Guidehouse

The Renewable Energy Economic Benefits of Microgrids

Produced for the Civil Society Institute

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CIVIL SOCIETY INSTITUTE
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RMI
ENERGY. TRANSFORMED.

Why This Report on Microgrids Was Commissioned

Microgrids are increasingly becoming part of a new, modern electrical energy system. Communities, businesses, and government institutions see them as unique solutions to meet the demand for clean, resilient, and efficient energy. Breakthroughs and cost reductions in solar and battery technologies are making microgrids increasingly accessible and cost-effective. Microgrids can be designed for varying sizes and purposes with a primary benefit of serving diverse community needs. For example, microgrids can link communities and provide people's energy needs, ranging from isolated rural communities to helping support grids in large cities and regions.

Simply put, interest and adoption of microgrids are growing because they help provide reliable, affordable, and resilient energy. And as the recent hurricanes and wildfires remind us, resilient energy systems are critical to protecting people. *They are the future.*

Microgrids provide resiliency in the face of extreme weather and natural disasters by providing people with reliable power during large-scale centralized grid outages. They protect livelihoods during times of crisis, allow critical infrastructure such as hospitals and schools to remain open, and reduce the transmission costs of energy, making electricity more efficient and less costly.

Anchored by solar and energy storage, renewable microgrid technologies could eventually provide a wide range of communities with clean energy and play a major role in a timely response to climate change. And they can help make the transition to EVs.

What is less well-known is the impact of microgrid development on jobs and the economy. To fill that gap, we commissioned this report from Guidehouse so that policymakers, businesses, and advocates could better understand the economic impact of this growing move toward microgrids. The findings prove that pursuing microgrids as a cornerstone of a more resilient America will produce well-paying jobs at all levels and significantly contribute to the economy.

Why This Report on Microgrids Was Commissioned (Continued)

This report shows that renewable microgrid assets can be a powerful engine for change, not only for our environment and for resiliency, but also for our economy.

A microgrid-driven resiliency revolution is at hand. The inertia of our current systems stands in the way because knowledge about solutions remains marginalized and the public remains unengaged—not because there are no alternatives. This report will hopefully give community activists, lawmakers, and the growing businesses involved in microgrids from electricians, construction workers, engineers, and technologists further proof that solutions are within our reach.

Sincerely,

CIVIL SOCIETY INSTITUTE
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Source:RMI

Executive Summary

This report quantifies the economic benefits of the renewable energy assets that underpin microgrids, including energy storage. Microgrids are aggregations of distributed energy resources providing resiliency more sustainably than the alternative of status quo diesel generators.

This report takes a high level forecast of microgrid growth nationally and provides more detail on California and Puerto Rico, two jurisdictions where resiliency has emerged as a major need.

California was selected because its fleet of microgrids has historically been more focused on renewable energy and other clean energy assets than the rest of the US. Because of public policies, this state is maximizing jobs and economic impacts attached to sustainable energy resources. Given the wildfire threats over the past 4 years and resulting power outages—both planned and unplanned—the need for microgrids is clear.

Puerto Rico was selected because it is a US territory where microgrids help reduce the impact of long duration power outages due to insufficient infrastructure spending in past decades. Microgrids are a key part of an overall clean energy transition to reduce the cost of imported fossil fuels.

Deployment of renewable energy microgrid assets across all US states will create nearly 500,000 new jobs over the next decade.

For every $1 million invested in renewable energy microgrid assets, 3.4 skilled jobs are created in addition to $500,000 in additional economic benefits.

Executive Summary

Investment in renewable microgrid assets continues to grow across the US. In 2021, 979 MW of renewable capacity additions will create 17,290 jobs. The national market is expected to more than triple by the end of the decade, potentially creating 496,700 jobs and generating $72.3 billion in GDP. This study captures the current and forecast impact of renewable microgrid assets for the US, including California and Puerto Rico.

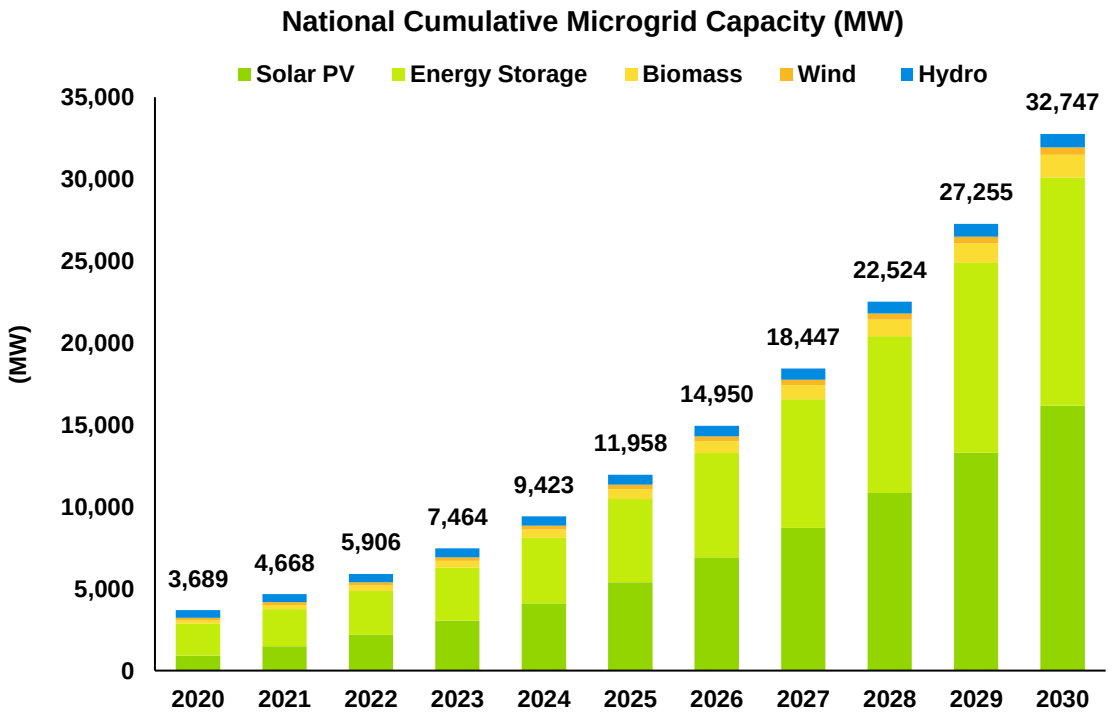
US

Current State:

- In 2021, 4,670 MW of renewable capacity resulted in **17,290 jobs** and contributed **$2.8 billion in GDP** and **$5.6 billion in business sales.**

Forecast Impact:

- Over the next 10 years, national renewable asset microgrid capacity is expected to grow 3.5 times, bringing the total to **32,470 MW by 2030.**
- The forecast spending on renewable microgrid assets is expected to lead to the creation of **496,700 jobs, a positive GDP contribution of $72.3 billion, and $146 billion in business sales.**



These forecasts do not include the tax benefits included in the MICROGRID Act proposed in Congress.

Executive Summary

Investment in renewable microgrid assets in California is forecast to create over 166,000 jobs by 2030 and generate over $22 billion in GDP. Overall installed capacity will grow 14.5 times its current size, a testament to the roles that public policy limiting fossil fuels *and* private sector business model innovation can play in stimulating microgrids that feature carbon-free resources and provide value to the larger grid.

California

Current State:

- As of 2021, microgrids have created **4,670 jobs** and contributed **$0.85 billion in GDP and $1.76 billion in business sales.**

Forecast Impact:

- Over the next 10 years, California's renewable asset microgrid capacity is expected to grow 14.5 times, bringing the total to **10,500 MW by 2030.**
- The forecast spending on renewable microgrid assets is expected to lead to the creation of **166,600 jobs, a positive GDP contribution of $22.2 billion, and $45.5 billion in business sales.**

Source: RMI

Executive Summary

Investment in renewable microgrid assets in Puerto Rico is forecast to create over 9,000 jobs by 2030, generating over $1.2 billion in GDP. Overall installed capacity will grow 3 times its current size. This jurisdiction has a great need for microgrids. If approved deployments of solar PV and energy storage capacity can be integrated into microgrids, these economic benefits can be amplified and bolster community resilience.

Puerto Rico

Current State:

- As of 2021, microgrids have created **163 jobs** and contributed **$26.94 million in GDP and $53.2 million in business sales**

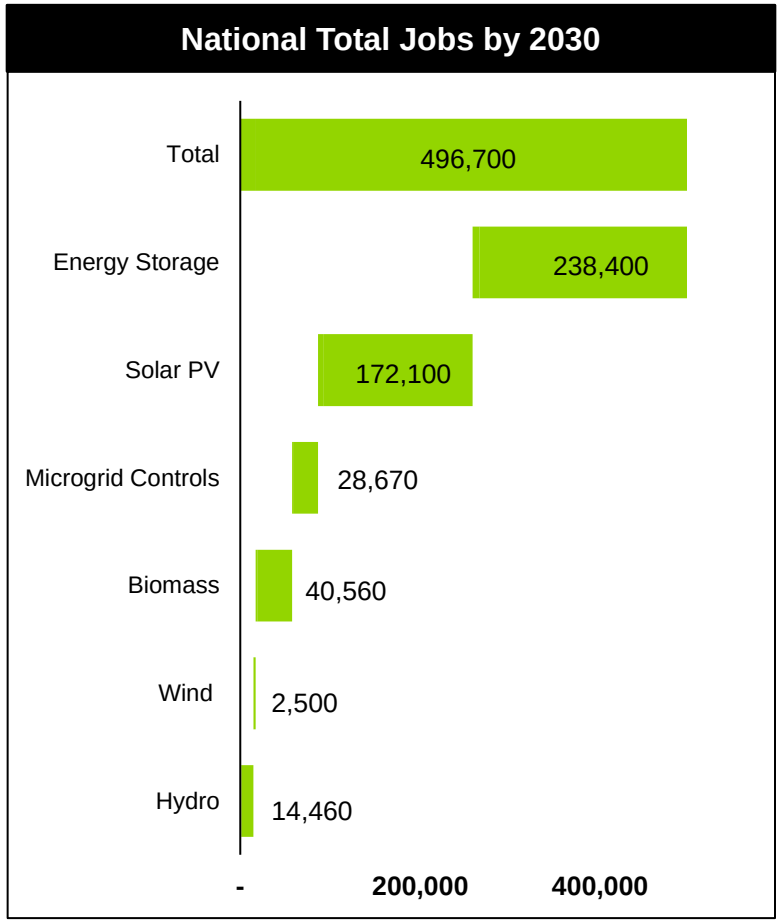
Forecast Impact:

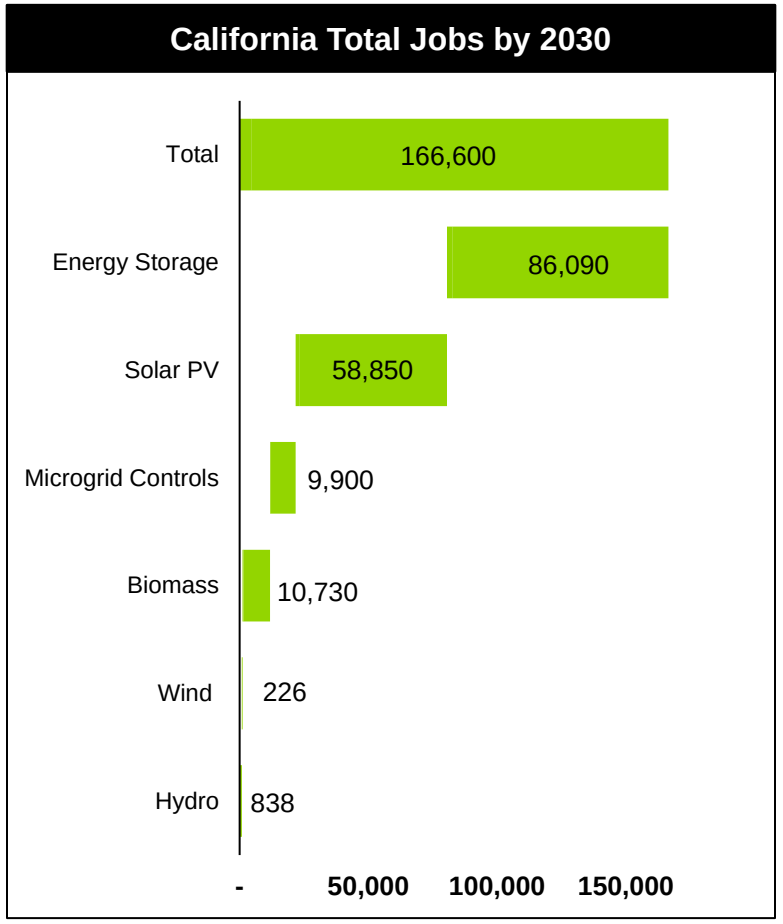
- Over the next 10 years, Puerto Rico's renewable asset microgrid capacity is expected to grow 3 times, bringing the total to **738 MW by 2030.**
- The forecast spending on renewable microgrid assets is expected to lead to the creation of **9,000 jobs, a positive GDP contribution of $1.27 billion, and $2.59 billion in business sales.**

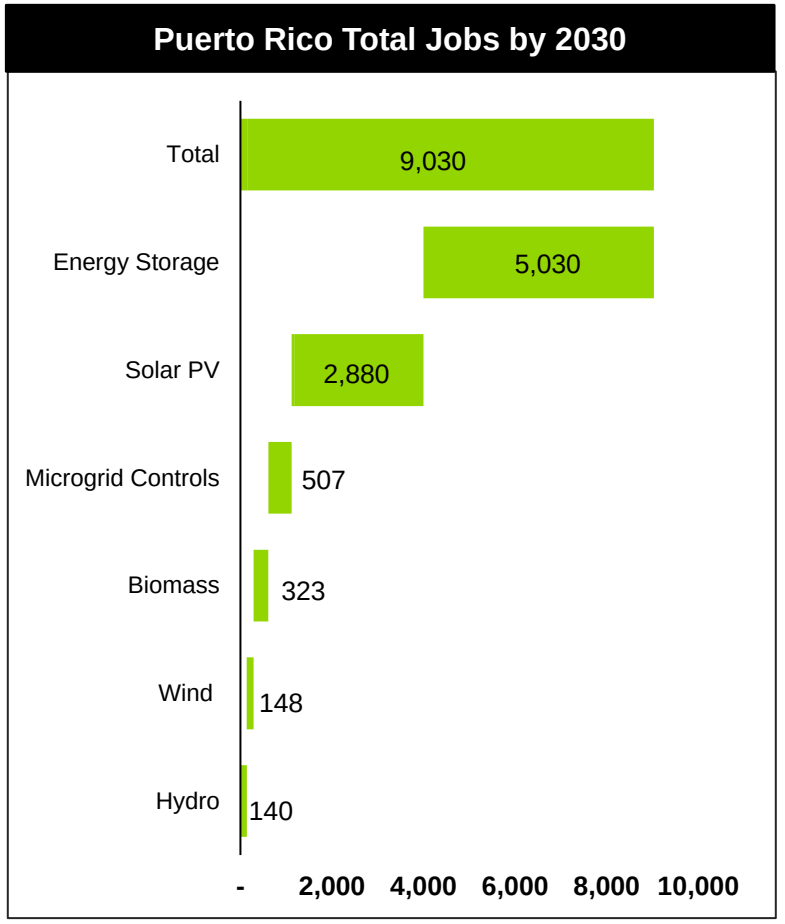
Source: RMI

Executive Summary

The total national, California, and Puerto Rico jobs numbers can be further broken out by microgrid asset type, demonstrating the job potential of each asset. Across all three jurisdictions, energy storage and solar PV assets are forecast to create the most jobs by 2030.







Report Contents

Report Overview

This study analyzes the current and forecast economic impacts of renewable microgrids across the US measured through job creation, with deep dive regional analyses for California and Puerto Rico. This report includes five sections:

1

Microgrids Overview

Introduces microgrids and provides details on renewable microgrid assets

2

Economic Impact Analysis Overview

Overview of the methodology used for the economic analysis

3

US National Impacts

Provides economic impacts of current and future renewable microgrid market conditions in the US

4

Regional Impacts: California and Puerto Rico

Provides economic impact of current and future market conditions in California and Puerto Rico

5

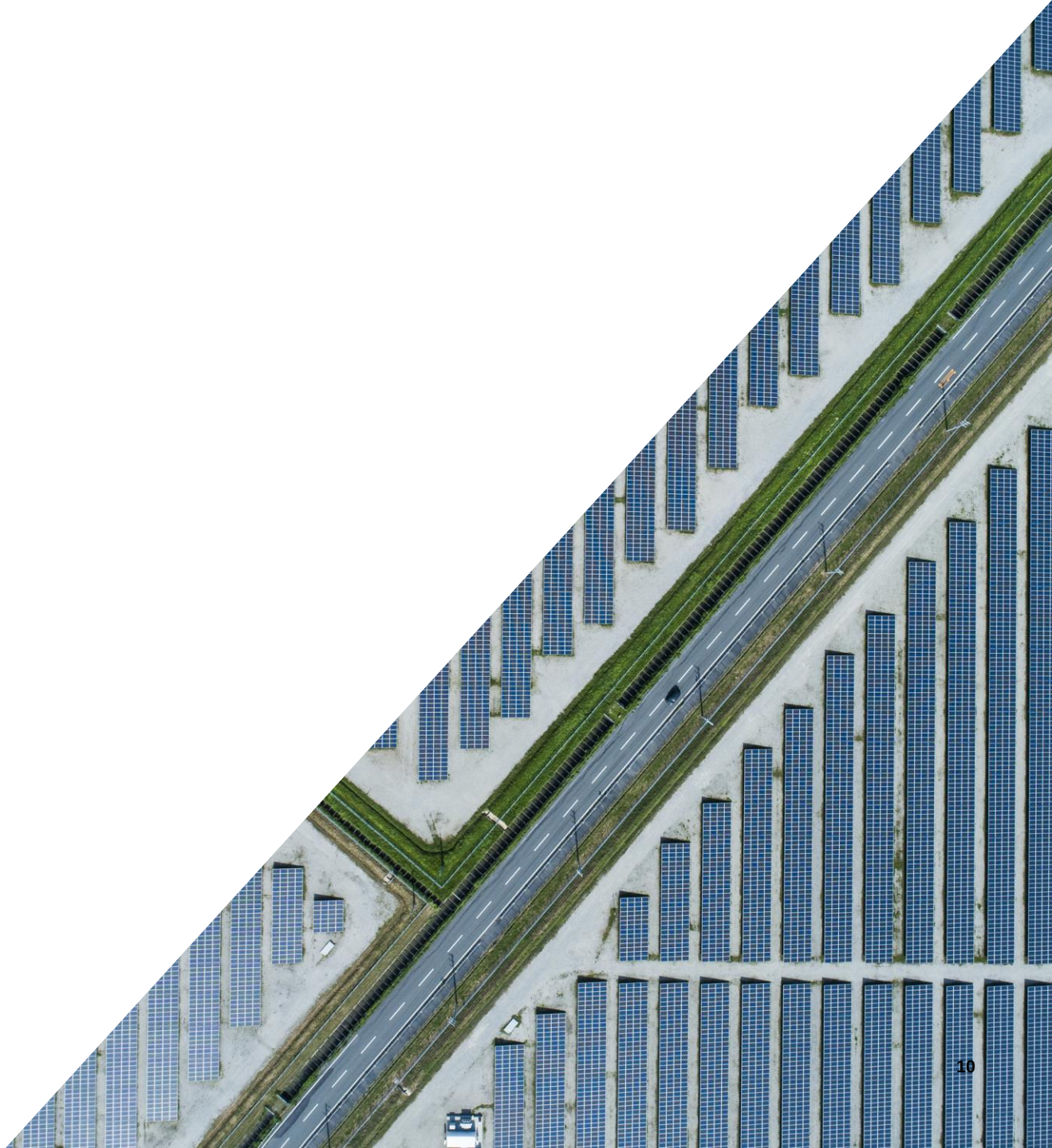
Strategic Observations and Best Practices

Provides insights based on the current market conditions in California and Puerto Rico

This report answers the following questions:

1. What are renewable microgrid assets?
2. What is the current market size of renewable microgrids?
3. How fast is the market for renewable microgrid assets expected to grow?
4. What is the forecast economic impact of renewable microgrids?

