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Microgrids and resilience: Using a systems approach to achieve climate adaptation and mitigation goals

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ABSTRACT

Although energy resource sustainability has been researched extensively, the understanding of how we use and interact with electricity sustainably is less understood. New electrical designs, like microgrids, provide opportunities to better address the immediate needs of electrical sustainability and urban development. This paper analyzes the role of microgrids in urban development and examines how greater systemic thinking between infrastructure planning and energy policymaking can increase a city's resilience.

1. Introduction

Meeting the challenges of long-term sustainability depend heavily on decisions that are being taken now. The most critical decisions that are being made are centered on our electricity infrastructure. Electricity plays a crucial role in all aspects of the global political economy, including both the source of power behind our homes and hospitals, but also as a main contributor to greenhouse gas emissions. In 2015, emissions of carbon dioxide (CO_2) by the U.S. electric power sector were 1925 million metric tons, or about 37% of the total U.S. energy-related CO_2 emissions of 5271 million metric tons (EIA, 2017). Whilst the challenges of carbon emissions reductions have generally relied on centralized governmental coordination stemming from the UNFCCC, resilience measures are actions that are best taken and coordinated at the city level. In an era of constant regulatory fluctuation, taking effective decisions at the local level can better contribute to the long-term challenges of sustainability. Microgrids in particular, can play an effective role in helping a city to overcome its carbon emissions reductions, and can also serve as a critical tool for addressing the economic and social dimensions of sustainable development such as in the case of many Japanese cities. Though several countries around the world are using microgrids for social purposes, microgrid deployment in the U.S. remains limited. Yet expanding upon the use and understanding of microgrids in the U.S. can help to build adaptive capacity to climate change, or the intersection between climate mitigation and adaptation, actions.

At the same time, expanding upon the usage of microgrids can help to provide a more diverse array of financing options for countries and nations who are looking to address their climate vulnerabilities immediately, yet are capitally constrained. Microgrids provide a more useful, and perhaps more attractive, area for sustainable investments when considering their potential to connect their social and environmental potential aims to a return on investment. This paper therefore examines the role of microgrids within the broader realm of resilience and sustainability, to better understand the motivations behind a resilient city plan based on the deployment of microgrids. It then moves to analyze the most recent trends in microgrid development to investigate how these new flexible technologies could better enhance broader urban development and sustainability. By explaining how environmental and social considerations can be applied to the design of microgrids, this paper shows how applying sustainability metrics increases the attractiveness of microgrids as an area for sustainable investment. The conclusions of this paper provide a better understanding of how both energy resilience goals and broader sustainable development strategies could be more strongly coordinated to deploy energy solutions that are dually useful in reducing the short- and long-term risks that stem from climate change.

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2. Research background

Climate change policy was born directly out of the environmental policy agenda area of sustainable development. Addressing climate change is therefore, an internationally recognized component of maintaining the stability among environment, economy, and broader civilian society. Climate change plays a significant role in increasing the earth's average surface temperature, fostering the phenomenon known as global warming.[1] If current fossil-fuel consumption trends continue, the average surface temperatures of the earth could rise by as much as 6.4 ° by 2100 (Stocker et al., 2013). Even under the most optimistic scenario, temperatures will still rise by 1.1–2.9 ° before this century's end (Stocker et al., 2013). Climate change poses a noted threat to global ecosystems, but poses an equivalent threat to the global political economy. It exposes many major security risks such as increasing volatility in food production, decreased reliability in energy supplies, and greater frequency of extreme weather events. These risks impact economic activity directly, but also indirectly in the case of price fluctuations in energy markets.

Overall, American climate studies for have focused on the inability of the U.S. to engage in the international climate arena. Rather than identifying how the U.S. could better engage with the international arena, studies on U.S. carbon emissions reduction began to focus on state and city-level examinations. (Bulkeley et al., 2011; Urpelainen, 2009; Matisoff, 2008; Betsill and Bulkeley, 2004). This is what is referred to as the "bottom-up" approach within U.S. climate policy literature, which looks at the merits of state and local climate mitigation policy. The literature here has mainly focused on identifying the benefits of using a decentralized approach to climate mitigation.

This research shifted the place of the U.S. within international climate discussions towards being domestically focused. Although this is problematic for the international arena, taking a domestic approach has had merits for climate progress by the U.S., which can be summarized into four main points. First, research has shown that using local levels of government within carbon mitigation policies are more likely to result in experimentation with new policy tools, and thus produce new types of tools (Buzbee, 2005). Second, the local level also allows solutions to be specifically tailored, requiring less government interference. Third, these solutions are likely to be easier to test at a municipal or state level, which is likely due to the fourth main aspect, that passing climate policy is easier done at the local level (Buzbee, 2005; Adler, 2005). Overall, the literature reviewing how the local level might be an effective strategy for change has yet to quantitatively show that these policies produce significant change.

