Synergies between net zero scenarios and air quality

- **TFIAM 2024:**
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- + D Mehlig, A Brighty, E Fonseca & N Ripoll-Kameid
- &collaboration with UKCEH & Mike Holland

IMPERIAL

Research linked to our modelling of future scenarios for air pollution in the UK with our integrated assessment model UKIAM

1. Follow on from last TFIAM: Improvement in air quality for energy scenarios towards net zero: illustrations for contrasting scenarios from the National Grid

2. Current work: Emission factors for new technologies e.g. hydrogen production and use, CCS. Linking UKIAM & TIMES model for energy projections.
   ->future work other fuels e.g. NH3 (potential use in shipping).

3. Other net zero measures, land-use and agriculture-> impacts on NH3 emissions

Consumer Transformation (CT)

- Consumer and demand-side engagement, reducing industrial and domestic energy demands
- Significant increases in electrification, wide BECCS usage in electricity generation, and hydrogen production using electrolysis (green)
- Complete phase-out of internal combustion vehicles by 2050

System Transformation (ST)

- Relies on flexibility on the supply-side, less reduction in demand by consumers
- Less emphasis on energy efficiency
- Largest amount of hydrogen within the energy system, predominantly blue hydrogen (steam methane reformation with CCS)
- Complete phase-out of internal combustion vehicles by 2050

Leading the Way (LtW)

- Both demand-side and supply-side improvements, fastest credible pathway to net zero
- Takes best elements from both Consumer Transformation and System Transformation
- Mix of electrification and hydrogen usage within the energy system
- Fastest phase-out of internal combustion vehicles by 2050

Falling Short (FS)

- Only scenario to not reach net zero, still shows some progress from the base year
- Partial decarbonisation of power and transport, less progress on building heating and industrial combustion
- Limited consumer behaviour change

National Grid Scenarios

National Grid Scenarios

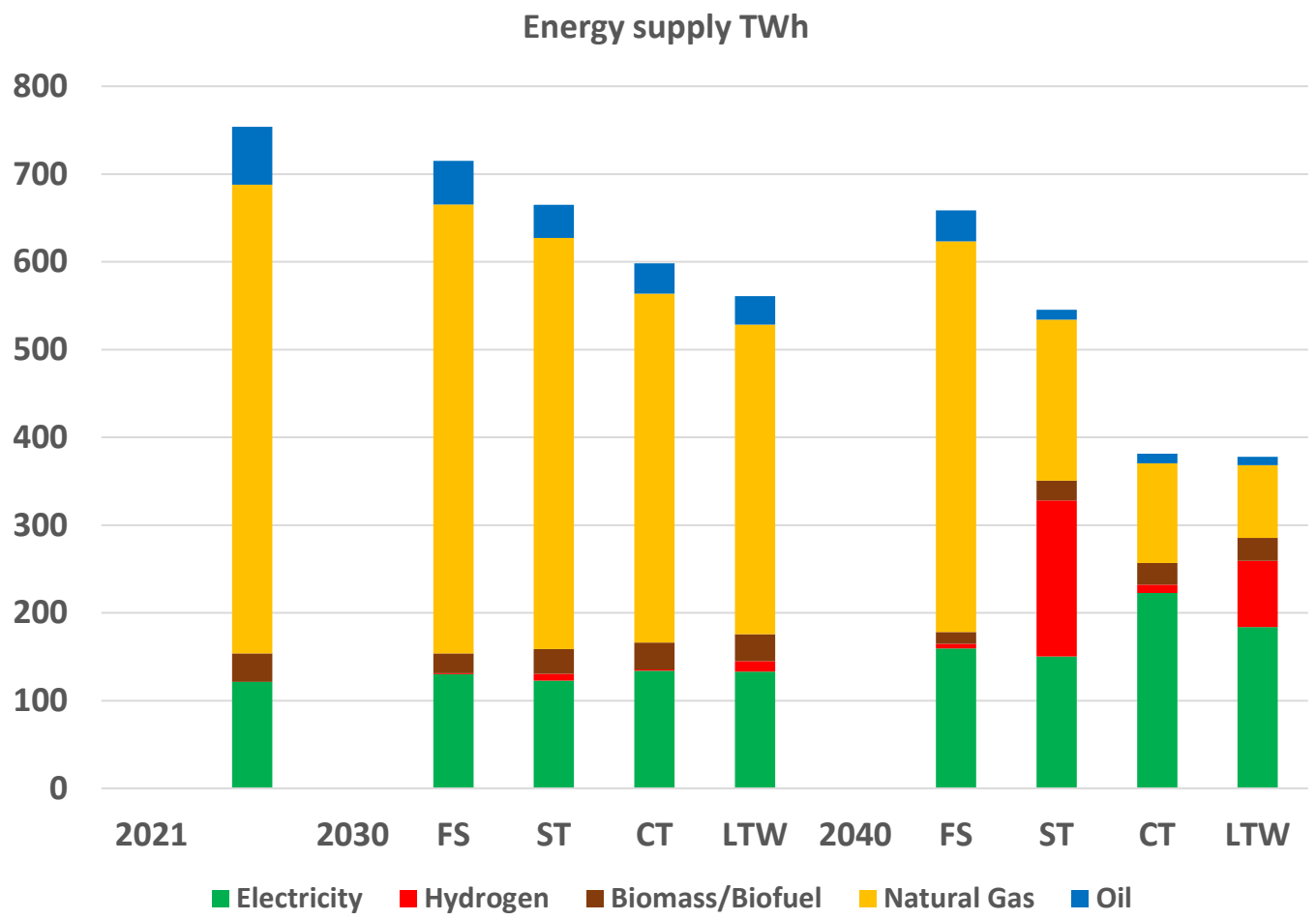
Falling short FS

System transformation ST (more hydrogen and CCS)

