The Climate Solutions Community
An AIChE Initiative

ENGINEERING, SCIENCE AND TECHNOLOGY COUNCIL OF HOUSTON
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Climate Solutions Symposium August 22, 2020

A Proposal For Decarbonizing Transportation And The Electric Power Supply In Texas

By

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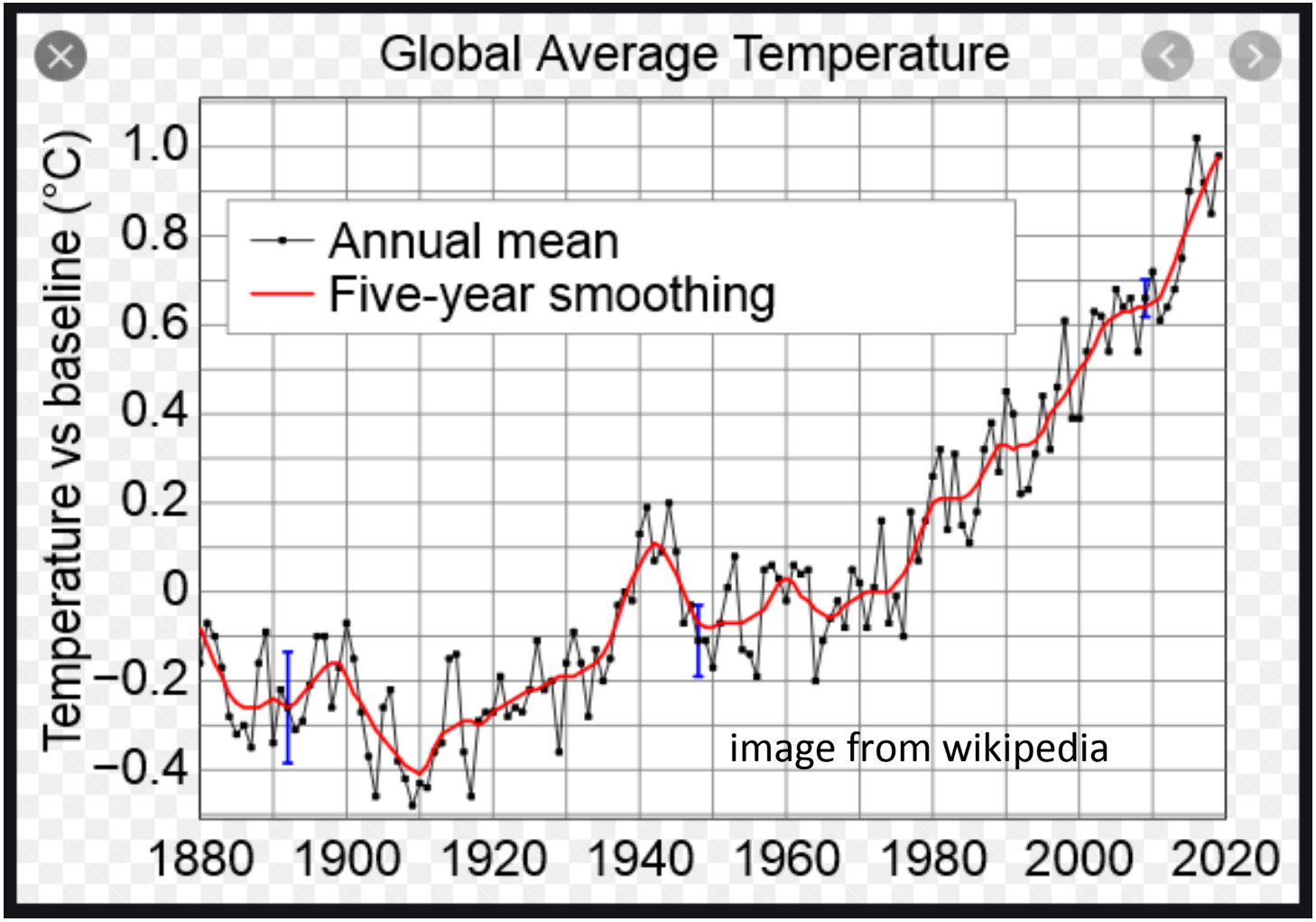
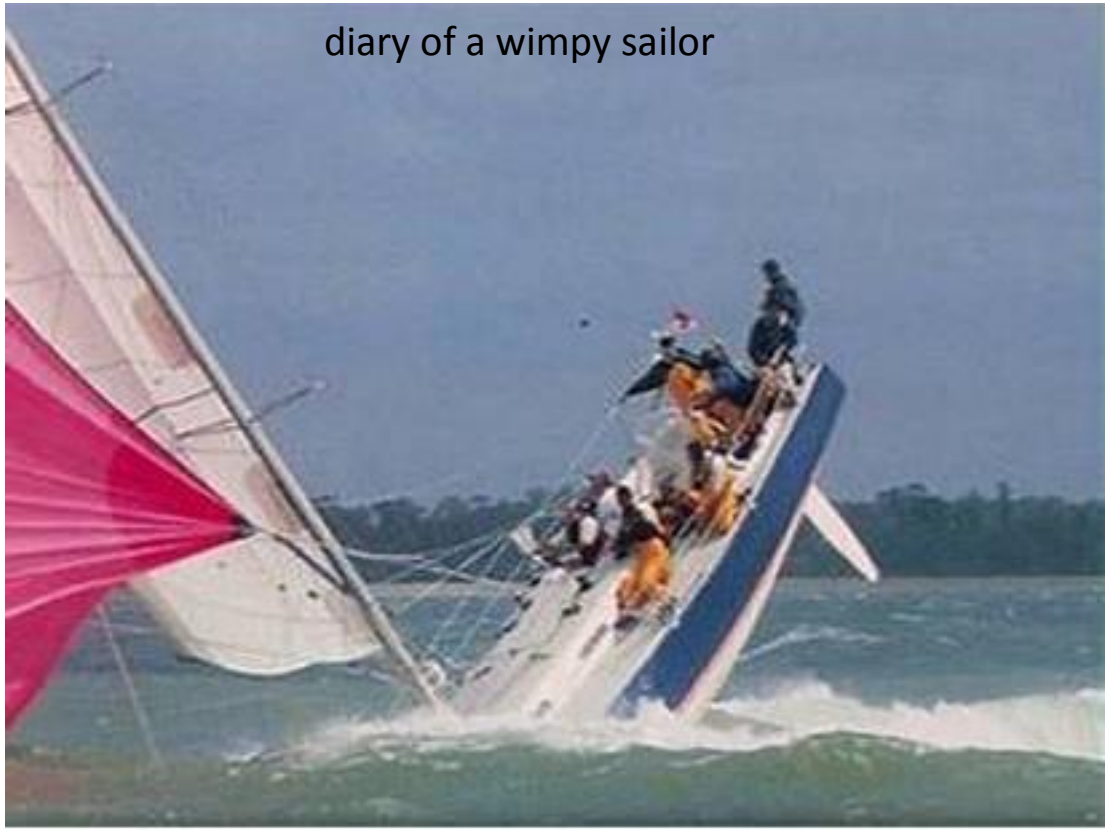
Global Warming is Real



