CORNWALL INSIGHT

CREATING CLARITY

Insight paper

MCS Charitable Foundation

Hydrogen Costs

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MCS CHARITABLE FOUNDATION

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Methodology

This paper follows a mixed methodology based on both quantitative (data collection and analysis) and qualitative methods (in-depth interviews). The interviews were conducted with key stakeholders within the energy sector throughout August 2022. Sources for the quantitative data can be found below charts or in text references.

Through our methodology we have analysed potential impacts of energy prices on GB businesses of different types, size and geographic location.

MCS Charitable Foundation Hydrogen Costs

1 Executive summary

MCS Charitable Foundation ("MCS") in its charity goal of decarbonising homes, heat and energy has commissioned Cornwall Insight ("we", "us", "our") to calculate the costs of blue and green hydrogen, based on current and projected gas prices. This report sets out our methodology for this forecast, and our findings in terms of delivered prices for green and blue hydrogen.

1.1 Key findings

The cost of using 100% hydrogen for domestic heating sees an increase on average of 70% for the period from 2025. The difference in prices of using hydrogen as a blend are also higher but circa 5%. These values are laid out in Figure 1 and for green hydrogen reach a peak of 94.7% in 2030 before declining to reach 66.3% higher in 2050. For blue hydrogen, a peak of 78.7% is reached in 2039, declining to 71.5% in 2050.

Figure 1: Forecast average percentage increase for retail costs from natural gas

Years	2025-2029	2030-2034	2035-2039	2040-2044	2045-2049
New build offshore wind (green)	56.0%	88.4%	78.3%	71.2%	66.9%
Blue hydrogen	37.6%	76.9%	78.1%	74.7%	71.7%
Green hydrogen blend	3.9%	6.2%	5.5%	5.0%	4.7%
Blue hydrogen blend	2.6%	5.4%	5.5%	5.2%	5.0%

Source: Cornwall Insight

Figure 2 shows a summary of the additional annual cost of hydrogen, compared to a natural gas baseline, to domestic consumers, based on Ofgem's medium Typical Domestic Consumption Value (TDCV) of 12,000kWh/year.

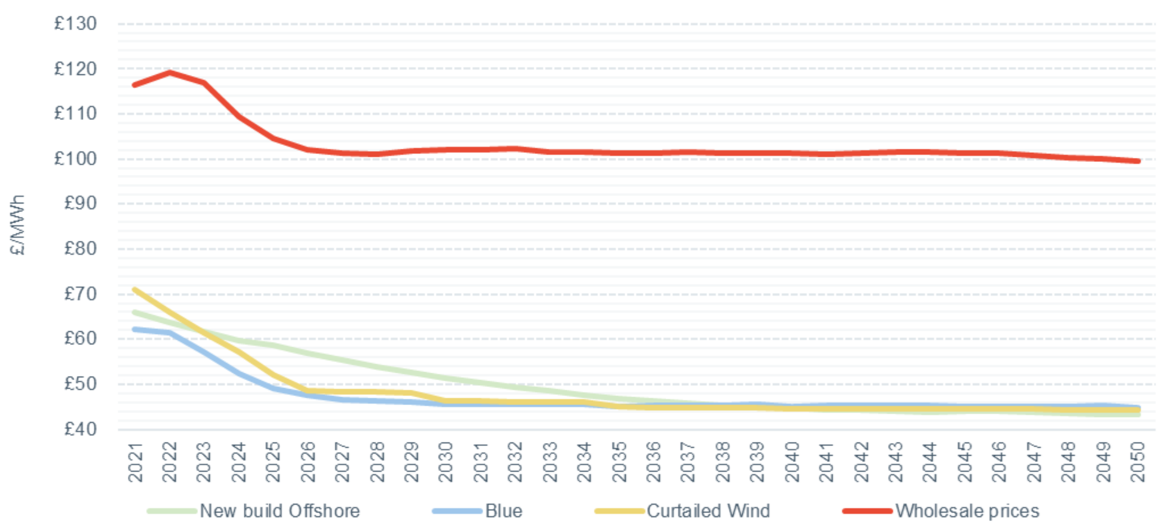
Figure 2: Forecast additional costs to consumers, selected years, compared to natural gas forecasts

Scenario	TDCV scenario	£/year cost to household 2025	2030	2040	2050
New build offshore wind (green)	Medium	£137.00	£393.34	£310.25	£278.29
Blue hydrogen	Medium	£49.95	£316.37	£318.33	£300.07
Green hydrogen blend	Medium	£9.59	£27.53	£21.72	£19.48
Blue hydrogen blend	Medium	£3.50	£22.15	£22.28	£21.00

Source: Cornwall Insight

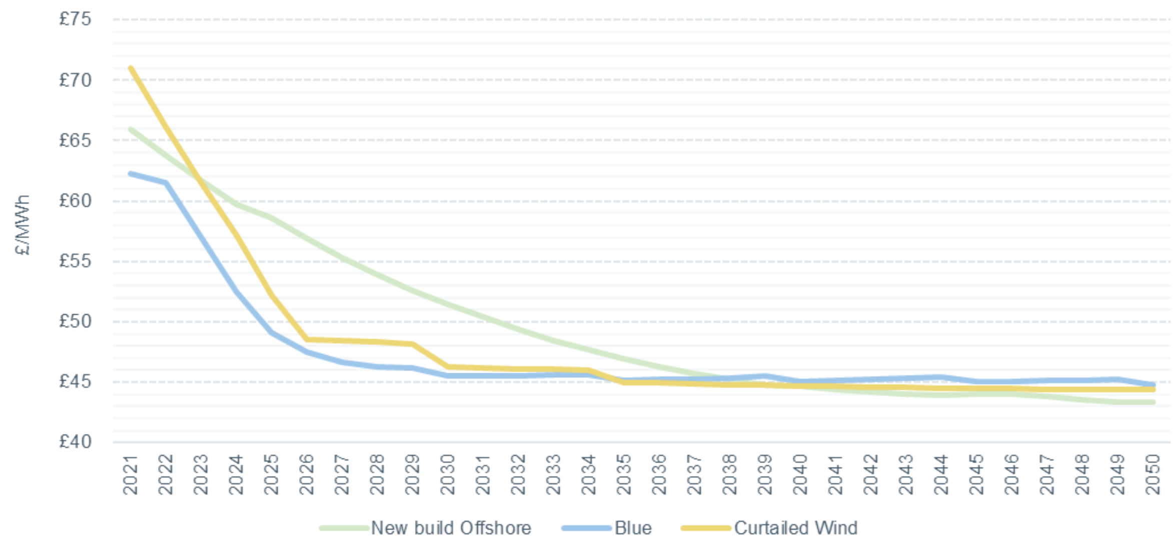
Hydrogen production costs for green hydrogen are forecast to decline relative to costs for blue hydrogen with cross-over points seen in 2039 when considering the cost of new build offshore wind. An earlier cross-over point is seen in 2035 when considering the availability of curtailed electricity volumes however the difference in the production costs between curtailed wind and blue hydrogen is less than 2% from 2030 meaning only a slight positive deviation in assumptions could result in an earlier cross-over point. This is illustrated in Figures 3 and 4 below with Figure 1 including the production costs of hydrogen when using prevalent wholesale prices for electricity and Figure 4 using the same data and homing in on the cross-over points. These wholesale price forecasts use Cornwall Insight's Q222 Benchmark Power Curve forecasts out to 2050.

