HYBRID ASSETS IN US ELECTRIC GRID INFRASTRUCTURE

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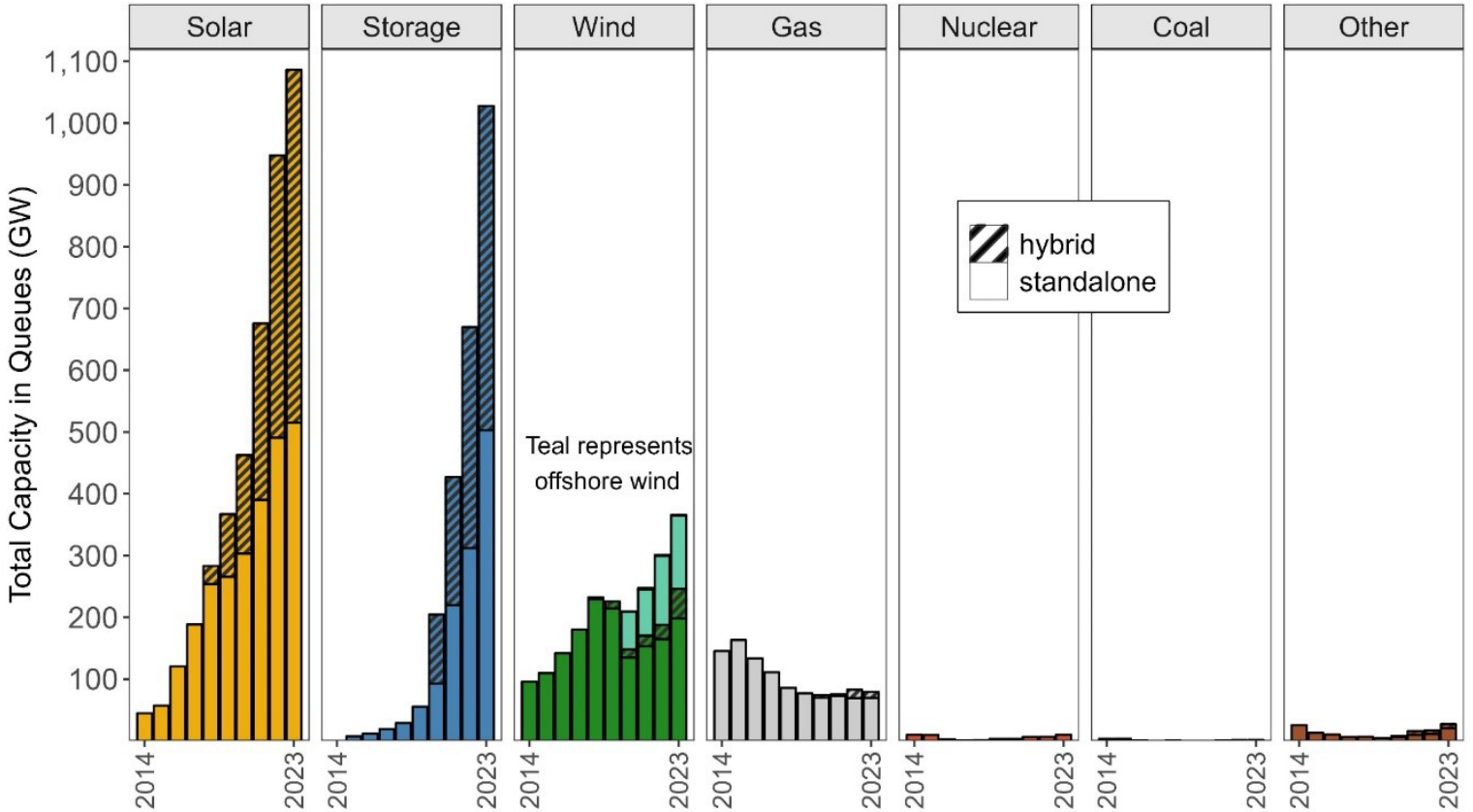
Outline

- Renewable-Battery Hybrid Resources Deployment Outlook
- Benefits of Hybrid Resources to Grids
- PV-Battery Hybrids
- Wind-Battery Hybrids
- Hydro-Battery Hybrids

