

Towards a Hydrogen Energy Economy Transition in Trinidad and Tobago, West Indies: Part I – A Strategic Framework

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Abstract: The global energy landscape is undergoing a significant transformation, shifting away from fossil fuels towards cleaner, more sustainable energy sources. Hydrogen, often hailed as a versatile energy carrier, is emerging as a promising solution to address pressing environmental and energy security challenges. Countries like Japan and South Korea are at the forefront of hydrogen technology development, investing heavily in infrastructure and research to reduce costs and increase production. Trinidad and Tobago (T&T), with its abundant natural gas reserves and strategic geographic location, is well-positioned to capitalise on the growing global demand for hydrogen. The study assesses the feasibility of blue hydrogen production, emphasising the role of carbon capture and storage (CCS) technology, alongside the development of green hydrogen through renewable energy-powered electrolysis. These approaches aim to modernise and enhance the existing natural gas infrastructure. Guided by global regulations and projected hydrogen pricing, the study evaluates key factors such as capital investment, operational costs, hydrogen production capacity, emissions reduction, and market demand. This paper assesses the economic potential of, and identifies the basic infrastructure for, a hydrogen economy in T&T. It also explores pathways of both blue and green hydrogen by using a levelised cost of hydrogen (LCOH) model and considering the country's history of making ammonia and natural gas. Important considerations are put on cost competitiveness, capital investment, production volume, and the ability to strategically retrofit facilities, like the Pointe-à-Pierre refinery and Point Lisas. Lastly, the paper sheds light on how domestic resources, export opportunities, and energy security all fit together and gives the country a plan for how to move towards the hydrogen economy.

Keywords: Hydrogen Economy, Green Hydrogen, Energy Transformation, Caribbean Sustainable Development, Trinidad and Tobago (T&T), West Indies

1. Introduction

Traditionally, the world has been driven by oil and gas. Today however, due to its environmental impacts and its changing nature (peak oil and increasing energy insecurity), the superfluous use of oil and gas has become unsustainable. Numerous stakeholders around the world are already preparing to make an oil and gas transition to the hydrogen economy at the same time as other energy agenda including enhanced energy security, long-term carbon constraints, and major energy diversification concerns (Falcone et al., 2021). The latter goal has already been outlined to be realised by companies and governments with a clear fleet strategy utilising increased reduced-carbon and non-carbon primary sources of energy,

increased end-use energy efficiency, and increased uptake by a relevant financial incentive for hydrogen for end uses and utilities.

Countries like Japan and South Korea are actively engaging in the testing and exploration of innovative policies designed to establish a robust hydrogen production and supply infrastructure. This is expected to significantly boost hydrogen production levels to approximately three million tons. In addition, these initiatives aim to reduce the costs associated with hydrogen back-end processes and to alleviate the substantial upfront capital investments that have traditionally been required for the development of hydrogen infrastructure as well as the implementation of both stationary and mobile systems (Stangarone, 2021).

It is imperative that this infrastructure is constructed thoughtfully and with careful planning, incorporating accurate demand signals that will facilitate the efficient utilisation of the zero-emission hydrogen that will be essential for future energy needs. Various policy tools have been identified as critical in this endeavour, such as forging strong partnerships with suppliers, financiers, and utility companies. Another important aspect is the clear elucidation of priority applications for hydrogen technologies. Standardising end-use applications with specific fuel characteristics is crucial to ensure secure compatibility across systems, equipment, and operational codes (Imdahl et al., 2021).

The implementation of thorough regulations is necessary to educate stakeholders about the fundamental safety and environmental standards that must be adhered to in hydrogen production, distribution, and utilisation systems. It is thus vital to develop comprehensive educational programmes targeted at potential users, service providers, and financiers, providing them with insights into the latest research and demonstration findings related to hydrogen technologies.

In Trinidad and Tobago (T&T), the petrochemical sector has significantly influenced the development of its current ammonia infrastructure. The Pointe-à-Pierre refinery, originally operated by Petrotrin until its closure in 2018, was the nation's sole oil refinery for nearly a century, serving as a cornerstone of the local economy by creating jobs and generating export income. Now managed by Paria Fuel Trading and Guaracara Refining, the refinery is being repurposed into a terminal and export center. This transformation preserves crucial logistical assets like storage tanks, pipelines, and port facilities, which are highly suitable for supporting ammonia and hydrogen production. This existing infrastructure, coupled with established technical expertise and a skilled workforce, provides a direct link between emerging green hydrogen and ammonia value chains and traditional fossil fuel operations. By leveraging electrolysis and renewable energy inputs, T&T is uniquely positioned to transform its legacy petrochemical capabilities into a strategic advantage within the rapidly expanding global hydrogen economy.

Green hydrogen and the hydrogen economy are emerging as key energy solutions globally, environmentally and economically. Endowed with energy resources, T&T is a country where green hydrogen can be produced, used, and exported as a key economic resource (see Table 1). With the current global focus on climate change, global energy needs, and sustainability, the potential of hydrogen to reduce reliance on carbon energy sources, to contribute to increasing the demand for low-carbon renewables, to reduce the use of carbon in industry, and aid the upgrade and expansion of domestic downstream hydrocarbon sectors, ensures its future role in the global economy. The primary scope of the hydrogen potential in T&T can be broken down into three areas: Green production and export of hydrogen; hydrogen for domestic

power and green hydrogen-based ammonia for the petrochemical sector; and the local benefits that can be derived through the local consumption of hydrogen and its use in the local manufacturing industry. Besides generating substantial export revenues, hydrogen could be an important driver of sustainable domestic industrial growth, downstream from the hydrocarbon industry. The demand for low-carbon hydrogen, of which ammonia is a major market, is expected to increase in the future, especially in Europe when the 'Green deal' was activated in 2023, North America, and Asia (Fattahi et al., 2024; Shirizadeh et al., 2023). This project proposes the development of an economic model that identifies and compares the amounts of ammonia and hydrocarbon-based fuels that could be produced if the resources involved in the production of hydrogen were used in Greenfield projects.

Moreover, T&T is in a unique position to bridge the transition to a low-carbon hydrogen economy because of its long-standing ammonia production infrastructure, which is anchored at Point Lisas, Couva (Central Trinidad), where 11 ammonia facilities with a combined capacity of 5.67 million tonnes per year are integrated into a petrochemical industrial hub. Historically dependent on abundant natural gas feedstock, the industry is now facing dwindling gas supplies and underutilised (roughly 70–80%) capacity. This surplus capacity offers a strategic opportunity: electrolytic "green" hydrogen, generated from renewable sources, can be co-fed into current Haber-Bosch systems at a rate of roughly 20–30% with minimal retrofit costs. NewGen Energy (2025) and other early adopters are already developing pilot projects for 108,500-ton-per-year low-carbon ammonia plants inside this framework. These projects benefit on-site electrolysis and use renewable energy sources of electricity. Thanks to this alignment with a national roadmap supporting carbon capture and storage, offshore wind, and solar integration, T&T is positioned to meet the rising demand in Europe, particularly in view of the EU Green Deal. It also keeps its export competitiveness and advances home economic diversification concurrently (Hinojosa et al., 2022).

