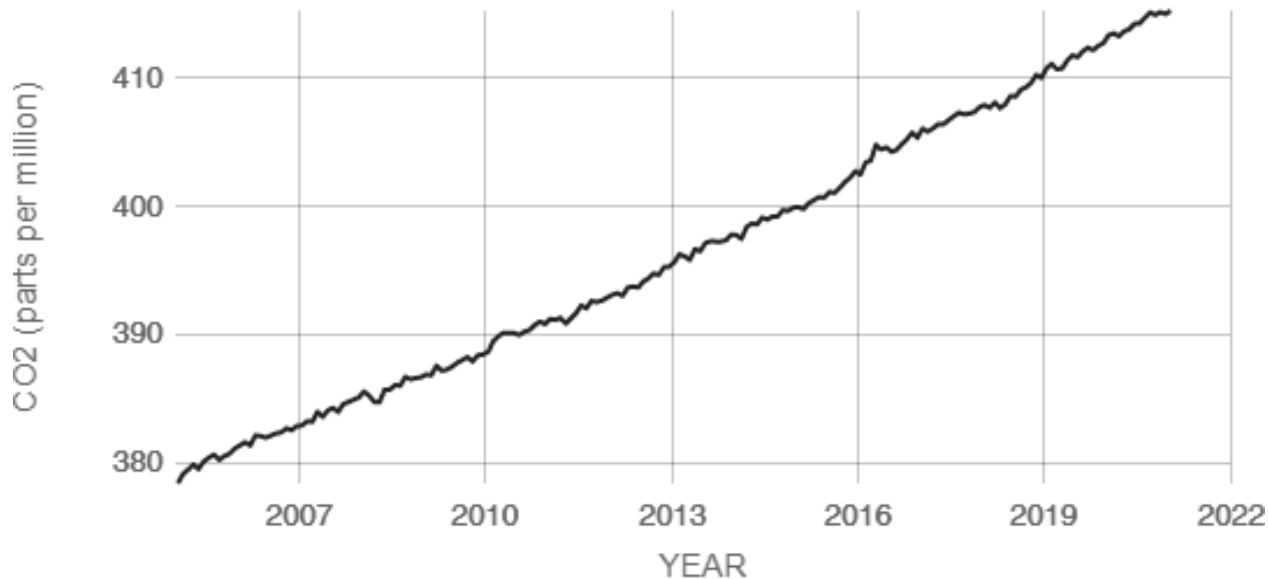


Plasma N₂: Emissions saving through production of low cost Fertilizers, using air as a raw material

- **Dr. Stella Kabiri**
- **Senior Research Officer**
- Mukono Zonal Agricultural Research and Development Institute,
- National Agricultural Research Organization (NARO)
- **Uganda**

CR4D Closing Workshop June 21st-June 23rd, Nairobi, Kenya 2021

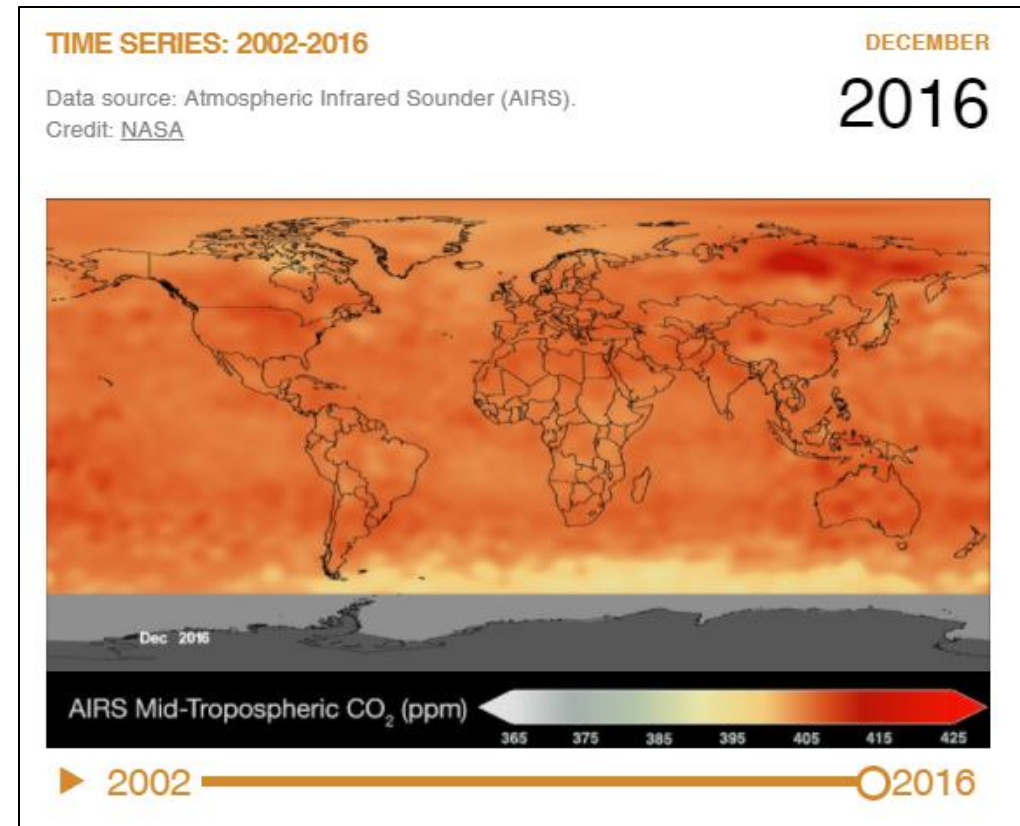
Carbon dioxide (CO₂) is a heat-trapping (greenhouse) gas



Source: climate.nasa.gov

- **Carbondioxide levels in the atmosphere are at the highest in 650,000 years.**
- **CO₂ released in the atmosphere through**
 - **deforestation and**
 - **burning fossil fuels,**
 - **respiration**
 - **volcanic eruptions**

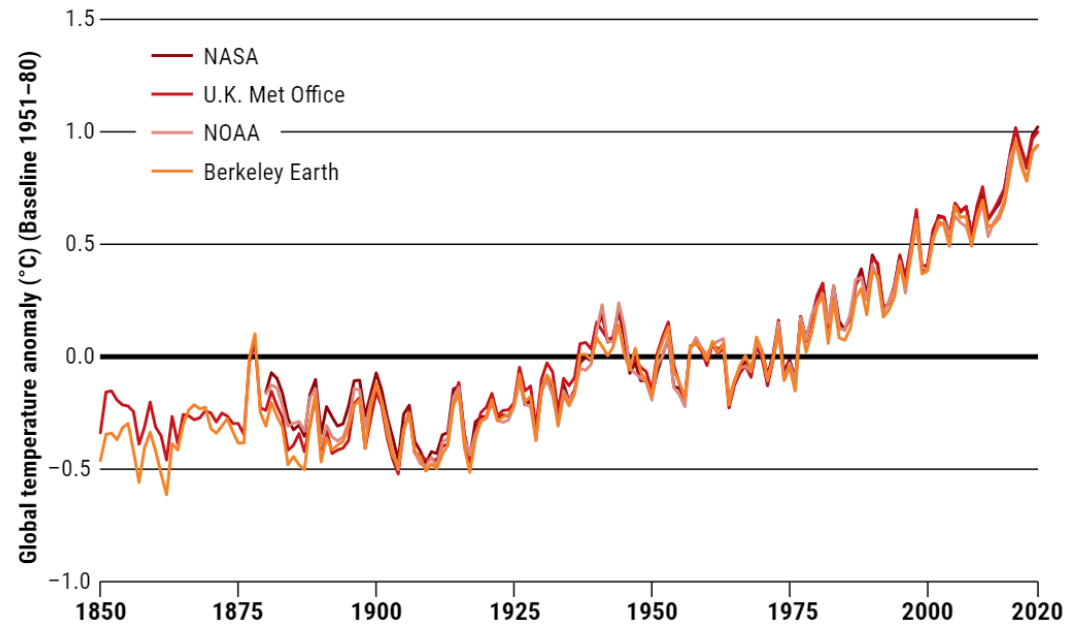
Human activities have raised CO₂ in the atmosphere by 48% above pre-industrial levels found in 1850



Global Temperatures are 1.25°C above preindustrial levels

Turning up the heat

Temperatures in 2020 were the hottest on record, tying levels set in 2016. Temperatures were about 1°C over a baseline of 1951–80 average temperatures, or about 1.25°C above preindustrial levels.

