

Market Assessment for Hydropower Turbine Design Tools Using Integrated Datasets of Dams, Turbines, Owners, and Fish



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Environmental Sciences Division

**MARKET ASSESSMENT FOR HYDROPOWER TURBINE DESIGN TOOLS USING
INTEGRATED DATASETS OF DAMS, TURBINES, OWNERS, AND FISH**

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October 2019

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ACRONYMS

| | |
|-------|---|
| BioDE | Biologically Based Design and Evaluation of Hydropower Turbines |
| BioPA | Biological Performance Assessment |
| DOE | US Department of Energy |
| EHA | Existing Hydropower Assets |
| FERC | Federal Energy Regulatory Commission |
| HUC | hydrologic unit code |
| NHAAP | National Hydropower Asset Assessment Program |
| NOAA | National Oceanic and Atmospheric Administration |
| ORNL | Oak Ridge National Laboratory |
| BuRec | US Bureau of Reclamation |
| USFWS | US Fish and Wildlife Service |

ABSTRACT

A US Department of Energy-funded project titled Biologically Based Design and Evaluation of Hydropower Turbines (BioDE) has developed modeling tools and data to inform the design and installation of more environmentally friendly hydropower turbines. A market assessment was conducted to identify prospective users of these products within the hydropower industry and regulatory community. The dataset of hydropower turbines and their defining characteristics (both physical and biological) was developed to refine program outreach and marketing associated with the BioDE tools and data. A specific objective of the analysis was to identify hydropower owners whose turbines could be likely candidates for refurbishing or replacement because of senescence or re-licensing. This report describes a dataset that combines turbine properties, licensing status, fish resources, and ownership information on nearly 5,500 turbines at nearly 2,200 hydropower projects throughout the United States. The data analysis categorizes turbines by design type, geographic region, owner, age, license expiration, fish species presence, and regulatory authority. The analysis identified federal and nonfederal (i.e., Federal Energy Regulatory Commission-licensed) owners with the most turbines of various types and the most turbines that have the potential to interact with fish species of concern.

1. BACKGROUND

A project titled Biologically Based Design and Evaluation of Hydropower Turbines (BioDE), funded by the US Department of Energy's (DOE's) Water Power Technologies Office, has developed modeling tools (specifically BioPA¹ and HBET²) and an experimental dose:response dataset to inform more environmentally friendly hydropower turbine designs. At project outset, we evaluated the number and distribution of turbine types (e.g., Kaplan, Francis, Pelton) in the United States to inform the analytical and experimental direction of BioDE research. The market assessment presented here takes that analysis a step further by including more detailed information on existing federal and nonfederal (i.e., private sector) hydropower projects and individual turbines. In this analysis, we wanted to use this information to inform communication and outreach promoting BioDE modeling tools and data products. In particular, we were interested in identifying project owners who might be considering turbine upgrade or replacement in the near future; our assumption was that they would be most interested in BioDE tools and data. We also wanted to identify other stakeholders (e.g., environmental regulators) who, based on their jurisdictional overlap with projects and aquatic resources, might also be interested in BioDE products.

The primary objectives of the BioDE market assessment were to:

1. identify potential users of BioDE tools and data (e.g., primarily turbine designers, project owners, environmental regulators), and
2. inform BioDE technical direction and priorities with regard to turbine types, project characteristics, and potential biological responses.

2. ASSESSMENT APPROACH

Figure 1 presents a framework for developing market assessment queries aimed at the two primary BioDE user groups: project owner and environmental regulators. Potential users have different areas of interest as

¹ Biological Performance Assessment (BioPA) Toolset.
<https://availabletechnologies.pnnl.gov/technology.asp?id=373>

² Hou H., Z. Deng, J.J. Martinez, T. Fu, J.P. Duncan, G.E. Johnson, and J. Lu, et al. 2018. "A Hydropower Biological Evaluation Toolset (HBET) for Characterizing Hydraulic Conditions and Impacts of Hydro-Structures on Fish." *Energies* 11, no. 4:990. PNNL-SA-124812. doi:10.3390/en11040990

defined by geographic scale; basis for interest (e.g., aging turbines, Federal Energy Regulatory Commission [FERC] relicensing); or presence of species of concern. Based on the scale and reason of interest, a different set of filtering variables would define an informational query. Queries of interest provided in this document were generated by the BioDE team to assist with programmatic outreach and research priorities.

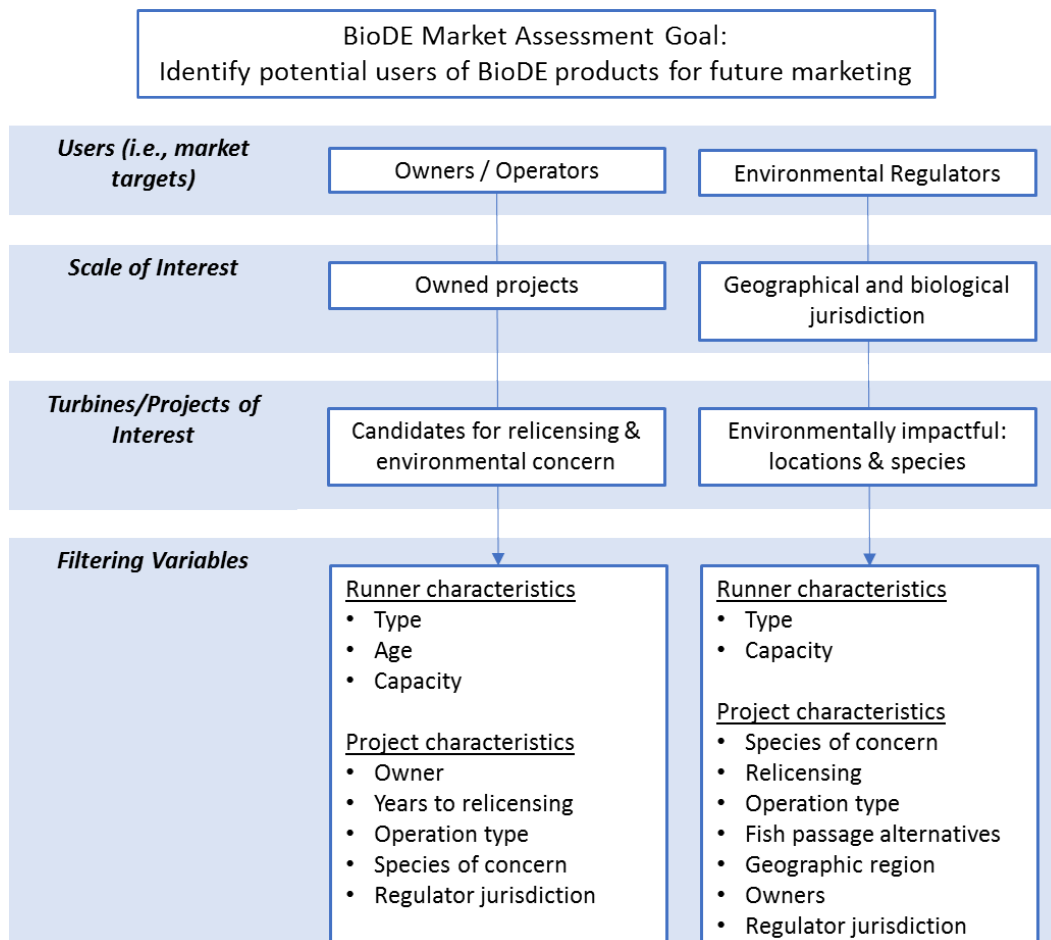


Figure 1. Conceptual framework for developing user-specific market assessment output.

2.1 DATA ANALYSIS

Three types of data were collected during this market assessment (Table 1):

1. **Project-level data:** Federal and private-sector hydropower projects names, locations, and owners (2016 version).
2. **Turbine-level data:** Individual generator/turbine characteristics at each hydropower project (2018 version).
3. **Migratory fish metrics:** Presence of fish species (mostly migratory species) that are of concern for turbine passage at the hydrologic unit code 8 (HUC 8) scale (NatureServe, 2018 version).