There are many benefits and opportunities that can be derived from investing in the hydrogen economy. Some of these include economic resuscitation and diversification, energy security, environmental and health benefits, mobility, productivity, and sustainability. Beneficiaries would include petrochemical and energy industries, developers, researchers, engineers, technical specialists, and the general populace. Furthermore, it aligns with many of the United Nations Sustainable Development Goals (SDG). For example, SDG 7 ensures access to affordable, reliable, sustainable, and modern energy for all, while SDG 9 focuses on building resilient infrastructure, promoting inclusive and sustainable industrialisation, and fostering innovation. It would also underpin T&T's relationship with global environmental agreements (Goubran et al., 2023). By leveraging the skillsets, know-how, and experiences of stakeholders, T&T can benefit from the economic scaling

Table 1. CO₂ Emissions per Capita by Country in 2022

#	Country	CO ₂ Emissions per Capita (Tons)	CO ₂ Emissions (Tons)	Population
1	Palau	76.41	1,357,050	17,759
2	Qatar	35.48	102,617,980	2,892,455
3	Bahrain	24.75	37,955,110	1,533,459
4	Kuwait	23.99	110,119,570	4,589,511
5	United Arab Emirates	21.36	218,799,350	10,242,086
6	Brunei	20.59	9,375,650	455,370
7	Trinidad and Tobago (T&T)	19.53	29,217,380	1,495,921
8	Oman	19.38	91,649,080	4,730,226
9	Saudi Arabia	18.89	607,907,500	32,175,352
10	New Caledonia	18.67	5,361,860	287,123
11	Gibraltar	17.65	663,620	37,609
12	Australia	15.01	393,162,550	26,200,984
13	Canada	14.99	582,072,950	38,821,259
14	United States	14.21	4,853,780,240	341,534,046
15	Russia	13.11	1,909,039,310	145,579,899
16	South Korea	12.27	635,502,970	51,782,512
17	Kazakhstan	12.27	245,886,290	20,034,609
18	Taiwan	11.77	275,573,980	23,420,111
19	Luxembourg	11.61	7,586,820	653,313

associated with the hydrogen economy. This allows energy industries to mutually benefit from the venture. To realise this, clear strategies would be needed to acquire the required funds, human capital, and technology. Human and capacity building are prerequisites for the success of this transition and include introducing or updating courses, awareness programs, and national training strategies.

Hydrogen infrastructure is the set of facilities and systems for manufacturing, storage, transportation, and distribution of hydrogen fuel. This covers pipelines, refuelling stations, storage tanks, electrolyzers, and end-of-life uses including fuel cells. Broad acceptance and commercial feasibility of hydrogen as an energy carrier depend on a strong hydrogen infrastructure. Zero Emissions Hydrogen is hydrogen generated free from greenhouse gas emissions into the atmosphere. Usually using green hydrogen production technologies, which use renewable energy (such solar, wind, or hydropower) to drive electrolysis to split water into hydrogen and oxygen, so producing no carbon emissions. Though true zero-emission status is more tightly linked with green hydrogen, blue hydrogen with carbon capture and storage (CCS) is also included in some contexts.

The research agendas are set forth for a Hydrogen Energy Economy across the country. These are:

- 1) To examine the energy situation now in T&T, including greenhouse gas emissions, renewable energy potential, and reliance on fossil fuels.
- 2) To assess the T&T's technical and financial viability for a hydrogen economy towards green and blue hydrogen generation technologies.
- 3) To identify the main drivers e.g., energy security, export prospects, climate targets and obstacles e.g., infrastructure, regulatory gaps, public acceptance to hydrogen adoption.

- 4) To assess policy frameworks and contrast international case studies that have effectively supported hydrogen transitions especially in Caribbean small island developing states (SIDS) or developing nations
- 5) To explore legislative changes, incentives, and policy tools meant to boost hydrogen technology innovation and investment.
- 6) To evaluate the potential social, financial, and environmental effects of switching to a hydrogen economy that is, employment creation, energy access, and emissions reduction such as employment creation, energy access, and emissions reduction.
- 7) To develop strategies for public-private alliances, stakeholder participation, and community education to boost support of hydrogen initiatives.

2. Current Energy Landscape in T&T

Trinidad and Tobago stands at a crucial juncture where the necessity to transition to a cleaner, more sustainable energy system is evident (see Figure 1). The international hydrogen market not only presents a clear opportunity for the country to embrace this shift but also offers a pathway toward environmental restoration and economic growth. Currently, the natural gas and petrochemicals industry in T&T, despite its economic contributions and benefits, faces significant challenges. The high negative externalities associated with this sector, which include industrial accidents and harmful pollution affecting our air, soil, and water bodies, cannot be overlooked.

As of 2022, T&T was ranked 7th largest emitter of carbon dioxide per capita (see Table 2). To genuinely progress, it was to prioritise investments that capitalise on the opportunities afforded by the transition to a hydrogen economy. This shift is vital if we intend to significantly minimise not only the environmental impact, but also

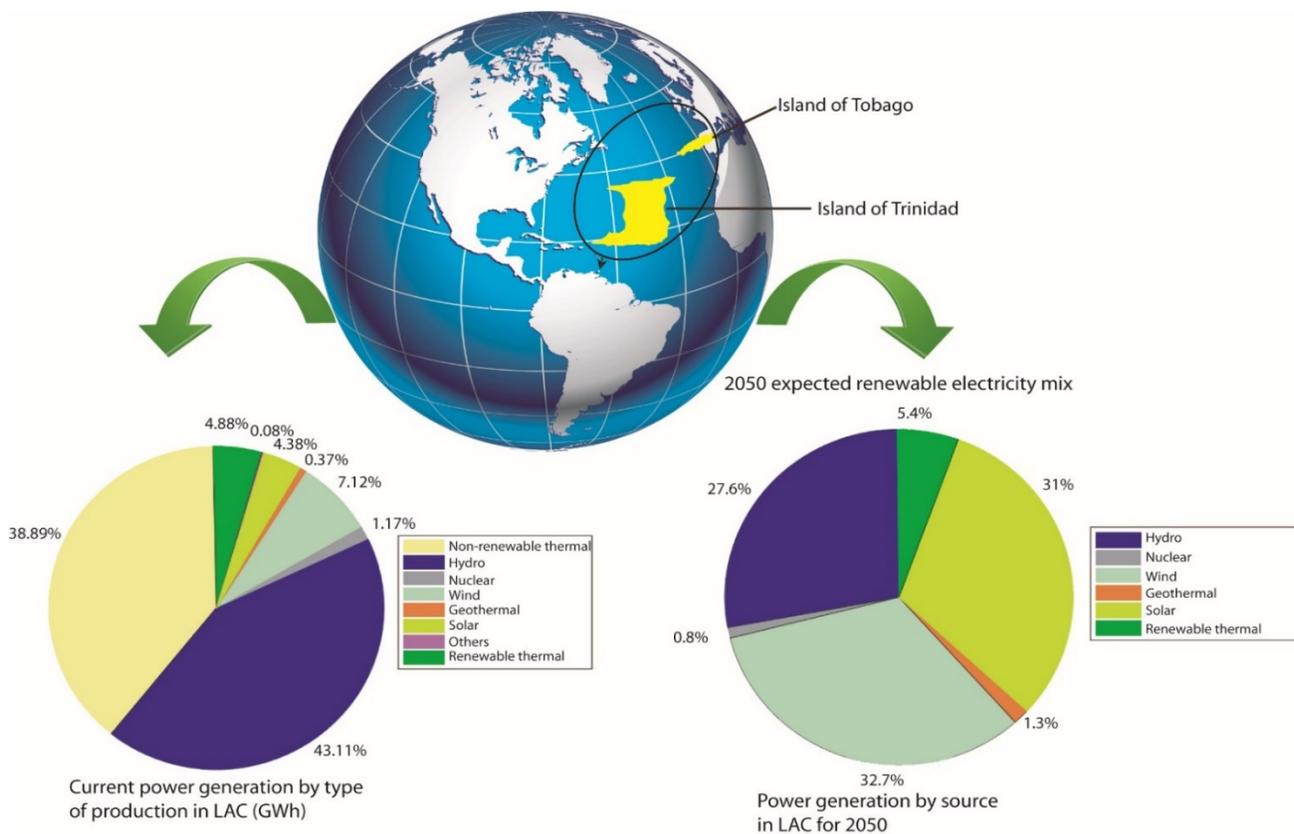


Figure 1. Smart Energy Planning for the Decarbonisation of Latin America and the Caribbean (LAC) in 2050
 Source: Adapted from Icaza-Alvarez et al. (2024) and Dreamstime (2025)

Table 2. Renewable Energy and Population Distribution in Selected Caribbean Countries

Country	Fossil Fuel % of Total Power	Renewable % of Total Power	% Population in Rural Communities
Antigua and Barbuda	93	7 (solar)	76
Barbados	95.4	4.6 (solar)	69
Curacao	67	33 (29 wind, 4 solar)	11
Dominica	63	37 (hydro)	28
Grenada	98.5	1.5	63
Guyana	92	8 (7 biomass)	73
Jamaica	89	11 (6.5 wind, 3.5 hydro, 1 solar)	43
St. Kitts and Nevis	95	5 (3 wind, 2 solar)	69
St. Lucia	99	1	81
St. Vincent and Grenadines	81	19 (17.7 hydro)	46
Suriname	40	60 (hydro)	34
Trinidad and Tobago	100	0	47

Source: Abstracted from De Silva et al. (2023)

human costs tied to current economic practices in T&T. By channelling investments into hydrogen, T&T can cultivate downstream businesses, enhance skills development, and foster technological advancements that can arise from a thriving hydrogen economy. There can be experience additional economic benefits and invigorated employment prospects that will pave the way for our future generations.

