December 2022

CAP23 Emissions Analysis

Key Scenarios

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Purpose of Analysis

- Purpose: develop prospective carbon emission budget compliant pathways for a range of scenarios requested by DECC as part of their Climate Action Plan preparations

- Not an indication by EirGrid Group of feasibility / deliverability of various emissions scenarios
  - Central Emissions Scenario (~80 Mt CO2 cumulative across decade) presented on 21/11/22 is very optimistic for 2030

- Analysis is Goal Seek
  - Understand impact of changes to uptake of renewable and conventional generation, demand, storage, renewable gas etc. on emissions.

- Comparative analysis based on scenarios requested by DECC
  - Indicative magnitudes of CO2 emissions
  - Emissions analysis is unconstrained
  - Detailed review using tool such as the Energy Transition Model (ETM) required
    - Standard approach across Europe – indicative analysis to inform detailed review

- Assumption: plan led approach rather than developer led approach implicit in analysis
  - Developer led approach will result in higher constraints, putting renewables / emissions targets at higher risk

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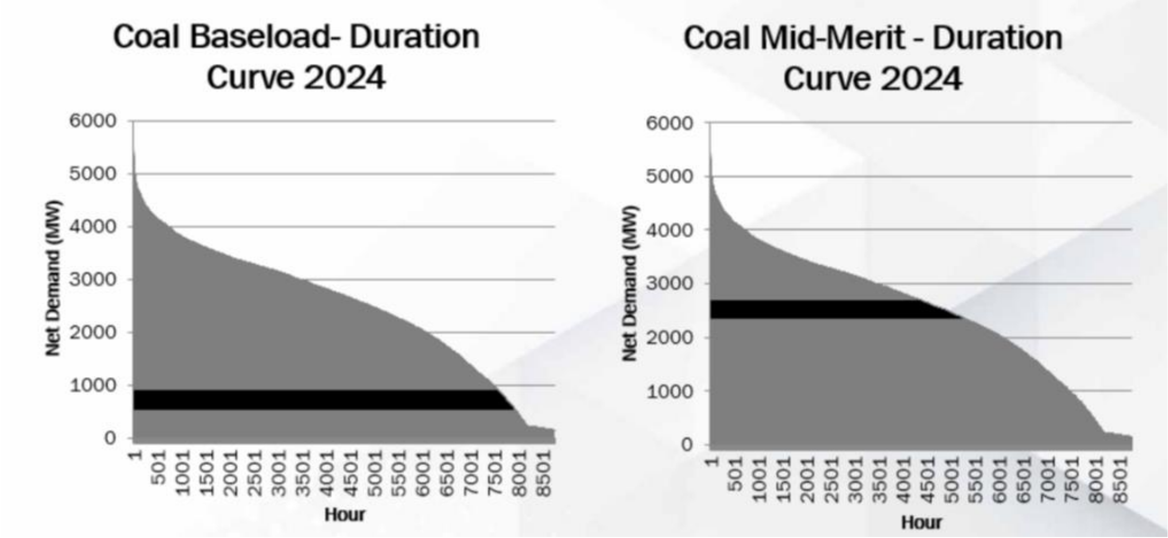
Emissions Study Approach (1)

Use a net load duration curve to calculate thermal running needs and, by extension, emissions

- Approach based on commercial software methodology, albeit focussed on emissions and leans into technical parameters and methods used by ENTSOE, industry
  - Total Electricity Requirement (TER) demand for each hour across 10 years taken GCS modelling
  - Net demand created by subtracting forecasted variable renewables and interconnection flows
  - Merit order approach to meet remaining demand from storage and conventional generation

- Validated against ETM emissions model, academia, peer analysis

- Emissions analysis the order of days versus weeks



Emissions Study Approach (2)

