Sustainable Energy Advantage, LLC

Maine Technical Potential for Renewable Development on Disturbed Land

Prepared for The Nature Conservancy - 9/15/2022

Overview

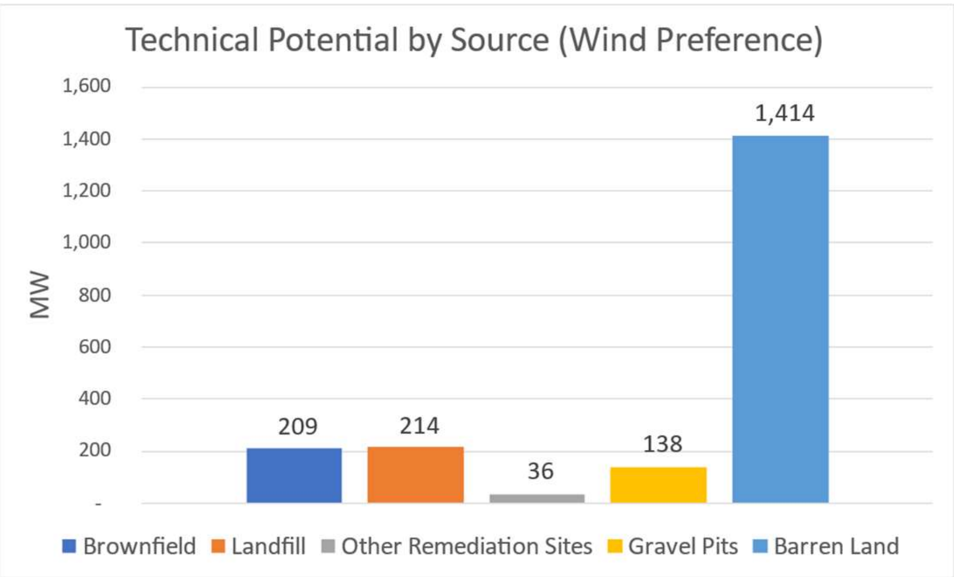
- In this analysis, SEA assessed the technical potential for renewable energy development on disturbed/degraded land in Maine
- The analysis focuses on solar PV and wind, as future land-based renewable energy development is expected to focus predominantly on these technologies
- This analysis is intended to assess the *aggregate* technical potential state-wide, and thus is not meant to assess the suitability of any given parcel for development
- The analysis focuses on the following types of disturbed/degraded land:
  - Gravel pits
  - Closed landfills
  - Brownfields
  - Other remediation sites (e.g., Superfund, VRAP, RCRA, Uncontrolled Sites)
  - Barren Land – defined by the National Land Cover Database as "areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover."
- An overview of the state-wide technical potential, including capacity from rooftop solar, is provided at the end of the presentation

