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Nitrogen assessment in small-scale biomass heating systems

Air as a Common Good. Policy, Actions and Technologies for Reducing Emissions from Residential Wood Burning. Verona, 21 February 2018.

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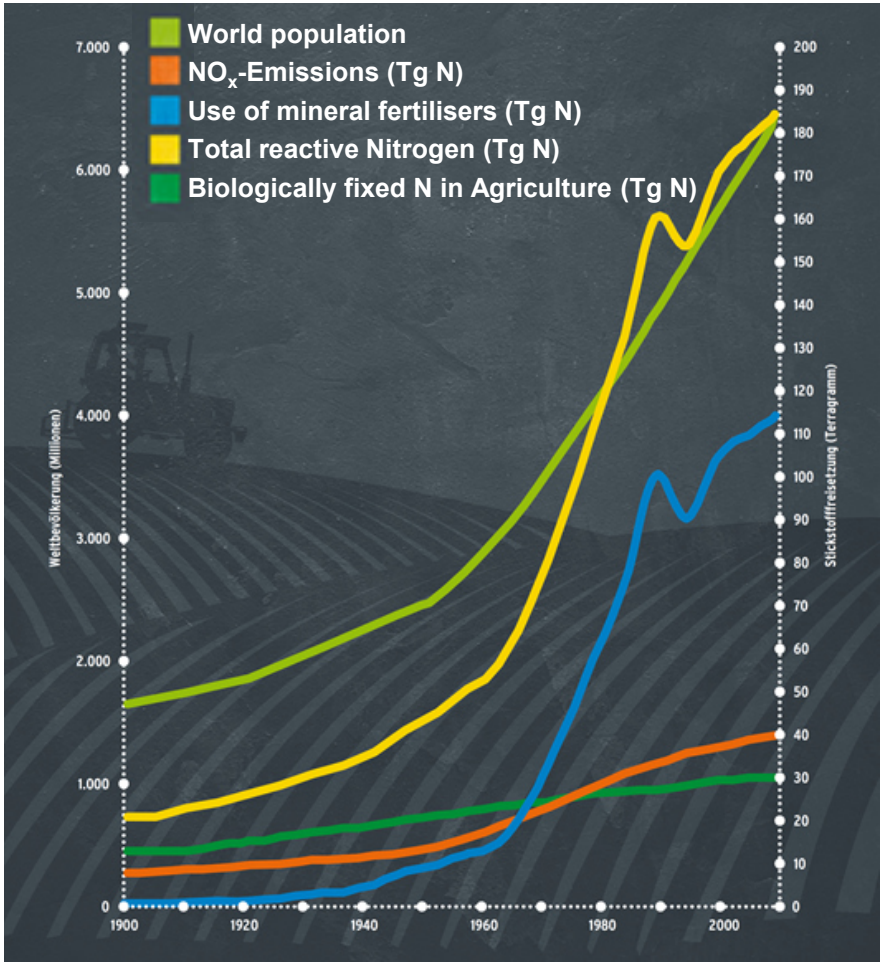
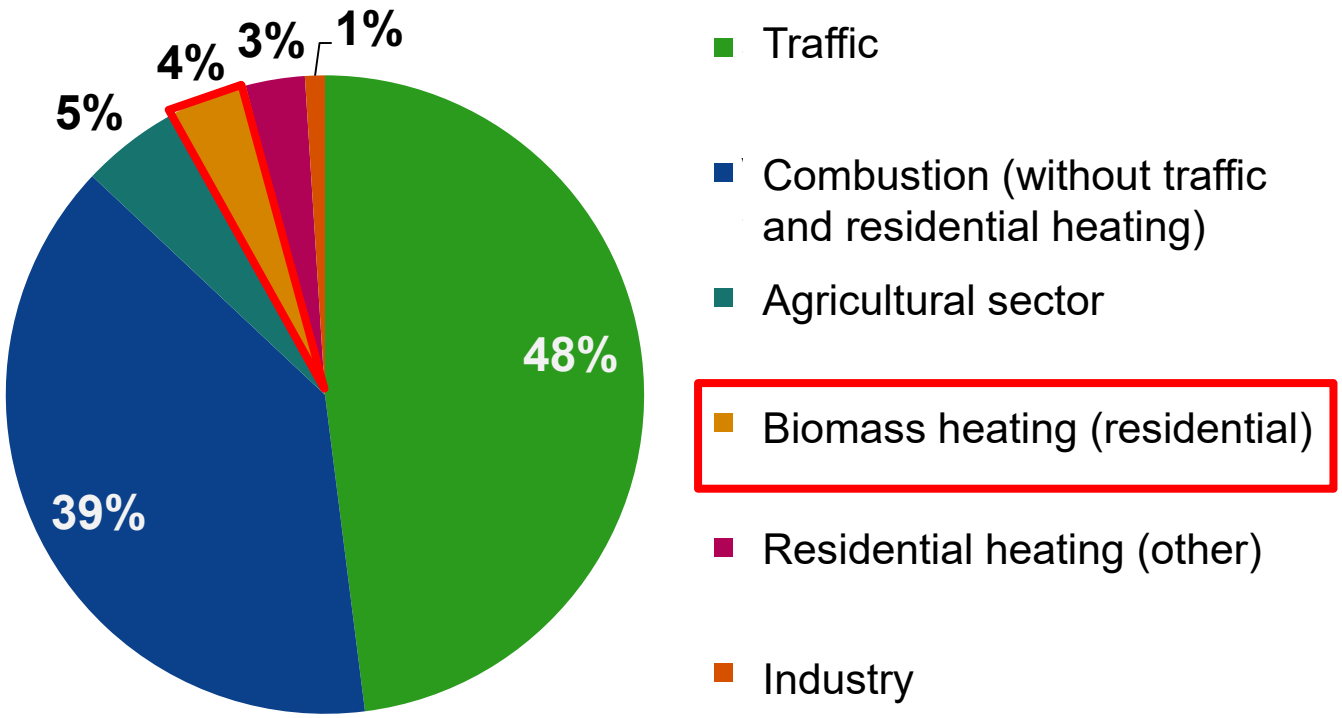
Background – Release of reactive Nitrogen

