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Climate change and energy security: an analysis of policy research

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Abstract The literature on climate change's impacts on energy security is scattered across disparate fields of research and schools of thought. Much of this literature has been produced outside of the academy by scholars and practitioners working in "think tanks," government agencies, and international/multilateral institutions. Here we reviewed a selected set of 58 articles and reports primarily from such sources and performed textual analysis of the arguments. Our review of this literature identifies three potential mechanisms for linking climate change and energy security: Climate change may 1) create second-order effects that may exacerbate social instability and disrupt energy systems; 2) directly impact energy supply and/or systems or 3) influence energy security through the effects of climate-related policies. We identify emerging risks to energy security driven by climate mitigation technology choices but find less evidence of climate change's direct physical impacts. We used both empirical and qualitative selection factors for choosing the grey literature sample. The sources we selected were published in the last 5 years, available through electronic media and were written in language accessible to general policy or academic readers. The organizations that published the literature had performed previous research in the general fields of energy and/or climate change with some analytical content and identified themselves as non-partisan. This literature is particularly valuable to scholars because identifies understudied relationships that can be rigorously assessed through academic tools and methodologies and informs a translational research agenda that will allow scholars to engage with practitioners to address challenges that lie at the nexus of climate change and energy security.

1 Introduction

Our analysis found that in contrast to the climate-conflict nexus, academic scholarship on the climate change-energy security nexus is small, and more disciplinarily focused. Study of the impacts of climate change on national and international security has become a broad area of

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research particularly in the last 5 years. Within this broad topic, academic scholarship has concentrated primarily on whether climate change is or may become a driver of violent conflict. This relationship remains highly contested (Barnett and Adger 2007; Gleditsch 2012), although security organizations have identified climate change as a contributor to particular conflicts and incorporated this concept into policy guidance documents (CNA 2007; DOD 2011; NIC 2008; UK MOD 2010).

The literature we examined is less contentious than the climate-conflict literature but certain reports that we reviewed are premised on the assumption that the climate change security linkage is valid. A search of social science literature found a small number of sources with a large percentage attributable to a single journal. Assuming that policymakers are more likely to rely on social science literature this leaves a small foundation. Our findings beg the question of whether there is another literature. We identified a grey literature on the nexus of climate change and energy security of a greater size than the body of peer-reviewed social science literature. We reviewed 58 recent reports, issue briefs and transcripts from this grey literature to better understand the nexus of climate change and energy security and to gain insight about the questions policymakers need answered by those commissioning this literature.

In the following sections we describe the nature of the sources reviewed; highlight possible climate change and energy security linkages found within those sources; identify some emerging risks; and offer some conclusions that can guide further research.

2 The nature of the sources

Typically, "peer-reviewed" literature is based on original research by an academic scholar in a given field of study and published by an academic publisher in an archived serial journal. These publications are generally known to scholars in relevant fields of study and have a commonly recognized and expected practice of peer review to determine whether a piece of work merits publication. A search on the Thomson Reuters Web of Knowledge academic search engine for sources in English using the terms "climate and energy security" in the title of peer-reviewed articles published from 2007 to 2012 yielded 20 results. The search timeframe was based on the publication of the latest IPCC Assessment on Global Climate Change that establishes the scientific baseline for most of the analysis. It is notable that six of these articles were published in the refereed journal *Energy Policy*. A Boolean search of peer-reviewed scholarship the PAIS database of political, social and public policy issues using the search terms of "energy security" within ten words of "climate change" yielded 39 results, 17 of which were found in *Energy Policy*. Further searches on Thomson Reuters indicate that narrow and usually technical issues relevant to climate change and energy security are treated in highly specialized academic journals on energy fuels, engineering, meteorology and atmospheric studies. Many of these sources can be obtained only on an expensive subscription only basis.

An alternative form of publication, commonly called "grey literature," is "information produced on all levels of government, academics, business and industry in electronic and print formats not controlled by commercial publishing" (Schöpfel and Farace 2010). The authors may not have conducted original research but may be well-informed or experienced on a topic.

