A Hydrogen Roadmap for the Pacific

Draft for Consultation | December 2024

The Efate outcome statement from the Fifth Pacific Regional Energy and Transport Ministers' Meeting held in Port Vila, Vanuatu in May 2023, recognised the need to consider the potential of green hydrogen and its derivatives in decarbonising the region and requested support in the development of a time-bound Pacific regional green hydrogen strategy. Responding to this request, the Australian Government's Department of Climate Change, Energy, the Environment and Water (DCCEEW) is leading the development of the Pacific Hydrogen Strategy, in partnership with UNSW Sydney, the International Renewable Energy Agency (IRENA) through the SIDS Lighthouses Initiative, the Pacific Community (SPC), and the University of South Pacific (USP). This report summarises the findings as part of the Pacific H_2 assessment and engagement, and based on these, proposes a roadmap/strategic action for furthering the development of the H_2/derivative industry in the Pacific region.

The report greatly benefited from the interviews and stakeholder engagements from both regional/global industrial and government partners and acknowledges their valuable inputs. It also acknowledges inputs from Ngedikes Olai Uludong (SPC), Tobias Gun (DCCEWW), Sam Wagstaff (DCCEWW), Aicha Ben Youssef (IRENA), Arieta Gonelevu Rakai (IRENA), Danielson Daniel Sousa dos Reis Dias (IRENA) and Nadia Mohammed (IRENA)

This report and all material produced as part of the Pacific Hydrogen Roadmap are available for download: https://pacifich2strategy.com/

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Executive Summary

The Pacific Islands and Communities (PICTs) reliance on imported fossil fuels exposes the region to economic risk as financing their imports accounts for a significant share of regional GDP that can be spent on regional uplift. Moreover, despite the PICTs contributing insignificantly to global carbon emissions, they are at the forefront of the impacts of climate change, with rising sea levels threatening their existence. Highlighting the urgent need to transition away from fossil fuels, the PICTs have made substantial progress with ambitious, world-leading climate and renewable energy goals. However, entirely replacing fossil fuels will require the integration of green hydrogen and its derivatives, in conjunction with expanding renewable energy capacity, to establish a resilient, scalable, and sustainable net-zero energy future.

PICT's Energy Outlook

Recognising the existential threat posed by climate change, the PICTs are emerging as leaders in the ambition and implementation of a transition to renewable energy despite their small size and limited resources. Almost all the PICTs have a climate commitment and a high renewable energy penetration target, which has seen several of them reach high levels of renewable energy penetration.[i].

Yet, cumulatively, fossil fuels drive ~two-thirds of the region's energy mix, almost all of which are imported into the region (equivalent to 6% of the regional GDP).[ii] This highlights the significant shortfall relative to the PICT's goal of reducing reliance on fossil fuels, which are often imported at high costs, and promoting energy self-sufficiency.

The Pacific's drive for Hydrogen and Derivatives

The Fifth Pacific Regional Energy and Transport Ministers' Meeting, held in Port Vila, Vanuatu, in May 2023, recognised the need to consider the potential of green hydrogen and its derivatives in decarbonising the region. The outcome statement from the meeting endorsed the development of a time-bound Pacific regional green hydrogen strategy to consider the potential and limitations of green hydrogen for the Pacific.

A Pacific Hydrogen Roadmap

In response to this request, the Australian Government's Department of Climate Change, Energy, the Environment and Water (DCCEEW) this document provides a preliminary Pacific Hydrogen Roadmap (PHR) in partnership with the University of New South Wales (UNSW) Sydney, the International Renewable Energy Agency (IRENA) through the SIDS Lighthouses Initiative, the Pacific Community (SPC), and the University of South Pacific (USP).

The PHR has been developed based on findings from a year-long series of activities, including regional workshops, engagement with industrial/government stakeholders and assessment reports. These resources aim to deliver a regional understanding of the role of green H_2 and derivatives in the PICTs, a techno-economic assessment of developing the

[i] PICTs such as Fiji (25%), Vanuatu (28%), Samoa (30%), Kiribati (37%), PNG (44%) and Solomon Islands (44%) have achieved high shares of non-fossil fuel-based energy shares. Refer to appendices of Report A.
[ii] Refer to Report A of the series available on the project website: https://pacifich2strategy.com/publications_/

green H_2 value chain in the PICTs, capacity-building resources (such as assessment tools and masterclasses on green H_2/derivative technologies) and propose a set of strategic actions for the development of the regionally integrated green H_2 value chains.

Pacific Hydrogen Assessment

UNSW Sydney, on behalf of DCCEEW, has led the Pacific Hydrogen Assessment with the support of IRENA, USP and SPC. The assessment includes the following reports:

- **Report A—*The Case for Green Hydrogen in the Pacific*:** As the first series of assessments, this report assessed the current state of energy markets across the PICTs. Identifying the role green H_2 and derivatives can play in the electricity sector (complement renewable energy generation and on-demand power generation in remote and off-grid locations) and renewable energy penetration across hard-to-abate sectors such as heavy-duty land transport, shipping and aviation sectors.
- **Report B—*Green Hydrogen and Derivatives Technology Assessment for the Pacific*:** The second report of the series, then conducted an in-depth review and assessment of the potential green H_2 and derivative technology from global overview and applicability to the PICTs. Note: Only renewable-based (electrolysis and bioenergy) pathways are considered, given the target of moving away from fossil fuels.
- **Report C—*Techno-economic Assessment of a Hydrogen Value Chain in the Pacific*:** The third assessment report then conducted a detailed techno-economic assessment of both regional production and end uses of H_2 and derivatives in the PICTs. Open-source assessment tools have also been developed as a regional resource.

These reports and supporting material have been made available for download on the project website: https://pacifich2strategy.com/

Pacific Hydrogen Engagement

In addition to the technical assessments, the PHR is developed based on findings from engagement with regional and international stakeholders. This engagement included a series of workshops, forums, and roundtable discussions with energy, industry, and government stakeholders facilitated by UNSW, DCCEEW, IRENA, SPC and USP. The purpose of the consultations was to identify the key barriers and opportunities across the key topic areas and formulate strategic next steps for the PICTs in understanding their green H_2 potential. These engagements established the following key themes:

- **Regional Coordination and Implementation:** The region must take a leadership role and come together to develop an integrated value chain. Resource-rich regions will emerge as central production and supply hubs, supporting smaller resource-deficient areas in achieving energy self-sufficiency.
- **Capacity Building:** Moreover, for the regional stakeholders to take the leadership role in developing the green H_2 value chain, capacity building and an understanding of the role of green H_2 and derivatives in the region by equipping them with knowledge/resources to drive the development of such a value chain would be required.
- **Policy, Regulation, and Social Acceptance:** Develop a framework to support the adoption of green H_2 and derivatives as part of the region's energy policy. In parallel, develop a regulatory framework (building upon emerging certification and standards) to source, deploy, and safely operate technology. Facilitate the social acceptability of green H_2 and derivatives to streamline the transition to new technology.
- **Project Development Support:** Understanding that a shift to H_2 and derivatives has an opportunity cost against renewable electrification and other economic activities.

