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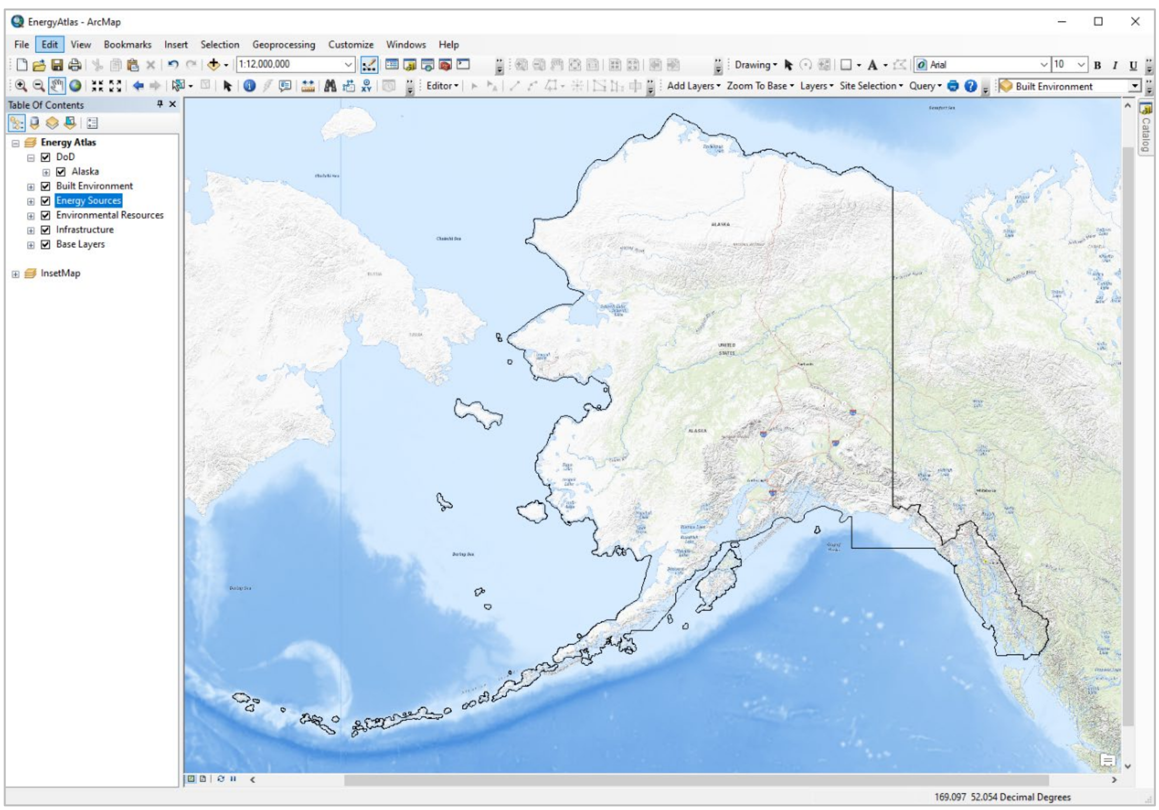
Energy Atlas—Mapping Energy-Related Data for DoD Lands in Alaska

Phase 1—Assembling the Data and Designing the Tool

Caitlin A. Callaghan, Matthew F. Bigl, Brandon K. Booker, Kyle M. Elliott, Paulina H. Lintsai, Marissa J. Torres, Kathryn P. Trubac, and Jacqueline M. Willan

October 2021



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Final Report

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Under PE 0633734A, Project T15, "Secure and Resilient Power Generation in Cold Region Environments"

Abstract

The U.S. Army is the largest Department of Defense (DoD) land user in Alaska, including remote areas only accessible by air, water, or wintertime ice roads. Understanding where energy resources and related infrastructure exist on and adjacent to DoD installations and training lands can help inform Army decision-makers, especially in remote locations like Alaska. The *Energy Atlas–Alaska* provides a value-added resource to support decision-making for investments in infrastructure and diligent energy management, helping Army installations become more resilient and sustainable.

The Energy Atlas–Alaska utilizes spatial information and provides a consistent GIS (geographic information system) framework to access and examine energy and related resource data such as energy resource potential, energy corridors, and environmental information. The database can be made accessible to DoD and its partners through an ArcGIS-based user interface that provides effective visualization and functionality to support analysis and to inform DoD decision-makers. The Energy Atlas–Alaska helps DoD account for energy in contingency planning, acquisition, and life-cycle requirements and ensures facilities can maintain operations in the face of disruption.

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Preface

This study was conducted for the U.S. Army Corps of Engineers under PE 0633734A, Project T15, "Secure and Resilient Power Generation in Cold Region Environments." The technical monitor was Dr. Thomas Douglas, U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory (ERDC-CRREL).

The work was performed by the Engineering Resources Branch (Dr. Caitlin A. Callaghan, Chief) of the Research and Engineering Division (Dr. George Calfas, Chief), ERDC-CRREL, with support from the Data Representation Branch (Mr. Vineet Gupta, Chief) of the Topography, Imagery, and Geospatial Research Division (Ms. Jennifer L. Smith, Acting Chief), Geospatial Research Laboratory (ERDC-GRL). At the time of publication, the Deputy Director of ERDC-CRREL was Mr. David B. Ringelberg, and the Director was Dr. Joseph L Corriveau. The Deputy Director of ERDC-GRL was Ms. Valerie L. Carney, and the Director was Mr. Gary W. Blohm.

COL Teresa A. Schlosser was Commander of ERDC, and Dr. David W. Pittman was the Director.

Acronyms and Abbreviations

AASHTO	American Association of State Highway Transportation Officials
AEA	Alaska Energy Authority
AEDI	Alaska Energy Data Inventory
AIA	Army Installation Atlas
AK DOT	Alaska Department of Transportation
ANL	Argonne National Laboratory
AOI	Area of Interest
CERL	Construction Engineering Research Laboratory
CERP	Clean Energy Resources and Projects
CRREL	Cold Regions Research and Engineering Laboratory
DGGS	Division of Geological and Geophysical Surveys
DHS	Department of Homeland Security
DISDI	Defense Installation Spatial Data Infrastructure
DNR	Department of Natural Resources
DoD	Department of Defense
DOE	Department of Energy
EIA	Energy Information Administration
EISPC	Eastern Interconnection States' Planning Council
ERDC	U.S. Army Engineer Research and Development Center
EZMT	Energy Zones Mapping Tool
FOUO	For Official Use Only
GIS	Geographic Information System

GISMO	Geographic Information Supporting Military Operations
GRL	Geospatial Research Laboratory
HIFLD	Homeland Infrastructure Foundation-Level Data
IE&E	Army Installation, Energy, and Environmental
IGI&S	Installation Geospatial Information and Services
IRENA	International Renewable Energy Agency
MIRTA	Military Installations, Ranges, and Training Areas
NCDC	National Climatic Data Center
NCEI	National Centers for Environmental Information
NOAA	National Oceanic & Atmospheric Administration
NREL	National Renewable Energy Laboratory
NWIS	National Water Information System
OPSEC	Operational Security
OSD	Office of the Assistant Secretary of Defense for Sustainment
PV	Photovoltaic
REAP	Renewable Energy Alaska Project
RE Atlas	NREL Renewable Energy Atlas
SERDP	Strategic Environmental Research and Development Program
USCRN	United States Climate Reference Network
USDA	United States Department of Agriculture
USGS	United States Geological Survey

1 Introduction

1.1 Background

The Army accounts for energy in contingency planning, acquisition requirements, and ensuring facilities can maintain operations in the face of disruption. Energy resources and related infrastructure exist on and adjacent to Department of Defense (DoD) installations, and access to information about these resources is critical for decision-makers. A robust and easily accessible data source is necessary to ensure that decision-makers have the best-available information on hand to perform efficient actions. This becomes especially important in remote locations like the DoD installations in Alaska where extreme environment conditions can cause significant disruptions to operations and planning.

Various entities have mapped energy resources across the State of Alaska by using approaches already applied across much of the U.S. The Energy Information Administration (EIA) collects, tabulates, and maps energy data across states, regions, energy consumer sectors, etc. and provides this information to public users in a variety of forms, including downloadable tabulated data and through maps and charts to help visualize data trends. To help energy decision-makers, the Department of Energy (DOE) National Laboratories have developed several resource mapping tools based on available energy resource data and resource constraints (e.g., water availability); infrastructure data (e.g., existing transmission and distribution systems and gas pipelines); and, primarily for project development, environmental data (e.g., sensitive habitat, species, resources, roads, and trails). Some of these mapping tools help inform policy decisions by offering the functionality to support analysis of policy options and to understand the risks associated with different options (e.g., implications of sea-level rise for siting of generation facilities). The existing suite of DOE lab tools comprise useful examples of functionality. Such mapping tools can help support sound, resilient, and sustainable DoD decision-making and investment.

Geographic information systems (GIS) provide a consistent framework to collect, organize, and examine location-based data and are increasingly used as more tools are developed to help a variety of decision-makers. To support DoD decision-makers, academic institution partners have also developed and utilized GIS technologies. For example, (Strategic Environmental Research and Development Program (SERDP) project RC-2110 developed the Geographic Information Supporting Military Operations (GISMO) support tool as part of a project to identify how a changing climate could impact U.S. Army Alaska training lands and to provide needed information to land managers to help them plan accordingly (T. Douglas 2016). William and Mary's Center for Coastal Resources Management applies GIS and remote-sensing techniques to help address coastal, watershed, and landscape issues. These are examples of the resource issues that could impact DoD lands. The technologies are sources of information, opportunities for data coordination (e.g., across GIS datasets), and examples of functionality needed to support decision-makers.

1.2 Objective

The objective of this project was to develop an underlying database of energy information related to DoD lands in Alaska and to make this database accessible through a user interface. This interface will provide effective visualization and functionality that supports analysis and informs DoD decision-makers and DoD partners. The *Energy Atlas* (here developed as *Energy Atlas–Alaska*) provides a value-added resource to support decision-making for investments in infrastructure and diligent energy management, helping DoD installations become more resilient and sustainable.

1.3 Approach

In this research, the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) is leveraging its expertise in cold regions and Arctic infrastructure to investigate and develop a data repository of energy-related information for DoD installations and their partners in Alaska. This effort draws on existing data, identifies data gaps, and makes recommendations for addressing those data gaps. We collected and organized data using a GIS-based framework and considered existing user interfaces to determine the most effective and efficient way to make the collected GIS data available to users.

Using this information, as well as feedback from representative stakeholders, Energy Atlas–Alaska was developed such that it is compatible with a currently available GIS platform already in use by DoD and the Army. Additional functionality built into Energy Atlas–Alaska simplifies access to underlying data and its visualization.

1.4 Impact to DoD and the Army

The largest DoD land user within Alaska is the U.S. Army, overseeing more than 600,000 hectares of land, including remote areas only accessible by air, water, or wintertime ice roads (T. Douglas 2016). Communicating the resources available across these lands and how they may be connected to resources adjacent to DoD lands is critical to the DoD investment and strategic decision-making process and will inevitably lead to increased resilience and sustainability. The importance of this type of information for installation and facility planning is compounded by the complications provided by the extreme climate and remote settings of these locations.

The Energy Atlas–Alaska helps DoD account for energy in contingency planning, acquisition, and life-cycle requirements and ensures facilities can maintain operations in the face of disruption. The framework developed during this project can easily be applied to assets in other states and tai-lored to meet specific environmental and regulatory constraints.

The Energy Atlas–Alaska uses spatial information and provides a consistent GIS framework to collect and examine energy and related resource data such as energy resource potential, energy corridors, and environmental data for DoD lands in Alaska. The database can be made accessible to DoD and its partners through an ArcGIS-based user interface that can provide effective visualization and functionality to support analysis and to inform DoD decision-makers and DoD partners. Its functionality and scope can also be iteratively expanded to include more data and tools to help a variety of decision-makers based on their needs, across all DoD lands within Alaska. Both open access and limited distribution datasets are available and will be detailed throughout this report.

This report explores the currently available data sources and tools both within Alaska and nationwide and outlines the functionality and benefits of the Energy Atlas–Alaska. In the following sections, we will review the current literature, decision support tools, and data repositories (section 2) and provide more detailed information about data collection and integration into the Energy Atlas–Alaska (section 3). Section 3 also reviews the stakeholder engagement and data gaps identified for future consideration. In sections 4 and 5, we provide a detailed description of the Energy Atlas–Alaska functionality along with an example use case. Section 6 outlines next steps for building on the work presented in this report and transitioning the developed atlas to a wider-reaching DoD platform.

2 Literature Review

Using spatial information to understand the world and its different environments is a longstanding practice. Over the past few decades, there have been significant advancements in GIS mapping software that have provided interactive platforms capable of storing and processing vast amounts of spatial data for manipulation, analysis, and management. For the ArcGIS platform used in this study, the geographic or spatial dataset overlaying a base map is referred to as a *data layer*. With the advancements in user-friendly GIS software and the expansion of geographic information science, a surfeit of data layers have been developed for a variety of applications, including environmental monitoring, product marketing, city planning, and land development. Most GIS applications use multiple layers, and identifying the most germane layers for an analysis among the many options available can be time consuming. The compilation of layers tailored to a specific application, referred to as an *atlas*, provides a simplified interface for policymakers, researchers, and the general public and can have huge impacts on project expedience and effectiveness. Atlases, and similar tools that combine relevant layers for assessing energy consumption, development opportunity, and environmental impact, have been developed for regional, state, national, and global applications. The following sections provide overviews of some of the examples that informed the Energy Atlas–Alaska's functional design and development.

2.1 Decision support

The information available to decision-makers has a high impact on wide-reaching financial and logistical determinations that are made every day. Some of this information is more readily available and usable and is, thus, more effective. Subject matter experts develop decision support tools to help improve access and usability of information and, consequently, to improve the quantity and quality of information available for decision-makers' consideration. Such tools have different scopes, functions, and user groups. Some tools are even designed to work with other tools (e.g., data inputs for analysis or visualization tools). Regardless, individually or collectively, these tools have a common purpose: to help decision-makers access and understand the information needed to make the best-informed decision possible.

A number of freely available decision support tools and data sources are available for decision-makers to use. Each of these tools has a specific purpose; but the underlying data, in many cases, are useful to address a variety of decision areas, including, but not limited to, the following:

- Infrastructure projects (e.g., electricity or telecommunication transmission towers)
- Transportation projects (e.g., roadways and railways)
- Energy policies (e.g., energy source diversity requirements and energy security objectives)
- Resilience planning (e.g., backup supplies)
- Resource acquisition (e.g., investments in new and additional equipment)

The Energy Atlas–Alaska aggregates data from several sources and provides a visualization of the data, based on user preferences, to inform several energy-related decision areas. The data layers in the Energy Atlas–Alaska are specifically selected to help DoD decision-makers consider information about the built and natural environments, both on and off DoD lands, and the infrastructure (e.g., road systems, water systems, electricity systems, and energy supply systems). For example, these data can help inform decisions about the following:

- Planning for new development
- Planning for retrofits or updates to the existing built environment
- Resilience investments (e.g., energy and water)
- Infrastructure analysis and expansion (e.g., electricity distribution networks and natural gas pipelines)
- Connectivity to and reliance on non-DoD supply networks
- Integration of alternative energy supplies (e.g., wind, solar, geothermal, and natural gas)
- Energy and resilience policies and objectives for DoD installations

While there are many other areas that the data compiled in the Energy Atlas–Alaska can inform, the above provide a representative list. Additionally, the Energy Atlas–Alaska is designed such that, as needed and available, more data can be integrated to provide a comprehensive tool with a readily understandable visualization of the data relevant to the user's inquiry. In this report, we illustrate the utility of the Energy Atlas–Alaska and demonstrate its capabilities to inform a hypothetical DoD installation inquiry (section 5).

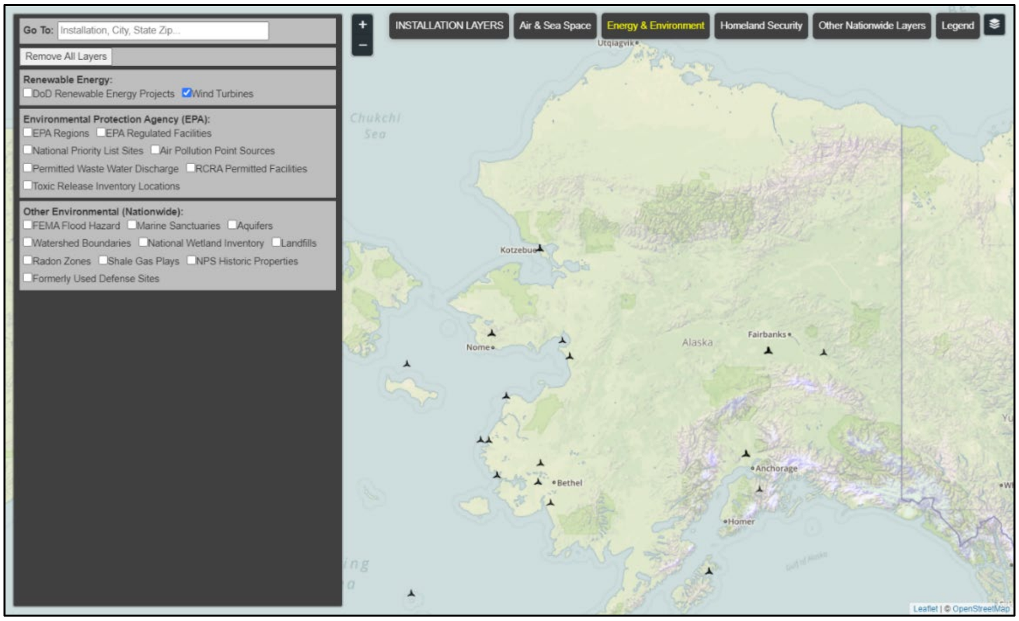
The discussion that follows (sections 2.2–2.5) provides an overview of a representative set of freely available data mapping tools and data sources that can inform DoD decision-makers as described above. This section is not a complete list of all available tools and data sources but illustrates the diversity of tools and data sources available relevant to potential energy-related analysis and decision-making. While a number of subscription or pay-for-access tools are available, we chose to include only those that are freely available. We expect that decision-makers with limited financial resources (e.g., government agencies) would likely use a free resource where available. Furthermore, a number of the tools and data sources highlighted below have been developed by or for federal or state agencies.

2.2 DoD data tools and sources

2.2.1 Defense Installation Spatial Data Infrastructure (DISDI) Program

The DoD uses geographic information systems and geospatial data to manage the existence and completeness of its property inventory. This technology has modernized how it operates and manages installations, ranges, and training lands. The Defense Installation Spatial Data Infrastructure (DISDI) Program has oversight of how this data is collected and managed and is responsible for "coordinating, standardizing, and leveraging geospatial information and analytics across DoD's global business mission areas to better manage installations and the warfighter support infrastructure" (OSD [Office of the Assistant Secretary of Defense for Sustainment] 2020). DISDI has developed an online atlas that catalogs comprehensive global geospatial datasets tailored to the U.S. defense sustainment mission, including energy, environment, and installations (OSD 2020). The DISDI atlas provides a platform (Figure 1) for sharing and viewing geospatial datasets across all departments of the DoD, which can be used for emergency response plans, environmental impact assessments and management, and facility and infrastructure planning. It includes layers that can be used to assess the potential for renewable energy development and to map existing and proposed utilities and means of transport for military lands. The majority of this geospatial data focuses on the contiguous U.S., leaving data gaps for Alaska (e.g., wind potential). This platform has dynamic map layers used for viewing purposes only; it does not have an analytical component. However, DISDI does provide geospatial analysis for DoD installations upon request (OSD 2020).