Rather than advancing a particular academic field, the grey literature addressed topics that may be of greater interest to practitioners than to academic scholars. Reports on the climate change energy security nexus appears to fall into this category. This is not surprising given the role of practitioners in creating this literature. Governments directly fund many of the organizations that we drew our sources from so research agendas are subject to control or influence. Others were drawn from “thinks tanks,” often staffed by people who have government experience and the explicit mission of informing policy. Likewise, reports by international organizations provide analytical policy support capability to their member countries’ governments. Because the grey literature involves practitioners to a greater extent than academic sources, the two literatures may contain distinct sets of insights that arise from different methods of analysis and frames of reference. This grey literature has many shortcomings but it provides insight into the questions that policymakers are asking. For example, the formulation of climate change as a “threat multiplier” originated from the *National Security and the Threat of Climate Change* (2007) a report from CNA Corporation, an American Think Tank, has been cited in a great number of scholarly articles and guided a whole literature on the climate change/conflict nexus and its implications for human security. A search on the Google Scholar search engine for “threat multiplier” yielded about 6,660 results.

This review considered grey literature consisting of 58 English language reports, issue briefs, and panel transcripts primarily from “think-tanks” and governmental organizations of some type (Table 1).

The large majority of these sources were written by American or Northern European authors. More analysis of this finding is warranted but it may be partially attributed to initial sampling bias of English language sources, and that other literatures such as those from major Asian energy producers were under-represented in the databases we selected so did not meet the accessibility selection criteria.

Research approaches in the literature ranged from interviews to scenario casting to sophisticated models, but were generally more qualitative than quantitative offering less assurance compared to peer-reviewed sources that any given source was not influenced by ideological predispositions. Hence, while the grey literature must be vetted carefully for soundness and credibility, it may offer unique insights lacking in the academic literature.

Our methodology for selecting the literature to include in our analysis was based on several criteria. First, we used internet searches and two online academic databases to obtain our initial sample of approximately 1,000 sources. After excluding peer-reviewed sources, we evaluated each source using the six empirical and qualitative criteria listed below (Table 2).

We included a small number of short desk papers in our review but most of the literature we selected had a minimum length of 20 pages and could best characterized as reports. Finally, in this paper we cited 42 of these 58 sources that best represented the general observed relationships between climate change and energy security.

3 Defining climate change and energy security

We adopt the Intergovernmental Panel on Climate Change’s definition of climate change as a change in the state of the climate that can be identified by changes in the mean and/or the

Table 1 Sources by publishing organization

NGOs/think tanks	Government	Multilateral agencies	Military/security organizations	Panels	Non peer- reviewed journals
27	11	7	5	4	4

Table 2 Criteria for selection of literature

The organizations sponsoring or publishing the sources enjoy reputations for high research standards
The organizations identify themselves as non-partisan
The organizations have research experience with energy and/or climate change issues
The sources are widely available and accessible through electronic media
The sources are accessible to readers from various backgrounds, including social and physical sciences and the humanities.
Each source was published between 2007 and 2012

variability of its properties and that persists for an extended period, typically decades or longer. It may be due to natural internal processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC 2007).

Defining energy security is arguably more contextual, and certainly more central, to our analysis. The literature offered a myriad of what we consider to be partial definitions. At the microeconomic level, energy security is the ability of [U.S.] households and businesses to accommodate disruptions of supplies in energy markets (CBO 2012). A more comprehensive definition is the availability of adequate, reliable, and affordable energy (Staley et al. 2009).[1]

We found that this definition is typical of the economics literature, which emphasizes energy supply over other elements of energy security. Winzer (2011) uses case study of three European countries finds that the definition that energy security that best serves clear policy goals is "energy supply continuity." For example, oil is the only fuel imported in significant quantities by the U.S. The avoidance of oil supply disruptions and the resultant economic effects of price volatility are especially important to policy-makers. Oil price shocks preceded almost every recession in the U.S. since WWII and many worldwide (Hamilton 1983).

Other organizations provide a more securitized definition. For example, the Center for a New American Security (CNAS) deemphasizes price and affordability altogether, defining energy security as maintaining energy supplies that are "geopolitically reliable, environmentally sustainable and physically secure" (Burke and Parthemore 2008). Other organizations also include the physical protection of energy resources or infrastructure in their definitions (UNCT 2008; U.S. Army 2012). Ladislaw and Nakano (2008) build on the CNAS definition by also taking geopolitical, sustainability, and social acceptability factors into consideration. This synthesized definition of energy security is new in the literature but it is one that illuminates and is responsive to the choices policymakers must make.