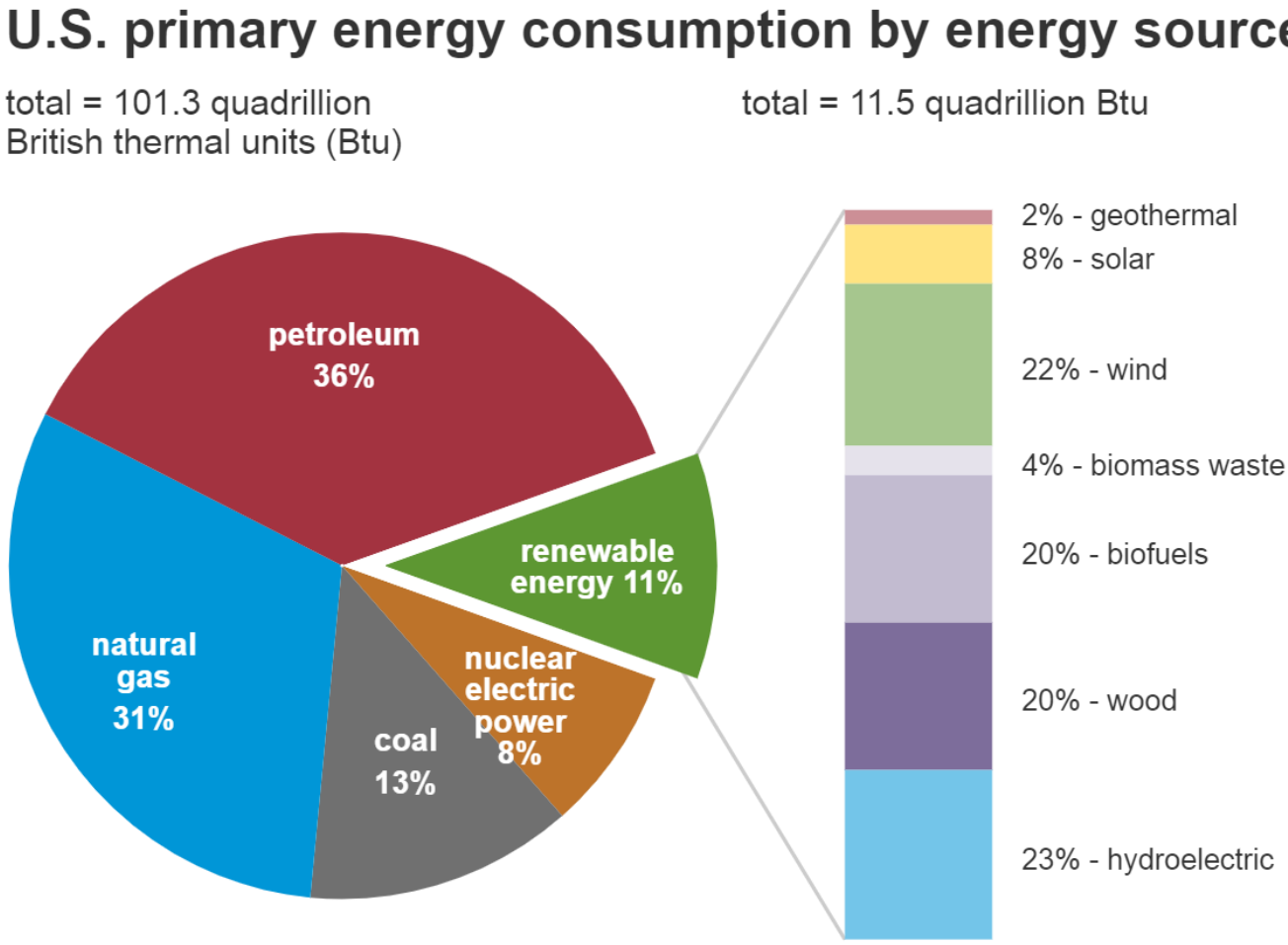
What happens if we take no action?

