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A policy analysis of low carbon development in the context of the water-energy-food nexus: Examining the low emission development strategy in Fiji

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Research Article

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Abstract

The Water-Energy-Food (WEF) nexus approach has proved valuable in the investigation of complex systems, allowing for tailored analysis for specific scopes. This is particularly relevant due to variations in WEF nexus interactions observed between countries and regions. This article uses qualitative methods to investigate the effects of Fiji's ambitious carbon mitigation policies through a WEF nexus approach. A framework for Policy Coherence assessment was used to score the strength and direction of policy interactions. Overall, the assessment revealed more synergies than trade-offs between Fiji's Low Emission Development Strategy (LEDS) and nexus sectoral policies, with the energy sector having the most interactions. Analysis of data obtained from key informant interviews and the policy coherence outcomes show important trade-offs and synergies between sectors, which are useful in informing national and sectoral level policy development. The research provides policy recommendations that address governance, technology and innovation, human capital, and land issues to overcome barriers to implementing climate mitigation targets in the LEDS and Nationally Determined Contributions. This study demonstrates the utility of the WEF nexus approach through applying qualitative methods to provide valuable insights for sectoral-level nexus research. Such an approach can be applied to other small island nations facing similar challenges.

Impact statement

This study assesses policy coherence in the frame of low-carbon development on Fiji through a water-energy-food nexus lens. The study shows that while synergies between policies exist, there are notable trade-offs which could hamper efforts towards a low-carbon future. This work identifies those trade-offs specifically in national policy documents. The study provides concrete recommendations for practice, governance, and policy in order to avoid or mitigate potential trade-offs and bottlenecks to achieve ambitious goals towards a low-carbon future. The work is replicable anywhere, and as such could be applied across small island development states globally.

Introduction

Earth's resources are finite and face increasing pressure from climate change, population growth, and socio-economic shifts. Meadows et al. (1972) estimated a doubling of the world population by 2003 from a 1970 population of 3.6 billion. Although the work received criticism at the time, global trends in population, resource consumption, and environmental degradation have largely supported their broad projections. The global population reached 8 billion in November 2022 and may reach 9.7 billion by 2050, putting pressure on already strained resources and the ability to attain the Sustainable Development Goals (SDGs) (United Nations Department of Economic and Social Affairs, 2022), which are unlikely to be met (United Nations, 2022). The Intergovernmental Panel on Climate Change (IPCC) has suggested that global risks to health, livelihoods, food security, water supply, human security, and economic growth would be more significant at 2°C compared to warming of 1.5°C (IPCC, 2018). Furthermore, freshwater stress is projected to increase by 25% with 2°C of warming (Mycoo et al., 2022), making water security objectives even more challenging to reach.

Unlike the more water-centric approach of Integrated Water Resources Management (IWRM), the Water-Energy-Food (WEF) nexus approach is multi-centric (Benson et al., 2015; Endo et al., 2017;

Grigg, 2019; Simpson and Jewitt, 2019; Sušnik et al., 2023). The WEF nexus received renewed impetus at the Bonn2011 Nexus Conference. Recognizing the interconnected challenges that global water, energy, and food resources face, the background article by Hoff (2011) highlighted that drivers such as urbanization, economic, and population growth would intensify resource demands leading to tradeoffs and synergies when developing and utilizing these resources. Since then, the concept of the WEF nexus has expanded rapidly, attracting an ever-larger stakeholder group.

Small Island Developing States (SIDS) face additional limitations due to geographical remoteness, a narrow resource base, and a high dependency on external trade, raising their vulnerability to exogenous shocks (Mycoo et al., 2022). SIDS are under pressure to develop sustainably (Fongar et al., 2021). Decarbonization strategies frequently mention phrases such as a 'resilient future' or 'achieving the SDGs' with very little evidence to demonstrate their feasibility. Policies are also considered integrated, inclusive, or holistic, yet rarely consider WEF nexus interactions. An example of an overlooked nexus interaction is the commitment to a 2°C emission reduction pathway on bioenergy which could negatively impact local food production, water consumption, and biodiversity (von Stechow et al., 2016; Scobie, 2019). A nexus approach can lead to a policy-coherent, resource-efficient, greener economy (Hoff, 2011). Unfortunately, many WEF nexus studies are undertaken in developed countries (Sušnik, 2022) where a mature legislative environment, which may not be transferable to other countries, exists. There is a need to understand the complexities of nexus relationships in SIDS due to their specific circumstances and assess how they are impacted by climate mitigation interventions.

Fiji contributes 0.006% to global carbon emissions (Ministry of Economy, 2020a), yet faces an inequitable share of climate vulnerability. A Climate Vulnerability Assessment for Fiji highlighted that climate change could significantly affect environmental conditions such as temperature, humidity, and water availability for agriculture and food consumption, along with increasing frequency and intensity of natural disasters potentially leading to production losses (Government of the Republic of Fiji, 2017). To demonstrate leadership in climate action, Fiji submitted its net-zero carbon strategy to the United Nations Framework Convention on Climate Change (UNFCCC) in 2018 and committed to its implementation in the updated Nationally Determined Contribution (NDC) in 2020. The net-zero strategy, namely the Low Emission Development Strategy (LEDS), focuses on achieving economy-wide decarbonization by 2050. The sectors include energy (electricity generation and transmission), land transport and domestic aviation, domestic shipping, waste, coastal wetlands, and the Agriculture, Forestry, and Other Land-use (AFOLU) sectors.

The LEDS strategy outlines four pathways for low-carbon development: Business as Usual Unconditional (BAU-UC); Business as Usual Conditional (BAU-C); High Ambition Scenario (HAS); and Very High Ambition Scenario (VHAS). Of all the scenarios, VHAS will achieve net-zero carbon emissions by 2050 by reaching ambitious goals of 100% renewable energy, 100% electric vehicles and maritime transport, afforestation and forest protection from deforestation, and reduction in agricultural emissions from enteric fermentation, manure management, and fertilizer usage. The strategy, however, does not outline resource security indicators, nor does it specify or quantify how outlined actions in the decarbonization pathways will influence other sectors or limited natural resources.

There is therefore a gap in understanding how net-zero strategies could influence WEF nexus security. This article aims to address this gap by assessing the key national policy interactions for water, energy, and food alongside the VHAS LEDS strategy in Fiji, as well as assessing the tradeoffs and synergies introduced by the VHAS strategy on WEF nexus resources on Fiji. This study also aims to promote similar nexus policy impact assessments on other SIDS.

Methods and case study

Policy coherence assessment

The aim of the policy coherence assessment is to map out the key national policy interactions for water, energy, and food alongside the VHAS LEDS net-zero strategy in Fiji. Nilsson et al. (2012) define policy coherence as '*an attribute of policy that systematically reduces conflicts and promotes synergies between and within different policy areas to achieve the outcomes associated with jointly agreed policy objectives*', and developed a policy-analytical framework focused on policy outputs (objectives and instruments) and policy implementation, looking at two policies at a time using a three-step assessment. In their approach, ratings of policy coherence range from 0 to 2, where 0 is neutral/no interaction, 1 is weak policy interaction, and 2 is a strong interaction. However, the *direction* of the interaction (negative/trade-off, or positive/synergistic) is not determined.

To address this gap, Munaretto and Witmer (2017) first redefined policy coherence as '*an attribute of policy referring to the systematic effort to reduce conflicts and promote synergies within and across individual policy areas at different administrative/spatial scales*', and second adapted the Nilsson et al. (2012) scoring to focus on the content of the policy to improve policy coherence and address conflicts that arise during implementation. In the Munaretto and Witmer (2017) scheme, scoring runs from −3 to +3, where 0 indicates no interaction between policies, −3 indicates strong tradeoffs between policies, and +3 indicates strong synergy (Table 1).

