INL/MIS-23-74964

Non-Powered Dam Hydropower Development and Ranking Opportunity Tool

September 2023

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ACRONYMS

CDC	Center for Disease Control
DOE	Department of Energy
HUC	hydrologic unit code
HYDRO	Hydropower Development and Ranking Opportunity
NERC	North American Electric Reliability Corporation
MW	megawatt
NG	natural gas
NPD	non-powered dam
PSH	pumped-storage hydropower

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Non-Powered Dam Hydropower Development and Ranking Opportunity Tool

1. ABOUT NON-POWERED DAMS

In pursuit of a net-zero-carbon emissions economy in the United States, non-powered dams (NPDs) represent a large opportunity to develop hydropower while leveraging existing infrastructure. With almost 600 NPD sites in the United States identified as having over 1 megawatt (MW) of potential capacity, only a small portion of the total potential capacity at these sites has been developed in recent years.[a,b] Conventional NPD retrofit feasibility analysis primarily focuses on the developer's perspective but fails to consider the broader impacts of developing a dam, including on the neighboring communities.

This tool, the Non-Powered Dam Hydropower Development and Ranking Opportunity Tool (NPD HYDRO), allows users to prioritize or rank NPD sites for future development based on user-defined priorities. Benefits can be evaluated in several categories: the grid, community, industry, and environment (referred to as the four impact scores in the tool as discussed in Section 2.2). In addition, the tool provides the user with a qualitative measure for the feasibility of adding energy storage during NPD conversion, specifically battery, hydrogen electrolysis, and pumped-storage hydropower (PSH). By taking a holistic approach to the potential range of benefits provided by NPD conversions with results tailored to the user's priorities, NPD HYDRO provides the opportunity for national-level screening and enables users to focus on the sites that are most closely aligned with their interests.

2. NPD HYDRO

2.1. Taking The User Survey

Each visitor to the NPD HYDRO tool is given the first step of filling out an optional questionnaire on the landing page. NPD HYDRO collects this information for internal use at the Department of Energy (DOE) to guide future research on interested users and their most pertinent benefits from NPD conversion. This information is not shared with other entities outside of the DOE and the national laboratories. This survey can be bypassed by clicking on the "Tool" tab in the upper right-hand corner of the tool webpage.

When selecting a User Group (such as community group; developer; environmental organization; NPD owner; tribal, state, or federal government entities; etc.), each user can only select one user group at a time (see Figure 1).

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[a] Hadjerioua et al. 2012 https://www1.eere.energy.gov/water/pdfs/npd_report.pdf.

[b] Hansen et al. 2021 https://doi.org/10.1016/j.rser.2021.111058.

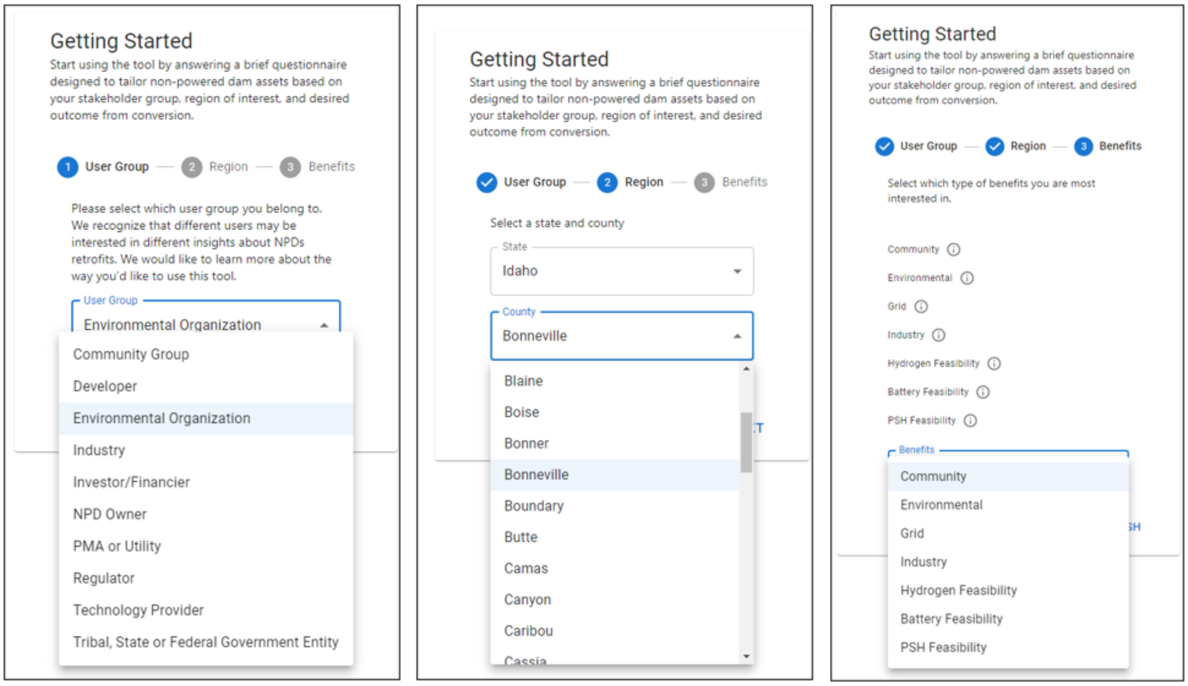


Figure 1. User group, region, and benefits selection.

The benefits selection in the final step of the questionnaire is used by the tool to calibrate an initial scoring weight for NPDs in the database. For example, if the user informs NPD HYDRO that they are most interested in the environmental benefits from NPD conversion, then upon completion of the questionnaire, the tool will organize its initial sort order based on the maximum weighting of the environmental impact score (details on each score calculation is provided in the next section, and equations are given in Appendix A). If a user is new to NPD HYDRO and would like to familiarize themselves with the benefit categories that can be selected in the user survey, they can hover over to the information tooltips (shown by the ⓘ icon) for a detailed description of the categories. The currently listed benefit categories are grid, community, industry, and environmental benefits and are calculated by the four impact scores in the tool. This list also includes technology feasibility in terms of hydrogen production, batteries, and PSH feasibility.

2.2. Exploring The Benefit Scores – Assigning Weights and Selecting Features

Once inside the tool, a user will see a panel on the left side of the page with scoring layers and weights. The sliders are used to adjust the preset weights for each benefit category (i.e., four impact categories). By selecting a weight of 0 (the lowest weight), that category is multiplied by zero, taking it out of the overall ranking calculation. By selecting a weight of 1 (the highest weight), that category is multiplied by 1 in the ranking calculation. The default weight for all categories is 0.5 unless the questionnaire is filled out with a particular focus on a given category, in which case that category is preset to a weight of 1. In addition to assigning weights, users may select which attributes contribute to each score, clicking on boxes to include or exclude any attribute(s) from the calculated score in any given category. This allows a great deal of flexibility with the tool, as it is possible to sort on a very narrow set of criteria. As an extreme example, it is possible to set all impact categories to zero, except for one category for which the user can select just one feature. This prioritizes the sites based on just this one feature. A detailed example of weight assignment and attribute selection is provided in Section 3. The parameters of each of the four impact scores is given in Sections 2.2.1–2.2.4 and full equations are given in Appendix A.

Upon hitting ***Calculate NPD Scores*** button the tool will calculate impact scores for each of the NPD sites included in this tool, outputting an attribute table showing the NPDs ranked highest to lowest based on the total score calculated from the four impact scores. In other words, the ranking is based on a composite of four individual impact scores (i.e., grid, community, industry, and environment). While energy storage technology feasibilities are also given in the attribute table, it is not part of the composite score that ranks the NPD sites. Note the features of each impact score are selected by the user. The scores do not have to contain all features. Please refer to Appendix A and the metadata file for more information on the equations and sources of each input feature along with their descriptions and units (if any).

