P2X - Enabling Indirect Electrification

Power-to-X has the potential to create a paradigm shift for NSW's hard to abate industries.

New South Wales (NSW) currently emits ~132 million tCO2e and the major sources of these emissions are from sectors such as stationary energy (~50%), Transport (~20%) and Industry (~10%). [1] These sectors present an alarming climate challenge for NSW, as they stand in the way of NSW's transition to a low-carbon economy.

The increase in renewable energy generation will form the 'bedrock' of NSW's march towards a low-carbon future. The NSW electricity grid currently has a renewable energy penetration of ~20% and the state has announced, it will continue to ramp up investment in the sector to reach a penetration of 35% by 2030. [2]

The cornerstone step for NSW to transition to a carbon neutral grid lies in the National Energy Markets (NEMs) ability to address the intermittency issues associated with the mismatched profile of renewable power generation with energy demand consumption. Utility-scale batteries are increasingly viewed as the solution to this intermittency void, however, another potential solution to this issue is through the use of Power-to-X (P2X) technologies. P2X is an umbrella term, to describe the conversion of renewable energy into renewable/low-carbon products and fuels. P2X offers a flexible production profile that compliments renewable energy generation.

Providing a solution to the intermittency gap is just one of the many benefits for embedding P2X technologies in NSW. The nucleus to this network of opportunities, is hydrogen. In its pure form it is a versatile energy carrier, capable of use as a thermal fuel (similar to natural gas) or electrochemical fuel for electricity applications (similar to a battery). The P2X pathway for producing hydrogen is via electrolysis, which involves the splitting of water using electricity. The use of renewable power generation to produce hydrogen, results in the production of 'renewable hydrogen', an emission-free energy carrier/feedstock.

There are two major P2X conversions pathways, primary and secondary. The primary conversion step involves the use of electrolysis to produce value-added products/ fuels (e.g. hydrogen, which is a high technology readiness level (TRL) pathway). Secondary conversion involves the combination of primary P2X products and other input products, to produce additional P2X derivatives (e.g. methanol).

The secondary conversion step for P2X holds the key to decarbonising NSW's hard to abate industries. The industries that benefit include: aviation, maritime, rail, chemical synthesis, and steel, as P2X products can be readily deployed in existing infrastructure, as low-carbon alternatives. Some of these industries also present the greatest challenge to decarbonising NSW, as they cannot be directly electrified – therefore, indirect electrification using P2X remains the key to these industries.

P2X unlocks a 'window of opportunity' for NSW to embed renewable electrons into all facets of NSW, but the challenge lies in the Government's appetite to foster this transition for existing industries This white paper aims to 'shed some light' on the prospect of embedding P2X technologies for NSW and the 'orchestrator role' the NSW Government can play in enabling this sector.

> "P2X can be a fluid solution to decarbonising 'carbon rigid' industries in NSW"
>
> *– Scientia Professor Rose Amal (Co-Director ARC Training Centre for the Global Hydrogen Economy (GlobH2E))*

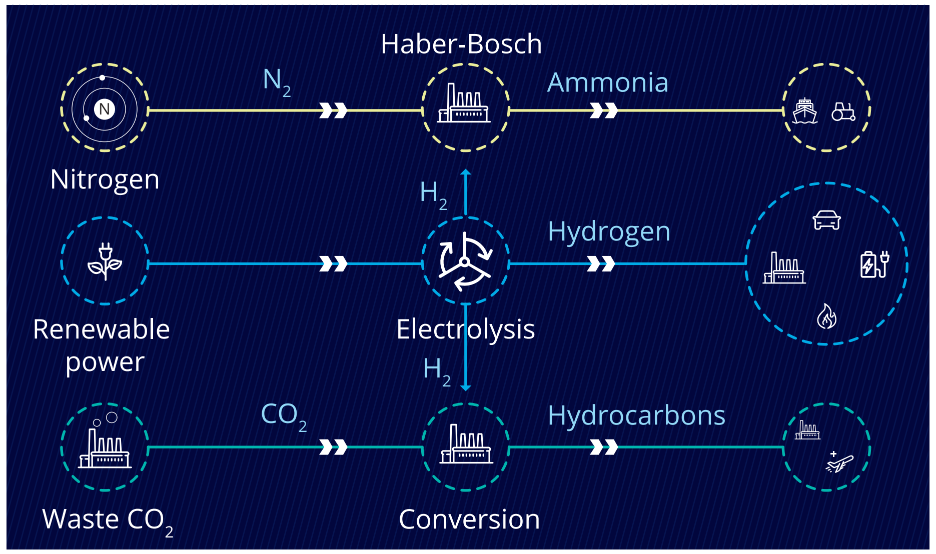
Hydrogen is the key to unlocking the network of opportunities.

