WORKSHOP BACKGROUND PAPER

ENERGY RESILIENCE IN PACIFIC ISLAND COUNTRIES & TERRITORIES

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USP THE UNIVERSITY OF THE SOUTH PACIFIC
University of Papua New Guinea
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ITP Renewables Consulting | Engineering | Implementation
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Background

This report is a preliminary output, intended to provide an understanding of energy resilience prior to further discussions in a series of workshops on Energy Resilience in Pacific Island Countries and Territories across three thematic areas:

- Planning and investing in more resilient energy systems
- Community energy resilience strategies in response to disasters
- Energy resilience and the political economy of off-grid solar.

Three online interactive workshops will be held on 1-4 December 2020 to gather further stakeholder input to inform research priorities for energy resilience in the Pacific region. This report seeks to inform the discussion by exploring the diversity of priorities and experiences on energy resilience within the Pacific context. The work involved an extensive literature review and targeted stakeholder interviews across the region.

The Energy Resilience in Pacific Island Countries and Territories Workshop Series is a collaboration between University of New South Wales, University of the South Pacific, University of Papua New Guinea and Loughborough University, with contributions from partners ITP Renewables, GSES and CSIRO. We will welcome participants from the Asia-Pacific Solar Research Conference, Urban Resilience Asia Pacific Conference and Geographic Information for Disaster Management Conference. The work is supported by the Australian Renewable Energy Agency's International Engagement Program, the Australian Research Council (ARC) and the Royal Academy of Engineering's Research Fellowship scheme. This workshop series also builds on previous work, including the Community Energy Resilience and Electricity Systems Workshop Series in 2018 and 2019 which focused on the UK, South Asia and Sub-Saharan Africa (Dvorakova et al. 2020).

Acknowledgement

The authors would like to thank the seventeen interviewees for taking the time - through COVID-19 and timezones - to share their valuable insights and experiences. These conversations shaped this report, and we look forward to touching base with you for the next stage. Thank you to our partners, listed on the cover page, for your expertise and support. Unless otherwise attributed, all images have been taken courtesy of Canva, under their Free Media License Agreement.

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TERMINOLOGY

Build back better (BBB)	'The use of the recovery, rehabilitation and reconstruction phases after a disaster to increase the resilience of nations and communities through integrating disaster risk reduction measures into the restoration of physical infrastructure and societal systems, and into the revitalization of livelihoods, economies, and the environment.'	UN 2016
Climate change adaption (CCA)	'The ability of a system to adjust to climate change to moderate potential consequences or to manage the consequences of those impacts that cannot be avoided.'	ICAO 2020
	'Anticipating the adverse effects of climate change and taking appropriate action to prevent or minimise the damage they can cause, or taking advantage of opportunities that may arise.'	EU 2020
Climate change mitigation	'A human intervention to reduce emissions or enhance the sinks of greenhouse gases.'	IPCC 2018
Community resilience	'The ability of individuals, communities, organizations or countries exposed to disasters, crises and underlying vulnerabilities to anticipate, prepare for, reduce the impact of, cope with and recover from the effects of shocks and stresses without compromising their long-term prospects).'	IFRC 2014
Disaster risk reduction (DRR)	'The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to 11 hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.'	UNISDR 2009
Energy access	'A household having reliable and affordable access to both clean cooking facilities and to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average.'	IEA 2019
Energy resilience	'Resilience in an energy system can be defined as its ability to reduce the impact of shocks and stresses, including the capacity to anticipate, absorb, adapt to, and rapidly recover from such events and to transform where necessary.'	ARUP 2019
Energy security	'The umbrella term for energy availability, resource affordability, environmental sustainability, energy efficiency and technology.'	Raghoo et al. 2018
Political Economy	'An analytical lens that focuses on how broader political and economic processes, across different scales, shape energy outcomes.'	Munro 2020

EXECUTIVE SUMMARY

Energy resilience describes the ability to achieve energy objectives, such as secure supply, affordable access and positive environmental outcomes, through changes and disruptions; and also refers to the role energy systems play in building adaptive capacity. Energy resilience is significant at different scales, including at national- through to local community-levels. In considering the role of governance at all levels, energy resilience reframes electrification as a sociotechnical issue that is occurring predominantly within the context of climate change. Currently, countries and territories across the Pacific are largely reliant on fossil fuels for energy. As the transition to renewable energy accelerates, characteristics such as redundancy and diversity in grids and mobility and decentralisation off-grid bring potential for wide-spread benefits. For the Pacific, unlocking these opportunities requires enhanced coordination of investment, policy and project planning under a common agenda and mutual understanding of resilience.

With COVID-19 weakening the global investment climate and an increasing prevalence of climate disasters, this study offers a timely exploration into the meanings of and opportunities for energy resilience across the Pacific region. Through literature review and seventeen stakeholder interviews in Australia, Papua New Guinea, Fiji, Vanuatu, Tuvalu and Tokelau, recurring themes have been identified for further exploration at the Energy Resilience in Pacific Island Countries and Territories Workshop Series on 1-4 December 2020. These themes fall within a cascading framework of agendas; from the Sustainable Development Goals (SDGs) to the Framework for Resilient Development in the Pacific, which in turn serve to inform nationally determined energy plans.

This report finds stakeholder focus shifting from short-term recovery efforts to 'building back better' (BBB), however, the scale of disasters – with cases of singular events eclipsing impacted nations' GDP – continues to force unplanned action. Such emergent responses bring new learning opportunities, and the case studies examine the varying degrees of success across different disaster recovery efforts. Commonly, a lack of techno-economic capacity within government departments is resulting in a strong reliance on external donors and multilateral development agencies. COVID-19, with travel restrictions and economic cuts, has exposed the risk of this dependency; highlighting how perpetual international aid undermines the importance of domestic and community resilience. To dismantle this cycle, countries and territories need to overcome challenges of institutional inertia, inflexible legislation and financial incentives that are cementing the dominance of incumbent energy providers. Bottom-up responses are an alternative approach and can more accurately reflect the localised nature of climate change impacts. With gender equality positioned as a core pillar of program design and uptake facilitated by community champions, there are opportunities to BBB through cost-effective initiatives that work within local power structures and build from local knowledge systems.

Some key findings arising from our case studies of six countries and territories in the Pacific are summarised in the table below, under the relevant thematic area and hence workshop.

Table of Themes

	Community energy resilience strategies in response to disasters	Energy resilience and the political economy of off-grid solar	Planning and investing in more resilient energy systems
Fiji		1. Focused on technical innovations, how can new energy systems can be resilient to the climate 2. Politics of the community, potential clashes with community values/aspirations and suggested energy systems	1. Planning to mitigate effects of climate change: policy change to increase building standards and minimise loss of infrastructure 2. Implementation of this policy is limited by financial barrier. Government support is limited, people cannot afford to build to new standards
Australia	1. Community engagement is needed to ensure the longevity of energy systems 2. Community representation and understanding community energy usage is important for the long life of energy systems		1. Setting a Federal target in energy resilience is needed for communities to maintain energy supply in disasters 2. Mini-grids and standalone power systems (SAPS) offer a pathway to energy resilience 3. Encourage mobility and flexibility in energy supply system infrastructure may minimise damage to infrastructure
Tuvalu	1. Engagement and understanding of the community regarding energy systems dictates their effectiveness and success 2. Community champions drive excitement and development of renewable energy projects 3. Security and availability of electricity supply is	1. Renewable energy systems displace fuel to reduce external dependency on global geopolitical and economic context 2. Local capacity building is crucial, although difficult, as technically skilled individuals often emigrate 3. Coordination between donors and separation from political agendas is required to	

	needed to ensure community energy resilience	streamline implementation	
Tokelau		1. Battery storage, and subsequent battery waste management, will be a crucial part of resilient electricity services 2. Solar generation, storage and distribution infrastructure must be innovative in order to continually meet demand 3. Climate change is important to consider for the longevity and resilience of energy systems	1. Reliance on donor funding constricts the design of energy projects and implementation timeframes 2. The government has a limited understanding of the complexities of energy systems and markets, undermining long-term success 3. Financial constraints of small nation budgets result in maintenance on failure 4. Tokelau's dependency on imported fuel presents huge financial and logistical challenges
Papua New Guinea	1. Communities in PNG have been adapting to natural disasters for thousands of years 2. Government-led energy resilience strategies remain disconnected from community-level projects 3. Local champions and "billboard" households will facilitate widespread uptake of new strategies		1. Resilience requires refurbished hydro and new solar, but LNG remains a political favourite 2. Planning for climate and resilience is being pegged on to a pre-existing energy access agenda 3. Diversified grid extension can achieve RET targets whilst building resilience
Vanuatu	1. Community power structures dictate the uptake and success of CER programs 2. A community-level resilience framework can integrate local priorities within national plans	1. The burgeoning off-grid solar (OGS) market is unlocking new opportunities for resilience 2. Limited internal capacity and lack of external trust creates a cycle of dependence,	

	3. Humanising energy project design enable continued success without external support	undermining resilience 3. Degrees of off-grid solar system resilience are increasingly governed by market factors	

1. INTRODUCTION

For many in Pacific Island Countries and Territories (PICTs), land is synonymous with livelihood (Steiner 2015). This expanse of ocean, spanning one-quarter of the globe, is split into regions of Melanesia, Micronesia and Polynesia, and is the world's greatest carbon sink. Its custodians, who view the Pacific as a 'sea of islands' (Steiner 2015), are both gravely concerned and ambitious for the future (Pacific Islands Forum Secretariat 2019). Comprising 26 countries and territories, the region is undergoing an unprecedented energy transition. For example, in 2012 Tokelau became the world's first fully solar-powered state and by 2030, another six PICTs are planning to follow suit with 100% renewable energy targets (ITP 2019). This is a significant undertaking, as fossil fuels currently represent up to one-third of total import costs per country, and few PICTs boast hydro power potential as an alternative source (Banks & Cole 2017). A renewable energy transition for PICTs in part stems from necessity: only PNG and Timor-Leste have fossil fuel reserves (ADB 2019) and climate change is 'the single greatest threat'. Renewable energy can both mitigate and provide resilience against the impacts of the climate crisis, but this ultimately requires global coordinated action. To fast-track such action, the Pacific exercises its collective voice and champions the belief 'to lead is to act' (Pacific Islands Forum Secretariat 2019).

Energy resilience is a complex and expansive topic, encompassing robustness and reliability, adaptive capacity and community involvement. Specifically, in the Pacific context, this covers policy and planning, climate change mitigation and adaption and responsibility for energy resilience. Numerous guidelines and frameworks have been established to inform action and planning on both the government and community level. Renewable energy provides communities with greater reliability and independence, provides diversification of energy supply and provides opportunities for stronger disaster response initiatives. Post-disasters, the concept of 'Build Back Better' is integral in ensuring effective disaster management, encouraging greater gender equality and supporting community level decision-making.

Section two discusses the methodology for the literature review and case studies, sections three to five cover the literature review, section six discusses interview responses, presented as six individual country case studies and section seven explores emerging themes.

2. METHODOLOGY

Energy resilience has a diversity of meanings, and one that will be heavily shaped by recent climatic events and COVID-19. To understand how meanings of energy resilience are being formed, the authors conducted a literature review focusing on studies from the past five years and led semi-structured stakeholder interviews with a diverse group of representatives who have worked and lived within six case study countries.

The literature review ran across three phases. First, A preliminary structured search first explored general definitions and frameworks for resilience, through the search terms of 'Resilience' *OR* 'Energy Security' *OR* 'Climate Change Adaptation' *OR* 'Vulnerable Community' *OR* 'Disaster Risk Reduction' in scholarly databases. The top fifty results were reviewed, and a conceptual framework for energy resilience drafted. Second, the search was repeated with geographical qualifiers of 'Pacific Island' *OR* 'Vanuatu' *OR* 'Fiji' *OR* 'PNG' *OR* 'Papua New Guinea' *OR* 'Small Island Developing States' *OR* 'SIDS'. Key organisations, countries and territories were listed for further investigation, based on unique projects or events that had catalysed a shift to energy resilience thinking, as conceptualised in the first stage. Third, energy project evaluations in databases of GIZ, the Compendium of Case Studies on Climate and Disaster Resilient Development in the Pacific, Pacific Data Hub, Pacific Regional Data Repository for SE4All, South Centre, Practical Action, World Bank, ADB, DFAT, IRENA and the Green Climate Fund were assessed for project-specific learnings.

