Commodities

Hydrogen Vs. Natural Gas For Electric Power Generation

Dec. 02, 2020 4:40 AM ET | GE, DUK, UNG... | 358 Comments | 121 Likes

ISTJ Investor
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Summary

- Hydrogen has been proposed to provide grid scale energy storage, replacing natural gas to power a net-zero carbon electric grid.
- The increasing preference for net-zero carbon status among institutional investors, and the increasingly stringent regulatory constraints, motivate these efforts.
- The most likely production method to produce hydrogen is via electrolysis, powered in the U.S. by utility scale solar.
- A simple model estimates that replacing the current natural gas used for electric power generation in the U.S. would require 100 BCF/day of hydrogen, powered by 2370 GW of dedicated solar.
- We discuss some implications for investors.

Introduction

The role of hydrogen in eliminating CO_2 emissions, particularly from the electrical grid, has attracted increasing interest, with potentially significant implications for investors in the natural gas, utility, and industrial equipment spaces.

Institutional investors, e.g. the Climate Action 100+ investors group representing $47 trillion in assets, are increasingly including environmental factors in their investment criteria.

This idea is often expressed as part of a "net-zero carbon grid by 2050" goal for utilities, for example discussed for Duke Energy (DUK) here, where hydrogen is identified as a candidate fuel to generate up to 30% of Duke's power in 2050.

A more ambitious goal for a "net-zero carbon economy" envisions the elimination of fossil fuels not only for power generation, but also for industrial heating, commercial and residential space and water heating, and transportation. This scenario would add additional loads on the electrical grid; for example, residential winter heating requirements now met by natural gas.

In this article, we are going to focus primarily on the net-zero carbon grid issue; can and will hydrogen replace natural gas for the U.S. electric grid? We will also concentrate on the most likely scenario, the use of utility scale solar power to generate hydrogen by electrolysis.

We discuss technical feasibility, operational and economic practicality, and some implications for investors.

Investment Thesis

The investment thesis we will look at today is simple: green hydrogen generated from renewable energy can provide grid scale energy storage similar to that provided today by natural gas - the ability to store very large amounts of energy for days to months. This will overcome the intermittency limitation of wind and solar power and allow replacement of natural gas for power generation, yielding a net-zero carbon electrical grid.

There will likely be significant investment in hydrogen for applications other than grid power generation; the potential overall economic footprint is significant.

The Hydrogen Council estimated $2.5 trillion in worldwide annual sales by 2050, half from hydrogen, half from equipment. In October 2020, the Fuel Cell and Hydrogen Energy Association, focusing on transportation and industrial feedstocks rather than grid power generation, estimated $750 billion in annual U.S. revenue from the hydrogen economy by 2050.

As they say, big if true.

Hydrogen 101

To discuss the potential for hydrogen in power generation, there are a few things we need to keep in mind.

Hydrogen is described as grey, blue, or green depending on how it is made; gray from fossil fuel with CO_2 emission, blue from fossil fuel with CO_2 captured, and green from renewable energy with no CO_2 emissions. When people speak of the future hydrogen economy, or zero-carbon economy, green hydrogen is usually implied.

Hydrogen (H_2) is lighter than air gas. One thousand cubic feet (MCF) of hydrogen at standard conditions weighs 2.41 kg or 5.3 lbs; this is about 15% of the weight of natural gas (i.e. methane, CH4).

The energy content of gas is measured in BTUs per cubic foot. Hydrogen has about 30% of the energy content of methane. That means it takes about 3.3 CF of hydrogen to deliver the same energy as 1 CF of natural gas.

To produce hydrogen by electrolysis, 39.4 kWh of input power is required to produce one kg of hydrogen, if the electrolysis process is 100% efficient.

Hydrogen costs may be quoted in $/kg or $/MMBtu. A price of $1/kg is equivalent to about $8/MMBtu. Natural gas is normally priced in $/MMBtu (e.g. at the Henry Hub).

When hydrogen is burned to produce power, no CO_2 is produced.

It is possible to mix hydrogen and natural gas in the fuel stream, with a reduction in CO_2 output, but because of the difference in energy content, to achieve a 50% reduction in CO_2 requires about 75% H_2 by volume.

Hydrogen has handling and safety issues that methane does not. Hydrogen can cause embrittlement of metals, and deterioration of plastic and rubber seals.

Technical Feasibility

For the hydrogen thesis to succeed, hydrogen must be generated, transported, stored, distributed, and combusted. Can we practically and safely handle hydrogen? Is this all still just in the lab? Could we technically do this?

All of these steps are in routine operation on an industrial, if not yet grid, scale - with one exception. Hydrogen generation via electrolysis is routine, but still on a less-than-industrial scale (we'll come back to this point).

Industry has decades of experience in generating and handling hydrogen. Worldwide annual production of hydrogen is about 70 million metric tons (MMT); U.S. production is about 10 MMT. Almost all of this production is grey hydrogen.

The first underground salt dome hydrogen storage facility was opened in Texas in 2007, to supply refineries and chemical plants in Texas and Louisiana via a 310 mile pipeline. Two additional underground storage facilities are now in operation in the U.S., with 1600 miles of hydrogen pipelines.

Hydrogen has been added to the fuel mix for gas turbines for decades, accumulating millions of operating hours with up to 50% hydrogen. The primary turbine vendors - Mitsubishi Power (MHI), GE (GE), and Siemens (OTC:SEIGY) - all expect to provide turbines to burn 100% hydrogen.

The $H_2$1 Leeds City Gate Project is a planned large scale demonstration project to use blue hydrogen to replace natural gas for heating and cooking for 1% of the U.K. population by 2030. There are about 350 pages of detail at the link, down the level of replacing gas appliances.

There are multiple small scale demonstrations of generation and storage of hydrogen, with power generated from fuel cells. One interesting demonstration in the French Alps has been on line for 5 years, where solar power generated hydrogen is stored to provide up to 16 days of power.

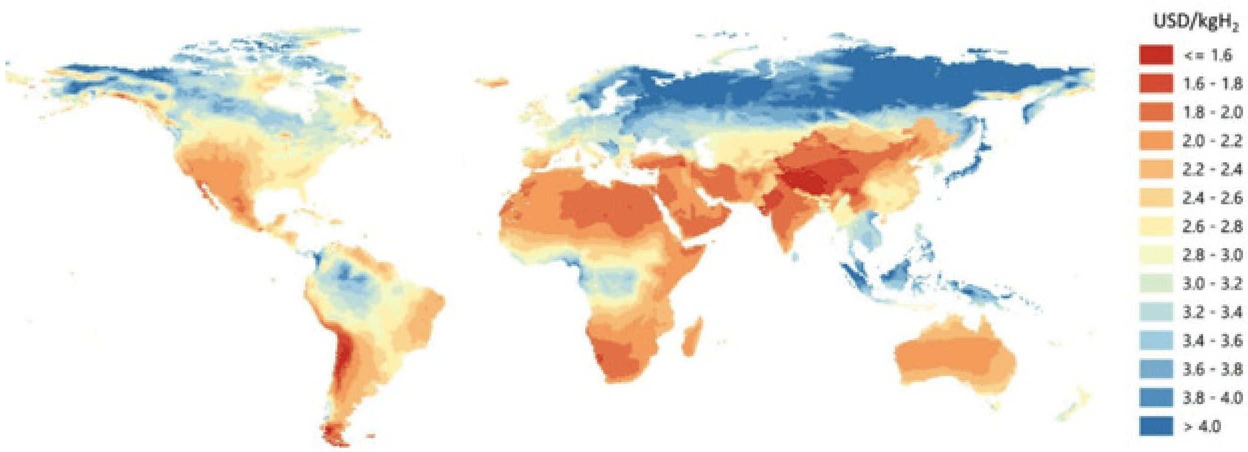
Overall, I'd assess it as technically feasible.

Economic Practicality

Estimates vary, but the cost today for hydrogen produced by electrolysis is in the range of $4-6/kg, which works out to about $32-48/MMBtu. Estimates from multiple sources (e.g. the DOE here) suggest that with industrial scale manufacturing of electrolysis equipment, a $1/kg cost may be achievable, i.e. $8/MMBtu.

There is an analogy between the cost of hydrogen at the point of production, and the cost of natural gas at the wellhead. In both cases, there is a transportation cost to get the gas to a storage and distribution point, and then on to the point of consumption. The International Energy Estimate below includes transportation.

