ERCOT's Continuing Decline in Reliability

by Gene Preston Presented to ECH January 15, 2022

ERCOT's reliability has declined to dangerously low levels and is continuing to decline. The current market rules do not provide a financial pathway to a reliable and environmental solution. The items below need to be addressed in planning the future ERCOT system.

Wakeup Call Trends:

1) The natural gas system is not reliable in cold weather: ref 1, ref 2, ref 3, ref 4, ref 5.
2) Future climate change regulations discourage the building of new fossil fuel plants.
3) ERCOT has the authority to uplift new transmission costs for conventional generation based on NERC reliability tests, but not for the variable power from renewables.
4) Renewables are taking away all the available transmission for coal and gas plants.
5) **Combining 1) – 4) above implies that fossil fuel capacity will continue to decline, possibly at an increased rate after the 2022 surge in new solar plant capacity.**
6) The capacity decline in fossil fuel plants is causing an increase in emergency events.
7) The price spikes from emergency events might be a basis for investing in more fossil fuel plants to reduce the yearly number of emergency events; however, the constraints imposed by 1), 2), and 4) are roadblocks to the building of new fossil-fuel plants.
8) The energy market does not provide enough revenue to support high capital cost projects such as large energy with high capacity battery storage, new nuclear plants, or CCS (carbon capture and storage) gas plants.
9) There is a recent rise in Generic Transmission Constraints which limit new generation.

Winter Storm Uri Impact on ERCOT and SPP (Southwest Power Pool):

10) Wind output drops in cold weather: ref 1, ref 2 (lost 47% of expected wind), ref 3.
11) Lost one nuclear unit due to a water in-take sensor (hopefully now winterized).
12) Lost about half the gas capacity thought to be firm capacity in SPP and ERCOT.
13) Despite loss of half the gas capacity, SPP had 30 GW more remaining firm capacity than ERCOT did during Uri; **ERCOT's dependency on renewables and gas is too high**:

Fuel	**ERCOT** p24	**SPP**
Type	MW	MW
Coal	14,703	22,899
Natural Gas	64,202/2 = 32,101	36,310/2 = 18,155
Nuclear	5,268	2,061
Other	1,268	5,115
Tie Lines	0	6,000
Available	53,340	54,230
Peak Demand	76,819	47,000
Reserve	**-23,479**	**7,230**

Climate Change Impact on Reliability:

High and low pressure weather systems today are larger, more frequent, and can cover a large geographical area for longer than a week. When large high and low pressure systems form alternately in a stream around the world, the jet stream is observed to zigzag, which creates a blocking event.

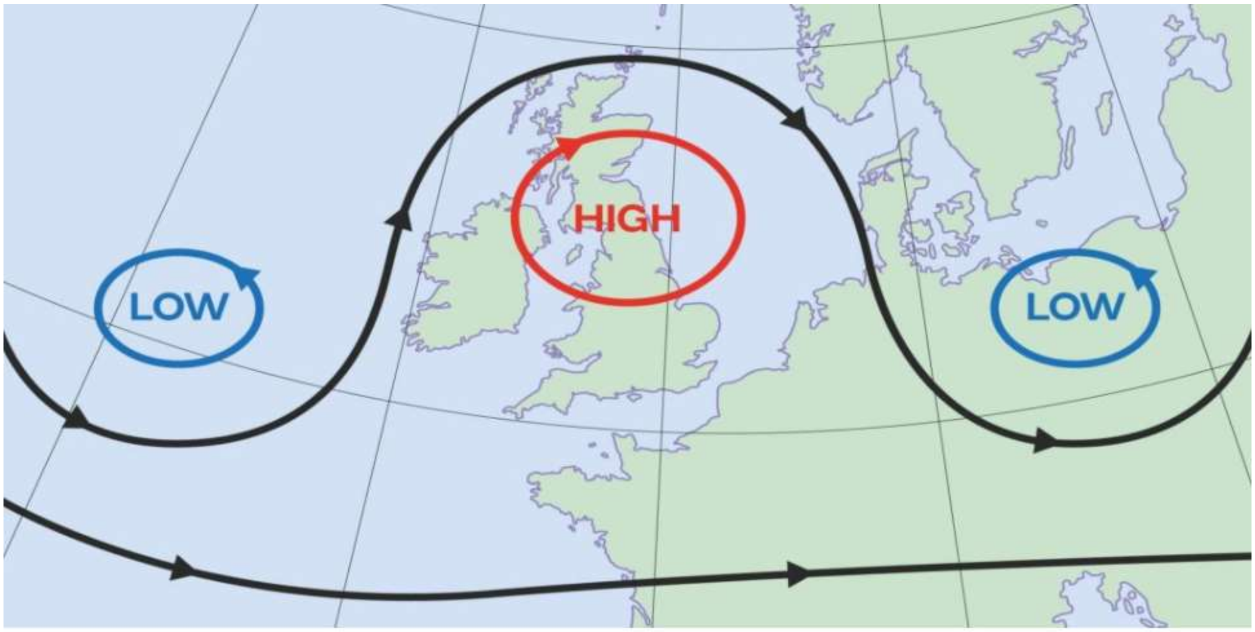


Illustration of an omega block over the UK. Credit: Met Office

The movement of the highs and lows eastward slows down and the heat wave and/or cold wave persists because of the blocking event. In 1970 I was planning the Austin system to meet peak demands at temperatures 102 F and 20 F. Today temperatures in the range of 115 F summer to 5 F in the winter seem possible. Deregulation interrupted the long range planning process. Texas ignoring climate change has caused a lack of preparation for dealing with the extreme temperatures.