Table 1. Hydropower project, generator, and migratory fish metrics for BioDE market assessment database.

| Metric | Description and units |
|--|--|
| Project-level metrics | |
| EHA_PtID | Hydropower project number |
| Item | Turbine number within each plant |
| EIA_PtID | US Energy Information Administration plant identification code |
| Lat | Latitude in decimal degrees |
| Long | Longitude in decimal degrees |
| Type | Conventional hydropower (HY) or pumped storage (PS) |
| Category | Federal or nonfederal license category (8 categories) |
| PtName | Plant name |
| OwName | Plant owner name |
| OwType | Specific type of private or public ownership |
| FcIssue | Date of FERC license issuance |
| FcExpire | Date of FERC license expiration |
| FcExpireYr | Year of FERC license expiration |
| HY_MWh | Average annual net hydropower generation, MWh |
| HY_CF | Capacity factor |
| Yr_Online | Year plant came online |
| State | US state abbreviation |
| City | City name |
| Water | River name |
| HUC2 | 2-digit HUC for project site |
| HUC2GRP | Watershed groupings for US states and Puerto Rico (10) |
| HUC10 | 10-digit HUC for project site |
| USFWS | USFWS region (8) |
| NOAA | NOAA fisheries region (5) |
| BuRec | BuRec region (5) |
| FERC | FERC hydropower licensing region (6) |
| Turbine-level metrics | |
| Item ID | Generator number |
| EIA_GnID | US Energy Information Administration generator identification code |
| MW | Total capacity from hydraulic turbine-generator units within each plant, MW |
| OpYear | Year that the first generator came online for conventional hydropower. |
| RhYear | The year a unit was refurbished/rehabilitated |
| TbTypeGen | Turbine type general - Francis, impulse, propeller, pump, other |
| Maker | Manufacturer of turbine |
| Speed | Turbine speed (RPM, revolutions per minute) |
| Head | Turbine rated head (feet) |
| Power | Turbine power (Hp, horsepower) |
| Capacity | Turbine hydraulic capacity (cfs, cubic feet per second) |
| RehabAge | Years since rehabilitation or “null” if not rehabilitated |
| TurbineAge | Younger of years since online or rehabilitated |
| TurbStatus | Active, rehabilitated, or retired |
| Migratory fish metrics | |
| PChink, PRbt, PLMBass, PBGill, PAmEel, PAmShd, PAtlSal, PStpBass, PSock, PWhtSt, PGrnSt, PAtlSt, PShtSt, PLakSt, PPalSt, PPadlfs | Presence of each species of concern within a reach’s HUC 8 watershed – Chinook salmon, rainbow trout/steelhead, largemouth bass, bluegill sunfish, American eel, American shad, Atlantic salmon, striped bass, sockeye salmon, white sturgeon, green sturgeon, Atlantic sturgeon, shortnose sturgeon, lake sturgeon, palid sturgeon, paddlefish. |

The turbine data were linked to the project data by a common project ID number, and the fish data were linked to each turbine by geographic location (i.e., stream reach location in the watershed, usually

HUC 8). The data were acquired from Oak Ridge National Laboratory's (ORNL's) Existing Hydropower Assets (EHA) database³ or other DOE-sponsored projects at ORNL, or they were generated specifically for this assessment. The database contains records on 2,303 hydropower projects and 5,482 turbines. Not every turbine entry has complete data for every metric.

Each project (and therefore turbine) is associated with a stream reach and several other geographic locators, including two-digit and ten-digit HUCs (i.e., HUC 2 and HUC 10); US state; and US Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA) fisheries, US Bureau of Reclamation (BuRec), and FERC administrative regions. For presentation purposes, we combined 18 HUC 2's into 8 regions of the conterminous US (Figure 2). These eight regions are used throughout this report to provide easy geographic reference and relevance to the summary data.

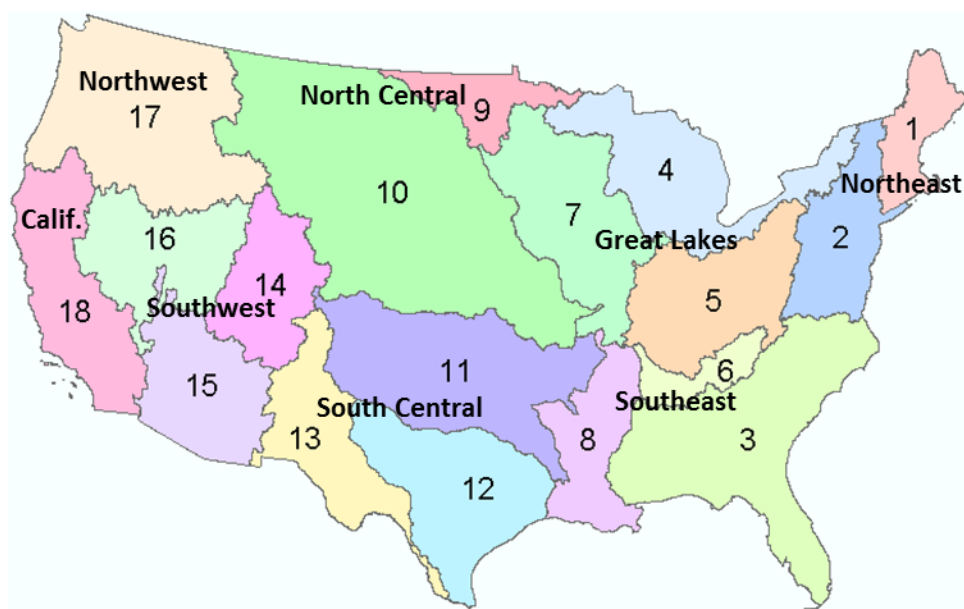


Figure 2. Eighteen HUC 2 watersheds (numbers) and eight watershed regions (text labels) for the conterminous US. Watershed regions were defined by combining 1–3 two-digit HUCs: Northeast–1 & 2; Southeast–3, 6, & 8; Great Lakes–4, 5, & 7; North Central–9 & 10; South Central–11, 12, & 13; Southwest–14, 15, & 16; Northwest–17; California 18.

This analysis used a variety of factors (e.g., turbine age, time to relicensing, geographic location, fish species presence) to filter and sort hydropower project and individual turbine information to focus the BioDE analysis and marketing prioritization and identify the project owners that could potentially benefit the most from the BioDE modeling tools and data.

3. RESULTS

The BioDE market assessment dataset is maintained as an Excel spreadsheet that is easily filtered or sorted by multiple combinations of metrics to show the distribution of turbine types and ages, geographic distribution, manufacturers, owners, and overlap with migratory fish species. Pivot tables were generated with a variety of filtering criteria to produce summaries of interest to address the market assessment task objectives. Results from the pivot table analyses are shown in the tables and figures in this section; analyses generally progress from simple to more complex queries.

³ M.M. Johnson, S.-C. Kao, N.M. Samu, and R. Uria-Martinez. 2019. Existing Hydropower Assets, HydroSource. Oak Ridge National Laboratory, Oak Ridge, TN.

3.1 GENERAL INFORMATION

The first level of analysis quantified the number of turbines in the United States for each of the major turbine types by owner category (Table 2). The source database for turbine types includes a variety of Francis turbines (e.g., horizontal and vertical) and propeller turbines (e.g., bulb, pit, Kaplan). Because the BioPA is presently most applicable to Francis and propeller turbines, we decided to combine turbine types to just the main categories of turbines defined on the DOE Water Power Program website (<https://www.energy.gov/eere/water/types-hydropower-turbines>). A second high-level analysis was conducted to examine the regional distribution of primary turbine types (Table 3).

Table 2. Number of turbines in the United States for each of the major turbine types by owner category.

| Owner category | Francis | Impulse | Propeller | Pump | Unknown | Total |
|----------------------------|--------------|------------|--------------|------------|--------------|--------------|
| Other | 6 | 15 | 2 | 1 | 54 | 78 |
| Private (FERC license) | 1,934 | 372 | 877 | 176 | 595 | 3,954 |
| Private (non-FERC license) | 18 | 5 | – | – | 281 | 304 |
| Private on BuRec sites | 51 | 2 | 24 | 3 | 85 | 165 |
| Private on USACE sites | 39 | 2 | 116 | 9 | 150 | 316 |
| Reclamation | 177 | 6 | 5 | – | 6 | 194 |
| Tennessee Valley Authority | 56 | – | 52 | 5 | 3 | 116 |
| US Army Corps of Engineers | 169 | – | 186 | – | – | 355 |
| Total | 2,450 | 402 | 1,262 | 194 | 1,174 | 5,482 |

Table 3. Number of turbines of the major types by major watershed for federal and nonfederal projects

| HUC 2 region | Francis | Impulse | Propeller | Pump | Unknown | Total |
|-------------------|--------------|------------|--------------|------------|--------------|--------------|
| Federal | | | | | | |
| Southeast | 103 | – | 72 | 5 | 3 | 183 |
| Great Lakes | 16 | – | 21 | – | – | 37 |
| North Central | 65 | – | 18 | – | – | 83 |
| South Central | 38 | – | 22 | – | – | 60 |
| Southwest | 50 | 5 | – | – | – | 55 |
| Northwest | 100 | 1 | 108 | – | – | 209 |
| California | 30 | – | 2 | – | 6 | 38 |
| Total | 402 | 6 | 243 | 5 | 9 | 665 |
| Nonfederal | | | | | | |
| Northeast | 640 | 35 | 378 | 76 | 149 | 1,278 |
| Southeast | 283 | 6 | 120 | 19 | 28 | 456 |
| Great Lakes | 513 | 6 | 275 | 25 | 369 | 1,188 |
| North Central | 54 | 29 | 17 | 5 | 38 | 143 |
| South Central | 29 | 7 | 19 | 6 | 39 | 100 |
| Southwest | 59 | 43 | 6 | – | 122 | 230 |
| Northwest | 239 | 107 | 156 | 52 | 113 | 667 |
| California | 207 | 132 | 31 | 6 | 247 | 623 |
| Total | 2,024 | 365 | 1,002 | 189 | 1,105 | 4,685 |

Note: Refer to figure 2 for HUC 2 watershed region coverage.

3.2 TURBINE AGE

For project owners, turbine age might be an important factor in planning for turbine replacement (Table 4). We found that nearly half of the turbines in operation today are more than 50 years old, and many are more than 100 years old. Though we conducted an analysis of retired turbines, we could not identify a common age at which turbines are replaced by owners. Instead, it appears that a variety of factors in addition to age contribute to the point at which a turbine is rehabilitated or replaced.

