INL/RPT-23-75297

Light Water Reactor Sustainability Program

Plan for a Database Approach to Evaluating LWR Plant Integration with Hydrogen and Industrial Facilities

October 2023

U.S. Department of Energy

Office of Nuclear Energy

INL/RPT-23-75297

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October 2023

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Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

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EXECUTIVE SUMMARY

This report provides an outline and scope of a database tool that could be used to identify potential opportunities via feedstock supply and product demand identification and locating for the non-grid use of heat and power in the locality of existing U.S. light water reactors (LWRs) including existing and potential new installations of hydrogen production or synthetic fuels and chemicals production using CO_2 sources from the area or other industrial uses such as existing chemical and industrial facilities. In addition, this siting tool should consider factors such as economics, geography, industries, residences, geological hydrogen storage, and key infrastructure near existing U.S. LWRs to enable and non-grid use of the nuclear power. The infrastructure to be considered could include pipelines or other storage and transportation facilities to carry the created products from the production facility to the end user. Also considered should be infrastructure that could deliver needed chemicals or gasses to allow the production of desired products such as ammonia or biofuels.

Below is a list of the supply and demand feedstocks and products that will be evaluated in proximity to existing LWRs. For each feedstock supply and product demand the size for heat, hydrogen, and electricity, the type, source, location, purity, costs and modes available capture, storage and transport will be identified to the extent possible. However, this list, is not all inclusive.

- Hydrogen demand, transport and storage options, including pipelines and geological storage
- Oxygen demand for oxy-firing of existing boilers for the purpose of CO2 effluent capture and other existing O_2 markets, transport and storage options
- CO_2 feedstock for synthetic fuels production, transport and storage options (carbon capture from ethanol, ammonia, steam methane reforming (SMR), gas turbine generators, or carbon from biomass via various conversion processes, etc.).
- Jet fuel demand at local major airports including existing piping and storage infrastructure
- Methanol demand
- Major industry (oil and gas production and refining, chemicals, metals, manufacturing, pulp and paper, etc.) distance from LWR and power, heat, and hydrogen demand
- Data centers and other large flexible demand users of heat and power.

This database tool should incorporate a feedstock supply and product demand analysis surrounding each existing U.S. LWR and allow for a screening study of any U.S. nuclear plant to identify potential opportunities and challenges to creating hydrogen hubs and energy parks around nuclear power plants. For this effort, it has been decided that the Siting Tool for Advanced Nuclear Development (STAND) developed by the University of Michigan would be used as the baseline to build, integrate and visualize this data. Currently, plans are being developed to modify the STAND tool, provide the capability necessary to perform screening of each U.S. commercial nuclear plant identify the best locations to site hydrogen and integrated industry and chemical production facilities and to show the existing facilities near the LWRs which may provide advantageous opportunities for providing zero carbon products using nuclear energy. Many features of the current STAND tool will be employed to meet this objective, but additional development structure and input of infrastructure data (such as the location of pipelines, etc.) may need to be added. In addition, new analysis capabilities may need to be added so economic considerations can be understood. These development needs and plan are discussed in this report.

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ACRONYMS

AHA	all hazards analysis
ANL	Argonne National Laboratory
CAPEX	capital expenditure
CEJST	Climate and Economic Justice Screening Tool
DOE	Department of Energy
EIA	energy information administration
FCEV	fuel cell electric vehicles
FPOG	flexible plant operation and generation
GIS	Geographic Information System
HDSAM	Hydrogen Delivery Scenario Analysis Model
HFTO	Hydrogen and Fuel Cell Technology Office
HTSE	high-temperature steam electrolysis
HyDRA	Hydrogen Demand and Resource Analysis
IES	integrated energy system
IIJA	Infrastructure Investment and Jobs Act
INL	Idaho National Laboratory
LMP	locational marginal pricing
LWR	light water reactor
NPP	nuclear power plant
NRIC	National Reactor Innovation Center
O&M	operational and maintenance costs
PTC	production tax credit
R&D	research and development
SMR	steam methane reforming
STAND	Siting Tool for Advanced Nuclear Development
UI	user interface
UX	user experience
WACC	weighted average cost of capital

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Plan for a Data Base approach for Evaluating LWR Plant Integration with Hydrogen and Industrial Facilities

1. Background

Nuclear energy can be a continuous source of thermal and electrical energy with near-zero emissions. Using the existing asset base of light water reactor (LWR) power stations, there are potential opportunities for coupling nuclear plants with a wide variety of processes including hydrogen production, industry such as oil and gas production and refining, chemicals, metals, manufacturing, and large demand flexible sources such as data centers etc. to increase the sustainability of nuclear technology, while producing supporting industrial decarbonization by making products and fuels with reduced emissions.

Recent technical and economic assessments have shown that nuclear power plants (NPPs) can be profitably operated as hybrid plants that produce electricity and hydrogen. As hybrid plants, the electricity that is most often directed to the electrolysis plants can be dispatched to the grid when non-spinning reserves for peak power are needed. The ability to rapidly dispatch power between the grid and the electrolysis plants or other loads may allow the nuclear hybrid plants to support grid stability.

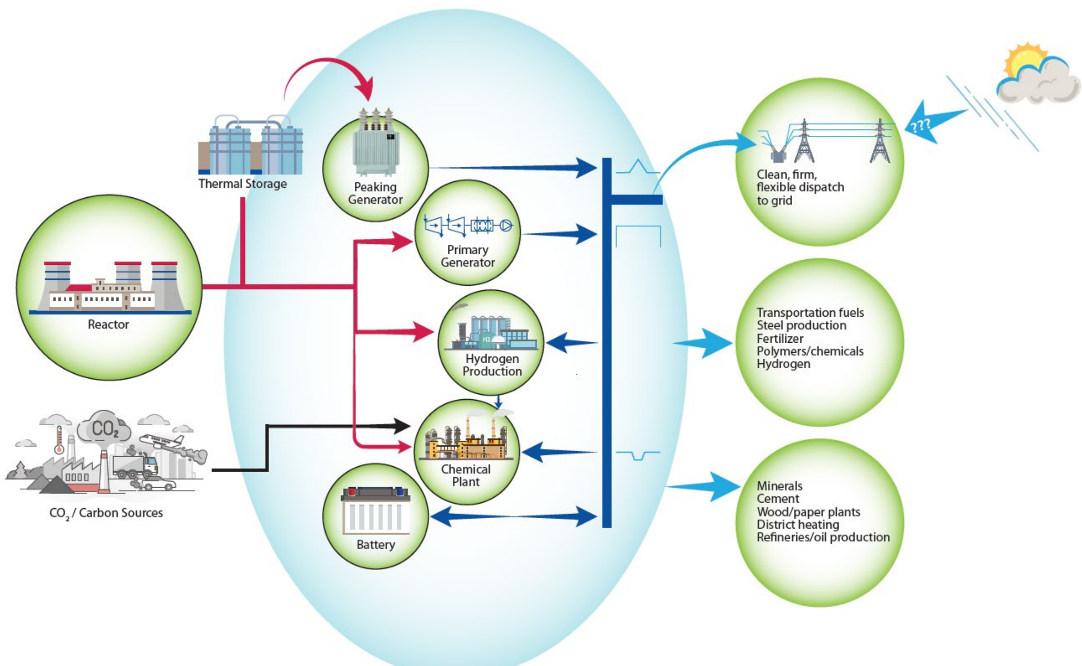

Figure 1. A new paradigm for nuclear power plants for decarbonizing industry and transportation.

Current and future hydrogen markets have largely been shown to be in the vicinity of nuclear plants, thus some nuclear plant owners and utility companies are looking to demonstrate and scale-up hydrogen production for these markets. The hydrogen produced by nuclear plants is carbon-free and can be provided to nearby refineries, ammonia fertilizer plants, iron ore reduction plants, and transportation sectors, and even combined with carbon from CO_2 to produce drop-in synthetic fuels of gasoline, diesel and jet fuel. .

Given clean hydrogen's potential to help decarbonize the chemical, fuel, transportation, and steel industries, interest in producing the same has been piqued in the U.S. The U.S. DOE has a goal to produce near-zero emissions of hydrogen at \$1/kg-H_2 by 2030, and to produce clean hydrogen, using electrolysis, for less than \$2/kg by 2025. Achieving these price targets would prompt industries to purchase clean hydrogen at a similar cost to conventional hydrogen produced by natural gas steam methane reforming with substantial carbon dioxide emissions. Additionally----PTC. Also, the bipartisan Infrastructure Investment and Jobs Act (IIJA) has appropriated approximately \$10B to help establish regional clean hydrogen hubs. DOE had recently selected the initial hydrogen hubs of which two are powered by clean nuclear power.

2. Introduction and Purpose

This report provides an outline and scope of the plan for the development needed in an existing database tool that could be used to identify potential opportunities of feedstock supply and product demand identification for the non-grid use of heat and power in the locality of existing U.S. LWRs such as new or existing hydrogen production, synthetic fuels and chemicals production using CO_2 sources from the area or integration with chemical and industrial facilities. In addition, this siting tool should consider factors such as economics, geography, industries, residences, pipelines for hydrogen, natural gas, transportation fuels (gasoline, diesel, jet), geological hydrogen storage, CO_2 transportation, and key infrastructure. The infrastructure to be considered could include pipelines or other storage and transportation facilities to carry the created products from the production facility to the end user. Also considered should be infrastructure that could deliver needed chemicals or gasses to allow the production of desired products such as ammonia, synthetic fuels and chemicals, or biofuels.

