

Decommissioning Solar Panel Systems

Information for local governments and landowners on the decommissioning of large-scale solar panel systems.



NEW
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1. Executive Summary

Decommissioning is an important aspect of the cradle-to-grave lifecycle planning for all renewable energy projects. With proper planning, local authorities ensure project owners are both committed to the responsible management of equipment disposal and financially equipped to complete the decommissioning process. Successful decommissioning is contingent on careful planning, which starts prior to the renewable energy project's construction, and thorough execution to ensure safety, environmental responsibility, and regulatory compliance with a goal to return the land to pre-construction condition so that the land may be repurposed for future use.

This document is intended to equip local governments with the knowledge for decommissioning renewable energy projects such as, solar photovoltaic (PV) systems, including a discussion on other options at the end of a renewable project's useful life, including repowering and recycling. This chapter will provide readers with the information needed to manage decommissioning activities for community scale renewable projects in their jurisdictions. Local governments can find template decommissioning plans in the [Model Solar Energy Local Law](#).¹

In New York State, utility scale renewable energy projects exceeding 25 MW (also referred to as major or large-scale renewable energy facilities/projects) are permitted at the State level through the Office of Renewable Energy Siting and Electric Transmission (ORES), which require decommissioning plans. Decommissioning plans include important information such as, removal of facilities/ equipment, the roles and responsibilities for project owners and stakeholders, conditions that trigger the decommissioning process, timing to complete decommissioning activities, cost estimates, and enforcement mechanisms. Renewable energy projects less than 25 MW are permitted at the local level and often require decommissioning plans. Most solar energy projects in New York State are community scale renewable energy projects (less than 5 MW).²

Financial and non-financial enforcement mechanisms provide municipalities with means to ensure the project owner is responsible for covering decommissioning costs. Estimation of decommissioning costs should be based on reasonable assumptions of long-term inflation to avoid excessively burdening project owners with large surety bonds or decommissioning trusts. Licensed engineers and cost estimating professionals should be retained by project owners to generate accurate decommissioning cost estimates.

Local governments should target the best practices discussed in this chapter to maximize the benefits from renewable energy projects, including:

- Reducing environmental impact of projects;
- Ensuring adequate planning occurs prior to decommissioning; and,
- Reducing the burden on landfills by encouraging recycling or resale of decommissioned projects.

Decommissioning includes the removal of equipment and structure, repurposing, recycling, or disposal of materials, and restoration of the project site. Another option for the end-of-life (EOL) of a renewable energy project is continued use via reuse, refurbishment, or repowering. **Table 1** below summarizes these options for the end of a project's useful life. While the recycling market is still emerging, future technological improvements may increase the viability of commercial recycling for renewable energy projects or expand opportunities for renewable energy projects to continue operations through the reuse, refurbishment, or repowering of equipment.

¹ [New York State Solar Guidebook - NYSERDA](#)

² [Statewide Distributed Solar Projects: Beginning 2000 | State of New York](#)

Table 1 | Options at the End of Initial Useful Life of a Renewable Energy Project

Continued Use	Decommissioning
Reuse: Continue to use and maintain the equipment beyond its useful life either at the project site or as part of a new project, such as residential use. Anticipate degradation in output over time.	Recycling: Recover high value materials such as metals and glass, between 80%-90% ³ of the weight of a solar panel or wind turbine made of recyclable materials.
Refurbishment: The operator may make repairs to a solar panel to extend its lifespan. This can be challenging due to finding older parts or sufficiently experienced labor for older technologies.	Repurpose: Use components, or parts of components to create new products. For example, wind turbine blades have been used in the construction of pedestrian bridges. This is not a high-volume option.
Repowering: Retrofitting or replacing components of the system to restore or improve the project's output. For solar, this is typically performed through installing new solar panel arrays and inverters. For wind, this can be accomplished by upgrading blades or even replacing the towers and foundation based on technological improvements.	Disposal: Landfill disposal is the least expensive option, though it has significant environmental drawbacks. Some solar panels contain fully enclosed, but trace amounts of lead and cadmium, ⁴ and may be considered hazardous waste under USEPA legislation. ⁵ Certain states have enacted policies to limit solar panel waste.

This chapter is for informational purposes only. The content does not, and is not intended to, constitute legal, financial, or tax advice. Readers should consult with their attorney, financial, and/ or tax advisor prior to taking, or refraining from taking, any particular action on the basis of information contained herein.

2. Introduction

At the end of a renewable energy project's initial service life, it can be decommissioned (removed) or repowered (using existing infrastructure with newer equipment). Decommissioning is the process of removing renewable energy projects, ancillary equipment, and related structures from a site and restoring the land to its pre-construction condition so that the land may be repurposed for future use. Given the low impact of renewables on the environment, land can be repurposed for various uses at the end-of-life (EOL). Decommissioning takes place after a renewable energy facility has been abandoned or reaches the end of its lifespan – on average after 25 to 30 years of operations. As the number of renewable energy projects has grown rapidly, the need to plan for the EOL considerations have become more important.

While many renewable energy projects are still young, some of the older projects are approaching their EOL. According to OpenNY's Solar Electric Programs supported by NYSERDA, over 8,000 megawatts-dc (MW-dc) have been installed since 2000. The earliest projects installed are now reaching 20 years of service and are approaching the end of their initial useful life, though the average age of all projects is about six years. Approximately 2,200 MW of onshore wind turbines have also been installed since 2000, some of which will be approaching EOL in the next five years. Battery energy storage system (BESS) is a newer technology, which has more time before those projects need to be decommissioned.

Even though decommissioning takes place long after a project is designed and constructed, a renewable energy developer is required to prepare plans for the decommissioning of their project during the planning and permitting phase, prior to project construction. Projects smaller than 25MW usually need to submit decommissioning plans, depending on local requirements.

Model Decommissioning Plan: Local officials should consult the template [Model Solar Energy Local Law](#) on NYSERDA's website, which includes a template decommissioning plan that local jurisdictions can be customized as needed.

³ WINDEXchange: End of Service Wind Turbine Guide (energy.gov)

⁴ Most solar panels in New York State are crystalline silicone (c-Si) and not cadmium telluride based, Technology Trends | Energy Markets & Policy (lbl.gov)

⁵ [End-of-Life Solar Panels: Regulations and Management | US EPA](#)

The decommissioning plans must include decommissioning surety bonds or another form of financial assurance that would secure either all or part of the costs required for decommissioning. The purpose of financial assurance is to provide the landowner of a renewable energy site, among other stakeholders, with proof that a decommissioning plan can fully be carried out in line with projected costs. The specific requirements for decommissioning are subject to the expected useful life of the equipment, the size of the project (defined in MW), and the rules and regulations of the state and local jurisdictions. Currently, there are no decommissioning requirements at the State level for solar and wind energy projects that are less than 25 MW.

Projects that are larger than 25 MW and any co-located system storing energy generated from such a renewable energy system prior to delivering it to the bulk transmission system are permitted through the Office of Renewable Energy Siting and Electric Transmission (ORES) which established procedural and substantive requirements for permits for the siting, design, construction, operation, compliance, enforcement, and modification of major renewable energy projects pursuant to Title 16 of the New York Public Service Law. ORES requirements specify the need for a decommissioning plan.

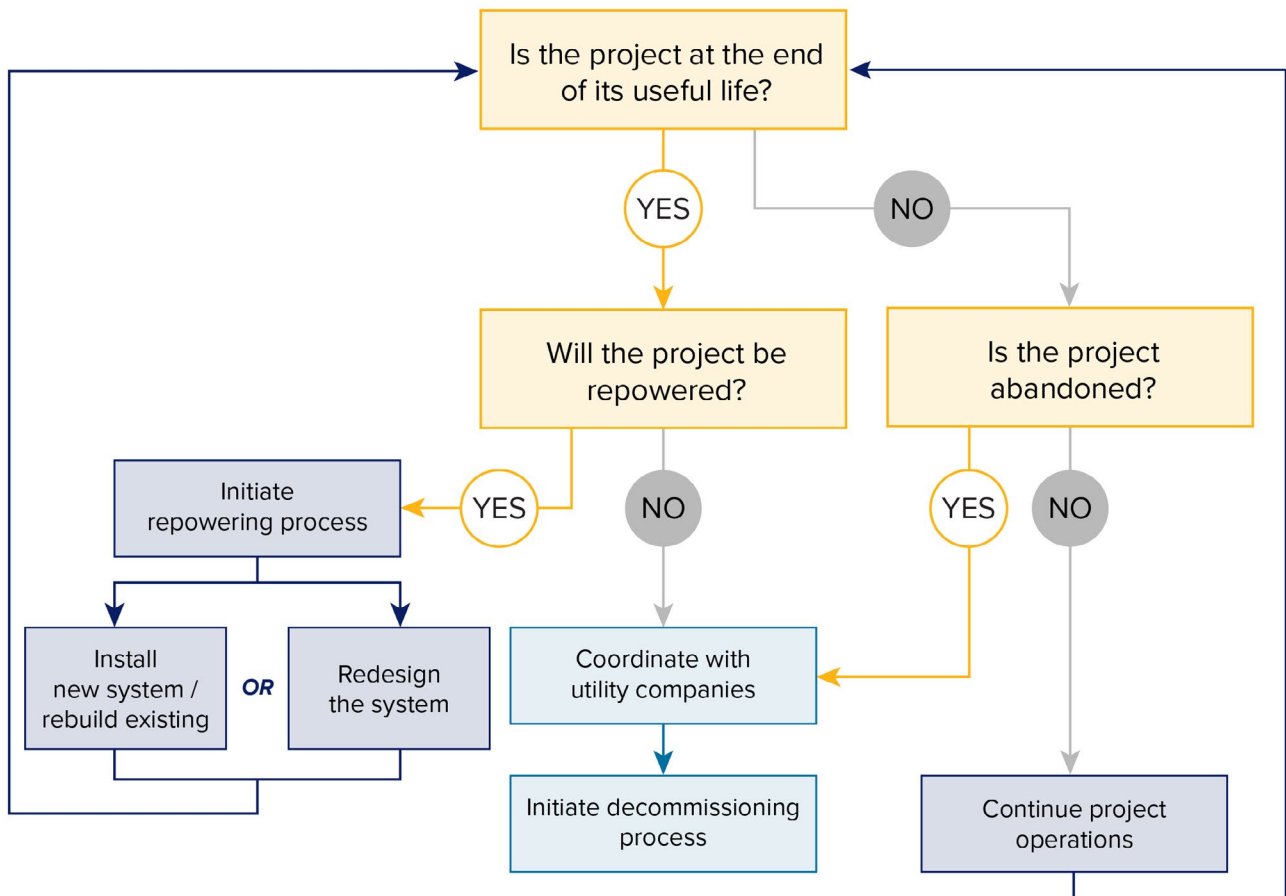
There are specific decommissioning requirements for battery energy storage systems, which can be found in *New York State Battery Energy Storage System Guidebook*.⁶ Many local authorities are directing project owners to commit to the responsible management for removal, disposal and/or recycling of equipment and the costs associated with those processes. Successful decommissioning is contingent on careful planning from the outset, and thorough execution to ensure safety, environmental responsibility, and regulatory compliance with a goal to return the land to a similar state in a sustainable manner.

This chapter will provide an overview of decommissioning and associated activities as they relate to renewable energy projects. In this document, “**renewable energy projects**” include solar, onshore wind, and battery storage energy projects, and **exclude offshore wind energy projects**, unless otherwise noted.

3. What options are available at the end of a renewable energy project's useful life?

There are two options available at the end of a renewable energy project's service life: repower utilizing existing infrastructure, which requires less capital expenditure; or remove the facility. Figure 1 below illustrates the EOL considerations and the decommissioning process for renewable energy projects.

Figure 1 | Renewable Energy Project's End of Useful Life Decision Process



4. Decommissioning Projects

What is decommissioning?