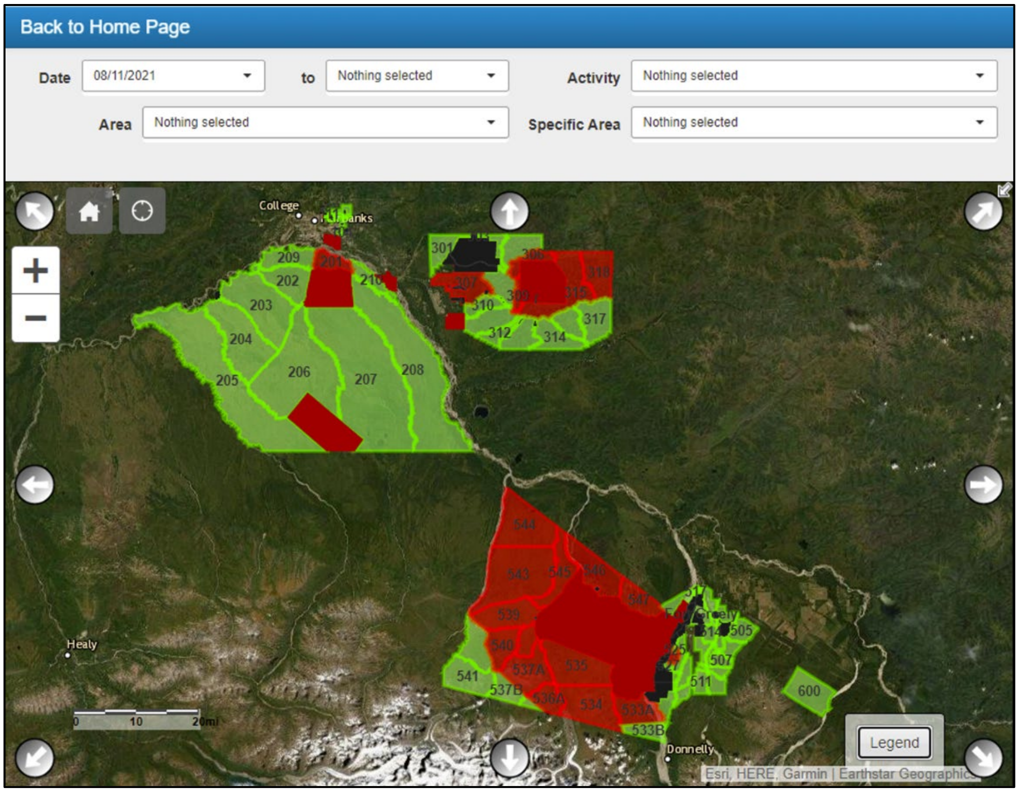
Figure 1. Example of the DISDI mapping tool displaying wind turbine power generation sites in Alaska. (Image reproduced from DoD 2020. Public domain.)



2.2.2 Fort Wainwright installation land-use map

Available in an open-source format in ArcGIS, this land-use map (Figure 2) focuses primarily on Fort Wainwright's land use and outlines ranges and training areas, restricted areas, roadways, and wildlife management regions and how they relate to outdoor recreational use (Taylor 2021). The purpose of this tool is to inform the public what areas are open for recreation or what locations may be closed temporarily during periods of military use. The goal is to avoid conflict between recreational activities and military missions (U.S. Army 2019). This data source provides a valuable breakdown of the installation's specific land use, which helps inform where to locate future energy projects.

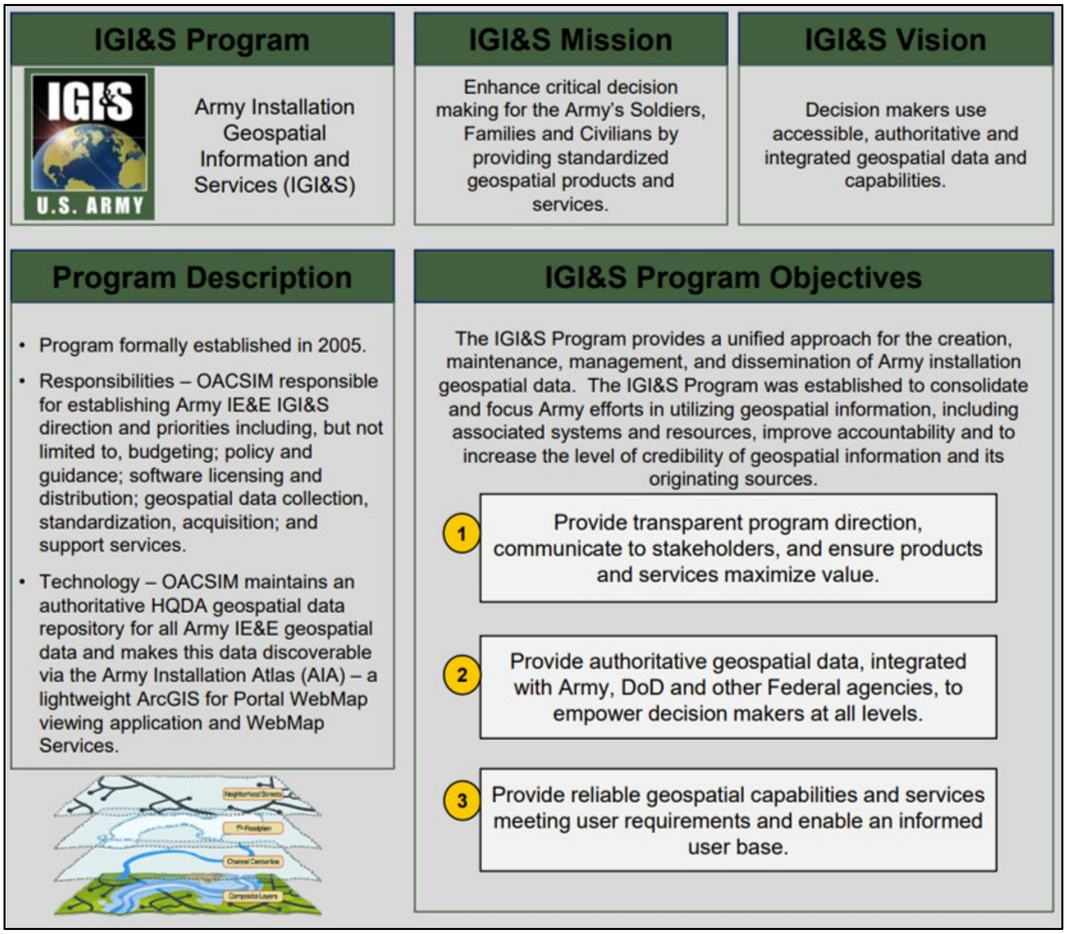
Figure 2. Fort Wainwright land-use map. (Image reproduced with permission from Taylor 2021.)



2.2.3 Army Installation Atlas (AIA)

The Army Installation Atlas (AIA) provides access to the Army Installation, Energy, and Environmental (IE&E) geospatial data through web services, maps, and applications. The site requires Common Access Card credentials to access the Army Installation Geospatial Platform that hosts the data. Furthermore, the user must then register to access the AIA (U.S. Army 2020a). The Installation Geospatial Information and Services (IGI&S) program was established in 2003 to consolidate and focus Army efforts on geospatial information, and there is an Army-wide policy for installations to use and update this tool as improvements are made (U.S. Army 2017). Figure 3 provides a visual overview of the IGI&S program, and Bauer et al. (2019) further details the AIA resource. IE&E datasets are related to public works, infrastructure (including electrical, thermal, and natural gas assets), natural resources, and installation land use (Bauer et al. 2019).

Figure 3. IGI&S program overview. (Image reproduced from Bauer et al. 2019. Public domain.)



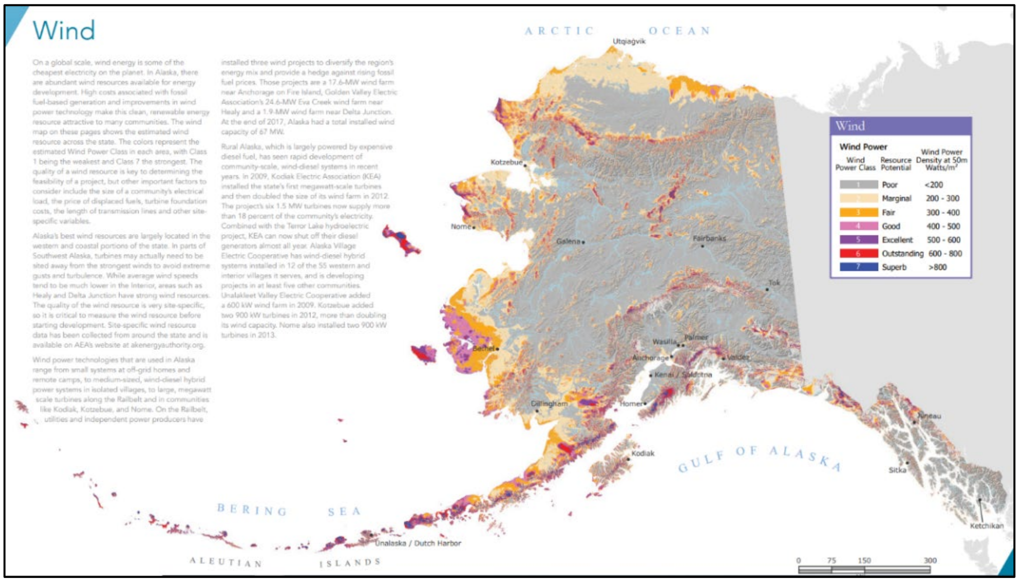
2.3 Alaska data tools and sources

2.3.1 Renewable Energy Atlas of Alaska

The Alaska Energy Authority (AEA) is an independent corporation established in 1976 that aims to "reduce the cost of energy in Alaska" by assisting in the development of reliable, efficient, and sustainable energy systems across Alaska (AEA 2021). AEA provides grant programs to organizations that federate geospatial data on Alaska's renewable energy potential, energy development, and economic planning. In 2006, AEA collaborated with the Renewable Energy Alaska Project (REAP) to develop the Renewable Energy Atlas of Alaska, a comprehensive report (Figure 4) that details renewable energy potentials across Alaska (AEA and REAP 2019). The Renewable Energy Atlas of Alaska incorporates geospatial data as static maps for the state's current energy infrastructure, including oil, coal, wind, solar, geothermal, hydro, biomass, and tidal energy resources (AEA and

REAP 2019). The Renewable Energy Atlas of Alaska was designed to provide free and relevant knowledge of Alaska's energy infrastructure for the public, policymakers, investors, and developers.

Figure 4. Example of the Renewable Energy Atlas of Alaska 2019 displaying the potential wind energy generation across the state. (Image reproduced with permission from AEA and REAP 2019.)



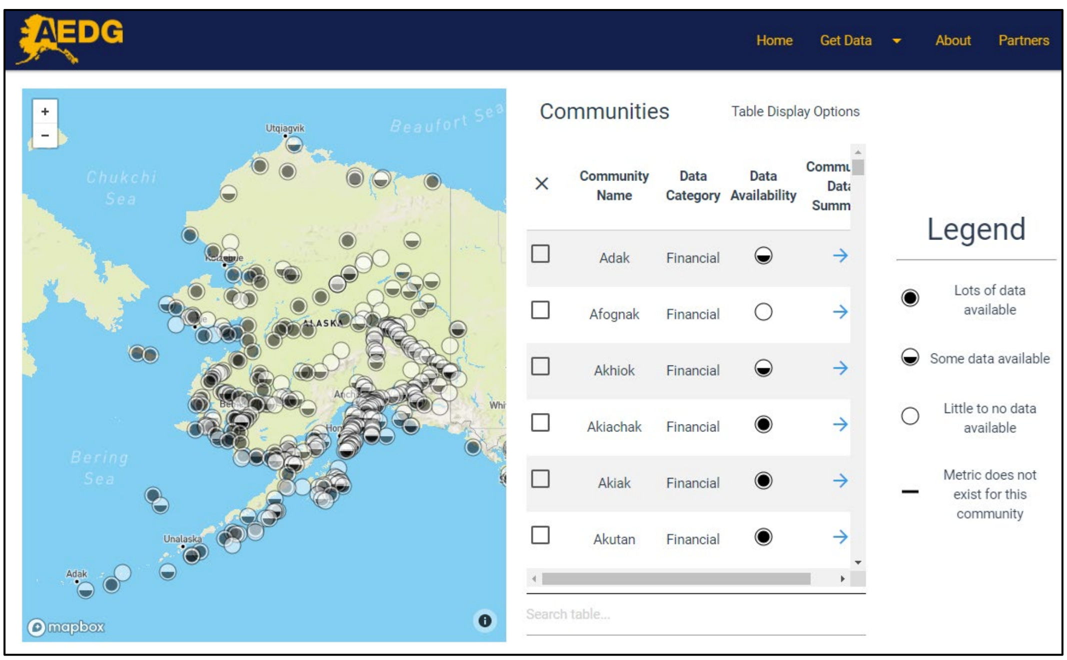
2.3.2 Alaska Energy Data Inventory (AEDI)

The Alaska Energy Data Inventory (AEDI), funded by AEA, includes an interactive energy atlas developed by the University of Alaska Fairbanks (AEA 2020). AEDI displays geospatial data layers for current energy projects and generation sites, including biofuels, biomass, geothermal, solar, wind, and hydropower. It also includes potential for renewable energies based on meteorological and land type data (e.g., forested for biomass production). It was designed to consolidate and inventory Alaskan energy resources data and is available to the public, policymakers, and investors to identify how to develop the most economic combination of energy resources to meet the public's needs. AEA recognizes that, due to a lack of high-quality data, this inventory does not represent many parts of rural Alaska (AEA 2020). The AEDI is current through 2018; but although the datasets are still accessible, the interactive atlas is no longer available. At the time of writing, the datasets of the AEDI are being updated and migrated to the AEA geospatial data clearinghouse.

2.3.3 Alaska Energy Data Gateway

The Alaska Energy Data Gateway (Figure 5) is implemented by the University of Alaska and several partners, with funding from AEA, DOE's Established Program to Stimulate Competitive Research, and the DOE's Grid Modernization Initiative. The site compiles comprehensive energy and selected socioeconomic data for communities across Alaska (University of Alaska 2020). The platform has three categories of data: (1) Financial Capacity Metrics, focusing on capital and regional costs of business; (2) Human Capacity Metrics, focusing on the skills required to develop, implement, and maintain energy projects in a target community; and (3) Technical Capacity Metrics, focusing on the current energy use for electric, transportation, and heating and cooling as well as the basic infrastructure of a community (University of Alaska 2020). These data provide the public, policymakers, and developers with a detailed understanding of the infrastructure, financial capacity, and available skillsets to make informed decisions about the potential to improve or modernize energy systems.

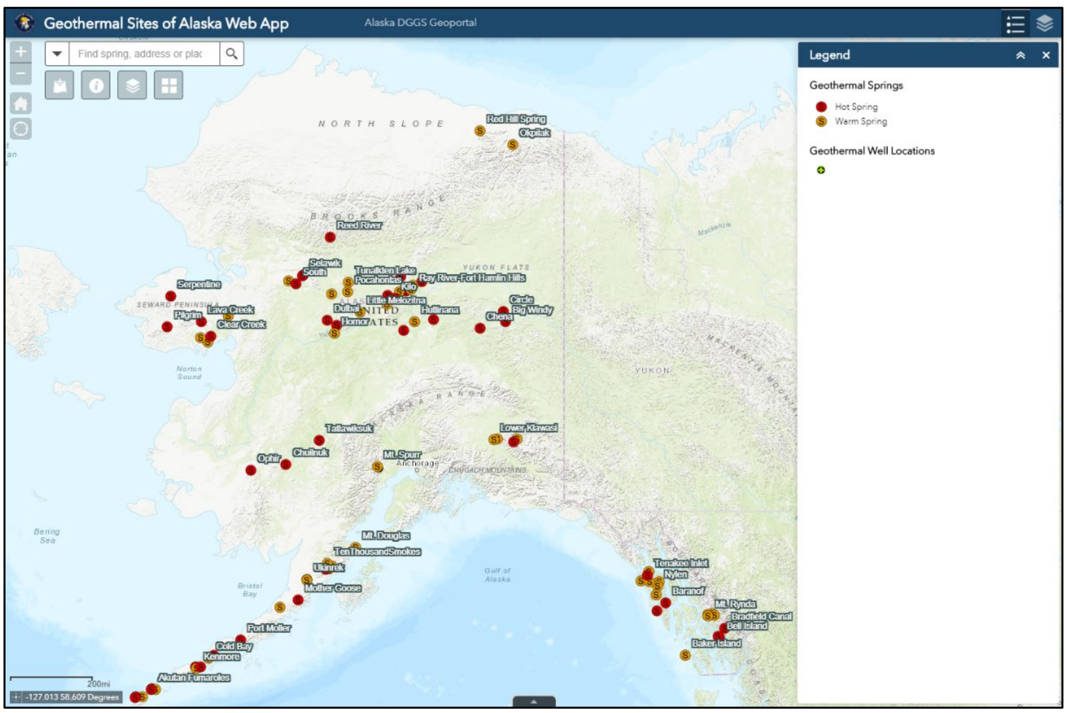
Figure 5. Example of the Alaska Energy Data Gateway mapping tool displaying financial capacity metrics across the state (Image reproduced with permission from University of Alaska 2020; background maps provided by Mapbox.)



2.3.4 Alaska Division of Geological and Geophysical Surveys (DGGS) GeoPortal

The Alaska Division of Geological & Geophysical Surveys (DGGS) GeoPortal is a collection of web apps containing geologic data, maps, and applications (Alaska DNR [Department of Natural Resources] 2020). The GeoPortal is open-source and easily accessed from the Alaska DNR website. This tool is part of the Alaska Spatial Data Infrastructure, and the Alaska GeoPortal is maintained by the Geologic Information Center team (Alaska DNR 2020). The GeoPortal contains data on resources such as geothermal sites, mineral sites, and geologic maps in Alaska. Each web app visualizes a given resource, which can then be downloaded for use elsewhere. Figure 6 illustrates the portal output for geothermal springs in Alaska.

