Utilities, DERs, & Interconnection

An Asynchronous Online Course Designed by Southface Institute

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Southface

Introduction

Welcome to the online training for *Utilities, Distributed Energy Resources (DERs), & Interconnection*. This course is designed for homeowners, government officials, development professionals, and any other members of the public who are interested in understanding the changing dynamics of the utilities industry, the role of DERs in the energy sector, and the processes through which DERs interconnect with utility transmission and distribution systems.

This training is divided into four sections, and each section is further split into a series of subtopics. Each section is organized identically, so you can easily work both through and across sections in the training as you progress. Each section takes the following format:

Section ➔ Subsection ➔ Subtopic ➔ Roadmap ➔ Required Resources ➔ Further Reading

Learning Objectives

By the end of this course, you will be able to:

- Identify, describe, and define different types of utilities and DER systems.
- Explain how DERs interact with utilities.
- Explain the general regulatory and policy contexts of utility systems.
- Evaluate general interconnection rules, policies, and regulations.
- Explain the physical interconnection process for DER systems.
- Work efficiently with local service providers to deliver DER technologies.

Course Topics

1. Utilities & DERs

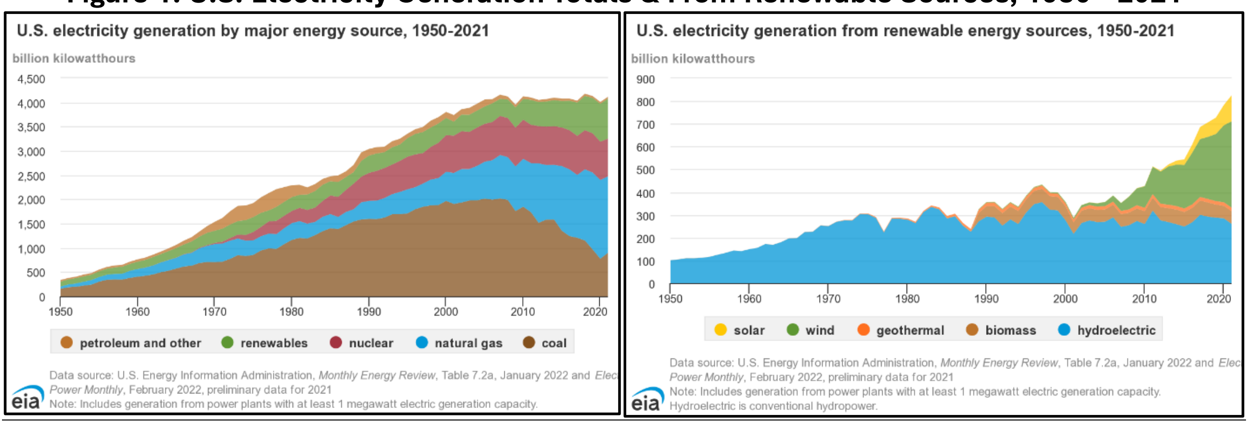
This section introduces you to fundamental terms, definitions, and concepts in energy and utility regulation, especially as it relates to DER systems. ***Utilities*** provide electricity, natural gas, water, and other essential services to homes and businesses. They play a critical role in the energy sector, ensuring that energy is delivered reliably and safely to customers. The utilities industry, however, is undergoing significant changes, driven by technological advancements, changing consumer preferences, and environmental change.

The resources in Section 1.A. introduces you to the basic structure, purpose, and functions of utility regulation in the U.S. Section 1.B. provides a common baseline of terms, acronyms, and concepts used throughout this training and foundational to interconnecting DER systems with your local utility. Section 1.C. situates utilities and energy regulation in the rapidly changing marketplace of technologies, ideas, and products related to DERs.

1.A. The purpose and structure of utilities and energy regulation in the U.S.

Energy regulation refers to the rules and policies that govern the production, distribution, and use of energy resources, which can include electricity, natural gas, oil, renewable resources, and other forms of energy. The goal of energy regulation is to ensure that energy is produced and distributed in a safe, reliable, and cost-effective manner. ***The regulatory compact*** is a concept that refers to the relationship between energy companies and the government. At the state-level, this is usually a Public Utility Commission (PUC), also called a Public Service Commission (PSC). Energy companies are given the right to produce and distribute energy to consumers, but in exchange, they must adhere to certain regulations and standards authorized by PUCs and PSCs. The government has the responsibility to ensure that energy companies are providing safe and reliable energy at a reasonable cost. In other words, the regulatory compact is a kind of agreement between energy companies and the government to ensure that consumers have access to safe and affordable energy, while also protecting the interests of the energy companies. The government sets the rules and standards for energy production and distribution, and energy companies must follow these rules to operate.

Figure 1. U.S. Electricity Generation Totals & From Renewable Sources, 1950 - 2021



Source: EIA (2022).

Subtopics: The Regulatory Compact; Types of Utilities; Federal vs. State Jurisdictions.

Roadmap: The resources below provide an overview of energy regulation in the U.S. The U.S. Department of Energy's (DOE) primer is an excellent introductory overview. The two chapters from the Regulatory Assistance Project (RAP) provide further detail on the structure of energy regulation in broad terms. In the optional, further readings, the EIA webpage introduces electricity transmission and provides additional resources in the *Electricity Explained* section if you want to dig further. Southface's overview of electricity in Georgia provides a comprehensive state example relevant to both vertically integrated utilities and public power.

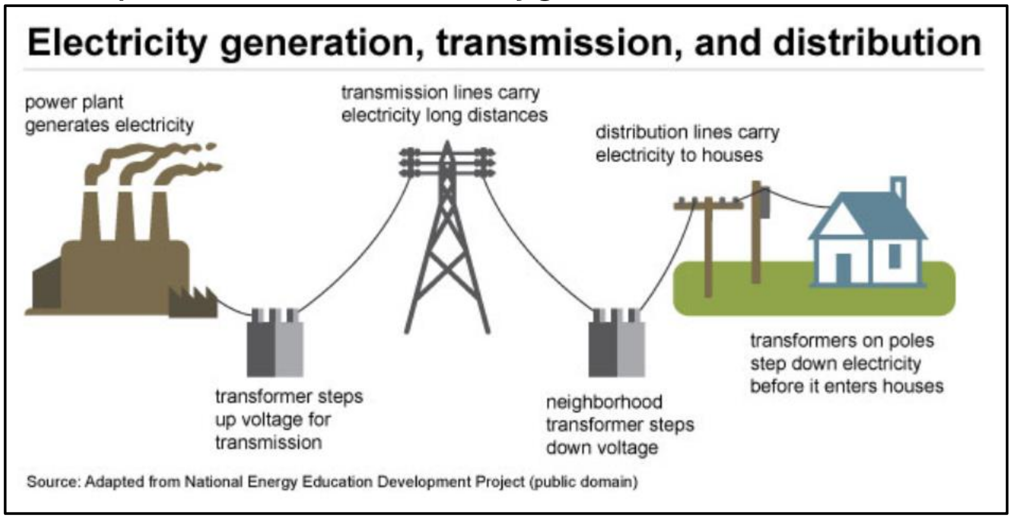
Required Resources:

- Chapter 1: The Purpose of Utility Regulation in *Energy Regulation in the US*
- Chapter 3: Industry Structure from *Energy Regulation in the US*
- Department of Energy's *U.S. Electricity Primer*

Further Reading:

- U.S. Energy Information Administration *(EIA) Electricity Explained*
- Southface's *Georgia Electricity Primer*

Figure 2. Simplified schematic of electricity generation, transmission, & distribution



Source: National Energy Education Development Project cited in EIA (2022).

1.B. Common utility concepts for DERs.

The purpose of this section is to familiarize you with general concepts associated with DER systems, and below are some commonly used terms along with their definitions:

- ***Solar photovoltaic (PV) system:*** DERs that converts sunlight directly into electricity using solar panels.
- ***Wind turbine:*** DERs that generates electricity by converting the kinetic energy of wind into electrical energy.
- ***Energy storage system (ESS):*** DERs that stores energy for later use, typically in batteries or other types of energy storage devices.
- ***Combined heat and power (CHP) system:*** DERs that generates both electricity and heat from a single fuel source, such as natural gas.
- ***Microgrid:*** A small-scale electricity grid that can operate independently or in conjunction with the larger utility grid. It typically includes a mix of DERs, such as solar PV systems, wind turbines, and ESS.
- ***Demand response (DR):*** Programs that incentivize customers to reduce their electricity usage during periods of high demand on the grid. This can be achieved through a variety of measures, such as adjusting thermostats or turning off non-essential appliances.
- ***Virtual power plant (VPP):*** A network of DERs that can be controlled and coordinated as a single entity, typically through a software platform. This allows them to be dispatched as needed to provide grid services such as frequency regulation and load balancing.
- ***Grid-connected DERs:*** DERs that are connected to the larger utility grid and can provide power to the grid or receive power from the grid as needed.
- ***Islanded DERs:*** DERs that operate independently of the larger utility grid, typically in areas where grid access is limited or unreliable.

- ***Net energy metering (NEM):*** A billing arrangement that allows customers with solar PV systems to receive credits on their utility bills for any excess electricity they generate and feed back into the grid.

Subtopics: Electricity 101, Grid Basics, Foundational Terms

Roadmap: In addition to the terms and concepts listed above, the resources below will provide a common baseline of terms, acronyms, and concepts used throughout this training and are foundational to interconnecting DER systems with your local utility. *Electricity 101* is an excellent introductory overview. The US Energy Information Administration's Electricity Generation, Capacity and Sales article is another useful overview in their Electricity Explained series. For a more expansive list of utility concepts and definitions, see Southface's Glossary for Georgia's 2022 Integrated Resources Plan. For an additional challenge, read the introduction of NREL's Overview of Distributed Energy Resource. We will pull more from this document as we progress further into DER interconnection topics.

Required Resources:
- Resources for the Future's (RFF) *Electricity 101: Terms & Definitions*.
- US Energy Information Administration's *Electricity Generation, Capacity, and Sales*

Further Reading:
- Terms in Southface's *Glossary for Georgia's 2022 Integrated Resources Plan*.
- Introduction of NREL's (2019) *Overview of Distributed Energy Resource Interconnection*.

1.C. Different DERs and their various interactions with utilities.

Distributed Energy Resources (DERs) are small-scale power generation systems that are installed close to the point of use. DERs, such as solar panels and wind turbines, offer numerous benefits, including reduced energy costs, increased energy independence, and environmental sustainability. However, integrating DERs into the electric grid requires careful planning and coordination to ensure that the grid remains stable and reliable. Some of the benefits of DERs for consumers, utilities, and the electric grid include:

- ***Cost Savings:*** DERs can help consumers save money on their energy bills by generating electricity on-site, reducing their reliance on traditional grid-supplied electricity, and potentially lowering their overall energy costs.
- ***Increased Resilience:*** DERs can help increase the resilience of the electric grid by providing backup power during outages or emergencies. This can help utilities avoid costly repairs and restore power more quickly.
- ***Reduced Emissions:*** DERs can help reduce greenhouse gas emissions by generating electricity from renewable sources like solar and wind power, which are cleaner and emit less carbon dioxide than traditional fossil fuels.
- ***Improved Grid Stability:*** DERs can help improve the stability of the electric grid by providing additional sources of electricity during periods of high demand or when traditional power plants are offline. This can help prevent blackouts and brownouts.

- ***Distributed Generation:*** DERs can help reduce the need for new transmission and distribution infrastructure by generating electricity closer to where it is consumed, which can reduce the load on the grid and help avoid costly grid upgrades.

DERs have the potential to transform the energy sector by making it more resilient, reliable, and sustainable for consumers, utilities, and the electric grid.

Subtopics: Reliability; Resilience; Load; Peak Demand.

Roadmap: The resources below provide a breakdown of different DER technologies within the context of the larger electrical grid. The Abstract, Executive Summary, and first Chapter of the International Energy Agency's *Unlocking the Potential of DERs* explores a number of different technologies and how each can impact the grid. The report dives deep into solar arrays, smart heat pumps, and microgrid technologies.

Required Resources:

- EPA's *Overview of Electric Utility Policies*
- Abstract and Executive Summary from International Energy Agency's *Unlocking the Potential of DERs*
- Chapter 1 from International Energy Agency's *Unlocking the Potential of DERs*.

Further Reading:

- *DER Summary Maps* from the Database of State Incentives for Renewables & Efficiency (DSIRE)

2. Legislative & Regulatory Contexts

Energy regulation is a critical component of the utilities industry, ensuring that utilities operate in a fair and transparent manner while maintaining the reliability and affordability of energy services. Regulatory frameworks are constantly evolving, as policymakers seek to balance the needs of different stakeholders, such as utilities, customers, and the environment.

