NH2-001 Final Report - Supplementary Document

Contents

SD.1. Data sources and preparation procedures

According to the UK Energy in Brief 2021 report by the UK's Department for Business, Energy and Industrial Strategy (BEIS)[1], the demand for diesel fuel for HDVs in the UK during 2019 was 6,179,000 tonnes. This translates to 5,252,150,000 litres of diesel and a total energy demand of 49,020,066,667 kWh based on the efficiency ratios for hydrogen fuel cell vehicles reported in [1, 2].

The initial data collection on the existing refuelling facilities included 1765 records of warehouse facilities[2], 291 service stations[3] and 53 ports[4]. For the dataset of warehouse facilities, features of each record such as the type of facility, latitude, longitude, and total area are known. The dataset was cleaned and filtered to only include warehouse facilities with a total area greater than 9,000 m^2 which resulted in a dataset of 382 records of warehouse facilities in GB. The dataset of HDV service stations include features such as the type, longitude, and latitude. This dataset was also cleaned and filtered to 111 records of HDV service stations in GB. The dataset of ports include features such as the longitude and latitude, and was cleaned and filtered to 48 records of ports. The three datasets were combined to create a set of 541 records of candidate facilities for hydrogen RSs.

According to the Petrol Retailers Association, approximately 75% of current diesel upliftment for HDV in GB occurs at warehouse facilities (from discussion with PRA in 2021); therefore, it is assumed that 75% of the total hydrogen demand will be supplied through warehouse facilities, and the remaining demand is equally divided between the sets of service stations and ports. The energy demand per warehouse facility is then calculated as a function of warehouse total area; that is, the larger a warehouse is, the larger the expected demand would be. Furthermore, it is assumed that the energy demand to be fulfilled by service

[1] Available at: https://www.gov.uk/government/statistics/uk-energy-in-brief-2021
[2] Data from the Valuation Office Agency (VOA)
[3] Data from ESSO fuels and INDEPENDENT directory
[4] Data from STATISTA

stations and ports are equally distributed amongst the facilities within each set. The set of 541 candidate facilities with their associated annual total demand measured in kWh is geographically plotted across the GB in Figure 1. As a final step, the demand at each facility is converted into kg/day demand. A full list of all facilities with their lat/lon and demand is given in Table S.1.

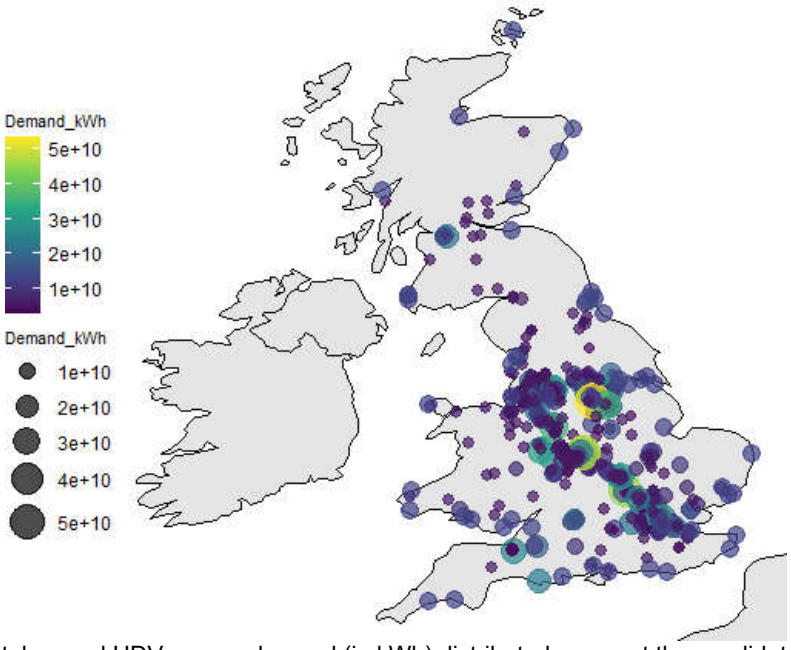

Figure 1 The total annual HDV energy demand (in kWh) distributed amongst the candidate facilities in GB

Production-related data for all the production technologies considered in the project were, on the other hand, adopted from "BEIS' Hydrogen Production Costs 2021" report[5] and tailored into our analysis. The provided data by BEIS includes costs for every 5 years from 2020 to 2050, but for the purposes of our scenario analyses we were only concerned with data from 2025, 2030 and 2050, with 2030 and 2050 being important milestone years for the government's net-zero commitments. All production-related cost elements and parameters for all the three years considered are given in Table S2. We shall refer to the document from BEIS for details on the data collection and assumptions adopted. Data on existing or planned hydrogen production sites in GB were also collected to be fed into the model. These sites with their locations in the grid structure, their production technology, capacity and expected year of launching are presented in Table S3 and were mainly adopted from [3, 4] and desktop search within other online resources and openly available data.

Storage-related data for all the storage technologies considered in the project were adopted from [5, 6] and tailored into our analysis. To extend the costs reported in this sources to the time horizons of 2025, 2030, and 2050 a learning rate related annual cost reduction of 5% is assumed. All storage-related cost elements and parameters for all the three years considered are available in Table S4. Data on identified underground hydrogen storage sites in GB were also adopted from [7]. These sites with their locations in the grid structure are presented in Table S5.

Finally, all transport-related data and parameters needed for the model are presented in Table S6. Note that the only transport mode considered in this study is tube trailer.

