



Unlocking the UK's Nuclear Hydrogen Economy to Support Net Zero:

A Cross-Sector Action Plan for Consideration
by the Nuclear Industry Council

JULY 2021

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NATIONAL NUCLEAR
LABORATORY

Foreword by Fiona Rayment

Chair of the Innovation Group

“The production of hydrogen from nuclear energy only requires today’s technologies to generate hydrogen with zero emissions. Driving nuclear hydrogen production today will de-risk the UK energy transition as we strive for net zero. A cross-sector approach, working collaboratively across the entire hydrogen value chain, will enable us to achieve economic prosperity and global leadership in delivering a nuclear hydrogen economy. The opportunity is enormous and this is the backbone of our action plan.”



The scale of the challenge ahead for the UK in reaching net zero by 2050 is undeniable. With legally binding targets in place to address the climate emergency and a post-pandemic economic recovery to deliver, we need all hands on deck.

Achieving net zero means the deep decarbonisation of our entire energy system - not just in electricity, but in how we heat our homes and decarbonise energy for industry. This means exploiting all our zero carbon energy technologies in all the ways that they can support decarbonisation.

Nuclear and hydrogen are two such technologies, which when combined provide opportunities for decarbonisation that are not currently recognised in the mainstream. This is changing. And the change cannot come soon enough.

The UK could seize on these opportunities today and see the difference tomorrow.

The production of hydrogen from nuclear requires only today’s technologies to generate hydrogen with zero emissions at the point of generation. It is already commercialised technology, capable of being deployed now.

Beyond what is ready and waiting for integration today, further innovation in new technologies offers more efficient hydrogen production with a competitive price; this will be essential to support a thriving UK economy based on zero carbon energy.

“An economy based on world-leading infrastructure, the cutting-edge innovation of the UK’s best scientific minds and one that will provide high-paid, high-skilled jobs up and down the country, together with an export revenue for world-class technology, skills and expertise”

In producing zero carbon hydrogen, the nuclear sector will achieve all this and more. Opening up the opportunity for clean energy exports; releasing the energy system planners of current constraints; and enabling a reliance on larger quantities of zero carbon hydrogen. Nuclear energy can enable the decarbonisation of heavy industry, transport and aviation at a competitive price through nuclear-derived hydrogen and sustainable / synthetic fuels.

Foreword by Fiona Rayment

Chair of the Innovation Group

By immediately and fully recognising this opportunity for zero carbon, nuclear-derived hydrogen, and deploying the required infrastructure at pace, I believe the UK can achieve net zero on time and affordably – and with far less reliance on unproven technologies.

The Climate Change Committee (CCC) estimates a future hydrogen production need of between 160 and 380 TWh per year – over ten times current production of 10 to 27 TWh per year derived from mostly fossil sources. The publication of the Nuclear Industry Association's (NIA) Hydrogen Roadmap, endorsed by the Nuclear Industry Council, has already outlined how nuclear could contribute massive quantities of zero carbon hydrogen to the future hydrogen economy.

We must not underestimate how enormous this opportunity is. The potential of clean hydrogen as a global export commodity will realise export opportunities beyond anything else we have seen in the UK's nuclear and hydrogen industry.

That landmark Roadmap has galvanised the nuclear sector behind a newfound purpose in delivering clean hydrogen to help secure net zero. We know the sector can make a major contribution with low-risk, proven

technologies by taking a portfolio approach – from conventional electrolysis available today, through to near-term innovations such as steam electrolysis, and more advanced options that offer greater efficiencies, including the heat-driven thermochemical technologies.

The nuclear sector is already making real investments and making great strides towards realising this opportunity. And in this report, we put forward our plan to deliver at pace; not in the future, but right now.

Crucially, to achieve what is needed for the UK, we must look beyond the nuclear sector and engage with the broader policy and industry landscape.

This is why I was delighted to chair the Nuclear Hydrogen Roundtable in May 2021. Timed to offer maximum value ahead of the Government publishing its Hydrogen Strategy, the Roundtable brought together some of the most influential minds from both nuclear and the wider energy sectors. It focused on identifying the challenges and actions required in Policy, Finance, Economics, Technology and Regulation to enable the UK to benefit from nuclear-derived clean hydrogen.

