# Renewable Integration in Indiana Based on History

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# We have many years of renewable experience

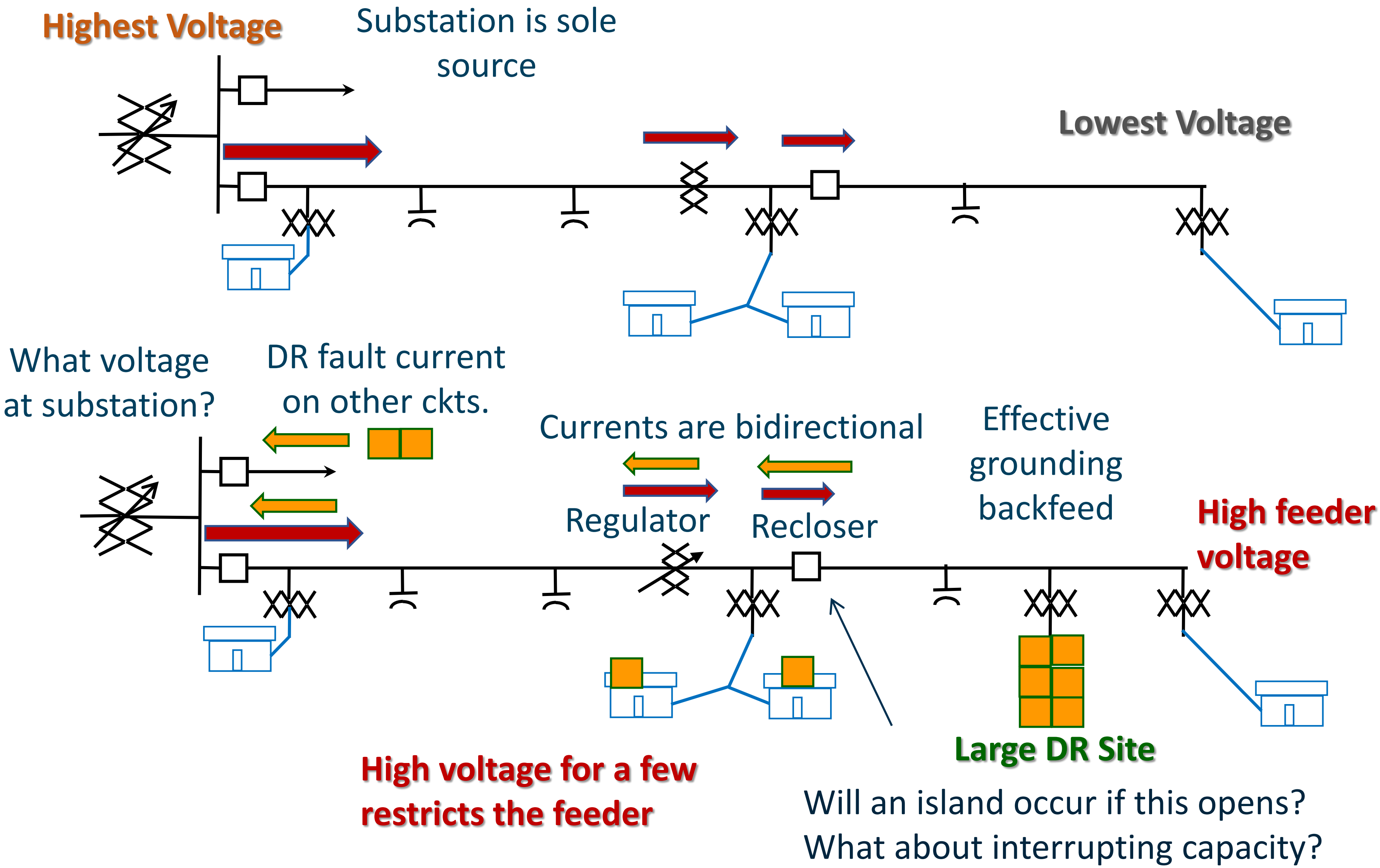
- Indianapolis was ***#2 in the nation in 2014*** according to the "Shining Cities" 2015 report

Table ES-2: The "Solar Stars" (Cities with 50 or More Watts of Solar PV per Person, End of 2014)

| City | State | Total Solar PV Installed (MW-DC) | Total Solar PV Rank | Per Capita Solar PV Installed (Watts-DC/Person) | Per Capita Rank |
|---|---|---|---|---|---|
| Honolulu | HI | 96 | 6 | 276 | 1 |
| Indianapolis | IN | 107 | 4 | 127 | 2 |
| San Jose | CA | 105 | 5 | 110 | 3 |
| San Diego | CA | 149 | 2 | 110 | 4 |
| Wilmington | DE | 7 | 28 | 101 | 5 |

- All on distribution, most is utility scale
- Also have many years of hourly wind data from MISO

# Distribution is much more complicated



# Distribution is much more complicated

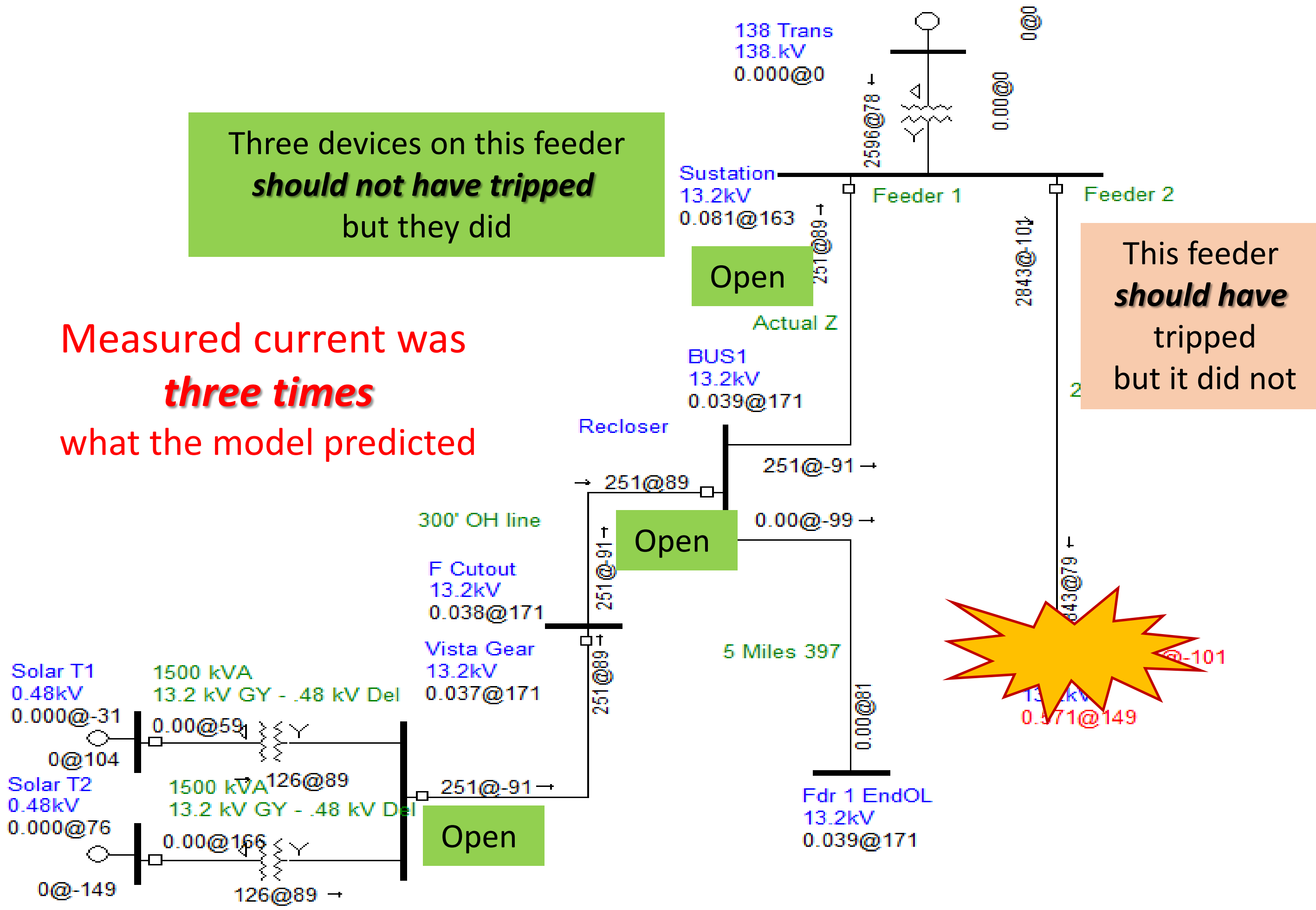
- High/low voltage concerns – tuning inverters will help
- Less certainty about peak load potential and future risks – more need for multi-year 8,760 hourly analysis
- Effective grounding concerns – what is best way?
- Higher short circuit currents may exceed interrupting rating
- Mutual coupling models on distribution
- Conservation Voltage Reduction verification is more difficult
- Smart inverter settings – coordinate local needs with MISO
- New rules allowing aggregation on distirbution
- How to figure out value of DR to distribution
- Prospect for marginal pricing
- What to do when feeder is “sold out”

# Three DG grounding options – there is no simple answer

- Ungrounded
  - Transient overvoltages at load rejection
  - No ground current back feed
  - Risk that phase to ground voltages become unstable
- Minimum effectively grounded
  - Now preferred by IPL and possibly IEEE 1547.8
  - Lower transient voltages
  - Some back feed current even when DG is not producing
  - Potential for overload of grounding equipment
- Strong effective grounding
  - Transient voltage fully controlled
  - Difficult coordinating protective devices and risk of false tripping
  - Short circuit current exceeds equipment rating
  - Highest risk of back feed even when no DG output

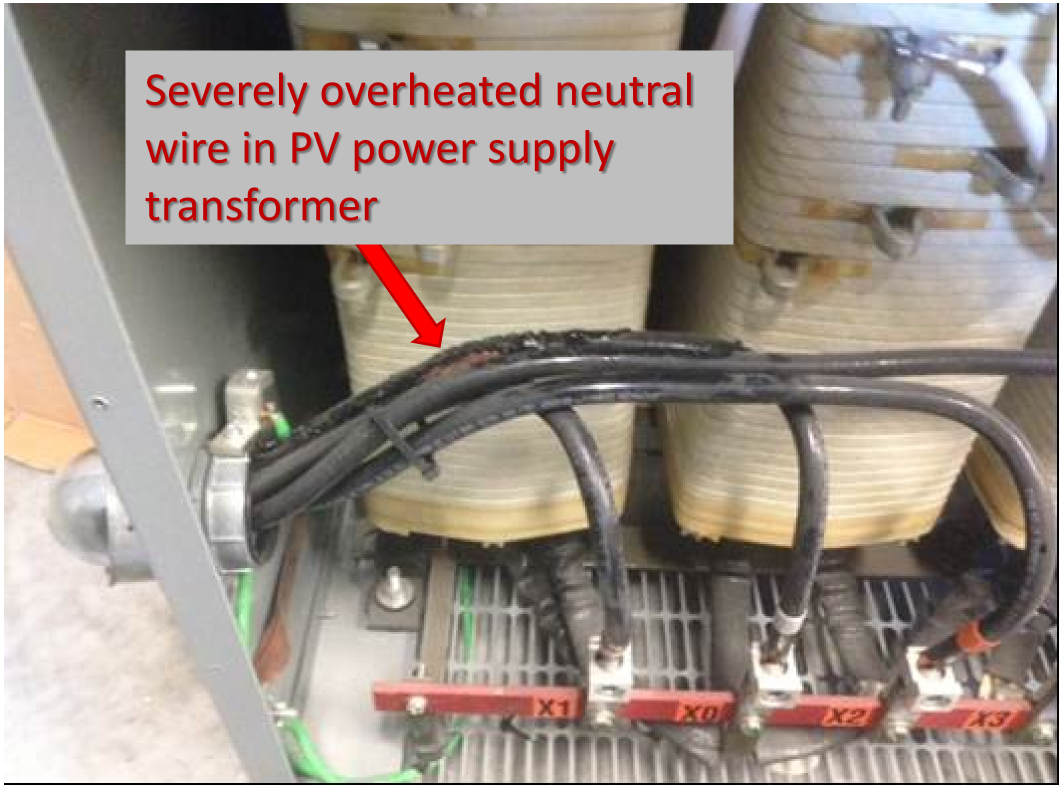
Note: IURC level 2 rules require acceptance if effectively grounded

# Strong effective grounding and mutual coupling caused the wrong circuit to trip



# Neutral overload and suspected back feed from effective grounding

- Two phases open on one 13 kV circuit
- One phase open on second 13 kV circuit with third phase in the clear
- Solar grounding likely back feed into other customers and possibly energized downed conductors in public area
- Neutral needs to be three times bigger than phase conductor
- Effective grounding needs to shut off in these situations