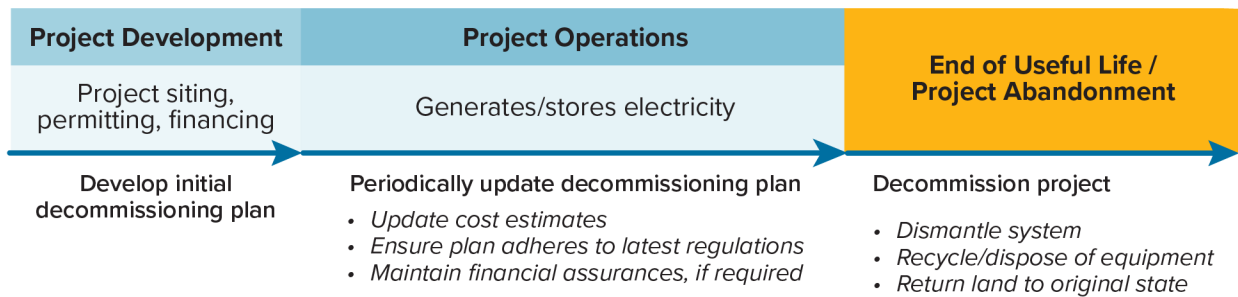
Decommissioning is the process of removing a renewable energy project and returning the project site to its original state through remediation and restoration.

Decommissioning is the process of removing an abandoned or EOL renewable energy project and remediating the land to its pre-construction condition. It includes the removal of the facility infrastructure and all ancillary components (i.e., solar panels or wind turbines, posts, electric wiring, fencing, inverters and transformers, substations, operations and maintenance building, foundations, access roads, generation tie line infrastructure, etc.) and the stabilization and re-vegetation of the site. Although the decommissioning process itself occurs at the closure of a renewable energy project, it involves planning for it from the beginning of the project as well and throughout the life of the project as shown in **Figure 2**. The specific requirements for decommissioning can vary by jurisdiction, and local governments have a fair amount of latitude in determining decommissioning processes for renewable energy projects. Large renewable energy projects (25 MW or more) require a decommissioning plan that complies with local government decommissioning regulations, if any, as part of ORES permitting and approval in the project development phase. As such, it is important for local governments to adopt decommissioning requirements into their local laws that meet the needs of their communities.

What is abandonment?

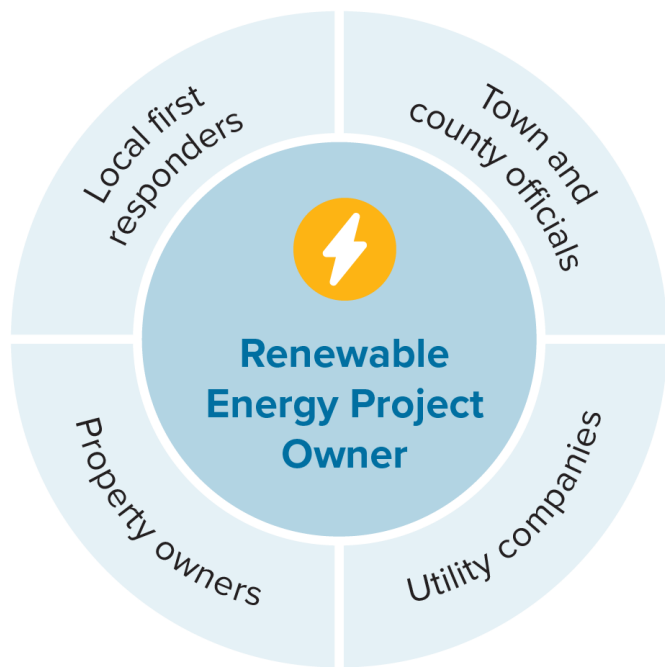
Abandonment is when a renewable energy facility is inactive (not producing energy) for a defined period of time. Precise timelines and definitions of abandonment are determined by local jurisdiction in local law but is typically considered 6-12 months of inactivity. If the energy facility's installation activities are inactive beyond the period allotted by local regulation, it must be decommissioned.

Figure 2 | Decommissioning Process Overview



Who is involved during decommissioning?

Figure 3 | Potential Stakeholders in Decommissioning a Renewable Energy Project



The goal of decommissioning is the safe and efficient removal of all renewable energy facility components and restoration of the site to conditions as close to pre-construction characteristics as possible, including restoration of native vegetation, habitat and/or land use. As such, the same safety protocols that are used during construction should be used during decommissioning. Decommissioning activities involve potential impacts on numerous stakeholders and the surrounding environment.

Figure 3 shows the many stakeholders that might need to be engaged before or during the decommissioning process.

Prior to the commencement of any decommissioning activities, it is recommended to notify relevant stakeholders including government officials, emergency personnel, the facility's property owner, the landowner(s) and the local utility service provider(s). While it is not required to notify all potential stakeholders, this is considered a best practice. Notification may be in the form of letters, newspaper notices, updates on the project owner's website, or direct communication.

As part of the changes introduced by the Climate Act and Renewable Action Through Project Interconnection and Deployment (RAPID) Act, stakeholder engagement, environmental assessments, and any other consultations with the public or other agencies are conducted while the project is in the initial permitting and siting stage. Decommissioning activities should not require additional permits or consultations.

When should a project be decommissioned?

The timing of decommissioning depends on the useful life of the critical equipment. The average lifespan of renewable energy projects is between 20-30 years, with newer solar panels lasting as long as 30-35 years. The decision to decommission a renewable energy project may be based on the site's permits, the economic viability of the project, and existing power purchase agreements (PPAs) in place governing the project's output.

Table 2 | Typical Lifespan of Renewable Energy Projects

Solar PV	Onshore Wind Turbines	Battery Energy Storage Systems
 <p>30-35 years (though typical performance warranty length is 25-30 years)⁷</p>	 <p>Approximately 30 years⁸</p>	 <p>Approximately 15-20 years (depending on battery type)⁹</p>

⁷ [End-of-Life Management for Solar Photovoltaics | Department of Energy](#)

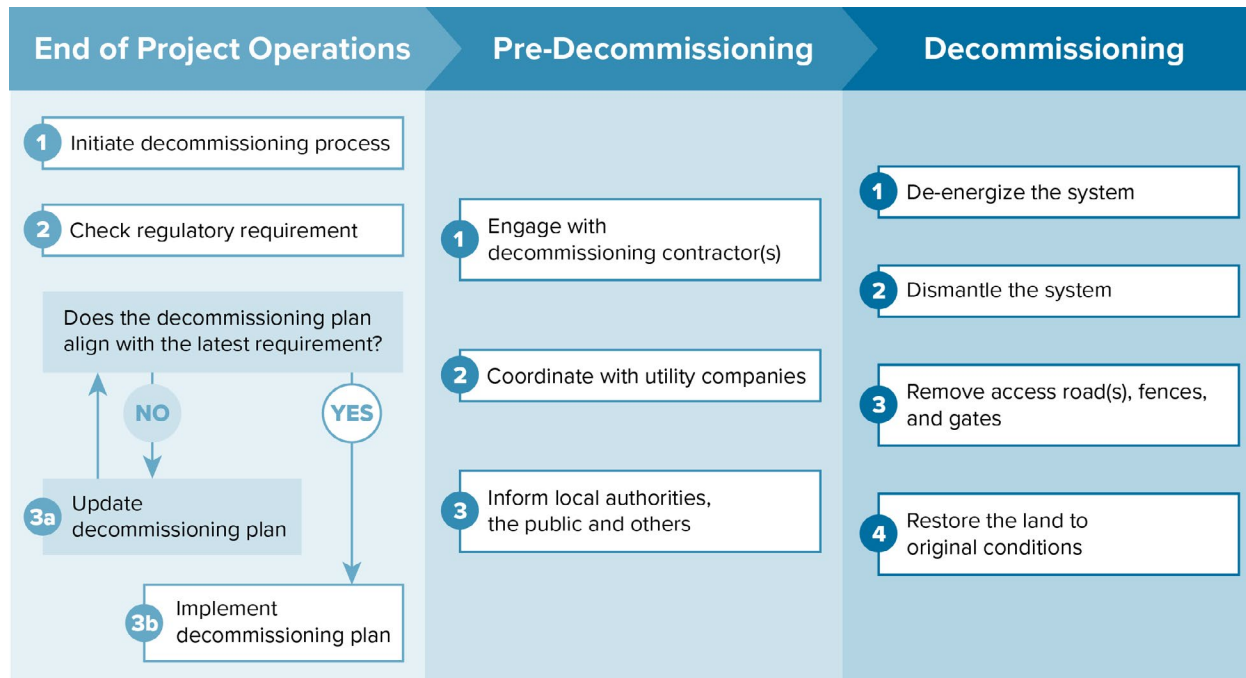
⁸ Benchmarking Anticipated Wind Project Lifetimes: Results from a Survey of U.S. Wind Industry Professionals | Energy Markets & Policy (lbl.gov) ([lbl.gov](#))

⁹ [Cost Projections for Utility-Scale Battery Storage: 2023 Update](#)

What types of activities are involved in decommissioning?

Decommissioning-related activities can be divided into: activities that take place at the end of project operations, pre-decommissioning activities, and decommissioning activities. Pre-decommissioning activities include developing and updating decommissioning plans, obtaining bonds, letters of credit, or sureties, and paying management fees. Decommissioning generally includes dismantling the system and restoring the land.

Figure 4 | Activities from End of Operations Through Site Restoration

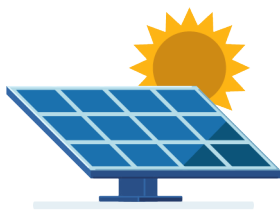


When renewable energy projects are being permitted, the submitted decommissioning plan will detail and govern the triggers, timing, and requirements for decommissioning a project. This ensures that all necessary steps for decommissioning are acknowledged by the project stakeholders before it is constructed, and there is an agreement in place to return the developed land back to its original state at the end of the project's life.

Decommissioning should not entail additional permitting or applications before decommissioning activities begin.

Original State | Unlike other types of real estate development, at the end of a solar project's lifecycle, the land it is sited on must be restored to pre-existing conditions.

Solar PV Decommissioning Activities



Dismantling activities include disassembling and transporting the equipment from a renewable energy project. Specific activities for solar projects include panel removal, posts & rack removal, and removal of inverters or other major equipment.

Restoration, remediation, and disposal activities include grading, seeding disturbed areas of ground, site restoration, conducting site decompaction (if applicable), and site monitoring with the aim of restoring land to its pre-project condition after infrastructure is removed. Its "pre-project" condition may vary depending on the type of land where the project is located, so developers

and local governments should ensure the correct standard is met for decommissioning and restoration. If the solar facility is within a state-certified Agricultural District and seeking funding from NY-Sun or awarded a Tier 1 Renewable Energy Certificate Agreement from NYSERDA's Large-Scale Renewable program,¹⁰ the project owner must notify New York State Department of Agriculture and Markets (NYSAGM) prior to decommissioning and follow specific decommissioning guidelines set forth in NYSAGM's Guidelines for Solar Energy Projects - Construction Mitigation for Agricultural Lands.¹¹ Stormwater basin

¹⁰ <https://www.nyserdera.ny.gov/All-Programs/Large-Scale-Renewables/RES-Tier-One-Eligibility>

¹¹ [Guidelines for Solar Energy Projects - Construction Mitigation for Agricultural Lands](#)

related infrastructure is also removed, and basins are filled in. Disposal entails trucking components to recycling centers or landfills. Precise restoration needs will depend on the project and the agreements in place between the developer and the landowner. Some infrastructure, such as roads and utility infrastructure, may remain in place. Utility infrastructure may include electrical distribution, fiber optic communication equipment.

Dismantling solar projects can take 12 months or more, depending on the size of the project. New York State does not currently have a time limit for when decommissioning must occur. Local governments have the authority to set decommissioning timelines for projects within their jurisdiction.