Hydrogen costs from hybrid solar PV and onshore wind systems in the long term



Source: IEA - The Future of Hydrogen - 2019

Bloomberg NEF estimates that

> renewable hydrogen could be produced for $0.8 to $1.6/kg in most parts of the world before 2050. This is equivalent to gas priced at $6-12/MMBtu ... When including the cost of storage and pipeline infrastructure, the delivered cost of renewable hydrogen in China, India and Western Europe could fall to around $2/kg ($15/MMBtu) in 2030 and $1/kg ($7.4/MMBtu) in 2050.

Natural gas prices at the Henry Hub have run ~ $3/MMBtu in recent years. It's a business judgement, but I suspect a preference for green energy isn't enough to overcome a 10x cost premium for hydrogen, but it may well be enough to overcome a 2-3X cost premium. Add a carbon tax into the mix, and the natural gas cost advantage might be made to disappear by 2050.

With a willingness to pay that 2-3x preference premium, I'd assess economic feasibility by 2040 or 2050 as likely, with the caveat that achieving those prices would require grid relevant scale up and deployment. And that would probably depend on having two or three GW size power plants burning hydrogen by 2030. We will look out one potential example below.

Niche applications might be less price-sensitive. Utilities sign purchase power agreements (PPA) today for solar power knowing that the power can only be delivered during daytime hours. They might pay a premium price for a PPA that could reliably deliver power at night.

Operational Practicality

The question here is can we do this in the real world, at grid scale?

Let's look at hydrogen generation first. Steam methane reforming accounts for about 95% of hydrogen production today. This method generates 5.5 kg of CO_2 per kg of H_2, so is not attractive for zero-net carbon goals in the absence of cost effective carbon capture. And given cost effective carbon capture, it's easier to just generate grid power directly with natural gas.

Electrolysis

Electrolysis is expected to be the future hydrogen production method of choice. This is sometimes termed Power-to-Gas (P2G). In electrolysis an electric current applied to water breaks the water molecules apart and generates hydrogen and oxygen gases: H_2O + power -> H_2 + O_2.

Nine kg of water is required to produce one kg of hydrogen. If the electrolysis process is 100% efficient, 39.4 kWh of input power is required to produce one kg of hydrogen.

Table 2-A: Electrolyser efficiency and stack lifetime

	Alkaline (ALK)		Polymer Electrolyte Membrane (PEM)		Solid Oxide (SOEC)	
Year	Efficiency (LHV)	Stack lifetime (hours)	Efficiency (LHV)	Stack lifetime (hours)	Efficiency (LHV)[15]	Stack lifetime (hours)
2020	63%-70%	50,000-90,000	56%-63%	30,000-90,000	74%-81%	10,000-30,000[16]
2030	63%-72%	72,500-100,000	61%-69%	60,000-90,000	74%-84%	40,000-60,000
2050	70%-80%	100,000-150,000	67%-74%	100,000-150,000	77%-84%	75,000-100,000

Source: EU - Hydrogen Generation in Europe - July 2020

Current commercial electrolysis processes efficiency estimates fall in the 56-81% range, 2050 maximum estimates in the 74-84% range. Stack lifetimes of ~ 10+ years are projected.

Supporting the figures above, NREL estimates for a 2040 50,000 kg/day PEM electrolysis plant suggest 77% efficiency (and a levelized cost of about $4.50/kg).

For our back-of-the-envelope purposes, I'm going to assume at least one of these technologies will reach grid scale, and **I'm going to use 80% efficiency** in the calculations below. At 80% efficiency, **49.3 kWh** of input power is required to produce one kg of hydrogen.

This power requirement figure may be overly generous, in the sense that it doesn't include any energy consumed outside the electrolysis cell.

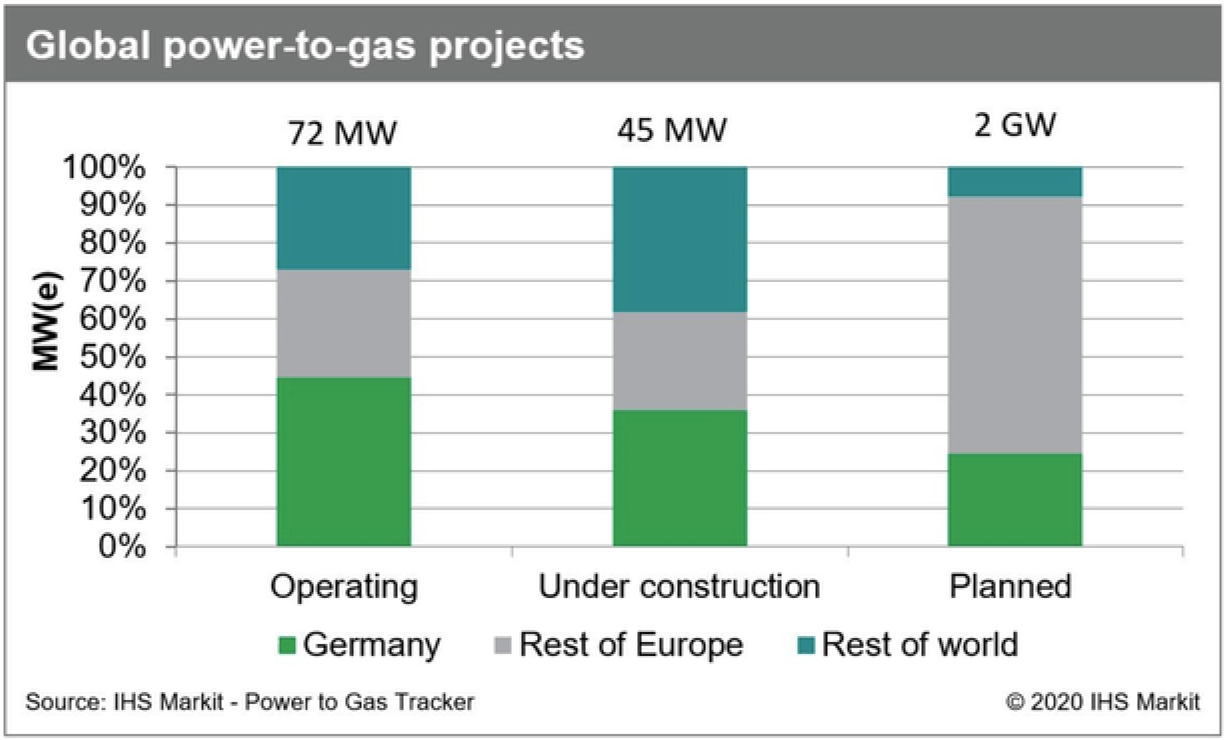
Electrolysis equipment is currently provided by several relatively small companies, for example: Nel ASA (OTCPK:NLLSF), ITM Power (OTCPK:ITMPF), Enapter (private), Sunfire (private). ITM Power is building a 1 GW annual PEM capacity plant in the U.K. A product spec for an ITM Power 10 MW unit producing 4,000 kg/day of hydrogen is available here.

Nel's PEM annual capacity is 40 MW, and ALK capacity is being expanded to 500 MW.

Source: Nel Q3 2020 Investor Presentation

As we will see, these companies would have to grow by orders of magnitude to meet grid demands.

Germany has about 45% of worldwide installed power to gas electrolysis capacity with 34 projects. Note the tiny capacity in grid terms.



Source: IHS Markit

Hydrogen For One Generator

Let's look at hydrogen for one gas turbine.

Consider the widely deployed GE 9F.04 gas turbine, which produces 288 MW of power. With 100% hydrogen fuel, GE (GE) states that this turbine would use about 9.3 million CF or 22,400 kg of hydrogen per hour. With an 80% efficient electrolysis energy cost of 49.3 kWh/kg, producing that one hour supply of hydrogen would require 1,104 MWh of power for electrolysis.

To generate the hydrogen to run the turbine for 12 hours (~ dusk to dawn) would require 12 x 1,104 MWh, or 13.2 GWh. Given a typical 20% solar capacity factor, that would require about 2.6 GW of solar nameplate capacity dedicated to generating the hydrogen to fuel this 288 MW generator overnight.