[5] Available at: https://www.gov.uk/government/publications/hydrogen-production-costs-2021

SD.2. General assumptions and the conversion rates

- 1 ton of diesel = 850 litres of diesel
- Energy (KWH) per litre of diesel = 10 KWH/L
- Efficiency coefficient for ICE HDVs = 0.42
- Efficiency coefficient for H2 HDVs = 0.45
- 1 MWH H2 (HHV) = 25.4 kg H2
- 1 USD = 0.74 GBP
- 1 EURO = 0.84 GBP
- 1 MW production facility output = 579 kg/day (assuming 95% efficiency)
- Capital cost calculation for production facility: Facility output (MW) × 24 × 365 × 0.95 × CAPEX (£/MWh H2) (Facility output and CAPEX are available from BEIS' Hydrogen Production Costs 2021)
- Operational cost calculation for production facility: all costs but CAPEX (£/MWh H2) × £/kg H2 (all other costs include fixed OPEX, variable OPEX, electricity cost, fuel cost, CO2 T&S cost, carbon cost, etc. and are available in BEIS' Hydrogen Production Costs 2021; £/kg H2 is equal to 0.03937 based on BEIS' Hydrogen Production Costs 2021)
- Blue hydrogen costs are based on "Industrial Retail Price (Central) Baseload" and green hydrogen costs are based on "Grid electricity: Industrial Retail Price (Central) Baseload" in BEIS' Hydrogen Production Costs 2021.
- For storage capital and operational costs an annual learning rate related cost reduction of 5% is considered.
- A capital cost factor (investment return period) of 3 years is assumed.

SD.3. Demand data

Total annual demand for hydrogen (kg) assuming the current road freight demand remains unchanged, and the full road freight fleet is converted into hydrogen powered HDVs is calculated to be 1,245,109,693 kg.

Details of all the Candidate Refuelling Facilities (CRFs) including their location, type and demand is given in Table S.1. The location of CRFs within the grid structure is shown in the figure below.

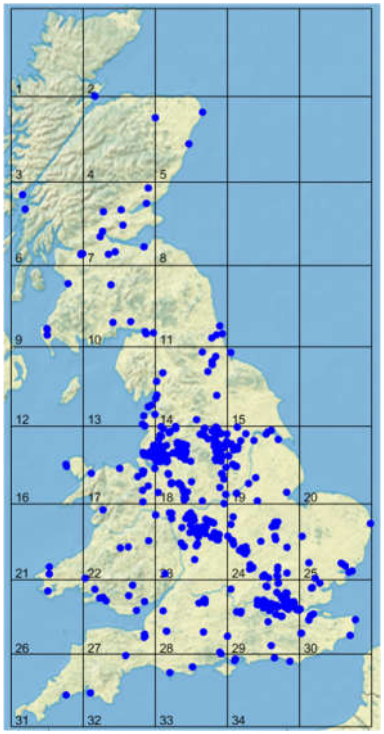

Table S.1. Candidate refuelling stations with their daily demands (W: Warehouse, S: service station, P: port)

CRF ID	Lat	Lon	Type	D (kg/day)
1	51.5575	-1.7257	W	2067.50
2	51.5921	-1.7485	W	1328.76
3	51.1104	-2.9834	W	8230.19
4	51.1064	-2.9958	W	966.39
5	53.4739	-1.4902	W	2054.79
6	51.1429	-2.9911	W	2225.98

CRF ID	Lat	Lon	Type	D (kg/day)
137	53.5371	-1.0374	W	3084.45
138	52.5535	-0.2414	W	2187.88
139	53.3998	-1.3788	W	8074.05
140	53.4255	-1.3603	W	1095.13
141	51.6246	-3.8615	W	1478.91
142	51.1554	0.2947	W	1600.10

CRF ID	Lat	Lon	Type	D (kg/day)
272	52.2777	-2.1598	W	3684.89
273	52.5823	-1.5526	W	9798.64
274	52.5858	-1.5585	W	1046.02
275	52.5771	-1.5452	W	3480.27
276	52.5977	-1.6276	W	1863.62
277	52.5935	-1.6249	W	4487.95

CRF ID	Lat	Lon	Type	D (kg/day)
407	52.8732	-2.1612	S	10244.02
408	52.8932	-2.1305	S	10244.02
409	52.6368	-2.1271	S	10244.02
410	53.9403	-2.7755	S	10244.02
411	53.7966	-2.9854	S	10244.02
412	53.8207	-3.0331	S	10244.02