Transitioning to economy is a strategic move to bolster the energy security. This transition presents us with remarkable opportunities for greenhouse gas mitigation,

especially by taking our first-mover status and the role as an early-stage transition facilitator. Hence, T&T must be often reminded of our historical legacy as pioneers in the oil and gas sector (see Figure 2). We are now presented with the imperative challenge and exceptional opportunity to explore, produce, and rapidly utilise hydrogen as a resource. This has the potential for global leaders in the energy landscape and, allowing us to write a new chapter in our energy narrative focused on sustainability and innovation.

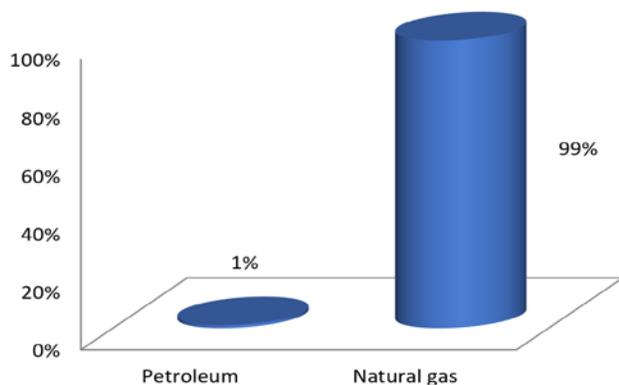


Figure 2. Trinidad and Tobago's Energy Resources Mix
Source: Adapted from De Silva (2011)

2.1. Historical Dependence on Oil and Natural Gas

The oil and natural gas industry have historically served as the vital cash cow for T&T, providing essential revenue and economic stability. As the world increasingly transitions to renewable energy sources in a concerted effort to reduce greenhouse gases in our atmosphere, it becomes paramount that our local economy undergoes a similar transformation. Table 3 shows that T&T rank among the lowest in the Caribbean with regards to renewable energy capacity. It is also important to note that T&T's position on certain initiatives or capabilities, particularly concerning renewable energy integration and sustainability, is expected to evolve significantly in 2025. This change can be influenced by the anticipated completion and commissioning of the LightsourceBP and Shell Brechin Castle 92MW solar farm plant, which will

further enhance our expertise and offerings in the sector. The challenge we face is that, despite the well-intentioned advocacy for this transition, there has not been sufficient serious deliberation.

In recent times there has been it is an undeniable fact that we are currently witnessing a growing shortage of sweet light crude oil and natural gas (see Figure 3). This further complicates the situation. In this new paradigm towards hydrogen, we can simultaneously promote the usage of hydrogen as a cleaner-burning fuel, fostering its adoption not only in Trinidad but also across our sister island chain of Tobago. This dual approach will not only strengthen the economy but is also more sustainable. This has the potential to ensure that T&T not only survives the transition but thrives in it, becoming a leader in innovative energy solutions (IMF, 2024).

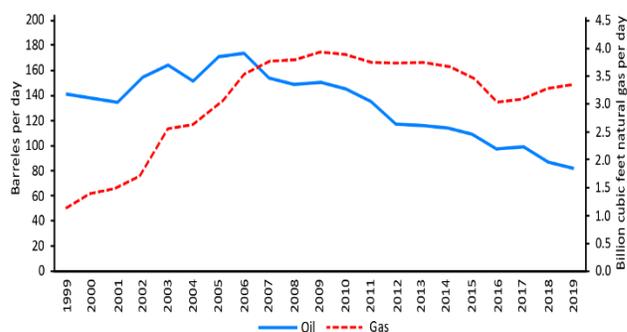


Figure3. Trinidad and Tobago' Crude oil and natural gas production, 1999-2019
Source: Abstracted from Mclean et al. (2021)

Table 3. Potential Challenges and Barriers to Implementing a Hydrogen Economy in T&T

Potential challenges and barriers	Description
1. Lack of Hydrogen Infrastructure	Currently, T&T does not have pipelines, storage facilities, or refuelling stations catered to hydrogen.
2. High Initial Capital Costs	Developing a hydrogen value chain from manufacturing through end-use calls for large financial outlay.
3. Uncertain Market Demand	Private investment may be limited without either clear domestic
4. Cost Competitiveness	Currently blue hydrogen and green hydrogen are less expensive
5. Capacity for Renewable Energy	Green hydrogen calls for big amounts of renewable energy. Brechin Castle, in Trinidad could be one of the larger renewable energy producing countries in the English-speaking Caribbean at 92MW, with Barbados currently at 50MW and Jamaica is 188MW
6. Water Availability	Electrolysis calls for large volumes of pure water, however the water demand is a very small percentage (%) of the Desalination Company of Trinidad and Tobago (DESALCOTT) water production and thus, is not a critical issue.
7. Lack of a Hydrogen Policy Framework	Not one thorough hydrogen strategy or legal framework
8. Regulatory Delays	Political cycles and bureaucratic procedures cause slow regulatory reform in energy policy
9. Limited Expertise	The workforce of today might not have the technical knowledge. However, The T&T workforce has technical experience for general industrial plant construction in equipment foundations, piping, welding, tank and vessel construction, instrumentation and controls, plant commissioning, etc. So, this would not be a problem, once combined with international expertise on the hydrogen process and safety side.
9. investments in STEM	Expanding local capacity requires major investment in science, technology, engineering, and mathematics education.
10. CCS Infrastructure Gaps	Should T&T pursue blue hydrogen, questions regarding carbon capture and storage (CCS)
11. Low Public Understanding	Many stakeholders and communities are unfamiliar with hydrogen's potential benefits and safety profile
12. Resistance to Change	Cultural and institutional inertia may slow the adoption of new technologies.

2.2. Challenges and Risks

To truly revitalise the economy of a Caribbean small island state like T&T, it is essential that investment capital becomes readily available at the local level. The most significant challenge in this endeavour lies in developing a robust business model that effectively partners with existing industries to foster cross-sector collaboration. Key hazards in international business and foreign investment including political unrest, regulatory challenges, currency fluctuations, and cultural barriers are emphasised in the image. It underlines how these elements legal complexity, economic uncertainty, and communication breakdowns may influence investment results. Reminding investors to carefully plan when entering foreign markets, the graphic acts as a visual summary of the several dimensions of global corporate risks (see Figure 4).



Figure 4. International Business Challenges and risks of foreign investment
Source: Based on Liu et al. (2020)

An exemplary approach could involve utilising excess electrical generating capacity to produce molecular hydrogen for export, which presents a novel opportunity for the local economy. This task encompasses not only securing the necessary financing but also collaborating with skilled technical partners to create and implement appropriate priority plans that align with the broader economic objectives of the region (Gallardo et al., 2021). This undertaking can be viewed as less of an economic risk and more of a strategic challenge, as it has the potential to attract visionary companies engaged in research and development, which are essential for driving economic growth in neighbouring countries that is more fortunate in certain respects (see Figure 5).

When local businesses rely heavily on international corporations that possess immense assets and manage to pay taxes in the myriad currencies available worldwide, the returns will benefit the management of such vast wealth.

These dynamics raises important questions about the distribution of economic benefits and the potential for local reinvestment, which are crucial for achieving sustainable development on the island. Thus, while the prospects appear daunting, they also offer a rich landscape of opportunities that could reshape the economic framework of T&T for the better (Hinojosa et al., 2022).