As a real world example, to replace the 2240 MW per hour dawn to dusk output of California's Diablo Canyon nuclear power plant (scheduled for 2025 retirement), it would take 8 of these turbines with hydrogen generation powered by 20 GWs of solar panels.

How Much Natural Gas Does the Grid Use?

How much hydrogen would it take to fully displace natural gas in electrical power generation in 2050?

According to the Energy Information Agency, the U.S. consumed 31 Trillion CF of natural gas in 2019, or 85 BCF per day. About 36% was used for electrical power generation, i.e. 30 BCF per day.

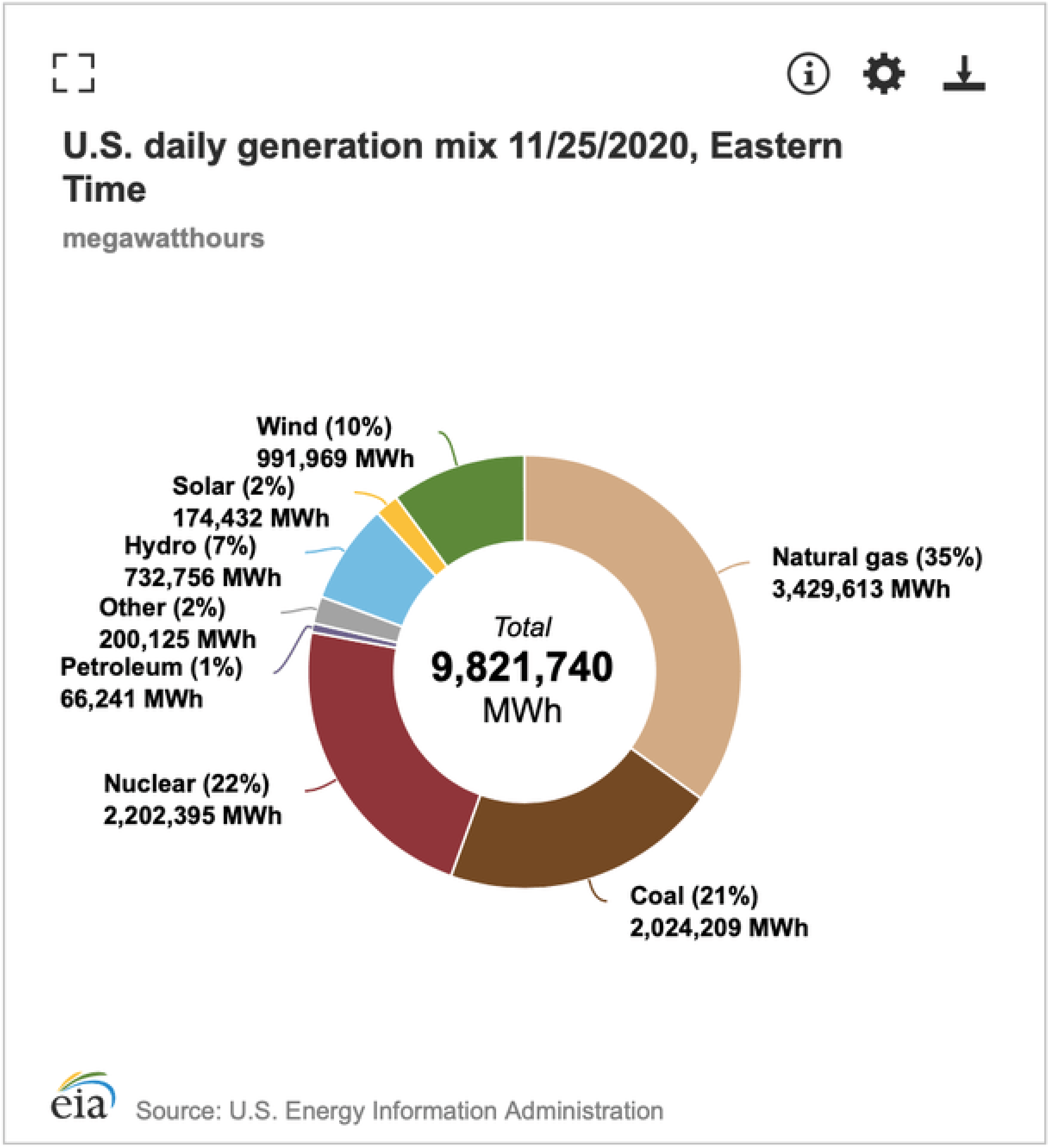
Natural gas use by U.S. consuming sectors by amount and share of total U.S. natural gas consumption in 2019

36%	33%	16%	11%	3%
11.31 Tcf	*10.24 Tcf*	*5.00 Tcf*	*3.52 Tcf*	*0.94 Tcf*
electric power	industrial	residential	commercial	transportation

Source: EIA

Natural gas currently generates 35% of U.S. electrical power. Here's an actual generation snapshot for 25 November 2020.

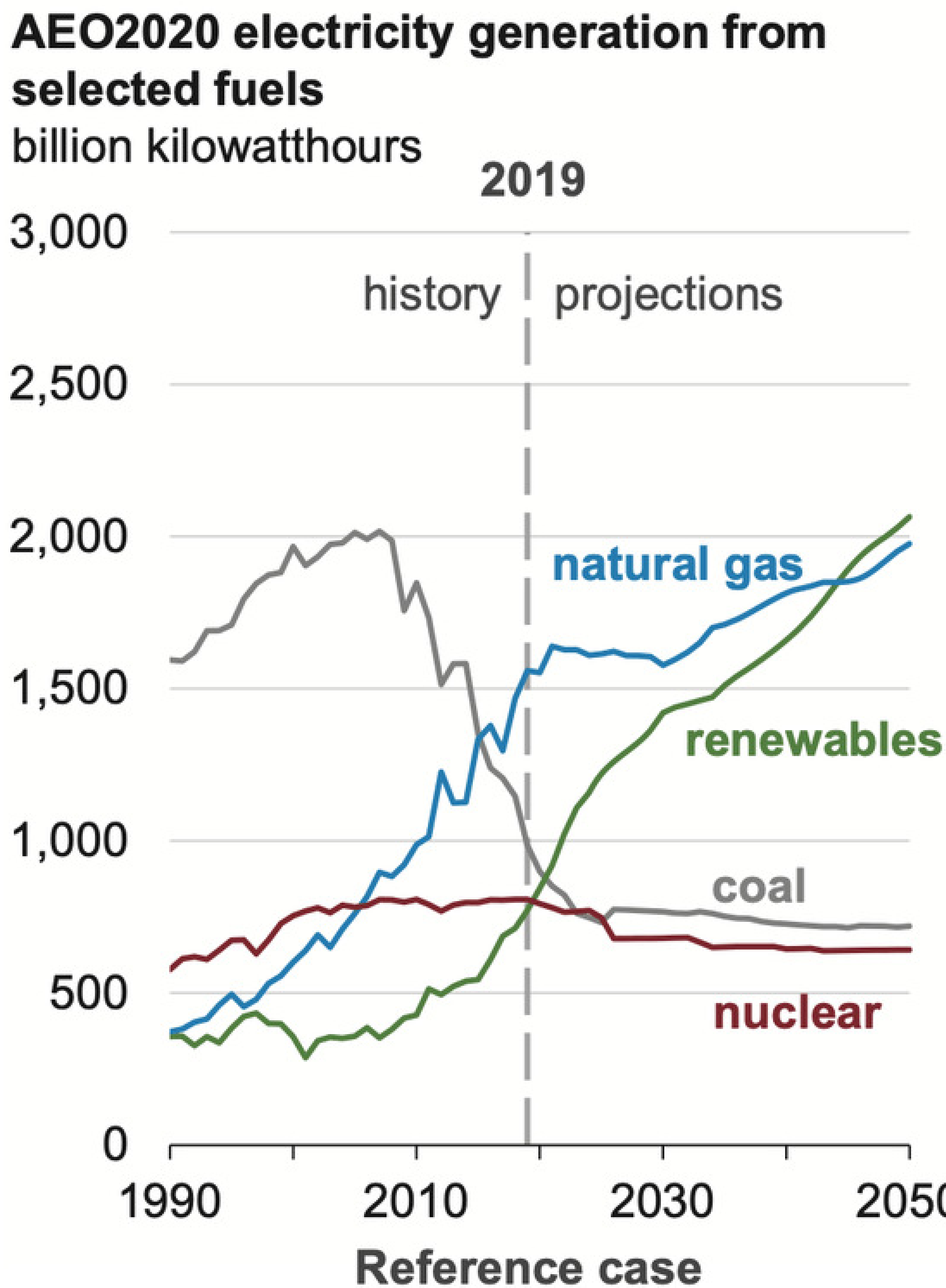
U.S. Daily Generation Mix (U.S. Lower 48)



