Energy, data, and decision-making: a scoping review

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Abstract

Access to energy is an important social determinant of health, and expanding the availability of affordable, clean energy is one of the Sustainable Development Goals. It has been argued that climate mitigation policies can, if well-designed in response to contextual factors, also achieve environmental, economic, and social progress, but otherwise pose risks to economic inequity generally and health inequity specifically. Decisions around such policies are hampered by data gaps, particularly in low- and middle-income countries (LMICs) and among vulnerable populations in high-income countries (HICs). The rise of "big data" offers the potential to address some of these gaps. This scoping review sought to explore the literature linking energy, big data, health and decision-making.

Literature searches in PubMed, Embase, and Web of Science were conducted. English language articles up to April 1, 2020 were included. Pre-agreed study characteristics including geographic location, data collected, and study design were extracted and presented descriptively, and a qualitative thematic analysis was performed on the articles using NVivo.

Thirty-nine articles fulfilled eligibility criteria. These included a combination of review articles and research articles using primary or secondary data sources. The articles described health and economic effects of a wide range of energy types and uses, and attempted to model effects of a range of technological and policy innovations, in a variety of geographic contexts. Key themes identified in our analysis included the link between energy consumption and economic development, the role of inequality in understanding and predicting harms and benefits associated with energy production and use, the lack of available data on LMICs in general, and on the local contexts within them in particular. Examples of using "big data", and areas in which the articles themselves described challenges with data limitations, were identified.

The findings of this scoping review demonstrate the challenges decision-makers face in achieving energy efficiency gains and reducing emissions, while avoiding the exacerbation of existing inequities. Understanding how to maximise gains in energy efficiency and uptake of new technologies requires a deeper understanding of how work and life is shaped by socioeconomic inequalities

between and within countries. This is particularly the case for LMICs and in local contexts where few data are currently available, and for whom existing evidence may not be directly applicable. Big data approaches may offer some value in tracking the uptake of new approaches, provide greater data granularity, and help compensate for evidence gaps in low resource settings.

Introduction

Energy usage has been central to human society from its earliest history, and is associated with many health benefits through the production of goods and services, transportation, housing, protection from extremes of heat and cold, communications, science and technology, overall increases in economic productivity and even public safety.[1] Access to energy is regarded by the World Health Organization (WHO) as an important social determinant of health,[2] and expanding the availability of affordable, clean energy is one of the United Nations Sustainable Development Goals (SDGs). An estimated 3 billion people still lack access to clean cooking fuels and technology, and 840 million people live without electricity.[3] In parallel, the global challenge of climate change has highlighted the importance of reducing emissions, and inherent in them, the inequalities associated with energy need and globally, including inequalities in the harm generated through energy production, and in efficiency and consumptions levels within and between countries.

Climate change itself has been observed to exacerbate global economic inequality,[4] with vulnerable populations and low- and middle-income countries (LMICs) disproportionately exposed to extreme weather events, sea-level rises, increased risk of infectious diseases, and food insecurity.[5] Following the science to tackle climate change will require difficult decisions at local, national, and international levels, and likely profound societal changes. These decisions may risk exacerbating existing inequities by preventing affordable energy access to those for whom this is an important health and developmental need, or by transitioning economic activity in ways that disproportionately disadvantages those with more limited wealth, education, and social capital.[6-8] Growing inequity, either due to the worsening effects of climate change, or the consequences of climate change mitigation efforts, risks widening attendant health gaps.[5,8]

It has been argued that climate change mitigation policies can, if well-designed in response to contextual factors, achieve environmental, economic and social progress, but otherwise pose risks to inequality generally and health inequities specifically.[9] The 2020 Report of the Lancet Countdown on Climate Change called for a high priority to be set on further understanding which populations are vulnerable to climate change, the health and environmental consequences of inaction, and potential side-effects of required mitigation efforts.[5]

In to that improve public support for these measures, and mitigate their effects on health inequalities, it is important that decision-makers are aware of the role of energy as a social determinant of health, both in the context of its production and its consumption. It has been argued that one way in which upstream determinants of health such as energy production and use can better inform decision-making is through expanding use of "big data" approaches.[10] However, little is currently known about the extent to which such approaches have been applied to energy as a determinant of health and to what extent this has featured in decision-making.

We report the findings of a scoping review that sought to address this gap by identifying and describing the available literature explicitly or implicitly linking energy - including energy production, consumption, conservation, and pollution - with use of data, and the implications for decision-making.

Methodology

Search strategy

The search strategy was formulated by an experienced Boston University librarian and revised and finalized by a three-person research team (2 researchers GR and SFK, 1 supervisor SMA). All articles available in Embase, PubMed, and Web of Science as of April 1, 2020 uncovered through our search strategy were initially considered.

In Embase, three separate searches returned articles with titles, abstracts, or author keywords (ti,ab,kw) related to data, decision-making, and energy respectively. These searches were combined resulting in 146 articles. In PubMed, two searches were combined. The first search identified 387 articles related to decision-making, health, and energy based on MeSH Terms and text words ([tw]). The second search identified 147 articles related to energy, decision-making, and data based on MeSH Terms and text words ([tw]). The search field tag [tw] was used to enhance the search strategy; [tw] generated results by searching titles, abstracts, other abstracts, MeSH Terms, MeSH Subheadings, Publication Types, Comment/Correction Notes, non-MeSH Subject Terms (keywords) and other Terms field (including author-supplied keywords). In total, 534 articles were returned from PubMed. In Web of Science, three separate searches returned articles with titles (TI) related to data, decision-making, and energy respectively. These search results were combined, returning a total 20 articles from Web of Science.

The full search strings for Embase, PubMed and Web of Science can be found in the Appendix. Articles written in a language other than English, conference proceedings and abstracts, and general reports were excluded.

Screening and selection of articles

One researcher (GR) downloaded the 700 articles identified across Embase, PubMed, and Web of Science to the citation manager Zotero,[11] and then uploaded the articles to Rayyan, a web application for collaborative systematic reviews developed by Hamad Bin Khalifa University and Qatar computing research institute.[12]

Two researchers (GR and SFK) independently used this software to identify and remove 61 duplicates, leaving 639 articles. These abstracts then underwent independent, blinded abstract screening. Two researchers (GR and SFK) used Rayyan to record and indicate their justification for including or excluding articles in the abstract screening stage. Discrepancies were addressed as they emerged through discussion between the researchers (GR and SFK) and disagreements were resolved by supervisor (SMA). Five hundred forty-one articles were excluded, leaving 98 articles which underwent independent and blinded full-text eligibility assessment. The articles were transferred from Rayyan to Excel, and justifications for inclusion and exclusion were noted, with discrepancies subsequently addressed through discussion between researchers (GR and SFK) and disagreements were resolved by supervisor (SMA). Forty-nine articles were excluded through this process, leaving 39 articles eligible for the final synthesis stage.