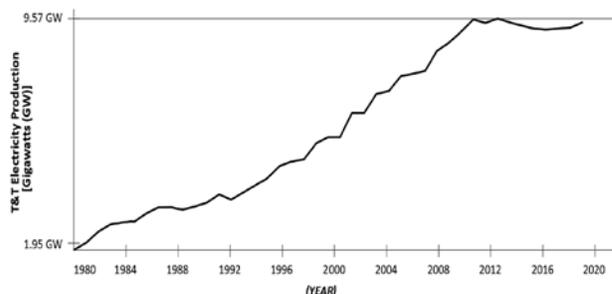


Figure 5. T&T electricity production billion Gigawatts GWh
Source: Abstracted from U.S. Energy Information Administration (2022)

3. Should T&T Transition to Hydrogen?

T&T can leverage various pathways to produce hydrogen, but not all are environmentally friendly. While challenges related to scale and economic viability exist, technological advancements are enabling the production of nearly zero-emission hydrogen. T&T is strategically positioned to adopt a multifaceted approach (Boretti, 2021). One promising option is to utilise its abundant natural gas reserves to produce hydrogen through electrolysis. This method ensures zero CO₂ emissions during production, eliminating the need for carbon capture and storage.

Additionally, T&T can explore other, less environmentally friendly but more cost-effective hydrogen production methods, such as methane pyrolysis, in conjunction with its natural gas resources. This approach can yield economic benefits while minimising environmental impact. T&T could initiate its transition to a hydrogen economy by prioritising the transportation sector. This would involve using hydrogen as the primary energy source for vehicles, paving the way for a broader adoption of hydrogen across the economy. This aligns with the global shift towards low-carbon solutions, as the hydrogen market gradually transitions to renewable-based production (United Nations Environment Programme, 2023).

A hydrogen economy offers numerous benefits, including enhanced sustainability, increased reliability, new export opportunities, energy security, and economic diversification, while preserving environmental integrity. This win-win approach can efficiently utilise T&T's natural gas resources. There are several proof-of-concepts that demonstrates the feasibility of methane pyrolysis, a process that thermally decomposes methane into hydrogen and solid carbon. The captured carbon can be sold or sequestered, avoiding CO₂ emissions associated with

traditional hydrogen production methods like steam methane reforming (SMR). This approach enables T&T to utilise its natural gas reserves more efficiently and reduce carbon emissions, making it a viable pathway towards a hydrogen economy.

The resultant hydrogen produced would essentially possess a zero-carbon footprint, thereby enabling avoidance of any associated high tax liabilities that might otherwise be incurred (Boodoo, 2023). The conversion process has also resulted in the generation of clean, sellable solids (carbon) which can either be sold or sequestered. The method referred to in the text for producing hydrogen is likely methane pyrolysis. Methane pyrolysis is a process where natural gas (methane) is thermally decomposed to produce hydrogen and solid carbon (Garner and Dehouche, 2023). As shown in Figure 6, natural gas (methane) is thermally decomposed to produce hydrogen and solid carbon. Based on the reformer technology, the figure shows that the CO₂ is emitted from both the energy requirements (redline) and reaction (green and blue lines). The process involves:

- 1) *Thermal Decomposition:* Methane (CH₄) is heated in the absence of oxygen, causing it to break down into its constituent elements, hydrogen (H₂) and solid carbon (C).
- 2) *Production:* The resulting solid carbon can be captured and either sold as a by-product for industrial applications (e.g., in batteries, tires, or as a construction material) or sequestered to prevent its release into the atmosphere. This avoids the emission of CO₂, which would occur with conventional hydrogen production methods like steam methane reforming (SMR).
- 3) *Hydrogen Output:* The hydrogen produced through methane pyrolysis has a significantly lower carbon footprint compared to traditional methods because it avoids direct CO₂ emissions. This makes it a cleaner alternative, particularly when the energy used for the pyrolysis process is derived from renewable sources.

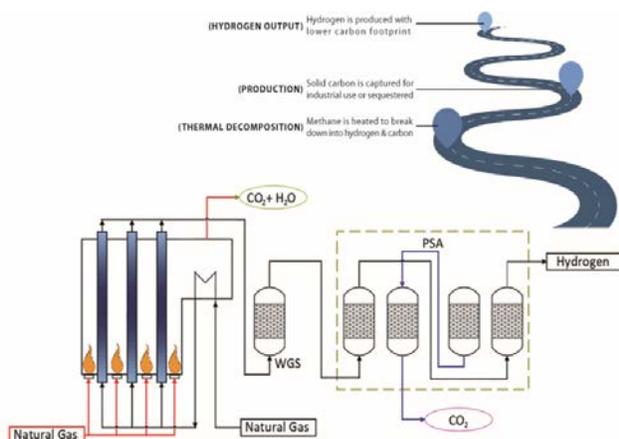


Figure 6. The Methane Pyrolysis Process and Production of Hydrogen based on the Reformer Technology

The method enables T&T to utilise its natural gas reserves more efficiently and aligns with the goal of reducing carbon emissions, making it a viable option for transitioning towards a hydrogen economy while leveraging existing natural resources. Natural gas is used both to fire methane burners and as a feed for the reaction, after being preheated in the convection section. The hydrogen content is increased in the water gas shift (WGS) reactor, and CO₂ is removed by pressure swing absorption (PSA)

3.1. Environmental and Climate Change Imperatives

It is critical to acknowledge that climate change is real, urgent, and primarily man induced. Despite the on-going acrimonious debates surrounding climate change at both the personal level among countries and within various groups and organisations, the stark reality is that scientists engaged in a multitude of research projects focused on climate change remain convinced by the overwhelming evidence highlighting its reality, seriousness, and urgent threat to humankind. The scientific community has developed well-documented research that articulately explains the rising global temperatures along with the increasing extremes of temperature, rainfall, and wind patterns. Additionally, they have documented the growing frequency, intensity, and duration of droughts, heatwaves, hurricanes, typhoons, and cyclones; the alarming rise in sea levels; the degradation of vital habitats and ecosystems; and the overall decline in the quality of water and air. Figure 7 shows the global average temperatures 1850-2023.

Taking decisive action against climate change while simultaneously contributing to sustainable development will represent the most effective and meaningful approach to addressing pervasive issues such as poverty alleviation, food security, water security, and health concerns among other pressing development challenges.

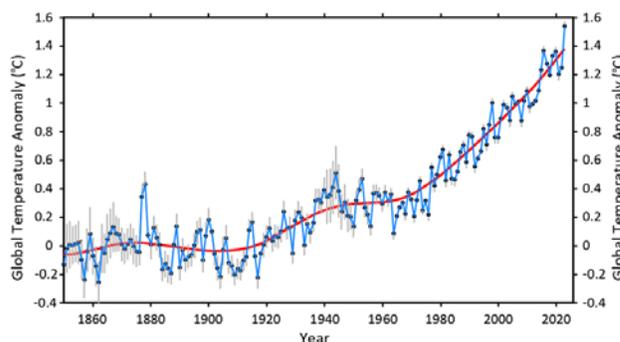


Figure 7. Global Average Temperatures 1850-2023
Source: Based on Rohde (2024)

3.2. Economic Diversification and Sustainability

An agreement on a hydrogen economy signifies a collective commitment to developing, operating, and

expanding a comprehensive hydrogen infrastructure. This commitment is underpinned by the dual objectives of economic diversification and environmental sustainability. When effectively managed, a hydrogen economy can significantly enhance the flexibility of economic policy. This increased policy flexibility can lead to substantial economic benefits. The pursuit of a hydrogen economy is fundamentally driven by concerns over energy security. For energy-rich nations facing declining fossil fuel reserves, the options for diversifying their energy mix and ensuring a secure energy supply are limited. Energy trade plays a crucial role in this context. A hydrogen economy can enhance energy security by reducing reliance on a single energy source and diversifying trade relationships.

The key principles underlying a hydrogen economy are diversity, sustainability, and security. A commitment to developing a hydrogen economy can significantly bolster the economic security of nations, regions, and businesses (see Figure 8). Moreover, decentralising decision-making processes can lead to more efficient and effective solutions (Combariza, 2024).

