# The Nitrogen Issue

Nitrogen is central to increasing plant yields to feed the world's growing population, however fertiliser technology has remained much the same for the last 50 years. More than a century ago Fritz Haber figured out a way to fix nitrogen which is abundant in the atmosphere, into ammonia, the active ingredient in synthetic nitrogen fertiliser. Humanity depends on fixed nitrogen to fertilise croplands, and helping nature in relation to nitrogen availability is a key aspect of world food security.

Nitrogen based fertilisers are environmentally unsustainable in the volumes that are being applied. Agriculture is the major driver of the global Nitrogen (N) cycle and is also the largest contributor to N pollution (Bodirsky et al, 2014). Agricultural run-off into the earth's oceans, soils and atmosphere have adversely affected the earth's nitrogen balance. The nitrogen boundary for the planet is set at 35 millions of tonnes per year removed from the atmosphere and this has been surpassed at 121 million tonnes (State of the Planet 5$^{th}$ August 2011).

The global nitrogen fertiliser market is forecast to be worth US $109.83 billion in 2017 (Lucintel: Global Nitrogen Fertilizer Industry 2012-2017). Global population growth and food quality are the major concerns in emerging countries. These issues drive the application of nitrogen fertiliser, and are leading the industry to future growth.

Approximately 2% of world energy use is dedicated specifically to the industrial manufacture of $N_r$, mainly through the Haber-Bosch process, so that $N_r$ prices are closely coupled to global energy prices (Global Overview on Nutrient Management).

**Nitrogen Pollution**

In agriculture, Nitrates are added in vast quantities to increase crop productivity. This is a very inefficient process with up to 30% of nitrates applied on the land ending up in coastal waters. Approximately half of all N applied to the arable land is lost to the environment before the crop can use it (Davidson et al, 2012). The application is increasingly expensive, and the excess nitrogen chemically binds with other elements in the environment to create pollution that fouls the water and air.

In 2012, 90% of the $NH_3$ emissions from Canada came from agricultural activity, primarily through direct synthetic N fertiliser application. Transportation, industry and other sources accounted for a mere 10%. In 2013 nitrous oxide ($N_2O$ ) accounted for 5% of all greenhouse gases in the USA, and, as with the high contributions agriculture makes to $NH_3$ emissions, agriculture contributed 74% of all $N_2O$ emitted in the USA in 2013 (EPA, 2015)

**Aquatic Environments**

Nitrogen leached into the atmosphere and waterways can have serious detrimental environmental effects, creating dead zones which affect many ocean areas and waterways. Nitrate contamination in groundwater affects drinking water and can adversely affect human health.

In the last 40 years the amount of fertilisers directly entering coastal waters has increased six fold due to the exponential growth of fertiliser use worldwide (Maranger et al. 2008[3]). We now have the situation where Nitrogen overload is becoming an alarming global issue.

The release of Nitrous Oxide is essentially a greenhouse gas. According to James N. Galloway of the University of Virginia "We are accumulating reactive Nitrogen in the environment at alarming rates, and this may prove to be as serious as putting carbon dioxide in the atmosphere."

There are two consequences of nitrate nutrient overloading:

- The creation of harmful algal blooms which produce toxins harmful to human and aquatic organisms (and indirectly affects fisheries and biodiversity in coastal areas).

- Depletion of oxygen, creating dead zones in our waterways and oceans. Dead zones form when fertiliser and other pollutants high in Nitrogen and Phosphorus are leached into the soil and then the waterways. This generates an explosive growth of algae, which then dies and rots. The dead algae are consumed by bacteria, which consumes oxygen and suffocates marine life.

There are many ocean areas and waterways that are affected by 'Dead Zones'. In the USA Chesapeake Bay, the Northern part of the Gulf of Mexico and the coastal regions of the North West Pacific are all affected by dead zones. The use of chemical fertilisers is considered the major human-related cause of dead zones around the world. Nitrogen pollution as a result primarily of agricultural run-off was found in 2012 to cause the formation of more than 300 hypoxic 'dead' zones along the coastline of the USA (Davidson et al, 2012).

**Air Pollution and Health**

Health can also be adversely impacted as a result of high nitrate runoff into aquifers and reservoirs. In 2012 it was found that 1.7 million Americans drink water with potentially damaging levels of nitrate (Davidson et al, 2012).

Blue baby syndrome can occur when nitrate-contaminated drinking water is used in conjunction with infant formula milk.

Nitrogen Oxide (NOx) can have an adverse effect on health. NOx gases react to form pollutants such as:

- Smog and acid rain
- The formation of fine particles (PM)
- Ground level ozone, both of which are associated with adverse health effects

The Haber-Bosch process uses N gas and hydrogen to form ammonia. This reaction requires a specific temperature and pressure in order to obtain a high yield which is energy and carbon intensive to maintain. Oxidised N substances such as nitrogen oxides (NOx), nitrous oxide ($N_2O$) and ammonia gas (NH3) are all potential pollutants. These substances can help cause tropospheric smog (NH3 and NOx) which causes health problems, in the stratosphere they can trap infrared radiation warming the planet (N2O) and also destroy ozone (Bodirsky et al, 2014).