In 2019, ~115 million tonnes of hydrogen was consumed globally for industrial processes such as, ammonia synthesis (55%), crude oil refining (25%) and methanol production (10%). [3] The current production profile for hydrogen, however, is dominated by fossil fuel pathways such as: steam methane reforming and coal gasification. Hydrogen sourced from fossil fuels, currently makes up ~97% of the global production profile. [4]

The global appetite for decarbonisation has resulted in a desire for the hydrogen economy to pivot towards carbon natural methodologies for hydrogen production. This can be achieved, using water electrolysis, where molecules of water are split into hydrogen and oxygen using renewable electricity.

The use of electrolysis to produce renewable hydrogen has expanded the notion of hydrogen applications beyond industrial processing, as it is a emission-free energy carrier. The emerging sectors for hydrogen as an energy carrier lie in transportation, specifically heavy-duty and high range applications, such as long-haul logistics and maritime. [4]

Another key emerging market for hydrogen is as a renewable feedstock for P2X chemicals/ fuels production, using secondary P2X conversions. This application profile for hydrogen expands the reach of indirect electrification to a range of applications. Secondary P2X conversion involves the reaction of renewable hydrogen with a secondary molecule (CO, N2 etc.) to produce P2X products. The key pathways are illustrated right:

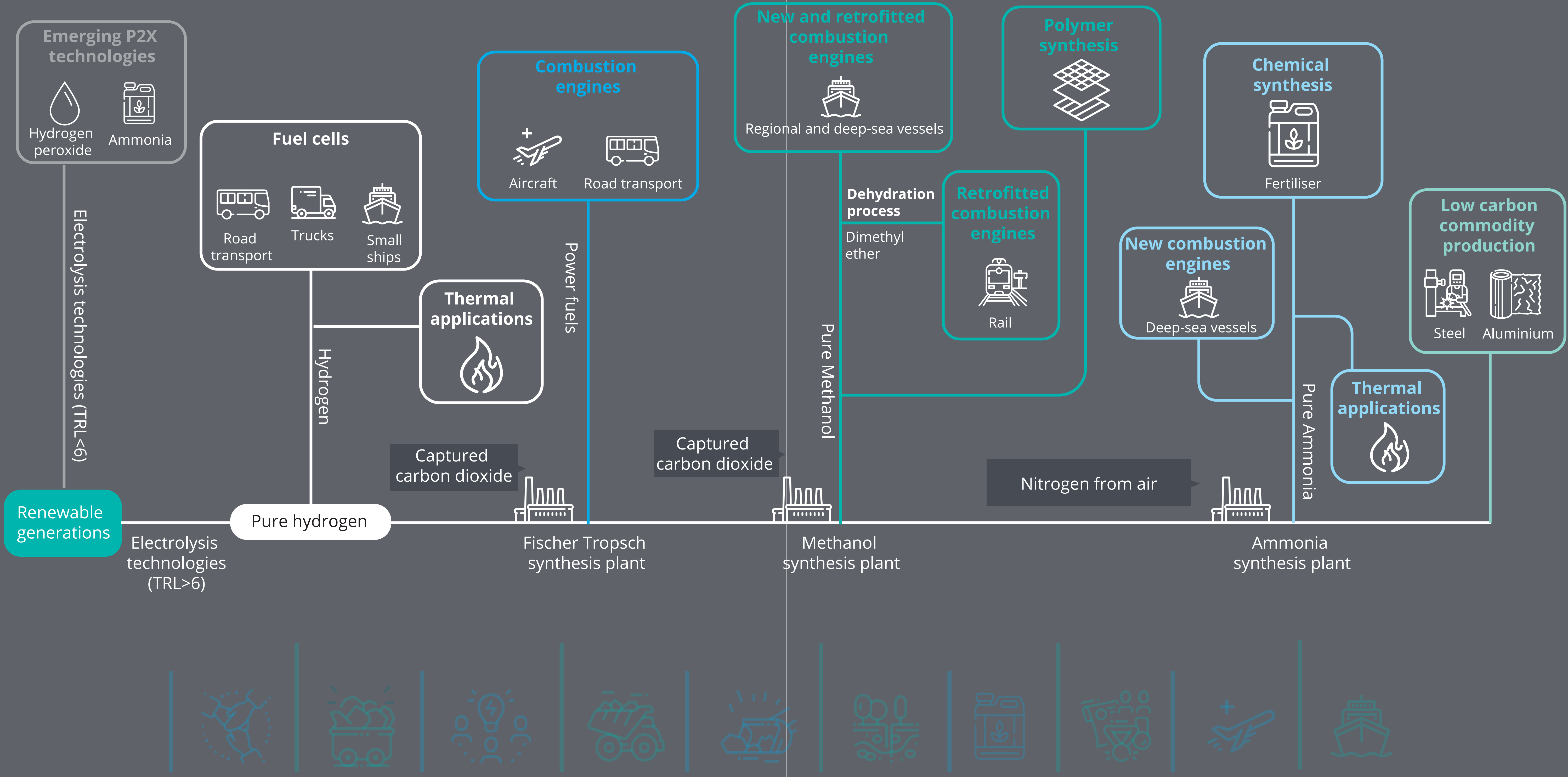


Secondary P2X conversion reactions present a multi-pronged solution for NSW, as P2X fuels can readily be deployed in existing fossil fuel infrastructure (in some cases minor modifications are required). Some examples of potential application are provided below:

- The substitution of renewable hydrogen with fossil fuel hydrogen in existing Haber-Bosch ammonia plants, will enable a seamless transition to low-carbon ammonia production. This is critical to decarbonising the fertiliser production and industrial explosives sectors, as ammonia is the base feedstock for the industry.
- The catalytic conversion of carbon monoxide (produced from thermal decomposition of waste carbon dioxide) and renewable hydrogen, produces low-carbon methanol, which can be readily deployed in maritime transportation. The use of methanol maximising 'sunk capital' in existing infrastructure, whilst promoting low-carbon operations. Methanol can also be utilised as a feedstock to produce many synthetic derivatives to fossil fuel-based chemicals, such as DME (used as a blending fuel) and olefins (used to produce synthetic fibre products). [5]

The P2X products listed above are the high maturity technology pathways for primary and secondary P2X, however, there are also emerging primary conversion technologies such as hydrogen peroxide electrolysis – this technology pathway if nurtured using suitable commercialisation activities, may emerge as another bespoke application for P2X. Hydrogen peroxide is a widely used chemical oxidant, mainly in industries such as pulp and paper [6]