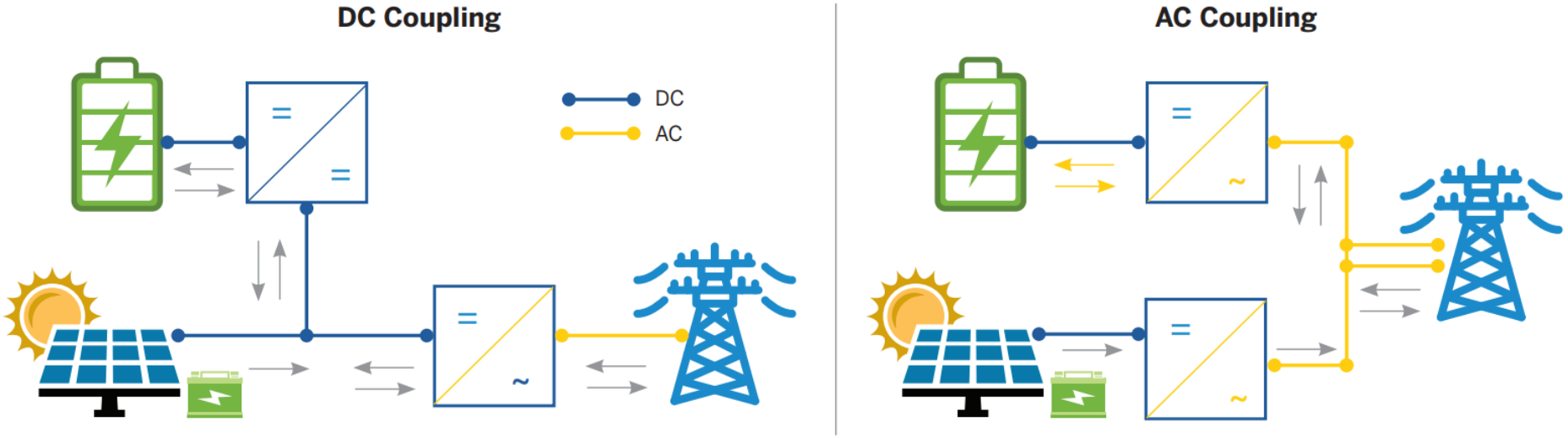
Most of the energy storage projects are hybrid resources

- Co-locating renewable and battery storage was the most popular deployment because of the investment tax credit (ITC) in the past, but the benefits go beyond economical
- 571 GW of solar hybrids (primarily solar+battery) and 48 GW of wind hybrids are currently active in the queues. Over half of the battery storage capacity in the queues is paired with some form of generation.