- Release of reactive nitrogen compounds due to anthropogenous activities has increased tenfold since mid of the 19th century – and is further increasing
- A worldwide volume of nitrogen four times the level that is considered sustainable is being converted into its reactive form
- Legislative Framework: Gothenburg Protocol, NEC-directive, 2008 EU air quality Directive, ECO design directive



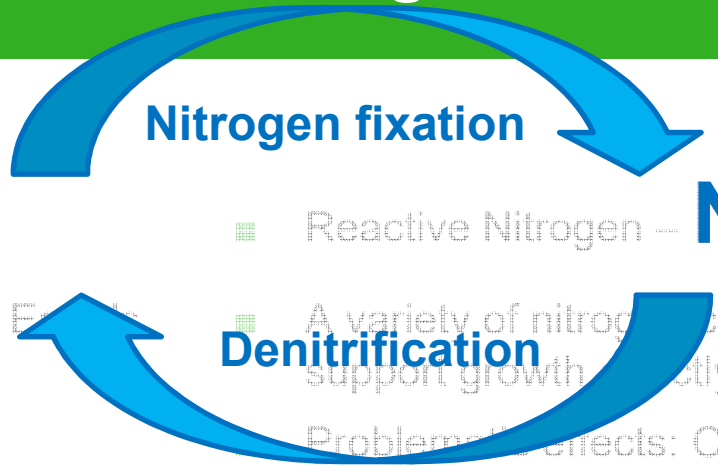
Source and Copyright: Stickstoff – zuviel des Guten? Überlastung des N-Kreislaufs zum Nutzen von Umwelt und Menschen wirksam reduzieren (2011)

Contribution of different sectors to NOx-emissions – example Austria (2014)



Source: Derived based on data from Statistik Austria, Federal Environment Agency and BIOENERGY 2020+

Elemental and Reactive Nitrogen



- Elemental Nitrogen — N_2
- constituting 78% by volume of E… atmosphere
- Chemically inert

- Reactive Nitrogen — N_r
- A variety of nitrog… compounds that support growth …ctly or indirectly
- Problematic effects: Ozone precursor, airborne dust, eutrophication, acidification, direct impact

