A UNIQUE WIN-WIN:

BOLSTERING TEXAS' ENERGY SECURITY BY LEVERAGING EXISTING INFRASTRUCTURE TO EFFECTIVELY DECARBONIZE

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Abstract

The 2021 Texas Winter Storm *Uri* was a watershed moment for many Texans regarding energy security. The statewide incident exacerbated an increasing tension between climate-centric sustainability goals and power demands anchored to energy security. While environmental activists saw decarbonization as even more critical, traditional energy advocates saw the need for hydrocarbons and pointed out liabilities created by unpredictable wind and solar. Despite these views, through innovative collaboration, it may be possible to generate a scenario that benefits the Texas economy and delivers on the goals for all advocates.

By making prudent use of existing infrastructure and embracing hydrocarbons, Texas can play a significant role in driving an economic resurgence that achieves greater decarbonization than a general shift toward renewables. Bountiful natural gas reserves position Texas uniquely to continue its exploration and production of methane, utilize its existing multi-million-mile pipeline network, and facilitate the generation of carbon-free hydrogen without new infrastructure buildouts, regulatory compliance, or waiting times associated with traditional decarbonization strategies. Moreover, this solution blending industry action with public policy would mean increased demand and consumption of natural gas – benefiting the economy – while potentially reversing the carbon balance of the energy sector through the use of a pre-combustion carbon capture technique to decarbonize natural gas to facilitate distributed hydrogen production.

Specifically, this would avoid the need for expensive new hydrogen pipelines or storage tanks, reduce the need for traditional carbon capture solutions, and save time and regulatory compliance associated with large-scale centralized hydrogen production and accompanying infrastructure requirements.

This type of strategy would not only benefit the energy sector but could satisfy even the objectives of the climate-centric sustainability advocates. What makes this solution unique is that it also offers potential to improve state infrastructure resilience. The pre-combustion carbon capture process (utilizing thermal methane pyrolysis on-site) results in clean hydrogen and solid carbon black. That carbon is in a powder form and can be sequestered into infrastructure like roads, bridges, sea walls, other construction materials and energy components, both lowering their own production-side carbon intensity and strengthening their structural integrity.

If policymakers embrace this solution and industry actors adopt it, Texas would be able to boast of its energy security, booming energy economy, and the resilience and utilization of its infrastructure, all while leading the decarbonization front and advancing sustainable practices that do not threaten another power demand crisis like 2021. Given the novelty of this model, several policy bumps may need to be cleared and industry actors informed of the potential and its tradeoffs. This report serves as a qualitative review of quantitative data found elsewhere to present a novel framework to achieve multiple industrial and policy goals simultaneously.

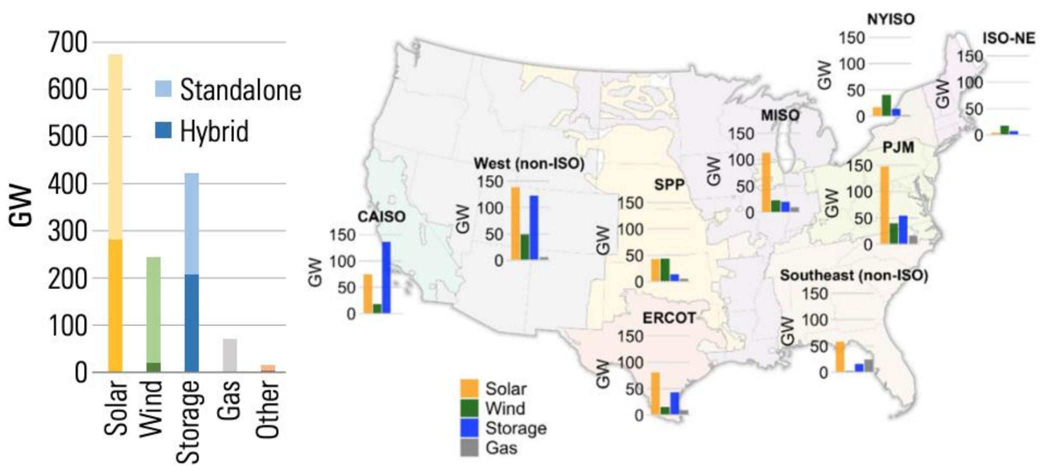
Introduction and Overview

Energy is fundamental to modern life, but ensuring its security, accessibility, and affordability is a delicate balance between public policy and industry action. Texas is a crucible for these issues and stands out within both the nation and the world given that it hosts robust supplies of oil and natural gas, the highest mileage of pipelines, and its own electrical grid. Texas also leads the nation in wind energy and has made strides toward lowering its grid emissions. This has created a tension with energy security, most prominently provoked during Winter Storm Uri in 2021. The path toward energy security and the resilient grid capable of delivering lower emissions is actually achievable, but it takes innovation and collaboration between industry and policy makers.