This database tool should allow a screening study of all U.S. nuclear plants to identify opportunities and barriers to creating hydrogen hubs around NPPs. It should also incorporate local and regional biomass carbon feedstocks data using the DOE Biomass Program Feedstock logistic and cost model.

For this effort, it has been decided that the Siting Tool for Advanced Nuclear Development (STAND) would be used to conduct this screening study which is a follow-on research project to this present effort. The STAND tool was developed as a National Reactor Innovation Center (NRIC) funded collaboration between Idaho National Laboratory (INL), Argonne National Laboratory (ANL), Oak Ridge National Laboratory, and the University of Michigan. The STAND tool is publicly available and is managed and hosted by the University of Michigan. It has over 350 current users and is being widely utilized by industry, research institutions, governments, and academia.

The STAND tool is an integrated application used to help identify and compare possible siting locations inside the continental U.S. for advanced nuclear facilities based on factors related to socioeconomics, proximity, and safety. STAND is a tool to help answer the question of “Where?” and “Why there?” The STAND tool employs publicly available infrastructure data combined with geospatial information to allow evaluation of possible industrial siting locations based on over 87 different factors. These factors can be evaluated in any number of combinations and then displayed on GIS layers down to the county government level. Section 4 and Appendix B provides a more detailed description of the features that are currently available in STAND.

Plans are being developed to modify the STAND tool to provide the capability necessary to perform screening of each U.S. commercial LWR nuclear plant to identify the best locations to site hydrogen or chemical production facilities. Many features of the current STAND tool will be employed to meet this objective, but additional infrastructure data (such as the location of pipelines) may need to be added to allow these locations to be fully vetted. In addition, new analysis capabilities may need to be added so economic considerations can we understood. The STAND tool modifications will be performed by the University of Chicago in collaboration with INL and ANL researchers.

There are a variety of publicly available tools that should be evaluated for the contribution that they could provide to this project. Much of the information is overlapping but could provide insights into the final design of the STAND tool. A brief summary of these products is included in Appendix A.

3. Work Plan for the Database/Tool Development

The STAND tool to be modified in this project will support decision-making for complex problems, i.e., novel approaches and solutions for energy systems. The energy system is already extremely complex due to many elements and very dynamic, complex interactions between them. The energy system is also subject to many external influences such as policy changes, national and global economics, social perspectives, etc. Hence, decision-making for investment strategies in energy systems is a complicated endeavor and comprehensive decision support tools are urgently needed.

A decision support tool is a product that in itself is novel and complex since it requires the integration of multiple elements and perspectives. Therefore, a systematic approach to product development is of utmost importance to ensure that 1) the right product is built or modified, and 2) it is built or modified correctly.

The well-established systems engineering discipline offers a general pathway for systems lifecycle development that is outlined below [1]

Requirements analysis: this is the initial step of any system development where the problem is defined. In this step, the "why" is defined – why the system is needed and being developed.

The process starts with the identification of all the stakeholders, i.e., people and organizations who will be using the final product. The future users of the product have specific needs which must be clearly identified. The stakeholder needs are translated into requirements, a formal description of the objectives for the product.

Functional definition: this is where the "why" is translated into "what" – what the system being developed must do to accomplish the "why(s)".

This phase starts with translating requirements (the why) identified and analyzed in the previous phase into functions (i.e., actions, tasks) that the system must accomplish (the what). The requirements are partitioned into functional categories, or building blocks, to specify which part of the product being developed will be responsible for a certain requirement (or a set of requirements).

For example, the requirement "*Stand tool shall present locations of industrial facilities within a 100-mi radius*", and the requirement "*Stand tool shall present natural gas pipelines within a 100-mi radius*" necessitate GIS-based capabilities. Therefore, one of the functions would be for example, to "*provide GIS capabilities*".

The last step in this phase is to define relationships and interactions between the functions and how the interactions should be accomplished, for example, how the GIS map will be bringing up layers with user-requested information that is stored in the database.

Physical definition: this is where the "what" is translated into "how".

In this phase, the functional system design is translated into system physical hardware and software components, including integration of the components to comprise the entire system. In the case of the STAND tool, the physical components would only consist of software elements.

System development: the phase where the actual product is developed integrating the physical elements identified above.

Validation and Verification: the last step that confirms that:

- The right product is built (i.e., validation) by comparing the product performance against all identified requirements.
- The product is built correctly (i.e., verification) by testing performance and assuring that the product functions as expected and produces expected results (e.g., the command to show chemical facilities

results in chemical facilities shown on the map in less than one second time every time the command is placed).

It should be noted that the typical product design includes the exploration of various design options, their assessment, and the selection of the final option based on a systematic analysis of the pros and cons of each candidate. In the case of the STAND tool modification, there may not be a need for a detailed exploration of options since the requirements for the revised STAND tool have already been identified as one of the initial requirements for the project. However, the design options for the additional features being developed could still be explored to identify the most suitable one(s).

4. Description of Siting Tool for Advanced Nuclear Development (STAND) and Related Database Tools

The STAND is a web application developed by the Fastest Path to Zero team at the Nuclear Engineering and Radiological Sciences department at the University of Michigan in collaboration with NRIC, Sandia National Laboratory and Oak Ridge National Laboratory. The STAND tool is a Geographic Information System (GIS) based tool. It relies on geographic data to compare potential deployment sites and any data point already present in the tool corresponds to a particular location.

This integrated tool uses a systematic approach to identify and compare siting locations inside the continental U.S., based on user priorities, for advanced nuclear facilities. Siting locations are evaluated based on socioeconomics, proximity, and safety factors. Socioeconomic factors include social, economic, and local energy policy factors that could influence the state-wide and local acceptance of the construction and operation of an advanced nuclear reactor, or an industrial facility powered by an existing reactor. Proximity factors encompass environmental and regulatory exclusion zone criteria, and distances to infrastructures are evaluated to determine the level of support for the construction and operation of the advanced nuclear reactor or chemical industrial facility. Finally, safety factors are considered regarding regulatory guidelines for environmental and geologic safety factors, safety risks and mitigation approaches.

The three main functions of the tool are site discovery, exploration, and comparison. In site discovery, the user sets priorities by answering a series of questions and top matches are reported and ranked. In site exploration, the user can view a reference map and select locations to compare. Site comparison allows the user to rank a series of factors related to nuclear restrictions, energy price, net electricity imports, nuclear sentiment, nuclear inclusive policy, market regulation, and construction labor rate. The site comparison output shows the best and worst quantitative measures across each site for each attribute previously ranked by the user.

While the STAND tool is currently focused on advanced nuclear reactors, several aspects, and the data it is based upon could be re-employed for the analysis of the existing fleet of nuclear reactors and the related industrial facilities they would power.

The revised STAND tool to be developed will examine opportunities for the existing fleet of nuclear reactors and will benefit from a similar GIS approach. With a map, the user can easily visualize the coupling and distances between a NPP and other facilities. For the analysis, using geospatial data is critical to compute transportation costs and distances to potential markets for new products. The existing database in STAND based on publicly available and reliable data sources that can be re-used and enriched for this intention.

5. Data Fields Needed for the Modified STAND Tool

5.1 Currently Available Data Fields in the STAND Tool

The STAND tool consists of a number of independent database tools that work together to create a clear picture of the desired strategy. These tools offer an extensive range of functionalities that empower users to delve into and glean insights from data encompassing various dimensions of socioeconomic, proximity, and safety considerations. One of the prominent components within this toolkit is the Climate and Economic Justice Screening Tool (CEJST), referred to as EJ40, which is a geospatial mapping instrument designed to identify areas across the nation grappling with significant societal burdens. These burdens are systematically categorized into eight distinct domains, spanning climate change, energy, health, housing, legacy pollution, transportation, water and wastewater, and workforce development. Moreover, STAND tools furnish users with a rich repository of data, including details on construction mean annual wages by state, electric energy generators, electricity market types by state, electric retail service territories, electric substations, energy-intensive facilities, and several variables such as those associated with the food industry, manufacturing, mining, fault lines, and hazardous facilities.

The toolkit further extends its coverage to encompass diverse industrial elements, including airports, biodiesel plants, biological products manufacturing, chemical manufacturing, ethanol plants, explosive manufacturing, liquefied natural gas import terminals, lubricating oils and grease terminals, natural gas compressor stations, natural gas import/export locations, natural gas processing plants, natural gas storage facilities, nitrogenous fertilizer plants, nuclear fuel plants, oil refineries, petroleum pumping stations, pharmaceutical preparations manufacturing, phosphatic fertilizer plants, export and import terminals, storage facilities, tank farms, landslide hazard, NERC Region, net electricity imports by state, nuclear facility distribution by county, nuclear inclusive policies at the state level, nuclear research and development (R&D) activities by county, nuclear restrictions by state, nuclear sentiment by county, 100-year flood mapping, open water and wetlands analysis, and demographic insights such as population data for 2018, 2020, and 2030, along with information on protected lands, retail energy prices by state, and a comprehensive summary of retiring generators by county. Additionally, STAND tools cover aspects like safe shutdown earthquake scenarios, slope analysis, social vulnerability index, streamflow data, transmission lines, transportation insights, and utility nuclear experience categorized by county.