Onshore Wind Turbine Decommissioning Activities



For wind projects, the turbines, blades, turbine foundation, meteorological tower, collection system, and other civil works are dismantled in the removal phase. Similar to solar facility decommissioning, civil infrastructure may remain in place, depending on the agreement in place with the landowner.¹² Wind projects permitted under Article 10 or ORES must adhere to a decommissioning and restoration plan approved by the applicable siting authority. Those projects are also required to provide the municipality(ies) with letters of credit or security bonds that will cover the cost of decommissioning in the event of abandonment by the facility owner.

Disassembling, demolishing, and removing wind turbine components and conducting site restoration can take between 6 and 24 months, depending on the size of the project. Some jurisdictions require projects to be fully decommissioned within 12 months of inactivity, or abandonment.

Battery Energy Storage Systems Decommissioning Activities



For battery energy storage systems, integrated battery storage units, inverter/transformer stations, support piers and foundations, electrical cable and conduits, and perimeter fencing are dismantled in the removal phase. While the *New York Battery Energy Storage Guidebook* does not prescribe precise agricultural mitigation guidelines, it is recommended to follow the guidance available for solar facilities: if the project is sited on Mineral Soils Groups 1 – 4, the project owner must notify NYSAGM prior to decommissioning and follow specific restoration, monitoring, and remediation guidelines.

Decommissioning activities of battery energy storage systems typically begin within 12 months of the project ceasing operation and are anticipated to be completed within 6 - 12 months of start of decommissioning, depending on the size of the project. For more information, please refer to *New York State Battery Energy Storage System Guidebook*.¹³

What is included in a decommissioning plan?

A decommissioning plan is typically required for renewable energy projects during the conditional use or zoning approval permitting period. It includes an estimate of the costs for decommissioning and may have a section on financial security. An example of a decommissioning plan can be found in the Model Solar Energy Local Law chapter of this Guidebook. If a renewable energy project that is larger than 25 MW is located on land that is not owned by the project owner (applicant), a decommissioning plan and guaranty/security agreement (if one is obtained) between the applicant and landowner is often included in a permit application to the ORES process.

A final decommissioning plan should include:¹⁴

- Contact information for all parties (landowner; solar developer; authorities having jurisdiction; and any known sources of services, such as recycling programs and emergency service providers);

Decommissioning activities are not anticipated to occur until project end of life, and regulatory requirements may change.

As such, before commencing any decommissioning activities, the project owner shall update the decommissioning plan in accordance with appropriate local, state, and federal requirements at the time of decommissioning. It is also common to require updates to the decommissioning plan, cost estimates, and any bond or other financial surety amounts every five years.

¹² [Guidelines for Wind Energy Projects – Construction Mitigation for Agricultural Lands](#)

¹³ [New York State Battery Energy Storage System Guidebook](#)

¹⁴ Decommissioning solar energy systems WEB.pdf ([cfra.org](#)).

- Any warranted recycling of PV panels or other components that were provisioned as part of the original procurement; any bonds to take back PV panels or other equipment (if applicable);
- Estimated lifespan of the project;
- Conditions that trigger the decommissioning (certain date, end of lease, system inoperative for 12 months, any other);
- Time period within which the decommissioning must be completed (e.g., 12 months or more; likely similar to how long it took to construct the project);
- Scope of work for decommissioning, which often includes removing all equipment,¹⁵ grading to restore water runoff characteristics, restoring ground cover (seed), or otherwise restoring the land to its original condition unless the landowner wishes to retain any of the infrastructure or improvements;
- Roles and responsibilities of the landowner, developer, and any other parties clearly delineated;
- Estimated cost of decommissioning (both the gross cost, considerations for inflation, and the cost net of any salvage value); and,
- Financial surety such as bond, letter of credit or another instrument.

For battery energy storage system specific decommissioning plan requirements, please refer to *New York State Battery Energy Storage System Guidebook*.¹⁶

What are New York State requirements for decommissioning?

There are several places where stakeholders may find information on decommissioning renewable energy projects that is specific to New York.

Projects smaller than 25 MW are permitted at the local level, so decommissioning requirements are specified by each municipality in the regulations that govern renewable energy projects. The Model Solar Energy Local Law [Chapter of this Guidebook](#) has model language that municipalities can consider for inclusion in their renewable energy laws. NYSERDA's model solar energy law also includes a model decommissioning plan that local municipalities can reference or look to include as a part of their land use regulations.

Renewable energy projects larger than 25 MW and any co-located energy storage systems require a decommissioning plan as part of the environmental review and permitting process under the RAPID Act, which was enacted on April 20, 2024 as part of the FY 2025 Executive Budget Legislation.¹⁷ The RAPID Act repealed the previous Section 94-c of the Executive Law, which was intended to establish an expedited review and permitting process with uniform permit standards for New York State renewable energy projects. It also repealed the previous Article VIII of the Public Service Law which governed the environmental review and permitting of major steam electric generation siting. The RAPID Act will continue to maintain all the environmental review and permitting requirements under Section 94-c established by ORES' 19 NYCRR Part 900 regulations until the new regulations are finalized in 2025. Based on the requirements of 16 NYCRR Part 1101, decommissioning cost estimates included in decommissioning plans should include the gross cost of decommissioning, plus a 15% contingency cost. The plan should also include a net decommissioning cost estimate in present day dollars, which is the gross cost (including contingency), less the total estimated salvage value of project components.¹⁸

ORES requires that developers of major renewable energy facilities include a Final Decommissioning and Site Restoration Plan in their compliance filing while seeking a building permit. The plan must include a decommissioning cost estimate, and proof that letters of credit or other financial assurance approved by ORES have been obtained in an amount equal to the decommissioning cost estimate. The letters of credit or other appropriate financial assurance must be provided to ORES after one year of project operation and updated every fifth year to include any changes to the structure of the financial assurance. These updates are intended to account for inflation or other cost increases to the initial decommissioning estimate.¹⁹

¹⁵ 94-c regulations no longer govern large scale projects; these regulations transferred to 16 NYCRR Part 1100 and Part 1101 which require components to be removed four feet below grade in agricultural land and three feet below grade in non-agricultural land.

¹⁶ [New York State Battery Energy Storage System Guidebook](#)

¹⁷ A.B. A8808B, 2024-2025 transportation, economic development and environmental conservation budget, 2023-2024 Leg. Sess. (New York, 2024). [Governor Hochul Announces Historic Investment of the FY 2025 State Budget](#) Accessed on December 15, 2024.

¹⁸ 16 NYCRR Part 1101

¹⁹ 16 NYCRR Part 1100

Decommissioning is a critical step in returning land to its original state, considered the state prior to construction. ORES regulations allow project owners to negotiate the conditions of the land at the end of the project life. The advantage of renewable energy projects over fossil fuel energy is that they do not emit harmful airborne or leak-prone pollutants where they generate energy. So, when decommissioning is completed, land that was once residential, or even arable agricultural land, can be more easily returned to that purpose.

The decommissioning estimate must include the removal of all project components up to four feet below grade in agricultural land or three feet below grade in non-agricultural land and the removal and restoration of access road locations, if appropriate.²⁰

The ORES website contains several valuable resources on permitting for renewable energy projects, from application guidance, webinars, and presentations on submitting permit applications to the new streamlined procedure.²¹ Local governments and developers can access their site to learn more about applications and the permitting process. They also publish application status updates on their website, which can provide valuable insight into decommissioning opportunities and challenges.²²

Finally, it is important to note that the precise decommissioning requirements may vary for solar, wind, and battery storage energy projects, depending on the local jurisdiction.

What are typical decommissioning costs?

Decommissioning plans require a cost estimate that is project specific, as each renewable energy project will have unique characteristics that result in variations in cost estimates. All costs and renewable energy capacities noted here are in alternating current (ac), unless otherwise noted. The following cost estimates were produced from an examination of over 100 solar decommissioning cost estimates produced within New York between 2021-2024 for projects exceeding 1 MW-ac. The average decommissioning cost estimate, prior to contingencies or salvage value, for solar projects was approximately \$50,000 (2024\$) per MW-ac.²³ The average inflation rate for these projects was 2.1% with the range between 10% and 25%.

Table 3 | Breakdown of Typical Decommissioning Costs for Solar Projects, 2024\$/MW*

	Low ²⁴	Median	Average	High ²⁵
Pre-Decommissioning Activities	\$254	\$1,823	\$5,696	\$30,572
Dismantling & Disposal Activities	\$2,787	\$24,257	\$28,741	\$60,126
Site Restoration & Remediation Activities	\$1,581	\$11,732	\$13,519	\$32,056
Total Decommissioning Costs, Excluding Contingency & Salvage Value	\$4,547	\$41,548	\$47,823	\$98,149
Contingencies	\$2,539	\$17,768	\$28,422	\$78,536
Salvage Value	\$5,047	\$19,143	\$27,949	\$59,146
Total Decommissioning Costs, Including Contingency & Salvage Value	\$1,094	\$41,860	\$51,383	\$117,260

*Values in bolded rows will not sum since they represent percentile values, not totals

²⁰ 16 NYCRR Part 1100

²¹ Resources | Office of Renewable Energy Siting ([ny.gov](https://www.ny.gov))

²² Permit Applications | Office of Renewable Energy Siting ([ny.gov](https://www.ny.gov))

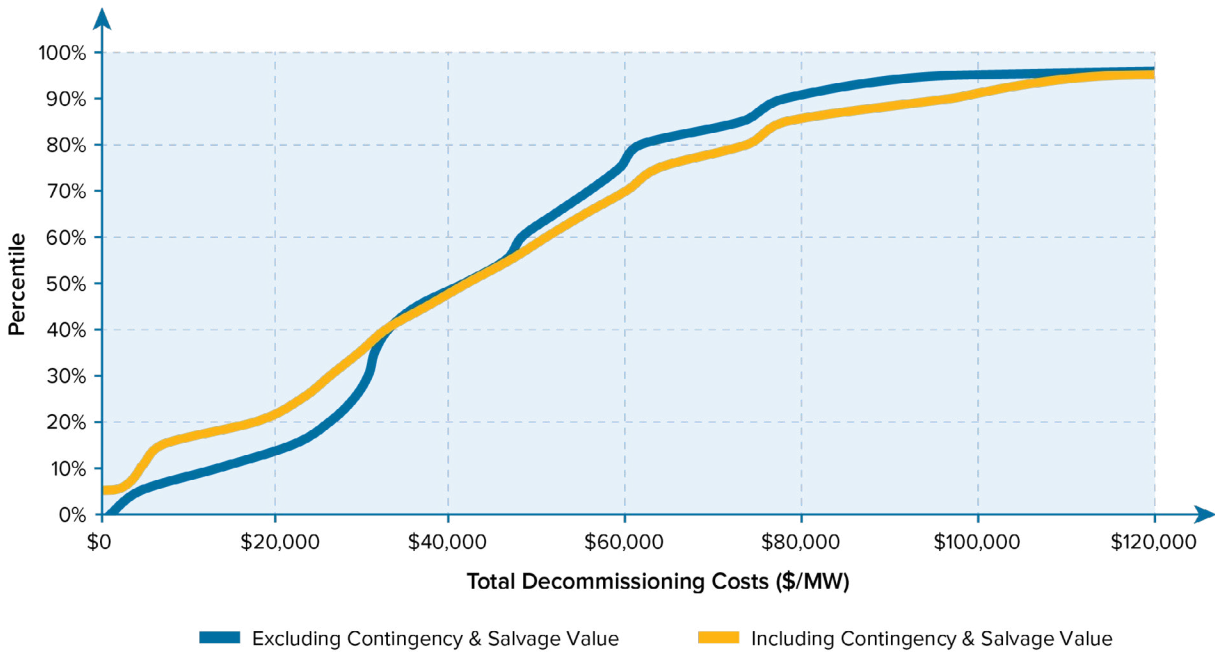
²³ Original source for this data is a NYSERDA internal database

²⁴ The low estimate used in the analysis are representative of the 5th percentile for cost estimates.

²⁵ The high estimate used in the analysis are representative of the 95th percentile for cost estimates.