The three steps carried out in the policy coherence analysis in this work are as follows (Figure 1):

1. Conduct an **inventory of the objectives and instruments** within the Fijian LEDS VHAS and WEF national policy documents (given in full in Supplementary Materials S1 and S3);
2. **Identify nexus critical objectives** (NCOs) for WEF nexus security by undertaking pairwise assessment between objectives

Table 1. Scoring matrix adapted from Munaretto and Witmer (2017) and Munaretto et al. (2018)

Score	Description
−3 (cancelling)	Progress on one objective makes it impossible to reach another leading to a trade-off
−2 (counteracting)	Pursuit of one objective counteracts another
−1 (constraining)	Pursuit of one objective places constraints and conditions on the achievement of another
0 (consistent)	No significant interaction between the two objectives
+1 (enabling)	Pursuit of one objective enables the achievement of another
+2 (reinforcing)	One objective creates conditions that lead to the achievement of another objective
+3 (indivisible)	One objective is intricately linked to another objective

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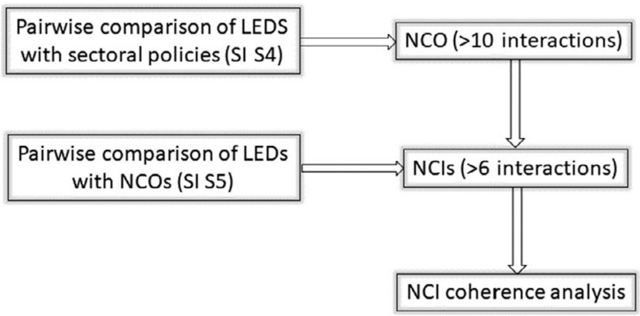

Figure 1. Process adopted in this research. Supplementary Materials S4 and S5 refer to the Supplementary Materials in which full details of the comparisons are given.

of sectoral policies using the scoring in Table 1. Policy objectives with a score = 0 (Table 1) were not considered to be interacting. If the score was not = 0, then this counted as an interaction between policy objectives. The scores for all interacting policy objectives were summed separately. Objectives with > 10 interactions qualify as NCOs. This is interpreted as meaning that WEF policy objectives are likely to be greatly affected by LEDS implementation.

3. **Identify nexus critical instruments** (NCIs) by undertaking pairwise comparisons of the 58 LEDS instruments with NCOs (step 2) using Table 1, following the Munaretto et al. (2018) approach. LEDS instruments having > six interactions are NCIs. This is taken to imply that LEDS instruments with greater impact on the NCOs are critical in achieving policy ambitions and will have nexus-wide impacts.

The Supplementary Materials S1 contains details of the policy documents analysed in this research. The lead author works on climate change policy development in Fiji and played an instrumental role in developing the LEDS. Due to the cross-cutting nature of climate change and the LEDS economy-wide approach, the lead author has been involved in sector policy development and understands sectoral policy objectives and interpretation of the impact of low carbon initiatives on these policies. To triangulate and validate the desktop policy analysis, 11 semi-structured interviews with key informants (KIs) in Fiji were carried out with experts in all three WEF sectors. Supplementary Materials S2 contains details of the key interviewees, as well as a sample of the semi-structured questionnaire administered. While stakeholders are not necessarily aware of the 'nexus concept' per-se, they are well aware of linkages between sectors. A similar policy coherence methodology has been applied to the Tana River Basin, Kenya, demonstrating its utility in assessing policy interactions and helping guide coherent natural resources management (Suda et al., 2024). While it could be argued that the scoring might be subjective (e.g. is an interaction −2 or −3?), what is more important is determining whether or not there is an interaction (i.e. that the score is not = 0), and the direction of that interaction (i.e. whether it is positive or negative). It is interacting policies that are of interest when analyzing policy interactions. The full rationale as to the scores assigned for every interaction is outlined in depth in Supplementary Materials S4 and S5.

Case study

Fiji, in the western South Pacific Ocean, is an archipelago with over 330 islands with a total landmass of 18 275 km^2 spanning 1.3 million km^2 of the Exclusive Economic Zone (EEZ) (Government of the Republic of Fiji, 2018). The two largest islands (Viti Levu and Vanua Levu; Figure 2), constitute 80% of the landmass. The island nation is abundant in biodiversity and natural resources, which are under threat from the changing climate and growing population. The total forest area is approximately 1.1 million ha (58% of the land area). There are five main sources of freshwater (rivers, creeks, peat swamps, groundwater, and lakes; Department of Environment, 2020). Viti Levu (10,429 km^2) has five main rivers. As for Vanua Levu (5,556 km^2), the main river is the Dreketi River. There are three major dams: Vaturu (160 ha), Monasavu (670 ha), Nadarivayu Dam, and the Navua Irrigation Dam near Wainikavika creek (80 ha) and one natural lake, Lake Tagimocia (213 ha), in Taveuni (Department of Environment, 2020).

El Nino and La Nina events substantially impact annual rainfall (Fiji Meteorological Service, 2022). However, no annual average rainfall changes have been recorded between 1958 and 2021. Similarly, trends in the national average wet (November–April) and Dry (May–October) months are not observed. In 2021, the annual rainfall recorded was 2984 mm, and the annual average mean temperature was 26.2°C, which is 0.6°C warmer than the historical average (Fiji Meteorological Service, 2022).

As per the 2017 national population census, 884 887 people inhabit one-third of the islands, with the most concentration on the main island of Viti Levu (FBoS, 2018). The Fijian economy is highly dependent on tourism and extremely volatile to global economic trends, especially the rising oil and food prices, higher trading partner inflation, ongoing shortages of raw materials, and high freight costs (RBF, 2021).

There are many nexus interactions on Fiji. The Water Authority of Fiji is a major electricity customer, with power shortages impacting supply and wastewater treatment, while the energy sector relies on a stable water resource for hydropower production. Similarly, rainfall patterns impact crop production and water supply is needed for commercial farming, forming a link between the water and food-producing sectors, with water itself being dependent on electricity generation. Crops and energy are interlinked, with biomass from forests and crop residues being used in bioenergy generation, with a share in the energy mix of 7% in 2021 (EFL, 2021). There are solar photovoltaic arrays for clean electricity generation, however, such schemes may conflict with land for food production. Poor land management practices have an impact on water quality, with an impact on treatment requirements and thus on energy demand in the water sector. Agriculture is the second highest greenhouse gas (GHG) emitting sector in Fiji, with production practices and animal varieties in need of reconsideration. WEF nexus interactions are magnified due to the context of the small island nation. Each sector has its own ambitions, and as such there may be opportunities and barriers for the LEDS VHAS achievement, the exploration of which is the main aim of this article.

