Climate mitigation strategies and air quality in the UK power sector: two birds, one stone?

An evaluation of the air quality impacts from established net-zero scenarios for electricity generation in the UK

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Introduction & Problem Statement

Poor air quality (AQ) is the 4th leading risk factor causing premature deaths worldwide, with an estimated 6.67 million deaths per year due to air pollution effects (HEI, 2020). On a UK scale, outdoor air pollution is responsible for around 40000 deaths a year, costing the UK economy more than £20 billion per annum (RCP, 2016).

Anthropogenic greenhouse gas (GHG) and air pollutant emissions are linked by the combustion of fuels. Further, the UK Government is attempting to reach net zero (NZ) GHG emissions by 2050. This provides a unique opportunity to improve UK air quality, whilst achieving climate targets. (**Fig. 1**) (AQEG, 2020).

The power sector is crucial for the UK and its net zero aspirations. This is not only due to the current significant emissions resulting from power generation, but also the planned future electrification of other UK sectors (BEIS, 2022). **In this work, we review the AQ impacts of two sets of future NZ power sector scenarios**.

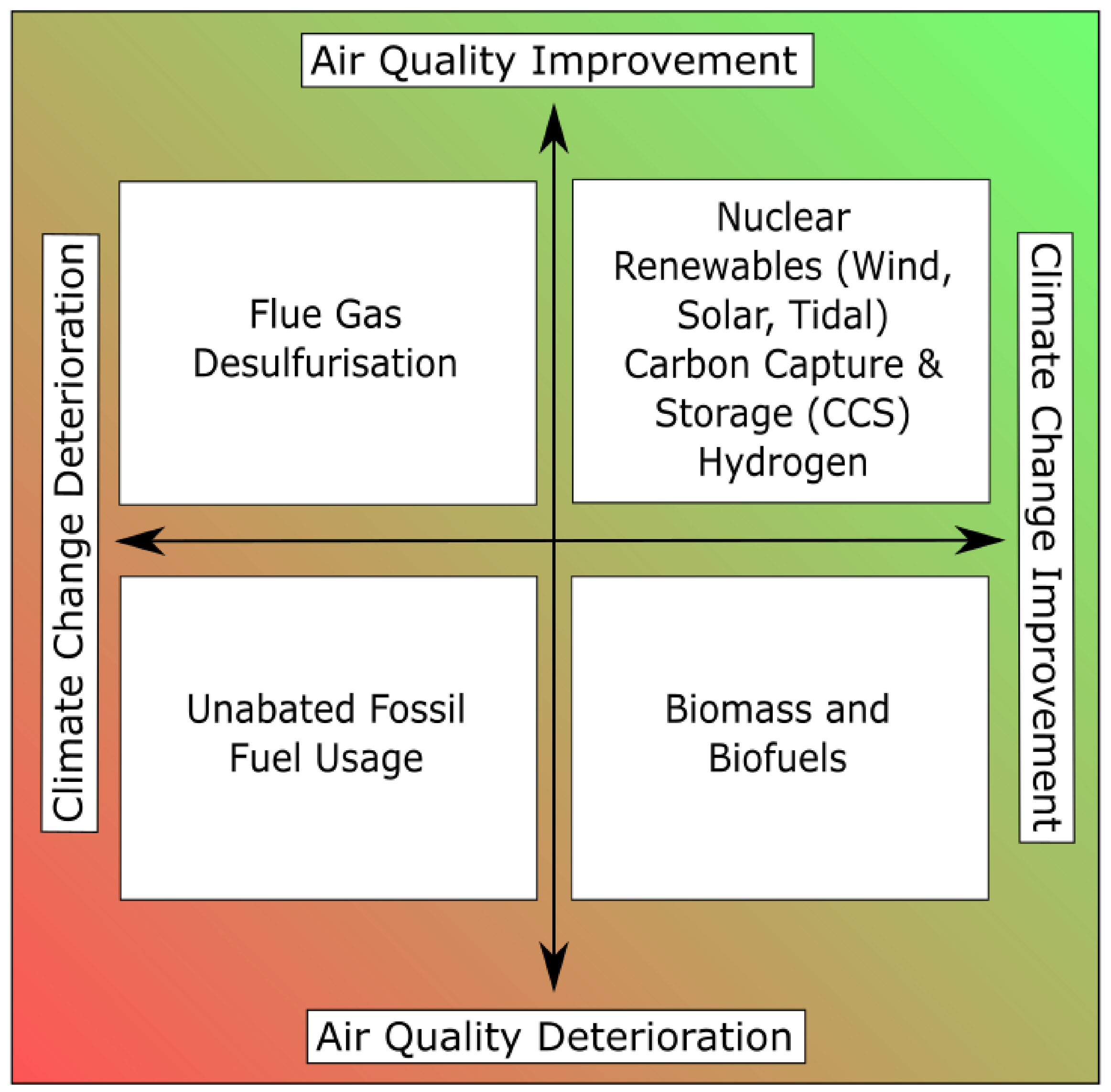

Figure 1: *Synergies and trade-offs between current and potential future electricity generation technologies to reach climate and air quality targets.*

Future Electricity Scenarios

The scenarios investigated were produced by the Committee on Climate Change (CCC) and the National Grid (NG). These vary on their overall ambition, direction to 2050 and cumulative CO_2e emissions (**Table 1**). An increase in domestic electricity production is seen in all cases.

