available countries is presented in Annex 7.

Proportion of children collecting wood or water

The overall prevalence of children aged 5 to 14 years gathering wood or water is generally higher in households that primarily rely on polluting cooking fuels. There are large differences among the LMICs surveyed in the proportion of children who collect wood or water. Rwanda, Burundi and Malawi have the highest rates of girls or boys collecting wood or water – all are above 80% for households cooking with polluting fuels (see Figure 30). Rwanda has the highest rate of the countries with available data – almost 85% of girls and boys reported collecting wood or water in the past week.

A few countries show more substantial differences between the percentages of children who collect wood or water based on the type of cooking fuel mainly used. In particular, Haiti, Niger and Vietnam report far larger percentages of children collecting wood or water coming from homes where cooking is done with polluting fuels, than from homes where cooking is done with clean fuels. For example, over 20% of girls and boys report collection of wood or water in polluting fuel-using households, compared to 3% in clean fuel households. This analysis also suggests that even households that primarily use clean fuels still have children who gather



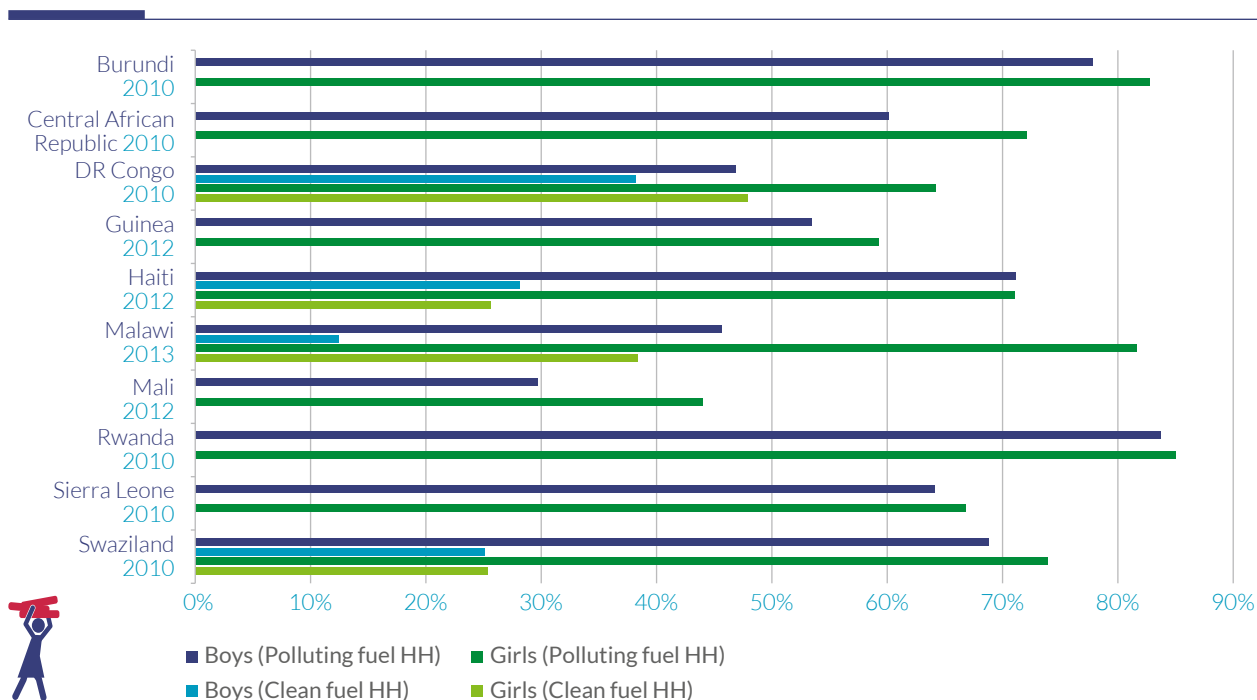
A young girl of Afghan descent carries dry wood for cooking to her home in a refugee settlement on the outskirts of Karachi, Pakistan. Credit: REUTERS/Akhtar Soomro

wood or water, which might signal that fuel-stove stacking is taking place (although it is not possible to distinguish whether wood, water or both are collected using these data).

The results of this analysis also indicate that a higher proportion of girls gather wood or water than boys in most of the countries analysed. Results from Burkina

Faso showed the greatest difference between the proportion of girls and boys collecting fuel and water: in households that cook with polluting fuels, 60% of girls gather wood or water, but only 35% of boys do; in Malawi homes that cook with polluting fuels the situation is similar with 82% of girls in collecting and less than 45% of boys.

Figure 30. Top ten countries for percentage of boys and girls who collected wood or water in the past week, disaggregated by household cooking fuel



Source: WHO Household energy database 2016

Note: The percentage of children who report collecting wood or water in the past week is disaggregated by country and by gender, showing that children from households that primarily cook with polluting fuels spend more time collecting wood or water than those whose households cook with clean fuels and that girls generally spend more time collecting than boys. Data from USAID DHS and UNICEF MICS collected since 2010. See Annex 7 for complete data. Countries with missing bars for clean fuels had fewer than 25 children using each of the individual clean fuels, therefore no rates were calculated.

How much time is lost to wood and water collection?

In all countries with sufficient data on fuel collection paired with data on the main cooking fuel used, it is evident that children living in households that cook mainly with clean fuels spend less time gathering wood or water than those from households primarily relying on polluting fuels (data from the ten countries with greatest average time burdens collecting wood or water shown in Figure 31). Children in Benin, Togo and Rwanda spend the most time collecting wood or water – on average, girls in households that cook with polluting fuels spend more than 30 hours per week.

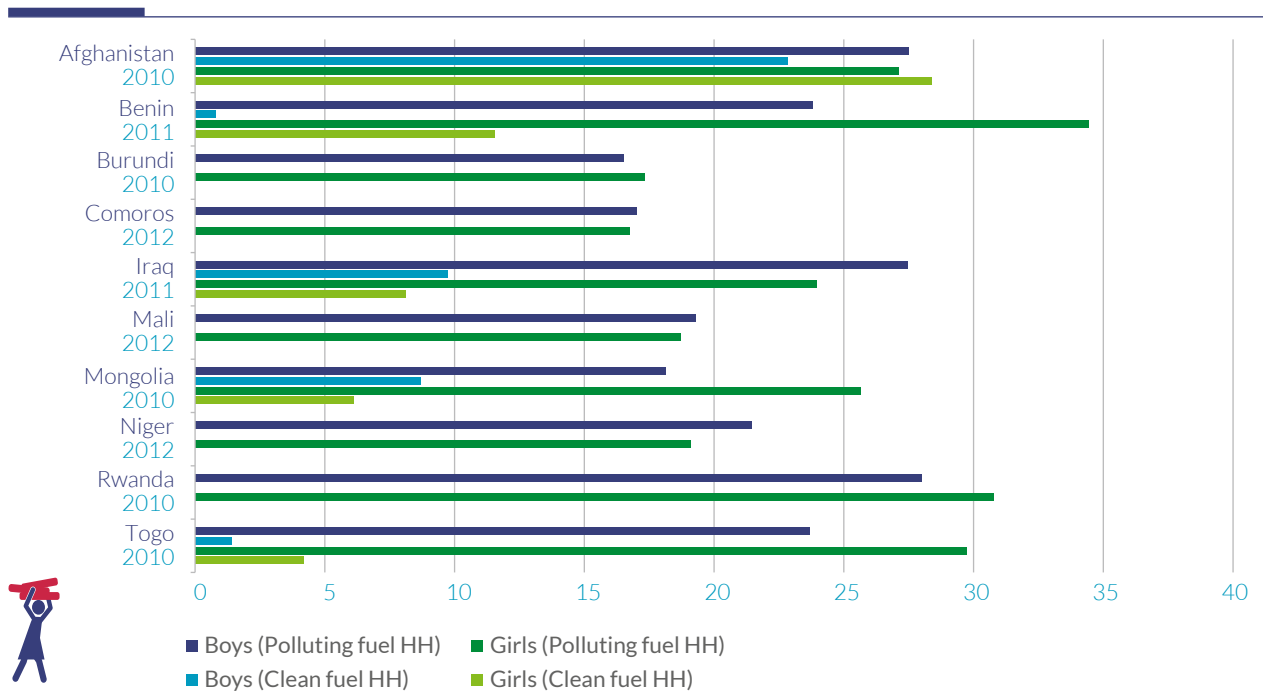
Both girls and boys spend a substantial amount of time gathering wood or water, although girls generally spend more time than boys. Limited data are available on the amount of time spent gathering wood or water by children from households that primarily cook with clean fuels. However, the available results show that both boys and girls in clean-fuel using households spent less time gathering wood or water than those from homes where mainly polluting fuels are used for cooking. Girls in Benin, for example, spend almost 12 hours per week gathering wood or water in households that cook mainly with clean fuels – this is less than half of the time that girls in polluting-fuel households spend. Other striking differentials in time burden between

households with polluting and clean cooking fuels are observed for children from countries such as Iraq, Mongolia and Togo.

Not surprisingly, these empirical data suggest that girls living in households cooking mainly with

polluting fuels bear the greatest time-loss burden collecting wood or water. The time differential is particularly striking in Benin, where girls in households that cook with polluting fuels spend over 10 hours more on weekly wood or water collection than boys.

Figure 31. Top ten countries for average number of hours spent collecting wood or water in the past week among boys and girls who collect wood or water, disaggregated by household cooking fuel



Source: WHO Household energy database 2016

Note: Children in households that cook with polluting fuels spend more time gathering wood or water than children in households that cook with clean fuels. Data are from USAID DHS and UNICEF MICS collected since 2010. Data for all available countries are presented in Annex 7.



A girl carries dried shrubs that she gathered for use as a cooking and heating fuel in her home on the outskirts of Kabul, Afghanistan. Credit: REUTERS/Omar Sobhani

BOX 16 – The potential of clean energy livelihoods



A boy studies by the light of a solar lamp sold by an enterprise set up by SolarAid, a nonprofit operating in different parts of Africa. Credit: Ashden Awards

Even as it brightens living spaces and kitchens, clean energy can brighten a household's economic prospects. Livelihood opportunities offered by the clean energy sector – from sales to manufacturing, installation, maintenance, and marketing – are an increasingly significant avenue for earning income, receiving training and securing reliable employment.

These opportunities can be especially transformative for women. And, given their firsthand experience of the costs and benefits of energy use, women can be especially effective in developing and disseminating clean energy solutions at the household level. Among the participants of an entrepreneurship training project in Kenya, for example, women sold almost three times as many new cookstoves as men (Shankar et al. 2015). The Africa Biogas Partnership Programme (ABPP) was launched in 2009 to promote household biogas systems across Burkina Faso, Ethiopia, Kenya, Uganda and the United Republic of Tanzania; as of June 2015, more than 51 000 units had been constructed, serving more than 205 000 people. From its outset, the ABPP has been focused on mainstreaming gender issues into the programme implementation and monitoring. This approach, informed in part by lessons learned from the dissemination of biogas systems in Nepal, has proven successful: many women are employed as masons in construction of the systems, and the ABPP has found that training women in digester maintenance can increase the efficiency and output of the biogas system (Energia, 2010).

A variety of case studies have found that women are effective energy entrepreneurs, employees and sales agents (Khan, 2001) (see Box 16). Empower Generation has built a network of women-led rural energy enterprises in Nepal, providing start-up loans to entrepreneurs selling solar lights and mobile-phone chargers in rural areas. In Kenya, BURN Manufacturing makes and distributes its “*jikokoa*” charcoal-burning stove (which reduces particulate emissions by over 60% compared to a conventional stove). Almost half of BURN's employees working in production of the stove are women, and two thirds of those in sales, management and administration are women (Ashden, 2015). There are similar opportunities across the clean energy sector and its various value chains. But, despite these bright spots, women's overall employment in the clean household energy sector remains quite low (Practical Action, 2014).

Meanwhile, a lack of access to clean, reliable energy compounds the many challenges women face each and every day. Without adequate light, the simplest tasks take longer and are harder to do, increasing the amount of time that has to be spent on domestic chores. Spending scarce income on kerosene limits investments in education or productive enterprises. There is emerging

evidence that clean energy can lift these various burdens from women and girls: for example, fuels such as LPG can reduce the amount of time it takes to cook certain meals. The nutrient-rich, pathogen-free slurry produced by biogas systems can be sold as a fertilizer for added income. Fuel savings from the use of more efficient solid fuel stoves can translate to savings of time and money – which can, in turn, be spent on productive investments, health and education (or simply rest and leisure). However, these benefits cannot simply be assumed – they must be measured and monitored (Pachauri and Rao, 2013). Some studies have found that gaining access to electricity, for example, can actually increase the amount of time women spend working: light and appliances extend the time they spend on income-generating work, even as domestic demands on their time remain the same (Costa et al., 2009).

This paradox highlights the need for surveys to capture more information on how domestic energy-related and other chores constrain women's time and mobility, and how involvement in the clean energy value chain influences livelihood opportunities for both women and men (Pachauri and Rao, 2013) (see Box 17). One example would be tracking the income generated in a household by participating in the

clean energy value chain. Another would be the number and quality of jobs created by the solar lighting or clean cookstove markets – including opportunities in manufacturing, distribution, sales and maintenance – in a given area.

Will having access to clean cooking, heating and lighting systems empower women and girls, and free up their *own* energy for more productive and life-enriching activities? The answers depend

on the context, on whether available technologies truly align with their preferences and needs, and on whether they have the freedom to express those preferences. But the lessons from populations that have already made the transition to clean energy suggest that, if gender-sensitive policy and social norms emerge, women are indeed likely to be more empowered and to benefit from access to cleaner fuels and technologies in a variety of ways.



*A girl carries dried shrubs home to use for cooking and heating in Bagram, Afghanistan.
Credit: REUTERS/Erik De Castro*



The retreat of snowfields and glaciers in the Himalayan region threatens communities dependent on meltwater to irrigate subsistence crops.
Credit: Jonathan Mingle



05

.....

**THE CLIMATE
BENEFITS
OF CLEAN
HOUSEHOLD
ENERGY**

“Clean household energy solutions offer the potential to save lives, increase local resilience to environmental change, and reduce climate-warming emissions.”

5 THE CLIMATE BENEFITS OF CLEAN HOUSEHOLD ENERGY

The climate impacts of household air pollution

The damage wrought by HAP extends far beyond the boundaries of the home, village or neighbourhood. Once aloft in the atmosphere, the smoke that streams up from hundreds of millions of hearth fires and kerosene lamps alters the climate in both the short and long term.

Household energy use is a significant source of climate-warming pollution. Indeed, recent research suggests that the climate impact of HAP is greater than previously thought. Emissions from the incomplete combustion of both biomass and fossil fuels in traditional stoves, open fires or wick lamps can include both greenhouse gases and short-lived climate pollutants (SLCPs) such as methane, black carbon and volatile organic compounds that contribute to the formation of ozone (a powerful warming agent). All of these pollutants are dangerous to human health. And all contribute to climate change to varying degrees.

