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Regional Matching of Hydrogen Supply and Demand for Off-Road
Vehicle Operations in Great Britain

Faculty of Engineering and Applied Sciences
MSc Renewable Energy

MSc
Academic Year: 2024 - 2025

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This thesis is submitted in partial fulfilment of the requirements for
the degree of MSc Renewable Energy

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Abstract

Off-road vehicles, including agricultural equipment, construction plant, and road-rail vehicles (RRVs), account for a significant share of UK diesel use, yet have received limited attention in decarbonisation planning. In parallel, the UK is investing heavily in green hydrogen production through the Hydrogen Allocation Rounds. Understanding how off-road vehicle demand aligns with committed supply is, therefore, critical to meeting net-zero targets.

This study quantifies hydrogen demand for off-road vehicles at the national and regional scales and compares it with HAR-funded green hydrogen projects. The analysis combines the Climate Change Committee's Balanced Net Zero pathway with regional diesel baselines and HAR project-level capacity data to generate the first NUTS Level 1 forecasts of supply and demand dynamics in Great Britain till 2050. A bottom-up approach was applied to estimate RRV demand using unique operational datasets from Network Rail.

Results show hydrogen demand increases from 46 kt in 2030 to 481 kt in 2050. Construction plants drive the early demand in the 2020s and 2030s, before agricultural equipment becomes the dominant consumer by 2050. While RRVs remain a minor contributor throughout. On the supply side, HAR 1 and HAR 2 projects provide only 58 kt of hydrogen production per year on average, leading to an initial national supply-demand surplus of 12 kt in 2030 but a deep deficit of 423 kt by 2050. On a regional level, the North East is the only region with a supply-demand surplus in 2050, while the South East and East of England face significant shortfalls.

The findings confirm hydrogen's central role in decarbonising off-road vehicles and highlight the urgency of aligning new HAR project capacity with high-demand regions and investing in inter-regional transfer and storage infrastructure. This evidence base can inform policy, infrastructure planning and strategic investment in decarbonising off-road vehicles in Great Britain.

Keywords:

Non-road Mobile Machinery (NRMM), Off-Road Mobile Machinery (ORMM), NRMM Decarbonisation Pathways, Balanced Net Zero Pathway, Hydrogen Allocation Rounds (HAR), Hydrogen Supply-Demand NUTS 1 Mapping.

Acknowledgements

I want to express my sincere gratitude to my supervisor, Prof. Nazmiye Ozkan, for her invaluable guidance, support, and encouragement throughout the completion of this thesis.

I am also grateful to the Network Rail team for providing access to the Road-Rail Vehicle operational datasets and for sharing valuable insights on shift operations, which significantly strengthened this study.

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List of Abbreviations

ATUV	All-Terrain Vehicle
AWE	Alkaline Water Electrolysis
BNZ	Balanced Net Zero Pathway
BSFC	Brake Specific Fuel Consumption
BTU	British Thermal Unit
CCC	Climate Change Committee
CCS	Carbon Capture and Storage
CESAR	Construction & Agricultural Equipment Security and Registration Scheme
CO	Carbon Monoxide
DEFRA	Department for Environment, Food & Rural Affairs
DESNZ	Department for Energy Security and Net Zero
DFT	Department for Transport
DUKES	Digest of UK Energy Statistics
ERM	Environmental Resources Management
EU	European Union
EV	Electric Vehicle
FC	Fuel Cell
FLH	Full Load Hours
GHG	Greenhouse Gas
GW	Giga Watt
H2FC	Hydrogen Fuel Cell
H2ICE	Hydrogen Internal Combustion Engine
HAR	Hydrogen Allocation Round
HC	Hydro Carbon
HGV	Heavy Goods Vehicle
HPBM	Hydrogen Production Business Model
HVO	Heavy Vegetable Oil
ICE	Internal Combustion Engine
IEA	International Energy Agency
kt	kilotonnes

kWh	Kilo Watt Hour
LCCC	Low Carbon Contracts Company
LCHA	Low Carbon Hydrogen Agreement
LHV	Lower Heating Value
MEWP	Mobile Elevated Working Platform
Mha	million hectares
MOU	Memorandum of Understanding
MtCO ₂ e	Mega Ton Carbon Dioxide Equivalent
NAEI	National Atmospheric Emissions Inventory
NESO	National Energy System Operator
NO	Nitrogen Oxide
NR	Network Rail
NRMM	Non-Road Mobile Machinery
NUTS	Nomenclature of Territorial Units for Statistics
NZHF	Net Zero Hydrogen Fund
OEM	Original Equipment Manufacturer
ONS	Office for National Statistics
ORMM	Off Road Mobile Machinery
PEM	Proton Exchange Membrane
PV	Photovoltaic
R&M	Repair and Maintenance
RDR	Red Diesel Replacement
RESP	Regional Energy Strategic Plan
RRV	Road-Rail Vehicle
SMR	Steam Methane Reforming
SOEC	Solid Oxide Electrolyser Cell
TWH	Tera Watt Hour
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
ZEV	Zero Emission Vehicle

1 Introduction

The United Kingdom (UK) has a legal commitment to achieve net-zero carbon emissions by 2050 under the Climate Change Act 2008 (DESNZ, 2023c), in line with the Paris Agreement objective of limiting global temperature rise to 2°C above pre-industrial levels (UNFCCC, 2015). This has resulted in a steady decline in national Greenhouse Gas (GHG) emissions, primarily driven by the decarbonisation of the energy sector, making domestic transport the largest single source, accounting for 29.1% of the total emissions in 2023 (DESNZ, 2024a).

Figure 1-1 from the Dft (2025) illustrates that, in 2023, more than half of domestic transport emissions arose from cars and taxis, followed by Heavy Goods Vehicles (HGVs) and light vans. However, their decarbonisation pathways are relatively well-established. The UK Government has introduced a range of measures to cater to these sectors, including the Zero Emission Vehicle (ZEV) mandate (Dft et al., 2024), and a £650 million Electric Car Grant launched in July 2025 that provides discounts of up to £3,740 on eligible EV purchases (Dft et al., 2025).

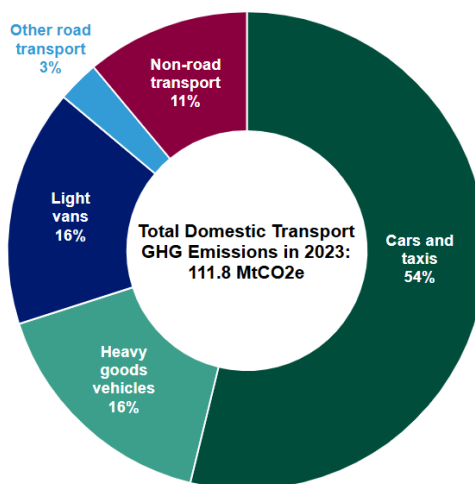


Figure 1-1 Domestic Transport Emissions 2023 (Dft, 2025)

While road transport dominates the UK's official GHG Inventory statistics, a significant sector of Off-road vehicles is invisible from the headline figures. In 2021, off-road vehicles accounted for 2.7% of the UK's total GHG emissions,

amounting to 11.4 MtCO₂e (DESNZ et al., 2023). The Climate Change Committee's (CCC) Sixth Carbon Budget also noted that policies for off-road vehicles "seemed to have fallen through the gaps" (CCC, 2020b). However, how the decarbonisation of off-road vehicles will be achieved has not been studied in comparable detail. This study aims to address this gap.

Off-Road Vehicles, also known as Non-Road Mobile Machinery (NRMM), refer to any mobile machine, equipment or vehicle with a combustion engine which is not intended for the transport of passengers or goods on road (DESNZ, DfT, et al., 2025). Until the 1990s, NRMMs were assumed to be minor emitters as compared to on-road vehicles; however, recent studies have changed this view, revealing that NRMM emissions were sizeable and will become the leading source of mobile emissions, considering the work being done to decarbonise the on-road fleet (Hagan et al., 2022). Additionally, studies have also shown that for the same amount of energy consumed, NRMMs tend to emit more pollutants such as Carbon Monoxide (CO), Hydrocarbons (HC), Nitrogen Oxides (NO_x) and Particulate Matter (PM) than on-road vehicles (Lončarević et al., 2022), while predominantly relying on diesel fuel (Transport & Environment, 2024). Therefore, in order to meet the UK's legally binding national and international targets, there is a need to decarbonise off-road vehicles.

NRMMs are utilised across various sectors, including agriculture, construction, mining, airports, and seaports, among others. Figure 1-2, compiled from 2022 National Atmospheric Emissions Inventory (NAEI) data, illustrates that Agriculture and Construction account for 73% of the total emissions associated with NRMMs (NAEI, 2025). As these two sectors represent the most significant mitigation opportunity, the present study will concentrate on them. Additionally, covering NRMMs in the Rail sector, known as Road-Rail Vehicles (RRVs) (RAIB, 2025), used to maintain the rail infrastructure, managed by Network Rail in Great Britain (Network Rail, n.d.). The RRV operational data, provided by Network Rail and comprising 3027 RRVs and 74,397 shifts for the period from 2024 to 2025, will add a unique perspective to this study.

Network Rail’s ambition to become net zero by 2050 (Network Rail, 2020) and rapid decarbonisation of construction and agricultural NRMMS, is dependent on the availability of low-carbon fuelling infrastructure (DESNZ et al., 2023). Given the spatial distribution of farmlands, construction sites and railway tracks and depots, this study focuses on sub-national assessment of NRMM low-carbon fuel demands.

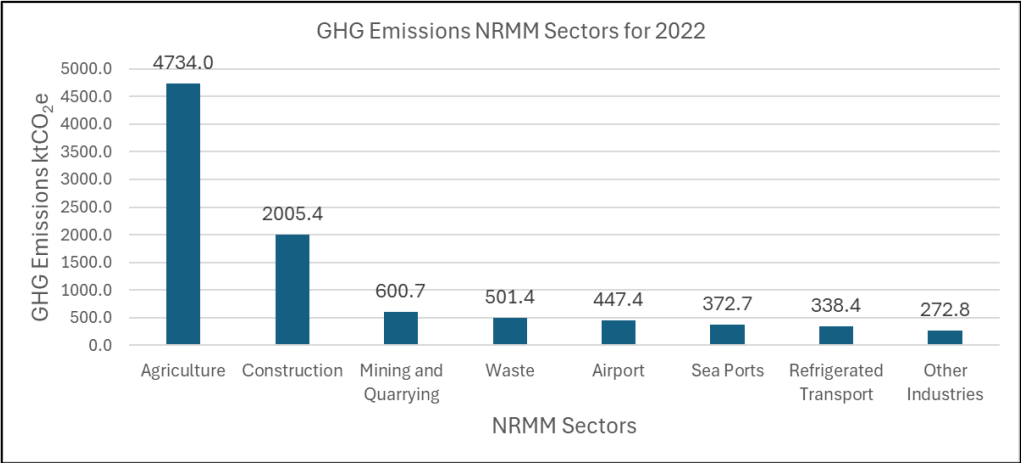


Figure 1-2 GHG Emissions for NRMM Sectors (2022) (NAEI, 2025)

1.1 Decarbonisation Options for NRMMS

A recent government survey by DESNZ et al. (2023) identified three broad pathways for the decarbonisation of NRMM: efficiency measures, process change, and fuel switching. Of these, only fuel switching offers a long-term route to complete decarbonisation, through the replacement of diesel with electrification via batteries or tethered power cables, use of hydrogen in Internal Combustion Engines (H2ICE) or Fuel Cells (H2FC), or the adoption of drop-in biofuels such as Hydrotreated Vegetable Oil (HVO).

The survey feedback, however, regarded biofuels as a short-term bridging option due to sustainability concerns, to be phased out in favour of electrification and hydrogen technologies (DESNZ, DEFRA, et al., 2025). This perspective aligns with the CCC’s Balanced Net Zero (BNZ) Pathway from the Sixth Carbon Budget, which identifies hydrogen and electricity as the principal long-term solutions, with

only temporary reliance on biofuels (CCC, 2020b). Building on this evidence, the present study focuses specifically on quantifying regional hydrogen demand for decarbonising NRMM under the BNZ Pathway scenario.

1.2 Green Electrolytic Hydrogen for Decarbonisation

While low-carbon hydrogen can be produced via the blue hydrogen process called Steam Methane Reforming (SMR), coupled with carbon capture and storage (CCS), this still leads to methane leakages, incomplete CO₂ capture of less than 60% (Ueckerdt et al., 2024) and a continued dependence on fossil fuels (House of Commons, 2022). In contrast, Green hydrogen produced through renewable energy-powered water electrolysis offers a zero-emission hydrogen production solution (Morgan, 2024), that can be utilised to decarbonise NRMM.

1.3 Aims and Objectives

While decarbonisation strategies for NRMM have been explored at a national level (ERM, 2023), two key gaps emerge from existing literature. Firstly, hydrogen demand has not been quantified nationally or regionally to decarbonise NRMM subsectors such as Construction, Agriculture and Rail. Secondly, to what degree this demand could be met from regionally sourced green hydrogen production has not been analysed. Assessment of regional supply through projects awarded under the UK government's Hydrogen Allocation Rounds (HAR) 1 and 2, a key policy mechanism for creating a hydrogen economy, can help identify potential areas with supply-demand imbalances. This study aims to address these gaps by modelling sub-sector off-road vehicle diesel displacement via hydrogen on a regional level through CCC's BNZ Pathway scenario and estimating green hydrogen supply potential from HAR Projects.

Considering the data limitations from Northern Ireland, this study will focus on Great Britain, specifically looking at the Regional Nomenclature of Territorial Units for Statistics (NUTS) Level 1.

To achieve the above aim, the study is guided by the following objectives:

1. Quantify baseline diesel consumption at Regional NUTS Level 1 for Off-road vehicle sub-sectors: Construction, Agriculture and Rail.

2. Forecast regional hydrogen demand to 2050 based on diesel displacement trends aligned with the CCC's Balanced Net Zero Pathway scenario.
3. Evaluate hydrogen demand projections against hydrogen output committed under government-funded projects and identify potential areas with supply-demand imbalances, and discuss their implications.

The remainder of this thesis is structured as follows. Chapter 2 presents a review of the existing literature relevant to the research gap. Chapter 3 outlines the data sources, methodology and modelling approach. Chapter 4 presents the results in relation to the set objectives. Chapter 5 discusses key implications of the supply-demand balance and the study's limitations. Finally, Chapter 6 provides a conclusion with key recommendations.

2 Literature Review

This study draws on a combination of academic and grey literature to address the following key areas: the technological and policy status of hydrogen in NRMMs, current approaches for estimating fuel demands for NRMMs in the construction, agricultural, and rail sectors, and an assessment of regional green hydrogen production.

2.1 Policies for Decarbonisation of NRMMs and Hydrogen

In recent years, UK policy has increasingly recognised hydrogen's role in NRMM decarbonisation. The Government now explicitly identifies hydrogen use through fuel cells or internal combustion engines for high-power and heavy-duty machinery and has committed to publishing an Off-Road Machinery Decarbonisation Strategy (DESNZ, 2024b). Regulatory barriers have also been eased, with Regulation 94 of the Road Vehicles (Construction and Use) Regulations 1986, which restricted hydrogen-powered NRMM use without a Vehicle Special Order, being amended in April 2025 (DfT, 2025). Policy incentives further support this transition, including the 2020 withdrawal of red diesel tax relief (HM Treasury, 2020), and the Red Diesel Replacement (RDR) competition. RDR has already backed 16 projects with £6.7 million (DESNZ, 2024e) and six projects with £25.7 million (DESNZ, 2024f) in phases 1 and 2 of the competition, respectively, to demonstrate low-carbon fuel use in construction and other sectors (see Table 2-1).

Table 2-1 RDR Programme Projects ((DESNZ, 2024e) , (DESNZ, 2024f))

Project Name	Funding	RDR Phase
Hybrid Gas Engine HE	£382,022	1
High Pressure Hybrid Pumping System for Hydrogen Storage and Dispensing	£437,700	1
HYDRATE – Hydrogen recuperated advanced thermal engine	£448,611	1

Decarbonised clean construction engines via retrofit hydrogen and ammonia flex fuelling	£425,071	1
Preliminary development of a mobile hydrogen refuelling station for offroad environments and NRMM refuelling	£453,498	1
NRMM to Net Zero using Flywheel and Battery Storage with H2 ICE	£460,000	1
Zero carbon hydrogen construction equipment for real-world use (ZECHER)	£418,613	1
H2Construction	£357,546	1
Demonstration of decarbonised quarrying operations through E-Diesel and hydrogen dispensing technologies	£6,274,318	2
Red garnet red diesel generator alternative	£4,823,728	2
Comprehensive hydrogen supply-chain solutions for NRMM (H2-to-Site)	£3,212,280	2
Element1: Leading the construction industry towards zero emissions future	£4,872,653	2

2.2 Hydrogen Capable Powertrains

Hydrogen Internal Combustion Engines (H2ICE) and Hydrogen Fuel Cells (H2FC) are two primary hydrogen powertrain options currently being explored and adopted in the NRMM sector (DESNZ, 2024b), with both offering unique operational benefits.

2.2.1 Hydrogen Internal Combustion Engine (H2ICE)

An industry-led working group, organised by the Department of Energy Security and Net Zero (DESNZ), strongly endorsed H2ICEs for NRMM decarbonisation due to their suitability for retrofitting to existing diesel machinery and robustness for use in harsh operating environments at a comparatively lower cost than other zero-emission technologies (H2ICE Sub-Group, 2024). This potential is exemplified by the JCB H2ICE development programme, which has demonstrated that hydrogen-powered Loadall telehandlers can deliver similar runtime, torque, power and responsiveness to their diesel counterparts (Abbott, 2023). Several field deployments in the construction sector across the UK further validate this performance (see Table 2-2).

Table 2-2 H2ICE Construction Sector Field Deployments

Equipment Type	Model	Trial Led by	Site Location
Telehandler	JCB 540-180H Loadall	BAM Construction	Birmingham (Laity, 2025)
Telehandler	JCB 540-180H Loadall	UK Forks	Arden (UK Forks, 2025)
Backhoe Loader	JCB 3CX	Barhale and Flannery Plant Hire	Wolverhampton (Barhale, 2025)

Academic studies support these operational findings. Rachi et al. (2025) simulated use in construction machinery by retrofitting diesel engines to run on 100% hydrogen while retaining 90% of the original diesel engine's power with a thermal efficiency of 39.7% and NO_x emissions of 0.4 g/kWh. In another study, Smigins et al. (2025) evaluated hydrogen-diesel dual fuel combustion in a KOHLER KDI-1903-M agricultural diesel engine and found up to 41% reduction in diesel consumption and 28% reduction in CO₂ emissions.

2.2.2 Hydrogen Fuel Cell (H2FC)

As H2FCs generate electrical energy through electrochemical processes, they are efficient at lighter loads, produce zero tailpipe emissions and offer quieter operations compared to combustion engines, thus making them an attractive option for urban and environmentally sensitive areas (H2ICE Sub-Group, 2024). A notable example is Komatsu's H2FC-operated medium-sized hydraulic excavator, which is designed to deliver powerful digging performance with reduced noise and vibration (KOMATSU, 2023). Another example is the electric-hydrogen powered road-rail vehicle, developed through collaboration between the University of Exeter and the Quattro Group, for use on the UK's rail networks (University of Exeter, 2023).

Complementing these field trials, Martini et al. (2024) provide academic evidence of viability, demonstrating through simulation that an H2FC-battery hybrid agricultural telehandler achieved near-identical performance to a diesel equivalent while significantly reducing its carbon footprint (see Table 2-3).

Table 2-3 H2FC-Battery Telehandler Performance (Martini et al., 2024)

Performance Test	Traditional Vehicle	H2FC-battery Hybrid Vehicle
Time for 0-40 km/h no load	12 s	12.5 s
Time for 0-40 km/h with 4200 kg	20 s	21 s
Max speed with 20% slope	9 km/h	8 km/h
Max slope with 4200 kg	15% @ 5 km/h	15% @ 5 km/h
Max slope at 15 km/h	12%	10%

2.2.3 Complementarity of H2ICE and H2FC Technologies

Figure 2-1 from H2ICE Sub-Group (2024) compares NRMM decarbonisation options across Tailpipe GHG emissions, costs, and readiness, using a red-amber-green coding system to indicate relative performance, with green denoting strengths and red denoting limitations. H2ICE is the most feasible near-term

option, but H2ICE and H2FC are complementary, not competing technologies, serving different load profiles while sharing delivery infrastructure, and together forming a key part of the UK’s NRMM decarbonisation pathway.

