A market commodity digest:

New Energies

Team Railfreight's actions to grow rail freight

November 2024

(Photo courtesy of Enfinium)

Contents

Introduction

Team Railfreight was set up in January 2024 to unify the freight teams across Great British Railways Transition Team (GBRTT) and Network Rail (NR), in the spirit of running a simpler, better, greener railway.

This Commodity Digest sits within the work undertaken on the Long-Term Strategy for Rail, the Growth Target and the Network Rail/GBRTT Market Development Plan alongside the Freight Development Delivery Plan. It is one of a developing series of rail freight market studies into new and emerging commodities. The purpose of the Commodity Digest is set out in the Network Rail/GBR Market Development Plan, which states:

Commodity Digests – the documentation of understood market need across a range of commodity areas, the constraints to growth and resultant proposed Railfreight Team development actions.

The UK energy market is both complex and vast in nature owing to the requirements on it to support industrial and private life. Rail freight currently plays a critical role in the energy supply chain from delivering fuels for power generation such as biomass and waste to delivering refined transportation fuels through to the safe and reliable transfer of nuclear waste. This commodity digest will primarily focus on the 'new energies' markets, namely the opportunities arising from hydrogen production, Carbon Capture Usage & Storage (CCUS) and Sustainable Aviation Fuel (SAF). A focus on potential new energy markets means we're better able to understand the potential addressable market for rail freight. Meeting or exceeding Government-set freight growth targets will require rail freight to attract new commodities to rail and establish new markets.

Team Railfreight has been engaging and supporting interested parties in the development of their policies and strategies around the emerging new energies market. This has involved introductory sessions to rail, working with organisations to understand and develop their Non-

Pipeline Transportation (NPT) elements including work on rail terminal design and connectivity where required.

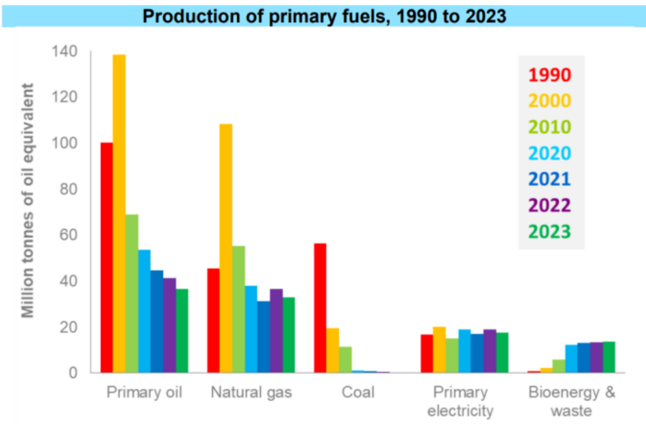
Market Background: UK Energy Market in 2024

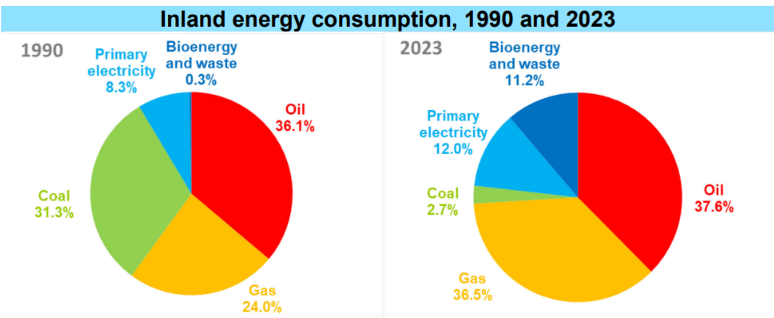
Current Energy Market: electricity production and fuel usage

The UK energy market acts as critical component of UK infrastructure in terms of production, consumption, employment, investment, and overall economic contribution. The market in 2024 represents a continuing trend of shifting production as the historical dominance of fossil fuel sources are gradually replaced by biofuels, fissile (nuclear) and other renewables. As of 2024, the UK remains a net importer of all fuel types particularly in the case of oil and gas.

2024 has also seen several key milestones in the UK energy market 30 September 2024 saw the closure of the UK's last coal fired power station, Ratcliffe-on-Soar which in turn heralded the end of 142 years of coal fired energy production.

The graph and table[1] below highlight's the changing energy production fuel source market with the dominance of oil, natural gas and coal reducing considerably in addition to overall equivalent energy production.





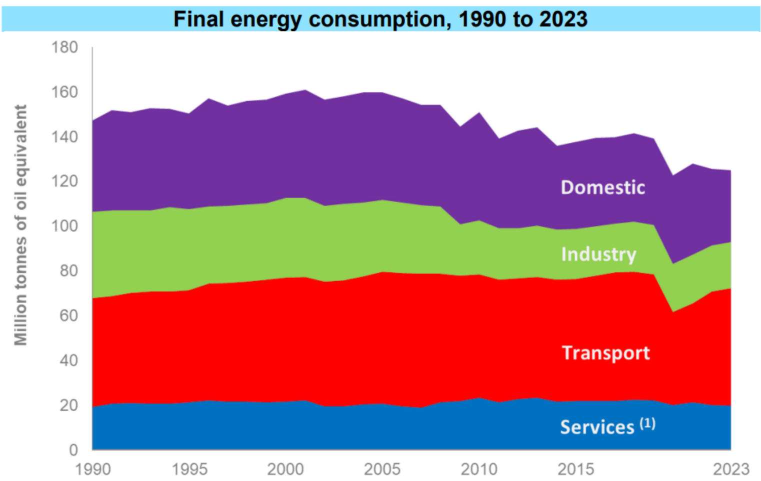
Note: Primary electricity includes nuclear, wind, solar, hydro and net imports.

[1] Production of Primary Fuels 1990 – 2023, Department for Energy Security & Net Zero UK Energy in Brief 2024 (publishing.service.gov.uk)

							Million tonnes of oil equivalent
	1990	2000	2010	2020	2021	2022	2023
Primary oil	100.1	138.3	69.0	53.6	44.7	41.3	36.6
Natural gas	45.5	108.4	55.3	37.8	31.3	36.4	32.9
Coal	56.4	19.6	11.4	1.2	0.7	0.5	0.4
Primary electricity	16.7	20.2	15.1	18.9	17.0	18.8	17.5
Bioenergy & waste	0.7	2.3	5.8	12.1	13.1	13.3	13.7
Total	**219.4**	**288.7**	**156.7**	**123.6**	**107.0**	**110.3**	**101.2**

The growth in the supply of energy from low carbon sources has also seen considerable growth and increasing prominence in the UK market over the last 20 years. As of 2023, low carbon sources contributed 20.7%[2] to the UK's energy production with bioenergy, nuclear and wind the largest contributors.

From an energy consumption perspective, transport and domestic markets represent the largest consumers of final energy, the energy delivered to consumers for consumption. The graphics and table[3] below highlight the respective consumer markets share of overall final energy consumption:



2023			Million tonnes of oil equivalent		
	Industry	Transport	Domestic	Services[1]	Total
Coal & manufactured fuels	1.0	0.0	0.3	0.0	**1.2**
Oil	2.2	48.9	2.1	3.5	**56.6**
Gas	7.5	0.1	20.4	7.7	**35.6**
Electricity	7.4	0.9	8.0	6.8	**23.1**
Bioenergy and heat	2.3	2.6	1.6	1.8	**8.4**
Total	**20.4**	**52.6**	**32.2**	**19.8**	**125.0**

(1) Includes agriculture, commercial, public administration and miscellaneous.

