Integrated Nitrogen Management

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for the
Integrated Nitrogen Committee
of the
USEPA Science Advisory Board

Farm, Ranch, and Rural Communities Meeting
Washington DC
February 23, 2009

Integrated Nitrogen Committee

- **A self-initiated project of the Science Advisory Board begun 1/2007, projected completion 9/2009**
- **Cross representation from universities, industries, government, and NGOs**
- **Based on the need to develop better strategies to manage Nr**
- **Draft report: http://yosemite.epa.gov/sab/sabproduct.nsf/MeetingCal/F5B0375541B31DB78525753800486151?OpenDocument.**
- ***Comments welcome through March 1***

Overview of Talk

- **Reactive Nitrogen (Nr) and the N Cascade**
- **Sources of Nr in the US.**
- **Nr Fate in the US.**
- **Consequences, Impacts and Metrics.**
- **Selected Recommendations**

What is Reactive Nitrogen?

All chemical forms of nitrogen, except N_2

Examples: NH_3-NH_4^+, N_2O, NO, NO2, NO_2^-, NO_3^-

Organic-N

Why do we need reactive nitrogen?

- **Human dietary Nr requirement = 4.3 kg/cap/yr**
- **US = 1.4 Tg/yr**
- **World = 28 Tg/yr**

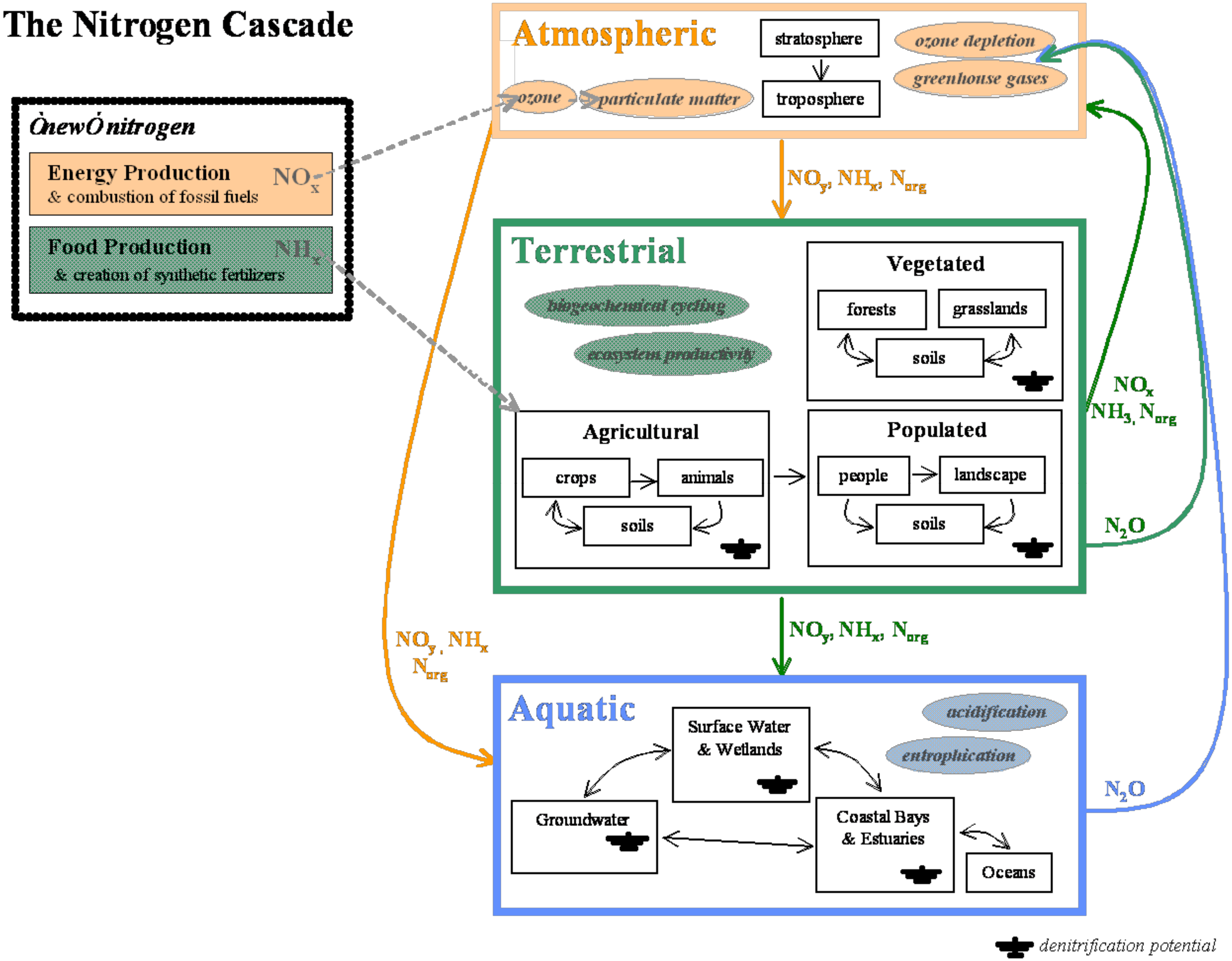
Nr Introduction into the US

- Fossil fuel combustion
  - stationary sources
  - transportation sources
- Haber Bosch Nr
  - produced in US
  - imported from other countries
- Import of N-containing commodities
  - grain and meat
- Biological nitrogen fixation (BNF)
  - managed lands
  - unmanaged lands

The Nitrogen Cascade

- The concept of the nitrogen cascade emphasizes that once a new Nr molecule is created, it can be sequentially transformed and travel throughout the environment and contribute to a series of major environmental problems.

The Nitrogen Cascade



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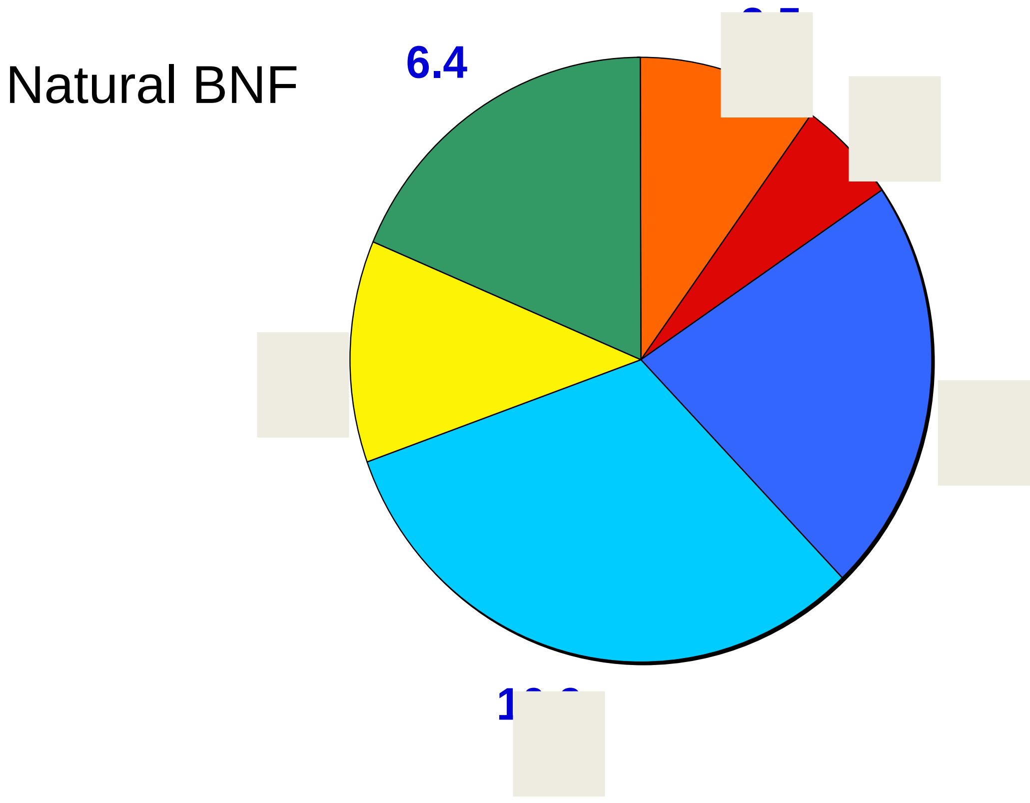
Nr Introduction into the US

Tg N/yr



Nr Introduction into the US

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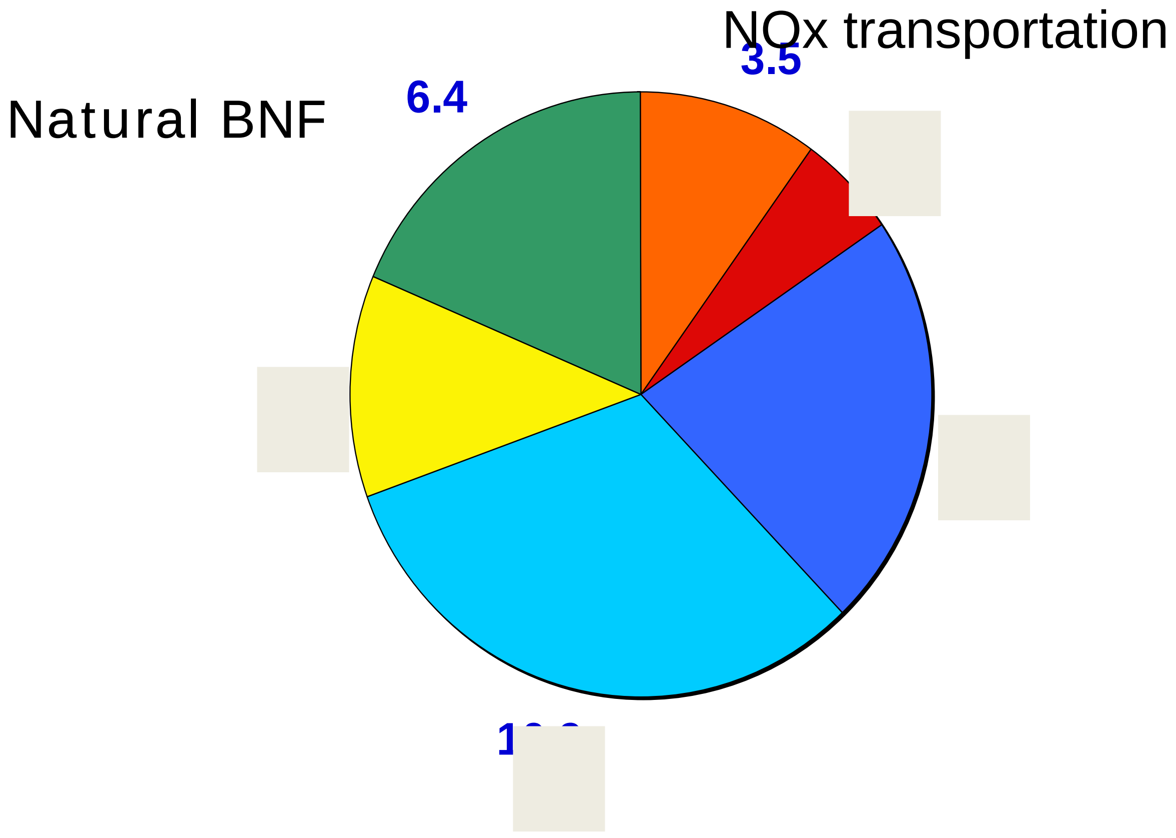

