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by H.D. Dziedzic and T. Oyewunmi

Decarbonization and the Integration of Renewables in Transitional Energy Markets: Examining the Power to Gas Option in the United States

Heather Dziedzic and Tade Oyewunmi***

1. Introduction

Over the last century, energy has been a defining characteristic of modern society. Economic and social development has been directly or indirectly tied to a society's capacity to secure affordable, reliable, and sustainable access to energy supply and services globally. In the electricity supply context, the conventional approach to enabling such access is through the stages of: (i) generation of electric energy from central sources such as hydropower-dams, coal, natural gas and nuclear; (ii) transmitting the energy through high voltage wires, substations, transformers and other network facilities; (iii) distribution via local networks to various classes of consumers such as commercial, industrial, and residential groups. The value chain is typically organized based on a patchwork of contracts, rules, regulations and policy frameworks dealing with vertically-integrated utilities, natural monopolies, access to essential networks, property rights, cost-of-service, just and reasonable rate-of-return to utility investors. Increasingly, such policies also include integrated planning by utilities and transmission network operators to balance demand and supply in real-time, while maintaining mid-to-long-term reliability and considering the physical nature of electric currents and power. These constraints make it complex to store electrical energy at the scale required to meet continuously growing and constant demand the medium to long-term. Notably, other forms of energy such as those in solid, gaseous or liquid forms have fewer storage complexities.

The falling costs of renewables such as wind and solar; progress in energy efficiency, and demand-side management programs have driven energy networks toward less centralized, and more distributed systems. Other essential factors pushing the exponential growth in the utilization of intermittent renewable energy sources include climate change mitigation and carbon emission reduction targets, behavioral changes of the 21st century consumer, and other initiatives at the state and local level, such as policy-driven electrification and generation portfolio standards.[1] Notwithstanding, there are operational, policy, and energy regulation

* Senior Analyst Lead, Environmental Regulations & Strategy at CMS Energy, Michigan, USA. Heather holds a Bachelor of Science degree from the University of Notre Dame, IN, USA, and a Master of Energy Regulation and Law degree from Vermont Law School's Institute for Energy and the Environment, VT, USA, where she researched extensively the development of a policy framework for Renewable Natural Gas.

** Assistant Professor and Senior Energy Research Fellow at Institute for Energy and the Environment (IEE), Vermont Law School, VT, USA, where Tade currently leads a research project on the legal, policy and regulatory issues in the integration of renewables and transitional electricity markets.

[1] US Energy Information Administration (EIA), 'Annual Energy Outlook 2019 with projections to 2050' (2019) 1-83 at 22 <https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf> accessed 21.05.2019; the International Energy Agency (IEA), *Renewables 2018*, (IEA Publications, 2019). The IEA forecasts that renewables will have the fastest growth in the electricity sector globally, providing almost 30% of power demand in 2023, up from 24% in 2017. Furthermore, renewables are projected to meet more than 70% of global electricity generation growth onwards to 2023, led by solar PV and followed by wind, hydropower, and bioenergy. The US EIA's Annual Energy Outlook 2019 reports that based on the current regulatory and legal framework, utility-scale solar plants that are under construction before January 1, 2020, receive a full 30% Investment Tax Credit (ITC), while those under construction before January 1, 2021, receive a 26% ITC and those under construction before January 1, 2022, receive a 22% ITC. Based on EIA assumptions there should be about 21 gigawatts of additional solar PV capacity coming online before January 1, 2024. New wind capacity additions continue at much lower levels after

challenges that arise following such growth in intermittent renewable sources. One such challenge is illustrated in the 'duck curve', a dilemma in which utilities and transmission operators must balance mismatched supply and demand across a typical day of renewable energy production and consumption. The dilemma is created when solar energy, generated when the sun is shining, exceeds typical demand; and, just as real-time generation drops in the evening, demand increases.[2] Emerging issues also include long-term planning and risk mitigation,[3] network congestion management and load balancing, renewable generation curtailment and redundancy, the 'missing money' problem and shirking by investors in traditional energy utilities leading to potential capacity inadequacies.[4]

In the US, the electricity sector contributed about 28% of total greenhouse gas emissions by economic sector in 2017-2018,[5] thus, arguably one of the major sources of environmental externalities and risks associated with climate change. Ensuring effective and efficient decarbonization of the sector constitutes one significant pathway to sustainability. There is also a fundamental need for cross-sectoral coordination to maximize low-carbon pathways across all energy uses, including transportation and space heating. Thus, a more comprehensive approach to energy policymaking is needed, as is a greater understanding of the various sectors, and the peculiar challenges that arise when integrating electric power from renewables, like solar PVs and wind, with energy markets that rely mostly on conventional energy systems such as gas-to-power utilities.[6]

Extant US federal, state, and regional energy policies aimed at decarbonization arguably fall short in recognizing the contribution of cross-sector cooperation and innovation to achieve technological synergies and cost-efficient carbon reduction. Technologies producing what is now commonly known as renewable natural gas (RNG), a "pipeline quality gaseous fuel

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production tax credits expire in the early 2020s. Although the commercial solar ITC decreases and the ITC for residential-owned systems expires, the growth in solar PV capacity continues through 2050 for both the utility-scale and small-scale applications because the cost of PV declines throughout the projection. Most electric generation capacity retirements occur by 2025 as a result of many regions that have surplus capacity and lower natural gas prices. The retirements reflect both planned and additional projected
retirements of coal-fired capacity. On the other hand, new high-efficiency natural gas-fired combined-cycle plants and renewables generating capacity is added steadily through 2050 to meet growing electricity demand.

[2] US Office Of Energy Efficiency & Renewable Energy, *Confronting the Duck Curve: How to Address Over-Generation of Solar Energy* (October 17, 2017) at <www.energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy> accessed on 12.09.2019.

[3] LeRoy Paddock and Karyan San Martano, 'Energy Supply Planning in a Distributed Energy Resources World', in Donald Zillman et al., (eds.) *Innovation in Energy Law and Technology: Dynamic Solutions for Energy Transitions* 371-389 (Oxford University Press, 2018).

[4] Amy L. Stein, 'Distributed Reliability' (2016) 87 *University of Colorado Law Review* 887-1008; William Boyd, 'Public Utility and the Low-Carbon Future' 61 (2014) *UCLA Law Review* 1614- 1711.

[5] See the US Environmental Protection Agency (US EPA), *Sources of Greenhouse Gas Emissions* at <www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions> accessed 12.09.2019; the US EPA, *the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2017*, (2019) at <www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2017> accessed 12.09.2019**.** Transportation, Industry, Commercial & residential, agriculture sectors account for about 29%, 22%, 12 % and 9% respectively.

[6] For more on the organizational structure of a typical gas-to-power market and value chain, see Tade Oyewunmi, *Regulating Gas Supply to Power Markets: Transnational Approaches to Competitiveness and Security of Supply* (Wolters Kluwer, 2018) 360 at 14-47; Tade Oyewunmi, 'Examining the role of regulation in restructuring and development of gas supply markets in the United States and the European Union' (2017) 40(1) *Houston Journal of International Law* 191-296.

derived from biomass or other renewable sources,"[7] create an avenue for exploring such cross-sectoral alignment and potential. RNG has lower lifecycle greenhouse gas emissions compared to conventional (i.e., fossil-based) natural gas, due to its ability to capture and condition greenhouse gases (GHG), such as methane and carbon dioxide (CO2), that are emitted from agricultural and other waste management activities. RNG can also be produced through advanced systems that convert excess electrical energy from renewables into gaseous energy forms. These systems, known as Power-to-Gas (P2G), create carbon-free gaseous fuels in the form of hydrogen, or carbon-neutral synthetic methane.[8] Both offer significant reductions in greenhouse gas emissions on their own. Several US states have recognized this benefit and have begun designing policy initiatives around renewable natural gas.[9] Another potential application of P2G is that upon conversion to its gaseous form of hydrogen or synthetic methane, the energy inherent in the excess electricity is essentially stored or transported to demand centers through existing gas supply networks.

Arguably, P2G technologies enable and enhance the integration of growing renewable-energy generation with the existing electric grid, as well as the natural gas supply system, energy storage, and waste reduction objectives while remaining net-carbon neutral.[10] The current regulatory framework in the United States lacks the flexibility and cross-sectoral paradigms that would be required to facilitate the scalable development of such technologies. There appears to be avoidable regulatory complexities, and underutilized resources, leading to a slower transition to low-carbon energy supply overall. The aim of this paper is to highlight and discuss the dynamics of such cross-sectoral complexities and the potential to fill the identified gaps in US energy policy pertaining to the integration of renewables and the development of considerable technologies such as P2G in the energy transitions movement. It seeks to understand the existing regulatory, legal and policy framework that impacts evolving power-to-gas options, and whether the framework effectively manages such potential applications to innovatively decarbonize the energy supply value chain or rather creates bottlenecks.

2. Developing the US Renewable Energy Market and Policy Framework for Energy Transitions

Over the years, the US electricity supply has relied on carbon-intensive sources such as coal, significantly contributing to GHG emissions. In 2018 alone, the CO2 emissions from the sector accounted for 1,763 million metric tons (MMmt) of CO2 or about 33% of total U.S. energy-related CO2 emissions, arising from coal (65%), gas (33%), petroleum (1%) and others.[11] A

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[7] American Gas Association, *Securing a Role for Renewable Natural Gas,* p. 2. <https://www.aga.org/sites/default/files/legacy-assets/our-issues/renewable-gas/Documents/AGA_RenewableGas_Summary_3.pdf>

[8] Martin Lambert, *Power-to-Gas: Linking Electricity and Gas in a Decarbonising World?* (Oxford Institute for Energy Studies (OEIS), OIES Insight: 39, October 2018); Ruven Fleming and Joshua P Fershee, 'The 'Hydrogen Economy' in the United States and the European Union: Regulating Innovation to Combat Climate Change,' in Donald Zillman et al., eds., *Innovation in Energy Law and Technology: Dynamic Solutions for Energy Transitions* 449 at 137-153 (Oxford University Press, 2018).

[9] California Bioenergy, Environmental Protection Agency webinar, *RNG Projects in the Ag Sector.* (March 27, 2019) <https://www.epa.gov/sites/production/files/2019-03/documents/dairy-digesters-in-california-kern-cluster-other-examples.pdf>

[10] Paula Schulze, et. al, European Power to Gas, *Power-To-Gas in A Decarbonized European Energy System Based on Renewable Energy Sources,* p. 8

[11] The US EIA, *How much of U.S. carbon dioxide emissions are associated with electricity generation?* At https://www.eia.gov/tools/faqs/faq.php?id=77&t=11> accessed 12.09.2019; In 2017 the electricity sector accounted for 28% of GhG emissions by sector according to the US EPA on *Sources of Greenhouse Gas Emissions* at <www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions>; energy-related CO2 emissions increased by

logical means to reduce energy-related greenhouse gas emissions is to incentivize generation of power from net-zero carbon sources, renewables, or less-carbon-intensive and more efficient systems such as gas-to-power. Gas-to-power facilities are unique, however, in that GHG impacts are not isolated to the point of electric generation. Increasingly, the emissions of these energy sources include lifecycle impacts, like those associated with upstream development and transportation. If the gas industry can reduce, capture, or innovatively deal with emissions attributable to that value chain,[12] then the credentials of natural gas as being relatively 'cleaner' or 'less-environmentally harmful' could be further validated in the context of decarbonization.

In the last 25 years, the energy industry in the US has seen a wave of laws and policies seeking to boost electricity generation from renewable sources. Since 1994, twenty-nine States and the District of Columbia have introduced Renewable Portfolio Standards (RPS), setting both voluntary and mandatory targets for renewable electric generation.[13] These targets have served to increase demand for renewable electric generation, primarily from wind and solar[14] by requiring the overall portfolio of electricity supply from utilities to include specific percentages of renewable energy capacity. It is reported that about half of all growth in U.S. renewable electricity generation and capacity since 2000 is associated with state RPS requirements, though not all of that is strictly attributable to RPS policies.[15] RPS seeks an indirect reduction in greenhouse gas emissions, by displacing traditional, carbon-intensive fuels like coal and oil. Furthermore, the Obama-era Clean Power Plan (CPP)[16], issued in 2015, sought to tackle the issue head-on, by limiting the emissions from electric generators.[17]

The EPA issued the CPP pursuant to the US Clean Air Act (CAA) section 111(b). It comprised a framework of performance-based standards upon which emissions of carbon dioxide (CO_2) from affected newly constructed, modified, and reconstructed fossil fuel-fired electric utility

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2.8% in 2018 but will decrease in 2019 and 2020. Despite the growing switch from coal-fired EGUs to gas-fired EGUs, the 2018 increase is the largest in energy-related CO2 emissions since 2010, perhaps due to weakening regulations, greater economic activities and growing demand and consumption patterns.

