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Coffee Break Seminar

Friday, 20th January 2023

# How to feed the global population with less greenhouse gas emissions?

## Flow analysis of global nitrogen fertilisers and opportunities for mitigation

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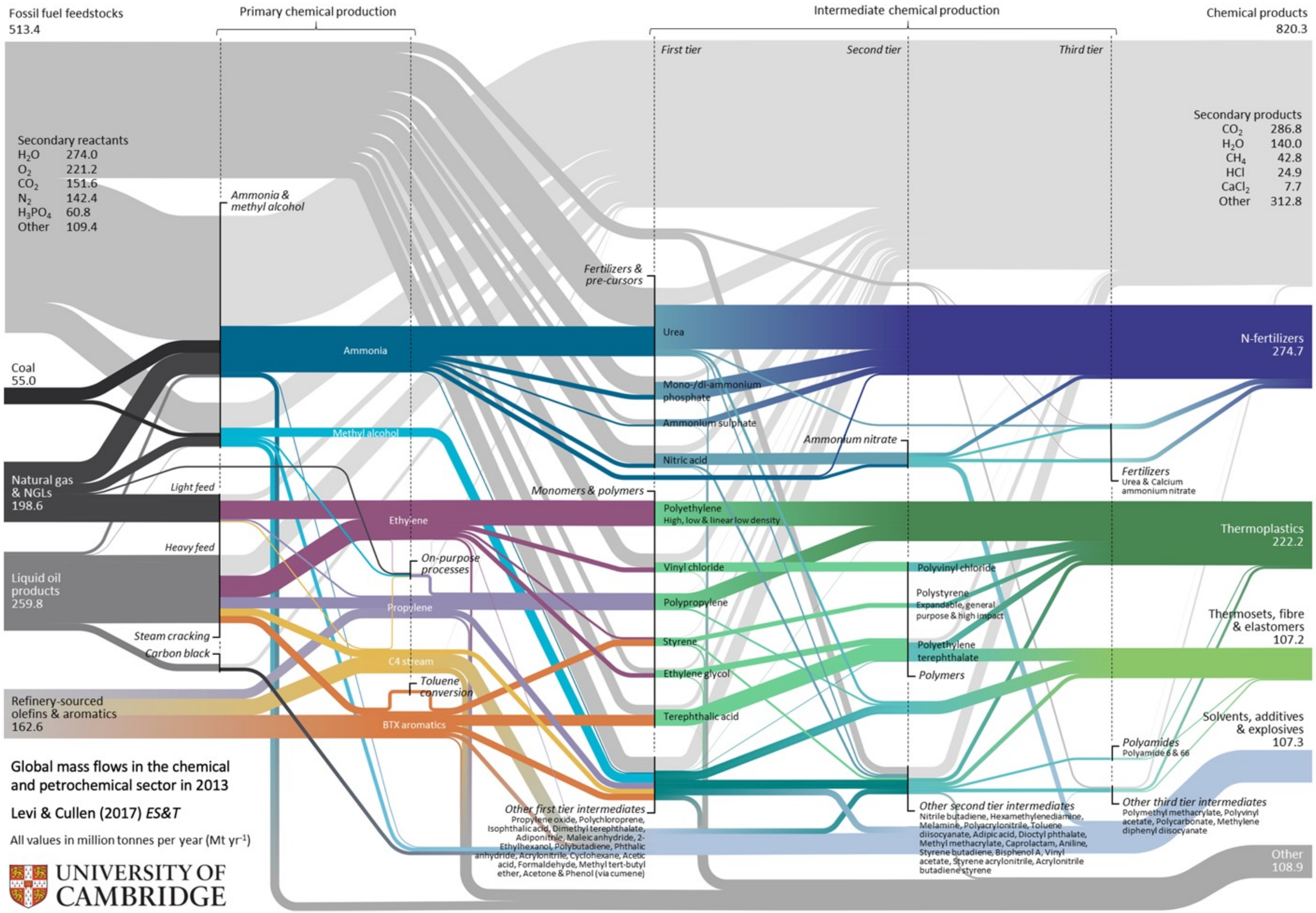
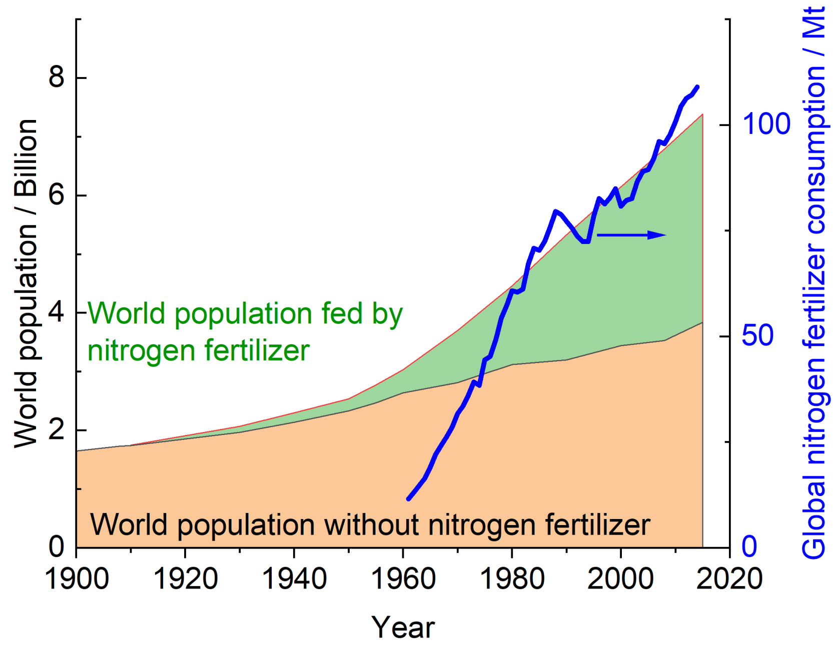
# Global petrochemical industry