- This emissions model allows an assessment of an array of scenarios in a very short period of time. Using more detailed analysis tools and inputs would take much more time and would not have aligned with Climate Action Plan 2023 timelines.
- The model uses a net demand approach to calculate thermal running needs and, by extension, emissions. By determining the thermal running needs to meet the demand a “near-perfect” dispatch is identified.
- In reality the near-perfect dispatch (market based economic dispatch) will differ from the operational real-time dispatch, as it does not consider the technical constraints of managing a safe, secure and reliable transmission network. The associated costs of managing this and moving units away from their market based schedule are generally referred to as imperfections costs.
- The reasons for imperfections costs include operational constraints such as generator must-run rules, min-gen limits, voltage regulation requirements, interconnector limits, SNSP limits etc.
- An “imperfection multiplier” is used in the model to represent these operational constraints.
- The value chosen for the imperfections multiplier accounts for all the imperfections due to operational constraints, and is based on an average of the emissions due to imperfections in 2019 and 2020 .
- The operational constraints cannot be individually tuned or adjusted in this model. That type of analysis is best carried out in more detailed techno-economic analysis software such as Plexos.

SOEF V1.1 Wave 2 – Emissions

Focus on central emissions scenario- very optimistic for 2030: (Central)

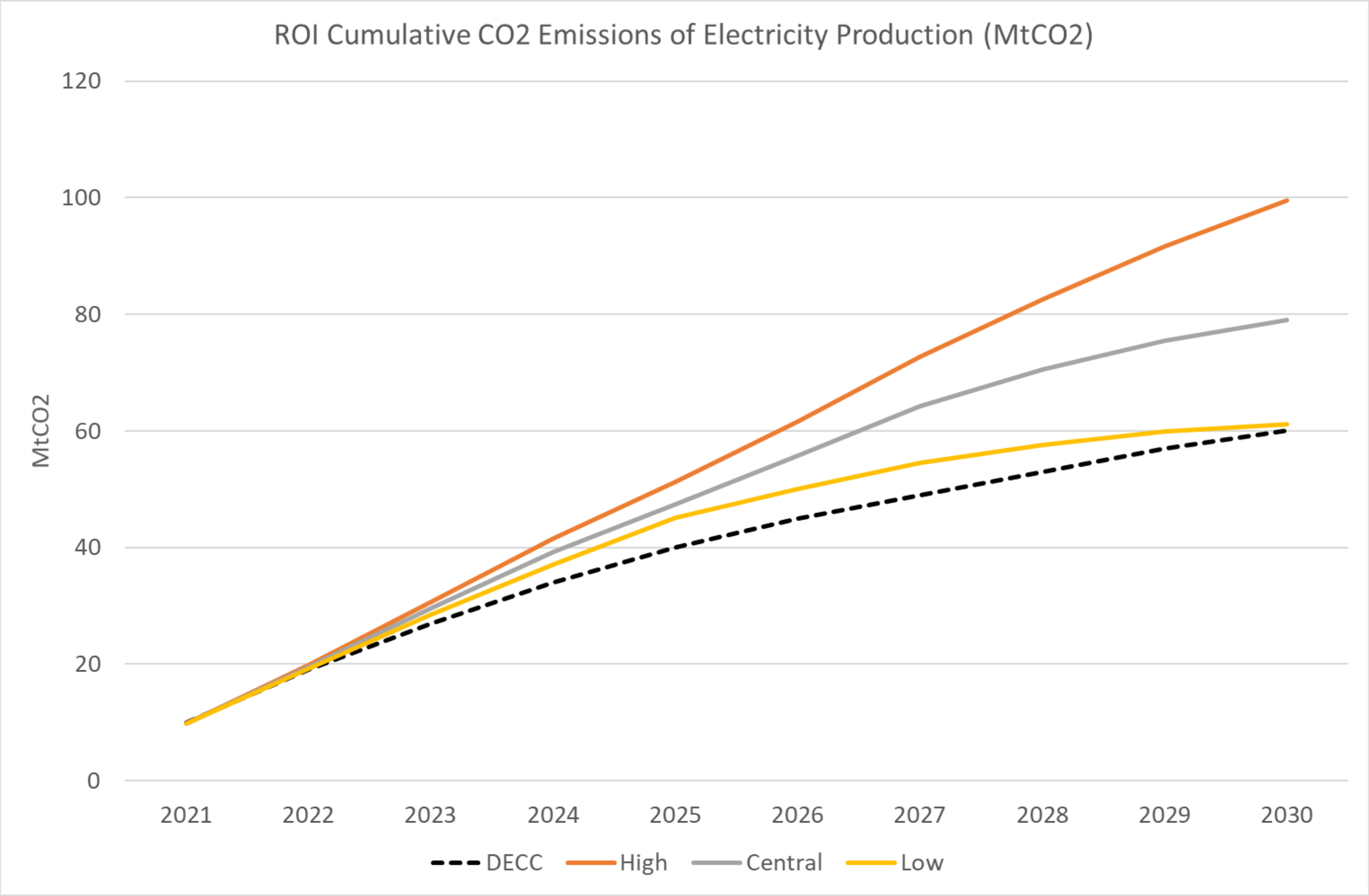
- ~ 13.5 GW of new renewable connections
- ~ 2GW of new thermal plant
- ~ 600 MW of new short duration batteries
- ~1700 MW of long duration batteries
- Transformation of transmission network (up to ~ 400 projects)
- Transformation of system operations (policies, standards, services, tools etc.)
- Transformation of electricity markets (RES alignment, integration with GB / EU)
- Significant levels of demand response (20%+)
- Additional HVDC interconnector

