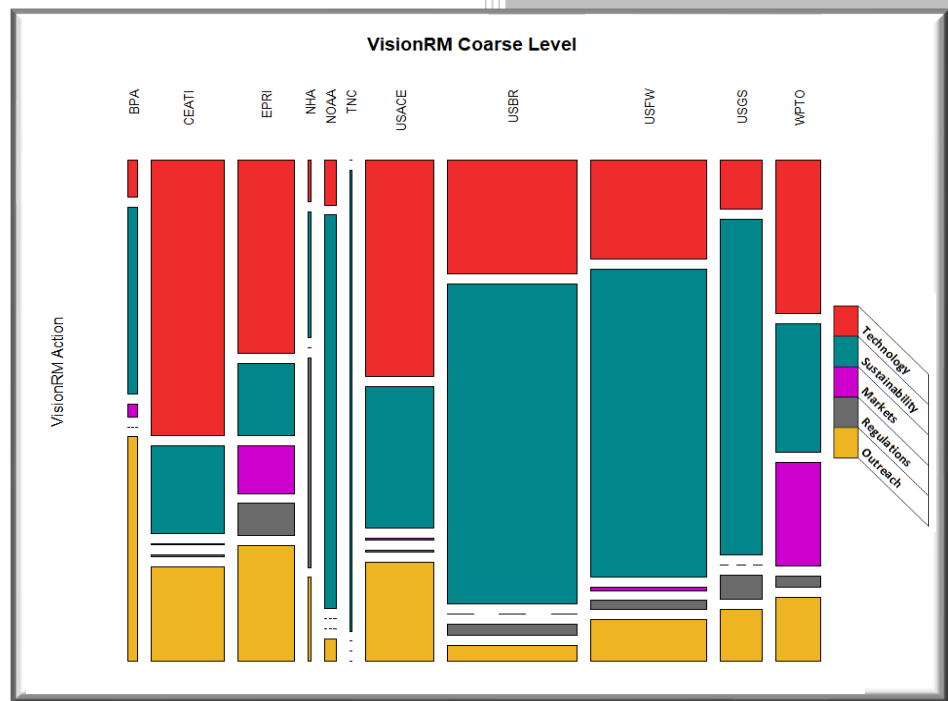


Oak Ridge National Laboratory Hydropower Vision Roadmap Reference Database Methods and Results



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March 2018

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Environmental Sciences Division

**Oak Ridge National Laboratory
Hydropower Vision Roadmap Reference Database Methods and Results**

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March 2018

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CONTENTS

LIST OF FIGURES	iv
LIST OF TABLES	iv
ABSTRACT.....	5
INTRODUCTION	5
1. DATABASE OVERVIEW	5
1.1 BACKGROUND	5
1.2 PROJECT SCOPE	6
2. DATABASE DEVELOPMENT.....	6
2.1 PROJECT REPORT SELECTION.....	6
2.1.1 Report Selection Assumptions	6
2.1.2 Report Search Methods and Results	7
2.2 DATABASE STRUCTURE	18
2.3 DATABASE CATALOGING	19
2.3.1 Tagging Process	19
2.3.2 Vision Roadmap Tag Structure.....	20
2.3.3 Functional Tagging Structure.....	23
3. ANALYSIS AND RESULTS.....	25
3.1 GAPS AND REDUNDANCY ANALYSIS	Error! Bookmark not defined.
4. MATURITY RUBRIC DEVELOPMENT AND SCORING	Error! Bookmark not defined.
5. SUBSEQUENT WORK	Error! Bookmark not defined.
6. REFERENCES	30

LIST OF FIGURES

Figure 1. Mosaic plot of reports by organization and major Vision Roadmap tags.	27
Figure 2. Mosaic plot of reports by organization and major Functional tags.	29
Figure 3. Mosaic plot of reports by organization and fine Vision Roadmap tags. The legend displays the tag number with its associated color.	Error! Bookmark not defined.
Figure 4. Mosaic plot of reports by organization and fine Functional tags. The legend displays the tag number with its associated color.	30
Figure 5. Example of the Maturity Matrix rubric with descriptions for each score level. Error! Bookmark not defined.	
Figure 6. Example of the maturity matrix score, score rationale, progress, similarities, and gaps.	Error! Bookmark not defined.

LIST OF TABLES

Table 1. Summary of reports included in database by source.....	7
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ABSTRACT

Much research is being conducted at national laboratories and industry with the aim of advancing the field of hydropower. However, there is no quantifiable way to identify where these efforts overlap and where they fall short. The authors of this report have created a database and categorization structure that classifies hydropower-focused activities and allows end users to submit queries to obtain information regarding research being conducted across various hydropower institutions. This effort includes 2,023 database reports classified within two different structures—the Hydropower *Vision Roadmap* (RM) structure and a *Hydropower Functional* structure. This report outlines in detail the methods used, assumptions made, and the final structure of the database.

INTRODUCTION

This report addresses the effort to develop a database of activities and categorize those activities with respect to the Vision structure. The information in this report will be used in the development of a Progress, Gaps, and Similarities Report (PGSR), that is an effort to examine the results and analyze the progress and gaps of the Vision action items since the Department of Energy (DOE) Water Power Technologies Office (WPTO) published the Hydropower *Vision* (US Department of Energy, 2016) in 2016.

1. DATABASE OVERVIEW

1.1 BACKGROUND

The need to measure, analyze, and communicate the hydropower community's progress toward growing and optimizing sustainable hydropower was identified in the Hydropower Vision report (US Department of Energy, 2016). This report focuses on increasing awareness among members of the hydropower community of programs and activities (planned and funded) being conducted and publicly documented across various hydropower institutions (agencies, consortia, and other interested organizations). Researchers seeking information on activities relevant to their work can submit queries and obtain quantifiable results. DOE and its laboratories will classify, and catalog short descriptions and a limited set of tags and attributes of activities undertaken by hydropower community institutions (agencies, consortia, and other interested organizations) into a publicly distributable (e.g., downloadable from HydroWISE) and documented relational database product. The structure, tagging, and indexing of activities in the database will align with the RM structure and support the analysis of progress, gaps, and similarities. The database product will include documentation on the sources and methods used to collect, classify, and catalog the activities of hydropower community institutions.

Several institutions within the hydropower community that have large documented portfolios of programmed activities were considered for inclusion in the database. These include the Center for Energy Advancement through Technological Innovation (CEATI), the Electric Power Research Institute (EPRI), the National Hydropower Association (NHA), the US Army Corps of Engineers (Corps), the US Bureau of Reclamation (USBR), and the US Department of Energy Water Power Technology Office (WPTO).

1.2 PROJECT SCOPE

The supporting tasks for the work conducted in this project are as follows:

- identify appropriate institutions to include in the database,
- develop report selection assumptions so that the most relevant content is included,
- conduct a report search,
- define a database structure,
- catalog reports to their respective Vision and Functional structures,

2. DATABASE DEVELOPMENT

2.1 PROJECT REPORT SELECTION

Hydropower consortia and organizations that conduct industry-supported hydropower research were searched for documented hydropower research reports.

- Center for Energy Advancement through Technological Innovation (CEATI)
- Electric Power Research Institute (EPRI)
- National Hydropower Association (NHA)
- National Oceanic and Atmospheric Administration (NOAA)
- The Nature Conservancy (TNC)
- United States Army Corps of Engineers (USACE)
- United States Bureau of Reclamation (USBR)
- United States Geological Survey (USGS)
- United States Fish and Wildlife Services (USFWS)
- Water Power Technologies Office (WPTO)

A description of the assumptions and search methods used to select the organizations, along with their mission statements, is presented in this section.