Nr Introduction into the US

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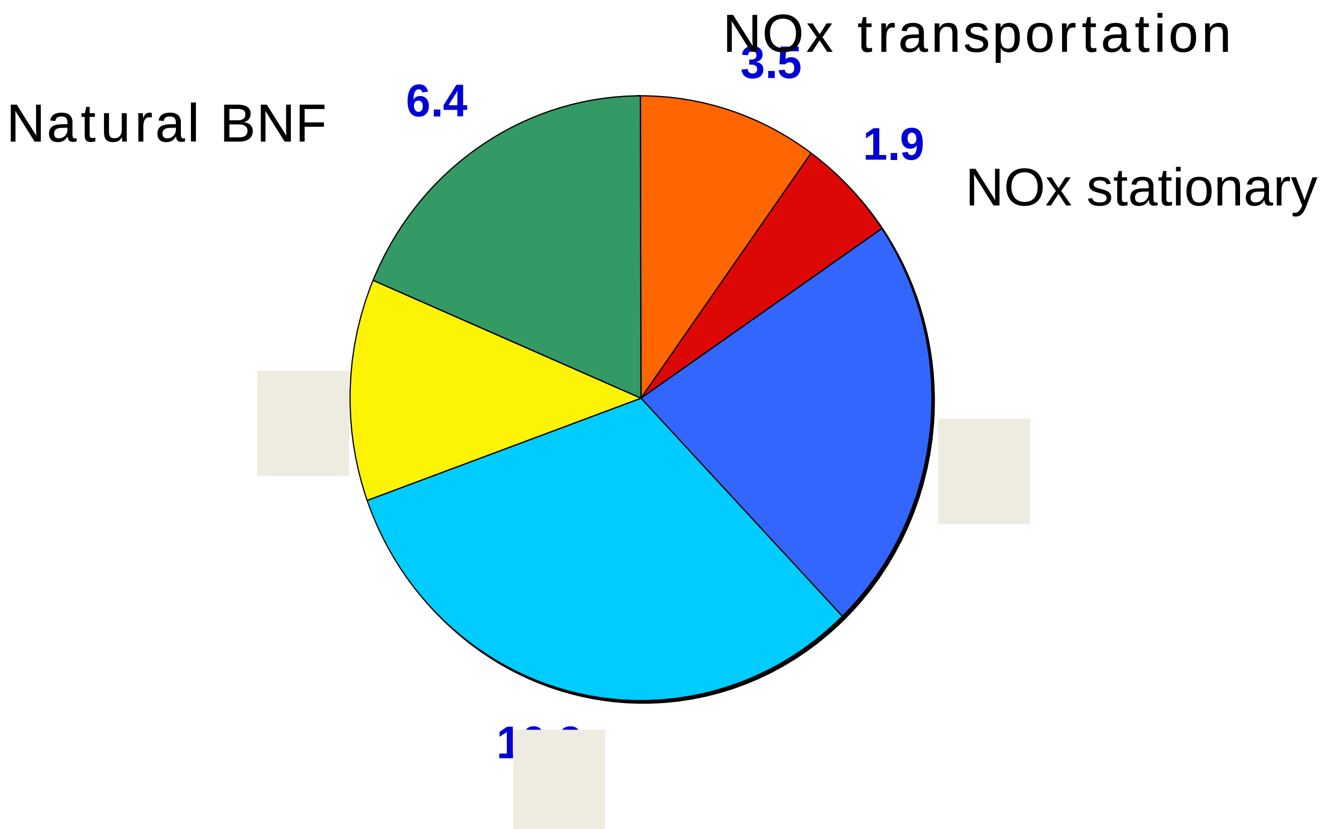

Nr Introduction into the US

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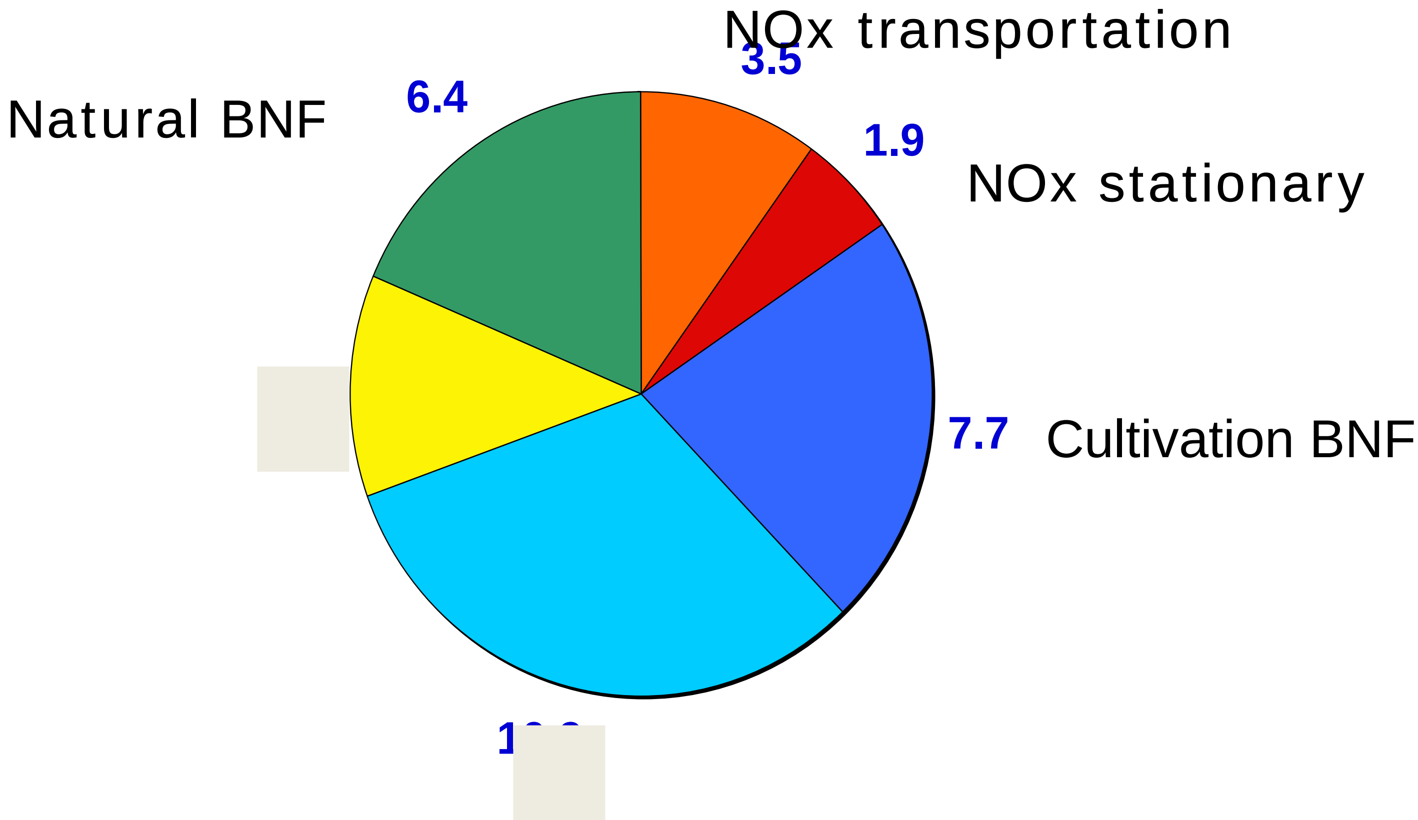