[12] There has been a lot of debate pertaining to emerging technologies such as Carbon Capture Utilization and Storage (CCUS), commercial acceptance of regulations pertaining to methane emissions midstream and prevention of waste and emissions through flaring in the upstream gas sector. See Bradley N. Kershaw, 'Flames, Fixes, and the Road Forward: The Waste Prevention Rule and BLM Authority to Regulate Natural Gas Flaring and Venting' (Winter 2018) 29(1) *Colorado Natural Resources, Energy & Environmental Law Review* 115-164; US EPA, *the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2017*, (2019) chapter on 'Energy' at <www.epa.gov/sites/production/files/2019-04/documents/us-ghg-inventory-2019-chapter-3-energy.pdf> accessed 12.09.2019; Ryan Collins, *Texas Oil Regulator Shifts Stance as Gas Flaring Hits Record*, Bloomberg Markets (August 7, 2019, Updated on August 8, 2019) at <www.bloomberg.com/news/articles/2019-08-07/texas-oil-regulator-shifts-stance-as-gas-flaring-hits-record> accessed 12.09.2019.

[13] Barbose, Galen, Lawrence Berkeley National Laboratory, *U.S. Renewable Portfolio Standards: 2018 Annual Status Report.* (November 2018), slide 8. <http://eta-publications.lbl.gov/sites/default/files/2018_annual_rps_summary_report.pdf>

[14] Ibid, slide 15

[15] See the National Conference of State Legislatures (NCSL), *State Renewable Portfolio Standards and Goals* at <http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx > accessed 12.10.2019; Galen L Barbose, Lawrence Berkeley National Laboratory, *U.S. Renewables Portfolio Standards: 2019 Annual Status Update* at <https://emp.lbl.gov/publications/us-renewables-portfolio-standards-2> accessed 12.09.2019. only about 30% of renewable energy generation developments in 2018 is attributable to RPS. The framework continues to play a significant role in particular regions such as the Northeast and Mid-Atlantic regions of the US.

[16] US EPA's *Standards of Performance for Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units* 80 Fed. Reg. 64510 (October 23, 2015) (40 CFR Parts 60, 70, 71, and 98)

[17] Georgetown Climate Center, *State-by-State Resources to Better Understand EPA's Carbon Pollution Rule.* (June 2, 2014). <https://www.georgetownclimate.org/articles/state-by-state-resources-to-better-understand-epas-carbon-pollution-rule.html#summary>

generating units (EGUs) could be curtailed. The Obama-EPA also issued guidelines for states to use in developing plans to limit CO_2 emissions from existing fossil fuel-fired EGUs under the CAA section 111(d). The highlighted regulatory steps aimed at curtailing carbon emissions from EGUs sector were intended to drive innovation by operating utilities via more cost-efficient or sustainable emission controls. Arguably, utilities that failed to innovate or achieve the standards, would have become less-competitive when compared to other less carbon-intensive or net-zero carbon sources. Such prospects were essentially obfuscated following the Trump administration's repeal of the CPP. In 2019, following prior stays by the courts,[18] and the proposed Affordable Clean Energy rule, the CPP stands repealed.[19]

To some, this was a setback in climate policy; others recognize that economics and state-level policies have already driven the electric industry to a 33% reduction in greenhouse gas emissions.[20] This surpasses the 32% reduction sought by the CPP and achieves that target a decade early. It also exceeds the initial commitment of the United States to the Paris Climate Agreement, which was a 28% reduction by 2025.[21] These achievements, however opportune they may be, demonstrate the ability of corporate sustainability, energy markets, state and regional policy, and economic incentives to drive meaningful change in the energy sector and its carbon footprint.

2.1. Energy Assets: Untapped & Underutilized Resources

Following the apparent success of RPS implementation, and other economic incentives,[22] renewables-based electric generation has doubled in the US within the last decade, and now provides 17.8% of the country's electricity.[23] Paired with the aforementioned reduction in greenhouse gas emissions, there is strong evidence that the energy system is headed in the right direction. But, if the system has already surpassed previous national and international targets for decarbonization, then where is the next signpost? Industry experts have different visions of the future system, some seeking an electric system powered 100% by wind, solar, and hydro.[24] Others have cautioned that this approach, while technically feasible, ignores the political, technical, and financial hurdles to achieve such an aggressive target.[25] Instead, analysis of future electric generation seems to have coalesced around a lower target of an 80% penetration

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[18] Stanford University, Stanford News Service, *Goodbye, Clean Power Plan: Stanford researchers discuss the new energy rule.* (June 21, 2019). <https://news.stanford.edu/press-releases/2019/06/21/goodbye-clean-power-plan-understanding-new-energy-rule/>

[19] EPA's Repeal *of the Clean Power Plan; Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units; Revisions to Emission Guidelines Implementing Regulations* (40 CFR Part 60) 84 Fed. Reg. 32520 (July 8, 2019)

[20] Shober, Maggie, Southern Alliance for Clean Energy, *Should we mourn the Clean Power Plan?* (June 18, 2019). <https://cleanenergy.org/blog/trump-replacing-clean-power-plan/>

[21] United Nations Framework Convention on Climate Change, Nationally Determined Contributions Registry. <https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx>

[22] Federal incentives include Production Tax Credits and Investment Tax Credits, United States Energy Information Administration, *U.S. renewable electricity generation has doubled since 2008* (March 19, 2019). At https://www.eia.gov/todayinenergy/detail.php?id=38752

[23] Ibid

[24] Jacobsen, Mark Z., et al., Proceedings of the National Academy of Sciences of the United States of America. *Low-cost solution to the grid reliability problem with 100% penetration of intermittent wind, water, and solar for all purposes.* PNAS, 112 (49) 15060-15065. (December 8, 2015) At https://www.pnas.org/content/112/49/15060?ijkey=ad4e81fadea8184253ab4229251f1cbac6996abb&keytype2=tf_ipsecsha

[25] Clack, Christopher T.M, et al., Proceedings of the National Academy of Sciences of the United States of America, *Evaluation of a proposal for reliable low-cost grid power with 100% wind, water, and solar.* PNAS 114 (26) 6722-6727. (June 27, 2017) at: https://www.pnas.org/content/114/26/6722.full

rate for renewables-based electricity, at least as a starting point for meaningful modeling.[26] Even at eighty percent, this target comes with significant challenges considering the nearly five-fold increase of renewables' contribution to the grid. It also confirms the current reliance on the electric grid to do the heavy lifting of decarbonizing our society.

Renewable energy sources are inherently intermittent and depend largely on weather or seasonal patterns. In other words, energy from renewable-based facilities such as solar PV systems and wind turbines is only available at a specific scale and time, when the sun shines and the wind blows, unless the capacity to adequately store that energy exists. Such solutions must also compete with other, existing forms of storage, such as pumped hydroelectric systems, while also meeting the required scale and duration to guarantee reliability, affordability, and security of a fully renewable energy supply. Unpredictability creates a plausible risk to long-term and real-time capacity and is not a desirable trait in either electric supply or grid management. Reliability requires an instantaneous balancing of both supply and demand, something that wind and solar especially struggle to achieve, depending on the time of the day, season, and location.

For grid managers, like Regional Transmission Operators (RTOs) and Independent System Operators (ISOs) (collectively, "grid operators"), these distributed and variable resources challenge their ability to maintain the grid's stability and reliability. Without examining the detailed engineering principles involved in the electric grid, it's sufficient to note here that balancing supply and demand, while maintaining frequency and voltage are key components of a secure and reliable electricity network.[27] These characteristics are captured in the Ancillary Service markets throughout the country, via the RTOs and ISOs. For the purpose of this evaluation, it must be assumed that as the penetration of intermittent renewable-based energy increases from 17% to 80%, there will be a growing need for system resources to contribute such ancillary services, which seek to level fluctuations of intermittent supply. Of interest here is the ability of non-traditional, non-electric resources to aid load leveling and energy storage.[28]

Because traditional renewables-based electricity is generated when the fuel (e.g., wind, water, or sunshine) is available, its contribution to electric supply is naturally independent of demand. During times of overproduction, when renewable supply exceeds demand, grid operators must eliminate this imbalance to inter alia (i) preserve the integrity of the electric system; (iii) prevent network congestion; and (iii) regulate supply's potential impact on market prices and cost-recovery projections. These issues lead to curtailment, which in essence limits the generation, or output of renewable energy to the grid, thus, decreasing the overall contribution of renewables-based electricity to energy consumption below what is achievable without curtailment.[29] Without significant changes in demand, expansion of transmission resources, or the development of adequate, cost-efficient storage solutions; increasing renewables on the grid will only serve to increase curtailment. Curtailment is generally low in terms of percentage of

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[26] National Renewable Energy Laboratory, *Renewable Energy Futures Study: Exploration of High-Penetration Renewable Electricity Futures*. Volume 1, Chapter 3, 3-3. At https://www.law.berkeley.edu/php-programs/courses/fileDL.php?fID=7308

[27] New England States Committee on Electricity, *Electricity Ancillary Services Primer.* (August 2017). <http://nescoe.com/resource-center/ancillary-services-primer-sep2017/#_Toc493764970>

[28] Mazza, Andrea, et al., Renewable and Sustainable Energy Reviews, *Applications of power to gas technologies in emerging electrical systems.* Volume 92, Pages 794-806, 3-1. (September 2008) <https://www.sciencedirect.com/science/article/pii/S1364032118303083>

[29] Bird, Lori, et al., National Renewable Energy Laboratory, *Wind and Solar Energy Curtailment: Experience and Practices in the United States.* (March 2014). <https://www.nrel.gov/docs/fy14osti/60983.pdf>

total generation, roughly 4% of wind supply annually for example.[30] Nevertheless, this curtailment equates to significant energy waste: hundreds of thousands of megawatt-hours (MWh) in each regional market.[31] It is noted that in 2013, the MidContinent Independent System Operator (MISO) curtailed over 1 million MWh of wind energy.[32] That is enough energy to power nearly 100,000 homes in that region alone, for an entire year.[33]

In addition to curtailment issues, renewable energy faces a continued barrier when trying to move electricity from the point of generation to areas of demand, due to the lack or inadequacy of necessary transmission and distribution infrastructure. With large-scale wind and solar projects sited for optimal production and not necessarily for proximity to transmission, this disparity manifests as stranded supply. These conditions are known as transmission constraints, and are the result of the infrastructure's physical limitations, system design, or reliability rules, any or all limiting cost-efficient and optimized power flow.[34] This limitation of power transmission below levels of market demand leads to 'grid congestion'. Again, using MISO as an example, there were $1.2 billion of costs associated with grid congestion in 2011, a figure that is increasing.[35] While not the sole indicator of congestion, the US Department of Energy has looked to interconnection queues as a gauge. Midwest interconnection requests totaled over 33 gigawatts (GW), with wind dominating the queue in 2012.[36] Correcting this issue at the transmission level is not as simple as building new infrastructure and high voltage wires. Transmission lines are both expensive and generally unpopular. "Often it may be easier, cheaper, and environmentally preferable to eliminate or shift demand, or to locate generation strategically than it is to build new lines."[37] This is a solution that is revisited throughout this paper.

Solutions that help to avoid the challenges of building new transmission networks include providing more on-site, location-specific energy conversion or storage options, like power-to-gas (P2G) technology. Rather than curtailment, excess energy from renewables can be converted into gaseous forms, such as hydrogen or methane, and stored in existing gas networks and storage facilities.[38] To the extent that the P2G option utilizes surplus renewable energy, results in pipeline quality hydrogen gas or synthetic methane, and the utilization of existing gas supply network or storage facilities, then it arguably exemplifies a pathway towards (a) preventing the stranded assets question faced by existing gas industry suppliers in a carbon-constrained world; and (b) supporting the growing net-zero-carbon energy industry by creating options to store excess renewable energy in usable and safe forms within existing supply

