



## CLEAN COOKING TO PROTECT MATERNAL AND CHILD HEALTH

Household air pollution is a leading risk factor for disease and death, especially among women and children. In 2016, over 2.6 million premature deaths were from household air pollution.<sup>1</sup> Burning biomass, coal, and kerosene to cook, heat, and light homes is the main cause.

Approximately 3 billion people around the world are still regularly exposed to household air pollution (HAP) despite declines in the proportion of households using biomass, coal and kerosene stoves.<sup>1</sup> **Almost one in seven children is exposed to health-damaging levels of outdoor air pollution, to which HAP substantially contributes.**<sup>2,3</sup> Reducing HAP can be an effective approach to protecting the health of women and children.

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**Household air pollution remains a leading risk factor for disease and premature death worldwide. Women and children are at highest risk of exposure.**

## KEY TAKEAWAYS



### Health impacts of HAP exposure

Burning biomass (wood, dung, charcoal, and crop waste), coal, and kerosene fuels in traditional and unvented stoves produces high levels of air pollutants. These pollutants have adverse health effects on birth, respiratory, and cardiovascular outcomes.



### Health benefits of reducing HAP

Switching to clean fuels or low-polluting improved stoves can decrease HAP and potentially reduce its adverse health impacts, including low birthweight in newborns, respiratory infections in children, and increased blood pressure in pregnant women.



### Moving toward effective implementation

Successful HAP interventions require consistent and exclusive use of clean fuels and improved stoves with confirmed efficiency and low emissions. Improving health may also require reducing air pollution from neighboring homes and other outdoor sources.



### Policies to reduce HAP

System-wide policies are needed for large-scale changes in clean cooking and household energy use to decrease HAP. Effective policies incentivize clean cooking and fuel use through subsidies and campaigns, while discouraging the burning of polluting fuels via bans or removing subsidies for kerosene.

## HEALTH IMPACTS OF HAP EXPOSURE



**Household air pollution (HAP) is a leading contributor to disease and premature death among adults and children. Children may be particularly susceptible to the health impacts of air pollution due to faster breathing rates and developing systems.<sup>4</sup>**

Evidence of the maternal and child health outcomes associated with exposure to HAP comes from observational studies and a small number of randomized controlled trials, which are the gold standard for evaluating interventions. These studies evaluate health impacts among users of traditional biomass stoves and open fires compared with users of clean stoves and fuels such as liquefied petroleum gas (LPG).

HAP comprises levels of particulate matter (including fine particulate matter  $PM_{2.5}$ ) and gases that can exceed air pollution exposures in even the most polluted urban settings.<sup>5</sup>

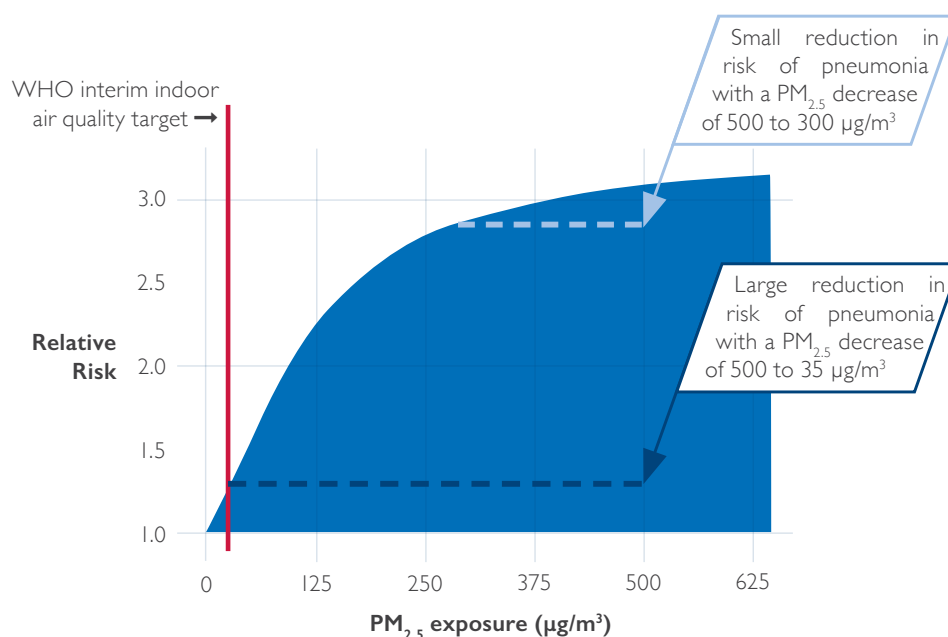
$PM_{2.5}$  can penetrate deep into the lungs and trigger systemic inflammation and oxidative stress, and is considered the best indicator air pollutant to estimate the negative health impacts of air pollution.<sup>6</sup> Exposure-response relationships between  $PM_{2.5}$  and risk of pneumonia, lung cancer, COPD, and cardiovascular outcomes estimate that exposure to HAP is detrimental to the health of infants, children, and adults.

