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Innovative technology in the Pacific: Building resilience for vulnerable communities

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ABSTRACT

Transitioning to sustainability will require innovation, not just in technological and economic terms but also in governance and culture. The work presented here sought a remote, vulnerable island context (Fiji, South Pacific) to enable further insight into the innovation process related to resilience and sustainability. The innovation targeted by this work was off-grid solar renewable energy (RE) systems framed as a development instrument to promote local, community-based resilience to climate change through increased livelihood security and reduction of climate change effects. Applying a local-level resilience framework to solar technology use, we conclude that the RE system can improve resilience, however, unintended consequences included a rush for energy usage causing a "tragedy of commons" of finite stored energy and subsequently increased supplementary fossil fuel use. This suggests that there are still missed resilience opportunities in the way that the innovation is implemented in developing countries and remote areas in particular. Further analysis demonstrated that improved planning at the socio-technological interface has the potential to strengthen communities' resilience. With significant RE investments required for a transition to a low-carbon future in many developing countries, there is a pressing need to effectively introduce innovative uses of technologies. Existential threats to many local communities, and some nations in the Pacific may mean that sub-optimal innovation will not be enough.

1. Introduction

1.1. Background

Sustainability is being increasingly seen as requiring a transformation or a transition, rather than being the inevitable consequence of contemporary development trajectories (Olsson et al., 2014). Successful achievement of ambitious Sustainable Development Goals (SDG) of the UN 2030 Agenda for Sustainable Development will require major transitions, not only in policies and technologies, but in modes of innovation. An expanding band of resilience scholars since the mid-1990s has been studying transitions toward improved ecosystem stewardship and sustainability (e.g. (Olsson et al., 2004; Chapin et al., 2010; Folke et al., 2010). Integrating transition management and resilience theory can contribute to the understanding of how to form niches for experimenting with initiatives that increase human well-being in the face of uncertainty and change, while simultaneously supporting ecosystem capacity (Olsson et al., 2014). This key research focus areas invokes innovation and the dynamics of interactive innovation within which peoples, researchers, businesses and policy makers, and others can co-produce resilience and sustainability.

Innovation is framed not just in technological and economic terms but also in governance and culture. Island communities lend themselves to understanding such processes of innovation as they encapsulate many of the sustainable development challenges (Kelman et al., 2015; Connell, 2013) but are relatively small scale and unbuffered against shocks such as oil price spikes and natural extreme events. This small scale of island communities can make it easier to encompass diverse disciplines and information data within the same study (Mercer et al., 2010; Mercer et al., 2010). This multidisciplinary understanding is required for effective local responses to sustainability challenges, which is why island case studies have had such a large impact on participatory

Abbreviations: CO_2, Carbon Dioxide; GHG, Greenhouse Gas Emissions; INDCs, Intended Nationally Determined Contributions; IPCC, Intergovernmental Panel on Climate Change; LED, Light-Emitting Diode; MMM, Management-Maintenance-Monitoring; NGO, Non-Governmental Organisations; OGSS, Off-Grid Solar Systems; PSIDS, Pacific Small Island Developing States; PV, Photovoltaic; SDG, Sustainable Development Goals; UN, United Nations; UNFCCC, United Nations Framework Convention on Climate Change; USD, United States Dollars

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processes for sustainable development (Kelman et al., 2011). There is resonance to the statement that *"Vulnerability is the birthplace of innovation, creativity and change"* (Brown, 2012) as measured by the interest of around 3.2 million people from around the planet (Walters, 2012). This work presented here sought a remote, vulnerable island context to enable further insight into the process of innovation implementation for resilience and sustainability.

1.2. Vulnerability, resilience and adaptation concepts in Pacific islands

Within the largest ocean of the world are located some of the smallest island countries. Pacific Small Island Developing States (PSIDS) are mostly remote and highly dispersed. Kiribati, for instance, has 112,000 inhabitants on 33 coral atolls which are spread over 3.5 million km^2 of ocean, an area larger than the land area of India. Most PSIDS have independent political systems with full jurisdictional autonomy and their own identity (Connor, 2008); they thus possess considerable self-determination of their development trajectory. However, this remoteness and self-governance is offset by economic reliance on other countries such as development assistance (World Bank, 2015; OECD, 2016). This high degree of international commitment in narrowly-based economics make those nations particularly attractive when it comes to promulgating innovation.

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as the degree to which a system is susceptible to and unable to address climate variability and climate adverse impacts (IPCC, 2014). Vulnerability can also be conceptualised as *"a combination of the geographical and temporal proximity to a hazard (exposure) and the propensity for exposure to result in harm (sensitivity)"* (Jacobs et al., 2014). Between 2001 and 2010, natural disasters have, on average, affected 232 million people and caused more than US$100 billion in damage worldwide each year (Guha-Sapir et al., 2011). In 2011, four PSIDS were in the top 15 World Risk positions (in terms of exposure, susceptibility, coping capacities and adaptive capacities) (United Nations, 2011a, 2011b). PSIDS are particularly sensitive to adverse impacts of climate change (United Nations, 2011a, 2011b; United Nations, 2011b; United Nations, 2015) leading to a capital stock loss 20 times greater each year compared to Europe and Central Asia (United Nations, 2015). Populations who live below the poverty line may be especially vulnerable to disasters (Maru et al., 2014); Fiji for example has >30% of the population living below the poverty line (Asian Development Bank, 2014).

