# The Winds of Change are coming!

## How Renewable Power and Efficiency will create a new paradigm for energy use.

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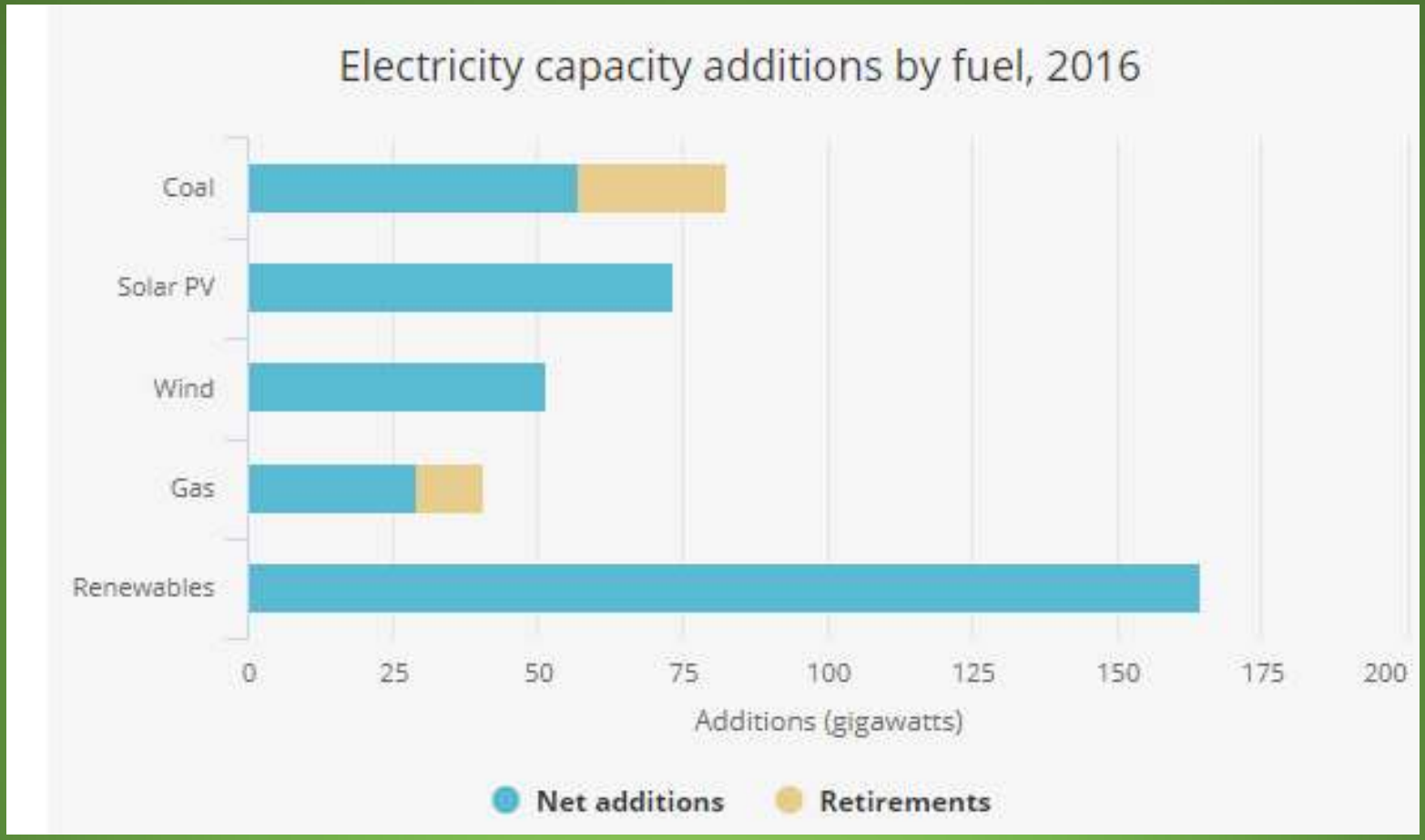
# How does the R&D community see efficiency and the grid

- In the Clean Energy world, it is generally broken into three areas:
  - Sustainable Transportation
  - Renewable Power
  - Energy Efficiency
- The DOE technology offices tied to Grid work are:
  - Solar Energy Technologies Office (SETO)
  - Water Power Technologies Office (WPTO)
  - Wind Energy Technologies Office (WETO)
  - Building Technology Office (BTO)