Ten countries were identified as potential case studies and narrowed down to six, based on achieving a diverse set of 'highlight characteristics', as outlined below:

1. Australia, due to recent bushfire responses
2. Fiji, due to recent cyclones responses
3. Vanuatu, due to use of a community resilience framework
4. Papua New Guinea, due to its abundance of energy sources
5. Tokelau, due to its transition to 100% solar energy
6. Tuvalu, due to community-based initiatives and 'champions'

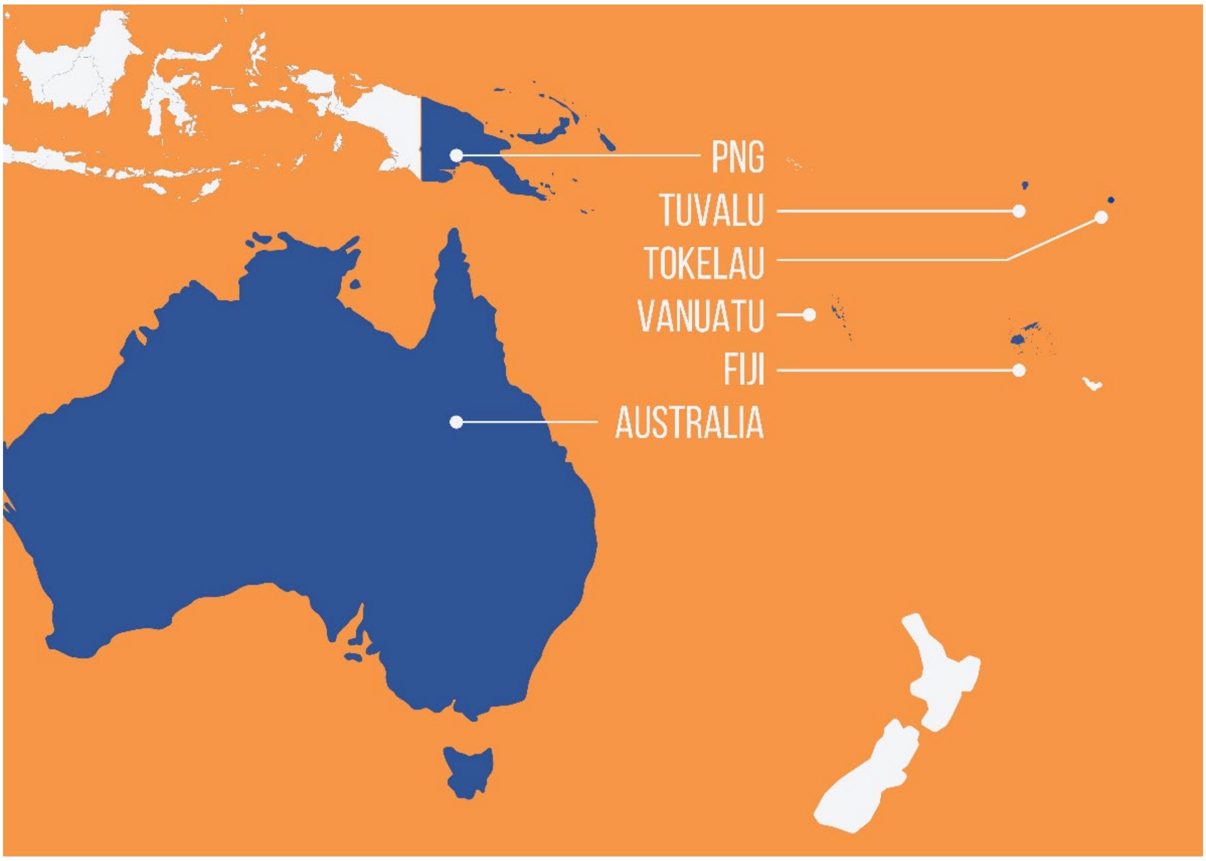

Figure 1: Case studies

For each country, a set of five interviewees were identified based on their roles within the energy sector or lived experience with disaster response, climate change adaptation or energy resilience initiatives. While not all identified stakeholders were available, seventeen semi-structured interviews were conducted with ten questions each extracted from three pools; a general set for all respondents, and a set based on the interviewee's profession and geographic region. The surveys were designed to capture the respondent's general understanding of energy resilience as a concept, and to capture learnings from a specific energy policy, project or climatic event. The interviewees represented local NGOs, academia, the private sector, multi-lateral development agencies and government departments. Interviews were recorded and transcribed, with anonymised learnings documented according to a common format. Unfortunately, respondents did not form a gender balance, with only 11% of interviewees female. Representation from community members was also lacking. As noted above, not all identified stakeholders could participate, but clear results emerged for recurring themes and this will inform the upcoming workshop series.

For each case study country, learnings were clustered according to the workshop thematic areas:

- Planning and investing in more resilient energy systems
- Community energy resilience strategies in response to disasters
- Energy resilience and the political economy of off-grid solar.

Authors then cross-checked key findings for every country against those of every other case study country - fifteen matches in all – to prioritise common themes based on prevalence. The findings are discussed at the conclusion of this report.

3. WHAT IS ENERGY RESILIENCE?

This section explores the classification and ideas of energy resilience, on both a technical and community level. Points of failure, those where implementing energy resilience has been unsuccessful, will also be outlined to establish a deeper understanding of how to plan for energy resilience.

3.1 Robustness and Reliability

Robustness and reliability are essential in planning for energy resilience (Shandiz 2020). Robustness is the ability for a system and its components to withstand disruption and reliability is the capacity to operate through instability, uncontrolled events, cascading failures, or unanticipated loss of system components (Shandiz 2020). While these are fundamental aspects of resiliency, they are often neglected within government policies (World Bank 2018).

In 2016, Category 5 Cyclone Winston hit Fiji with devastating impacts on infrastructure. Without a strong focus on infrastructure resilience in government policy and standards to resist extreme weather events, a significant portion of what was built was damaged (World Bank 2018). Building standard policies have since improved to better prepare for and withstand such disasters.

There have been similar occurrences in Australia. Legislative frameworks at the time of the 2019 - 2020 bushfires did not account for energy resilience. Most affected communities were dependent on poles and wires, many of which were damaged in this extreme weather event (Byrne 2019). As such, there were large scale power outages in times where energy supply was crucial in recovery efforts. These cases highlight the need for effective energy resilience targeting and integration within national energy plans and policies.

3.2 Adaptive Capacity and Renewable Energy

Molyneaux et al. (2016) argues energy resilience is synonymous with adaptive capacity, defining resilience as “the state or quality of a system’s capacity to cope with the unexpected”. Strong adaptive capacity requires diversity in energy supply, efficiency (energy efficiency, highly structured and organised systems), and redundancy (spare capacity). This has gained relevance as a result of climate change and it should be noted that preparing for energy resilience also presents an opportunity for improvement to energy supplies.

Energy resilience has also been described as a component of energy security, of which, renewable energy is imperative for improving both factors (Raghoo 2018). Specifically, in light of climate change, resilience has been defined as the capacity to mitigate and adapt to environmental changes and alleviate disruptions (Raghoo 2018). An escalating prevalence and severity of climatic events threatens to destabilise efforts to make energy resilient systems, and it is vital for actors to maintain a proactive outlook and response. Currently, there is limited diversity of renewables in the energy mix of SIDS. There is a strong reliance on fossil fuel imports, accounting for over 70% the Pacific SIDS energy mix (Raghoo 2018). Transitioning to renewable energy inherently enables resilience, as consumers are counteracting the privatisation of fossil fuels in favour of an abundant and shared renewable resource. Resilience also requires a focus on co-operation over competition and grassroots implementation of technologies (Furlong 2020).

3.3 Community Energy Resilience

Hills (2018) states that 'resilience relies on all levels of the community, incorporating systems, countries, communities, and households. Furthermore, it is the dynamic, adaptive ability to respond to challenge and change by maintaining living conditions with a long-term focus'.

Energy resilience exists at the intersection of 'community resilience' and the 'resilience of energy systems'. It is concerned with the interrelationship between energy infrastructure and community structures/perspectives (Dvorakova 2020). 'Resilience-building should be seen as a continuous process of learning and practice' (Twigg 2007) and considerations for community resilience is of equal importance to technical aspects. Importantly, program design must emphasise 'what communities can do for themselves … rather than concentrating on their vulnerability to disaster' (Twigg 2007).

In short, community resilience is the capacity to (Twigg 2007):

- Anticipate, minimize and absorb potential stresses or destructive forces through adaptation or resistance
- Manage or maintain certain basic functions and structures during disastrous events
- Recover or 'bounce back' after an event.

Energy resilience research should be holistic in nature to capture the lived experience of communities that utilise different combinations of energy systems (on-grid, mini-grids, off-grid) in response to context-specific challenges (Dvorakova 2020).

This socio-technical system (To 2019) is illustrated in **Figure 2** below.

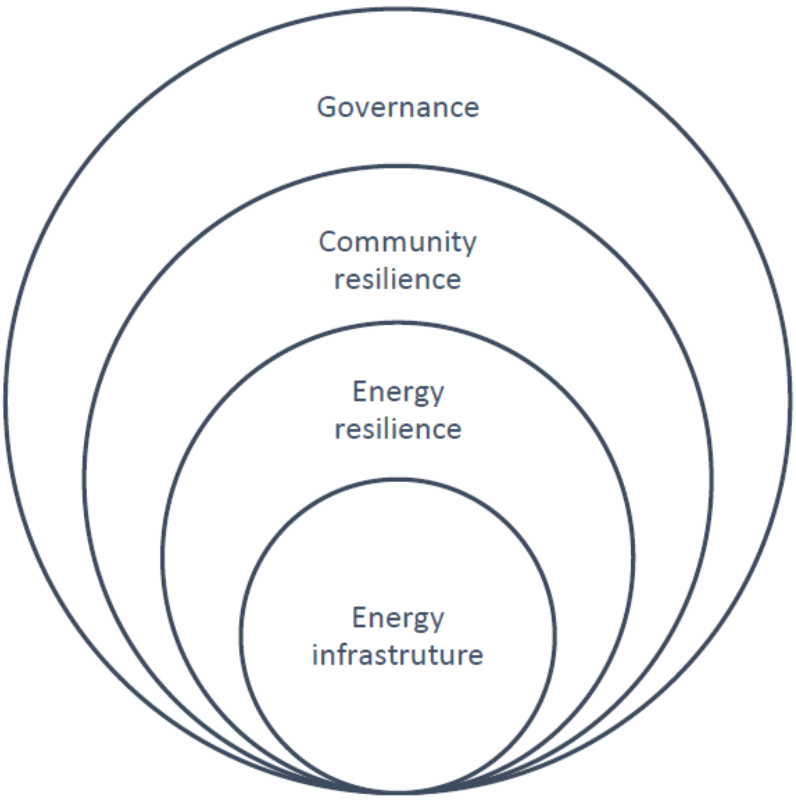

Figure 2: Framework for Community Resilience (To 2019)

Disaster response is highly contextual for local communities and if policies do not consider this framework, it raises concerns of policy effectiveness.

4. RESILIENCE AND ENERGY IN THE PACIFIC CONTEXT

Energy provision in the PICTs is dominated by imported fossil fuels in almost all jurisdictions. Local energy resources are almost entirely renewable with some exceptions such as PNG. Imported liquid fuels are used for virtually all transport and substantial power generation. While larger population centres are typically served by interconnected grids in the tens to hundreds of MW, in many of the PICTS, energy infrastructure is often small-scale in fitting with the small and dispersed populations, on isolated islands. Over the past two decades, renewables have offered a quite different yet highly complementary infrastructure pathway for the power generation sector. Solar photovoltaics (PV) is a modular technology that can be deployed on- and off-grid. Small stand-alone systems offer the potential to catalyse a shift from privatisation and centralisation (associated with fossil fuels) to decentralised and community-owned assets (Furlong 2020). Through capacity building for operation and maintenance, this can enhance community autonomy, in turn strengthening adaptability (Hills et al. 2018). However, to achieve scale-efficiencies and manage programmatic risk, national energy access planning usually sees large-scale programs, centralised planning and standardised approaches prioritised ahead of local efforts, dampening the voices of underrepresented groups. This trade-off between efficiency and empowerment (Finkbeiner 2018) must be recognised and navigated by energy departments, policy makers and program designers.

4.1 Policy and Planning Outlook

Electricity Sector planning, commonly conducted through national and multi-year electrification pathways, exists within a cascading series of global frameworks. At the global level, Sustainable Development Goal (SDG) 7 focuses on ensuring access to affordable, reliable, sustainable and modern energy for all. While universal energy access supports the attainment of other SDGs, such as health and education, a clean energy transition is critical to reducing the risks of climate change, as reflected in the Paris Agreement (IEA 2020). The twin goals of energy access and sustainability are reaffirmed by initiatives including:

- 2014 - 2024 being declared as the Decade on Sustainable Energy for All (United Nations, 2013);
- the SAMOA Pathway, providing an action plan for Small Island Developing States (SIDs) to combat climate change and foster sustainable development (United Nations 2014), and;
- the Sendai Framework, establishing an agreement for roles of the state and other stakeholders in disaster risk reduction (DRR) (UN 2015).

Drawing from the Paris Agreement, SAMOA Pathway and Sendai Framework respectively, in 2016 the Secretariat of the Pacific Community (SPC) developed the 'Framework for Resilient Development in the Pacific' (FRDP), a set of guidelines for:

- prioritising prevention of the adverse effects of climate change;
- improving adaptive capacity, and;
- building back better (BBB, which views disaster recovery efforts as an opportunity to strengthen infrastructure against future shocks).

Under the goal of 'low-carbon development', FRDP targets energy efficiency, reduced carbon intensity of development processes, conservation of ecosystems and resilience of energy infrastructure (SPC 2016). Looking forward, these initiatives will be mapped to the 2050 Strategy for the Blue Pacific Continent (Pacific Island Forum Secretariat 2019), a long-term climate action plan with the goal of consolidating regional efforts and frameworks under a common agenda.

These frameworks attempt to address challenges that are global in nature, however, even geographically proximate villages will experience different impacts of climate change (Maina et al. 2016). As climate change and related shocks manifest through nuanced consequences occurring at the community level (Ensor 2015), responsibilities for planning and implementation are not distinct. The majority of programs remain driven by governments and international donors, but the community-level is increasingly emerging as the appropriate scale of focus (Ensor 2015).

4.2 Responsibility for Energy Resilience

While the concept of resilience is most often used in the context of PICTs to frame discussions on climate change adaptation, it is also a useful concept to reframe electrification projects. Such framing moves the focus from past circumstances and present vulnerabilities towards future shocks and intergenerational outcomes (Finkbeiner 2018). This challenges traditional mechanisms of international aid, often designed to 'fix' existing problems rather than pre-empt and design for new circumstances. The Pacific is one of the most aid-dependent regions in the world (Dayant 2019), and uptake of alternative development pathways, such as 'cashless adaptation' initiatives (those that do not require funding) (Weir & Kumar 2020), internal investment and marketisation have been deprioritised as a result (Raghoo 2018). Now, with significant government revenue shortfalls forecast due to COVID-19 and subsequent cut-backs to services that enable resilience (Sokona 2020), cost-effective pathways to resilience are of significant interest. In particular, Indigenous knowledge systems might become a source of community resilience over time (Finkbeiner 2018). Strong social capital (Weir 2020) is common across many communities in the Pacific, and is likely to be an important asset for resilience, including where social influence approaches are useful (Barnes et al. 2020).

Community energy resilience sits within a cascading system of energy infrastructure, energy resilience, community resilience and governance (Subedi & To 2019). Village-scale programs must be sufficiently broad so as to consider the household intricacies of diversity and intersectionality, aspirations and perceptions, alongside institutional factors such as accountability, investment risks, and responsibility (To et al. 2020).

4.3 COVID-19 and Climate Change

The Pacific will face disproportionately the impacts of climate change (Asch et al. 2018; Finkbeiner et al. 2018) while their ability to adapt is hampered by increasing debt burdens (South Centre 2014), limited access to technology, inadequate infrastructure, lack of suitable financing mechanisms (Montes 2016; Michalena & Hills 2018) and more recently, the socio-economic consequences of the COVID-19 pandemic. The pandemic, with devastating short and long-term consequences, has exposed the vulnerabilities of systems and institutions (Sokona 2020) to multiple shocks – natural, climate and humanitarian - occurring in parallel (Shandiz et al. 2020). In T*racking SDG 7: The Energy Progress Report* (2020), the International Energy Agency (IEA) points to the 'urgent need … [for modern energy access] for hospitals and health facilities to treat patients, for schools to prepare children for the digital economy, for communities to pump clean water, and for people to gain access to information'. The compounding disasters of COVID-19 and climate change underscore the foundational role energy plays in building resilience.

