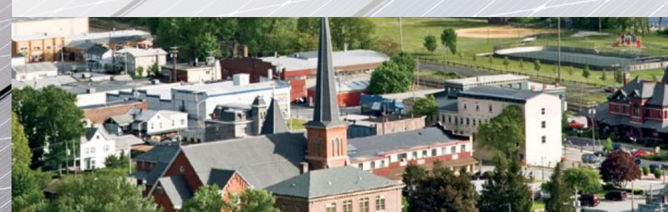
Guide

Conducting a Solar Resource and Infrastructure Assessment

Community Planning for Solar



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Clean Energy Extension

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The outline below summarizes the *Community Planning for Solar* steps and associated documents. For more information, please visit our website at ag.umass.edu/solarplanning.

Community Planning for Solar: Toolkit Steps and Documents

1. Gather your planning team and set goals

- **a. Guide**: Community Planning for Solar - Toolkit Overview
- **b. Fact Sheet**: Forming a Collaborative Community Solar Planning Team

2. Conduct a solar resource and infrastructure assessment

- **a. Fact Sheet**: The Electric Grid, Distributed Generation, and Grid Interconnection
- **b. Guide**: Conducting a Solar Resource and Infrastructure Assessment — You Are Here
- **c. Template**: Solar Resource and Infrastructure Summary
- **d. Example**: Solar Resource and Infrastructure Report

3. Evaluate solar financing and ownership options

- **a. Guide**: Understanding and Evaluating Solar Financing and Ownership Options
- **b. Fact Sheet**: Solar Financing and Ownership Options
- **c. Financial Tool**: Solar Financing and Ownership Options: Cash Flow Model

4. Assess community preferences regarding solar development and financing

- **a. Guide**: Defining Realistic Solar Development Options
- **b. Example**: Realistic Solar Development Options
- **c. Fact Sheet**: Assessing Community Preferences Regarding Solar Development
- **d. Guide**: Conducting Focus Groups for Solar Planning
- **e. Guide**: Conducting a Community Solar Survey
- **f. Template**: Community Solar Survey

5. Develop a *Community Solar Action Plan* to guide solar decision-making and development

- **a. Guide**: Compiling a Community Solar Action Plan
- **b. Example**: Community Solar Action Plan

6. Keep your *Community Solar Action Plan* current

- **a. Fact Sheet**: Monitoring, Evaluating, and Updating Your Community Solar Action Plan

TERM	MEANING
Photovoltaic (PV)	Photovoltaic (PV) systems are solar arrays composed of panels that generate electricity from sunlight. These panels are a different type of technology than the types of panels used in "solar hot water" or "solar thermal" systems.
Capacity	Capacity of a solar array is a description of the instantaneous power output of the panels at top production (i.e., in full sun). It is typically measured in kilowatts (kW) or megawatts (MW). A residential-size solar system is typically 5-10 kW in capacity. Large, ground-mounted solar arrays in Massachusetts are often 1 MW or greater in size.
Annual Generation or Annual Energy Production	The annual generation or annual energy production (AEP) of a solar array is a measure of the yearly electricity output produced by the panels. It is typically measured in kilowatt-hours (kWh) or megawatt-hours (MWh). In New England, annual generation is approximately equal to the array's capacity (in DC) *14% * 8,760 hours per year.
Voltage	Voltage of an electric power line can be thought of as the equivalent of pressure in a water line. The voltage of transmission and distribution power lines is typically measured in kilovolts (kV). One kilovolt is equivalent to 1000 volts (V). In residential use in the United States, electrical wires within a household carry electricity at 120 V.
Three-Phase vs. Single-Phase Power Lines	Distribution lines are either three-phase lines or single-phase lines; the "phase" describes the distribution of power across them. Single-phase lines typically have one line that carries power and one neutral line. Three-phase lines have three wires which are all carrying power out of phase with each other, exactly 120 degrees apart; in some configurations, there is also a fourth neutral and line and ground. The practical implication is that three-phase lines provide a more consistent source of electricity and are better able to handle higher electricity loads. They typically are used to serve commercial and industrial buildings and can power large industrial electric motors. Single-phase lines are suitable for serving residential lighting and heating loads. Three-phase lines can also accommodate larger inputs of energy from distributed electricity generation facilities (such as solar arrays) than single-phase lines.
Abbreviations & Acronyms	
AC	AC is the abbreviation for *alternating current*, the type of electricity flowing into the grid from a solar array, after it has gone through an inverter.
CEE	UMass Clean Energy Extension
DC	DC is the abbreviation for *direct current*, the type of electricity produced by solar panels. The DC capacity of a solar array is a good indication of its size, and footprint on the landscape.
DOER	Massachusetts Department of Energy Resources
kV	kilo-volt, a standard unit of voltage
kW	kilowatt, a standard unit of solar PV capacity
kWh	kilowatt-hour, a standard unit of electricity production or consumption
MDAR	Massachusetts Department of Agricultural Resources
MVP	Municipal Vulnerability Preparedness plan, a municipal planning document
MW	megawatt, a standard unit of solar PV capacity, equal to 1000 kw
MWh	megawatt-hour, a standard unit of electricity production or consumption, equivalent to 1000 kwh
NREL	National Renewable Energy Laboratory
OSRP	Open Space and Recreation Plan, a municipal planning document
SEIN	Solar Energy Innovation Network, a program of the National Renewable Energy Laboratory, funded by the U.S. Department of Energy's Solar Energy Technologies Office
sf	square feet

Table of Contents

Introduction

This guide describes how to conduct a Solar Resource and Infrastructure Assessment. The guide is designed to assist community officials, volunteers, and regional planning agency staff in conducting a preliminary assessment for a municipality, community, or other jurisdiction, based primarily on a desktop analysis of existing documents and data. The guide provides a process that can be used to inventory and describe existing infrastructure, community needs, and resources from the perspective of solar development planning.

Contents of This Guide

Conducting a *Solar Resource and Infrastructure Assessment* involves gathering relevant information within three categories:

1. **Federal, State, and Local Policies**
    - Federal programs supporting solar development
    - State regulations, policies, and incentives relevant to solar development
    - Current municipal solar zoning bylaws and community planning documents
    - Town conservation priorities and protected land

2. **Community Infrastructure**
    - Electricity grid infrastructure and the potential to interconnect additional solar facilities
    - Existing renewable energy facilities
    - Existing structures (e.g., residences, businesses, institutions, and municipal buildings)
    - Priority energy storage sites
    - Sites with potentially moderate to high electricity use
    - Large parking lots
    - Major roads and highways
    - Important viewsheds, conserved areas, and greenways

3. **Technical Potential for Solar (on different types of sites)**
    - Residential rooftops and properties
    - Medium to large-scale rooftops
    - Parking lots
    - Landfills and brownfields
    - Other previously developed sites
    - Farms
    - Undeveloped land available for large, ground-mounted development

The following chapters provide a guide to gathering the information listed above.

Purpose of the Assessment

Information gathered in the solar resource and infrastructure assessment will be useful in multiple steps in the *Community Planning for Solar* process. It will serve as a starting point in *Defining Realistic Solar Development Options* (Step 4, Item a). These options can then be utilized as part of a *Community Solar Survey*, and other activities aimed at assessing community preferences (such as focus groups), to gain a more in-depth perspective on community solar planning goals (Step 4, Items c-f). The assessment will inform Step 5: *Develop a Community Solar Action Plan to guide solar* *decision-making and development,* for next steps that can be taken by the community to prepare for or promote solar development in preferred locations. The assessment can also provide a preliminary inventory of some appropriate sites for solar development which might be the subject of future site-specific solar evaluations.

A Focus on Solar PV in Rural Communities

In this guide, we focus specifically on solar photovoltaic (PV) development for electricity generation, although a similar approach could potentially be used for other clean energy technology planning. This project focuses on rural communities, although many aspects of this approach would be applicable to larger communities.

Throughout, we provide specific examples of how to obtain relevant data for **municipalities in Massachusetts**. In many cases, comparable data, information, and documents are available for other states and regions. Appendix C provides information about equivalent data sources for other New England states (CT, ME, NH, RI, VT) and New York, where we were able to identify them.

Associated Documents

Several additional components of our *Community Planning for Solar* toolkit may be helpful in shaping a *Solar Resource and Infrastructure Report* for your community. These documents are referenced, where appropriate, in the text of this guide, but also collectively noted here:

- For an template outline of a *Solar Resource and Infrastructure Report*, see Appendix A.
- For a template *Solar Resource and Infrastructure Summary*, see ag.umass.edu/solarplanning2.
- For example survey questions about community infrastructure that could be distributed to municipal representatives and community leaders, see Appendix B.
- For a listing of data sources for other New England states and New York, see Appendix C.
- For an example *Solar Resource and Infrastructure Report* from one of the municipalities which participated in this project, see ag.umass.edu/solarplanning2.
- For an example *Solar Resource and Infrastructure Summary* from one of the municipalities which participated in this project, see ag.umass.edu/solarplanning2.

Notes on Solar Facility Size and Terminology

Solar Capacity: Solar PV facilities vary greatly in capacity and project footprint. A rooftop solar array intended to meet the needs of a single residential household might be 5-10 kW in size (or even less), and take up several hundred square feet of roof space. Large, ground-mounted facilities in Massachusetts typically range in size from 0.5 MW (500 kW) up to about 10 MW (10,000 kW) DC, covering from several acres up to 50-80 acres of land. In regions with more land area, solar facilities of 50-100 MW are becoming common, and facilities of over 500 MW have been constructed in some states. Because large, ground-mounted Massachusetts facilities which feed directly into the electricity grid typically fall in the range of 0.5-10 MW DC, this is the size we refer to when discussing availability of land for development of large, ground-mounted systems. Depending on the energy market in your state or region, you may wish to consider locations suitable for much larger systems – up to 50, 100, 500, or even 1000 MW. You may also wish to differentiate between locations suitable for different sizes of large, ground-mounted solar facilities (e.g., 1-20 MW, 20-50 MW, greater than 50 MW).

Solar Size Descriptions: Some agencies, organizations, and companies refer to different sizes of large, ground-mounted systems using different terminology. For example, they might refer to facilities of 1-10 MW DC as “community-scale” facilities, or describe systems larger than 50 MW as “utility-scale” solar or “commercial-scale” solar. However, these terms are not used consistently from state to state or organization to organization. Therefore, we have avoided the use of these terms in this guide. If you do choose to use these terms in a *Solar Resource and Infrastructure Report* for your community, we recommend defining these terms very clearly at the beginning of your report, so that all stakeholders and participating parties understand how the terms are being used.

AC:DC ratio: In some contexts, solar facility capacity is described in megawatts (MW) without reference to whether MW DC or MW AC are intended. In the absence of energy storage, a typical DC to AC ratio for solar array capacity is about 1.25:1, so describing a project in MW DC or AC would not result in a radically different description of the project size. However, battery storage systems are becoming much more common at large solar facilities. With energy storage, the AC:DC ratio can be significantly higher (e.g., 2:1), since excess electricity can be stored in batteries during the day, and released into the grid during the night, when the panels are not generating electricity. As energy storage becomes more common, it is more important to explicitly define project size using MW DC or MW AC, since the project footprint and generation potential can vary greatly between, for example, a 100 MW DC and a 100 MW AC facility. Because MW DC provides a more consistent representation of project footprint and electricity generation potential than MW AC, we recommend using this metric to define potential technical capacity in Step 2: *Conduct a Solar Resource and Infrastructure Assessment.*

Project Footprint: The amount of land required for a ground-mounted solar facility of a given capacity (e.g., 1 MW DC) varies on a site by site basis, depending on the terrain and configuration of the array. It also depends on the type of solar panels – solar panels that move to track the sun tend to require more space than fixed panels. However, because tracking panels are following the sun, they receive more direct sunlight over the course of a day, and generate more electricity per kW of capacity. The land footprint of a project can also be defined in different ways. The *direct area* taken up by solar facility includes the area under and between rows of panels. The *total area* includes the area disturbed by the solar facility and managed as part of the facility. The *total area* typically is bordered by a security fence and includes such features as access roads and stormwater basins and swales. In 2013, NREL completed a study of solar projects across the United States (Ong et al. 2013)[1]. This study was completed before energy storage systems became common at solar PV facilities, and facility capacity was expressed in MW AC. NREL found that for solar PV facilities of 1-20 MW, fixed panel systems took up an average of 5.5 acres of land per MW AC in direct area, and 7.6 acres of land per MW AC in total area (Ong et al. 2013). Single and dual-axis tracking systems took up 6.3-9.0 acres of direct land area per MW AC, and 8.7-13 acres of total land area per MW AC. For larger facilities (> 20 MW AC), the direct area of impact was similar – 5.8 acres per MW AC in direct area for fixed systems, and 6.1-9.0 acres per MW AC for tracking systems. The total area of impact per MW AC was also similar for larger systems, averaging 7.5 acres per MW AC for fixed systems, and 8.1-8.3 acres per MW AC for tracking systems.

Assuming a DC:AC ratio of 1.25:1, these values equate roughly to a nation-wide average of 6 acres of total area per MW DC for fixed systems, and 7 acres for single-axis tracking systems. As solar panels become more efficient, the acres required per MW DC has decreased since 2013, and is expected to continue to decline. In Massachusetts, most systems constructed to date have been fixed panel systems, although tracking systems are becoming more common. A requirement of about 5 acres of total area per MW DC is a rough rule of thumb, and that is the value we used in this analysis. Depending on what information is available in your area, you may wish to use the national average available from NREL, or a more localized value.

[1] Ong, S., Campbell, C., Denholm, P., Margolis, R., & Heath, G. (2013). *Land-use requirements for solar power plants in the United States* (No. NREL/TP-6A20-56290). National Renewable Energy Laboratory (NREL), Golden, CO (United States).