Potential for P2X in NSW



P2X - Enabling Indirect Electrification

Snapshot of the 'low hanging fruit' for NSW

NSW's steel industry could be an immediate entry point for P2X technologies as existing furnace infrastructure (blast furnace, basic oxygen furnace and shaft furnace) can be retrofitted to enable blended fuel input. As hydrogen can be readily blended with either coke or natural gas (depending on the furnace type), as an intermediary step for decarbonising thermal operations within the steel industry. Furthermore, the application of blended fuels will enable the sector to recoup existing investments in current infrastructure, prior to shifting to carbon neutral technologies in the longer term. [7]

In the medium-long term, the transition to electric arc furnace (EAF) technologies combined with completely hydrogen-based reduction processes, presents a key pathway for the sector to build a resilient, sustainable, low-emission industry, that protects Australian exports from any forthcoming carbon export mandates. [7]

In NSW, ammonia is a key feedstock that is utilised for the production of fertilisers and industrial explosives. This sector is an immediate entry point for embedding renewable hydrogen as existing ammonia production processes can be leveraged to enable immediate decarbonisation of their operations.

The development of a low-carbon ammonia economy in NSW, however is not limited to domestic applications, as renewably sourced ammonia is expected to emerge as the next 'green commodity' for applications such as fertiliser production, chemical synthesis and net-zero thermal applications. A medium-long term opportunity for NSW would be to export renewable ammonia.

Japan has announced a requirement of 3 million tons p.a. of renewable ammonia by 2030 in Japan's 'National Hydrogen Strategy'. The development of NSW's capabilities to meet this demand can therefore usher the next generation of local export economy jobs for NSW. [8]

The development of a methanol economy in NSW will enable the deployment of both carbon capture and indirect electrification technologies operating in tandem, enabling a multi-pronged approach to decarbonising various industries in NSW. As industrial carbon outputs will be valorised for applications such as low-carbon fuel production for the maritime industry in NSW, therefore, providing much needed decarbonisation assistance to 'carbon rigid sectors'. [9] Low-carbon methanol can also be used to produce dimethyl ether, which is a synthetic fuel that can be readily blended with diesel for applications such as long-distance rail (i.e. the inland rail project), which is another 'carbon rigid sector'.

