



# Renewable Electricity, Storage and Electrification

Amazing progress, transformations and challenges

Mark Ahlstrom, ESIG and NextEra Energy Resources



# Satirical humor – The Onion (www.theonion.com)

NEWS

## Incredible Humility: Warren Buffett Just Revealed That He Always Flies Cargo Instead Of First Class

3/20/19 2:10pm • SEE MORE: WARREN BUFFETT ▾



## Study: Universe Probably Not Computer Simulation

10/12/17 9:47am • SEE MORE: OPINION ▾



By studying the quantum behavior of particles, two physicists claim to have disproved a theory that our physical universe is just an elaborate simulation. What do you think?



“I’m going to have to start making better decisions then.”

RICHARD PROKASH • SHELLAC APPLIER



“It’s nice to know I’m not part of a random, meaningless simulation but rather a random, meaningless reality.”

DAN WIEDEMAN • BOAT VALET



“No computer would be this cruel.”

SARAH BALISTRERI • SHOT PUT JUDGE

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# Also from the Onion?



JILLIAN GOULD • JOIST MAKER

## **Idaho Power Sets Goal Of 100% Clean Energy By 2045**



CAINE DONOVAN • CARPETING SALESMAN

## **With Cincinnati On Board, 100 U.S. Cities Now Committed To 100% Clean Energy**



LEVISON KEMP • COCKTAIL INSPECTOR

## **Xcel Energy Commits to 100% Carbon-Free Electricity by 2050**

The 80 percent by 2030 goal will be fairly easy and affordable to meet with currently available technologies... incremental cost of renewable energy generation is now less than the embedded cost of existing fossil fuels.

# Drivers for clean energy are strong and growing

## Driven by global sense of urgency

- Annual global rate of growth is ~60 GW wind, ~120 GW solar

## Driven by states, cities, companies and utilities

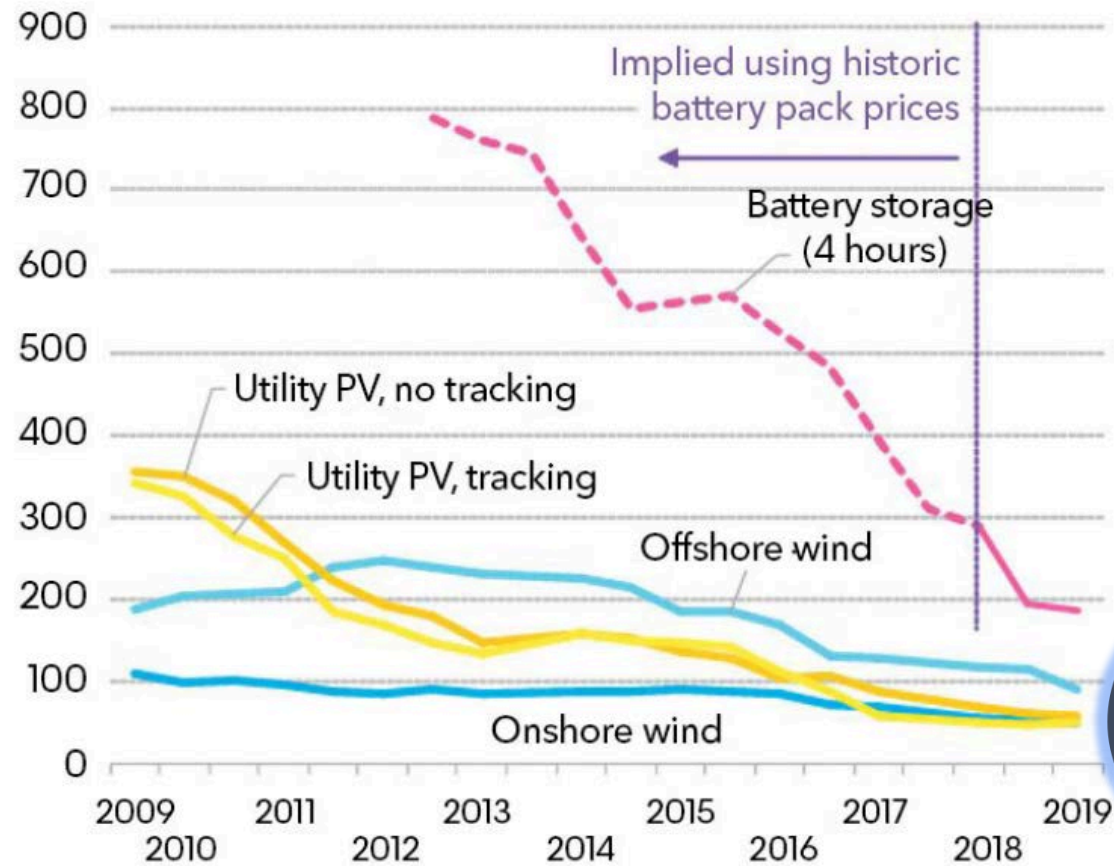
- Commitments are typically 80% by 2030, 100% by 2050, or some variation thereof
- Pledges from >130 cities, states (HI, CA, NM, NV, WA, CO, NY, ME), utilities, companies