Household combustion of fossil fuels adds carbon dioxide to the atmosphere. But new estimates suggest that household burning of biomass is also a significant source of greenhouse gas emissions. Bioenergy accounts for about 10% of global primary energy use; the majority of this consumption is the burning of biomass for household cooking and heating in the developing world (IEA, 2010). More than half of all wood harvested globally is used for fuel. Even as this demand for wood and other biomass fuels causes widespread deforestation, and disrupts ecosystems and wildlife habitat on a large scale, it also contributes to global warming. A recent study found that burning wood for fuel accounts for more than one gigaton of carbon dioxide-equivalent emissions per year, about 2% of total global emissions. This is because about one third of global wood fuel harvesting is unsustainable – trees and plants are not replanted to replace what is harvested, resulting in a net addition of heat-trapping carbon to the atmosphere (Bailis et al., 2015).

This would be true even if that wood were burned efficiently. Under ideal conditions, the combustion

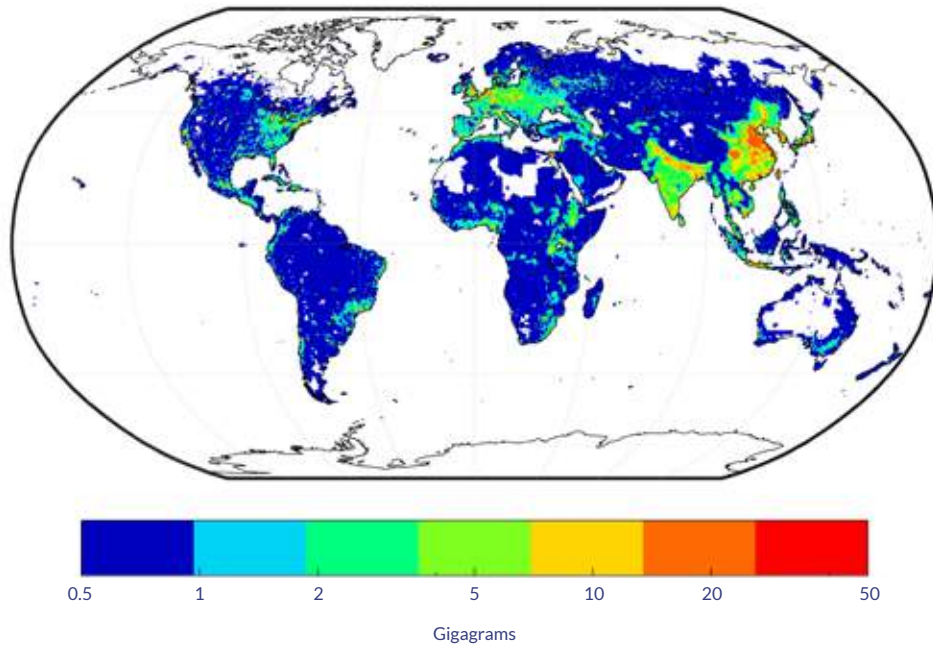
of any fuel produces only useful heat, carbon dioxide and water. But household combustion is far from ideal – rather, it is always incomplete, and often quite inefficient. Thus wood fires emit “products of incomplete combustion”, such as methane, volatile organic compounds, black carbon and other particulate matter. While carbon dioxide can linger in the atmosphere for several decades before it cycles out, these pollutants persist for weeks to years. These SLCPs are also major contributors to climate change.

Methane and black carbon, in particular, are powerful warming agents on shorter timescales. Black carbon can disrupt regional systems such as the south Asian Monsoon, and it has been shown to be a major, if not the primary, driver of glacier retreat and thinning in the Himalaya and Tibetan Plateau region (Ramanathan & Carmichael, 2008). When these SLCPs are accounted for, the use of biomass fuels compares unfavourably, in terms of climate impacts, with fossil fuels such as LPG, which burns much more completely (WHO, 2015) (Figure 32). Methane is a strong greenhouse gas, and also a precursor to the formation of tropospheric ozone, a greenhouse gas that impedes the growth of agricultural crops and directly damages human health. Ozone exposure led to an estimated 150 000 premature deaths in 2010 (Lim et al., 2012).



*A mud stove used for both cooking and heating in a household in northern Nepal.
Credit: Jonathan Mingle*

Figure 32. Global black carbon emissions from residential combustion, in Gigagrams (Gg). This includes emissions from fossil fuels and biofuels such as household biomass (i.e., wood, charcoal, dung, crop waste) used for cooking.



Note: Estimates are based on 2000 emissions. Data source and map production by Tami Bond, developed using materials from the United States National Imagery and Mapping Agency and reproduced with permission.

There is increasing evidence that many household energy solutions that are “clean” for health are also clean and beneficial for the environment (see Box 17). A recent report prepared by WHO, in partnership with the Climate and Clean Air Coalition (CCAC), examined a suite of measures that would reduce exposure to air pollution and have environmental, climate and economic benefits. In the household energy sector, three actions were modelled: switching to low-emission cookstoves and fuels; improving lighting to replace kerosene

lamps; and implementing passive design principles to reduce fuel consumption for space heating (together with ventilation and daylighting). These measures would result in significant reductions of both carbon dioxide and SLCP emissions. Reduced demand for biomass for cooking and heating would lead to reduced deforestation rates, and increased absorption of carbon dioxide by trees. Clean-burning stoves can also reduce emissions of methane and carbon monoxide.

BLACK CARBON

The rapid transition of three billion people from using polluting to clean fuels and technologies could be one of the most effective black carbon mitigation opportunities of all



Household air pollution contributes to climate-warming emissions that accelerate the loss of snow and ice in mountain regions. Credit: Jonathan Mingle

BOX 17 – Taking the long view

The life cycle impacts of fuels



Indonesian workers prepare LPG (liquid petroleum gas) tanks in Semarang, Central Java province, as part of a program to accelerate the switch from kerosene to LPG for cooking. Credit: REUTERS/Stringer

When evaluating household energy solutions, the full life cycle of any fuel must be taken into account. Electricity may be the cleanest way to cook in the kitchen, but that is because it takes the combustion out of the household and effectively moves it elsewhere.

If that electricity is generated by a coal-fired power plant, for example, it is a source of climate-warming pollution. Depending on how that plant's emissions are controlled and where it is located, it may expose some distant community to health-damaging pollution. And electricity starts to look like a very inefficient way to cook a meal, once you take into account the thermal efficiency of the power plant, the losses during transmission and distribution, and the losses when the current is turned into heat – only some of which may enter the cooking pot. If the electricity is generated renewably on-site, these concerns are less relevant – but the manufacture of

solar panels and lead-acid batteries can also produce toxic by-products, as well as a carbon footprint. For these reasons, the entire value chain behind the fuel and device must be considered.

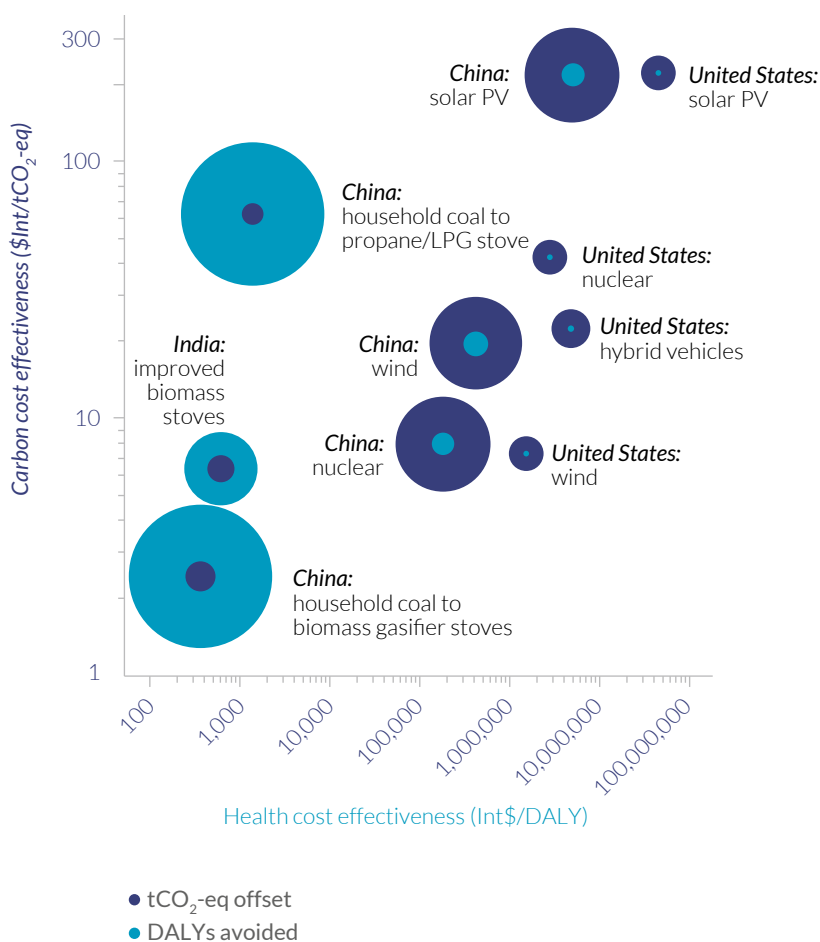
As fossil fuels, LPG and PNG are also sources of climate-warming pollution. Their extraction, processing, refining and distribution can also have negative environmental impacts and negative health impacts for communities close to their point of production. Leaks from gas pipelines or containers send methane, a potent greenhouse gas, into the atmosphere. The use of LPG and PNG for cooking, however, is not a major source of global greenhouse gas emissions compared to other sectors such as power generation, transport and industry. Even if more than a billion people switched from burning solid fuels to using LPG for cooking, the projected effect on petroleum demand and greenhouse gas emissions would be very small (IEA, 2010). When the climate-warming effects of short-lived pollutants from combustion of solid fuels – such as methane and black carbon – are considered, switching to LPG and PNG could even provide net climate benefits, according to some analyses (WHO, 2015).

Balancing climate and health goals in the household energy sector can entail trade-offs, or at least careful consideration of how to target climate policies to minimize their impact on the poor and maximize health benefits. One recent modelling study found that aggressive climate mitigation policies could translate to higher energy prices in south Asia, putting clean cooking fuels such as LPG beyond the reach of 20% of the population. This would make it difficult to achieve universal access to clean cooking by 2030 in India, forcing more than 700 million south Asians to continue to rely on polluting solid fuels and stoves for cooking. To avoid this scenario, policies to offset the anticipated rise in the price of LPG will be needed, such as subsidies to cover the upfront costs of gas stoves, as well as to support consumers' regular purchase of the fuel (Cameron et al., 2016).

Expanding access to clean and efficient fuels and technologies will thus be critical to achieving climate mitigation goals at both the national and global levels. WHO's SLCP study builds on previous work by the United Nations Environment Programme (UNEP) and others, which concluded that implementation of 14 measures reducing black carbon and methane emissions could avoid 0.5 degrees Celsius of warming by 2050 (Shindell et al., 2012). This aggressive action on SLCPs would substantially increase the likelihood of meeting the global target, agreed upon by 195 nations at the UN Conference of Parties (COP)21 meeting in Paris in December 2015, of "holding the increase in the global average temperature to well below 2 °C above pre-industrial levels," and of pursuing efforts to limit the increase to 1.5 °C above pre-industrial levels.

A key research recommendation in the recent WHO IAQ guidelines calls for policies designed to harness climate and health synergies, and more research to support the development of these "co-control" policies (see Annex 3) (Figure 33). Maximizing both climate and health benefits via mitigation measures in the household energy sector will require greater interdisciplinary collaboration between practitioners and scientists in their respective fields, and an integrated approach to turning their findings and recommendations into sound policy at the local, national and global levels. The alternative – health and climate policies developed and pursued in isolation from each other – could lead to unintended adverse effects, and missed opportunities to gain significant leverage on two of the great, and interconnected, challenges of our time.

Figure 33. Illustrative co-benefits comparison of the health and climate cost-effectiveness of selected household, transport, and power sector interventions



Note: Scoping comparison of the health and climate cost-effectiveness of household, transport, and power sector interventions. The area of each circle denotes the total social benefit in international dollars from the combined value of carbon offsets (valued at 10\$/tCO₂-eq) and averted DALYs [\$7450/DALY, which is representative of valuing each DALY at the average world GDP (PPP) per capita]. See the original reference for details of the calculations in this figure (Smith and Haigler, 2008).

Source: Smith and Haigler (2008). Reproduced with kind permission of the *Annual Review of Public Health*.

Clean energy and climate resilience

Reductions of emissions from household combustion would improve health in other, more indirect ways. SLCPs influence regional climate systems, increasing the likelihood of disasters such as glacial lake outburst floods as a result of melting glaciers, and disruption of monsoon rains on which billions depend (see Box 18). Ozone damages crops and black carbon reduces the sunlight reaching them, reducing yields of staples like wheat and rice, threatening food security and nutrition in vulnerable populations.

Expanding energy access will be critical for helping communities adapt to climate change as well. In the summer of 2012, the largest power outage in history unfolded in 22 of India's 28 states, affecting more than 620 million people. Trains stopped running, traffic lights winked out, water treatment plants shut down and life-saving equipment in hospitals had to be operated manually. A variety of factors precipitated the crisis. They included extreme high temperatures that caused power demand for cooling to reach record levels. A late monsoon had led farmers to increase their use of electric pumps to irrigate their fields with well water, and also left hydropower stations operating at low capacity.

The outage highlighted the vulnerability of India's infrastructure – including its electrical grid – to climate change. India is far from alone in this respect: climate change is expected to lead to increased intensity and frequency of severe weather events, floods and droughts in many parts of the world. Floods can block roads and energy supply chains. Droughts can lead to stress on forests and ecosystems upon which many people depend for fuel, food and other essentials.

Such events are a direct threat to health, but they also threaten health indirectly, by undermining access to energy, water and food for large, already vulnerable populations. Climate change is likely to impact rural people in the developing world more than any other population group. And in those areas, it is the poorest citizens who have, by definition, the least capacity to withstand the shocks of displacement, crop failure, or the stresses of extreme weather.

Because energy touches every facet of life, energy system failure can imperil development on every front. Hospitals cannot function, vaccines cannot be stored, children cannot go to school. Businesses cannot operate, and workers lose income and risk sliding into poverty.

Fortunately, even as access to clean energy directly reduces the health impacts of pollution, it builds the capacity of the poor to adapt to climate change. Access to reliable sources of energy is an essential characteristic of a resilient household or community. Solar microgrids, solar home lighting systems and other decentralized and distributed clean and renewable energy systems can expand economic opportunity and reduce vulnerability to extreme weather events and other disasters, even as they obviate the future need for fossil-fuel-generated electricity to meet growing demand from growing populations. These and other innovative household energy solutions offer the potential to save lives, increase local resilience to environmental change, and reduce climate-warming emissions (Alstone, Gershenson and Kammen, 2015).