General Scenario Strategy:

- Increase the variable renewable (wind, solar) share. Largest share by 2050.
- Maintain a small, fixed load of nuclear energy.
- Deploy low-carbon dispatchable generation sources:
  1. Natural gas with carbon capture and storage (CCS)
  2. Bioenergy (plant biomass and energy crops, for example) with CCS (BECCS)
  3. Hydrogen
- NG scenarios use notably more BECCS, whilst the CCC scenarios strike a balance between BECCS and gas CCS. Hydrogen has a much smaller contribution to power generation (**Fig. 2**).

Dispatchable Generation Sources

Generation technologies that modify their output to help meet demand. Essential for ensuring security of supply. In the case of BECCS, electricity can be provided with a net negative carbon intensity. This leads to the UK power sector becoming a net CO_2 sink during the NZ transition (**Table 1**).

Table 1: *A summary of the scenarios investigated for their AQ impacts. NB: Tech – focusses on technological and structural changes, reducing costs of low-carbon technologies. Societal – focusses on consumer engagement and high low-carbon technology uptake.*

	National Grid			
Scenario	C.T.	S.T.	L.T.W.	S.P.
Ambition	Medium	Medium	High	Not NZ
Direction	Societal	Tech	Both	Not NZ
Cumulative CO_2e Emissions ($MtCO_2$e)	-349	-206	-248	506

	CCC				
Scenario	Balanced	Headwinds	Tailwinds	W.E.	W.I.
Ambition	Medium	Low	High	Medium	Medium
Direction	Both	Both	Both	Societal	Tech
Cumulative CO_2e Emissions ($MtCO_2$e)	-179	-455	-641	-81	-186