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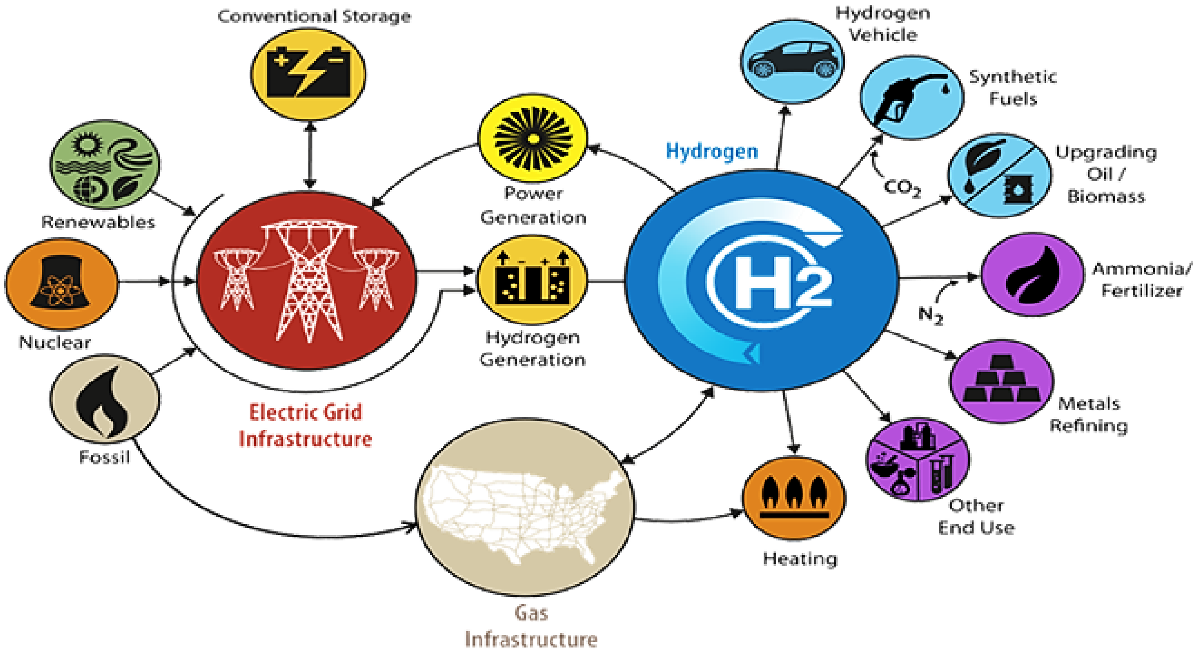
[30] Bird, Lori, et al., National Renewable Energy Laboratory, *Wind and Solar Energy Curtailment Practices*. (October 17, 2014). <https://www.nrel.gov/docs/fy15osti/63054.pdf>
[31] Ibid
[32] Ibid
[33] 1,000,000 MWh= 1e+9 kwh. Calculated using 2017 average US household electric consumption of 10,399 kwh/year. United States Energy Information Administration, Frequently Asked Questions. (October 26, 2018). <https://www.eia.gov/tools/faqs/faq.php?id=97&t=3>
[34] US Department of Energy. *National Electric Transmission Congestion Study.* p. viii (September 2015). <https://www.energy.gov/sites/prod/files/2015/09/f26/2015%20National%20Electric%20Transmission%20Congestion%20Study_0.pdf>
[35] Ibid
[36] Ibid, p. xiv
[37] Welton, Shelly, Columbia Law School, Sabin Center for Climate Change Law, *Non-Transmission Alternatives.* p.2. (Sept 2014). <https://web.law.columbia.edu/sites/default/files/microsites/climate-change/files/Publications/welton_-_non-transmission_alternatives.pdf>
[38] Kevin Harrison (National Renewable Energy Laboratory*), How to Use Utility Pipelines to Store Electric Power: Discussing Power-to-Gas (P2G) & Utility Pipelines as the Better Battery*, RNG WORKS Technical Workshop & Trade Expo, Nashville, TN, USA, RNG Coalition, (September 11, 2019).

systems. Figure 1 below shows the potential uses in which hydrogen or synthetic methane produced from a P2G facility could be deployed (e.g. in transportation, power generation on-demand and residential uses).[39]

Figure 1: Schematic on the US H2@Scale concept and Integration of Energy Supply Systems[40]



In the US, natural gas accounts for about 31% of total primary energy consumption and 35% of that consumption went into electricity generation.[41] Thus, gas supply networks play a major role in electricity supply. Thus, when considering national energy reliability, security and competitiveness objectives, one should consider the natural gas transmission and distribution system, as well as the electric transmission system. The nation's electric network is comprised of roughly 240,000 miles of high-voltage transmission lines.[42] Similarly, there are over 300,000 miles of natural gas transmission pipelines nationwide.[43] One advantage that the natural gas value chain has, that is unmatched by the electric sector, is energy storage capacity. As also depicted in Figure 2 below, there are around 400 active storage facilities spread across 30 states with the capacity to store roughly 4 trillion cubic feet (Tcf) of natural gas for consumer

[39] See also Lambert (n8) at 5. Some identifiable challenges to the deployment of P2G technologies include scalability and finding the demand centers for by productions such as hydrogen in different economic sectors such as transportation where for instance hydrogen gas may have to compete with traditional gasoline or traditional battery powered EVs. hydrogen refueling standards, station permitting process limitations, unclear or inadequate guidelines for ensuring safe blends with natural gas networks are some of the other considerable challenges.

[40] Source: The US Department of Energy- Office of Energy Efficiency and Renewable Energy on *H2@Scale Project* at <https://www.energy.gov/eere/fuelcells/h2scale> accessed 12.09.2019

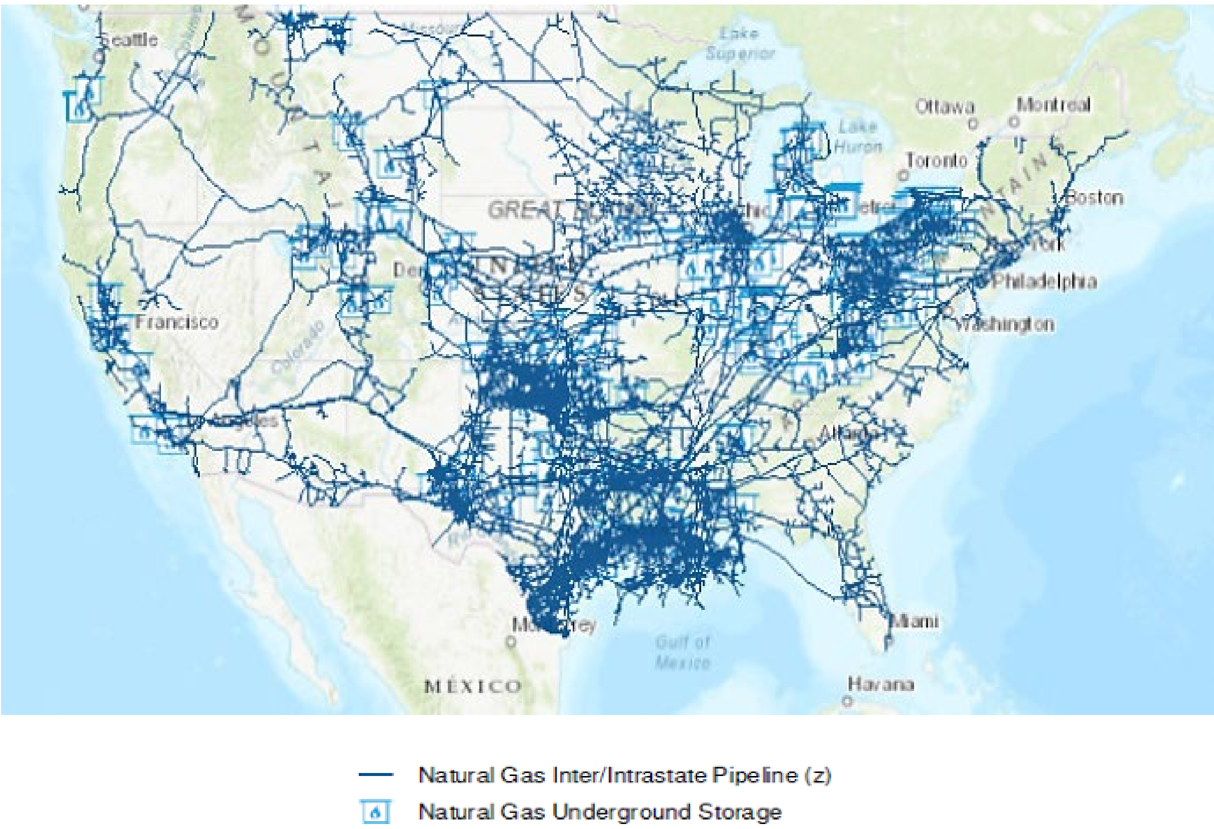
[41] See the US EIA's *Annual Energy Outlook to 2050* (AEO2019) 1-83 at 22 <www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf> accessed 12.09.2019. in its 2050 projections for electricity generation by fuel sources, the US EIA reports that by 2050 39% of electric generation capacity will be fuelled by natural gas, (up from 34% in 2018) while renewables will grow from 18% in 2018 to 31% by 2050. Nuclear is expected to decline from 19% in 2018 to 12% by 2050 while coal continues to decline from 28% in 2018 to 17% by 2050.

[42] Edison Electric Institute, Transmission. <https://www.eei.org/issuesandpolicy/transmission/Pages/default.aspx>

[43] American Gas Association, *Gas Industry Miles of Pipeline and Main by State and Type,* Table 5-3. (2017). <https://www.aga.org/contentassets/71fe352cf6fa4291a29be724ab0622b8/table5-3.pdf>

use in the US.[44] This is enough storage to accommodate 20% of all natural gas consumed in the US. By comparison, storing 20% of the electricity consumed would require 85 GW of advanced battery storage,[45] more than triple the available electrical energy storage installed in the US to date.[46]

Figure 2: US Natural Gas Pipeline Transmission Network and Storage Facilities[47]



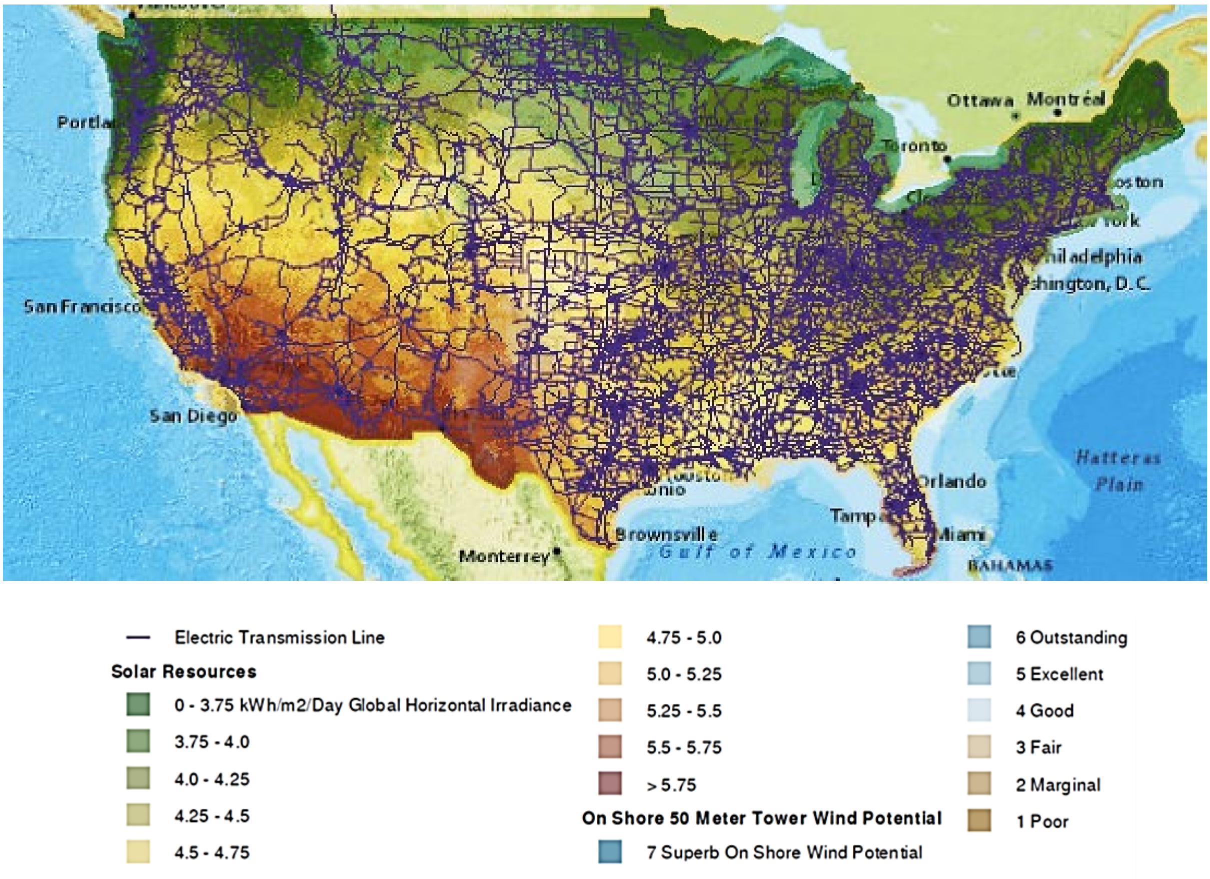
[44] American Gas Association, *Reliable Natural Gas.* <https://www.aga.org/natural-gas/reliable/>

[45] Based on 2017 consumer energy sales of 3,723,356 thousand megawatt hours. United States Energy Information Administration, *Summary Statistics for the United States, 2007 – 2017.* <https://www.eia.gov/electricity/annual/html/epa_01_02.html>

[46] 25.2 GW of installed storage, 94% provided by pumped hydro systems. University of Michigan, Center for Sustainable Systems, *U.S. Grid Energy Storage*. (August 2018). <http://css.umich.edu/sites/default/files/U.S._Grid_Energy_Storage_Factsheet_CSS15-17_e2018.pdf>

[47] The US EIA Energy Mapping System at <https://www.eia.gov/state/maps.php> accessed 19.10.2019. For more about the U.S. natural gas pipeline network and storage see US EIA, *Natural gas explained: Natural gas pipelines Basics* at <www.eia.gov/energyexplained/natural-gas/natural-gas-pipelines.php>

Figure 3: The US Electricity Transmission Network and Geographic Spread of Onshore Wind and Solar Resources[48]



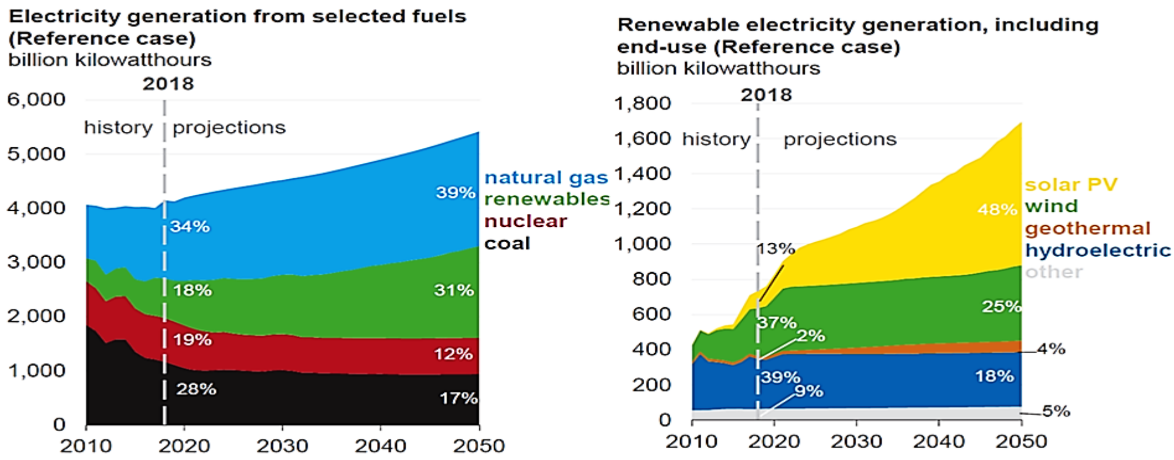
The question for future energy policymakers will be whether the vast gas supply networks can efficiently decarbonize and play a key role in the unfolding energy transition and low-carbon future. Over the past two decades, gas supply networks have become increasingly interconnected with the electricity market,[49] while electricity generated from renewables such as solar and wind is expected to gain more market share onwards to 2050 as shown in figure 4 below.[50]

[48] The US EIA Energy Mapping System at <https://www.eia.gov/state/maps.php> accessed 19.10.2019. The bulk of existing transmission assets is concentrated in the North West and eastern areas that have comparatively less solar and wind energy intensities or resources.