Results

Inventory of policy objectives and instruments (step 1)

Step one of the policy coherence assessment is to identify objectives and instruments in Fiji's LEDS and five national sectoral policies. The complete list of policy objectives and instruments is detailed in Supplementary Materials S3, while Table 2 summarises the number of objectives and instruments in each sectoral policy analysed, along with the LEDS and National Development Plan (NDP). In terms of the LEDS VHAS, there are 58 instruments, which are categorized into 16 objectives (Table 2; Supplementary Materials S3). The

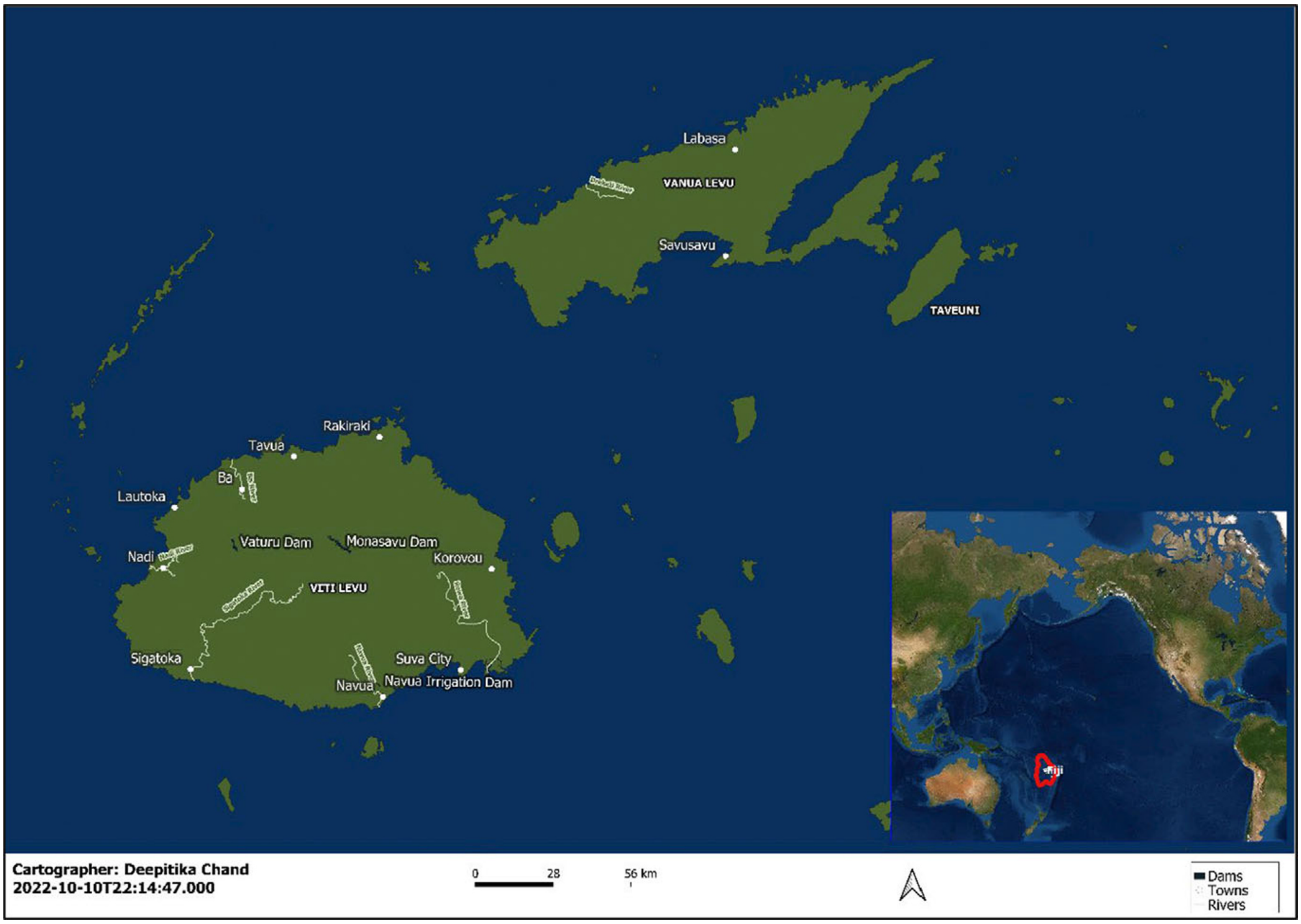

Figure 2. Map of the Fiji archipelago.

Table 2. Summary of the inventory of policy objectives and instruments analysed

Policy	LEDS	NDP	Agriculture	Water and sanitation	Energy	Waterways
Number of objectives	16	6	4	17	5	1
Number of instruments	58	30	52	20	27	4

objectives and instruments include energy (electricity generation and transmission, land transport, maritime transport, domestic aviation), waste, AFOLU (Agriculture, Forestry and Other Land Use), and coastal wetlands. Most of the LEDS objectives (9 of 16) were directed towards the energy sector, being Fiji's largest greenhouse gas emitting sector.

The objectives and instruments for the National Development Plan (NDP) and the sectoral policies for Water and Sanitation, Energy, Agriculture, and Waterways were analysed and assessed. Many of the objectives for the sectoral policies such as A1 (Improve food and nutrition security for all Fijians), W1 (To ensure that water supply and sanitation are provided to all Fijians in urban and rural areas, to standards that comply with international norms) and E1 (energy security and resilience) are closely aligned to NDP objectives (see Supplementary Materials S3 for details on the notation, e.g. A1, W1, etc.).

When mapped alongside the LEDS, many sectoral policies fall short on mitigation measures. For example, the Ministry of Agriculture's 5-year Strategic Development Plan focusses on improving productivity, nutrition security, sustainable resource management, climate-smart agriculture, and improving agriculture commodities. Similarly, the draft Water and Sanitation Policy is largely focused on climate adaptation having its objectives aligned to meeting consumer demand, protecting water resources, and managing flood situations. On the contrary, the National Energy Policy has more elements of climate mitigation and net-zero transition and energy security, accessibility, sustainability, efficiency, and governance. Overall, there are more synergies than trade-offs between the goals of the LEDS and sectoral objectives. These are elaborated in Section "Nexus critical objectives (step 2)".

Nexus critical objectives (step 2)

Pairwise comparisons were carried out to assess how the 16 LEDS objectives affected the 33 sectoral policy objectives using the scoring matrix in Table 1. The Supplementary Materials S4 contains scoring details of the interactions between LEDS and the NDP, as well as explanations for each interaction. The scoring of interactions

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Table 3. Summary of interactions between Fijian policy objectives and the LEDS. Total interactions > 10 are classified as Nexus Critical Objectives (NCOs). For a definition of the policy codes (e.g. N1, W3, etc.) see Supplementary Materials S3.

LEDS interaction	N1	N2	N3	N4	N5	N6	A1	A2	A3	A4	W1	W2	W3	W4	W5	W6	W7
Indivisible (+3)	1	6	0	1	0	3	0	0	0	0	1	1	0	1	0	0	2
Reinforcing (+2)	5	4	3	1	1	0	3	2	0	1	5	4	2	2	0	0	0
Enabling (+1)	3	0	5	4	2	4	7	4	3	3	3	2	0	4	2	1	4
Consistent (0)	6	5	0	7	11	5	6	8	17	11	7	9	14	9	14	14	9
Constraining (-1)	2	3	0	2	0	4	0	0	1	2	2	0	0	0	0	0	0
Counteracting (-2)	0	0	0	1	2	0	1	0	0	0	0	0	0	0	0	0	1
Cancelling (-3)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Synergies	9	10	8	6	3	7	10	6	3	4	9	7	2	7	2	1	6
Trade-offs	2	4	0	3	2	4	1	0	1	2	2	0	0	0	0	0	2
Total interactions	11	14	8	9	5	11	11	6	4	6	11	7	2	7	2	1	8

LEDS interaction	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	E1	E2	E3	E4	E5	WE1
Indivisible (+3)	0	0	0	1	0	1	1	0	0	1	2	3	5	2	2	3
Reinforcing (+2)	1	1	1	1	0	0	0	2	2	0	1	1	2	1	2	1
Enabling (+1)	2	2	2	1	1	1	0	3	3	4	6	4	3	6	6	4
Consistent (0)	12	13	11	13	15	13	16	10	10	11	7	7	5	7	6	6
Constraining (-1)	1	0	0	0	0	0	0	0	0	0	1	2	2	0	0	2
Counteracting (-2)	0	0	0	0	0	1	0	1	1	0	0	1	0	0	0	0
Cancelling (-3)	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0
Synergies	3	3	3	3	1	2	1	5	5	5	9	8	10	9	10	8
Trade-offs	1	0	2	0	0	1	0	1	1	0	1	3	3	0	0	2
Total interactions	4	3	5	3	1	3	1	6	6	5	10	11	13	9	10	10

between the LEDS and sectoral policy objectives provide information on the synergies and trade-offs between Fiji's net-zero carbon strategy and individual sectoral goals. A summary of how LEDS objectives affect sectoral policy is shown in Table 3. A sum of 10 or more interactions are classified as NCOs.