Figure 3: LCOH of blue and green hydrogen scenarios



Source: Cornwall Insight

Figure 4: LCOH of 3 scenarios



Source: Cornwall Insight

2 Wholesale hydrogen costs – Green and Blue

2.1 Background

The path to decarbonising heating (space heating, hot water, and cooking) in homes and businesses remains unclear, with possible options including heat pump electrification, deployment of heat networks, conversion of gas infrastructure to hydrogen, and widespread adoption of hydrogen for heating. The government has committed to making a decision on heat decarbonisation policy by 2026.

Hydrogen is expected to play an important role in the transformation of the decarbonising the UK's energy system. Beginning with applications in transportation and industry, a market may develop with the potential to play a role in industrial decarbonisation and hard-to-abate users in carbon emitting industries. To support the development of hydrogen, the government has set a target of 10GW of hydrogen production by 2030, with the expectation that this will increase significantly beyond 2030.

The government proposed three milestones to expand the knowledge base on the role of hydrogen in heating:

- Neighbourhood hydrogen trial by 2023
- Large hydrogen village by 2025
- Possibility of a hydrogen town by 2030 (at most 1TWh)

The UK Hydrogen Strategy has identified a small hydrogen demand up to 1TWh of hydrogen in 2030. Based on a typical household's annual energy consumption of 12,000kWh, this equates to approximately 83,333 homes or a typical UK town. It is possible that hydrogen cluster towns will emerge by 2035, and the UK Hydrogen Strategy states that there could be up to 45TWh of hydrogen demand for heat.

Similarly, based on typical heat consumption, this equates to approximately 3.8 million homes.

Although hydrogen is the most abundant element in the universe, there is little naturally occurring hydrogen on Earth and nearly all hydrogen required has to be manufactured. Though there are four main sources of commercial hydrogen production (natural gas, oil, coal and electrolysis), only reformation of natural gas and electrolysis of water are seen as viable in a net zero economy. The process of Steam Methane Reformation (SMR) combines natural gas with steam, resulting in the output of hydrogen and carbon dioxide as a by-product. Through an additional process of carbon capture and storage (CCS), hydrogen can be produced with minimal release of carbon into the atmosphere. The output of SMR with CCS is widely known as blue hydrogen. The production of hydrogen through the electrolysis of water, where the source of electricity is renewable (wind, solar, geothermal, hydro), is known as green hydrogen.

Both blue and green hydrogen production offer pathways to net zero and given success of either is reliant on other aspects of the value chain it is not yet clear which is most cost efficient in the long run to achieve net zero. Blue hydrogen for example is reliant on the success of CCS and large scale deployment of this technology in the UK is unlikely before the end of the decade. With green hydrogen, success is dependent on inter-connecting hydrogen production to electricity generation and to ensure electricity supply requirements dovetail with other electricity demand growth areas for examples electric vehicles and heat pumps. Both hydrogen production methods will require the development of hydrogen transport and storage infrastructure to connect production facilities to end-user demand. Furthermore, there are other new emerging technologies including pyrolysis which may offer more economically efficient solutions in the future.

MCS asked Cornwall Insight to forecast future blue and green hydrogen prices. We have created forecasts of these future prices, using our forecasts for gas and electricity prices, technology efficiencies, capital and operational costs, and future learning rates for hydrogen production technologies.

2.2 Methodology and assumptions

We have used our knowledge and understand of the GB energy markets to forecast levelised costs of hydrogen production (LCOH) through several routes, explained below:

- **Blue hydrogen** – produced from Steam Methane Reformation (SMR) with Carbon Capture and Storage (CCS)
    - Forecast cost of wholesale gas
    - Capital and operational costs of SMR
    - Capital and operational costs of CCS
    - Conversion and efficiency losses of SMR and CCS
    - Learning rates for falling capital and operational costs, and improving efficiency rates, of both SMR and CCS are included

- **Green hydrogen** – produced with electricity from new offshore wind turbines
    - Forecast levelised cost of electricity from new offshore wind turbines
    - Capital and operational costs of alkaline electrolysers
    - Conversion and efficiency losses of electrolysis
    - Learnings rates for electrolysers

- **Green hydrogen** – produced with electricity from the grid
    - Forecast cost of importing electricity from the public networks, including carbon costs
    - Electrolyser capital and operational costs, losses and earning rates as above

- **Green hydrogen** – produced with electricity which would otherwise have been curtailed due to insufficient demand for the electricity or due to network constraints
    - An assumed zero cost of electricity, with availability based on historic curtailment rates to 2025 and forecast curtailment rates thereafter
    - Electrolyser capital and operational costs, losses and earning rates as above

Cornwall Insight produces a quarterly Benchmark Power Curve (BPC) forecast, which uses a bottom-up approach to model a view of future wholesale energy prices. Using the current state of play and insight into future commodity costs, technology costs, and demand forecasts, we provide a least cost optimisation modelling expertise to deliver a net zero economy by 2050. Through this process we provide insight into the projected electricity generational mix and the technological pathways towards net zero.