In summary, STAND tools present a robust and comprehensive suite of resources that enable users to explore, analyze, and derive valuable insights from an extensive array of geospatial data, socioeconomic factors, and safety-related information, offering a multifaceted perspective on various critical aspects of societal and environmental well-being.

5.2 Additional data that will be needed

Based on the flexible plant operation and generation of the existing LWR, energy is required to supply the industrial process commodity (e.g., hydrogen, methanol) when the price of producing the commodity is lower than the cost of producing the electricity. Therefore, there is a need to extend the existing STAND tool for selecting potential sites on nuclear-integrated chemical production facilities such as hydrogen production. If the tool is going to be extended to be used for the siting of nuclear-integrated hydrogen production, three categories of inputs including NPP site-specific data, finance parameters, and IES-specific parameters are required to be added.

- NPP site-specific data:
    - Locational marginal pricing (LMP) data of electricity. The STAND tool has the electricity price obtained from the electric energy generators from the Energy Information Administration (EIA). However, the electric energy generators may not be able to capture the regional electricity price at the local NPP. Therefore, there is a need for LMP electricity as the input for estimating the cost of hydrogen production.
    - NPP thermal efficiency. This value is required to estimate the thermal energy price.
    - Natural gas prices for all the locations where existing or potential NPP sites are seated. The natural gas price is used to calculate the existing cost of hydrogen produced from steam methane reforming (SMR) and compare it with the cost of nuclear-integrated hydrogen production.

- Power capacity for each existing plant and the potential advanced reactor designs. Specifically, the power required to produce hydrogen includes the electricity and thermal energy produced from NPPs.

- Finance parameters
  - Weighted average cost of capital (WACC)
  - Production tax credit (PTC)
  - Income tax rates including state and federal tax
  - Property tax and insurance rate
  - Inflation rate
  - Percentage of equity financing
  - Debt interest rate (if having debt from the bank)
  - Start-up year
  - Start-up period
  - Labor cost rates.
- Integrated Energy System specific parameters
  - High-temperature steam electrolysis (HTSE) plant life
  - HTSE stack service life
  - HTSE stack costs
  - HTSE plant operating capacity factor
  - Number of HTSE plant staff
  - Length of construction for HTSE plant
  - HTSE modular block capacity
  - Hydrogen production rate
  - Hydrogen market price
  - Hydrogen transportation piping diameter
  - Density of process and cooling water
  - HTSE process water rate
  - HTSE cooling water rate
  - HTSE stack replacement costs
  - Capital expenditure (CAPEX) including direct and indirect capital costs
  - Fixed operational and maintenance costs (O&M)
  - Variable O&M.
- Evaluation of commercial products and services
  - May need a trade study.
- Additional infrastructure
  - Hydrogen demand, and transport/storage options
  - Oxygen demand and transport/storage options
  - CO_2 sources for synthetic fuels prod and transport/storage options (carbon capture from ethanol, ammonia, SMR, gas turbine generators, etc.)
  - Jet fuel demand at local major airports
  - Methanol demand

- Pulp and paper plants distance and power/heat demand
- Geological storage potential for hydrogen/CO_2
- Pipeline capacity for hydrogen, CO_2, jet fuel to airports
- Data centers
- Location of steel plants near the reactors
- Location of ammonia plants
- Location of refineries
- Location of hydrogen underground storage
- Location of hydrogen pipelines.

In addition to all these parameters, understanding the algorithm of the current STAND tool before replicating or improving it for a new tool is vital for several reasons. First, it helps maintain accuracy and reliability by allowing a critical assessment of the original tool. This understanding enables to avoid potential errors or limitations during the replication. Second, it aids in identifying weaknesses and inefficiencies in the algorithm, providing the foundation for optimization in the new tool. Last, a profound knowledge of how the tool works is essential for troubleshooting and problem-solving. In essence, understanding the existing algorithm is the cornerstone for building and improved, and customized solution while leveraging the strength of the original tool.

6. Database Structure and Potential Modifications Needed

When embarking on the development of software requirements for data visualization and graphics, it is essential to follow a structured approach. To begin, it is crucial to define the project's objectives clearly. This involves identifying the specific problems to solve and the insights intending to be derived from the visualizations. Clarity on the project's purpose is fundamental.

Stakeholder involvement is another critical step. Identifying the key stakeholders, such as end-users, data analysts, and decision-makers, and understanding their expectations and interactions with the visualizations is vital. Their input will shape the software's requirements and functionalities.

Gathering comprehensive requirements is the foundation of the process. These requirements encompass both functional aspects (what the software should do) and non-functional aspects (performance, security, scalability, etc.). Consider factors like data sources, formats, and potential data preprocessing needs.

Selecting the right visualization tools is paramount. Choose tools and libraries that align with your project's specific requirements, data complexity, and the skill set of your development team. The software's user interface (UI) design should also be meticulously designed, adhering to user experience (UX) principles, and tailored to user needs and preferences.

To ensure the accuracy and relevance of data, the development process should include data processing components that clean, transform, and prepare data for visualization. Subsequently, you can proceed to build the visualizations that effectively convey the desired information and insights.

As part of the software quality assurance and development process, software design and test/use case identification provide a foundation for clarity and precision in the actual software development. Attention to design and test cases should be prioritized before embarking on significant development.

Loosely the requirements can be considered for this software in terms of three key areas: capability, reliability, and accessibility. This list is not meant as a final list of software requirements, but areas and examples of requirements that can be iterated with the software designers as the final design is established.

6.1 Capability

- Ability to select a NPP and observe data regarding that NPP.
- Ability to view a variety of metrics for potential IES for the selected NPP.
- Users should have the possibility to give unequal weight to the variety of metrics, allowing comparison of siting opportunities based on a specific set of priorities.
- Users should be able to select multiple NPPs for comparing multiple potential siting opportunities, using a similar bevy of metrics to evaluate potential benefits.
- The software and the databases on which the software is built should be sufficiently modular and extensible so that if future development is considered, there is no prohibitive software burden to extend the existing capabilities.
- Users should be able to download the results of the exploratory analysis in a common format such as CSV.

6.2 Reliability

- At a minimum, manual system tests need to be established to test each of the capability requirements described above.
- Preferably, automated tests covering unit tests, integration tests, and system tests should be developed and used to monitor changes to the software and assure consistent behavior.
- Data traceability adds significant reliability for users of the tool. The tool should provide methods for users to trace where data originates and how decision metrics are calculated.

6.3 Accessibility

The tools primary purpose is to provide users with a quick and informative exploration for users. For this reason, the tool should be hosted in a way that ensures broad accessibility and quick responsiveness to user input. For instance, changing inputs should provide feedback in seconds, not minutes or hours.

Visibility of information is key; data representing the IES potential of a specific NPP should be viewable graphically in addition to numerically. Comparison of relative desirability metrics should be displayed in a way that comparisons are visually straightforward.

The foundation of the tool's visualization should be in GIS format, bringing geographic and regional impacts to the front of the user experience.

Next steps – Planning for database modifications.

To proceed to the next step in this project, a detailed specification of what fields and what functions will be needed to perform the evaluations as contemplated for each of the U.S. commercial nuclear plants using the STAND tool should be prepared. This can be best achieved by a series of discussions with knowledgeable representatives of the University of Chicago to determine what functions are currently available, what data fields are lacking and the level of effort required to create a functional assessment tool for general use by industry and the laboratories. Since the hydrogen hub awards have been announced, time is of the essence to bring this capability to the users and companies that are contemplating utilizing nuclear plants to generate alternate products in addition to electricity.

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Appendix A
Analysis Tool Database

Appendix A

Analysis Tool Database

Several tools and models are available in the public domain that can be accessed and incorportated in the STAND tool as needed. Following is a brief summary of each tool:

Hydrogen Delivery Scenario Analysis Model (HDSAM) (Argonne National Laboratory)

Objectives: Provide platform for comparing the cost of alternative hydrogen delivery and refueling options. Identify cost drivers of current hydrogen delivery and refueling technologies for various market penetrations of fuel cell electric vehicles (FCEVs).

Key Attributes & Strengths: The tool is highly flexible, allowing end-users the ability to change many detailed input assumptions and to perform sensitivity analyses. HDSAM evaluates the cost of hydrogen delivery and refueling for various fuel cell vehicle market penetrations in U.S. cities with population of 50,000 or greater. The model incorporate optimization algorithms to identify least cost delivery and refueling configurations. All assumptions and calculations are transparent and key components and drivers of cost are easily identified.