1 Microgrids Overview



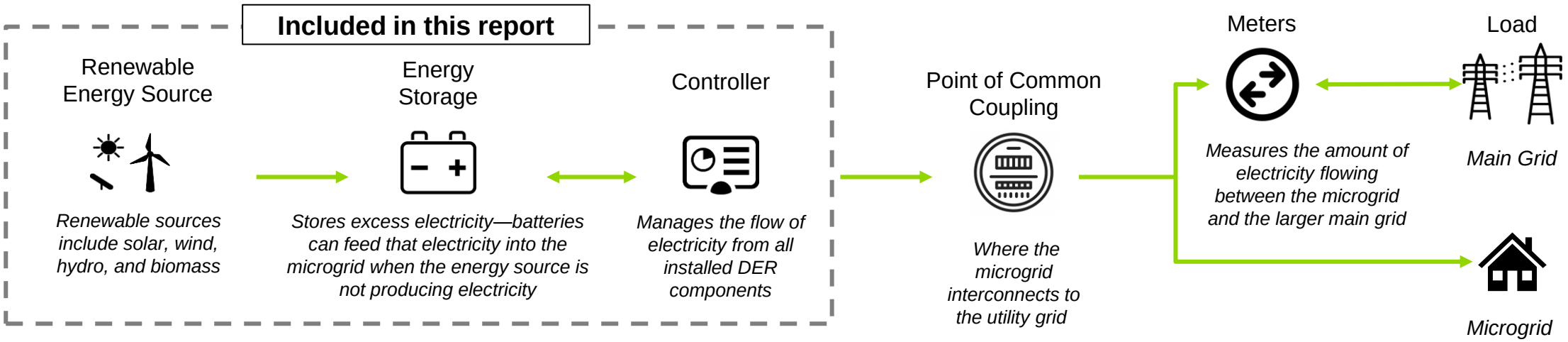
1 Microgrids Overview

What is a microgrid?

- A microgrid is a distribution network incorporating a variety of possible distributed energy resources (DER) that can be optimized and aggregated into a single system. This system can balance loads and generation and run while disconnected from the traditional utility power grid (islanding).
- The key distinguishing feature of a microgrid, especially those that interconnect with the larger utility distribution grid, is the ability to island from the larger grid at the point of common coupling (PCC). Microgrids are typically hybrid systems comprised of renewable and fossil fuel DER assets.

A microgrid at the University of California, Irvine

How do microgrids work?



1 Microgrids Overview | Renewable Technologies

This report focuses on the economic impact of six different renewable microgrid technologies measured through jobs creation. While all six technologies are expected to see significant investment and growth over the next 10 years, solar and energy storage are most dominant today.

Distributed Generation (DG) Solar

Solar technologies rely on chemical reactions to generate electricity. This technology is emerging as the favored renewable energy asset for microgrids.

Distributed Generation (DG) Wind

Wind turbines convert kinetic energy into electricity. They are most often deployed in remote microgrids, often in hybridized systems that may include solar PV, diesel generation, or battery energy storage.

Distributed Generation (DG) Hydro

Micro-hydro technologies use turbines to convert flowing water into electricity. For remote communities, hydroelectricity is an economical renewable energy source.

Distributed Generation (DG) Biomass

Biomass encompasses diverse fuels ranging from wood to sewage sludge to cow manure. These fuels are refined and combusted to generate electricity, often in municipal microgrids or remote systems.

Energy Storage

Energy storage options for microgrids typically come in the form of advanced batteries, though they may also include flywheels and ultracapacitors. Most modern microgrids include some form of energy storage.

Microgrid Controls

Microgrid controls orchestrate generation, storage, and load and enable islanding—the key distinguishing feature of a microgrid for providing resiliency services. They can also maximize renewable energy generation.

Key Renewable Energy Source | Energy Storage | Controller

1 Microgrids Overview | Advantages of Renewables for Enhanced Resiliency

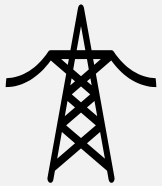
Microgrids make it easier for critical facilities, utilities, communities, and commercial and industrial customers to leverage advances in renewable energy technologies and batteries to work toward a more sustainable, renewable, and reliable energy future.

Advantages of Microgrids Featuring High Renewable Energy Content

Increased Deployment of Renewable Energy Sources

Microgrids offer the opportunity to deploy renewable energy technologies at the distribution level in a way that enhances the reliability of DER installations at customer sites.

Note: Between 1997 and 2020, California installed enough renewable microgrid capacity to power up to 900,000 homes.*



Greater System Efficiency

As microgrids generate energy locally, they reduce the amount of energy that is lost through transmission lines, heat, and other inefficiencies.

Note: In the traditional grid, up to 15% of energy generated is lost during transmission from centralized power plants to end-use customers.

Enhanced Grid Resiliency

Microgrids provide an added layer of resiliency. In the event of a grid outage, microgrids keep critical facilities continuously powered without contributing to climate change.

Note: Microgrids can be more reliable than fossil fuel generators that are currently used to provide emergency power.

Improved Local Electricity Management

When placed strategically within the larger grid, microgrids help alleviate grid congestion, thereby lowering electricity prices and reducing peak power requirements.

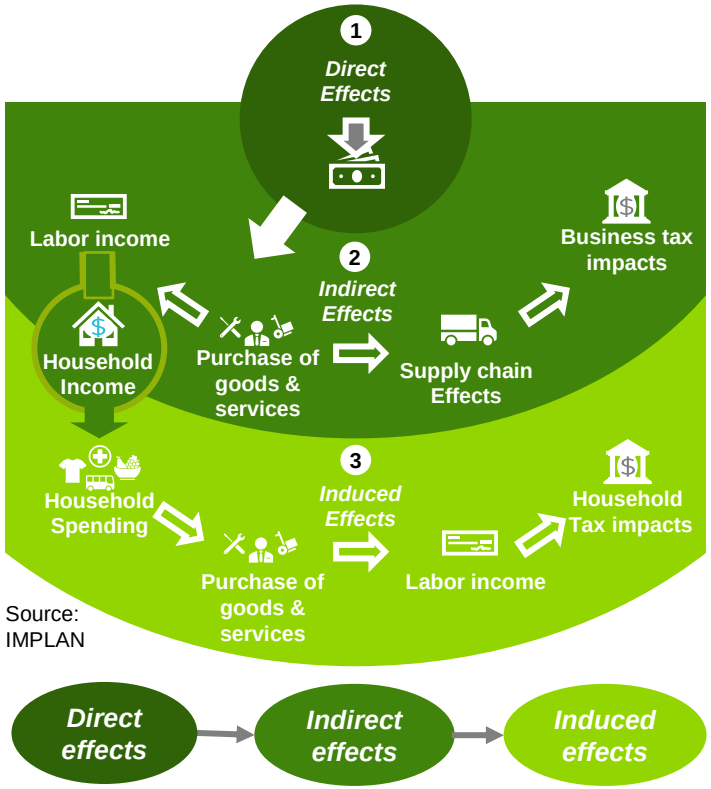
Note: Renewable DER assets can often generate electricity at prices lower than the cost of electricity from many utilities.

*Estimate assumes 668 kWh of monthly power consumption per home

2 Economic Impact Analysis Overview

2 Economic Impact Analysis Overview

This report uses input-output analysis models that show how money circulates through the economy through a supply chain. The effects are categorized into direct, indirect, and induced. This analysis results in three types of metrics referenced in this report: jobs, GDP, and business sales.



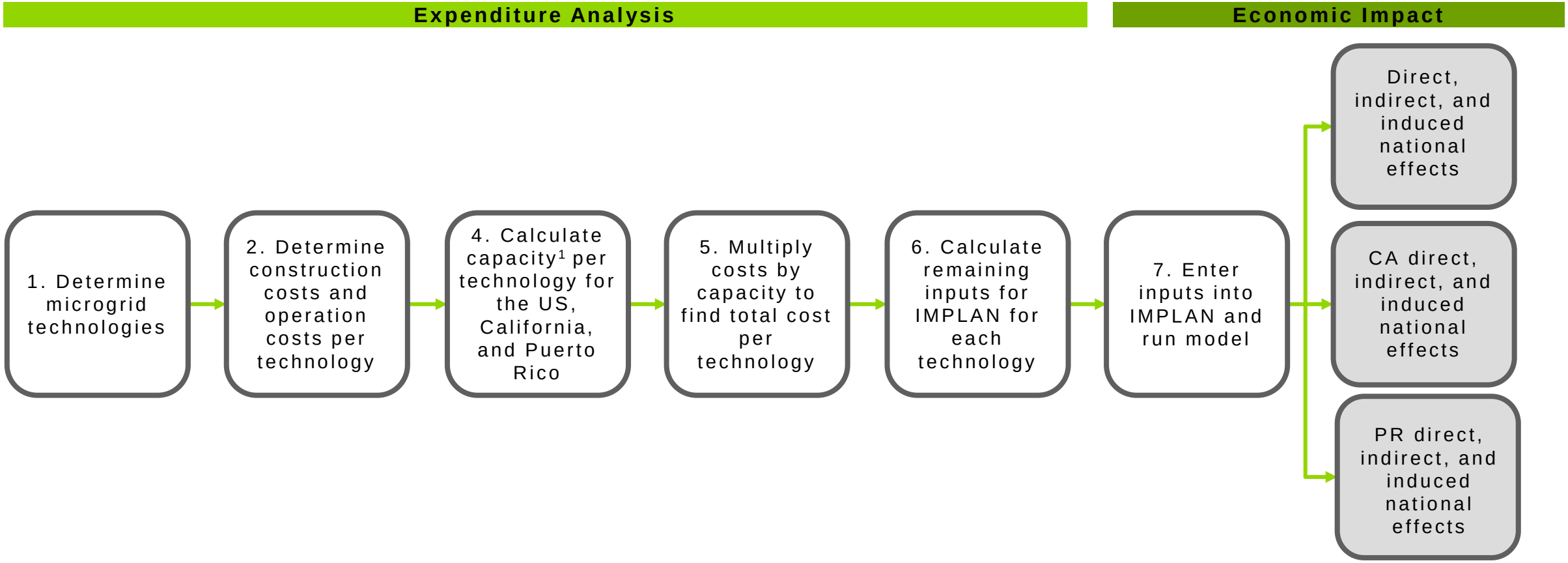
Source: IMPLAN

Type of impact	Example
Direct Effects resulting from direct spending	Spending within the microgrid value chain
Indirect Effects resulting from industries purchasing from each other	Spending on materials, components, and services
Induced Effects resulting from household spending of labor income	Spending on housing, healthcare, transportation, food, retail and entertainment by workers

Metrics used in this report	
Jobs	The number of jobs created from the supply chain activity stimulated through expenditure
GDP	The sum of the value added or 'premium' created from each stage of the supply chain
Business Sales	Sales of goods and services across the supply chain

2 Economic Impact Analysis Overview | Methodology

This report calculates the total current economic impact and the estimated future economic impact of renewable microgrids across the US, in California (CA), and in Puerto Rico (PR). This diagram illustrates the methodology used to calculate both the current and future economic impact of renewable microgrids in sections 3 and 4 of this report. Additional information for the analyses can be found in the appendix.



[1]Guidehouse Insights' *Microgrid Deployment Tracker* provides foundational data for regional DER in microgrid market forecasts, the market shares of which are adjusted by primary and secondary research and overall growth rates for each DER type regionally.

3 US National Microgrid Market – Growth Forecasts

3 US | High Level Summary of Jobs and Economic Impacts

Investment in renewable microgrid assets across the US is expected to continue growing, creating nearly half a million jobs by 2030 and generating over $65 billion in GDP. Installed capacity will grow 3.5 times its current size, with solar PV and energy storage continuing to dominate.

Total Economic Impact

By 2030, renewable microgrids in the US will provide…

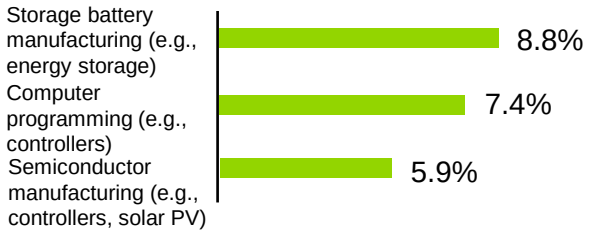
496,653 jobs

$72.3B GDP

$146B biz sales

Top Impacted Industries

Forecast Indirect Impacts



Domestic Production

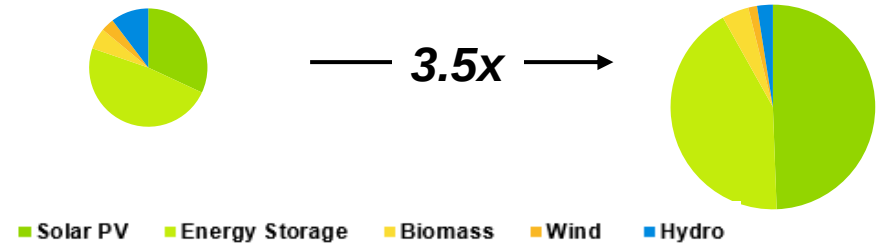
Solar PV	15%
Energy Storage	8%
Wind	60%
Biomass	50%
Hydro	60%

Installed Capacity Inventory

By 2030, installed capacity will grow **3.5 times** its current size, with solar PV and energy storage making up the majority of inventory.

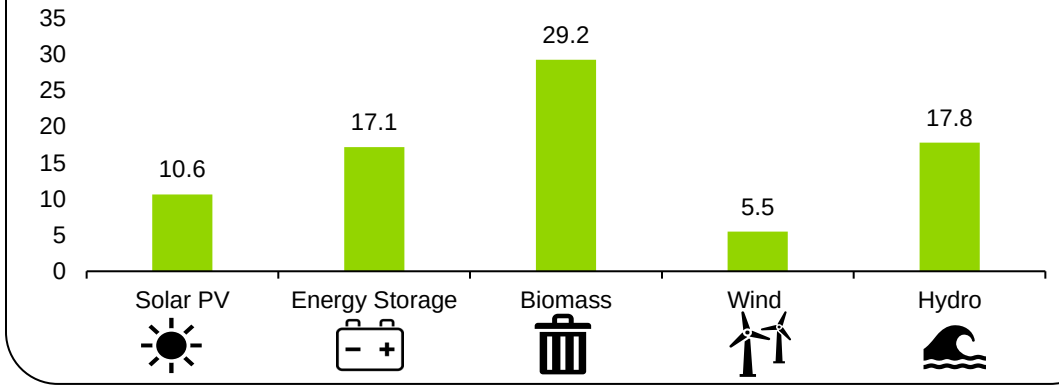
Current (2021)
Total: 9,423 MW

Future (2030)
Total: 32,747 MW



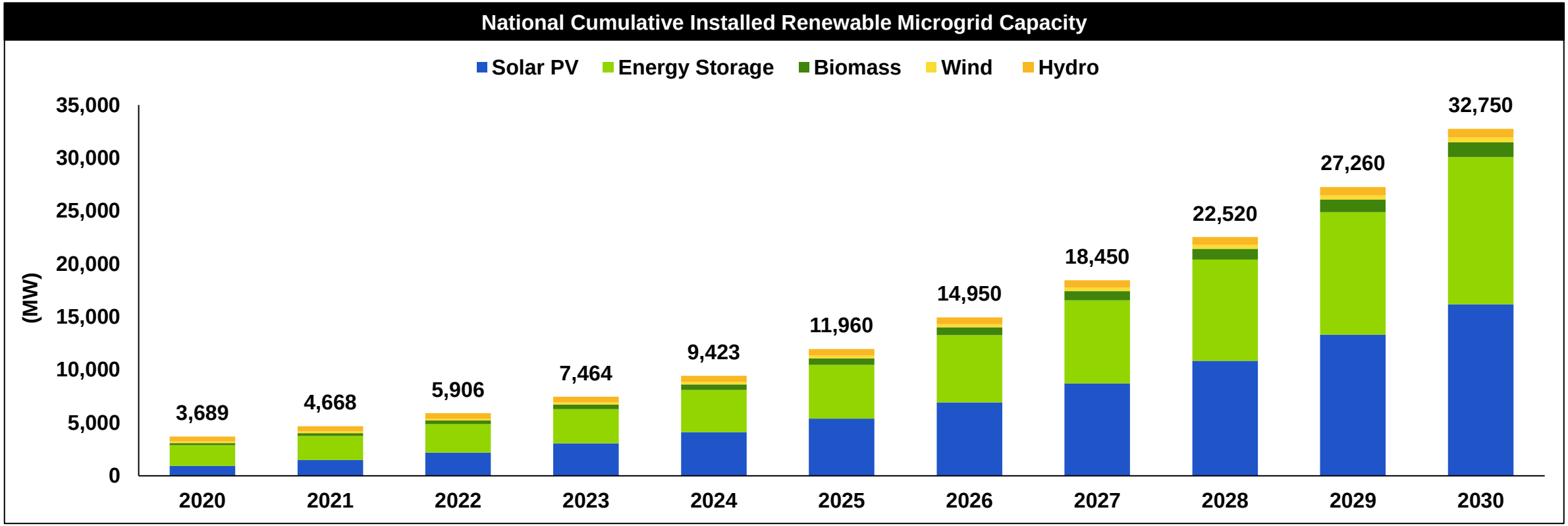
Jobs Created per MW Installed Capacity

Biomass and energy storage will create the most jobs per MW.