Overall, LEDS objectives are focused on enabling energy efficiency, promoting electrification of cooking and transport sectors, fuel efficiency, increasing renewables in the energy mix (including the promotion of biofuels), reducing deforestation, increasing afforestation and forest productivity, and improving livestock productivity, reducing the use of synthetic fertilizer, and recovering methane from landfill and biogas digesters. The main findings are summarized below (see the Supplementary Materials S3 for the policy numbering key, e.g. A1, N1, E3, etc.).

Energy sector policy objectives on resource efficiency, cost-effective and environmentally sustainable energy (N1), security and resilience (E1), access and equity (N2 and E2), sustainability (E3), efficiency (E4), and governance (E5), had synergies with the LEDS due to the focus on enabling energy efficiency, promoting electrification of cooking and transport sectors, fuel efficiency, and increasing renewables in the energy generation mix. Trade-offs are mainly due to the focus of forest protection to increase carbon sinks which constrain efforts for biomass for electricity generation by limiting feedstock. Low feedstock is an existing challenge (KI02, 03, and 05). At the current rate of electricity generation and transmission infrastructure upgrade, the ambition of 100% electrification of the transport sector will add demand to the electricity grid.

Water sector objectives focus on supply and sanitation. There are many inconsistencies or neutral interactions between the LEDS and water sector objectives which can be attributed to the LEDS interests in energy-related goals. Existing issues in the water sector include water quality deterioration, low accessibility, and increasing vulnerability to a changing climate. Objectives on clean water availability (W1 and N1), supply security (W2 and W4), efficient sewage disposal (W3 and W5), improved service delivery (W6), and reduction of water losses (W14) address issues of accessibility and security. LEDS implementation has the potential to provide synergies as it focuses on energy efficiency to allow water and energy savings from non-revenue water and long-term cost savings. Increases in renewable energy could ensure electricity security for water treatment and supply. Renewable electricity is beneficial for remote locations where both water and electricity connections do not currently reach. The water sector focuses on achieving watershed management and planning (KI07), maintenance of river banks and beds (W8), establishing a water allocation framework (W9), managing groundwater for sustainability and quality (W10), minimizing flood risk and exposure (W11), improving drainage to prevent rural and urban flooding (W12), becoming climate resilient (W13 and WE1), maintaining water quality (W15), maintaining the health of water bodies (W16), and including stakeholders in decision-making processes (W17). A need for energy policy review as stated in the LEDS could improve coordination between the sectors by allowing placeholders for water allocation for hydropower and geothermal plants. Dams for water supply or hydropower serve as flood mitigation measures.

Some LEDS objectives may impede the achievement of water sector goals, for example, enhancing biomass for energy could negatively impact watersheds by reducing infiltration, increasing runoff, and riverbank erosion that further cascades into poor water quality impacting the food chain. Similarly, hydropower dams may alter water courses and their hydrology, impacting fish and other living organisms that communities are dependent on. However, KI03 argued that during the process of any infrastructure development, a complete environmental impact assessment (EIA) is conducted to ensure minimal harm to ecosystems.

Major food sources include land crops, livestock, fish, and imported rice and wheat. Local rice production is a major consumer of water, and agriculture is a main driver of deforestation. **Food sector policy objectives** are focused on availability and security (N3 and A1), competitive and sustainable value-added agriculture

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(N5 and A4), increasing farmer income (A2), a sustainable sugar industry (N4), climate-smart agriculture (A3) and sustainable forest management (N6). LEDS objectives on fuel efficiency, biofuels, low carbon marine vessels, and increased renewable source electricity could help towards increased shelf life of food and allow for long-distance transportation, helping ensure food is available and accessible, and that the market for distribution is competitive and healthy. The need for increased biomass for electricity is synergistic with the sectoral goal of the sugar industry but may be conflicting with food production goals, a major trade-off. It is demonstrated that bagasse (sugarcane pulp) is a reliable biomass for electricity generation (KI03). KI03 further mentioned that agricultural waste was currently in use at the Nabou Green Energy biomass plant. Irrigation of rice can be efficient with solar pumps. The reduction of deforestation and increasing afforestation and forest productivity coincides with the food sector goals of sustainable forest management and climate-smart agriculture in the form of agroforestry or what KI10 refers to as 'food forests'. Manure management can lead to savings in fertilizers through the production of compost.

There are important trade-offs to consider in the food sector. The agriculture sector is primarily focused on food productivity (KI10). Therefore, reducing fertilizer inputs could impact food production while overusing fertilizer can produce feedback and pollute water sources. Food productivity in livestock could lead to increased short-term emissions as breeding lower methane-emitting livestock takes several years. Biomass remains a threat to forest conservation unless a sustainable alternative is found. Creating a competitive market for produce such as coconut, cassava, and other feedstock for biofuel could negatively impact the biofuel plans of Fiji as the costs of biofuel production make no economic sense with high market prices. It is not certain if these products would be available from farmers as biofuels due to their high demand as food or beauty products with greater market value.

NCO interactions

From the interactions analysed, there are 10 nexus critical objectives identified from the policy coherence assessment (Table 3). These NCOs between the LEDS and sectoral policy objectives are described here.

i. **W1**: '*To ensure that water supply and sanitation is provided to all Fijians in urban and rural areas, to standards that comply with international norms*', and;

ii. **N1**: '*Clean and safe water in adequate quantities and proper and adequate sanitation for every Fijian household*' both had nine synergistic and two contrasting interactions with the LEDS objectives as they are dependent on electricity for treatment and distribution. The similarities between N1 and W1 are that the sectoral water policy is derived and built from the NDP. The Water Authority of Fiji (WAF) metered operation and decentralised water and wastewater treatment require a reliable electricity supply. Increasing renewable energy will help GHG emissions and the cost of production, and secure the supply of electricity. Mitigation interventions such as reducing synthetic fertiliser, livestock manure management, afforestation, and reduced deforestation reinforce water resource security. However, if not planned well, ventures using raw materials from forests for traditional canoe-making could constrain water quality improvement efforts and lead to unsustainable logging and sedimentation.

iii. **N2**: '*A resource-efficient, cost-effective and environmentally sustainable energy sector*' has 14 interactions and the greatest number of synergies with the LEDS. Promoting energy efficiency and renewable energy will indivisibly contribute to achieving N2. However, ambitious interventions without proper plans for 100% electric vehicles and 100% electric stoves could cause unnecessary pressures on the grid leading to the burning of diesel to meet new demand. Fiji already has an aging infrastructure and the rate of upgrade has been slow (KI08).

iv. **N6**: '*Sustainable management and development of forestry resources*' has many synergies due to the LEDS focus on carbon sequestration. An energy and biofuel strategy could focus on land use planning for forest management as forestry is a source of biomass and fuelwood. Unsustainable biomass and the failure of electric stoves could lead to deforestation and forest degradation.

v. **A1**: '*Improve food and nutrition security*' has no trade-offs with LEDS objectives.

vi. **E1**: '*Energy security and resilience*' has nine synergies and one trade-off. Solar is widely available and can augment electricity access. The one constraint is the low resilience of solar panels in category five cyclones in Fiji. Resilience can be enhanced with improved standards and regulation of imported materials for solar farms.