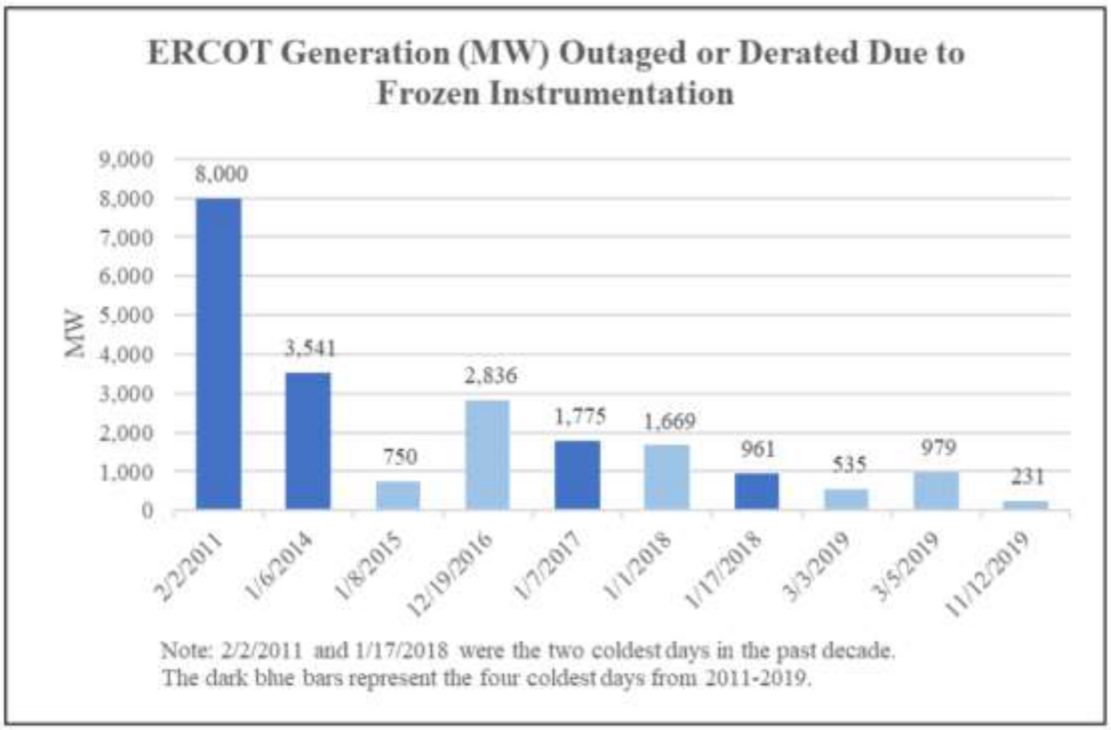
Long Range Generation Planning 1970-1995:

In 1973 the primary fuel was natural gas. However the cold winter of 1973 with gas shortages and burning of oil at gas plants around the clock revealed natural gas was not dependable in very cold weather. Oil tanks were added at many gas plants in Texas about 47 years ago. A need to diversify the fuel sources led to several new coal and nuclear plants being planned and constructed. These coal and nuclear plants served us well through the 2011 cold spell, preventing load shedding from being necessary, even when gas supplies are limited. Deregulation laws in the late 1990s removed the ability of Texas to perform long range generation planning because these alternative sources of power are more expensive than natural gas, but necessary for diversification. We did not know the impact that climate change would have on the power system when deregulation laws were passed and the current energy market was set up.

The Early Years of Deregulation 2000-2011:

After deregulation there was a rapid growth toward high efficiency combined cycle gas generators with about 14 GW of new plants being installed in a few years after deregulation. As these new plants were being added, and before older gas and coal plants were retired, there was quite a large amount of excess capacity. Wind grew rapidly as a result of the new CREZ lines. By the cold spell of 2011 there was plenty of capacity. However, that cold spell did reveal problems with weatherizing power plants. The Uri NERC report graph below suggests ERCOT was improving the weatherization of its power plants.

Figure 15: ERCOT Generation (MW) Outaged or Derated Due to Frozen Instrumentation



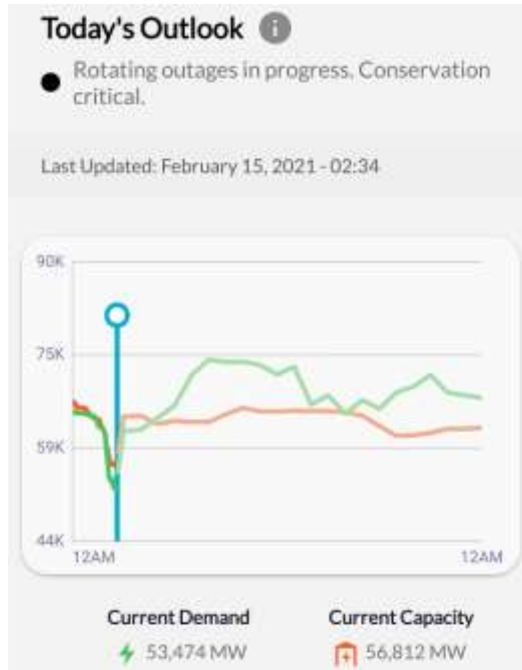
Years 2011-2021 Before Winter Storm Uri:

By 2018 the combination of low gas prices and growth in wind resources in ERCOT was having a negative impact on the economic viability of the coal plants and older gas plants. About 6 GW of coal plants were retired in the 2018 time frame that had not been predicted by Potomac Economics in 2018. ERCOT was showing signs of capacity deficiency in its power flow data which I reported to the IEEE Resource Adequacy Working Group in August 2020. I made a similar presentation to ECH with an opening remark about a need to focus on keeping the lights on. I reported that emergency load curtailments could increase to 54 days of shortfall in 2027. The 2020 Potomac Economics State of the Market Report warned ERCOT on page 76 the nuclear plants may be operating at a loss in 2020. Recently I have added a new *harmers/helpers* analysis that shows how a solar plant can cause gas plants to be displaced by the solar plant's power injection. It might be 100 miles away and still cause a gas plant to decrement power.