Platform, Requirements & Availability: HDSAM model uses an Excel-based platform with graphical user interface (UI), and is freely available to the public from the Systems Analysis program's website: http://hydrogen.energy.gov/h2a_analysis.html

https://www.hydrogen.energy.gov/program-areas/systems-analysis/h2a-analysis

H2FAST: Hydrogen Financial Analysis Scenario Tool

The Hydrogen Financial Analysis Scenario Tool, (NREL tool) H2FAST, provides a quick and convenient in-depth financial analysis for hydrogen and nonhydrogen systems and services.

H2FAST is available as a downloadable Excel spreadsheet. The model uses a generally accepted accounting principles analysis framework and provides annual projections of income statements, cash flow statements, and balance sheets. H2FAST allows users to generate a side-by-side scenario analysis, where a base system can be tested by varying key operating or financing parameters. Detailed capital structure, taxation, and incentives are included. The model has built-in risk analysis allowing impact assessment of parameters bearing user-specified uncertainty ranges. Financial articulation is presented in graphical and tabular format for the user-specified analysis period. The model is self-documented, with embedded help functions and annotation of input parameters.

https://www.nrel.gov/hydrogen/h2fast.html

Hydrogen Demand and Resource Analysis (HyDRA) Model (National Renewable Energy Laboratory)

Objectives: To allow analysts, decision-makers, and general users to view, download, and analyze hydrogen demand, resource, and infrastructure data spatially and dynamically.

Key Attributes & Strengths: HyDRA is an application that has the look, feel, and functionality of a traditional client-based GIS application. Users are able to create their own spatial datasets and upload them into the HyDRA application to create a completely customizable and dynamic analysis tool. HyDRA contains more than 100 datasets, including resource cost and availability, hydrogen production potential, hydrogen production cost, resource consumption, hydrogen demand, infrastructure, and results from integration with other hydrogen models.

Platform, Requirements & Availability: HyDRA exchanges data between different platforms and provides a UI with customizable maps and querying and download capability. Freely available to the public from the website: http://maps.nrel.gov/hydra.

https://www.hydrogen.energy.gov/program-areas/systems-analysis/h2a-analysis

Colorado School of Mines Siting Tool

Geospatial Analytics for Energy and Resiliency Analysis

CSM develop a web-based visualization tool for simple comparisons of conventional, renewable and nuclear power options. It utilizes an application programmer interface (API) with a database for customized tools for educational, nonprofit or policy analysis uses.

All Hazards Analysis (AHA)

A methodology and tool designed for modeling function, commodity, and service flows of interconnected systems. Developed by Idaho National Laboratory (INL), AHA identifies dependencies and associated risks, giving decision-makers and emergency managers a comprehensive view of interconnected infrastructure systems. The tool facilitates scalable and repeatable assessments of system behaviors suitable for vulnerability, consequence, and risk analysis. It is optimized for the collection, storage, analysis, and visualization of critical infrastructure information and provides the ability to model infrastructure systems as linked multilayer networks. https://inl.gov/ics-aha/

EJScreen: Environmental Justice Screening and Mapping Tool

https://www.epa.gov/ejscreen

DOE H_2 Matchmaker Tool

H_2 Matchmaker is an online information resource intended to help foster partnerships by increasing awareness and aligning potential needs in specific regions of the U.S. H_2 Matchmaker includes an interactive map containing self-reported clean hydrogen producers, hydrogen consumers, infrastructure provider/operators, and other key stakeholders (e.g., government, Tribal, labor, workforce development, safety codes and standards, financier/investor, environmental justice organizations), as well as contact information and core H2Hub related capabilities of DOE’s National Laboratories. Participation by underrepresented groups and workforce organizations, including labor unions, is highly encouraged. H_2 Matchmaker includes a Justice40 status designation to indicate participants that may be relevant to the Justice40 Initiative's intent to increase benefits and reduce harm. H_2 Matchmaker will be regularly updated to reflect new teaming partners who provide their organization’s information. Any organization that would like to be included in H_2 Matchmaker is encouraged to fill out the H_2 Matchmaker Self-Identification form available at https://www.energy.gov/eere/fuelcells/h2-matchmaker.

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Appendix B

Web Application Tool

Appendix B

STAND Tool

Web Applications

There are currently 4 web applications either complete or in development. Each of these applications provides data and information to aid in the siting of advanced reactors.

1. ANSL (Advanced Nuclear Site Locator) Completed Fall 2020
2. PLANET (Public and Local Attitudes about Nuclear Energy Technology) Completed Spring 2021
3. STAND (Siting Tool for Advanced Nuclear Development) Completed Fall 2021
4. PEANuT (Perspectives on the Export of Advance Nuclear Technology) Currently in Beta
5. Community Focused Tool (Currently Unnamed) Planned Beta Version Fall 2023

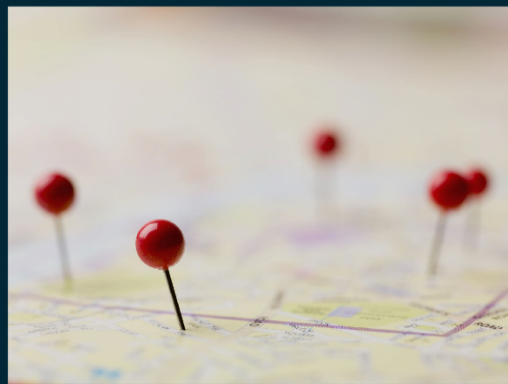
Tool Access

https://fptz.org/

Siting Tool for Advanced Nuclear Development - STAND

What is it?:

- An integrated tool used to help identify and compare possible siting locations inside the continental U.S. for advanced nuclear facilities based on factors related to Socioeconomics, Proximity, and Safety



A tool to help answer the question of "Where?" and "Why there?"

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Siting Tool for Advanced Nuclear Development - STAND

Factors

- 3 categories of factors are considered based on user priorities and preferences

Factors	Definition
Socioeconomic	Social, economic, and local energy policy factors that could potentially influence state and local acceptance of construction and operation of the facility.
Proximity	Environmental and regulatory exclusion zone criteria, distances to infrastructure that could facilitate or support construction and operation of the facility.
Safety	Regulatory guidelines for environmental and geologic safety factors, safety risks, mitigation approaches.