Source: EIA Hourly Electric Grid Monitor

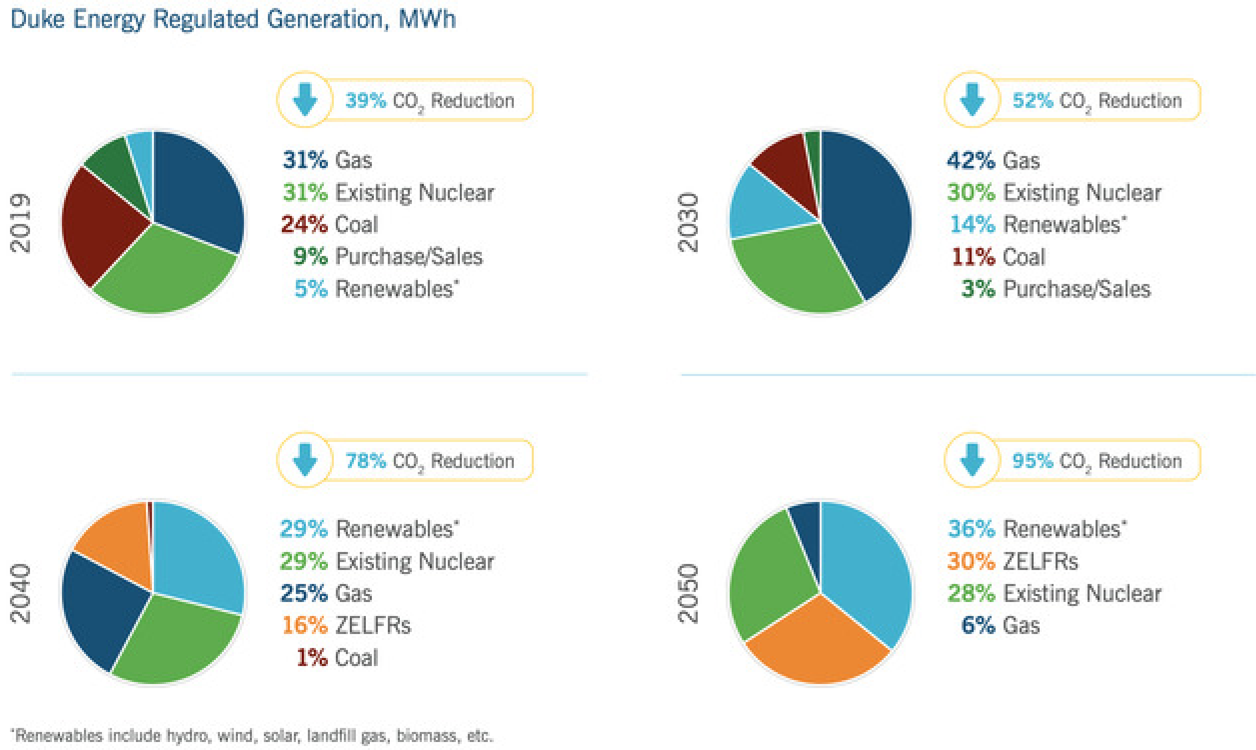
Natural gas consumption will probably change between today and 2050. It will increase as it continues to replace coal, decrease as more solar and wind come online, potentially increase as transportation and other areas are electrified.

The EIA 2020 Annual Energy Outlook reference case predicts that natural gas will generate about 30% more electricity in 2050 than today. Under the most natural gas adverse EIA scenario, it would decline by about 30%.



Source: EIA 2020 Annual Energy Outlook

A bottom-up analysis by Duke Energy shows similar trends with today's 31% changing to 6% gas and 30% ZELFR by 2050 (ZELFR is new technology - hydrogen, natural gas with carbon capture, or new nuclear); see this SA article for a more detailed discussion of Duke Energy's plans.



Source: Duke Energy

Hydrogen to Replace Natural Gas for the Grid

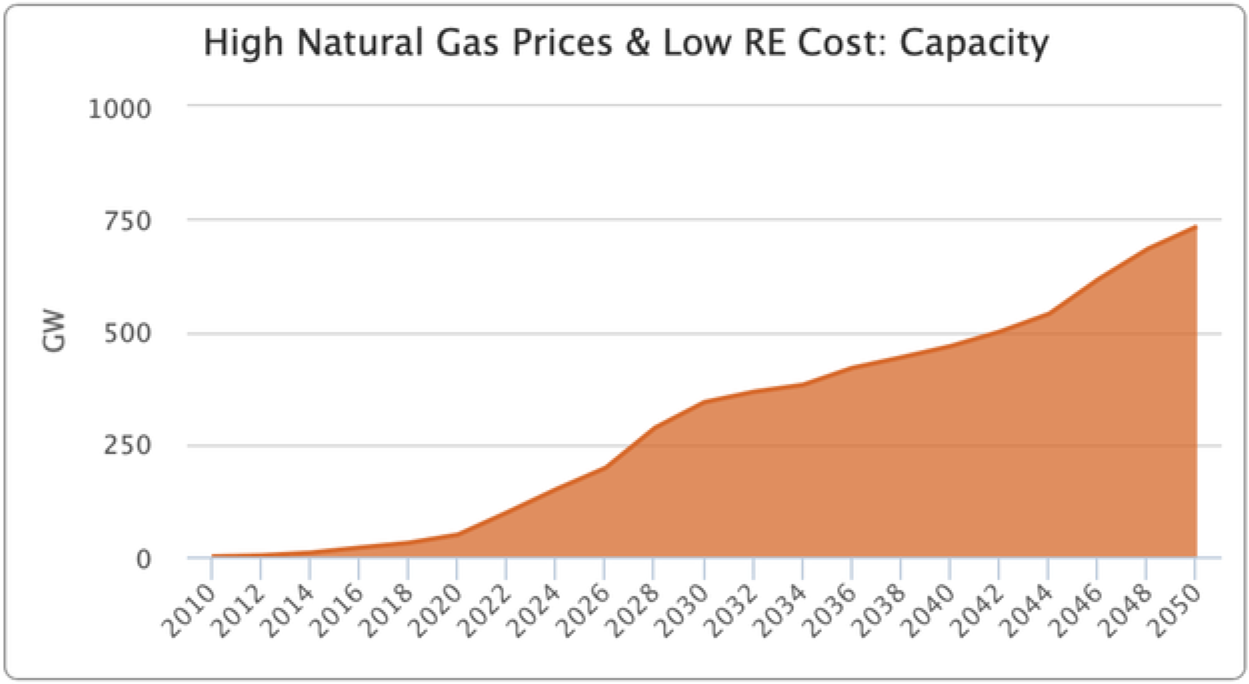
For our back-of-the-envelope hydrogen estimate, we will take the 30 BCF/day gas currently used for electric power and **assume no growth** for 2050. This gives 30 BCF/day of natural gas energy to be replaced. Recalling that the energy content of hydrogen is about 30% that of natural gas means that we need 3.3 CF of hydrogen to replace 1 CF of natural gas.

Doing the math and rounding, we need to 100 BCF/day or 240 million kg/day or 260 thousand tons/day of hydrogen.

With 80% efficient electrolysis, we need 49.3 kWh to produce 1 kg of hydrogen. That would be 11,800 GWh / day. Assuming a 20% capacity factor for solar, that would require 2,370 GW of solar capacity devoted to hydrogen production.

If you assume the IEA Reference case of 30% growth, it would be about 3,100 GW of solar.

The National Renewable Energy Agency provides an interactive model that estimates capacity and generation out to 2050 for a number of scenarios. The figure below shows 733 GW of U.S. utility scale solar capacity in 2050, for high natural gas and low renewable energy costs. Bloomberg NEF makes a similar estimate for U.S. 2050 solar capacity. The Baseline Technology estimate, not shown here, is 525 GW of solar.



Source: NREL Scenario Results Viewer

The 2,370 GW of additional dedicated solar is 3.2 times the currently projected 2050 solar capacity, 4.5 times the NREL baseline projection. It's a very large amount of utility scale solar.