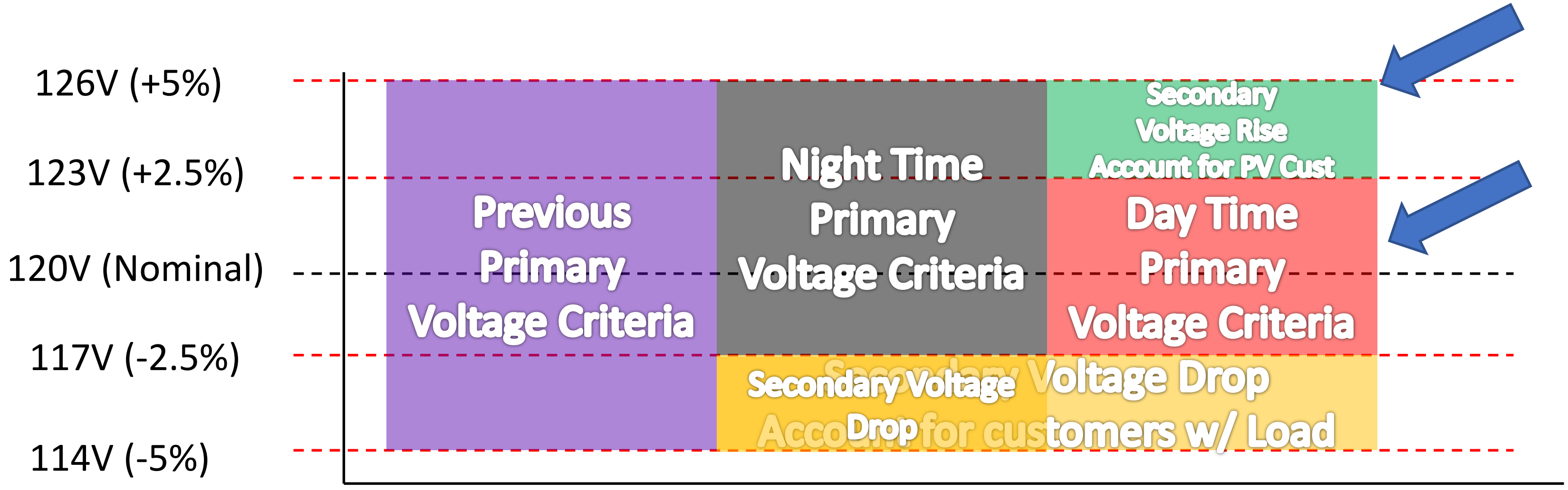


# Some hosting capacity criteria we considered in California – When to accept without detailed study

## Now commercial software will calculate

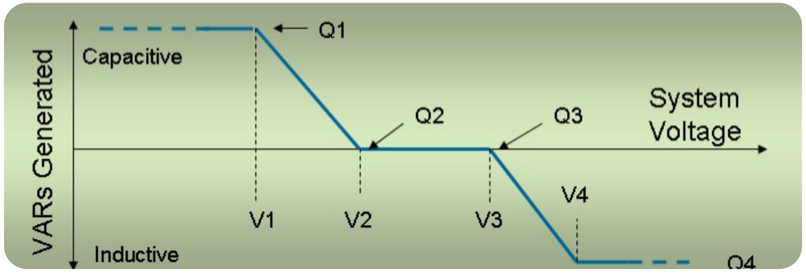
| Category | Criteria | Basis | Flag |
|---|---|---|---|
| Voltage | Overvoltage | Feeder voltage | ≥ 1.05 Vpu |
| | Voltage Deviation | Deviation in voltage from no PV to full PV | ≥ 3% at primary<br>≥ 5% at secondary<br>≥ ½ band at regulators |
| | Unbalance | Phase voltage deviation from average | ≥ 3% |
| Loading | Thermal | Element loading | ≥ 100% normal rating |
| Protection | Total Fault Contribution | Total fault current contribution at each sectionalizing device | ≥ 10% increase |
| | Forward Flow Fault Contribution | Forward flow fault current contribution at each sectionalizing device | ≥ 10% increase |
| | Sympathetic Breaker Tripping | Breaker zero sequence current due to an upstream fault | ≥ 150A |
| | Breaker Reduction of Reach | Deviation in breaker fault current for feeder faults | ≥ 10% decrease |
| | Breaker/Fuse Coordination | Fault current increase at fuse relative to breaker current increase | ≥ 100A increase |
| | Anti-Islanding | PV beyond each sectionalizing device | ≥ 50% minimum load |
| Power Quality | Individual Harmonics | Harmonic magnitude | ≥ 3% |
| | THDv | Total harmonic voltage distortion | ≥ 5% |
| Control | Regulator | Increased duty | > basecase+1 |
| | Capacitor | Increased duty | > basecase+1 |

# Hawaii Electric had to lower daytime voltage to accept more solar

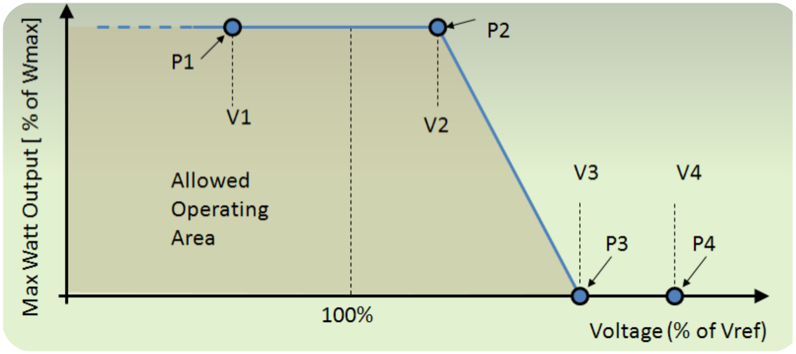



Smart inverters for providing grid support functions will help control voltage

Volt-var Control**



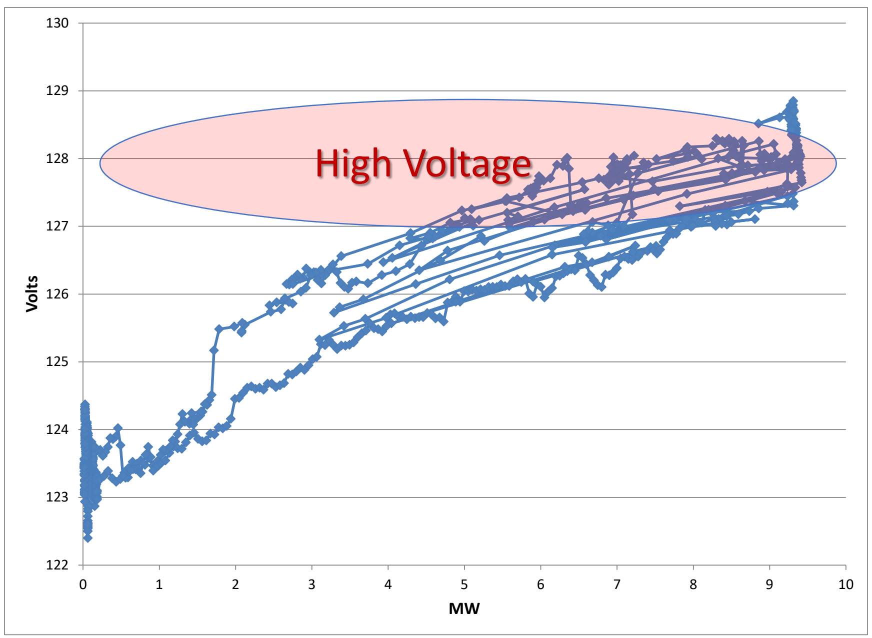

Volt-Watt Control**



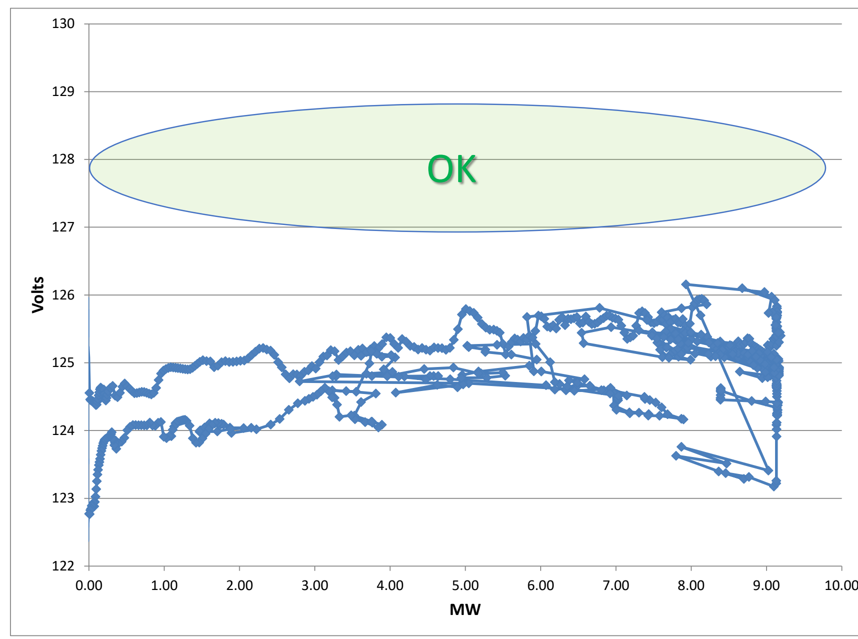
# Power factor tuning at some Indiana sites

## Had to "tune" power factor at large sites to prevent high voltage problems – also added auto shut off

Before Tuning




After tuning



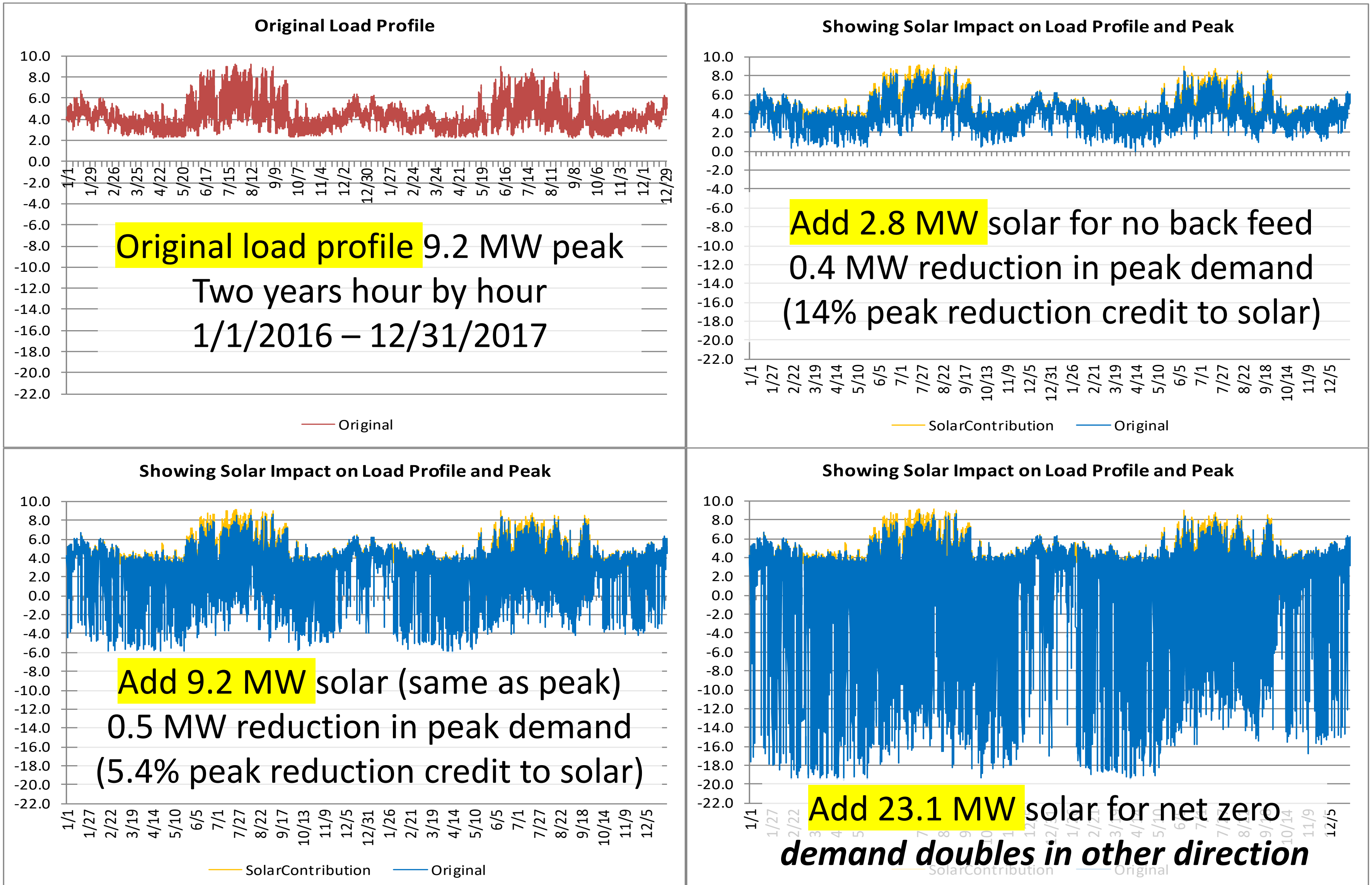
# Recent change in C84.1 for renewables

- C84.1 is the longstanding standard for voltage
  - All the way from the generator to the wall outlet
  - Nominal voltage
  - Maximum and minimum voltages
- IEEE 1547 may have introduced some confusion
  - Sets continuous overvoltage trip setting at 110%
  - C84.1 Range A is 105%
  - 1547 requires DR to keep Range A at point of common coupling but it is not clear how to do it.
- Challenged appliance and equipment suppliers to consider allowing higher voltage in C84.1
  - All opposed the change
  - Adding an annex suggesting *5% rise only in dedicated circuits*

# Why do *what would have happened* model

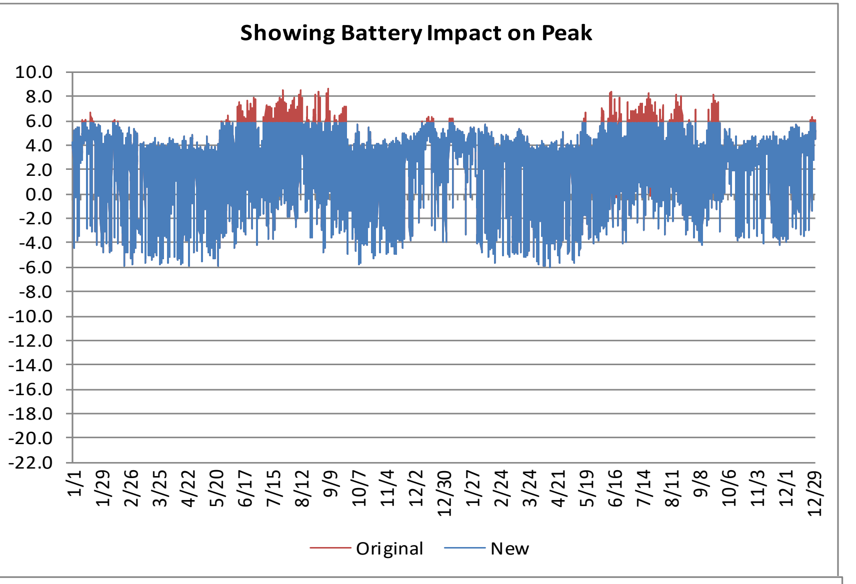
- Many years observing solar output and sending it to State Utilities Forecast Group
- Observed occasional coincident low output of intermittent resources (wind and solar)
- Concern that traditional peak load resource models were no longer adequate
- Needed a simplistic way to understand what could happen
  - Building tools in Excel workbooks so it is easily understood
  - Modeling what would have happened is easier to understand
  - Simulate different resource mixes based on known performance
  - Use what we learn to inform needs for future analysis
- One model for distribution and one for larger systems

