On my web page https://egpreston.com/ERCOT_phasing_out_gas.pdf is a sophisticated Excel spreadsheet that has ERCOT 2021 hourly profiles for demand, wind, and solar. Nuclear is treated as a fixed reliable capacity. All the nameplate capacities can be adjusted as well as storage energy. Battery capacity is entered as a MWh value and the program automatically uses it in an optimal manner to take maximum advantage of all sources except fossil fuels which are handled as peaking after the nuclear, wind, and solar are optimally dispatched with the battery storage. Gas is the slack variable automatically added as a minimum needed to serve load. The phasing out of fossil generation is achieved by adding other resources so both the fossil fuel capacity and energy go to zero. You will find it's not easy to totally eliminate fossil fuels and be affordable.

https://egpreston.com/ERCOT22A.xlsx is the 2021 ERCOT historical profiles with the wind and solar resources added in 2022. The load is set to 78 GW peak and 67 GW peak winter. The winter load has an extra 100 hours of extreme cold weather during Uri. Wind icing is retained in the data although gas is treated as reliable when we know it's not completely reliable during a Uri event unless oil backup is assumed. Consider this base case as an idealization for gas reliability and that wind cannot afford de-icing add on equipment. The cases below are decarbonizing scenarios.

https://egpreston.com/ERCOT22B.xlsx is a scaling up of wind and solar and storage capacities until the gas capacity and energy drops out. Its cost is quite high. The next page gives a table of the results. This is not a feasible plan because there is too much wind and solar in the plan to be supported by new transmission. The cost of the battery storage is also too costly. This case shows that a 100% wind and solar and battery plan is not feasible unless there is considerable advancement in energy storage. A green hydrogen scenario case needs to be added to these cases.

https://egpreston.com/ERCOT22C.xlsx is an interesting application of Charles Forsberg's nuclear and thermal energy storage concept. http://xylenepower.com/Solar%20Paces%20Sept%202020%20Forsberg%20Final.pdf 25 GW of thermal only nuclear drives 61.2 GW of electric generators deriving their power from 5,500 GWh of thermal storage. The plan is optimized for wind and solar with an energy cost of 11.3 cents/kWh. This is the lowest cost plan and is the only valid plan for getting completely off the reliance on fossil fuels while holding down costs and making good use of renewables. Case ERCOT22C has no electrical batteries and no need for maintaining capacity in fossil fuels.

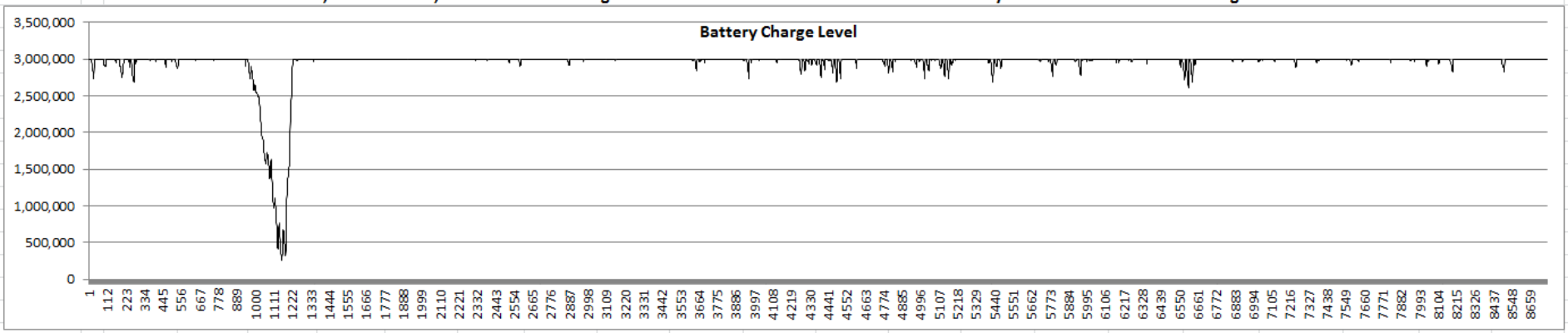
https://egpreston.com/ERCOT22D.xlsx is a Per Peterson concept called MK1 PB-FHR. https://fhr.nuc.berkeley.edu/pb-fhr-technology/ The high temperature nuclear reactor drives twelve 100 MW electrical turbines as a 1200 MW nuclear generator. 20 of these could provide 24 GW of nuclear power. The turbines have an interesting feature. Being rated at 243 MW each and running hot on nuclear power an additional boost of 140 MW could be had from each of the 100 MW turbines by injecting natural gas. This might allow very low gas capacity factors used only during emergencies. However the ability of emergency gas to be provided with very low capacity factors might not be very reliable.

https://egpreston.com/ERCOT22E.xlsx is a balanced resource plan with 40 GW each of wind, solar, and nuclear and a 26.8 GW gas with capacity factor of 2.63%. These resources minimize the amount of transmission and battery storage needed. The energy cost is a fairly low 11.7 cents/kWh. In this simulation gas is not allowed to participate in charging up the battery which results in the need to have an additional 6.8 GW of gas capacity. https://egpreston.com/ERCOT22.xlsx tab 404040 is the same case with gas capacity allowed to charge up the same 63 GWh battery. This allows the battery to be cycled less frequently and a smaller 20 GW of gas capacity is needed. However, now the gas capacity factor is 6.33%. The energy cost is 11.3 cents/kWh so there is a slight economic penalty for not allowing gas to be used to charge up the battery. More CO2 is emitted though.

