UNIVERSITY of DENVER

COLORADO EVALUATION AND ACTION LAB

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COLORADO **BRIGHT**FIELDS

Inventory and Analysis of Brightfields in Colorado

REPORT HIGHLIGHTS:

- **Innovative New Mapping Tool:** COLORADO **BRIGHT**FIELDS is an innovative, free, and publicly available mapping application that provides access to information about thousands of marginalized sites suitable for solar energy and wind power.
- **100% Renewable Energy Goal:** Conceived to help the state achieve Governor Polis's bold goal of 100% renewable energy for the grid by 2040 and position Colorado as a leader in the clean energy economy.
- **Targeting Compromised Land:** Addresses the challenge that large, flat, open land close to utility infrastructure will become more difficult to secure for renewable energy generation as the demand for renewable energy increases.
- **One-of-a-Kind Consolidated Dataset:** Combines over 100 publicly-available datasets into one application, making it easy for renewable energy developers, communities and other stakeholders to identify marginalized properties for potential redevelopment with renewable energy ahead of utility procurement processes.

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SUPPORTING MATERIALS:

- https://brightfields.colorado.gov
- Fact Sheet
- User Guide
- FAQs
- Resources that Support Development

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BRIGHT RAIN SOLUTIONS

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Abstract

Colorado, like other states, has set ambitious goals related to renewable energy generation, specifically the conversion of the state's electrical grid to 100% renewable energy by 2040. While most renewable energy development to date has been focused on large projects sited on open, primarily agricultural land, the State's new goals will eventually require the development of smaller projects sited in closer proximity to electricity demand with minimal, if any, requirements for transmission upgrades. Many sites, such as brownfields, can offer a number of attributes that make them attractive for renewable energy development, including proximity to population centers and utility infrastructure, and the potential to make productive use of property that may have restrictions on other types of development. When such properties are made available for or are developed with renewable energy, they can be described as "brightfields."[i]

While the benefits of energy development on brownfields and other underutilized sites are well established, the relatively short timelines associated with utility procurement can be an impediment to the use of these sites when participating in renewable energy requests for proposals (RFPs). Early identification can help position sites to be development-ready when a renewable energy RFP is issued. This project built a geodatabase and web-mapping application, COLORADO **BRIGHT**FIELDS, that enables stakeholders to search for brightfield sites in Colorado. Identifying suitable sites ahead of utility procurement processes and making that information available to the broadest array of stakeholders possible will help encourage the use of brownfields and other marginalized properties for renewable energy development.

[i] A brownfield is a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant. The terms 'brownfield,' 'brightfield,' and 'marginalized' in this project refer to lands that are designated by state or federal agencies as brownfields, as well as mine-scarred lands, former landfills and dump sites, abandoned industrial and commercial sites, potential contaminated land, and other vacant and/or abandoned land that have limitations for other uses.

Table of Contents

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Data Sources

COLORADO **BRIGHT**FIELDS was developed using only publicly-available datasets. The project team did not change the attributes or geometry of any source data; any inaccuracies or inconsistencies in the data can typically be traced back to the original data sources.

Suggested Citation

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Introduction

Every tract of land has some uses for which it is better suited than others. In many cases, the highest and best use for blighted or compromised sites in the state may be renewable energy. Pairing brownfields and other underutilized and potentially contaminated properties with clean, renewable electricity generation will improve land use, help protect the health of Colorado communities, promote local economic development, and reduce greenhouse gas emissions.

'Brightfields' are marginalized sites that have the potential to be or have already been redeveloped through the incorporation of solar energy, wind power, or other renewable energy sources. Former land uses may include mining, oil and gas processing, and landfills, as well as industrial, manufacturing, and commercial enterprises. Some are publicly owned, others privately held. Many of these sites, or parcels, require no clean up at all while others may require action under a regulatory program or be eligible for cleanup undertaken free of regulatory pressure through a state or federal grant. Developing brightfields helps turn blighted or underutilized lands into valuable resources that support local economies while preserving lands with other characteristics for their unique uses.

*COLORADO **BRIGHT**FIELDS is an innovative, free, and publicly available web-mapping application that provides access to information about thousands of marginalized sites suitable for solar energy and wind power.*

COLORADO BRIGHTFIELDS makes it easy for users to search for and identify marginalized properties for potential renewable energy development in advance of utility procurement processes.

Governor Polis has set a goal of 100% renewable energy for the grid by 2040, positioning Colorado as a leader in the clean energy economy. Numerous approaches will be required to meet this goal; developing on brightfields is one of them. The benefits of renewable energy development to the climate are well documented. But a rapid increase in renewables development is not without risk. Such a shift could negatively impact communities, agricultural lands and cultural resources, as well as waterways, wildlands, and wildlife habitat if development continues to take large, open, easy to develop tracts of land out of their previous use and convert them to generate clean energy.

