Green Hydrogen Futures a Global Opportunity for Energy Transformation to Achieve Sustainability, Social Equality and Societal Change

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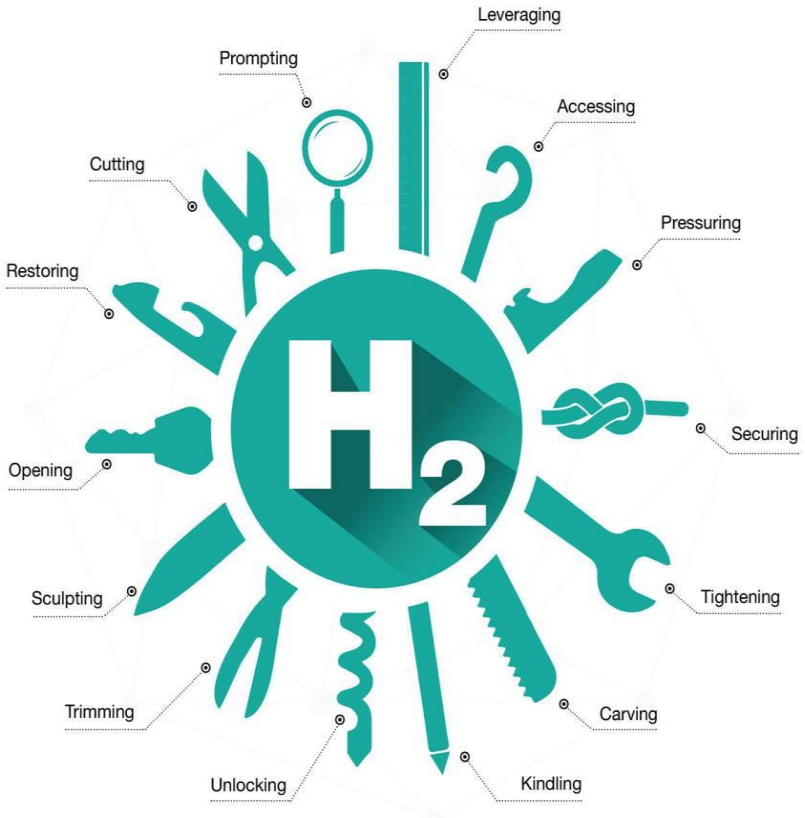

Green Hydrogen the multifaceted energy Swiss Army knife

Hydrogen is the 'tool' that delivers economic leverage, can unlock inequalities, open new economic opportunities and much more....

Foreword

As the world continues to address the urgent need to transition to clean and sustainable sources of energy, green hydrogen has emerged as a promising solution. With its potential to decarbonize various sectors, including transportation and industry, green hydrogen has been the subject of much discussion in recent years. However, while the focus has largely been on the power applications of green hydrogen, such as fuel cells and energy storage, the next energy steps in green hydrogen power to x, or P2X, are now coming into view.

P2X - *P2x²*

P2X refers to the use of green hydrogen for power applications beyond traditional energy production. This includes the conversion of hydrogen into other valuable products, such as ammonia and synthetic fuels, through processes like electrolysis and methanation. By utilizing green hydrogen in this way, P2X has the potential to further reduce carbon emissions and create new economic opportunities in the clean energy sector.

So, what's next for P2X in the application of meeting our energy needs as we seek to reduce our carbon footprint? One key development is the scaling up of production facilities for green hydrogen and its derivatives. As governments and industries invest in infrastructure for green hydrogen production, distribution, and utilization, the cost of green hydrogen is expected to decrease, making it more competitive with fossil fuels. Another important next step for P2X is the development of new technologies and processes to improve the efficiency and sustainability of green hydrogen production. This includes advancements in electrolysis technology, as well as the integration of renewable energy sources like solar and wind power to power electrolysers. Additionally, research is ongoing into the use of alternative feedstocks for green hydrogen production, such as biomass and seawater.