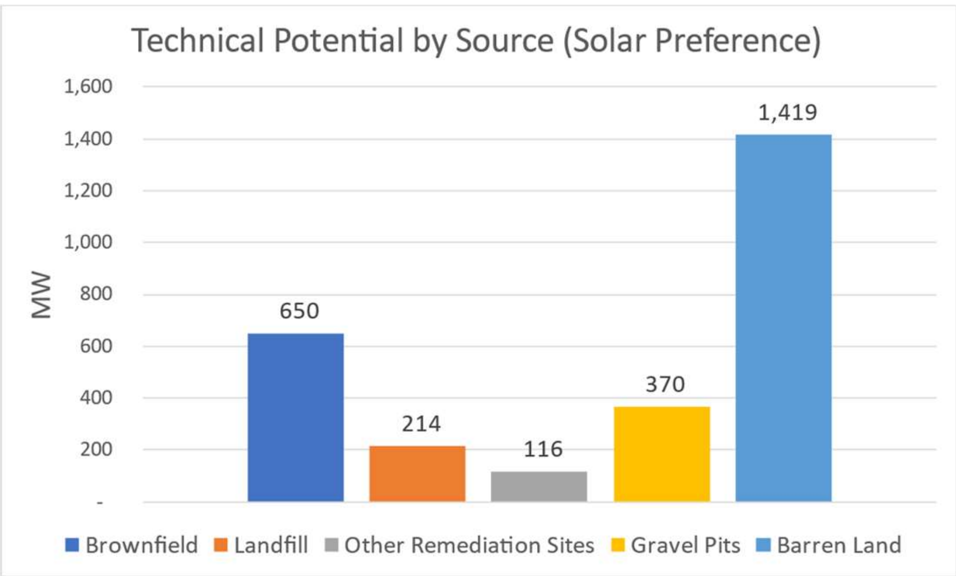
Exclusionary Criteria

- Each dataset was filtered according to several spatial criteria:
  - **Distance to T&D Infrastructure:** Site must be within 1 mile of a transmission or distribution line, or within 3 miles of a substation
    - SEA obtained shapefiles of CMP's distribution circuit only ➔ utilized state-wide transmission lines/substations as proxy for extent of distribution circuit outside of CMP territory
  - **Slope:**
    - **Solar:** Sites with average slope over 5% were removed from consideration if they were not south-facing. For south-facing slopes, a cutoff of 20% slope was used. South-east and south-west facing parcels are considered south-facing for this criteria.
    - **Wind:** Sites with average slope over 20% were removed from consideration
  - **Wind Speed:** Sites with average wind speed at 80m hub height under 5 m/s were removed from consideration for wind development
  - **Existing Solar Facilities:** Any overlap with existing solar facilities was removed
    - Note: The dataset provided by TNC only contains solar facilities which have undergone DEP permit review ➔ no data for smaller facilities
  - Barren land overlapping **protected conservation lands** and **railroads** was removed
    - Because the existence of a brownfield/landfill/gravel pit implies that the area is not protected, this criteria was only applied to barren land
    - Railroads are subject to mis-classification by the NLCD (whereas roadways are generally classified as "urban area") ➔ remove railroads (with a 40 ft buffer)
  - Barren land within 250 m of **water bodies** was removed to avoid counting shoreline/beaches/sand dunes
  - Barren land within 400 m of **urban areas** (5x the assumed hub-height) was removed from consideration for wind development

Overview of Results

- Overall, the analysis results in roughly **2.7 GW of technical potential** from the combined parcels (0.1 GW from Wind, 2.6 GW from solar, assuming preference is given to solar)
  - Because certain parcels can be utilized for either solar or wind, the total capacity differs depending on which technology is preferred in these dual-use cases
    - Preference for wind yields total of 2 GW
  - In general, wind is unable to utilize the full parcel (only room for a single turbine) ➔ total potential is greater with preference for solar