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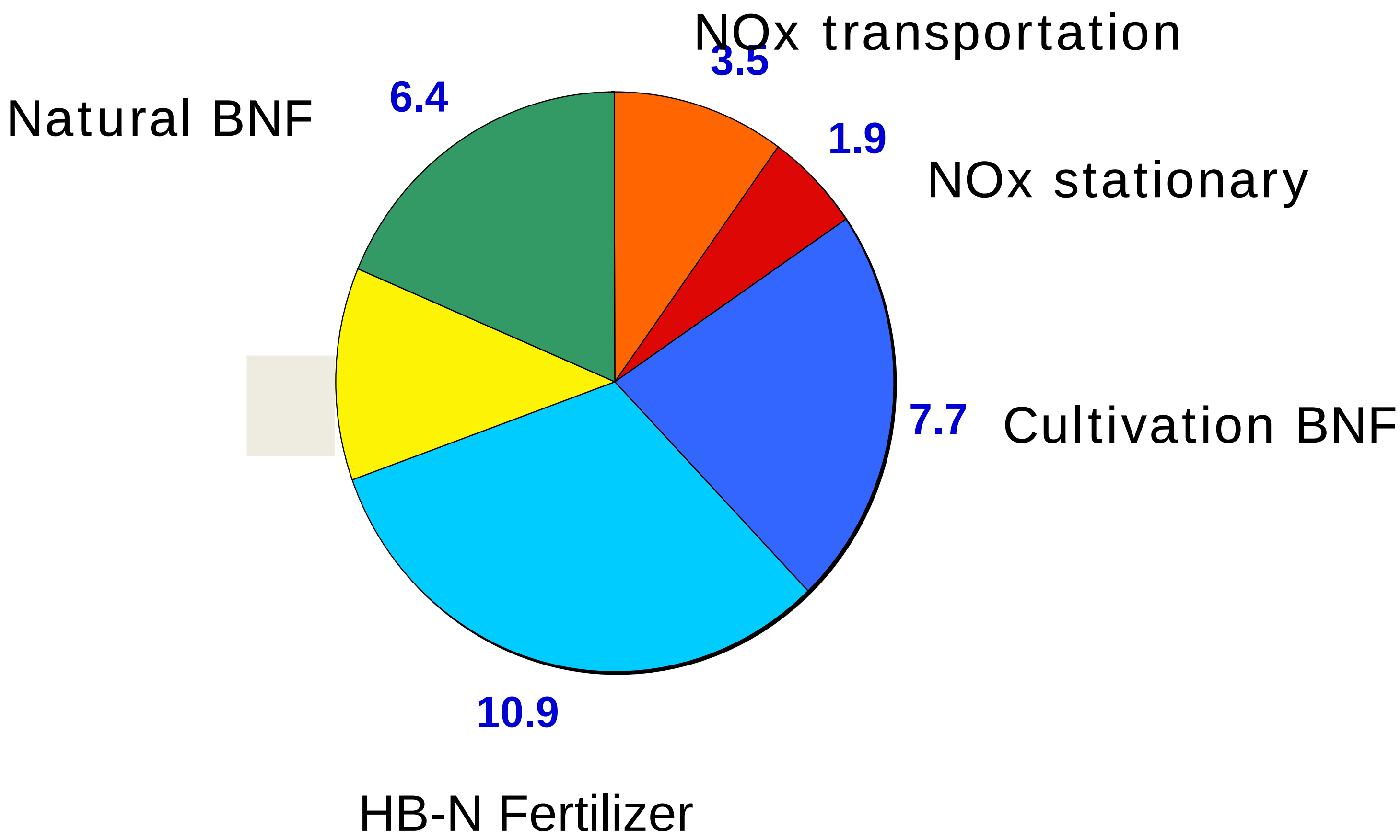
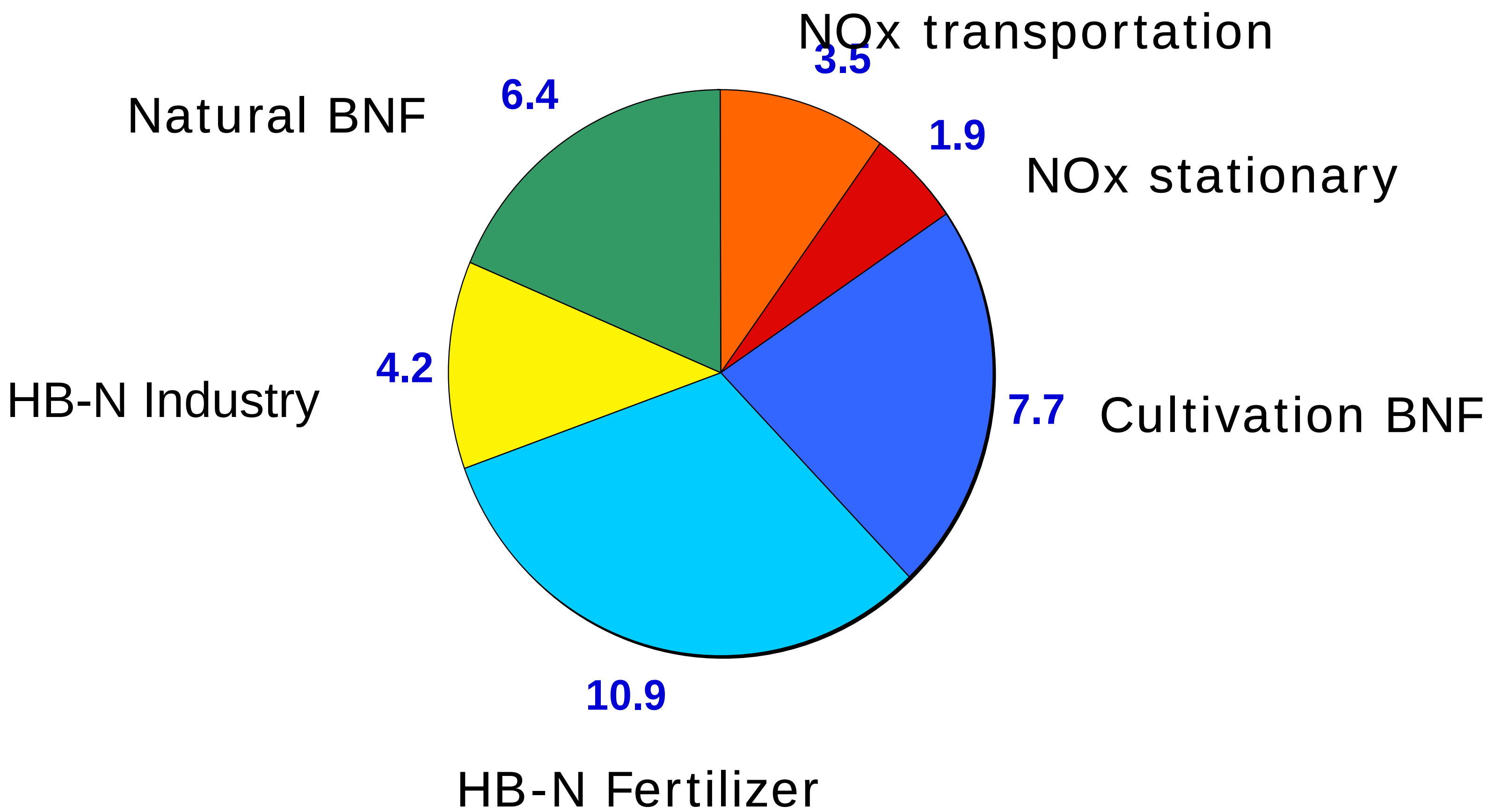


Nr Introduction into the US

Tg N/yr



Natural, 6.5 Tg N/yr

Anthropogenic, 29 Tg Nr/yr

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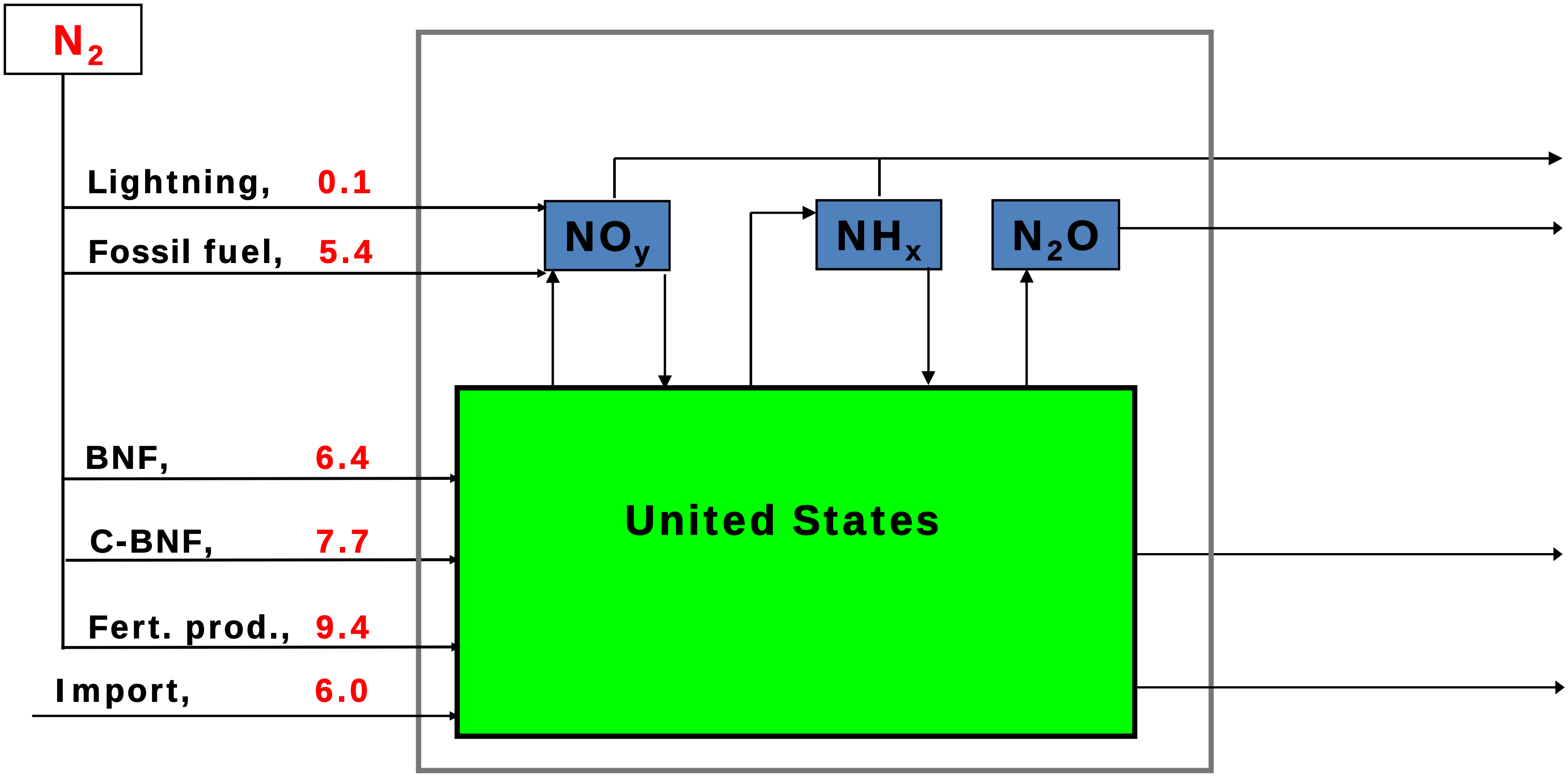
Fate of Introduced Nr

- Lost as Nr from US
  - via rivers
  - via atmospheric advection
  - via exports
- Stored as Nr
  - in soils & vegetation
  - In groundwater
- Denitrified to N_2

US Nitrogen Budget

Tg N yr^{-1}



US Nitrogen Budget

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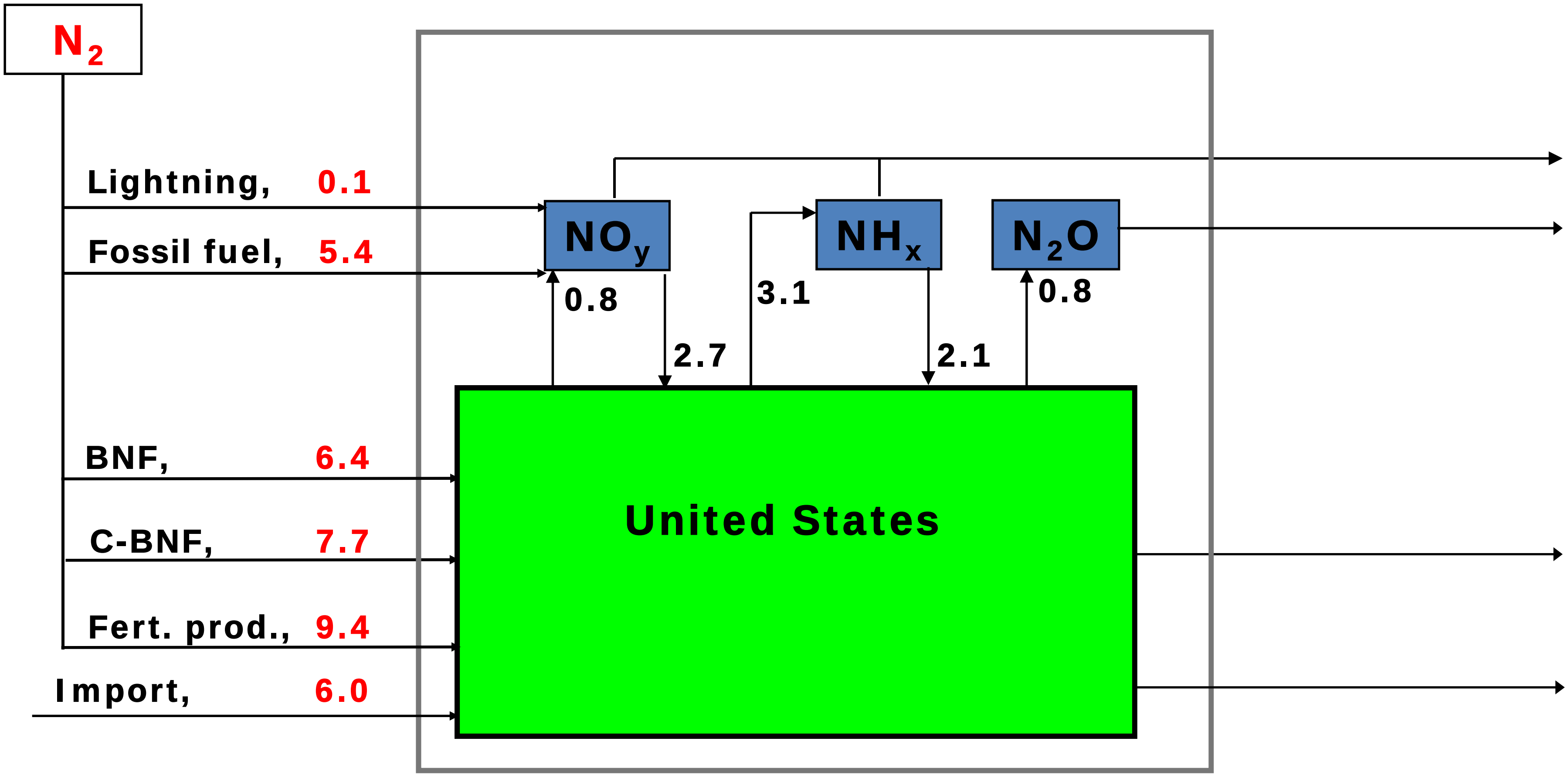