## Driven by economics and technology

- NextEra Energy CEO: solar and wind plus storage will be cheaper than coal, oil or nuclear, and massively disruptive to the conventional fleet (unsubsidized, early in the 2020s)

## Global benchmarks - PV, wind and batteries

LCOE (\$/MWh, 2018 real)



Source: BloombergNEF. Note: The global benchmark is a country weighted-average using the latest annual capacity additions. The storage LCOE is reflective of a utility-scale Li-ion battery storage system running at a daily cycle and includes charging costs assumed to be 60% of whole sale base power price in each country.

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# Our digital revolution – disruptive change

## Non-synchronous resources are electronically coupled to the grid

- This is a digital revolution in power generation, with the ability to program the behaviors that we desire, but the need to understand exactly what we want

## Storage – What is it?

- We are familiar with generators and loads, but storage is both and neither
- Does some storage enhance almost everything?

## Storage Hybrids – Even more disruptive

- Hybrid “solar + storage” power plants... or “anything + storage” power plants
- Virtual power plants (VPPs)
- Aggregated distributed energy resources (DERs)

Given enough of three key ingredients  
(energy, electronics, software)...

we can emulate any machine that we want or need  
(real or imagined).

# With choices, trend to versatility and flexibility

## Storage and hybrids – more versatile, flexible power plants

- Hybrids greater than the sum of their parts – alters designs, capacity factors and capabilities
- Solid-state plants with sophisticated controls, computing/communications, analytics

## Grid resources – “more ideal” characteristics

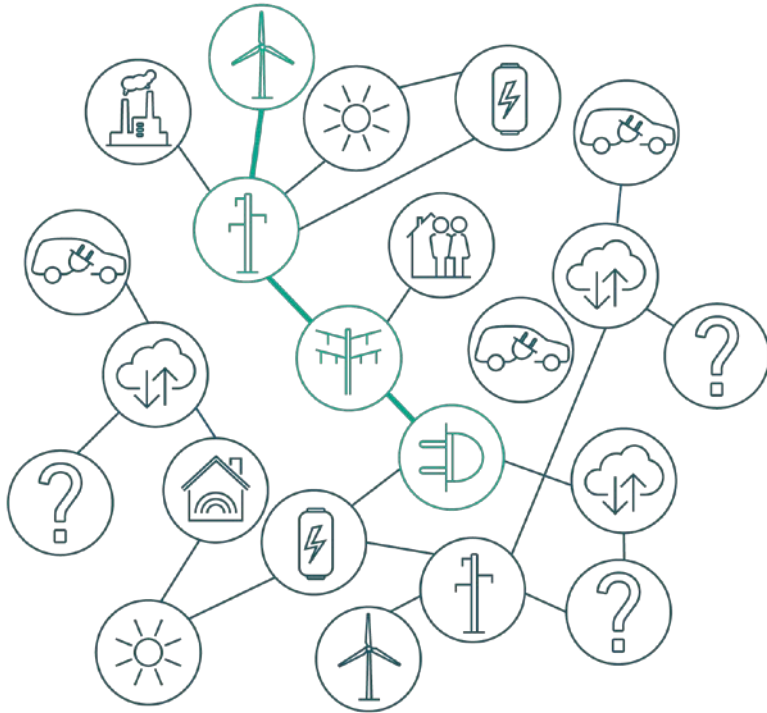
- Reducing/eliminating startup time, minimum run time, minimum down time, etc.
- Ramping – fast, accurate and on command across a broad range without discontinuities
- Flexible, fast and accurate provision of a versatile set of higher-level grid services