2.2.1. Community Score

The community score measures the potential social and economic impacts of NPD conversion and is calculated using the following inputs:

- Social vulnerability (socioeconomic and demographic factors that affect community resilience)
- Overall air quality
- Natural hazard risks
- Proximity of the dam to hospitals and public schools
- Relevant regulatory policies at the state level that promote hydroelectricity
- Number of policies supporting hydropower in the state
- Number of financial incentives for hydroelectricity in the state
- Regional (i.e., state) per capita energy consumption and expenditure
- The ratio between potential capacity at the dam and surrounding fossil fuel-based power plants' operating capacity.

Social vulnerability, overall air quality, and natural hazard risks (all at the county level) are included in the score to measure the local community's socioeconomic and environmental vulnerability. We use the Center for Disease Control's (CDC) social vulnerability index to consider community features such as unemployment levels, demographics, housing type, etc., and how they contribute to the ability of the community to respond to hazardous events. Proximity to hospitals and schools is included in the score to measure the potential benefit to critical public services (in terms of achieving resilience), while financial and regulatory incentives measure the favorability of the local policy landscape to hydroelectricity development. Per capita energy consumption and expenditures measure local energy demand and costs and can approximate local energy burdens, while fossil fuel plant proximity and operating capacity approximate the potential for an NPD conversion to replace fossil fuel generation with zero-carbon energy. A higher community impact score implies a more significant, positive socioeconomic benefit to the local community from adding a converted NPD to the local generation mix. See the metadata file for more information on the source of each input, along with units, and descriptions.

2.2.2. Environment Score

The environment score considers the potential environmental impacts of converting an NPD by incorporating five data inputs:

- Number of ocean and inland fish species present in the hydrologic unit code (HUC) 8
- Whether or not a fish passage is likely to be required at the site (based on the percent of dams in the HUC 8 that have fish passages)

- Dam removal considerations (based on hazard potential, age, connectivity, and degree of regulation)
- The ratio between potential capacity at the dam and surrounding fossil fuel-based power plants' operating capacity
- Overall air quality (at the county level).

Dams receive a higher environment score if fewer fish species are present, fish passage is likely to be required, dam removal is unlikely, a higher ratio of fossil fuel energy could be replaced by conversion, and regional air quality is poor. A higher environment score is given if a fish passage is likely to be required since there is a larger potential positive environmental impact if the dam were to be converted and a fish passage introduced. However, in the grid score, higher fish passage likelihood lowers the grid score as it would increase development complexity.

2.2.3. Grid Score

The grid score is calculated by considering data from seven different criteria:

- Potential generation capacity of the NPD
- Regional capacity factor (at the HUC 2 level)
- Proximity to the nearest electrical substation
- Proximity to energy-intensive facilities (such as manufacturing plants and heavy industry)
- Whether or not a fish passage is likely to be required at the site (based on the percent of dams in the HUC 8 that have fish passages)
- Per capita energy consumption in the region (i.e., state)
- Average wholesale prices of electricity in the region (or purchase price agreement price for regions not in a wholesale market)
- Daily peak load in the region (i.e., North American Electric Reliability Corporation [NERC] region).

The grid score intends to assess the relative impact that converting the NPD and connecting it would have on the regional electrical system. A higher score implies a more significant, positive impact on the grid.

2.2.4. Industry Score

The industry score is calculated by considering data from five different criteria:

- Potential generation capacity of the NPD
- Regional capacity factor (at the HUC 2 level)
- Proximity to the nearest electrical substation
- Proximity to energy-intensive facilities (such as manufacturing plants and heavy industry)
- Average retail prices of electricity for the region (i.e., state).

A higher score implies that there is a significant industrial presence in the region and that those facilities are likely paying a higher-than-average price for electricity. Thus, adding a converted NPD to the generation mix has the potential to positively impact industries in the region and provide opportunities for industrial decarbonization.

2.2.5. Energy Storage Technologies

NPD HYDRO provides qualitative feasibility ratings of adding batteries, hydrogen (H_2) electrolysis, and PSH to an NPD conversion project. Energy storage feasibility does not affect the rankings of the sites. For a given site, the tool provides a high-, medium-, or low-feasibility marker for each category of energy storage technology, and a user can filter results based on these markers. Adding energy storage has the potential to increase the operational and financial viability of the project, and thus is an important consideration when taking a holistic approach to NPD feasibility analysis.

Battery feasibility is based on seven criteria:

- Potential generation capacity of the NPD
- Regional capacity factor (at the HUC 2 level)
- Proximity to the nearest electrical substation
- Proximity to energy-intensive facilities (such as manufacturing plants and heavy industry)
- Proximity to hospitals
- Average wholesale prices of electricity in the region (or purchase price agreement price for regions not in a wholesale market)
- Daily peak load in the region (i.e., NERC region).

Because there must be a grid tie for batteries to provide value, the potential capacity of the dam, regional capacity factor, and the distance to the nearest substation are important considerations for batteries. In addition, the presence of critical infrastructure, such as hospitals and energy-intensive facilities, increases the importance of backup power systems, such as batteries, and thus has a positive impact on their feasibility rating. Battery feasibility is calculated as a score between 0 and 1. Dams with a value lower than 0.33 receives low feasibility, while dams with the value higher than 0.67 receives high feasibility. All other dams receive medium feasibility.

Hydrogen (H_2) feasibility is based on six criteria:

- Potential generation capacity of the NPD
- Regional capacity factor for hydropower (at the HUC 2 level)
- Proximity to hospitals
- Proximity to energy-intensive facilities (such as manufacturing plants and heavy industry)
- Proximity to natural gas compressor stations
- Average wholesale prices of electricity in the region (or purchase price agreement price for regions not in a wholesale market).

By adding low-temperature H_2 electrolysis technology at the NPD site, electricity generated by the converted dam can be used to produce clean hydrogen that can be used as an industrial feedstock for processes, such as fertilizer production and steel production. In addition, the natural gas industry is interested in H_2 on numerous fronts including blending into fuel for compression equipment to reduce direct emissions. H_2 feasibility is calculated as a score between 0 and 1. Dams with a value lower than 0.33 receives low feasibility, while dams with the value higher than 0.67 receives high feasibility.

PSH feasibility uses existing geospatial data on suitable closed-loop PSH reservoir locations and determines their proximity to the NPD sites. The smaller the distance between suitable PSH reservoir locations and NPD sites, the higher the feasibility of adding PSH to a project (e.g., less than 1 mile is considered high feasibility, and greater than 3 miles is considered low feasibility). This should be considered a very high-level screening of PSH feasibility, as calculating a more detailed feasibility rating will require significant site-specific analysis.

2.3. Interacting with the Map

NPD HYDRO renders a map interface using an open-source ArcGIS library and enables users to explore spatial data related to the location of NPD candidates. Users can zoom in, explore the map, and click on NPD candidates to view more detailed information about them (see Figure 2).