Future Energy Strategy

[2] UK Energy in Brief 2024 (publishing.service.gov.uk), Department for Energy Security & Net Zero
[3] Final Energy Consumption 1990 – 2023, Department for Energy Security & Net Zero; UK Energy in Brief 2024 (publishing.service.gov.uk)

The UK Government has a stated ambition[4] to deliver clean homegrown energy to meet both energy security needs and tackle climate change. 'Great British Energy' is envisioned as a key delivery arm for these aims. In the drive for clean energy, it is likely that focus will be on the delivery of new renewable energy sources such as off and on-shore wind farms, solar and hydro projects. In addition to these, the development and delivery of further nuclear power in the form of large-scale reactors, Small Modular Reactors (SMRs) and Advanced Modular Reactors (AMRs) will likely be prominent.

New Energies

Hydrogen

In the UK's drive towards decarbonisation, hydrogen can be regarded as both an alternative fuel source and also a replacement for fossil fuels in manufacturing and transport environments. Its primary use today is relatively small scale and focused on industrial processes and industry with a small amount utilised as alternative fuel for transport. The UK Government produced its first 'UK Hydrogen Strategy'[5]in 2021 which set out a roadmap for achieving 10GW of low carbon hydrogen production capacity by 2030. For context the peak demand for electricity in the UK is estimated at 61.1 GW. [6]

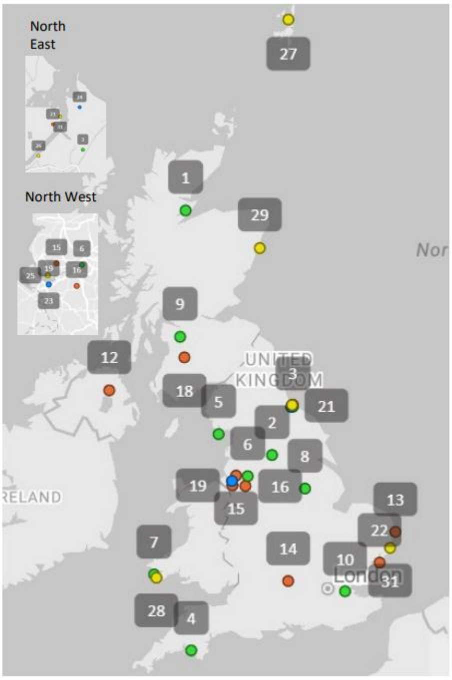
The UK Hydrogen Strategy estimates that to meet Net Zero aims by 2050, hydrogen will make up 20-35%[7] of the UK's final energy demand. As part of its hydrogen strategy, the UK Government has developed investment models establishing the link between producers and users or 'offtakers'. In the October 2024 budget, the UK Government confirmed £2bn funding for 11 hydrogen projects established through the 'Hydrogen Allocation Round 1' (HAR1) process. The application deadline for consideration in HAR2 ended in April with successful applicants due to be announced. Additional schemes are backed by the 'Net Zero Hydrogen Fund' (NZHF) which aims to support capex investment in the development and delivery of hydrogen projects. The image below highlights the schemes currently being progressed[8];

[4] Great British Energy Bill overarching factsheet - GOV.UK (www.gov.uk)
[5] UK Hydrogen Strategy (publishing.service.gov.uk)
[6] 'The Energy Challenge' National Grid download (nationalgrid.com)
[7] UK government launches plan for a world-leading hydrogen economy - GOV.UK
[8] Hydrogen Net Zero Investment Roadmap

Successful Projects

HAR1		
Project name	Developer	No.
Cromarty	Storegga	1
Bradford Hydrogen	Hygen	2
Tees Green	EDF	3
Langage Green Hydrogen	Carlton Power	4
Barrow Green Hydrogen	Carlton Power	5
Trafford Green Hydrogen	Carlton Power	6
West Wales Hydrogen	H2 Energy & Trafigura	7
HyMarnham	JG Pears	8
Whitelee Green Hydrogen	Scottish Power	9
Green Hydrogen 3	HYRO	10
Hybont	Marubeni	11

NZHF Window 2		
Project name	Developer	No.
Grenian Hydrogen Speke	Grenian Hydrogen	25
Tees Green Methanol	EDF	26
Sullom Voe Terminal Green Hydrogen Project	Enquest Hydrogen	27
Pembroke 200 MW Green Hydrogen Electrolyser Phase II	RWE Generation	28
Aberdeen Hydrogen Hub	Bp Aberdeen Hydrogen Energy Limited	29
Tees Valley Hydrogen Vehicle Ecosystem (HYVE)	Exolum International UK	30
Suffolk Hydrogen	Hydrab Power	31



Projects offered support through windows 1 and 2 of the NZHF and HAR 1, and the CCUS enabled hydrogen projects in the latest stage of the Track-1 cluster sequencing process

NZHF window 1		
Project name	Developer	No.
Ballymena Hydrogen	Ballymena Hydrogen	12
Conrad Energy Hydrogen Lowestoft	Conrad Energy	13
Didcot Green Hydrogen Electrolyser	RWE	14
Green Hydrogen St Helens	Progressive Energy	15
Green Hydrogen Winnington and Middlewich	Progressive Energy	16
Mannok Green Hydrogen Valley	Mannok	17
Knockshinnoch Green Hydrogen Hub Project	Renantis	18
Hynet HPP2	Vertex	19
Kintore Hydrogen	Statera	20
H2 NorthEast	Kellas	21
Felixstowe Port Green Hydrogen	Scottish Power	22

CCUS Sequencing		
Project name	Developer	No.
Hynet HPP1	Essar Energy Transition Hydrogen	23
bpH2Teesside	bp	24

It's important to note that type of production method denotes a varying colour code for hydrogen[9]. In the UK, the most common form of hydrogen produced today is grey with blue hydrogen seen as having scalable potential in line with the development of Carbon Capture, Usage and Storage (CCUS) technology. Green hydrogen is seen as optimal owing to the lack of associated emissions. The colour spectrum of hydrogen production is a follows:

- **Green** – produced using surplus renewable energy and an electrolysing process to split the components with zero CO2 emissions as a result.
- **Blue** – produced using natural gas and a process of steam reforming which also creates CO2 as a byproduct of the process. Carbon Capture is utilised to reduce impact of CO2 emissions to keep the hydrogen low carbon.
- **Grey** - produced using natural gas or methane and processed via steam reformation but without the capture of CO2 emissions.
- **Black/Brown** - produced using coal or lignite in the process. Hydrogen produced via fossil fuel gasification is often classified in this category.
- **Pink** - produced via nuclear energy powered electrolysis.
- **Turquoise** - Produced via process of 'methane pyrolysis'.
- **Yellow** - produced via solar powered electrolysis process.
- **White** - naturally occurring hydrogen obtained via natural stores and fracking.

One of the key industry challenges facing hydrogen is that of managing supply and demand effectively. Given the considerable capital investment required for hydrogen production

[9] The hydrogen colour spectrum| National Grid Group

schemes an established demand market is critical to unlocking said investment. In turn, a viable demand market can only be established with certainty around production. The establishment of the 'offtake' commercial model which commits a hydrogen consumer to purchase an agreed volume aids the commercial development of hydrogen production projects.

