

## What are some surprising details about using ammonia as a fuel?

Did you know ammonia (NH<sub>3</sub>) has been a very good fuel and it could be our clean energy salvation?

The scientists and others that do know about how good using ammonia as an energy currency, fuel and for conversion of CO<sub>2</sub> into urea cannot understand why the public and our politicians do not know, and they have written so in published research in 1967, 1981 and in 2012. I will provide more about this and the other scientific verification below but first I thought you would like to know more about the long history of using ammonia as a fuel and solar energy conversion tool.

The Saint Charles Avenue Streetcar in New Orleans was established as "The New Orleans and Carrollton Rail Road Company" in February 1833, and a service began in 1835. Through the early years the cars were successively powered by horses, mules, overhead cables, Lamm's ammonia engines, and steam engines. There were a number of ammonia motors or engines developed in the late 1800s or early 1900s.

And the French engineer Charles Tellier was a pioneer in the field of solar ammonia energy in 1885, when he installed a roof-top solar collector very similar to the flat-plate collectors used today for heating domestic water. His collector system was composed of ten units made of two iron sheets riveted together and connected by piping to form a single array. The collector plates were filled with ammonia, and after exposure to sunlight, sufficient pressure was created in the ammonia gas to power a water pump that Tellier had placed in his well, at the rate of some 300 gallons per hour during daylight.

<http://www.douglas-self.com/MUSEUM/POWER/ammonia/ammonia.htm>

A pick up truck was converted to run on ammonia in 1933 by Industrial giant Norsk Hydro (who also made ammonia from electricity until 2009).<sup>Å</sup>

<http://www.hydro.com/en/About-Hydro/Our-history/1918---1928/1919-Research-as-driving-force-and-inspiration/>

In 1938 Ammonia Casale Ltd., J.L. Restieau and E. Kroch received a patent (applied for in 1936) for a system to burn a mixture of ammonia and hydrogen in internal combustion engines known as the Gazamo process.<sup>Å</sup> This system was first presented to the public in Belgium at the Alternate Fuel Exhibition organized by the Association of the University of Brussels Engineers in June 1942. The Gazamo process was the first application of using ammonia as a fuel in a large scale road tested on about 100 vehicles which were equipped for using it in 1941-1942.

<http://www.google.com/patents/US2140254>

In November 1942, Belgium's public bus system ground to a halt, crippled by a wartime shortage of diesel. Engineers at the country's public transport company got to work and by April 1943 the service was up and running again. They had adapted about 100 buses to run on an alternative fuel "liquid

ammonia, pumped into tanks on the buses'™ roofs. The buses travelled over 100,000 km without a single accident or spill and several private vehicles were converted that used the buses ammonia fuelling station.

<https://www.newscientist.com/article/mg21929283.500-look-to-the-past-for-the-fuel-of-the-future/#.Uh49hg1GpG8.wordpress>

[http://www.claverton-energy.com/wordpress/wp-content/files/NH3\\_bus\\_1945\\_JInstPetrol31\\_Pg213.pdf](http://www.claverton-energy.com/wordpress/wp-content/files/NH3_bus_1945_JInstPetrol31_Pg213.pdf)

During the 1960s there was a major effort by the US Military called the Energy Depot Project which had as an objective the production of a fuel from indigenous materials - earth, air, and water. Fuel possibilities included hydrogen, ammonia and hydrazine. (Ethyl Corporation's Detroit Research Laboratories briefly examined the engine performance of ammonia in a single cylinder Waukesha engine... Through their study, the authors have shown that there would be no incentive to use ammonia as a fuel in the civilian market as long as hydrocarbons are available.)

[http://www.alternatewars.com/Fiction/SF\\_Tech/SP-263\\_Discussion.htm](http://www.alternatewars.com/Fiction/SF_Tech/SP-263_Discussion.htm)

There was also a substantial amount of work done using ammonia as a rocket fuel, including using it for the X-15, the fastest aircraft ever built. The XLR99 engine used anhydrous ammonia and liquid oxygen as propellant, and hydrogen peroxide to drive the high-speed turbo pump that delivered fuel to the engine. It could burn 15,000 pounds (6,804 kg) of fuel in 80 seconds, could be throttled, and were the first such controllable engines that were man-rated.