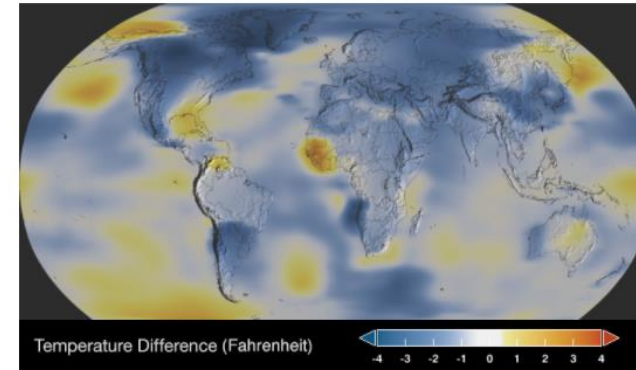


(GRAPHIC) N. DESAI/SCIENCE; (DATA) MET OFFICE; NASA; BERKELEY EARTH; NOAA

TIME SERIES: 1884 TO 2020

1884

Data source: NASA/GISS
Credit: NASA Scientific Visualization Studio

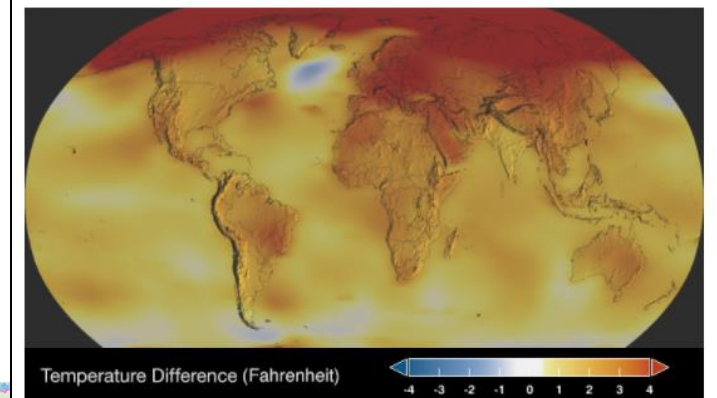


1884 2020

TIME SERIES: 1884 TO 2020

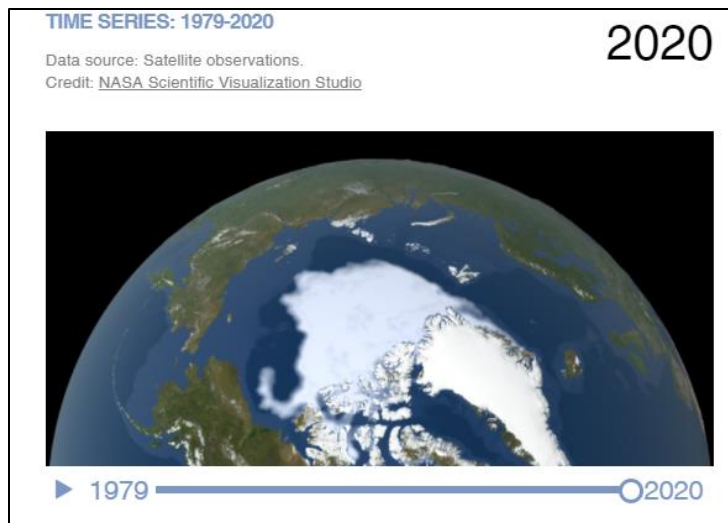
2020

Data source: NASA/GISS
Credit: NASA Scientific Visualization Studio



1884 2020

Loss of Sea ice



- **Arctic sea ice has melted at a rate of 13.1% per year**
- **Ice sheets lost**
 - **150 billion metric tons lost in Antarctica**
 - **278 billion metric tons lost in Greenland**
- **Sea levels have risen by 3.3 mm per year**

Alarming Environmental concerns of the Fertilizer industry



Photo By Alex Wierbinski

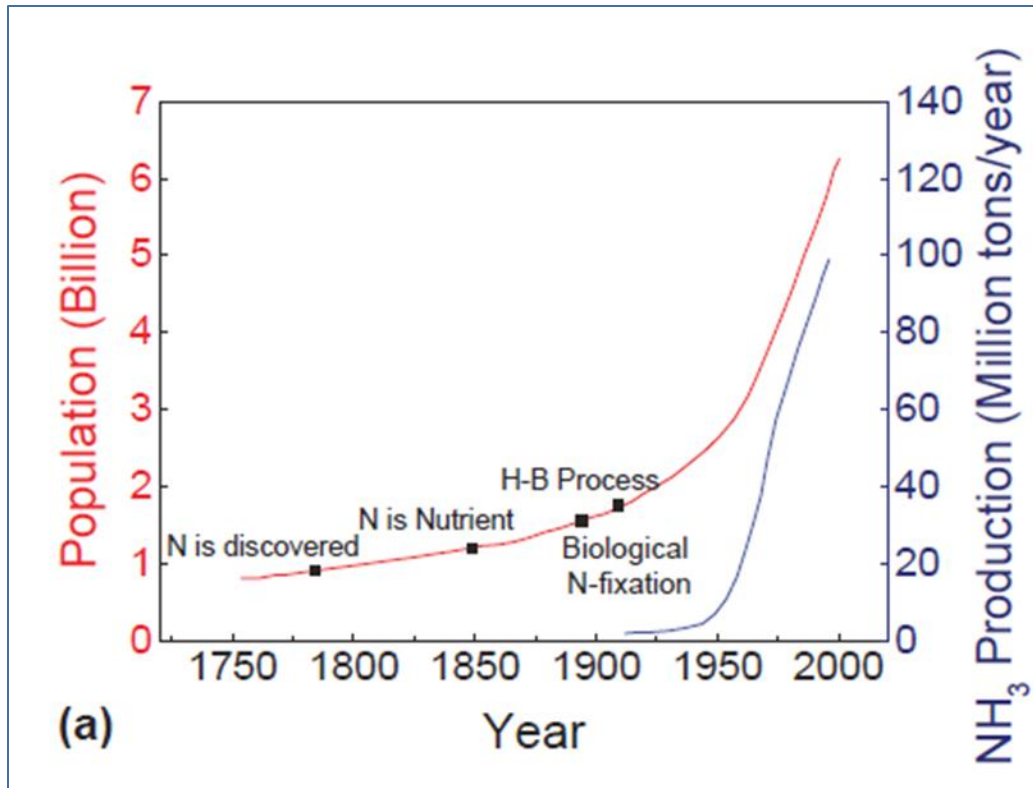


Haber-Bosch Ammonia synthesis

- **Leading CO₂ emitter**
 - **Emits over 830 mega tons of CO₂**
 - **42% of the total industrial process emission of CO₂**
 - **Consumes,**
 - **1-2% of the world's total energy production**
 - **3-5% of the world's total natural gas output**