Integral to energy security is the reliability of our energy systems. All the power generation in the world is useless if systems cannot carry it to end users. The independent Texas grid, named after the Electric Reliability Council of Texas (ERCOT), comprises thousands of miles of high voltage power lines connecting energy projects from across the state. Many of those lines connect to the wind farms in the western region of the state and to the many power generation facilities burning hydrocarbons to produce electricity. Reliability concerns or failures of the electrical grid mean customers and citizens of Texas do not have access to power.

The 52,700 miles of transmission lines in Texas will not be enough for expected future demand. Additional growth of the energy sector and policy hurdles that hinder the efficient construction of transmission infrastructure will lead to greater congestion and higher costs that create new vulnerabilities for Texan and their energy grid.

Figure 1. Power Plants Seeking Transmission Connection by Type (left) and Mapped to Region (right)



Notes: (1) Hybrid plants are those paired with one or more other type of generation or storage. (2) Data for Alaska and Hawaii were not collected. Represents queues as of the end of 2021.

Figure 1: Supply to Transmission Gap. (Source: US Dept of Energy)[1]

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[1] U.S. Department of Energy. (2022). *Queued Up…But in Need of Transmission*. United States. Department of Energy. Retrieved from https://www.energy.gov/sites/default/files/2022-04/Queued%20Up%E2%80%A6But%20in%20Need%20of%20Transmission.pdf.

As of 2021, Texas had over 150 GW in capacity waiting to be connected by transmission lines for wind, solar, and storage projects.[2] As ERCOT and the U.S. Department of Energy report, "Texas anticipates major east-west in-state congestion as demand grows."[3] If the state moves further toward electrification, this congestion and long transmission building times will only worsen.

A solution therefore is needed that delivers energy security, relieves strain, provides robust energy, and can be implemented quickly in a sustainable fashion. Doing so through renewables and electrification would be running harder into the same challenges already in place, while centralized green hydrogen production would result in the same with further added infrastructure requirements. Traditional nuclear power is expensive and slow largely due to public policy requirements and engineering standards, while small modular reactors are not yet commercially available. Even needed policy changes like permitting reform are not positioned to quickly enough level the roadblocks to prevent further deadweight loss.[4]

In fact, this problem is not exclusive to a shift toward electrification as a decarbonization strategy. More demand for transmission will come from a general demand for more power on the one hand and from the need to retire or replace older transmission infrastructure at the end of its lifecycle and to ensure resilience for the future. Reducing the demand on transmission capacity and the need for new transmission infrastructure requires looking away from traditional growth in energy capacity. Renewables generate electricity directly, while other energy sources like hydrocarbons are generally used to produce electricity which is added onto the grid. Non-grid solutions for decarbonization that can still produce high amounts of energy[5] are the location to look for energy security and environmental benefit.

All of these considerations require leveraging the infrastructure already in place and avoiding solutions that would require new power generation, new power storage, or new power transmission. It also requires leveraging a resource that is resilient to changes in weather, temperature, and other conditions and can be utilized at all hours. That is central to the energy security versus environmental debate, because hydrocarbons are reliable but lead to emissions, while renewables are intermittent while not producing source emissions.

The issue in 2021 was not primarily that the grid itself failed – that is the electrical transmission and distribution lines – but that generating facilities were unable to put enough power onto the grid. Wind was not blowing in the plains (or the turbines were not winterized to withstand the weather), connection points and facilities froze up or were not able to function properly, and in some cases, certain pipelines failed to deliver their product reliably. It was an energy security failure in a state primarily known for its abundant energy resources. The irony though was not a

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[2] *Id.*

[3] U.S. Department of Energy. (2023). *National Transmission Needs Study*. United States Department of Energy. Retrieved from https://www.energy.gov/sites/default/files/2023-12/National%20Transmission%20Needs%20Study%20-%20Final_2023.12.1.pdf.

[4] Dierker, B. (September, 2023). *Pathways to Decarbonizing Heat: Building a Holistic Framework for Evaluating and Ranking Decarbonization Strategies for Industrial Heat in Light of Economic Efficiency, Public Policy, Timing Readiness, and Infrastructure Realities*. Alliance for Innovation and Infrastructure.