To minimize the disease burden of HAP, the WHO recommends achieving an interim indoor air quality target of  $35 \mu\text{g}/\text{m}^3$  for annual mean  $PM_{2.5}$ , although adverse health outcomes occur at concentrations well below this target.<sup>7,8</sup> The WHO also advises against the indoor use of coal and kerosene.<sup>9</sup>



## Risk of childhood pneumonia at different levels of PM<sub>2.5</sub> exposure

The exposure-response curve for PM<sub>2.5</sub> and risk of childhood pneumonia is steep at low levels of exposure and flattens at ~200 µg/m<sup>3</sup> of PM<sub>2.5</sub>. Average HAP exposures are 2-15 times higher (~70-500 µg/m<sup>3</sup>) than the WHO interim target of 35 µg/m<sup>3</sup> of PM<sub>2.5</sub>.<sup>10</sup> A stove intervention that reduces PM<sub>2.5</sub> exposure from 500 to 200 µg/m<sup>3</sup> is predicted to reduce the relative risk of childhood pneumonia by just 0.5 whereas a substantially clean intervention that reduces PM<sub>2.5</sub> exposure from 500 to 35 µg/m<sup>3</sup> is predicted to decrease the relative risk by 1.8. **Clean stove and fuel interventions that substantially reduce PM<sub>2.5</sub> exposures to levels that meet or improve upon the WHO target are required to achieve the desired health benefits.**



## HAP remains a leading risk factor for premature death

HAP is the 8th leading risk factor for early death globally and the second leading risk factor for early death in low-income countries where its ranking has remained relatively stable since 1990 and exceeds major risk factors including smoking and unsafe water and sanitation.<sup>11</sup>

### Leading risk factors for premature death in low-income countries,<sup>a</sup> 1990 and 2016<sup>11</sup>

1990	2016
1. Child growth failure	1. High systolic blood pressure
2. Low birth weight and short gestation	<b>2. Household air pollution from solid fuels</b>
<b>3. Household air pollution from solid fuels</b>	3. Low birth weight and short gestation

Figure note: The estimates do not include additional deaths from outdoor air pollution emitted from household biomass and coal burning.

**“I have seen firsthand the importance of access to energy and clean cookstoves... it must play a central role in our work to ensure the realization of human needs and fundamental rights.”**

ANTÓNIO GUTERRES  
Secretary-General of the United Nations

<sup>a</sup> Includes 38 countries that ranked lowest in a sociodemographic index (SDI) based on average income per person, educational attainment, and total fertility rate. A complete list of countries is available from the Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2016 (GBD 2016) Socio-demographic Index (SDI) 1970–2016. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2017.