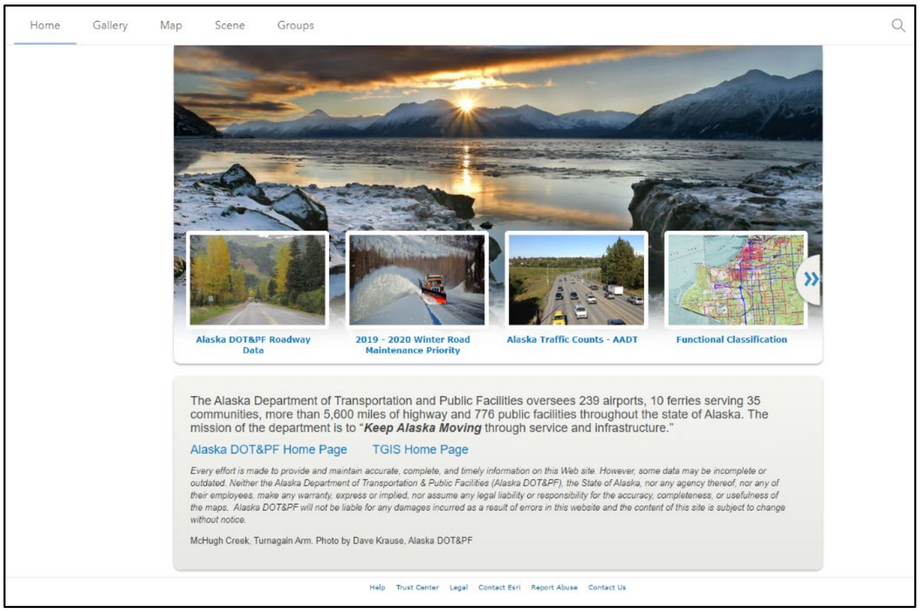
Figure 6. Example of the DGGS GeoPortal mapping tool displaying geothermal springs across Alaska. (Image reproduced with permission from Alaska DNR 2020.)



2.3.5 Alaska Department of Transportation (AK DOT)

The Alaska Department of Transportation (AK DOT) has developed a GIS database (Figure 7) of the State's roadway infrastructure. More spatial information is provided with secure login credentials; however, AK DOT is working to provide more information to the general public outside the State's firewall. In collaboration with the American Association of State Highway Transportation Officials (AASHTO), there is a national effort to create a web-based decision-making mapping and informational tool for project development and tracking, easily sharable between agencies and the public. AASHTO serves as a national nonprofit and provides support for all aspects of transportation (Alaska Department of Transportation and Public Facilities 2020).

Figure 7. AK DOT GIS data collection home page (Image reproduced with permission from Alaska Department of Transportation and Public Facilities 2020).

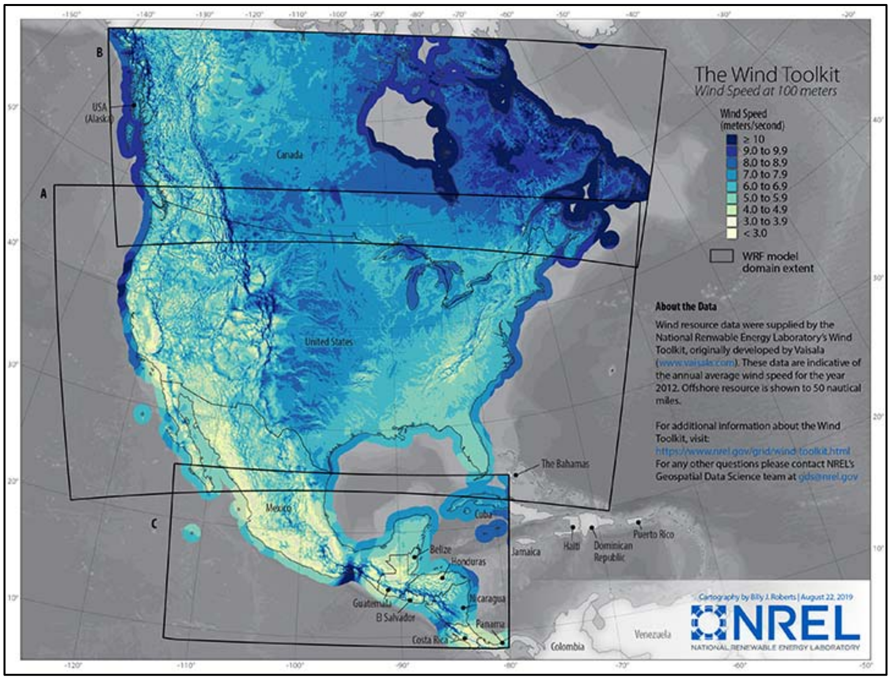


2.4 U.S. data tools and sources

2.4.1 National Renewable Energy Laboratory (NREL) Geospatial Data Science Data and Tools Repository

The National Renewable Energy Laboratory (NREL) Geospatial Data Science Data and Tools Repository hosts a collection of renewable geospatial energy data from numerous government and university sources (NREL 2020a). Partners include the DoD, state governments, industry-leading companies, universities, and over 80 countries. With a focus on biomass, geothermal, hydrogen, marine and hydrokinetic, solar, and wind, national and international datasets are available in an open-source platform. NREL's intent is to bring together available data for continued research and public education in order to optimize energy systems (NREL 2020a). Through the ability to download raw data, NREL enables the user to easily adapt files into new or existing data files. While limited, several available datasets offer real-time graphical displays of national resources, such as wind and solar. Figure 8 is a representative image of the Wind Toolkit made accessible through the NREL website.

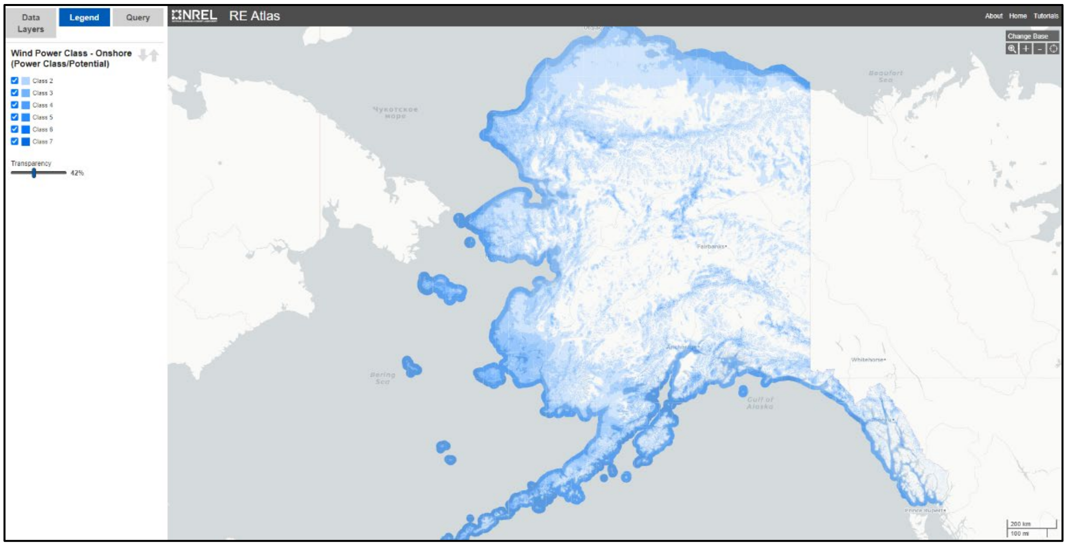
Figure 8. NREL Geospatial Data Science Data and Tools Repository, Wind Toolkit (Image reproduced from NREL 2020a. Public domain.)



2.4.2 NREL Renewable Energy Atlas (RE Atlas)

The NREL Renewable Energy Atlas (RE Atlas) is a mapping tool that provides a platform to map the potential for renewable energy resources across the U.S. (Figure 9). This tool is available online for free via the NREL website and was designed to help develop energy policy, increase investment in renewables, and educate users by making high-quality data accessible and understandable (G. Douglas 2012). The NREL Geospatial Data Science team designed and developed the tool for policy makers, planners, developers, and anyone looking to gain a better understanding of the various potentials for the most common renewable energy resources in the U.S. (G. Douglas 2012). The RE Atlas incorporates dynamic geospatial data layers for wind (on and offshore), solar (photovoltaic [PV] and concentrated solar potentials), geothermal, biomass, and hydropower. However, some of the renewable resource layers include data for the contiguous U.S. only (e.g., geothermal and concentrated solar). This toolkit is primarily for viewing the distribution of renewable energy potential and does not include an analytical component; however, the layers can be extracted and uploaded to a GIS software package for analysis.

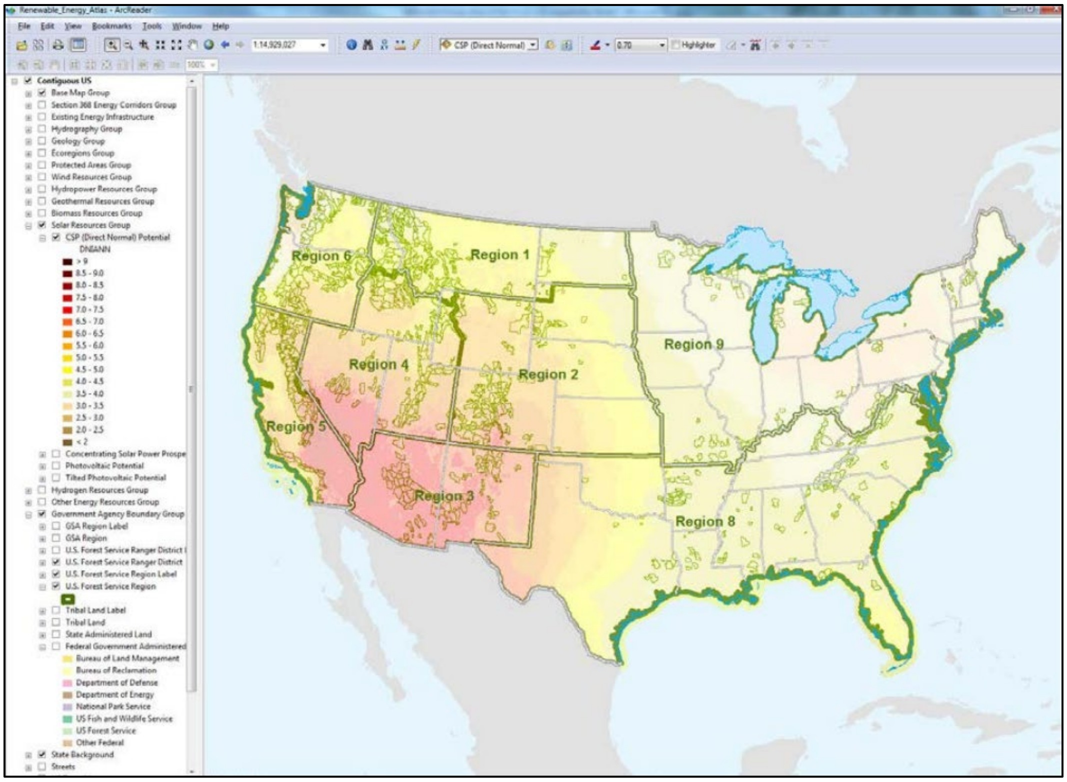
Figure 9. Example of the RE Atlas mapping tool displaying the potential for wind energy generation across Alaska. (Image reproduced from NREL 2020b. Public domain.)



2.4.3 Argonne National Laboratory (ANL) Renewable Energy Atlas of the United States

Argonne National Laboratory (ANL) developed their own Renewable Energy Atlas of the United States 2013. The atlas, designed for the U.S. Department of Agriculture (USDA), the U.S. Forest Service, and other federal land management agencies, is a compilation of geospatial data for renewable energy resources and federal lands (Kuiper et al. 2013). The atlas includes geospatial data layers for renewable energy development, federal land boundaries, ecoregions, energy corridors, archeologic sites, and existing energy infrastructure. The geospatial data layers that pertain to existing energy infrastructure are limited due to commercial licensing or designations of Official Use Only (Kuiper et al. 2013). The geospatial data for the Renewable Energy Atlas of the United States supported programmatic environment impact statements assessing the environmental, social, and economic impacts of utility-scale solar development in the southwestern U.S. (DOE 2012, 2008). Figure 10 illustrates the Renewable Energy Atlas of the United States use for viewing solar potential. The ANL Renewable Energy Atlas of the United States has recently been superseded by the Energy Zones Mapping Tool described in section 2.4.4.

Figure 10. Example of the Renewable Energy Atlas of the United States displaying solar potential across the U.S. (Image reproduced from Kuiper et al. 2013. Public domain.)



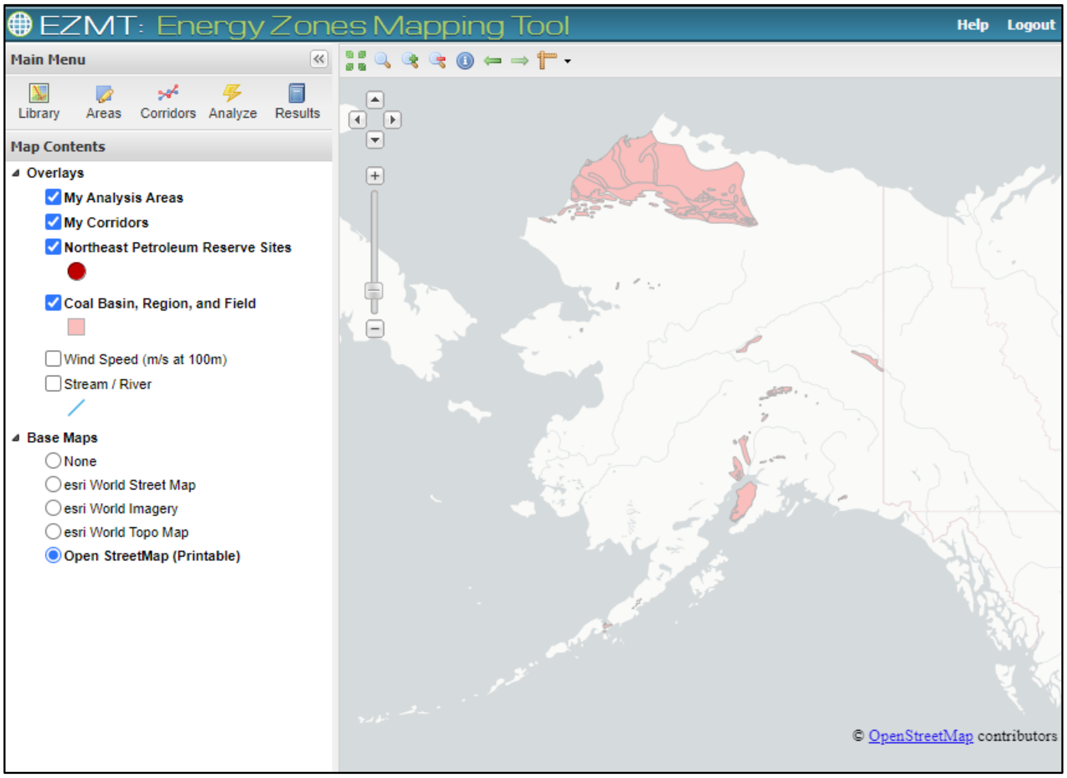
2.4.4 ANL Energy Zones Mapping Tool (EZMT)

The Energy Zones Mapping Tool (EZMT) is an open-source mapping tool available online to help users identify potential energy resource areas and energy corridors in the U.S. The DOE Office of Electricity funded the development of the EZMT by the Eastern Interconnection States' Planning Council (EISPC).* ANL, NREL, and Oak Ridge National Laboratory provided research support and technical assistance in this effort. The tool was developed so that EISPC members and stakeholders could use a methodology and comprehensive mapping tool to identify areas in the U.S. that are well suited for producing clean (low- or no-carbon) power. EZMT also was meant to promote collaboration between state-level energy-planning entities by enabling a consistent and coordinated direction for electricity analyses and planning (ANL 2020a). The EZMT (Figure 11) contains data for energy sources, including solar, wind, coal, oil, and natural gas, and for

* EISPC is "an organization of energy planning and regulatory offices from 39 states in the eastern part of the U.S., the District of Columbia, the City of New Orleans, and 8 provinces in Canada" (ANL 2013); it was originally funded by the DOE through an American Recovery and Reinvestment Act of 2009 funding opportunity.

natural resources, such as hydrology and waterbody data. The tool also includes data for infrastructure and can be used via an interactive map or can be downloaded for the user to analyze locally on their own computer.

Figure 11. EZMT user's screen. (Image reproduced from ANL 2020b. Public domain.)

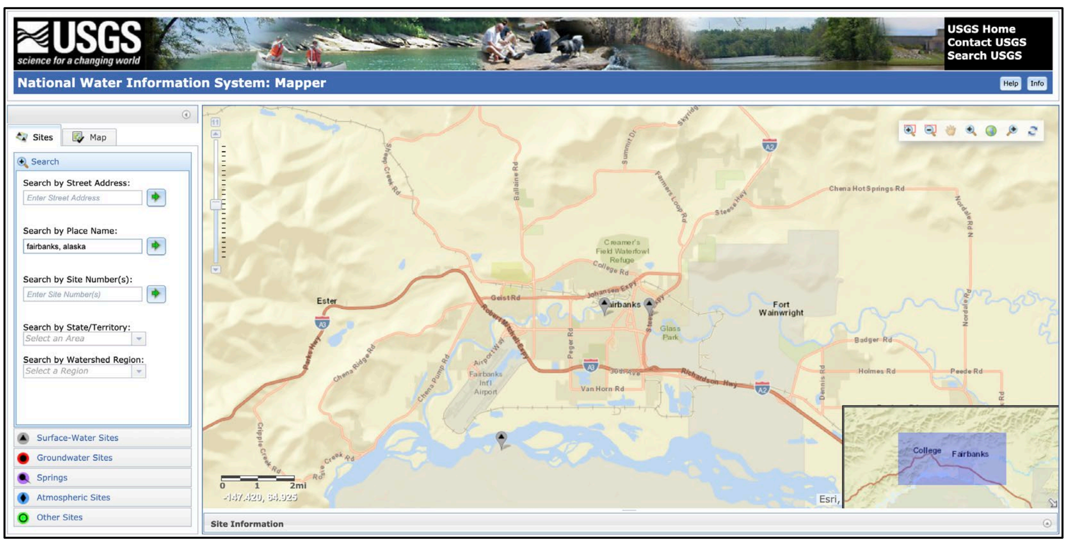


2.4.5 U.S. Geological Survey (USGS)

The U.S. Geological Survey (USGS) is the leading organization for natural science expertise and data collection, providing water resources data (among other natural resources) across the U.S. and its territories to all levels of federal, state, and local governments and to the public. The USGS has a collection of GIS data focused primarily on natural resources but also provides other useful information, like hydrological units, geothermal potential, flooding zones, and other shape files. Available to the public, these data are meant for citizens and other government agencies to get a better understanding of the nation's resources and land use (USGS 2020a). USGS data can be accessed from the Energy Resources Program page (USGS 2020a) on the USGS website and filtered based on type, topic, year, etc. Several state websites (often on their natural resources page) also link to the USGS data.