Figure 5 shows the distribution of the examined decommissioning cost estimates for solar projects within New York in 2023. From these projects, 95% of the estimates had a cost less than \$100,000 per MW before contingencies and salvage value.

Figure 5 | Distribution of Typical Decommissioning Costs Estimates for Solar Projects in New York, 2024\$/MW-ac



There was limited data on decommissioning cost estimates for onshore wind energy projects from NYSERDA's internal data, and as a result they are not included in the decommissioning cost discussion here.

Some decommissioning planning costs are incurred before the project even enters operations, such as the initial decommissioning plan writing and cost estimation, and legal and financial costs to obtain any financial sureties required. However, the vast majority of costs are incurred when the project is decommissioned, disposed, or recycled at the end of its useful life.

How does inflation impact decommissioning costs?

Since decommissioning costs are not incurred until years after the initial decommissioning cost estimate, it is important to recognize there will be growth in costs over time. Inflation is used to measure the average change in prices over time, allowing for the estimation of costs into the future.

Decommissioning cost estimates are typically prepared in present day dollar terms, without inflation, because of the uncertainty around future prices. However, municipalities require developers to bond for the current decommissioning cost plus an added amount to capture inflation.

For a more detailed discussion of inflation and how it is measured, see the accompanying [NYSERDA Inflation Primer](#).

Recent periods of high inflation - driven in part by the COVID-19 pandemic and supply chain shock - have highlighted inflation's impact on project costs and brought it to the forefront of industry discussions. It is important to remember that reported inflation numbers represent a point-in-time estimate measuring the change in prices relative to the previous year. While there may be variability in year-over-year estimates due to changing market forces, the Federal Reserve strives to maintain price stability by targeting a long-run inflation target of 2%.²⁶ Since inflation can play a significant role in the required bonded amount due to the compounding effect, it is important to remember over longer-term horizons, inflation has tended to remain at or around 2%. Short term inflation forecasts can be found through various institutions including the Federal Reserve, commercial banks and other financial institutions, and economic research think tanks.

²⁶ The Fed - Why does the Federal Reserve aim for inflation of 2 percent over the longer run?

The two statistical agencies that produce inflation estimates are the Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics (BLS). The BEA produces key measures of inflation, such as the Consumer Price Index (CPI) and the Producer Price Index (PPI). The BEA produces the Implicit GDP Deflator, a national level inflation measure that also has forecasts published by the White House Office of Management and Budget.²⁷ For a more detailed discussion of inflation rates and escalation, consult the [Inflation Primer in Appendix A](#).

What are the financial mechanisms used to ensure decommissioning activities take place?

Financial mechanisms can be effective means to ensure compliance with decommissioning requirements. Financial assurance mechanisms for decommissioning are obtained prior to the start of decommissioning, and may be held by a financial institution, the local government, or the third-party landowner.²⁸ For renewable energy projects permitted at the state level (through ORES), financial assurances are to be provided after one year of operations. Financial assurance requirements will vary for projects permitted at the local level. The amount of the financial assurance should be equal to the estimated cost of decommissioning, minus salvage value. Projects permitted at the state level must include a security agreement between the applicant and the landowner if the project is not located on the applicant's property. Local governments have several options when it comes to what type of compliance mechanism to require. The types of financial mechanisms for decommissioning include decommissioning trusts or escrow accounts, removal or surety bonds, and letters of credit. Selection of any specific financial mechanism may have consequences beyond the scope of this document and as such local governments are advised to obtain legal counsel and/or financial advice with respect to such a decision.

For a local example, see the General City Law. The laws and regulations around enforcement mechanisms are described in several places in the General City Law, particularly Article 3, 27-a, 27-b, and 33.²⁹

Town of Geneva* | Local Penalties

The Town of Geneva's Code Chapter 130 states that projects that fail to implement the decommissioning plan within the allotted 180-day period following the end of electricity production may be subject to various financial penalties.** The Town may provide for the restoration of the site in accordance with the decommissioning plan and recover expenses from the owner and/or operator, or from the performance bond obtained at the outset of the project. Further liens may be applied to the property, and any unrecovered costs are assessed against the property, and collected in the same manner as other taxes.

**The Town of Geneva is chosen for illustrative purposes only and is not intended to be representative of local government policies around the state.*

***Source: Town of Geneva Legislation through 08-08-2023*

What are letters of credit?

Letters of credit are documents that assure payment based on certain conditions being met. In the case of decommissioning, renewable energy developers may obtain letters of credit that, should they fail to fully remove their system, entitles the landowner or Authority Having Jurisdiction (AHJ) to payment so they may decommission the installation themselves. The letter of credit should include terms such as the conditions for payment, supporting documentation needed from the landlord, and an expiration date. It must be renewed or replaced over the life of the project until decommissioning obligations are met. Banks typically require a pledge of securities or cash as collateral for issuing a letter of credit.³⁰

A letter of credit is an agreement between three parties:

1. The issuer (bank or financial institution issuing the letter);
2. The customer of the issuer (applicant/ project owner); and
3. The beneficiary (obligee/ AHJ).

²⁷ [White House Office of Management and Budget, Table 10.1](#)

²⁸ 16 NYCRR Part 1101

²⁹ [NYS Open Legislation | NYSenate.gov](#)

³⁰ Letter of Credit (LoC) in Renewable Energy Project Finance ([renewablesvaluationinstitute.com](#))

Letters of credit act as a financial guarantee to the AHJ, who can call on the letter under specified conditions, (e.g., if the developer defaults on decommissioning or abandons the renewable project), and as an interest-accumulating loan for the project owner. The financial institution has no obligation to ensure the successful completion of the project and solely focuses on financial compliance. Banks also collect a fee for service, typically a percentage of the size of the letter of credit.³¹

According to ORES regulations, letters of credit for major renewable energy facilities must be provided after one year of system operation, and every five years thereafter.³²

What are decommissioning trusts or escrow accounts?

Trusts or escrow accounts are two financial assurance options that are utilized to meet the expected cost of decommissioning at the end of the renewable energy project's lifecycle. An AHJ may require the project owner to either post full funding for decommissioning at the beginning of the project's life or according to a fee schedule set out in the use permit approval.

The specific terms of the account, such as the payment amount and frequency, can be included in the land lease agreement or use permit. If applicable, the provisions of the trust or escrow account will be described in the decommissioning plan.

A renewable energy project owner may deposit funds into a cash escrow account maintained by a federally insured financial institution. Once the project owner fulfills the decommissioning requirements set by the AHJ at the end of the facility's life, the bank will release the funds deposited in the cash escrow account back to the developer. If the solar project is abandoned or not decommissioned according to local regulations, the bank will grant the AHJ access to the cash escrow account to complete the decommissioning process.

What are removal or surety bonds?

Providing bonds is another way for renewable energy developers to ensure sufficient funds are available for decommissioning. The amount of the bond should equal the total decommissioning costs for the project and must remain valid until all decommissioning obligations are met. If the timing or costs of decommissioning changes over the course of the project, then the bond must be renewed to reflect the new conditions. A removal or surety bond is a special type of performance bond.³³

A surety bond is an agreement between three parties:

1. The "obligee" requiring the bond - here, the AHJ;
2. The "principal" purchasing the bond (applicant/ project owner); and
3. The "surety" guaranteeing the payment of valid claims against the bond (a bank or other financial institution).³⁴

The main advantage from the principal's (project owner's) standpoint is that a surety bond does not require a large initial upfront cash payment, tie up the principal's working capital, or credit line. In the case of renewable projects, this could potentially be for a period of many years. If the principal does not meet their obligations as defined in the decommissioning plan, the bond ensures that funds will be available to cover the cost of decommissioning.

This bond also applies should the principal abandon the facility during its' useful life (where abandonment is defined in the decommissioning agreement), so it protects the obligee throughout the entire duration of the project. If the project owner violates the terms or conditions of the bond, the AHJ can file a claim against the bond. A surety bond reduces the risk of financial burdens on the local government in the long-term by requiring bonds at the outset of the project.³⁵

What are the non-financial mechanisms used to ensure decommissioning activities take place?

Local governments have several options to enforce decommissioning of renewable energy projects through legal means which can supplement the financial mechanisms described above. These include decommissioning provisions in land use regulations, land-lease agreements, or abandonment and removal clauses.

³¹ [Decommissioning of Solar Sites: A Key Consideration of the Project - SolUnesco](#)

³² [50-States-of-Solar-Decommissioning-2023-Snapshot-NCCETC-2024.pdf \(ncsu.edu\)](#)

³³ [What are performance bonds? | Allianz Trade \(allianz-trade.com\)](#)

³⁴ [What is a Surety Bond? Surety Bonds Explained. \(suretybondsdirect.com\)](#)

³⁵ [Solar Decommissioning Bonds \(thehortongroup.com\)](#)

How can land use regulations be used to ensure decommissioning activities take place?

Special-use permits are another option for local governments that can be issued to renewable energy project developers. Once a local government determines a solar panel system is abandoned (as defined by the decommissioning plan or by the local law) and has provided written notice (within a legislated time frame) to the owner, it can take enforcement actions, including imposing civil penalties/fines, and removing the system.

Local governments can issue a variance (a re-zoning of a property) for an agreed-upon term with the project developer. For example, if a solar energy system has an expected lifespan of 30 years, then a variance can be granted for that time period. If it is not renewed at the end of that 30-year term, the site would no longer comply with local zoning, and the jurisdiction could then use their regular zoning enforcement authority to require the removal of the project.

What are decommissioning provisions in land-lease agreements?

Renewable energy installations are often located on private land where the project owner negotiates a land-lease agreement with the landowner. For these kinds of projects, the decommissioning requirements can vary depending on the preferences of the landowner. For example, the landowner may prefer a buyout clause rather than a full decommissioning of a renewable energy project.³⁶ Or, if access roads are built in the project construction phase, leaving them after decommissioning could be negotiated in the land-lease agreement. The landowner could also assign responsibility in the case of abandonment: such a clause could mean the developer is responsible for paying the costs of removal, if they abandon the project.

What are abandonment and removal clauses?

Rather than apply financial penalties directly in cases of abandonment, abandoned renewable energy projects may be re-zoned under abandonment and renewal clauses in lease agreements. Then, abandoned renewable energy projects would be classified as zoning enforcement violations, and project owners are required to remove equipment or face penalties, fines, or liens on the property. To maximize the effectiveness of these clauses, the local government must clearly include a definition of abandonment: how long must a project be out of service to be considered abandoned, a reasonable timeline for removal of the renewable energy system, and clearly define “removal” based on other remediation or reclamation requirements.

What happens to dismantled renewable energy equipment?

After renewable energy equipment has been dismantled, there are three main ways to deal with the equipment: recycling, repurposing, or disposal.

Recycling or resale involves the re-use of some or all materials that comprise a renewable energy facility. Both of these options ensure the recovery of resources which will reduce waste, minimize the environmental impacts, and the total energy needed to mine, transport, refine virgin materials, and manufacture new renewable energy equipment.

Approximately 95% of a PV panel is recyclable and between 85 to 90% of a wind turbine is comprised of materials that can currently be commercially recycled. Products recovered through recycling, including rare earth and precious metals and recyclable plastics, can be used for domestic manufacturing or listed for resale in the commodity market. Domestic recovery of these resources can reduce U.S. dependence on foreign imports and alleviate resource constraints.

The bulk of the unrecycled materials in wind turbines are fiber-reinforced composites (carbon fiber and fiberglass). These materials can be found in various forms in wind turbine blades, nacelle covers, and the cover for the hub that connects the blades to the wind turbine.³⁷ However, much of a wind turbine can be recycled, since it is composed of metals or electrical components that are readily recyclable. This section focuses on recycling solar PV panels since there are currently a limited number of facilities able to recycle or resell wind turbine blades in the US.

³⁶ [What Happens At The End Of A Solar Lease? \(palmetto.com\)](https://palmetto.com)

³⁷ U.S. Department of Energy. “Wind Turbine Sustainability.” <https://www.energy.gov/eere/wind/wind-turbine-sustainability>

What materials are typically found in solar panels and wind turbines?