<https://www.youtube.com/watch?v=vM4Flfa1gXU>

The University of Tennessee's ammonia-fueled urban vehicle competed in the 1972 Urban Vehicle Design Competition; designed and built by undergraduate engineering students working under Prof. Jeffrey Hodgson, the team finished fifth in a field of 65 entries (the vehicle actually had the second highest raw score). Alternate fuels for transportation. Part III. Ammonia for the automobile, Mech. Eng.; Journal Volume: 96:7, 1974-07-01 (and New Scientist 24 Aug 1972, p 398)

<http://www.osti.gov/scitech/biblio/5238745>

<http://www.osti.gov/scitech/search/author:%22Hodgson,%20J.W.%22>

By 1978, actors Jack Nicholson and Marlon Brando, Joanne Carson and others were involved with co-inventor of the transistor and light emitting devices and diodes Prof. Herbert F. Matar, in an unsuccessful solar to hydrogen to ammonia project that ultimately failed because two of the founders were convicted of fraud. (<https://www.youtube.com/watch?v=TjfONpsFvyM>)

Subsequently, several of the investors from Canada headed my family organized a new company working with many of their staff and successfully converted and drove a 1981 across Canada, arriving on Parliament Hill in Ottawa on Nov. 5, 1981. (See Hydrofuel's NH3 ammonia car.)

<https://www.youtube.com/watch?v=8vwmzkn0paM>

In 2003 the NH3 Fuel Association mentioned above was formed, the first NH3 Fuel Conference was held in 2004 and ongoing conference presentations and extensive details of research and other current developments are published and updated on their website.

<https://nh3fuelassociation.org/events-conferences/>

In 2007 Hydrofuel Inc. released a new retrofit dual fuel ammonia conversion system at the Fourth Ammonia Fuel Conference in San Francisco, California, and Greg Vezina of Hydrofuel Inc. gave a presentation. In HTML (easier to read on screen) or PDF (better for printing) formats.

[http://nh3fuel.com/images/stories/gvezina\\_nh3fuel\\_presentation\\_oct07.pdf](http://nh3fuel.com/images/stories/gvezina_nh3fuel_presentation_oct07.pdf)

In 2008 we converted a diesel fuelled 2007 Dodge Truck and a 2008 gasoline fuelled Ford Crown Victoria to run on NH3.

<http://nh3fuel.com>

With respect to the academic reports on using ammonia as a fuel and related matters including the fact that it was proven a viable and valid option in many applications and with some further research and development and commercial demonstration it was even more likely to be

The first report about using ammonia as a fuel, energy currency and for carbon conversion into urea and other chemical was, Energy Needs versus Environmental Pollution: A Reconciliation? By Leon Green Jr., Science 16 Jun 1967: Vol. 156, Issue 3781, pp. 1448-1450

[http://www.ganino.com/games/Science/science%20magazine%201966-1967/root/data/Science%201966-1967/pdf/1967\\_v156\\_n3781/1722310.pdf](http://www.ganino.com/games/Science/science%20magazine%201966-1967/root/data/Science%201966-1967/pdf/1967_v156_n3781/1722310.pdf)

Dr. Green wrote about this again in, An ammonia energy vector for the hydrogen economy,

in the International Journal of Hydrogen Energy -1(4) pp. 1265-1272 December 1980

<https://docs.google.com/viewerng/viewer?url=ftxt.eurekamag.com/000/000818684.pdf>

There were two studies done about ammonia for the 1980 US EPA Fuels Safety Report, the first was, Ammonia: An introductory assessment of safety and environmental control information, U.S. Department of Energy, Report W in Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: Second Status Report, Volume 3, DOE/EV-0085, 1980, pp 151- 204, was written by D. J. McNaughton and D. L. Brenchley.

<http://www.osti.gov/scitech/servlets/purl/6891566>

The second study in 1980 US EPA Fuels Safety report, Ammonia as a fuel, U.S. Department of Energy, DOE/EV-0085, Report X in Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: Second Status Report, 1980, vol. 3., pp 205-246, by H. J. Bomelberg and D. J. McNaughton

<http://www.osti.gov/scitech/servlets/purl/6891566>

After a careful comparison of hydrogen and ammonia, they wrote: "It is not understandable why hydrogen as a future fuel is widely promoted, whereas ammonia is presently not considered at all. The most likely explanation appears to be that the potential use of ammonia as a substitute fuel is just too unknown, even within the technical community."

The research and prototype development work on ammonia energy production and utilization continued rather quietly over the next thirty years except for the above mentioned activities of the NH3 Fuel Association.

In 2012 the first of two major studies on using ammonia were released. I have attached a link below to a three part file that starts with very well written four page Prologue by Jim Esch, Proceedings of the IEEE Contributing Editor, to the most thorough examination of the subject "The Dual-Fuel Strategy: An Energy Transition Plan." (Digital Object Identifier 10.1109/JPROC.2013.2245039)

The Dual Fuel Strategy: An energy Transition plan, by CalPoly Tech prof. William Ahlgren, is the second part of a very detailed three part submission made to the California Energy Commission in, William Ahlgren Comments: Plan to completely decarbonize the electric power sector, which contains the four page Prologue mentioned above and two major studies:

1. W. L. Ahlgren, "The Dual-Fuel Strategy: An Energy Transition Plan." Proceedings of the IEEE 100, 3001-3052 (2012).

2. W. L. Ahlgren, "Planning for Hundred-fold Increase in Global Ammonia Production." Ammonia Plant Safety and Related Facilities, Vol. 54, pp. 81-90 (American Institute of Chemical Engineers, 2013).

