How Well Do Renewables Displace Fossil Fuel Generation Capacity in the 2030 ERCOT Climate Protection Plan?

Emerging Technologies Working Group

By Gene Preston, PE, PhD

Prepared December 3, 2015

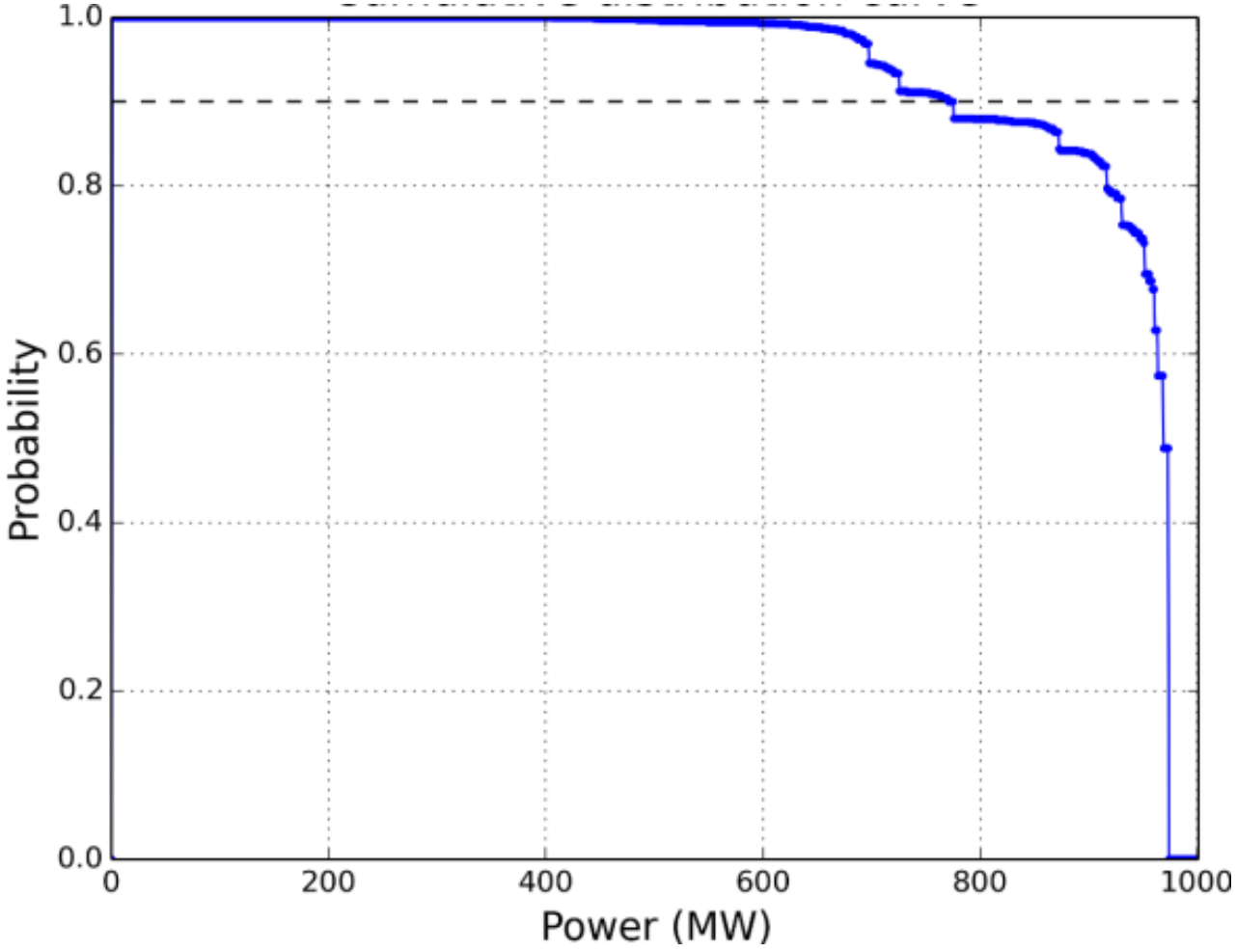
- **Advancements in the calculation of the LOLE**
- **Modeling LOLE of the 2030 Clean Power Plan**
- **Fossil Fuel Capacity Displaced by Renewables**