Green Hydrogen is a vector that delivers more than just green power and it is the 'beyond energy' the *P2x²* opportunities that excites the mind, green hydrogen has the potential to deliver a range of additional benefits in the new clean economy. For example, the production of green hydrogen can create new jobs and stimulate economic growth in regions with abundant renewable energy resources. Furthermore, the use of green hydrogen in industries like transportation and manufacturing can help reduce air pollution and improve public health.

Introduction

Green Hydrogen is the energy equivalent of the Swiss Army knife. It is a clean multi-tool vector can open new energy markets, it can help cut ties to fossil fuels, it can prize the lid of energy restrictions, it can build opportunity driven innovation, it can create lasting social change, and it can shape a just transition to net zero and much more.

Hydrogen can provide countries and regions with significant economic leverage through the strategic advantage gained by having full control over their energy value chains and the resultant position of being able to achieve economic and social goals, especially in relation to reducing energy inequality and poverty. Countries can utilise renewable resources to create new market positions and maximize economic benefits and influence outcomes, not least in other important systems that society depends upon, and which are related to the energy system, such as electricity, food, heating and cooling and transport.

Hydrogen offers the potential for countries to secure energy independence and reduce their dependence on imported energy sources, particularly corporate controlled fossil fuels. By developing a robust hydrogen infrastructure and leveraging domestic resources for hydrogen production, countries and sub-national regions can enhance their energy security and reduce vulnerability to price fluctuations or supply disruptions. This increased energy independence can provide economic leverage by reducing trade imbalances, improving the balance of payments, and strengthening the overall economic stability of a nation. Such a transition in the energy system also opens up the possibility of a more diversified political economy of energy ownership and control,

enabling for example, the greater democratisation of the hydrogen energy means of production, including transforming electricity from being a commodity to a human right (Treat, 2022).

Countries with significant renewables and resultant Green Hydrogen production can utilise the excess to lower the consumption price of energy domestically or as a clean energy export. Countries with ample renewable energy resources can create a market position and establish themselves as hydrogen exporters, opening new markets and revenue streams, as well as providing clean and cheap energy for citizens. Exporting hydrogen can enhance national trade balance, create jobs in the hydrogen value chain, and stimulate economic growth. By becoming a major hydrogen exporter, a country can increase its geopolitical influence and strengthen its position in global energy markets, as well as enhance its energy security and reduce energy poverty by providing much cheaper energy domestically. renewables increase and green hydrogen production becomes a commodity, previous energy poor countries will undergo significant industrial transformation.

The widespread adoption of hydrogen will drive the transformation of industries and create new economic opportunities. Hydrogen can be used as a feedstock in industrial processes, such as ammonia production, steelmaking, and chemical manufacturing. By transitioning to hydrogen-based processes, industries can reduce their carbon emissions, comply with stricter environmental regulations, and gain a competitive advantage in sustainable markets. This industrial transformation will as a result attract investments, spur innovation, and position countries as leaders in the clean energy economy, while also opening up opportunities for reducing energy costs for domestic users and the possibility of a more pluralistic structure of the hydrogen economy, with a much great role for nationalised and democratised ownership and control.

The latter in particular has the potential for achieving UN SDG 7 ‘Ensure access to affordable, reliable, sustainable and modern energy for all’, and reducing energy poverty, by progressively transforming energy provision from one based on energy as a commodity, to energy as a right (Bulet and Pastorelli, 2023).

‘*Sculpting’* A Clean energy economy.

Hydrogen plays a crucial role in the development of a new clean energy economy. As a versatile and zero-emission energy carrier, hydrogen offers many economic, social and environmental benefits for transitioning to a sustainable and low-carbon future. Green hydrogen can be used to decarbonise many sectors, including transportation, industry, power generation, and heating, as a clean alternative to fossil fuels. By replacing carbon-intensive fuels like coal, oil, and natural gas with hydrogen, emissions can be significantly reduced, contributing to the decarbonization of industry and giving rise to a new clean energy economy.