vii. **E2**: '*Energy access and equity*' has links with renewable energy development. Renewable energy such as micro-hydro or solar has the potential to supply electricity to remote off-grid communities or informal settlements, ensuring increased access to electricity. The Government under the Rural Electrification scheme is providing solar home systems to non-accessible areas. According to KI03, the government is paying for the cost of grid extensions to remote areas and improving the wiring of homes to ensure the safe supply of electricity, which is becoming increasingly challenging as the cost of electrical materials has increased since COVID-19 (KI08). The Establishment of the Fiji Rural Electrification Fund (FREF) is allowing for the setting up of solar micro-grids across the country. Efforts on forest conservation and reducing deforestation could curb fuel wood cutting, driving people to adopt clean cooking using electric stoves or LPG. However, this would be challenging for poor communities due to unaffordability. Electric stoves and EV vehicles introduction may lead to increased electricity demand and rationing of electricity.

viii. **E3**: '*Energy sustainability*' has five indivisible interactions with the LEDS objectives because the LEDS requires enabling energy efficiency through policy, codes, standards, regulation, and capacity building. The LEDS derives the need for more sustainable renewable energy sources to cater to increasing demands. The interventions of afforestation and reduced deforestation could cancel any unsustainable biomass plans.

ix. **E5**: '*Energy governance*' related interactions with the LEDS objectives are all synergistic. Energy governance requires measures such as enabling frameworks, laws, and bilateral and multilateral agreements to be put in place to achieve multisectoral policy goals.

x. **WE1**: '*Building resilience to climate change and waterways-related hazards through irrigation, improved drainage, flood control, riverbank, and coastal protection*' has nine synergies and one trade-off with LEDS objectives. Due to its broadness, renewable energy can have both synergies and trade-offs with this objective. While hydropower dams provide flood control and water for small-scale irrigation, they would have an impact on the water ecosystem due to sedimentation. Similarly, biomass could pose a threat to the forests which would impact the watershed health and ecosystem. Interventions to increase biofuel feed can add to the threat of deteriorating coasts and rivers.

Comparison between LEDS instruments and NCOs (step 3)

From the inventory of all policy instruments (Supplementary Materials S3), the LEDS VHAS instruments were compared with the NCOs as the LEDS VHAS instruments provide the Fijian pathway to net zero. Table 4 summarizes the direction and strength of the impact of LEDS instruments on the NCOs. From this assessment, 14 instruments were chosen as NCIs (Table 5) as they had more than six interactions with the NCOs. Each NCI represents an action from the LEDS VHAS which is likely to have the greatest nexus-wide impact if implemented. A full description of each LEDS instrument and NCO interaction scored in Table 4 is shown in Supplementary Materials S5.

Discussion

WEF nexus interactions on the ground and in policy

Water and energy

Water and energy are intricately linked, with hydropower providing 50–60% of the country's electricity generation (KI08), contrary to other island nations relying heavily on fossil fuel-based electricity (Raghoo et al., 2018). Hydropower is considered the most viable source of electricity to meet Fiji's base load due to its reliability (KI08), and stakeholders from Energy Fiji Limited suggested a

Table 4. Scored interactions between LEDS instruments and NCOs

NCO affected	N1	N2	N6	A1	W1	E1	E2	E3	E5	WE1	
LEDS Instruments affecting											Total significant interactions
LEDS1	2	3	1	1	1	3	3	3	3	1	10*
LEDS2	1	3	1	0	3	3	3	0	0	0	6*
LEDS3	2	2	2	0	2	3	3	0	1	0	7*
LEDS4	0	2	0	0	0	2	2	0	1	0	4
LEDS5	1	2	0	0	1	1	0	1	2	0	6*
LEDS6	0	0	0	0	0	0	0	0	2	0	1
LEDS7	0	1	0	0	0	1	1	1	1	0	5
LEDS8	0	1	1	0	0	1	1	1	1	1	7*
LEDS9	0	1/−1	1	1	0	0	−1	0	0	0	5
LEDS10	0	1/−1	1	1	0	0	−1	0	0	0	5
LEDS11	3	3	−1	2/−1	3	3	3	3	2	1	11*
LEDS12	2	3	0	0	1	3	3	3	0	2	7*
LEDS13	1	0	0	0	0	2	2	2	0	1	5
LEDS14	−1/ 2	2	−1	0	−1	2	2	1	1	−1	10*
LEDS15	1	2	0	0	0	2	0	2	0	0	4
LEDS16	1	3	2	3	1	3	2	2	2	1/−1	11*
LEDS17	1	3	3	0	1	3/−1	2	3	1	3	10*
LEDS18	1	2	0	0	0	2	0	2	0	0	3
LEDS19	0	1	0	0	0	1	0	0	0	0	2
LEDS20	0	2	0	0	0	0	0	0	0	0	1
LEDS21	−1	2/−1	0	0	−1	−1	0	−1	0	0	6*
LEDS22	0	1	0	0	0	1	0	0	0	0	2
LEDS23	0	1	0	0	0	1	0	0	0	0	2
LEDS24	0	1	0	0	0	0	0	0	0	0	1
LEDS25	0	1	0	0	0	0	1	1	0	0	3
LEDS26	0	1	0	0	0	1	0	1	0	0	3
LEDS27	0	1	0	0	0	1	0	1	0	0	3
LEDS28	0	0	0	0	0	0	0	0	0	0	0
LEDS29	1	1	0	0	1	1	0	1	0	0	5

(*Continued*)

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Table 4. (*Continued*)

NCO affected	N1	N2	N6	A1	W1	E1	E2	E3	E5	WE1	
LEDS Instruments affecting											Total significant interactions
LEDS30	0	0	0	0	0	0	0	0	0	0	0
LEDS31	0	0	0	0	0	2	0	2	0	0	2
LEDS32	0	0	0	0	0	0	0	0	0	0	0
LEDS33	0	0	0	0	0	1	0	2	0	0	2
LEDS34	0	0	0	0	0	1	0	2	0	0	2
LEDS35	0	0	0	0	0	2	0	2	0	0	2
LEDS36	0	1	0	2	1	0	0	0	0	0	3
LEDS37	0	0	−2	0	0	0	0	0	0	−1	2
LEDS38	0	0	0	0	0	0	0	1	0	0	1
LEDS39	0	0	0	0	0	0	0	1	0	0	1
LEDS40	0	0	0	0	0	0	0	1	0	0	1
LEDS41	0	0	0	0	0	0	0	1	0	0	1
LEDS42	0	0	0	0	0	0	0	1	0	0	1
LEDS43	1	0	0	0	0	0	0	0	0	0	1
LEDS44	2	−2	3	0	1	−2	1	−1	1	1	9*
LEDS45	2/−1	1	3	0	1	0	0	1	1	1	8*
LEDS46	2/−2	1	3	0	1	0	0	1	1	1	8*
LEDS47	0	0	0	0	0	0	0	0	0	0	0
LEDS48	1	1	0	0	0	0	0	0	0	3	3
LEDS49	1	0	0	1	0	0	0	0	0	3	3
LEDS50	1	0	0	1	0	0	0	0	0	3	3
LEDS51	0	3	0	0	1	0	0	3	1	0	4
LEDS52	0	1	0	0	0	0	0	1	0	0	2
LEDS53	0	0	0	0	0	0	0	0	0	0	0
LEDS54	0	0	0	0	0	0	0	0	0	0	0
LEDS55	0	0	0	0	0	0	0	0	0	1	1
LEDS56	0	1	0	0	0	0	0	1	0	0	2
LEDS57	0	0	0	0	0	0	0	0	0	0	0
LEDS58	0	1	0	0	0	0	0	1	0	1	3

Note: Asterisks show NCIs identified from the policy coherence assessment. See Supplementary Materials for details of the LEDS instrument codes. NCO codes are detailed in Section "NCO interactions".

combination of solar and hydropower as a practical solution for more renewable grid electricity (KI104). Some interviewees (e.g. KI03 and KI04) preferred hydropower over solar due to the latter's intermittent nature. According to the VHAS, solar is set to have the highest share in the energy mix (26%), followed by hydropower (25%), geothermal (17.7%), diesel (15.4%), wind (8.84%), and biomass (6.59%). KI02 suggested that pumped hydropower with solar could be a solution, where excess water can be pumped between reservoirs to be reused in turbines. While stakeholders from the energy sector agree that this is promising, feasibility studies need to be carried out to determine viability (KI03, KI03, and KI08). Interviewees KI02, KI03, and KI04 mentioned the Nagado Hydropower station could be a test location, where water from Vaturu Dam is channelled for hydropower generation before being returned for treatment and supplied to the public. However, the plant has not been operational since 2016 due to low water pressure from Vaturu Dam (EFL, 2021). From interviews, it was suggested that due to the commercialisation of EFL, the company is conservative on investments in new forms of renewables, hampering efforts towards renewable energy policy goals.