*COLORADO **BRIGHT**FIELDS addresses the challenge that large, flat, open properties close to utility infrastructure will become more difficult to secure for renewable energy generation as the demand for renewable energy increases.*

COLORADO **BRIGHT**FIELDS is a web-mapping application that combines over 100 publicly available data sources into one easy to use inventory of marginalized parcels in the state that users can search, browse, and filter to identify land to develop for renewable energy projects. It was conceived to support the state's transition to renewable energy in a way that minimizes the impact of significant increases in generation by shifting the focus of development to more marginalized lands and away from lands with higher and better value.

Project Goals

Project Goal #1: Design, build, and populate an easy-to-use web-mapping application that provides useful data to support the identification, visualization, and analysis of brightfield parcels in the state of Colorado.

While the benefits of energy development on marginalized land are well established, the relatively short timelines associated with utility procurement can be an impediment to the use of these sites when participating in renewable energy RFPs. To help facilitate the process of identifying appropriate sites and accelerate the timeline for renewable energy projects, the project team developed a geodatabase that can be accessed for free through an easy-to-use web-mapping application.

The project team consulted with key federal and state agencies, as well as experts in renewable energy, electric utility infrastructure, and redevelopment of contaminated lands to help determine the answers to three key questions that guided the development of the geodatabase and web-mapping application: 1) what criteria should be used to define appropriate parcels; 2) what criteria should be used to identify the best sites for renewable energy development; and 3) given limited time and resources, which counties across the state should be prioritized for inclusion in the project? The process through which these questions were answered and the geodatabase was created and compiled is discussed in Project Goals #2 through #4.

Project Goal #2: Establish consistent and replicable methods for identifying potential brightfields in Colorado.

The project team looked to the U.S. Environmental Protection Agency's (EPA's) RE-Powering America's Lands program[1] as a starting point to identify the types of contaminated and marginalized lands that should be included in the COLORADO **BRIGHT**FIELDS geodatabase. Property types identified included sites documented in various state and federal environmental programs, such as those that track brownfields, abandoned mines, and landfills, and those that manage voluntary and mandatory cleanup processes. In addition, the team added a unique category of land called 'vacant industrial' that is based upon zoning designation and includes undeveloped sites zoned for industrial use. In all, the team identified 12 categories of contaminated, previously contaminated, underutilized, or marginalized land to be included in the geodatabase and web-mapping application.

Project Goal #3: Identify a set of site attributes that would be most helpful in the decision-making process used for determining site feasibility for a renewable energy project and develop a methodology for collecting, calculating, and tabulating this data for each brightfield parcel.

The process of identifying a site for renewable energy development requires a wide variety of data from numerous sources. Information including legal status, past and current land uses, physical characteristics, economic zone status, solar and wind resource availability, and proximity to utility infrastructure are among the crucial data needed to make a recommendation about parcel development. Final determination of which attributes to include in the geodatabase and web-mapping application were made by the project team in consultation with an advisory committee and other renewable energy and brownfields specialists. Computation of the needed attributes was accomplished through a series of geoprocessing tools, as outlined in the Geodatabase: Data Collection, Preparation and Analysis section.

Project Goal #4: Given limited time and resource availability, identify and prioritize the Colorado counties to be included in the first version of the geodatabase and web-mapping application.

Initial funding for this project provided for the development of the geodatabase and web-mapping application and the identification and analysis of brightfield sites for 10 of Colorado's 64 counties. To determine which 10 counties would be included in this initial deployment of COLORADO **BRIGHT**FIELDS, the project team developed a methodology for ranking and prioritizing counties. This was accomplished by assigning points to three categories of metrics: 1) potential demand for new energy sources; 2) local enthusiasm or advocacy for renewable energy development; and 3) number of potential brightfield parcels. Each category was tabulated and total scores were awarded to each county. To ensure geographic diversity, the highest-ranked county within each of Colorado's 14 Planning and Management Regions[2] was awarded additional points. This process resulted in the following list of ten counties, in order from highest to lowest priority: Denver, Ouray, Mineral, Adams, San Juan, Hinsdale, Jefferson, Pueblo, Lake, and Weld. Since three of these counties (Mineral, San Juan, and Hinsdale) did not have available parcel data, the next three highest-ranked counties (Arapahoe, El Paso, and Montezuma) moved into the top 10 group.

