Analyse & Kritik 02/2014 (© Lucius & Lucius, Stuttgart) S. 315–343

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Climate Change, Energy Policy and Justice: A Systematic Review*

Abstract: Energy efficiency and energy security are emerging concerns in climate change policy. But there is little acknowledgment of energy justice issues. Marginalised and vulnerable communities may be disproportionately exposed to both climate change impacts (e.g. heat, flooding) and costs associated with energy transitions related to climate change mitigation and adaptation (e.g. particulate exposure from biofuel combustion). Climate change is producing energy-related impacts such as increased cooling costs. In some cases it threatens energy security. Higher electricity costs associated with 'climate proofing' energy network infrastructure may exacerbate 'fuel poverty'—itself a form of injustice. In this paper we critically review the literature about multiple interrelations between energy policy, justice and climate change. We identify key issues, illuminate knowledge gaps, and synthesise findings to develop a conceptual model. We chart a research agenda and highlight policy implications.

1. Introduction

Energy generation from fossil fuels is a major driver of anthropogenic climate change (Davis et al. 2010). The mining and combustion of fossil fuels such as coal, oil and shale gas produce a range of environmental impacts, including air pollution, groundwater contamination, and greenhouse gas pollution—the latter contributing to climate change (Jenner/Lamadrid 2013; Campbell et al. 2014). Climate change in turn produces environmental impacts such as increases in extreme weather events, flooding, coastal erosion, drought and heat-waves. These impacts have social consequences, including disease, death and economic disruption (Byrne et al. 2009). Some climate change impacts also involve complex feed-back loops (Hou et al. 2012). For example, climate change can increase average temperatures, resulting in more energy consumption for cooling, in turn driving more fossil fuel use, exacerbating climate change (Dale et al. 2011).

Effective climate change responses thus require both mitigation (reducing greenhouse gas production and sequestering carbon) and adaptation—e.g. preparing for future climate regimes. There is a spectrum of energy-related mitigation

* We gratefully acknowledge the assistance of the reviewers in helping to improve this paper. We are indebted to their patience and guidance. We are also grateful to the editors for their understanding in the delays we experienced. While every attempt has been made to ensure the manuscript is correct, any omissions, errors and inaccuracies, remain those of the authors.

strategies, including sequestering carbon, more efficient fossil fuel combustion (e.g. 'cleaner' coal), improving energy efficiency (thus reducing emissions), and transitioning to alternative energy sources (e.g. solar, wind, geothermal, biofuel and nuclear) (Mathiesen et al. 2011). Responding to less than effective international efforts to mitigate greenhouse gas pollution (i.e. carbon dioxide and methane), many nations have necessarily also focused on developing climate change adaptation strategies (Ford et al. 2011). Energy-related adaptation responses include upgrading network infrastructure to cope with higher energy demand and/or damage from natural hazards (e.g. fire and flood), moving energy infrastructure away from vulnerable locations (e.g. flood-prone land), storing oil to minimise disruption from supply failures, and developing 'smart-grids' that enable 'real time' re-routing of electricity and/or switching-off high-consumption appliances (Schaeffer et al. 2012).

While there are burgeoning separate literatures on climate change mitigation, climate change adaptation, and energy transitions, few researchers have considered the combined effects of climate change mitigation, adaptation, and energy policy. Moreover, the complex interconnections between energy, climate change and socio-ecological outcomes are poorly understood, and knowledge is scattered across a range of disciplines with little synthesis. Few researchers have assessed the consequences of these combined effects for marginalised and vulnerable communities (Klinsky et al. 2012; Bulkeley et al. 2014b). This poses problems for policy analysts and decision-makers concerned with redressing environmental inequalities associated with climate change and energy. Bickerstaff et al. (2013) have highlighted how climate change and energy generation produce spatially uneven impacts that are inequitably distributed among marginalised and vulnerable populations, driving what some have termed 'climate justice' and 'energy justice' imperatives to correct these inequalities (Walker/Day 2012).

Problems associated with the socially and spatially uneven distribution of environmental harms and benefits are collectively referred to as environmental inequalities. Environmental justice is an ethical approach aimed at redressing such issues. Arising from a social movement that began in the United States in the 1980s, environmental justice advocates espouse a type of 'civil rights environmentalism' (Bullard/Johnson 2000). The basic premise of environmental justice is that:

> "Everyone has the right to inhabit clean, healthy and safe environments, and to enjoy equal access to safe and healthy workplaces, schools, recreation areas and nutritious food, irrespective of race, ethnicity, gender, class, disability and other 'axes of difference'." (Byrne/MacCallum 2013, 165)

Impacts arising from environmental inequality include increased morbidity (disease) and mortality (death), diminished education and employment prospects, reduced quality of life, and impaired livelihoods (Wolch et al. 2014). The causes of environmental inequality are varied, but include intentional targeting, uneven law enforcement, the operation of land markets, biased-decision-making, and limited public consultation and participation (Steele et al. 2012; Byrne/MacCallum

2013). Many environmental justice problems are attributable to industrial pollution, waste (mis)management, food production, and water resource protection and management (Carruthers 2007; Schweitzer/Stephenson 2007). Although environmental justice activists and researchers have also recently become attentive to impacts stemming from energy generation and climate change, as separate issues (e.g. Adger 2001; Carruthers 2007; Barnett 2009; Wilson et al. 2010; Corner et al. 2011), little attention has been given to the combined environmental justice effects of energy generation and management, energy policy, and climate change (Walker/Day 2012).

The literature on energy and climate change has given substantially more attention to evaluating energy policies and strategies being developed in response to climate change (both mitigation and adaptation) than to examining potential environmental inequalities stemming from those policies. This paper addresses that knowledge gap. We begin by reviewing and assessing the emergent literature on energy, climate change and environmental (in)justice, illustrated with an example from an Australian perspective. Using a systematic quantitative literature review technique devised by Pickering and Byrne (2014), we analyse the key findings of the international literature to identify knowledge gaps. We then synthesise insights derived from the literature review to develop a conceptual model to explain some of the interrelationships that we have identified, and point to directions for future research.

Two primary research questions undergird this study: 'What energy policies and strategies are being developed in response to climate change?' and 'Are there any unintended environmental justice consequences stemming from those responses?'. As we show in this paper, much of the research has been focused on Europe, with less attention on North America and Asia and very little attention to continents such as Africa and Australia, where energy problems related to climate change are likely to be severe. Less attention has also been given to the scales of the body, household and neighbourhood, where many environmental justice consequences will manifest strongest. Considerable attention has been given to energy security and energy efficiency, but not to environmental justice issues around these topics, and scant research has examined vulnerability associated with race, ethnicity or household composition and family structure.