The research which underpins this product, and the outturn wholesale energy costs from the BPC, have been used to underpin the future costs of producing hydrogen. All values are shown as real 2021-22 prices.

2.2.1 Key assumptions

The key assumptions in calculating the cost of blue and green hydrogen are provided below and unless stated these values prevail for the entire forecast period. References to external sources are provided in the appendices Section 5.1.

2.2.2 Blue hydrogen cost assumptions

Figure 5 sets out the assumptions used to calculate the levelised cost of producing hydrogen using SMR and CCS.

Figure 5: Blue hydrogen inputs

Blue hydrogen inputs	Value	Source
Cost of gas	Annual prices	Cornwall Insight
Carbon capture and storage (CCS) costs	£28/tonne	BEIS
Stream methane reformation (SMR) process costs	300MW reference plant size	BEIS
SMR Fixed opex	£28.07/kW/year	BEIS
SMR Variable opex	£0.0001/kWh	BEIS
Hurdle rate	8%	Cornwall Insight
Carbon price	Annual prices	Cornwall Insight
Asset life	40 years	BEIS
Load factor	95%	BEIS
CO_2 capture rate	90%	BEIS
Thermal conversion efficiency	74%	BEIS and others

Source: Cornwall Insight

2.2.3 Green hydrogen cost assumptions

For the green hydrogen cost calculation using offshore wind, three scenarios were modelled, each using the base assumptions as shown in Figure 7 and Figure 8. The three scenarios modelled are shown in Figure 6 and highlight the three alkaline electrolysis plant use cases envisaged in managing the intermittent nature of offshore wind generation output.

Figure 6: Green hydrogen scenarios

Green hydrogen scenario	Value
1	Dedicated new build offshore wind
2	Grid connected alkaline plant
3	Curtailed wind

Source: Cornwall Insight

The assumptions underpinning the cost of offshore wind are taken from our BPC modelling assumptions, which reference various public sources including BEIS. We also apply a technology learning rate which decreases the cost over time. For capital expenses (capex) values this includes the electrolyser system (the stack), all necessary balance of plant (drier, cooling, de-oxo and water de-ionisation equipment), civil works (building and foundations) and the electricity grid connection. This data is then used to calculate a levelised cost of energy (LCOE) for offshore wind which is used as an input into the cost of hydrogen via an alkaline electrolysis plant.

Figure 7: Offshore wind inputs

Offshore wind inputs	Value	Source
Asset lifetime	30 years	BEIS
Capex	Annual amounts	BEIS, Cornwall Insight, others
Fixed opex	£68,421/MW/year	BEIS, Cornwall Insight, others
Variable opex	£3.325/MWh	BEIS, Cornwall Insight, others
Load factor	55%	BEIS, Cornwall Insight, others
Offshore wind discount rate	6.3%	BEIS

Source: Cornwall Insight

We have chosen to only consider alkaline electrolysers as opposed to proton exchange membrane (PEM) as research indicates PEM is currently more expensive and has a lower production capability when compared to alkaline. Both technologies are forecast to have lower production costs going forward.

Figure 8: Alkaline plant inputs

Alkaline plant inputs	Value	Source
Asset lifetime	30 years	BEIS
Capex	10MW reference plant	BEIS
Fixed opex	Medium input values	BEIS
Variable opex	Medium input values	BEIS
Discount rate	8%	Cornwall Insight
Plant efficiency	Between 77-82%	BEIS

Source: Cornwall Insight

Values for capex and opex, in five-year interval periods directly from BEIS' Hydrogen Production Cost 2021 report and its annex. For the discount rate 8% is used to mirror the SMR discount rate, although it is noted that this is lower than BEIS' 10% value. For plant efficiency we used BEIS' medium case for electrical conversion efficiency which starts at 77% in 2020 and improves over time to 82% by 2050.

2.2.3.1 Dedicated new build offshore wind scenario

In this scenario all of the offshore wind output is fed directly into the alkaline electrolysis plant and since the load factor of offshore wind is 55%, the same load factor is assumed in operating the alkaline electrolysis plant.

2.2.3.2 Grid connected alkaline plant

For this scenario, the alkaline plant is connected to the national grid and is assumed to be operating at maximum capacity. The load factor of the plant therefore improves from 55% seen in the dedicated new build case to the maximum available operating capacity of the plant which, using BEIS as the source is seen at 98%.

The supply of electricity to the electrolysis plant is from a portfolio of renewable energy sources that is priced at prevalent market rates. For these prices we have used the outputs from our Q222 BPC modelling central case results, using annual prices.

2.2.3.3 Curtailed wind

In this scenario we are using surplus renewable energy and thus is supplied to the alkaline electrolyser at an electricity cost of zero, in line with BEIS as reported in its Hydrogen Production Costs 2021 publication. This follows from recognising that the build out of offshore wind and other forms of generation capacity is set to continue and at times the volume of generation supply will exceed demand and rather than curtail this supply, it is diverted to electrolyser plant and used to produce hydrogen.

Curtailed wind could also be made available due to local network constraints where generated volumes are unable to be transported to areas of demand. The volume of curtailed wind thus represents the load factor of electricity supply in this scenario. For the volume of curtailed wind used in this calculation we have referenced two public sources which cite historic curtailed volumes and is shown in Figure 9. Based on this we have assumed a load factor of 4% for the years to and including 2025. Post 2025 we have used a load factor of 25%, again referencing BEIS' Hydrogen Production Costs 2021 report.

We note that the volumes of power available to produce hydrogen through this methodology are not forecast to be sufficient to provide sufficient quantities to have a significant impact on decarbonising GB domestic heating. We have therefore excluded this methodology later in the report.

