FACTSHEET: HYDROGEN & LOW-CARBON GASES IN NEW YORK'S ELECTRICITY FUTURE

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Background

As New York's electricity supply becomes cleaner through the use of low-cost and variable renewable resources like wind and solar photovoltaics (PV), the system will require zero-emission resources that can be dispatched to meet extended gaps in renewable energy supply. The Draft Scoping Plan (DSP) developed by the Climate Action Council models hydrogen as the energy carrier used to provide the long-duration energy storage that meets this need.

In the DSP, hydrogen is exclusively generated by electrolysis, which is a process of splitting water, using zero-emission electricity. Afterwards, it is stored until needed, and then run through fuel cells to produce electricity without emissions. Hydrogen is a potent greenhouse gas, so this "green hydrogen" pathway can approach zero emissions only if leakage is closely controlled. Green hydrogen is inefficient as an electric generation resource, compared to direct use of clean electricity. In a cost-effective portfolio, green hydrogen supplies are limited by the cost (both monetary and in terms of land use) of zero-emission generation to produce the hydrogen. The highest and best uses of a limited hydrogen supply are for energy needs that are difficult to decarbonize by any other means, specifically industrial processes and heavy transport. Similarly, potential low-carbon renewable gas or synthetic methane gas is not used for electric generation in the DSP because of its limited availability and its better application in other sectors.

Other approaches to hydrogen production and use are technically possible, but can produce substantial emissions. For example, using combustion, rather than fuel cells, to produce electricity from hydrogen can generate air pollutants, particularly nitrogen oxides (NO_x). Hydrogen can also be produced by steam methane reformation (in which the hydrogen is removed from methane molecules, rather than from water) coupled with carbon capture and storage. However, this approach results in emissions due to methane leakage and incomplete carbon capture.

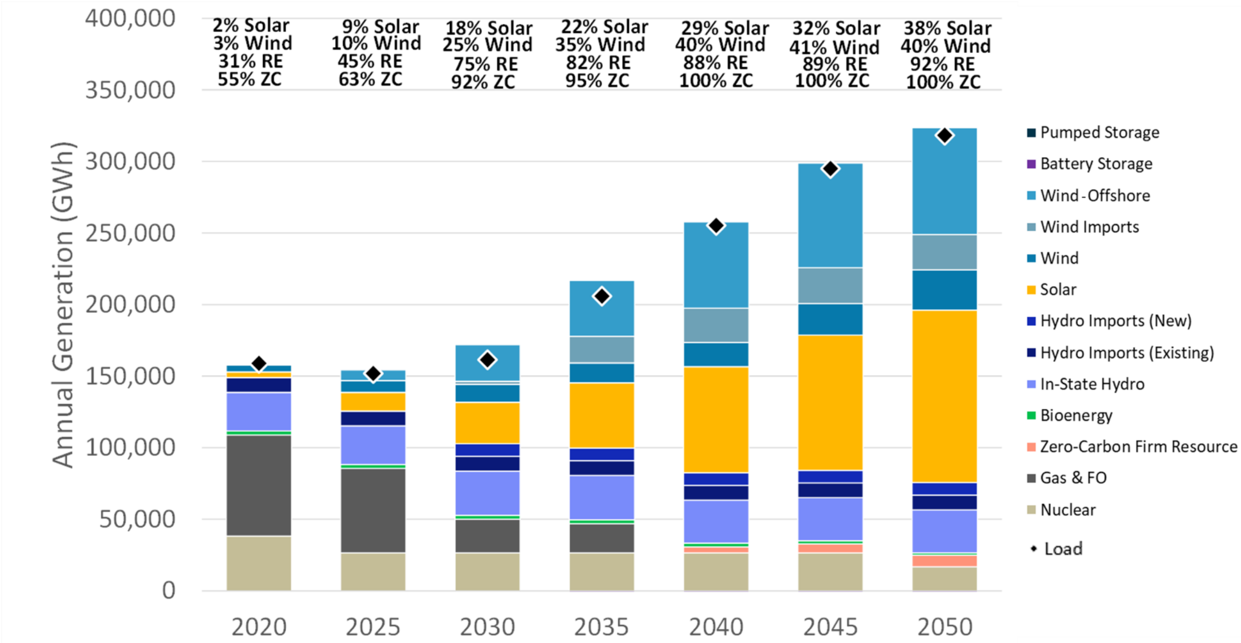
The DSP's approach is not the only potential option to fill in the gaps in renewable energy supply, and future technology developments will shape which pathways are the most achievable and cost-effective. For example, other technologies such as compressed air and novel batteries could compete with hydrogen to provide long-duration energy storage. Long-duration storage is the only application for which hydrogen makes sense in New York's electric mix; other applications are hindered by hydrogen's low efficiency and resulting need for extensive additional renewable generation build-out coupled with hydrogen storage and pipeline cost.