US Nitrogen Budget

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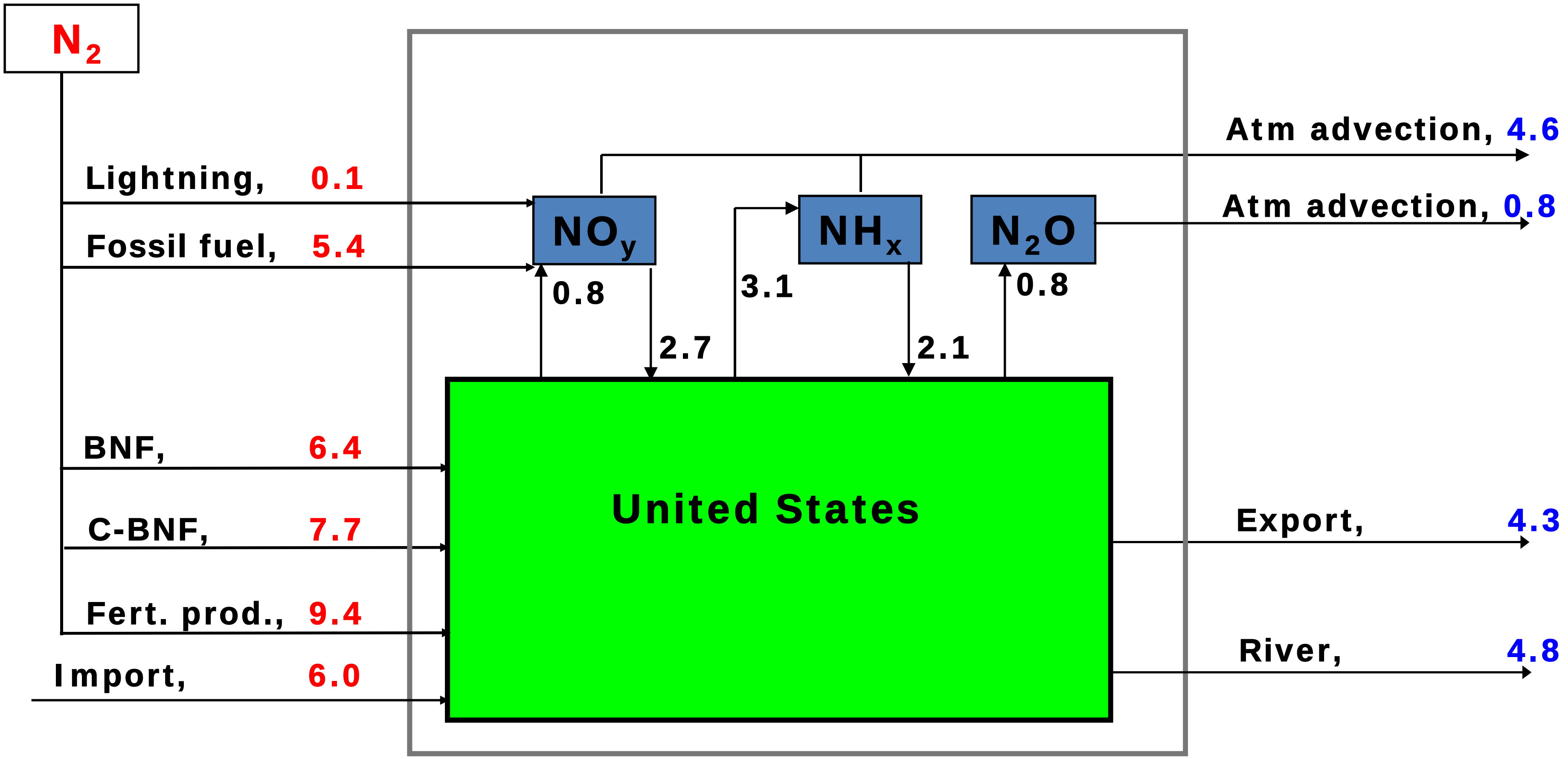

US Nitrogen Budget

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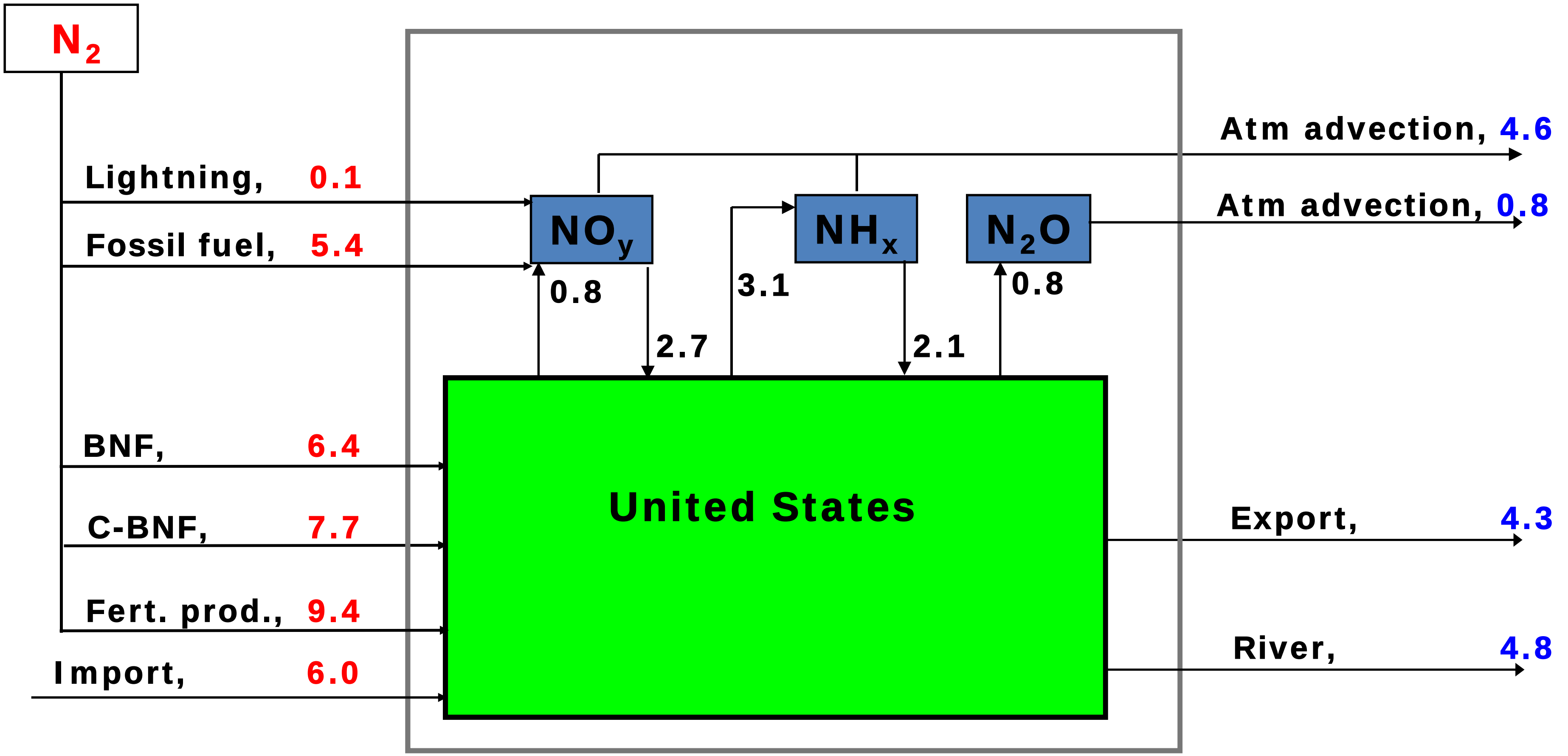