Figure 9: Historic curtailed wind volumes

Year	Total wind generation, TWh	Volume Curtailed, TWh	% Curtailed
2018	56.91	1.85	3.3%
2019	63.80	2.04	3.2%
2020	75.37	3.82	5.1%
2021	64.70	2.30	3.6%

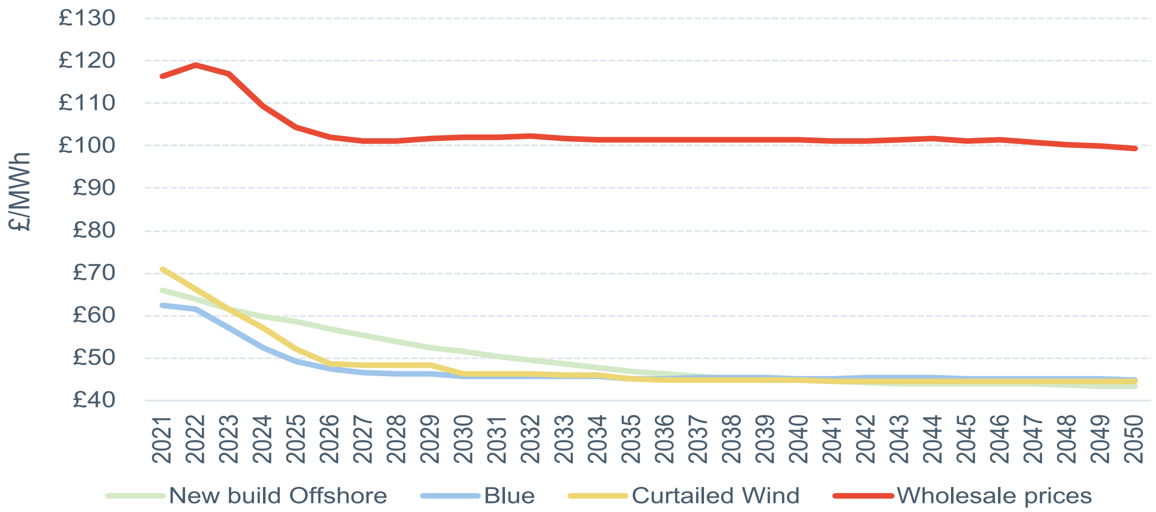
Source: Cornwall Insight

2.3 Results

The results fall into two areas; first, comparing the levelised costs of hydrogen (LCOH) of the four scenarios and these are shown in Figure 10; and secondly comparing this from a natural gas/hydrogen blend where an 80:20 ratio by volume is assumed.

2.3.1 Levelised cost of hydrogen results

Figure 10: LCOH of the 4 scenarios

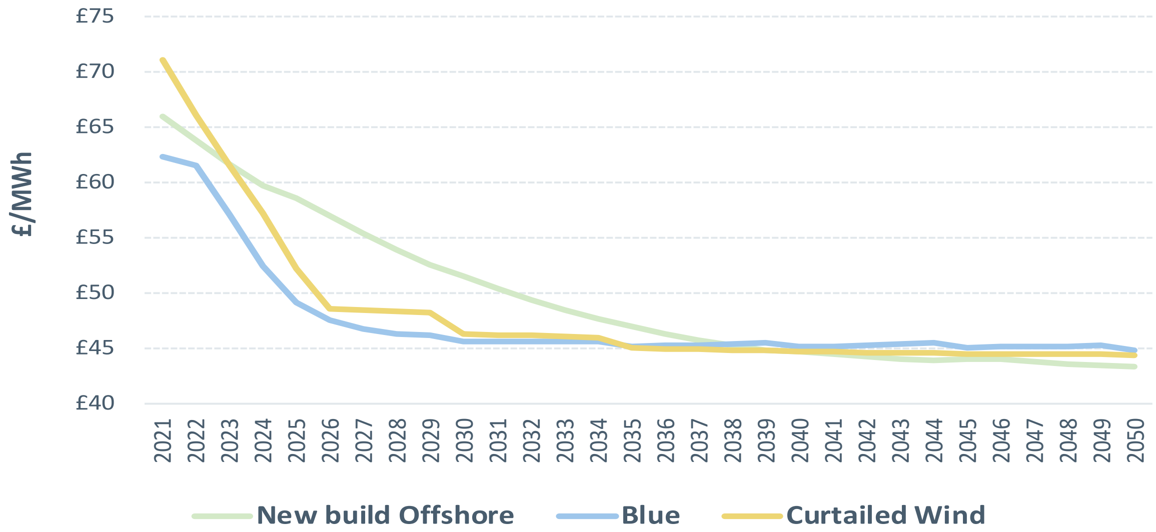


Source: Cornwall Insight

It can be seen in Figure 10 that the production of green hydrogen using prevalent wholesale electricity prices does not currently provide a compelling economic case to switching away from the use of blue hydrogen. This can be explained by the need for some gas powered electricity in the generation mix, which will need to use carbon capture and storage technology in a net zero economy, to balance electricity demand with supply. Since there are efficiency losses from the use of natural gas to produce electricity, it follows that the wholesale price of electricity will be higher than the wholesale price of gas.

To further develop the results shown in Figure 10 has been re-charted in Figure 11, removing the wholesale price result to highlight clearer the cross-over points between the other three scenarios.

Figure 11: LCOH of 3 scenarios



Source: Cornwall Insight

In Figure 11 it can be seen that the use of curtailed wind closely aligns with that of blue hydrogen with a cross-over seen in 2035, and the declining trend in the cost of dedicated new build offshore wind providing a cross-over point from 2039. Furthermore, the difference in the production costs between curtailed wind and blue hydrogen is less than 2% from 2030 meaning only a slight positive deviation in assumptions could result in an earlier cross-over point. Numerical data for this and other selected years from Figure 11 years are listed in Figure 12.