7	53.4738	-1.4885	W	2010.55
8	51.5481	-1.8523	W	3096.31
9	51.5237	-0.0079	W	2383.67
10	52.7060	-2.4227	W	2201.40
11	51.5045	0.0175	W	7124.57
12	51.5228	-0.0047	W	906.47
13	53.4718	-2.8613	W	1283.59
14	53.4788	-2.8484	W	2007.21
15	51.5222	-0.2794	W	3018.14
16	51.4967	-0.2125	W	1123.81
17	53.3674	-1.4847	W	2828.74
18	53.7893	-2.6469	W	1021.46
19	51.5120	-0.2223	W	1601.20
20	53.4874	-2.8467	W	2531.23
21	53.5114	-1.1255	W	2027.90
22	53.4810	-2.8630	W	2893.65
23	51.5176	-0.2217	W	983.21
24	51.5234	-0.2597	W	889.13
25	51.5191	-0.2239	W	2602.15
26	51.5442	-0.3486	W	4739.59
27	51.5427	-0.3649	W	4319.53
28	53.7822	-1.0466	W	1301.04
29	53.7840	-1.0498	W	6049.85
30	51.5424	-0.3441	W	2106.51
31	53.4039	-2.8115	W	1617.37
32	51.3777	-0.1126	W	2285.02
33	54.3451	-2.7385	W	1261.89
34	51.5287	0.1381	W	1138.91
35	55.8758	-4.3177	W	4209.39
36	55.8752	-4.2867	W	6985.52
37	51.5261	-0.6281	W	7139.19
38	53.4631	-2.3949	W	1123.13
39	51.6212	-0.0400	W	8008.85
40	51.5236	0.1463	W	4578.58
143	52.3166	-1.8838	W	1474.43
144	51.7297	-1.1849	W	1429.10
145	51.5060	-0.4284	W	2413.43
146	51.4515	-0.3835	W	3919.87
147	51.5373	-0.4873	W	1620.59
148	52.1845	-0.8852	W	1140.93
149	53.4597	-2.3038	W	2588.32
150	53.6798	-1.7349	W	4737.82
151	53.4585	-2.3258	W	3028.49
152	52.2181	-0.9500	W	3297.61
153	51.6555	-0.0228	W	3133.03
154	54.8726	-1.5834	W	3518.61
155	51.6567	-0.0283	W	1286.69
156	52.2207	-0.9589	W	921.16
157	52.2134	-0.9511	W	2021.86
158	54.5485	-1.5741	W	2027.14
159	51.6798	-0.0295	W	1035.62
160	52.2760	-0.8706	W	1023.00
161	52.4621	-1.7293	W	1376.05
162	52.4598	-1.7310	W	2804.81
163	51.4967	-0.2125	W	4112.91
164	53.4675	-2.3071	W	3188.00
165	51.5004	-0.2177	W	1770.67
166	53.4657	-2.3392	W	1595.09
167	53.4570	-2.1661	W	1750.91
168	53.4260	-2.2332	W	944.72
169	53.4233	-2.2099	W	1931.11
170	53.4308	-2.2318	W	4607.66
171	53.4333	-2.2312	W	1139.83
172	53.4714	-2.3397	W	2274.88
173	52.3730	-1.4664	W	944.60
174	52.4222	-1.5162	W	1652.77
175	52.3657	-1.4775	W	3701.30
176	52.2207	-0.8579	W	1885.29
278	52.5970	-1.6111	W	14916.97
279	52.5899	-1.6325	W	7144.14
280	52.5259	-1.7738	W	2458.57
281	52.5823	-1.6600	W	1380.78
282	52.5375	-1.7029	W	2535.78
283	52.5253	-1.7030	W	2155.83
284	52.5245	-1.7122	W	1845.53
285	52.5296	-1.7014	W	1910.13
286	52.5268	-1.7012	W	5231.13
287	52.5233	-1.7090	W	1901.05
288	52.5292	-1.6980	W	1569.16
289	53.5562	-1.3507	W	2067.43
290	53.5519	-1.3701	W	5185.58
291	52.6573	-1.1374	W	1792.66
292	53.5394	-1.5105	W	7697.31
293	53.4906	-1.4929	W	9170.96
294	52.5139	-1.8792	W	1647.17
295	52.5228	-1.8880	W	2592.90
296	53.6944	-1.8282	W	2043.16
297	53.6939	-1.8214	W	2007.23
298	53.3525	-2.7467	W	1469.40
299	52.3463	-0.5563	W	2718.47
300	51.6408	-0.1422	W	1249.41
301	51.6420	-0.1325	W	1542.81
302	52.9883	-2.1761	W	10979.59
303	52.9792	-2.1753	W	1748.49
304	51.1326	-2.9951	W	1966.39
305	51.1372	-2.9969	W	1730.77
306	51.5202	-0.0731	W	982.48
307	53.2682	-2.7762	W	1391.96
308	53.2057	-2.4987	W	7196.56
309	53.2037	-2.4978	W	2454.77
310	53.1942	-2.4908	W	3379.61
311	53.1941	-2.4868	W	4026.98
413	53.7718	-1.7308	S	10244.02
414	52.7084	-2.0255	S	10244.02
415	52.6587	-1.9678	S	10244.02
416	52.3246	-2.2239	S	10244.02
417	54.1382	-2.7579	S	10244.02
418	52.2610	-3.4971	S	10244.02
419	52.5559	-2.0330	S	10244.02
420	52.6163	-1.9520	S	10244.02
421	52.5092	-1.8454	S	10244.02
422	52.4991	-1.9092	S	10244.02
423	52.4472	-1.9134	S	10244.02
424	52.4058	-1.8619	S	10244.02
425	52.4453	-1.7213	S	10244.02
426	54.4497	-2.6100	S	10244.02
427	51.9286	-2.5622	S	10244.02
428	54.4497	-2.6100	S	10244.02
429	51.8704	-4.2331	S	10244.02
430	57.4397	-2.7662	S	10244.02
431	52.4622	-1.8411	S	10244.02
432	56.6390	-2.9141	S	10244.02
433	55.0685	-3.2822	S	10244.02
434	55.0591	-3.6530	S	10244.02
435	54.7024	-1.7827	S	10244.02
436	53.4672	-3.0204	S	10244.02
437	53.0482	-2.9141	S	10244.02
438	53.2958	-4.6222	S	10244.02
439	53.4723	-2.3287	S	10244.02
440	53.0801	-0.8131	S	10244.02
441	52.8606	-0.6299	S	10244.02
442	52.2604	-0.9490	S	10244.02
443	52.2320	-1.0047	S	10244.02
444	51.7811	-3.2436	S	10244.02
445	56.3955	-5.4892	S	10244.02
446	52.3703	-0.2444	S	10244.02