The resources in Section 2.A introduce you to common state policies, legislation, and utility rate designs that often govern DER installation and operation. Section 2.B provides an overview of renewable portfolio standards, another concept that many states employ to regulate DER usage. Section 2.C explores the various codes and standards that are in place to regulate DER installations while Section 2.D places the previous 3 sections in context using multiple state case study examples.

2.A. Federal, state, and local legislative and regulatory contexts for DER systems.

While state regulatory policies vary across the country, this section will provide high-level concepts and frameworks for how to identify and assess common rate design policies and legislations. We will explore net metering, a billing arrangement that allows customers with solar PV systems to receive credits on their utility bills for any excess electricity they generate and feed back into the grid, and other alternative policies or tariff structures that states and local governments employ.

Subtopics: State legislation; Utility regulation; Rates/tariffs.

Roadmap: The resources below provide an introduction to common policies that states and utilities use to regulate DER technologies. NREL's *Net Metering* introduces the concept of a net metering rate design. The Interconnection and Net Metering section of EPA's State Energy and Environmental Guide to Action begins with a general introduction of the current regulatory context before diving into more technical applications of the most prominent rate design strategies. The next two resources, sections of the National Regulatory Research Institute's Review of State Net Energy Metering and Successor Rate Designs, explore net metering alternatives that some states now use. In the Further Reading section, DSIRE produces DER maps summarizing common policies and incentives across the country. There is also an appendix to the aforementioned NRRI report that catalogues ten examples of state rate design policies in practice.

Required Resources:
- NREL's *Net Metering Basics*
- Sections 1 and 2 of EPA's *State Energy and Environment Guide to Action: Interconnection and Net Metering*
- Part III: Inventory of Related State Regulatory Actions within National Regulatory Research Institute's *Review of State Net Energy Metering and Successor Rate Designs*

Further Reading:
- *DER Summary Maps* from the Database of State Incentives for Renewables & Efficiency (DSIRE)
- Resources for the Future's *The Role of Electricity Tariff Design in Distributed Energy Resource Deployment*
- National Regulatory Research Institute's *Summaries of Recent State Actions on Net Energy Metering Policies in Five Vertically Integrated and Five Restructured States*

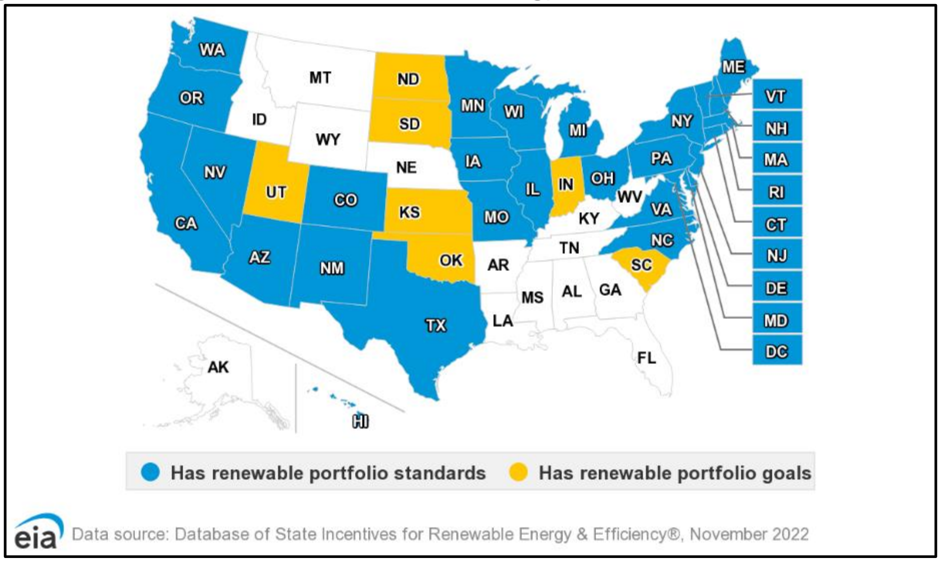
2.B. Renewable Portfolio Standards.

Renewable portfolio standards (RPS) are policies that require a certain percentage of electricity generation to come from renewable sources, such as wind, solar, and geothermal power. Below are some state-specific examples of RPS:

- *California:* RPS requires that 60% of electricity sold by retail providers come from renewable energy sources by 2030, and the state is aiming to achieve 100% carbon-free electricity by 2045.
- *New York:* RPS requires that 70% of the state's electricity come from renewable energy sources by 2030, and the state is aiming to achieve 100% carbon-free electricity by 2040.
- *Massachusetts:* RPS requires that 35% of the state's electricity come from renewable energy sources by 2030, and the state is aiming to achieve net-zero emissions by 2050.
- *Colorado:* RPS requires that 50% of the state's electricity come from renewable energy sources by 2030, and the state is aiming to achieve 100% carbon-free electricity by 2050.
- *Hawaii:* RPS requires that 100% of the state's electricity come from renewable energy sources by 2045. Hawaii is the first state in the U.S. to adopt a 100% RPS.

These are just a few examples of RPS. The specific requirements and timelines for RPS will vary by jurisdiction. RPS are an important policy tool for promoting the deployment of renewable energy and reducing greenhouse gas emissions from the power sector.

Figure 3. U.S. States with Renewable Energy Portfolio Standards and Goals



Source: EIA RPS, https://www.eia.gov/energyexplained/renewable-sources/portfolio-standards.php.

Subtopics: Renewable portfolio standards; Decarbonization; Renewables.

Roadmap: The resources below give a brief introduction to the concept of renewable portfolio standards, before offering a current picture of these standards in practice. EIA's *Portfolio Standards* and the chapter from Regulatory Assistance Project (RAP) place RPS policies within the larger regulatory context of state and local utilities. The Berkleley Lab report details renewable portfolio standards in practice, highlighting trends and specific state examples.

Required Resources:

- EIA's *Portfolio Standards* within their *Renewables Energy Explained* series
- Chapter 18: Renewable Energy in *Energy Regulation in the US*

Further Reading:

- Lawrence Berkeley National Laboratory's *U.S. Renewable Portfolio Standards* report.

