European Commission

Science for Environment Policy

Nitrous oxide could be removed from the atmosphere with simultaneous generation of renewable energy

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Nitrous oxide (N_2O) is a potent greenhouse gas and atmospheric pollutant. A new study proposes tackling both problems by removing N_2O from the atmosphere using a combination of two innovative technologies — photocatalytic breakdown of the N_2O to nitrogen and oxygen, and this within a solar chimney power plant that generates renewable electricity. Although some way off from commercial development, the researchers say this approach is feasible, and they outline how these two technologies can be integrated to reduce the climate impact and polluting effects of N_2O emissions.

Greenhouse gases (GHGs) produced from human activities, such as burning fossil fuels, are contributing to climate change and rising global temperatures. To limit damage from climate change, global GHG emissions must be reduced. The primary international focus has been on curbing carbon dioxide (CO_2) emissions, although human activities have also increased emissions of other GHGs, such as N_2O.

N_2O is a potent GHG that remains in the atmosphere for about 121 years. It has a global warming potential 298 times greater than that of CO_2 over a 100 year time frame. N_2O is also an important ozone-depleting substance that thins the ozone layer responsible for protecting life on Earth from ultraviolet radiation.

About 45% of N_2O emissions are produced naturally by bacteria breaking down nitrogen compounds in soil and water. The other 55% of emissions come from human activities, especially from burning fuels, from industrial processes, and from the use of nitrogen fertilisers and manure in agriculture.

This study proposes removing N_2O from the atmosphere as a viable method to help curb global warming. The researchers further suggest combining two innovative technologies, the photocatalytic breakdown of N_2O and a solar-chimney power plant, that can act together to remove N_2O from the atmosphere and, at the same time, generate renewable energy.

The photocatalytic breakdown of N_2O into nitrogen and oxygen occurs when air containing N_2O flows over a catalyst (a substance which speeds up chemical reactions but does not get consumed in the reaction), using the energy from sunlight or artificial light. Among the photocatalytic materials that researchers have tested, titanium dioxide is one of the most efficient. Titanium dioxide is activated by sunlight at the ambient temperatures of hot and arid climates and also has long-term stability, low toxicity and is abundant and relatively cheap.

A solar chimney power plant (SCPP) consists of a tall chimney with a turbine in the base. The chimney is surrounded by a large greenhouse (called a collector), open to the air at the sides. Solar radiation heats up the air under the greenhouse and the hot air rises through the chimney, turning the blades of the turbine, which generates electricity. The continuous up-draught of heated air pulls new air from the atmosphere under the collector.

Continued on next page.

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1. According to various published studies, the life expectancy of SCPPs is between 80 and 120 years, compared to 30 to 40 years for fossil fuel, 40 to 60 years for nuclear and 25 years for PV power plants, and 25 to 30 years for wind turbines.

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By coating the inside surfaces of a SCPP greenhouse with a photocatalytic material, the researchers say both technologies can work together to remove N_2O from the atmosphere while generating renewable electricity. The SCPP provides the continuous airflow over the photocatalyst and the greenhouse surfaces provide sheltered and transparent supports for a large surface area of photocatalyst to be exposed to the sunlight and air flow. In order to produce cheap electricity, the SCPP is best located in an area that receives 2 000 kilowatts per square metre or more of solar radiation a year — areas such as Crete, Sicily or the south of Spain may be suitable.

A prototype SCPP with a 200-metre high chimney was built and successfully tested in Spain in the 1980s. However, no commercial-scale SCPP has yet been built, mainly because of the high initial costs. However, the researchers estimate that a SCPP of 200 megawatt capacity could generate 680 gigawatt hours of non-intermittent renewable electricity each year and continually clean N_2O from the atmosphere. Several studies have proposed cost assessments for SCPP of different sizes, two of which have estimated the price of energy for an SCPP 750m high with a collector of 3500-m diameter as between 0.075 and 0.090 €/kwh.

The researchers highlight the strength of a SCPP, saying that one would last two to three times longer than a fossil fuel, nuclear, wind, CSP (concentrated solar power) or PV power plant[1]. SCPPs also require minimal maintenance. Previous research has found that the largest life-cycle impacts in terms of energy consumption from a SCPP come from the glass or plastic material of the greenhouse collector. One material, ethylene tetrafluoroethylene, however, has an energy returned on energy invested (usable energy delivered compared with energy used to deliver the energy) measure of 14 (the higher the number the better), suggesting it is a promising greenhouse material.

Nanosized titanium dioxide coatings can be made thin enough to be transparent and allow light through the greenhouse collector. These types of photocatalytic materials can also be designed to be self-cleaning to prevent dirt build-up on the greenhouse structures. The researchers say that self-cleaning paints, coatings and cements that also decompose and reduce the concentration of atmospheric pollutants, such as nitrogen oxides, have been safely used around the world for over ten years with no unintended consequences[2].

SCPPs with photocatalytic capabilities activated by sunlight or artificial light could also operate at night, unlike other solar power plants. Instead of illuminating the photocatalytic coatings at night, other types of catalysts have been developed that are activated by the higher temperatures found at the base of a solar chimney. Coating these types of thermally-activated catalysts at chimney entrances would also enable the SCPPs to operate in the dark; during the day, the ground under the greenhouse collector heats up and this heat is released at night, which maintains the air flow past the thermal catalyst coatings.

The researchers say that although more research is needed before the commercial potential of the combined technologies can be achieved, this approach could help to mitigate global warming and reduce the atmospheric concentration of a harmful pollutant.

2. Unlike titanium dioxide nanoparticles found in many food, personal care and pharmaceutical products, which after use can enter the environment, particularly via surface waters, the researchers say that the coatings under a SCPP are designed to stay on the glass and have little opportunity to pass into the environment. See also Chabas, A. *et al*, (2014). Long term exposure of self-cleaning and reference glass in an urban environment: A comparative assessment. *Building and Environment*, 79, 57–65.