Solar panels and wind turbines may both offer positive economic value at the end of their service lives, based on salvage values for the project components. Most solar panels in New York use crystalline silicon (c-Si) cells.

c-Si solar panels contain easily recyclable materials including:³⁸

- Glass, which accounts for between 55%-80% of the mass of panels;
- Aluminum, which accounts for between 8%-22% of the mass of panels;
- Copper, which accounts for between 0.5%-4% of the mass of panels; and
- Plastic, which accounts for between 1%-3% of the mass of panels.³⁹

While glass and aluminum make up the majority of the mass of recyclable materials, these materials tend to be of low value in secondary markets. Other valuable materials can be found in smaller quantities in solar panels, though these materials may be more difficult to extract for recycling, including:

- Silicon, which accounts for between 2%-5% of the mass of panels;
- Tin, which accounts for less than 0.2% of the mass of panels;
- Lead, which accounts for less than 0.1% of the mass of panels; and
- Silver, which accounts for less than 0.1% of the mass of panels.⁴⁰

Wind turbines also have a majority of material by mass that can be recycled. Wind turbines are comprised of the following materials:

- Steel, which accounts for between 66%-80% of the mass of turbines;
- Fiberglass, resins, and plastic, which accounts for 11%-16% of the mass of turbines;
- Iron, which accounts for 5%-17% of the mass of turbines;
- Copper, which accounts for 1% of the mass of turbines; and
- Aluminum, which accounts for less than 2% of the mass of turbines.⁴¹

The value of these materials per ton fluctuates depending on prevailing market conditions. Silicon can be recycled, potentially for reuse in solar panels, but it is an expensive, energy intensive process to do so. Silver and copper are valuable materials used in a variety of industrial processes and account for a significant portion of the value of recycled materials from c-Si solar panel. Mounting piles, racking, and even transformers may also be recycled at the end of the solar panel's service life.

Many decommissioning plans include forecasted costs for these goods but recognize that it is impossible to predict the market price for commodities up to 30 years in the future. This highlights the need to update decommissioning cost estimates on an ongoing basis.

Decommissioning plans typically include options for salvage and resale of project components since many objects will retain significant residual value at the end of initial useful life. For example, the Decommissioning Cost Analysis for the Dakota Range Wind Project compares the full cost of decommissioning with salvage and part resale scenarios.⁴² Certain parts are sold for scrap, while others are resold because they have been purchased later in the project's life. The plan includes the gearbox, generator, and blades among items that can potentially be sold to offset decommissioning costs.

It is likely that progress will be made on recycling and disposal options for projects over the next few years, as shown by the variety of government regulations, scientific research, and industry initiatives being explored. This means that local governments will need to stay abreast of policies and practices to ensure that projects are decommissioned properly. Salvage value and resale impact the financial bottom line of developers, but recycling or reselling can also reduce the burden on community landfills.

³⁸ <https://www.epa.gov/hw/solar-panel-recycling>

³⁹ Mulazzani, Andrea, Panagiotis Eleftheriadis, and Sonia Leva. 2022. "Recycling c-Si PV Panels: A Review, a Proposed Energy Model and a Manufacturing Comparison" *Energies* 15, no. 22: 8419. <https://doi.org/10.3390/en15228419>.

⁴⁰ Mulazzani, Andrea, Panagiotis Eleftheriadis, and Sonia Leva. 2022. "Recycling c-Si PV Panels: A Review, a Proposed Energy Model and a Manufacturing Comparison" *Energies* 15, no. 22: 8419. <https://doi.org/10.3390/en15228419>.

⁴¹ <https://www.nrel.gov/docs/fy17osti/66861.pdf>

⁴² <appendixp.pdf> (sd.gov)

Where can renewable energy equipment be recycled?

As of December 2024, there are 29 facilities with solar recycling capabilities across the United States.⁴³ The closest facility to New York State is Electronic Recyclers International (ERI) in Lincoln Park, New Jersey. ERI processes crystalline silicon (c-Si), the most common type of solar panel used in New York, and cadmium telluride (CdTe) panels for recycling.⁴⁴

Most first-generation wind turbine blades are treated as waste and destined for landfill. However, there have been some efforts at developing alternatives for turbine blade recycling. Some options include:

- Mechanical recycling, where blades are ground or shredded into materials that can be repurposed;
- Thermal decomposition recycling, where heat is used to recover glass fibers that can be upcycled into new composite products; or
- Repurposing, which involves the direct use of the decommissioned turbine blade to create pedestrian bridges, playgrounds, benches, or other goods.⁴⁵

Carbon Rivers

A Tennessee company, Carbon Rivers, has commercialized a process to recover clean, mechanically intact glass fiber from decommissioned wind turbine blades.* In addition, Veolia North American runs a program that turns turbine blades into cement.**

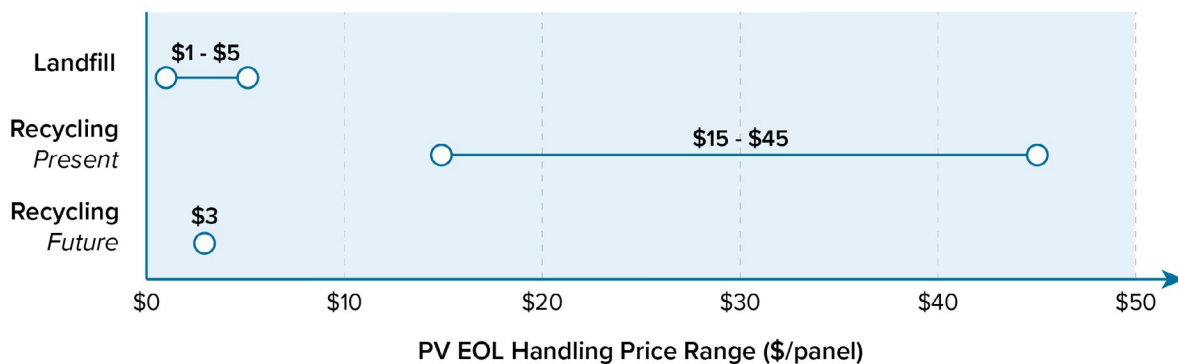
*Source: US Department of Energy "[Carbon Rivers Makes Wind Turbine Blade Recycling and Upcycling a Reality With Support From DOE](#)"

**Source: Chemical & Engineering News "[How can companies recycle wind turbine blades](#)"

What is the cost to recycle PV panels?

The current economics of PV panel EOL handling are unfavorable to recycling. The cost to recycle PV panels is significantly higher than landfill tipping fees. Recycling one solar panel costs \$15 to \$45—significantly more than the \$1 to \$5 per-panel cost of sending it to a landfill,⁴⁶ and significantly more than the anticipated value of recovered materials, estimated at \$2 per panel.⁴⁷ The Solar Energy Technologies Office (SETO) has announced a new target to bring the cost of recycling solar panels to about \$3 per panel by 2030.⁴⁸

Figure 7 | PV EOL Handling Price Range



⁴³ Mulazzani, Andrea, Panagiotis Eleftheriadis, and Sonia Leva. 2022. "Recycling c-Si PV Panels: A Review, a Proposed Energy Model and a Manufacturing Comparison" *Energies* 15, no. 22: 8419. <https://doi.org/10.3390/en15228419>

⁴⁴ Solar Energy Technologies Office. U.S. Department of Energy. "Solar Manufacturing Map." [Solar Manufacturing Map | Department of Energy](#) Accessed on July 19, 2024.

⁴⁵ WINDEXchange: End of Service Wind Turbine Guide ([energy.gov](#))

⁴⁶ Hutchingson, 2023. Bloomberg Law. "States Weigh Making Industry Pay Millions For Solar Panel Waste." <https://news.bloomberglaw.com/environment-and-energy/states-weigh-making-industry-pay-millions-for-solar-panel-waste>

⁴⁷ <https://www.nrel.gov/docs/fy21osti/74550.pdf>

⁴⁸ Iaconangelo, 2022. E&E News. "What happens to used solar panels? DOE wants to know." <https://www.eenews.net/articles/what-happens-to-used-solar-panels-doe-wants-to-know/#:~:text=The%20Solar%20Energy%20Technologies%20Office,solar%20power%20by%20decade's%20end.>

What is salvage value?

The salvage value is the estimated value of an asset at the end of its useful life. Renewable energy projects have many components, including steel, copper, aluminum, silver, silicon, and others. These materials can retain their value and be sold to recyclers during the decommissioning phase of solar or wind projects.

Salvage value is determined by the quantity of a solar or wind project's constituent elements, taking into account the cost to process these materials. These prices tend to fluctuate since they are used in industries other than renewable energy. In order to maximize published salvage values, materials must be cleaned, cut, and prepared according to Institute of Scrap Recycling Industries (ISRI) standards. Current values of salvaged materials can be found by visiting recycling and scrap indexes and websites online.

Some jurisdictions allow salvage values to be subtracted from total decommissioning costs to estimate the net cost of decommissioning, reducing the financial burden on project developers. However, developers should carefully note the requirements of the jurisdiction they fall under when constructing a project. To protect against fluctuations in the value of materials, certain jurisdictions may require a buffer on the value of salvage estimates to account for price changes over the lifespan of the project. Since project decommissioning costs are typically updated every five years, current estimated prices may not reflect future market conditions. Monitoring costs and including a buffer can help protect against price volatility in recyclable material prices.

Are there state or federal regulations mandating the recycling of renewable energy equipment?

Currently there are no federal statutes or regulations that mandate recycling-based recovery of solar PV panels in the U.S. However, state- and industry-led policies have started to emerge to address EOL PV panel management concerns. Washington, New Jersey, North Carolina, and California are the only U.S. states with laws or regulations that directly address PV panel recycling.⁴⁹

In addition, there are global and national voluntary industry standards that may encourage environmentally sustainable EOL management decisions of PV.⁵⁰ There are no current federal or state regulations around wind turbine recycling since these processes are still in their infancy.

What opportunities and challenges exist in the resale market?



Solar PV Panels

Used solar panels can be redeployed as replacement parts for or add-ons to existing systems, utilized in off-grid systems and repurposed into new, lower energy consuming builds. The secondary market in the U.S. has been gaining momentum in recent years. The volume of used panels listed for resale has increased by almost threefold.⁵¹

The resale price of solar panels increased by 29 percent in the U.S. over the three-year period, indicating an emerging secondary solar panel market.⁵²

Solar system owners could conduct hardware audits during decommissioning to determine if resale is feasible. Typically, panels can be resold if they are:⁵³

- Functional;
- Capable of producing power for a minimum of 10-12 years;
- The degradation rate is equal to an average of 0.5 to 1.9% per year over the panels' total years of operation; and
- Free of defects.

⁴⁹ Curtis et al, 2021. NREL. "Solar Photovoltaic Panel Recycling: A Survey of U.S. Policies and Initiatives." <https://www.nrel.gov/docs/fy21osti/74124.pdf>

⁵⁰ Curtis et al, 2021. NREL. "Solar Photovoltaic Panel Recycling: A Survey of U.S. Policies and Initiatives." <https://www.nrel.gov/docs/fy21osti/74124.pdf>

⁵¹ Pickereel, January 2024. Solar Power World. "Remarketed solar panels are retaining resale value, EnergyBin report finds." <https://www.solarpowerworldonline.com/2024/01/remarketed-solar-panels-are-retaining-resale-value-energybin-report-finds/>

⁵² Schmid, January 2024. EnergyBin. "2023 PV Panel Price Index - Secondary Solar Market." <https://resources.energybin.com/solar-resources/2023-pv-panel-price-index-secondary-solar-market>

⁵³ Schmid, June 2023. EnergyBin. "Resell or Recycle: A Guide for Handling Used Solar Panels." <https://resources.energybin.com/solar-resources/resell-or-recycle-a-guide-for-handling-used-solar-panels>.