Hydrogen can be produced and transported as a clean energy carrier, facilitating international energy trade and cooperation. Countries such as Ireland and the UK rich in renewable resources can produce clean, green hydrogen and export it to regions with limited renewable energy potential, promoting global energy transitions, reducing dependence on fossil fuel imports and contribute to addressing the worsening climate crisis. In 2018, the European Commission adopted a strategic, long-term vision for climate change set out in the report *A Clean Planet* for all (EU Commission, 2018). The strategy confirms Europe’s commitment to lead global climate action and presents cost-effective ways to achieve a net zero contribution to greenhouse gas emissions by 2050 through a socially fair transition. However, we need to bear in mind the following, as Treat reminds us, in discussing the green, clean energy potential of hydrogen:

It is important to emphasize the dual nature of the task involved in realizing hydrogen’s potential for decarbonization. First, in order for hydrogen to play a meaningful role in decarbonization, its application must be expanded into sectors where it is currently hardly used at all—into more industrial applications, as well as more widely into transport, power generation and more.

Second, its own production must also be decarbonized—either by 'capturing' the emissions generated during its production, or by producing it through processes that do not generate significant emissions to begin with. (Treat, 2022, p.6; emphasis added)

'Carving' **a Pathway to Sustainable Development**

It's important to note that the widespread adoption of hydrogen in a clean energy economy faces challenges as well as providing opportunities. These include the high costs of hydrogen production, development of infrastructure, ensuring the sustainability of hydrogen production methods, and addressing safety considerations.

Nevertheless, ongoing advancements in technology and supportive policies are paving the way for hydrogen's integration into a new clean energy economy, offering a pathway towards decarbonisation and sustainable development.

As hydrogen burns at a temperature comparable to that of 'natural gas' it could be a potentially vital source of sustainable and climate-friendly heat for domestic or industrial uses. Perhaps most importantly, in principle hydrogen can be produced from carbon-free sources and used as a fuel in ways that produce only water as 'waste', which in turn could be integrated into other chemical- industrial processes. Hydrogen thus presents opportunities for international collaboration and trade. Countries with abundant renewable resources can produce and export green hydrogen, supporting the development of a global hydrogen market. This cooperation can foster energy security, economic ties, and knowledge exchange among nations.

'Kindling' Economic activity.

The establishment of a hydrogen infrastructure will require significant investments in production, storage, transportation, and distribution facilities. This infrastructure development will fast track the embryonic clean energy economy and stimulate economic activity, generate jobs, and create a multiplier effect across various sectors. Additionally, countries that invest in hydrogen infrastructure early on can become green energy investment opportunities of choice, attract foreign direct investment, foster innovation clusters, and become preferred destinations for clean energy investments. The development of a robust hydrogen infrastructure can provide a competitive advantage and economic leverage in the global energy transition. It can also open up the potential for lowering energy for households and businesses as well as decommodifying energy to some extent and in so doing reducing energy injustice and poverty, along the lines of how many countries treat health care or education as rights not based on your ability to pay. This element is vital if we are to generate popular democratic /public support for the energy transition in general and the hydrogen piece in particular, to enable citizens to see how the evolution of a green hydrogen energy system directly benefits them, their families and communities.

'Opening' Skills & Training Opportunities

Advancements in hydrogen-related technologies, such as fuel cells, electrolysers, and hydrogen storage systems, will lead to the development of cutting-edge technologies and intellectual property and create positions of technological leadership for countries with significant hydrogenewable[1] opportunities. Developing cutting edge technology and delivering research and innovation projects will create a

[1] The phrase hydrogenewables refers to hydrogen from renewable technologies – a sector coupling of green electrons for green molecules.

new knowledge economy.

This in turn will create education and training opportunities for self-development and long- term prospects for economic prosperity, job creation and wellbeing.

Countries or companies that pioneer and dominate these technologies can gain economic leverage through licensing, technology transfer agreements, and the export of related equipment and know-how. By positioning themselves as leaders in hydrogen-related technologies, entities can attract investments, create high-value jobs, and foster a culture of innovation that drives economic prosperity, economic and energy security.