The complete submission with the Prologue and two reports can be downloaded here:

[http://docketpublic.energy.ca.gov/PublicDocuments/15-IEPR-04/TN204490\\_20150504T125450\\_William\\_Ahlgren\\_comment\\_to\\_AB1257\\_Natural\\_Gas\\_Act\\_Report.pdf](http://docketpublic.energy.ca.gov/PublicDocuments/15-IEPR-04/TN204490_20150504T125450_William_Ahlgren_comment_to_AB1257_Natural_Gas_Act_Report.pdf)

There have been numerous other studies and real world demonstrations of manufacturing and utilizing ammonia as a fuel, for energy storage and for heating and cooling economically, in large scale very quickly relative to other options.

By simply searching "ammonia fuel" or "ammonia engine" or "Solar ammonia" on the Internet it reveals many viable solutions have already emerged. NH<sub>3</sub> engines patented by the University of Ontario Institute of Technology and Toyota; NH<sub>3</sub>-fueled cars in Canada, the U.S., Italy and South Korea; NH<sub>3</sub> fuelled buses in China; solar-ammonia, wind-to-ammonia, and waste-to-ammonia fertilizer plants in the U.S., NH<sub>3</sub> fuel cells powering cell phone transmission towers in urine to ammonia projects in Africa, Japan is developing a zero CO<sub>2</sub> hydrogen energy economy primarily based on using ammonia to do it and dozens of other commercial applications already exist.

Most of the media in Canada, the US and around the world is not really covering this stuff to any extent, but they are starting to notice the groundswell of academic and industry support and activity, especially the most recent advances including actual commercial demonstrations of multiple applications and uses, including green manufacturing and use of ammonia made from off peak, excess or remote renewable power such as the wind to ammonia fertilizer and fuel farm, and several municipal garbage and sewer, animal and agricultural waste to ammonia projects around the world to name just a few.

Academic frustration with the slow pace in the large scale development of green ammonia production and utilization technologies is being published more frequently now, most recently on June 29, 2015, in a Financial Times article calling for far greater public investment in clean R&D called, Ammonia is a genuine contender, perhaps the contender, for carbon-free energy:

According to academics from the University College London and the University of Oxford/Rutherford Appleton Laboratory some extremely promising clean technologies like ammonia are currently being overlooked

"Because ammonia not only offers practical ways to tackle many of their articulated challenges but also has a profoundly important track record for enabling innovation at about the scale required. Ammonia is a genuine contender, perhaps the contender, for carbon-free energy that competes with fossil fuels"

"The sun provides roughly 5,000 times our global energy requirement and innovative uses of ammonia can open up greater access to that energy, with solutions that range from massive energy storage for grid-balancing intermittent renewable energy production to the zero-carbon provision of energy for transportation. Decriers will say that ammonia is not safe, but petrol, hydrogen and batteries all have their safety issues. And surely "safe ammonia" is an achievable challenge.

Importantly, ammonia addresses all three neglected R&D areas that King and colleagues identify. It targets the base-load generation challenge for renewables, and, in addition to technology road mapping, can tackle the incentives and consequences that otherwise stop or

delay good innovation.â€•

Â Â Â But really, at the end of the day, whether government and private enterprise work together or against each other, nothing may be more important than introducing some kind of competitive â€œarms raceâ€• factor into the scenario.

Â Â Â Consider in that regard not only the successes of the Manhattan Project and the Apollo missions, but also the human genome project, an international effort to sequence the human genome, which was completed much earlier than expected precisely because of the inadvertent oneupmanship sparked by a private-public race to the finish line.

The quote is from a group of British academics including Bill David, who contributed to two technical papers at the 2014 NH3 Fuel Conference (â€œInvestigating and Understanding Ionic Ammine Materialsâ€• and â€œA novel approach to ammonia decomposition,â€• both available on this site).

<https://nh3fuelassociation.org/2015/06/29/ammonia-is-a-genuine-contender-perhaps-the-contender-for-carbon-free-energy/>

We have kept quietly working ourselves and not only developed a multi-fuels retrofit or aftermarket conversion system for diesel engines to operate on any single fuel or dual fuels including ammonia, but we have entered into commercial sales of demonstration conversion kits and other goods and services and registered the Hydrofuel® trademark for six classifications in the US (Reg. #4863411, classes 9, 37, 39, 40, 42 and Reg #4184929, class 4), three in the EU (Reg. #006331854, classes 9, 37, 41) and one in Canada Reg. #TMA292288, class 4).