Federal Programs

As a signatory to the Paris Agreement, the United States is expected to take significant actions towards reducing greenhouse gas emissions and furthering the development of renewable energy resources over the coming decades. These efforts may include programs which promote solar development, and which could have a significant impact at the state or local level. When planning locally for solar, it is worthwhile to consider whether there are current federal programs which may fund or promote certain types of solar development, and to keep these programs in mind as community planning efforts are conducted.

At present, the main policy supporting solar development at the federal level is the **Investment Tax Credit** (ITC). The ITC has historically provided strong incentive for the development of solar PV by homeowners and businesses. The ITC provides a 26% tax credit for the cost of solar projects installed on both residential and commercial properties. Credit from the ITC is applied to income taxes of the individual or business that owns a solar project. If a home or business owner purchases a solar PV system, that individual or company receives the ITC; if a home or business owner purchases solar-generated electricity through a power purchase agreement or leases a solar system, then the company which offers the power purchase agreement or provides the leased system can claim the ITC. The ITC will be reduced to 22% in 2023; in 2024, the ITC will be limited to 10% and will only apply to solar projects owned by commercial entities (i.e., it will no longer apply to residential homeowners).

Be aware that other solar policies and incentives could be implemented moving forward. For more information about federal programs supporting solar development, check out the DSIRE website (https://www.dsireusa.org/). Selecting your state will pull up state-specific policies, but also identify federal policies applicable across the country.

Current State Regulations, Policies, and Incentives

Individual state policies play an influential role in solar development, often including stipulations which affect the placement, economics, or pace of development of solar installations. It is important to understand the ramifications of state policies which can affect solar development, and incorporate relevant components into community planning efforts.

State Renewable Energy Policies

More than half of states have some kind of Renewable Portfolio Standards (or RPS), which require that a certain portion of annual electricity use be generated from renewable sources. Through RPS programs, utilities and competitive electricity suppliers are required to purchase a specified percentage of their electricity supply from renewable sources. Typically, these standards require that the percentage increases year to year, thereby promoting the development of additional renewable energy resources over time. The types of renewable energy technologies included in RPS vary from state to state, but most states include certain types of solar PV facilities within these programs.

State Solar PV Policies

A number of states have additional incentive programs which specifically promote solar PV development. These programs can influence the size of solar PV arrays, where they are located, and what kinds of projects are developed (e.g., ground-mounted, roof-mounted, parking lot canopies), depending on what types of projects are eligible for incentives, and how the incentive levels vary with different project scales and types.

State Conservation Policies

State regulations regarding environmental protection, farmland conservation, and historic preservation can also play an important role in solar build-out, because they may influence which properties or portions of properties are available for solar development. Some buildings and land parcels may not be eligible to be developed for solar, due to their environmental, agricultural, social, or historical value.

Future Regulatory Changes

Having a basic understanding of state regulations and policies is important to planning for where solar can legally be developed <u>and</u> where it is most economically feasible. It is helpful to keep in mind that state regulations and policies may change over time; community members conducting long-term planning efforts will want to consider which policies and regulations may be expected to change substantively in the short term (e.g., over the next 5-10 years), and which might be well-established and expected to remain in place for decades.

Massachusetts Example:

State Renewable Energy Policies

Under the RPS program in Massachusetts, utilities and commercial electricity suppliers are required to obtain a specified percentage of their electricity from renewable energy sources, by purchasing Renewable Energy Credits (RECs). Electricity generated from renewable sources within the New England grid that meet certain criteria are eligible for Massachusetts RECs. Each megawatt-hour (MWh) of renewable energy that is generated from eligible sources can receive one REC. Massachusetts recognizes several different types of RECs, but the most relevant to solar PV production are Class I RECs. Class I RECs are available for electricity generated from new renewable energy facilities (including solar PV) that meet certain eligibility criteria and began operation after 1997. [The state of Massachusetts also has Class II RECs for eligible renewable electricity derived from generation sources that began operation before 1998, but only one small solar PV facility (0.1 MW in capacity) falls into this category.]

Under the current RPS program, as well as an associated program known as the "Clean Energy Standard," the Massachusetts electricity supply is on a state-mandated trajectory to increase the percentage of electricity generated from renewable sources which qualify for Class I RECs. On an annual basis, electricity utilities operating in the state are required to obtain the number of RECs equal to the specified percentage of the total electricity (MWh) they supply. Utilities obtain these credits through negotiated purchase agreements or through auction, so RECs have monetary value.

Since 2009, the requirement for Class I RECs has been increasing by 1% per year (e.g., from 13% of electricity use in 2018 to 14% in 2019). In 2019, the state legislature voted to begin increasing Class I RECs requirements by 2% per year. In March 2021, the Act Creating a Next Generation Roadmap for Massachusetts Climate Policy updated the RPS requirements to make Class I RECs increase 3% annually from 2025 to 2029 to reach 40% by 2030.

Currently, most solar PV projects in Massachusetts are supported by state incentives which specifically promote solar rather than renewable energy generally, since solar incentive payments are higher than the value of RECs. However, most solar incentive payments are distributed for only 10 or 20 years. After this incentive period, solar PV projects can still provide RECs to their system owner, which can be sold to utilities or competitive electricity suppliers which operate within the state.

State Solar PV Policies

The state of Massachusetts has implemented three successive programs to provide incentives specifically for solar development, which have been overseen by the state Department of Energy Resources (DOER). The first two programs were known as the Solar Carve-Out (2010-2013) and Solar Carve-Out II (2014-2018) programs. Under these programs, new solar PV systems within the state were eligible to qualify for a special kind of Class I REC known as a Solar Renewable Energy Credit (SREC). Hence, these programs were commonly known as SREC and SREC II. SRECs were issued to system owners based on how much electricity their solar panels generated for 10 years from when they first began operation. Under SREC II, the state set different fractions of an SREC which could be earned for each MWh of power generated by a solar system depending on the size and type of PV system. The goal was to encourage a mix of different development types. About 2,100 MW of solar PV capacity were installed in the state under the two SREC programs.

In November 2018, the Solar Carve-out II program was replaced by the Solar Massachusetts Renewable Target Program, or SMART. The SMART regulation provides incentives in the form of direct "tariff" payments to the solar PV system owner for each kWh of power generated, with credit for the renewable content of the electricity going directly to the utility company in the form of RECs. SMART provides a base compensation incentive rate for solar arrays up to 5 MW AC in size, based on system size, utility service area, and timing of entrance into the program. Additional incentives are available for projects located on buildings, parking lot canopies, landfills, brownfields, and "dual-use" solar and agriculture projects, as well as certain types of projects that benefit public entities, like municipalities, or that provide lower-cost electricity to multiple customers ("community-shared"). These incentives influence where and how solar facilities are constructed. The SMART program initially was designed to provide incentives for 1,600 MW of solar development.

The SMART program was the subject of an emergency rulemaking, which culminated in an emergency regulation issued in April 2020. The updated regulation doubled the size of the program to a total of 3,200 MW. It also limited the types of large, ground-mounted projects which can receive incentives when they are sited on undeveloped land designated as BioMap2 Critical Natural Landscapes or Core Habitat by the state MassWildlife Natural Heritage and Endangered Species Program. Though some solar projects currently in the permitting phase are expected to be grandfathered in without these restrictions, moving forward, it is expected that these land use restrictions will influence where large, ground-mounted solar PV projects are sited and how they are developed.

State Climate Change Mitigation Policies

In 2008, the Massachusetts legislature passed the Global Warming Solutions Act, which mandated that the state cut its emissions by at least 80% by 2050. This goal was updated in March 2021 through an Act Creating a Next Generation Roadmap for Massachusetts Climate Policy. This legislation updated the greenhouse gas emissions limits, committing Massachusetts to achieve Net Zero emissions by 2050, and authorized the Secretary of Energy and Environmental Affairs to establish an emissions limit of no less than 50% for 2030, and no less than 75% for 2040. The legislation also authorized EEA to establish emissions limits every five years, as well as sub-limits for at least six sectors of the Massachusetts economy - electric power, transportation, commercial and industrial heating and cooling, residential heating and cooling, industrial processes, and natural gas distribution and service. These emissions reductions are a legally binding commitment, and will likely require extensive renewable energy development.

State Conservation Policies

Massachusetts has a number of regulations relevant to solar development, in that they may limit or prohibit development in certain locations. While the list below is not exhaustive, relevant environmental policies include:

- ***Wetlands Protection Act****: This Act (M.G.L .c. 131, §40) protects wetlands and the public interests they serve (such as flood control, prevention of pollution and storm damage, and protection of public and private water supplies, groundwater supply, fisheries, land containing shellfish, and wildlife habitat). Any proposed activity that could alter a wetland, floodplain, riverfront area, waterway, water body, or the ocean is subject to a careful review by the Conservation Commission at the municipal level to ensure public interests are protected and that alterations are avoided, minimized, or mitigated for. This regulation typically comes into play for solar projects sited within 100 feet of a wetland or 200 feet of a river or stream.*
- ***Massachusetts Endangered Species Act****: This Act (M.G.L .c. 131A) protects rare species and their habitats throughout the state. Any project proposed in habitat identified as Priority or Estimated Habitat for species listed by the state as Endangered, Threatened, or of Special Concern is required to undergo MESA review, to ensure that it does not have adverse impacts on the species.*
- ***Conservation Restriction Act****: This Act (M.G.L. c.184, §§31-33) was the first of its kind in the United States. It allows for the creation of a legally binding, recordable, and enforceable commitment that a property may not to be developed or substantially altered, a requirement that is passed along to future owners of the property as a restriction on the property deed. This legal commitment is commonly known as a conservation restriction or CR. CRs can be purchased, donated, or bequeathed. CRs are commonly placed on natural landscapes (e.g., forests, grasslands, beaches) to protect their ecological value. However, the Act also allows for similar restrictions to be placed on farmland or historic properties through comparable mechanisms known as Agricultural Preservation Restrictions (APRs) and Historic Preservation Restrictions (HPRs). Unless removed by an act of the legislature, most properties preserved under a CR cannot be developed for solar or other purposes.*

- ***Scenic Mountains Act**: This Act (M.G.L .c. 131, §39A) is only applicable within Berkshire County. It provides municipalities with a local option to adopt a statute to regulate activities on land at higher elevations.*
- ***Public Lands and Public Trust Doctrine:** Under Article 97 of the state's constitution, anyone seeking to alter the use of, lease, or sell public land originally acquired for natural resource purposes in most cases would require an act of the legislature and approval by the governor before that activity could occur. In addition, many individual statutes within state law strictly regulate development on a variety of types of public properties, including cemeteries, parks, and city or town forests.*
- ***Public Shade Tree Act (M.G.L. c.87):** This Act regulates the cutting of trees situated within or along public ways (e.g., public streets) in Massachusetts. Except in cases where a tree represents an immediate danger to public safety, a public hearing and approval of the local Tree Warden are typically required before trees along public ways can be removed for any purpose, including creating access to a solar facility site or cutting trees to reduce shading of a solar array. The **Scenic Roads Act** (M.G.L. c.40, §15C) augments this Act with additional requirements concerning the removal of trees along designated Scenic Roads.*

Future Regulatory Changes

An important take-away from this brief review is that further development of renewable energy – including solar – is currently incentivized by Massachusetts state programs, and this development is likely to continue over the coming decades in order to meet state-mandated greenhouse gas emission reduction goals. The current state solar program places restrictions on the size and location of solar arrays eligible for incentives. These restrictions are helpful to keep in mind, but it is also evident from the multiple solar incentive programs that have been implemented since 2010 that solar incentive programs will likely evolve over time. These programs are sensitive to the solar development market and other state concerns (including environmental and equity issues), as well as subject to legislative changes. They may be expected to be updated in a relatively short timeframe (less than 5-10 years), and perhaps even every couple of years. In addition, over time, solar technology may become cost-efficient enough that solar incentives are no longer necessary to support development.

By contrast, a number of Massachusetts environmental laws have been in place for decades. The state Conservation Restriction Act was enacted in 1966, the state Wetlands Protection Act has been in place since 1972, and the state Endangered Species Act took effect in 1990. These types of laws are unlikely to go away, and may not be expected to change substantially over the coming years. When planning for solar, it is important to consider areas protected from development through conservation restrictions or under Article 97. In addition, wetlands and rare species habitat (BioMap2) should also be examined as part of the planning process.

Existing Bylaws, Ordinances, and Planning Documents

Many municipalities, as well as other types of jurisdictions, have a suite of planning documents intended to guide development within their boundaries, outline planned infrastructure, detail emergency response plans, and highlight important environmental, recreational, agricultural, and historical resources. These documents provide a backdrop against which the suitability and need for solar development in different locations can be considered.

In some cases, but not always, planning guidance may be formalized in municipal zoning bylaws or ordinances governing the types of development that can occur in a particular portion or zoning district of a town or city. Such bylaws or ordinances may address development generally, or contain specific language regarding solar PV development. Bylaws may address issues associated with the safety of development, such as in proximity to public water supplies, floodplains, or on steep slopes, may require property line setbacks, or may limit tree clearing. In this way, bylaws have the potential to influence the properties on which solar projects can be developed. Reviewing these bylaws is important for a clear understanding of where and what type of projects can currently be developed and how complex the process is for permitting different types of projects. After further steps have been taken to assess community preferences, the municipality may determine that bylaws or ordinances should be updated to promote or discourage solar facilities in certain locations or configurations.

In addition to reviewing general zoning and solar bylaws, it is also important to consider any existing bylaws which may restrict solar development in some locations. For example, some local wetlands bylaws may prohibit or place additional restrictions on development in proximity to wetlands and water bodies. Other local bylaws might protect scenic views, historic stone walls, or other features of cultural, historic, or conservation value.

