Energy Economics and Technology Committee, AAPG Energy Minerals Division*[*]
Jeremy Platt, co-chair and principal author
Dieter Bieke, co-chair
June-July 2021 **Exploring the Energy Transition: Crosscurrents**

The oil and gas industry is shifting attention to decarbonization only two years after setting records in oil, gas and products production and exports in 2019. This review examines the market turnaround after the pandemic, the shocks of the February winter storm across Texas and into the central U.S., and the heightened awareness it created about carefully constructing paths of decarbonization.

Getting to this Point. Over much of the past decade, we have noted with some irony how "fracking" (the technologies of geosteering, horizontal drilling, pressure pumping/hydraulic fracturing) enabled the "shale revolution" – arguably the greatest transformation in the United States' energy posture during most of our lifetimes. For those both familiar with the oil/gas industry and those on the outside, it has always been difficult to convey the sense of scale of this transformation. Already awash in natural gas, the States' relentless oil production and declining imports triggered the late-2014 oil price collapse and, likewise, an extraordinary step-jump in global consumer energy cost savings (e.g. gasoline, jet fuel, natural gas and its twin, electricity, internationally traded pipeline gas, and liquefied natural gas). This consumers' side of things was addressed in our 2016 review, whereas the 2017 review placed this transformation in a historical context going back about fifty years. Portents of change on the environmental front received some attention in our 2018 review, yet the story that year was primarily one of burgeoning production.

The topic of decarbonization was touched on in our 2019 review *("Unease at the Top")* amid the election cycle's political scramble. Curiously, we also found that the seemingly new attention to the social dimensions of energy brought to the fore by the Green New Deal in early 2019 had been preceded by not only the U.N.'s Sustainable Development Goals but also a long history of formal U.S. government reporting, dating back over thirty years.[1] In 2020 *("Zenith to Nadir: Oil's Woes in the Throes of Pandemic")*, it was necessary to put aside decarbonization and give attention to the heated topic of the oil/gas industry's deteriorating financial condition (in a nutshell, over-reliance on debt and equity financing and inadequate attention to free cash flow). Those are problems which long preceded the Pandemic. We also tracked events unfolding that spring (lockdown/stay-at-home measures portrayed across both producing and consuming states, and the resulting demand shock). Accompanying these topics, we added some perspective on natural gas liquids markets and wellhead economic evaluations (Permian and Haynesville examples).

[*] American Association of Petroleum Geologists

[1] U.S. Global Change Research Program, established 1990, released its 1.5 C Special Report in 2018, with its Sixth Assessment Report scheduled for June 2022. The Intergovernmental Panel on Climate Change (IPCC) established 1988 under the United Nations Environmental Programme and the World Meteorological Association.

Today. The current moment is characterized by an almost schizoid tension between financial relief and looming existential catastrophe, only presaged in 2018. The prospect of better financial times in the short to intermediate term, hinging on the rollout of vaccinations, is already evident. The change in U.S. government administration to one with an activist stance on climate change certainly signals greater action on that front, although it is hardly the only such signal and possibly not the most important in terms of what will drive oil and natural gas demand over the intermediate term. Here, we have in mind continuing and ratcheting individual state policies (also cities' building codes and fleets, and their port operations), individual initiatives by energy producers (e.g. oil, gas, transmission/distribution, refining) and by major consuming companies (e.g. server farms, fleets, power producers, and a host of other companies). To this, outside pressures on companies' boards and emergent anti-fossil lawsuits such as that waged against Royal Dutch Shell may accelerate steps regardless of prior announced greening policies or even their feasibility.[2]

We will briefly address the financial turnaround, and then give attention to society's not-so-sudden awakening to the challenges and opportunities presented by decarbonization.

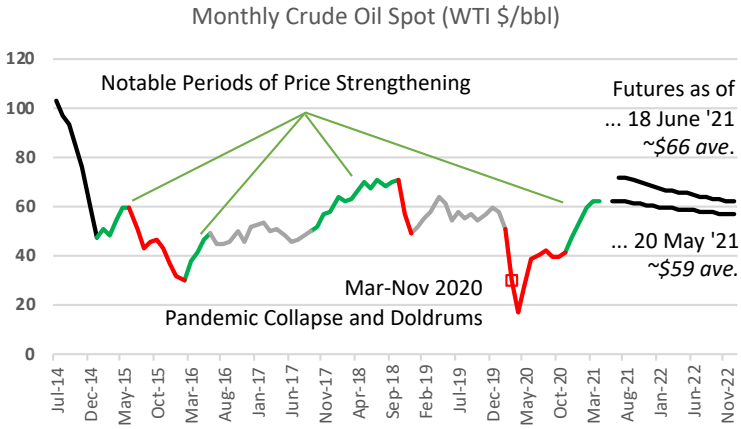
Financial Turnaround: Oil's Advance, Natural Gas Climbing out of a Deep Hole

We begin with a short perspective on the post-Pandemic turnaround in oil and gas prices, followed by a summary of recent and projected changes in collective revenues across the oil/gas sector. The contrast to events in the spring of 2020 couldn't be greater. Last March and April experienced back-to-back impacts from the Saudi Arabia-Russia oil price war and the initial pandemic-response demand-collapse.

Crude Oil. Oil prices are plotted in the first chart. Sitting at $40 per barrel for most of 2020 (excluding the sharpest drops), prices rose $20 to ~$60 per barrel between December 2020 and February 2021 (West Texas Intermediate monthly spot averages). This break-out brought a sense of relief similar to that experienced by this observer during the spring 2015 uptick from the 2014-15 price collapse, when prices also reached ~$60 per barrel. Much worse happened after that -- monthly averages prices plunged to the low $30s by the end of that year and didn't break $60 until January 2018. The current firming is far less gloomy, matching 2018's highs near $70 for the rest of 2021 and holding above $60 per barrel through 2021. This bullish outlook gained a remarkable 10-15% boost between mid-May and mid-June. Underpinning price strengthening are continued yet variable global economic recovery, particular growth in travel fuels demand, continued discipline across shale producers, and no dramatic international developments. Some observers see this strengthening as the oil and gas industry's last big

[2] "Chevron investors back proposal for more emissions cuts", Reuters, May 26, 2021. https://www.reuters.com/business/energy/chevron-shareholders-approve-proposal-cut-customer-emissions-2021-05-26/ "Climate activists score a third ExxonMobil board seat", Axios, June 2, 2021, by Andrew Freedman: https://www.axios.com/exxonmobil-board-seat-activist-investor-1f019368-3e8a-4da4-97a6-181922b53df5.html ; "Shell Loses Climate Case That May Set Precedent for Big Oil", Bloomberg, May 26, 2021, by D. Baazil, H. Miller and L. Hurst: https://www.bloomberg.com/news/articles/2021-05-26/shell-loses-climate-case-that-may-set-precedent-for-oil-industry?sref=nfGWux2z

hurrah, yet also a chance to redirect some funds to both shareholders and toward the energy transition.[3]



Data source: CME Group

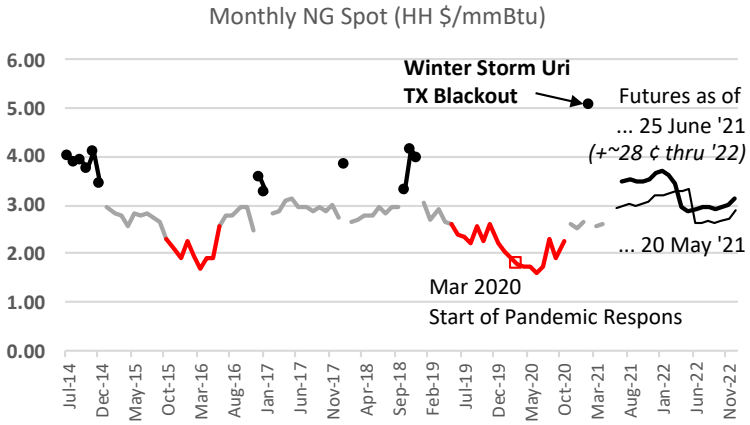
In keeping with our portrayal of 98 cent gasoline in Detroit a year ago April, we offer this photo documenting the $4.50-5.00 per gallon seen by mid-2021 in a different region.



Gasoline Prices, June 6, Palo Alto, California. *Photo Credit, J. Platt*

Natural Gas. The sister chart for natural gas prices shows the few winter months over the past six years when prices approached $4.00 per million Btu (isolated black circles, February's 2021 havoc being the most extreme). The post-2014 norm of prices in the $2.50-sub-$3.00 range (or slightly above) is tracked in gray, and the deep doldrums of prices near or well below $2-2.50 are in red. As described in our 2020 review, natural gas' woes characterize essentially this entire stretch of years, with some of the lowest months preceding the Pandemic by almost a year. Against this backdrop, seemingly sustained futures prices near or above $3.50 through the first quarter of 2022 are a truly dramatic rise. Like oil, natural gas gained a considerable boost in just the five weeks from mid-May to near the end of June, when the average through the end of 2022 rose 28 cents with not a month even 5 per cent below $3.00. EIA's short term projections are not quite as bullish as the signals from the futures market.

[3] *"The Last Oil Price Boom May Be in Sight",* Boston Consulting Group, June 14, 2021, by J. Webster, R. Fitz, M. Berns, C. Follette, and A. Gordon: https://www.bcg.com/fr-fr/publications/2021/preparation-for-last-oil-price-boom



Data source: CME Group

What's behind this loft? Among the usual suspects, natural gas storage levels are at five-year norms (i.e., no significant upward or downward price pressure). The power sector is pulling back from its 2020 low-price-driven record demand and the residential, commercial and industrial sectors were each approaching but not exceeding 2019 levels (first quarter 2021 data). The same is true of production, thus pointing quite convincingly to exports, running 48% ahead of 2019 levels during the first quarter of 2021.[4] By the week ending June 23, 2021, a record high of 7 billion cubic feet per day (Bcf/d) went to Mexico and deliveries to export terminals averaged 10 Bcf/d, 18% of production (on a dry basis).[5] The EIA likewise identifies exports behind the largest changes in the natural gas market balance through 2022.[6]

This price firming has a substantial impact on project economics, where profitability can swing on a dime (or more like 25 cents), as calculated in last year's review. For a core Haynesville well, we saw that a change of 25 cents in the Henry Hub index could cause a swing of about 12-13% in Internal Rate of Return. As Michael Link of Haas Engineering then wrote, a five-year forward strip near or above $3.00 might look very good, but there had been plenty of times in just the preceding 18 months when such a well would have proven to be uneconomic (e.g. red highlighting on the chart). While volatility is always a concern, the latest trends hold promise for a very different mindset.