Project Highlights

Innovative New Mapping Tool

Typically, developers need to access dozens of individual data sources to find the information needed to first screen for and then analyze whether a parcel may be a viable option for a renewable energy project. To address this challenge, the project team built a geodatabase that identifies more than 4,000brightfield parcels in 10 Colorado counties and provides more than 40 fields of data about each parcel.

The project team simultaneously built an online mapping interface that provides renewable energy developers, communities, and other stakeholders with an easy-to-use application to search, filter and browse the geodatabase. The web-mapping application provides tabular data for viewing and download and links to external data sources. In addition, 14 geographic information systems (GIS) layers of contextual datasets are provided to enable visualization of site conditions, including five-foot topographic contours, presence of Federal Emergency Management Agency (FEMA)-designated flood hazard areas, existence of conservation easements, and land ownership status. These GIS data layers can be toggled on and off to visualize and analyze physical features, legal boundaries, and regulatory constraints. The types of data that can be accessed in the mapper are summarized in Table 1.

Table 1: Data Provided in the Geodatabase and Web-Mapping Application

Legal Information	Physical Environment	Renewable Energy and Electric Infrastructure
- Street Address†	- Land Cover†	- Solar GHI (kWh/m2/day)†
- Zip Code†	- Brightfield Type◊†	- Solar DNI (kWh/m2/day)†
- City◊†	- Parcel Area◊† (acreage as measured on the ground and reported to county assessor's office)	- Windspeed at 80m (m/sec) ◊†
- County◊†	- GIS Parcel Area (acreage as measured using GIS software)	- Utility Service Area◊*†
- Assessor's Parcel Number†	- Parcel Perimeter†	- Transmission Lines and Electric Substations*† (including location, ownership, size, distance to each parcel and other characteristics)
- Legal Description	- Parcel Shape Index†	- Xcel Hosting Capacity*
- Zoning†	- Built Area†	
- Land Use†	- Canopy Area†	
- Owner Type†	- FEMA Flood Hazard*	
- Owner Name(s)†	- Wetlands*	
- Easement Type(s)*†	- Rivers and Streams*	
- Easement Area (acres)*†	- Lakes and Ponds*	
- Opportunity Zone◊*†	- Topographic Contours*	
- Enterprise Zone◊*†	- Distance to Nearest Road†	
- County Boundaries*		
- Brightfield Parcel Boundaries*		
- Public Land Ownership*		
- Conservation Land Ownership*		
- Link to Assessors Data†		

Note. ◊data for which filters can be applied; *data included in a map layer; †data included in pop-up data table

To design the geodatabase and mapping application, the project team evaluated over 200 publicly available datasets; engaged an advisory committee whose members included government agency staff and specialists in renewable energy, electric utility infrastructure, and redevelopment of contaminated lands; researched other mapping applications; and solicited use case recommendations to identify the data and features users would need to successfully complete searches.

Supports 100% Renewable Energy Goal

> **COLORADO BRIGHTFIELDS helps the state achieve Governor Polis's bold goal of 100% renewable energy for the grid by 2040 and position Colorado as a leader in the clean energy economy.**

Colorado Governor Jared Polis set a goal of 100% renewable energy for the grid by 2040 "motivated by the moral imperative to fight climate change and curb pollution of our air and water, as well as the opportunity to drive innovation and harness the consumer savings and economic benefits of leading the transition to a clean energy economy."[3] Numerous approaches will be required to meet this goal—COLORADO **BRIGHT**FIELDS is one of them.

Replacing conventional fossil fuel generation with renewable energy will curb water and air pollution and reduce greenhouse gas emissions, thereby helping to mitigate the human health and climate impacts of electricity generation. However, the large amount of land Colorado will need in the coming years to meet

its renewable energy goal could negatively affect agricultural lands, wildlands, and sensitive habitats if not thoughtfully sited. Developing new electric power capacity on brightfields will help conserve lands with better and higher value for purposes marginalized lands cannot serve.

Moreover, brightfield redevelopment helps stimulate local economies and support a just transition in communities adversely affected by revenue and job losses resulting from the closure of coal mines and coal-fired power plants. Developing brightfields improves local tax bases by increasing revenue where once there was underutilized land and replacing revenue where conventional power generation used to be. Brightfield development also provides new clean energy jobs and drive innovation to improve the lives of Coloradans and position Colorado as a leader in the clean energy economy.

Targeting Compromised Land

> **COLORADO BRIGHTFIELDS addresses the challenge that large, flat, open land close to utility infrastructure will become more difficult to secure for renewable energy generation as the demand for renewable energy increases.**

Large, flat, open land close to utility infrastructure is the easiest, least expensive, and most efficient to develop. Many such parcels have already been repurposed for renewable energy projects while others are valued for other development purposes. As renewable energy penetration increases in the state, so too will the difficulty of acquiring the easy-to-develop sites.