Consumer Transformation CT (more reliance on energy efficiency and electrification)

Leading the way LTW- combined measures-> biggest improvements

Energy supplied (TWh)



National Grid Scenarios

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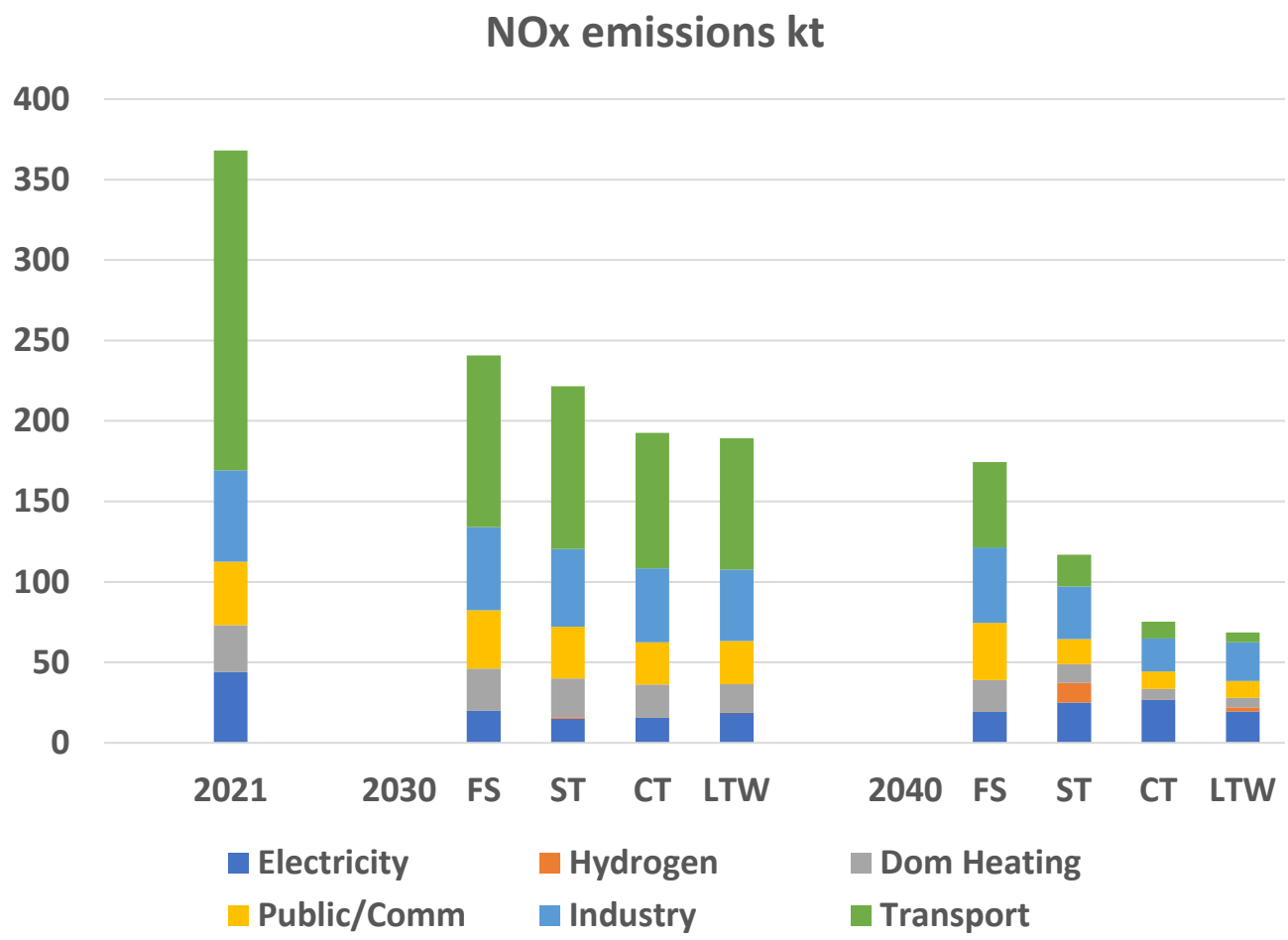
NOx emissions (kt)