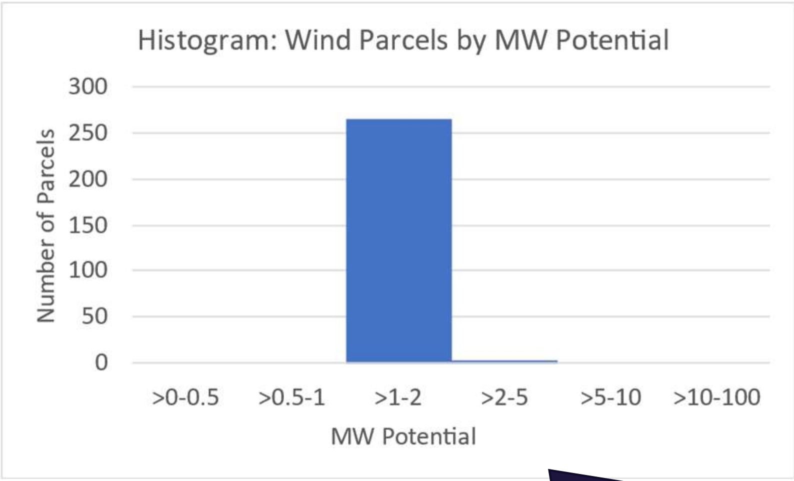


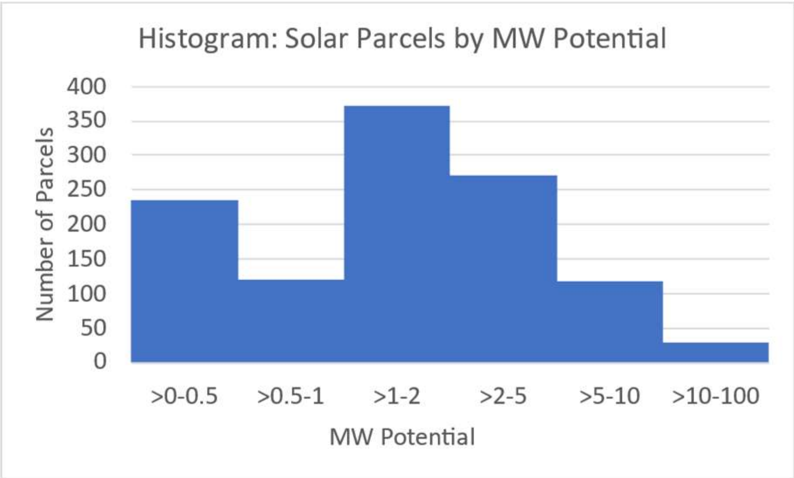


Note: For solar, capacity is in DC

Distributed Generation vs Utility Scale

- 19% of the total technical potential is provided by parcels that could support facilities over 10 MW
  - 9% is from parcels supporting development over 20 MW
- As such, most development on disturbed/degraded parcels is likely to only support smaller facilities
- However, in the real world, a facility could partially utilize a disturbed parcel while expanding into the surrounding area ➔ expanded potential for utility scale development subject to site-specific conditions





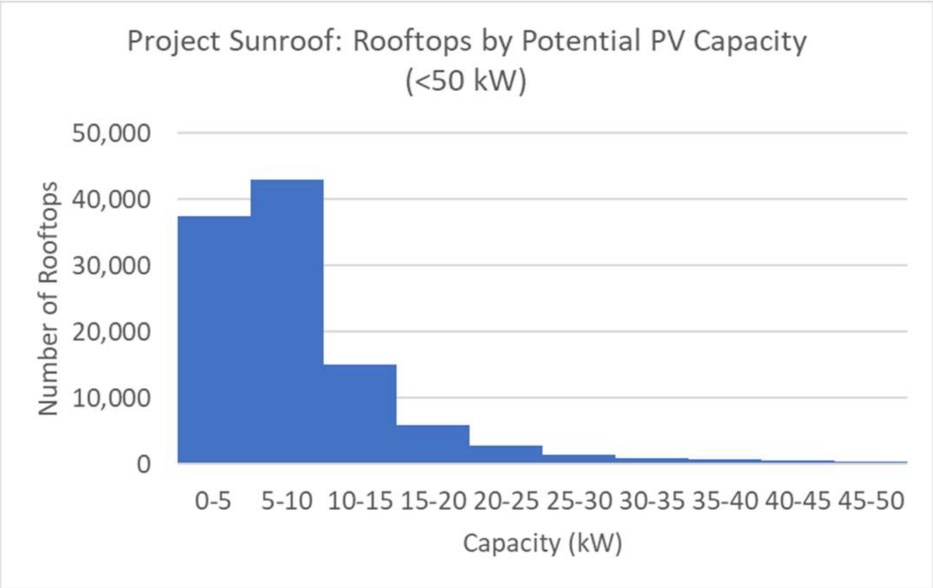
Almost all sites can only support a single turbine (1.5 MW) due to spacing requirements