We recognise that nascent research has begun to address energy justice—a concept referring to "the [uneven] social and spatial distribution of energy poverty and [...] the justice dimensions of [...] energy systems" (Bickerstaff et al. 2013, 2). But there are broader environmental justice concerns relating to who suffers pollution from energy, sovereignty of Indigenous communities, displacement of harm, and imbricated sources of harm (e.g. food vs. fuel), that are yet to be fully considered. This has implications for future research, policy-making and for people's lives.

2. Background

The burning of fossil fuels has increased the concentration of greenhouse gases in the atmosphere leading to climate change and variability (Steffen et al. 2014, 17). Between 1951 and 2010 for example, there was an average global surface warming of 0.5°C–1.3°C (Intergovernmental Panel on Climate Change 2013, 20). The IPCC predict an increase in the average global surface temperature between 0.3°C and 0.7°C for the period 2016–2035, with temperature increases likely to exceed 1.5°C by the end of the 21st century (IPCC, 2013 20). These increases in average surface temperature are a major concern because they have the potential to shift global climate regimes and produce extreme temperatures, with implications for food security, water security, and energy demand and supply (Steffen et al. 2014, 17)—among other concerns.

The predicted impacts of climate change include: increased vector-borne disease, storm intensity and flooding, coastal erosion, prolonged drought, more frequent wildfires and extreme heatwaves (Byrne et al. 2009; Steffen et al. 2014). Heatwaves are an especially important environmental justice problem, with implications for climate change related energy policy. Climate change is making heatwaves more frequent and intense, heightening their 'impacts on people, property, communities and the environment' (Steffen et al. 2014, 20), which in turn is driving increased energy use for refrigeration and thermal comfort. While sociopolitically marginalised and vulnerable populations are increasingly disproportionately exposed to the impacts of heat, they also tend to lack the capacity to adapt to extreme heat.

Health impacts stemming from heatwaves include elevated core temperature, loss of concentration and coordination, dehydration, fatigue and lethargy, and death (Xiang et al. 2014, 93–4). These health impacts vary, depending on social vulnerability, with the people most affected being elderly, children, those with a pre-existing illness, overweight people, low-income households, outdoor workers and Indigenous communities (Cutter et al. 2006; Hughes/McMichael 2011). During an extreme heatwave, poor people, elderly, migrants, and young children are differentially affected. They have the least ability to cope because they have reduced access to cooling, may live in poorly-designed buildings (e.g. no insulation, little cross-ventilation), and have reduced personal mobility. Higher population densities and urban heat island effects can magnify heatwave impacts. Denser cities have less vegetation, elevated surface temperatures, and require more electricity to cool households (Steffen et al. 2014). Heatwaves can also impact built environments by damaging critical infrastructure, leading to cascading social impacts.

For example, many Australian cities are at risk of power blackouts and infrastructure failure during heatwaves (Loughnan et al. 2013). In January 2009, a heatwave in Victoria, Australia resulted in widespread power outages. Major disruptions occurred, including the failure of essential infrastructure such as water provision, sewage treatment and public transport (ABC News 2009) as well as the loss of refrigeration and air conditioning. Impacts were strongest felt by disadvantaged communities and older people (Loughnan et al. 2010; Tong et

al. 2014). In Sydney in 2011, a severe heatwave resulted in 13% higher rate of mortality, mostly among the elderly (Schaffer et al. 2012). A more recent multi-day heatwave in January 2014 affected state-wide areas of southeast Australia, surpassing the 2009 record, with the average maximum temperature in Victoria exceeding 41°C on four successive days (Australian Government 2014). Yet heatwaves remain an underdeveloped area of research in energy policy, climate change adaptation, and environmental justice (Maller/Strengers 2011). Much of the research has tended instead to focus on fuel poverty and extreme cold (Huynen et al. 2001; Hajat et al. 2007; Ma et al. 2013), leaving important knowledge gaps.

3. Methods

The research reported in this paper has employed a methodology devised by Pickering and Byrne (2014). This method has proven to be robust and reliable across a range of topics in the social and natural sciences (e.g. Steven et al. 2011; Guitart et al. 2012; Roy et al. 2012). We have sought to answer two interrelated research questions, using this approach: 'What energy strategies are being developed in response to climate change?' and 'Are there any unintended environmental justice consequences of these strategies?'. To answer these questions, we systematically reviewed the literature, assessing: (i) who conducted the research; (ii) when; (iii) the geographic distribution of the research; (iv) the types of methods used; (v) the types of subjects and variables examined; and (vi) the patterns or relationships found in the research. Scholarly databases were searched between 8th August and 12th September 2014. The databases used included Google Scholar, Science Direct, ProQuest Central, Web of Science, SAGE Publications and Taylor & Francis Social Science and Humanities Library.

Keywords searched initially were 'climate change' and 'energy' in combination with 'environmental justice', 'social vulnerability' and/or 'public health'. There were however, some difficulties with the broad definition of 'energy', which required narrowing the scope. This was achieved by searching additional databases, and by pairing the word 'climate change' with various energy-related terminology such as 'energy security', 'energy policy', 'energy demand', 'energy justice', 'climate justice', 'energy efficiency', 'alternative energy', 'fuel poverty' or 'energy poverty'. Papers examined were limited to original peer-reviewed articles reporting the results of empirical research. While we examined books, book chapters, literature reviews and government publications, to gain a background understanding of the topic, they were not included in the systematic review.

Data about each article was entered into a customised database that included the author, date, title, journal and location of research for each paper we assessed. In addition, the database also contained information about: the methods used (qualitative or quantitative); the topic(s) of the research (and whether they are described or demonstrated); the response measured; and the results obtained. After the preliminary database was constructed, the first 10 papers were entered and the database was evaluated for its utility. This process enabled identifica-

tion of missing criteria, and checking of the database for coverage, scope and appropriateness. Categories were tested and revised, the database was modified, and then the bulk of the papers were entered. Following this, summary tables were produced and analysed (Pickering/Byrne 2014).

4. Results

We found twenty-two (22) peer-reviewed articles about energy strategies and climate change, which at a minimum touched on environmental justice consequences. Reflecting the nascent character of this research topic, over half of these articles (55%) were published between 2012 and 2014 (*appendix 1*). When considering the contributing factors potentially underpinning the environmental justice consequences of energy strategies, that is, spatial factors, social factors and biophysical factors, it is possible to discern temporal, spatial and conceptual trends within the literature. Patterns are also evident, based on: the geographic distribution of the research, disciplines involved, methods used by researchers, recognition of potential climate change impacts, and how vulnerability has been framed. And we can see trends related to how researchers have addressed core foci of energy policy responses to climate change, that is: (i) governance considerations, (ii) spatial planning strategies, and (iii) socio-economic outcomes. We examine these in turn.