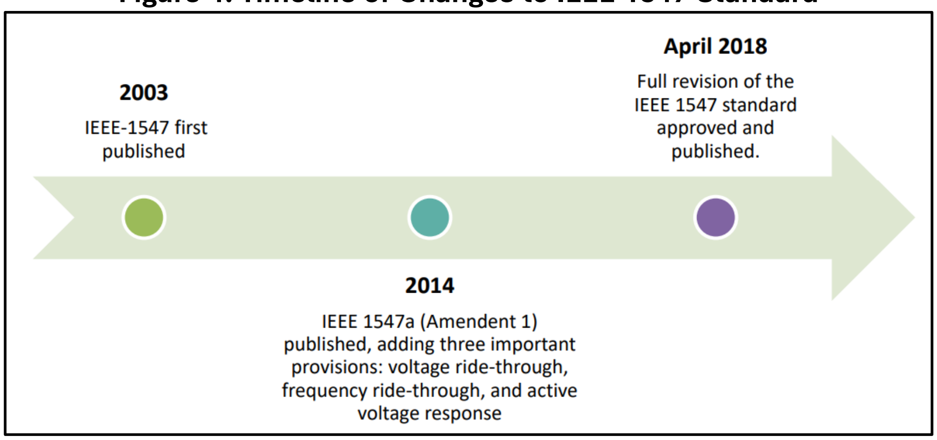
2.C. Interconnection Standards

Interconnection standards are rules and technical requirements that govern how DERs can connect to the electric grid. They help ensure that DERs can be safely and reliably integrated into the grid, without causing disruptions or safety issues. Below are a few key interconnection standards:

- ***IEEE 1547:*** This is a set of technical standards developed by the Institute of Electrical and Electronics Engineers (IEEE) that govern the interconnection of DERs with the electric power system. It covers a wide range of issues, such as safety, power quality, and communications.
- ***National Electric Code (NEC):*** The NEC is a set of safety standards developed by the National Fire Protection Association (NFPA) that covers electrical installations in buildings and other structures. It includes provisions related to the interconnection of DERs, such as grounding requirements, overcurrent protection, and equipment ratings.
- ***FERC Order 2006:*** This is an order issued by the Federal Energy Regulatory Commission (FERC) that establishes interconnection standards for small generators (up to 20 MW) that connect to the transmission grid. It includes requirements related to technical studies, equipment standards, and safety requirements.
- ***State-level interconnection standards:*** Many states have developed their own interconnection standards for DERs, which are often based on the IEEE 1547 standard. These standards can vary widely from state to state, but they generally cover issues such as technical requirements, safety requirements, and dispute resolution procedures.

These are just a few examples of interconnection standards. The specific requirements and technical details will depend on the jurisdiction and the type of DER being interconnected.

Figure 4. Timeline of Changes to IEEE 1547 Standard



Source: [NREL (2019)]

Subtopics: Specific federal and state interconnection standards

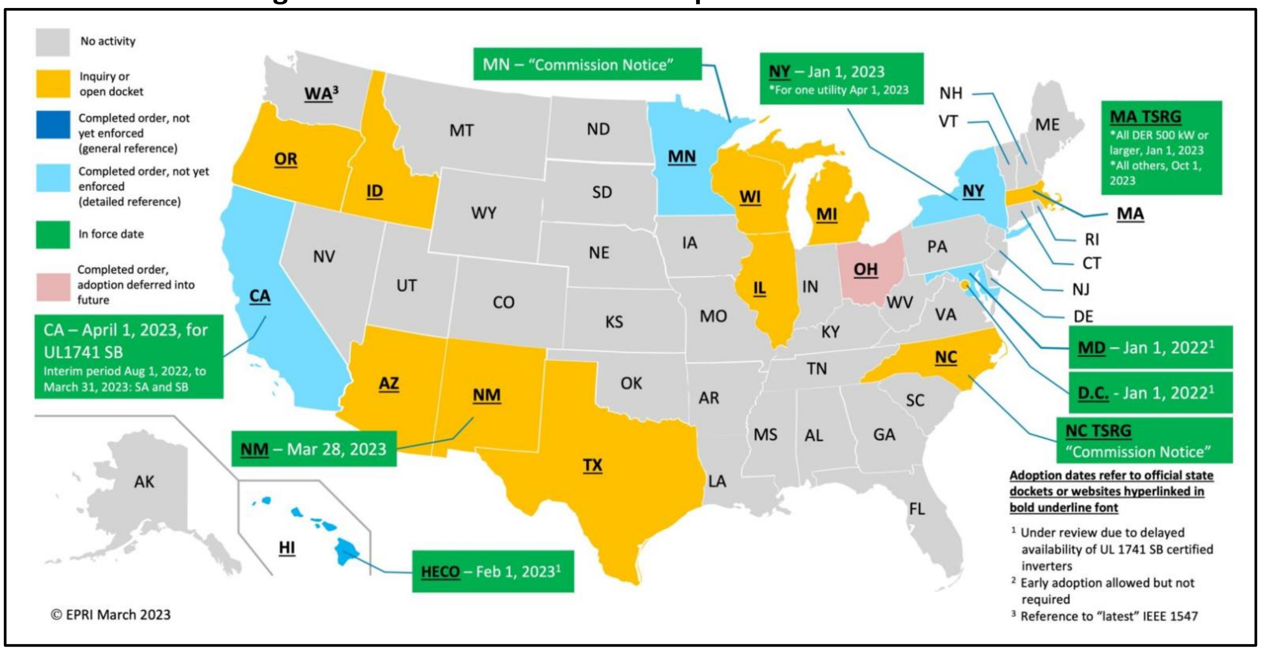
Roadmap: The resources below explore the IEEE's Standard 1547. The NREL article, *Interconnection Standards* provides an excellent overview of the various standards that govern DER interconnection to the electric grid. The next resource links to the IEEE Standards Coordinating Committee 21's website. This committee oversees the development of standards in the areas of fuel cells, photovoltaics, dispersed generation, and energy storage. While the standards listed are extremely technical and expensive to access, the committee site provides useful overview descriptions and supplementary materials. Focus on these resources when exploring the site. To dive deeper on important interconnection standards, see NREL's 2014 report on IEEE 1547. This document details the history and development process of the 1547 Standard before outlining each of the standard's sections.

Required Resources:

- NREL's *Interconnection Standards*
- IEEE *Standards SCC21*

Further Reading:
- NREL's *IEEE 1547 and 2030 Standards for Distributed Energy Resources Interconnection and Interoperability with the Electricity Grid*

Figure 5. IEEE Standard 1547 Adoption Status in the U.S.