Economically, especially in the near term, a change to green H_2 and derivatives will incur a premium against incumbent fuels. Therefore, an investment framework for targeted regional and foreign funding (e.g., capital support and incentives) is needed to support the development of opportunities that deliver tangible environmental benefits. Moreover, technical challenges, such as access to feedstocks and support infrastructure, would have to be considered. Resource allocation frameworks would have to be established to enable access to and manage competition for resources such as land, water, biomass, and renewable energy. The region has a critical opportunity to leverage existing infrastructure to use derivatives such as methanol, renewable diesel, or SAF as drop-in blends or fuels. Therefore, an assessment of infrastructural readiness and compatibility for these fuels is needed.

Timebound Action Plan

The overall findings from the assessment are then used to draft the proposed timebound actions and roadmap to facilitate the development of PICT's H_2 market and strategy.

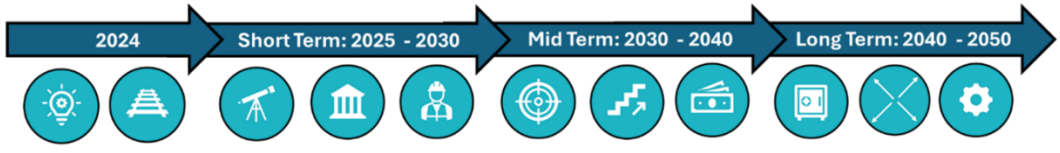
This includes the identification and recognition of stakeholders and key regional drivers for delivering the Pacific H_2 roadmap. These include:

- G — PICT's Regional Governments
- P — Private Sector
- I — International Collaboration financing support, such as the World Bank
- SPC — SPC – The Pacific Community
- USP — USP – University of the South Pacific
- RC — Greater PICT's regional community

In addition, the time-bound action plan is proposed for the following timelines:

- **Initial Foundation Stage:** Near-term actions for 2025 to 2030 that will focus on laying foundations such as regulatory/policy adoption, capacity building and initial market development.
- **Scale-Up Stage**: Medium-term actions for scale-up in 2030 – 2040, when we expect technology to become inherently cost-competitive with incumbent fossil fuels, making it an ideal time for large-scale offtake.
- **Course Correction Stage:** Long-term actions for 2040 onwards to adapt and upgrade regional green H_2 strategy/policy, considering progress and future changes in energy policy.

The proposed time-bound action plan shown below is detailed in the main body of the report.



- T1. Regional consensus on exploring a H_2 and derivative opportunity.
- T2. Development of the Pacific H_2 Roadmap.
- T3. Development of a regional integrated H_2 strategy.
- T4. Adoption of regulatory and policy support.
- T5. Development of early-stage demonstration projects
- T6. Regional capacity building
- T7. Identification of niche markets
- T8. Setting foundations for project scale ups
- T9. Access to funding for market development
- T10. H_2 & derivatives become a bankable opportunity
- T11. H_2 & derivatives become an established tool within the energy transition.
- T12. Course correction and definition of long term H_2 & derivative roles.

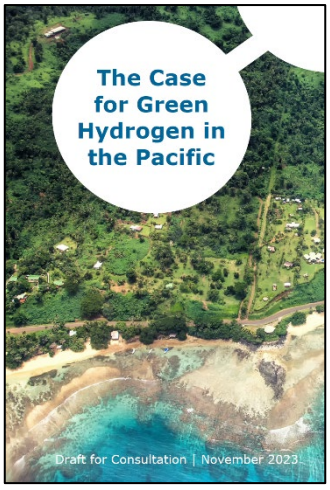
1. Overview of PICT's H_2 and Derivative Opportunity

1.1. Pacific Hydrogen & Derivative Opportunity Assessment

The Efate outcome statement from the Fifth Pacific Regional Energy and Transport Ministers' Meeting held in Port Vila, Vanuatu, in May 2023, recognises the need to consider the potential of green hydrogen and its derivatives in decarbonising the region. This included endorsing the development of a timebound Pacific regional green hydrogen strategy. In Response to this request, the Australian Government's Department of Climate Change, Energy, the Environment and Water (DCCEEW) is leading the development of the Pacific Hydrogen Strategy in partnership with the University of New South Wales (UNSW) Sydney, the International Renewable Energy Agency (IRENA) through the SIDS Lighthouses Initiative, the Pacific Community (SPC), and the University of South Pacific (USP). The strategy was then developed across workshops, stakeholder engagement, and a series of assessment reports.

1.2. Report A — The Case for Green Hydrogen in the Pacific

Report A of the series provides a state of play of the PICT's energy mix and links it with the potential for H_2 and derivatives technology to be deployed across the PICTs.



An assessment of the present energy outlook of 13 central Pacific Island Countries and Territories (PICTs) was conducted. The evaluation provided an overview of the current energy supply, demand, policy, and distribution of renewable energy (solar, wind, and hydro) and bioresources across the PICTs.

Salient findings included:

- Despite ambitious climate/renewable energy targets and progress, ~70% of the PICTs' primary energy supply is driven by fossil fuels. The bulk of the demand is from electricity generation (61%), followed by the land mobility sector (32%), aviation (4%) and maritime sector (3%). [iii]
- Moreover, almost all fossil fuels used across the PICTs are imported energy, exposing the region to economic risks (accounting for US$2 billion, or 6% of regional GDP) and energy reliance.
- Altogether, the PICTs have firm commitments and ambitions to reduce reliance on fossil fuels; as such, green H_2 and derivatives (generated through renewable electrolysis or biomass-based pathways) can complement renewable electrification of

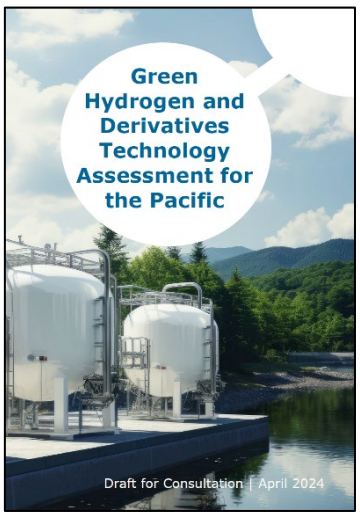
[iii] These estimates are based on regional review of publicly available data and stakeholder engagement. Refer to appendices of Report A for detailed modelling and relevant data references. Refer to the project website: https://pacifich2strategy.com/publications and appendices of report A.

the regional economy, especially in hard-to-electrify sectors like shipping and aviation (**Table 1**). It can also play a complementary role in the power sector by enabling long-term seasonal storage of renewables and on-demand power generation. Whereas in land mobility, battery electric vehicles (BEVs) are likely to be a scalable and more widely adopted solution (due to costs, maturity of technology and availability), but niche opportunities can exist for fuel cell-powered vehicles and drop-in fuel replacements such as methanol and SAF.