2.1.1 Report Selection Assumptions

Because of the amount of research related to the hydropower industry, deciding which reports to include in the database is an important step in the process. The following criteria represent a comprehensive study of the work being done in the hydropower industry while narrowing the effort enough to be feasible. The criteria used for including or excluding reports is as follows:

Study Inclusion Criteria:

- Projects or research that have available reports
- Reports must describe research, technology development, or other such efforts that advance the hydropower industry forward
- Existing funded and/or completed industry-led/funded hydropower projects
- Existing funded and/or completed WPTO projects
- Must be hydropower focused
- Study area: the focus is within the United States, although reference to international work is not means for exclusion

Study Exclusion Criteria:

- Does not include marine hydrokinetics

- Does not include activities having to do with coal or gas
- Does not include solar or wind unless used in conjunction with pumped storage
- Does not include activities focused on marine wildlife
- Does not include sites that are current projects or efforts associated with them to advance the hydropower industry

All sources included in the database adhered to the criteria outlined above. Any activities that became evident during the searches but were not within the scope of this effort were documented separately and not included in the database (with the exception of NOAA and USFWS). Internal publications, such as newsletters, were not considered. This assumption was made after examining some of the newsletters and determining that all the projects described appeared elsewhere. To avoid repetition, the newsletters were left out. The final assumption made for all the sources was the keywords used. Not all sites used keyword searches, but those that did all used the same set of keywords—hydropower, renewable energy, hydroelectric power plants, hydroelectric power, energy storage, licensing, and distributed energy resources. These keywords were chosen because they were used by the first source researched and the authors thought that the same keywords should be used to maintain consistency across all sources.

2.1.2 Report Search Methods and Results

Table 1 provides a list reports obtained and their sources. Although the format of each source website varied widely, the process of accessing the reports was basically the same. The number of reports that were found on each site is shown in the second column, and those that were entered into the database are shown in the third column. Search methods and results for each of the 10 source organizations are discussed in the following sections.

Table 1. Summary of reports included in database by source. * designates a total number obtained from search but not all activities were sorted through.

Organization	Total activities from search	Included in Vision Roadmap Activity Database
EPRI	500	203
BPA	313	37
CEATI	901	264
NHA	41	11
WPTO	367	172
USBR	1,559	471
USACE	796	247
NOAA	5,455	41
TNC	15	7
USFWS	88,623*	419
USGS	798	151
Totals	99,368	2,023

2.1.2.1 Bonneville Power Administration (BPA)

The mission of the BPA is as follows:

“The Bonneville Power Administration's mission as a public service organization is to create and deliver the best value for our customers and constituents as we act in concert with others to assure the Pacific Northwest:

- *An adequate, efficient, economical and reliable power supply;*
- *A transmission system that is adequate to the task of integrating and transmitting power from federal and non-federal generating units, providing service to BPA's customers, providing interregional interconnections, and maintaining electrical reliability and stability; and*
- *Mitigation of the impacts on fish and wildlife from the federally owned hydroelectric projects from which BPA markets power.*

BPA is committed to cost-based rates, and public and regional preference in its marketing of power. BPA sets its rates as low as possible consistent with sound business principles and the full recovery of all of its costs, including timely repayment of the federal investment in the system” (BPA, 2018a).

The authors started by searching for the Bonneville Power Administration. Once at the homepage the authors navigated to their Technology innovation projects site and retrieved 33 activities from this site. After this effort, the authors found the BPA library and used it to search the keywords. A filter was used to only include activities that BPA was listed as the author. The results of this search are included below (BPA, 2018b).

Hydropower – 16 activities
Renewable Energy – 55 activities
Hydroelectric Power Plants – 86 activities
Hydroelectric Power – 105 activities
Energy Storage – 11 activities
Licensing – 5 activities
Distributed Energy Resources – 2 activities

The results after sorting all of the BPA activities into the database can be seen below.

313 activities total
60 activities fit the scope
160 activities did not fit the scope and were documented
93 activities repetitive between searches.

2.1.2.2 Center for Energy Advancement through Technological Innovation (CEATI)

The mission statement for CEATI is as follows:

“CEATI's efforts are driven by 130+ participating organizations (electric & gas utilities, governmental agencies, provincial and state research bodies), represented within 19 topic-

focused programs across generation, transmission and distribution. Continuously expanding its international reach, CEATI's participants represent 20 countries on 6 continents, a diversity that contributes to the strength of CEATI and brings value directly to the participants.

In addition to facilitating information exchange through its programs and industry conferences, CEATI International brings partners together to collaborate on technical projects with a strong practical focus and develops customized training solutions to fit the participants' needs. To do this, CEATI leverages a large network of technology suppliers, with representatives from 1,500 companies worldwide.” (CEATI, 2017a)

Because ORNL is a member of CEATI, the authors started by creating an account and viewing projects from within their Mycolate portal (CEATI, 2017b). The keywords were searched, and activities were recorded in the database. These activities were cross-referenced with the list of hydropower-related activities provided from CEATI in the October 10, 2017, email sent to MyCEATI members. Several activities from this email were added to the database.

Each keyword search produce a number of activities on the MyCEATI portal. Results for each keyword are listed below.

Hydropower – 294 activities

Renewable Energy – 149 activities

Hydroelectric Power Plants – 14 activities

Hydroelectric Power – 21 activities

Energy Storage – 162 activities

Licensing – 5 activities

Distributed Energy Resources – 17 activities

Added from CEATI's Hydro Report Highlights October 10, 2017, email – 239 activities

The results of the CEATI keyword search and the email are listed below.

901 activities in total

264 activities fit the scope

84 activities did not fit the scope and were documented

553 activities were repetitive between searches

2.1.2.3 Electric Power Research Institute (EPRI)

The mission statement for EPRI is as follows.

“The Electric Power Research Institute (EPRI) conducts research, development, and demonstration projects for the benefit of the public in the United States and internationally. As an independent, nonprofit organization for public interest energy and environmental research, we focus on electricity generation, delivery, and use in collaboration with the electricity sector, its stakeholders and others to enhance the quality of life by making electric power safe, reliable, affordable, and environmentally responsible.” (EPRI, 2017a)

EPRI has made many of their reports available to the public. Those that are not available at least have accessible abstracts and limited other information. For this reason, the authors went to EPRI's homepage (EPRI, 2017b) and searched for the word “hydropower.” A list of terms came up, and the keywords could all be found within that list, so no other searches were run.

Because one search brought up all the keywords, only the total number of activities were recorded.

500 activities total

203 activities that fit the scope

227 activities did not fit the scope and were documented

70 remaining activities were newsletters

2.1.2.4 National Hydropower Association (NHA)

The mission statement for NHA is as follows.

“The National Hydropower Association (NHA) is a nonprofit national association dedicated to promoting the growth of clean, affordable U.S. hydropower. It seeks to secure hydropower’s place as a climate-friendly, renewable and reliable energy source that serves national environmental, energy, and economic policy objectives.

NHA unites the diverse North American hydropower community, providing a powerful advocacy voice among U.S. decision makers, the general public and the international community. Through membership, individuals and organizations gain access to regulatory bodies, influence over energy and environmental policy and a means to exchange valuable information within the industry.

NHA represents more than 200 companies in the North American hydropower industry, from Fortune 500 corporations to family-owned small businesses. Our members include both public and investor-owned utilities, independent power producers, developers, manufacturers, environmental and engineering consultants, attorneys, and public policy, outreach, and education professionals.

NHA members are involved in projects throughout the U.S. hydropower industry, including both federal and non-federal hydroelectric facilities. NHA members own and operate the majority of the non-federal waterpower generating facilities in the United States.

The NHA Annual Conference provides a forum for industry, legislative and regulatory agency staff to exchange knowledge and expertise pertinent to the hydroelectric industry. Don’t miss this opportunity to network with 500+ hydroelectric professionals in our nation’s capital this spring” (NHA, 2017a).

The search engine on NHA’s homepage did not give relevant results when the word “hydropower” was searched. To circumvent this problem, the authors went to the “Resources” tab from the home page (NHA, 2017b) and then selected the “Waterpower Library” option. The search bar from this screen was used to find activities. The type of document selected was “Technical Reports,” and the keywords were searched for independently. Each keyword search produced a number of activities, as listed below.

Hydropower – 25 activities
Renewable Energy – 4 activities
Hydroelectric Power Plants – 0 activities
Hydroelectric Power – 2 activities
Energy Storage – 7 activities
Licensing – 3 activities
Distributed Energy Resources – 0 activities

The total number of activities, sorted by relevance, are listed below.

