Project description

Nitrogen-Based Alternative Fuel

1. Scientific and technological objectives

Developing a sustainable and secured energy system is perhaps one of the greatest challenges our society must address. In particular, developing carbon-neutral energy storage and energy carrier (i.e., fuels) technologies are the key enabling elements allowing us to withdraw energy from the sun even when the sun doesn't shine.

The chemical bonds within fuels are the most attractive form of large scale energy storage. Future photo-catalytic water splitting processes can potentially become a low-cost alternative to the contemporary fossil fuel derived hydrogen. However, although hydrogen is often considered as a sustainable alternative fuel, the feasibility of a pure hydrogen economy is questionable due to safety issues as well as its extremely low volumetric energy density. Nonetheless, once the solar hydrogen technology is able to produce massive amounts, the hydrogen could be chemically stored via two major fuel carriers: carbon and nitrogen. While the entrapment of carbon is a challenge due to scarce levels of atmospheric CO$_2$, the global accessibility to atmospheric nitrogen enables a large scale production of ammonia and its fertilizer derivatives.

The proposed project aims to develop a novel nitrogen-based fuel consisting of an aqueous Urea and Ammonium Nitrate solution (UAN). This nonflammable, nonexplosive and nontoxic fuel has shown initial promise to produce an environmental friendly effluent gas consisting of 73.0% H$_2$O, 21.6% N$_2$, and 5.4% CO$_2$ on a mole basis (Reaction R1) upon combustion. Thus, the goal of this project is to efficiently retrieve the stored energy in the nitrogen-based alternative fuel while minimizing its pollutant levels.

$$3\text{NH}_4\text{NO}_3\text{aq} + \text{N}_2\text{H}_4\text{aq} + 5.56\text{H}_2\text{O}_\text{l} \rightarrow 4\text{N}_2\text{g} + 13.6\text{H}_2\text{O}_\text{l} + \text{CO}_2\text{g}, \quad \Delta H_{\text{Rxn}}^{\circ} = -3.28 \text{ MJ/kg} \ (\text{R1})$$

In order to achieve this goal, the appropriate combustion conditions in terms of pressure, flow regime, and residence time as well as a proper catalyst for post-combustion gas treatment must be further investigated and simulated. In addition, in order to demonstrate the feasibility of the process, a high pressure turbine must be devised, manufactured, and tested. Coupling these two elements to a commercial small generator is a straightforward step to demonstrate the electricity generation using a low-carbon fuel.

2. State of the Art

Currently, pumped hydroelectric storage and compressed air energy storage are the only mature technologies capable of providing large scale (above 100 MW) energy storage. However, both technologies can be implemented only where the appropriate
geographical or geological conditions are available, and do not provide an energy carrier solution. Compared to other emerging technologies (e.g., batteries, flywheels, regenerative fuel cells, supercapacitors and molten salts) fuels have by far the highest energy density, and they are easily transported. Aqueous UAN is a safe and nontoxic nitrogen-based fuel, and it has an energy density of 3.3 MJ/kg (917 Wh/kg).

Preliminary continuous combustion investigation of the fuel shows that the \( N_2 \) yield increases with pressure (Fig. 1), and at 200 bar a yield of 99.89% was attained. In addition, at these conditions NOx emissions (127 mg/MJ) were below the USA EPA regulation standards for stationary power generation turbines (290 mg/MJ).

![Graph](image)

**Fig. 1.** \( N_2 \) yield of aqueous UAN continuous combustion process at a constant fuel flow rate of 10 ml/min. Data from: Grinberg Dana A., Shter G.E., Grader G.S., "Nitrogen-Based Alternative Fuel: An Environmental Friendly Combustion Approach", *RSC Advances*, in review.

3. **Collaboration agenda and requirements**

The researchers are seeking to initiate a Horizon 2020 project under the Call for Competitive Low-Carbon Energy: LCE-11-2014. The work will be carried out by work packages as delineated below:

WP1: Combustion investigation in a plug flow reactor (PFR) environment

WP2: Selection of appropriate catalysts for the combustion process

WP3: Computerized Simulation of the Combustion process (CHEMKIN)

WP4: Engineering & Process planning of the High Pressure Turbine
WP5: Life cycle analysis
WP6: Demonstration and validation of the technology in an industrial environment
WP7: Coordination and management

4. **Description of Technion Institute of Technology partnership**

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5. **Required partners**

- Catalysts for the combustion process
- Turbine characterization, simulation, analysis
- Turbine manufacturer
- Financial consultants
- Electric company

For more information, kindly contact Prof. Gideon Grader: grader@technion.ac.il