Massachusetts Example:

Planning Documents

There are a number of planning documents commonly developed for Massachusetts municipalities that are helpful to review as part of the solar planning process. Some of these documents may be available on a municipal website. Older, hard-copy files may be available from the town clerk, town coordinator, town administrator, or Select Board in smaller communities, or from a city planning department in larger communities. They may also be on file with a regional planning agency, if that organization was involved in compiling the original plan. Note that not every municipality will have all of the following plans available, and some plans may be old and out-of-date.

- ***Master Plan****: A Master Plan is designed to provide a basis for decision-making regarding the long-term physical development of a municipality. It can address such issues as land use, housing, economic development, community services and facilities, open space and recreation lands, and natural, cultural, and historic resources.*

- ***Open Space and Recreation Plan**: Open Space and Recreation Plans are developed through a public participation process (typically a survey and analysis) that allows the community to describe recreational, natural, agricultural, cultural, and historic resources, and to identify priorities for conservation or recreational use. These documents can provide insight into community values regarding conservation priorities, and which areas should not be developed. These plans often identify and map public and private conservation land throughout the municipality.*
- ***Municipality Vulnerability Preparedness Plan/Hazard Mitigation Plan**: These plans are concerned with potential hazards facing a community, and may provide insight into potential energy storage sites to increase resiliency in the face of a power outage or other situation requiring designation of an emergency shelter.*
- ***Energy Reduction Plan**: This plan, completed as part of a municipality's application for Green Communities status (https://www.mass.gov/green-communities-designation-grant-program), typically focuses on energy efficiency. However, it may also discuss goals for renewable energy development in a community.*
- ***Complete Streets Planning:** The goal of the Complete Streets program is to provide safe and accessible options for all travel modes - walking, biking, transit and vehicles – for people of all ages and abilities. Planning conducted through this program may provide insight into transportation goals and potential locations for electric vehicle charging stations, which could be complemented by solar electricity generation.*

Bylaws and Ordinances

Massachusetts municipalities will always have a zoning bylaw or ordinance. As with planning documents, zoning bylaws should be available on the municipal website, or on file at town or city offices and available upon request. The zoning bylaw will discuss property uses that are allowable in different zoning districts within the community, property line setbacks for new infrastructure, and any required specifications (e.g., in terms of size, height, aesthetics, safety issues). It may not necessarily have a section which specifically addresses solar PV arrays - but as these facilities spread across the landscape, specific sections devoted to solar development are becoming increasingly common and detailed in content.

Wetlands Bylaws

Massachusetts communities can choose to adopt wetlands protection bylaws that are more restrictive than state law as defined in the Wetlands Protection Act. For example, a municipal bylaw might provide larger "no-build" buffer zones around jurisdictional wetlands or provide additional protections for vernal pools. These bylaws can affect solar development on properties containing or adjacent to wetlands, streams, rivers, and other water bodies.

Existing Grid Infrastructure

When planning for solar PV development, it is helpful to consider existing electricity grid infrastructure. The layout of the grid can place significant constraints on where solar PV arrays – especially large facilities – can be economically built. This is because grid infrastructure often requires upgrades before it can safely and reliably accommodate large inputs of additional electricity generation, and in many cases, new electricity generation facilities are expected to cover the costs of these upgrades before they are allowed to interconnect to the grid. In fact, the expected cost of interconnection plays a major role in decision-making by commercial solar companies when choosing a site for development. Areas where the grid requires significant upgrades may not be appropriate for the addition of large solar projects in the short-term.

One challenge in incorporating electricity grid infrastructure into long-term planning is that infrastructure can change over time – sometimes rapidly. For example, if a substation undergoes an upgrade, or a distribution line is converted from single-phase to three-phase power, additional room for solar capacity may open up very quickly. When carrying out long-term planning efforts, it is important to be aware of existing infrastructure, but we recommend focusing primarily on community goals and values regarding which areas are best for solar development. If the United States is to construct and interconnect sufficient renewable energy capacity to meet state and national goals for greenhouse gas emission reductions, the buildout of renewable energy must be accompanied by a large increase in transmission capabilities and improvement of the underlying grid infrastructure. Thus, planning efforts can be seen as a way for communities to identify areas where they would like to see grid infrastructure improve to allow for additional solar development. Such plans can then be shared with the local utility or state or regional planning authorities. This may result in opportunities to conduct collaborative planning to encourage grid infrastructure improvements in areas which would further the goals of local communities and other interested parties.

Massachusetts Example:

For an overview of how the New England electricity grid functions and how solar PV facilities are able to interconnect to this system, see our fact sheet *The Electric Grid, Distributed Generation, and Grid Interconnection* at ag.umass.edu/solarplanning2. We recommend reviewing this factsheet before reading the remainder of this section, since only a short synopsis of the factsheet contents is provided below.

- *In Massachusetts, the large majority of solar PV facilities are connected to the grid via distribution lines. Distribution lines are typically owned by the local electricity utility – Eversource, National Grid, Unitil, or a municipal utility. Electricity facilities that connect to the grid via distribution lines are sometimes referred to as distributed generation facilities.*
- *The two major utilities operating in the state – Eversource and National Grid – are required by the Massachusetts Department of Public Utilities (MA DPU) to publicly share*

information about the capacity for individual distribution lines to accommodate the interconnection of additional solar and other distributed generation electricity facilities. This public information includes a listing of all medium-to-large energy facilities that are either operating or proposed to be connected to distribution lines. Also included is information about whether additional energy facilities can be accommodated, and if so, how much capacity for accommodating additional projects is currently available. The capacity available for accommodating additional facilities is known as hosting capacity.

- *Distribution lines that cannot immediately accommodate additional large facilities are described as saturated. At minimum, most three-phase lines, even "saturated" ones, tend to be able to accommodate additional small-to-medium scale solar projects (under 200 kW) without upgrades, and most single-phase lines can accommodate additional solar projects under 50 kW in size. If lines are currently saturated, it does not mean that no more large distributed generation systems can be added to the circuit, but does suggest that upgrades are needed before additional facilities can be interconnected. Upgrades may involve significant delays and costs, which the energy facility developer is typically expected to pay for as a condition of interconnection.*

For more information about this topic, please see the fact sheet referenced above.

Hosting Capacity Maps

Hosting capacity information is provided by the utilities using navigable, on-line maps. These maps show three-phase lines color-coded to display the currently available hosting capacity; single-phase lines are shown in gray (Eversource) or pink (National Grid). Clicking on a distribution line will bring up an information box providing more detail about the circuit, its remaining capacity to connect additional distributed generation electricity sources, and the related substation. **See Figure 1 next page.**

Hosting capacity maps are available at the following links:

- ***Eversource East:*** *https://eversource.maps.arcgis.com/apps/webappviewer/index.html?id=7b13d31f908243e49406f198b359aa71*
- ***Eversource West:*** *https://eversource.maps.arcgis.com/apps/webappviewer/index.html?id=eea778f65e5d4bac87a7ad83bde9f999*
- ***National Grid:*** *https://ngrid.apps.nationalgrid.com/NGSysDataPortal/MA/index.html*

More information about how to use and interpret these maps is also available from the utilities. For example, see:

- ***Eversource – Hosting Capacity Map FAQs****:* *https://www.eversource.com/content/wma/about/about-us/doing-business-with-us/builders-contractors/interconnections/massachusetts/hosting-capacity-map*
- ***National Grid - Data Portal Help Guide:***

  http://ngrid-ftp.s3.amazonaws.com/MASysDataPortal/MA_Data_Portal_Help_Guide_v1.pdf

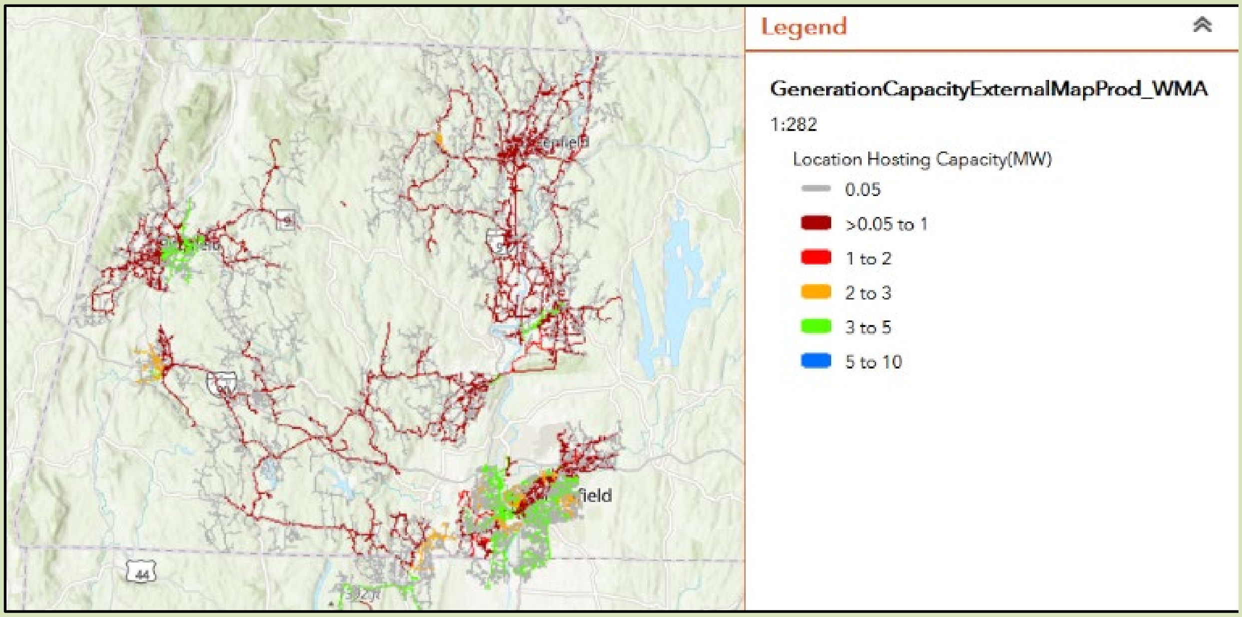
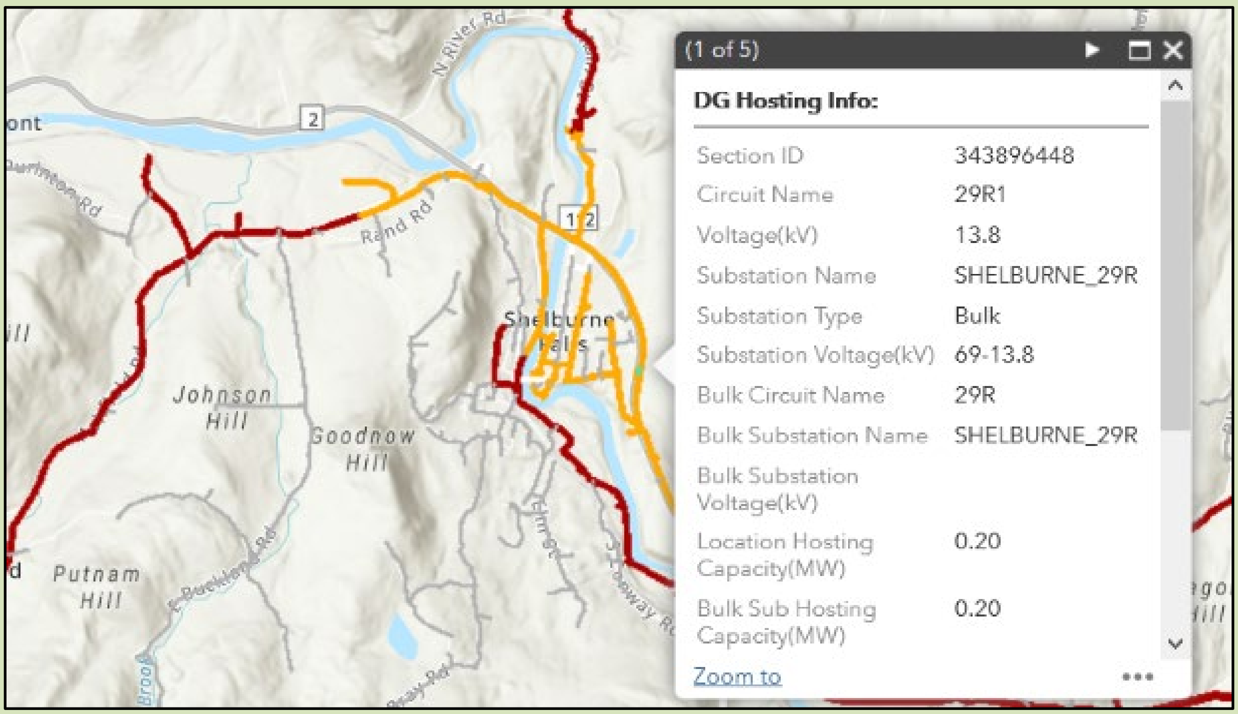


Figure 1. Example hosting capacity maps from the Eversource West service area, showing Eversource distribution lines in western Massachusetts (above) and a close-up of one town (below) displaying the pop-up information box providing more detail about the circuit. Lines shown in blue are able to accommodate the largest new solar projects; lines shown in dark red or gray are only able to accommodate smaller new solar projects without significant upgrades to the system. Light red and orange lines are intermediate.



Distributed Generation Energy Facilities

DOER provides publicly available data detailing all medium to large distributed generation electricity facilities associated with each distribution line circuit.