# New Capacity is Renewable

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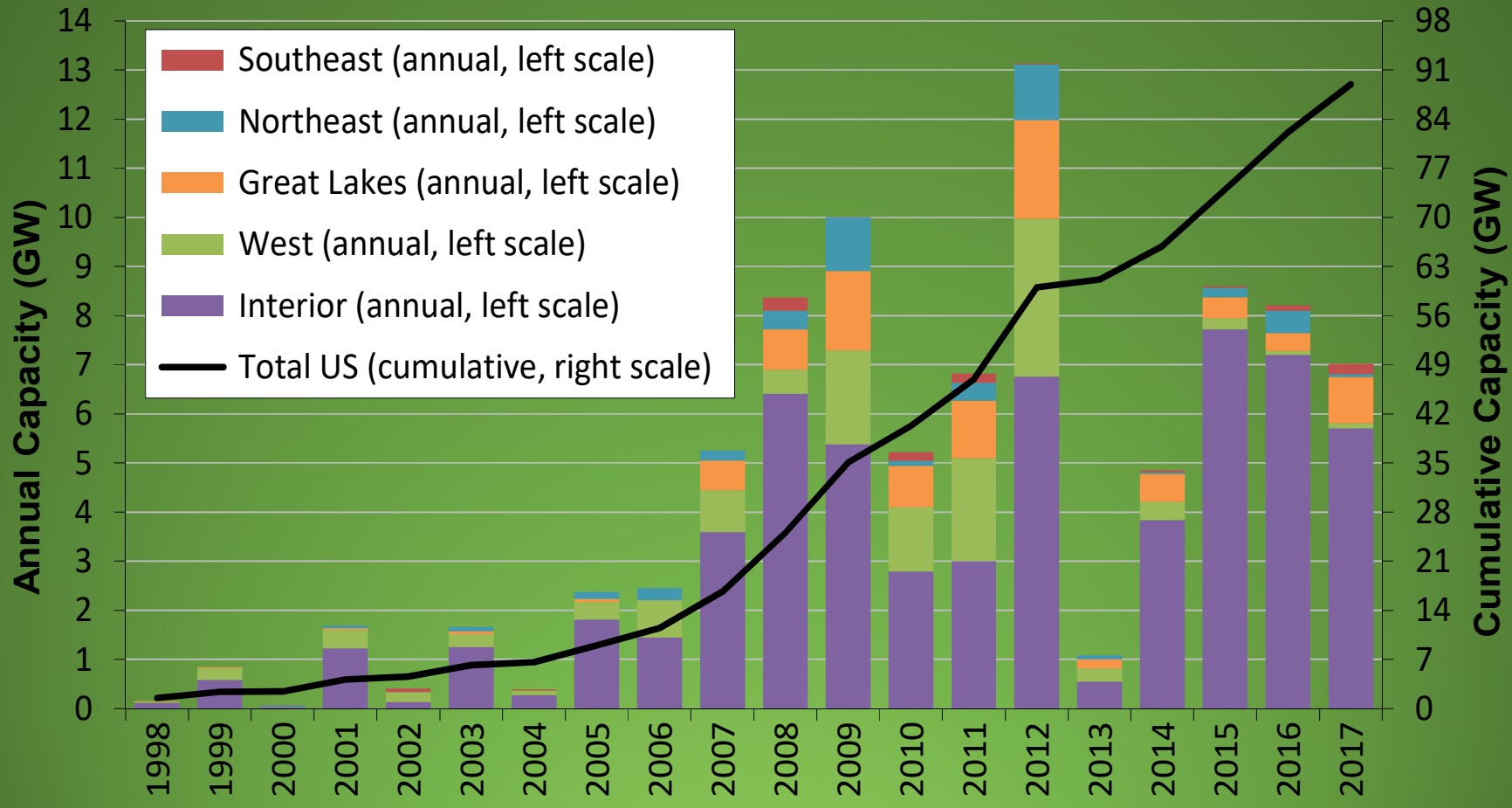
# Wind Power Additions Continued at a Rapid Pace in 2017, with 7,017 MW of New Capacity, Bringing the Total to 88,973 MW