Technology	Tailpipe GHG	Well to Work GHG	Air Quality (NOx, Pm/Pn)	Onboard Storage	Refuelling Speed	Fuel Costs	Fuel Supply to Site / Machine	CapEx & Other Costs	Implementation Readiness (large NRMM)
HVO ICE									
Hydrogen ICE									
Hydrogen Fuel Cell									
Battery Electric									
Tethered Electric									

Figure 2-1 NRMM Decarbonisation Options Comparison (H2ICE Sub-Group, 2024)

2.3 Review of Off-road Vehicle Fuel Demand Modelling

Most studies identified during this review predominantly focused on estimating national-level emissions, with fuel consumption calculated indirectly through a bottom-up approach. A prime example is Tripathi et al. (2025), who modelled off-road machinery emissions in the USA by combining fleet population data, including vehicle type and power rating, with activity parameters such as load factors and operating hours to calculate the energy demand of the fleet in Btu/hr (see Figure 2-2). However, despite its detailed fleet characterisation, this analysis lacked regional granularity.

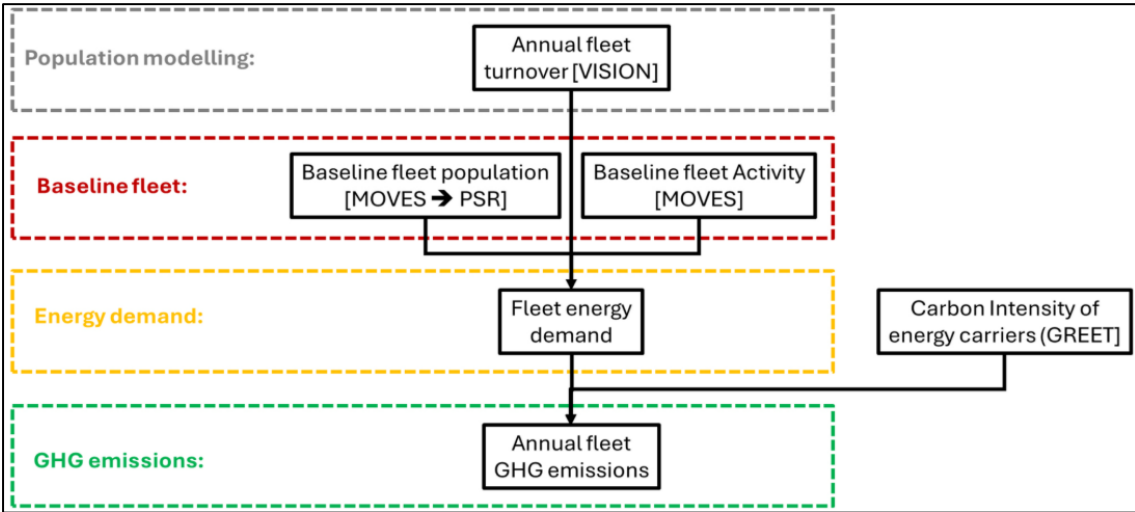


Figure 2-2 Bottom-up Fuel & Emissions Modelling (Tripathi et al., 2025)

An analysis by Lončarević et al. (2022) identifies significant data limitations within the NRMM sector, such as incomplete machinery lists, missing activity data, and limited research in the sector, which necessitate the use of proxy methods for estimating fuel demand. Raeesi et al. (2024) illustrates this approach by converting national-level HGV diesel consumption into hydrogen demand through energy-based conversion factors and then spatially allocating it across 539 potential refuelling sites, using location size as a primary proxy; the authors assumed that larger sites correlated directly with higher fuel consumption. This research offers a practical framework applicable to NRMM regional fuel demand estimations.

2.3.1 Construction

Two major studies have examined UK construction NRMM fuel consumption and emissions. First is the methodology report by Ricardo (2025a) on NAEI’s non-agricultural NRMM emissions calculation on a national level, where the study estimates emissions by employing fuel consumption calculations. The report sources NRMM data through desk reviews, stakeholder interviews, market surveys, and notably, the Construction and Agriculture Equipment Security and Registration Scheme (CESAR) anti-theft plant scheme dataset, which also serves as a de facto NRMM inventory (CESAR, 2025). Although not publicly available, the RICARDO model is reportedly capable of geographically disaggregating emissions data, as illustrated in Table 2-4.

Table 2-4 Spatial Allocation of Emissions Data (Ricardo, 2025a)

Geographic Region	Area Type
England (London)	Urban / Rural
England (outside London)	Urban / Rural
Scotland	Urban / Rural
Wales	Urban / Rural
Northern Ireland	Urban / Rural

Building on the NAEI database developed using RICARDO's methodology, the ERM (2023) report explores decarbonisation pathways for industrial NRMMs at a national level. As shown in Figure 2-3, the report provides a detailed breakdown of fuel consumption by industrial NRMM subsectors for the year 2021, the most recent available data, with the construction NRMM accounting for 820 kt of fuel consumption annually.

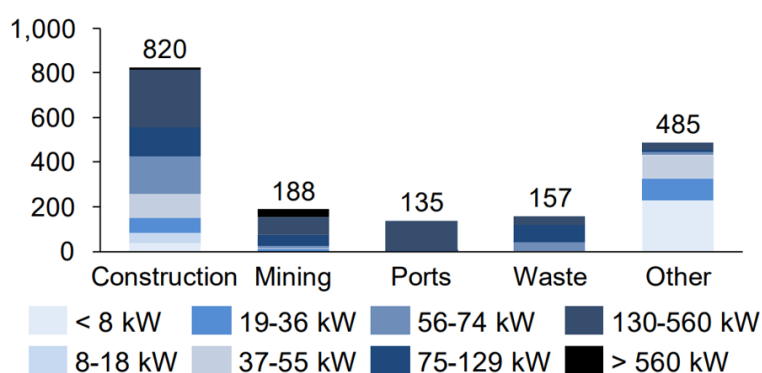


Figure 2-3 Fuel Consumption of Industrial NRMMs (2021) (ERM, 2023)

2.3.2 Agriculture

Similar to the construction sector, Ricardo (2025b) methodology report for NAEI's agricultural NRMM emissions utilises CESAR's dataset to estimate agricultural NRMM emissions on a national level through fuel consumption calculations. Figure 2-4 below provides a sample of the dataset used by Ricardo during their study.

Machine type	Average hours worked per year					Estimated power rating (kW)	Typical load factor (%)	Time in idle (%)
	New	Year 5	Year 10	Year 15	Year 20			
Tractor 38 - 75 kW	450	450	300	150	75	70	30%	25%
Tractor 75 - 89 kW	650	600	500	250	125	82	30%	25%
Tractor 90 - 104 kW	650	600	500	250	125	97	30%	25%
Tractor 105 - 119 kW	750	750	650	325	162.5	112	35%	25%
Tractor 120 - 149 kW	800	800	700	350	175	135	40%	25%
Tractor over 149 kW	850	800	750	375	187.5	176	40%	25%
Combine harvester	350	350	250	200	150	181	65%	25%
Telehandler (agricultural)	1000	1000	800	400	200	117	30%	25%
Forager	450	450	400	300	200	472	75%	40%
Sprayer	600	600	500	250	125	165	55%	40%

Figure 2-4 Sample Agriculture NRMM Dataset (Ricardo, 2025b)

However, Ricardo's model does not provide disaggregated data on fuel use. This limitation is addressed by the Sub-national Residual Fuel Consumption dataset, which reports petroleum use across local authorities and NUTS Level 1 regions (DESNZ, 2024c). Residual fuels, as defined by DESNZ (2024d) include non-gas, non-electricity, and non-road transport fuels, such as petroleum and coal, used in the agricultural and industrial sectors, among others. The sub-national allocation of residual fuels is performed using the UK Spatial Emissions Methodology report, where Agricultural off-road emissions are disaggregated using pasture and arable land use data (Ricardo, 2024a).

2.3.3 Road-Rail Vehicles

While several studies have addressed emissions and fuel for NRMMs, RRVs remain entirely overlooked. The NAEI Improvement Reports for both Non-Agricultural NRMM (Ricardo, 2025a) and Agricultural NRMM (Ricardo, 2025b) specifically exclude rail-based machinery from their scope, thereby omitting RRVs from both emission inventories and fuel consumption analysis. This exclusion highlights the absence of an official methodology or baseline data for RRVs, rendering them one of the least studied NRMM sub-sectors. A key contribution that this study aims to make is to effectively address this gap in the literature by using operational data provided by Network Rail (Ahmed & Ozkan, 2025).

2.4 Regional Assessment of Green Hydrogen Supply

To support low-carbon hydrogen production in the UK, the government has launched Hydrogen Allocation Rounds (HAR), which provide revenue support to compete against high-carbon fuels through the Hydrogen Production Business Model (HPBM) and Low Carbon Hydrogen Agreement (LCHA), and capital funding through the Net Zero Hydrogen Fund (NZHF) (DESNZ, 2025b). So far, HAR1 has allocated funding to 11 green electrolytic hydrogen projects with a combined capacity of 125MW (DESNZ, 2023), and HAR2 has shortlisted 27 projects, with due diligence ongoing (DESNZ, 2025a).

Kakoulaki et al. (2021) performed the only existing study of assessing green hydrogen production across the European Union (EU), including the UK, at a sub-national level; however, the study focused on NUTS Level 2, and the primary focus was to identify high-carbon intensive hydrogen hubs spatially and replacing them with green hydrogen production using the theoretical potential of renewable electricity generation (see Table 2-5).

Table 2-5 Green Hydrogen Potential at NUTS 2 (Kakoulaki et al., 2021)

NUTS Level 2 Code	Area Name	Renewable Electricity Potential (TWH)	Electricity Demand to replace high-carbon Green Hydrogen Production (TWh)
UKD1	Cumbria	16.67	6.47
UKL2	East Wales	38.34	3.34
UKF3	Lincolnshire	28.75	2.29
UKM7	Eastern Scotland	105.52	2.19
UKE4	West Yorkshire	17.35	1.73

The International Energy Agency's (IEA) Global Hydrogen Review Assumptions provides a methodological framework for calculating water electrolysis hydrogen output, with the study assuming a conversion efficiency of 65% and the average full-load operating hours for electrolyzers powered by different renewable sources, as shown in Table 2-6 (IEA, 2023).

Table 2-6 EU Full Load Hours for Green Hydrogen Production (IEA, 2023)

Renewable Source	Full Load Hours
Onshore Wind	3690
Offshore Wind	4980
Solar PV	2170

2.5 Summary

This literature review highlights the growing policy and technological support for hydrogen in NRMM applications, while also identifying persistent data gaps, particularly in regional fuel demand estimation. Although several proxy-based and national-level studies exist, the regional alignment of hydrogen supply and demand remains underexplored. This thesis addresses that gap by combining hydrogen fuel demand modelling with hydrogen supply assessments, enabling a more regionally informed evaluation of hydrogen's role in off-road vehicle decarbonisation.

3 Methodology

As outlined in the flowchart in Figure 3-1, this chapter describes the methodological framework used to estimate regional hydrogen demand as a diesel replacement for NRMM in the Construction, Agriculture and Rail sectors. It also details the approach for estimating green hydrogen production from HAR projects and the subsequent assessment of regional supply-demand balances.

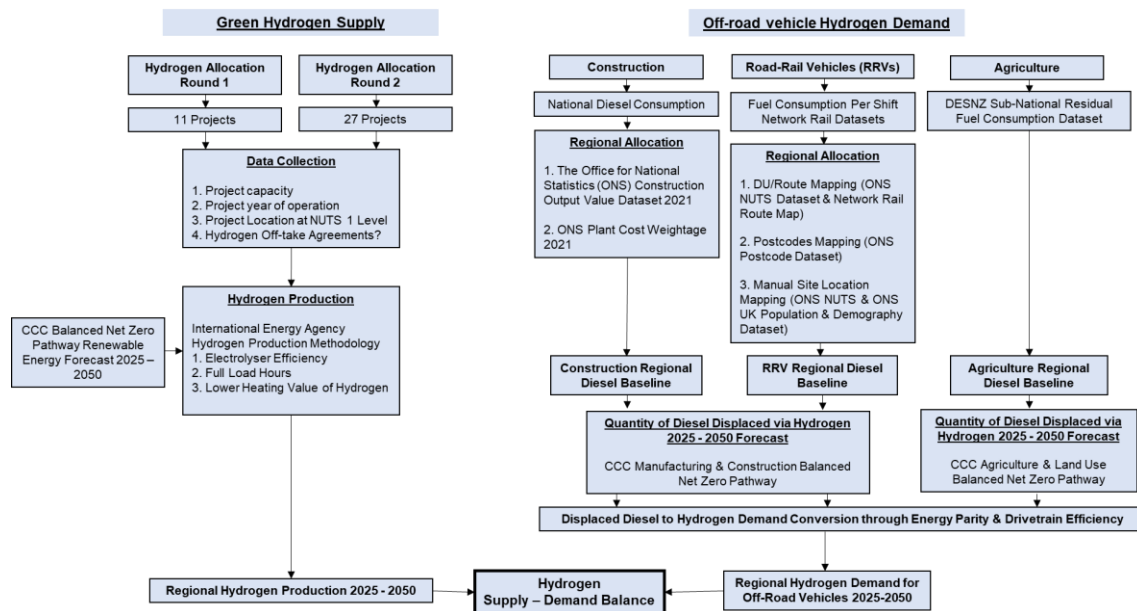


Figure 3-1 Methodology Flow Chart

Demand and supply were allocated at NUTS Level 1 in ArcGIS Pro 3.3, with regional boundaries taken from Office for National Statistics (2018). Figure 3-2 shows the resulting regional reference map.

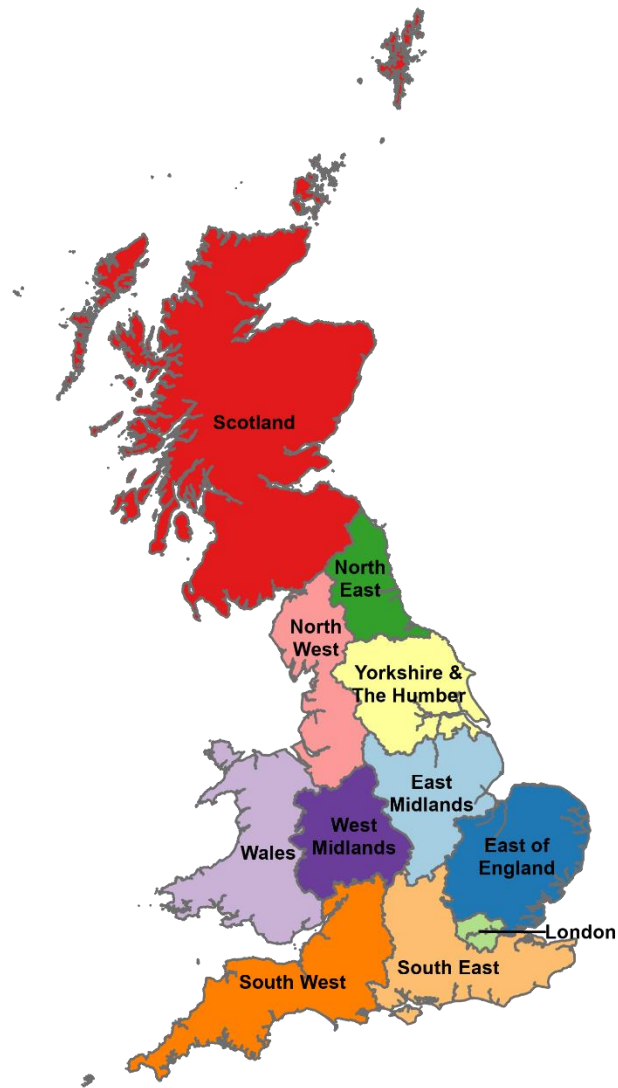


Figure 3-2 Great Britain NUTS Level 1 Reference Map

3.1 Baseline Diesel Consumption Estimation

3.1.1 Construction

A national fuel consumption baseline of 820 kilotonnes (kt) for construction NRMMs in 2021 was adopted from ERM (2023) study. Although this figure aggregates diesel, petrol, and liquid petroleum gas, it is assumed to represent diesel only, due to the absence of further breakdown data and diesel's dominant share of 83% in industrial NRMM emissions.

To allocate this national baseline across NUTS 1 regions, a proxy based on regional construction output value (£ million) was developed. Output values for

categories such as New Housing, Infrastructure, Other Works, Housing Repair and Maintenance (R&M), and Non-Housing R&M were obtained from the ONS (2025a) dataset, which reflects the chargeable cost of construction activity in each region (ONS, 2022b). These values were then adjusted using the percentage share of plant costs for each category, as reported by ONS (2021b) (see Table 3-1), ensuring that the regional allocation more accurately reflects NRMM-related expenditure rather than total construction value.

Table 3-1 Percentage share of Plant costs in each category (ONS, 2021b)

Category (i)	Labour %	Material %	Plant (W) %
Housing	44.3%	50.2%	5.5%
Infrastructure	47.5%	40.4%	12.1%
Other Works	54.5%	39.9%	5.7%
Housing R&M	60.6%	35.8%	3.6%
Non-Housing R&M	24.8%	69%	6.2%

Equation 3-1 calculates the total NRMM-related construction cost (P_r) for each region, illustrated in Table 2-1 along with the initial construction output value for all categories.

$$P_r = \sum_i C_{r,i} * W_i$$

Equation 3-1 Total NRMM-related Construction Cost per region (P_r)

Here, $C_{r,i}$ and W_i represent construction output value for region (r) and category (i), and plant cost percentage share for category (i), respectively.

Table 3-2 Initial Construction Values and Calculated Pr Value for regions

Region (r)	New housing (i) £ million	Infrastructure (i) £ million	Other Work (i) £ million	Housing R&M (i) £ million	Non-Housing R&M (i) £ million	Total (Pr) £ million
North East	1483	1216	1487	653	837	348.6
North West	5238	3003	3989	2666	4098	1044.2
Yorkshire and the Humber	3112	2177	2138	2128	3053	677.0
East Midlands	2726	1853	2498	1909	1807	590.9
West Midlands	3691	2823	2279	2466	2693	784.0
East of England	4080	1956	4059	4165	4084	853.4
London	12055	7222	11368	4711	4252	2379.0
South East	5353	2465	3752	6273	4565	989.1
South West	3440	1904	2661	4004	1851	649.6
Wales	1357	494	1494	1264	1101	263.8
Scotland	3521	4596	3342	1944	2618	1046.5

Finally, the regional diesel consumption (D_r) is estimated by distributing the national total of 820 kt (D_{total}) based on each region's share of total NRMM-related construction cost (P_r) using Equation 3-2.

$$D_r = \frac{P_r}{\sum_r P_r} * D_{total}$$

Equation 3-2 Regional Diesel Consumption (D_r)

3.1.2 Agriculture

The baseline diesel consumption for agricultural NRMM was sourced from the 2022 Sub-national Residual Fuel Consumption dataset (DESNZ, 2024c), illustrated in Table 3-3 below. Although this dataset provides petroleum fuel consumption at the NUTS 1 Level and is aligned with national energy totals from Digest of UK Energy Statistics (DUKES) and NAEI, ensuring its robustness and reliability, it does not disaggregate between mobile machinery and stationary combustion (Ricardo, 2024b). Due to the absence of other available proxies, this study adopts a conservative assumption that all residual petroleum fuel used in the agricultural sector corresponds to Agricultural NRMM use.

Table 3-3 Agriculture Residual Fuel Consumption Data (DESNZ, 2024c)

NUTS Level 1 Region	Diesel Baseline (kt)
North East	40.9
North West	123.8
Yorkshire and the Humber	141.5
East Midlands	148.7
West Midlands	206.9
East of England	212.3
London	3.3
South East	243.6
South West	280.6
Wales	137.1
Scotland	241.9

3.1.3 Road Rail Vehicles

For this analysis, Network Rail's dataset of 74,397 shifts during the 2024 operational year (29th March 2024 - 28th March 2025), alongside an inventory of

3,027 RRVs, was used (Ahmed & Ozkan, 2025). A bottom-up approach was applied to estimate per-shift fuel consumption and allocate it spatially across NUTS 1 regions.

3.1.3.1 Fuel Consumption per Shift

3.1.3.1.1 Fuel Consumption Rate

This fuel consumption methodology utilises the work done during “Group Project A”, which evaluated the carbon footprint of RRVs within Network Rail (Khobiyan et al., 2025).

The Shift dataset consists of fields such as Site, DU/Route, Date, Client Type, Work Type, Machine ID, Machine Type, OEM, Model, and Commissioning Year. Moreover, the Machine Inventory dataset comprises 16 Machine Types (see Table 3-4), with fields including Machine ID, OEM, Model, and Commissioning Year.

Table 3-4 RRV Machine Types (Ahmed & Ozkan, 2025)

Machine Type	Quantity	Machine Type	Quantity
Excavator	1646	Flas	15
MWEP	638	Drainage Machine	10
Lorry	324	Tractor	8
Bulldozer	114	Trailer	4
Personnel Carrier	123	Ballast Broom	2
Dumper	74	Drum Roller	1
Crane	44	ATUV-HP	1
Rail Trolley	22	MMPV	1

Although the datasets are comprehensive, they lack specific values for fuel consumption rates, load factors and power ratings for RRVs. Therefore, Equation 3-3, taken from Stark (2017), has been used to estimate the fuel consumption rate.

$$mf = \frac{BSFC * P}{1000}$$

Equation 3-3 Fuel Consumption Rate (Stark, 2017)

Here, mf, P and BSFC represent the mass flow rate of fuel in kg/h, engine power in kW and Brake Specific Fuel Consumption (BSFC) in g/kWh.