4 Elements of the climate change energy security nexus

The literature we reviewed identifies linkages between climate change and energy security that can be divided into three into three mechanisms.

4.1 Climate change, fragile states and energy security

The idea that climate change may act as a "threat multiplier" or a "conflict accelerant" originated in the grey literature (CNA 2007; WBGU 2007). According to the U.S. Department of Defense

[1] Other organizations that have used the same or similar definitions include the International Energy Agency (IEA), the European Commission, and the U.S. Senate (Staley et al. 2009).

(DoD), climate change could affect environmental or resource problems that communities already face by intensifying grievances, overwhelming coping capacities and possibly spurring population displacement in areas that lack resilience (DSB 2011). Indeed, many politically volatile areas are experiencing physical climate impacts, such as changes in temperature and precipitation (IPCC 2007), that can exacerbate extreme weather events or droughts. Risks associated with climate change in the Middle East may exacerbate existing factors, such as historical and current levels of internal conflict, competition for scarce resources and income disparities within oil-producing nations (CNA 2007).

However, the literature we sampled, mainly sponsored by defense and foreign ministries, indicates that potential for climate change to trigger conditions that may interrupt oil supplies seems most plausible in Africa. The U.S. DoD observes that many African states are critical to continued U.S. success in securing strategic mineral and fuel resources and that climate change impacts could destabilize fragile states by overwhelming their political systems and eroding government legitimacy (DSB 2011). Greater reliance on African oil makes China even more vulnerable to supply disruptions than the United States.

Since the 1990s rebel groups in southern Nigeria, where the majority of oil infrastructure is located, have reacted to political and income disparities by pirating oil, sabotaging oil equipment, and holding oil company employees hostage (Werz and Conley 2012). This insurgency may have no connection to climate change, but it demonstrates that energy systems can be attractive targets for attack when conflict ignites. Climate impacts are starker in northern Nigeria, where 200 villages have been abandoned due to desertification. Resultant migration and unrelated population growth have created instability. Boko Haram, a militant Islamic group affiliated with Al Qaida, has grown and escalated violence in regions impacted by climate change (Werz and Conley 2012). Boko Haram activity is not co-located with major energy infrastructure, but if climate stressors cause social instability in these areas, they may become more susceptible to violence. Taken, together, the insurgencies in Nigeria suggest that climate change has strong potential to amplify energy insecurity.

The on-going conflict in Sudan's Darfur region which possesses significant oil reserves is socially complex but, the literature we reviewed attributes competition for dwindling ecological resources stemming in part from climate change as one cause (CNA 2007; WBGU 2007). Busby et al. have studied North Africa using vulnerability indicators to determine the role that climate might play in conflict, migration, and terrorism. Their work, which is displayed graphically using GIS techniques, found that the lack of a direct causal relationship between climate change and conflict, but that the situation was more complex (Busby et al 2010). More recently, the conflict between Sudan and South Sudan, that shares some common roots with the Darfur conflict, has led Sudan to interrupt the flow of oil from pipelines crossing its territory that the South relies on to ship its oil to market (Mantshantsha 2012). Again, the direct climate/conflict link is inconclusive but this region remains a focal point for further analysis.

Other potential hot spots for supply disruptions are in areas adjacent to sensitive maritime chokepoints for oil transport, such as the Straits of Malacca. Indonesia, which is highly vulnerable to climate change (IPCC 2007), is susceptible to droughts and extreme storms. The government's insufficient response to natural disasters has eroded its authority in the province of Aceh, home to an active insurgency for several decades. If the central government continues to prove unable to respond to future disasters, separatists might renew previous activities, including piracy in the Straits (Busby 2007). While tanker traffic could be diverted to the adjacent Lombok and Makasser Straits avoiding Indonesian territorial water altogether, a tanker heading from the Arabian Gulf to Japan would be forced to take a costly diversion around Australia. Komiss and Huntzinger (2011) estimated that a 20 %

disruption of traffic in the straits, a generous estimate of the pirates' capabilities, would block 5 million bbd of 84 million bbd world production level based on 2006 estimates. While no oil destined for the U.S. is transported through the straits, much more significant quantities of Australian and Asia crude oil are and the world price of oil could rise correspondingly (Komiss and Huntzinger).