Haber-Bosch ammonia synthesis processes, the necessary Evil

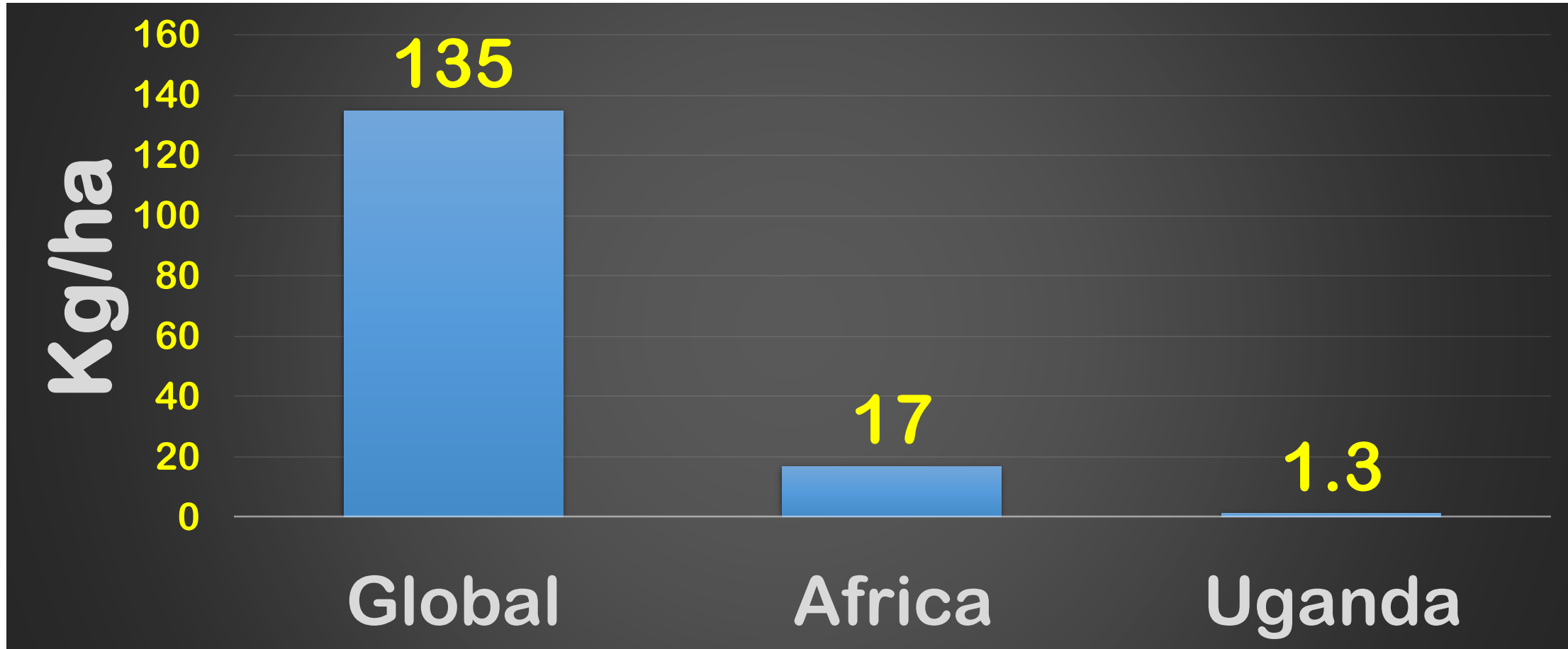
Population growth - Haber-Bosch ammonia synthesis process Relationship



(Source: Royal Swedish Academy of sciences, 2010)

- Feeding an increasing world population is a huge challenge.
- Forecasts say there will be almost **10 billion people in 2050.**
- Artificial fertilizers feed the world
- Nitrogen is one of the three main macronutrients used by plants to grow (next to phosphorus and potassium).
- **In 2015, one in every two humans was fed by food that was cultivated using nitrogen-based fertilizer,**

Fertilizer usage in Uganda vs. Global



Uganda: The world's most expensive fertilizer market



The Ugandan farmer pays double the sum paid by farmers in USA and Europe

Using Plasma technology to feed the world



• Research Team

- At the National Agricultural Research Organization (NARO-Uganda)
- Eindhoven University of Technology (TU/e), the Netherlands
- **We built a state-of-the-art plasma technology to make cheap fertilizer for small farmers.**
- **It is a small powered plasma-plant that produces nitrogen-based liquid fertilizers using only sun, water and air**
- **The plant is easy to set up, sustainable and very efficient**

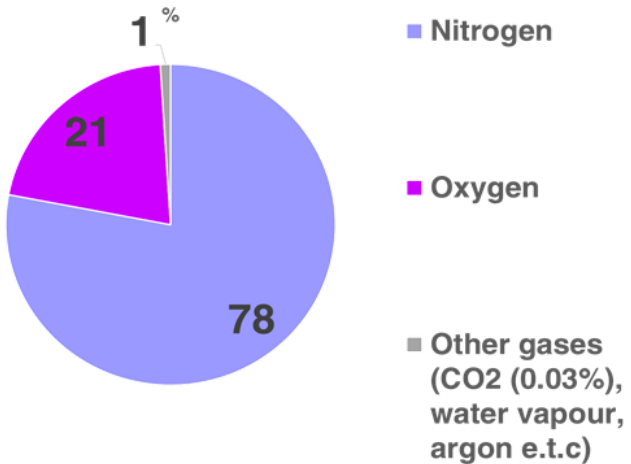
What is plasma?

- **Plasma**
 - **A hot ionized gas; Positively charged ions = Negatively charged electrons.**
- **The characteristics of plasmas are different from ordinary neutral gases**
- **Plasmas are considered a distinct "fourth state of matter."**