Nitrous oxide has other adverse effects on the environment, it:

- Contributes to global warming and is the third most important greenhouse gas in the UK.
- Has a high "global warming potential" (310 times that of carbon dioxide).
- Damages the ozone layer, thus reducing the protection offered from harmful UV sun rays.

The EU air quality directive (2008/EC/50) has two limit values for nitrogen dioxide ($NO_2$) for the protection of human health: the $NO_2$ hourly mean value may not exceed 200 micrograms per cubic metre (µg/m3) more than 18 times in a year and the $NO_2$ annual mean value may not exceed 40 micrograms per cubic metre (µg/m3).

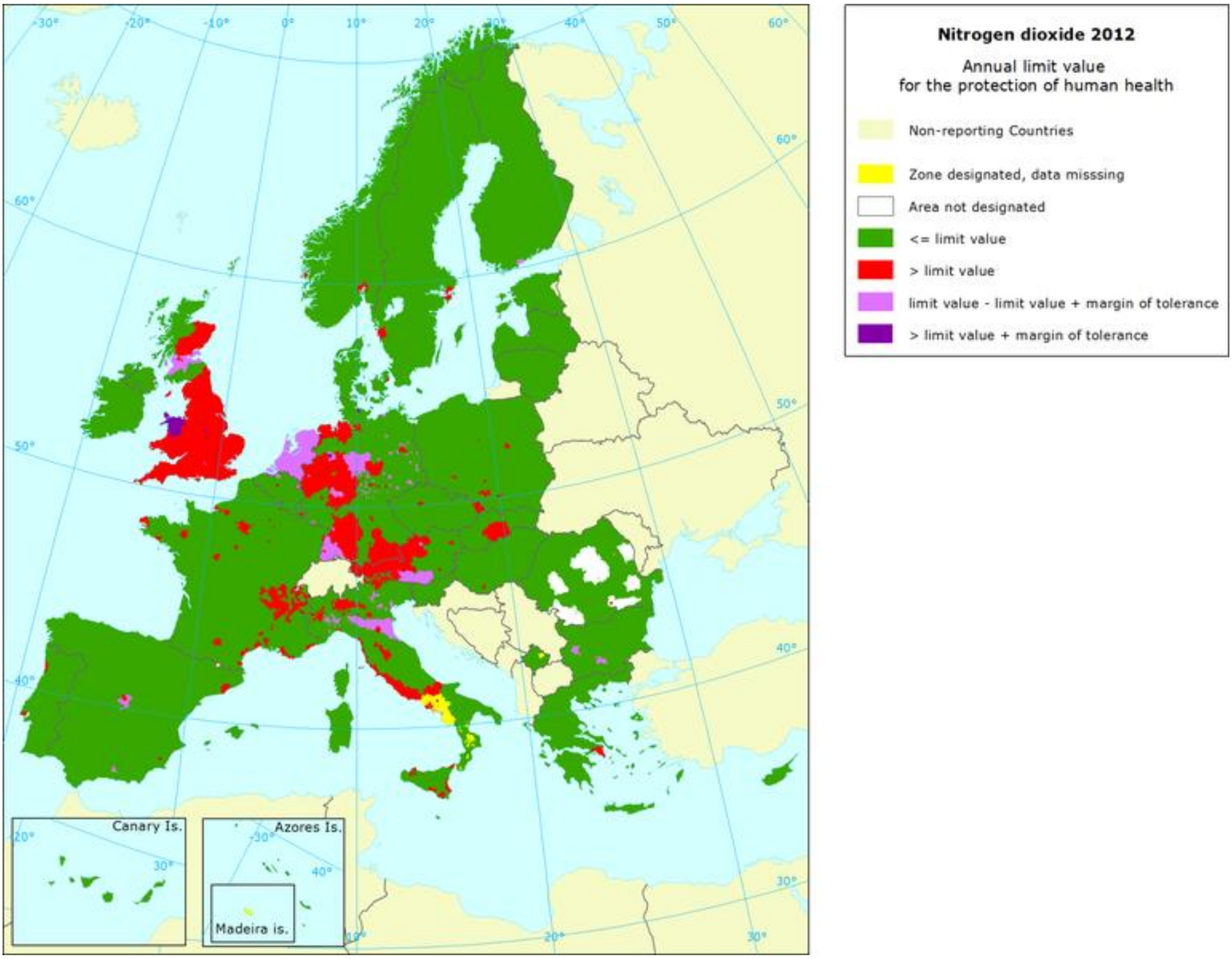


Figure 1. Source: European Environmental Agency

**Cost of Nitrogen Pollution**

The European Nitrogen Assessment (ENA) released in 2011 stated that the cost of Nitrogen pollution to Europe was $80 - $440 billion per year (Sutton et al, 2011; Figure 2). The majority of this figure would be spent on health-related issues, $NO_2$ is a reactive gas emitted from combustion engines in cars or power plants and has been linked to respiratory problems. Agricultural release of $NO_2$ from soils is thought to contribute 2 – 4 Mt of $NO_2$, which is largely dependent on the amount of fertiliser applied to the crops. Global warming potential (GWP) is a measure of how much warming a substance will cause to the planet when emitted; $CO_2$ is used as the standard with a GWP of 1. $N_2O$ has a GWP of 310 therefore it has a longer lifetime in the lifetime and has the potential to cause 310 times as much warming as $CO_2$.