In terms of energy for water, interviewees KI01, KI03, and KI09 highlighted that the Water Authority of Fiji is the major electricity consumer. However, KI09 highlighted that recently, WAF had to purchase 52 diesel generators for backup power when EFL failed to supply electricity, highlighting capacity and/or infrastructural deficiencies in the grid which could hamper water-related policy goals. Electricity access issues for pumping groundwater in remote areas were noted. KI02 and KI08 emphasized that electricity sources from solar are crucial in such locations.

Policy ambitions in these sectors should be harmonized to ensure that they complement each other. For example, rapid water infrastructural expansion may place considerable stress on the electricity

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Table 5. Nexus critical instruments (NCIs) derived from a comparison between the LEDS instruments in the NCOs in Table 4

LED Instrument	Brief description
LEDS1	Energy policy. Review, update, and endorsement of the national energy policy
LEDS2	Energy Efficiency. Energy efficiency measures, capacity building, and education are implemented economy-wide
LEDS3	Codes and standards. Updating of codes and standards for buildings and industry Minimum Energy Performance Standards and Labelling.
LEDS5	Energy efficiency in the business community. Adoption of ISO 50001:2011 – Energy Management
LEDS8	Capacity Building for Renewable Energy and Smart Grids. Capacity-building needs for renewable energy development and smart grids will be continuously addressed
LEDS11	New solar with storage installation. 522 MW solar PV with storage (including extensive rooftop)
LEDS12	New hydropower installation. 435 MW hydropower
LEDS14	New biomass installation. 256 MW of biomass power is installed by 2050
LEDS16	New geothermal and ocean energy installation: 350 MW geothermal
LEDS17	New wind installation: 350 MW wind (on and offshore)
LEDS21	Electric Vehicles (EV)s. Adoption of electric vehicles (EVs) – All vehicles 100% electric
LEDS44	Reduced Deforestation. Decrease emissions from deforestation by 80%. The avoidance of clearing/ cutting and land use changes can be achieved by designating protected areas or restrictions on use. Possible compensation areas for alternative land use must be designated. This requires adapted land use planning policies.
LEDS45	Increased plantation Productivity. Increase productivity in forest plantations by 40%. Further increases in productivity can be achieved through tree improvement and the cultivation of alternative tree species. This requires extensive forest growth trials. These measures are taken by the operators of the plantations and do not require any specific policy measures other than financial support and permission to grow non-native tree species.
LEDS46	Afforestation. Afforestation of 77,400 ha with mahogany, pine, other hardwood species, and native species. These measures require adapted land-use planning policies.

Note: Each LEDS instrument is explained in full in Supplementary Materials S3.

infrastructure leading to potential reductions in energy supply reliability, with implications for water infrastructural expansion setbacks and supply disruption. This analysis can help identify opportunities and threats, as with the policy coherence approach adopted by Suda et al. (2024). There are more synergies or neutral interactions (Table 3) between energy-focused LEDS targets and water policy objectives than trade-offs, suggesting that meeting LEDS ambitions will contribute significantly towards achieving water-related objectives, presenting an opportunity to enhance the effectiveness and efficiency of (LEDS) policy implementation and to promote policy coherence between these two sectors.

Food and water

The relationship between food and water was rarely mentioned in interviews. Because Fiji is not under water stress, with just 0.3% of freshwater resources being withdrawn annually (https://data.worldbank.org/indicator/ER.H2O.FWST.ZS?locations=FJ), water supply is not high on the policy agenda. KI10 from the Ministry of Agriculture mentioned that water is crucial for crop productivity. According to KI11 from the Department of Waterways, many farmers situate themselves along rivers to access water. Other methods of irrigation are rainwater harvesting and surface runoff collection, which are common in Pacific island countries (Fongar et al., 2021). KI11 highlighted that rivers, estuaries, and the ocean constitute a source of food. During drought situations, soil organic matter becomes crucial for crop and livestock productivity, as expressed by KI10. Groundwater for agriculture has yet to be fully exploited.

Climate Smart Agricultural practices such as composting and biochar in designing agroforestry have been recommended as they improve soil organic matter and soil moisture content for crops (KI05). Soil carbon enhancement can reduce dependency on fertilizer and prevent water pollution (Milne et al., 2015). Agroforestry has been termed a broad concept by the Ministry of Agriculture. KI10 explained that the Government uses the term' food forests', which refers to the coexistence of forests with crops such as dalo, ferns, and fruits. Agroforestry could act as a solution towards the reduction of deforestation on Fiji as well as water conservation, allowing the coexistence of forests and food, with co-benefits for the water sector (reduced pollution loads, increased soil moisture, flood, and drought mitigation, etc.; cf. Ramachandran et al., 2009), thus contributing to goals in both the water and food/agricultural policy sectors.

Water and food in Fiji are less closely related than water and energy, yet care should be taken to ensure that the expansion of agriculture does not come at the expense of forestry land or water-related policy objectives. In terms of interactions with the LEDS, most are synergistic, with few trade-offs (Table 3). This suggests that the implementation of LEDS objectives will generally help meet agricultural goals. A sensitive connection is that of reducing fertilizer inputs, especially in the sugar industry which may be seen as a trade-off, leading to reduced sugar production. While reduced fertilizer usage could reduce food crop productivity, in the case of Fiji's sugar industry the continuous application of fertilizer has led to increased soil acidity, reducing sugar production. This, with other issues such as low renewal of land leases, has seen the sugar industry shrink. The cost of sugar production has increased, giving little returns to farmers facing an increasing cost of living. Farmers engaged in the industry are mostly over 40 years old, while younger generations have resorted to other jobs (Champathi et al., 2020).

Energy and food

The relations between the energy and food sectors are quite tightly connected, especially in the food-for-energy direction. In the energy-for-food direction, the relationship is indirect, being linked to transport costs and fuel prices, largely externalities outside the control of Fijian policy. Fiji's most anticipated food and energy project is the agro-photovoltaic project on Ovalau. According to KI02, the success of the project would be a win-win for three sectors: energy, food, and land, making it a significant contributor to LEDS objectives and sectoral development policies alike, presenting an opportunity for translating nexus thinking into nexus doing (Simpson and Jewitt, 2019). KI02 and KI08 highlighted the setting up of an accredited biodiesel lab. Fiji is working towards developing blend B5 (95% diesel, 5% coconut oil) biodiesel and blend E10 (10% ethanol, 90% diesel). The raw material for ethanol would be molasses, a sugar by-product. The Fiji Sugar Corporation (FSC) is the main electricity supplier during the cane-crushing season on the northern island of Fiji. FSC is supporting Nabou Energy which uses

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biomass to generate electricity (KI03). The future of Nabou may be questionable as the very high ambition scenario aims for 80% protection of forests (to 1.03 million ha from 2036). Biomass plants, requiring land potentially currently used for forests, are to be included in the mix. Expanding biomass plants for energy production would require careful planning to balance feedstock and forest protection to avoid policy trade-off situations.