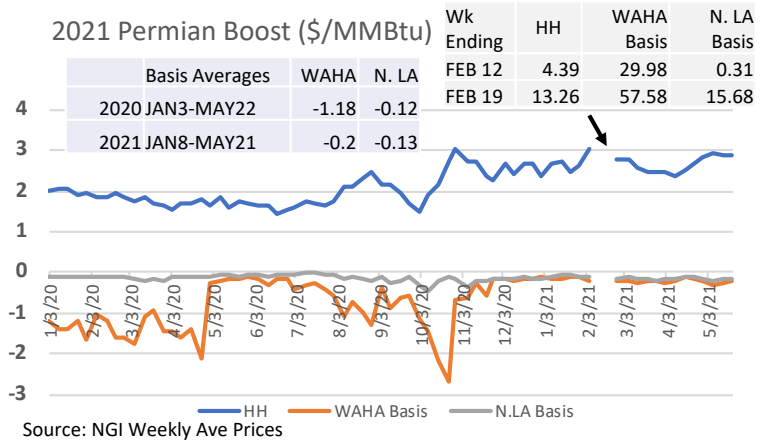
Waha Surprise. One of the most dramatic price turnarounds has been an extended price uplift across the Permian Basin. This is illustrated on the next chart, which also shows Haynesville prices (N. Louisiana). A year to year comparison shows Waha prices have risen a dollar on average from the first of the year to the third week in May vs. the year before, owing to improvements in takeaway capacity. Winter Storm Uri's aberration which drove prices to unprecedented heights has been removed from the chart, but is captured in the table insert. The Haynesville basis, true to form, maintained its typical close proximity to the Henry.

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[4] *Monthly Energy Review*, EIA, June 24, 2021. Table 4.1: Natural Gas Overview and Table 4.2, Natural Gas Trade by Country.

[5] *Natural Gas Weekly Update*, EIA, June 24, 2021.

[6] "U.S. natural gas exports and non-power sector demand to drive higher prices through 2022", by C. Ricker. EIA *Today in Energy*, June 23, 2021.

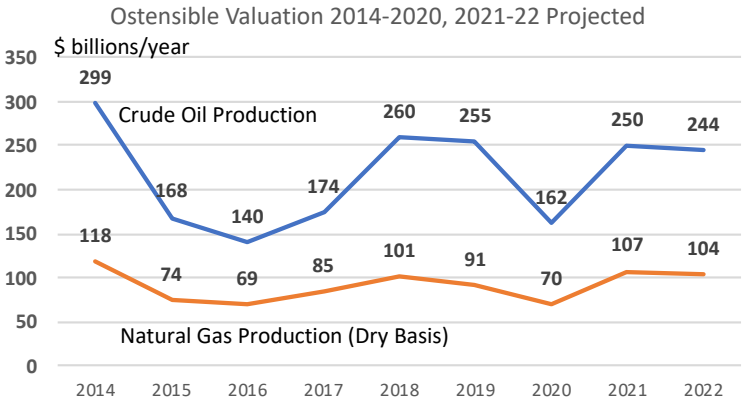


Source: NGI Weekly Ave Prices

Bounceback of Sector Top-line Revenues. A 64,000-foot view of the general financial health of the oil and gas industry as it fell into the pandemic and began to emerge is shown in the next panel. The top table represents "ostensible" revenues for crude oil and natural gas production based on the simple product of annual production multiplied by annual average prices.[7]

Ostensible O/G Valuation (Prod X Price), $B and % Change vs. 2019

	2019	2020	2021	2022
Oil	255	162 (-36%)	250 (-2%)	244 (-4%)
NG	91	70 (-22%)	107 (+18%)	104 (+15%)



Compared to 2019, the pandemic had the effect in 2020 of draining top-line oil revenues by 36% and natural gas by 22%. Drawing on the EIA's *Short Term Energy Outlook*, oil's rebound will be essentially complete in 2021 whereas natural gas' will grow by nearly 20%, supported by its relatively greater price-firming.

The scale of these changes, and the reasons, are portayed back to 2014 at the verge of the great price collapse. The largest production gains occurred between 2017 and 2019.

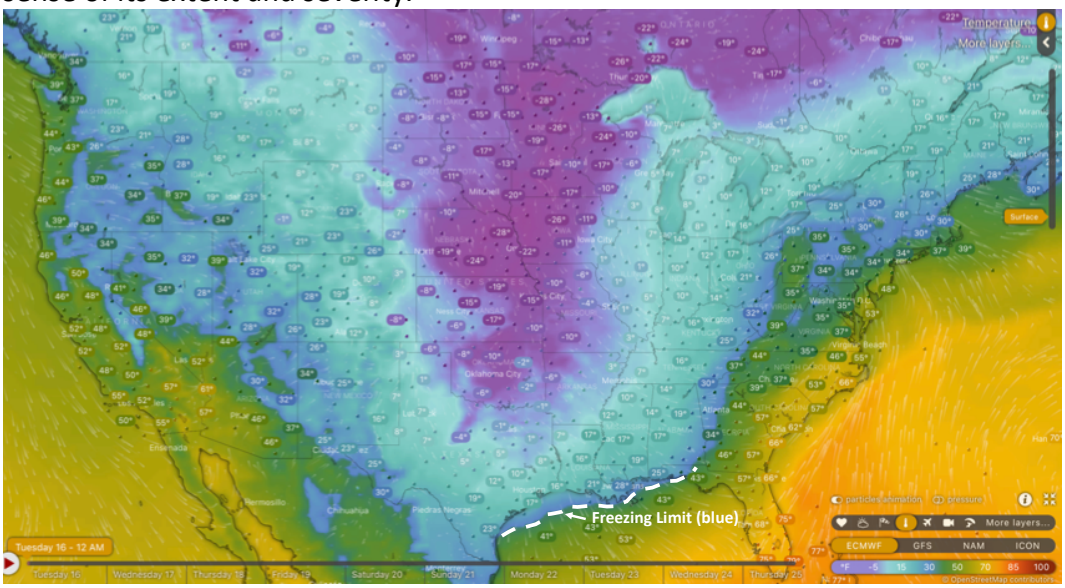
	Crude Prod MM bbls/d	WTI Spot $/bbl	NG Prod Bcf/d	NGHH Spot $/mmBtu
2022*	11.79	56.74	93.93	2.93
2021*	11.08	61.85	92.18	3.07
2020	11.31	39.17	91.35	2.03
2019	12.25	56.99	93.06	2.57
2018	10.96	65.07	84.31	3.15
2017	9.37	50.79	74.91	2.99
2016	8.85	43.33	72.66	2.51
2015	9.45	48.67	74.15	2.63
2014	8.79	93.17	70.93	4.39

Data: Energy Informaton Administration; *June '21 Short Term Energy Outlook

[7] These theoretical totals exclude consideration of lags, price hedges, costs, taxes or any other obligations. Nor is the path of revenues from natural gas liquids production included.

The Texas Winter Storm – A Defining Moment

While Texas/New Mexico have experienced frigid weather problems before, most notably within the past decade the early February 2011 freeze[8], the extent, cascading effects, and human costs of the Texas winter storm, formally labeled Winter Storm Uri, will likely not be forgotten for a very long time. The Texas winter storm didn't just happen in Texas but spread across much of the country east and north. Severe weather was anticipated many days in advance. The screenshot below from one of the author's weather-monitoring apps gives a sense of its extent and severity.



Winter Storm Uri: Sub-freezing Temperatures Beyond the Gulf of Mexico Shoreline
Screenshot: 2:10 AM Central Time, Tuesday Feb. 16, 2021. J. Platt "Windy.com" app

The National Centers for Environmental Information, part of the National Oceanic and Atmospheric Administration, maintains a tally of "billion-dollar weather and climate disasters". It provides a succinct summary:

> Historic cold wave and winter storm impacts many northwest, central and eastern states. Temperature departures exceeding 40.0 degrees F (22.2 degrees C) below normal occurred from Nebraska southward to Texas. The prolonged arctic air caused widespread power outages in Texas, as well as other southern states, with multiple days of sustained below-freezing temperatures. *At the peak of the outage, nearly 10 million people were without power.* Additional impacts were frozen water pipes, which burst upon thawing causing water damage to buildings. These extreme conditions also caused or contributed to the deaths of more than 125 people in Texas alone, and this number is expected to increase further, after additional reporting. There were also snow and ice impacts across numerous states including Oklahoma, Arkansas, Missouri, Illinois, Kentucky, Tennessee, Louisiana,

[8] Extensive analysis from the Federal Energy Regulatory Commission and North American Electric Reliability Corporation (FERC/NERC): "Outages and Curtailments During the Southwest Cold Weather Event of February 1-5, 2011: Causes and Recommendations". August, 2011. https://www.ferc.gov/sites/default/files/2020-04/08-16-11-report.pdf

> Mississippi, Colorado, Oregon and Washington. Damage costs are not yet certain for this [sic] events but already exceed $10.0 billion making it the most costly U.S. winter storm/coldwave on record surpassing the March 1993 'Storm of the Century'.[9]

Unofficial estimates peg the storm's damages at $100-200 billion or more[10], which would place it on a dollar-scale ahead of every other such event in the United States since 1980 – even beyond #1 Hurricane Katrina (August 2005, New Orleans and eastern Gulf, $172.5 B and 1,833 deaths). Because the worst multi-billion storms are household names, they provide a frame of reference from which to better appreciate the likely enormous damages from Winter Storm Uri. As bad as Katrina was, it was followed a month later by #15 Rita ($25.5 B). #2 is Harvey (August 2017, $133.8 B) whose impacts are still very fresh of mind. # 3 is Maria (September 2017, $96.3 B) which devastated Puerto Rico before hitting the Gulf which was marked by an astonishing 2,981 deaths. It was part of a double-whammy having been closely preceded by #5 Irma ($53.5). The fourth place in monetary damages is Sandy, the record storm hitting New York, New Jersey and New England in October 2012 ($75.4 B). All these top-ranking events are compressed into relatively recent times, but it is important to recognize the long-held most notorious event prior to these, now in the sixth position, was Hurricane Andrew (Florida, August 1992, $25.5 B). Of these disasters, Katrina-Rita and Harvey also stand out due to their impacts on the petroleum sector.