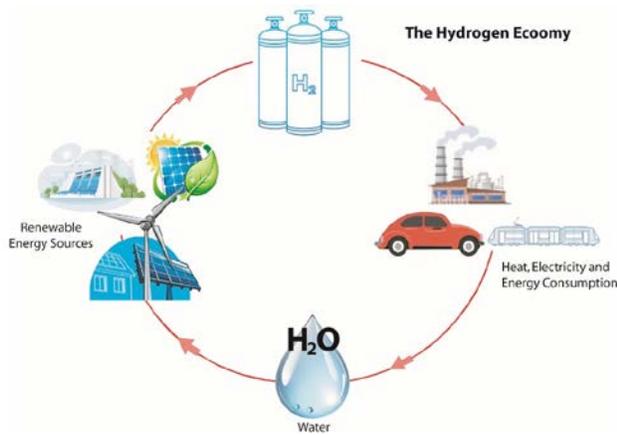


Figure 8. A Hydrogen Economy with Circular Economy
Source: Fuel Cells and Hydrogen Joint Undertaking (2020)

To fully realise the potential of a hydrogen economy, a strong technological foundation is essential. A hydrogen economy involves the production, storage, transportation, and utilisation of hydrogen as an energy carrier. It is envisioned to reduce fossil fuel consumption and greenhouse gas emissions (Arsad et al., 2022). One of the primary drivers of the hydrogen economy is the belief that a decentralised energy system can mitigate the negative impacts of carbon emissions, facilitate greater penetration of renewable energy sources, and reduce the cost of energy, transportation fuels, and water, all while minimising environmental damage. These converging forces are propelling the global shift from fossil fuels to a hydrogen-based energy system as shown in Figure 9.

4.1. H₂ Production Methods

As mentioned previously, grey hydrogen (the most

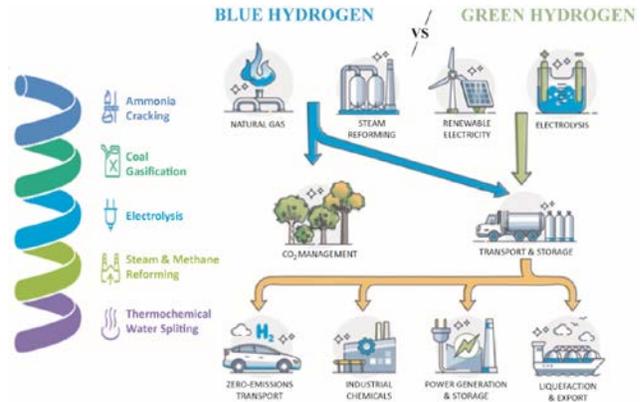


Figure 9. Blue Hydrogen (Right) and Green Hydrogen (Left)
Source: Adopted from Shutterstock (2022)

common globally, the production method also produces carbon dioxide), blue hydrogen (grey hydrogen, but with carbon capture storage), and green hydrogen (using renewable energy) exist (see Figure 9). Ammonia Cracking, coal gasification, Electrolysis, Steam Methane Reforming, and Thermochemical Water Splitting are the most common methods to produce hydrogen. These processes are:

- 1) *Ammonia Cracking*: Cracking ammonia with heat that results in producing nitrogen and hydrogen.
- 2) *Coal Gasification*: Exposing coal to a mixture of carbon monoxide, methane, and hydrogen with steam, oxygen, or air at high temperatures that decompose the coal and form synthesis gas (syngas).
- 3) *Electrolysis*: Splitting water that uses electricity to separate water into oxygen and hydrogen.
- 4) *Steam Methane Reforming*: Introducing a catalyst and high-temperature steam to natural gas and either purified or impure industrial carbon dioxide that results in a reaction that produces syngas (CO and H₂).
- 5) *Thermochemical Water Splitting*: Exposing sustained high-temperature heat that results in steam dissociation within which the metal oxides or element transfer the oxygen to the steam and form hydrogen.

Figure 10 illustrates H₂ production sources.

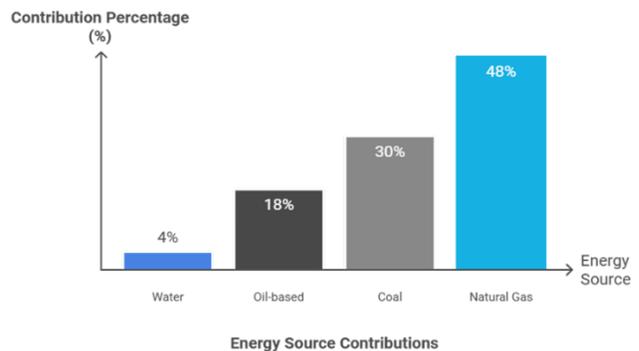


Figure 10. Potential H₂ Production from Energy Sources
Source: After Perreault et al. (2023)

Production of hydrogen should be decentralised i to avoid the issues associated with long-distance transportation and supply-chain risks. As a result, a localised production network comprised of smaller facilities generating hydrogen as a by-product of other plant processes or dedicated hydrogen production stations such as those offered by HyGear (Netherlands) and Siemens should be established to ensure industrial applications are protected against fuel transition risk. Despite being primarily designed for on-site refuelling of duty vehicles, the development of these stations for on-site/point of use installations coupled with modular/turnkey fuelling stations for consumer use - can facilitate accelerated transition by allowing industrial-scale hydrogen consumers to service their own fuel requirements and save on logistics and distribution (freight) costs (Kountouris et al., 2024). These stations utilise compressed or liquid hydrogen technology. Figure 11 shows a typical structure of hydrogen generation sources at various transportation sectors. It is generally acknowledged that due to spillage hazards, it is neither economically nor environmentally wise to convert compressed hydrogen delivery tankers into carriers.

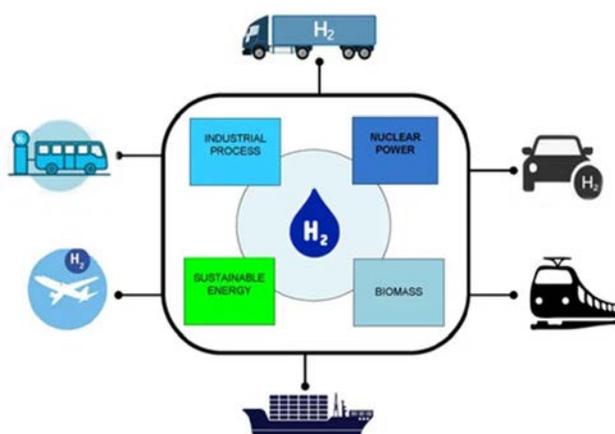


Figure 11. Structure of Hydrogen Generation Sources at Various Transportation Sectors

Source: Adopted from Schlupbach and Züttel (2001)

The completion of the physical hydrogen production infrastructure will not only create jobs but also provide the competence necessary for the development and manufacture of advanced (intelligent) hydrogen fuel cell technology required to improve efficiency and reduce cost. The belief that the global demand for larger fuel cells can be serviced from a local manufacturing base is supported by the long-term vision of the Neoen group owner of the 150 MW Hornsdale wind farm which also includes the world's most prominent utility-scale battery. This French company recently announced plans to build a gigawatt-scale wind farm with associated large-scale hydrogen technology in South Australia by 2024, with an initial investment of 1.1 billion Australian dollars towards the

target of being a major player in the global hydrogen market by 2030. It is now the responsibility of Trinidad and Tobago Electricity Commission (T&TEC) and other state enterprises to engage with large multinational energy corporations such as BP Trinidad and Tobago LLC (bpTT), a Trinidadian subsidiary of the British oil company BP P.L.C, the National Gas Company of Trinidad and Tobago (NGC), and EOG Resources, Inc to further the development of this transformative energy solution (Cullen et al., 2021; Ajanovic and Haas, 2021).

5. Policy and Regulatory Frameworks

Government support and an enabling policy and regulatory environment can assist in developing and sustaining a hydrogen economy of T&T. There are ample examples from around the world that demonstrate how a country's climate, energy, and infrastructure policies can drive its development of a hydrogen economy. For example, private and public partnerships, research and development (R&D) funding, and fiscal incentives have been shown to be important drivers of the development of hydrogen economies in countries such as Germany, Australia, South Korea, and Japan.