4.1 Geographical Scope of the Research

The research has primarily been focused on Europe (50%), with fewer studies from Asia (27%) and North America (27%). There has been limited research within South America (two papers), and Africa, Australia, and New Zealand (one paper each), while three papers have examined energy strategies across multiple countries (Bulkeley et al. 2014; Chakravarty/Tavoni 2013; Urge-Vorsatz/Metz 2009). Some scalar patterns are also evident. Research was predominantly directed at the national scale (68% of papers), with the remaining papers focussed either globally (14%) or at the city scale (18%). There were no articles discussing energy strategies and their environmental justice consequences at other scales, such as the body, household, neighbourhood or region.

4.2 Disciplines Involved in the Research

The journals publishing papers on this topic were reasonably diverse. Broad disciplinary fields involved in the research included: energy (15 papers), policy (7 papers), science and environment (6 papers), built environments and engineering (4 papers), sustainability (2 papers) and economics (2 papers). Surprisingly, no articles were published from urban studies disciplines (Figure 1). An overlap between energy and policy disciplines was identified. Papers were frequently published in the journal Energy Policy (27%).

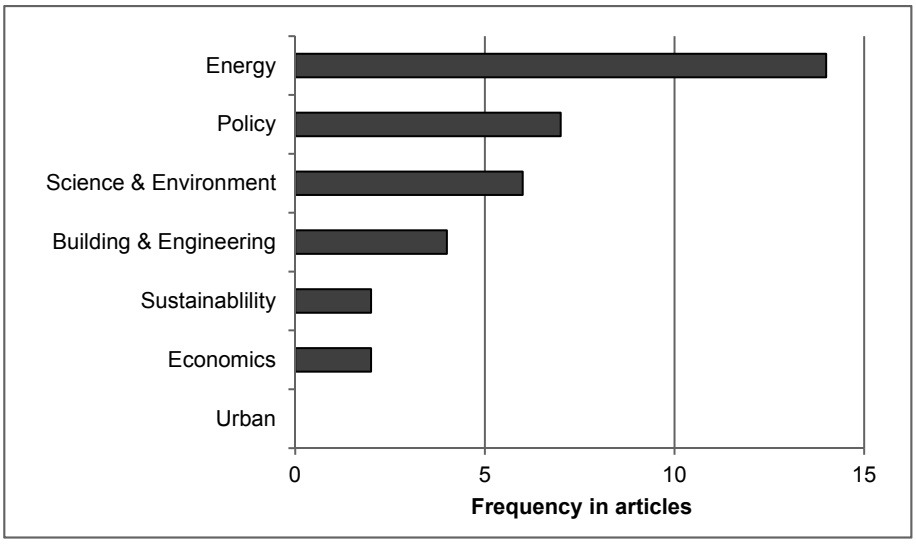

Figure 1: Distribution of articles by broad discipline area

Methods used in the research

Researchers examining this topic used a variety of research methods, although some methods were favoured over others, perhaps reflecting the scale of the research. Quantitative methods (13 papers) were favoured over qualitative methods (6), with only a few studies using mixed methods. Most studies employed various types of modelling (10 papers), followed by document analysis (6) and interviews (4). Less common were surveys (3), case studies (3), observations (3) and census analysis (2). Meta-analysis and field research were only used on one occasion, and focus groups were not used by any studies.

When the scale of the research is considered, some patterns are more salient. Census analysis and meta-analysis were only employed by researchers examining issues at the national scale. Document analysis (83%), interviews (75%) and surveys (67%) were also primarily undertaken by researchers investigating the issue predominantly at this scale, albeit with some studies using these methods at the city scale. Case studies and observations were split among research at the national and city scales, whereas studies employing modelling were tran-scalar (Figure 2). These patterns show that there is considerable scope for innovative research at more localised scales, which has yet to occur.

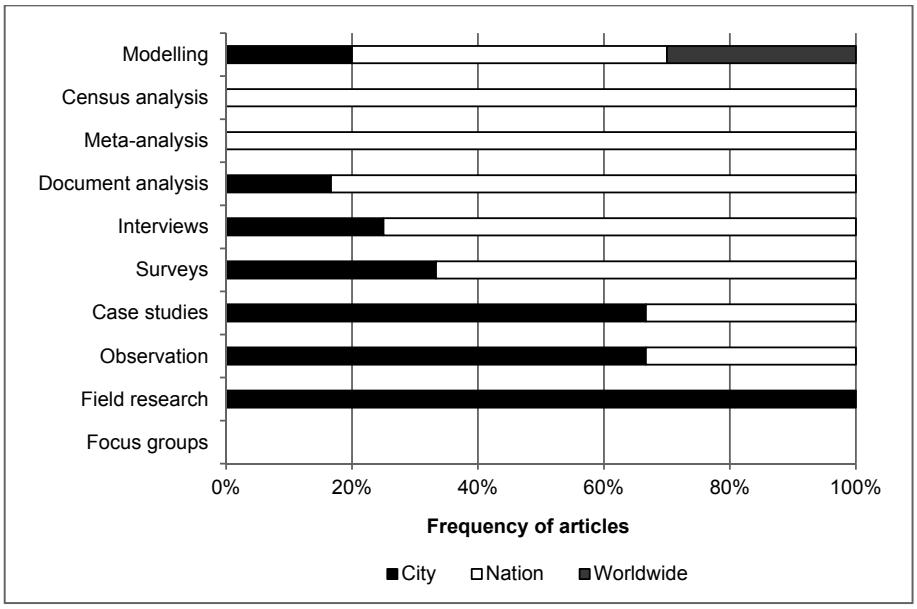

Figure 2: Methods used in the research

4.3 Climate Change Impacts

All the papers we analysed identified and discussed climate change impacts, but only three of those papers defined what was meant by impacts and not surprisingly, just three demonstrated that actual impacts were occurring (Ürge-Vorsatz/Metz 2009; Bang 2010; Wang et al. 2010). Three main climate change impacts identified in the literature were increased temperature (50%), extreme heatwaves (27%), and extreme weather events such as cyclones and thunderstorms (23%).

Articles reported that impacts vary considerably, depending on geographical scale. The literature suggests that cities are predominantly exposed to impacts from heightened storm intensity (67%), changes in rainfall (50%), extreme weather events (40%), and extreme heatwaves (33%). At the national scale, increased temperature was the most frequent impact identified, followed by extreme heatwaves, increased flooding and storm surge, and extreme weather events. In all papers assessed, the spread of vector-borne diseases and sea level rise were only reported as city-scale impacts, whereas prolonged drought and damage to ecosystems were identified as national impacts. No articles identified coastal erosion and wildfires as likely impacts (*table 1*).

Impact	City	Nation	Worldwide
Increased temperature	1	7	3
Heightened storm intensity	2	1	
Changes in rainfall	2	2	
Extreme weather events	2	3	
Extreme heatwaves	2	4	
Prolonged drought		1	
Increased flooding and storm surges		3	
Disruption/damage of ecosystems		2	
Spread of vector-borne diseases	1		
Sea level rise	1		
Severe coastal erosion			
Frequent wildfires			

Table 1: Geographical scale of climate change impacts

Insofar as policy responses are concerned, mitigation was identified by just over half of the articles (59%), followed by both mitigation and adaption (23%), and adaptation alone (9%). Several articles did not identify any policy response (9%). Interestingly, the two articles discussing adaptation also discussed peak demand for electricity, which was demonstrated by both those studies.