**File ERCOT22B.xlsx peak demand = 78 GW.  Winter peak demand is 67 GW with Uri's 4 extra days.**

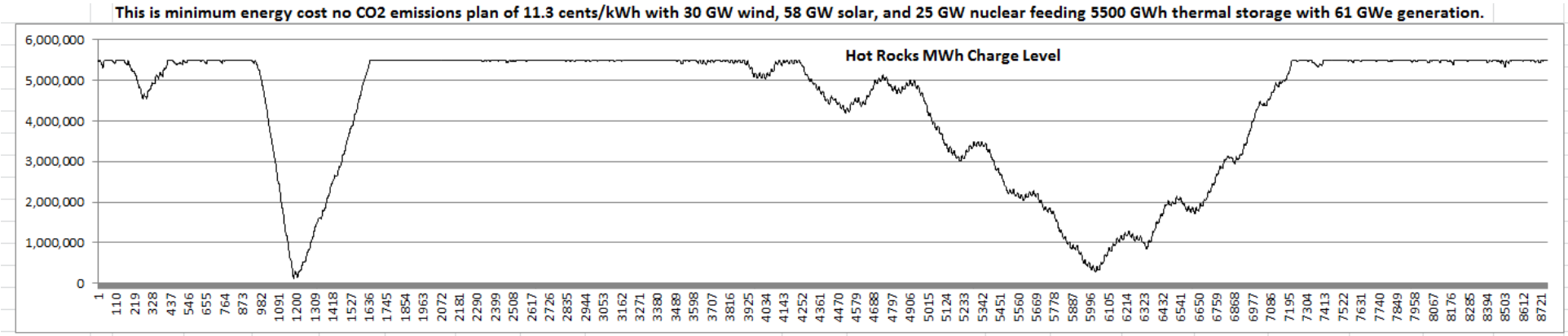
| Wind GW | Solar GW | Storage GWh | Gas GW | Gas Cap Factor | Average c/kWh |
|---|---|---|---|---|---|
| 40 | 20 | 0 | 61 | 40% | 7.50 |
| 50 | 30 | 0 | 61 | 31% | 8.00 |
| 60 | 45 | 0 | 61 | 23% | 8.70 |
| 70 | 70 | 100 | 60 | 12% | 11.2 |
| 90 | 90 | 500 | 60 | 4.7% | 15.7 |
| 120 | 120 | 1000 | 59.4 | 1.2% | 21.9 |
| 150 | 150 | 2000 | 58.4 | 0.7% | 32.0 |
| 200 | 200 | 3000 | 0 | 0% | **42.7** |

**ERCOT22B has 200 GW wind, 200 GW solar, and 3000 GWh storage to zero out fossil fuels.  Storm Uri is in the hourly data shown as a sustained high load level of 67 GW for over 100 hours.**




| Nuclear MW = | | 5,268 | | | | Battery Storage Max MWh = | | 3,000,000 | Foss= | 0 MW max | | | | Battery Storage Costs: | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Uri is blue | | PeakMW= | 78,000 | WinPmx= | 200,000 | SolPmax= | 200,000 | NonFoss | BS MWh | BStor MW | Fossil | Nuclear | Solar | Wind | 0.80 | $/W | 46.2 | 57.8 | GW | | |
| YYYYMMDDHH | D | load pu | loadMW | wind pu | windMW | solar pu | solarMW | MW | 3,000,000 | (-in/+out) | MW | MW | MW | MW | 0.30 | $/Wh | 900.0 | 51.9 | Hrs | | |
| 2021010101 | 6 | 0.59901 | 46,723 | 0.44812 | 89,624 | 0.00000 | 0 | 94,892 | 3,000,000 | 0 | 0 | 5,268 | 0 | 41,455 | Battery Cost: | | 946.2 | $Bn | | | |
| 2021010102 | 6 | 0.59032 | 46,045 | 0.45204 | 90,408 | 0.00000 | 0 | 95,676 | 3,000,000 | 0 | 0 | 5,268 | 0 | 40,777 | | | | | annual | Annual | uplifted |
| 2021010103 | 6 | 0.58603 | 45,710 | 0.46578 | 93,156 | 0.00000 | 0 | 98,424 | 3,000,000 | 0 | 0 | 5,268 | 0 | 40,442 | 78 | GW Peak | 48 | GW Avg | capt cost | Cost M$ | cent/kWh |
| 2021010104 | 6 | 0.58411 | 45,561 | 0.45250 | 90,500 | 0.00000 | 0 | 95,768 | 3,000,000 | 0 | 0 | 5,268 | 0 | 40,293 | 3000 | GWh BS | 315 | $/kWh | 0.100 | 94,624 | 22.674 |
| 2021010105 | 6 | 0.58684 | 45,774 | 0.40520 | 81,040 | 0.00000 | 0 | 86,308 | 3,000,000 | 0 | 0 | 5,268 | 0 | 40,506 | 200 | GW Solar | 1500 | $/kW | 0.100 | 30,000 | 7.189 |
| 2021010106 | 6 | 0.59231 | 46,200 | 0.38662 | 77,324 | 0.00000 | 0 | 82,592 | 3,000,000 | 0 | 0 | 5,268 | 0 | 40,932 | 200 | GW Wnd | 2500 | $/kW | 0.100 | 50,000 | 11.981 |
| 2021010107 | 6 | 0.60638 | 47,298 | 0.35249 | 70,498 | 0.00000 | 0 | 75,766 | 3,000,000 | 0 | 0 | 5,268 | 0 | 42,030 | 5 | GW Nucl | 7000 | $/kW | 0.100 | 3,688 | 0.884 |
| 2021010108 | 6 | 0.61933 | 48,308 | 0.34405 | 68,810 | 0.00000 | 0 | 74,078 | 3,000,000 | 0 | 0 | 5,268 | 0 | 43,040 | 0 | GW Foss | 1000 | $/kW | 0.100 | 0 | 0.000 |
| 2021010109 | 6 | 0.62467 | 48,724 | 0.32052 | 64,104 | 0.01074 | 2,148 | 71,520 | 3,000,000 | 0 | 0 | 5,268 | 2,148 | 41,308 | 0 | Avg GW | 40 | $/MWh fuel cost | | 0 | 0.000 |
| 2021010110 | 6 | 0.62375 | 48,653 | 0.31196 | 62,392 | 0.23206 | 46,412 | 114,072 | 3,000,000 | 0 | 0 | 5,268 | 43,385 | 0 | | | | | total | 178,311 | 42.728 |
| 2021010111 | 6 | 0.62197 | 48,514 | 0.33748 | 67,496 | 0.41209 | 82,418 | 155,182 | 3,000,000 | 0 | 0 | 5,268 | 43,246 | 0 | | | | verify | total | 178,311 | |
| 2021010112 | 6 | 0.61621 | 48,064 | 0.35892 | 71,784 | 0.49138 | 98,276 | 175,328 | 3,000,000 | 0 | 0 | 5,268 | 42,796 | 0 | | | | | | | |
| 2021010113 | 6 | 0.60681 | 47,331 | 0.34553 | 69,106 | 0.49228 | 98,456 | 172,830 | 3,000,000 | 0 | 0 | 5,268 | 42,063 | 0 | | | max % CF | act % CF | unused% | cent/kWh | AnnualM$ |
| 2021010114 | 6 | 0.59405 | 46,336 | 0.29690 | 59,380 | 0.50975 | 101,950 | 166,598 | 3,000,000 | 0 | 0 | 5,268 | 41,068 | 0 | | Solar | 23.14 | 10.58 | 12.56 | 16.185 | 30,000 |
| 2021010115 | 6 | 0.58100 | 45,318 | 0.26109 | 52,218 | 0.44201 | 88,402 | 145,888 | 3,000,000 | 0 | 0 | 5,268 | 40,050 | 0 | | Wind | 33.56 | 10.61 | 22.96 | 26.908 | 50,000 |
| 2021010116 | 6 | 0.57209 | 44,623 | 0.20971 | 41,942 | 0.45661 | 91,322 | 138,532 | 3,000,000 | 0 | 0 | 5,268 | 39,355 | 0 | | Nuclear | 100.00 | 100.00 | | 7.991 | 3,688 |
| 2021010117 | 6 | 0.56998 | 44,458 | 0.16199 | 32,398 | 0.43382 | 86,764 | 124,430 | 3,000,000 | 0 | 0 | 5,268 | 39,190 | 0 | | Fossil | 100.00 | 0.00 | | 0.000 | 0 |
| 2021010118 | 6 | 0.58544 | 45,664 | 0.11547 | 23,094 | 0.14767 | 29,534 | 57,896 | 3,000,000 | 0 | 0 | 5,268 | 29,534 | 10,862 | | Battery | | | | | 94,624 |
| 2021010119 | 6 | 0.62145 | 48,473 | 0.10655 | 21,310 | 0.00000 | 0 | 26,578 | 2,978,105 | 21,895 | 0 | 5,268 | 0 | 21,310 | | | | verify total annual cost in M$ | | | 178,311 |