41 activities in total
11 activities were in-scope and included in database
30 activities were not in scope and documented

2.1.2.5 National Oceanic and Atmospheric Administration (NOAA)

The mission statement for NOAA is as follows.

“To understand and predict changes in climate, weather, oceans and coasts: Science at NOAA is the systematic study of the structure and behavior of the ocean, atmosphere, and related ecosystems; integration of research and analysis; observations and monitoring; and environmental modeling. NOAA science includes discoveries and ever new understanding of the oceans and atmosphere, and the application of this understanding to such issues as the causes and consequences of climate change, the physical dynamics of high-impact weather events, the dynamics of complex ecosystems and biodiversity, and the ability to model and predict the future states of these systems. Science provides the foundation and future promise of the service and stewardship elements of NOAA’s mission.

To share that knowledge and information with others: Service is the communication of NOAA’s research, data, information, and knowledge for use by the Nation’s businesses, communities, and people’s daily lives. NOAA services include climate predictions and projections; weather and water reports, forecasts and warnings; nautical charts and navigational information; and the continuous delivery of a range of Earth observations and scientific data sets for use by public, private, and academic sectors.

To conserve and manage coastal and marine ecosystems and resources: Stewardship is NOAA’s direct use of its knowledge to protect people and the environment, as the Agency exercises its direct authority to regulate and sustain marine fisheries and their ecosystems, protect endangered marine and anadromous species, protect and restore habitats and ecosystems, conserve marine sanctuaries and other protected places, respond to environmental emergencies, and aid in disaster recovery. The foundation of NOAA’s long-standing record of scientific, technical, and organizational excellence is its people. NOAA’s diverse functions require an equally diverse set of skills and constantly evolving abilities in its workforce.

Also underlying NOAA’s continued success is its unique infrastructure. NOAA’s core mission functions require satellite systems, ships, buoys, aircraft, research facilities, high-performance computing, and information management and distribution systems. The agency provides research-to-application capabilities that can recognize and apply significant new understanding to questions, develop research products and methods, and apply emerging science and technology to user needs. NOAA invests in and depends heavily on the science, management, and engagement capabilities of its partners. Collectively, NOAA’s organizational enterprise-wide

capabilities — its people, infrastructure, research, and partnerships — are essential for NOAA to achieve its vision, mission, and long-term goals” (NOAA, 2018a).

For the NOAA activities, an internet search brought the authors to the NOAA homepage (NOAA, 2018b). From there, they went to the “Our Work,” “Research,” “Go to Oceanic and Atmospheric Research site,” “OAR Labs,” and finally “NOAA Institutional Repository” tabs. Once at the repository, the keywords were entered, and the initial number of activities were recorded.

Hydropower – 322 activities
Renewable Energy – 527 activities
Hydroelectric Power Plant – 189 activities
Hydroelectric Power – 248 activities
Energy Storage – 1631 activities
Licensing – 528 activities
Distributed Energy Resources – 2034 activities

Because there were so many projects, repeated activities and those not within the scope were not recorded in the database. Information was collected only on those activities that were included in the database. Reports were determined to be in scope or not by first reading the title. Then, if not excluded based on the title, the abstract was read. As a result, 41 activities were included in the database.

2.1.2.6 The Nature Conservancy (TNC)

The mission statement for TNC is as follows.

“The mission of The Nature Conservancy is to conserve the lands and waters on which all life depends.

Our vision is a world where the diversity of life thrives, and people act to conserve nature for its own sake and its ability to fulfill our needs and enrich our lives. How do we achieve this mission and vision?

- *Through the dedicated efforts of our diverse staff, including more than 600 scientists, all of whom impact conservation in 72 countries.*
- *With the help of our many partners, from individuals and governments to local nonprofits and corporations.*
- *By using a non-confrontational, collaborative approach and staying true to our five unique core values.*

That’s how The Nature Conservancy has done more than anyone else to advance conservation around the world since our founding in 1951” (TNC, 2018a).

An internet search led the authors to the TNC homepage (TNC, 2018b). From there, they followed the links “Our Work,” “Science,” “Latest Research,” and finally “Science Article Database.” The keywords were used to find the activities below.

Hydropower – 8 activities
Renewable Energy – 4 activities
Hydroelectric Power Plant – 0 activities

Hydroelectric Power – 0 activities
Energy Storage – 1 activities
Licensing – 2 activities
Distributed Energy Resources – 0 activities

The results were as follows.

15 activities total
7 activities included in the database
8 activities did not fit the scope and were recorded

2.1.2.7 United States Army Corps of Engineers (USACE)

The mission statement for USACE is as follows.

“The U.S. Army Corps of Engineers has approximately 37,000 dedicated Civilians and Soldiers delivering engineering services to customers in more than 130 countries worldwide. With environmental sustainability as a guiding principle, our disciplined Corps team is working diligently to strengthen our Nation’s security by building and maintaining America’s infrastructure and providing military facilities where our servicemembers train, work and live. We are also researching and developing technology for our war fighters while protecting America’s interests abroad by using our engineering expertise to promote stability and improve quality of life.

We are energizing the economy by dredging America’s waterways to support the movement of critical commodities and providing recreation opportunities at our campgrounds, lakes and marinas.

And by devising hurricane and storm damage reduction infrastructure, we are reducing risks from disasters.

Our men and women are protecting and restoring the Nation’s environment including critical efforts in the Everglades, the Louisiana coast, and along many of our Nation’s major waterways. The Corps is also cleaning sites contaminated with hazardous, toxic or radioactive waste and material in an effort to sustain the environment.

Through deeds, not words, we are building strong” (USACE, 2017a)

Much like NHA, the search bar located on USACE’s homepage failed to provide relevant activities. From the homepage (USACE, 2017b), the “Library” tab was selected, and from there the “Engineer Research and Development Venter Library” link was chosen. This webpage offered a search that provided relevant activities. Each keyword was searched for with the option of “Technical Reports” selected for the type of document.

The initial results divided by keywords are listed below.

Hydropower – 121 activities
Renewable Energy – 33 activities
Hydroelectric Power Plants – 224 activities
Hydroelectric Power – 323 activities
Energy Storage – 111 activities

Licensing – 7 activities

Distributed Energy Resources – 0 activities

Total activities, sorted by relevance, are listed below.

796 activities total

247 activities in scope and included in database

288 activities not in scope and documented

261 activities were repetitive between searches

2.1.2.8 United States Bureau of Reclamation (USBR)

The mission statement for USBR is as follows.

“Established in 1902, the Bureau of Reclamation is best known for the dams, powerplants, and canals it constructed in the 17 western states. These water projects led to homesteading and promoted the economic development of the West. Reclamation has constructed more than 600 dams and reservoirs including Hoover Dam on the Colorado River and Grand Coulee on the Columbia River.

Today, we are the largest wholesaler of water in the country. We bring water to more than 31 million people and provide one out of five Western farmers (140,000) with irrigation water for 10 million acres of farmland that produce 60% of the nation's vegetables and 25% of its fruits and nuts.

Reclamation is also the second largest producer of hydroelectric power in the United States. Our 53 powerplants annually provide more than 40 billion kilowatt hours generating nearly a billion dollars in power revenues and produce enough electricity to serve 3.5 million homes.

Today, Reclamation is a contemporary water management agency with a Strategic Plan outlining numerous programs, initiatives and activities that will help the Western States, Native American Tribes and others meet new water needs and balance the multitude of competing uses of water in the West. Our mission is to assist in meeting the increasing water demands of the West while protecting the environment and the public's investment in these structures. We place great emphasis on fulfilling our water delivery obligations, water conservation, water recycling and reuse, and developing partnerships with our customers, states, and Native American Tribes, and in finding ways to bring together the variety of interests to address the competing needs for our limited water resources” (USBR, 2017a).

Much like the two previous sources, the search bar on USBR’s home page did not provide useable reports. From the homepage (USBR, 2017b), the authors navigated to the “Water and Power” tab. From there, they linked to “Projects,” “Powerplants,” and “Dams”, and all sites were included.