It is not yet clear what form the production of hydrogen will take in terms of liquified, gaseous or via a carrier such as ammonia or methanol. The growth of the hydrogen market also affords the potential growth of other linked markets such as products created using hydrogen known as hydrogen derivatives. These range from products such as ammonia, a key component of fertiliser, green synthetic fuels and methanol, a key component in everyday products and industrial processes.

Carbon Capture Usage and Storage (CCUS)

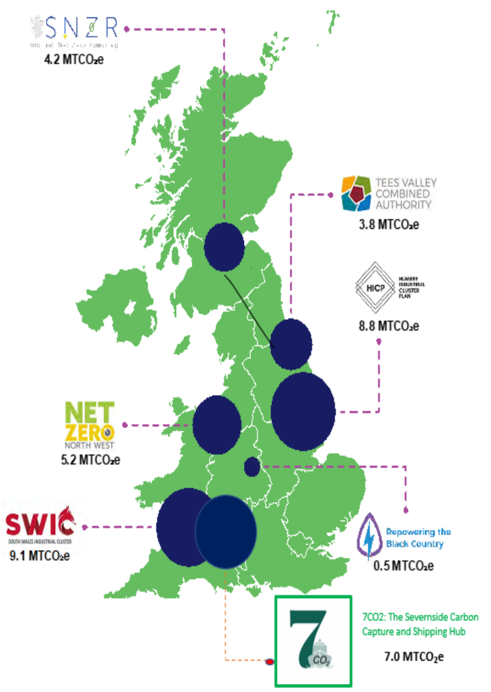
Recent years have seen increased focus on the potential of CCUS as a key component of the UK's decarbonisation strategy. CCUS refers to the concept of capturing CO2 at the point of emission and subsequent storage underground with transfer typically undertaken via either pipeline or Non-Pipeline Transport (NPT) solutions. The UK has an estimated 78 billion tonnes[10] of potential CO2 storage capacity with storage variously split between sandstone saline aquifers, chalk saline aquifers and exhausted former gas and oil fields.

UK Government has identified two initial storage clusters within it's 'Track 1' with further clusters considered for 'Track 2' in the form of 'Acorn'[11] in Scotland and 'Viking'[12] in Humber. In October 2024, the UK Government announced[13] £21.7bn funding over a 25 year period principally in the North West (Hynet)[14] and Teesside (East Coast Cluster)[15] CO2 storage cluster projects. The investment is seen as key to progressing and building confidence in the CCUS market. The UK Government anticipates capturing around 20-30 mega tonnes of CO2 by 2030 as part of the Track 1 and Track 2 projects. The linked role of CCUS in the production of 'blue' hydrogen is seen as a key benefit to the investment in the technology in that it serves two purposes or markets. Both HyNet, in the form of 'HPP1 – HyNet Hydrogen Production Plant and associated pipeline network, and East Coast Cluster, in the form of 'bpH2 Teesside', are considered key elements of the CCUS Track-1 investments. In wider industry, September 2024[16] saw a key milestone when Enfinium, operator of the Ferrybridge EfW facility launched the UK's first carbon capture pilot.

The Carbon Capture Usage and Storage (CCUS) market, like hydrogen, requires significant capital investment in order to achieve scalability and widespread industrial adoption. Likewise, the fundamental mechanics of the market in the form of the supply and demand will need to mature in order to expand the market. In the case of supply, emitters are generally aware of

[10] CCUS Investment Roadmap; CCUS Net Zero Investment Roadmap (publishing.service.gov.uk)
[11] Acorn | Growing Our Decarbonised Future - The Acorn Project
[12] Viking CCS | Humber CCS | Carbon Capture and Storage - Viking CCS
[13] Government reignites industrial heartlands 10 days out from the International Investment Summit - GOV.UK (www.gov.uk)
[14] HyNet North West
[15] Net Zero Teesside | The UK's first decarbonised industrial cluster
[16] UK-first carbon capture pilot on energy from waste facility goes live (enfinium.co.uk)

their current and forecasted CO2 volumes which in turn provides a base volume for those developing storage clusters to work from. This in turn also informs the discussions around Pipeline and NPT transportation from emitter to storage cluster site. The below graphic[17] highlights the scale of carbon capture tonnages particularly around industrial areas located near committed or proposed coastal storage clusters.



Sustainable Aviation Fuel (SAF)

The development of Sustainable Aviation Fuel (SAF) is seen as a key driver to decarbonising the aviation industry with the potential to reduce emissions by 70%[18] on a whole life cycle basis. It is expected that whilst SAF will play a key role, the development of electric short haul flight capability and development and utilisation of alternative fuels such as hydrogen will also contribute.

Like the other new energies in this digest, it also holds the potential to drive wider economic growth and employment. The UK Government announced in the July 2024 King's Speech that they would work to introduce a bill to support the development of SAF production. Key to this support is a planned SAF mandate due to begin 1 January 2025. The planned mandate sets targets to increase the contribution of SAF to the UK's aviation jet fuel mix with a 2%[19]

[17] Provided by 7CO2 project and Carbon Capture Industry Association.
[18] Sustainable aviation fuel initiatives - GOV.UK
[19] Sustainable aviation fuel initiatives - GOV.UK

contribution by 2025 rising to 10% by 2030 and 22% by 2040. Based on 2019 industry figures[20], the 10% by 2030 equivalent tonnage for the UK is 1.2 million tonnes.

Key to the scaled development and adoption of SAF is its production method. There are currently seven approved methods which utilise a range of feedstocks and are outlined in the table below[21]:

Pathway	Feedstock	Max. Blending Limit
FT-SPK	Biomass (e.g. trash/rubbish, forestry residues, grasses)	50%
HEFA-SPK	Waste lipids & fats (e.g. UCO, tallow, DCO)	50%
HFS-SIP	Sugars to hydrocarbon (e.g. molasses, sugar beet, corn dextrose)	50%
FT-SPK / A	Same feedstock as FT-SPK, but slightly different process	10%
ATJ-SPK	Agricultural waste (e.g. forestry slash, crop straws)	50%
CH-HK	Plant and animal fats, oils and greases (FOGs)	50%
HC-HEFA-SPK	Bio-derived hydrocarbons, fatty acid esters	10%
Co-processed HEFA*	Fats, oils, and greases (FOG) co-processed with petroleum	5%
Co-processed FT*	Fischer-Tropsch hydrocarbons co-processed with petroleum	5%

Of the mandated 1.2 million tonnes of SAF requirement by 2030, around 0.6 million tonnes is expected to be produced by previously announced projects which are summarised below[22]. This will as a result require the development of further production facilities to address the 0.6 million tonne shortfall in production demand.

[20] Sustainable-Aviation-SAF-Roadmap-Final.pdf
[21] Sustainable-Aviation-SAF-Roadmap-Final.pdf
[22] Sustainable-Aviation-SAF-Roadmap-Final.pdf

There are several SAF projects at different stages of development in the UK, mostly focused on the AtJ and FT pathways

	Approved pathways				Under certification
	HEFA/Co-processing	AtJ	Gas+FT	PtL[3]	HTL
# of projects in the UK[1]	1	3	4	0	1
Project developer(s)	Philips 66 (Co-processed HEFA)	1. Lanzatech 2. Carbon Engineering 3. Nova Pangaea[2]	1. ABSL 2. Alfanar 3. Fulcrum 4. Velocys	Note ambitions: 1. ScottishPower and Storegga 2. Acorn Project	Green Fuels Research
Intermediate inputs	Waste lipids	Alcohols	Syngas	Hydrogen, Carbon	-
Example Feedstocks	Used cooking oil, inedible tallow, other waste fats, oils, and greases	Biogenic wastes, woody residues, industry flue gases, DAC, water (hydrogen)	MSW, residual waste and industrial waste	Renewable electricity	Sewage sludge

Notes: (1) Including GFGS competition winners (2) Nova Pangaea produce cellulosic ethanol which will be processed by LanzaJet. (3) PtL has been shown stand-alone, but would use the ASTM certified AtJ or FT-SPK pathways for SAF production. PtL may also use the methanol route, which is not yet certified.
Sources: https://ee.ricardo.com/gfgs.