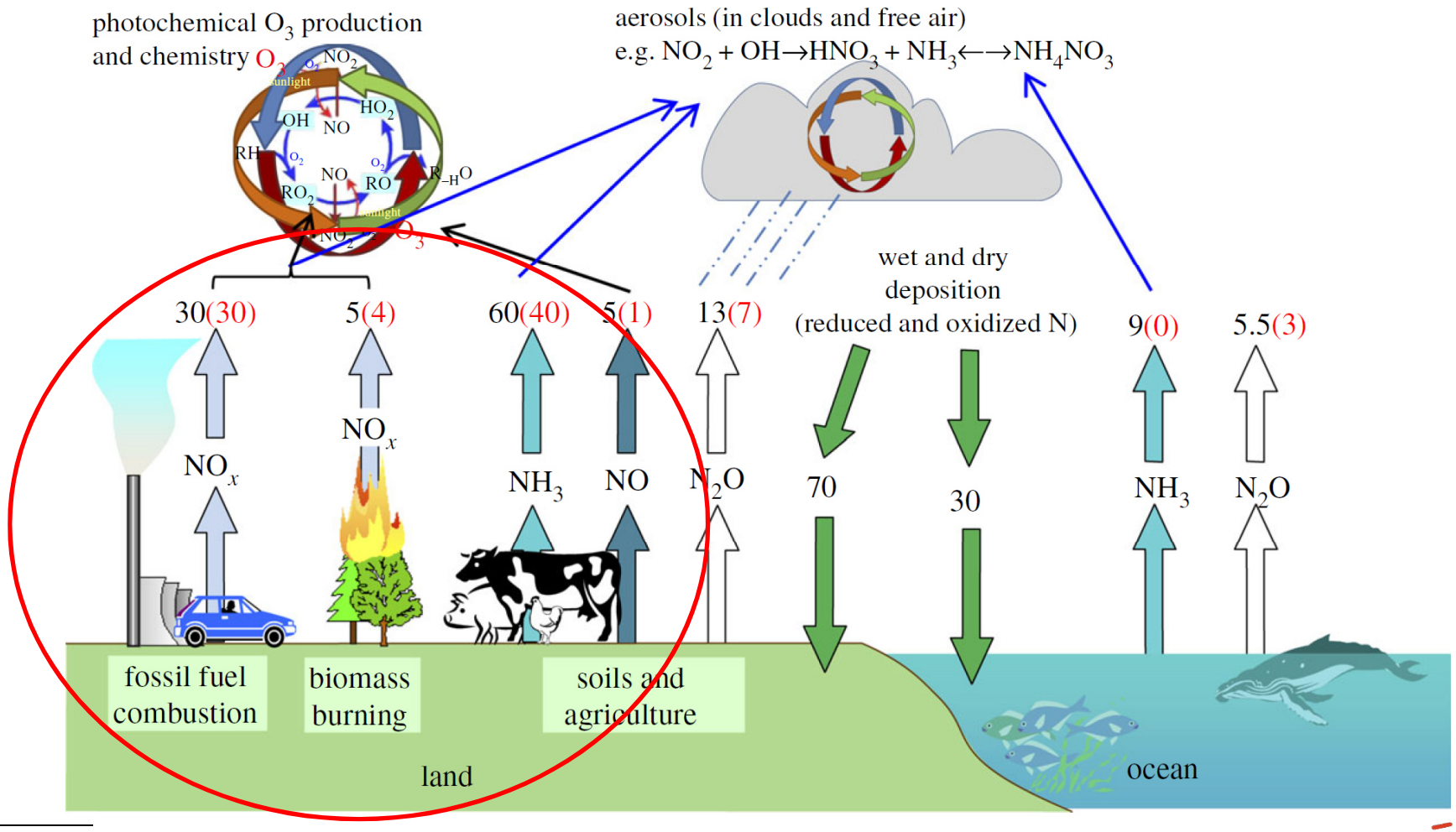
NO_x (= Sum of NO and NO_2)

NH_3 (Ammonia)

N_2O (nitrous oxide)

+ reaction products (e.g. HNO_3, NH_4NO_3)

