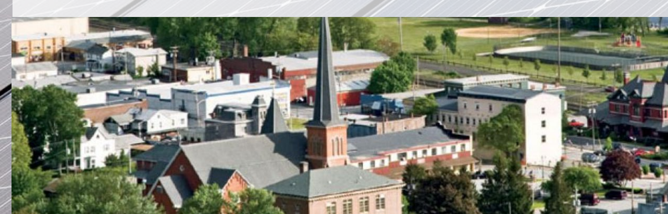
Guide

Defining Realistic Solar Development Options

Community Planning for Solar



UMass Amherst

Clean Energy Extension

Development of this guide was funded by the U.S. Department of Energy through the National Renewable Energy Laboratory's Solar Energy Innovation Network cohort program for Solar in Rural Communities, as part of a multi-stakeholder team project to develop a community-informed proactive solar siting and financing model.

The *Community Planning for Solar* project team included UMass Clean Energy Extension (CEE), the UMass Department of Environmental Conservation, Colby College Department of Environmental Studies, the Massachusetts Department of Energy Resources (DOER), the Massachusetts Department of Agricultural Resources (MDAR), the Pioneer Valley Planning Commission (PVPC), the Franklin Regional Council of Governments (FRCOG), the Western Massachusetts Community Choice Energy Task Force, UMassFive College Credit Union, Northeast Solar, PV Squared, Co-op Power, and the Massachusetts towns of Blandford, Wendell and Westhampton.

If you'd like to cite this document, the following format is recommended: UMass Clean Energy Extension, "Guide: Defining Realistic Solar Development Options." *Community Planning for Solar Toolkit*, prepared by Zara Dowling, March 2022. www.ag.umass.edu/solarplanning.

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
- **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 — You Are Here
- **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 is designed to aid in assessing community preferences for solar development and financing alternatives, Step 4 in the *Community Planning for Solar* process (ag.umass.edu/solarplanning). In order to evaluate community preferences regarding solar, it is necessary to define the range of realistic options for solar development possible in a community, including potential future targets for solar capacity, the mixes of development possible based on the solar resources available, and potential community benefits and solar ownership structures. This guide can help community officials, volunteers, and regional planning agency staff in constructing a realistic suite of options for solar development, based on existing state and local laws, available solar resources and infrastructure, and economic and financial considerations. The construction of these options is based in part on the information gathered through the processes outlined in the guides *Conducting a Solar Resource and Infrastructure Assessment* (Step 2, Item b) and *Understanding and Evaluating Solar Financing and Ownership Options* (Step 3, Item a).

Once realistic solar development options have been defined using the methods described in this guide, these options can be included in discussions with community focus groups, or incorporated into the template *Community Solar Survey* (Step 4, Item f) provided as part of *Community Planning for Solar* toolkit. Please review the guide *Conducting Focus Groups for Solar Planning* (Step 4, Item d) for information on how to conduct focus group meetings, and the guide *Conducting a Community Solar Survey* (Step 4, Item e) for information on how to design, distribute, and analyze a *Community Solar Survey*.

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. Where relevant, we provide specific examples of how solar development options were derived for municipalities in Massachusetts. In many cases, comparable data, information, and documents are available for other states and regions.

Associated Documents

Several additional components of our *Community Planning for Solar* toolkit may be helpful in defining realistic solar development options. These documents are referenced, where appropriate, in the text of this guide.

Defining Alternative Options for Solar Development

Overview of the Process

Potential scenarios of solar development in a community can incorporate any number of factors - size, type, location, financing structure, etc. – and resident preferences may vary based on all of these variables. For example, residents might generally be opposed to the idea of farmland or forestland being converted into large-scale solar development, but might ultimately be supportive of a specific solar energy project that occupies fallow land in between agricultural fields on a local farm, or one that is sited in a stand of relatively young trees in an area near a highway and owned in common by local residents.

Attempting to address all possible parameters of solar development simultaneously (e.g., permitting process, size, type, location, ownership) can become quite complex quite quickly. Describing a diversity of detailed scenarios may make it hard for residents to evaluate the relative merits of different solar development options, as well as make it difficult for planners to interpret which aspects of a particular solar development scenario are important to community members. Instead of attempting to devise and evaluate complex scenarios of solar development, we recommend parsing out scenarios into different parameters that can be addressed individually in the *Community Solar Survey*.

In this guide, we discuss solar development options in the context of four parameters. There may be other parameters beyond these, but a large number of considerations are encapsulated within these four categories. Depending on the options for solar development in your area of focus, there may be other parameters you choose to consider in the context of your community.