4.4 Social Vulnerability Assessment

Many articles addressed the issue of social vulnerability in the context of energy transitions related to climate change. The most frequently identified form of vulnerability related to geographic location (11 papers), followed by age, housing condition, employment status, and type (7 papers each) and socioeconomic status (5 papers). Articles equally recognized sex, health status, and housing tenure as important forms of vulnerability (3 papers each). However, few papers identified ethno-racial background and family structure as indicators of vulnerability. Contrary to our expectations, and to emerging research (Dale et al. 2011), there were no articles addressing land use as a potential determinant of vulnerability (*figure* 3).

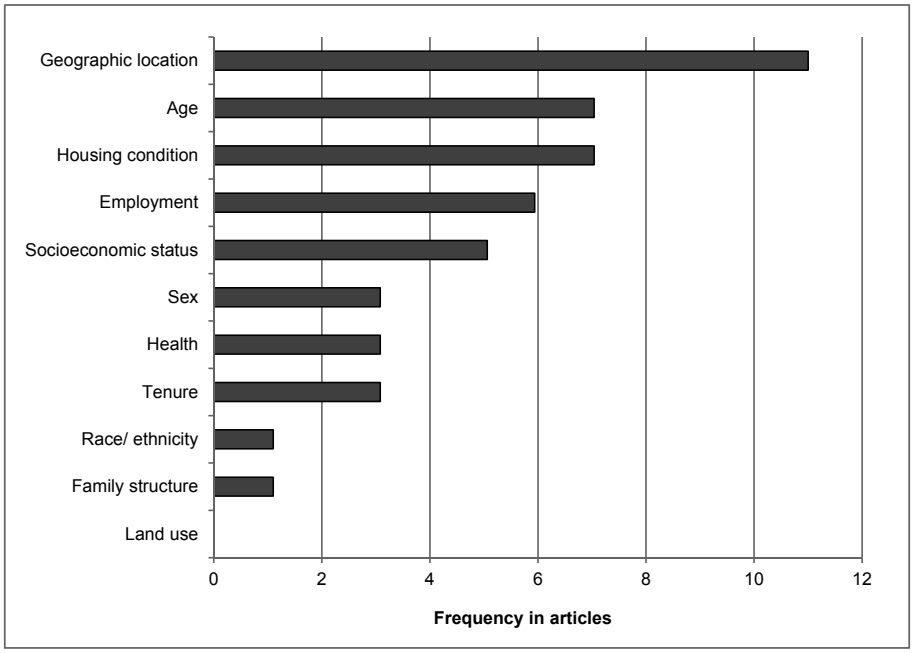

Figure 3: Framing of social vulnerability

In the remainder of the results, we turn our attention to reporting on key issues within the research that are related to energy policy decision-making in response to climate change. As we suggest in our conceptual model (at the end of the paper), these issues cluster within three broad policy foci: (i) governance, (ii) spatial planning responses, and (iii) socio-economic concerns. In reporting the results, we distinguish between instances where researchers simply discussed an issue and those instances where an empirical study actually demonstrated that the issue was occurring. For example, many articles discussed energy security, but far fewer defined what this term meant, and just four papers demonstrated that energy security was a problem. This is a concern, which we return to in the discussion section.

4.4.1 Governance

Governance is a term referring to 'the process of governing' (Bulkeley et al. 2014a). For those papers assessing governance issues related to energy and climate change, we have identified four issues that are most relevant - energy security, energy policy, energy demand and energy supply.

(i) Energy security

Energy security refers to how energy services are provided to end-users in a reliable way. Brown et al. (2003, 7) define energy security as a 'resilient energy system' which can supply secure and affordable energy. Specifically, energy security refers to: "unimpeded access or no planned interruptions to sources of energy, not relying on a limited number of energy sources, not being tied to a particular geographic region for energy sources, abundant energy resources, an energy supply which can withstand external shocks, and/or some form of energy self-sufficiency" (Chester 2010, 887).

Over half of the articles (55%) addressed energy security, but only two defined what was meant by this term, and just four papers demonstrated energy security was a problem (*table 2*). Many energy security articles also discussed energy policy (11 papers), which was predominantly focused at the national level, and directed towards climate change mitigation. Energy security papers also addressed energy efficiency and energy demand. And some papers mentioned alternative energy, fuel poverty, and energy poverty. Just one article mentioned environmental justice (Ürge-Vorsatz/Metz 2009), and no articles mentioned energy justice and climate justice. These results show how environmental justice is a neglected concern in energy policy, a point we return to in the discussion.

Eight papers discussing energy security highlighted a major economic risk associated with climate change—dependency on imported energy resources—as a key concern for governance. For example, many economies depend upon imported oil and natural gas. If pipelines rupture due to climate change impacts such as flooding or landslides, or shipping is disrupted due to a major storm event, critical services such as transportation, food delivery, and health services would be profoundly disrupted, resulting in cascading impacts. The Brisbane Floods in 2011 illustrate the vulnerability of cities to imported energy resources. The floods crippled petroleum refining, electricity supply and transport in Queensland; some cities were just days away from catastrophic failures in essential services (Butler 2011).

Insofar as adaptation is concerned, five articles discussed fossil fuel dependency, and just three discussed issues associated with switching to renewable energy. Some articles also identified energy independence (5), securing access to energy (3), and social resilience (2) as strategies to address energy security concerns. Just two articles demonstrated how a combined policy agenda addressing climate change, air pollution, and energy security policies might enable countries to both reduce dependency on fossil fuel imports and future energy demand while mitigating some health impacts associated with air pollution (Bollen et al. 2010; van Vliet et al. 2012).

Studied aspect	Number of papers	Percent of papers
Climate Change	22	100%
Energy Efficiency	19	86%
Energy Policy	16	73%
Energy Demand	15	68%
Alternative Energy	13	59%
Energy Security	12	55%
Public Health	10	45%
Energy Poverty	6	27%
Fuel Poverty	5	23%
Peak Demand	3	14%
Environmental Justice	3	14%
Climate Justice	2	9%
Energy Justice	1	5%

Table 2: Studied aspects in papers on energy strategies to address climate change

(ii) Energy policy

Energy policy is a term referring to official statements of intent about how an organisation will act, which are enshrined in organisational planning and management documents (Jacobsson/Lauber 2006). Almost three quarters of the articles (73%) discussed energy policy implications arising from climate change, but just five papers demonstrated energy policy issues. Most articles were focused on the national level of policy-making and implementation (13 papers), followed by international, state, and local.