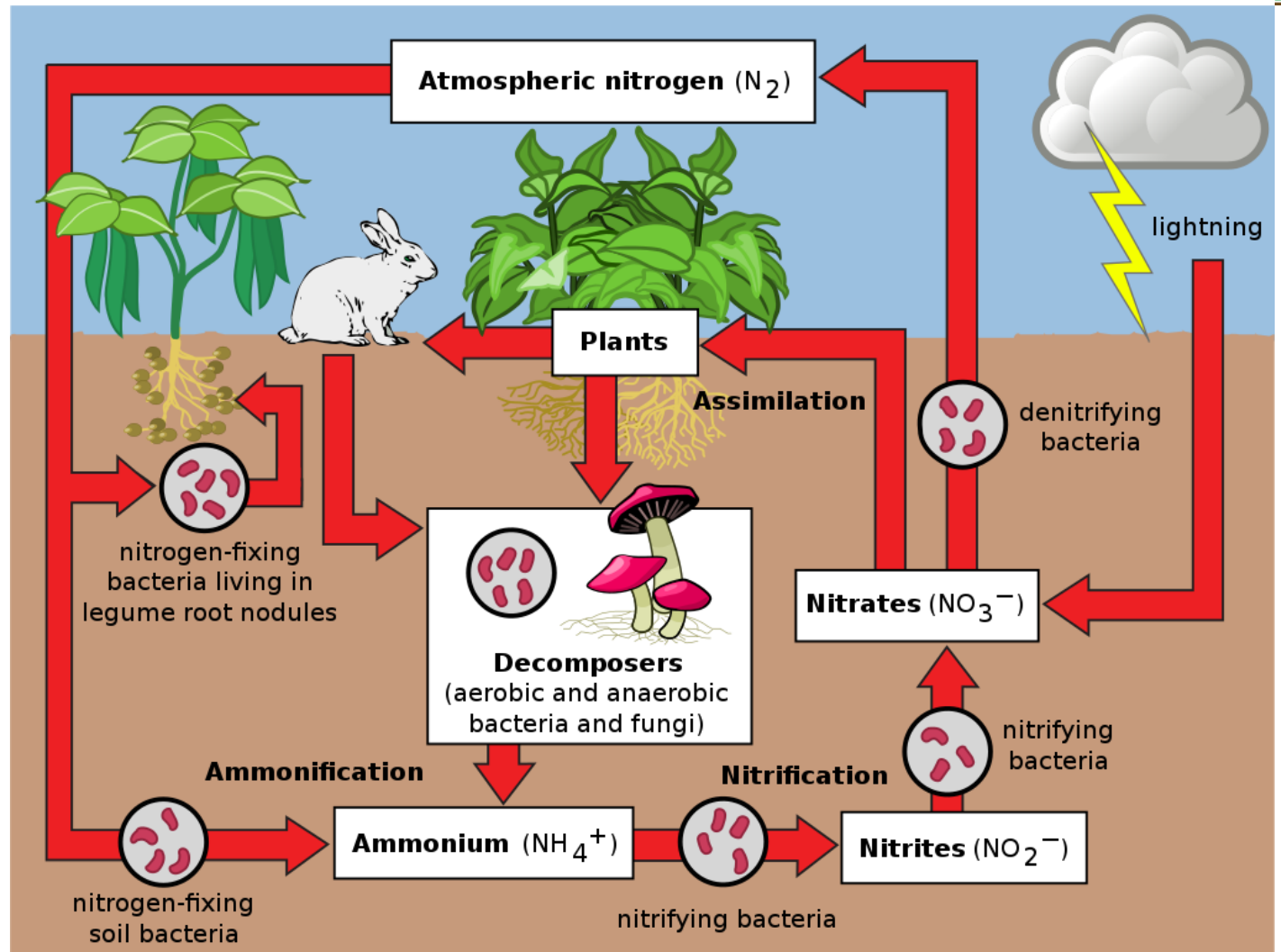


The Northern Lights are an example of a plasma you can see. (National Geographic)

Nitrogen fixation in Nature

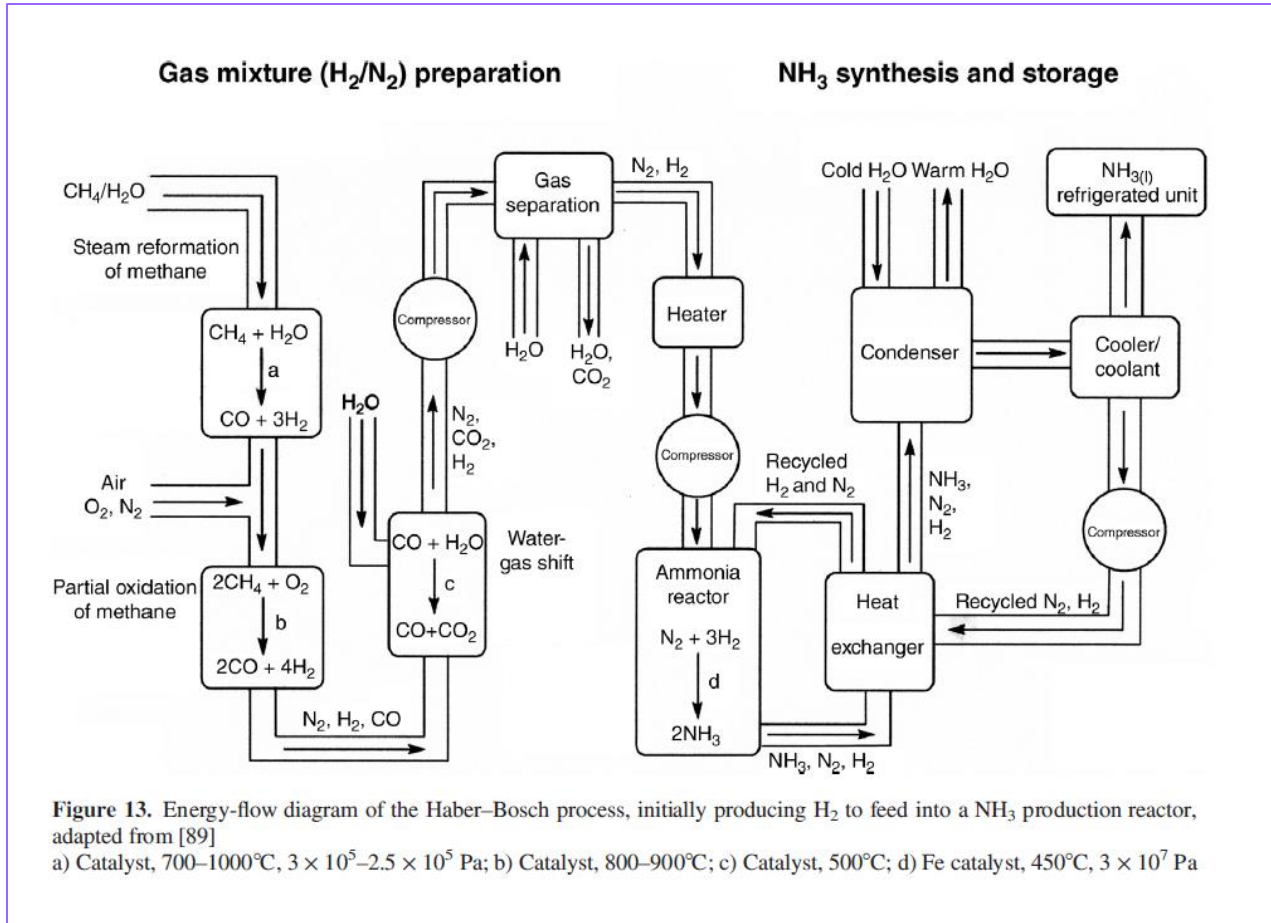


- The majority of Earth's atmosphere (78%) is atmosphere Nitrogen making it the largest source of nitrogen
- However, atmospheric nitrogen is not readily available to plants.
- The nitrogen cycle is the biogeochemical cycle by which nitrogen is converted into multiple chemical forms as it circulates among atmosphere, terrestrial, and marine ecosystems.
- the nitrogen cycle includes
 - Fixation,
 - Ammonification,
 - Nitrification, and
 - Denitrification



CREDITS: https://commons.wikimedia.org/wiki/File:Nitrogen_Cycle.svg

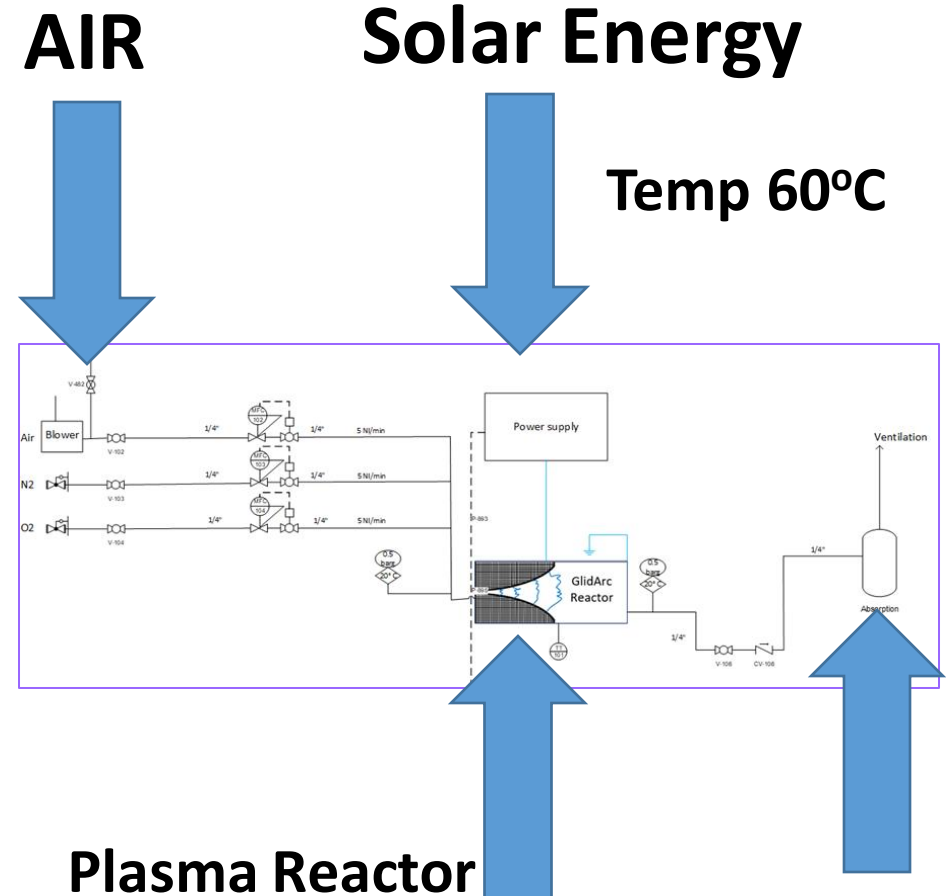
Haber Bosch process vs Plasma assisted Nitrogen fixation



Haber Bosch Ammonia synthesis

Reaction of nitrogen with hydrogen Temp at **$450, 600^\circ C$** and **$150-350$** bar in the presence of a catalyst.