COLORADO **BRIGHT**FIELDS can help mitigate the impact of a significant increase in renewable energy generation by shifting the focus of development to more marginalized lands and away from lands with higher and better value. Developing new electric power capacity on brightfields will help reduce land use conflicts and help conserve lands that have better and higher value for purposes that marginalized lands cannot fill. Sites that have limitations for other uses – such as brownfields, mine-scarred lands, closed landfills and dump sites, abandoned industrial and commercial sites, and other vacant and/or abandoned land - can offer a number of attributes that make them attractive for renewable energy development, including proximity to population centers and utility infrastructure, the potential to make productive use of property that may have restrictions on development, and the opportunity to integrate economic development and habitat improvement.

Properties that previously hosted mining, oil and gas, landfills, large commercial developments, or industrial processes may be well-suited for medium- to large-scale wind and solar development. Smaller sites that previously housed dry-cleaning operations, automotive service shops, and certain building materials (e.g., asbestos) tend to be concentrated in more populated areas such as main streets and strip malls and are typically well-suited to small solar arrays, rooftop arrays, or other types of local economic redevelopment.

The state may require certain parcels to undergo some level of remediation for their proposed new use; others may require no cleanup at all to be redeveloped with renewable energy. Many may be eligible for subsidized cleanup, undertaken free of regulatory pressure through the Colorado Department of Public Health & Environment's (CDPHE's) Voluntary Cleanup Program.[4] Highly contaminated sites may require action under a federal regulatory program such as Comprehensive Environmental Response, Compensation, and Liability Act, also known as Superfund, or the Resource Conservation and Recovery Act (RCRA), the federal law that requires the proper management of hazardous and non-hazardous solid waste.

One-of-a-Kind Consolidated Dataset

> **COLORADO BRIGHTFIELDS combines over 100 publicly-available datasets into a geodatabase and web-mapping application, making it easy for renewable energy developers, communities, and other stakeholders to identify marginalized properties for potential redevelopment with renewable energy ahead of utility procurement processes.**

The value of this new tool is in the acquisition, consolidation, analysis, and presentation of diverse datasets. While all data in COLORADO **BRIGHT**FIELDS are free and publicly available via the internet and/or direct requests from federal, state, local, and county agencies, renewable energy developers wishing to replicate the information contained in COLORADO **BRIGHT**FIELDS would need to spend dozens, if not hundreds, of hours finding, acquiring, and analyzing the over 100 individual geospatial datasets that were used.

In addition to the source datasets used in parcel analysis, other geospatial layers provide geographic context for visual confirmation of physical site features or additional utility and regulatory information. Together, these many and varied layers create a useful tool for remote site reconnaissance and suitability assessments that provide a level of efficiency not available elsewhere. It is important to note that the administrative data upon which the geodatabase relies is not perfect and can become outdated. While the mapping application is efficient for broad exploration and identification of potential sites, it is incumbent upon the user to verify through other means that a given site meets their specific needs.