Onshore Wind Turbines

As of February 2025, there is limited information on wind turbine resale. As noted above, many turbine blades are landfilled at EOL. However, there are increasing efforts to recycle, or potentially reuse wind turbines once they have reached their initial useful life.

Battery Energy Storage Systems



As batteries degrade over time, their cycle time and ability to recharge will decrease, until they are no longer economically viable. Refurbishing or reconditioning batteries for second use is an arduous process. First, batteries need to be tested to determine usability. The batteries must then be assembled into panels suitable for use. Coupling batteries of varying conditions can require more advanced control systems, which remains a significant challenge. The cost savings and the performance of reconditioned batteries need to be significant enough to make refurbishing appealing compared to purchasing new batteries. The discounted cost of reconditioned batteries relative to new ones must offset increased integration costs and reduced performance relative to new ones for a robust market to develop for these

reconditioned batteries, as costs for new batteries continue to fall and performance continues to improve. Designing for reuse at the outset could reduce refurbishment costs substantially and increase the commercial viability of reuse and resale. Refurbished battery system applications in the U.S. are also currently limited to pilot demonstrations and small projects, which also affects resale value.⁵⁴

What industry-led initiatives are available?

There are several industry-led initiatives that developers should consider at the end of the system performance period.

Certain solar panel manufacturers require recycling commitments in purchase agreements. This ensures that solar panels aren't landfilled at the end of their initial useful life.

International voluntary stewardship standards such as National Sanitation Foundation/American National Standards Institute (NSF/ANSI) 457 provide a detailed description on how to reuse or recycle PV panels and inverters instead of disposing them. Specifically, the NSF/ANSI 457 standard establishes sustainable performance criteria and corporate performance metrics, which include categories for EOL management and corporate responsibility, exemplify sustainable leadership in the solar market.⁵⁵ In addition, there are also U.S. national industry-led efforts from the Solar Energy Industries Association (SEIA) that could aid plant owners in material management decision making.

What federal and state environmental regulations need to be followed when disposing of material?

Disposal involves landfilling renewable energy equipment during the decommissioning process. Disposal is the least expensive option, though it has significant environmental drawbacks such as unwanted release of harmful toxins and/or unsustainable waste accumulation.

⁵⁴ U.S. ESA 2020. "End-of-Life Management of Lithium-ion Energy Storage Systems." <https://energystorageassociationarchive.org/wp-content/uploads/2020/04/ESA-End-of-Life-White-Paper-CRI.pdf>

⁵⁵ NREL 2021. "Best Practices at the End of the Photovoltaic System Performance Period." [U.S. Solar System Decommissioning Policies \(nrel.gov\)](https://www.nrel.gov/solar/pv/ssl/pubs/best-practices-at-the-end-of-the-photovoltaic-system-performance-period.html)



Solar PV Panels

When discarded, solar panels are regulated either under Subtitle C or D of the Resource Conservation and Recovery Act (RCRA), depending on whether the panel is classified as solid waste or hazardous waste. Hazardous waste solar panels that are recycled may be able to use regulatory exclusions available under RCRA.⁵⁶

Solar panels are designed to withstand extreme weather events and be safe for human health and the environment while in use. However, if disposed of irresponsibly, they can release toxins. Hazardous waste testing on solar panels in the marketplace has revealed that solar panels have a variety of different metals present in the semiconductor and solder, some of which, are harmful to human health and the environment, like lead and cadmium. However, c-Si solar panels, which constitute over 90% of the US market, typically do not contain any cadmium and may only contain trace amounts of the other hazardous materials.⁵⁷ The hazardous waste classification can vary between panels even within the same model and manufacturer, and requires a toxicity characteristic leaching procedure test to determine if the waste is hazardous. If it is known that specific models of solar panels have previously been deemed hazardous, the solar panel waste can be classified as hazardous without the need for testing.⁵⁸

Project owners should review up-to-date federal and state level environmental regulations when disposing solar panels during decommissioning.



Wind Turbines

Wind turbine blades accounted for 50,000 tons, or 0.017% of total solid waste in the United States in 2018.⁵⁹ As of February 2025, there are no federal or state laws that regulate disposal of wind turbine blades. Unlike solar panels, they are not considered hazardous waste, so there are fewer disposal restrictions and considered less hazardous to the environment when they are landfilled at the EOL. Since much of a wind turbine's structure can be recycled, disposal is of lesser concern relative to disposal of solar PV panels.



Battery Energy Storage Systems

Once a battery is removed from service and diverted toward EOL management, it is designated as "Universal Waste," a special category of hazardous waste under EPA regulations.⁶⁰ Similar to solar PV panels, battery energy storage systems are regulated under Subtitle C and D of the RCRA. These rules generally require recordkeeping, labeling, and storage methods that keep material out of the environment, and they outline approved recycling or disposal pathways. Damaged cells, e.g., where the cell casing has been breached, may face additional requirements than those imposed under Universal Waste rules.⁶¹ A battery intended for refurbishment and reuse is not considered "waste" under RCRA because it is not discarded.

⁵⁶ US EPA. "End-of-Life Solar Panels: Regulations and Management." <https://www.epa.gov/hw/end-life-solar-panels-regulations-and-management>

⁵⁷ Solar panels are classified as hazardous waste if they exhibit any of the four characteristics of hazardous waste, which are toxicity, ignitability, reactivity, and corrosivity. Heavy metals in solar panels are subject to the Toxicity Characteristic Leaching Procedure (TCLP) test as defined by the EPA. Further details can be found in the EPA's guidance. <https://www.epa.gov/hw-sw846/sw-846-test-method-1311-toxicity-characteristic-leaching-procedure>

⁵⁸ [End-of-Life Solar Panels: Regulations and Management | US EPA](#)

⁵⁹ WINDEXchange: End of Service Wind Turbine Guide (energy.gov)

⁶⁰ [40 CFR § 273](#)

⁶¹ U.S. EPA. "May a handler of universal waste manage broken or damaged batteries as universal wastes?" [EPA: FAQ About Universal Waste](#)

5. Repowering Projects

Repowering refers to retrofitting or upgrading a renewable energy system with new equipment or redesigning with new infrastructure. The repowering process can occur during or at the end of a renewable energy project's initial service life and may result in a higher project capacity and/or greater generation output. It is the more expensive option relative to removing the facility. According to the Center for Rural Affairs (CFRA), it can cost about 80% of the total project value, depending on how much of the initial project is retrofitted or upgraded.⁶² Despite the high cost, repowering offers several advantages. The advantages and disadvantages of repowering are discussed below.

Recent Repowering | Cohocton and Steel Winds Wind Farm Repowering Project

In December 2021, Brookfield Renewable U.S. completed the repowering of the 35 MW Steel Winds (I and II) wind farms, and the 125 MW Cohocton Wind Farm.* The repowering was completed by replacing the original turbine blades with new models. The more efficient models allowed Brookfield to increase annual generation by almost 30 percent with the same number of units. The turbines combined generate enough power for 60 thousand homes. The repowering will extend the useful life of the project for another 20 years, based on the terms of the PILOT secured by the project owner with the local community.**

*Source: [Cohocton Steel Wind Press Release](#)

**Source: [TerraForm Power 4th Quarter Report](#)

Repowering is an umbrella term for several types of rebuilding, upgrading, or retrofitting options. Table 4 shows the various types of repowering that renewable energy installations may implement at or before the end of the energy installation's service life.⁶³ Generally, these are split between a full repower and a partial repower.

Full repowers replace a significant portion of existing equipment and will repower an installation at or greater than its prior output. This is most commonly performed to ensure renewable energy output is able to meet the terms agreed upon within a power purchase agreement (PPA).⁶⁴ If an installation is repowered at greater than its previous output (in megawatt-hours or project area), the owner may have to renegotiate PPAs and revisit interconnection agreements and permitting requirements for the "new" installation.

A full repowering at the previous -level of output (typically within a +/- 10% margin) may not require these kinds of negotiations or permitting and interconnection changes. Review local laws to ensure compliance with environmental permitting for the renewable energy project's location.

As of February 2025, NYISO Interconnection Agreement rules state that for repowering where capacity increases by greater than 10%, NYISO has to review the changes to determine if additional studies are needed to classify the project as a Permissible Technological Advancement. ORES Regulations (16 NYCRR Part 1100) do not explicitly refer to repowering projects. However, based on the declaratory ruling to AES in October 2023 regarding the proposed repowering of six wind farms, a repowering that results in any increase in nameplate capacity falls under ORES's jurisdiction, and thus requires a hearing under the "major modification" process described in 16 NYCRR Part 1100-111.⁶⁵

A partial repower will be less extensive than the full repower option. Partial repowers may comprise either a partial rebuild or a retrofit/upgrade improvement. Partial rebuilds entail component upgrades, but this may be limited to inverters, certain ground or electrical infrastructure for solar, and turbine blade replacements for wind installations. A software/retrofit upgrade typically includes material upgrades or technological improvements that do not increase the total capacity of the generation facility. Certain smaller components could also be upgraded to constitute a retrofit. New software could be included to better manage energy output. It should be noted that if total output of the system increases, it does not qualify as a software system upgrade. **Table 4** contains a summary of considerations and classifications for repowering options.

⁶² [Decommissioning solar energy systems WEB.pdf \(cfra.org\)](#)

⁶³ Repowering and Decommissioning: What Happens in Communities When Solar and Wind Projects End? - Great Plains Institute ([betterenergy.org](#))

⁶⁴ To Repower or Not to Repower? That's the Question; Here's How Asset Owners Can Answer It ([powermag.com](#))

⁶⁵ 16 NYCRR Part 1100 – 111.1 Accessed December 17, 2024

Table 4 | Repowering Options Comparison

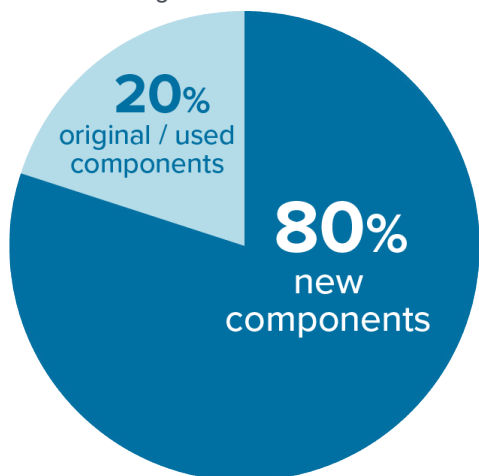
Repowering			
Full Repower		Partial Repower	
Exceeds Original Output	Equivalent to Original Output	Partial Rebuild	Software/Retrofit Upgrade
Most involved type of upgrade. Electricity generation is greater than former system’s output, requiring a new negotiation with the state’s regulatory utility commission, ISO/RTO, local, environmental, state, or county permitting.	Electricity generation is roughly equal to prior system’s output and should not require negotiation with the public utility commission or the utility. The utility must be notified of repowering regardless of output changes.	Component upgrades but not extensive to constitute a full repower. Some examples could be installing longer turbine blades or replacing PV panels with more efficient ones.	Material upgrades or technological improvements, such as new software, upgrading electrical components. If total output of the system increases, then it does not qualify as a partial repower.

What are the opportunities associated with repowering?

Repowering offers several advantages to developers and local governments. Repowering extends the life of the generation asset and generally allows the project owner to leverage existing land-use agreements, permits, and utility interconnections.⁶⁶ These can be costly to initiate for a new project, both in financial and administrative terms. For example, initial project stages may take several years of coordination between the developer, landowner, manufacturer, and local government. Repowering an existing project can considerably reduce the burdens in this uncertain phase of project development. For developers, repowering can be supported by accessing tax incentives such as the Clean Electricity Investment Tax Credit (CEITC) or Clean Electricity Production Tax Credit (CEPTC). These can significantly offset the costs of building and operating a renewable energy project. Developers and municipalities can assess the impacts of the tax credits against project costs using [NYSERDA’s ITC/PTC Calculator Tool](#).

Use our [NYSERDA ITC/PTC Calculator Tool](#).