Nr Inputs: 35 Tg N
Nr Outputs: 14 Tg N

Nr Missing: 21 Tg N

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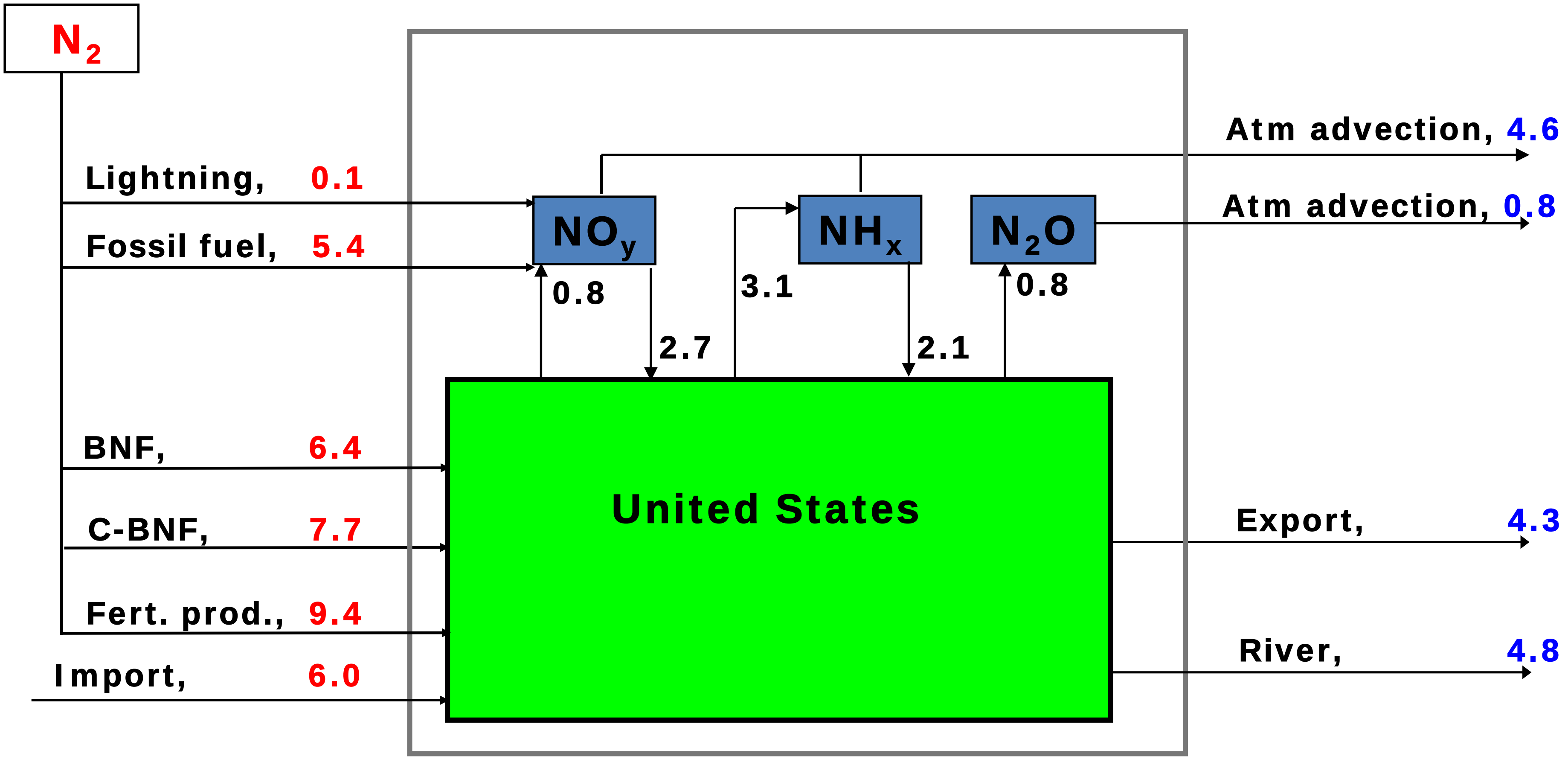

Nr Inputs: 35 Tg N
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Nr Storage: 5 Tg N
~ 2 Tg soils&vegetation
~ 3 Tg groundwater

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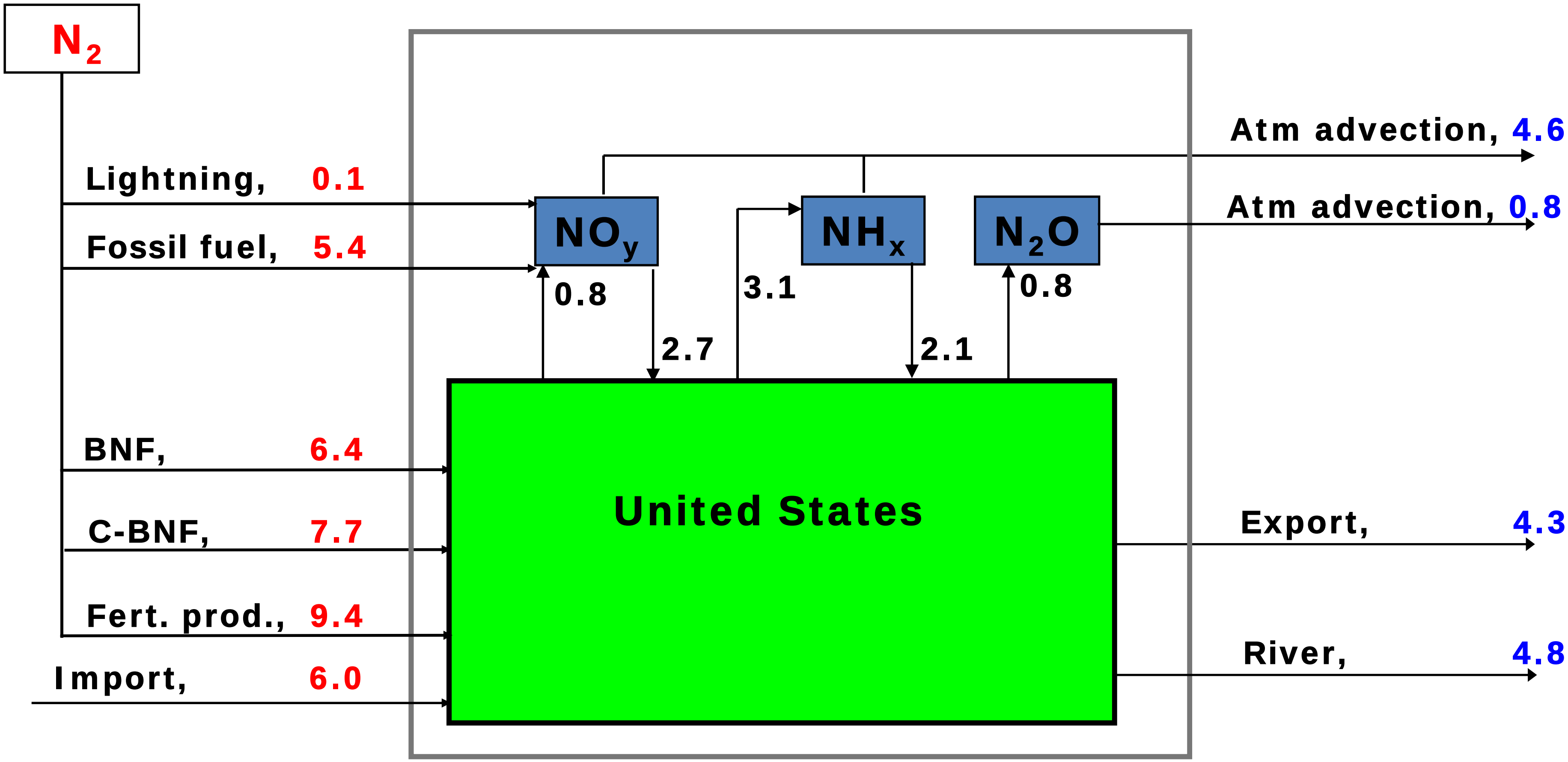

Nr Inputs: 35 Tg N
Nr Outputs: 14 Tg N

Nr Missing: 21 Tg N

Nr Storage: 5 Tg N
~ 2 Tg soils&vegetation
~ 3 Tg groundwater

Nr Denitrified to N_2:
21 Tg N - 5 Tg N = 16 Tg N

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Impacts of manufactured Nr

Positive

- Protein requirements for ~3 billion humans
- Fertilization of forests

Negative

- Air quality impairment
- Eutrophication/hypoxia
- Loss of biodiversity
- Global warming
- Acid rain
- Ozone depletion
- Drinking water contamination

Major (US) federal laws for managing nitrogen

- **CAA (1990) regulates NO_x emitted into atmospheric systems**
- **CWA (1977) regulates NH_3 and total Nr released into aquatic systems**
- **SDWA (1996) regulates NO_3^- and NO_2^- in potable waters**
- **EISA (2007) requires the setting of biofuel standards based on life cycle**