**File ERCOT22C.xlsx is a min energy cost plan using 25 GW nuclear, 30 GW wind, and 58 GW solar. Storm Uri is served in this design without gas.**

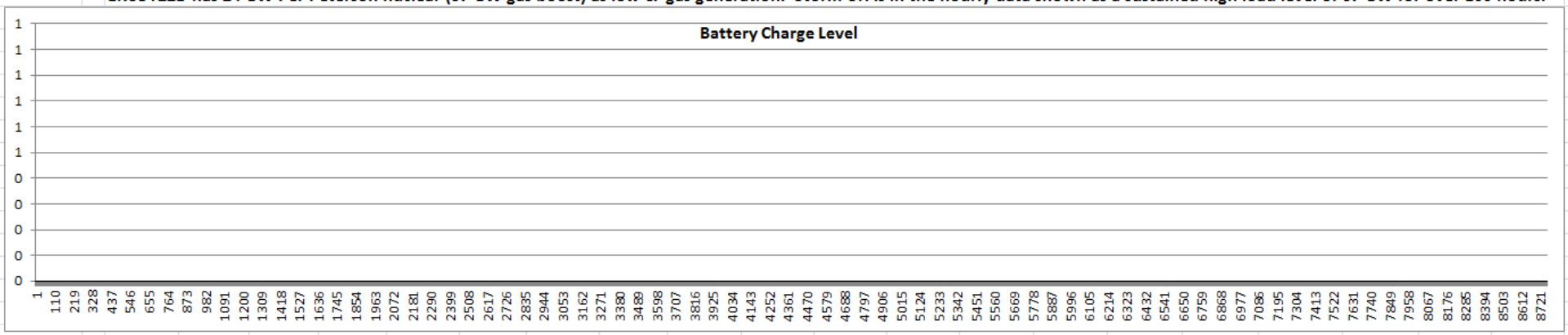



| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | this needs to be >0 | >>> | 122,426 | for no fossil energy | | | | | | | | | | | | |
| Base Nucl MW = | | 5,268 | | | | | | | | Nucl Thermal MW= | | 25,000 | 220 | hours | | | 8,000 | $/kW nucl | 200.0 | | 5,500 | GWh | Peaking | Max/Min |
| Uri is blue | | PeakMW= | 78,000 | WinPmx= | 30,000 | SolPmax= | 58,000 | Nuclear | Wind | Solar | Peaking | Ramp | HR MWh | HotRocks | GasPeak | | 2,000 | $/kW | 50.0 | | 25.0 | GW | 30,139 | MW/hr |
| YYYYMMDDHH | D | load pu | loadMW | wind pu | windMW | solar pu | solarMW | MW | MW | MW | MW | MW/hr | 5,500,000 | MW | MW | | 4 | $/kWh | 22.0 | | 220.0 | Hrs | -32,364 | MW/hr |
| 2021010101 | 6 | 0.59901 | 46,723 | 0.44812 | 13,444 | 0.00000 | 0 | 5,268 | 13,444 | 0 | 28,011 | 0 | 5,496,989 | 28,011 | 0 | | Hot Rocks Cost: | | 272.0 | $Bn | | | | |
| 2021010102 | 6 | 0.59032 | 46,045 | 0.45204 | 13,561 | 0.00000 | 0 | 5,268 | 13,561 | 0 | 27,216 | -795 | 5,494,773 | 27,216 | 0 | | | | | | | annual | Annual | uplifted |
| 2021010103 | 6 | 0.58603 | 45,710 | 0.46578 | 13,973 | 0.00000 | 0 | 5,268 | 13,973 | 0 | 26,469 | -747 | 5,493,304 | 26,469 | 0 | | 78,000 | MW Peak | 48 | GW Avg | | capt cost | Cost M$ | cent/kWh |
| 2021010104 | 6 | 0.58411 | 45,561 | 0.45250 | 13,575 | 0.00000 | 0 | 5,268 | 13,575 | 0 | 26,718 | 249 | 5,491,587 | 26,718 | 0 | | 61,210 | MW Rock | 4444 | $/kW | | 0.100 | 27,200 | 6.518 |
| 2021010105 | 6 | 0.58684 | 45,774 | 0.40520 | 12,156 | 0.00000 | 0 | 5,268 | 12,156 | 0 | 28,350 | 1,632 | 5,488,237 | 28,350 | 0 | | 58,000 | MW Solar | 1500 | $/kW | | 0.100 | 8,700 | 2.085 |
| 2021010106 | 6 | 0.59231 | 46,200 | 0.38662 | 11,599 | 0.00000 | 0 | 5,268 | 11,599 | 0 | 29,334 | 984 | 5,483,903 | 29,334 | 0 | | 30,000 | MW Wnd | 2500 | $/kW | | 0.100 | 7,500 | 1.797 |
| 2021010107 | 6 | 0.60638 | 47,298 | 0.35249 | 10,575 | 0.00000 | 0 | 5,268 | 10,575 | 0 | 31,455 | 2,121 | 5,477,449 | 31,455 | 0 | | 5,268 | MW Nucl | 7000 | $/kW | | 0.100 | 3,688 | 0.884 |
| 2021010108 | 6 | 0.61933 | 48,308 | 0.34405 | 10,322 | 0.00000 | 0 | 5,268 | 10,322 | 0 | 32,718 | 1,263 | 5,469,730 | 32,718 | 0 | | 0 | MW Foss | 1000 | $/kW | | 0.100 | 0 | 0.000 |
