Hybrid Storage Resources

Implications for Grid Services and Market Design

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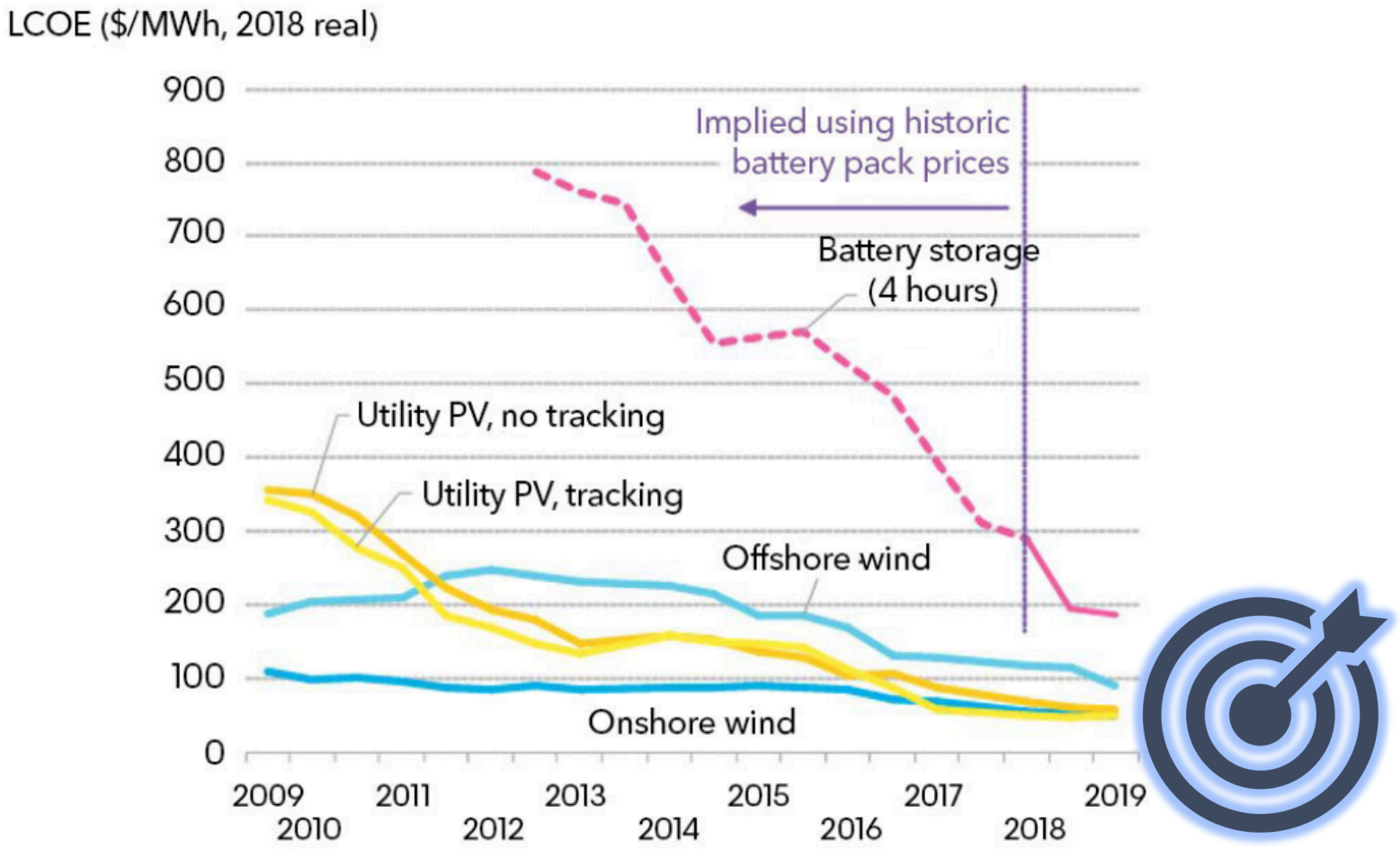
Global benchmarks - PV, wind and batteries



Source: BloombergNEF. Note: The global benchmark is a country weighed-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.

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 used to 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).

If we can can make what we want, then why not make “more ideal” resources?

What might a more ideal resource be?

- No startup time, no minimum run time, no minimum down time, etc.
- Ramps quickly and on command across its entire power range
- Linear operational characteristics without discontinuities/non-convexities

How can we make them?

- Current resources plus storage services can become ideal resources (physically or virtually)
  - Solar PV + battery storage hybrid power plants
  - Renewable + battery + gas hybrid power plants
  - Aggregated DERs or Distribution System Operators
  - Virtual power plants

Hybrid resources – game changers

Renewable hybrids are getting surprisingly affordable

- Leads to dramatic internal design changes and higher effective renewable capacity factors
- Oversizing generation, using planned self-curtailment, efficiency/optimization/analytics

Hybrids will change market products, market design and market participation

- Offer prices are based on the hybrid's perception of future opportunity cost
- Conventional assumptions of offers based on marginal fuel cost are no longer relevant
- Market operator will not know (nor nor should they know) the hybrid's internally optimal performance strategy, and this strategy will vary based on forecasts and risk tolerances

Hybrids will provide the "Grid Services" that system operators really want

Grid Services

Concepts

- How would we define the desired, high-level services from scratch today?
- Can we directly align services with the “prime directive” of the system operator?