Scoping Plan models of New York's future electric supply portfolio

To support the DSP, Energy and Environmental Economics, Inc. (E3) used its RESOLVE model to develop optimized portfolios of electric supply resources that meet the state's requirement for zero greenhouse gas emissions. These portfolios account for the increased electricity demand from electrifying large portions of the transportation, industry, and buildings sectors. Nearly 70 percent of generation comes from variable wind and solar resources in 2040, rising to almost 80 percent in 2050. For the grid to meet demand at each moment while using large portfolios of variable resources, the system requires flexibility. This flexibility comes from controllable loads (such as EV charging), some controllability in hydroelectric generation, and three forms of storage: pumped hydroelectric, batteries, and hydrogen.

In the DSP, pumped hydroelectric storage, which already exists today, and a rapidly increasing fleet of batteries are used to shift electricity within a day or two to match daily load shapes to the profiles of wind and solar generation. Meanwhile, hydrogen is used to provide a "zero-carbon firm" resource that does not become exhausted during extended (e.g., multi-day) periods when called upon. This long-duration storage resource provides less than 3 percent of New York's electric energy, but is essential to address extended periods with both low wind and low solar generation.

Figure 1. New York electric supply portfolio in the DSP, Advisory Panel case. RE = renewable energy; ZC = zero carbon.

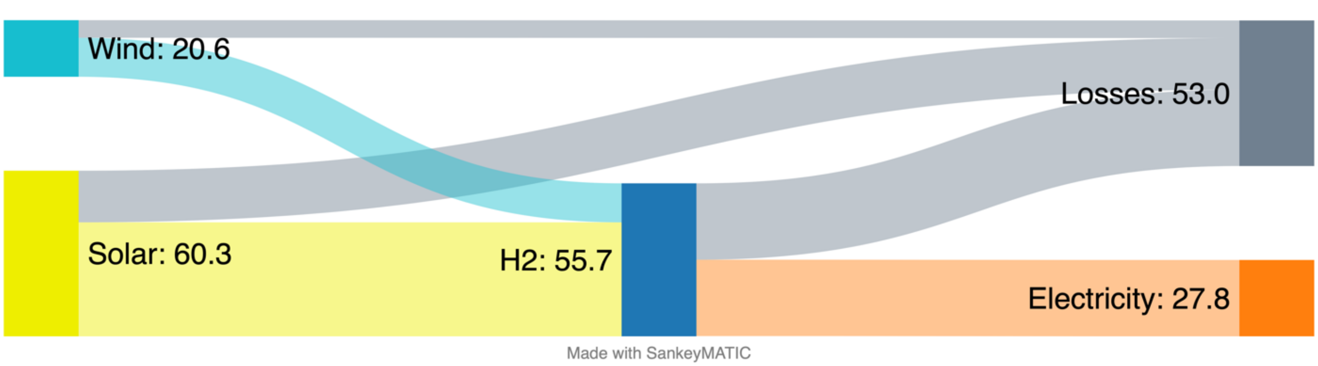


DSP shows limited role for hydrogen in electricity, exclusively as a non-combustion resource

The DSP modeling identified a need for a large capacity of zero-carbon firm resources, modeled as hydrogen fuel cells, but the energy produced by those resources is small. The resources have a capacity factor of less than 4 percent, meaning they sit idle for a vast majority of the time when other resources are sufficient to meet load. They play a role similar to that of gas turbine peaking plants today.

According to the DSP and supporting analysis, even when used only to generate less than 3 percent of New York's electricity in 2050, the process of using electrolysis to create hydrogen for use in the electric sector requires about 81 TBTU of electricity, equivalent to about 15 percent of New York's 2020 electricity demand, to make 56 TBTU of hydrogen. Another 139 TBTU of electricity are used to make hydrogen for other sectors. While some of the electricity used to make hydrogen is "excess" generation from variable sources that would otherwise have been curtailed, New York requires enough hydrogen between industry, transport, and electricity that all curtailed power is used and additional generation is built just to produce hydrogen. The total electricity used to produce hydrogen for long-duration storage is equivalent to the output of 5.2 GW of wind or 11.3 GW of solar PV.