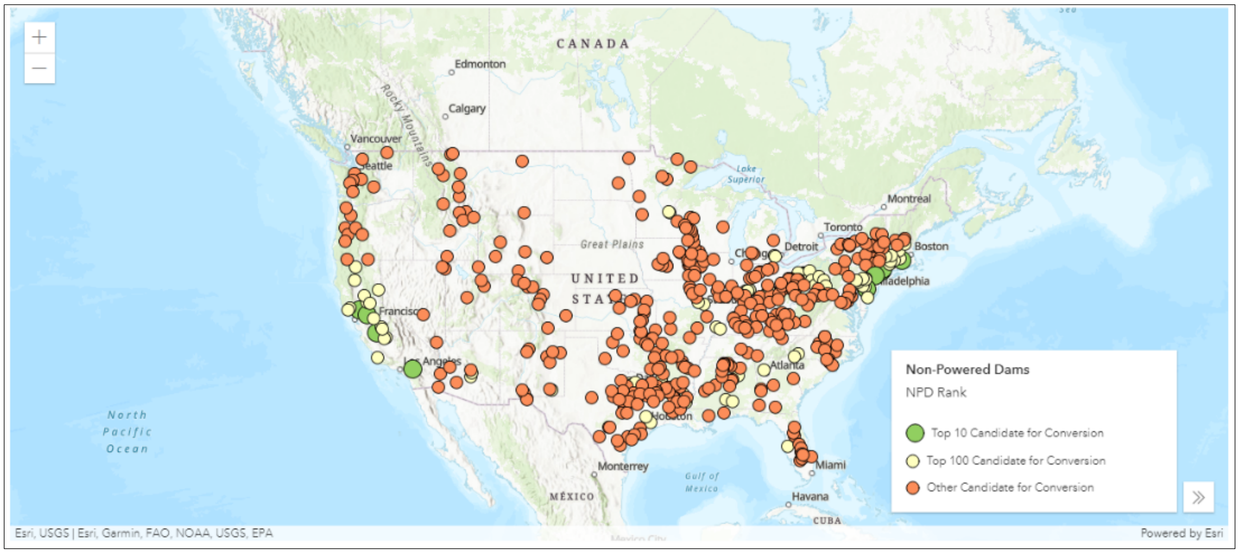


Figure 2. NPD candidates rendered on the map.

2.3.1. Map Interactivity – Selection, Zooming, and Popup Windows

The map is highly interactive, giving users the ability to explore NPD candidates and their associated metadata in detail.

Users can:

1. Zoom in or out using the scroll wheel on their mouse
2. Translate the view with a left click + drag movement
3. Rotate the view with a right click + drag movement
4. Select NPD candidates or other visible layers on the map with a single left click.

When a user clicks on any spatial data on the map, like an NPD, a popup is rendered above the point clicked, and will display any metadata, like the NPD features, associated with that dam (see Figure 3).

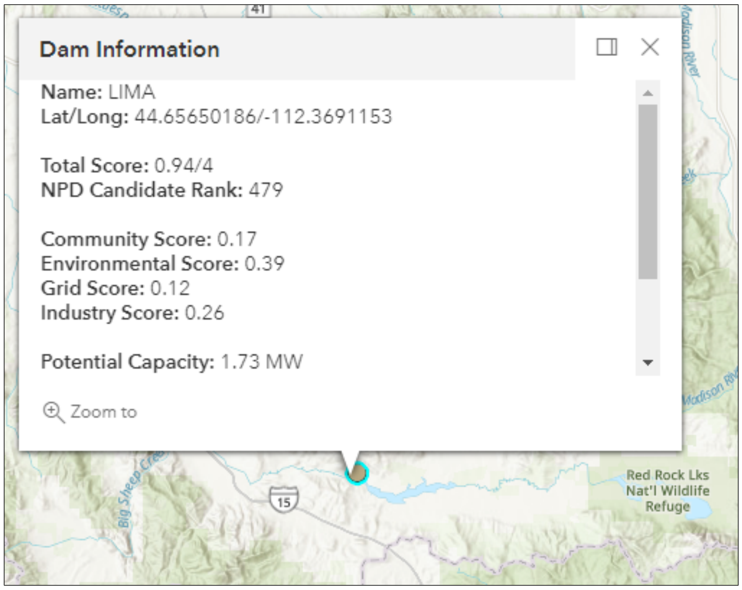


Figure 3. NPD metadata is rendered upon clicking a point on the map.

When multiple NPDs or other visible layers overlap, users can click the resulting arrows on the popup that allow them to navigate to the metadata of interest.

2.3.2. Enabling Legends

The map legend lives in the bottom right-side corner of the map view (see Figure 4). It contains information about all active layers on the map, ranging from the NPD candidate rank to the inclusion of all selected visible layers (more details in Section 2.5). Users can also minimize the legend for convenience.

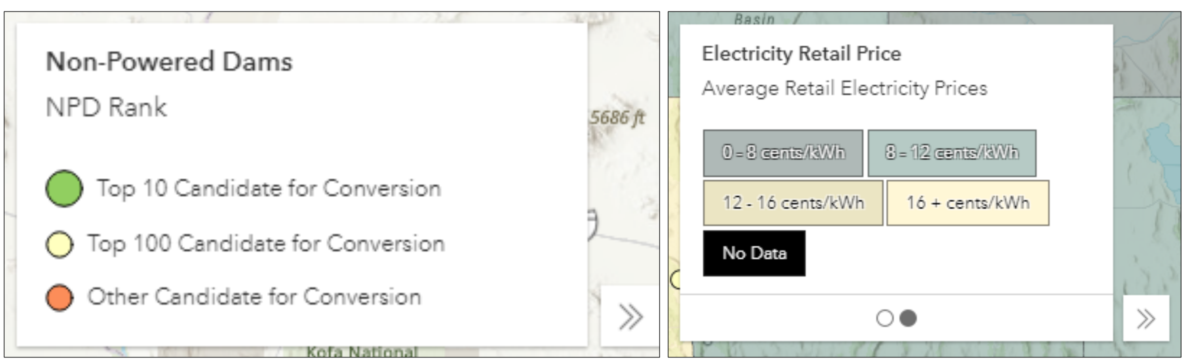


Figure 4. The map provides legends for each visible layer currently in use.

2.4. Interacting with the Attribute Table

Beneath the map is an interactive table that enables users to explore NPD features and metadata in greater detail. Figure 5 allows the users to search for, sort, filter, and otherwise explore the features of each NPD.

2.4.1. Exploring the Attribute Table

The interactive table is composed of several column groups that describe the NPD, including the NPD candidate rank, basic identifying information, owner information, individual and energy storage feasibility scores, land use restrictions, grid information, and economic features.

The attribute table is composed of around two dozen columns, so users must scroll horizontally to explore every feature of the NPD candidate. Users can hover over each of the column headers for informative tooltips that describe each column.

EXPORT NPD RESULTS

					Owner Information			Grid Information
Rank	Total Score	Name	State	County	Owner	Federally Regulated	Owner Type	Potential Capacity (MW)
1	1.54/2.0	FAIRMOUNT	PENNSYLVANIA	PHILADELPHIA		NO	LOCAL GOVERNMENT	9.18
2	1.53/2.0	FLAT ROCK	PENNSYLVANIA	PHILADELPHIA	DEP	NO	STATE	5.87
3	1.47/2.0	BOONTON DAM	NEW JERSEY	MORRIS	JERSEY CITY MUNICIPAL UTILITIES AUTHORITY	NO	LOCAL GOVERNMENT	2.7
4	1.4/2.0	NEW CROTON RESERVOIR DAM	NEW YORK	WESTCHESTER	NYCDEP DAMS EAST OF THE HUDSON RIVER	NO	LOCAL GOVERNMENT	8.79
5	1.37/2.0	GORGE PLANT DAM	OHIO	SUMMIT		NO	PUBLIC UTILITY	1.38
6	1.37/2.0	LAKE ONTELAUNEE	PENNSYLVANIA	BERKS	READING AREA WATER AUTHORITY	NO	LOCAL GOVERNMENT	1.54
7	1.36/2.0	GEDDES DAM	MICHIGAN	WASHTENAW	CITY OF ANN ARBOR	YES	LOCAL GOVERNMENT	1.25
8	1.35/2.0	NORRISTOWN (SWEDE STREET)	PENNSYLVANIA	MONTGOMERY	MONTGOMERY COUNTY COMMISSIONERS, PARKS AND HERITAGE SERVICES	NO	LOCAL GOVERNMENT	3.27

Figure 5. NPD HYDRO attribute table.