[5] Although not necessarily electricity. A broader use of energy here includes process heat and other energy applications in addition to electricity generation.

failure to tap resources, but a failure of infrastructure to facilitate their utilization. The path to security, therefore, runs through infrastructure itself that has inherent resilience and a long-proven track record.

To enhance energy security, Texas can capitalize on its abundant and valuable natural resources, which entails continued exploration and production of natural gas. The state can also continue to make prudent use of wind and solar as well as nuclear and complementary power sources. But to reduce vulnerabilities and prevent added strain or long wait times, the state's focus must leverage certain infrastructure networks already in place. In Texas, that means a half million miles of pipelines.[6]

By focusing on pipelines, which remain buried beneath the surface and far less susceptible to weather events or surface/air-level risks, the pipeline network is best positioned for resilience and therefore delivering energy security. The payload it carries is energy dense and reliable. But it comes with a drawback – making effective use of that resource often means combustion, which results in emission of carbon dioxide and certain harmful pollutants.[7]

The innovative solution would not aim to avoid the methane and the inherent carbon it involves, but to utilize them. In doing so, Texas can increase its energy capacity without needing to build new transmission lines or other pipelines. Making the most of existing infrastructure to maximize and create new value avoids costs for infrastructure build outs, time delays to put new projects into service, legal challenges and permitting regulations, and more.[8]

Given that Texas critical infrastructure includes assets and systems owned by the private sector and public, including multiple Fortune 500 companies in the energy and transportation sectors, new solutions must seamlessly blend private action with public policy to effectively serve large populations.[9,10] Such collaborative approaches require all parties and stakeholders to be informed and aligned. Failure to agree on the process may undermine key elements or lead to other vulnerabilities and risks like those that Uri revealed.

Moreover, while the state must effectively combat cascading effects, it is incumbent on legislators and policymakers to seek innovative solutions that not only prevent downstream failures, but that can generate positive knock on effects that ripple upstream to solve problems. This potential to not only leverage challenges but convert them into direct wins may change the relationship policymakers have with infrastructure. This may ultimately foster a circular

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[6] Railroad Commission of Texas. (2021). *Texas Pipeline System Mileage*. Retrieved from https://www.rrc.texas.gov/pipeline-safety/reports/texas-pipeline-system-mileage/.

[7] U.S. Environmental Protection Agency. *Chapter 1: External Combustion Sources - Section 4: Boilers*. Retrieved from https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s04.pdf.

[8] Dierker, B. (2023). *Why Renewables Will Fail, Unless…*, Alliance for Innovation and Infrastructure. https://www.aii.org/why-renewables-will-fail-unless.

[9] Ladd, C. (2022). *What's Critical - A Sector-by-Sector Tour of Critical Infrastructure in Texas*. Texas Office of Homeland Security. Retrieved from https://kec-txtp.teex.tamus.edu/Resources/documents/2022%20The%20Conference/What%E2%80%99s%20Critical%20-%20%20A%20Sector-by-Sector%20Tour%20of%20Critical%20Infrastructure%20in%20Texas.pdf.

[10] Peterson, D. (2022). *The Myth of 85% of U.S. Critical Infrastructure Being Privately Owned*. Retrieved from https://www.linkedin.com/pulse/myth-85-us-critical-infrastructure-being-privately-owned-peterson/.

economy with a positive feedback loop that benefits those seeking more sustainable energy practices and those promoting and reliant on hydrocarbons, while offering physical infrastructure advocates a solution as well.

Finally, leaders should prioritize cross-sectoral collaboration by pairing assets and liabilities among seemingly unrelated sectors. Texas can leverage its highly-rated energy sector, which the American Society of Civil Engineers (ASCE) rated as a B+ and aid the state's D+ rated highways and roads.[11] If optimized, this relationship would uplift both sectors at once, improving resilience, and bolstering critical infrastructure components.

Gap Assessment and Problem Statement

Within policy debates, there often tend to be two camps that, either by perception or in reality, are at odds with one another. These may even be multiplied and compounded across the political landscape. For example: Republican v. Democrat, Industry v. Regulators, Oil and Gas v. Renewables, Energy Security v. Emission Reduction, and other competing factions.

These oppositional dynamics can lead to false choices, where compromise is ineffective or only one priority wins over another. Along with these tensions are fundamental realities: we do need to expand and improve our infrastructure, we do need energy security, and we do need to improve the resilience and emission reduction of the grid.