'Leveraging' **a new Knowledge economy and Women in Hydrogen.**

The new green economy will develop and open opportunities throughout the training, technician qualification, engineering, project development, research and academia, provide pathways to self-sustaining education and innovation cycle. Bolstering not only technical development but also human resource enrichment. Unlike other industrial sectors, there is no incumbent workforce to displace.

It is not the same as displacing a mature industry from motor vehicle development in competition with established OEMs such as Fiat Chrysler Automobiles (FCA) Mercedes Benz and BMW. The nascent hydrogen fuel cell maintenance sector or electrolyser plant operation can be arranged at local level by established and reconfigured educational and skills providers. This offers a once in a generation opportunity for less developed economies and underrepresented segments of the engineering workforce to create a new economic space and harness the new technologies as the market expands.

'Cutting' Social Inequalities

Hydrogen as the catalyst for the emerging green economy will also open opportunities to create an equitable transition to Net Zero and address social inequalities, especially energy poverty and injustice. Transitioning our society and economy to a state where energy equity will afford the opportunity where the burden and benefits of the transition could be shared fairly among different groups and sectors of society.

Especially important here is to design the green hydrogen transition to ensure the most marginalised and energy poor sections of populations are prioritised in enjoying the benefits of clean, secure, and cheap or free energy.

Putting people and inclusivity at the centre of all clean energy transitions will play a crucial role in effectively implementing energy and climate policies. Optimizing the social leverage of green hydrogen also presents an important opportunity to address existing social and economic inequalities. Equality and inclusion must also be built into clean energy policies to mitigate the risk of disproportionate or unintended consequences for certain segments of society.

Through the levers provided by the new economy the transition will enable government to enact a fair distribution of costs and benefits, address social and economic disparities and engage with affected communities. This community wide engagement and participation of affected communities will enable greater social cohesion, reduce disparities and is crucial for an equitable transition. As the just transition to Net Zero will lead to job displacements in the 'fossil based' energy sector, the green energy empowered just transition will need to open opportunities in new clean energy sectors and require the provision of support and retraining programmes for affected workers to transition into new industries. This will ensure that the workforce is not left behind and that workers have access to decent and secure employment opportunities in the clean energy sector. At the same time the energy transition

As we transition to net zero, we must ensure that the people most vulnerable to the

effects of climate change are protected, and that the burden of transitioning to a low-carbon economy is shared fairly within societies and between developed and developing countries. Hydrogen can be the catalyst for delivering a European clean-energy transition based on solidarity, security, competitiveness, and innovation.

***'Trimming'* Centralized Production**:

Hydrogen can be produced from various sources, including renewable energy, natural gas, and water electrolysis. This decentralized production model allows regions with abundant renewable resources or natural gas reserves to become self- sufficient in hydrogen production. This reduces dependence on imported energy sources and creates economic opportunities for countries that may not have significant fossil fuel reserves.

Consequently, it can lead to a more balanced distribution of economic power globally. A new clean energy economy centered around hydrogen requires the development of a robust hydrogen infrastructure co located with renewable energy infrastructure. This includes the establishment of hydrogen production facilities, distribution networks, and refuelling stations for hydrogen-powered vehicles. The infrastructure development process would create new job opportunities and drive economic growth.

***'Prompting'* Rebalance and Repopulation:**

The new green economy can create regional quality job creation and lead to repopulation of remote regions and rebalance spatial and economic imbalances and inequalities. The hydrogen industry can create a wide range of job opportunities, spanning from research and development to manufacturing, installation, and maintenance and upgrading of hydrogen infrastructure.

These jobs can be distributed across different regions, helping to address unemployment and inequality. Additionally, since hydrogen production can be localised, it can promote regional economic development, especially in areas where traditional industries have declined. In this way green hydrogen can be key element of a new industrial and regionally balanced spatial development strategy for a country.