The regional extent and anomalous frigidity of the storm is portrayed in this side-by-side chart of snow/ice cover and historic low temperature extremes.[11]

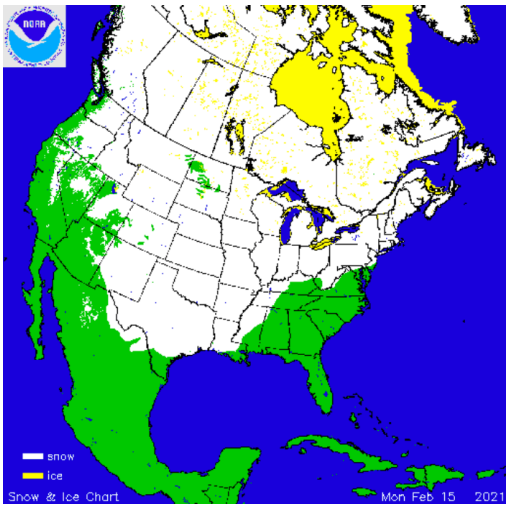
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[9] "Billion Dollar Weather and Climate Disasters: Events", https://www.ncdc.noaa.gov/billions/events

[10] $100 B, Texas. "Cost of Texas' 2021 Deep Freeze Justifies Weatherization", G. Golding, A. Kumar and K. Mertens, Federal Reserve Bank of Dallas. April 15, 2021. https://www.dallasfed.org/research/economics/2021/0415.aspx AccuWeather issued an estimate of $155 billion on March 5, 2021, of which $130 billion is due to damages and losses in Texas alone: "Damages from Feb. winter storms could be as high as $155 billion", Mark Puleo. https://www.accuweather.com/en/winter-weather/damages-from-feb-snowstorms-could-be-as-high-as-155b/909620 . A figure of $295 billion for Texas was cited with no supporting details in the March 29 report "The Winter Storm of 2021", Hobby School of Public Affairs, University of Houston https://uh.edu/hobby/winter2021/

[11] NOAA National Centers for Environmental Information, News: Assessing the U.S. Climate in February 2021 "Polar vortex ushered in coldest air across central U.S. in more than 30 years; Alaska's coldest February since 1999" https://www.ncei.noaa.gov/news/national-climate-202102 and State of the Climate: National Climate Report for February 2021, published online March 2021, https://www.ncdc.noaa.gov/gov/sotc/national/202102.1; https://www.ncdc.noaa.gov/sotc/snow/202102

Maximum Extent of Snow and Ice
Feb. 15, 2021



All Time Minimum Temperatures
62 Locations, Feb. 15-16, 2021



Selected Meteorological Specs at the Storm's Worst

Natural Gas Snapshot. Natural gas prices always track expectations of coming weather disturbances. As shown on the insert to the Permian Boost chart, average spot nat gas prices the week before had climbed a full dollar. EIA's tables of daily spot prices show the climb beginning Wednesday.

Spot Prices ($/MMBtu)	Thu, 04-Feb	Fri, 05-Feb	Mon, 08-Feb	Tue, 09-Feb	Wed, 10-Feb	Thu, 11-Feb	Fri, 12-Feb	Mon, 15-Feb	Tue, 16-Feb	Wed, 17-Feb	Thu, 18-Feb	Fri, 19-Feb	Mon, 22-Feb	Tue, 23-Feb	Wed, 24-Feb
Henry Hub	2.92	3.39	3.18	3.20	3.68	5.88	6.00	Holiday	16.96	23.61	7.50	4.99	2.84	2.79	2.75
New York	3.04	4.52	4.11	4.18	4.69	5.93	5.77	Holiday	15.00	13.50	5.87	7.06	2.69	2.59	2.65
Chicago	2.95	3.50	3.18	3.28	3.99	8.06	129.52	Holiday	22.08	18.82	6.22	3.94	2.72	2.72	2.68
Cal. Comp. Avg.*	3.14	3.56	3.51	3.50	4.28	9.33	39.26	Holiday	44.27	15.09	5.03	3.80	3.27	3.19	3.16
Futures ($/MMBtu)															
March contract	2.935	2.863	2.882	2.835	2.911	2.868	2.912	Holiday	3.129	3.219	3.082	3.069	2.953	2.879	2.854
April contract	2.889	2.841	2.862	2.823	2.879	2.836	2.876	Holiday	2.983	3.032	2.970	2.991	2.936	2.857	2.795

* Avg. of NGI's reported prices for Malin, PG&E Citygate, and Southern California Border Avg.
Source: NGI's Daily Gas Price Index, as reported in EIA *Natural Gas Weekly* reports of Feb. 11, 18 and 25, 2021

As widespread as these impacts were, they didn't last long. A broader view of pre-storm and storm price and production impacts was issued by the Texas Oil and Gas Association two months later. Serious production losses were largely confined to the Permian Basin, whereas price uplift and spikes were far more widespread.

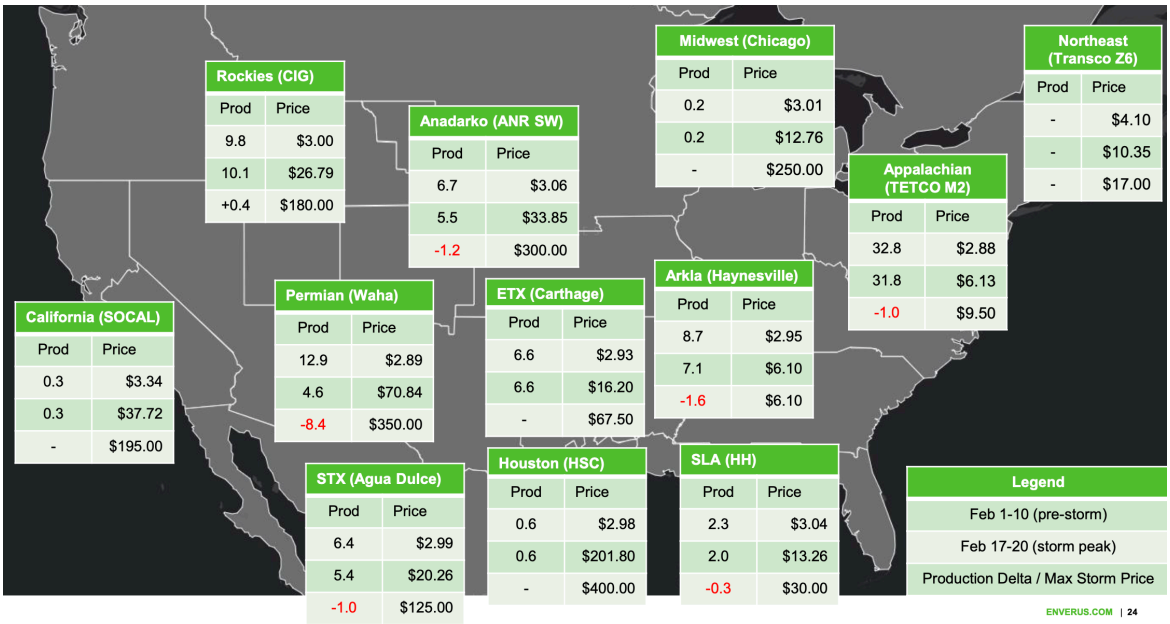


Chart: Storm Impacts on Natural Gas Production and Prices, Texas Oil and Gas Association[12]

A retrospective issued by the EIA just a week after the storm showed Texas production had returned to normal, whereas at its peak (for natural gas impacts) on Wednesday the 17th, statewide production fell 45% from 21.3 to 11.8 Bcf/d, which compares to 65% for the Basin per the chart above. Nationwide, production that day fell 21% from ~88.6 to 69.7 Bdf/d.[13]

Official statistics on a monthly basis are presented in EIA's Drilling Productivity Reports, allowing a broader geographic view of the storm's impacts. No surprise, neither the Bakken nor northeast production were affected much. Permian and Anadarko production fell nearly 20%, relatively higher for Anadarko oil and less for Haynesville gas, 10%, with Eagle Ford impacts trailing those of the Permian.

	Oil Milion Bbl/d			Natural Gas Bcf/d		
	Jan Prod'n	Feb Decline	%	Jan Prod'n	Feb Decline	%
Bakken	1.17	(0.06)	-5.2%	2.9	(0.1)	-4.9%
Anadarko	0.42	(0.11)	-27.0%	6.4	(1.2)	-18.0%
Permian	**4.35**	**(0.81)**	**-18.6%**	**17.5**	**(3.3)**	**-19.1%**
Eagle Ford	1.05	(0.17)	-16.3%	5.7	(0.7)	-12.1%
Haynesville	0.03	(0.006)	-18.0%	12.5	(1.2)	-9.5%
Appalachia	0.13	(0.005)	-3.9%	35.6	(0.7)	-1.9%

Source: EIA Drilling Productivity Report

[12] "Winter Storm Uri – Natural Gas", prepared by Envirus for Texas Oil and Gas Association, April 22, 2021. Slide 24: "Production and Price Activity Around the Storm". Envirus acquired the well-known natural gas data consultancy DrillingInfo in 2019. Production estimates are based on their proprietary sampling and modeling based on interstate flows. Apart from this neutral chart, the Association is a voice in storm controversies, discussed later.

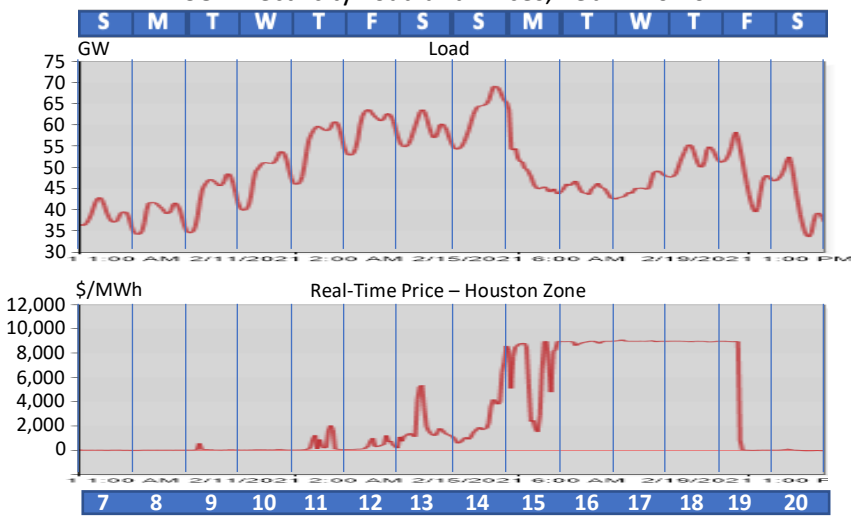
[13] "Texas production fell by almost half during recent cold snap", EIA *Today in Energy*, by Stephen York. February 25, 2021. https://www.eia.gov/todayinenergy/detail.php?id=46896

Electricity Snapshot. Raw data on electrical load (demand) and prices capture the most basic elements of electric system performance over the preceding week, during harshest days, and some time thereafter. These are shown in the next chart.[14] Heating requirements took off starting Tuesday.