You Were Thinking About Lowering Your Sails Until Surprise! – You Waited Too Long



Just **thinking** we need to take action on climate change means we need to take action **now** in dealing with climate change.

Large CO_2 Emitters Are Cars And Electric Power



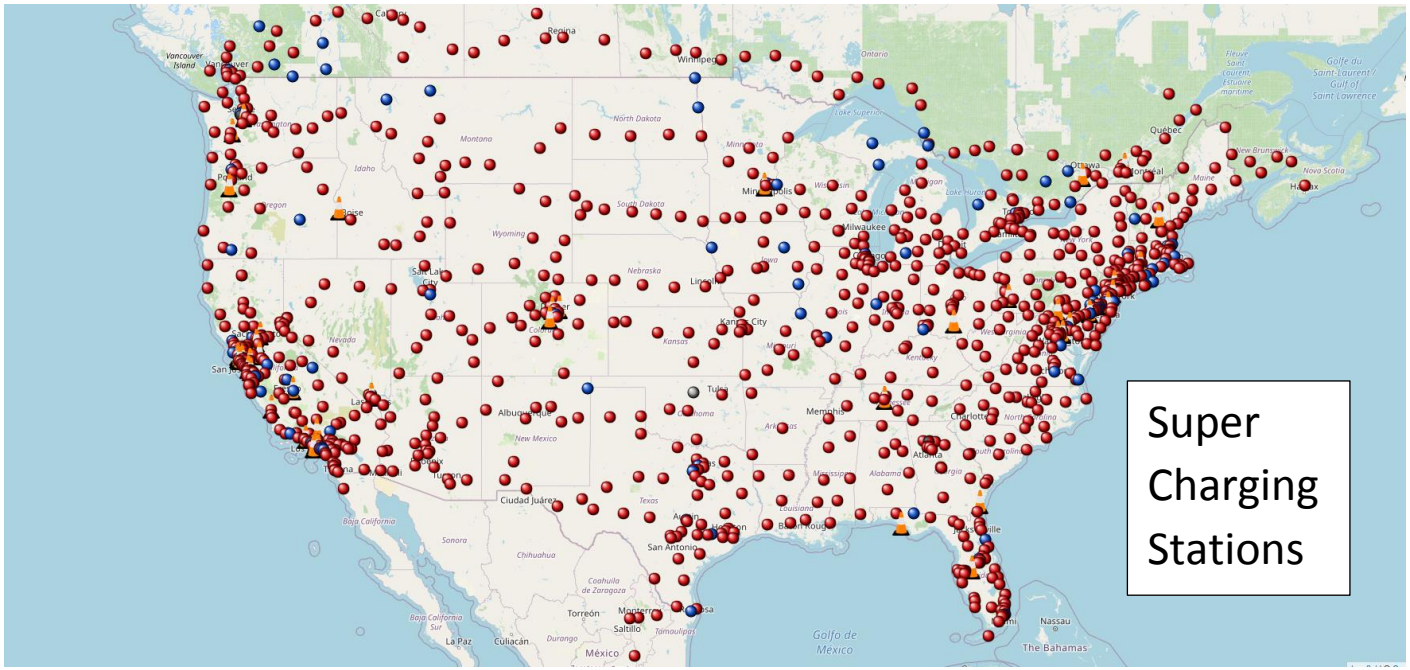
38.3 Quads ~ 38% for Electric Power

28.3 Quads are for Transportation

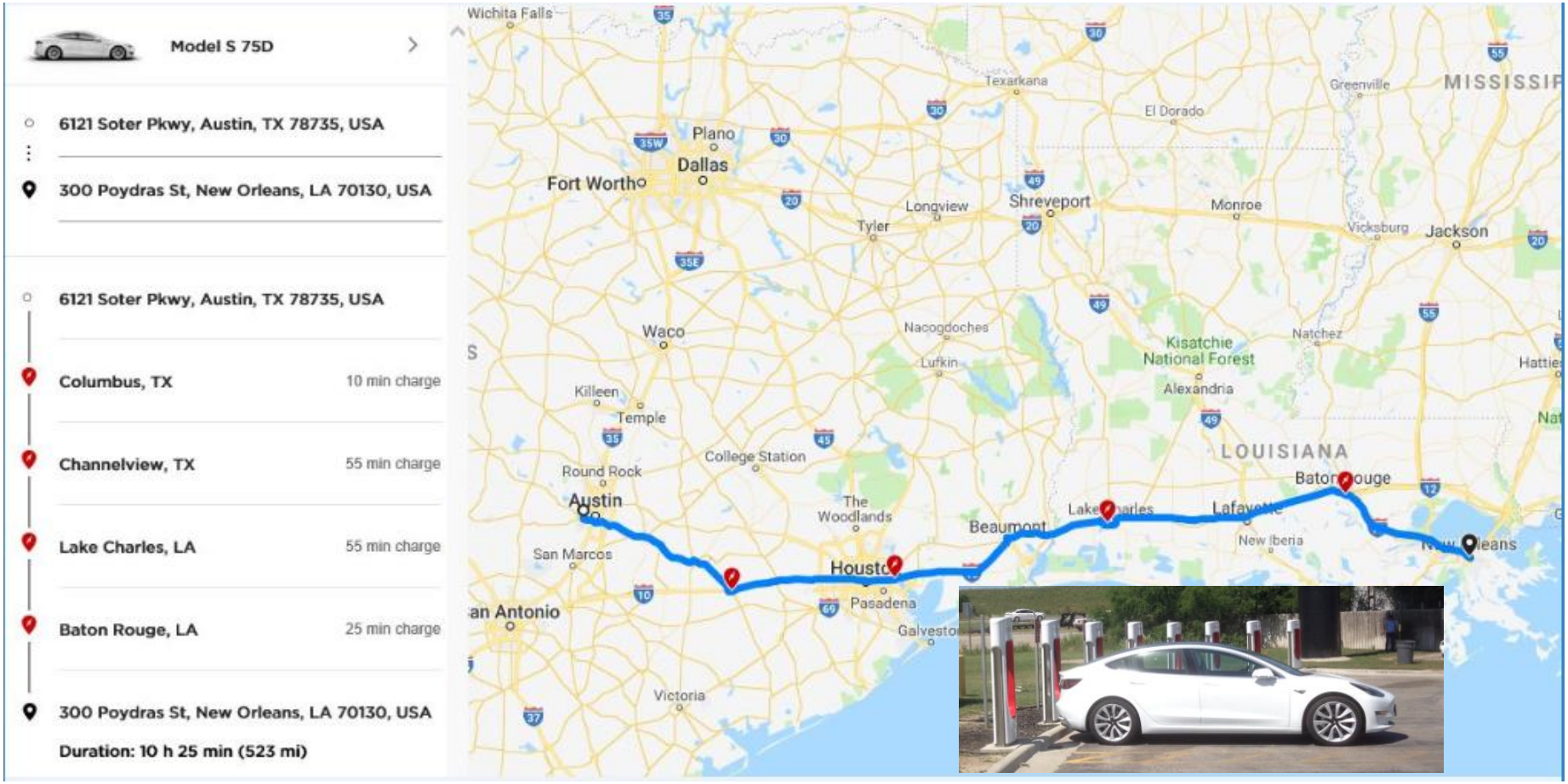
https://www.eia.gov/energyexplained/us-energy-facts/

Electric cars move into the mainstream

- Most advanced battery technology and soon a million mile battery.
- Very powerful motors, 450 HP in the Tesla is a common option.