Technically and geographically remote regions can now have access to Energy: Hydrogen can also improve access to clean and affordable energy, particularly in regions with limited access to traditional electricity grids. Hydrogen fuel cells can provide reliable power for off-grid applications, such as rural electrification, remote communities, and disaster-stricken areas. By enabling energy access, hydrogen can contribute to poverty alleviation, education, healthcare, and overall social development.

***'Pressuring'* Global Energy Transition:**

Hydrogen can play a crucial role in the global energy transition by enabling the decarbonization of various sectors, such as transportation, industry, and heating. As countries strive to reduce greenhouse gas emissions, the demand for clean hydrogen as an alternative to fossil fuels is increasing. This shift presents an opportunity for countries to develop their hydrogen industries and position themselves as leaders in the clean energy sector, which can drive economic growth and enhance their international standing.

It's important to note that the widespread adoption of hydrogen in a clean energy economy faces challenges. These include the high costs of hydrogen production, development of infrastructure, ensuring the sustainability of hydrogen production methods, and addressing safety considerations. Nevertheless, ongoing advancements in technology and supportive policies are paving the way for hydrogen's

integration into a new clean energy economy, offering a pathway towards decarbonization and sustainable development.

However, and going back to the issue of the need for a more diversified political economy of the green hydrogen energy economy, in short that it should be viewed solely to mainly in terms of 'tradition' corporate or private ownership and control, green hydrogen, if it is to be part of an energy transformation strategy it must be focused on the latter not on energy expansion (Sweeney, Treat and Chavez, 2021). That is, and this is something insufficiently recognised in the energy transformation debate in general and the green hydrogen element of that in particular, is the need to avoid what some have called 'fossil fuel plus', whereby a renewable energy is simply adding more to the existing fossil fuel energy load rather than displacing it (Dunlap, 2021). The avoidance of this can only be done in via a state-coordinated not a market –coordinated strategy.

That is, any market-based transition has to be closely regulated and firmly within an energy transition pathway determined and monitored by the state, informed by the most up to date climate science and energy transition knowledge. The reason for this is very simple: unless we have a state organised energy transition, which includes but goes beyond simply adding more renewable energy, but most importantly (and as recognised in the 'just transition' policy framing) this requires the planned but equitable winding down and retiring of fossil fuel energy, the promise of the green hydrogen transition in tackling the climate crisis will be not delivered. Therefore, any credible hydrogen transition needs to be decoupled from the fossil fuel sector, and this requires strong state, not market-based strategies and policies.

A major reason for more state-based hydrogen strategies is that the speed and scale of investment and deployment required to bring hydrogen production and storage in line with reaching 'net zero', and identifying and solving the multiple technical challenges involved in hydrogen's production, storage, distribution and use, call for levels of integrated planning, coordination and cooperation that private interests are not suited to provide (Treat, 2022, p.8). The importance of central planning and coordination is all the more significant if we take the International Energy Agency's 'Net Zero 2050' modelling which states that, from 2030 onward, clean hydrogen in the its NZ scenario

requires adding 2 GW of electrolyser-based hydrogen production capacity, and replacing *three fossil-fuel-based industrial plants with hydrogen-based plants every month until 2050* (IEA, 2021, p.19). This pace, scale and necessary ambition is more akin to the 'wartime' mobilisation of resources than 'normal market conditions', without discounting the role of the private sector. Such a 'whole of society' effort (in keeping with recent IPCC reports), requires state not market led strategies.

'Unlocking' **Opportunity driven Innovation and Technology Development:**

The widespread adoption of hydrogen as an energy carrier requires advancements in various technologies, such as fuel cells, electrolysers, and hydrogen storage systems. Investing in research and development in these areas can spur technological innovation, leading to cost reductions, helping reduce energy poverty, improved efficiency, and new market opportunities.

Smaller and emerging economies can leverage this opportunity to participate in technology development, narrowing the technological gap between countries and promoting social equality.