Additional exploration of USBR led to other activities as well. Starting again from the homepage, the “Resources and Research” tab was selected and then the “Environmental Resources and Reports” tab. This led to a site with links to each of USBR’s regions. Because a comprehensive list of projects across all regions was not accessible, each site was explored for additional activities. Each website was different, so the process for each of these regions varied slightly, as described below.

Upper Colorado – Clicked “Alphabetical Listings”

Pacific Northwest – Navigated to “Site Map” and then to “A-Z Listing”

Lower Colorado – Navigated to “Site Index”

Mid-Pacific Region – Navigated to “Environmental Documents”

- Clicked on each region on interactive map to get activities

Great Plains – Could not find individual projects presented in a manner consistent with those presented from the other regions.

The activities initially collected from USBR are shown by location found below.

From “Water and Power” tab

- Navigated to “Projects” – 186 sites
- Navigated to “Powerplants” – 58 sites
- Navigated to “Dams” – 335 sites

Upper Colorado – 237 activities available

Pacific Northwest – 193 activities available

Lower Colorado – 186 activities or links available

Mid-Pacific Region

- CCAO – 58 activities
- KBAO – 19 activities
- LBAO – 30 activities
- NCAO – 56 activities
- SCCAO – 201 activities

Great Plains – 0 activities found

After collecting activities from so many pages in the USBR website, the reports were totaled and sorted, as shown below.

1,559 activities reports and sites

471 activities in-scope and included in database

1,028 activities and sites not-in scope and documented

60 activities were repetitive between searches

2.1.2.9 United States Fish and Wildlife Services (USFWS)

The mission statement for USFWS is as follows.

“Work with others to conserve, protect and enhance fish, wildlife and plants and their habitats for the continuing benefit of the American people.

We are a bureau within the Department of the Interior. Our Objectives:

- 1. Assist in the development and application of an environmental stewardship ethic for our society, based on ecological principles, scientific knowledge of fish and wildlife, and a sense of moral responsibility.*
- 2. Guide the conservation, development, and management of the Nation's fish and wildlife resources.*

3. *Administer a national program to provide the public opportunities to understand, appreciate, and wisely use fish and wildlife resources.*

Functions. Here are a few of the ways we try to meet our mission:

- *Enforce federal wildlife laws,*
- *Protect endangered species,*
- *Manage migratory birds,*
- *Restore nationally significant fisheries,*
- *Conserve and restore wildlife habitat such as wetlands,*
- *Help foreign governments with their international conservation efforts, and*
- *Distribute hundreds of millions of dollars, through our Wildlife Sport Fish and Restoration program, in excise taxes on fishing and hunting equipment to State fish and wildlife agencies” (USFWS, 2016).*

The authors searched the internet for the USFWS home page (USFWS, 2018). From there, the “Library” tab was selected. The filters “USFWS Only” as well as “English” were applied to retain only the publications from USFWS that were useful. The initial search results still led to an extensive number of activities, as shown below.

Hydropower – 4,854 activities

Renewable Energy –20,275 activities

Hydroelectric Power Plant – 938 activities

Hydroelectric Power – 2,167 activities

Energy Storage – 21,972 activities

Licensing – 18,652 activities

Distributed Energy Resources – 19,765 activities

The total number of activities to come up in the searches was 88,623. Due to time and budget constraints, it was not feasible for the authors to search through every activity.

3,500 activities searched

419 activities included in the database

2.1.2.10 United States Geological Survey (USGS)

The mission statement for USGS is as follows.

“The USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.

USGS is a world leader in the natural sciences through our scientific excellence and responsiveness to society's needs.

As the Nation's largest water, earth, and biological science and civilian mapping agency, USGS collects, monitors, analyzes, and provides science about natural resource conditions, issues, and problems. Our diverse expertise enables us to carry out large-scale, multidisciplinary investigations and provide impartial scientific information to resource managers, planners, and other customers” (USGS, 2018a).

The authors searched the internet for the USGS homepage (USGS, 2018b). From there they went to “Products” and then “Publications Warehouse.” A keywords search provided the activities listed below.

Hydropower – 152 activities
Renewable Energy – 75 activities
Hydroelectric Power Plant – 24 activities
Hydroelectric Power – 126 activities
Energy Storage – 241 activities
Licensing – 125 activities

After each search, a list of activities was downloaded directly from the USGS site into a CSV file. The files were compiled into one document and sorted line by line. The information needed was then recorded in the database, the results of which are listed below.

798 activities total
151 activities included in database
596 activities did not fit in scope and were recorded
51 activities repetitive between searches

2.1.2.11 Water Power Technologies Office (WPTO)

The mission statement for WPTO is as follows.

“The U.S. Department of Energy's Water Power Technologies Office (WPTO) is advancing cutting-edge technology to modernize the U.S. hydropower fleet and drive U.S. leadership in new ocean and river energy, with the goal of delivering low-cost power and resiliency to the nation's power grids.” (EERE, 2017)

An internet search was not conducted for the WPTO activities. Instead, projects were taken from a spreadsheet, HydroWISE_ProjectInformation_r6_ORNLUpdates.docx Excel Document, and put into the database.

The activities on the spreadsheet were examined like those from other sources. The results of this process are shown below.

29 activities in total
29 activities included in database

Additional activities were included from publications lists from WPW, FY17Publications_r1.docx and FY18 EWRSPublications.docx.

54 activities in total
49 activities in scope and included in the database
5 activities did not fit the scope and were documented

Additional activities were added by other labs as they reviewed the database. These activities were WPTO activities that the reviewers were aware of at their respective labs that had not been included in the preceding sources.

19 activities in total
19 activities included in database

Additionally, the authors were made aware of an excellent source in the form of a literature review and decided to incorporate the included references into the database. The report describes itself in the first paragraph of the introduction as follows.

The following document represents the results of an extensive literature review investigating the development and application of valuation techniques in the power sector. A total of 137 documents were studied with a purpose to document best practices in the power industry and understand the state of the art for not only valuation techniques but also assessing the value streams which comprise the overall valuation of the service provided. The review had a cross-cutting approach with a focus ranging from 1) Energy Storage Technologies, 2) Conventional Hydropower, 3) Utility Scale and Distributed Solar, 4) Other Distributed Energy Technologies, and 5) Other Generation Technologies. Despite the wide breadth of technologies studied, the primary intent of this work is to support a Department of Energy (DOE) effort to develop and apply a valuation methodology and guidance applicable to pumped storage hydropower plants. This is considered of particular importance given the dynamics and trends of the domestic and international grid, which are shifting from a more predictable and centralized generation to a larger share of variable and distributed generation (Christian, 2018).

The authors included activities from both the reference section and review summary appendix. The results of this inclusion are as follows.

253 activities in total
68 activities included in the database
145 activities not in scope and documented
40 activities already in database

2.2 DATABASE STRUCTURE

The following items comprise the structure of the database and are provided, where available, for each of the project reports.

Report Identifier (Report_ID) – This identifier will be composed of the source organization’s acronym as well as a number to make it unique. In the database structure, it will be used to link projects across tables.

Report Title – The title of the report that is being classified. This, along with the abstract, when available, were used to tag the reports.

Abstract – The abstract or overview presented in the report. It gives a general description of the project and results. This, along with the report title, will be used to tag the reports.

Functional Tag Structure Code (Func-Code) – The number associated with the functional tag structure that the project primarily fits within. This code is assigned to the report based on the report title, abstract, and the definition of the tags.

Functional Tag Structure Tag (Functional Tag) – The tag associated with the functional tag structure that the project primarily fits within.

Functional Tag Structure Assumptions (Functional Assumptions) – Any assumptions made while the projects were being assigned to the functional tag structure.

Vision Roadmap Tag Structure Code (VRM-Code) – The number associated with the Vision Roadmap tag structure that the project primarily fits within. This code is assigned to the report based on the report title, abstract, and the definition of the tags.

Vision Roadmap Tag Structure Tag (Vision RM Tag) – The tag associated with the Vision Roadmap tag structure that the project primarily fits within.