Focus on low emissions scenario – very significant concerns: (Low)

- Accelerated median measures above (already very optimistic, e.g. transmission)
- Accelerated renewables & storage deployment
- MP as a peaker from 2025 (assumption: adequate for SOS)
- Biomethane and hydrogen injection
- Low GCS demand forecast

Focus on high emissions scenario: (High)

- Delayed median measures above
- RES-E of 80% achieved in 2033
- High GCS demand forecast



Key Scenarios

Scenario	Demand	Moneypoint	Capacities: Renewable	Capacities: Storage	Capacities: Thermal	Fuel: Renewable Gas
Central	Median	Baseload to 2025 then mid-merit	SOEF	GCS22-31 and SOEF	GCS22-31	No
High	High	Baseload to 2025 then mid-merit	Delayed	GCS22-31 and SOEF	GCS22-31	No
Low	Low	Baseload to 2025 then peaker	Accelerated	Accelerated	GCS22-31	Yes
DECC Final Low	Median	Baseload to 2025, mid-merit in 2026 then peaker	Increased (2GW) and Accelerated	Increased & Accelerated+	Increased	Yes (delayed)

Key Scenarios- annual emissions estimates

Scenario	Central	High	Low	DECC Low Final
Year	**Central**	**High Demand Delayed RES**	**Low Demand Accel RES Accel Stor 100% Ren. Gas**	**DECC Final Scenario**
2021	9.9	9.9	9.9	9.9
2022	9.7	10.1	9.4	9.8
2023	10.0	10.8	9.3	10.1
2024	9.6	10.8	8.6	9.2
2025	9.4	10.9	7.7	8.8
2026	8.1	10.1	5.0	6.2
2027	8.2	10.7	4.5	5.7
2028	6.2	9.7	3.0	3.2
2029	4.8	8.8	2.4	2.7
2030	3.5	7.6	1.2	1.4
Total	**79.5**	**99.2**	**61.0**	**66.9**

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Demand (1)

Scenario	Demand	Moneypoint	Capacities: Renewable	Capacities: Storage	Capacities: Thermal	Fuel: Renewable Gas
Central	Median	Baseload to 2025 then mid-merit	SOEF	GCS22-31 and SOEF	GCS22-31	No
High	High	Baseload to 2025 then mid-merit	Delayed	GCS22-31 and SOEF	GCS22-31	No
Low	Low	Baseload to 2025 then peaker	Accelerated	Accelerated	GCS22-31	Yes
DECC Final Low	Median	Baseload to 2025, mid-merit in 2026 then peaker	Increased (2GW) and Accelerated	Increased & Accelerated+	Increased	Yes (delayed)

Demand was taken from GCS22-31

Energy Demand (TER)	Units	2022	2023	2024	2025	2026	2027	2028	2029	2030
Low	TWh	33.0	34.1	35.4	36.0	37.0	37.8	38.6	39.3	40.0
Median	TWh	33.7	35.7	37.5	38.5	39.9	41.3	42.7	43.9	45.1
High	TWh	34.4	37.2	40.1	41.6	43.6	45.6	47.4	48.8	50.1