This report summarises the findings, which I fully support, that:

1. Nuclear-derived hydrogen can be a low-risk route to additional hydrogen production that should be recognised by all stakeholders.
2. With the actions in this report, the nuclear sector, in a cross-sector approach, could deliver gigawatts of flexible generation today. By 2050, 12GW of dedicated production could support the energy transition.
3. Rapid development and delivery of the first use case will demonstrate the entire value chain from production to user, and contribute from today to meeting current policy targets.

With decades of nuclear experience, the UK sits on a wealth of skills, talent and capability that can deliver nuclear hydrogen at scale. This capability can create the world's first nuclear hydrogen economy, delivering net zero at lower cost to consumers. The UK could spur a future global commodity market for hydrogen, enhancing exports of skills and innovative technology.

I very much hope and expect that, given its scope and timing, this document will be seen as a turning point for the role of nuclear in the future hydrogen economy and a call to action for the sector to take this one-time opportunity and grab it with both hands. This is an opportunity that can be realised, only with true cross-sector collaboration.

As an immediate next step, I will be fully supporting a stronger industry and government collaboration to unlock nuclear hydrogen through the Nuclear Industry Council's Innovation Group.

Delivering the Nuclear Hydrogen Economy: A Cross-Sector solution

Hydrogen is a global commodity providing the UK with an opportunity to be the first mover in this internationally competitive market. A nuclear hydrogen industry represents a huge economic opportunity for the UK. However, nuclear will need to make a very strong environmental and financial case to ensure we capitalise on this opportunity. This needs to be done very quickly, at pace and should build on existing hydrogen infrastructure.

On 13 May 2021, leaders from across the government, financial, energy and hydrogen sectors gathered with the shared aim of unlocking the nuclear hydrogen economy.

This event, called the Nuclear Hydrogen Roundtable, was a pivotal cross-sector meeting that sought to identify the challenges that must be overcome to enable nuclear-derived hydrogen to contribute to a net zero energy system and a resilient green recovery.

It built upon the already announced government targets to deliver 5GW (42TWh) of hydrogen generation in the UK by 2030.

The Roundtable and this report are delivered as part of the Nuclear Sector Deal, which is a commitment by the sector to work collectively, with support from government, to drive clean growth throughout the economy and make civil nuclear power an integral part of the UK's energy future.