This drop in power keeps the grid reliable in meeting the N-1 line outage test but eventually this could cause a financial failure of the gas plant(s) leading to solar increases causing gas capacity decreases.

Winter Storm Uri:

Austin's freezing weather began on February 11 and continued through February 20. Uri ran for 100 hours longer than the 2011 storm and the coldest part of [Uri appeared in that last 100 hours](). If the temperature had not dropped so low and the storm had ended 100 hours earlier, there is a good chance the load shedding would have been minimal in ERCOT. This is what ERCOT expected and had planned for. ERCOT did appeal for [load reduction](). Climate change may be responsible for the extra duration due to the jet stream dragging cold air south and remaining in place longer.



I captured an image on my cell phone just as ERCOT was approaching a blackout. ERCOT was expecting a peak demand of about 67 GW but the low 7 F for an extended period caused the projected peak demand to rise 10 GW higher to 77 GW if there were no load sheddings. ERCOT did not have sufficient reserves to serve a 77 GW load even if it had not had any storm-related forced outages.

A [spreadsheet]() has been set up to model a simulated Uri weather event imposed on an ERCOT 2019 hourly wind, solar, and demand profiles. ERCOT's SARA [Seasonal Assessment of Resource Adequacy]() is used to set the following quantities:

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76819 MW Projected Peak Uri demand (SPP was 47000 MW*)
67529 MW SARA Nov 2020 final thermal and hydro
 -420 MW hydro (doesn't have the energy content)
 3631 MW private networks
-4074 MW maintenance (normally scheduled)
-5151 MW nuclear (5268 in NERC report not fossil)
61515 MW fossil firm capacity

Wind and Solar hourly profiles are explicitly modeled.
30000 MW Uri wind capacity (Uri wind capacity is half)**
 6000 MW Uri solar capacity

36957 MW 2022 wind capacity (Uri wind capacity is half)
19682 MW 2022 solar capacity
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* ERCOT's Uri peak demand is almost 30,000 MW greater than SPPs although the firm capacity of both regions is about the same. ERCOT having to load shed much sooner than SPP also led to huge problems.

** Not only was there icing of wind generators but the wind also dies down after fronts pass. SPPs Sunflower Electric Power Corporation lost more than 50% of their wind capacity.

NERC Winter Storm Uri report firm generation capacity in ERCOT and SPP (see page 24).

Figure 6: Installed Generation Capacity (MW) by Fuel Type

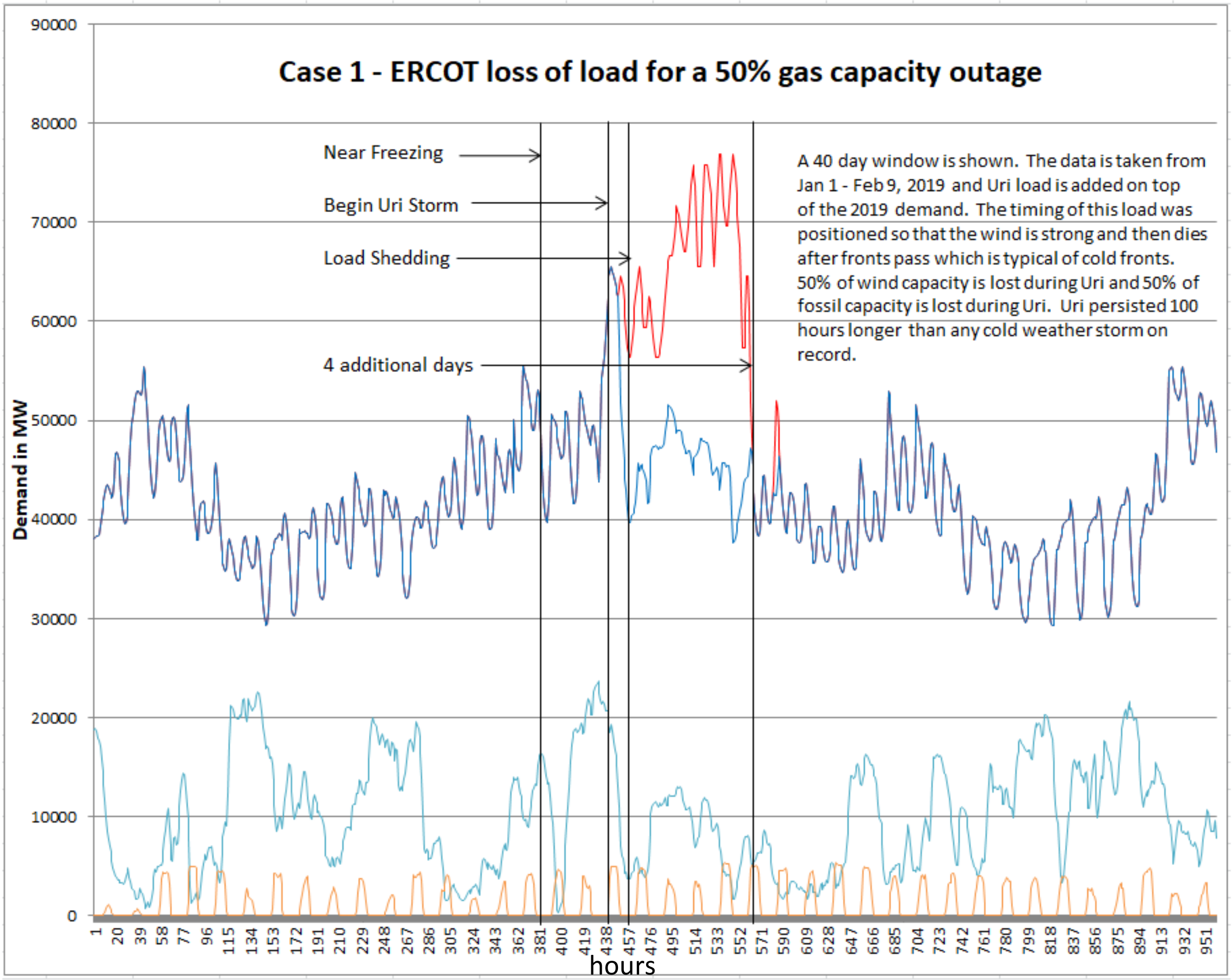
Fuel	ERCOT		SPP	
Type	MW	Percent	MW	Percent
Coal	14,703	11.9%	22,899	24.3%
Natural Gas	64,202	52.2%	36,310	38.5%
Nuclear	5,268	4.3%	2,061	2.2%
Other	1,268	1.0%	5,115	5.4%
Solar	6,202	5.0%	235	0.2%
Wind	31,414	25.5%	27,612	29.3%
TOTAL MW	123,057		94,232	