In PICTs, losses from the worst natural disasters such as Cyclones Pam and Winston, have exceeded the annual GDP of some of these nations (Weir & Kumar 2020). In emerging from COVID-19, those prone to the long-term ramifications of such disasters, particularly remote island communities, should focus on multi-faceted disaster planning that incorporates opportunities for economic recovery (Sokona 2020).

5. OPPORTUNITIES & BARRIERS TO ENERGY RESILIENCE

Despite the many challenges and barriers to energy resilience that PICTs face, there are also extensive opportunities. Barriers are faced in the energy landscape, climate change, energy policies and the responsibilities of individuals and governments towards energy resilience, with opportunities encompassing disaster response initiatives, diversification and strengthening community involvement in energy systems and planning.

It is important to note that the countries comprising the PICTs are diverse in their location, climate conditions and community and government structures. Although the barriers and opportunities described below are broadly relevant, each nation has a unique set of challenges and pathways to achieving energy resilience.

5.1 Barriers

Government and policies impeding change

Strong governance and government policy are indispensable in ensuring the resilience of energy infrastructure, from recognising escalating difficulties and maintaining strong communication, to allocating resources to support infrastructure and human recovery (Bundhoo et al. 2018). ARUP (2019) identifies the key measures of resilience leadership and strategy to be a 'clear vision, effective regulations and inclusive governance'. Although many PICTs have RETs in place, governments need to target expansion, diversification and technical sophistication of energy infrastructure in order to achieve greater resilience (Bundhoo et al. 2018). Without strong government support and enforcement of renewable energy policies and projects, there is limited capacity for resilience and energy security (Raghoo et al. 2018). A lack of collaboration among decision-making bodies hinders progress aimed at advancing and adapting renewable energy policy and projects (Bundhoo et al. 2018). New lines of communication between suppliers, consumers and policymakers is required to ensure the reliability and adaptability of energy systems.

In many PICTs, there is minimal private sector funding being invested in renewable energy due to an unfavourable investment climate and lack of information and regulation surrounding investments (Montes 2016; Michalena & Hills 2018). In specific cases such as Fiji, investors are further polarised by the low Independent Power Producers (IPP) tariffs (Michalena & Hills 2018).

Administrative burden has been identified as a barrier, and by reducing it and providing greater support for small businesses, the transition towards renewable energy would be advanced (Furlong 2020). Furthermore, attaining a balance between international aid (aimed at the development of large-scale renewable energy to improve energy security and meet high RETs) and subsidies provided on a household level is crucial (Keeley 2017). Yet, despite an abundance of opportunity for increasing renewable energy reliance, there is a political limitation to the extent of which governments can invest in energy systems (Raghoo et al. 2018). Although there is an undeniable need for international aid, it also has the potential to adversely impact private investments and distort energy markets (Keeley 2017).

Limited technical capacity and supply chain difficulties

Spread across more than 25,000 islands, atolls and islets (Costa & Sharp 2011), the remoteness and small size of Pacific Island countries and territories significantly constrains their economic development (Weir & Kumar 2020). As a result, a key barrier to the development of renewable energy systems is economy of scale; comprising the expensive task of sourcing external technical expertise due to limited local maintenance capacity (IRENA 2013).

Beyond funding the systems, an understanding of who is required to maintain the system must be established in order for them to be upkept (Hills et al. 2018). In many PICTs, a limited adoption of renewable energy can be in part explained by a lack of awareness among communities and decision makers regarding the technology (Raghoo et al. 2018). Notably, larger-scale projects have a lower likelihood of community acceptance, thereby leading to diminishing maintenance (Richmond & Sovacool 2012). Without a strong maintenance agenda, when paired with the limited technical capacity available, many renewable energy systems in the Pacific inadvertently end up in a state of disrepair, compromising resilience.

The vast spread of the islands within PICTs creates complications in supply chains and distribution of technical components and expertise. Despite a strongly distributed population and land area, there is a strong focus in SIDS towards centralised power supplies (Dornan & Shah 2016). As a result, rural electrification has become a lower priority, partially due to a lack of funding and maintenance challenges (Dornan & Shah 2016). By focusing on the development and restoration of largely centralised systems, BBB opportunities for remote communities are impeded (To & Subedi 2019).

Gender inequality and inequity

In the aftermath of natural disasters, women have been identified as much less likely to receive aid and regain food security than men. Violence against women has been found to escalate and women are more likely to be withdrawn from their education (Drolet et al. 2015). Disaster response has a strong capacity to reinforce gender inequalities if the process of BBB neglects the importance of women's involvement and disaster preparedness (Drolet et al, 2015; Twigg 2009). Without community energy services aligning to the needs of all genders and energy services for women's productive use contributing to female empowerment, resilience is jeopardised (ENERGIA 2019). In many SIDS, men and women have distinctly different energy requirements due to existing gender roles; a fact often fatally overlooked by policies and programs (ENERGIA 2019; Sterrett 2015). Gender inequalities compound community vulnerability as equity is fundamental to achieving resilience for society as a whole (Sterrett 2015).

> 'A key pillar of the energy transition should be to ensure that the opportunities it creates are equally accessible, and the benefits it bestows, equitably distributed.' (IRENA 2019)

Women play a crucial role in rebuilding lives after disasters. Including women in delivering energy resources creates a knock-on effect, stimulating a shift in the social and cultural norms that were previously acting as barriers (Drolet et al. 2015; IRENA 2019). Over time, gender roles have been challenged and engagement with women in the energy sector has increased, especially in areas of climate variability and adaptive capacity (Sterrett 2015). Long-term planning and equitable involvement in decision-making is pivotal to address gender inequality, 'not only to meet the immediate aims of crisis response, but as a key to preventing future crises and building resilience' (Lafrenière et al. 2019; Sterrett 2015).

5.2 Opportunities

Effectively augment disaster response initiatives

The consequences of disasters in the Pacific are immense and can amount to substantial financial and broader societal damage. This accentuates the need for multi-faceted master planning for different disasters which may occur simultaneously, including climate and humanitarian challenges

(Shandiz et al. 2020). The opportunity to BBB cost-effective responses to abrupt changes, especially disasters, that focus on the long-term resilience of energy systems. BBB ensures an effective disaster risk response program and strong community involvement whilst restoring energy security (Drolet et al. 2015). Silicon PV is the 'cheapest and fastest-growing power source on Earth' (Sivaram 2018) and is rapidly becoming the financially viable electrification solution for many small nations. With well-fastened PV panels and robust ground-mounted infrastructure, renewable energy systems are capable of withstanding cyclones commonly experienced in the South Pacific (Weir & Kumar 2020). Deploying 'mobile systems' quickly to areas of need can complement large-scale grid-connected energy systems to increase resilience in post-disaster situations (Weir & Kumar 2020).

Stage (2010) identifies two methods for approaching CCA – autonomous and planned adaptation. Autonomous adaptation, largely undertaken by private entities regardless of government actions, can have small but effectual impacts. When paired with planned adaption, the decisions made by governing bodies, the outcome largely depends on the policy and initiatives which are put in place. To ensure success, planned adaptation must be conscious as to not limit the options of private entities' autonomous adaptation.

Ensuring a cohesive, well-planned and appropriate post-disaster management plan will enable a faster, more effective and cost-sensitive response. Collaborative partnerships are essential, ensuring decision-making and disaster response transcends social divisions (Drolet et al. 2015). Focussing on the synergies of climate change mitigation, renewable energy and energy security are highlighted to be measures imperative to improving resilience and security of energy sources (Raghoo et al. 2018).

Diversification and decentralisation of the energy mix

Between 12% and 37% of the total import value for Small Island Developing States (SIDS) is fossil fuels, compromising the security of their energy supply (Cole & Banks 2017). Hence, there is an immense opportunity for renewable energy to aid PICTs to reduce their dependency on imported fossil fuels by diversifying their energy mix. Energy resilience ensures communities do not experience energy insecurity, cushioning them from shocks stemming from the price or availability of energy (Molyneaux et al. 2016). Solar PV is the most widespread renewable energy technology in the Pacific; however, there are possibilities for biofuels and biomass, wind and hydro (in Fiji and Papua New Guinea) to strengthen the energy mix (Cole & Banks 2017). Maintaining diversity and redundancy are crucial to ensure autonomy and independence, such that should one component of a multifaceted system fail, other aspects of the system are still capable of operating (Bundhoo et al. 2018). With a reduction in cost of renewable energy, diversifying energy sources can be a viable means of energy security (Bazilian et al. 2011; Weir & Kumar 2020).

Decentralised energy systems reduce vulnerability and increase adaptability and reliability, facilitating resilience. For example, small scale distributed energy systems are less susceptible to outages during extreme weather conditions affecting the centralised grid (Bundhoo et al. 2018). A modular energy system provides communities with flexibility and increases the speed with which electricity can be returned to homes after a natural disaster. Innovations in the energy sector, specifically surrounding renewable energy, establish a foundation to achieve both sustainable energy supplies and resilient energy responses (Hills et al. 2018).

Strengthening community responses to energy challenges

There is significant potential to enhance the resilience of energy systems through a higher level of engagement and commitment at a community level in many Pacific Island countries and territories. Distinctly, the 'sustainability of energy projects largely depends on the degree of acceptance within its host population' (Gonzalez et al. 2016). With successful integration and strong support from communities, there is a greater chance the operation and maintenance of renewable energy technology will be effective (Hills et al. 2018). Furthermore, empowering community decision making strengthens adaptability through cooperation, collaboration and partnerships, whereby should other layers of resilience fall short, there is capacity for community intervention (Shandiz et al. 2020).

> 'A focus on resilience means putting greater emphasis on what communities can do for themselves and how to strengthen their capacities, rather than concentrating on their vulnerability to disaster or environmental shocks and stresses, or their needs in an emergency.' (Twigg 2009, p. 8)

Another opportunity to strengthen community responses to energy challenges is the leadership and creativity of key individuals in response to unforeseen shocks and stresses (Molyneaux et al. 2016). Community champions instigate excitement and enthusiasm around renewable energy, promoting longevity and sustainability (Furlong 2020).

Creating community resilience through local support

It is important to explore energy resilience on a local level, as regional and national research may inhibit understanding on a community scale (Hills 2018). For example, increasing reliance on an energy system within a community can result in increased energy resilience. Having the community view the energy system 'business' may incentivise uptake of an energy resilience action plan for existing assets before disruption (Arup 2019).

However, it has also been recommended under BBB programs to invest in community-owned decentralised renewable energy, as it will enable local economic development through job and business creation (Mullins 2020). Support for community owned systems, such as a renewable energy microgrids, will result in a cost savings for the community, as well as a productive use of energy, ultimately aiding in building community resilience.

To date, development of energy resilience frameworks has trended towards large-scale projects in the urban setting (Arup 2019). By incorporating community resilience – a socio-ecological system – this concept can be reframed for communities in developing countries with a dependence on renewables (To 2019).

To unlock the beneficial characteristics of renewables, such as redundancy, diversity and local availability, local technical capacity must be paired with local technical expertise. This was shown in Nepal following two major earthquakes in 2015. Official restoration efforts, which utilised a largely centralised approach, impeded access to BBB opportunities for remote communities (To 2019). Community resilience was seen here as informal networks that were set up to aid in the recovery and reconstruction after the earthquakes. The community relied on local information and competencies to ensure consistency in energy supply. This was however limited in some respects, as some repairs were too technical. As such, the importance of local training was shown to ensure safe and reliable energy supply after disasters.

From these earthquakes, locally sourced and made energy systems were helpful in establishing energy supply but were not entirely safe (To 2019). Community Rural Electricity Entities (CREE), who buy electricity and manage the distribution of energy in areas not seen by the grid, were able to restore energy supply. However, they lacked the means to do so safely. It was difficult to reach some remote areas after the disaster and repairs were required over a large area. Overall, this emphasised the importance of locally trained technicians in these communities, as community resilience was limited without this.

6. CASE STUDIES

6.1 Fiji

Key statistics

Population	898,441 (World Population Review 2020)
Geographical layout	• Remote Islands in the Pacific • Near/at sea level • Mountainous
Characteristics	• Remoteness • Prone to natural disasters (flooding and cyclones) • Climate Change Impacts
Renewable Energy Target (RET)	99% RE by 2030 (ADB 2018)
Electrification	100% electrification by 2020 (ADB 2018)

Introduction

Fiji is regularly impacted by cyclones and floods. As a result, electricity infrastructure, including renewable energy systems are often severely damaged by these events presenting challenges for reliable electricity supply. The Fijian government, recognising the importance of the robustness of renewable energy infrastructure, put in place stricter building standards after Cyclone Winston; a category 5 cyclone with devastating impacts on the country.

Figure 3: Ground-mount PV, Fiji

Overview of themes

Planning and investing in more resilient energy systems	*Energy resilience and the political economy of off-grid solar*
• Focused on technical innovations, how can new energy systems be resilient to the climate • Politics of the community, potential clashes with community values/aspirations and suggested energy systems	• Planning to mitigate effects of climate change: policy change to increase building standards and minimise loss of infrastructure • Implementation of this policy is limited by a financial barrier. Government support is limited, people cannot afford to build to new standards

Energy landscape

The generation mix of Fiji's electricity sector is summarised in **Table 1** below (Global Petrol Prices 2017):

Table 1: Fiji electricity generation by fuel type (average from 2011-2016) (Global Petrol Prices 2017)

Energy Generation Type	Percentage of Total Energy Generation in Fiji
Hydro	52.37%
Fossil Fuel	46.6%
Solar	0.55%
Wind	0.48%

Hydro currently provides the majority of electricity supply for Fiji's main grids, primarily due to the mountains found in Fiji. Large scale wind generation is not being deployed, as it is difficult to maintain in Fiji due to the frequency of cyclones. Solar is a relatively cheaper and viable form of generation, but is scarcely seen in grid electricity generation, given the focus on hydro generation. A number of solar PV projects are being planned including a World Bank supported 15 MW system (Tsanova 2020).