41	51.5667	0.1313	W	2230.87
42	51.1698	-1.7582	W	3176.01
43	51.5535	0.1420	W	2347.59
44	51.5997	-1.7335	W	1218.52
45	51.5512	-1.7258	W	1566.90
46	52.5220	-2.2094	W	8937.64
47	53.5008	-2.6337	W	8538.52
48	53.4888	-2.6119	W	4561.48
49	53.5531	-2.6683	W	2776.35
50	53.5564	-2.6663	W	5987.16
51	53.5174	-2.6553	W	2874.48
52	53.5052	-1.1194	W	1364.34
53	53.4998	-1.1264	W	1445.62
54	53.5709	-1.2100	W	1014.24
55	53.6146	-0.9803	W	4444.84
56	53.5091	-1.0433	W	2161.81
57	52.0644	1.1244	W	2069.98
58	51.7610	-0.4282	W	1094.75
59	51.6614	-0.0219	W	1815.21
60	51.5881	-1.7249	W	2594.33
61	51.6005	-1.7328	W	2321.05
62	51.7695	-0.4442	W	5948.98
63	51.7685	-0.4441	W	1207.05
64	51.5834	-1.7586	W	4262.21
65	51.5855	-0.0180	W	2093.81
66	51.6009	-0.0074	W	1002.84
67	51.5855	-0.0180	W	1552.77
68	51.4890	-0.0083	W	1170.96
69	51.4904	-0.0201	W	933.27
70	51.4881	-0.5025	W	894.69
71	51.5132	-0.0283	W	1525.10
72	51.7711	-0.4368	W	1166.41
73	53.0854	-2.2689	W	2324.82
74	52.8597	-1.7810	W	1424.61
177	52.2187	-0.8546	W	4832.23
178	51.9011	-0.2177	W	1172.43
179	51.9055	-0.2186	W	3704.32
180	51.8961	-0.2030	W	1894.35
181	51.6478	-0.0545	W	1126.91
182	52.1882	-0.8927	W	3171.21
183	52.2110	-0.8606	W	4657.05
184	52.2198	-0.9074	W	7716.24
185	52.2140	-0.8595	W	4869.39
186	52.2257	-0.8533	W	1030.81
187	52.2252	-0.8578	W	8861.39
188	52.2219	-0.8718	W	3137.88
189	52.2238	-0.8677	W	2098.93
190	52.2230	-0.8497	W	1985.62
191	51.6533	-0.0263	W	1894.05
192	51.5051	-0.4350	W	1523.72
193	53.1523	-0.6645	W	1189.22
194	52.3739	-1.4797	W	2942.88
195	53.5560	-2.5337	W	1973.72
196	52.4314	-1.4320	W	2992.33
197	52.4309	-1.4291	W	1552.18
198	52.4370	-1.4384	W	1630.71
199	52.4564	-1.5267	W	3177.83
200	52.4572	-1.5303	W	2862.10
201	52.4570	-1.5216	W	2872.30
202	52.3988	-1.5957	W	935.11
203	53.2378	-3.0311	W	3379.39
204	53.2318	-3.0103	W	1914.68
205	53.2300	-3.0145	W	1933.53
206	51.4633	0.2436	W	5858.48
207	51.5020	-0.4284	W	3226.71
208	51.4552	0.2443	W	2302.73
209	51.4580	0.2414	W	1475.46
210	53.4228	-1.2269	W	2057.21
312	51.5176	-0.0568	W	1505.81
313	51.6793	-0.0089	W	1719.33
314	53.2813	-1.2860	W	4072.80
315	52.9849	-2.1780	W	2864.51
316	53.3524	-2.6539	W	1528.79
317	53.4287	-1.2378	W	1929.00
318	53.5105	-1.3857	W	2533.57
319	51.6020	-0.1071	W	8756.99
320	53.5795	-1.4512	W	2574.42
321	51.8939	-0.5180	W	7710.88
322	51.8950	-0.5125	W	1134.45
323	51.9145	-0.4811	W	2767.28
324	52.9746	-2.0942	W	1499.66
325	51.1798	-2.5302	W	6122.80
326	51.1818	-2.5324	W	3762.02
327	53.6378	-1.6625	W	3170.50
328	53.7609	-1.7452	W	3955.33
329	51.4850	0.1759	W	1643.79
330	51.4940	0.1643	W	963.58
331	52.9582	-1.0653	W	4425.77
332	51.4623	0.1919	W	5307.26
333	52.4091	0.3056	W	3390.48
334	53.3589	-1.3907	W	16582.49
335	53.2954	-1.0663	W	6129.67
336	53.2965	-1.0919	W	4885.78
337	53.2988	-1.0789	W	2210.14
338	53.3194	-1.1384	W	10938.64
339	53.3219	-1.1472	W	1756.29
340	53.5345	-2.1610	W	9811.77
341	53.5332	-2.1682	W	1628.93
342	53.5589	-2.1106	W	3047.27
343	53.5321	-2.1656	W	3235.25
344	53.4824	-2.1191	W	3233.54
345	51.6306	-0.1283	W	2975.60
447	52.4094	-0.2628	S	10244.02
448	56.3657	-3.8527	S	10244.02
449	50.8137	-1.0890	S	10244.02
450	51.4711	0.2683	S	10244.02
451	51.9246	-4.9882	S	10244.02
452	50.9036	-1.4170	S	10244.02
453	53.0690	-2.2651	S	10244.02
454	54.6489	-1.5027	S	10244.02
455	51.5746	-0.4690	S	10244.02
456	52.6857	-2.0771	S	10244.02
457	52.6569	-1.9723	S	10244.02
458	52.0145	-0.2025	S	10244.02
459	51.5878	-0.6282	S	10244.02
460	53.7132	-2.4764	S	10244.02
461	52.2689	-0.0088	S	10244.02
462	51.3045	-0.4060	S	10244.02
463	50.8597	-3.3850	S	10244.02
464	53.7727	-1.4713	S	10244.02
465	52.5316	-0.3207	S	10244.02
466	53.1339	-1.3320	S	10244.02
467	51.1151	-1.2547	S	10244.02
468	54.4650	-1.6651	S	10244.02
469	54.9501	-2.9790	S	10244.02
470	52.4116	-1.2475	S	10244.02
471	51.6875	-0.2219	S	10244.02
472	55.8972	-3.6077	S	10244.02
473	55.8685	-3.7475	S	10244.02
474	56.3880	-3.4817	S	10244.02
475	56.2088	-3.4440	S	10244.02
476	56.0761	-3.9216	S	10244.02
477	56.1371	-3.8703	S	10244.02
478	55.5075	-3.6960	S	10244.02
479	53.6976	-1.2667	S	10244.02
480	54.1792	-2.7337	S	10244.02