3 US | Current and Forecast Renewable Microgrid Asset Inventory

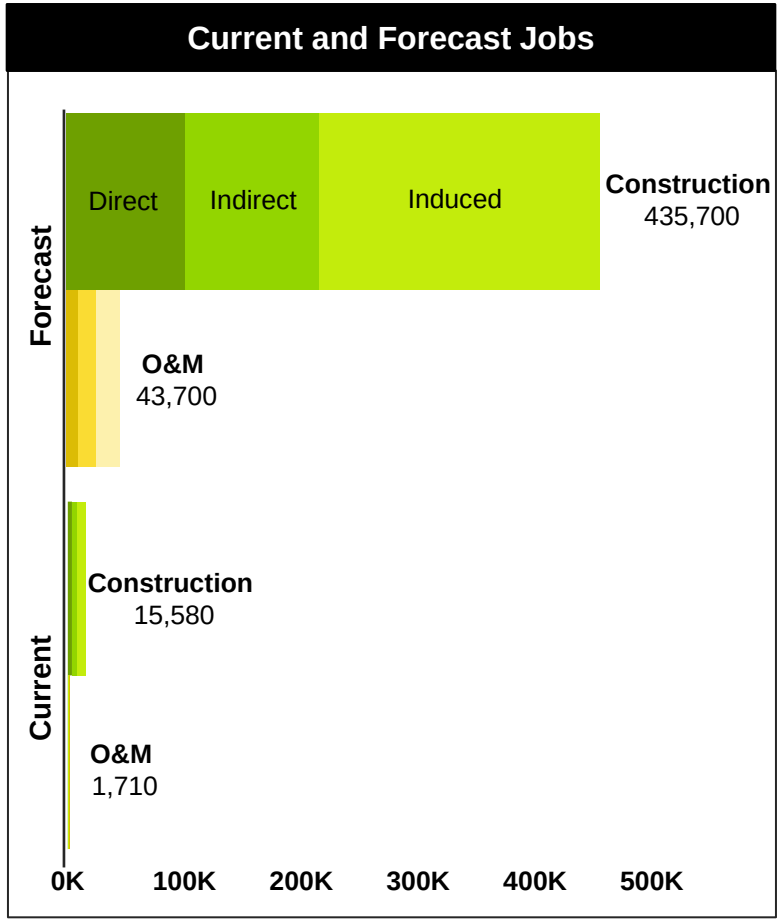
Nationally, renewable microgrid assets are forecast to grow at a compound annual growth rate (CAGR) of 22.5%, with cumulative capacity rising from 4,668 MW in 2021 to 32,750 MW by 2030. The growth in installed capacity reflects a national trend toward integration of renewable energy assets into microgrids to increase grid resiliency while reducing emissions contributing to climate change.

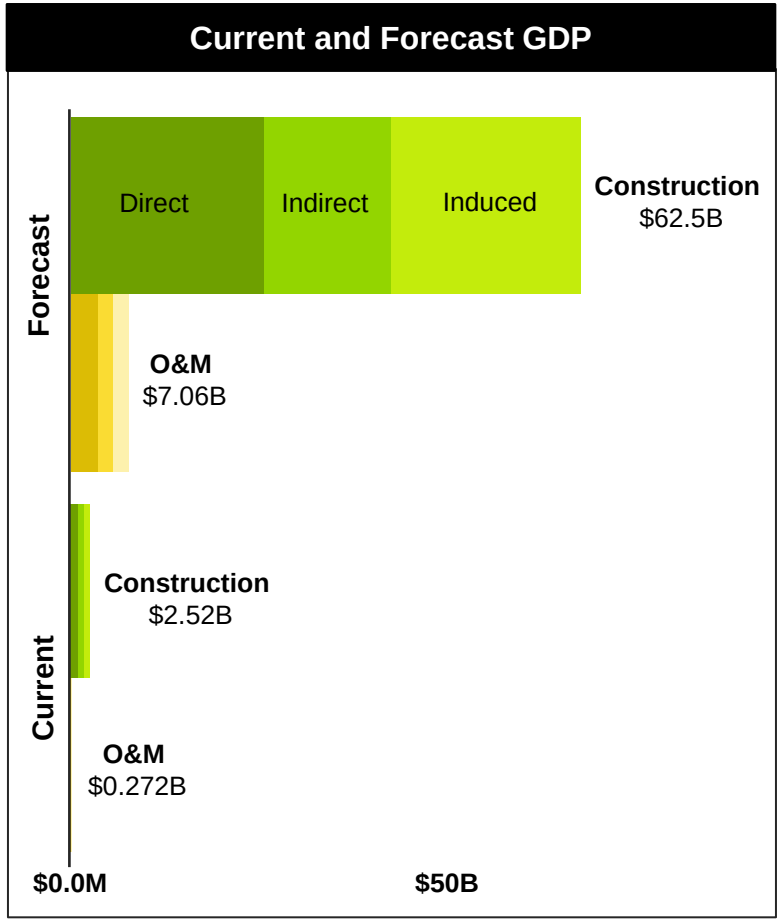


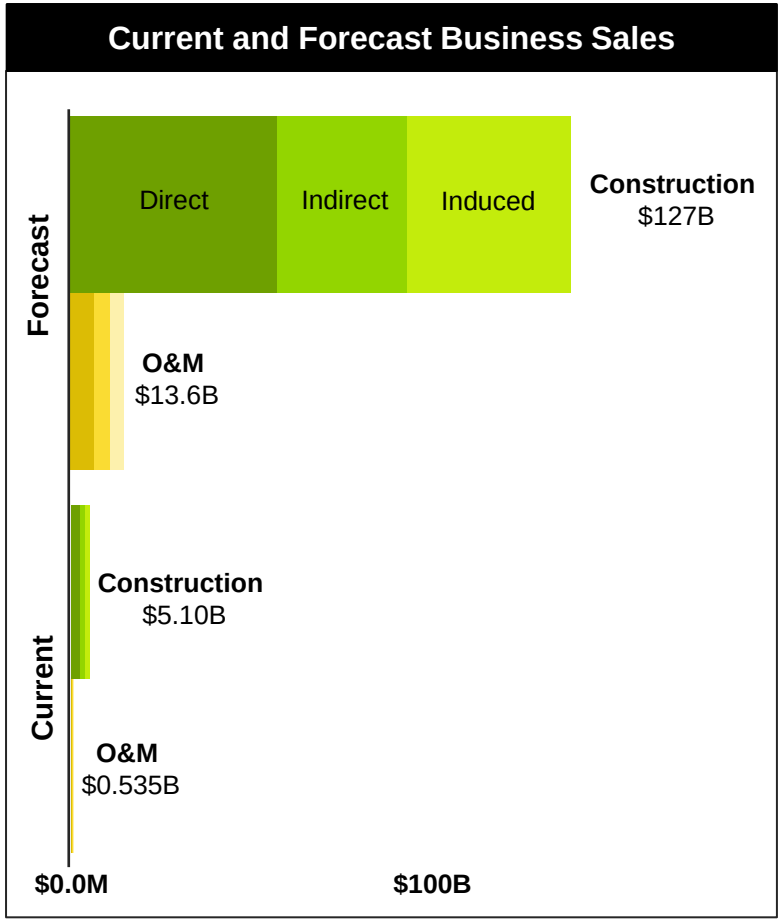
Note: Some historic microgrid installations may be excluded due to data availability issues.

3 US | Impact of Renewable Microgrid Assets

Current and forecast jobs, GDP, and business sales through 2030 are included in the charts below. Across all three metrics, construction accounts for the largest impact, creating 435,700 jobs in addition to generating $62.5 billion in GDP and $127 billion in business sales by 2030.

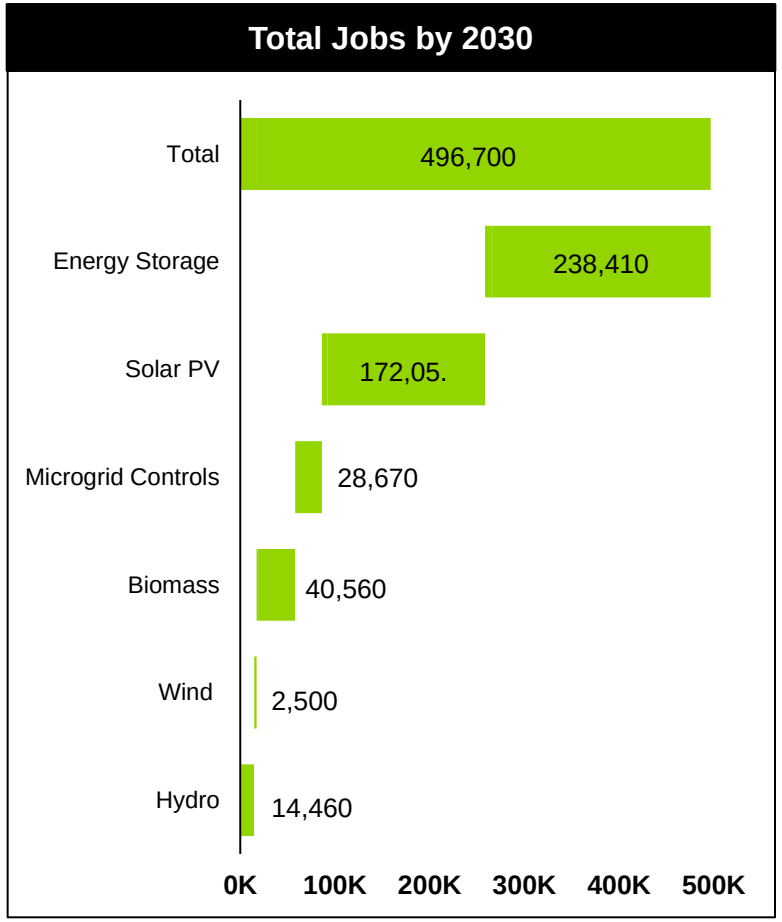


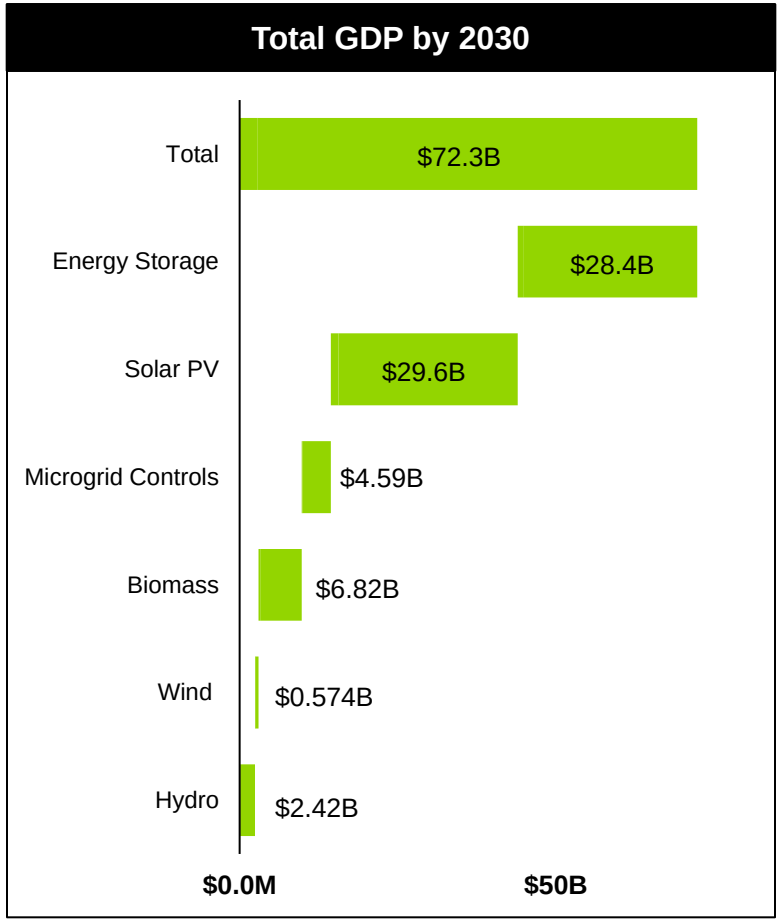


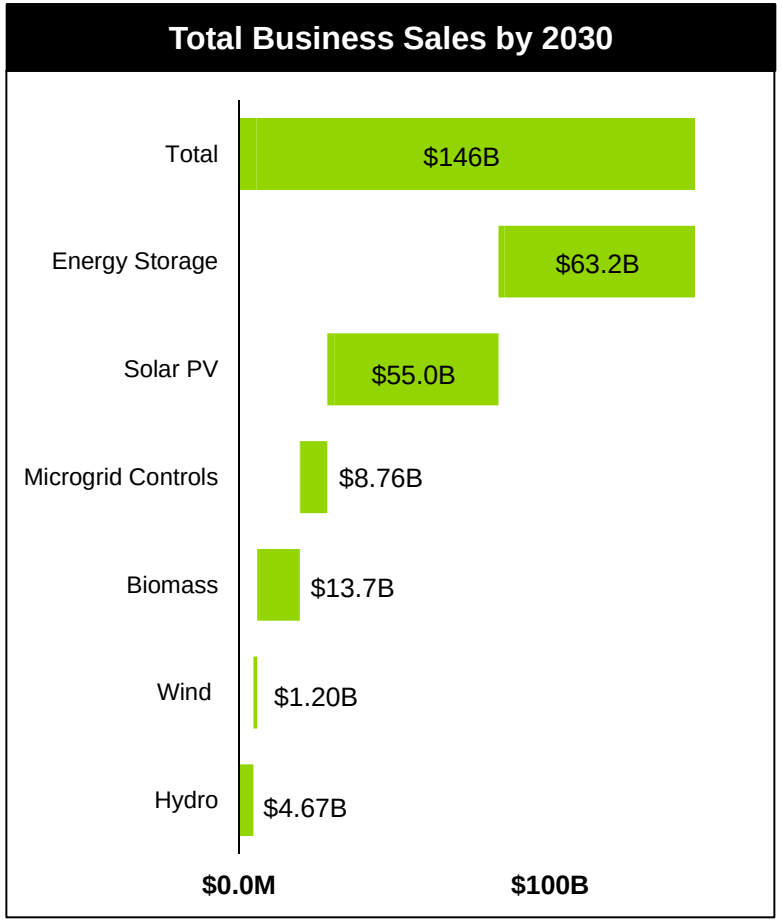


3 US | Impact by Technology Type

The charts below list the combined current and forecast jobs, GDP, and business sales associated with renewable microgrids assets. By 2030, renewable microgrid assets will account for 496,700 jobs—479,400 new jobs will be added over 10 years on top of 17,300 existing jobs.

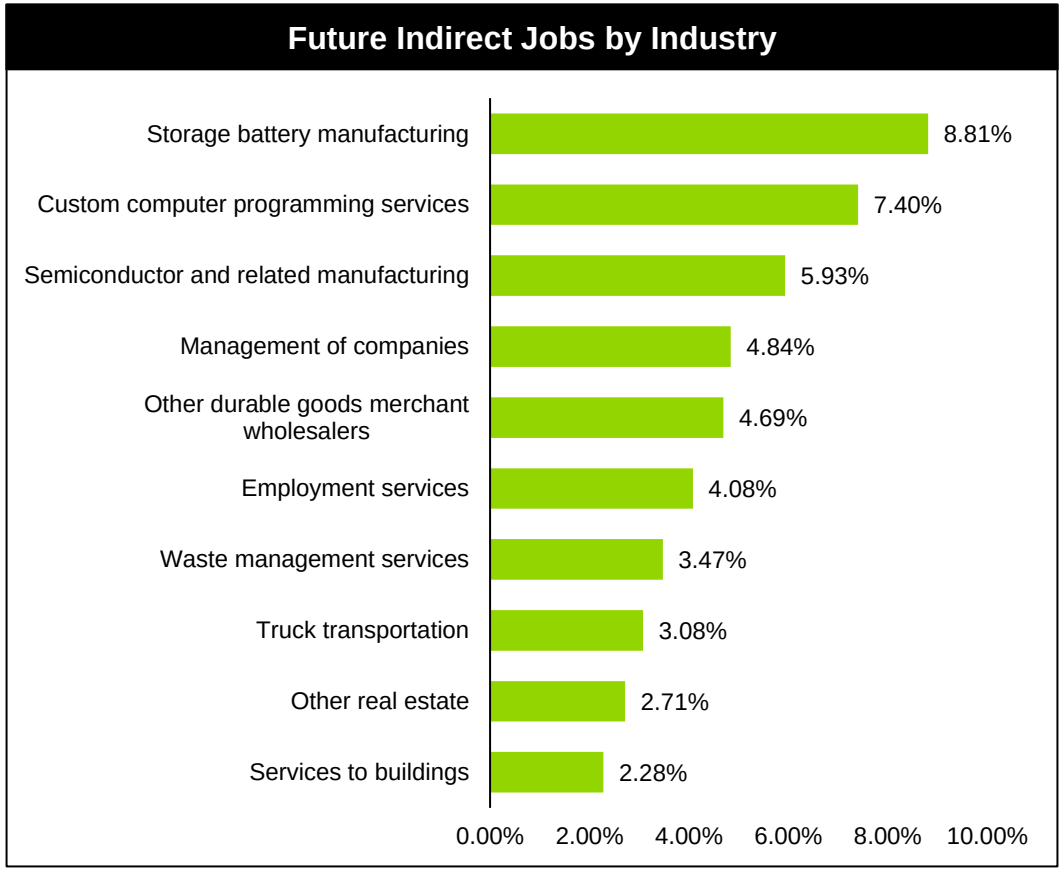


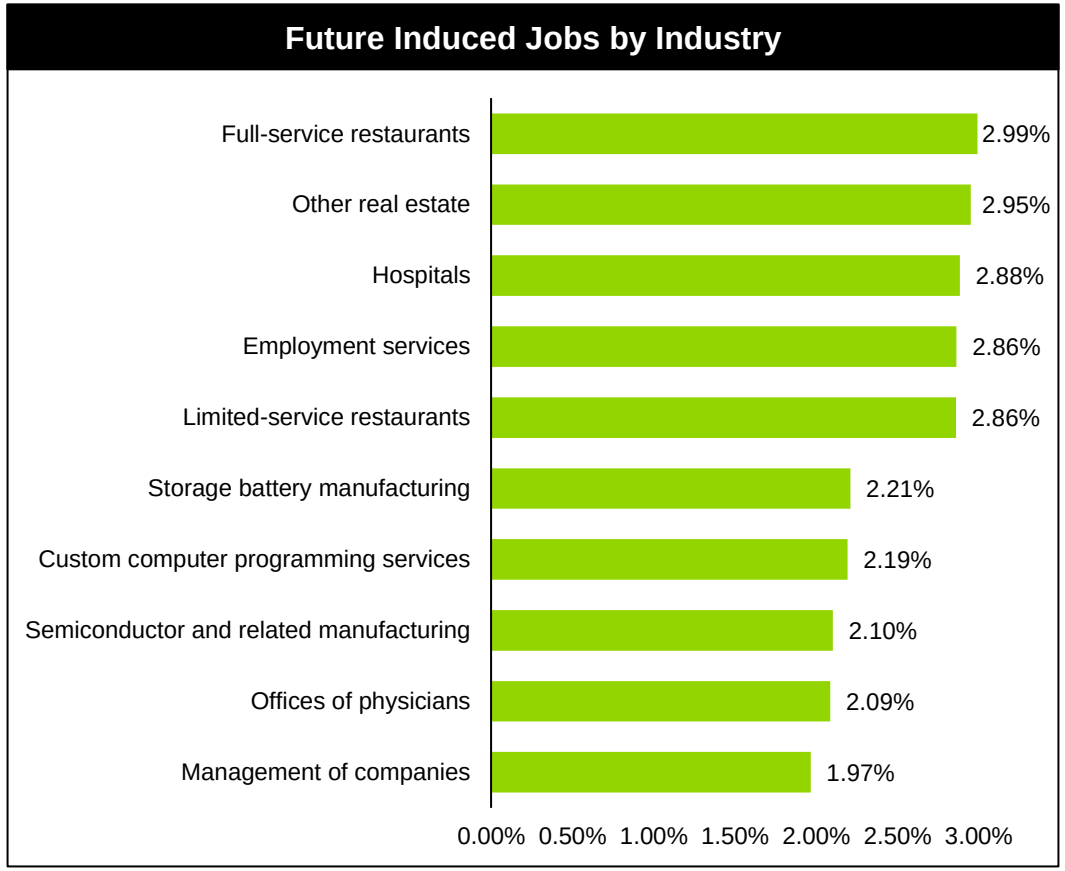




3 US | Forecast Economic Impact on Job Industries

The significant forecast growth in renewable microgrid asset installations will have spillover effects, creating jobs in a wide range of industries. The top three industries for indirect jobs are storage battery manufacturing, computer programming services, and semiconductor and related manufacturing. The top three industries for induced jobs are full-service restaurants, real estate, and hospitals.