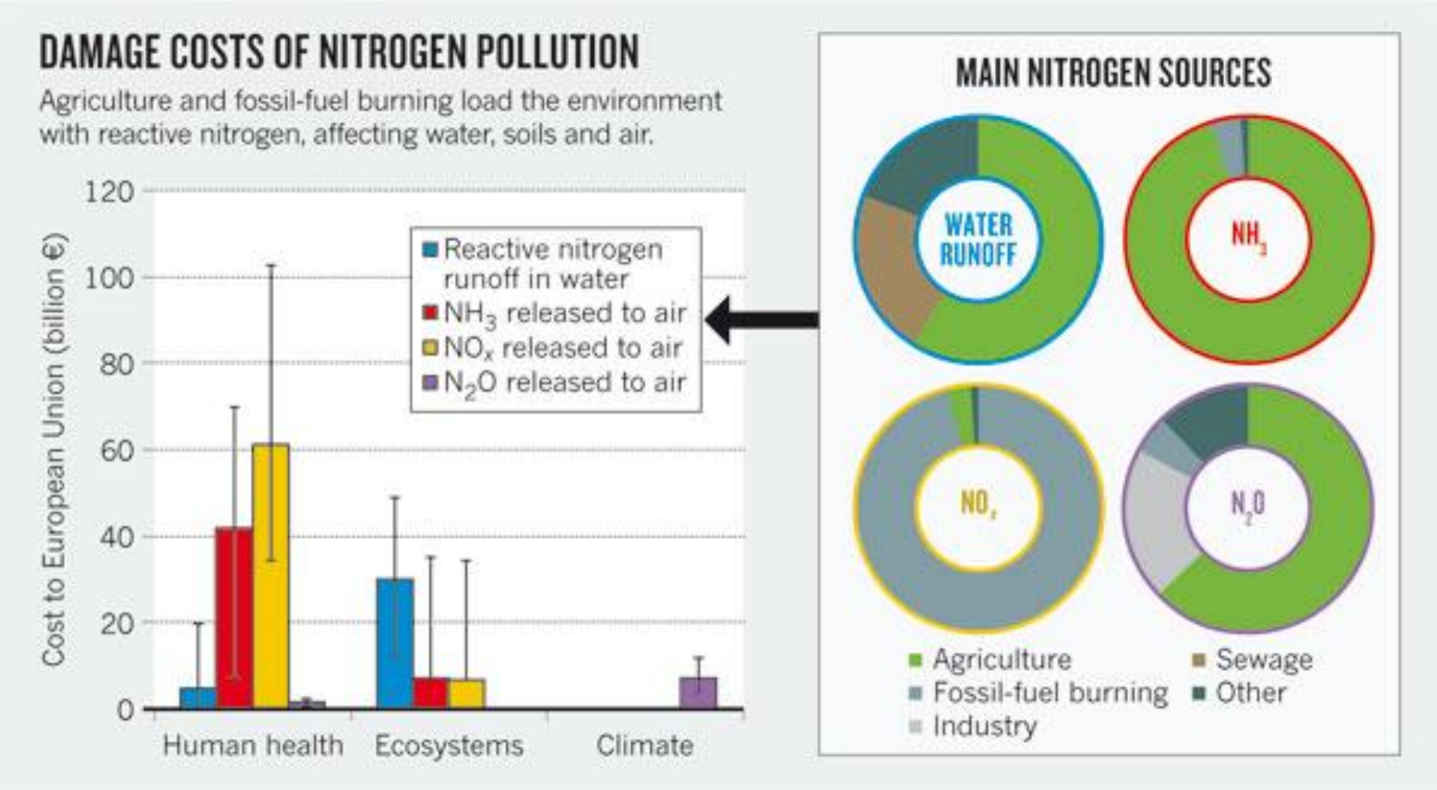


**Figure 2. S**hows the cost (€) of Nitrogen pollution to the EU in terms of human health, ecosystems and climate. The main N pollutants and their participation to each of these costs are also illustrated. Source: Sutton et al, 2011.

In 2009 and 2012 respectively 70% of land in England and 55% of land in France was classified as a nitrate vulnerable zone (NVZ) (Environment Agency, 2014; EC, 2015, Figure 5.4.1), meaning that run-off or percolation on/through this land ends up in surface or ground water with a nitrate content ≥ 50 mg/l of nitrate.

There is a desperate need for Nitrogen pollution control which results from excessive fertiliser application in agriculture. New technologies and their resultant products are urgently required.

A new nitrogen-fixing technology has been developed which will help transform agriculture. This patented technology enables all crops to take up nitrogen from the atmosphere rather than from expensive and potentially environmentally damaging nitrogen based fertilisers. Agriculture needs an alternative to bulk fertilisers now – this N-fix® technology will revolutionise agricultural practice.