Table 4. Number of major turbine types by turbine age (in 2019) for turbines at federal and nonfederal projects.

| Turbine age (years) | Francis | Impulse | Propeller | Pump | Unknown | Total |
|----------------------------|----------------|----------------|------------------|-------------|----------------|--------------|
| Federal | | | | | | |
| 1–10 | 65 | 2 | 14 | – | – | 81 |
| 11–20 | 87 | 1 | 37 | – | – | 125 |
| 21–30 | 55 | 3 | 27 | – | 2 | 87 |
| 31–40 | 24 | – | 30 | 3 | 1 | 58 |
| 41–50 | 32 | – | 40 | 1 | – | 73 |
| 51–60 | 52 | – | 38 | – | 6 | 96 |
| 61–70 | 63 | – | 48 | 1 | – | 112 |
| 71–80 | 14 | – | 7 | – | – | 21 |
| 81–90 | 3 | – | 2 | – | – | 5 |
| 91–100 | 7 | – | – | – | – | 7 |
| Total | 402 | 6 | 243 | 5 | 9 | 665 |
| Nonfederal | | | | | | |
| 1–10 | 15 | 3 | 34 | – | 72 | 124 |
| 11–20 | 54 | 11 | 23 | – | 20 | 108 |
| 21–30 | 150 | 45 | 136 | 17 | 107 | 455 |
| 31–40 | 343 | 156 | 375 | 117 | 161 | 1,152 |
| 41–50 | 33 | 4 | 25 | 12 | 32 | 106 |
| 51–60 | 88 | 11 | 86 | 33 | 73 | 291 |
| 61–70 | 122 | 18 | 85 | – | 60 | 285 |
| 71–80 | 79 | 10 | 51 | – | 40 | 180 |
| 81–90 | 126 | 10 | 60 | 2 | 54 | 252 |
| 91–100 | 485 | 16 | 91 | 2 | 180 | 774 |
| 101–110 | 361 | 35 | 16 | 2 | 106 | 520 |
| 111–128 | 186 | 62 | 35 | 3 | 206 | 492 |
| Total | 2,042 | 381 | 1,017 | 188 | 1,111 | 4,739 |

Of the 1,912 turbines in the database that are 50+ years in age, 73% are Francis, and 21% are propeller. The companies having the greatest number of age 50+ turbines in their fleet are found across the United States (Table 5).

Table 5. Project owners with more than 20 turbines that are 50+ years in age.

| Owner | Turbine type | | | |
|---------------------------------------|--------------|---------|-----------|-------|
| | Francis | Impulse | Propeller | Total |
| Erie Boulevard Hydropower LP | 115 | – | 25 | 140 |
| Duke Energy Carolinas, LLC | 60 | 1 | 6 | 67 |
| Pacific Gas & Electric Co. | 40 | 23 | 1 | 64 |
| PacifiCorp | 51 | 9 | – | 60 |
| Georgia Power Co. | 44 | – | 10 | 54 |
| Brookfield White Pine Hydro LLC | 41 | – | 9 | 50 |
| Southern California Edison Co | 14 | 34 | – | 48 |
| Great Lakes Hydro America LLC | 34 | – | 11 | 45 |
| Northern States Power Co – Minnesota | 33 | – | 10 | 43 |
| Great River Hydro, LLC | 30 | – | 6 | 36 |
| Consumers Energy Co. | 32 | – | 3 | 35 |
| Portland General Electric Co. | 22 | – | 12 | 34 |
| Wisconsin Public Service Corp. | 30 | – | 3 | 33 |
| Green Mountain Power Corp. | 29 | – | 3 | 32 |
| NorthWestern Energy | 24 | 2 | 5 | 31 |
| Alabama Power Co. | 11 | – | 20 | 31 |
| Consolidated Water Power Co. | 29 | – | 2 | 31 |
| Appalachian Power Co. | 20 | – | 11 | 31 |
| Idaho Power Co. | 15 | – | 14 | 29 |
| Eagle Creek RE LLC | 10 | – | 15 | 25 |
| Wisconsin Electric Power Co. | 17 | – | 7 | 24 |
| South Carolina Electric & Gas Company | 22 | – | – | 22 |
| Avista Corp. | 18 | – | 3 | 21 |
| Brookfield Black Bear Hydro LLC | 13 | – | 7 | 20 |
| New York Power Authority | 4 | – | 16 | 20 |

A separate database within the EHA database at ORNL includes information on 400+ turbines that have been retired in the last 120 years. Knowing how old these turbines were when retired might help predict the age at which active turbines would be good candidates for replacement. Figure 3 shows that most turbine retirements occur when turbines are 50–100 years old, although age by itself does not appear to be a consistent indicator of retirement.

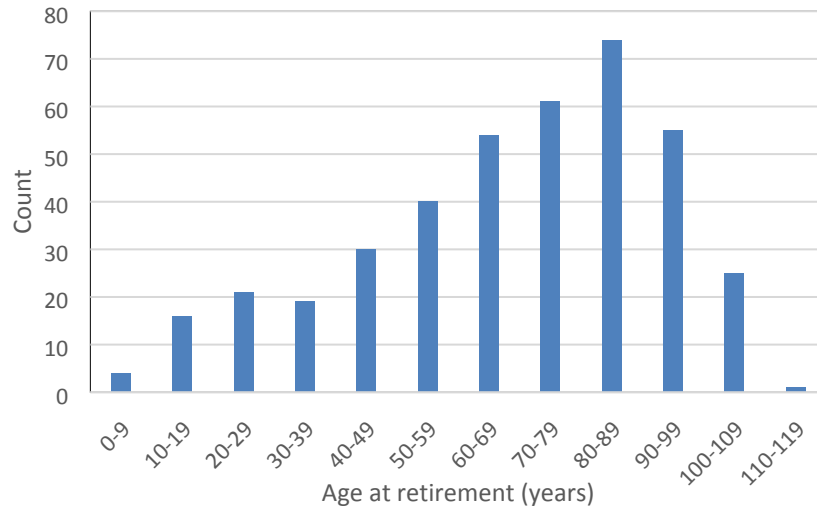


Figure 3. Number of turbines retired by 10-year age groupings.

3.3 FERC RELICENSING

Because major renovations to a project can result in the re-opening (or reassessment) of a project’s FERC license—an option most owners avoid—owner instead typically consider turbine replacement or rehabilitation at the beginning of a new licensing application cycle, even if a turbine might have several years of operational life left. Turbine replacement options are probably considered at least 5 years before license expiration and perhaps as early as 10 years prior to expiration. Two to three hundred turbines are up for relicensing in the period 2023–2026, as well as a similar amount in 2033–2037 (Figure 4).

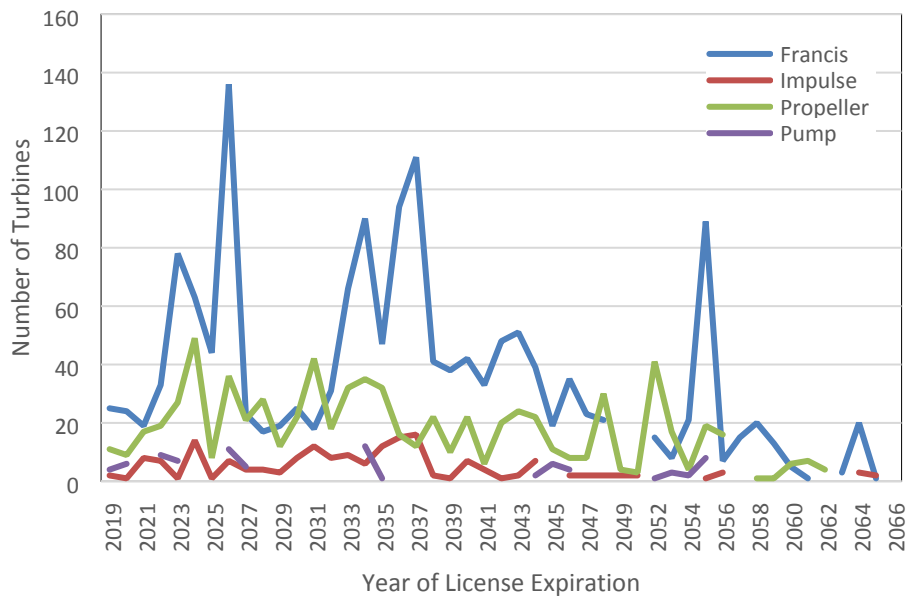


Figure 4. Number of major turbine types affected by FERC license expiration by year of expiration.

The geographic distribution of projects up for relicensing in the next 20 years is skewed toward the Northeast and Great Lakes regions, where nearly two-thirds of those projects exist (Table 6). Although decisions to replace or rehabilitate turbines at federal projects are not affected by licensing, the federal agencies that operate hydropower projects often have long-range plans for when turbines will be considered for replacement or rehabilitation. These schedules would be useful for BioDE tool marketing; however, they are not part of this assessment.

Table 6. Number of turbines affected by FERC license expiration in the next 20 years (2021–2040) by watershed region.

| HUC 2 | Francis | Impulse | Propeller | Pump | Total |
|---------------|--------------|------------|------------|-----------|--------------|
| Northeast | 308 | 8 | 181 | 28 | 525 |
| Southeast | 104 | 4 | 45 | 11 | 164 |
| Great Lakes | 370 | 5 | 143 | 2 | 520 |
| North Central | 26 | 5 | 10 | – | 41 |
| South Central | 23 | 3 | 14 | – | 40 |
| Southwest | 31 | 18 | – | – | 49 |
| Northwest | 103 | 24 | 77 | 4 | 208 |
| California | 53 | 57 | 10 | 3 | 123 |
| Total | 1,018 | 124 | 480 | 48 | 1,670 |

Note: Refer to figure 2 for HUC 2 watershed region coverage.