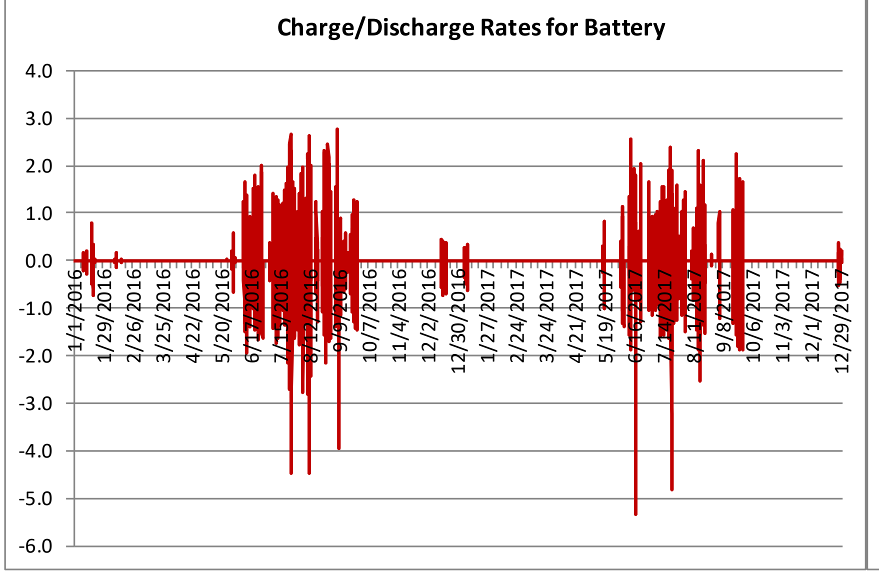
# Add solar to a summer peaking distribution circuit

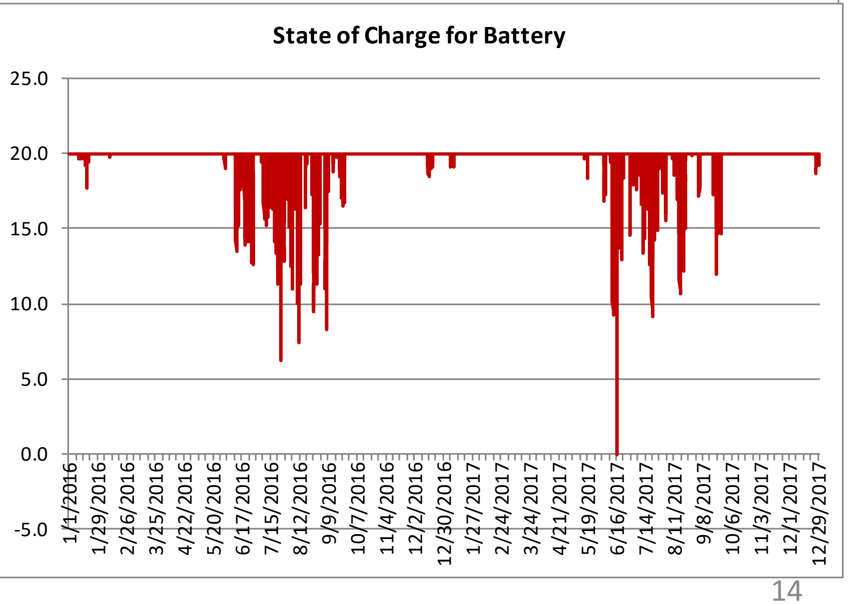


# Same circuit 9.2 MW solar & 20 MWh battery

- Try adding 20 MWh battery and 9.2 MW of solar for circuit with 9.2 MW demand
- Peak demand dropped to from 9.2 MW to 5.9 MW
- Use battery only for peak reduction (not daily smoothing)

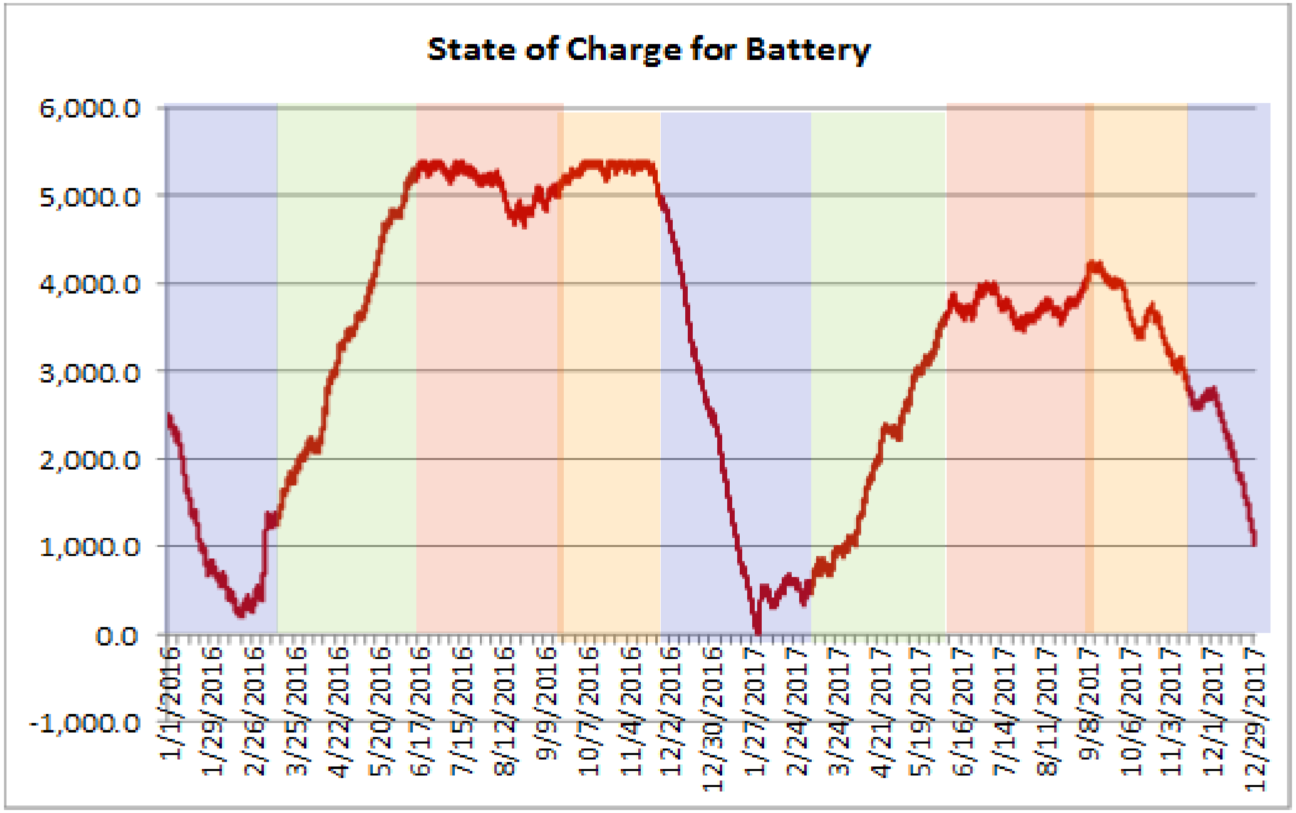


# Net zero or microgrid with only solar and battery

- 9.2 MW summer peaking circuit
- Needs 23 MW of solar and 5,380 MWh of battery (~400,000 Tesla PW II)
- Battery is best described as seasonal rather than daily or hourly



# User inputs to Excel workbook bulk model

- 5-year actual coincident history in ***per unit*** of rated capacity and of peak load
  - Load profile (using MISO Midwest in examples)
  - Wind production (using MISO wind performance)
  - Solar (using central Indiana in examples)
- Accepts any resource mix in MW and MWh
  - Dispatchable (typically fossil) assumes 100% credit
  - Wind – inputs rated MW and estimates MISO capacity credit
  - Solar – inputs rated MW and estimates MISO capacity credit
  - Battery MWh - charge/discharge rate assumes 4-hour with no round trip losses
- Always uses renewables and battery before dispatchable
- Review one example in detail – then three more side by side comparisons
- All examples use 1,000 MW peak load, and all graphs use the same scale for good visual comparison

# How the model works

| Avg Energy MWh | 4,637,767 | LF | 53% | Peak Load Input | Solar | Wind | Battery (4 Hr Dur) | Fossil | Total Annual Fixed Charges at 15% LFCR | Avg Annual Energy Cost | Total Capacity, Ope | Capital Inve |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg Fossil MWh | 2,988,726 | LF | 42% | 1,000 | 400 | 400 | 100 | 815 | | | 1,715 | Installed M |
| Avg Renewable MWh | 1,649,041 | LF | 24% | Cost / kW or kWh | $ 1,000 | $ 1,400 | $ 200 | $ 1,100 | $ 281 | $ 159.40 | 1,103 | Credit MW |
| Avg Renew Curtail MWh | 3,651 | PCT Ren | 36% | Capital $M | $ 400 | $ 560 | $ 20 | $ 897 | Average cost per kWh | | 10% | Reserves |
| Battery discharge rate | 25% | 25 | MWh | Energy /$ MWh | $ - | $ - | $ - | $ 32.00 | $ 0.0951 | per kWh | $ 441 | M$ Annual |
| | | | | ~ MISO Capacity | 200 | 63 | 25 | 815 | 1,103 | Total MISO | $ 1,877 | M$ Total C |

| Date /Time EST Hour Ending | Load PU of Peak | Wind PU of Rated | Solar PU of Rated | Model Load | Model Solar Available | Model Wind Available | Wind and Solar Excess | Stored Amount | Battery Contribution | Fossil Dispatch | Total Resource | Excess / Shortage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/22/15 10:00 | 0.536 | 0.542 | 0.086 | 536 | 34 | 217 | -284 | 0 | 0 | 284 | 536 | 0 |
| 3/22/15 11:00 | 0.535 | 0.573 | 0.366 | 535 | 146 | 229 | -159 | 0 | 0 | 159 | 535 | 0 |
| 3/22/15 12:00 | 0.531 | 0.568 | 0.712 | 531 | 285 | 227 | -19 | 0 | 0 | 19 | 531 | 0 |
| 3/22/15 13:00 | 0.525 | 0.549 | 0.906 | 525 | 362 | 219 | 57 | 25 | -25 | 0 | 557 | 32 |
| 3/22/15 14:00 | 0.517 | 0.566 | 0.947 | 517 | 379 | 226 | 89 | 50 | -25 | 0 | 580 | 64 |
| 3/22/15 15:00 | 0.512 | 0.554 | 0.949 | 512 | 380 | 222 | 90 | 75 | -25 | 0 | 576 | 65 |
| 3/22/15 16:00 | 0.511 | 0.527 | 0.978 | 511 | 391 | 211 | 91 | 100 | -25 | 0 | 577 | 66 |
| 3/22/15 17:00 | 0.517 | 0.528 | 0.964 | 517 | 386 | 211 | 80 | 100 | 0 | 0 | 597 | 80 |
| 3/22/15 18:00 | 0.525 | 0.516 | 0.819 | 525 | 328 | 207 | 9 | 100 | 0 | 0 | 534 | 9 |
| 3/22/15 19:00 | 0.538 | 0.520 | 0.457 | 538 | 183 | 208 | -147 | 75 | 25 | 122 | 538 | 0 |
| 3/22/15 20:00 | 0.572 | 0.545 | 0.277 | 572 | 111 | 218 | -243 | 50 | 25 | 218 | 572 | 0 |
| 3/22/15 21:00 | 0.572 | 0.586 | 0.055 | 572 | 22 | 234 | -315 | 25 | 25 | 290 | 572 | 0 |
| 3/22/15 22:00 | 0.553 | 0.609 | 0.000 | 553 | 0 | 244 | -310 | 0 | 25 | 285 | 553 | 0 |
| 3/22/15 23:00 | 0.527 | 0.587 | -0.002 | 527 | -1 | 235 | -293 | 0 | 0 | 293 | 527 | 0 |
| 3/23/15 0:00 | 0.507 | 0.556 | -0.002 | 507 | -1 | 222 | -285 | 0 | 0 | 285 | 507 | 0 |

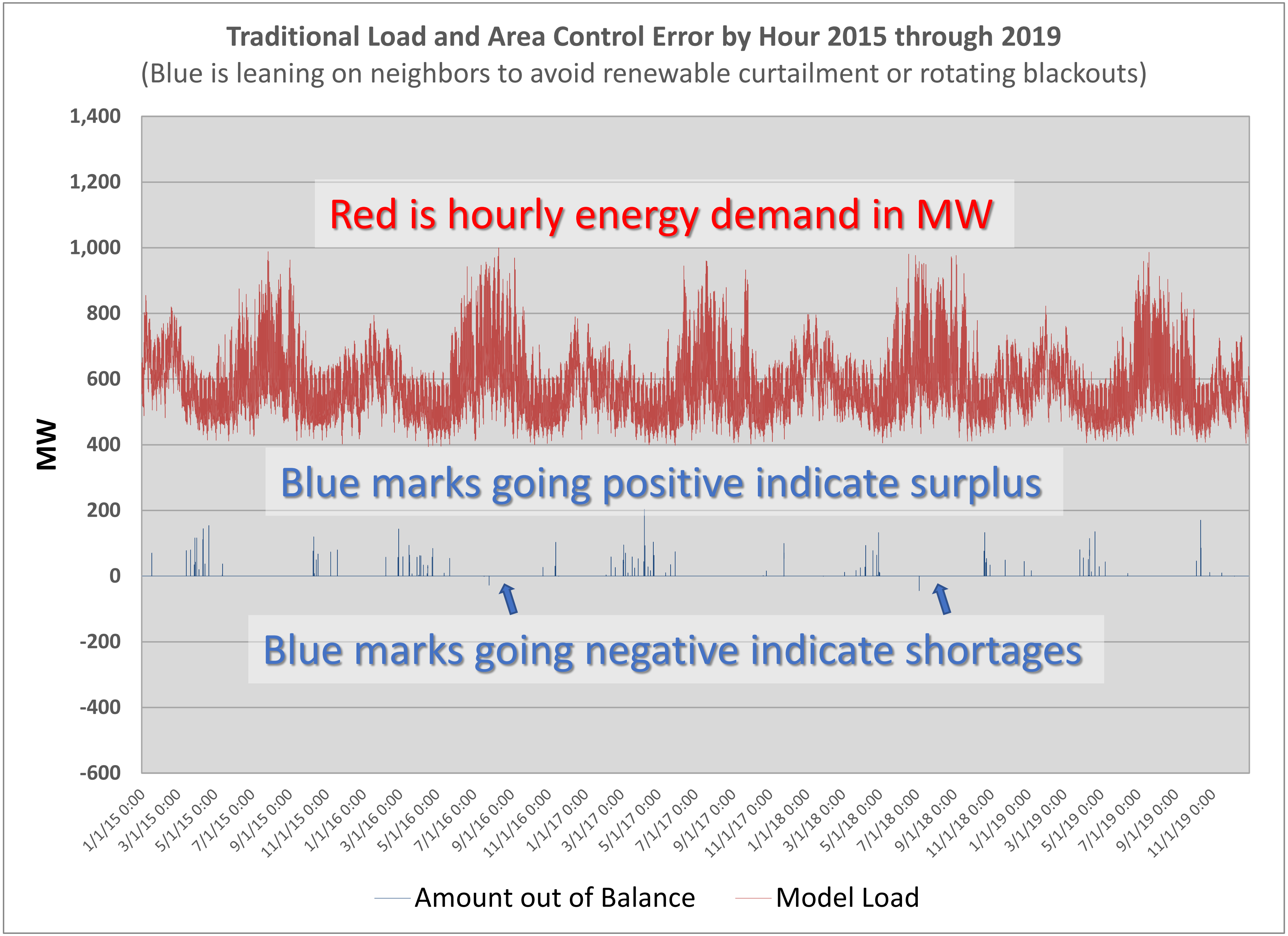
Per Unit Values
System Peak
Renewable
Nameplate