Peak Demand	Units	2022	2023	2024	2025	2026	2027	2028	2029	2030
Low	GW	5.7	5.8	5.9	5.9	5.9	6.0	6.0	6.0	6.1
Median	GW	5.8	6.1	6.4	6.5	6.6	6.7	6.8	6.9	7.0
High	GW	6.0	6.3	6.7	6.8	7.0	7.2	7.3	7.4	7.5

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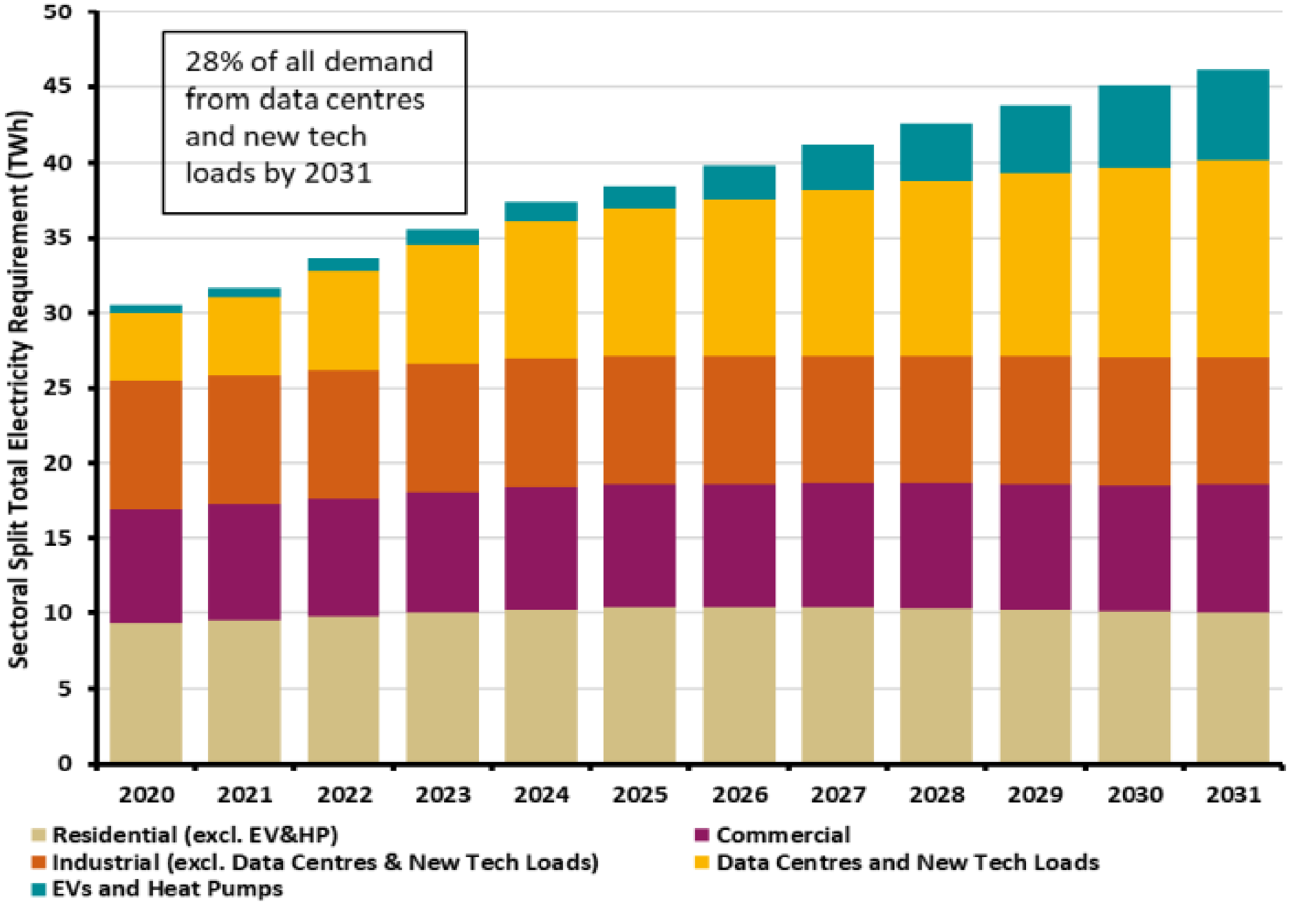
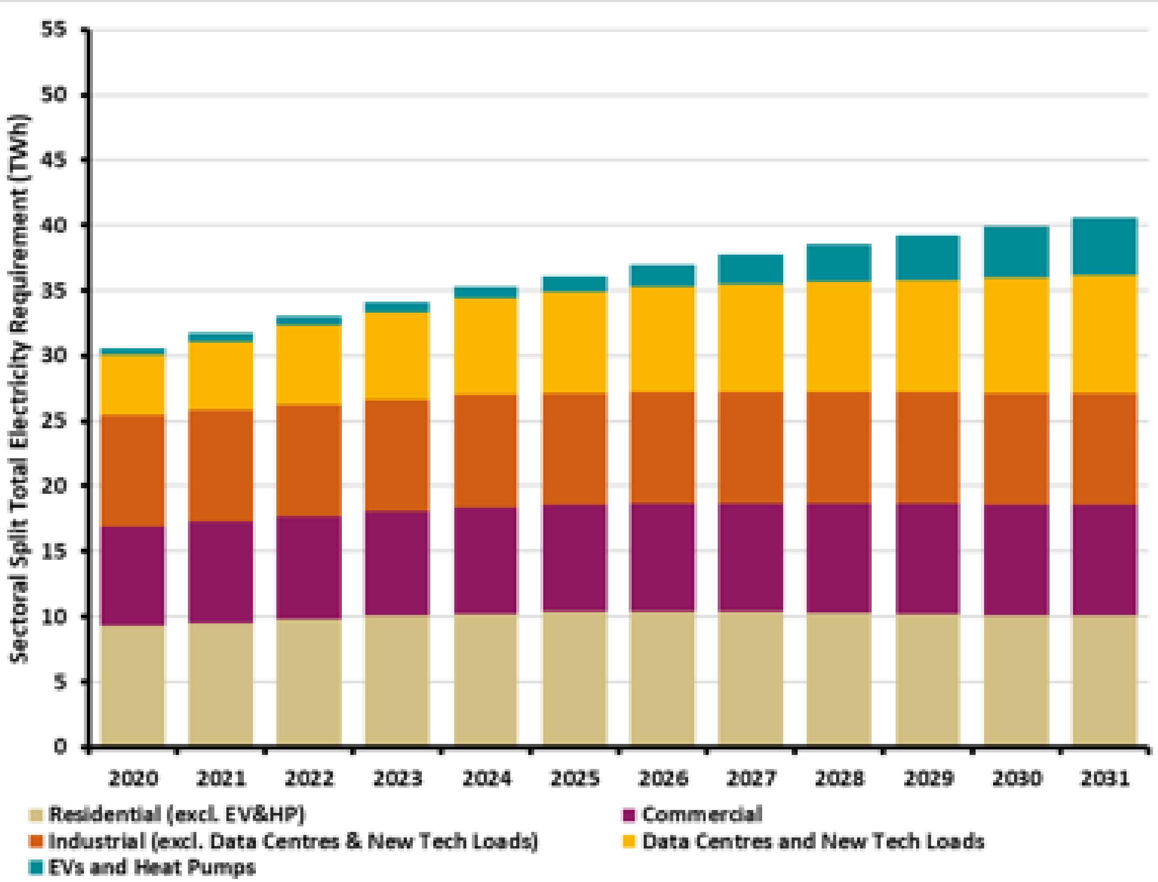
Demand (2)