3.4 OWNERS

The primary objective of this market assessment is to identify project owners that could benefit from BioDE tools and data. It stands to reason that the owners with the most turbines might be most interested in obtaining new assessment tools and information. Owners with the most turbines are a mix of federal and nonfederal entities (Table 7).

Table 7. Owners with 25+ of the two major turbine types.

| Owner | Francis | Propeller | Total |
|---------------------------------------|---------|-----------|-------|
| Erie Boulevard Hydropower LP | 124 | 33 | 157 |
| USACE Northwestern Division | 48 | 105 | 153 |
| Tennessee Valley Authority | 56 | 52 | 108 |
| Duke Energy Carolinas LLC | 69 | 8 | 77 |
| Eagle Creek RE LLC | 27 | 35 | 62 |
| Brookfield White Pine Hydro LLC | 42 | 17 | 59 |
| Georgia Power Co. | 46 | 12 | 58 |
| US BuRec – Pac NW | 52 | 3 | 55 |
| PacifiCorp | 53 | – | 53 |
| Great Lakes Hydro America LLC | 34 | 18 | 52 |
| Pacific Gas & Electric Co. | 50 | 1 | 51 |
| Northern States Power Co. – Minnesota | 34 | 17 | 51 |
| US BuRec – Great Plains | 42 | – | 42 |
| Green Mountain Power Corp | 34 | 8 | 42 |
| New York Power Authority | 17 | 24 | 41 |
| Great River Hydro LLC | 35 | 6 | 41 |
| Consumers Energy Co. | 38 | 3 | 41 |
| Alabama Power Co. | 18 | 23 | 41 |

Table 7. Owners with 25+ of the two major turbine types (continued).

| Owner | Francis | Propeller | Total |
|---------------------------------------|---------|-----------|-------|
| Consumers Energy Co. | 38 | 3 | 41 |
| Wisconsin Public Service Corp | 35 | 5 | 40 |
| Idaho Power Co. | 16 | 23 | 39 |
| Consolidated Water Power Co. | 32 | 6 | 38 |
| USACE-Missouri River District | 25 | 11 | 36 |
| Portland General Electric Co. | 22 | 12 | 34 |
| PUD No. 1 of Chelan County | 6 | 25 | 31 |
| South Carolina Electric & Gas Company | 31 | – | 31 |
| Appalachian Power Co. | 20 | 11 | 31 |
| NorthWestern Energy | 24 | 6 | 30 |
| USACE – Nashville District | 13 | 15 | 28 |
| USACE – Mobile District | 10 | 17 | 27 |
| USACE – Little Rock District | 18 | 9 | 27 |
| Avista Corp. | 22 | 5 | 27 |
| US BuRec – Mid-Pacific | 24 | 2 | 26 |
| US BuRec – Lower Colorado | 26 | – | 26 |
| CHI Energy Inc. | 14 | 12 | 26 |
| US BuRec – Upper Colorado | 25 | – | 25 |
| Brookfield Black Bear Hydro LLC | 13 | 12 | 25 |

Note: Federal owners are highlighted in grey.

3.5 SPECIES OF CONCERN

By merging information on fish species presence (original data source: *NatureServe*), we were able to evaluate whether there are specific turbine types or owner categories (e.g., federal vs. private) that overlap most with the habitats of various migratory and resident fish species of concern. The list of 16 species evaluated includes four salmon/trout species and 6 sturgeon species. Most of the 16 species have been represented either directly or with surrogate species in the laboratory dose–response studies conducted as part of the BioDE project or from other sources. Because the species have large geographic distributions, their overlap with hydropower turbines is extensive (Table 8).

Because our BioDE dose–response work targets specific fish taxa and because regulatory concerns seem to focus on select species, it is useful to identify project owner by the number of turbines they operate that could interact with species of greatest concern. Tables 9 and 10 contain federal and nonfederal owners for a few select species as examples; Tables A-1 and A-2 in appendix A include all species of interest. The data in Table 10 apply only to owners with licenses expiring in the next 20 years. We also conducted this analysis on projects whose licenses expire in the period 2023–2027 (see table A-3 in appendix A), as those owners might be most likely to consider turbine replacement or rehabilitation in the very near future.

Table 8. Number of turbines of the major types that overlap with the distribution of various species of turbine passage or regulatory concern.

| Row labels | Francis | Impulse | Propeller | Pump | Unknown | Total |
|------------------------------|--------------|------------|--------------|------------|--------------|--------------|
| Chinook salmon | 382 | 136 | 209 | 20 | 190 | 937 |
| Rainbow trout/steelhead | 517 | 195 | 275 | 45 | 320 | 1,352 |
| Largemouth bass | 997 | 15 | 524 | 52 | 379 | 1,967 |
| Bluegill sunfish | 830 | 9 | 468 | 48 | 352 | 1,707 |
| American eel | 1,104 | 44 | 677 | 98 | 267 | 2,190 |
| American shad | 518 | 21 | 255 | 64 | 87 | 945 |
| Atlantic salmon | 539 | 23 | 275 | 51 | 105 | 993 |
| Striped bass | 322 | 13 | 220 | 29 | 36 | 620 |
| Sockeye salmon | 157 | 38 | 165 | 9 | 48 | 417 |
| White sturgeon | 256 | 64 | 207 | 17 | 96 | 640 |
| Green sturgeon | 53 | 35 | 23 | 9 | 52 | 172 |
| Atlantic sturgeon | 263 | 11 | 172 | 33 | 23 | 502 |
| Shortnose sturgeon | 240 | 10 | 124 | 29 | 30 | 433 |
| Lake sturgeon | 527 | 9 | 324 | 31 | 291 | 1,182 |
| Pallid sturgeon | 30 | 0 | 26 | 0 | 2 | 58 |
| Paddlefish | 267 | 0 | 235 | 15 | 72 | 589 |
| Total no. of turbines | 2,450 | 402 | 1,262 | 194 | 1,174 | 5,482 |

Table 9. Federal owners with 5+ turbines located at projects that overlap with Chinook salmon, American eel, and American shad.

| Owner | Francis | Propeller | Total |
|---------------------------------|-----------|------------|------------|
| Chinook salmon | | | |
| California | 8 | 2 | 10 |
| US BuRec – Mid-Pac | 8 | 2 | 10 |
| Northwest | 76 | 102 | 178 |
| USACE Northwestern Div. | 40 | 102 | 142 |
| US BuRec – Pac NW | 36 | – | 36 |
| American eel | | | |
| Great Lakes | 12 | 12 | 24 |
| USACE – Nashville District | 12 | 7 | 19 |
| USACE – Detroit District | – | 5 | 5 |
| North Central | 8 | 11 | 19 |
| USACE – Missouri River District | 8 | 11 | 19 |
| South Central | 29 | 18 | 47 |
| USACE – Little Rock District | 18 | 9 | 27 |
| USACE – Tulsa District | 11 | 9 | 20 |
| Southeast | 35 | 56 | 91 |
| Tennessee Valley Authority | 18 | 42 | 60 |
| USACE – Mobile District | – | 14 | 14 |
| USACE – Wilmington District | 12 | – | 12 |
| USACE – Vicksburg District | 5 | – | 5 |
| American shad | | | |
| Southeast | 29 | 3 | 32 |
| USACE – Savannah District | 20 | 3 | 23 |
| USACE – Wilmington District | 9 | – | 9 |

Note: Refer to table A-1 in appendix A for a full list of species.

Table 10. Nonfederal owners with 12+ turbines located at projects with FERC licenses expiring in the period 2021–2040 and that overlap with Chinook salmon, American eel, and American shad.

| Owner | Francis | Propeller | Total |
|---|------------|-----------|------------|
| Chinook salmon | | | |
| California | 18 | 3 | 21 |
| Pacific Gas & Electric Co. | 15 | – | 15 |
| Northwest | 46 | 27 | 73 |
| PUD No. 1 of Chelan County | 4 | 14 | 18 |
| Portland General Electric Co | 3 | 12 | 15 |
| City of Tacoma – WA | 14 | 1 | 15 |
| PacifiCorp | 13 | – | 13 |
| City of Seattle – WA | 12 | – | 12 |
| American eel | | | |
| Great Lakes | 129 | 30 | 159 |
| Erie Boulevard Hydropower LP | 65 | 11 | 76 |
| Northern States Power Co – Minnesota | 18 | 11 | 29 |
| Northeast | 220 | 95 | 315 |
| Great Lakes Hydro America LLC | 34 | 14 | 48 |
| Brookfield White Pine Hydro LLC | 27 | 11 | 38 |
| Green Mountain Power Corp | 22 | 5 | 27 |
| Boott Hydropower, Inc. & E. L. Field Hydroelectric Facility Trust | 19 | – | 19 |
| Great River Hydro LLC | 15 | – | 15 |
| City of Holyoke Gas and Electric Dept. | 10 | 5 | 15 |
| Safe Harbor | 2 | 12 | 14 |
| Brookfield Black Bear Hydro LLC | 5 | 8 | 13 |
| BIF III Holtwood LLC | 10 | 2 | 12 |
| Southeast | 48 | 18 | 66 |
| Georgia Power Co. | 25 | 6 | 31 |
| American shad | | | |
| Northeast | 131 | 59 | 190 |
| Brookfield White Pine Hydro LLC | 23 | 10 | 33 |
| Great Lakes Hydro America LLC | 22 | 5 | 27 |
| Boott Hydropower, Inc. & Eldred L. Field Hydroelectric Facility Trust | 19 | – | 19 |
| City of Holyoke Gas and Electric Dept. | 10 | 5 | 15 |
| Safe Harbor | 2 | 12 | 14 |
| Brookfield Black Bear Hydro LLC | 5 | 8 | 13 |
| BIF III Holtwood LLC | 10 | 2 | 12 |
| Southeast | 47 | 4 | 51 |
| Georgia Power Co. | 25 | 2 | 27 |

Note: Refer to table A-2 in appendix A for a full list of species.