4 Regional Impacts: California's Microgrid Market

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4 California | High Level Summary

Investment in renewable microgrids in California is expected to continue growing, creating over 166,000 jobs by 2030 and generating over $22 billion in GDP. Overall installed capacity will grow 14.5 times its current size, with solar PV and energy storage continuing to dominate the market.

Total Economic Impact

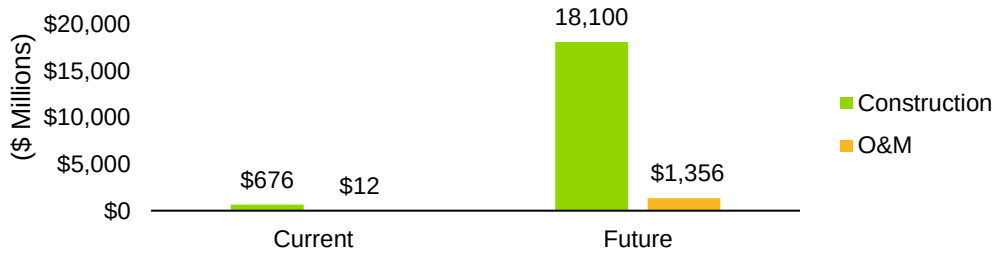
By 2030, renewable microgrids in Puerto Rico will provide…

166,632 jobs

$22.2B GDP

$45.5B biz sales

Total Costs



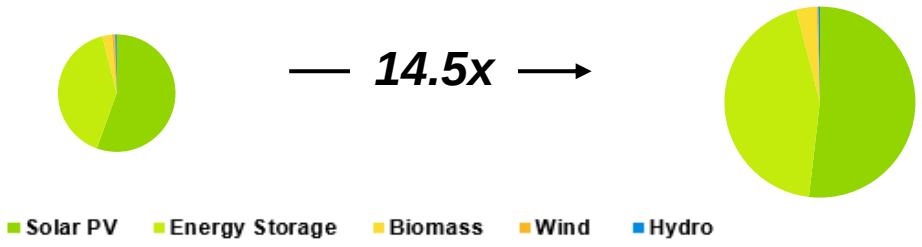
Installed Capacity Inventory

By 2030, installed capacity will grow **14.5 times** its current size, with solar PV and energy storage making up the majority of the inventory.

Current (2021)
Total: 722 MW

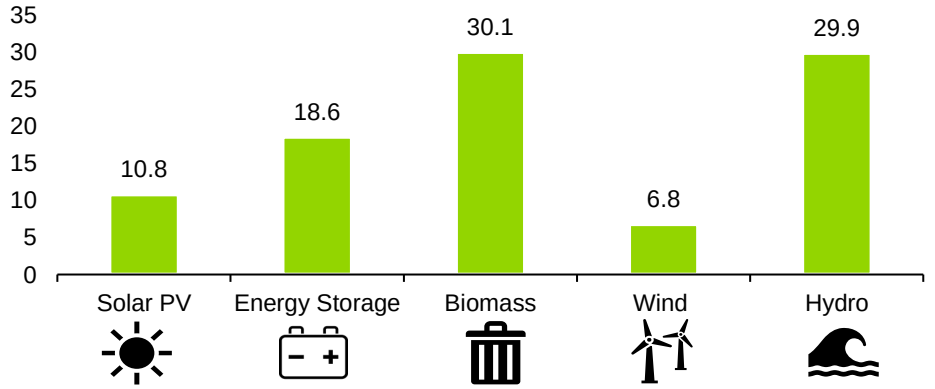
14.5x

Future (2030)
Total: 10,469 MW



Jobs Created per MW Installed Capacity

Biomass and hydro will create the most jobs per MW.



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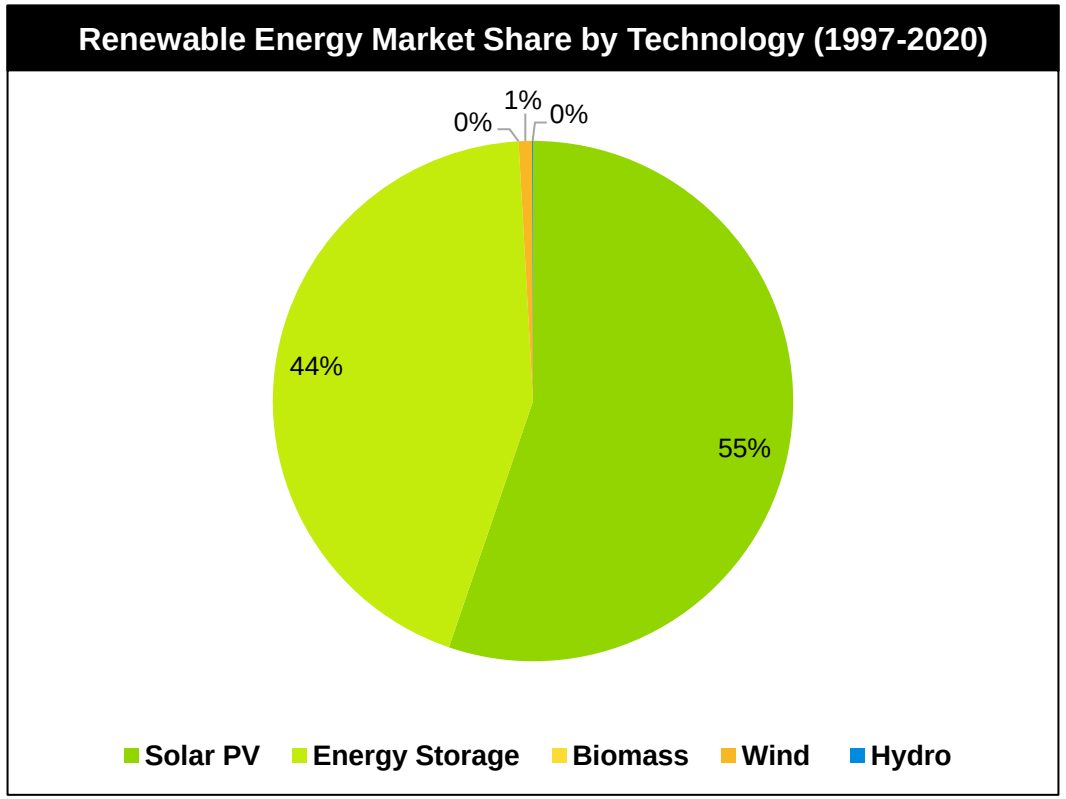
4 California | Historical Capacity Analysis

Over the past 20 years, California's installed renewable microgrid asset capacity has been concentrated primarily in solar and energy storage. These two technologies compose 435.1 MW of capacity. A single hydroelectric DER is installed, producing 0.25 MW, and an additional 3.9 MW of wind turbine DER assets are installed in California. Most microgrids developed in the past are renewable and fossil fuel hybrids.

Renewable Energy Capacity by Technology (1997-2020)		
Technology	**Installed Capacity (MW)**	**% of Total Capacity**
Hydroelectric	0.250	0.0570%
Wind	3.642	0.830%
Biomass	0.0	0.0%
Energy Storage	192.6	43.7%
Solar PV	242.5	55.2%
Total Installed Capacity	**439.0**	**100%**
Controller Total Capacity[1]	**439.0**	**100%**

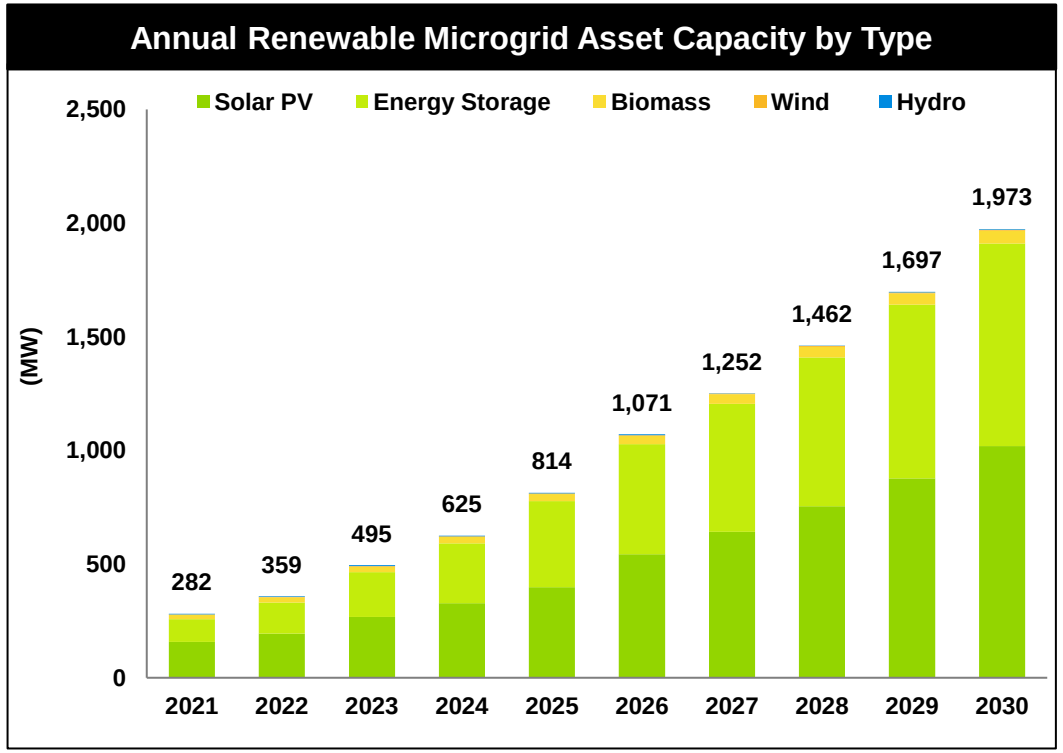
[1] The Sum of Total Power Capacity is the same as the Controller Total Capacity because each renewable DER microgrid asset needs to be optimized by a controller.

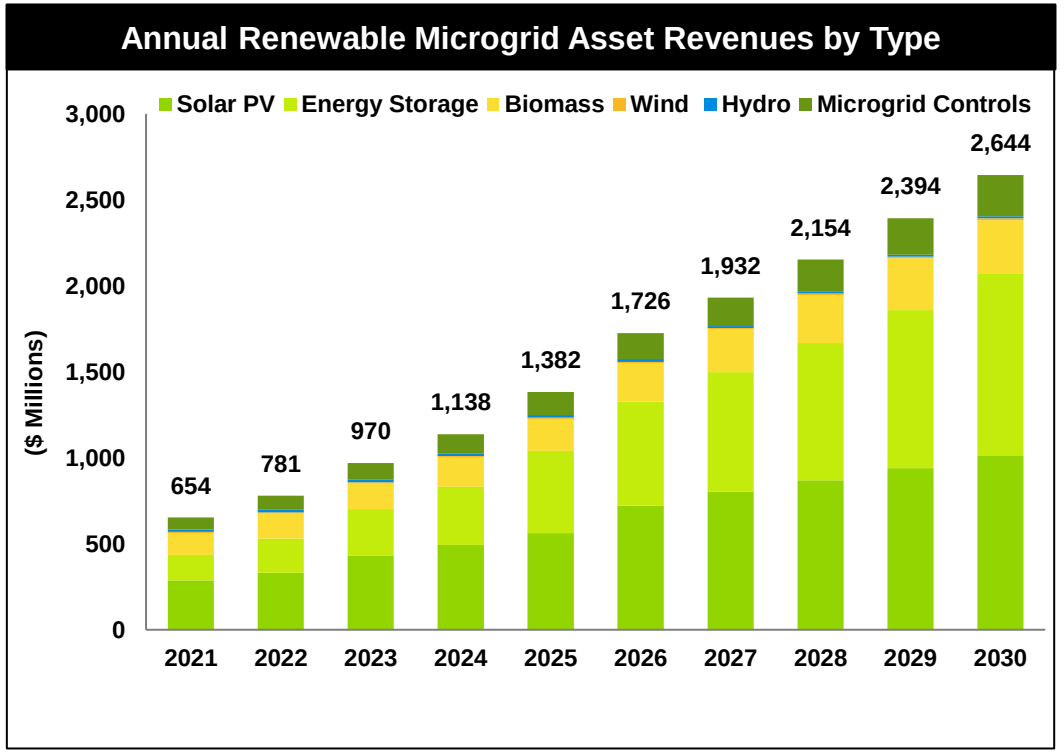
Note: All figures are per Guidehouse Insights' *Microgrid Deployment Tracker,* which includes data on identified specific operating and planned microgrid projects.



4 California | Forecast Renewable Microgrid Asset Trends

Over the next decade, California's installed renewable microgrid asset capacity is expected to grow from 283 MW to over 1,973 MW. The strong growth in microgrid capacity will result from an increased usage of solar PV buffered by energy storage. In the same time period, California's installed renewable DER asset microgrid revenue is forecast to grow from $635.5 million to $2.6 billion annually.

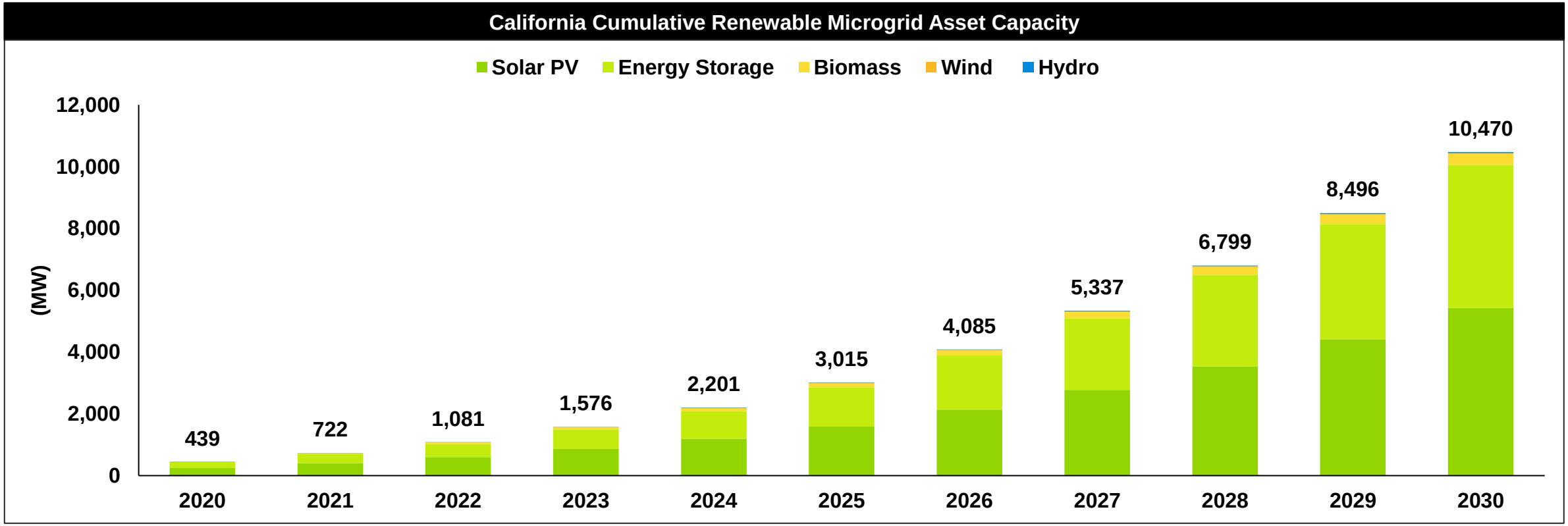




California's renewable DER microgrid assets and revenue are forecast to grow a 17.7% CAGR over the next 10 years.

