Program STORAGE by Eugene Preston, January 13, 2018, There are no copyrights.

How to download and run the STORAGE program.

Download STORAGE.zip from www.egpreston.com/storage.zip and manually copy the files to a directory you have created in file manager. Then double click on STORAGE.exe to run the program. You can run any of the three hourly system files supplied in the .zip for ERCOT, CAISO, or the modernized IEEE RTS data at https://github.com/GridMod/RTS-GMLC. You can also create your own hourly file for any other system.

STORAGE.exe is Fortran 77 using an old Compaq Fortran complier. The source code is provided as STORAGE.txt if you wish to see the details on how it runs or modify the program. I have also tested it using Watcom 77 Fortran which is available on the internet at no cost. These old F77 programs will run under any version of past and present windows.

When you run the program, the storage should not have to reach too far into the past because we are talking about battery storage. If the days are greater than 30 I would advise increasing the resources until the storage days is 30 or less. This is easily done iteratively and conversationally. A YouTube video showing how to run the program conversationally is posted at https://youtu.be/6v0jtNESXiU.

All you do to run the program is double click on STORAGE.exe in the file manager in windows. This is the same procedure for any version of windows.

You next enter in the name of the hourly file which contains historical profiles for several years of data for these values: demand, hydro, wind 1, wind 2, solar 1, solar 2, and fully dispatchable generation which I call 24/7 generation.

The program will ask you for the MW for each of these. If you have no resources for an item like hydro, just enter a 0. If you make a mistake on the entry the program will let you enter it in again. If you enter in too little generation or too high a load level then there is a warning you have insufficient generation. Answer the question again with more generation or less load.

When the program gives you back a one line answer, note the number of days storage. If there are too many days, simply increase one of the resources and run it again. Repeat this until you have the result you wish to have. The program calculated long term and short storage or no storage at all if you enter enough generation. Too little energy production prints out the message to add more generation.

With this simple program you can get a pretty good idea what your future system is most likely to look like. Once you know how much nameplate power there is in each category, then go plan the transmission system to get you from here to there.