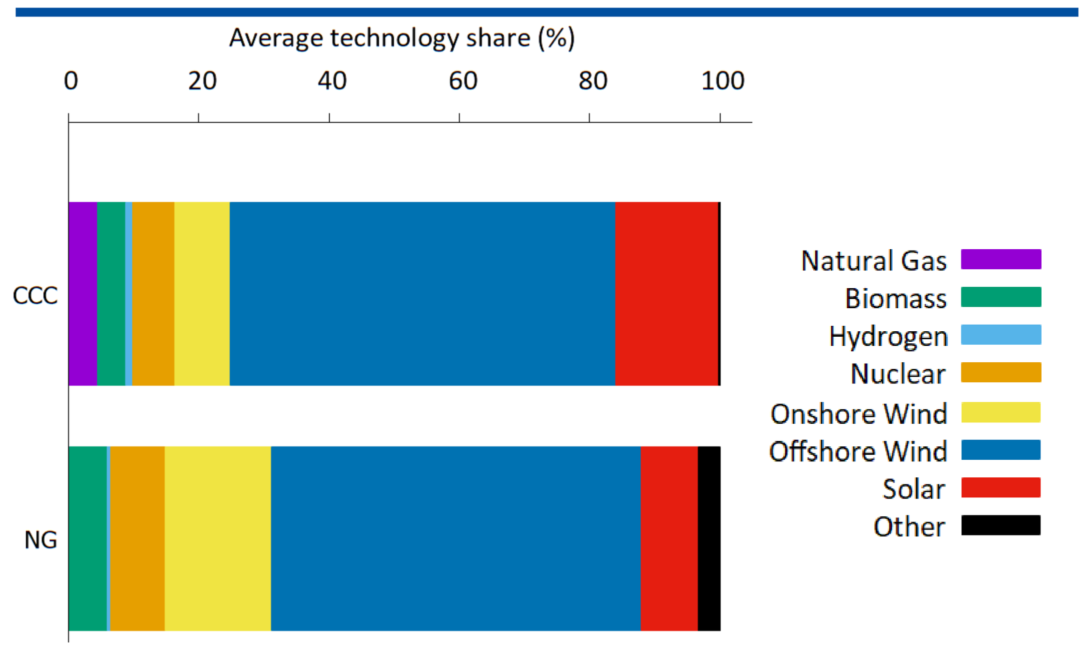

Figure 2: *The average percentage contribution of each generation technology across the scenario sets in 2050.*