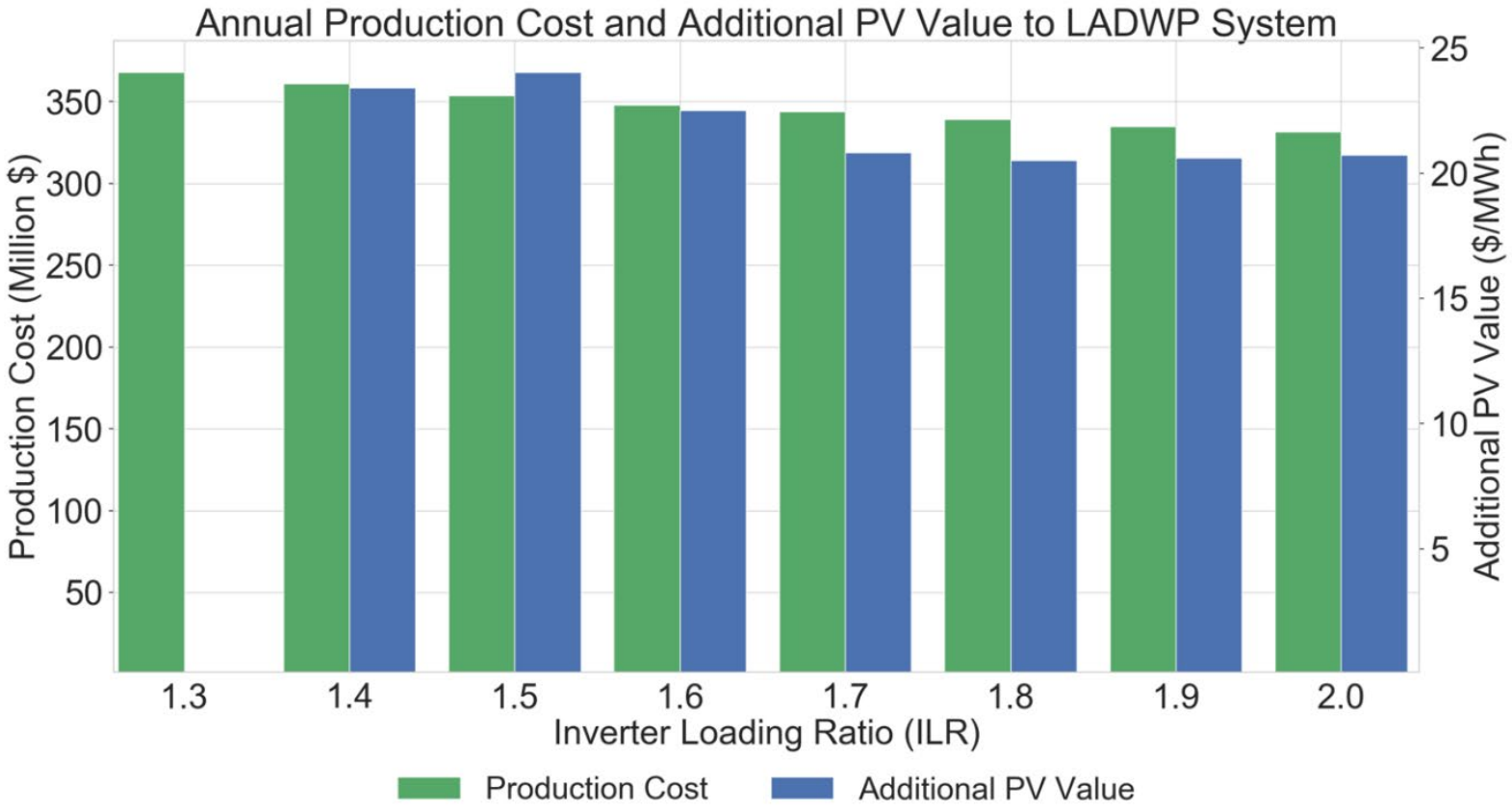
Hybrids improve the utilization factor of grid infrastructure

- A shared point of interconnection for multiple resource types can minimize the need for interconnection upgrades while maximizing available energy and grid services that can be provided at the point of interconnection.
- Shared costs for engineering, land, interconnection, and equipment for multiple resources can reduce overall costs of infrastructure
- Combining multiple resources at a single location can reduce the land needed for renewable projects.