Analysis

We used a "descriptive-analytical" method within the narrative tradition, as proposed by Arksey & O'Malley,[13] presenting our findings in the form of a descriptive numerical summary, and including a qualitative thematic analysis as recommended by Levac *et al.*[14] For the numerical summary, a common framework was applied for all the papers included to collect standard information on key issues and themes around energy, data, and decision-making. Both researchers (GR and SFK) involved in article screening used the framework independently to review articles apiece in Excel. The two Excel files were later merged and finalized.

The qualitative thematic analysis was performed by an experienced qualitative researcher (NM) (separate to those involved in the abstract and full-text screening steps) who read and iteratively coded[15] all articles using NVivo (NVivo qualitative data analysis software; QSR International Pty Ltd. Version 12).

Results

After screening 639 titles and abstracts and 98 full text articles, 39 unique articles were included in this review (see Figure 1 and Table 1).

Topics covered

The articles identified in this review attempted to estimate the health and economic effects of a range of different energy generation types, energy uses and emission reduction approaches, such as changes to fuel composition in ships[16,17] and cars,[18,19] oil price changes,[20] transport electrification,[21,22] environmental standards,[23] coal power plants,[24,25] and cooking fuels.[26,27] In doing so, authors examined the health benefits of increasing efficiency and reducing pollution,[16,18,28-31] and how improvements in pollution control might affect these outcomes.[16,17,19] In some articles this included estimating the non-health benefits of increased energy efficiency and reducing pollution, including cost reductions for consumers,[21,23] improvements to the physical environment,[23,32] economic benefits,[32] increased productivity,[23] and national security.[31,33] In others this included estimating the non-health harms of pollution, such as crop loss,[31] and the eutrophication of coastal waters.[23]

Several key themes were identified in our analysis of these articles in the intersection of energy, data, and decision-making. These included the relationship between energy consumption and economic development, and linked to this theme, a clear need to understand the role of inequality in understanding and predicting harms and benefits associated with energy production and use in more granular and nuanced ways. Relatedly, the limitations and foci of these studies emphasize the importance of understanding local contexts and microenvironments in decision-making, be that in reducing health inequities, or monitoring uptake of new approaches and technologies. Through these studies, examples of the potential value of applying "big data" approaches to overcome these challenges were identified, along with areas in which the articles themselves identified a need for more granular data. We expand on each theme below.

Energy and national economic development

Energy is an important pillar of economic growth, and the link between CO2 emissions and globalization was described as an inverted U shape, in which countries emissions increased with economic development before declining due to greater environmental awareness, cultural exchange, and improvements in fuel efficiency.[34] By contrast, economic recession was noted to have a retarding effect on the pace of improvements in efficiency.[31] Greater energy usage was associated with improvements in infant mortality in countries with a high baseline infant mortality rate and low life expectancy. However, based on time series data from 41 countries, these health benefits exhibited diminishing returns, and in countries with infant mortality less than 100/1,000 live births, benefits were not observed.[35] At the national level these correlations reflect the links between economic development, energy use, and health, and the particular needs and exigencies facing developing economies.

Relatedly, as economies change emphasis over time, patterns of energy generation and use, and therefore exposures to environmental pollution, also shift. For example, in Western Europe during the late 1980s and early 1990s, industry emissions declined but were offset by increases in private car and motorbike ownership, even as Gross domestic product (GDP) declined.[31] In LMICs, smoke produced during the burning of biofuels remains a significant contributor to poorer health for children and adults.[27] In these settings, economic status is a pivotal factor in a family's ability to choose to use more expensive but cleaner and less health-harming fuels, described as moving up the household "energy ladder".[36] This represents one example of the links between energy and inequality both between and within countries. This is a critical consideration for decision-makers seeking to balance improvements in health through economic progress in LMICs on the one hand, and reductions in emissions and other harms associated with greater energy production on the other.

Energy and social inequality

Social inequality emerged from the review as a critical consideration in how energy constitutes a determinant of health. Benefits to improvements in energy efficiency, and developments towards healthier types of energy generation in general are often patterned unequally between and within countries, with the greatest harm, both in terms of energy production, and consumption patterns, accruing to those of lower socioeconomic status. For example, at the global level, the proportion of households using solid fuels for cooking declined between 1980-2010. However, because of population growth, particularly in Africa and South east Asia, the absolute number of persons using such fuels, and therefore being exposed to indoor air pollution, has remained fairly constant, according to multi-level modelling of national survey data.[26] Exposure to environmental pollution caused by energy production is strongly correlated with geographic location. For example, communities in close proximity to roads,[37] or in large urban centers,[25,32,38] face much higher levels of particulate matter. Coastal communities are more susceptible to pollution by shipping traffic,[16,17] and agricultural and shipping pollutants combine to disrupt local coastal ecosystems and food supplies with economic and health implications that disproportionately affect those who can least afford to migrate inland and are most reliant on locally produced food.[16,17,23,39]

The studies identified also show how risks from pollution were patterned in intersectional ways in the context of age, gender and socioeconomic status. Those with a lower than high school education in China faced greater relative risk of poor health effects from air pollution,[38] and women, children and the elderly were identified as particularly vulnerable.[37,38] Children have higher baseline ventilation rates, and spend more time outdoors engaged in physical activity than adults, and are thus overexposed to pollution hazards.[37]

Women and children in low-income settings are also disproportionately exposed to pollution due to proximity to household cooking and heating fuels during use,[27] with such effects exacerbated by poor ventilation. The use of such energy sources is associated with other harms often not included in attempts to model burden of disease from indoor air pollution. For example, the use of such methods in cramped conditions is likely to increase the risk of burns and scalds.[26] The need to seek such fuels, typically by women, combined with poor infrastructure, street lighting, and public safety, lead to an increased risk of experiencing violence.[26] These studies provide examples of the ways in which understanding local exposures, activity patterns and contexts, particularly in low-income settings, and among vulnerable populations, is a critical, technically challenging aspect of modelling the effects of energy use and pollution.