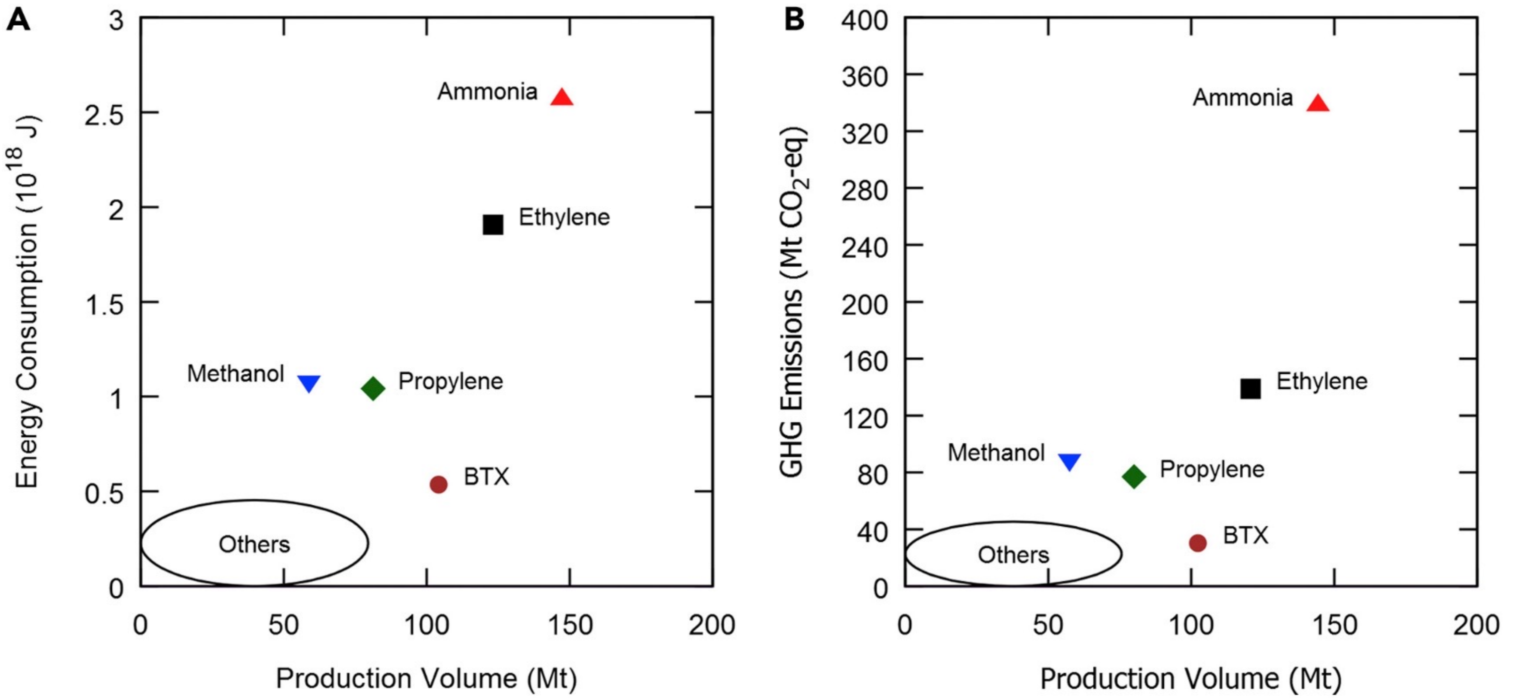


# Nitrogen fertilisers

- 80% of ammonia is converted to nitrogen fertilizers
- Ammonia synthesis: 2% of global energy consumption, after steel (9%) and cement (3%)
- Ammonia has higher energy consumption and GHG emissions than other chemicals




The world population with and without N-fertilisers




Energy consumption and carbon footpr/int of staple chemicals

*Schiffer ZJ et al.* (2017)

# GHG emissions of N-fertilisers

## 1. Production

- Process $CO_2$ emissions (from coal/natural gas)


<u>Coal</u>: 3.92 kg $CO_2$e/kg N

| | |
|---|---|
| Partial oxidation | $2CH_n+O_2 \rightarrow 2CO+nH_2$ |
| Water gas shift | $CO+ H_2O \rightarrow CO_2+H_2$ |
| Haber Bosch | $3H_2 + N_2 \rightarrow 2NH_3$ |

n=0.456

<u>Natural gas</u>: 1.21 kg $CO_2$e/kg N

| | |
|---|---|
| Steam methane reforming | $CH_n+H_2O \rightarrow CO+(n/2+1)\ H_2$ |