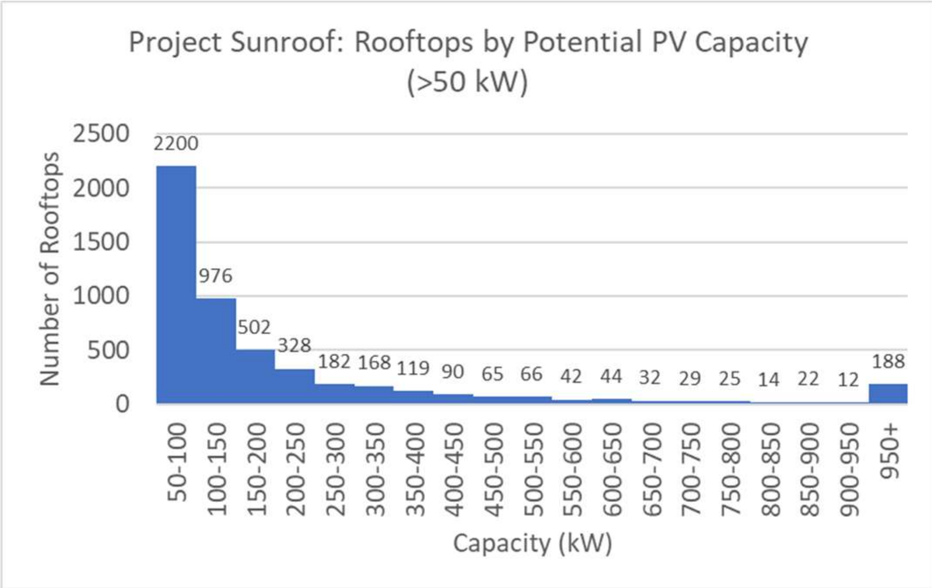
Layering on Rooftop Technical Potential

- To consider the capacity contributions from rooftop solar, we rely on existing research conducted by NREL and Google:
  - NREL: Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment (Gagnon et al., 2016)
    - Uses LIDAR imagery data to spatially analyze a sub-set of the state, and uses statistical models to extrapolate the results state-wide using census data on small, medium, and large buildings
    - Findings: **6.3 GW available state-wide**
      - 4.2 GW from small buildings
      - 2.1 GW from medium/large budlings
  - Google: Project Sunroof – Maine (last updated 11/2018)
    - Uses satellite imagery and machine learning to assess the technical potential of individual rooftops, considering slope, available space, irradiance, and shading
    - Only covers certain areas (~19% of buildings state-wide, with focus on cities) ➔ **2.1 GW potential**
      - Results in imputed 11 GW state-wide. However, because the areas assessed (cities) likely include larger buildings, extrapolating state-wide likely biases results ➔ rely on NREL data for state-wide potential
    - Useful to understand distribution of rooftop sizes and resulting capacity (see next slide)

Project Sunroof – Rooftop Statistics

- Based on an analysis of 115k roofs, project sunroof provides the following statistics:



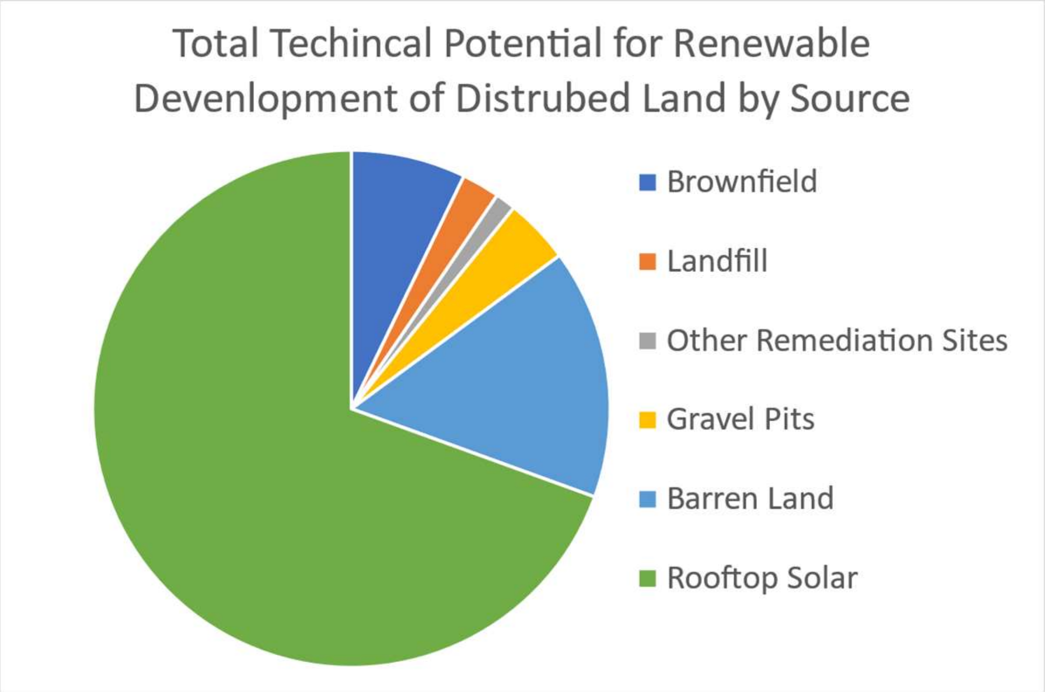


Note: Based on 19% coverage of state-wide buildings

Disturbed Land Technical Potential - Overview

- After layering on rooftop technical potential, the total technical potential for renewable energy development on disturbed/degraded land is as follows:

Source	MW
Brownfield	650
Landfill	214
Other Remediation Sites	116
Gravel Pits	370
Barren Land	1,419
Rooftop Solar	6,300
TOTAL	**9,070**



Note: Assumes preference for solar development on parcels suitable for wind or solar

Other Sources of Technical Potential

- Other potential sites for renewable energy development not assessed in this analysis include:
  - Solar carports
    - Carports were not considered due to a lack of robust, publicly available datasets on parking lot locations and extents
  - PFAS contaminated land
    - Such lands were not considered due to lack of data on the boundaries or size of contaminated parcels
    - In addition, many of the PFAS sites reported in Maine represent the site of testing (e.g., groundwater, river, fish, livestock) and thus are not a reliable indicator for the site of contamination (or may represent a single source of contamination appearing in multiple tests)
    - SEA conducted a high-level screening and found that 3014 out of 3331 sites were within the T&D constraints

Takeaway: The capacity resulting from this analysis does not account for the above sources, and thus may under-state Maine's total technical potential for renewable energy development on disturbed/degraded land

Caveats to Results

- This analysis is intended to assess the *aggregate* technical potential state-wide, and thus is not meant to assess the suitability of any given parcel for development
- Although this analysis does consider certain factors that influence the feasibility of development on a parcel (e.g., distance to transmission), the economic/social feasibility of development on parcels (including the hosting capacity of T&D infrastructure near parcels) was not explicitly considered in this analysis ➔ real-world developable capacity likely lower
    - This is especially true for barren land parcels, which may be in remote areas that are challenging to access/develop (and may require land disturbance to access)
- For wind especially, total realistic developable potential is likely less than technical potential:
    - Wind development benefits greatly from economies of scale ➔ lack of small-scale wind development in recent years
    - Wind is more sensitive to local siting concerns re: noise, flicker, ice throw, aesthetics, etc.
    - Wind development likely requires buffers beyond the extent of the land that will be directly impacted by development for the project to be permitted

Notes and Data Sources

Other Exclusionary Criteria

- For development on barren land, which is generally more remote than the other sites assessed in this analysis, we applied differential minimum capacities based on distance to T&D infrastructure
  - Goal = exclude unrealistically small development in remote areas (away from load)
  - Specific inputs are as follows:
    - For wind, development located over 0.5 miles from T&D infrastructure must support two turbines
    - For solar, any development must be at least 1 MW, development located over 0.5 miles from T&D infrastructure must be at least 5 MW, and development over 1 mile from T&D infrastructure must be at least 10 MW
  - This criteria was not applied to brownfields, landfills, or gravel pits, which are generally assumed to be sited in less remote areas (with road access at minimum)
- Any barren land overlapping with a brownfield, landfill, or gravel pit was removed to prevent double counting
- Wind development on landfills is prohibitively expensive due to the challenges of developing on unstable fill ➔ remove landfills from consideration for wind development