TABLE 1. EARLY MARKET OPPORTUNITIES FOR HYDROGEN TECHNOLOGIES IN THE PACIFIC REGION.

Application	Hydrogen	Methanol	Ammonia	RD	SAF
Seasonal Power Storage	✓			✓	
On-Demand Power Generation	✓			✓	
Land transport fuel	✓	✓		✓	
Maritime fuel		✓	✓	✓	
Aviation fuel					✓

1.3. Report B — Green Hydrogen & Derivatives Technology Assessment for the Pacific



Report B of the series then reviewed and assessed hydrogen and derivative technology from a global perspective and its applicability to PICTs.

The report assesses the status of current and emerging green H_2 and derivatives technologies. Note: Only green, renewable–driven electrolysis and bio-based production technologies were considered. Moreover, the assessment covered both production, distribution (storage and transport), and end use of H_2 and derivative technologies. A detailed literature analysis and market overview were conducted to develop a technical and economic overview of these technologies and establish their suitability for adoption in the PICTs.

From a production perspective, green H_2 production using renewable-driven electrolysis and subsequent conversion to ammonia using the Haber Bosch process have reached high levels of technology maturity. Biopathways such as gasification, Fischer Tropsch, HEFA, and Alcohol to Jet pathways for SAF, RD, and methanol production all have high commercial maturity. Economically, bio-production pathways are more competitive against fossil fuel processes compared to e-pathways. On a technical level, bio-pathways are more energy efficient and scalable than e-pathways, whereas e-pathways are more dynamic in terms of operational flexibility.[iv]

[iv] Refer to Report B of the series available here: https://pacifich2strategy.com/publications for more details.

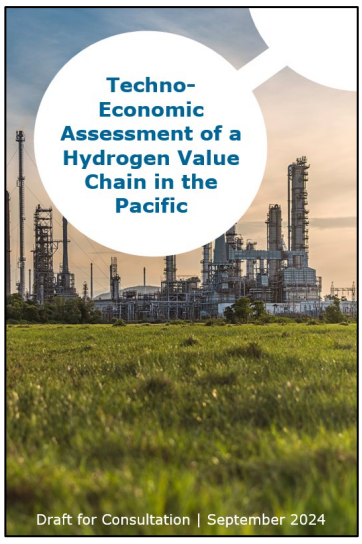
TABLE 2. PERFORMANCE MATRIX FOR THE HYDROGEN AND DERIVATIVES END-USE APPLICATIONS IN THE PACIFIC. NOTE: B = BIOGENIC PATHWAY, E = ELECTROLYTIC PATHWAY.

Metric	Hydrogen		Ammonia			Methanol B|E			SAF B|E		Renewable Diesel B|E	
	Power Storage	Road Fuel	Power Storage	Maritime Fuel	Fertiliser	Power Storage	Road Fuel	Maritime Fuel	Aviation Fuel		Road Fuel	Maritime Fuel
Technology Maturity (TRL)												
Economic Feasibility												
Fossil Displacement Potential												
Emission Reduction Potential												
Infrastructure Readiness												
Scale of Opportunity												

Rank	Guide
High	Best Performing Hydrogen Derivatives
Average	Average Performing Hydrogen Derivatives
Low	Least Performing Hydrogen Derivatives

1.4. Report C — Techno-Economic Assessment of an H_2 Value Chain in the Pacific.

Report C of the series then builds on the findings from the previous two reports and conducts a detailed techno-economic assessment of the hydrogen and derivatives opportunity in the PICTs.



A techno-economic assessment (TEA) framework was developed and used to conduct the assessment in this report. The framework is then used to estimate the amounts of H_2 and derivatives needed to displace fossil fuels used in the region, including for specific end-use applications. Subsequently, it is used for an economic assessment to evaluate the present and future forecasts of production and end-use costs. Their cost competitiveness is compared with incumbent fossil fuels to make a case for shifting to H_2 and derivatives.

The key findings from the assessment include[v]:

- Overall, it was estimated that fossil fuels provide ~40 TWh of energy. Displacing this would require 1.1 Mtpa of H_2, 5.3 Mtpa of ammonia, 6.2 Mtpa of methanol, 3.6 GL/yr of RD (3.1 Mtpa) and 0.3 GL/yr of SAF (0.2 Mtpa).

[v] Refer to Report C for the detailed analysis, available on the project website: https://pacifich2strategy.com/publications

- **Table 4** provides an economic outlook of the identified H_2 and derivative opportunities. Overall, biofuels are more likely to be cost-competitive to produce. Moreover, from the end-user perspective, RD and SAF are likely to be most competitive for land, maritime, and aviation applications.

TABLE 3. ECONOMIC OUTLOOK OF H_2 AND DERIVATIVE OPPORTUNITIES IN THE PICTS.

Production	Economic Viability of H_2 and Derivative Production				
	H_2	Ammonia	Methanol	Renewable Diesel	SAF
E-pathway					
Bio-pathway					
End Use	**Economic Viability of H_2 and Derivative Use versus Incumbent Fossil Fuel**				
	H_2	Ammonia	Methanol	Renewable Diesel	SAF
Power-Gen		-	-		-
Land Transport		-	-		-
Maritime Use	-				-
Aviation Use	-	-	-	-	

Rank	Guide
	Not Applicable
	It is very unlikely to be competitive without supporting actions.
	It is unlikely to be competitive without supporting actions.
	Likely to be competitive
	Very Competitive

These assessment studies provide a technical and economic context for the Pacific Hydrogen Strategy. While there is significant demand and economic potential for developing a hydrogen and derivatives value chain in the PICTs, essential challenges such as competition for feedstock, shortage of local expertise skills, capital-intensive nature of e/bio-pathways, uncertainty, and gaps in infrastructural readiness, policy, regulation, and social acceptability were uncovered. These were then shared with regional stakeholders in the engagement and road mapping exercises elaborated in the following sections of the report.

Note: These studies are accompanied by a database of underlying assumptions, feedstock data (renewable energy profiles and biomass availability) and costing tools as a resource for knowledge sharing and capacity building. These resources are publicly available on the project website: https://pacifich2strategy.com/

2. Road Mapping and Stakeholder Engagement

In parallel to the technical and economic assessment, road mapping and stakeholder engagement exercises were conducted to identify preliminary barriers and potential opportunities for the PICTs in realising a regional hydrogen value chain.