I would assess the required build out of the electrolysis and solar capacity to fully replace natural gas for electric power generation as unlikely. And even if this was achieved, it would still leave untouched the other 64% of natural gas that currently goes to other uses.

Analysis

I'd like to make four points here.

First, displacement of natural gas for grid power is not currently the primary target of hydrogen efforts. IHS Markit recently noted:

> in the US and in Asia, the primary focus is simply transport. In mainland China, Japan and South Korea, a combination of local and central government works with industry to drive development of fuel cell vehicles and the associated infrastructure.
>
> In Europe, there is interest in transport, but there are many other projects underway to look at the use of hydrogen ... in buildings, industry and power.

For example, the U.S. Department of Energy's 2020 Hydrogen Program Plan envisions increased hydrogen use primarily in transportation.

Table 2. Current consumption and future economic consumption potential of hydrogen in the United States (MMT/year)[25]

		Today	R&D Success Scenario
Demand Applications	Oil refining	6	7
	Metals refining	*negligible*	4
	Ammonia production	3	4
	Biofuels/synfuels production	1	9
	Transportation FCEVs (LDVs, MDVs, HDVs)[25]	*negligible*	17
Total hydrogen market		**10**	**41**

Source: U.S. Department Of Energy 2020 Hydrogen Program Plan

The Leeds City Gate Project illustrates a path to move the point of carbon displacement or capture from the residential water heater to the centralized gas plant, while preserving the gas network's current seasonal storage capability. There are also advantages to a mixed gas and electric infrastructure; it's an advantage to be able to heat your house and your food even if power is down.

Second, a very large amount of input energy is required to generate the amount of green hydrogen required to displace current natural gas used for electrical generation. We estimated above ~ 2,370 GW of dedicated U.S. solar capacity.

Considered against the projected 525-733 GW of U.S. utility scale solar, the use of "excess" solar capacity to produce hydrogen for the grid is only going to be a minor factor at best.

Third, hydrogen in grid relevant amounts requires a huge amount of electrolysis capacity. Our back-of-the-envelope case for the U.S. would require about 500 GW of electrolysis running 24/365, or about 1200 GW running on a 10 hour solar day. It would require many years to build that capacity at current manufacturing rates. And the U.S. is not the only market.

Fourth, there is a considerable decarbonization effort going on at the national and international level. This is likely to show up as both technical advances, standards setting, and regulation. The discussions at the October 2020 International Renewable Energy Agency conference give a good indication of the scope of this effort.

Things to Keep an Eye On

Thirty years is a long time. It would be prudent to revisit this analysis in five years or so. If hydrogen is going to be really significant by 2050, it should be much more evident by then. What kind of things might one look for?

Germany. Germany reportedly has the largest number of power to gas projects today. With significant intra-German power transmission issues as renewables reach high levels of market penetration, hydrogen could serve as a buffer. This could provide a national scale pilot project.

The Mitsubishi Power Advanced Clean Energy Storage Project in Utah. This is the only project I know of trying to pilot grid scale hydrogen in the U.S. If this is commercially operating, it should provide a great deal of hard data on real-world operational and cost performance.

Electrolysis scale up. It would be significant if a Global 500 firm (e.g. Siemens) is cranking out 100 GW a year of electrolysis capacity in an automated plant.

Commercialization of modular nuclear reactors. A viable near-term path to significant new nuclear power, perhaps factory built modular reactors, would reduce the push for hydrogen for the grid.

Commercial carbon capture. Commercially (effective, cheap) carbon capture would remove much of the motivation to displace natural gas.

Regulatory mandate. A de facto or de jure regulatory mandate (no natural gas used to generate electricity after 2045, for example, is already the current Renewable Portfolio Standard law in California).

Investor Takeaway

I think green hydrogen is technically feasible, and that costs will come down enough by 2040 or 2050, that a willingness to pay a 2-3x green premium will bridge any cost gap with natural gas. However, the scaling up required build and power the required electrolysis capacity makes it unlikely that hydrogen will displace a significant amount of the natural gas used to generate electricity by 2050. In any case, deployment before 2030 is likely to be very limited.

I consider myself a long term investor - ideally forever, but I seldom buy anything I don't plan to hold for 10 years. After spending time over the past couple of weeks looking into hydrogen and thinking about it, I'm personally comfortable maintaining my modest investments in natural gas - E&P, midstream, and gas utilities.

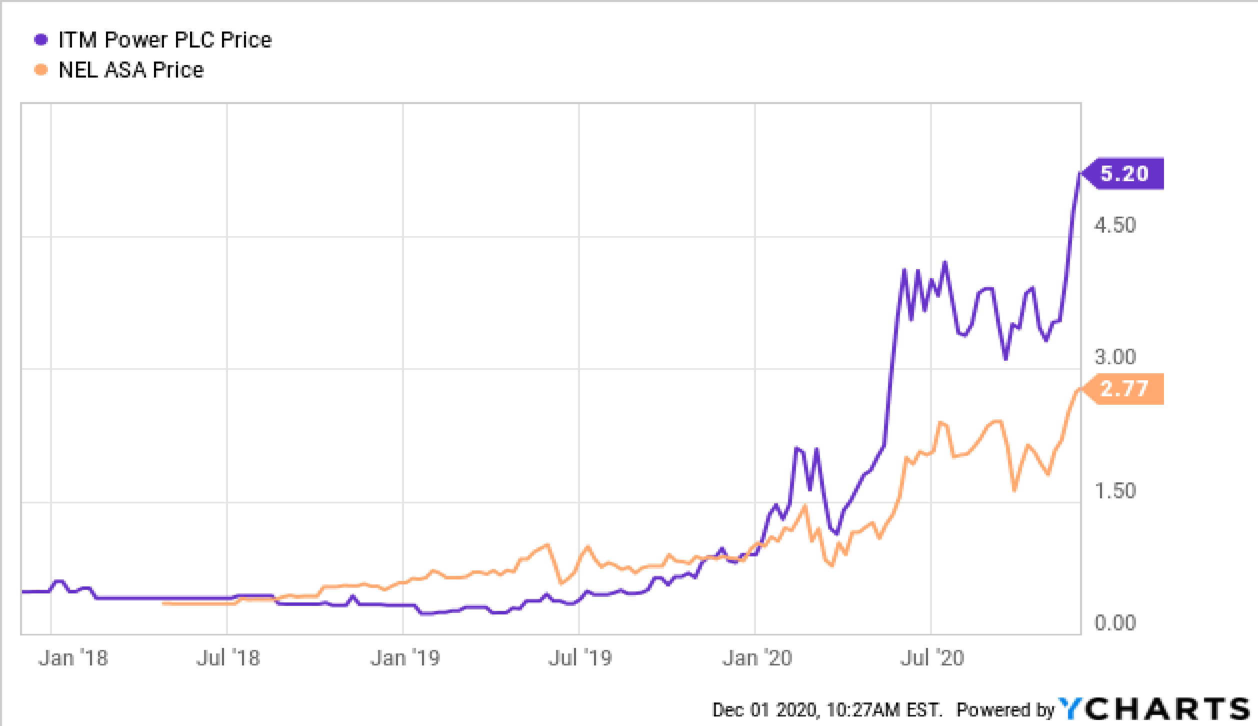
I might be wrong, and 30 years is a long time. It would be prudent to check back in 5 years. In the meantime, investments.

A large amount of energy would be required to generate the green hydrogen to replace natural gas. In the U.S. I think this would be largely solar in the U.S. (in most of Europe it might be largely wind). In our simple model above, we estimate it would require 3-4X above an already aggressive amount of utility scale solar. Solar investments that do well without hydrogen should do even better with it.

The actual turbine market is split among three very large players: Mitsubishi Power, Siemens, and GE. Whether their turbines continue to burn natural gas or transition to hydrogen over a couple of decades seems unlikely to move the needle.

The highest alpha opportunity I see here is the electrolysis companies, like Nel ASA or ITM Power, although I would consider these very speculative. The potential market for hydrogen even outside the grid is large enough that someone should do well here. It appears from the chart below that other people think so as well.

I would consider all the electrolysis companies candidates for acquisition by large industrial firms - Mitsubishi, Siemens, etc.