Figure 2. Estimated flow of electric energy through hydrogen to electricity (using fuel cells), showing total conversion losses. Units are TBTU (trillions of BTUs).



The approximate round-trip efficiency of E3's modeled hydrogen-based long-term storage is just 34 percent. However, this is higher than it would be if the hydrogen were burned instead of run through fuel cells. Hydrogen fuel cells can be 50 percent efficient, or greater, while new gas turbines are generally about 35 percent efficient. This means that by using fuel cells instead of gas turbines, New York avoids building about 4.5 GW of additional wind and solar. Fuel cells also avoid the risk of criteria pollutants from gas combustion: hydrogen burns hotter than methane so hydrogen turbines would produce high levels of NO_x pollution unless substantial mitigating steps are taken. Even setting aside the climate impacts of leaked hydrogen, due to NO_x emissions, combustion-based approaches to zero-carbon firm resources may also violate New York's policy of using only zero emission electric generation resources by 2040.

Other technology can also provide (or reduce need for) long-term energy storage

Hydrogen is not New York's only option for long-duration energy storage or zero-carbon firm resources. Compressed air storage and novel long-duration batteries are competing technologies to deliver the same service for the electric sector, although these options cannot displace hydrogen in the industry or heavy transportation sector. If these long-duration storage technologies have higher round-trip efficiency than 34 percent estimated for the hydrogen-based approach, they could reduce the need to build wind and solar generation.

All long-duration energy storage approaches, including hydrogen, require additional technology development before they are commercially available and ready to meet New York's needs after 2040. Continued research, development, and demonstration projects will be required to determine the most cost-effective portfolio.

Energy efficiency—particularly weatherization and high-efficiency cold-climate heat pumps—can reduce the magnitude of energy needs during supply gaps. In addition, new technologies may also enable New York to use less long-duration storage by reducing both the share of electricity generation from variable sources and the magnitude of supply gaps. New technology such as enhanced geothermal or advanced nuclear generators (if available, proven, safe, adequately regulated, and cost-effective) could compete with wind, solar, and storage to meet New York's needs. However, given the need for rapid transformation in the electric sector there is no need to wait for these technologies to be mature before deploying today's cost-effective variable renewable resources.

Existing plants and technologies can also impact the need for new zero-carbon firm resources. Maintaining capacity at existing zero-carbon generators reduces the scale of new builds required, while greater levels of transmission interconnection with neighboring regions can allow New York to draw on a more diverse portfolio of variable resources. By increasing transmission capacity over distances larger than the scale of typical weather systems (e.g., more than 1000 miles), power from wind and solar resources could flow around the eastern United States and Canada and reduce the need for local storage. Put simply: while New York may see multiple days of calm, cloudy weather, it is unlikely to be calm and cloudy over the entire eastern half of North America at the same time.

Why hydrogen isn't used as a bulk generation resource in the DSP

E3's RESOLVE electric portfolio modeling uses cost and performance estimates for different generation resources as part of developing an optimized portfolio. That optimized portfolio requires some use of hydrogen to play the role of long-duration storage and rarely-used zero-carbon firm generation, but not as a bulk generation resource.

Using hydrogen for this additional purpose would be more expensive than other approaches because of hydrogen's overall low efficiency. By examining what bulk hydrogen use would entail, we can see why this is so.

> Generating 10 percent of New York's 2050 electricity demand from hydrogen (instead of the 3 percent in the DSP's base case) would require 24.5 GW more wind and solar generation than the base case. Used directly instead, that is enough additional wind and solar to meet 21 percent of the state's electric needs.

Using hydrogen as a bulk generation resource, akin to how the grid uses gas today, would decrease the need for variable renewable generation at the time when the hydrogen plants are generating. However, this would substantially increase the overall amount of variable renewables because of the need to produce the hydrogen in the first place. Given the 34 percent system efficiency of turning electricity into hydrogen and back into electricity, generating 10 percent of New York's 2050 electricity demand from hydrogen (instead of the 3 percent in the DSP's base case) would require 24.5 GW more wind and solar generation than the base case. Used directly instead, that is enough additional wind and solar to meet 21 percent of the state's electric needs. Because onshore and offshore wind and solar resources generate at different times, this diverse portfolio (see Figure 1) would leave only some periods where zero-carbon firm resources are required—as shown in the RESOLVE results.