Metrics for Nr

Quantity: **Mass, concentration, flux, loading**

Impacts: **Category and ecosystem services**

Policy**:** **Adverse risk**

Economic**:** **Price of benefits and costs**

Regulatory: **Criteria, Standards & Thresholds**

Metrics Case Study: Chesapeake Bay

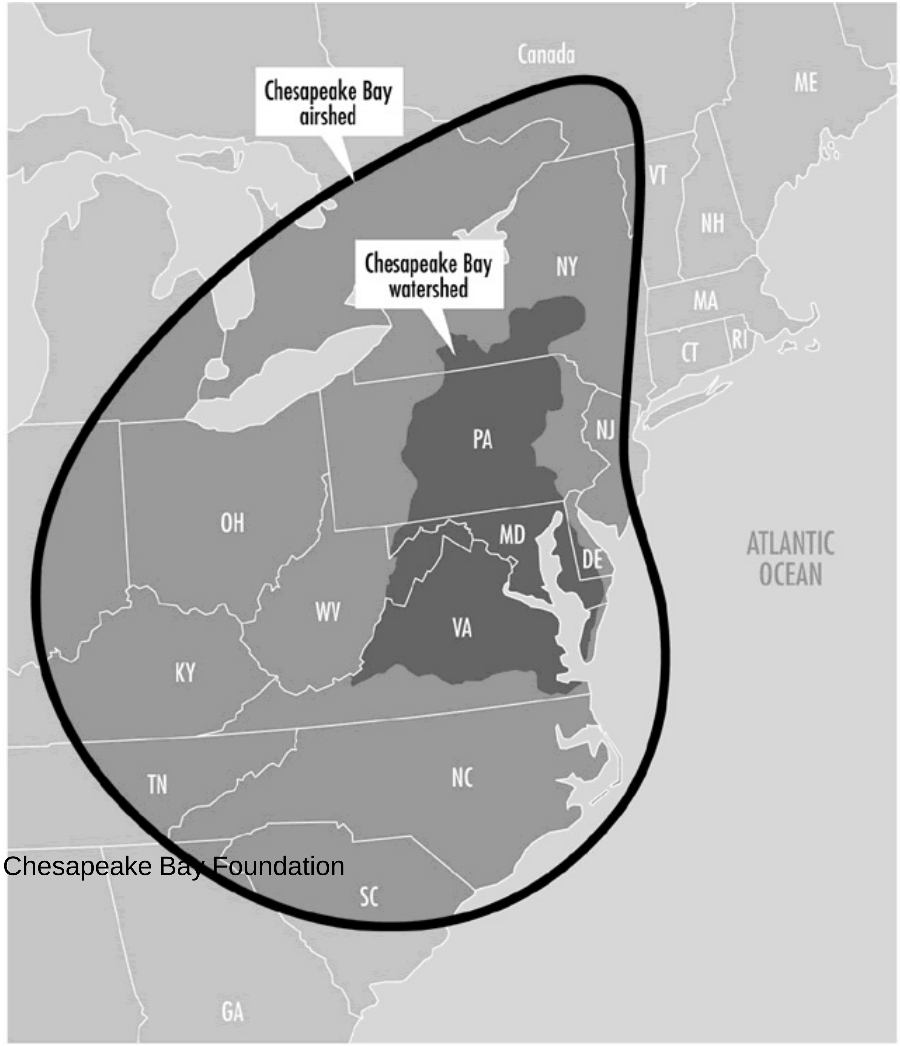
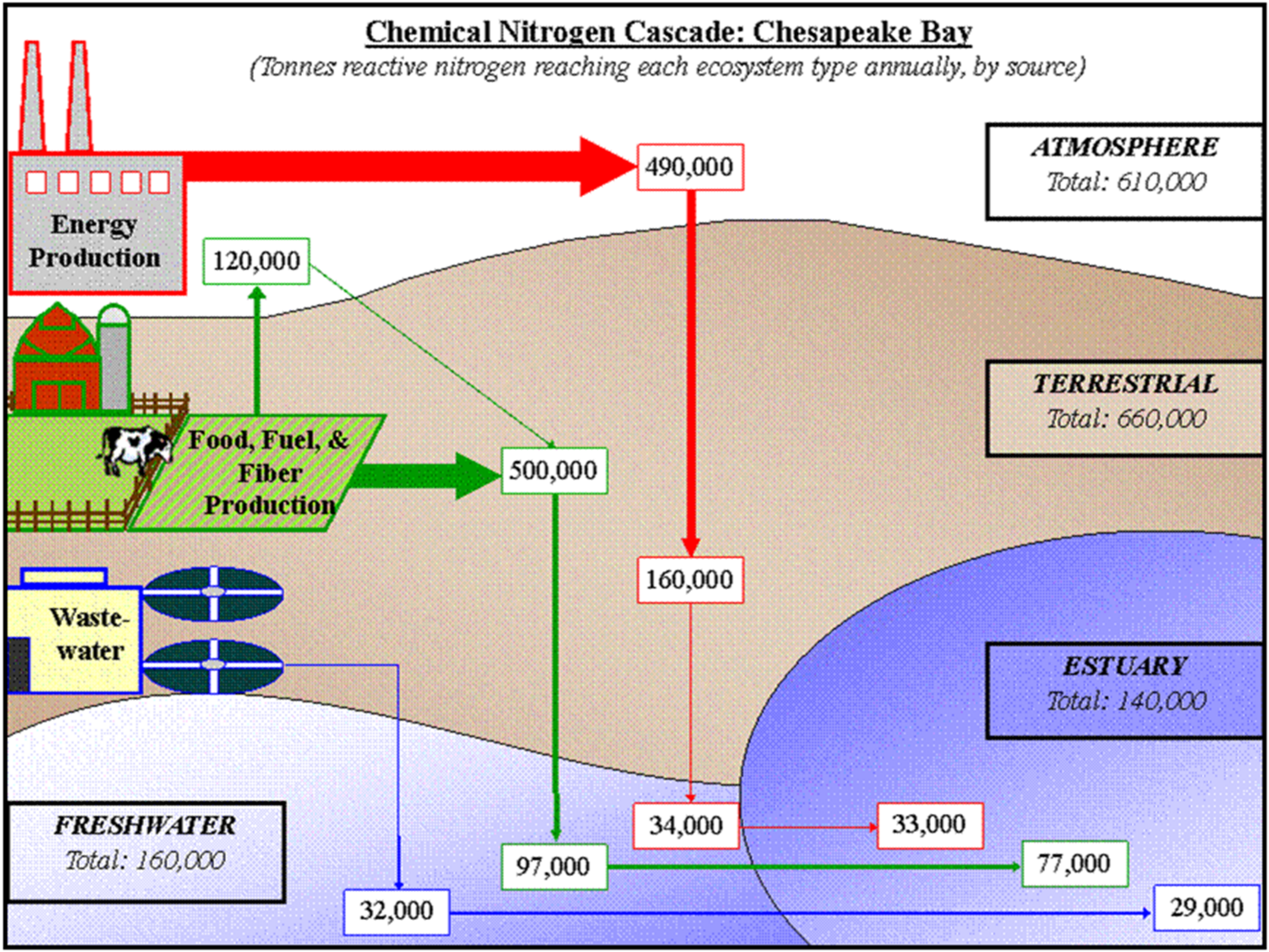
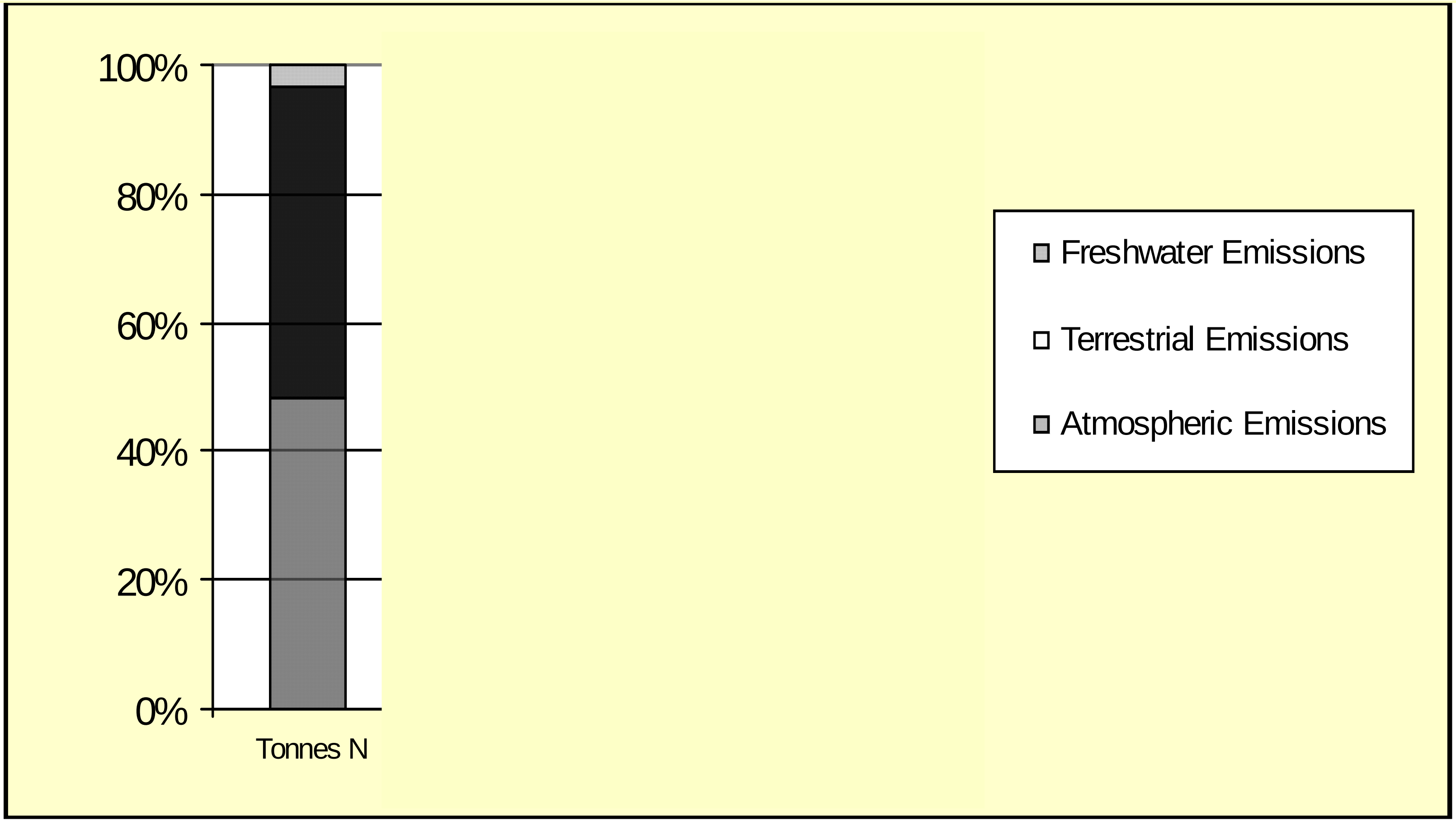


Image from Chesapeake Bay Foundation

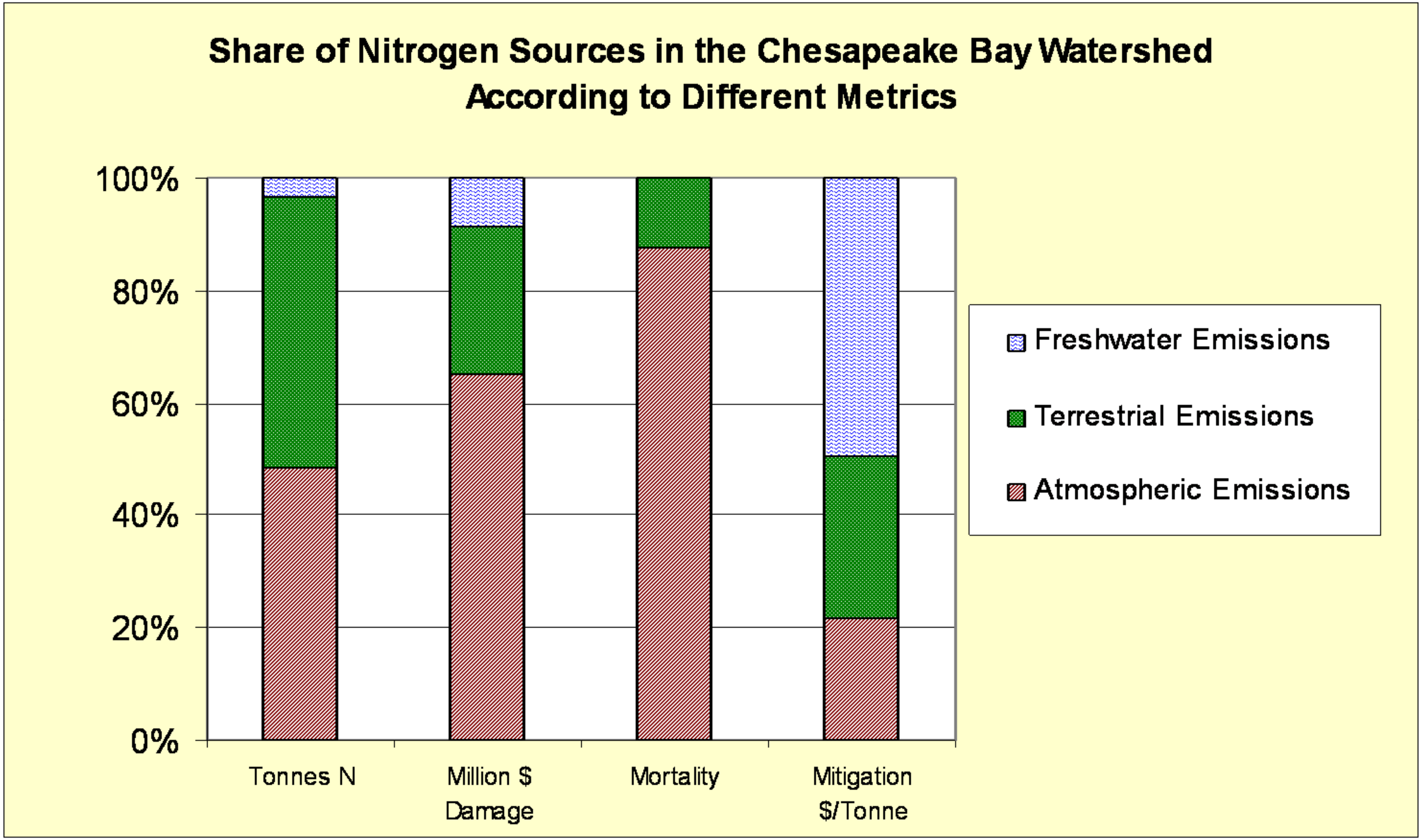

Chemical Nitrogen Cascade: Chesapeake Bay
(Tonnes reactive nitrogen reaching each ecosystem type annually, by source)
Energy Production
490,000
ATMOSPHERE
Total: 610,000
120,000
Food, Fuel, & Fiber Production
500,000
TERRESTRIAL
Total: 660,000
160,000
Waste-water
ESTUARY
Total: 140,000
FRESHWATER
Total: 160,000
34,000
33,000
97,000
77,000
32,000
29,000

