

Is Ammonia the Ideal Energy Currency?

An energy currency is a means of reserving and transmitting energy and anhydrous ammonia (NH₃) is the ideal energy currency for green electricity. In the human body, ATP (Adenosine TriPhosphate) is often considered a biological energy currency because it can either be consumed or stored, depending on the body's needs. With respect to renewable power, an energy currency is basically the ability to put electricity into a bottle so that it can be stored when there is a surplus and used when there is a shortage.

Using ammonia as energy currency is essentially what the US Army was trying to do with their Mobile

Energy Depot program and it considered hydrogen (H₂), ammonia (NH₃), hydrazine (N₂H₄), and hydrogen peroxide (H₂O₂) – all compounds of hydrogen. The authors of THE

THEORY OF OPERATION OF AN AMMONIA BURNING INTERNAL COMBUSTION ENGINE (Charles G. Garabedian and John H. Johnson) wrote “Factors concerned with physical and chemical properties, handling, storage, and dispensing of the four fuels led to the choice of ammonia as the fuel with the greatest potential.

The holy grail of "green" fuels has traditionally been hydrogen, an element that is also very scarce in its pure form on earth. Green in the sense that it is produced from renewable sources, the most common being the electrolytic cracking of water. Hydrogen may also be produced from "brown" sources such as the refining of petroleum. Brown in the sense that by-products of this production are greenhouse gases and other forms of pollution. Almost all of the world's H₂ is produced by steam reforming of natural gas, or as by-products of petroleum refining. Very little is currently produced by electrolysis although there is no technical reason that it can't be produced in large-scale wind farms in Ontario, the US Midwest, or even Patagonia.

Why would anyone consider using anhydrous ammonia rather than hydrogen? Hydrogen, after all, contains more LHV (lower heating value) energy than ammonia (51,500 BTU/lb vs 7,987 BTU/lb or 119.93 kJ/g vs 18.577 kJ/g) on a weight basis. However, on a volume basis ammonia is a much better hydrogen carrier than even liquefied hydrogen. The energy density of liquefied hydrogen is 8,491 kJ/litre compared to ammonia's 11,308 kJ/litre. Although ammonia contains 17.65% of hydrogen by weight, the fact that there are 3 hydrogen atoms attached to a single nitrogen atom allows ammonia to contain about 48% more hydrogen by volume than even liquefied hydrogen. That is to say, a cubic meter of liquid hydrogen contains 71 kg of hydrogen compared with 105 kg for liquid anhydrous ammonia.

Often, people look to hydrogen as an energy currency but it is extremely impractical for the following reasons:

- The low energy density of compressed hydrogen gas makes storage and transport very expensive. Transporting compressed hydrogen gas any significant distance by truck can consume more energy in diesel fuel than what is contained in hydrogen. Liquefied hydrogen is obviously more energy dense than compressed hydrogen gas but a significant amount of energy must be expended to liquefy hydrogen and keep it refrigerated because its boiling point is -423 °F (-253 °C). Liquefaction requires about 30% of the energy content of liquid hydrogen while compression to 800 bar requires about 10-15% of

energy carried by the hydrogen.

- Hydrogen's molecules are very small and difficult to contain.
 - Hydrogen will slowly leak out from hoses and its rate of leakage is much higher than larger molecule gases like ammonia and propane.
 - Hydrogen also causes embrittlement in metals which requires periodic replacement of metallic tubing, valves, and tanks.
- Hydrogen is typically transported as a compressed gas and a 40 ton truck that can carry 26 tons of gasoline can only carry about 400 kg (0.4 tonnes) of compressed hydrogen due to the weight of the high pressure hydrogen tanks.

On the other hand, ammonia makes more sense:

- Ammonia, in comparison, stores and handles very much like LPG.
 - Its boiling point is $-33.35\text{ }^{\circ}\text{C}$ ($-28.03\text{ }^{\circ}\text{F}$). Propane, the main constituent of LPG, has a boiling point of $-42.07\text{ }^{\circ}\text{C}$ ($-43.73\text{ }^{\circ}\text{F}$).
- Extremely small rates of leakage are easily detectible by the human nose and the risk of explosion or fire is so low that MSDS labels show it as a non-flammable gas with an NFPA flammability rating of 1.
- Ammonia has no embrittlement issues and therefore no need for periodic replacement of metallic tubing, valves, and tanks.
- Any leakage dissipates into the atmosphere where it is eventually destroyed through photodissociation.

An excellent discussion of ammonia as an energy currency is The Dual-Fuel Strategy: An Energy Transition Plan (Dr William L. Ahlgren, Vol. 100, No. 11, November 2012 | Proceedings of the IEEE). In this document, Dr Ahlgren concludes:

Business as done now relies

predominantly on fossil energy sources with fossil fuels and electric power as vectors. This is unsustainable; fossil sources must be replaced by renewable and perhaps nuclear sources. We have three choices for our global energy future, differentiated by energy vectors, as follows:

- the hydrogen economy: electric power and hydrogen fuel as vectors;
- the electron economy: electric power the sole vector "no fuel";
- the dual-fuel strategy: electric power and two (or few) liquid renewable fuels as vectors.

The dual-fuel strategy is the best choice. In this plan electric power plays a central but not exclusive role. Fossil fuels are replaced with low-carbon (ultimately, zero-carbon) alternatives: ammonia (or nitrofuel) and methanol (or carbofuel). Because they are liquids, both of these renewable fuels are compatible with existing infrastructure. This enables the transition to be triggered using lowcost fossil sources (probably natural gas, perhaps coal) at the beginning; they are phased out later. The transition is gradual at first, but accelerates as market feedback kicks in. Innovation is encouraged by enabling competition between all energy sources. Entrepreneurs adopting the dualfuel strategy harness the same market feedback that creates economic inertia to overcome it and drive the transition to a new global

economy. They will supplant their fossil competitors by developing a more efficient energy market. This will enable them to offer a superior product: carbon-free energy with more stable supply and at lower cost. They will be able to do so because they are more agile. They can take advantage of low-cost fossil sources, including petroleum, when available; and they can equally well turn to alternative fossil and nonfossil sources of energy when petroleum is not available. The dual-fuel strategy provides a hedge, not only against the risk of unstable oil supply, but also against the risk of global warming. Because it uses the existing energy infrastructure, the transition to a post-petroleum system can be accomplished in a relatively short time, a few decades. The dual-fuel strategy enables an order of magnitude reduction in global carbon emissions early in the transition period, perhaps by 2030, and zero net carbon at its completion, perhaps by 2050. The dual-fuel strategy is a feasible plan to make the transition to a postpetroleum zero-carbon global energy system as rapidly as possible, perhaps by midcentury.

See also Dr Ahlgren's document Planning for Hundred-Fold Increase in Global Ammonia Production. For more online references to ammonia's use as an energy currency, let us suggest the following:

- Ammonia
for Renewable Energy Systems
- Alternative
Fuels: Taking A Second Look at Ammonia
- Banking
on Energy