Generating and using hydrogen to provide essential long-duration storage services for the electric grid, as modeled in the DSP, would require overcoming numerous technological and siting challenges. Using more hydrogen than envisioned in the DSP would exacerbate these challenges.

The DSP envisions mitigating some siting challenges by importing half of the state's hydrogen from outside New York, but this simply shifts burdens to others, with no assurance they are willing to bear them. Meeting national and global climate change mitigation objectives will require actions in all states that are commensurate with New York's actions, so importing hydrogen will make it more difficult for other states to meet their goals.

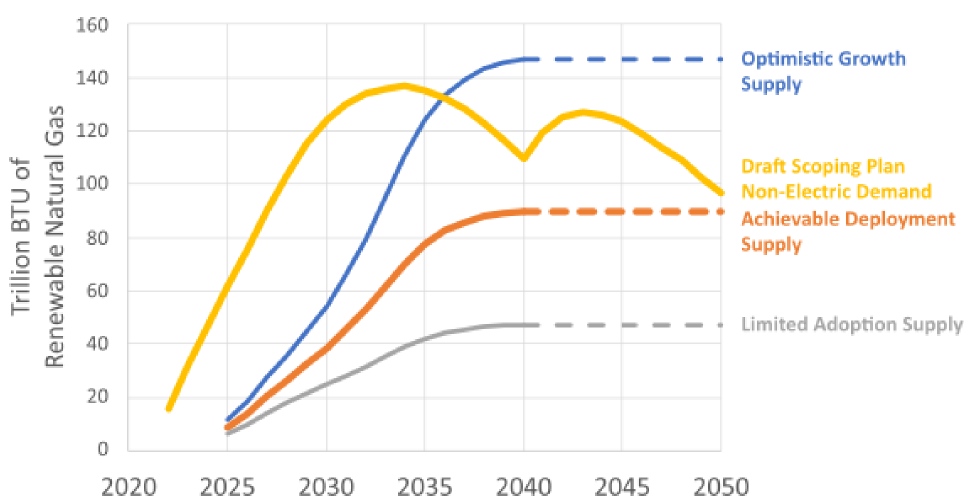
Importing hydrogen also adds transportation challenges. The existing methane transmission pipeline system is overwhelmingly made of steel pipes, which may be embrittled by hydrogen unless they are protected. Because hydrogen is less dense than methane, the same flow volume of hydrogen provides less energy than that of gas. Electric transmission, rather than conversion to and from hydrogen, would mean less generation is needed while also providing inter-regional resilience to gaps in wind and solar production.

No role for new bioenergy in New York's future electricity generation

Sustainably grown biomass is a limited resource, both in New York and globally. E3's analysis for the DSP uses this limited resource in applications where alternatives are more expensive or not available. This is primarily long-distance heavy transportation (where it displaces diesel and jet fuel) and industry (where it displaces fossil gas), along with application in some buildings. The only bioenergy in the electric sector in the core DSP scenarios comes from existing woody biomass and landfill gas plants.

Looking specifically at biomethane, New York will be a net importer of this fuel, which is likely to be demanded by many states to play a role in their decarbonization strategies. New York's "achievable" biomethane supply (as estimated by ICF for NYSERDA) is below the amount that the DSP uses for hard-to-decarbonize building, industrial, and transportation end uses, leaving no potential in-state supply to use for electric generation. Even ICF's "optimistic growth" level of NY biomethane supply requires imports until the late 2030s.

Figure 3. *Comparison of the demand for RNG for transportation, industry, and buildings in the DSP (yellow line), compared with in-state supply development trajectories developed by ICF for NYSERDA (blue, orange, and grey lines)*



Using all reasonably available biomass to make and combust biomethane would raise sustainability, emissions, and environmental justice concerns. More than 86 percent of the "achievable" potential biomethane that ICF identifies for New York in 2040 would come from sources with positive net lifecycle GHG emissions. Pipeline leakage would further increase emissions, and combustion of this gas would produce the same local air pollutants as fossil methane. Incremental imported biomethane for electric generation would exacerbate each of these challenges.

Conclusions

Hydrogen will play a limited role in the future of New York's electric sector. Its most promising electric application is as long-duration energy storage, where it is converted back to electricity using non-emitting fuel cells. However, hydrogen will compete with other technologies to provide this service. Given their combination of cost and limited availability, both hydrogen and RNG will be primarily applied in sectors and end uses that are hard to electrify, such as industry and heavy transport, with limited applications for RNG in buildings.