Energy is vital for food accessibility due to price and market access. Fiji has sufficient food for food security. Food insecurity is mainly due to a lack of affordability or accessibility due to the island's remoteness. Fongar et al. (2021) state that due to the remoteness of Tongan islands, food prices are susceptible to fuel prices associated with transportation. On the other hand, Fiji has a list of 15 basic food items under price control. The Fijian Consumer and Competition Commission (FCCC) considers importation, processing, and distribution costs before deciding on retail and wholesale prices. KI07 mentioned that because Fiji does not have a significant threat to food insecurity, the WFP was determined to make food systems resilient and addressed food availability issues by providing food vouchers ensuring the nutritional needs of families are met.

Synergies and trade-offs in the Fijian nexus policy landscape

While making decisions between WEF security and the implementation of mitigation interventions such as the LEDS, the security of resource availability is the underlying factor, a choice driven by socio-economic considerations. For example, WAF has the potential to set up solar photovoltaics on the Vaturu dam. However, the infrastructural investment for Transmission Distribution Retail (TDR) will require millions of dollars, exceeding the cost of water sales by WAF and thus not a feasible (economic) option. Thus, economic considerations often override resource and sustainability concerns. Although WAF spends money on fuel, it is still profitable in comparison to the potential solar farm, representing a clear trade-off between policy objectives, but stemming from exogeneous (i.e. economic) factors (KI09). Electricity costs need to be sustained by EFL regarding the development of new renewable energy options, which are commercially unviable for the utility. Both utilities choose to burn diesel to provide a continuous and reliable supply of water and electricity to their domestic customers rather than investing in longer-term renewable energy initiatives. This leads to LEDS and sectoral policy ambitions being compromised by exogeneous factors. As this analysis shows, there are many synergies between the LEDS and sectoral policy, and between sectoral policies. If these could be harnessed to make the economic case more viable, there could be the potential for nexus-wide policy attainment for the benefit of the nation, despite exogenous forces. Decoupling food productivity from carbon emissions is challenging on Fiji, making the exploitation of synergies challenging. A good example of why this is the case came from KI10: if agriculture is included in the emissions inventory, the challenge is how to reduce emissions. For example, if a target is to cut emissions from livestock, the number of animals would need to be reduced, leading to a trade-off with a food policy which aims for self-sufficiency in meat production. The trade-offs between biofuels, food production, and forestry maintenance were discussed in the previous section. Clear multi-sectoral coordination and dialogue are required to overcome such situations, for example by identifying zones where non-food crops could expand without detriment to food crop production and forestry preservation.

Policy recommendations and barriers

It is incontestable that the scenarios proposed in the LEDS VHAS are very ambitious and likely unachievable by mid-century. Barriers can be a valuable foundation for enabling conditions created by policy suggestions to boost synergies and lessen trade-offs between low-carbon development and WEF Nexus security. It has been 5 years since the endorsement of the LEDS, and Fiji is to implement any concrete actions identified in the LEDS. The challenges and recommendations for implementing these ambitious targets are concentrated on four key areas (governance; technology and innovation; human capital; and land issues), elaborated below. Similar studies that used policy and governance coherence approaches have been used to suggest practical reforms and changes to integrated natural resources management, demonstrating the possible impact of this study (John et al., 2023; Suda et al., 2024).

Governance

The institutional arrangements vital to mainstream mitigation into WEF nexus sectors were emphasised by interviewees KI05 and KI07 who explained that while the decisions for Government Ministries are taken at the Cabinet level, utility decisions are made by Boards of Governors. KI09 pointed out that it is crucial to consult institutions such as utilities before announcing decarbonisation targets, otherwise, there is a risk of governance and implementation incoherence (cf. John et al., 2023). While KI06 stated that FCCC is responsible for setting electricity tariffs to allow Independent Power Producers to contribute electricity to the grid, they must sign a Power Purchase Agreement with EFL which is essentially a monopoly with no ambition or necessity to encourage private producers from entering the renewable energy market. For producers who do enter the market, EFL purchases power at a very low rate, a rate which they determine (KI07). There is therefore a need for political intervention in this arrangement to allow for faster implementation of the VHAS in terms of renewable energy deployment.

Given the importance of institutional arrangements in mainstreaming mitigation into WEF nexus sectors, it is recommended that the government engage in consultations with key institutions such as utilities and end-users to ensure their capacities and support for national decarbonisation targets. Additionally, there is a need for political interventions and reforms to accelerate the implementation of high-ambition scenarios. The government should consider reforming the monopoly held by EFL to encourage the participation of independent power producers in the energy sector. Clear and direct messaging about national plans is crucial for effective policy implementation, and the government should revise the wording of national targets to remove ambiguity and provide the necessary endorsement of the energy policy to facilitate the transition to renewable energy sources. A review of the Electricity Act 2017 would be beneficial to remove certain powers of EFL that determined the engagement and interest of public-private partnerships. History suggests this could be a long and cumbersome process. However, other avenues for change and transition could be through the shareholders of EFL. Currently, 51% of shares are with the Fiji Government, 44% with the Japanese Company, and the remaining with Fijians, where a greater push from local shareholders is needed to leverage energy transition and renewable energy infiltration into the grid.

Technology and innovation

Fiji needs technology and the mechanisms to finance technologies to achieve the ambitious VHAS. One initiative is the Fiji Rural

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Electricfication Fund (FREF), a collaboration between the Government and the private sector to electrify rural communities. Fiji is at the end of the supply chain and is receiving end technology, for which infrastructure needs to be in place. All new technology must be financially and technically feasible for widespread adoption (e.g. electric vehicles), otherwise, there could be viability issues like with the Nabou Green Biomass plant and Butoni windmills (KI05). Solar has potential, however, the infrastructure is not resilient to Category 5 cyclones.

Concerning biofuels, problems with competing markets for feedstock are problematic. For example, KI02 and KI08 explained that secondary applications of coconut oil give it a greater market value which is not used by biodiesel producers, resulting in insufficient feed for biodiesel production. To address the issue of insufficient feedstock for biodiesel production, the government can consider implementing policies to promote the cultivation of crops specifically for biofuel production. The revival of the sugar industry would create opportunities for ethanol and electricity production, provide co-benefits by improving socio-economic conditions for rural farmers, and boosting sugar exports.

To address the need for technology and financing mechanisms, the government of Fiji can consider implementing a green investment scheme such as the existing FREF green bonds which have given way for projects such as the installation of new solar home systems for rural households (Ministry of Economy, 2020b) incentivizing private sector investment in renewable energy. The government can work with development partners to provide low-interest loans or grants to help finance renewable energy projects. Apart from traditional grants and loans provided by the Green Climate Fund for implementing the agro-photovoltic project on Ovalau, Fiji has an innovative solution to scale electricity access for the 4% of the population not connected to EFLs grid. This initiative is financed through the Fiji Rural Electrification Trust Fund. Communities are assessed from funds available and supported by other development partners. Once the microgrids are set up, a levy is charged for the electricity consumption that goes back to the maintenance of the infrastructure. Expanding these schemes would speed up the ambition towards 100% electrification access.

Regarding new infrastructure needs, a national energy infrastructure plan could be developed prioritizing the development of resilient infrastructure capable of withstanding natural disasters. This plan can include the development of microgrids and energy storage solutions that can provide electricity to communities even in the event of power outages. Alternatively, these measures can be included in the existing processes, such as the power development plans. Regarding larger grid transitions to renewables, Fiji explored the Clean Development Mechanism (CDM) for its hydropower dam in the past. There is an appetite to use carbon markets as a financing mechanism to implement large-scale renewable energy technology as outlined in Fiji's updated Nationally Determined Contribution (NDC) from 2020 and in its recent Carbon Market Strategy Roadmap from 2024. Although there is interest from the private sector in engaging in public-private partnerships, unless the Electricity Act in Fiji is amended, the bottleneck will continue to exist at EFL, which is unable to provide lucrative grid feed-in tariffs for the private sector. The financial mechanisms, technical, and capital needs for demand-side energy efficiency improvements are outlined in the Fiji NDC Investment Plan and Project Pipelines. However, work is needed to translate these concept notes into full project proposals.