Four Parameters of Solar Development

The four parameters we use in this guide are outlined below:

1. **Regulation of Solar Development**: This parameter addresses planning and permitting processes for solar. Residents may have preferences about the level of involvement of local representatives and community members in the process of planning for solar development and permitting of solar PV projects in their communities. There may be existing laws or regulations that affect what planning and permitting processes are allowable or commonly practiced.
2. **Scale of Solar Development**: This parameter addresses how much solar development residents would like to have in their community. Residents may have preferences regarding the scale of total solar PV capacity that is ultimately developed in their communities. There are several ways this preferred scale might be defined, including a target for the total capacity of solar (MW) to be installed, a percentage of the solar potential of different development types, or a percentage of current or future electricity generation needed to meet local, state, or regional electricity demands.
3. **Development Types**: This parameter addresses *where* and *how* solar is developed. Residents may have preferences about what types of locations are used for solar development within their community, including whether development should occur on previously developed structures and spaces, working lands (like agricultural fields), or natural areas. Residents may also have preferences about where projects are located relative to other community features (e.g., along roadsides vs. hidden from view, near municipal buildings or away from the town center). Residents may also have preferences

about the size of individual projects (e.g., multiple small or medium-scale projects vs. a single large commercial project), or land use under and around solar arrays (e.g., dual-use solar and agriculture; native, "pollinator-friendly" vegetation).

4. **Community Benefits**: Residents may be more supportive of solar projects which provide financial or other benefits to the community, such as reduced electricity rates, community or municipal ownership, direct payments reducing the local property tax burden, or energy storage and microgrid opportunities.

Background Information and Data

The range of feasible options for each parameter is dependent on a host of factors (see Table 1 below for examples). If you are following the *Community Planning for Solar* process, you will already have collected much of the necessary background information about these factors through the processes outlined in the guides *Conducting a Solar Resource and Infrastructure Assessment* (Step 2, Item b) and *Understanding and Evaluating Solar Financing and Ownership Options* (Step 3, Item a), including completing a review of existing renewable energy facilities, local and state laws, local and regional planning documents, the solar resource potential on different structures and land types, and the community benefits associated with different ownership structures.

. Additional information that may be of use in defining feasible options might include:

- Current electricity demand within the community
- Current sources of electricity
- Projected future electricity needs for the community, region, or state
- Current costs for different types of solar development
- Financial incentives relevant to solar PV specifically, or renewable energy more generally

Organizing data regarding these factors helps to ground potential scenarios of solar development in reality, and avoid wasting time discussing alternatives or options that are not realistic. For example, it would not be valuable to present a scenario to residents in which half of local electricity demand is derived from solar built on brownfields within a community, if there is simply not enough brownfield acreage available to produce that amount of solar electricity generation.

Table 1. Example factors influencing the range of realistic options available.

Parameter	Example Factors Influencing the Range of Alternatives Available
Solar Regulation	• State laws; local zoning bylaws/ordinances • Local planning & permitting processes • Land ownership (public vs. private)
Development Types	• Building stock (residential and commercial buildings, roof age, historical buildings) • Parking lots and other parking structures • Land characteristics (Land use, ownership, presence of previously developed/degraded lands, agricultural and other working lands, natural lands)
Scale of Development	• Technical solar resource potential • State laws; local zoning and permitting bylaws/ordinances • Existing or new goals for clean energy development or GHG emission reduction • Electricity infrastructure; hosting capacity; utility plans • Current and future electricity needs
Community Benefits	• State laws regarding financial structures; solar incentive programs • Community needs & priorities • Community financial resources

Assumptions Used in Our Methodology

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 whether solar panels are fixed or tracking systems. When constructing scenarios of solar development that included development of ground-mounted solar arrays, we used a value of 5 acres of land developed per 1 MW DC of solar capacity. In our experience, this value represents a roughly accurate estimate of land use for solar projects developed in Massachusetts. Capacity density (MW per acre) may vary regionally. If you are not able to obtain a realistic estimate for your area, you could choose to use the nationwide average of roughly 6-7 acres per MW DC obtained by Ong et al. (2013)[1]. It is worth noting, however, that capacity density (MW per acre) is expected to improve over time as technology advances. **Please see *Conducting a Solar Resource and Infrastructure Assessment* (Step 2, Item b) and Ong et al. (2013)[1] for more information on this topic.**

Capacity of Large, Ground-Mounted Solar Facilities: Large, ground-mounted facilities in Massachusetts typically range in size from 500 kW up to about 10 MW (10,000 kW) DC, covering from several acres up to 50 acres of land or more. In regions with more land area, solar facilities of 50-100 MW are now 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 1-10 MW DC, this is the size we referenced when describing options which involved development of "large" ground-mounted solar PV systems in the communities we worked in. Depending on the energy market in your state or region, you may wish to include options for much larger systems – up to 50, 100, 500, or even 1000 MW.

Defining a Range of Alternatives for Each Parameter

For each parameter, the sections below provide:

- **Considerations for Defining Options:** A list of considerations and questions to aid in development of community-specific options for each parameter.
- **Massachusetts Examples:** Text boxes providing examples of how the range of options was defined for rural Massachusetts communities.
- **Example Survey Questions:** In this guide, we refer to specific questions within the template *Community Solar Survey* (Step 4, Item f) to provide examples of the types of questions that may be included to identify community preferences regarding the alternatives identified in each parameter category. Note that in some cases, the alternatives developed may need to be simplified for the purpose of the *Community Solar Survey*, so that they can be understood by residents not familiar with the details of solar development. The use of focus groups as part of the assessment of community preferences can help define the level of detail necessary to include in the *Community Solar Survey*, as well as aid in identifying common terminology used and understood by community members.

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). https://www.nrel.gov/docs/fy13osti/56290.pdf

Parameter 1: Regulation of Solar Development

The purpose of this set of alternatives is to allow residents to define their preferences regarding planning and permitting processes for solar development in their communities.