The European Union's transition to net-zero carbon emissions by 2050 is a big challenge, but also a massive opportunity to modernise the continent's economy and promote growth, employment, opportunity driven innovation, technological advancement and social inclusion. The transition is economically and technically feasible and is becoming easier as the cost of hydrogen technologies declines. Considering that half of the greenhouse gas emissions reductions expected by 2050 will require clean hydrogen technologies and applications that are not yet ready for the market (indeed worryingly, some of them not even at the demonstration stage), research and innovation activities are crucial to supply the technologies needed for the green and digital energy transition and to deliver on the European Green Deal and REPowerEU objectives.

'Restoring' Climate Balance

Green Hydrogen is a clean energy vector crucial in restoring balance to our climate system (which is after all an energy imbalance i.e., the amount of energy the planet receives from the sun increasing over the amount then returning to space). We are amid a climate crisis, one that has been caused human activities leading to increased greenhouse gas emissions and global warming. Hydrogen is main part of our renewable energy transition, enabling us to shift away from fuels to renewable energy sources, such as solar, wind, hydro, and geothermal power, and is a critical step in rebalancing the climate. Increasing the share of renewable energy in the global energy mix helps reduce greenhouse gas emissions and mitigate the drivers of climate change. In order to achieve a climate balance we must also look to address our consumption lifestyles. Encouraging sustainable consumption patterns and promoting lifestyles that are less carbon-intensive can contribute to climate rebalance. This involves reducing waste, adopting circular economy principles, promoting energy-efficient practices, and making conscious choices about the products and services we consume. But more than that, we need to change the structure of production, from energy, transport, food, housing and so on. It is a mistake therefore to view the energy transition as one of simply using green hydrogen to 'fuel the hummer' (Barry, 2016), as if tacking the climate and ecological crisis and the creation of a new clean, green energy economy is simply a matter of 'greening' or 'decarbonising business as usual'. The science is definitive. We cannot 'decouple' an ever growing and expanding human economy on a finite planet now up against 'planetary boundaries' (Rockström et al, 2009). In this way, the transformation of our energy system should also be viewed as the transformation of the structure of our economy, from production to consumption, require a scaled down and more sustainable economy within the planet's fixed boundaries. Thus, for scientific/biophysical reasons we must view the transition to a renewable energy economy as the transition to a different type and structure of the economy, not a green version of the status quo.

'Tightening' Energy Autonomy

Utilizing hydrogen as an energy carrier can reduce reliance on imported fossil fuels, enhancing energy independence and security for countries and populations. By diversifying energy sources and utilizing domestic renewable resources for hydrogen production, nations can decrease their vulnerability to geopolitical tensions or disruptions in global energy markets. Hydrogen is seen as a potential key component in building energy security and autonomy for countries that are dependent on fossil fuel imports:

Green hydrogen from renewables can be used as a means of energy storage, which can be later converted back into electricity or used as a fuel for various applications, providing flexibility and balancing intermittent renewable energy sources. This capability helps enhance energy security by ensuring a stable and reliable energy supply. In this way green hydrogen can reduce the vulnerabilities of countries who are need fossil fuel energy importers, lessen the power of hostile or 'rouge' fossil fuel exporting countries, and in this way transform geopolitical imbalances and tensions based in whole or part of the disparity in power between fossil fuel importing and fossil fuel exporting countries and regions (Friedrichs, 2017).

Incorporating hydrogen into the energy mix helps diversify energy sources, reducing dependence on a single primary energy resource like fossil fuels. By producing hydrogen from renewables, national and sub-national energy systems can become more resilient and less vulnerable to supply disruptions or price volatility. Hydrogen production can occur at various scales, ranging from large-scale industrial facilities to decentralised units located closer to the point of consumption. This decentralisation contributes to energy autonomy by reducing reliance on centralised energy infrastructure and facilitating local energy production, which can be particularly beneficial in remote or isolated areas. Such decentralisation also allows for reducing energy insecurity by enabling more smart grids and modular energy and electricity systems, so that if one part of the electricity system is compromised, unlike with centralised grids, the entire system is not compromised.