Although we can see that attention is being given to high-level policy responses, the converse is not occurring. Few studies have addressed the repercussions of energy policy for individuals and households. There is a 'disconnect' between how policy responses are framed and how climate change impacts will likely be felt. Peak demand is an example. Policy responses aimed at reducing the vulnerability of network infrastructure to climate change impacts (e.g. ice storms, fire and flood), may paradoxically drive up the risk of fuel poverty for many households because cost-recovery for infrastructure investment typically drives up electricity prices.

(iii) Energy demand

The term energy demand refers to the existing and future requirements of end consumers for energy (Pindyck 1979). A high proportion of articles discussed (68%) and demonstrated (32%) energy demand impacts in the research they reported (*table 2*). As would be expected, most of these papers also discussed energy efficiency (14 papers). In all cases, multiple energy efficiency strategies were suggested. The most frequently reported strategy was adopting new tools, technologies and policies (11 papers), followed by implementing new building designs, and upgrading and retrofitting existing buildings, and establishing building performance/efficiency standards. Most articles predicted a decrease in heating demand associated with climate change impacts, and an increase in cooling demand. Articles examining an increasing demand for cooling focused on two climate change impacts—increased temperature and extreme heatwaves.

An important aspect of energy demand associated with climate change is 'peak demand'. Peak demand is that time of the day when the demand for energy peaks, and in many cases may exceed local supply capacity (Powells et al. 2014). While climate change may exacerbate problems associated with peak demand, due to increased temperature, just three articles addressed peak demand, and only two papers demonstrated a peak-demand impact. Research was focused on North America and Australia. Contrary to our expectations, no papers addressing peak demand discussed energy justice, climate justice, energy poverty, environmental justice, or alternative energy.

(iv) Energy supply

Energy supply is defined as the mix of resources that are used to produce energy and how that energy is delivered to end-users (Armaroli/Balzani 2007). There was a limited discussion of energy supply. Articles reported a variety of renewable and non-renewable energy sources to address climate change mitigation. The two most frequently examined forms of non-renewable energy were coal and oil (9 papers), whereas bioenergy was the most frequently reported renewable energy source (5 papers). Within those articles addressing nuclear power (5 papers), there was a consensus that the benefits of improved energy efficiency and energy security from nuclear power must be balanced against high construction costs and long construction times (Bang 2010; Goldthau/Sovacool 2012). Yet there was no discussion of radioactive waste management or the potential environmental justice consequences stemming from the use of nuclear energy (Leonard III 1996; Fan 2006).

4.4.2 Spatial Planning Strategies

Effective spatial planning strategies are important for the delivery of energy in an era of climate change, for resolving energy-related conflicts, and for ensuring equitable outcomes in both energy supply and climate change response (both mitigation and adaptation) (Steele et al. 2012). Although we would expect that spatial planning strategies would address the justice dimensions of both climate change and energy transitions, there was a very limited discussion of justice in

the literature on spatial planning and energy. Given the international focus on mitigation and the role that energy efficiency is expected to play in reducing carbon emissions, it was also surprising few articles addressed energy efficiency. And the role of energy transitions also received less attention than we expected.

(i) Climate justice

Climate justice refers to a social outcome where climate change impacts and the responsibility for mitigating and adapting to climate change are equitable. Equity here can refer to distributional equity (e.g. north-south obligations), and to intra-and inter-generational equity. Equity will occur when there is a fair distribution of costs involved in alleviating harm to fundamental human interests caused by climate change (Duus-Otterstrom/Jagers 2012, 747). Key considerations include energy generation costs (e.g. carbon pollution), access to energy (e.g. fuel poverty) and the potentially regressive effects of energy policy (energy poverty).

Only two articles examined climate justice (*table 2*). These papers identified social vulnerability due to climate change and energy policy as manifesting strongest within developing countries and low-income households. Other vulnerable populations identified included the working poor and children. Climate vulnerability was partly attributed to building condition, and studies recognised that there were potential public health consequences from energy policy and climate change, including infectious disease, respiratory disease, and cardiovascular disease.

(ii) Energy efficiency

Energy efficiency refers to: "using less energy to produce the same amount of services or useful output" (Patterson 1996, 377). More articles discussed energy efficiency (86%) as a strategy to address climate change impacts on energy than other forms of climate response (*table 2*). Energy efficiency was typically reported as a climate change mitigation initiative. Oddly, none of those papers defined the term, and only five papers demonstrated that energy efficiency was being achieved. Of these papers, most addressed energy strategies focused on renewable energy, predominantly solar, wind, and hydropower. Articles identified three strategies to bolster energy efficiency: adopting new tools, technologies and policies; improving building design via upgrades and retrofitting; and improving building performance through efficiency standards (*table 3*). However, there was little recognition that disparities in energy efficiency are a justice issue. Low-income earners are less likely to afford to upgrade to new energy efficient appliances or to live in newer more energy efficient accommodation (Head 2012; Instone et al. 2013), exacerbating fuel poverty.

Strategy objectives	**Frequency in papers**
Energy Efficiency	
Adopting new tools, technologies and policies	16
Implementing building design via upgrades and retrofitting	10
Establishing building performance/ efficiency standards	6
Installing energy efficient appliances/ equipment	5
Increasing operating efficiencies of vehicles	4
Standardising indoor temperatures	2
Alternative Energy	
Adopting renewable energy technologies	12
Promoting renewable energy diversity/mix	5
Shifting to carbon sequestration/ carbon capture and storage	3
Establishing renewable electricity standards	1
Improving access / availability of renewable energy	1

Table 3: Strategy objectives to address energy efficiency and alternative energy

(iii) Energy transitions

A range of potential environmental justice impacts may occur as countries transition their energy supplies away from fossil fuels into renewable energy sources. Over half the reviewed papers addressed energy transitions (13 papers), but only four articles demonstrated that environmental justice issues were emerging from energy transitions related to climate change. Energy policy issues related to energy transitions were frequently discussed, with an emphasis on national and international policies. Only two articles discussed climate justice and environmental justice, highlighting public health issues (*table 3*).

4.4.3 Socio-economic Concerns

There are a wide range of socio-economic issues related to energy policy for climate change mitigation and adaptation. As discussed elsewhere in this paper, climate change is producing impacts that will potentially create socio-economic disparities, such as disrupting livelihoods, education and wellbeing. We address three core issues that are salient within the literature: fuel poverty, energy poverty and health impacts.