This table is reconstructed showing the firm capacity in each region including imported power over tie lines, while omitting the variable resources of wind and solar from the table as shown below:

Fuel	ERCOT	SPP
Type	MW	MW
Coal	14,703	22,899
Natural Gas	64,202	36,310
Nuclear	5,268	2,061
Other	1,268	5,115
Imported	0	6,000
Total	85,441	72,385
Reserve Capacity	8,622	25,385
Less ½ Gas	-32,101	-18,155
Available	53,340	54,230
Peak Demand	76,819	47,000
Reserve Actual	-23,479	7,230

ERCOT's low reserve capacity, high dependency on natural gas, high dependency on wind and solar, and lack of tie lines for importing power meant it was much more vulnerable to shedding load than SPP was.

Recreation of the load shedding in ERCOT during the Winter Storm Uri event is shown below.



The projected peak demand would have exceeded the summer peak demand by a few MW. The above graph shows an assumption for fossil fuels and wind power dropping 50% during the coldest weather. The Uri 2019 and 2022 systems are in this spreadsheet. Future Uri type systems with storage are here.

The 2019 spreadsheet Uri insert is January 1 - February 9, although the freezing weather was actually from February 11 - February 20, 2021. Recreated Uri loads were positioned in the 2019 data so that the wind dies at the end of the storm period, in order to show decreasing winds after the fronts pass.

https://youtu.be/nZmRuHUIX2k?t=577 Southwest Power Pool (SPP) gas supply issue.

https://youtu.be/nZmRuHUIX2k?t=829 High gas prices - Feds approved gas purchase with guarantees.

https://youtu.be/nZmRuHUIX2k?t=3134 Lack of gas and paying for available gas were major problems.