RRVs are modified NRMMS, adapted for rail use, featuring track wheels and additional weights. However, as this specific conversion data was not available, RRVs have been assumed equivalent to their base models for this analysis. Power ratings have been sourced from the Khobiyan et al. (2025) findings, where 3,027 RRVs were categorised into 447 sub-groups based on Machine Type, OEM and Model. These ratings were identified using grey literature, except for a small subset representing 850 shifts (1.1% of the dataset), for which power ratings were unavailable. See Appendix B for details.

The BSFC values were estimated according to engine stages defined in Directive 97/68/EC, ranging from Stage 1 to 5 (DieselNet, n.d.). Following Bonnel et al. (2014), the upper-bound values of the BSFC ranges for Stages 3A, 3B, and 4 were adopted as a precautionary assumption to avoid underestimating fuel consumption. For stages with no reliable empirical data, Stages 1 and 2 were assumed to be equivalent to Stage 3A, as emissions and performance data for these early engine generations are sparse and no longer systematically reported. Conversely, Stage 5 was assumed equivalent to Stage 4, reflecting the limited availability of BSFC data for this recently introduced standard. Table 3-5 summarises the BSFC values.

Table 3-5 Engine Stages and BSFC Values

Stage	Min Power (kW)	Max Power (kW)	Year Implemented	BSFC Value (g/kWh)
1	130	560	1999	250

1	75	129	1999	250
1	37	75	1999	250
2	130	560	2002	250
2	75	129	2003	250
2	37	74	2004	250
2	18	36	2001	250
3A	130	560	2006	250
3A	75	129	2007	250
3A	37	74	2008	250
3A	19	36	2007	250
3B	130	560	2011	240
3B	75	129	2012	240
3B	56	74	2012	240
3B	37	55	2013	240
4	130	560	2014	210
4	56	129	2014	210
5	1	7	2019	210
5	8	18	2019	210
5	19	36	2019	210
5	37	55	2019	210
5	56	129	2020	210
5	130	559	2019	210
5	561	-	2019	210

3.1.3.1.2 Operating Hours and Load Factor

Shift operating hours and load factors were provided by Network Rail based on the fields of Client Type and Work Type, as illustrated in Table 3-6, where Operational Hours and Idle Hours represent an RRV operation at 100% and 30% load factors, respectively.

Table 3-6 RRV Operating Hours

Client Type	Work Type	Total Shift hours (h)	Operational hours (h)	Idle hours (h)
Delivery Unit	Core	8	3	5
Delivery Unit	Drainage	8	6	2
Delivery Unit	Follow Up	8	7	1
Delivery Unit	Prep	8	7	1
Delivery Unit	Vegetation	8	7	1
Delivery Unit	OHLE	8	4	4
Principal Contractor	Core	10	3	7
Principal Contractor	Drainage	10	2	8
Principal Contractor	Follow Up	10	9	1
Principal Contractor	Prep	10	9	1
Principal Contractor	Vegetation	10	9	1
Principal Contractor	OHLE	10	5	5
Works Delivery	Core	10	3	7
Works Delivery	Drainage	10	2	8
Works Delivery	Follow Up	10	9	1
Works Delivery	Prep	10	9	1

Works Delivery	Vegetation	10	9	1
Works Delivery	OHLE	10	5	5

Shift operating hours can be multiplied by the fuel consumption rate to achieve the fuel consumption for all 74,397 shifts.

3.1.3.2 Regional Allocation of Shifts

The DU/Route and Site fields in the Shifts dataset were used to allocate shifts to NUTS1 regions. DU/Route refers to Network Rail route names, while Site represents the work location. Due to inconsistent contractor entries, a three-tiered methodology was applied.

In Tier 1, of 73,397 shifts, the DU/Route field contained 52 unique values: 12 official routes and 40 towns or cities. These were matched to the NUTS 1 regions using the ONS NUTS 1, 2 and 3 datasets (ONS, 2022a) and Network Rail's route map (Smithers, 2021) (see Table 3-7).

Table 3-7 Regional Allocation - Tier 1

DU / Route	NUTS Level 1 Region	DU / Route	NUTS Level 1 Region
Anglia	East of England	London Bridge	London
Ashford	South East	Manchester	North West
Bedford	East of England	Motherwell	Scotland
Birmingham	West Midlands	Newcastle	North East
Bletchley	South East	Orpington	London
Brighton	South East	Outer Wessex	South West
Cardiff	Wales	Perth	Scotland
Carlisle	North West	Peterborough	East of England
Crewe	North West	Preston	North West

Croydon	London	Romford	London
Derby	East Midlands	Saltley	West Midlands
Doncaster	Yorkshire and the Humber	Sandwell And Dudley	West Midlands
Edinburgh	Scotland	Scotland	Scotland
Euston	London	Sheffield	Yorkshire and the Humber
Glasgow	Scotland	Shrewsbury	West Midlands
Inner Wessex	South West	Stafford	West Midlands
Ipswich	East of England	Sussex	South East
Lancs And Cumbria	North West	Tottenham	London
Leeds	Yorkshire and the Humber	Wales	Wales
Liverpool	North West	York	Yorkshire and the Humber

The 12 official routes represented 34,042 shifts, as detailed in Table 3-8.

Table 3-8 DU/Route entries corresponding to official Network Rail routes and their associated shift counts

DU/Route	Number of Shifts
North & East	7813
Central	6582
Western	6582
North West	4154
East Midlands	3622

East Coast	3612
Wessex	2825
Kent	1226
Western West	967
WCMLS	896
Western East	775
Western Central	723

In Tier 2, the Site field of the remaining 34,042 shifts was checked for postcodes, enabling 16,593 to be allocated using the ONS National Statistics Postcode Lookup (May 2025) dataset (ONS, 2025b).

In Tier 3, the 17,549 remaining shifts were grouped into 2,100 unique DU/Route-Site combinations. Manual review of these combinations identified city or town references in 434 cases, enabling 2,617 additional allocations using ONS datasets (ONS (2021a) and ONS (2022a)). The final 15,037 unallocated shifts represent a 20.2 allocation error for this study (see Table 3-9).

Table 3-9 RRV Regional Allocation Summary

Allocation Approach	Datasets Used	Shifts Allocated
DU/Route	ONS NUTS 1, 2 and 3 datasets (ONS, 2022a) and Network Rail's route map (Smithers, 2021)	40,355
Postcodes	ONS National Statistics Postcode Lookup (May 2025) dataset (ONS, 2025b)	16,593
Manual Allocation	ONS NUTS 1, 2 and 3 datasets (ONS, 2022a) and ONS UK Population & Demography Dataset (ONS, 2021a)	2,617

Unallocated	Unallocated due to inconsistent data entry	15,037
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3.2 Application of Decarbonisation Scenario

To forecast diesel replacement over time, sector-specific decarbonisation trajectories from the CCC's sixth carbon budget were applied to the baseline diesel demand.

3.2.1 Construction and RRVs

According to the CCC (2020a), emissions from off-road mobile machinery in the Manufacturing and Construction sector were 6.8 MtCO_{2e} in 2020. Under the Balanced Net Zero (BNZ) Pathway, these emissions are expected to fall by 6 MtCO_{2e} by 2050, with 4.6 MtCO_{2e} reduced through hydrogen adoption, 1.4 MtCO_{2e} through electrification and 0.8 MtCO_{2e} remaining unabated.

This breakdown indicates that hydrogen is expected to deliver 67.56% of the total emissions reduction. To estimate the annual amount of diesel that could be replaced by hydrogen, this study utilises the CCC's projected emissions reduction trajectory and applies a 67.56% hydrogen share to each year's cumulative emissions abatement.

Since the analysis begins in 2025, the CCC's emissions trajectory was normalised to that year. The same percentages are applied to both Construction and RRV baselines, since the CCC does not provide a distinct pathway for RRVs, and their operational role aligns closely with construction NRMMs in maintenance and capital works. These values are summarised in Table 3-10, showing the remaining emissions under the BNZ Pathway, their normalisation to 2025, the share of total emissions abated and the resulting percentage of diesel displacement through hydrogen.

Table 3-10 CCC BNZ trajectory, normalised to 2025 with associated hydrogen displacement shares

Year	CCC BNZ Pathway's Projected Emissions Reduction Trajectory (%)	BNZ Pathway Remaining Emissions Normalised to 2025 (%)	Total Emissions Abated (%)	Diesel Displacement through Hydrogen (%)
2020	98.2	-	0.0	0.0
2021	97.0	-	0.0	0.0
2022	96.0	-	0.0	0.0
2023	94.9	-	0.0	0.0
2024	93.9	-	0.0	0.0
2025	92.8	100.0	0.0	0.0
2026	88.0	94.8	5.2	3.5
2027	83.4	89.9	10.1	6.8
2028	79.0	85.2	14.8	10.0
2029	74.9	80.7	19.3	13.0
2030	71.0	76.5	23.5	15.9
2031	67.3	72.6	27.4	18.5
2032	63.9	68.8	31.2	21.1
2033	60.2	64.8	35.2	23.8
2034	56.3	60.7	39.3	26.6
2035	51.8	55.8	44.2	29.8
2036	47.0	50.6	49.4	33.3

2037	41.9	45.2	54.8	37.0
2038	37.1	39.9	60.1	40.6
2039	32.0	34.5	65.5	44.2
2040	26.8	28.9	71.1	48.0
2041	21.5	23.1	76.9	51.9
2042	18.0	19.3	80.7	54.5
2043	16.9	18.2	81.8	55.3
2044	15.9	17.1	82.9	56.0
2045	14.8	16.0	84.0	56.8
2046	14.3	15.5	84.5	57.1
2047	13.9	15.0	85.0	57.4
2048	13.4	14.5	85.5	57.8
2049	13.0	14.0	86.0	58.1
2050	12.5	13.5	86.5	58.5

3.2.2 Agriculture

The CCC (2020a) reports that in 2020, emissions from mobile and stationary fuel combustion in the agricultural sector amounted to 4.57 MtCO₂e.

According to the CCC's BNZ Pathway dataset (CCC, 2020c), a total of 2.68 MtCO₂e emissions will be reduced by 2050 through the use of electricity and low-carbon hydrogen in the agricultural machinery sector. The energy required to achieve this reduction is projected at 3.97 TWh. Since this represents only 58.5% of the total sector emissions, the total energy requirement for complete decarbonisation is estimated at 6.79 TWh.

To estimate how much diesel could be displaced by hydrogen over time, the annual hydrogen demand values from the CCC pathway were normalised against

the 6.79 TWh figure. This gives the percentage of baseline diesel demand that could be replaced by hydrogen each year. Table 3-11 summarises this modelling, leading to 52.25% of the diesel being displaced through hydrogen by 2050.

Table 3-11 CCC Balanced Net Zero trajectory for agriculture with projected hydrogen demand and diesel displacement

Year	BNZ Pathway CO ₂ Reduction (Mt CO ₂ e)	BNZ Pathway Low-carbon Hydrogen Demand (TWh)	% Diesel Displaced by Hydrogen
2020	0.00	0.00	0.00%
2021	0.00	0.00	0.00%
2022	0.03	0.00	0.00%
2023	0.07	0.00	0.00%
2024	0.14	0.00	0.00%
2025	0.16	0.00	0.00%
2026	0.24	0.00	0.00%
2027	0.29	0.00	0.00%
2028	0.35	0.00	0.00%
2029	0.46	0.00	0.00%
2030	0.49	0.02	0.28%
2031	0.52	0.02	0.31%
2032	0.67	0.03	0.46%
2033	0.74	0.04	0.52%
2034	0.88	0.05	0.67%
2035	0.97	0.05	0.75%
2036	1.09	0.13	1.86%

2037	1.20	0.23	3.38%
2038	1.32	0.36	5.30%
2039	1.43	0.52	7.59%
2040	1.55	0.69	10.22%
2041	1.67	0.89	13.07%
2042	1.78	1.10	16.24%
2043	1.90	1.34	19.73%
2044	2.01	1.60	23.54%
2045	2.13	1.88	27.67%
2046	2.24	2.18	32.12%
2047	2.36	2.51	36.89%
2048	2.47	2.85	41.97%
2049	2.59	3.22	47.38%
2050	2.68	3.55	52.25%

3.3 Diesel to Hydrogen Conversion

To translate the displaced diesel by hydrogen into the mass of hydrogen required by NRMMS, this study uses an energy parity approach derived from Raeesi et al. (2024) and Rubio et al. (2023), where the mass of displaced diesel is converted into energy (kWh) using diesel's Lower Heating Value (LHV) and drivetrain efficiency. This useful energy is then supplied by hydrogen, accounting for the LHV value of hydrogen and the efficiency of hydrogen drivetrains. Since no definitive source specifies the future mix of hydrogen powertrains, this study assumes a 60% share for H2ICE and 40% for H2FC. The higher share for H2ICE reflects their lower upfront costs, faster market readiness, and retrofit potential as explained in Section 2.2. The parameter values adopted for this analysis are summarised in Table 3-12 (ERM, 2023).

Table 3-12 Parameter values for diesel-to-hydrogen energy parity conversion (ERM, 2023).

Parameter	Unit	Value
Lower Heating Value Diesel (LHV_{Diesel})	kWh/kg	11.91
Lower Heating Value Hydrogen (LHV_{Hydrogen})	kWh/kg	33.33
Diesel Drivetrain Efficiency (η_{Diesel})	%	33.00
Hydrogen Fuel Cell Drive Train Efficiency ($\eta_{\text{H2-FC}}$)	%	45.00
Hydrogen Internal Combustion Engine Drivetrain Efficiency ($\eta_{\text{H2-ICE}}$)	%	30.00

Equation 3-4, below, summarises the conversion process into one formula.

$$\text{Hydrogen (kt)} = \frac{(\text{Diesel (kt)} * LHV_{\text{Diesel}} * \eta_{\text{Diesel}})}{LHV_{\text{Hydrogen}}} * \left(\frac{0.6}{\eta_{\text{H2-ICE}}} + \frac{0.4}{\eta_{\text{H2-FC}}} \right)$$

Equation 3-4 Diesel to Hydrogen Conversion

3.4 Regional Hydrogen Supply Estimation

To estimate regional hydrogen supply, project-level data for HAR1 and 2 was collected through grey literature sources (see Table 3-13).

Unless stated otherwise in the tables below, data for the project name, location and electrolyser capacity for HAR1 and 2 were obtained from DESNZ (2023) and DESNZ (2025a) respectively. For HAR2 projects lacking a defined commissioning year from developers, a standard assumption of 2029 was applied, in line with the UK government's stated commissioning deadline (DESNZ, 2023b). The “Potential Hydrogen Off-takers” field shows developer-reported end-use sectors. Where no formal agreements exist, hydrogen is assumed to be used in NRMM. For projects with mixed off-takers, a 50% NRMM share is applied. Additionally, Hartlebury Green Hydrogen and Walsall Green Hydrogen are excluded from analysis due to the unavailability of capacity data.

Table 3-13 Hydrogen Allocation Rounds 1 and 2 Project Data

Project	HAR	Location	Capacity (MW)	Year	Potential Hydrogen Off-Takers	NRM M Use
Barrow Green Hydrogen	1	North West	35 (Carlton Power, 2022)	2027 (LCCC, 2025a)	KIMBERLY-CLARK - High Temperature Industrial Process (Carlton Power, 2022)	No
Bradford Low Carbon Hydrogen	1	Yorkshire and the Humber	24.5	2027 (LCCC, 2025b)	Local transportation (Hygen Energy, 2023)	Yes
Cromarty Hydrogen	1	Scotland	35 (Scottish Power, 2021)	2027 (LCCC, 2025c)	Local distilleries and heavy transport (Iberdrola, 2023)	Yes
Green Hydrogen 3	1	South East	15 (Environment Agency, 2025)	2027 (LCCC, 2025d)	KIMBERLY-CLARK High Temperature Industrial Process (HYRO Energy Ltd, n.d.)	No
HyBont	1	Wales	7.5 (HyBont, 2025)	2027 (HyBont, 2025)	Local transportation (HyBont, 2025)	Yes
HyMarnham	1	East Midlands	9.3	2025 (LCCC, 2025e)	Geopura Hydrogen Powered (energy-pedia, 2023)	No
Langage Green Hydrogen	1	South West	10	2027 (LCCC, 2025f)	Imerys and Sibelco to decarbonise clay mining operations (Carlton Power, n.d.)	No
Tees Green Hydrogen	1	North East	8 (Hynamics, 2025b)	2027 (LCCC, 2025g)	British Steel Lackenby High Temperature Processes and Heavy Transport (EDF, 2022)	Yes (50%)
Trafford Green Hydrogen	1	North West	20 (Trafford Green Hydrogen, n.d.)	2027 (LCCC, 2025h)	Paper, Food Processing, and Mobility (Argus Media, 2024)	Yes

West Wales Hydrogen	1	Wales	20 (MorGen Energy, n.d.)	2027 (MorGen Energy, n.d.)	Port and Industrial Operations (MorGen Energy, n.d.)	Yes
Whitelee Green Hydrogen	1	Scotland	7.1	2027 (LCCC, 2025i)	Use in local distilleries and heavy transport (ScottishPower Renewables, 2024)	Yes
Aldbrough Hydrogen Pathfinder	2	North East	35 (SSE Thermal, n.d.)	2029 (SSE Thermal, n.d.)	Hydrogen Storage and Electricity Production through H2 Turbines (SSE Thermal, n.d.)	No
Bardon Hill Hydrogen	2	East Midlands	30 (FuelCellsWorks, 2025)	2029	Aggregate industry and Hydrogen for open market use (FuelCellsWorks, 2025)	Yes
Binn Ecopark Hydrogen Facility	2	Scotland	70 (Green Cat Hydrogen, 2025)	2026 (Green Cat Hydrogen, n.d.-b)	Local industries and public sector operations (Green Cat Hydrogen, n.d.-a)	Yes
Creca Hydrogen Facility	2	Scotland		2029	Local industries and public sector operations (Green Cat Hydrogen, n.d.-a)	Yes
Strathallan Hydrogen Facility	2	Scotland		2029	Local industries (Green Cat Hydrogen, n.d.-a)	Yes
Fawley Green Hydrogen	2	South East	120 (Hynamics, 2025a)	2029 (Hynamics, n.d.)	ExxonMobil Petrochemical High Temperature processes (Hynamics, 2025a)	No
Grangemouth Green Hydrogen	2	Scotland	200 (RWE, 2024a)	2029 (RWE, 2024a)	INEOS for industrial processes (RWE, 2024a)	No
Green Hydrogen 5	2	Wales	7.5 (Young, 2025)	2029	No use defined	Yes

Grenian Hydrogen St Helens	2	North West	15 (Grenian Hydrogen, n.d.)	2027 (NSG, 2024)	NGS Group low-carbon architectural glass (NSG, 2024)	No
Harper Lane Hydrogen	2	London	20 (FuelCellsWorks, 2025)	2029	Asphalt production facility and Mobility Users (FuelCellsWorks, 2025)	Yes (40%)
Hartlebury Green Hydrogen	2	West Midlands	-	2029	-	-
Humber H2ub®	2	East Midlands	120 (Uniper, n.d.)	2029 (Uniper, n.d.)	Phillips 66 Limited for high temperature processes in the refinery (Uniper, n.d.)	No
Irvine Green Hydrogen Project	2	Scotland	15 (Young, 2025)	2029	No use defined	Yes
Lhyfe Kemsley	2	South East	80 (Lhyfe, 2025)	2029	Industrial users and transport operators (Lhyfe, 2025)	Yes
Lhyfe Wallsend	2	North East	20 (Lhyfe, 2025)	2029	Industrial users and transport operators (Lhyfe, 2025)	Yes
Magor Net Zero	2	Wales	17.5 (Protium, 2022a)	2027 (Magor Net Zero, n.d.)	Magor Brewery (Protium, 2022a)	No
Pembroke Green Hydrogen 1	2	Wales	100 (RWE, 2024b)	2029	Local industrial users (RWE, n.d.)	Yes
Selms Muir Hydrogen	2	Scotland	20 (onmine, n.d.)	2029	Local buses and heavy vehicles (onmine, n.d.)	Yes
Shetland Hydrogen Project 1	2	Scotland	60 (Krumpelmann, 2025)	2029	Conversion to green ammonia (Cope, 2025)	No
Singleton Birch Kilns	2	East Midlands	10 (Centrica plc, 2025)	2029 (Singleton)	Singleton Birch Lime Kiln High Temperature process (Singleton Birch, 2025)	No

				Birch, 2025)		
South Tees Net Zero	2	North East	68.8 (Protium, 2022b)	2029	Local community and businesses (Protium, 2022b)	Yes
St Austell Green Hydrogen	2	South West	20 (Four Zeros Energy, n.d.)	2029	Mining and Mineral Extraction industry (Four Zeros Energy, n.d.)	No
Tees Green Hydrogen Phase 2	2	North East	100 (Hynamics, 2025b)	2029	MOU - British Steel Lackenby (High Temperature Processes) and PD Ports (Heavy Transport) Transport (EDF, 2022)	Yes (50%)
Teesside Green Hydrogen	2	North East	60 (French, 2025b)	2029 (French, 2025a)	Teesside industrial cluster (Heynes, 2025)	Yes
Tyseley 10MW	2	West Midlands	10 (FuelCellsWorks, 2025)	2029	Public transport and construction equipment (FuelCellsWorks, 2025)	Yes
Walsall Green Hydrogen	2	West Midlands	-	2029	-	-
Whitelee Green Hydrogen Phase 2	2	Scotland	10 (Black & Veatch, 2025)	2029	Public transport and heavy freight vehicles (ScottishPower Renewables, 2024)	Yes

3.4.1 Hydrogen Production Estimation

To estimate the hydrogen production, this study applies the methodology outlined by the IEA (2023), summarised by Equation 3-5.

$$Hydrogen\ (kg) = \frac{Capacity\ (MW) * Full\ Load\ Hours\ (h)}{Efficiency * LHV_{Hydrogen}(kWh/kg)}$$

Equation 3-5 Hydrogen Production Calculation (IEA, 2023)

Where Capacity is the rated power of the electrolyser plant in MW, Full Load Hours (FLH) represent the number of hours per year the plant operates at full capacity, and LHV is the Lower Heating Value of hydrogen. Efficiency is assumed to be 65%, representing the average across Proton Exchange Membrane (PEM), Alkaline Water Electrolysis (AWE), and Solid Oxide Electrolyser Cell (SOEC) technologies. Since most HAR1 projects have not confirmed the electrolyser type, HAR2 remains under consultation, a uniform 65% value from IEA (2023) is applied.