[49] See Oyewunmi (n6) on *Regulating Gas Supply to Power* at 85-96. As the markets and organization of natural gas supply to power developed in the US, the role of gas and network infrastructure also grew since the 1990s till date, driven largely by the policy-led restructuring of the interstate gas market, independent economic regulation initiatives, competitiveness and security of supply edge compared to coal and other base load sources, technological advancements and efficiency improvements in gas-to-power facilities, abundance of gas supply from local shale gas production boom and the attendant effects on reducing the price and costs of gas-to-power, growing fuel-switching patterns from coal to gas for environmental and commercial reasons.

[50] The US EIA (n41) *Annual Energy Outlook to 2050* (EIA19).

Figure 4: US Electricity Generation by Source Outlook to 2050[51]



Notwithstanding the energy storage, reliability, capacity adequacy and intermittency challenges, the utilization of renewable energy sources such as solar and wind continue to grow due to factors such as falling costs of installation and project development, concerns relating to decarbonization and climate change mitigation, demand for new, domestic energy supplies, as well as direct policies such as renewable portfolio standards and federal tax incentives.[52] The remainder of this paper explores the evolving and future scenario, the technologies and assets that are positioned to support the effort, the regulatory bodies that may govern, and the role of law and regulation in its success.

2.1.1. Dissecting the Current Energy Supply System and Operators

The network of electric transmission lines, most of which is depicted in Figure 3 above, comprises the main part of the complex power supply grid in the US, which is often categorized into three interconnected network systems (i.e., the eastern interconnection,[53] the western interconnection,[54] and the Electric Reliability Council of Texas (ERCOT)).[55] Power generation, supply, and consumption within these interconnected network systems could be entirely within a State's territory (i.e. intrastate) or from one state to consumers in another state (i.e. interstate). Operators in the value chain include an extensive collection of (i) public, private, and cooperative utilities; (ii) over 1,000 independent power generators; (iii) seven independent system operators (ISO) and 4 regional transmission operators (RTO)[56] , and (iii) an increasing number of distributed homes and businesses with onsite generating systems.

[51] Ibid at 21-22.
[52] Troy A. Rule, 'Still Growing: How America's Renewable Energy Industry is Surviving in the Trump Era" OGEL 4 (2018) at <www.ogel.org/article.asp?key=3785> accessed 11.09.2019.
[53] Including the region east of the Rockies, excluding most of Texas, but including adjacent Canadian provinces except Québec;
[54] Extending from the Rockies to the Pacific Coast, again including adjacent Canadian provinces.
[55] Covering most of Texas.
[56] See the Federal Energy Regulatory Commission (FERC), *United States Electricity Industry Primer*, Office of Electricity Delivery and Energy Reliability U.S. Department of Energy DOE/OE-0017 (July 2015) 1-92 at 26-28. There are currently seven ISOs within North America, comprising: CAISO—California ISO, NYISO—New York ISO, ERCOT—Electric Reliability Council of Texas; also, a Regional Reliability Council, MISO—Midcontinent Independent System Operator, ISO-NE—ISO New England, AESO—Alberta Electric System Operator, IESO—Independent Electricity System Operator, additionally, there are currently 4 RTOs within North America: PJM—

Wholesale electricity markets formed after the enactment of the Public Utilities Regulation Act 1978 (PURPA)[57] prompted the growth of qualified non-utility generators, including small scale renewables, while the Energy Policy Act 1992 ("EPAct 1992")[58] facilitated the emergence of wholesale electricity generators in the US.[59] FERC also initiated several regulatory actions to introduce competition and a market-based approach to supply, pricing, and access to interstate transmission networks.[60] Among other things, the EPAct 1992 was implemented pursuant to FERC's Order No. 888, 18 C.F.R. pts. 35, 385, and Order 889, 18 C.F.R. pt. 37. In addition, FERC's Order 888 provides that public utilities that own or operate interstate transmission facilities are to file non-discriminatory open access tariffs outlining the minimum terms and conditions for non-discriminatory service. Order 888 also requires utilities to "functionally unbundle" their transmission service from their generation and power marketing functions and to provide unbundled ancillary transmission services. Currently, the traditional wholesale electricity markets exist in the Southeast, Southwest, and Northwest where utilities are responsible for system operations and management, while providing power to retail consumers. Such utilities are vertically integrated to the extent that they own the generation, transmission and distribution systems used to serve electricity consumers.[61]

As a result of Order 888, several transmission network operators and owners formed ISOs from existing power pools, helping to facilitate open access to supply networks. Going a step further, in FERC's Order No. 2000, the Commission encouraged utilities to join regional transmission organizations (RTOs) which, like an ISO, would operate the transmission systems and develop innovative procedures to manage transmission equitably. Each of the ISOs and RTOs have energy and ancillary services markets in which buyers and sellers could bid for or offer generation, capacity, and other valuable services. The ISOs and RTOs use bid-based markets to determine economic dispatch. While major sections of the country operate under more traditional market structures, two-thirds of the nation's electricity load is served in RTO regions. Notably, FERC's Order 1000, issued in 2011, had the effect of requiring transmission operators to cooperate with neighboring systems and to consider state-level policy on such matters as renewable energy, energy efficiency, environmental, and land-use regulatory authorities, so far as decisions by those regulatory bodies impact the ability of the transmission operators to accurately assess system reliability.

PJM Interconnection, MISO, SPP—Southwest Power Pool; also a Regional Reliability Council, ISONE—ISO New England; also an RTO.

[57] Pub. L. 95-617, 92 Stat. 3117 (Nov. 9, 1978).

[58] PL 109–58, August 8, 2005, 119 Stat 594.

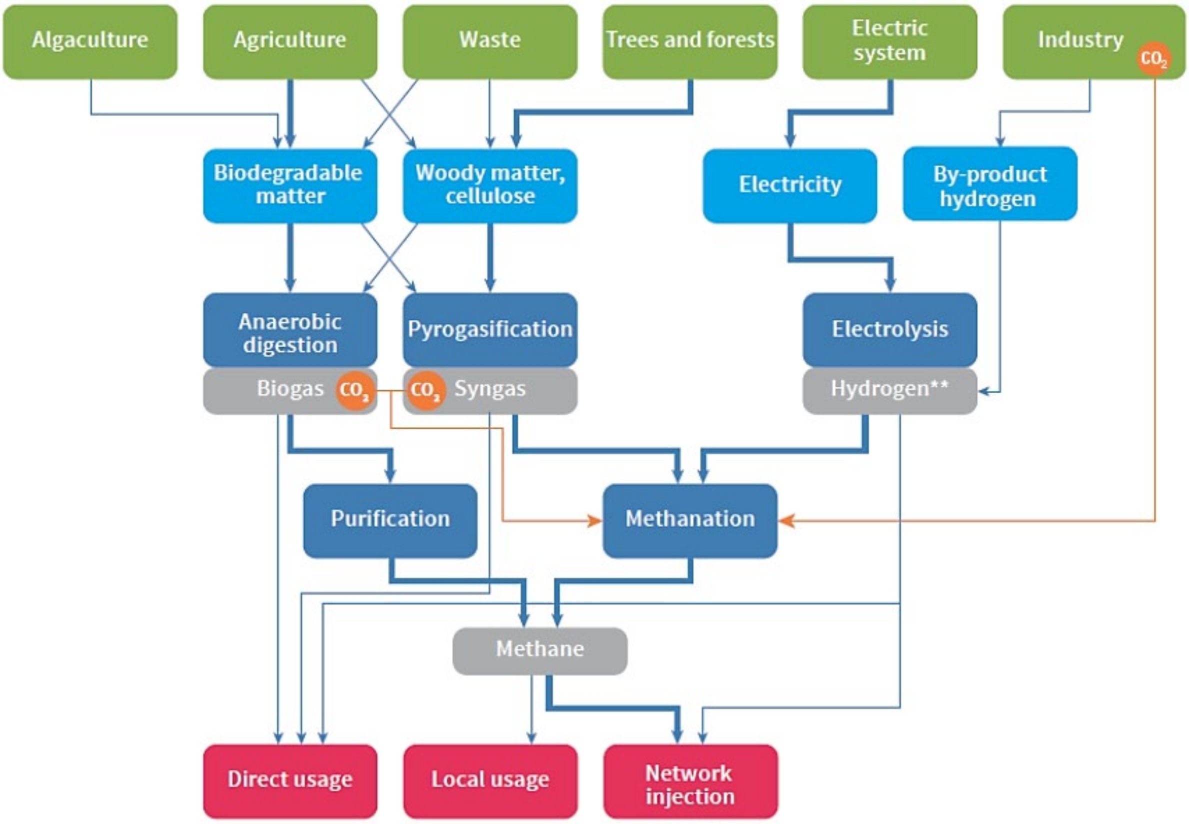
[59] Joseph Tomain and Richard Cudahy, *Energy Law in a Nutshell*, (3rd edition, West Publishing Co., 2016) 394-402.

[60] Ibid at 402-403.

[61] FERC (n56) ibid. Wholesale physical power trade typically occurs through bilateral transactions, and while the industry had historically traded electricity through bilateral transactions and power pool agreements, Order No. 888 promoted the concept of independent system operators (ISOs).

2.2. Renewable Natural Gas (RNG)

Figure 5: The Different Production Channels of Renewable Gas[62]



Renewable Natural Gas is "pipeline quality gaseous fuel derived from biomass or other renewable sources."[63] Two important categories of RNG are worth distinguishing. As depicted in Figure 5 above, the first category includes gaseous fuels that are created by processes not directly associated with energy production. These include waste gases that are collected from a variety of feedstocks, such as wastewater treatment digesters, manure, and other agricultural wastes or landfill gases. These waste gases are captured and either used locally for heat or electricity or conditioned further for injection into an existing natural gas pipeline. Most often associated with methane, a potent greenhouse gas, these waste gases have a large carbon footprint, and their capture results in a carbon-negative fuel supply. This is because methane is

[62] Source: the French Environment and Energy Management Agency (ADEME), *A 100% renewable gas mix in 2050? – Technical/economic feasibility study* (ADEME, 2018) 1-24 at 13-14. RNG comes from three main sectors- (a) Anaerobic Digestion i.e. biological method using micro-organisms to break down organic matter and produce a mixture called biogas which comprises mainly of methane and CO2; (b) Pyrogasification i.e. thermo-chemical methods for producing synthetic gas (comprising of methane, hydrogen, carbon monoxide and carbon dioxide) from organic matter. The process can be completed by methanation or separation to produce a gas whose thermodynamic properties are equivalent to those of natural gas; and (c) Power-to-gas (P2G) which entails the conversion of renewables-based electricity into synthetic gas through the electrolysis process involving water and production of hydrogen. It could also include a second step of converting the hydrogen to methane via a methanation.