Source: IEEE Standard 1547-2018.

2.D. State-specific policy & regulatory contexts for DERs. (Breadth & Depth)

Section 2.A, 2.B, and 2.C have outlined various regulatory and policy concepts at a high-level, from net metering and alternative rate designs to renewable portfolio and interconnection standards. In this section, the learner will apply the concepts from the previous three sections to state-specific case studies.

Subtopics: Participants select state-specific materials relevant to their work.

Roadmap: The resources below highlight various policy and regulatory case studies across the country. The last section in the EPA's Interconnection and Net Metering Overview explores different NEM policies in Massachusetts, Virginia, California, and Utah. DSIRE produces DER maps summarizing common policies and incentives across the country. DSIRE also hosts a database of state incentives and policies. Using the database, spend some time with multiple states, exploring different programs and policies from different regions of the country. The Further Reading section also provides state examples from Georgia and Missouri, as well as a NNRI review detailing the policy outlook in 10 different states.

Required Resources:

- Case Study examples in *EPA's Interconnection & Net Metering Overview*
- *DER Summary Maps* from the Database of State Incentives for Renewables & Efficiency (DSIRE)
- *DSIRE*

Further Reading:

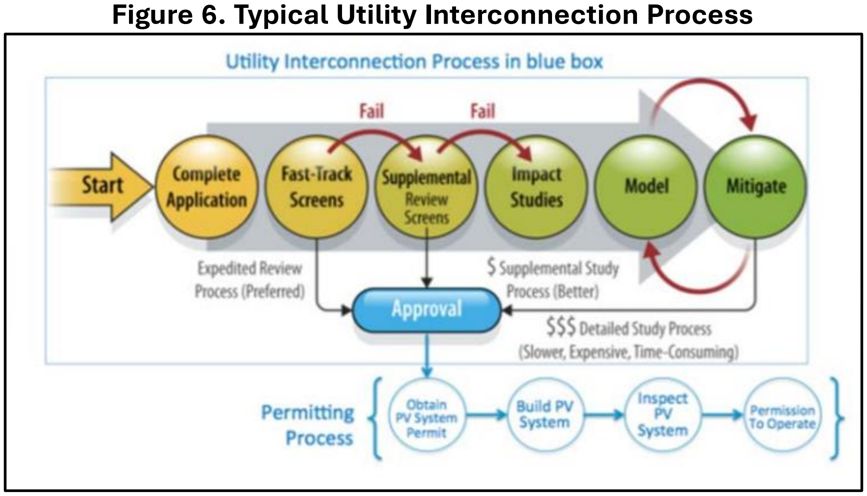
- Georgia Case Study Materials:
  - *Georgia SB 210*
  - *Georgia Power's RNR tariff*
  - *Georgia's net metering fight*
- Missouri solar policy development: *SOLAR IN SMALL COMMUNITIES: CASE STUDY OF COLUMBIA, MO*
- National Regulatory Research Institute's *Summaries of Recent State Actions on Net Energy Metering Policies in Five Vertically Integrated and Five Restructured States*

3. Interconnection Applications, Reviews, & Agreements

The interconnection process for DERs with utilities is a crucial step in ensuring that these small-scale energy systems can be safely and reliably connected to the electric grid and operate in parallel with the utility's power system. The interconnection process usually involves a series of six steps, including application, review, agreement, installation, testing, and operation. In this section, you will evaluate and engage in *the first three steps* in the interconnection process.

The resources in Section 3.A. will outline common procedures and best practices that utilities use during the application stage of the interconnection timeline. Section 3.B will discuss the primary components of the review step within the interconnection timeline, including hosting capacity analyses and technical reviews. And Section 3.C will present common elements and requirements of interconnection agreements.

Figure 6. Typical Utility Interconnection Process



Source: NREL (2019)

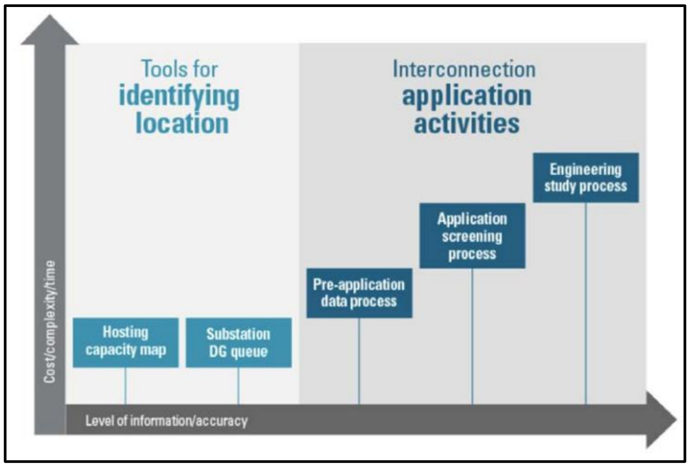
3.A. Interconnection Applications for DERs

The first step in the process is to apply through your utility to connect the DER to the grid. The application typically includes information about the type and capacity of DER system, its location, and the expected electrical output. More specifically, a DER interconnection application typically includes the following components:

1. *Customer Information:* Includes information about the customer or the owner of the DER system, including the customer's name, address, contact information, and the type of DER system being installed.
2. *Interconnection Service Request (ISR):* The formal request made by the customer to interconnect their DER system to the utility's grid. The ISR typically includes details such as the capacity of the DER system, voltage levels, and system specifications.
3. *Electrical One-Line Diagram:* Provides a detailed illustration of the DER system and its interconnection with the utility grid. This diagram includes details such as the equipment, wiring, protection systems, and other components required for the interconnection.
4. *System Protection and Control:* Provides details on how the DER system will be monitored and controlled to ensure that it does not cause any harm to the grid. This includes details on protection systems such as overcurrent, undervoltage, and overvoltage protection.
5. *Equipment Specification:* Includes the technical specifications of the equipment used in the DER system, such as inverters, transformers, and switchgear. This information is important for the utility to ensure that the DER system meets the interconnection requirements.
6. *Safety Requirements:* Outlines the safety protocols that will be put in place to ensure that the DER system installation and operation does not pose a hazard to the customer or the utility personnel.
7. *Testing and Commissioning Plan:* Outlines the testing and commissioning procedures followed to ensure that the DER system is installed and operating correctly.
8. *Tariff and Agreement:* Includes the tariff and agreement terms that the customer and the utility agree to regarding the interconnection of the DER system.
9. *Insurance and Bonding:* Includes the insurance and bonding requirements that the customer must meet to ensure that any damages resulting from the DER system are covered.