# Household air pollution was responsible for an estimated 2.6 million premature deaths in 2016.<sup>1</sup>

## STRONG AND SUPPORTIVE EVIDENCE <sup>b</sup> OF CHILD AND NEWBORN HEALTH IMPACTS FROM HAP EXPOSURE

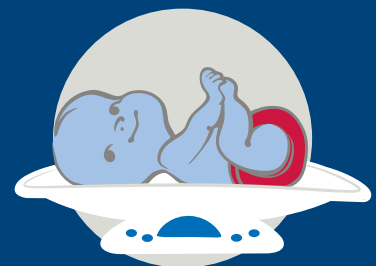


**Increased risk of stillbirth<sup>c, 12</sup>**

**Increased risk of all-cause mortality in young children<sup>d, 13</sup>**

**Increased risk of acute lower respiratory infections in children**

a leading cause of child death<sup>13</sup>



**Greater risk of low birthweight (<2,500 grams)**

and lower birthweight by an average of 86 grams<sup>f, 12</sup>

## EMERGING EVIDENCE <sup>g</sup> OF CHILD AND NEWBORN HEALTH IMPACTS FROM HAP EXPOSURE

**Increased risk of moderate-to-severe anemia<sup>h, 14</sup>**

which can impact child growth and development

**Increased risk of severe and moderate childhood stunting<sup>14, 15, 16</sup>**

indicators of poor growth and development<sup>i</sup>

**Increased risk of impaired child cognitive development<sup>17</sup>**

including lower performance on visual-spatial integration, memory recall, and fine motor performance<sup>j</sup>

<sup>a</sup> Strength of evidence is based on the Bradford Hill criteria in the WHO Guidelines ([http://apps.who.int/iris/bitstream/10665/141496/1/9789241548885\\_eng.pdf?ua=1](http://apps.who.int/iris/bitstream/10665/141496/1/9789241548885_eng.pdf?ua=1)).

<sup>b</sup> Based on five studies in India and Pakistan.<sup>12</sup>

<sup>c</sup> Pooled odds ratio from five studies with 10 independent estimates for all-cause mortality was 1.27 (95% CI: 1.07, 1.50). Based on five studies in Tanzania, India, Indonesia, and South Africa.<sup>19</sup>

<sup>d</sup> Pooled odds ratio from 26 studies of HAP exposure and non-fatal, severe, and fatal ALRI in children was 1.73 (95% CI: 1.47, 20.03).<sup>9</sup> HAP accounted for 41.6 % of deaths from lower respiratory infections (pneumonia) in children under five years.<sup>18</sup>

<sup>e</sup> Reduction in birthweight (95% CI: 55.5-117.4). Based on 13 studies in Guatemala, Peru, Serbia, Zimbabwe, Ghana, Pakistan, India, the Gaza Strip.<sup>8</sup> Low birthweight increases the risk of newborn mortality 2-5 fold compared with normal birthweight infants.<sup>12, 19, 15</sup>

<sup>f</sup> Emerging evidence is limited to individual studies on these topics.

<sup>g</sup> Based on a national family health survey from 1998-99 in India among children 0-35 months. An estimated 31% of anemia in children is attributable to exposure to HAP.<sup>14</sup>

<sup>h</sup> Pooled odds ratio from three studies of fuel type (solid fuel use vs. LPG or kerosene) was 1.27 (95% CI: 1.12, 1.43) for moderate stunting, and 1.55 (95% CI: 1.04, 2.30) for severe stunting.<sup>9</sup> Kerosene was characterized as a "clean fuel," which could have led to an underestimate of the odds ratio. Based on two studies in India and data from population-based surveys compiled from Cambodia, Dominican Republic, Haiti, Jordan, Moldova, Namibia, and Nepal.<sup>14, 15, 16</sup>

<sup>i</sup> Based on a study of infants with exposure to woodsmoke in Guatemala.<sup>17</sup>





Cooking on open fires and polluting stoves produces high levels of air pollution in household and communities.



Cooking with clean fuels and improved stoves can significantly reduce air pollution when technological and behavioral factors work in tandem.

