Brownfield to Brightfield Initiative in Oak Ridge, TN – 12346

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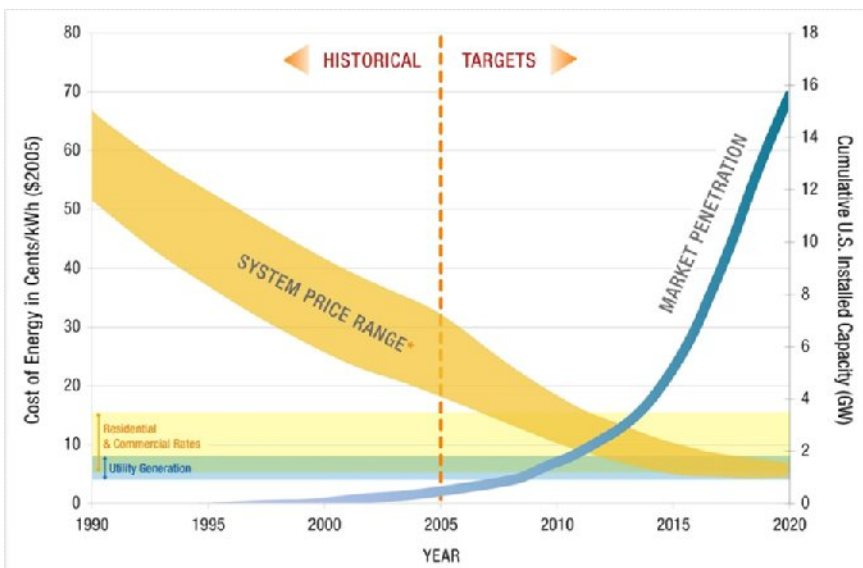
ABSTRACT

Experience characterizing, permitting, and restoring "Brownfield" sites—government or industrial sites with restricted future use due to the presence or potential presence of hazardous substances, pollutants, or contaminants—is being leveraged to identify opportunities for redevelopment into solar power generating facilities which, in this context, are called "Brightfields." Brownfield sites offer the expansive land necessary for large photovoltaic (PV) solar farms, but require an in-depth working knowledge of complicated regulatory restrictions and environmental constraints to develop them. As a part of the effort to identify opportunities for redevelopment of Brownfield sites for solar applications, a technical guide[1], was composed specifically for the development of solar generation on restricted use sites. The basis of the technical guide gives specific consideration to environmental requirements and installation methods breaking that into three areas for assessing: 1) levels of contamination, 2) ground penetration requirements, and 3) the requirements for aesthetics and maintenance. Brightfield projects are underway to support the technical guide and expand reindustrialization efforts for the former DOE Gaseous Diffusion Plant in Oak Ridge, TN.

INTRODUCTION

While market prices for solar remain high today the installed cost of solar per kWh continues to decline even as electricity from traditional sources escalates. The cost of solar is expected to reach grid parity (the point where solar is comparable to retail power) in most places in the United States between 2016 and 2018. See attached graph.



Market Sector	Current U.S. Market Price Range (¢/kWh)	Cost (¢/kWh) Benchmark 2005	Cost (¢/kWh) Target 2010	Cost (¢/kWh) Target 2015
Residential	5.8-16.7	23-32	13-18	8-10
Commercial	5.4-15.0	16-22	9-12	6-8
Utility	4.0-7.6	13-22	10-15	5-7

Fig. 1. President's goal for the Solar America Initiative making solar cost-competitive nationwide by 2015

As forecasted by the U.S. Energy Information Administration's (EIA's) *Annual Energy Outlook 2008* [3], the U.S. demand for electricity will increase by nearly 30% by 2030. In 2008, the contribution of solar PV to the nations demand was about 0.9%. EIA projects that solar PV electric generation will grow at a rate of 14.2% annually through 2035. This represents the largest increase of any of the renewable energy technologies. According a 2011 national study[4] conducted by the national Solar Energy Industry Association/Greenmedia Research, the solar industry is one of the fastest growing sectors of the U.S. economy. In fact, the first quarter of 2011 saw 66 percent growth in solar installations, staying on par with the 67 percent growth seen throughout 2010.