2.4.2. Sorting, Filtering, and Searching

When hovering over any column header, an ellipse icon is rendered. Clicking this icon allows the user to explore the table’s search, sort, and filter capabilities on that column.

These search, sort, and filter capabilities are described below:

1. Unsort – Disabled by default, only available if the user has previously sorted the table by the values in a column.
2. Sort by ASC – Sort the NPDs in the table in this column, by ascending alphanumerical value.
3. Sort by DESC – Sort the NPDs in the table in the column, by descending alphanumerical value.
4. Filter – Filter the NPDs in the table based on a value in this column.
   i) To Filter, a user selects the column that they’re interested in filtering.
   ii) Next, the user selects an operator to perform the filter, like “contains,” or “is any of.”
   iii) Finally, the user enters a filter value.
5. Hide – Hide this column.
6. Show Columns – Select or deselect multiple columns to show or hide.

2.5. Viewing and Interacting with Visual Layers

NPD HYDRO provides interactive visual layers that are related to the calculation of the four impact scores that define the overall NPD Rank. These visual layers are intended to inform users about important local features surrounding the NPD. If a user has questions about any of these visual layers, they can hover over the tooltips (shown by the ⓘ icon) for a description of the data to be added to the view.

2.5.1. Enabling Additional Visual Layers

The following visual layers are available for exploration on the map view:

1. Hospitals
2. Public Schools
3. Fossil Fuel Power Plants
4. Energy-Intensive Facilities
5. Natural Gas Compressor Stations
6. Social Vulnerability
7. Natural Hazards
8. Drought Index
9. Air Quality
10. Retail Price of Electricity.

Users can add visual layers to the map view by following these steps (see Figure 6):

1. Expand the visual layers element on the left-side toolbar of the application
2. Select the desired visual layers to render on the map
3. At the top of the toolbar, click the ***Calculate NPD Scores*** button, to query the database for the additional data.

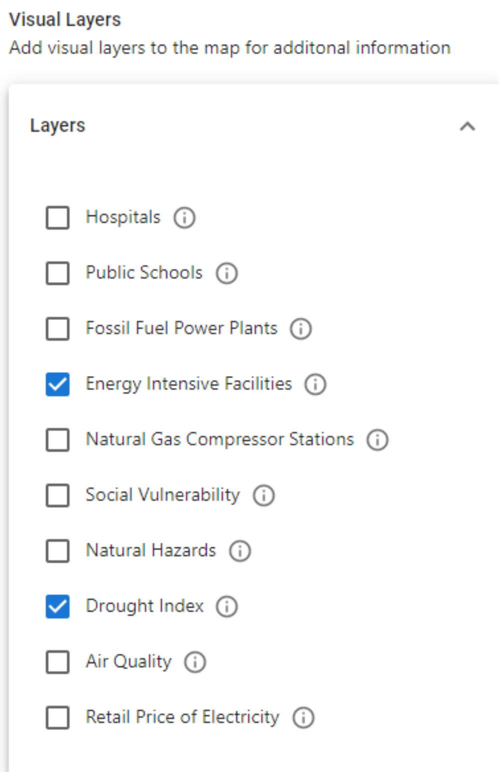


Figure 6. The visual layer selection interface.

2.5.2. Interacting with the Visual Layers

After selecting desired visual layers and clicking the ***Calculate NPD Scores*** button, the map view is rendered with NPDs, as well as the additional visual layers. Figure 7–Figure 9 illustrate the locations of energy-intensive facilities and the drought index are shown.

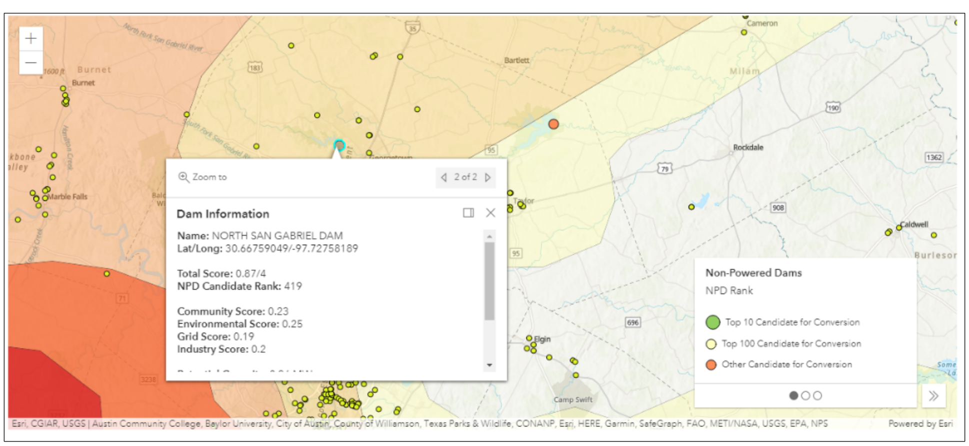


Figure 7. An NPD in Central Texas.

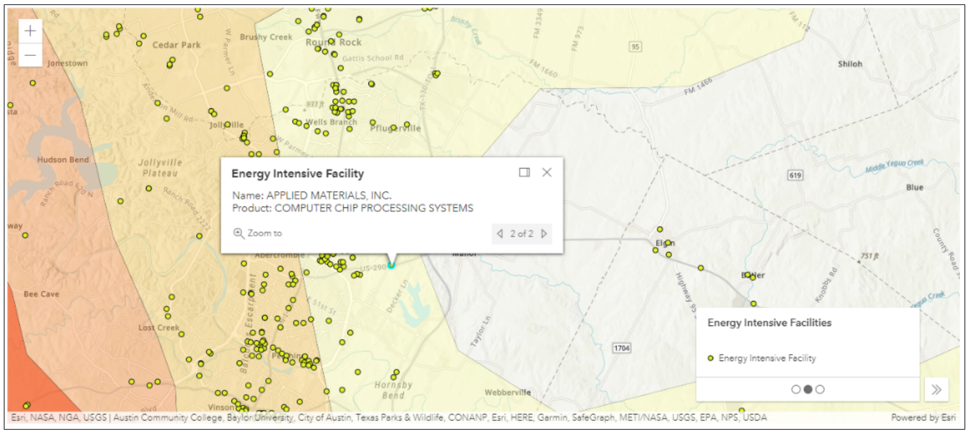


Figure 8. Energy-intensive facilities in Central Texas.