Women cooking in Varanasi, India.
Credit: Corbis/David Lefranc

BOX 18 – The household climate opportunity

Black carbon and the co-benefits of clean household energy



Villagers walk on a street as the haze shrouds Pulau Mentaro village in Muaro Jambi, on the Indonesian island of Sumatra. Credit: REUTERS/Beawiharta Beawiharta

The primary SLCP of concern found in HAP is black carbon, a light-absorbing aerosol and component of fine particulate matter (PM_{2.5}). Black carbon is scientists' term for the fine particles in soot that make it dark. Black carbon contributes to climate change in a variety of ways. Aloft in the atmosphere, black carbon absorbs solar energy and re-radiates it as heat, and influences cloud formation. When it settles out onto snow and ice surfaces, it reduces the amount of light they reflect, accelerating the melting of glaciers and snowfields from the Himalayas to the Arctic. Among all warming pollutants, black carbon is estimated to be the second-most important contributor to positive radiative forcing (net addition of energy to the atmosphere) after carbon dioxide (Bond et al., 2013). Household combustion is one of the leading sources, producing a quarter of total global black carbon emissions (Figures 32 and 33). The vast majority of those residential emissions come from developing country households (UNEP/WMO, 2011). In Asia and Africa, residential solid fuel use accounts for between 60 and 80% of total black carbon emissions (Bond et al., 2013)

Black carbon washes out of the atmosphere after one to two weeks, on average. Concentrations therefore tend to be higher – and the associated impacts tend to be greater – closer to the source of emissions. In cold mountain regions, for example, many people burn polluting fuels for space heating, producing black carbon that may contribute to the deterioration of nearby glaciers and snowfields on which they depend for seasonal water supplies. But, for all the damage it wreaks, soot also presents an opportunity: due to its short lifespan in the atmosphere, reducing black carbon will almost immediately slow warming. A recent study modelled various mitigation options for SLCPs and found that “in terms of volume, the largest contribution to the reduction in Arctic warming comes from an improved domestic heating and cooking sector in Asia and in the rest of the world” (Sand et al., 2015). These benefits would be realized in large part through reductions in black carbon.

Because black carbon is often co-emitted with cooling aerosols, there is some uncertainty around the climate mitigation potential of certain measures. Smoke from some sources, however – such as combustion of kerosene, diesel, and certain biofuels – is richer in black carbon. Targeting these sources offers a higher likelihood for realizing climate and health co-benefits. Kerosene particulate emissions, for example, are almost 100% black carbon. Kerosene burned for lighting is the source of 270 000 tonnes of black carbon per year (Lam et al., 2012). These emissions contribute the warming equivalent of 240 million tonnes of carbon dioxide (Jacobsen et al., 2013). With many clean, affordable alternative technologies for lighting coming onto the market, replacing kerosene lamps is “low-hanging fruit” for achieving climate and health goals (see Box 11).

Tackling black carbon thus offers leverage on the two biggest challenges facing humanity in the twenty-first century: poverty and climate change. The rapid transition of three billion people from using polluting to clean fuels and technologies might be one of the most effective black carbon mitigation opportunities of all. The climate mitigation case for addressing HAP is even stronger when carbon dioxide emissions from kerosene use, and the emissions of other SLCPs such as methane and carbon monoxide from solid fuel combustion, are considered.



Filter papers collected from homes to monitor household air pollution in Uttarakhand, India. Credit: Jessica Lewis

In recognition of this opportunity, in 2012, UNEP, together with the US State Department, launched the Climate and Clean Air Coalition (CCAC). The CCAC is a voluntary initiative comprising more than 60 countries and institutional partners. It works to accelerate efforts to reduce emissions of black carbon, methane, hydrofluorocarbons (HFCs), and other SLCPs by bolstering existing efforts and spurring new research and action. The CCAC is working to reduce SLCP emissions from cooking and heating through new finance mechanisms, supporting the development of new standards and testing protocols with partners such as GACC, and funding research and pilot programmes to deploy clean cooking solutions.



*A family in China's Guangxi Province uses a biogas digester - fed with waste from the pigs they keep - to provide fuel for both lighting and cooking.
Credit: Corbis/Andrew Rowat*



06

.....

**THE
OPPORTUNITY**

“ Closing the energy access gap is now a firmly fixed priority on the global sustainable development agenda. As a global community, we can choose to extend clean energy to every corner of the world. ”

6 THE OPPORTUNITY

Key conclusions

- Household air pollution (HAP) is a global health crisis. Exposure to HAP is responsible for 4.3 million premature deaths each year, making it the single most important environmental health risk factor worldwide.
- New WHO indoor air quality guidelines on household fuel combustion provide the first definitive guidance on what counts as “clean” household energy – including emissions rate targets for fuel and stove combinations, and recommendations to avoid the use of unprocessed coal and kerosene as household fuels. These guidelines will inform efforts by countries, relevant international agencies and other institutions to promote energy solutions that result in meaningful reductions in the health risks associated with household combustion.
- Ensuring access to clean household energy will unblock progress towards multiple SDGs and targets. Accelerating the rate at which poor households gain access to clean energy presents an invaluable opportunity to make progress towards several SDGs, via current synergistic initiatives that encompass energy, gender and health. But current trends suggest that the global community is moving too slowly (see Box 19). Without dramatically increased effort and investment, we are likely to fall short of SDG 7.
- A new focus on “polluting” and “clean” fuels and technologies enables more complete estimates of the impacts of household energy use on health and other factors. The new indicator used to track progress towards SDG 7 is based on new evidence of the health risks associated with the full range of household energy end-uses beyond cooking, including space heating and lighting. It also encourages innovation in renewable household energy technologies and highlights their important role not only for sustainable development but also health.
- Universal energy access cannot be achieved without more gender-responsive programmes and policies – which in turn require better data collection and indicators. These and other significant data gaps must be addressed to inform effective action. There is an urgent need for harmonized indicators and questions for use in household surveys, in order to gain a more complete understanding of the range of health, development, and environmental consequences of household energy use.
- Reducing HAP offers an unparalleled opportunity to realize climate and health co-benefits. Accelerating access to clean energy for cooking, heating and lighting can avert a significant amount of atmospheric warming in the next few decades, and help protect vulnerable systems such as the Arctic and high mountain glaciers.



COOKING

Today, roughly the same number of people cook with polluting energy systems as did 30 years ago



GENDER

Universal energy access cannot be achieved without more gender-responsive programmes and policies – which in turn require better data collection and indicators



A woman in Cambodia cooks with an efficient biomass stove.
Credit: Faraz Usmani

BOX 19 – The state of energy access in 2016

Key findings from new analyses of clean and polluting fuel use for cooking, heating and lighting

Cooking: Building upon the estimates using the previous indicator (i.e. “primary reliance on solid fuels for cooking”), this analysis of “polluting fuels” (i.e. solid fuels plus kerosene) confirms that the rate of the global transition to using clean cooking energy is slow at best. The inclusion of kerosene within this indicator has pushed previous global estimates of 2.9 billion people exposed to HAP associated with cooking to more than three billion people (3.1 billion). For some countries, such as Djibouti, Fiji and Guyana, the inclusion of kerosene has significantly increased the percentage of households mainly using polluting fuels for cooking, compared to previous estimates reporting only on solid fuel use.

The WHO African Region reports the highest proportion of households – an average 84% of the population – mainly using polluting cooking fuels. The situation is worse in rural areas, where on average almost 95% of the population mainly use polluting cooking fuels, compared to about 70% of the urban population. In terms of sheer numbers, the South-East Asia region is home to the greatest number of people exposed to the health risks associated with polluting cooking methods. More than 1.2 billion people in the South-East Asia Region – equivalent to around 65% of the population – mainly used polluting fuels for cooking in 2014. As in the African Region, the situation is much bleaker in rural areas of the South-East Asia Region, where around 85% of the rural population cook mainly with polluting fuels, compared to one third of the urban population.

Currently collection of data on the types of cooking stoves used in the home is neither comprehensive nor harmonized enough to permit the derivation of global and/or national estimates of the health risks posed by cooking fuels paired with the stove technologies in use. As surveys are enhanced to gather more data on the types of cooking stoves used, our tracking of the health impacts from household energy will also be improved.

Heating: Few data are available on the fuels and technologies used for space heating. Even with a comprehensive search of household surveys, censuses and related reports, data from only 14 countries could be identified. This paucity clearly illustrates the need for more comprehensive data collection on both the fuels and technologies used by households for keeping warm. One striking finding from this small set of countries, however, is the important role that kerosene plays in the space heating energy mix. In some countries of the Eastern Mediterranean and African Regions, kerosene is used by a large fraction of the population. For example, recent surveys from Lesotho and Jordan report 34% and 64% of households, respectively, use mainly kerosene

for space heating. This small sample of surveys also highlights the importance of biomass for space heating, even in those countries that mainly use cleaner fuels for cooking. For example, in Armenia less than 5% of the population use mainly polluting fuels for cooking, but over 50% of households rely on biomass fuels for heating. Statistics from countries like Bhutan and the Democratic People’s Republic of Korea are a bleak reminder that coal also poses an important health risk that cannot be overlooked.

Lighting: Although not as complete as the data on cooking fuels, the data on primary lighting energy highlight both the important health risk still posed by inefficient lighting and the increasing feasibility of transitioning to clean lighting sources. Of the households surveyed, two thirds rely primarily on clean fuels for lighting (mostly electricity) and one third on polluting lighting fuels (mostly kerosene). The highest proportion of kerosene use is in Rwanda and Sierra Leone, where around 94% of households use kerosene as their primary lighting fuel. As in the case of use of polluting fuel for cooking, in terms of sheer numbers, the South-East Asia Region dominates. India has more people using kerosene for lighting than the nine next highest countries combined, with almost 400 million people relying mainly on kerosene lamps. This substantial dataset also reveals the significant roles that other energy sources, both clean and polluting play in the household lighting mix. For example, the use of clean and renewable solar energy systems has become more widespread in some countries, like Nepal, where around 8% of households mainly use solar energy for lighting. On the other hand, these surveys also reveal that more than half of the population still uses firewood, candles and other biomass fuels for lighting.

These findings highlight the importance of addressing all polluting household energy end-uses, and doing so with targeted interventions based on understanding of the national context, as substantial inter-country variations exist that are not necessarily evident when looking at regional or global figures.

All told, these analyses reveal some encouraging progress: worldwide, primary reliance on polluting fuels for cooking declined from over 65% to 42% between 1980 and 2010 (Figure 15). But they also reveal that the decline in regions such as Africa and South-East Asia is not steep enough – a stark reminder of the significant distance we as a global community must travel before reaching the goal of access to clean energy for cooking, heating and lighting in every household.

BOX 20 – Making the clean available



A woman makes tea using a stove fueled by liquefied petroleum gas (LPG) in a village near New Delhi, India. Credit: REUTERS/Anindito Mukherjee

Over half of the world's population cooks with gas or electricity, using proven technologies that are widely available in both urban and rural areas of the developed world (and in many urban areas of the developing world). These cooking systems have emissions rates that meet WHO's new rigorous IAQ standards for "clean" air. They are familiar and tested, safe and convenient to use.

So how can these proven clean cooking solutions be made available to the billions who currently depend on polluting fuels and technologies?

To be able to use electric cooking devices, including new, highly efficient induction cookers, people need reliable, affordable electricity. That means expanding the power grid to those living without electricity, or installing decentralized power systems such as micro-grids, but it also means improving the reliability of supply to those who already have connections. For wider and more rapid adoption of LPG, governments need to work with the private sector to create enabling environments. Behind the gas burner and cylinder in the kitchen lies an extensive infrastructure: gas bottling and storage facilities, distribution networks and points, facilities for maintenance, and retail outlets for associated equipment like stovetop burners.

Providing choices to consumers is key to increasing the uptake of clean household energy solutions. Examples include investing in portable filling stations, and offering smaller LPG bottle sizes that are easier to transport in rural areas. Tailored consumer financing mechanisms, via micro-credit products or mobile-phone-based "pay as you go" services, can also align payment schedules with individual household budgets, which can fluctuate widely, especially in poorer, rural settings.

Targeted subsidies can help low-income households afford LPG refills, for example. These investments can create virtuous cycles: studies demonstrate that households are often willing to spend more on clean energy, if they have access. In many settings, fuels like gas and electricity have an aspirational quality for many people, and are perceived as more convenient, hygienic and "modern", than biomass or coal. Indonesia offers an encouraging example. In 2007, its government reallocated subsidies for kerosene to LPG, resulting in 50 million households (40% of the population) shifting to cooking primarily with LPG by 2011 (Budhya & Arofat, 2011). This strategic shift resulted in enormous savings in subsidy payments for the government. Indonesia's experience shows that, with the right policies and committed political leadership, the clean can be made available quickly, and on a large scale.

Both grass-roots and government-supported social campaigns can play a role in expanding access, too. In 2015, the government of India launched the "Give It Up" campaign, which calls on middle-class households that can afford the market price to voluntarily cancel their right to an LPG subsidy, and transfer it to a low-income household. More than 5.8 million households elected to give up their subsidies in 2015, transferring hundreds of millions of dollars to the poor to enable them to use clean energy in lieu of dung and wood. India's Ministry of Petroleum and Natural Gas has partnered with Indian Oil to bring LPG cooking to rural residents across the country, as part of its "smokeless village" campaign.

The way forward



*A woman and her electric light in Bhubaneswar, India.
Credit: Dinodia/Corbis*

These findings present us with some stark lessons, and an urgent imperative.

Serious data gaps are impeding global progress towards cleaning up air in and around the home, especially in LMICs. A lack of detailed data – on heating and lighting energy use, on gender roles and decision-making within the household, and on the gender-related determinants of health inequities – makes it impossible to properly target

the use of finite resources to reduce health risks and end energy poverty. These data gaps must be quickly addressed. More coordinated action is needed to develop, harmonize and deploy better indicators and survey questions. Rigorous monitoring and evaluation are essential to track the adoption of those interventions that are effective for improving health – and to identify areas that need more focused efforts. The same holds true for verifying the potential economic benefits and climate benefits of clean household energy fuels and technologies.

Past efforts to measure fuel use and to monitor and evaluate the effectiveness of various interventions have suffered from a lack of clarity on what is clean – on what produces meaningful reductions in health risks from HAP and household energy use. The new WHO IAQ guidelines have provided the health benchmark and, together with the new ISO cookstove standards, the SE4All GTF and other initiatives, significant steps have been made towards establishing common points of reference and protocols for measuring and tracking clean household energy use.

Several decades of research, national stove programmes and international initiatives have yet to produce a significant reduction in the population depending on polluting fuels and technologies to meet their daily energy needs. Today, roughly the same number of people cook with polluting energy systems as did 30 years ago. If current trends continue, the total number of people relying on polluting cooking energy will remain roughly the same in 2030 as it is today (GTF, 2015). The World Bank projects that by 2030, only 72% of the global population will have access to modern energy for clean cooking – well short of the target of universal access by 2030.

BOX 21 – A biogas success story in Nepal

The Biogas Sector Partnership (BSP) is a unique public-private partnership that has installed more than 260 000 household biogas systems across all of Nepal's 75 districts. BSP subsidizes the upfront installation cost, sets up supply chains and maintenance protocols, supervises the construction and trains the household members on how to operate the system safely. The units can last 20 years. Dung and other materials added to the tank and mixed with water every day are free, and so is the gas that comes out of the pipe. The fuel savings from avoided LPG, wood and kerosene usage exceed the cost of the system within three years. The BSP is a model ripe

for replication and scaling up in other settings, especially rural areas where people rely on polluting fuels and technologies for cooking, and where keeping livestock is common.

Effective policies and creative partnerships that increase the accessibility and affordability of proven clean fuels are urgently needed, at the national, regional and global levels. Increased investment in supply chain and distribution infrastructure, and new household financing mechanisms, are essential to expand access to already proven and clean cooking solutions that can save lives, time and money for the world's poorest.