GCS 2022 Data - Median Demand



GCS 2022 Data - Low Demand



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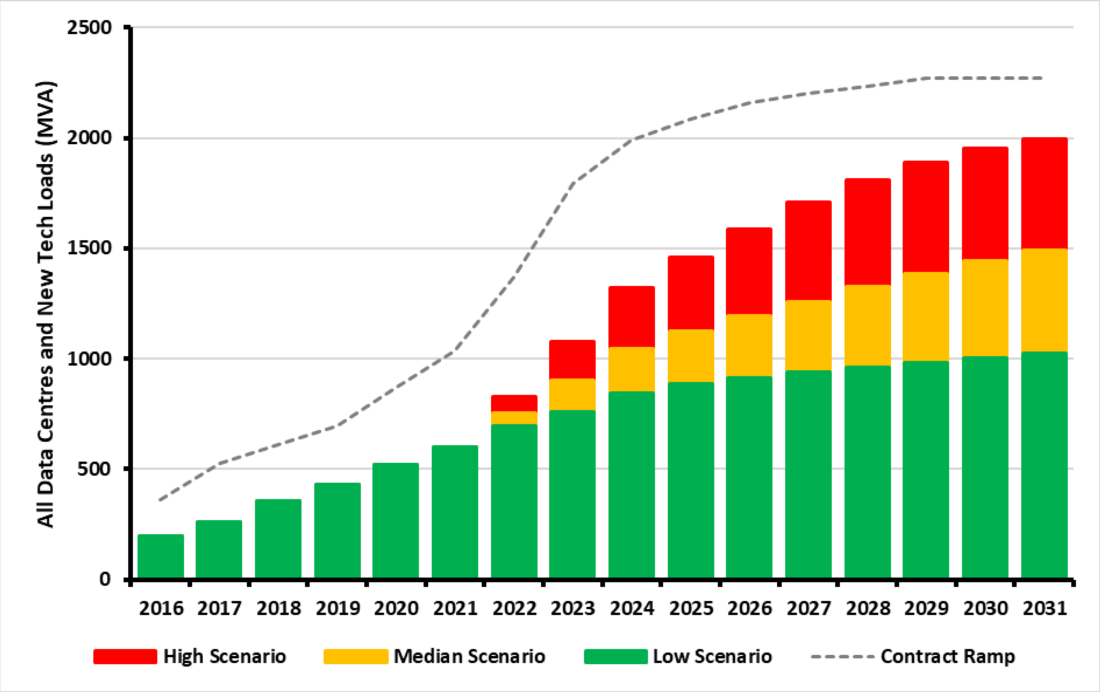
Demand (3) - LEU



	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030
Low	TWh	6.1	6.7	7.4	7.8	8.0	8.2	8.4	8.6	8.8
Median	TWh	6.6	7.9	9.1	9.8	10.4	11.0	11.6	12.1	12.6
High	TWh	7.3	9.4	11.6	12.8	13.9	15.0	15.9	16.6	17.1

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Renewable Deployment

			Capacities			Fuel
Scenario	Demand	Moneypoint	Renewable	Storage	Thermal	Renewable Gas
Central	Median	Baseload to 2025 then mid-merit	SOEF	GCS22-31 and SOEF	GCS22-31	No
High	High	Baseload to 2025 then mid-merit	Delayed	GCS22-31 and SOEF	GCS22-31	No
Low	Low	Baseload to 2025 then peaker	Accelerated	Accelerated	GCS22-31	Yes
DECC Final Low	Median	Baseload to 2025, mid-merit in 2026 then peaker	Increased (2GW) and Accelerated	Increased & Accelerated+	Increased	Yes (delayed)

Central (SOEF)

Plant	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030
Onshore Wind	MW	4717	5046	5531	5800	6100	6400	6700	7000	7000
Solar PV	MW	462	1121	1870	2569	3155	3741	4327	4914	5500
Offshore Wind	MW	25	25	25	25	25	25	725	2865	5000

Accelerated

Plant	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030
Onshore Wind	MW	4717	5046	5531	6004	7000	7000	7000	7000	7000
Solar PV	MW	462	1121	1870	2569	4000	5500	5500	5500	5500
Offshore Wind	MW	25	25	25	25	25	25	1200	2865	5000