Real-time and historical surface and groundwater observations, their quality, and their uses are contained with the National Water Information System (NWIS). First announced in 2001, the NWIS is the home for the distributed network of servers and computers that collect, process, review, and store water data from 1.5–1.9 million stations (USGS 2011). These data include river stage (i.e., height) and streamflow (i.e., discharge) conditions at major rivers, lakes, and reservoirs. The NWIS Web Mapper interface offers an Esri GIS web tool (Figure 12) for users to query by geographic area or by data category (e.g., surface water). Station names and locations can be exported in a variety of file types (e.g., .txt, .csv, or .shp) from the Web Mapper. From there, water data can be accessed on each respective station webpage.

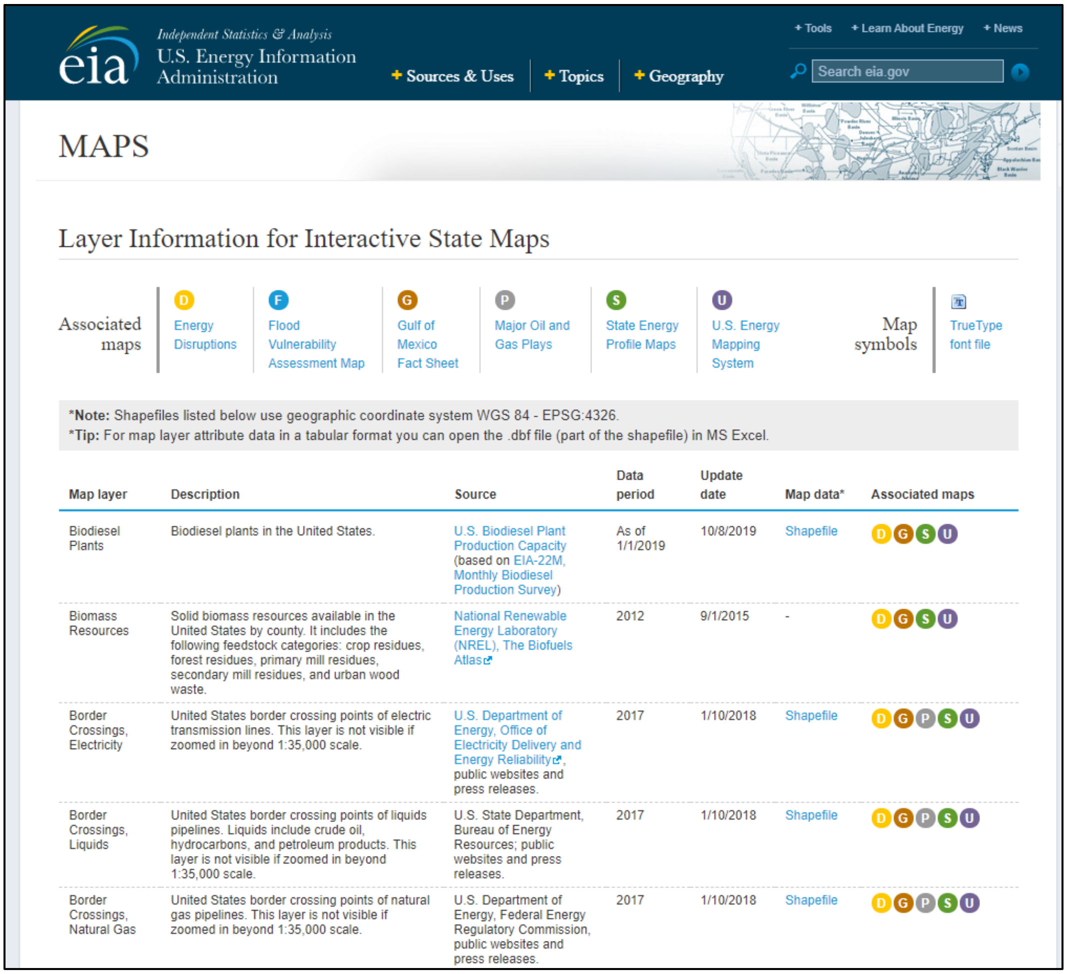
Figure 12. USGS NWIS Web Mapper interface. (Image reproduced from USGS 2020b. Public domain.)



2.4.6 U.S. Energy Information Administration (EIA)

EIA has a collection of data on electrical transmission lines, substations, natural gas resources, and power plants, to name a few. It provides a wide range of data to inform both military and nonmilitary installation decisions. Available in a web-based tool, access is easy, but user customization options are limited (EIA 2020; Figure 13).

Figure 13. EIA data collection home page. (Image reproduced from EIA 2020. Public domain.)



Map layer	Description	Source	Data period	Update date	Map data*	Associated maps
Biodiesel Plants	Biodiesel plants in the United States.	U.S. Biodiesel Plant Production Capacity (based on EIA-22M, Monthly Biodiesel Production Survey)	As of 1/1/2019	10/8/2019	Shapefile	D G S U
Biomass Resources	Solid biomass resources available in the United States by county. It includes the following feedstock categories: crop residues, forest residues, primary mill residues, secondary mill residues, and urban wood waste.	National Renewable Energy Laboratory (NREL), The Biofuels Atlas	2012	9/1/2015	-	D G S U
Border Crossings, Electricity	United States border crossing points of electric transmission lines. This layer is not visible if zoomed in beyond 1:35,000 scale.	U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, public websites and press releases.	2017	1/10/2018	Shapefile	D G P S U
Border Crossings, Liquids	United States border crossing points of liquids pipelines. Liquids include crude oil, hydrocarbons, and petroleum products. This layer is not visible if zoomed in beyond 1:35,000 scale.	U.S. State Department, Bureau of Energy Resources; public websites and press releases.	2017	1/10/2018	Shapefile	D G P S U
Border Crossings, Natural Gas	United States border crossing points of natural gas pipelines. This layer is not visible if zoomed in beyond 1:35,000 scale.	U.S. Department of Energy, Federal Energy Regulatory Commission, public websites and press releases.	2017	1/10/2018	Shapefile	D G P S U

2.4.7 National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) portal

A suite of meteorological networks is available through the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) portal. The NCEI is the national leading authority for environmental information, including oceanic, atmospheric, and geophysical datasets. Under the Consolidated and Further Continuing Appropriations Act of 2015, Public Law 113-235, the NCEI was formed as the aggregate of NOAA's National Climatic Data Center (NCDC), the National Geophysical Data Center, and the National Oceanographic Data Center (NOAA 2019). Included in the consolidation was the NCDC Climate Data Online portal (NOAA 2020a; Figure 14), which provides access to a global archive of historical hourly, daily, monthly, and yearly historical observations of temperature, precipitation, wind, etc. in the NCEI Map

Viewer web interface (NOAA 2020b). Here, users are able to query the archive by geographic area and data category, which includes, but is not limited to, time series observations, surface maps, and regional climate indices. The Map Viewer provides each dataset as a separate layer.

Figure 14. NOAA's Climate Data Online Portal. (Image reproduced from NOAA 2020a. Public domain.)

2.4.8 Department of Homeland Security (DHS) Homeland Infrastructure Foundation-Level Data (HIFLD)

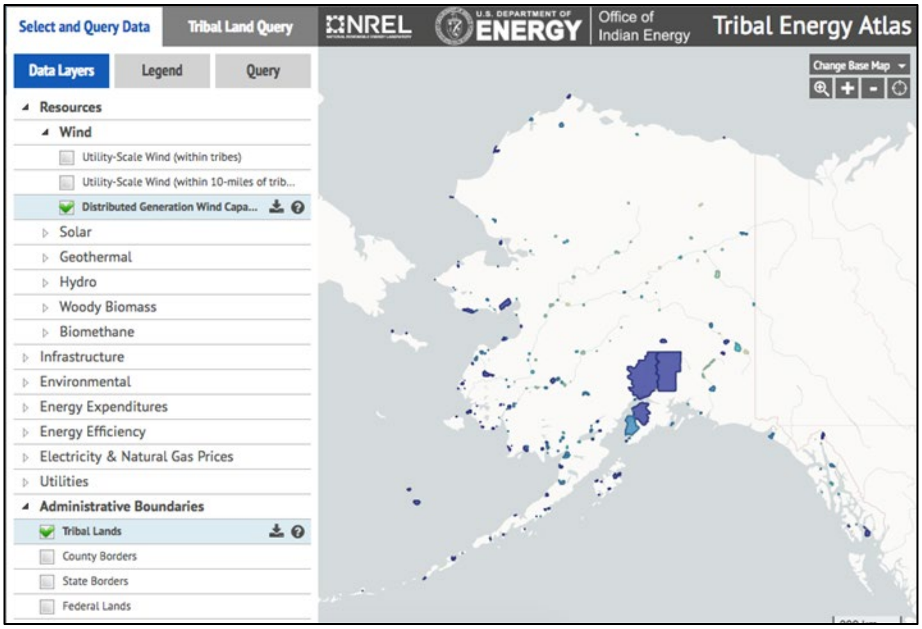
The Homeland Infrastructure Foundation-Level Data (HIFLD) catalog currently provides infrastructure data covering 25 separate categories (Figure 15). The HIFLD, operated by the Department of Homeland Security (DHS), is available through both open and secure online platforms. Here we will outline only the open catalog, which is available through the DHS Homeland Security Information Network on the Geospatial Information Infrastructure portal. The HIFLD subcommittee was formed in 2002 to focus on improving the geospatial information collection, processing, and sharing across the U.S. Government. This process was to provide secure access to geospatial information of critical importance and to create a common foundation from which to visualize and analyze those data (DHS 2017). The HIFLD Open Data portal was brought online in February 2016 and contains 320 public datasets, such as Agriculture, Borders, Boundaries, Chemicals, Communications, Energy, Natural Hazards, and Air/Ground/Water Transportation (DHS 2018). Sources in the energy category include petroleum reserves, pipelines, oil refineries, power transmission lines, as well as data for electrical regions. The HIFLD also includes data related to flood risk and monitoring systems, which can be crucial for long-term infrastructure planning. Data is hosted through ArcGIS Online and can be investigated through a search or by category; downloaded as a table; or downloaded directly as a CSV, KML, or shapefile for visualization or analysis through a desktop mapping software.

Figure 15. DHS HIFLD data dashboard. (Image reproduced from DHS 2017. Public domain.)

2.4.9 DOE Tribal Energy Atlas

The DOE Office of Indian Energy Policy and Programs has created a Tribal Energy Atlas tool (Figure 16) that specifically focuses on Tribal areas. This tool includes data on energy sources, infrastructure, energy expenditures, and efficiency. A useful feature is energy potential. For example, an optional dataset provided to the user is the concentrated solar power potential within *x* miles of tribal lands that may not be currently utilized. Potential energy sources not yet tapped into, especially those that allow for an installation to become more energy resilient and independent, could provide DoD installations with useful planning information (DOE 2020). A feature of this type would be useful to include in any DoD-centric energy data portal.

Figure 16. DOE Tribal Energy Atlas user's view. (Image reproduced from DOE 2020. Public domain.)

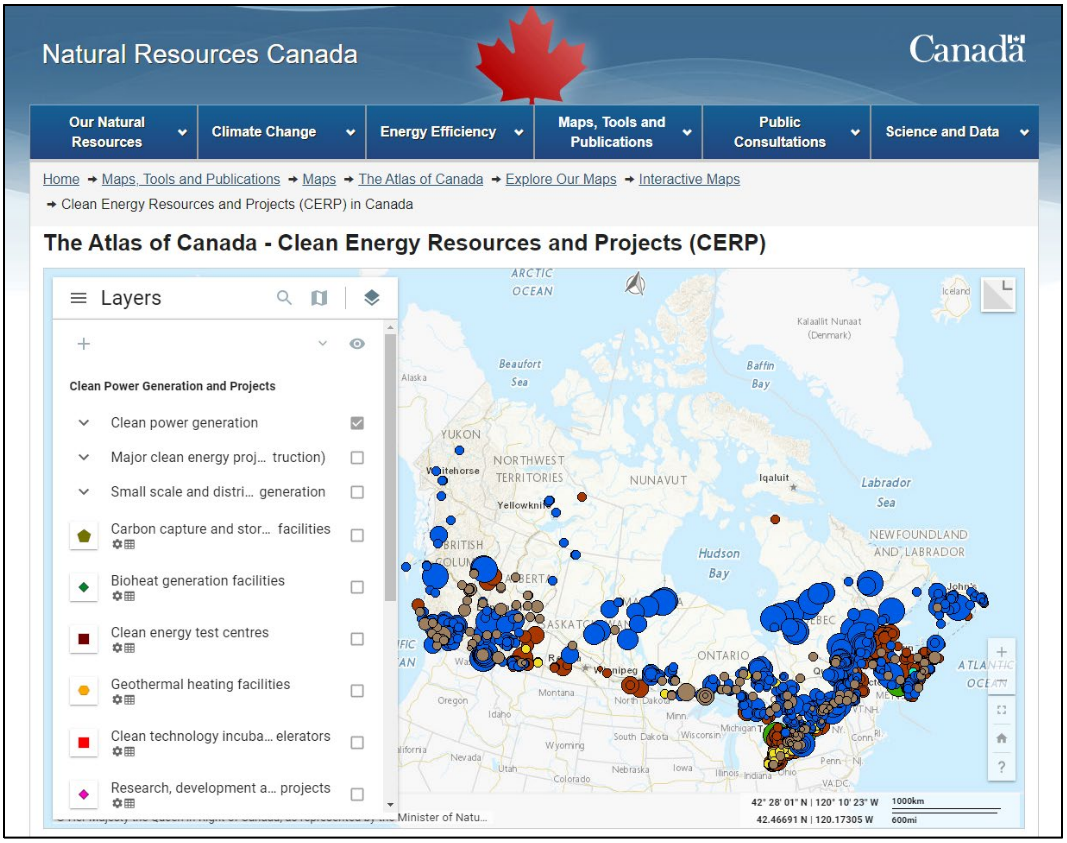


2.5 International energy data tools and sources

2.5.1 Clean Energy Resources and Projects (CERP)

Canada's Natural Resources Department has created the Clean Energy Resources and Projects (CERP) interactive map laying out energy use and potentials from renewable sources (Government of Canada 2018). This tool provides infrastructure, energy transportation methods, and current and future clean energy projects. Data layers for the clean energy potential for various sources are also available. Useful features include the ability to adjust the transparency of layers, to lighten or darken based on user preferences, and the ability to search layers. Additionally, the inclusion of a viewable attribute table allows users to generate a table of attributes for each layer, which can be filtered by attribute values to adjust what is visible on the data display. Lastly, the user has the ability export both figures and data tables for selected layers in an easy-to-follow format. The report includes the visual information found in the map and tabular data from the attribute table. The tool is available in an open-source platform (Figure 17) to be as user-friendly as possible (Mackinnon 2014).

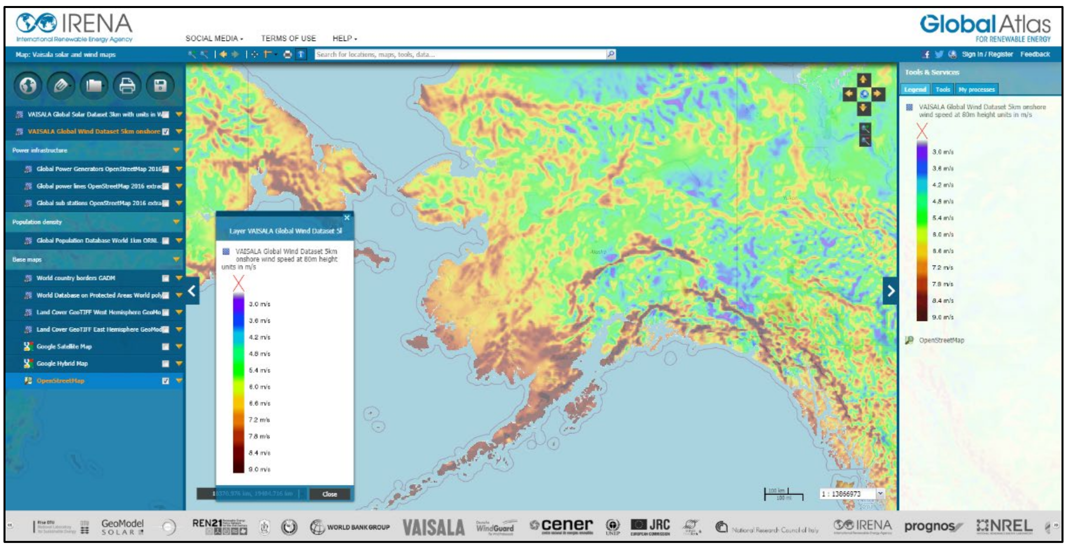
Figure 17. CERP home page. (Source: “Atlas of Canada – Clean Energy Resources and Projects (CERP)” Canada Centre for Mapping and Earth Observation [CCMEO], Natural Resources Canada, 2018. Reproduced with the permission of the Department of Natural Resources, 2021.)



2.5.2 International Renewable Energy Agency (IRENA) Global Atlas for Renewable Energy

The International Renewable Energy Agency (IRENA), an intergovernmental organization, works to transition countries to sustainable and secure energy systems. There are currently over 180 countries that are working with IRENA toward a more sustainable energy future. IRENA serves as “the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy” (IRENA 2020). IRENA aims to integrate relevant knowledge of renewable energies and make them free and publicly available (Estima et al. 2013). To achieve this, IRENA developed and maintains a Global Atlas for Renewable Energy (Figure 18) composed of geospatial datasets of renewable energy resources from across the world (IRENA 2020). The atlas includes geospatial data layers for wind, solar, biomass, geothermal, hydro, and tidal changes for the U.S. IRENA offers a bioenergy simulator tool and geospatial analysis tools for assessing site readiness for concentrated solar and photovoltaic systems, though only some of these were designed for datasets of the contiguous U.S. Although the geospatial data layers for this atlas include some coverage of Alaska, there are limited analytical capabilities for this region. It is difficult to make an all-inclusive program for global applications because each country and region will have its own barriers and challenges to energy development (Kempener et al. 2015), highlighting the need for state- or country-specific atlases to strengthen analyses.

Figure 18. Example of the IRENA mapping tool displaying the potential for wind energy generations across Alaska. (Image reproduced with permission from “Global annual average wind speed at 80 m height,” IRENA: Global Atlas for Renewable Energy, Map data: VAISALA, 2021.)



By reviewing these various online data repositories and tools, we were able to identify datasets to incorporate into the Energy Atlas–Alaska and also potential functionality to include in our effort. Through consulting sources from state, federal, and international entities, we were able to diversify the data utilized in our atlas and to ensure we have the most up-to-date information available. Next, we discuss the specific datasets and data organization scheme of the Energy Atlas–Alaska.

3 Technical Approach Overview

Development of the Energy Atlas–Alaska concurrently identified similarly purposed decision support tools that are currently available and relevant to potential Energy Atlas–Alaska users and collected the underlying data from reliable and relevant sources. Sections 2.2–2.5 review the available tools considered. The following sections describe the data supporting the Energy Atlas–Alaska. Appendix A identifies specific data sources.