Figure 12: LCOH results for selected years, £/MWh

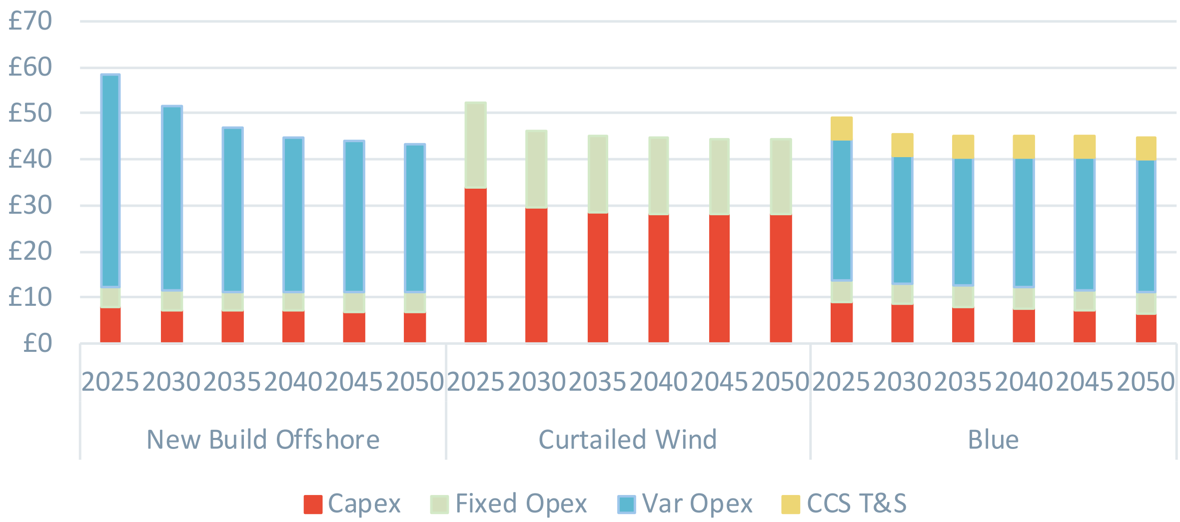
Year	2029	2030	2031	2032	2033	2034	2035	2038	2039	2040
New Build Offshore	52.57	51.48	50.39	49.39	48.47	47.65	46.94	45.24	44.81	44.70
Blue	46.15	45.55	45.55	45.56	45.58	45.62	45.14	45.38	45.48	45.09
Curtailed Wind	48.18	46.27	46.20	46.13	46.06	45.98	44.97	44.80	44.74	44.67

Source: Cornwall Insight

This suggests that accelerating the roll out of renewable generation will have two positive impacts. Firstly a larger early deployment of offshore wind could accelerate the declining trend in the cost of offshore wind to then reach an earlier cost-over point to that of blue hydrogen. Secondly, an increase in the volume of curtailed wind could increase the load factors of curtailed wind electrolysers which in turn could decrease the production cost leading to an earlier cross-over point before 2035. In addition, it is noted that our gas price assumes that the price of wholesale gas declines from current high levels from 2025 and any shift in this assumption towards later would add a third positive impact for accelerating the offshore wind rollout. Despite this assumed wholesale gas price decline our modelling forecasts for wholesale power prices are still significantly above average beyond 2030 and this is as a result of the need to still use some gas powered electricity in the generation mix and the conversion efficiency from gas to electricity.

The two positive impacts are further illustrated in Figure 13 which charts the various components making up the levelised cost of hydrogen in terms of capex, fixed and variable opex and finally CCS costs. A reduction in the capex costs of new build offshore wind leads to a reduction in the variable costs to the electrolyser in terms of electricity costs and thus a trending decline in its LCOH. For curtailed wind the capex and variable opex values are seen higher in £/MWh terms since it is producing less hydrogen for the same capex spend as new build offshore wind. Curtailed wind does not have any variable opex costs since the supplied electricity is priced at zero.

Figure 13: Breakdown of cost components of LCOH



Source: Cornwall Insight

2.3.2 Natural gas and hydrogen blend results

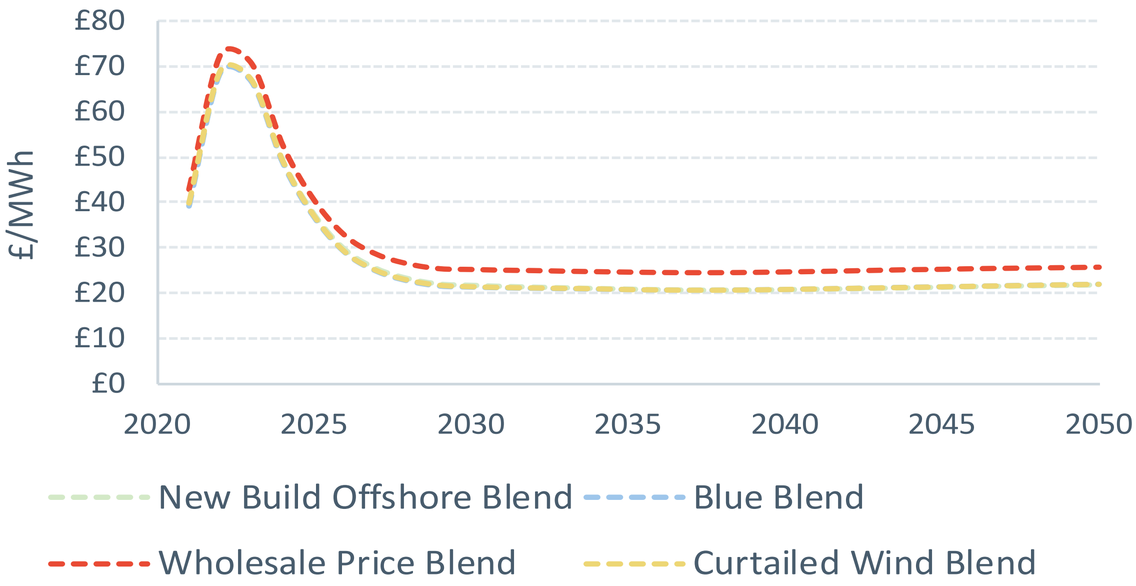
An 80:20 blend of natural gas with hydrogen by volume is equivalent to a 93:7 blend by energy. This is due to the higher heating value (HHV MJ/m³) of hydrogen being a third to that of natural gas and since wholesale prices are measured in energy terms the calculation requires a 93:7 ratio to convert volume into energy. The result of this calculation is shown in Figure 14 for selected years in tabular form and in Figure 15 as a chart. It can be seen that blending to an 80:20 volume ratio does not materially change the commodity component of domestic gas supply.