Share of Nitrogen (Mass) to the Chesapeake Bay Watershed by Source



Modified from Moomaw and Birch, 2005

Nr to Chesapeake Using Different Metrics



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Control Points

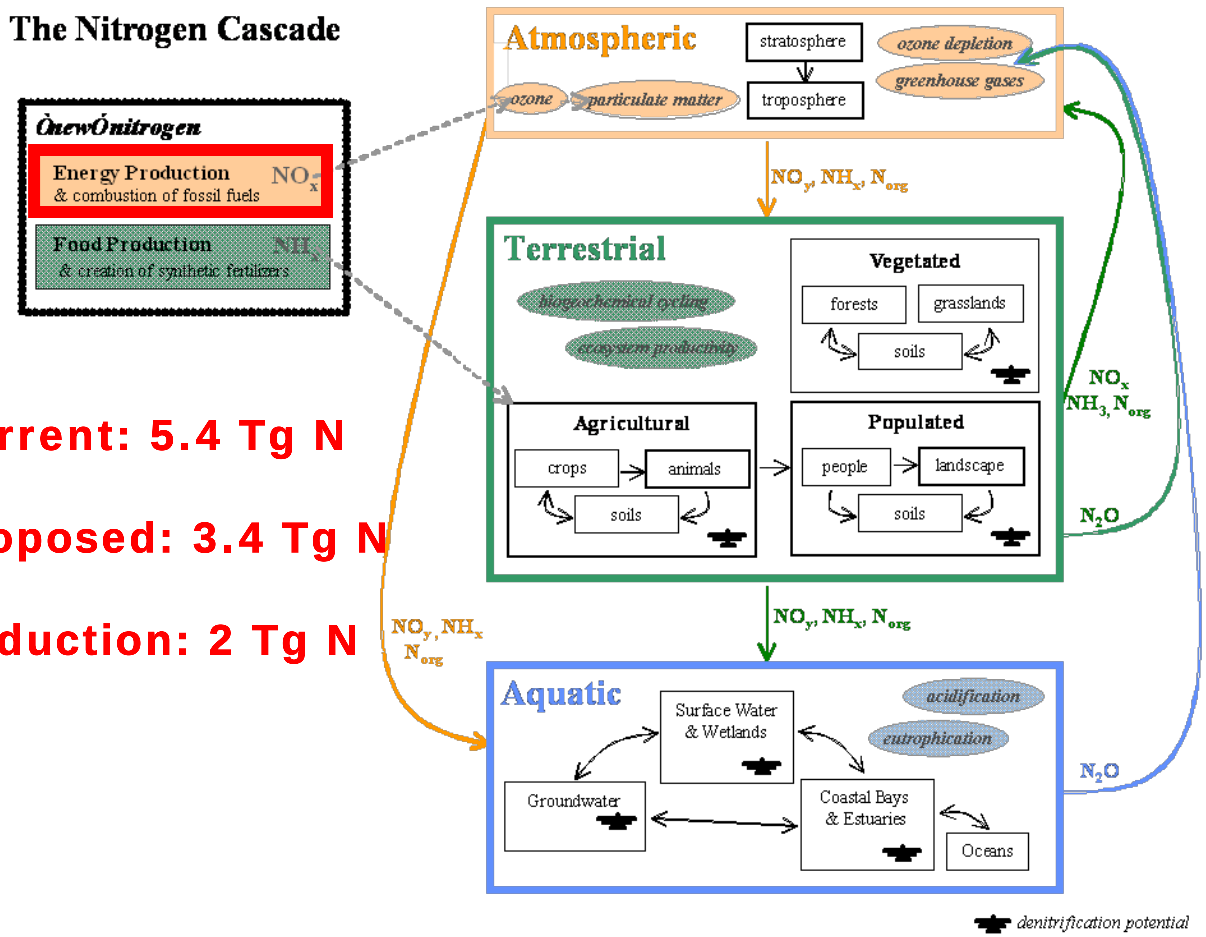
- **The overarching objective is to maintain the benefits of nitrogen while minimizing the losses to the environment.**
- **Control points are locations in the N cascade where:**
  - **N uptake processes can be improved**
    - **e.g., nitrogen use efficiency**
  - **N losses to environment can be better managed**
    - **e.g., wastewater**

Selected Recommendations

- **INC makes the following five recommended actions at control points**

- **These recommendations, if enacted, would reduce the anthropogenic Nr load to the US environment by 20%**

Control Point: Combustion



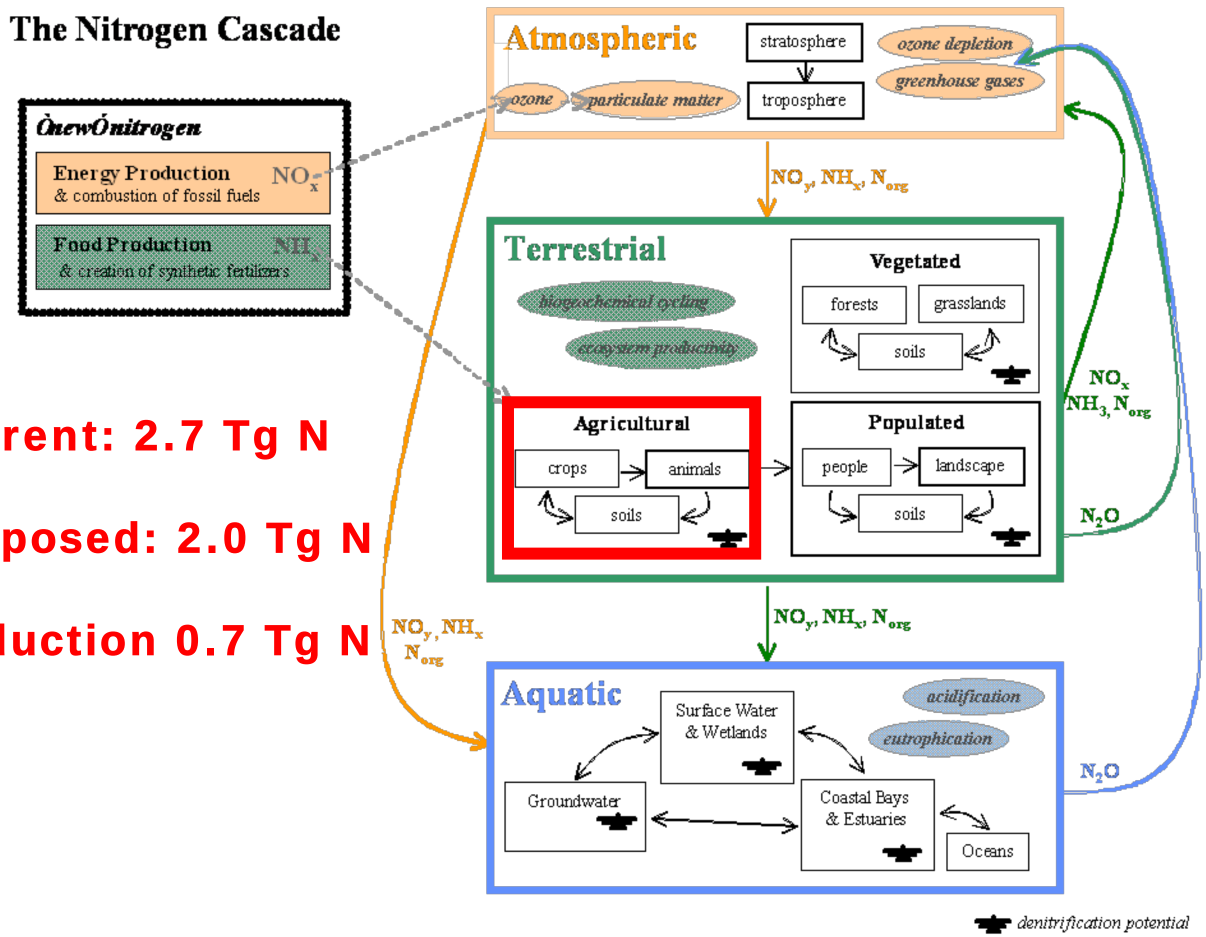
Current: 5.4 Tg N

Proposed: 3.4 Tg N

Reduction: 2 Tg N

- **We recommend that the EPA expand its NOx control efforts to include 90% decreases of emissions from heavy-duty on-road, all off-road mobile sources and currently uncontrolled electricity generation and industrial processes.**