Calculated Load
and Renewable
Output

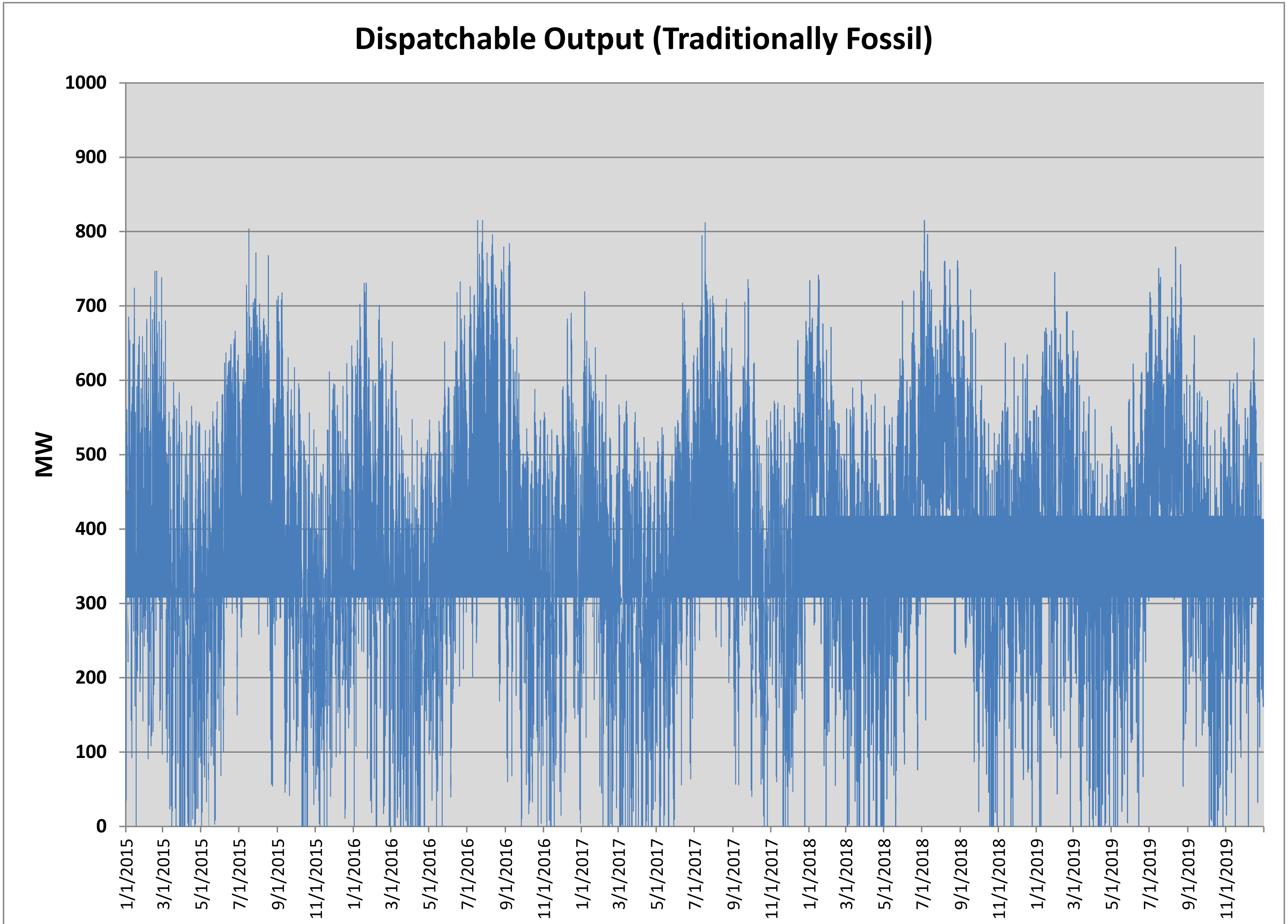
Resource & Battery Dispatch
Uses Fossil as Last Resort

# Sample detail outputs follow

- Use inputs from the previous slide
- Outputs are as large as possible (No slide headings)
- Output slides to follow in order
    - Traditional load and control area error shows hourly load profile and how much one entity will be leaning on neighbors
    - Output from dispatchable resources
    - Hourly percent of customers possibly without power if no external resources are available
    - Average number of days of shortage per year by month and hour of day
    - Coincident output of wind and solar for 5 years
    - Battery state of charge



Traditional Load and Area Control Error by Hour 2015 through 2019
(Blue is leaning on neighbors to avoid renewable curtailment or rotating blackouts)
Red is hourly energy demand in MW
Blue marks going positive indicate surplus
Blue marks going negative indicate shortages
MW
1,400
1,200
1,000
800
600
400
200
0
-200
-400
-600
1/1/15 0:00
3/1/15 0:00
5/1/15 0:00
7/1/15 0:00
9/1/15 0:00
11/1/15 0:00
1/1/16 0:00
3/1/16 0:00
5/1/16 0:00
7/1/16 0:00
9/1/16 0:00
11/1/16 0:00
1/1/17 0:00
3/1/17 0:00
5/1/17 0:00
7/1/17 0:00
9/1/17 0:00
11/1/17 0:00
1/1/18 0:00
3/1/18 0:00
5/1/18 0:00
7/1/18 0:00
9/1/18 0:00
11/1/18 0:00
1/1/19 0:00
3/1/19 0:00
5/1/19 0:00
7/1/19 0:00
9/1/19 0:00
11/1/19 0:00
Amount out of Balance
Model Load



Dispatchable Output (Traditionally Fossil)
MW
1000
900
800
700
600
500
400
300
200
100
0
1/1/2015
3/1/2015
5/1/2015
7/1/2015
9/1/2015
11/1/2015
1/1/2016
3/1/2016
5/1/2016
7/1/2016
9/1/2016
11/1/2016
1/1/2017
3/1/2017
5/1/2017
7/1/2017
9/1/2017
11/1/2017
1/1/2018
3/1/2018
5/1/2018
7/1/2018
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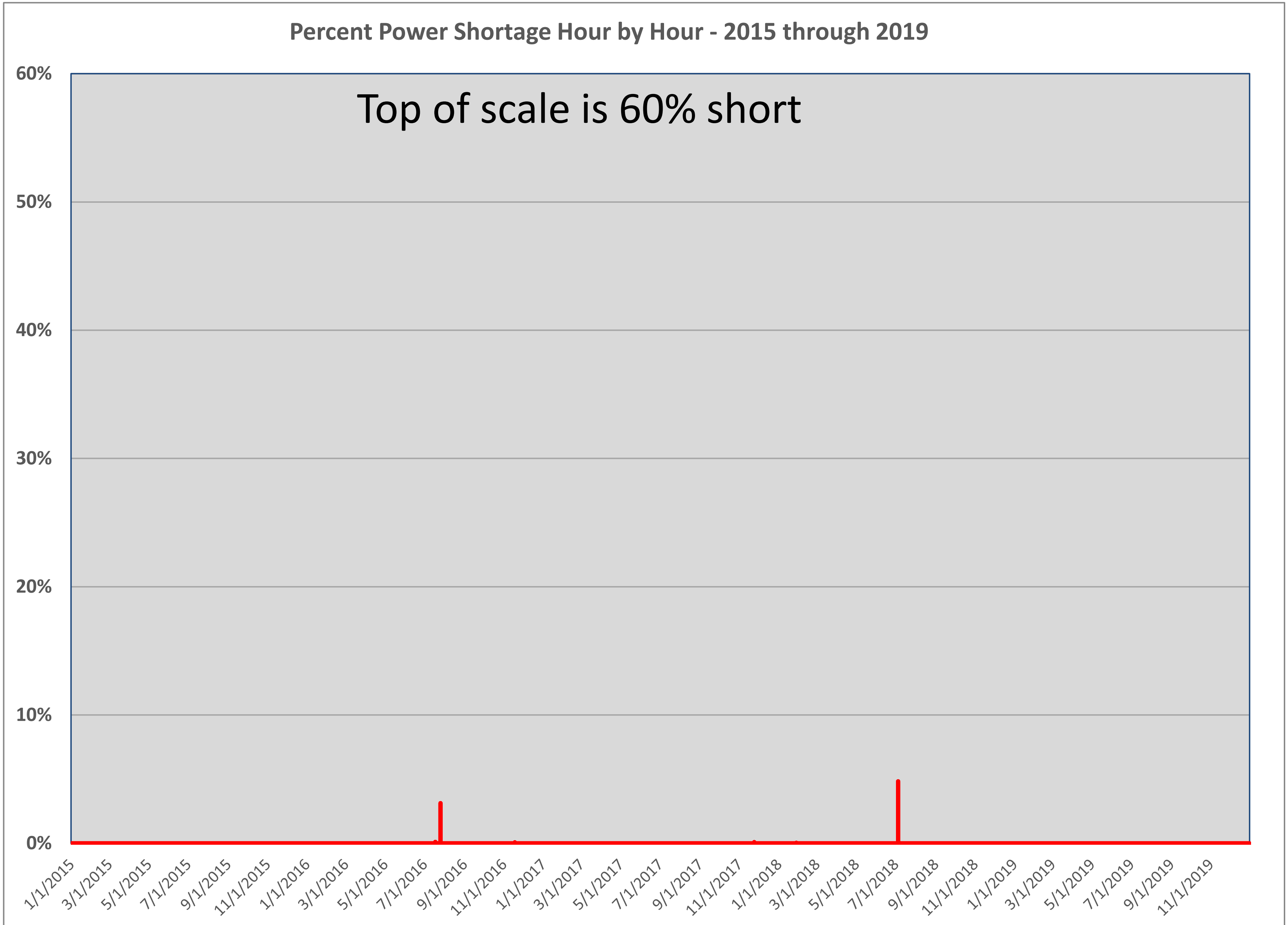
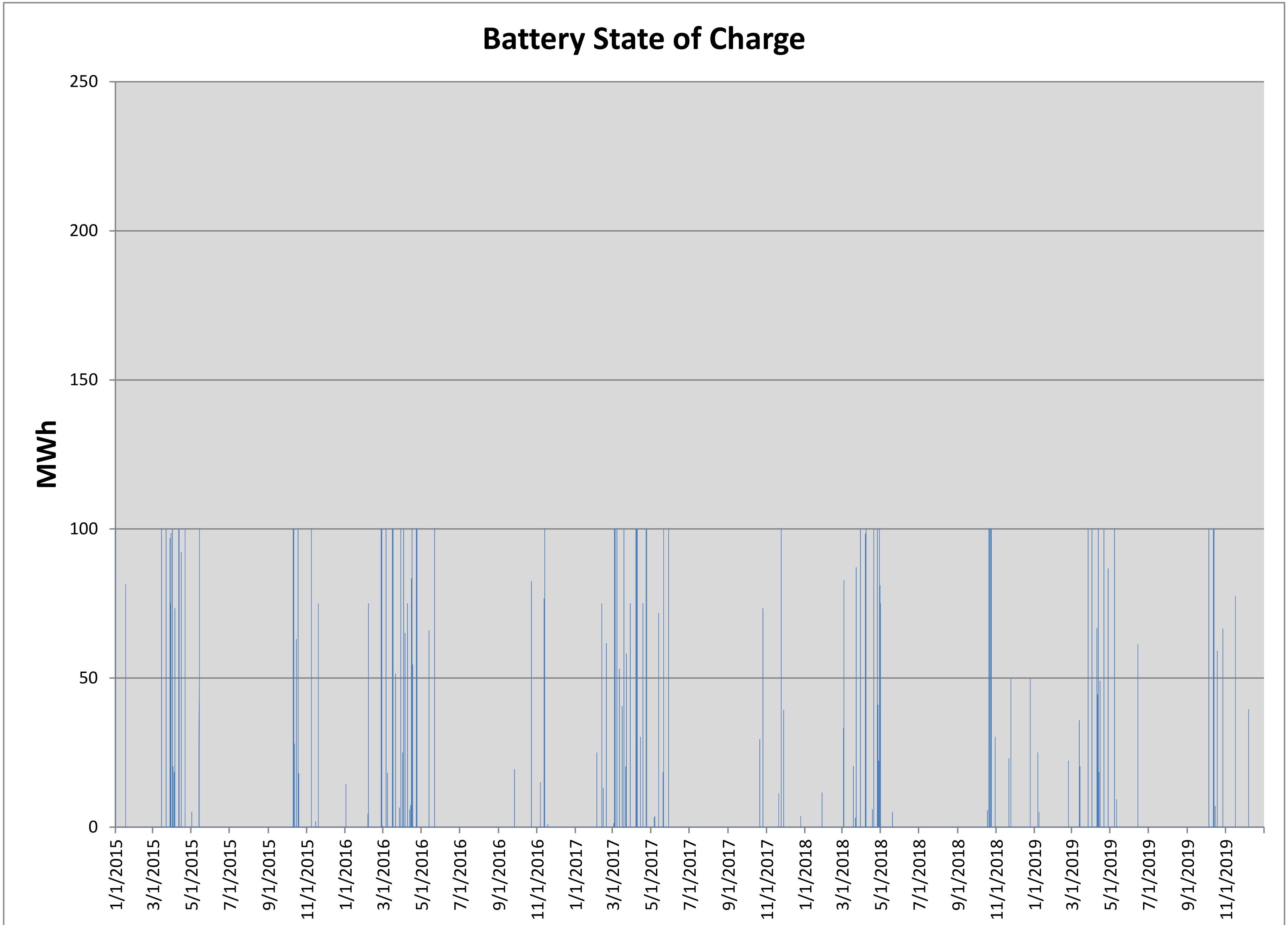
7/1/2019
9/1/2019
11/1/2019