Figure 14: Table of blending 20% hydrogen results for selected years, £/MWh

Year	2025	2030	2035	2040	2045	2050
Wholesale Price Blend	52.57	25.52	24.88	24.72	25.32	25.78
Blue Blend	48.59	21.63	20.97	20.81	21.38	21.95
New Build Offshore Blend	49.10	22.08	21.11	20.77	21.28	21.82
Curtailed Wind Blend	48.92	21.78	21.00	20.76	21.32	21.89

Source: Cornwall Insight

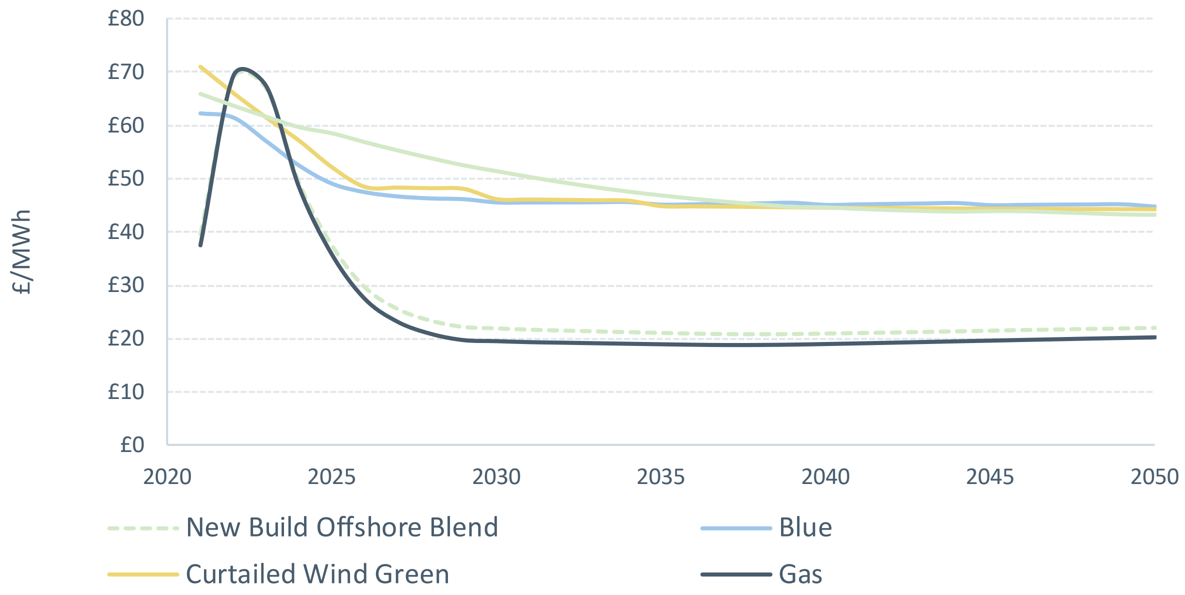
Figure 15: Blending 20% hydrogen results



Source: Cornwall Insight

When comparing the 80:20 blend to that of pure hydrogen, as shown in Figure 16, the lower absolute cost of natural gas and thus a green hydrogen blend prevails to highlight its cost effectiveness to that of using pure hydrogen.

Figure 16: Comparison of a green blend v pure hydrogen v gas



Source: Cornwall Insight

3 Retail heating cost comparison

In this section, we examine the costs to the domestic consumer of switching to a hydrogen-based gas system. All values are shown as real 2021-22 prices.

3.1 Methodology and assumptions

Cornwall Insight produces a quarterly Third Party Charges (TPC) report, which sets out the unit costs for a range of consumers of the non-wholesale elements of the retail bill. These include, for domestic gas consumers:

- Gas transmission costs
- Gas distribution costs
- Supplier costs for the Warm Home Discount
- Supplier costs for the Energy Company Obligation
- The Green Gas Levy
- Smart metering charges for the Data Communications Company
- Smart metering charges for Smart Energy GB

In addition, we have forecast an allowance for supplier's costs and margin, and the costs of hedging wholesale gas. These costs change every year, but average around 10% of the TPCs.

In order to understand the impact of switching to hydrogen as a replacement for some or all of the current natural gas blend, we have added these TPCs and supplier costs to the forecast prices of wholesale fuels, to create a retail cost to consumers in terms of p/kWh costs. For TPCs we have used the current pricing formula which is valid until 2026 and then applied a rolling four year average look back for subsequent years.

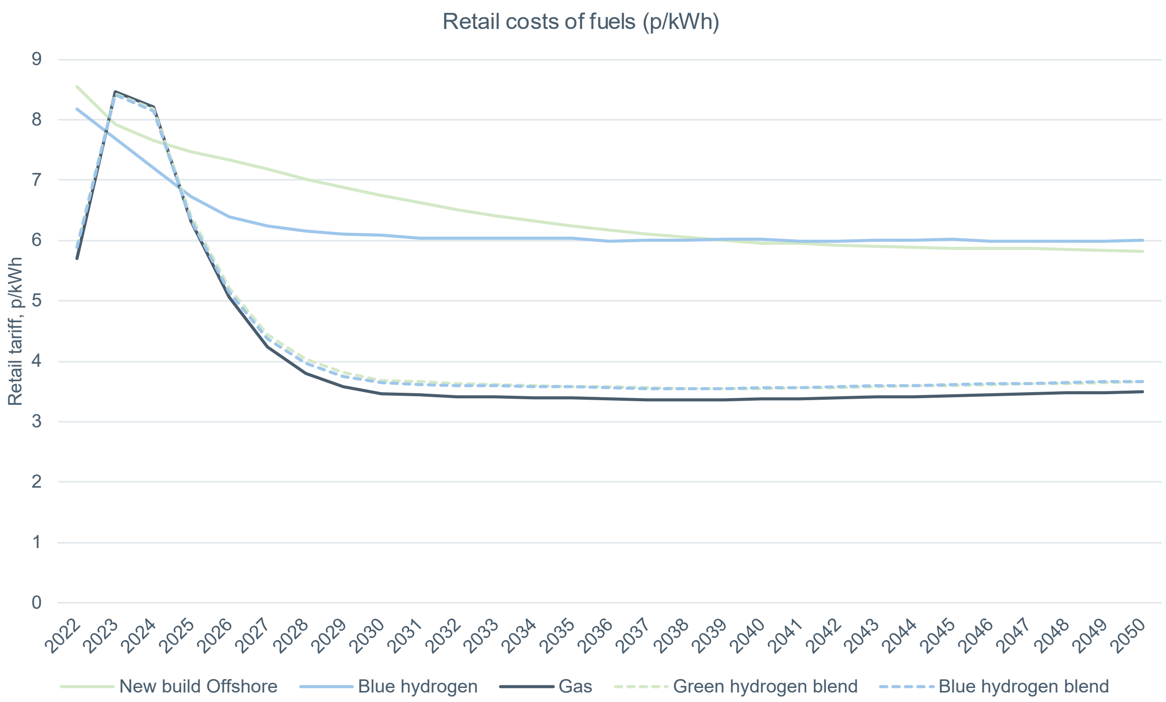
Note that these figures do not include the costs of hydrogen storage on the network, on a short-term or seasonal basis, or other future policy levies like the mooted hydrogen levy.