Today, the pledges from cities and states only encompass about 10% of the greenhouse gas emissions in the U.S. California's climate programs, known for being the most aggressive in the U.S., only are responsible for about 6% of America's overall share (Buzbee, 2005). Although research has pointed to the need for bottom-up climate actions to eventually become intertwined with a top-down approach to legislation, there has been a lack of attention to the types of institutional adjustments that are needed to amount to serious action on carbon emissions reductions.

Although research has predicted that the lower-level "push" for sustainability will perhaps result in larger-scale legislation (Bang et al., 2007; Selin and VanDeveer, 2007), current climate legislation does not necessarily support the intersection between adaptation and mitigation efforts. Instead, there is significant worry that fragmented schemes without international coordination and consensus on needed reductions will instead lead to a "race to the bottom," in which firms would relocate to regions with lower environmental standards (Newell, Pizer and Raimi, 2013, p. 123). This fear is founded on the notion that industries will relocate to cities, states, or countries that do not monetarily regulate environmentally, so to avoid paying environmental fees (Newell, Pizer and Raimi, 2013 pp. 123–146). This fear is even more acute when it comes to emissions trading schemes, where bottom-up legislation has been a concern. In the U.S., given the diversity of climate policies and number of local governing bodies, fragmented local-level approaches could potentially create an internal race to the bottom. Heavy polluters avoiding states like California, Washington, and Oregon could seek to relocate to Pennsylvania, Ohio, and West Virginia, states that lack carbon policies. Although bottom-up approaches have been effective in the initial launching phases of emissions schemes, without international consensus on the targets, it becomes difficult to ensure emissions trading schemes are meeting their environmental ambitions (Newell, Pizer and Raimi, 2013, pp. 123–146). Despite the positive progress on launching markets as displayed by the EU ETS, the Regional Greenhouse Gas Initiative, and New Zealand, the progress has been slow meeting ambitious reductions (Newell, Pizer and Raimi, 2013, pp. 123–146). Although the bottom-up approach is useful and easier, nations still need to agree on the larger-scale contributions needed for climate change. Without doing so, "regulating states will bear a disproportionate share of the costs from such regulation with no guarantee of reaping proportionate benefits," (Adler, 2005).

In order to achieve strong carbon policies, governing areas need to better focus on the policy-outcomes that lead to success in carbon policy. Success in carbon policy is defined as "the ambition or stipulation of ambitious objectives that could produce real change in behavior, and compliance, to the extent to which implementers, including target groups, work to follow the stipulated requirements," (Bressers, Bruijn, Lulofs, and O'Toole, 2011, pp.187-208). In general, this success refers to meeting targets that contain agreed upon ambitions, reductions for quantity, and a baseline year for achievement. Although there has been significant research that investigates what types of actions are needed to achieve success in both the short and long term, there is a significant research gap on the types of coordination between these two actions to ensure meaningful carbon reductions are achieved. Rather than focusing on the short-term impacts or long-term causes of climate change, deep carbon reductions may be made more achievable by focusing on the intersection of these actions. This would require identifying both the infrastructures and institutions that are needed to protect society from climate risks. This therefore requires increasing the immediate resilience of systems, but in a manner that coincides more neatly with long-term emissions reductions.

3. Building a conceptual framework for resilience

In order for economies and nations to reduce the impacts of climate change, a range of measures have been developed to move societies and institutions towards a more sustainable means of living. These measures are actions that are taken to remove the concentration of greenhouse gases from the earth's atmosphere, and are referred to as emissions reductions (IPCC, 2014). Global emissions by gas also include methane, nitrous oxide, and fluorinated gases (IPCC, 2014). Reductions are needed across a variety of gases, but carbon dioxide reductions play a significant role in achieving effective results. Carbon dioxide emissions from fossil fuels and industrial processes, as well as from forestry and land use, contribute to over 76% of emissions globally (IPCC, 2014). However, addressing the consequences is an extensive process as nearly all current methods of economic consumption and production rely primarily on activities that produce carbon. These emissions are generally produced across six main categories including: electricity and heat production; industry and agriculture; transportation; buildings, and energy (IPCC, 2014). Therefore, reducing carbon emissions requires fundamentally creating change in production and consumption in each of these sectors.

The research investigating how to create meaningful change for carbon emissions reductions is a relatively new topic within the social sciences. Despite the subject being new, political scientists have produced a high quantity of research that touches upon how to create change in the short term and in the long term. Today, these research investigations are most generally separated into two main areas of