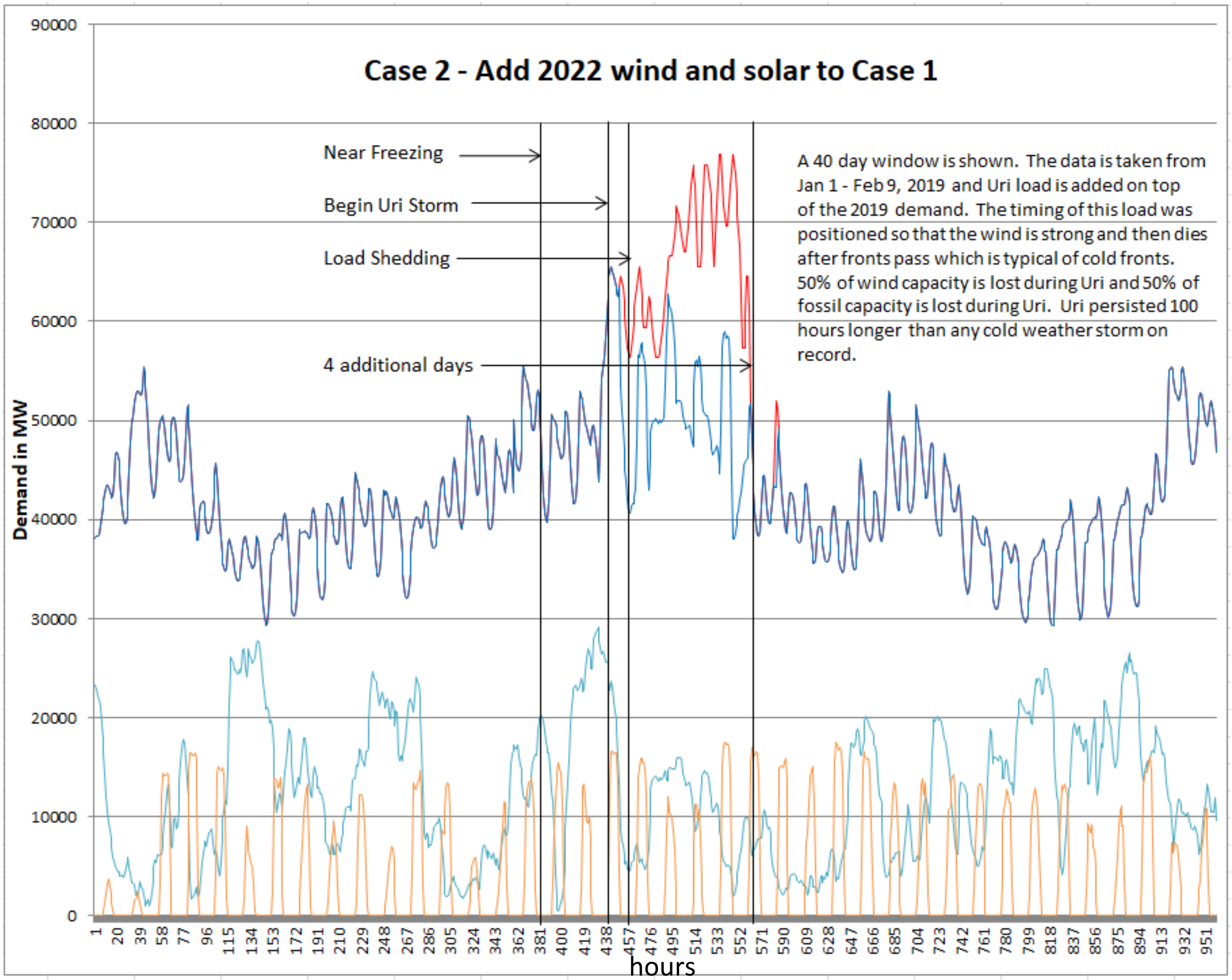
https://youtu.be/nZmRuHUIX2k?t=3514 Most gas plant outages were tied to the fuel supply.

https://youtu.be/nZmRuHUIX2k?t=4295 Additional gas storage was studied and is not affordable.

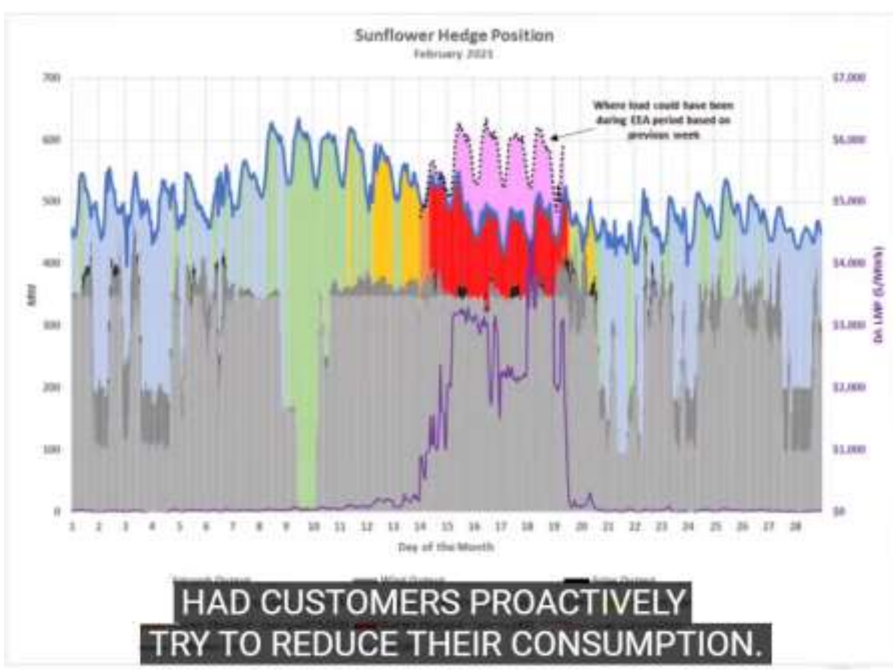
https://youtu.be/LUbKS7btfH8?t=9140 57% gas capacity was outaged due to a lack of fuel.

https://youtu.be/LUbKS7btfH8?t=9283 Weatherization issues were not the largest factor in SPP.

2022 adds a lot of new wind and solar in ERCOT which only helps close the Uri gap by a small amount:

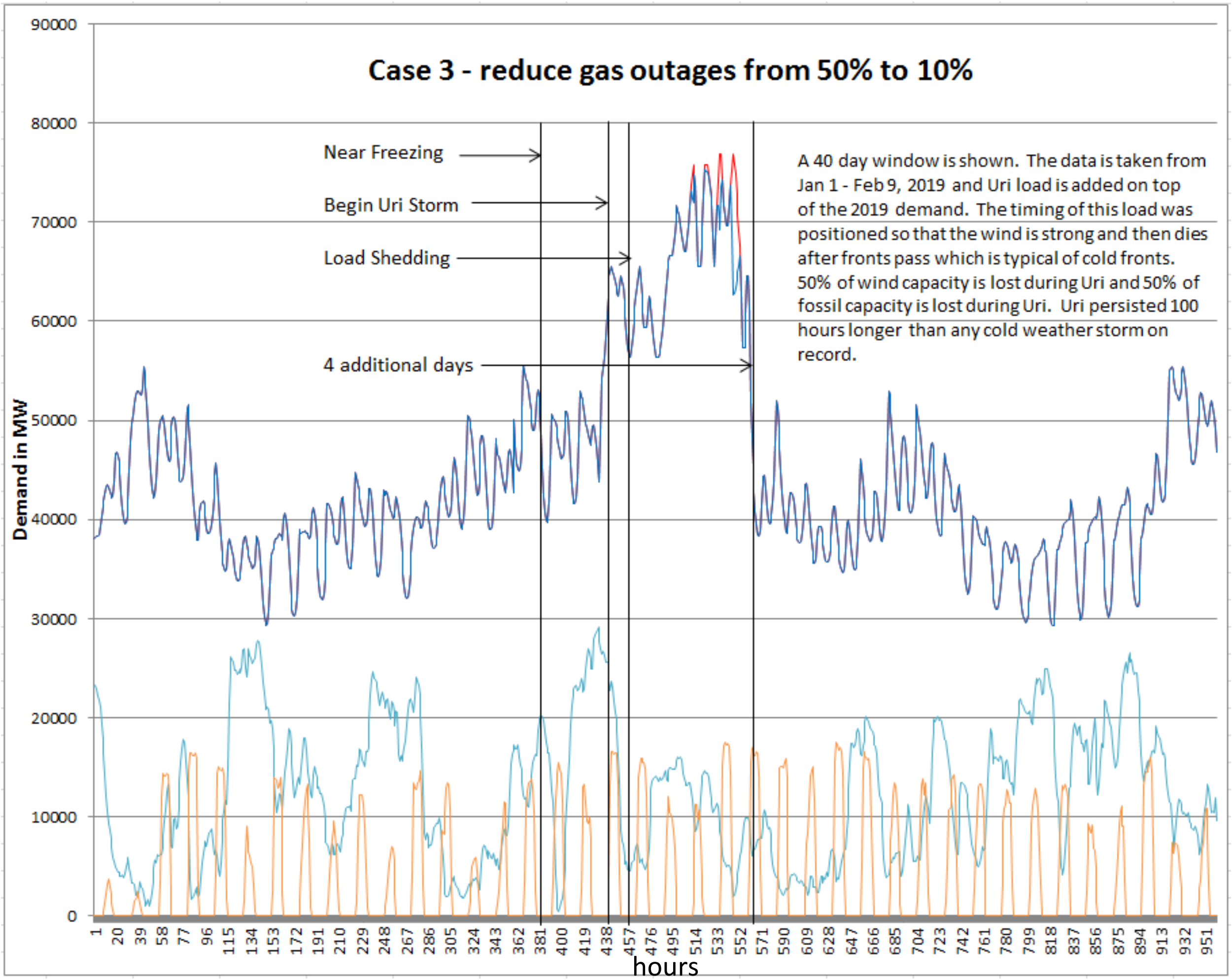


SPP's appeal to the public in the last 100 hours was very effective as you can see in this testimony and this graphic shown in the presentation. By this time the gas prices were very high and the appeal was concerned more about reducing customer costs than load shedding. Gas supplies were inadequate



in the last 100 hours and SPP was trying to help its customers reduce their electric bills.

Reducing the cold weather forced outages to 10% is still not quite enough to fully serve the peak load.



What have we learned?

1) The expectation that gas alone will provide reliability fails. This was the problem 47 years ago.
2) The expectation that wind, solar, and gas will provide a reliable source of energy also fails.
3) The SPP problems with wind and gas supplies are nearly identical with ERCOT's experience.
4) Low reserve margins in ERCOT lead to rolling outages (or worse) in extremely cold weather.
5) Load shedding beyond contracted interruptible load constitutes a **failure to meet the NERC requirement** of one day in ten years loss of load. This means that during one day once every ten years there will occur a loss of load for a few hours. An equivalent definition is the sum of daily peak LOLPs each year being less than or equal to 0.1 days per year. The peak LOLP each day is the probability of that day having loss of load. Summing the probabilities gives the total days per year expected generation will be sufficient taking all random variables into account. ERCOT falls short on this value although for the summer peak it appears ERCOT may meet the requirement for the summer of 2022. See https://egpreston.com/ERCOT_2022_Reliability.pdf This analysis did not take gas fuel uncertainty into account, however.

6) The solution is the same now as it was 47 years ago. **Diversify generation to reduce dependency on unreliable energy sources, which probably means add more nuclear power.**

A Study of Future Non CO2 Emitting Possibilities (https://egpreston.com/Future.xlsx)**:**

Assumptions (units are in MWs):

NERC Ref https://www.nerc.com/news/Pages/Final-Report-on-February-2021-Freeze-Underscores-Winterization-Recommendations.aspx

SARA Ref https://www.ercot.com/files/docs/2020/11/05/SARA-FinalWinter2020-2021.xlsx

67529	SARA Nov 2020 final thermal and hydro
-420	hydro (doesn't have the energy content)
3631	private networks
-4074	maintenance (normal scheduled)
-5151	nuclear (5268 in NERC report) (nuclear was not outaged in the spreadsheet)
61515	Non-nuclear firm capacity

30000	Uri wind installed capacity (Uri wind MWs are half expected)
6000	Uri solar installed capacity (2019 hourly profiles wind & solar)

36957	2022 wind capacity (wind drops to half expected**)
19682	2022 solar capacity

**The reason wind MWs drop is due to icing and also calm after the cold fronts pass.

Case Summaries:

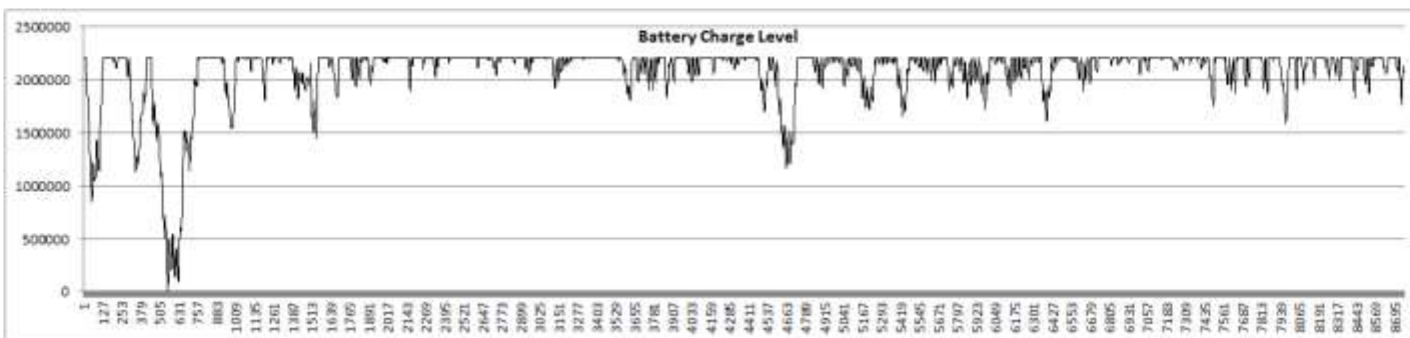
	2022	MaxVer1	MaxVer2	NewNucl
demand MW	.9*76819	.9*81000	.9*90000	.9*90000
wind MW	36,959	80,000	100,000	40,000
solar MW	19,682	80,000	100,000	40,000
gas MW	61,515	0	10,000	10,000
curtailed %	10	0	0	0
nuclear MW	5,268	5,268	0	40,000
batt stor GW	6.4	63.1	65.3	28.7
batt stor hrs	5.0	59.3	33.9	29.5
capt cost $Bn	**15**	**1,350**	**963**	**557**

Note: The peak demand is clipped off to 90% of the peak forecast in each case. This is adjustable in the spreadsheet. The 10,000 MW gas in the last two cases above is intended to represent small gas plants at business locations for reliability, such as the Enchanted Rock unmanned gas generators at HEB stores.

MaxVer1 is a retirement of fossil fuel generation and batteries are added to manage wind and solar.
The graph below shows the amount of energy in the battery for every hour of the future test year.

This case has 80 GW wind, 80 GW solar, existing nuclear, and a huge battery costing ~1.2 trillion dollars. What makes the plan not feasible is the very large amount of wind and solar. Too many transmission lines are needed to be added to the existing system and the public is not likely to want to approve the construction nor the cost of the power lines and probably not the cost of the battery either.

MaxVer2 retires nuclear, increases wind and solar to 100 GW each, and adds 10 GW small unmanned generation to the case. The extra wind and solar allows a smaller battery costing $716 billion.



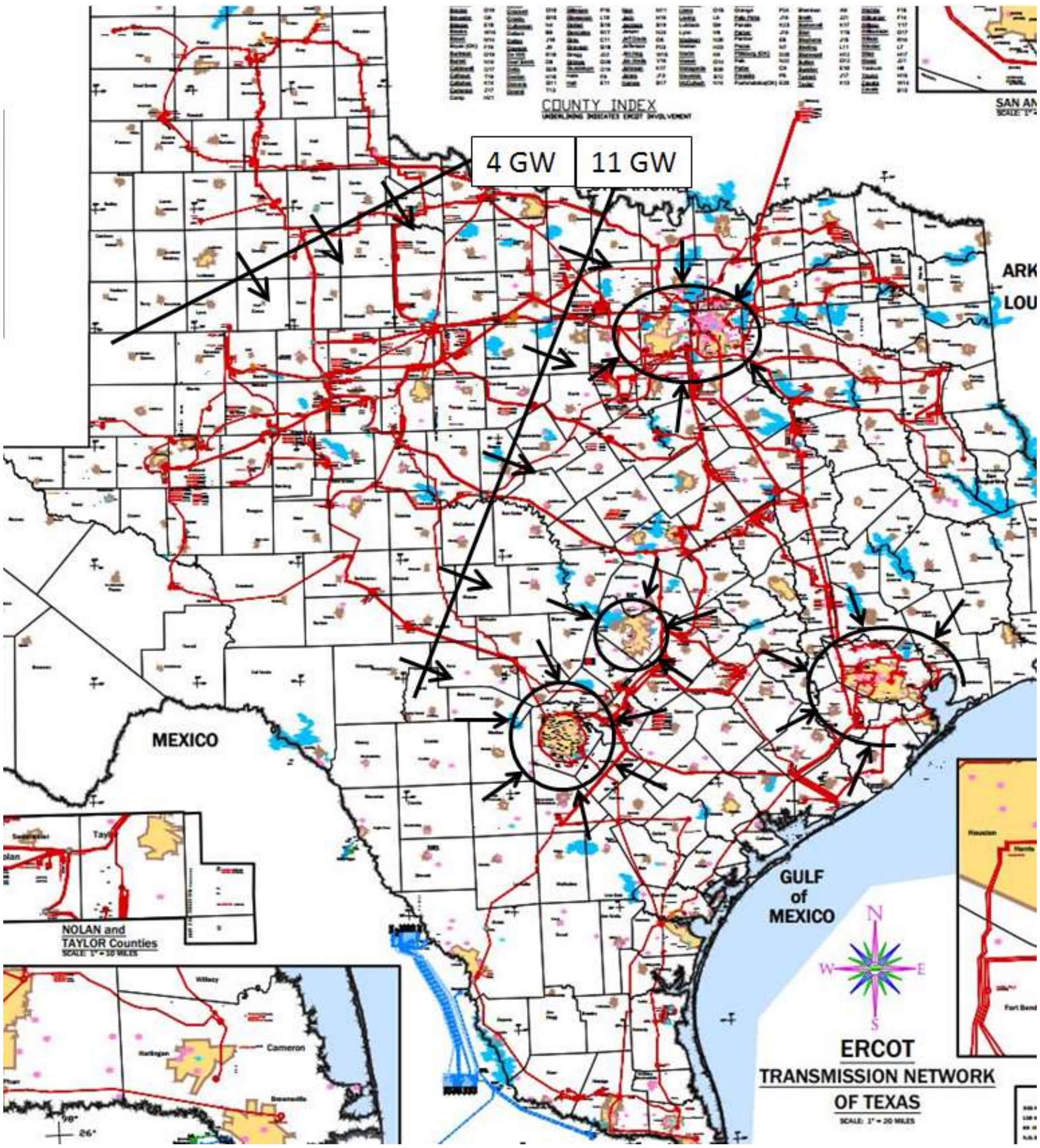
As in the previous case the very large amount of new wind and solar make this plan infeasible because of a lack of transmission. The public is unlikely to approve the power lines or the plan cost.