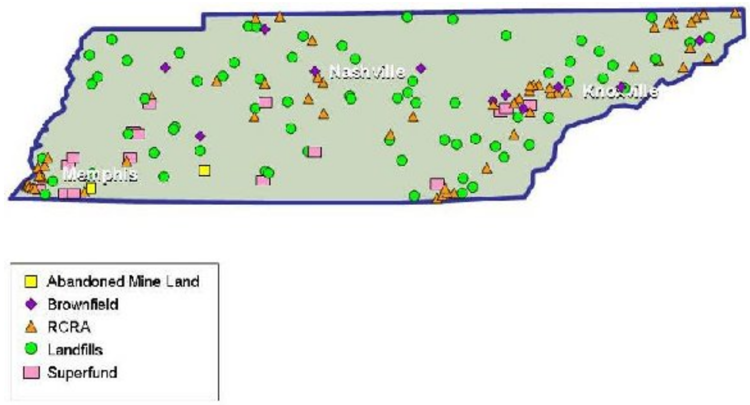


Fig. 2. Locations within Tennessee available for solar PV installations

The requirement for large amounts of land or surface area is a major constraint to the growth of PV systems. An average solar generating facility requires five or more acres for each MW of power generated. As a result, it is crucial to minimize the impact to previously undeveloped land. One solution is to reuse land that has been determined to have restricted future use such as Resource Conservation and Recovery Act of 1976 (RCRA)/Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) sites, former industrial sites, abandoned mines, or landfills that otherwise cannot be put to other beneficial use for many years. The U.S. Environmental Protection Agency tracks more than 11,000 of these sites, totaling over 14 million acres potentially suitable for solar PV installations. Many of these sites within Tennessee, and across the nation could be appropriate to be developed as solar PV farms. The combination of a predicted increase in the demand for PV generating capacity nationwide and the availability of potential sites within Tennessee and the country, make this initiative a major business opportunity.

A comprehensive site assessment allows for the review of a parcel of land using readily available data and on-site evaluation to better establish a path forward for the design and technical restraints relating to restricted use Brownfields. This assessment is used to make an educated decision on land use, economic value, and cost benefits related to the site as it pertains to Renewable Energy development. The ability to perform a detailed analysis on such sites and understand and/or mitigate the constraints is an added value to the success of future development.

Due to the complexity of restricted use sites and the potential economic value of its usability, an order of detail must be utilized. Building on current site assessment constituents, it is important to take into account the specific variables that can affect the feasibility of these sites. With that said, general rules still apply to lay out the approach for a site assessment.

SITE ASSESSMENT

A comprehensive site assessment allows for the review of a parcel of land using readily available data and on site evaluation to better establish a path forward for the design and technical restraints relating to restricted use sites or Brownfields. This assessment is used to make an educated decision on land use, economic value, and cost benefits related to the site as it pertains to Renewable Energy development. The ability to perform a detailed analysis on such sites and understand and/or mitigate the constraints is an added value to the success of future development.

Due to the complexity of restricted use sites and the potential economic value of its usability, an order of detail must be utilized. Building on current site assessment constituents, it is important to take into account the specific variables that can affect the feasibility of these sites including: solar energy availability, site access, proximity to the power grid, usable area and zoning, amount of shade/sun exposure, terrain/topography, economic incentives, climate, operation & maintenance costs,
community impact, and aesthetics and maintenance. Developing on restricted use sites requires an in depth evaluation including: surface/subsurface contamination, regulated use constraints, environmental concerns, disturbance/penetration concerns (subsurface utilities/structures, landfill cap specifications), restricted access, topographic constraints, and specific site restrictions to determine project feasibility and installation requirements.

