Below is the introduction to a November 2012 report, "The Dual-Fuel Strategy: An Energy Transition Plan", published in the IEEE Journal which is attached.

The report concludes 80% of all renewable energy (and 100% of petroleum energy) can be converted into ammonia and carbon based commodities, thereby capturing the CO2 and substantially reducing Nitrogen based emissions. What is does not do is study the costs of capturing verses venting the CO2 or the cost benefit or additional uses for the carbon itself, which our research concludes is cheaper than venting or burning it in any event without the need for carbon taxes or credits, and that the CO2 could be added to soil as char or other high carbon based fertilizer, reducing or eliminating the emissions from using ammonia and the runoff or related pollution. Indeed, the research show that by using deep placement of this fertilizer and high carbon carbon content nutrients instead of using ammonia, the net benefits include substantial increases in yields with substantial decreases in input costs, and the virtual elimination of the pollution in both the manufacture and use of it.

I attached a summary of the economics of using the carbon vented in the manufacture of ammonia along with about 70% of it to make urea instead, and converting all the carbon into fertilizer and a higher net revenue that by simply venting it. In addition, we could simply convert the CO2 into char and add that to liquid urea for deep injection (more than a foot deep) because, surprisingly, the char is stable and does not migrate, except to feed the plant, thereby reducing or eliminating the need for liquid ammonia, which can then be diverted for use as a fuel or energy currency.

Since NH3 has about 70% of the fertilizer market, if we doubled existing manufacturing capacity but added the urea production stage to it and appropriate technology to existing plants, we could supply enough urea and char based fertilizer to replace all the present NH3 fertilizer demand and we would have a supply of NH3 left over about the size of the total present supply, which according to Professor Smil, would represent about 2.5% of the global hydrocarbon fuel (gasoline & diesel) supply. This could be done within ten years if there was a concerted effort.

In the United States, application of N fertilizer, together with legume cultivation, tillage, and other cropping practices, contributes approximately 70% of total national N2O emissions (USEPA, 2011). Annually, over one third of US agricultural land is used for corn production (NASS, 2011), and this portion receives more than 40% of the total N fertilizer consumed nationally (ERS, 2011). Thus, mitigation of N oxide emissions from corn production systems has the potential to significantly affect total national greenhouse gas (GHG) emissions and other measures of air quality. Anhydrous ammonia (AA) accounted for 35% of all N fertilizer consumed in 2008 in the United States, whereas urea accounted for 24% (ERS, 2011).

A recent survey of corn producers in Minnesota indicated that 46% of farmers used AA and another 45% used urea as their primary N fertilizer source in the 2009 growing season (unpublished data). Despite the importance of these two fertilizer chemical sources, there have been relatively few direct side-by-side comparisons of their relative effects on N oxide emissions.

Four studies in the United States (Breitenbeck and Bremner, 1986a; Thornton et al., 1996; Venterea et al., 2005, 2010) and one in Canada (Burton et al., 2008) have compared N2O emissions from AA and urea, and two of these studies also examined NO emissions (Thornton et al., 1996; Venterea et al., 2005). Although there have been a few studies examining effects of fertilizer placement depth on N2O emissions (e.g., Hosen et al., 2002; Drury et al., 2006; Liu et al., 2006), **only one study has examined depth effects with AA as the fertilizer source** (Breitenbeck and Bremner, 1986b). See "Broadcast Urea Reduces N2O but Increases NO Emissions Compared with Conventional and Shallow-Applied Anhydrous Ammonia in a Coarse-Textured Soil" and related documents: http://www.torna.do/s/Broadcast-urea-reduces-N2O-but-increases-NO-emissions-compared-with-conventional-and-shallow-applied-anhydrous-ammonia-in-a-coarse-textured-soil/

According to the conclusions of a report in the Australian Journal of Soil Research, 2007, 45, 629–634, "Agronomic values of greenwaste biochar as a soil amendment";

Application of greenwaste biochar alone to a hardsetting soil did not result in significant increases in radish dry matter yield, even at the highest rate of application (100 t/ha). However, significantly yield increases additional to that due to N fertiliser were observed when biochar was applied together with the fertiliser, therefore highlighting the role of biochar in improving N fertiliser use efficiency. *http://www.publish.csiro.au/paper/SR07109.htm*

See also: Annals of Environmental Science / 2009, Vol 3, 217-225, ISSN 1939-2621 217, BIOMASS DERIVED, CARBON SEQUESTERING, DESIGNED FERTILIZERS. This work explores the hypothesis that functionalized biomass-derived chars (charcoal) can act as fertilizer delivering,carbon-sequestering soil amendments.
http://iris.lib.neu.edu/cgi/viewcontent.cgi?article=1040&context=aes

A report from the Department of Crop and Soil Sciences, College of Agriculture and Life Sciences, Cornell University, entitled *"Terra Preta: Soil Improvement and Carbon Sequestration"* also concluded this option is viable and necessary.
www.css.cornell.edu/faculty/lehmann/research/terra%20preta/Flyer%20terra%20preta%20landuse%20strategy.pdf

According to the conclusions of another recent report, "*Energy Innovation From the Bottom Up*", A JOINT PROJECT OF CSPO AND CATF, Made Possible Through the Support of the National Commission on Energy Policy, a project of the Bipartisan Policy Center:

A decarbonized energy system is a public good akin to national defense, individual and community health and safety, and protection from natural disasters. In providing such public goods, the U.S. government has often acted to spur technological innovation. The Korean War cemented U.S. commitment to a high-technology military. Since the 1960s, recognition that only government could safeguard the environment has underlain policies for both protection and remediation. If government treats energy-climate innovations as a public good, then major new avenues of public policy and investment open up, for example through purchasing and procurement, not just research and development.