These queries can be refined to identify owners for specific types of hydropower projects (e.g., nonfederal owners with propeller-type turbines) located at projects with FERC licenses expiring in the period 2023–2027 and that overlap with American eel presence (Table 11). The 5-year span from 2023–2027 was selected based on the assumption that any decisions regarding replacement or rehabilitation in the next 3–4 years would have probably already been made.

Table 11. Nonfederal owners with propeller-type turbines located at projects with FERC licenses expiring in the period 2023–2027 and that overlap with American eels.

| Owner | Propeller |
|-------------------------------|-----------|
| Great Lakes | |
| Erie Boulevard Hydropower LP | 7 |
| Ampersand Mount Ida Hydro LLC | 8 |
| Northeast | |
| Great Lakes Hydro America LLC | 14 |
| | |

3.6 REGULATORS

Although project owners are the primary target of BioDE outreach efforts, we have also interacted with regulators in the past and expect to continue to market BioDE information to regulators who influence hydropower infrastructure and operations decisions. For the BioDE tools to be most useful to project owners, the tools should not only help them make decisions related to turbine replacement and rehabilitation, but ideally should also be accepted by the regulatory community as scientifically sound and reliable.

NOAA fisheries, which are responsible for addressing hydropower licensing issues related to ocean-run migratory fish, are organized into five regions (Figure 5). Note that some of the regions extend beyond the range of anadromous fish, but NOAA has some jurisdiction in these areas, including activities in upstream watersheds where those activities might affect downstream migratory fish or their habitats. Federal hydropower projects reside mostly in NOAA’s West Coast and Southeast regions, while nonfederal projects with upcoming FERC license expirations are most prevalent in the New England–Mid-Atlantic region (Table 12).

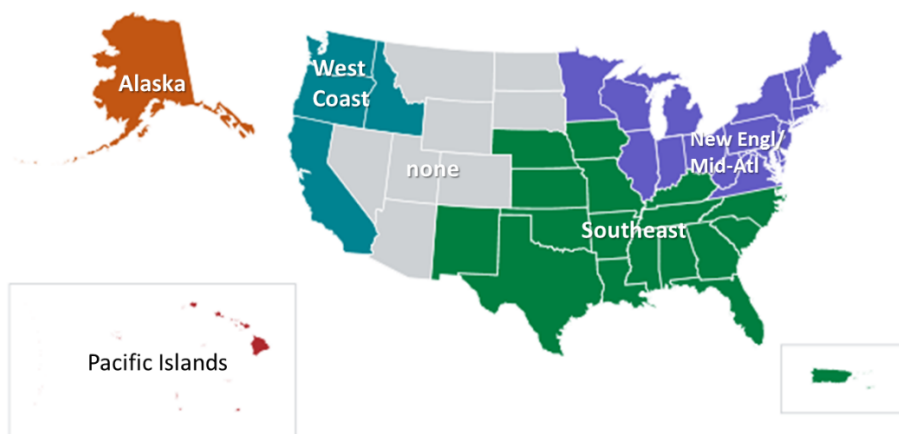


Figure 5. Five NOAA fisheries regions.

Table 12. Count and distribution of major turbine types by NOAA fisheries region at federal projects, nonfederal projects, and nonfederal projects with upcoming expiring FERC licenses (2021–2040).

| NOAA fisheries region | Francis | Impulse | Propeller | Pump | Total |
|---|--------------|------------|------------|--------------|--------------|
| Federal | | | | | |
| None (inland) | 120 | 5 | 8 | – | 133 |
| West | 127 | 1 | 110 | – | 238 |
| South | 143 | – | 120 | 5 | 268 |
| Northeast | 12 | – | 5 | – | 17 |
| Total | 402 | 6 | 243 | 5 | 656 |
| Nonfederal | | | | | |
| None (inland) | 97 | 86 | 5 | 14 | 202 |
| West | 438 | 232 | 58 | 187 | 915 |
| South | 319 | 5 | 22 | 157 | 503 |
| Northeast | 1,170 | 44 | 104 | 660 | 1,978 |
| Alaska | 24 | 28 | – | 1 | 53 |
| Pacific Islands | – | 1 | – | – | 1 |
| Total | 2,048 | 396 | 189 | 1,019 | 3,652 |
| Nonfederal (FERC license expiring 2021–2040) | | | | | |
| None (inland) | 51 | 29 | 8 | – | 88 |
| West | 155 | 78 | 86 | 7 | 326 |
| South | 119 | 3 | 61 | 8 | 191 |
| Northeast | 693 | 16 | 325 | 33 | 1,067 |
| Alaska | 17 | 19 | – | – | 36 |
| Total | 1,035 | 145 | 480 | 48 | 1,708 |

The USFWS, which is organized into eight regions across the United States (Figure 6), is most concerned with fish listed under the Endangered Species Act. Federal hydropower projects reside mostly in regions 1, 4, and 6, while about half of nonfederal projects with upcoming FERC license expirations are found in regions 3 and 5 (Table 13).



Figure 6. Eight USFWS regions.

Table 13. Count and distribution of major turbine types by USFWS region at federal projects, nonfederal projects, and nonfederal projects with upcoming expiring FERC licenses (2021–2040).

| USFWS region | Francis | Impulse | Propeller | Pump | Total |
|---|--------------|------------|--------------|------------|--------------|
| Federal | | | | | |
| 1 | 76 | 1 | 102 | – | 179 |
| 2 | 40 | 1 | 13 | – | 54 |
| 3 | 5 | – | 13 | – | 18 |
| 4 | 120 | – | 96 | 5 | 221 |
| 5 | 12 | – | – | – | 12 |
| 6 | 105 | 3 | 17 | – | 125 |
| 8 | 44 | 1 | 2 | – | 47 |
| Total | 402 | 6 | 243 | 5 | 656 |
| Nonfederal | | | | | |
| 1 | 164 | 54 | 90 | 17 | 325 |
| 2 | 23 | – | 7 | 6 | 36 |
| 3 | 339 | 3 | 155 | 1 | 498 |
| 4 | 275 | 5 | 135 | 16 | 431 |
| 5 | 847 | 41 | 514 | 103 | 1,505 |
| 6 | 162 | 132 | 86 | 40 | 420 |
| 7 | 24 | 28 | 1 | – | 53 |
| 8 | 214 | 133 | 31 | 6 | 384 |
| Total | 2,048 | 396 | 1,019 | 189 | 3,652 |
| Nonfederal (FERC license expiring 2021–2040) | | | | | |
| 1 | 66 | 9 | 44 | 3 | 122 |
| 2 | 19 | – | 2 | – | 21 |
| 3 | 266 | 3 | 93 | – | 362 |
| 4 | 96 | 3 | 52 | 8 | 159 |
| 5 | 431 | 13 | 239 | 33 | 716 |
| 6 | 87 | 41 | 40 | 1 | 169 |
| 7 | 17 | 19 | – | – | 36 |
| 8 | 53 | 57 | 10 | 3 | 123 |
| Total | 1,035 | 145 | 480 | 48 | 1,708 |

For the purposes of hydropower project licensing, FERC partitions the country into six regions (Figure 7). Although they are the two smallest regions in terms of area, the New England and Mid-Atlantic regions had more turbines at licensed projects than the other regions (Table 14). The distribution of turbines at projects with licenses expiring in the period 2021–2040 is virtually the same as the overall distribution.

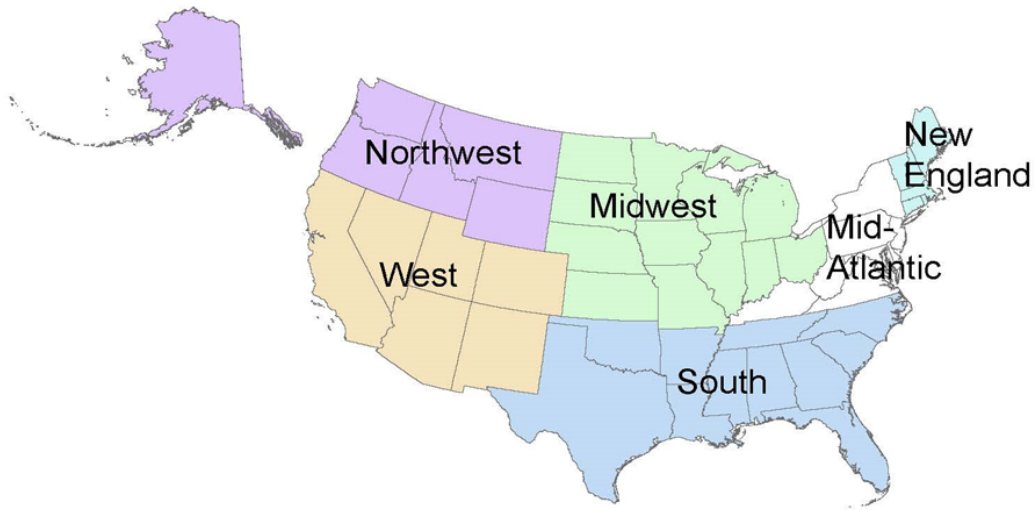


Figure 7. Six FERC regions.