Percent Power Shortage Hour by Hour - 2015 through 2019
Top of scale is 60% short
60%
50%
40%
30%
20%
10%
0%
1/1/2015
3/1/2015
5/1/2015
7/1/2015
9/1/2015
11/1/2015
1/1/2016
3/1/2016
5/1/2016
7/1/2016
9/1/2016
11/1/2016
1/1/2017
3/1/2017
5/1/2017
7/1/2017
9/1/2017
11/1/2017
1/1/2018
3/1/2018
5/1/2018
7/1/2018
9/1/2018
11/1/2018
1/1/2019
3/1/2019
5/1/2019
7/1/2019
9/1/2019
11/1/2019

| Days Short per Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour Ending | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 20 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 21 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 22 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 23 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 24 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |



Battery State of Charge
MWh
250
200
150
100
50
0
1/1/2015
3/1/2015
5/1/2015
7/1/2015
9/1/2015
11/1/2015
1/1/2016
3/1/2016
5/1/2016
7/1/2016
9/1/2016
11/1/2016
1/1/2017
3/1/2017
5/1/2017
7/1/2017
9/1/2017
11/1/2017
1/1/2018
3/1/2018
5/1/2018
7/1/2018
9/1/2018
11/1/2018
1/1/2019
3/1/2019
5/1/2019
7/1/2019
9/1/2019
11/1/2019

# Run four scenarios to illustrate differences

## Scenario 1

*This is previous example*

| | |
|---|---|
| Solar | 400 |
| Wind | 400 |
| Battery | 100 |
| Dispatchable | 815 |
| Total Nameplate | 1,715 |

## Scenario 2

| | |
|---|---|
| Solar | 1,000 |
| Wind | 1,000 |
| Battery | 200 |
| Dispatchable | 500 |
| Total Nameplate | 2,700 |

## Scenario 3

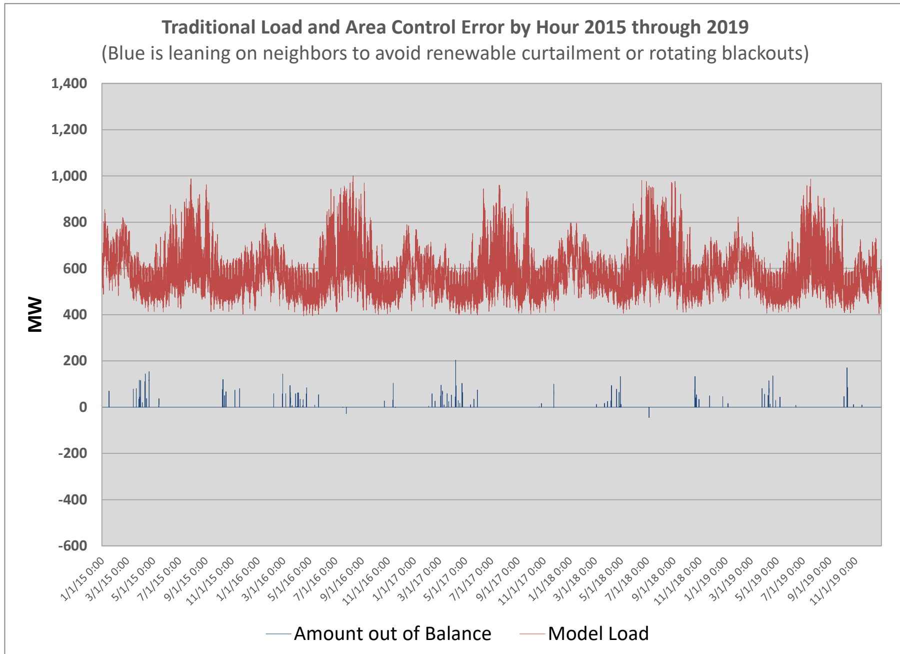
| | |
|---|---|
| Solar | 1,008 |
| Wind | 319 |
| Battery | 106 |
| Dispatchable | 761 |
| Total Nameplate | 2,195 |

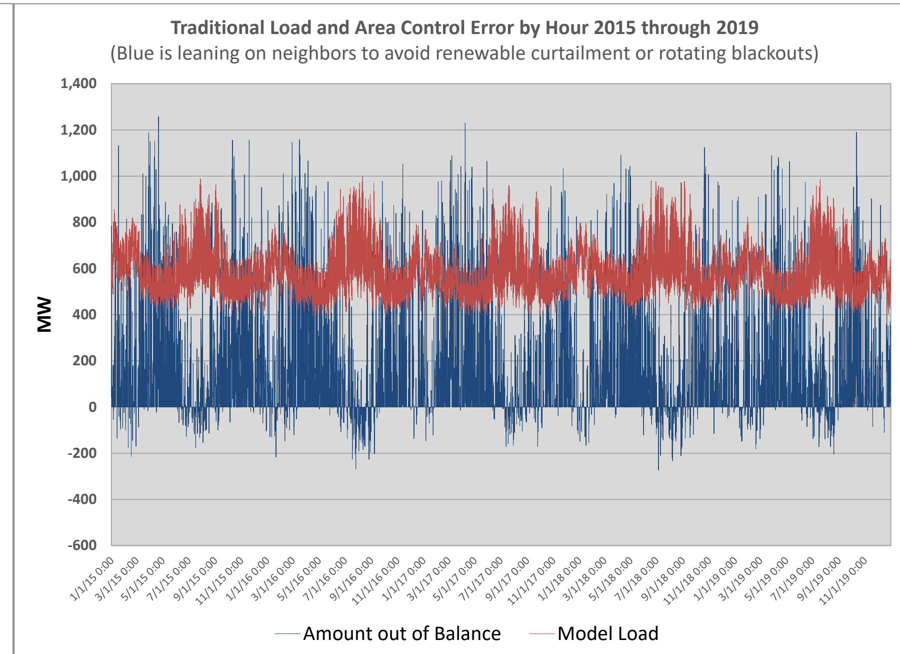
## Scenario 4

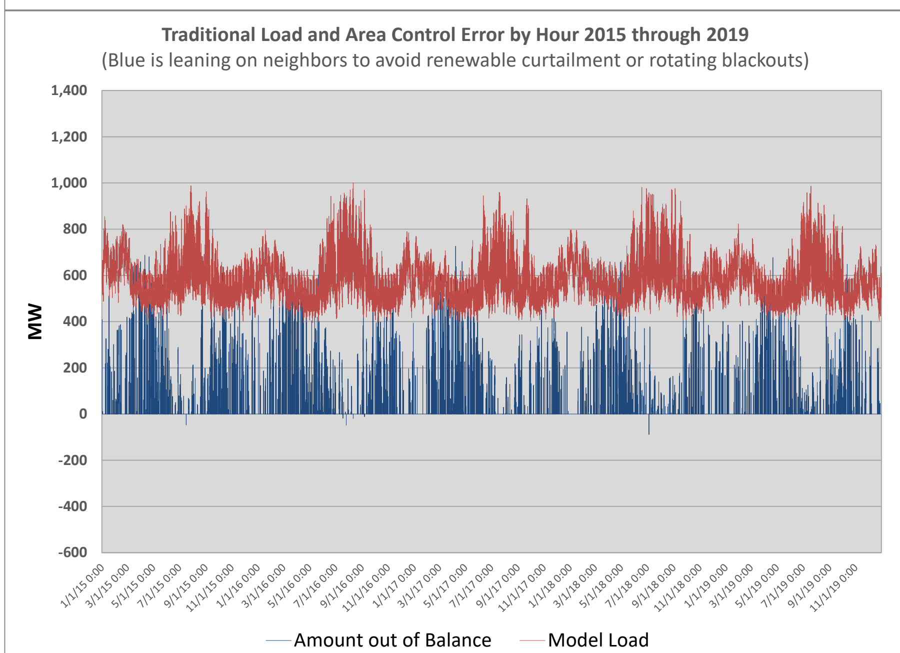
| | |
|---|---|
| Solar | 1,303 |
| Wind | 567 |
| Battery | 170 |
| Dispatchable | 320 |
| Total Nameplate | 2,360 |

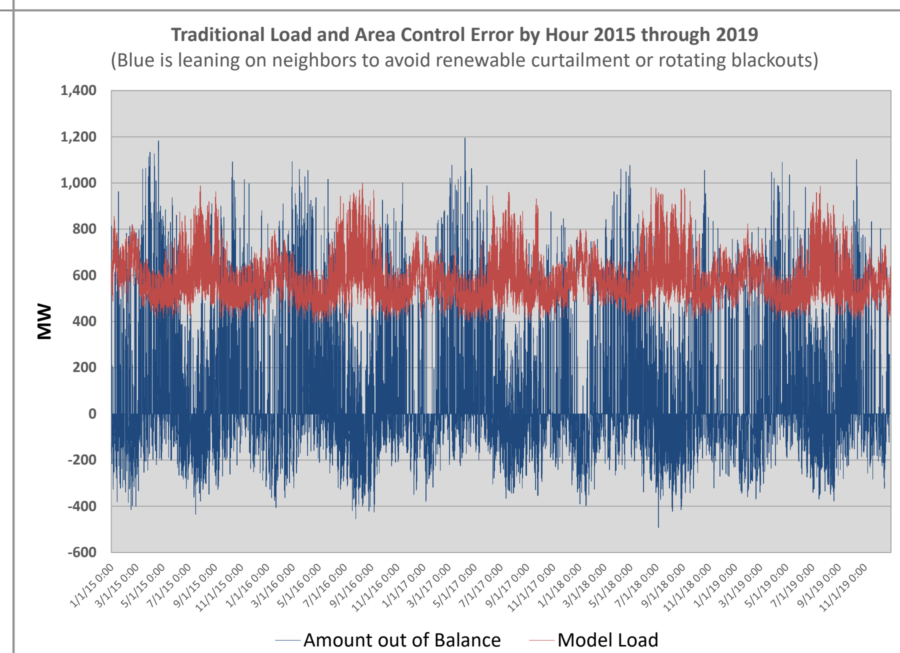
All scenarios serve the same load profile with 1,000 MW peak

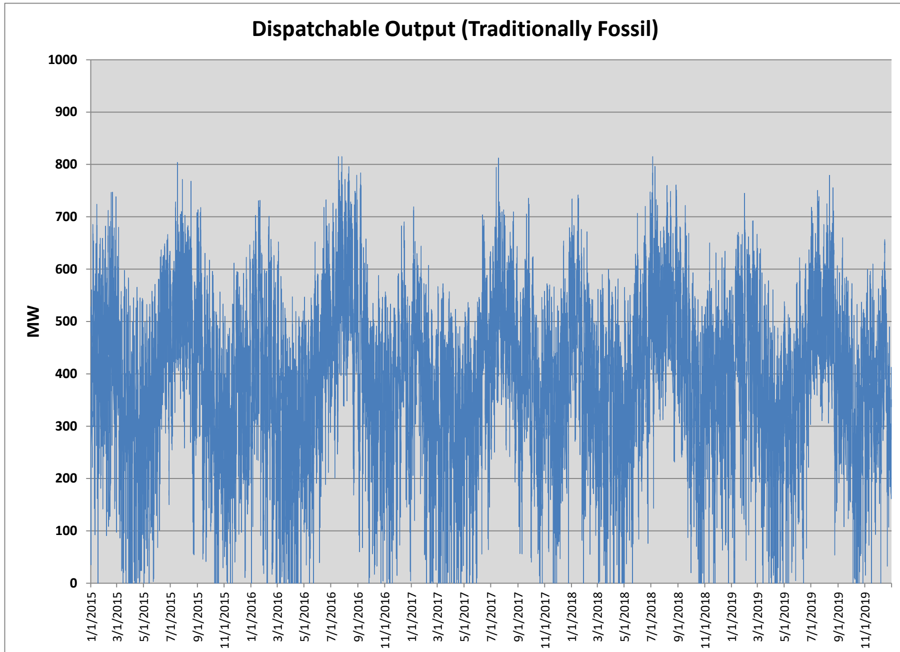
Results will be in the same quadrants as the inputs on slides

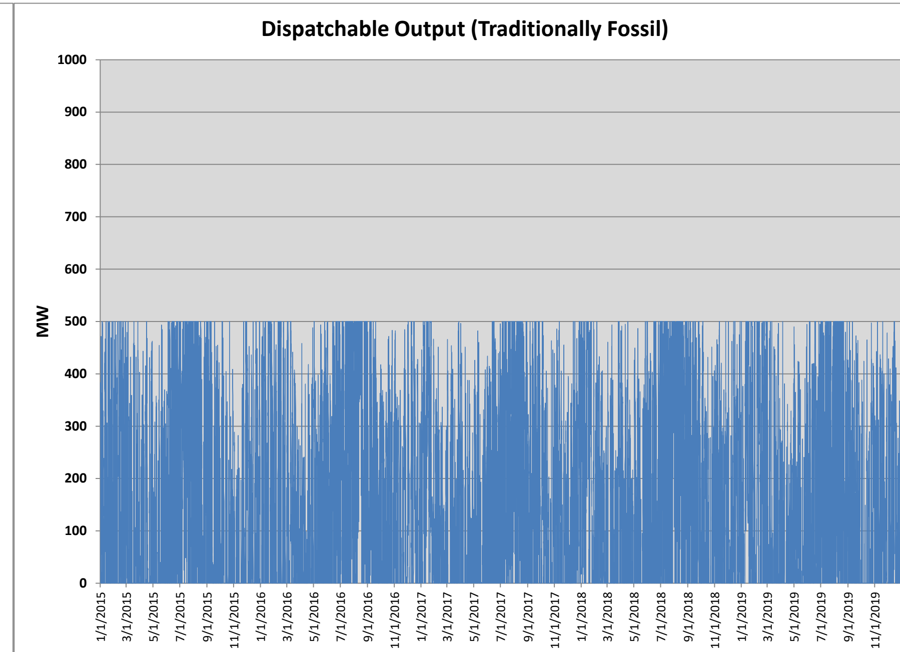

Traditional Load and Area Control Error by Hour 2015 through 2019
(Blue is leaning on neighbors to avoid renewable curtailment or rotating blackouts)
MW
1,400
1,200
1,000
800
600
400
200
0
-200
-400
-600
1/1/15 0:00
3/1/15 0:00
5/1/15 0:00
7/1/15 0:00
9/1/15 0:00
11/1/15 0:00
1/1/16 0:00
3/1/16 0:00
5/1/16 0:00
7/1/16 0:00
9/1/16 0:00
11/1/16 0:00
1/1/17 0:00
3/1/17 0:00
5/1/17 0:00
7/1/17 0:00
9/1/17 0:00
11/1/17 0:00
1/1/18 0:00
3/1/18 0:00
5/1/18 0:00
7/1/18 0:00
9/1/18 0:00
11/1/18 0:00
1/1/19 0:00
3/1/19 0:00
5/1/19 0:00
7/1/19 0:00
9/1/19 0:00
11/1/19 0:00
Amount out of Balance
Model Load