- **Advancements in the calculation of the LOLE**
  - Monte Carlo programs have these limitations:
    - Reduced transmission networks are hard to create and poorly represent the full network problems.
    - Transmission constraints are too few in number.
    - Sequential MC has an LOLE definition problem.
  - My Direct Calculation Probabilistic Generation and Transmission 1997 PhD model had these limitations:
    - Every transmission line was overloaded to some extent, which was too much overload information.
    - There was not a unique way to map probabilistic line overload effects back into the subarea LOLEs.
    - Renewables were not correctly modeled.

Advancements in the calculation of the LOLE

- Definition of LOLE - the Loss of Load Expectation.
  - Count the number of Monte Carlo loss of load 'events' and divide by the number of years run.
  - Counting all 'events' during a day is problematic.
  - Fixed by identifying the greatest LOLP of each day.
  - The LOLE = $\sum_{365 \text{maxdaily}}$LOLP is historically consistent.
  - Hourly LOLP = 1 – F(x $_{\text{load MW}}$) is a 'look-up' table.
  - F(x) cumulative capacity distribution can be done from a Monte Carlo process or a direct calculation.
  - The direct calculation of F(x) is 'exact' to 16 digits for the full range of 0 < x MW < $\sum_{\text{all generator}}$ Pmax.
  - An example F(x) curve is shown on the next page.

- **Advancements in the calculation of the LOLE**
  - F(x) for the 10 generator example OPDC.txt.
  - The hourly LOLP = 1 – F(x) where x = net MW firm load.



- **Advancements in the calculation of the LOLE**
  - net load = hourly load – ∑ hourly renewables MW.
  - MW's of all this data is scaled to a future test year.

3 6 HISTORICAL YEARS AND NUMBER OF RENEWABLES TO BE MODELED AVG The puDEV and AVG DEV are not input data.

YYMMDDHH	DAY	NORMAL PK	PU WEIGHT	ACTUALLD	FCST PK	puDEV	DEV	The weather is found to cause ~3% load uncertainty
10082316	6	65997	.450	65997	64056	.0303	.03	
11080317	4	68274	.100	68274	65206	.0471		
12062616	3	66562	.450	66562	65665	.0137		

YYMMDDHH	DAY	ERCOT LOAD	WTXWND	INSTWTX	Coastal	CoastIns	Panhan	PanhanIns	AEsolar	AEsolIns	CPSsolar	CPSsolIns	WTXsolar	WTXsolIns
10010100	6	32148	852	8213	515	767	729	1000	0	1008	0	965	0	1009
10010101	6	32053	615	8213	572	767	760	1000	0	1008	0	965	0	1009
10010102	6	32178	481	8213	609	767	760	1000	0	1008	0	965	0	1009
10010103	6	32255	911	8213	528	767	827	1000	0	1008	0	965	0	1009
10010104	6	32675	1866	8213	496	767	881	1000	0	1008	0	965	0	1009
10010105	6	33567	2372	8213	411	767	957	1000	0	1008	0	965	0	1009
10010106	6	34825	2595	8213	274	767	858	1000	0	1008	0	965	0	1009
12123112	2	36497	1791	9397	880	1671	203	1000	0	1008	0	965	964	1009
12123113	2	35873	1710	9397	801	1671	174	1000	0	1008	0	965	912	1009
12123114	2	35046	2448	9397	693	1671	174	1000	0	1008	0	965	666	1009
12123115	2	34204	2522	9397	980	1671	322	1000	0	1008	0	965	428	1009
12123116	2	34005	2376	9397	850	1671	284	1000	21	1008	23	965	632	1009
12123117	2	34411	2040	9397	747	1671	284	1000	52	1008	56	965	385	1009
12123118	2	36737	1548	9397	873	1671	258	1000	2	1008	3	965	17	1009
12123119	2	36061	1648	9397	800	1671	322	1000	0	1008	0	965	0	1009
12123120	2	34607	1962	9397	571	1671	322	1000	0	1008	0	965	0	1009
12123121	2	33081	2018	9397	477	1671	322	1000	0	1008	0	965	0	1009
12123122	2	31697	1439	9397	440	1671	596	1000	0	1008	0	965	0	1009
12123123	2	30349	2342	9397	513	1671	162	1000	0	1008	0	965	0	1009

Note: As this data is read in, the net load that dispatchable generators "see" can be calculated as each line is read. That net load "x" is then directly applied to the LOLP = 1 - F(x) calculation.