| Water gas shift | $CO+ H_2O \rightarrow CO_2+H_2$ |
| Haber Bosch | $3H_2 + N_2 \rightarrow 2NH_3$ |

n=3.951

# GHG emissions of N-fertilisers

1. Production
    - Process $CO_2$ emissions (from coal/natural gas)
    - Energy uses: direct fossil fuel combustion + electricity generation
    - Fossil fuel extraction

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# GHG emissions of N-fertilisers


1. Production
    - Process $CO_2$ emissions (from coal/natural gas)
    - Energy uses: direct fossil fuel combustion + electricity generation
    - Fossil fuel extraction
    - $N_2O$ emissions from nitric acid production

        - 1 kg $N_2O$: 273 kg $CO_2$
        - 0.7 kg $N_2O$/t nitric acid in Europe (catalyst)
        - 5-7 kg $N_2O$/t nitric acid in other regions



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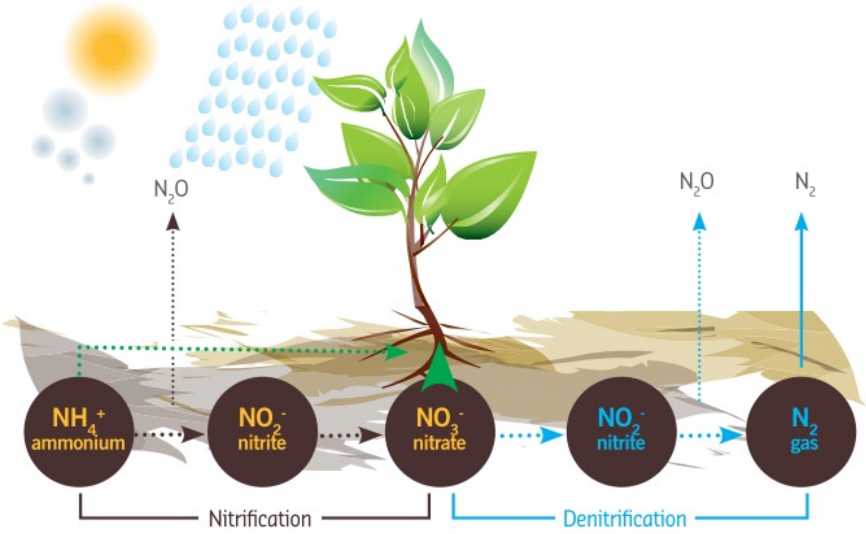
# GHG emissions of N-fertilisers