To compile a list of energy facilities associated with the distribution line circuits in the municipality you are assessing, download a copy of the data as a spreadsheet available at **this link:**

https://sites.google.com/site/massdgic/home/interconnection

You will want to download the "RAW DATA" spreadsheet available under the heading *Utility Reporting & Circuit Analysis for Locational Value*.

The list of all energy facilities in the state is in the Tracking Data tab of the RAW DATA spreadsheet. This list can be filtered by the City/Town column to see only those projects approved, proposed, or withdrawn for your community. We also recommend filtering by Zip Code to see any projects for which the name of your municipality may have been misspelled, or where a village or neighborhood within the community is referenced instead of the municipality proper. Alternatively, or in addition, the list can be filtered by the circuits which feed your municipality, which can be identified using the Saturation Map described above. This filter can be applied using the Circuit Name column. Keep in mind that the circuit names listed in this table may differ slightly from circuit names listed in the Saturation Map, with missing or additional spaces or zeroes. If you aren't sure if a particular Circuit Name in the spreadsheet is one that is relevant for your town, filter by that Circuit Name and look to see if the list of facilities includes facilities listed for your municipality, or neighboring municipalities which are served by the same circuit on the Saturation Map.

	A	B	C	D	E	F	BD	BE	BF
1	Company Name	City/Town	Facility ID (if any)	ZIP Code	Design Capacity (kW)	Fuel Type (Solar, Wind, etc)	Status of Project	Project count	Circuit Name Edits
2800	National Grid	WENDELL DEPOT	185644	01379	220	Solar	2 - In Process	1	09-705W1
2802	National Grid	WENDELL	17101060	01379	480	Solar	1 - Cancelled	1	09-705W1
2803	National Grid	WENDELL	17185929	01379	480	Solar	1 - Cancelled	1	09-705W1
5843	National Grid	WENDELL	184433	01379	2600	Solar	1 - Cancelled	1	09-705W1
5844	National Grid	WENDELL	192888	01379	1000	Solar	1 - Cancelled	1	09-705W1
5845	National Grid	WENDELL	188655	01379	3100	Solar	2 - In Process	1	09-705W1
5846	National Grid	WENDELL	270599	01379	2791	Battery Add-On	2 - In Process	1	09-705W1
5847	National Grid	WENDELL	14163198	01379	1000	Solar	4 - Authorized	1	09-705W1
5850	National Grid	WENDELL	25121839	01379	2791	Solar	2 - In Process	1	09-705W1
5851	National Grid	WENDELL	25538927	01379	1125	Solar	1 - Cancelled	1	09-705W1
5852	National Grid	WENDELL DEPOT	25700042	01380	4800	Solar	1 - Cancelled	1	09-705W1
11845									
11846									

Figure 2. Example distributed energy project data from DOER's RAW DATA spreadsheet. This example is filtered by the City/Town column to show projects in the town of Wendell. Note the "Design Capacity" column, which shows the size of the project, and the "Status of Project" column, which shows the project's interconnection status.

Note that DOER staff are available to provide assistance regarding use of these resources. For assistance, visit this website to find up-to-date contact information: https://sites.google.com/site/massdgic/home/interconnection/dispute-resolution

Community Infrastructure and Solar Technical Potential

We recommend cataloguing community infrastructure, types of land and structures present in town, and potential solar resources using a three-step method. The first step consists of compiling an initial inventory of important features using general databases and local knowledge. Where available, the second step consists of using tax assessment information to further identify and map the location of important features. The third step consists of using geospatial data layers to quantify the technical potential for solar within different categories of structures and land types.

Initial Inventory

Compiling an inventory of existing community infrastructure can help identify potential energy storage sites and areas of high electricity use. It can also help provide a complete picture of the types of structures and land available for solar development within a community, as well as identify areas which might be of conservation value or already protected from development and hence inappropriate for the siting of solar arrays.

As part of a solar resource and infrastructure assessment, we recommend cataloguing the following:

- Approximate community size (i.e., number of households)
- Local businesses and farms
- Local institutions (including colleges, hospitals, places of worship, private schools, and non-profit organizations)
- Municipal buildings and public schools
- Federal, state, or county facilities
- Medium to large parking lots
- Existing renewable energy facilities
- Priority energy storage sites
- Conservation and recreation areas
- Publicly owned properties (e.g., municipal, county, state, or federal lands)

Depending on the scale at which the Solar Resource and Infrastructure Assessment is being conducted, you may wish to adjust the scope and granularity of your inventory. For small, rural towns, it may be reasonable to include any business in town which has a physical location distinct from a residential property, and to include all municipal buildings which are commonly used and in good repair. Planners focused on larger communities or jurisdictions (e.g., a county-level analysis) might want to focus at a larger scale, for example, only considering businesses or municipal buildings over a certain threshold of size.

There are a number of resources which can provide data to inform the initial inventory of community infrastructure. If planning staff are not already included directly as part of the project team, a good place to start is to reach out to your community's planning department, county planning agency, or regional planning agency to find out what local plans and resources they have available which can aid in the inventory process. Ask planning staff if they have any planning documents available for your municipality, county, or region which may contain inventories of infrastructure, on-line maps, or other information of value for a solar assessment.

Other data sources and resources applicable across the country include:

- **General information**: Conduct brief surveys of local representatives and community leaders (see example questions in Appendix B).
- **Renewable energy generation facilities**: Nationally, all electricity generating facilities with a capacity of 1 MW or greater are mapped by the Energy Information Administration (https://hub.arcgis.com/datasets/f18b0ae4d06743bd87cbaea51e8109e9?geometry=-72.719%2C42.432%2C-71.676%2C42.610). State-specific databases may also be available; see Appendix C for New England and New York.
- **Number of households**: American Communities Survey data, available from the U.S. Census Bureau, provide an estimate of the number of households per municipality or county (https://www.census.gov/programs-surveys/acs).
- **Businesses**: Businesses are listed by NAICS code by the U.S. Census Bureau (https://www.census.gov/programs-surveys/susb.html). Google Maps displays many businesses as landmarks (https://www.google.com/maps). Reference USA provides a database of businesses by zip code (http://www.referenceusa.com/Home/Home); check to see if this database is available for free through your local library;
- **Institutions**: Google Maps displays many institutions as landmarks (https://www.google.com/maps).
- **Degraded sites**: The Environmental Protection Agency maintains a database of Superfund sites and hazardous waste sites on the National Priorities list (https://www.epa.gov/superfund/search-superfund-sites-where-you-live).
- **Conserved areas**: Conduct a review of properties owned by large conservation organizations active in your state (e.g., The Nature Conservancy, Audubon Society), state-owned lands, or lands owned by local land trusts. Google Maps displays many conserved areas in green (https://www.google.com/maps);

Tax Assessment Information: After conducting an initial inventory, tax assessment data, where available, can be used to further identify businesses, institutions, municipal properties, and conserved areas. Owner information and use codes (e.g., residential, commercial, multi-use, vacant) listed in tax assessment data can help highlight any businesses or farms active in the community which were not identified in the initial inventory, identify municipal and state-owned properties, and call out conserved lands. Often, geospatial data layers are available that allow tax assessment information to be linked to mapped properties in a geospatial data layer. These data layers are extremely helpful in informing the location and extent (acreage) of important features.

Solar Technical Potential: As a third step, geospatial data layers can be used to provide an estimate of the available technical potential for solar development on different types of structures and for different categories of land. Potential solar resource categories to consider will vary with municipality and region, but could include:

- Residential-scale solar potential (which could include systems mounted on the roofs of houses or outbuildings, as well as small, ground-mounted systems on residential properties)
- Medium to large roofs (defined, in this analysis, as roofs greater than 5,000 sf in area)
- Parking lots
- Landfills and brownfields
- Other previously disturbed lands

- Agricultural land and farms; other working landscapes (e.g., pine plantations)[2]
- Undeveloped, natural landscapes available for large-scale solar development[2]

Estimates of technical potential can be calculated for each of the solar resource categories above using geospatial data. A wealth of geospatial data layers are publicly available from national, state, or non-profit sources. Recommended geospatial data sources and estimation methods for calculating technical potential are discussed in much greater detail in subsequent subsections, associated with each type of potential solar resource.

This quantitative assessment can be quite useful in providing an upper limit on the amount of solar development of each type that can occur within a community. It is important to keep in mind that this method, which focuses on geospatial data layers, is only ***a preliminary, desktop-based analysis.*** It does not take into account the economic feasibility of development in a certain location, or the site-specific details of roof structure, localized topography, economics, or interconnection opportunities. Thus, it likely represents an over-estimate or upper boundary on the total availability of space for different types of solar development.

Massachusetts Example:

As noted above, helpful information can be gleaned from a variety of national data sources, as well as from the local knowledge of municipal representatives, using a brief survey, such as that included in Appendix B.

Initial Inventory

Additional sources of data specific to Massachusetts include the following:

- ***General:*** *As discussed earlier in this guide, municipal planning documents - such as Master Plans, development plans, or Open Space and Recreation Plans – may contain useful inventories of community features. These documents may be available from town officials or from regional planning agencies (RPAs). There are twelve RPAs in Massachusetts, each of which covers a different section of the state (https://www.apa-ma.org/resources/massachusetts-regional-planning-agencies/).*
- ***Farms:*** *The Farm Finder from the Community Involved in Sustaining Agriculture program (https://www.buylocalfood.org/find-it-locally/) can be used to identify businesses producing agricultural products.*

[2] Note that for working lands and undeveloped lands, there are technical constraints on development (e.g., steep slopes or permanent conservation protections), which may preclude development on certain properties. Some of these constraints can be identified using geospatial data layers, and those properties can then be excluded from estimates of technical potential. There may also be social constraints on development. After community preferences regarding development of working and undeveloped lands have been evaluated (Step 4: *Assess community preferences regarding solar development and financing*), it will be helpful to revisit this category of solar resource to further categorize and refine estimates of technical potential for these types of land based on community preferences and how different types of land are valued by community members.

- ***Existing renewable energy facilities:*** *DOER's spreadsheets of qualified generation facilities list solar projects receiving incentives in the state (https://www.mass.gov/service-details/lists-of-qualified-generation-units). Google Maps can be used to confirm locations. Clark University is currently compiling a GIS-based map of large solar facilities by town (https://taoshiqi.users.earthengine.app/view/solarpanelsbytowns).*
- ***Important viewsheds, conserved areas, and greenways:*** *To identify these areas, review town Open Space & Recreation Plans. Review properties owned by large conservation organizations in Massachusetts (e.g., Mass Audubon, The Nature Conservancy, Trustees of Reservations).*

Tax Assessment Information

Tax assessment information and land parcel geospatial data layers are available for each Massachusetts municipality through MassGIS. These files include tax assessment information about the property (e.g., use codes, owner information, buildings on the property) which can be linked to polygon files showing the tax parcels on a map.

1. *Accessing Massachusetts tax parcel data.*

Tax parcel data is available for each municipality from MassGIS:
https://www.mass.gov/info-details/massgis-data-property-tax-parcels
The data for an individual municipality is downloaded as a zip file. The zip file includes 3 shapefiles and 3 tables of metadata. The shapefile containing the land parcels will be labeled MA###TaxPar; the relevant metadata table will be labeled MA###Assess. The ### represents the municipal ID, and is the number of the municipality if listed in alphabetical order with all Massachusetts municipalities (i.e., a number between 1 and 351). These files can be opened in a GIS program, such as ArcGIS or QGIS.

2. *Organizing Use Codes*

Use Codes comprise a column within the MA###Assess data table. These codes represent Massachusetts tax assessors' evaluations of the primary use of each property. These codes can be organized into categories in order to summarize availability of land and building types for different types of solar resources. A description of most Use Codes is available from the MA Department of Revenue:
https://www.mass.gov/files/documents/2016/08/wr/classificationcodebook.pdf
Use Code data typically requires quality control. In some cases, codes used may be obsolete, may include an extra '0' at the end, or may not be listed in the Department of Revenue classification. "Mixed Use" properties, in particular, are often designated with confusing codes. These properties are supposed to only have 3 numbers; the first number should be '0,' the second number should be the primary use category (e.g., '1' = residential), and the third number should be the secondary use (e.g., '7' = agricultural). In some cases, however, municipal assessors appear to begin with the primary use (e.g., '1' = residential), and then follow up with two additional codes. In cases of unknown codes that don't meet the 'mixed use' format, it may be necessary to look up the actual properties on MassMapper (https://maps.massgis.digital.mass.gov/MassMapper/MassMapper.html) or Google Maps, and assign an appropriate designation.

Use Codes data can be exported from the MA###Assess table into Excel for organizing and quality control purposes. For an example of one way to categorize Use Codes, see this spreadsheet.

3. *Joining Tax Assessor Data, Land Parcels, and Use Codes*

Once Use Codes have been organized into categories, the Excel document can be added back into the GIS program. The Excel document can then be joined with the MA###Assess table and MA###TaxPar files by USE_CODE and LOC ID columns to create a shapefile and map displaying different tax parcels by type of use (e.g., residential, commercial, Chapter 61A residential land, etc.). Acreage information is included in the MA###Assess tax parcel information, or can be calculated based on the size of the polygon using tools in the GIS program.

Solar Technical Potential

MassGIS, the state's Bureau of Geographic Information, has a wealth of geospatial data layers available for download which are helpful in calculating technical potential; these will be discussed in much greater detail in subsequent subsections.

Potential Energy Storage Sites

Energy storage systems help to balance differences between electricity demand and generation, and are especially valuable complements to intermittent energy sources like wind and solar, which do not produce energy 24 hours a day, and may not be producing during times of peak demand. Although battery storage costs are dropping quickly, energy storage remains a relatively expensive technology. However, energy storage systems have a number of advantages which can offer value under the right circumstances. For example, these systems can provide a reliable source of energy during outages, which means that they also provide value in terms of public safety and health. In addition, energy storage systems have the potential to allow larger solar facilities to be built in areas where interconnecting a medium or large solar array could otherwise exceed the ability of the local distribution lines to accommodate additional renewable energy capacity.