Policy Implications

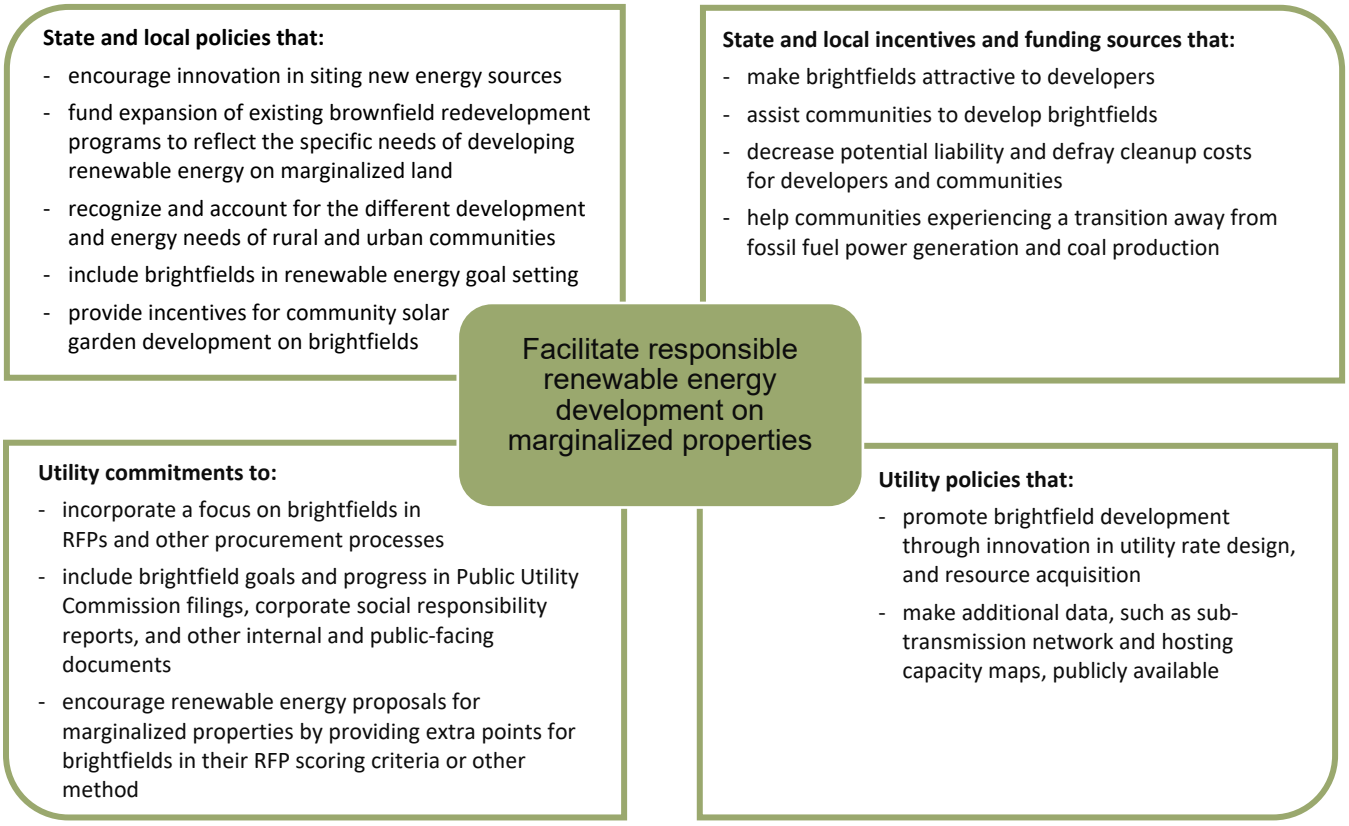
There is both great opportunity and considerable need to develop brightfields to help the state meet its goal of 100% renewable energy by 2040. This need will continue to grow as the easiest-to-build sites are developed. However, barriers to brightfield development may be significant in individual cases and include potential increases in environmental liability, cleanup costs, construction complexities, and regulatory hurdles when compared to developing renewable energy projects on more pristine properties.

Implementing policies and incentives that encourage the use of brightfields and mitigate the real or perceived risks and costs associated with developing on marginalized land will be a crucial step to helping meet the Governor's goal of 100% renewable energy.

Specific Recommendations

A diverse stakeholder group that includes legislators, state and local agencies, utilities, renewable energy developers, economic development organizations, conservation non-governmental organizations, and others should work together to formulate and implement appropriate policies and incentives to mitigate the barriers and promote the use of marginalized land for renewable energy projects. New state policies, incentives and funding sources, as well as utility policies and commitments, are needed to facilitate and accelerate responsible brightfields development. Some actions the state and utilities should consider are captured in Figure 1.

Figure 1: Policy and program options to facilitate development of brightfields



Colorado's existing brownfields programs may provide a start for building new brightfields capacity. The state currently funds programs that help address the risks and costs associated with developing on marginalized properties by providing resources to characterize contamination, cleanup sites, or indemnify owners against future action related to site contamination and the property's new use.[5]

- The Voluntary Cleanup Program (VCUP) provides resources to communities and private parties to clean up contaminated sites to a level required for reuse or intended new use.
- Targeted Brownfield Assessments (TBAs) provide funds and expertise to public and nonprofit groups to evaluate sites for contamination.
- The Colorado Brownfields Revolving Loan Fund (CBRLF) offers financing with reduced interest rates and flexible loan terms to local governments and non-profits.
- 1306 Brownfields Cleanup Grants fund remediation of contaminated abandoned properties by non-profits, non-federal governmental entities, and watershed and other community organizations.
- The Colorado Brownfields Tax Credit provides a tax credit for qualifying entities that perform environmental remediation associated with capital improvements or redevelopment projects.

Solar and wind developers and communities can and should avail themselves of these resources when needed to prepare marginalized properties for renewable energy projects. But these programs alone do not provide enough incentive, support, or liability reduction to encourage the amount of brightfields development that Colorado needs to meet its renewable energy goals. The specific recommendations above, which include expanding the existing brownfield redevelopment programs to reflect the specific needs of developing renewable energy on marginalized property, should help move Colorado toward a more holistic approach to brightfields development.