Figure 8 | 80/20 Rule



Projects that are repowering may be able to claim CEITC/CEPTC credits under the Internal Revenue Service’s 80/20 Rule. The 80/20 Rule allows projects to claim these tax benefits if the retrofitted property’s original or used components are no more than 20 percent of the fair market value of the total value of the property.⁶⁷ In other words, a developer repowering a renewable energy project must spend at least 80% of the total project fair market value to satisfy the rule and unlock additional CEITC/CEPTC benefits.

Repowering keeps a power generation project in the same jurisdiction, which can provide local residents with access to more affordable renewable energy sources. Other benefits include reduced greenhouse gas emissions in the area, induced economic activity near the project, sustained employment, renewed land leases, and improved health impacts. It will also ensure the local government continues to receive a stream of tax payments into the future.

By the time a project is ready for repowering, the 15-year limit set in the Real Property Tax Law (RPTL) § 487 has likely been reached. As noted in RPTL 487(5), the tax exemption is offered for renewable energy projects constructed prior to January 2, 2030.⁶⁸ As a result, repowering projects are likely not eligible for further exemptions depending on the nature of the upgrades and repowering taking place, and when it occurs. See additional information on Real Property Tax Law 487 (RPTL 487) and Payment in Lieu of Taxes (PILOT) Chapter of the Solar Guidebook.

⁶⁶ The specific requirements for repowering will vary by project, and project developers must ensure they are compliant with local regulations. Laws are subject to change and may impact permits required to repower or operate renewable energy projects.

⁶⁷ [Federal Register: Definition of Energy Property and Rules Applicable to the Energy Credit](#)

⁶⁸ [NYS Open Legislation | NYSenate.gov](#)

What are the challenges associated with repowering?

While repowering a site may be simpler than developing a new site, there are challenges to repowering a renewable energy project. It is a more complex option than decommissioning an existing system. New design, components, permits, potential new interconnection agreements and PPAs may be required depending on the nature of the repowered installation.

Renewable energy projects typically have high upfront costs and much lower operating costs than fossil fuel energy generation projects. Repowering is committing to a longer payback period, as there is significant cash outlay up front. Finally, repowering can entail a significant redesign and upgrade to the existing project, which will introduce new complexities to the project. Challenges with repowering can include fitting new panels or wind turbines onto existing racking or tower support structures, and in some cases the existing balance of plant electrical systems may not be sufficient for new output. The organized complexity of upgrading a project needs to be carefully managed to meet its electricity output goals. Repowering requires planning, resources, coordination, and financing to be completed successfully.

6. Conclusion

Decommissioning is an important aspect of lifecycle planning for renewable energy projects. Successful decommissioning is contingent on careful planning, which starts prior to the project's construction, and thorough execution to ensure safety, environmental responsibility, and regulatory compliance with a goal to return the land to its original state. Local governments have a significant role to play in ensuring decommissioning is handled properly at the local level. Key considerations include:

- Depending on the project size, developments may require a decommissioning plan:
 - Utility scale projects exceeding 25 MW are permitted at the State level through the Office of Renewable Energy Siting and Electric Transmission and require decommissioning plans;
 - Smaller projects are permitted at the local level and often require decommissioning plans;
- Decommissioning plans are initially written during the project development stage, and updated periodically over the renewable energy project's useful life;
- Decommissioning plans include important information such as the roles and responsibilities for project owners and stakeholders, conditions that trigger the decommissioning process, and timing to complete decommissioning activities;
- Financial and non-financial enforcement mechanisms provide municipalities with the means to ensure the project owner is responsible for covering decommissioning costs;
- Estimation of decommissioning costs should be based on reasonable assumptions of long-term forecasting to avoid excessively burdening project owners with large surety bonds or decommissioning trusts;
- Licensed engineers and cost estimating professionals should be retained by project owners to generate accurate decommissioning cost estimates; and
- There are a growing number of options to recycle, salvage, or repower renewable energy projects to extend their useful lives, avoid disposing of components in landfills, burdening local services and potentially damaging the environment.

Appendix A: Inflation Primer

Understanding inflation can help local governments manage setting accurate contingencies for decommissioning cost estimates. A renewable energy developer's upfront project financing will need to obtain a bond, letter of credit, or other financial instrument to ensure an appropriate amount of funds are available to cover full project decommissioning costs. The calculation of the full decommissioning costs 30 years into the future can be challenging and requires using reasonable assumptions to prevent significantly over- or under- estimating these costs. In practice, developers estimate costs in present day terms, and apply a contingency factor to capture some risk of inflation. The assumptions for the rate of inflation can significantly impact the required decommissioning cost estimate provided for renewable energy projects as the compounding effects of inflation can significantly magnify costs and create undue burden on renewable energy developers.

Decommissioning plans for renewable energy projects are initially developed up to 30 years before actual activities commence. Thus, it is important to use realistic, data-driven measures of inflation because of the effect of compounding over longer horizons. Recent periods of high inflation - driven in part by the COVID-19 pandemic and supply chain shock - have highlighted inflation's impact on project costs and brought it to the forefront of industry discussions.

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This primer will provide guidance for estimating inflation assumptions by answering the following questions:

- What is inflation?
- What are the best practices for inflation forecasting?
- What are the best sources for inflation data?
- What are the best sources for inflation forecasts?
- Can I revise the inflation assumptions over the 30-year period?

What is inflation?

Inflation refers to the general increase in prices in the economy over time.¹ Prices can change for several different reasons. For example, due to supply and demand of certain goods and services, or changes in the money supply. Inflation is estimated by several government agencies by comparing prices for the same goods at different points in time. These agencies track the prices of thousands of goods, that are compiled into indices.

What are the best practices for estimating inflation?

It is important to use realistic, data-driven measures of inflation. Using accurate estimates of inflation that reflect long-term trends will allow developers to have access to sufficient funds to cover future decommissioning costs without overburdening project costs. This can be a challenging balance to strike during periods of unusually high or low inflation. Given these yearly fluctuations and the expected lifetime of renewable energy projects, it is crucial for developers and local governments to use long-term inflation expectations for planning decommissioning.

For long-term inflation estimates, the Federal Reserve will implement policy in an effort to maintain inflation at or near its target of 2% annually.² Based on current forecasts as shown in Figure 1, inflation is anticipated to stabilize at a rate of around 2% annually by 2026.

¹ What is Inflation? [clevelandfed.org](https://www.clevelandfed.org)

² [The Fed - Why does the Federal Reserve aim for inflation of 2 percent over the longer run?](https://www.federalreserve.gov/monetarypolicy/2022-08-01-why-does-the-federal-reserve-aim-for-inflation-of-2-percent-over-the-longer-run/)

Federal reserve target rate

Since over the long-term inflation is managed by the Federal Reserve, it is likely reasonable to assume general inflation will be near 2% for longer term inflation projects. *Source: [The Fed](#)*

Understanding the upper and lower bounds of prevailing rates may be helpful for selecting a reasonable short-term inflation estimate as the project nears its anticipated decommissioning. Projects in New York can consider using the region-specific implicit gross domestic product (GDP) Deflators or regional construction indexes, as opposed to national-level inflation measures to gather current measures of region-specific inflation.

Selecting an appropriate inflation estimate for decommissioning cost estimates should be driven by the estimated time horizon of when actual activities are expected to be taking place. For activities occurring at least five or more years in the future, using the Federal Reserve's long-term inflation target may be most representative of anticipated changes in prices. For near-term activities, reviewing current inflation rates and available short term inflation outlooks can be more representative of anticipated market conditions.

What are the best sources for inflation forecasts?

There are several organizations that publish inflation forecasts, including the Federal Reserve, commercial banks and other financial institutions, and economic research think tanks.³ Two major data agencies in the U.S., the Bureau of Labor Statistics (BLS) and Bureau of Economic Analysis (BEA) do not produce inflation forecasts. The inflation forecasts are frequently a part of a broader economic outlook analysis and are reported together with forecasts of other economic variables such as GDP growth, employment growth, or unemployment rate. These forecasts are typically national short-term outlooks for the next 2-3 years and focus on the aggregate PCE inflation or CPI inflation.

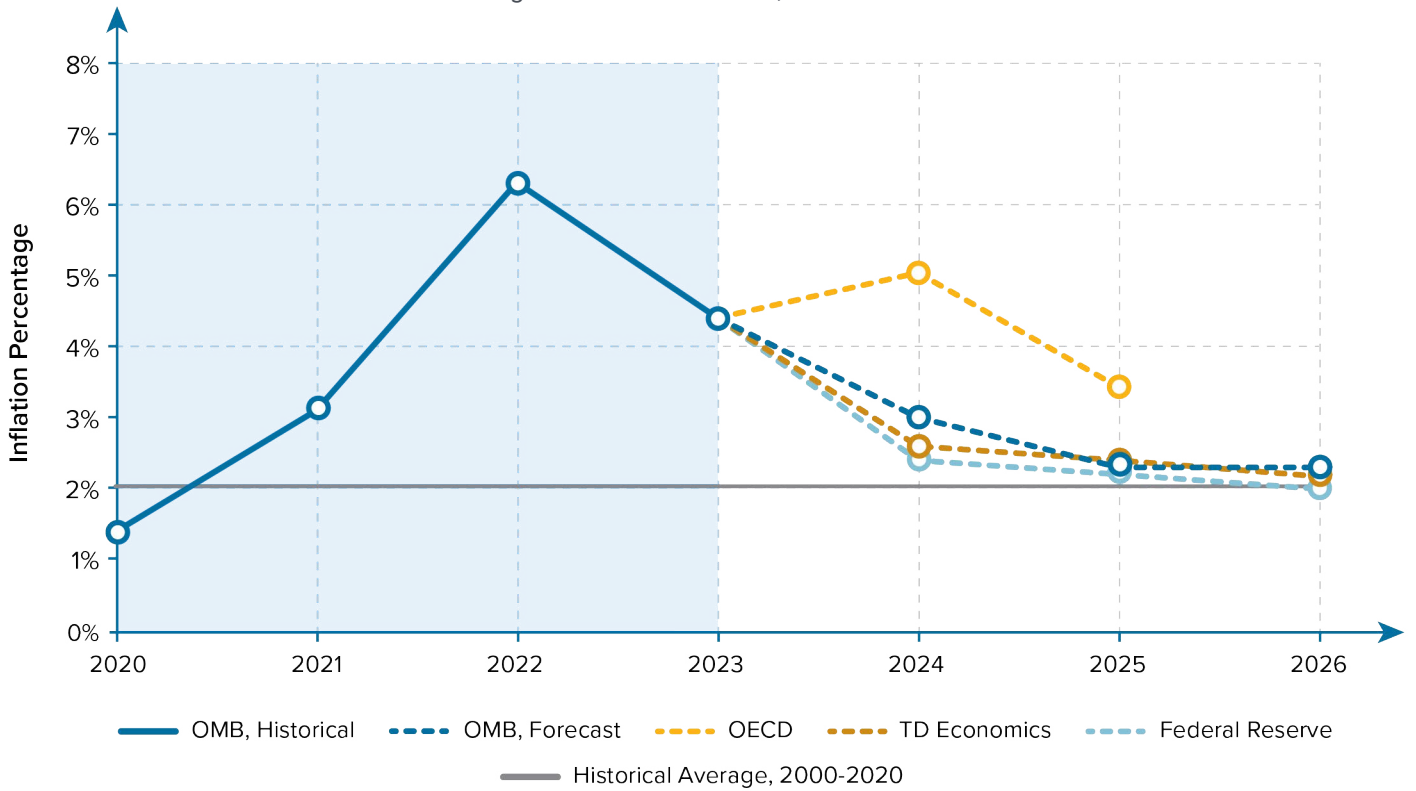
Alternatively, the forecasted inflation rate can be calculated from the total GDP deflator forecasts prepared by the White House Office of Management and Budget, which currently has forecast data available through 2029.⁴ Inflation is anticipated to stabilize around 2% annually by 2025, which is in line with the Federal Reserve's inflation target.⁵ Since the Federal Reserve will implement policy to attempt to maintain inflation at or near 2% annually, it is likely reasonable to assume general inflation will be near 2% for longer term inflation projections. **Figure 1** contains a comparison of inflation forecasts from 2023 to 2026.

