Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 135 (2017) 3–13

Energy Procedia

www.elsevier.com/locate/procedia

11th International Renewable Energy Storage Conference, IRES 2017, 14-16 March 2017, Düsseldorf, Germany

The Nitrogen Economy: The Feasibility of Using Nitrogen-Based Alternative Fuels

Oren Elishav[a], Gal Tvil[b], Bar Mosevitzky[b], Prof. Daniel Lewin[b], Dr. Gennady E. Shter[b], Prof. Gideon S. Grader[b]*

[a]*The Nancy and Stephen Grand Technion Energy Program, Technion I.I.T, Haifa 3200003, Israel.*
[b] *The Wolfson Department of Chemical Engineering, Technion I.I.T, Haifa 3200003, Israel.*

Abstract

We present herein a techno-economic feasibility for implementation of nitrogen-based fuels. Firstly, we compared the nitrogen- and carbon-based routes for chemical hydrogen storage. The above hydrogen carrier routes were evaluated on an energy basis, under defined system boundaries by comparing seven alternative fuels. Ammonia was found to be the best energy vector, followed by methane, methanol, and aqueous ammonium-hydroxide urea. Secondly, we evaluated the economic feasibility of a model nitrogen-based fuel by using levelized cost of storage analysis. The results indicated that a nitrogen-based fuel is competitive with other storage technologies under development. Furthermore, a decrease in the hydrogen cost can lead nitrogen-based fuels to be competitive with currently-used mature technologies. Thirdly, the utilization of the nitrogen-based fuel route was demonstrated. The auto-ignition process of a model fuel, aqueous urea ammonium nitrate (UAN) was described. The results indicate that this fuel is safe to use, store and handle under ambient pressure. We studies potential storage and reaction vessel materials, pointing out favorable metal alloys for these purposes. In addition, a catalyst screening study aimed at pollution reduction during batch combustion of this fuel is reported, as are preliminary results for continuous catalytic combustion. This work demonstrates the feasibility of catalytic pollution abatement for UAN combustion and the clean utilization of this fuel.

Keywords: nitrogen economy; alternative fuels; catalytic combustion; energy analysis; economic analysis; fuel safety

* Corresponding author. Tel.: +972-4-8292008; fax: +972-77-8871840.
E-mail address: grader@technion.ac.il

1876-6102
10.1016/j.egypro.2017.09.482

1. Introduction

Renewable energy sources (such as wind and solar) are expected to provide an increasing portion of our global energy demand. However, on a large-scale these sources suffer from fundamental drawbacks of intermittency and deliverability. Several energy storage technologies were previously suggested to provide the needs for large scale storage: pumped-storage hydroelectricity (PSH), compressed air energy storage (CAES), batteries, and synthetic fuels including hydrogen [1]. Currently, PSH and CAES are the most mature available technologies. However, both technologies can be implemented only where geological or geographical conditions are available.

Nomenclature

AAN	Ammonium-hydroxide ammonium nitrate
AHU	Ammonium-hydroxide urea
AN	Ammonium nitrate
CAES	Compressed air energy storage
CNG	Compressed natural gas
DME	Dimethyl ether
DTA	Differential thermal analysis
FTIR	Fourier transform infra-red spectroscopy
LCOES	Levelized cost of energy storage
MeOH	Methanol
PFP	Power to fuel to power
PSH	Pumped-storage hydroelectricity
SCR	Selective catalytic reduction
SS	Stainless steel
TGA	Thermal gravimetric analysis
UAN	Urea ammonium nitrate

Future hydrogen produced economically by water splitting will open new opportunities for implementing renewable energy. However, a pure hydrogen economy presents unresolved challenges in terms of transportability, volumetric energy density and infrastructure [2]. Therefore, although hydrogen is a key ingredient in renewable synthetic fuels, it cannot provide the solution in its pure form. An attractive approach is to chemically store hydrogen in the form of synthetic fuels, using carbon or nitrogen as the main hydrogen carriers**.**

Renewable carbon-based fuels relay on large scale CO_2 separation. The source for CO_2 can be either atmospheric or concentrated gas flue stream. Separation from the atmosphere is an energy intensive and challenging task [3], while separation of CO_2 from existing power plants positioned in various locations is not simple either. The methanol economy [4] is a representative of a carbon-based economy. Methanol could be directly converted into other energetic species such as dimethyl ether (DME), by dehydration. Additional liquid organic hydrogen carriers could also be synthesized from methanol [5]. This future economy is not limited to the energy sector since methanol is the precursor to other synthetic organic products such gasoline, ethylene, propylene and other synthetic products used in the chemical, petrochemical, plastic and pharmaceuticals industries [4].

An alternative route is to use atmospheric nitrogen to upgrade hydrogen to nitrogen-based fuels. In this scenario nitrogen-based compounds are produced to meet the demands of both the fertilizer and energy sectors. The global accessibility and abundance of nitrogen in the atmosphere make it a convenient hydrogen carrier. Ammonia was previously suggested as an alternative hydrogen carrier [6]. Currently, ammonia is the second-largest synthetic commodity produced worldwide mainly for the fertilizer industry [7]. Ammonia is primarily used for the production of urea and ammonium nitrate (AN) [8]. Ammonia can be used in gas turbines with little modifications [9]. However, more effective and safe technologies should be developed for widespread use of ammonia as a fuel. Therefore, safe solutions of ammonia and its derivatives could play an important role as alternative fuels [10,11].