Plasma Assisted Nitrogen fixation



How it works

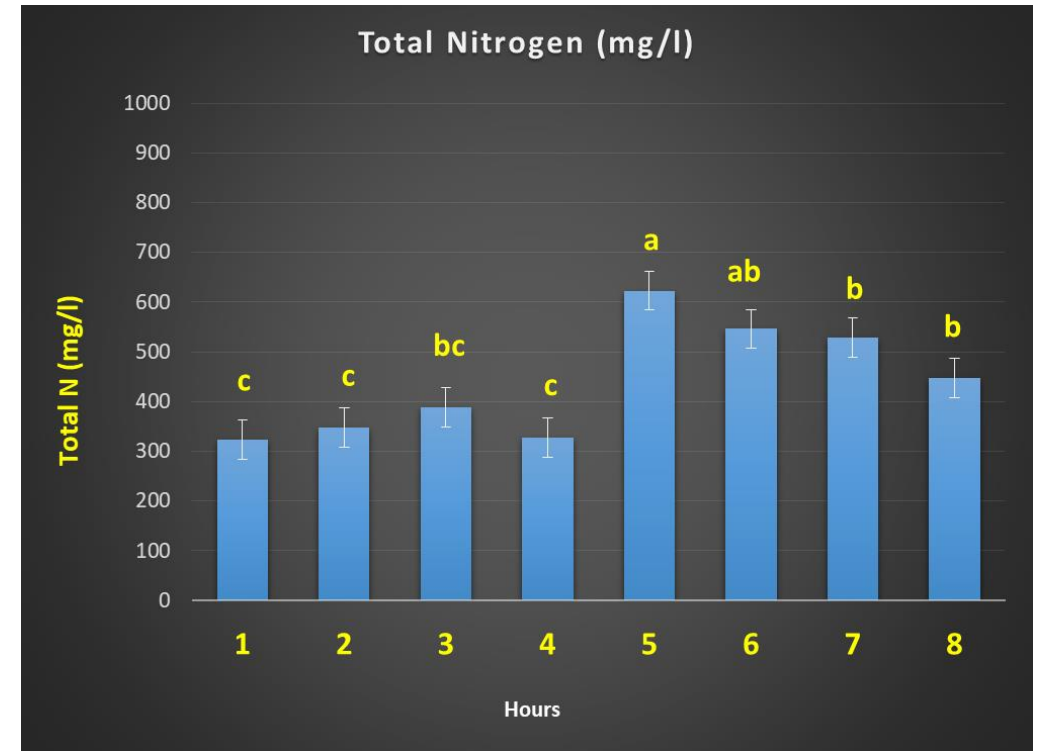
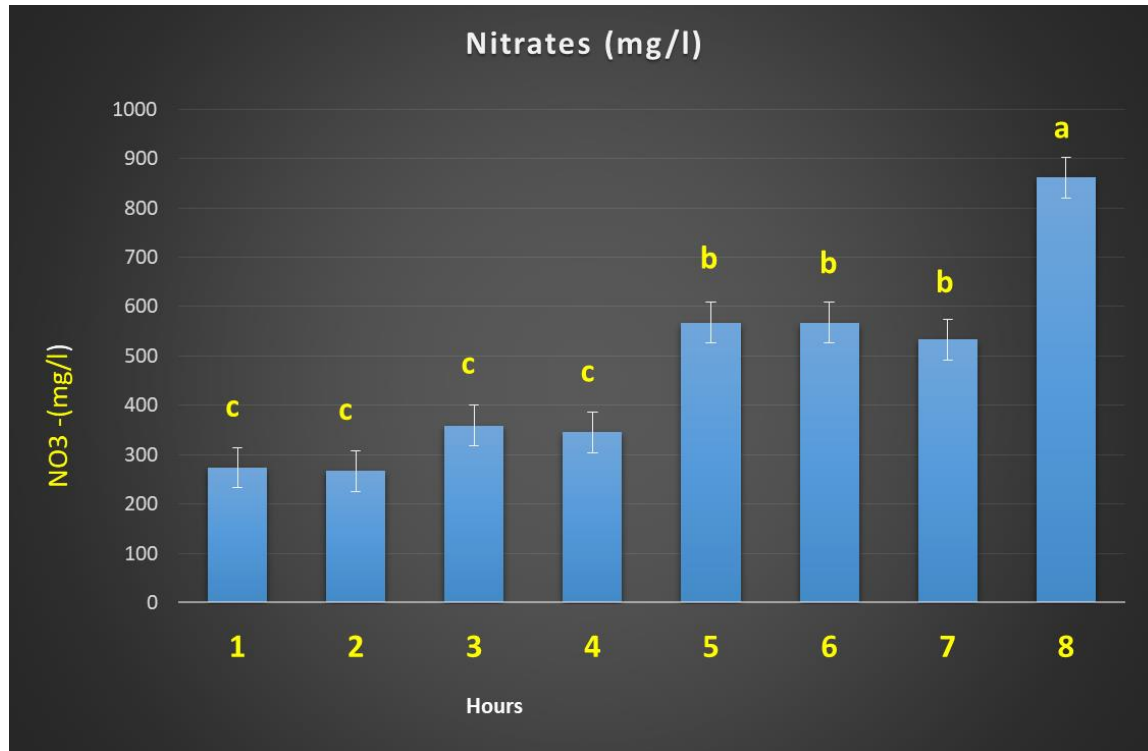
Plasma Reactor



The Plasma system is switched on when the sun is shining.

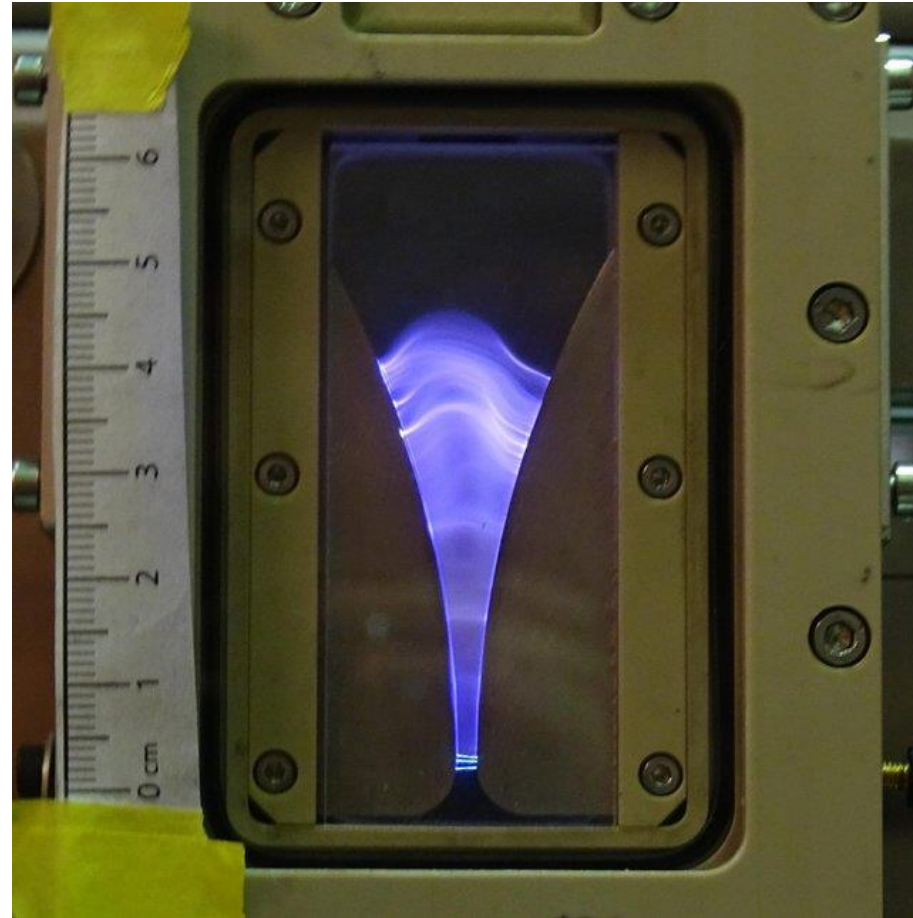
- **Does not use fossil fuels but runs solar energy**