## How would we redesign grid operations and markets from scratch today?

- *Balanced, reliable system across planned and unplanned conditions in an economic way*
- *Sufficient energy, flexibility and reserves to maintain a desired level of reliability*
- Top-down control versus growing populations of more intelligent, sophisticated agents



# A time of amazing transition and transformation



From Peter Jørgensen, Energinet

From slow and heavy to fast and light  
From thermal/mechanical to electronic/digital  
From grid following to grid forming  
From energy to flexibility/balancing  
From top-down control to distributed,  
intelligent agents

# Fascinating challenges, questions and problems

Transmission

Offshore wind

Market design with very low  
marginal cost energy

Longer-duration capacity

100% clean electricity versus  
80% clean energy

Electrification

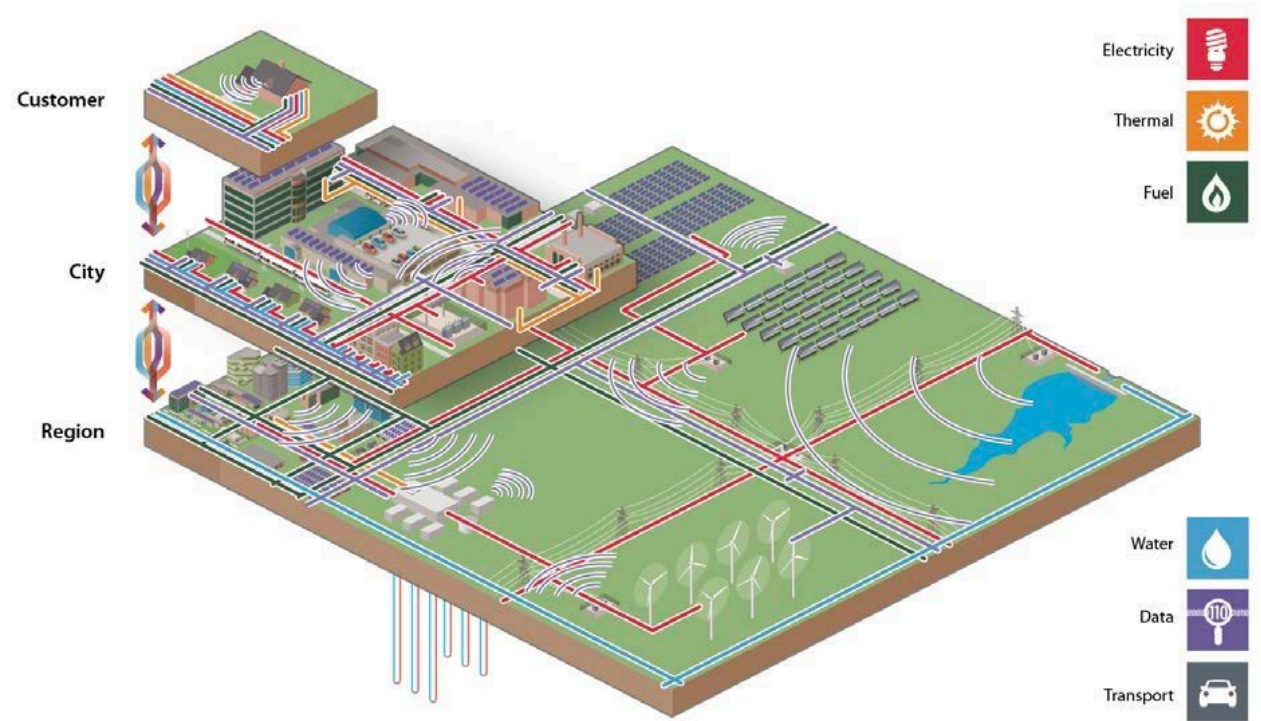


Figure from "Energy Systems Integration: Defining and Describing the Value Proposition" - <https://www.nrel.gov/docs/fy16osti/66616.pdf>

