

# Improving quantification of the uncertainty in emissions of air pollutants

Overview of DEFRA RDE project  
11<sup>th</sup> May 2026

IMPERIAL



**Aether** 

1. Improvements to historical uncertainty methods and tools
2. Development of projections uncertainty methods
3. Interpretation of output
4. Next steps for integration into the UK inventory

**No quantification of projection uncertainties**



**Concerns with existing uncertainty quantification approaches**



**Poor infrastructure to understand and improve uncertainty quantification**



**Challenges communicating uncertainty**



No quantification of projection uncertainties



Concerns with existing uncertainty quantification approaches

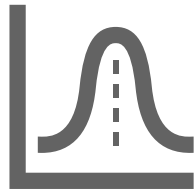


Poor infrastructure to understand and improve uncertainty quantification

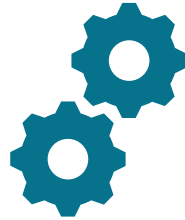


Challenges communicating uncertainty





Robust implementation of Approach 2 (Monte Carlo simulation)

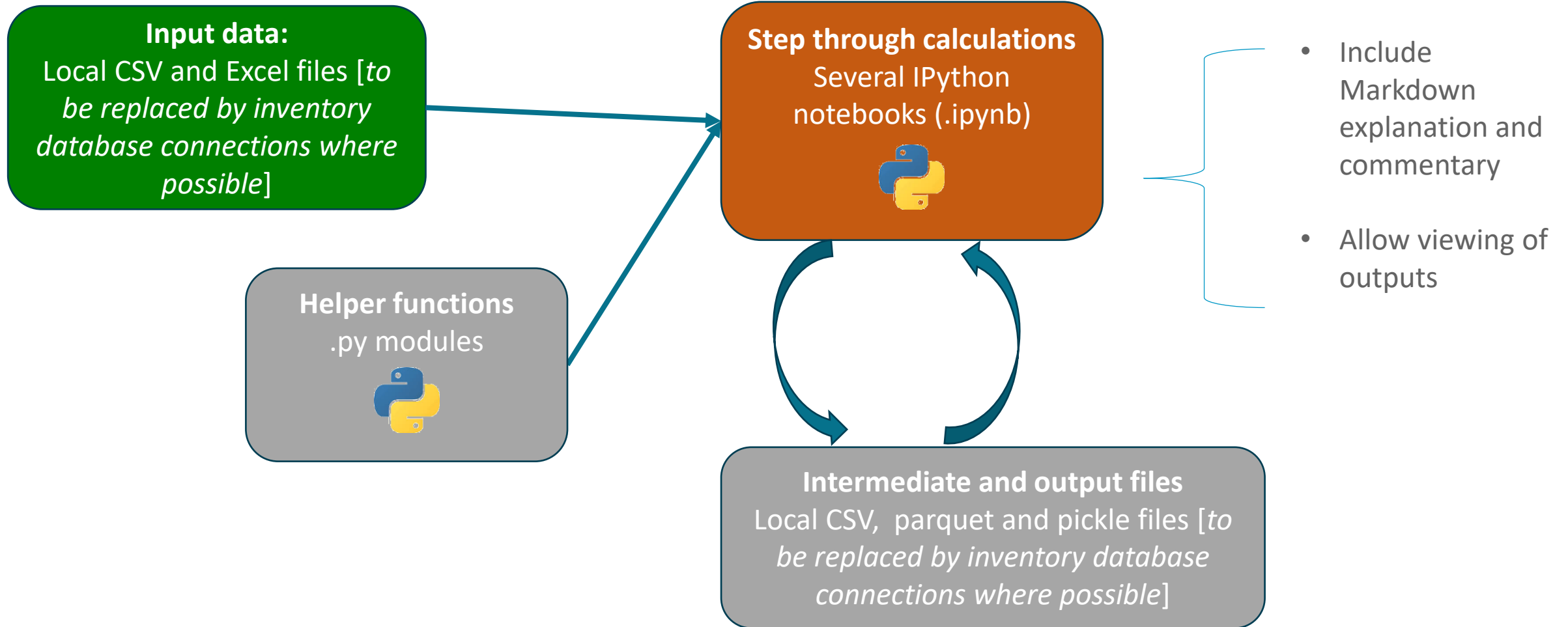


Infrastructure developed to interrogate inputs/outputs



Visualisations created that improve communication of uncertainty

- **Post-Compilation process**



# 1. Critical review and improvements to historical uncertainty methods and tools



## Examined IIRs/NIDs and conducted interviews with other inventory teams

- Build an impression of best-practice and the extent to which other nations have overcome common challenges -> **We're very grateful for the contributions of those interviewed – Thank you!**