Considerations

Questions you may wish to consider in developing alternative options for this parameter include:

- Do residents think community planning for solar development is important, or is the current situation working? Should the community have a comprehensive plan for solar, or do residents feel simple guidance is sufficient?
- What existing planning and permitting processes for other types of development within the community might be applicable to solar development? Does the community have a Master Plan, processes for regulating other types of energy development, or conservation planning tools?
- What is the current permitting process for solar development within the community? What role(s) could community members play in the permitting process?
- What range of local permitting approaches are taken across communities in the county, region, or state? These might include anything from a laissez-faire approach with no local bylaws/ordinances addressing solar development, to a specific section in the local bylaws/ordinances regarding solar arrays, to outright prohibition of certain types of solar energy projects.
- What range of options for local regulation of solar are legally allowable? You may wish to constrain the list of alternative options based on what is currently allowable under state law. For example, in Massachusetts, municipalities can regulate but cannot currently prohibit solar development, so we chose not to provide town-wide prohibition of solar development as a solar development option. Alternatively, you may wish to include options for local regulation that are not currently allowable under state law in the *Community Solar Survey*. Doing so recognizes that state laws can be updated based on the collective will of the citizens – including rural residents. Support for options not currently allowable under state law could provide evidence for municipal associations or regional planning agencies to advocate for policy changes that better reflect the preferences of rural residents.

Massachusetts Example 1:

For Massachusetts communities, we came up with four potential scenarios for community regulation of solar development.

Constrained Solar Development: In this scenario, solar development is permanently slowed or halted in the community, due to strict regulation or outright prohibition of solar development. *Potential costs and benefits:* In this scenario, consequences may include the community requiring a net import of electricity, with costs and benefits of solar development accruing to other communities. Local government could face litigation asserting local regulations are too restrictive, since state law forbids “unreasonable” regulation of solar by local bylaws.

Unregulated Solar Development: In this scenario, solar development is allowed to occur in a *laissez-faire* environment, in which the free market – and willingness of landowners to lease or sell their land – are the primary determinants of where projects are installed, with little restriction or oversight by community boards or government. *Potential costs and benefits:* There is little local control of what projects look like or where they are sited, and little restriction or oversight by community boards or government. However, rapid development of available sites may help meet state or national goals for renewable energy development and to combat climate change. Community financial costs and benefits depend on how much solar is developed, and whether developers are motivated to provide community benefits by programs at the state or federal level.

Status Quo Solar Development: In this scenario, solar development is allowed to occur under the current local bylaws or ordinances. These regulations are likely to provide some restrictions on solar, but the primary decision-makers in terms of where projects are installed are still likely to be solar developers and landowners with large tracts of land. *Potential costs and benefits:* Local representatives have some control of what projects look like and how they are sited, though likely not where. Legal challenges to bylaws or permitting decisions are possible.

Planned Solar Development: In this scenario, the community goes through a detailed process to develop a plan for where and how residents prefer to see solar developed in their communities. Outcomes of this process are then incorporated into community bylaws or ordinances and into community planning documents. *Potential costs and benefits:* In this scenario, there is significant community input regarding solar bylaws or ordinances. There is also much greater potential for community influence on siting decisions. Municipal officials and volunteers may need to devote more hours to solar planning and permitting. Legal challenges to any solar bylaw are possible, but the backing of a community in the planning process could give a bylaw or ordinance more weight in court. In Massachusetts, “unreasonable” restrictions on solar development are not allowable under law, but solar zoning restrictions may be implemented to benefit the “public welfare.”

For example survey questions relevant to this category, see the *Community Solar Survey* template (Step 4, Item f), questions 11, 12, and 14.

Parameter 2: Scale of Solar Development

The purpose of this set of alternatives is to allow residents to define their preferences regarding the scale of future development in their community. The scale of future solar development could be described in a number of different terms – the total capacity of solar (MW) installed, the total space it would occupy on buildings and land, the amount of electricity generation relative to electricity needs at the community, state, or regional level, and/or relative to goals for solar development at the local, state, regional, or national level.

Residents can also be asked about their preferences regarding the percentage of different development types that are ultimately developed – see Parameter 3 for an example of this type of question.

Considerations

When developing alternative options for this parameter, you may wish to consider the following:

- Begin with a clear understanding of the total technical potential for solar development within the community, on existing infrastructure (e.g., roofs and parking lots), previously disturbed sites (e.g., brownfields, landfills), working lands (e.g., agricultural fields, timber production forests), and natural landscapes (e.g., forests, grasslands). The total technical potential for solar of different development types can be drawn from the *Solar Resource and Infrastructure Assessment*, completed as part of Step 2 of the planning process.
- If you need to calculate potential electricity generation based on technical potential for solar capacity, you can use the PV Watts calculator (https://pvwatts.nrel.gov/), or download SolarGIS's PVOUT dataset (https://solargis.com/maps-and-gis-data/tech-specs).
- Consider any targets for solar development set by your local, regional, or state government, regional planning agencies, or utility companies.
- Consider estimates of future solar PV needs available from researchers or academics working in the fields of energy or climate change response. The Stanford Solutions Project[2] and NREL Solar Futures study[3] are two sources that can provide state-level estimates of future solar capacity needs across the country.
- Consider the clearest, most appropriate, and most accessible terms in which to describe potential scales of solar development. For instance, the scale of development might be described in terms of the capacity of solar arrays (MW), the percentage of available rooftops covered with solar, the percentage of available parking lots covered with solar, or acreage of land converted to solar.
- Define a realistic range of the scale of solar development which may occur. The upper limit could be based on the total potential for solar development within the community, but might be further limited based on energy needs, solar energy build-out goals, or by realistic financial constraints or other parameters.