Table 14. Count and distribution of major turbine types by FERC region at all FERC-licensed projects and at FERC-licensed projects with licenses expiring in the period 2021–2040.

| FERC region | Francis | Impulse | Propeller | Pump | Total |
|---|--------------|------------|--------------|------------|--------------|
| FERC-licensed projects | | | | | |
| Midwest | 344 | 6 | 161 | 1 | 512 |
| New England | 466 | 24 | 268 | 47 | 805 |
| Mid-Atlantic | 381 | 17 | 256 | 56 | 710 |
| Northwest | 299 | 148 | 165 | 51 | 663 |
| South | 293 | 3 | 131 | 22 | 449 |
| West | 259 | 181 | 36 | 11 | 487 |
| Total | 2,042 | 379 | 1,017 | 188 | 3,626 |
| FERC-licensed projects 2021–2040 | | | | | |
| Midwest | 266 | 3 | 93 | – | 362 |
| New England | 239 | 6 | 113 | 18 | 376 |
| Mid-Atlantic | 192 | 7 | 126 | 15 | 340 |
| Northwest | 147 | 47 | 84 | 4 | 282 |
| South | 110 | 1 | 53 | 8 | 172 |
| West | 81 | 79 | 11 | 3 | 174 |
| Total | 1,035 | 143 | 480 | 48 | 1,706 |

4. CONCLUSIONS

The primary objective of the BioDE market assessment task reported here was to develop a dataset of hydropower turbines and their defining characteristics (both physical and biological) for the purpose of refining program outreach and marketing of BioDE tools and data. The results presented here identified

the federal and nonfederal owners with the most turbines of various types and the most turbines that have the potential to interact with various species of interest.

The data did not reveal a reliable relationship between turbine age and point of replacement or rehabilitation, so we focused our analysis on number of years until FERC license expiration as an indicator of when project owners might consider replacement. The resulting dataset is maintained as an Excel spreadsheet, and although most of the results shown in the report were derived from pivot table analysis, the spreadsheet is also populated with filters (i.e., pull-down menus) that can be used to easily generate specific queries. Furthermore, once specific owners are identified, the pull-down menus can be used to filter the main dataset by an owner and other attributes (e.g., turbine type and year of FERC license expiration) to find project details. For example, for the seven propeller turbines owned/operated by Erie Boulevard Hydropower that have licenses expiring soon and have American eels present (see Table 11), we find that those seven turbines are located at two FERC-licensed projects (P-2538 and P-2569) on the Black River in upstate New York and that they have a capacity range of 900–1800 cfs, a head range of 15.5–32 ft, and a nameplate capacity range of 0.7–2.8 MW.

This type of information could be useful in marketing the BioDE modeling tools and dataset if we can cite other successful applications at projects with similar characteristics. Similarly, we can specifically target projects with characteristics that match those where BioDE tools have been applied successfully. In the analysis presented, other than turbine type, we did not summarize by turbine characteristics such as runner speed, head, or generating capacity, but such analyses could easily be conducted if some marketing objective included a more specific project target (e.g., a specific turbine size).

We have tried to present in this report a variety of analyses so that users of the dataset can quickly identify which queries best match their needs. With that in mind, however, the data summary in table A-3 in appendix A is probably most useful for identifying owners to whom BioDE should be marketed based on when their licenses expire, the types of turbines they have, where they are located, and the species with which they potentially interact.

5. ACKNOWLEDGMENTS

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APPENDIX A. EXPANDED OUTPUT

Table A-1. Federal owners with 5+ turbines located at projects that overlap with seven species of interest.

| Owner and Species | Turbine Type | | Total |
|-------------------------------------|--------------|-----------|-------|
| | Francis | Propeller | |
| Chinook salmon | | | |
| California | 8 | 2 | 10 |
| US BuRec – Mid-Pac | 8 | 2 | 10 |
| Northwest | 76 | 102 | 178 |
| USACE Northwestern Division | 40 | 102 | 142 |
| US BuRec – Pac NW | 36 | | 36 |
| Total | 84 | 104 | 188 |
| Rainbow trout/steelhead | | | |
| California | 30 | 2 | 32 |
| US BuRec – Mid-Pac | 22 | 2 | 24 |
| California Dept. of Water Resources | 8 | | 8 |
| Northwest | 91 | 102 | 193 |
| USACE Northwestern Division | 48 | 102 | 150 |
| US BuRec – Pac NW | 43 | | 43 |
| Total | 121 | 104 | 225 |
| Largemouth bass | | | |
| Great Lakes | 16 | 16 | 32 |
| USACE – Nashville District | 13 | 15 | 28 |
| North Central | 8 | 10 | 18 |
| USACE – Missouri River District | 8 | 3 | 11 |
| USACE – Kansas City District | | 7 | 7 |
| South Central | 33 | 22 | 55 |
| USACE – Little Rock District | 18 | 9 | 27 |
| USACE – Tulsa District | 13 | 9 | 22 |
| USACE – Fort Worth District | 2 | 4 | 6 |
| Southeast | 103 | 72 | 175 |
| Tennessee Valley Authority | 54 | 52 | 106 |
| USACE – Mobile District | 10 | 17 | 27 |
| USACE – Savannah District | 20 | 3 | 23 |
| USACE – Wilmington District | 12 | | 12 |
| USACE – Vicksburg District | 7 | | 7 |
| Total | 160 | 120 | 280 |
| Bluegill sunfish | | | |
| Great Lakes | 16 | 21 | 37 |
| USACE – Nashville District | 13 | 15 | 28 |
| USACE – Detroit District | | 5 | 5 |

Table A-1. Federal owners with 5+ turbines located at projects that overlap with seven species of interest (continued).

| Owner and Species | Turbine Type | | Total |
|---------------------------------|--------------|------------|------------|
| | Francis | Propeller | |
| North Central | 8 | 10 | 18 |
| USACE – Missouri River District | 8 | 3 | 11 |
| USACE – Kansas City District | | 7 | 7 |
| South Central | 36 | 22 | 58 |
| USACE – Little Rock District | 18 | 9 | 27 |
| USACE – Tulsa District | 13 | 9 | 22 |
| USACE – Fort Worth District | 2 | 4 | 6 |
| Southeast | 91 | 72 | 163 |
| Tennessee Valley Authority | 54 | 52 | 106 |
| USACE – Mobile District | 10 | 17 | 27 |
| USACE – Savannah District | 20 | 3 | 23 |
| USACE – Vicksburg District | 7 | | 7 |
| Total | 151 | 125 | 276 |
| American eel | | | |
| Great Lakes | 12 | 12 | 24 |
| USACE – Nashville District | 12 | 7 | 19 |
| USACE – Detroit District | | 5 | 5 |
| North Central | 8 | 11 | 19 |
| USACE – Missouri River District | 8 | 11 | 19 |
| South Central | 29 | 18 | 47 |
| USACE – Little Rock District | 18 | 9 | 27 |
| USACE – Tulsa District | 11 | 9 | 20 |
| Southeast | 35 | 56 | 91 |
| Tennessee Valley Authority | 18 | 42 | 60 |
| USACE – Mobile District | | 14 | 14 |
| USACE – Wilmington District | 12 | | 12 |
| USACE – Vicksburg District | 5 | | 5 |
| Total | 84 | 97 | 181 |
| American shad | | | |
| Southeast | 29 | 3 | 32 |
| USACE – Savannah District | 20 | 3 | 23 |
| USACE – Wilmington District | 9 | | 9 |
| Total | 29 | 3 | 32 |
| Atlantic salmon | | | |
| Total | 0 | 0 | 0 |

Table A-2. Nonfederal owners with 5+ turbines located at projects with FERC licenses expiring in the period 2021–2040 and that overlap with seven species of interest.