Local contexts and microenvironments

A key emergent theme from our review of these studies is the importance of understanding local context and microenvironments in determining the harms associated with energy production, and the benefits associated with its use, even though such data are often lacking. Pollution is typically highly geographically patterned, and this characteristic is acknowledged in modelling studies that seek to assess the effects of such pollution, or the likely health improvements associated with reductions in emissions. This is particularly important in the context of urban environments, as they can combine high levels of pollution with high numbers of people exposed.[18,30,40] A modeling study found that the health effects of coal powerplants were highly patterned, with New Taipei City, Taipei City, and Taoyuan City alone estimated to account for 68.3% of all pre-mature deaths attributable to PM2.5 in Taiwan.[25]

The importance of local context is especially relevant in the context of understanding effects on particularly vulnerable populations. However, much of the original research used to model air pollution mortality harms and benefits is from high-income country (HICs) settings, and so may not reflect the combination of pollutants and other environmental factors arising from energy use and expenditure in lower income settings. These include the role of indoor air pollution,[41] or building design differences, such as level of ventilation, height of chimneys, or the health harms associated with specific combinations of atmospheric variables and particulate types.

Beyond modelling challenges, socioeconomic inequality imposes a triple burden and obstructs improvements in emissions and health overall. First, lower socioeconomic status has a constraining effect on the ability to take up more modern, more efficient, and less polluting energy uses, to adapt to energy price changes, or to mitigate extreme exposures through ventilation or air-conditioning. Second, lower socioeconomic status has an overexposing effect in terms of more direct exposure to environmental pollution through patterns of work and daily life for both adults and children. Third, these exposures pattern onto existing inequality along other dimensions such as access to nutrition, clean water, education and safe home and work environments that contribute to poorer baseline health and shorter life expectancy, and make these groups more vulnerable to pollution and its consequences.[42]

Local context and microenvironments are therefore critical in understanding the mediating pathways by which this burden is perpetuated, and ensuring these are encompassed in data collection and modelling studies that can inform decision-making.

Examples of big data utilization

"Big data" are broadly defined as "digital data of high volume, velocity, and variety passively derived from everyday interactions with digital products or services, including mobile phones, credit cards, and social media" that "require new tools and methods to capture, curate, manage, and process."[43,44] The rise of "big data" approaches offers the possibility of improving the granularity of our understanding of local variations in energy use and exposure to energy-related pollution, particularly where data have traditionally been lacking. The rise of "big data" may also aid our understanding of trends in human activity over time, such as uptake of new technologies, travel and exposure patterns.

Studies included in this review demonstrate the value of big data in identifying vulnerable populations. An analysis of Medicare data in New Orleans, USA allowed for the identification of individuals especially vulnerable to power outages due to reliance on home ventilator use.[45] Another study used a data analytics approach combining building footprint, gas bills and climate data in Cambridge, USA to identify the most efficient type and number of buildings town planners might prioritize for retrofitting.[46] Cai et al used a data mining approach to individual travel patterns to identify the most common taxi trajectories in Beijing and estimate real-world implications of fleet electrification, and the most cost-effective incentives for plug-in hybrid vehicles.[21] In doing so, this approach helps overcome challenges in estimating common vehicle travel patterns, which can often vary widely by local region.[20] Through the use of high-resolution data from the ship-based Automatic Identification System, in combination with atmospheric model and health risk functions, Sofiev et al were able to improve the geospatial resolution of ship pollution-related health effects globally, and identify those regions likely to experience the largest mortality and morbidity benefits.[16]

Challenges that could be overcome through using big data

The studies in this review also highlighted the challenges to be overcome in order to improve the use of big data in energy and decision-making around health. These include the need for better data on the complex interplay between energy affordability and health, particularly for disadvantaged groups, as well as the role of waste products other than air emissions, which may become increasingly prominent as new technologies proliferate.[29] As patterns of activity change in heterogeneous ways over time in response to technological and economic changes, particularly in countries with fast-growing economies, so too does the distribution and nature of pollutants such as sulfur dioxide and volatile organic compounds. These require better monitoring data both in relation to emissions, and in relation to activity patterns, and a greater understanding of the local contexts in which they occur,[47] all of which big data could help inform. The use of state or even county-wide estimates of population density and health status in countries such as the US,[48] while helpful, likely mask the health damage accruing to local populations that are disproportionately vulnerable due to their physical and social microenvironments. These types of data, including the proportion of citizens living in poverty, is at times not known and therefore not included in modelling estimates.[49]

Beyond providing greater data granularity focused solely on exposure or activity, big data may help address challenges along the causal chain between energy generation and health outcomes.[50] This could include providing data on the extent to which new regulations are implemented, the type and nature of emissions in a greater range of locations, levels of ambient air quality, personal and population-level exposures to pollutants, and the extent to which mitigating actions are implemented in ways that minimize harm to those most at risk.

Priorities for further research

There are limitations as to how big data approaches could resolve these issues. Many of these challenges require a more conscious prioritization of data collection and research rather than use of existing data repositories. Part of the challenge inherent in several of the studies in this review was the use of exposure-response functions based primarily on US and Western European populations,[51] highlighting a need for greater data granularity at the global level to better inform modelling of air pollution and climate change impacts. Critically, in many contexts the local conditions in LMICs, including the physical and chemical nature of pollutants, their distribution, and the activities of local populations, including health behaviors such as smoking or physical activity, may differ significantly from HIC counterparts.[38,42,51-53]

Even in HICs, while childhood diseases associated with air pollution were included in studies assessing health impacts, the life-course effects of air pollution and other environmental exposures in energy generation on children in particular were usually not considered.[36] This is concerning as this exposure and therefore effect, may be highest in those contexts for which data is most lacking, and such consequences may represent a significant fraction of overall health and economic harms in the longer term.

Conclusions

This scoping review identified a number of ways in which big data approaches might help to inform decision-making in the context of energy as a determinant of health. It is clear that big data may be able to bridge gaps in understanding and predicting the localized harms and benefits associated with energy production and use. It is also clear that significant data gaps remain, especially in understanding and predicting changes in energy generation and use in LMICs.

This scoping review identifies some of the ways in which there is a need to make data and evidence regarding energy use and pollution widely available to better reflect and serve diverse global contexts. Expanding the use of big data, including those data made available through private providers, could better help decision-makers at global, national, and local levels better determine the nature of their energy challenges, and inform decisions about the most feasible and cost-effective courses of action in mitigating health effects for the most vulnerable.