- No annual servicing of the car is needed. If your car has a problem Tesla can remotely fix it, or a home visit, or take it to a service center.
- Lower cost energy. Electricity is much cheaper than gasoline.
- An advanced on board computer is tied to the internet with maps.



Electric cars move into the mainstream

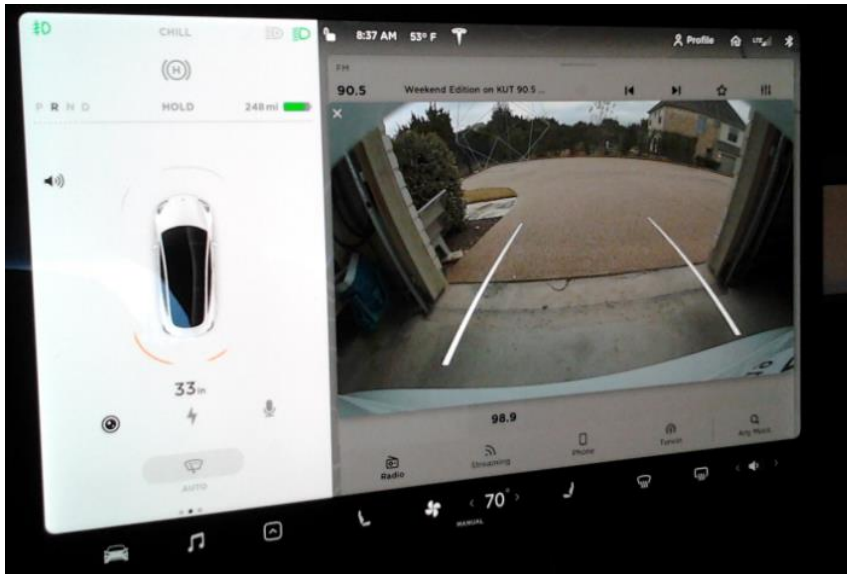


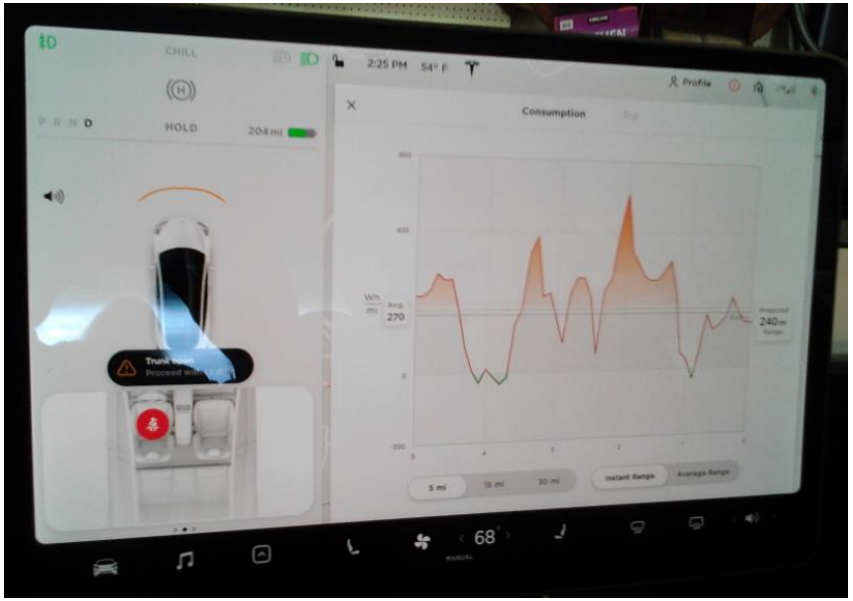
Eat lunch at Channelview TX while charging and stop overnight at Baton Rouge; charge up overnight. Drive to New Orleans the next day to the AiCHE meeting. Spend two days in New Orleans. Use same route home.