[63] See American Gas Association (n7)

25 times more potent in terms of global warming impact than carbon dioxide, which is the resulting emission from natural gas combustion.[64]

A simple way to visualize this positive environmental attribute is a methane capture equal to –25 plus a combustion emission of +1 is equal to a total greenhouse gas impact of -24.[65] The number of RNG facilities in this category has nearly doubled in the last five years.[66] These facilities have the potential to displace up to 10% of natural gas supplied from traditional, fossil-based sources.[67] However, their positive impact on decarbonization, by reducing greenhouse gases, far exceeds their impact on natural gas supply, due to the global warming potential of methane mentioned earlier. One study of a southern California gas utility found that replacing 14% of the gas system's throughout, for that single utility, could achieve the same greenhouse gas reduction as electrifying *all* buildings in California.[68] These environmental benefits have been noted by both regulators and utilities nationwide, and both are moving forward with investments, laws, and policies that support further development of these resources.[69]

Some states have required RNG potential studies and voluntary procurement targets for utilities to further motivate the expansion of this industry.[70] Because these RNG facilities are finding a supportive policy, at least in some states, and because these renewable energy supplies remain isolated within the gas system, this paper does not evaluate the details of capture-based RNG any further than noted above. There are many opportunities for further study associated with these fuels, their end-uses, regulatory support, and the need for incentives. However, the path is much clearer than for the next category: Power to Gas.

Power to Gas in its simplest form is the conversion of renewable electricity to gas, using electrolysis. As shown in Figure 5 above, two gaseous fuels can be produced from these systems: hydrogen and/or synthetic methane. Hydrogen results from the first of two potential processes: electrolysis. By completing a second step in the process, methanation, a P2G system can also produce methane. This second step involves the added benefit of carbon capture, as the chemical conversion of hydrogen to methane requires the addition of a carbon source. In both cases, these systems are categorized as carbon neutral. Hydrogen production and use does not require nor emit greenhouse gasses. Methane production requires carbon as an input, which creates a carbon-sink. Methane's end-use, however, involves combustion and release of carbon

[64] United States Environmental Protection Agency, Global Warming Potentials. <https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>

[65] This does not include upstream impacts associated with potential land use changes.

[66] Danigelis, Alyssa. Energy Manager Today, *Renewable Natural gas Production Facilities Grow by 85% in four years*. (April 20, 2018). <https://www.energymanagertoday.com/renewable-natural-gas-production-growth-0176212/>

[67] American Gas Foundation, *The Potential for Renewable Gas*, p.1. (Sept 2011). <http://www.gasfoundation.org/researchstudies/agf-renewable-gas-assessment-report-110901.pdf>

[68] Navigant Consulting, *Gas Strategies for a Low-Carbon California Future*, p.42. (2018)

[69] State of Nevada SB154, <https://www.leg.state.nv.us/Session/80th2019/Bills/SB/SB154.pdf> , Oregon SB98, <https://olis.leg.state.or.us/liz/2019R1/Downloads/MeasureDocument/SB98/A-Engrossed>, and California CA SB 605 <https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB605>

[70] In Oregon, a SB98 for Renewable Natural Gas Bill was recently signed into law which outlines the objectives of adding as much as 30% RNG into the state's pipeline system. The new law sets voluntary RNG goals for Oregon's natural gas utilities. Additionally, it: (i) allows utility investment in the interconnection of renewable natural gas production; (ii) supports targets of 15% by 2030, 20% by 2035 and 30% by 2050; and (iii) provides local communities a potential revenue source to turn their waste into energy.

dioxide, thus the synthetic methane produced by P2G is carbon-neutral.[71] These fuels can then be used on-site for heat or electricity or injected into the natural gas pipeline system.

Because Power-to-Gas systems rely on electricity as the primary input, it is imperative that this energy comes from low-carbon or carbon-neutral renewable sources to make any logical argument for its greenhouse gas benefits. The most interesting quality of P2G systems though is not necessarily their direct impact on greenhouse gas reductions. It is, instead, their interaction with the electric system and their role in overall energy management. The systems' ability to utilize electricity in novel ways creates opportunities that do not exist with other, more traditional loads.

There is now a growing class of energy consumers in an increasingly decentralized electricity value chain, because of the distributed nature of renewable energy generation and energy storage systems. With the adoption of ancillary technologies such as net metering and smart meters, electricity supply stakeholders that were previously primarily consumers can sell excess energy they produce to the conventional grid and also provide essential grid services such as storage, efficiency, and demand response. This growing class of electricity sector stakeholders are widely referred to as 'prosumers'.[72]

The P2G option and concept aligns well with the evolving paradigm in which consumers and suppliers of distributed renewable-based electricity are increasingly involved in grid reliability issues, demand response, and energy storage.[73] Conversely, it could also be argued that scaling-up P2G adds additional regulatory complexity to the natural gas and electricity regulatory framework from a legal and institutional perspective.[74] For instance, policymakers would have to consider issues such as (i) what is/are the most effective approach(es) and rules for access regulation and pricing in shipping or storing hydrogen produced via P2G in existing natural gas systems; and (ii) which institutions (state or federal) will oversee the development of P2G projects and transactions involving interstate or intrastate supply or supplies for bulk 'storage' purposes.

3. Regulatory Oversight of P2G

In order to address the regulatory complexity of power to gas systems, it is beneficial to evaluate each market supply separately, before we can understand the interplay between the two. P2G's electric supply can be reasonably procured from a variety of sources and markets and by a diverse number of buyers as shown earlier in Figure 1 above. Energy can be sourced from three basic categories: Interstate transmission, intrastate transmission, and distribution, or local generation. The first two are traditional "grid" supplies, while the third is most commonly associated with isolated systems such as co-generation or self-generation facilities, where no connection to external grids exists, thus, mostly independent of distribution networks. Another

[71] Evaluation of carbon footprint for P2G systems does not include lifecycle emissions associated with renewable energy production, land use changes, or other potential contributors to greenhouse gas emissions such as material or equipment fabrication.

[72] Sharon B. Jacobs, 'The Energy Prosumer' (February 1, 2017), 43(3) Ecology Law Quarterly 519-580; Amy L. Stein, 'Distributed Reliability' (2016) 87 U Colo L Rev 887 to 1008. <https://pdfs.semanticscholar.org/a12e/e551544803fd04803c359b2ec9fe4aef6f91.pdf>

[73] Power-to-Gas-to-Power systems add a third step to the process, where synthetic methane is combusted in a standard gas-fired turbine to produce electricity.

[74] Jacobs (n72) supra. See also Oyewunmi (n6) in *Regulating Gas Supply to Power Markets* at 86-101 on 'Economic Regulation and Restructuring in the US Gas Supply Industry'.

example of this isolated generation could include local microgrids, where energy is physically isolated to local infrastructure.[75] The locational aspect of the sourced energy is key in identifying whether power is purchased in wholesale or retail markets, or outside of existing market structures. The importance of these market differences, if not already apparent, will be detailed further in this section.

In addition to the physical location of energy offtake, power purchasers range from private firms and power marketers to traditional investor-owned electric utilities. Because the ultimate product in most power-to-gas systems is gaseous fuel (i.e. hydrogen or synthetic gas), there is a high likelihood that gas producers and gas utilities also become power purchasers. Additionally, on the issue of energy purchases, there are notable differences in regulatory oversight when traditionally regulated firms are involved. Gas utilities are typically associated with local distribution networks and are regulated by state Public Utility Commissions and institutions. Such gas utilities could also own and operate interstate pipelines, thus subject to the jurisdiction of the Federal Energy Regulatory Commission.[76] This distinction is significant as we look to identify the regulatory framework affecting power-to-gas systems, their energy supply, and their gas production.

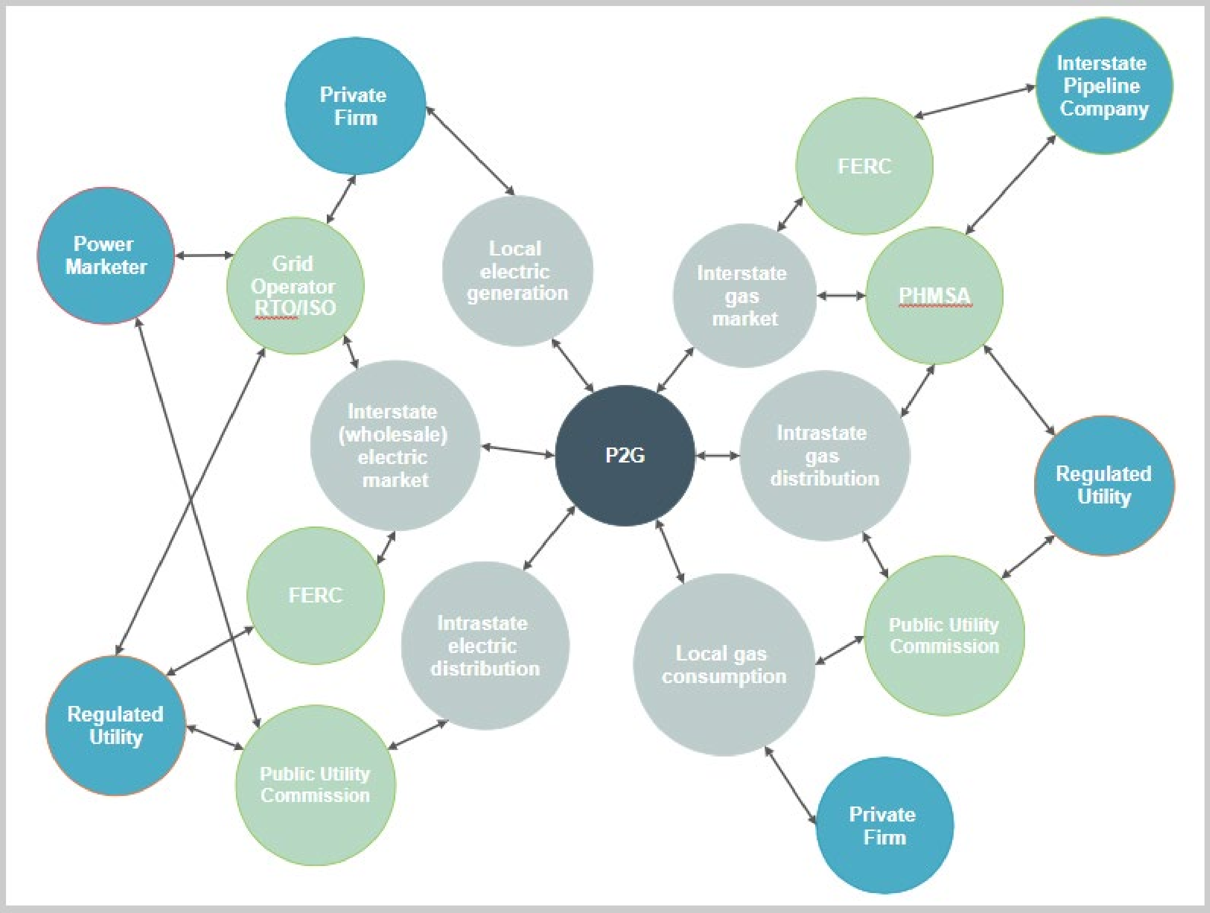
The final group of variables that must be considered is the ultimate disposition of the gas from the P2G system. Here too, we see a wide array of options available to P2G facilities. The first, and by far most simplistic in terms of regulatory obligations, would be consumption. In this case, gas is combusted locally, eliminating the interaction with pipelines or other existing infrastructure. This consumptive use can be expanded to include the broader category of power-to-gas-to-power, where the resulting renewable gas is combusted in a steam turbine system, for electric generation. While arguably the least efficient use of the P2G system, it is a route worth exploring. The more likely scenarios involve existing pipelines and underground storage systems. P2G products could be transported through interstate pipelines, distribution systems, and/or retained in underground storage fields for future use or transport.

As detailed above, the energy source, the identity of the P2G developer, and the disposition of gas can each play a pivotal role in the ultimate framework affecting these systems. Figure 6 shows this intricate relationship.

[75] Ton, Dan T. and Smith, Merrill A., The Electricity Journal, *The U.S. Department of Energy's Microgrid Initiative, p.* 84, (2012). <https://www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy's%20Microgrid%20Initiative.pdf>

[76] Federal Energy Regulatory Commission, Section 311 Pipelines. <https://www.ferc.gov/industries/gas/gen-info/intrastate-trans/section-311.asp>

Figure 6: Power-to-Gas regulatory interactions by power source and gas disposition[77]



3.1. Energy procurement

In order to understand the policies and regulations affecting P2G facilities, each of the potential sources outlined above is further discussed throughout this section, categorized at the federal, state, and local levels of jurisdiction. For purposes of this discussion, it is generally assumed that these categories are synonymous with each of the potential energy sources: interstate transmission, distribution, and on-site generation, respectively, unless specifically noted. Additionally, it is assumed that any firm type has open access to each category of energy supply.

a. Federal

Interstate energy supplies require electric transmission systems and are primarily managed by RTOs and ISOs in the United States. Many of these grid operators have also developed and now manage robust energy markets as a means of understanding risk associated with the system, and the supply more generally. These energy markets are commonly referred to as wholesale markets, as they are the primary resource for traditional utilities, power producers, and power marketers to secure or sell energy that is not covered by other supply contracts, such as power purchase agreements (PPAs). Because the majority of transactions in these markets occur as a means to serve a consumer that is *not* the buyer, these activities are "sale for

[77] Author's own diagram

resale."[78] These transactions are clearly regulated by the Federal Energy Regulatory Commission (FERC).[79] However, in a Power-to-Gas system, the energy purchased in wholesale markets is no longer a "sale for resale" because it is consumptive.[80] Therefore, in the case of P2G, the purchase of energy from the wholesale market does not immediately, nor clearly trigger FERC jurisdiction as a wholesale transaction.