  Maintain a balanced, reliable system across planned and unplanned conditions in an economic way
- In the long run, can we allow markets and system operators to focus on the services that they really want rather than the technology-specific variants they are offered?

Implications

- The real time operator in the control room (and therefore, the market software and energy management software) wants to know that they have sufficient *energy, flexibility and contingency reserves* available to maintain a desired level of reliability at all times and places
- Expecting the market or system operator to be responsible for technology-specific quirks could become a historical artifact when sufficient future resources (both conventional and renewable) can directly provide Grid Services at low cost

Once we have the *capability* to make an ideal resource, does it become an *obligation* to perform like one to participate?

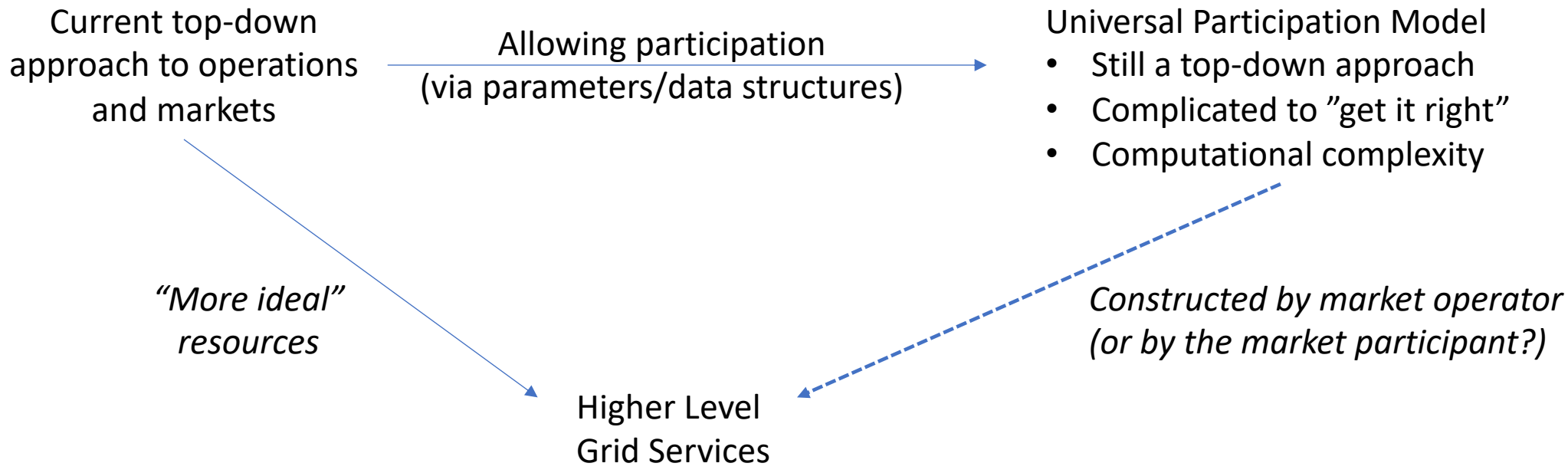
No, the market can still construct what it needs from non-ideal parts.

But should we use Grid Services as the basis for assigning value?

Yes, because if a hybrid can construct the Grid Service cheaper than the market can, then we should allow it to do so.

Seek elegance, not complexity

If we're expecting disruption from storage, growth in market participants, and innovation at the digital pace, then what do we do?



System operator should want "more ideal" resources because they directly provide the Grid Services that are really needed. Should this eventually become the standard model?

Implications for future market design

Over time, the “more ideal” resources will become increasingly attractive

- Ability to innovate and optimize behind the fence as a single resource (virtual/physical)
- Optimized for cost and performance, they will eventually dominate market products
- Innovation will include hybrids with both renewable and conventional resources

The market operator will no longer have (nor should they need to have) the information needed for some top-down optimization approaches

- Hybrids are aggregated, intelligent subsystems with sophisticated optimization strategies
- Their offers will depend not only on fuel costs or arbitrage spreads, but on their own strategies, forecasts and perceptions of their opportunity costs
- Markets can still work, based on offers of Grid Services from the resources

The Regulatory Debate About Energy Storage Systems

(IEEE Power & Energy Magazine; Sep/Oct 2017; Enés Usera, Pablo Rodilla, Scott Burger, Ignacio Herrero, Carlos Battle)

Guiding market design principles from this paper

- Technology-specific restrictions and products should be avoided where possible
- Only technical requirements based on actual physical limitations of the system should be preserved
- Bring market-clearing closer to real time to allow agents to exhaust their ability to correct their forecasting errors and variability
- Short-term flexibility through technology-neutral market products that respond to actual system needs
- Long-term reserve markets as call options to facilitate storage and VER participation
- Capacity products that more closely reflect system operations and flexibility needs

What is flexibility? Are we looking at it wrong?

- Isn’t flexibility more than just ramping energy?
  - If flex is priced at lost opportunity cost, and energy clears at zero, then is flex worthless?
  - Should flexibility products suppress scarcity pricing?
- If system balancing is the real objective, is flexibility the real product?
  - Is flexibility really optionality (more than just ramping of energy)?
  - What is the benefit of deferring decisions until the last reasonable moment (as in ERCOT)?
- How do our concepts of flexibility and capacity change in the future?
  - Much more flexibility on both the load and generation sides
  - Larger populations of intelligent agents that are flexible, sophisticated and automated

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