ENVIRONMENTAL CONSIDERATIONS

When evaluating a development plan for a solar farm on a restricted use site, several environmental regulations need to be addressed to ensure that the project location, design, construction, and operation are compliant with the environmental regulatory requirements. Also, the environmental conditions need to be evaluated to ensure that the project is environmentally suitable. CERCLA, RCRA, RCRA Brownfields Prevention Initiative, National Environmental Policy Act (NEPA), National Historic Preservation Act (NHPA), the Endangered Species Act, and State-listed species protection laws contain environmental regulations and/or environmental considerations that need evaluation and the aspects of each that could be encountered. Other environmental considerations include assessing the impact to/from floodplains, wetlands, bird airstrike hazard near aircraft runways, erosion and wildfire risks, and unexploded ordnance potential.

ECONOMIC APPROACH AND ANALYSIS

The EPA is encouraging renewable energy development, especially PV solar, on potentially contaminated land and mine sites across the United States. Restricted use/Brownfield sites across the country number in the thousands including, abandoned sites cleaned up under the Superfund program, sites cleaned up by viable responsible parties under consent orders or agreements with state or federal regulators, and federal facilities cleaned up by the responsible federal department or agency. In particular, federal facilities that have undergone cleanup pursuant to various regulatory drivers, e.g., CERCLA, RCRA, Uranium Mill Tailings Radiation Control Act (UMTRCA), offer the potential for utility-scale sites based on land area, electric grid access, favorable sun exposure, and other site characteristics.

A key economic factor for solar site development at restricted use sites is that the land value typically is diminished due to the presence of residual contamination. Although the presence of residual contamination can present some challenges for the design and installation of solar panel infrastructure, the economic benefits of diminished land value, coupled with several other typical features of these sites, significantly outweigh these challenges. Economic considerations for solar development of restricted use sites include:

- Diminished land value that creates opportunities to purchase or lease properties far below the market value of comparable land.
- Residual soil contamination at restricted use sites is a factor having the potential to offset the advantage of diminished land values when is requires more expensive design and installation.
- Site preparation and environmental impacts that have been addressed in remediation efforts can offer costs savings associated with preparing a previously unused site.
- Security and site maintenance that may exist at the site provides a ready-made and already-expensed security infrastructure for a new solar installation.
- Grid Access may be readily available at many former industrial or federal facilities. However, some of the federal sites best suited for utility scale solar development are far from the grid and despite all of the advantages of site preparation and active maintenance and security, the economy and feasibility of connection to the grid should be evaluated rigorously.

DESIGN BASIS

Fig. 3. Restrictions on ground disturbance and aesthetic/maintenance requirements impact the design and installation of solar PV arrays

The predominant factors affecting the installation of solar on Restricted Use Sites are ground disturbance and maintenance/aesthetics. As with any site, these are factors that affect cost, environment, and overall feasibility of the project. However, they are especially important for these specific sites. The ability to circumvent these challenges by using collective knowledge and characterization expertise is a valuable strength. For the purposes of the technical Guide, three specific case models have been developed – 200kW Design, 1MW Design, and 10MW Design.

- **200kW Design:** The model chosen for this site is an Unconstrained/Highly Visible area. Due to its characteristics, ground disturbance options are vast, however, maintenance/aesthetics are of high concern. This site would be in a highly visible area where grounds maintenance, visual appeal, and architecture drive the design. Examples of sites that fit this model may be government facilities, remediated sites, or road frontage sites.
- **1MW Design:** The model chosen for this site is a Minimal Disturbance/Moderate Aesthetic Concern area. Due to its characteristics, ground disturbance is a concern and the options are more constrained. Also, the concern for maintenance/aesthetics is a constraint. This site may not be in a visible area but may have other maintenance concerns such as undergrowth or erosion concerns as well as disturbance concerns due to contamination or shallow burial constraints. Examples of sites that fit this model may be military bases, Brownfields, or wetlands.
- **10MW Design:** The model chosen for this site is a Non-Intrusive/Minimal Aesthetic Concern area. Due to its characteristic, ground disturbance is not allowed but

maintenance/aesthetics are of no concern. This site may be highly contaminated or have a cap of some sort and low vegetation/ low visibility concerns. Examples of sites may be landfills or Brownfields.