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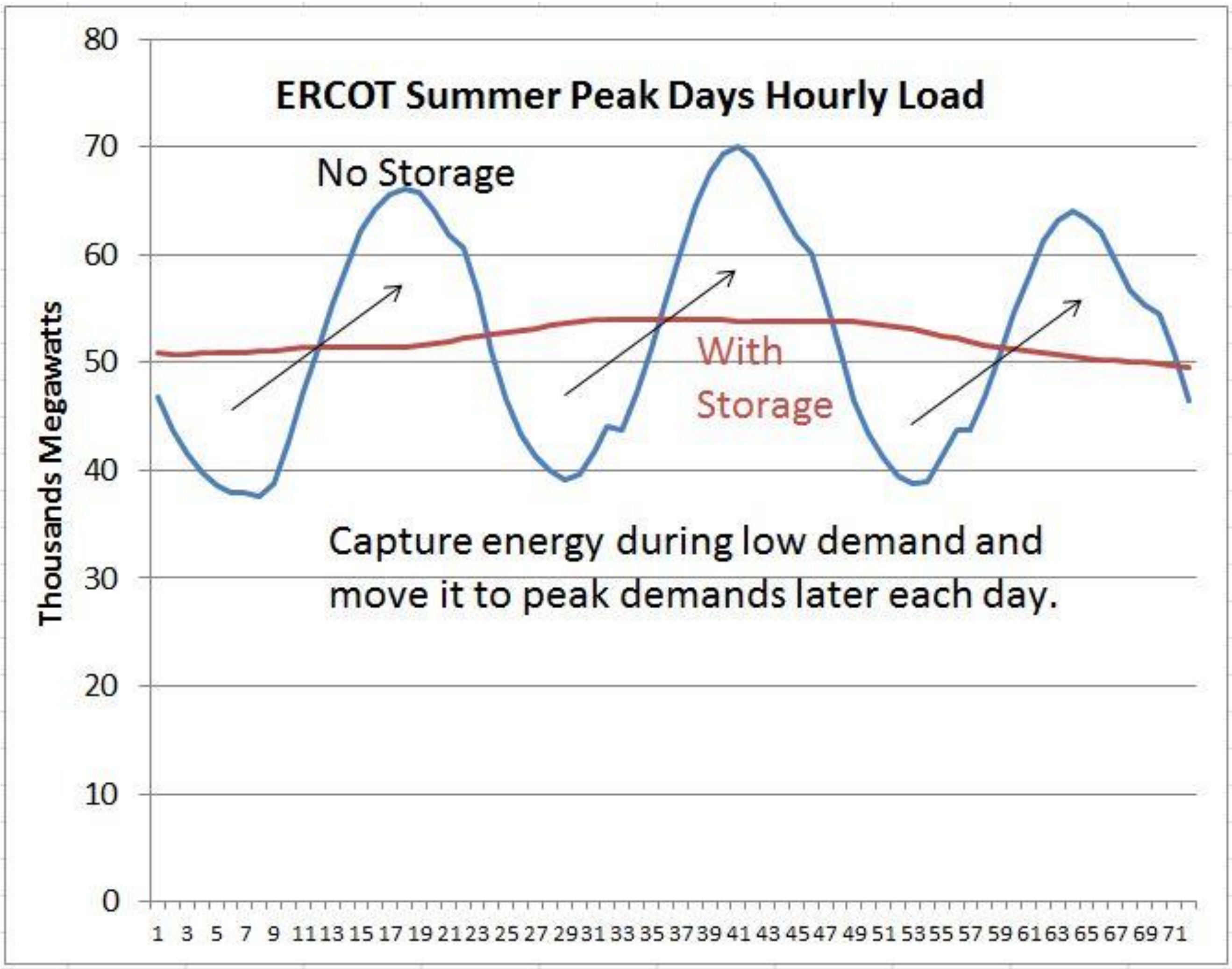
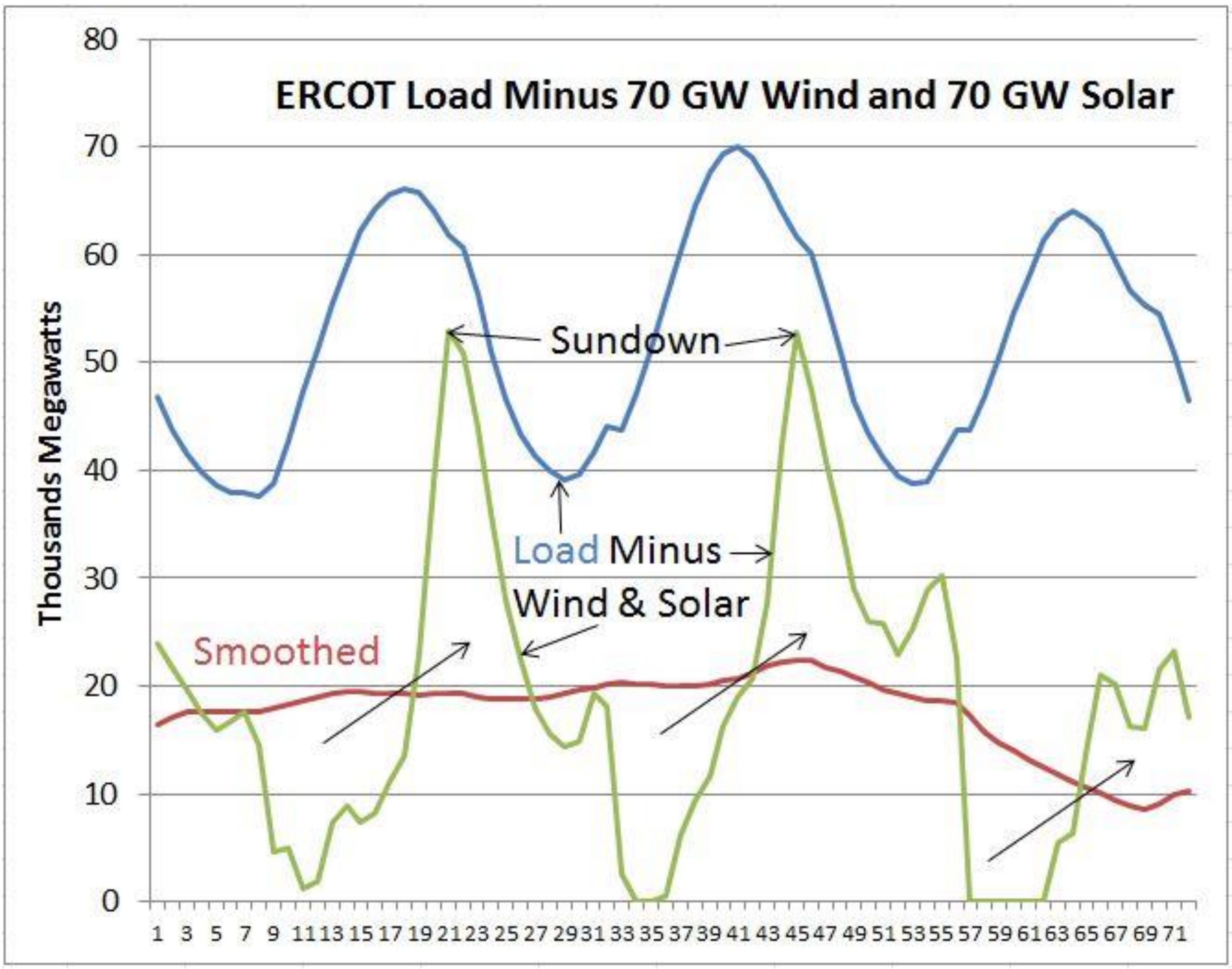
With renewable energy we are going to need storage to move energy. Storage also smooths out the hourly fluctuations in the demand.