Because energy storage systems can be paired with solar PV development, it is useful to identify sites where considering energy storage possibilities may be worthwhile. These include:

- **Sites with large electricity loads**: In small rural communities, there often are few sites with a high electricity load that might justify the cost of energy storage. Schools, businesses, and institutions may be the largest electricity users.
- **Energy reliability**: Emergency shelter sites, hospitals, urgent care centers, and group housing for older or handicapped individuals are all locations where dependable sources of energy during a power outage or other emergency situation can be beneficial.
- **Electric vehicle charging sites**: Looking to the future, we can expect to see a rapid rise in use of electric vehicles over the coming decades, and an associated need for electric vehicle charging stations. Central points within a community where residents and visitors stop for work, education, shopping, medical needs, or leisure may all be considered as potential electric vehicle charging locations, as may service facilities along major roads or highways. These sites do not necessarily require incorporation of energy storage, but slow charging of energy storage systems on-site has the potential to reduce demand charges charged by electricity utilities associated with rapid charging of electric vehicles.

  New models for energy storage may also be developed as electric vehicles become more common. For example, electric buses, used by schools or regional transit agencies, require large battery storage systems to carry out their daily routes. These large vehicle batteries have the potential to serve as mobile electricity storage systems which could, for example, serve as emergency back-up power to be deployed to emergency shelters, schools, or other sites in case of power outage.

Identification of priority energy storage sites can be informed by multiple steps in this assessment, including the review of community planning documents, surveys of community officials and representatives, and the inventory of major businesses, institutions, municipal buildings, and parking lots.

Massachusetts Example:

All of the information sources discussed above are relevant to identifying potential energy storage sites in Massachusetts municipalities. In addition:

- ***Municipality Vulnerability Preparedness*** *plans, if available, can provide information about potential sites for emergency shelters or where energy reliability is important.*
- ***Complete Streets*** *plans, if available, are good sources of information about plans for future electric vehicle infrastructure.*



Small Residential Rooftops

This section focuses on estimating the technical potential for residential solar on small rooftops. In rural areas, residential properties are often single-family homes, small multi-family homes, or residential outbuildings, all of which fall into this category. In more developed areas, multi-family housing may be more common, and larger multi-family buildings may instead fall into the *Medium and Large Roofs* category. For the purposes of estimating solar technical potential, National Renewable Energy Laboratory categorizes “small” roofs as those with a roof area of under 5,000 sf. Depending on the distribution of roof sizes and residence types in your jurisdiction, this may be an appropriate cut-off, or you may choose to adopt a different standard to define this category. For example, in the rural Massachusetts towns we worked with, the vast majority of residences (>98%) are single-family homes, and most houses and outbuildings have roof areas of 5,000 sf or less. However, we found that a few house rooftops fell into the 5,000-6,500 sf range. Because there were relatively few of these rooftops, and they were not materially different from the resource provided by residential rooftops of 5,000 sf or less, we included these slightly larger roofs in our estimate of small residential rooftop potential. Meanwhile, we included large barns and other large structures on residential-zoned properties in the *Medium and Large Roofs* category.

The most appropriate method for estimating the technical potential for residential solar depends on the distribution of residential housing types, data availability, project goals, and the time and expertise of those conducting the assessment.

- At a minimum, rough estimates of the potential for solar on small, residential rooftops and properties can be obtained based on the number of single-family properties and assumptions about how much solar can be developed per property. In rural areas where the large majority of households occupy single-family homes, the number of households is likely a reasonable proxy for the number of single-family properties.
- For states where roof area data are available, a slightly more complex, but not necessarily more accurate, estimate of solar technical potential can be calculated based on the area of small rooftops.
- Where experts are involved, technical potential for individual roofs can be estimated using lidar data.

Data Sources

Below is a list of types and sources of data which it may be possible to locate and which can prove helpful in performing different types of calculations to estimate residential-scale solar potential. In some cases, these values are based on national data, or are available for all parts of the country. For other data, they may be available in some states and not others. For a list of where state-specific data can be obtained for New England states and New York, please see Appendix C.

Table 1. Data sources for estimating residential-scale solar potential.

Type of Data	Availability	Source
Total number of households; % of households that occupy single-family homes	Available for most municipalities, counties, and other jurisdictions	American Communities Survey, U.S. Census Bureau
Total area of small rooftops; total number of small rooftops; average area of small rooftops	Available for most locations	Microsoft maps has released country-wide building footprint data (https://github.com/microsoft/USBuildingFootprints). Many states also provide geospatial data layers showing building roofprints or footprints as polygons.
% of small building roof area suitable for solar	Nationwide average of 26%	Gagnon et al. 2016[3]
% of small building roofs appropriate for solar	Available for many municipalities and jurisdictions; if not available, a nearby jurisdiction with comparable characteristics should be available	Download the "Rooftop PV Technical Potential" spreadsheet from https://data.nrel.gov/submissions/121; the fraction of small roofs suitable for solar is in the "Small Building Suitability" tab, Column K.
% of small rooftops that can accommodate >10m^2 of solar panels	Available for a subset of zip codes within most states; select the most similar jurisdiction from among available options	Download the "Rooftop PV Technical Potential" spreadsheet from https://data.nrel.gov/submissions/121; the percentage of small rooftops with >10m^2 suitable for solar can be found in the "Rooftop PV with Lidar Coverage" tab by dividing Column O by Column K.

[3] Gagnon, P., Margolis, R., Melius, J., Phillips, C., & Elmore, R. (2016). *Rooftop solar photovoltaic technical potential in the United States. A detailed assessment* (No. NREL/TP-6A20-65298). National Renewable Energy Laboratory (NREL), Golden, CO (United States).

Type of Data	Availability	Source
Average capacity (kW) of residential solar arrays currently in the jurisdiction	Determine availability for your state.	If available, it may be found in state databases of renewable energy facilities qualifying for Renewable Energy Credit or other renewable energy incentive programs
Reasonable average capacity (kW) of a residential solar array	Can be estimated based on assumptions made by those carrying out the assessment	Estimation
Lidar data	Should be available for most localities by 2022	See this status map for USGS mapping efforts: https://www.usgs.gov/faqs/what-lidar-data-and-where-can-i-download-it?qt-news_science_products=0#qt-news_science_products

Estimation Methods

Household Count Method

Perhaps the simplest estimate of residential-scale solar potential can be derived by considering the potential for roof-mounted OR small-scale ground-mounted arrays to support residential use. This can be accomplished using the calculation:

Solar technical potential (MW) **=**
Number of single-family residences
x % of single-family residences able to accommodate solar
x average size of an array per residence (kW)
x conversion factor (kW to MW) **of 0.001**

Number of single-family residences: The approximate number of households in a municipality or other jurisdiction can be found in American Communities Survey data available from the U.S. Census Bureau. If the community is rural, the number of households may be roughly equivalent to the number of single-family residences. If there are significant numbers of multi-family homes, these may fall into the "medium and large roofs" category, and you may which to remove multi-family homes from the total number of single-family homes.

Percentage of single-family residences able to accommodate solar: Assumptions can be made about the percentage – or range of percentages - of single-family residences that might physically be able to accommodate a solar installation. For example, depending on tree cover, you might estimate that 67%, 75%, or 90% of households could theoretically install solar systems.

Average size of an array per residence: The anticipated average size of a residential solar array can be based on the current average size of a residential solar system in the municipality, if known, or one could make assumptions about the average system size based on average residential solar system size across a county or state, average household electricity needs, average parcel and roof space, or other data.

Roof Area Methods

In many states, roof area data are available, which can allow for estimates of solar technical potential based on the area of residential rooftops. Some states have publicly available geospatial data layers displaying roofprints as polygons, making it possible to obtain the area for each roof in your community. Alternatively, there may be tax assessment data available listing the building footprint area of all structures on a given property, which can also be used to estimate roof area.

Where tax assessment information and roofprint data are both available, it may be possible to spatially join each roof to the underlying tax parcel in a GIS analysis program; this information can then be used to differentiate residential rooftops from commercial or institutional rooftops. If this information is not available, an assumption can be made that all small rooftops occur on residential properties. This assumption is likely not completely accurate, but in the rural Massachusetts communities we assessed, almost all small rooftops occurred on residential properties, as houses, garages, and sheds. Only a few small businesses and farm outbuildings also fell into our “small roof” category.

One simple, back-of-the-envelope method for calculating solar technical potential using rooftop area is the following:

Solar technical potential (MW) **=**
Total area of small roofs (sf)
x % of small building roof area suitable for solar
x capacity density (kW per sf)
x conversion factor (kW to MW) **of 0.001**

Total area of small roofs. As described above, where available, this data can be derived from geospatial data which displays roofprints as polygons. The area of individual roofs can be found in the attribute table associated with the data layer. Medium and large roofs (those over 5,000 sf) can be removed, and the remaining values can be summed to obtain total area.

Percentage of small building roof area suitable for solar. Nationwide, NREL has found that an average of 26% of the roof area of small buildings is suitable for solar[4].

Capacity density. NREL use a capacity density of 1.486 kW per 100 sf of roof area (Gagnon et al. 2016).

Keep in mind, this the *technical* resource available, and does not take into account the fact that many small roofs may have only a small area available for solar, which may not be economical to develop.

A second back-of-the-envelope estimation method using roof area, which incorporates the economic assumption that the building would need to accommodate at least a 1.6 kW system for a solar array to be worthwhile, is the following:

Solar technical potential (MW) **=**
Total # of small building roofs

[4] Gagnon, P., Margolis, R., Melius, J., Phillips, C. and Elmore, R., 2016. *Rooftop solar photovoltaic technical potential in the United States. A detailed assessment* (No. NREL/TP-6A20-65298). National Renewable Energy Laboratory (NREL), Golden, CO (United States).

x % of small buildings with at least 10 m^2 suitable for solar
x average roof area of a small building roof
x 50%
x capacity density (kW per sf)
x conversion factor (kW to MW) **of 0.001**

Total number of small building roofs AND average roof area of a small building roof. Both of these values can be derived from a roofprint geospatial data layer.

Percentage of small building roofs with having at least 10 m^2 of roof space suitable for solar. NREL provides detailed data and estimates regarding the suitability of small building roofs for solar in individual municipalities (see Table 1 above). This data can be used to calculate the percentage of small building roofs estimated to have at least 10 m^2 area suitable for solar.

Estimated # of small building roofs with at least 10 m^2 of roof available for solar: Multiplying the percentage of small building roofs with some solar suitability having at least 10 m^2 of roof space for solar by the total number of small building roofs in the town, one can estimate the number of buildings which could support at least 1.6 kW of solar.

Capacity density: NREL provides a capacity density 1.486 kW per 100 sf of roof area (Gagnon et al. 2016).

50% assumes half of the roof space of small buildings has the proper aspect for solar.

Lidar Method

A final option for estimating technical potential on residential roofs is to use lidar (light detection and ranging) data, a remote-sensing technique that uses laser light to densely sample surfaces. This method requires significant technical expertise and analysis work, but can provide a much more detailed assessment of technical potential, since it includes data regarding roof pitch, aspect, and shading by trees (Gagnon et al. 2016).

Massachusetts Example:

Number of Households

In addition to census data, another source for the total number of households in Massachusetts communities is the local census, which municipalities are required to conduct annually by state law. This source is typically available from the city or town clerk, and may be referred to variably as the annual town census, the street listing, or the annual resident listing. It is commonly more accurate and up-to-date than federal estimates of population size or number of households.

Building Roofprints

Building roofprint data layers are available for each Massachusetts municipality through MassGIS. These files include tax assessment information about the property (e.g., use codes, owner information, buildings on the property) which can be linked to polygon files showing the tax parcels on a map.

1. *Accessing Massachusetts building roofprint data.*

Building roofprint data layers are available for all of Massachusetts through MassGIS:
https://www.mass.gov/info-details/massgis-data-building-structures-2-d

Data can be downloaded as one file for the entire state (~350 MB), or for individual municipalities through a spreadsheet with links. This data layer can be added to a map in a GIS program.

2. *Joining roofprints with tax parcels.*

Roofprint data can be joined with tax parcel data layers (see *Tax Assessment Information* under *Community Infrastructure and Solar Technical Potential*) to allow building roofs to be categorized by type (e.g., residential, commercial, institutional) or associated with specific owners and businesses.

3. *Quantifying roof area.*

The AREA_SQ_FT column in the data layer attribute table provides the area of each roofprint in square feet. The table can be exported to Excel to organize and summarize roofprint area data for residential roofs, including the total number of roofs under 5,000 sf, the average size of a roof under 5,000 sf, and the total area of roofs under 5,000 sf. These values can be used in the estimation methods described previously.

In general, we found that in rural communities in western Massachusetts, the vast majority of buildings with roofs under 5,000 sf were on residential properties, and the vast majority of buildings with roofs over 5,000 sf were on commercial, institutional, municipal, or agricultural properties. However, depending on the degree of accuracy desired, it is possible to review any buildings with a roof under 5,000 sf that does not occur on a residential property and to remove it from the quantification of technical potential for residential roofs if it is not in fact a residential building. It is also possible to review any buildings over 5,000 sf that do occur on residential properties and determine if they are residential and should be added to the estimate of technical potential. In our analysis, we did find some large houses with roofs in the 5,000-6,000 sf range, but they represented only a small percentage of residential buildings.