1. Production
   - Process $CO_2$ emissions (from coal/natural gas)
   - Energy uses: direct fossil fuel combustion + electricity generation
   - Fossil fuel extraction
   - $N_2O$ emissions from nitric acid production


2. Use
   - $N_2O$ from nitrification/denitrification
   - Indirect $N_2O$ from $NH_3$ volatilisation
   - Indirect $N_2O$ from $NO_3^-$ leaching
   - $CO_2$ from urea decomposition
   - $CO_2$ from liming





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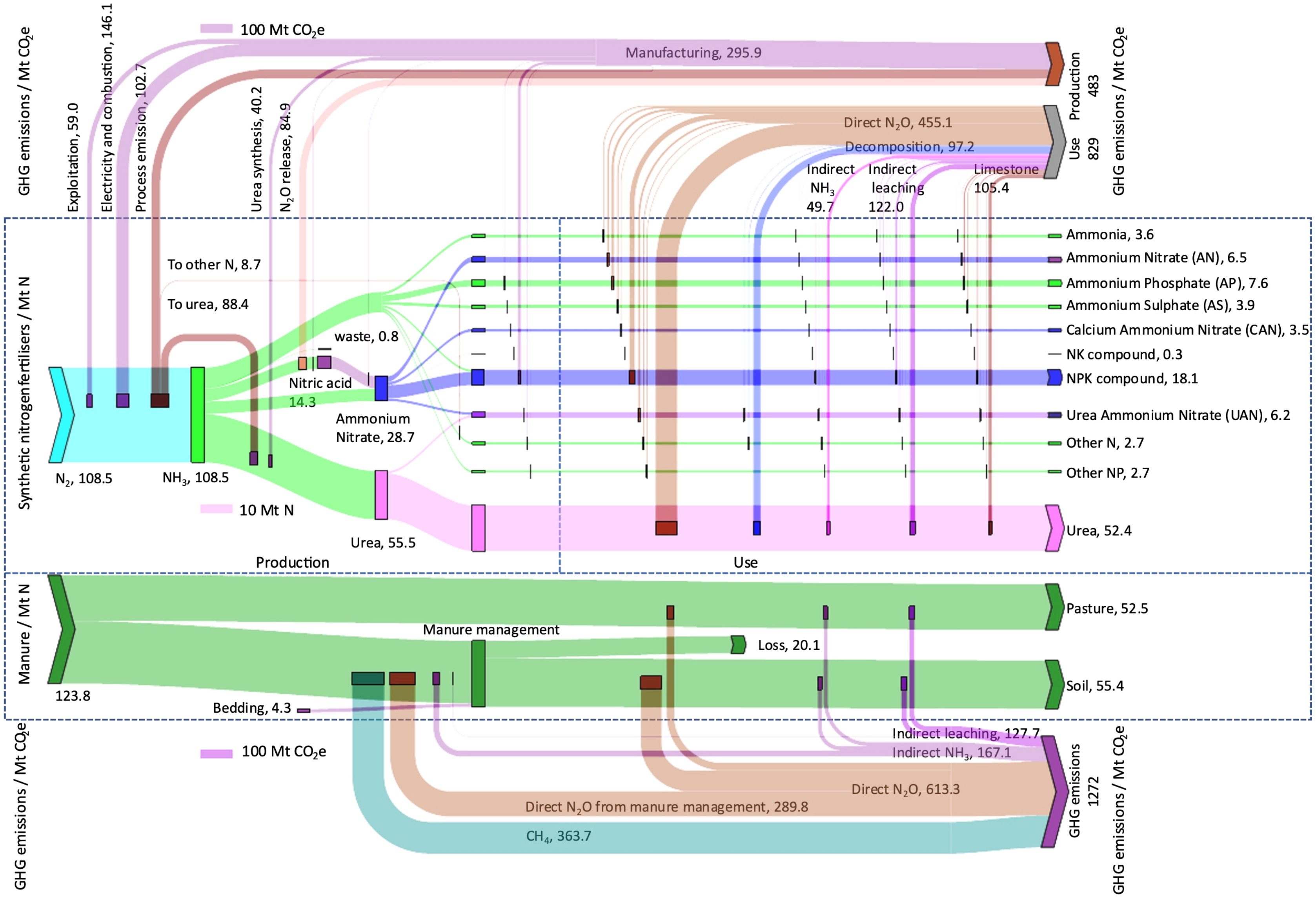
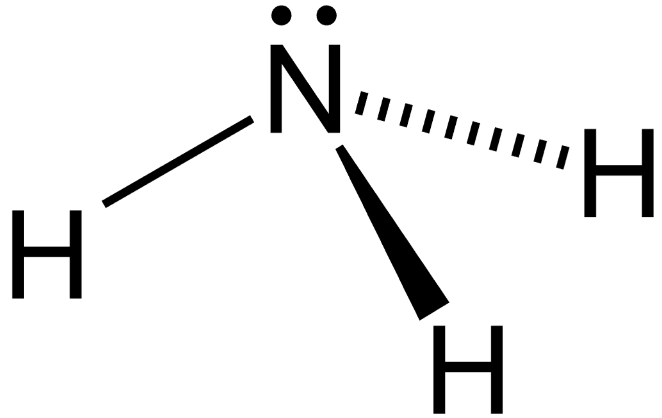
# Global flows and GHG emissions of N-fertilisers