Many believe the primary gap is technical – that the physics and engineering specifications needed do not overlap with the priority goals to achieve the many varied interests all at once. But the primary gap is often communication. Parties talk past one another, lack a shared vocabulary, or begin with such different presuppositions that they seem unable to meet on one plane of collaboration.

These factors have set Texas up for both a challenge and potential for leadership through innovative partnerships. Texas has vast reserves of natural gas. There is also a broad movement in favor of reducing the emissions of the grid. At the same time, energy security is of utmost importance. As the fatal winter storm revealed in 2021, Texas was not prepared to deliver energy to all of its residents. The rare event brought the contentious dynamics to greater light than ever before, potentially setting back dialogue and progress for years.

A single weather event capable of causing such a toll in human life and economic impact was a wake up moment for the single point of failure of the grid. The cascading effects therefrom include deaths and hospitalizations, economic losses, and as detailed above, elevated the temperature in policy debates and hindered effective communication and collaboration needed to advance the resilience of the grid, the potential for robust energy, the securing of energy supplies, the limitation of emissions, and the overall state of critical infrastructure.

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[11] American Society of Civil Engineers. (2021). *Texas Infrastructure Report Card 2021*. ASCE. Retrieved from https://infrastructurereportcard.org/wp-content/uploads/2021/07/TxIRC_2021_Brief.pdf.

In many ways, each wing of advocacy doubled down on its own solutions. For those concerned about having enough power, hydrocarbons are the key. For those concerned about the environment and mitigating the effects of climate change, renewables are they key.

A challenge that remains is the background regulatory framework. Even if all parties were agreed that wind and solar were the best solution, this would lead to increased need for land acquisition, eminent domain, permitting for the energy project itself along with onerous environmental and cost/benefit studies, and then all of these factors for the new transmission lines to connect the power.[12] The difficulty and time to achieve this solution would be costly, and at least a decade delayed.

If all parties agreed to fossil fuel usage, there would be reliable and robust power generated, but emissions would continue or even increase. Each of these has a cost and a benefit, but it centers on the energy sector. Innovative partnerships can reduce the costs, increase the benefits, and generate positive production externalities that bolster other sectors.

Topic Discussion

Over recent decades, the state of Texas has gone to great lengths to mitigate the potential for a single point of failure. While operating its own distinct grid, such action is essential. The long-term energy strategy has sought – and to a great extent achieved – this objective by creating a dynamic base of energy sources. These in turn also reduce source emissions. But the same investments in low-carbon energy, such as wind power, has served as one of the points of vulnerability to energy security. Uri made this clear.

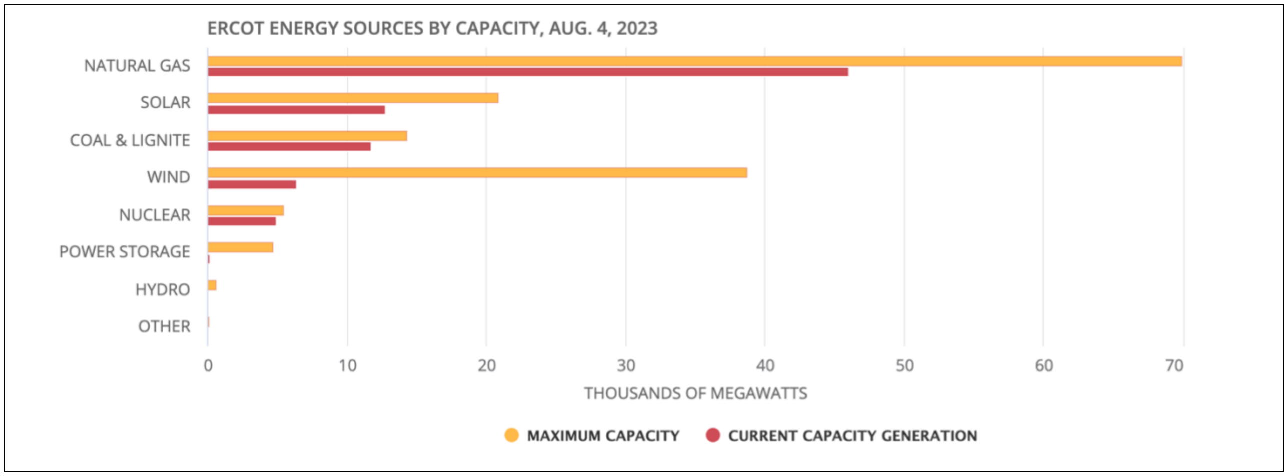

Figure 2: Texas energy assets and output (source: Texas Comptroller)[13]

It is noteworthy that the capacity versus generation output is most unrealized with wind power. That is because installed capacity only means potential, but if the wind is not blowing, 40 GW capacity leads to zero power generation. By contrast, natural gas, which also does not always

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[12] *Supra*, note 8.