Green hydrogen production relies on renewable energy sources, reducing dependence on imported fossil fuels. By utilising domestic renewable resources for hydrogen production, we can enhance our energy independence and security, while at the same time reducing energy poverty and providing cheap and secure energy for households, state services such as education and healthcare and businesses. This will lead to reduced exposure to volatile fossil fuel markets, geopolitical risks, and price fluctuations, contributing to a more stable and resilient economy.

'Accessing' **Green Prosperity**

Green hydrogen has the potential to contribute to the greening of prosperity and enable the long-overdue transition beyond orthodox GDP-measured economic growth, and focus on job creation, provision of high quality and affordable public services and increase economic prosperity while simultaneously reducing carbon emissions and resource and negative environmental impacts.

The production, infrastructure development, and deployment of green hydrogen technologies can create significant employment opportunities across various sectors. This includes the construction and operation of hydrogen production facilities, electrolyser manufacturing, hydrogen fuel cell vehicles, and related supply chains. Green hydrogen projects can stimulate selective economic growth in specific sectors, even as the macro- economy needs to remain stable and in a non-growth state, in in keeping with planetary boundaries (Barry, 2022), attracting investments and fostering innovation in the clean energy sector, while the fossil fuel sector is wound down, its assets redeployed and workers retrained.

Green hydrogen as a clean energy vector facilitates the integration of renewable energy sources into the energy system. Excess renewable energy, can be used for electrolysis to produce green hydrogen. This increases the value and market demand

for renewable energy, driving investment in additional renewable generation capacity and supporting the growth of the clean energy industry. Green hydrogen can be utilised to decarbonise key sectors such as transportation, industry, and heating, where decarbonisation is challenging using other methods. By replacing fossil fuels with green hydrogen, emissions can be significantly reduced, enabling the achievement of climate targets and improving air quality. This transition supports sustainable development and helps avoid the environmental and health costs associated with fossil fuel use.

Green hydrogen can simultaneously be an export commodity, creating new markets and trade opportunities, and at the same time a vital element in restructuring the domestic economy enabling a just transition to a clean green economy within planetary boundaries, creating jobs and reducing energy poverty and injustice. However, as outlined above, the technological transition alone to green hydrogen cannot achieve this, neither can a pure market-based approach.

The full realisation of the multiple, economic, social, employment, energy security and other benefits of any green hydrogen energy transition requires a state-led and coordinated, planned and science-based strategy. Such a planned and coordinated approach could allow countries with abundant renewable energy resources which can produce green hydrogen and export it to regions with limited renewable energy potential. This promotes global energy transitions, strengthens international cooperation, and establishes new revenue streams for economies, contributing to the transition to a very different post-carbon and post-GDP growth green economy, based around prosperity, meeting the needs of all and ‘full spectrum innovation’ in technology, the economy and society. Green hydrogen production does not emit greenhouse gases or pollutants when produced using renewable energy sources. By transitioning to green hydrogen, we can reduce our carbon footprint, improve air quality, and mitigate the impacts of climate change.

'Securing' Government Support

Realising the full potential of hydrogen for economic leverage and social equality requires careful planning, policy support, collaboration between governments, industry and civil society and long term cohesive economic and social vision. Considerations such as ensuring sustainability in hydrogen production, addressing distribution challenges, and promoting inclusivity in the workforce are essential for harnessing the benefits of hydrogen in an equitable manner.

Governments will need to coordinate businesses, citizens, consumers and other stakeholders, such has trades unions, to work together to create an enabling environment that promotes hydrogen adoption, incentivises investments, and ensures a fair distribution of benefits to maximise the economic and social justice potential of hydrogen.

To fully harness the potential of hydrogen in a clean energy economy, it is essential to continue investing in research and development, advance hydrogen production technologies (including green hydrogen), identify, test and establish supportive policies and regulations, expand infrastructure for hydrogen storage, transportation, and distribution, and foster international collaboration to drive innovation and cost reduction. To realise the potential of green hydrogen as an essential element of the transformation of the structure of our economies towards clean and green economic systems, will require state planning, leadership and coordination, alongside supportive policies, regulations, and the involvement of market mechanisms and actors. The latter includes financial incentives, carbon pricing, research and development funding, and the establishment of hydrogen infrastructure. Collaboration between governments, industries, civil society organisations, citizens and academia (as examples of the 'whole of society' effort that is required as outlined above) is crucial to overcome technological and economic challenges, foster innovation, and create a sustainable hydrogen-based economy that promotes both economic growth and environmental stewardship.