3.1 Data collection

Data collection efforts during this project focused on federal, state, and open-source repositories and online tools. We also pursued data collection directly from the primary case study location (Fort Wainwright, Fairbanks, Alaska) by communicating with the U.S. Army Garrison Alaska Fort Wainwright IGI&S Program and collaborators at the U.S. Army Engineer Research and Development Center's Construction Engineering Research Laboratory (CERL). While Fort Wainwright is the case study location, we collected statewide datasets as they are pertinent to energy concerns both on and off the installation, and their inclusion will streamline expansion of the Energy Atlas–Alaska to other DoD locations within Alaska. As described above, the primary focus areas of this investigation were *energy sources*, *environmental resources*, *infrastructure (off installation)*, *infrastructure (on installation)*, and the *built environment*. During this process, collection efforts focused on spatial data (raster* and vector†) and tabular data that could be related to a spatial dataset to better portray the energy data portfolio of the case study location.

3.1.1 Energy sources

For the purposes of this study, *energy sources* are defined as the natural resource assets used for energy production, not the developed energy extraction assets themselves. For example, this definition includes, but is not limited to, wind potential, solar potential, geothermal, etc. as opposed to wind turbines, hydropower plants, and coal power plants, which will instead be included as built environment in section 3.1.5. We used the NREL Geospatial Data Science Data and Tools repository to collect data relating

* A raster data model is "a regular 'grid cell' approach to defining space. Usually square cells are arranged in rows and columns" (Bolstad 2019).

† A vector data model is "a representation of spatial data based on coordinate location storage for shape-defining points and associated attribute information" (Bolstad 2019).

to potential wind, solar, biomass, and geothermal resources for the state of Alaska (NREL 2020a). These data include annual average wind speeds, direct and normal solar irradiance, total solid biomass resources, and identified and estimated hydrothermal sites. We also used the EZMT (see section 2.4.1) to collect data relating to wind resources and oil and natural gas reservoirs (ANL 2020b). To collect data for existing coal beds and geothermal resources for the state, we used the Alaska DNR Open Data Site (AEA 2021). Finally, we used the HIFLD open data site to collect data relating to oil and natural gas fields (DHS 2017).

3.1.2 Environmental resources

For the Energy Atlas–Alaska, the *environmental resources* include, but are not limited to, hydrologic data (e.g., streamflow gauges and watersheds), precipitation and temperature data, and land-use boundaries. We collected the location and spatial extent of rivers and waterbodies in Alaska from Google Open Street Map sources as shapefiles. For the streamflow characteristics of the rivers, gauge locations were queried from the USGS NWIS as XY data and downloaded as shapefiles (USGS 2020b). Watershed shapefiles came from the USDA Natural Resources Conservation Service National Geospatial Center of Excellence (USDA 2019). We gathered the latest available land cover or land-use shapefiles from Multi-Resolution Land Characteristics Consortium (2020). Additionally, the NOAA contains several networks of precipitation and temperature stations in the region. Station locations were gathered as an XY dataset from (1) the NCEI NCDC hourly/subhourly and daily observational network and (2) the U.S. Climate Reference Network (USCRN) for Alaska. URL links were also added to sensor data for NCDC daily observations and USCRN data (NOAA 2020b, 2020c). The length of record, recording interval (e.g., hourly vs. daily), and the types of data offered varies between stations. These environmental stations may include some or all of the following measurements: precipitation, air and surface temperature, wind speed and direction, solar irradiance, and relative humidity.

3.1.3 Infrastructure (off installation)

For the purposes of this study, *infrastructure* pertains to energy assets such as utility corridors, power lines, natural gas wells, etc. and is split between infrastructure that exists on and off the installation. We collected *off-installation* infrastructure data from HFILD and EZMT and directly from Fort Wainwright through collaborators at CERL. These datasets include, but are not limited to, electrical utility lines, oil and gas pipelines, developed solar and wind sites, and oil and natural gas wells (Appendix A; Ostrom 2019). Several infrastructure datasets (e.g., utility lines) include layers that exist both on and off the installation and serve both data collection purposes. We used the DISDI portal (DoD 2020) in addition to these sources to collect data related to oil and gas pipelines, electric transmission lines, and railroads.

3.1.4 Infrastructure (on installation)

We sourced *on-installation infrastructure* from Fort Wainwright (through CERL) and the DISDI data portal. These datasets include, but are not limited, to military training ranges, impact areas, electrical utilities (e.g., lines, nodes, generators, meters, and junctions), wastewater utilities (e.g., valves, pumps, and discharge), and water utilities (e.g., hydrants, pumps, and meters). As discussed in section 3.1.3, certain infrastructure includes layers that extend to areas both on and off the installation and serve both data collection purposes.

3.1.5 Built environment

The *built environment* includes built assets both on and off the installation. We sourced these data from Fort Wainwright, the DISDI portal (DoD 2020), the AIA (U.S. Army 2020b), and HIFLD (DHS 2017). These data include, but are not limited to, installation boundaries, parcel data, buildings, roads, power plants, oil and gas wells, and dams.

3.2 Data integrated into the Energy Atlas–Alaska

3.2.1 Energy sources

The energy sources data include both raster and vector data relating to both conventional and the renewable energy availability or potential within Alaska. These data are crucial when assessing and planning for energy resiliency in the future. Being able to determine the feasibility of alternative energy sources is vital when performing site assessments and site suitability analyses for additional power generation both on and off the installation. Many regions will vary in the accessibility of alternative sources of conventional and renewable energy. This problem is even more profound in northern regions where the annual climate varies significantly and is expected to change drastically over the coming century. In a state like Alaska, solar power is suitable for the summer months but cannot be relied on during the much darker winter months. In addition to extreme climate, the local and regional topography and weather patterns will also affect the feasibility of certain power generation schemes. Wind might be a viable alternative for winter months, but icing of wind turbines is a significant challenge to overcome. These are just a couple of examples of how a full understanding of energy source data can be utilized along with knowledge of the local and regional environment to better plan for future energy resiliency.

Organizing these data into the Energy Atlas–Alaska plus using existing environmental resources, infrastructure, and the built environment data allows not only for in depth analysis of projected power generation but also for the ability of the local, regional, and state energy systems to accommodate that new power source. These data also have implications on how well an installation can both island itself from the local power grid and feed back into the local grid in times of energy insecurity, such as grid disruption due to natural or human-caused hazards.

3.2.2 Environmental resources

Water resources are also a vital component of cooling for certain types of power generation systems and are a critical resource for steam power generation. In addition, for hydropower, certain water resources, such as river or tidal waters, are a critical component of power generation.* Access to water resources and the variability of that access, such as during drought conditions, should be considered when making planning or investment decisions. Geospatial polygon layers of rivers and bodies of water are provided from data housed within the Google Open Street Map dataset. Identification of nearby sources of fresh water are pertinent to the stability of a city, village, or an individual facility.

In conjunction with the river locations, hydrologic stream gauges from the USGS that provide access to real-time and historical records of streamflow characteristics are readily available. Streamflow is especially important during the spring thaw season when snowmelt begins in the region. In some areas, snowmelt runoff is vital to riverside communities that rely on the abundance of freshwater during that time of year. On the other hand,

* Given the limited availability of such hydropower water resources in proximity to DoD lands in Alaska, Phase 1 does not include these resources. However, they may be added in future phases to expand the Energy Atlas datasets for Alaska as well as for other geographic areas.

extensive flooding due to snowmelt runoff can be detrimental to some communities or facilities. These processes further rely on local and regional elevation and land-use characteristics on or near a facility.

Streamflow is also coupled with meteorological conditions in the region. The NCEI houses multiple networks of precipitation and temperature gauges across the U.S., providing real-time and historical hourly to daily measurements. Altogether, these environmental monitoring stations around Alaska provide a web of information from which stakeholders can make tactical decisions and assess energy resource potential.

The Energy Atlas–Alaska tool aggregates all of these resources into a single, user-friendly location for DoD decision-makers. In digesting all of these environmental datasets, energy resource potentials with respect to these environmental elements can be more easily understood.

3.2.3 Infrastructure (off installation)

The off-installation infrastructure data compiled in the Energy Atlas–Alaska consists of primarily vector data relating to power lines, utility corridors, power generation sites, etc. that stakeholders could use to perform analyses. No installation exists in a vacuum, so it is crucial to understand how prospective improvements or a shift in the energy portfolio will affect and be affected by the local, regional, and state infrastructure. As discussed in earlier sections, data availability both on and off base highly impacts the ability to perform feasibility and site suitability analyses. The capacity of local power generation sites to support the installation and any potential expansion or increased power demand will be directly impacted by the off-installation interconnected infrastructure. As installations plan for the future, additional off-installation power sources may need to be considered and the location of potential renewable energy projects investigated. In addition to this, preparing for how a sudden loss of service from local power supplies affects the base is a critical consideration. These challenges inspire the need to better understand the local, regional, and state infrastructure adjacent to DoD installations and other DoD sites, in addition to the other focus areas that the Energy Atlas–Alaska addresses.

3.2.4 Infrastructure (on installation)

As discussed in section 3.2.3, installations do not exist in a vacuum; however, it is helpful for base planning and logistics to have a detailed understanding of their own infrastructure. The on-installation infrastructure data in the Energy Atlas–Alaska consists of primarily vector data that stakeholders can use for a variety of investigations. For example, the location of a new or temporary building is greatly affected by the placement and structure of the stormwater, wastewater, primary utility lines, and backup generator systems. By structuring the data storage scheme of the Energy Atlas–Alaska to include both on- and off-installation infrastructure, only the dataset of concern needs to be queried to answer site suitability questions. These data become extremely important when building an "inside-the-fence-line" energy monitoring system. The location of utility meters, transformers, power lines, and substations will greatly affect the location of monitoring links on the installation, the associated project cost, and the level of detail included in the design. When moving into the future of installation management, smart metering will become a necessary tool; and the current base infrastructure will greatly influence that system's design. The utility of the on-base infrastructure data is also not limited to the energy portfolio of the installation. Even though that is the primary focus for development of the Energy Atlas–Alaska, these data are universal and can be used for almost any type of installation planning.

3.2.5 Built environment

As discussed earlier, the built environment datasets are a collection of vector data relating to roads, installation boundaries, buildings, etc. collected from federal, state, open-source repositories, and collaborators at CERL. These data are crucial when performing installation planning and future development. Building footprints, as an example, can be related to tabular data for their approved occupancy, heating source type, building heat envelop, and window efficiency; and with smart metering improvements, real-time data can be displayed on energy usage. Understanding the built environment not only is related to where and how it is built but also its energy and heating footprint relative to the rest of the installation. These data can be compiled to better understand what buildings may need renovation in the near term and which buildings can wait. In addition to this and of concern in northern environments, new and legacy construction projects can be coupled with environmental data, such as permafrost maps, to perform suitability analyses for better long-term installation planning into an uncertain climatic future. As with all of the above datasets, the built environment information becomes a much more powerful tool when it is directly coupled with infrastructure, environmental resources, and energy data.

3.3 Stakeholder engagement

The Energy Atlas–Alaska is primarily for DoD decision-maker use but can support other DoD-related reviews, analyses, and activities. The ArcGIS framework developed under this project can easily be adapted to serve other states and the requirements therein. To inform the development of the Energy Atlas–Alaska, we sought input and feedback from a variety of intended and potential users:

- Installation energy manager
- Developers of installation energy and water plans
- Academic research partners
- DoD researchers

The Energy Atlas–Alaska project team provided a demonstration to a representative set of stakeholders. The team documented the feedback from the stakeholders and, as appropriate, integrated it into the Energy Atlas–Alaska. The feedback from 38 stakeholders across 6 separate organizations included varying amounts of guidance and falls into three focus areas that the following subsections will detail.

3.3.1 Dataset and function expansion

There was significant discussion with stakeholders regarding how the Energy Atlas–Alaska could be expanded to include additional datasets and functions. Given the focus on Alaska, one of the primary areas of expansion suggested was the addition of soils and permafrost datasets to include historical, current, and projected permafrost statewide. We will vet specific suggested data sources for suitability moving forward. In addition to this, the ability to include datasets related to projected future air temperatures, coastal position, and sea-level rise were also discussed. We will assess suitable datasets to satisfy this need as we refine the Energy Atlas–Alaska in future work.

In addition to the above datasets, other interests included Formerly Used Defense Sites and their associated status, environmental challenges such as wildfire risk, and the ability to assess coastal energy capabilities. Functionality requested from stakeholders included the ability to incorporate dynamic datasets, and section 3.3.2 will discuss the potential for this.

3.3.2 Ease of access—portal development

Stakeholders briefed on the Energy Atlas–Alaska also expressed interest in the development of an online portal to access the atlas as opposed to a stand-alone ArcGIS Desktop tool. Academic research partners were also interested in increasing ease of access to the datasets provided and making the datasets and functions compatible with open-source GIS software. The migration of the Energy Atlas–Alaska to an online portal would satisfy both of the above requests while also ensuring data security (section 3.3.3). The online portal could also be linked to regularly updated data sources, pending permissions, which allows for the capability to include dynamic datasets as needed and appropriate.

3.3.3 Operational security

During discussions, stakeholders raised the operational security (OPSEC) of specific datasets relating to installation infrastructure. The Energy Atlas–Alaska, in the form presented in this technical report, contains FOUO (for official use only) data. The Energy Atlas–Alaska is not intended to contain any classified or similarly designated data that would exceed the FOUO designation.

The Energy Atlas–Alaska currently exists as a standalone desktop-installed product with distribution limited by the FOUO designation. However, users who cannot receive the desktop-installed version may request non-FOUO data separate from the Energy Atlas–Alaska tool. Further development of the Energy Atlas–Alaska into an online-accessible portal will take into consideration any OPSEC requirements necessary to manage access to FOUO data.

Stakeholders also inquired about other agency or organization data that may require protection or access control. If such data is integrated into the Energy Atlas–Alaska, the project team will work with the agency or organization to understand what protections or access controls are necessary and to implement those measures. No data requiring protection or access control will be integrated into the Energy Atlas–Alaska unless the appropriate measures can be and are implemented.

3.4 Data gaps

We assessed data gaps and future data needs based on discussions with stakeholders and within the Energy Atlas–Alaska project team. The main data gaps identified included additional environmental data that would be useful for future installation planning. As mentioned in section 3.3.1, datasets relating to soils and permafrost are of particular interest to stakeholders. Other environmental data identified include projected temperature and sea-level rise. These data would be of particular interest for coastal installations trying to plan for and mitigate coastal erosion. Additional coastal datasets related to potential power generation from wave action would also be of interest. The ability to compare historical datasets is also of interest to stakeholders. When possible, it would be important to make available historic and cultural resource data, with appropriate protections in place to preserve the resources. However, filling all of these data gaps is subject to data availability and use restrictions. In addition to this, to satisfy future data needs and capabilities of the Energy Atlas–Alaska, an OPSEC review will be needed as mentioned in section 3.3.3.

4 Energy Atlas–Alaska Toolbar

4.1 Design

The Energy Atlas–Alaska functions within Esri's ArcGIS Desktop application, ArcMap. The software is commercial-off-the-shelf software that is available to the Army. We selected the 10.6.1 Desktop version of ArcGIS for development due to its widespread availability within the Army. The Energy Atlas–Alaska system consists of a set of tools that are available through a custom Add-In toolbar (Figure 19).

Figure 19. Energy Atlas–Alaska Add-In toolbar listing the available functions developed under Phase 1 of this project.

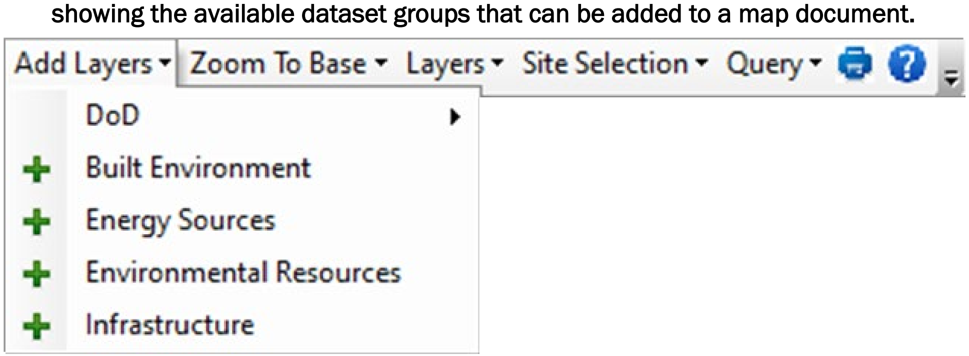
We used Python code to create the tools for the Add-In. The Add-In toolbar can be used in ArcGIS versions 10.6.1 and 10.7.1. Data is stored in ArcGIS file geodatabases and symbolized with layer files. The Add-In toolbar is not accessible in the ArcGIS Pro version; however, the data layer files can be viewed there.

4.2 Functions

4.2.1 Add Layers tool

This tool allows users to easily add groups of data layers to the Table of Contents. The Add Layers tool has a dropdown tool for each data layer group: DoD, Built Environment, Energy Sources, Environmental Resources, and Infrastructure (Figure 20).

Figure 20. Energy Atlas–Alaska toolbar with the Add Layers dropdown selected showing the available dataset groups that can be added to a map document.

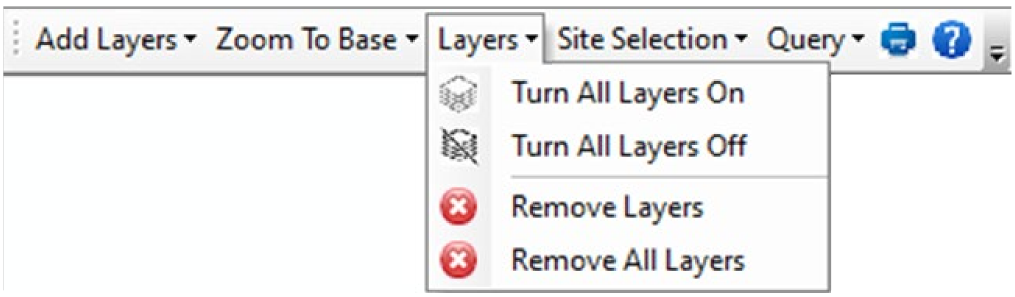


One thing to note is that the layers are not visible when added because they are not checked on. To make a layer visible, check individual layers on; or to have all of the layers visible, select Layers, Turn All Layers On.

4.2.2 Layers tool

This tool allows users to easily turn layers on or off or to remove layers from the Table of Contents. The Layers tool has a dropdown menu for each function: Turn All Layers On, Turn All Layers Off, Remove Layers (to remove individual layers), and Remove All Layers (Figure 21).

Figure 21. Energy Atlas–Alaska toolbar with the Layers dropdown selected showing the available functions.

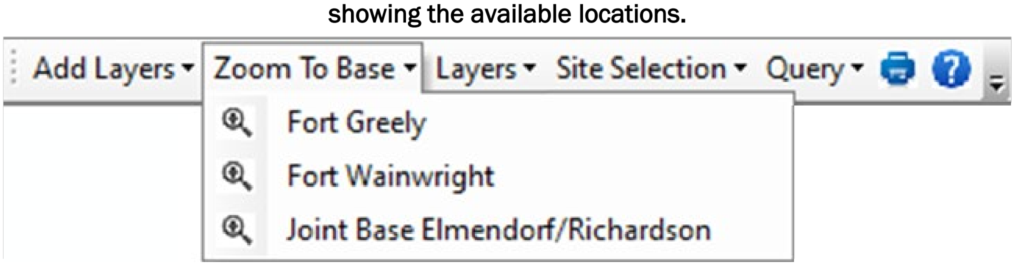


Remove all Layers removes all layers except the base layers.