75	53.5386	-1.1201	W	1651.08
76	52.5619	-1.1833	W	3019.50
77	54.5889	-1.5771	W	924.12
78	52.4589	-2.0427	W	2408.11
79	54.5499	-1.5711	W	923.97
80	53.6013	-1.2662	W	2658.03
81	51.9823	-0.2068	W	2765.75
82	52.0293	1.2119	W	1224.33
83	54.9093	-1.4869	W	5723.18
84	51.4833	-0.0258	W	1259.40
85	52.0124	-0.7252	W	2855.68
86	52.0143	-0.7445	W	13943.15
87	53.6051	-1.2749	W	1712.29
88	52.0111	-0.7295	W	1270.10
89	52.0458	-0.7824	W	1624.90
90	52.0218	-0.7722	W	1093.92
91	51.9890	-0.7909	W	1225.46
92	51.9918	-0.7849	W	5273.13
93	52.0138	-0.7360	W	3034.83
94	52.0026	-0.7330	W	992.05
95	51.6816	-0.0340	W	1640.94
96	53.5926	-2.3102	W	6123.60
97	53.5735	-2.3024	W	922.60
98	53.5694	-2.3032	W	4906.51
99	51.8054	-0.1965	W	2135.29
100	52.6286	-1.7121	W	3943.14
101	51.8090	-0.1872	W	6636.26
102	53.3551	-2.5274	W	1070.74
103	53.7239	-0.4099	W	1262.21
104	53.3496	-2.5288	W	1501.41
105	50.6337	-2.4607	W	7136.21
106	52.6053	-1.6448	W	11235.81
107	53.4149	-2.6118	W	2865.08
108	52.5113	-1.8198	W	3913.48
211	51.8752	-0.3943	W	923.29
212	52.3658	-1.4451	W	1407.53
213	53.3867	-1.5121	W	1939.38
214	52.3724	-1.4537	W	2827.49
215	53.7840	-1.4896	W	2835.88
216	53.7832	-1.5029	W	1582.70
217	53.5004	-2.2028	W	6227.42
218	53.5689	-2.1677	W	2832.44
219	53.5398	-2.7780	W	888.80
220	51.7520	0.5184	W	954.52
221	53.5560	-2.8025	W	1004.18
222	53.5587	-2.7955	W	943.67
223	53.0720	-2.2638	W	2672.61
224	53.7362	-1.5803	W	984.21
225	51.7436	0.5030	W	4352.78
226	51.7457	0.5169	W	4822.16
227	53.6714	-1.5246	W	1770.64
228	53.6436	-1.5119	W	1367.62
229	51.3865	0.4852	W	2947.94
230	51.5109	-0.3658	W	1307.71
231	52.8265	-1.3259	W	1591.94
232	53.0635	-2.2297	W	3481.81
233	53.7199	-1.4181	W	1255.92
234	53.7063	-1.3950	W	1099.04
235	53.6981	-1.3987	W	3764.10
236	53.7024	-1.3969	W	3281.26
237	53.7019	-1.3910	W	1093.59
238	51.4672	0.0209	W	995.68
239	51.4976	-0.2046	W	1050.32
240	53.4267	-2.7042	W	5998.02
241	51.5868	-0.4991	W	1228.83
242	53.7128	-1.5211	W	1449.78
243	53.7145	-1.5247	W	1671.09
244	51.5855	-0.0180	W	5233.80
346	53.7252	-2.4527	W	1080.00
347	51.8906	-0.5080	W	2165.74
348	53.4496	-2.1314	W	1455.68
349	53.4776	-1.4705	W	1233.16
350	53.4459	-1.4622	W	4618.53
351	53.4007	-1.3869	W	3688.64
352	53.4039	-1.4019	W	3643.83
353	52.6004	-1.9947	W	3505.63
354	53.4167	-2.2399	W	2891.20
355	54.1742	-1.4807	W	1095.30
356	52.9431	-1.2945	W	1256.59
357	52.6342	-2.4228	W	9627.50
358	52.2884	-1.9089	W	1173.32
359	53.0880	-2.4176	W	1978.77
360	53.0906	-2.4324	W	4116.38
361	53.0861	-2.4277	W	2310.01
362	53.0881	-2.4304	W	3606.87
363	53.0804	-2.4189	W	3232.88
364	51.5161	-0.0270	W	1384.84
365	51.3259	0.4477	W	2304.75
366	51.3363	0.4467	W	2264.57
367	51.4341	-1.0664	W	1482.38
368	52.5051	-1.9690	W	1723.98
369	51.5214	0.0020	W	1514.26
370	55.8770	-4.3175	W	930.61
371	51.5681	-1.7489	W	5795.54
372	51.4011	-0.2428	W	921.34
373	53.3901	-2.5793	W	2734.79
374	51.1546	0.2836	W	1239.52
375	53.4662	-2.3362	W	2066.04
376	51.3784	-0.1309	W	3082.88
377	52.5214	-1.7739	W	1400.90
378	53.3787	-2.1415	W	4031.28
379	53.5360	-2.1701	W	2550.02
481	55.5220	-4.5926	S	10244.02
482	53.7662	-2.3385	S	10244.02
483	53.3725	-1.4717	S	10244.02
484	53.6315	-2.6908	S	10244.02
485	53.4566	-2.3365	S	10244.02
486	53.3606	-2.5071	S	10244.02
487	51.6450	-3.3228	S	10244.02
488	51.8693	0.5819	S	10244.02
489	50.9916	-0.3411	S	10244.02
490	53.4693	-2.7738	S	10244.02
491	52.2738	-3.3309	S	10244.02
492	52.1120	-1.9438	S	10244.02
493	53.8749	-1.9032	S	10244.02
494	57.1436	-2.0635	P	23689.30
495	52.9679	-0.0151	P	23689.30
496	51.4482	-2.6036	P	23689.30
497	54.9743	-5.0299	P	23689.30
498	51.4527	-3.1610	P	23689.30
499	55.8651	-4.3238	P	23689.30
500	57.6833	-4.0333	P	23689.30
501	51.1258	1.3146	P	23689.30
502	56.4620	-2.9526	P	23689.30
503	51.9646	1.3542	P	23689.30
504	52.0167	-4.9833	P	23689.30
505	53.9220	-3.0080	P	23689.30
506	55.9558	-3.0027	P	23689.30
507	50.3361	-4.6336	P	23689.30
508	56.5619	-5.5456	P	23689.30
509	53.7007	-0.8699	P	23689.30
510	52.5730	1.7375	P	23689.30
511	53.6305	-0.1933	P	23689.30
512	51.9485	1.2858	P	23689.30
513	54.0346	-2.9145	P	23689.30
514	53.3195	-4.6390	P	23689.30