Nature Food, accepted

# Mitigation options: production




Ammonia

$N_2$

- Internal combustion of air (natural gas)
- Cryogenic distillation (coal) **renewables**

$H_2$

- Coal gasification **+ $CO_2$ + CCS / electric heating**
- Steam methane reforming **+ $CO_2$ + CCS /electric heating**
- Water electrolysis
- Methane pyrolysis **low TRL**



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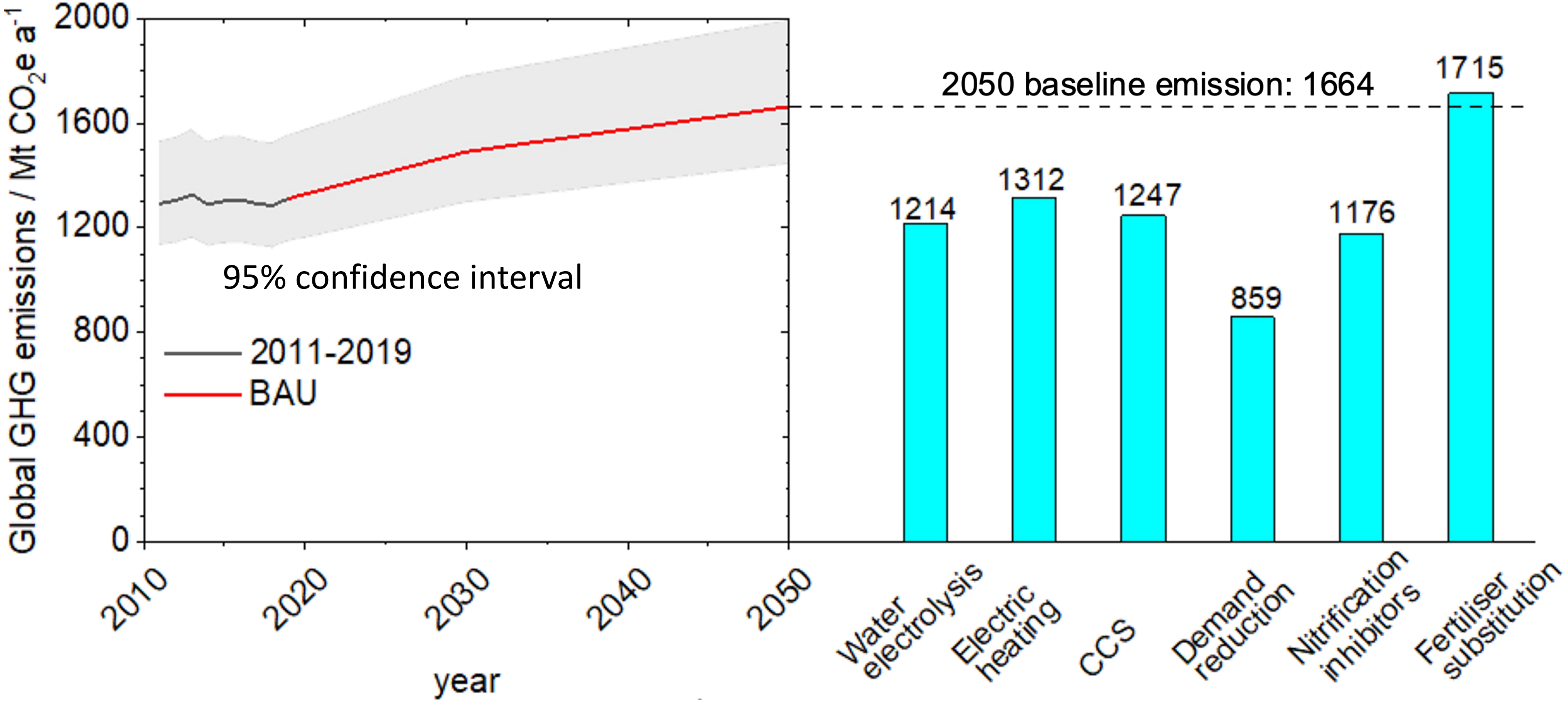
# Mitigation potential: production