(i) Fuel poverty

Fuel poverty refers to the inability of an individual or household to access sufficient energy services required to secure healthy environments and thermal comfort (Moore 2012, 20–21). There is consensus within the literature that fuel poverty occurs when a person spends more than 10% of their income on all fuel use and to heat their household to a satisfactory standard of warmth (Howden-Chapman et al. 2012; Thomson/Snell 2013). Nearly a quarter of papers (23%) discussed fuel poverty as an important socio-economic concern to be addressed by energy strategies. Four of those articles defined fuel poverty, but their definitions were inconsistent. Strong associations were made between fuel poverty and energy policy. Articles highlighted a range of social vulnerability indicators linked to fuel poverty, including: housing design, socioeconomic status, age and tenure. Energy efficiency measures to combat fuel poverty were discussed, including adopting new policies directed at building design, such as upgrades and retrofitting. One paper suggested that fuel poor households could achieve an 80 to 90% reduction in energy use by retrofitting conventional buildings with passive technology (Tirado Herrero/Ürge-Vorsatz 2012). As pointed out above this is unrealistic because these households are already financially constrained and retrofitting can be prohibitively expensive.

(ii) Energy poverty

Energy poverty is defined as a lack of reliable access to energy for heating, cooling, cooking and transportation, denying opportunities for customs, activities, livelihoods and lifestyles (Buzar 2007, 225). Over one quarter of the articles discussed energy poverty as a justice concern (e.g. Ürge-Vorsatz/Metz 2009; Wang et al. 2010; Howden-Chapman et al. 2012; Bulkeley et al. 2014b). Chakravarty and Tavoni (2013) argue that energy policies directed at climate change should address the complex interrelationships between energy demand and energy poverty. For instance, heat-waves have both energy and health impacts.

(iii) Health impacts

A health impact can be defined as a long-term effect on human health, resulting in disease or death. Almost half the papers (45%) identified public health impacts stemming from climate change impacts, including prolonged drought, extreme heatwaves, heightened storm intensity, and increased flooding. Where reported, health impacts were found to be most prevalent in developed countries. The most common illnesses reported were infectious diseases (associated with changes in temperature and flooding and vectors such as mosquitos), respiratory diseases (associated with mould from flooding) and cardiovascular diseases (associated with extreme temperatures). Few papers reported health issues associated with energy transitions.

4.4.4 Discussion

We opened this paper by highlighting lacunae in the energy policy and climate change literature with regard to environmental justice impacts and outcomes. The literature on energy and climate change has directed more effort to evaluating energy policies and strategies being developed in response to climate change (both mitigation and adaptation) than to examining the potential justice consequences stemming from those policies. This paper has sought to address that knowledge gap.

We found some unexpected results in our review of the literature. These results pertain to: the location and scale of the research, disciplines involved in the research, methods employed, assessment of vulnerability and determinants of vulnerability, and attention to issues of justice and equity.

Location and scale: It is surprising that research was focused predominantly on Europe with some attention given to Asia and North America. Many studies suggest that as global temperatures rise, fuel poverty in relation to heating will become less of an issue. But few studies have acknowledged that the converse is not the case. As temperatures rise in countries with hot climates, fuel poverty will likely result in increases in disease and death associated with the inability to keep cool. Ethno-racially and socio-economically marginalised and vulnerable communities may bear the brunt of these impacts.

Existing research has also been biased by scale. Much of the research has focused upon the national level, with less attention given to cities, and little consideration of scales such as the body, household, neighbourhood or region. Because energy supply and demand fluctuate locally, it might be reasonably expected that cities and regions would feature prominently in the research. And since climate change impacts manifest viscerally at a human scale, we might expect to see studies directed towards the body, household and/or neighbourhood. While health certainly is a national-scale policy issue, what is missing from much of the current research is attention to how health impacts stemming from climate change and energy policy are socio-spatially differentiated. Climate change will hit some cities and some parts of cities harder than others, and we need to recognise inequitable impacts on vulnerable populations in future research. The ways that heat-waves harm residents living in high-density areas with scant green-space is a case in point (Roy et al. 2012).

Methods: Much of the research has employed modelling of energy demand related to climate change and to a lesser extent modelling the vulnerability of core infrastructure to events such as fire or flood, likely due to the dominance of scholars from disciplines such as economics. Although climate change impacts will manifest strongly at the city scale, no studies were found from urban studies disciplines, which often favour different methods such as surveys, focus groups and interviews. Those methods can illuminate the material experiences of real people. Future research would do well to shift scales (e.g. to the body, household, and neighbourhood) and adopt methods better suited to answering questions at those scales (Schweitzer/Stephenson 2007).

Determinants of vulnerability: Many studies reported that vulnerability to climate change impacts and energy policy adjustments was manifest through

locational disadvantage. Although it is true that some places will be hit harder than others, more attention needs to be given to the poly-valent character of mobility. Residents of places such as caravan parks on flood-prone land, or of older dwellings not compliant with new building codes (e.g. for higher intensity storm events), are often socio-economically marginalised and vulnerable. They may be new migrants, may have young children, may be older, or may have a disability. If climate change impacts manifest differentially upon areas of concentrated poverty and vulnerability, where people have less ability to adapt or escape, then environmental inequalities will occur—as we saw when Hurricane Katrina devastated New Orleans (Elliott/Pais 2006). Wealthier residents of hotter houses can simply turn up the air-conditioning. But this luxury may not be available to households experiencing fuel poverty. Future research needs to assess how multiple axes of difference, such as ethno-racial composition, household structure, or age may predict vulnerability to both climate change and energy transitions associated with mitigation and adaptation.

Health impacts: Finally, studies have tended to overlook some of the health issues associated with climate change and energy policy. Respiratory illness, vector-borne disease and health-effects associated with heatwaves are gaining attention. But there are also mental health impacts associated with climate change, especially for households experiencing fuel and energy poverty. And there may be secondary impacts. Are obese people more vulnerable to heatwaves? Could policy-driven transitions to solar, biofuel and wind energy have unintended health impacts such as exposure to carcinogenic chemicals (from photovoltaic panel production) or increases in asthma (from combustion of biofuels)? We presently lack the research necessary to answer these questions. To chart a way forward, we have synthesised the results of this review into a conceptual model, which seeks to illustrate the interrelationships between the relevant topics and to point to new research directions.

5. Climate Change, Energy and Justice: A Conceptual Model

The literature suggests that biophysical, socio-economic, and spatial factors potentially contribute to environmental inequalities associated with energy policy responses to climate change (both mitigation and adaptation). Many of these factors may be interconnected but there has been limited research investigating their interplay, or to their manifestation across different scales (i.e. the body to the globe). We offer a conceptual model that depicts how environmental inequalities may result from energy transitions associated with climate change mitigation and adaptation (*figure 4*). Three dimensions warrant closer scrutiny—governance, spatial planning and socio-economic issues.