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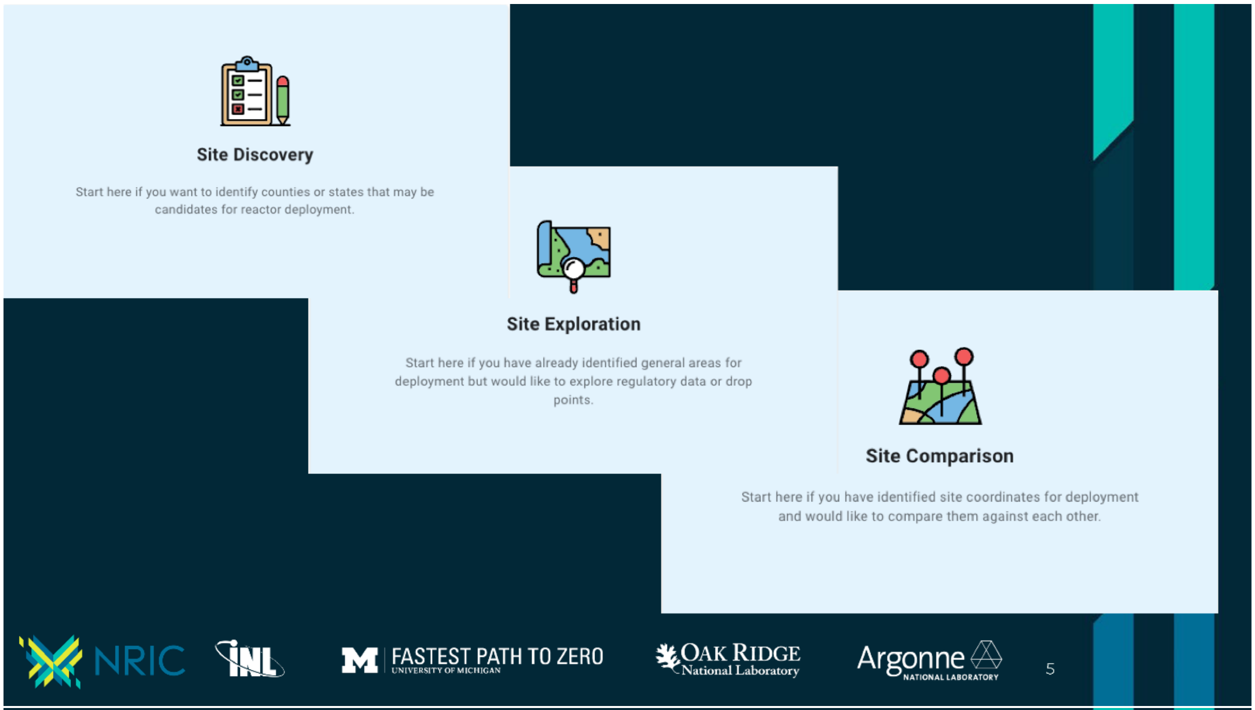
Site Discovery
Start here if you want to identify counties or states that may be candidates for reactor deployment.
Site Exploration
Start here if you have already identified general areas for deployment but would like to explore regulatory data or drop points.
Site Comparison
Start here if you have identified site coordinates for deployment and would like to compare them against each other.
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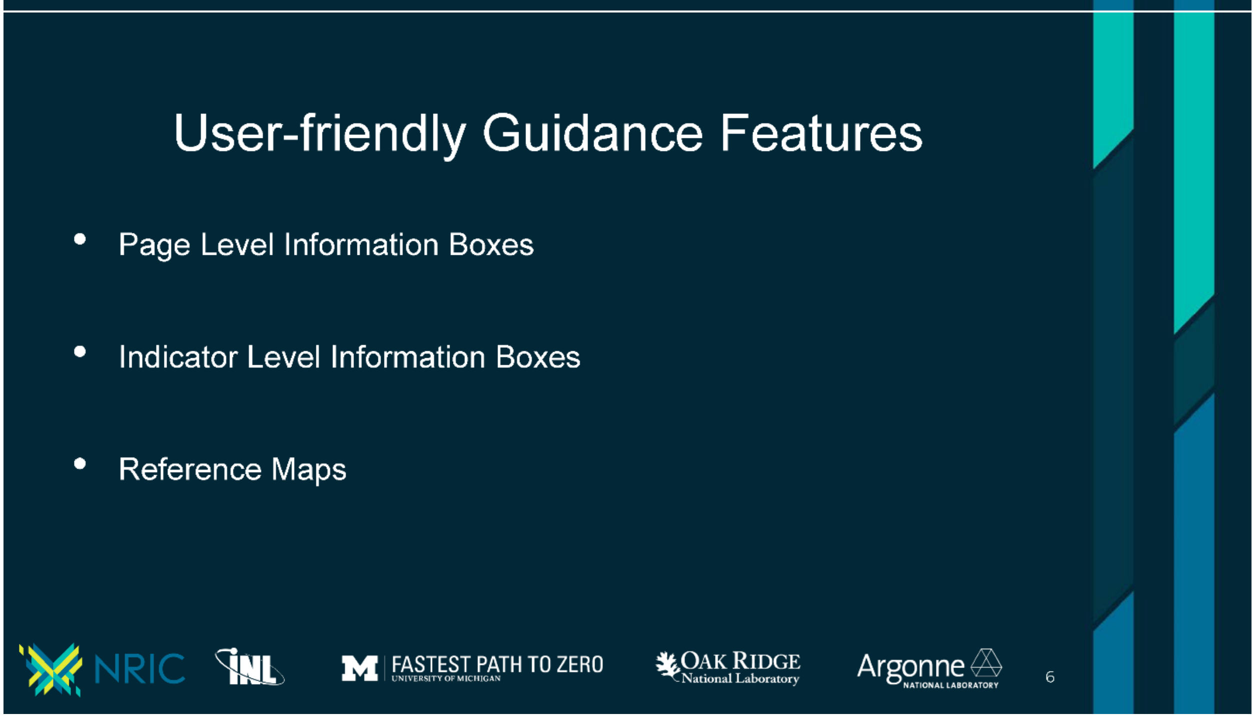
User-friendly Guidance Features
Page Level Information Boxes
Indicator Level Information Boxes
Reference Maps
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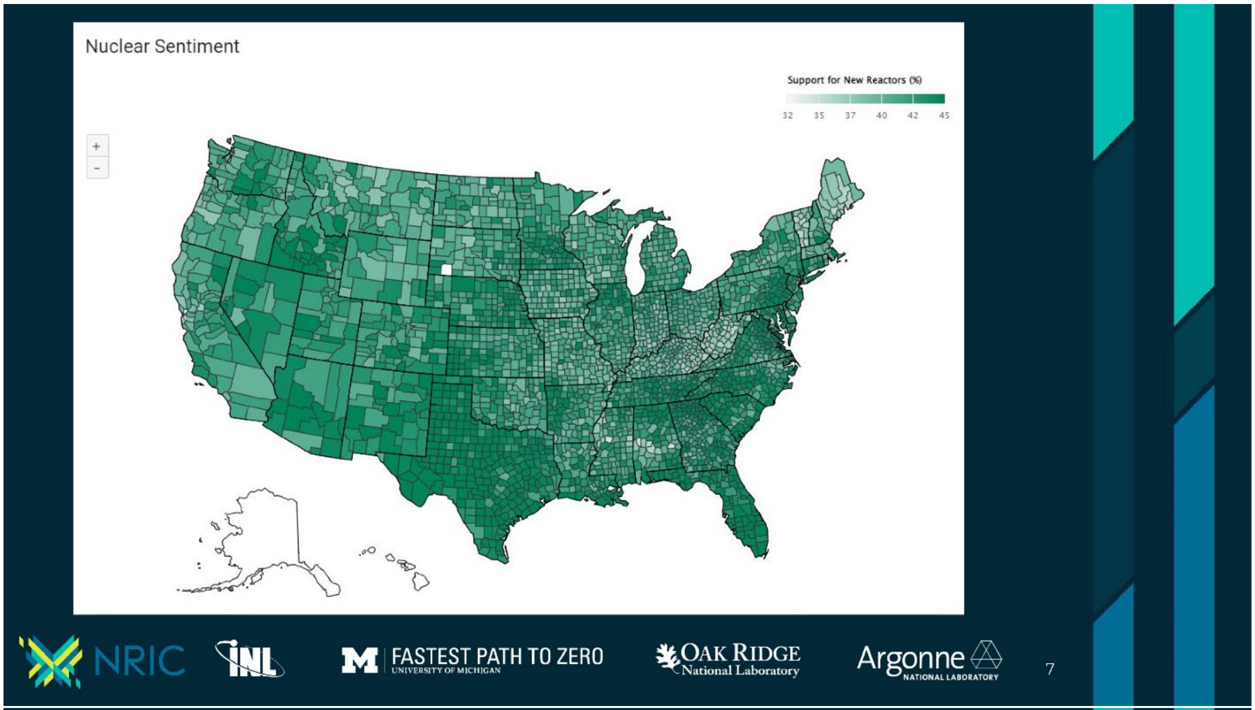

Nuclear Sentiment
Support for New Reactors (%)
32 35 37 40 42 45
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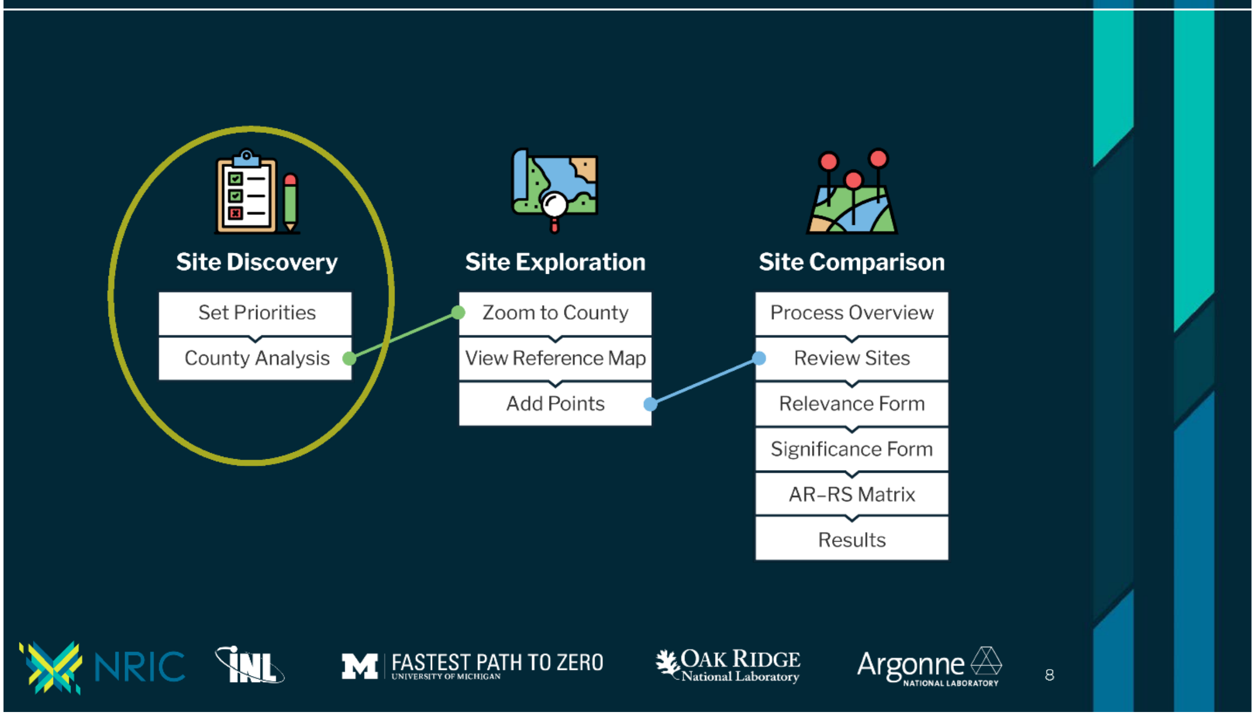