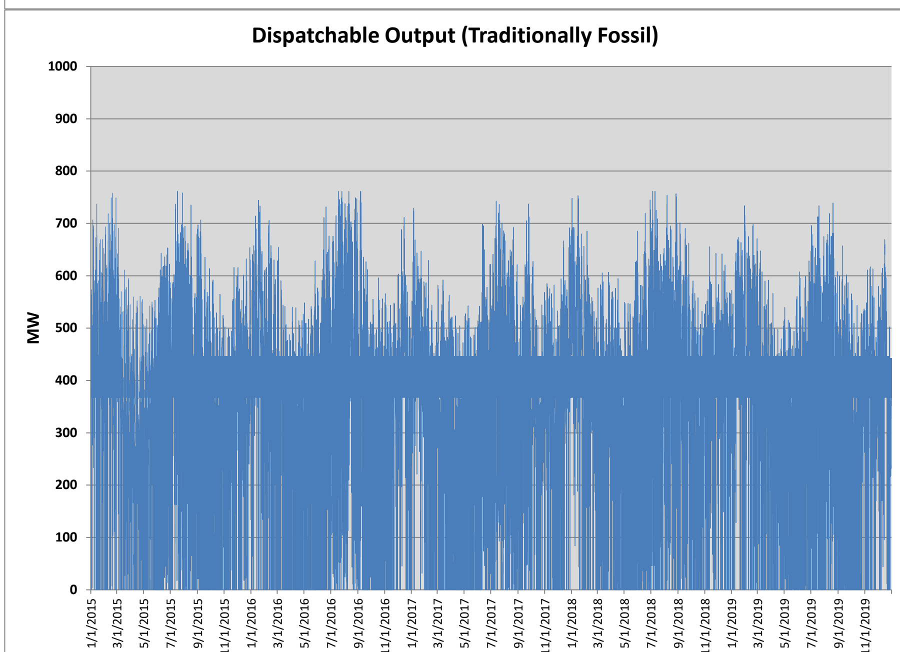

Traditional Load and Area Control Error by Hour 2015 through 2019
(Blue is leaning on neighbors to avoid renewable curtailment or rotating blackouts)
MW
1,400
1,200
1,000
800
600
400
200
0
-200
-400
-600
1/1/15 0:00
3/1/15 0:00
5/1/15 0:00
7/1/15 0:00
9/1/15 0:00
11/1/15 0:00
1/1/16 0:00
3/1/16 0:00
5/1/16 0:00
7/1/16 0:00
9/1/16 0:00
11/1/16 0:00
1/1/17 0:00
3/1/17 0:00
5/1/17 0:00
7/1/17 0:00
9/1/17 0:00
11/1/17 0:00
1/1/18 0:00
3/1/18 0:00
5/1/18 0:00
7/1/18 0:00
9/1/18 0:00
11/1/18 0:00
1/1/19 0:00
3/1/19 0:00
5/1/19 0:00
7/1/19 0:00
9/1/19 0:00
11/1/19 0:00
Amount out of Balance
Model Load

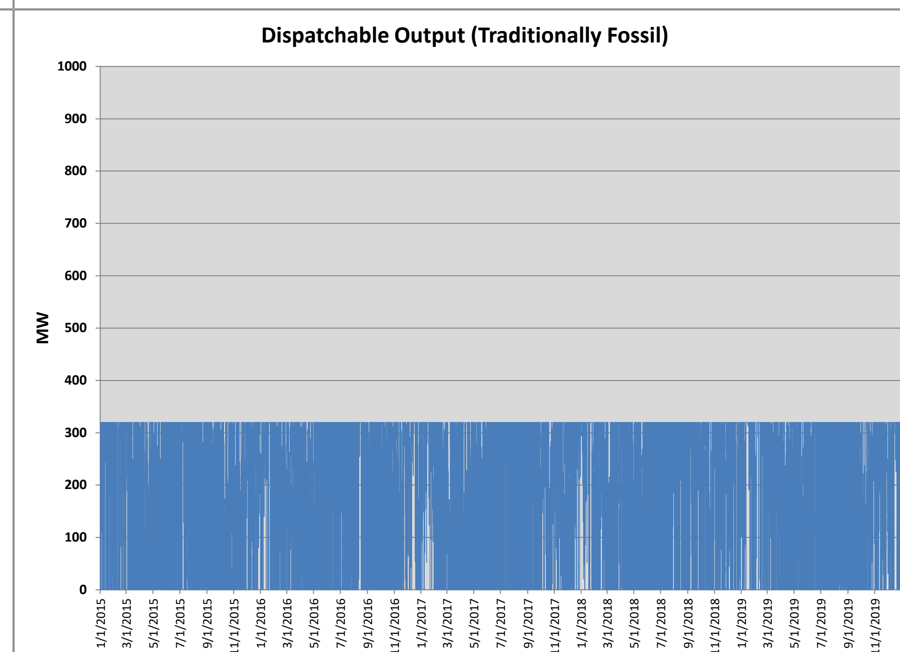

Traditional Load and Area Control Error by Hour 2015 through 2019
(Blue is leaning on neighbors to avoid renewable curtailment or rotating blackouts)
MW
1,400
1,200
1,000
800
600
400
200
0
-200
-400
-600
1/1/15 0:00
3/1/15 0:00
5/1/15 0:00
7/1/15 0:00
9/1/15 0:00
11/1/15 0:00
1/1/16 0:00
3/1/16 0:00
5/1/16 0:00
7/1/16 0:00
9/1/16 0:00
11/1/16 0:00
1/1/17 0:00
3/1/17 0:00
5/1/17 0:00
7/1/17 0:00
9/1/17 0:00
11/1/17 0:00
1/1/18 0:00
3/1/18 0:00
5/1/18 0:00
7/1/18 0:00
9/1/18 0:00
11/1/18 0:00
1/1/19 0:00
3/1/19 0:00
5/1/19 0:00
7/1/19 0:00
9/1/19 0:00
11/1/19 0:00
Amount out of Balance
Model Load

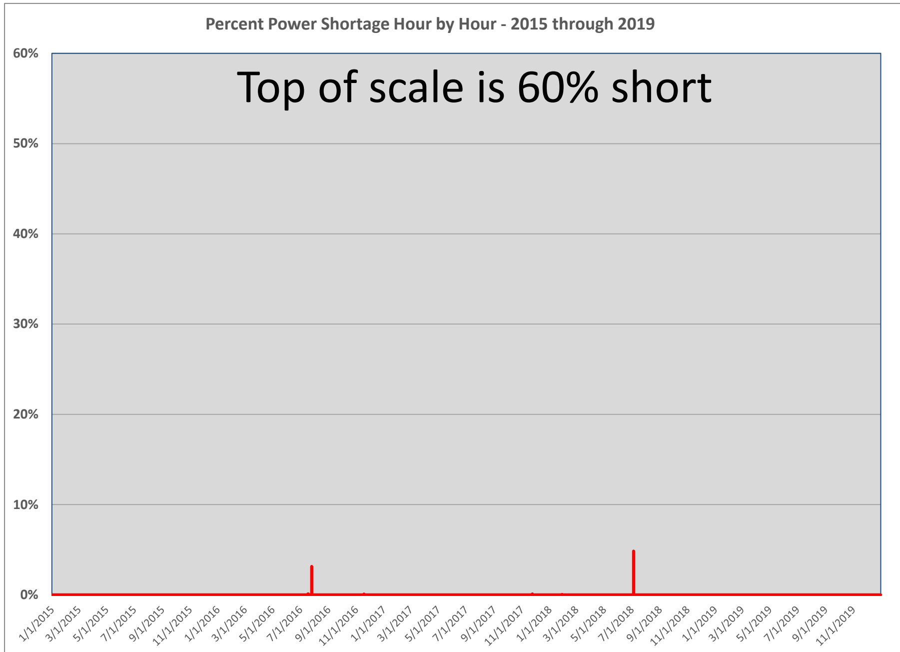

Traditional Load and Area Control Error by Hour 2015 through 2019
(Blue is leaning on neighbors to avoid renewable curtailment or rotating blackouts)
MW
1,400
1,200
1,000
800
600
400
200
0
-200
-400
-600
1/1/15 0:00
3/1/15 0:00
5/1/15 0:00
7/1/15 0:00
9/1/15 0:00
11/1/15 0:00
1/1/16 0:00
3/1/16 0:00
5/1/16 0:00
7/1/16 0:00
9/1/16 0:00
11/1/16 0:00
1/1/17 0:00
3/1/17 0:00
5/1/17 0:00
7/1/17 0:00
9/1/17 0:00
11/1/17 0:00
1/1/18 0:00
3/1/18 0:00
5/1/18 0:00
7/1/18 0:00
9/1/18 0:00
11/1/18 0:00
1/1/19 0:00
3/1/19 0:00
5/1/19 0:00
7/1/19 0:00
9/1/19 0:00
11/1/19 0:00
Amount out of Balance
Model Load

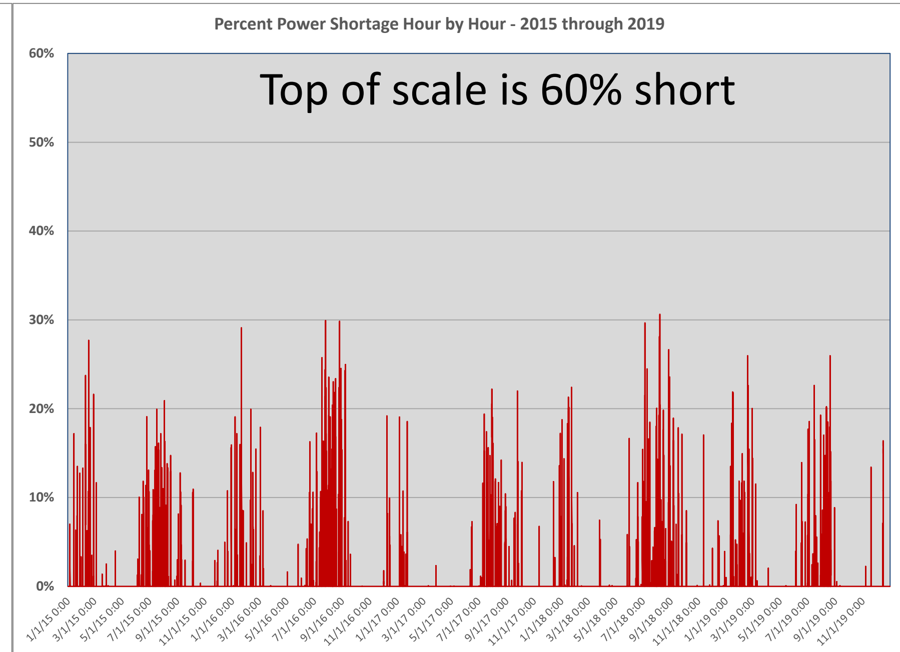

Dispatchable Output (Traditionally Fossil)
MW
1000
900
800
700
600
500
400
300
200
100
0
1/1/2015 3/1/2015 5/1/2015 7/1/2015 9/1/2015 11/1/2015 1/1/2016 3/1/2016 5/1/2016 7/1/2016 9/1/2016 11/1/2016 1/1/2017 3/1/2017 5/1/2017 7/1/2017 9/1/2017 11/1/2017 1/1/2018 3/1/2018 5/1/2018 7/1/2018 9/1/2018 11/1/2018 1/1/2019 3/1/2019 5/1/2019 7/1/2019 9/1/2019 11/1/2019

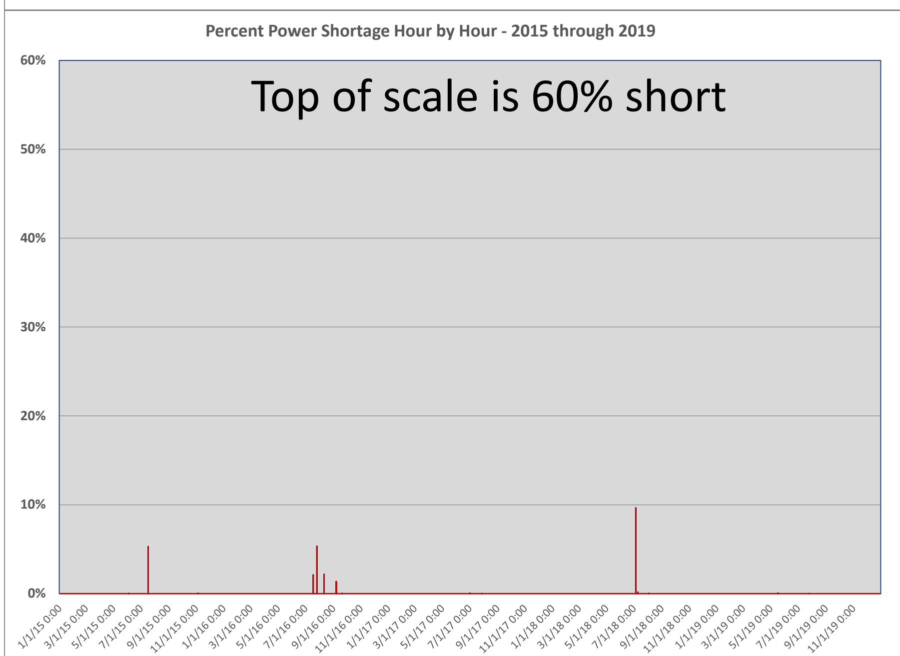

Dispatchable Output (Traditionally Fossil)
MW
1000
900
800
700
600
500
400
300
200
100
0
1/1/2015 3/1/2015 5/1/2015 7/1/2015 9/1/2015 11/1/2015 1/1/2016 3/1/2016 5/1/2016 7/1/2016 9/1/2016 11/1/2016 1/1/2017 3/1/2017 5/1/2017 7/1/2017 9/1/2017 11/1/2017 1/1/2018 3/1/2018 5/1/2018 7/1/2018 9/1/2018 11/1/2018 1/1/2019 3/1/2019 5/1/2019 7/1/2019 9/1/2019 11/1/2019