Based on their own corporate modeling of the severity of the coming storm, which indicated loads the following week would exceed ERCOT's projections by 10,000 MW, one stakeholder claimed "we saw this coming" and "on Wednesday, Feb. 10, we sounded the alarm and let ERCOT and others know we thought their projections were off".[15] They also pointed to that other early-warning indicator, price movements in natural gas and power trading.

The collapse of load Monday the 15th and onward represents just the load that could be served, not the load that was desired – which would have continued to climb. Later charts dissect the gap caused by units that were shut down or derated for a number of reasons. The first major price spike occurred on Saturday and remained at or near the system operator's $9,000/MWh price levels most of the time from just after midnight Sunday until Friday.

ERCOT Electricity Load and Prices, Feb. 7-20 2021



Source: EnergyOnline.com, ERCOT data. Region compilations provided by LCG Consulting.

In his testimony to the U.S. House of Representatives, the President and CEO of the North American Electric Reliability Corporation emphasized the geographic scope of the freeze, its impacts on power systems, its human toll, and its many predecessors where sufficient preventative or anticipatory actions had not been taken.[16] NERC is moving quickly to prompt

[14] LCG Consulting EnergyOnline: http://www.energyonline.com/ Links to price, load data and custom charts can be accessed for user-defined time periods for the electric market regions of ERCOT, MISO, NYISO, NEISO and CAISO.
[15] WFAA reporting "Energy executive to Texas lawmakers: This event has shaken me like no other", by J. Whitely. Vistra Corp. CEO C. Morgan prepared testimony to Texas Joint House Committee, Feb. 25, 2021 on blackouts. https://www.wfaa.com/article/news/local/texas/vistra-energy-executive-curt-morgan-texas-lawmakers-power-outages-winter-weather/287-123c0c0d-2eb1-4d06-8a11-970045b608e7
[16] Hearing "Power Struggle: Examining the 2021 Texas Grid Failure". Testimony by James Robb, U.S. House Energy and Commerce Committee. March 24 2021. https://energycommerce.house.gov/committee-activity/hearings/hearing-on-power-struggle-examining-the-2021-texas-grid-failure

bolder actions. This excerpt from NERC chief James Robb's testimony gives a concise summary and introduces a number of important concepts such as impacts beyond Texas and load shedding decisions:

> Extreme, record-breaking arctic weather descended upon the central part of the nation during the second week of February, forcing power outages throughout the region. States in the middle south were especially hard hit, particularly Texas where the extreme cold forced generators offline, resulting in a massive deficit of energy to serve customers during record winter demand conditions. The system operator for the majority of Texas – the Electric Reliability Council of Texas (ERCOT) – was forced to order unprecedented load shedding as a last resort measure to restore frequency and protect system stability. At its peak, 52,277 MW of generation across *all* fuel types within ERCOT were unavailable, or 48.6% of total installed capacity.[17] The crisis lasted more than a week, ultimately subjecting more than 4 million Texans to localized blackouts and millions more to a range of compounding impacts. Many municipal water systems failed with 14 million under boil-water notices. Natural gas deliveries were curtailed due to frozen infrastructure and little to no dual-fuel capability was available in Texas. This serves as a sobering reminder of the essentiality of electric service to support all other critical infrastructures. And, most tragically, lives were lost in the crisis.
>
> While the scale in Texas was especially dramatic, extreme winter weather also caused significant forced outages and load shedding in states throughout the central part of the country from North Dakota to Louisiana. To maintain system stability, the Midcontinent Independent System Operator (MISO) ordered 1,430 MW of load shedding on February 16, affecting citizens from southern Louisiana, Arkansas, Mississippi, east Texas, and Illinois. MISO reported a peak of 59,322 MW of generation was unavailable throughout the entire balancing authority area on February 14. This includes 8,081 MW that was weather related. The Southwest Power Pool service area experienced 3,443 MW of load shedding and the loss of 25,000 MW of generation across a range of resources. Outages occurred in Arkansas, Louisiana, Texas, Oklahoma, Kansas, Missouri, Nebraska, North Dakota and South Dakota. This crisis shows the increased vulnerability of the electric supply system to an extreme common condition that spans electric systems.
>
> The human toll – suffering, death, and economic loss – makes the 2021 extreme cold weather event highly significant. To be clear, load shedding is an unwelcome last resort measure to avoid uncontrolled cascading outages across an entire interconnection. Faced with untenable choices during an emergency event when decisions must be made within minutes, actions taken by grid operators helped prevent even more widespread suffering. Data presented by ERCOT show the entire electric system was within minutes of frequency and voltage collapse, necessitating the dramatic action they took.

These words are sobering and dramatic, but they don't fully explain what "uncontrolled cascading outages across an entire interconnection" might mean. This means blanket, not rolling, blackouts across multistate regions which could last for weeks, a point repeatedly made by Magness in a spate of hearings.

A different angle from an electrical perspective is provided in EIA's tally of "Major Disturbances and Unusual Occurrences, Year-to-Date 2021".[18] Of the 67 events between Sat. Feb. 13 and Wednesday Feb. 17, 32 involved firm load shedding of 100 megawatts or more (needed to guard against frequency and voltage collapse mentioned by Robb) or loss of electric

[17] The testimony cites ERCOT sources. More recent ERCOT data is included in the "root causes" discussion below.
[18] EIA *Electric Power Monthly:* Appendix B. https://www.eia.gov/electricity/monthly/

service for other reasons affecting 50,000 customers or more. 27 were public appeals to cut back on electricity use to reduce risk to the bulk electric system. A handful of fuel supply emergencies were noted, plus several significant transmission problems. The majority of the events, 30, occurred in Texas, yet following the storm track 12 occurred in states to the north and 25 to the east or northeast from Texas. The bulk of these events, 53, were initiated on Monday and Tuesday, but we should keep in mind that many lasted 100 hours or more.

For the sake of comprehensiveness, in the Appendix we include a table showing changes in monthly generation in some of the nearby states. Dynamics at play include massive variability in wind output and relative changes in the competitiveness of natural gas vs. coal-fired generation given 2021's higher natural gas prices, whereas storm effects appear to be somewhat muted.

Refinery Utilization Snapshot. Texas, with its severe impacts from Winter Storm, just so happens to be the nation's heart of refining with one-third of U.S. crude refining capacity, twice as large as the next largest state, Louisiana.[19] This allows one to measure the storm's impact through a very different kind of metric, refinery utilization. In only 3 instances since 2000 did U.S. refinery utilization fall much below 80%, highlighted in **bold**: Hurricane Ike in 2004 for just one month, the Pandemic from April to December 2020, and Winter Storm Uri for just one month. It is the depth, not the duration, which distinguishes this event. Somewhat comparable shocks rocked other parts of the petroleum sector including flow-driven and intentional cessations of LNG and Mexico gas exports and shutdowns of a variety of petchem commodities.

Refinery UtilizationRates (%) and Plunges, 2000-2021

Date	Event	Month	Prior Month	Month 1	Month 2 (if > 1 mo)	Subsequent Month	Max Plunge	Comment
2004	H. Ivan	Sept	97.1	90.1	90.2	94.4	-7.0	
2005	Katrina-Rita	Sept-Oct	92.7	83.6	81.3	89.3	-11.4	
2008	Ike	Sept	87.1	**74.6**	-	85.3	-12.5	
2012	Isaac	Sept	91.1	87.6	87.1	88.6	-4.0	
2017	Harvey	Sept	92.9	85.4	88.4	92.6	-7.5	
2019	Laura	Sept	94.8	88.9	85.8	90.6	-9.0	
2020	Pandemic	April-ff	83.1	**70.2**	72.0	76.3	-11.1	Below 80% throuh Dec.
	"	Feb 2020 Utilizn:	86.7	**70.2**	72.0	76.3	-16.5	Max Decline vs. Feb rate
2021	Uri	Feb	82.5	**70.8**		82.0	-11.7	

Source: EIA U.S. Utilization of Refinery Operable Capacity

Controversies. The Texas example is a microcosm of the fact that natural gas supplies and delivery and electricity generation are closely linked, with the importance of these linkages magnified during periods of stress. By early June, state legislation had been enacted to help insure against future disasters by promoting weatherization, setting up the Texas Energy Reliability Council as a formal entity to dissect gas-electric coordination, and establishing close

[19] EIA, Number and Capacity of Operable Petroleum Refineries by PAD District and State as of January 1, 2021 https://www.eia.gov/petroleum/refinerycapacity/table1.pdf

state-house oversight of the independent system operator (ERCOT). Diagnosis is continuing at the federal level by NERC. ERCOT's conclusive root-cause analysis is due in August.[20]

Much has already been written or said in hearings and the media. A chief controversy has been determining who or what's to blame.

A. Representatives of the natural gas industry point to loss of electric power a key and possibly dominant cause, rather than well freeze-offs which also occurred. This position is characterized by the statement:

> "…power outages, which originated at power generation units, were the principal factor for natural gas production and transportation reductions or shutdowns during Winter Storm Uri. …failures occurred up and down the line of our state's electricity system."[21]

Their proposed solutions emphasize determining which natural gas system assets are involved in serving electric generators and assuring their electricity is not shut off. This involves a kind of "mapping" to figure out what is needed, a recommendation later enacted (footnote 14).