2.1. Road Mapping and Engagement Framework

The road-mapping exercise is carried out in the following stages:

1. **Techno-Economic Assessment:** This stage involved the publication of **Report A-C**, findings, and underlying data, which were verified through stakeholder engagement with technology/H_2 project developers, regional stakeholders (facilitated by DCCEEW and SPC), and collaboration with IRENA.
2. **Identification of Key Action Themes:** Based on the technical assessment, key themes underlined in the section below were identified as points of engagement during the road mapping exercise.
3. **Road Mapping and Engagement:** The critical action themes were then discussed through in-region engagements and international collaborations (refer to **Section 2.2. Road Mapping Timeline**).
4. **Draft of the Timebound Action Plan:** The findings from the road mapping and engagement activities were then synthesised into a time-bound action plan. The action plan then provides actions and targets (short, medium and long-term) to address the identified action themes.

Figure 1 illustrates the road mapping and engagement process undertaken.

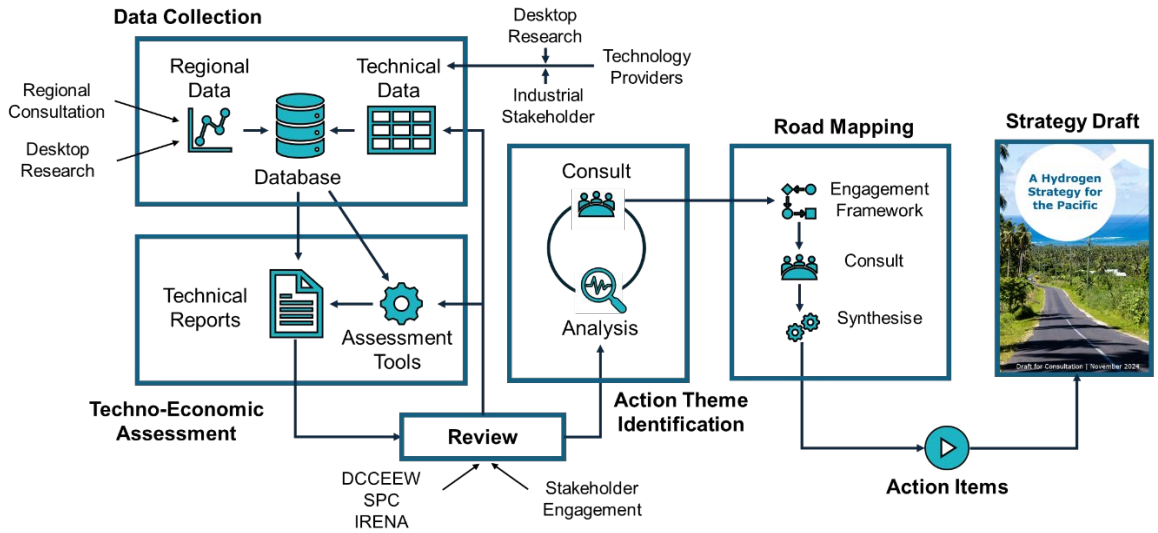


FIGURE 1. FRAMEWORK FOR THE PACIFIC HYDROGEN STRATEGY ROAD MAPPING.

2.2. Engagement Timeline

Our analysis in these reports has provided critical insights into the potential for green hydrogen and derivatives application within the Pacific Islands region. This work has been complemented by a region-wide engagement with industry, government, and relevant stakeholders through in-country workshops.

These include:

- **5th Regional Energy and Transport Minister's Meeting:** The meeting hosted at Port Villa in Vanuatu in 2023 laid the foundation and groundwork for this work. The Pacific Hydrogen Strategy project stems from the outcome of Efate's statement from the event, which recognised the need for innovative technologies, including H_2, required to accelerate regional decarbonisation. A call was made to IRENA and other partners to examine further the potential role of green hydrogen and its derivatives with a view to developing a timebound Pacific regional green hydrogen strategy. In particular, the energy officials came to a resolution that H_2 and derivatives can play a role in the deepening of decarbonisation efforts in PICTs.
- **Energy Transition Workshop:** UNSW and DCCEEW hosted a workshop on Planning Frameworks and Capacity Expansion Modelling Tools for the Pacific Islands in Fiji (September 2023). The session included frameworks and energy modelling tools developed by UNSW. It also included a workshop on Renewable Hydrogen for the Pacific Islands. The workshop provided opportunities and challenges of renewable H_2/derivatives value chain, including tools and frameworks that can help regional stakeholders assess opportunities. Setting the scene for the Pacific to undergo sector coupling their growing renewable energy capacity to generate synthetic fuels for energy storage, diesel substitution, international bunkering, domestic navigation and aviation
- **Workshop on Renewable Hydrogen for the Pacific Islands in Suva:** Following up on the Efate statement, a workshop was conducted in Fiji in September 2023. Here, representatives from the project consortium from DCCEEW, UNSW, IRENA, SPC, USP, and Pacific Power Association (PPA) elaborated on the current energy outlook of the Pacific region and its compatibility for H_2/derivative production to regional energy, industry, and government stakeholders.
- **Overview of IRENA's clean energy initiatives in the Pacific Region:** IRENA also hosted a presentation in the region on their energy initiatives in September of 2023. The event elaborated on the Small Island Developing States (SIDs) Lighthouse initiatives by IRENA. The event highlighted the efforts and progress made by IRENA, including an analysis of the tools and renewable energy roadmaps that they have developed and used in the region, providing an overview of how they can assist the Pacific Islands.
- **30th PPA Annual Conference:** Representatives from UNSW delivered a workshop at the Pacific Power Association's Annual Conference, held in Saipan, Northern Mariana Island. The session discussed the challenges of energy planning with emerging technologies, with a particular focus on hydrogen.
- **Project Launch at COP28:** The project was showcased at the 28th United Nations Climate Change Conference (COP28), that was hosted in Dubai in 2024. Where DCCEEW arranged a session with representatives from the project consortium, including IRENA, SPC, UNSW, and USP, to introduce the project. The event highlighted

the pivotal role hydrogen can play in assisting Pacific nations to meet their decarbonisation aspirations, particularly in hard-to-abate sectors.

- **Industrial Stakeholder Engagement: From February to June 2024,** UNSW representatives held several meetings and workshops with energy project developers and technology providers to collect technical data, insights, and lessons learned.
- **SPC Heads of Maritime Meeting:** SPC hosted a workshop with Heads of Maritime from 16 PICTs in Nadi in April 2024. The gathering co-developed and adopted the Pacific Regional One Maritime Framework (POMF), enhancing the resilience and safety of maritime operations across the region. Included in the proceedings was a session on the role of H_2 and derivatives in the marine sector. The session hosted by UNSW and DCCEEW came to a consensus that these new fuels can play a role in decarbonising heavy-duty maritime operations and help the Pacific emerge as a green shipping corridor.
- **Stakeholder Engagement Workshop on the Pacific Hydrogen Strategy**: UNSW representatives hosted a workshop with energy ministers and utility providers in Vanuatu (May 2024). The session presented the potential opportunities for Vanuatu and the Pacific as a whole. A fundamental understanding developed was the role of H_2 and derivatives as a drop in fuels.