## HEALTH BENEFITS OF REDUCING HAP



**Emerging data suggest that introducing clean stoves and fuels can reduce HAP and protect maternal and child health.**

Successful cookstove interventions that reduced  $PM_{2.5}$  in kitchens include a 41% reduction with an advanced combustion stove intervention and an 83% reduction with two ethanol stoves that replaced biomass fuel stoves.<sup>20</sup> Personal exposures to  $PM_{2.5}$  were reduced by 55% after replacing open fires with wood-burning chimney stoves.<sup>20</sup> Though none of the improved biomass burning stove interventions reduced indoor  $PM_{2.5}$  to levels that met the WHO interim indoor air quality target of  $35 \mu g/m^3$ , they still showed considerable reductions in HAP.

A small number of randomized controlled trials show that clean cooking can reduce the leading causes of child mortality and chronic disease in women:

### Reduction in severe pneumonia in young children

Reduction in physician-diagnosed severe pneumonia by 33% among young children <18 months in Guatemala after a wood-burning chimney stove with enclosed combustion chamber was installed in kitchens, compared with children in households with open woodfires.<sup>21</sup>

### Reduced duration of respiratory infections in children

Reduced duration of upper and lower respiratory infections in Mexican children living in homes that received a wood-burning chimney stove, compared with children in homes using an open fire.<sup>22</sup>

### Lower blood pressure in pregnant women

Lower diastolic blood pressure by 2.8-3.6 mmHg and hypertension prevalence by 4.5-7% among pregnant women in Nigeria who received ethanol cookstoves, compared with pregnant women using firewood or kerosene stoves.<sup>23</sup>

### Reductions in blood inflammatory biomarker in pregnant women

Reductions in the blood inflammatory biomarker (TNF- $\alpha$ ) in pregnant women in Nigeria after switching to an ethanol cookstove, compared with a subgroup of pregnant women using firewood stoves.<sup>24</sup> Elevated levels of TNF- $\alpha$  may increase risk of obstetric complications.<sup>25</sup>

### Improved neurological development in children

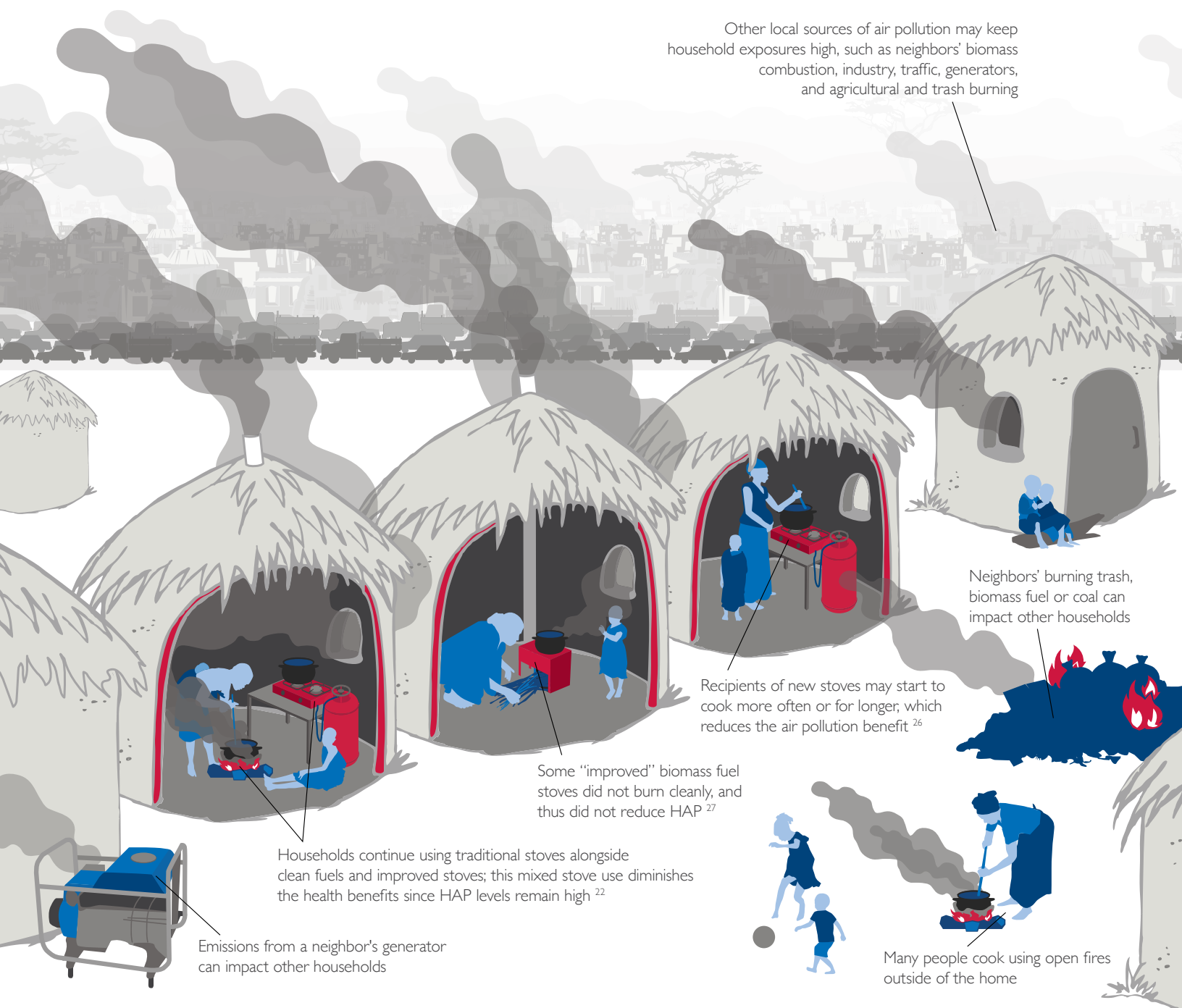
Improved neurological development among children 6-7 years old in Guatemala with reduced in utero exposure to HAP from their mother's use of a wood-burning chimney stove with enclosed combustion chamber, compared with children whose mothers used open woodfires.<sup>17</sup>