Exclusionary Criteria - Summary

A summary of the exclusionary criteria as it applies to each dataset and technology is provided below:

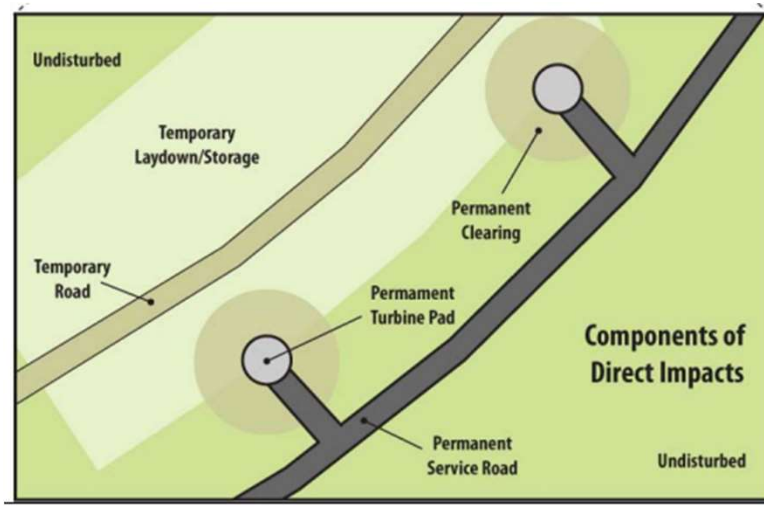
Criteria	Applied to Brownfields?	Applied to Landfill?	Applied to Gravel Pit?	Applied to Barren Land?	Applied to Solar?	Applied to Wind?
Distance to T&D Infrastructure	Yes	Yes	Yes	Yes	Yes	Yes
Average Slope	Yes	Yes	Yes	Yes	Yes - Under 20% for south-facing, under 5% otherwise	Yes – Under 20%
Avg. Wind Speed	Yes	Yes	Yes	Yes	No	Yes – Over 5 m/s
Protected Areas	No	No	No	Yes	Yes	Yes
Railroads (w/ 40 ft buffer)	No	No	No	Yes	Yes	Yes
Existing Solar Facilities	Yes	Yes	Yes	Yes	Yes	Yes
Distance to Urban Areas	No	No	No	Yes	No	Yes