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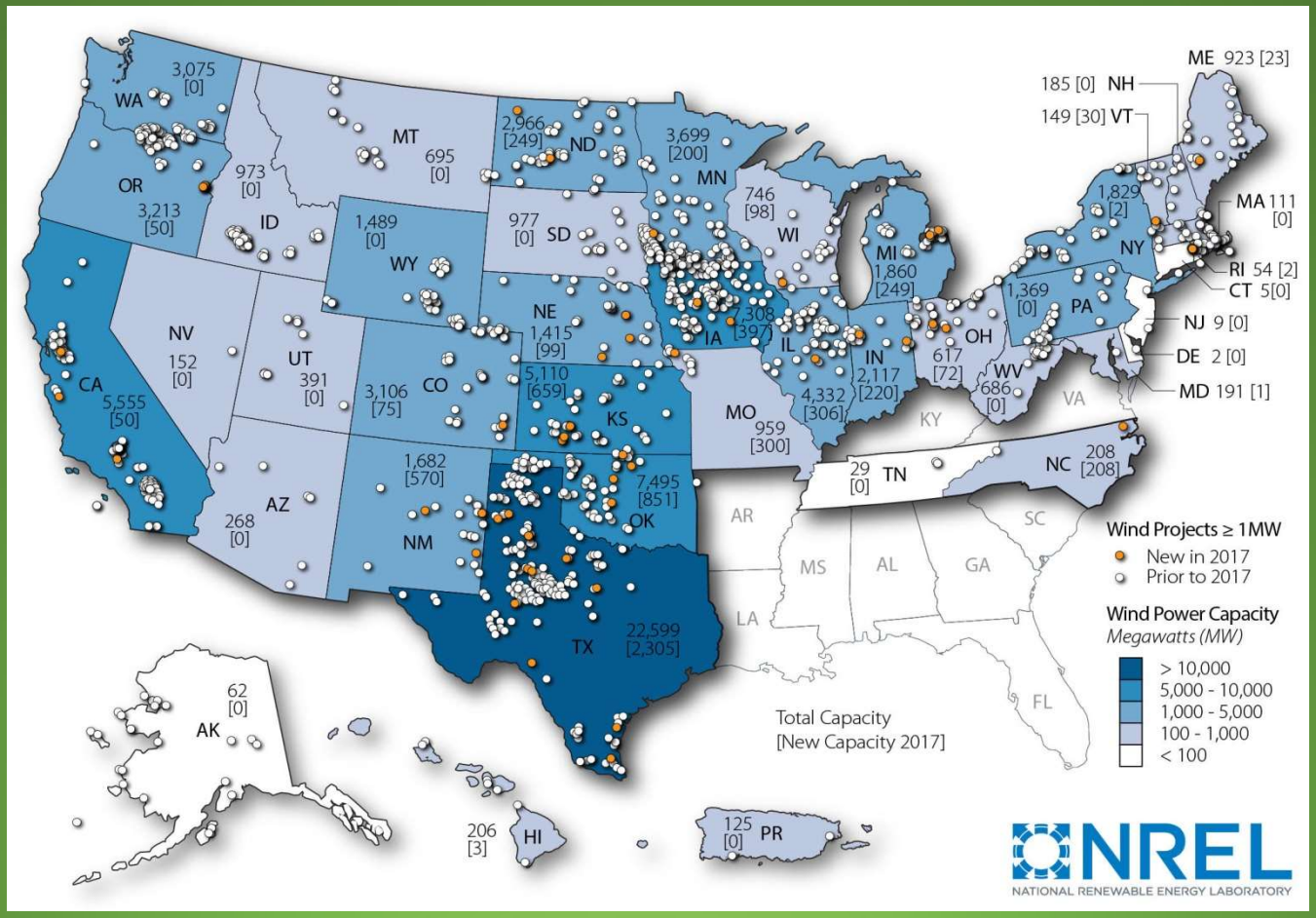
# The Geographic Spread of Wind Power Projects Across the United States Is Broad, with the Exception of the Southeast