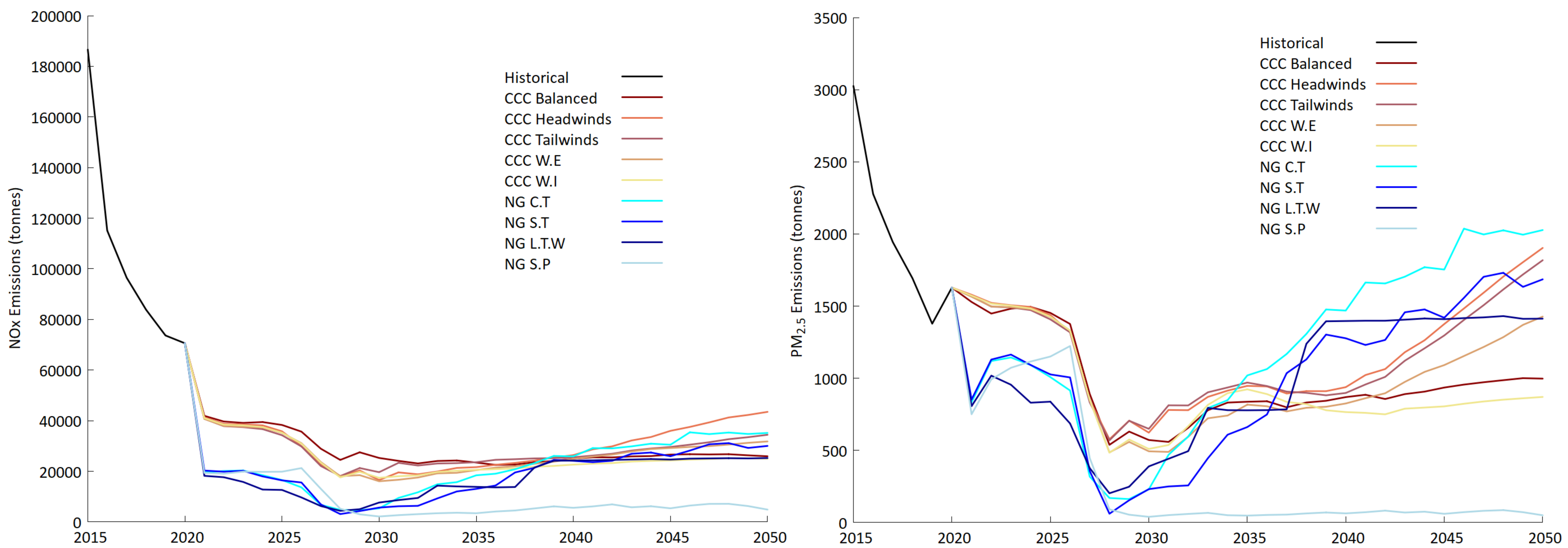

Figure 3: *Left – Projected timeseries of NO_x emissions (tonnes) for each scenario of the UK power sector (excluding interconnection) between 2020 and 2050. Right - Projected timeseries of $PM_{2.5}$ emissions (tonnes) for each scenario of the UK power sector (excluding interconnection) between 2020 and 2050.*

Method, Results & Discussion

Emission factors (EFs), derived from the NAEI and DUKES, were used to project $PM_{2.5}$ and NO_x emissions up to 2050 for each future scenario. The EFs were technology specific and included CCS (EEA, 2011). Pollutant emissions come solely from the share of dispatchable generation technologies in each scenario. In these future scenarios, **combustion of biomass (BECCS) emits the highest amount of pollutants per unit of electricity** (**Table 2**).

Table 2: *Emission factors (g/kWh) for the dispatchable generation technologies used in the CCC and NG future energy scenarios*

Emission Factors (g/kWh)	NO_x	$PM_{2.5}$
Natural Gas	0.21	0.0027
Biomass	0.59	0.048
Hydrogen	0.15	

In these future scenarios, **BECCS has the largest influence on air pollutant emissions**. Emissions reach their lowest between 2028 and 2030, *immediately prior to BECCS deployment*, before increasing again up to 2050. The correlation (R^2) between biomass-generated electricity and $PM_{2.5}$ emissions is 0.988. Similarly, for NO_x emissions, the correlation is 0.773.

Table 3: *Change in $PM_{2.5}$ and NO_x emissions from 2020 to 2050. Both the lowest and highest emitting scenarios are highlighted.*

Pollutant	2020 emissions (tonnes)	Lowest 2050 (tonnes)	Highest 2050 (tonnes)
$PM_{2.5}$	1628	50 (NG S.P.)	2027 (NG C.T.)
NO_x	70581	4875 (NG S.P.)	43468 (CCC Headwinds)

Importantly, the non-NZ *NG S.P* scenario has significantly lower NO_x and $PM_{2.5}$ emissions, whilst employing minimal biomass. This appears to be a **notable trade-off between climate and air quality policy:** BECCS may be a key factor in climate mitigation, but it could lead to worsening air pollutant emissions from the power sector, when used extensively (**Fig. 3**).

Conclusions and Implications

Projections of NO_x and $PM_{2.5}$ emissions in a selection of future NZ power sector scenarios have been investigated. Whilst NO_x emissions projections show moderate improvements to 2050, $PM_{2.5}$ emissions are anticipated to increase compared to 2020 in a number of these NZ scenarios. This is predominantly due to the deployment of BECCS in the late 2020s and 2030s. Efforts should be taken by the UK government to limit the impact of BECCS emissions, as well as those from other dispatchable generation technologies, on the UK population.

References

Air Quality Expert Group (2020) *Impact of Net Zero pathways on future air quality in the UK*.
Department for Business, Energy and Industrial Strategy (BEIS) (2022) *2020 Greenhouse Gas Emissions, Final Figures.*
EEA (2011) *Air pollution impacts from carbon capture and storage (CCS)*. Available at: https://www.eea.europa.eu/publications/carbon-capture-and-storage (Accessed 29 April 2022)
Health Effects Institute (2020) *State of Global Air 2020*. *Special Report.* Boston, MA: Health Effects Institute.
Royal College of Physicians (2016) *Every breath we take: the lifelong impact of air pollution*. Report of a working party. London: RCP.