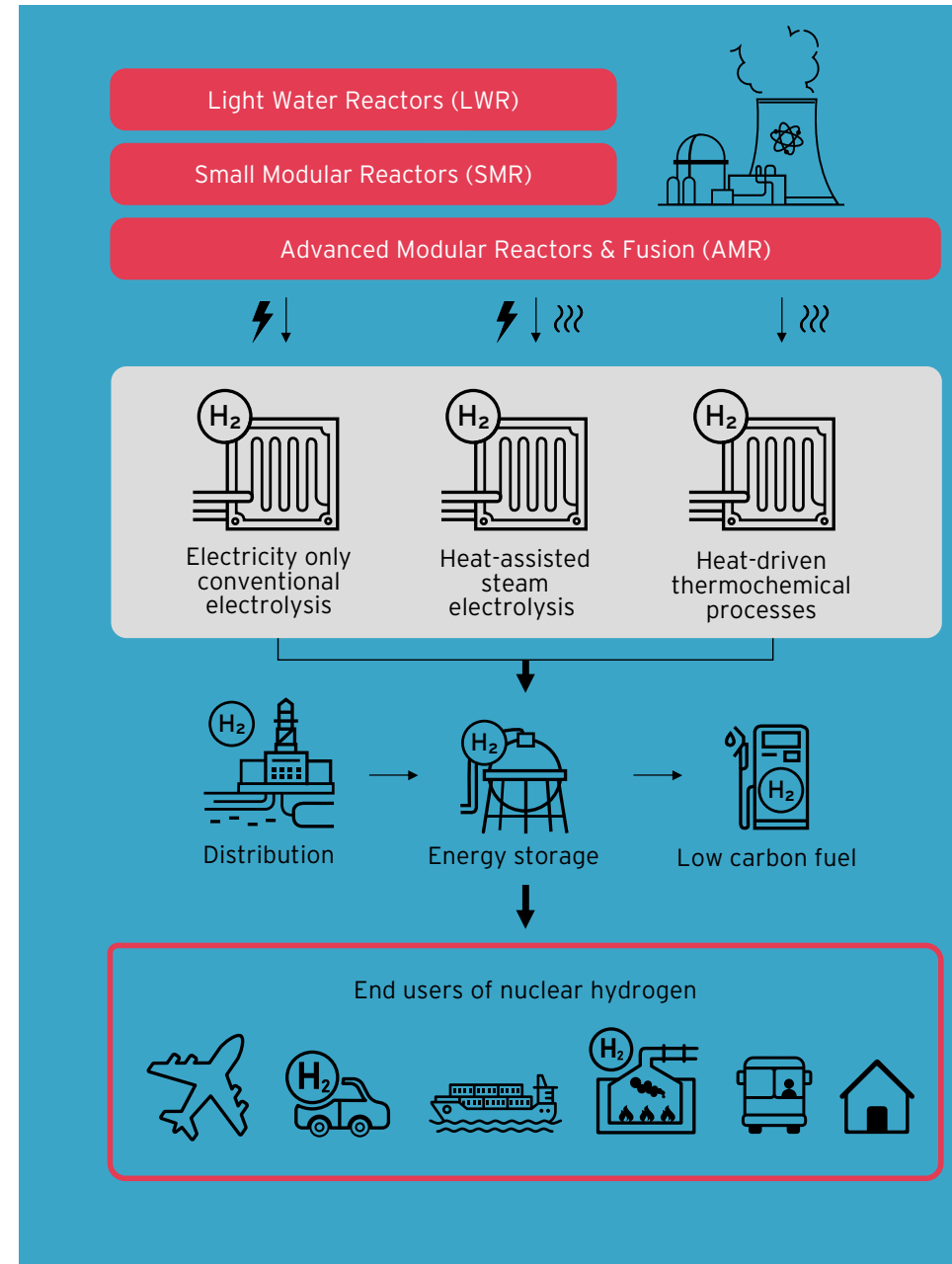
This document details the action plan required by both industry and government to realise the potential for nuclear-enabled hydrogen to contribute to a future net zero energy system through delivery of cost competitive, zero carbon hydrogen at scale.

Successful and rapid delivery of this plan, which can be implemented through the Nuclear Sector Deal, will enable nuclear energy to make a significant contribution to a world-leading hydrogen economy.

Helping the UK secure net zero on time and on budget.

10 Actions 10 Commitments

A Cross-Sector Plan for Climate Change



The Case for Nuclear Hydrogen: A summary

Large Scale - Low-cost - Zero Carbon



Sites previously identified as having potential for new nuclear could provide up to 90% of 2050 zero carbon hydrogen demand. Around 3GW of nuclear capacity, with today's technology, could meet the whole of the UK's current hydrogen demand.



Operating 24/7, a nuclear energy source maximises the utilisation of electrolyzers, reducing unit costs of hydrogen generated.



Sites for nuclear new build are spread right across the country, levelling up regions across the UK with high-value jobs.



Hydrogen derived from nuclear is a zero carbon source, emitting no CO₂ at the point of generation.



Nuclear hydrogen cost estimates include the full lifecycle of the power plant and fuel cycle including decommissioning and final disposal of nuclear waste underground.



The UK has gigawatts of current generating capacity that could, in part, be utilised for hydrogen production.



Beyond 2030, rapid deployment of nuclear hydrogen projects can provide solutions for decarbonisation in aviation, heavy industry and shipping.



All the technologies required to produce nuclear hydrogen are commercially available today and can be deployed with low risk.



Innovation can accelerate commercialisation of new delivery models and technologies that uniquely exploit both heat and electricity from nuclear, further driving down costs by extracting more useful energy from reactors.



The International Atomic Energy Agency (IAEA) forecasts that high purity nuclear hydrogen could reach lower than £1.50/kg - competitive with other low-carbon hydrogen technologies.