The Government-owned utility Energy Fiji Limited (EFL) is responsible for transmission, generation and retail of electricity on the major islands of Viti Levu, Vanua Levu and Ovalau, accounting for around 90% of Fiji's population (EFL 2020). The off-grid systems that supply remote island communities are mostly provided through government or development partner programs, and usually government or community owned. Nand et al. (2015) state that 82% of rural dwellers have access to electricity, with solar home systems becoming far more popular. As a result of the Rural Electrification Initiative, 5700 solar home systems have been installed. Diesel generators are also heavily subsidised under the initiative, with 500 diesel generators based mini-grids being introduced since 1994 (Nand 2015).

Planning and investing in more resilient energy systems

Fiji is particularly vulnerable to climate change given its frequency to cyclones and low elevation above sea level. Dependence on hydro generation creates vulnerability especially in the dry season as Fiji frequently faces droughts, which increases reliance on expensive diesel generation. Stakeholders highlighted the advantages of solar PV generation with no ongoing fuel costs, and noted that there are efforts in remote areas for solar diesel hybrid systems.

Cyclones and floods are also prevalent in Fiji. In 2016, Fiji was hit by category 5 Cyclone Winston, which had devastating impacts on the country's infrastructure, destroying the equivalent of around 30% of Fiji's GDP (World Bank 2018). Actions to "build back better" has included increasing building standards to withstand extreme cyclones. These standards apply to all structures that face wind loads (outside of offshore structures and transmission lines) (Ministry of Industry, Trade and Tourism 2010).

Previous building standards required a tolerance to category 4 cyclones; however, these standards were not largely followed in rural areas (Aquino 2018). Standards were followed for compliance certificates for insurance purposes, but were not strict enough to be implemented in rural areas (Aquino 2018). Prior to Cyclone Winston, Fiji's National Building Code utilised Australia's building standards (AS/NZS 1170.2) (Aquino 2017). Under this standard, the load and resistance factor design (LRFD), for basic wind speed was 70 m/s. However, gusts from Cyclone Winston exceeded this with speeds of 82.7 m/s. As a result, it was not uncommon to see rooftops fly off houses (and hence rooftop solar with it). From this, a new rating standard was implemented, under the guidance of the reactivated Fiji Building Standards Committee. New infrastructure being built now has to be rated to withstand category 5 cyclones (World Bank 2018).

However, some new infrastructure is not meeting this standard due to financial constraints. To aid in implementation, the Fijian government provides financial assistance to help fund the building of more resilient infrastructure. For households earning under US$25 000, a prepaid card was provided to be used at retailers for building materials (RNZ 2016). The amount provided was up to $3500, and this amount was dependant on the damage felt from the cyclone. Support was also provided for transportation of materials to remote areas. However, the amount provided is insufficient to completely cover the cost of rebuilding to resist category 5 cyclones. Many individuals cannot afford to fund the remainder required to meet the standard.

Poor quality hardware was also noted as a key issue. Some stand-alone systems only last around three years due to poor quality components. Verification and inspection of components before implementation is recommended to reduce premature failures of energy systems. The pressure to rebuild infrastructure quickly and at low cost after disasters has resulted in contracts awarded to companies based on lower bids, further compromising the quality of rebuilt infrastructure.

There is a need to consider during the planning phase weather related risks in specific locations and how to protect infrastructure. One stakeholder noted that infrastructure was rebuilt in flood prone areas, without considering the threat of future flooding. Strategic placement of infrastructure could include raising infrastructure in flood prone areas to minimise the risk of damage and moving energy systems away from the coast to help mitigate the risk of floods cyclones destroying the systems.

One participant also noted administrative complexity of rebuilding under the new standards at the residential level. There are eight different authorities working on different aspects of the standards, which could not agree on the standards or relinquish responsibility when they did not have the capacity to complete tasks required, increasing the difficulty in implementation.

Overall, Fiji has set good policies for growth in resilience in the country. A strong national renewable energy target has been set, as well as the Rural Electrification Initiative, aiding in achieving the goal of 100% electrification in 2020. However, there is a lack of alignment between these policies and the financial capacity to implement these policies well, as seen with the new BBB standards.

Energy resilience and the political economy of off-grid solar

The Fijian government has various programs and funds to implement stand-alone power systems in remote communities. The Minister for Infrastructure, Transport, Rural and Maritime Development, the Hon. Jone Usamate, estimates around $157 million has been spent on rural electrification in the past 5 years, benefiting 25 000 households (The Fijian Government 2020). Currently, 17% of Fiji's population is dependent on stand alone systems, including solar home systems and diesel generators (Fiji Department of Energy 2020). Since 2016, around 5000 households have had solar homes systems installed, reaching a total of about 13,500 systems (Fiji Department of Energy 2020). Under the new Rural Electrification Fund, there is a target to electrify over 300 communities by 2036, with an estimated 17,000 households being electrified (Fiji Rural Electrification Fund 2020). In addition to this, the national budget has allocated a further $5.4 million for Solar Home System Programs in 2019/2020 (Krishant 2019). Under Section 5.2.1 of the Fiji National Energy Policy (2012-2020), electrifying unelectrified communities using least cost solutions has become a priority, utilising solar home systems in part to achieve this (Government of Fiji 2020).

However, designing these systems is very contextual and dependent on the community's need. As one stakeholder said, 'there is no one size fits all for these implementations'. In implementing electricity access programs, the government considers community size and needs, for example, if there are many households in a community, a mini-grid will be implemented. But, when considering only one or two households, standalone power systems will be used instead.

Given the need for energy to provide multiple services, energy resilience is a key part of broader community resilience. When a cyclone hits, housing, schools and water supply are all affected. This creates a strong economic and community incentive to ensure resilience and preservation of existing infrastructure to maintain the normal way of life (World Bank 2018).

One stakeholder noted that most challenges for the long-term success of electrification programs were not with technical design, but rather the social structure of the community and how this shapes the ability to maintain and pay for energy systems. There are cases in which an energy system is government owned, but the community claims it as their own and refuses to pay for it. This typically occurs when an influential member of the community refuses to pay energy fees and creates a domino effect within the community. In other cases, a member of communities has run for elected office claiming that if successful, no one would have to pay for electricity. Consequently, payment of fees would drop, and not enough money would be available to maintain the system. A pre-pay system, organised outside of the community and with control to shut down energy supply if fees are not paid, was recommended by one stakeholder to ensure payment.

Another stakeholder suggested that community ownership of energy systems could increase energy resilience. In particular, where there is a productive use of the energy (e.g., businesses being created), the community will be incentivised to maintain and collect sufficient fees to manage the system. Understanding the local communities needs and aspirations and aligning with the economic incentives of the community when planning electrification initiatives can create the buy-in needed to build energy resilience within the community.

However, energy planning should not be treated in isolation since complementary capacity building will be required for communities to build the awareness, skills and knowledge required to make a profit from these systems. One stakeholder noted that some communities that had developed a productive use for energy were worse off as the cost to buy and maintain the system exceeded the profits created from its productive use. Without support for small enterprise development including on how to sell products, as well as a market connection to sell products, the community will likely be disincentivised to use the system and pay for it.

Operation and maintenance are critical to ensure that energy systems continue to operate, even in the absence of shocks and stresses. This presents a particular challenge in remote areas. It may take several hours by boat to reach an island community in Fiji and can be even more difficult when affected by extreme weather events. Without access to external support, if communities do not have some capacity to maintain energy systems, they are more likely to fail before their expected lifetime. One stakeholder suggested that communities need to have the capacity to do their own operation and maintenance, including monitoring. Community engagement was highlighted by another stakeholder, as an important means of creating buy-in and commitment to operation maintenance and use of the system.

It was noted that Fijian communities are familiar with cyclones and floods and have built a resilient mindset overtime. They themselves can provide insights on how to survive these conditions.

To explore

- What incentives can be created for remote communities to motivate them to take responsibility for their energy systems?
- Are there any technical/financial innovations to reduce the financial barriers to resilient energy infrastructure?
- What technical innovations are there to ensure energy resiliency during and after severe cyclones?

6.2 Papua New Guinea (PNG)

Key statistics

Population	8.9M (UNFPA 2020)
Characteristics	1. Remote and rugged landscape 2. Lack of technical capacity and transparent decision making 3. Traditional community livelihoods
Renewable Energy Target (RET)	70% by 2030 (PNG 2017)
Electrification	100% by 2030 (PNG 2009)

Introduction

> *'PNG is blessed with both conventional and renewable energy resources in terms of gas, hydro, solar and biomass. With effective planning and access to capital it can continue delivering the energy the country needs through a climate-changed world.'*

This case study investigates the relationships between governance and remote community dynamics, finding that disconnection between high-level planning and local projects undermines PNG's potential to achieve electrification and resilience in parallel.

Figure 4: Off-grid village, Papua New Guinea

Overview of themes

Planning and investing in more resilient energy systems	*Community energy resilience strategies in response to disasters*
• Communities in PNG have been adapting to natural disasters for thousands of years • Government-led energy resilience strategies remain disconnected from community-level projects • Local champions and "billboard" households will facilitate widespread uptake of new strategies	• Resilience requires refurbished hydro and new solar, but LNG remains a political favourite • Planning for climate and resilience is being pegged on to a pre-existing energy access agenda • Diversified grid extension can see renewable energy objectives achieved whilst building resilience

Energy landscape

Despite boasting an abundance of renewable energy resources, including significant hydro potential (IRENA 2013), sustainable energy access has not historically been prioritised within PNG's energy sector (Independent State of Papua New Guinea 2017). This is changing. By 2030, the nation aims for carbon neutrality and the National Energy Roll out Plan (NEROP) targets 70% electrification (ADB 2018). Since 2010, PNG has experienced the fastest annualised increase in energy access across the Pacific. Now at 59% according to the IEA, half of the country's electricity is delivered through renewable sources (IEA 2020).

PNG's *National Energy Policy 2017 – 2027* identifies climate and weather, geophysical (volcanoes, earthquakes), environmental (erosion, desertification), and human (accidents, sabotage, technological failure) hazards as 'constant threats' that must be considered (Independent State of Papua New Guinea 2017). Despite an awareness around the increasing frequency of natural disasters and a tripling of energy demand between 2010 and 2030 (Independent State of Papua New Guinea, 2010), resilience is not explicitly prioritised within current NEROP proposals (The Earth Institute & Economic Consulting Associates 2017).

> *'Theoretically, PNG's energy resilience is massive. They have incredibly large reserves of gas. Hydro is cheap. You can do biomass and you can do solar. But the problem is getting the electrons from the point of generation to the point of end-use.'*

PNG represents an 'energy paradox'. There is abundant potential, but previous substantial rural electrification and SHS programs (beyond distribution of pico-products) have achieved limited success due to poor institutional capacity and community understanding (Sovacool, D'Agostino & Bambawale 2011). Many of these challenges will persist if and when programs shift to focus on energy resilience.

Planning and investing in more resilient energy systems

> *'PNG has wonderful policies. The first country to sign up for the Intended Nationally Determined Contributions (INDCs). All renewable energy by 2030 ... but there is a lack of mid-level effective bureaucracy to deliver.'*

Governing policies and plans – from energy to climate change – must align to the *Papua New Guinea Vision 2050*, which seeks to create a smart, wise, fair and happy society, with progress measured through gains on the UN Human Development Index (HDI). A focus area is 'Climate Change and Environmental Sustainability', within which community resilience is just one of many priorities

(Independent State of Papua New Guinea 2009). Electrification initiatives are underpinned by a goal of energy security; which is threatened by a reliance on imported petroleum, climate change and geophysical hazards (Independent State of Papua New Guinea 2017).

> *'PNG suffers from a legacy grid expansion philosophy, but for resilience and risk mitigation, you need a portfolio approach to generation.'*

Grid extension for 75% of those currently without access is currently viewed as the least-cost electrification pathway. For the remainder, isolated hybrid grids – "C-Centres" – (PV/diesel/micro-hydro) and remote SHS will be deployed (The Earth Institute & Economic Consulting Associates 2017).

> *'You can measure failures in resilience by the amount of diesel generators seen around town.'*

Survey responses indicate that poor governance and a lack of capital has limited PNG Power Limited's capacity to be proactive in its approach to electrification planning, and at best, resilience is pegged on to a pre-existing access agenda. This is a concern on two counts: it risks replicating past shortcomings of rural electrification efforts (Sovacool, D'Agostino & Bambawale 2011) and does not enable programs to build on the inherent resilience that already exists within communities (Maina et al. 2016).

Community energy resilience strategies in response to disasters

> *'At a community level the national government really is not there. You'll be struggling to find a police officer or a teacher …'*

PNG's community energy setting is uniquely challenging. Characterised by remote and mountainous landscapes, communities are defined by clan- and kinships rather than geographic boundaries. 'In many tribes, no word for "future" exists' (Sovacool, D'Agostino & Bambawale 2011) and communities are therefore not predisposed for mitigative action (Maina et al., 2016). This challenge is compounded by a general lack of technical capacity (IRENA, 2013).

In the second-half of the twentieth century, PNG experienced the highest number of natural disasters across the Pacific (Richmond & Sovacool 2012). However, archaeology shows that communities have thrived through volcanic events for 40,000 years; with traditional practices enabling their resilience to persist and gradually improve over time (Torrence 2016) through the process of adaptation. An example is the long-term trading of obsidian in the Willaumez Peninsula. Groups build social capital through exchange relationships, and therefore have access to a place of refuge post-disaster (Torrence, 2016). Similarly, in response to the compounding pressures of population growth and climate change in West New Britain Province, smallholder farmers are reverting to kinship-based land exchange relationships with neighbours as a risk-sharing mechanism (Koczberski 2018). These findings suggest energy resilience thinking must extend beyond geographic boundaries to leverage long-standing cultural relationships.

Between and within villages, household bonds strongly influence adaptive capacity. Families replicate the adaptive behaviour of others within their social network, and these networks are often clustered by common livelihood strategies (Barnes et al. 2020, Weir & Kumar 2020). To spark transformative action at the local level, energy resilience programs must appeal across clusters and work to preserve (or amplify) traditional practices that already bolster resilience.