3.4.1.1 Estimating FLH and Hydrogen Production Forecast

FLH values derived from IEA (2023) EU estimates, assumed to represent UK conditions in this analysis due to the lack of local data. As most HAR projects do not specify renewable energy inputs, a weighted national average was calculated using CCC's BNZ Pathway projection for offshore wind, onshore wind, and solar PV generation to 2050.

Equation 3-6 applies this weighted method; the average FLH (FLH_{avg}) is computed by multiplying the projected generation from each technology (E_i) by its corresponding FLH Value (FLH_i) from Table 3-14, summing the results and dividing by the total generation. The resulting values, summarised in Table 3-15, are then used to estimate hydrogen production.

$$FLH_{avg} = \frac{\sum_i (E_i * FLH_i)}{\sum_i E_i}$$

Equation 3-6 Weighted Full Load Hours Calculation

Table 3-14 EU Full Load Hours (IEA, 2023)

Renewable Source	Full Load Hours (FLH _i)
Onshore Wind	3690
Offshore Wind	4980
Solar PV	2170

Table 3-15 CCC BNZ Pathway Renewable Energy Forecast and Calculated FLH Trajectory

Year	Offshore Wind (TWh)	Onshore Wind (TWh)	Solar PV (TWh)	Full Load Hours (FLH_{avg}) (h)
2025	89.2	38.2	15.0	4338.5
2026	108.5	39.2	16.4	4391.4
2027	128.8	39.8	18.3	4430.8
2028	142.0	38.6	19.6	4455.9
2029	153.6	37.6	20.9	4474.6
2030	164.0	36.9	22.7	4481.9
2031	172.8	40.7	30.0	4418.7
2032	183.9	44.4	37.2	4370.3
2033	190.1	48.1	44.5	4318.0
2034	200.0	51.9	51.8	4280.6
2035	208.4	55.6	59.0	4244.3
2036	221.6	59.3	66.3	4222.9
2037	234.8	58.2	69.1	4236.2
2038	248.0	55.6	71.8	4251.7
2039	261.3	53.3	74.7	4264.0
2040	274.5	53.8	79.8	4260.5
2041	287.7	54.4	80.2	4279.9
2042	301.0	50.7	82.3	4296.6
2043	314.2	47.0	85.0	4308.5
2044	327.4	44.7	85.8	4327.4

2045	340.6	41.6	84.8	4354.7
2046	353.9	38.6	84.4	4378.1
2047	367.1	34.5	85.7	4394.5
2048	380.3	31.5	86.7	4409.6
2049	393.6	26.9	86.7	4431.4
2050	406.8	23.6	83.3	4464.9

4 Results

This section presents the modelling outcomes, beginning with baseline diesel consumption across sectors and regions, followed by projected hydrogen demand under the CCC's BNZ Pathway. It then examines potential hydrogen supply from HAR-funded projects and evaluates the resulting supply-demand balance.

All detailed numerical outputs supporting the figures in this section are provided in Appendix C.

4.1 Baseline Diesel Consumption

Off-road vehicles in Great Britain currently consume approximately 2,606.6 kt of diesel annually, Table 4-1 provides the sub-sector level breakdown.

Table 4-1 Sub-sector NRMM Baseline Diesel Consumption

Off-road Vehicle Sector	Baseline Diesel Consumption per year (kt)
Agriculture	1780.5
Construction	820
RRVs	6.1
Total	2606.5

Regional allocation highlights the South West (336.3 kt), Scotland (331.9 kt), and South East (328.2 kt) as the largest consumers, with significant demand also in the East of England (285.4 kt) and West Midlands (274.2 kt). These distributions are illustrated in Figure 4-1.

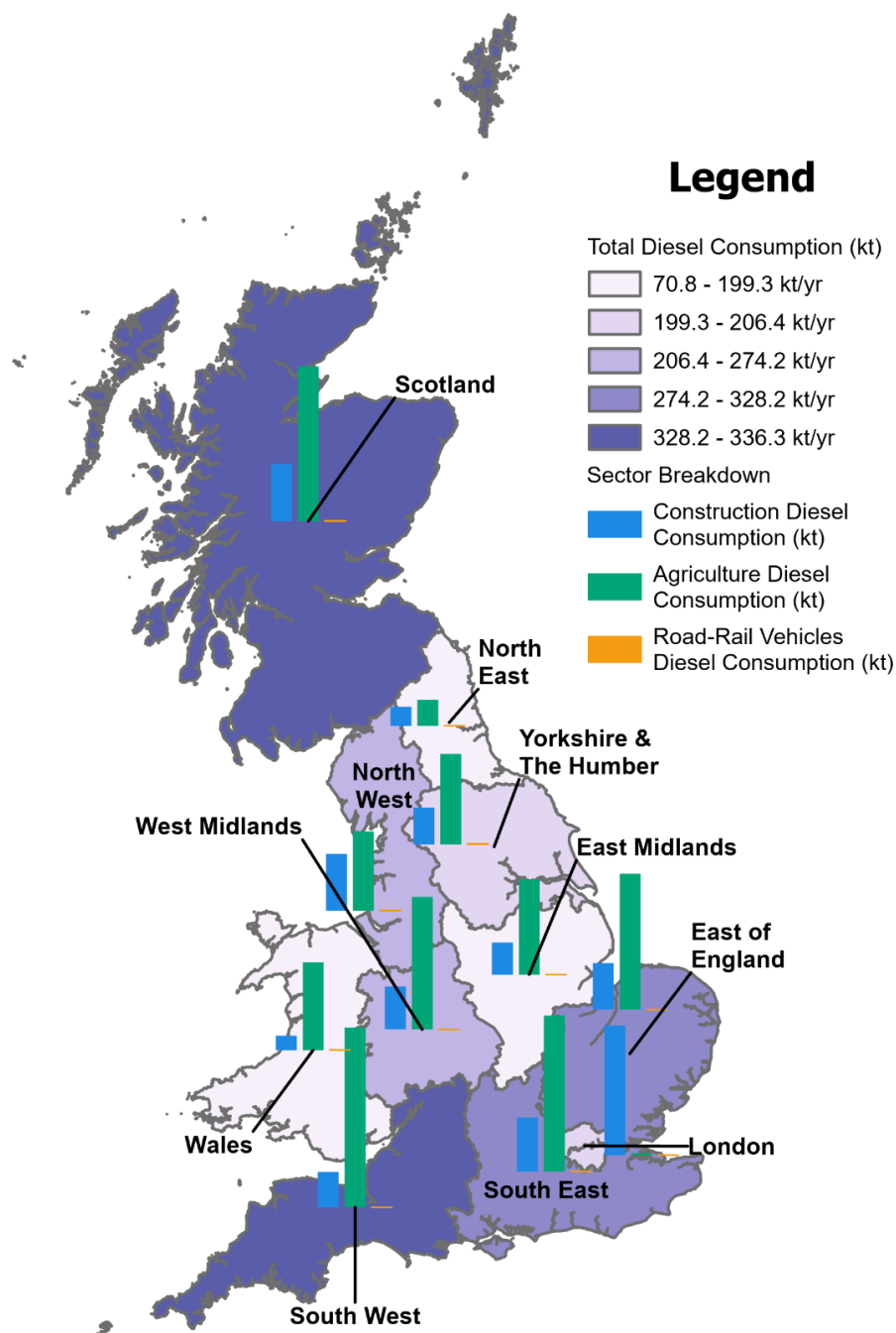


Figure 4-1 Total and Sub-sector Regional Baseline Diesel Consumption

4.2 Diesel Displacement Trajectories

Figure 4-2 shows the modelled amount of diesel displaced by year for each sector. Displacement remains minimal until 2030 but accelerates thereafter, reaching a total displacement of 1,413.2 kt by 2050. Agriculture is the most

significant contributor, displacing 930.2 kt of diesel by 2050, while construction displaces 479.4 kt and RRVs displace 3.6 kt.

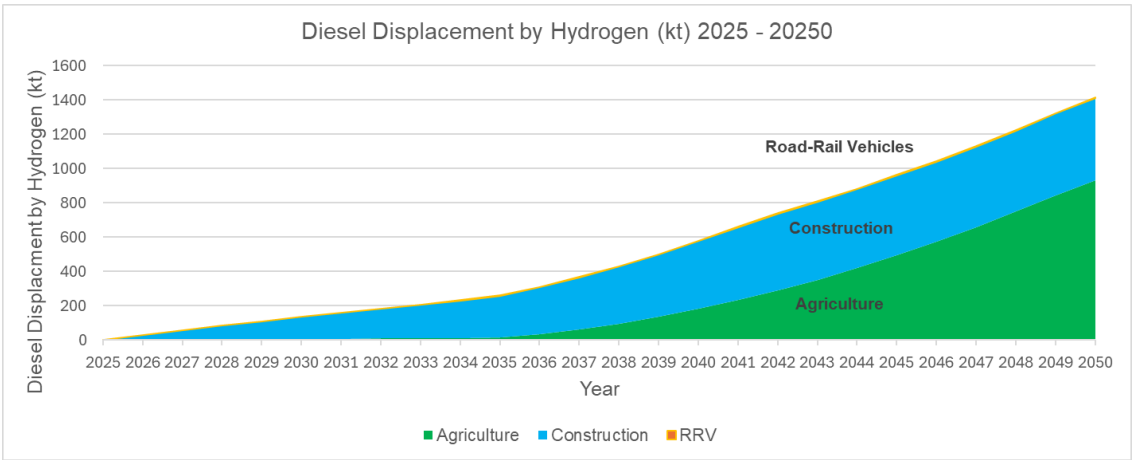


Figure 4-2 Sub-sector Diesel Displacement by Hydrogen Trajectory

4.3 Hydrogen Demand Projections

4.3.1 National Demand

Figure 4-3 summarises the hydrogen demand by sector. The national hydrogen requirement for NRMMS rises from 46.38 kt in 2030 to 197.14 kt in 2040 and 481.42 kt in 2050. Construction NRMMS dominate demand in the early years of the transition, but agriculture overtakes by mid-century due to its much higher diesel baseline. While RRVs remain minimal throughout the timeline.

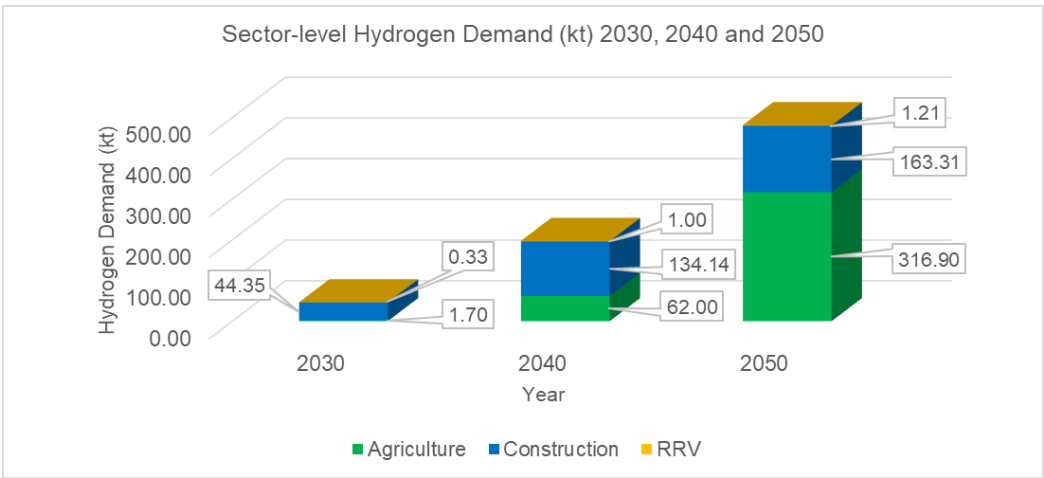


Figure 4-3 Sub-sector Hydrogen Demand for 2030, 2040 and 2050 (kt)

4.3.2 Regional Demand

Hydrogen demand is expected to evolve significantly across regions from 2025 to 2050, as illustrated in Figure 4-4. London, Scotland and the North West emerge as the most significant demand centres in 2030. By 2050, demand is expected to shift to agriculture-dominated regions, with the South West, Scotland, and South East each requiring around 60 kt of hydrogen annually.

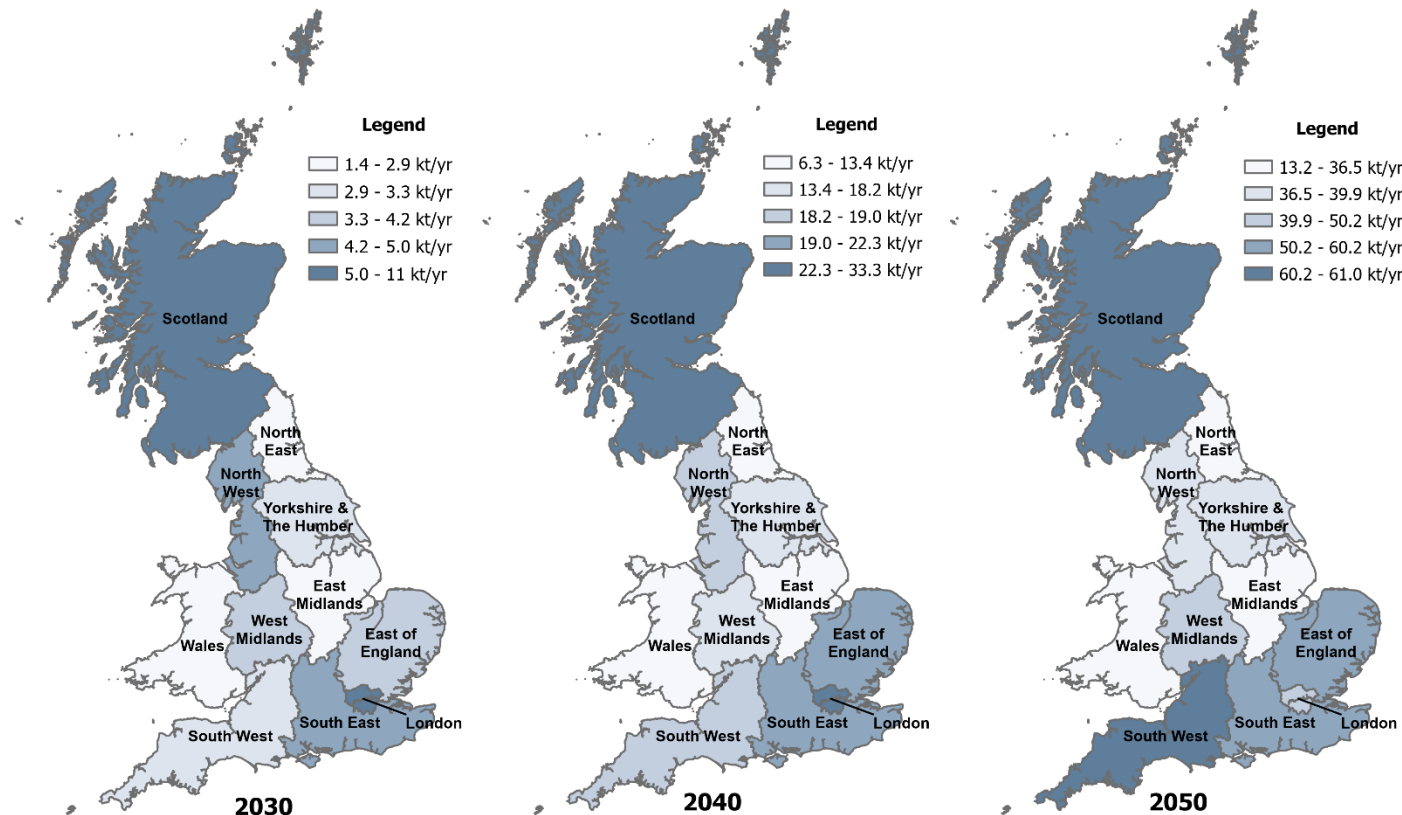


Figure 4-4 Regional Hydrogen Demand Projections for 2030, 2040 and 2050

Table 4-2, Table 4-3, and Table 4-4 present regional hydrogen demand for sub-sectors in 2030, 2040, and 2050. While, Figure 4-5, Figure 4-6, and Figure 4-7 show spatial distribution of sub-sector hydrogen demand in 2050.