The policy environment in respect to the transition into a hydrogen economy is one that is nascent. Many other sectors that can use hydrogen stand to benefit from the potential of a hydrogen economy. Ability to access country markets by having products produced with 'clean fuel' can generate better discretionary pricing by foreign consumers, especially as more target consumer countries continue to integrate into a low carbon/ green hydrogen economy. The timely implementation of a dedicated hydrogen strategy in T&T to support these broader initiatives has the potential to provide significant economic diversification and additional export markets for ample natural gas supplies in production and/or reserves post the Liquefied Natural Gas peak and decline. Small as it may be a hydrogen economy is not to be dismissed. Such an economy will have upfront costs; however, it has documented benefits that outweigh the traditional 'green' moniker argument (Jugessur et al., 2022)

5.1. Policy Suggestions to Advance T&T's Hydrogen Development

There is a need for T&T to follow-suit as the global energy scene moves towards low-carbon solutions changes. Table 4 shows a policy and regulatory roadmap for hydrogen. Legal frameworks are to set up for realising and supporting the hydrogen potential as the global energy scene moves towards low-carbon solutions. Transforming the significant natural gas reserves and advanced petrochemical infrastructure of the country into a competitive hydrogen economy calls both proactive and sharp legislative action. These suggestions are meant to fit T&T's institutional capabilities, financial framework, and past participation in global energy markets.

Table 4. Policy and Regulatory Roadmap for Hydrogen in T&T

Action Item		Responsible Entity	Timeline	Notes
Draft National Hydrogen Strategy		Ministry of Energy	Q4 2025	Align with Paris goals and Vision 2030
Update regulatory framework for CCS		Environmental Authority	Q2 2026	Include emissions thresholds and reporting
Launch green hydrogen pilot projects		NGC / Intl. Partners	Q3 2026	Focus on solar-powered electrolysis near Point Lisas
Set hydrogen blending targets in gas grid		T&TEC / Regulator	Q1 2027	Begin with 5% blend in selected regions
Workforce training programs on hydrogen tech		Ministry of Education	Q1 2026 – Q4 2027	Collaborate with UWI and technical institutes

Like Germany and Australia, T&T can create a comprehensive National Hydrogen Strategy with the goals for hydrogen manufacture, use, and export. This strategy should outline short, medium, and long-term goals, pinpoint priority industries (such ammonia and methanol), and define the roles of public and business players. It can also include processes of monitoring and assessing to guarantee efficiency and openness. The government can create fiscal incentives for green hydrogen technologies including tax credits, accelerated depreciation, and duty-free imports, so encouraging private investment and innovation. These technologies will not only help to ease the shift from pilot projects to mass production but also encourage private sector involvement in hydrogen projects.

Including hydrogen as a strategic energy vector should be specifically mentioned in T&T's present National Energy Policy Framework. While also proving policy coherence to possible investors and development partners, this would match national objectives with climate goals.

The government can develop public-private partnerships (PPPs) models to support hydrogen technology research, development, and deployment using T&T's natural gas producing experience. Local energy businesses such as NGC and foreign businesses with hydrogen experience working together could hasten project implementation and technology transfer.

Leading regional hydrogen development initiatives will help T&T establish itself as a Caribbean hydrogen hub both domestically and internationally. The government should also seek technical assistance and funding from organisations like the Inter-American Development Bank (IDB) and the Green Climate Fund (GCF), as well as participate in international forums including the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE).

T&T must participate in education and skill development in hydrogen domains if it is to facilitate a long-term change. Local talent pipelines can be developed by means of collaborations among industry players, vocational institutions, and universities. Furthermore, encouraging innovation in hydrogen generation, storage, and use technologies could be a national R&D budget. By using a customised, multifarious policy approach that fits with its economic strengths and simultaneously satisfies world sustainability targets, T&T may create an

environment fit for hydrogen development. These models will not only help with the energy change but also help T&T be a competitive actor in the future hydrogen economy.

5.2 International Best Practices

Trinidad and Tobago must realise that many parts of the world are advancing into the hydrogen economy. Several governments have formulated energy transition policies which support hydrogen utilisation. Among the countries that are energy transition leaders concerning hydrogen use are Japan and Germany. They are joined by China, France, South Korea, the Netherlands, and the UK. Japan has more than 3000 relevant fuel cell patents and has interesting costs for the installation of hydrogen generation and fuel cell systems. These rates can be used in pulling together a project concept. Some emerging energy transition leaders include Australia and Singapore. It has also been suggested, for application in T&T, that one useful approach to determine and include hydrogen demand priorities is to identify sectors with high consumption of hydrogen and build demand categories based on product/raw material choices. The T&T government should commission public studies to investigate how the current energy advantages, particularly a lower cost of day load kilowatt power from hydrogen energy, might be harnessed in national development.

Even if business-as-usual calculations indicate that hydrogen now derived from natural gas can be competitive, as much as possible of the national energy research budget should be directed at process improvements which unambiguously show the world that "delivering the promise" (that is, dramatically cheaper zero pollution renewable hydrogen energy) is just a series of R&D improvements away. Such success might also guide the possibility of delaying for ten years or more, national inter-generational political strife, resulting from the high further annual transfers out of earned wealth, to fund promised national benefits from largely disappearing soon oil and gas revenues (Das et al., 2021).

5.2.1 Target Hydrogen Production: Strategy and Goals

Japan has detailed a methodical strategy for boosting hydrogen supply. The objectives of Japan, by 2030, are to

Raise hydrogen annual supply to roughly 3 million tonnes. Including ammonia, supply should have risen to roughly 12 million tonnes yearly by 2040. Try to yearly reach roughly 20 million tonnes by 2050, with a decrease in hydrogen supply costs to 30 yen(¥)/Nm¹ by 2030 and 20 yen(¥)/Nm¹ by 2050. Japan's Basic Hydrogen Strategy comprises these targets, the strategy calls for using the Green Innovation Fund (METI, 2023) and pushing technological development in the hydrogen and ammonia sectors.

5.2.2 Goals and Strategy of South Korea Regarding Hydrogen Generation

By 2030: Supply 3.9 million metric tonnes of hydrogen annually, which includes: 940,000 metric tonnes of grey hydrogen, 750,000 metric tonnes of blue hydrogen, 250,000 metric tonnes of locally produced green hydrogen, and 1.96 million metric tonnes of imported green hydrogen. By 2050: Increase supply to 27.9 million metric tonnes of hydrogen annually, including: 3 million metric tonnes of green hydrogen, 2 million metric tonnes of blue hydrogen, and 22.9 million metric tonnes of imported green hydrogen. The plan also calls for lowering the cost of green hydrogen by Korean yen (₩) 2,500/kg by 2025 and ₩3,500/kg (\$3/kg) by 2030. By 2025, South Korea also intends to set up more than 2,000 hydrogen charging stations all around and encourage hydrogen use in industry, transportation, and power generation.

5.3 Local Considerations and Challenges

The geographic location of T&T makes it ideal for a hydrogen refuelling industry. The downside to its location is the presence of classic continental shelves. One of the great merits of methane production in Trinidad is its safety in transmission by pipelines. There is also a common use of pipelines at this time, particularly on land for the transfer of natural gas, but for even a longer period of time, the use of tankers of various sizes, very much bigger tankers with significantly more product versatility and strategic security implications, some of them retrofitted from the fleet of converted oil carriers designed to take crude to coastwise refineries (Alves et al., 2020). This means that hydrogen becomes very important in both the potential export and potential household distribution categories. Significantly more than the mere modification of the refit of automotive engines and the conversion of used and retired storage tank fabricating capacity is the obvious and challenging task of getting actual hydrogen into those engines and into those tanks. Before that, the hydrogen obviously must be made, stored and, to try to at least reduce the antinomic and chilling possibilities, transported.

6. Potential Sectors for Hydrogen Integration

If hydrogen is the fuel of the future, there are several sectors where it can be integrated. It can be used for industrial applications in the iron, steel and cement industries, renewable energy production from solar and

wind power, for building heating, for providing backup power for renewable energy production, in the maritime sector, for government services, and for the transportation sector. Figure 13 illustrates a typical green hydrogen supply chain.