The above example shows storage smoothing out the daily demand fluctuations. This would be necessary if we want to retire some peaking capacity that would normally be used to serve the peak demand. If all gas peaking generation is phased out, then only storage can be used to serve peak demands. If you already have hydro for serving peak demands, consider yourself lucky. If you don't have hydro, you may need battery storage to smooth out the daily peaks.

In addition to smoothing out the demand, we must also collect excess renewables energy on a daily basis for the purpose of supplying that excess energy to a later day that is insufficient in daily renewable energy production. The figure on the next page shows how a large amount of renewables in a system can cause the net demand to swing wildly.

Here we have a typical day in ERCOT with peak demand set to 70 GW and 70 GW of wind and 70 GW of solar. Note that this amount of renewables produces insufficient energy for the day as shown by the red line. The green line is the demand blue line minus renewable power every hour. I.e. the green line uses the renewables power immediately, not storing the energy. The green line must be smoothed down to the red line using battery energy storage (in ERCOT since hydro is not available). Note the green line dips below the 0 MW level. There is some energy that would be collected and made available in a later day, such as the next day. Program STORAGE looks at the energy each day and finds the worst day of energy shortage of many years historical profiles and then reaches back as far into the past as necessary collecting the excess energy for serving the current day that is deficient. The program tells you the worst case of how many days it had to reach back. If you see the program reaching back more than a few days you have not put enough renewable energy into your system.



Can we really operate a system like this? I doubt the transmission system can hold together unless we position storage all over the system and operate it “smartly”.

Reliance on 100% renewables such as wind, solar, and hydro introduces a need to study daily energy production and consumption. Energy short on a day means looking back to earlier days to pick up the energy needed. How many days back is a feature in program STORAGE.

Below are a few test case sample runs for ERCOT, CAISO, and the new IEEE 2020 RTS.

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Case	Peak Demand MW	Hydro MW	Wind1 Wind2 MW	Solar1 Solar2 MW	24/7 Nu/Gas MW	Storage MWH	Storage MW Pk Dischg	Stor Hrs @Pk	Days	Storage Cost* $Bn
1	ERCOT 70,000	0	24,000 4,000	5000 5000	48,000 Fossil	115,341	13,721	5.1	0	30
2	ERCOT 70,000	0	30,000 6,000	40,000 80,000	24,000 Fossil	388,022	34,552	11.2	7	95
3	ERCOT 70,000	0	36,000 8,000	64,000 180,000	0 NoFoss	809,418	58,106	13.9	22	191
4	ERCOT 70000	0	36,000 8000	64,000 140,000	5000 Nucl[3]	719,058	53,106	13.5	19	171
5	ERCOT 70000	0	36000 8000	40000 80000	0 LTS[4]	921606	58106	15.9	1018	213
6	CAISO 50,000	10,000	5,000 0	10,000 0	44,000 Fossil	0	0	0	0	0
7	CAISO 50,000	10,000	10,000 0	100,000 0	20,000 Fossil	167,159	23,159	7.2	17	45
8	CAISO 50,000	10,000	20,000 0	600,000 0	0 NoFoss	523,557	42,147	12.4	28	126
9	CAISO 50,000	10,000	20,000 0	400,000 0	6,000 Nucl[5]	379,557	36,147	10.5	28	110
10	CAISO 50,000	10,000	20,000 0	80,000 0	0 LTS[6]	564663	42147	13.4	1027	134
11	RTS3 8,192	1000	2508 0	1555 1161	6228 Fossil	0	0	0	0	0
12	RTS3 8,192	1000	2508 0	1555 1161	4000 Fossil	18,968	2,228	8.5	18	4.9
13	RTS3 8,192	1000	8000 0	8000 8000	0 NoFoss	57,698	6,068	9.5	12	14.6
14	RTS3 8,192	1000	8000 0	8000 6000	400 Nucl[7]	52,675	5,668	9.3	13	13.4