---

2 Delucchi, M.A., M.Z. Jacobson, G. Bazouin, and Z.A.F. Bauer, 2015. Spreadsheets for 50-state 100% wind, water, and solar roadmaps, http://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html

3 US Department of Energy, 2021. Solar Futures Study. https://www.energy.gov/eere/solar/solar-futures-study

Massachusetts Example 2:

For Massachusetts communities, we came up with five alternatives for how community residents might think about future solar capacity to meet renewable energy goals.

Status Quo: "Ad-hoc" development; the community makes no plan to help meet renewable energy goals; individual landowners might still choose to develop solar.

Developed Spaces: The community encourages development on previously developed areas such as roofs, parking lots, and previously disturbed lands, but discourages development of open lands (agricultural and natural landscapes), even if it means not developing sufficient solar capacity to help meet community, regional, or statewide energy goals.

Community Self-Sufficiency: Within Massachusetts, some communities have onshore wind potential or existing hydropower dams; however, for the most part, solar PV is the primary renewable energy resource available within rural communities. In this option, a rural municipality sets a goal of electric self-sufficiency – that is, generating sufficient energy from solar PV within its boundaries to provide electricity for all community residents and businesses, provide electrified heating for all buildings, and support an electrified fleet of personal vehicles and public transport.

Regional Energy Goal: Many rural towns are primarily residential. Community residents may travel out of the town to larger towns and cities for work, shopping, or other activities. Larger towns and cities in the region may provide a wider variety of these social goods, while small towns may contribute a larger share of outdoor recreation opportunities and conservation value – as well as greater expanses of undeveloped spaces which could provide sites for economical development of solar PV. Rural towns could consider it their "fair share" to contribute to regional self-sufficiency. In Massachusetts, many residents in the four counties of the western part of the state identify as being part of "Western Mass," in order to differentiate themselves from the more developed, eastern part of Massachusetts. In this option, all communities in the Western Mass region contribute an equal percentage of their land area for solar development to provide their "fair share" of electricity generation to meet regional self-sufficiency needs for the four-county region.

Statewide Energy Goal: Many consumer goods used in rural towns are produced or manufactured elsewhere. Hence, a town's true "fair share" of energy use and energy generation may represent a much larger portion of state or national goals than the amount of energy measurably consumed directly within the town's boundaries. Rural towns could consider it their "fair share" to contribute to statewide goals based on the municipality's land area relative to the state as a whole. In this option, rural municipalities support state self-sufficiency by taking a rough statewide goal of 40 GW of solar PV capacity, and dividing it amongst all municipalities in the state based on land area.

For example survey questions relevant to this category, see the *Community Solar Survey* template (Step 4, Item f), questions 22 and 23. For detailed information on how values were calculated for use in these questions, see Appendix A.

Parameter 3: Development Types

The purpose of this set of alternatives is to address resident preferences for development of different types. This might include a number of different aspects of solar projects, including:

- Development on different structures and land uses, including rooftops, parking lots, previously disturbed areas (e.g., brownfields, landfills), and agricultural or natural landscapes
- Where projects are located relative to other community features (e.g., adjacent to roadsides or out of view)
- Project sizes (e.g., many smaller facilities or one large one)
- Who owns the land (i.e., development on private or public lands)
- How the land is managed under and around the solar array (e.g., seeded with native, "pollinator-friendly" vegetation, managed through sheep grazing)

Considerations

When developing alternative options for this parameter, you may wish to consider the following:

- Be sure to conduct a *Solar Resource and Infrastructure Assessment* to quantify technical potential for solar development on different types of structures and land uses.
- Consider different parties with agency in developing different resource types (e.g., municipalities, state, or federal government, businesses and institutions, homeowners, landlords).
- Consider the range of options for potential placement of solar facilities relative to existing infrastructure and natural resources. See Massachusetts Example 5 below, for an example listing of the types of placements we compiled.
- Consider the different sizes of ground-mounted solar projects that could be developed – e.g., as multiple small arrays or as one large array; see page 8 for a discussion of what constitutes a "large" ground-mounted facility.
- Consider the different vegetation management that might be practiced as a site. For example, a facility could be planted with turfgrass, or as a "pollinator-friendly" habitat of native plants; sites could be managed with sheep grazing, or other types of agricultural production could be incorporated into the design.
- Think about the appropriate level of detail when describing different resource types. On the one hand, breaking down development types into multiple different categories as needed can aid in an accurate assessment of residents' preferences. On the other hand, it is important to be cognizant of the potential for "survey fatigue" and limit the categories to those that are truly meaningful.
- Solar development on natural and agricultural areas may be particularly controversial. There is a great deal of diversity across these "greenfield" sites, and residents may be accepting of solar on some sites, but not others. Residents' relative preferences for these different types of sites are often overlooked in solar opinion surveys. When coming up with alternatives for these sites:
    - Consider the open, undeveloped land types which occur in the community.

