

As I understand it, if hydrogen is burned, the only “exhaust” is water. We currently send tons of carbon dioxide into the atmosphere; has anyone looked at how much water we’d be sending out, I presume as vapor, under the hydrogen economy and what effect all that water would have? I visualize something like Venus, where the planet’s surface ends up covered in a huge cloud—at least as bad as carbon dioxide—that traps in all the heat. Is that what would happen?

Phil Stripling
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Crabtree, Dresselhaus, and Buchanan reply: Peter Feibelman raises a good point in advocating NH_3 as a hydrogen storage medium. He points out many advantages, including its high storage capacity, the significant ammonia infrastructure already in place, and our extensive chemical knowledge and industrial experience with ammonia.

The problem of effective hydrogen storage is one of the most challenging in the hydrogen economy, and we should pursue all promising options. The use of ammonia in a hydrogen economy has been discussed since at least the 1970s; Ali T-Raissi summarizes its history and its possibilities.¹ The subject remains vibrant today; new mechanisms for the release of hydrogen from ammonia over catalysts at acceptable temperatures are continuing topics of research.² A major challenge is toxicity, as Feibelman points out, but all hydrogen storage proposals come with safety issues.

Ammonia can be used effectively in other hydrogen storage media as well,^{1,3} notably in combination with its borane analog, BH_3 . NH_3BH_3 releases more than 12% of its mass as H_2 in decomposing to NHBH at low temperature and ambient pressure. Its release rate and decomposition chemistry can be significantly improved by nanoscale structuring in porous hosts.³ This example shows how the richness of hydrogen chemistry and the influence of nanopatterning lead to new horizons in hydrogen storage.

Lewis Glenn correctly points out that the energy used to split water is only partially recovered on recombination of H_2 and O_2 to make water. No energy conversion process is 100% efficient; some energy will always be lost. The higher potential efficiency of fuel cells over internal combustion engines is an appealing advantage of hydrogen over gasoline. As a carrier

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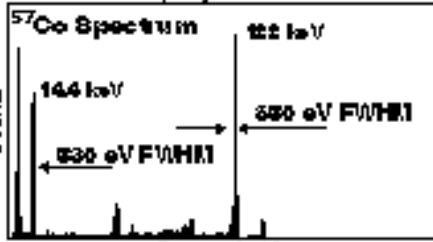
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of energy, hydrogen costs more to produce than gasoline, whose energy originates naturally in the crude oil from which it is refined. Although gasoline outperforms hydrogen in cost, hydrogen is the winner in the long-term sustainability of supply, security of access, and freedom from environmental pollution and climate change. These long-term quality-of-life issues are strong justification for strategic research now to enable the hydrogen economy in the future.

The switch from fossil fuel to hydrogen replaces emission of the greenhouse gas CO_2 with emission of H_2O , as Phil Stripling points out. Wouldn't there be a potentially serious environmental impact from that additional water? The hydrogen required to supply the world's energy for one year, 13 TW-yr, would make approximately 31 km^3 of water as “exhaust.” This is about twice the volume of Crater Lake in Oregon. The total water on Earth amounts to $1.4 \times 10^9 \text{ km}^3$, and that in the atmosphere to $12\,000 \text{ km}^3$. Thus even if all the exhaust water produced in one year from a hydrogen economy remained in the atmosphere, it would

increase atmospheric water vapor by less than 1%. The actual increase would be much less, since the residence time of water vapor in the atmosphere is about nine days.

References

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