Together, the engagements strengthened the role and potential for H_2 and derivatives in the region. However, significant barriers, including technical and economic challenges, policy, commercial (both societal and industrial) and infrastructure readiness to deliver the value chain, were identified. These challenges are identified as action items in the following sections.

2.3. Road Mapping Action Themes

Table 5 summarises the critical action themes identified during the road mapping stage.

TABLE 4. KEY ACTION THEMES IDENTIFIED IN THE ROAD MAPPING STAGE.

Theme	Consideration
Leadership & Ownership	▪ The green H_2 and derivative opportunities provide the region with an opportunity to achieve energy sufficiency through the integration and exchange of expertise, resources, and infrastructure
Policy Readiness	▪ How H_2 and derivatives fit into the more significant energy transition. ▪ Alignment with NDCs and renewable energy targets ▪ Impact on resource availability and their allocation. ▪ Potential hurdles and limitations in current policy and regulatory frameworks.
Economic Concerns	▪ Development of financing mechanisms through public, private, and foreign funding. ▪ Streamlining access to funding and approvals. ▪ Development of potential cost interventions – grants and incentives. ▪ Regulatory framework for funding allocation. Competition against other efforts, such as renewable energy capacity expansion.
Technical Concerns	▪ Status of regional capacity – availability of skills, expertise, and technology. ▪ Infrastructural readiness – accessibility to infrastructure and its compatibility to support H_2 and derivatives. Especially for drop-in fuels such as SAF and RD.

Social Acceptance	▪ Regional capacity building: Creating social understanding of benefits, limitations and risks of H_2 and derivatives. ▪ Adopting a robust social licensing framework for an inherent capacity during the early stages of project development to mitigate risks and hazards while maximising societal benefit by enabling tangible environmental and economic benefits – job/value creation and reducing the financial cost of the project on the public. ▪ Facilitate and incentivise a shift to H_2 and derivative end-use technologies.

2.4. Consolidated Findings

Integrating the results from the techno-economic analysis and building on the identified action themes, the key findings from the road mapping and stakeholder engagement are consolidated below:

Regional Coordination and Implementation

- The green H_2 and derivative opportunities provide the region with an opportunity to achieve energy sufficiency through the integration and exchange of expertise, resources, and infrastructure. Yet, the regional H_2 strategy needs to acknowledge that green H_2 and derivatives are not a blanket solution but one of many tools for decarbonisation.
- It was noted that the strategy needs to be timebound with clearly defined short-, medium-, and long-term milestones and targets to drive success.
- The region has, altogether and on individual country/territory level, already placed itself as a global leader in emission reduction commitments and renewable energy targets. H_2 and derivatives provide an additional decarbonisation toolkit for PICTs and have the potential to play a broad role across the energy spectrum. Yet, realistic expectations (both regionally and globally) are that they will play a secondary complementing role within the existing NDCs and renewable energy targets, with the bulk of energy transition to be led by electrification. Early market opportunities for H_2 and derivatives lie in the biofuel markets that can be deployed as drop-in replacements in existing distribution and end-use infrastructure. Meanwhile, medium- to long-term opportunities lie in hard-to-abate sectors such as heavy-duty transport, aviation, and maritime sectors, where electrification and alternatives are not competitive.
- Given the present lack of regional H_2/derivative-ready knowledge, expertise, and technology (particularly for e-pathways and new fuels such as H_2, ammonia, and methanol), the region expects and is open to international support and collaboration as a transitional step for building regional capacity, policy, and regulation.
- Consensus that the strategy will have to be delivered through private-public partnerships. The regional governments will have to play an oversight role in ensuring that H_2 and derivatives complement long-term energy and economic strategies and that they implement conducive policies, support mechanisms, and regulations to facilitate private and foreign investment. The private sector will, in turn, support the public sector by prioritising the development of region-benefiting projects and capacity building. Regional knowledge institutes such as universities and training institutes (e.g. the University of South Pacific – USP, the Pacific Community – SPC and the Pacific Power Association - PPA) to develop and propagate green H_2/derivative ready knowledge and skills. The international community supports the adoption of H_2/derivative technology by developing investment channels, regulatory/social acceptability frameworks and regional capacity building.

- The H_2 strategy needs to be both proactive and reactive. Provisions such as rollback and mitigation measures should be included, given that the region has been actively pursuing renewable energy targets and commitments, progress against which has been tedious and challenging. Learnings from prior and ongoing decarbonisation efforts should be leveraged to avoid similar shortcomings, challenges, and failures while developing H_2/derivative value chains.

Capacity Building

- A stark lack of regional H_2/derivative-ready skills was identified across the different engagement sessions. The Pacific Islands possess a growing pool of skills and expertise in renewable energy and bioenergy, driven by local initiatives and partnerships aimed at enhancing sustainable energy solutions for their communities. This provides a foundation for transferable skills.
- A consensus was formed that developing forums and resources to spread knowledge and skills/expertise is an important action step in the first phase of the regional H_2 strategy development. As highlighted above, universities and training institutes are expected to play a driving role in this space. These institutes are already engaged in research and knowledge/skill sharing on renewable energy generation and bioenergy, the scope of which can be expanded to include green H_2 and derivatives.

Note: A knowledge hub with links to resources, including masterclasses/training and open-source tools for assessing green H_2 and derivative opportunities, has been made available on the project website: https://pacifich2strategy.com/

Policy, Regulation, and Social Acceptance

- Currently, there is no policy or regulation regarding the production or use of green hydrogen and derivatives in the region. New policies to adopt H_2 and derivatives need to build upon existing achievements and progress by complementing NDC and renewable energy targets.
- A robust and functional regulatory framework that defines and imposes clear laws, standards, and compliance mechanisms while facilitating transparency, adaptability, and engagement needs to be adopted. Moreover, a regional integrated and focused oversight body should be established and tasked to lead the development of the PICT's H_2 market. This would provide several benefits, such as enabling a synchronised approach with a clear focus and communicated targets for region-wide benefits and avoiding overburdening individual regional governments.
- Standards need to be adopted to ensure compliance of H_2 and derivative technology and project development with regional laws and the environment. For example, the region's experience with battery systems has been unfavourable, with the harsh environmental conditions impacting their performance.
- Given that the public is a crucial stakeholder as both a driver for H_2/derivative adoption by shifting away from incumbent fossil fuel technology to H_2-ready end-use applications and will be impacted by the transition by bearing the risks and economic burden of the transition, a robust social licensing framework that protects their interest needs to be adopted.
- Acknowledgment that several aspects of a potential H_2 value chain may be more challenging to gain social acceptance given the limited knowledge and experience with fuels such as H_2, ammonia and methanol, which at present have a no to limited

presence in the PICTs. Therefore, significant effort must be placed on adopting a balanced approach to foster social acceptance. Emphasis on value addition such as new job creation, environmental benefits, and shift away from fossil fuels from green H_2/derivative transition should also acknowledge and recognise potential risks and hazards, competition for resources such as infrastructure, water, land and biomass, and possible economic burden of developing new projects and infrastructural changes in the early stages of strategy implementation.