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# Mitigation options: use

- Use less
  - Demand for fertilisers can be reduced without loss of productivity

- Change in type of fertiliser
  - Ammonium nitrate leads to ~ -30% use-phase emissions than urea, but it is explosive.

- Use of nitrification inhibitors
  - Nitrification inhibitors can be mixed with nitrogen fertilizers to reduce direct $N_2O$ emissions by ~50%


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# Potential for demand reduction


Zhang X, et al. Nature Food, 2021, 2(7): 529-540.



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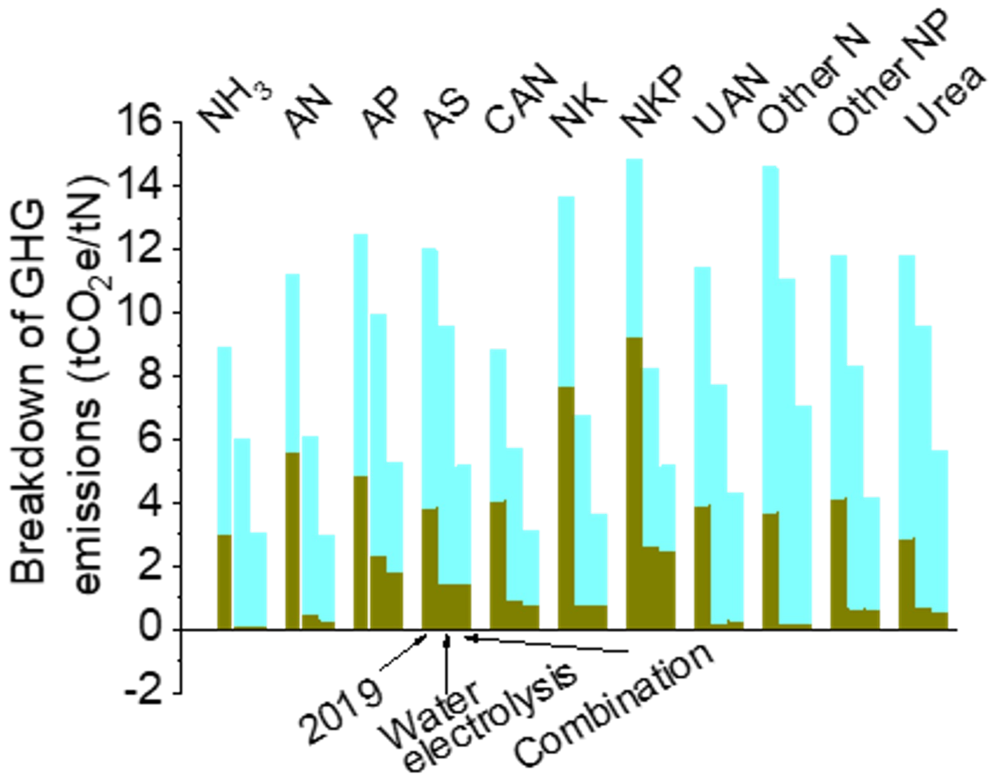
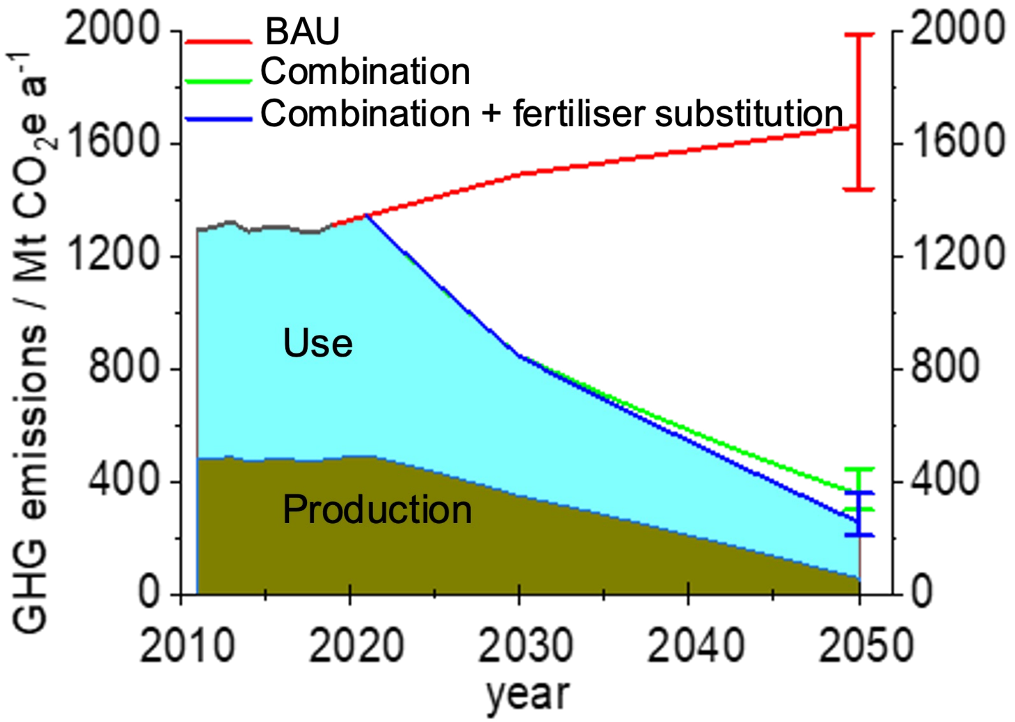
# Mitigation potential: combination of interventions

Combination: water electrolysis + demand reduction + nitrification inhibitors
Fertiliser substitution: urea, ammonium bicarbonate, UAN → AN



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# Further questions

- Understand factors influencing future demand and the potential for demand reduction:
  - Global nitrogen use efficiency in the supply chain: 8%
  - 33% of produced food is wasted
  - Diets: beef 10%, pork 20%, poultry 34%

- Understand factors influencing the implementation of mitigation options in production:
  - Effect of vintage of existing plants
  - Pace of implementation of CCS / water electrolysis
  - Catalysts for $N_2O$ decomposition in nitric acid production
  - Nitrification inhibitors



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# Key messages

- Even if we are able to decarbonise the production of fertilisers, **2/3 of current use phase** emissions would remain.
- Combining **demand reduction, nitrification inhibitors, optimising fertiliser mix, and decarbonising production** are required to enhance mitigation potential
- Even after this, approx. **1/5 of current emissions would remain**



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Thank you



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