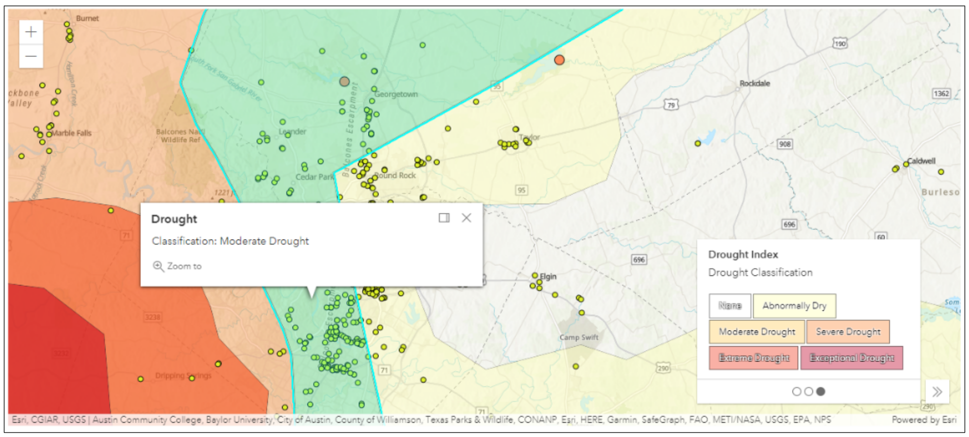


Figure 9. Drought conditions in Central Texas.

3. CASE STUDY – NPD HYDRO TUTORIAL

3.1. Case Study 1 – Community Benefits

This section provides an example of using NPD HYDRO from a hypothetical case in which a user prioritizes community benefits.

To prioritize community benefits in this case study, we expand the community element on the left-side toolbar and drag the slider to a maximum weight, and leave all environmental, grid, and industry benefits at their neutral weights (see Figure 10).

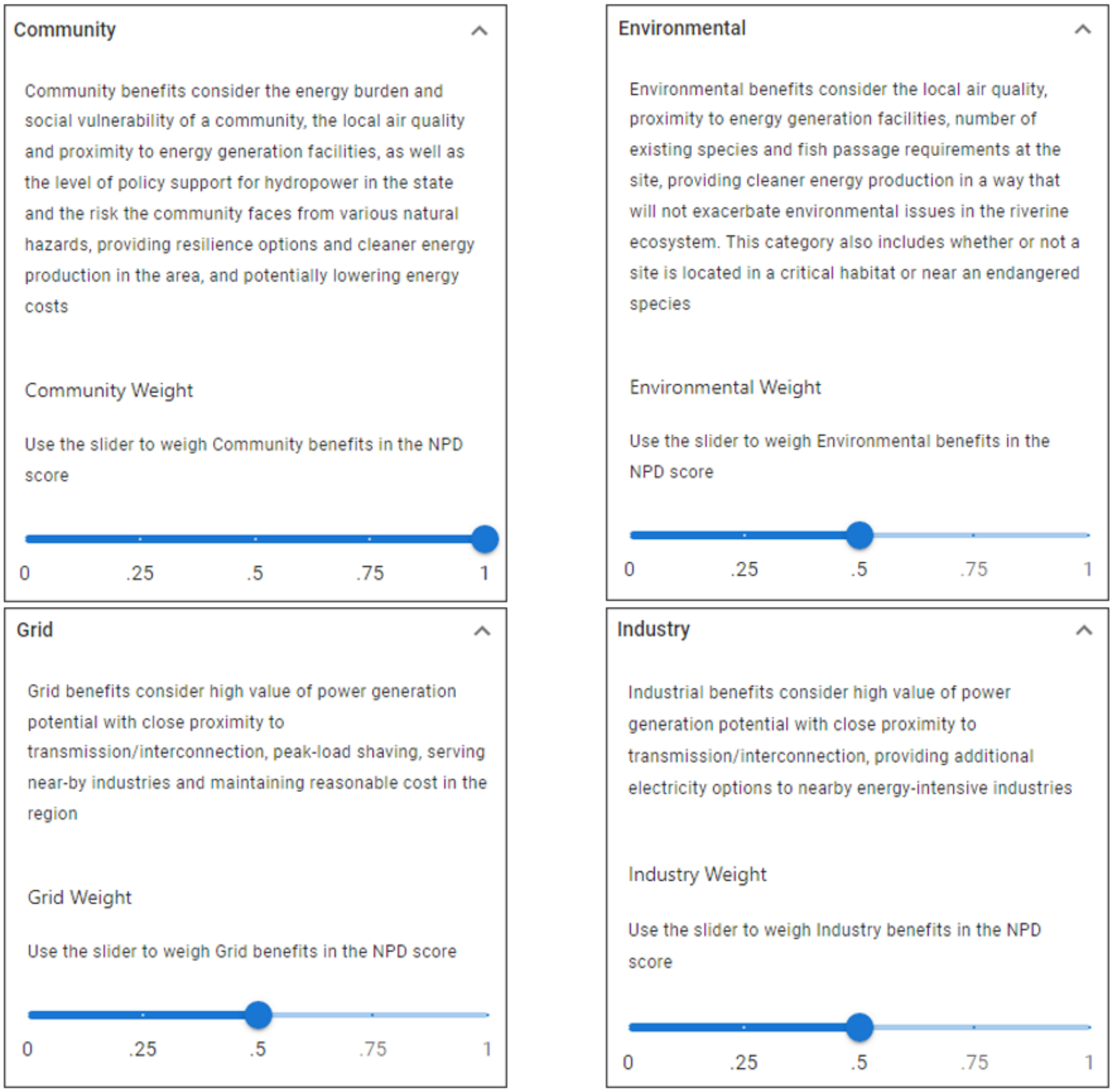


Figure 10. The community, environmental, grid, and industry weights for the first case study.

After setting these weights, query the database by clicking the ***Search*** button on the left-side toolbar, and the map is rendered. Users can now explore NPD candidates in the database, ranked with a preference towards community benefits in conversion (see Figure 11).