Human capital

From interviews, it was understood that there were two types of human capital issues. Firstly, there is a lack of technical expertise to undertake feasibility studies and designing of projects and programs. Secondly, Fiji 'exports' technically skilled people. To address such issues, the government could implement programs to incentivize and retain technical experts and skilled workers. One approach could be establishing partnerships between the government and private sector to fund technical training programs for people in Fiji. Another recommendation is to create job opportunities, attractive employment packages, and career development programs in technical fields. The Fiji Development Bank Small and Medium Enterprise Loans and Awards are an excellent example of promoting employment, innovation, resilience, and economic growth for sustainable development. Further synergies can be created by scaling up such initiatives to incorporate low-carbon development and WEF resource security. The government could provide tax incentives to companies that hire and retain local technical experts. These policies would help build a strong technical expertise foundation to support the development and implementation of sustainable projects and programs in Fiji.

Land issues

Fiji has limited land. Since the most viable source of electricity is hydropower, the construction of dams requires flooding riverine communities leading to the loss of livelihoods and cultural heritage (KI02, KI08). Land development is a political and controversial topic that requires a robust Environment Impact Assessment (KI03), and that incurs expensive royalties to landowners that make many developments financially unviable. To address land-related bottlenecks, the government could consider implementing policies and programs prioritising sustainable land use and community engagement in development planning. One approach could involve local communities in the decision-making process for land development projects, ensuring that their perspectives and concerns are considered. This could be achieved through participatory approaches such as community meetings and consultations, which would help to build trust and cooperation between the government, private sector, and local communities. Another recommendation could be to provide incentives for developers to use sustainable land use practices such as agroforestry. Additionally, tax incentives or subsidies for landowners who prioritize sustainable land use practices and those who prioritize the conservation of cultural heritage sites could be brought in.

Another point is made on the potential political and economic implications of implementing the VHAS policy on Fiji. Fiji has fiscal deficits that need to be financed through domestic and external loans. The Fiji Government's debt stood at 4.3 million USD for the fiscal year 2023 and 4.5 million USD for the fiscal year 2024, making up 80% and 78.3% of the annual Gross Domestic Product (GDP), respectively (Ministry of Finance, Strategic Planning, National Planning, and Development, 2023; 2024). Much national expenditure goes to infrastructure development in the transport, water, and sewerage sectors, with little attention given to the health sector. With major transitions to electrification infrastructure, Fiji would further increase its debt-to-GDB ratio and continue to face socio-economic tradeoffs in the health sector, with potential political and well-being implications.

This work offers practical policy reformulation advice. For example, Fiji has limited natural and financial resources. The minerals and rivers in Fiji belong to the Government, yet catchments

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belong to native people if the river passes through a native land holding. Currently, EFL is undertaking feasibility studies to develop hydro dams in the resource-rich province of Namosi which could result in 90% of electricity generation in Fiji coming from renewable sources, saving billions of dollars on fuel importation. However, there is strong retaliation from landowners and occupants as they are concerned about the occurrence of floods and the preservation of their land and resources for hunting and food. Some mataqali (land holding units) are further considering engaging in forest rehabilitation, restoration, and protection for carbon trading to protect their land and resources from future development of dams and mines[1]. Such nexus policy analysis helps identify these trade-offs and can enable discussion to mitigate or avoid them in future developments.

Limitations and further prospects

While this study aimed to be comprehensive, a number of limitations and prospects for future research are acknowledged. Firstly, only the Very-High Ambition Scenario in the Fijian LEDS was analysed, offering an opportunity to explore the impacts of lower-ambition LEDS scenarios. The VHAS was chosen as it is the only one that aims to achieve net-zero emissions. In terms of the NDCs, only those instruments related to water, energy, and food were selected. Other socio-economic sectors and resources were not considered, offering an opportunity to further expand the scope of this research. This limitation could have led to an underassessment of nexus interactions and perhaps not given a complete picture of the situation. However, with ample time, future studies can undertake a thorough analysis of all components of the policies to provide a detailed overview of the WEF nexus. Some policies such as the National Water Resources Management and Sanitation Policy and National Energy Policy are yet to be endorsed by the Fijian Cabinet.[2] However, this study could add value to draft documents, considering its findings on synergies and trade-offs arising from implementing ambitious mitigation actions. Similarly, current strategic plans for the Ministry of Waterways and Ministry of Agriculture were used due to the absence of their updated policies. However, both strategic plans draw linkages from the national and sectoral objectives of the NDP. Another limitation is the potential subjectivity of the strength of policy interaction scores (e.g. is an interaction −2 or −3?). The scores could be refined and validated in stakeholder settings with sufficient time and budget that were not available for this study. Despite this, the rationales for every interaction assessed are given in Supplementary Materials S4 and S5 and were triangulated via the interviews. Cost-benefit analyses could also be included to better quantify policy interactions, and scenario analysis employed to gauge the range of interactions. This could be done by including the other Ambition Scenarios in the Fijian LEDS.

Conclusions

This article qualitatively assesses key Fijian national and sectoral policies and the impact of a highly ambitious mitigation policy and its impacts on the behaviour of nexus interactions. The qualitative assessment involved a Policy Coherence assessment which analyzed the interactions between Fiji's Low Emission Development strategy and five other sectoral water, energy, and food policies. Based on the direction and strength of interaction, the policies were weighted on a scale of −3 to +3, with more synergies than trade-offs identified. The assessment also identified 10 Nexus Critical Objectives (NCOs) of which two were related to water security, five were related to energy security, and the remaining three were related to food security. This indicated that the energy sector dominates the WEF nexus in Fiji, as evidenced by the nexus critical instruments derived from the interaction between instruments from the LEDS and the NCOs, which were also dominated by energy sector instruments. From the analysis, the article offers policy recommendations that target governance, technology and innovation, human capital, and land issues to address the barriers to implementing the net-zero strategy, promote synergies, and minimize trade-offs between low-carbon development and WEF nexus security in Fiji.

This research provides valuable insights for more detailed sectoral-level nexus research to understand individual sectors, as it highlights important linkages that require closer inspection in the Fijian policy landscape. The outcomes are useful for informing and supporting short- and long-term decision-making around important interactions affected by ambitious mitigation actions. Lastly, this article adds value to the research field by demonstrating the complexity of the WEF nexus using qualitative methods and suggests that with sufficient data, it could be expanded to quantitative modelling assessments. The work is replicable to most other contexts, and especially to other small island developing states, many of which are resource-constrained and face issues similar to those on Fiji.

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Competing interests. The authors declare none.

[1]Sources: https://www.fbcnews.com.fj/news/study-underway-for-proposed-namosi-hydro-project/; https://www.fbcnews.com.fj/news/resistance-in-namosi-villagers-oppose-hydro-dam-project/; https://fijivillage.com/news/Some-Namosi-mataqali-have-not-agreed-and-signed-leases-for-proposed-hydro-dams-52krs9; https://www.fijitimes.com.fj/namosi-hydro-talks-land-portions-will-be-permanently-inundated-eia-report/; https://www.fijitimes.com.fj/namosi-hydro-talks-villagers-fear-flooding-and-diminishing-food-stock/; https://mataqalinabukebuke.com/post-1/

[2]The National Energy Policy was endorsed in 2024, after the completion of this study.

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