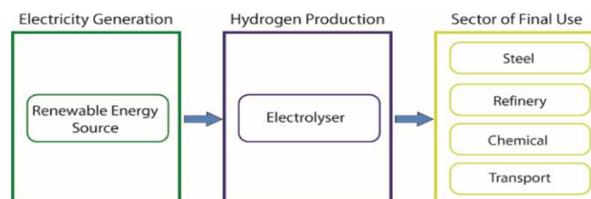


Figure 12. Green Hydrogen Supply Chain
Source: Adopted from Franco et al. (2024)

Regarding the transportation sector, we can learn from England, which has issued a hydrogen strategy for the world-class economy. The English government, outlining its ambition to be at the global forefront of hydrogen production and consumption, has already set out ambitious plans to have a 5 GW low-carbon hydrogen capacity by 2030 and will support decarbonising industrial clusters by 2030. Notably, the government has promised to set a firm hydrogen blending target for the gas grid and increase it in the 2030s up to 20% (García-Herrero et al., 2021). The British government set out a UK automotive transformation strategy and UK aviation and aerospace decarbonisation task force, that is looking at decarbonising international aviation and published a transport decarbonisation plan for a greener and healthier future - alongside its hydrogen strategy.

If T&T moves along the hydrogen fuel chain, then international models for quantifying errors and uncertainties in energy forecast models confirm that the stock of zero-emission vehicles will exponentially increase in a hydrogen transition scenario. Model estimations of 90% hydrogen refuelling stations opening in 2025 predict 33 fuel cell electric vehicles in service that year in Italy, 120 in France, 140 in Germany, and 750 in Spain (De et al., 2020). The progress of stationary hydrogen fuel cell storage systems goes together with the development of the hydrogen refuelling infrastructure and the consolidated adoption of fuel cell electric vehicles. Data shows rapid progress in their number and production. Four countries successfully dominate the market, though North America represents almost 60% of both the power capacity and the annual production of megawatt and kilowatt-class hydrogen fuel cell storage systems. With more than 850 plant builds ramified throughout hundreds of clients and over 14 years of operation, the U.S. is the capital of stationary hydrogen fuel cell storage systems (Avargani et al., 2022; Azarpour et al., 2022).

6.1. Insufficient Hydrogen Refuelling Infrastructure

Presently, T&T lacks hydrogen refuelling stations, which

is essential to enable hydrogen-powered cars. Creating such infrastructure calls for a lot of money and planning considering supply logistics, safety rules, and connection with current transportation systems. Hydrogen fuelling stations must be built if T&T adopts hydrogen vehicles to be supported and guarantee their useful applications.

6.2. Restricted Prospective Renewable Energy

Green hydrogen creation calls for a sizable supply of renewable energy sources. T&T is beginning to explore solar and wind energy, but not enough capacity exists to create green hydrogen on a sizable basis. As previously mentioned, if the Brechin Castle 92 MW solar farm plant comes onstream soon, this will significantly change. Expansion of renewable energy infrastructure is essential to provide the electricity required for the electrolysis processes used in the manufacturing of green hydrogen.

The effective integration of hydrogen technologies depends on the creation of thorough legislative systems covering operational procedures, safety, and environmental standards. T&T is currently working on these kinds of rules. Policies and financial incentives also help to make hydrogen powered transportation financially feasible for consumers and companies as well as promote investment in hydrogen infrastructure. The transition to a hydrogen-powered transportation system calls for not only technical developments but also changes in public view and labour capacity. Public awareness campaigns are required to let the public know the advantages and safety of hydrogen vehicles; training programs are meant to equip the workforce with the knowledge required for running and maintaining them.

6.1. Transportation

Transforming the transport sector across the country, with gasoline prices reaching record highs, a transition to a carbon-free society is imperative. Although electric cars pose a good mobility solution, the industry is struggling to keep up with the expected market demand. It will take a couple of years to re-engineer the existing infrastructure to properly recharge the vehicles. Thus, the hydrogen vehicle provides an excellent short-term solution. The hydrogen fuel cell poses a viable option for long-haul transportation as it does not have the energy density or weight restrictions of batteries because hydrogen is not the energy carrier (Otto et al., 2022).

Unlike gasoline, hydrogen contains no carbon, and so when burned, hydrogen will not release either greenhouse gases or atmospheric pollutants (including particulates) as shown in Figure 13. Gasoline or diesel conversion is unsuitable for hydrogen fuel cells because sulphur contaminates metals, with and nitrogen-containing compounds in the fuels, are poisonous to the catalysts. Furthermore, when evaporated to the atmosphere, the fuel must not participate in smog formation for which nitrogen oxides are required generally.

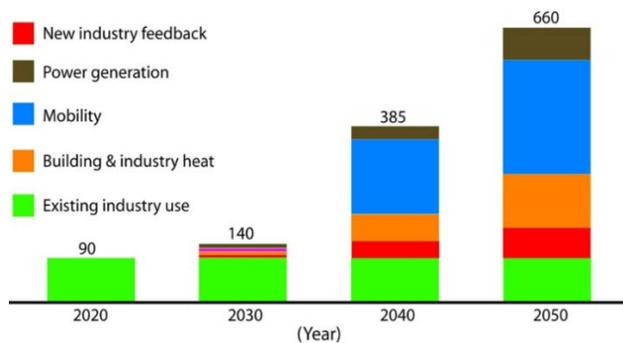


Figure 13. Hydrogen Demand by Sectors End Users
Source: Abstracted from Furukawa et al. (2013)

The hydrogen cycle is green when produced by electrolysing water, and the hydrogen process cycle is closed. The hydrogen economy combines energy, environmental, and security benefits by expanding the available sources of energy for storage and distribution, for electricity generation, and for stationary heating and cooling applications. If the required precautions appear excessive, keep in mind that energy demands are a leading cause of world conflict, thus, discoveries of hydrogen conversion capabilities only offer a greater range of choices for a presently embargoed society.

The transition to the hydrogen transport economy will be more comfortable since the individuals can use the fuel of gasoline democratically. They can adapt existing engines and new fuel cells gradually. Small volumes of hydrogen will be bought for retail gasoline stations and leased in portable cartridges. As infrastructure grows, it will allow the use of hydrogen fuel cells. During these transition stages, no new process emissions will need to be installed by the gasoline vehicle. As the hydrogen economy expands, at each stage, it will remove a growing volume of carbon dioxide from the transportation atmosphere, while producing small and large business opportunities for companies involved in hydrogen production, storage, distribution, supply, education, and advocacy. Engines, fuel cells, and automobile manufacturers will also benefit, charging customers for total energy and vehicle efficiency for improved performance.

Educational efforts would need to be established in partnership with governments, academic institutions, and industry stakeholders. These programs should address a wide range of audiences, including technicians, engineers, policymakers, and the public, with a focus on hydrogen safety, technology uses, and sustainability implications.

Meanwhile, regulatory frameworks must cover production standards, safety measures, pollution thresholds, and infrastructure certification. Enforcement could be carried out by national energy agencies and international standard-setting groups (e.g., ISO, IEC), but issues include harmonising standards across jurisdictions, assuring compliance in decentralised markets, and keeping up with rapidly changing technology. Furthermore, there is

frequently a gap between technological innovation and the creation of related rules, resulting in legal uncertainty and slow deployment.

6.2. Power Generation

When electricity is generated using hydrogen, it is emissions-free and environmentally friendly. There are three main power generation systems involving hydrogen: the use of fuel cells; their use in internal combustion engines; and using hydrogen in gas-powered turbines. The fuel cell is the most likely hydrogen technology from a Caribbean standpoint, and there are several different types of fuel cells. However, none is currently suggested for large-scale hydrogen-to-electricity transitions. The use of hydrogen in gas-powered turbines is a relatively new venture and is still in the research phase. Although it combines a gas turbine and an air separation unit, it is quite able to meet the frequency, and voltage demands of an electric power system. Hybrid solid oxide fuel cell gas turbine power plants have the potential to improve the thermal efficiency of a power plant to over 50% (Butt et al., 2021).