[13] Texas Comptroller. (2023). *Economy.* Texas Comptroller of Public Accounts. Retrieved from: https://comptroller.texas.gov/economy/economic-data/energy/2023/ercot-snap.php.

achieve its full capacity, here *currently generates* well over the *maximum capacity* of wind. This is facilitated by the pipeline network and the abundance of the resource.

We cannot rely on capacity alone, so installing more wind power cannot be the solution. As *Figure 1* demonstrates, this also adds to backlogs for transmission demand. Policymakers and industry must reconsider plans and priorities that add demand to an overburdened system. This removes added power generation capacity as a solution from the slate of available options to deliver meaningful results most quickly.

Hydrogen has been proposed as a way to achieve emission reductions.[14] Solutions like wind and solar add demand directly, while centralized green hydrogen production would do so indirectly, first by requiring new capacity from wind and solar and their accompanying transmission infrastructure, and then by requiring new infrastructure to produce, compress, store, and transport the hydrogen.

Thinking about the problem as power generation helps reveal many of these infrastructure contingencies and their associated timelines and costs, but we can tend to think only in terms of infrastructure. The above context though helps see what challenges make the infrastructure topic so complicated. To change perspectives on the topic of energy security and balancing power with environmental impact, it may help to think about the problem chemically.

Natural gas is primarily composed of methane, which is CH_4. Hydrogen is not found naturally, but it is produced in the form of H_2. Burning natural gas leads to carbon dioxide and other emissions, so the challenge is leveraging CH_4 to produce H_2 without the C becoming an offending molecule. The problem is much simpler when looking at these basic elements, because all the potential already exists within natural gas, whereas wind or solar are more abstract power sources and require infrastructure and technology to harness.

To align with the objective of not increasing demand or necessitating new infrastructure, the conversion of natural gas into hydrogen must be distributed rather than centralized. A distributed solution happens across the system, often on site at points of use. A centralized process would bring inputs to one location, then send out a product from that location – inherently requiring new infrastructure and transportation solutions.

A distributed, or decentralized, process leverages the existing natural gas pipeline network, meaning the same natural gas that currently flows through the same natural gas pipelines as today can continue to do so without new infrastructure required. The gas is already routed to natural gas users at commercial and industrial scales. Then, once the gas has entered the facility, but before it is burned, it can be fully decarbonized using a number of techniques, including pyrolysis.

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[14] Hydrogen can be used to generate electricity, which could add demand to the grid or bring the emissions level down from current grid capacity. It can also be used to lower the emissions for industrial and commercial process heat, where it is burned directly on site, with no new infrastructure needed. Finally, it can be utilized in fuel cells for electric vehicles and similar applications.

While many methods of pyrolysis exist, using different levels of energy input, catalysts, and with different outputs, a thermal methane pyrolysis method is best suited to achieving all the goals the various stakeholders seek.[15,16,17]

The process uses heat to decompose the methane molecule into its carbon and hydrogen components – only the hydrogen remains gaseous, and the carbon is a solid. This process effectively decarbonizes natural gas, resulting in the very H_2 and C output that avoids carbon dioxide emissions. The heat reaction can begin with the natural gas entering the system, which would result in trace source emissions, but as soon as the system is functioning, it can be sustained on its own hydrogen.

A feedback loop then allows natural gas to enter the system, breaking CH_4 into $2H_2$ and C. The thermal process can be sustained with H_2 running back to maintain the temperature, while the other H_2 enters the facility to be burned either in a blend or in place of the natural gas that would otherwise have entered a forge, furnace, boiler, or other combustion chamber.[18] The carbon is collected from the system as a powder known as carbon black. It never enters the atmosphere and remains a solid, providing both an effective decarbonization method that is so verifiable it can be seen and held, while also offering itself as a valuable input to be employed elsewhere.[19]

Potential Benefits

The impacts of this type of model span critical infrastructure in both direct and indirect ways. It delivers on all the competing goals primarily because it leverages existing infrastructure to avoid new build outs, wait times, and regulatory compliance. A solution like this can be implemented immediately, with immediate results.