- Review conservation plans, land use siting guidelines, bylaws, ordinances, and laws at the local, regional, or state level for potential categories to include.
- See Massachusetts Example 6 below, for an example listing of the types of "greenfield" sites we compiled.

Massachusetts Example 3:

Attitudes towards solar projects: We asked residents about their attitudes towards solar energy projects on residential rooftops, in residential yards, on municipal properties, and built as large, ground-mounted projects.

For example survey questions relevant to this category, see the *Community Solar Survey* template (Step 4, Item f), questions 4, 5, 9, and 13.

Massachusetts Example 4:

Percentage of resource to be developed: For this question, we allowed residents to identify the amount of each resource type within their communities they ideally would prefer to see developed. Residents defined that preference based on the percentage of the resource they would like to see developed, but the total potential solar capacity (MW) was also provided. The total potential solar capacity was derived from the methodology outlined in the guide *Conducting a Solar Resource and Infrastructure Assessment* (Step 2, Item b).

For this survey questions, see the *Community Solar Survey* template (Step 4, Item f), question 24.

Massachusetts Example 5:

Locations relative to community features: For Massachusetts communities, we came up with the following list of different types of places that solar facilities could be sited relative to community features:

- Areas near rivers, lakes, and ponds
- Areas near wetlands
- Areas near public recreational areas
- Areas near the town center
- Areas near historic buildings
- Areas near residences
- Areas in the business district
- Areas along rural roadsides
- Areas along major roads and highways
- Areas visible from scenic vistas
- High elevation areas, easily visible from many points in town
- Low elevation areas, not easily visible

For an example survey question relevant to this category, see the *Community Solar Survey* template (Step 4, Item f), question 19.

Massachusetts Example 6:

Types of working and natural lands: For Massachusetts communities, we came up with the following list of different types of agricultural and natural lands that solar facilities might be sited on:

- Agricultural land vs. forestland vs. shrubland vs. natural meadows
- Agricultural land used for vegetable production vs. fruit production vs. corn vs. hay vs. cattle grazing vs. horses
- High quality agricultural soils
- Marginal land on farms not suitable for farming
- Large tracts of unfragmented farmland
- Important habitat for rare species
- "Climate-resilient" landscapes
- Large tracts of unfragmented forest
- Former quarries or sand-and-gravel extraction sites

For example survey questions relevant to this category, see the *Community Solar Survey* template (Step 4, Item f), questions 17 and 18.

Parameter 4: Community Benefits

The purpose of this set of alternatives is to allow residents to identify their preferences regarding alternative financial and ownership structures and potential community benefits associated with solar development.

Considerations

- Consider what financial structures are available in your state or might be allowable under state law. Consider whether financial structures available in other states might be adapted for use in your state.
- Review alternative ownership structures and the costs/benefits associated with each structure. Refer to the financial tools available as part of Step 3 of this planning process for some potential alternatives.
- Consider potential economic benefits of solar to a municipal government, such as:
    - Payments from the solar facility owner in the form of PILOT payments or tax revenue serving town budget needs
    - Reduced electricity rates (due to the solar developer offering a lower electricity rate) for municipal buildings
    - Solar incentive payments and reduced electricity costs associated with municipally owned solar facilities
    - More money in the local economy leading to a larger tax base
- Consider potential economic benefits for community residents or businesses, such as:
    - Reduced electricity rates (due to the solar developer offering a lower electricity rate) for some or all residents
    - Electricity cost stabilization (due to the solar developer offering a fixed electricity rate) for some or all residents
    - Solar PV incentives and reduced electricity costs associated with solar facilities owned by community residents
    - Reduced property taxes due to increased municipal PILOT or tax revenue from solar facilities
    - Solar facility payments to the town in the form of PILOT payments or tax revenue leading to improved town infrastructure
    - Job opportunities in solar facility development, construction, or maintenance
- Consider potential ancillary benefits, such as:
    - Greater energy reliability and provision of back-up power, if solar is combined with energy storage as part of a small array serving one building, or a larger micro-grid
    - Opportunities to pair solar with electric vehicle charging infrastructure
    - Opportunities to pilot innovative solar deployment techniques, such as dual-use agriculture or floating solar
    - Educational opportunities in energy, engineering, construction, research design, etc.

Massachusetts Example 7:

For Massachusetts communities, we identified four ownership structures possible over the lifetime of the array. Based on the *Solar Financing and Ownership Options: Cash Flow Model* (ag.umass.edu/solarplanning3) developed for the purpose, we were able to estimate investment costs, local benefits, and third-party benefits associated with each ownership structure.