Main sources and products of reactive Nitrogen



NO_x from biomass combustion – reaction pathways

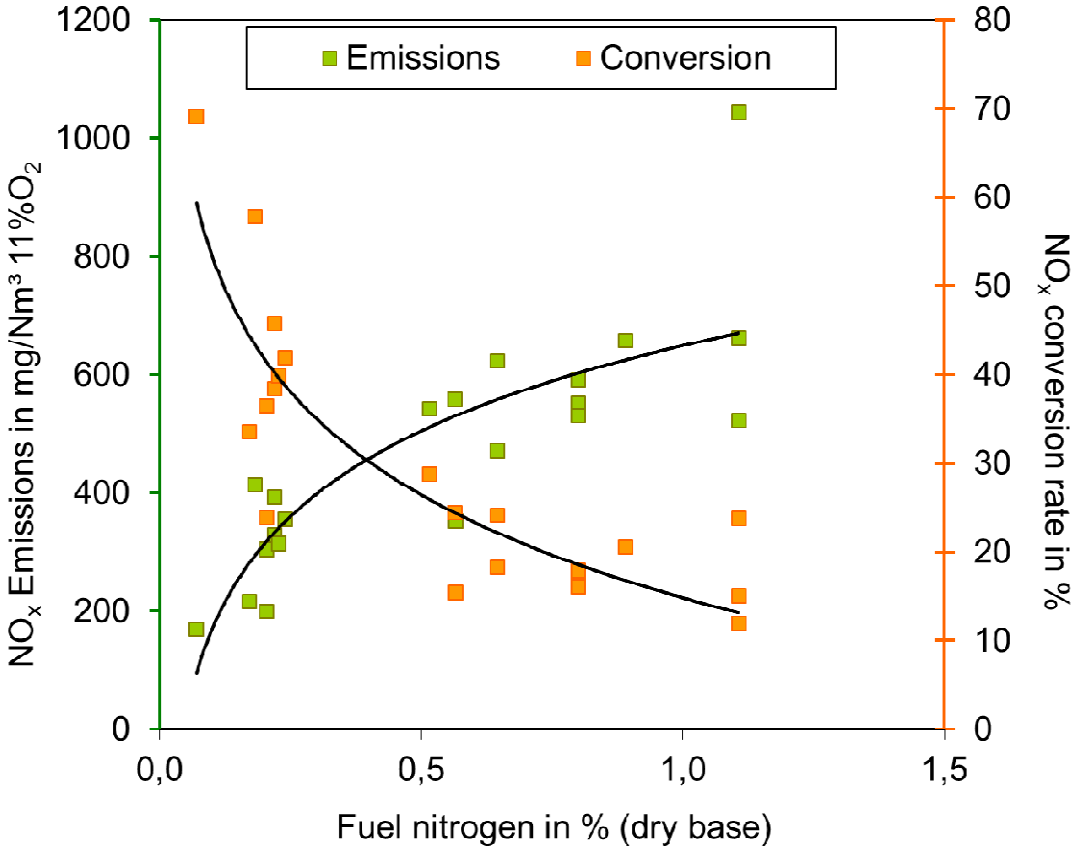
- Thermal NO_x
  is produced by the reaction of atmospheric oxygen and atmospheric **nitrogen** in combustion air at elevated temperatures – significant amounts only above 1300°C – 1400°C
- Prompt NO_x
  is formed by the reaction of hydrocarbon radicals with atmospheric **nitrogen** – very high temperatures required

not relevant in biomass combustion processes

- NO_x from fuel Nitrogen
  arises from the reaction of the organically bound **nitrogen** in the fuel with oxygen.