109	53.4317	-2.5098	W	6718.52
110	51.4384	-0.9712	W	3941.89
111	53.3666	-1.4972	W	1846.88
112	51.4185	-0.9808	W	905.63
113	53.6842	-2.6675	W	1518.52
114	52.5908	-0.2630	W	4188.49
115	53.1917	-1.3588	W	3245.19
116	53.4185	-2.6025	W	7315.63
117	53.4086	-2.5341	W	1588.32
118	53.2049	-1.3815	W	2974.07
119	52.5418	-0.2383	W	1725.03
120	52.5014	-1.8532	W	966.16
121	53.0299	-1.4126	W	4061.68
122	51.9387	-0.0110	W	3001.12
123	54.0567	-2.8422	W	3761.49
124	54.9343	-2.8070	W	2070.13
125	51.6757	-0.0246	W	1637.97
126	51.4874	-0.3293	W	2402.80
127	52.5927	-0.2020	W	3659.58
128	53.6724	-2.6461	W	5148.69
129	53.6718	-2.6397	W	1601.27
130	52.5240	-1.8814	W	8067.67
131	54.9221	-2.9585	W	1481.26
132	52.5376	-0.3116	W	3836.10
133	53.5377	-1.0394	W	6439.11
134	53.7894	-2.3424	W	1477.76
135	53.7911	-2.3428	W	1507.72
136	53.5766	-1.1728	W	8382.21

245	51.5855	-0.0180	W	1295.42
246	53.5732	-2.1907	W	7993.01
247	51.5855	-0.0180	W	1815.04
248	51.3979	0.5169	W	1640.74
249	51.3935	0.5124	W	1582.98
250	52.3541	-1.1625	W	929.10
251	52.3577	-1.1595	W	1489.78
252	52.3543	-1.1423	W	4052.46
253	52.3541	-1.1625	W	3015.89
254	52.3054	-1.1260	W	3564.29
255	51.7291	-4.0319	W	3033.76
256	51.5855	-0.0180	W	2073.29
257	53.4617	-2.3121	W	2576.49
258	52.9534	-1.0603	W	1539.54
259	51.8086	0.6765	W	2381.43
260	52.0715	0.4489	W	2507.68
261	53.0168	-2.1971	W	5177.09
262	51.3732	-0.1307	W	1670.02
263	52.3545	-2.9053	W	2663.33
264	52.5278	-1.7882	W	2877.96
265	52.5351	-1.7367	W	1897.42
266	53.5836	-1.5317	W	4442.45
267	53.5262	-1.3270	W	1138.92
268	53.5453	-1.5348	W	3626.34
269	53.5067	-1.4504	W	6046.06
270	52.2816	-2.1759	W	4231.07
271	52.2798	-2.1588	W	3638.84

380	53.5242	-2.1421	W	1227.81
381	51.1013	-2.9983	W	1172.38
382	53.5322	-2.1688	W	1222.40
383	54.4497	-2.6100	S	10244.02
384	53.2699	-3.5121	S	10244.02
385	53.1670	-3.1340	S	10244.02
386	53.2054	-3.0227	S	10244.02
387	53.2062	-4.1065	S	10244.02
388	52.9935	-3.0312	S	10244.02
389	53.3610	-2.7394	S	10244.02
390	53.4224	-2.9150	S	10244.02
391	53.4570	-2.9160	S	10244.02
392	52.9669	-2.7055	S	10244.02
393	52.8494	-3.0266	S	10244.02
394	53.0737	-2.4356	S	10244.02
395	52.7470	-3.8611	S	10244.02
396	52.6818	-2.7609	S	10244.02
397	53.5396	-2.2831	S	10244.02
398	53.3582	-2.0254	S	10244.02
399	53.5183	-2.1455	S	10244.02
400	53.5927	-2.2837	S	10244.02
401	52.7088	-2.4712	S	10244.02
402	53.1016	-2.0097	S	10244.02
403	53.7640	-2.5975	S	10244.02
404	52.9082	-2.1624	S	10244.02
405	53.7307	-2.4526	S	10244.02
406	52.6401	-2.4271	S	10244.02

515	53.7437	-0.3382	P	23689.30
516	52.0534	1.1553	P	23689.30
517	53.4354	-3.0044	P	23689.30
518	54.9833	-5.0333	P	23689.30
519	51.5069	-0.0728	P	23689.30
520	53.4720	-2.2986	P	23689.30
521	51.4068	0.5441	P	23689.30
522	51.7052	-5.0137	P	23689.30
523	50.7833	0.0500	P	23689.30
524	51.5693	-2.9919	P	23689.30
525	58.9855	-2.9602	P	23689.30
526	57.5021	-1.7778	P	23689.30
527	50.3639	-4.1232	P	23689.30
528	50.7090	-1.9864	P	23689.30
529	51.5778	-3.7980	P	23689.30
530	50.7930	-1.1045	P	23689.30
531	51.3314	1.4235	P	23689.30
532	53.6182	-0.7014	P	23689.30
533	53.6968	-0.4443	P	23689.30
534	50.8300	-0.2716	P	23689.30
535	50.8848	-1.3935	P	23689.30
536	54.9069	-5.0296	P	23689.30
537	60.4610	-1.2963	P	23689.30
538	54.9226	-1.3646	P	23689.30
539	51.6134	-3.9286	P	23689.30
540	54.6965	-1.1875	P	23689.30
541	55.0170	-1.4171	P	23689.30