Medium and Large Roofs

For the purposes of estimating total solar potential on a roof, NREL defines a "medium building" as one with a roof area of 5,000 sf - 25,000 sf, and a "large building" as one with a roof area of greater than 25,000 sf. We recommend using these definitions in categorizing medium and large roofs.

Estimating Solar Potential of Medium and Large Roofs

Perhaps the simplest method for estimating the solar potential of medium and large roofs is to use the equation:

Solar potential of medium-sized roofs (MW) **=**
total area of medium-sized roofs
x % of medium-sized building roof area suitable for solar
x capacity density (kW per sf) of solar panel capacity on roofs
x conversion factor (kW to MW) of 0.001

AND

Solar potential of large roofs (MW) **=**
total area of large roofs
x % of large building roof area suitable for solar
x capacity density (kW per sf) of solar panel capacity on roofs
x conversion factor (kW to MW) of 0.001

Total area of roofs: If geospatial data showing roofs as polygons is available for your area, it is possible to obtain the area for each roof in your community. Alternatively, there may be tax assessment information listing the building footprint area of all buildings on a given property, which can be tallied to arrive at an estimate of roof area. Where tax assessment information and roofprint data are both available, it may be possible to spatially join each roof to the underlying tax parcel in a GIS analysis program; this information can then be used to definitively differentiate residential rooftops from commercial or institutional rooftops. If this information is not available, an assumption can be made – at least for rural areas - that all medium and large rooftops are commercial, institutional, or municipal buildings – not residences. In the rural Massachusetts communities we assessed, there were very few large rooftops, and almost all medium and large rooftops occurred on non-residential properties. For small communities, individual buildings can also be viewed on using Google Maps or satellite imagery to determine if they are residential or non-residential properties. For example, buildings with roofs just over 5,000 sf may be worthwhile to review to determine if they are large houses.

Percentage of roof area suitable for solar: NREL's analysis suggests that virtually all (>99%) medium and large-scale buildings have a roof plane suitable for solar, and that, on average, approximately 49% of area on medium-sized roofs is available for solar, and 66% of large-sized roofs.

Capacity density: NREL provides a capacity density 1.486 kW per 100 sf of roof.

Alternative approaches: As with residential solar potential, much more complex approaches can be utilized by those with expertise in GIS or in conjunction with a third-party expert. One option is to use lidar (light detection and ranging) data, a remote-sensing technique that uses laser light to densely sample surfaces. This method requires significant technical expertise and analysis work, but can provide a much more detailed assessment of technical potential, since it includes data regarding roof pitch, aspect, and shading by trees.

Massachusetts Example:

Building roofprint data layers are available for Massachusetts municipalities through MassGIS. These files include tax assessment information about the property (e.g., use codes, owner information, buildings on the property) which can be linked to polygon files showing the tax parcels on a map.

1. *Accessing Massachusetts building roofprint data.*

Building roofprint data layers are available for all of Massachusetts through MassGIS: https://www.mass.gov/info-details/massgis-data-building-structures-2-d

Data can be downloaded as one file for the entire state (~350 MB), or for individual municipalities through a spreadsheet with links. This data layer can be added to a map in GIS.

2. *Joining roofprints with tax parcels.*

Roofprint data can be joined with tax parcel data layers (see *Tax Assessment Information* under *Community Infrastructure and Solar Technical Potential*) to allow building roofs to be categorized by type (e.g., residential, commercial, institutional) or associated with specific owners.

3. *Quantifying roof area.*

The AREA_SQ_FT column in the data layer attribute table provides the area of each roofprint in square feet. The table can be exported to Excel to organize and summarize roofprint area data for medium (5,000-25,000 sf) and large roofs (>25,000 sf). These values can be used in the estimation methods described previously.

In general, we found that in rural communities in western Massachusetts, the vast majority of buildings with roofs over 5,000 sf were on commercial, institutional, government, or agricultural properties. In our analysis, we did find some large houses with roofs in the 5,000-5,500 sf range, which we included in the estimation of residential solar potential rather than in this category. Because there were few medium or large roofs in the municipalities we assessed (typically less than 25 roofs over 5,500 sf), we were in many cases able to use tax parcel data and Google Maps to match up roof areas with specific farms, businesses, institutions, municipal buildings, or state facilities identified at earlier stages in the analysis.

4. *Cataloguing large roofs.*

Because there were few roofs in the medium and large roofs category, we provided a list of all medium and large roofs in the final assessment in order to inform community representatives of which buildings may have substantial space for solar development.

Parking Lots

Parking lots are important to quantify as part of the assessment of solar technical potential. They offer a unique solar resource because they may be appropriate for solar parking canopies, which allow for renewable electricity generation while still providing space for cars to park beneath.

Some states or jurisdictions may have geospatial data layers available that specifically identify parking lots. Often these data are not available; instead, it may be necessary to manually identify parking areas and, if desired, digitize these areas in a newly created GIS data layer.

Land cover data layers are typically available which include a category for impervious surfaces. The impervious surfaces category will include roads, but these can be fairly easily identified by shape, or by overlaying a geospatial data layer of streets over the impervious surfaces data. In impervious surface data layers, different parking lot areas may be connected by roads and be rendered as one polygon in the geospatial data layer. This means that it is typically not possible to sort or search polygons by size to identify large parking lots. Instead, the most effective approach is to visually scan the data layer in a GIS program at a relatively fine scale (e.g., 1/8 of the municipality at a time) to identify large areas of impervious surfaces. These areas can then be checked against satellite imagery to ensure they are in fact parking lots. Measurement tools (such as the Measure feature in ArcGIS or the Measure Area feature in QGIS) can then be used to outline the parking lot and

Figure 3. Example parking lot geospatial data showing impervious surfaces in yellow and roads in red. Building roofprints are shown in black. The large building at center is a regional high school with a large paved parking lot to the rear.

estimate the total area. Since there are many paved areas which may be quite small (e.g., driveways), it is important to identify a minimum size for consideration. For example, you might choose to include areas with at least 0.25 acres of impervious surface or areas with at least 1 acre of impervious surface.

Estimating Solar Potential of Parking Lots

Perhaps the simplest method for estimating the solar potential of parking lots is to use the equation:

Solar potential of parking lots (MW) **=**
Area of parking lots
x capacity density (kW per acre) of solar canopies
x conversion factor (kW to MW) of 0.001

Area of parking lots: Some data layers may render parking lots as polygons. The total area for these polygons may be read in an Attribute Table, or by clicking on a specific polygon. However, as described above, in impervious surfaces data layers, different parking lot areas are often connected by roads, and parking lot areas can therefore not be calculated based on polygon size. Instead, use a measurement tool in your GIS software to manually outline the parking lot and estimate the total area of that parking lot in acres.

Capacity density: One study reported that parking lots developed with solar canopies could on average accommodate 263 kW of solar PV per acre of parking lot[5]. This was the value used in our analysis. Other, more accurate estimates may be available.

[5] Krishnan, Ram. 2016. *Technical solar photovoltaic potential of large scale parking lot canopies*. Dissertation, Michigan Technological University.

Massachusetts Example:

Land use/land cover data layers are available for all of Massachusetts through MassGIS. These data layers include a category for impervious surfaces.

1. *Accessing Massachusetts land use/land cover data.*

Land use/land cover data layers are available for all of Massachusetts through MassGIS: https://www.mass.gov/info-details/massgis-data-2016-land-coverland-use
Data can be downloaded as one file for the entire state (2.8 GB), or for individual parts of the state, either via a spreadsheet with links or by selecting an area on a map. This data layer can then be added to a map in a GIS program.

2. *Selecting impervious surfaces.*

Impervious surfaces are listed as “2” under the Class Number column in the attribute table for this data layer. These areas can be selected and saved as their own data layer. It may also be worthwhile to review large areas identified as “20”, which is “Bare Land.” Some of these areas may be dirt parking lots.

3. *Adding road data.*

Adding road data will help in distinguishing roads and medians from parking lots. A road data layer is available for all of Massachusetts through MassGIS: https://www.mass.gov/info-details/massgis-data-massachusetts-department-of-transportation-massdot-roads

Landfills, Brownfields, and Other Previously Disturbed Sites

Community residents, environmental organizations, and others often prefer to see large, ground-mounted solar arrays constructed on land that was previously disturbed or developed, even if some of that area has since reverted to forest or other natural vegetation. In addition, some types of previously disturbed sites may be eligible for special solar incentives. It is therefore recommended to categorize these types of sites separately from undisturbed, natural landscapes when conducting an assessment, and to quantify the technical potential for solar development on these lands separately.

Landfills and brownfields are often the first categories of land that come to mind when considering previously disturbed areas. The Environmental Protection Agency maintains a database of Superfund sites and hazardous waste sites on the National Priorities list (https://www.epa.gov/superfund/search-superfund-sites-where-you-live). Former landfills and brownfield sites are often identified in state documents or databases, such as might be available from a state department of environmental protection (see Appendix C for New England and New York data sources). Other types of sites may be identifiable on the ground or known to local residents – such as former commercial or industrial sites which were paved or otherwise developed, but have since fallen into disuse.

It is useful to think creatively about the kinds of sites which might fall into this category. Former quarries and gravel pits may be preferred for development over tracts of intact forestland or native meadow habitat. Former junkyard or autobody sites, where oil or gas could have leaked into the soil, might also fall into this category. Transmission powerline right-of-ways may be difficult to develop, but these are another already disturbed type of land that might be preferred for development. Even "stump dumps," where natural debris are deposited, may be preferred for development over less disturbed sites.

It is also useful to think about unused spaces which, if not previously developed, are adjacent to developed areas. For example, highway medians or areas along major roads may be preferred for development when compared to areas in intact natural landscapes.

In Massachusetts, we have found that large, ground-mounted PV facilities have an average project footprint of 4-5 acres per MW DC. Therefore, we divided the total acreage available by 5 to provide a rough estimate of the total technical potential for solar. This rough rule-of-thumb used in our analysis is a bit lower than the nationwide average calculated by NREL (Ong et al. 2013). See *Project Footprint* sub-section in the *Notes on Solar Facility Size and Terminology* section for more details (page 7).

Massachusetts Example:

Landfills. Massachusetts does not have a list of closed landfills eligible for solar development, but many municipal officials and community officials will be aware of the location of any former landfills in town. We recommend including a question about closed landfills in the brief survey of municipal officials. The state of Massachusetts is supportive of renewable energy development on closed landfills, and has a website devoted to the topic (https://www.mass.gov/siting-clean-energy-at-closed-landfills). This website also has a list of landfills where solar projects are already sited (https://www.mass.gov/lists/closed-landfills-with-permits-for-renewable-energy). The current state solar incentive program (SMART) provides an incentive adder of 4 cents per kWh for solar projects developed on landfills, in addition to the base compensation rate available for solar PV installations.

Brownfields. Information about brownfield locations can be found on this website, provided by the Massachusetts Department of Environmental Protection: (https://www.mass.gov/service-details/find-brownfields-sites). The lists available on this site are not comprehensive, because not all sites are known to the state of Massachusetts. Some RPAs run brownfield programs and may have a list of brownfield sites on file. Municipal officials or community residents may also be aware of potential brownfield locations.

Gravel Pits & Quarries. Gravel pits and quarries may be identifiable using the tax assessment information described previously (see *Tax Assessment Information* under *Community Infrastructure and Solar Technical Potential*). Gravel pits and quarries should be listed under Use Codes 410-413. Gravel pits and quarries may also be designated as “Bare Soil” in the Land Use/Land Cover data layer (see *Massachusetts Example* under *Parking Lots*). Areas designated as Bare Soil can be compared against satellite imagery to determine whether they are in fact gravel pits and quarries. The area of a gravel pit or quarry may then be estimated based either on the size of the polygon comprising Bare Soil, or using manual measurement tools in a GIS program. As with parking lots, you can use a measurement tool in your GIS software to manually outline the gravel pit or quarry and estimate the total area of the site in acres.

Roadsides & Highway Medians. Areas adjacent to highways and major roads can be identified using the roads data layer described in *Massachusetts Example* under *Parking Lots*.

Right-of-Ways. Transmission powerline right-of-ways should be identified in the Land Use/Land Cover data layer (described in *Massachusetts Example* under *Parking Lots*) as USEGENCODE 55. These areas can also often been identified by shape (long, narrow, and straight-edged) on a map of the full Land Use/Land Cover data layer displaying Land Cover, and confirmed using satellite imagery. As with parking lots, you can use a measurement tool in your GIS software to manually outline the ROW and estimate the total area of the site in acres.

Farms and Agricultural Areas

Farms and agricultural areas could be grouped in with other solar resource categories. For example, barns often have medium or large roofs which will show up in that part of the assessment; agricultural fields could be lumped in with other undeveloped areas. However, it is often worthwhile to consider agricultural resources independently from other categories. Farms often operate differently than other businesses, with farmers placing particular value on the land, and community members having both aesthetic and practical concerns about how any development that occurs in these areas is carried out. In addition, farms and agricultural land may be subject to specific regulations, may be protected by specific conservation restrictions, or may be eligible for certain programs, grants, or incentives which do not apply to other businesses or types of properties.

Farms can often be identified through business registries noted earlier, or databases and lists specific to farms and food production. Agricultural areas may be identified by land cover data showing pasture, hay production, or cultivation. Potential agricultural areas may also be identified using soil maps showing areas with prime or high quality farmland soils. Some agricultural areas may be identifiable by tax assessment data showing agricultural land use or participation in programs associated with an agricultural tax rate. Depending on state regulations and programs, some agricultural lands may be under a permanent preservation restriction.