Site Discovery
Set Priorities
County Analysis
Site Exploration
Zoom to County
View Reference Map
Add Points
Site Comparison
Process Overview
Review Sites
Relevance Form
Significance Form
AR-RS Matrix
Results
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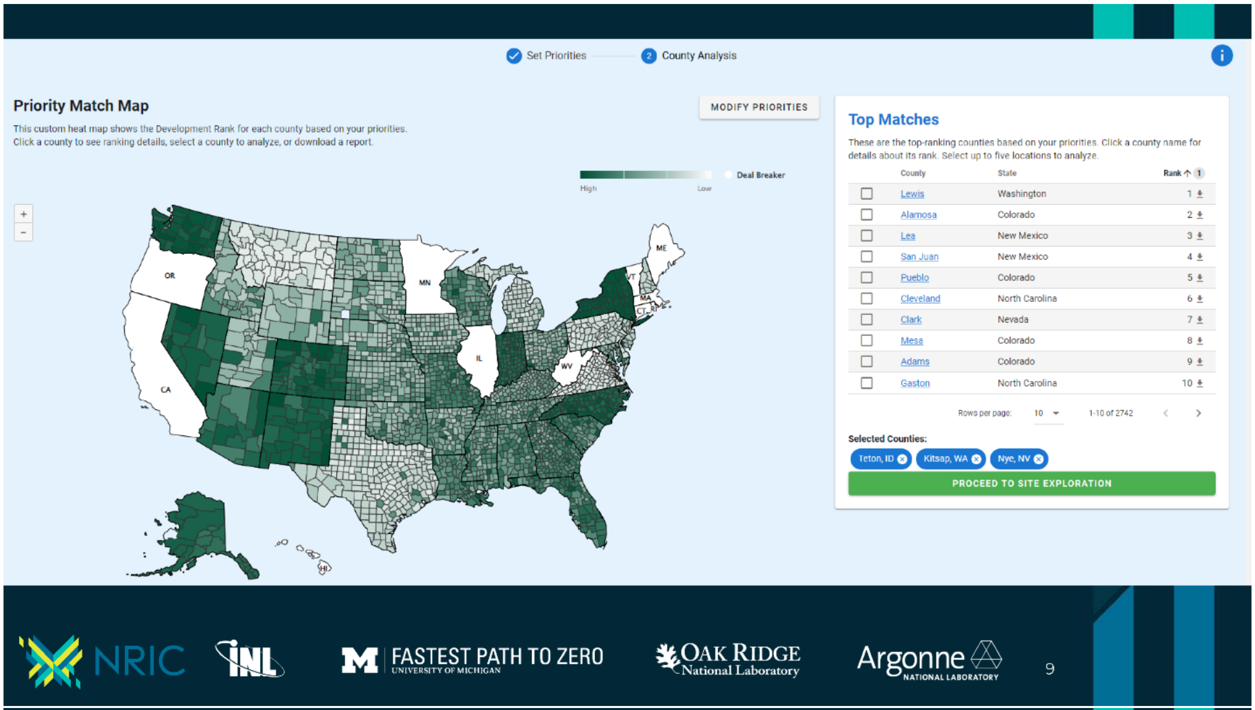

Set Priorities
County Analysis
Priority Match Map
MODIFY PRIORITIES
This custom heat map shows the Development Rank for each county based on your priorities.
Click a county to see ranking details, select a county to analyze, or download a report.
High
Low
Deal Breaker
OR
CA
MN
IL
WV
ME
Top Matches
These are the top-ranking counties based on your priorities. Click a county name for details about its rank. Select up to five locations to analyze.
County
State
Rank
Lewis Washington 1
Alamosa Colorado 2
Lea New Mexico 3
San Juan New Mexico 4
Pueblo Colorado 5
Cleveland North Carolina 6
Clark Nevada 7
Mesa Colorado 8
Adams Colorado 9
Gaston North Carolina 10
Rows per page: 10
1-10 of 2742
Selected Counties:
Teton, ID
Kitsap, WA
Nye, NV
PROCEED TO SITE EXPLORATION
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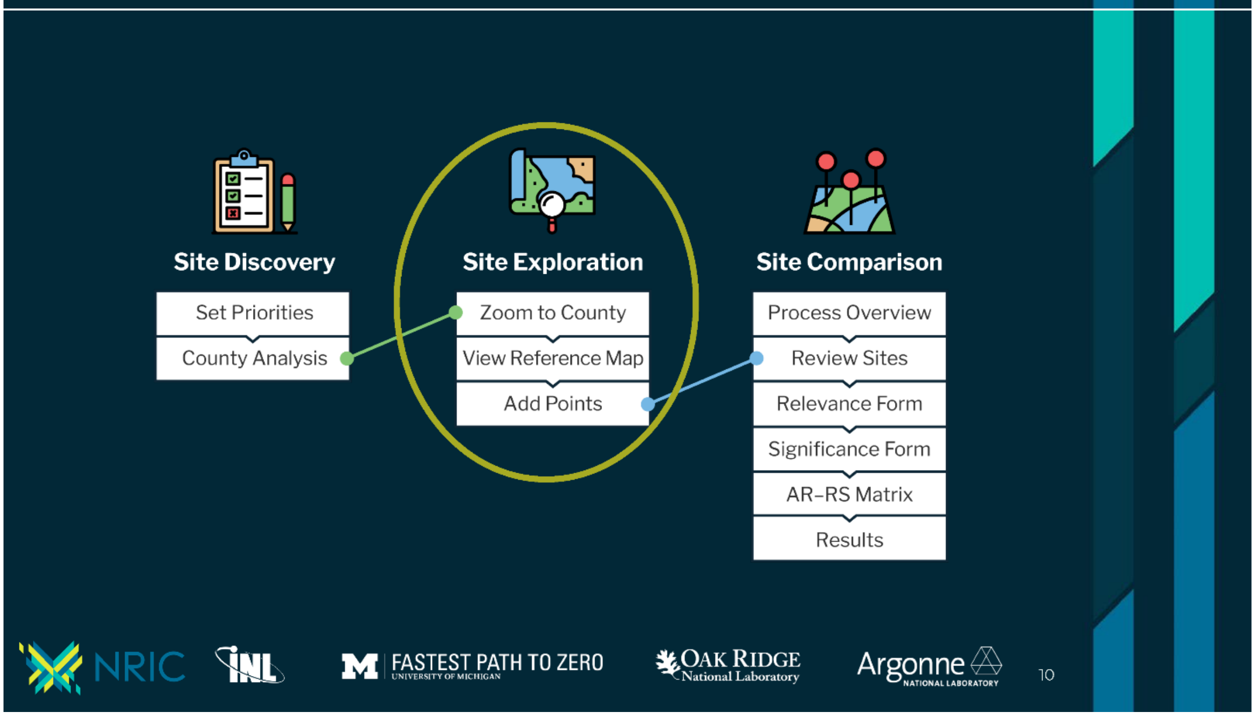