4.2.3 Zoom to Base tool

This tool allows user to easily zoom in to installations. The tool loads the base boundary and other nested groups, then zooms to the extent of the base (Figure 22).

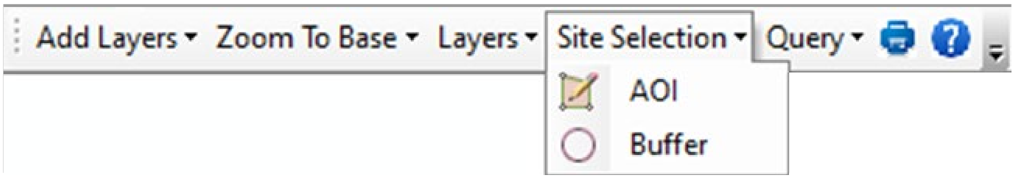
Figure 22. Energy Atlas–Alaska toolbar with the Zoom To Base dropdown selected showing the available locations.



4.2.4 Site Selection tool

This tool allows the user to begin site selection analysis. The Site Selection tool has a dropdown menu for each function: AOI (area of interest) and Buffer (Figure 23).

Figure 23. Energy Atlas–Alaska toolbar with the Site Selection dropdown selected showing the available functions.



The AOI tool allows the user to draw the area of interest on the map. This area of interest can then be displayed with other data layers to start an analysis of an area. The Buffer tool allows the user to specify the distances for buffer analysis of a proposed site. This could assist the user in determining proximity of a possible site to existing infrastructure.

4.2.5 Query tool

This tool allows the user to query data features. The Query tool has a dropdown menu for each function: Identify, Select Features, and Clear Selected Features (Figure 24).

Identify tool allows the user to select a point and view the attribute features on an attribute graphical user interface (Figure 25).

The Features tool allows the user to select a feature or features by point or rectangle and view the attribute features on a graphical user interface (Figure 26).

Figure 24. Energy Atlas–Alaska toolbar with the Query dropdown selected showing the available functions.

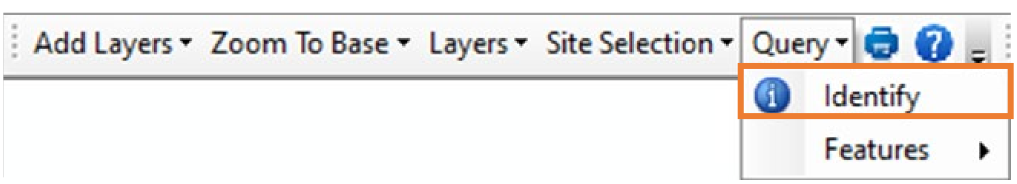


Figure 25. Energy Atlas–Alaska map document showing the Identify pop-up window following use of the Query dropdown and Identify tool.

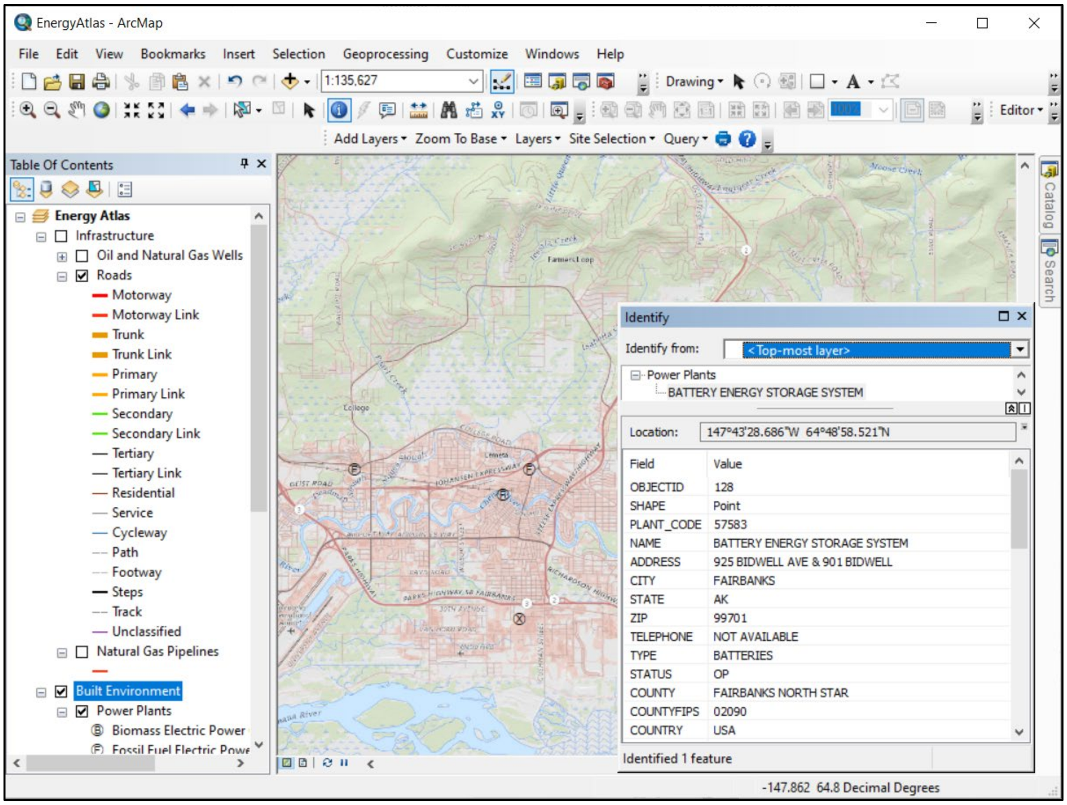
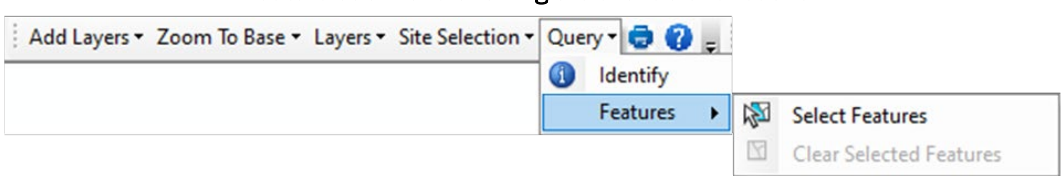


Figure 26. Energy Atlas–Alaska toolbar with the Query dropdown highlighting the feature sub-menu showing the available functions.

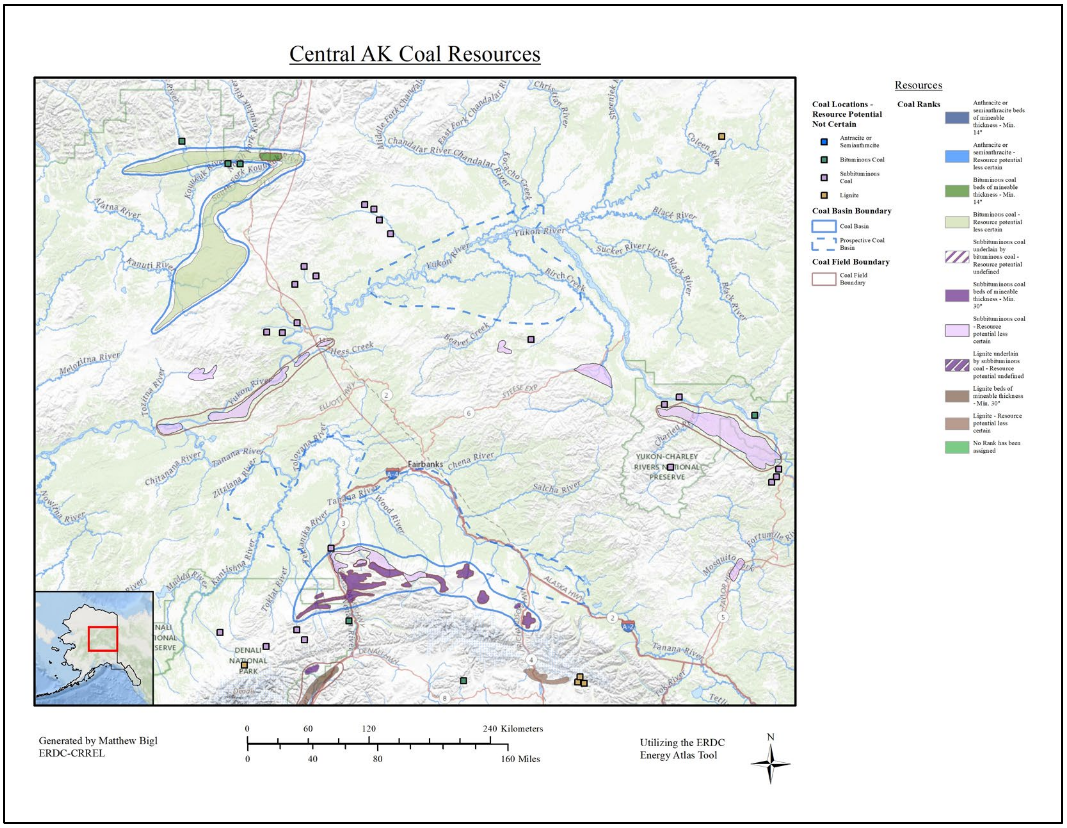


4.2.6 Print tool

This tool allows the user to print the current layers and visible extent of their map view (Figure 27). The tool automatically adds an inset map, legend, scalebar, and north arrow. The user has the option to specify a title, author, and organization (Figure 28).

Figure 27. Energy Atlas–Alaska toolbar with the print function button highlighted with an orange box.

Figure 28. Example figure resulting from the use of the print function built into the Energy Atlas–Alaska toolbar.



The tool also allows the user to specify the output format with choices of PDF, JPEG, PNG, and TIFF.

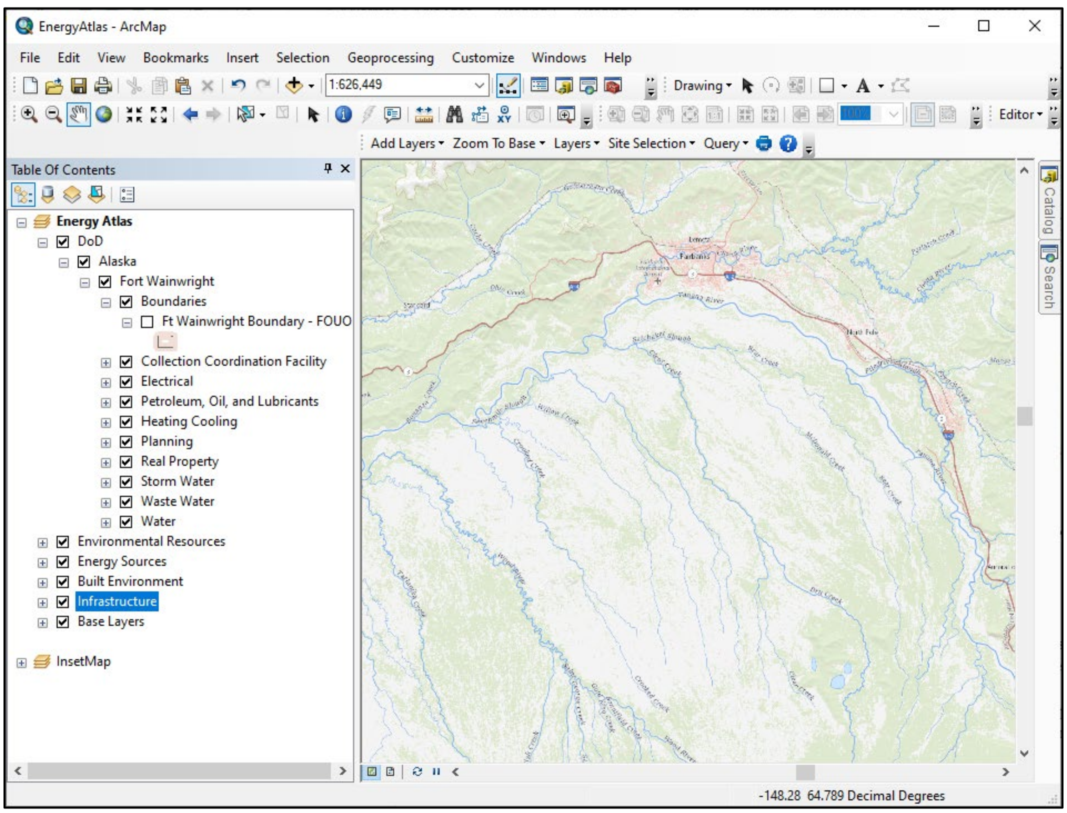
4.2.7 Full Extent tool

Clicking on this tool  in the main window allows the user to zoom to the custom extent of Alaska.

5 Illustrative Use Case: Identification of a Potential Solar Site

This case study demonstrates use of the Energy Atlas–Alaska to efficiently narrow potential site identification for solar infrastructure. For this specific use case, the goal is to identify areas to site solar minigrids where solar PV panels can be installed. This demonstration is not meant to be an in-depth, multicriteria site suitability analysis and instead is meant to serve as an example of how a user can query the data layers and tools within the Energy Atlas–Alaska. After opening the Energy Atlas–Alaska, adding all layers, and using the Zoom to Base tool to navigate to Fort Wainwright, the user would see the screen in Figure 29.

Figure 29. Map-view of the greater Fort Wainwright area.

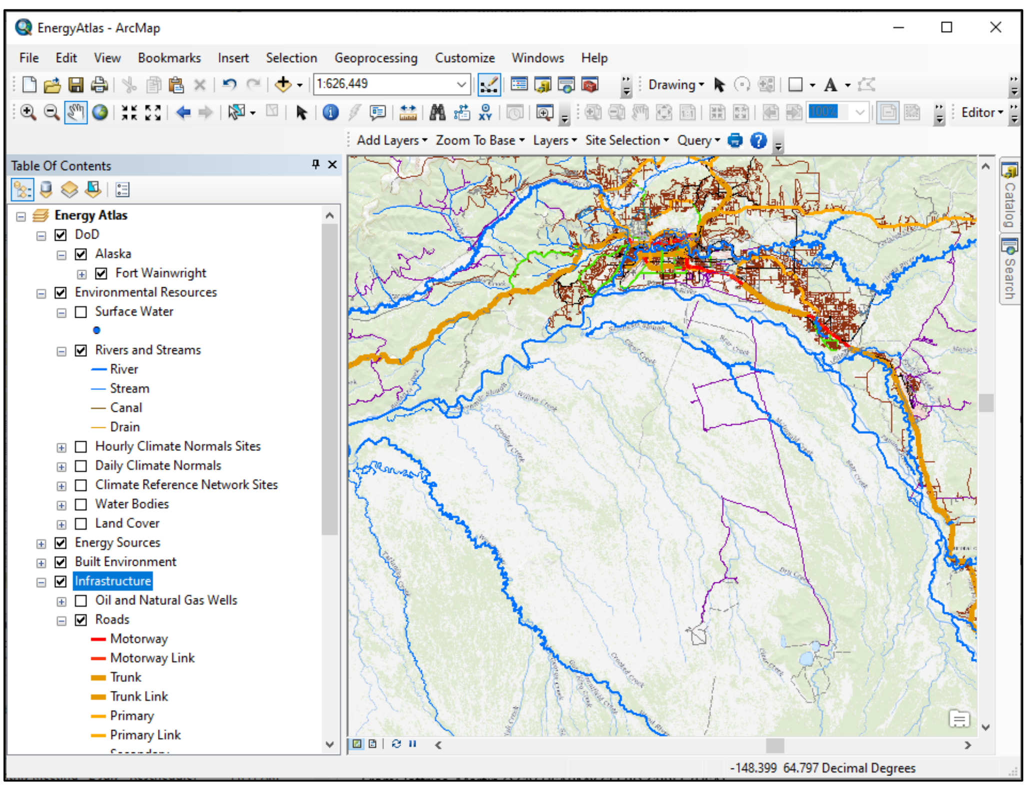


Following this, layers of interest can easily be loaded from the associated layer groups. The factors we are going to consider for this initial investigation are the following:

- Rivers—Any features such as rivers (Figure 30) would need to be avoided.
- Roads—Use of an existing road network will be needed so that the site can be easily constructed and maintained.
- Slope—Low slope is preferred (<5%) for installation and maintenance and for maximizing sun exposure.
- Solar PV—Annual average kilowatt hours per day is needed to calculate potential solar power generation.
- Land Cover—Certain land cover types should be avoided (e.g., wetlands).

These layers can then be used to further refine an area of interest for solar site selection. A multicriteria site suitability analysis would consider many other factors; these layers are meant to serve as baseline criteria.

Figure 30. The Rivers and Streams layer and the Roads layer added to the Fort Wainwright area.



As Figure 31 shows, there is a large region with 3.5–4.0 kWh/m²* per day annual average that should be prioritized for further investigation. This can be accomplished by using the AOI function under the Site Selection

* For a full list of the spelled-out forms of the units of measure used in this document, please refer to *U.S. Government Publishing Office Style Manual*, 31st ed. (Washington, DC: U.S Government Publishing Office, 2016), 248–252, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

tool as shown in Figure 32. Following this, the slope layer can then be compared to this area of interest. Figure 33 shows the slope layer in comparison to the area of interest. Anywhere the slope layer is green is a slope of less than 5% and can be considered suitable for installation of PV panels. When examining the slope layer alone, there are many areas that could be considered suitable for PV panels. However, combining this information with other datasets within the Energy Atlas–Alaska quickly narrows down the area of interest.

Based on the slope layer, the solar area of interest, and the proximity of roads, a refinement of the area of interest can be made once again with the AOI function (Figure 34).

Figure 31. Annual average kilowatt-hours per square meters per day overlain on the Rivers and Streams layer and the Roads layer in the Fort Wainwright Area. The *green* region (3.5–4.0 kWh/m²) should be prioritized for further investigation as it has the highest values of solar input.