The success of programs designed to improve energy resilience will also depend on acceptance among energy consumers (Sovacool, D'Agostino & Bambawale 2011; Gonzalez 2016). In turn, this is influenced by local power dynamics. Those 'in charge' may be resistant to initiatives which are perceived to threaten their current standing (Barnes, 2020). Securing leaders' support and on-siding 'local champions' (Furlong 2020) is likely to be important to facilitate uptake and maintenance of new systems.

> *'My view on how to implement energy development in PNG is small bottom-up projects. Once you have a beachhead of projects under non-government control, this creates the critical mass needed for roll out in a more coordinated way.'*

Community ownership is of particular importance in PNG, where there is a pattern of communities comfortably regressing to previous energy situations following a shock (Sovacool 2011). Although national agencies plan for homogenous and cost-effective electrification at scale, management actions will inevitably take place at the community scale. When outcomes are written in 'broad and administrative terms rather than in terms of the outcomes for system users', it becomes difficult to realise success (Urmee & Harris 2009). Even for geographically proximate villages, adaptive capacity and relative exposure to climate extremes can vary significantly (Maina et al. 2016). If energy resilience is deemed a priority for PNG, national planning must be integrated with and tailored to specific community needs or substituted for a community-led approach.

> *'Access to energy is a right for all. Whenever an energy choice is made, we should be cognisant of the fact that climate change is an issue.'*

To explore

- How can the technical capacity for solar and hydro be developed within government departments?
- How can traditional knowledge and resilience practices be integrated within planning?
- Can RE-powered mini-grids solve energy access issues for remote communities?

6.3 Tokelau

Key statistics

Population	1647 (Government of Tokelau 2019)
Geographical layout	3 atolls with a land area of 12 km^2 (IRENA 2013)
Characteristics	• Only access to the nation is by boat, with no airports • Average height above sea level is 3 m (Jorissen et al. 2019) • Susceptible to storm surges, cyclones and droughts (Lefale et al. 2017)
Renewable Energy Target (RET)	100% by 2012 (IRENA 2013)
Electrification	100% (IRENA 2013)

Introduction

In the face of climate adversity, Tokelau pioneered adoption of solar energy in the Pacific. In 2012, in the space of a year, the nation transitioned from relying solely on imported fuels to utilising almost 100% renewable energy to meet their electricity demand. This transition has been motivated by the concern of individuals and the Tokelauan Government towards the threat of climate change for the low-lying atoll nation (Guevara-Stone 2013).

> 'We stand to lose the most of any country in the world due to climate change and the rising sea levels, so leading the way by making the highest per person investment in the world is a message to the world to do something.' (Toloa 2004)

In 2019, sea levels in Tokelau reached their highest since the establishment of formal records. The accompanying risks are severe (New Zealand 2020). Storm surges that accompany tropical cyclones are already common and cause serious damage, capable of submerging entire portions of the small nation. The Government of Tokelau has identified tropical cyclones, severe weather non-tropical cyclone systems and droughts as having extreme societal impacts (Lefale et al. 2017).

Tokelau faces many unique challenges in meeting electricity demand and yet has pioneered a path to high renewable energy penetration, sharing knowledge and providing hope for other PICTs.

Overview of themes

Energy resilience and the political economy of off-grid solar

- Battery storage, and subsequent battery waste management, will be a crucial part of resilient electricity services
- Solar generation, storage and distribution infrastructure must be innovative in order to continually meet demand
- Climate change is important to consider for the longevity and resilience of energy systems

Planning and investing in more resilient energy systems

- Reliance on donor funding constricts the design of energy projects and implementation timeframes
- The government has a limited understanding of the complexities of energy systems and markets, undermining long-term success
- Financial constraints of small nation budgets result in maintenance on failure
- Tokelau's dependency on imported fuel presents huge financial and logistical challenges

Energy landscape

Tokelau is a non-self-governing territory and has been a New Zealand dependency since 1926 (Government of Tokelau 2020). The statutory position of Administrator of Tokelau is held by a senior public servant from New Zealand; however, the Titular Head of State (*Ulu-o-Tokelau*) is largely responsible for governing, with this position rotating between atoll leaders each year (Government of Tokelau 2020).

Tokelau's National Energy Policy and Strategic Action Planning (NEPSAP) set an ambitious target of achieving 100% renewable energy by 2012 (IRENA 2013). Created in 2004, the focus of the policy was to reduce dependency on imported fuel to become energy independent and the goal was reignited through the Strategic National Plan (2010-2015). To tackle the challenges of natural hazards, the government established Living with Change (LivC), a national climate change strategy, in 2017 with the goals of (Lefale et al. 2017):

1. Decarbonising development
2. Strengthening integrated risk reduction and adaption to enhance climate change and disaster resilience
3. Capacity building, education, training, public awareness and outreach

The Department of Energy (DOE) is positioned to oversee and advise on energy matters. Each of the three atolls have a *Taupulega* (village council) that own and operate the energy systems, and it is ultimately up to their jurisdiction to implement any of the DOE's recommendations.

To reach their goal, the Tokelau Renewable Energy Project (TREP) was installed in 2012, comprised of 930 kWp of PV and 8064 kWh of battery storage (Government of Tokelau 2013). The project was designed to provide 90% of the nation's electricity needs, and in the first two years of operation, was able to supply 100% of the electricity demand on certain days. Since then, electricity demand has increased, and despite an additional 30kW of PV installed on each island in 2016, there has been a reduction in renewable energy contribution. To elevate Tokelau to 100% renewable energy, the Tokelau Renewable Energy Expansion Project (TREEP) was set to be installed in 2020, but the COVID-19 global pandemic has halted operations. The TREEP will distribute a further 210kW of PV and almost 2MWh of battery capacity.

Energy resilience and the political economy of off-grid solar

A crucial factor for Tokelau achieving energy resilience is the reliability of generation, storage and distribution infrastructure. To do so, energy systems must be capable of consistently meeting demand regardless of shocks and stresses experienced by system. Tokelau has endeavoured to accomplish this through technical innovations in climate resilient measures, load growth projections, diversification and storage capacity.

The planning and installation of the TREP was recognised as a huge success, enabling Tokelau's transition to one of the highest PV contributions in the world. However, the system alone was unable to bolster to the resilience of the small nation due to inadequate distribution infrastructure. The TREP introduced 24-hour electricity for communities; however, consumer demand subsequently climbed rapidly and the infrastructure in place was not able to handle the increased load (Wier 2018). A project was initiated in 2015 to upgrade the distribution in villages to create redundancy by introducing a second power cable, safeguarding the system should one fail. In Tokelau, alongside the TREP, appropriate infrastructure capacity was required to increase the resilience of the energy system.

Solar PV has been utilised extensively in Tokelau’s energy projects due to its effectiveness, simplicity, reliability and ease of management. The rarity of technical issues experienced with solar, minimised through modular and robust installations, is crucial in Tokelau, with limited maintenance capacity. A stakeholder identified the uptake of solar PV in the Pacific to be 'the biggest and most efficient method of power generation other than using fossil fuels.’ With the prices of solar dropping, it is becoming cheaper and more viable as a large-scale renewable energy source. The world learnt many lessons from Tokelau’s challenges in design, implementation and ongoing operation. Despite these challenges, one respondent claimed, 'It was a landmark project, which paves the way for a lot of other projects of this scale across the South Pacific.’

However, the abundance of solar energy resource in Tokelau means there has been limited diversification in renewable energy generation methods. Despite each atoll harbouring its own mini-grid and significantly reducing the amount of imported fuel required (Raturi et al. 2015; Eras-Almeida & Egido-Aguilera 2019), variation in generation requires ‘a bit of lateral thinking and…daydreaming.’ A current project is underway exploring the feasibility of installing wind turbines on each atoll to provide a clean alternative generation method, as cloudy days in Tokelau are often characterised by strong winds. Diversifying Tokelau’s energy mix would ensure greater reliability and consistency in meeting the demand.

With an average elevation above sea level of 3 meters, climate change is at the forefront of energy planning in Tokelau, evident through their national climate strategy. This considers the resilience of the infrastructure, ability for community members to respond effectively to natural disasters and implementing measures that allow for adaption to future changes. For Tokelau, 'Renewable energy becomes part of climate change. As soon as you step away from fossil fuels, you are on a path to climate change prevention.’

One of the major challenges of energy systems in Tokelau is the tropical environment, necessitating long-term planning for the longevity and resilience of the systems. The frequency and severity of storm surges in Tokelau entails consideration into the placement, structural integrity and corrosion protection of energy infrastructure. Tokelau’s power station is positioned in the most resilient location to sea level rise, safeguarding for continued operation regardless of climate change impacts. In the past 50 years, major damage has resulted from 6 cyclones, and will continue to do so with the increasing frequency and intensity of the El Nino/La Nina cycles (Jacobs 2019).

To achieve energy independence, batteries are a crucial aspect of energy systems for remote locations. At night, Tokelau relies on batteries to supply the energy demand and reduce fuel consumption. However, battery recycling has been largely disregarded, with one interviewee commented, ‘I cannot tell you how many thousands of batteries are lying around the Pacific, not being recycled, simply because no one bothered with them. They use them as weights on the roof to keep the tin flying off.’ Careful consideration into battery recycling is needed to ensure that waste is dealt with and does not compromise the enhanced resilience batteries provide off-grid systems.

Planning and investing in more resilient energy systems

A significant challenge faced by Tokelau is a lack of financial capital required to install and maintain energy systems. As a dependency of New Zealand, Tokelau has means of obtaining funds; however, access to other sources of funding is limited (Wade 2004). This greatly constrains the planning and installation of projects, especially the implementation timeframe which is determined by the donor. As the TREP was an experimental project which had not been proven in remote locations such as Tokelau, the New Zealand Government was hesitant to provide funding, delaying the implementation several years. A dependency on donor funds inhibits Tokelau attaining energy independence due to a reliance on external parties, leaving them with indirect control over their energy infrastructure and implementation timeline.

The success of renewable energy systems rests in part on the financing model in which they operate. In Tokelau, the government has a limited understanding of the complexities of energy markets and pricing, resulting in poorly designed tariff structures. Although subsidised tariffs enable a widespread uptake of renewables, it simultaneously requires the government to have strategies in place to ensure the longevity and resilience of this pricing scheme (Eras-Almeida & Egido-Aguilera 2019). Even after the TREP was installed, expensive diesel is still relied upon at certain times.
The *Taupulegas* had the opportunity to collect tariffs for the expansion of the system; however, this was not carried out and unfortunately meant Tokelau was once again reliant upon the New Zealand Ministry of Foreign Affairs and Trade (MFAT) funding for the project. Conversely, the government has implemented strong energy policies, which aim to reduce the vulnerability of communities in responding to climate change related events, but more importantly, support the proactive implementation of resilience enhancing measures for Tokelau.

In Tokelau, 'Everything is two weeks away,' including maintenance assistance and spare parts. Further, due to the small internal budget of the Energy Department, repairs and upgrades are only undertaken when it is crucial or financially viable, establishing a 'maintenance on failure' approach. Limited by the local technical maintenance capacity, external expertise must be brought to the island. The remote and widespread geographical layout of Tokelau renders this a long and costly process, involving a 24-hour boat trip from Samoa. Dependence on imported maintenance capacity limited Tokelau's ability to become truly energy resilient, as a myriad of external factors dictate the when and how of this process. The COVID-19 pandemic has impeded the return of numerous Tokelauans, not only impacting the current energy landscape, but hindering the progression of the TREEP project. Under the current border closures, should equipment fail, it will remain unusable until such time the required parts or personnel are able to get to Tokelau.

Fuel dependency has been and continues to be a primary concern for Tokelauans, limiting energy resilience through their reliance on the external geopolitical and global economic context. One interviewee commented that 'Diesel is an expensive and logistically demanding source of fuel,' which accentuates the vulnerability of Tokelau in relying on it. Only one ship per month delivers diesel to each of the atolls, thus in the case of bad weather or the boat needing repairs, the communities just do not get diesel and instead must go without for long periods of time. The transition from diesel to PV has increased flexibility in energy generation and significantly reduced vulnerability, by primarily relying on self-generation capacity. Now, Tokelau spends merely 10% of their previous budget for diesel, creating additional funds for new projects and maintenance.

In their pursuit of renewable energy, Tokelau has attempted to harness the synergies between energy infrastructure, financing and policy. Although limited by financial capital, climate change and remoteness, Tokelau has accomplished a remarkable amount in their energy sphere.

To explore

- What role could electric vehicles play in reducing dependency and propagating the shift to a more sustainable community?
- How could Tokelau be assisted in their journey to energy independence through a financial framework?

6.4 Vanuatu

Key statistics

Population	0.3M (UNFPA 2020)
Characteristics	1. Highly vulnerable to climate disasters 2. Politicised and multi-stakeholder energy transition 3. Opportunities for increased gender equality
Electrification	70% by 2020 (ADB 2018)
Renewable Energy Target (RET)	65% by 2030 (ADB 2018)

Introduction

> *'Energy resilience forms the centre of our response to disasters. As we are consistently hit by Category 3, 4 and 5 cyclones, this term needs to be instilled in the minds of the local and off-grid communities - across all genders - to enable preparation.'*

This case study compares Vanuatu's top-down and community-level adaptation efforts, and how these have been shaped by three factors: politics, marketisation and the increasing prevalence of natural disasters. While the integration of local implementation efforts within high-level planning stands out as a relative success in the Pacific, Vanuatu's energy resilience is limited by a reliance on external funding and capacity support.

Figure 5: Norther coast of Efate, Vanuatu

Overview of themes

Energy resilience and the political economy of off-grid solar	*Community energy resilience strategies in response to disasters*
• Community power structures dictate the uptake and success of CER programs • A community-level resilience framework can integrate local priorities within national plans • Humanising energy project design enables continued success without external support	• The burgeoning off-grid solar (OGS) market is unlocking new opportunities for resilience • Limited internal capacity and lack of external trust creates a cycle of dependence, undermining resilience • Degrees of off-grid solar system resilience are increasingly governed by market factors

Energy landscape

Stretching 1200km South to North, Vanuatu is an archipelago of 83 islands, 80% of which are inhabited. Two major islands – Efate and Espiritu Santu – account for one-fifth of the population, with over 90% of electricity supplied by Vanuatu Utilities and Infrastructure Limited (VUI) and Union Electrique de Vanuatu Limited (UNELCO) (IRENA 2016). These private utilities manage and operate Vanuatu's government-owned power assets, with tariffs and tenders regulated by the Utilities Regulatory Authority (URA) (ADB 2018).