> "In Texas, 80% of the natural gas produced daily is not used for the production of electricity, so it is imperative we focus on the most directly impacted assets." *and*
>
> "We also agree that proper weatherization of both power-generation and natural gas facilities directly connected to power generation are key elements of reform.
>
> "…Some have suggested that all natural gas infrastructure – including 86,000 natural gas wells and another 164,000 oil wells that produce associated natural gas – should weatherize. In fact, many operators already weatherize at various levels. Yet without power, no amount of weatherization matters. To truly increase reliability, the research all points to focusing on the necessary infrastructure, contracts, weatherization, and storage..."[22] [emphasis added]

B. An executive in charge of the largest Texas electricity generator and one of the largest users of natural gas in the state seemed to take a middle-of-the-road stance with the simple observation "the main cause of the power outages was a failure of the integrated natural gas and power systems."[23] He stated the gas-electric connection: "we need … gas to fuel our power plants that, in turn, power the critical gas infrastructure — when it works, it is a virtuous cycle."

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[20] Synopsis of state legislative measures spawned by the storm: "Texas Governor Enacts Grid Reliability Measures, Including Power Plant Weatherization, ERCOT Reforms", by Sonal Patel, *Power Magazine*, June 9, 2021. https://www.powermag.com/texas-governor-enacts-grid-reliability-measures-including-power-plant-weatherization-ercot-reforms/

[21] "Power Outages Up and Down the Natural Gas Supply Chain Impacted Production and Transportation of Natural Gas During Winter Storm, Analysis Finds", April 22 2021 News, Texas Oil and Gas Association.

[22] "Texas must fix the natural gas-power—power-generation supply loop to prevent another blackout", Opinion by Todd Staples of Texas Oil and Gas Assoc., Dallas Morning News, May 16, 2021. https://www.dallasnews.com/opinion/commentary/2021/05/16/texas-must-fix-the-natural-gas-power-generation-supply-loop-to-prevent-another-blackout/

[23] "Vistra CEO: Gas companies should not profit from their own dysfunction", Opinion, Houston Chronicle, by Curt Morgan. May 14, 2021. https://www.houstonchronicle.com/opinion/outlook/article/Vistra-CEO-Gas-companies-should-not-profit-from-16178009.php Vistra owns TXU Energy.

He also pointed to shared responsibility, namely, "…some natural gas and power assets were not properly weatherized."[24]

Exasperation with the natural gas industry, however, is revealed in other remarks:

> "Some natural gas companies have reported making billions in profits from the storm. But before and during the storm, natural gas production fell by half, gas suppliers canceled contracted deliveries to customers, critical gas equipment failed, pressures on pipelines dropped — and gas prices skyrocketed."
>
> "Some gas companies failed to do the paperwork that would have kept their facilities from having power curtailed." referring to "…the failure … to register natural gas infrastructure to keep power from being cut." *and*
>
> "Some gas companies voluntarily curtailed their operations so they could sell their electricity and profit instead of performing their critical function."

C. Early during the event, outages of some renewable sources had taken the blame. This apparently became a popular political talking point[25], dismissed by both later analysis (below) and by a terse comment in testimony at the federal government level submitted by the mayor of Houston:

> "Any claim that this systemwide failure was caused primarily by the use of renewables is blatantly false."[26]

As recently as July 6, the Texas governor seemingly carried his campaign against renewables a step further, issuing a letter directing the Public Utilities Commission to "allocate reliability costs to generation sources that cannot guarantee reliability, such as wind and solar power".[27]

The letter argues that when such generators fail to perform as anticipated, they should "shoulder the costs of that failure" in order to create an even "playing field between non-renewable and renewable generators". What might this mean? One of our Committee's contacts suggests the special status afforded nenewable generators if they fail to meet their obligations when bidding in the "day ahead" market could be withdrawn. Currently, a fossil unit participating in the "day ahead" market which fails to meet its target must acquire power

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[24] Information on technical aspects of weatherization for power, industrial and gas systems, including gas system cost considerations, is appended to the FERC/NERC report on the 2011 freeze, cited in Footnote 8.

[25] "When the power went out, Texas oil and gas regulators rushed to defend the industry's image", Texas Tribune republished in Houston Chronicle, by E. Douglas and M. Ferman. April 5, 2021. https://www.houstonchronicle.com/politics/texas/article/When-the-power-went-out-Texas-oil-and-gas-16078087.php

[26] Hearing "Power Struggle: Examining the 2021 Texas Grid Failure". Testimony by Mayor Sylvester Turner, U.S. House Energy and Commerce Committee. March 24 2021. https://energycommerce.house.gov/committee-activity/hearings/hearing-on-power-struggle-examining-the-2021-texas-grid-failure

[27] "Governor Abbott Directs Public Utility Commission To Take Immediate Action To Improve Electric Reliability", Office of the Texas Governor | Greg Abbott Press Release, June 6 2021. https://gov.texas.gov/news/post/governor-abbott-directs-public-utility-commission-to-take-immediate-action-to-improve-electric-reliability

in the "real time" market to make up the difference. Renewables are exempted. The letter seems to suggest that wind and solar generation should incur the same consequences.[28]

The preceding points of controversy (A-C) are just some of the many issues raised by the disaster. A more inclusive list was submitted in testimony on March 4th by the same Vistra CEO cited above and is included in this document as an Appendix.[29] Despite the sentiments quoted above, this earlier submittal is even-handed and may serve as a checklist of future accomplishments or missed opportunities. In addition to cementing the priority that must be assigned to critical natural gas assets to avoid power cutoffs, examples include such things as improved communications across all parties, early warnings when conditions get dicey, and mindfulness to whether market participants have the capacity to incur the risks they can create.

Getting to Root Causes: Electric Sector Perspective. By April 27, ERCOT issued its most comprehensive assessment to date of the timeline, occurrences and types of outages. First pointing out the severity of the storm compared to the February 2011 event, they show how close the system came to "uncontrolled cascading outages". They show how the event evolved with a pattern of different units going on- and offline throughout the period. They answer questions about which types of generation went out of service and for how long. And they demonstrate how typical measurements of the scale of outages – based on units' generation capacity – are not suitable when applied to variable generation. An outage of a solar unit at midnight is meaningless. Likewise, the meaning of an outage or derate for a wind unit depends on what it could have produced under existing wind speeds in any given moment, not its rated capacity.

These points are best conveyed through a selection of ERCOT's public charts.[30]

Temperature plots show how much colder the 2021 storm was compared to the 2011 event. Beyond this comparison, other differences were cited. 3 ½ times more capacity (52.3 vs 14.7 GW) was forced out of service at the maximum point (we reiterate that this measure is reduce somewhat depending on the method of calculation, addressed in the fifth, last chart in this sequence). Nearly twice as many generators incurred outages (356 vs 193) and seven times as

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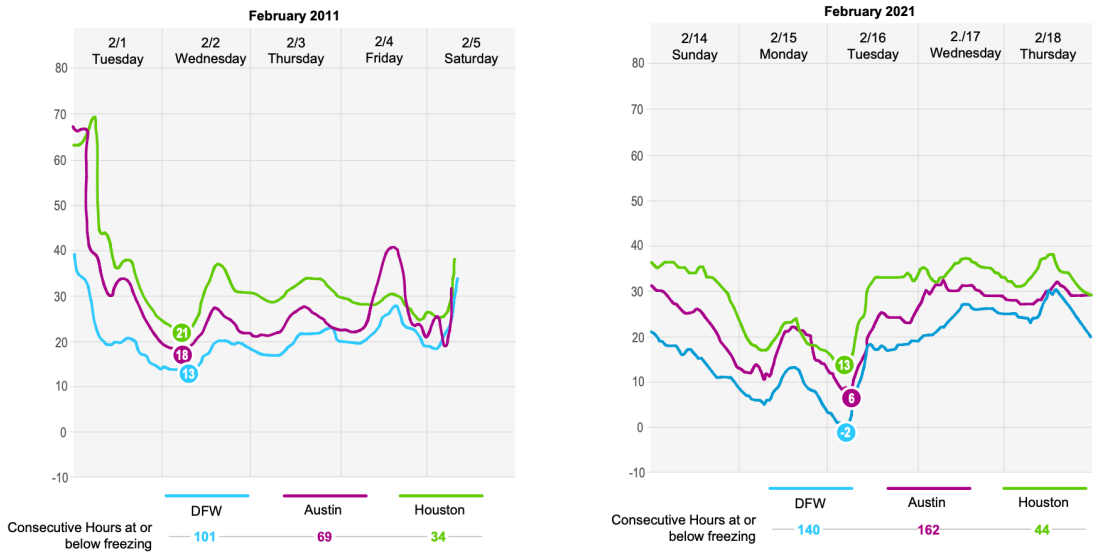
[28] J. Platt, personal communication, Energy Economics and Technology Committee contact (name withheld), July 6 2021.

[29] "ERCOT 2021 Winter Storm – Policy Response Options", March 4/5, 2021, submitted to Texas Joint Committee. Appendix. Follow-up to Feb. 25 Hearing, Statewide electrical blackout – contributing factors and response. Docket: http://interchange.puc.texas.gov/search/filings/?UtilityType=A&ControlNumber=51825&ItemMatch=Equal&DocumentType=ALL&SortOrder=Ascending (Item 3).

[30] ERCOT: (1) Storm information resources: http://www.ercot.com/news/february2021 ;
(2) Review of February 2021 Extreme Cold Weather Event – ERCOT Feb. 24 Presentation to Texas Senate Business and Commerce Committee and House Joint Committee on State Affairs and Energy Resources by Bill Magness. Similar to Feb. 24 presentation to ERCOT Board
http://www.ercot.com/content/wcm/lists/226521/Texas_Legislature_Hearings_2-25-2021.pdf ;
(3) "Update to April 6, 2021 Preliminary Report on Causes of Generator Outages and Derates During the February 2021 Extreme Cold Weather Event". April 27, 2021. 2021.
http://www.ercot.com/content/wcm/lists/226521/ERCOT_Winter_Storm_Generator_Outages_By_Cause_Updated_Report_4.27.21.pdf

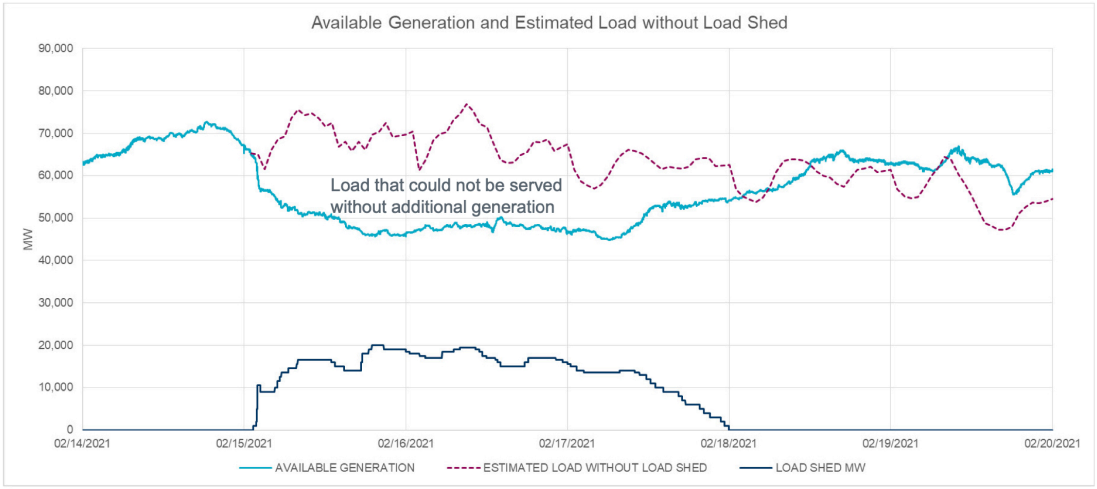
much gas generation was derated due to “supply issues” (9.3 vs 1.3 GW). And five times as much load shedding was needed at the worst times (20 GW vs 4 GW).