- Shifting to e-fuels such as H_2, ammonia, and methanol will require changes to infrastructure and end-use applications. Efforts to support and encourage these changes are needed to facilitate a large-scale transition to such fuels.

Project Development Support

Commercial Viability

- There is industry interest in green hydrogen projects in the region. However, regional stakeholders see the economics as a primary driver, followed by environmental aspects of green hydrogen.
- The economic viability of hydrogen and derivatives is a primary concern to the region, given the current cost premium of renewable fuels versus fossil-derived fuels, particularly in the near term (2025 – 2030 timeline), where the inherent cost of the technologies remains high. Moreover, supply projects would have to be developed at scale for them to be economical, requiring high upfront fees. In addition, this capital investment is locked in for the long term as the projects needed to be financed over the long term (20 years) for them to become profitable. Absorbing and sustaining these investments would be a challenge.
- Recognition that the public sector and international support is needed in the form of grants and targeted incentives such as tax benefits would be required to support early-stage projects and longer until the technologies become inherently viable. Several mechanisms, such as targeted incentives such as emission intensity linked tax cuts, low-interest debt, green bonds, international climate finance through direct investment or other measures such as contracts for differences and carbon trading, can be adopted.
- Financing measures should support equipment procurement and additional project costs, such as labour and engineering costs, which will be significantly higher in the PICTs. These costs will become a key driver of overall economics.
- The public sector should prioritise and focus on identifying and deploying such mechanisms while implementing the H_2 strategy. Regulatory and facilitatory frameworks should be adopted to streamline access to funding mechanisms.

Technical Viability

- Developing the value chain will require parallel and multi-focused actions.
- On the production and supply side of the value chain, the development of production facilities will require the allocation of land, access to renewable energy resources, water, and biomass feedstocks. Therefore, resource allocation frameworks need to be established and adopted.
- Secondly, distribution channels would have to be put into place. A potential hub-to-spoke model would be required to distribute the H_2 and derivatives from central production hubs in larger and resource-rich islands to smaller islands and distribute end

users in remote locations. To support this, distribution channels facilitated by harmonised regulation would have to be adopted across the PICTs.

- There is potential for the import of renewable fuels through collaboration and establishing trade networks with other emerging H_2/derivative hubs within the greater Pacific region (such as Australia, Malaysia, Singapore, and the US). Yet the status quo for the region must remain the same—reducing and mitigating energy price volatility, ensuring regional energy security, and reducing the environmental footprint.
- End uses, particularly shifts to H_2 and ammonia/methanol-based technologies, will require the adoption of new end-use technologies. Therefore, biofuels such as SAF and RD offer a more attractive pathway as drop-in replacements that can leverage existing distribution and end-use infrastructure, requiring little to no changes and disruption in infrastructure.
- Aviation and maritime fuel bunkering, especially in the form of SAF and renewable/methanol, is a critical long-term market, especially for international travel and freight channels. Therefore, support mechanisms such as storage and dispensing facilities at airports and major ports need to be developed. Parallelly, the supply and production of these fuels should adhere to global certification and standards.
- In addition to the lack of regional access to technology and operational skills, long-term repair and maintenance of equipment will be a challenge. Regionally advised standards should be shared with technology OEMs to make provisions for operating within the Pacific environment (e.g., high humidity, corrosive salts, high rainfall, and natural disasters), leading to lower maintenance and subsequent downtimes.

Altogether, these action themes and findings provide a strong foundation for developing a time-bound action plan to roll out an effective H_2 strategy. The following section details the proposed action plan.

Alignment with Existing Energy Frameworks

Note that the action themes also build upon and align with existing regional energy policies and frameworks, such as the Framework for Energy Security and Resilience in the Pacific (FESRIP).

FESRIP provides a set of six priority items for a regionally integrated energy initiative. Priority A items focus on energy policy and planning, highlighting the need for robust national energy policies and capacity development. The proposed actions for the H_2 market also emphasise similar factors, highlighting the fact that a PICT's regional H_2 strategy needs to be built around national energy targets and priorities, integrating them to ensure region-wide benefits. Moreover, they also recognise that this strong capacity building both within the regulatory bodies along with the energy sector, private sector and society is needed given that H2 and derivative markets will bring in new technologies, concepts and risks that would need in-house understanding and expertise to regulate.

These factors also lead to FESRIP Priority B, which aims to foster energy sector cooperation and enable financing. Under the financing priorities, dedicated funding will need to be allocated to setting up a regulatory body and frameworks. This could also benefit a future H_2 market if regulatory frameworks acknowledge and include provisions for H_2 and derivative use across the region. Similarly, enabling access to finance, both public and private, is essential for capacity building, supply chain development and

ultimately, project development, which would be necessary for the scale-up of the H_2 & derivative markets.

FESRIP also prioritises the electric sector with a focus on expanding capacity and access to renewables, enabling greater renewable energy penetration. These factors also tie in with the scope of H_2 and derivatives; access to low-cost and allocated renewable energy sources is critical to driving down the cost of production and scaling up the production capacity of H_2 and derivatives. In turn, H_2 and derivatives can further complement renewable penetration within land transport, maritime and aviation sectors, which is a key commitment in regional NDCs and a deliverable of FESRIP. Key to these would be a drop in replacement fuels (particularly biofuels); offtake of these will be supported and complemented by the upkeep and maintenance of existing infrastructure, such as fuel storage and distribution networks, which is again a priority of FESRIP.

3. A Time-bound Action Plan

The Efate Statement expressed the need for a time-bound Pacific regional H_2 strategy. As such, the findings from the assessment and engagement are used to propose a set of actions (*elaborated below*) that can inform the development of the regional H_2 strategy. Note that this action plan is proposed as a set of recommendations with the expectation that the region will take a leading role and define its own targets and action plan based on regional priorities.