Various forms of adaptation can be used to alleviate climate change vulnerabilities (Pelling, 2011). Adaptation refers to the decision-making process and the set of actions undertaken from individuals, communities, organisations and governments to deal with current or future predicted change (Engle, 2011; McLennan and Handmer, 2012; Fidelman et al., 2013; Keys et al., 2014). Increasingly authors argue that adaptive capacity is a function of household-level adaptive decision-making and action (Moser and Pike, 2015; Collins, 2015; Elrick-Barr et al., 2016). However, adaptation cannot suppress all climate-related impacts (Warner and Van der Geest, 2013; Warner et al., 2013; Mathew and Akter, 2015) particularly in small island states (Alliance of Small Island States, 2008; Monnereau and Abraham, 2013).

Most definitions of "resilience" include two key-elements: a) resilience concerns systems, countries, communities or households, b) resilience concerns the ability to manage exposure to hazards, shocks or stresses through maintaining or transforming living standards aiming at long-term prospects (Christopher and Rutherford, 2004; UNISDR, 2005; Cutter et al., 2008; UkAid, 2011; Akter and Mallick, 2013). Resilience is, therefore, a dynamic process and is characterised by multiple adaptive cycles interacting across a range of scales and dimensions (Brown and Westaway, 2011; Craeynest, 2010; Manyena, 2006). Fostering resilience, however, is difficult as is measuring resilience (CARI, 2017). This is probably the reason why there are projects aimed at improving the livelihood of vulnerable communities but which miss the chance to reach optimal resilience gains.

1.3. Resilience and energy innovation in the Pacific islands

Innovation is generally considered to be the result of a process that brings together novel ideas/technologies in a way that they affect society and meet growing consumer demand (OECD, 2005; EPSC, 2017; OECD, 2010). The ability to innovate is also location specific (Tim, 2002). The miniscule land area of PSIDS within a vast ocean (1.8% land and 98.2% water (Fifita, 2012)) and limited domestic fossil fuel resources result in a heavy reliance on imported fossil fuels (Singh, 2012) and challenges related to energy security (Dornan, 2014; Michalena and Hills, 2016). Long diesel supply routes lead to oil cost escalation (Prasad et al., 2013) and the limited population spread across thousands of islands challenges fuel delivery. >95% of fossil fuel is imported into the Pacific (Woodruff, 2007a) and the energy demand keeps increasing (Bayar and Alp Ozel, 2014). It is estimated that 70% of Pacific households do not have access to electricity and the majority of those households are located in rural areas (Dornan, 2014). In Fiji, for example, more than one-third of Fiji's total import bill at the end of 2008 was accounted for by fossil fuels alone (Singh, 2012); this forces the Government to heavily subsidize electricity supply (Wolf et al., 2016). This state of energy poverty make PICs among the most vulnerable and indebted countries in the world and highly exposed to sudden or abrupt changes in external factors (Wolf et al., 2016).

Innovation in energy systems is a viable option to address energy resilience and security in countries with growing electricity demand, challenging economic circumstances and environmental targets (Michalena and Frantzeskaki, 2013; Chalvatzis and Rubel, 2015). All PSIDS are progressing with the roll-out of renewable energy (IRENA, 2016). Although PSIDS do not emit large quantities of CO_2 themselves (EU, JRC, 2011), the Pacific region is an assistance priority for development partners (Nutall et al., 2014; New Zealand Government, 2016). The focus on mitigation, through increased renewable energy feeding to grids, is apparent in the INDCs (Intended Nationally Determined Contributions) submitted by PSIDS to UNFCCC (Republic of Fiji, 2015). However, this focus misses some of the most vulnerable parts of PSIDS societies, the off-grid rural poor communities that produce negligible GHG emissions per capita but bear the brunt of climate change impacts. For those communities RE has no mitigation function as in their case they are trying to initiate electricity supply rather to switch to a lower carbon supply option.

Innovation in energy systems, both technological and integrative is fundamental in solidifying the benefits of renewable energy either in terms of controlling emissions (Zafirakis et al., 2015) or facilitating the energy supply chain in a wider interconnected system (Zafirakis et al., 2016). The innovative use of energy technologies can also create resilience for individuals, households and communities against the effects of climate change. The literature which tackles renewable energy's potential capacity to address adaptation and building resilience to climate variability at a local/community level, is limited (Stone, 2013; Perera et al., 2015). A systematic review (Perera et al., 2015) notes that "*only a few*" documents contained "*evidence demonstrating the link all the way through from access to energy to adaptation and building resilience to climate change and climate variability*"; this finding was significant in framing the energy innovation process as the object of study.

1.4. Scope and aims

Our research lens focuses on small, remote and traditional Fijian communities with customary tenure of natural resources. These communities are located in inherently vulnerable coastal locations with implemented household- and community-innovation in the renewable energy sector. Within this focus, we exclusively target innovation-created, place-based resilience accrued at the household- or village-level and accessible to the vulnerable and poor members of these