At the national level, however, there have been promising examples of rapid, wide-scale improvements in household energy practices. In China, the National Improved Stoves Program disseminated about 180 million fuel-saving stoves. In Indonesia, the government transitioned 50 million people from cooking primarily with kerosene to much cleaner LPG. The Biogas Sector Partnership in Nepal has built 260 000 household biogas systems covering every district of the country (see Box 21). These impressive achievements hint at what is possible with concerted, effectively targeted, coordinated action. Meanwhile, the adoption of SDG 7 demonstrates that the global development community is finally treating HAP and energy as the urgent crisis – and vast opportunity – that it is.

The stakes could not be higher, and time is short. As a global community, we must learn from our failures, build on recent successes, and leverage new momentum to achieve universal access to clean household energy for all.

The role of WHO and its international partners

Building on successes

WHO and its Member States and partners have made great strides in terms of monitoring the exposure to HAP from household energy use, estimating the related burden of disease and, more recently, in harnessing the evidence for effective interventions in cooking, heating and lighting for protecting health. These successes should be leveraged and built upon, in particular with regard to the following categories of action.

1. Tracking change and evaluating progress

For more than a decade, WHO has been regularly reporting information on energy use for cooking from its global Household energy database. This database is now being upgraded in association with international and national surveys and censuses to include data on heating and lighting fuels and technologies and emission rates, and to disaggregate data by sex and age whenever possible.

The burden of disease estimates based on these data will continue to be regularly updated, based on ongoing assessments of the relative risks and exposures associated with the use of fuels and technologies for cooking, heating and lighting – including kerosene (now categorized as a polluting fuel). These estimates will inform targeted

interventions to reduce exposure to emissions from polluting energy systems, and efforts to monitor their progress.

2. Building the evidence base on effective interventions to address the sources of HAP and reduce adverse health outcomes

Based on extensive evidence reviews, the WHO *guidelines for indoor air quality: household fuel combustion* (IAQ guidelines) provide emissions rate targets for fuel and stove combinations that can be considered clean for health. These guidelines can help policy-makers accelerate access to clean fuels, and advance optimal transitional technologies, such as highly efficient biomass-burning stoves. The IAQ guidelines are an important tool for planning effective energy, development and public health policy, as they steer stakeholders away from polluting fuels, such as kerosene and unprocessed coal, and towards solutions that are truly clean and beneficial for health.

Further development of the evidence on effective interventions should continue to be summarized and disseminated using the strict criteria for evaluation developed by WHO, to ensure the impartiality and scientific rigour of those assessments.



A health worker checks the blood pressure of a woman - the primary cook in her household - in Odisha, India. Credit: Jessica Lewis

3. Engagement with governments in support of concerted action to reduce HAP and expand access to clean household energy

In May 2015, the World Health Assembly (WHA) unanimously adopted a resolution on air pollution and health, calling for increased cross-sector cooperation and the integration of health concerns into national, regional and local air pollution-related policies. A draft road map defining an enhanced

global response to the adverse effects of air pollution in line with this resolution has been developed and should be adopted at the 2016 Health Assembly.

The road map outlines four categories of work:

- a. expanding the knowledge base;
- b. monitoring and reporting;
- c. global leadership and coordination; and
- d. institutional capacity strengthening.

Each category includes activities that build the capacity of Member States and other stakeholders to improve public health by addressing HAP, and to regularly review their own progress.

One key activity that spans the four categories is the development of a clean household energy toolkit for policy-makers at a national or local level. The toolkit is intended to provide the means for bringing the evidence and recommendations found in the WHO IAQ guidelines to the attention of health sector decision-makers and professionals. At the same time, it should provide them with the knowledge and resources to assist them in engaging effectively with and influencing the energy planning process. Another fundamental activity is enhancing the capacity of Member States to monitor household energy use and its health impacts. This will be done through the updating and harmonization of national-level surveys, the continued improvement of the WHO Household energy database to include data on all household energy end uses and on gender differentiated impacts such as fuel wood collection. WHO will also develop an updated catalogue of methods that give specific guidance on diverse evaluation options, and how to develop an evaluation strategy.

In the near-term, WHO will continue to expand its own efforts to engage the health sector, support planning and programme delivery at the national level, and promote research to address critical data gaps.

Engaging the health sector

WHO will continue to identify and pursue opportunities for mainstreaming household energy and fuel interventions as part of the health sector's activities to reduce NCDs, promote maternal, child and adolescent health, and deliver primary health care at the community level.

- The global strategy for the prevention of noncommunicable diseases adopted at the UN General Assembly does not include air pollution as one of the key risk factors to prevent NCDs, partly because the evidence of the link between NCDs, heart disease and strokes and air pollution has only been accumulated over the past 10 years. Some WHO regional offices, such as the one in South-East Asia, have already adopted a resolution to intervene to

reduce indoor air pollution as part of their strategy to prevent NCDs. Actors working to reduce NCDs should engage much more actively with the reduction of HAP through clean household energy interventions, in view of the considerable impact of air pollution on NCDs and of the high levels of exposure to air pollution in the home.

- Child survival and other objectives of the Global Strategy for Maternal, Newborn and Adolescent Health, recently adopted by the UN General Assembly, can be achieved through targeted action to improve household energy, which has the potential to halve the pneumonia deaths (the highest cause of death in children aged under five years), as well as helping to prevent the almost half a million annual deaths from COPD in women caused by HAP. Targeting household energy should be considered as a key element of the Global Strategy for Women's, Children's and Adolescents' Health.
- Clinical practitioners and nurses have made substantial contributions to the prevention of diseases associated with tobacco smoking, unhealthy diets, physical inactivity or excessive use of alcohol, by providing advice to patients and to the communities they work with. These physicians and health-care professionals are trusted sources of information and guidance. The power of health workers in advising individuals, households and communities on preventive measures to reduce their exposure to HAP could be unleashed through targeted programmes to build capacity in the primary health-care sector.
- Women's health programmes could take up access to clean household energy fuels and technologies as a key area of focus. Such efforts would help empower women in their daily decisions to address the health risks of energy use in the home, informed by evidence of the roles that women and women's organizations can play to support a transition towards clean energy in the home.

Planning and programme delivery

There is an immense opportunity waiting to be realized to improve public health around the globe, through the development of comprehensive action plans to tackle HAP at the national level. Governments can reduce the burden of NCDs and childhood pneumonia in their populations by formulating detailed national action plans and policies to promote clean household energy in their countries. Promising models and pilot efforts should be identified for testing and scaling up. Country-level strategies will need to take stock of the emerging evidence on effective interventions, local circumstances, including strengths of institutions and service capacity, as well as opportunities for finance and delivery

mechanisms. International agencies and stakeholders can improve their coordination to channel investments and provide technical support to accelerate access to clean energy for health and climate co-benefits.

Filling the evidence gap

WHO will continue to promote research efforts comparing the relative effectiveness of household energy interventions for improving health, including identifying the interactions between exposure levels and fuel stacking and sustained adoption. Rigorous impact evaluation of the health and other benefits of proposed household energy interventions – whether they include adoption of LPG or electricity, or cleaner-burning biomass stoves – is essential.

Likewise, more research is needed into the complex factors of user preferences, behaviour change, adoption and sustained use. Gender roles are especially important and overlooked determinants of decision-making on energy in the household. Adoption and sustained use of clean energy solutions hinge on improved understanding of these intra-household dynamics, and of sex-specific impacts and opportunities related to involvement in the energy value chain. A lack of reliable, consistent empirical evidence on these varied impacts impedes the development of gender-responsive policies and interventions to improve and expand access to clean, safe, reliable energy.

Planning for interventions should consider all sources of HAP – from cooking, heating and lighting – and their impacts should be comprehensively

evaluated, taking into account fuel stacking, as well as impacts on energy efficiency, on indoor air quality, and on health.

More research is needed on these varied impacts, which are often overlooked by existing surveys and data collection efforts. There is a general consensus that a failure to acknowledge and investigate gender roles and intra-household dynamics, as a determinant of health outcomes, and of the resulting health inequities among and between women and men, has impeded the global transition to clean energy. Much more detailed measurements and analyses of those inequities and their determinants are required.

Even as this evidence base is expanded, focused action need not wait. The level of historical investment in technology development for clean delivery of household energy services is a pittance compared to the estimated value of their potential benefits. Dramatically expanded investment, research and development are needed to develop breakthrough innovations in clean household cooking, heating and lighting. To achieve the SDG 7 target of universal access by 2030, two parallel efforts should be continued and accelerated. One is the ongoing project of making energy solutions that are clean for health at the point-of-use – gas, electricity, biogas and others – more widely available, especially among the poor in the developing world (see Box 20). The other is the task of creating the next generation of efficient stoves that can cleanly burn biomass fuels – fuels that are already widely available in many parts of the world (see Box 22). Supporting research and development of such innovative, low-emissions technologies to provide household energy services should be a top priority for the global development agenda.



Survey of household energy use in Uttarakhand, India.
Credit: Jessica Lewis

BOX 22 – Making the available clean



Newly manufactured clay cooking devices are laid out to dry before electric coils are fitted onto them, in a workshop in Bhaktapur, Nepal. Credit: REUTERS/Navesh Chitrakar

A host of entrepreneurs, development agencies and research institutions are producing, testing and selling stoves that burn solid fuels much more completely than traditional stoves and fires. But are they clean?

Not quite. The systematic review of available interventions made for the 2014 WHO Guidelines for indoor air quality did not identify any solid fuel stoves currently available for purchase that meet the stringent emissions rate targets. Although some promising new devices are available in certain regions, their emissions reductions are not steep enough to lower health risks to acceptable levels.

This makes clear the need for more technological innovation in advanced solid fuel stoves. A large fraction of the world's population still burns solid fuels in a polluting manner to cook their daily meals, mainly because these fuels – whether wood, dung, crop waste, coal or charcoal – are either free to gather or relatively cheap to purchase. In other words, people depend on these fuels because they are readily available and affordable for people living in poverty. And most live in rural areas, where supply chains for modern fuels have yet to reach, or are often disrupted or unreliable. So they harvest wood from the forest, gather woody brush from the roadside, glean straw and other crop residues from their fields, and then burn those “free” fuels – with high, hidden health and other costs. These households will not gain access to clean fuels such as gas and electricity overnight. Even with accelerated efforts to expand access, this transition will take time. In the meantime, how can devices that burn biomass and coal be improved to produce less health damaging pollution, and approach WHO recommended limits in their emissions performance? In other words, how can the available be made clean?

Most past efforts, including national programmes such as those undertaken in India and China in the 1980s and 1990s, to develop “improved” stoves were focused on increasing fuel efficiency relative to traditional stoves and open fires. These large-scale efforts were largely motivated by concerns about deforestation and fuel scarcity. Other smaller-scale programmes implemented by development agencies and civil society groups, in a variety of different settings, have produced incremental improvements in the performance of solid fuel stoves. But despite more than 50 years of experimentation and dissemination, little progress has been made in alleviating the burden of disease from HAP associated with burning solid fuels for cooking (Smith & Sagar, 2014).

How can wood be burned like gas? Thorough mixing of fuel and air is key to achieving more complete combustion, and reducing particulate and other emissions. Gaseous and liquid fuels are much easier to burn almost completely, because they can be premixed with air, avoiding the formation of oxygen-starved pockets of fuel. (Simple kerosene stoves and lamps that are not pressurized are the exception – they can produce copious particles because the fuel and air are unevenly mixed.) Breaking solid fuels down into smaller pieces improves heat transfer and mixing of oxygen. Stoves that use uniformly sized, small biomass pellets and coal briquettes are cleaner burning in part for this reason.

Although this principle has been long understood, creating stoves that burn solid fuels cleanly remains a daunting engineering challenge. Combustion is an extremely complex process, with many stages. Fuels vary in composition, energy density and moisture content. Users have different habits, and operate stoves in different ways. Designing a device that can handle this variability and produce reliably clean emissions is not easy. A number of new and established companies have taken up that challenge in recent years: BioLite, Philips, StoveTec, Burn Manufacturing and EnviroFit are just a few of the firms that have rolled out new, cleaner-burning stoves for sale in low-income settings, using advanced manufacturing techniques and novel engineering strategies. Forced-draft stoves, some of which use electricity to power fans to dramatically improve combustion efficiency, and two-stage combustion are two such strategies that seem to offer the most promise for reducing emissions (Kar et al., 2012). These advances offer hope of finally solving an ancient problem – one that has confronted humanity since the very first hearth fire. But producing a stove that is robust, versatile, durable, and affordable enough to meet the needs of demanding consumers and cooks from Bangladesh to Ghana – and that is truly clean for health – will require sustained investment, iteration and innovation.

A call to action

Many cultures have some variation on this old proverb: “If you want fire, you must endure the smoke.” For much of human history, pollution seemed to be the price people had to pay to unlock the useful energy stored in fuels like wood and coal.

As this report shows, the latest evidence on the extent of household dependence on smoke-producing energy systems – and on the associated health risks – suggests that that price is much higher than we realized. About half of the world’s people cook their meals, and heat and light their homes using dangerously polluting fuels and devices.

The consequences are tragic: 4.3 million dead each year, just from breathing in smoke from fires lit for cooking alone. Most of them are women and children. These deaths are preventable – as are those caused by pollution from combustion for heating and lighting. So too are the countless and uncounted hours lost to gathering wood, and the significant contribution to atmospheric warming made by pollution from all household combustion.

The scourge of HAP is one of the largest overlooked health crises of our time. Like a quietly smouldering fire that has finally burst into full flame, we can no longer ignore it.

Fortunately, the proverb no longer holds true. The benefits of fire – vital energy services such as light and heat – can be harnessed without exposing the most vulnerable among us to dangerous smoke.

Clean alternatives exist – indeed, the majority of humanity already uses the main ones: electricity and gas. Meanwhile, efforts to develop and disseminate affordable transitional solutions such as cleaner-burning biomass stoves are gaining momentum.

The potential benefits for averting climate chaos, for expanding economic opportunity, and for reducing human suffering and protecting human health – especially for women and children – make investing in household energy interventions one of the most effective ways to spark progress towards a whole range of sustainable development goals.

As a global community, we can choose to extend clean energy to every corner of the globe. And, by doing so, we can turn the tale of cleaning up the twenty-first century hearth into one of the great success stories of human history.

A hot meal. A warm room. A well-lit home. These will always be fundamental human needs. With coordinated and concerted effort, we can make the use of polluting fuels and devices to meet them a relic of the past.