From a feedstock perspective, municipal solid waste (MSW) and agricultural waste are seen as key sources. One potential challenge with this is the competing demand for feedstocks from other industries such as the energy from waste plants.

UK Energy Market & Rail

Since its inception as a transportation mode for coal from pit to market, rail has and continues to play a critical role in the transportation of products associated with the energy industry. From its historical dominance as a rail freight commodity, July 2024 saw the last scheduled energy related coal delivery to Ratcliffe Power Station, prior to its closure. Biomass in turn has become the dominant energy related rail freight commodity with both Drax, North Yorkshire and Lynemouth, Northumberland receiving a typical weekly total of 150 loaded trains conveying around 175,000 tonnes of imported wood pellets. Several EfW facilities are served by rail playing an important role in municipal waste processing, energy generation and component recovery. Rail also serves an important role in the transferring of nuclear waste for processing and storage.

Outside of energy production, rail plays a critical role in the distribution of refined fuels for both domestic use and within the wider transportation industry such as aviation. Likewise, rail also moves chemicals such as natural gas condensate. Historically rail also moved large quantities of CO2 and similar products until the late 1980s, highlighting a precedent for the movement of such materials.

Rail, Energy and CCUS Case Study: Drax

The inclusion of this example highlights the complete development, deployment and evolution of a rail-based energy strategy for a single user. This could see replication within the new energies market. Since 2023 Drax Power Station, based in Selby North Yorkshire, has been powered solely by biomass making it the UK's largest renewable power operator. Drax provides 6%[23] of the UK's energy requirement which in turn constitutes 11% of the UK's renewable energy output. Drax are considerable users of rail with around 17 daily loaded rail services arriving from North West (Liverpool) and East Coast (Tyne, Hull, Immingham) ports and each loaded train conveying around 1,600 tonnes of biomass. Drax has also invested heavily both in terms of their rail infrastructure and in particular the design, development and procurement of 255 wagons. Each wagon can convey 71.6 tonnes of biomass, a 30% increase on previously utilised wagon capability. Drax Group has considerable plans for the development of its Bioenergy Carbon Capture Use & Storage (BECCS) technology[24] which will see it develop carbon capture technology on site. The captured carbon will in turn be processed and transported via pipeline or NPT as rail for permanent storage under the North Sea.

Rail Freight Addressable Market

This section of the digest will focus on the addressable market of the new energy commodities of hydrogen, CCUS and SAF. From the outset it's important to note that the addressable market for rail for both hydrogen and CCUS will likely be dependent on a number of factors that are both in and out of rail freight's control, namely:

Hydrogen

[23] Key Facts; Drax Power Station - Drax UK
[24] BECCS and negative emissions - Drax Global

- **Market Scale**: The market demand for hydrogen is expected to develop and crystalise in the coming years both in terms as a low carbon alternative for electricity production and as an alternative transportation fuel. The relative success of the initial funded production sites will likely drive further schemes over a wider geographical spread.
- **Pipeline vs Non-Pipeline Transportation**: Where hydrogen production facilities are not located on existing pipeline networks there is an opportunity for rail to supply consumers. This in turn has the benefit of increasing the geographic reach and market for hydrogen given the relatively high cost of pipeline development, installation and maintenance compared with utilising NPT networks. Given its small molecular size, hydrogen may also be more susceptible to leakage from both established and new pipeline networks.
- **Capital Investment & Market Development**: The UK Government's £2bn announcement via the HAR1 process represents a significant and timely financial commitment to the UK hydrogen market. This investment however represents a relatively small proportion of required overall further investment both from public and private sources to achieve the scalability required to develop the market.
- **Energy Policy & Incentives**: 2025 is expected to see significant developments in the UK hydrogen market. UK Government is expected to announce the successful applicants to its second wave ('HAR2') development funding process whilst simultaneously committing to the development of new business models for hydrogen transport and storage infrastructure[25]. These funded initiatives should prove key to both progressing the market and encouraging private sector investment through enhanced market confidence.
- **Technological Development**: As the hydrogen market develops so will the technological capabilities of the production sites. This in turn should lead to efficiencies and increased output which will be crucial in the scalability of hydrogen as an alternative low carbon fuel. The tandem technological development of CCUS at sites to create 'blue' hydrogen represents a key opportunity to further grow the market.

CCUS

- **Market Scale:** As with the hydrogen market, the relative success of the development and delivery of the Track-1 CCUS projects will be key to developing confidence to grow the CCUS market. In tandem, the success of private CCUS projects such as Enfinium's pilot at Ferrybridge will be critical in developing market interest. The potential for the UK's EfW industry to lead the adoption of CCUS is considerable. For context, the estimated collective negative emissions from the existing 57 EfW plants sits at around 6 million tonnes per annum[26].
- **Pipeline vs Non-Pipeline Transportation**: The first wave of Track-1 CCUS in the North West and East Coast were notable for utilising existing and new build pipelines to transport hydrogen and to move captured CO2 for under sea storage. Rail's biggest opportunity in the new energies market centres around geographical locations that are

[25] Hydrogen - great.gov.uk international
[26] CM09-Carbon-capture-from-energy-from-waste-EfW-Final.pdf

not currently on or likely to ever be served by the existing UK pipeline Network particularly in terms of linking in-land emitters with coastal storage clusters. It is notable that two of the proposed clusters in the form of 7CO2 at Avonmouth and SWIC (South Wales Industrial Cluster) in South Wales require NPT to receive CO2 feedstocks for processing and onward storage. Given the relative cost of new pipeline infrastructure the utilisation of existing NPT networks such as rail represents a key opportunity to support the growth of this market. In 2024, the Department for Energy Security and Net Zero (DESNZ) launched a consultation covering the NPT transportation market for CO2.[27]

- **Capital Investment & Market Development**: In line with comments around scale, for the CCUS market to develop, significant public and private investment will likely be required to end the 'chicken and egg' development cycle. Emitters will need confidence in both the market and supporting infrastructure in order to justify the business case for CCUS investment. In tandem, private sector development of coastal storage clusters will require confidence around the supply of CO2 feedstocks.
- **Energy Policy & Incentives**: The potential for CCUS development and deployment within the EfW market is seen as a key prospect that could be aided by Government policy. For instance, the UK's Emissions Trading Scheme (ETS), will from 2028, include EfW facilities. The UK ETS scheme aims to limit the amount of greenhouse gases that can be emitted by selected industries. The scheme will tax only the fossil produced emissions of EfW's (circa 50% of the total), but the introduction of CCUS means the captured biogenic CO2 (the other 50%), if captured and stored, will be classed as 'negative emissions' where the EfW could be paid a carbon removal price by companies looking for carbon offsets. Working on a 'cap and trade' principal, participants can trade unused allowances under their cap. This approach is seen as key to industries such as EfW investing in CCUS. Likewise, the ability for EfW's to monetise their 'negative emissions' is seen as critical to driving investment decisions in CCUS technologies.
- **Technological Development**: Notwithstanding the need for capital investment, an element of technological development will also be required if the CCUS market is to scale. At present, the scale of CCUS has been relatively small with small amounts of carbon capture. To meet prospective market demand, the scaling of the technology will be essential.