As explained in Section 2.2.3.3, hydrogen produced using curtailed wind is not expected to deliver volumes to have a significant impact on decarbonising GB domestic heating. We have therefore excluded this methodology in this section and the green hydrogen blend uses new build offshore wind as its source of green hydrogen.

3.2 Results

Figure 17 presents our forecast findings for the period 2022 to 2050, for retail costs of various fuel mixes.

Figure 17: Forecast retail costs of gas, hydrogen, and blended fuels to domestic consumers[1]



Source: Cornwall Insight

Given recent very high gas prices, in the short term the cost of hydrogen is forecast below the cost of the existing natural gas supply. This is due to the methodology used, which spreads costs over asset lifetime through a process based on the net present value and therefore further analysis is only shown from 2025 onwards. As gas prices fall later in the decade and into the 2030s natural gas is seen as the cost effective solution for domestic heating. This leaves hydrogen as a much more expensive heating fuel than natural gas and thus to fully decarbonise domestic heating perhaps alternative technologies are currently best considered.

These results are tabulated and shown as Figure 18 in five-year average blocks

1 Note that these p/kWh rates include some elements which suppliers allocate to standing charges

from 2025. Figure 19 shows the same values as percentage increases to that of natural gas and for individual years from 2025 to 2050 these are found in appendices Section 5.2.

When viewing them as a percentage increase to that of natural gas, the values for 100% hydrogen are on average 70% higher for the period from 2025, regardless of whether blue or green hydrogen is considered. These differences in prices, for green hydrogen reach a peak of 94.7% in 2030 before declining to reach 66.3% higher in 2050. For blue hydrogen, a peak of 78.7% is reached in 2039, declining to 71.5% in 2050.

Figure 18 : Forecast average retail costs in five-year blocks, p/kWh

Years	2025-2029	2030-2034	2035-2039	2040-2044	2045-2049
New build offshore	7.18	6.43	6.01	5.88	5.83
Blue hydrogen	6.33	6.04	6.01	6.00	6.00
Gas	4.60	3.41	3.37	3.43	3.49
Green hydrogen blend	4.78	3.62	3.56	3.61	3.65
Blue hydrogen blend	4.72	3.60	3.56	3.61	3.67

Source: Cornwall Insight

Figure 19: Forecast average percentage increase for retail costs from natural gas

Years	2025-2029	2030-2034	2035-2039	2040-2044	2045-2049
New build offshore	56.0%	88.4%	78.3%	71.2%	66.9%
Blue hydrogen	37.6%	76.9%	78.1%	74.7%	71.7%
Gas	0.0%	0.0%	0.0%	0.0%	0.0%
Green hydrogen blend	3.9%	6.2%	5.5%	5.0%	4.7%
Blue hydrogen blend	2.6%	5.4%	5.5%	5.2%	5.0%

Source: Cornwall Insight

Blending hydrogen into the gas mix has a smaller impact on costs. A blended mix of natural gas and 20% offshore wind generated hydrogen is forecast to be on average 5.3% more expensive than 100% natural gas, and a mix of natural gas and 20% blue hydrogen is forecast to be 4.9% more expensive than 100% natural gas, again from the period 2025 to 2050.

3.3 Impact on consumers

In terms of the cost impact on consumers, Figure 20 presents costs for typical households, using Ofgem's Typical Domestic Consumption Values. These are set every two years, based on consumption data, and were last updated in 2020. For gas, they are 8,000kWh/year (low), 12,000kWh/year (medium) and 17,000kWh/year (high). These are presented in terms of additional costs, compared to a baseline of natural gas retail costs.

Figure 20: Forecast additional costs to consumers, selected years, compared to natural gas forecasts

		£/year cost to household			
Scenario	**TDCV scenario**	**2025**	**2030**	**2040**	**2050**
Natural gas comparator	Low	£505.70	£276.81	£269.79	£279.77
	Medium	£758.55	£415.21	£404.68	£419.66
	High	£1,074.62	£588.22	£573.30	£594.51
New build offshore wind (green)	Low	£91.33	£262.23	£206.83	£185.53
	Medium	£137.00	£393.34	£310.25	£278.29
	High	£194.08	£557.23	£439.51	£394.24
Blue hydrogen	Low	£33.30	£210.92	£212.22	£200.04
	Medium	£49.95	£316.37	£318.33	£300.07
	High	£70.77	£448.19	£450.97	£425.09
New build offshore wind green blend	Low	£6.39	£18.36	£14.48	£12.99
	Medium	£9.59	£27.53	£21.72	£19.48
	High	£13.59	£39.01	£30.77	£27.60
Blue blend	Low	£2.33	£14.76	£14.86	£14.00
	Medium	£3.50	£22.15	£22.28	£21.00
	High	£4.95	£31.37	£31.57	£29.76

Source: Cornwall Insight

These figures indicate the additional cost to consumers, per year, of transitioning to a hydrogen blend. These are low for blended mixes but adds several hundred pounds a year to consumer bills if looking to transition to a 100% hydrogen network.