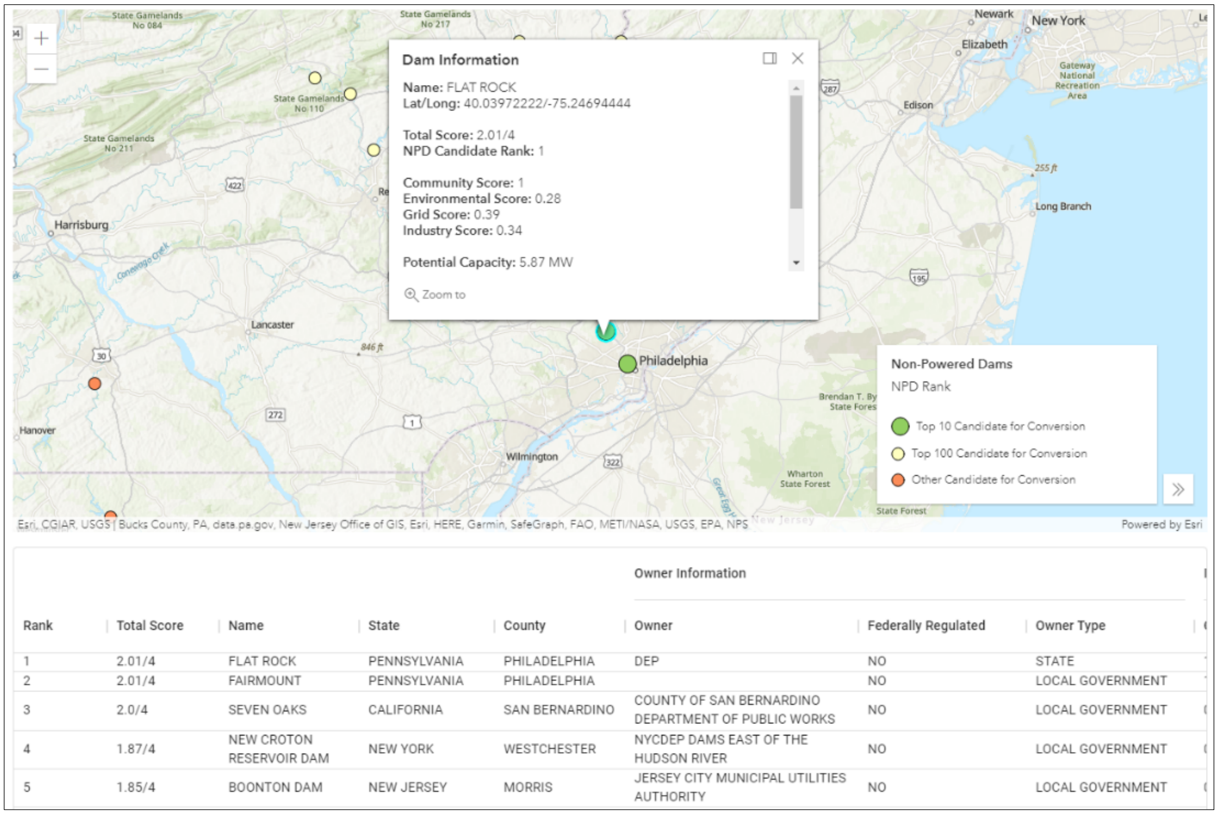


Figure 11. The top-ranked NPD for community benefits is the Flat Rock dam in Pennsylvania.

3.2. Case Study 2 – Industry Benefits

The second NPD HYDRO case study involves prioritization of industry benefits, with additional specificity in limiting the features considered for this score. To prioritize Industry benefits in this case study, expand the industry element on the left-side toolbar and drag the slider to a maximum weight, and lower all environmental, grid, and community benefits at their minimum weights (see Figure 12).

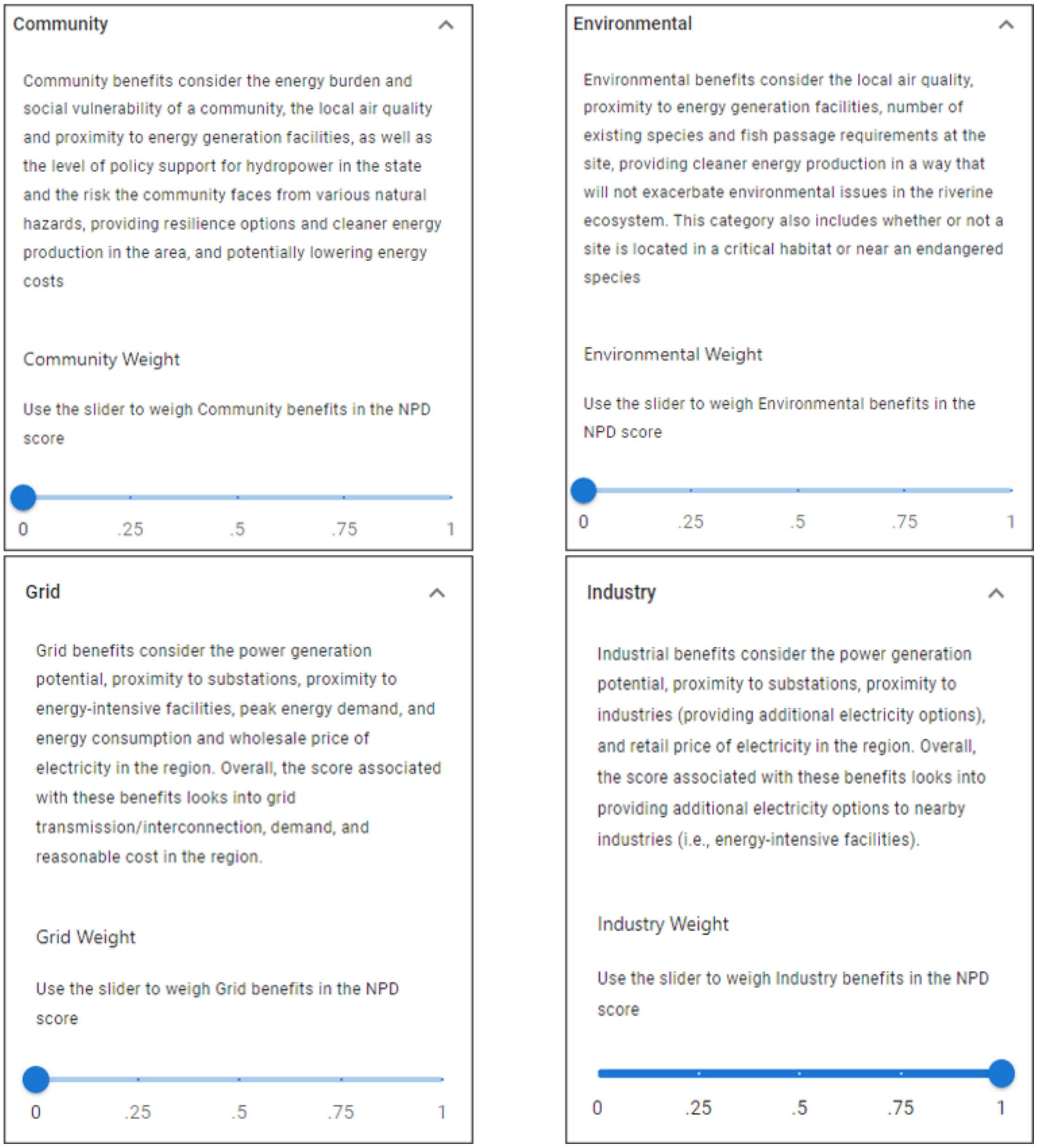


Figure 12. The community, environmental, grid, and industry weights for the second case study.

Next, underneath the industry weight, we manually select the features considered in the industry score (see Figure 13). For this case study, we will target only the potential capacity, regional capacity factor, proximity to energy-intensive facilities, and retail price of electricity attributes. We removed proximity to substation, assuming the facility will be behind-the-meter.