*A woman cooks under her new solar-powered light, installed by a social enterprise called Mera Gao Power, in a village in Sitapur District, Uttar Pradesh, India.
Credit: Karan Vaid*



Children stand beneath a wind turbine that produces clean energy for a village northwest of Karachi, Pakistan.
Credit: REUTERS/Akhtar Soomro

ANNEX 1: WHO REGIONS

Table A1.1. List of WHO regions (LMIC countries)

African Region		
Algeria	Rwanda	
Angola	South Africa	
Benin	South Sudan	
Botswana	Swaziland	
Burkina Faso	Togo	
Burundi	Uganda	
Cabo Verde	United Republic of Tanzania	
Cameroon	Zambia	
Central African Republic	Zimbabwe	
Chad	Region of the Americas	
Comoros	Antigua and Barbuda	
Congo	Argentina	
Côte d'Ivoire	Barbados	
Democratic Republic of the Congo	Belize	
Equatorial Guinea	Bolivia, Plurinational States of	
Eritrea	Brazil	
Ethiopia	Chile	
Gabon	Colombia	
Gambia	Costa Rica	
Ghana	Cuba	
Guinea	Dominica	
Guinea-Bissau	Dominican Republic	
Kenya	Ecuador	
Lesotho	El Salvador	
Liberia	Grenada	
Madagascar	Guatemala	
Malawi	Guyana	
Mali	Haiti	
Mauritania	Honduras	
Mauritius	Jamaica	
Mozambique	Mexico	
Namibia	Nicaragua	
Niger	Panama	
Nigeria	Paraguay	
	Peru	

Saint Lucia
Sao Tome and Principe
Senegal
Seychelles
Sierra Leone
Eastern Mediterranean Region
Afghanistan
Djibouti
Egypt
Iran (Islamic Republic of)
Iraq
Jordan
Lebanon
Libya
Morocco
Pakistan
Qatar
Saudi Arabia
Somalia
Sudan
Syrian Arab Republic
Tunisia
United Arab Emirates
Yemen
European Region
Albania
Armenia
Azerbaijan
Belarus
Bosnia and Herzegovina
Bulgaria
Croatia
Czech Republic
Estonia
Georgia
Kazakhstan
Kyrgyzstan
Latvia
Montenegro
Republic of Moldova
Romania
Russian Federation
Serbia
Slovakia
Slovenia
Tajikistan
The former Yugoslav Republic of Macedonia

Turkey
Saint Vincent and the Grenadines
Suriname
Trinidad and Tobago
Uruguay
Venezuela, Bolivarian Republic of
Turkmenistan
Ukraine
Uzbekistan
South-East Asia Region
Bangladesh
Bhutan
Democratic People's Republic of Korea
India
Indonesia
Maldives
Myanmar
Nepal
Sri Lanka
Thailand
Timor-Leste
Western Pacific Region
Cambodia
China
Cook Islands
Fiji
Kiribati
Lao People's Democratic Republic
Malaysia
Marshall Islands
Micronesia (Federated States of)
Mongolia
Nauru
Niue
Palau
Papua New Guinea
Philippines
Republic of Korea
Samoa
Solomon Islands
Tonga
Tuvalu
Vanuatu
Viet Nam

ANNEX 2: ADDITIONAL NOTES ON METHODOLOGY

Cooking fuel analysis

Survey data on household cooking fuels were obtained from the WHO Household energy database, which is a systematic compilation of estimates of household energy use from nationally representative surveys and censuses. Cooking fuel data are routinely collected at the national and subnational levels in most countries using censuses and surveys. Household surveys found in the database include: United States Agency for International Development (USAID)-supported Demographic and Health Surveys (DHS); United Nations Children’s Fund (UNICEF)-supported Multiple Indicator Cluster Surveys (MICS); WHO-supported World Health Surveys (WHS); World Bank’s Living Standard and Measurement Study and other reliable and nationally representative country surveys censuses. At the time of analysis, the WHO database contained data from 824 surveys on household cooking fuels collected from 161 countries (including high income countries) between 1970 and 2014.

Only those surveys that included a breakdown of individual clean fuel types were included, in order to be certain that the “clean” fuel category comprised only fuels meeting the WHO guidelines. Therefore, electricity, gas (e.g., LPG and natural gas) and solar energy were considered clean fuels but biomass, solid fuels and kerosene were considered polluting fuels. It was not possible to distinguish whether cooking devices fuelled with biomass had been produced using advanced technologies, therefore all use of biomass and solid fuels was considered “polluting”. If a survey was missing a fuel category, it was assumed that there was no use of that fuel or that it was included under “others”.

Global aggregate analysis of clean and polluting cooking fuels

To derive global estimates of the fuel and technologies used for cooking, a multilevel statistical

model using around 700 nationally representative data sources with cooking fuel data from the WHO Household energy database was used.

The statistical model used only accounts for regions, countries and time as a spline function, and resulting estimates were restricted to values ranging from zero to one. More details on the model are published elsewhere¹. All analyses were conducted using Stata software.

Countries classified as high-income with a gross national income (GNI) of more than US\$ 12 746 per capita² are assumed to have made a complete transition to using clean fuels and technologies as the primary source of domestic energy for cooking. When no information on cooking was available for the LMIC, the regional population-weighted mean was used. Note that this approach was also applied to Equatorial Guinea, instead of the one used for high-income countries.

The fuel category “other” was used if surveys recorded use of “other” as a fuel, if the households did not cook, or if the data were missing. Country-level estimates of polluting fuel use were obtained by dividing the proportion of the population using polluting fuels by the total population not using “other” fuels.

Countries are population-weighted to obtain regional aggregates; for countries with no data, the regional mean exposure is assumed; for countries with less than 5% of polluting fuel use, 0% is assumed for the calculation of regional or global means; for countries with more than 95% of polluting fuel use, 95% is assumed in the calculation of the mean.

There may be discrepancies between internationally reported and nationally reported figures for the following reasons:

¹ Bonjour, S. et al., 2013. Solid Fuel Use for Household Cooking: Country and Regional Estimates for 1980-2010. *Environmental health perspectives*, 784(7), pp.784–790. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23674502>.

² The World Bank, <http://data.worldbank.org/news/2015-country-classifications>, accessed December 2015.

- modelled estimates have been used instead of survey data points;
- estimates expressed as a percentage of population using polluting fuels as compared to percentage of households using solid fuels;
- use of different total population estimates;
- in the estimates presented here, values above 95% solid fuel use are reported as “>95%”, and values below 5% as “<5%”.

Regional analysis of individual cooking fuels

Owing to inconsistencies in the available survey data for countries, use of individual cooking fuel types (e.g. wood, charcoal, coal, kerosene and LPG) are only presented here as regional averages rather than country-level or global estimates. The regional values are derived using data from the most recent survey for a country, with no survey dated earlier than 2000. One hundred and thirty LMICs are included in the regional analysis of individual fuel use.

Lighting analysis

The lighting analysis utilizes nationally representative country-level survey data for primary lighting fuels. Survey data disaggregated by individual lighting fuels were included; surveys that only reported clubbed variables, i.e. “solid” and “clean” were excluded owing to discrepancies in the definition of these categories. Surveys from before 2000 were excluded. For the WHO African, Eastern Mediterranean and South-East Asia regions, a population-weighted regional average and median are presented in addition to the range of households lighting with different fuels. The range is defined by the minimum and maximum country-level estimates for each fuel type. “Electricity” includes electricity, generators and batteries. “Biomass” includes wood, straw and dung. “All other” includes households that report no source of lighting, missing households and households that record use of “other” for their lighting fuel.

At the time of analysis, the WHO lighting database contained a total of 171 surveys collected between 1963 and 2014. After selecting the most recent record for each country, the final dataset included 75 countries, 57 countries of which were LMICs. The analysis presented here covers only LMICs

classified according to the World Bank designations.³

For lighting, “clean” fuels are LPG, natural gas, electricity, battery, generator, solar, and oil lamps. Polluting fuels are kerosene, biomass (firewood, grass and dung), and candles. (“Other” refers to households that reported no lighting, those that recorded “other” on surveys, and missing data.) *Note:* A few countries use grass and wood for lighting. Grass is used for lighting in Malawi (2%) and South Sudan (15%). Dung is used for lighting in South Africa (negligible) and Iraq (negligible). Firewood is reported as a lighting fuel in South Sudan (35%), Rwanda (15%), Ethiopia (11%), Zambia, Kenya, and several other countries.

Heating Analysis

The analysis of household space heating uses nationally representative country-level data for primary space heating fuels from the WHO space heating database. Only the most recent survey data are analysed for each country. Survey data disaggregated by individual space heating fuels were included; surveys that only reported clubbed variables, i.e. “solid” and “clean” were excluded owing to discrepancies in the definition of these categories. Surveys from before 2000 were excluded. At the time of analysis, the WHO space heating database contained a total of 42 surveys collected between 1980 and 2012. After selecting the most recent record for each country, the final dataset included 75 countries, 57 countries of which were LMICs. The analysis presented here covers only LMICs classified according to the World Bank designations.⁴

For household space heating, “clean” fuels are central heating, electricity, fuel oil, natural gas, LPG and solar. “Polluting” space heating fuels are kerosene, coal, firewood, dung, grass and crop waste.

Methodology for analysis of firewood or water collection time

The analysis of wood or water collection uses survey data from nationally representative USAID DHS and UNICEF MICS household and child labour surveys undertaken since 2010. Surveys were omitted if they were not nationally representative or if there was

³ <http://data.worldbank.org/news/2015-country-classifications>, accessed December 2015.

⁴ <http://data.worldbank.org/news/2015-country-classifications>, accessed December 2015.

no use of polluting fuels in the surveyed population. Two questions are included on a subset of these surveys and were analysed in relation to the main type of cooking fuel used:

1. *During the past week, did [NAME] fetch water or collect firewood for household use?;*
2. *Since last [DAY OF THE WEEK], about how many hours did he/she fetch water or collect firewood, for household use?*

Survey questions on wood or water collection are addressed to the mother of the children in the survey. The questions pertain to children aged 5 to 14 years in all countries except Rwanda (5 to 16) and Serbia, Democratic Republic of Congo, Montenegro, Malawi,

Mongolia, Macedonia, Bhutan and Vietnam (5 to 17). For the Montenegro and Serbia MICS surveys, MICS data is separated into national population and Roma populations; the national population data is presented here.

Survey points exceeding 50 hours of wood or water collection in the past week for a child were recoded as 50 hours. Data points for the number of children collecting and/or the amount of time spent collecting wood or water were excluded if fewer than 25 children surveyed lived in homes using a particular fuel type. It is important to note that the data analysed for hours spent collecting wood or water could include time spent gathering either wood or water or both.

ANNEX 3: SUMMARY OF RECOMMENDATIONS FROM WHO GUIDELINES FOR INDOOR AIR QUALITY: HOUSEHOLD FUEL COMBUSTION (2014)

Specific recommendations

Recommendation 1: Emission rate targets

Recommendation	Emission rate targets		Strength of recommendation
Emission rates from household fuel combustion should not exceed the following emission rate targets (ERTs) for PM _{2.5} and CO.	PM _{2.5} (unvented)	0.23 (mg/min)	Strong
	PM _{2.5} (vented)	0.80 (mg/min)	
	CO (unvented)	0.16 (g/min)	
	CO (vented)	0.59 (g/min)	

Remarks

1. These emission rate targets will result in 90% of homes meeting WHO Air quality guideline values for PM_{2.5} (annual average) and CO (24-hr average). This assumes model inputs for kitchen volume, air exchange rate and duration of device use per 24 hours, as set out in Table R1.1.
2. Intermediate emission rate targets (IERT) show the rates that will result in 60% of homes meeting interim target-1 (IT-1) for PM_{2.5} (Table R1.2) and 60% of homes meeting the 24-hr AQG for CO (Table R1.3). The value of 60% is arbitrary, but was selected so that a majority of homes would meet the specified guideline level.
3. Separate guidance is provided for unvented and vented stoves as those technologies with chimneys or other venting mechanisms can improve indoor air quality through moving a fraction of the pollutants outdoors.

4. Table R1.2 illustrates the percentage of homes that would meet IT-1 (35 µg/m³) for PM_{2.5}.
5. Devices should meet both PM_{2.5} and CO emission rate targets to be considered to have met the recommendation.
6. For this recommendation, a high quality of evidence was available on the average concentrations of PM_{2.5} and CO at which health risks are minimal, as described in previously published WHO Air quality guidelines (i.e. WHO

Air quality guidelines, 2005 update, WHO guidelines for indoor air quality: selected pollutants (4, 5)). A moderate quality of evidence was available for laboratory testing of emissions from fuel and technology combinations, and for the emissions model. A low quality of evidence was available for field testing of emissions from fuel and technology combinations.

Table R1.1: Input distributions for air exchange rates, kitchen volumes and device burn times used in the development of the ERTs

Parameter	Unit	Geometric mean	Range		SD*
			minimum	maximum	
Air exchange rate (a)	per hour	15	5	45	7.5
Kitchen volume (V)	m ³	30	5	100	15
Device burn time	hours per day	4	0.75	8	2

* Standard deviation

Table R1.2: Emission rate targets for meeting WHO annual mean AQGs for PM_{2.5}

Emissions rate targets (ERT)	Emission rate (mg/min)	Percentage of kitchens meeting AQG (10 µg/m ³)	Percentage of kitchens meeting AQG IT-1 (35 µg/m ³)
Unvented			
Intermediate ERT	1.75	6	60
ERT	0,23	90	100
Vented			
Intermediate ERT	7,15	9	60
ERT	0,80	90	100

Table R1.3: Emission rate targets for meeting WHO 24 h. AQGs for CO

Emissions rate targets (ERT)	Emission rate (g/min)	Percentage of kitchens meeting 24 h. AQG
Unvented		
Intermediate ERT	0,35	60
ERT	0,16	90
Vented		
Intermediate ERT	1,45	60
ERT	0,59	90

Recommendation 2: Policy during transition to low emission technologies

Recommendation	Strength of recommendation
Governments and their implementing partners should develop strategies to accelerate efforts to meet these air quality guidelines ERTs (see Recommendation 1). Where intermediate steps are necessary, transition fuels and technologies that offer substantial health benefits should be prioritized.	Strong

Remarks

1. Implementing agencies should work to increase access to, and sustained use of, clean fuels as widely and rapidly as is feasible. Selection of optimal 'interim' technologies and fuels should be made on the basis of evidence provided in these guidelines, as outlined below.
2. Evidence provided in the systematic review of 'Intervention impacts on HAP and exposure' (Review 6) demonstrated that despite achieving large percentage reductions of PM_{2.5} compared to baseline (solid fuels with traditional stoves) none of the improved solid fuel stoves reviewed reached the WHO IT-1 for annual average kitchen PM_{2.5} (and therefore did not meet the AQG). A few types of vented (chimney) stoves did reach levels close to WHO IT-1, in the range of 40–60 µg/m³. These findings can be used as a guide to the current 'in field' performance of a range of technology and fuel options.
3. Evidence provided on the relationship between exposure and risk of child acute lower respiratory infection described in the systematic

review 'Health risks of HAP' (Review 4) can be used as a guide to assessing the magnitude of the health benefit from the intervention under consideration.

4. Technologies and fuels being considered for promotion should have emission rates tested (See Recommendation 1), and where possible, actual air pollution levels in everyday use in homes should be measured.
5. Plans for the development of guidance and tools to assist with the assessment of optimal interventions are described in Section 5 of the guidelines.
6. For this recommendation, quality of evidence was moderate for health risks, the integrated exposure response (IER) functions and population levels of exposure to HAP. The quality of evidence for impacts of interventions on HAP

was moderate for natural draft solid fuel stoves, but low for advanced solid fuel stoves and clean fuels. The quality of evidence available for factors influencing adoption was moderate.