| 2021010109 | 6 | 0.62467 | 48,724 | 0.32052 | 9,616 | 0.01074 | 623 | 5,268 | 9,616 | 623 | 33,218 | 499 | 5,461,513 | 33,218 | 0 | | 0 | Avg MW | 2000 | $/MWh fuel cost | | | 0 | 0.000 |
| 2021010110 | 6 | 0.62375 | 48,653 | 0.31196 | 9,359 | 0.23206 | 13,459 | 5,268 | 9,359 | 13,459 | 20,566 | -12,652 | 5,465,946 | 20,566 | 0 | | | | | | | total | 47,088 | 11.283 |
| 2021010111 | 6 | 0.62197 | 48,514 | 0.33748 | 10,124 | 0.41209 | 23,901 | 5,268 | 10,124 | 23,901 | 9,220 | -11,346 | 5,481,726 | 9,220 | 0 | | | | | | verify | total | 47,088 | |
| 2021010112 | 6 | 0.61621 | 48,064 | 0.35892 | 10,768 | 0.49138 | 28,500 | 5,268 | 10,768 | 28,500 | 3,529 | -5,691 | 5,500,000 | 3,529 | 0 | | | | | | | | | |
| 2021010113 | 6 | 0.60681 | 47,331 | 0.34553 | 10,366 | 0.49228 | 28,552 | 5,268 | 10,366 | 28,552 | 3,145 | -384 | 5,500,000 | 3,145 | 0 | | | | max % CF | act % CF | | unused% | cent/kWh | AnnualM$ |
| 2021010114 | 6 | 0.59405 | 46,336 | 0.29690 | 8,907 | 0.50975 | 29,566 | 5,268 | 8,907 | 29,566 | 2,595 | -550 | 5,500,000 | 2,595 | 0 | | | Solar | 23.14 | 21.08 | | 2.06 | 8.123 | 8,700 |
| 2021010115 | 6 | 0.58100 | 45,318 | 0.26109 | 7,833 | 0.44201 | 25,637 | 5,268 | 7,833 | 25,637 | 6,581 | 3,985 | 5,500,000 | 6,581 | 0 | | | Wind | 33.56 | 33.56 | | 0.00 | 8.504 | 7,500 |
| 2021010116 | 6 | 0.57209 | 44,623 | 0.20971 | 6,291 | 0.45661 | 26,483 | 5,268 | 6,291 | 26,483 | 6,580 | 0 | 5,500,000 | 6,580 | 0 | | | Nuclear | 100.00 | 100.00 | | 0.00 | 7.991 | 3,688 |
| 2021010117 | 6 | 0.56998 | 44,458 | 0.16199 | 4,860 | 0.43382 | 25,162 | 5,268 | 4,860 | 25,162 | 9,169 | 2,589 | 5,500,000 | 9,169 | 0 | | | Fossil | 100.00 | 0.00 | | 100.00 | 0.000 | 0 |
| 2021010118 | 6 | 0.58544 | 45,664 | 0.11547 | 3,464 | 0.14767 | 8,565 | 5,268 | 3,464 | 8,565 | 28,367 | 19,198 | 5,496,633 | 28,367 | 0 | | | Hot Rocks | 100.00 | 80.31 | | 19.69 | 15.47 | 27,200 |
| 2021010119 | 6 | 0.62145 | 48,473 | 0.10655 | 3,197 | 0.00000 | 0 | 5,268 | 3,197 | 0 | 40,009 | 11,641 | 5,481,624 | 40,009 | 0 | | | | | verify total annual cost in M$ | | | | 47,088 |

This plan uses 5,500 GWh of thermal storage charged up by 25 GW of nuclear power not connected to the grid. There is no battery storage. Wind and solar are optimized capacities of 30 and 58 GW respectively. There is very little curtailment of the resources. This is a fossil fuel free plan with an energy cost of (11.3) cents per kWh. Case ERCOT22C has no electrical batteries and no need for maintaining capacity in fossil fuels.