Vision Roadmap Tag Structure Assumptions (Vision RM-Assumptions) – Any assumptions made while the projects were being assigned to the Vision Roadmap tag structure.

Publication Date – The date the report was published. In some cases, this date marks the completion of a major milestone in the overall project.

Status – The current activity level of the project. The status of a project can be “Completed”, which means all effort has stopped or that the report is a final report. The project has reached its original goals. “Ongoing at time of publication” means that the report is a status update or a report on a major milestone but that the major effort has not been completed. “Interim” is used specifically when the source organization used the term interim report to describe the type of document presented. These projects have not yet met their final objectives. “Terminated” means that the project was initially started but that the final goal was never realized for a variety of reasons.

Methods – The methods section describes the tools or processes that were used throughout the project. When available this description will be copied and pasted directly from the document. While the abstract is generally an overview of the entire project, this is a specific description of the inner workings of the project at a more detailed level.

Report Website – The website associated with the specific activity. This is where the information from the report is found and, if available, where the report can be downloaded from.

Date Accessed – The most recent date that the report website was accessed.

Report Number – The number associated with the report on the report website.

Citation – The citation as given by the organization executing the study.

2.3 DATABASE CATALOGING

Each report obtained from a source site and entered into the database was subsequently placed in various categories of the Vision RM and Functional catalog structure. A description of the process used to catalog, or tag, the reports, as well as an overview of each tagging structure, is provided in the following sections.

2.3.1 Tagging Process

The tagging process is defined as cataloging each of the research reports into categories of the Functional and Vision groups. A systematic way is used to maximize consistent report evaluations within each of the two Functional and Vision groups. There are seven and five coarse-level categories for the Functional and Vision structures, respectively. For the Functional group, there are secondary-level categories for five of the seven categories. For the Vision group, there are secondary- and tertiary-level categories for all five high-level categories. This results in 20 and 64 category levels for the Functional and Vision structures, respectively.

All coarse-level categories for both the Functional and Vision groups were first tagged. Then, for the Vision and Functional groups, items that were tagged with the same coarse-level category were grouped and isolated so that they could be tagged with secondary-level categories. This approach helped ensure a more consistent assessment of items since they were grouped in the same category. For the Vision group, this approach was repeated for the tertiary level, but at this level, it proved helpful to assess secondary-level category placement based on tertiary-level categories since this level provides a detailed description of the category. At this point, items were placed in their respective finest level.

Each of the research report items contains at least a title and was used to help catalog and tag the categories. Many times, an abstract was used to filter important keywords that could help in tagging a report to a particular category. Most times it was important to read and reread the abstract to fully comprehend the nature and intent of the research since tagging based on a keyword could sometimes be misleading with respect to the appropriate category. For example, it may not be appropriate to tag research associated with keywords such as “climate” with Vision category 2.1 (Increase Hydropower’s Resilience to Climate Change). It may be more appropriate to categorize it with Vision category 4.3 (An Analysis of Policy Impact Scenario).

2.3.2 Vision Roadmap Tag Structure

The Vision RM tag structure was developed in the Hydropower Vision report and taken directly from Chapter 4, “The Hydropower Vision Roadmap: A Pathway Forward.” This chapter identifies specific actions that the hydropower industry must take to move forward. These actions can be used as a metric against which the projects in the database can be compared, and this comparison will allow the gap analysis to be conducted.

2.3.2.1 Description of Vision Roadmap Coarse-Level Tags

The following definitions of the high-level tags are taken directly from the executive summary of the Hydropower Vision document (US Department of Energy, 2016). These definitions were used to tag each project within the correct category.

1. ***Technology Advancement*** to advance development of innovative technologies and system design concepts needed to reduce costs and improve both power production efficiencies and environmental performance
2. ***Sustainable Development and Operation*** to further integrated approaches that incorporate the principles, metrics, and methodologies required to balance environmental, social, and economic factors
3. ***Enhanced Revenue and Market Structures*** that appropriately compensate and incentivize new and existing hydropower, given the numerous energy production and grid support services it provides
4. ***Regulatory Process Optimization*** by increasing access to shared data, making information on relevant scientific advances available, and furthering other means of enhancing process efficiency and reducing risks and costs
5. ***Enhanced Collaboration, Education, and Outreach*** including dissemination of best practices for maintaining, operating, and constructing facilities; and developing curricula for vocational and university programs to train new hydropower professionals.

2.3.2.2 Vision Roadmap Tagging Assumptions

Tagging of the Vision RM group is based on the following assumptions for each of the seven categories provided below.

1.0 Technology Advancement: *Research or activities focused on the following.*

- Any new or alternative application of hydropower or energy storage systems is tagged in category 1.1 (*Develop Next-Generation Hydropower Technologies*). This would include Pumped Storage Hydropower (PSH) technologies, Standard Modular Hydropower (SMH), new material such as turbine blade coatings, and new manufacturing or construction techniques and would be tagged to the most appropriate tertiary category. Some issues related to dam safety are included here.
- Any biological (fish), chemical (mercury, etc.), naturally occurring or weather-related (icing, some erosion mechanisms, temperature) event in which the environment, the hydropower facility structure, and/or equipment are the main subjects and driving factors in the research is tagged to category 1.2 (*Enhance Environmental Performance of New and Existing Hydropower Technologies*). This would include fish-friendly turbines, assessment of trash racks, and effects related to the specific hydropower improvements/changes based on new technology and would be tagged to the most appropriate tertiary category.
- Any assessment, studies, methods, or evaluation performed to determine the feasibility, compliance, and optimal operation that has been tested in industry is tagged to the most appropriate tertiary category within category 1.3 (*Validate Performance and Reliability of New Hydropower Technologies*). Some issues related to dam safety are included here.
- The roles of hydropower in conjunction with other renewable energies, such as with wind, solar, energy storage systems, etc., are tagged within the appropriate tertiary categories under category 1.4 (*Ensure Hydropower Technology Can Support Increased Use of Variable Renewable Generation Resources*).

2.0 Sustainable Development and Operation: *Research or activities focused on the following.*

- An assessment or studies whose main objective is to investigate the role of climate change on future demands, expectations, and planning with respect to future conditions are tagged within the appropriate tertiary categories under category 2.1 (*Increase Hydropower's Resilience to Climate Change*).
- The coordination, use, scheduling, and dispatching of hydropower are tagged within the appropriate tertiary categories under category 2.2 (*Improve Coordination among Hydropower Stakeholders*). This category contains projects related to hydropower system operation, water use, and coordination and cases where previous performance and lessons learned can be shared. In some cases, especially in Resource activities, the research may be strictly scientific and not directly applied or related to hydropower, reservoir, and/or water management issues. In these instances, the decision to include them in the database was made based on the potential of the scientific research to be applicable to hydropower, reservoir, and/or water management.
- Planning and use of water as a resource, potential hydropower use, land management issues surrounding reservoirs, and some items related to dam safety are tagged within the appropriate tertiary categories under category 2.3 (*Improve Integration of Water Use within Basins and Watersheds*).

- Any biological (fish), chemical (mercury, etc.), naturally occurring or weather-related (icing, some erosion mechanisms, temperature) event in which the environment and the operation of a hydropower facility are the main subjects and driving factors in the research is tagged to category 2.4 (*Evaluate Environmental Sustainability of New Hydropower Facilities*). This would include effects related to the water release strategies, stream restoration, methods used to improve site characteristics in the vicinity of hydropower facilities to improve environmental capability, etc., and are tagged to the most appropriate tertiary category. Emphasis is placed on including activities that state or imply an involvement with hydropower. For example, there are several activities related to fish populations and preservation; however, unless the activity is related to hydropower or dam structure involvement with the population or preservation, it is not included in the database.
- Dam safety, such as geologic issues, loadings on structures that could compromise safety, etc.