Predominant reaction

Nitrogen-conversion rates in small-scale combustion



→ 50% of fuel-nitrogen is released as NO_x

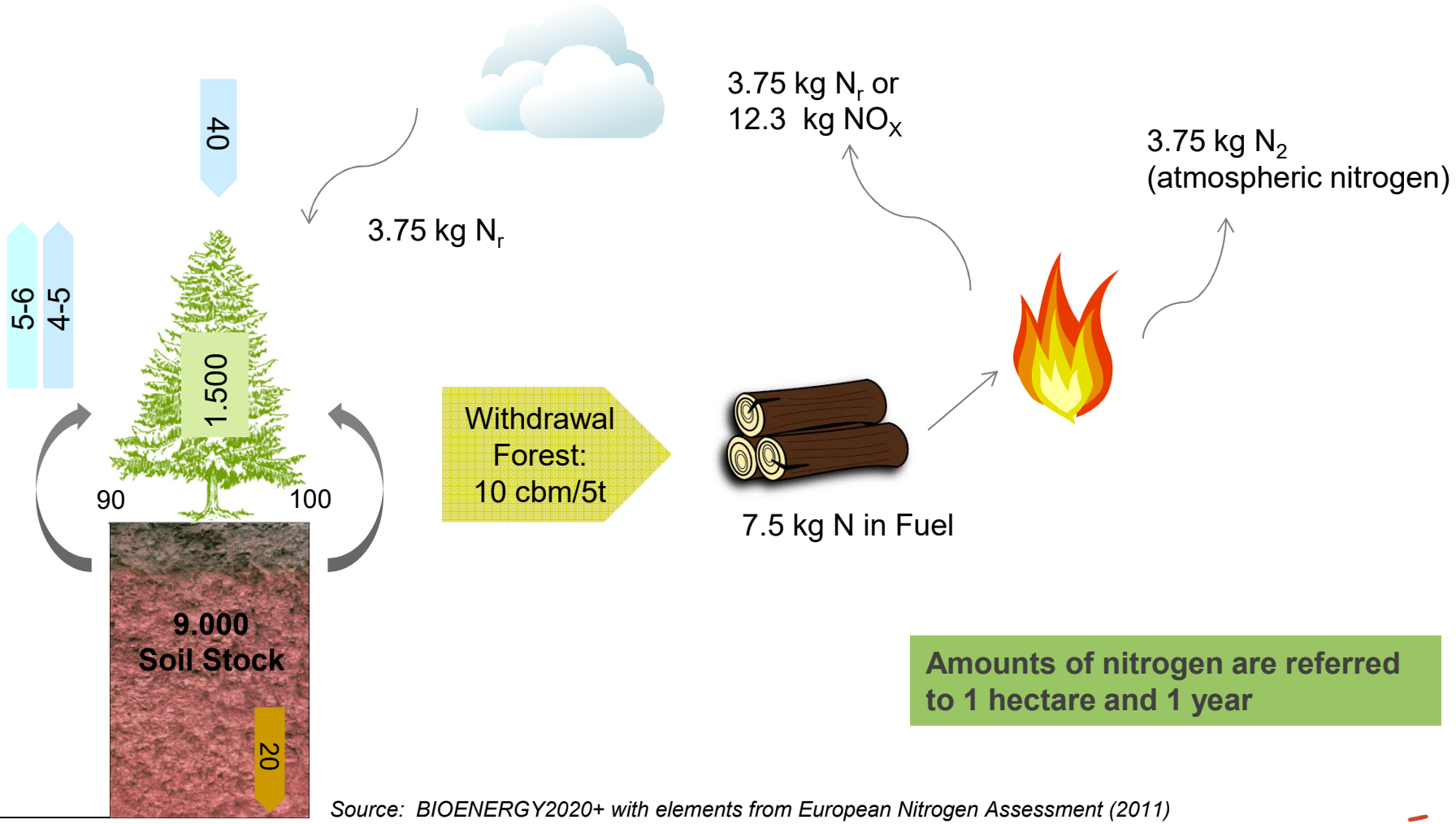
→ 50% of fuel-nitrogen is converted to N_2

Source: Measurments by BIOENERGY 2020+

Comparison of the most relevant N_r sources

	Transport	Soils and Agriculture	Biomass combustion
Origin of N	Mainly N_2 (from combustion air)	Mainly N_2 (from air)	Reactive Nitrogen compounds (NH_4 > NO_3 > Org. N).
Formation of N_r (reactive Nitrogen-compounds: NH_4, NO_3, N_2O)	Mainly **NO_x**: Oxidation at high temperatures in engines	**NH_4** und NO_3: Fertiliser production by synthesis of ammonia from hydrogen in a direct reaction with atmospheric nitrogen in the Haber-Bosch process.	Assimilation of N_r from forest soil through the roots, Input to soil almost 100% N_r from atmosphere
Additional N_r released to the cycle	Yes	Yes	No