Vanuatu has no fossil fuel resources (JICA & TEPSCO 2017), yet diesel accounted for 77% of its grid electricity production in 2019 (URA 2020). Increased hydropower capacity saw diesel generation fall from 90% in 2009 to 56% in 2013 (IRENA 2015), but continuance of this trend and energy access are contending priorities within The People's Plan; Vanuatu's central policy framework (GoV 2016a). Both goals are operationalised by the Department of Energy (housed within the Ministry of Climate Change Adaptation) through the Vanuatu National Energy Roadmap (NERM). Initially released in 2013, the plan was reissued in 2016 subsequent to Cyclone Pam, taking a renewed focus on 'green growth'. The NERM looks to increase energy accessibility, affordability, security and reliability, whilst enhancing sustainability through increased uptake of renewable energy, energy efficiency and biofuels (GoV 2016b).

In addition to hydro, coconut oil and wind have contributed to grid diversification, but PV penetration remains a minor contributor. Grid expansion initiatives are largely enabled by external funding (JICA for hydro, European Investment Bank for wind and ADB for solar) (IRENA 2016; Munro 2020), as government- and utility-led initiatives have been marred by politicisation. The establishment of URA and introduction of VUI, designed to disband the power sector monopoly, failed to achieve outcomes in terms of electrification, with grid connection rates increasing only in line with population growth (Munro 2020). The marketisation approach – championed by AusAID – saw investment stagnate due to ongoing legal disputes around the tendering of concession areas. Conversely, marketisation of OGS has seen an explosion in uptake from 2.8% of households in 2009 to 64% in 2016 (Munro 2020).

In the past five years, Vanuatu has been hit by Pam and Harold - two Category Five cyclones. The latter sustained USD 1.5M in damages (GoV 2020), with urban distribution lines the most vulnerable of infrastructure assets. An increasing prevalence of natural disasters (Sovacool 2012) places another stress on the country's underdeveloped grid. To avoid the trap of playing catch up when rebuilding, the National Energy Services Cluster was activated in 2020 to focus on 'building back better'. This unit integrates energy-specific recovery tactics within centrally coordinated disaster responses, but survey responses suggest it operates with a predominantly urban lens. The disassembly and mobility of off-grid solar suits decentralised recovery efforts. However, for the 88% of the rural population not connected to the grid (VNSO 2017), it is important to ensure that rollout of these modular and disaster-resilient technologies is also deliberate in its goal of driving sustainable development and social justice.

Energy resilience and the political economy of off-grid solar

> *'The way that donors work doesn't generate resilience within ministries; there is a consistent dependency on outside technical capacity support. There are weaknesses in:*
>
> *a. the energy ministry's ability to design and take responsibility for the systems going out, and*
> *b. the donors having the trust in their local partners to run projects themselves.*
> *c. It is very much a chicken and egg scenario.'*

As with many PICTs, Vanuatu has been subject to numerous rural electrification experiments. In 2010, Lighting Vanuatu launched with a goal of delivering 24,000 solar lanterns via a supply-side subsidy. Two local NGOs, already active in the pico-solar market, were funded by AusAID under direct grants, and savings were passed on to consumers. The project was a quantitative success, providing double its expected target and catalysing the transition to OGS (Kelly et al. 2014; Walton & Ford 2020), but neither NGO maintained pico-solar operations beyond the program's completion (Munro 2020).

> *'In Vanuatu, projects are engineering-heavy.'*

Technical system quality is a vital aspect of energy resilience, but as one respondent noted, 'there is only so much resilience you can buy'. Once a technology has been deemed fit for purpose, deployment often remains seen as a problem of economics, rather than sociocultural elements. The Vanuatu Rural Electrification Program (VREP) (2016 – 2022) utilises a demand-side subsidy of 50% for 'plug and play' and 33% for larger SHS to accelerate rural electrification. Funded by the NZ Ministry of Foreign Affairs and Trade and administered by World Bank (GoV 2016b), the program is 80% of the way to achieving its 2020 target of 20,500 households (DOE 2019). However, the unintended consequences of marketisation are also at play. Communities of high demand are not synonymous with communities of high need. Munro (2020) found resellers were catering to urban customers, some already connected to the grid, and survey responses point out that vendors opt to operate within the 'grey areas' of product catalogues. These issues are annoyances, but when amplified by politics and bureaucracy within administering organisations, they distract from the opportunity to build community resilience.

Left unchecked, market mechanisms can enable the relatively rich to secure their own resilience while leaving the poor stranded. In 2017, Vanuatu acknowledged it was not on track to meet NERM targets and launched the Barrier Removal for Achieving the NERM Targets of Vanuatu (BRANDTV) project with GEF and UNDP. A lack of government presence (guidelines, standards and incentive policies), and local technical capacity for maintenance and repairs were identified as key problem areas (GEF 2018). These findings were strongly reiterated throughout all surveys. To address such gaps, a promotion program is rolling out village-scale demonstration projects, accompanied by training. If the government remains a common thread from design through to implementation, gender planning is mainstreamed and extensive community consultations are carried out as proposed, BRANDTV might see OGS unlock its true potential in terms of outcomes for both disaster resilience and social justice.

> *'With solar, it's always the pesky humans that mess things up. Stress-test by asking the question 'what can break it'? Then, work with the community to come up with solutions.'*

Community energy resilience strategies in response to disasters

> *'A lot of the work on resilience is project work by NGOs. Then you have communities being resilient more in their relationship with the NGO … but NGOs are not going to be there forever. The government is.'*

For Vanuatu, Cyclone Harold and Covid-19 are compounding disasters. The Vanuatu Recovery Strategy acknowledges that 'internal lockdown would heavily impact private and domestic sector participation in recovery', underscoring the importance of community resilience (GoV 2020). This is not an unforeseen scenario: Vanuatu is located within the 'ring of fire' and 'cyclone belt' (Sovacool 2012) and is one of the most at risk of PICTs in terms of capacity to respond to climate-risk (Bundhoo et al. 2018). In response, Vanuatu offered a world first certificate-level course in climate change and disaster risk reduction (Buliruarua & Hemstock 2018) and community-based adaptation, climate literacy and resilience-building have been embedded areas of focus for local NGOs and the Ministry of Climate Change Adaptation alike.

Climate risk is an international challenge, but its impacts are hyper-localised. The Vanuatu Community Resilience framework, developed by a consortium of local NGOs from 2012 - 2015, was successful in integrating community-scale DRR and CCA within national planning (SPC 2015). Figure 6 illustrates the eight tenets of community resilience, prioritised through a series of participatory community workshops.

Figure 6: Vanuatu Community Resilience Framework (Webb et al. 2015)

The foundation for this empowering framework was Twigg's (2009) 'Characteristics of a Disaster Resilient Community', but Ensor (2015) warns against conceptualising 'communities' in overly romantic terms. Community-based resilience projects often overlook gender issues (Twigg 2009), due to an underlying assumption that these entities are capable of fair decision-making. Recurring land disputes, endemic domestic violence and widespread marginalisation of less-abled peoples in Vanuatu highlight a potential for resilience-building initiatives to unintentionally sustain pre-existing social injustices (Ensor 2015).

> *'Power structures themselves are very resilient. Domestic violence is very resilient as a practice … and very harmful to building resilience within the community. Having half of a community living under threat is not conducive to being adaptive.'*

While program designers must heed Kastom (Vanuatu's traditional governance system), culture and custom are not set in stone. Local power structures shape local understandings of risk, but 'a focus on equitable decision making can support the emergence of ... future adaptive actions that benefit the whole community' (Ensor 2015; Barnes 2020). The Vanuatu Community Resilience Framework achieved this through the direct involvement of local staff and with access to untied funding over a long period of time. The former saw talent progress from the community level through to leadership positions in NGOs and the UN. Lines of communication and collaboration stayed open, keeping villages linked with national planners and now supporting an effective response to 2020's compound disaster. The latter enabled NGOs to act predominantly as sources of information, empowering communities to make effective decisions and maintain upkeep of their own assets. In the context of renewable energy, this approach also minimises the repurposing of technologies to suit real community needs.

Trust underpinned the success of this program: trust in local staff by NGOs, trust in NGOs by government and trust in government by international donors.

To explore

- Can the community-level capacity building programs championed by local NGOs be replicated to build capacity within government departments?
- Village-scale PV is a BRANDTV priority. How can pilot projects be designed to build community resilience?
- What renewable energy technologies are best suited for Vanuatu to achieve NERM targets in the context of increasing climate disasters? Pico-hydro and biofuels?

6.5 Tuvalu

Key statistics

Population	11,646 (UNFPA 2020)
Geographical layout	Nine atolls spread across 26 km^2 (DFAT 2020)
Characteristics	• Average elevation of 2 meters (Thaman et al. 2016) • Droughts, cyclones and floods are common (OCHA 2017)
Renewable Energy Target (RET)	100% by 2025 (Government of Tuvalu 2009)
Electricity access	98% (ADB 2018)

Introduction

Tuvalu is at the forefront of the climate crisis. With an average elevation of 2 meters, rising sea levels threaten to submerge the nation (Thaman et al. 2016); however, part of the Tuvaluan identity is resilience and resourcefulness (Steiner 2015). Tuvalu is characterised by limited land space for development, one of the lowest GDPs in the world and a plethora of extreme climate challenges (IFRC 2014; Bundboo et al. 2018). International aid has, and will continue to be, crucial in ensuring Tuvalu's adaptive capacity to such challenges (Mortreux & Barnett 2009).

The disparity between emissions production and the catastrophic impact of climate change for a nation such as Tuvalu is alarming. Despite being one of the smallest nations in the world, Tuvalu will disproportionately experience the effects of climate change (Toloa 2004). Tuvalu have taken charge of their renewable energy transition, implementing an ambitious RET, energy efficiency measures and energy education programs.

Figure 7: A cyclone-damaged building in the South Pacific

Overview of themes

Community energy resilience strategies in response to disasters	*Energy resilience and the political economy of off-grid solar*
• Engagement and understanding of the community regarding energy systems dictates their effectiveness and success • Community champions drive excitement and development of renewable energy projects • Security and availability of electricity supply is needed to ensure community energy resilience	• Renewable energy systems displace fuel to reduce external dependency on global geopolitical and economic context • Local capacity building is crucial, although difficult, as technically skilled individuals often emigrate • Coordination between donors and separation from political agendas is required to streamline implementation

Energy landscape

Tuvalu is a constitutional monarchy with an elected Government supported closely by the *Kaupule* (Island council) who preside over judicial matters (UNDP 2011).

In 2009, the government introduced the *Tuvalu National Energy Policy* (TNEP), with an ambitious goal of achieving 100% renewable energy by 2025 for electricity generation and a 30% increase in energy efficiency (Government of Tuvalu 2009). The goal of the policy is "to improve the well-being of the Tuvalu people by promoting the use of its renewable energy resources and implementing cost effective, equitable, reliable, accessible, affordable, secure and environmentally sustainable energy systems." This follows on from Tuvalu's *National Strategy for Sustainable Development* (Te Kakeega II), established in 2005 to increase the uptake of renewable energy (e8 2009).

Tuvalu has an electrification rate of 98%, all of which is supplied by the state-owned Tuvalu Electricity Corporation (TEC) (ADB 2018). Prior to 2015, electricity was only available for 18 hours per day (excluding the capital, Funafuti), and on occasion, an even shorter period (Cole & Banks 2017). In 2015, renewable energy supplied an estimated 22% of the 2.1MW peak load (ADB 2018) and energy projects are currently underway to boost this further (MFAT 2016). As of 2018, the New Zealand and Abu Dhabi governments have funded a total of 1.5MW of solar, and a further 1MW of solar, wind and battery storage are being financed by the World Bank (ADB 2018).

Community energy resilience strategies in response to disasters

One measure of the resilience of energy systems is the extent to which the community understands and interacts with them. The 'sustainability of energy projects largely depends on the degree of acceptance within its host population' (Gonzalez et al 2016). Therefore, ensuring the community embraces the project is paramount in its prolonged success. In doing so, greater autonomy on decision making and community level communication is achieved, strengthening adaptability and response to abrupt change (Hills et al. 2018).

> *'Part of the problem is the people themselves, because they don't recognise what is going to happen in the long term because they don't have experience with that particular thing, especially storage.'*

Communities do not have an innate understanding of the role and operation of new energy systems within their village, and this dampens their desire to work with the technology. Leveraging the synergies between renewable energy and energy efficiency measures can have transformational impacts, thereby ensuring the longevity of systems (IRENA 2018).

Community champions, dedicated to invigorating excitement for change, is one effective mechanism to catalyse the local shift to renewable energy and energy efficiency. In this regard, many respondents recognised and commended the work of Mafalu Lotolua, General Manager of the TEC, who has been campaigning for Tuvalu's achievement of their RET. With limited Government level capacity for renewable energy deployment (IRENA 2013), it becomes the passion and drive of individuals that incites change.

'Politicians often don't understand RE, but appreciate the political value.'

With an increasing climate risk, effective energy policy becomes imperative to harnessing the synergies of renewable energy and energy security for improved resilience (Raghoo et al. 2019). Despite being a key aspect of Tuvalu's national energy policy, limited public awareness surrounds energy efficiency measures (IRENA 2013). This emphasises the need for proficient and technical individuals – such as community champions – to inform key policy decisions and represents an opportunity for upskilling at the community-level to promote energy resilience.

Access to a consistent energy supply underpins community energy resilience. Renewable energy is reliable and accessible, offers a low cost of energy and an approachable technical learning curve. Together, these factors can mobilise communities in the direction of independence (and resilience). For Tuvalu, batteries are a fundamental component of energy systems, as the nation is still reliant on diesel for night-time energy production. To minimise the impacts of cloud cover, Tuvalu has implemented distributed solar augmented with centralised battery storage to secure a sustainable and available electricity supply. Furthermore, the size of the systems in the TUVESDP have been prescribed through studies of the electricity consumption on Funafuti to ensure they do not fall short of the needs of the community.

To establish a community with the ability to dynamically and adaptively respond to challenges and change whilst maintaining living conditions, energy planning must incorporate the insidious impacts of climate change (Bundhoo et al. 2018; Hills et al. 2018). In 2015, Tropical Cyclone Pam displaced families and communities across some Tuvalu atolls, disrupting access to power supply and interisland communication (OCHA 2017). This event illustrates the need for robust systems that continue operation in the aftermath of climate disasters.