Data by YCharts

This article was written by

ISTJ Investor

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Myers-Briggs ISTJ. Detail oriented, data driven, planner, long time horizon. Individual investor for 20 plus years. Did the CFP exam for grins years ago, but never certified. Interest in energy, tech.

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Disclosure: I/we have no positions in any stocks mentioned, and no plans to initiate any positions within the next 72 hours. I wrote this article myself, and it expresses my own opinions. I am not receiving compensation for it (other than from Seeking Alpha). I have no business relationship with any company whose stock is mentioned in this article.

121 Likes

358 Comments

Comments (358)

Sort by Newest

pete.m

07 Jan. 2021, 6:31 PM

Comments (8) | + Follow

People, I tried to make all of you aware of the HUGE security risk of having big hydrogen tanks in your backyard. By shooting a comparable low powerenuclear warhead at such a tank it would turn it into a HYDROGEN BOMB OF IMMENSE DESTRUCTIVE POWER (a hydrogen bomb needs a big tank of hydrogen that can not be "delivered" the way a nuclear war head can)

Just compare the 50oooooot bomb the USSR played with to the a few 10000t needed to detonate it.

Reply Like

Cogitatio Rationalis

07 Jan. 2021, 7:05 PM

Comments (2.57K) | + Follow

@pete.m

Wow 😱 🤣 Will it also shift Earth of its axis?

Reply Like (1)

Robert van der Westhuizen

08 Jan. 2021, 10:02 AM

Comments (12) | + Follow

*@pete.m*I think you are wrong. It is 40 years since my last physics class but I believe it is only when you have a specific isotope of hydrogen.

Reply Like

BenSlone 08 Jan. 2021, 2:43 PM

Comments (102) | + Follow

@Robert van der Westhuizen Yes, the second and third isotopes of hydrogen commonly called deuterium and tritium. Most known hydrogen has only one proton in the nucleus whereas the two isotopes have one and two neutrons respectively in addition to a proton in the nucleus. Tritium is radioactive and has to be "produced." A D+T fusion reaction also requires other attributes to initiate.

Reply Like (1)

See More Replies

viperultimaevolution 26 Dec. 2020, 8:54 AM

Comments (106) | + Follow

HYSR Sun Hydrogen has solar to hydrogen panels being tested now. News is slow with them, but stock is moving up lately, Go HYSR

Reply Like (3)

13427872 17 Dec. 2020, 4:24 PM

Comments (757) | + Follow

Hello, Hydrogen: A U.S. Power Plant Aims To Curb Carbon Emissions By Tapping Nature's Most Abundant Element
December 16, 2020
A lower-carbon revolution is brewing on the banks of the Ohio River.
Next fall, in Hannibal, Ohio, a massive new gas turbine built by GE and running on a blend of natural gas and hydrogen will power a 485-megawatt power plant with enough capacity to light up the equivalent of 400,000 U.S. homes.
Operated by Long Ridge Energy Terminal, a unit of private-equity companies Fortress Investment Group and GCM Grosvenor, the new plant is on track to be the first in the U.S. to use a large-scale gas turbine fired by a blend of hydrogen and gas, another milestone in the power industry's journey to shrink its carbon footprint. “A lot of combined-cycle gas plants will transition to hydrogen in the future,” predicts Long Ridge Energy President Robert Wholey.

www.us19.list-manage.com/...

Reply Like (4)

A

AT_Energy

14 Dec. 2020, 1:08 PM

Comments (8) | + Follow

Wow - really thoughtful and supported summary of where we are today with hydrogen and the recommendation to check back in five years to understand how markets and technologies continue to evolve - Thank you

I also like that you looked at the practicality of using solar power to produce hydrogen. Solar power production using tomorrow's technology will not meet the world's energy demands economically as you mathematically demonstrated- it is helpful but not practical in the near future. Wind power has made great advances and will decrease the trillions of dollars needed for batteries and future solar panel installations but also not practical 24/7. That said I am supportive of hydrogen generation based on excess solar, wind, hydro, and nuclear power for those locations and times of day/night when excess power exists in a few markets.

So hydrogen has a niche that will grow for long term low carbon energy storage - think below freezing for more than 30 days in Wisconsin and every other similarly situated northern community with limited sunlight for days and freezing winds that could shutdown wind turbines.

What do you think about methanation? Extract carbon and combine it with hydrogen so we can use our existing energy infrastructure: pipelines and distribution systems while approaching carbon neutrality.

For those of us investing might we think about the energy system today and tomorrow and allocate a small portion of our funds to the long shots technologies but also the energy technologies today. What are the key components. Near term companies such as: Clean water Suez/Veolia/Solenis/Kurita , Clean dry natural gas SWN/EOG, metallurgy JM for the electrolyzers, H2 storage vessels, overlooked salt cavern operators for H2 storage.

Long term: lower cost, safe reliable nuclear power from SMRs which still need energy storage for those peak periods when demand is high and sunshine and wind are not available.

Great article, several insightful comments, Good investing my thoughtful friends!

Reply   Like (6)

gyurka 16 Nov. 2021, 1:45 PM

Comments (1) | + Follow

@AT_Energy "That said I am supportive of hydrogen generation based on excess solar, wind, hydro, and nuclear power for those locations and times of day/night when excess power exists in a few markets." While geothermal energy can be also considered, I would not eliminate the use of any power generated off-peak by fossil fuel plants until they are decommissioned. It may help to build up faster the Hydrogen infrastructure while helping the profitability of the fossile plants meant to be shut down.

Reply Like

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pete.m 12 Dec. 2020, 5:33 PM

Comments (8) | + Follow

You really would not want a hydrogen bomb in your backyard. And I mean a REAL hydrogen bomb only waiting to get ignited by a nuclear device!!!

Reply Like

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gutcheck 12 Dec. 2020, 8:08 AM

Comments (5.35K) | + Follow

The highest alpha opportunity I see here is the electrolysis companies, like Nel ASA or ITM Power, although I would consider these very speculative

wait for bubble to pop

Reply Like (2)

ISTJ Investor 12 Dec. 2020, 8:21 AM

Comments (970) | + Follow

Author's Reply *@gutcheck*

That's my view as well. They are on my watch list.

Reply Like

T38Talon

08 Dec. 2020, 3:10 PM

Comments (1) | + Follow

New to this and so refreshing to see an intelligent discussion. At the risk of dumbing it down:

Any thoughts on ocean geothermal hydrogen/electrical generation? I had an interesting talk with the founder of oceangeothermal.org. The thrust is exploiting supercritical conditions coincident with undersea vents making electrolysis efficient. Remotely operated plants use the natural thermal energy to run turbines. Power is fed to the grid nightly/as needed, excess power is used for onsite electrolysis during the day. The hydrogen would already be partially pressurized and pumped to ??? (Ships, platforms, piped onshore?) Desalination for feed stock shouldn't be an issue.

There are many obvious attractions to this concept. What other deal killers are there besides:

Electrical transmission losses

Freeing a gas such that it can leave our planet forever

Huge capital expenses/technical issues

Obvious safety issues

Thanks

Reply Like (2)

S

swarfer

05 Dec. 2020, 11:48 AM

Comments (538) | + Follow

Hydrogen will never be a viable alternate fuel in mass quantities as it essentially requires a whole new infrastructure. Cheap low or zero CO2 electrically generated power is required to produce H2 and if you have that you've already solved the problem. Backup power for 100% capacity can be from thermally efficient natural gas combined cycle plants.

There is no need to completely eliminate natural gas, just substantial reduce the use. This is where all the schemes break down including H2. We can live with 80% carbon neutral and possible much less. Unfortunately when domestic eco-politicians combine with global eco-politicians from countries that have little or no fossil fuel resources, mantra become accepted science.

US taxpayers will end up paying the price to fund inefficient non-competitive energy schemes. In the end all that fossil energy will go unused in the name of zero carbon while the natural world continues to produce coal and natural gas deep within its bowels as it has for billions of years.