Recommendation 3: Household use of coal

Recommendation	Strength of recommendation
Unprocessed ¹ coal should not be used as a household fuel. Strong	Strong

Remarks

1. This recommendation is made for the following three reasons, over and above the documented health risks from products of incomplete combustion of solid fuels.
 - i. Indoor emissions from household combustion of coal have been determined by the International Agency for Research on Cancer (IARC) to be carcinogenic to humans (Group 1).
 - ii. Coal – in those parts of the world where coal is most extensively used as a household fuel and the evidence base is strongest – contains

toxic elements (including fluorine, arsenic, lead, selenium and mercury) which are not destroyed by combustion and lead to multiple adverse health effects.

- iii. There are technical constraints on burning coal cleanly in households.
2. For this recommendation, a high quality of evidence was available from the IARC assessment of carcinogenicity, while a moderate quality of evidence was available for the risk estimates for lung cancer and toxic contaminants.

Recommendation 4: Household use of kerosene¹

Recommendation	Strength of recommendation
The household use of kerosene is discouraged while further research into its health impacts is conducted Conditional	Strong

¹ 'Unprocessed' coal refers to forms of this fuel that have not been treated by chemical, physical, or thermal means to reduce contaminants. Unless otherwise specified, this applies throughout the discussion of this recommendation, as the great majority of the available evidence reviewed draws on studies in which households used unprocessed coal. Where reference is made to one of the few studies on the use of coal which has been processed to reduce toxic emissions this is stated.

Remarks

- Existing evidence shows that household use of kerosene can lead to PM levels that exceed WHO guidelines, substantially so in developing country homes using simple unvented combustion technologies (e.g. wick cookstoves and lamps). Levels of CO, nitrogen dioxide (NO₂), polyaromatic hydrocarbon (PAH) and sulfur dioxide (SO₂) may also exceed guideline levels provided in the WHO Air quality guidelines: 2005 update and the WHO guidelines for indoor air quality: specific pollutants (4, 5).
- Epidemiological evidence on risks of respiratory and other health outcomes is currently not conclusive.
- The risk of burns, fires and poisoning, associated with the use of kerosene in developing countries is a cause for concern.
- For this recommendation, a low quality of evidence was available for disease risks from kerosene combustion emissions, and a moderate quality of evidence for safety risks with kerosene use.

Good practice recommendation: Securing health and climate co- benefits

Good practice recommendation

Considering the opportunities for synergy between climate policies and health, including financing, we recommend that governments and other agencies developing and implementing policy on climate change mitigation consider action on household energy and carry out relevant assessments to maximize health and climate gains.

Remarks

- Evidence reported in these guidelines, in particular the IER functions describing risk of important health outcomes with increasing levels of PM_{2.5} exposure, provide an initial basis for assessing the health benefits of specific climate change mitigation actions on household energy.
- Guidance and tools for further characterization of health impacts of climate change mitigation strategy that involves household energy, including both benefits and harms, need to be developed.

implementation of the guidelines in LMIC, recognizing that higher income countries will have mechanisms and resources to address the risks identified – mainly from use of solid heating fuels – more easily.

Implementing these recommendations may be challenging, particularly for lower income and/or more rural populations. This will require a coordinated effort by ministries, other national stakeholders (NGOs, public and private sectors), supported by international development and financial organizations.

WHO will work with countries to support this process through its regional and country offices, and is preparing web-based guidance and tools that build on the evidence reviews used to inform these guidelines, available at: <http://www.who.int/indoorair/guidelines/hhfc>. In addition to general support provided in this way, WHO will work closely with selected countries to learn from initial implementation of the guidelines, and use this experience to revise the guidance and tools.

Implementation of the guidelines

Although these guidelines are global, the main focus of the evidence review has been on LMIC where the health burden from household fuel combustion is by far the greatest. WHO is also focusing technical support for

ANNEX 4: COUNTRY DATA FOR HOUSEHOLD COOKING FUELS

Table A4.1. List of all countries, sorted by reliance on clean fuels and technologies.

Country	Households primarily relying on clean cooking fuels (%)	Population primarily relying on polluting fuels for cooking	Country income level	WHO region	Note
Primary reliance on clean fuels and technologies for household cooking					
Algeria	>95	3 893	LMIC	AFR	
Andorra	>95	–	High income	EUR	*
Antigua and Barbuda	>95	9	High income	AMR	
Argentina	>95	61 206	High income	AMR	
Armenia	>95	865	LMIC	EUR	
Australia	>95	–	High income	WPR	*
Austria	>95	–	High income	EUR	*
Azerbaijan	>95	294 962	LMIC	EUR	
Bahamas	>95	–	High income	AMR	*
Bahrain	>95	–	High income	EMR	*
Barbados	>95	71	High income	AMR	
Belarus	>95	1 815	LMIC	EUR	
Belgium	>95	–	High income	EUR	*
Brunei Darussalam	>95	–	High income	WPR	*
Canada	>95	–	High income	AMR	*
Chile	>95	605 787	High income	AMR	
Costa Rica	>95	192 695	LMIC	AMR	
Cyprus	>95	–	High income	EUR	*
Czech Republic	>95	1 054	High income	EUR	
Denmark	>95	–	High income	EUR	*
Ecuador	>95	307 788	LMIC	AMR	
Egypt	>95	8 958	LMIC	EMR	
Finland	>95	–	High income	EUR	*
France	>95	–	High income	EUR	*
Germany	>95	–	High income	EUR	*
Greece	>95	–	High income	EUR	*

Grenada	>95	32	LMIC	AMR	
Hungary	>95	-	High income	EUR	*
Iceland	>95	-	High income	EUR	*
Iran (Islamic Republic of)	>95	71 869	LMIC	EMR	
Iraq	>95	663 852	LMIC	EMR	
Ireland	>95	-	High income	EUR	*
Israel	>95	-	High income	EUR	*
Italy	>95	-	High income	EUR	*
Japan	>95	-	High income	WPR	*
Jordan	>95	742	LMIC	EMR	
Kuwait	>95	-	High income	EMR	*
Latvia	>95	52 182	High income	EUR	
Lebanon	>95	561	LMIC	EMR	
Lithuania	>95	-	High income	EUR	*
Luxembourg	>95	-	High income	EUR	*
Malaysia	>95	2 990	LMIC	WPR	
Maldives	>95	1 791	LMIC	SEAR	
Malta	>95	-	High income	EUR	*
Mauritius	>95	9 183	LMIC	AFR	
Monaco	>95	-	High income	EUR	*
Morocco	>95	209 056	LMIC	EMR	
Nauru	>95	383	LMIC	WPR	
Netherlands	>95	-	High income	EUR	*
New Zealand	>95	-	High income	WPR	*
Norway	>95	-	High income	EUR	*
Oman	>95	-	High income	EMR	*
Poland	>95	-	High income	EUR	*
Portugal	>95	-	High income	EUR	*
Qatar	>95	217	High income	EMR	
Republic of Korea	>95	5 007	High income	WPR	
Russian Federation	>95	27 546	High income	EUR	
Saint Kitts and Nevis	>95	-	High income	AMR	*
Saint Lucia	>95	228	LMIC	AMR	
Saint Vincent and the Grenadines	>95	11	LMIC	AMR	
San Marino	>95	-	High income	EUR	*
Saudi Arabia	>95	3 089	High income	EMR	
Seychelles	>95	53	High income	AFR	
Singapore	>95	-	High income	WPR	*
Slovakia	>95	542	High income	EUR	
Slovenia	>95	37 060	High income	EUR	
Spain	>95	-	High income	EUR	*
Sweden	>95	-	High income	EUR	*
Switzerland	>95	-	High income	EUR	*
Syrian Arab Republic	>95	1 877	LMIC	EMR	
Trinidad and Tobago	>95	135	High income	AMR	

Tunisia	>95	1 113	LMIC	EMR	
Turkmenistan	>95	531	LMIC	EUR	
Ukraine	>95	1 112 824	LMIC	EUR	
United Arab Emirates	>95	909	High income	EMR	
United Kingdom	>95	–	High income	EUR	*
United States of America	>95	–	High income	AMR	*
Uruguay	>95	27 205	High income	AMR	
Venezuela, Bolivarian Republic of	>95	899 478	High income	AMR	
Croatia	94	239 402	High income	EUR	
Republic of Moldova	93	265 465	LMIC	EUR	
Jamaica	93	187 713	LMIC	AMR	
Brazil	93	14 134 713	LMIC	AMR	
Dominican Republic	92	838 310	LMIC	AMR	
Dominica	92	5 873	LMIC	AMR	
Kazakhstan	92	1 416 303	LMIC	EUR	
Estonia	92	109 410	High income	EUR	
Colombia	91	4 211 113	LMIC	AMR	
Niue	91	145	LMIC	WPR	
Suriname	91	49 340	LMIC	AMR	
Uzbekistan	90	2 865 772	LMIC	EUR	
Cuba	87	1 455 812	LMIC	AMR	
Belize	87	45 004	LMIC	AMR	
Mexico	86	17 351 610	LMIC	AMR	
Panama	86	556 115	LMIC	AMR	
El Salvador	83	1 060 610	LMIC	AMR	
Romania	82	3 553 148	LMIC	EUR	
South Africa	82	9 802 177	LMIC	AFR	
Cook Islands	80	4 134	LMIC	WPR	
Bolivia, Plurinational States of	79	2 191 396	LMIC	AMR	
Bulgaria	79	1 502 393	LMIC	EUR	
Kyrgyzstan	76	1 378 044	LMIC	EUR	
Thailand	76	16 354 180	LMIC	SEAR	
Montenegro	74	161 589	LMIC	EUR	
Gabon	73	453 109	LMIC	AFR	
Tajikistan	72	2 348 857	LMIC	EUR	
Serbia	71	2 561 244	LMIC	EUR	
Cabo Verde	71	149 769	LMIC	AFR	
Bhutan	68	244 493	LMIC	SEAR	
Peru	68	10 032 968	LMIC	AMR	
Albania	67	951 320	LMIC	EUR	
Paraguay	64	2 370 383	LMIC	AMR	
Tonga	63	38 562	LMIC	WPR	
Botswana	63	832 081	LMIC	AFR	
Yemen	62	9 911 759	LMIC	EMR	

The former Yugoslav Republic of Macedonia	61	799 152	LMIC	EUR	
Guyana	61	297 098	LMIC	AMR	
Palau	58	8 792	LMIC	WPR	
China	57	589 335 104	LMIC	WPR	
Indonesia	57	110 335 864	LMIC	SEAR	
Georgia	55	1 816 533	LMIC	EUR	
Viet Nam	51	45 377 676	LMIC	WPR	
Nicaragua	49	3 057 794	LMIC	AMR	
Honduras	48	4 133 844	LMIC	AMR	
Angola	48	12 683 557	LMIC	AFR	
Namibia	46	1 299 720	LMIC	AFR	
Philippines	45	54 677 512	LMIC	WPR	
Pakistan	45	102 061 808	LMIC	EMR	
Mauritania	45	2 193 654	LMIC	AFR	
Marshall Islands	41	31 052	LMIC	WPR	
Bosnia and Herzegovina	40	2 299 720	LMIC	EUR	
Fiji	37	562 683	LMIC	WPR	
Guatemala	36	10 228 762	LMIC	AMR	
Senegal	36	9 415 951	LMIC	AFR	
Swaziland	35	821 066	LMIC	AFR	
India	34	852 814 464	LMIC	SEAR	
Mongolia	32	1 981 035	LMIC	WPR	
Lesotho	32	1 438 742	LMIC	AFR	
Zimbabwe	31	10 474 969	LMIC	AFR	
Papua New Guinea	31	5 129 255	LMIC	WPR	
Sao Tome and Principe	30	129 621	LMIC	AFR	
Tuvalu	30	6 951	LMIC	WPR	
Samoa	27	139 114	LMIC	WPR	
Nepal	26	20 823 498	LMIC	SEAR	
Micronesia (Federated States of)	25	78 195	LMIC	WPR	
Sudan	23	30 358 860	LMIC	EMR	
Equatorial Guinea	22	644 173	LMIC	AFR	
Ghana	21	21 228 052	LMIC	AFR	
Sri Lanka	19	16 637 584	LMIC	SEAR	
Côte d'Ivoire	18	18 068 922	LMIC	AFR	
Congo	18	3 709 970	LMIC	AFR	
Cameroon	18	18 765 398	LMIC	AFR	
Afghanistan	17	26 154 140	LMIC	EMR	
Zambia	16	13 193 828	LMIC	AFR	
Vanuatu	16	217 307	LMIC	WPR	
Eritrea	14	4 407 531	LMIC	AFR	
Cambodia	13	13 272 191	LMIC	WPR	
Djibouti	10	787 188	LMIC	EMR	
Bangladesh	10	142 992 016	LMIC	SEAR	

Myanmar	9	48 582 564	LMIC	SEAR	
Somalia	9	9 563 719	LMIC	EMR	
Solomon Islands	9	521 266	LMIC	WPR	
Haiti	9	9 659 056	LMIC	AMR	
Comoros	7	716 332	LMIC	AFR	
Burkina Faso	7	16 365 340	LMIC	AFR	
Democratic People's Republic of Korea	7	23 368 714	LMIC	SEAR	
Benin	7	9 903 015	LMIC	AFR	
Togo	6	6 666 112	LMIC	AFR	
Kenya	6	42 085 700	LMIC	AFR	
Democratic Republic of the Congo	6	70 438 400	LMIC	AFR	
Guinea	6	11 582 149	LMIC	AFR	
Burundi	<5	10 588 741	LMIC	AFR	
Central African Republic	<5	4 707 681	LMIC	AFR	
Chad	<5	13 102 984	LMIC	AFR	
Ethiopia	<5	95 019 560	LMIC	AFR	
Gambia	<5	1 851 852	LMIC	AFR	
Guinea-Bissau	<5	1 745 848	LMIC	AFR	
Kiribati	<5	106 976	LMIC	WPR	
Lao People's Democratic Republic	<5	6 383 519	LMIC	WPR	
Liberia	<5	4 308 560	LMIC	AFR	
Madagascar	<5	23 100 280	LMIC	AFR	
Malawi	<5	16 163 654	LMIC	AFR	
Mali	<5	16 744 302	LMIC	AFR	
Mozambique	<5	26 020 794	LMIC	AFR	
Niger	<5	18 515 886	LMIC	AFR	
Nigeria	<5	173 365 408	LMIC	AFR	
Rwanda	<5	11 114 713	LMIC	AFR	
Sierra Leone	<5	6 189 315	LMIC	AFR	
South Sudan	<5	11 536 815	LMIC	AFR	
Timor-Leste	<5	1 116 042	LMIC	SEAR	
Uganda	<5	37 027 312	LMIC	AFR	
United Republic of Tanzania	<5	50 786 168	LMIC	AFR	
Libya	Data not available		LMIC	EMR	
Turkey	Data not available		LMIC	EUR	

Note: Percentage of the population relying on clean fuels for cooking is derived from modeled estimates (see Annex 2). Designation of LMICs from World Bank (2015), which categorizes high-income countries as those with gross national income per capita of US\$ 12 746 or more. Equatorial Guinea was classified as an LMIC owing to its high use of polluting fuels.

* For high income countries with no information on polluting fuel use, the estimate is assumed to be <5%.