Figures and tables

Figure 1 Flow diagram of articles assessed through the different phases of the review

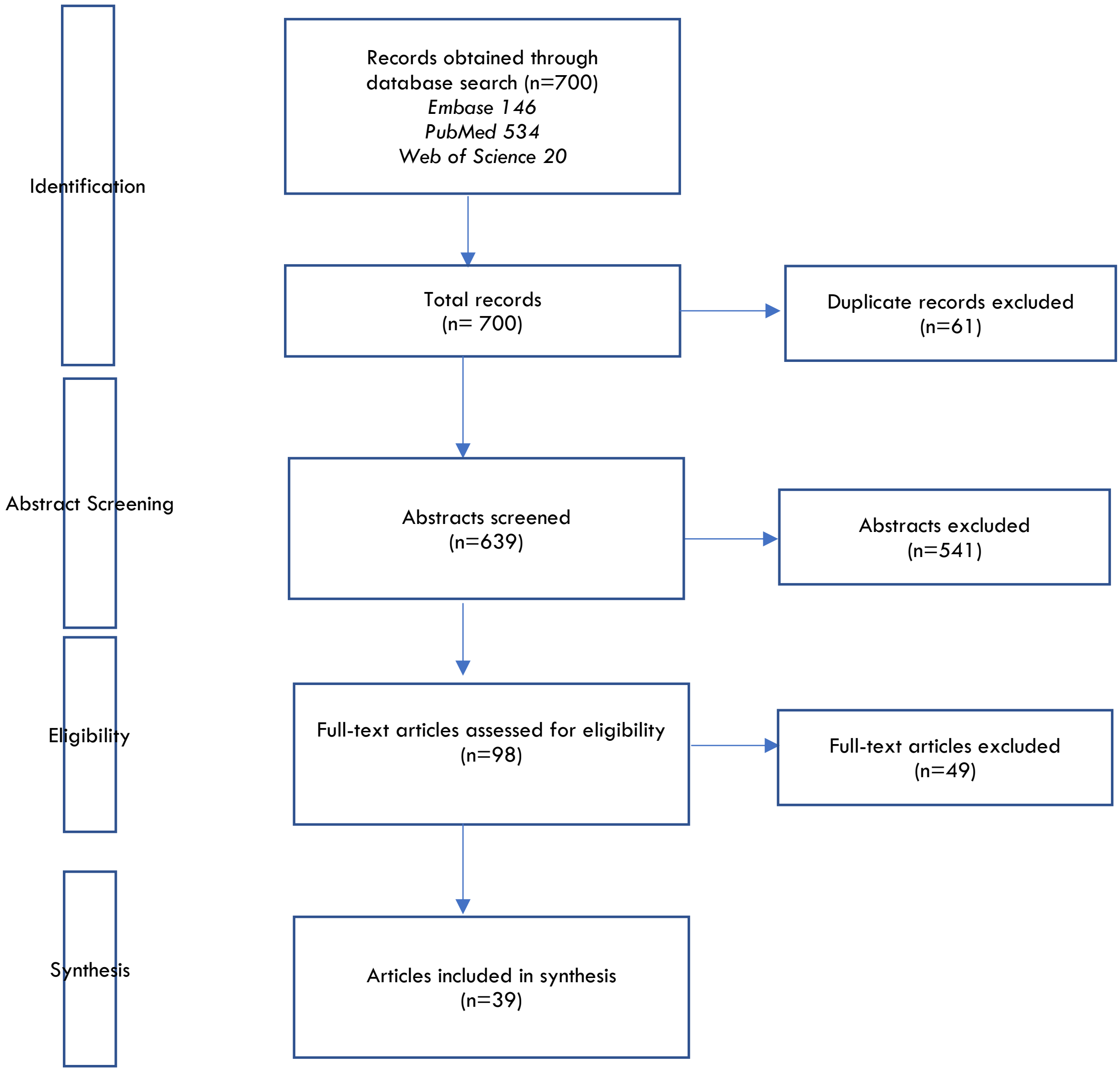

***Table 1** Overview of included studies*

First Author	Year	Location	Data	Study Design	Energy, data, health, decision-making
Mardani	2019	Varies	Varies (review)	Systematic review	Energy, Health, Decision-Making
Markandya	2009	More than 5 countries	Secondary	Cross- sectional	Energy, Health, Decision Making
Torres-Duque	2008	More than 5 countries	Secondary	Review in service of report	Energy, Health
Chen	2007	Shanghai, China	Secondary	Cross- sectional	Energy, Data, Health, Decision Making
Courtemanche	2011	United States	Secondary	Retrospective & prospective modeling	Energy, Health, Decision-Making
Lin	2019	More than 5 countries	Secondary	Retrospective & prospective modeling	Energy, Health, Decision-Making
Chio	2019	Taiwan	Secondary	Prospective modeling	Energy, Health, Decision-Making
Davis	1997	More than 5 countries	Secondary	cross- sectional	Energy, Data, Health, Decision Making
Dockery	2013	Ireland	Primary/secondary	Longitudinal cohort study/report	Energy, Health
Nanaki	2015	Greece	Secondary	Cost/benefit analysis and Total Cost of Ownership	Energy, Health, Data, Decision-Making
Xiao	2006	Hong Kong & China	Secondary	Comparative modeling and economic valuation	Energy, Health, Decision-Making
Kan	2012	China	Secondary	Systematic review	Energy, Health, Decision-Making
Staff Mestl	2007	China	Secondary	Exposure assessment	Energy, Health, Decision-Making
Kyu	2010	More than 5 countries	Secondary	Cross-sectional	Energy, Health, Decision-Making
Cai	2013	Beijing	Primary/secondary	Predictive modeling	Energy, Health, Decision-Making
Spitzer	1996	United States	Secondary	Comparative modeling	Energy, Health, Decision-Making
Partridge	2012	China	Secondary	Comparative modeling & comparative cost/benefit analysis	Energy, Health, Decision-Making
Hays	2016	More than 5 countries	Secondary	varying deisgns	Energy, Health
Li	2003	Shanghai, China	Secondary	Cross- sectional	Energy, Data, Health, Decision Making