3.0 Enhanced Revenue and Market Structures: *Research or activities focused on the following.*

- Issues related to the value and cost of hydropower and the effect of its ancillary services on the market and the role of integration of renewables and energy storage concepts and effects of power delivery, etc., are tagged within the appropriate tertiary categories under category 3.1 (*Improve Valuation and Compensation of Hydropower in Electricity Markets*).
- Issues related to the value and use of pump storage hydropower and its effect on the power delivery, etc., are tagged within the appropriate tertiary categories under category 3.2 (*Improve Valuation and Compensation of PSH in Electricity Markets*).
- Issue related to educating and improving the system of financing hydropower projects are tagged within the appropriate tertiary categories under category 3.3 (*Remove Barriers to the Financing of Hydropower Projects*).
- Methods and analyses for better understanding the role of renewable technologies and bulk storage concepts in the markets are tagged within the appropriate tertiary categories under category 3.4 (*Improve Understanding of and Eligibility/Participation in Renewable and Clean Energy Markets*).

4.0 Regulatory Process Optimization: *Research or activities focused on the following.*

- Methods and case experiences that may improve understanding of the legal and regulatory processes for successful licensing and regulation of hydropower are tagged within the appropriate tertiary categories under category 4.1 (*Provide Insights into Achieving Improved Regulatory Outcomes*).
- Collaboration and use of methods for improved regulatory process are tagged within the appropriate tertiary categories under category 4.2 (*Accelerate Stakeholder Access to New Science and Innovation for Achieving Regulatory Objectives*).
- Studies, methods, or tools used to investigate different cases for policy effects are tagged within the appropriate tertiary categories under category 4.3 (*Analyze Policy Impact Scenarios*).
- Reports and cases that provide guidance for better understanding the regulatory process are tagged within the appropriate tertiary categories under category 4.4 (*Enhance Stakeholder Engagement and Understanding within the Regulatory Domain*).

5.0 Enhanced Collaboration, Education, and Outreach: *Research or activities focused on the following.*

- Publications or workshops used to communicate aspects of hydropower are tagged within the appropriate tertiary categories under category 5.1 (*Improve Valuation and Compensation of PSH in Electricity Markets*).
- Cases and documentation of hydropower-related studies with the intention of sharing and disseminating the results and lessons learned with others are tagged within the appropriate tertiary categories under category 5.2 [*Compile, Disseminate, and Implement Best Practices and Benchmarking in Operations and Research and Development (R&D)*].
- Procedures, guidance, and training for operators and hydropower personnel are tagged within the appropriate tertiary categories under category 5.3 (*Develop and Promote Professional and Trade-Level Training and Education Programs*).
- Data made available from federal reports are tagged under category 5.4 (*Leverage Existing Research and Analysis of the Federal Fleet in Investment Decisions*).
- Any case for which the Hydropower Vision RM can be updated is tagged under category 5.5 (*Maintain the Roadmap in Order to Achieve the Objective of the Hydropower Vision*).

2.3.3 Functional Tagging Structure

The Functional Tagging Structure was developed by Brennan Smith, ORNL Program Manager. In developing this structure, he reviewed the work of other subject matter experts in the hydropower field and analyzed projects from the perspective of users from industry in an effort to expand the project to a broad audience.

2.3.3.1 Description of Functional Coarse-Level Tags

The coarse-level functional tags are divided into broad groups that encompass the main facets of the hydropower and energy industry. They are based on a professional practitioner's view of the industry and structured with respect to categorical components of interest, such as policy, system management, science, technology, and operations. The seven specific functional categories and their respective definitions are as follows.

1. **Policy** is associated with the legal and governing regulations imposed on the hydropower and energy industry markets with respect to complying with energy and environmental issues.
2. **Water and Power System Management** incorporates the planning of hydropower facility needs, prediction of hydrological inputs and energy demands, and the appropriate selection and use of hydropower resources for hydropower generation.
3. **Environmental Science** entails all chemical, biological, and physical aspects of the natural world and their interaction with hydropower and energy facilities, operations, and planning.
4. **Civil Design and Technology** entails all aspects of a hydropower facility with a focus on the static facility and its function to safely pass water. Technological and safety-related aspects of design, construction, and installation of the facility in addition to its water passage function are included.

5. ***Powerhouse and Electro-Mechanical Design and Technology*** entails all aspects of the dynamic equipment used in the energy transfer of water to plant-side power. Aspects of design and technology as well as monitoring and control of equipment are included.
6. ***Electrical Design and Technology*** entails all aspects of the equipment and functions used in the energy transfer and delivery of the power on the wire-side of the system, i.e., delivery of power from the hydropower facility.
7. ***Hydropower Operations and Maintenance*** entails the functions carried out by the hydropower facility to generate electricity and safely control water passage through flood control structures as well as the activities performed to maintain a safe and reliable facility.

2.3.3.2 Functional Tagging Assumptions

Tagging of the Functional group is based on the following assumptions for each of the seven categories.

1.0 Policy: *Research or activities focused on the following.*

- Any subject that affects or requires legal involvement or governing body oversight is tagged to category 1.2 (*Energy Regulation*) or 1.3 (*Environmental Regulation*). Studies to develop or perform a resource assessment are tagged to category 1.4 (*Resource Assessment*).
- Costs and issues surrounding hydropower, group performance, or grid use are tagged to category 1.1 (*Hydropower Economic Analysis, Grid Integration, and Fleet Intelligence*).

2.0 Water and Power System Management: *Research or activities focused on the following.*

- Any type of water or land resources application, such as potentially new hydropower or assessment of future water or power use or any indication of the need to plan or assess the future, is tagged in category 2.1 (*Planning*).
- The assessment or prediction of future demand is tagged in category 2.2 (*Forecasting*).
- The application of hydropower generation, optimization of units, etc., is tagged in category 2.3 (*Dispatch*).
- In general, most of the hydrologically (as opposed to hydraulically) related items are tagged herein since most hydraulic items are related to either fish, sediment study, or physical modeling and are tagged in either categories 3.0 or 4.0.

3.0 Environmental Science: *Research or activities focused on the following.*

- Any biological (fish), chemical (mercury, etc.), naturally occurring or weather-related (icing, some erosion mechanisms, temperature) event in which the environment was the main subject and driving factor in the research is appropriately tagged to category 3.1 (*Environmental Assessment*), e.g., review, field studies, modeling, and qualitative cases; category 3.2 (*Environmental Monitoring and Compliance*), e.g., policy-related performance monitoring or measurement, specific field studies that focus on measurement or quantitative assessments as opposed to qualitative; or category 3.3 (*Environmental Technology*), e.g., equipment such as turbines, trash racks effect on fish or methods of stream restoration or adjustment for environmental compatibility.

4.0 Civil Design and Technology: *Research or activities focused on the following.*

- Anything related to the physical aspects of the hydropower plant itself with respect to design, construction, and installation methods is tagged to categories 4.1 (*Facility Design*) and 4.2 (*Construction and Installation*).
- Hydraulic structures such as trash racks, spillways, etc., in which the focus is not on the environment and include field and model studies that are hydraulically focused are tagged category 4.3 (*Hydraulic Structures Design and Technology*).
- All safety, earthquake, or foundation issues related to dams are tagged to categories 4.4 (*Dam Safety*) or 4.5 (*Geotechnical*).

5.0 Powerhouse and Electro-Mechanical Design and Technology: *Research or activities focused on the following.*

- All turbine-related research (including fish friendly/environmental) is tagged to category 5.1 (*Turbomachinery Design and Technology*).
- All supporting and auxiliary power plant systems used to deliver power (not generation) is tagged to category 5.2 (*Balance-of-Plant*).
- Items related to quantitative measurements and control of power generation equipment are tagged category 5.3 (*Instrumentation, Control, and Monitoring Design and Technology*).

6.0 Electrical Design and Technology: *Research or activities focused on the following.*

- All items related to power related issues and equipment used in the system pertaining to post-generation.

7.0 Hydropower Operation and Maintenance: *Research or activities focused on the following.*

- Anything related to inspections, maintenance, retrofitting, hydropower operation education/guidance (operator control), etc.
- Hydropower operations relationship to hydraulic transients, water hammer, etc., that may damage or require maintenance or replacement (or prevention thereof) of equipment and hydropower infrastructure.
- Special methods and products such as lubrication, etc., that improve reliability and maintenance cost, activity, and concern.