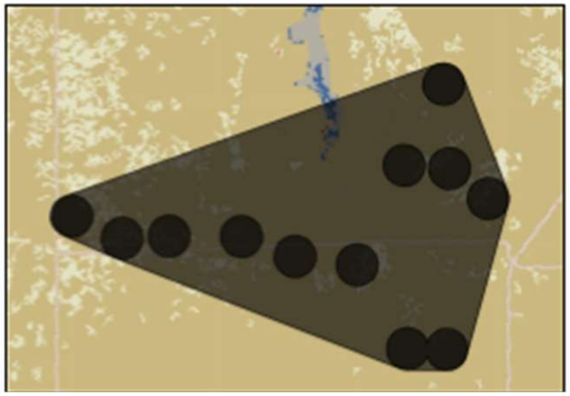
Estimating Capacity Density - Solar

- To estimate capacity density (acre ➔ MW), we utilized two NREL Studies:
  - A widely cited 2013 study, Land-Use Requirements for Solar Power Plants in the United States by Ong et al., which analyzed solar facilities nationwide to determine an average "direct impact" area (defined as the extent of solar panels) and "total area" (defined as the project site boundary, larger than direct impact)
  - A recent 2022 NREL update, Land Requirements for Utility-Scale PV: An Empirical Update on Power and Energy Density by Bolinger, which found a "direct impact" capacity density of 86.49 MW_{DC}/km^2
    - Captures recent improvements in module efficiency
    - Because we are interested in the **total** impacted land area (as opposed to direct impacts of panel racking), we calculated the average ratio of direct to total area based on the Ong et al. dataset to translate the Bolinger capacity density figure from direct ➔ total area
    - We originally hypothesized that the ratio of direct area to total area would scale with the nameplate capacity of the solar project; analysis revealed that no such correlation exists → the direct area to total area ratio was consistently ~0.74, regardless of a project's capacity
  - After adjusting for direct ➔ total area we are left with solar capacity density of **63.69** MW_{DC}/km^2

Estimating Capacity Density - Wind

- To estimate capacity density, we again relied on two studies:
  - Land-Use Requirements of Modern Wind Power Plants in the United States, 2009, by Denholm et al., a widely cited study that found a **direct impact** of 1 hectare/MW, or 100 MW/km^2
    - Denholm et al. included both temporary and permanent impacts and defined "direct impact" as "disturbed land due to physical infrastructure development." See image to the right for the study's sample image
  - Dynamic Land use Implications of Rapidly Expanding and Evolving Wind Power Deployment, 2022, by Atlas et al., which studied the **total area** of wind plants, defined as "all lands contained within outermost bounds of a wind plant" found a total area for wind plants in 2020 of ~4.8 MW/km^2 in the Northeast. See the image on the right for an example of the study's methodology



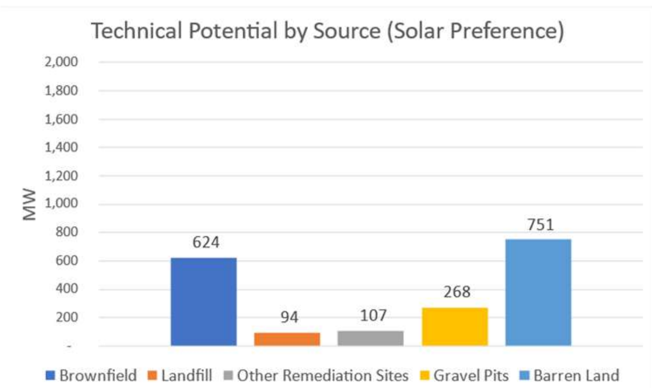


Estimating Capacity Density – Wind (2)

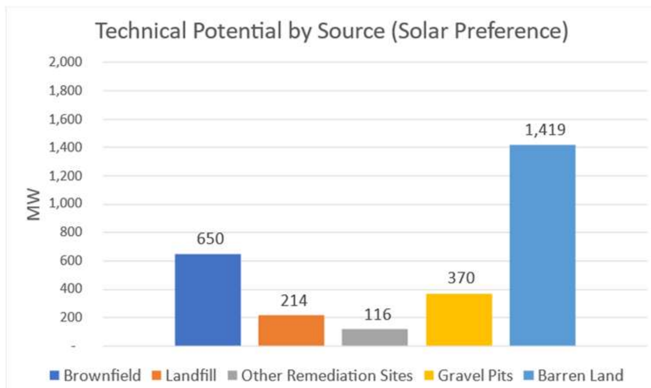
- Based on Denholm et al.'s findings, we estimate that the minimum parcel size necessary to install a single turbine (assumed 1.5 MW) is 3.7 acres
- Based on Atlas et al.'s findings, we estimate that the minimum parcel size necessary to install a two turbines is 154 acres
- To calculate the wind capacity on any given parcel we use a three-step function as follows:
  1. Is the parcel under 3.7 acres?
     I. If yes → 0 MW
     II. If no → Proceed to step 2
  2. Is the parcel equal to or greater than 3.7 acres, but under 154 acres?
     I. If yes → 1.5 MW
     II. If no → Proceed to step 3
  3. For parcels over 154 acres, calculate parcel capacity as acres * 0.02 (MW/Acre equivalent of Atlas et al.'s findings)