Gohlke	2011	More than 5 countries	Secondary	Comparative predictive modeling	Energy, Health, Decision-Making
Aunat	1998	Hungary	Secondary	Cost/benefit analysis	Energy, Health, Decision-Making
De Salvo	2014	New Orleans, Louisiana, USA	primary	Cross-sectional	Data, Energy, Health, Decision Making
Chestnut	2005	United States	Secondary	Cost/benefit analysis	Energy, Health, Decision-Making
He	2017	China	Secondary	Panel data analysis	Energy, Health, Decision Making
Bell	2006	Mexico, Chile and Brazil	Secondary	Cross- sectional	Data, Energy,Health, Decision Making
Marcus	2017	California, USA	Secondary	Cohort study	Energy, Health, Decision Making
Sofiev	2018	More than 5 countries	Secondary	Comparative prospective modeling	Energy, Health, Decision-Making
Liu	2020	More than 5 countries	Secondary	panel data analysis	Data, Energy
Qomi	2016	Cambridge, USA	Secondary	Spatial analysis & modeling	Energy, Health, Data, Decision-Making
Scovronick	2016	São Paulo State, Brazil	Secondary	Comparative modeling	Energy, Health, Decision-Making
Perera	2019	More than 5 countries	Secondary	Case-control, cohort studies and meta–analyses	Energy, Health
Wang	2010	Taiwan	Secondary	Ecological study	Energy, Data, Health
Georges	2007	São Paulo, Brazil	Secondary	Mixed methods	Energy, Health, Decision Making
Bonjour	2013	More than 5 countries	Secondary	Cross- sectional	Energy, Data
Penn	2017	Continental US	Secondary	Modeling	Energy, Health, Decision-Making
Wu	2010	Taiwan	Secondary	Mixed methods	Data, Energy, Decision Making
Winebrake	2009	More than 5 countries	Secondary	Cross sectional	Energy, Health, Data, Decision Making
Xing	2019	More than 5 countries	Secondary	Cross sectional	Energy, Data, Health,
Guo	2018	Beijing-Tianjin-Hebei Region, China	Secondary	Prospective modeling	Energy, Health, Decision-Making

Appendix

Appendix 1 Search strategy for Embase, PubMed and Web of Science

Embase search strategy

1 April 2020

Search #	Query	Items Found
1	'machine learning':ti,ab,kw OR 'big data':ti,ab,kw OR 'data science':ti,ab,kw OR 'data sciences':ti,ab,kw OR 'data scientist':ti,ab,kw OR 'data scientists':ti,ab,kw OR 'data analytics':ti,ab,kw OR 'data analytic':ti,ab,kw OR 'data driven':ti,ab,kw OR 'datadriven':ti,ab,kw OR 'data mining':ti,ab,kw OR 'datamining':ti,ab,kw OR 'text mining':ti,ab,kw OR 'textmining':ti,ab,kw OR 'smart city':ti,ab,kw OR 'smart cities':ti,ab,kw OR 'data analysis':ti,ab,kw OR 'data analyses':ti,ab,kw	169,035
2	'policy':ti,ab,kw OR 'government':ti,ab,kw OR 'government programs':ti,ab,kw OR 'policy making':ti,ab,kw OR 'legislation as topic':ti,ab,kw OR 'decision making':ti,ab,kw OR legislation:ti,ab,kw OR jurisprudence:ti,ab,kw OR 'policy':ti,ab,kw OR 'policies':ti,ab,kw OR 'policymaker':ti,ab,kw OR 'policymakers':ti,ab,kw OR 'government':ti,ab,kw OR 'governments':ti,ab,kw OR 'legislation':ti,ab,kw OR 'legislative':ti,ab,kw OR 'decision making':ti,ab,kw OR 'making decisions':ti,ab,kw OR 'choice behavior':ti,ab,kw OR 'choice behaviour':ti,ab,kw OR 'choice behaviors':ti,ab,kw OR 'choice behaviours':ti,ab,kw OR 'decision process':ti,ab,kw OR 'decision processes':ti,ab,kw OR 'judgement':ti,ab,kw OR 'judgements':ti,ab,kw OR 'judgment':ti,ab,kw OR 'judgments':ti,ab,kw	676,208
3	'electric power supplies':ti,ab,kw OR 'energy-generating resources':ti,ab,kw OR 'fuel':ti,ab,kw OR 'fuels':ti,ab,kw OR 'oil':ti,ab,kw OR 'oils':ti,ab,kw OR 'coal':ti,ab,kw OR 'gas':ti,ab,kw OR 'petroleum':ti,ab,kw OR 'petroleums':ti,ab,kw OR 'nuclear':ti,ab,kw OR 'biofuel':ti,ab,kw OR 'biofuels':ti,ab,kw OR 'biogas':ti,ab,kw OR 'biodiesel':ti,ab,kw OR 'biodiesels':ti,ab,kw OR 'bioelectric':ti,ab,kw OR 'solar':ti,ab,kw OR 'electric plant':ti,ab,kw OR 'electric plants':ti,ab,kw OR 'power plant':ti,ab,kw OR 'power plants':ti,ab,kw OR 'electric power':ti,ab,kw OR 'nuclear power':ti,ab,kw OR 'atomic power':ti,ab,kw OR 'power supply':ti,ab,kw OR 'power supplies':ti,ab,kw OR 'power source':ti,ab,kw OR 'power sources':ti,ab,kw OR 'wind power':ti,ab,kw OR 'tidal power':ti,ab,kw OR 'hydropower':ti,ab,kw OR 'hydroelectric power':ti,ab,kw OR	1,204,395

	'thermoelectric power':ti,ab,kw OR 'biomass power':ti,ab,kw OR 'geothermal power':ti,ab,kw OR 'energy source':ti,ab,kw OR 'energy sources':ti,ab,kw OR 'sources of energy':ti,ab,kw OR 'sources of energies':ti,ab,kw OR 'source of energy':ti,ab,kw OR 'source of energies':ti,ab,kw OR 'energy generating':ti,ab,kw OR 'energy resource':ti,ab,kw OR 'energy resources':ti,ab,kw OR 'atomic energy':ti,ab,kw OR 'atomic energies':ti,ab,kw OR 'renewable energy':ti,ab,kw OR 'renewable energies':ti,ab,kw OR 'sustainable energy':ti,ab,kw OR 'sustainable energies':ti,ab,kw OR 'geothermal energy':ti,ab,kw OR 'geothermal energies':ti,ab,kw OR 'energy supply':ti,ab,kw OR 'energy supplies':ti,ab,kw OR 'supply of energy':ti,ab,kw OR 'supplies of energy':ti,ab,kw OR 'supply of energies':ti,ab,kw OR 'supplies of energies':ti,ab,kw OR 'biomass energy':ti,ab,kw OR 'biomass energies':ti,ab,kw OR 'hydroelectric energy':ti,ab,kw OR 'hydroelectirc energies':ti,ab,kw OR 'hydroenergy':ti,ab,kw OR 'hydroenergies':ti,ab,kw OR 'water energy':ti,ab,kw OR 'water energies':ti,ab,kw OR 'wind energy':ti,ab,kw OR 'wind energies':ti,ab,kw OR 'windmill energy':ti,ab,kw OR 'windmill energies':ti,ab,kw OR 'tidal energy':ti,ab,kw OR 'tidal energies':ti,ab,kw	
4	1 AND 2 AND 3	146