The Texas economy would stand to see benefit. Because this solution leverages natural gas, it would result in continued exploration and production. By sustaining a thermal reaction with

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[15] Singhania, R, Lefkofsky, S., Molloy, P. (2023). *Hydrogen Produced from Methane Pyrolysis: Key Considerations for Investors*. Third Derivative. Retrieved from https://www.third-derivative.org/blog/hydrogen-produced-from-methane-pyrolysis-key-considerations-for-investors#:~:text=Methane%20pyrolysis%20is%20the%20process,depending%20on%20the%20reactor's%20efficiency).

[16] Sanchez-Bastardo, N., Schlgol, R., Ruland, H. (2021). *Methane Pyrolysis for Zero-Emission Hydrogen Production: A Potential Bridge Technology from Fossil Fuels to a Renewable and Sustainable Hydrogen Economy*. Industrial & Engineering Chemistry Research. Retrieved from https://pubs.acs.org/doi/10.1021/acs.iecr.1c01679.

[17] Idrissov, C. (2023). *Methane Pyrolysis: Unlocking the Potential of Turquoise Hydrogen*. IDTechEx. Retrieved from https://www.idtechex.com/en/research-article/methane-pyrolysis-unlocking-the-potential-of-turquoise-hydrogen/29395.

[18] Modern Hydrogen. *Methane Pyrolysis*. Modern Hydrogen. Retrieved from https://modernhydrogen.com/technology/methane-pyrolysis/.

[19] Prabowo, J., Lai, L., Chivers, B., Burke, D., Dinh, A., Ye, L., Wang, Y., Wang, Y., Wei, L., Chen, Y. (2024). *Solid Carbon Co-Products from Hydrogen Production by Methane Pyrolysis: Current Understandings and recent progress*. Science Direct. Retrieved from https://www.sciencedirect.com/science/article/pii/S0008622323007522#abs0010.

hydrogen to avoid emissions while decarbonizing the natural gas, it may even increase demand for natural gas.[20] This would be a boon to the sector.
Resources are spared, as industry actors and policymakers are not fighting to achieve permitting compliance for additional demand to power generation sources, renewables, transmission lines, or even future hydrogen pipelines. In fact, no new storage or transportation for hydrogen are needed with a distributed solution, because the hydrogen can be moved and stored in the form of natural gas in existing facilities. Only on-demand and at point-of-use is the natural gas decarbonized and converted into hydrogen.

Environmental and climate goals are achieved by emission reduction. Through this method, carbon can be removed from the equation in a unique way not possible through other methods. Traditional carbon capture happens after a combustion reaction has occurred and attempts to keep the carbon dioxide from entering the atmosphere. These processes rarely capture 100 percent of the fugitive carbon, take their own energy to facilitate, and then the carbon dioxide must be compressed, stored, transported, utilized, or buried geologically. All of these take added energy and often result in facilitating carbon emissions. Some even require new carbon dioxide pipelines, which can take years to build and have regulatory and construction costs and impacts.

Distributed natural gas decarbonization through thermal methane pyrolysis effectively captures 100 percent of the carbon in a pre-combustion carbon capture process, leaving no gases to escape or require storage. The carbon can be safely handled, stored, and transported as a powder.

An environmental drawback to this model is that the existing pipeline network is imperfect and may have leaks, while an unknown volume of methane leaks during the exploration and production process in the first place. Adding increased demand would necessarily increase these oilfield releases. There are a few reasons this is not a fatal concern for this model.

First, pipelines are the safest and most effective method of transporting gases and hazardous materials. Natural gas pipelines move product with 99.999 percent effectiveness, meaning only a thousandth of one percent is leaked from the pipeline network. By contrast, source emissions in the oilfield do happen at higher levels, but there is not a well-established direct proportional relationship with extracting more natural gas and methane emissions into the atmosphere. Twice the demand may not result in twice the emissions. Rather, once a well has been established, emissions can be relatively consistent. New rigs may result in increases, but horizontal drilling and other processes can reduce that. The Environmental Protection Agency (EPA) asserts that around one percent of oil and gas production ends up entering the atmosphere, while researchers have estimated this to be as high as 2.95 percent.[21] Those leaks vary considerably, with small or

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[20] Natural gas users may be concerned about the cost of more gas required. This area demands future attention and close collaboration with policymakers. Two immediate policy resolutions are to reduce costs for businesses that demonstrate emissions reductions and lowering costs on the production of natural gas. In the first case, businesses using more natural gas may offset the cost with their emissions reduction compliance (through credits, regulatory relief, etc), while in the second case, the use of more natural gas would be less expensive because of increase in natural gas supplies.