2011 vs. 2021 Event Temperature Comparison



The load and price chart presented above in the “Electricity Snapshot” section indicated a “gap” between actual load and a likely higher load which could never be served because of the collapse in generation. The next chart presents ERCOT’s estimation of what the load might have been (purple dashed line) out to the end of the week (Friday the 19th). The amounts of necessary load-shedding from Monday through Wednesday are also presented.

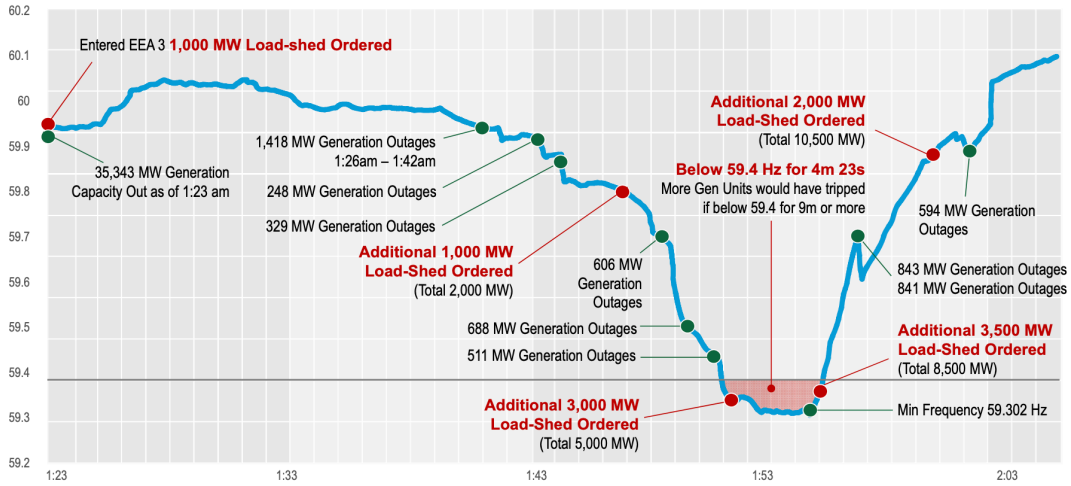
Available Generation and Estimated Load Without Load Shed



Available Generation shown is the total HSL of Online Resources, including Quick Starts in OFFQS. The total uses the current MW for Resources in Start-up, Shut-Down, and ONTEST.

Just how close the system came to total collapse is apparent from how much system frequency was changing early in the morning of the 15th, about 1:53 AM to be exact. Had frequency remained in the red zone, below 59.4 Hz, for nine minutes, generators would have tripped automatically across the system. With additional load shedding (6,500 MW were ordered during four precarious minutes), the frequency drop was arrested and started to climb. The red zone lasted 4 minutes 23 seconds, just 4 minutes 37 seconds away from collapse.

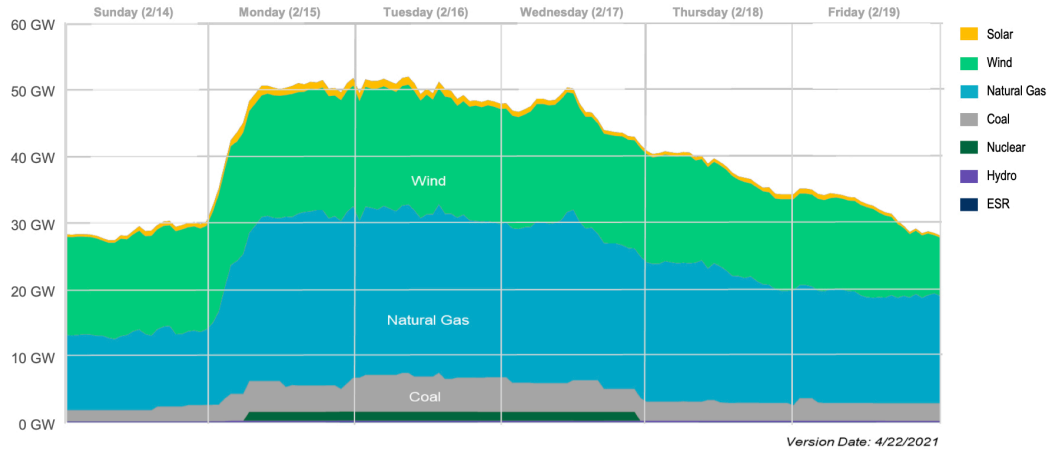
Rapid Decrease in Generation Causes Frequency Drop



The next two charts present outages by type of generation. The top calculates wind in the traditional way, i.e. measured against the capacity of the equipment regardless of what was happening at the time (wind speed, for example).

Chart: Outages using traditional capacity metric:

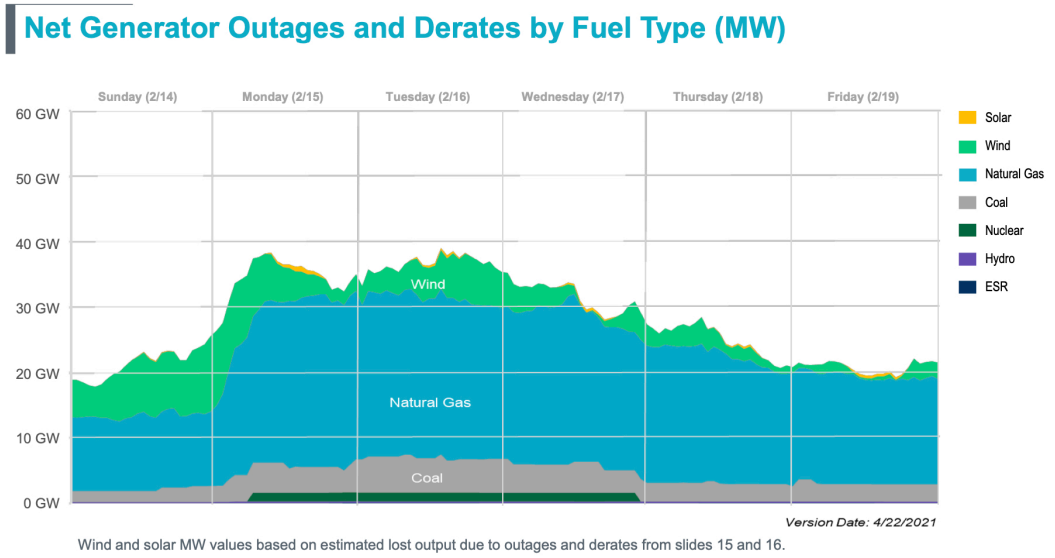
Net Generator Outages and Derates by Fuel Type (MW)



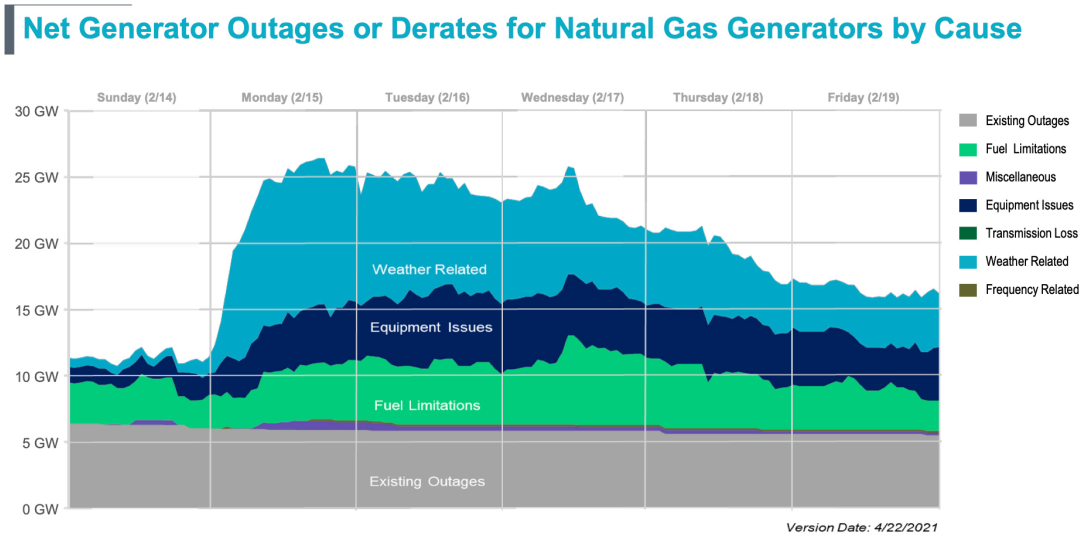
Outage and derate MW for Wind in this graph are based on capacity.

The second chart greatly shrinks how much wind underperformed by measuring its underperformance against what it could have produced without any problems. That is based on "backcasting" to estimate how much wind output could have been under the observed conditions. This sort of quantitative analysis shows that wind's problems were still somewhast significant from mid-Sunday into early Monday. After that, outages were dominated by what happened to gas generation.

Chart: Outages incorporating backcasting of performance under actual conditions:



The last chart in this diagnosis prepared by ERCOT breaks down the principal causes of natural gas generation's failures.