³ The latest PCE inflation forecasts from the Federal Reserve (news release from the December 12-13, 2023 meeting of Federal Open Market Committee) are available at [Federal Reserve Board - Federal Reserve Board and Federal Open Market Committee release economic projections from the December 12-13 FOMC meeting](#). Examples of forecasts from international organizations include OECD at [Prices - Inflation forecast - OECD Data](#). Canadian banks also produce US economic forecasts with TD Bank as one of such examples ([see Latest Forecast Tables \(td.com\)](#))

⁴ See Historical Tables, Table 10.1 – Gross Domestic Product and Deflators Used in the Historical Tables: 1940-2028, [Historical Tables | OMB | The White House](#).

⁵ [The Fed - Why does the Federal Reserve aim for inflation of 2 percent over the longer run?](#)

Figure 1 | Inflation Forecast, 2020-2026



What are the best sources for current inflation data?

There are two primary sources of inflation data that produce various indices that can be used to measure inflation. Measuring the changes of these indices is a way to estimate current and historical annual inflation. Given that these measures can only be used to estimate current and historical inflation rates, these sources are not ideal for projecting longer term inflation on costs that have yet to be incurred due to larger variability in year-over-year estimates due to changing market forces. **Table 1** compares the BLS and BEA sources for inflation forecasts.

Table 1 | Comparison of Sources for Inflation Data

Bureau of Labor Statistics (BLS)	Bureau of Economic Analysis (BEA)
<p>3 main categories of price indices: Consumer Price Index (CPI), Producer Price Index (PPI), Employment Cost Index (ECI)</p>	<p>3 main categories of price indices: Implicit GDP Deflator, Personal Consumption Expenditure (PCE) Price Index, Implicit Regional Price Deflators (IRPD)</p>

Bureau of Labor Statistics (BLS)

The three main categories of price indices for measuring current and historical inflation produced by the BLS are the CPI, the PPI and the ECI. These indices are frequently used to escalate various contractual payments and obligations. BLS provides guidance on potential applicability of these indices in contract escalation (although it does not encourage or discourage the use of specific adjustments, or contractual language).⁶

⁶ See [Contract Escalation: U.S. Bureau of Labor Statistics \(bls.gov\)](https://www.bls.gov).

Table 2 | Comparison of Various Price Indices Produced by BLS

	CPI	PPI	ECI
Measures average change in:	Consumer prices for a basket of consumer goods & services	Prices paid to domestic producers for their output	Wages and benefits paid by employers
Available at:	Major metropolitan area, regional, and national level	Industry sector level	Industry sector level
Typically used for escalation:	In private sector collective bargaining agreements, rental contracts, etc.	By business firms for long-term sales and purchase contracts	By business owners and HR for staff pay adjustments

Bureau of Economic Analysis (BEA)

The BEA collects data to produce a range of price indices and implicit price deflators which can be used to assess inflation in the economy from various points of view and geographic levels (i.e., nationwide, statewide, and county/regional economy). BEA produces three primary indices that can be used to measure inflation: the implicit GDP deflator, personal consumption expenditure (PCE) price index, and implicit regional price deflators (IRPD), which are summarized in **Table 3**.

Table 3 | Comparison of Various Price Indices Produced by BEA

	Implicit GDP Deflator	PCE Index	IRPD
Measures average change in:	Consumption and investment patterns across the entire economy	Average household spending	Regional prices
Available at:	National level, though can be calculated at regional levels	National level, though can be calculated at regional levels	State level
Additional Characteristics:	Recommended for use in federal benefit-cost analysis guidance	Includes expenditures made on behalf of consumers, like government assistance programs to estimate accurate measure on cost of living	Allows for estimating state-specific inflation rates

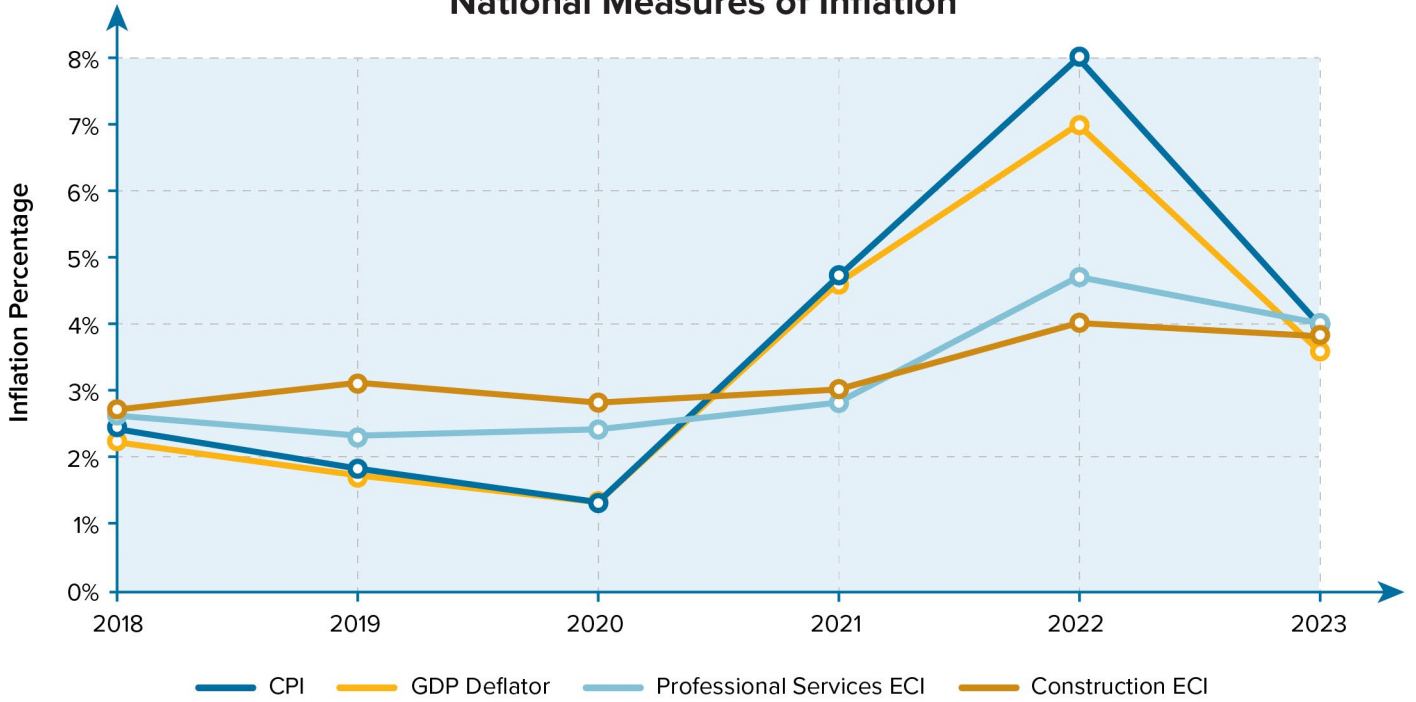
Despite all these different ways to measure inflation, the overall economy-wide inflation estimates produced by the various indices typically trend together in a similar range, as shown in the charts below. Industry-specific measures of inflation will produce greater variability and offer insight on whether an industry is trending above or below average inflation levels. At the national level, the Construction ECI index has shown less variation than overall CPI in recent years. New York State measures of current and historical inflation are typically below national level indicators.

The inflation measures shown in **Figure 2** represent a point-in-time estimate measuring the change in prices relative to the previous year. While there may be larger variability in year-over-year estimates due to changing market forces, the Federal Reserve strives to maintain price stability by targeting a long-run inflation target of 2%.⁷

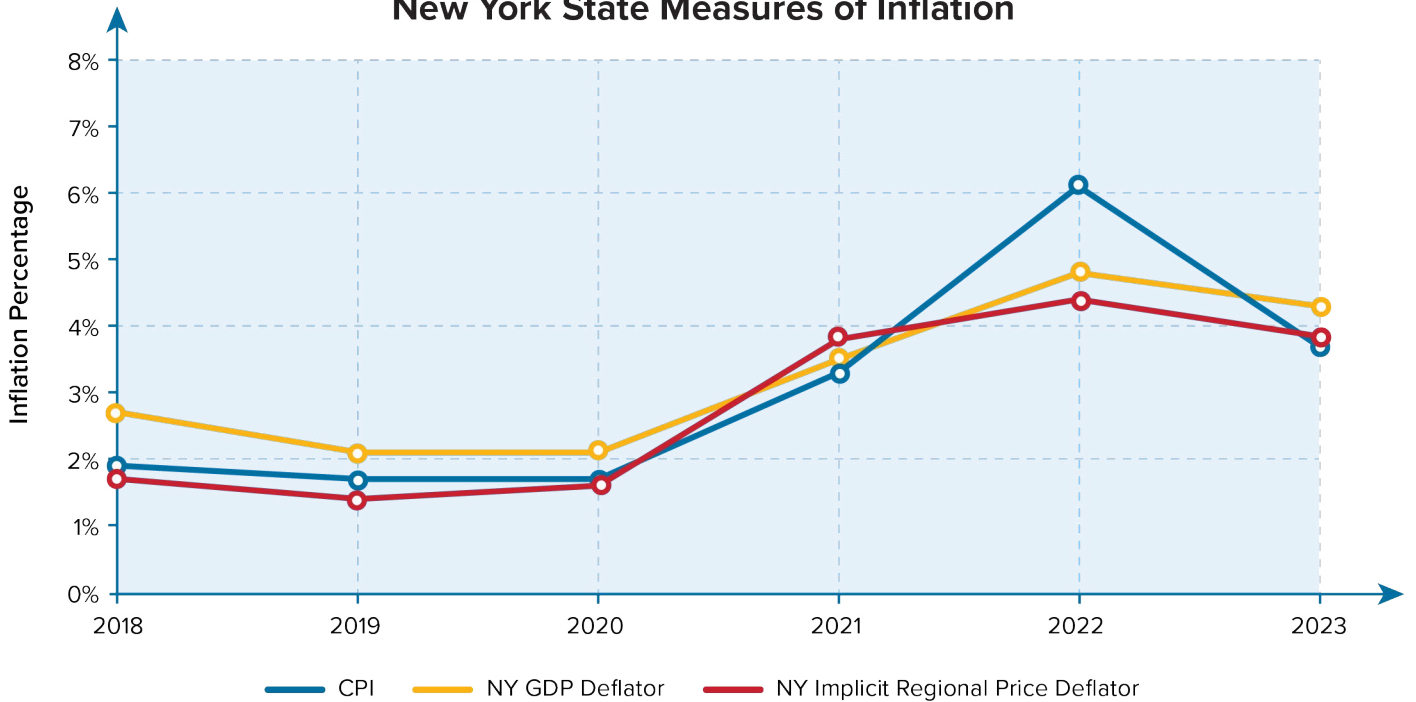
⁷ [The Fed - Why does the Federal Reserve aim for inflation of 2 percent over the longer run?](#)

Figure 2 | Comparison of Levels of Inflation, National and State-Level, %

National Measures of Inflation



New York State Measures of Inflation



Can I revise the inflation assumptions over the 30-year period?

Given that decommissioning plans are anticipated to be updated roughly every five years, this can be used as an opportunity to update the decommissioning cost estimates and capture changes in underlying costs and revisit the inflation assumptions to more accurately capture current conditions throughout a project's lifecycle. Updating decommissioning cost estimates will implicitly incorporate changes in market prices since the previous update, and contingency values also be updated to reflect changes in risk since the last estimate. As project costs are locked-in prior to when these costs are actually incurred, changes after projects reach commercial operation can be difficult for the project to adjust. Therefore, it is important to provide a quality inflation forecast to estimate impacts for future decommissioning costs that will occur 30 years after project commissioning.