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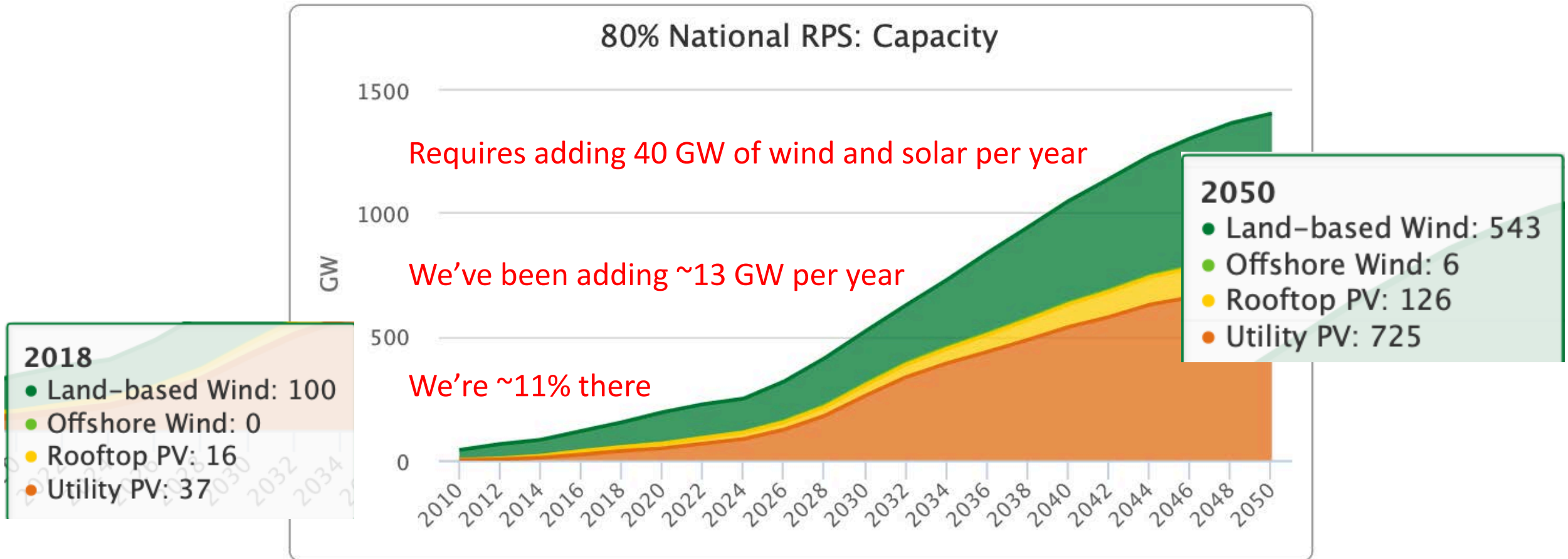


- Formed by DOE, EPRI, EEI, NRECA, APPA and utilities in 1989 as the Utility Wind Interest Group
- Non-profit educational association that provides workshops, resources, working groups and education
- Total system view of the energy systems we use today, focusing on the combined strength of electricity, heat and fuel systems
- Committed to industry collaboration, forward thinking and knowledge sharing
- Supports engineers, researchers, technologists, policymakers and the public with the transformation of energy systems in a way that is economic, reliable, sustainable, thoughtful and collaborative





# More to do – Renewable energy in the U.S.



Source: NREL Standard Scenarios Report, <https://www.nrel.gov/docs/fy19osti/71913.pdf>, generated by <https://openai.org/apps/reeds/#>





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