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# Texas Installed the Most Wind Power Capacity in 2017; 14 States Exceed 10% Wind Energy, 4 States Exceed 30%

| Installed Capacity (MW) | | | | 2017 Wind Generation as a Percentage of: | | | |
|---|---|---|---|---|---|---|---|
| Annual (2017) | | Cumulative (end of 2017) | | In-State Generation | | In-State Load | |
| Texas | 2,305 | Texas | 22,599 | Iowa | 36.9% | North Dakota | 58.3% |
| Oklahoma | 851 | Oklahoma | 7,495 | Kansas | 36.0% | Kansas | 47.1% |
| Kansas | 659 | Iowa | 7,308 | Oklahoma | 31.9% | Iowa | 43.0% |
| New Mexico | 570 | California | 5,555 | South Dakota | 30.1% | Oklahoma | 40.9% |
| Iowa | 397 | Kansas | 5,110 | North Dakota | 26.8% | Wyoming | 26.3% |
| Illinois | 306 | Illinois | 4,332 | Maine | 19.9% | South Dakota | 25.7% |
| Missouri | 300 | Minnesota | 3,699 | Minnesota | 18.2% | New Mexico | 19.7% |
| North Dakota | 249 | Oregon | 3,213 | Colorado | 17.6% | Maine | 19.5% |
| Michigan | 249 | Colorado | 3,106 | Idaho | 15.4% | Colorado | 17.5% |
| Indiana | 220 | Washington | 3,075 | Texas | 14.8% | Nebraska | 17.4% |
| North Carolina | 208 | North Dakota | 2,996 | Nebraska | 14.6% | Texas | 17.3% |
| Minnesota | 200 | Indiana | 2,117 | New Mexico | 13.5% | Minnesota | 16.7% |
| Nebraska | 99 | Michigan | 1,860 | Vermont | 13.4% | Montana | 14.8% |
| Wisconsin | 98 | New York | 1,829 | Oregon | 11.1% | Oregon | 13.5% |
| Colorado | 75 | New Mexico | 1,682 | Wyoming | 9.4% | Idaho | 10.4% |
| Ohio | 72 | Wyoming | 1,489 | Montana | 7.6% | Illinois | 8.3% |
| Oregon | 50 | Nebraska | 1,415 | California | 6.8% | Washington | 8.3% |
| California | 50 | Pennsylvania | 1,369 | Hawaii | 6.5% | Hawaii | 6.9% |
| Vermont | 30 | South Dakota | 977 | Washington | 6.5% | California | 5.5% |
| Maine | 23 | Idaho | 973 | Illinois | 6.2% | Vermont | 5.2% |
| *Rest of U.S.* | 7 | *Rest of U.S.* | 6,774 | *Rest of U.S.* | 1.1% | *Rest of U.S.* | 1.2% |
| **TOTAL** | **7,017** | **TOTAL** | **88,973** | **TOTAL** | **6.3%** | **TOTAL** | **6.9%** |

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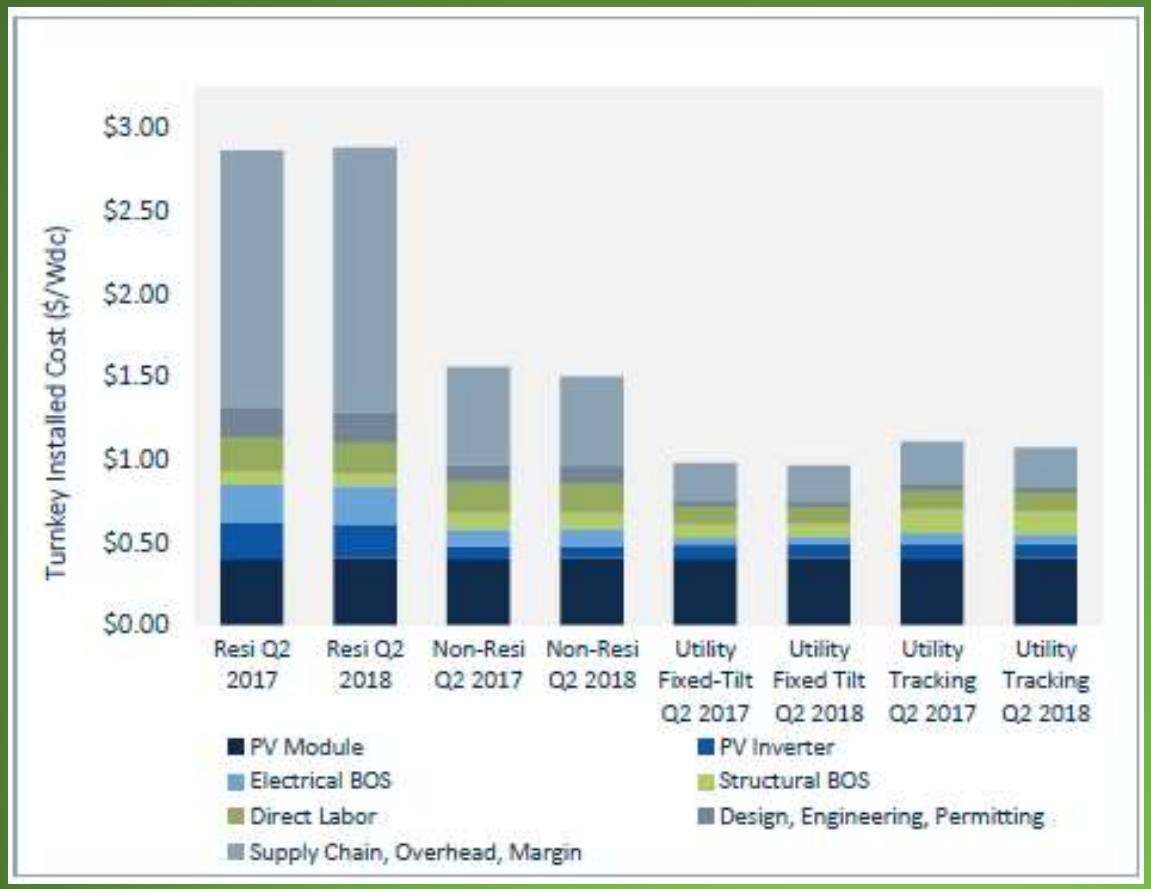
# Solar Power