Source: WHO Household energy database, 2016

ANNEX 5: COUNTRY-LEVEL DATA ON HOUSEHOLD HEATING

Table A5.1. Survey estimates of on primary energy source for household heating in LMIC

Country	Year	WHO region	Households primarily relying on clean fuels for space heating (%)	Source
Albania	2005	EUR	40	LSMS
Armenia	2011	EUR	61	National Survey
Bhutan	2012	SEA	21	National Survey
Bosnia-Herzegovina	2007	EUR	17	National Survey
Democratic People's Republic of Korea	2008	SEA	6	National Census
Iran	2011	EMR	98	National Census
Jordan	2004	EMR	30	IPUMS
Lesotho	2006	AFR	5	National Census
Poland	2011	EUR	87	Other
Romania	2002	EUR	44	IPUMS
Serbia	2007	EUR	39	LSMS
South Africa	2007	AFR	60	National Survey
Turkey	2011	EUR	100	National Census

Note: AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region.

IPUMS, Integrated Public Use Microdata Series; LCMS, Living Conditions Monitoring Survey.

Source: WHO Household energy database, 2016

ANNEX 6: COUNTRY-LEVEL DATA ON HOUSEHOLD LIGHTING

Table A6.1. Survey estimates of primary energy source for household lighting in LMIC

Country	Year	WHO region	Households primarily relying on clean lighting fuels (%)	Source
Afghanistan	2005	EMR	22	Other
Albania	2005	EUR	99	LSMS
Armenia	2001	EUR	98	NatCen
Bangladesh	2011	SEAR	60	NatCen
Belize	2010	AMR	89	NatCen
Benin	2008	AFR	33	Other
Bhutan	2012	SEAR	88	NatSur
Burkina Faso	2009	AFR	64	NatSur
Cambodia	2009	WPR	66	NatSur
Cameroon	2007	AFR	48	NatSur
Cabo Verde	2014	AFR	85	NatCen
Chad	2011	AFR	68	NatSur
Congo	2011	AFR	42	DHS
Dominican Republic	2012	AMR	97	NatSur
Egypt	2010	EMR	100	NatSur
El Salvador	2011	AMR	93	NatSur
Ethiopia	2011	AFR	36	NatSur
Fiji	2007	WPR	79	NatCen
Gabon	2005	AFR	82	NatSur
Ghana	2008	AFR	50	LSMS
Grenada	2000	AMR	87	NatCen
Guinea-Bissau	2010	AFR	6	NatSur
India	2011	SEAR	67	NatCen
Iraq	2006	EMR	98	LSMS
Jamaica	2001	AMR	79	IPUMS
Jordan	2004	EMR	98	IPUMS
Kenya	2009	AFR	25	NatCen

Lesotho	2006	AFR	10	NatCen
Liberia	2013	AFR	91	DHS
Madagascar	2010	AFR	13	NatSur
Malawi	2014	AFR	84	NatSur
Nauru	2011	WPR	99	NatCen
Nepal	2011	SEAR	75	NatCen
Nicaragua	2005	AMR	69	NatCen
Nigeria	2006	AFR	38	NatCen
Pakistan	2008	EMR	91	NatSur
Panama	2010	AMR	86	IPUMS
Peru	2012	AMR	90	DHS
Philippines	2000	WPR	69	IPUMS
Rwanda	2013	AFR	66	NatSur
Saint Lucia	2010	AMR	93	NatCen
Saint Vincent and the Grenadines	2007	AMR	86	NatSur
Samoa	2011	WPR	97	NatCen
Senegal	2014	AFR	94	DHS
Sierra Leone	2004	AFR	7	IPUMS
Solomon Islands	2009	WPR	21	NatCen
Somalia	2002	EMR	7	NatSur
South Africa	2011	AFR	84	NatSur
South Sudan	2009	AFR	4	NatSur
Sri Lanka	2009	SEAR	87	NatCen
Togo	2011	AFR	63	NatSur
Tonga	2006	WPR	92	Other
Uganda	2009	AFR	12	NatSur
United Republic of Tanzania	2012	AFR	36	DHS
Vanuatu	2009	WPR	36	NatCen
Viet Nam	2009	WPR	97	IPUMS
Yemen	2013	EMR	76	DHS
Zambia	2010	AFR	36	LSMS

AFR, African Region; AMR, Region of the Americas; EMR, Eastern Mediterranean Region; EUR, European Region; SEAR, South-East Asia Region; WPR, Western Pacific Region.

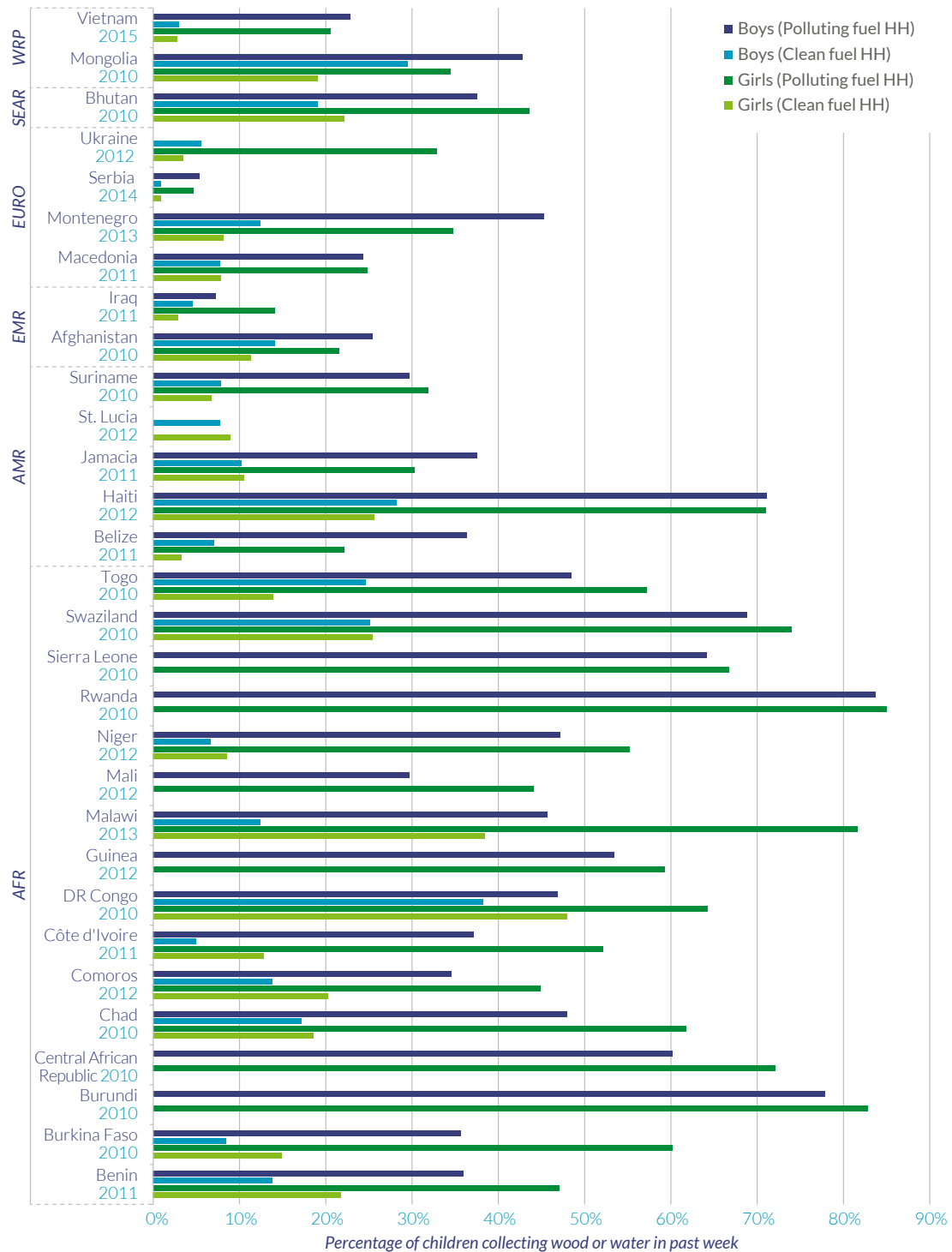
DHS, Demographic and Health Surveys; IPUMS, Integrated Public Use Microdata Series; LCMS, Living Conditions Monitoring Survey; NatCen, national census; NatSur, national survey.

Note: Clean lighting fuels include electricity, gas, LPG, solar and batteries. Polluting lighting fuels include biomass (wood, straw, dung), kerosene and oil lamps. Households that did not report a source of lighting, recorded "other" as primary lighting fuel, or were missing from households surveys were omitted from this table.

Source: WHO Household energy database, 2016

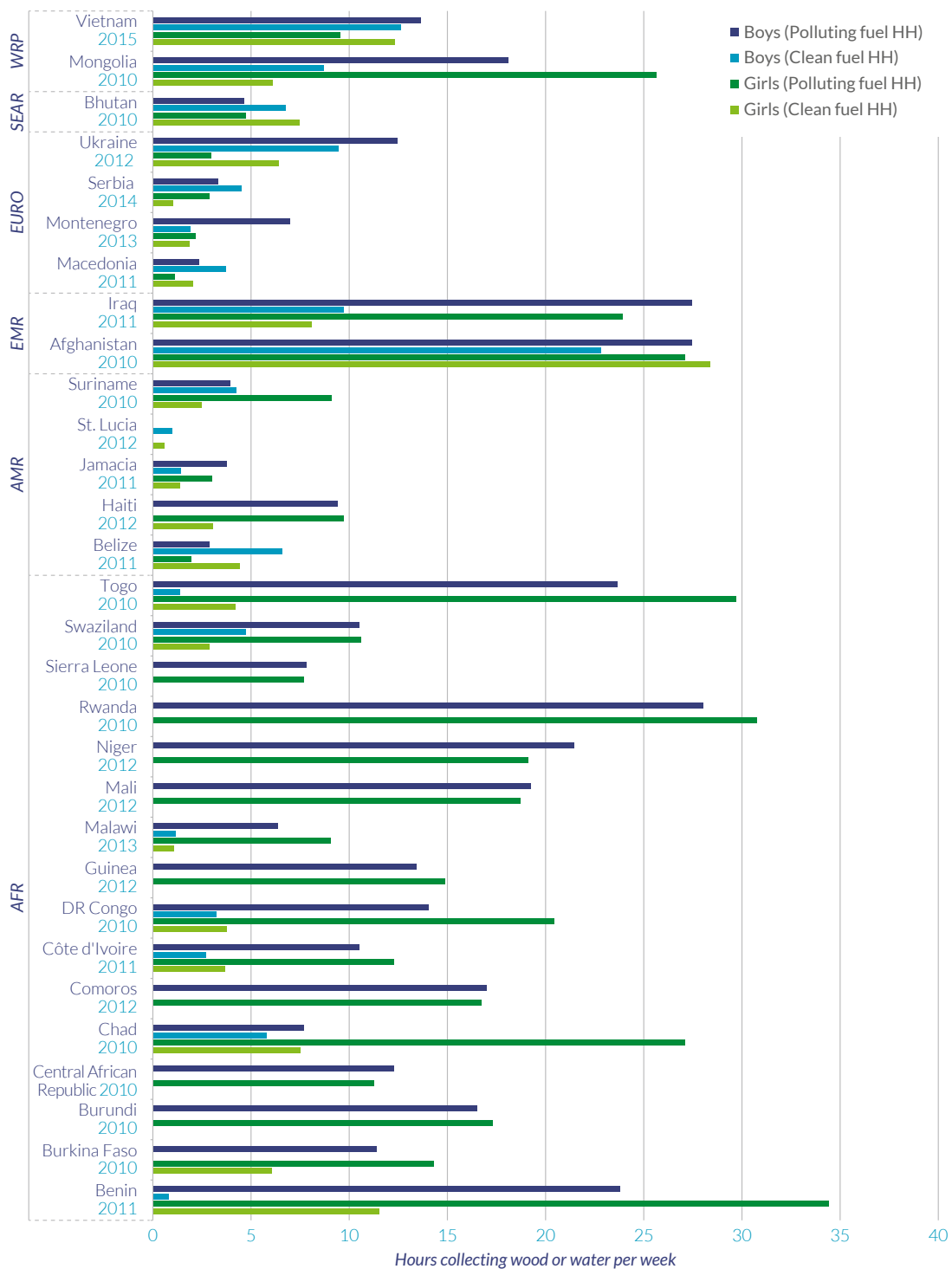
ANNEX 7: COUNTRY-LEVEL DATA ON WOOD AND WATER GATHERING

Figure A7.1 Percentage of boys and girls gathering wood or water in the past week disaggregated by primary household cooking fuel



Source: WHO Household energy database 2016

Figure A7.2 Hours spent by boys and girls gathering wood or water in the past week, disaggregated by primary household cooking fuel



Source: WHO Household energy database 2016

Note: USAID DHS surveys: Benin, Burkina Faso, Burundi, Comoros, Côte d'Ivoire, Guinea, Haiti, Mali, Niger, Rwanda; UNICEF MICS surveys: Afghanistan, Belize, Bhutan, Central African Republic, Chad, Democratic Republic of Congo, Iraq, Jamaica, Macedonia, Mongolia, Malawi, Montenegro, St. Lucia, Serbia, Sierra Leone, Suriname, Swaziland, Togo, Ukraine, Viet Nam.