Another emerging market for NSW is the establishment of 'micro-factories' for P2X, this involves developing decentralised P2X economies throughout NSW. This pathway may involve, the roll-out of hydrogen/ ammonia/ methanol infrastructure specific to mining (FCEV mining trucks, energy storage etc.) or data centre applications, which require small P2X systems (<1 MW), thus reducing the procurement and development lead times. Furthermore, the deployment of these technologies across NSW, will enable economies of scale, therefore accelerating the commercialisation of the technologies. One of the pathways for developing a micro-precinct, could be through the implementation of micro-fertiliser production facilities in rural NSW also presents a lucrative pathway for establishing a P2X economy in NSW – enabling regions such as Wagga Wagga to transition into a micro economy for low-carbon fertiliser, which can be readily used locally.

P2X - Enabling Indirect Electrification

How the NSW Government can enable power-to-X opportunities

Play a 'Leadership' role in Promoting Industry Collaboration

The development of a P2X economy will require the collaboration of stakeholders from energy generation, utility planning, P2X technology providers, logistics and foreign trade. The NSW government is required as the 'key orchestrator' to facilitate dialogue and promote the collaboration required to develop this sector.

Map out the P2X Decarbonisation Pathways for High Emitting Industries

The opportunity for P2X chemicals and fuels to be embedded into existing supply chains as a decarbonisation enabler has not been socialised with industry. The addressing of this information barrier in conjunction with 'first mover' investigations incentive and financial incentives will promote the activation of decarbonization in NSW.

Continued Support for P2X Technology R&D and Innovation

The 'bedrock' of NSW's P2X capabilities is the interconnection between R&D and innovation, this sector needs continued support from the government with further promotion of commercialisation activities locally, through grants and subsidies for local manufacturing.

NSW is also in a unique position to facilitate the translation of low TRL (<6) technologies and establish NSW as a 'global superpower' in P2X technology innovation. The promotion of these technologies through grant pathways and connections with industrial stakeholders, can propel NSW's P2X future.

Promote 'First Mover' Investigations

One key barrier to entry for P2X technologies is the lack of awareness surrounding the cost of implementation and operation for the solutions.

The NSW Government can de-risk industry investment through public-funded feasibility study for prospective regions, locations and facilities.

Provide Economic Incentive for Investment in P2X

UNSW's current hydrogen model indicates a green hydrogen production price of $5.90 - $7.40 per kg of hydrogen (varies depending on region and renewable power generation). This is a 200 – 300% premium on the current fossil fuel counterpart, therefore limiting the financial incentive for investment in P2X pathways.

The NSW government can promote this shift to green hydrogen by providing financial incentives (e.g. subsidies, tax breaks, innovative financing) reducing the barriers to entry for these companies.

Promote Large-Scale P2X Projects

Economies of scale is required to improve the feasibility of P2X technologies, therefore strategic investment towards large scale P2X projects are needed to address key technology and supply chain risks.

UNSW's key collaborators for establishing a P2X network in NSW

Contact us

Scientia Professor Rose Amal
Co-Director,
ARC Training Centre for
Global Hydrogen Economy
r.amal@unsw.edu.au

Dr Rahman Daiyan
Chief Investigator,
ARC Training Centre for
Global Hydrogen Economy
r.daiyan@unsw.edu.au

Khushal Polepalle
Senior Analyst,
Deloitte Financial Advisory
kpolepalle@deloitte.com.au

Bibliography

1. https://climatechange.environment.nsw.gov.au/about-climate-change-in-nsw/nsw-emissions.
2. https://reneweconomy.com.au/state-of-the-renewable-nation-nsw-and-queensland-have-work-to-do-64507/.
3. https://www.hydrogeneurope.eu/.
4. https://www.iea.org/reports/the-future-of-hydrogen.
5. http://scholar.google.com.au/scholar?q=Gasification+%26+Syngas+Technologies+Conference+(2017&hl=en&as_sdt=0&as_vis=1&oi=scholart.
6. https://onlinelibrary.wiley.com/doi/abs/10.1002/anie.200503779.
7. https://www.hybritdevelopment.se/en/.
8. https://www.argusmedia.com/en/news/2184741-japan-targets-3mn-tyr-of-ammonia-fuel-use-by-2030.
9. https://www.methanex.com/about-methanol/methanol-marine-fuel#:~:text=Methanol%20is%20a%20safe%2C%20cost,meet%20increasingly%20strict%20emissions%20regulations..

General use restriction