- **Third-Party Ownership:** A developer or out-of-town company finances, develops, and owns the project for the entire 30 years. Any additional costs from delays or problems are the responsibility of the third party. Revenues come from the third-party developer, in annual payments to the town and/or landowner. The process is quite simple for the community, but there is little role for local decision-making and fewer local economic benefits.
- **"Flip" Model Ownership**: A developer or out-of-town company finances, develops, and owns the project for the first six years. Then, the project is sold to a local partner (non-profit, community group, or municipality) at fair market value. Any additional costs from delays or problems are the responsibility of the third party until ownership switches. Revenues increase to the town once the ownership switches because the local owner/community earns the money from electricity sales. There is the possibility for a greater role for the community in decision-making.
- **"Taxable" Community Ownership:** A local entity finances, develops, and owns the project for the entire 30 years. The local entity could be a group of residents or a local business. The local entity gains the benefits of any tax credits associated with development. Any additional costs from delays or problems are the responsibility of the local entity. Revenues stay in the local economy, and decision-making is local.
- **"Non-Taxable" Community Ownership:** A municipality or local non-profit finances, develops, and owns the project for the entire 30 years. Any additional costs from delays or problems are the responsibility of the local entity. Revenues stay in the local economy, and decision-making is local. Because the owner is a non-taxable entity, there is no tax credit revenue available to partially reimburse the local owner for the cost of

For example survey questions relevant to this parameter, see the *Community Solar Survey* template (Step 4, Item f), questions 16, 20, and 21. Note that the third and fourth options above were combined in the survey for simplicity.

Addressing Trade-Offs across Multiple Parameters

In general, as discussed in earlier sections, we recommend discussing different parameters of solar development individually, rather than attempting to incorporate multiple parameters into complex scenarios. However, there may be particular trade-offs, concerns, or considerations which are brought up often in local discussions around solar energy, and which you feel it necessary to address in the *Community Solar Survey*.

In Massachusetts, one issue which comes up often in discussions of solar development is the trade-off between, on the one hand, developing primarily on previously disturbed and developed structures and spaces (such as buildings, parking lots, brownfields) which results in many smaller projects that are relatively higher cost ($ per kWh of electricity generated), and on the other hand, development of large “greenfield” sites, which often produce cheaper electricity ($ per kWh) but commonly result in loss of previously undeveloped forest and farmlands. We felt it would be important to assess how community residents were thinking about these trade-offs. See Massachusetts Example 8 below.

In considering these trade-offs, we attempted to constrain the scenarios in ways that kept the number of parameters being compared relatively simple. For example, we placed all “undeveloped land” in one category, and did not attempt to include different types of “greenfield” sites, as outlined in Massachusetts Example 6. We created potential solar development mixes based on a **fixed** capacity value (Parameter 2), and did not include different ownership options (Parameter 4).

If you are interested in developing **mix scenarios** as we did, please see Appendix B.

Massachusetts Example 8:

We created potential mixes of solar development types at a fixed capacity value for comparison. The capacity value we used was based on the estimated solar capacity necessary to allow the community to meet 100% of future electricity needs, including electrified transportation, electrified heating, and some necessary curtailment of renewables. For each town we developed four mixes, based on our assessments of availability of various solar resources within the town. The scenarios include 25%, 50%, 75%, and 90% large, ground-mounted, greenfield solar development respectively, with the balance made up of developed and previously disturbed sites such as rooftops, parking lots, former landfills, and gravel pits. Because the communities we worked with already had some level of large, ground-mounted on undeveloped or agricultural land, and some "greenfield" development was necessary to meet the community self-sufficiency capacity value, we did not include a scenario with no large, ground-mounted, greenfield solar development. To help residents envision each scenario, we included 1) the percentage each resource type contributed to the total, 2) the fraction of residential roofs, large building roofs, and large parking lots developed, 3) the acreage of previously disturbed and undeveloped land converted to solar, and 4) additional electricity costs associated with that development type based on the monthly electricity bill.

- **Scenario 1:** Large, ground-mounted "greenfield" development was set at 25% of all solar development. Most (60-85%) of residential properties that could host residential-scale solar arrays did. Most large roofs suitable for solar had arrays on them. Parking lot canopies were built on large and small lots. Old landfill sites were covered with commercial-scale arrays.
- **Scenario 2:** Large, ground-mounted "greenfield" development was set at 50% of all solar development. About half (50-60%) of all residential properties hosted residential-scale solar arrays. About half (40-55%) of all large roofs suitable for solar had arrays on them. Parking lot canopies were built on multiple lots. One commercial-scale solar array was built on a municipal landfill in each town.
- **Scenario 3:** Large, ground-mounted "greenfield" development was set at 75% of all solar development. About one-third (33-35%) of all residential properties hosted residential-scale solar arrays. About one-third (30-35%) of all large roofs suitable for solar had arrays on them. Parking lot canopies were built on one or several lots. One commercial-scale solar array was built on a large landfill in each town.
- **Scenario 4:** Large, ground-mounted "greenfield" development was set at 90% of all solar development. Less than a quarter (10-20%) of all residential properties hosted residential-scale solar arrays. Less than a third of all large roofs suitable for solar had arrays on them. Parking lot canopies were built on one or several lots.

For examples of how estimates of these scenarios were developed for Massachusetts municipalities, please see Appendix B.

For example survey questions relevant to these scenarios, see the *Community Solar Survey* template (Step 4, Item f), questions 25 and 26.

Next Steps

Once realistic, alternative options have been developed, you will be ready to convene focus groups and begin developing a *Community Solar Survey*. See Step 4: *Assess community preferences regarding solar development and financing* for guides to these activities.