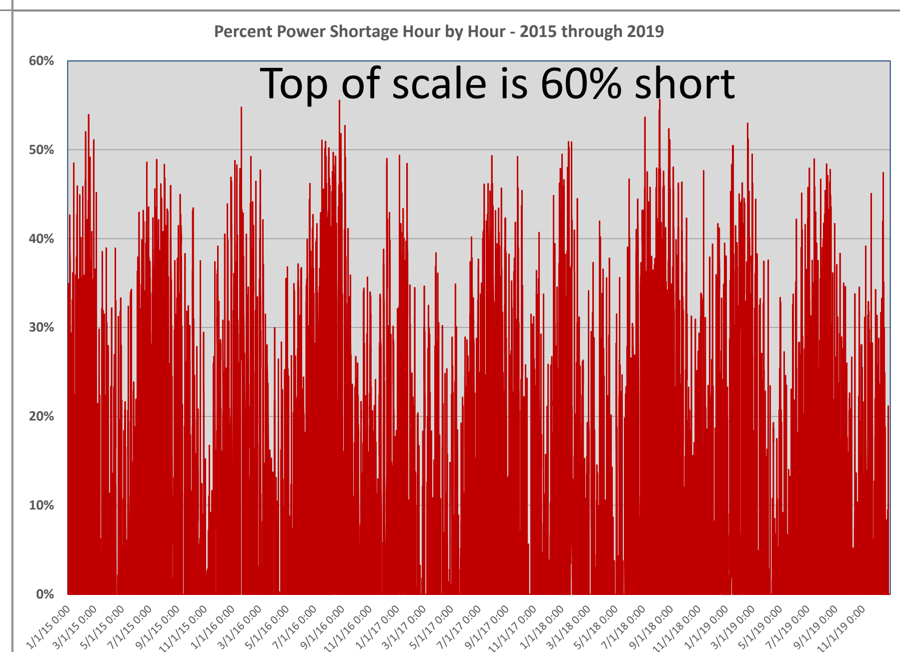

Dispatchable Output (Traditionally Fossil)
MW
1000
900
800
700
600
500
400
300
200
100
0
1/1/2015 3/1/2015 5/1/2015 7/1/2015 9/1/2015 11/1/2015 1/1/2016 3/1/2016 5/1/2016 7/1/2016 9/1/2016 11/1/2016 1/1/2017 3/1/2017 5/1/2017 7/1/2017 9/1/2017 11/1/2017 1/1/2018 3/1/2018 5/1/2018 7/1/2018 9/1/2018 11/1/2018 1/1/2019 3/1/2019 5/1/2019 7/1/2019 9/1/2019 11/1/2019


Dispatchable Output (Traditionally Fossil)
MW
1000
900
800
700
600
500
400
300
200
100
0
1/1/2015 3/1/2015 5/1/2015 7/1/2015 9/1/2015 11/1/2015 1/1/2016 3/1/2016 5/1/2016 7/1/2016 9/1/2016 11/1/2016 1/1/2017 3/1/2017 5/1/2017 7/1/2017 9/1/2017 11/1/2017 1/1/2018 3/1/2018 5/1/2018 7/1/2018 9/1/2018 11/1/2018 1/1/2019 3/1/2019 5/1/2019 7/1/2019 9/1/2019 11/1/2019


Percent Power Shortage Hour by Hour - 2015 through 2019
Top of scale is 60% short
60%
50%
40%
30%
20%
10%
0%
1/1/2015
3/1/2015
5/1/2015
7/1/2015
9/1/2015
11/1/2015
1/1/2016
3/1/2016
5/1/2016
7/1/2016
9/1/2016
11/1/2016
1/1/2017
3/1/2017
5/1/2017
7/1/2017
9/1/2017
11/1/2017
1/1/2018
3/1/2018
5/1/2018
7/1/2018
9/1/2018
11/1/2018
1/1/2019
3/1/2019
5/1/2019
7/1/2019
9/1/2019
11/1/2019


Percent Power Shortage Hour by Hour - 2015 through 2019
Top of scale is 60% short
60%
50%
40%
30%
20%
10%
0%
1/1/15 0:00
3/1/15 0:00
5/1/15 0:00
7/1/15 0:00
9/1/15 0:00
11/1/15 0:00
1/1/16 0:00
3/1/16 0:00
5/1/16 0:00
7/1/16 0:00
9/1/16 0:00
11/1/16 0:00
1/1/17 0:00
3/1/17 0:00
5/1/17 0:00
7/1/17 0:00
9/1/17 0:00
11/1/17 0:00
1/1/18 0:00
3/1/18 0:00
5/1/18 0:00
7/1/18 0:00
9/1/18 0:00
11/1/18 0:00
1/1/19 0:00
3/1/19 0:00
5/1/19 0:00
7/1/19 0:00
9/1/19 0:00
11/1/19 0:00


Percent Power Shortage Hour by Hour - 2015 through 2019
Top of scale is 60% short
60%
50%
40%
30%
20%
10%
0%
1/1/15 0:00
3/1/15 0:00
5/1/15 0:00
7/1/15 0:00
9/1/15 0:00
11/1/15 0:00
1/1/16 0:00
3/1/16 0:00
5/1/16 0:00
7/1/16 0:00
9/1/16 0:00
11/1/16 0:00
1/1/17 0:00
3/1/17 0:00
5/1/17 0:00
7/1/17 0:00
9/1/17 0:00
11/1/17 0:00
1/1/18 0:00
3/1/18 0:00
5/1/18 0:00
7/1/18 0:00
9/1/18 0:00
11/1/18 0:00
1/1/19 0:00
3/1/19 0:00
5/1/19 0:00
7/1/19 0:00
9/1/19 0:00
11/1/19 0:00


Percent Power Shortage Hour by Hour - 2015 through 2019
Top of scale is 60% short
60%
50%
40%
30%
20%
10%
0%
1/1/15 0:00
3/1/15 0:00
5/1/15 0:00
7/1/15 0:00
9/1/15 0:00
11/1/15 0:00
1/1/16 0:00
3/1/16 0:00
5/1/16 0:00
7/1/16 0:00
9/1/16 0:00
11/1/16 0:00
1/1/17 0:00
3/1/17 0:00
5/1/17 0:00
7/1/17 0:00
9/1/17 0:00
11/1/17 0:00
1/1/18 0:00
3/1/18 0:00
5/1/18 0:00
7/1/18 0:00
9/1/18 0:00
11/1/18 0:00
1/1/19 0:00
3/1/19 0:00
5/1/19 0:00
7/1/19 0:00
9/1/19 0:00
11/1/19 0:00

# Average number of days short of supply per year

| Days Short per Year | | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Hour Ending | 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 10 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 11 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 12 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 13 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 14 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 15 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 16 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 17 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 18 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 19 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 20 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 21 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 22 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 23 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 24 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| Days Short per Year | | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Hour Ending | 1 | 1.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.4 | 0.6 | 1.8 | 0.2 | 0.0 | 0.0 | 0.4 |
| | 2 | 0.8 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 3 | 0.8 | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 4 | 0.8 | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 5 | 1.0 | 1.0 | 0.2 | 0.0 | 0.0 | 0.2 | 0.2 | 1.2 | 0.0 | 0.0 | 0.0 | 0.4 |
| | 6 | 2.0 | 2.0 | 0.2 | 0.0 | 0.0 | 0.6 | 0.6 | 3.2 | 0.2 | 0.0 | 0.0 | 0.6 |
| | 7 | 4.2 | 3.0 | 1.6 | 0.0 | 0.0 | 1.6 | 3.2 | 5.6 | 0.8 | 0.6 | 0.0 | 1.2 |
| | 8 | 5.8 | 3.8 | 2.0 | 0.0 | 0.2 | 4.2 | 8.4 | 10.6 | 1.2 | 1.0 | 0.2 | 2.2 |
| | 9 | 6.4 | 3.8 | 2.2 | 0.2 | 0.2 | 3.8 | 11.6 | 15.8 | 3.6 | 0.8 | 0.4 | 2.6 |
| | 10 | 5.0 | 2.4 | 1.4 | 0.2 | 0.0 | 1.4 | 4.6 | 9.2 | 2.6 | 0.8 | 0.2 | 2.2 |
| | 11 | 3.2 | 1.0 | 0.6 | 0.0 | 0.0 | 0.6 | 1.6 | 3.8 | 1.2 | 0.4 | 0.2 | 1.4 |
| | 12 | 2.6 | 0.8 | 0.2 | 0.0 | 0.0 | 0.0 | 0.8 | 2.6 | 0.4 | 0.0 | 0.0 | 0.8 |
| | 13 | 2.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 1.4 | 0.4 | 0.2 | 0.0 | 0.6 |
| | 14 | 2.0 | 0.6 | 0.0 | 0.0 | 0.2 | 0.0 | 1.4 | 1.6 | 0.2 | 0.0 | 0.2 | 0.6 |
| | 15 | 1.6 | 0.6 | 0.0 | 0.0 | 0.2 | 0.0 | 1.0 | 1.4 | 0.0 | 0.0 | 0.2 | 0.4 |
| | 16 | 1.8 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 1.2 | 0.0 | 0.2 | 0.2 | 0.4 |
| | 17 | 2.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 0.8 | 0.2 | 0.0 | 0.4 | 0.6 |
| | 18 | 3.4 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.8 | 0.2 | 0.0 | 0.8 | 1.8 |
| | 19 | 5.8 | 1.8 | 0.6 | 0.0 | 0.0 | 0.4 | 2.4 | 1.6 | 0.4 | 0.2 | 0.8 | 2.2 |
| | 20 | 5.4 | 4.0 | 0.6 | 0.0 | 0.2 | 0.4 | 3.4 | 4.4 | 1.8 | 0.4 | 0.8 | 1.8 |
| | 21 | 5.4 | 3.0 | 0.8 | 0.2 | 0.2 | 1.0 | 8.2 | 10.4 | 4.0 | 0.8 | 1.0 | 1.0 |
| | 22 | 4.6 | 2.4 | 0.6 | 0.2 | 0.6 | 4.4 | 11.6 | 11.6 | 2.6 | 0.6 | 0.4 | 0.6 |
| | 23 | 3.0 | 2.4 | 0.2 | 0.0 | 0.2 | 3.4 | 8.6 | 7.0 | 1.0 | 0.0 | 0.0 | 0.6 |
| | 24 | 1.8 | 1.0 | 0.2 | 0.0 | 0.0 | 1.6 | 2.8 | 3.4 | 0.4 | 0.0 | 0.0 | 0.6 |

