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TOWARDS BETTER ENERGY TRANSITION MODELLING IN PACIFIC ISLAND COUNTRIES AND TERRITORIES

Summary

Energy modelling tools play a central role in planning effective energy transitions, yet their suitability for Pacific Island Countries and Territories (PICTs) remains limited. This paper discusses the importance of model characterisation and identifies key gaps in existing approaches, including poor multisectoral integration, low local capacity, and weak treatment of uncertainty. Building on a review of classification frameworks and regional experiences, it proposes key considerations for rethinking modelling tools to better support PICT energy transitions. Future directions emphasise simplicity, transparency, open access, and alignment with long-term energy transition goals.

Keywords: Energy transition, Planning, Modelling tools, Classification frameworks, Gaps

1. Introduction

Energy modelling tools are essential for effective energy planning, offering structured, analytical approaches to understand and manage the complexities of modern energy systems (Jebaraj and Iniyan, 2006). By simulating energy supply, demand, and technology interactions under different scenarios, models support evidence-based decision-making for infrastructure development, investment prioritisation, and policy design (Hung et al., 2014). Modelling tools vary widely in their structure and purpose, and can be classified according to characteristics such as time horizon and resolution, analytical methodologies, geographical and sectoral coverage, level of detail, and programming techniques (Van Beeck, 1999). This characterisation is key to selecting appropriate tools for specific planning activities, ensuring that the chosen models align with user needs, data realities, and planning objectives.

For Pacific Island Countries and Territories (PICTs), selecting appropriate modelling tools is particularly critical. The region faces distinct challenges including geographic dispersion, small and fragmented energy markets, heavy reliance on imported fossil fuels, vulnerability to climate change, and significant capacity constraints (Dornan, 2014, Wolf et al., 2016, Raghoo et al., 2018). These factors demand modelling approaches that are not only technically robust, but also simple, transparent, and adaptable to local contexts, which generally have limited planning capacity due to staff shortages and broader institutional capacity constraints.

In this context, clear tool characterisation becomes a prerequisite for ensuring that selected models can effectively address multisectoral planning needs, resource constraints, and resilience considerations critical to successful energy transitions in the Pacific. Building on a review of available tools and regional experiences, this paper identifies key gaps in current modelling practices and proposes considerations for rethinking the application and development of energy modelling tools for PICTs.

2. Tool Characterisation Framework

Given the wide range and proliferation of energy modelling tools, classification frameworks are essential to guide their selection based on specific user needs and planning activities (Van Beeck, 1999). By categorising tools according to their underlying methodologies, sectoral scope, and analytical approaches, planners can better identify models that are suited to address particular challenges. This is a particularly critical step in PICTs, where limited technical capacity, high vulnerability to climate change, and the need for multisectoral coordination demand that models be both fit-for-purpose and context-appropriate.

A range of classification approaches have been proposed in the literature. Some, such as Pfenninger et al. (2014), group models based on their dominant methodologies: optimisation, simulation, market-based frameworks, qualitative methods, and hybrid approaches. Others focus on specific technical aspects: Hungerford (2019), for instance, identifies four major types of power system models, including short-term stability studies, unit commitment and economic dispatch, capacity expansion planning, and residential demand modelling. At a finer level, Després et al. (2015) propose classification based on represented energy vectors, time evolution, computational logic, system boundaries, and temporal resolution, with a particular emphasis on how renewable energy impacts system costs and reserves. More recent frameworks attempt to capture broader characteristics. Prina et al. (2020) classify bottom-up energy models according to sectoral and geographical coverage, time resolution, modelling methodology, and programming approach. Langevin et al. (2020) introduce a two-dimensional framework, distinguishing models along a top-down versus bottom-up axis and a white-box versus black-box modelling philosophy.

Importantly, IRENA (2018) underscores the need for multiple modelling and decision-support tools to address PICT-specific planning issues, including power system stability, generation adequacy, and network performance. The IRENA report notes that many technical challenges in the Pacific can be addressed by identifying generator requirements – but doing so requires a suite of complementary modelling approaches tailored to island-specific operating conditions. In line with this, the Pacific SIDS Lighthouses Initiative has emphasised that sectoral integration, model accessibility, and spatial and temporal granularity are essential features when selecting models for small island contexts. Practical model selection requires combining various dimensions – such as analytical assumptions, mathematical formulations, data intensity, and system boundaries. Figure 1 synthesises insights from multiple frameworks into a consolidated classification matrix to support context-aware tool selection for energy transition planning in the Pacific.