Somali pirates have occasionally interdicted oil tankers in the Arabian Sea. From 2008 to 2012, actual and attempted robberies against ships outnumbered those in the Straits of Malacca by 447 to 9 (ICC International Maritime Bureau 2013). Climate change is one of the several factors that created the conflict and societal power vacuum in Somalia that the pirates emerged from (Webersik 2010).

So while there have been situations where energy supplies have been disrupted by social instability, and where climate stresses have played a role in social instability, the literature we reviewed has not identified a strong case where the is a direct cause and effect. The evidence is sufficient at this point only to suggest potential vulnerability of energy infrastructure in regions where climate impacts may destabilize social systems.

4.2 Physical impacts of climate change on energy systems and resources

The literature we reviewed indicates that direct physical impacts of climate change, such as increased frequency and severity of storms, heat waves, and droughts are likely to impact energy security in a number of ways. Even in developed countries, energy infrastructure is susceptible to disruption by weather conditions (CNA 2007). A blackout that crippled most of the U.S. Northeast in 2003 occurred on a hot summer day when electricity demand was high and an overheated power line in a small Ohio town sagged and came into contact with a single tree. This normally unremarkable incident interacted with several other power system failures to create a major regional blackout that affected 50 million people in the U.S. and Canada and caused financial losses between $4 and $10 Billion in the U.S. (CNA 2007). Increased frequency of extreme heat is likely to put greater stress on aging electrical grids. In the wake of Hurricane Katrina in 2005, many offshore oil platforms, onshore oil refineries, and other energy related facilities were completely or partially shut down for weeks or months (IEA 2007). Two dozen nuclear power facilities and numerous refineries along the U.S. coasts are susceptible to storms, which are projected to become more intense with climate change (NIC 2008; IPCC 2007).

Melting of the Arctic ice sheet accelerated by climate change is expected to bring new oil supplies online as the Arctic sea ice retreats and allows seabed oil to be exploited. Between 2008 and 2011 a spate of major policy announcements and actions focused on re-militarizing the region suggests the possibility of emerging interstate competition for control and access to the region's resources (Huebert et al. 2012).

Maintaining adequate water supply in the face of climate change is a major emerging issue. In many regions, climate change is likely to reduce precipitation (IPCC 2007), increase surface water evaporation, and decrease river flows. Production of all sources of energy requires some water, often in large quantities. The energy sector accounts for 8 % of worldwide water withdrawals and is the fastest growing consumer of water in the United States (Brune 2011).

Water scarcity will diminish hydro electrical generation capacity in some nations working to increase low-carbon and diverse energy sources. China generated approximately 16 % of its electricity from hydropower in 2009 and plans to double this capacity by 2020 (CNAS 2012). However, capacity has been declining due to recent droughts (CNAS 2012) and climate models predict reduced precipitation in some areas of China (IPCC 2007). Declining hydropower capacity is likely to increase reliance on coal-fired power plants; China's cheapest alternative. Dwindling Himalayan glaciers may also decrease the potential for hydroelectric generation in China and in South and Southeast Asia.

Nuclear reactors and fossil fuel electric generation plants use water for functions including cooling, steam generation, and waste disposal. Adding carbon capture and storage (CCS) technologies to coal plants- a solid greenhouse gas mitigation option- would more than double their water consumption (Atlantic Council 2011).[2] Water scarcity is also a factor in the liquid fuels sector where biofuels and synthetic fuels production is very water intensive (CNA 2011). Net withdrawal of water competes with other uses, including agriculture and human consumption, complicating adaptation measures (Stover 2012).

5 Climate change mitigation policy's effects on energy security

According to our sources, policies to mitigate climate change will have "a significant effect on the development of societal norms, the cost and usage of energy, land use, and economic development strategies by 2040" (UK MOD 2010).[3] Climate policies may be compatible or may work at cross-purposes with energy security.

Policies designed to mitigate climate change and that promote energy security can also be mutually reinforcing. Energy conservation is described as a "no regrets" strategy for enhancing energy security while reducing climate change (at least in developed nations). In many cases, policies that reduce demand for energy—especially oil—through technology innovation require greater energy efficiency that may also address both challenges (CNA 2011).