The Roadmap to the UK Nuclear Economy

We can act now and see results fast

How we will get there:

- Rapidly embed a nuclear hydrogen economy now in the UK using existing nuclear, helping to build back better and level up in the regions that need it most.
- Enable accelerated development of future nuclear hydrogen systems using planned new nuclear build.
- Deliver on net zero through providing reliable, high grade and low-cost clean hydrogen, making best use of new delivery models for economic success.
- Position the UK as a 'first mover' for a nuclear hydrogen economy - maximising economic growth and regional prosperity.

By...

Creating genuine demand for nuclear hydrogen using electrolysis.

Developing our supply chain and skills base.

Securing technology development and innovations for steam electrolysis and thermochemical processes.

... the UK will

See a rapid increase in demand as new demand-side technologies come online (e.g. hydrogen for heat, transport and heavy industry).

Have a world-leading supply chain, allowing us to capitalise on global export opportunities.

Have a homegrown skills base across the entire hydrogen value chain (including nuclear) to support the domestic fleet and export markets, keeping jobs here in the UK and technology-derived revenue flowing back to the UK.

Enable the commercial deployment of steam electrolysis and thermochemical processes - taking advantage of the further efficiencies created by these advanced production methods.

The Roadmap to the UK Nuclear Economy

We can act now and see results fast



Our Approach



Our Approach

Getting the right people around the table

We know that nuclear technologies have the potential to produce zero carbon hydrogen at high efficiency and capacity factors. We can do this at the scale required for deep decarbonisation, and with modest land area usage.

If cost-effective solutions can be deployed within the right timescales - and alongside the right policy solutions - these technologies could make a major contribution to net zero alongside other proposed options for large-scale hydrogen production.

So, with this Nuclear Hydrogen Roundtable we have brought together a broad cross-section of experts and industry leaders to help us map the actions that are required to realise this opportunity.

Economic - Technical - Regulatory - Policy - Finance

What we did: Participants came together through the Roundtable to identify action that needs to be taken to ensure zero carbon hydrogen from nuclear energy can play its role in a future energy system. Actions were identified across the five themes, as shown, that can enable the accelerated contribution of nuclear energy to future UK and international hydrogen demand.

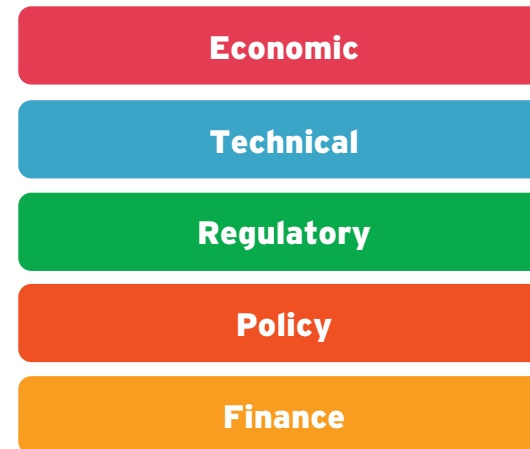
With over 80 participants from across the hydrogen value chain, including generation, distribution and utilisation, actions were identified from multiple perspectives and considered the complete hydrogen supply value chain.

These actions have been subsequently reviewed and refined to provide credible options for accelerating the deployment of nuclear-derived hydrogen production and storage in the UK.

What we have produced: This document describes the resulting action plan required by both industry and government to realise the potential for nuclear-enabled hydrogen to contribute to a net zero energy system through delivery of cost-effective, zero carbon hydrogen at scale. There are ten clear actions that enable this contribution. Successful completion of this plan could enable nuclear energy to make a significant contribution to a world-leading hydrogen economy.

With the urgency of the climate challenge, the actions within this plan need to be taken now if this vision is to be realised.

As well as embedding the full value chain for nuclear-derived hydrogen into our economy, it will put the UK at the forefront of global innovation in the race to net zero.



Our Approach

How we will get there?