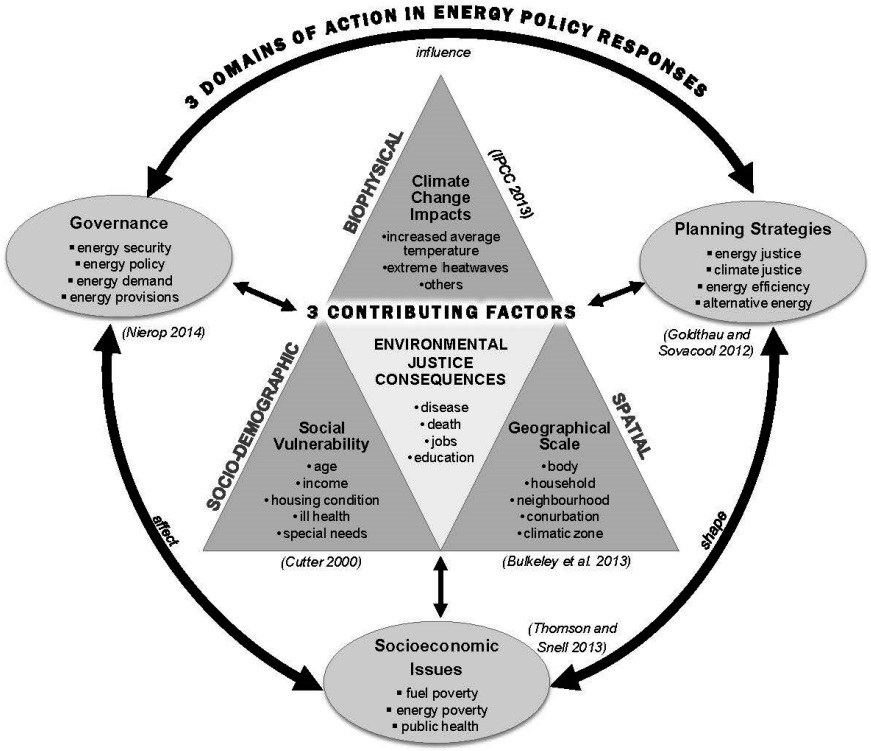

Figure 4: Conceptual model illustrating domains of action in energy policy responses to climate change and their interconnections with factors contributing to environmental (in)justice

Dimension 1—Governance

Within the governance domain, energy security is managed; energy demand is monitored and predicted; and energy policies are implemented or revised. Energy security is an example of how climate change policy decisions can impact marginalised and vulnerable people, through market-based models of service delivery, via the uneven distribution of energy resources, or due to problems with aging infrastructure (Goldthau/Sovacool 2012). Maintaining energy security in an age of climate change is vitally important because it affects multiple social sectors such as telecommunications, health and transit (Nierop 2014). Climate change has the potential to cripple existing energy infrastructure in many cities. But we need to give closer attention to the differential effects of these impacts on different populations.

For example, Nierop (2014) suggests that energy policies should be implemented to reduce the vulnerability of electricity infrastructure to climate change impacts including decreased energy efficiency resulting from higher average surface temperatures, and an escalation in energy demand. Increases in peak demand are likely, especially during hotter summer months and during intense heatwaves, when periods of prolonged high electricity usage will strain the capacity of electricity infrastructure (Nierop 2014, 79). Many developed nations are already devising and implementing targeted policy interventions (e.g. new building codes, promoting investment in renewable energy). But energy poverty issues, which plague many developing countries, where there is little or no access to electricity and safe and clean fuel for cooking, have mostly been ignored (Chakravarty/Tavoni 2013). People with limited or no access to electricity who have contributed little to global greenhouse gas emissions, arguably have different responsibilities for mitigating climate change (Adger et al. 2006), and need more assistance with adapting.

Dimension 2—Spatial Planning

There is a close link between governance and spatial planning, which is often seen as a logical mechanism for climate response (Hurlimann/March 2012). Spatial planning practices include zoning land for certain uses, regulating land and property development, implementing building codes, and directing investment in energy efficient buildings and public transportation systems (op. cit.). Although spatial planning is regarded by many as providing useful tools for effecting climate change mitigation and adaptation, it is also vulnerable to political intervention (Day et al. 2009), and can have differential impacts upon marginalised and vulnerable populations (Byrne/MacCallum 2013).

Moreover, energy disparities already exist within contemporary energy systems—outside the domain of spatial planning. Planning is usually not retroactive. Planning cannot require property owners to retrofit existing buildings, only to improve a structure if there is a development application. Although "low income households pay proportionally more for energy services", planning is unable to directly intervene in rental property markets or to require landlords to upgrade appliances to improve energy efficiency or to use renewable energy (Goldthau/Sovacool 2012, 236). And spatial planning responses to climate change may trigger new problems.

For instance, some spatial planning strategies such as urban densification seek to mitigate climate change by using land more efficiently, accommodating populations in high-rise buildings to preserve green-space. But these responses can increase urban heat-island impacts (through more hard surfaces), may force up land values, and may push lower income households into vulnerable locations. Moreover, emerging literature suggests that higher-density built environments are more energy intensive (Gray et al. 2010). There is an urgent need to rethink the capacity of spatial planning to respond to climate change and to recognise that some energy-related strategies may inadvertently harm marginalised and vulnerable populations (Bulkeley et al. 2013).

Dimension 3—Socioeconomic Issues

The socioeconomic issues originating from 'fuel poverty' and 'energy poverty' can have pernicious consequences for public health. Howden-Chapman et al. (2012, 135) identify three factors, which can intensify fuel poverty: thermal inefficiency of households; high levels of income inequality; and increases in electricity prices. Belonging to a fuel poor household has various health consequences, including: increased risk of influenza, heart disease, strokes and asthma, and increased use of public health services (Thomson/Snell 2013). It can also affect mental well-being and social contact, causing depression, social isolation and even mobility constraints (Walker/Day 2012).

Operationalising the conceptual model—an Australian case example

The Australian electricity sector has been identified as one of the world's most carbon-intensive electricity production systems (McGuirk et al. 2014). Proposals to transition away from fossil-fuel dependency are strongly contested. Federal government elections have been fought and lost based on proposals to mitigate climate change, such as the adoption of a carbon pollution market or implementation of a carbon tax. Although energy efficiency is a climate governance pathway in Australia, energy transmission and distribution companies have prioritised investment in network upgrades to address peak demand, rather than promoting household energy efficiency or switching to renewable energy (McGuirk et al. 2014).

The federal government's focus on coal (which is Australia's largest export) has also inhibited investment in renewable energy (Effendi/Courvisanos 2012). The Renewable Energy Target of 20% renewables by 2020 has lead to some investment in alternative energy, (with the target likely to be achieved much sooner), but the powerful coal industry is pushing for its abolition or substantial reduction. And generous feed-in tariffs for household rooftop photovoltaic systems (e.g. 44 cents per kilowatt hour), have increased the number of installations from around 8,000 rooftop solar systems in 2000 to over 1 million by 2014 (Bahadori et al. 2013). In the process, these measures have achieved parity between wholesale solar power and thermal coal-generated power (Campbell et al. 2014). Rooftop photovoltaic systems have also shifted peak demand (Cludius et al. 2014). Photovoltaic systems generate the most power in the afternoon when temperatures are the hottest, thus lessening electricity demand for cooling.