One tension inherent in policies for climate change mitigation and energy security is that policies addressing each may require implementation on different timescales. Climate mitigation may phase in greenhouse gas emissions (GHG) reductions over time because climate risks evolve over decades and many of the solutions, including capital stock replacement, also require decades to implement. However, the risks associated with energy security affect national economies on daily to annual time scales. Climate policies can undermine energy security by limiting near term energy supply options. Consequently, Furman et al. (2007) suggest that greenhouse gas emissions reductions would be less disruptive to energy security if they were implemented only after key technological solutions, such as carbon capture and sequestration, become available for large-scale deployment.[4]

Some long-run solutions to climate change and energy security will require higher prices for gasoline, electricity, and home heating oil (Furman et al 2007). Carbon pricing is expected to increase the cost of fossil fuels, diminishing energy security for many consumers in the short term, while stimulating the development of cleaner technologies in the longer term (UK MOD 2010). The key to cross-compatibility of climate and energy security is for efficiency measures to provide near-term cost reductions while maintaining or increasing

[2] Photovoltaic (solar) and wind plants that produce a negligible amount of total world power are the only two generation technologies that do not require significant quantities of water for operation (Atlantic Council 2011).

[3] The international community defines climate mitigation as the "stabilization of greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system" (UN 1992).

[4] This recommendation is at odds, however, with others such as (Yohe 2010) who argue that significant GHG emissions reductions must begin immediately to achieve any long-term climate stabilization goal at the minimum cost.

supply availability and reliability (Furman et al 2007). Whether consumption reductions can completely offset cost increases associated with more efficient technologies remains a point of contention in the grey literature.

Policies designed to increase energy security may have the perverse effect of accelerating GHG emissions. A desire to reduce reliance on foreign oil and take advantage of abundant coal reserves has led some countries to explore coal-to-liquid fuel conversion processes (CTL). Emissions from these fuels exceed those of fuels obtained from crude oil by a factor of two (CNA 2011).

Regulatory uncertainty surrounding long-term climate policies, particularly in major emitter nations, has also had an indirect negative impact on energy security. In the United States, this uncertainty has caused power companies to delay capital investment decisions, such as building new natural gas, nuclear or renewable generation facilities that would lower carbon emissions and diversify the fuel mix (Ferguson 2012). New coal-fired plants are also on hold, causing generation capacities to lag demand growth. Meanwhile, the economics of renewable and nuclear energy plant construction remains hazy.[5]

A German decision to shut down 7 of its 17 reactors and phase out nuclear energy by 2020 in light of the accident at the Japanese Fukushima plant has implications for climate change mitigation policy and energy security. In 2010 renewable energy produced more power than the nuclear sector (Schneider et al 2011). However a bridge fuel is necessary until it becomes technically and economically feasible for renewables to supply critical baseload power (Schneider et al 2011). Germany has essentially three energy choices: coal, natural gas and imported nuclear power. Coal will substantially increase GHG emissions; natural gas supply and nuclear power are susceptible to monopolization by Russia and France respectively.

5.1 Emerging strategic policy risks

Policies encouraging transition to a more secure, low-carbon energy supply are likely to entail emerging strategic and political risks that must be considered in order to address energy security, human security and maintain policy flexibility. The grey literature identifies areas where policymakers have commissioned research analysing some of the following geopolitical risks.

World demand for nuclear energy may grow in response to climate mitigation policy and dual use technology could lead to weapons development. Every nation surrounding the volatile South China Sea that does not possess nuclear power—Vietnam, Malaysia, Indonesia, the Philippines and Singapore—is considering acquiring nuclear energy (CNAS 2012). Iran is actively developing nuclear technologies, insisting its program is purely for peaceful purposes, but most world governments believe it seeks nuclear weapons (Toukan and Cordesman 2010). Disposing of waste is another consideration, because while there is widespread scientific agreement about how the waste disposal should be approached, the politics are complicated (USEIA 2011a, b).