Methods

County Ranking and Prioritization

The criteria used to determine county prioritization for inclusion in the geodatabase and web-mapping application were broken down into three categories: 1) potential demand for new energy sources; 2) local enthusiasm or advocacy for renewable energy development; and 3) number of potential brightfield parcels. The factors that went into measuring each of the criteria are detailed below. The prioritization guided the order in which counties were added to the COLORADO **BRIGHT**FIELDS geodatabase. Any counties for which key datasets were unavailable were omitted from consideration, pending such data becoming available.

Potential Demand for New Energy Sources

Four metrics contributed to this category:

- County population
- County growth rate over the past decade
- Recent and upcoming fossil-fuel power plant closures
- Designation as an Opportunity Zone

Population and growth rate were each normalized to a 10-point scale based on most recent available data from the state. The power plant closure data included all sites closed within the past 10 years or projected to close within the next 10 years. The total nameplate generation in each county was calculated and normalized to a 20-point scale, as a means to quantify a just transition from fossil fuels to renewables. Opportunity zones were compared to the total county area and normalized to a 10-point scale, such that 10 points meant that 100% of the county area was covered by an opportunity zone. All totaled, the maximum score for this category was 50 points, which was approximately 32% of the total score.

County 'Enthusiasm' for Renewable Energy

This category was a compilation of various measures of counties' interest in pursuing renewable energy development, including:

- local regulations and financial incentives for renewable energy projects (both at the county level and for cities within each county).
- pursuit of renewable energy funding by cities and counties (as measured by Department of Local Affairs letters of interest and planning grants for renewable energy projects).

- rankings and awards from national renewable energy advocacy groups (including SolSmart community designations and the Sierra Club's 'Ready for 100' program).

When initially calculated, it was found that this category heavily favored the most populous counties in the state (generally in the northern Front Range), which tend to have the greatest resources to pursue renewable energy grants, loans, and technical assistance. In order to counter that bias, the population of each county was factored in by dividing the total renewable energy scores for each county by that county's population and normalizing the results to a 50-point scale. The maximum score for this category was therefore 50 points, which was approximately 32% of the total score.

Number of Potential Brightfield Parcels

This category used a subset of brightfield data sources to estimate the potential number of brightfield parcels available in each county. Three measures were used to create this estimate:

- The number of sites in each county designated by the EPA as a brownfield.
- The number of sites designated by CDPHE as a brownfield (eliminating those that were captured in the federal data).
- The number of closed landfills in each county.

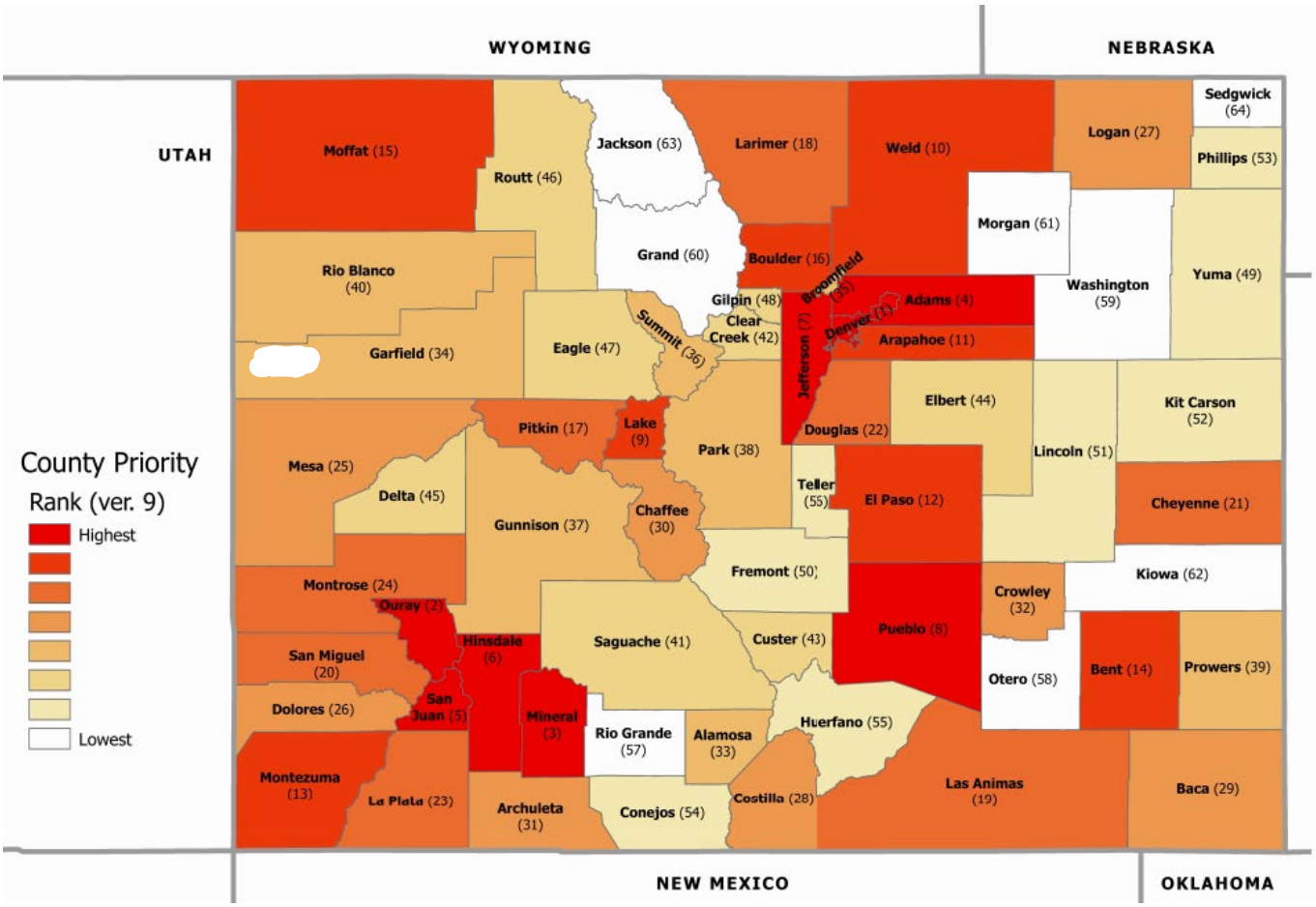
While these sources are not complete measures, the project team felt they were likely to provide a proxy for the relative number of brightfield sites in each county. The total number of brightfield sites identified in each county was summed and normalized to a 50-point scale, making the maximum score in this category 50 points, which was approximately 32% of the total score.