A basic decision that must be made when initiating the design of a large ground mounted photovoltaic system is the type of solar module to be used. There are two types of modules suitable for this application: thin film (amorphous) and crystalline. Because of cost, efficiency, and operational advantages, crystalline modules were chosen as the basis for each of the three case models.

Ground Disturbance Considerations
Many Brownfield sites will have limits as to the degree of intrusion into the surface or subsurface at the site. These limits may be the result of soil contamination, shallow groundwater contamination, buried contaminated material, or to protect an engineered feature such as a clay, membrane, or asphalt cap. If the site is a regulated site, these restrictions may be spelled out in a decision document such as a ROD or an Action Memorandum. This design report will consider three ground disturbance scenarios, unconstrained, minimal disturbance, and non-intrusive.

Maintenance/Aesthetic Considerations
It is imperative to know the importance of aesthetic appeal of the solar site being evaluated so the appropriate design considerations and costs can be considered. A site close to public access such as a major road, subdivision, or park will require much more attention to aesthetics than a site isolated from public view and access. The designs and maintenance requirements for these two sites are significantly different. Maintenance/aesthetic considerations are categorized at three levels—minimal concern, some concern, high concern/visibility—to determine the design.

GENERIC STRUCTURAL DESIGN RECOMMENDATIONS

When evaluating a restricted use site for potential solar-PV installations the first variable that should be investigated is ground disturbance. For the purpose of our technical guide ground disturbance has been separated into three unique categories: Unconstrained, Minimal Disturbance, and Non-Intrusive. Variables like ground penetration, depth of ground penetration, soil conditions, and levels of contamination (if any) should be evaluated at this time. Acquiring a current geotechnical report of the proposed site will aid with this evaluation.

Determining the extent of ground disturbance will provide important information on what type of structural racking will be permitted to use with the solar-PV system in the proposed site. For the purpose of this report structural racking refers to the support systems that the solar-PV modules are mounted onto. These support systems are manufactured from a variety of materials (steel, metal, aluminum, plastic, composite or membrane structure). Structural racking can either penetrate the ground or rest on top of the ground without any penetration. When soil conditions are good and ground penetration is acceptable, structural racking can be pile driven into the earth using the technologies like helical piles or earth screws. In some scenarios where soil conditions are poor, the structural racking may need to be accompanied by a concrete foundation/footer. This concrete foundation/footer will provide additional structural support to secure the solar-PV array into place. In poor soil conditions where ground penetration is unacceptable, structural racking can be mounted onto a concrete ballast system. Additionally, emerging technologies like photovoltaic groundcover systems that adhere solar thin-film directly onto a membrane structure that rest on top of the ground can be an optimal solution for scenarios where soil conditions are poor and ground penetration is unacceptable. Soil conditions along with local wind/snow load requirements will determine the depth of ground penetration for the structural racking and foundations. All structural racking and foundations must be constructed in accordance will all federal, state, and local codes/permits. Federal, state, and local codes/permits may require a state licensed professional engineer to approve of all system drawings and ensure that the solar-PV system will abide with all federal, state, and local codes. The proposed solar-PV module for the system should be cross-referenced with the structural racking system for compliance.

Site-specific maintenance/aesthetic concerns should be addressed following the establishment of a site-specific ground disturbance category. Maintenance/aesthetic concerns are also divided into three unique categories: Minimal Concern, Some Concern and High Concern. Variables like grounds cover, grounds maintenance, mowing ability, and landscaping should be evaluated at this time. Maintenance/aesthetic information will illustrate how the finale system will be perceived by the public as well as how much time and resources will be required for upkeep of the system. Maintenance/aesthetic concerns affect the types of structural racking in many ways. Should there be a high concern for grounds maintenance/mowing ability one should choose a structural racking system with a 4-foot minimum clearance to allow for mowing machinery and physical labor upkeep. In most cases, higher concern for maintenance/aesthetics is typically associated with additional cost.