| Owner and Species | Turbine Type | | Total |
|--------------------------------------|--------------|-----------|-------|
| | Francis | Propeller | |
| Chinook salmon | | | |
| California | 18 | 3 | 21 |
| Pacific Gas & Electric Co. | 15 | | 15 |
| East Bay Municipal Util. Dist. | 3 | 3 | 6 |
| Northwest | 46 | 27 | 73 |
| PUD No. 1 of Chelan County | 4 | 14 | 18 |
| Portland General Electric Co | 3 | 12 | 15 |
| City of Tacoma – WA | 14 | 1 | 15 |
| PacifiCorp | 13 | | 13 |
| City of Seattle – WA | 12 | | 12 |
| Total | 64 | 30 | 94 |
| Rainbow trout/steelhead | | | |
| California | 19 | 3 | 22 |
| Pacific Gas & Electric Co. | 16 | | 16 |
| East Bay Municipal Util. Dist. | 3 | 3 | 6 |
| Northwest | 52 | 58 | 110 |
| Idaho Power Co. | 2 | 20 | 22 |
| PUD No. 1 of Chelan County | 4 | 14 | 18 |
| Portland General Electric Co. | 3 | 12 | 15 |
| City of Tacoma – WA | 14 | 1 | 15 |
| PacifiCorp | 13 | | 13 |
| City of Seattle – WA | 12 | | 12 |
| Boise-Kuna Irrigation District | 2 | 3 | 5 |
| City of Spokane | | 5 | 5 |
| Columbia Basin Hydropower | 2 | 3 | 5 |
| Total | 71 | 61 | 132 |
| Largemouth bass | | | |
| Great Lakes | 303 | 71 | 374 |
| Erie Boulevard Hydropower LP | 60 | 11 | 71 |
| Northern States Power Co – Minnesota | 29 | 14 | 43 |
| Consolidated Water Power Co. | 32 | 6 | 38 |
| Consumers Energy Co. | 30 | 3 | 33 |
| Wisconsin Public Service Corp. | 29 | 1 | 30 |
| Wisconsin Electric Power Co. | 15 | 5 | 20 |
| Domtar Industries, Inc. | 14 | | 14 |
| ALLETE, Inc. | 12 | 1 | 13 |
| Wisconsin River Power Company | | 9 | 9 |
| Wisconsin Power & Light Co. | 8 | 1 | 9 |

Table A-2. Nonfederal owners with 5+ turbines located at projects with FERC licenses expiring in the period 2021–2040 and that overlap with seven species of interest (continued).

| Owner and Species | Turbine Type | | Total |
|---------------------------------------|--------------|------------|------------|
| | Francis | Propeller | |
| N E W Hydro LLC | 3 | 6 | 9 |
| Northbrook Lyons Falls LLC | 8 | | 8 |
| Renewable World Energies LLC | 7 | | 7 |
| Domtar Paper Company Rothschild | 7 | | 7 |
| Boyce Hydro Power LLC | 3 | 4 | 7 |
| Northern Indiana Pub Serv Co. | 7 | | 7 |
| Ampersand Hydro LLC | | 7 | 7 |
| Appalachian Power Co. | 7 | | 7 |
| Indiana Michigan Power Co. | 7 | | 7 |
| C-S Canal Hydro, LLC | 6 | | 6 |
| Northbrook Wisconsin LLC | 6 | | 6 |
| Thunder Bay Power Co LLC | 6 | | 6 |
| Brainerd Public Utilities | 5 | | 5 |
| City of Hamilton – OH | 2 | 3 | 5 |
| Northeast | 22 | 8 | 30 |
| Green Mountain Power Corp. | 19 | 5 | 24 |
| Sheldon Vermont Hydro Co., Inc. | 3 | 3 | 6 |
| South Central | 10 | 6 | 16 |
| Grand River Dam Authority | 10 | | 10 |
| Arkansas Electric Coop Corp. | | 6 | 6 |
| Southeast | 80 | 20 | 100 |
| Georgia Power Co. | 40 | 10 | 50 |
| South Carolina Electric & Gas Company | 12 | | 12 |
| Duke Energy Carolinas, LLC | 10 | | 10 |
| Alabama Power Co. | 9 | 1 | 10 |
| First National Bank-Commerce | | 8 | 8 |
| Lockhart Power Co. | 5 | | 5 |
| PowerSouth Energy Cooperative | 4 | 1 | 5 |
| Total | 415 | 105 | 520 |
| Bluegill sunfish | | | |
| Great Lakes | 236 | 60 | 296 |
| Erie Boulevard Hydropower LP | 39 | 7 | 46 |
| Northern States Power Co – Minnesota | 29 | 14 | 43 |
| Consolidated Water Power Co. | 32 | 6 | 38 |
| Wisconsin Public Service Corp. | 29 | 1 | 30 |
| Wisconsin Electric Power Co. | 15 | 5 | 20 |
| Domtar Industries, Inc. | 14 | | 14 |
| ALLETE, Inc. | 12 | 1 | 13 |

Table A-2. Nonfederal owners with 5+ turbines located at projects with FERC licenses expiring in the period 2021–2040 and that overlap with seven species of interest (continued).

| Owner and Species | Turbine Type | | Total |
|---------------------------------------|--------------|-----------|------------|
| | Francis | Propeller | |
| Wisconsin River Power Company | | 9 | 9 |
| Wisconsin Power & Light Co. | 8 | 1 | 9 |
| N E W Hydro LLC | 3 | 6 | 9 |
| Northbrook Lyons Falls LLC | 8 | | 8 |
| Indiana Michigan Power Co. | 7 | | 7 |
| Domtar Paper Company Rothschild | 7 | | 7 |
| Northern Indiana Pub Serv Co. | 7 | | 7 |
| Ampersand Hydro LLC | | 7 | 7 |
| Renewable World Energies LLC | 7 | | 7 |
| C-S Canal Hydro LLC | 6 | | 6 |
| Northbrook Wisconsin LLC | 6 | | 6 |
| City of Hamilton – OH | 2 | 3 | 5 |
| Brainerd Public Utilities | 5 | | 5 |
| Northeast | 10 | 1 | 11 |
| Green Mountain Power Corp. | 10 | 1 | 11 |
| South Central | 10 | 6 | 16 |
| Grand River Dam Authority | 10 | | 10 |
| Arkansas Electric Coop Corp. | | 6 | 6 |
| Southeast | 80 | 20 | 100 |
| Georgia Power Co. | 40 | 10 | 50 |
| South Carolina Electric & Gas Company | 12 | | 12 |
| Duke Energy Carolinas, LLC | 10 | | 10 |
| Alabama Power Co. | 9 | 1 | 10 |
| First National Bank-Commerce | | 8 | 8 |
| Lockhart Power Co. | 5 | | 5 |
| PowerSouth Energy Cooperative | 4 | 1 | 5 |
| Total | 336 | 87 | 423 |
| American eel | | | |
| Great Lakes | 129 | 30 | 159 |
| Erie Boulevard Hydropower LP | 65 | 11 | 76 |
| Northern States Power Co - Minnesota | 18 | 11 | 29 |
| Wisconsin Power & Light Co. | 8 | | 8 |
| Ampersand Hydro LLC | | 8 | 8 |
| Northbrook Lyons Falls LLC | 8 | | 8 |
| Appalachian Power Co. | 7 | | 7 |
| Northern Indiana Pub Serv Co. | 7 | | 7 |
| C-S Canal Hydro, LLC | 6 | | 6 |
| ALLETE, Inc. | 5 | | 5 |

Table A-2. Nonfederal owners with 5+ turbines located at projects with FERC licenses expiring in the period 2021–2040 and that overlap with seven species of interest (continued).

| Owner and Species | Turbine Type | | Total |
|---|--------------|-----------|------------|
| | Francis | Propeller | |
| CHI Energy, Inc | 5 | | 5 |
| Northeast | 220 | 95 | 315 |
| Great Lakes Hydro America LLC | 34 | 14 | 48 |
| Brookfield White Pine Hydro LLC | 27 | 11 | 38 |
| Green Mountain Power Corp. | 22 | 5 | 27 |
| Boott Hydropower, Inc. & E. L. Field Hydroelectric Fac. Trust | 19 | | 19 |
| Great River Hydro, LLC | 15 | | 15 |
| City of Holyoke Gas and Electric Dept. | 10 | 5 | 15 |
| Safe Harbor | 2 | 12 | 14 |
| Brookfield Black Bear Hydro, LLC | 5 | 8 | 13 |
| BIF III Holtwood LLC | 10 | 2 | 12 |
| Eagle Creek RE LLC | 3 | 8 | 11 |
| PE Hydro Generation, LLC | 10 | 1 | 11 |
| New York Power Authority | 4 | 6 | 10 |
| KEI (Maine) Power Management LLC | 6 | 3 | 9 |
| Central Vermont Pub Serv Corp. | 4 | 4 | 8 |
| Potomac Edison Co. | 5 | 2 | 7 |
| Merimil Ltd Partnership | 6 | 1 | 7 |
| Palmer Hydroelectric | 2 | 5 | 7 |
| Sheldon Vermont Hydro Co., Inc. | 3 | 3 | 6 |
| Brookfield Power New England | 6 | | 6 |
| Erie Boulevard Hydropower LP | 6 | | 6 |
| Public Service Co. of NH | 4 | 2 | 6 |
| Consolidated Hydro NH Inc. | 5 | | 5 |
| Virginia Electric & Power Co. | 5 | | 5 |
| Central Maine Power Co. | 2 | 3 | 5 |
| Appalachian Power Co. | 5 | | 5 |
| South Central | 10 | 6 | 16 |
| Grand River Dam Authority | 10 | | 10 |
| Arkansas Electric Coop Corp. | | 6 | 6 |
| Southeast | 48 | 18 | 66 |
| Georgia Power Co. | 25 | 6 | 31 |
| South Carolina Electric & Gas Company | 8 | | 8 |
| Alabama Power Co. | 7 | 1 | 8 |
| First National Bank-Commerce | | 8 | 8 |
| Appalachian Power Co. | 4 | 2 | 6 |
| PowerSouth Energy Cooperative | 4 | 1 | 5 |

Table A-2. Nonfederal owners with 5+ turbines located at projects with FERC licenses expiring in the period 2021–2040 and that overlap with seven species of interest (continued).