But a paradox of environmental (in)justice is that policy changes to address one problem can have unintended consequences that differentially impact other populations (Bullard/Johnson 2000). Solar subsidies in Australia have tended to benefit middle-class residents who have the income necessary to make an up-front purchase (Byrne et al. 2009). While increased demand for rooftop solar systems has driven down the cost of solar systems, it has had some unanticipated consequences. Photovoltaic technologies have toxic production processes (Mulvaney 2014). Cheap solar panels are sourced mainly from China, where environmental regulation practices are comparatively lenient, resulting in the disproportionate exposure of Chinese workers to environmental toxins. In other

words, middle class Australians are exporting their solar pollution costs to China while reaping the 'clean energy' benefits in Australia.

Moreover, energy utilities in Australia who 'platinum plated' network infrastructure to cope with peak demand have been faced with reduced demand (due to the success of rooftop solar). To recover redundant investment costs in network infrastructure utilities have increased domestic tariffs. In turn, price rises have created a feed-back loop, making rooftop photovoltaic solar even more attractive. However, low-income earners and renters who cannot switch to solar have been left with higher electricity bills (Nelson et al. 2011). Many of these households have also been displaced to the urban periphery (where public transportation is scarce), due to land use policies of urban consolidation. These households face multiple energy problems—electricity costs are rising, private transportation expenses are prohibitive, and the new suburbs are hotter than their inner-suburban counterparts due to tree clearing for development and smaller lot sizes. If we are going to be able to effectively combat climate change, adapt to expected impacts, and transition to alternative energy, we will need holistic policy responses that address these sorts of problems.

6. Conclusions

In this paper we have reported the results of a systematic quantitative review of the literature addressing the combined issues of energy, justice and climate change. In the literature, the impacts of climate change are seen as having repercussions for energy supply and demand. Problems with cooling households, transporting people, supplying water, treating sewage and providing food can occur when energy supply is disrupted due to climate change impacts such as flooding or heatwaves. And adapting energy networks to cope with direct and indirect climate change impacts (e.g. storms vs. peak demand) as well as transitioning to alternative energy sources to mitigate climate change, may produce spatially and socially uneven impacts on livelihoods, health and wellbeing. Yet very little research has recognised the complex interplay between these issues.

As we have shown in this paper, there are pernicious consequences of not clearly thinking through imbricated problems and feedback loops associated with energy, climate change and justice. Researchers need to turn their collective attention to these sorts of complex problems. Future analyses could consider the different forms of justice involved in ensuring fair outcomes (e.g. distributive, procedural, identification). New research might also consider how affected populations are mobilising these different conceptions of justice and for what ends.

For instance, could new generation batteries designed to fix intermittency supply problems associated with renewable energy create new problems through mining scarce metals used as catalysts, through fugitive emissions from batteries, and/or during the safe disposal of batteries in the future? Could the valorisation of a discourse of 'greener' is 'cleaner' silence community objections to emerging technologies such as hydrogen-based systems, fuel cells, co-generation, waste to energy, and next-generation nuclear? Are energy transitions in response to cli-

mate change potentially displacing environmental problems? Could wind-farms harm the sovereignty of Indigenous peoples? Does coal-seam gas mining disproportionately impact rural populations while benefiting city dwellers? Attention to these types of questions now, and to the different dimensions of justice they invoke, could prevent longer-term environmental justice consequences in the decades that lie ahead.

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Appendix 1

Authors (year)	Title	Journal	Countries Examined
Bang (2010)	Energy security and climate change concerns: Triggers for energy policy change in the United States?	Energy Policy	United States
Berger et al. (2014)	Impacts of climate change upon cooling and heating energy demand of office buildings in Vienna, Austria	Energy and Buildings	Vienna, Austria
Bollen et al. (2010)	An integrated assessment of climate change, air pollution, and energy security policy	Energy Policy	Europe
Bulkeley et al. (2013)	Climate justice and global cities: Mapping the emerging discourses	Global Environmental Change	Philadelphia, USA Quito, USA Toronto, Canada
Bulkeley et al. (2014)	Contesting climate justice in the city: Examining politics and practice in urban climate change experiments	Global Environmental Change	Bangalore, India Monterrey, Mexico Hong Kong, China Philadelphia, USA Berlin, Germany
Chakravarty and Tavoni (2013)	Energy poverty alleviation and climate change mitigation: Is there a trade off?	Energy Economics	Europe Africa
Corner et al. (2011)	Nuclear power, climate change and energy security: Exploring British public attitudes	Energy Policy	England Scotland Wales
Dolinar et al. (2010)	Predicted changes in energy demands for heating and cooling due to climate change	Physics and Chemistry of the Earth	Slovenia
Frank (2005)	Climate change impacts on building heating and cooling energy demand in Switzerland	Energy and Buildings	Switzerland
Howden-Chapman et al. (2012)	Tackling cold housing and fuel poverty in New Zealand: A review of policies, research, and health impacts	Energy Policy	New Zealand
Katuwal and Bohara (2009)	Biogas: A promising renewable technology and its impact on rural households in Nepal	Renewable and Sustainable Energy Reviews	Nepal
Li et al. (2013)	Future climate change and building energy demand in Tianjin, China	Building Services Engineering Research and Technology	Tianjin, China
Nierop (2014)	Envisioning resilient electrical infrastructure: A policy framework for incorporating future climate change into electricity sector planning	Environmental Science & Policy	United States

Authors (year)	Title	Journal	Countries Examined
Rogers-Hayden et al. (2011)	'Energy security' and 'climate change': Constructing UK energy discursive realities	Global Environmental Change	United Kingdom
Sovacool and Mukherjee (2011)	Conceptualizing and measuring energy security: A synthesized approach	Energy	United States
Thomson and Snell (2013)	Quantifying the prevalence of fuel poverty across the European Union	Energy Policy	United Kingdom Ireland
Tirado Herrero and Urge-Vorsatz (2012)	Trapped in the heat: A post-communist type of fuel poverty	Energy Policy	Hungary
van Vliet et al. (2012)	Synergies in the Asian energy system: Climate change, energy security, energy access and air pollution	Energy Economics	China Indonesia Malaysia South Korea
Urge-Vorsatz and Metz (2009)	Energy efficiency: how far does it get us in controlling climate change?	Energy Efficiency	United Kingdom Brazil Japan
Wang et al. (2010)	Assessment of climate change impact on residential building heating and cooling energy requirement in Australia	Building and Environment	Australia
Wang et al. (2014)	China's regional assessment of renewable energy vulnerability to climate change	Renewable and Sustainable Energy Reviews	China
Xu et al. (2012)	Impacts of climate change on building heating and cooling energy patterns in California	Energy	United States

Table 4: Details of the 22 papers examining energy strategies