3.1. The Roadmap Timeline

This roadmap builds on the engagement feedback and subsequently identified action themes that are spread across short-, medium- and long-term timelines. These timelines are defined as:

- **Near Term – *Initial Foundation Stage*:** This stage of the roadmap focuses on the present to 2030 timeframe that defines actions for preliminary development for the Pacific H_2 value chain. Given that H_2 and derivatives are generally likely to become competitive at scale post-2030, the actions during this timeframe focus on setting the foundation measures to support a future scale-up of the market. This involves adopting the regulatory, policy and facilitatory frameworks, as well as capacity development. Moreover, the projects developed at this stage are likely to be small-scale (kW to a few MW scale or a few tpd of production), which are not commercially motivated but instead used for demonstration and capacity/experience building. In parallel, prerequisites such as access to feedstocks and renewable energy (cheap and high-capacity factors) can be adapted to facilitate the upcoming H_2 market.
- **Medium Term - *Value Chain Scale-Up Stage*:** Post 2030, based on the findings from the economic study, large-scale adoption of H_2 and derivatives will become a competitive opportunity compared to incumbent fossil fuels. Therefore, in this stage, it is expected that H_2 and derivatives will emerge as a vital tool in the region's overall energy and environmental policy. This could involve the regional government setting a mandate or formal target on H_2 and derivative opportunities, as well as introducing supporting mechanisms to help the private sector develop an H_2/derivative value chain. Altogether, based on the market development and findings would have to be used to

determine the competitive advantage of H_2 and derivatives within the regional energy context.

- **Long Term - *Course Correction Stage*:** Post 2040, there is a strong potential for H_2 and derivatives to become inherently viable and commercially bankable technologies. As such, this stage of the roadmap is focused mainly on course correction, with the foundation and scale-up already undertaken in the early stage. Key actions would include a rollback of public funding and opening the sector for private financing to drive future scale-up. It is also likely that at this stage, H_2 and derivatives would have achieved vertical growth and captured niche markets and opportunities such as hard-to-abate sectors of heavy-duty vehicles, shipping and aviation. Moreover, there is an expectation that at this stage, understanding and identifying additional opportunities for horizontal growth in new sectors that would require H_2 and derivatives would be recognised. Therefore, the focus of this stage would be to build on existing success and remove the remaining challenges and hurdles in the mass adoption of H_2 and derivatives.

3.2. Key Stakeholders and Drivers of the Pacific H_2 Roadmap

Additionally, a vital aim of the roadmap is to define a regionally oriented leadership and ownership of the Pacific H_2 Roadmap. Therefore, the regional government, local communities, and the private sector are recognised as the key drivers and stakeholders, with support from international collaboration.

Table 6 identifies the key stakeholders of the Pacific Hydrogen Strategy and highlights their role in its implementation.

TABLE 5. STAKEHOLDERS WITHIN THE PROPOSED PACIFIC HYDROGEN COMMUNITY.

Drivers	Prospective Role in Delivering the Pacific Hydrogen Strategy	Icon
Primary Drivers		
PICT's Regional Government	Regional Governments will play a pivotal driving role in all aspects of a potential hydrogen economy. This includes developing and adopting a formal region-wide H_2 strategy and target within the greater energy and environmental framework. This would, in turn, require adopting harmonised policies, regulations, standards, and certifications and introducing supporting mechanisms. They would also need to increase public awareness and acceptance, upskill the workforce, and engage with investors and the private sector.	G
Private Sector	The private sector could be primarily responsible for the implementation and operation of hydrogen projects in the region. This should include developing projects that align with the regional H_2 strategy, capacity building and upskilling the workforce. The private sector would also need to collaborate with the regional governments in developing and adopting harmonised policies, regulations, standards, and certifications, as well as introducing supporting mechanisms.	P
International Collaborators	International collaboration is expected to support the region in realising a hydrogen economy. This may include direct support from national governments, relevant knowledge-sharing for regional capacity building, or foreign direct investment. Regional markets such as Australia, Malaysia, and others that also share H_2 and derivative ambitions can partner with the PICTs to develop a regionally integrated market.	I
Regional Community	The regional community will need to adapt and support an H_2 value chain by adopting and transitioning to new H_2 and derivative end-use technologies. They will also be key stakeholders in developing a social acceptance framework to ensure their interests are protected.	RC

Facilitating Institutions		
SPC	The Pacific Community can facilitate sustainable development by bringing together governments, the private sector, and regional communities. A key role that SPC can enable through OPERA (Office of the Pacific Energy Regulators Alliance) is to support the development of a regulatory oversight committee.	SPC
Universities and Training Centres	Universities and training centres, such as the University of the South Pacific (USP), can play a leading role in capacity building and workforce upskilling. They can also facilitate the adoption of frameworks and tools for developing the Pacific H_2 value chain.	USP

3.3. Proposed Action Roadmap

Near Term - Initial Foundation Stage

Short-term targets are expected to be achievable from the present to 2030. The relevant action items and ownership are outlined in **Table 7**.

TABLE 6. SHORT-TERM ACTION ITEMS.

Theme	Action	Primary Ownership	Supporting Ownership
Regional Strategy	▪ Identification of regional roles and strengths	G	SPC P I
	▪ Development of a regional H_2 oversight body	G	SPC P
Capacity Building	▪ Knowledge, expertise and resource sharing	I	G SPC USP P
	▪ Workforce upskilling	G P	I SPC USP
	▪ Demonstration Projects	G P	I
Policy, Regulation & Social Acceptance	▪ Defining green H_2 and derivative role in regional energy policy and objectives	G P	SPC I
	▪ Adoption of regulatory standards and framework	G P	SPC I
	▪ Review and promote social acceptance	G	SPC RC
Project Development Support	▪ Detailed feasibility studies and project mapping	G P	I SPC USP RC
	▪ Identification and facilitation of initial supply/offtake markets	G P	I
	▪ Adoption of capital and grant support mechanism and regulatory framework	G P	I
	▪ Facilitation of regional and foreign investment	G	I
	▪ Adoption of regulatory framework for infrastructure and resource distribution	G P	I
	▪ Review of existing infrastructure for compatibility with H_2 and derivatives.	G P	I

Medium Term - Value Chain Scale-Up Stage

Medium-term targets are expected to be achievable from 2030-2040. The relevant action items and ownership are outlined in **Table 8**.

TABLE 7. MEDIUM-TERM ACTION ITEMS.