- 29% of all capacity brought online in first half of 2018 was Solar
- Total installed U.S. PV capacity is expected to more than double over the next five years. By 2023, over 14 GWdc of PV capacity will be installed annually
- SunShot Goal of $0.06/kWh for 2020 was met early in 2017 – Prompting new goal of $0.03/kWh by 2025

# Solar Installations and Prices

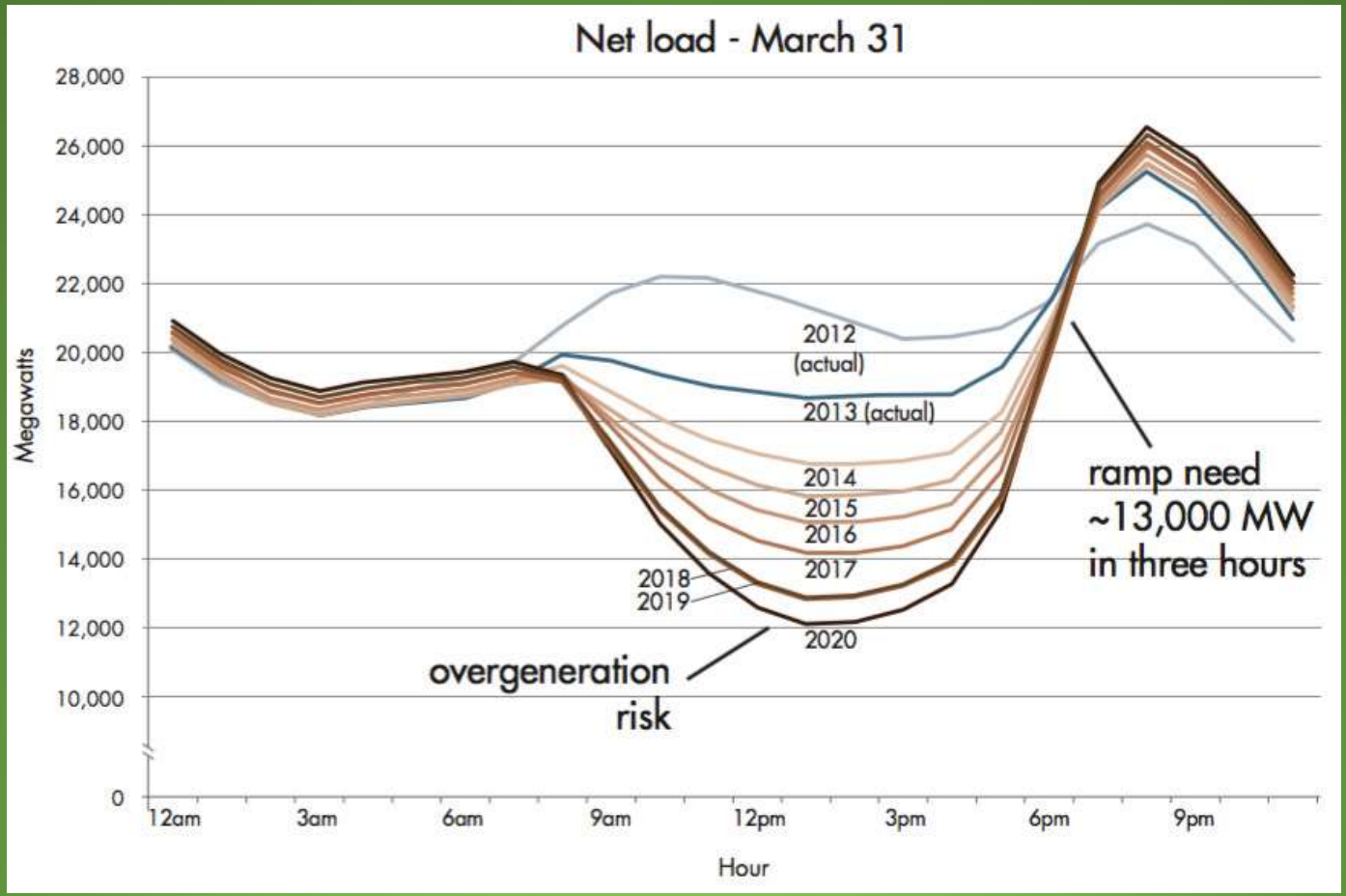



| | Rank | | |
|---|---|---|---|
| State | 2016 | 2017 | Q2 2018 |
| California | 1 | 1 | 1 |
| Texas | 6 | 4 | 2 |
| Arizona | 7 | 7 | 3 |
| New York | 12 | 12 | 4 |
| New Jersey | 10 | 11 | 5 |
| Massachusetts | 8 | 5 | 6 |
| Minnesota | 14 | 6 | 7 |
| Nevada | 5 | 9 | 8 |
| North Carolina | 4 | 2 | 9 |
| South Carolina | 20 | 8 | 10 |
| Maryland | 13 | 13 | 11 |
| Colorado | 11 | 20 | 12 |
| Florida | 9 | 3 | 13 |
| Connecticut | 21 | 21 | 14 |
| Hawaii | 19 | 17 | 15 |
| New Mexico | 15 | 26 | 16 |
| Pennsylvania | 25 | 27 | 17 |
| Washington | 28 | 34 | 18 |
| Utah | 2 | 19 | 19 |
| Virginia | 17 | 10 | 20 |
| Oregon | 18 | 14 | 21 |
| Illinois | 39 | 41 | 22 |
| Indiana | 23 | 24 | 23 |
| Ohio | 36 | 29 | 24 |
| Washington, D.C. | 31 | 40 | 25 |
| Delaware | 30 | 37 | 26 |
| Idaho | 16 | 16 | 27 |
| Iowa | 35 | 35 | 28 |