## Key learnings:

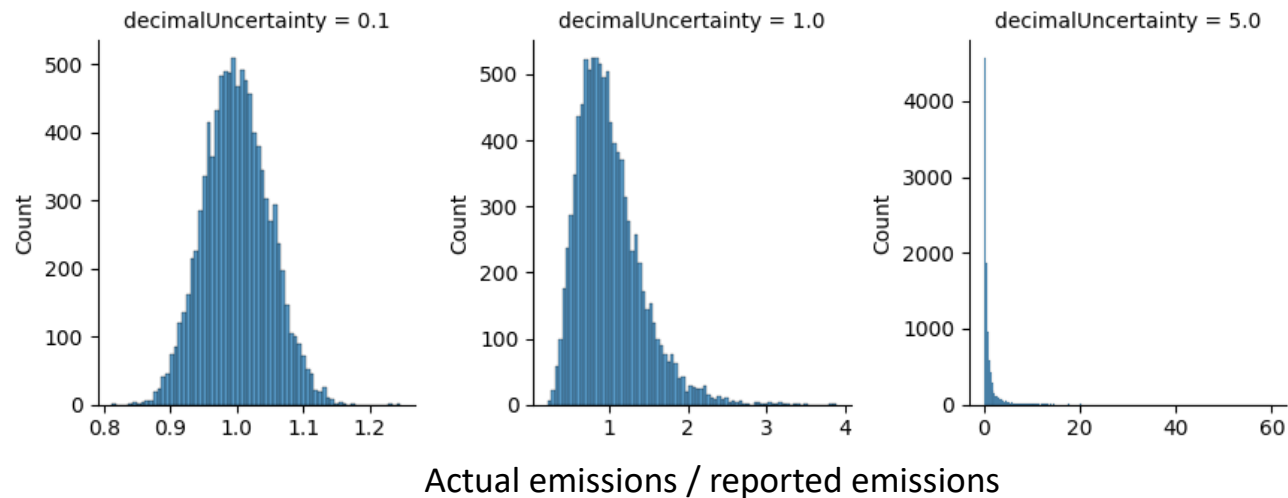
- Monte Carlo simulation is challenging but can be implemented successfully and adds value when done well
- Computational complexity and the challenging of input data / assumptions are cited as barriers
- Main driver in all cases for air pollution inventories is **identifying inventory improvements**, and for GHG also **reporting requirements**

## Methodology

- Programmatic **Error Propagation** developed
  - Can be run alongside Approach 2 simulation as a baseline (code is more robust)
  - Enables extension to multiple years (too computationally expensive to do in spreadsheet form)
- **Monte Carlo simulation** recommended as standard methodology going forwards
  - Addresses issues with asymmetry. This is particularly impactful for certain pollutants.
  - Can be improved over time (e.g. defining correlation structure)

- Importance of good input data

Uncertainty	Mean	Mode	Median	95% Confidence Interval	Probability reported value is an overestimate
10%	1	0.996	0.999	[0.907, 1.10]	51.0%
100%	1	0.793	0.923	[0.428, 2.00]	57.8%
500%	1	0.042	0.349	[0.020, 6.00]	76.6%



## 2: Development of projections uncertainty methods

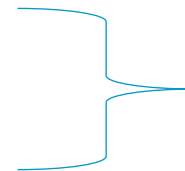


## Main aim for this project:

- Allow **policymakers** to understand uncertainty on projections, for:
  - Understanding likelihood that current firm & funded policies are sufficient to meet existing emission reduction commitments (2030 ERCs under the NECR)
  - Informing setting of 2040 ERCs in Gothenburg Protocol renegotiations