- **Modeling LOLE of the 2030 Clean Power Plan**
  - The first step is to create a base case – use PSSE data.
    - 2017 Summer Peak was selected; renewables and tie lines are excluded from this calibration case.
    - Non-renewable generation capacity is 80967 MW.
    - Nuclear is held to a constant 5150 MW capacity.
    - Set a peak demand of 70406 MW for 15% reserve.
    - The generator FOR's (forced outage rates) are varied until FOR=0.068 gives LOLE = 0.1 d/y.
    - **The study objective is to see how effectively renewables power displaces fossil fuel capacity.**
    - Renewables are added and fossil MW are reduced.
    - This process is a measure of the minimum fossil fuel capacity needed to maintain an LOLE = 0.1 d/y.

- **Fossil Fuel Capacity Displaced by Renewables**
  - Study results are shown below:

SCENARIO FILENAME	PKGW DEMD	WN GW	SO GW	ST GW	FOSSL PMXMW	CHG%	DELTA MW	MIN DEM	UP-DWN MW/MIN	RNEW ENGY	RESVE MARGN	WND EFFECTIVE%	SOL EFFECTIVE%	STOR ADDED COASTAL
17BASE0	70	0	0	0	75817	0	0	23	94 201	0%	15%	-	-	-
17WIND19	70	19	0	0	73034	-3.67	-2782	9	154 195	18%	15.8%	14.6	-	-
30BASE0	88	0	0	0	95909	+26.5	20092	29	118 251	0%	14.8%	-	-	-
30WIND19	88	19	0	0	93027	+22.7	17210	15	162 245	15%	15.3%	15.2	-	-
30SOLAR13	88	19	13	0	84991	+12.1	9174	12	245 245	21%	21%	-	61.8	-
30WIND24	88	24	0	0	92118	+21.5	16301	11	176 240	18%	16.8%	18.2	-	-
30SOLAR26	88	24	26	0	80965	+6.79	5148	-4	349 283	32%	33.7%	-	42.9	-
30STORE10	88	24	26	10	70153	-7.47	-5664	1	203 254	32%	21.4%	-	-	108

WIND GW PMAX
SOLAR GW PMAX
STORAGE GW AT 8 HRS
LOWEST NET GW DEMAND

notes:
All cases have 5150 MW nuclear. There are 3 wind areas and 3 solar areas.
All generation is from the 2017Sum1.raw dated June 20, 2014. Omit tie lines.
Reserve margin uses 56% of coastal, 12% of non coastal, and 100% of solar Pmax.
Hourly solar data is from https://www.solaranywhere.com/Public/SelectData.aspx
The system may not actually be operable for the extreme conditions modeled.
The purpose of the report is for illustration of the effectiveness of very high levels of wind and solar generation for displacing fossil fuel capacity.
Eugene Preston assumes no responsibility for any direct or indirect outcomes that might happen when others might try to apply the findings in this report.

- **Fossil Fuel Capacity Displaced by Renewables**
  - A Few Observations:
    - The reserve margin renewable multipliers will need to be updated frequently as renewables are added.
    - LOLE analysis will show renewables have lower capacity value than approximation formulas.
    - Solar plays an important role in displacing peaking generation; however, as more and more solar is added, the solar peaking capacity value diminishes.
    - The fossil fuel capacity reduction effectiveness of wind also diminishes as more wind is added.
    - To make deep MW reductions in fossil fuel capacity will require the same MW storage with at least 8 hours energy storage at that same MW capacity.