Efficiency of the Plasma Reactor in producing Nitrates and Nitrogen from air

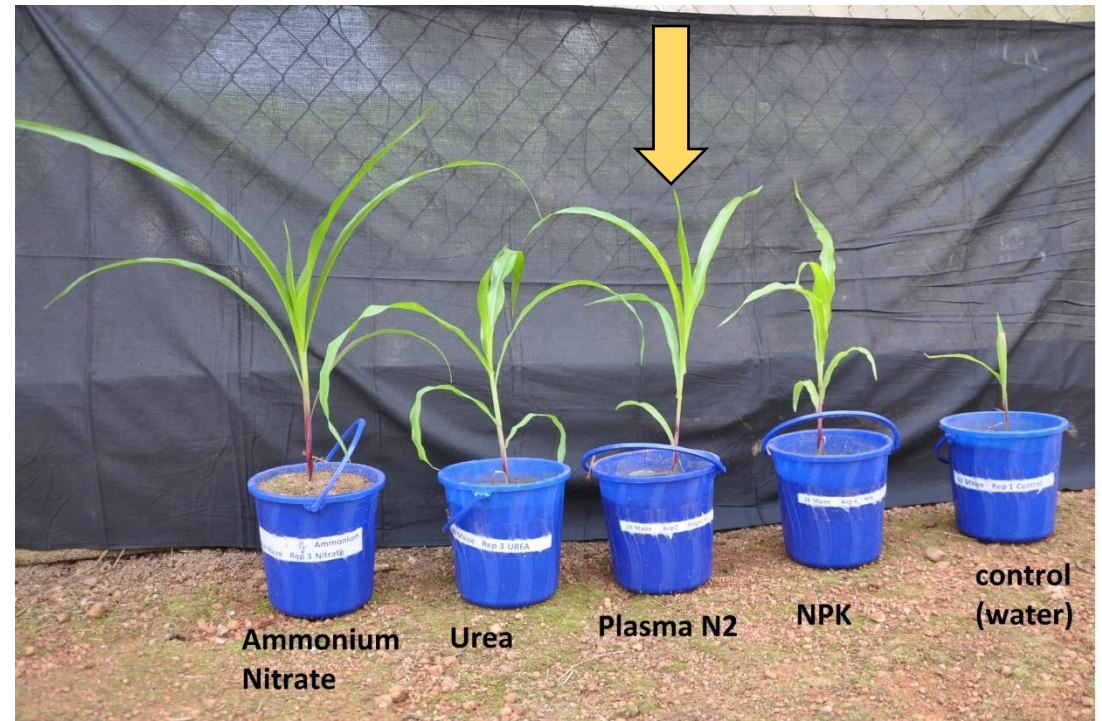
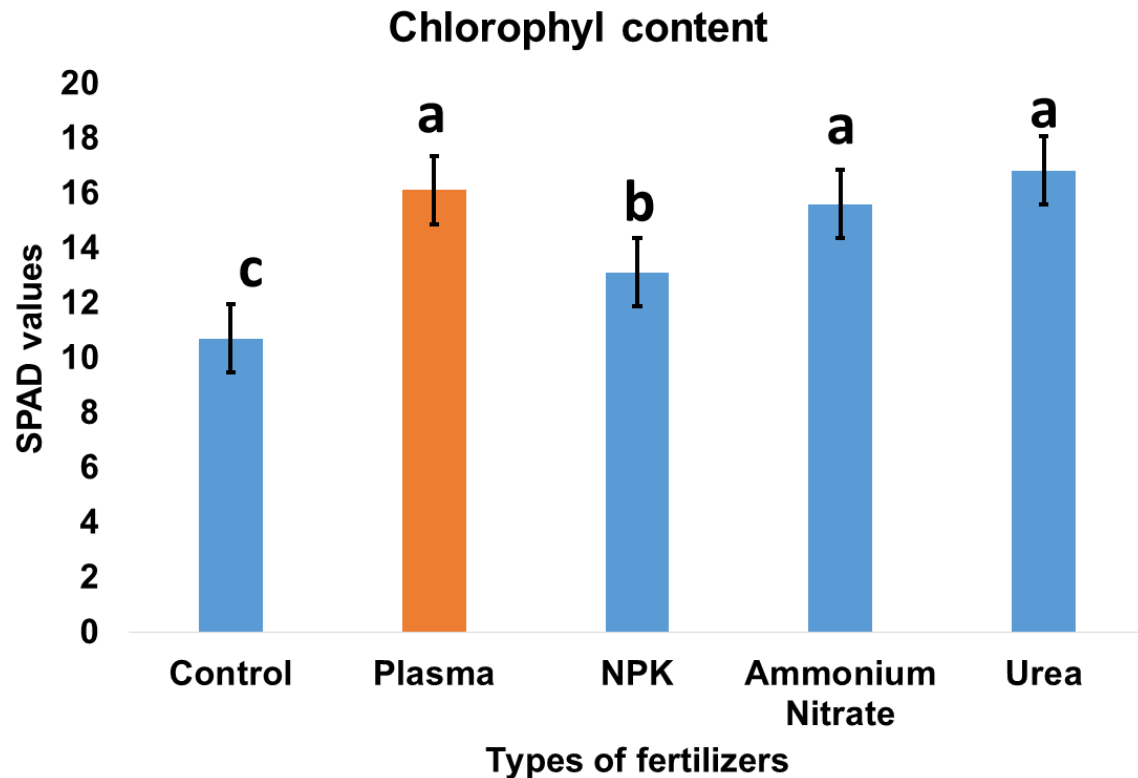


- Nitrate levels increase with time of running the plasma reactor ($P<0.001$)
- Total Nitrogen was highest at 5 and 6 hours ($P<0.001$)