The next question to consider focuses on the delivery of electricity to the purchaser or P2G facility owner. If electricity is purchased directly from a generator on the wholesale market and transmitted via the interstate transmission lines, such activity will ordinarily be within the FERC's jurisdiction.[81] For many large industrial customers with access to transmission lines, FERC rates are part of the total cost of energy, meaning a P2G facility would pay FERC-regulated rates for moving electricity to the point of consumption. However, the P2G facility is unlikely to be directly regulated by FERC, as it is simply a consumer. Recently, as private firms have shown an increased demand for renewable energy and/or lower-cost energy, this scenario is becoming more prevalent.[82] While a direct, physical connection is possible for a P2G system to directly access the transmission system, it is not necessary to take advantage of wholesale energy supplies. Facilities can connect to the grid wherever it may be convenient, including through lower-voltage distribution lines, while still benefitting from wholesale market access. Systems designed to purchase energy wholesale but be physically connected to low voltage distribution would require additional coordination with the local utility and fees for the use of the system.

By purchasing energy from the wholesale market, P2G systems maximize potential income-earning opportunities. Facilities also have the option of bilateral contracts, or Power Purchase Agreements (PPAs) between a renewable energy supplier and the P2G facility. To date, however, PPAs offer considerably less flexibility and remain insulated from day-ahead, and spot market pricing. While PPAs are ideal for investors and developers looking for price stability, P2G's benefits stem most directly from its ability to perform under volatile market conditions. The buyer (the P2G facility) would provide more grid services if they were to bid demand into the wholesale market, based on specific price signals, minimum load requirements, or curtailment orders. These conditions are variable and restricting a P2G system's response to these market signals limits the benefit to the facility, by limiting access to the lowest cost energy, increasing the likelihood that excess electric supply goes unutilized.

Wholesale markets are regulated by FERC but managed by RTOs and ISOs in most regions. These organizations are given considerable latitude under FERC's oversight to develop rules and markets to suit the needs of their regional energy supply, including interconnection approvals. For instance, the New York ISO (NYISO) which was launched in 1999 following FERC approval, covers the entire state of New York and thus, is responsible for operating wholesale power markets that trade electricity, capacity, transmission congestion contracts, and related products, in addition to administering auctions for the sale of capacity.[83] Likewise, the

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[78] Federal Power Act, Section 201 (b)(1), U.S.C. § 824 (d)
[79] Ibid
[80] With the exception of Power-to-Gas-to-Power applications, energy is used, not resold.
[81] Federal Power Act, Section 201 (b)(1), U.S.C. § 824 (b)
[82] Penndorf, Sarah, 3 Degrees, *Renewable energy power purchase agreements*. (February 5, 2018). <https://3degreesinc.com/latest/ppas-power-purchase-agreements/>
[83] See FERC's Electric Power Markets: New York (NYISO) at <www.ferc.gov/market-assessments/mkt-electric/new-york.asp> (accessed 12.09.2019). NYISO operates New York's high-voltage transmission network and performs long-term planning. The chronic transmission constraints in NYISO are in the southeastern portion of the state, leading into New York City and Long Island as a result of significantly higher energy demand in

PJM Interconnection is the RTO that operates a competitive wholesale electricity market and manages the reliability of the transmission grid in all or part of 13 states in the US.[84]

Ultimately, an RTO must have commission-approved tariffs that outline how the market rules will impact transmission costs, reliability, and wholesale markets.[85] Rules which may incentivize power-to-gas systems would impact both system reliability and payments to P2G facilities from ancillary service markets. These ancillary service payments are part of market-based rates, requiring FERC approval when initially developed by the RTOs.[86]

For many purchasers, such as utilities or existing power marketers, purchasing energy for power to gas systems would not spur any unique oversight from FERC. Because the markets and their rules are managed by FERC, market participants are bound more closely to the rules of the RTOs. For purchasers that are not already market participants, such as private firms or gas producers, there is a requirement that these firms register as Market Participants in the appropriate regional market. This activity is often regulated by state utility commissions, in terms of who may register and/or participate in wholesale markets, as noted below.

Future consideration of P2G in FERC and RTO rulemaking is discussed further below, as P2G facilities are likely to behave similarly to other distributed energy resources (DERs) and energy storage systems. Both DERs and storage systems have recently been evaluated by FERC, but these decisions have not included, nor specifically addressed power to gas as a player in such markets. This is an area of future policy development and expansion.

b. State level

Electric purchases within each state may originate in wholesale energy markets, as described above. Alternatively, P2G facilities can simply interconnect with existing distribution systems and purchase energy through their local electric utility. This arrangement is familiar to consumers, regulators, and utilities and would function similarly to other commercial or industrial energy use. Energy purchases in this system are regulated by each state's public utility commission and any relevant tariffs of the utility. Here too, overarching policies from

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those areas. With growing ambitions to push on with decarbonization, the New York's Clean Energy Standard was revised in 2019 to require 100% carbon-free electricity by 2040 although currently about 29% of New York's in-state generation at both large- and small-scale facilities come from renewable sources. In addition, natural gas, nuclear power, and hydroelectricity have provided more than nine-tenths of New York State's net generation since 2012. More than half of New York's generating capacity is at natural gas-fired power plants, and about two-thirds of that capacity is at units with dual-fuel capability that can use either natural gas or petroleum. To boost power supply from renewables and foster a more reliable and efficient integration of expected growth in renewable-energy based electricity, the NYISO will be expected to play a key role in coordinating and managing the energy and capacity markets.

84 See the FERC's *Electric Power Markets: PJM* at <https://www.ferc.gov/market-assessments/mkt-electric/pjm.asp> accessed on 12.09.2019. the 13 states covered by OJM includes Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia and the District of Columbia. The PJM's markets include energy (day-ahead and real-time) and it also provides open access to the transmission and performs long-term planning. In managing the grid, PJM centrally dispatches generation and coordinates the movement of wholesale electricity capacity and ancillary services.

85 Final Rule; Order 2000A on Rehearing, *Regional Transmission Organizations*, F.E.R.C. STATS & REGS. ¶ 61,201 (2000). <https://www.ferc.gov/legal/maj-ord-reg/land-docs/2000A.pdf>

86 Final Rule; Order 697, *Market-Based Rates for Wholesale Sales of Electric Energy, Capacity and Ancillary Services by Public Utilities*, F.E.R.C. STATS & REGS. 119 FERC ¶ 61,295 (2007).<https://www.ferc.gov/whats-new/comm-meet/2007/062107/E-1.pdf>

FERC and the RTOs dictate activities within the markets by non-utility firms, even when purchasing at the retail level.[87]

Arguably more important than access to markets, at the state level, is the presence or absence of supportive policy. As noted earlier, state RPS laws have fostered a significant acceleration of renewable electricity, primarily from wind and solar. However, few of these include innovative technologies like renewable natural gas, as qualified producers.[88] Those that do, require that renewable gas be used for electric generation. Therefore, only power-to-gas-to-power facilities would have the potential to meet such standards. A secondary question arises for P2G systems, with respect to certifying the power generated from their system: Would power purchased from the grid have to be from renewable sources, in order to qualify under RPS programs? By design, the power to gas systems would be taking excess renewable energy from the grid, and only that energy, because it is the most economical option for P2G systems. However, it could be argued that the secondary generation, in power-to-gas-to-power systems, is produced via renewable natural gas, a gas that can be produced endlessly, so long as electricity is available. Though, this argument is unlikely to resonate with the spirit of the RPS regulations and policy. Therefore, a power-to-gas-to-power facility is expected to purchase verifiable renewable energy in order to participate in RPS programs.

Lastly, energy purchases made by regulated utilities must undergo additional evaluation by State utility commissions, where they will be scrutinized against "prudent", "least-cost", and "used and useful" standards.[89] While seemingly familiar, power-to-gas facilities are due proper consideration under this assessment. If an electric utility is the owner-operator of a P2G facility, the initial investment would undergo rigorous approval processes to determine its usefulness and the appropriate rate of return. However, the ongoing operation may trigger a broader discussion on whether the subject P2G system is utilized in a sufficient capacity to qualify as "used" by commissioners. Additionally, electric utilities' purchases of energy for the P2G facilities will be judged against the least-cost and prudency benchmarks. In the ideal P2G system, power purchases would only be made in times of surplus, thus eliminating the competition between utility customers and its P2G operations.

c. Local level

Considering the option for on-site, local P2G facilities, there are few regulatory triggers related to the necessary electricity. For private firms, locally generated electricity is analogous to the now-familiar rooftop solar, or off-grid movement.[90] The driver behind such movements is the absence of regulatory oversight and independence from grid infrastructure. P2G systems could exist today, without connections to the electric grid, and have no regulatory requirements other than those associated with siting and local operations. For these systems, the more tangible oversight occurs at the point of production of the gaseous fuel, be it hydrogen or methane.

[87] Example of overlapping market rules is evidenced in F.E.R.C. Order 745, where market access is dictated by state utility commissions, but compensation and market rules are constructed by the F.E.R.C for the RTOs. Final Rule; Order 745, *Demand Response Compensation in Organized Wholesale Energy Markets*, F.E.R.C. STATS & REGS. 134 FERC ¶ 61,187 (2011). <https://www.ferc.gov/EventCalendar/Files/20110315105757-RM10-17-000.pdf>

[88] National Conference of State Legislators, *State Renewable Portfolio Standards and Goals.* (February 1, 2019) <http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx>

[89] State of Vermont Public Utility Commission, Electric Alternative Regulation. <https://puc.vermont.gov/electric/electric-alternative-regulation>

[90] Thompson, Cadie, CNBC News Website, *Why living off the grid will get a lot easier in 25 years.* (November 27, 2014). <https://www.cnbc.com/2014/11/27/why-living-off-the-grid-will-get-a-lot-easier-in-25-years.html>

While this option can reasonably produce gas, without interacting with electric regulations, this is not necessarily true for power-to-gas-to-power systems. Generating power on the back end of these systems triggers many of the federal and state regulations discussed earlier, potentially including net metering policies.

While not specifically Power-to-Gas, one illustration of this local option is the landfill gas system. Through methane capture systems, landfills serve as RNG producers. In most cases, the RNG is combusted on-site to produce energy. As with other renewable fuels, landfill gas production is variable, and thus not perfectly matched to on-site energy demand. Net-metering, also known as net-billing or net-generation can apply to landfill gas generation in the same way it applies to residential rooftop solar, for any excess electricity produced at the landfill, assuming it is connected to the grid.[91] However, if these systems are not conveying electricity to the grid (i.e., locally isolated) then excess gas, not utilized for electric generations could be transported to the gas grid. The structure of these systems, and the current RNG markets have created alternative opportunities for landfills to redirect captured and conditioned RNG to pipelines. This flexibility means that these systems may interact with regulatory structures in a similar fashion to power-to-gas systems, in that they have touchpoints with both electric and gas market rules, laws, and regulations.

3.2. Gas Supply Arrangements

Power to Gas systems, as previously noted, have the capability of converting electric energy to gaseous fuel, typically hydrogen or methane. Methane, in this regard, is in the form of synthetic natural gas, and thus similar to conventional, fossil-based natural gas for purposes of this discussion. The technical and physical features of hydrogen bring up issues on its compatibility with existing gas networks which calls for a critical consideration of things like blending limits, effects on pipeline integrity, and the compatibility with a variety of end-use infrastructure.[92] A further consideration of the technical and physical concerns are beyond the scope of this paper. Rather, the aim is to highlight the potential roles of P2G in the integration of renewables in existing electricity supply structures from a policy and regulatory perspective.

The transmission of methane or hydrogen produced via P2G is analogous, in many ways, to the procurement of energy already discussed. Compared to electricity, the gas system has one key distinction worth noting, even if apparent to most readers. Natural gas supply does not need to be instantaneously matched to demand. Natural gas can be stored (e.g. in empty aquifers, depleted reservoirs, and/or underutilized pipelines), and therefore does not rely solely on the transmission and distribution pipelines that make up the gas "grid." Applicable laws and regulations are dependent upon the disposition of the gas, specifically whether the gas is injected into pipelines, where along the system gas is introduced, and whether it is fully or partially combusted on-site. The following sections follow the same structures, with federal, state, and local regulatory oversight detailed throughout. Here, we also expand on the storage potential of natural gas and energy in a gaseous form.