**File ERCOT22D.xlsx adds 24 GW nuclear using Per Peterson's MK1 PB-FHR concept. Separate gas fired generators may not be needed.**

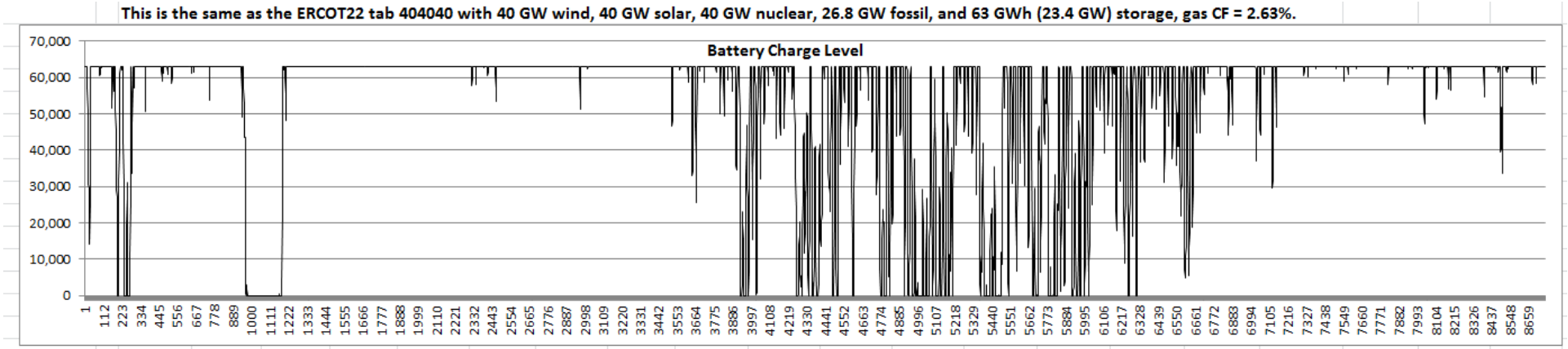
**ERCOT22D has 24 GW Per Peterson nuclear (37 GW gas boost) as low CF gas generation. Storm Uri is in the hourly data shown as a sustained high load level of 67 GW for over 100 hours.**




| Nuclear MW = | | 29,268 | | | | Battery Storage Max MWh = | | 0 | Foss= | 37,070 | MW max | | | Battery Storage Costs: | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Uri is blue | | PeakMW= | 78,000 | WinPmx= | 36,959 | SolPmax= | 19,682 | NonFoss | BS MWh | BStor MW | Fossil | Nuclear | Solar | Wind | 0.80 | $/W | 0.0 | 0.0 | GW | | |
| YYYYMMDDHH | D | load pu | loadMW | wind pu | windMW | solar pu | solarMW | MW | 0 | (-in/+out) | MW | MW | MW | MW | 0.30 | $/Wh | 0.0 | 0.0 | Hrs | | |
| 2021010101 | 6 | 0.59901 | 46,723 | 0.44812 | 16,562 | 0.00000 | 0 | 45,830 | 0 | 0 | 893 | 29,268 | 0 | 16,562 | Battery Cost: | | 0.0 | $Bn | | | |
| 2021010102 | 6 | 0.59032 | 46,045 | 0.45204 | 16,707 | 0.00000 | 0 | 45,975 | 0 | 0 | 70 | 29,268 | 0 | 16,707 | | | | | annual | Annual | uplifted |
| 2021010103 | 6 | 0.58603 | 45,710 | 0.46578 | 17,215 | 0.00000 | 0 | 46,483 | 0 | 0 | 0 | 29,268 | 0 | 16,442 | 78 | GW Peak | 48 | GW Avg | capt cost | Cost M$ | cent/kWh |
| 2021010104 | 6 | 0.58411 | 45,561 | 0.45250 | 16,724 | 0.00000 | 0 | 45,992 | 0 | 0 | 0 | 29,268 | 0 | 16,293 | 0 | GWh BS | 0 | $/kWh | 0.100 | 0 | 0.000 |
| 2021010105 | 6 | 0.58684 | 45,774 | 0.40520 | 14,976 | 0.00000 | 0 | 44,244 | 0 | 0 | 1,530 | 29,268 | 0 | 14,976 | 20 | GW Solar | 1500 | $/kW | 0.100 | 2,952 | 0.707 |
| 2021010106 | 6 | 0.59231 | 46,200 | 0.38662 | 14,289 | 0.00000 | 0 | 43,557 | 0 | 0 | 2,643 | 29,268 | 0 | 14,289 | 37 | GW Wnd | 2500 | $/kW | 0.100 | 9,240 | 2.214 |
| 2021010107 | 6 | 0.60638 | 47,298 | 0.35249 | 13,028 | 0.00000 | 0 | 42,296 | 0 | 0 | 5,002 | 29,268 | 0 | 13,028 | 29 | GW Nucl | 7000 | $/kW | 0.100 | 20,488 | 4.909 |
| 2021010108 | 6 | 0.61933 | 48,308 | 0.34405 | 12,716 | 0.00000 | 0 | 41,984 | 0 | 0 | 6,324 | 29,268 | 0 | 12,716 | 37 | GW Foss | 1000 | $/kW | 0.100 | 3,707 | 0.888 |
| 2021010109 | 6 | 0.62467 | 48,724 | 0.32052 | 11,846 | 0.01074 | 211 | 41,325 | 0 | 0 | 7,399 | 29,268 | 211 | 11,846 | 6 | Avg GW | 40 | $/MWh fuel cost | | 1,954 | 0.468 |
| 2021010110 | 6 | 0.62375 | 48,653 | 0.31196 | 11,530 | 0.23206 | 4,567 | 45,365 | 0 | 0 | 3,287 | 29,268 | 4,567 | 11,530 | | | | | total | 38,340 | 9.187 |
| 2021010111 | 6 | 0.62197 | 48,514 | 0.33748 | 12,473 | 0.41209 | 8,111 | 49,852 | 0 | 0 | 0 | 29,268 | 8,111 | 11,135 | | | | verify | total | 38,340 | |
| 2021010112 | 6 | 0.61621 | 48,064 | 0.35892 | 13,265 | 0.49138 | 9,671 | 52,205 | 0 | 0 | 0 | 29,268 | 9,671 | 9,125 | | | | | | | |
| 2021010113 | 6 | 0.60681 | 47,331 | 0.34553 | 12,770 | 0.49228 | 9,689 | 51,727 | 0 | 0 | 0 | 29,268 | 9,689 | 8,374 | | | max % CF | act % CF | unused% | cent/kWh | AnnualM$ |
| 2021010114 | 6 | 0.59405 | 46,336 | 0.29690 | 10,973 | 0.50975 | 10,033 | 50,274 | 0 | 0 | 0 | 29,268 | 10,033 | 7,035 | | Solar | 23.14 | 22.31 | 0.83 | 7.676 | 2,952 |
| 2021010115 | 6 | 0.58100 | 45,318 | 0.26109 | 9,650 | 0.44201 | 8,700 | 47,617 | 0 | 0 | 0 | 29,268 | 8,700 | 7,350 | | Wind | 33.56 | 22.74 | 10.82 | 12.549 | 9,240 |
| 2021010116 | 6 | 0.57209 | 44,623 | 0.20971 | 7,751 | 0.45661 | 8,987 | 46,006 | 0 | 0 | 0 | 29,268 | 8,987 | 6,368 | | Nuclear | 100.00 | 100.00 | | 7.991 | 20,488 |
| 2021010117 | 6 | 0.56998 | 44,458 | 0.16199 | 5,987 | 0.43382 | 8,538 | 43,793 | 0 | 0 | 665 | 29,268 | 8,538 | 5,987 | | Fossil | 100.00 | 15.04 | | 11.590 | 5,661 |
| 2021010118 | 6 | 0.58544 | 45,664 | 0.11547 | 4,268 | 0.14767 | 2,906 | 36,442 | 0 | 0 | 9,222 | 29,268 | 2,906 | 4,268 | | Battery | | | | | 0 |
| 2021010119 | 6 | 0.62145 | 48,473 | 0.10655 | 3,938 | 0.00000 | 0 | 33,206 | 0 | 0 | 15,267 | 29,268 | 0 | 3,938 | | | | verify total annual cost in M$ | | | 38,340 |