Geographic Representation

To improve geographic representation across the state, the project team assigned 10 bonus points to the top-ranking county (the county with the greatest point total based on all other categories) in each of the state's 14 Planning and Management Districts. The result was a more equitable geographic distribution across the entire state. Without these bonus points, the far eastern and western counties ranked in the bottom half in all other metrics tested. The only possible score in this category was 10 points, which was approximately 4% of the total.

Each county's overall ranking is captured in Figure 2.

Figure 2: County Prioritization



Geodatabase: Data Collection, Preparation, and Analysis

Data was sourced and acquired through state agencies and other organizations, or through known online data portals. Input from an advisory committee was used to identify crucial data to be included in the geodatabase as well as in the web-mapping application, which included: 1) the criteria that should be used to define what constitutes a brightfield parcel; 2) the parcel-specific metrics that could be used to identify the best sites for renewable energy development; and 3) which counties across the state should be prioritized for inclusion in the project.

Brightfields Inclusion

Identification of brightfields was determined based on a property's inclusion in one of the following datasets:

- CDPHE Brownfields
- CDPHE Closed Landfills
- Division of Oil and Public Safety Petroleum Brownfields

- CDPHE Uranium Mill Tailings Remedial Action Sites
- Division of Reclamation, Mining and Safety Inactive Mines
- CDPHE Institutional Control Sites
- CDPHE Voluntary Cleanup and Redevelopment Sites
- EPA Superfund Sites
- EPA Brownfields
- EPA RCRA Corrective Action Sites
- EPA Landfill Methane Outreach Program Sites
- Vacant Industrial Sites

The above-listed categories are also the names of publicly-available datasets, except for "Vacant Industrial Sites," which were compiled by identifying parcels zoned for industrial use that did not contain any building footprints according to the latest available assessor's data. These 12 categories of sites were geographically cross-referenced with parcel data in each of the completed counties in order to identify brightfield parcels.

Upon completion of the identification and documentation of each county's brightfield parcels, data was standardized and compiled into county-based file geodatabases for the purposes of project collaboration and efficiency during the data analysis phase.

Parcel-Specific Metrics

Once the brightfield parcels were identified, attribute data was added to each parcel record. Some of the attribute data was pulled in directly, while other data was used to calculate new attribute fields in order to provide additional, detailed information about each parcel. That data, which can be viewed in the associated pop-up table in the web-mapping application, as well as the CSV download file, includes the data related to legal information and physical environment that is marked with a dagger (†) in Table 1.

Parcels zoned exclusively for residential uses were excluded from the geodatabase. Any parcels with less than an acre of land available after subtracting the footprint area of permanent structures were likewise excluded. However, brightfield parcels of less than one acre in size that had no permanent structures and were contiguous with other brightfields that together totaled an acre or more in size remained in the geodatabase.