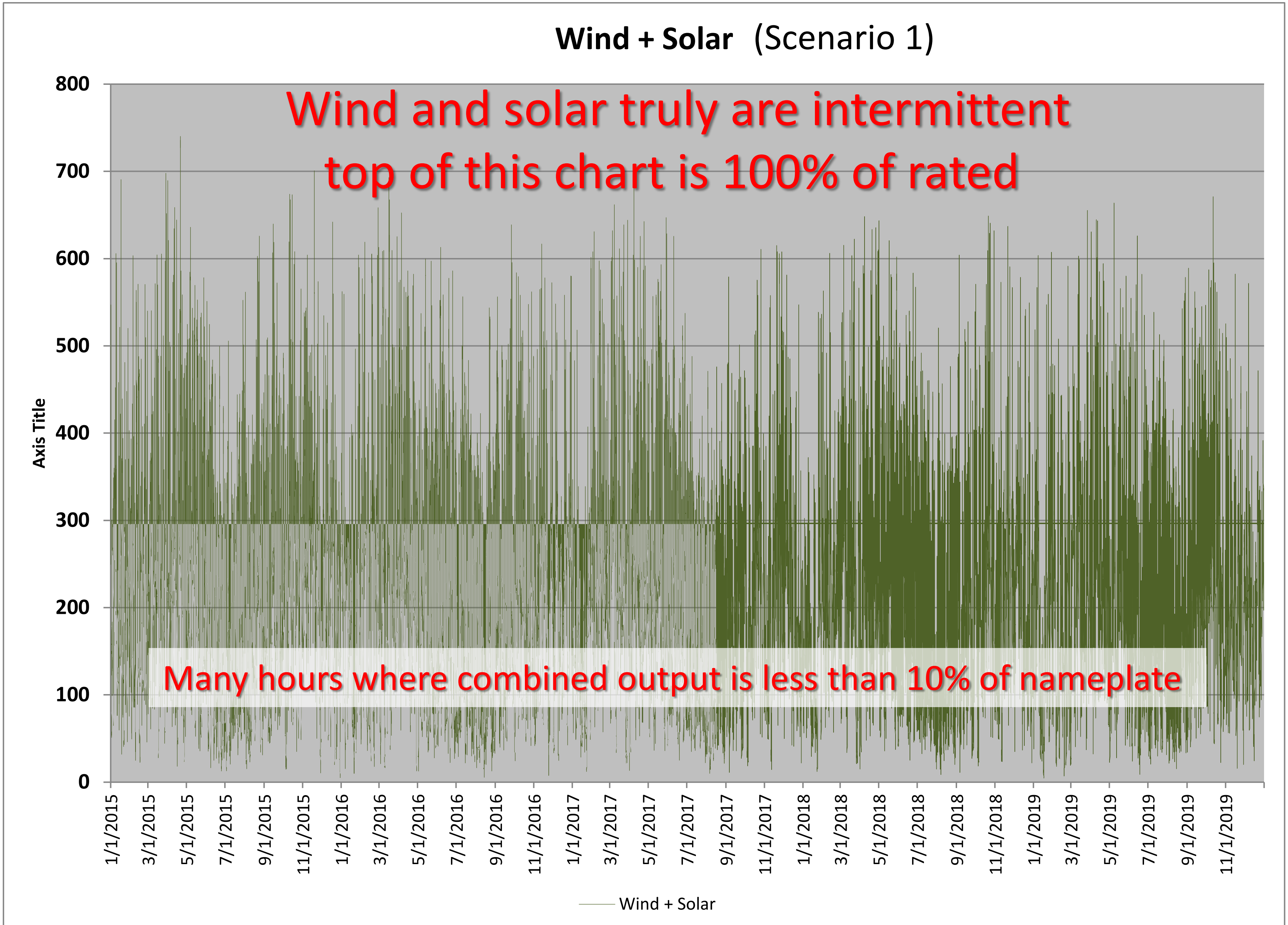
| Days Short per Year | | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Hour Ending | 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 10 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 |
| | 11 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 12 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 13 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 14 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 15 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 16 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 17 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 18 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 19 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 20 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 21 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 |
| | 22 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 23 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 24 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| Days Short per Year | | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Hour Ending | 1 | 19.4 | 12.2 | 8.6 | 4.8 | 10.8 | 19.6 | 28.2 | 26.6 | 13.4 | 6.6 | 8.8 | 10.8 |
| | 2 | 17.6 | 11.6 | 8.8 | 4.4 | 8.4 | 17.8 | 26.8 | 25.4 | 12.4 | 5.6 | 8.4 | 10.6 |
| | 3 | 18.2 | 11.8 | 9.4 | 4.6 | 8.0 | 16.4 | 26.4 | 24.0 | 12.0 | 4.8 | 8.6 | 10.6 |
| | 4 | 18.0 | 13.0 | 10.6 | 5.8 | 8.6 | 16.2 | 26.6 | 24.4 | 12.4 | 6.4 | 8.2 | 10.4 |
| | 5 | 18.2 | 13.2 | 12.2 | 8.0 | 10.0 | 17.6 | 27.6 | 26.0 | 14.4 | 9.4 | 9.6 | 11.6 |
| | 6 | 19.0 | 14.8 | 16.2 | 11.2 | 14.6 | 19.8 | 28.8 | 27.2 | 18.2 | 12.2 | 13.0 | 14.2 |
| | 7 | 21.4 | 17.8 | 19.0 | 13.2 | 18.2 | 24.2 | 29.8 | 28.2 | 21.0 | 15.0 | 14.2 | 17.8 |
| | 8 | 24.0 | 19.4 | 19.0 | 14.6 | 20.4 | 26.2 | 30.6 | 29.2 | 23.4 | 15.4 | 15.2 | 20.4 |
| | 9 | 25.2 | 19.8 | 19.6 | 14.8 | 16.2 | 23.8 | 30.0 | 29.6 | 25.8 | 18.4 | 15.4 | 20.8 |
| | 10 | 23.6 | 13.8 | 14.0 | 5.8 | 5.8 | 8.8 | 19.2 | 24.6 | 20.8 | 15.0 | 9.0 | 18.6 |
| | 11 | 14.6 | 9.2 | 7.6 | 2.0 | 3.2 | 3.6 | 6.4 | 9.4 | 5.8 | 6.8 | 5.8 | 11.8 |
| | 12 | 11.6 | 6.0 | 3.8 | 1.6 | 1.0 | 2.8 | 3.8 | 5.6 | 2.8 | 3.2 | 3.6 | 8.6 |
| | 13 | 9.2 | 4.4 | 2.8 | 0.2 | 0.4 | 1.2 | 2.2 | 5.0 | 1.8 | 2.2 | 2.8 | 6.4 |
| | 14 | 8.2 | 3.0 | 1.4 | 0.2 | 0.6 | 1.2 | 2.4 | 3.2 | 1.4 | 1.0 | 2.0 | 5.6 |
| | 15 | 8.6 | 2.8 | 1.2 | 0.0 | 0.2 | 1.2 | 2.6 | 2.2 | 0.8 | 1.2 | 2.2 | 5.8 |
| | 16 | 8.6 | 3.2 | 1.4 | 0.2 | 0.0 | 0.8 | 2.0 | 2.2 | 1.2 | 1.6 | 2.4 | 6.8 |
| | 17 | 11.4 | 3.6 | 2.0 | 0.2 | 0.4 | 1.6 | 3.0 | 2.6 | 1.8 | 2.0 | 4.0 | 8.6 |
| | 18 | 17.2 | 7.0 | 2.4 | 0.2 | 0.2 | 1.6 | 4.6 | 2.8 | 2.4 | 2.6 | 8.6 | 15.2 |
| | 19 | 24.4 | 14.0 | 4.8 | 0.6 | 1.0 | 2.0 | 5.8 | 6.0 | 3.4 | 4.8 | 15.4 | 21.0 |
| | 20 | 26.0 | 19.8 | 9.8 | 1.8 | 2.0 | 4.4 | 9.8 | 13.0 | 10.2 | 11.6 | 15.4 | 19.8 |
| | 21 | 24.2 | 19.0 | 12.2 | 6.0 | 9.4 | 15.6 | 26.2 | 28.4 | 20.0 | 13.2 | 14.0 | 18.2 |
| | 22 | 23.8 | 17.4 | 12.6 | 9.8 | 16.6 | 24.4 | 30.2 | 29.2 | 19.2 | 10.2 | 13.4 | 17.8 |
| | 23 | 22.4 | 16.2 | 10.6 | 6.6 | 14.8 | 23.4 | 30.0 | 28.0 | 16.6 | 8.4 | 11.8 | 15.0 |
| | 24 | 19.8 | 13.4 | 9.2 | 6.0 | 12.2 | 21.0 | 29.0 | 27.0 | 16.4 | 7.0 | 9.4 | 12.2 |

# Model results summary for four scenarios

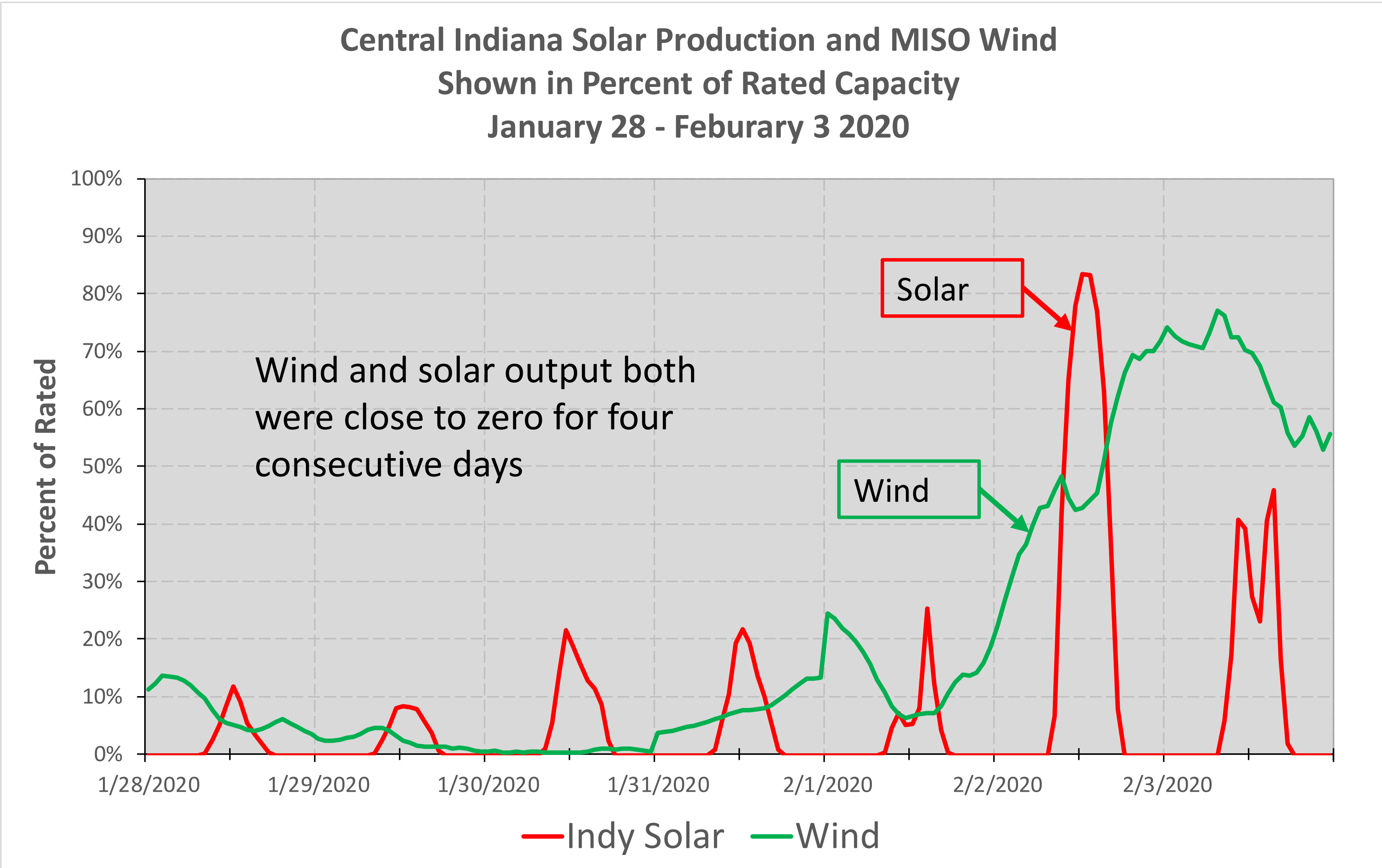
| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Solar | 400 | 1,000 | 1,008 | 1,303 |
| Wind | 400 | 1,000 | 319 | 567 |
| Battery | 100 | 200 | 106 | 170 |
| Dispatchable | 815 | 500 | 761 | 320 |
| Total Nameplate | 1,715 | 2,700 | 2,195 | 2,360 |
| | | | | |
| Approx Renewable % | 36% | 74% | 44% | 58% |
| Max Percent Out | 5% | 31% | 10% | 56% |
| Max MW shortfall | 44 | 272 | 89 | 492 |
| Hours Short Per Year | 2 | 391 | 4 | 3,423 |
| Dispatch Stop/Start | 28 | 320 | 239 | 312 |
| Curtail MWh | 3,651 | 791,590 | 241,462 | 669,037 |

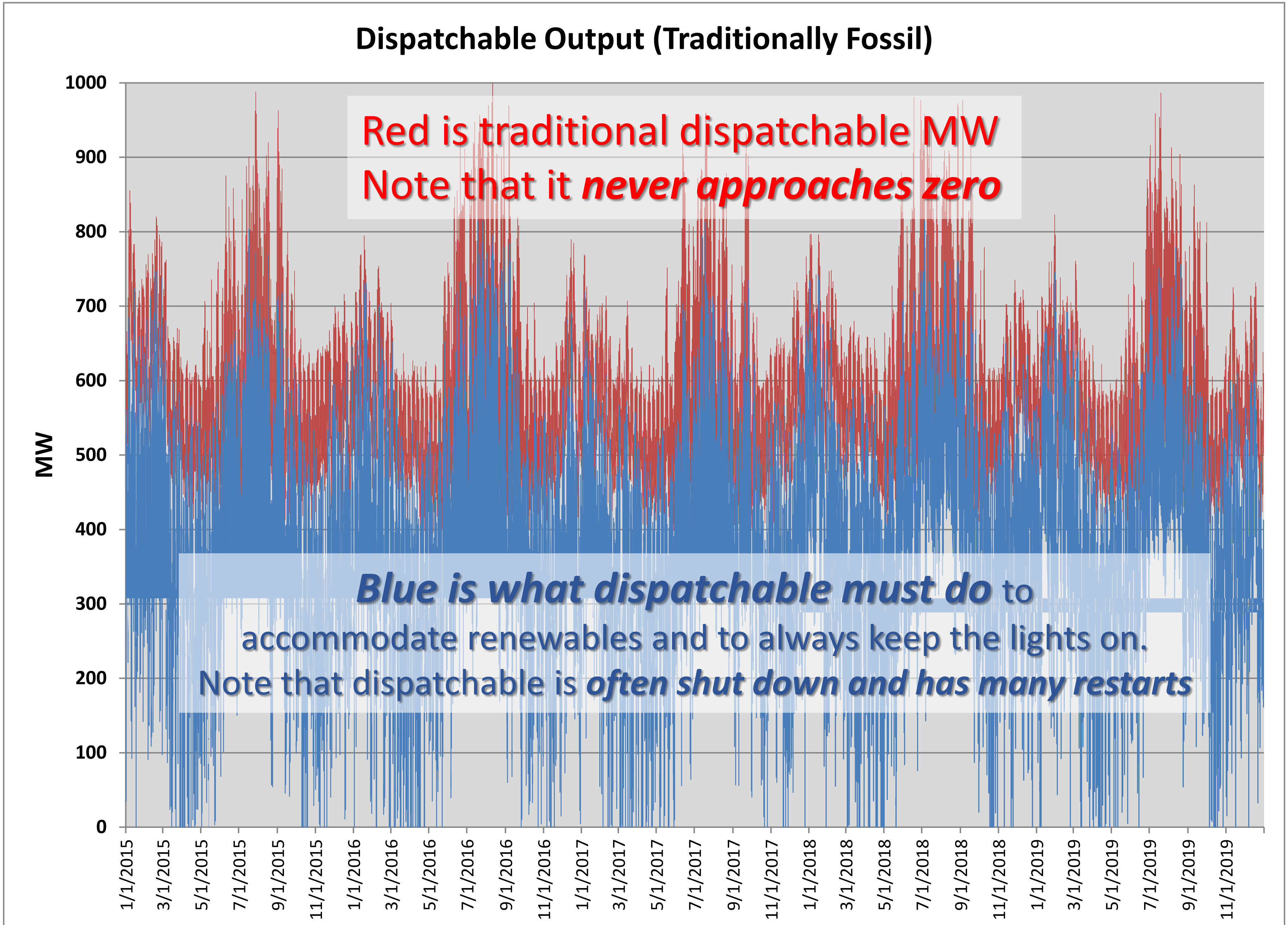
*Why do the high dispatchable work better?*



Wind + Solar (Scenario 1)
Wind and solar truly are intermittent
top of this chart is 100% of rated
Many hours where combined output is less than 10% of nameplate
Axis Title
800
700
600
500
400
300
200
100
0
1/1/2015
3/1/2015
5/1/2015
7/1/2015
9/1/2015
11/1/2015
1/1/2016
3/1/2016
5/1/2016
7/1/2016
9/1/2016
11/1/2016
1/1/2017
3/1/2017
5/1/2017
7/1/2017
9/1/2017
11/1/2017
1/1/2018
3/1/2018
5/1/2018
7/1/2018
9/1/2018
11/1/2018
1/1/2019
3/1/2019
5/1/2019
7/1/2019
9/1/2019
11/1/2019
Wind + Solar

# January 2020 central Indiana solar with MISO wind




Dispatchable Output (Traditionally Fossil)
Red is traditional dispatchable MW
Note that it never approaches zero
Blue is what dispatchable must do to
accommodate renewables and to always keep the lights on.
Note that dispatchable is often shut down and has many restarts
MW
1000
900
800
700
600
500
400
300
200
100
0
1/1/2015
3/1/2015
5/1/2015
7/1/2015
9/1/2015
11/1/2015
1/1/2016
3/1/2016
5/1/2016
7/1/2016
9/1/2016
11/1/2016
1/1/2017
3/1/2017
5/1/2017
7/1/2017
9/1/2017
11/1/2017
1/1/2018
3/1/2018
5/1/2018
7/1/2018
9/1/2018
11/1/2018
1/1/2019
3/1/2019
5/1/2019
7/1/2019
9/1/2019
11/1/2019

# Questions?