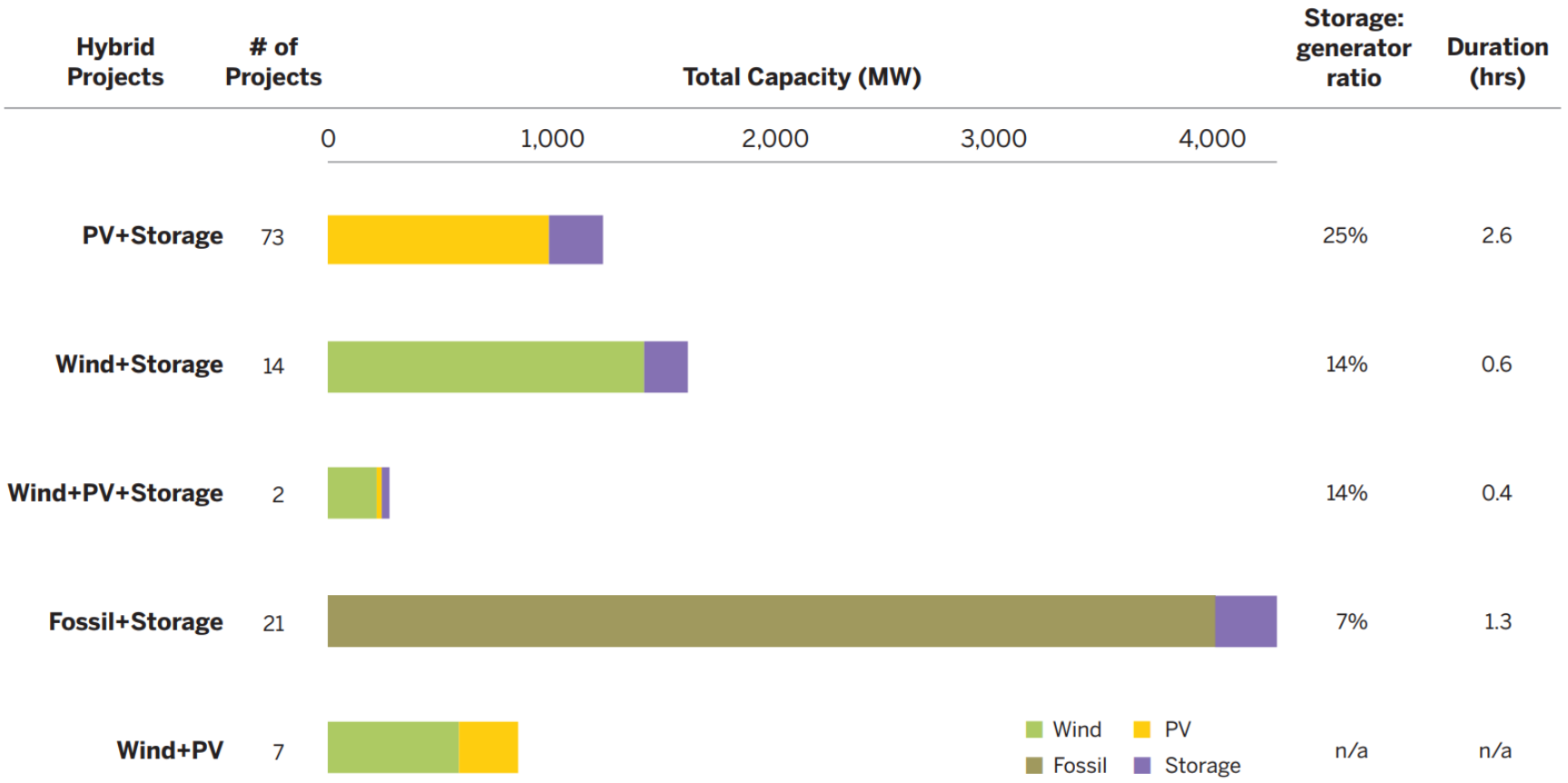
Storage systems enable to capture clipped DC energy

- Clipping losses—which occur when solar plants are designed with a high inverter loading ratio to increase production but lead to some curtailment—can be captured if battery storage is DC-coupled to the solar resource
- Inverter loading ratio is the ratio of DC power over AC inverter
- There is a sweet spot when it comes to sizing batteries for hybrid systems