4 California | Current and Forecast Renewable Microgrid Asset Inventory

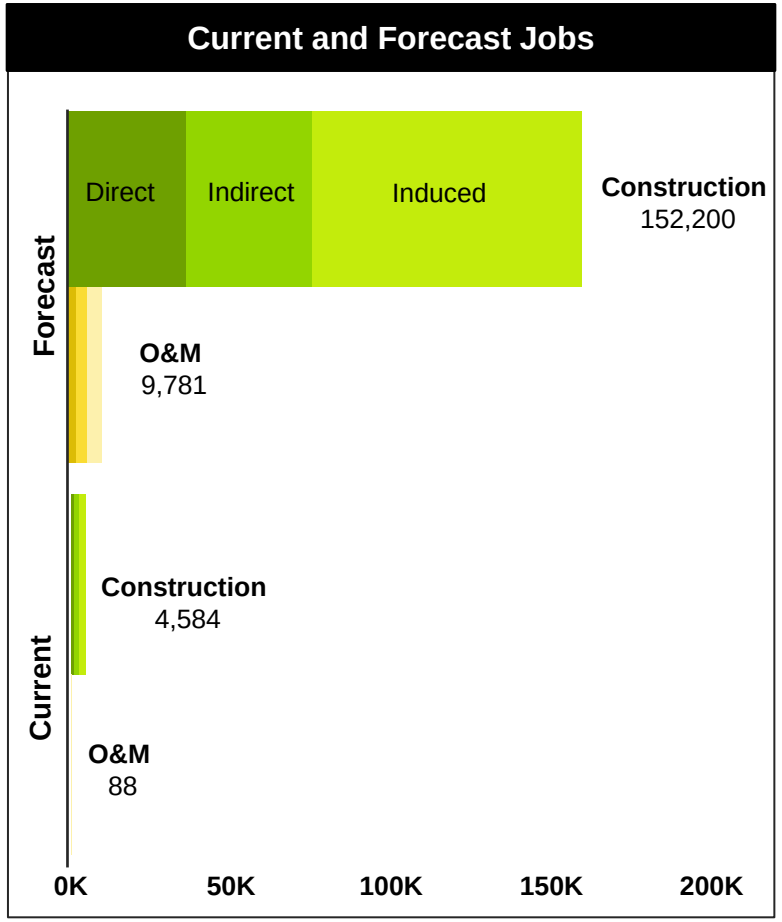
The emergence of viable long-term energy storage solutions, a need to increase grid resiliency to reduce wildfire risks, and an ambitious statewide goal of 100% renewable energy by 2045 all support California's microgrid growth. California is forecast to have 10,470 MW of cumulative installed capacity by 2030, with these renewable microgrid assets growing at a CAGR of 17.7%

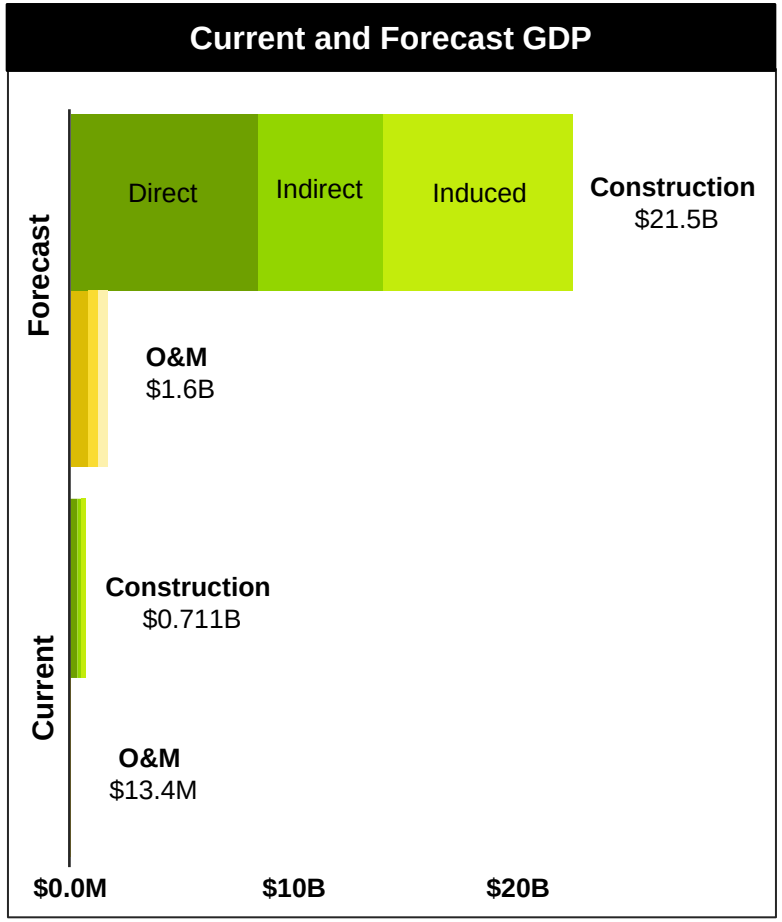


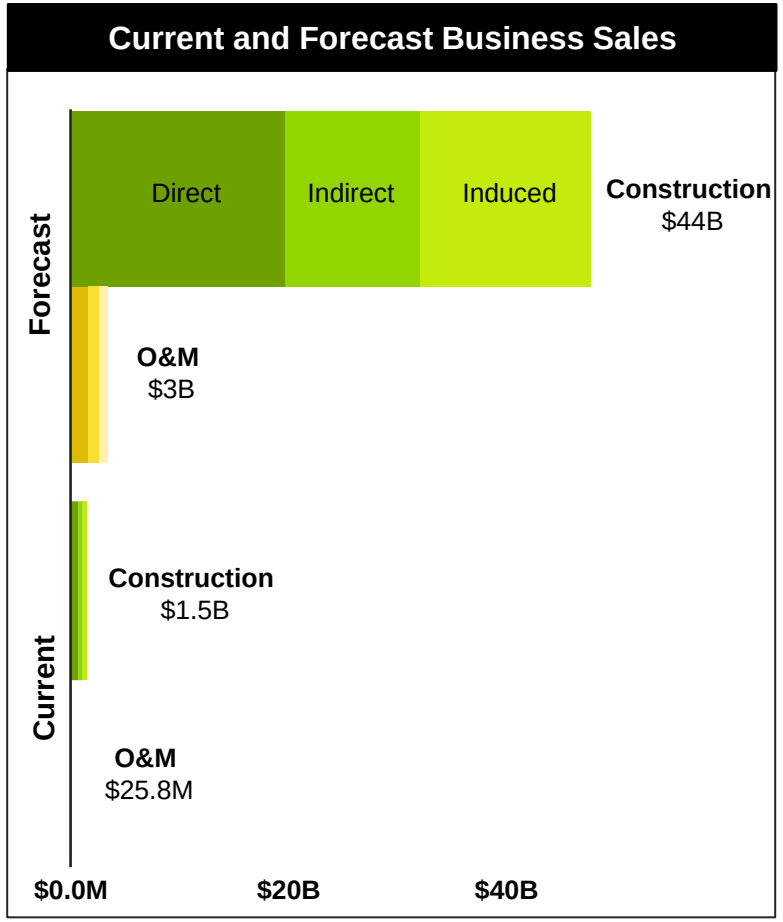
Note: Some historic microgrid installations may be excluded due to data availability issues.

4 California | Impact of Renewable Microgrid Assets

Current and forecast jobs, GDP, and business sales through 2030 are included in the charts below. Across all three metrics, construction accounts for the largest impact, creating 152,200 jobs in addition to generating $21.5 billion in GDP and $44 billion in business sales by 2030.

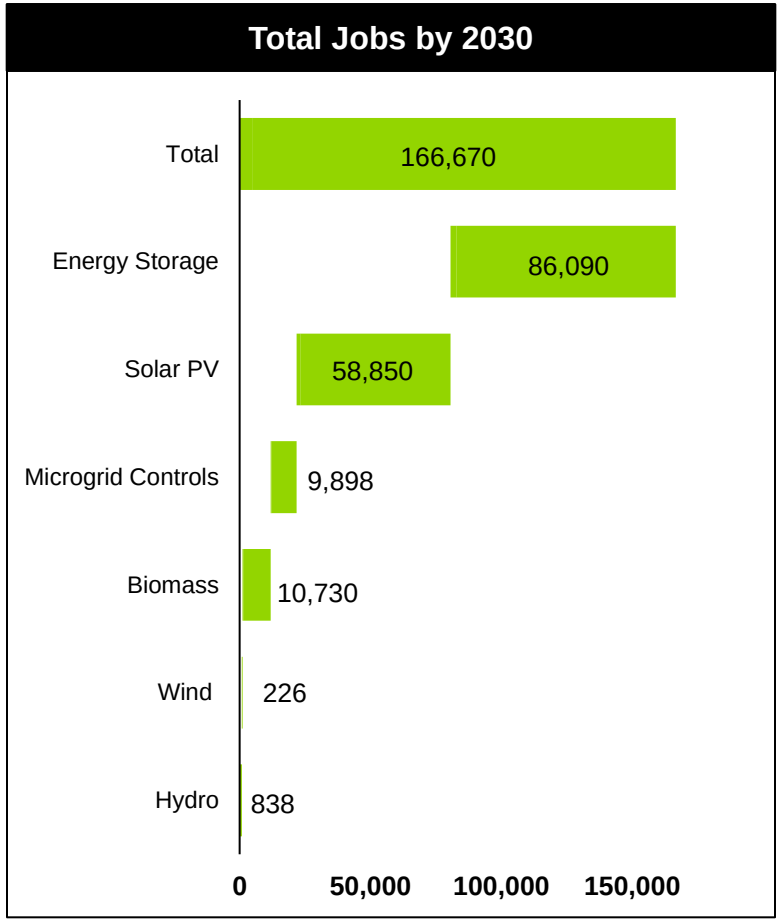


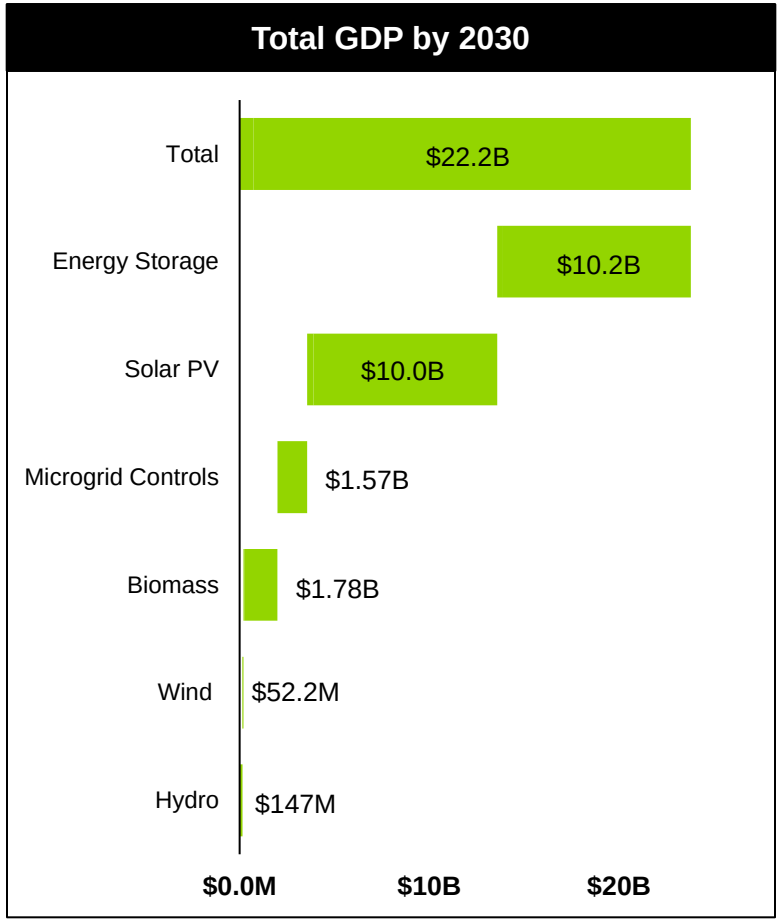


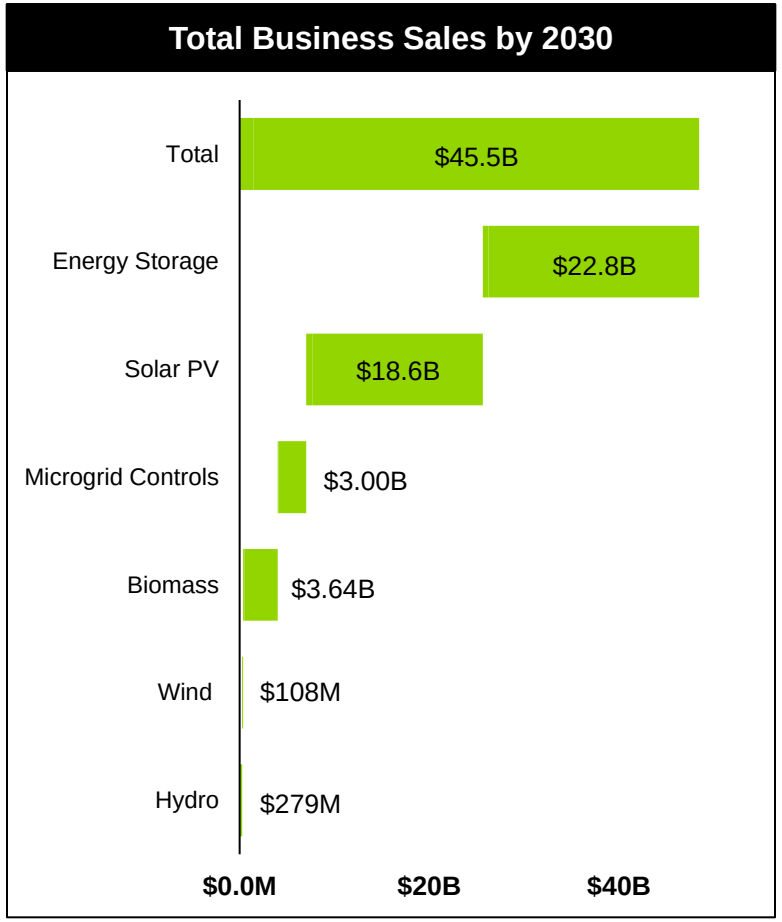


4 California | Impact by Technology Type

Included in the charts below are the combined current and forecast jobs, GDP, and business sales associated with renewable microgrid assets by 2030. Of the expected 166,670 jobs, 4,670 are currently existing jobs, with 162,000 to be added over the next 10 years.







4 California | Strategic Insights

California's microgrids are already cleaner than the national average due to several public policies and regulations. That trend will likely continue as specific state supports for microgrids gain traction and definition, aided by climate change weather impacts on grid reliability and market forces benefiting the overall US microgrid market.

Policies Impacting the Installation of Renewable Microgrid Assets Include:

- California committed to reducing carbon emissions in 2006 with AB 32, the first comprehensive climate change program in the country requiring emissions to be reduced to 1990 levels by 2020. The state met that goal 4 years early in 2016.
- In 2013, California enacted SB 1254, which set targets for deployments of 1,325 MW of energy storage technologies, the most comprehensive government program at that point in time. This capacity is expected to be online by 2024.
- In 2018, California enacted SB 100, which set a goal of 100% renewable (non-carbon) energy by 2045. The state released a report in 2021 determining that this goal is feasible but would require an additional 6,000 MW of annual clean energy capacity additions to meet the target.
- With the passage of SB 1339 in 2018, the California Public Utilities Commission launched a statewide microgrid incentive program to encourage consumers to build microgrids. The program addressed several barriers to microgrid deployment, including:
  - Allowing for the deployment of microgrids by local governments to serve critical facilities located on adjacent parcels of land
  - Requiring each of the state's three major investor-owned utilities to create a renewable energy asset microgrid tariff
  - Creating a $200 million Microgrid Incentive Program to fund clean energy microgrids to serve vulnerable communities and to test new technologies and regulatory approaches to microgrid development
  - Setting up a program to shift from fossil fuel emergency microgrids to clean mobile microgrids by 2022
- The California Energy Commission does not allow any of its funding for new microgrids to support fossil fuel technologies.

4 California | Strategic Insights

Within California, the adoption of microgrids and renewable microgrid assets specifically continues to be hampered despite broad state-level support for carbon reductions, energy storage, renewable energy, and microgrids. End users and private sector vendors lament missed opportunities and the continued reliance on fossil fuels.

Regulatory Obstacles to Further Adoption:

- Connecting microgrids to the larger microgrid is cumbersome and involves time-consuming permitting processes. The process is being reformed but continues to hamper the deployment of new clean energy microgrid projects.
- State regulators are still determining how to ensure an equitable deployment of utility microgrids. Regulators must grapple with whether the benefits of microgrids should only be received by those who can afford them or whether the benefits should be distributed across all ratepayers.
- Regulations prohibiting the transfer of electricity over public rights-of-way or over-the-fence transactions impact the deployment of larger microgrids intended to serve entire communities.

Workers install solar panels on the roof of a Walmart in Mountain View, California.

Technological Obstacles to Further Adoption:

- Many residential energy storage systems can only provide resiliency for 2 to 4 hours due to their reliance on lithium ion batteries and the system size. Power outages may last days due to extended wildfires or utility Public Safety Power Shutoff events.
- While a plethora of vendors offer microgrid products and services in California, the largest and most established vendors tend to be expensive and require long lead times; the smaller vendors are lower cost but have a higher failure rate (especially long-duration battery vendors).

Next Steps: Policymakers should focus on the removal of regulatory impediments to spur further adoption of renewable technologies within microgrids. Additionally, regulations encouraging the deployment of modular, clean energy microgrids under an energy as a service business model replicating the success of rooftop solar PV leasing programs would further incentivize microgrids as a realistic solution to California's clean energy aspirations.

4 Regional Impacts: Puerto Rico's Microgrid Market

Guidehouse

4 Puerto Rico | High Level Summary

Investment in renewable microgrid assets in Puerto Rico is expected to continue growing, creating over 9,000 jobs by 2030 and generating over $1.2 billion in GDP. Overall installed capacity will grow 3 times its current size, with solar PV and energy storage continuing to dominate.

Total Economic Impact

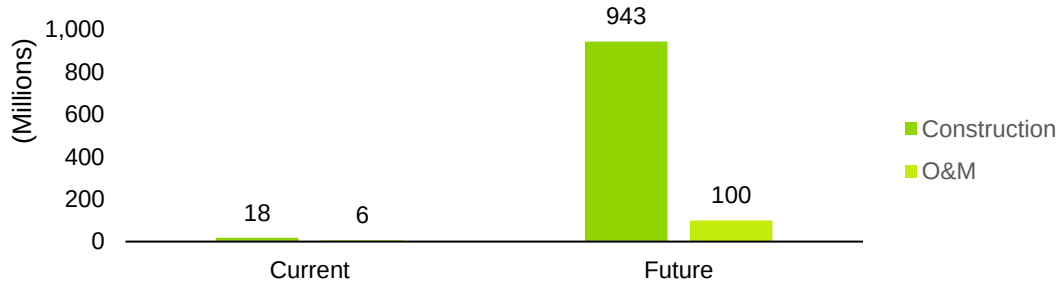
By 2030, renewable microgrids in Puerto Rico will provide…

9,033 jobs

$1.27B GDP

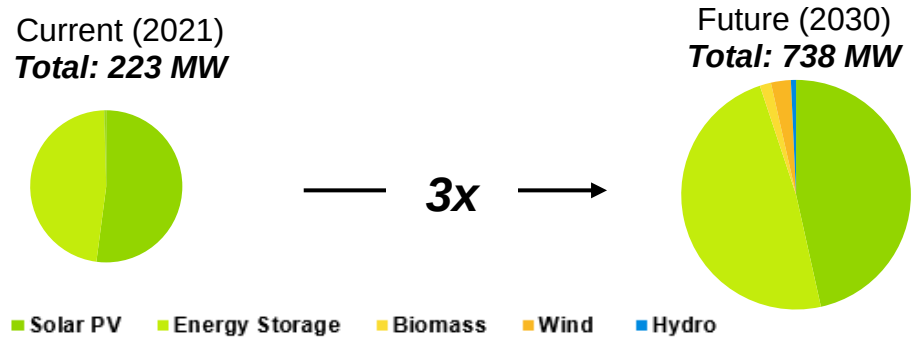
$2.59B biz sales

Total Costs



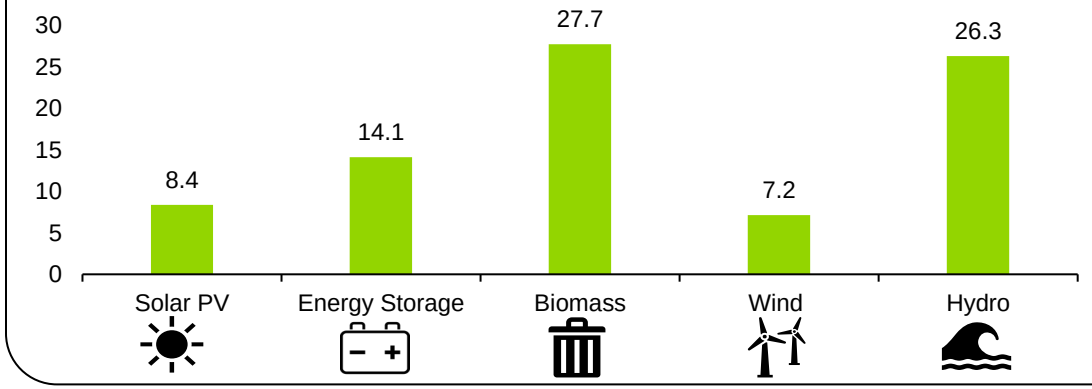
Installed Capacity Inventory

By 2030, installed capacity will grow **3 times** its current size, with solar PV and energy storage making up the majority of the inventory.