PubMed search strategy
April 1, 2020

Search #	Query	Items Found
1	(((("judgement"[tw] OR "judgements"[tw] OR "judgment"[tw] OR "judgments"[tw] OR "choice behavior"[tw] OR "choice behaviour"[tw] OR "Decision Making"[Mesh] OR "Decision making"[tw] OR "making decisions"[tw] OR "decision process"[tw] OR "decision processes"[tw] OR "Legislation as Topic"[Mesh] OR "legislation and jurisprudence"[Subheading] OR "legislation"[tw] OR "legislative"[tw] OR "Government"[Mesh] OR "Government Programs"[Mesh] OR "government"[tw] OR "governments"[tw] OR "Policy"[Mesh] OR "Policy Making"[Mesh] OR "Policy"[tw] OR "policies"[tw] OR "policymaker"[tw] OR "policymakers"[tw]))) AND (("health"[MeSH] OR "health status"[Mesh] OR "population health"[MesH] OR "health status"[tw] OR "population health"[tw]))) AND (((((((("fuel oils"[MesH] OR "fossil fuels"[MesH] OR "fuel oils"[tw] OR "fossil fuels"[tw]))) OR (("Electric Power	387

	Supplies"[MesH] OR "Electric Power Supply"[tw] OR "Power Supplies"[tw] OR "Electric Power Sources"[tw] OR "Power Sources"[tw]))) OR (("solar energy"[MesH] OR "Solar energies"[tw] OR "Solar Power"[tw]))) OR ((("power plants" [MesH] OR "Thermoelectric Power Plants" [tw] OR "Electric Power plants" [tw] OR "Hydroelectric Power Plants"[tw])))) OR (("renewable energy" [MesH] OR "Renewable Energies"[tw] OR "Sustainable¬†Energy"[tw]))) OR (("nuclear energy"[MesH] OR "Atomic Energy"[tw]))))) AND ("1900/01/01"[Date - Publication] : "2020/04/01"[Date - Publication])	
2	((("Power Plants"[Mesh] OR "Electric Power Supplies"[Mesh] OR "Energy-Generating Resources"[Mesh] OR “fuel”[tw] OR “fuels”[tw] OR “oil”[tw] OR “oils”[tw] OR “coal”[tw] OR “gas”[tw] OR “petroleum”[tw] OR “petroleums”[tw] OR “nuclear”[tw] OR “biofuel”[tw] OR “biofuels”[tw] OR “biogas”[tw] OR “biodiesel”[tw] OR “biodiesels”[tw] OR “bioelectric”[tw] OR “solar”[tw] OR “electric plant”[tw] OR “electric plants”[tw] OR “power plant”[tw] OR “power plants”[tw] OR “electric power”[tw] OR “nuclear power”[tw] OR “atomic power”[tw] OR “power supply”[tw] OR “power supplies”[tw] OR “power source”[tw] OR “power sources”[tw] OR “wind power”[tw] OR “tidal power”[tw] OR “hydropower”[tw] OR “hydroelectric power”[tw] OR “thermoelectric power”[tw] OR “biomass power”[tw] OR “geothermal power”[tw] OR “energy source”[tw] OR “energy sources”[tw] OR “sources of energy”[tw] OR “sources of energies”[tw] OR “source of energy”[tw] OR “source of energies”[tw] OR “energy generating”[tw] OR “energy resource”[tw] OR “energy resources”[tw] OR “atomic energy”[tw] OR “atomic energies”[tw] OR “renewable energy”[tw] OR “renewable energies”[tw] OR “sustainable energy”[tw] OR “sustainable energies”[tw] OR “geothermal energy”[tw] OR “geothermal energies”[tw] OR “energy supply”[tw] OR “energy supplies”[tw] OR “supply of energy”[tw] OR “supplies of energy”[tw] OR “supply of energies”[tw] OR “supplies of energies”[tw] OR “biomass energy”[tw] OR “biomass energies”[tw] OR “hydroelectric energy”[tw] OR “hydroelectirc energies”[tw] OR “hydroenergy”[tw] OR “hydroenergies”[tw] OR “water energy”[tw] OR “water energies”[tw] OR “wind energy”[tw] OR “wind energies”[tw] OR “windmill energy”[tw] OR “windmill energies”[tw] OR “tidal energy”[tw] OR “tidal energies”[tw]) AND ("Policy"[Mesh] OR "Government"[Mesh] OR "Government Programs"[Mesh] OR "Policy Making"[Mesh] OR "Legislation as Topic"[Mesh] OR "Decision Making"[Mesh] OR "legislation and jurisprudence" [Subheading] OR	147

	“Policy”[tw] OR “policies”[tw] OR “policymaker”[tw] OR “policymakers”[tw] OR “government”[tw] OR “governments”[tw] OR “legislation”[tw] OR “legislative”[tw] OR “decision making”[tw] OR “making decisions”[tw] OR “choice behavior”[tw] OR “choice behaviour”[tw] OR “choice behaviors”[tw] OR “choice behaviours”[tw] OR “decision process”[tw] OR “decision processes”[tw] OR “judgement”[tw] OR “judgements”[tw] OR “judgment”[tw] OR “judgments”[tw]) AND ("Big Data"[Mesh] OR "Data Science"[Mesh] OR "Data Mining"[Mesh] OR "Machine Learning"[Mesh] OR "big data"[tw] OR "data science"[tw] OR "data sciences"[tw] OR “data scientist”[tw] OR “data scientists”[tw] OR "data analytics"[tw] OR "data analytic"[tw] OR "data driven"[tw] or “datadriven”[tw] OR "data mining"[tw] OR "datamining"[tw] OR "text mining"[tw] OR “textmining”[tw] OR “smart city”[tw] OR “smart cities”[tw] OR “data analysis”[tw] OR “data analyses”[tw]))) AND ("1900/01/01"[Date - Publication] : "2020/04/01"[Date - Publication])	