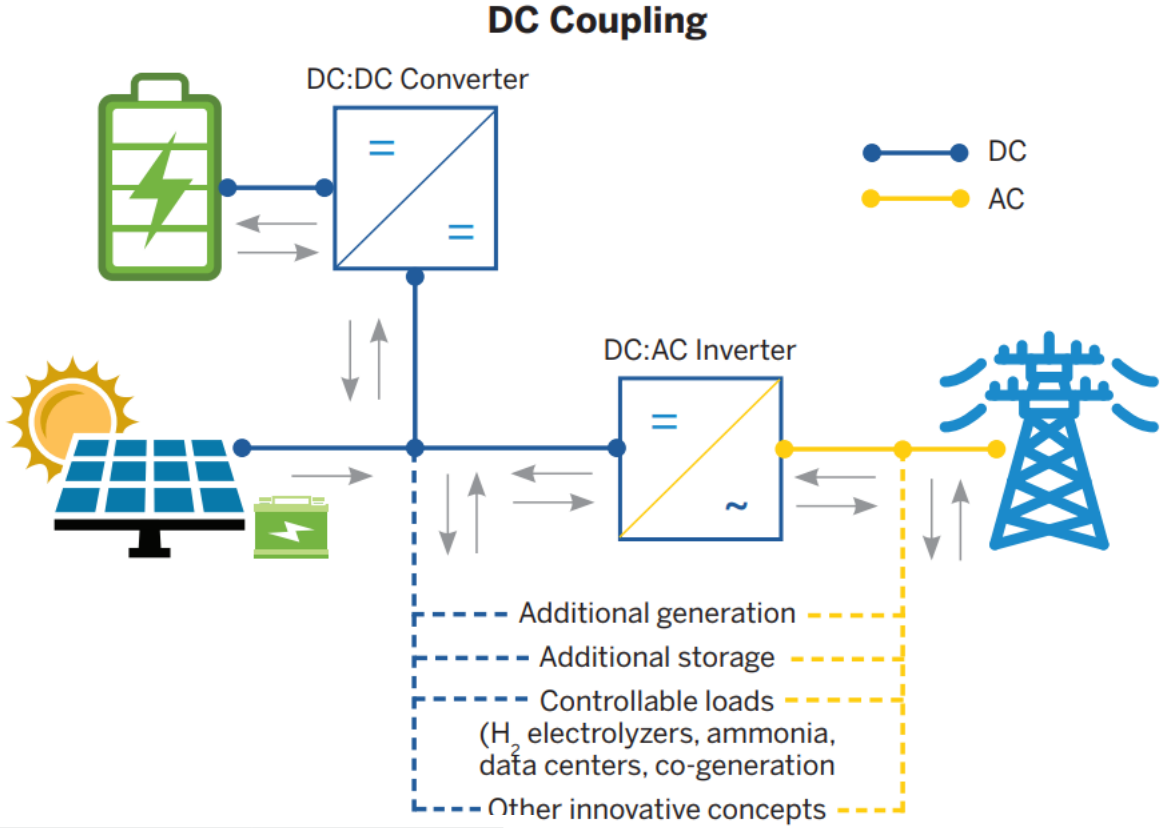
Existing hybrid projects are designed to improve flexibility

- Economic sustainability of energy storage devices limit hybrid resources to have short duration batteries
- Market participation and energy mix in the future will drive long-duration storages



Leverage existing points of interconnection is the biggest strength of hybrid resources

- Leveraging the existing point of interconnection will reduce the need for developing new POI and improve utilization factor of exiting infrastructure
- Improves grid flexibility by adding deferred loads at the POI
- Hybrid setup will ultimately provide renewable system asset owners the ability to meet performance targets (ramp rates, power factor, voltage) defined by system operators



Wind + Solar + BESS Hybrid

100 MW wind
+ 100 MW_{dc} PV
+ 40 MW 4-hour storage

240 MW of resources
100 MW POI

	Capacity Factor of Wind	Capacity Factor of Solar	Capacity Factor of the Hybrid Resource	Curtailment of the Hybrid Resource
New York	32%	23%	48%	1.5%
Texas	40%	34%	63%	1.2%
California	37%	38%	61%	2.6%

Opportunities, challenges, and recommendations

Opportunities:

- FERC Order 845 is a good initiative that made a couple of provisions that allowed hybrid assets to request interconnection lower than their capacity, and change technology during the interconnection study process
  - Increases capacity factor and utilization factor by under sizing POI limit
  - Storage developers are allowed to modify their ‘storage technology type’ if it can meet the targets

Challenges:

- Complex control mechanism: Multiple technologies interact behind the POI but must react to the grid signals as a single inverter-based technology.
  - It is common to see a “fighting” effect the two sources in hybrid act against each other
- Weak grid conditions are POI that have high IBR, and interconnecting a hybrid resource to that POI may decrease voltage stability
  - Changes during the design stage must be employed such that controls can be tuned accordingly

Recommendation:

System operators must update interconnection study assumptions and control considerations