Going into this period there were about 6 GW of existing outages. Of gas units' additional 15-20 GW outage throughout most of the week, fuel deliveries accounted for a relatively persistent ~5 GW of the problems, jumping up by an additional ~2.5 GW midday Wednesday and gradually declining thereafter. Later iterations of root cause analysis will shed light on that and other problems, including to what degree fuel limitations were caused by curtailments of power to vital natural gas assets. The bulk of the outages were "weather related", referring to various impacts from freezing equipment.

Implications for the Energy Transition. The outlines of the story presented here are incomplete, leaving out questions of how power prices were set, massive financial liabilities related to natural gas as well as power, Texas' unique energy-only power market design, impacts on water supplies, and more.

Several things have come to the foreground. Failures may occur across many different types of generation at essentially the same time. Better inter-regional connection might not help very much if everyone is experiencing the same kinds of problems (frigid weather, heat waves, maybe even cyber-attacks?). Problems are not simply technocratic: with the best information in hand, responses to the frigid event ten years earlier did not lead to adequate responses.

To be cynical or to be optimistic?

The former is captured by the adage: "Success has many fathers, failure is an orphan." This seems to be an inescapable part of the human condition, put on display by the casting of blame on renewables, or on fuel supply, or on power curtailments. Too, the very next week, different agencies, individuals and even the state legislature got caught up in the crossfire.[31] One lesson emerging from this mess may be to not jump to conclusions, to wait for facts.

An optimistic view is captured by the observation: "A great navy is like oxygen. You notice it only when it is gone." "[32] In this case, the "great navy" is a well-functioning electric grid, fully integrated with an equally well-functioning natural gas system. The storm brings needed attention to this normally invisible, complex, joint infrastructure. Fully appreciating how it operates when the unexpected occurs will be ever more important as the system changes with further moves toward decarbonization on both the fuel and power side.

The energy transition was very much on the mind of the head of NERC when he testified on March 11th before the Senate Committee on Energy and Natural Resources.[33] In addition to the

[31] "The Lege This Week: Adventures in Circular Finger Pointing", by Justin Miller, *Texas Observer*. Feb 26, 2021. https://www.texasobserver.org/the-lege-this-week-adventures-in-circular-finger-pointing/

[32] "America's Elegant Decline", *The Atlantic*, November 2007. https://www.theatlantic.com/magazine/archive/2007/11/america-s-elegant-decline/306344/

[33] Hearing on Reliability, Resiliency, and Affordability of Electric Service. Testimony by James Robb, Pres. and CEO, North American Electric Reliability Corp. "Reliability, Resiliency, and Affordability of Electric Service in the United States Amid the Changing Energy Mix and Extreme Weather Events" March 11, 2021. *(cont'd next page)*

winter storm, he remarked on several additional weather extremes including California's August 2020 heat wave with rolling blackouts and a "near miss" winter cold extreme in New England. By January 8 2018, the region came within "just several more hours of freezing weather" of requiring load shedding, since the inventory of fuel oil was nearly exhausted. This was the region's backup fuel because prolonged cold weather had already led to natural gas shortages.

These events were all leading NERC to develop more robust reliability standards. Moreover, they've been tracking regional and growing vulnerabilities due to fuel delivery risks, power sector performance, or both for many years. Currently at the top of the list are California, Texas into Louisiana, New England and the Maritimes, the Upper Midwest, and much of the Rockies into the Northwest. They now conclude risks are increasing because the mix of generation is changing.

> "Managing the pace of change is the central challenge for reliability. The rapid evolution of the generation resource mix is altering the operational characteristics of the grid. … It is imperative to understand and plan for the different operating characteristics of variable, inverter-based resources [i.e, solar, wind].
>
> "More transmission and natural gas infrastructure is required to improve the resilience of the electric grid. Electric transmission investment must keep pace with the increase in utility scale wind and solar resources… Additional pipeline infrastructure (including gas storage) is needed to reliably serve load and enable natural gas as a balancing resource. …[But} few long-haul transmission lines and pipelines are actually being planned and built.
>
> "Natural gas is essential to a reliable transition. As variable resources continue to replace other generation sources, natural gas will remain essential to reliability … unless or until very large-scale battery deployments are feasible or an alternative flexible fuel such as hydrogen can be developed. …Growth in the use of natural gas as a fuel for electric generation and other applications can stress the natural gas supply infrastructure when necessary expansions do not keep pace.
>
> "Regulation and oversight of natural gas supply for electric generation needs to be rethought. – While natural gas is key to supporting a reliable transformation of the grid, the natural gas system is not built and regulated to serve the needs of an electric power sector that is increasingly dependent upon reliable natural gas service.
>
> "Energy storage can and will be a game changer. …[Energy storage] resources will become a game changer. However, we have to appreciate the gap that currently exists and the scale that we need to obtain. …[A NERC] assessment stresses the need to plan for a significant increase in the critical mass of battery storage or other balancing resource (such as hydrogen) *at scale* before natural gas reduces its role…. Investment in energy storage technologies and/or a hydrogen production and delivery system will be required if the vision of a largely/completely decarbonized electric system can be realized*." [italics above per original testimony]*

In a nutshell, the transition is going to be a difficult balancing act as regions weave options not yet known into systems that will continue to need investment to assure reliability – always mindful of *scale*.

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https://www.nerc.com/news/Headlines%20DL/NERC%20Reliability%20Hearing%20Testimony%203-11-21%20-%20Final.pdf

This summary naturally leads us to delve further into the challenges of decarbonization, implications for natural gas, timetables of possible change, and the like. Ongoing Committee analysis is moving in this direction, initially highlighting the more foreseeable changes in transportation (EVs) and electric power (renewables, and natural gas' schizoid status as a green replacement for coal but nevertheless a source of emissions, including methane).[34] Yet there is one more rather disturbing takeaway from Winter Storm Uri which applies to how effectively society might be able to grapple with the demands of the energy transition. This was revealed by a representative survey across most of Texas conducted from March 9-19 by an organization called YouGov on behalf of the Hobby School of Public Affairs, part of the University of Houston.[35]

The survey elaborated impacts, such as: (1) over 2/3s of Texans lost electric power an average of 42 hours, 22% of those for 71 hours or longer, and (2) half lost running water altogether an average of 52 hours, and for those who didn't, 40% could not drink it. The survey also details difficulties shopping for food and bottled water, spoiled food, and other inconveniences.

With these impacts fresh on people's minds, fully 78% were in favor of winterizing both electricity supply and natural gas pipelines. This makes it all the more surprising that only 18% favored a consumer fee for electric winterization, with 62% against, and only 32% favored natural gas winterization, with 44% against. The distaste of paying for any fees on the electric side is magnified by a question of how much one might be willing to pay any fees. 51% selected zero dollars per month, and 25% indicated only $5.00 extra. While survey research is always imperfect, these results put a very raw spotlight on matters of affordability which, going forward, will be part and parcel of the stringency, pace and methods of achieving decarbonization.

[34] Committee activities include submitting a summary of investment tensions facing the oil and gas industry, examining through literature and experts top questions about the energy transition, and hosting an event at the September 2021 International Meeting for Applied Geoscience & Energy (IMAGE), 2021's combined annual meeting for the American Association of Petroleum Geologists, the Society for Sedimentary Geology, and the Society of Exploration Geophysicists. This Zoom panel, titled "Energy Transition: Oil and Gas in the Crosshairs", highlights speaker from the investment, auto and power sectors.

[35] Press Release "New Report Details Impact of Winter Storm URI on Texans", March 29, 2021: https://uh.edu/news-events/stories/2021/march-2021/03292021-hobby-winter-storm.php and *The Winter Storm of 2021*, The Hobby School of Public Affairs: https://uh.edu/news-events/stories/2021/march-2021/03292021-hobby-winter-storm.php

Appendices

1. Jan, Feb, March Generation by Source, Arkansas, Kansas, Oklahoma and Texas

2. Vistra Submittal of Winter Storm Policy Issues

ELECTRICITY SOURCE	Jan	Feb	Mar	Jan	Feb	Mar	Jan-Feb ch	Jan-Feb ch %	Feb-Mar ch	Feb-Mar ch %
	GENERATION (Megawatthours)			Shares of Monthly Gen %						
ARKANSAS Total	**5,183,463**	**4,482,136**	**4,488,751**				**-701,327**	**-13.5%**	**6,615**	**0.1%**
Coal	**2,302,243**	**1,935,561**	**1,337,404**	**44%**	**43%**	**30%**	**-366,682**	**-15.9%**	**-598,157**	**-30.9%**
Pumped Storage	934	4,891	13,846							
Hydroelectric Conventional	370,102	317,089	380,147							
Natural Gas	**1,014,148**	**919,866**	**1,362,790**	**20%**	**21%**	**30%**	**-94,282**	**-9.3%**	**442,924**	**48.2%**
Nuclear	**1,369,932**	**1,207,132**	**1,278,617**	**26%**	**27%**	**28%**	**-162,800**	**-11.9%**	**71,485**	**5.9%**
Other	1,009	457	575							
Petroleum	3,309	10,227	1,323							
Solar Thermal and PV	23,928	20,135	39,364	0.46%	0.45%	0.88%	-3,793	-15.9%	19,229	95.5%
Other Biomass	9,893	8,294	8,961							
Wood & Wood Deriv. Fuels	87,963	58,484	65,723							
KANSAS Total	**4,672,387**	**4,291,005**	**4,918,530**				**-381,382**	**-8%**	**627,525**	**15%**
Coal	**1,465,965**	**1,791,444**	**1,372,693**	**28%**	**40%**	**31%**	**325,479**	**22%**	**-418,751**	**-23%**
Hydroelectric Conventional	2,257	1,837	2,336							
Natural Gas	**160,698**	**238,860**	**226,976**	**3%**	**5%**	**5%**	**78,162**	**49%**	**-11,884**	**-5%**
Nuclear	**911,616**	**823,212**	**676,419**	**18%**	**18%**	**15%**	**-88,404**	**-10%**	**-146,793**	**-18%**
Other	413	412	413							
Petroleum	7,650	32,939	9,768							
Solar Thermal and PV	3,209	3,485	3,878							
Other Biomass	5,438	4,862	5,372							
Wind	**2,115,139**	**1,393,954**	**2,620,675**	**41%**	**31%**	**58%**	**-721,185**	**-34%**	**1,226,721**	**88%**
OKLAHOMA Total	**7,057,005**	**6,146,437**	**6,380,751**				**-910,568**	**-13%**	**234,314**	**4%**
Coal	**890,995**	**1,030,626**	**512,574**	**13%**	**17%**	**8%**	**139,631**	**16%**	**-518,052**	**-50%**
Pumped Storage	-5,924	-7,099	-5,509							
Hydroelectric Conventional	341,306	288,503	344,491							
Natural Gas	**3,009,331**	**2,822,042**	**1,907,465**	**43%**	**46%**	**30%**	**-187,289**	**-6%**	**-914,577**	**-32%**
Other	-51	-681	-1,194							
Petroleum	2,974	6,151	2,321							
Solar Thermal and PV	3,864	4,253	6,570							
Other Biomass	7,081	4,302	5,997							
Wind	**2,785,087**	**1,988,757**	**3,588,174**	**39%**	**32%**	**56%**	**-796,330**	**-29%**	**1,599,417**	**80%**
Wood & Wood Deriv. Fuels	22,342	9,583	19,861							
TEXAS Total	**38,675,546**	**34,889,865**	**33,859,451**				**-3,785,681**	**-10%**	**-1,030,414**	**-3%**
Coal	**7,958,851**	**6,812,395**	**4,911,932**	**21%**	**20%**	**15%**	**-1,146,456**	**-14%**	**-1,900,463**	**-28%**
Hydroelectric Conventional	159,178	142,876	170,730							
Natural Gas	**17,707,461**	**17,402,496**	**13,464,651**	**46%**	**50%**	**40%**	**-304,965**	**-1.7%**	**-3,937,845**	**-23%**
Nuclear	**3,799,445**	**3,313,548**	**3,369,279**	**10%**	**9%**	**10%**	**-485,897**	**-13%**	**55,731**	**1.7%**
Other Gases	217,989	82,320	93,892							
Other	50,599	27,433	23,776							
Petroleum	12,510	52,879	10,897		0.15%		40,369	323%	-41,982	-79%
Solar Thermal and PV	646,451	646,797	1,000,686	1.7%	1.9%	3.0%	346	0.1%	353,889	55%
Other Biomass	34,700	29,520	33,941							
Wind	**8,012,164**	**6,316,134**	**10,704,360**	**21%**	**18%**	**32%**	**-1,696,030**	**-21%**	**4,388,226**	**69%**
Wood & Wood Deriv. Fuels	76,198	63,468	75,307							