Jobs Created per MW Installed Capacity

Biomass and hydro will create the most jobs per MW.



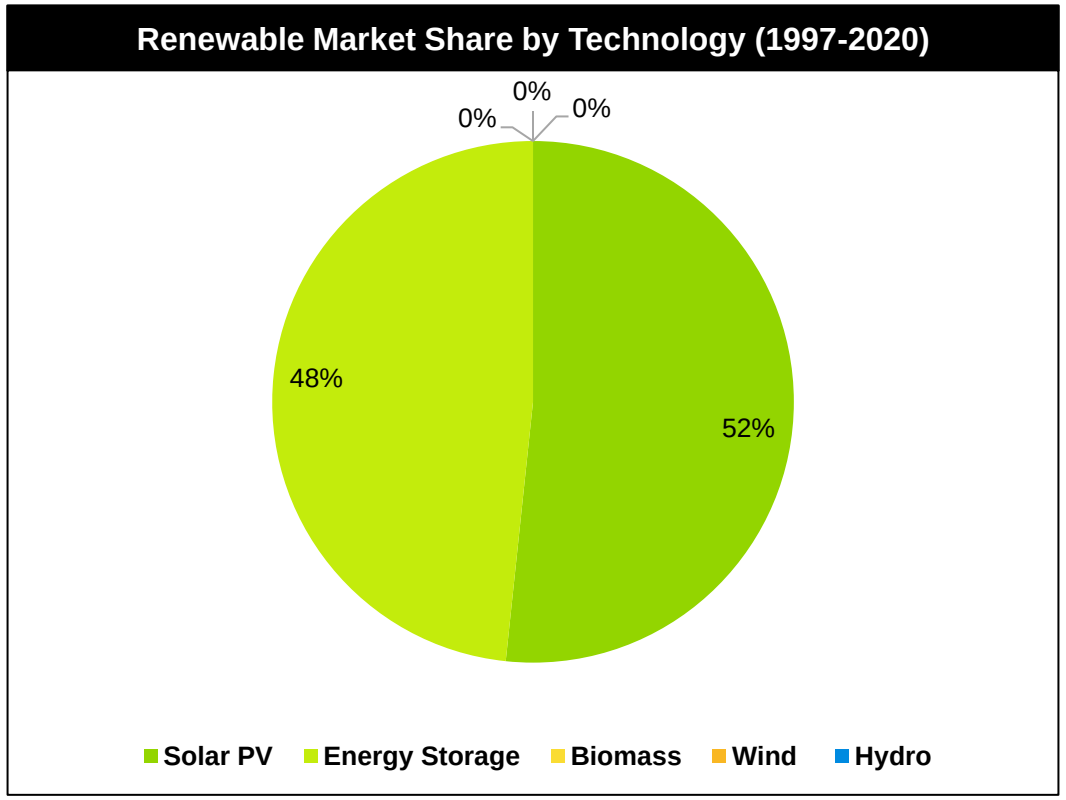
4 Puerto Rico | Historical Capacity Analysis

Puerto Rico's renewable microgrid asset capacity is entirely concentrated in solar and energy storage. The solar power leverages the island's abundance of sunlight to generate renewable power. As of 2020, there are no installed wind, hydroelectric, or biomass microgrids installed within the territory, though nascent hydroelectric developments are on the horizon.

Renewable Energy Capacity by Technology (1997-2020)		
Technology	**Installed Capacity (MW)**	**% of Total Capacity**
Hydroelectric	0.0	0.0%
Wind	0.0	0.0%
Biomass	0.0	0.0%
Energy Storage	108.2	48.4%
Solar PV	115.6	51.6%
Total Installed Capacity	**223.8**	**100%**
Controller Total Capacity[1]	**223.8**	**100%**

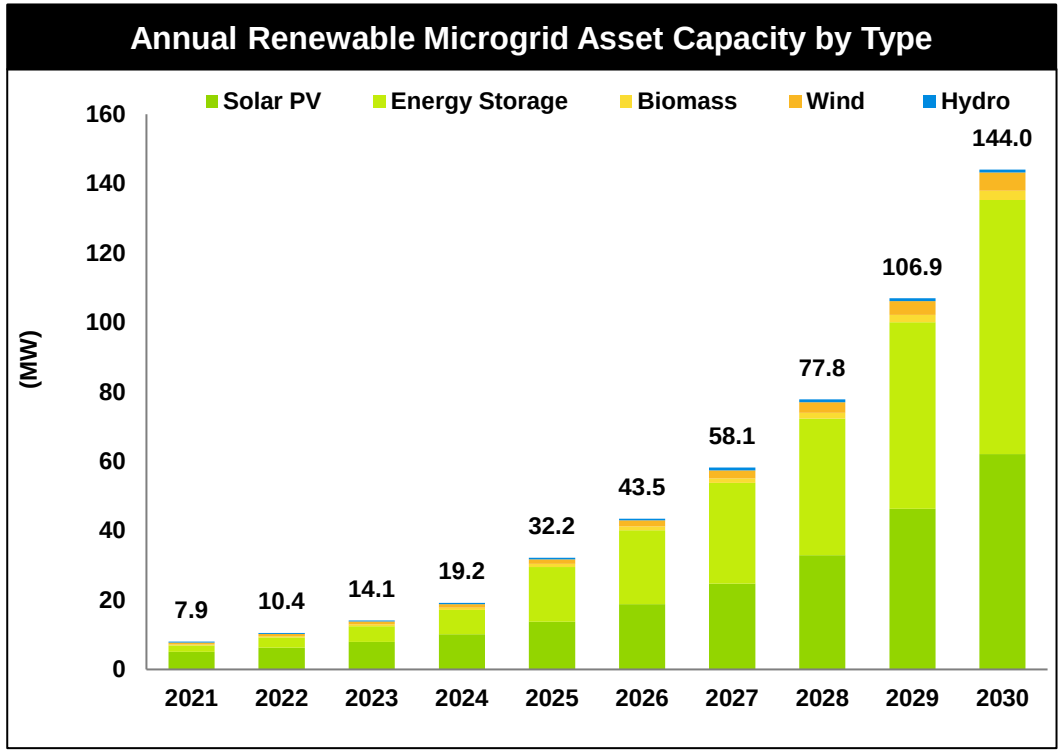
[1] The Sum of Total Power Capacity is the same as the Controller Total Capacity because each renewable DER microgrid asset needs to be optimized by a controller.

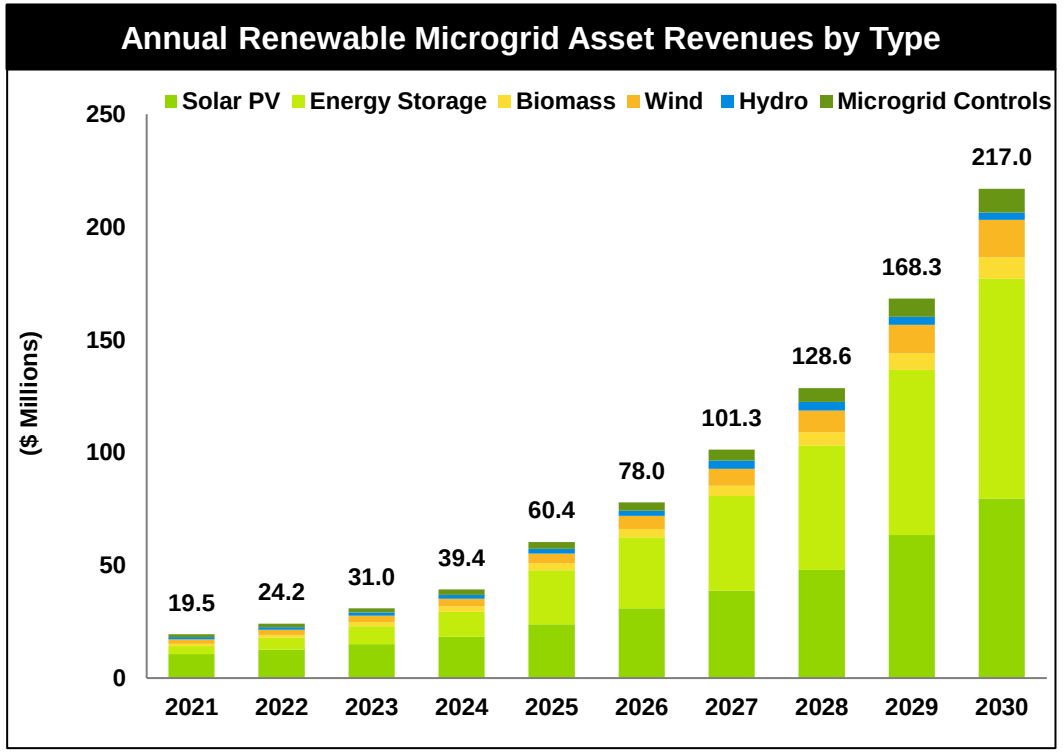
Note: All figures are per Guidehouse Insights' *Microgrid Deployment Tracker,* which includes data on identified specific operating and planned microgrid projects.



4 Puerto Rico | Forecast Renewable Microgrid Asset Trends

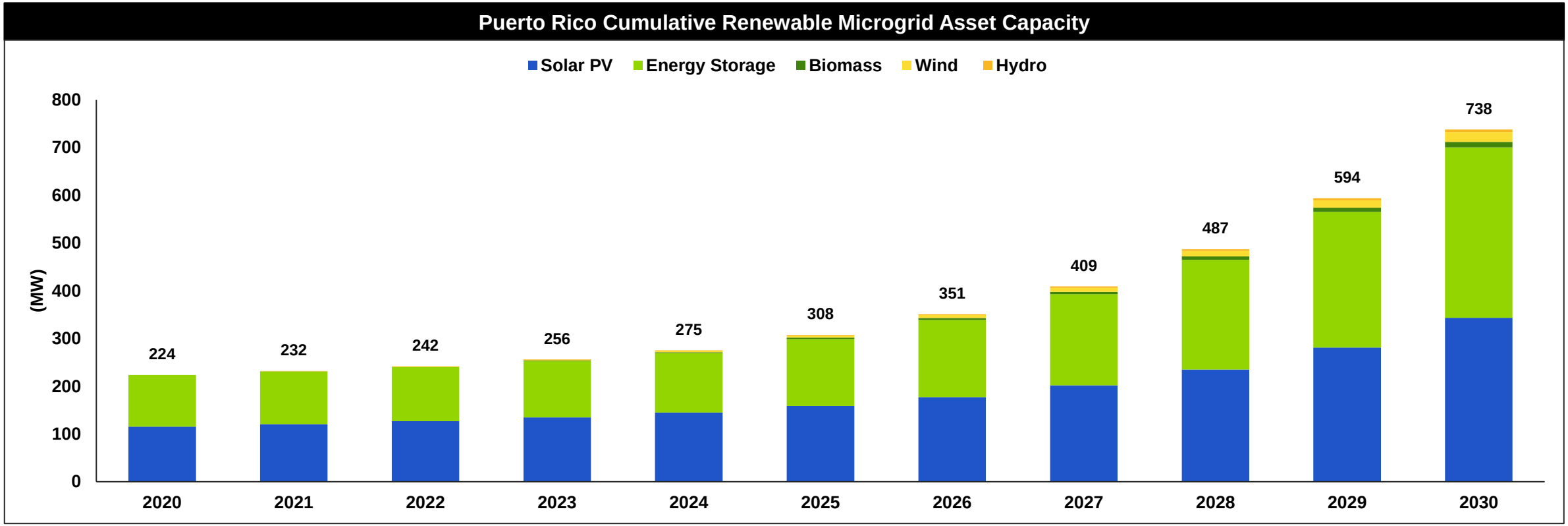
Over the next 10 years, Puerto Rico's renewable microgrid asset capacity is anticipated to increase from 7.9 MW in 2021 to 144 MW by 2030. In the same period, renewable asset microgrid revenue is forecast to jump from $19.5 million in 2021 to $217 million annually by 2030. Therefore, Puerto Rico is forecast to have a 30.8% CAGR for DER asset revenue, but its installed capacity (MW) is smaller than California.





4 Puerto Rico | Current and Forecast Renewable Microgrid Asset Inventory

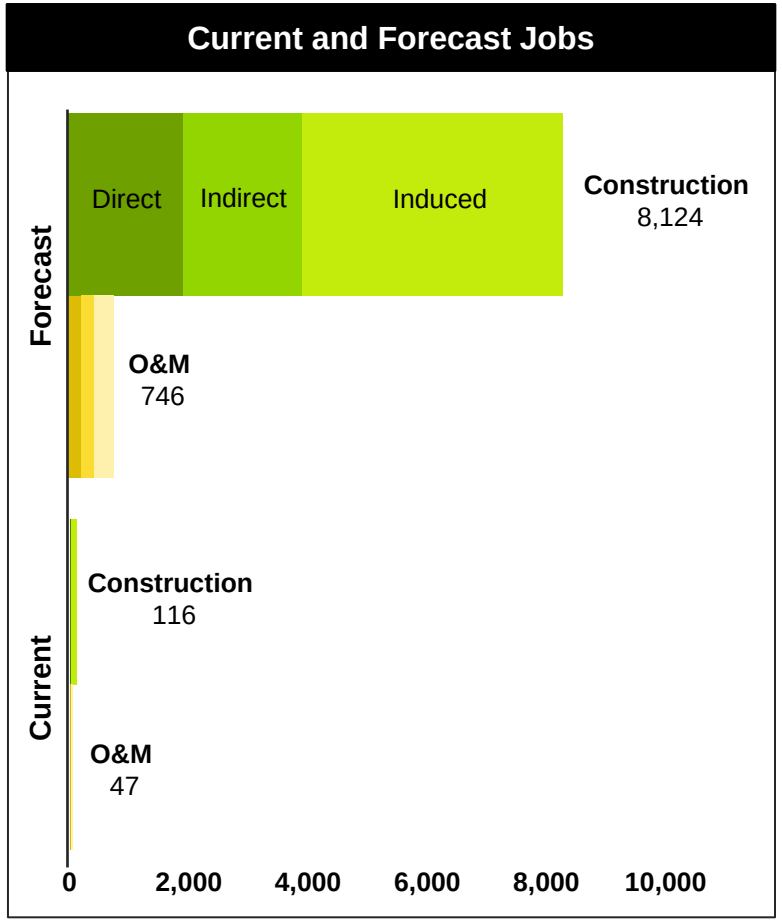
Over the next 10 years, cumulative renewable microgrid capacity is expected to triple from 232 MW to 738 MW. Although a much smaller market than California, Puerto Rico's grid modernization needs and history of hurricane-related sustained outages require microgrids, especially for disadvantaged communities. The growth in renewable microgrid capacity is linked to Puerto Rico's mandate of 100% clean energy by 2050.

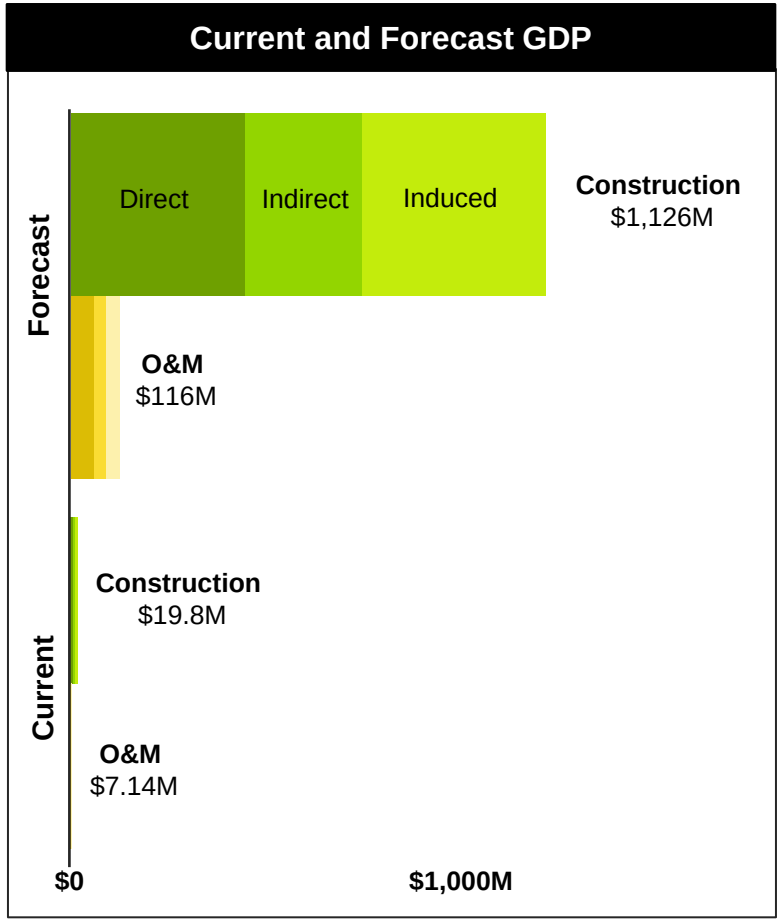


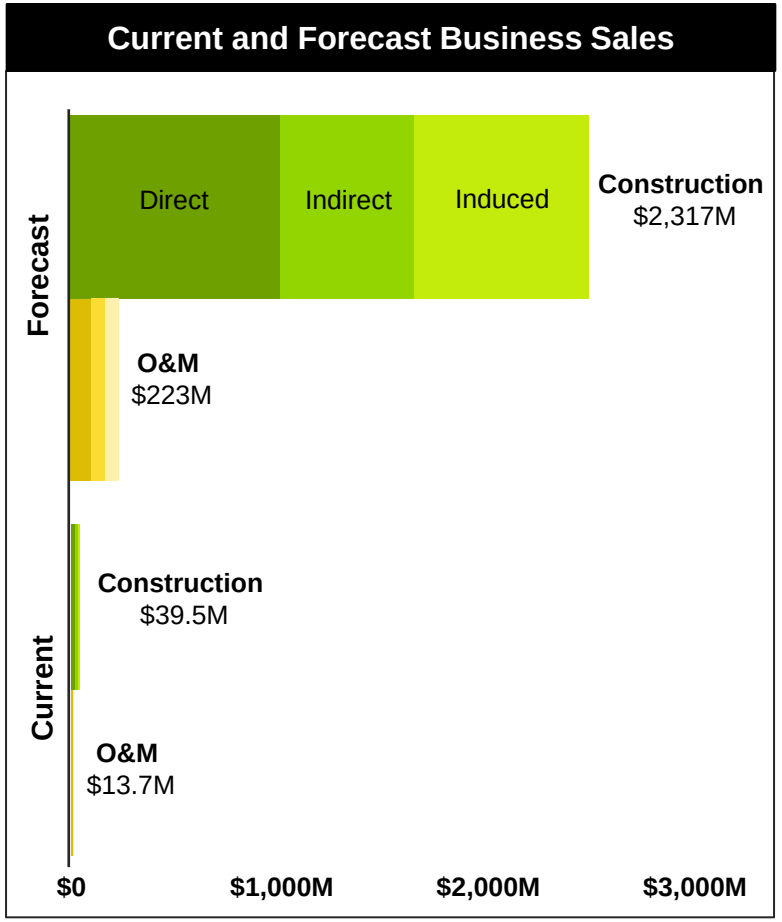
Note: Some historic microgrid installations may be excluded due to data availability issues.