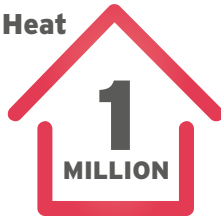


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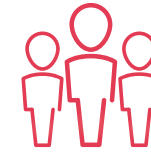
of all UK aviation emissions

Heat



homes with low carbon hydrogen

3GW of nuclear power with today's technology could:



Create

25,000

high value jobs

Meet

45% of 2030

hydrogen target

Deliver

10% of 2050

predicted hydrogen demand

Decarbonise

50%



of UK shipping emissions

Fuel **40,000** hydrogen buses



Clean Energy



Our Recommendations



Our Recommendations

10 Actions 10 Commitments

A Cross-Sector Plan for Climate Change

Economic	Technical	Regulatory	Policy	Finance
<p>1. Now: Embed the nuclear hydrogen economy</p> <p>Create the appropriate measures to deliver an immediate term use case for nuclear-derived zero carbon hydrogen that will activate the market.</p>	<p>3. Now: Enhance and grow a complete UK hydrogen ecosystem</p> <p>Enhance UK supply chain capability to its full potential across the entire hydrogen value chain and capitalise on enormous future export markets for hydrogen based products.</p>	<p>5. Now: Enable accelerated deployment through innovative regulation</p> <p>Drive innovative regulation and active collaboration between regulators and industry that will enable accelerated deployment of technologies in the delivery of nuclear-derived hydrogen.</p>	<p>7. Now: Deliver a siting strategy that supports the need for levelling up of UK regions</p> <p>Create a comprehensive siting strategy that ensures maximum contribution to the levelling up agenda that drives high-skilled, high-value jobs across multiple UK regions.</p>	<p>9. Now: Instil investor and public confidence in nuclear hydrogen products</p> <p>Establish a focused effort on communicating the benefits of nuclear hydrogen products to demonstrate the societal value of nuclear-derived hydrogen.</p>
<p>2. Next: Establish the hydrogen economy and incentivise the market</p> <p>Establish support schemes to incentivise the full hydrogen value chain for a range of markets, building on the first use case.</p>	<p>4. Next: Deliver future technologies and enable technology innovation</p> <p>Focus innovation funding now, to accelerate technology innovation that delivers increased efficiencies and scalability, utilising heat and electricity from nuclear power plants, and includes innovation in demand side technology.</p>	<p>6. Next: Capitalise on the full potential of an export market by harmonising international standards</p> <p>Enable international collaboration to harmonise the UK with international standards, creating an increased export market.</p>	<p>8. Next: Maximise the proposition for nuclear hydrogen products</p> <p>Enable policy that will embrace the potential for nuclear to decarbonise sectors such as heavy industry, transport (including through synthetic fuels) and direct heat.</p>	<p>10. Next: Create a route to commercialisation by unlocking finance</p> <p>Define a low (and zero) carbon hydrogen standard now, to ensure consistent access to finance and market mechanisms for all relevant technologies as they come to commercialisation.</p>

Our Recommendations

10 Actions 10 Commitments

A Cross-Sector Plan for Climate Change

Ten recommendations

Now: Embed the nuclear hydrogen economy now

Create the appropriate measures to deliver an immediate term use case for nuclear-derived, zero carbon hydrogen that will activate the market.

Next: Establish the hydrogen economy and incentivise the market

Establish support schemes to incentivise the full hydrogen value chain for a range of markets, building on the first use case.

Now: Enhance and grow a complete UK hydrogen ecosystem

Enhance UK supply chain capability to its full potential across the entire hydrogen value chain and capitalise on enormous future export markets for hydrogen-based products.

With an industry promise

To build a cross-sector hydrogen value chain proposition to government for an early use case. A superb example of industry working cross-sector to achieve success is the Freeport East Hydrogen Hub, and an early use case could link strongly to this initiative.

To work closely with government, sharing data to support the development of a compelling case for support schemes to create a long-term market pull.

To articulate and enable the full potential of nuclear-derived hydrogen to contribute to the wider hydrogen economy, including the skills and infrastructure required to deliver this capability.

And a government ask

To consider the economic support to create a first use case.

To consider the appropriate capital funding agreements and economic support required to enable the range of use case across the hydrogen economy.

To consider investments that will initiate the development of the supply chain talent pipeline.