The attribute data was then standardized across all included counties using geoprocessing tools, such that each feature class of the same data type in the geodatabase contained the same set of consistently-named attribute fields and values.

Renewable Energy Development Criteria

The parcels in each county were further analyzed in order to provide solar, wind, and utility information that may be useful in identifying suitable candidates for renewable energy development. That data, marked with a dagger in the category 'Renewable Energy and Electric Infrastructure' in Table 1, can be viewed in the associated pop-up table in the web-mapping application as well as in the CSV download file.

Once all data analysis for each county was complete, all county-based file geodatabases were combined into a single statewide file geodatabase, which provides the data backbone for the web-mapping application.

Web-Mapping Application: Design, Features and Capabilities

The mapping application was designed to be an intuitive, user-friendly interface for accessing and analyzing the data in the geodatabase. The project team used widely accepted, free services to create a customized application that is client-side and standards-based with minimal dependencies. Standard HTML, CSS, and JavaScript comprise the application itself; Vue.js provides the foundational framework; ArcGIS is used for mapping functionality, service consumption, and tools; and npm supports package management and developer operations.

To inform design of COLORADO **BRIGHT**FIELDS, the project team circulated a use case survey that sought input on stakeholders' preferences for interacting with the mapping application. The survey included questions about potential users, which variables (inputs) they would like to control, and their desired output from using the application.

Results of the use case survey guided design of the mapping application. Features were built into the application to give users the ability to interact with the data in multiple ways: filter criteria can be selected to narrow down parcel selection; the search function can be used to locate addresses, places, and specific brightfields; layers can be turned on and off to visually inspect physical conditions and regulatory constructs; and additional tools provide the opportunity to navigate, zoom, measure, download data, and print maps.

Methods to filter sites by manipulating the expression of certain criteria include multi-selection menus, on/off toggles, and threshold-setting slider scales. Available filters are marked with a diamond (◊) in Table 1. As filters are selected and deselected, the brightfield parcels that result from each filter combination are visually displayed on the map. Criteria that can be chosen from multi-selection menus include brightfield type, utility service area, city, and county. Toggles allow the user to filter for sites that are in designated Opportunity and/or Enterprise Zones. Scale sliders allow users to set thresholds for minimum parcel size and minimum wind speed. A search bar allows users to search specific brightfields, addresses, and locations.

Additional tools were included to help users interact with parcels and other elements directly in the mapping environment. Most prominent among these are the overlays, which are marked with an asterisk (*) in Table 1, that can be toggled on or off by users.

Users can drill down for additional information by selecting map elements from many of these overlays, including transmission lines, substations, publicly-owned land, and conservation areas, to reveal specific data about each element. Available zoom scales range from a statewide view to a less than 100 square foot view. Linear distances and polygonal areas can be measured in a variety of units. Users can switch between a simple street base map and aerial imagery, download tabular data about selected parcels to a CSV file, and print maps.

Conclusion

The first version of the COLORADO **BRIGHT**FIELDS web-mapping application, with over 4,000 parcels in 10 counties, was launched in May 2021. Initial reaction has been quite positive.

To build a user base and continue adding counties and data to the geodatabase, key next steps include 1) creating awareness about COLORADO **BRIGHT**FIELDS, the benefits this approach offers, and how to access and use the geodatabase and mapping application; 2) growing interest in, and financial support for expanding the geodatabase and web-mapping application to include more counties; and 3) convening interested stakeholders to recommend and advocate for new polices, programs, and incentives. These steps have not yet been funded; the project team is actively seeking grants and other investment funding to continue to build out COLORADO **BRIGHT**FIELDS.

Endnotes

[1] U.S. Environmental Protection Agency. RE-Powering America's Land. Retrieved from https://www.epa.gov/re-powering

[2] Colorado Association of Regional Organization. 2019. Colorado Planning and Management Regions. Retrieved from https://www.colorado.gov/pacific/sites/default/files/Caro%20Brochure%20and%20Directory%20Link.pdf

[3] Colorado Governor's Office. (2019). Polis Administration's Roadmap To 100% Renewable Energy By 2040 And Bold Climate Action. Retrieved from https://drive.google.com/file/d/0B7w3bkFgg92dMkpxY3VsNk5nVGZGOHJGRUV5VnJwQ1U4VWtF/view

[4] Colorado Department of Public Health & Environment. Voluntary Cleanup and Redevelopment Program. Retrieved from https://cdphe.colorado.gov/voluntary-cleanup,

[5] See *Resources that Support Development* document linked on front page