Energy resilience and the political economy of off-grid solar

The biggest concern for Tuvalu regarding their energy supply is a reliance on imported fossil fuels. This renders Tuvalu vulnerable to external factors and shocks in the economic sphere (Cole & Banks 2017). Shipping is subject to disruptions and unforeseen challenges, and without a guarantee of a resilient supply chain, the security and availability of energy systems is jeopardised. Currently, the eight outer atolls are powered by hybrid PV-diesel mini-grids, requiring constant diesel shipments (MFAT 2016). Renewable energy systems displace fuel, reducing exposure to geopolitical factors and limiting outages due to fuel shortages. The TUVESDP will represent the first solar arrays in the country exceeding 150 kWp, the installation of which will mitigate the extremely high cost of transporting fuel to the nation and between atolls.

'Maintenance capacity is always an issue. If you train someone in a particular skill, that can be easily exported.'

A lack of energy system operation and maintenance experience compromises resilience across PICTs (IRENA 2013), but capacity-building in a population of just over ten thousand is a unique challenge that somewhat necessitates external technical assistance. However, with only three flights per week, this is both expensive and logistically problematic, resulting in poorly kept energy systems that are not maintained to standards or regularity. Development of equipment that can be better supported with local capacity and only limited remote support will ensure longevity and lower costs, strengthening resilience.

Tuvalu has attempted to address this through high level 'roadmaps', aiming to encourage more examples, such as that of New Zealand, of aid being delivered in a manner that bolsters national priorities (Allen & Clarke 2017). Without this, there is dissociation between the political intentions of donors, and the specific needs of the community. This is crucial to avoid conflicts in timing, overlap of scope and ensuring common technical specification to streamline implementation.

To explore

- What management processes could be implemented to avoid conflicts of timing, technical scope overlap/gaps and consistent technical specifications in donor projects to streamline implementation?
- How can local utilities be better equipped to maintain and manage technical assets over their lifetime?
- How might we harness the infectious energy and excitement of Mafalu Lotolua to increase a sense of ownership over community RE assets?
- How might we grow more Mafalu's in Tuvalu and the Pacific?

6.6 Australia

Key statistics

Population	25.7 million (ABS 2020)
Geographical layout	• Diverse range in geography including: • Mountains • Flat terrain • Desert
Characteristics	• Prone to natural disasters (e.g floods, bush fires) • Dense urban centres and remote communities • Abundant renewable energy potential
Renewable Energy Target (RET)	NSW, QLD, VIC: 100% by 2050 SA: 100% by 2030 (Green Energy Markets 2019)
Electrification	100%

Introduction

Australia is a vast country with most of its population residing on the coast and in major cities. However, there are also remote communities, and many faced an intense 2019/20 summer season with devastating bush fires. The effects were felt long after the fires took place, as homes, infrastructure and community assets were lost. Seventeen million hectares were burned across Australia and over 3,000 homes lost (Richards 2020) On December 31st, Essential Energy, the Distributed Network Service Provider serving regional and remote NSW, had 37 000 consumers without power. After an enormous effort to bring energy supply back to these communities, 25 000 of these energy consumers had energy supply again by January 3rd. However, given the scale of these bushfires, a further 35 000 energy consumers were affected again in the following week (Lewis 2020).

Figure 8: 2019/20 bushfires Australia, aerial view

The *Royal Commission into National Natural Disaster Arrangements Report* (2020) did not outline energy resilience in the recommendations from the 2019-2020 bush fires. However, Recommendation 9.4 *Collective awareness and mitigation of risks to critical infrastructure* outlined the need to identify critical infrastructure, assess risks, understand how to mitigate these risks, make this infrastructure more resilient and track progress in achieving this with an agreed upon plan.

These events highlighted community dependence on vulnerable infrastructure assets, revealing how energy legislation has overlooked the importance of energy resilience.

Overview of themes

Community energy resilience strategies in response to disasters	*Planning and investing in more resilient energy systems*
• Community engagement is needed to ensure the longevity of energy systems • Community representation and understanding community energy usage is important for the long life of energy systems	• Changing Federal policy in the energy sector to include energy resilience is needed for communities to maintain energy supply in disasters • Mini-grids and standalone power systems (SAPS) offer a pathway to energy resilience • Encourage mobility and flexibility in energy system infrastructure, to relocate safely in extreme weather events, may minimise damage to infrastructure

Energy landscape

Australia's energy landscape is shaped by Governments Federal and State in terms of policy, with rule making by the Australian Energy Market Commission (AEMC), regulation through the Australian Energy Regulator (AER), and power system and gas network operation undertaken by the Australian Energy Market Operator (AEMO) and various distribution and transmission network service providers. Approximately one-quarter of Australia's energy supply is renewable (hydro, solar and wind) (Clean Energy Council 2020), with the remainder produced by black and brown coal and gas.

Despite Australia's National Energy Market (NEM) boasting a 99.998% reliability standard for energy supply (AEMO 2018), until recently, there has been minimal focus on energy resilience or support for remote communities within the context of large-scale natural disasters (Howell 2020). Following the bushfires, a rule change was introduced to encourage DNSPs to operate mini-grids where it is economically efficient to do so (AEMC 2020). By reducing reliance on disaster-vulnerable transmission lines, this will increase energy resilience.

Planning and investing in more resilience energy systems

Many remote communities were ill-prepared for the scale of Australia's recent bush fire crisis. Preparation and risk mitigation were rarely considered within the context of energy**,** and when poles and wires were downed, it took time to repair these systems. The majority of communities are reliant on this infrastructure for energy, and in response, NSW DNSPs implemented new risk mitigation strategies:

- Helicopter patrols and high-resolution imagery used to locate potential hazards to transmission lines (AusGrid 2020)
- Increased inspection of private property poles and wires

- Waiving reconnection fees and offering bespoke advice for grid reconnection (Bushfires and Our Network 2020)

Another factor is the potential for poorly maintained poles and wires to start or propagate bushfires, but stakeholders highlighted a challenge in that maintenance labour is intensive and expensive.

A unique disaster response initiative was the short-term electrification of impacted communities through stand-alone power systems. The Resilient Energy Collective (funded by Mike and Annie Cannon-Brookes) was established to rapidly deploy solar and battery systems within bush fire effected communities (Resilient Energy Collective 2020), helping energy providers implement safe sources of energy in the aftermath of the crisis. However, this initiative was met with issues in that the DNSPs resisted the necessary legislative change for such systems to be introduced. Reportedly, a lack of DNSP control over these systems would limit DNSP's capability to address system breakdown, but there was also a financial disincentive; standalone systems take business away from DNSP infrastructure. To add to this, from a legislative perspective, SAPS being implemented are currently subject to the jurisdiction of states and territories, which may not have appropriate consumer protection due to lack of experience and penetration of these systems (AEMC 2020). As a result, only a few systems were set up under this initiative, but there is future potential for DNSP-implemented standalone systems, as some cases are economically efficient, and several Australian Government programs are supporting such an approach such as the Federal Government's Regional and Remote Community's Reliability Fund (Maisch 2019).

At present, there is a risk that the energy interruptions caused by the 2019/20 bushfires will be repeated in future bushfire seasons. One interviewee emphasised the importance of increased flexibility and mobility in community energy supply. Community mini grids – contributing to a broader palette of energy sources – has the potential to enhance resilience to extreme climate events through diversifying energy supply. Another stakeholder supported this view and stated that energy resilience should be distributed rather than centrally managed energy. Having a distributed system allows energy supply to be maintained for most energy users if there is a point of failure, rather than every user being affected in a centralised system, as experienced in the recent bushfires.

Furthermore, a stakeholder suggested that if a system can be packed up and deployed quickly, it can be moved out of harm's way during disaster events and relocated for essential services immediately afterwards. One stakeholder summarised this by saying 'Work around the climate, not against it'.

Overall, to see effective change for these communities, a stakeholder suggested strong federal regulatory change for energy resilience in Australia. Small communities alone struggled to deal with the scale of the bushfires. A focus on energy resilience can mitigate the effects felt by natural disasters. There is also no focus on sustainability in energy supply legislation. As stated by one stakeholder, 'energy resilience needs sustainable access'.

Community energy resilience strategies in response to disasters

Mini-grids and SAPS creating energy resilience through diversification of energy supply and mobility has been established. However, the operation and maintenance (O&M) organised by the community is equally important to ensure a holistic approach to energy resilience. In this section, understanding how the gaps in knowledge of energy systems inhibits community resilience, and increases the risk of technical failures, will be explored. In addition to this, understanding how to break financial barriers in the community to support O&M will be discussed, to demonstrate creating stronger energy resilience.

In isolated communities, operation and maintenance of energy systems is often difficult. If a component breaks down, it may require a trained technician to travel long distances to resolve the problem. The problem is further exacerbated in extreme weather where fires or floods block road use. A stakeholder suggested that community involvement can increase the lifetime of the system and minimise the risk of a system break down.

The stakeholder noted energy resiliency is essential in remote access communities and is equivalent to energy systems meeting or exceeding their expected lifetime. They stated that they had seen many 'dead pilot systems' that have been set up with good intentions but were poorly maintained and thus failed before the expected lifetime. Some key errors that result in this include:

- Poor community engagement and education around how to maintain the system and ask for help when needed
- A lack of consumer understanding around energy limitations on systems, resulting in depleted batteries and reduced component lifetimes (e.g air conditioning usage)
- Using low quality components which are cheaper but are more likely to break down and incur significant repair costs within remote communities.

Within rural communities, often characterised by low levels of income, regular maintenance is a challenge and one that can depend on the prevailing socioeconomic climate. This issue was addressed by the Bushlight program (Bushight Program 2012), which provided energy systems to Indigenous communities in Australia. To prevent excessive battery discharge, an energy management unit (EMU) was used to inform consumers of energy usage within a daily energy budget. If this budget was exceeded, only essential circuits (such as refrigeration) were prioritised and kept on after the limit had been met.

Participants under the program also paid a small fee to a community trust, which was set up to ensure financial coverage of maintenance in the event of breakdowns. The trust was managed by a community board, which represented the community's views. This program offers learnings in how program designers might embrace the 'sociotechnical' opportunities of community-owned renewable energy systems.

To explore

- How can we increase flexibility and mobility of energy systems prior to disaster events?
- How might we better integrate the themes of resilience and sustainability within energy supply legislation?
- Within the remote Australian community context, what is an appropriate focus to increase the lifetime of energy systems?
- What would Federal regulatory change in energy resilience look like for Australia?

7. EMERGING THEMES

7.1 Responses to Unprecedented Disasters

A pattern of forced innovation in policy in response to disasters has been exemplified in multiple Pacific countries. Unprecedented disasters are a motivator for significant change in policy. They demonstrate the need to rectify any failings in energy resilience policies, and act as a catalyst to shape new policy directions, resulting in a top-level change in planning.

Fiji is a clear example of this with BBB policy. Before Cyclone Winston, standards and regulations were not designed for infrastructure to withstand category 5 cyclones (World Bank 2018). After Cyclone Winston hit Fiji, strengthening building policies to ensure that resilient infrastructure was being built became a priority. Consequently, funding for this was increased from $89 million to $359 million FJD (World Bank 2018).

Similarly, Vanuatu has also reoriented their policies after experiences with disasters. The *National Energy Road Map* (NERM), initiated in 2013, had goals of moving towards renewable electricity production and away from fossil fuels (GoV 2016a). However, after cyclone Pam hit in 2016, the plan was reissued under the banner of 'green growth', increasing efforts to address the energy trilemma (security, equity and sustainability).

Although Tokelau has not had any devastating cyclones recently, their government is aware of the long-term effects of climate change. Tokelau is especially vulnerable, given the average elevation of Tokelau is only 3 meters above sea level and experiences frequent storm surges. In response to this, resilient energy infrastructure is presently considered, including increased storm surge protection via strategic location in a resilient area, as well as preparing the community's ability to respond, and allowing for future adaptations in planning.

However, this pattern of policy innovation was not apparent in the Australian government's recent bushfire response. Remote communities are largely dependent on centralised systems for their energy supply, as micro-grids are not supported well within current regulations (AEMC 2020). As discussed in the Australia Case Study, policy has been slow to change. Distributed Network Service Providers want their infrastructure to be used, rather than focus on mini grids which minimise the need for their investments. A conflict between financial incentives in the industry, towards energy resilience, has hence been created.

PNG recognises the effects of climate change as a threat for the country. As part of PNG's National Energy Roll Out Plan (NEROP), the country is aiming for carbon neutrality and 70% electrification by 2030 (ADB 2018). Climate and weather are noted as constant threats and will likely triple energy demand between 2010-2030 (The National Energy Policy 2017-2027). However, resilience is not a priority according to NEROP proposals (The Earth Institute & Economic Consulting Associates 2017).

7.2 Technoeconomic Capacity in Governments

To ensure energy resiliency, national governments need to have financial means and technical understanding to achieve policy goals in practice. Unfortunately, there are examples in the Pacific region where policies are not well supported, and energy resilience goals are unable to be met.

To implement tariffs well, strong strategies are required to ensure that schemes last and are resilient (Eras-Almeida & Egido-Aguilera 2019). However, this was not seen in Tokelau as the government had limited understanding of energy market complexities. Subsidised tariffs were used to encourage renewable generation but were poorly strategised to support these energy systems. In addition to this, the *Taupulegas* did not collect the tariffs for the intended use. This lack of finances resulted in a reliance on donor funding and diesel generation, reducing energy resilience for Tokelau. However, it should be noted that the Tokelau government has implemented energy policies aimed at reducing community vulnerability and the implementation of resiliency measures.

Fiji is known for creating strong policies. However, there is difficulty for Fiji in implementing their policies. For example, BBB policies are limited by a financial barrier. As noted above, the government has increased funding for building new resilient infrastructure. However, it is not enough to cover the entire cost. As Fiji is a developing country, some stakeholders cannot afford to fund the remainder of the build. As a result, the new standards are not being met and this infrastructure is not fully equipped to deal with category 5 cyclones.

Similar to Fiji, PNG has a lack of means to introduce changes from newly established policies. The PNG Government is enthusiastic in sustainable energy policy, but one stakeholder noted that 'the government puts policy in place in PNG, but there is no mid-level effective bureaucracy to deliver. There's a political statement and on the ground nothing changes.' Although policy changes are made with good intent, there is minimal support available from the government to effectively implement them.