Site Discovery
Set Priorities
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Site Exploration
Zoom to County
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Site Comparison
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Significance Form
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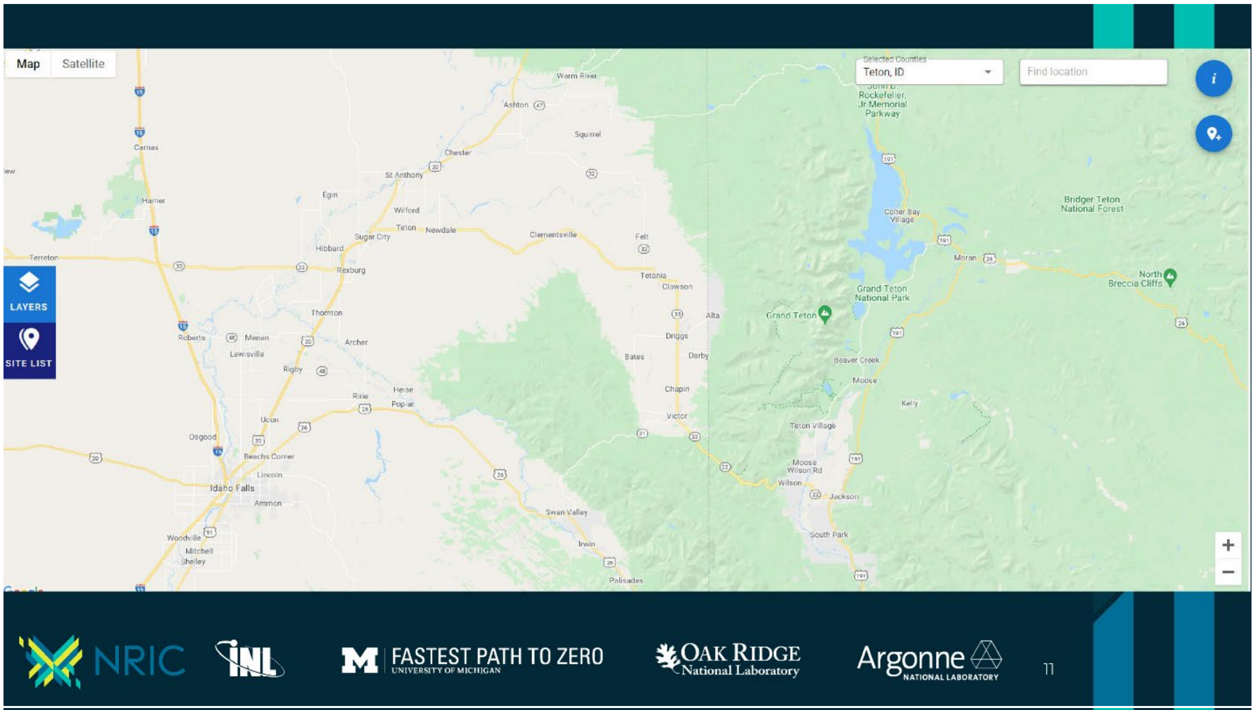
Map
Satellite
Selected Counties
Teton, ID
Find location
LAYERS
SITE LIST
Idaho Falls
Grand Teton National Park
Bridger-Teton National Forest
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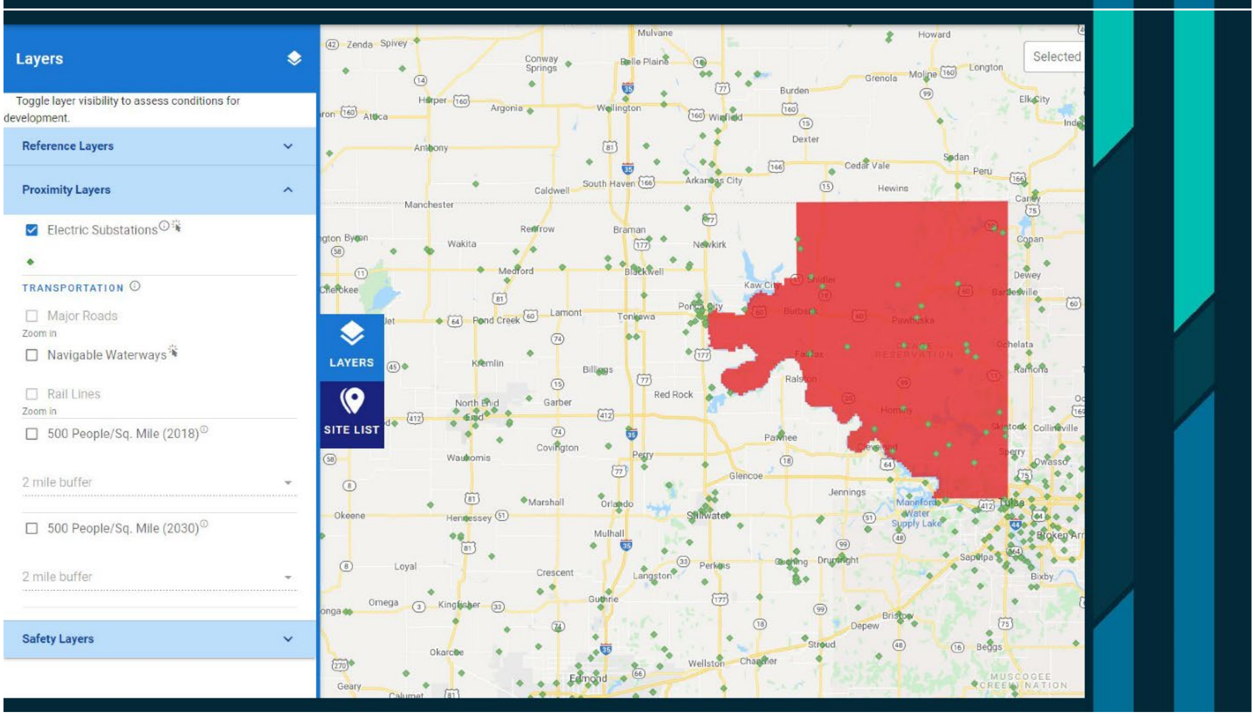
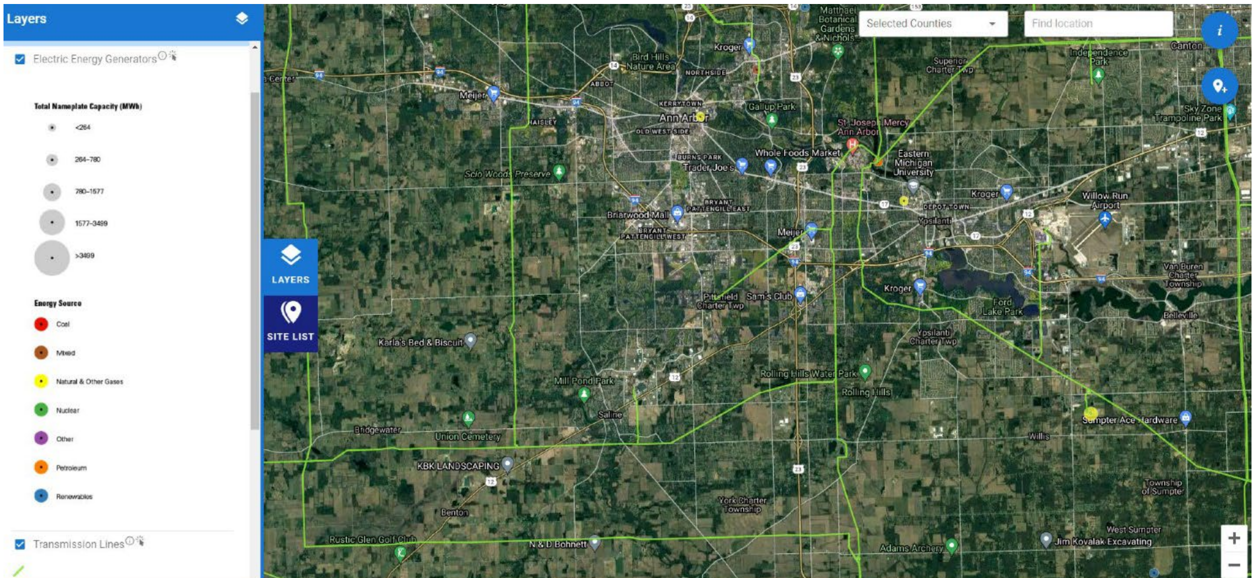

Layers
Toggle layer visibility to assess conditions for development.
Reference Layers
Proximity Layers
Electric Substations
TRANSPORTATION
Major Roads
Zoom in
Navigable Waterways
Rail Lines
Zoom in
500 People/Sq. Mile (2018)
2 mile buffer
500 People/Sq. Mile (2030)
2 mile buffer
Safety Layers
LAYERS
SITE LIST
Selected



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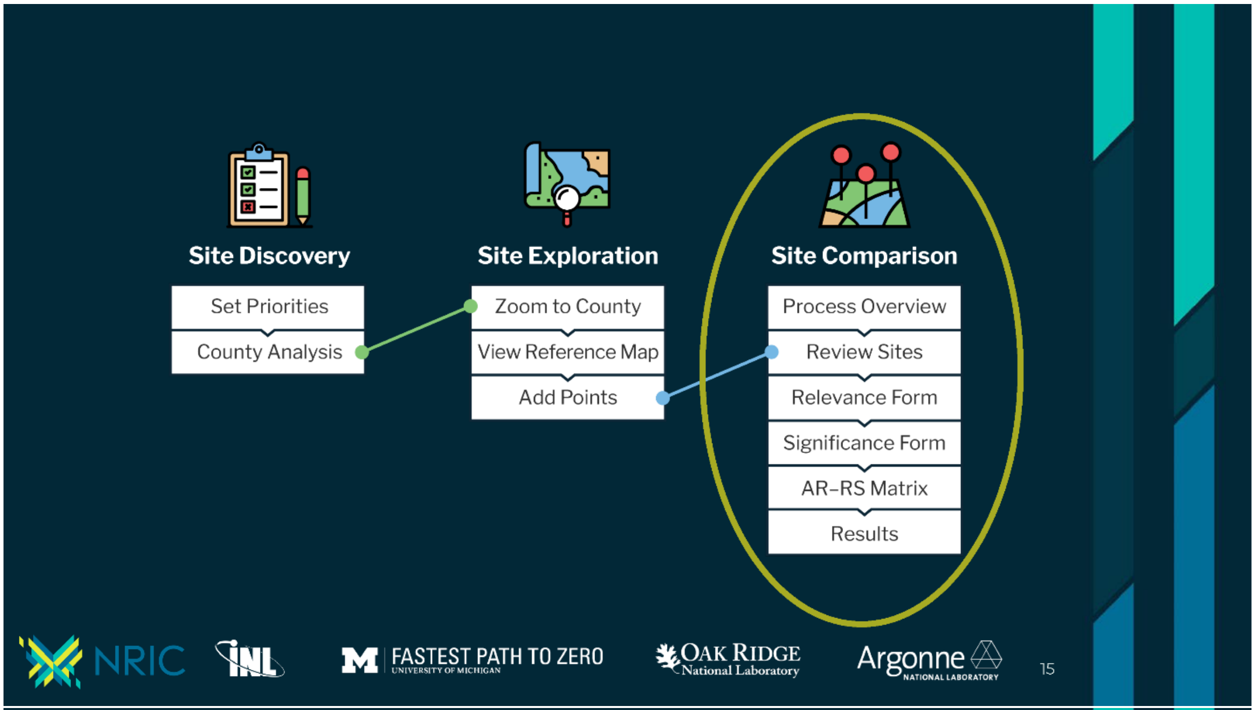
ELECTRIC ENERGY GENERATORS | **TRANSMISSION LINES**