SAF

- **Market Scale**: The mandating of SAF providing 10% of the UK aviation jet fuel mix by 2030, equivalent of 1.2 million tonnes per annum provides an element of scale to the prospective market. In tandem with this is the global expectation that demand for flights will increase. The Department for Transport's (DfT), 'Aviation 2050'[28] forecast an increase in annual journeys from 284 million (2018 levels) to 435 million by 2050. To

[27] Carbon capture, usage and storage (CCUS): non-pipeline transport and cross-border CO2 networks - GOV.UK
[28] Aviation 2050

provide an indication of relative scale, Alfanar's 'Lighthouse Green Fuel's'[29] project aims to convert over 1 million tonnes of waste/waste biomass into 175 million litres of SAF and 30 million litres of green naptha which can be utilised in the production of hydrogen or used as an alternative fuel. The 175 million litres of SAF produced is enough to fuel the equivalent of 25,000 short haul or 2,500 long haul flights per annum.

- **Pipeline vs Non-Pipeline Transportation**: Of the announced SAF production schemes, a number have rail connectivity. As an example, Alfanar's project[30] based in North Teesside aims to utilise the Navigator Terminals North Tee's railhead as part of its production. This could see inbound feedstock and outbound SAF by rail. Given the cost of new pipeline development and the potential dispersed aviation market, NPT solutions such as rail could prove as a catalyst for the market. Rail has proven capability of moving aviation fuel from refinery to consumer site with regular daily movements on the UK Network serving key aviation hubs such as Heathrow.
- **Capital Investment & Market Development**:As with all new energies developments the scale of capital investment to develop the market is significant. The aforementioned Alfanar SAF project on North Teesside for instance will see around £1.5 billion of private investment into the project.
- **Energy Policy & Incentives**: The UK Government's mandating policy around the contribution of SAF to the UK aviation fuel industry has done much to provide some certainty over production requirements. Whilst 0.6 million tonnes of production have been identified through existing or announced projects, the remaining 0.6 million tonnes of production capacity will need to be quickly established, developed and delivered if the 2030 target and beyond is to be met.
- **Technological Development**: The development of SAF production methods will likely evolve as the market develops particularly around the efficient use of a mix of sustainable feedstocks.

Scale of Rail Opportunity

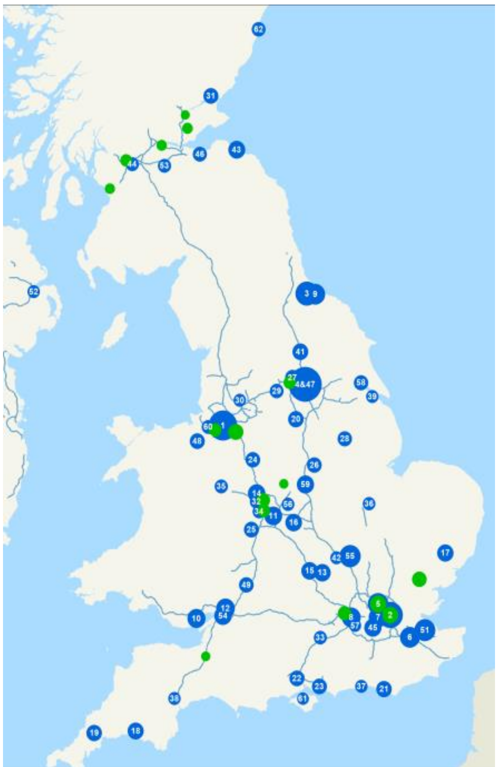
In this section the focus will largely be on the CCUS market given the relative ability to better understand likely source and storage location. As the hydrogen and SAF markets develop from both a production and demand perspective, it should become clearer as to where the potential production and consumer locations are likely to be.

Team Railfreight Action: Chart and map hydrogen and SAF opportunities as they develop focussing on rail connectivity.

With an estimated 78 billion tonnes of storage potential around the UK emitting around 302.8 million tonnes[31] per annum, the potential scope and scalability of the CCUS market is considerable. To provide further scale it is important to consider the potential scope of carbon capture of individual emitters. For example, in the Energy from Waste/Recovery market, typical

[29] Lighthouse Green Fuels – The Jet Fuel for Net Zero
[30] EN010150-000062-Lighthouse Green Fuels_Section 46 Notice_15 May 2024.pdf
[31] 2023 UK greenhouse gas emissions, provisional figures (publishing.service.gov.uk)

plants emit between 250,000 – 600,000 tonnes[32]. As of 2024 there are 62[33] EfW facilities across the UK with a further 15 sites in development. Of the active sites, it has been estimated that 60-65%[34] have the capability in terms of minimum capacity and space requirements to fit CCUS. The below map[35] highlights their geographic spread. Focussing in on inland industrial areas such as the West Midlands highlights a spread of 9 facilities. Of the 9 facilities, none had an direct rail connection although a number of others, such as Tyseley, exist adjacent to connected rail infrastructure.



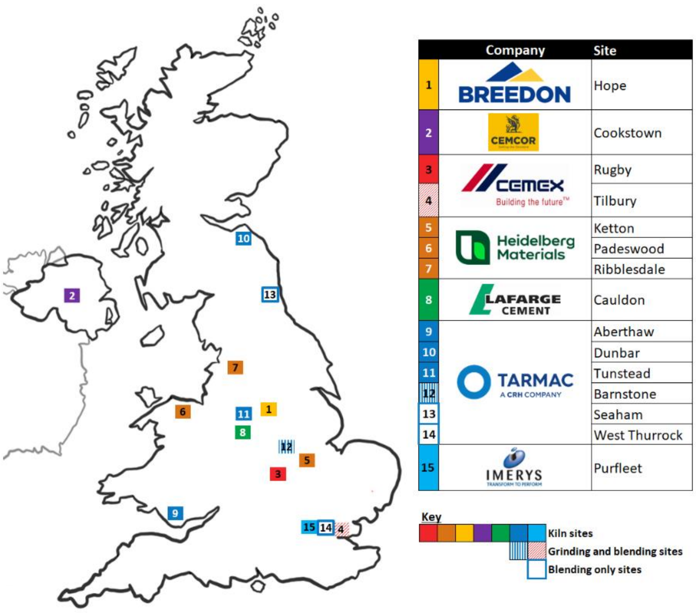
Location	Site Operator	Rail Connected
Tyseley	Veolia	No
Coventry	CSWDC	No
Hartlebury	Mercia Waste Services	No
Dudley	Urbaser	No
Wolverhampton	North Midlands Operations	No
Hanford	North Midlands Operations	No
Four Ashes (Staffordshire)	Veolia	No
Ardley (Oxfordshire)	Viridor	No
Battlefield (Shropshire)	Veolia	No

As a further example of a carbon intensive industry in the form of cement production and processing which forms a critical element of UK infrastructure, a large cement plant could produce around 800,000 tonnes of Co2 per annum[36]. As of 2024 there are 15[37] UK cement production facilities. Of those sites:

- Rail Connected; Hope, *Tilbury, Ketton, Padeswood, Ribblesdale, Aberthaw, Dunbar, Tunstead, Seaham, West Thurrock, Purfleet.*
- Indirect Rail Connection/Future Rail Connection; *Rugby (indirect), Ribbledale (future).*

32 Anonymised information based on interviews with relevant market businesses.
33 UK Energy from Waste Statistics - 2023 - Tolvik
34 CM09-Carbon-capture-from-energy-from-waste-EfW-Final.pdf
35 UK Energy from Waste Statistics - 2023 - Tolvik
36 Padeswood CCS | Padeswood CCS
37 About Us (mineralproducts.org)

- No Rail Connection; *Barnstone, Cauldon.*



Team Railfreight Action: Chart and map wider geographical emission clusters along with likely type of rail freight solution and proximity to established or future suitable railheads.