[21] Sherwin, E., Rutherford, J., Zhang, Z., Chen, Y., Wetherley, E., Yakovlev, P., Berman, E., Jones, B., Cusworth, D., Thorpe, A., Ayasse, A., Duren, R., Brandt, A. (2024). *US Oil and Gas System Emissions from Nearly One Million Aerial Site Measurements*. Nature. Retrieved from https://www.nature.com/articles/s41586-024-07117-5.

relatively consistent leaks associated with most operating production, and larger and short-lived leaks happening at few locations.

Moreover, a distributed hydrogen model can be optimized to combat even increases in emissions elsewhere in the system. When leveraged to its full extent, it can deliver completely carbon-negative power. That would mean a net reduction in carbon in the atmosphere while producing power.

If renewable natural gas (RNG) is added to existing pipelines, when the gas is ultimately decarbonized, it is reversing the carbon balance sheet. That is because RNG is a carbon-neutral energy resource, a biogas generated through methane capture at sources like landfills, wastewater treatment, and farms.[22,23] Methane capture can also be utilized at places like coal mines and oil rigs, collecting the gas where it is most concentrated before it escapes into the atmosphere, then in some cases with light processing, fed into the existing pipeline network.

The final reason a distributed natural gas decarbonization method is not counterproductive environmentally is that alternative methods simply lead to greater emissions hidden in prior causal chains. As detailed above, alternative solutions within traditional models would require new wind and solar farms, new battery storage, new high-voltage transmission infrastructure, and potentially new storage tanks, processing facilities, and pipelines either for hydrogen or carbon dioxide. In each case, greater emission will result from the heavy equipment involved in the mining, processing, and transporting of raw materials, manufacturing, the supply chains for finished components, and the decade-long regulatory and construction process.

Leveraging existing infrastructure to decarbonize a bountiful resource and valuable state asset avoids the costs, compliance, and emissions of other models. For the infrastructure already in place, all of these costs, time, and emissions are already accounted for. This model represents an immediate opportunity to expand the energy economy while flipping the script on emissions.

All of these benefits are possible, but there is one more that makes this unique. Up to this point, the process may be described as a “win-win” to include energy and emissions wins. To make this a truly unique *win-win-win* that also improves the resilience of the state’s critical infrastructure, carbon can be viewed as an asset. Rather than a negative production externality, this can be viewed as a positive production externality when the carbon is in solid form and utilized as a construction material.

This carbon can be sequestered into the built environment like roads, bridges, levees, and storm walls. One identified use for carbon black from the thermal pyrolysis process is in asphalt. This has even debuted in Texas already through a partnership with a utility in Washington, a

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[22] U.S. Environmental Protection Agency. (2024). *Renewable Natural Gas*. U.S. EPA. Retrieved from https://www.epa.gov/lmop/renewable-natural-gas.

[23] U.S. Department of Energy. *Renewable Natural Gas*. U.S. Department of Energy. Retrieved from https://afdc.energy.gov/fuels/natural-gas-renewable.

Northwestern technology company, and a Texas county.[24,25,26] Alternative processes may be geared toward other projects as well, depending on the grade and molecular characteristics of the carbon.[27]

Leveraging existing infrastructure and leaning into cross-sectoral collaboration can result in truly innovative outcomes: decarbonizing natural gas, producing clean hydrogen, generating commercial and industrial scale process heat and power, reversing emissions, and improving the quality and resilience of state roadways. If industry participants and state policymakers are aligned, the state's critical infrastructure can be improved from energy security to bolstering the transportation sector.

Way Forward

To move effectively into the future, policymakers and industry leaders must think creatively about ways to achieve their interests. Through innovation and collaborative dialogue, once competing and seemingly mutually exclusive priorities can be achieved together.

Each party must also view the issues of energy security in tandem with concepts of grid reliability, maximal strategic utilization of existing infrastructure, and emissions goals. Without a comprehensive view and a long-term vision, there will be contradictory policy that creates unintended hurdles to successful implementation and realization of the benefits.

One example may be an emission standard in law that use proxies rather than measurements. If a local law or regulation calculates a facility's emissions by its metered consumption of natural gas, but the facility is decarbonizing the natural gas behind the meter, the industry-leading utility will be penalized even though they are effectively fulfilling (and over-delivering) on the goal of the regulation, which is to reduce emissions. Waivers and exemptions should be considered alongside new policy structures that promote innovation and do not prescribe processes but articulate performance goals.

