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## Energy transitions, air quality and health

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## Abstract

The way we produce and use energy is transforming. Policy in this area intersects decisions that affect climate change, air quality, and the economy. The exponential increase in use of fossil fuel and nuclear energy has now essentially replaced human and animal energy (McKinney 2019 *Curr. Pollut. Rep.* **5** 394–406; Solomon and Krishna 2011 *Energy Policy* **39** 7422–31). These transitions have contributed to notable gains, such as improvements in mortality rates attributable to improved heating, water quality and transportation (Rayner 2012 *Ecological Public Health: Reshaping the Conditions for Good health/Geof Rayner and Tim Lang* (Abingdon, Oxon: Earthscan); Rosen 2015 *A History of Public Health* (Jhu Press); Pain 2017 *Nature* **551** S134–7; Cutler and Miller 2005 *Demography* **42** 1–22). However, such transitions have also been accompanied by health detriments. Improvements in transportation and occupational efficiencies have promoted lifestyle transitions that have contributed to the chronic disease epidemic (Heath 2009 *Am. J. Lifestyle Med.* **3** 27S–31S). Certain energy-related accidents and waste products have been long-established as carcinogenic (Guizard *et al* 2001 *J. Epidemiol. Community Health* **55** 469; Cardis and Hatch 2011 *Clin. Oncol.* **23** 251–60) and potential precursors to genetic mutations (Beir 1990 *Health Effects of Exposure to Low Levels of Ionizing Radiation* (Washington, DC: National Academy of Sciences); Desouky *et al* 2015 *J. Radiat. Res. Appl. Sci.* **8** 247–54). Moreover, air pollution emissions are increasingly becoming recognised as a major contributor the global burden of disease, particularly cardiovascular and respiratory mortality (Cohen *et al* 2017 *Lancet* **389** 1907–18). Although renewable energies can be perceived as ‘clean’, the shift to renewables has been relatively more recent and consequently, less is known about associated health impacts. The *life course* of renewable energy begins with the process of manufacturing renewable technologies, includes the means of transportation for the distribution and collection of these technologies as well as the disposal of their waste products and subsequent contamination. All of these stages have potential to involve direct chemical exposures through the groundwater, soil or air; and have potential to affect health through indirect pathways. A relatively understudied area, and the topic of this Focus Issue on *Energy Transitions, Air Quality and Health*, is the relevance of energy transitions and their associated environmental factors in a contemporary setting, how such factors affect health now, and will affect health in future.

## 1. Ambient exposures and vulnerable subpopulations

An energy transition towards renewable sources is expected to directly reduce levels of anthropogenic ambient air pollution. The amount by which mortality and morbidity will be reduced as a consequence of this transition will depend on the distribution of exposure. In this issue Cooper *et al* examined differences in air pollution levels experienced across the Australian population, with a focus on particulate matter air pollution and nitrogen dioxide, which have various sources including combustion emissions, forest fires and dust storms [1]. The authors observed high concentrations in areas of socioeconomic disadvantage and areas with a higher proportion of ethnic minorities. The magnitude of the observed differences in the air pollutant concentration levels was small but the authors suggest that reductions in the associated health burden are appreciable at the population level. Although this conservative conclusion was well-justified for the overall findings of the study, the associations were complex, and sometimes non-monotonic. At the area-level, higher exposures were associated with non-Indigenous ethnicity. Higher exposures were associated with older age (age 65 years or over) in rural areas but not urban areas, and children (age under 15 years) were the least likely to be exposed to high concentrations. Does this mean that the most substantial health gains from reduction in air pollution levels, perhaps from a shift to renewable energy technologies, will be achieved by non-Indigenous populations of ages 15–64 years? Most likely not. This is because the health burden is borne most among older adults already affected by age-related decline in physiological function, among young children whose organ systems are immature and rapidly developing, and among Indigenous populations who experience burden of disease more than twice that of non-Indigenous populations. Further, energy transitions have implications for climate change, which affect populations far from the source.

## 2. Energy transitions: fuel use at the household-level

In this issue, Shupler *et al* report on results on fuel switching in rural communities from nine non-high income countries—Chile, South Africa, China, Colombia, Bangladesh, India, Pakistan, Tanzania and Zimbabwe [2]. The authors found that more than half of these households switched to gas and electricity from the more traditional fuels such as wood, dung, agricultural waste and coal. Changes were associated with education, wealth and community level factors such as population density. Although improvements were observed over the decade long study not all households improve fuel quality over

time, and some switched from clean fuel to a polluting fuel. This large-scale study successfully quantified the magnitude and direction of fuel switching in the lower income countries. The reasons for using specific fuels and the use of multiple fuels in households was not able to be investigated in such a large study and warrant further investigation. Billah *et al* were able to address these issues from a cohort study they conducted in Bangladesh [3], which according to Shupler *et al* had the lowest proportion of households that switched to a cleaner fuel (2%) [2]. The authors found that nearly all households in Bangladesh had multiple cookstoves and identified both barriers to use of clean fuels and potential opportunities for intervention. Whether perception of the alleviated health problems is a viable target to promote clean fuel use needs to be confirmed by further studies but it is likely that population scale improvements cannot be achieved without government support in countries like Bangladesh, where LPG is expensive, biomass is free, and financial subsidies are severely limited.