Rail Freight Solutions

Overview

This section will focus on the opportunity for rail freight to deliver NPT solutions. Through development work between Team Railfreight and the wider industry, two types of rail loading scenarios are envisaged for NPT for each of the new energies markets. Broadly these are split between 'bulk' transportation typically in the form of dedicated rail tanker wagons, and 'intermodal' typically in the form of bulk containers loaded onto intermodal flat wagons. Each scenario may in turn evolve into variations which at stages may also include interaction with existing or new pipeline infrastructure. Likewise, the potential for both dedicated tank wagon or ISO bulk container or 'bulktainer' to act as temporary storage will likely also evolve as a solution.

The conveyance of hydrogen, CO2 and SAF by rail are covered by the established and effective industry 'Dangerous Goods' regulations with historic and current precedence both domestically and around the world. The regulations are used on Network Rail infrastructure daily to cover the conveyance of a range of commodities. The below picture[38] highlights a GBRf hauled service conveying gas condensate between North Walsham and Harwich.

[38] Picture courtesy of GBRf.

Team Railfreight Action: Build on internal Network Rail and wider industry work to 'de-mystify' dangerous goods regulations and general safety related topics.

For additional context, the below wagon specifications have been developed by VTG[39] as part of their 'new energies' market offering based on established development in Europe. Other wagon manufacturers are also actively developing solutions.

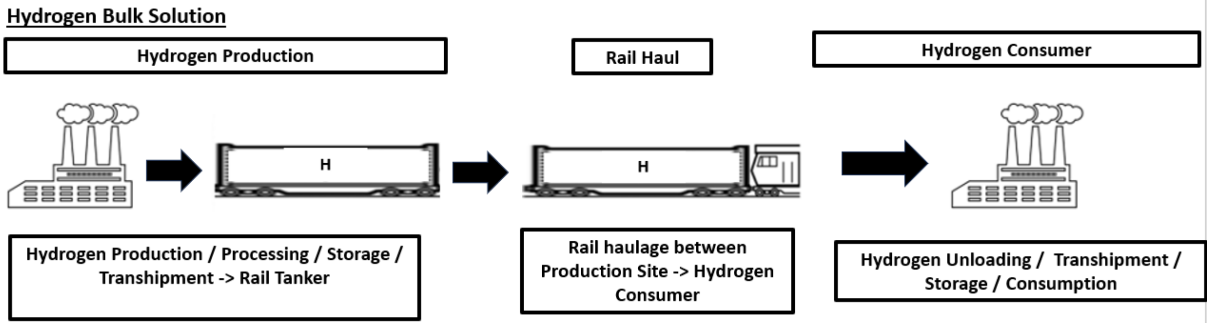
Hydrogen

Bulk Solution: in this scenario, a hydrogen producer site with a direct rail connection is able to directly load into a rail tanker wagon. Once loaded, the service would be hauled via the

39 Wagon details courtesy of VTG.

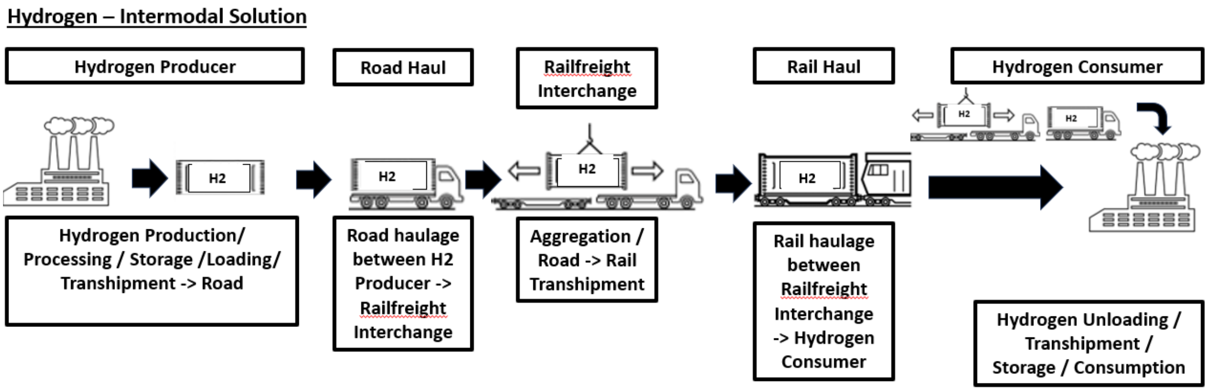
National rail network to the hydrogen consumer's site location for discharge, storage and consumption.

Worked Rail Bulk Solution: With an estimated payload of 72 tonnes[40] per wagon, a conservative estimate of what could form a typical service offering of a 500m length train (1 x locomotive and 26 x tanker wagons) could have a payload of around 1,872 tonnes. For context, 1,872 tonnes of hydrogen would produce around 61,776MWh of energy capability.



Intermodal Solution: In this scenario, the hydrogen production site has no direct or adjacent rail connectivity. As such, the hydrogen produced is loaded into ISO 'bulktainers' (typically 20ft liquid or gaseous capable containers) before transhipment to road haulage. Road haulage is utilised to access a suitable railhead for container aggregation and onward loading to rail. Rail haulage is then utilised to reach the final consumption destination.

Worked Rail Intermodal Solution: Assuming the same parameters as 'Worked Rail Bulk Solution' above, a 500m length train (1 x locomotive and 23 x 'FCA/FYA' type bulk intermodal flat wagon capable of conveying 3 x 20ft ISO bulktainers per wagon) with each ISO 'bulktainer' having a payload of 19.8 tonnes would have a payload of around 1,366 tonnes. For context, 1,366 tonnes of hydrogen would produce around 45,078MWh of energy capability.



