Hybrid Resources as Power Plants

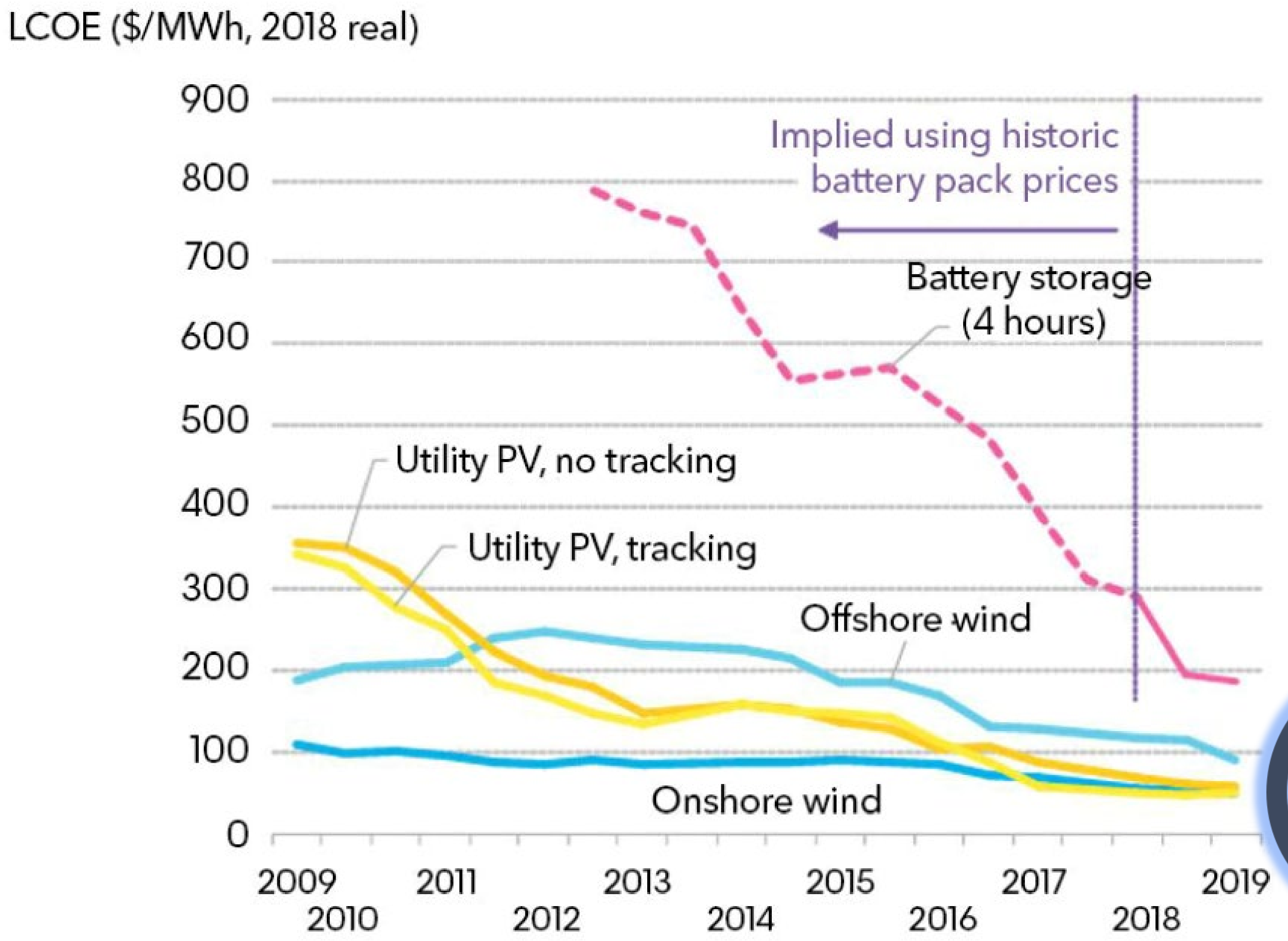
Creating value for probabilistic solar energy forecasts

Mark Ahlstrom, ESIG and NextEra Energy Resources

ESIG

ENERGY SYSTEMS INTEGRATION GROUP

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

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?