Difference from the Central scenario shown in red

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Renewable Deployment

			Capacities			Fuel
Scenario	Demand	Moneypoint	Renewable	Storage	Thermal	Renewable Gas
Central	Median	Baseload to 2025 then mid-merit	SOEF	GCS22-31 and SOEF	GCS22-31	No
High	High	Baseload to 2025 then mid-merit	Delayed	GCS22-31 and SOEF	GCS22-31	No
Low	Low	Baseload to 2025 then peaker	Accelerated	Accelerated	GCS22-31	Yes
DECC Final Low	Median	Baseload to 2025, mid-merit in 2026 then peaker	Increased (2GW) and Accelerated	Increased & Accelerated+	Increased	Yes (delayed)

Increased (2GW) and Accelerated

Plant	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030
Onshore Wind	MW	4717	5046	5531	6004	7000	8000	9000	9000	9000
Solar PV	MW	462	1121	1870	2569	4000	5500	5500	5500	5500
Offshore Wind	MW	25	25	25	25	25	25	1200	2865	5000

Delayed

Plant	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030
Onshore Wind	MW	4717	5046	5531	5800	6129	6279	6428	6579	6729
Solar PV	MW	462	1121	1870	2569	2935	3302	3668	4035	4401
Offshore Wind	MW	25	25	25	25	25	25	25	1020	2015

Difference from the Central scenario shown in red

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Storage Deployment

			Capacities			Fuel
Scenario	Demand	Moneypoint	Renewable	Storage	Thermal	Renewable Gas
Central	Median	Baseload to 2025 then mid-merit	SOEF	GCS22-31 and SOEF	GCS22-31	No
High	High	Baseload to 2025 then mid-merit	Delayed	GCS22-31 and SOEF	GCS22-31	No
Low	Low	Baseload to 2025 then peaker	Accelerated	Accelerated	GCS22-31	Yes
DECC Final Low	Median	Baseload to 2025, mid-merit in 2026 then peaker	Increased (2GW) and Accelerated	Increased & Accelerated+	Increased	Yes (delayed)

Central

Plant	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030
Short Duration	MW	31	264	250	571	577	690	730	770	800
4 hour	MW	0	0	11	50	120	150	220	290	375
6 hour	MW	0	0	0	0	40	140	280	420	550
8 hour	MW	0	0	0	0	0	190	380	570	750

Accelerated

Plant	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030
Short Duration	MW	31	264	250	571	577	730	770	800	800
4 hour	MW	0	0	11	50	120	220	290	375	375
6 hour	MW	0	0	0	0	40	280	420	550	550
8 hour	MW	0	0	0	0	0	380	570	750	750

Difference from the Central scenario shown in red

Scenario	Demand	Moneypoint	Capacities: Renewable	Capacities: Storage	Capacities: Thermal	Fuel: Renewable Gas
Central	Median	Baseload to 2025 then mid-merit	SOEF	GCS22-31 and SOEF	GCS22-31	No
High	High	Baseload to 2025 then mid-merit	Delayed	GCS22-31 and SOEF	GCS22-31	No
Low	Low	Baseload to 2025 then peaker	Accelerated	Accelerated	GCS22-31	Yes
DECC Final Low	Median	Baseload to 2025, mid-merit in 2026 then peaker	Increased (2GW) and Accelerated	Increased & Accelerated+	Increased	Yes (delayed)

Storage Deployment

Increased (500 MW) and Further Accelerated

Plant	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030
Short Duration	MW	31	264	250	571	577	730	770	800	800
4 hour	MW	0	0	11	50	220	290	375	375	375
6 hour	MW	0	0	0	40	280	420	550	650	800
8 hour	MW	0	0	0	0	380	570	750	850	1000

Difference from the Central scenario shown in red

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			Capacities			Fuel
Scenario	Demand	Moneypoint	Renewable	Storage	Thermal	Renewable Gas
Central	Median	Baseload to 2025 then mid-merit	SOEF	GCS22-31 and SOEF	GCS22-31	No
High	High	Baseload to 2025 then mid-merit	Delayed	GCS22-31 and SOEF	GCS22-31	No
Low	Low	Baseload to 2025 then peaker	Accelerated	Accelerated	GCS22-31	Yes
DECC Final Low	Median	Baseload to 2025, mid-merit in 2026 then peaker	Increased (2GW) and Accelerated	Increased & Accelerated+	Increased	Yes (delayed)