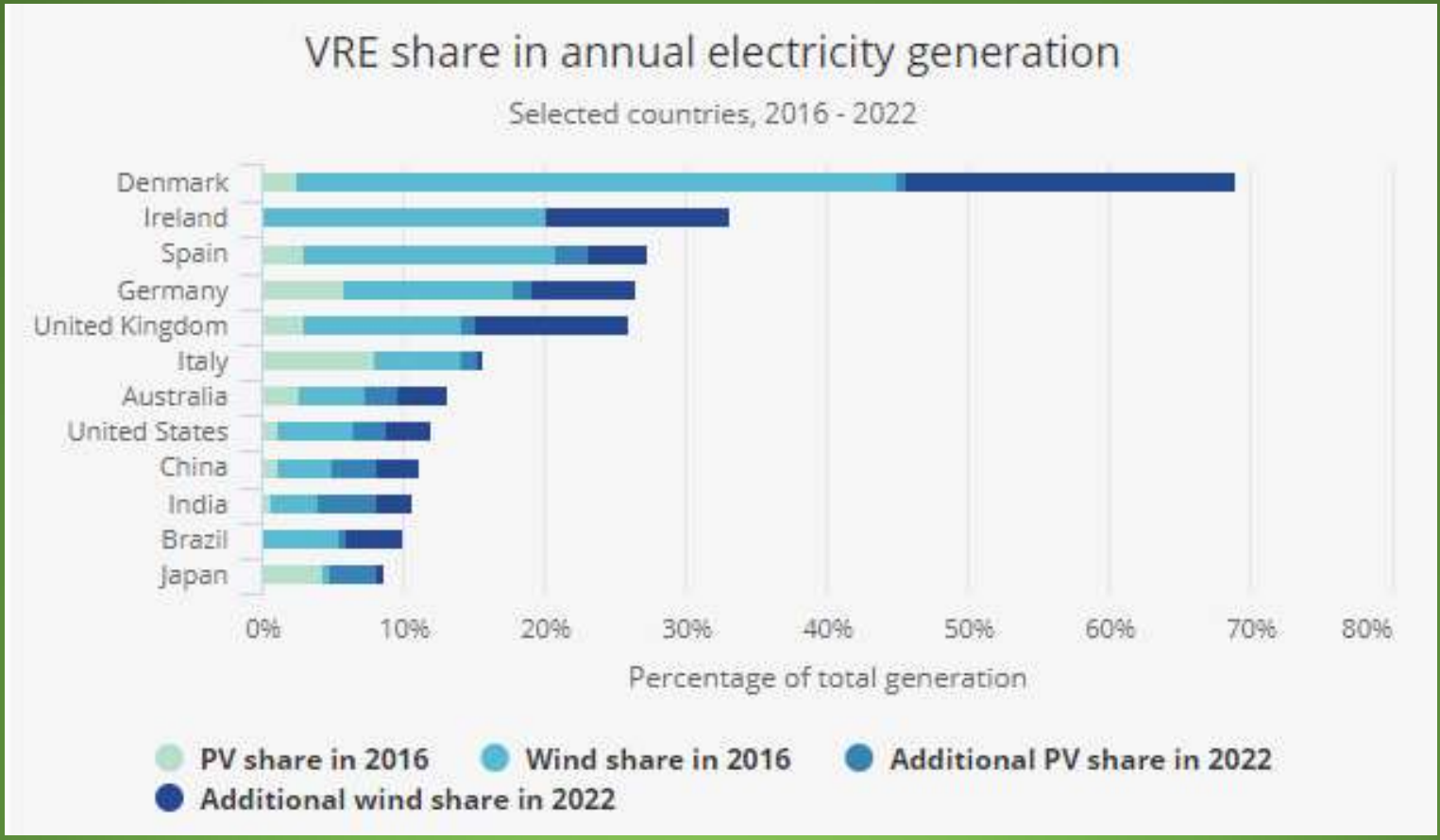
# Challenges and Opportunity

- Renewable Energy is Different than traditional generation
- Non-Dispatchable
- Uncertain Output
- Transmission System
- Inverter Driven

# Duck Curve


Net load - March 31
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
0
Megawatts
12am