4 Puerto Rico | Impact of the Renewable Microgrid Asset Industry

Current and forecast jobs, GDP, and business sales through 2030 are included in the charts below. Across all three metrics, construction accounts for the largest impact, creating 8,124 jobs in addition to generating $1,126 million in GDP and $2,317 million in business sales by 2030.

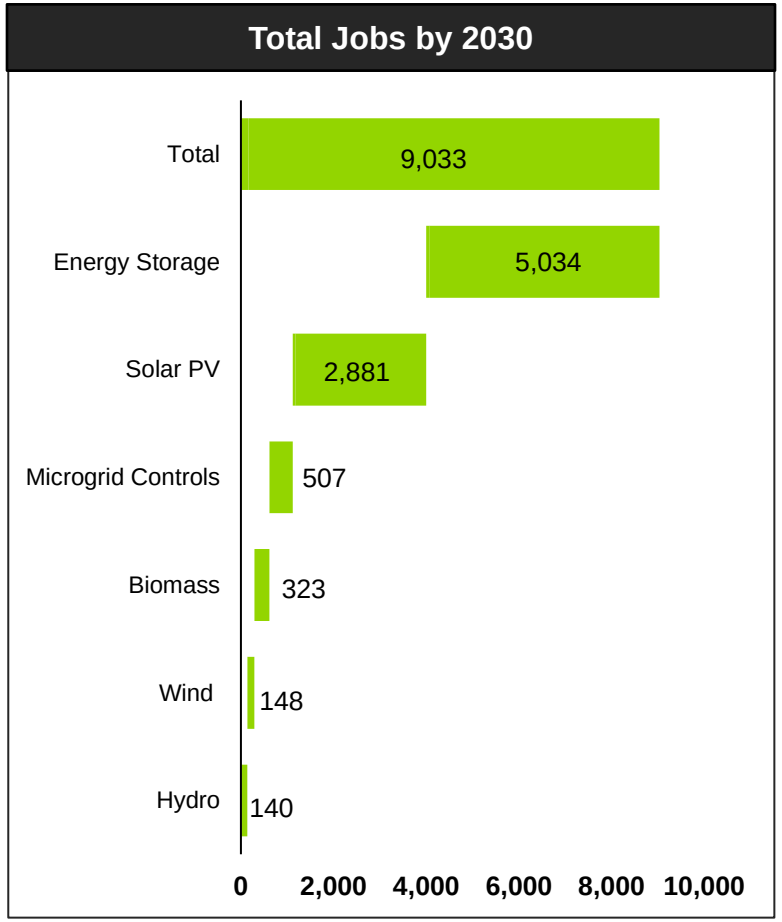


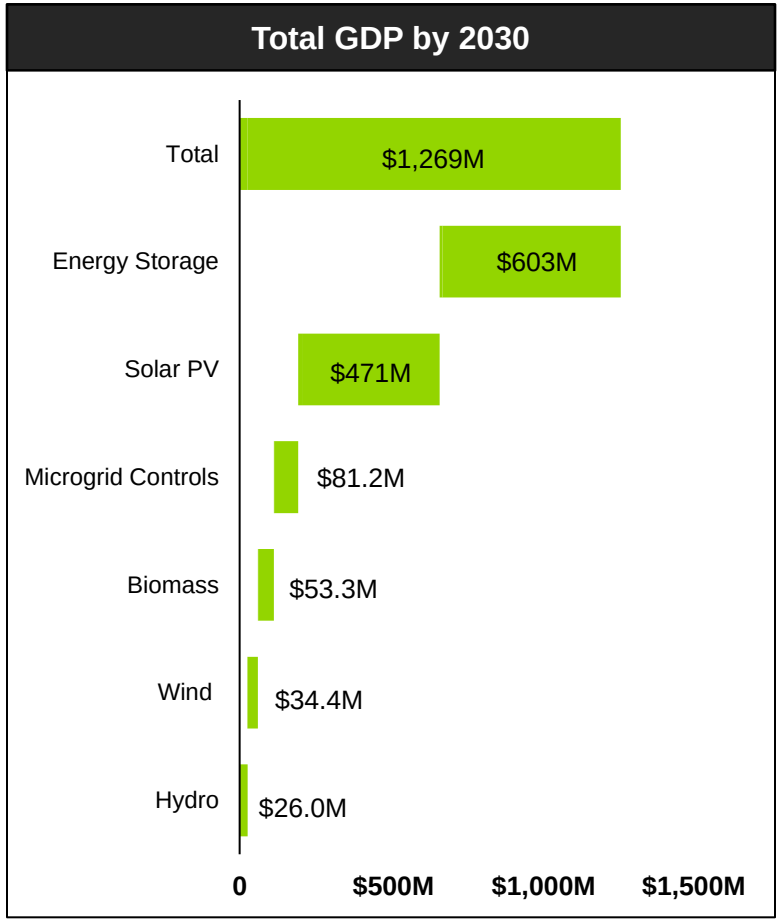


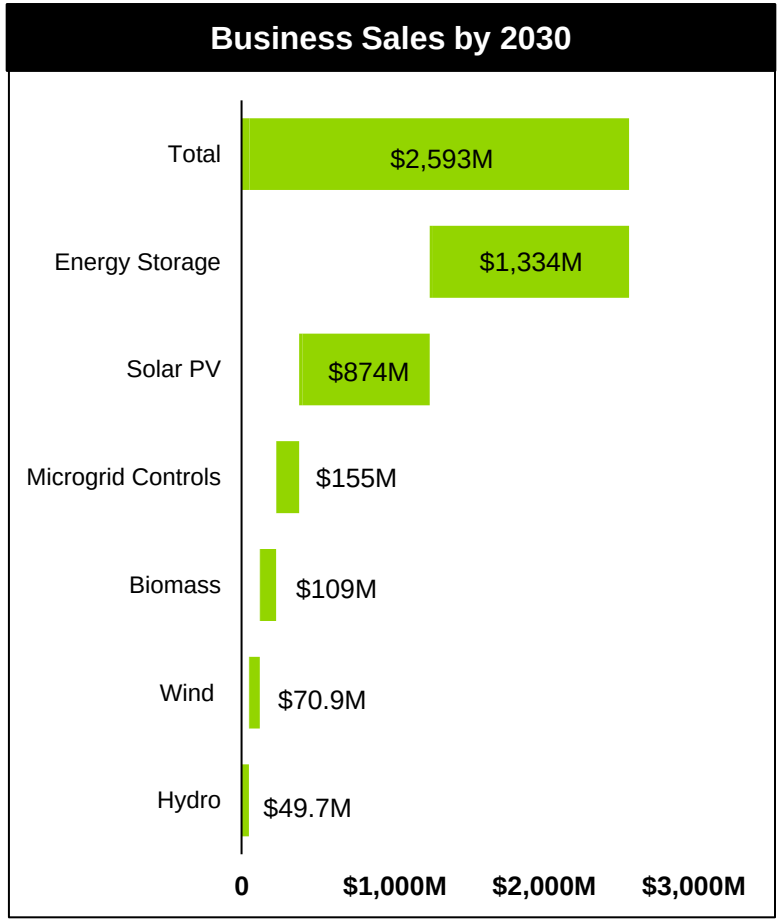


4 Puerto Rico | Impact by Technology Type

Included in the charts below are the combined current and forecast jobs, GDP, and business sales associated with renewable microgrid assets by 2030. Of the expected 9,033 jobs, 163 are currently existing jobs while 8,870 will be added over the next 10 years.





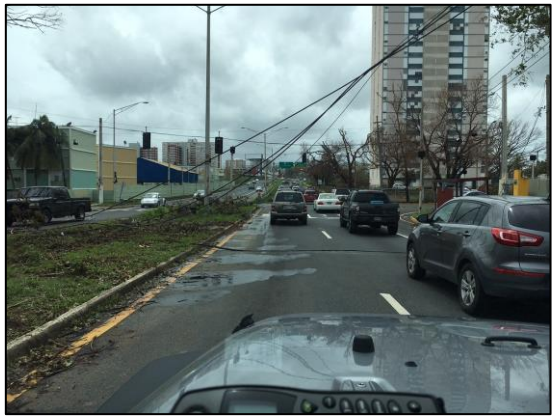


4 Puerto Rico | Strategic Insights

Puerto Rico faces ongoing major challenges to grid performance because its incumbent (and insolvent) utility PREPA recently handed off ongoing transmission and distribution operations to new JV LUMA Energy under a 15-year contract. Addressing grid issues and improving customer service during this urgent crisis will require solutions that rely upon outside capital and innovative business models.

Current Status of Microgrids Within Puerto Rico:

- After Hurricanes María and Irma, Puerto Rico suffered the longest power outage in US history with devastating consequences and a prolonged, troubled recovery. The event spurred a major desire for community resilience, with microgrids as a component of that strategy. As part of the Integrated Resource Plan (IRP), Siemens' proposal to subdivide the entire island's grid into eight large 'minigrids' was rejected by the regulator but is currently being studied further.
- Like California, Puerto Rico has set a 100% clean energy goal with a 2050 target date, but this goal is not yet integrated into a process that would maximize resiliency in the form of microgrids. Similar to other island jurisdictions, Puerto Rico seeks to reduce dependence on fuel imports and improve resilience against climatic threats.
- Most microgrids installed to date have been supported by nonprofits such as the American Red Cross, many of which support critical facilities such as water pumping stations.



Downed power lines in Puerto Rico following Hurricane Maria in 2017.

Opportunities for Further Adoption:

The Federal Emergency Management Agency is considering spending $9.6 billion on grid upgrades in Puerto Rico, but consensus on how best to spend the funds is lacking. A portion could be earmarked for clean energy microgrids.

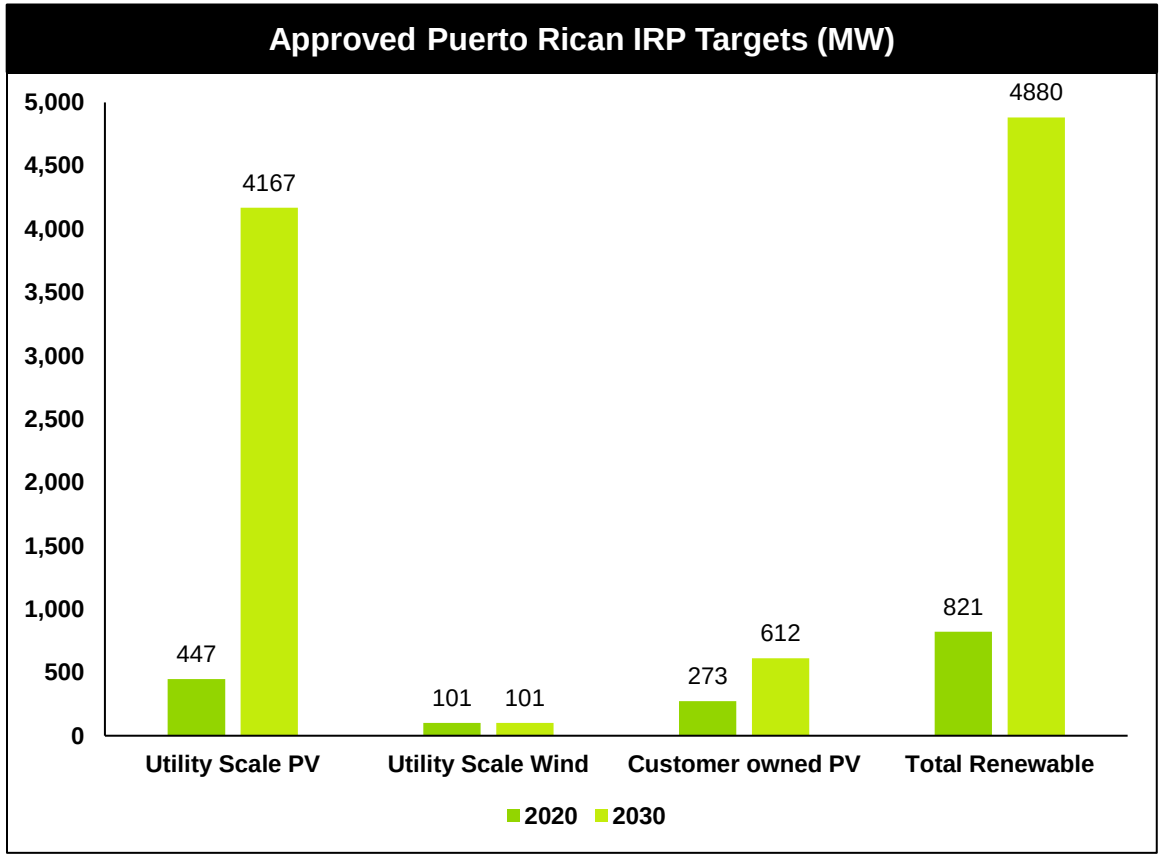
4 Puerto Rico | Strategic Insights

Given the targets for solar PV and energy storage included in the approved IRP for the coming decade, microgrids could grow significantly beyond these forecasts if adequate federal funding and regulatory reforms are optimized for microgrids.

Given the current challenges with Puerto Rico's grid, microgrids offer benefits to customers and should factor into utility analysis, private and nonprofit initiatives, and government efforts.

- With the support of billions of dollars in federal post-disaster reconstruction funds, Puerto Rico will be significantly investing in grid infrastructure. In the approved IRP ratified by the Puerto Rico Energy Bureau in August 2020, more than 4 GW of new solar PV will be installed in the coming decade, augmented by 1.28 GW of energy storage. Many of these future resources could be deployed in a distributed format, planting seeds for future microgrids.
- Per the approved IRP, the customer-owned and distributed market share would only be 12% of the total in 2030. Other examined scenarios found ways for the customer-owned and distributed solar PV and energy storage market share to reach 30% or more. Leveraging federal funds could expand the microgrid market in Puerto Rico beyond the forecasts included in this report.

Increasing the customer-owned solar PV market share via microgrids (and tapping into wind and hydro) can increase community resilience while securing a renewable energy pathway forward.



5 Key Takeaways, Insights, and Policy Recommendations

5 Looking Ahead | Key Takeaways and Insights

Most microgrids feature hybrid renewable and fossil fuel assets. The emergence of more cost-effective energy storage enables an increased reliance on renewable energy. The forecast growth in reliance upon renewables for resiliency will have a massive impact on the economy. The industry has already contributed $2.8 billion in GDP, which is forecast to increase to $72.3 billion over the next decade.

Key Takeaways:

- Many of the renewable and energy storage assets deployed in microgrids are currently manufactured overseas. The two dominant assets—solar PV and energy storage—are primarily manufactured in China and other countries. To maximize the economic benefit of future microgrids in the US, the federal government should look to implement policies to increase domestic market share from the current 15% and 8% for solar PV and energy storage, respectively.
- The national renewable microgrid asset market would create almost half a million jobs over the next decade. California is forecast to capture roughly one-third of these jobs, a reflection of the state's emphasis on clean energy.
- Puerto Rico's wholescale rebuilding of its grid following the devastation of Hurricane Maria makes the island a prime candidate for further microgrid deployments. The current transition of operations between PREPA and LUMA and future uncertainty on the IRP offer both challenges and opportunities for future microgrids incorporating renewable energy assets.

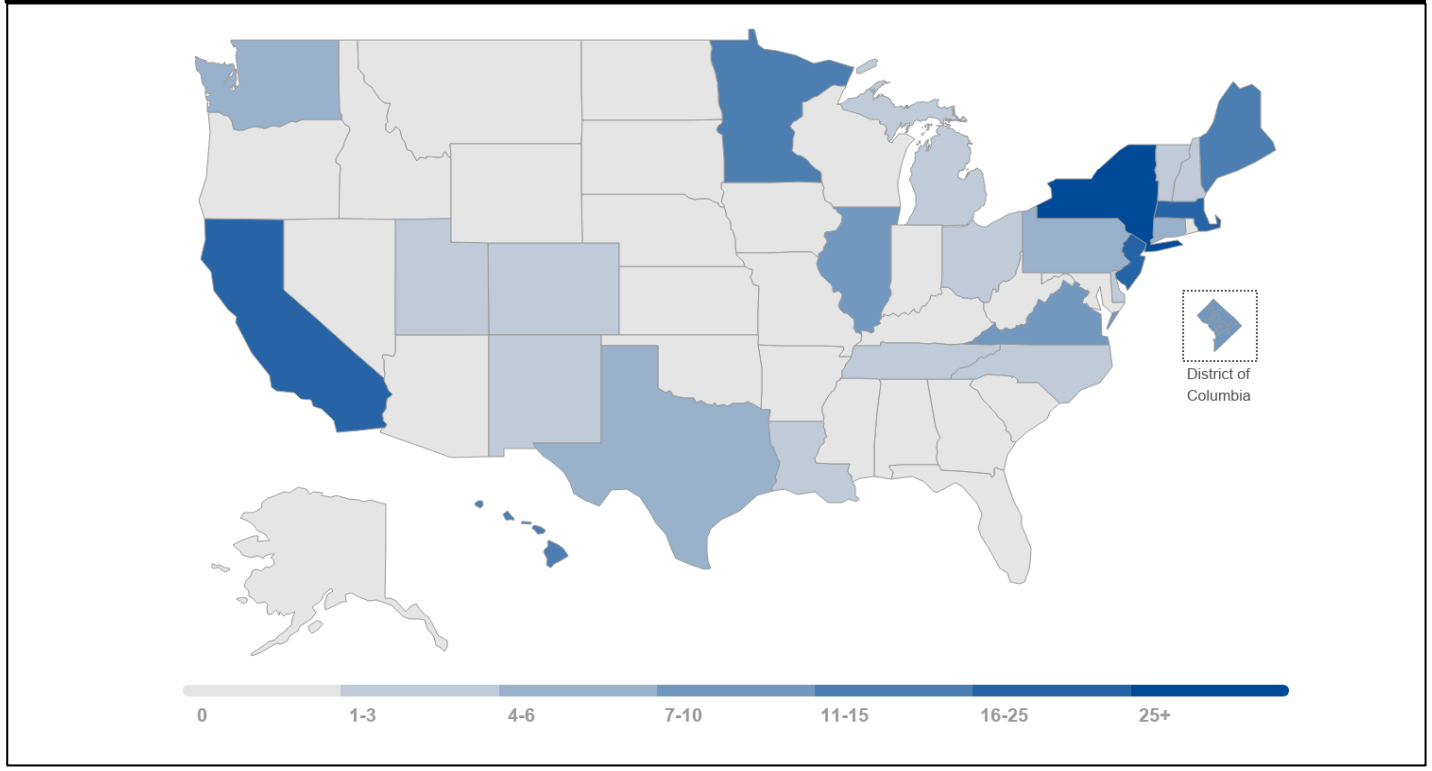
The Salmon Creek Dam provides power to Juneau, Alaska, one of several remote microgrids serving the state.

