ESIG
ENERGY SYSTEMS INTEGRATION GROUP

HYBRID RESOURCES

What They Are and Why Interest Is Surging

FACT SHEET

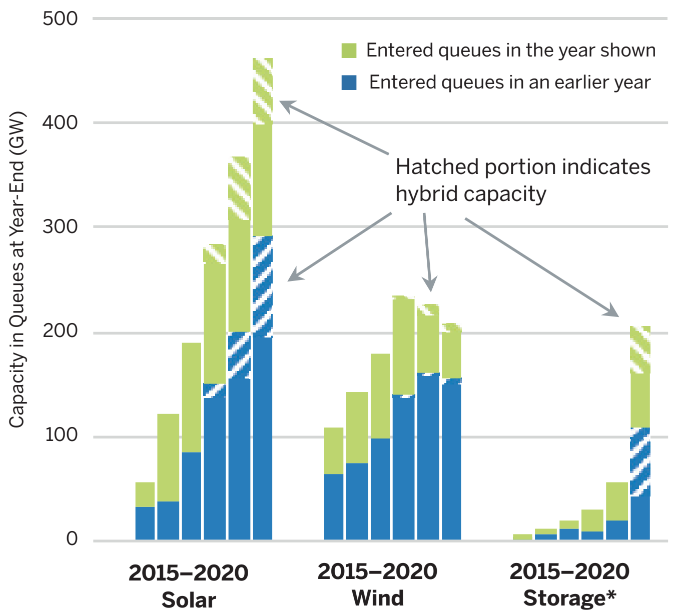
Hybrid resources are broadly defined as multiple resources—some combination of generation, storage, and/or flexible load—sharing a common point of interconnection and operated as a single integrated resource. Electric power systems have seen surging interest in hybrid resources in recent years. Between 2018 and 2021, the total number of hybrid resources proposed in U.S. interconnection queues increased from almost nothing to more than 150 GW, with hybrids constituting approximately one-third of all new solar proposals and more than half of new storage proposals in 2021. Similar trends are occurring globally.

Hybrid resources can offer several advantages for grid operators, resource owners, and project developers, including more efficient use of scarce transmission interconnections, provision of grid services that solar or wind alone often cannot economically deliver, and increased flexibility in how the resource is operated and monetized over time. Hybrids can also help to reduce the need for transmission upgrades.

Recent cost declines and tax incentives for battery energy storage have led to rapid growth in the size, number, and types of hybrid energy systems. Currently, the most common form of hybridization is battery storage combined with utility-scale solar projects and other generation technologies—as shown in Figure 1—but new forms of hybrids are on the rise.

Similar technology is used by wind, solar, and battery energy storage systems to interface with the grid. This commonality of system components, along with the modularity of these systems, makes hybrid configurations particularly economical and reduces engineering challenges. The power electronics where the hybrid resource connects to the grid allow for a common control system that can coordinate the hybrid's overall output and the utilization of its component technologies. By combining renewable energy, storage, controls, flexible loads, and/or other innovative technologies, a hybrid plant can emulate traditional generation, if necessary, and can provide significant flexibility and a wide spectrum of evolving grid services.

FIGURE 1
Wind, Solar, Storage, and Hybrid Project Capacity in U.S. Interconnection Queues



Increasing amounts of proposed wind, solar, and storage projects in U.S. interconnection queues. Hashed portions indicate hybrid capacity that combines solar, wind, and/or storage.

* Hybrid storage capacity was estimated using storage:generator ratios from projects that provide separate capacity data. Storage capacity in hybrids was not estimated for years prior to 2020.

Source: M. Bolinger, W. Gorman, J. Rand, R. H. Wiser, S. Jeong, J. Seel, C. Warner, and B. Paulos, *Hybrid Power Plants: Status of Installed and Proposed Projects* (Berkeley, CA: Lawrence Berkeley National Laboratory, 2021).

This fact sheet is adapted from ESIG's report Unlocking the Flexibility of Hybrid Resources.