Table 4-2 Agricultural NRMM Hydrogen Demand (kt) for 2030, 2040 and 2050

Region	2030	2040	2050
North East	0.04	1.4	7.3
North West	0.12	4.3	22.0
Yorkshire and the Humber	0.13	4.9	25.2
East Midlands	0.14	5.2	26.5
West Midlands	0.20	7.2	36.8
East of England	0.20	7.4	37.8
London	0.00	0.1	0.6
South East	0.23	8.5	43.4
South West	0.27	9.8	49.9
Wales	0.13	4.8	24.4
Scotland	0.23	8.4	43.0

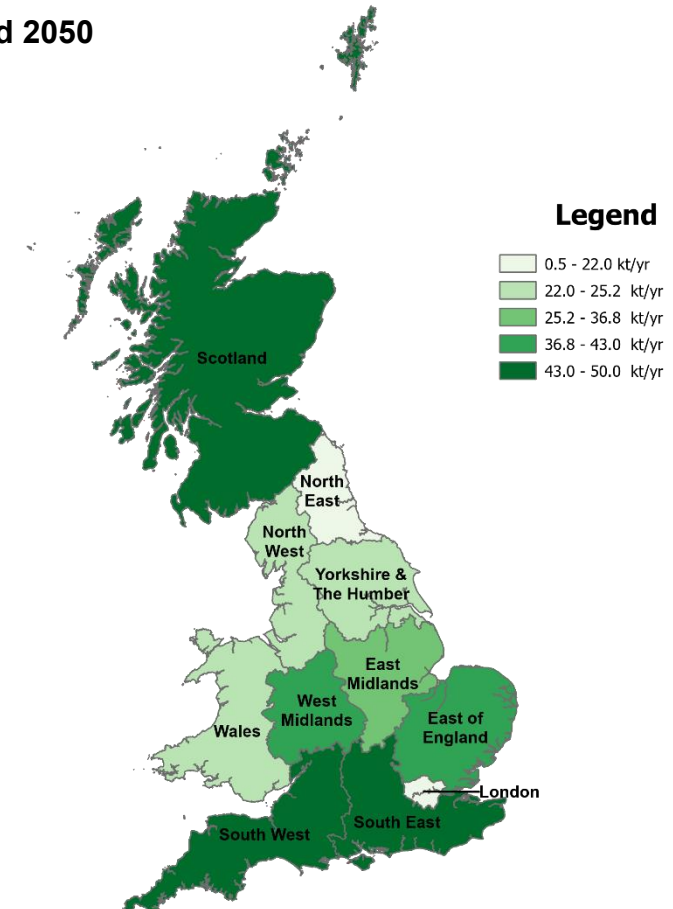


Figure 4-5 Agricultural NRMM Regional Hydrogen Demand Map - 2050

Table 4-3 Construction NRMM Hydrogen Demand (kt) for 2030, 2040 and 2050

Region	2030	2040	2050
North East	1.6	4.9	5.9
North West	4.8	14.6	17.7
Yorkshire and the Humber	3.1	9.4	11.5
East Midlands	2.7	8.2	10.0
West Midlands	3.6	10.9	13.3
East of England	3.9	11.9	14.5
London	11.0	33.2	40.4
South East	4.6	13.8	16.8
South West	3.0	9.1	11.0
Wales	1.2	3.7	4.5
Scotland	4.8	14.6	17.8

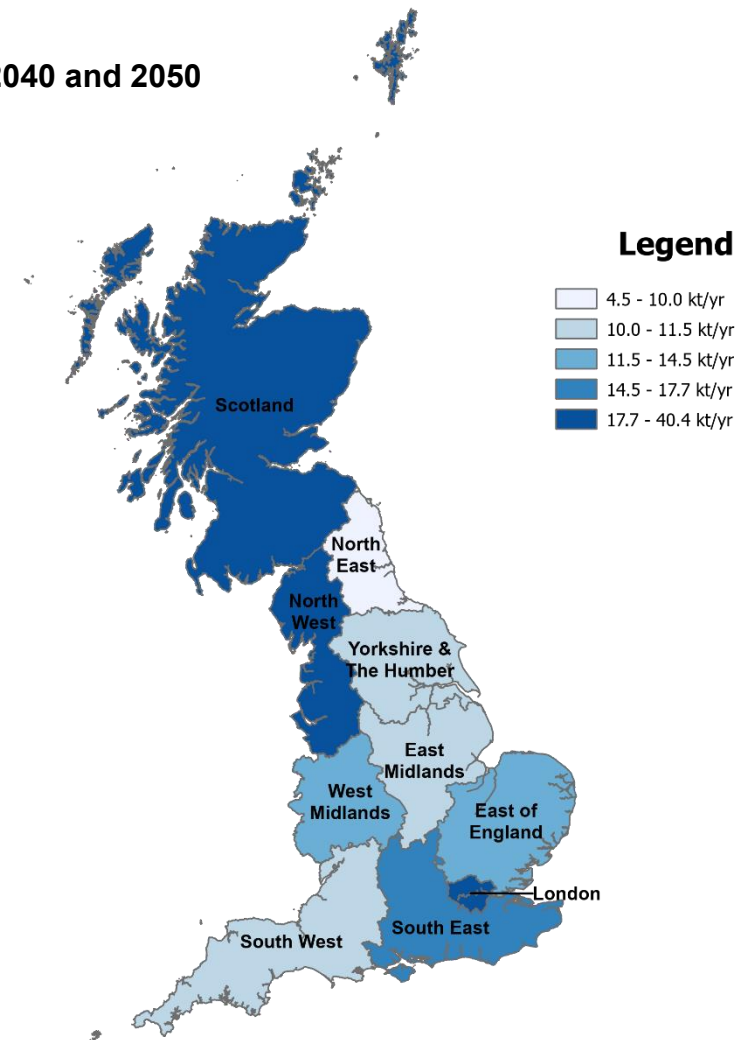


Figure 4-6 Construction NRMM Regional Hydrogen Demand Map - 2050

Table 4-4 RRV Hydrogen Demand (kt) for 2030, 2040 and 2050

Region	2030	2040	2050
North East	0.01	0.04	0.05
North West	0.04	0.13	0.15
Yorkshire and the Humber	0.06	0.19	0.23
East Midlands	0.01	0.04	0.05
West Midlands	0.03	0.08	0.10
East of England	0.02	0.07	0.08
London	0.03	0.08	0.10
South East	0.02	0.06	0.07
South West	0.02	0.06	0.07
Wales	0.03	0.10	0.12
Scotland	0.05	0.14	0.18

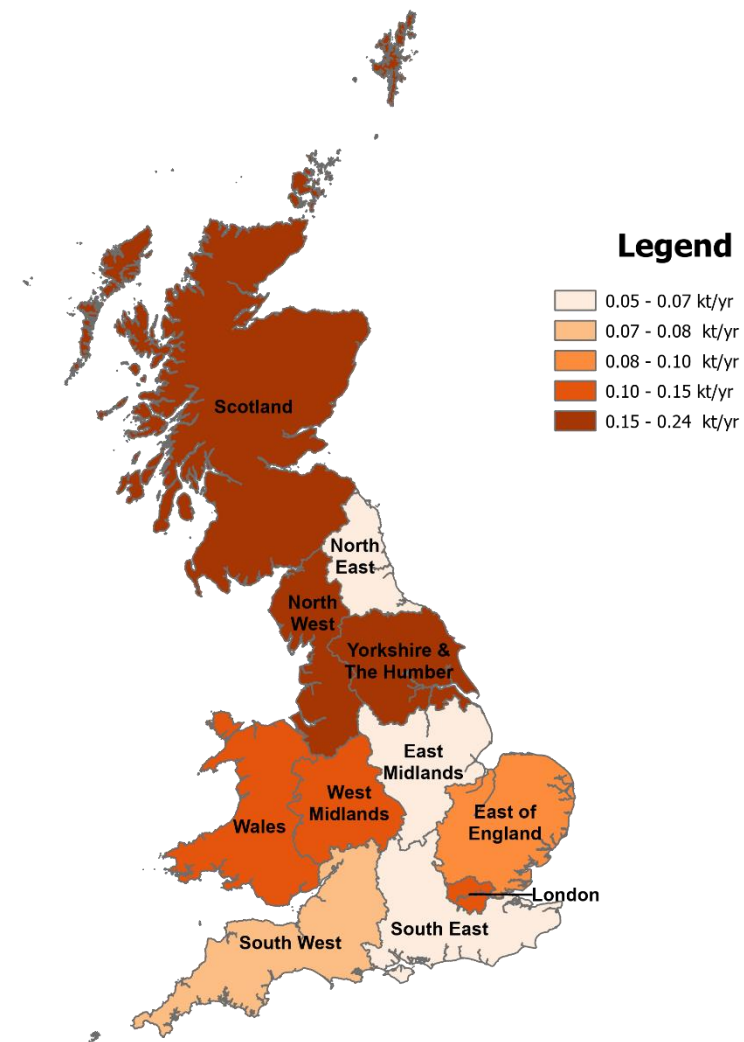


Figure 4-7 RRV Regional Hydrogen Demand Map - 2050

4.4 Hydrogen Supply from HAR Projects

Table 4-5 below presents the regional hydrogen supply potential for 2030, 2040 and 2050. Additionally, Figure 4-8 illustrates the spatial distribution of hydrogen supply in 2030, assuming all projects are operational. The North East emerges as the dominant supplier, with an estimated annual output of 17.7 kt of green hydrogen. This is followed by Scotland and Wales with 13.7 kt and 11.8 kt, respectively. Conversely, London contributes only 0.7 kt, while both the South West and East of England record no supply.

Table 4-5 Regional Hydrogen Supply (kt) 2030, 2040 and 2050

Region	2030	2040	2050
North East	17.73	16.85	17.66
North West	1.75	1.66	1.74
Yorkshire and the Humber	2.14	2.04	2.13
East Midlands	2.62	2.49	2.61
West Midlands	0.87	0.83	0.87
East of England	0.00	0.00	0.00
London	0.70	0.66	0.70
South East	6.99	6.65	6.97
South West	0.00	0.00	0.00
Wales	11.80	11.22	11.75
Scotland	13.71	13.06	13.58

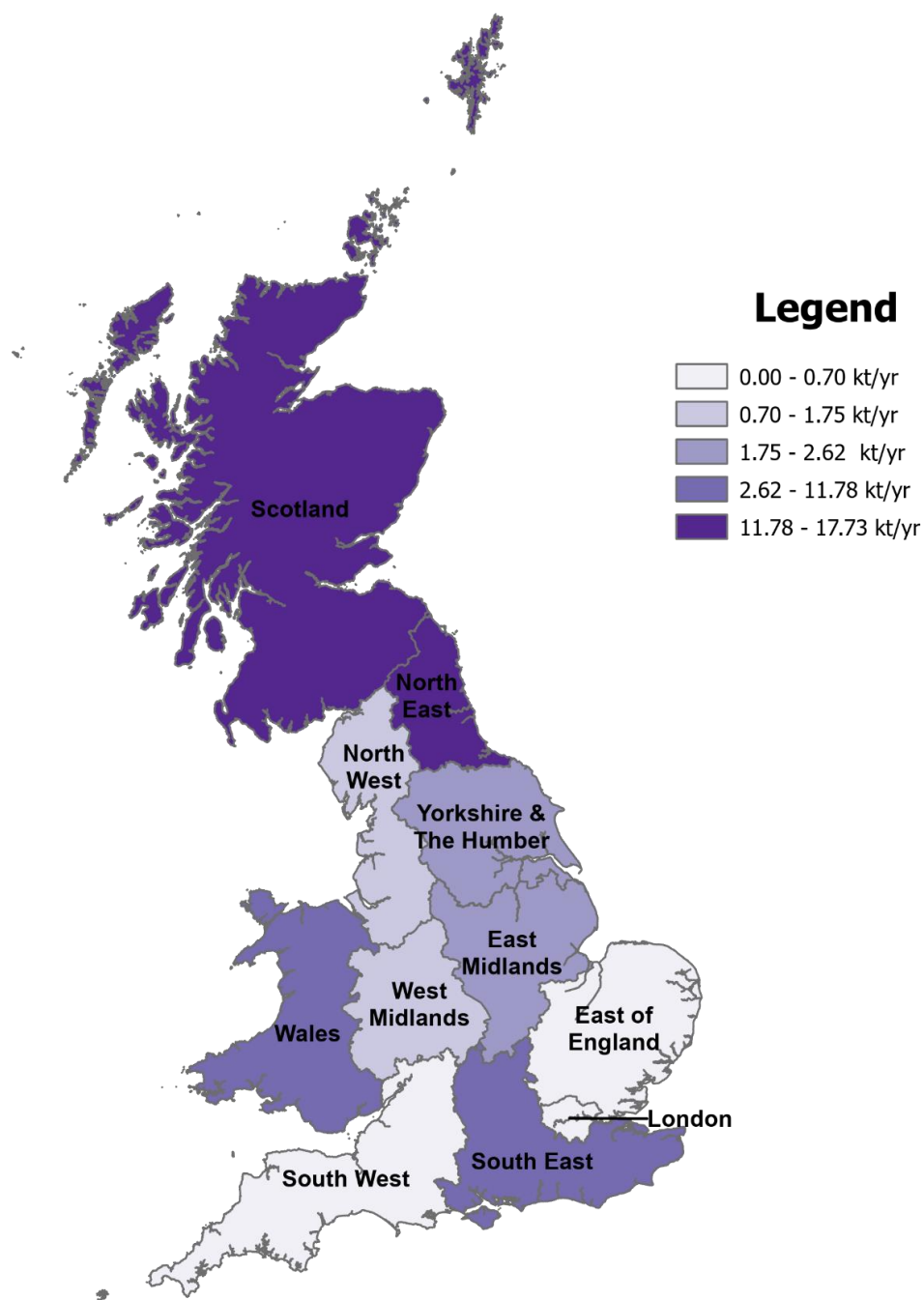


Figure 4-8 Regional Hydrogen Supply Map - 2030

4.5 Supply–Demand Imbalance

A comparison of projected hydrogen demand for NRMM against hydrogen production through HAR projects reveals a substantial national imbalance. Figure 4-9 presents the net supply-demand balance for Great Britain from 2025 to 2050.

In 2030, total demand reaches 46 kt, while supply from HAR1 and 2 projects is projected at 58 kt, resulting in a modest surplus of 12 kt.

However, the supply-demand dynamic changes significantly in the following decades. By 2040, hydrogen demand is projected to increase to 197 kt, while supply remains relatively constant at around 55 kt, resulting in a national deficit of approximately 142 kt. These gaps continue to widen, and by 2050, total demand is projected to climb to 481 kt, whereas supply remains at 58 kt, resulting in a shortfall of 423 kt.

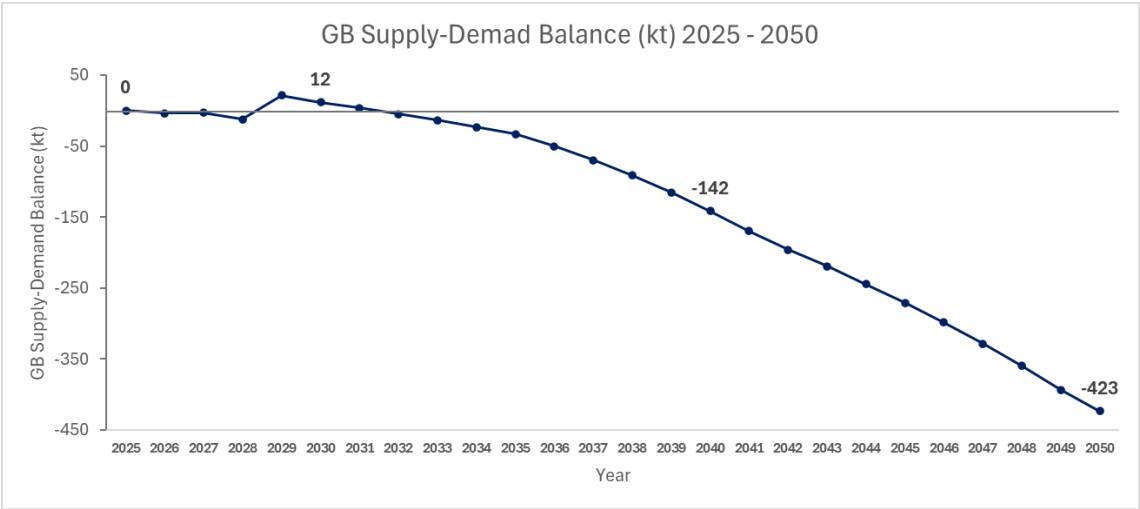


Figure 4-9 National Hydrogen Supply-Demand Balance 2025 - 2050

Table 4-6 presents the regional hydrogen supply-demand balance for milestone years 2030, 2040, and 2050. In 2030, the North East, Wales, Scotland and the South East regions experience modest surpluses.

By 2040, the regional picture worsens, with only the North East and Wales having minor surpluses, while all other regions enter into deeper deficits. This trend continues into 2050, where every region except the North East experiences a substantial shortfall. Deficits range from 17 kt in Wales to 61 kt in the South West, underlining a growing spatial mismatch between hydrogen supply and off-road vehicle demand.

Table 4-6 Regional Hydrogen Supply-Demand Balance (kt) 2030, 2040, and 2050

Region	2030	2040	2050
North East	+16.1	+10.5	+4.4
North West	-3.2	-17.3	-38.2
Yorkshire and the Humber	-1.2	-12.5	-34.8
East Midlands	-0.3	-11.0	-33.9
West Midlands	-3.0	-17.4	-49.4
East of England	-4.2	-19.4	-52.3
London	-10.3	-32.7	-40.3
South East	+2.2	-15.7	-53.2
South West	-3.3	-18.9	-61.0
Wales	+10.4	+2.7	-17.3
Scotland	+8.6	-10.1	-47.4

Figure 4-10 presents spatial maps of the regional hydrogen supply-demand balance for the milestone years 2030 and 2050. The 2030 map illustrates the initial net balance following the full commissioning of HAR-funded projects, while the 2050 map highlights the projected regional deficits that must be addressed through future hydrogen allocation rounds to meet the CCC's BNZ Pathway decarbonisation trajectory for off-road vehicles.

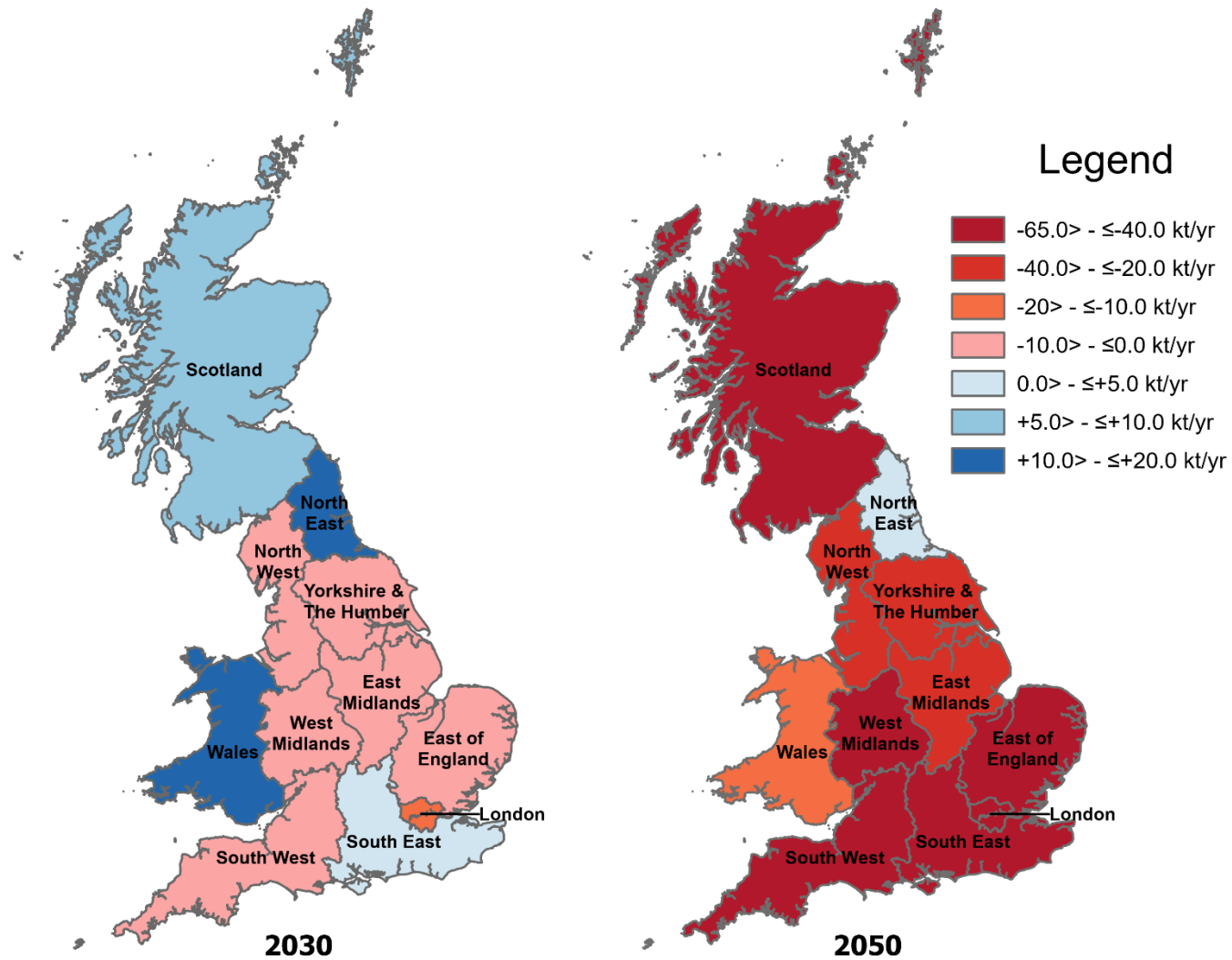


Figure 4-10 Regional Hydrogen Supply-Demand Balance Map - 2030 and 2050

5 Discussion

This section critically evaluates the results in the context of the study's aims and objectives, addressing the research gap in Section 1. It interprets key findings from the sectoral and regional demand patterns and supply-demand imbalances from the results section. The discussion also evaluates the modelling methodology, identifying its strengths and limitations.

5.1 Interpretation of Key Findings

5.1.1 Sectoral Demand Patterns

The most striking outcome of this study is the dominance of agricultural off-road vehicles in total hydrogen demand, which is expected to account for nearly two-thirds of the total by 2050. This outcome is driven by the sector's significant diesel baseline of 1,780.5 kt per year across Great Britain, compared with 820 kt for construction and just 6.1 kt for rail. The prominence of agriculture reflects the highly mechanised nature of UK farming, with sales of agricultural machinery averaging 44,406 units annually between 2019 and 2023 (AEA, n.d.). By comparison, construction machinery sales averaged 32,575 units annually over 2019-2022 (Cosgrove, 2023). RRVs are far smaller in scale, with only 3,207 units in the national fleet, explaining their relatively negligible hydrogen demand. When viewed together, agriculture accounts for around 55.5% of the combined turnover of new agricultural and construction machinery plus the total RRV fleet, a share closely aligned with its projected hydrogen demand of almost two-thirds by 2050.

However, in the near term, construction is the leading driver of hydrogen demand. From 2025 to the early 2040s, the sector outpaces agriculture, a trend that is particularly evident in Figure 5-1. This is due to the early adoption of hydrogen in the construction sector. In contrast, the agriculture sector's first uptake of hydrogen begins in 2029, with less than 10% diesel displacement through hydrogen by 2040, as shown in Table 3-11.