Theme	Action	Primary Ownership	Supporting Ownership
Regional Strategy	▪ Adoption of legislated H_2 and derivative targets	G	P
	▪ 5-year review of Regional H_2 strategy	G	P
Capacity Building	▪ Continued Workforce Upskilling	G P	SPC USP I
	▪ Development of H_2 and derivative knowledge forums	SPC USP	I G P
Policy, Regulation & Social Acceptance	▪ Review and update of standards and certification definitions.	G P	I
	▪ Update regulatory framework to tie incentives with tangible environmental benefits	G	
	▪ Develop and adopt a social licensing framework for project approvals	G P	RC
Project Development Support	▪ Adoption and access to financing mechanisms	G	I
	▪ Increase access to public funding	G	SPC
	▪ Removal of barriers and challenges to private and public investment	G	P I
	▪ Develop global supply chains to support local availability of technology and support services	G P	I
	▪ Update infrastructure to support access to feedstocks, energy, and land availability	G P	
	▪ Development of designated H_2 production hubs and distribution channels.	G	P
	▪ Legislation to impose a shift to H_2 & derivative end use technology	G	

Long Term - Course Correction Stage

Long-term targets are expected to be achievable from 2040-2050, as outlined in **Table 9**.

TABLE 8. LONG-TERM ACTION ITEMS.

Theme	Action	Primary Ownership	Supporting Ownership
Regional Strategy	▪ Reassess and align regional H_2 strategy considering the greater Net Zero Transition.	G	
Policy, Regulation & Social Acceptance	▪ Reassess and update policy, regulation and social licensing frameworks considering learning from projects.	G	
Project Development Support	▪ Roll back public funding for projects – given technology likely to become inherently viable and competitive.	G	
	▪ Streamline access to private investments	G P	I
	▪ Reassess and re-align infrastructure development activities	G	P

4. The Way Forward

Overall, significant progress has been made by the PICTs to shift towards replacing fossil fuels through renewable energy penetration. While there is still a long way to go to achieve complete decarbonisation of the region, the primary focus needs to remain on furthering renewable energy capacity and electrification of the energy value chain and leaving green hydrogen and derivatives to play a complementary role to renewable energy development in the medium to long term, especially in market sectors such as drop-in replacement for fossil fuels that can be done without significant changes to existing infrastructure, seasonal energy storage and in hard to electrify sectors such as maritime and aviation sector.

Delivering such a balanced approach to developing an electrification-led and green hydrogen-complemented energy future for the PICTs will require a regional integration of national governments, the private sector, and the regional community, strongly supported by international collaboration. Building on the action plan suggested above, **FIGURE 2** maps out the way forward and measures of success.

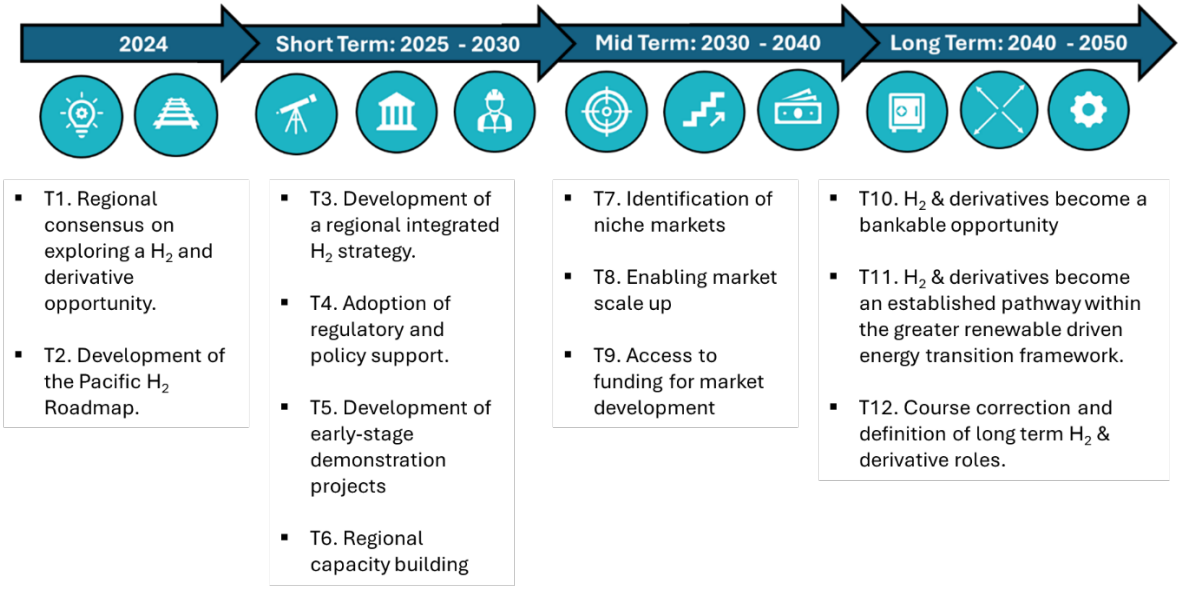


FIGURE 2. THE PACIFIC HYDROGEN ROADMAP

In the short term, a key challenge for the adoption of green H_2 and derivatives is the high costs and limited regional capacity and understanding. While the bulk of cost reductions on the technology end are likely to be achieved through global R&D, the PICTs can take regional measures and steps to create the foundations for a future scale-up. As such, the initial focus needs to be placed on regional capacity building through knowledge sharing, skills development, and raising public awareness. Equipping the region with skills, expertise and understanding to develop and scale up H_2 markets. Secondly, an oversight regulatory body needs to be established (independent or within the pretext of exiting bodies) to facilitate the development and implementation of H_2 support policies. Within the domain of the regulatory body, the development of a unified regional H_2 strategy that builds on the existing energy policies and targets defines H_2 and derivates its role and scope. This defined scope can then be used as a blueprint for developing and proposing initial demonstration projects to assess the practical viability and feasibility of H_2 projects within the PICTs. In parallel, facilitatory measures such as expanding access to renewable

energy resources (including biomass feedstock allocation) and infrastructure should be delivered to support the transition to the next phase of market scale-up.

In the medium term, as the global H_2 markets evolve and develop, leading to cost reduction and a better understanding of H_2 and derivative use, the PICTs can also shift focus from foundation actions to market scale-up. This involves taking in learnings from the demonstration projects and targets identified in the regional H_2 strategy to clearly define niche market opportunities for H_2 and derivatives (particularly those that are economically/technically feasible while aligned with regional energy goals) and further strengthening regulation and compliance by adopting globally accepted standards and certifications and facilitating market scale up by streamlining project approvals and enabling measures such as access to funding or targeted incentives such as tax breaks or subsidies to facilitate market scale up.

Altogether, targeted cost measures and incentives will enable economies of scale and project derisking, paving the way for H_2 and derivatives to become inherently bankable technologies and investments. At this stage, a shift of focus from public support to the private sector can be seen as the cost of H_2 and derivatives becoming competitive and reaching parity with incumbent fossil fuels. Moreover, based on findings and results from regional and global demonstrations and commercial projects could lead to the identification of key strengths and weaknesses of H_2 and derivative technologies; as such, the scope of these technologies can be further refined.