Definitions

While the definitions of hybrid resources are often (intentionally) vague, there is some consensus that a hybrid:

- Consists of more than one resource, which may include different types of generation (wind, solar, fossil, etc.) and/or controllable end-use loads
- Includes some amount of energy storage
- Is located behind a single point of interconnection
- Is operated and coordinated to appear as a single resource to the system operator
- Incorporates controls that coordinate the output across multiple resources to maximize value to the system and/or plant owner

These elements of a definition should not be understood overly narrowly or as static. For nascent technologies it can be beneficial to keep definitions intentionally imprecise, to ensure that market constructs and interconnection rules remain malleable for future changes. Market design, interconnection requirements, and incentive mechanisms for hybrid resources should be designed to allow engineers, developers, and resource owners to creatively design systems that meet the physical and financial needs of the system in a reliable and cost-effective manner.

Why the Trend Toward Hybridization?

As the renewable power industry accelerates, utilities, grid operators, plant owners, and developers continue to seek new functionality from wind and solar technologies. This is driven in part by system reliability needs, as grid services formerly provided by fossil fuel power plants must be replaced. Hybrid systems can provide grid services that solar or wind alone often cannot economically provide, and their design can be tailored to fit specific site conditions, grid needs, interconnection rules, and market conditions.

Hybrids often include storage technologies, providing a destination for excess renewable energy while managing the instantaneous injection of power to comply with the interconnection limits and avoid expensive network upgrades. Hybrids can also allow project owners to access additional revenue streams, and reduce plant costs through shared equipment. Key drivers for hybridization are listed in the table.

TABLE 1
Key Drivers for Resource Hybridization

Rank	Key Driver
1	Tax incentives (U.S. investment tax credit)
2	Avoided transmission and distribution upgrades
3	Avoided curtailment of wind and solar
4	Lower development costs
5	Lower financing costs
6	Captured DC clipping losses: Reduced loss of output that results from a solar or wind plant's production exceeding the limit of the plant's inverter ratings
7	Market design rules that limit the market participation of solar or wind alone
8	Simplified procurement for utility off-takers
9	Hybrid resources' flexibility to adjust operations and timing of energy production in the future due to a changing resource mix
10	Land constraints, where co-location of multiple resources can make better use of limited land (i.e., siting solar and wind on a smaller footprint)

This ranking of key drivers for resource hybridization was generated by the members of the Energy Systems Integration Group's Hybrid Resources Task Force.

Source: Energy Systems Integration Group.

Guiding Principles for Market Policies, Interconnection Requirements, and Incentive Mechanisms

Because hybrid resources are still in their infancy, it is important that system operators, policymakers, and regulators take care in how they define market rules and requirements that govern hybrids' use. The following guiding principles should be considered when implementing market policies, interconnection requirements, and incentive mechanisms for hybrid resources.

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- Be less prescriptive and more technology-agnostic with definitions
- Leverage existing points of interconnection for additional resources
- Create multiple, broad participation models to facilitate greater flexibility and innovation, while allowing resources to offer all grid services within their capability
- Develop broad participation models in advance for technologies that are not yet tested
- Allow the resource owner to manage internal operation of the hybrid facility, as long as they meet performance targets defined by the system operator
- Consider synergistic effects and diversity benefits of combining complementary resources
- Reconsider traditional requirements that close doors for future flexibility and services in a transforming grid

The full report, *Unlocking the Flexibility of Hybrid Resources*, provides more specific guidance on the transmission interconnection of hybrids, the market rules and operations for hybrids, and the contributions of hybrids to resource adequacy. All three considerations are essential for the continued deployment of hybrid resources and their important contributions to a reliable, decarbonized power system.

Adapted from *Unlocking the Flexibility of Hybrid Resources,* a report by the Energy Systems Integration Group's Hybrid Resources Task Force. Four fact sheets and the full report are available at https://www.esig.energy/unlocking-the-flexibility-of-hybrid-resources.

To learn more about the recommendations described here, please send an email to info@esig.energy.

The Energy Systems Integration Group is a nonprofit organization that marshals the expertise of the electricity industry's technical community to support grid transformation and energy systems integration and operation. Additional information is available at https://www.esig.energy and info@esig.energy.