Reply   Like (3)

S

SORNG

18 Dec. 2020, 9:03 AM

Comments (58) | + Follow

There is a better answer for hydrogen than water electrolysis. "Green Hydrogen" can be made from Renewable Natural Gas. Renewable Natural Gas is the identical methane molecule as fossil natural gas but rather than coming from the ground, it comes from capturing biogas released from organic waste (animal waste, landfill gas, municipal waste, food waste, any organic waste). The "waste" is placed in a biodigester and the biogas is recovered and converted to RNG. There is an ENDLESS and PERPETUAL "feed stock" of organic waste from which to produce RNG which is then injected into the existing natural gas line. Google Maas Energy to see how it is done in dairy farms in California. All they need is cow manure which cows produce in abundance, every day!! The RNG can be transported in existing natural gas lines and, in fact, can be mixed in any proportion with fossil natural gas to allow a "seamless transformation" from fossil natural gas to any percentage of RNG. The RNG can be piped to a HyGear unit which is "on site" at a filling station or industrial plant that uses hydrogen. The RNG is converted to "Green Hydrogen," (just as "Green" as with hydrolysis but much cheaper to produce. Natural gas is the main source of "Blue Hydrogen" production--using "Renewable" RNG instead of fossil natural gas makes it "Green Hydrogen." You then pipe the hydrogen in specialty pipes "across the street" to the transportation filling station or the industrial plant that uses hydrogen. No mass storage of hydrogen (remember the Hindenburg?), no need to transport hydrogen over hundreds of miles (not an easy or particularly safe thing to do). Renewable Natural Gas is the only carbon negative, near zero emission fuel. In addition to transportation, it can also be used in ANY way that we now use fossil natural gas. Heating, cooking, fuel for electric power plants, any industrial use for natural gas. RNG is completely renewable, it requires no drilling or fracking, and there is minimal loss of methane to the atmosphere compared to "well head" loss of methane with fossil natural gas. Oh--and if we don't capture the biogas from organic waste, it gets released into the atmosphere as one of the most damaging Greenhouse Gases. RNG sounds like a win/win/win/win/win..........

Reply   Like (3)

ISTJ Investor 18 Dec. 2020, 9:45 AM

Comments (970) | + Follow

Author's Reply *@SORNG* Thanks for reading and commenting.

The problem with RNG is available volume and cost. Right now RNG production is a fraction of 1% of gas demand. It might grow to supply single digits of demand, depending on how aggressively it was pursued. Cost is projected to be $7-30 / MMBTU, so say 2-10 times current geological natural gas. Still, one has to do something with the bio methane - vent it, flare it, burn it on site for heat or power, or convert it to RNG.

For the largest wastewater and animal waste processing sites, it's worth looking into.

See my October 2020 article on RNG here seekingalpha.com/...

Reply Like (5)

CuPoTKa 20 Dec. 2020, 12:48 AM

Comments (768) | + Follow

@SORNG OMG

If it would be economically viable to produce any reasonable amount of NG from biomass - everyone will be doing it right now and burning it.

But no, Germany insists to have a NG pipe from Russia - because there's no other source of NG, but from underground.

Second it doesn't matter from where NG is produced - in both cases burning it or converting to H_2 emits same amount of CO_2 (that wasn't there before).

Reply Like (2)

See More Replies

jackshelt 05 Dec. 2020, 11:40 AM

Comments (9) | + Follow

Outstanding overview of the state of hydrogen research, relative costs for production, pilot projects and risk analysis etc.

Reply Like (1)

ISTJ Investor 05 Dec. 2020, 11:55 AM

Comments (970) | + Follow

Author's Reply *@jackshelt*

Thanks for the positive comment.

Reply Like

Jalb 05 Dec. 2020, 10:56 AM

Comments (401) | + Follow

Very encouraging.

But the economics are significantly (probably massively) improved if you view Hydrogen as a means to store energy produced by windmills/windfarms when the wind is blowing and solar power as a means to provide for energy peaks during daytime (my pet idea is legislating to have all office airconditioning systems in newbuilsd offices powered by solar panels on the walls/roof).

It may not be quite as bad your side of the big pond but in the UK we have a variability in wind-power supplied to the grid of >140:1 so we need back-up for 99.7% of wind-capacity [99.7% rather than 99.3% because the wind-power supply is negatively correlated with demand].

If you have carbon-neutral and extremely safe nuclear power for much of your base-load and a combination of solar, wind, hydro and pumped hydro then the use of surplus power to electrolyse water into H2 for fuel cells for cars can cope with excess power production during sunny windy days.

Burning H2 to produce heat is ridiculous, IMHO; transportation is around one-third of energy use in "advanced" economies.

Reply Like (5)

ISTJ Investor 05 Dec. 2020, 12:04 PM

Comments (970) | + Follow

Author's Reply *@Jalb*

I think the high variability of wind you point out is not widely understood. It means we need enough non-solar non-wind backup capacity to cover essentially 100% of dusk-to-dawn load. Even if we only have no wind nights a few times a year.

Reply Like (3)

Balaland

04 Dec. 2020, 6:37 PM

Comments (4.46K) | + Follow

@ISTJ Investor ,

The water required would have to be Mineral Free (Clean) ..

Your California example should also add desalination , as California already has water issues ..

Reference Tampa Florida's Plant for producing drinkable water , the Filter's are a Huge cost ..

Thanks for the read , Great work ..

Reply Like (5)

ISTJ Investor

05 Dec. 2020, 8:23 AM

Comments (970) | + Follow

Author's Reply *@Balaland*

Thanks for the comment. ITM Power's specs say "drinking water" quality input water for their unit, but don't say how they handle the minerals. The article was already getting too long, but that might be something to look into in more detail.

Reply Like (3)

B

Balaland

05 Dec. 2020, 10:06 AM

Comments (4.46K) | + Follow

@ISTJ Investor ,

I wrote a Paper in College on Hydro-electric Cars back in 1979 , and used Popular mechanics Fall issues as one of my sources , as G.M. already had Vehicles , and semi's testing on the road back then ..

The fuel was deemed Too explosive and G.M. shelved it ..

Tech is prob. caught up , but the electrolysis process using Mineral-Free water prob. hasn't changed , because (I Believe) , it would further hold down costs to produce the compressed gas ..

The exhaust pipes had to be stainless-steel , as when burned , it gave off water and O2 emissions ...

Oh , what about wave energy , instead of solar ? .. Hmmm

Reply Like (3)

Wembley Fraggle

04 Dec. 2020, 3:44 PM

Comments (209) | + Follow

When "burned" the H2 gas produces water - pure water. Therefore it makes sense to integrate the new hydrogen electrolsys and power production into existing water treatment facilities. Every town in the world has one.

The water treatment facilities can produce H2 in other ways, as part of waste treatment, H2-producing bacteria, and so on. Many treatment plants have wind and solar on site, or have space to add solar.

Finally, when "burned" the H2 combustion produces pure water, relieving part of the water treatment plant's burden to produce clean water.

Reply Like

M

martyr1777

08 Dec. 2020, 4:12 PM

Comments (8.7K) | + Follow

Nice idea but the water still has to be treated for the H2 process.

Reply Like

SORNG 04 Dec. 2020, 9:58 AM

Comments (58) | + Follow

Hydrogen from fossil natural gas is "Blue Hydrogen." Hydrogen for Renewable Natural Gas is "Green Hydrogen" because it is produced from a renewable energy source. Use of RNG is also "carbon negative" because of the capture of biogas from organic waste that would otherwise be released to the atmosphere. It is cheaper to produce hydrogen from RNG than from hydrolysis. It is possible to produce hydrogen from RNG "on site" at large Truck Plaza filling stations. Pipe RNG to the filling station. Send some to the "RNG filling pumps" and send some to the equipment to convert it to hydrogen for the "Hydrogen filling pumps." Minimal transport distance for the hydrogen which is problematic to transport by pipeline over long distances.

RNG can be produced at EVERY organic waste site (farms, landfills, food waste, municipal sewage) and it is "interchangeable and mixable" with fossil natural gas. The resultant "digestate" after removal of biogas can be used for high grade organic fertilizer. Time to get on board with Renewable Natural Gas

Reply Like (2)

ISTJ Investor 04 Dec. 2020, 10:43 AM

Comments (970) | + Follow

Author's Reply *@SORNG*

Thanks for the comment. I wrote an article on renewable natural gas in October, see seekingalpha.com/...

Volume is pretty small, << 1% of geologic natural gas. With reasonable exploitation, 15x growth, might reach 3%. Cost estimates $7-30/MMBtu.