## Key requirements for projections uncertainty:

- Operational feasibility
- Statistical robustness
- Transparent method and scope of uncertainties
- Compatible with historical inventory uncertainties



Especially relevant to this project

## Shortlisted options tested:

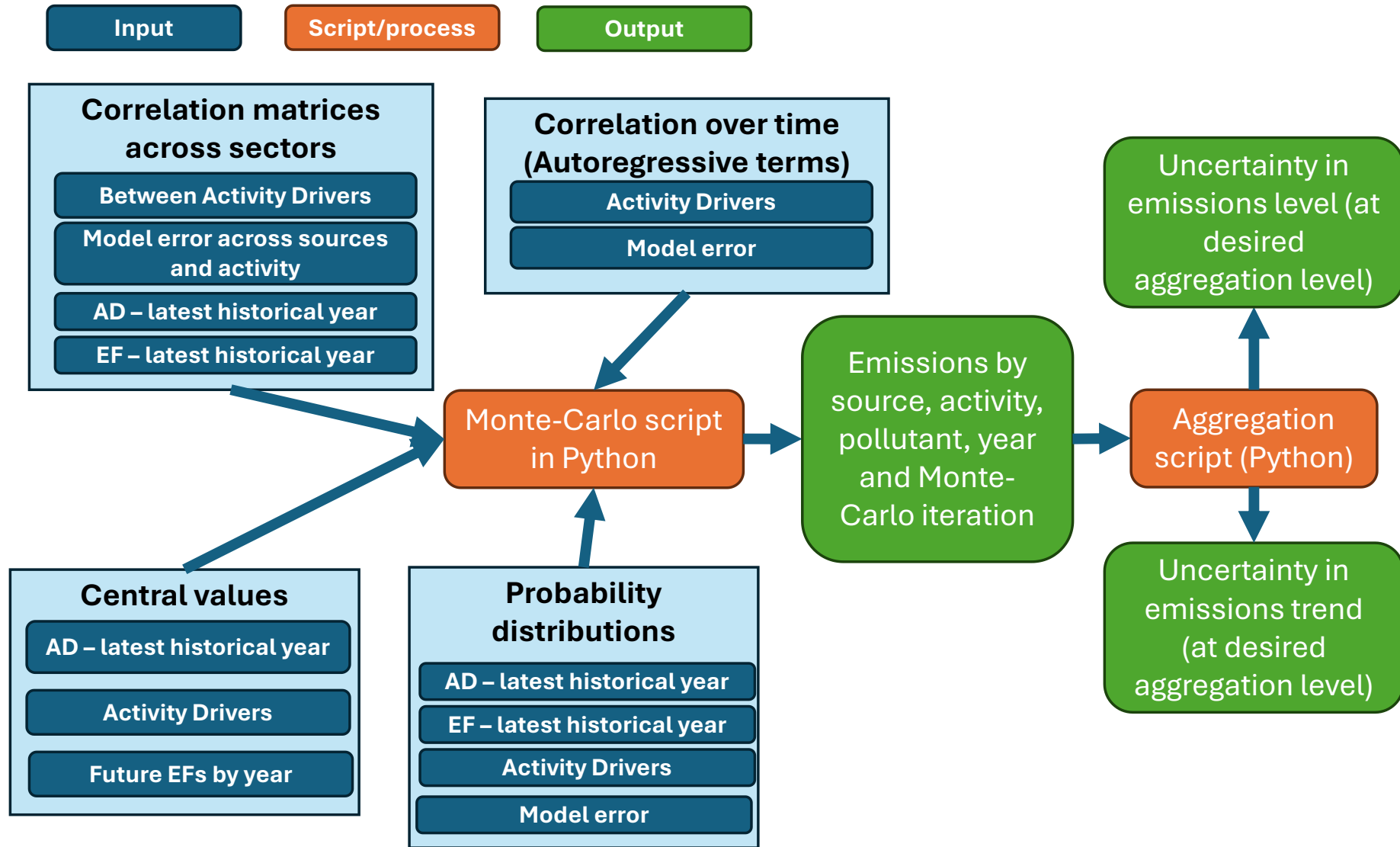
- **Error propagation** extended to future years
- **Standard Monte Carlo** extended to future years
- **Bespoke Monte Carlo** approach (using activity data drivers)
- *Adopted method maybe a combination of these (to handle sector-specific complexities)*