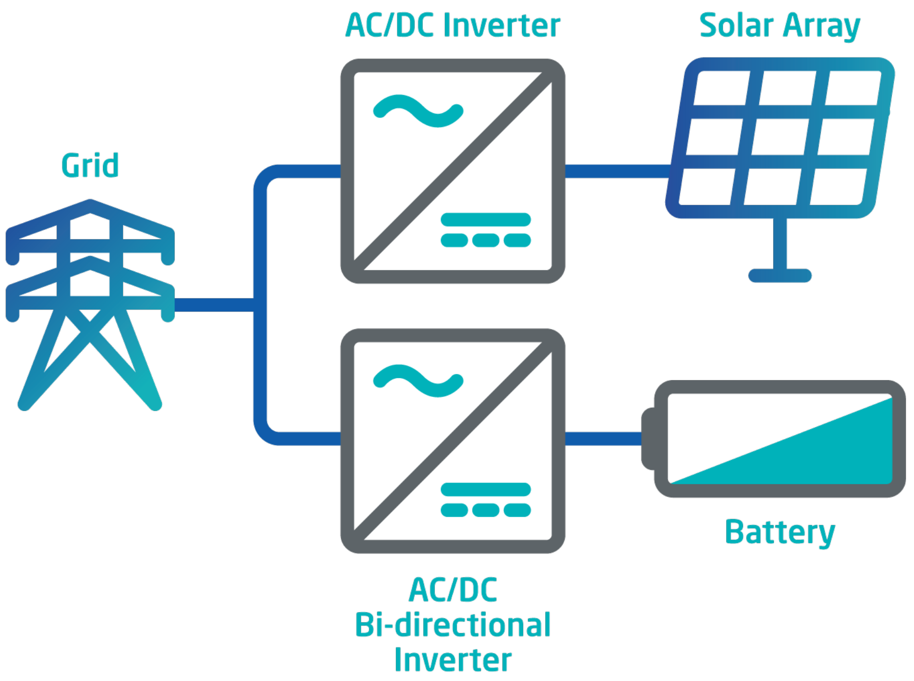
- We are familiar with generators and loads, but storage is both and neither
- Does some storage enhance almost everything?

Storage Hybrids – Even more disruptive? Or are they easier?

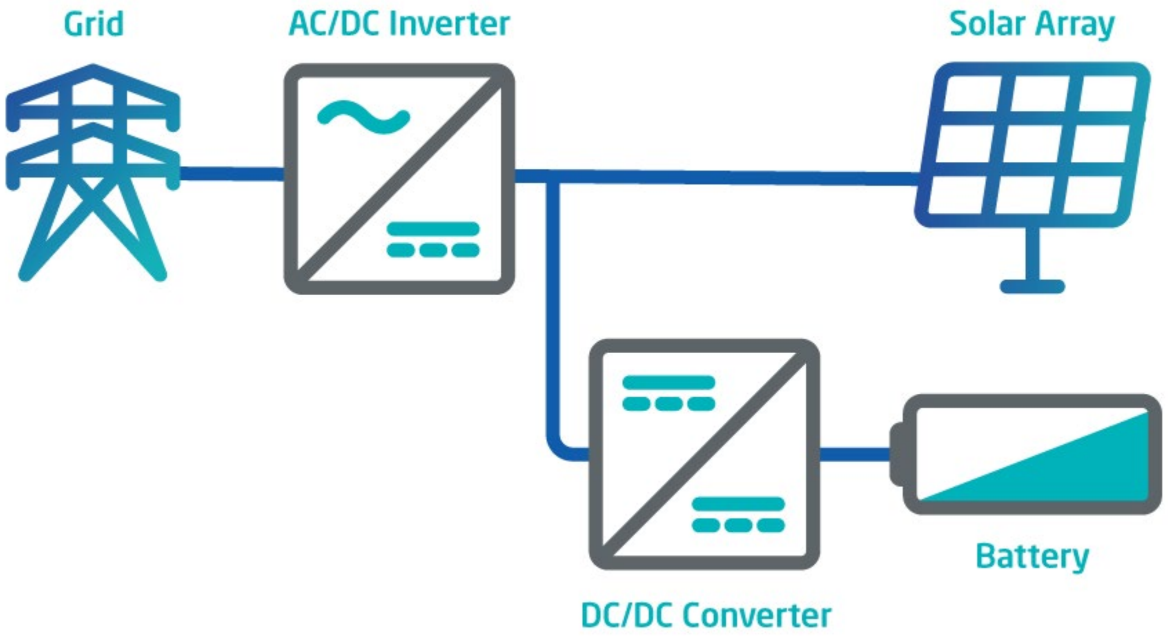
- Hybrid “solar + storage” power plants… or “anything + storage” power plants
  - May also apply to virtual power plants and aggregated distributed energy resources