As you will see in further detail in the readings below, the interconnection application is a comprehensive document that provides all the necessary details required for the utility to evaluate the proposed interconnection of a DER system to the grid.

Figure 7. Mapping of different tools for identifying interconnection location and activities



Source: Xcel (2018) cited in NREL (2019)

Subtopics: Interconnection application processes and policies

Roadmap: The resources below outline the common procedures and requirements for interconnection applications. Section one of the SRP's *Distributed Generation Interconnection Handbook* outlines the interconnection process as a whole before diving into the application process in section 2. Chapter one of NREL's DER Interconnection Overview details strategies and procedures that utilities are using to increase the efficiency of DER application management. See NREL's State-Level Comparison for a broad overview of different interconnection processes. Read Georgia Power's Interconnection Summary and Application for a state-specific example. To put this information in practice, try finding the specific requirements and procedures for a DER application in your state.

Required Resources:

- Section 1, Parts I and II of SRP's *Distributed Generation Interconnection Handbook*.
- Chapter 1: Interconnection Application Procedures and Management of NREL's *Overview of Distributed Energy Resource (DER) Interconnection: Current Practices and Emerging Solutions*

Further Reading:

- NREL's *A State-Level Comparison of Processes and Timelines for Distributed Photovoltaic Interconnection in the United States*
- Georgia Power's *Interconnection Summary & Application.*
- Find the specific application for your state

3.B. Interconnection Reviews for DERs

The utility will review the application to determine if the DER can be safely and reliably connected to the grid without causing any adverse effects on the system. The review will typically consider factors such as the DER's size and location, the impact on voltage and frequency, the ability of the DER to disconnect from the grid during an outage, and its compliance with relevant regulations and standards. In broad terms, therefore, you can divide the review process into at least two components:

1. ***Technical Review:*** Once the application is submitted, the utility will conduct a technical review of the proposal. This may include assessing the system's capacity, output, and compatibility with the utility's grid. The utility will also evaluate the system's impact on the grid, including its ability to provide power during times of high demand, its impact on voltage and frequency stability, and its ability to integrate with other DER systems on the grid.
2. ***Regulatory Compliance:*** In addition to the technical review, the utility will also assess the proposal for compliance with relevant regulations and standards. This may include evaluating the safety of the proposed system, assessing its impact on the environment, and ensuring that it meets all necessary interconnection requirements.

Subtopics: Example interconnection reviews; Technical Reviews; Regulatory Review; Hosting Capacity

Roadmap: The resources below detail important elements of the review process within the interconnection timeline. The first two resources from NREL and IREC provide an overview of hosting capacity analysis, an important element of many review processes. Section 2 of NREL's DER interconnection overview details the various technical screens that take place during the review stage of many DER installations. You can find more examples of elements of interconnection procedures from a Georgia Power case study in the Further Reading section.

Required Resources:

- NREL's *Hosting Capacity Analysis Publications & Case Studies*
- IREC's *Hosting Capacity Analysis*
- Section 2: Technical Screens for DER Interconnection of NREL's *Overview of Distributed Energy Resource (DER) Interconnection: Current Practices and Emerging Solutions*

Further Reading:

- Example of Georgia Power's *transmission* & *distribution* interconnection procedures with checklist for key parties and timelines
- "Review" Section of Energy Trust of Oregon *Interconnection Guidebook*
- Eversource's *Massachusetts Hosting Capacity Map*

3.C. Interconnection Agreements for DERs

If the utility determines that the DER system can be safely interconnected, it will issue an ***interconnection agreement*** that outlines the terms and conditions of the connection. This agreement will typically include requirements for safety, reliability, and compliance with applicable standards and regulations as well as any fees or charges that may be associated with its installation and operation. An interconnection agreement is a contract between the owner or operator of a DER system and the utility that manages the electric grid to which the DER is connected. The specific terms of a DER interconnection agreement may vary depending on the type of DER system, the location of the installation, and the regulations governing the interconnection process. Nonetheless, some common elements of a DER interconnection agreement typically include:

- *Technical Requirements:* The agreement may specify the technical requirements for the DER system, including the voltage and frequency levels, the maximum capacity of the system, and any protection and control systems required to ensure safe and reliable operation.
- *Operational Requirements:* The agreement may also specify the operational requirements for the DER system, including the protocols for starting and stopping the system, the procedures for disconnecting the system during emergencies or maintenance activities, and the requirements for monitoring and reporting the system's performance.
- *Interconnection Fees:* The agreement may specify any fees or charges associated with the interconnection of the DER system, including any costs for reviewing and approving the interconnection application, any fees for upgrades to the distribution system to accommodate the DER, and any ongoing fees for operating and maintaining the system.
- *Liability and Insurance:* The agreement may also specify the liability and insurance requirements for the DER system. This may include requirements for the owner or operator of the DER system to maintain adequate insurance coverage and to indemnify the utility for any damages resulting from the installation or operation of the system.
- *Termination and Dispute Resolution:* The agreement may specify the procedures for terminating the agreement and resolving any disputes that may arise between the owner or operator of the DER system and the utility.

The interconnection agreement is a critical component of the DER installation process. It ensures that the DER system is installed and operated safely, reliably, and in compliance with all relevant regulations and standards.

Subtopics: Examples interconnection procedures

Roadmap: The resources below give a brief overview of interconnection agreements. The FERC link provides a list of interconnection agreement standards for small generators. The Agreements section of Energy Trust of Oregon's *Interconnection Guidebook* outlines elements of their interconnection agreement and associated risks and timelines. There is also an example of Georgia Power's transmission and distribution sized interconnection procedures. While these two types of generating systems are much larger than a residential DER system, it still represents a common interconnection process.