3. RESULTS

While the Vision Roadmap Reference database is not comprehensive for all existing research in Hydropower, it does provide an overview of information that was publicly available and is a useful resource. To provide brief overview assessment of the types of information discovered, mosaic plots were created. Mosaic plots show fractions or percentages on two axes. In this case, the horizontal axis

represents the total number of activities. Each column width shows the fraction that one organization contributes to the whole. For example, in Figure 1 CEATI has about a tenth of the activities and hence is shown as a column a tenth as wide as the chart. For the vertical axis, let us consider one column at a time. The data represented here is the percentage of the activities that belongs to a category. The colors divided into the 5 topical areas: Technology Advancement, Enhanced Revenue & Market Structures, Sustainable Development & Operation, Regulatory Process Optimization and Enhanced Collaboration, Education, & Outreach. For example, more than half of the projects in CEATI are in the Technology Advancement category represented by the red color in Figure 1. It is worth noting here that the Vision Plots include more organizations because the Functional tags were deemed secondary in effort after the first database inclusion search, and hence were only assigned for the first few organizations. To understand a further depth the amount of documented progress within the 64 actions items, a mosaic plot of the Vision Roadmap 64 action items is shown in Figure 2. The fine level still associates the 5 topical areas by color. In, Figure 3, the major functional areas (Policy, Water and Power System Management, Environmental Science, Civil Design and Technology, Powerhouse and Electro-Mechanical Design and Technology, Electrical Design and Technology and Hydropower Operations and Maintenance) are represented with differing pastel colors and for further refined view we have considered the sub-functional areas in Figure 4.

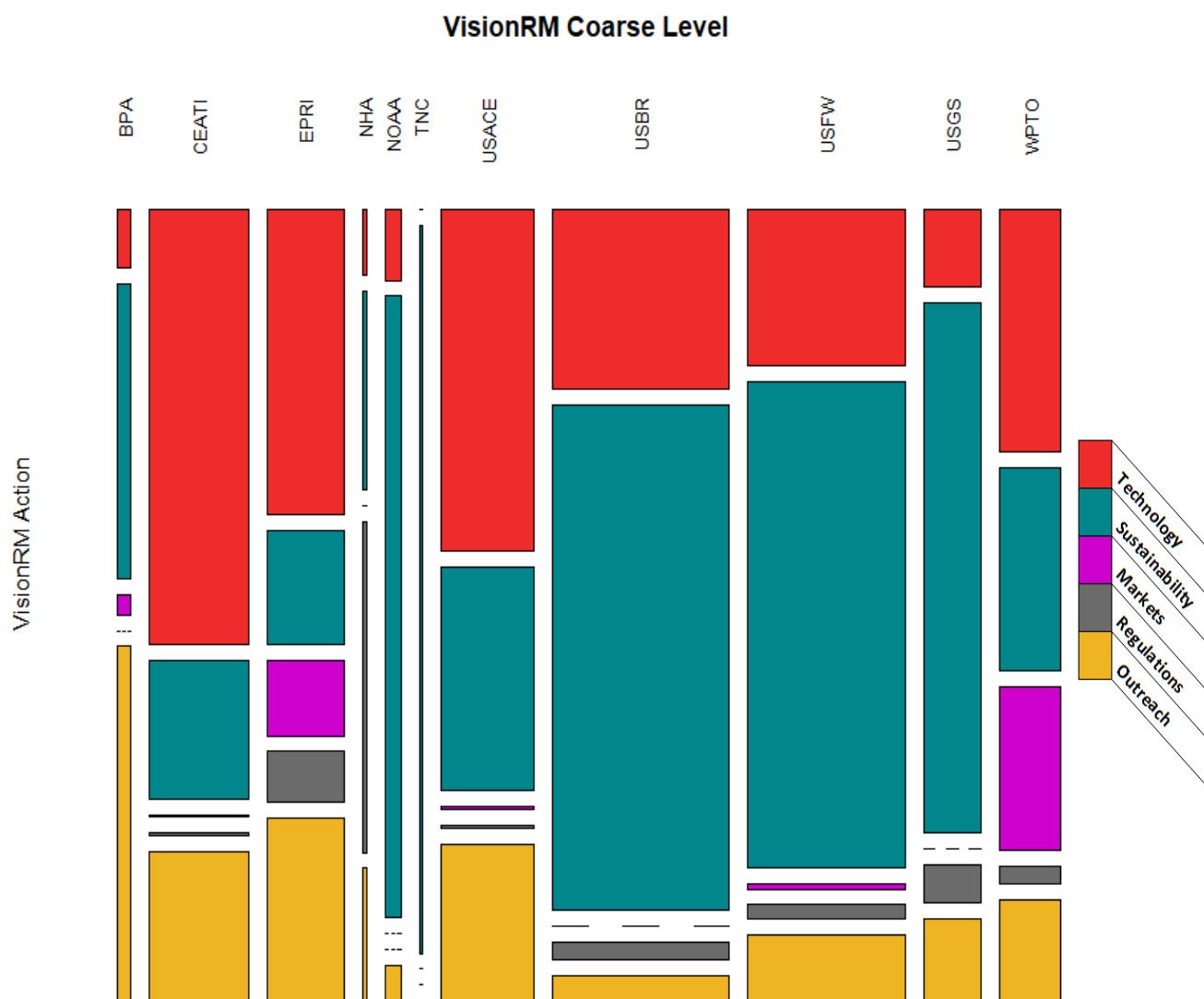


Figure 1. Mosaic plot of reports by organization and major Vision Roadmap tags.