AC versus DC Coupling

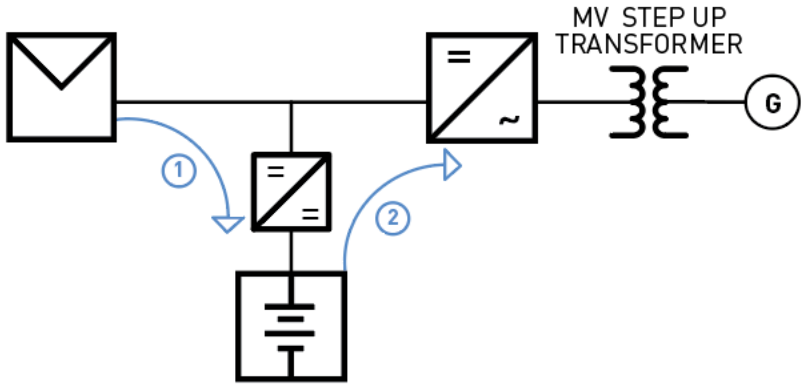
AC Coupled

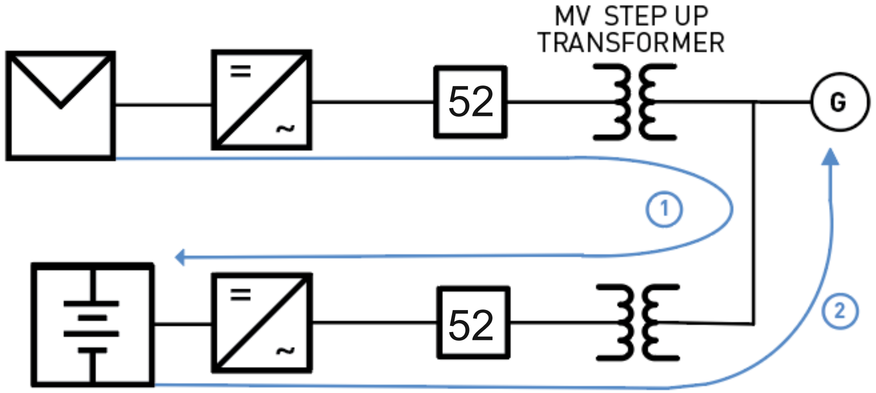


DC Coupled



HIGHER EFFICIENCY





DC-COUPLED

- 3 power electronic conversions
- 1 battery charge and discharge
- 1 transformer conversion

Efficiency = 89.2%

= .95 * .982 * .982 * .984 * .99

AC-COUPLED

- 3 power electronic conversions
- 1 battery charge and discharge
- 3 transformer conversions