National Grid Scenarios

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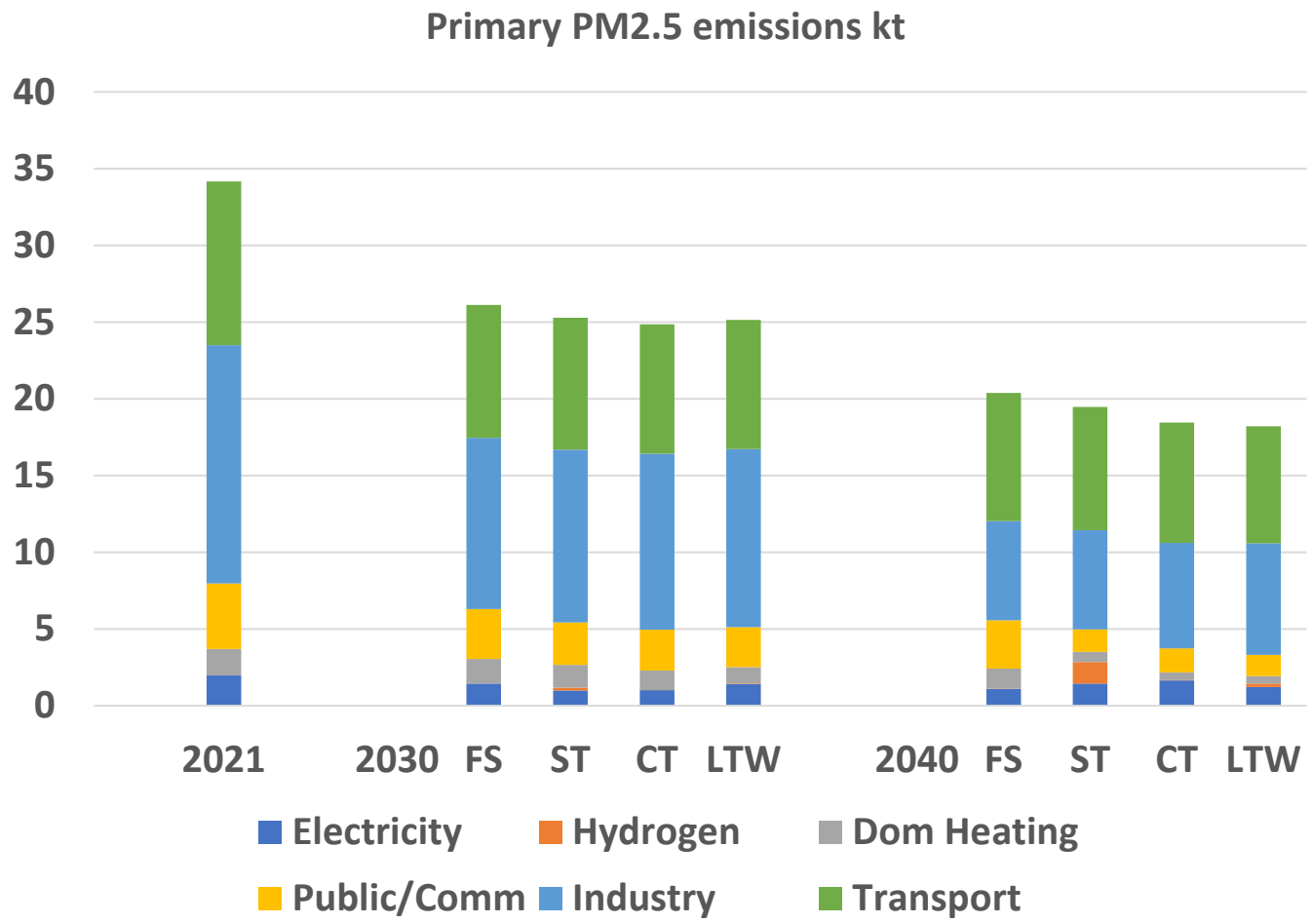
Primary PM2.5 emissions (kt)