* Assumptions and Results are on the next page.
Fossil means any form of fossil 24/7 generation plus nuclear.
NoFoss means no dispatchable fossil generation capacity and no nuclear.
Nucl means only nuclear capacity is available and there is no fossil capacity at all.
LTS means long term storage, for years at a time, with no losses (but this does not exist).

Notes:

1) Estimated Storage Cost = 0.5 $/W + 0.2 $/Wh for both short term and long term storage.
2) Solar Rooftop Cost = 2$/W with CF = 18%. 1 Axis Tracking Solar CF = 27%.
3) ERCOT Nuclear = (191-171) $Bn storage + (180-140)*2 $Bn divided by 5 GW = **20 $/W.**
4) ERCOT LTS (if it were possible) saves ((64-40)+(180-80))*2 – (213-191) = **226 $Bn**.
5) CAISO Nuclear = (126-110) $Bn storage + (600-400)*2 $Bn divided by 6 GW = **69 $/W.**
6) CAISO LTS (if it were possible) saves ((600-80)*2 – (134-126) = **1032 $Bn**.
7) RTS Nuclear = (14.6-13.4) $Bn storage + (8-6)*2 $Bn RTsolar div'd by 0.4 GW = **13 $/W.**

In Case 4 the 5000 MW nuclear existing in ERCOT is added back in and then rooftop solar dropped to 140,000 MW. This drops storage cost by 20 $Bn. The 40,000 MW drop in rooftop solar is another 80 $Bn saved. The 5000 MW of existing nuclear is worth 20 $/W !

However, Case 5 shows that if long term storage were available, then ERCOT could get by with a lot less renewables capacity saving 226 Billion Dollars and not needing either fossil or nuclear generation. The problem is that long term storage for years does not exist.

In Case 9 the 6,000 MW nuclear is used instead of 2300 MW currently in CAISO to allow nuclear to provide enough base load energy to ride through 2014-2015 drought years. In both cases 8 and 9 the lookback days are carefully set to 28 days. The problem with solar is that the excess energy each day is too brief a period of time, requiring many days or a whole lot of solar installed capacity to make up for the loss of hydro during drought conditions. Nuclear provides a whole lot more day to day energy when the hydro is deficient. This is the reason the 6000 MW of nuclear in the CAISO is so valuable. If there were such a thing as long term storage where energy could be set aside for years ahead of drought periods in large hydro generation areas, then nuclear would be of less value. The surprising conclusion here is that a high dependence on hydro energy has its downside when there is drought creating a serious reliability energy supply problem for those drought years. Traditionally the hydro utilities in the west have used natural gas as a backup. In this model natural gas is removed entirely from the model. ERCOT having little hydro energy skips this problem altogether. The RTS with one year of data misses seeing the reliability effects of drought years.

In Case 10, long term storage is made available to CAISO and it greatly reduces the amount of solar capacity needed since the energy can be stored for years. This saves over a trillion dollars in the system investment and no other resources are needed other than wind, hydro, solar, and long term storage. The only problem with this is that long term storage does not exist. Our best option until long term storage does exist is to plan for nuclear base load capacity to provide enough energy.

A weekly energy report WKLY.txt was added to STORAGE which allows graphs to be produced for ERCOT and the CAISO. Renewable energy production appears to swing more widely in the CAISO than in ERCOT. The graphs suggest that both regions could use 20 GW of base loaded nuclear energy generation.

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