Electric cars move into the mainstream

Tesla Model 3 pictures

A Rather Clean Looking Interior





Backing guide lines on the screen.

Energy usage in a real time graph.

Additional electrical transportation load

- Electric vehicles are more efficient than ICE cars.
- The Tesla Model 3 has an EPA rating of 130 mpg.
- The Tesla Model 3 gets about 3.8 miles/kWh.
- A Toyota Camry equivalent to M3 gets 41 mpg.
- The ERCOT* load averages ~45 GW annually.
- A giant leap is assuming 41/130 holds for all EVs.
- One EV load estimate is 45*(28.3/38.3)*(41/130)=~10.5 GW average.
- 22 million Teslas driving 16,000 mi/yr in Texas is a load of ~11 GW.
- For an average electric customer using 18,000 kWh annually this adds 18,000*(28.3/38.3)*(41/130) = 4195 kWh or ~16,000 miles per year.
- Conversion of trucks and buses and trains would add much more load.
- Problem – ERCOT in 2027 may not be reliable enough to depend on.

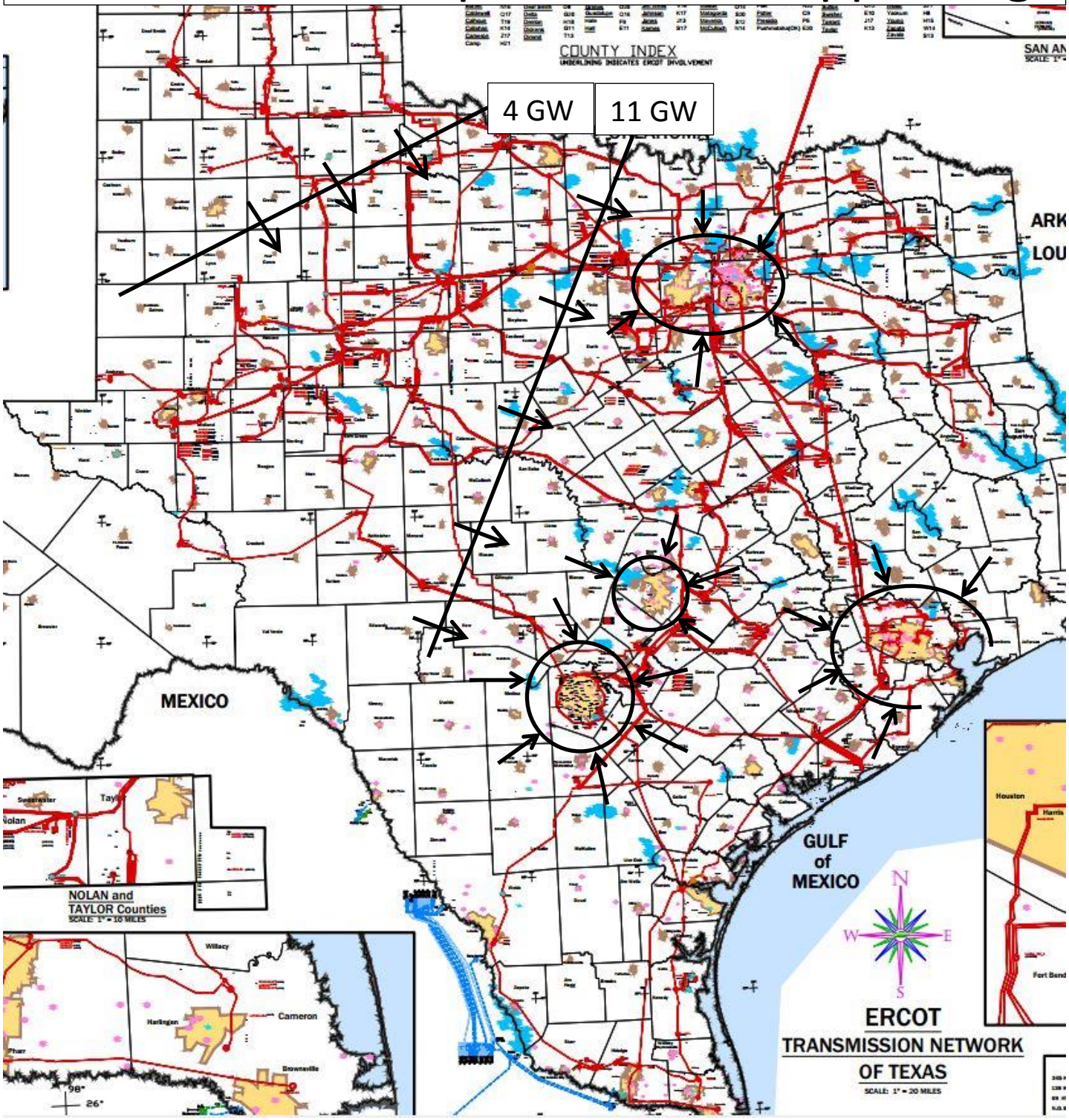
* ERCOT is the Electric Reliability Council of Texas www.ercot.com