National Grid Scenarios

Falling short FS

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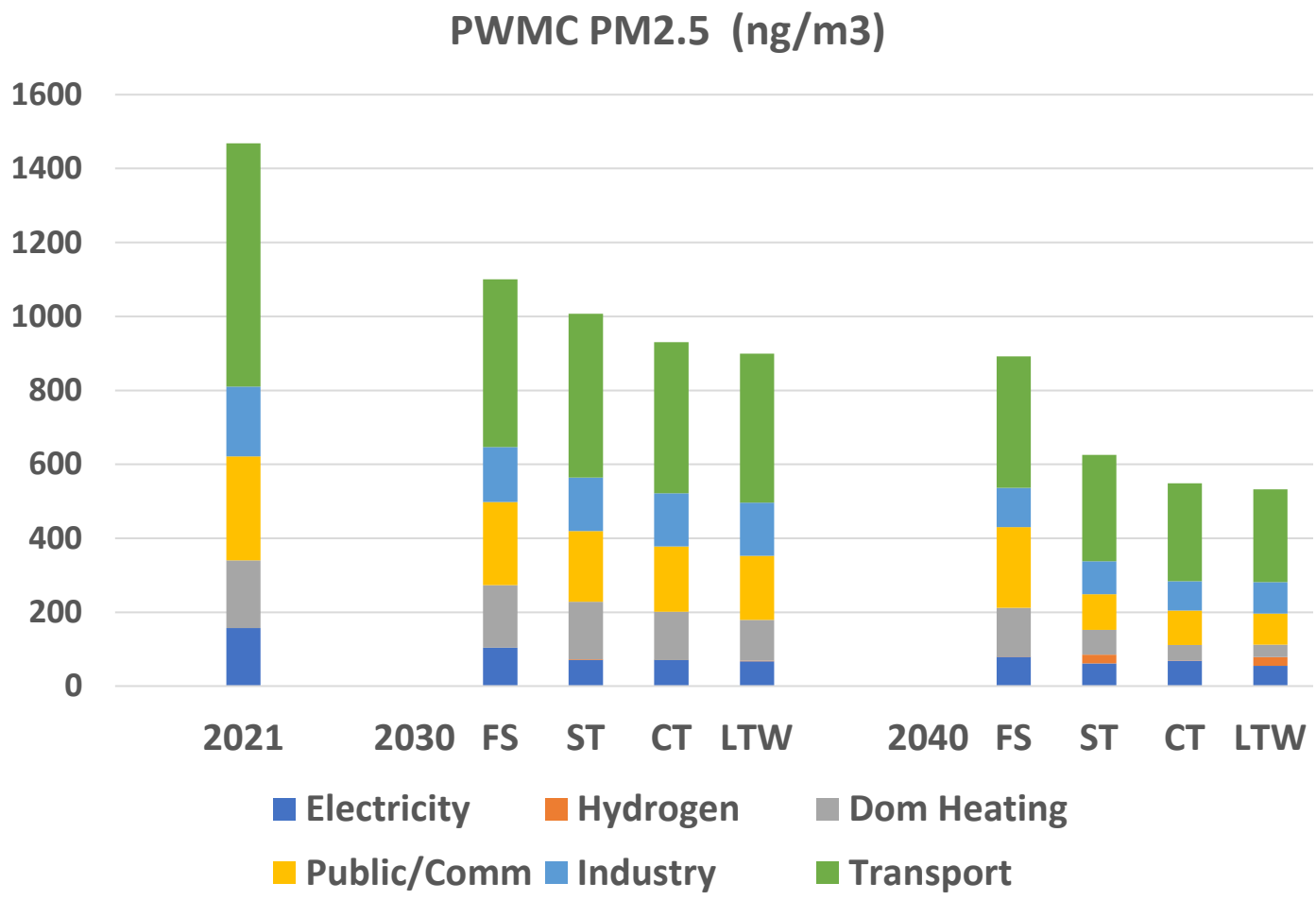
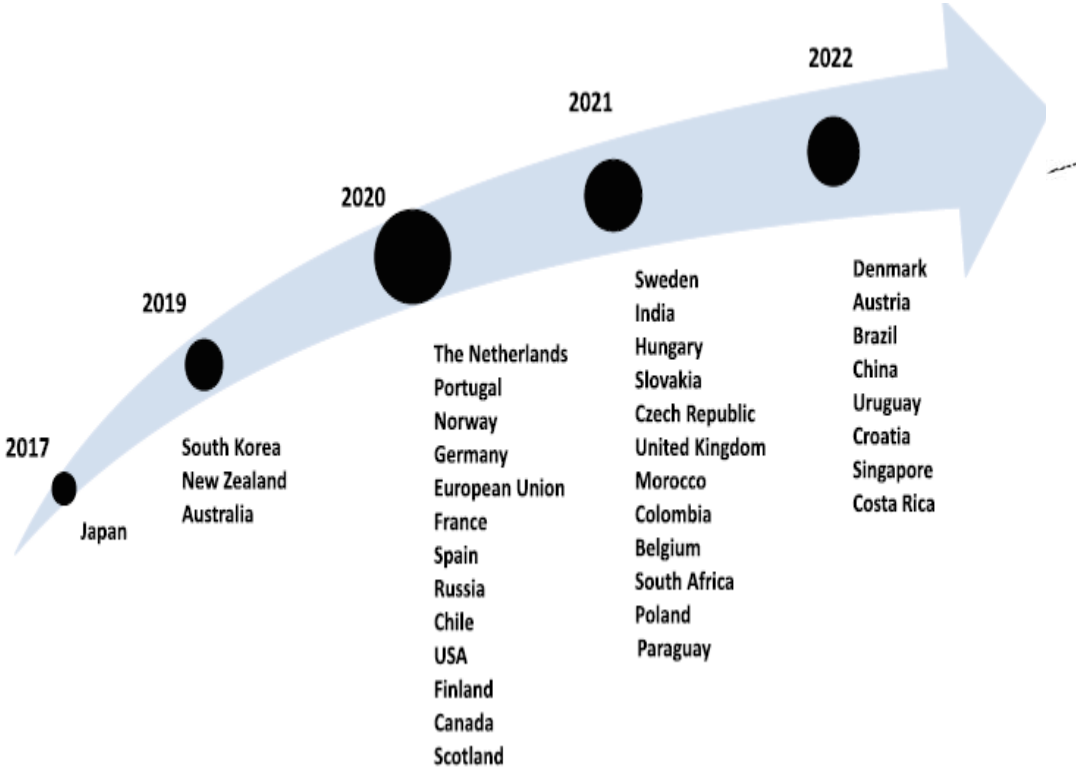
Leading the way LTW- combined measures-> biggest improvements

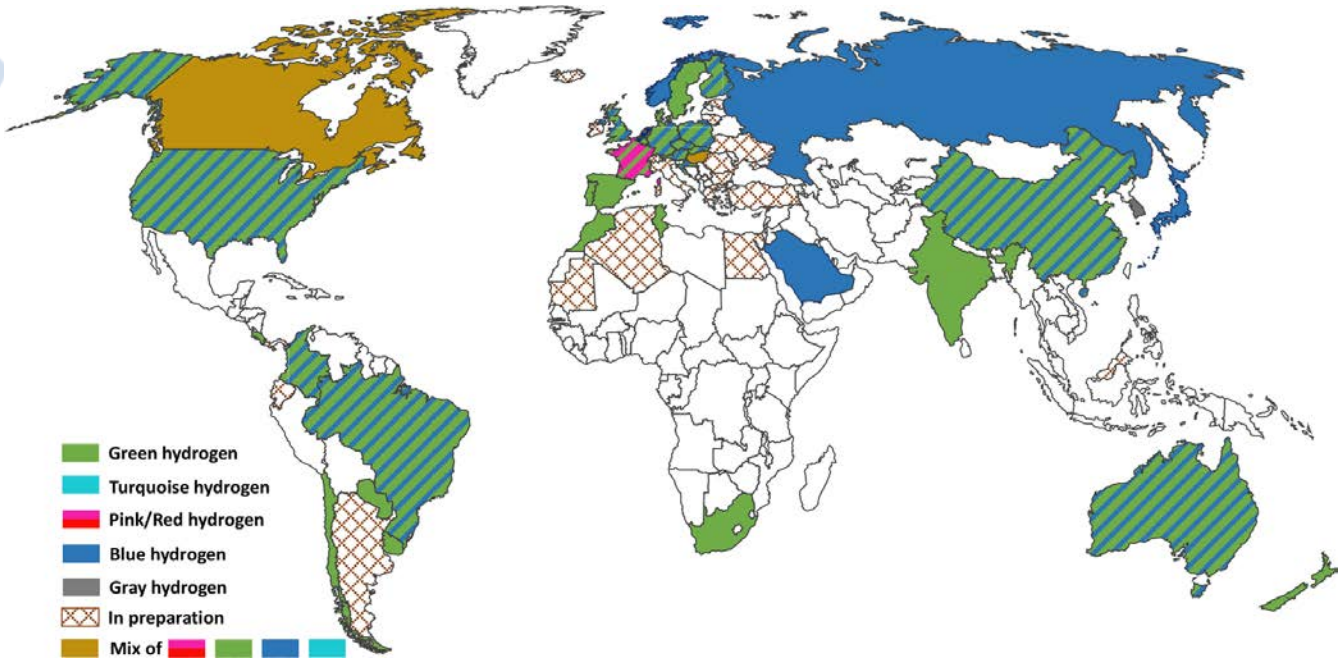
NB annual health benefit reduction of 1ug/m3 in PWMC ~£3.7 billion