Our Recommendations

10 Actions 10 Commitments

A Cross-Sector Plan for Climate Change

Ten recommendations

Next: Deliver future technologies and enable technology innovation

Focus innovation funding now to accelerate technology innovation that delivers increased efficiencies and scalability, utilising heat and electricity from nuclear power plants, and includes innovation in storage and demand-side technology.

Now: Enable accelerated deployment through innovative regulation

Drive innovative regulation and active collaboration between regulators and industry that will enable accelerated deployment of technologies in the delivery of nuclear-derived hydrogen.

Next: Capitalise on the full potential of an export market by harmonising international standards

Enable international collaboration to harmonise the UK with international standards, creating an increased export market.

With an industry promise

To establish the innovation needs of the entire hydrogen value chain, from nuclear energy to demand-side technologies.

To support a cross-sector working group that enables innovative regulation and delivers the data and resources required to underpin this.

To support harmonised international regulatory standards development through engaging with relevant working groups and providing the data required to underpin these standards.

And a government ask

To enable innovation investment for the development of nuclear coupled hydrogen systems beyond the first use case.

To support the implementation of a working group that can enable accelerated deployment of nuclear hydrogen generation and storage.

To support and promote the development of harmonised standards internationally through the IAEA, OECD-NEA and other relevant forums.

Our Recommendations

10 Actions 10 Commitments

A Cross-Sector Plan for Climate Change

Ten recommendations

Now: Deliver a siting strategy that supports the need for levelling up of UK regions

Create a comprehensive siting strategy that ensures maximum contribution to the levelling up agenda that drives high-skilled, high-value jobs across multiple UK regions

Next: Maximise the proposition for nuclear hydrogen products

Enable policy that will embrace the potential for nuclear to decarbonise sectors such as heavy industry, transport (including through synthetic fuels) and direct heat.

Now: Instil investor and public confidence in nuclear hydrogen products

Establish a focused effort on communicating the benefits of nuclear hydrogen products to demonstrate the societal value of nuclear-derived hydrogen.

Next: Create a route to commercialisation by unlocking finance

Define a low (and zero) carbon hydrogen standard now, to ensure consistent access to finance and market mechanisms for all relevant technologies as they come to commercialisation.

With an industry promise

To deliver an assessment on optimised siting requirements for nuclear hydrogen production for different hydrogen markets, recognising the related socioeconomic impacts. There are also a number of low-carbon industrial clusters supported by BEIS through their "Industrial Clusters Mission" and there may be opportunity for the nuclear industry to link in with these where they include developing hydrogen infrastructure.

To deliver a feasibility study for nuclear-derived hydrogen that will contribute to a future hydrogen switchover for the gas network.

To deliver a campaign to demonstrate the societal value of nuclear-derived hydrogen representing each element of the hydrogen value chain.

To provide data sets and deliver underpinning evidence that supports nuclear hydrogen's classification as a zero carbon contributor to the UK's net zero economy. To provide information on cost of capital variations on the downstream hydrogen costs as part of this assessment.

And a government ask

To consult on appropriate siting policy for nuclear-derived hydrogen beyond the existing nuclear siting policy.

To include nuclear-derived hydrogen in the Heat and Buildings Strategy and Industrial Decarbonisation Strategy. To consider the appropriate funding streams that should be available to enable nuclear hydrogen feasibility studies.

To support the inclusion of nuclear on government advisory bodies, such as the Hydrogen Advisory Council.

To support inclusion of nuclear-derived hydrogen in incentive structures designed to support the deployment of zero carbon energy solutions such as the Renewable Fuel Transport Obligation. To consider a full systems approach in understanding costs of nuclear hydrogen.

In Conclusion

Current nuclear technology can make a difference to the hydrogen economy now as well as in the future. The UK nuclear sector stands ready to deliver on this action plan and fulfil the true potential of its role in a hydrogen economy.

We believe the key to unlocking the nuclear hydrogen economy is cross-sector collaboration, with the entire hydrogen value chain working together to achieve success. This is the backbone of our action plan.

Achieving success will require an industry and government partnership focused on the outcomes described in this report.

We look to secure a way forward on nuclear-derived hydrogen through the existing partnership between industry and government (Nuclear Industry Council), turning these recommendations into reality.