These results offer key insights for government policymakers, who face the mammoth task of decarbonising off-road vehicles, to focus on the construction

sector initially. Early financial incentives and procurement policies may target hydrogen-ready construction equipment, with targeted tax breaks for OEMs and buyers. As agricultural hydrogen uptake grows in the 2040s, incentives should shift accordingly in the late 2030s to support heavy-duty farm equipment.

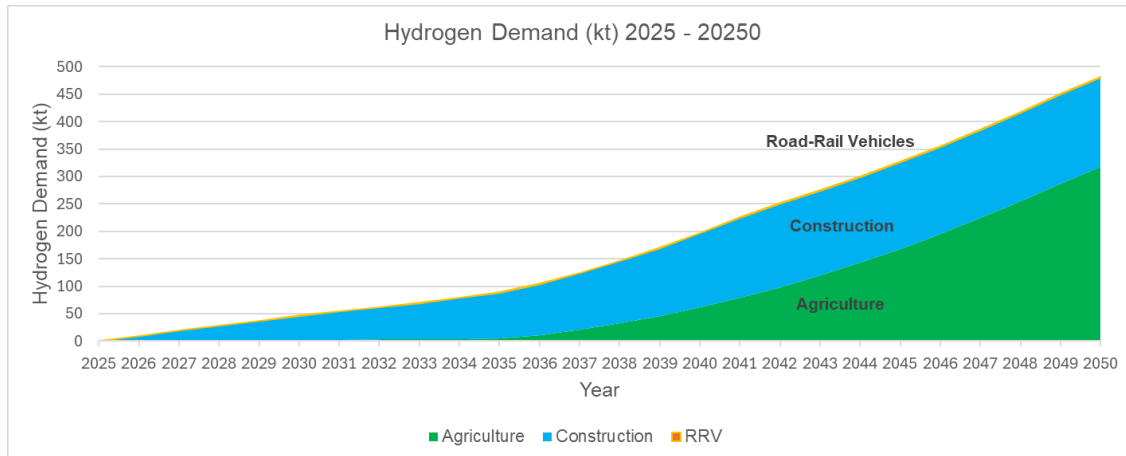


Figure 5-1 Sub-sector Hydrogen Demand Forecast (kt) 2025 - 2050

5.1.2 Regional Demand Patterns

The regional distribution of hydrogen demand for NRMMs changes substantially between 2025 and 2050 (see Figure 4-4). By 2030, London is expected to remain the largest consumer, followed by Scotland and the North West, reflecting the early uptake in construction within dense urban areas and infrastructure hubs.

By 2040, agricultural adoption begins to reshape regional demand profiles; however, London remains the most significant regional consumer, while rural regions such as the South East and Scotland show rapid growth due to increasing hydrogen use in agriculture.

By 2050, agriculture's dominance becomes decisive, with the South West and Scotland as the most significant regions and the North East the smallest. The prominence of hydrogen demand in the South West aligns closely with it being the largest farmed area in England, with 1.72 million hectares (Mha). In contrast, the North East, which has the smallest farmed area of 0.58 Mha, has the smallest demand (DEFRA, 2025). Scotland, despite having the UK's largest farmed area of 5.15 Mha, shows demand comparable to the South West, because of its

extensive grazing lands (Scottish Government, 2024), which have the lowest fuel use among farm types (DEFRA, 2013).

Hydrogen demand from RRVs is modest overall, but regionally uneven. It peaks in Yorkshire and the Humber, reflecting Transpennine Route upgrade works (Network Rail, 2024) and rail freight from the Humber ports, including Immingham, the UK's largest port by tonnage (ABP, n.d.). The North East records the lowest demand, consistent with its lowest passenger journeys in Great Britain (ORR, n.d.). Though small, this demand offers valuable guidance for Network Rail and policymakers.

These trends have clear policy implications. In the short term, the hydrogen supply chain infrastructure should prioritise urban and industrial centres in London, Scotland, and the North West, which have high construction demand, ensuring higher utilisation rates and lower initial distribution costs. Transitioning to the long-term scenario will pose a significant challenge, as the established urban hydrogen refuelling networks will need to be expanded and adapted to serve more dispersed rural areas in agriculturally dominant regions such as the South West and Scotland, which will become the primary demand centres by mid-century. Proactive planning, including rural pipeline extensions, mobile refuelling solutions and targeted incentives for decentralised hydrogen production, will be essential to bridge this spatial shift in demand.

5.1.3 Supply-Demand Imbalance

The modelling reveals an apparent and persistent mismatch between the growth in off-road vehicle hydrogen demand and the supply committed under HAR-funded projects. As shown in Table 3-13, all projects are scheduled for commissioning by 2029. Consequently, from 2030 onwards, total hydrogen supply in this analysis remains almost constant, averaging around 56 kt per year, with only minor fluctuations driven by forecasted changes in FLH. This static supply contrasts sharply with steadily rising demand, resulting in a widening national deficit over time, as illustrated by Figure 4-9.

A critical constraint is that a significant proportion of HAR capacity is already committed to other sectors. Specifically, 52.33% of the total 1,400.2 MW is under official off-take agreements with industries such as mining, asphalt production and other industrial energy users. This portion is therefore excluded from the NRMM decarbonisation potential considered in this analysis. As a result, only 667.4 MW of capacity is assumed to be available for NRMMs.

In the short term, the simultaneous commissioning of HAR projects against relatively low NRMM demand creates a temporary national surplus in 2030. Regional surpluses arise where major HAR projects are located, notably in the North East, Wales and Scotland. This temporary surplus provides a critical window of opportunity for policymakers to plan and invest in future HAR projects, establish interregional transmission infrastructure and start moving hydrogen from surplus to deficit regions. By using this head start effectively, the UK can mitigate the risk of sharp supply-demand imbalances emerging in the later years. Conversely, several regions enter the 2030s with immediate deficits. London faces the most significant shortfall of 10.3 kt, driven by high construction-related hydrogen demand linked to the UK's largest regional construction output cost (ONS, 2025a). At the same time, its hydrogen supply is limited to a single HAR project, with only 40% of its output allocated to mobility applications and the remainder being committed to asphalt production (Hygen Energy, 2025). The South West records no available supply in the model, as both HAR projects, Langage Green Hydrogen (Carlton Power, n.d.) and St Austell Green Hydrogen (Four Zeros Energy, n.d.), are tied to existing offtake agreements in the Mining and Mineral Extraction Industry, while there is no HAR project in the East of England.

Over the long term, these imbalances deepen. By 2050, national supply from HAR1 and HAR2 will only meet about 12% of the projected demand for off-road vehicle hydrogen, with the North East remaining the only region with a surplus. The North East's persistent surplus throughout the timeline aligns with the Tees Valley Cluster's vision of achieving 2.5 GW of low-carbon hydrogen capacity by 2030, building on existing hydrogen pipeline infrastructure in the region linked

with underground storage and industrial users, and plans to export hydrogen to neighbours, including the Humber, Cumbria, and Scotland (Arup, 2022). All other regions face substantial deficits, with the South West requiring over 60 kt of hydrogen per year, the South East and East of England both exceeding 50 kt deficits, and the West Midlands approaching a 50 kt shortfall.

As shown in Figure 22, the result is a shift from a mix of regional surpluses and deficits in 2030 to an almost entirely deficit-driven map by 2050. Essentially, the challenge is not just about total capacity but also a spatial problem. A regional strategy is required to align future hydrogen production with the spatial distribution of NRMM demand, while also investing in infrastructure to transfer hydrogen from surplus to deficit regions.

This aligns with National Energy System Operator's (NESO) Regional Energy Strategic Plans (RESP), which aim to create an integrated framework across electricity, gas and hydrogen sectors at national, regional and local levels to target investment where it is most needed (NESO, n.d.). The 1.5 GW of green hydrogen capacity expected from HAR3 and HAR4, scheduled for 2026 and 2028 (Protium, 2025), together with a further 11 GW planned by 2050 (RenewableUK & Hydrogen UK, 2025), alongside Project Union's proposed 1,500-mile hydrogen transmission network linking regions, production sites, storage facilities, and industrial clusters (National Gas, n.d.), together provide a pathway to balance hydrogen availability with NRMM demand across Great Britain.

5.2 Critical Evaluation of Research

This analysis is subject to several limitations and uncertainties. For agriculture, baseline diesel consumption estimates are drawn from a sub-national residual fuel consumption dataset, which does not distinguish between mobile machinery and stationary fuel use. The assumption that all residual fuel represents diesel consumed by mobile machinery may therefore overestimate hydrogen demand for this sector.

The construction baseline is estimated by applying plant cost percentage shares to regional construction output values, which reflect the current distribution of

construction activity across regions but cannot account for potential future changes in that distribution. In addition, the baseline diesel consumption for construction is based on 2021 data, a year when COVID-19 restrictions reduced activity (ONS, 2022a), meaning actual demand may be understated.

The RRV model also involves simplifications. RRVs are treated as equivalent to their base models before conversion in terms of power rating and BSFC values, with only two load factors considered: idle at 0% and operational at 100%. In reality, NRMMs operate at intermediate loads and follow task-specific duty cycles (Heidari & Marr, 2015). Further uncertainty arises from rounding BSFC values across engine stages. Data completeness was another limitation, as 1.1% of the shifts lacked power rating information, and 20.2% could not be allocated to regions due to incorrect location entries from Network Rail contractors, which reduced the apparent regional demand in this sector.

On the conversion side, the model assumes fixed powertrain efficiencies for H2FC and H2ICE technologies across the entire projection period. Technological advances are likely to improve these efficiencies, potentially lowering future hydrogen demand (Atkins et al., 2021).

On the supply side, this study assumes that the portion of HAR project capacity not already committed to other industries could be fully allocated to NRMM decarbonisation. However, in practice, this capacity may be diverted to competing applications such as industrial heating, power generation, or heavy road transport. If so, the hydrogen supply figures presented here would overestimate the amount ultimately available for NRMMs. For instance, the North West region projects a hydrogen demand of 50 TWh by 2050 across industry, power, transport and homes (Cadent Gas, 2024). Likewise, the East Coast Hydrogen Programme forecasts hydrogen demand of 23.1 TWh for industrial and commercial use and 34.5 TWh for the power sector by 2037 across Teesside, Humber and the East Midlands (East Coast Hydrogen, 2023). Electrolyser efficiency is also held constant, with no differentiation between PEM, AWE, or SOEC technologies. The assumption that all HAR projects remain operational until 2050 may be optimistic, given asset lifetimes and operational uncertainties.

The FLHs applied are based on EU averages from IEA (2023) and do not reflect UK-specific differences driven by renewable generation patterns and grid congestion.

Another constraint arises from the structure of the CCC's BNZ pathway itself. Applying this pathway means that out of the total 2,606.0 kt of diesel currently consumed annually by off-road vehicles, only 1,768.3 kt will be displaced through a combination of hydrogen and electrification, leaving 838.3 kt still in use by 2050. This residual diesel use represents 32.16% of the total baseline, indicating that even under a balanced decarbonisation trajectory, a significant proportion of off-road vehicle diesel consumption will remain unabated without more ambitious policy interventions.

Finally, the lack of directly comparable studies means there is no external benchmark for validating the projections from this study. While this limits the ability to assess the accuracy, it also highlights the originality of the work. Despite these limitations, the study makes a novel contribution by generating the first NUTS Level 1 estimates for off-road vehicle hydrogen demand in Great Britain, benchmarked against committed HAR supply. It combines agriculture, construction, and RRVs within a single analytical framework, applies a bottom-up allocation of RRV fuel demand using operational datasets provided by Network Rail, and develops regional surplus-deficit profiles from 2025 to 2050. These profiles help illustrate potential future imbalances and provide a baseline for more refined analysis to support future HAR project allocation and NRMM decarbonisation research.

6 Conclusion and Recommendations

This study addressed two key gaps in the literature: the absence of national and regional estimates of hydrogen demand for off-road vehicles, and the lack of analysis on how this demand aligns with regional green hydrogen supply from the UK's HARs. By combining the CCC's BNZ pathway with regional diesel baselines and HAR project-level data, the study delivers the first NUTS Level 1 forecast of off-road vehicle hydrogen supply-demand dynamics to 2050.

The results demonstrate that hydrogen will be central to long-term decarbonisation of NRMM. Construction is the early adopter in the 2020s and 2030s, but agriculture becomes the dominant consumer by 2050. Existing HAR projects fall well short, with a national deficit reaching 423 kt/year by mid-century. This shortfall is unevenly distributed; high-demand regions, such as the South West and East of England, have no hydrogen production, while the North East benefits from a modest surplus. Without intervention, these imbalances risk undermining diesel displacement. Additional supply capacity from forthcoming projects, such as HAR3 and HAR4, will be essential, but insufficient to address spatial disparities alone. Strategic initiatives, such as NESO's RESP and Project Union, outline a framework for rebalancing regional supply and demand, but their delivery depends on robust financing mechanisms. The government's Hydrogen Transport and Storage Business Model, expected to announce its first successful projects in Q4 2025, will be critical to enabling this infrastructure (DESNZ, 2023a).

In terms of knowledge contribution, this study introduces a methodology that couples regional modelling with national policy scenarios. It provides the first spatially resolved forecast of off-road vehicle hydrogen demand in Great Britain, with applications in infrastructure planning, policy design, and investment prioritisation. The NUTS 1 lens enables stakeholders to anticipate supply bottlenecks and align production, distribution, and machinery deployment with where and when demand will emerge.

6.1 Future Recommendations

Several evidence-based recommendations follow from these findings. Improving the quality of NRMM data should be the top priority. A comprehensive national inventory, disaggregated by region and sub-sector, is needed to replace partial datasets such as CESAR. Mandating telemetry across NRMM fleets would enable direct measurement of hours, load factors, and fuel use, shifting from top-down estimation to a precise bottom-up approach. The current construction (2021) and agricultural (2022) NRMM fuel consumption baselines are outdated and understated due to the impact of COVID-19; therefore, updated studies should be commissioned on an annual basis.

For RRVs, Network Rail should mandate postcode-based site locations and standardised templates with drop-down inputs for their contractors to eliminate entry errors, addressing the 20.2% allocation gap identified in this study.

Future HARs should prioritise high-demand, undersupplied regions. Investment in inter-regional transfer infrastructure will also be essential to move surplus production to deficit regions and maintain system balance.

Finally, the UK Government should accelerate publication of the overdue Off-Road Machinery Decarbonisation Strategy, ensuring NRMM is recognised in national hydrogen and net-zero planning. With demand projected to reach 481 kt/year by 2050, early policy clarity will be vital to directing infrastructure investment and aligning public and private actions. If these steps are taken, hydrogen can play a transformative role in decarbonising NRMMs, turning a hard-to-abate sector into a key contributor to the UK's net-zero future.

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Appendices

Appendix A Ethical approval letter



26 June 2025

Dear Mr Ahmed ,

Reference: CURES/25828/2025

Project ID: 29362

Title: Local (regional) Matching of Hydrogen Supply and Demand for Off-Road Vehicle Operations in Great Britain

Thank you for your application to the Cranfield University Research Ethics System (CURES).

We are pleased to inform you your CURES application, reference CURES/25828/2025 has been reviewed. You may now proceed with the research activities you have sought approval for.

If you have any queries, please contact CURES Support.

We wish you every success with your project.

Regards,

CURES Team

Appendix B Methodology

B.1 RRV Power Ratings Sheet

Machine Type	OEM	Model	Power Rating (kW)
ATUV-HPV	Kubota	RTVX900	16.10712
Ballast Broom	Windhoff		0
Bulldozer	Komatsu	D41P-6	82
Bulldozer	Caterpillar	D4C	65.6216
Bulldozer	Caterpillar	D4	97
Bulldozer	Caterpillar	D4K	84
Bulldozer	Komatsu	D41E	82
Bulldozer	Caterpillar	D4 Laser Dozer	97
Bulldozer	Komatsu	D51	99
Bulldozer	Caterpillar	D5	127
Bulldozer	Komatsu	D41	82
Bulldozer	Caterpillar	DH4	90
Bulldozer	Caterpillar	D4H	90
Bulldozer	Caterpillar	D3	0
Bulldozer	Komatsu	D37	67.7
Bulldozer	Caterpillar	D5M	126.769
Bulldozer	Caterpillar	D3GXL	57.4189
Bulldozer	Komatsu	D37EX	67.7
Bulldozer	Komatsu	D41P	82
Bulldozer	Caterpillar	D4G	64.8759
Bulldozer	Caterpillar	D5N	90.2297
Bulldozer	Caterpillar	D5C	74.57
Bulldozer	Caterpillar	D5H	123.0405
Bulldozer	Caterpillar	D5K	71.5872
Bulldozer	Komatsu	D37 PX-24	67.7
Bulldozer	Komatsu	D41PX	82
Bulldozer	Komatsu	D37P	67.7
Bulldozer	Caterpillar	CAT D6K2	96.941
Bulldozer	Komatsu	D37E	67.7
Crane	PKR	Crane	0
Crane	Sennebogen	Sennebogen Crane	0
Crane	Sennebogen	Sennebogen Crane	0
Crane	Doosan	DX170W-5	113
Crane	Doosan	DX170CR	113
Crane	Doosan	DX170 Ultimate 270	113
Crane	Doosan	DX170 Ultimate 250	113
Crane	Doosan	Crane	113

Crane	SRS	Front Mount Hiab	160
Crane	Liebherr	A900ZW/1033	105
Crane	Demag	AC55 City	240
Crane	Demag	AC40 City	205
Crane	Kobelco	E200SR-15	92
Crane	Demag	AC100-4L	340
Crane	Spiering	1265-AT6	395.2
Crane	Demag	AC35L	205
Crane	Demag	AC80-2	315
Crane	Demag	AC60	260
Crane	Demag	AC300-6	460
Crane	Demag	AC30	170
Crane	Colmar	T10000	182.6965
Crane	Kobelco	E200	92
Crane	Colmar	T10000FSCG/9A	182.6965
Drainage Machine	Land Rover	Defender	0
Drainage Machine	Unimog	U400 R/R	130
Drainage Machine	Daf	FA 60 Drainliner	112
Drainage Machine	Unimog	M21 VAC	130
Drainage Machine	Mercedes	U1650	114
Drainage Machine	Mercedes	U400 Unimog	130
Drainage Machine	Unimog	U400	130
Drainage Machine	Mitsubishi	Canter	96.941
Drum Roller	Bomag Roller	BW213	95
Dumper	Unknown	Unknown	0
Dumper	Deici Rail-Lite		0
Dumper	Chavtrac		0
Dumper	Thwaites	Accessrailer 14	0
Dumper	Benford	Unknown	0
Dumper	Philmor	Merlin	112
Dumper	JCB	714	107
Dumper	Thwaites	8T	55.4
Dumper	Thwaites	Dumper	55.4
Dumper	Barford	SXR8000	75
Dumper	Terex	Terex R/Rail Dumper	62.5
Dumper	Benford	6001 Swivel Skip	62.5
Dumper	Barford	6000 Swivel Skip	60
Dumper	Thwaites	TD12	80
Dumper	Thwaites	5T	55.4

Dumper	Thwaites	Personnel Carrier	55.4
Excavator	Unknown	Unknown	0
Excavator	Komatsu	D37	0
Excavator	Komatsu	Road Rail Vehicle Tracked	0
Excavator	Galmac	2002	0
Excavator	Galmac	2004	0
Excavator	Galmac	2003	0
Excavator	Galmac	2001	0
Excavator	Tracked	Rail Robot	0
Excavator	Doosan	Unknown	0
Excavator	Thwaites	TD12	0
Excavator	Alumicart		0
Excavator	Rail Bug	Rail Bug	0
Excavator	Liebherr	A924	160
Excavator	Neotec	EW140	105
Excavator	Colmar	T7000FS	115
Excavator	Komatsu	PC138us-2RM	72.6
Excavator	JCB	Rail MAX	128.4
Excavator	JCB	Rail-Max	128.4
Excavator	Doosan	DX170 Ultimate 250	113
Excavator	Colmar	Wheeled Excavator > 20 tonne	112
Excavator	Doosan	DX270 UHL	113
Excavator	JCB	RA310	81
Excavator	Atlas	Atlas Wheeled Heavy Lift	115
Excavator	Atlas	Atlas Tracked Heavy Lift	115
Excavator	Atlas	Atlas	115
Excavator	Atlas	Atlas	115
Excavator	Liebherr	A900 ZW	105
Excavator	Doosan	Doosan	113
Excavator	Terex	Gigarailer	93.9582
Excavator	Komatsu	PW320	110
Excavator	Terex	Gigarailer 12	93.9582
Excavator	Terex	TYPE 9B	93.9582
Excavator	Volvo	Neotec	105
Excavator	Komatsu	138	72.6
Excavator	Kobelco	E200	118
Excavator	Case	988SP2 9B-1	86
Excavator	Case	988SP2 9B	86
Excavator	Case	988P	86
Excavator	Case	988P 9B-1	86
Excavator	Case	988P 9B	86
Excavator	Case	988	86
Excavator	Case	Mega 10	76.4
Excavator	Atlas	9B-1	95
Excavator	JCB	JZ140	81