On farms, consider the variety of projects which might be most appropriate and compatible with continued use of the buildings and land for agricultural production. Opportunities may be available to site solar projects on barn roofs, or to create canopy solar arrays that farm vehicles could be parked beneath. Some greenhouses and greenhouse production practices are compatible with placing solar panels on greenhouse roofs. Small or medium-sized arrays can be placed around field margins, between fields, or separating different areas (such as organic from conventional production). Some states and organizations are now experimenting with dual-use solar and agriculture systems, with raised panels designed to allow continued use of the land underneath for agriculture. The study of solar combined with agriculture is often referred to “agrivoltaics.” Though this technology is in the early stages, it appears it may be most effective in arid or dry, drought-prone areas, where shading from panels can reduce evaporative water loss, heat stress, and the need for irrigation.

Agricultural fields are often a target for solar development, since these flat, open landscapes can be relatively easily converted to solar, with little land clearing or grading required. Conversion of agricultural land to solar may raise concerns among community residents and organizations about loss of local food production potential, loss of prime farmland, and aesthetic considerations. Once the assessment of community preferences (Step 4: *Assess community preferences regarding solar development and financing*) has been completed, we recommend revisiting the assessment of solar technical potential within this category, and refining estimates based on community preferences and how different types of land are valued by community members.

Note that agricultural fields are sometimes grouped with other "working lands;" for example, slash pine plantations. In Massachusetts, forests managed for timber production are not typically managed as monocultures, and hence we decided to group timber production forests with other undeveloped forestland (see next section). However, depending on the diversity of land uses in your community, you may choose to group other types of working lands with agricultural fields, in a separate category, or with undeveloped land.

Massachusetts Example:

In Massachusetts, there are a number of different ways to identify agricultural lands and areas of agricultural value. These include the following:

- ***Chapter 61A Lands****: Lands in the Chapter 61A program receive a lower property tax rate at the municipal level because they are used for agricultural activities. These areas can be identified in tax assessment data because they have a unique set of Use Codes. Depending on locally adopted rules, these may be designated with Use Codes 710-720 (which define the type of agricultural activity), or may be identified as Open Space under Use Codes 270-279. Use Code 037 is for multi-use properties with some land in Chapter 61A.*
- ***Other Agricultural Lands****: Lands in agricultural production not in the Chapter 61A program may be designated with various Use Codes. For example, Use Code 317 is for Farm Buildings; Use Code 393 is for Agricultural Land not in Chapter 61A.*
- ***Agricultural Land Cover****: Land use/land cover data identifies Cultivated Land and Pasture/Hay fields with land cover Class Numbers 6 and 7 respectively. The USEGENCODE in this data layer also identifies agricultural land with Use Code 7.*
- ***APR Land****: Lands with an Agricultural Preservation Restriction (APR) are permanently protected from development and designated for agricultural use. These areas can be identified using the Protected and Recreational OpenSpace data layer available from MassGIS (https://www.mass.gov/info-details/massgis-data-massachusetts-department-of-transportation-massdot-roads). APR land is listed with a level of protection ("LEV_PROT") of "P" for "In Perpetuity," for the primary purpose ("PRIM_PURP") of agriculture, designed with an "A".*
- ***Prime Soils****: Soils defined as "Prime Farmland," "Farmland of Unique Importance," and "Farmland of Statewide Importance" can all be identified using the NRCS SSURGO-Certified Soils data layer from MassGIS (https://www.mass.gov/info-details/massgis-data-soils-ssurgo-certified-nrcs).*

In many cases, areas with agricultural land cover or in the Chapter 61A program map well with the locations of farms as identified using the CISA Farm Finder, Google Maps, or business databases, and can be matched with specific farms based on proximity or land ownership information listed in tax assessment data.

Large, Ground-Mounted Solar Facilities on Undeveloped Land

Many rural communities have large expanses of agricultural or natural lands. Large tracts of open, undeveloped land are often considered to be the most economical places to develop solar PV, in terms of the monetary cost of capacity ($ per MW installed) or electricity ($ per MWh of electricity generated). These “greenfield” sites typically do not have the same kind of liability concerns which might be associated with previously developed or disturbed sites – for example, they do not have contaminated soils which could erode into neighboring streams, landfill caps at risk of penetration, or the potential for theft or safety issues alongside highways. On the other hand, “greenfield” sites may provide food production, environmental value, aesthetic value, and ecosystem services. Quantifying the technical solar potential of these types of lands is a more location-specific process for than it is for other solar resource categories, because identifying which areas are appropriate, or even eligible, for solar development is strongly based on community values, as well as state and local regulations.

Some properties or areas may be initially screened out of commercial-scale development potential based on legal environmental protections or solar program incentive structures. Legal environmental protections and solar program incentives may be identified earlier in the assessment in the *Current State Regulations, Policies, and Incentives* section.

After the *Community Solar Survey* has been conducted and analyses have been completed, certain undeveloped land types or locations may be removed from the estimate of solar potential based on community values about which types of land should and should not be developed. The planning team will be better informed about the characteristics of sites preferred by the community after Step 4: *Assess community preferences regarding solar development and financing* has been completed. Hence, the identification of technical potential of undeveloped land in this stage (Step 2: *Conduct a solar resource and infrastructure assessment*) should be seen as preliminary, and can be further refined later in the process, after assessment of community preferences.

Some parameters to consider when categorizing and quantifying the solar potential on undeveloped land include the following:

Minimum Parcel Size: What constitutes a “large” or “commercial-scale” solar array will vary from state to state, dependent on land use and development patterns. Depending on the situation in your state or region, you might set a different minimum bound on the lower end of property size appropriate for large, ground-mounted solar development. In highly developed states, a parcel of 5 acres or more might be considered a reasonable site for commercial solar development; in less developed states, so-called “utility-scale” solar arrays on the order of 50-100 MW (250-500 acres!)

are not uncommon. See the *Project Footprint* sub-section in the *Notes on Solar Facility Size and Terminology* section for more details (page 7).

Interconnection Opportunities: As noted in the *Existing Grid Infrastructure* section, we generally recommend that interconnection access be considered for short-term development goals, but play less of a role in long-term planning. However, commercial-scale development of solar can be expected to be the most affected by interconnection access, since these large systems will provide more electricity generation and thus occupy greater hosting capacity on a distribution line. Sites near existing three-phase distribution lines or near an existing substation may be the most economical to develop, although, as noted, grid infrastructure must expand significantly across the country if national renewable energy development is to be sufficient to meet the climate goals of the Paris Agreement.

Site Conditions: Developing solar PV on steep slopes may not be appropriate, especially in areas where underlying soils are prone to erosion. Stormwater and erosion management at solar facilities can be a challenge during both the construction and operations phases**.** With this in mind, some municipalities may ban development on slopes over a certain grade. Other important site conditions might include a lack of easy site access, underlying geology (such as exposed bedrock) which might not be economical to build on, or inadequate setbacks from neighboring property lines. Screening out sites based on some of these criteria may be difficult, but for most parts of the country, it is possible to obtain geospatial data on slope, which can be used to screen out very steep sites.

Protected Land: Some lands may be unable to be developed due to permanent protected status. This might have to do with conservation restrictions on the property associated with ecological, agricultural, historic, or cultural values. Alternatively, one may be able to make assumptions about a property's ineligibility for development due to its current use. This category includes properties which are serving another public purpose – e.g., a town common, fairgrounds, a public park, a cemetery. Many states have geospatial data layers displaying protected land status. The Protected Areas Database provides a national-level data layer (https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/science/protected-areas).

Flood Zones: It may be inappropriate to develop solar facilities in a flood-prone area. Many states and municipalities have designated areas at risk of flooding. See also the National Flood Hazard Layer available from the Federal Emergency Management Agency (https://www.fema.gov/flood-maps/national-flood-hazard-layer).

Environmental Considerations: While development of undeveloped land may be economical from a monetary perspective, there are other potential costs, including the ecological values these lands provide to wildlife and the ecosystem services they provide to humans. Regulatory environmental data layers that preclude or limit development within certain habitat types, such as rare species habitat, wetlands, or habitats sensitive to disturbance, should be included in the mapping process, and considered for exclusion from development. Some of these environmental concerns will not preclude development of all portions of a property, but may reduce the acreage available for development. Depending on community preferences (Step 4: *Assess community preferences regarding solar development and financing*), the planning team may also choose to incorporate non-regulatory environmental data layers into the assessment of technical potential –

for example, the "resilient landscapes" data layer available from The Nature Conservancy (https://maps.tnc.org/resilientland).

Incentives: Depending on state policy, there may be areas or types of landscapes where solar development is allowed but where incentives are not available. This issue is worth considering, because at least in the short term, a lack of incentives may make development on these sites uneconomical.

Residential Development: Depending on community preferences, the planning team may choose whether to exclude properties including or adjacent to residential dwellings from the assessment of technical potential for large, ground-mounted solar development.

In Massachusetts, we have found that large, ground-mounted PV facilities have an average project footprint of 4-5 acres per MW DC. Therefore, we divided the total acreage available by 5 to provide a rough estimate of the total technical potential for solar. This rough rule-of-thumb used in our analysis is a bit lower than the nationwide average calculated by NREL (Ong et al. 2013). See the *Project Footprint* sub-section in the *Notes on Solar Facility Size and Terminology* section for more details (page 7).

Massachusetts Example:

Minimum Parcel Size: In Massachusetts, much of the state is broken up into individual properties that are fairly small in size. The typical size for a commercial-scale solar array is 1 MW or greater, equivalent to about 5 acres of land. The largest solar array the state of Massachusetts will currently provide incentives for is a 5 MW AC system, which with energy storage might be as much as 10 MW DC (roughly 50 acres). When identifying potential tracts of open land eligible for commercial-scale development, we screened out properties covering less than 5 acres based on tax assessment data.

Interconnection Opportunities: As described in the *Existing Grid Infrastructure* section, three-phase lines with the capability to host large solar projects can be identified using publicly available tools. However, these tools may not be useful for long-term planning, since significant infrastructure upgrades are expected over coming decades.

Site Conditions: In Massachusetts, slope data may be obtained from the NRCS SSURGO-Certified Soils data layer from MassGIS (https://www.mass.gov/info-details/massgis-data-soils-ssurgo-certified-nrcs) described in the *Massachusetts Example* under *Agricultural Resources*. Slopes are listed in the "SLOPE" column with a code, A through E, depending on the grade. Some towns prohibit development on slopes of 15% grade or higher.

Protected Land: Lands that are unable to be developed due to permanent protected status will be identified in the Protected and Recreational OpenSpace data layer available from MassGIS (https://www.mass.gov/info-details/massgis-data-protected-and-recreational-openspace), listed with a level of protection ("LEV_PROT") of "P" for "In Perpetuity." Some properties with a level of protection of "L" for "Limited" may also be effectively unavailable due to their use – for example, as cemeteries or fairgrounds. These properties can be viewed using satellite imagery to identify their use, or reviewed in tax assessment data to understand what Use Code they are listed under, and whether current use is likely to preclude development. Using tax assessment data, it is also possible to identify properties under the temporary protection of Chapter 61 (forest land) or Chapter 61B (recreation land) programs.

Environmental Considerations: As described earlier, important environmental considerations in Massachusetts include regulated wetlands, floodplain areas, and rare species habitat. Regulated wetland data layers are available from MassDEP on the MassGIS site (https://www.mass.gov/info-details/massgis-data-massdep-wetlands-2005). BioMap2 Priority Habitat and Critical Natural Landscapes data layers are also available through MassGIS (https://www.mass.gov/info-details/massgis-biomap2).

Land Cover: Some towns have bylaws which limit forest clearing or development of agricultural land to no more than 50% of a parcel. Land use/land cover data can be combined with tax parcel data to determine which parcels would still have at least 5 acres available for development if no more than 50% of the parcel can be cleared of forest or developed from agricultural land.

Incentives: Under the updates made to the SMART regulation in April 2020, undeveloped areas mapped as BioMap2 habitat or parcels with 50% or more BioMap2 habitats are not eligible for incentives for large, ground-mounted solar development (with the exception of "Public Entity" projects that provide electricity to the municipality). The areas that fall into this category can be viewed in a GIS program using the BioMap2 data layer described above, or on this map provided by the state DOER (https://mass-eoeea.maps.arcgis.com/apps/webappviewer/index.html?id=757833bf8c784d6c868379a8f929fdfb).

Residential Development: If excluding properties with residential development is desirable, the planning team can do so using tax assessment data. This data includes a BLDG_VAL column listing the value of any buildings on the property. Depending on the average home value, you can set a threshold for the value of a building necessary to be considered residential development, and narrow the list of parcels to residential properties by Use Code. For example, a residential parcel with a building valued at more than $30,000 could be excluded from consideration for development.

Compiling a Report

Once the *Solar Resource and Infrastructure Assessment* is completed, the final step is to summarize all of the information collected in a format that is accessible to community members and to municipal officials. We recommend preparing two documents describing the findings. The first is a full report on the assessment, detailing relevant federal, state, and local policies, providing estimates of solar technical potential in relevant categories, identifying potential energy storage locations, and describing existing grid and renewable energy infrastructure. This report should include a description of the methodology and data sources used in the analysis. An example outline for a *Solar Resource and Infrastructure Report* is provided in Appendix A. Example reports from towns which participated in this project are available on the *Community Planning for Solar* toolkit website at ag.umass.edu/solarplanning2.

The second document we recommend preparing is a 2-3 page summary of the findings. This should provide a highlight of the important points of the assessment, but need not include details of assumptions, methodology, or data sources. A template for this *Solar Resource and Infrastructure Summary* and example summaries from towns which participated in this project are available on the *Community Planning for Solar* toolkit website at ag.umass.edu/solarplanning2.

Once these documents have both been finalized, they should be made available on a municipal website, or other public venue, and shared with municipal board members and officials.