Efficiency = 86.2%

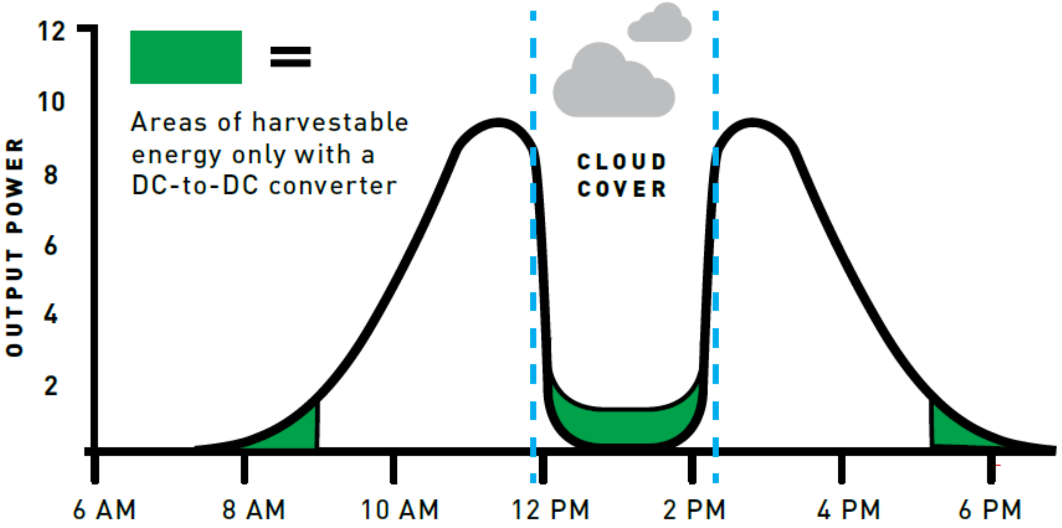
= .95 * .984 * .99 * .99 * .984 * .984 * .99

Assumed efficiencies: PV inverter = 98.4%, Battery inverter = 97.5%, DC-DC = 98.2%, transformer = 99%, batteries = 95% round trip

DYNAPOWER COMPANY
Trusted Worldwide Since 1963

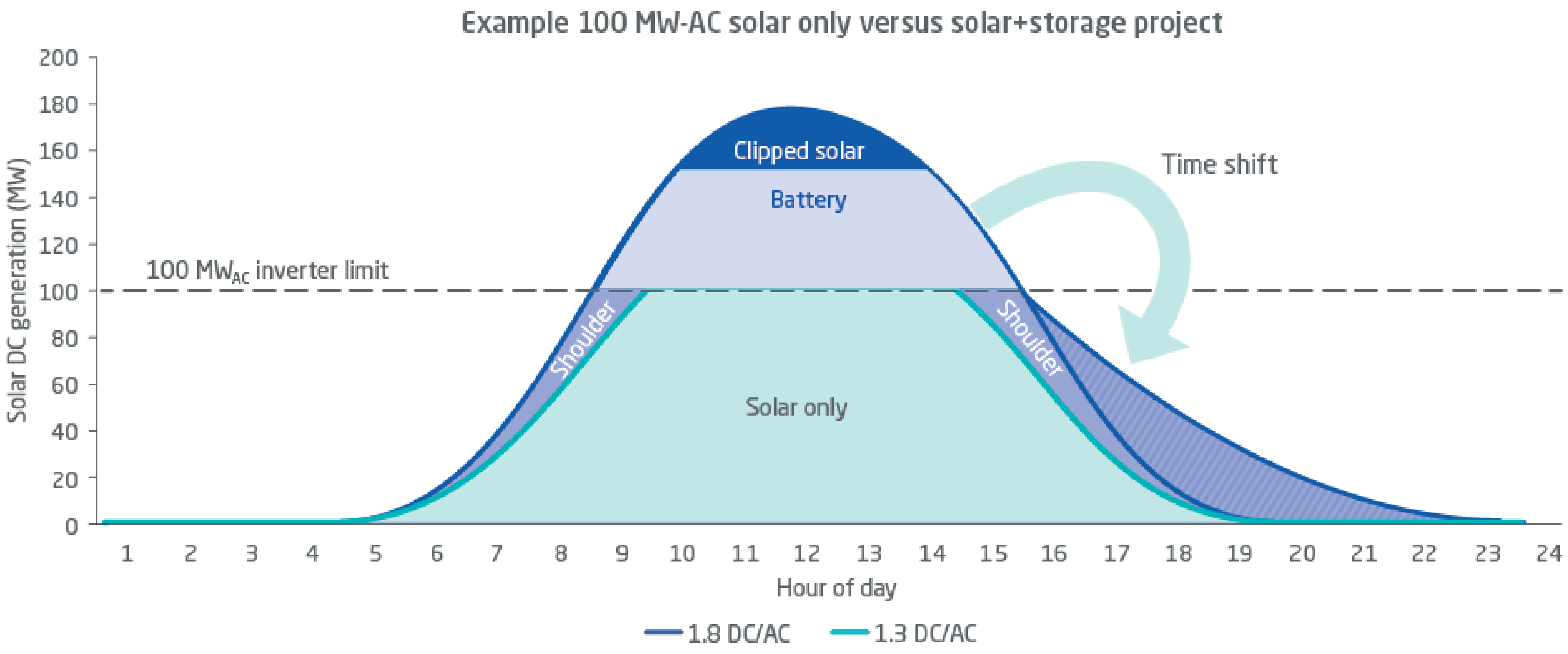
LOW VOLTAGE HARVEST (LVH)