Population weighted mean concentrations primary plus secondary PM2.5





National hydrogen strategies



Main colours considered in each countrys Hydrogen National Plan, Strategy, or Roadmap.

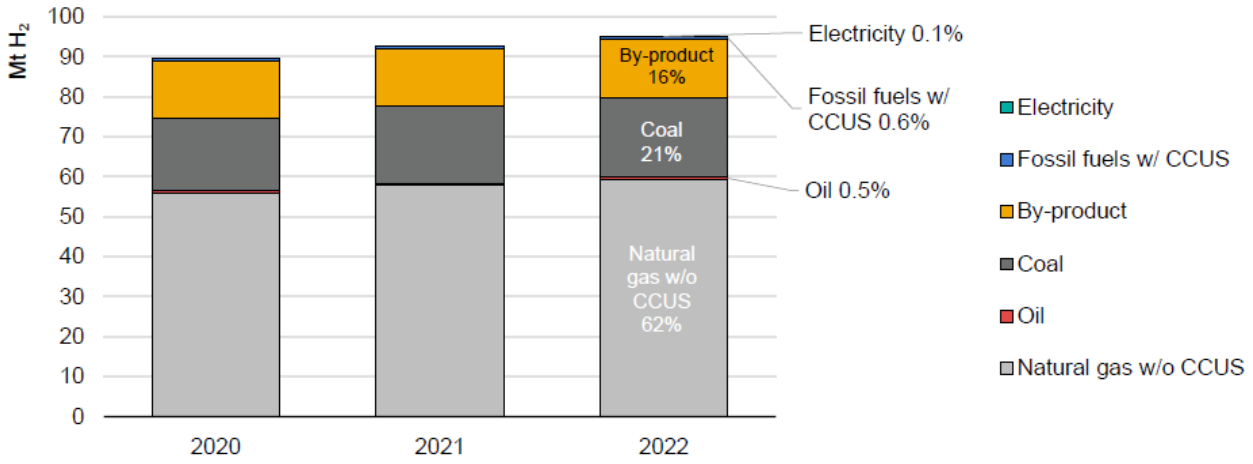
Taken from "Colors" of hydrogen: Definitions and carbon intensity Jimena Incer-Valverde *, Amira Korayem, George Tsatsaronis, Tatiana Morosuk Energy Conversion and Management https://doi.org/10.1016/j.enconman.2023.117294

Hydrogen is not directly a greenhouse gas, but its chemical reactions change the abundances of the greenhouse gases methane, ozone, and stratospheric water vapor, as well as aerosols. Modelling estimates give a GWP100 of 11.6 (+/- 2.8). Hence leakage important.

A multi-model assessment of the Global Warming Potential of hydrogen. Maria Sand et al

COMMUNICATIONS EARTH & ENVIRONMENT | (2023) 4:203 | https://doi.org/10.1038/s43247-023-00857-8 | www.nature.com/commsenv