APPENDIX A – Example Report Outline

EXAMPLE OUTLINE FOR A *SOLAR RESOURCE AND INFRASTRUCTURE REPORT*

For sample text, please see example Solar Resource and Infrastructure Reports on the CEE website (ag.umass.edu/solarplanning2).

FRONT MATTER

Title Page
Executive Summary
Terms, Abbreviations, & Acronyms used in the Report
Table of Contents

1. INTRODUCTION

a. Briefly describe the purpose of the Solar Resource and Infrastructure Assessment.
b. Include the geographic scope of the assessment (e.g., a municipality, county, or other jurisdiction). You may wish to describe the population or number of households in the area, the number of businesses, and the approximate geographic location (e.g., the county, or location within the state).
c. Describe the planning team carrying out the analysis.
d. Acknowledge any funding sources which supported the work.
e. Consider including a description of next steps following completion of the assessment.

2. METHODOLOGY

[The report should include a description of the basic methodology used and references for all data sources. This information can be included as its own chapter, as demonstrated in this outline, included as an appendix, or scattered throughout the report as separate sub-sections within each of the following chapters.]

3. FEDERAL, STATE, & LOCAL POLICIES

a. Briefly describe any relevant federal policies, incentives, or programs affecting the siting or economics of solar development.
b. Describe any relevant state policies, incentives, regulations or programs affecting the siting or economics of solar development.
c. Briefly summarize any existing municipal bylaws relevant to solar development.
d. Briefly summarize the current permitting process for proposed solar developments.
e. Note any municipal wetland bylaws or other conservation bylaws which may affect the siting of solar projects.
f. If the town has an Open Space & Recreation Plan or other conservation planning document, briefly summarize conservation priorities and note any specific high-priority sites which have not yet been protected.
g. List any other municipal planning documents which were reviewed as part of the assessment process. If information from these documents is included elsewhere in the assessment report, note where.

4. GRID INFRASTRUCTURE ASSESSMENT

a. Introduction: Briefly describe what is included in this chapter.

b. Describe the basics of how solar PV systems connect to the grid, or reference the CEE fact sheet *The Electric Grid, Distributed Generation, and Grid Interconnection* (ag.umass.edu/solarplanning2).

c. Describe how electricity enters the municipality (i.e., transmission lines, substation).

d. Describe the voltage, locations, and extent of three-phase lines serving the community. Where possible, include maps showing three-phase and single-phase lines.

e. Describe the current hosting capacity (available capacity in MW) for all three-phase lines serving the municipality.

f. Provide a table showing the energy facilities currently proposed or approved for all three-phase lines serving the municipality.

5. SOLAR RESOURCE ASSESSMENT

a. **Introduction:** Briefly describe what is included in this chapter.

b. **Residential-Scale Resources:** Describe the potential residential-scale resource, including how many residential-scale systems are estimated to be able to be built in the municipality, average estimated system size, and the total technical potential.

c. **Medium to Large Roofs:** Describe the potential resource, including how many medium or large roofs are in the municipality and the total technical potential. Include a table of the top 10-25 largest roofs, with area (sf), location, and type of ownership (e.g., municipal, commercial, residential).

d. **Parking Lots:** Describe the potential resource, including how many parking lots over a specified size are present in the municipality. You may wish to include a table of large parking lots, including location, area (acres), technical potential (MW), and type of ownership (e.g, municipal, commercial).

e. **Landfills and Brownfields:** Describe any former landfills or brownfields in town, including any known challenges in development (steep slopes, runoff, etc.). Include locations, area (acres), and type of ownership (e.g., municipal, private).

f. **Other Previously Disturbed Sites:** If there are few previously disturbed sites in the municipality, this category can be included with landfills and brownfields (above). Otherwise, it may be appropriate to have several sections. For each type of previously disturbed land type, include the approximate locations, area (acres), and type of ownership (e.g., municipal, private) of previously disturbed sites.

g. **Agricultural Resources:** List the farms present in the municipality, and summarize associated farmland, including lands included in Chapter 61a, Agricultural Preservation Restrictions, and in cultivation or managed for grazing/hay production. You may choose to include potential farmland based on the area of land categorized as having prime farmland soils.

f. **Commercial-Scale Sites on Undeveloped Land:** Provide a description of how undeveloped parcels in the municipality were selected to be included in estimate of technical potential, or removed from the assessment (e.g., based on parcel size, slope, land cover, presence of protected areas, etc.). Include a summary of the total number of parcels, the total area available (acres), and estimated technical potential. Note that this estimate will be further refined based on community preferences regarding “greenfield” development. As appropriate, reference maps included in the Appendices.

g. **Table:** Provide a summary in table format of the technical potential for solar development in each of the categories listed above. We recommend a table with 3 columns: Resource Type (e.g., Medium to Large Roofs); Resources Available (brief text detailing resources including # of sites, square footage or acreage); Estimated Technical Potential (capacity in MW, with caveats as needed).

6. OTHER COMMUNITY INFRASTRUCTURE

a. Provide a brief introduction regarding what aspects of community infrastructure are included in this chapter.
b. Summarize existing renewable energy facilities already present within the community. Include the number and total capacity of small residential, commercial, or municipal solar PV arrays. Also include the capacity and approximate location for large, ground-mounted solar projects constructed or permitted for development.
c. Describe potential energy storage sites identified in this assessment. Include information about how potential energy storage sites were identified.
d. Describe any other relevant infrastructure not included in the Solar Resource Assessment (next chapter).

APPENDICES

Appendix A – Maps of Solar Resources and Infrastructure

Include maps relevant to the solar resources and infrastructure identified. These might include:

- A.1 Roads and Property Outlines
- A.2 Existing Grid Infrastructure
- A.3 Land Cover
- A.4 Protected Land & Land Subject to Environmental Regulations
- A.5 Agricultural Resources (farms, farmland, areas with prime agricultural soils)
- A.6 Parcels available for Commercial-Scale Development

Include other Appendices as needed.

APPENDIX B – Example Questions for Municipal Representatives

Municipal Planning Documents and Bylaws

1. **Planning Documents:** Do you have electronic copies of any of the following documents that you would be able to share with us? Municipal Vulnerability Preparedness (MVP) plan, Master Plan, Open Space and Recreation plan, Zoning Map, Zoning Bylaw
2. **Solar Zoning:** If you have a solar bylaw separate from your zoning bylaw, could you share a copy of it with us? If you have a solar overlay district, could you share a map of the overlay district with us? Are you aware of your town planning any changes to its solar zoning bylaw within the next year?
3. **Wetlands:** If you have any municipal bylaws specifically related to wetlands or protection of open space, could you share a copy with us?

Existing Infrastructure and Energy Use

4. **Municipal Solar:** Do you have existing solar installations on any municipal buildings in town? Are there any ground or canopy-mounted solar installations owned by the town? Are any solar arrays planned for installation on town buildings or properties in the next several years?
5. **Other Existing Solar Installations:** Are you aware of any large ground-mounted solar arrays in town, any large arrays that have been permitted to be built, or large arrays that are currently in the permitting process?
6. **Emergency Shelter**: Have any buildings in your town been designated as an emergency shelter, or considered as a potential emergency shelter site?
7. **Energy Reliability:** Does your municipality have any buildings or institutions where energy reliability would be of increased importance, such as hospitals, nursing homes, or designated housing for seniors?
8. **Large Electricity Consumers**: Are there any sites in town which you expect would be large consumers of electricity, such as a school or large business? Are there any areas of clustered housing development which might function as a hub of high electricity use?
9. **Parking Lots**: Are there any large parking lots you are aware of in your town (e.g., ¼ acre in size or larger[6])? Do you know if they have been evaluated for a solar canopy?
10. **Landfills**: Does your town have a closed landfill? If yes, do you know if it has been evaluated for solar?
11. **Farms**: Are there any large farms in town which you think might have interest in a solar array, or other renewable energy project?

Specific to Massachusetts:

Municipal Energy Tracking: Does your town have a Mass Energy Insight (MEI) account to track municipal energy usage? If yes, would you be willing to grant us access to review electricity use by town and school buildings?

[6] The size of a "large" parking lot will depend on the size of the community and amount of developed spaces. Depending on how large and area you are considering, you may wish to set a minimum size of ¼ acre, ½ acre, 1 acre, etc.)

APPENDIX C – Data Sources for New York and New England States

For useful GIS data layers and data sources for New York and New England states (other than Massachusetts), see the information below, as well as the associated tables (A1-A6) available on the *Community Planning for Solar* Step 2: *Conduct a solar resource and infrastructure assessment* webpage (ag.umass.edu/solarplanning2).

Connecticut

GIS Data Layers

In Connecticut, many GIS data layers are available through the state Department of Energy & Environmental Protection (CT DEEP) GIS Open Data website (https://ct-deep-gis-open-data-website-ctdeep.hub.arcgis.com/pages/gis-data---downloadable-feature-layers). On this site, you can browse data layers by topic category or search for data layers by keyword. Most data layers can be viewed as an on-line map or downloaded for use in a variety of file formats. The Connecticut Environmental Conditions Online (CT ECO) program, housed at the University of Connecticut (UConn) also has a variety of data layers, including some older (2012) layers showing building roofprints and impervious surfaces (https://cteco.uconn.edu/data.htm). Through Map and Image Services, CT ECO offers a variety of maps for online, cloud-based use or download to GIS software. There are a few data download options through the Download option. While some of the data layers are older, UConn's Map and Geographic Information Center (MAGIC) also has a repository of GIS data layers (http://magic.lib.uconn.edu/connecticut_data.html). Table A1 summarizes a number of the most relevant data layers, but more are available through the sources listed above. The most up-to-date content appears to be on the CT DEEP site.

Other Data Sources

The CT DEEP also has a site dedicated to brownfields, landfills, superfund sites, and other contaminated or potentially contaminated sites. Lists of these types of sites and their locations are available via https://portal.ct.gov/DEEP/Remediation--Site-Clean-Up/List-of-Contaminated-or-Potentially-Contaminated-Sites-in-Connecticut.

Maine

GIS Data Layers

In Maine, many GIS data layers are available through ArcGIS Hub (https://maine.hub.arcgis.com). On this site, you can search for data layers by keyword, or narrow the list of data layers by topic category, type of data file, or agency providing the data. Most data layers can be viewed as an on-line map or downloaded for use in a variety of file formats. The *Beginning with Habitat* program within the Maine Department of Inland Fisheries & Wildlife also provides a series of maps and data relevant to natural resources and wildlife (https://www.maine.gov/ifw/fish-wildlife/wildlife/beginning-with-habitat/maps/index.html). Formats available through the program include an on-line map viewer, digital data, printable PDF maps, and large, printed maps available upon request. Table A2 summarizes a number of the most relevant data layers, but more are available through the Hub.

New Hampshire

GIS Data Layers

In New Hampshire, many GIS data layers are available through the New Hampshire GeoData Portal (https://www.nhgeodata.unh.edu). On this site, you can search for data layers by keyword or browse by topic category. Most data layers can be viewed as an on-line map or downloaded for use in a variety of file formats. Some New Hampshire data layers have not yet been transferred to the Portal, and instead can be found in an older system, the NH GRANIT repository (https://www.granit.unh.edu). Several state agencies also provide maps and data which may not be available through the Portal or NH GRANIT. The New Hampshire Department of Transportation maintains an on-line map viewer showing roads in the planning, design, or construction stages (https://nhdotprojects.sr.unh.edu/). The New Hampshire Department of Environmental Services provides an interactive map of wetlands, with some download capabilities. Table A3 summarizes a number of the most relevant data layers, but more are available through the Portal and NH GRANIT.

New York

GIS Data Layers

In New York, GIS data layers available from state agencies and other organizations (e.g., municipalities, land trusts) are collected at GIS.NY.GOV (http://gis.ny.gov/gisdata/). On this site, you can browse by the organization that provided the data or by the data set name. You can also search for data layers by the organization that provided the data or by "theme." An "Advanced Search" option also allows you to narrow your search by county. For some data layers, permission may be required to download the data set. DATA.NY.GOV also has a wealth of data and inventory information. Some data are viewable on an interactive map or available for download. The NY Solar Map (https://nysolarmap.com/) shows solar resource potential on building rooftops and also provides information about existing installed capacity. The New York Protected Areas Database (https://www.nypad.org/Download) provides an interactive map and downloadable data layers of areas protected for conservation or recreation purposes. The New York Department of Environmental Conservation has a site devoted to remediation sites (https://www.dec.ny.gov/chemical/102009.html). Table A4 summarizes a number of the most relevant data layers.

Rhode Island

GIS Data Layers

In Rhode Island, many GIS data layers are available through the Rhode Island Geospatial Data Hub (https://www.rigis.org/). On this site, you can browse by topic category, search for data layers by keyword, or narrow the search by data type, data source, or category. Most data layers can be viewed as an on-line map or downloaded for use in a variety of file formats. Statewide data are available, but the site also features municipal-level information, including information on the status of digital parcel data, zoning data, each town's GIS point of contact, and links to online GIS resources (both interactive maps and static PDF maps) (https://www.rigis.org/pages/municipal-gis-resources). Table A5 summarizes a number of the most relevant data layers, but more are available through the Hub.

Other Data Sources

The Rhode Island Department of Environmental Management (RI DEM) maintains lists of a variety of types of contaminated sites, including landfills, other waste facilities, and remediated sites. See Table A5 for more information.

Vermont

GIS Data Layers

In Vermont, most GIS data layers are available through the Vermont Open Geodata Portal (https://geodata.vermont.gov/#data). On this site, you can search for data layers by topic area or agency. Most data layers can be viewed on an on-line map or downloaded for use in a variety of file formats. Table A6 summarizes a number of the most relevant data layers, but many more, including areas of conservation interest based on a variety of metrics, are available through the Portal.