Some clean energy technologies require large supplies of minerals or rare earth elements. Electric vehicles generally use lithium ion batteries. Worldwide lithium deposits are concentrated in the hands of a few countries. Advanced automotive technologies require significant quantities of other rare earth minerals; at least 50 % are concentrated in China which has exerted geopolitical leverage by threatening to cut off supplies swapping of one

[5] For a review of a possible timeline for environmental regulations in the U.S. power utility sector see, World Resources Institute's factsheet at http://pdf.wri.org/factsheets/factsheet_response_to_eei_timeline.pdf.

dependency (foreign oil) for another (foreign rare earth minerals), with significant implications for the geopolitical landscape (Burke 2009; Parthemore 2011).

The U.S. has discovered vast natural gas reserves in shale deposits, and the exploitation of shale gas deposits is likely to expand to other countries within the coming decade (USEIA 2011a, b). A debate has emerged about the environmental consequences of a gas extraction technique called hydraulic fracturing that is becoming more prevalent. Howarth et al. (2012) and other argue that this technique may release methane, one of the most potent greenhouse gases. As the least carbon-intensive fossil fuel, natural gas is widely viewed as a bridge in the transition to lower carbon emissions. Policies that discourage the carbon-intensive fossil fuels, such as coal and oil, could encourage countries to import natural gas. Russia's threats to cut off gas supplies and inadequate investment in infrastructure place European economies in a vulnerable position (Frank et al. 2009; NIC 2008).

Natural gas and biofuels as well as electricity generated using renewable resources (e.g., solar power, wind power, biomass) could be used to power private vehicles and public transport systems. Policies that encourage the transition from petroleum-based transportation to alternatives could destabilize rentier oil states as their revenues decline, while transferring wealth to other suppliers, with major implications for strategic and geopolitical interests (CNA 2011). Biofuels reduce reliance on oil, boost farmers' incomes, and can decrease GHG emissions when best practices are applied. However, crops grown to produce biofuels could displace food crops, potentially affecting food prices and increasing food insecurity.

6 Conclusion

We have identified and categorised a grey literature on the nexus of climate change and energy security. From our perspective climate change is the "actor" that may 1) create second-order effects that may exacerbating social instability and disrupt energy systems; 2) directly impact energy supply and/or systems or 3) influence energy security through the effects of climate-related policies. This heuristic frame may be helpful to those who are responsible for mitigation policymaking and management of energy transportation infrastructure.

However, the grey literature we reviewed had modal characteristics that limited its utility. A research agenda that addresses the following gaps and limitations would enhance understanding of the climate change-energy security nexus:

- **Currency of the science:** Most of the recent grey literature on climate change relies heavily on the 2007 IPCC assessment report. Scientific progress since 2006 is therefore generally neglected. This issue has been identified as a key gap for informing national security decision makers about the risks and solutions to climate change (Rogers and Gulledge 2010). Likewise, analysts that develop policy scenarios must be guided by awareness of the latest and most likely scientific advances in energy technologies. Stronger working partnerships between organizations that produce grey literature and scientific experts could help fill the gap.
- **Regional focus:** The majority of the literature we located and reviewed was produced in and focuses on issues in the global North. While selection bias may partially explain this outcome, the few sources we found describe impact of climate change on developing nations in isolation from energy security. A research agenda focusing on human security is needed that includes greater emphasis on developing nations where climate impacts are expected to be especially severe, where the resilience of energy systems to withstand

those impacts is expected to be low, and where many countries depend on energy exports for economic growth.

- **Level of Analysis:** The reviewed literature is focused primarily on the national level. Climate change and energy security are concepts that require evaluation on both wider (transboundary) and narrower (household) scales. Improved resolution of climate models is playing a vital role in this analysis. However, better coordination of social science and natural science sources is needed to integrate climate data with socioeconomic and political information (Rogers and Gulledge 2010). Research methodologies, capabilities and motivations vary widely among organizations that produce grey literature and the academy is needed to bring stringency and state-of-the-science techniques to filling research gaps.

Due to the complexity of the decisions policymakers must tackle, a literature that fully considers climate change and its consequences for energy security requires an interdisciplinary approach; yet interdisciplinary capacity remains limited in academia, with some notable exceptions (Rogers and Gulledge 2010). Much of the grey literature is aimed at integrating across disciplines and in order to synthesize the information most tailored to inform public policy decisions and is likewise a useful resource for those conducing integrated climate change assessments, such as the IPCC reports. Moreover this literature can guide translational academic research that enables policymakers to solve complex problems at the nexus of climate change and energy security.

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