Energy-climate innovation policies must be tailored to particular technologies and suites of technologies. There are many proven policy tools available for stimulating innovation. Different technologies, at different stages of development, are likely to respond to different policy approaches. Yet government has relied heavily on R&D funding, while neglecting other policies that, as part of a portfolio, would foster innovation. For example, the Pentagon's insistence on competition and non-proprietary technologies had powerful long-term effects on information technology, as did its support for academic programs in fields such as software engineering and materials science.
http://archive.cspo.org/projects/eisbu/

However, if you read the IEEE report alone, someone with little or knowledge about ammonia energy will clearly understand what has motivated me, and other supporters of using NH3 as an energy currency for over fifty years. I will send a message with the other scientific data on using the CO2 and reducing the nitrogen (N) pollution and emissions as well, but the correctness of the approach we have been preaching for decades is now undeniable. The evidience is so compelling that one could probably now get courts to order governments to legislate industry to make changes, and injunctions to shut down present practices until changes can be made.

"*The Dual-Fuel Strategy: An Energy Transition Plan*"

The transition from fossil to renewable and nuclear energy sources is enabled by developing liquid renewable fuels. Electric power and electrochemical energy conversion have central roles.

Introduction:

Many of the ideas presented here have a long history.

As early as 1967 Leon Green, Jr., writing in Science magazine [1], formulated a concept for the large-scale use of ammonia as fuel. He observed: BThe long-term consequences of the greenhouse effect due to CO2 buildup in the atmosphere are of serious concern. . . . To remove the offending elements (carbon and sulfur) from the fuel prior to combustion is a much more efficient and less expensive procedure than trying to clean up the combustion products. . . . Outlined below is a concept for energy generation in which the fossil fuels are not burned directly but serve as raw materials for the synthesis of a clean fuel. . . This clean fuel is ammonia. . . . In commercial high-tonnage production of ammonia, natural gas is used as raw material for steam reforming to generate hydrogen for the synthesis reaction. In the course of this process sulfur is removed and recovered in elemental form, and CO2 is scrubbed from the stream and may be recovered for sale or use. Although current practice is to discharge this CO2 to the atmosphere, the point is that the CO2 is under control and can be condensed or caused to react so that the carbon is tied up in some useful form. . . .large amounts of CO2 are recovered per unit of ammonia produced, and the commercial value of this CO2 will have a major bearing on the economic attractiveness of the concept.

Green's concept, published nearly half a century ago, is stunning in its prescience. Why has it received so little attention? Over three decades ago the U.S. Department of Energy conducted a comprehensive study of liquefied gaseous fuels, including LNG, LPG, hydrogen, and ammonia. The latter alternatives were studied because of *the extreme explosion hazard associated with LNG and LPG. Bomelberg and McNaughton coauthored the report on ammonia [2], published in 1980. 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.

In 2012, the potential use of ammonia as fuel remains just too unknown. Why is this? Perhaps it is because the well-known hazards of ammonia cause its use as fuel to be dismissed out-of-hand. There is also a widely held (but erroneous) notion that nitrogen-based fuels must necessarily produce excessive NOx in their exhaust. These misconceptions must be dispelled; one objective of the present essay is to do so. At the same time, the validity of these concerns must be acknowledged. Ammonia is a hazardous substance, and NOx is found in the exhaust of ammonia combustion processes. We argue that ammonia can nevertheless be safely used as fuel if it is not required to serve all purposes. We outline a plan, the dual-fuel strategy that supplements ammonia with a complementary substance, methanol, well known as an alternative fuel.

Ammonia and methanol each has strength that compensates the other's weakness: ammonia is carbon-free, but has high relative toxicity;2 methanol has low relative toxicity, but contains carbon. Their use together yields a good (not perfect) solution for liquid renewable fuel, which we assert to be sine qua non for a post-petroleum global energy system.

Further, we note that ammonia and methanol are but one example of such a dual-fuel pair. Other, better pairs might be found, and must be sought. What we reject is hydrogen. Hydrogen is disqualified because it is a gas. In our view, the use of hydrogen as an energy vector has been thoroughly explored over a period of half a century, and has failed to come to fruition. It is now time to move on.

A purpose of this essay is to contribute to a discussion initiated in these Proceedings by Bossel [3] and continued by Abbott [4], [5]. Bossel points out the deficiencies of the hydrogen economy, and advocates an electron economy in which batteries play a central role and fuel is unnecessary. Abbott insists that fuel is essential and that the hydrogen economy is the only realistic alternative to business as done now. We agree with Bossel that hydrogen is deficient, and with Abbott that renewable fuel is indispensible. We suggest that liquid fuels, ammonia and methanol, answer many of the objections raised by Bossel, while acknowledging Abbott's observation that renewable fuel is an essential component of any future energy strategy.

This essay is an unapologetically rhetorical work. Our purpose is to convince as many readers as possible to adopt the dual-fuel strategy and to adjust their research priorities accordingly. What the reader will find is a mixture of scientific fact, reports on demonstrated technology, speculation about what might be possible, and future-scenario narratives. This mixture is appropriate to the grand scope of our topic. The astute reader will have no difficulty identifying the character of any given statement or passage, and treating it accordingly. Further, we approach the problem at hand how best to put the global energy system on a sustainable course as one that cannot be compartmentalized. Issues of energy, environment, and economics are inextricably intertwined yet are traditionally classified in distinct intellectual categories. These three categories cannot be separated; all must be addressed simultaneously. Commercial and financial issues in particular are touched on in this essay. It is essential to do so.

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