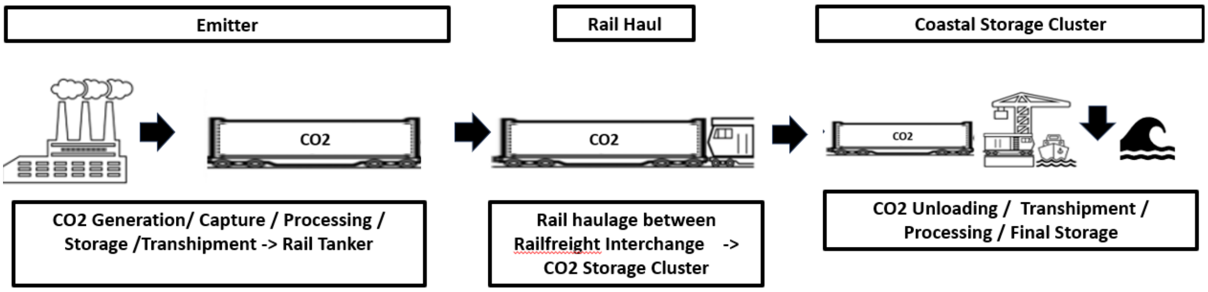
CCUS

Bulk Solution: In this scenario, an emitter site with a direct rail connection is able to capture and liquify CO_2 for either temporary storage pending onward movement or direct loading. In

[40] Based on development work by wagon manufacturer VTG

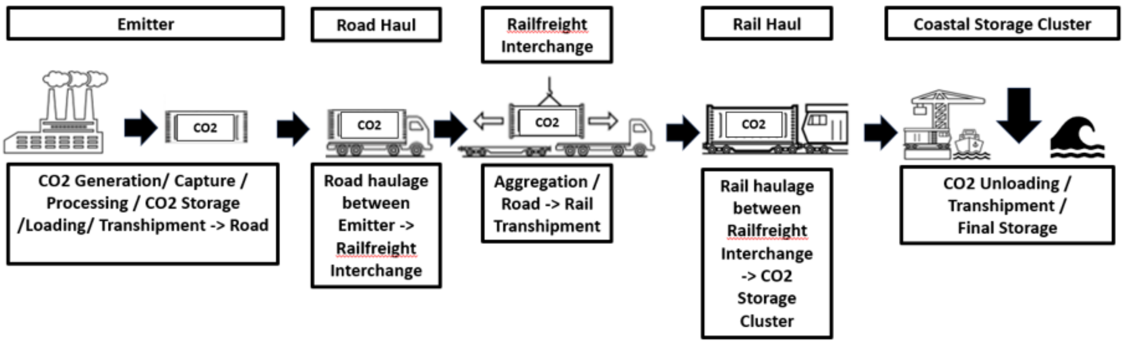
this scenario, the use of rail tanker wagons would be ideal. Once loaded, the service would be hauled via the national rail network to the CCUS storage location for discharge and final storage.

Worked Rail Bulk Solution: With an estimated payload of 72 tonnes[41], a conservative estimate of what could form a typical service offering of a 500m length train (1 x locomotive and 26 x tanker wagons) could have a payload of around 1,872 tonnes. For an emitter producing and capturing 500,000 tonnes of CO2 per annum this would equate to a loaded daily train assuming five day per week operation.



Intermodal Solution: In this scenario, the emitter site has no direct or adjacent rail connectivity. As such, the captured and liquified CO2 is loaded into ISO 'bulktainers' (typically 20ft liquid or gaseous capable containers) before transhipment to road haulage. Road haulage is utilised to access a suitable railhead for container aggregation and onward loading to rail. Rail haulage is then utilised to reach the final storage destination. This solution could also be utilised to load hydrogen from a hydrogen production facility without direct or indirect rail connectivity.

Worked Rail Intermodal Solution: Assuming the same parameters as 'Worked Rail Scenario 1', a 500m length train (1 x locomotive and 23 x 'FCA/FYA' type bulk intermodal flat wagon capable of conveying 3 x 20ft ISO bulktainers per wagon) with each ISO 'bulktainer' having a payload of 19.8 tonnes would have a payload of around 1,366 tonnes. For an emitter producing and capturing 500,000 tonnes of Co2 per annum this would equate to a loaded daily train assuming a six day per week operation.

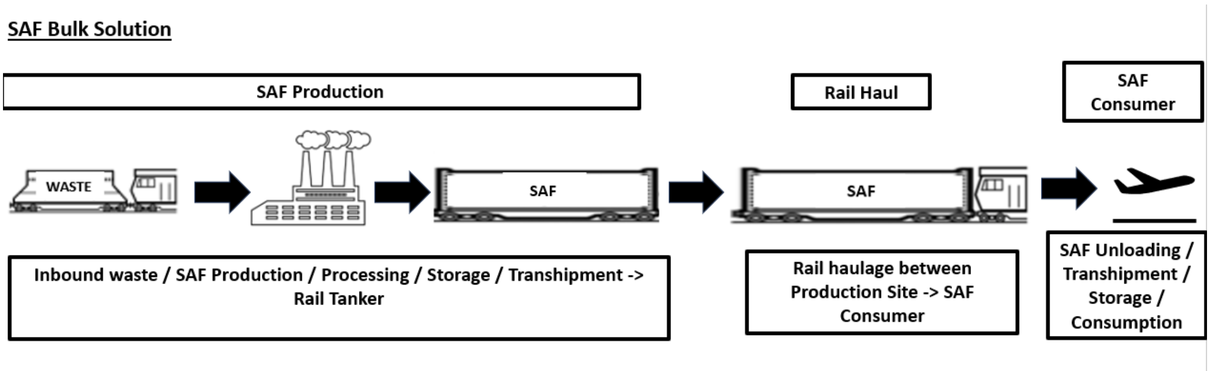


41 Based on development work by wagon manufacturer VTG

SAF

Bulk Solution: in this scenario, a SAF producer site with a direct rail connection is able to directly load into a rail tanker wagon. Once loaded, the service would be hauled via the National rail network to the SAF consumer's site location for discharge, storage and consumption. In this scenario, the direct rail connection may also result in the capability to deliver feedstock to the facility pre-production.

Worked Rail Bulk Solution: Utilising an existing bulk aviation fuel tanker wagon such as the 'TEA-E' which has a payload capability of 75.6 tonnes and a length of 18.3m, on the parameters used above, a 500m train (1 x locomotive and 26 x tanker wagons) could have a payload of around 1,965 tonnes of SAF per train. For comparison, Heathrow typically receives 12 loaded trains of aviation fuel per week from Grain with each train made up of 20 TEA-E wagons.

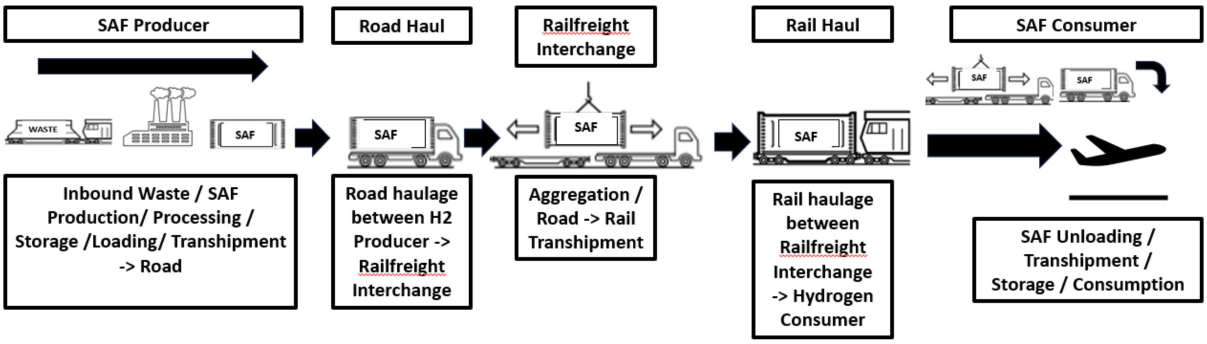


Intermodal Solution: In this scenario, the SAF production site has no direct or adjacent rail connectivity. As such, produced SAF is loaded into ISO 'bulktainers' (typically 20ft liquid or gaseous capable containers) before transhipment to road haulage. Road haulage is utilised to access a suitable railhead for container aggregation and onward loading to rail. Rail haulage is then utilised to reach the final storage destination either via direct rail connection or via a rail interchange and final mile road delivery.