Grid transmission problems are appearing

1) Point of injection transmission constraints exist in most of ERCOT making new generation siting more difficult.
2) New Generic Transmission Constraints limit the maximum power coming out of the Panhandle to about 4 GW and out of all of West Texas to about 11 GW. There could easily be 35 GW of wind and solar in West Texas by 2027. New lines are not likely to be built.
3) As older gas and coal power plants within cities are retired, power flowing into cities such as DFW, Austin, San Antonio, and Houston over transmission lines causes a dangerous dependency on the transmission system which limits each load area's remote power options.

Grid transmission problems are appearing

The ERCOT transmission grid is showing problems handling increased wind and increased loads while at the same time is retiring gas and coal plants near large city load centers.



Grid power supply problems are appearing

4) Reserve generation capacity is an excess of generation above the peak demand to be served (the definition).
5) Reserve margins were high in the 1980s when new coal and nuclear plants were coming on line to replace gas.
6) 1990s deregulation made generation planning a market activity which ERCOT's role is to just oversee the market.
7) Gas fracking caused a rapid growth in merchant gas plants and for a while the reserve margin remained high.
8) Now wind and solar are displacing gas and coal plants and the reserve margin is dropping with load growth.
9) Panda is an example of an energy market not providing sufficient revenue to finance a new gas plant in ERCOT.

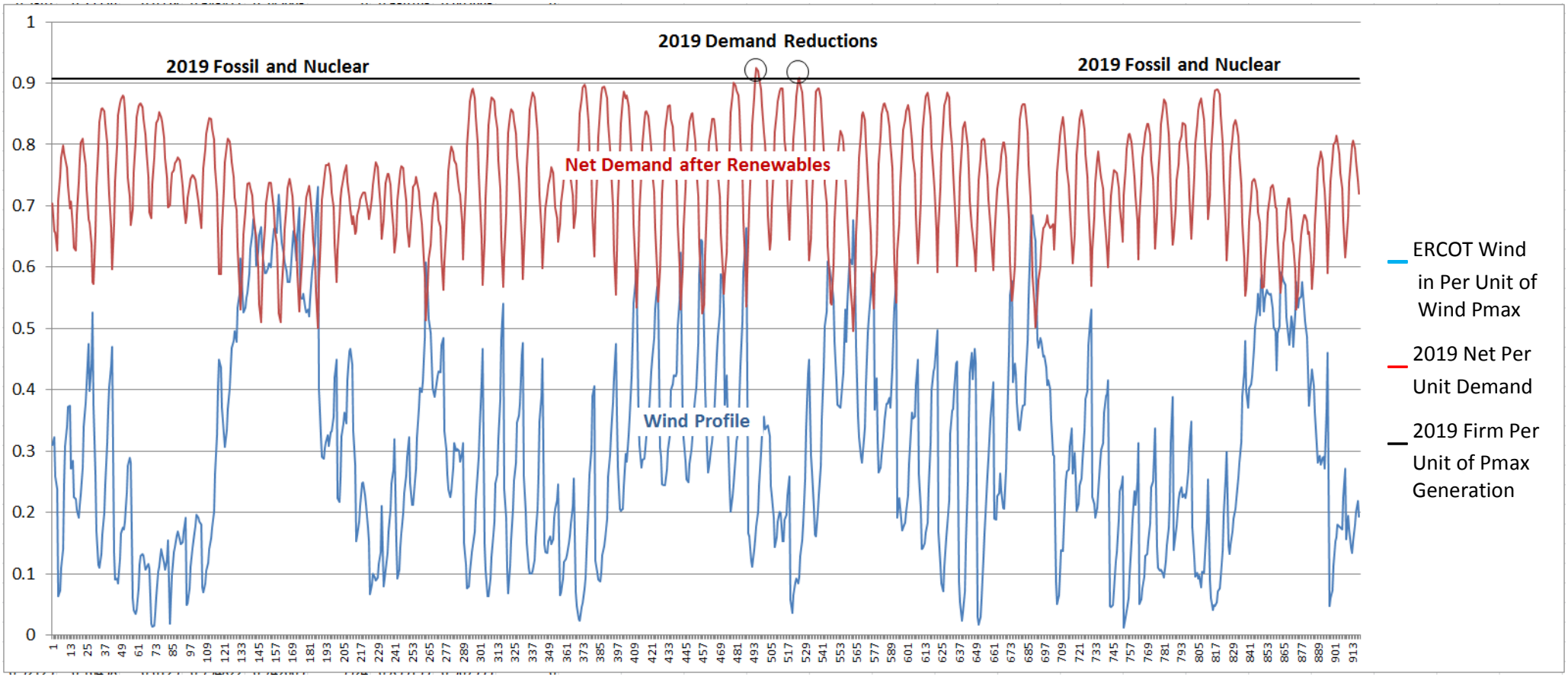
A Discovery Was Recently Made About ERCOT's Data

Year	load flow created	load flow load+losses	fossil+nucl firm Pmax	Wind Pmax run @ %	Wind extra MW	Solar Pmax	short d/y
2018	Feb-18	83219 MW	73417+4981	21744@24%	921	1242@75%	0
2019	Oct-18	85213 MW	72413+4960	26257@28%	2275	1583@75%	2
2021	Jun-19	93346 MW	73648+4960	31239@44%	7850	4150@74%	18
2023	Mar-20	97989 MW	72762+4960	32126@51%	10464	7542@74%	32
2027	Jun-20	104215 MW	72355+4973	35829@52%	11283	11884@76%	54

The "load flow" mentioned above is just an electrical model which calculates transmission line currents and substation (or node) voltages. Power is injected into the grid at power sources and taken out of the grid at load centers.