Improving the efficiency of the Plasma Reactor

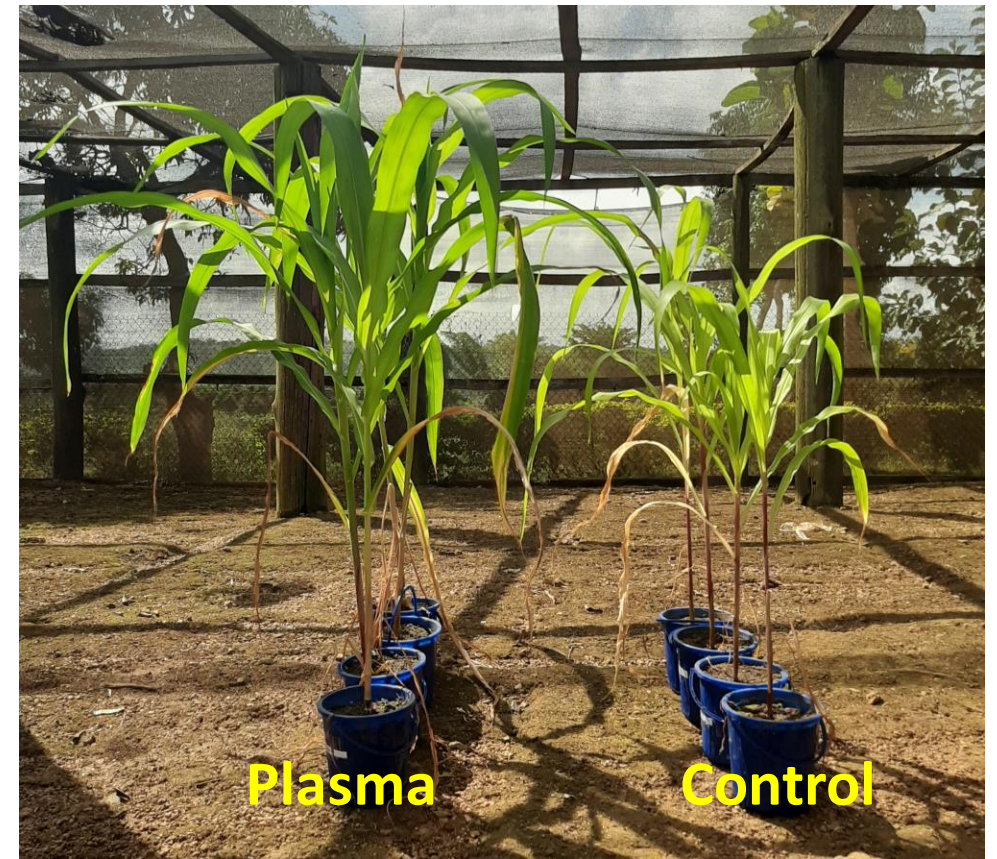
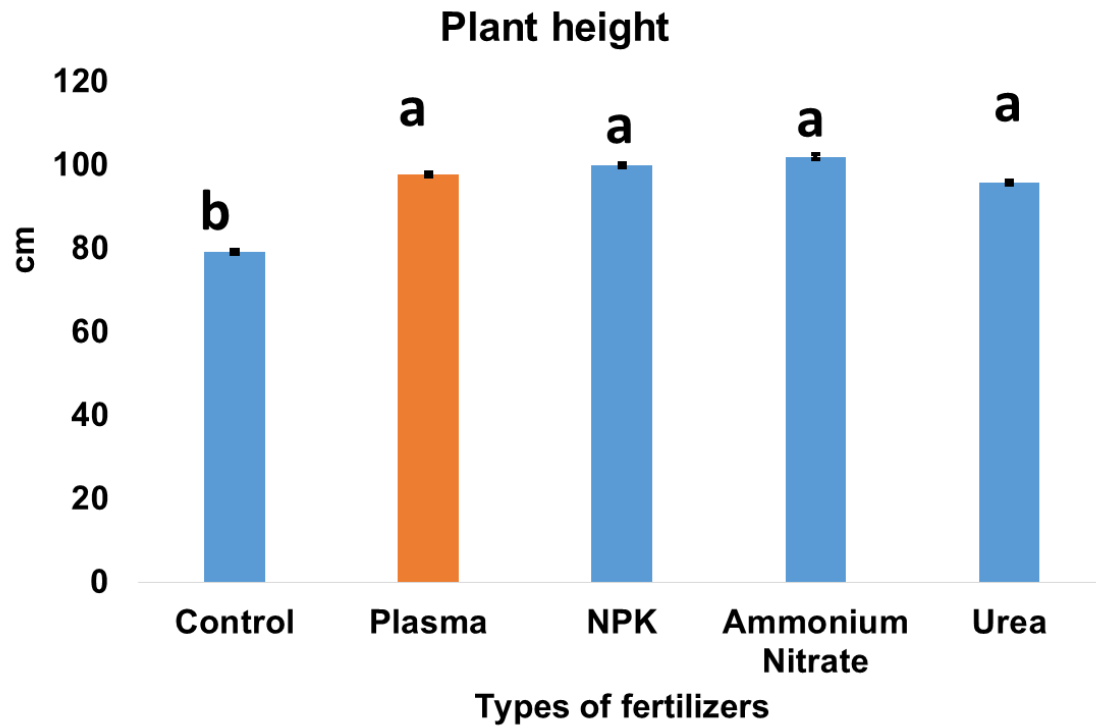


Response of Maize (Chlorophyll content) to Plasma fertilizers



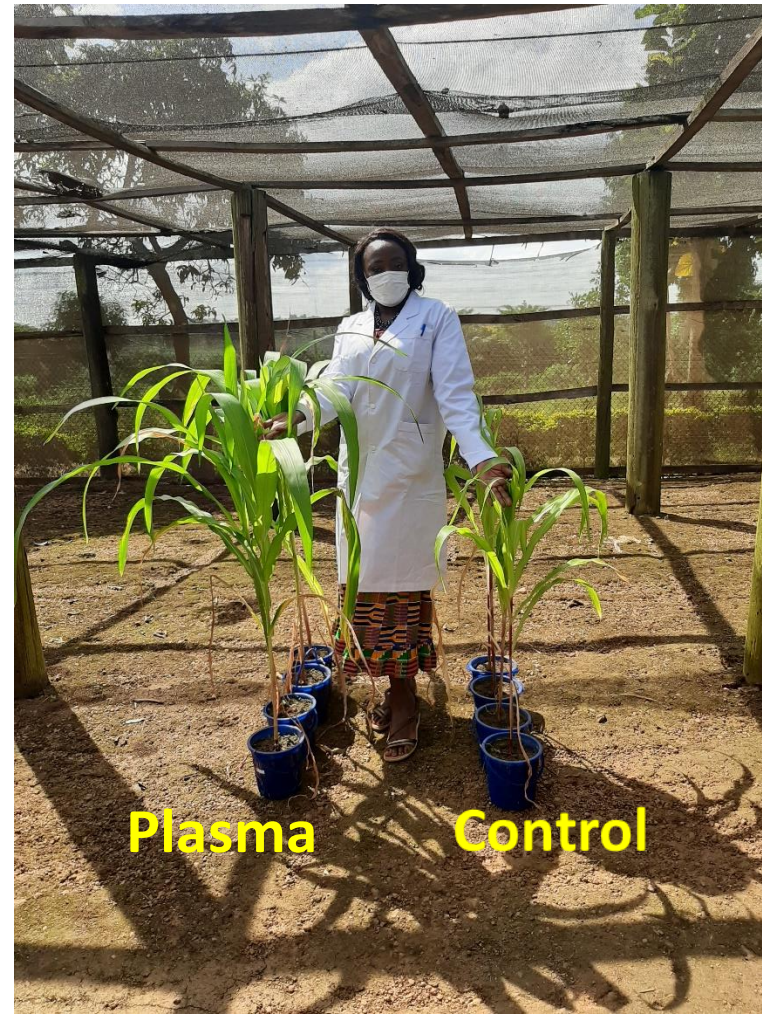
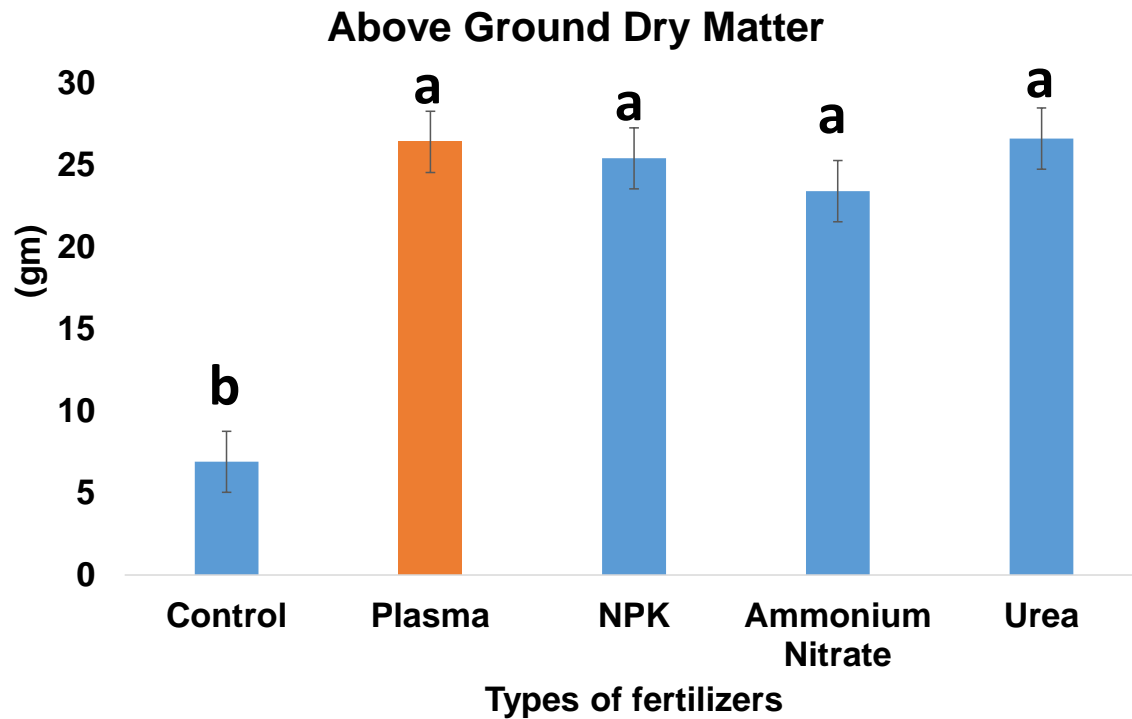
- Plasma fertilizers performed similar to ammonium nitrate and urea ($P < 0.001$)
- Were significantly different from the control and NPK ($P < 0.001$)