3am
6am
9am
12pm
3pm
6pm
9pm
Hour
2012
(actual)
2013 (actual)
2014
2015
2016
2017
2018
2019
2020
overgeneration
risk
ramp need
~13,000 MW
in three hours

# Variable Renewable

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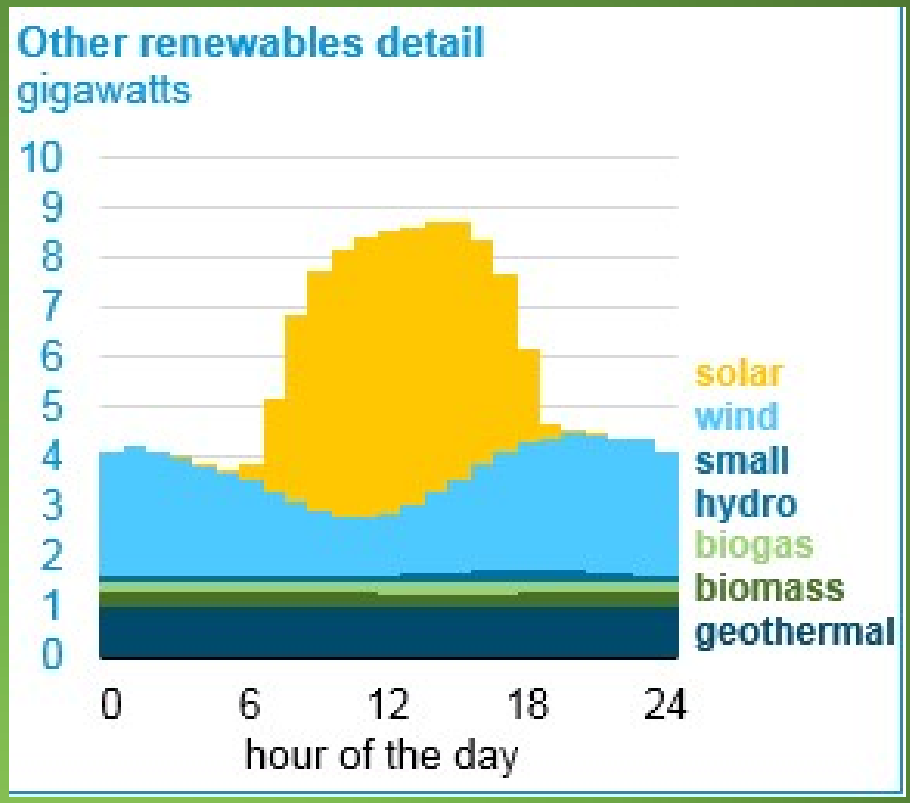
# How do we Balance the Variable Energy Sources