Fig. 1: Energy model classification | Modified after Tomaschek (2013) and Cao et al. (2016)

3. Energy Modelling Gaps for PICTs

Identifying gaps in existing modelling practices is essential to ensure that energy planning processes in PICTs are robust, context-sensitive, and aligned with long-term development goals. Table 1 below summarises key modelling gaps observed across the region, along with their underlying causes and implications for effective energy transition planning.

Tab. 1: Issues around available energy modelling tools in PICTs

Identified Gap	Context & Underlying Issues	Implications for Energy Planning
Limited multisectoral integration (e.g. transport, cooking, cooling, water)	Most modelling tools focus on electricity systems only. Sectoral data is fragmented and managed by different institutions. Integrated planning approaches are rare.	Leads to siloed planning and missed opportunities for cross-sector synergies. Limits accurate assessment of renewable energy potential and demand-side interventions.
Lack of local modelling capacity and institutionalisation	Modelling is often consultant-led with little local involvement. Tools are complex, poorly documented, and not designed for long-term local ownership. Training and capacity-building are insufficient.	Inhibits model uptake, ownership, and policy influence. Planning processes become donor-dependent and difficult to replicate or update.
Inadequate spatial and temporal resolution	National models often use highly aggregated assumptions. Outer islands, rural areas, and community-level variation are overlooked. Temporal variation in demand and supply is underrepresented.	Undermines targeted energy access planning and system resilience. Results may not reflect actual conditions in dispersed island geographies.
Lack of risk, uncertainty, and scenario analysis	Most models used are deterministic and assume ideal conditions. Few tools include probabilistic approaches or sensitivity analyses. Data on variability is limited.	Plans are vulnerable to shocks (fuel prices, weather, demand shifts) and fail to incorporate resilience or flexibility.
Limited access to open, adaptable, and appropriate tools	Many tools are proprietary or donor-specific. Few are designed for small-scale, data-sparse contexts. Open-source options may lack support or regional tailoring.	Reduces transparency, peer learning, and tool customisation. Limits uptake and ongoing use by government and local institutions.
Short time horizons and weak transition pathways	Planning often focuses on 5-10 year timelines or single-project scopes. Longer-term decarbonisation strategies and technology transitions are not embedded in tools.	Misalignment with NDCs and net-zero goals. Missed opportunities for staged investment, strategic pipelines, and system transformation.
Poor data availability, quality, and interoperability	Energy data is often outdated or incomplete. Lack of coordination across ministries and institutions. Few standardised data-sharing protocols.	Affects input quality and model credibility. Prevents effective monitoring, evaluation, and long-term scenario development.

4. Conclusions

Addressing the persistent gaps in energy modelling across PICTs requires a fundamental rethinking of how tools are designed, selected, and applied. Rather than relying on complex, externally developed models with limited regional relevance, future efforts must focus on developing simpler, transparent, and adaptable tools that align with local capacities, data realities, and multisectoral planning needs. This shift calls for moving beyond purely techno-economic optimisation toward approaches that accommodate uncertainty, support cross-sectoral integration, and embed long-term transition pathways. Energy models must be seen not only as technical instruments, but also as participatory platforms that build institutional knowledge, foster regional collaboration, and inform inclusive, resilient energy transitions.

Key considerations for future modelling efforts include the need for simplicity and transparency to ensure local adaptability, the integration of multiple sectors such as electricity and transport (both land and maritime), and the ability to incorporate uncertainty through scenario analysis and risk assessments. Tools should be open-access or easily modifiable to foster institutionalisation and peer learning, while explicitly supporting long-term transition pathways aligned with national and regional climate targets. Above all, tools must reflect the unique geographic, economic, and governance realities of PICT contexts, where dispersed populations and supply chain vulnerabilities demand tailored, flexible approaches. Continued collaboration across governments, academia, and development partners will be essential to develop the modelling ecosystems needed to support sustainable and inclusive energy transitions across PICTs.

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