Reply Like (2)

SORNG 18 Dec. 2020, 9:08 AM

Comments (58) | + Follow

I think the world of RNG is changing very quickly. 70% of the trucks in California running on natural gas use 100% RNG. Europe is rapidly expanding RNG production. Maas Energy in California is rapidly expanding RNG production in dairy farms. It's a new income stream for farmers. Xebec Adsorption has developed the "Biostream" which is a "manufactured" unit specifically designed for smaller farms and other sources of biogas that are too small for the usual RNG set ups. The Biostream is delivered to the site on a flat bed trailer, plugged into the source of RNG, and is producing RNG to inject in the natural gas line in a day or two. It is then possible to use an "on site" unit by HyGear to produce "Green Hydrogen" if there is a use for hydrogen. RNG is carbon negative and near zero emission. It is the ideal transportation fuel to replace diesel. Total Electric heavy duty trucks are not available and probably not feasible. It's also hard to find "renewable" lithium and cobalt to make the batteries work.

Reply Like

Robert van der Westhuizen 04 Dec. 2020, 1:52 AM

Comments (12) | + Follow

Just a few comments:

a) What surface area will be required for those vast solar generators

b) How much raw products will you need to mine for those solar panels and what environmental impact will this have

c) I will rather make a bet on nuclear power or even fusion than this energy inefficient option

Reply Like (4)

Skaterdude 04 Dec. 2020, 9:59 AM

Comments (5.22K) | + Follow

You've heard of Google, no?

www.vivintsolar.com/...

Reply Like

SORNG 04 Dec. 2020, 11:23 AM

Comments (58) | + Follow

Take a close look at Renewable Natural Gas (RNG) as the Renewable Energy Source for transportation, heating, cooking, fueling power plants, and the production of "Green Hydrogen." Is the ONLY carbon negative, low emission fuel. As a "bonus," it also takes organic waste (animal waste, sewage, food waste) and turns it into high grade organic fertilizer with no chemicals. It's a win/win/win. d No mining, no fracking, no batteries, actually leaves the environment cleaner AFTER production and combustion than it was BEFORE.

Reply Like (5)

Skaterdude 04 Dec. 2020, 12:32 PM

Comments (5.22K) | + Follow

How much organic waste would it take to supply the equivalent of the petroleum and NG currently used globally? How much space would that take for the fermentation? How much would it cost, all in, compared to drilling for it? I think once you answer those questions, you'll see how impractical that is. We currently grow corn to make ethanol for fuel blending. Recent articles I've read say it's only recently become net energy positive, and costs more to make than it's energy value from petroleum and NG (hence the need for RINs and subsidies). I'll be the first to agree that the petroleum industry has external costs that are not included in the price you pay at the pump or home heating bill, but until that's reflected in the cost, something like RNG is at a stalemate, even if you could figure out how to get enough waste, transport it, ferment it, clean it, dispose of the leftover waste, etc. *(edited)*

Reply Like (1)

See More Replies

Duffy Duck 04 Dec. 2020, 12:12 AM

Comments (71) | + Follow

So many comments; not sure if this has been mentioned: if we burn all this oxygen for energy, will we still be able to breath one day?

Reply Like (2)

Skaterdude 04 Dec. 2020, 10:02 AM

Comments (5.22K) | + Follow

Ummm, that would fit right in with the comments from people who don't realize that water is recyced through the earth, oceans, etc. and is never "consumed". When you electrolyze water to get hydrogen, you also get oxygen. When you recombine that hydrogen with oxygen to get energy, you get water. It's a cycle. See?

Reply Like (3)

Wembley Fraggle 04 Dec. 2020, 5:14 PM

Comments (209) | + Follow

Oxygen is released in equal parts during electrolysis (H20 => H2 + O2) and consumed during combustion (H2 + O2 => H2O). Start with water, end with water. There is no excess of any element created or destroyed. (unless you should lose your H2 to leakage)

Reply Like

ChrisAuw 03 Dec. 2020, 8:58 PM

Comments (101) | + Follow

Just another FAKE issue.

STOP buying a new iphone every 2 year;

STOP owning 2 or more cars in one single family;

STOP eating "all you can eat";

These are the ONLY way to save the earth, but no body cares.

Reply Like (9)

Flactuary58 04 Dec. 2020, 12:28 AM

Comments (128) | + Follow

Maybe you should go to your safe room and hug your emotional support animal.

Reply Like (5)

Diamond-Hands

04 Dec. 2020, 8:37 AM

Comments (2.51K) | + Follow

@ChrisAuw

You forgot:

STOP breeding like rabbits.

The real problem is the planet has way too many people, and they are messing up everything. If there were a lot fewer people, we wouldn't have all these problems.

I estimate the long-term sustainable carrying capacity of the Earth is no more than 1 billion people (about the world population in Napoleon's time). Frankly, that's still too many, if they all want a U.S. standard of living.

But no worries. As the planet inexorably warms, we will get down to that 1 billion level or lower, possibly within a century. The chastened survivors, if there are any, will have learned a lesson that maybe they can remember and use.

Reply Like (6)

Ta0

04 Dec. 2020, 1:18 PM

Comments (9.01K) | + Follow

@$Das Kapital

I think one child per family is a good start. It would, over a couple of generations, shrink the human population down to a dull roar.

And then there are people like me who have zero children. We help bring that number down a little bit faster, so the rest of humanity has a little more breathing room.

Reply Like (2)

See More Replies

ronald61239

03 Dec. 2020, 8:22 PM

Comments (5.32K) | + Follow

I found this article very informative. I do agree hydrogen should not be expected to supply or replace all the energy used. Any more than the electric auto will solve the problems of carbon monoxide, manufactured in the world. Together they will reduce it some.

Forestry will B a great help also.

Reply Like

Balaland

05 Dec. 2020, 9:40 PM

Comments (4.46K) | + Follow

@ronald61239@outlook.com ,

Situation is , that every Oil well drilled produces NG ...

Currently , when the pressure increases , and gets too high , It's just burned off ..

NG , IMO , is and will always be here to stay , why not use it with Carbon capture Tech. that already exists ...

Forestry is exactly correct .. When Country's started nailing the rain forests , plants that provide medicines were destroyed , many undiscovered , and now extinct .. Drugs that were never discovered , tested , because of a Human extinction event , invading these valuable resources ..

This evolving Planet gave us everything we needed to survive , yet lack of NOT building in coastal areas , produces Pollution from Natural Causes , like earthquakes , Hurricanes , Etc , as all this Crap only ends up in our Oceans , and travels along the underwater Streams , and ends up everywhere ..

Bottom-line , we all know the Problems , and as usual , it all comes down to the almighty $$$ ... As Stated in most of the above posts ..

Reply Like (1)

Bredving 03 Dec. 2020, 8:11 PM

Comments (1) | + Follow

A great article except missing a deeper dive into alternate ways to produce Hydrogen. Electrolysis is never gonna be a feasible way to produce Hydrogen at a larger scale. Batteries will probably always be the best way to store electricity from solar production. As of right now there are no technology to compete with electrolysis but 10 to 20 years out there might be some other techniques coming to fruition. For instance this one www.sciencedaily.com/...

Using a graphene as a membrane there might be a way to mechanically separate hydrogen from other gases. Say for instance natural gas is pushed through a membrane of graphene. Only the smallest part, Hydrogen, passes through. The CO2 part of the natural gas is pumped back under ground or could be used for production of fertilizer.

Reply Like (1)

Tyreaus 04 Dec. 2020, 1:27 PM

Comments (20) | + Follow

Your deep dive is a little shallow. Technology exists to produce hydrogen from NG using microwave induced plasma. This results in clean hydrogen and carbon, no CO2. See www.transformmaterials.com. This is one of three companies that I know of that are developing this process

Reply Like (2)

Cogitatio Rationalis 04 Dec. 2020, 9:05 PM

Comments (2.57K) | + Follow

@Bredving

Industry uses microns thin Palladium membranes for that. Both for steam methane reforming and now trialing inside a well too.

proton.energy/...

Reply Like (2)

Jimghad 03 Dec. 2020, 6:13 PM

Comments (4.26K) | + Follow

In the last year Ballard power has done well for the hydrogen fuel cells.

Reply Like (2)

P

Pierre Peau

03 Dec. 2020, 6:10 PM

Comments (1) | + Follow

Very interesting!

Reply   Like

Disagree with this article? Submit your own. To report a factual error in this article, click here. Your feedback matters to us!