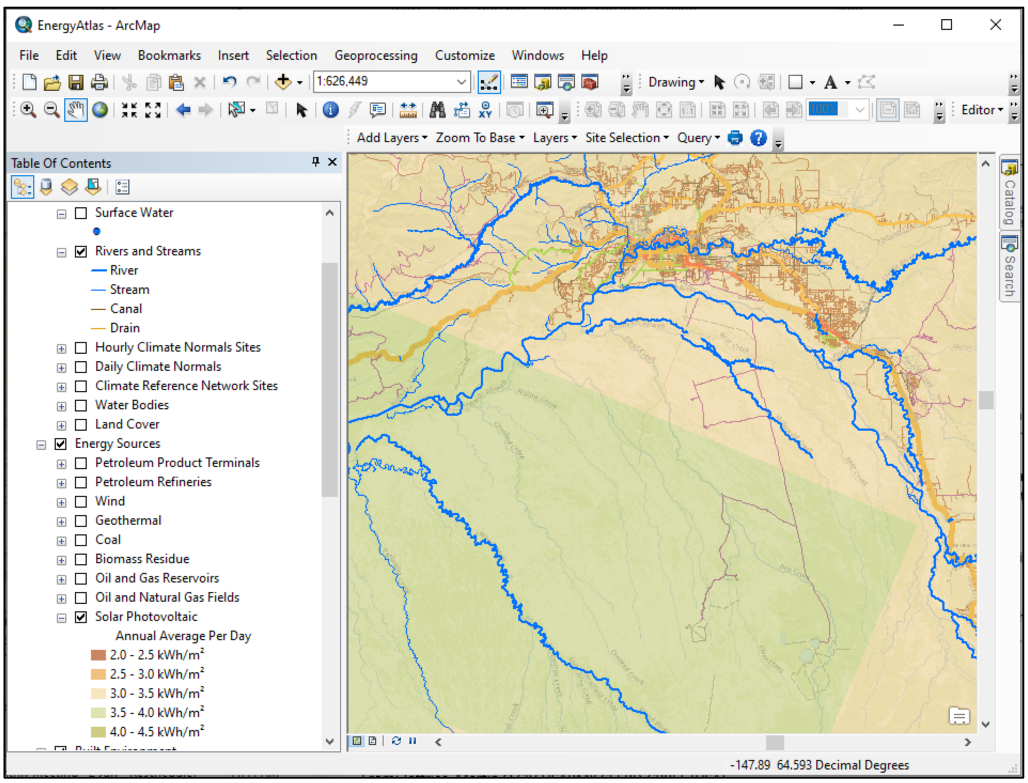


Figure 32. Area of Interest created using the AOI function under the Site Selection tool.

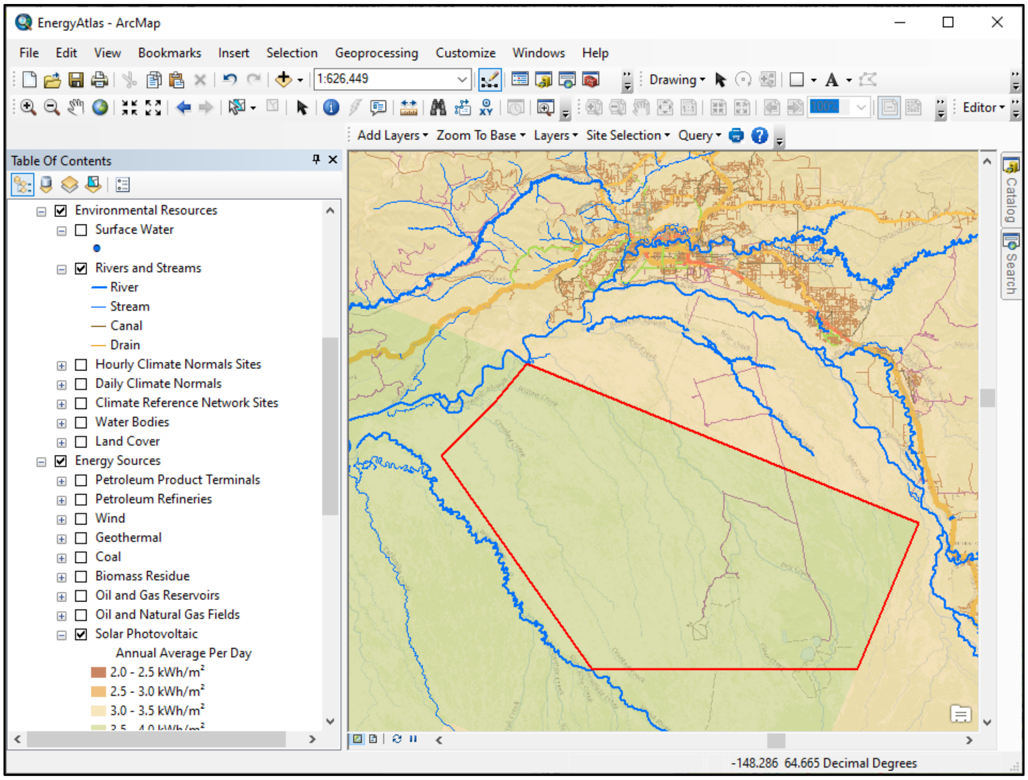


Figure 33. Slope layer in comparison to the area of interest created by the AOI function. The *green* in the slope layer indicates a slope less than 5% and is suitable for the installation of PV panels.

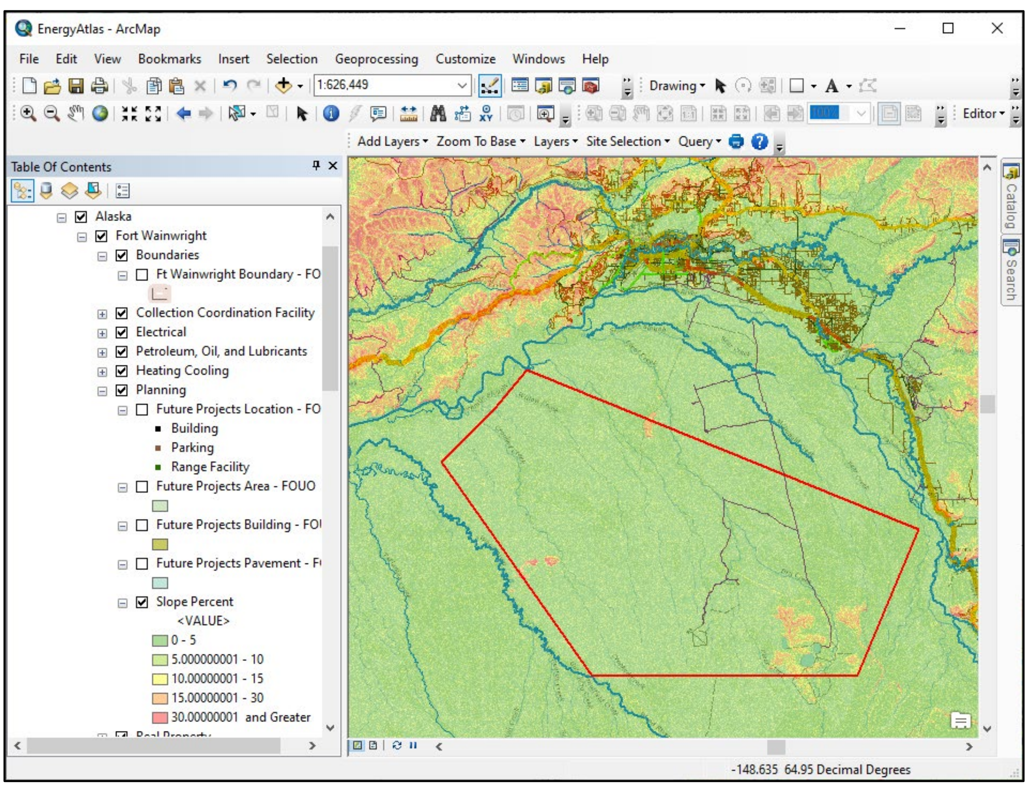


Figure 34. A refined area of interest using the AOI function, suitable slopes, and proximity to roads.

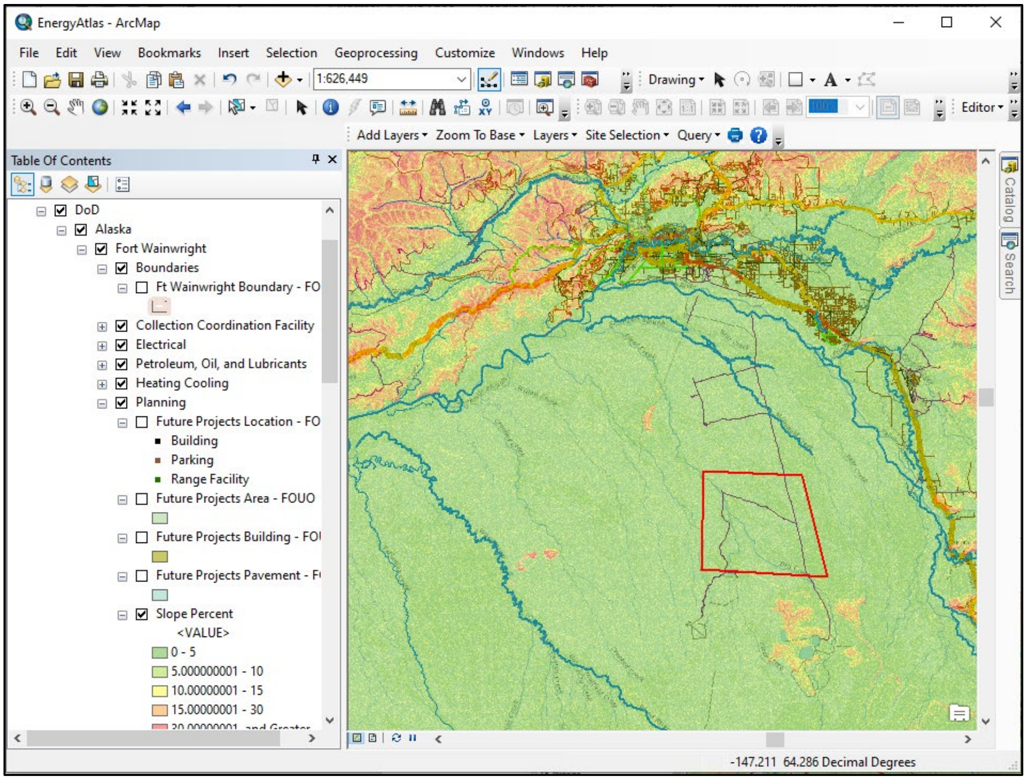
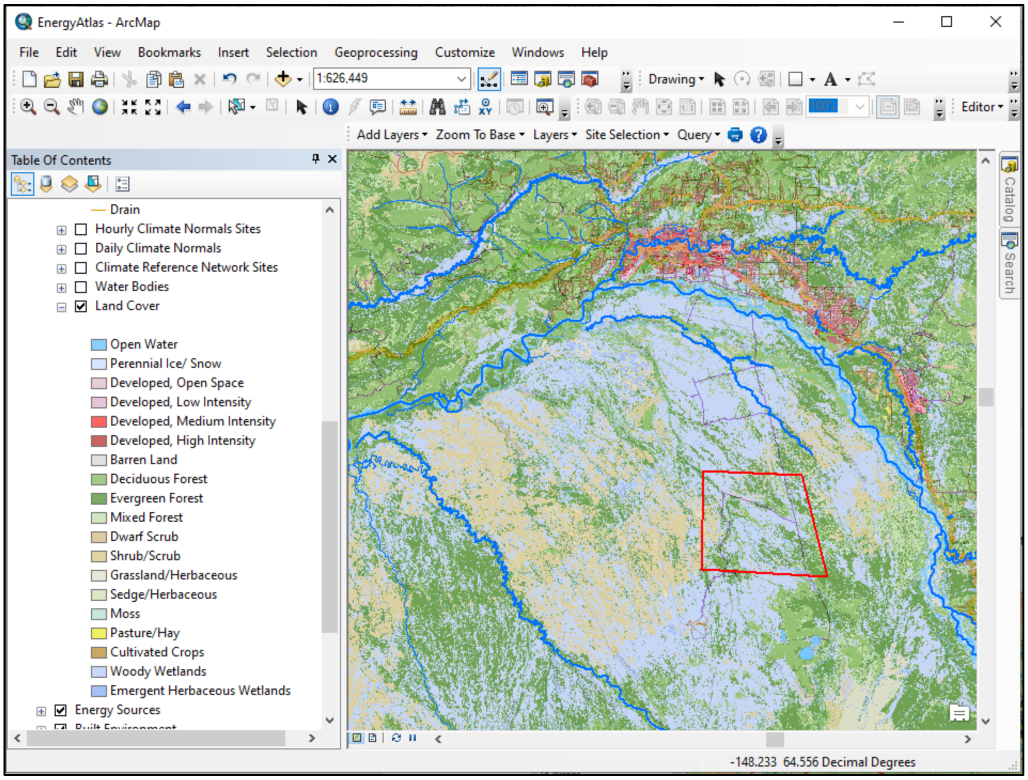


Figure 35 shows the refined area of interest in comparison to the land cover layer. The purple in the land cover layer indicates areas that are classified as wetlands and should be avoided when siting a PV installation. There are several locations within the refined area of interest that appear to have suitable land cover, to be located in close proximity to roads, to have suitable slope, and to have high average annual kilowatt-hours per square meter values. Ground truthing can now be performed in these areas to further investigate their suitability for siting a PV installation. This is just one example of how the Energy Atlas–Alaska can be used to perform site investigations with little to no initial investment. Additional layers within the Energy Atlas–Alaska could also be used to further refine this site selection investigation and narrow down locations for a PV installation.

Figure 35. Refined area of interest in comparison to land cover layer; *purple* areas indicate wetlands, which PV installations should avoid.



6 Next Steps

The Energy Atlas–Alaska is an evolving tool that we expand both in terms of data and capability in response to not only user feedback and decision-maker need but also the availability of new datasets and functions. The first year of this effort focused on identifying relevant data and sources as well as the inaugural design of the tool and its functions. Throughout this effort, both the project team and the stakeholders engaged during the project identified avenues for expansion beyond this initial work. Moving forward, the project team anticipates addressing several of these while realizing that additional opportunities and needs may continue to arise. Separate from the Phase 2 goals discussed below, the framework developed for Energy Atlas–Alaska can easily be applied to other states and territories.

The project team currently plans to address the following opportunities in the next phase of the Energy Atlas–Alaska effort:

First, we will transition the current stand-alone desktop installation into a web-based portal for ArcGIS to improve accessibility by the DoD community. The portal design will not only consider options such as user-input data sources but also the ability to connect to dynamic data sources. The project team will investigate various hosting options to ensure that appropriate OPSEC and data access controls can be implemented for FOUO and other protected data within the Energy Atlas–Alaska.

Second, the project team will expand the data available through the Energy Atlas–Alaska. The data gaps described in section 3.4 and data identified through further stakeholder engagement will continue to be sourced and integrated into the Energy Atlas–Alaska based on resources available. This effort will also include additional DoD land data as available. Stakeholder input will inform the prioritization of this effort.

Finally, the project team will be investigating additional DoD data efforts to evaluate the potential expansion of the Energy Atlas–Alaska to encompass additional resource information and to support broader DoD decision-making. The results of this effort will inform future development of the Energy Atlas–Alaska, likely beyond the next phase.

Through collecting and organizing relevant energy, infrastructure, and environmental data for DoD lands across Alaska, the Energy Atlas–Alaska tool serves as a value-added resource for decision-makers. By breaking down data silos and organizing all these data in one easy-to-use resource, the Energy Atlas–Alaska saves time and money while helping to make our Arctic DoD installations more efficient, resilient, and cost effective as we move into the future.

References

AEA (Alaska Energy Authority). 2020. *Alaska Energy Data Gateway (AEDG) and Inventory (AEDI)*. Anchorage, AK: Alaska Energy Authority. http://www.akenergyauthority.org/Portals/0/Fact%20Sheets/2016.06.14%20Alaska%20Energy%20Data%20Inventory%20Fact%20Sheet.pdf?ver=2021-01-15-145159-393.

———. 2021. "Welcome." Alaska Energy Authority. http://www.akenergyauthority.org/Who-We-Are/About-Us/Welcome.

AEA (Alaska Energy Authority) and REAP (Renewable Energy Alaska Project). 2019. *Renewable Energy Atlas of Alaska*. Anchorage, Alaska: Alaska Energy Authority. http://www.akenergyauthority.org/Portals/0/Programs/RenewableEnergyAtlas/2019HighRes.pdf.

Alaska Department of Transportation and Public Facilities. 2020. Alaska Department of Transportation and Public Facilities GIS. https://akdot.maps.arcgis.com/home/index.html.

Alaska DNR (Department of Natural Resources). 2020. "Alaska DGGS GeoPortal." Department of Natural Resources; Geologic & Geophysical Surveys. https://geoportal.dggs.dnr.alaska.gov/portal/home/.

ANL (Argonne National Laboratory). 2013. "Energy Zones Study for Eastern Interconnection." Center for Energy, Environmental, and Economic Systems Analysis. https://ceeesa.es.anl.gov/projects/eispc/eispc.html.

———. 2020a. "About the Project." EZMT: Energy Zones Mapping Tool. https://ezmt.anl.gov/about_the_study.

———. 2020b. EZMT: Energy Zones Mapping Tool. https://ezmt.anl.gov/mapping/viewer.

Bauer, J., B. Biesecker, and V. Nicchitta. 2019. "Defense Installations—Supporting Readiness with GIS." Presented at the 2019 Esri Federal GIS Conference, Washington, DC. https://proceedings.esri.com/library/userconf/fed19/papers/fed_102.pdf.

Bolstad, P. 2019. "Appendix A: Glossary." In *GIS Fundamentals: A First Text on Geographic Information Science*. Ann Arbor: XanEdu.

DHS (U.S. Department of Homeland Security). 2017. "HIFLD Open Data." Homeland Infrastructure Foundation-Level Data (HIFLD). https://hifld-geoplatform.opendata.arcgis.com/.

———. 2018. *HIFLD Open*. Washington, DC: U.S. Department of Homeland Security. https://gii.dhs.gov/hifld/sites/default/files/2018-05/HIFLD_Open_One_Pager_FINAL.pdf.

DoD (U.S. Department of Defense). 2020. Defense Installations Spatial Data Infrastructure (DISDI) Portal. https://rsgisias.crrel.usace.army.mil/disdiportal.

DOE (U.S. Department of Energy). 2008. *Programmatic Impact Statement, Designation of Energy Corridors on Federal Lands in 11 Western States*. DOE/EIS-0386. Washington, DC: U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2015/08/f25/EIS-0386-FEIS-FrontMatter-2008.pdf.

———. 2012. *Final Programmatic Environmental Impact Statement (PEIS) for Solar Energy Development in Six Southwestern States*. DOE/EIS-0403. Washington, D.C.: U.S. Department of Energy.

———. 2020. "Tribal Energy Atlas." Office of Indian Energy Policy and Programs. https://www.energy.gov/indianenergy/projects/tribal-energy-atlas.

Douglas, G. 2012. "News Release: Electronic Atlas Maps U.S. Renewable Energy Resources." National Renewable Energy Laboratory, 6 January 2012. https://www.nrel.gov/news/press/2012/1681.html.

Douglas, T. A. 2016. *Final Report: Addressing the Impacts of Climate Change on U.S. Army Alaska with Decision Support Tools Developed Through Field Work and Modeling*. SERDP RC-2110. Hanover, NH: U.S. Army Corps of Engineers Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory. https://apps.dtic.mil/sti/pdfs/AD1030958.pdf.

EIA (Energy Information Administration). 2020. "Layer Information for Interactive State Maps." Maps. U.S. Energy Information Administration. https://www.eia.gov/maps/layer_info-m.php.

Estima, J., N. Fichaux, L. Menard, and H. Ghedira. 2013. "The Global Solar and Wind Atlas: A Unique Global Spatial Data Infrastructure for All Renewable Energy." In *Proceedings of the 1st ACM SIGSPATIAL International Workshop on MapInteraction*, 36–39. https://dx.doi.org/10.1145/2534931.2534933.