## 3. Energy transitions: measuring exposure changes under variable meteorology

Effectiveness of energy transitions in high-income countries is commonly assessed at levels higher than households, sometimes by comparing air pollution levels at different stages of a transition. Results from some transitions can serve as ‘natural experiments’ that provide compelling evidence for changes in exposures and consequential health outcomes. In the lead-up to the 2008 Beijing Olympics, the Chinese government limited operation of industrial and commercial combustion facilities as well as motor vehicle traffic. Particulate and most gaseous criteria air pollution levels reduced by 13–60% during the event and increased after the limits on emission-related activity was relaxed; air pollution reductions were correlated with improvements in pathophysiological markers for cardiovascular disease [4]. More recently, reductions in economic activity during COVID-19 lock-downs led to decreases in population-weighted ambient concentrations of particulate matter by 31% and nitrogen dioxide by 60% according to a study that was conducted in 34 countries this year [5]. Temporal changes in weather also contribute to changes in air pollution concentrations. In this issue Henneman *et al* produce a framework for identifying the improvement in ambient air pollution levels that is independent of changes in meteorology and which will contribute to improving studies that apply methods for exposure assessment that do not account for meteorology [6]. For larger-scale energy transitions over longer time periods, evaluation of population health impacts are further complicated by feedback processes between air pollution and meteorological conditions, all of which are superimposed on a changing climate that is also influenced

by anthropogenic air pollution. With this in mind, although independent effects of weather, air pollution or extreme events or episodes of these exposures are relevant to establishing etiology and causation, it is their joint influence [7] that are most relevant to population health *impact*, and therefore warrant further research.

#### 4. Health effects: waste to energy processes

One well-established method for producing energy is through the conversion of waste, which has attracted further attention due to the large and increasing amount of global waste production. What can we learn from studies that have already been conducted on the health effects of waste to energy emissions? In this issue Cole-Hunter *et al* conducted a systematic review of studies on airborne emissions from waste to energy facilities and health outcomes [8]. The researchers identified a significant gap, with few epidemiological studies on the topic. Based on the current evidence, albeit limited, the authors concluded that risks from modern waste to energy plant emissions are lower than those from most current waste management practices, which include land-fill and incineration of unsorted waste. The authors discuss the potential for poorly fed waste to energy facilities to emit dioxins and heavy metals that are harmful to health but also the potential for waste to energy technology to offset fossil fuel combustion for electricity generation and reduce total greenhouse gas and criteria air pollutant emissions. The disposal of waste during renewable energy life course, such as waste from batteries and solar modules and their associated health impacts, remains an avenue for further research.

#### 5. Health co-benefits: renewable energy policy

Climate change policies that promote a transition to renewable energy sources, have potential to result in improvements to air quality and health as ‘co-impacts’, often called ‘co-benefits’. A synthesis of policy documents by Workman *et al* indicate that consideration of human-health facilitated the introduction of ambitious mitigation policies in the United States during the Obama administration, highlighting ‘health as a motivator for climate action’ [9]. What is the expected co-benefit? In this issue Dimanchev *et al* estimated the future health-related co-benefits of carbon pricing and policies that require electricity suppliers to obtain electricity from renewable technologies in the ‘Rust Belt’ region of the United States [10]. The researchers projected that the health co-benefits per unit of CO<sub>2</sub> reduced and renewable energy deployed would exceed the costs by approximately one third. The influence of carbon pricing was projected to result in greater

health co-benefits than renewable portfolio standards, which was due to a range of factors, including the stronger influence of carbon pricing on reducing coal-fired power generation. These results are likely to be conservative estimates if the reductions in particulate matter air pollution considered in this study are also accompanied by reductions in exposure to other pollutants. Human health improvements extend beyond mortality risk reductions considered in this study, and include reductions in the incidence of non-fatal cancers, chronic morbidities and reduced reproductive or developmental effects. Although, death and disease-related endpoints can be monetized using economic valuation methods, *health*, according to the Constitution of the World Health Organization, is defined as ‘a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity’ [11]. Our knowledge of the true range of health effects from climate change related policies that promote energy transitions remains limited. Further avenues of research include consideration of the potential for unintended adverse health effects—co-harms [12]—and identifying co-benefits using a broader definition of *health*.

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#### Conflict of interest

The authors have no potential conflicts of interests to disclose.

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