Appendix A – Calculating Solar Capacity Needs

Community Self-Sufficiency

For this scenario, we estimated the electricity required to provide community self-sufficiency based on 1) existing electricity use, 2) converting existing building heating load to air-source heat pumps, and 3) converting all existing private vehicles and annual vehicle miles traveled to electric. The estimate of total annual electricity use was then divided by 1,200 to estimate the total capacity of solar required to fully power the town. The value of 1,200 represents a rough approximation of the number of kWh generated annually per kW DC of solar installed in Massachusetts[4]. Renewable energy sources may need to occasionally be turned off or "curtailed" at certain points when renewable energy generation is particularly high (e.g., on a bright, sunny, summer day, on a particularly windy day) to preserve the stability of the grid. Because some curtailment of renewable energy sources is expected (13% or 27% depending on the expansion of energy storage[5]), we multiplied this initial capacity figure by 1.13 and 1.27 respectively to arrive at estimates of solar capacity needs which include the potential for curtailment.

State and Regional Self-Sufficiency

In Massachusetts, there are no solar capacity goals currently defined regionally for states which comprise the New England electricity grid (CT, RI, MA, ME, NH, VT). The state of Massachusetts has requirements for greenhouse gas emission reductions, but does not have a set goal for solar capacity. Currently, there is an interim Climate and Clean Energy Plan for Massachusetts working its way through the public participation process (https://www.mass.gov/info-details/massachusetts-clean-energy-and-climate-plan-for-2025-and-2030). This plan currently calls for 3,200 MW to be built under current solar incentive programs and an additional 2,000 MW of distributed generation to be commissioned between 2025-2030, much of which might come from solar. While the plan has not been finalized, it might be summarized to represent a goal of about 7,500 MW across the state by 2030 (including 2,500 MW already developed). Within MA, there are no county or local-level goals for solar development of which we are aware.

There are several state and regional estimates of solar capacity needs available from researchers working for the federal government or academic institutions.

- The **Brattle Group**[4] estimates about 107 GW of solar PV must be built across New England to achieve an 80% reduction in greenhouse gas emissions for the region. Massachusetts represents about 46% of New England electricity use, so could be considered responsible for up to **50 GW** of solar PV development – although wind development off the coast of Massachusetts will also represent an important portion of the state's contribution to the New England electricity supply.

[4] The PVWatts Calculator (https://pvwatts.nrel.gov/) estimates a solar PV system in central Massachusetts would generate 1,285 kWh per kW annually. The Massachusetts Clean Energy Center reports the net capacity factor for solar PV systems installed through 2018 was 13.35%, which equates to 1,169 kWh per kW annually. The efficiency and associated capacity factor of solar PV panels is expected to increase over time.

[5] Weiss, J. and J.M. Hagerty, 2019. Achieving 80% GHG reduction in New England by 2050, https://www.brattle.com/insights-events/publications/brattle-study-achieving-new-englands-ambitious-2050-greenhouse-gas-reduction-goals-will-require-keeping-the-foot-on-the-clean-energy-deployment-accelerator/

- The **Stanford Solutions Project**[6] estimates **38.4 GW** of solar PV will be needed state-wide to achieve 100% renewable fuel use across Massachusetts, including electrified heating and transportation sectors. Under this scenario, 29.5% of Massachusetts electricity comes from solar.
- The **National Renewable Energy Laboratory**[7] estimates as much as 3,200 GW of solar PV would be needed nationwide by 2050 to fully decarbonize all energy sectors. Solar would provide about half of all electricity generations under this scenario. Massachusetts is envisioned to contribute **30-70 GW** to this total.

Based on these sources, we used a rough estimate of 40 GW of solar PV capacity needed state-wide in Massachusetts by 2050, to help the state meet its greenhouse gas emission reduction goals and work towards 100% renewable energy sources.

Regional Self-Sufficiency: In order to estimate the total solar capacity required to support this region, we first estimated what percentage of total state electricity use western Massachusetts might represent, if all transportation were electrified, and all buildings currently heated with fossil fuels were converted to electric sources. Based on MassSave data, current electricity use in western Massachusetts represents about 11.0% of the state total. Our projections suggest electricity to power an electrified transportation sector would represent about 12.7% of the state total, for privately-owned vehicles. Census data indicates western Massachusetts households represent about 12.4% of all households statewide, and 11.8% of the households statewide heated with fossil fuels, although these households may represent a somewhat larger percentage of overall heating fuel use, since homes in western Massachusetts are more likely to be detached, single-family structures, which on average consume more heating fuel. Based on these calculations, we assumed future electricity use in western Massachusetts might represent about 12% of statewide electricity use. Under a scenario in which 40 GW of solar are required statewide, 4,800 MW of solar would be required to help power the region. This regional solar capacity was divided amongst all municipalities within western Massachusetts based on total land area (in acres) to determine the "fair share" by town under this scenario.

State Self-Sufficiency: Assuming capacity of 40 GW of solar are required statewide, we divided this capacity amongst all municipalities in Massachusetts based on total land area (in acres) to determine the "fair share" by town under this scenario.