NewNucl has 40 GW each in nuclear, wind, and solar, adds 10 GW unmanned gas, minimizes battery storage, and keeps the transmission system as a realistic expansion by capping the new wind and solar.

The battery is sized to handle a Uri event. The $277 Bn battery could be shaved to $30 Bn if we only wanted to meet summer peak demands. Public acceptance of safe new nuclear technology is necessary.

Transmission Constraints:

There are significant transmission constraints in ERCOT. The Sierra Club shows several important GTCs generic transmission constraints that do not overload lines but may cause an instability if the power flows across certain lines become too great. For wind and solar the 4 GW Panhandle GTC and the 11 GW west to east transfer GTC limit how much generation can be placed in West Texas. This severely limits the amount of solar we can put in West Texas which would otherwise be a great place to put it. Solar is not likely to happen, however, because there are not funds to build more new transmission lines and ERCOT's economic justification shows gas plants to be lower cost than building new transmission lines for more wind and solar in West Texas and the Panhandle. If you look at the Sierra Club link you will see more constraints. If I were to show every transmission constraint I have run into in my studies the map would be nearly completely covered in bottleneck transmission constraints.



What are the solutions?

A purely 100% wind and solar plus batteries plan is out of the question because there are not enough transmission lines to handle the 80 GW to 100 GW each for wind and solar. The battery storage needed may cost over a trillion dollars. Extra wind and solar are needed to ensure the batteries are being charged sufficiently to cover the load energy all the time, even in extremely hot and cold weather. Furthermore, use of limited lithium and cobalt metals in land based grid storage seems like a waste of resources needed for electric vehicles.

A plan with 40 GW each of solar, wind, and nuclear looks attractive because the amount of new transmission is less, and the overall plan cost is less than a renewables plus large battery plan. Nuclear would need to be constructed in a few years. China and South Korea have shown that this can be done. Texas military bases need to build SMRs (small modular reactors) to ensure they have a reliable power supply in times of conflict.

The Texas coast can use floating nuclear power plants such as the design proposed by Thorcon. An advantage to the floating designs is that the nuclear power plant is built offsite at a factory and floated to the Texas coast. Paying for the plant would be a simple purchase power contract. If the plant fails it can be floated back to the factory for repair or decommissioning.

The new nuclear plants are designed for safety. NRC approval is needed as soon as possible for these new nuclear plant designs so we can effectively deal with climate change. ERCOT needs new rules that allow and promote these new nuclear power plant designs.

Another possibility is to produce a gas (e.g., hydrogen) from clean power and pump it via pipe lines to load centers. This is an excellent way to ship large amounts of energy long distances. This concept should replace the national backbone electric grid proposed in the Green New Deal. Local substations scattered across the US can use the hydrogen gas to fill large 18 wheeler trucks or convert the hydrogen into electricity using fuel cells for charging EVs and powering the grids. The national development of a hydrogen fuel economy can be powered by all the non CO_2 sources -- wind, solar, and nuclear.

A less attractive option is to build new gas plants using CCS (carbon capture and sequestration). The University of Texas Bureau of Economic Geology needs to formally identify suitable sites in Texas for storing CO2 so the generator developers will have a basis for designing new power plants that can utilize the CCS technology in applicable locations. This study shows earthquakes may be caused by large volumes of injection. CCS might have a few acceptable locations to pump CO_2.

Geothermal energy is a possibility; however, the best sites are in [the western US].

Hydro resources are not applicable to Texas because there is not sufficient rainfall.

More wind generators on the Texas coast have a host of environmental problems as well as the possibility of damage from hurricanes. Twenty miles offshore the winds are too low and costs too high to make offshore wind feasible.

The current wind-solar-battery expansion plans relying on an unreliable gas supply and aging gas plants with little oil burning capability is a recipe for frequent power outages. We need to work together to fix this reliability problem and we need to do this as soon as possible.