Excavator	Colmar	T10000FSC	116.3292
Excavator	Colmar	T10000FS	116.3292
Excavator	Case	988SP2	86
Excavator	Daewoo	S130	99
Excavator	Daewoo	S140 WV	96
Excavator	Komatsu	PC110	71.8
Excavator	O&K	MH5S	82
Excavator	JCB	JS175W	129
Excavator	Atlas	Atlas RA300	115
Excavator	Schaeff	HR42	64
Excavator	Mecalac	MBX	82
Excavator	Liebherr	A900CZW	98
Excavator	Liebherr	A900ZW	98
Excavator	Colmar	T10000FS/9B	116.3292
Excavator	Case	WX170	105
Excavator	Doosan	DX170 Ultimate 270	103
Excavator	Komatsu	PW170	76
Excavator	Komatsu	PW150 GOS	74
Excavator	Komatsu	PC128	64
Excavator	Komatsu	PW150 Ultra	80
Excavator	Komatsu	PC138	72.5
Excavator	Komatsu	PC118	72
Excavator	Komatsu	PC138US-11	72.5
Excavator	Kobelco	E200 FSE	118
Excavator	Takeuchi	TB250 Rosenquist Mini Digger	29.1
Excavator	Case	CX135SR Crawlerailer	70.9
Excavator	Case	988P Superailer	86
Excavator	Komatsu	PC138US	72.6
Excavator	Doosan	DX170	113.3464
Excavator	Volvo	EW140	76.5
Excavator	Komatsu	PW150	64
Excavator	Doosan	270	36
Excavator	Komatsu	PW160-11	110
Excavator	Doosan	140	85.7555
Excavator	Doosan	DX170CR	113.3464
Excavator	Caterpillar	M312	100
Excavator	Komatsu	PW160-9	110
Excavator	Doosan	DX160-260 Ultimate	94.7039
Excavator	Colmar	T4300	33.5565
Excavator	Mecalac	14MXT	82
Excavator	Caterpillar	CAT 22/250 TRR-UP	123
Excavator	Fiat Hitachi	EX16.5	76
Excavator	Kobelco	E95	112
Excavator	Volvo	EW180	112
Excavator	Komatsu	PW160	97

Excavator	New Holland	MH2.6	75
Excavator	Komatsu	PW160-7	90
Excavator	Komatsu	PW160-8	97
Excavator	Komatsu	PW118	72
Excavator	Fiat Hitachi	EX80u	40
Excavator	Volvo	EC210B	119
Excavator	Case	CK135SR	70.9
Excavator	Fiat Hitachi	EX50u	26.8
Excavator	Hitachi	EX50U	27.9
Excavator	Hitachi	ZX50U-2	29.8
Excavator	Hitachi	ZX85US	41.8
Excavator	Hitachi	ZX135US	74.9
Excavator	LiuGong	CLG908C3	60
Excavator	Hitachi	ZX17U	10.8
Excavator	McCulloch	Infinity	20
Excavator	McCulloch	Trac Rail Transposer	18.5
Excavator	Liebherr	A900ZW/1033	98
Excavator	UNAC/CAT	22TRR	108
Excavator	Doosan	DX140	134
Excavator	Komatsu	PW150ES Ultimate 250	84
Excavator	GOS	Doosan	113
Excavator	Mecalac	14MBX	82
Excavator	Kobelco	SK135	69
Excavator	Atlas	1604	78
Excavator	Colmar	T4300FS	33.5565
Excavator	Liebherr	A900ZW-972	98
Excavator	Takeuchi	TB250	29.6
Excavator	Atlas	1604 ZW Series	115
Excavator	Doosan	DX170W-5	113.3464
Excavator	Komatsu	PW95	56
Excavator	Hitachi	FH85	42.4
Excavator	Komatsu	PW130	78
Excavator	Komatsu	PW160-8	97
Excavator	JCB	JS145	93
Excavator	Komatsu	PW110	70.9
Excavator	New Holland	E200SR	92
Excavator	Colmar	T7000	33.5565
Excavator	Liebherr	A900	95
Excavator	Liebherr	A922	120
Excavator	Case	WX170 Megarailer	105
Excavator	Kobelco	SK135 RailBug	73
Excavator	Kobelco	SK140	86
Excavator	UNAC/CAT	CAT 22/250 TRR-UP	129
Excavator	Komatsu	PC110RR	71.8
Excavator	Komatsu	PC138US-2	65.6216

Excavator	Mecalac	12MXT	74
Excavator	Doosan	DX160-220	99
Excavator	Takeuchi	TB145	27.96375
Excavator	JCB	535	55
Excavator	Case	988 Superaier	86
Excavator	Case	CX135	70.9
Excavator	Terex	Wheeled Excavator	74.4
Excavator	Case	988 Megarailer	86
Excavator	Doosan	220	109
Excavator	Doosan	DX235/9A	141
Excavator	GOS	Doosan Superbug	141
Excavator	Case	988SP2S	95
Excavator	Colmar	T10000	116.3292
Excavator	Liebherr	A920	120
Excavator	Case	688	67
Excavator	Daewoo	Solar 140	81
Excavator	Liebherr	A900czw-1384	105
Excavator	Liebherr	A900zw-612	105
Excavator	Hitachi	AP235US	128.4
Excavator	JCB	JZ140R	72.8
Excavator	Terex	TW160SR	105
Excavator	Komatsu	PC95	61.52025
Excavator	Case	988P Megarailer	86
Excavator	Komatsu	PW130ES Xtra	78
Excavator	Case	988 Superaier	86
Excavator	Komatsu	PW150ES Ultra Mod K150RH	84
Excavator	Komatsu	PC128US	64.05563
Excavator	Kobelco	SK200	118
Excavator	Kobelco	E135	62.5
Excavator	Kobelco	SK138 RailBug	74
Excavator	Mecalac	14MBXRR	82.7727
Excavator	Colmar	T10000FS/9B-i	116.3292
Excavator	Colmar	T10000FSC/9A	116.3292
Excavator	Colmar	T12000FS	180
Excavator	Colmar	T8000FSCE	150
Flass	McCulloch	Flass	0
Flass	McCulloch	HD Flass	33
Lorry	Unimog	U1650 (427)	0
Lorry	Bedford	Lorry	0
Lorry	Chavtrac	Railboss	0
Lorry	Land Rover	Defender	0
Lorry	Iveco	Truck 33t	0
Lorry	Foden	9A	0
Lorry	Renault	9A	0
Lorry	Road Rail Lorry	9A	0

Lorry	Mercedes	U1650	120
Lorry	CRRC/SRS	Icon 10 Mewp	160
Lorry	CRRC/SRS	Icon 8 Mewp	160
Lorry	Mercedes	Unimog	210
Lorry	MAN	Rocket	186
Lorry	MAN	MPV	186
Lorry	MultiCar	Multi Car	100
Lorry	vroom	madvax	320
Lorry	Zagro	U1650 R/R Vactor Unit	120
Lorry	Volvo	FE4x2	260.995
Lorry	SRS	LRB 12-2T1	160
Lorry	Volvo	Volvo FE 4X2 18T Rigid Truck	260.995
Lorry	Volvo	FE4X2 18tonne rigid truck	260.995
Lorry	SRS	PRB 10-KL	160
Lorry	SRS	Zeck	256
Lorry	SRS	LRB 10-2T1	160
Lorry	SRS	Tensioner	156
Lorry	SRS	LRB 8-2T1	156
Lorry	SRS	PRB 8-KL	156
Lorry	Unknown	Unknown	0
Lorry	JCB	714	107
Lorry	Mitsubishi	Canter (Type 9C)	96.941
Lorry	Land Rover	Road Rail Landrover	184.1879
Lorry	Mitsubishi	Canter	96.941
Lorry	Mercedes	1650	114
Lorry	Mercedes	Unimog 1650	114
Lorry	Zagro	Unimog	0
Lorry	Mercedes	U400	130
Lorry	Volvo	FL6E	130.4975
Lorry	Unimog	U2150	177
Lorry	Mercedes	U400 Unimog	130
Lorry	Unimog	U1650	157
Lorry	Mitsubishi	Canter 7.25t	96.941
Lorry	Geismar	V2R-840-CGR	250
Lorry	Mercedes	400	130
Lorry	Mercedes	1450	100
Lorry	Mercedes	U427	200
Lorry	SRS	FL6E	156
Lorry	SRS	PRB 8 KL RRV Drum Carrier	156
Lorry	Unimog	U900 R/R Chipper Unit	62
Lorry	Unimog	U417 R/R Chipper Unit	82.027
Lorry	Unimog	U1650 R/R Vactor Unit	114
Lorry	Unimog	U1650 R/R Flail Unit	114
Lorry	Unimog	U1650L Crewcab	114
Lorry	Unimog	U400	130

Lorry	Unimog	OUTREACH SCORPION	0
Lorry	Unimog	U400 R/R	130
Lorry	Mercedes	Road Rail Jet/Vac	140
Lorry	Scania	Scania R420 + Cormach 71tm Crane	313.194
Lorry	Land Rover	110 Crew Cab	184.1879
Lorry	Unimog	U1600	116
Lorry	Unimog	U1100	124
Lorry	Unimog	U1400	119.89
Lorry	Unimog	U1400	119.89
Lorry	Mercedes	Road Rail Van	0
Lorry	Zagro	U400	170
Lorry	Zagro	U423	171.511
Lorry	Mitsubishi	978/LH Group/Canter/9C	96.941
Lorry	Zagro	U1650	120
Lorry	Unimog	U1100L	124
Lorry	SRS	SRS RBM 25 HIAB	156
Lorry	Iveco	5.5t	134.226
Lorry	SRS	SRS LRB17 Boom	160
Lorry	SRS	SRS LRB18 Boom	160
Lorry	SRS	SRS Volvo RB32M - 32 Tonne Lorry	160
Lorry	SRS	KRB26	160
Lorry	SRS	25 Tonne Lorry Loader Hiab	160
Lorry	SRS	Front Mount Hiab	179
Lorry	SRS	17 Tonne Crewcab Mewp	160
Lorry	SRS	17 Tonne Mewp	156
Lorry	SRS	3 Boom Mewp	156
Lorry	SRS	25 Tonne Modular Mewp	156
Lorry	SRS	25 Tonne Modular Wiring unit	156
Lorry	SRS	Boom Mewp	156
Lorry	SRS	44 Tonne Artic Hiab	156
Lorry	SRS	25 Tonne Modular Hiab	156
Lorry	SRS	17 Tonne Viaduct Inspection	156
Lorry	SRS	17 Tonne Mewp	156
Lorry	SRS	17 Tonne Lorry Loader Hiab	156
Lorry	SRS	Icon 10 Mewp	160
Lorry	Volvo	FES300	280
Lorry	Mercedes	Shunter	170
Lorry	Unimog	U1000	70.8415
Lorry	Unimog	U1650(427)	157
Lorry	Unimog	U1250	93.2125
Lorry	Mercedes	1617	125
Lorry	Schorling Brock	Actros	460
Lorry	Volvo	25 Tonne Lorry Loader Hiab	225
Lorry	Daf	75	186.425

Lorry	Unimog	U1000 Shunter	75
Lorry	Unimog	1650	114
Lorry	Daf	9A	186.425
Lorry	Mercedes	9A Actross	235
Lorry	Mercedes	Actros	235
Lorry	Mercedes	U1000	75
MEWP		TD18	0
MEWP	Chavtrac	MEWP Module	0
MEWP	LH Access Technology Skyboom		0
MEWP	Terex	Accessrailer 17	0
MEWP	Niftylift	AR17	0
MEWP	Niftylift	RM14 Niftylift	0
MEWP	Elan Mewp - Neotec	9A	0
MEWP	Mercedes	1650	0
MEWP	HTT	HP950	156
MEWP	Doosan		113
MEWP	Neotec	Skyrailer 160	28
MEWP	Neotec	Skyrailer	28
MEWP	Genie	Genie Access Platform	42
MEWP	Neotec	Skyrailer 400RR	34.1
MEWP	SRS	SRS RBM 25 HIAB	156
MEWP	Genie	942/Rexquote/Genie Z6/9B	42
MEWP	Manirail	MRT1742	74.5
MEWP	Genie	Z60/34	38.5
MEWP	Rail Products UK	ART17TH	34.3
MEWP	Manitou	ART17TH	34.3
MEWP	Neotec	Skyrailer 400	34.1
MEWP	Manitou	RR AP ART 17 T(H) MEWP (Type 9A)	34.3
MEWP	Manitou	ART 17	34.3
MEWP	Plasser & Theurer	DTS 62-N/Wiring Train Cradle-Jib Platoform Module	370
MEWP	EVO	RR14 EVO	36
MEWP	Promax	RR14 EVO2-400	36
MEWP	Platform Basket	RR14 EVO-2-400	36
MEWP	Promax	RR14 EVO 1	36
MEWP	Genie	Z60	38
MEWP	Rail Products UK	RP450 V	18.7
MEWP	Evo	RR14	36
MEWP	Promax	RR14 EVO-2	36
MEWP	Rail Products UK	ART17T(H)	34.3
MEWP	Evo	2 RR14	36
MEWP	Evo 2	RR14 EVO-2-400	36
MEWP	Evo 2	RR14 EVO-2-400	36

MEWP	Terex Genie	Z62/40	55
MEWP	Genie	Z60/34 V3 Accessrailer	38.5
MEWP	Genie	Z60/34 V3	38.5
MEWP	Mecalac	11CX	56
MEWP	Genie	Z45/22	47
MEWP	Manitou	ART 17 Panto	34.3
MEWP	Unimog	U400	172.2567
MEWP	ProMax	RR14 EVO 2	36
MEWP	Evo	14-2 RR	36
MEWP	Thwaites	Skyjack	18.49336
MEWP	Mercedes	Unimog	172.2567
MEWP	Promax	EVO14	36
MEWP	Evo 2	Promax RR14 EVO	36
MEWP	Evo 2	Promax RR14 EVO 2	36
MEWP	Platform Basket	RR19 500kg	55.9
MEWP	Promax	RR19/500	55.9
MEWP	Terex Genie	Z60-34	38.5
MEWP	Terex Genie	Z60/34	38.5
MEWP	Mercedes	U400	172.2567
MEWP	Genie	Z62/40	55.1818
MEWP	Platform Basket	RR14EVO	36
MEWP	Manitou	160 ATJ	17.8968
MMPV	McCulloch	MMPV	0
Personnel Carrier	Land Rover	Defender	0
Personnel Carrier	Polaris		0
Personnel Carrier	Terex	PT12AWS	0
Personnel Carrier	Terex	Terex R/Rail Dumper	0
Personnel Carrier	Ford	Rail Ranger Crewcab	0
Personnel Carrier	Bremach	Xtreme 60	0
Personnel Carrier	Mercedes	9A	0
Personnel Carrier	Geismar	Runner Wizard	17.8
Personnel Carrier	Geismar	Mini 4x4	17.8
Personnel Carrier	Bremach		70
Personnel Carrier	Kubota	RTVX900	16.10712
Personnel Carrier	Kubota	RTV900	16.10712

Personnel Carrier	John Deere	Gator	39.5221
Personnel Carrier	Kawasaki	Mule	9.9
Personnel Carrier	EGO4	Rail EGO4 People carrier	0
Personnel Carrier	Fumo	multicar	107
Personnel Carrier	John Deere	Buggy	39.5221
Personnel Carrier	Mitsubishi	Canter (Type 9C)	96.941
Personnel Carrier	Mitsubishi	Welfare Canter	96.941
Personnel Carrier	Isuzu	D-Max	122.2948
Personnel Carrier	JD	Gator	39.5221
Personnel Carrier	Nissan	Navara	121.5491
Personnel Carrier	Ford	Rail Ranger	0
Personnel Carrier	Mitsubishi	Canter	96.941
Personnel Carrier	EGO4	ST/09/04C	0
Personnel Carrier	EGO4		0
Personnel Carrier	Kawasaki	Mule 9C	9.9
Personnel Carrier	Thwaites	5T	55.4
Personnel Carrier	Kubota	RTV	16.10712
Rail Trolley	McCulloch	Rail Trolley	0
Tractor	Valtra	TYPE 9B	173
Tractor	Valtra	T38343; 2172; SV100	173
Tractor	Valtra		173
Tractor	Valmet	830.3	99.9238
Tractor	Valtra	T Series	115.5835
Trailer	Chieftan		0

Appendix C Results

C.1 Regional Diesel Baseline

Region Name	Total Diesel Consumption (kt)	Agriculture Diesel Consumption (kt)	Construction Diesel Consumption (kt)	RRV Diesel Consumption (kt)
North East	70.80	40.85	29.70	0.25
North West	213.48	123.76	88.95	0.78
Yorkshire and The Humber	200.36	141.52	57.67	1.17
East Midlands	199.26	148.67	50.33	0.26
West Midlands	274.21	206.91	66.79	0.51
East of England	285.40	212.30	72.69	0.41
London	206.42	3.26	202.66	0.51
South East	328.23	243.62	84.26	0.35
South West	336.31	280.61	55.34	0.36
Wales	160.22	137.13	22.47	0.62
Scotland	331.88	241.85	89.15	0.89

C.2 Diesel Displacement by Hydrogen

C.2.1 Regional RRVs Diesel Displacement by Hydrogen (kt)

Year	North East	North West	Yorkshire and the Humber	East Midlands	West Midlands	East of England	London	South East	South West	Wales	Scotland
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2026	0.01	0.03	0.04	0.01	0.02	0.01	0.02	0.01	0.01	0.02	0.03
2027	0.02	0.05	0.08	0.02	0.03	0.03	0.03	0.02	0.02	0.04	0.06
2028	0.03	0.08	0.12	0.03	0.05	0.04	0.05	0.04	0.04	0.06	0.09
2029	0.03	0.10	0.15	0.03	0.07	0.05	0.07	0.05	0.05	0.08	0.12
2030	0.04	0.12	0.19	0.04	0.08	0.06	0.08	0.06	0.06	0.10	0.14
2031	0.05	0.14	0.22	0.05	0.09	0.08	0.09	0.06	0.07	0.11	0.16
2032	0.05	0.16	0.25	0.05	0.11	0.09	0.11	0.07	0.08	0.13	0.19
2033	0.06	0.18	0.28	0.06	0.12	0.10	0.12	0.08	0.09	0.15	0.21
2034	0.07	0.21	0.31	0.07	0.14	0.11	0.13	0.09	0.10	0.16	0.24
2035	0.08	0.23	0.35	0.08	0.15	0.12	0.15	0.10	0.11	0.18	0.26
2036	0.08	0.26	0.39	0.09	0.17	0.14	0.17	0.12	0.12	0.21	0.30
2037	0.09	0.29	0.43	0.09	0.19	0.15	0.19	0.13	0.13	0.23	0.33
2038	0.10	0.32	0.47	0.10	0.21	0.17	0.21	0.14	0.15	0.25	0.36
2039	0.11	0.34	0.52	0.11	0.23	0.18	0.22	0.16	0.16	0.27	0.39
2040	0.12	0.37	0.56	0.12	0.25	0.20	0.24	0.17	0.17	0.30	0.42
2041	0.13	0.40	0.61	0.13	0.27	0.21	0.26	0.18	0.19	0.32	0.46
2042	0.14	0.42	0.64	0.14	0.28	0.22	0.28	0.19	0.20	0.34	0.48
2043	0.14	0.43	0.64	0.14	0.28	0.23	0.28	0.19	0.20	0.34	0.49
2044	0.14	0.44	0.65	0.14	0.29	0.23	0.28	0.20	0.20	0.35	0.50
2045	0.14	0.44	0.66	0.15	0.29	0.23	0.29	0.20	0.21	0.35	0.50

2046	0.15	0.44	0.67	0.15	0.29	0.23	0.29	0.20	0.21	0.35	0.51
2047	0.15	0.45	0.67	0.15	0.29	0.23	0.29	0.20	0.21	0.36	0.51
2048	0.15	0.45	0.67	0.15	0.30	0.24	0.29	0.20	0.21	0.36	0.51
2049	0.15	0.45	0.68	0.15	0.30	0.24	0.29	0.20	0.21	0.36	0.51
2050	0.15	0.45	0.68	0.15	0.30	0.24	0.30	0.20	0.21	0.36	0.52

C.2.2 Regional Construction Diesel Displacement by Hydrogen (kt)