ONLY WITH DC-COUPLED



PV inverters harvest DC input when the array or string voltage is above a certain threshold. *This impacts generation at beginning of day, end of day and in heavy cloud cover.*

Maximizing solar with DC-coupled energy storage



Hybrid Resources – Definition

A combination of multiple technologies that are physically and electronically controlled by the Hybrid Owner/Operator behind the point of interconnection ("POI") and offered to the grid as a *single resource* at that POI

Proposed Hybrid Resources Concept

An "intelligent agent" approach whereby the Hybrid Owner/Operator internalizes the characteristics of the components behind the POI and offers energy and/or ancillary services at the POI in the same way as a conventional resource, but with more flexibility and fewer constraints through coordinated use of energy, storage, power electronics and software technologies

Benefits to System/Market Operator

- Use existing "conventional" market participation models
- Treat hybrid like conventional resources, not renewable or storage resources
- Hybrid Owner/Operator manages state-of-charge (often through their offers)
- Hybrid offers energy and ancillary services in both DA and RT markets
- Offers of energy and ancillary services can be co-optimized from all resources
- Doesn't curtail renewable for headroom – services from battery rate-of-charge
- Provides fully convex, one-part offers* without advance commitment requirements, startup costs, minimum generation levels or other constraints

* Monotonically increasing energy offers without startup or no-load fees. For a good explanation of convexity and offers, see: https://www.iso-ne.com/static-assets/documents/2015/06/price_information_technical_session11.pdf

Benefits to Hybrid Owner/Operator

- Can participate in all market products using an existing market participation model (changing a master data file, not creating a new participation model)
- Treated like conventional resource with full co-optimization of energy and ancillary services offers using existing day ahead and real time constructs
- Allows the renewable component of the Hybrid Resource to generate fully without the need to be curtailed to retain headroom to provide services
- Allows the storage component of the Hybrid Resource to be charged from the renewable component of the Hybrid Resource (or from grid, if allowed)
- Same incentives/penalties for performance as for conventional resources

PV Hybrid Resources – Offers and Operations

Offer strategy based on high-confidence PV forecast

- Offers use probabilistic PV forecast backed by storage to firm variability and forecast uncertainty (day ahead, hour ahead, eventually intra-hour?)
- Creates products by controlling the battery, NOT by retaining headroom on PV
- Battery often used around middle of its range most daylight hours, charged for evening
- Battery state-of-charge is often controlled via the offers of energy and ancillary products (e.g., regulation-up and spin are usually charging the battery)

Hybrid Resources internalize the non-convexities* and the renewable forecasts

- One-part offers*, Pmin=0, Pmax=offer based on P95+ forecast
- No startup time, startup cost, min-run time or other constraints

* Monotonically increasing energy offers without startup or no-load fees. For a good explanation of convexity and offers, see: https://www.iso-ne.com/static-assets/documents/2015/06/price_information_technical_session11.pdf