Web of Science
April 1, 2020

Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI
Timespan=All years

Search #	Query	Items Found
1	TI=('Big Data' OR 'Data Science' OR 'Data Mining' OR 'Machine Learning' OR 'big data' OR 'data science' OR 'data sciences' OR 'data scientist' OR 'data scientists' OR 'data analytics' OR 'data analytic' OR 'data driven' OR 'datadriven' OR 'data mining' OR 'datamining' OR 'text mining' OR 'textmining' OR 'smart city' OR 'smart cities' OR 'data analysis' OR 'data analyses')	194,824
2	TI=('Policy' OR 'Government' OR 'Government Programs' OR 'Policy Making' OR 'Legislation as Topic' OR 'Decision Making' OR 'legislation and jurisprudence' OR 'Policy' OR 'policies' OR 'policymaker' OR 'policymakers' OR 'government' OR 'governments' OR 'legislation' OR 'legislative' OR 'decision making' OR 'making decisions' OR 'choice behavior' OR 'choice behaviour' OR 'choice behaviors' OR 'choice behaviours' OR 'decision process' OR 'decision processes' OR 'judgement' OR 'judgements' OR 'judgment' OR 'judgments')	497,216
3	TI=('Power Plants' OR 'Electric Power Supplies' OR 'Energy-Generating Resources' OR 'fuel' OR 'fuels' OR 'oil' OR 'oils' OR 'coal' OR 'gas' OR 'petroleum' OR 'petroleums' OR 'nuclear' OR 'biofuel' OR 'biofuels' OR 'biogas' OR 'biodiesel' OR 'biodiesels' OR 'bioelectric' OR 'solar' OR 'electric plant' OR 'electric plants' OR 'power plant' OR 'power plants' OR 'electric power' OR 'nuclear power' OR 'atomic power' OR 'power supply' OR 'power supplies' OR 'power source' OR 'power sources' OR 'wind power' OR 'tidal power' OR 'hydropower' OR 'hydroelectric power' OR 'thermoelectric power' OR 'biomass power' OR 'geothermal power' OR 'energy source' OR 'energy sources' OR 'sources of energy' OR 'sources of energies' OR 'source of energy' OR 'source of energies' OR 'energy generating' OR 'energy resource' OR 'energy resources' OR 'atomic energy' OR 'atomic energies' OR 'renewable energy' OR 'renewable energies' OR 'sustainable energy' OR 'sustainable energies' OR 'geothermal energy' OR 'geothermal	1,515,154

	energies' OR 'energy supply' OR 'energy supplies' OR 'supply of energy' OR 'supplies of energy' OR 'supply of energies' OR 'supplies of energies' OR 'biomass energy' OR 'biomass energies' OR 'hydroelectric energy' OR 'hydroelectirc energies' OR 'hydroenergy' OR 'hydroenergies' OR 'water energy' OR 'water energies' OR 'wind energy' OR 'wind energies' OR 'windmill energy' OR 'windmill energies' OR 'tidal energy' OR 'tidal energies')	
4	1 AND 2 AND 3	20

References

1. Smith KR, Frumkin H, Balakrishnan K, et al. Energy and Human Health. *Annual Review of Public Health.* 2013;34(1):159-188.
2. World Health Organization. *Energy: Shared interests in sustainable development and energy services.* Geneva: World Health Organization;2013.
3. United Nations. Sustainable Development Goals Overview. United Nations. https://unstats.un.org/sdgs/report/2019/overview/. Published 2020. Accessed 1/14/2021, 2020.
4. Diffenbaugh NS, Burke M. Global warming has increased global economic inequality. *Proceedings of the National Academy of Sciences.* 2019;116(20):9808-9813.
5. Watts N, Amann M, Arnell N, et al. The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. *The Lancet.* 2021;397(10269):129-170.
6. Khan U, Zhang Y. The global inequalities and climate change. *Environmental Science and Pollution Research.* 2021.
7. Rao ND, Min J. Less global inequality can improve climate outcomes. *WIREs Climate Change.* 2018;9(2):e513.
8. Jessel S, Sawyer S, Hernández D. Energy, Poverty, and Health in Climate Change: A Comprehensive Review of an Emerging Literature. *Front Public Health.* 2019;7:357-357.
9. Markkanen S, Anger-Kraavi A. Social impacts of climate change mitigation policies and their implications for inequality. *Climate Policy.* 2019;19(7):827-844.
10. Galea S, Abdalla SM, Sturchio JL. Social determinants of health, data science, and decision-making: Forging a transdisciplinary synthesis. *PLoS Med.* 2020;17(6):e1003174.
11. Coar JT, Sewell JP. Zotero: harnessing the power of a personal bibliographic manager. *Nurse Educ.* 2010;35(5):205-207.
12. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan—a web and mobile app for systematic reviews. *Systematic Reviews.* 2016;5(1):210.

13. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *International Journal of Research Methodology, Theory and Practice.* 2005;8( ):19-32.
14. Levac D, Colquhoun H, O'Brien K. Scoping studies: advancing the methodology. *Implement Sci.* 2010; :20:69.
15. Hsieh HF, Shannon SE. Three approaches to qualitative content analysis. *Qual Health Res.* 2005;15(9):1277-1288.
16. Sofiev M, Winebrake JJ, Johansson L, et al. Cleaner fuels for ships provide public health benefits with climate tradeoffs. *Nat Commun.* 2018;9(1):406.
17. Winebrake JJ, Corbett JJ, Green EH, Lauer A, Eyring V. Mitigating the Health Impacts of Pollution from Oceangoing Shipping: An Assessment of Low-Sulfur Fuel Mandates. *Environmental Science & Technology.* 2009;43(13):4776-4782.
18. Scovronick N, França D, Alonso M, et al. Air Quality and Health Impacts of Future Ethanol Production and Use in São Paulo State, Brazil. *Int J Environ Res Public Health.* 2016;13(7).
19. Spitzer HL. An analysis of the health benefits associated with the use of MTBE reformulated gasoline and oxygenated fuels in reducing atmospheric concentrations of selected volatile organic compounds. *Risk Anal.* 1997;17(6):683-691.
20. He L-Y, Yang S, Chang D. Oil Price Uncertainty, Transport Fuel Demand and Public Health. *International journal of environmental research and public health.* 2017;14(3):245.
21. Cai H, Xu M. Greenhouse gas implications of fleet electrification based on big data-informed individual travel patterns. *Environ Sci Technol.* 2013;47(16):9035-9043.
22. Nanaki EA, Xydis GA, Koroneos CJ. Electric vehicle deployment in urban areas. *Indoor and Built Environment.* 2016;25(7):1065-1074.
23. Chestnut LG, Mills DM. A fresh look at the benefits and costs of the US acid rain program. *Journal of Environmental Management.* 2005;77(3):252-266.
24. Lin CK, Lin RT, Chen T, Zigler C, Wei Y, Christiani DC. A global perspective on coal-fired power plants and burden of lung cancer. *Environ Health.* 2019;18(1):9.
25. Chio CP, Lo WC, Tsuang BJ, et al. Health impact assessment of PM(2.5) from a planned coal-fired power plant in Taiwan. *J Formos Med Assoc.* 2019;118(11):1494-1503.