The gas industry in the US was largely restructured between the 1980s to 2000s, resulting in the unbundling and deregulation of competitive segments such as upstream production and downstream sales and marketing, as well as the development of economic regulation and an

[91] Interstate Renewable Energy Council, *State and Utility Net Metering Rules for Distributed Generation*. (April 27, 2012) <https://irecusa.org/wp-content/themes/IREC/includes/dsire-xml-feed/fs-net-metering-table.php>
[92] Lambert (n8) ibid; Fleming and Fershee (n8) ibid.

open-access regime to midstream transmission networks. Regulation for interstate supplies is through FERC, while local distribution is regulated at the state level.[93] Although wholesale prices are generally set by competitive markets in various hubs, state public utility commissions can exercise regulatory authority over retail gas prices and are responsible for consumer protection, natural gas facility construction and environmental issues that are not covered by FERC or the Department of Transportation (DOT).[94] Importantly, there are numerous natural gas marketers, who serve as middlemen to connect producers and end-users by offering both bundled and unbundled services.[95]

a. Federal level

As noted above, the management of pipeline infrastructure, for reliability purposes is slightly less onerous than the equivalent electric system. Whether driven by key technical differences or a dissimilar industry history, the natural gas grid is not managed by regional transmission operators (RTOs) like the electric transmission system. Electric grid operators' role ensures the physical stability of the system, but also key balancing of supply and demand. The equivalent manager on the gas system is the transmission pipeline owner. Interstate pipeline owners manage their available capacity and balance supply and demand via transportation contracts. FERC regulates these natural gas pipelines through cost-of-service tariffs, which would affect the rates for P2G facilities transporting gas through interstate assets.[96] Unlike electric RTOs, pipeline operators align gas quality requirements and other rules across the national system.[97] Electric RTO rules and wholesale markets are regional and do not necessarily align from region to region. Natural gas markets are therefore much more streamlined, with less variational across the system.[98]

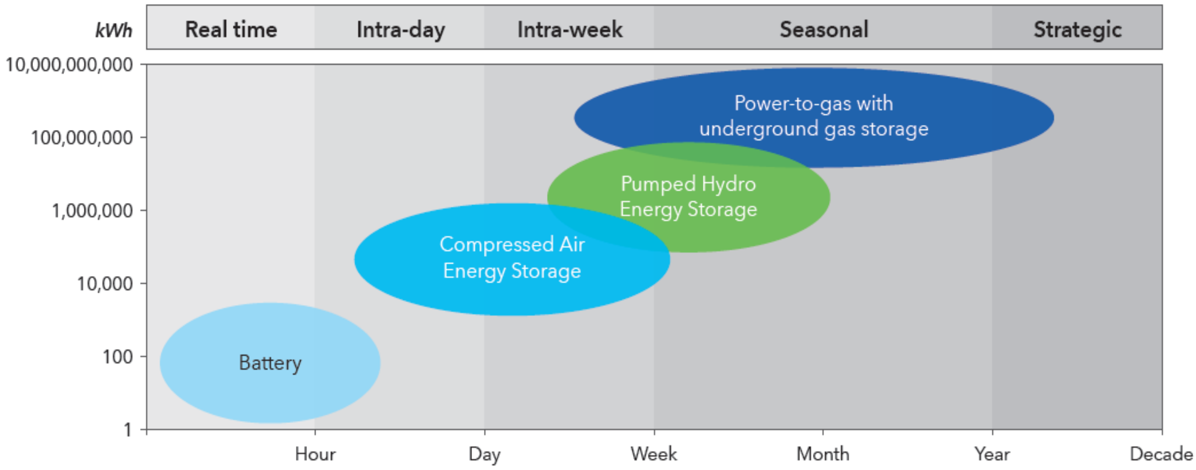
For P2G systems, the most likely point of interaction with federal regulations is the physical connection (i.e., the interconnect) to an interstate pipeline, should the location or technical requirements require it. Connecting to this interstate system pulls the subject P2G pipeline under FERC's jurisdiction, and would require the same Certificate of Public Convenience and Necessity that is required of any new interstate pipeline.[99] If the P2G facility retains ownership of the pipeline, additional operational regulations begin to apply. The Pipeline and Hazardous Materials Administration (PHMSA) under the federal Department of Transportation (DOT) manages the construction, operation, and maintenance of interstate pipelines and natural gas storage to ensure public safety.[100] PHMSA also regulates the transportation of hydrogen but recognizes the need for further research and development if new infrastructure is necessary for

[93] Oyewunmi Oyewunmi (n6) on *Regulating Gas Supply to Power* at 85-96 the International Energy Agency (IEA), *Energy Policies of IEA Countries: United States 2019 Review,* (IEA Publications, 2019) 1-280 at163
[94] Ibid.
[95] Ibid.
[96] The Federal Energy Regulatory Commission, Cost-of-Service Rate Filings.<https://www.ferc.gov/industries/gas/gen-info/rate-filings.asp>
[97] Interstate Natural Gas Association of America, *The Interstate Natural Gas Transmission System: Scale, Physical Complexity and Business Model*, p.7. <https://www.ingaa.org/file.aspx?id=10751>
[98] American Petroleum Institute, Understanding Natural Gas Markets, p. 16.<https://www.api.org/~/media/Files/Oil-and-Natural-Gas/Natural-Gas/API-Understanding-Natural-Gas-Markets.pdf>
[99] United States Permitting Dashboard, Certificate of Public Convenience and Necessity for Interstate Natural Gas Pipelines. <https://www.permits.performance.gov/tools/certificate-public-convenience-and-necessity-interstate-natural-gas-pipelines>
[100] United States Department of Transportation, PHMSA Regulations. <https://www.phmsa.dot.gov/phmsa-regulations>

expanded production.[101] Assuming most early P2G system would utilize existing natural gas pipelines, and blend hydrogen with natural gas, then the existing rules would apply.

By converting renewable electricity to natural gas, significant storage capacity can also be realized. Natural gas storage offers medium to long-term seasonal storage options, which are familiar to gas operators, as opposed to the hourly or daily capacities offered through current battery technologies, a comparison depicted in Figure 7 below. Over-reliance on battery technologies also comes with risks of vulnerability to the few supply sources for the inputs of building batteries themselves such as cobalt and lithium which are only available in a few countries globally.[102]

Figure 7: Storage capabilities over time, by storage resource type[103]



PHMSA retains federal oversight of natural gas storage operations, in both pipelines and underground storage reservoirs. Currently, electric RTOs do not consider P2G plus storage, and thus only view these systems as consumptive. If P2G systems have the capability to pull gas out of storage, either from pipelines or from underground reservoirs, and convert that back to electricity, those systems would align more directly with FERC and RTO rules being developed around energy storage and DERs.[104] With few projects are developed beyond pilot stages; therefore, it is too early to determine whether this flexibility will be economically viable.

b. State level

It is possible for P2G systems to be co-located with storage and remain within the confines of the local distribution system. Intrastate gas storage companies could utilize P2G as supplemental supply for peak demand, with gas injected directly into the distribution pipeline

[101] 49 CFR Part 192, as referenced by United States Department of Transportation, PHMSA Website. <https://primis.phmsa.dot.gov/comm/Hydrogen.htm?nocache=5671>
[102] See Kevin B. Jones et al., *The Electric Battery: Charging Forward to a Low-Carbon Future* (Praeger, 2017) 1-212 at 39-42.
[103] Schulze, et al., (n10) ibid on European Power to Gas,
[104] Final Rule; Order 841, *Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators.* F.E.R.C. STATS & REGS. 162 FERC ¶ 61,127 (2018). <https://www.ferc.gov/media/news-releases/2018/2018-1/02-15-18-E-1.asp#.XUylJ-hKg2w>

or local reservoirs. If the P2G operator is also the owner of the distribution pipeline, then the regulatory oversight would be limited to the public utility commission. For non-utility firms needing to connect to the distribution system, an interconnection agreement with the local utility would be required. Unlike interstate pipelines, the safety of intrastate pipelines is managed by the public utility commissions. In some states, underground storage is also managed by state agencies overseeing oil and gas operations, distinctly separated from pipeline transportation. For example, in Michigan, the Department of the Environment, Great Lakes, and Energy oversees surface facilities, like P2G, connected to gas storage reservoirs.[105] In Texas, however, the Railroad Commission would regulate all facets of P2G gas production, with and without storage.[106] Unique to state energy policy, and also unique to oil and gas production, is the concept of waste prevention.[107] These conservation regulations do not necessarily apply to P2G facilities, but such waste prevention policies could be expanded to incentivize P2G and renewable gas production facilities, a recommendation further explored below.

Another unique point of regulation for local P2G systems may be the disposition of hydrogen into fuel cells. While this research did not investigate the ultimate disposition of produced fuels (i.e., end-use), storage of hydrogen for local fueling stations is expected to be regulated at the local and state level. To date, California is the only state with publicly accessible hydrogen fueling stations, which are regulated by the California Air Resources Board and Department of Transportation.[108,109]

c. Local level

Like electricity procurement and generation, producing gas for local combustion triggers few if any additional laws and/or regulations. Examples of P2G systems that may utilize this local model include co-generation facilities that may combust produced gas on-site, for local heating systems or industrial processes. Because the gas is not being placed in a pipeline for transport off-site, the federal and state regulations governing transport and sale of gas do not apply. Combusting gas for on-site electric generation may involve net-metering rules of the local utility if excess electricity is exported to the grid.

4. Power-to-Gas and the Benefits of Developing an Integrated Policy Framework

The novelty of P2G is the fact that the whole is greater than the sum of its parts. Electric consumption is not created equal, nor is renewable gas production interchangeable with fossil gas development. Power to gas systems, as described throughout this paper, offer opportunities to flatten supply curves, reduce curtailment, alleviate grid congestion, and store energy. These benefits allow the electric system to take on greater percentages of intermittent energy

[105] Michigan Department of the Environmental, Great Lakes, and Energy, Oil, Gas, and Minerals Division. <https://www.michigan.gov/egle/0,9429,7-135-3306_57064---,00.html>

[106] Railroad Commission of Texas, Railroad Commission Authority and Jurisdiction. <https://www.rrc.state.tx.us/about-us/resource-center/faqs/railroad-commission-authority-and-jurisdiction-faq/>

[107] Joel Eisen et al., *Energy, Economics and The Environment: Cases and Materials* (University Casebook Series, 4th edition, Foundation Press, 2015) 1-1089 at 169.

[108] US Department of Energy, Energy Efficiency and Renewable Energy, *Hydrogen Laws and Incentives in California.* <https://afdc.energy.gov/fuels/laws/HY?state=CA>

[109] US Department of Energy, Energy Efficiency and Renewable Energy, *Hydrogen Fueling Stations*. <https://afdc.energy.gov/fuels/hydrogen_stations.html>

resources, like wind and solar, and defer or eliminate costly investments in electric transmission expansions.

Power-to-Gas systems also have the ability to sequester carbon and decarbonize heat and transportation fuels. While not discussed in detail in this paper, many other studies and policy initiatives have outlined the importance of the latter, in terms of meeting larger greenhouse gas reduction goals.[110] Seeking significant reductions in greenhouse gas emissions, or carbon-neutral societies, will require a significant shift in energy system design. The current question among industry analysts and policymakers is whether the electric system alone can supply enough renewable energy, at a swift enough pace, to meet decarbonization targets, while maintaining energy reliability, security of supply, and environmental sustainability. Recent studies suggest that aggressive electrification models achieve end-use penetration of only 52% by 2050 while continuing to rely on natural gas for electric generation.[111] Such aggressive electrification is expected to double the demand for electric supply by 2050,[112] further stressing current grid infrastructure. In order to accommodate this level of electrification, considerable costs are anticipated to complete necessary upgrades to transportation systems and bolster generation supplies.[113] A 2018 study modeled an aggressive electrification profile, assuming 100% electrification of residential and commercial buildings, in addition to significant electrification of several industrial processes. That study concluded that electrification alone can achieve only a 20% reduction in greenhouse gas emissions.[114]

In order to achieve notable reductions, closer to 70%, significant grid decarbonization must occur, in the form of increased low-carbon supply. The same study assumed 33% of electric supply would come from wind and solar, with an additional 22% from other low-carbon sources like nuclear.[115] Yet, "… these combined measures…are insufficient to achieve the 2050 emission levels indicated by climate scientists to reduce the most severe impacts of climate change."[116] 28% of the electric supply, in that model, is still sourced from natural gas. Therefore, looking at electric supply alone, decarbonization of gas supply has considerable value. When the end-use of natural gas is added to this system-wide emission profile, we see that low-carbon and carbon-neutral renewable natural gas has a significant role to play in decarbonizing energy supplies. European studies have shown that minimizing gas use, often as part of larger, policy-driven electrification, increases the costs of decarbonization. Alternatively, by utilizing existing gas infrastructure to supply renewable natural gas and hydrogen, one study estimated that across all sectors, the European Union can save 217 billion Euros per year, when compared to the "minimal gas" scenario studied.[117] This detailed analysis

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[110] Partridge, Audrey, e21 Initiative, *Decarbonizing Natural Gas End Uses in Minnesota*. (June 11, 2019) <https://e21initiative.org/decarbonizing-natural-gas-end-uses-in-minnesota/>; Van Melle, Timme, et al., Navigant for Gas for Climate Consortium, *Gas for Climate: How gas can help to achieve the Paris Agreement target in an affordable way.* (February 15, 2018). <https://www.gasforclimate2050.eu/gas-for-climate>

[111] Electric Power Research Institute, *US National Electrification Assessment,* p. 8, (April 2018). <http://ipu.msu.edu/wp-content/uploads/2018/04/EPRI-Electrification-Report-2018.pdf>

[112] Mai, Trieu, et al., IEEE Power Magazine, An Electrified Future: Initial Scenarios and Future Research for US Energy and Electricity Systems, p. 35, (July/August 2018), <http://www.nxtbook.com/nxtbooks/pes/powerenergy_070818/index.php#/36>

[113] Plas, Patrick, Green Tech Media, *Expediting a Renewable Energy Future with High-Voltage DC Transmission.* (July 6, 2017). <https://www.greentechmedia.com/articles/read/expediting-a-renewable-energy-future-with-high-voltage-dc-transmission#gs.wflqpm>

[114] Mai (n112), p.44

[115] Mai (n112), p.42

[116] Mai (n112), p.45

[117] Van Melle (n110), p. 92

of the European energy system is a reasonable proxy for the United States, with the exception of Europe's early adoption and implementation of hydrogen fuels across multiple sectors.