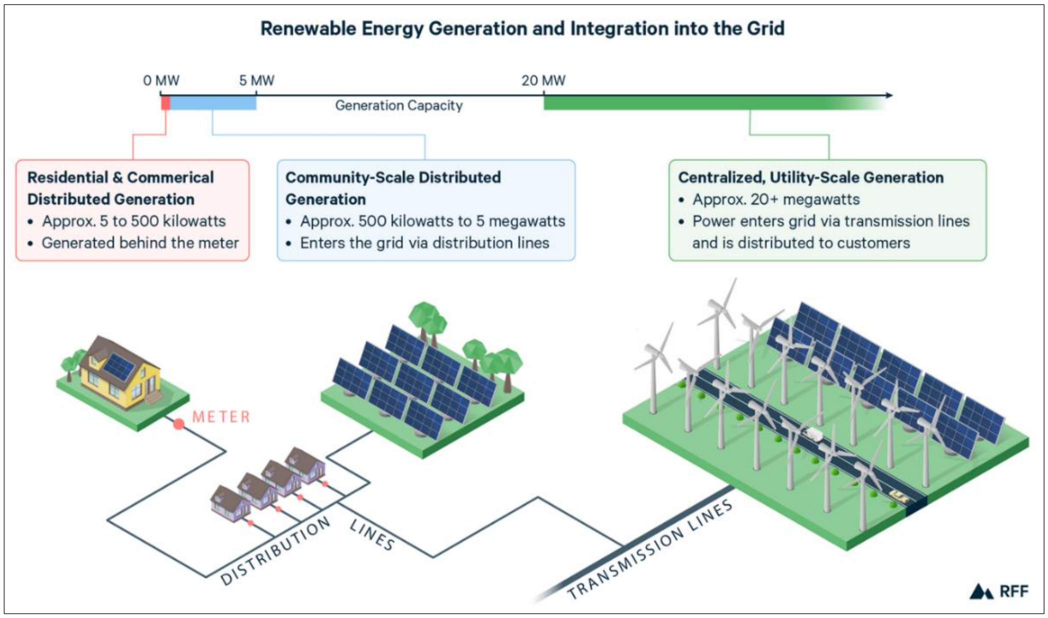
Required Resources:

- *FERC standard interconnection agreements*
- "Agreements" Section of Energy Trust of Oregon *Interconnection Guidebook*

Further Reading:

- Example of Georgia Power's *transmission* & *distribution* interconnection procedures with checklist for key parties and timelines

Figure 8. Renewable Energy Generation and Integration into the Grid



Source: [Resources for the Future](#) (2020)

4. Interconnection Installations & Your Utility

As you learned in the previous section, the interconnection process for DERs with utilities is a crucial step in ensuring that these small-scale energy systems can be safely and reliably connected to the electric grid and operate in parallel with the utility's power system. To reiterate, the interconnection process usually involves a series of six steps, including application, review, agreement, installation, testing, and operation. In this section, you will evaluate and engage in the *final three steps* in the interconnection process.

The resources in Section 4.A detail the installation process of DER technologies that often takes place after the connection agreement. Although this process can be incredibly complicated and should be carried out by professional installers, there are some introductory materials that describe this step in the interconnection process. Section 4.B tackles the testing process that is often required before DERs can begin operation. Section, 4.C outlines common operating and maintenance requirements before providing summaries of all the interconnection process as a whole to close the module.

4.A. Installing DERs.

Once the interconnection agreement is signed, the DER can be installed and connected to the grid. The installation process typically involves the installation of equipment such as inverters, protective relays, and meters, as well as the configuration of control and monitoring systems. This also likely involves coordination with the utility. The specific process for physically installing a DER system can vary depending on the type of technology being installed, the location of the installation, and any local regulations or requirements. Nonetheless, some general steps that are typically involved in the installation process include:

- *Site Assessment:* Before beginning the installation process, a site assessment may be performed to determine the optimal location for the DER system. This may involve evaluating factors such as the orientation and slope of the roof, the available space for ground-mounted systems, and the proximity to any shading or obstructions that could impact the performance of the system.
- *Permitting and Approvals:* Depending on the location of the installation and the type of DER system being installed, permits and approvals may be required from local authorities and the utility company. This may involve submitting plans and specifications for the installation, as well as obtaining any necessary permits or approvals before beginning work.
- *Installation of Equipment:* Once the necessary approvals have been obtained, the installation process can begin. This may involve installing solar panels, wind turbines, batteries, or other components of the DER system. The specific process for installing each component will vary depending on the type of technology being installed and the specific requirements of the manufacturer.
- *Electrical Wiring and Connection:* Once the equipment is installed, it must be connected to the electrical system of the home and to the grid. This may involve running electrical wiring from the DER system to an inverter or charge controller, which converts the DC power generated by the system to AC power that can be used in the home or fed back into the grid. The inverter or charge controller is then connected to the main electrical panel in the home and to the utility's meter or distribution system.
- *Testing and Commissioning:* Once the DER system is installed and connected, it must be tested and commissioned to ensure that it is operating as intended and follows all relevant regulations and standards. This may involve testing the system's performance under different conditions, verifying the accuracy of the metering and monitoring systems, and ensuring that all safety and protection systems are functioning properly.

Subtopics: Installing DERs; Prioritize what to ask your utility

Roadmap: The resources below provide an overview and deep dive into the physical interconnection of DER technologies and the grid. The NREL document outlines the physical interconnection concept while offering some specifics. The South Carolina Energy Office's Consumer Solar resources walk through the entire solar array installation process from a homeowners perspective. The final resource in the required section, a section of an SRP (Arizona based utility) DER Handbook, outlines requirements for connecting to the grid in more technical detail than the first two documents. To dive deeper into technical materials, Section two of the same document provides additional DER system and technical requirements for interconnection within the Further Reading category.

Required Resources:

- NREL's *Connecting Your Solar Electric System to the Utility Grid*
- South Carolina Office of Regulatory Staff – Energy Office: *A Consumer Guide to Solar for the South Carolina Homeowner*
- Section 1, Part III (1-3-1) of SRP's *Distributed Generation Interconnection Handbook*

Further Reading:

- Section 2, Part I & II of SRP's *Distributed Generation Interconnection Handbook*
- Georgia Power's *Interconnection Summary & Application*

4.B. Testing & Verifying DERs.