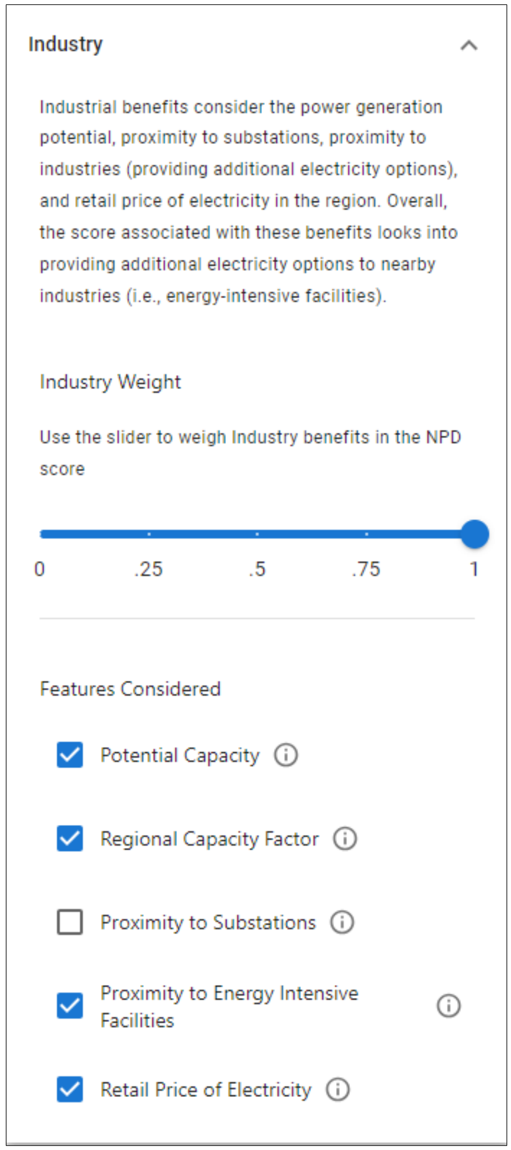
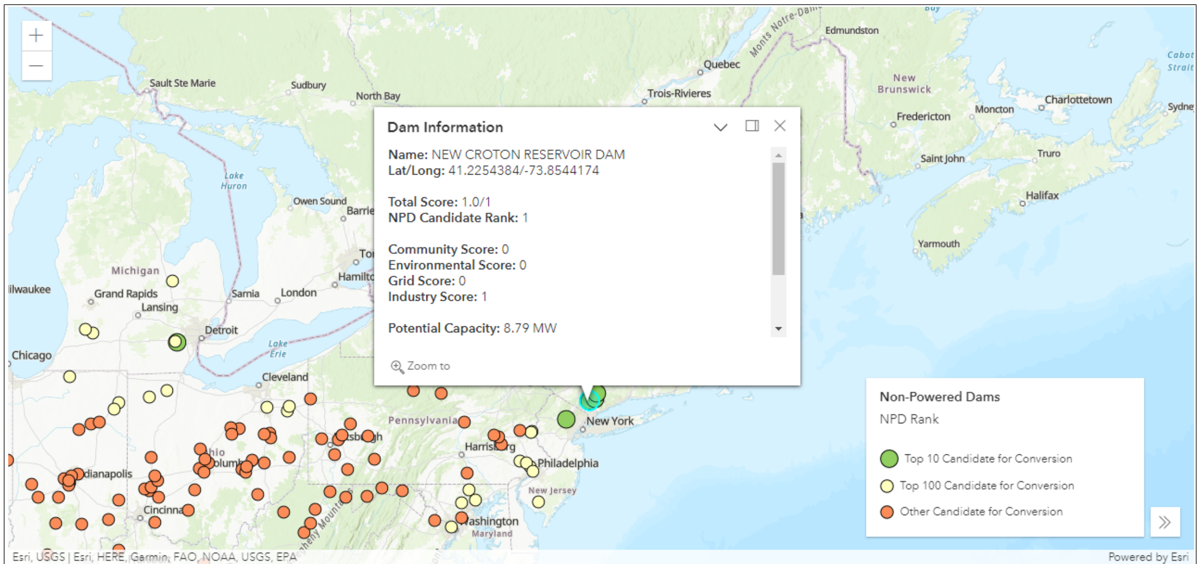


Figure 13. Industry score features.

The industry score will now only consider these attributes. After setting the weights and selecting the relevant attributes, we query the database by clicking the ***Calculate NPD Scores*** button on the left-side toolbar, and the map is rendered (see Figure 14).

Users can now explore NPD candidates in the database, ranked with a bias considering only Industry benefits in conversion, but only through its analysis of a potential behind-the-meter application.

Figure 15 shows that this NPD is not in a critical habitat or on protected land but is on an impaired stream. It has a potential capacity of 8.79 MW.



					Owner Information		
Rank	Total Score	Name	State	County	Owner	Federally Regulated	Owner Type
1	1.0/1	NEW CROTON RESERVOIR DAM	NEW YORK	WESTCHESTER	NYCDEP DAMS EAST OF THE HUDSON RIVER	NO	LOCAL GOVERNMENT
2	1.0/1	MUSCOOT DAM	NEW YORK	WESTCHESTER		NO	LOCAL GOVERNMENT
3	0.98/1	WEST THOMPSON DAM	CONNECTICUT	WINDHAM		NO	FEDERAL
4	0.96/1	CROTON FALLS DAM	NEW YORK	PUTNAM	NYCDEP DAMS EAST OF THE HUDSON RIVER	NO	LOCAL GOVERNMENT
5	0.92/1	ENFIELD DAM	CONNECTICUT	HARTFORD	AHLSTROM NONWOVENS, LLC	YES	PRIVATE

Figure 14. The top-ranked NPD for industry benefits in terms of its fitness as a behind-the-meter installation is New Croton Reservoir Dam.

Land Use Restrictions			Grid Information
Critical Habitat	Protected Land	Impaired Stream	Potential Capacity (MW)
NO	NO	YES	8.79

Figure 15. NPD details.

4. CONCLUSION

This user guide details the purpose and functionality of NPD HYDRO, a tool that allows the prioritization of NPDs based on multiple impact scores and selection criteria. Including the addition of energy storage technologies, the tool allows the users to explore NPD conversion potentials through the lens of several stakeholders by offering a range of benefit categories, including grid, community, industry, and environment (i.e., through four impact scores). The tool recognizes that developing an NPD site offers an array of potential benefits, opportunities, and challenges, many of which are specific to the site's characteristics (including geophysical, regulatory, and economic constraints). NPD HYDRO provides a user-friendly way to prioritize NPD sites based on users' primary concerns and goals. The tool is designed as a national-level prioritization tool to identify sites that are the highest priority for detailed site-specific analysis.

Appendix A

Calculations

For all the score calculations described below, each feature on the right-hand side of the equation represents the standardized value of the feature (i.e., a unitless number scaled between 0 and 1).

The final scores (i.e., grid score, community score, industry score, environment score, battery feasibility, and H_2 feasibility) are also standardized (i.e., unitless numbers scaled between 0 and 1) for consistency and ease of interpretation. The overall score of each dam is derived by the following equation:

> ***NPD Score*** *= (Grid weight)(Standardized grid score) + (Community weight)(Standardized community score) + (Industry weight)(Standardized industry score) + (Environmental weight)(Standardized environmental score)*.

Below are the equations of each of the impact scores and energy storage technology scores followed by Table A-1–Table A-6 listing the features with their brief descriptions and sources.

Community Score *= Social vulnerability + Overall air quality + Potential capacity to surrounding fossil-fuel-based capacity ratio + Risks from natural hazards + Proximity to hospitals + Proximity to public schools + Regulatory policies promoting hydroelectricity + Financial incentives promoting hydroelectricity + Per capita energy consumption + Per capita energy expenditures.*

Table A-1. Community score parameters.

Input Feature	Brief Description	Source
Social Vulnerability	Social vulnerability index of the county where the dam is located	Centers for Disease Control and Prevention (CDC) 2021
Overall Air Quality	Overall air quality index of the county where the dam is located based on diesel particulate matter, air toxics cancer risk, air toxics respiratory hazard index, traffic proximity, ozone, and particulate matter 2.5	EPA EJScreen 2021
Potential Capacity to Surrounding Fossil-Fuel-based Capacity Ratio	Ratio between the potential generation capacity of the dam and the total operating capacity of the fossil fuel power plants in the 50-mile radius of the dam	ORNL Non-Powered Dam Characteristics Inventory 2022 Homeland Infrastructure Foundation-Level Data (HIFLD) 2022
Risks from Natural Hazards	Total hazard score of the county where the dam is located based on hurricane, flood, tornado, volcano, wildfire, winter weather, and earthquake risk scores	University of Minnesota Hazard Data (aggregated from FEMA, USGS, NOAA, American Red Cross, Sandford University Libraries, BIA, BLM, USFS, FWS, NPS)
Proximity to Hospitals	Number of hospitals in the 50-mile radius of the dam	Homeland Infrastructure Foundation-Level Data (HIFLD) 2022
Proximity to Public Schools	Number of schools in the 50-mile radius of the dam	Homeland Infrastructure Foundation-Level Data (HIFLD) 2022
Reg. Policies Promoting Hydroelectricity	Number of regulatory policies promoting hydropower technologies of the state where the dam is located	Database of State Incentives for Renewables & Efficiency (DSIRE) 2022
Fin. Incentives Promoting Hydroelectricity	Number of financial incentives promoting hydropower technologies of the state where the dam is located	Database of State Incentives for Renewables & Efficiency (DSIRE) 2022
Per Capita Energy Consumption	Per capita energy consumption of the state where the dam is located	Energy Information Administration (EIA) 2020
Per Capita Energy Expenditures	Per capita energy expenditure of the state where the dam is located	Energy Information Administration (EIA) 2020

***Environment Score** = Overall air quality + Potential capacity to surrounding fossil-fuel-based capacity ratio + (1 - Affected oceanic and inland species) + Fish passage requirements + Dam removal considerations.*

Table A-2. Environment score parameters.