Alternatively, building a power island with a hydrogen storage plant could be considered. This power island idea is quite efficient since the power plant and hydrogen storage can be tightly connected to a new bus bar with a fast-responding source. The heat extracted from the power station can be taken for the industrial requirement using the right infrastructure. Overall, although converting a gas turbine plant to hydrogen is not a large task, the incentives do not outweigh the costs. As said before, the best method of large-scale hydrogen-to-electricity current production is probably the Solid Oxide Fuel Cell (SOFC). The PEMFCs are also most appropriate for small power generation and are extremely suitable for mobile operation when high power density is required. Such situations are found in the automotive sector, forklifts, and small stationary power generators in the few hundreds of kW powering portable office units (Bhaskar et al., 2020).

It is also feasible to transition to a hydrogen economy in steps. One intermediate step involves using ammonia to directly feed a solid oxide fuel cell. Because of the high operating temperature of such fuel cells (~800 °C), the ammonia spontaneously decomposes into its constituent nitrogen and hydrogen within the fuel cell anode. Once hydrogen is produced, the fuel cell operates as it normally does. The main difference is that hydrogen does not have to be produced externally, stored and transported to the fuel cell (Tota-Maharaj and Paul, 2015; Tota-Maharaj, 2020). Thus ammonia-fed fuel cells can serve as a stepping stone technology until a hydrogen economy is fully developed.

7. Investment and Financing Opportunities

Realising the nation's vision of becoming a global hub for clean green hydrogen production, consumption, and export by 2030 necessitates significant private sector investment.

Over half of the required capital investment must originate from private sources. This paper explores potential financing avenues to propel T&T's green hydrogen transformation. As a leading exporter of ammonia and a major player in the global petrochemical, LNG, steel, and methanol industries, T&T is strategically positioned to benefit from the growing demand for clean hydrogen. The country's favourable geographic location and abundant natural resources create a strong foundation for a hydrogen economy T&T's goal should not be only to decarbonise its domestic industries and power sector through green hydrogen but also to support regional energy transition and establish a robust global export market.

By leveraging its unique advantages and attracting substantial private investment, T&T can solidify its position as a key player in the global clean energy landscape. The successful socio-economic integration of hydrogen technology requires collaborative efforts from both the public and private sectors.

As hydrogen technology is rolled out globally, concerns regarding job displacement and the safety of hydrogen storage, shipping, and transfer must be addressed. However, it's important to recognise that technological advancements can drive economic growth and create new opportunities. If the private sector can consistently achieve high returns on modest investments in hydrogen technology, the transition to a hydrogen economy may progress smoothly without significant government intervention. In such cases, public-private partnerships will be crucial to accelerate the decarbonisation of society and alleviate fuel poverty through the adoption of hydrogen solutions.

If the Government of Trinidad and Tobago (GOVTT) is actually serious about fostering a hydrogen economy and not just engaging in domestic fuel switching, it should start planning for taxes on carbon content-less products, subsidising carbon price differentials between grey hydrogen and green hydrogen, considering fair hydrogen trade regulations, subsidising accelerated hydrogen transition, and funding the development of hydrogen refuelling infrastructure. Additionally, carbon tax exemptions for hydrogen should be anti-competitive. Only hydrogen with more than 90 percent yield with capture and storage of 95% driven by renewable energy should receive an exemption. Incentives to export lower case power with CHP power should not be mixed with antiquated textile tariffs. It is recommended that there are independent regulators to monitor and ensure compliance for priority sustainable development policies determined to mitigate the inappropriate use of renewable subsidies either through a tax on carbon content of imported goods and services or direct promotion of support instruments.

Building hydrogen infrastructure calls for big upfront financial outlay depending on its location and capacity, a single hydrogen refuelling station might run anywhere from \$1 million to \$2 million. Moreover, building a green hydrogen manufacturing facility especially one that uses

electrolysis run on renewable energy for mid-scale plants producing 10,000–50,000 kg daily could set costs above \$100 million (Bloomberg NEF, 2022). Particularly in the lack of public-private partnerships and coordinated policy support, these outrageous expenses show the financial obstacles to increasing hydrogen infrastructure (IEA, 2021).

8. Global Examples of Hydrogen Economy Implementation

Trinidad and Tobago must take its cue from multiple global initiatives that are accelerating the development of a hydrogen economy. The United States, for instance, has identified the petroleum industry as a key target for decarbonisation, with fuel cell trucks already being deployed in Texas (Li et al., 2022). China, another global leader in clean energy technology, is aggressively pursuing the production of 60 million tons of green hydrogen by 2030 through various pilot projects. Moreover, the country mandates the use of hydrogen in all new coal-to-chemical projects, reflecting a commitment to reducing greenhouse gas emissions and weaning itself off coal and methane gas (Li et al., 2022). India, a rapidly developing nation, is also making significant strides in the hydrogen sector.

The country has launched initiatives to promote green hydrogen production, particularly in regions with abundant renewable energy resources. For example, the state of Rajasthan has emerged as a hub for green hydrogen development, leveraging its solar and wind energy potential (Brown and Grünberg, 2022). In addition to government-led initiatives, India's younger generation is increasingly drawn to technology-driven sectors, including renewable energy and cleantech. This shift in labour preferences aligns with the global trend towards sustainable and high-tech job creation.

Agriculture, often regarded as T&T's failing golden calf, has embarked on making enormous and potentially transformative investments in innovative hydrogen farming. This strategic move aims to revolutionise their agricultural practices, enhancing sustainability and productivity while addressing challenges such as climate change and food security. By integrating hydrogen energy solutions, the agricultural sector in T&T hopes to emerge more resilient and efficient, ultimately benefiting local farmers and the economy.

Australia, on the other hand, anticipates the ambitious installation of 1,750 megawatts of electrolyzers by the year 2040, a move that reflects their commitment to harnessing hydrogen as a clean energy source. The Australian aim is for a substantial 10% of their energy needs to be satisfied through the gaseous cows that thrive in their vast sun-drenched pastures, a testament to their natural resources. Meanwhile, Saudi Arabia is boldly hoping to sustainably power the rising tide of their desalinated caravans, making strides towards a more environmentally friendly future. In Europe, Norway is strategically planning for a third of their

carbon-free currents to flow seamlessly in their Norwegian Sea, indicating a robust commitment to sustainability. The democratically controlled European Union stretches its ambitious renewable energy targets further and introduces a comprehensive certification framework aimed for implementation. Each of these significant hydrogen-driven initiatives, while promising, takes many years to achieve full fruition. Some of these initiatives even exceed the typical lifespan of automobiles, residences, and the very careers of their builders. The overarching goal for a complete transition by 2050 necessitates the establishment of clear, measurable, and reliable annual targets that all stakeholders can work towards. These specific targets in Korea were pronounced in the first medium-term and long-term hydrogen roadmaps that were unveiled in 2019, laying the groundwork for the duration leading up to 2040 and beyond (Jugessur et al., 2022).

9. Conclusion

Trinidad and Tobago's journey to a hydrogen economy is both a chance and a problem. The country has certain important advantages, such as a strong industrial base, competent workers, and a good position for exports. Blue hydrogen is a short-term answer, whereas green hydrogen is a long-term aim. The results show that T&T can become a regional leader in hydrogen if it gets the right legislative support, invests in pilot projects, and trains its workers in new technologies. Regulatory clarity, international cooperation, and increasing investment should all be top priorities right now to get from feasibility to execution.

To successfully transition towards a hydrogen economy, it is recommended to:

- 1) develop a comprehensive national hydrogen strategy with a clear, phased roadmap outlining short-, medium-, and long-term goals for production, infrastructure, and export market development; strengthen policy and regulatory frameworks through supportive policies, incentives, safety standards, and international certification mechanisms.
- 2) foster public-private partnerships to mobilise investment for pilot projects and large-scale deployment. prioritise research and innovation by supporting targeted T&T in low-cost production technologies, carbon capture for blue hydrogen, and storage solutions suited to T&T's conditions.
- 3) invest in skills development and workforce transition by establishing training programmes at tertiary and vocational institutions.
- 4) enhance stakeholder and community engagement by means of national education campaigns and consultations to foster support and inclusion.
- 5) promote regional collaboration by means of Caribbean partnerships to jointly develop infrastructure, share best practices, and
- 6) access new markets and implement pilot projects, such as hydrogen-fuelled transport fleets and hydrogen.

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