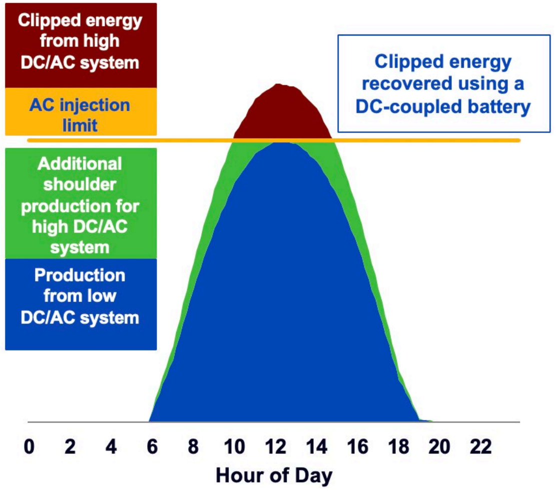
Motivates Beneficial Behavior from the Hybrid

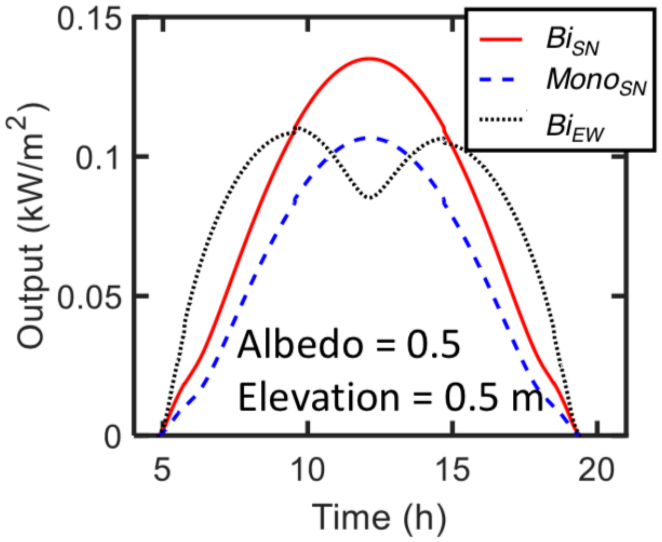
- Sophisticated Analytics – Deeply understanding battery degradation costs, opportunity costs, forecasts and risks, and working to improve them
- Using the best available forecasts of the renewable resource (and investing in improving those forecasts, including probabilistic forecasts that better reflect risk and certainty around the forecasts), because this allows offers of larger volumes of services while managing delivery risks
- Forecasting and offering services so as to be most available during the most critical hours of system need, as this should align with periods of highest value
- Optimizing the power plant design to maximize the services that are useful to and valued by the system while minimizing their risk of delivering such service

Changing Plant Design to Improve Offers

Hybridizing changes plant design

- Leads to dramatic internal design changes and higher effective renewable capacity factors
- Variability is reduced by pushing much of it into clipped region and controlling battery charge rate
- Power forecasting skill can be improved as viewed from the POI
- Many options to optimize layout, orientation, bifacial PV panels, etc.
- Optimizes use of interconnection





From Sun, Khan, Deline, Alam
Optimization and Performance of Bifacial Solar Modules: A Global Perspective
https://www.sciencedirect.com/science/article/pii/S0306261917317567

Hybrid Resources – Summary and Future Steps

Hybrid Resources can initially compete as “generic flexible generators”

- Allow treatment as a single resource – a unified system controlled by an intelligent agent
- Hybrid would give up renewable DIR/PIR-type settlement and other VER accommodations
- Treat Hybrid Resource comparably to a conventional generation resource with a typical forced outage rate, comparable incentives/penalties for performance and contingency treatment

Hybrid resources, operated as a single resource, will eventually change market products, market design and market participation

- No advance commitment, startup costs, minimum generation levels or other constraints

Will we build standalone storage, or mostly just Hybrid Resources?

- Which is better, a highly flexible generator or a battery storage resource?
- What, exactly, is the difference? How does it affect planning, markets and operations?

Mark Ahlstrom
President, Energy Systems Integration Group
VP, Renewable Energy Policy, NextEra Energy Resources
mark.ahlstrom@nexteraanalytics.com
Twitter/LinkedIn @markahlstrom

www.esig.energy

ENERGY SYSTEMS INTEGRATION GROUP