Input Feature	Brief Description	Source
Overall Air Quality	Overall air quality index of the county where the dam is located based on diesel particulate matter, air toxics cancer risk, air toxics respiratory hazard index, traffic proximity, ozone, and particulate matter 2.5	EPA EJScreen 2021
Potential Capacity to Surrounding Fossil-Fuel-based Capacity Ratio	Ratio between the potential generation capacity of the dam and the total operating capacity of the fossil fuel power plants in the 50-mile radius of the dam	ORNL Non-Powered Dam Characteristics Inventory 2022 Homeland Infrastructure Foundation-Level Data (HIFLD) 2022
Affected Oceanic and Inland Species	Total number of ocean and inland species in the HUC 8 where the dam is located (species include ocean sturgeon, inland sturgeon/paddlefish, ocean clupeid, ocean eel/lamprey, ocean salmonid, inland salmonid, other inland species)	ORNL Non-Powered Dam Characteristics Inventory 2022
Fish Passage Requirements	Percent of mitigation sites in the database that had Tier 1 fish passage mitigation required	ORNL Non-Powered Dam Characteristics Inventory 2022
Dam Removal Considerations	Dam removal consideration composite score (based on hazard potential, age, connectivity, and degree of regulation)	National Anthropogenic Barrier Dataset (NABD) 2021

Grid Score *= Potential capacity + Regional capacity factor + (1 – Proximity to substations) + Proximity to energy-intensive facilities + Per capita energy consumption + Max. daily peak load + Wholesale price/PPA rate of electricity – Fish passage requirements*

Table A-3. Grid score parameters.

Input Feature	Brief Description	Source
Potential Capacity	Estimated nominal power capacity of the dam	ORNL Non-Powered Dam Characteristics Inventory 2022
Regional Capacity Factor	Regional capacity factor of the HUC 2 where the dam is located (ratio of actual energy output to the max possible energy output) based on 2001-2008 data	ORNL Non-Powered Dam Characteristics Inventory 2022
Proximity to Substations	Distance from the dam to the existing substation	ORNL Non-Powered Dam Characteristics Inventory 2022
Proximity to Energy-Intensive Facilities	Number of manufacturing facilities in the 50-mile radius of the dam	Homeland Infrastructure Foundation-Level Data (HIFLD) 2022
Per Capita Energy Consumption	Per capita energy consumption of the state where the dam is located	Energy Information Administration (EIA) 2020
Max. Daily Peak Load	Maximum daily peak load (across all seasons) of the NERC region where the dam is located	Energy Information Administration (EIA) 2020
Wholesale Price/PPA Rate of Electricity	Wholesale electricity price of the ISO region where the dam is located or the PPA rate (for non-ISO regions) for the 2022 fourth quarter (considering the price rate increase)	Energy Information Administration (EIA) 2023 Berkeley Lab Electricity Markets & Policy 2021 Level10 Energy 2022
Fish Passage Requirements	Percent of mitigation sites in the database that had Tier 1 fish passage mitigation required	ORNL Non-Powered Dam Characteristics Inventory 2022

Industry Score *= Potential capacity + Regional capacity factor + (1 – Proximity to substations) + Proximity to energy-intensive facilities + Retail price of electricity.*

Table A-4. Industry score parameters.

Input Feature	Brief Description	Source
Potential Capacity	Estimated nominal power capacity of the dam	ORNL Non-Powered Dam Characteristics Inventory 2022
Regional Capacity Factor	Regional capacity factor of the HUC 2 where the dam is located (ratio of actual energy output to the max possible energy output) based on 2001-2008 data	ORNL Non-Powered Dam Characteristics Inventory 2022
Proximity to Substations	Distance from the dam to the existing substation	ORNL Non-Powered Dam Characteristics Inventory 2022
Proximity to Energy-Intensive Facilities	Number of manufacturing facilities in the 50-mile radius of the dam	Homeland Infrastructure Foundation-Level Data (HIFLD) 2022
Retail Price of Electricity	Average retail electricity price of the state where the dam is located	Energy Information Administration (EIA) 2020

Battery Feasibility *= Potential capacity + Regional capacity factor + (1 – Proximity to substations) + Proximity to energy-intensive facilities + Proximity to hospitals + Max. daily peak load + Wholesale price/PPA rate of electricity.*

Table A-5. Battery feasibility parameters.

Input Feature	Brief Description	Source
Potential Capacity	Estimated nominal power capacity of the dam	ORNL Non-Powered Dam Characteristics Inventory 2022
Regional Capacity Factor	Regional capacity factor of the HUC 2 where the dam is located (ratio of actual energy output to the max possible energy output) based on 2001-2008 data	ORNL Non-Powered Dam Characteristics Inventory 2022
Proximity to Substations	Distance from the dam to the existing substation	ORNL Non-Powered Dam Characteristics Inventory 2022
Proximity to Energy-Intensive Facilities	Number of manufacturing facilities in the 50-mile radius of the dam	Homeland Infrastructure Foundation-Level Data (HIFLD) 2022
Proximity to Hospitals	Number of hospitals in the 50-mile radius of the dam	Homeland Infrastructure Foundation-Level Data (HIFLD) 2022
Max. Daily Peak Load	Maximum daily peak load (across all seasons) of the NERC region where the dam is located	Energy Information Administration (EIA) 2020
Wholesale Price/PPA Rate of Electricity	Wholesale electricity price/PPA rate (for non-ISO regions) for the 2022 fourth quarter (considering the price rate increase)	Energy Information Administration (EIA) 2023 Berkeley Lab Electricity Markets & Policy 2021 Level10 Energy 2022

H2 Feasibility *= Potential capacity + Regional capacity factor + Proximity to energy-intensive facilities + Proximity to natural gas (NG) compressing stations + Wholesale price/PPA rate of electricity.*

Table A-6. Hydrogen feasibility parameters.

Input	Brief Description	Source
Potential Capacity	Estimated nominal power capacity of the dam	ORNL Non-Powered Dam Characteristics Inventory 2022
Regional Capacity Factor	Regional capacity factor of the HUC 2 where the dam is located (ratio of actual energy output to the max possible energy output) based on 2001-2008 data	ORNL Non-Powered Dam Characteristics Inventory 2022
Proximity to Energy-Intensive Facilities	Number of manufacturing facilities in the 50-mile radius of the dam	Homeland Infrastructure Foundation-Level Data (HIFLD) 2022
Proximity to NG Compressing Stations	Number of NG compressor stations in the 50-mile radius of the dam	Homeland Infrastructure Foundation-Level Data (HIFLD) 2022
Wholesale Price/PPA Rate of Electricity	Wholesale electricity price/PPA rate (for non-ISO regions) for the 2022 fourth quarter (considering the price rate increase)	Energy Information Administration (EIA) 2023 Berkeley Lab Electricity Markets & Policy 2021 Level10 Energy 2022