Once site-specific ground disturbance and maintenance/aesthetic concerns have been formulated multiple structural design solutions that will work for each specific scenario can be established. Within each unique scenario numerous solutions are provided. Client and general contractor should evaluate each solution within the selected scenario to determine the most appropriate and economical approach to integrate the potential solar-PV system.

ELECTRICAL AND DESIGN RECOMMENDATIONS

Material Specifications

When evaluating potential product and equipment vendors and installers, there are several criteria that should be evaluated related to the materials used in the project. The following provides reasonable guidelines to follow but is not all inclusive.

Module Design Elements

There are two basic types of solar modules considered for large ground mount installations on restricted use sites, thin film modules and crystalline modules. Each of these module types has varying capacities and properties and each has its own unique advantages and disadvantages. These distinctions between solar modules are used in large utility or ground mounted arrays.

Inverter Selection

There are several factors to consider when determining the appropriate inverter to implement into a project. These factors include, but are not limited to, utility infrastructure (single phase vs. three phase), module type, project size/array layout, and warranty requirements. Inverters come in all shapes and sizes and are offered from many vendors. Selecting the correct inverter is key to maximizing the performance of the prospective system.

PV Array

The PV array shall be laid out to provide the greatest return on investment. Great effort should be made to provide an aesthetically pleasing design. Modules shall be grouped together for ease of wiring and mounting, symmetrical arrangements, and to keep costs down. Modules should face south and be at optimum tilt when possible to obtain maximum power. Physical and shading obstructions should be avoided. Open air space should be made available behind the panels to avoid panel overheating and maximization of power.

Interconnection options

There are several issues to be considered regarding the interconnection of a PV system to the local utility grid. These include, but are not limited to:

- Electrical infrastructure available at the site
- Specific utility interconnection requirements
- Net meter vs. generation meter options

BROWNFIELD TO BRIGHTFIELD INITIATIVE IN OAK RIDGE, TN

Two solar projects have been identified to support the outcomes of the Brownfield to Brightfield technical guide. Phase one of the Brownfield to Brightfield initiative is a 200 kW solar array to be owned, designed and operated by Restoration Services, Inc. (RSI) in cooperation with DOE, Oak Ridge. The project will serve as a model for technical solutions that require special consideration on aesthetics and have no penetration constraints. Power generated will be sold to the Tennessee Valley Authority (TVA) as a part of the Generation Partners Program.

The 200 kW project is located directly to the right of the main entrance to East Tennessee Technology Park (ETTP). ETTP started as the Oak Ridge Gaseous Diffusion Plant which began operations in World War II as part of the Manhattan Project. Its original mission was to produce uranium enriched in the uranium-235 isotope for use in atomic weapons. The plant produced enriched uranium for the commercial nuclear power industry from 1945 to 1985 and was permanently shut down in 1987. Restoration of the environment, decontamination and decommissioning of the facilities, and management of the legacy wastes have since been major activities at the site. Reindustrialization efforts of the site began in 1996, and the site was renamed ETTP in 1997.

DOE is converting ETTP into a private industrial park, and reuse of key site facilities through title transfer is part of the closure plan for the site. The accelerated cleanup approach offers uncontaminated buildings, suitable for immediate private industrial use, for title transfer to the Community Reuse Organization of East Tennessee (CROET). CROET then leases this property to private industry. RSI is purchasing 1.25 acre from CROET that is known as ED-4W located directly on TN State Highway 58 in a high visibility location.

Phase two of the Brownfield to Brightfield initiative is to develop a large, utility-scale, megawatt solar farm on a Brownfield site. The proposed location for the Phase II initiative addresses development on a contaminated site with restricted penetration capabilities and minimal aesthetic/maintenance requirements.

CONCLUSION

There are exciting opportunities to turn Brownfields into Brightfield solar energy solutions for meeting the future renewable energy needs of our country. Brownfields that offer the large surface area required for solar PV farms coupled with the technical guide for the installation of solar farms on restricted use sites supports efforts to develop the solar capacities and expertise to tap this future market. The initial projects designed following the technical guide will provide verification of the installation requirements and beneficial reuse of restricted use sites.