EMISSION FACTORS FOR NEW TECHNOLOGIES: HYDROGEN PRODUCTION



Department for Energy Security & Net Zero

GREY: Steam Methane Reforming, SMR
most mature technology

NO_X	$PM_{2.5}$	CO	CH_4	N_2O	SO_X
Kt/TWh					
0.0234	0.0072	0.0132	0.0010	0.0002	0.0014

Guidelines re GHG emissions but not AQ pollutants

UK Low Carbon Hydrogen Standard

Guidance on the greenhouse gas emissions and sustainability criteria

Version 2

April 2023

GREEN ~0.1% 2022 production

Electrolysis + renewable energy

PINK

Electrolysis + nuclear

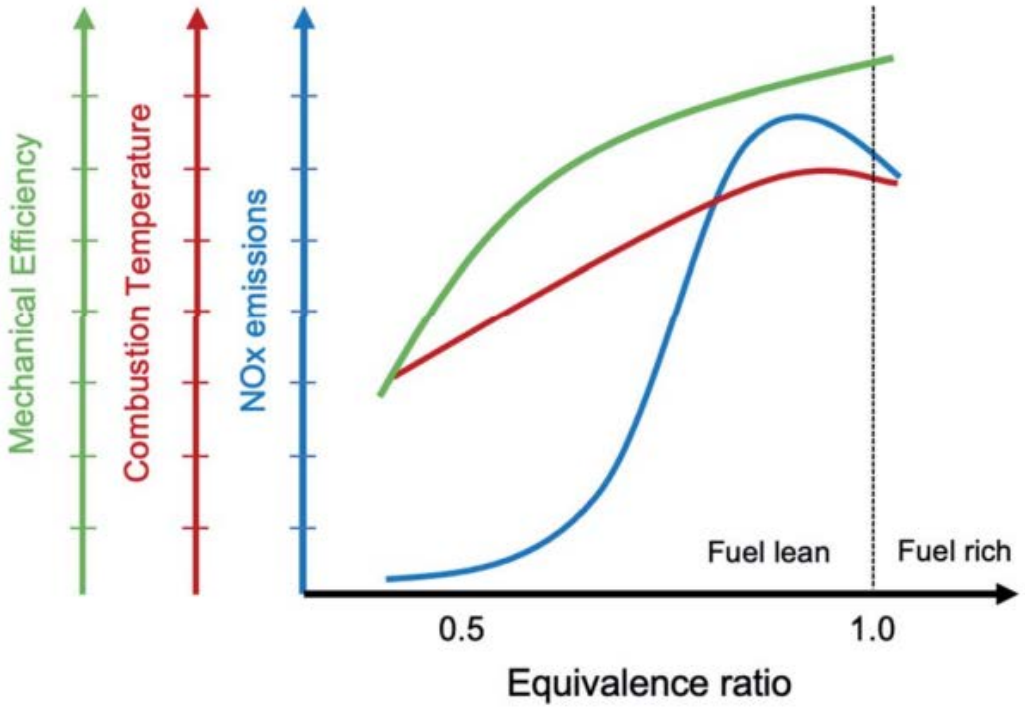
BLUE ~0.6% 2022 production

SMR+CCS **CCS-> efficiency penalty ~10%**
BECCS **nitrosamines toxicity ?**

Lack of info on mature CCS plants
Hydrogen pressure nor purity specified

Emissions from use of hydrogen: combustion

(as opposed to fuel cells)



Lewis, A. 2021 - DOI: 10.1039/d1ea00037c

Emissions of NOx depend on combustion characteristics

Blend of hydrogen and natural gas:

For domestic appliances- cookers, gas-fires etc in indoor environments can give higher NOx emissions

But for premix boilers operating on lean combustion can give lower emissions of NOx

e.g evidence from EU ThyGa project

Combustion of pure hydrogen

Boilers e.g. for industry, can be designed to minimise NOx emissions

➔ potential for tighter standards?

Application to hard-to decarbonize such as steel/cement which also contribute to AQ.

Need emission factors for new technologies- new fuels (hydrogen, NH3), CCS->started compilation of a database of emission factors for air pollutants

i) production of hydrogen, SMR etc

ii) use of hydrogen for domestic sector including as a blend with gas

iii) now working on industry (also biomass/BECCS)

limited information and some large uncertainties other factors: purity, storage and distribution etc. But also potential to tighten standards for e.g NOx emissions

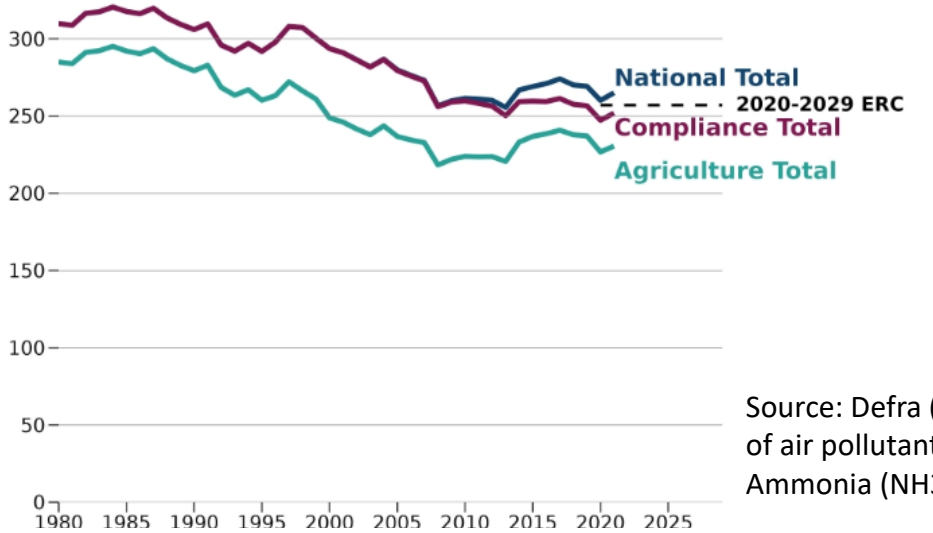
NB use of NH3 as a fuel proposed for shipping to reduce GHG emissions-> scoping study indicates need for further investigation in future work

NET ZERO-> LAND USE & AGRICULTURE-> NH3 EMISSIONS

Huw Woodwood

NH3 emissions in the UK and Critical Load/Level exceedances

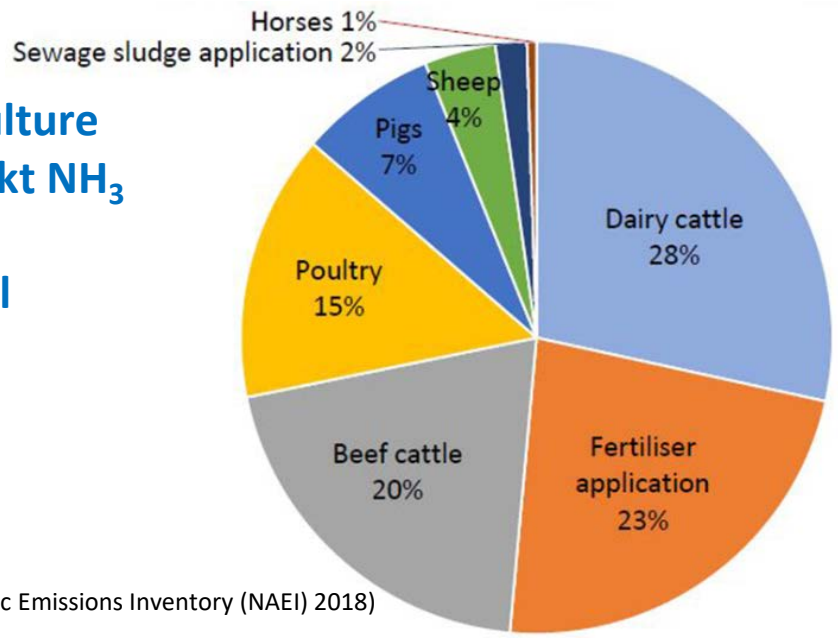
UK NH_3 emissions (kt)