SD.4. Production data

As stated in the report the following production technologies are considered:

- Steam Methane Reformer with Carbon Capture, Usage and Storage (SMR with CCUS)
- Autothermal Reformer with Carbon Capture and Storage (ATR with CCUS)
- Autothermal Reformer with Gas Heated Reformer with Carbon Capture, Usage and Storage (ATR+GHR with CCUS)
- Alkaline Electrolysis (A-E)
- Proton Exchange Membrane Electrolysis (PEM-E)
- Solid Oxide Electrolysis (SO-E)

Table S2. Capital and operational cost of each production technology for different total outputs

Production technology		**SMR with CCUS**		**ATR with CCUS**		**ATR+GHR with CCUS**		**A-E**	**PEM-E**	**SO-E**
Plant size (MW)		300	1000	300	1000	300	1000	10	10	10
Minimum production capacity (kg/d)		869	5791	869	5791	869	5791	29	29	29
Maximum production capacity (kg/d)		173736	579120	173736	579120	173736	579120	5791	5791	5791
Capital cost (£)	**2025**	24,615,920	62,008,676	29,267,794	65,751,654	29,569,530	63,131,569	844,501	828,567	1,611,239
	2035	21,644,180	54,522,719	25,435,768	57,142,804	25,771,072	55,021,783	739,835	588,562	1,128,206
	2050	17,879,974	45,040,507	20,992,839	47,161,528	21,271,361	45,414,805	695,997	520,085	850,167
Unit production cost (£/kg)	**2025**	2.06	2.06	2.08	2.08	1.88	1.88	6.39	6.62	5.26
	2035	2.25	2.25	2.20	2.20	1.99	1.99	5.98	5.99	4.78
	2050	2.37	2.37	2.25	2.25	2.03	2.03	5.87	5.84	4.61

Table S3. Data on existing or planned hydrogen production sites in GB

Name of site	**Location in the grid**	**Production technology**	**Capacity (MW)**	**Operationalised by:**
Teesside	15	Blue	1,000	2030
South Wales Industrial Cluster	26	Blue	1,000	Mid 2020s
Gigastack H2 Project	19	Green	20	2022
Acorn Project	5	Blue	300	2025
H21 North of England Project	18	Blue	12,500	2035
Green H2 for Humberside Project Deployment	15	Green	1,000	2040
EMR Dolphyn Project	5	Green	4,000	2032
Whitelee green hydrogen projects	9	Green	20	2030
Mayflower Immingham h2 project	19	Green	20	2025
H2 Green Project	34	Green	60	2025
Net Zero Teesside	15	Blue	1,000	2025
Caledonia Clean	7	Blue	1,000	2024
DelpHYnus	19	Blue	1,800	2027
Hynet Northwest	17	Blue	300	2025
H2H Saltend	19	Blue	1,800	2026-2027

SD.5. Storage data

As stated in the report the following storage technologies are considered:

- Underground Pipe Storage (UG-PS)
- Underground Lined Rock Cavern (UG-LRC)
- Underground Salt Cavern (UG-SC)
- Overground Compressed hydrogen gas tank at 700 MPa (OG-CH2 GT)

Table S4. Capital and operational cost of each storage technology

Storage technology		**UG-PS**	**UG-LRC**	**UG-SC**	**OG-CH2 GT**		
Minimum storage capacity (kg)		5,000	5,000	5,000	0	5,100	12,500
Maximum storage capacity (kg)		500,000	500,000	500,000	5,000	10,000	25,000
Storage capital cost (£)	**2025**	163,690,035	97,072	49,963	4,884,759	8,312,330	17,095,763
	2035	98,007,271	58,121	29,915	2,924,685	4,976,899	10,235,865
	2050	45,405,909	26,927	13,859	1,354,981	2,305,754	4,742,187
Unit storage cost (£/kg/day)	**2025**	0.07	0.03	0.03	7.98	4.14	0.64
	2035	0.04	0.02	0.02	4.78	2.48	0.39
	2050	0.02	0.01	0.01	2.21	1.15	0.18

Table S5. Data on existing underground hydrogen storage sites in GB

Name of site	**Location in the grid**	**Storage technology**
Hornsea - Atwick	24	UG-SC
Hornsea - Aldbrough	19	UG-SC
Saltholm (Teesside)	24	UG-SC
Holford, H-165	7	UG-SC
Hole House Farm	18	UG-SC
Byley	18	UG-SC
Preesall	22	UG-SC

SD.6. Transportation data

Table S6. Transport-related parameters

Transportation mode	Tube trailer
Transport unit capacity (kg/mode)	900
Fuel economy within grid (km/L)	2.30
Fuel economy between grids (km/L)	2.55
Average speed within grid (km/hr)	25
Average speed between grids (km/hr)	55
Mode availability within grid (hr/d)	15
Mode availability between grids (hr/d)	18
Load/unload time (hr)	2
Driver wage (£/hr)	17.02
Fuel price (£/L)	1.49
Maintenance expenses (£/km)	0.0732
General expenses (£/d)	6.08
Transport mode cost (£/mode)	185,000

