Overcoming Carbon-Free Fuel Challenges: Laser-Induced Ammonia Combustion

Overview/Abstract

Decarbonization of the power production, transportation, industrial and building heating sectors is pivotal for meeting net-zero carbon goals of 2050. As solar and wind are rapidly brought online to decarbonize the power grid, we are faced with the intermittent availability of renewable energy. Battery grid storage and pumped hydro has proven to be a significant lever to mitigate daily and weekly intermittency issues, but seasonal intermittency remains a challenge. The peak renewable energy production in the summer to the increasingly larger energy demand in the winter months (that will become the new peak!) has yet to be addressed, and existing solutions are not capable of addressing this.

Green hydrogen from renewable energy is already being worked on to solve renewable energy intermittency issues. However, hydrogen raises unique storage challenges due to its low energy density and poor material compatibility; thus, there is a need for a secondary alternative fuel choices as long-duration reserve fuels. More complex fuel molecules such as ammonia (NH_3) can solve the energy density problem (liquid at 25° C and 10 Bar) and can readily be decomposed, on-demand, to generate hydrogen.

While potentially easier to store, the challenges with NH_3 come inside the combustion chamber. Ammonia has a high auto-ignition resistance, a high ignition temperature requirement, and low flame speeds making the fuel difficult to use in reciprocating piston engines, especially compression-ignition genset engines that are widely used in Department of Defense applications for back-up rand remote primary power.

PI Dimitris Assanis and Co-PI David Hwang **aim to overcome** the **high ignition temperature requirement** and **challengingly slow flame speeds** associated with NH_3 combustion by evaluating and understanding the use of a) **laser-induced photochemical pathway for ammonia fuel decomposition** into intermediate chemical species of NH_2 and NH as well as b) **laser-induced breakdown pathway for ammonia fuel ignition**.

Problem

Ammonia is carbon-free fuel with great long-duration storage capabilities that can be made from renewable energy and can help decarbonize the ~2B internal combustion piston engines in the world so we can meet our ambitious net-zero carbon goals. The problem is that Ammonia combustion is challenged by high ignition temperature requirements and slow flame speeds thus requires hydrogen addition or a new, innovative approach.

Innovation

Laser-induced decomposition and ignition can break the parent fuel, Ammonia, into more reactive intermediate kinetic species of NH2, NH and other radical species that are more readily ignitable and can achieve faster combustion propagation rates.

Team

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Follow-on Funding Opportunities

Recognizing the importance of this issue, funding programs have been initiated from the following:
- ✓ NSF (CBET or CFS Directorates)
- ✓ DOE Basic Energy Sciences
- ✓ NSF/CAREER
- ✓ DoD (ONR or NAVFAC EXWC)

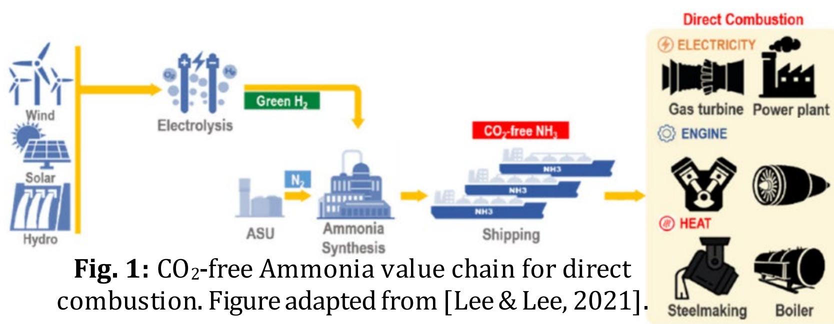

Fig. 1: CO_2-free Ammonia value chain for direct combustion. Figure adapted from [Lee & Lee, 2021].