## By making the code flexible, tested the impact of switching on and off:



- Different sources of uncertainty
- Correlations between sectors
- Correlations over time

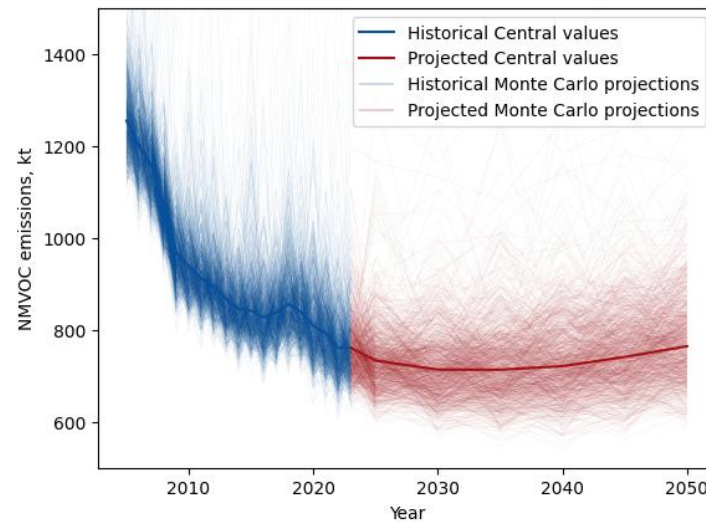
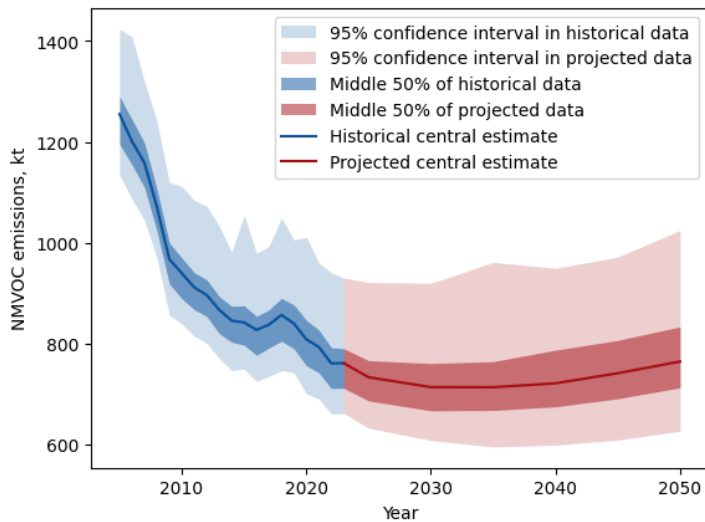
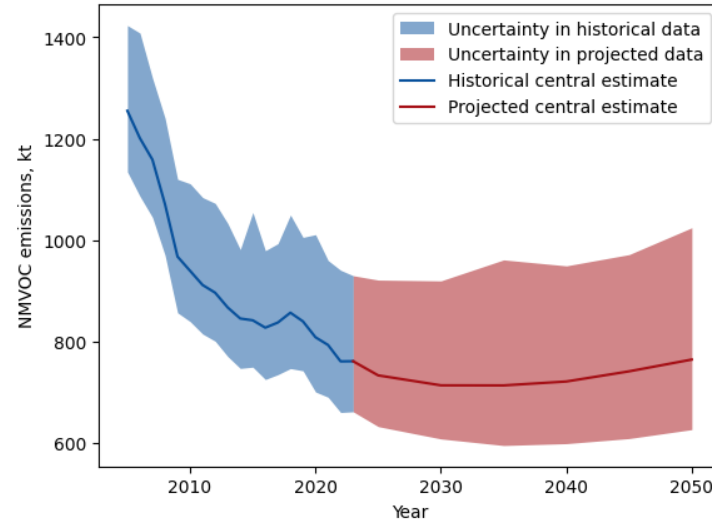
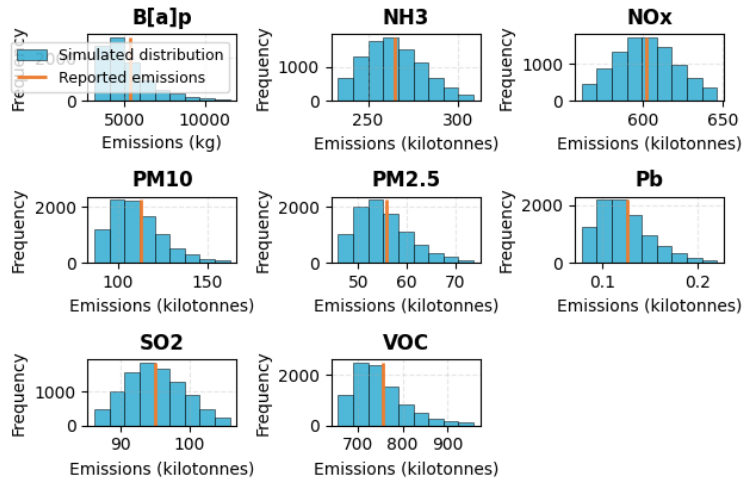