Conclusion

In conclusion, the next energy steps in green hydrogen power to x are focused on scaling up production, improving efficiency, and exploring new applications beyond energy. By continuing to invest in research and development, as well as policy support for green hydrogen, we can unlock the full potential of this versatile and sustainable energy source in the transition to a greener future.

However as we have explored Green Hydrogen is multifaceted, it is a diamond in the rough. As we 'cut and polish' we reveal a new face, a new clean energy use that has multiple benefits beyond the obvious contribution to decarbonising our societies and tackling the planetary crisis. As we build the new clean energy economy, we will realise new hydrogen technologies and applications that have multiple benefits that we must use on our collective journey to a just transition to net zero. It is not a panacea, but under the right policy and regulatory conditions has great potential to enable our transition to a new economy, beyond both the ecocidal and sub-optimal current fossil fuel one, but equally importantly, beyond scientifically unproven and risky proposals (even as these are popular and dominate policy and academic discussions) for 'greening business as usual'. As governments plot their green energy transitions with green hydrogen as the navigation aid it presents a unique opportunity to address existing socio-economic inequalities by putting people and inclusivity at the centre of the plans. Green hydrogen if it is to deliver on its promise to help use create a new green, clean economy must be inexorably linked to *greening business as unusual*.
Overall, the power of green hydrogen extends far beyond just its energy applications. With *P2x²* we have the opportunity to transform entire industries and create a more sustainable and environmentally friendly economy. As we continue to explore the potential of green hydrogen, it is clear that the possibilities are endless.


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References

Barry, J. (2016), 'Transdisciplinary Thoughts on Techno-Optimism and Innovation in the Transition from Unsustainability', in Byrne, E. et al. (eds), *Transdisciplinary Perspectives on Transitions to Sustainability*, (London: Routledge), pp. 106-124.

Bulut., M and Pastorelli, S. (2023), 'Energy is a human right and should be treated as such!', Greenpeace, available at: https://www.greenpeace.org/eu-unit/issues/climate-energy/46654/energy-is-a-human-right-and-should-be-treated-as-such/ (accessed 14/8/23)

Dunlap, A. (2021), 'Does Renewable Energy Exist? Fossil Fuel+ Technologies and the Search for Renewable Energy', in Batel, S and Rudolph, D. (eds), *A Critical Approach to the Social Acceptance of Renewable Energy Infrastructures: Going beyond Green Growth and Sustainability*, (Cheltenham: Edward Elgar), pp. 83-102.

EU Commission (2021), *A Clean Planet for All*, available at: https://climate-adapt.eea.europa.eu/en/metadata/publications/a-clean-planet-for-all (accessed 14/8/23)

Friedrichs, J. (2017), *The Future Is Not What It Used to Be: Climate Change and Energy Scarcity*, (Boston, Mass: MIT Press).

International Energy Agency (2021), *Net Zero by 2050*, available at: https://www.iea.org/reports/net-zero-by-2050 (accessed 14/8/23)

Rockström, J et al. (2009), A Safe Operating Space for Humanity', *Nature*, 461, pp.472–475

Sean S., Treat, J. and Chavez, D. (2021), *Energy Transition or Energy Expansion?,* (New York: Trades Unions for Energy Democracy), available at: https://www.tni.org/en/publication/energy-transition-or-energy-expansion (accessed 14/8/23)

Treat, J. (2022), *True Colors: What Role Can Hydrogen Play in the Transition to a Low-Carbon Future?*, (New York: Rosa Luxembourg Siftung), available at: https://rosalux.nyc/trade-unions-for-energy-democracy-working-paper-15/ (accessed 14/8/23)