SD.7. Optimisation results

Table S7. Optimisation results for scenarios SC_0 to SC_5 for different KPIs

KPI	Scenario					
	SC_0	**SC_1**	**SC_2**	**SC_3**	**SC_4**	**SC_5**
Cost per kg H2 at pump (£/kg)	£3.13	£3.32	£2.88	£2.64	£3.79	£3.80
Percentage on-site production	72%	55%	92%	97%	1%	0%
Percentage centralised production	28%	45%	8%	3%	99%	100%
Percentage Green H2	1%	1%	1%	2%	1%	0%
Percentage Blue H2	99%	99%	99%	98%	99%	100%
Total daily cost of HSC (£/day)	£10.68 Million	£11.34 Million	£9.82 Million	£9.00 Million	£12.93 Million	£12.95 Million
Total capital investment (£)	£3.51 Billion	£3.92 Billion	£2.90 Billion	£2.05 Billion	£4.68 Billion	£4.79 Billion
Capital investment requirement for production facilities (£)	£2.37 Billion	£2.09 Billion	£2.54 Billion	£1.88 Billion	£421.27 Million	£412.77 Million
Capital investment requirement for storage facilities (£)	£912.18 Million	£1.46 Billion	£275.15 Million	£136.22 Million	£3.46 Billion	£3.57 Billion
Capital investment requirement for transport infrastructure (£)	£231.13 Million	£360.27 Million	£81.95 Million	£35.55 Million	£798.86 Million	£810.01 Million
Daily operating cost of all production facilities (£/d)	£7.00 Million	£7.00 Million	£7.03 Million	£7.07 Million	£7.02 Million	£6.92 Million
Daily operating cost of storage facilities (£/d)	£2,000.00	£3,200.00	£600.00	£300.00	£7,400.00	£7,400.00
Daily operating cost of transportation network (£/d)	£474.86 Thousand	£761.08 Thousand	£135.27 Thousand	£58.24 Thousand	£1.63 Million	£1.64 Million
Number of transport units needed	1,249	1,947	443	192	4,318	4,378
No of SMR with CCUS 300 MW	1	1	1	1	0	0
No of SMR with CCUS 1000 MW	0	0	0	0	0	0
No of ATR with CCUS 300 MW	0	0	0	0	0	0
No of ATR with CCUS 1000 MW	0	0	0	0	0	0
No of ATR+GHR with CCUS 300 MW	110	95	118	87	13	13
No of ATR+GHR with CCUS 1000 MW	0	1	0	0	3	3
No of A-E 10 MW	0	0	0	0	0	0
No of PEM-E 10 MW	0	0	0	0	0	0
No of SO-E 10 MW	9	10	14	17	10	0
No. of large (up to 500 t H2) UG-PS storage sites	20	32	6	3	74	74
No. of large (up to 500 t H2) UG-LRC storage sites	0	0	0	0	0	0
No. of large (up to 500 t H2) UG-SC storage sites	0	0	0	0	0	0
No. of Small (up to 5 t H2) OG-CH2 GT storage sites	3	7	2	0	77	154
No. of medium (up to 10 t H2) OG-CH2 GT storage sites	0	0	0	0	0	0
No. of large (up to 250 t H2) OG-CH2 GT storage sites	0	0	0	0	0	0

Table S8. Optimisation results for scenarios SC_6 to SC_11 for different KPIs

	Scenario					
KPI	**SC_6**	**SC_7**	**SC_8**	**SC_9**	**SC_10**	**SC_11**
Cost per kg H2 at pump (£/kg)	£6.19	£14.63	£4.03	£3.12	£3.53	£3.41
Percentage on-site production	11%	31%	100%	40%	100%	88%
Percentage centralised production	89%	69%	0%	60%	0%	12%
Percentage Green H2	100%	31%	31%	0%	12%	2%
Percentage Blue H2	0%	69%	69%	100%	88%	98%
Total daily cost of HSC (£/day)	£21.13 Million	£9.98 Million	£2.75 Million	£10.66 Million	£12.05 Million	£11.63 Million
Total capital investment (£)	£4.30 Billion	£3.35 Billion	£842.37 Million	£2.88 Billion	£4.30 Billion	£4.62 Billion
Capital investment requirement for production facilities (£)	£538.16 Million	£377.90 Million	£842.37 Million	£2.41 Billion	£4.30 Billion	£3.74 Billion
Capital investment requirement for storage facilities (£)	£3.16 Billion	£2.44 Billion	£0.00 Thousand	£762.25 Thousand	£0.00 Thousand	£786.98 Million
Capital investment requirement for transport infrastructure (£)	£598.32 Million	£529.78 Million	£0.00 Thousand	£471.82 Million	£0.00 Thousand	£95.35 Million
Daily operating cost of all production facilities (£/d)	£15.73 Million	£5.76 Million	£1.98 Million	£7.02 Million	£8.12 Million	£7.21 Million
Daily operating cost of storage facilities (£/d)	£6,600.00	£5,300.00	£0.00	£2,750.00	£0.00	£1,600.00
Daily operating cost of transportation network (£/d)	£1.47 Million	£1.16 Million	£0.00 Thousand	£1.00 Million	£0.00 Thousand	£197.97 Thousand
Number of transport units needed	3,234	2,864	0	2,550	0	515
No of SMR with CCUS 300 MW	0	0	19	4	135	69
No of SMR with CCUS 1000 MW	0	0	0	20	0	0
No of ATR with CCUS 300 MW	0	0	0	0	0	0
No of ATR with CCUS 1000 MW	0	0	0	0	0	0
No of ATR+GHR with CCUS 300 MW	0	12	20	53	27	86
No of ATR+GHR with CCUS 1000 MW	0	1	0	1	0	0
No of A-E 10 MW	0	0	0	0	0	0
No of PEM-E 10 MW	0	3	3	512	0	0
No of SO-E 10 MW	633	89	89	0	113	26
No. of large (up to 500 t H2) UG-PS storage sites	66	53	0	0	0	8
No. of large (up to 500 t H2) UG-LRC storage sites	0	0	0	0	0	0
No. of large (up to 500 t H2) UG-SC storage sites	0	0	0	55	0	0
No. of Small (up to 5 t H2) OG-CH2 GT storage sites	123	28	0	0	0	1
No. of medium (up to 10 t H2) OG-CH2 GT storage sites	0	0	0	0	0	0
No. of large (up to 250 t H2) OG-CH2 GT storage sites	0	0	0	0	0	0

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