4.1. Proactive, Integrated Policy: Next Steps

The US electric energy landscape, as it exists today, is a complex web of regulated, semi-open, and fully open markets.[118] This variability is typically created from the absence of a national renewable energy standard and the general flexibility granted to the states in recent court decisions.[119] While natural gas markets are generally more streamlined, a patchwork of renewable natural gas laws and regulations has been developed.[120] On the whole, however, the regulation of renewable natural gas has, thus far, mirrored its fossil-based counterpart.

As demonstrated from this preliminary research into power-to-gas, the legal construct that exists today is capable of regulating P2G facilities. Power-to-gas is unique when viewed as a holistic energy system. But, when viewed through the lens of jurisdiction, the system functions as two separate points of regulation: electric consumption and gas production. Power-to-gas-to-power systems add a third: electric generation. Undoubtedly, the latter creates another layer of complexity, yet does not stray from the existing framework for such generators.[121] As already outlined above, these systems provide added value above their contribution to their respective, segregated markets, and future regulation must recognize and incentivize these multi-industry benefits to achieve maximum decarbonization potential.

Existing laws and regulations are agnostic to the benefits P2G systems provide. This approach is by design, where RTO/ISOs are concerned. While neutrality may be appropriate for system operators, it does not satisfy, nor align with the greater policy goals of state and federal lawmakers seeking to decarbonize energy supplies.

From the RTO/ISO Council (IRC) report on Emerging Technologies, several key positions were identified in the pursuit of increased renewable penetration.[122] Two of these positions are especially relevant.

1. *[The IRC] Generally supports policies and positions that recognize the electricity system's ability to reliably and efficiently accommodate large-scale amounts of renewables and realize their growing technological potential.*
2. *[The IRC] Is agnostic to specific technologies that may be applied to the renewable integration problem while simultaneously ensuring that policies include the greatest possible optionality for new and emerging technologies to be applied to renewable integration.*

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[118] Retail Energy Supply Association, State by State programs. Available at: https://www.resausa.org/states
[119] *Rocky Mountain Farmers Union v. Corey*, 730 F.3d at 1089, as referenced in Denning, Brannon, Case Western Reserve Law Review, *Environmental Federalism and State Renewable Portfolio Standards.* (2014) Vol 64, Issue 4, p. 30. Available at: https://scholarlycommons.law.case.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1159&context=caselrev
[120] State of Nevada (n69)
[121] Public Utility Regulatory Policies Act, 16 U.S.C. ch. 46 § 2601 et seq
[122] RTO/ISO Council, *Emerging Technologies: How ISOs and RTOs can create a more nimble, robust bulk electricity system*. (March 2017), p.6. Available at: https://isorto.org/wp-content/uploads/2018/05/PUBLIC_IRC_Emerging_Technologies_Report.pdf

If the goal of system operators is to integrate as much renewable electricity as possible, while balancing the grid reliability, then power-to-gas is at least an equal competitor with battery storage. Yet, the recent ruling by FERC relating to energy storage makes no mention of gas as an energy storage medium, nor the potential of existing storage assets to play a role in seasonal capacity.[123] The final rule instead creates a split definition of energy storage that prioritizes a storage resource's ability to "inject electric energy back onto the grid" while remaining neutral on the storage medium:

> *"The Commission stated that this definition is intended to cover electric storage resources capable of receiving electric energy from the grid and storing it for later injection of electric energy back to the grid, regardless of their storage medium (e.g., batteries, flywheels, compressed air, and pumped-hydro)."*[124]

This definition is supportive of Power-to-Gas-to-Power systems, as these facilities would be "physically designed and configured to inject electric energy back onto the grid."[125] However, FERC Orders 841 and 841a do not address energy conversion systems, like P2G, despite the ability to provide analogous grid services, while achieving improved storage capacity. Furthermore, Order 841 requires RTOs/ISOs to revise tariffs in order to establish a participation model for electric storage resources. One of the requirements of the participation model is that the RTOs "ensure that a resource using the participation model can be dispatched and can set the wholesale market clearing price as *both* a wholesale seller and wholesale buyer consistent with existing market rules."[emphasis added][126] This obligation further limits the participation of P2G in storage markets by requiring facilities to be wholesale sellers to the electric market. In order to take full advantage of P2G, it is preferable to move produced gas into other markets in need of decarbonization, such as heat and transportation. Additionally, hydrogen can be redirected to energy storage via hydrogen fuel cells. None of these pathways currently qualifies under FERC's rules for electric storage resources. FERC's interpretation of storage resources is decidedly focused on electricity storage, rather than energy storage. The resulting framework, therefore, excludes P2G and any benefits it may bring to the grid. FERC could consider segregating the buyer-side participation from the seller-based obligation, by lifting the dual requirement in Order 841. This would allow P2G facilities to participate as a storage resource, without the responsibility of returning power to the grid.

Alternatively, because the most significant benefits of P2G occur on the demand-side of the electric market, FERC could also consider P2G as a distributed energy resource (DER). Though traditionally defined as a generation resource on the distribution system, the interpretation has evolved to include a wide variety of resources and interactions with the energy system, depending upon jurisdiction. Currently, FERC's proposed definition is

> *"A source or sink of power that is located on the distribution system, any subsystem thereof, or behind a customer meter. These resources may include, but are not limited*

[123] FERC Order 841a, Order on Rehearing, *Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators* (2019). Available at: https://www.ferc.gov/whats-new/comm-meet/2019/051619/E-1.pdf
[124] F.E.R.C. Order 841(n104) as quoted in Order 841a, Ibid
[125] F.E.R.C Order 841a (n123)
[126] F.E.R.C. Order 841(n104)

to, electric storage resources, distributed generation, thermal storage, and electric vehicles and their supply equipment."[127]

This definition continues to exclude non-generation and non-electric resources. A preferred definition and one that is likely to suit power-to-gas applications is from National Association of Regulated Utility Commissioners (NARUC):

"A resource sited close to customers that can provide all or some of their immediate electric and power needs and can also be used by the system to either reduce demand (such as energy efficiency) or provide supply to satisfy the energy, capacity, or ancillary service needs of the distribution grid. The resources, if providing electricity or thermal energy, are small in scale, connected to the distribution system, and close to load."[128]

By including ancillary services, demand reduction, and thermal energy in their definition, NARUC leaves the door open for novel DERs like power-to-gas systems. If FERC were to adopt a similarly broad definition, then P2G may have access to wholesale markets as DERs as an alternative pathway to storage. As of the writing of the paper, FERC has not yet issued the long-awaited order on distributed energy resources; therefore, a definitive interpretation of what constitutes a DER does not yet exist.

What these two examples demonstrate is a clear focus by FERC on electric energy resources. While not surprising, the scope of FERC's oversight does not preclude them from taking a broader view. In 2012, the Commission issued an Order directing further conferences and reports on the interaction of natural gas and electric industries.[129] While this order was focused on improving the knowledge and coordination of the sectors as it related to natural gas generation, the same coordination need can be identified for power-to-gas applications. FERC is in a unique position, with authority over both electric and gas transmission assets. By taking an integrated view of both systems, the agency could leverage the assets and capabilities of both to foster a more efficient system, with a higher percentage of renewable energy resources. Regulated States also have this advantage, with Public Utility Commissions retaining authority over both electric and gas distribution systems. Here too, the Commissions have the capability to regulate both sectors to maximize the overall efficiency and decarbonization pathways.

Some preliminary framework already exists in State policy. As mentioned earlier,[130] State regulation of oil and gas development is based in significant part on the concept of waste avoidance, and these policies are generally known as Conservation Regulation. This regulation is meant, traditionally, to prevent the physical waste of valuable oil and gas resources, prevent economic waste, and protect correlative rights.[131] While drafted during the last century, and ever-evolving, these conservation regulations establish a valuable history of regulating for

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[127] Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators, 157 FERC ¶ 61,121, at P 1 (2016) as referenced in FERC Staff Report, *Distributed Energy Resources Technical Considerations for the Bulk Power System,* p. 8, (February 2018), <https://www.ferc.gov/legal/staff-reports/2018/der-report.pdf>

[128] National Association of Regulatory Utility Commissioners, Distributed Electric Resource Manual at p. 45, as referenced in Ibid, p. 9

[129] Order directing further conferences and study, C*oordination Between Natural Gas and Electricity Markets,* 141 FERC ¶ 61,125 (2012). <https://www.ferc.gov/whats-new/comm-meet/2012/111512/M-1.pdf>

[130] Eisen (n107)

[131] Anderson, Owen, University of Arkansas Law Review, *The Evolution of Oil and Gas Conservation Law and the Rise of Unconventional Hydrocarbon Production*, Vol 68, p.241, (2015). <https://law.uark.edu/alr/PDFs/68-2/68ArkLRev231-Anderson-Foreword.pdf>

efficiency and waste reduction. In the systems discussed throughout this paper, it is evident that, across multiple sectors, there are ample opportunities to reduce or avoid waste energy.

Specifically, as already outlined, curtailed renewable energy and vented methane are two readily identifiable sources of waste that could be prevented. The federal Bureau of Land Management (BLM), in 2018, drafted a rule designed to minimize waste associated with oil and gas development on BLM land, and limited venting and flaring of methane.[132] This rule is an expansion of traditional conservation regulation by including vented gas, a byproduct or waste of development. State Conservation Commissions, or other agencies with authority for such regulations,[133] could reasonably amend conservation regulation to address similar economic and energy waste, depending upon the authority granted each agency under state law. Alternatively, the responsibility for these conservation rules could be shifted to utility commissions, with the intent of managing all energy resources under a single entity. Where this model fails is in deregulated states, where many functions of the utility commissions are no longer relevant and where energy systems are managed primarily by market design. In these states, and as an option in regulated states, new agencies could be created to address energy management in all its forms, regulated and unregulated, gas and electric, with the goal of creating the most efficient, lowest carbon system possible, at a reasonable cost. A drastic shift from business as usual, expanding conservation regulation beyond conventional oil and gas development could provide a route for cross-industry synergies that today are unrealized, such as power to gas and renewable natural gas.

With this mindset, States also have the opportunity, via legislative action, to expand Renewable Portfolio Standards to gas utilities. To date, no state has taken this step and there are no equivalent RPS laws governing natural gas. Similar in function to an RPS, some states have set voluntary targets or study requirements around renewable natural gas, but none have set strict limits. For the regulated gas utility, an RPS would provide the same benefit as demonstrated in the electric utility. It would serve to drive demand for renewable natural gas and lower technology costs while providing a mechanism for utilities to invest in these systems. Without this definitive and clarifying legislative solution, regulated utilities are typically unable to pursue such innovative solutions, even if those solutions offer low-carbon options for customers or provide reliability benefits via storage. These are generally not least-cost options and are therefore unlikely to pass the scrutiny of some regulators. However, some progressive states, including North Carolina and California have recognized the benefits of renewable natural gas, primarily biogas, and have begun building frameworks to capture waste from agricultural operations. But, even in states fostering waste reduction, most renewable gas is still routed to electric generation or vented to the atmosphere. A gas RPS would ensure RNG has value as an end-use fuel, without conversion to electricity.

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[132]Waste Prevention, Production Subject to Royalties, and Resource Conservation; Rescission or Revision of Certain Requirements.83 Fed. Reg. 49,184 (Sept. 28, 2018) <https://www.govinfo.gov/content/pkg/FR-2018-09-28/pdf/2018-20689.pdf>

[133] Many States have retained specific agencies to oversee Oil and Gas operations and Conservation regulations, including but not limited to Idaho, Wyoming, West Virginia, Colorado, and Arizona. Other states, however, have delegated Conservation regulation to other agencies. Michigan's conservation rules are managed by the Department of the Environmental, Great Lakes, and Energy. Texas conservation regulation is managed by the Railroad Commission of Texas.

5. Conclusion

Power to Gas and Renewable Natural Gas have the potential to contribute significantly to the decarbonization pathway of not only the energy industry but other economic sectors as well. These innovative solutions exist today, and as outlined throughout this research they can be reasonably assimilated into existing laws and regulations. However, RNG and P2G are positioned just as renewable electric generation was two decades ago, with few supportive policies to move the needle. Even in the absence of federal clean energy laws, market demand and state RPS laws have shaped the renewable electricity market. In order to realize the greatest potential penetration of renewable electricity on the grid, novel technologies, like P2G are necessary. Likewise, decarbonizing heating and transportation fuels will require equally innovative solutions. Renewable electric resources created a blueprint for regulators, which can be expanded to other industries, including natural gas. While technological advancement and markets would undoubtedly foster innovative solutions such as P2G, it is unlikely this will occur within a relevant timeframe, meaning without legislative or regulatory intervention, P2G is unlikely to aid the realization of essential greenhouse gas emission reduction goals. Therefore, it is imperative that regulators and policymakers begin to evaluate the energy system in a more holistic and integrated context, to capture all available technologies and pathways for decarbonization, including renewable natural gas and power-to-gas systems.