There is only Per Peterson's 24 GW of nuclear plant capacity with 37 GW of instant on gas boost capacity. There is no battery storage. Wind and solar are held at the 2022 planned levels of investment. This nuclear plan is low in fossil fuel usage and has an energy cost of (9.2) cents/kWh.

https://egpreston.com/ERCOT22E.xlsx is a 40 GW each of wind, solar, and nuclear and a 26.8 GW gas with capacity factor of 2.63%.

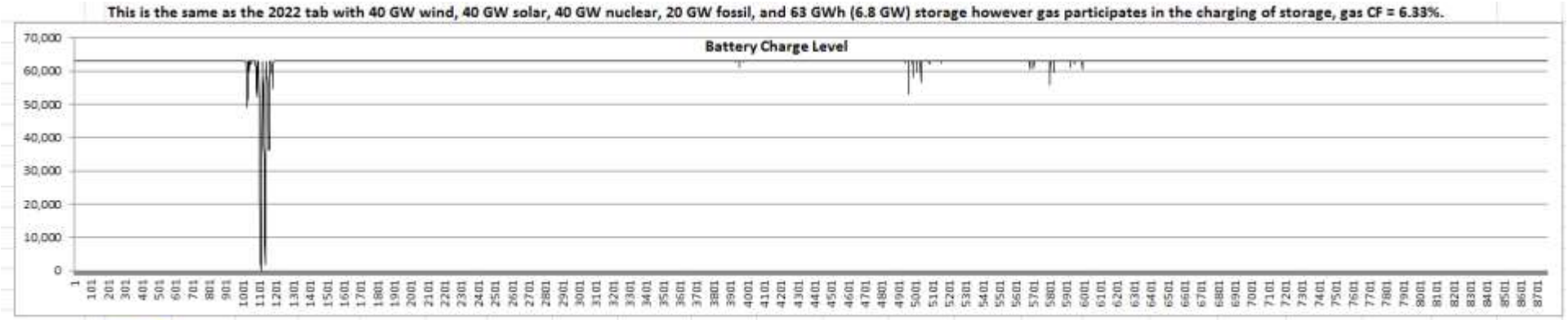



| Nuclear MW = | | 40,000 | | | | Battery Storage Max MWh = | | 63,000 | Foss= | 26,791 | MW max | | | Battery Storage Costs: | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Uri is blue | | PeakMW= | 81,000 | WinPmx= | 40,000 | SolPmax= | 40,000 | NonFoss | BS MWh | BStor MW | Fossil | Nuclear | Solar | Wind | 0.80 | $/W | 18.7 | 23.4 | GW | |
| YYYYMMDDHH | D | load pu | loadMW | wind pu | windMW | solar pu | solarMW | MW | 63,000 | (-in/+out) | MW | MW | MW | MW | 0.30 | $/Wh | 18.9 | 2.7 | Hrs | |
| 2021010101 | 6 | 0.59901 | 48,520 | 0.44812 | 17,925 | 0.00000 | 0 | 57,925 | 63,000 | 0 | 0 | 40,000 | 0 | 8,520 | Battery Cost: | | 37.6 | $Bn | | |
| 2021010102 | 6 | 0.59032 | 47,816 | 0.45204 | 18,082 | 0.00000 | 0 | 58,082 | 63,000 | 0 | 0 | 40,000 | 0 | 7,816 | | | | | annual | Annual |
| 2021010103 | 6 | 0.58603 | 47,468 | 0.46578 | 18,631 | 0.00000 | 0 | 58,631 | 63,000 | 0 | 0 | 40,000 | 0 | 7,468 | 81 | GW Peak | 49 | GW Avg | capt cost | Cost M$ |
| 2021010104 | 6 | 0.58411 | 47,313 | 0.45250 | 18,100 | 0.00000 | 0 | 58,100 | 63,000 | 0 | 0 | 40,000 | 0 | 7,313 | 63 | GWh BS | 598 | $/kWh | 0.100 | 3,765 |
| 2021010105 | 6 | 0.58684 | 47,534 | 0.40520 | 16,208 | 0.00000 | 0 | 56,208 | 63,000 | 0 | 0 | 40,000 | 0 | 7,534 | 40 | GW Solar | 1500 | $/kW | 0.100 | 6,000 |
| 2021010106 | 6 | 0.59231 | 47,977 | 0.38662 | 15,465 | 0.00000 | 0 | 55,465 | 63,000 | 0 | 0 | 40,000 | 0 | 7,977 | 40 | GW Wnd | 2500 | $/kW | 0.100 | 10,000 |
| 2021010107 | 6 | 0.60638 | 49,117 | 0.35249 | 14,100 | 0.00000 | 0 | 54,100 | 63,000 | 0 | 0 | 40,000 | 0 | 9,117 | 40 | GW Nucl | 7000 | $/kW | 0.100 | 28,000 |
| 2021010108 | 6 | 0.61933 | 50,166 | 0.34405 | 13,762 | 0.00000 | 0 | 53,762 | 63,000 | 0 | 0 | 40,000 | 0 | 10,166 | 27 | GW Foss | 1000 | $/kW | 0.100 | 2,679 |
| 2021010109 | 6 | 0.62467 | 50,598 | 0.32052 | 12,821 | 0.01074 | 430 | 53,250 | 63,000 | 0 | 0 | 40,000 | 430 | 10,169 | 1 | Avg GW | 40 | $/MWh fuel cost | | 247 |
| 2021010110 | 6 | 0.62375 | 50,524 | 0.31196 | 12,478 | 0.23206 | 9,282 | 61,761 | 63,000 | 0 | 0 | 40,000 | 9,282 | 1,241 | | | | | total | 50,691 |