| Owner and Species | Turbine Type | | Total |
|---|--------------|------------|------------|
| | Francis | Propeller | |
| Total | 407 | 149 | 556 |
| American shad | | | |
| Northeast | 131 | 59 | 190 |
| Brookfield White Pine Hydro LLC | 23 | 10 | 33 |
| Great Lakes Hydro America LLC | 22 | 5 | 27 |
| Boott Hydropower, Inc. & E. L. Field Hydroelectric Fac. Trust | 19 | | 19 |
| City of Holyoke Gas and Electric Dept. | 10 | 5 | 15 |
| Safe Harbor | 2 | 12 | 14 |
| Brookfield Black Bear Hydro LLC | 5 | 8 | 13 |
| BIF III Holtwood LLC | 10 | 2 | 12 |
| Eagle Creek RE LLC | 3 | 6 | 9 |
| KEI (Maine) Power Management LLC | 6 | 2 | 8 |
| Palmer Hydroelectric | 2 | 5 | 7 |
| Merimil Ltd Partnership | 6 | 1 | 7 |
| Brookfield Power New England | 6 | | 6 |
| Central Maine Power Co. | 2 | 3 | 5 |
| Virginia Electric & Power Co. | 5 | | 5 |
| Consolidated Hydro NH Inc. | 5 | | 5 |
| Appalachian Power Co. | 5 | | 5 |
| Southeast | 47 | 4 | 51 |
| Georgia Power Co. | 25 | 2 | 27 |
| Duke Energy Carolinas LLC | 10 | | 10 |
| South Carolina Electric & Gas Company | 8 | | 8 |
| Appalachian Power Co. | 4 | 2 | 6 |
| Total | 178 | 63 | 241 |
| Atlantic salmon | | | |
| Great Lakes | 79 | 11 | 90 |
| Erie Boulevard Hydropower LP | 65 | 11 | 76 |
| Northbrook Lyons Falls LLC | 8 | | 8 |
| C-S Canal Hydro LLC | 6 | | 6 |
| Northeast | 171 | 57 | 228 |
| Great Lakes Hydro America LLC | 34 | 14 | 48 |
| Brookfield White Pine Hydro LLC | 27 | 11 | 38 |
| Green Mountain Power Corp. | 22 | 5 | 27 |
| Boott Hydropower, Inc. & E.L. Field Hydroelectric Fac. Trust | 19 | | 19 |
| Great River Hydro LLC | 15 | | 15 |

Table A-2. Nonfederal owners with 5+ turbines located at projects with FERC licenses expiring in the period 2021–2040 and that overlap with seven species of interest (continued).

| Owner and Species | Turbine Type | | Total |
|--|--------------|-----------|------------|
| | Francis | Propeller | |
| City of Holyoke Gas and Electric Dept. | 10 | 5 | 15 |
| Brookfield Black Bear Hydro LLC | 5 | 8 | 13 |
| Public Service Co. of NH | 7 | 2 | 9 |
| KEI (Maine) Power Management LLC | 6 | 3 | 9 |
| Merimil Ltd Partnership | 6 | 1 | 7 |
| Brookfield Power New England | 6 | | 6 |
| Sheldon Vermont Hydro Co., Inc. | 3 | 3 | 6 |
| Central Vermont Pub Serv Corp. | 4 | 2 | 6 |
| Central Maine Power Co. | 2 | 3 | 5 |
| Consolidated Hydro NH Inc. | 5 | | 5 |
| Total | 250 | 68 | 318 |

Table A-3. Nonfederal owners with 5+ turbines located at projects with FERC licenses expiring in the period 2023–2027 by the species of interest they overlap.

| Owner and Species | Turbine Type | | Total |
|---------------------------------------|--------------|-----------|-------|
| | Francis | Propeller | |
| Chinook Salmon | | | |
| California | 5 | | 5 |
| Pacific Gas & Electric Co. | 5 | | 5 |
| Northwest | 12 | | 12 |
| City of Seattle – WA | 12 | | 12 |
| Total | 17 | | 17 |
| Rainbow trout/steelhead | | | |
| California | 5 | | 5 |
| Pacific Gas & Electric Co. | 5 | | 5 |
| Northwest | 12 | | 12 |
| City of Seattle – WA | 12 | | 12 |
| Total | 17 | | 17 |
| Largemouth bass | | | |
| Great Lakes | 104 | 26 | 130 |
| Erie Boulevard Hydropower LP | 33 | 7 | 40 |
| Consolidated Water Power Co. | 18 | 6 | 24 |
| Domtar Industries Inc | 14 | | 14 |
| Northern States Power Co. – Minnesota | 4 | 4 | 8 |
| Northbrook Lyons Falls LLC | 8 | | 8 |
| Ampersand Hydro LLC | | 7 | 7 |
| Domtar Paper Company Rothschild | 7 | | 7 |
| Appalachian Power Co. | 7 | | 7 |
| N E W Hydro LLC | 3 | 2 | 5 |
| Brainerd Public Utilities | 5 | | 5 |
| Wisconsin Public Service Corp. | 5 | | 5 |
| Northeast | 9 | 3 | 12 |
| Sheldon Vermont Hydro Co., Inc. | 3 | 3 | 6 |
| Green Mountain Power Corp. | 6 | | 6 |
| Southeast | 14 | | 14 |
| South Carolina Electric & Gas Company | 8 | | 8 |
| Georgia Power Co. | 6 | | 6 |
| Total | 127 | 29 | 156 |
| Bluegill sunfish | | | |
| Great Lakes | 97 | 26 | 123 |
| Erie Boulevard Hydropower LP | 33 | 7 | 40 |
| Consolidated Water Power Co. | 18 | 6 | 24 |
| Domtar Industries Inc. | 14 | | 14 |
| Northbrook Lyons Falls LLC | 8 | | 8 |

Table A-3. Nonfederal owners with 5+ turbines located at projects with FERC licenses expiring in the period 2023–2027 by the species of interest they overlap (continued).

| Owner and Species | Turbine Type | | Total |
|---|--------------|-----------|------------|
| | Francis | Propeller | |
| Northern States Power Co. – Minnesota | 4 | 4 | 8 |
| Domtar Paper Company Rothschild | 7 | | 7 |
| Ampersand Hydro LLC | | 7 | 7 |
| Wisconsin Public Service Corp. | 5 | | 5 |
| Brainerd Public Utilities | 5 | | 5 |
| N E W Hydro LLC | 3 | 2 | 5 |
| Southeast | 14 | | 14 |
| South Carolina Electric & Gas Company | 8 | | 8 |
| Georgia Power Co. | 6 | | 6 |
| Total | 111 | 26 | 137 |
| Great Lakes | 48 | 15 | 63 |
| Erie Boulevard Hydropower LP | 33 | 7 | 40 |
| Ampersand Hydro LLC | | 8 | 8 |
| Northbrook Lyons Falls LLC | 8 | | 8 |
| Appalachian Power Co. | 7 | | 7 |
| Northeast | 98 | 25 | 123 |
| Great Lakes Hydro America LLC | 32 | 14 | 46 |
| Boott Hydropower, Inc. & E. L. Field Hydroelectric Fac. Trust | 19 | | 19 |
| Green Mountain Power Corp. | 9 | | 9 |
| New York Power Authority | 4 | 4 | 8 |
| Potomac Edison Co. | 5 | 2 | 7 |
| Brookfield Power New England | 6 | | 6 |
| Sheldon Vermont Hydro Co., Inc. | 3 | 3 | 6 |
| Erie Boulevard Hydropower LP | 6 | | 6 |
| PE Hydro Generation, LLC | 6 | | 6 |
| Appalachian Power Co. | 5 | | 5 |
| Public Service Co of NH | 3 | 2 | 5 |
| Southeast | 14 | | 14 |
| South Carolina Electric & Gas Company | 8 | | 8 |
| Georgia Power Co. | 6 | | 6 |
| Total | 160 | 40 | 200 |
| American shad | | | |
| Northeast | 52 | 5 | 57 |
| Great Lakes Hydro America LLC | 22 | 5 | 27 |
| Boott Hydropower, Inc. & E. L. Field Hydroelectric Fac. Trust | 19 | | 19 |
| Brookfield Power New England | 6 | | 6 |
| Appalachian Power Co | 5 | | 5 |
| Southeast | 14 | | 14 |

Table A-3. Nonfederal owners with 5+ turbines located at projects with FERC licenses expiring in the period 2023–2027 by the species of interest they overlap (continued).

| Owner and Species | Turbine Type | | Total |
|---|--------------|-----------|------------|
| | Francis | Propeller | |
| South Carolina Electric & Gas Company | 8 | | 8 |
| Georgia Power Co. | 6 | | 6 |
| Total | 66 | 5 | 71 |
| Atlantic salmon | | | |
| Great Lakes | 41 | 7 | 48 |
| Erie Boulevard Hydropower LP | 33 | 7 | 40 |
| Northbrook Lyons Falls LLC | 8 | | 8 |
| Northeast | 72 | 19 | 91 |
| Great Lakes Hydro America LLC | 32 | 14 | 46 |
| Boott Hydropower, Inc. & E. L. Field Hydroelectric Fac. Trust | 19 | | 19 |
| Green Mountain Power Corp. | 9 | | 9 |
| Brookfield Power New England | 6 | | 6 |
| Sheldon Vermont Hydro Co., Inc. | 3 | 3 | 6 |
| Public Service Co of NH | 3 | 2 | 5 |
| Total | 113 | 26 | 139 |