26. Bonjour S, Adair-Rohani H, Wolf J, et al. Solid fuel use for household cooking: country and regional estimates for 1980-2010. *Environ Health Perspect.* 2013;121(7):784-790.

27. Kyu HH, Georgiades K, Boyle MH. Biofuel smoke and child anemia in 29 developing countries: a multilevel analysis. *Ann Epidemiol.* 2010;20(11):811-817.

28. Wu W-T, Tsai P-J, Yang Y-H, Yang C-Y, Cheng K-F, Wu T-N. Health impacts associated with the implementation of a national petrol-lead phase-out program (PLPOP): Evidence from Taiwan between 1981 and 2007. *Science of The Total Environment.* 2011;409(5):863-867.

29. Markandya A, Armstrong BG, Hales S, et al. Public health benefits of strategies to reduce greenhouse-gas emissions: low-carbon electricity generation. *The Lancet.* 2009;374(9706):2006-2015.

30. Xiao F, Brajer V, Mead RW. Blowing in the wind: the impact of China's Pearl River Delta on Hong Kong's air quality. *Sci Total Environ.* 2006;367(1):96-111.

31. Aunan K, Pátzay G, Asbjørn Aaheim H, Martin Seip H. Health and environmental benefits from air pollution reductions in Hungary. *Sci Total Environ.* 1998;212(2-3):245-268.

32. Guo X, Zhao L, Chen D, et al. Air quality improvement and health benefit of PM(2.5) reduction from the coal cap policy in the Beijing-Tianjin-Hebei (BTH) region, China. *Environ Sci Pollut Res Int.* 2018;25(32):32709-32720.

33. Courtemanche C. A silver lining? The connection between gasoline prices and obesity. *Econ Inq.* 2011;49(3):935-957.

34. Liu M, Ren X, Cheng C, Wang Z. The role of globalization in CO2 emissions: A semi-parametric panel data analysis for G7. *Science of The Total Environment.* 2020;718:137379.

35. Gohlke JM, Thomas R, Woodward A, et al. Estimating the global public health implications of electricity and coal consumption. *Environ Health Perspect.* 2011;119(6):821-826.

36. Torres-Duque C, Maldonado D, Pérez-Padilla R, Ezzati M, Viegi G. Biomass fuels and respiratory diseases: a review of the evidence. *Proc Am Thorac Soc.* 2008;5(5):577-590.

37. Marcus M. On the road to recovery: Gasoline content regulations and child health. *J Health Econ.* 2017;54:98-123.

38. Kan H, Chen R, Tong S. Ambient air pollution, climate change, and population health in China. *Environment International.* 2012;42:10-19.

39. Mbow C, Rosenzweig, C., Barioni LG., Benton, TG., Herrero, M., Krishnapillai, M., Liwenga, E., Pradhan, P., Rivera-Ferre, MG., Sapkota, T., Tubiello, FN., Xu, Y., . Food Security. In: *Climate Change and Land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* International Panel on Climate Change; 2019.

40. Li J, Guttikunda SK, Carmichael GR, Streets DG, Chang Y-S, Fung V. Quantifying the human health benefits of curbing air pollution in Shanghai. *Journal of Environmental Management.* 2004;70(1):49-62.

41. Roth GA, Abate D, Abate KH, et al. Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet.* 2018;392(10159):1736-1788.

42. Davis DL. Short-term improvements in public health from global-climate policies on fossil-fuel combustion: an interim report. *The Lancet.* 1997;350(9088):1341-1349.

43. United Nations. Big Data for Sustainable Development. United Nations. Global Issues Web site. https://www.un.org/en/global-issues/big-data-for-sustainable-development. Published 2021. Accessed 4/5/2021, 2021.

44. Snyder N. *UN Global Working Group on Big Data.* Washington DC: United Nations Economic Commission for Europe;2015.

45. DeSalvo K, Lurie N, Finne K, et al. Using Medicare data to identify individuals who are electricity dependent to improve disaster preparedness and response. *Am J Public Health.* 2014;104(7):1160-1164.

46. Abdolhosseini Qomi MJ, Noshadravan A, Sobstyl JM, et al. Data analytics for simplifying thermal efficiency planning in cities. *J R Soc Interface.* 2016;13(117).

47. Partridge I, Gamkhar S. A methodology for estimating health benefits of electricity generation using renewable technologies. *Environ Int.* 2012;39(1):103-110.

48. Penn SL, Arunachalam S, Woody M, Heiger-Bernays W, Tripodis Y, Levy JI. Estimating State-Specific Contributions to PM2.5- and O3-Related Health Burden from Residential Combustion and Electricity Generating Unit Emissions in the United States. *Environmental health perspectives.* 2017;125(3):324-332.
49. Xing X, Wang J, Liu T, Liu H, Zhu Y. How Energy Consumption and Pollutant Emissions Affect the Disparity of Public Health in Countries with High Fossil Energy Consumption. *International journal of environmental research and public health.* 2019;16(23):4678.
50. Dockery DW, Rich DQ, Goodman PG, et al. Effect of air pollution control on mortality and hospital admissions in Ireland. *Res Rep Health Eff Inst.* 2013(176):3-109.
51. Chen C, Chen B, Wang B, et al. Low-carbon energy policy and ambient air pollution in Shanghai, China: a health-based economic assessment. *Sci Total Environ.* 2007;373(1):13-21.
52. Mestl HE, Aunan K, Seip HM. Health benefits from reducing indoor air pollution from household solid fuel use in China--three abatement scenarios. *Environ Int.* 2007;33(6):831-840.
53. Wang S-I, Lee L-T, Zou M-L, Fan C-W, Yaung C-L. Pregnancy outcome of women in the vicinity of nuclear power plants in Taiwan. *Radiation and Environmental Biophysics.* 2010;49(1):57-65.