6 Delucchi, M.A., M.Z. Jacobson, G. Bazouin, and Z.A.F. Bauer, 2015. Spreadsheets for 50-state 100% wind, water, and solar roadmaps, http://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html

7 US Department of Energy, 2021. Solar Futures Study. https://www.energy.gov/eere/solar/solar-futures-study

Appendix B – Developing Mix Scenarios

Overview

If you are planning to develop mix scenarios, as we did, you will need estimates of solar technical potential from the *Solar Resource and Infrastructure Assessment*. You will need to choose a fixed amount of solar capacity to be developed, which could be based on community self-sufficiency, or some other value. If the amount of solar capacity chosen greatly exceeds the potential resource available on developed and disturbed spaces, the mixes will not be very different, because they will all include a large amount of greenfield development.

As features describing the scenario, you may wish to estimate the amount of each solar resource developed – for example, the fraction of roofs and parking lots in town developed for solar under each scenario, and the acreage of previously disturbed and undeveloped land converted to solar. You may also wish to include costs and benefits, such as the cost of electricity associated with more expensive development mixes, or the loss of carbon storage associated with solar development on forest land.

The sections below describe how we calculated values for mix scenarios in Massachusetts.

Community-Specific Capacity

For each municipality, we began with the estimate of total solar capacity necessary to achieve community self-sufficiency, using the higher renewable energy curtailment estimate reported by the Brattle Group, of 27%. These values were rounded to the nearest even number for simplicity.

Land Use Estimates

For simplicity, 1 MW DC of ground-mounted solar was estimated to take up 5 acres of land (see *Project Footprint*, page 8.

Cost Estimates ($ per kWh)

Few estimates of the cost of different types of solar development are available in Massachusetts. We first reviewed a recent survey conducted for VoteSolar[8], estimating the average cost of different types of development (parking canopy, building-mounted, greenfield), across a range of project sizes. These values were based on a $ per watt basis. When converted to $ per kWh, they were comparable to adders (additional incentives for building and canopy systems) used in SMART, the Massachusetts solar incentive program.

We estimated the cost of different types of projects based on the SMART incentives offered in Block 8 in the respective utility service area (National Grid or Eversource West)[9], since these values are representative of the cost to the electricity ratepayer for each type of development. Most costs were straightforward to calculate based on the base compensation rate, adders, and subtractors incorporated into SMART incentives for a 20-year period ($/kWh)[10]. Several costs required slightly more complex calculations, as follows:

[8] Vote Solar, 2019. Final Northeast Solar Cost Fact Sheet.

[9] http://masmartsolar.com/

[10] https://www.mass.gov/doc/225-cmr-2000-final-071020-clean/download

- **Residential Systems:** Residential systems are only provided incentives for 10 years, compared to 20 years for most other systems, but they typically continue to produce electricity for at least another 10 years after SMART incentives expire. We therefore estimated the cost to ratepayers of these systems relative to commercial-scale projects based on the present value of money and a discount rate of 5%. These calculations suggested these systems cost the ratepayer 1.24x the cost of a commercial-scale system, with the balance of system costs paid by the system owner, or covered through tax rebates.
- **Subtractor:** SMART incentives are typically based on a $/kWh value, but the "greenfield subtractor" for solar development on undeveloped land is a reduction in the incentive expressed in $ per kWh per acre of solar panels. Therefore, it was necessary to estimate the subtractor value for a "large, ground-mounted, greenfield solar development of a specific size. Here, we estimated the subtractor value based on a 3 MW DC array – the average of the minimum project in this size class (1 MW) and maximum (5 MW).

In order to estimate the overall cost of a particular scenario's development mix, we multiplied the cost per kWh for the development type by the percentage of the mix that development type represented, and summed across all development types, to obtain the average cost per kWh. Since Scenario 4 had the lowest cost per kWh, we used this scenario as the baseline ($0) for comparison.

Cost Estimates (cost to ratepayer)

The average monthly electricity use by a Massachusetts household is 600 kWh/month. In order to put the increased cost of Scenarios 1-3 in context for residents, we multiplied the electricity rate ($/kWh) by 600 kWh to obtain the differences in monthly bills expected under these scenarios. According to the Brattle Group study[11], solar is expected to represent ~37% of all electricity generation under a 80% GHG reduction scenario. We therefore multiplied the difference in monthly bills expected under these scenarios by 37%, to represent the lower expected increase in costs associated with solar development scenarios 1-3, and by 100% to represent the highest expected increase in cost. We also considered that a community choosing to power itself through solar development might obtain 90-100% of its energy from local solar, and therefore set the highest expected increase in the monthly bill for 90-100% of the electricity coming from solar. Under future scenarios, we would actually expect electricity use, and potentially electricity bills, to roughly double, with conversion to electrified transportation and heating systems. However, we would also expect a corresponding elimination of building heating fuel and vehicle fuel bills. Because the purpose of using a monthly electricity bill increase was to make the cost of different scenarios more understandable to residents, we used *current* monthly usage rates, rather than those under a future scenario, where other aspects of home economics would be drastically altered.

[11] Weiss, J. and J.M. Hagerty, 2019. Achieving 80% GHG reduction in New England by 2050, https://www.brattle.com/insights-events/publications/brattle-study-achieving-new-englands-ambitious-2050-greenhouse-gas-reduction-goals-will-require-keeping-the-foot-on-the-clean-energy-deployment-accelerator/