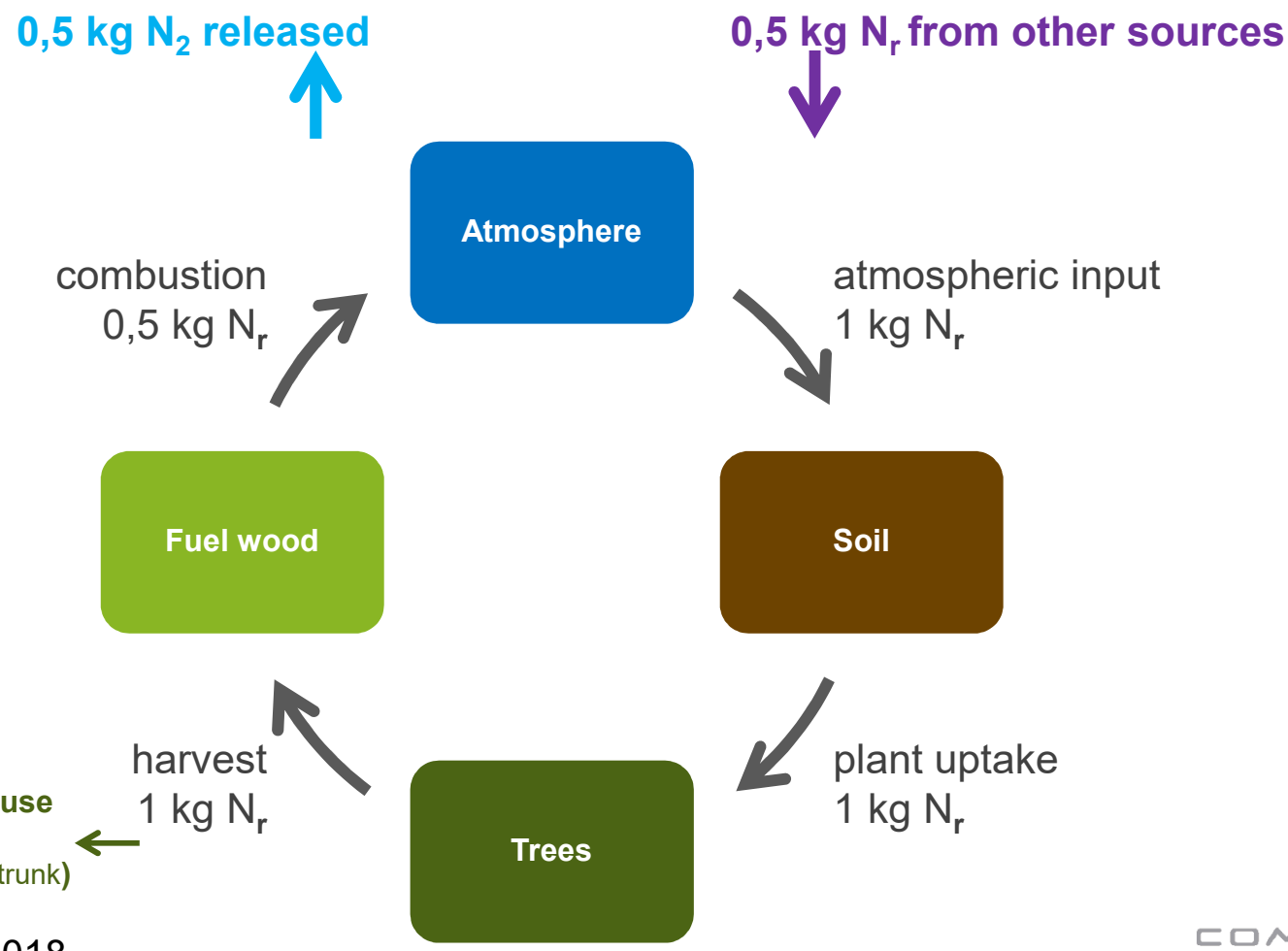
Model of N-cycle during biomass combustion based on a spruce forest in Germany



Amounts of nitrogen are referred to 1 hectare and 1 year

Source: BIOENERGY2020+ with elements from European Nitrogen Assessment (2011)

Simplified cycle of reactive nitrogen N_r in small-scale wood combustion



Conclusions

- Severe problems are relatded to excessive release of N_r
  - Direct effects on human health
  - Indirect effects on clima and ecological systems (eutrophication, N_2O emissions)
- Main NO_x-sources are traffic and agriculture
- Nitrogen forming NO_x has different origins
  - Traffic and agriculture: Atmospheric N_2 is transferred to reactive N_r → additional release of N_r
  - Biomass combustion: NO_x is formed from reactive nitrogen components of wood, built from N_r from forest soil → no additional release of N_r
- About 50 % of fuel nitrogen are transferred to N_2 during biomass combustion, only 50 % are released as NO_x → sink function
- A differentiated assessment of NO_x-emissions from small-scale biomass combustion is required with regard to
  - Immission control
  - National Emission Ceilings

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Thank you for your attention

Acknowledgement

This study has been funded within the FFG (Austrian Research Promotion Agency) programme COMET (Competence Centers for Excellent Technologies).

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