Renewable Gas

Generation

Fuel	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030
Renewable Gas	TWh	0	0	0	1.2	1.4	1.6	1.8	2.2	2.4

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			Capacities			Fuel
Scenario	Demand	Moneypoint	Renewable	Storage	Thermal	Renewable Gas
Central	Median	Baseload to 2025 then mid-merit	SOEF	GCS22-31 and SOEF	GCS22-31	No
High	High	Baseload to 2025 then mid-merit	Delayed	GCS22-31 and SOEF	GCS22-31	No
Low	Low	Baseload to 2025 then peaker	Accelerated	Accelerated	GCS22-31	Yes
DECC Final Low	Median	Baseload to 2025, mid-merit in 2026 then peaker	Increased (2GW) and Accelerated	Increased & Accelerated+	Increased	Yes (delayed)

Central Scenario Conventional Generation Existing Generation

Plant	Units	2022	2023	2024	2025	2026	2027	2028	2029	2030
Gas OCGT	MW	270	270	180	180	296	296	296	296	296
Gas CCGT	MW	3378	3378	3378	3378	3378	3378	3378	3378	3378
Waste	MW	78	78	78	78	78	78	78	78	78
Biomass/Biomass CHP	MW	148	148	148	148	148	148	148	148	148
Distillate	MW	324	324	324	324	208	208	208	208	208
MP1/3*	MW	570	570	570	570	570	570	570	570	570
MP2*	MW	250	250	250	250	250	250	250	250	250
CHP	MW	324	324	324	324	324	324	324	324	324
Oil	MW	241	241	0	0	0	0	0	0	0
Hydro	MW	242	242	242	242	242	242	242	242	242
Pumped Storage	MW	292	292	292	292	292	292	292	292	292

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Scenario	Demand	Moneypoint	Capacities: Renewable	Capacities: Storage	Capacities: Thermal	Fuel: Renewable Gas
Central	Median	Baseload to 2025 then mid-merit	SOEF	GCS22-31 and SOEF	GCS22-31	No
High	High	Baseload to 2025 then mid-merit	Delayed	GCS22-31 and SOEF	GCS22-31	No
Low	Low	Baseload to 2025 then peaker	Accelerated	Accelerated	GCS22-31	Yes
DECC Final Low	Median	Baseload to 2025, mid-merit in 2026 then peaker	Increased (2GW) and Accelerated	Increased & Accelerated+	Increased	Yes (delayed)

Thermal Deployment

Additional thermal capacity assumptions

Central

Plant	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030
CCGT	MW	0	0	0	0	0	0	0	0	0
Gas OCGT	MW	0	0	0	325	816	915	915	915	915

Increased

Plant	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030
Gas OCGT	MW	0	0	0	0	0	300	300	300	300
Gas CCGT	MW	0	0	0	0	0	0	450	900	900

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DECC Scenario requested 01/12/22

Scenario/Sensitivity: Accelerated Decarbonisation

1. Demand:
   a. Assume GCS '22 Median Demand Scenario
   b. Increase demand flexibility assumption (if possible) and post-scenario run, calculate MT CO2e required to be delivered by demand flexibility per carbon budget.

2. Renewables:

Plant	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030
Onshore Wind	MW	4717	5250	5870	6,004	7,000	8,200	9,000	9,000	9,000
Solar PV	MW	262	721	1700	2,900	3,500	4,000	4,500	5,000	5,500
Solar PV non-Grid	MW	0	0	500	1,000	1,300	1,600	2,000	2,250	2,500
Offshore Wind	MW	25	25	25	25	25	25	1200	2865	5000

3. Storage: Assume 'Increase 500 MW and Accelerated' Scenario and move forward all storage capacities by 1 year

4. Thermal: Confirm whether 'Increased and Accelerated' CCGT Deployment is used in recent scenarios. Include this in Accelerated Decarbonisation Scenario. Also describe briefing the thermal portfolio over the decade.

5. Renewable Gasses: Aggregate two rows and delay deployment compared to existing scenarios:

Fuel	Unit	2022	2023	2024	2025	2026	2027	2028	2029	2030
Renewable Gasses	Twh				0.6	0.8	1.0	1.5	2.0	2.4

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