After installation, the DER must be tested to ensure that it operates safely and reliably in parallel with the utility's power system. The testing process typically involves commissioning tests, performance tests, and grid compatibility tests. The specific process of testing and verification for DERs may vary depending on the type of technology being installed and the specific requirements of the utility or regulatory agency overseeing the installation. Nonetheless, some common steps in the process typically include:

- *Pre-Commissioning Tests:* Before the DER is commissioned, a series of tests may be performed to verify that all components are installed properly and that there are no defects or issues with the equipment. This may include tests of the electrical system, control systems, and any communication systems used to manage the DER.
- *Performance Tests:* Once the DER is installed and connected to the grid, performance tests may be performed to verify that the system is operating as intended. This may include tests of the system's output, efficiency, and response to changing grid conditions. The results of these tests may be compared to the design specifications and any regulatory requirements to ensure that the DER complies.
- *Safety Tests:* Safety tests may also be performed to verify that the DER is installed and operating in a safe manner. This may include tests of the system's grounding, protective devices, and emergency shut-off systems.
- *Interconnection Tests:* In addition to testing the DER, tests may also be performed to verify that the system is properly interconnected with the utility's grid. This may include tests of the DERs' ability to respond to changes in grid conditions, its ability to control power flows, and its ability to operate in parallel with other DERs and the utility's distribution system.
- *Regulatory Compliance Verification:* The results of all tests performed on the DER are often used to verify compliance with relevant regulatory requirements.

Subtopics: Testing; Interconnection tests; Performance & Safety Tests.

Roadmap: The resources below demonstrate how many of the commissioning, performance, and safety tests mentioned above are used in practice. While you shouldn't spend too much time with these documents as they are extremely professional and geared towards professionals, they should give you a sense of the types of tests that are required to receive a permission to operate order.

Required Resources:

- NREL's *DER Testing and Verification - Overview of IEEE P1547.1*
- Section 5: Testing and Maintenance within Eversource's *Information and Technical Requirements for the Interconnection of Distributed Energy Resources*
- First Energy Corp's *Commissioning Testing Requirements*

Further Reading:

4.C. Operating, Monitoring, & Maintaining DERs.

Once the DER has been tested and approved for operation, it can begin generating electricity and supplying it to the grid. The utility will typically install a net meter to measure the energy generated by the DER and the energy consumed by the customer, and the customer will be compensated for any excess energy generated by the DER that is fed back into the grid. This may also include regular inspections, maintenance activities, and performance monitoring to ensure that the DER system is delivering the expected benefits to the customer and the grid.

Subtopics: Operation & Maintenance; Timelines; Summaries & Guidebooks; Cost-Benefit

Roadmap: The resources below complete the interconnection process, detailing operational and maintenance requirements to be aware of after you are granted permission to operate. Use both NREL documents to help budget or estimate the number of days that each step within the interconnection process may take. There are a few cost-benefit resources within the Further Reading section that will help you decide if DER technologies make sense for you. And finally, there are full guidebooks or summaries that will outline the entire DER implementation process from a consumer's perspective.

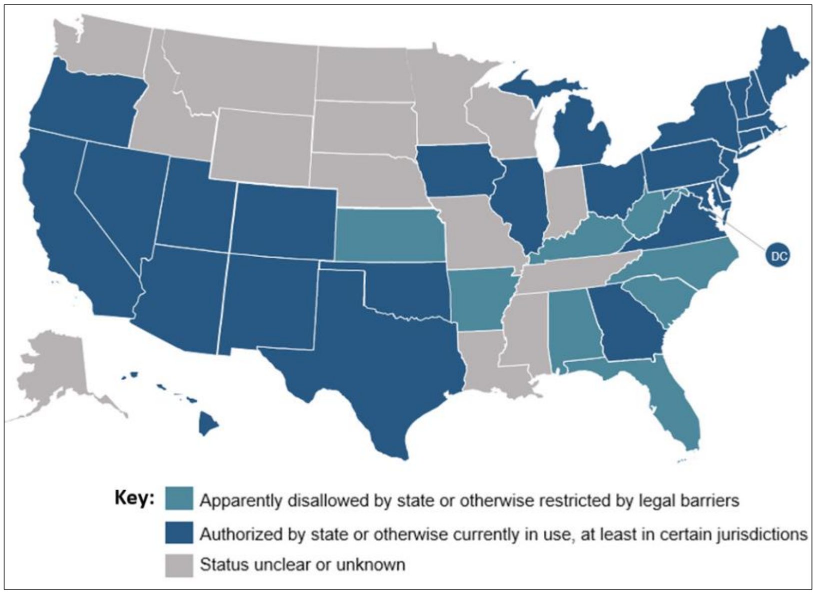
Required Resources:

- Section 2, Part 5: Operation and Maintenance Requirements of SRP's *Distributed Generation Interconnection Handbook*
- NREL's *A State-Level Comparison of Processes and Timelines for Distributed Photovoltaic Interconnection in the United States*
- Georgia Power's *Interconnection Summary & Application*

Further Reading:

- Guidebooks
  - Austin Utilities' *Interconnection Process*
  - Georgia Power's *Interconnection Summary & Application*
  - Energy Trust of Oregon's *Interconnection Guidebook*
  - Ameren Illinois's *Distributed Energy Resources Interconnection Policy Public Facing Guide*
  - New York Public Service Commission's *New York State Standardized Interconnection Requirements and Application Process*
- Georgia Public Service Commission's *Framework for Determining The Costs and Benefits of Renewable Resources in Georgia*

Figure 9. Map of State Status on Third-Party Ownership of Self-Service Generation



Source: NCSU-CETC (2018) cited in National Regulatory Research Institute (2019)

BONUS SECTION: The Inflation Reduction Act (IRA) and DERs

A. IRA Opportunities

The resources in this section will outline future funding opportunities for DER technologies that are within the Inflation Reduction Act (IRA). Explore key program timelines, energy and cost savings calculators and general overview documents below.

Subtopics: IRA timelines and overall funding

Required Resources:

- *White House Guidebook on the IRA* Chapter - "Making Homes and Buildings Cleaner and More Efficient to Save Consumers Money and Cut Pollution" (pg. 105-112)
- *Rewiring America's Guide to IRA*
  - Calculate your home's savings with *Rewiring America's IRA Calculator*

Further Reading:

- *Climate Program Portal*
- Princeton's *REPEAT Project*

A. IRA Implementation

The resources in this section explore the various tax credits, incentives, and rebates within the Inflation Reduction Act (IRA).

Subtopics: Investment tax credit; Production tax credit; Rebates

Required Resources:

- World Research Institute's *How Distributed Energy Resources Can Lower Power Bills, Raise Revenue in US Communities*
- Department of Energy's *Clean Energy Tax Credits for Consumers*

Further Reading:

- IRS's *FAQ Factsheet*
- Sealed's *What does the Inflation Reduction Act mean for homeowners?*