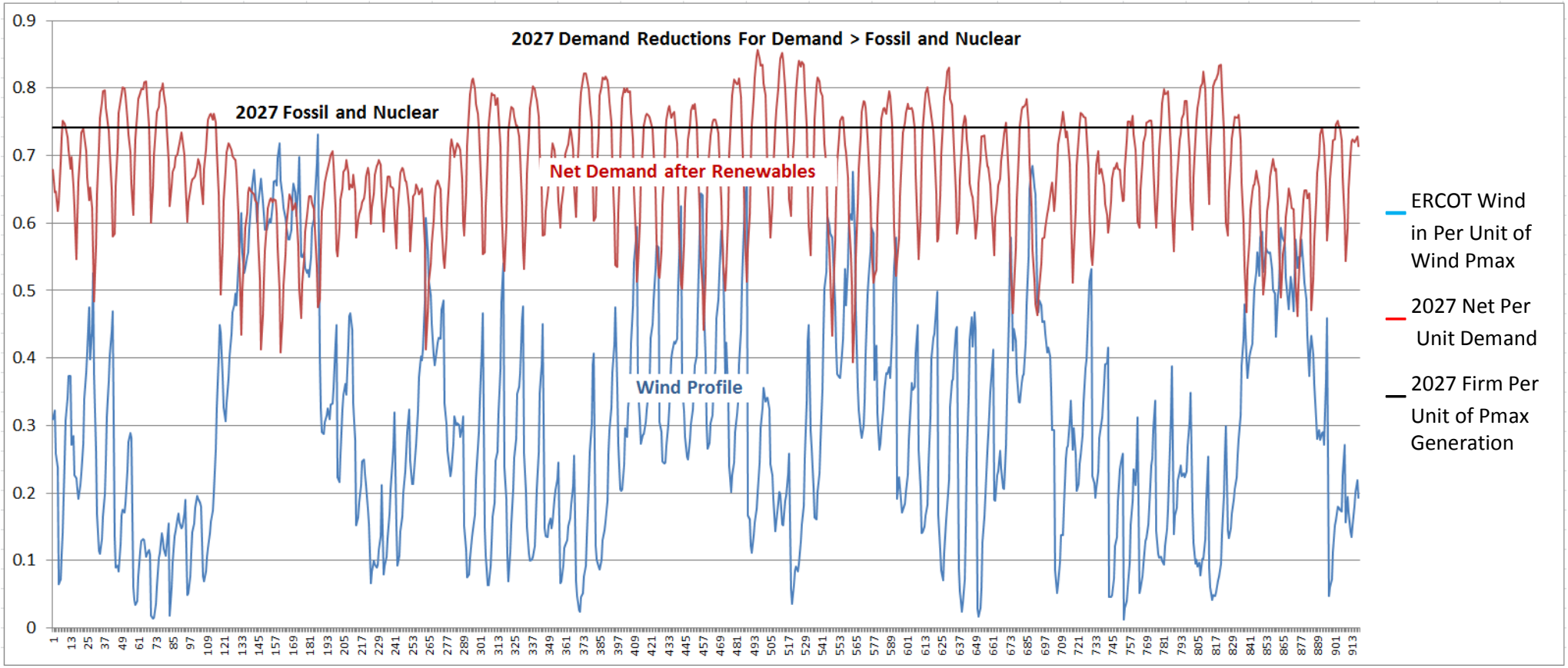
There must be enough generation all the time to serve the load and losses. The 2019 historical hourly load, wind, and solar MW profiles are scaled up in future years and run through a simple hourly calculation to see if there is sufficient generation to meet the load+loss all the time. The discovery that was made is that the deficiency gets progressively worse in future years. By 2027 there are 54 days out of the year where emergency load reductions are projected to be needed. This is not a reliable system even before electric cars are added.

Below are the 2019 Capacity Shortages – Barely a Blip



The above graph shows when ERCOT was slightly deficient in 2019. Only hours with loads > 0.7 Per Unit of the 1.0 PU peak are plotted, 913 hours. The two little circles near the top are the Aug 13 & 15 dates in 2019 where grid prices went to $9000/MWh. ERCOT allows the price of energy to go very high when there is a capacity shortage.

Below are the 2027 Capacity Shortages – Frightening



In this graph wind and solar power is subtracted from the ERCOT load every hour. The 2027 capacity shortage is very extensive with 54 days the load is in excess of the supply. Adding wind and solar does not solve the shortage problem. More nuclear would help but the time needed to build the nuclear is beyond 2027. This shortage must be fixed to avoid great hardships on our electric customers and puts our society at risk of anarchy.