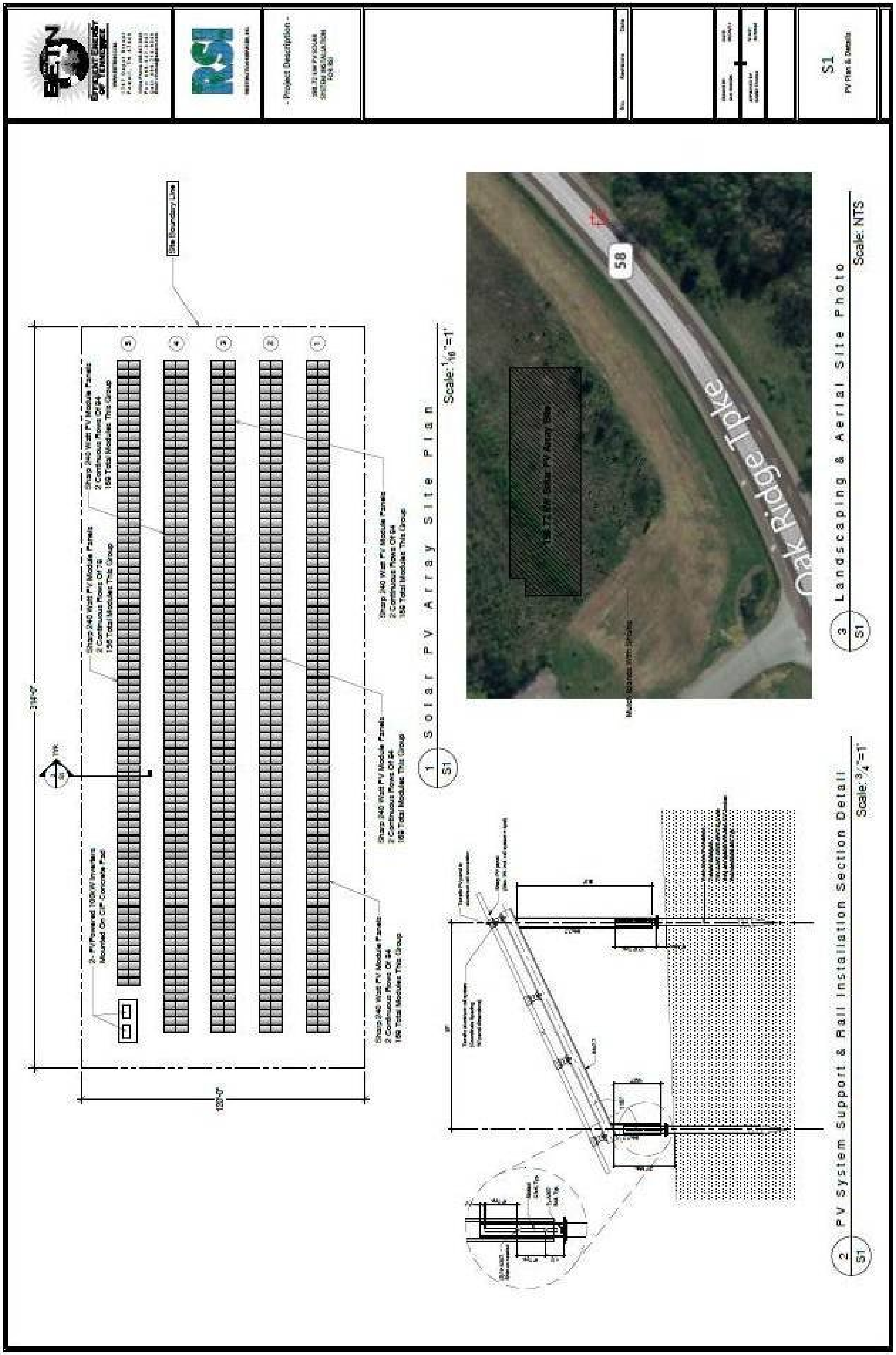


Fig. 3. Phase One project design

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