Control Point: NH_3 from Manure and Fertilizer



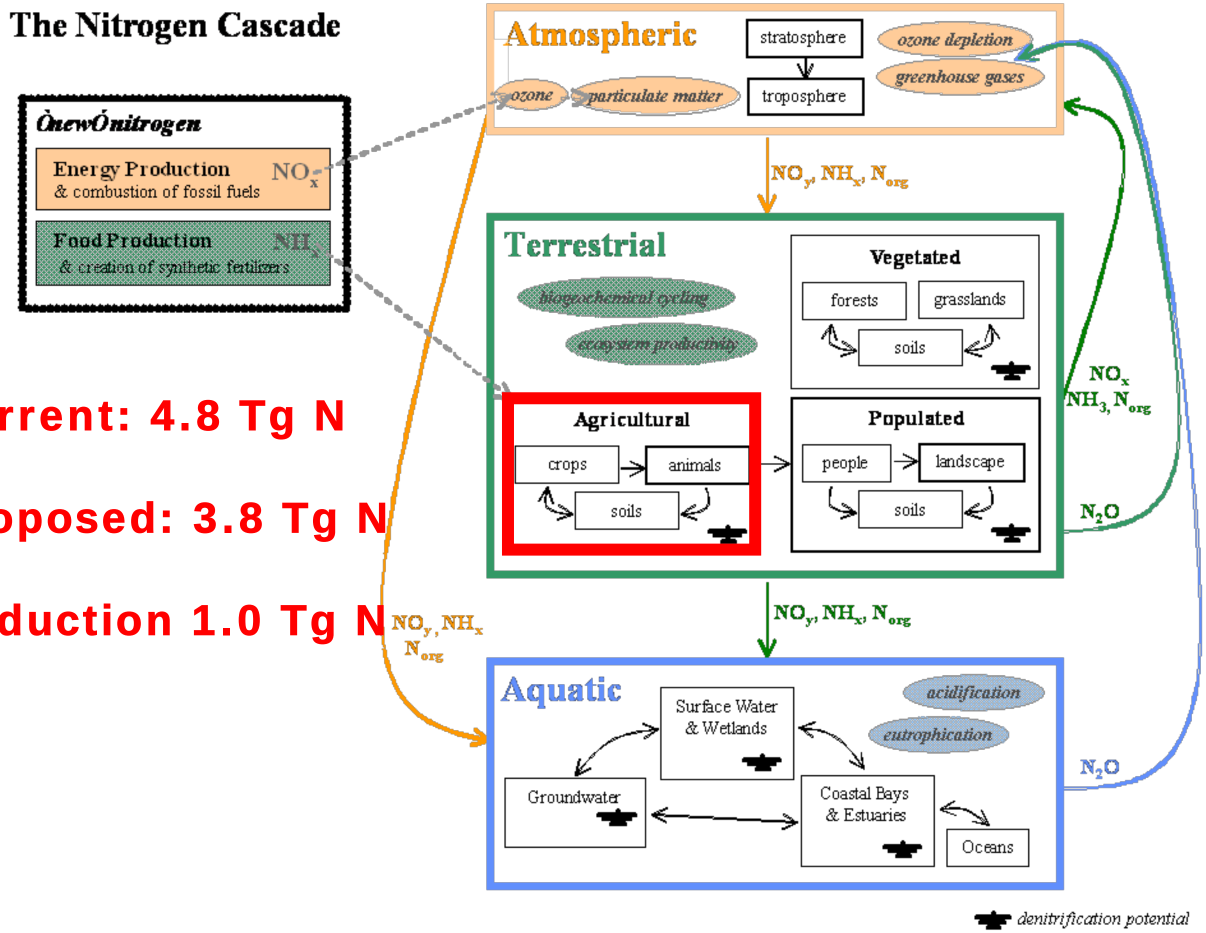
Current: 2.7 Tg N

Proposed: 2.0 Tg N

Reduction 0.7 Tg N

- **We recommend decreasing livestock-derived ammonia emissions to approximately 80% of 1990 emissions, a decrease of 0.5 Tg N per year.**
- **We recommend decreasing ammonia emissions derived from fertilizer applications by 20%, a decrease by ~0.2 Tg N per year.**

Control Point: Nr losses from Croplands



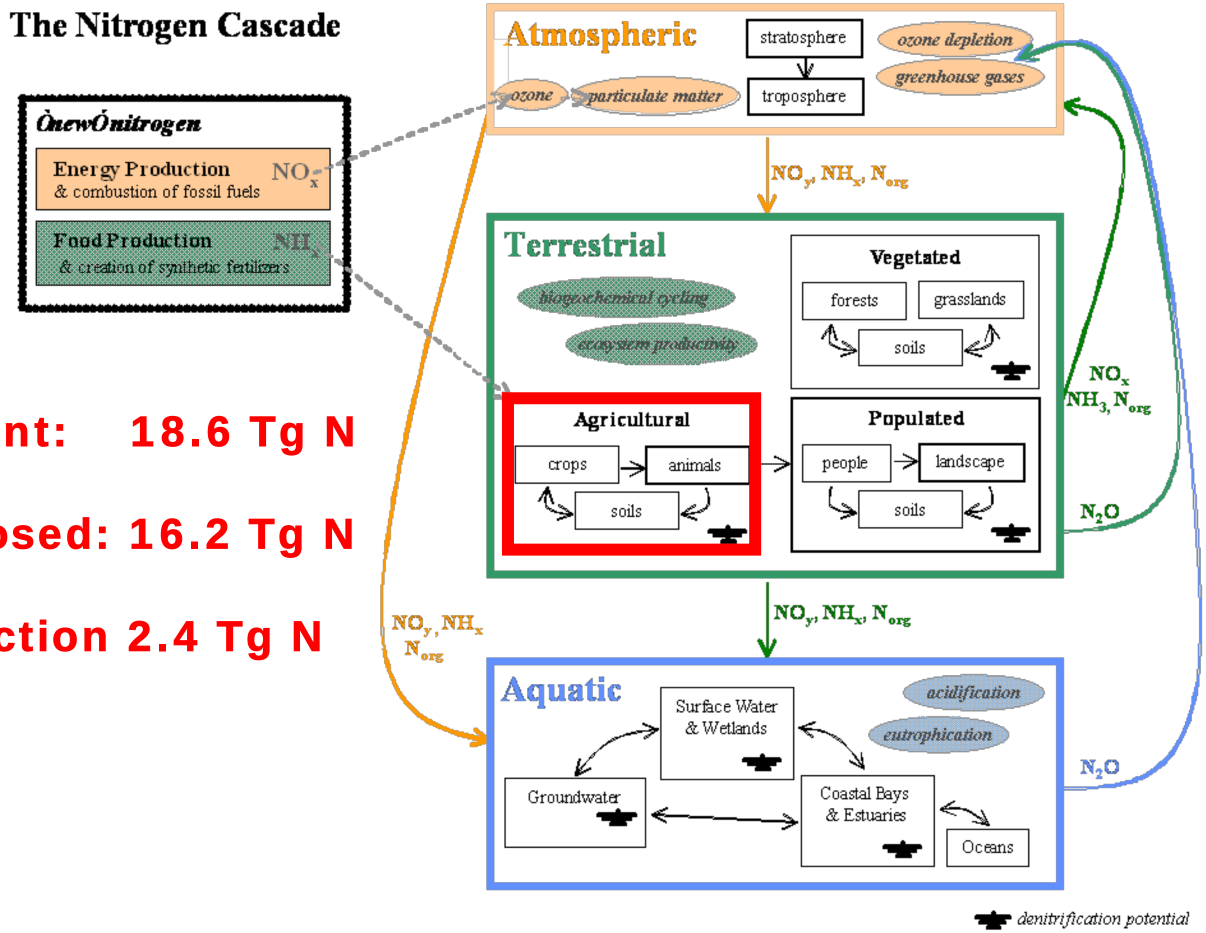
Current: 4.8 Tg N

Proposed: 3.8 Tg N

Reduction 1.0 Tg N

- **We recommend decreasing flows of Nr into streams, rivers, and coastal systems by approximately 20% through improved landscape management, including wetland management improved tile-drainage systems and riparian buffers on crop land, etc.**

Control Point: Nitrogen Use Efficiency



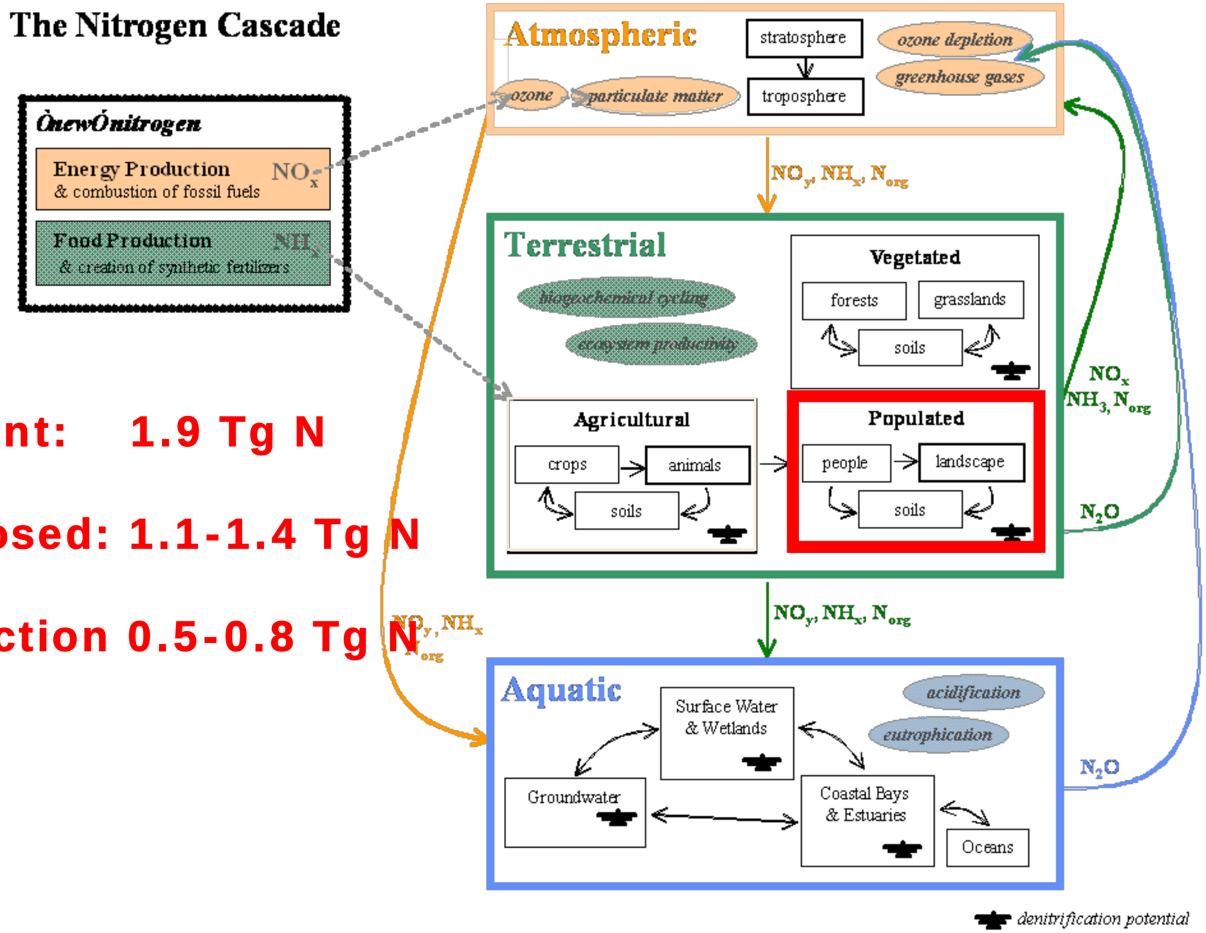
Current: 18.6 Tg N

Proposed: 16.2 Tg N

Reduction 2.4 Tg N

- **We recommend an increase in crop N-uptake efficiencies of 25% over current levels through a combination of knowledge-based practices and advances in fertilizer technology (such as controlled release).**

Control Point: Wastewater Treatment



Current: 1.9 Tg N

Proposed: 1.1-1.4 Tg N

Reduction 0.5-0.8 Tg N

- **We recommends that a high priority be assigned to nutrient management through a targeted construction grants program for improved wastewater treatment under the CWA**

Integrated Nitrogen Committee
Summary of Findings

- **Human action controls Nr introduction into the US.**
- **Added Nr has positive impacts for human health--food production.**
- **Added Nr increases the risk to both human and ecosystem health--N cascade.**
- **Challenge is how do we achieve positive benefits at acceptable risk.**
- **And how do we do this in an integrated fashion?**