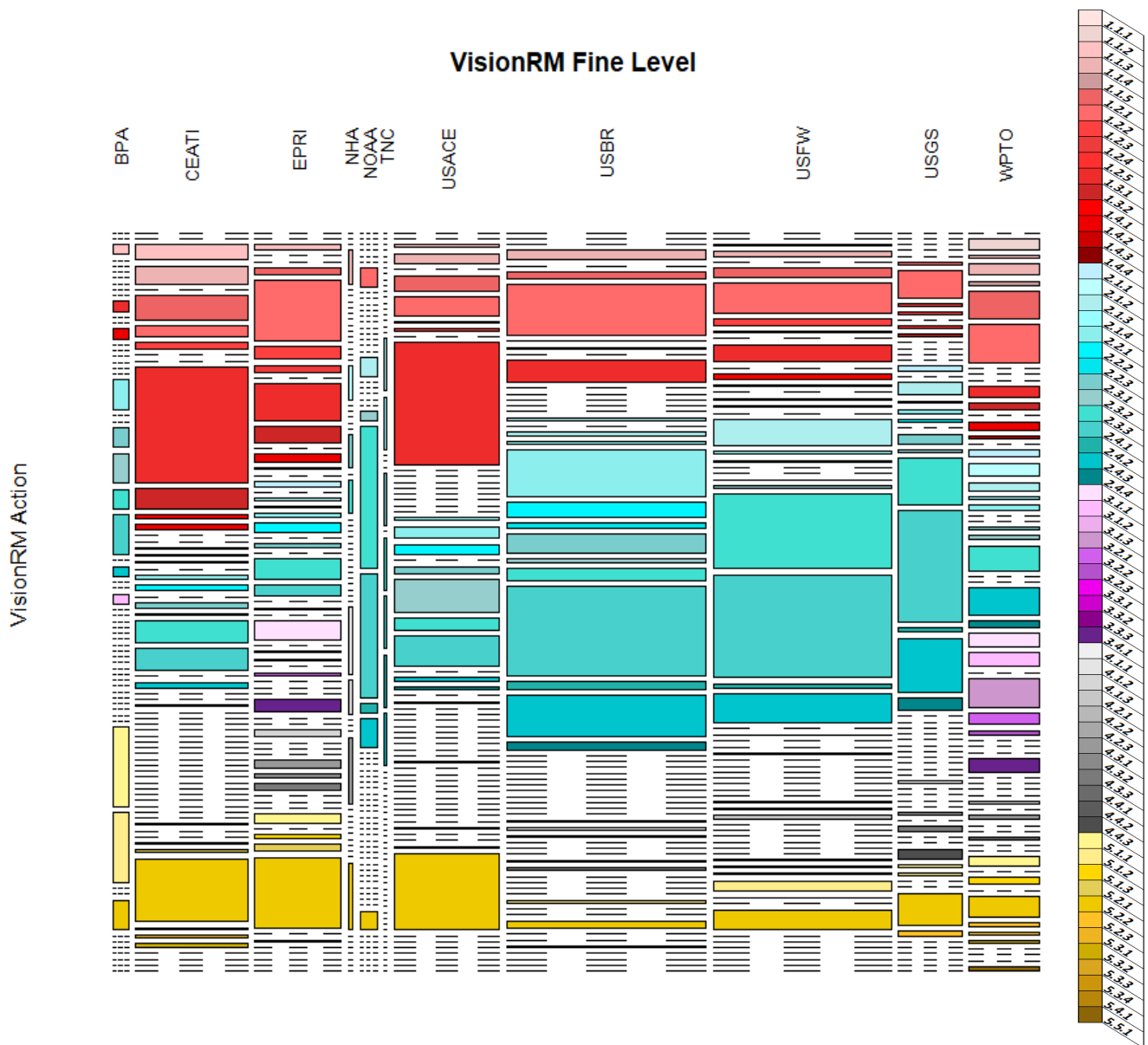


Figure 2: Mosaic plot of reports by organization and fine Vision Roadmap tags. The legend displays the tag number with its associated color.

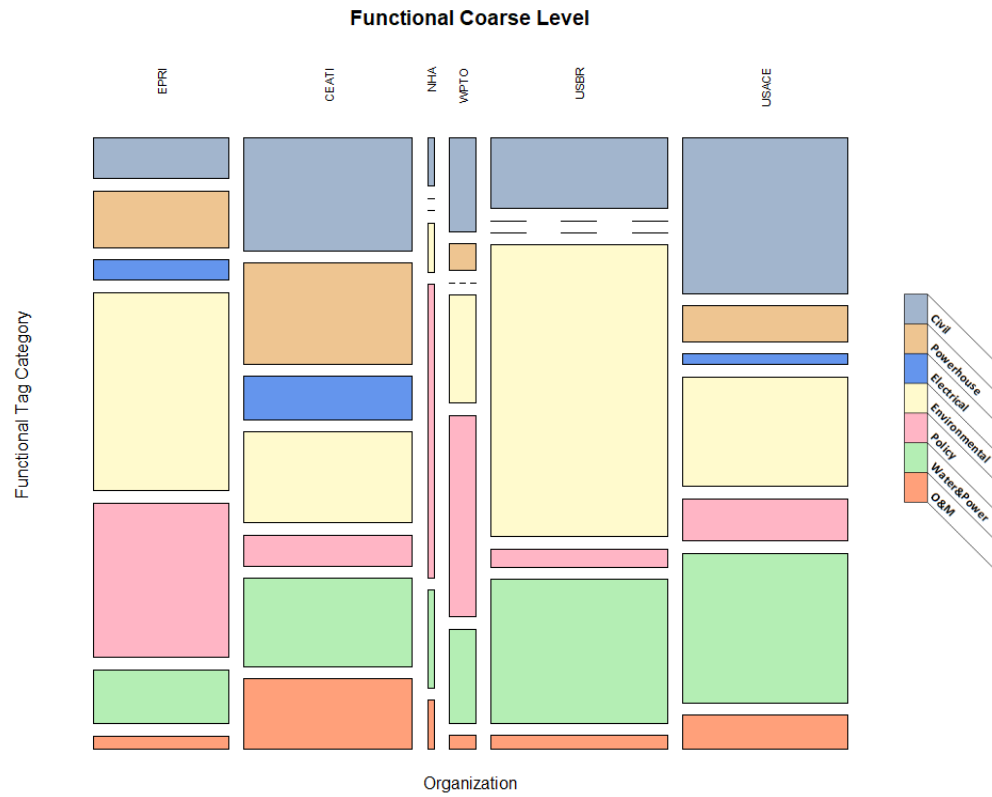


Figure 3. Mosaic plot of reports by organization and major Functional tags.

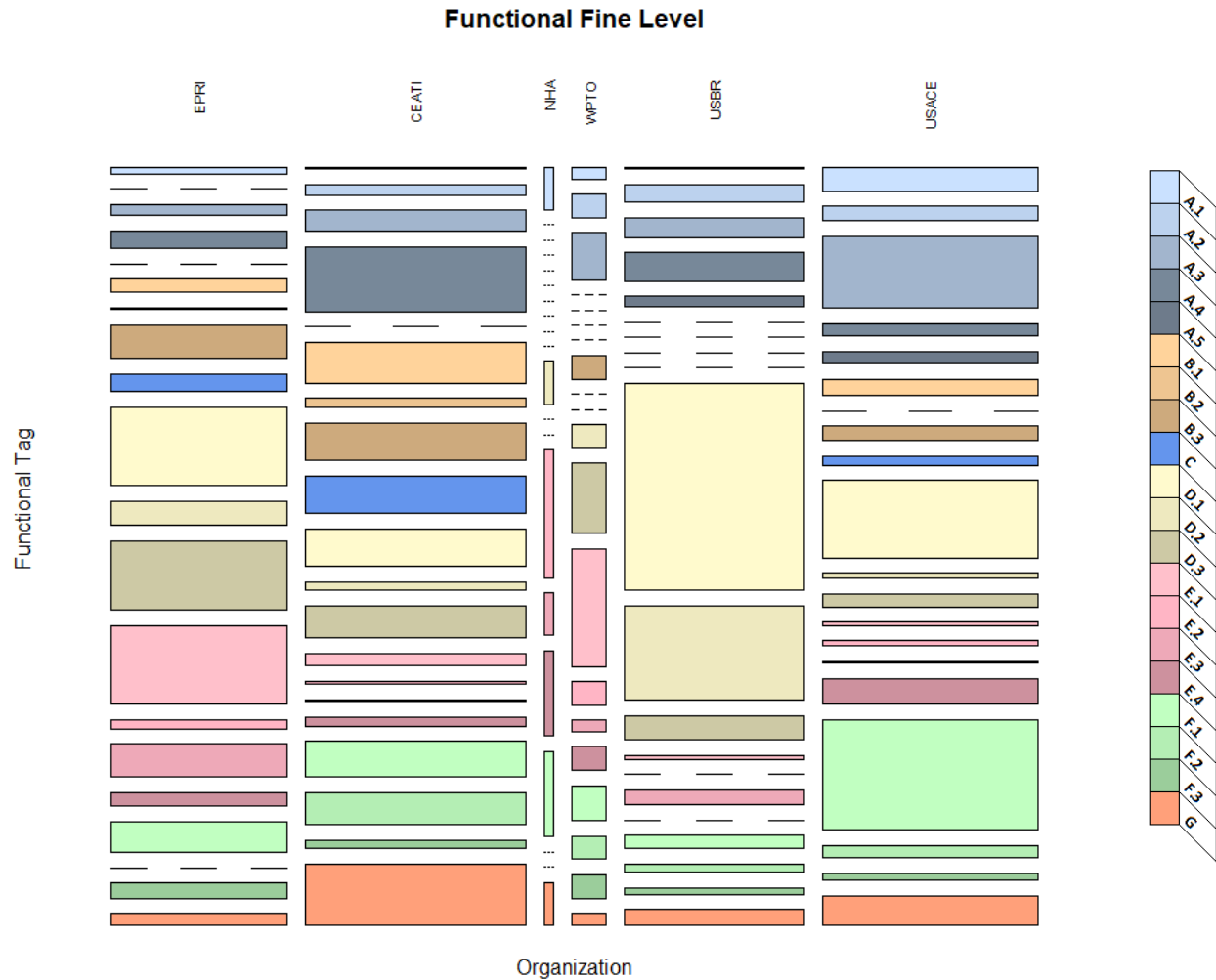


Figure 4. Mosaic plot of reports by organization and fine Functional tags. The legend displays the tag number with its associated color.

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