Comparison to February of Year Before			
Texas 2020 Total	**35,782,446**	**2.6%**	***% Difference of Feb 2020 gen. compared to Feb. 2021***
Coal	**4,822,873**	**-29%**	29 % less coal gen in Feb 2020 than Feb 2021
Hydroelectric Conventional	179,482		
Natural Gas	**18,693,106**	**7%**	slightly higher nat gas and nuclear in Feb 2020
Nuclear	**3,548,014**	**7%**	
Other Gases	251,578		
Other	29,878		
Petroleum	10,662		
Solar Thermal and PV	396,374		
Other Biomass	33,062		
Wind	**7,731,453**	**22%**	22% more wind output in Feb 2020
Wood & Wood Deriv. Fuels	85,964		

Source: EIA Preliminary Monthly 2021 Generation Data, EIA-923 Report, for months through April, issued June 2021

AMANDA FRAZIER
Sr. Vice President
Regulatory Policy

March 5, 2021

Public Utility Commission of Texas
Chairman Arthur C. D'Andrea
Commissioner Shelly Botkin
1701 N. Congress Avenue
Austin, TX 78711

RE: Project No. 51812, Issues Related to the State of Disaster for the February 2021 Winter Weather Event; Project No. 51825, Investigation Regarding the February 2021 Winter Weather Event

Dear Commissioners:

Last week at hearings held by the Texas House Committees on State Affairs and Energy Resources and the Senate Committee on Business and Commerce, our CEO, Curt Morgan, was asked to provide those committee members with ideas that should be considered to address the impacts of the mid-February storm. Under separate cover, we provided the attached list to those members yesterday, March 4, 2021.

You will note that the list provided is long, covers a wide range of concepts and ideas, and raises issues that would need to be addressed in some cases through legislation, and in some cases through regulation, either by the Public Utility Commission of Texas or the Railroad Commission of Texas. The concepts are described at a high level, and details will matter. This list is our attempt at brainstorming ideas, but we stand ready, and look forward to, discussing these ideas with you and our fellow stakeholders.

Sincerely,

Amanda Frazier

ERCOT 2021 Winter Storm – Policy Response Options

Statutory Policies

	Policy Category	Policy Concept	Description
1.	**Electric & Gas Coordination**	**Joint Gas/Power Regulatory Oversight**	Create accountability and authority to ensure coordination and integration over gas and electric sectors.
2.	**Electric & Gas Coordination**	**Force Majeure Limitations**	Prevent critical fuel supplies from declaring force majeure to power plants during emergencies
3.	**Emergency Operations & Preparedness**	**Winter Storm Warning Communications Requirements**	Support Texas emergency management plan by providing earliest possible notice to Texas Division of Emergency Management of possible power outages or gas curtailments due to winter weather, with defined communications roles and reporting responsibilities. Plan for low-frequency/high-impact events.
4.	**Market Design**	**ERCOT Financial Integrity**	Modify ERCOT certification standard to require sufficient financial backing to support power market exchange clearing functions while insuring against uplift risk from defaults. Establish standards for financial market expertise at ERCOT governance and leadership levels.
5.	**Market Design**	**Forward Resource Adequacy**	Procure resource adequacy either annually or seasonally on forward basis through ERCOT-administered or bilateral market, tied to risk-weighted reliability standards and analysis
6.	**Market Design**	**Predicate Municipally Owned Utility (MOU)/Electric Cooperative (EC) Debt Forgiveness on Competitive Retail Opt-In**	MOUs and ECs that seek and utilize socialized financial assistance have demonstrated an inability to manage risks associated with serving customers. Those risks are best borne by private investors, and not customers. Requiring these MOUs and ECs to open to retail competition would help to ensure customers are protected from significant price risks, while providing the added benefit of customer choice.
7.	**Market Design**	**Winter Fuel Storage Incentive**	Provide market incentive (e.g., seasonal resource adequacy qualifications) to weatherize fuel and fuel handling facilities
8.	**Market Design**	**Generation Reserve Requirement for Renewables**	Increase generation reserve purchases* and assign incremental costs to intermittent renewables. Costs to be allocated based on expected reliability of renewable megawatts produced and included in renewables bids. *Generation reserves includes ancillary services procured by ERCOT to maintain reliable electric system; could include other constructs
9.	**Market Design**	**Dispatchable Portfolio Standard**	Legislative mandate to purchase minimum amount of energy from dispatchable resources.

2 Note: Policy concepts are not mutually exclusive; some may be alternatives for others listed, or otherwise complimentary or additive.

ERCOT 2021 Winter Storm – Policy Response Options

Regulatory Policies

	Policy Category	Policy Concept	Description
1.	**Electric & Gas Coordination**	**Restrict Critical Infrastructure from Participating in Electricity Demand Response Programs**	Restrict critical infrastructure from participating in electricity demand response programs in order to avoid perverse incentives during weather events that impact both power and gas production
2.	**Electric & Gas Coordination**	**Gas Winterization**	Clear, standardized and enforceable requirements to winterize - wellhead, pumps, compressors, processing facilities, etc. Consideration of back-up power.
3.	**Electric & Gas Coordination**	**Prioritize Gas and Electric Infrastructure**	Permanently prioritize gas and power infrastructure during electric and gas curtailments (all times or during extreme weather). Require TDUs to annually audit critical load lists. Require critical infrastructure (e.g., natural gas production, processing, and transport facilities) to demonstrate critical load registration.
4.	**Emergency Operations & Preparedness**	**Power Plant Winterization**	Implement clear, standardized and enforceable requirements for winterizing power plants (including wind turbines and solar facilities) with annual certification prior to the season
5.	**Emergency Operations & Preparedness**	**Rational Outage Allocations**	Align outage allocations with seasonal demand expectations (instead of just summer peak)
6.	**Emergency Operations & Preparedness**	**Smart Outage Rotation**	Require outage implementation to be more granular and customer-specific (vs. feeder-based); ensure fair distribution across retail electric providers' customers
7.	**Emergency Operations & Preparedness**	**Load Restoration Transparency**	Require visibility into TDU load restoration plans
8.	**Emergency Operations & Preparedness**	**Reassess Black Start Needs**	Review black start contracting requirements and plans. Provide financial incentives for generators that can operate on dual fuel sources
9.	**Market Design**	**Reduce Cap and Extend Demand Curve for Dispatchable Resources**	Change the shape of the Operating Reserve Demand Curve (ORDC) with lower overall price cap and longer tail, paid to dispatchable resources in order to reduce volatility while maintaining reliability incentives
10.	**Market Design**	**Mandate Firm Fuel Recoverability**	Ensure that ERCOT appropriately compensates for firm fuel contracts through verifiable cost and mitigated offer processes
11.	**Market Design**	**Set Wholesale Price to Reflect Cost of Thermal Resources During Off-Peak Periods**	Account for the cost of dispatchable generation by setting price at thermal marginal price at low-sustained level (LSL) operation, when intermittent resources are over-supplied during low demand periods, to reflect the reliability provided by the thermal resources.

Note: Policy concepts are not mutually exclusive; some may be alternatives for others listed, or otherwise complimentary or additive.

ERCOT 2021 Winter Storm – Policy Response Options

	Policy Category	Policy Concept	Description
12.	**Market Design**	**Protect Small Customers from Wholesale-Tied Prices**	Restrict Griddy-style rates for residential/small commercial customers. Variable/month-to-month rates should remain permissible under Public Utility Commission rules
13.	**Market Design**	**Retail Financial Standards**	Increase creditworthiness and collateral requirements for retail electric providers
14.	**Market Design**	**Intrastate Gas Market Transparency**	Facilitate increased transparency by requiring publication of tariffs and posting on Electronic Bulletin Boards to show available pipeline capacity and enable shippers' ability to bring additional supply into the market.
15.	**Market Design**	**Increase Customer Protections and Gas Market Oversight**	Strengthen affiliate rules for gas pipelines and gas marketers. Apply general prohibition on market manipulation or exercise of market power to natural gas industry. Clarify that Railroad Commission complaints regarding discrimination can be pursued for past events, not just prospectively.

4 Note: Policy concepts are not mutually exclusive; some may be alternatives for others listed, or otherwise complimentary or additive.