Near term options for better grid reliability

10) ~12000 MW new gas capacity - not likely
    a. Renewables displace energy sales
    b. Too many idle hours for operators
    c. Opposition to new fossil fuel plants
    d. Financing difficult with climate change
    e. Plants are located too far from loads
    f. Unmanned plants are a bit too small
    g. Litigation still active on a failed gas plant
    h. Future gas supply is ultimately finite

Near term options for better grid reliability

11) Adding more wind and solar
    a. 2027 add 99 GW wind & 58 GW solar for 0 d/y
    b. Not possible because of limited transmission
    c. Great difficulty building new transmission lines
12) Battery storage works for daily storage
    a. Not suitable for seasonal storage
    b. Fails separation of load and generation
    c. Grid storage not financeable in market
    d. Possibly utilize storage in EVs as V2G

Near term options for better grid reliability

13) Utility demand side management - DSM
    a. Renewables are only intermittently available
    b. Increasing the turning off of summer AC load
    c. Shifting the timing of non-critical loads
    d. Sending grid price signals to customers
14) Customer produced energy - gas and solar
    a. At levels needed - grid problems are certain
    b. There are utility rules limiting innovation
    c. There are rules preventing lower cost solar

Near term options for better grid reliability

15) Sending price signals to customers is equivalent to selling customers energy without a guarantee for reliable service – problem is dumped on users
    a) Most electric users will add backup generation
    b) Customers with backup generation will cut their ties to the grid when prices rise too high
    c) Tesla Power Wall customers can cut their tie to the grid is the purchase from Griddy Energy

Near term options for better grid reliability

16) Getting power into the cities is a problem
    a. Before 1965 cities had local gas and coal generation
    b. New transmission interconnected cities after 1965
    c. Coal and nuclear plants distant from load centers used the new transmission lines - loading them up
    d. New wind and solar also remote from loads is displacing and retiring older gas and coal plants
    e. Retirement of these gas and coal plants near load centers is causing line overloads near load centers
    f. These transmission systems are limiting how much power can be imported from all remote generators

Non-nuclear power supply option for reliability

In 2027 increase solar from 11884 MW to 25000 MW and add 9000 MWh storage (4500 MW for two hours)

PEAKDEM	EV	HYDRO	WIND1	WIND2	SOLR1	SOLR2	PSTOR	NUCLR	GAS	
104215	0	0	35829	0	25000	0	9000	4973	72355	MW
Sources Energy:		0	113631	0	57238	0		43563	321603	GWh
+CapFact -Lost:		0	0	0	0	0		100	45	%
Energy to Load:		0	113631	0	57238	0		43563	321603	GWh
Energy to Load:		0	21	0	11	0		8	60	%
Capital Cost :		0	143	0	75	0	6	50	201	$BN

GAS(80977. MW 8754 hrs 45 %CF 60% of load energy, peak MW gas on 2019081420)

GAS(72355. MW 8760 hrs 51 %CF 1 starts added 6 hrs/start to smooth out gas)

PS (4500. MW 2 hrs 9 GWh capacity 6 GWh load 1 discharges)

CASE 2 475 $BN Load From: Storage= 0% Renewable = 32% Lost = 0%

The generation exactly matches the needed amount to deterministically avoid emergency events. Storage costs $9bn. Fossil fuels are 60% of the energy. Notice there is no extra EV load in this simulation. Can Tesla provide the EV energy?

Nuclear power supply option for reliability

In 2027, no new wind, 10 GW solar, 20 GW base load nuclear with 20 GW load following nuclear.

PEAKDEM	EV	NewNucl	WIND1	WIND2	SOLR1	SOLR2	PSTOR	NUCLR	GAS	
104215	0	20000	24000	0	10000	0	0	-24973	47764	MW
Sources Energy:		175200	76116	0	22895	0		218763	69965	GWh
+CapFact -Lost:		0	0	0	0	0		88	17	%
Energy to Load:		175200	76116	0	22895	0		191864	69965	GWh
Energy to Load:		33	14	0	4	0		36	13	%
Capital Cost :		180	96	0	30	0	0	70	76	$BN

GAS(47764. MW 5109 hrs 17 %CF 13% of load energy, peak MW gas on 2019081317)

GAS(47764. MW 6843 hrs 17 %CF 289 starts added 6 hrs/start to smooth out gas)

PS (0. MW 0 hrs 0 GWh capacity 0 GWh load 0 discharges)

CASE 4 452 $BN Load From: Storage= 0% Renewable = 51% Lost = 0%

-24973 tells the program to dispatch this as load following. It's still at 88% capacity factor.

This plan is $23bn cheaper than the no nuclear plan. 24 GW fossil fuels are retired. This has 87% fossil fuel free energy. 47 GW gas is used for peaking. There is no storage and no EV load.

Most useful types of nuclear for ERCOT

17) Charles Forsberg's thermal storage nuclear could provide the 20 GW base generation and 20 GW peaking which can eliminate the need for battery storage on the grid.
18) Per Peterson's nuclear plant design with 12 off the shelf turbines per reactor can be used for seasonal generation as well as meeting all the spinning and responsive reserve requirements.
19) IFR nuclear could provide thousands of years of nuclear fuel supply with little mining and waste.

Impediments to progress that need correcting

20) Problem – The energy market does not support capital investments in nuclear and storage.
21) Solution - A new business model is needed that supports capital investments for climate change, grid reliability, and a cleaner environment.
22) Rules preventing innovation need to be removed
23) Customers need to build in their own off grid power supplies for improved resiliency.
24) We need our governments to support nuclear power for R&D and commercialization.