- New Operating Sequences
  - Hydropower
  - Pumped Storage
  - Fossil Plants
  - Nuclear Plants
- Technology
  - Batteries
  - Energy Efficiency
  - Electric Vehicles
  - Hybrid Solutions

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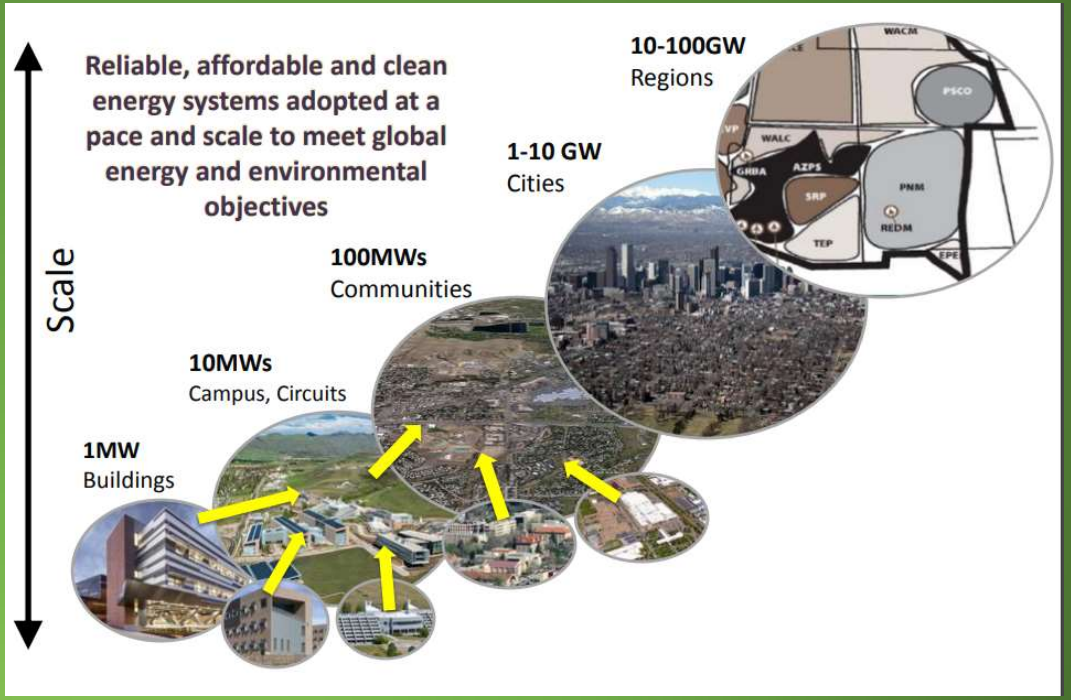
# Beyond Batteries

- While Batteries continue to be the “holy grail” of the power grid as stated by Secretary Rick Perry
- Batteries may not be the only solution
- Energy Efficiency is a prominent application in this effort
  - Using Buildings and their controllability
  - Future markets for efficiency technology
  - Future Opportunity for those that can aggregate buildings, distributed load and batter storage to balance grid services

# The Future

- Lower costs of Renewable Power will eventually drive down energy prices
  - Energy Efficiency provides Grid Services
  - System Integration Drives Grid
  - New opportunities to leverage efficiency installations

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