## MOVING TOWARD EFFECTIVE IMPLEMENTATION



Lessons from previous cookstove interventions show the importance of addressing cooking behaviors and other sources of air pollution to achieve anticipated health benefits of reduced HAP.

Clean cooking interventions may achieve greater health benefits if other factors are addressed in addition to promoting clean fuels and improved stoves. Effective implementation includes assuring the availability of fuels, reliable cookstoves, long-term service, and replacement; promoting consistent and exclusive use; and, reducing community sources of air pollution. The figure below shows various challenges to overcome to help reduce HAP and protect health.



## POLICIES TO REDUCE HAP



### Polymakers' role in reducing air pollution in homes and outdoors.

Policy initiatives, particularly those that improve energy access, can encourage communities to use clean fuels, such as LPG, ethanol, biogas, processed biomass, and well-implemented, low-emission biomass stoves. Policy initiatives can also take a broader approach to regulate other sources of outdoor air pollution, which in turn affect exposures.

Examples of country-level policies that could have an impact for reducing household and outdoor air pollution:

POLICIES	EXAMPLES
 <b>Low-income Subsidies</b> Providing subsidies for LPG to low-income households.	<b>Ghana</b> The Rural LPG Promotion Programme: <a href="http://energymin.gov.gh/brief-background">energymin.gov.gh/brief-background</a>  <b>India</b> <a href="http://MyLPG.in">MyLPG.in</a>
 <b>Campaigns</b> Creatively promoting ways to provide clean fuels for cooking.	<b>India</b> The "give it up" campaign that asks wealthier households to voluntarily give up their LPG subsidy to the poor: <a href="http://givitup.in">givitup.in</a> .  The Pradhan Mantri Ujjwala Yojana campaign to provide LPG connections to the poor: <a href="http://pmujjwalayojana.com">pmujjwalayojana.com</a>  <b>Nigeria</b> The "Upgrade to Gas" campaign.
 <b>Universal Access to Clean Fuels and Stoves</b> Improving access to clean fuels for cooking with: LPG connections, IT-based policy instruments, clean technology promotions, kerosene bans, reduced tariffs for key material imports.	<b>Peru</b> The Fund of Social Energy Inclusion (FISE): <a href="http://fise.gob.pe/que-es-fise.html">fise.gob.pe/que-es-fise.html</a> .
 <b>Updates to Subsidies and Regulations</b> Removing kerosene subsidies, lightly increasing LPG subsidies, changing regulations for fuel cylinder safety, removing taxes on LPG.	<b>Kenya</b> <a href="http://mygov.go.ke/state-abolishes-tax-on-cooking-gas-to-ease-cost-of-living/">mygov.go.ke/state-abolishes-tax-on-cooking-gas-to-ease-cost-of-living/</a>  <b>Indonesia</b> The Kerosene to LP gas conversion program in Indonesia: <a href="http://wlpga.org/wp-content/uploads/2015/09/kerosene-to-lp-gas-conversion-programme-in-indonesia.pdf">wlpga.org/wp-content/uploads/2015/09/kerosene-to-lp-gas-conversion-programme-in-indonesia.pdf</a> .
 <b>Frameworks</b> Creating a supportive framework for biogas digesters. Integrating environment and health planning to achieve sustainable use of natural resources and reduce emissions.	<b>Cambodia</b> <a href="http://nbp.org.kh/NationalPolicy.aspx">nbp.org.kh/NationalPolicy.aspx</a>

## ONGOING STUDIES ON THE BENEFITS OF CLEAN COOKING

### A multi-country randomized controlled trial of LPG stoves began in 2017.

The trial is taking place in India, Guatemala, Peru, and Rwanda, and is known as the HAP Investigation Network (HAPIN). This ongoing study is jointly-funded by the U.S. National Institutes of Health and the Bill and Melinda Gates Foundation. HAPIN is evaluating whether introducing LPG stoves to homes can improve health outcomes and establish biomarkers for both acute and chronic conditions in infants and adults.

Community transition to clean cookstoves and fuels can dramatically reduce air pollution exposures and reduce disease burden in children and women. Effecting this transition will require appropriate programs and policies.

## RESOURCES AND REFERENCES

This brief focused on maternal and child health impacts of household stove interventions in low- and middle-income countries. Findings were synthesized from systematic reviews and resulting meta-analyses, exposure-response associations, and publications from individual randomized controlled trials and observational studies.