IRENA (International Renewable Energy Agency). 2020. "About IRENA." International Renewable Energy Agency. https://www.irena.org/aboutirena.

———. 2021. "Global Atlas for Renewable Energy." International Renewable Energy Agency. Accessed 13 August 2020. https://globalatlas.irena.org/workspace.

Kempener, R., E. Assoumou, A. Chiodi, U. Ciorba, M. Gaeta, D. Gielen, H. Hamasaki, et al. 2015. "A Global Renewable Energy Roadmap: Comparing Energy Systems Models with IRENA's REmap 2030 Project." In *Informing Energy and Climate Policies Using Energy Systems Models*, edited by G. Giannakidis, M. Labriet, B. Ó Gallachóir, G. Tosato, 30:43–67. Switzerland: Springer International Publishing. https://doi.org/10.1007/978-3-319-16540-0_3.

Kuiper, J., K. Hlava, H. Greenwood, and A. Carr. 2013. *Renewable Energy Atlas of the Unites States*. ANL/EVS-13/2. Argonne, IL: Argonne National Laboratory. https://www.osti.gov/biblio/1039875/.

Mackinnon, T. 2014. "Ontario's Renewable Energy Atlas and Maps." Canadian GIS and Geospatial Resources, 19 June 2014. https://canadiangis.com/ontarios-renewable-energy-atlas-and-maps.php.

Multi-Resolution Land Characteristics Consortium. 2020. Multi-Resolution Land Characteristics (MRLC) Consortium. https://www.mrlc.gov/.

Natural Resources Canada. 2018. "The Atlas of Canada - Clean Energy Resources and Projects (CERP)." Canada Center for Mapping and Earth Observation (CCMEO), Natural Resources Canada. https://atlas.gc.ca/cerp-rpep/en/.

NOAA (National Oceanic and Atmospheric Administration). 2019. *Privacy Impact Assessment for the Data Archive Management and User System NOAA5011*. Washington, DC: National Oceanic and Atmospheric Administration. https://osec.doc.gov/opog/privacy/NOAA%20PIAs/NOAA5011_PIA_SAOP_Approved.pdf.

———. 2020a. "Climate Data Online." National Oceanic and Atmospheric Administration. https://www.ncdc.noaa.gov/cdo-web/.

———. 2020b. "NCEI GIS Map Portal." National Centers for Environmental Information. https://gis.ncdc.noaa.gov/maps/ncei.

———. 2020c. "U.S. Climate Reference Network." Air Resources Library: Atmospheric Turbulence & Diffusion Division. https://www.atdd.noaa.gov/crn/.

NREL (National Renewable Energy Laboratory). 2020a. "Geospatial Data Science Data and Tools." Geospatial Data Science. https://www.nrel.gov/gis/data-tools.html.

———. 2020b. "RE Atlas." National Renewable Energy Laboratory. https://maps.nrel.gov/re-atlas.

OSD (Office of the Assistant Secretary of Defense for Sustainment). 2020. "Defense Installations Spatial Data Infrastructure (DISDI)." Office of the Assistant Secretary of Defense for Sustainment. https://www.acq.osd.mil/eie/BSI/BEI_DISDI.html.

Ostrom, C. 2019. Fort Wainwright Geodatabase (FWA_SDE31.gdb). USAG Alaska Fort Wainwright IGI&S Program, SDSFIE-V 4.0.2 Army Adaptation. Retrieved 23 March 2020. https://atlas.obs.army.mil/portal/home/.

Taylor, J. 2021. "Fort Wainwright Production Checkin Map." ArcGIS Online. Last modified 18 March 2021. https://www.arcgis.com/home/item.html?id=d2583fed78014368856ac73df63ffe88.

U.S. Army. 2017. *Installation Geospatial Information and Services*. AR 115-13. Washington, DC: Headquarters, Department of the Army. https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/ARN1614_AR115-13_Web_FINAL.pdf.

———. 2019. "USARTRAK – U.S. Army Garrison Alaska." iSportsman. https://usartrak.isportsman.net/.

———. 2020a. "Army Installation Geospatial Platform." Deputy Chief of Staff, G-9 IGI&S Portal. https://atlas.obs.army.mil/portal/home/.

———. 2020b. "Army Installation Geospatial Platform: Army Installation Atlas." Deputy Chief of Staff, G-9 IGI&S Portal. https://atlas.obs.army.mil/portal/apps/sites/#/aia.

University of Alaska. 2020. Alaska Energy Data Gateway (AEDG). https://akenergygateway.alaska.edu.

USDA (U.S. Department of Agriculture). 2019. "National Geospatial Center of Excellence." Natural Resources Conservation Service. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/ngce/.

USGS (U.S. Geological Survey). 2011. "About the USGS Water Data for the Nation Site." National Water Information System: Help System. https://help.waterdata.usgs.gov/faq/about-the-usgs-water-data-for-the-nation-site.

———. 2020a. "Data and Tools." Energy Resources Program. https://www.usgs.gov/energy-and-minerals/energy-resources-program/data-tools.

———. 2020b. "National Water Information System: Map View." National Water Information System. https://maps.waterdata.usgs.gov/mapper/nwisquery.html.

Appendix A: Data Sources

Table A-1. Data sources integrated into the Energy Atlas–Alaska.

Data	Description	Sources/Citations & URLs
DOD Site Locations—FOUO	Locations of DoD sites	Defense Information Spatial Data Infrastructure (DISDI)—Homeland Infrastructure Foundation-Level Data (HIFLD) secure data portal. Retrieved 4/2/2020 from https://gii.dhs.gov/gii/home/
DOD Buildings—FOUO	Locations of buildings and structures on DoD sites	DISDI—HIFLD secure data portal. Retrieved 4/2/2020 from https://gii.dhs.gov/gii/home/
DOD Site Boundaries—FOUO	Boundaries of DoD sites, installations, ranges, and training areas	DISDI—HIFLD secure data portal. Retrieved 4/2/2020 from https://gii.dhs.gov/gii/home/
Roads on Installations—FOUO	Road centerlines located on DoD sites	DISDI—HIFLD secure data portal. Retrieved 4/3/2020 from https://gii.dhs.gov/gii/home/
Roads—FOUO	Major roads and roads located on DoD sites	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Fort Greely Space Missile Command—FOUO	Created from Installation layer, which was split into two layers (Fort Greely Space Missile Command and Installation boundaries near Fort Wainwright)	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Helipad—FOUO	Pavement section airline—helipads on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Levee—FOUO	Levees on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Railroad—FOUO	Rail segment—railroads on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Fence—FOUO	Fence on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Landuse—FOUO	Landuse on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Vehicle Parking—FOUO	Vehicle parking on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Pavement Section Road—FOUO	Pavement section road on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Pavement Section Airfield—FOUO	Pavement section airfield on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Airfield / Helipad Markings—FOUO	Airfield / helipad markings on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Outlet—FOUO	Electrical utility outlet on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Generator—FOUO	Electrical utility generator on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)

Data	Description	Sources/Citations & URLs
Electrical Utility Node Junction—FOUO	Electrical utility node junction on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Meter—FOUO	Electrical utility meter on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Substation—FOUO	Electrical utility substation on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Switch—FOUO	Electrical utility switch on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Transformer—FOUO	Electrical utility transformer on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Segment—FOUO	Electrical utility segment on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Utility Feature Support—FOUO	Utility feature support on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
POL Utility Junction—FOUO	Petroleum, oil, and lubricants utility junction on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
POL Storage Tank—FOUO	Petroleum, oil, and lubricants storage tank on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
POL Utility Pipeline—FOUO	Petroleum, oil, and lubricants utility pipeline on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Thermal Utility Node—FOUO	Thermal utility node on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Thermal Utility Fitting—FOUO	Thermal utility fitting on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Thermal Utility Valve—FOUO	Thermal utility valve on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Thermal Utility Line—FOUO	Thermal utility line on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Future Projects Location—FOUO	Future projects location on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Future Projects Pavement—FOUO	Future projects pavement on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Future Projects Building—FOUO	Future projects building on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Future Projects Area—FOUO	Future projects area on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Towers—FOUO	Towers on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Access control—FOUO	Access control on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Building Location—FOUO	Building location on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Land Management Zone—FOUO	Land management zone on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Structure—FOUO	Structure on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)

Data	Description	Sources/Citations & URLs
Land Parcel—FOUO	Land parcel on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Installation—FOUO	Installation layer was split into 2 layers (Fort Greely Space Missile Command and Installation boundaries near or on Fort Wainwright)	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Outside Installation—FOUO	Outside installations near Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Building Footprint—FOUO	Building footprint on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Site—FOUO	Site on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Stormwater Utility Inlet—FOUO	Stormwater utility inlet on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Stormwater Utility Discharge—FOUO	Stormwater utility discharge on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Stormwater Utility Junction—FOUO	Stormwater utility junction on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Culvert—FOUO	Culvert on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Stormwater Utility—FOUO	Stormwater utility on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Stormwater Utility Open Drainage—FOUO	Stormwater utility open drainage on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Wastewater Utility Sludge Bed—FOUO	Wastewater utility sludge bed on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Wastewater Utility Fitting—FOUO	Wastewater utility fitting on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Wastewater Utility Junction—FOUO	Wastewater utility junction on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Wastewater Utility Pump—FOUO	Wastewater utility pump on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Wastewater Utility Valve—FOUO	Wastewater utility valve on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Wastewater Utility Segment—FOUO	Wastewater utility segment on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Fitting—FOUO	Water utility fitting on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Hydrant—FOUO	Water utility hydrant on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Meter—FOUO	Water utility meter on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Pump—FOUO	Water utility pump on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Tank—FOUO	Water utility tank on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)

Data	Description	Sources/Citations & URLs
Water Utility Treatment Plant—FOUO	Water utility treatment plant on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Valve—FOUO	Water utility valve on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Segment—FOUO	Water utility segment on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Power Plants	Electric power plants	DISDI—HIFLD secure data portal. Retrieved 4/2/2020 from https://gii.dhs.gov/gii/home/
Biomass	Biomass	National Renewable Energy Laboratory (NRL). Retrieved 5/19/2020 from https://maps-data.nrel.gov/ows?outputFormat=SHAPEZIP&propertyName=name%2Cstate_name%2Ccrops%2Cmanure%2Cforest%2Cprimm ill%2Csecmill%2Curban%2Clandfill%2Ctotal%2Cthe_geom_4326&request=GetFeature&service=WFS&typeName=re_atlas%3AReAtlas_biomass&version=1.0.0
Coal District Boundary	Coal district boundary	Alaska Department of Natural Resources (DNR) Division of Geological and Geophysical Surveys (DGGS). Retrieved 5/4/2020 from https://dggs.alaska.gov/pubs/id/2636
Coal Basin Boundary	Coal basin boundary	Alaska DNR DGGS. Retrieved 5/4/2020 from https://dggs.alaska.gov/pubs/id/2636
Coal Field Boundary	Coal field boundary	Alaska DNR DGGS. Retrieved 5/4/2020 from https://dggs.alaska.gov/pubs/id/2636
Coal Locations	Coal locations—location of coal occurrence of unknown extent	Alaska DNR DGGS. Retrieved 5/4/2020 from https://dggs.alaska.gov/pubs/id/2636
Coal Ranks	Coal ranks	Alaska DNR DGGS. Retrieved 5/4/2020 from https://dggs.alaska.gov/pubs/id/2636
Heat Flow	Heat Flow—geothermal gradient test hole	Alaska DNR DGGS. Retrieved 4/28/2020 from https://dggs.alaska.gov/pubs/id/671
Thermal Springs	Thermal springs—hot springs data file was split into two feature classes using symbol field, based on map published by DGGS: thermal springs and thermal wells	Alaska DNR DGGS. Retrieved 4/28/2020 from https://dggs.alaska.gov/pubs/id/671
Volcanic Rocks	Volcanic rocks—Quaternary or Quaternary-Tertiary volcanic rocks	Alaska DNR DGGS. Retrieved 5/4/2020 from https://dggs.alaska.gov/pubs/id/2636
Volcanic Vents	Volcanic vents	Alaska DNR DGGS. Retrieved 4/28/2020 from https://dggs.alaska.gov/pubs/id/671
Oil and Gas Reservoirs	Oil and gas reservoirs	Argonne National Laboratory (ANL)—Energy Zones Mapping Tool (EZMT). Retrieved 3/17/2020 from https://ezmt.anl.gov/viewer

Data	Description	Sources/Citations & URLs
Oil and Natural Gas Fields	Oil and natural gas fields	Oak Ridge National Laboratory / ANL—HIFLD open data portal. Retrieved 4/2/2020 from https://gii.dhs.gov/gii/home/
Petroleum Product Terminals	Petroleum product terminals	ANL—EZMT. Retrieved 6/4/2020 from https://ezmt.anl.gov/viewer
Petroleum Refineries	Petroleum refineries	ANL—EZMT. Retrieved 5/28/2020 from https://ezmt.anl.gov/viewer
Wind Resource Potential at 50 m	Wind resource potential at 50 meters—data layer had over 1.3 million polygons without any attribute information so a DISSOLVE operation was performed, reducing the number of polygons to 9	NRL—Wind Energy Resource Atlas of the United States. Retrieved 1/28/2020 from http://www.nrel.gov/gis/wind_maps.html
Wind Speed at 100 m	Wind speed at 100 meters	ANL—EZMT. Retrieved 5/11/2020 from https://ezmt.anl.gov/viewer
Wind Speed at 80 m	Wind speed at 80 meters	ANL—EZMT. Retrieved 5/11/2020 from https://ezmt.anl.gov/viewer
Solar Photovoltaic	Solar photovoltaic	NRL—Renewable Energy Atlas. Retrieved 5/20/2020 from https://maps.nrel.gov/re-atlas/?aL=AMzVXM%255Bv%255D%3Dt&bL=clight&cE=0&lR=0&mC=63.421030654064175%2C-141.6796875&zL=5
Climate Reference Network Sites	Climate reference network sites—added URLs for sensor site data, which includes daily data at that site	National Oceanic and Atmospheric Administration (NOAA)—National Centers for Environmental Information (NCEI) portal. Retrieved 6/9/2020 from https://gis.ncdc.noaa.gov/maps/ncei/
Hourly Climate Normals Sites	Hourly climate normals sites	NOAA—NCEI portal. Retrieved 6/9/2020 from https://gis.ncdc.noaa.gov/maps/ncei/
Daily Climate Normals Sites	Daily climate normals sites—added URLs for station site data, which includes daily data at that site	NOAA—NCEI portal. Retrieved 6/9/2020 from https://gis.ncdc.noaa.gov/maps/ncei/
Rivers/Streams	Rivers/streams from Open Street Map	U.S. Army Geospatial Center (AGC)—Common Map Background Online Portal. Retrieved 3/9/2020 from https://agcwfs.agc.army.mil/CMB_Online/default.html
Surface Water	Surface water	U.S. Geological Survey (USGS)—National Water Information System Portal. Retrieved 3/24/2020 from https://waterdata.usgs.gov/ak/nwis
Water Bodies	Waterbodies from Open Street Map	AGC—Common Map Background Online Portal. Retrieved 3/9/2020 from https://agcwfs.agc.army.mil/CMB_Online/default.html
Natural Gas Pipelines	Natural gas pipelines	U.S. Department of Homeland Security—HIFLD Open Data Portal. Retrieved 3/13/2020 from https://gii.dhs.gov/gii/home/

Data	Description	Sources/Citations & URLs
Oil and Natural Gas Wells	Oil and natural gas wells	U.S. Department of Homeland Security—HIFLD Open Data Portal. Retrieved 3/31/2020 from https://gii.dhs.gov/gii/home/
Roads	Roads from Open Street Map	AGC—Common Map Background Online Portal. Retrieved 3/9/2020 from https://agcwfs.agc.army.mil/CMB_Online/default.html
Land Cover	Land cover	Multi-Resolution Land Characteristics Consortium—2016 National Land Cover Database. Retrieved 5/22/2020 from https://www.mrlc.gov/data?f%5B0%5D=region%3Aalaska&f%5B1%5D=region%3Aalaska
Slope Percent	Slope Percent for each cell of the raster. Created from 30 meter resolution digital terrain elevation data Level 2 for Fort Wainwright area	AGC—Common Map Background Online Portal. Retrieved 5/22/2020 from https://agcwfs.agc.army.mil/CMB_Online/default.html
County Boundary	County boundary—Topologically Integrated Geographic Encoding and Referencing Line file	U.S. Census Bureau. Retrieved 3/10/200 from https://www.census.gov/cgi-bin/geo/shapefiles/index.php
State Boundary	State Boundary— Topologically Integrated Geographic Encoding and Referencing Line file	U.S. Census Bureau. Retrieved 3/10/200 from https://www.census.gov/cgi-bin/geo/shapefiles/index.php
CADRG TLM50—Fort Greely, Fort Wainwright, Joint Base Elmendorf-Richardson	Compressed arc digital raster graphics of topographic line maps 1:50,000 scale for three areas: Fort Greely, Fort Wainwright, Joint Base Elmendorf-Richardson	AGC Common Map Background Online Portal. Retrieved 4/4/2020 from https://agcwfs.agc.army.mil/CMB_Online/default.html
USGS Topographic Reference Map	USGS topographic reference map	USGS—The National Map. Retrieved 3/11/2020 from https://basemap.nationalmap.gov/arcgis

Table A-2. Data sources not integrated into the Energy Atlas–Alaska.

Source	Consideration	Sources/Citations & URLs
Military Installations, Ranges, and Training Areas (MIRTA) Boundary Data	Compared the Defense Information Spatial Data Infrastructure site boundaries file and the MIRTA boundaries file and found that the files are essentially the same except the DIDSI file also includes training sites and training areas, which are not in the MIRTA file	DoD—Data.gov portal. Retrieved 4/14/2020 from https://catalog.data.gov/dataset/military-installations-ranges-and-training-areas
Rivers/Streams, Waterbodies	Rivers/streams, waterbodies—not used because data was not as detailed as the Open Street Map data	Alaska Department of Natural Resources. Retrieved 3/26/2020 from http://www.asgdc.state.ak.us/#30

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14. ABSTRACT
The U.S. Army is the largest Department of Defense (DoD) land user in Alaska, including remote areas only accessible by air, water, or wintertime ice roads. Understanding where energy resources and related infrastructure exist on and adjacent to DoD installations and training lands can help inform Army decision-makers, especially in remote locations like Alaska. The *Energy Atlas–Alaska* provides a value-added resource to support decision-making for investments in infrastructure and diligent energy management, helping Army installations become more resilient and sustainable.

The Energy Atlas–Alaska utilizes spatial information and provides a consistent GIS (geographic information system) framework to access and examine energy and related resource data such as energy resource potential, energy corridors, and environmental information. The database can be made accessible to DoD and its partners through an ArcGIS-based user interface that provides effective visualization and functionality to support analysis and to inform DoD decision-makers. The Energy Atlas–Alaska helps DoD account for energy in contingency planning, acquisition, and life-cycle requirements and ensures facilities can maintain operations in the face of disruption.

15. SUBJECT TERMS
ArcGIS, Energy conservation, Geographic information systems, Land use, Renewable energy sources--Alaska, United States--Department of Defense

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