Sensitivities: Slope

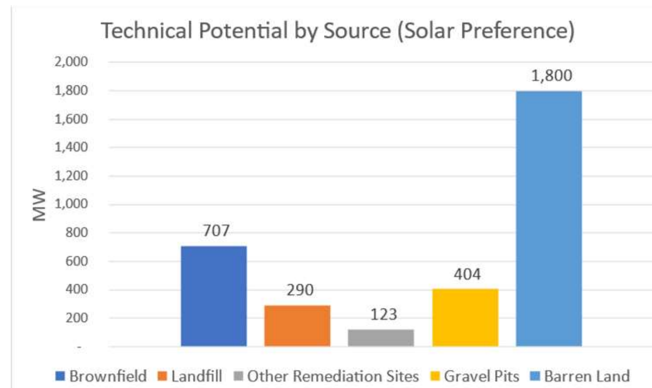
- For solar, the analysis is heavily sensitive to the cutoff applied for average parcel slope and aspect (direction of slope)
  - Especially true for project sited on barren land
- Given that some degree of leveling may be possible on certain sites, SEA tested a range of slope criteria as follows:



Low Case
5% slope for non-south facing parcels
10% slope for south facing parcels
Only consider true south (157-202 degrees)
➔ 1.8 GW total



Base Case
5% slope for non-south facing parcels
20% slope for south facing parcels
Consider SW-SE (112-247 degrees)
➔ 2.7 GW total



High Case
10% slope for non-south facing parcels
25% slope for south facing parcels
Consider SW-SE (112-247 degrees)
➔ 3.3 GW total

Data Sources

SEA identified the following data for use in the analysis:

Land Type	Data Source	Last Updated	Data Cleaning / Formatting
Landfill	ME DEP Remediation Sites	Aug 4, 2022	Area of each facility was provided in integer values with ~25% of sites rounded down to 0 ➔ assume 0.5 acres. Removed two largest brownfields (Dow Airfield and Great Northern Paper) due to existing plans for development. Excluded Hatch Hill Landfill due to existing landfill gas facility. Excluded all brownfields that were dams. Excluded landfills with existing solar development (per DEP report provided by TNC). Excluded duplicates.
Brownfields			
Other Remediation Sites			
Gravel Pits	ME DEP Mining Sites	March 2020	Cross referenced with 2021 DEP licensed facilities report to derive status and type of each site. Supplemented with 2022 report (obtained via data request) for any updates. Used text scrubbing to ID type of sites with no reference in either report. Filtered for gravel pits that were inactive and not a quarry (assuming majority are filled with water). Acreage of each site obtained by manual review of description fields. For sites with no data provided (n=84), SEA used average acreage from known sites (n=23) ➔ 19 acres
Barren Land	2019 National Land Cover Database (NLCD)	2019	Disproportionate amount of barren land on coast (rocky beaches) or islands ➔ Removed all barren land within 250m of water

Exclusionary Criteria – Data Sources

Data Layer	Data Source	Last Updated	Notes
Statewide Transmission Lines/Substations	Homeland Infrastructure Foundation-Level Data (HIFLD)	April 2, 2022	
CMP Distribution Circuit	Central Maine Power	May 17, 2022	Used both 3 and 1-2 phase distribution circuits in analysis
Slope	US Geological Survey - 3D Elevation Program	November 9, 2021	
Aspect			
Wind Speed	National Renewable Energy Laboratory	September 2017	Used wind speed at 80 m to approximate hub-height of smaller wind facilities (more likely to be sited on smaller disturbed parcels)
Protected/Conserved Areas	State of Maine	January 28, 2022	Includes gap status 1-3 lands
Railroads	ME DOT	June 2021	Applied 40 ft buffer around railroad lines
Existing Solar Facilities	ME DEP via TNC	November 2021	Dataset provided by TNC only contains solar facilities which have undergone DEP permit review (mostly 20+ acres)
Urban Areas	2019 National Land Cover Database (NLCD)	2019	

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