Worked Rail Intermodal Solution: Assuming the same parameters as above, a 500m length train (1 x locomotive and 23 x 'FCA/FYA' type bulk intermodal flat wagon capable of conveying 3 x 20ft ISO bulktainers per wagon) with each ISO 'bulktainer' having a payload of 19.8 tonnes would have a payload of around 1,366 tonnes. For context, this tonnage would not be dissimilar to the current rail tanker deliveries of traditional aviation fuel from Grain to Colnbrook to serve Heathrow. This solution could ideally benefit aviation hubs with smaller fuel requirements.

Great British Railways TRANSITION TEAM

SAF – Intermodal Solution



As the above worked examples show, the potential for a single typically average hydrogen or SAF producer or CO2 emitter to generate the equivalent of a daily train requirement highlights the potential scalable opportunity for rail freight. Furthermore, for inland new energies production sites and emitters who are not directly or indirectly connected to the UK's pipeline network, rail freight represents a logical NPT transportation solution. Whilst diesel hauled rail freight typically emits 76% less CO2 than equivalent road haulage, the potential utilisation of HVO fuelled or bi/tri-mode electric locomotives represent a further opportunity for decarbonisation. Likewise, the utilisation of electric HGVs in the intermodal solutions.

Potential Quantum of Rail Services by 2035

Whilst looking at the potential scale of rail opportunity across the new energies markets it's worth considering what the quantum of services might actually look like by 2035 when the market will have developed considerably. This enables some base work to be undertaken when considering required capacity, routing and so forth. This work will develop in line with market developments and requirements. Based on industry conversations, research and subject to ongoing review we believe that as a conservative estimate, the following daily circulations could be in place by 2035;

- Hydrogen – 10 x daily rail circulations.
- CCUS – 15 x daily rail circulations.
- SAF – 20 x daily rail circulations (split between 10 x inbound feedstock and 10 x outbound SAF).

Terminal Requirements

Whilst the chosen operating solution will likely define specific terminal requirements across all three new energies considered in this digest which, in turn will vary depending on location, available space and potential co-habitation with other commodities, there will also be commonalities across all options. For instance, the technological solution developed to enable loading and discharge of hydrogen, CO2 or SAF to either tanker wagon or ISO bulk container will feasibly be of a similar design. In turn, an established design and process that can be replicated across multiple terminals will undoubtedly aid the development of the market. It is envisaged that for intermodal 3 scenarios where ISO bulk containers are used, the railheads at which the containers are aggregated for onward loading will already have or be capable of utilising standard industry loading practices and equipment. The use of intermodal solutions also however promotes the possibility of utilising railheads that handle other commodities particularly where an emitter site may not have a traditional container railhead within reasonable distance. In this instance the modification of such terminals to enable container handling whilst requiring capital investment also affords the opportunity for Freight End Users (FEU's) to diversify their traffic offering.

Team Railfreight Action: Explore potential of freight estate to support new energies markets and further establishing terminal requirements as market and technology develops.

Challenges To Modal Shift

- **Market Uncertainty/Scalability:** The 'chicken and egg' nature of the new energies market development represents a challenge to modal shift. Whilst rail freight has proven both flexible and responsive to market changes, uncertainty presents potential challenges. For instance, the required investment in rail terminals and rail wagons, both tanker wagon and ISO 'bulktainer' solutions, requires an element of market certainty to underpin the business case. In return, the new energies markets require certainty over NPT transportation solutions. This challenge equally applies from a scalability perspective in that the exact future demand will unlikely be known at the point at which key investment decisions are required. Furthermore, the nature of the commercial elements of the market may also present challenges. For instance, in the CCUS market, the challenge of CO2 ownership, i.e. the emitter or the storage entity, potentially complicates the NPT haulage element in terms of who procures it.
- **Development Timescales:** Given the relative infancy in development terms of the new energies markets the likely best case scenario for rail freight activity is from 2030 - 2035 onwards based on industry conversations. Whilst it is positive that work is underway currently within the wider industry to develop rail related NPT solutions, the need to understand and establish key elements such as rail network strategic capacity will become key. Establishing such strategic capacity when many of the details are unknown presents a challenge albeit not an insurmountable one.

Team Railfreight Action: Further work to establish likely key rail axis' of path requirements and quantum of paths to embed into strategic planning processes and future timetable development.

- **Rail Capacity, Capability and Connectivity:** Whilst a considerable number of emitters have a direct rail connection it is equal to say that many more do not. Whilst these emitters are covered by the potential highlighted under intermodal solutions, it does present challenges. The use of container and wagon combinations may present gauging issues for services operating on non-traditional containerised routes. From a hydrogen perspective, it should be noted that a number of former power stations with rail connectivity, notably Ratcliffe and Aberthaw, have been cited as being potential candidates for new technology hubs.

- **Awareness of rail freight:** The awareness of rail freight and its potential as an NPT solution is critical to its ultimate scaled adoption. This awareness is as key in the private sector as it is in wider UK Government departments who have responsibility for related policy development. Equally important is to engage within the wider established rail freight sector through established trade bodies such as the Rail Freight Group to garner interest in the potential of the new energies markets.

- **Team Railfreight Action:** Host joint 'new energies' conference with Rail Freight Group to highlight the potential of the market for rail freight, encourage discussion on overcoming challenges to modal shift and engaging with a wider audience.
- **Team Railfreight Action**: Continued engagement with both emitters and potential storage entities to develop their NPT rail related proposals.
- **Team Railfreight Action:** Use of established lines of communication with UK Government departments to promote the potential for rail as an NPT solution for both hydrogen and CCUS.
- **Team Railfreight Action:** As markets develop, look to create bespoke digests for each of the new energies considered.

Summary of Team Railfreight Actions for Growth

The below summary of actions focusses on key actions to aid the wider development of the market and rail freight's role within the future supply chain. As this document is updated, future versions will contain an action log identifying what has been done and its impact along with developing new actions as and when required.

- Chart and map hydrogen, CCUS and SAF opportunities as they develop focussing on rail connectivity.
- Chart and map wider geographical emission clusters along with likely type of rail freight solution and proximity to established or future suitable railheads.
- Build on internal Network Rail and wider industry work to 'de-mystify' dangerous goods regulations and general safety related topics.
- Explore potential of freight estate to support new energies markets and further establishing terminal requirements as market and technology develops.
- Further work to establish likely key rail axes of path requirements and quantum of paths to embed into strategic planning processes and future timetable development.
- Host joint 'new energies' conference with Rail Freight Group to highlight the potential of the market for rail freight, encourage discussion on overcoming challenges to modal shift and engaging with a wider audience.
- Continued engagement with both emitters and potential storage entities to develop their NPT rail related proposals.

- Use of established lines of communication with UK Government departments to promote the potential for rail as an NPT solution for both hydrogen and CCUS.
- As markets develop, look to create bespoke digests for each of the new energies considered.

Glossary

FOC – Freight Operating Company

NR – Network Rail

GBRTT – Great British Railways Transition Team

EfW – Energy from Waste

CCUS – Carbon Capture Utilisation and Storage

NPT – Non-Pipeline Transportation

RFG – Rail Freight Group

DfT – Department for Transport

DESNZ – Department for Energy Security & Net Zero