| 2021010111 | 6 | 0.62197 | 50,380 | 0.33748 | 13,499 | 0.41209 | 16,484 | 69,983 | 63,000 | 0 | 0 | 40,000 | 10,380 | 0 | | | | verify | total | 50,691 |
| 2021010112 | 6 | 0.61621 | 49,913 | 0.35892 | 14,357 | 0.49138 | 19,655 | 74,012 | 63,000 | 0 | 0 | 40,000 | 9,913 | 0 | | | | | | |
| 2021010113 | 6 | 0.60681 | 49,152 | 0.34553 | 13,821 | 0.49228 | 19,691 | 73,512 | 63,000 | 0 | 0 | 40,000 | 9,152 | 0 | | | max % CF | act % CF | unused% | cent/kWh |
| 2021010114 | 6 | 0.59405 | 48,118 | 0.29690 | 11,876 | 0.50975 | 20,390 | 72,266 | 63,000 | 0 | 0 | 40,000 | 8,118 | 0 | | Solar | 23.14 | 13.39 | 9.75 | 12.785 |
| 2021010115 | 6 | 0.58100 | 47,061 | 0.26109 | 10,444 | 0.44201 | 17,680 | 68,124 | 63,000 | 0 | 0 | 40,000 | 7,061 | 0 | | Wind | 33.56 | 9.66 | 23.90 | 29.530 |
| 2021010116 | 6 | 0.57209 | 46,339 | 0.20971 | 8,388 | 0.45661 | 18,264 | 66,653 | 63,000 | 0 | 0 | 40,000 | 6,339 | 0 | | Nuclear | 100.00 | 98.80 | | 8.088 |
| 2021010117 | 6 | 0.56998 | 46,168 | 0.16199 | 6,480 | 0.43382 | 17,353 | 63,832 | 63,000 | 0 | 0 | 40,000 | 6,168 | 0 | | Fossil | 100.00 | 2.63 | | 47.415 |
| 2021010118 | 6 | 0.58544 | 47,421 | 0.11547 | 4,619 | 0.14767 | 5,907 | 50,526 | 63,000 | 0 | 0 | 40,000 | 5,907 | 1,514 | | Battery | | | | |
| 2021010119 | 6 | 0.62145 | 50,337 | 0.10655 | 4,262 | 0.00000 | 0 | 44,262 | 56,925 | 6,075 | 0 | 40,000 | 0 | 4,262 | | | | verify total annual cost in M$ | | |

| AnnualM$ | uplifted cent/kWh |
|---|---|
| | |
| | |
| | |
| | 0.869 |
| | 1.385 |
| | 2.309 |
| | 6.464 |
| | 0.619 |
| | 0.057 |
| | 11.703 |
| | |
| | |
| AnnualM$ | |
| 6,000 | |
| 10,000 | |
| 28,000 | |
| 2,926 | |
| 3,765 | |
| 50,691 | |

In this simulation the 26.8 GW gas capacity is automatically added but not allowed to participate in charging up the battery. The next page shows the same simulation with gas allowed to charge up the battery. This is a 40 40 40 nuclear, wind, and solar plan that has high capital costs in nuclear and batteries as well as maintaining the cost of gas peaking capacity which is not used very often. Not allowing the battery to be charged up from gas to reduce CO2 emissions carries an economic penalty. The simulation on the next page is the same case that allows gas to charge the batteries.

https://egpreston.com/ERCOT22.xlsx (tab 404040) is the same case with gas capacity allowed to charge up the same 63 GWh battery.




Fossil MW = 20,000
Nuclear MW = 40,000
Uri is blue

Enter 0 for BS MWh in K21 and the light gray box L19 shows the number to be hand typed into K21