Source: Defra (2023) Emissions of air pollutants in the UK – Ammonia (NH3)

Total UK agriculture emission = 226kt NH_3

87% of UK total emission



(UK National Atmospheric Emissions Inventory (NAEI) 2018)

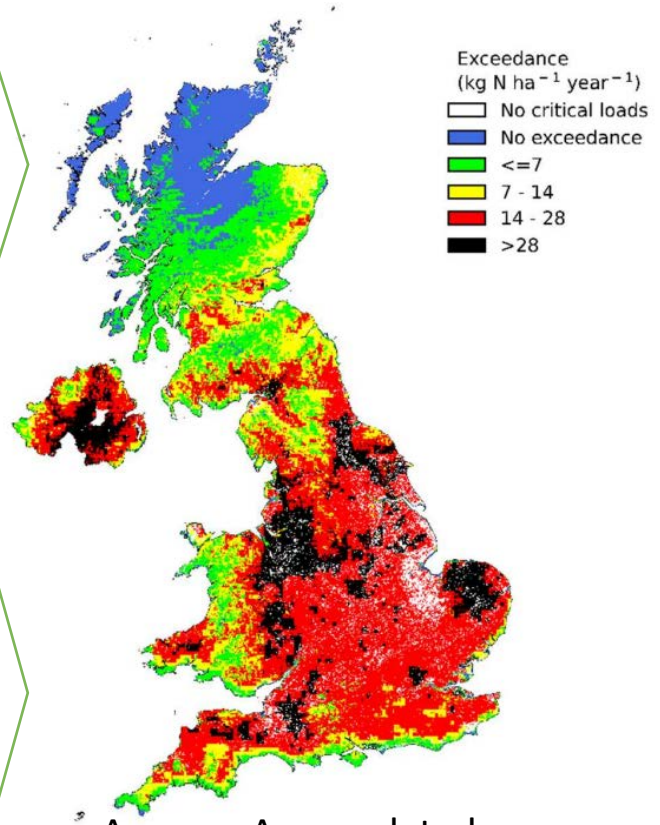
UK Critical Load/Level exceedances

67.7% of the area of N-sensitive habitats in exceedance of nutrient N critical load.

-(2022 Trends report)

6.3% of UK land area exposed to NH_3 concentrations above the critical level for *higher plants* ($3\mu g/m^3$) and **69.2%** to concentrations above the critical level set to protect *lichens and mosses* ($1\mu g/m^3$).

-(2022 Trends report)



Average Accumulated Exceedance (AAE) in 2018-20 of critical loads for nutrient nitrogen

-(2022 Trends report)

NH_3 emissions projected to change

Technological measures towards achieving national emission ceiling

These include:

- Low emission spreading
- Rapid incorporation
- Urease inhibitors
- Low protein diets
- Slurry covers & slurry acidification

These measures have not delivered significant reductions in UK NH_3 emissions so far

Net zero land use change measures

- Afforestation
  - 30 kha yr-1 from 2025
  - 50 kha yr-1 from 2035
- Peatland restoration
  - 100% upland by 2045
  - 75% lowland cropland by 2050
  - 50% lowland grassland by 2050
- Bio-energy crop production
  - 0.7 million hectares
- Agroforestry & hedgerows

Land use change -> replacing agricultural land -> reduction in NH_3 emissions

**NH_3 reduction achieved will depend on other factors such as intensification*

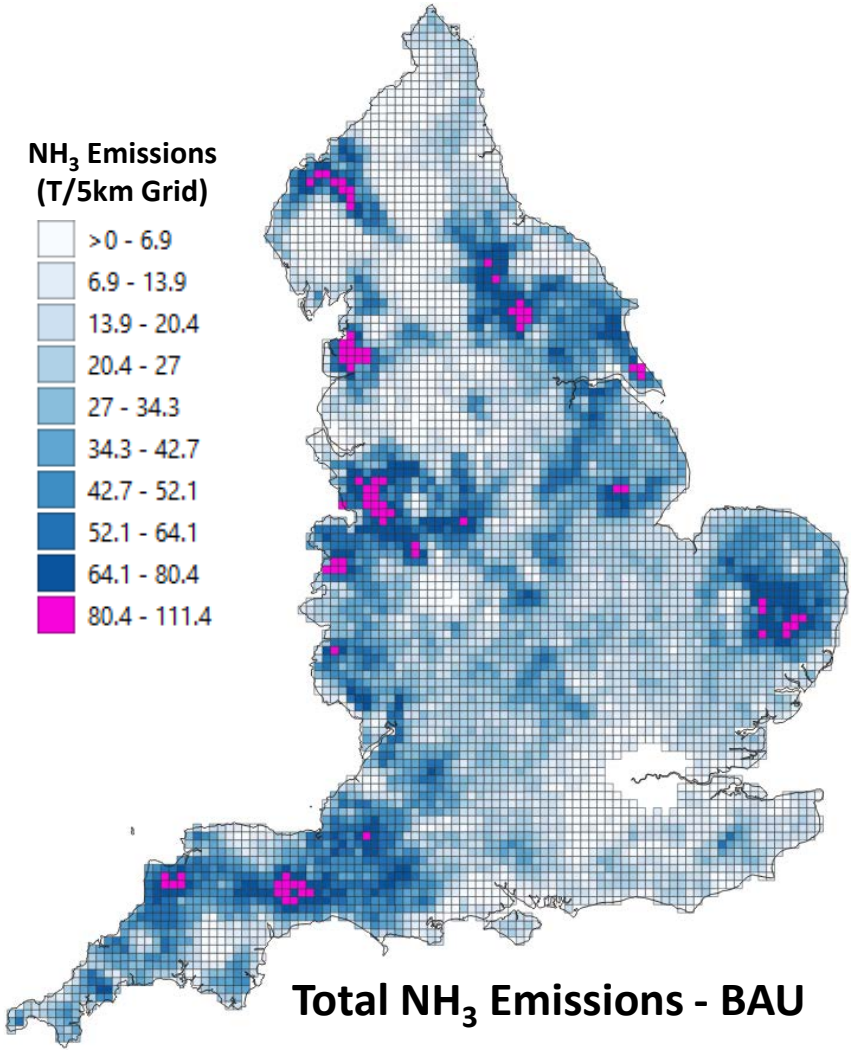
Other Net Zero measures?