Response of Maize (height) to Plasma fertilizers



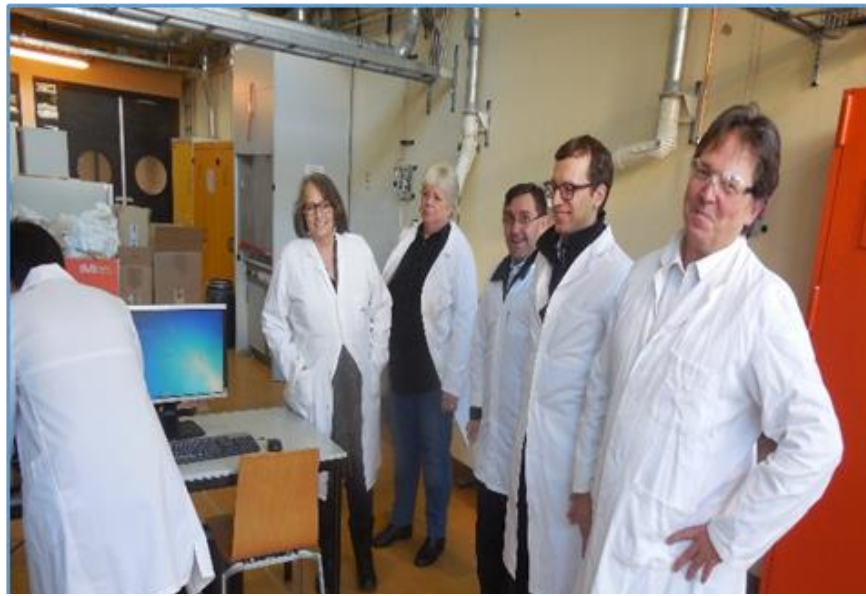
- Plasma fertilizers performed similar to other fertilizers ($P < 0.021$)
- Were significantly different from the control ($P < 0.021$)













Response of Maize (Biomass) to Plasma fertilizers



- Plasma fertilizers performed similar to other fertilizers and significantly different from the control ($P < 0.033$)

Research Team



		<p>Prof. Fausto Gallucci Dr. Sirui Li Prof. Volker Hessel</p>			<p>Dr. Francis Tetteh</p>
		<p>Prof. Darelle Van Greunen Prof. Paul Watts</p>			<p>Dr. Filipe Soares</p>
		<p>Dr. Stella Kabiri</p>			<p>Dr. Jurgen Lang</p>

NEXT STEPS 1

- **At present the cost of the mini-plant is still quite high**
 - **40,000 Euros**
 - **Eindhoven University of Technology (TU/e), the Netherlands spin-off 4th State Technologies to bring the mini-plant to the market.**
 - **Improve the efficiency of the plasma reactor**
- **One day farmers in Africa will be able to buy their own fertilizer unit, individually or as a village**
- **Demonstrates a way out of industrial processes responsible for Global warming.**

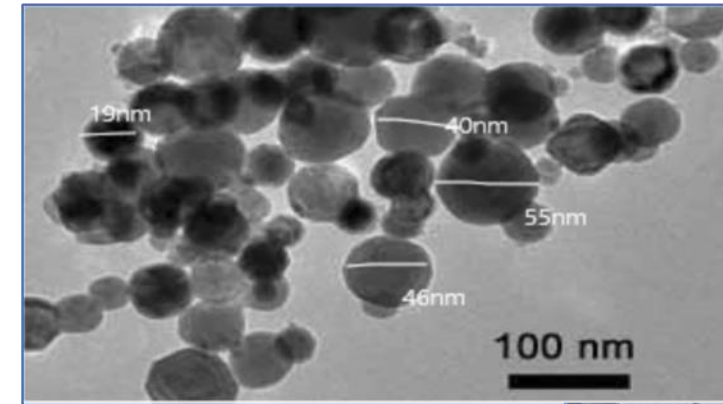
NEXT STEPS 2

- Develop a Research team that is dedicated to Negative GHG Emissions in Plant Nutrition by
 - **Capacity building (PhD, MSc, BSc)**
- Exploring new fertilizer production paradigms such as
 - **Development of Nano-fertilizer blends from Plasma fertilizers**

Nano particles are from plant cellulose from agricultural waste

Over-fertilizing is reduced

Nutrients do not leach preventing wastage and pollution

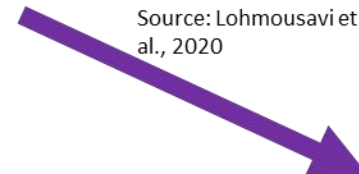


Nano particles from banana peelings

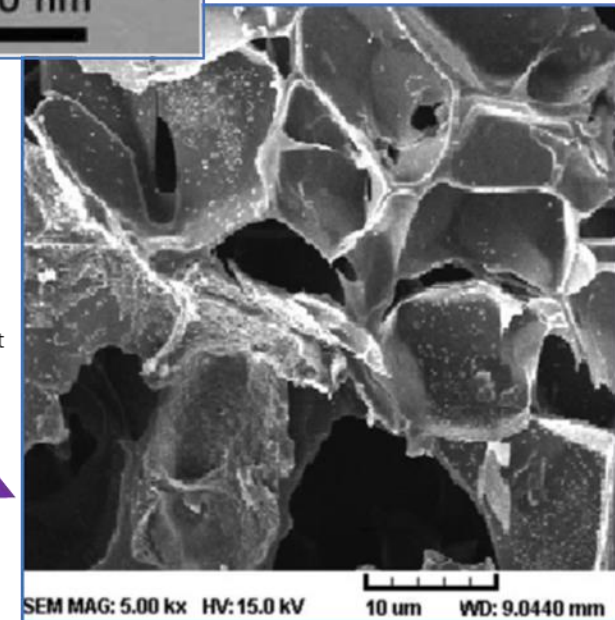


Source: Hussein et al., 2019

Nano particles from banana peelings containing fertilizers



Source: Lohmousavi et al., 2020



Acknowledgements



A Long term EU-Africa research and innovation Partnership on food and nutrition security and sustainable AGRiculture



Thank you for Listening



**Before
CR4D**



**After
CR4D**

Mission of the lab: 'Negative GHG Emissions in Plant Nutrition'