1. GBD 2016 Risk Factors Collaborators, Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *The Lancet*, 2017. 390: p. 1345-1422.
2. UNICEF. UNICEF Report: Clear the air for children- the impact of air pollution on children. 2016.
3. Chafe, Z.A., et al., Household cooking with solid fuels contributes to ambient PM2.5 air pollution and the burden of disease. *Environ Health Perspect*, 2014. 122(12): p. 1314-20.
4. Bearer, C.F., How are children different from adults? *Environ Health Perspect*, 1995. 103 Suppl 6: p. 7-12.
5. Brauer, M., et al., Exposure assessment for estimation of the global burden of disease attributable to outdoor air pollution. *Environ Sci Technol*, 2012. 46(2): p. 652-60.
6. Chow, J.C., et al., Health effects of fine particulate air pollution: lines that connect. *J Air Waste Manag Assoc*, 2006. 56(10): p. 1368-80.
7. Crouse, D.L., et al., Ambient PM2.5, O(3), and NO(2) Exposures and Associations with Mortality over 16 Years of Follow-Up in the Canadian Census Health and Environment Cohort (CanCHEC). *Environ Health Perspect*, 2015. 123(11): p. 1180-6.
8. Weichenthal, S., et al., Biomass Burning as a Source of Ambient Fine Particulate Air Pollution and Acute Myocardial Infarction. *Epidemiology*, 2017. 28(3): p. 329-337.
9. WHO. (2014). "World Health Organization guidelines for indoor air quality: household fuel combustion." from <http://www.who.int/indoorair/guidelines/hhfc/en/>.
10. Clark, M.L., et al., Health and household air pollution from solid fuel use: the need for improved exposure assessment. *Environ Health Perspect*, 2013. 121(10): p. 1120-8.
11. Institute for Health Metrics and Evaluation (IHME). GBD Compare. 2017 [cited 2017 September 16, 2017]; Available from: <https://vizhub.healthdata.org/gbd-compare/>.
12. Amegah, A. K., R. Quansah and J. J. Jaakkola (2014). "Household air pollution from solid fuel use and risk of adverse pregnancy outcomes: a systematic review and meta-analysis of the empirical evidence." *PLoS One* 9(12): e113920.
13. Bruce, N.G., et al., Control of household air pollution for child survival: estimates for intervention impacts. *BMC Public Health*, 2013. 13 Suppl 3: p. S8.
14. Mishra, V. and R. D. Retherford (2007). "Does biofuel smoke contribute to anaemia and stunting in early childhood?" *Int J Epidemiol* 36(1): 117-129.
15. Kyu, H. H., K. Georgiades and M. H. Boyle (2009). "Maternal smoking, biofuel smoke exposure and child height-for-age in seven developing countries." *Int J Epidemiol* 38(5): 1342-1350.
16. Tielsch, J. M., J. Katz, R. D. Thulasiraj, C. L. Coles, S. Sheeladevi, E. L. Yanik and L. Rahmathullah (2009). "Exposure to indoor biomass fuel and tobacco smoke and risk of adverse reproductive outcomes, mortality, respiratory morbidity and growth among newborn infants in south India." *Int J Epidemiol* 38(5): 1351-1363.
17. Dix-Cooper, L., B. Eskenazi, C. Romero, J. Balmes and K. R. Smith (2012). "Neurodevelopmental performance among school age children in rural Guatemala is associated with prenatal and postnatal exposure to carbon monoxide, a marker for exposure to woodsmoke." *Neurotoxicology* 33(2): 246-254.
18. GBD 2015 Risk Factors Collaborators (2016). "Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015." *Lancet* 388(10053): 1659-1724.
19. Katz, J., et al., Mortality risk in preterm and small-for-gestational-age infants in low-income and middle-income countries: a pooled country analysis. *Lancet*, 2013. 382(9890): p. 417-25.
20. Pope, D., et al., Real-life effectiveness of 'improved' stoves and clean fuels in reducing PM2.5 and CO: Systematic review and meta-analysis. *Environ Int*, 2017. 101: p. 7-18.
21. Smith, K.R., et al., Effect of reduction in household air pollution on childhood pneumonia in Guatemala (RESPIRE): a randomised controlled trial. *Lancet*, 2011. 378(9804): p. 1717-26.
22. Schilman, A., et al., Children's Respiratory Health After an Efficient Biomass Stove (Patsari) Intervention. *Ecohealth*, 2015. 12(1): p. 68-76.
23. Alexander, D., et al., Randomized Controlled Ethanol Cookstove Intervention and Blood Pressure in Pregnant Nigerian Women. *Am J Respir Crit Care Med*, 2017. 195(12): p. 1629-1639.
24. Olopade, C.O., et al., Effect of a clean stove intervention on inflammatory biomarkers in pregnant women in Ibadan, Nigeria: A randomized controlled study. *Environ Int*, 2017. 98: p. 181-190.
25. Brogin Moreli, J., et al., Interleukin 10 and tumor necrosis factor-alpha in pregnancy: aspects of interest in clinical obstetrics. *ISRN Obstet Gynecol*, 2012. 2012: p. 230742.
26. Aung, T.W., et al., Health and Climate-Relevant Pollutant Concentrations from a Carbon-Finance Approved Cookstove Intervention in Rural India. *Environ Sci Technol*, 2016. 50(13): p. 7228-38.
27. Mortimer, K., et al., A cleaner burning biomass-fueled cookstove intervention to prevent pneumonia in children under 5 years old in rural Malawi (the Cooking and Pneumonia Study): a cluster randomised controlled trial. *Lancet*, 2017. 389(10065): p. 167-175.

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