4 Glossary

Alkaline electrolyser
A type of electrolyser, characterised by cheap catalysts, high durability and high gas purity. Believed to be one of the most promising technologies

BEIS
Department for Business, Energy and Industrial Strategy. BEIS sets UK energy policy

Black or brown hydrogen
The production of hydrogen using coal or lignite, using steam reformation, without carbon capture

Blue hydrogen
The production of hydrogen using a combination of Steam Methane Reformation and Carbon Capture and Storage

Carbon Capture and Storage (CCS)
The process by which carbon dioxide emissions are separated from exhaust gases and transported to a storage facility in order to reduce its effect on climate change

Carbon costs
A tax on carbon dioxide emissions

CO2 capture rate
A value, usually shown as a percentage, stating the volume of carbon dioxide emissions captured by a carbon capture facility

Curtailed electricity
Electricity from a generator which cannot be put onto the network due to physical restrictions or low electricity demand

Data Communications Company
Company set up to manage and deliver the smart meter communications network

Decarbonising heating
The use of fossil fuels for the generation of heat with low carbon alternatives

Delivered price
The total price at which users pay for goods

Efficiency losses
Electricity lost in the networks between generation and consumption

Electricity generation mix
The types and proportions of electricity generation on the system

Electrolysis
Production of hydrogen by applying electricity to water

Fracking
Extraction of gas from rock by applying high-pressure water

Gas distribution costs
Cost incurred to pay for the gas distribution network

Gas transmission costs
Cost incurred to pay for the gas transmission network

Green Gas Levy
A levy placed on gas suppliers to support the production of biomethane which is put into the gas grid

Green Hydrogen
The production of hydrogen by electrolysis using electricity generated by renewable electricity sources (wind, solar, geothermal, etc)

Grid
The national gas grid, operated by National Grid Gas Transmission

Health and Safety Executive
UK government agency for the regulation and enforcement of workplace health, safety and welfare

Heat network
A network of premises supplier with heat from a central source via pipeline

Heat pump
A device that transfers heat from one source to another using the refrigeration cycle

Higher heating value (HHV MJ/m^3)
Also known as the gross calorific value or gross energy. HHV of a fuel is defined as the amount of heat released by a specified quantity (initially at 25 °C) once it is combusted and the products have returned to a temperature of 25 °C

Hurdle rate
The minimum acceptable rate of capital return on a project

Hydrogen
The most abundant chemical element in the universe. It is colourless, odourless, tasteless, non-toxic and highly combustible

Learning rates
The cost reduction of a technology, each time deployed capacity is doubled

Least cost optimisation
A modelling technique that evaluates outcomes based on the cheapest available mix of technologies

Levelised cost of energy (LCOE)
The total units of energy produced by an asset over its lifetime, divided by the total costs of the asset over its lifetime

Levelised cost of hydrogen (LCOH)
The total units of hydrogen produced by an asset over its lifetime, divided by the total costs of the asset over its lifetime

Load factor
The actual output of a generator, divided by the maximum output possible. Solar load factors are around 11% in GB, whereas wind might by 30-35%

National grid
The national gas grid, operated by National Grid Gas Transmission

New build offshore wind
Installation of new wind turbines in coastal waters

Pink hydrogen
The production of hydrogen by electrolysis using electricity generated by nuclear power

Proton exchange membrane (PEM)
Also known as polymer-electrolyte membrane. PEM fuel cells split pure water into its constituent hydrogen and oxygen elements using electricity

Pyrolysis
Produces hydrogen and solid carbon using molten metal as a catalyst. A possible future hydrogen production technology

Real 2021-22 prices
The price of goods in the future, adjusted to costs in 2021-22 using forecasts of inflation

Smart Energy GB
A government backed, not-for-profit campaign helping everyone in Britain understand the importance of smart meters and their benefits to people and the environment

Smart meter
Gas and electricity meters that can be read remotely and allow consumer more accurate and timely consumption information

Solar thermal
The process of using solar energy to capture useful heat

Steam Methane Reformation (SMR)
Producing hydrogen by reacting steam with methane gas. Carbon dioxide is a by-product of this reaction

Supplier
A party licensed by Ofgem to sell gas and/or power to end-users

Thermal conversion efficiency
The ratio between the useful output of heat energy from its energy input

Thermal storage
The storage of heat energy

Third Party Charges (TPC)
Unit costs for a range of non-wholesale elements of the retail bill

Turquoise hydrogen
The production of hydrogen and solid carbon using methane pyrolysis

Typical Domestic Consumption Value (TDCV)
Industry standard values for the annual gas and electricity usage of a typical domestic consumer

Warm Home Discount
A discount of £140/year on energy bills for certain eligible, usually disadvantaged, domestic consumers

White hydrogen
Naturally occurring hydrogen found in underground deposits

Wholesale prices
The commodity price for either gas or electricity

Yellow hydrogen
The production of hydrogen by electrolysis using electricity generated by solar PV

5 Appendices

5.1 Appendix 1: References

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5.2 Appendix 2: Additional figures

Figure 21: Percentage difference of 100% hydrogen v gas

Year	2025	2026	2027	2028	2029	2030	2031	2032
New build Offshore	18.1%	45.1%	69.6%	84.6%	92.1%	94.7%	92.7%	90.6%
Blue hydrogen	6.6%	26.4%	47.3%	61.8%	70.8%	76.2%	75.5%	76.4%
Year	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**
New build Offshore	88.2%	86.1%	84.2%	82.6%	81.2%	79.8%	78.3%	76.7%
Blue hydrogen	77.0%	77.6%	78.2%	77.3%	78.0%	78.5%	78.7%	78.7%
Year	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**
New build Offshore	75.8%	74.3%	73.0%	71.9%	70.8%	70.5%	69.8%	68.6%
Blue hydrogen	76.9%	76.6%	76.2%	75.7%	75.3%	73.5%	73.0%	72.5%
Year	**2049**	**2050**						
New build Offshore	67.5%	66.3%						
Blue hydrogen	72.0%	71.5%						

Figure 22: Percentage difference of blended hydrogen v gas

Year	2025	2026	2027	2028	2029	2030	2031	2032
Green hydrogen blend	1.3%	3.2%	4.9%	5.9%	6.4%	6.6%	6.5%	6.3%
Blue hydrogen blend	0.5%	1.8%	3.3%	4.3%	5.0%	5.3%	5.3%	5.3%
Year	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**
Green hydrogen blend	6.2%	6.0%	5.9%	5.8%	5.7%	5.6%	5.5%	5.4%
Blue hydrogen blend	5.4%	5.4%	5.5%	5.4%	5.5%	5.5%	5.5%	5.5%
Year	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**
Green hydrogen blend	5.3%	5.2%	5.1%	5.0%	5.0%	4.9%	4.9%	4.8%
Blue hydrogen blend	5.4%	5.4%	5.3%	5.3%	5.3%	5.1%	5.1%	5.1%
Year	**2049**	**2050**						
Green hydrogen blend	4.7%	4.6%						
Blue hydrogen blend	5.0%	5.0%						

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