It should be noted that PNG is also limited by slow policy work. A rooftop solar program has been on hold, and further limited by COVID-19, for two years. There have also been experiences where implementation of new renewable energy projects, even when reported as the lowest LCOE of available options, has been stalled by government actors. A lack of capacity, or conflicts of interest, within the government limit the implementation of renewable energy and hence diversity in energy supply, which is essential for energy resilience.

In Vanuatu, some ministries do not have the capacity to scope energy projects. When there is a limited budget, companies who bid on tenders will forsake energy resilience for a cheaper bid. As one stakeholder stated 'budgets are capped. There is only so much resilience you can buy'. This limited scope may result in some bids not even providing technical specifications. Ultimately, this financial barrier undermines energy resiliency for Vanuatu. However, a focus on energy efficiency in community energy resilience has been recommended and is a viable means to increase resilience, especially when budgets are constrained (To 2019).

7.3 Transitioning Energy Systems Towards Resilience

The Pacific relies on fossil fuels for more than half of its energy mix. This is an uncomfortable reality in the context of climate change, but for states like Tuvalu, the reliance on transborder supply chains also represents a significant barrier to energy security. Fuel shipments, across and within borders, particularly for remote communities, is logistically difficult and costly. PNG, even with plentiful local fuel reserves, demonstrates that the same challenge eventuates in-country due to last-mile delivery challenges. Ambitious RETs are now driving a rapid energy transition and while each has a unique energy plan and technological pathway, PV is the prevailing choice for PICTs; the plummeting cost curve and flexibility in deployment cannot be paralleled by large and bespoke infrastructure projects. Even for those with opportunities for further diversification, namely Fiji, PNG and Vanuatu via hydro and biomass, PV dominates electrification pathways.

For Fiji, where hydroelectricity accounts for more than half of the grid's supply, an increasing susceptibility to droughts threatens resilience, with diesel generation capacity required to ensure redundancy in dry periods. Vanuatu has had a similar experience, where hydro was ineffective in displacing diesel over the long term. Initially boosting the share of renewables to the grid, lower costs then enabled communities to shift higher up the energy ladder. Demand soon outstripped supply and the nation regressed to diesel dependence. In Tokelau, the same 'stress' of increased demand was observed, but the choice of PV enabled new capacity to be added faster. The inherent modularity of PV enables this technology to bypass the inhibitive upfront costs associated with new hydro projects. Such flexibility could be leveraged further through decentralised deployment; however, large-scale grid-connect projects tend to be favoured. Energy transitions are tied to the context of the energy landscape in which they take place. Legacies of past experiences overshadow the potential for new technologies to achieve electrification targets alongside enhanced community development outcomes.

Grid-extension, while it can be cost-effective and technologically sound, limits opportunities for community ownership, innovative tariff structures and mobility during disasters. From Australia's bushfires to Cyclones Pam, Winston and Harold; transmission and distribution systems are repeatedly found to be a key point of vulnerability. Downed transmission lines can devastate entire communities, with restoration efforts requiring trained professionals and taking days, weeks or months depending on the remoteness of the community ('everything is two weeks away in Tokelau'). The alternative - SAPs - are thus gaining consideration among energy professionals across the Pacific. Experiences in Tuvalu show that ground-mounted systems can withstand cyclones, but in the aftermath of disasters, mobility and modularity are characteristics of crucial importance. In Australia, some new systems have been designed for rapid deployment and redeployment, and in Fiji, community energy assets have been built to be dismantled and stored away prior to disasters.

For the transmission lines and hydro that are already vital components of national electricity grids, a shift towards resilience will be actualised when authorities overcome the 'maintenance on failure' mindset. Fiji has shown that, despite strict legislation around infrastructure standards, a lack of finance in the chaos of rebuilding means that opportunities to build back better are missed(I16). Thus, disaster preparedness and disaster risk reduction are equally important. New techniques implemented by Australia – such as helicopter patrols for hazard identification – are costly (AusGrid 2020). In Tokelau, redundancy has been achieved through a second distribution cable. A more replicable approach is to focus on strengthening the weakest points of transmission systems pre-disaster, when the luxury of time for planning still exists. This, and explicitly including quality assurance as a requirement in new tenders, will prove to be cost-effective in the long term.

There is no singular path to resilience in designing energy systems. Fossil fuels and biomass are dispatchable, but difficult to transport. SAPs are modular and flexible, but undermine traditional business models and technological roadmaps. Considering vulnerability to disaster in asset and infrastructure investment can shift the economics to favour modular solutions, however, overcoming institutional inertia remains a challenge for many PICTs.

7.4 Overcoming Institutional Inertia

Power outages in Australia are a rarity, but bushfires in the 2020 holiday period saw tens of thousands of residents spend days without electricity (Lewis 2020). In response, the Resilient Energy

Collective (REC) developed the technical and organisational capacity to restore supply within hours, through rapid roll-out of modular solar-battery systems. Proof-of-concept for SAPs was established, demonstrating value as a community resilience asset, but legislative barriers remain as a hindrance to uptake. This case study shows that progress can be made despite institutional inertia, but requires an influential individual or funding body, as highlighted by interview responses in Australia, Tuvalu and Tokelau. These actors are responsible for driving significant change, but in doing so, gain an inordinate degree of control over a region's energy future, and therefore resilience. The same pattern exists with donor funding and progress becomes dependent on the funder, rather than on society as a whole and its governance.

Vanuatu offers an alternative pathway. Working within communities, a consortium of local NGOs cocreated an energy resilience framework. The involvement of village-level leaders as staff members enhanced uptake, and as the framework gained traction, it was integrated within progressively higher levels of government. This is a unique example of planning that has filtered up, rather than down and the approach has potential to be replicated in technological interventions.

Where geopolitics, powerful incumbents, technological capacity, financial mis-incentives and sticky legislation compound to inhibit government-led progress, community projects can effectively garner the local support needed to build a groundswell for change. Private funding and marketisation are the key enablers, but as above, the former has potential to create a reliance on the donor and the latter brings barriers to access for the most vulnerable, as observed in Vanuatu's NREP. Emphasis must therefore be placed on community-led transitions, necessitating flexible funding over longer periods of time. When communities view their energy assets as productive it unlocks the 'billboard effect'.

PNG respondents were particularly vocal in advocating for this bottom-up approach, but these calls for action are often based on the assumption that proof-of-concepts and community level action will expedite change at the government level. In much the same way that PICTs are leading on climate action in the hope that others will follow, it is ultimately the responsibility of governments to listen and act on community needs. Only Tokelau reports a conducive connection between ministerial leaders and its communities, and for a state of less than 2000 people, they have an advantage in this area. This research shows that onus is on governments to listen. If not through community groundswell, progress towards resilience will be forced by disaster events.

7.5 Complexities of Donor Policies and Foreign Aid Energy Projects

Many PICTs have limited capacity to meet the capital cost of energy infrastructure as a result of their small national budgets. As a result, donors and foreign aid funded projects are prevalent in these nations and in many cases, unavoidable due to the limited budget channelled into energy projects.

There is a fundamental concern for assets where capital costs were fully subsidised by agencies who then assume responsibility for operation and maintenance. Many of the energy projects in Tokelau, for example, are funded by MFAT but are owned by each village. This establishes a sense of possession and an urge for upkeep. Similarly, in Fiji, community ownership inaugurates productive uses for the systems, thereby incentivising community involvement to ensure its longevity. Management actions towards energy infrastructure in PNG is implemented at a community level, emphasising the significance of community ownership to enable fast disaster response.

The product of perpetual aid is dependency. In Tuvalu, innovative and large-scale solar systems were introduced, with increasingly complex maintenance requirements. This effectively substituted dependency on fossil fuels for a dependence on external maintenance capacity. Likewise, Vanuatu is reliant on outside technical support, and donors often implement systems without lending ongoing maintenance assistance for the community. In Fiji, energy systems are framed such that they provide a productive use for the community, hence along with a market connection outsider their immediate village, individuals need to gain an understanding of the systems to make profits.

Furthermore, with knowledge of impending aid, there is limited drive to become financially self-sufficient. For example, the Tokelau Renewable Energy Expansion Project was originally intended to be part Government funded; however, the long-term financial scheme established to collect the required funds was unsuccessful and subsequently the expansion was again reliant on MFAT funding.

This is further exacerbated when governments are bypassed by donors entrusting development banks, rendering the community reliant on the donors in place of their government. Vanuatu exhibits the need for trust to cultivate success through the Vanuatu Community Resilience Framework, which saw each stakeholder involved maintaining open communication between the community, NGOs and government. Yet, without this trust in local partners to run projects, there is limited success for donor projects.

In conjunction with donor funding comes mismatched aid. In Tuvalu, this is in the form of numerous inverters, control systems and technologies to be assimilated into existing systems. More broadly in the Pacific, different countries and places are at a different point in the energy journey. Some have little to no infrastructure and projects are targeted at improving energy access, whereas others are investigating large-scale generation and storage to diversify and strengthen their energy supply. An understanding of the unique needs of countries is crucial to ensure it meets the needs of communities, avoiding projects that aim 'to maximise numbers rather than maximise quality'.

7.6 Community Participation Fosters Success of Energy Projects

The participation of key community members and local stakeholders is paramount to cultivate and encourage energy resilience. Many case studies identified the value of 'local champions' in initiating a community level drive for renewable energy uptake. In doing so, they have laid a path forward for the widespread adoption of sustainable electricity generation. Tokelau utilised a student's poster competition to equip local kids with an understanding of energy saving measures and empowered them to assist their families to save electricity. In doing so, Tokelau achieved a 5% national decrease in energy demand for a period of three months, highlighting the power of individual's actions.

The concept of a 'billboard effect' is prevalent across the Pacific. Instead of imposing a technology on communities, you allow the organic uptake amongst neighbours and peers. In PNG, individuals see the work and success of energy systems around their communities and are encouraged to take action of their own. To achieve this, however, the projects and systems must be culturally sensitive and appealing to the whole community. When carried out successfully, this catalyses a 'domino effect' of resilient projects. Tokelau has employed this response to their advantage, replacing all streetlights with solar powered streetlights with conjunctive battery storage, precipitating interest in renewable energy amongst the villagers. Fiji is an interesting example of how the 'billboard effect' can operate in reverse, where communities often claim ownership of government energy system and refuse to pay for them. As a result of influential citizens refusing to contribute, quickly all members of society follow suit and likewise refuse to pay. Consequently, fees have to be lowered, sabotaging maintenance procedures due to a lack of funds.

Interviewees commented on the resilience of political power structures. Program designers must therefore consider the role of community politics and customs in dictating the successes and shortcomings of energy initiatives. This introduces a question around the best way to use power structures to enhance uptake and ownership of energy systems. For example, power structures in Vanuatu are one of the contributing factors to longstanding trends of domestic violence, prompting a debate around dismantling them for the sake of social justice. Conversely, working with local leaders can see new systems promoted and incorporated within daily life.

There is a need for community engagement to secure the success of energy systems. In the context of Tokelau and Tuvalu, 'the core of any resilience is at the community level'. As the provision of energy is so important to these communities, it brings them closer to achieving not only equity and equality, but also to maintain contact with the outside world, have a higher quality of life and gain access to basic needs such as refrigeration. Likewise, for Fiji, people want to preserve normalcy and are therefore more inclined to ensure community action to counteract the devastating impacts of natural disasters on their energy infrastructure.

From a broad perspective, the outlook for community participation in Australia is in stark contrast to the Pacific, but when it is broken down, the similarities are surprising. Australia, like many PICTs, has some very remote and rural areas, with limited access to technical support and equipment. Compounded by frequent bushfires and flooding, communities can experience periods of isolation. In such cases, the need for local understanding and maintenance of energy needs is exacerbated, and utilising technology that is appropriate for the location and purpose is crucial.

8. CONCLUSION

This report has explored a diversity of meanings and experiences of energy resilience in the Pacific through a review of the literature and six case studies. We focused on energy planning and investments; political economy of off-grid systems; and the role of communities in building energy resilience. We found that disasters can act as catalysts for change and encourage energy resilience, and this has been seen in multiple PICTs. Fiji increased building standards to resist category 5 cyclones after Cyclone Winston and Vanuatu's National Energy Road Map was adjusted for "green growth" after Cyclone Pam.

While these responses to natural disasters aim to enable energy resilience, techno economic capacity often limits effective implementation. Fiji's new building standards have not been fully implemented due to financial constraints. Vanuatu has also faced similar financial constraints which has been felt in tender bids demonstrating value for money over energy resilience. Tokelau's tariff structure limited funding for their energy systems, resulting in reduced energy resilience.

To remedy the issues faced with loss of energy resilience, community ownership has been suggested as a potential solution. A sense of concern and upkeep of energy systems is created with community ownership and this has been demonstrated in Fiji, PNG and Tokelau. This is further strengthened with productive uses of energy and market connections. With this, understanding the communities needs and aspirations can enhance community engagement. Local champions can be instrumental in this, encouraging the adoption of energy systems and new innovations for energy resilience. Local champions utilising the "billboard effect" has also been demonstrated as a useful means to creating curiosity and encouraging community participation.

However, there have been examples of this influence being used counterproductively. Community members higher up in the community social structure have occasionally set a poor precedent in not paying fees for energy systems. Again, a lack of financing for these energy systems results in failure and ultimately reduces energy resilience. A similar type of influence has been seen in Australia with institutional inertia. Legislative barriers were created against effective standalone solar and battery systems after the 2019/2020 bushfires, resulting in continual reliance on centralised transmission and distribution systems (which remain vulnerable to natural disasters) and reduced energy diversity.

A solution to this has been shown in Vanuatu with the aligning of community engagement with NGOs. Through collaboration with local communities, NGOs and community leaders were able to establish an energy resilience framework and this resulted in stronger community participation. PNG has called for similar action, allowing for communities to lead their government in response to climate change. This has been echoed with PICTs as they set the standard in response to climate change with ambitious renewable energy targets, with Tokelau being a successful example of this.

Further research on energy resilience challenges and existing practices across political economy, planning and community dimensions in PICTs could lead to the development of innovative strategies to support national and regional climate mitigation and adaption agendas in the Pacific region and beyond. The Energy Resilience in Pacific Island Countries and Territories Workshop Series in December 2020 will be an opportunity to share further experiences across the region and build a collective agenda for action.

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