Year	North East	North West	Yorkshire and the Humber	East Midlands	West Midlands	East of England	London	South East	South West	Wales	Scotland
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2026	1.04	3.10	2.01	1.75	2.33	2.53	7.06	2.94	1.93	0.78	3.11
2027	2.03	6.07	3.94	3.44	4.56	4.96	13.83	5.75	3.78	1.53	6.09
2028	2.98	8.92	5.78	5.05	6.70	7.29	20.32	8.45	5.55	2.25	8.94
2029	3.87	11.60	7.52	6.56	8.71	9.48	26.43	10.99	7.22	2.93	11.62
2030	4.72	14.12	9.16	7.99	10.60	11.54	32.18	13.38	8.79	3.57	14.15
2031	5.51	16.49	10.69	9.33	12.38	13.48	37.58	15.62	10.26	4.17	16.53
2032	6.26	18.74	12.15	10.60	14.07	15.31	42.69	17.75	11.66	4.73	18.78
2033	7.05	21.13	13.70	11.95	15.86	17.27	48.13	20.01	13.14	5.34	21.17
2034	7.89	23.64	15.33	13.38	17.75	19.32	53.86	22.39	14.71	5.97	23.69
2035	8.86	26.54	17.21	15.02	19.93	21.69	60.47	25.14	16.51	6.71	26.60
2036	9.90	29.66	19.23	16.78	22.27	24.24	67.57	28.09	18.45	7.49	29.72
2037	11.00	32.95	21.36	18.64	24.74	26.92	75.06	31.21	20.50	8.32	33.02

2038	12.05	36.09	23.40	20.42	27.10	29.49	82.22	34.19	22.45	9.12	36.17
2039	13.14	39.35	25.51	22.26	29.54	32.16	89.64	37.27	24.48	9.94	39.43
2040	14.26	42.71	27.69	24.17	32.07	34.91	97.31	40.46	26.57	10.79	42.81
2041	15.42	46.19	29.94	26.14	34.68	37.75	105.23	43.75	28.73	11.67	46.29
2042	16.18	48.47	31.42	27.43	36.39	39.61	110.43	45.91	30.15	12.25	48.58
2043	16.41	49.15	31.86	27.81	36.90	40.16	111.97	46.55	30.58	12.42	49.26
2044	16.64	49.82	32.30	28.19	37.41	40.72	113.51	47.20	31.00	12.59	49.93
2045	16.86	50.50	32.74	28.58	37.92	41.27	115.06	47.84	31.42	12.76	50.61
2046	16.96	50.80	32.93	28.75	38.14	41.52	115.74	48.12	31.60	12.84	50.91
2047	17.06	51.10	33.13	28.92	38.37	41.76	116.42	48.41	31.79	12.91	51.21
2048	17.16	51.40	33.32	29.09	38.59	42.01	117.11	48.69	31.98	12.99	51.52
2049	17.26	51.70	33.52	29.26	38.82	42.25	117.79	48.98	32.17	13.06	51.82
2050	17.36	52.00	33.71	29.43	39.05	42.50	118.48	49.26	32.35	13.14	52.12

C.2.3 Regional Agriculture Diesel Displacement by Hydrogen (kt)

Year	North East	North West	Yorkshire and the Humber	East Midlands	West Midlands	East of England	London	South East	South West	Wales	Scotland
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2026	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2027	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

2028	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2029	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.11	0.35	0.40	0.42	0.58	0.59	0.01	0.68	0.79	0.38	0.68
2031	0.13	0.38	0.44	0.46	0.64	0.66	0.01	0.75	0.87	0.42	0.75
2032	0.19	0.57	0.65	0.68	0.94	0.97	0.01	1.11	1.28	0.63	1.10
2033	0.21	0.65	0.74	0.77	1.08	1.11	0.02	1.27	1.46	0.71	1.26
2034	0.27	0.83	0.95	1.00	1.39	1.42	0.02	1.63	1.88	0.92	1.62
2035	0.31	0.93	1.07	1.12	1.56	1.60	0.02	1.84	2.12	1.03	1.82
2036	0.76	2.30	2.63	2.77	3.85	3.95	0.06	4.53	5.22	2.55	4.50
2037	1.38	4.19	4.79	5.03	7.00	7.18	0.11	8.25	9.50	4.64	8.19
2038	2.17	6.56	7.50	7.88	10.97	11.25	0.17	12.91	14.87	7.27	12.8 2
2039	3.10	9.39	10.74	11.28	15.70	16.11	0.25	18.48	21.29	10.4 0	18.3 5
2040	4.18	12.65	14.47	15.20	21.15	21.70	0.33	24.90	28.68	14.0 2	24.7 2
2041	5.34	16.18	18.50	19.44	27.05	27.76	0.43	31.85	36.69	17.9 3	31.6 2
2042	6.64	20.10	22.99	24.15	33.61	34.49	0.53	39.57	45.58	22.2 8	39.2 9
2043	8.06	24.42	27.93	29.34	40.83	41.89	0.64	48.08	55.38	27.0 6	47.7 3
2044	9.62	29.14	33.32	35.00	48.71	49.98	0.77	57.36	66.06	32.2 8	56.9 4
2045	11.30	34.25	39.16	41.14	57.25	58.75	0.90	67.41	77.65	37.9 4	66.9 2
2046	13.12	39.75	45.46	47.75	66.46	68.19	1.05	78.25	90.13	44.0 4	77.6 8
2047	15.07	45.65	52.20	54.84	76.32	78.31	1.20	89.86	103.5 0	50.5 8	89.2 1
2048	17.15	51.94	59.40	62.40	86.84	89.10	1.37	102.25	117.7 8	57.5 5	101. 51

2049	19.35	58.63	67.05	70.44	98.03	100.58	1.54	115.42	132.9 4	64.9 7	114. 58
2050	21.34	64.66	73.94	77.68	108.10	110.92	1.70	127.29	146.6 1	71.6 4	126. 36

C.3 Hydrogen Demand

C.3.1 Regional Agriculture Hydrogen Demand (kt)

Year	North East	North West	Yorkshire and the Humber	East Midland s	West Midlan ds	East of Englan d	London	South East	Sout h West	Wal es	Scotl and
2025	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2026	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2027	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2029	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2030	0.0	0.1	0.1	0.1	0.2	0.2	0.0	0.2	0.3	0.1	0.2
2031	0.0	0.1	0.1	0.2	0.2	0.2	0.0	0.3	0.3	0.1	0.3
2032	0.1	0.2	0.2	0.2	0.3	0.3	0.0	0.4	0.4	0.2	0.4
2033	0.1	0.2	0.3	0.3	0.4	0.4	0.0	0.4	0.5	0.2	0.4
2034	0.1	0.3	0.3	0.3	0.5	0.5	0.0	0.6	0.6	0.3	0.6
2035	0.1	0.3	0.4	0.4	0.5	0.5	0.0	0.6	0.7	0.4	0.6
2036	0.3	0.8	0.9	0.9	1.3	1.3	0.0	1.5	1.8	0.9	1.5
2037	0.5	1.4	1.6	1.7	2.4	2.4	0.0	2.8	3.2	1.6	2.8
2038	0.7	2.2	2.6	2.7	3.7	3.8	0.1	4.4	5.1	2.5	4.4
2039	1.1	3.2	3.7	3.8	5.3	5.5	0.1	6.3	7.3	3.5	6.3
2040	1.4	4.3	4.9	5.2	7.2	7.4	0.1	8.5	9.8	4.8	8.4
2041	1.8	5.5	6.3	6.6	9.2	9.5	0.1	10.9	12.5	6.1	10.8
2042	2.3	6.8	7.8	8.2	11.4	11.7	0.2	13.5	15.5	7.6	13.4

2043	2.7	8.3	9.5	10.0	13.9	14.3	0.2	16.4	18.9	9.2	16.3
2044	3.3	9.9	11.4	11.9	16.6	17.0	0.3	19.5	22.5	11.0	19.4
2045	3.9	11.7	13.3	14.0	19.5	20.0	0.3	23.0	26.5	12.9	22.8
2046	4.5	13.5	15.5	16.3	22.6	23.2	0.4	26.7	30.7	15.0	26.5
2047	5.1	15.6	17.8	18.7	26.0	26.7	0.4	30.6	35.3	17.2	30.4
2048	5.8	17.7	20.2	21.3	29.6	30.4	0.5	34.8	40.1	19.6	34.6
2049	6.6	20.0	22.8	24.0	33.4	34.3	0.5	39.3	45.3	22.1	39.0
2050	7.3	22.0	25.2	26.5	36.8	37.8	0.6	43.4	49.9	24.4	43.0

C.3.2 Regional Construction Hydrogen Demand (kt)

Year	North East	North West	Yorkshire and the Humber	East Midlands	West Midlands	East of England	London	South East	South West	Wales	Scotland
2025	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2026	0.4	1.1	0.7	0.6	0.8	0.9	2.4	1.0	0.7	0.3	1.1
2027	0.7	2.1	1.3	1.2	1.6	1.7	4.7	2.0	1.3	0.5	2.1
2028	1.0	3.0	2.0	1.7	2.3	2.5	6.9	2.9	1.9	0.8	3.0
2029	1.3	4.0	2.6	2.2	3.0	3.2	9.0	3.7	2.5	1.0	4.0
2030	1.6	4.8	3.1	2.7	3.6	3.9	11.0	4.6	3.0	1.2	4.8
2031	1.9	5.6	3.6	3.2	4.2	4.6	12.8	5.3	3.5	1.4	5.6
2032	2.1	6.4	4.1	3.6	4.8	5.2	14.5	6.0	4.0	1.6	6.4
2033	2.4	7.2	4.7	4.1	5.4	5.9	16.4	6.8	4.5	1.8	7.2
2034	2.7	8.1	5.2	4.6	6.0	6.6	18.3	7.6	5.0	2.0	8.1
2035	3.0	9.0	5.9	5.1	6.8	7.4	20.6	8.6	5.6	2.3	9.1
2036	3.4	10.1	6.5	5.7	7.6	8.3	23.0	9.6	6.3	2.6	10.1
2037	3.7	11.2	7.3	6.4	8.4	9.2	25.6	10.6	7.0	2.8	11.2
2038	4.1	12.3	8.0	7.0	9.2	10.0	28.0	11.6	7.6	3.1	12.3
2039	4.5	13.4	8.7	7.6	10.1	11.0	30.5	12.7	8.3	3.4	13.4
2040	4.9	14.6	9.4	8.2	10.9	11.9	33.2	13.8	9.1	3.7	14.6

2041	5.3	15.7	10.2	8.9	11.8	12.9	35.8	14.9	9.8	4.0	15.8
2042	5.5	16.5	10.7	9.3	12.4	13.5	37.6	15.6	10.3	4.2	16.5
2043	5.6	16.7	10.9	9.5	12.6	13.7	38.1	15.9	10.4	4.2	16.8
2044	5.7	17.0	11.0	9.6	12.7	13.9	38.7	16.1	10.6	4.3	17.0
2045	5.7	17.2	11.2	9.7	12.9	14.1	39.2	16.3	10.7	4.3	17.2
2046	5.8	17.3	11.2	9.8	13.0	14.1	39.4	16.4	10.8	4.4	17.3
2047	5.8	17.4	11.3	9.9	13.1	14.2	39.7	16.5	10.8	4.4	17.4
2048	5.8	17.5	11.4	9.9	13.1	14.3	39.9	16.6	10.9	4.4	17.5
2049	5.9	17.6	11.4	10.0	13.2	14.4	40.1	16.7	11.0	4.5	17.7
2050	5.9	17.7	11.5	10.0	13.3	14.5	40.4	16.8	11.0	4.5	17.8

C.3.3 Regional RRV Hydrogen Demand (kt)

Year	North East	North West	Yorkshire and the Humber	East Midlands	West Midlands	East of England	London	South East	South West	Wales	Scotland
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2026	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.01
2027	0.01	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
2028	0.01	0.03	0.04	0.01	0.02	0.01	0.02	0.01	0.01	0.02	0.03
2029	0.01	0.03	0.05	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.04
2030	0.01	0.04	0.06	0.01	0.03	0.02	0.03	0.02	0.02	0.03	0.05
2031	0.02	0.05	0.07	0.02	0.03	0.03	0.03	0.02	0.02	0.04	0.06
2032	0.02	0.06	0.08	0.02	0.04	0.03	0.04	0.03	0.03	0.04	0.06
2033	0.02	0.06	0.09	0.02	0.04	0.03	0.04	0.03	0.03	0.05	0.07
2034	0.02	0.07	0.11	0.02	0.05	0.04	0.05	0.03	0.03	0.06	0.08
2035	0.03	0.08	0.12	0.03	0.05	0.04	0.05	0.04	0.04	0.06	0.09
2036	0.03	0.09	0.13	0.03	0.06	0.05	0.06	0.04	0.04	0.07	0.10
2037	0.03	0.10	0.15	0.03	0.06	0.05	0.06	0.04	0.05	0.08	0.11
2038	0.04	0.11	0.16	0.04	0.07	0.06	0.07	0.05	0.05	0.09	0.12

2039	0.04	0.12	0.18	0.04	0.08	0.06	0.08	0.05	0.05	0.09	0.13
2040	0.04	0.13	0.19	0.04	0.08	0.07	0.08	0.06	0.06	0.10	0.14
2041	0.04	0.14	0.21	0.05	0.09	0.07	0.09	0.06	0.06	0.11	0.16
2042	0.05	0.14	0.22	0.05	0.10	0.08	0.09	0.07	0.07	0.11	0.16
2043	0.05	0.15	0.22	0.05	0.10	0.08	0.10	0.07	0.07	0.12	0.17
2044	0.05	0.15	0.22	0.05	0.10	0.08	0.10	0.07	0.07	0.12	0.17
2045	0.05	0.15	0.23	0.05	0.10	0.08	0.10	0.07	0.07	0.12	0.17
2046	0.05	0.15	0.23	0.05	0.10	0.08	0.10	0.07	0.07	0.12	0.17
2047	0.05	0.15	0.23	0.05	0.10	0.08	0.10	0.07	0.07	0.12	0.17
2048	0.05	0.15	0.23	0.05	0.10	0.08	0.10	0.07	0.07	0.12	0.17
2049	0.05	0.15	0.23	0.05	0.10	0.08	0.10	0.07	0.07	0.12	0.18
2050	0.05	0.15	0.23	0.05	0.10	0.08	0.10	0.07	0.07	0.12	0.18

C.4 Regional Hydrogen Supply (kt)

Year	North East	North West	Yorkshire and the Humber	East Midlands	West Midlands	East of England	London	South East	South West	Wales	Scotland
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2026	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.92
2027	0.35	1.73	2.12	0.00	0.00	0.00	0.00	0.00	0.00	2.38	9.60
2028	0.35	1.74	2.13	0.00	0.00	0.00	0.00	0.00	0.00	2.39	9.69
2029	17.70	1.75	2.14	2.62	0.87	0.00	0.70	6.98	0.00	11.78	13.65
2030	17.73	1.75	2.14	2.62	0.87	0.00	0.70	6.99	0.00	11.80	13.71
2031	17.48	1.72	2.11	2.59	0.86	0.00	0.69	6.89	0.00	11.63	13.73
2032	17.28	1.70	2.09	2.56	0.85	0.00	0.68	6.82	0.00	11.51	13.54

2033	17.08	1.68	2.06	2.53	0.84	0.00	0.67	6.74	0.00	11.3 7	13.3 9
2034	16.93	1.67	2.05	2.50	0.83	0.00	0.67	6.68	0.00	11.2 7	13.2 3
2035	16.79	1.66	2.03	2.48	0.83	0.00	0.66	6.62	0.00	11.1 7	13.1 1
2036	16.70	1.65	2.02	2.47	0.82	0.00	0.66	6.59	0.00	11.1 2	13.0 0
2037	16.75	1.65	2.02	2.48	0.83	0.00	0.66	6.61	0.00	11.1 5	12.9 4
2038	16.82	1.66	2.03	2.49	0.83	0.00	0.66	6.63	0.00	11.1 9	12.9 8
2039	16.86	1.66	2.04	2.49	0.83	0.00	0.67	6.65	0.00	11.2 3	13.0 3
2040	16.85	1.66	2.04	2.49	0.83	0.00	0.66	6.65	0.00	11.2 2	13.0 6
2041	16.93	1.67	2.04	2.50	0.83	0.00	0.67	6.68	0.00	11.2 7	13.0 5
2042	16.99	1.68	2.05	2.51	0.84	0.00	0.67	6.70	0.00	11.3 1	13.1 1
2043	17.04	1.68	2.06	2.52	0.84	0.00	0.67	6.72	0.00	11.3 4	13.1 6
2044	17.11	1.69	2.07	2.53	0.84	0.00	0.68	6.75	0.00	11.3 9	13.2 0
2045	17.22	1.70	2.08	2.55	0.85	0.00	0.68	6.79	0.00	11.4 6	13.2 6
2046	17.32	1.71	2.09	2.56	0.85	0.00	0.68	6.83	0.00	11.5 3	13.3 4
2047	17.38	1.71	2.10	2.57	0.86	0.00	0.69	6.86	0.00	11.5 7	13.4 1
2048	17.44	1.72	2.11	2.58	0.86	0.00	0.69	6.88	0.00	11.6 1	13.4 6
2049	17.53	1.73	2.12	2.59	0.86	0.00	0.69	6.91	0.00	11.6 7	13.5 1
2050	17.66	1.74	2.13	2.61	0.87	0.00	0.70	6.97	0.00	11.7 5	13.5 8

C.5 Regional Hydrogen Supply-Demand Balance (kt)

Year	North East	North West	Yorkshire and the Humber	East Midlands	West Midlands	East of England	London	South East	South West	Wales	Scotland
2025	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2026	-1.1	-0.7	-0.6	-0.8	-0.9	-2.4	-1.0	-0.7	-0.3	4.9	-1.1
2027	-0.4	0.7	-1.2	-1.6	-1.7	-4.7	-2.0	-1.3	1.8	7.5	-0.4
2028	-1.3	0.1	-1.7	-2.3	-2.5	-6.9	-2.9	-1.9	1.6	6.6	-1.3
2029	-2.2	-0.5	0.4	-2.1	-3.2	-8.3	3.2	-2.5	10.8	9.7	-2.2
2030	-3.2	-1.2	-0.3	-3.0	-4.2	-10.3	2.2	-3.3	10.4	8.6	-3.2
2031	-4.1	-1.8	-0.8	-3.6	-4.8	-12.1	1.3	-3.8	10.0	7.8	-4.1
2032	-4.9	-2.4	-1.3	-4.3	-5.6	-13.9	0.4	-4.4	9.6	6.7	-4.9
2033	-5.8	-2.9	-1.8	-5.0	-6.3	-15.8	-0.5	-5.0	9.3	5.7	-5.8
2034	-6.7	-3.6	-2.4	-5.7	-7.1	-17.7	-1.5	-5.7	8.9	4.5	-6.7
2035	-7.8	-4.3	-3.0	-6.5	-8.0	-20.0	-2.6	-6.4	8.5	3.3	-7.8
2036	-9.3	-5.6	-4.2	-8.1	-9.6	-22.4	-4.6	-8.1	7.6	1.2	-9.3
2037	-11.1	-7.0	-5.6	-10.1	-11.7	-25.0	-6.9	-10.3	6.7	-1.2	-11.1
2038	-13.0	-8.7	-7.2	-12.2	-13.9	-27.5	-9.5	-12.8	5.5	-3.8	-13.0
2039	-15.1	-10.5	-9.0	-14.7	-16.5	-30.0	-12.4	-15.6	4.2	-6.8	-15.1
2040	-17.3	-12.5	-11.0	-17.4	-19.4	-32.7	-15.7	-18.9	2.7	-10.1	-17.3
2041	-19.7	-14.7	-13.1	-20.3	-22.4	-35.4	-19.1	-22.4	1.1	-13.6	-19.7
2042	-21.8	-16.7	-15.1	-23.1	-25.3	-37.2	-22.5	-25.9	-0.6	-17.0	-21.8
2043	-23.5	-18.5	-17.0	-25.7	-28.0	-37.8	-25.6	-29.3	-2.2	-20.0	-23.5
2044	-25.4	-20.5	-19.0	-28.6	-31.0	-38.4	-28.9	-33.1	-4.0	-23.4	-25.4
2045	-27.3	-22.6	-21.3	-31.7	-34.2	-38.9	-32.5	-37.2	-5.9	-27.0	-27.3

2046	-29.3	-24.8	-23.5	-34.9	-37.5	-39.2	-36.3	-41.5	-8.0	- 30.6	-29.3
2047	-31.4	-27.2	-26.0	-38.3	-41.0	-39.5	-40.3	-46.2	-10.2	- 34.6	-31.4
2048	-33.6	-29.7	-28.6	-42.0	-44.7	-39.8	-44.6	-51.1	-12.5	- 38.8	-33.6
2049	-36.0	-32.4	-31.4	-45.9	-48.7	-40.1	-49.2	-56.3	-15.0	- 43.4	-36.0
2050	-38.2	-34.8	-33.9	-49.4	-52.3	-40.3	-53.2	-61.0	-17.3	- 47.4	-38.2