Additionally, the merging of industries and disciplines is essential to maximize benefits. Road builders or TXDOT likely would not naturally find themselves in a conversation about power generation and emissions reduction. But without those parties at the table, there would be less benefit extracted from the decarbonization of natural gas. The carbon black byproduct being incorporated directly into asphalt is an infrastructure solution born out of leveraging other infrastructure. Through additional collaboration, including partnerships in research and

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[24] Marquez, R., Barraza, A. (2023). *Bexar County Using Unique Asphalt to Patch Up Pothole Problems on Roads*. KSAT News. Retrieved from https://www.ksat.com/news/local/2023/11/16/bexar-county-using-unique-asphalt-to-patch-up-pothole-problems-on-roads/.

[25] NW Natural. (2022). *NW Natural to Partner with Modern Electron on Exciting Pilot Project to Turn Methane into Clean Hydrogen and Solid Carbon. NW Natural*. Retrieved from https://ir.nwnaturalholdings.com/news/news-details/2022/NW-Natural-to-Partner-with-Modern-Electron-on-Exciting-Pilot-Project-to-Turn-Methane-into-Clean-Hydrogen-and-Solid-Carbon/default.aspx.

[26] Modern Hydrogen. (2024). *Modern Asphalt Innovation*. Retrieved from https://modernhydrogen.com/library/modern-asphalt-innovation/.

[27] This could include graphite for use in batteries and energy storage or grades of carbon better suited to other construction materials.

development, additional uses may be identified that can reduce costs, improve infrastructure resilience, and further reduce net emissions across the spectrum of critical state infrastructure.[28,29]

More use of pipelines, more natural gas flowing, decarbonization, distributed hydrogen production, carbon sequestration, and finally road maintenance and repair – this achievable chain of events is only possible with maximum stakeholder engagement and collaboration, and it requires industry participants and public policymakers to be at the same table.

Conclusion

A third-party is often needed to intake the perspectives of differing industries and translate them into a shared language and priority. This requires rejecting false choices by identifying the hidden assumptions within them, stripping them down to physical realities, and mapping that against existing proven technology.

Where Texas is concerned, all parties can achieve their key objectives when they unite around a shared end goal rather than bringing preconceived preferences for achieving goals. In other words, an end goal with no added assumptions and stripped of conventional wisdom allows innovators to view any options that might deliver – even when it means moving away from a longstanding preference. Most parties would already agree that everyone wants all Texans to have access to power. But they still have assumptions and expectations for how to provide that power. By suspending those preferences and allowing innovative practices to achieve results in unexpected ways, win-win outcomes can be achieved.

The challenge is to identify a goal and assess the available resources to address it. Because some strategies require extensive new infrastructure building, these would add delays to the solution, come with high capital and operational costs, and include their own emissions and resilience challenges. Leveraging existing infrastructure, then, can help avoid time, costs, and emissions. But utilizing the state's pipeline network is not enough, there must still be new innovation added to the equation. That is where decarbonizing natural gas before combustion and avoiding traditional carbon capture practices takes place.

One plausible route is through embracing natural gas and even increasing exploration and production. This will be at odds with climate-focused advocates, but environmental benefit comes through the same model. By leveraging the existing multi-million mile network of pipelines, this natural gas can be most efficiently routed to its end users in the industrial, commercial, and energy sectors. With existing pipelines already demonstrating impressive efficiency rates over 99.999 percent, there is little emission concern. This same natural gas, containing methane, can then be decarbonized after the meter at its point of use. By

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[28] Prabowo, J., Lai, L., Chivers, B., Burke, D., Dinh, A., Ye, L., Wang, Y., Wang, Y., Wei, L., Chen, Y. (2024). *Solid Carbon Co-Products from Hydrogen Production by Methane Pyrolysis: Current Understandings and recent progress*. Science Direct. Retrieved from https://www.sciencedirect.com/science/article/pii/S0008622323007522#abs0010.

[29] XPRIZE Foundation. *Carbon Removal*. XPRIZE. Retrieved from https://www.xprize.org/prizes/carbonremoval.

decarbonizing methane (CH_4), energy users are left with clean hydrogen ($2H_2$) and easy-to-sequester solid carbon (C).

To achieve sustainable progress, thought leaders must engage with how to most effectively leverage existing infrastructure to achieve varied goals without compromising results. This requires both discussion of innovative practices in the energy sector and informed policy reforms at the regulatory and legislative level.

Emerging from this review, a distributed or decentralized, solution is especially important. It makes the most effective use of Texas's two key assets: natural gas and the pipelines that facilitate it. Pairing cross-sectoral collaboration with the transportation industry or others elevates the potential for improving the resilience of other critical infrastructure and unlocking new possibilities yet to be contemplated.

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