| | | | | | | | | | Unserved | *add this: | 0 | | | | | | | Battery Cost Assumption: | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PeakMW= | 81,000 | WinPmx= | 40,000 | SolPmax= | 40,000 | Supply | Load MW | BS MWh* | BSto or MW | nuclear | renewables | wind | solar | fossil | 0.80 | $/W | 5.4 | 6.8 | GW | | |
| YYYYMMDDHH | D | load pu | loadMW | wind pu | windMW | solar pu | solarMW | MW | 6,791 | 62,964 | (-in/+out) | MW | MW | MW | MW | MW | 0.30 | $/Wh | 18.9 | 9.3 | Hrs | | |
| 2021010101 | 6 | 0.59901 | 48,520 | 0.44812 | 17,925 | 0.00000 | 0 | 77,925 | 0 | 62,964 | 0 | 40,000 | 8,520 | 8,520 | 0 | 0 | | Battery Cost: | 24.3 | $Bn | | | |
| 2021010102 | 6 | 0.59032 | 47,816 | 0.45204 | 18,082 | 0.00000 | 0 | 78,082 | 0 | 62,964 | 0 | 40,000 | 7,816 | 7,816 | 0 | 0 | | | | | annual | Annual | uplifted |
| 2021010103 | 6 | 0.58603 | 47,468 | 0.46578 | 18,631 | 0.00000 | 0 | 78,631 | 0 | 62,964 | 0 | 40,000 | 7,468 | 7,468 | 0 | 0 | 81 | GW Peak | 49 | GW Avg | capt cost | Cost M$ | cent/kWh |
| 2021010104 | 6 | 0.58411 | 47,313 | 0.45250 | 18,100 | 0.00000 | 0 | 78,100 | 0 | 62,964 | 0 | 40,000 | 7,313 | 7,313 | 0 | 0 | 63 | GWh BS | 386 | $/kWh | 0.100 | 2,432 | 0.562 |
| 2021010105 | 6 | 0.58684 | 47,534 | 0.40520 | 16,208 | 0.00000 | 0 | 76,208 | 0 | 62,964 | 0 | 40,000 | 7,534 | 7,534 | 0 | 0 | 40 | GW Solar | 1500 | $/kW | 0.100 | 6,000 | 1.385 |
| 2021010106 | 6 | 0.59231 | 47,977 | 0.38662 | 15,465 | 0.00000 | 0 | 75,465 | 0 | 62,964 | 0 | 40,000 | 7,977 | 7,977 | 0 | 0 | 40 | GW Wnd | 2500 | $/kW | 0.100 | 10,000 | 2.309 |
| 2021010107 | 6 | 0.60638 | 49,117 | 0.35249 | 14,100 | 0.00000 | 0 | 74,100 | 0 | 62,964 | 0 | 40,000 | 9,117 | 9,117 | 0 | 0 | 40 | GW Nucl | 7000 | $/kW | 0.100 | 28,000 | 6.464 |
| 2021010108 | 6 | 0.61933 | 50,166 | 0.34405 | 13,762 | 0.00000 | 0 | 73,762 | 0 | 62,964 | 0 | 40,000 | 10,166 | 10,166 | 0 | 0 | 20 | GW Foss | 1000 | $/kW | 0.100 | 2,000 | 0.462 |
| 2021010109 | 6 | 0.62467 | 50,598 | 0.32052 | 12,821 | 0.01074 | 430 | 73,250 | 0 | 62,964 | 0 | 40,000 | 10,598 | 10,598 | 0 | 0 | 1 | Avg GW | 40 | $/MWh fuel cost | | 443 | 0.102 |
| 2021010110 | 6 | 0.62375 | 50,524 | 0.31196 | 12,478 | 0.23206 | 9,282 | 81,761 | 0 | 62,964 | 0 | 40,000 | 10,524 | 10,524 | 0 | 0 | | | | | total | 48,876 | 11.284 |
| 2021010111 | 6 | 0.62197 | 50,380 | 0.33748 | 13,499 | 0.41209 | 16,484 | 89,983 | 0 | 62,964 | 0 | 40,000 | 10,380 | 10,380 | 0 | 0 | | | | verify | total | 48,876 | |
| 2021010112 | 6 | 0.61621 | 49,913 | 0.35892 | 14,357 | 0.49138 | 19,655 | 94,012 | 0 | 62,964 | 0 | 40,000 | 9,913 | 9,913 | 0 | 0 | | | | | | | |
| 2021010113 | 6 | 0.60681 | 49,152 | 0.34553 | 13,821 | 0.49228 | 19,691 | 93,512 | 0 | 62,964 | 0 | 40,000 | 9,152 | 9,152 | 0 | 0 | | | max % CF | act % CF | unused% | cent/kWh | AnnualM$ |
| 2021010114 | 6 | 0.59405 | 48,118 | 0.29690 | 11,876 | 0.50975 | 20,390 | 92,266 | 0 | 62,964 | 0 | 40,000 | 8,118 | 8,118 | 0 | 0 | | Solar | 23.14 | 7.36 | 15.78 | 23.278 | 6,000 |
| 2021010115 | 6 | 0.58100 | 47,061 | 0.26109 | 10,444 | 0.44201 | 17,680 | 88,124 | 0 | 62,964 | 0 | 40,000 | 7,061 | 7,061 | 0 | 0 | | Wind | 33.56 | 14.31 | 19.26 | 19.950 | 10,000 |
| 2021010116 | 6 | 0.57209 | 46,339 | 0.20971 | 8,388 | 0.45661 | 18,264 | 86,653 | 0 | 62,964 | 0 | 40,000 | 6,339 | 6,339 | 0 | 0 | | Nuclear | 100.00 | 98.79 | 1.21 | 8.089 | 28,000 |
| 2021010117 | 6 | 0.56998 | 46,168 | 0.16199 | 6,480 | 0.43382 | 17,353 | 83,832 | 0 | 62,964 | 0 | 40,000 | 6,168 | 6,168 | 0 | 0 | | Fossil | 100.00 | 6.33 | 93.67 | 22.040 | 2,443 |
| 2021010118 | 6 | 0.58544 | 47,421 | 0.11547 | 4,619 | 0.14767 | 5,907 | 70,526 | 0 | 62,964 | 0 | 40,000 | 7,421 | 4,619 | 2,802 | 0 | | Battery | | | | | 2,432 |
| 2021010119 | 6 | 0.62145 | 50,337 | 0.10655 | 4,262 | 0.00000 | 0 | 64,262 | 0 | 62,964 | 0 | 40,000 | 4,262 | 4,262 | 0 | 6,075 | | | | verify total annual cost in M$ | | | 48,876 |

This allows the battery to be cycled less frequently and a smaller 20 GW of gas capacity is needed. However, now the gas capacity factor is 6.33%. The energy cost is 11.3 cents/kWh so there is a slight economic penalty for not allowing gas to be used to charge up the battery. 2.5 times as much CO2 is emitted when the gas capacity is allowed to charge the battery for mostly serving peak demands. The purpose of these cases ERCOT22 and ERCOT22E is to show the differences in more (22) or less (22E) allowing gas to participate in the hourly dispatch. Note that in these two plans the addition of new base load nuclear keeps the cost of adding batteries to a minimum. However in doing so, the expansion of wind and solar becomes limited. Case ERCOT22C overcomes this problem by using nuclear energy in a peaking mode. Case 22C has no electrical batteries and no need for maintaining capacity in fossil fuels.