- Reduce food waste
- Improve crop yields
- Increase grazing intensity
- Anaerobic digestion
- NH_3 as a fuel for shipping

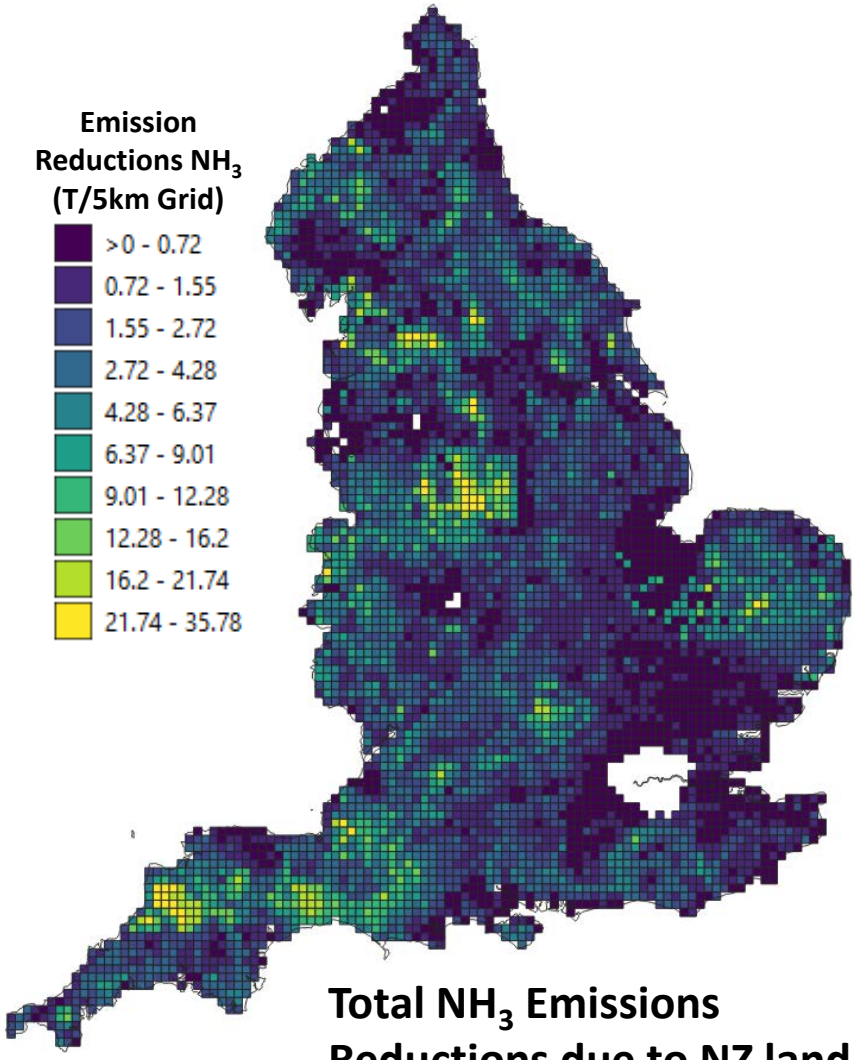
Some of these NZ measures will increase NH_3 emissions

Total NH_3 Emissions Reductions due to land use change policies

Maps produced by Elizabeth Fonseca



Total NH_3 Emissions - BAU



Total NH_3 Emissions Reductions due to NZ land use measures

	Ammonia Emissions Reductions, kt	Methane Emissions Reductions, MT CO2e	Nitrous Oxide Emissions Reductions, MT CO2e
Afforestation	6.6	1.0	0.3
Bioenergy	5.5	0.4	0.4
Agroforestry & Hedges	2.1	0.2	0.1
Peatland	1.6	0.2	0.1
Total	**15.8**	**1.8**	**0.8**
% of NECR Ammonia Emission Reduction 2030	**41%**		
% of CCC BP Diet Change CO2e 2050		**26%**	

Current scenarios assume that technological measures can achieve 23 – 30kt reduction by 2040 in England. However -> Optimistic assumptions – need to consider feasibility, enforcement, efficacy, cost of measures + limited impact of tech measures so far

The path to reducing exceedance – UKIAM modelling