- Although biomass and hydro create the most jobs per MW and feature some of the highest domestic manufacturing content, they are the least utilized renewable energy assets in microgrids, especially in California and Puerto Rico. This implies that diversification of renewable energy asset types would maximize domestic manufacturing jobs.
- Though heavily reliant on fossil fuel resources, the leading state for microgrids today is Alaska. Lessons learned from Alaska and other states with similar demographics can be applied to ensure that Puerto Rico rebuilds its grid in a practical manner that reduces carbon emissions while increasing resiliency during the annual hurricane season.

5 Looking Ahead | Key Takeaways and Insights

Between 2015 and September 2021, 23 states have proposed and enacted legislation promoting the deployment of microgrids, with the five most recent states being Delaware, Louisiana, North Carolina, Tennessee, and Texas according to the Smart Electric Power Alliance (SEPA). The SEPA heat map below reflects legislative activity by state; with darker colors representing more proposed and enacted legislation.

Proposed and Enacted Microgrid Legislation by State



Source: Smart Electric Power Alliance

Key Takeaways:

- The Northeast is where the most concentrated legislative activity has taken place to date.
- The states with the most legislative activity include New York and California, followed by Massachusetts and New Jersey.
- While Alaska ranks as the nation's top state for microgrid deployments, it has not enacted any state legislative support.
- The regions of the US with the least legislative activity are the deep South and middle and upper Great Plains.
- The uneven distribution of policy support for microgrids implies that a federal program may be necessary to maximize job creation.

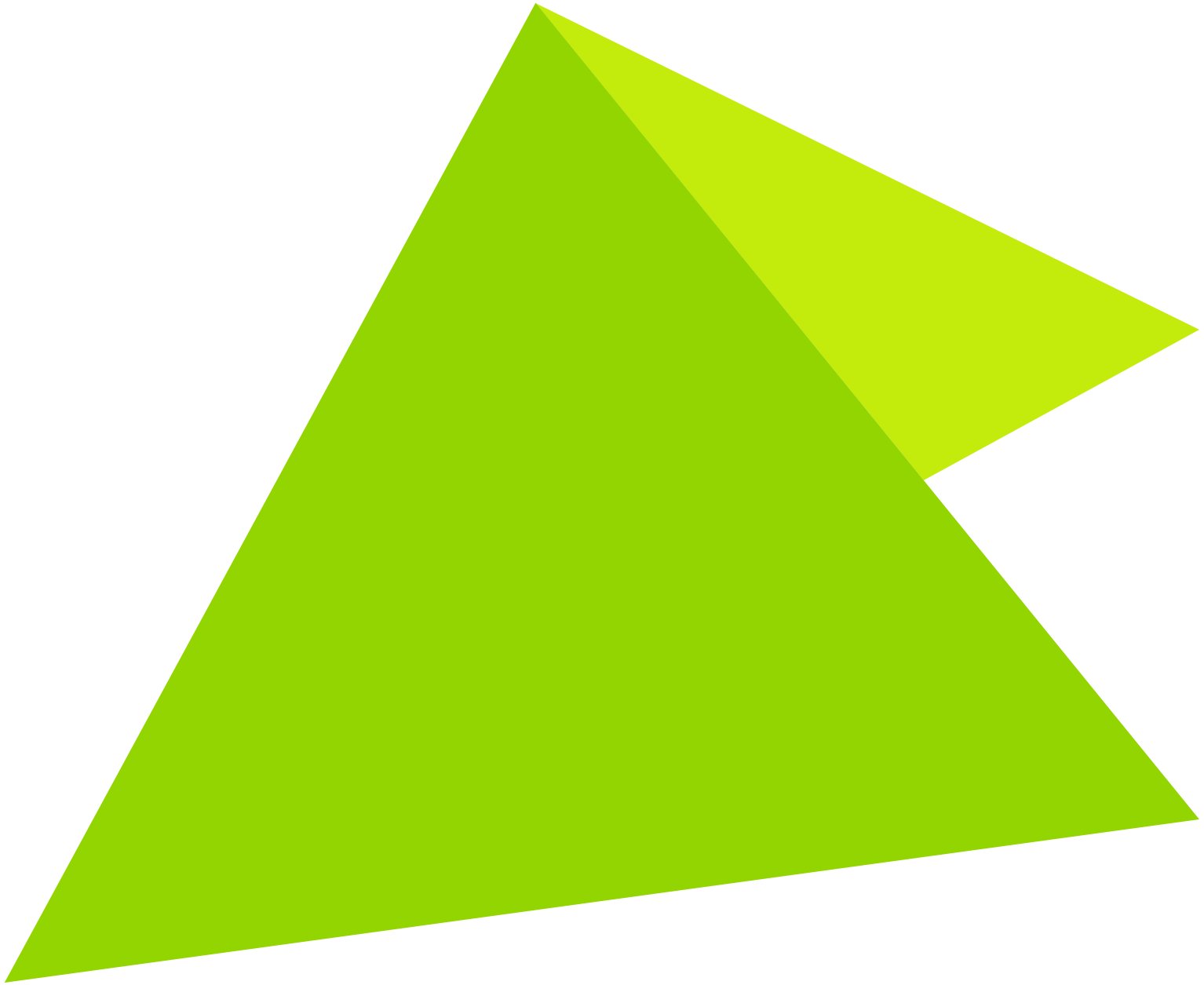
5 Looking Ahead | Best Practices in Policy

Public policies supporting microgrids have traditionally been developed at the state level, though federal incentives for key renewable energy assets such as solar PV and energy storage help drive adoption. Because microgrids allow for the deployment of renewable technologies while increasing grid resiliency, further adoption is in the best interest of policymakers and the public.

Policy Drivers Include:

- ***Shift from grants to market-based incentives –*** To develop a sustainable microgrid market, policymakers should link funding to market-based incentives such as emissions reductions, resiliency duration service goals, or other metrics that reward superior project performance. Grants may still be necessary in disadvantaged communities where the cost of a microgrid may be prohibitive.
- ***Target government funds toward new clean and smart technologies –*** Rather than supporting the entire gamut of technologies wrapped into any single microgrid, follow the lead of California and target government funds toward clean energy resources and technologies such as AI and advanced controls. These can maximize the clean energy value of a microgrid internally *and* externally to the larger grid network.
- ***Prioritize projects that foster new financing models –*** As the technologies within microgrids continue to mature, the focus of future innovation lies in financing. Leveraging the investment community's focus on ESG, private investment is critical for streamlining the microgrid development process. Trends such as more modular microgrids and energy as a service structures will unlock further innovation.
- ***Create metrics that capture the value of resiliency –*** The primary value that a clean energy microgrid provides—sustainable resiliency—is not systematically recognized by regulators or markets. Governments can develop trans-jurisdictional policies to incentivize microgrids over diesel generators or other renewable energy technologies that are not available during outages.
- ***Allow for flexibility and midcourse corrections –*** Microgrids are an emerging technology, and there are opportunities for significant innovation. Build-in periodic reviews of policies and incentives to respond to changing markets, unforeseen circumstances, and new opportunities.

Appendix



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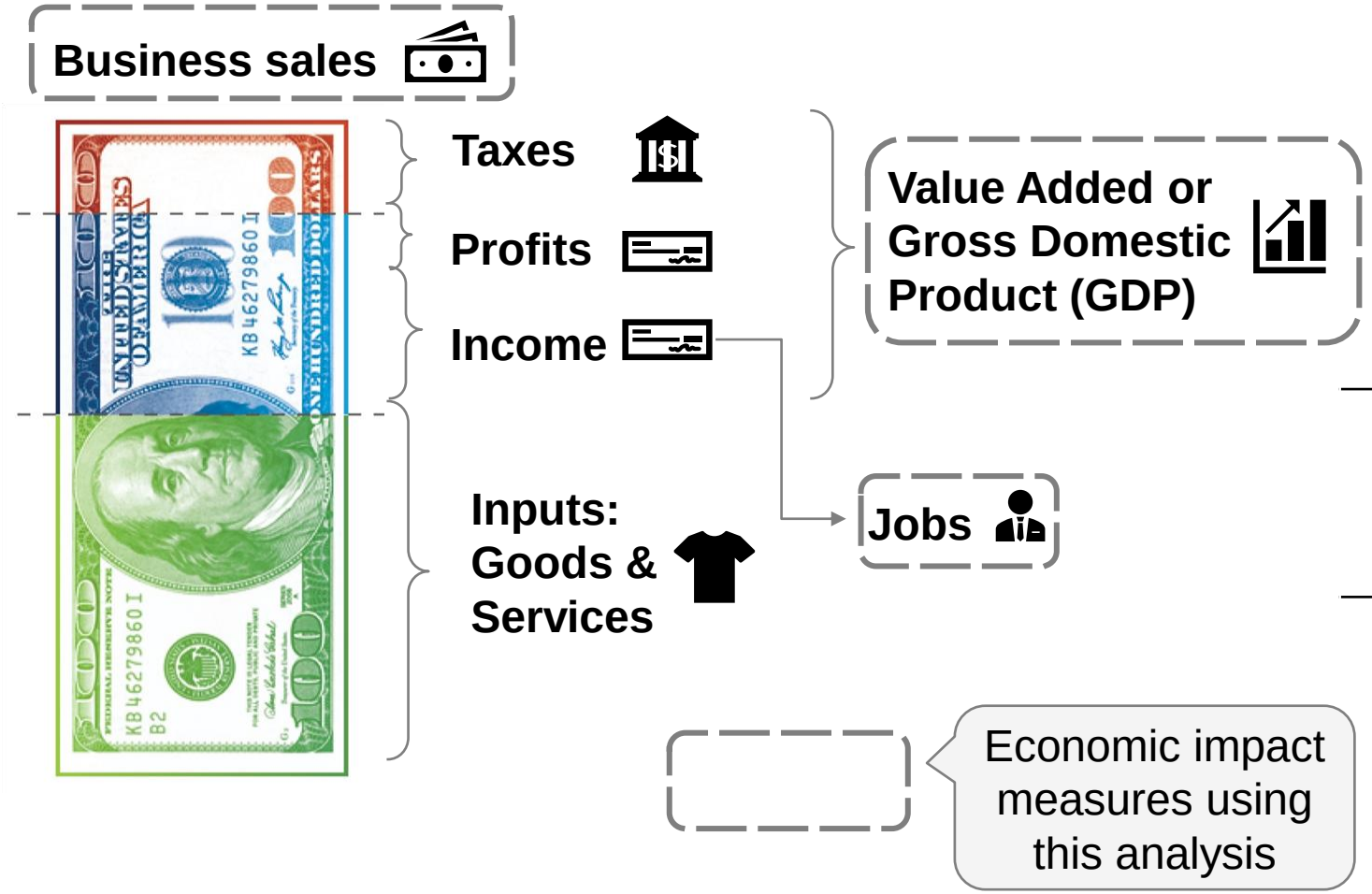
Appendix Contents

Economic Analysis Additional Information | Economic Impacts

Economic impact measures reflect changes in the economy and are subsets of one another, meaning that they should not be added together.



Taxes
Profits
+ Income

= Value Added (GDP)

+ Inputs

= Business Sales

Economic Analysis Additional Information | Construction and O&M Costs

To comprehensively forecast the economic impact of renewable microgrids in California and Puerto Rico, it was necessary to obtain accurate estimates of the CAPEX and operating costs of the various technologies under study. The following are the cost estimates used to forecast the economic impacts.

Distributed Generation (DG) Solar

Cost Type	Unit	Cost
Construction Costs[1]	($ per MW)	$3,370,000.00
Operations & Maintenance[1]	($ per MW-year)	$386,515.73

[1]**Source:** Lazard's 2020 Levelized Cost of Energy Analysis

Distributed Generation (DG) Wind

Cost Type	Unit	Cost
Construction Costs[1]	($ per MW)	$1,712,182.00
Operations & Maintenance[2]	($ per MW-year)	$35,000.00

[1]**Source:** Pacific Northwest Laboratory Distributed Wind Report
[2]**Source:** National Renewable Energy Laboratory Cost of Wind Energy Review

Distributed Generation (DG) Hydro

Cost Type	Unit	Cost
Construction Costs[1]	($ per MW)	$4,236,000.00
Operations & Maintenance[1]	($ per MW-year)	$122,000.00

[1]**Source:** 2021 U.S. Department of Energy Hydropower Market Report

Distributed Generation (DG) Biomass

Cost Type	Unit	Cost
Construction Costs[1]	($ per MW)	$3,370,000.00
Operations & Maintenance[2]	($ per MW-year)	$386,515.73

[1]**Source:** Department of Energy Transparent Cost Database
[2]**Source:** Department of Energy's 2021 Cost of New Generation Resources

Energy Storage

Cost Type	Unit	Cost
Construction Costs[1]	($ per MW)	$3,370,000.00
Operations & Maintenance[1]	($ per MW-year)	$386,515.73

[1]**Source:** Guidehouse Insights Internal Analysis

Controller

Cost Type	Unit	Cost
Construction Costs[1]	($ per MW)	$1,712,182.00
Operations & Maintenance	($ per MW-year)	N/A[2]

[1]**Source:** Guidehouse Insights Internal Analysis
[2]**Note:** For the analysis, controllers are assumed to have no operating costs.

Economic Analysis Additional Information | Assumptions

For the California- and Puerto Rico-specific analyses, the results represent the national impact of the installation of renewable microgrid assets within these regions. In other words, IMPLAN inputs are at the local level while IMPLAN outputs are at the national level.

This study uses this approach for the following reasons:

1. Operating costs and CAPEX for each technology are at the national average level.
2. Nationwide results helps us better account for the distributed nature of supply chains.
3. Within the US, labor is mobile because people will relocate to areas with economic opportunity.

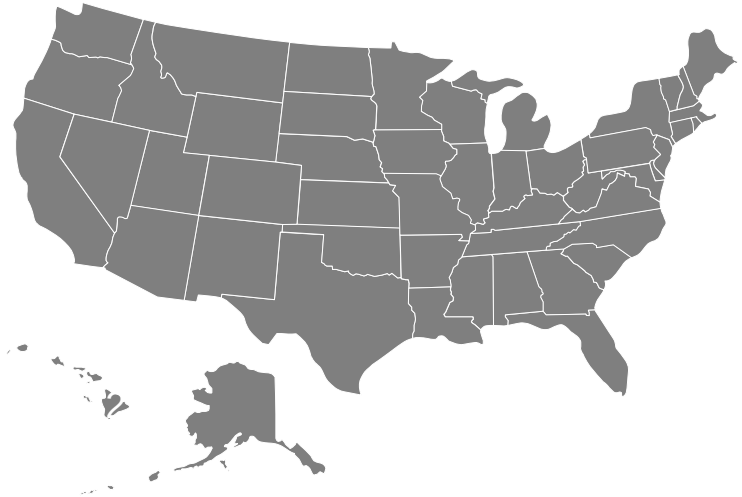
Inputs (Local Level)

California

Puerto Rico

IMPLAN

Outputs (National Level)



Economic Analysis Additional Information | Assumptions

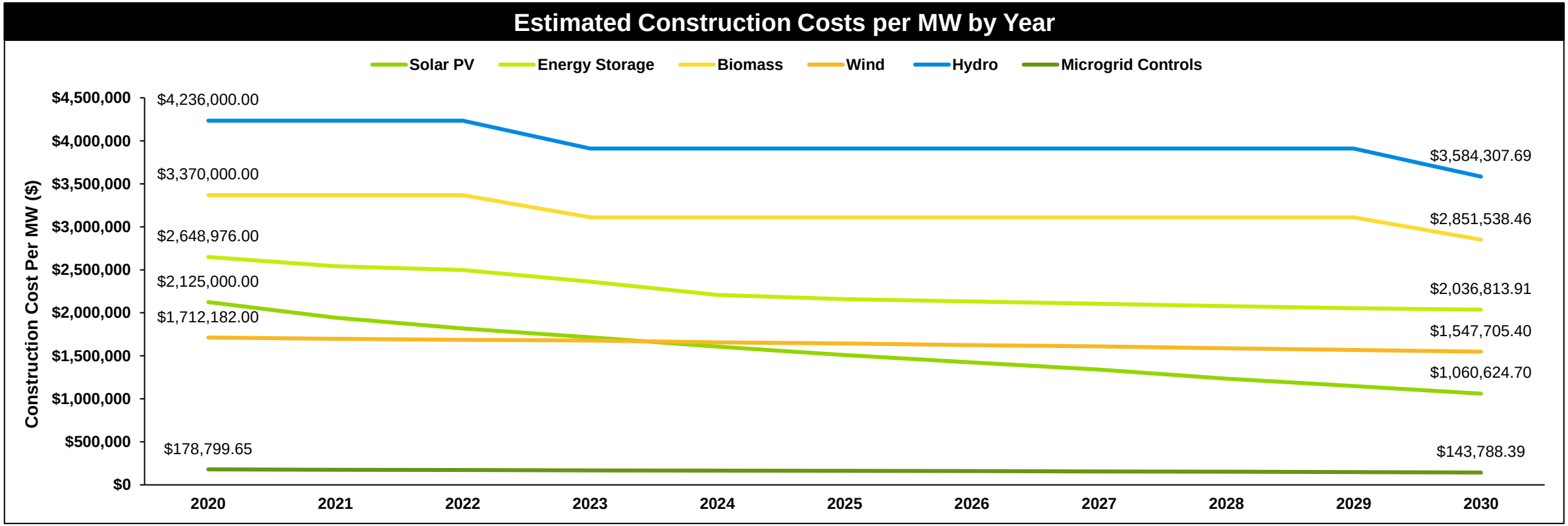
To accurately, thoroughly, and completely model the economic impacts of renewable microgrids, it was necessary to make limited assumptions regarding the capacity, use, and deployment of microgrids.

Model Assumptions:

1. All balance of system costs (e.g., meters, wiring, switches) were excluded because these costs tend to vary widely, making it difficult to accurately model spending for these categories. (They are also not directly linked to clean energy.)
2. This report uses Guidehouse Insights' forecasting to understand the market for renewable DER microgrid assets over the next 10 years. Once initial capacity estimates are rendered for the first year of the forecast, growth rates for each DER type in each region are calculated. Values for each DER technology market segment in dollars per megawatt are applied to regional markets to calculate revenue values.
3. Forecasts in this report have been updated to account for COVID-19 disruptions.
5. Construction and operating costs are the same in both California and Puerto Rico.
6. All renewable DER only begin to incur operating and maintenance expenses the year after installation.
7. Controllers do not incur any operating or maintenance expenses.

Economic Analysis Additional Information | Assumptions

Investments in renewable energy are anticipated to result in meaningful reductions in the acquisition and installation costs of various technologies. Indeed, the construction cost (acquisition and installation) of 1 MW of solar capacity is expected to decrease by 50% over the next 10 years. The graph below illustrates the assumed reductions in the construction costs of the various renewable technologies under study.



Note: Operating and maintenance expenses were assumed to be constant for the duration of the period under study.