### 3. Interpretation of results

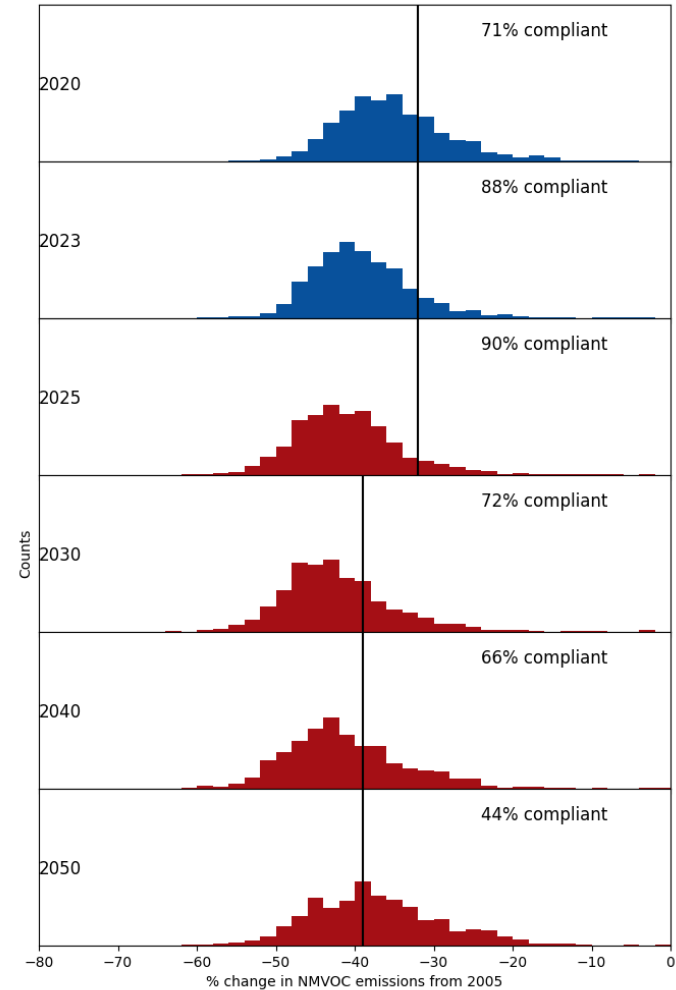


- Static visualisations combining historical and projections uncertainties

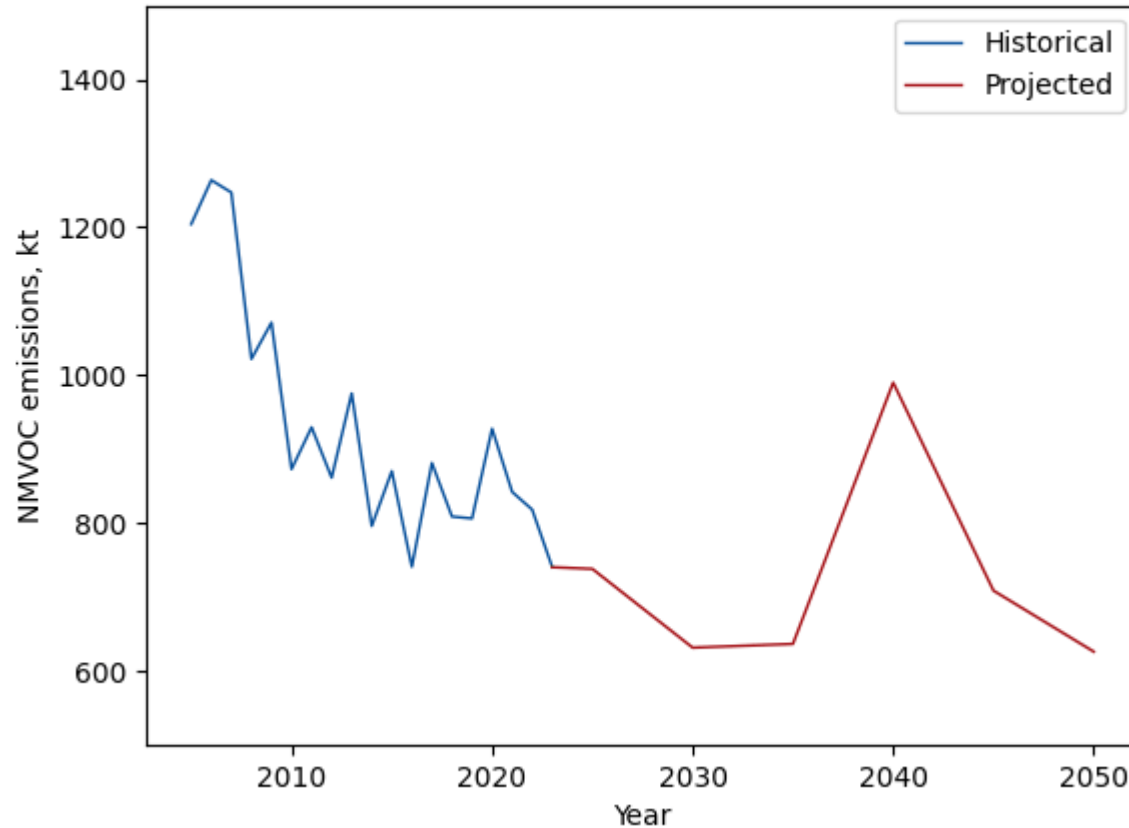
**e Carlo Simulation Results: Emissions Uncertainty Distribu**  
**95% Confidence Intervals (10,000 simulations)**



For illustrative purposes only,  
not real data



- Matplotlib animations – Hypothetical Outcome Plots
  - Helpful for giving a feeling of uncertainty, beyond a single number



- Two types of visualisations developed:
  - **Exploratory:** Enable sector experts to interrogate results (and inputs)
  - **Explanatory:** Allow policy makers to develop understanding of progression against targets
- The programmatic approach means these can be **recreated** (e.g. for different sectors/pollutants) or **developed** (iteratively improved over time) easily

# Next steps for integration into the UK inventory



This project has explored a lot of ground, but outputs need further work to operationalise



**Historic inventory code** ready for adoption

Code and process will be improved over time



Decisions to be made for **projections code**

DEFRA, coordinating with inventory agency, are exploring options



[Kieran.lee@aether-uk.com](mailto:Kieran.lee@aether-uk.com)

[Richard.german@aether-uk.com](mailto:Richard.german@aether-uk.com)