REFERENCES

- Alem Y, Hassen S, Köhlin G (2013). The dynamics of electric cookstove adoption: panel data evidence from Ethiopia. Working Papers in Economics, Department of Economics, University of Gothenburg (https://gupea.ub.gu.se/bitstream/2077/32452/1/gupea_2077_32452_1.pdf, accessed 17 February 2016).
- Alstone P, Gershenson D, Kammen DM (2015). Decentralized energy systems for clean electricity access. *Nature Clim Change*. 5:305–14. doi:10.1038/nclimate2512.
- Anenberg SC, Balakrishnan K, Jetter J, Masera O, Mehta S, Moss J, et al. (2013). Cleaner cooking solutions to achieve health, climate, and economic cobenefits. *Environ Sci Technol*. 47(9):3944–52.
- Armstrong JRM, Campbell H (1991). Indoor air pollution exposure and lower respiratory infections in young Gambian children. *Int. J. Epidemiol*. 20(2):424–9. doi: 10.1093/ije/20.2.424.
- Ashden Awards (2015). Winner case study summary: BURN Manufacturing, Kenya. (https://www.ashden.org/files/case_studies/Burn%2C%20Kenya.pdf, accessed 29 February 2016).
- Bailis R, Drigo R, Ghilardi A, Masera O (2015). The global footprint of traditional woodfuels. *Nature Clim Change*. 5:266–72. doi:10.1038/nclimate2491.
- Barrett, JR (2015). How good is good enough? cookstove replacement scenarios to reach indoor air goals. *Environ Health Perspect*. 123(8):A216. doi:10.1289/ehp.123-A216.
- Bates MN, Chandyo RK, Valentiner-Branth P, Pokhrel AK, Mathisen M, Basnet S, et al. (2013). acute lower respiratory infection in childhood and household fuel use in Bhaktapur, Nepal. *Environ Health Perspect* 121(5):637–42. doi: 10.1289/ehp.1205491.
- Bond TC, Doherty SJ, Fahey D, Forster P, Berntsen T, DeAngelo B, et al. (2013). Bounding the role of black carbon in the climate system: A scientific assessment. *J Geophys Res*. 118(11):5380–552.
- Bonjour S, Adair-Rohani H, Wolf J, Bruce N, Mehta S, Prüss-Ustün A, et al. (2013). Solid fuel use for household cooking: Country and regional estimates for 1980–2010. *Environ Health Perspect*. 121(7):784–90.
- Bruce N, Dherani MK, Das JK, Balakrishnan K, Adair-Rohani H, Bhutta ZA et al. (2013). Control of household air pollution for child survival: estimates for intervention impacts. *BMC Public Health*. 13(suppl 3):S8. doi:10.1186/1471-2458-13-S3-S8.
- Bruce, N, Smith, KR et al. (2014). WHO Guidelines for indoor air quality: household fuel combustion – Review 4: Health effects of household air pollution exposure. Geneva: World Health Organization.
- Budya H, Arofat MY (2011). Providing cleaner energy access in Indonesia through the megaproject of kerosene conversion to LPG. *Energy Policy*. 3(12):7575–86.
- Cameron C, Pachauri S, Rao ND, McCollum D, Rogelj J, Riahi K (2016). Policy trade-offs between climate mitigation and clean cookstove access in South Asia. *Nature Energy*. 1:Article number: 15010. doi:10.1038/nenergy.2015.10.
- Chafe ZA, Brauer M, Klimont Z, Van Dingenen R, Mehta S, Rao S, et al. (2014). Household cooking with solid fuels contributes to ambient PM_{2.5} air pollution and the burden of disease. *Environ Health Perspect*. 122(12):1314–20. doi:10.1289/ehp.1206340.
- Chen Y, Ebenstein A, Greenstone M, Li H (2013). Evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River policy. *PNAS*. 110(32):12936–41. doi: 10.1073/pnas.1300018110.
- Cheng, C, Urpelainen J (2014). Fuel stacking in India: changes in the cooking and lighting mix, 1987–2010. *Energy*. 76: 306–317.
- Cordes L (2011). Igniting change: a strategy for universal adoption of clean cookstoves and fuels. Washington (DC): Global Alliance for Clean Cookstoves (<http://cleancookstoves.org/binary-data/RESOURCE/file/000/000/272-1.pdf>, accessed 17 February 2016).
- Costa J, Hailu D, Silva E, Tsukada R (2009). The implications of water and electricity supply for the time allocation of women in rural Ghana. Working Paper Number 59, International Policy Centre for Inclusive Growth.

(<http://www.ipc-undp.org/pub/IPCWorkingPaper59.pdf>, accessed 28 February 2016).

Dietert, RR, Etzel, RA, Chen D, Halonen, M, Holladay SD, Jarabek AM, et al. (2000). Workshop to identify critical windows of exposure for children's health: immune and respiratory systems work group summary. *Environ Health Perspect.* 108(3):483–490.

Energia (International Network on Gender and Sustainable Energy) (2010). A Guide on gender mainstreaming in the Africa Biogas Partnership Programme (ABPP). The Netherlands (<http://www.seachangecop.org/sites/default/files/documents/2010%2007%20ENERGIA%20-%20A%20Guide%20on%20Gender%20Mainstreaming%20in%20the%20Africa%20Biogas.pdf>, accessed 17 February 2016).

Food and Agriculture Organization (FAO) (2012). Gender Inequalities in Rural Employment in Ghana: An overview. Rome: FAO. (<http://www.fao.org/3/a-ap090e.pdf>, accessed 29 February 2016).

Foell W, Pachauri S, Spreng D, Zerriffi H (2011). Household cooking fuels and technologies in developing economies. *Energy Policy.* 39(12): 7487–96.

Global Alliance for Clean Cookstoves (GACC) (2014). Clean cooking and child survival workshop meeting report.

Global Alliance for Clean Cookstoves (GACC) (2016). Clean cooking catalog (<http://catalog.cleancookstoves.org/>, accessed 17 February 2016).

Guttikunda SK, Lodoysamba S, Bulgansaikhan B, Dashdondog B (2013). Particulate pollution in Ulaanbaatar, Mongolia. *Air Qual Atmos Health.* 6(3):589–601. doi:10.1007/s11869-013-0198-7.

Guttikunda S (forthcoming). Household energy consumption, emissions, pollution, and health impacts in India.

Hanna R, Duflo E, Greenstone M. (2016). Up in smoke: the influence of household behavior on the long-run impact of improved cooking stoves. *American Economic Journal: Economic Policy* 2016. 8(1):80–114. (<https://www.povertyactionlab.org/sites/default/files/publications/52%20Up%20in%20Smoke%20AEJ2016.pdf>, accessed 1 March 2016).

Heltberg R (2003). Household fuel use and fuel switching in Guatemala. Joint UNDP/World Bank Energy Sector Management Assistance Programme. (http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2003/12/10/000012009_20031210144937/Rendered/PDF/272740ESMAP0Te1361030HouseholdOfuel.pdf, accessed 29 February 2016).

International Energy Agency (IEA) (2010). Paris: World energy outlook 2010.

International Energy Agency (IEA) (2014). Paris: World energy outlook 2014.

International Energy Agency (IEA) (2015). Paris: World energy outlook 2015.

International Energy Agency (IEA) and the World Bank (2015). Sustainable

Energy for All 2015 – Progress toward sustainable energy (June). Washington (DC): World Bank. doi: 10.1596/978-1-4648-0690-2.

Jack DW, Asante KP, Wylie BJ, Chillrud SN, Whyatt RM, Ae-Ngibise KA et al. (2015). Ghana randomized air pollution and health study (GRAPHS): study protocol for a randomized controlled trial. *Trials.* 16:420. doi 10.1186/s13063-015-0930-8.

Jacobson A, Bond TC, Lam NL, Hultman N (2013). Black carbon and kerosene lighting: An opportunity for rapid action on climate change and clean energy for development. Washington, DC: Global Economy and Development, The Brookings Institution. (<http://www.brookings.edu/research/papers/2013/04/climate-change-clean-energy-development-hultman>, accessed 29 February 2016).

Janssen N, Hoek G, Simic-Lawson M, Fischer P, van Bree L, ten Brink H, et al (2011). Black carbon as an additional indicator of the adverse health effects of airborne particles compared with PM₁₀ and PM_{2.5}. *Environ Health Perspect.* 119(12):1691-9.

Johnson, MA, Chiang RA (2015). Quantitative guidance for stove usage and performance to achieve health and environmental targets. *Environ Health Perspect.* 123(8):820–6. doi: 10.1289/ehp.1408681.

Kammila S, Kappen JF, Rysankova D, Hyseni B, Putti VR (2014). Clean and improved cooking in Sub-Saharan Africa: a landscape report. Washington (DC): World Bank Group (<http://documents.worldbank.org/curated/en/2015/07/24853349/clean-improved-cooking-sub-saharan-africa-landscape-report>, accessed 17 February 2016).

Kar A, Rehman IH, Burney J, Puppala SP, Suresh R, Singh L, et al. (2012). Real-time assessment of black carbon pollution in Indian households due to traditional and improved biomass cookstoves. *Environ Sci Technol.* 46(5):2993–3000.

Khan H (2001). Battery-operated lamps produced by rural women. In: Misana S, Karlsson G, editors. *Generating opportunities: Case studies on energy and women.* New York: United Nations Development Programme.

Lam NL, Chen Y, Weyant C, Venkataraman C, Sadavarte P, Johnson MA, et al. (2012). Household light makes global heat: High black carbon emissions from kerosene wick lamps. *Environ Sci Technol.* 46(24):13531–8.

- Lam NL, Smith KR, Gauthier A, Bates MN (2012). Kerosene: A review of household uses and their hazards in low-and middle-income countries. *J Toxicol Environ Health B Crit Rev.* 15(6): 396–432. doi: 10.1080/10937404.2012.710134.
- Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: A systematic analysis for the global burden of disease study 2010. *Lancet.* 380(9859): 2224–60. doi: 10.1016/S0140-6736(12)61766-8.
- Matinga MN (2010). We grow up with it: An ethnographic study of the experiences, perceptions and responses to the health impacts of energy acquisition and use in Rural South Africa. [Thesis] Enschede: University of Twente (doc.utwente.nl/75414/1/thesis_M_Matinga.pdf, accessed 17 February 2016).
- Miller G, Mobarak M (2013). Gender differences in preferences, intra-household externalities and low demand for a new technology: experimental evidence on improved cookstoves. NBER Working Paper Series No 18964. Cambridge (MA): National Bureau of Economic Research (<http://www.nber.org/papers/w18964>, accessed 8 February 2016).
- Mills E (2005). The specter of fuel-based lighting. *Science*, 308:263–4 (http://light.lbl.gov/pubs/mills_science_fbl_full.pdf, accessed 29 February 2016).
- Mills E (2015). Can technology free developing countries from light poverty? *The Guardian*, 30 July 2015.
- Mills E (2016). Identifying and reducing the health and safety impacts of fuel-based lighting. *Energy for Sustainable Development.* 30: 39–50.
- Mingle J (2015). *Fire and ice: soot, solidarity and survival on the roof of the world.* New York: St. Martin's Press.
- Mishra, V. (2001). Gender aspects of indoor air pollution and health: an analysis of gender differentials in the effect of cooking smoke on acute respiratory infections in children. (<http://www.who.int/gender/documents/Vmishra.pdf>)
- Pachauri S, Rao ND (2013). Gender impacts and determinants of energy poverty: are we asking the right questions? *Curr Opin Environ Sustain.* 5(2):205–15.
- Parikh J (2011). Hardships and health impacts on women due to traditional cooking fuels: A case study of Himachal Pradesh, India. *Energy Policy.* 39(12):7587–94.
- Practical Action (2014). *Gender and livelihoods impacts of clean cookstoves in South Asia.* Washington (DC): Global Alliance for Clean Cookstoves (<http://cleancookstoves.org/binary-data/RESOURCE/file/000/000/363-1.pdf>, accessed 17 February 2016).
- Puzzolo E, Rehfuess E, Stanistreet D, Pope D, Bruce N (2014). WHO guidelines for indoor air quality: household fuel combustion – Review 7: Factors influencing the adoption and sustained use of improved cookstoves and clean household energy. Geneva: World Health Organization.
- Ramanathan V, Carmichael G (2008). Global and regional climate changes due to black carbon. *Nature Geoscience.* 1(4):221–7.
- Rath, A (2005). *Energy, women and rural poverty: A review focusing on Latin America.* Ottawa: Policy Research International. (http://agrireregionieuropa.univpm.it/sites/are.econ.univpm.it/files/materiale/2007/publications_050921_amitav.pdf, accessed 29 February 2016).
- Rehfuess EA, Puzzolo E, Stanistreet D, Pope D, Bruce NG (2013). Enablers and barriers to large-scale uptake of improved solid fuel stoves: a systematic review. *Environ Health Perspect.* 122(2):120–30. doi:10.1289/ehp.1306639.
- Ruiz-Mercado I, Masera O (2015). Patterns of stove use in the context of fuel–device stacking: rationale and implications. *EcoHealth.* 12(1): 42–56. doi: 10.1007/s10393-015-1009-4.
- Ruiz-Mercado I, Masera O, Zamora H, Smith KR (2011). Adoption and sustained use of improved cookstoves. *Energy Policy.* 39(12): 7557–66. doi:10.1016/j.enpol.2011.03.028.
- Ruiz-Mercado I, Canuz E, Walker JL, Smith KR (2013). Quantitative metrics of stove adoption using Stove Use Monitors (SUMs). *Biomass Bioenergy.* 57:136–48.
- Sand M, Berntsen TK, von Salzen K, Flanner MG, Langner J, Victor DG (2015). Response of Arctic temperature to changes in emissions of short-lived climate forcers. *Nature Climate Change.* doi: 10.1038/nclimate2880.
- Shankar AV, Onyura M, Alderman J (2015). Agency-based empowerment training enhances sales capacity of female energy entrepreneurs in Kenya. *J Health Commun.* 20 (Suppl 1):67–75.
- Shindell D, Kuylenstierna JC, Vignati E, van Dingenen R, Amann M, Klimont Z, et al. (2012). Simultaneously mitigating near-term climate change and improving human health and food security. *Science.* 335(6065):183–9.

- Smith KR, Haigler E (2008). Co-benefits of climate mitigation and health protection in energy systems: scoping methods. *Annu Rev Public Health*. 29:11–25.
- Smith, KR Sagar A (2014). Making the clean available: Escaping India's Chulha Trap. *Energy Policy* 75:410-414.
- Smith KR, McCracken JP, Weber MW, Hubbard A, Jenny A, Thompson LM, et al. (2011). Effect of reduction in household air pollution on childhood pneumonia in Guatemala (RESPIRE): a randomised controlled trial. *Lancet*. 378(9804):1717–26.
- Smith KR, Woodward A, Campbell-Lendrum D, Chadee DD, Honda Y, Liu Q (2014). Human health: impacts, adaptation, and co-benefits. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE et al. editors. *Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.
- Sovacool, BK (2012). The political economy of energy poverty: A review of key challenges. *Energy for Sustainable Development*. 16:272-282.
- United Nations Environment Programme and World Meteorological Organization (UNEP/WMO) (2011). *Integrated assessment of black carbon and tropospheric ozone*. Nairobi (http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_report.pdf, accessed 17 February 2016).
- UNICEF and WHO (2013). *Ending preventable child deaths from pneumonia and diarrhoea by 2025: The integrated Global Action Plan for Pneumonia and Diarrhoea (GAPPD)*. Geneva: World Health Organization (http://www.who.int/maternal_child_adolescent/documents/global_action_plan_pneumonia_diarrhoea/en/, accessed 17 February 2016).
- US Environmental Protection Agency (2012). *Report to congress on black carbon*. Triangle Park: North Carolina.
- WHO (2006). *Environmental health criteria 237: Principles for evaluating health risks in children associated with exposure to chemicals*. World Health Organization: Geneva.
- WHO (2006). *Fuel for life: household energy and health*. Geneva: World Health Organization.
- WHO (2014a). *WHO guidelines for indoor air quality: household fuel combustion*. Geneva: World Health Organization (<http://www.who.int/indoorair/guidelines/hhfc/en/>, accessed 17 February 2016).
- WHO (2014). *Mortality from ambient air pollution for 2012*. Geneva: World Health Organization (http://www.who.int/phe/health_topics/outdoorair/databases/en/, accessed 17 February 2016).
- WHO Global Health Observatory (GHO). *Public health, environmental and social determinants of health (PHE)* (http://www.who.int/phe/health_topics/outdoorair/databases, accessed 28 February 2016).
- WHO (2015a). *Improving and harmonizing methods and tools that incorporate measurement of fuel stacking and impacts on women and children*. Geneva: World Health Organization.
- WHO (2015b). *Reducing global health risks through mitigation of short-lived climate pollutants. Scoping report for policy-makers*. Geneva: World Health Organization.
- World LP Gas Association (2014). *Cooking with gas: Why women in the developing world want LPG and how they can get it*. (http://energia.org/wp-content/uploads/2015/04/01-WLPGA_-_Cooking_with_LP_Gas_Report_-_FINAL_PbP.pdf, accessed 17 February 2016).



Contact:

**Department of Public Health, Environmental and Social
Determinants of Health (PHE)**

Family, Women's and Children's Health (FWC)
Avenue Appia 20
World Health Organization
CH 1211 Geneva 27
www.who.int/phe

ISBN 9 789241 56523 3



9 789241 565233