Owner	Status	Substation 1	Substation 2	Type	Voltage Class	Voltage
NOT AVAILABLE	IN SERVICE	SUPERIOR	COVENTRY	AC; OVERHEAD	100-161	120
NOT AVAILABLE	IN SERVICE	SUPERIOR	WAYNE	AC; OVERHEAD	100-161	120
NOT AVAILABLE	IN SERVICE	SUPERIOR	PIONEER	AC; OVERHEAD	100-161	120
NOT AVAILABLE	IN SERVICE	SUPERIOR	TAP137299	AC; OVERHEAD	100-161	120
NOT AVAILABLE	IN SERVICE	SUPERIOR	COVENTRY	AC; OVERHEAD	100-161	120
NOT AVAILABLE	IN SERVICE	SUPERIOR	TAP138716	AC; OVERHEAD	100-161	120
NOT AVAILABLE	IN SERVICE	COLLINS	SUPERIOR	AC; OVERHEAD	100-161	120
NOT AVAILABLE	IN SERVICE	MILAN	MCAULEY	OVERHEAD	100-161	120
NOT AVAILABLE	NOT AVAILABLE	SUPERIOR	NOT AVAILABLE	OVERHEAD	NOT AVAILABLE	-999999
NOT AVAILABLE	IN SERVICE	MCAULEY	SUPERIOR	AC; OVERHEAD	100-161	120

Rows per page: 10 1-10 of 10

NRIC INL 14



Site Discovery
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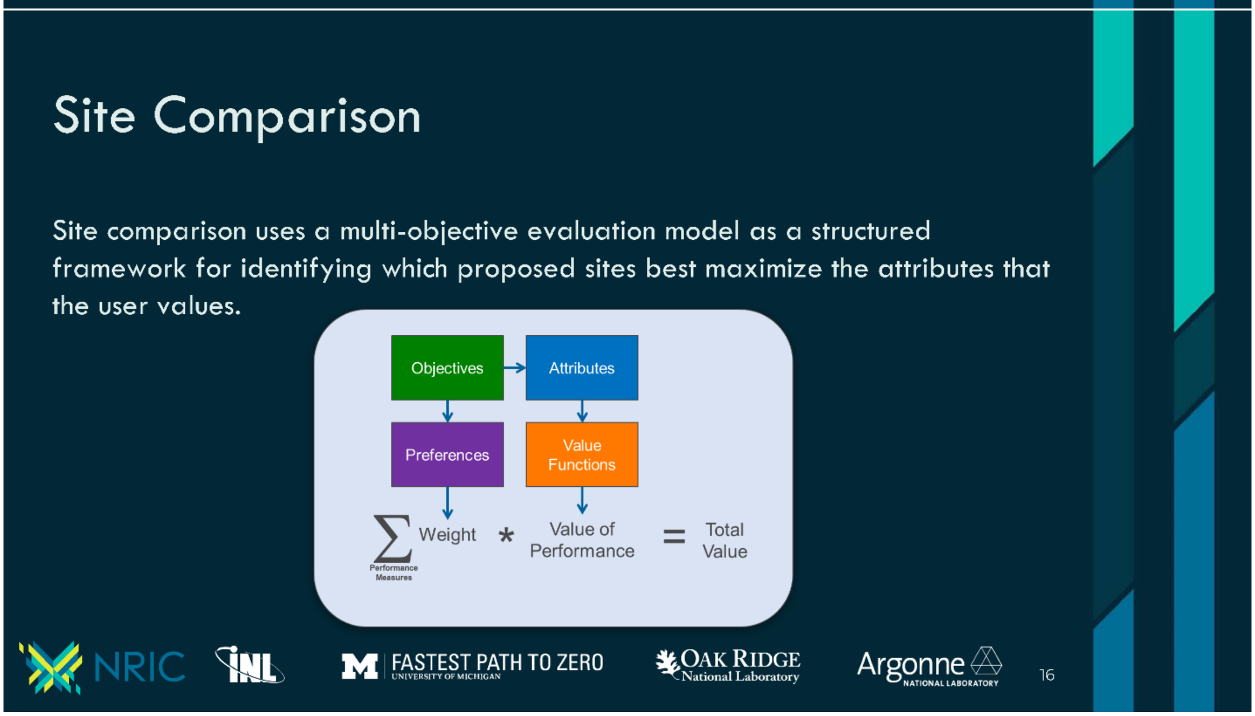

Site Comparison
Site comparison uses a multi-objective evaluation model as a structured framework for identifying which proposed sites best maximize the attributes that the user values.
Objectives
Attributes
Preferences
Value Functions
Performance Measures
Weight
*
Value of Performance
=
Total Value
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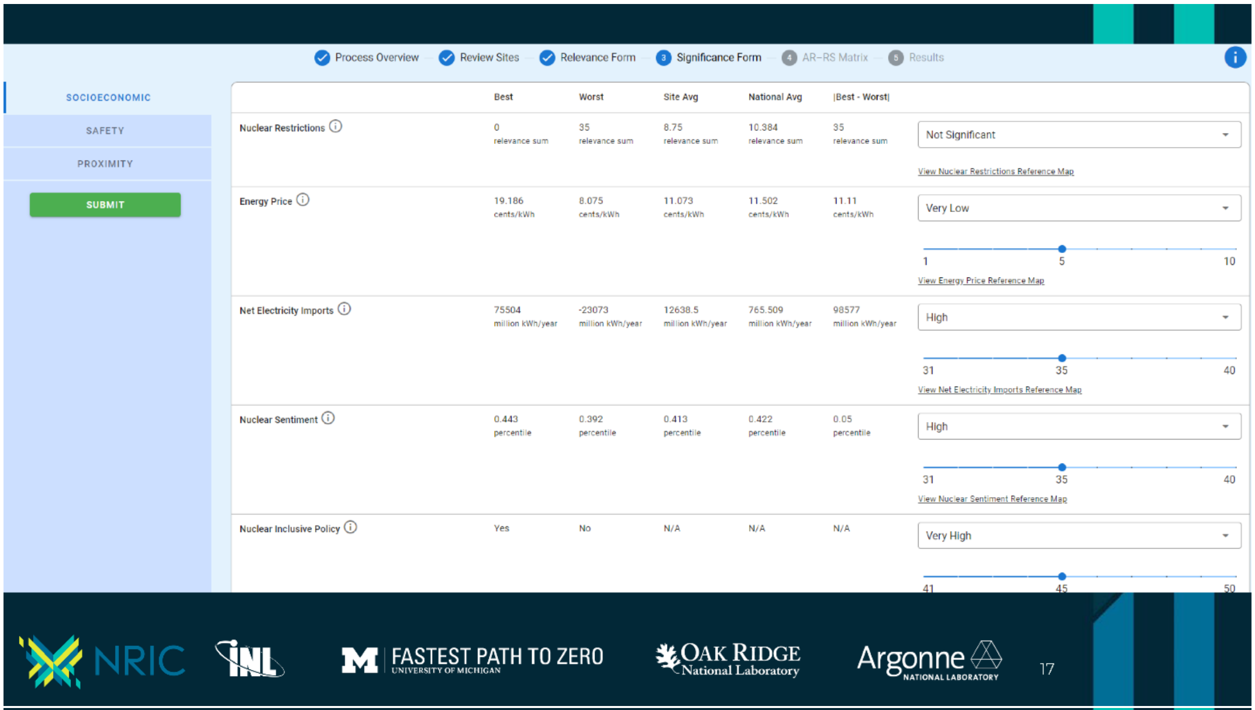
Process Overview
Review Sites
Relevance Form
3 Significance Form
4 AR–RS Matrix
5 Results
SOCIOECONOMIC
SAFETY
PROXIMITY
SUBMIT
Best
Worst
Site Avg
National Avg
|Best - Worst|
Nuclear Restrictions
0 relevance sum
35 relevance sum
8.75 relevance sum
10.384 relevance sum
35 relevance sum
Not Significant
View Nuclear Restrictions Reference Map
Energy Price
19.186 cents/kWh
8.075 cents/kWh
11.073 cents/kWh
11.502 cents/kWh
11.11 cents/kWh
Very Low
1
5
10
View Energy Price Reference Map
Net Electricity Imports
75504 million kWh/year
-23073 million kWh/year
12638.5 million kWh/year
765.509 million kWh/year
98577 million kWh/year
High
31
35
40
View Net Electricity Imports Reference Map
Nuclear Sentiment
0.443 percentile
0.392 percentile
0.413 percentile
0.422 percentile
0.05 percentile
High
31
35
40
View Nuclear Sentiment Reference Map
Nuclear Inclusive Policy
Yes
No
N/A
N/A
N/A
Very High
41
45
50
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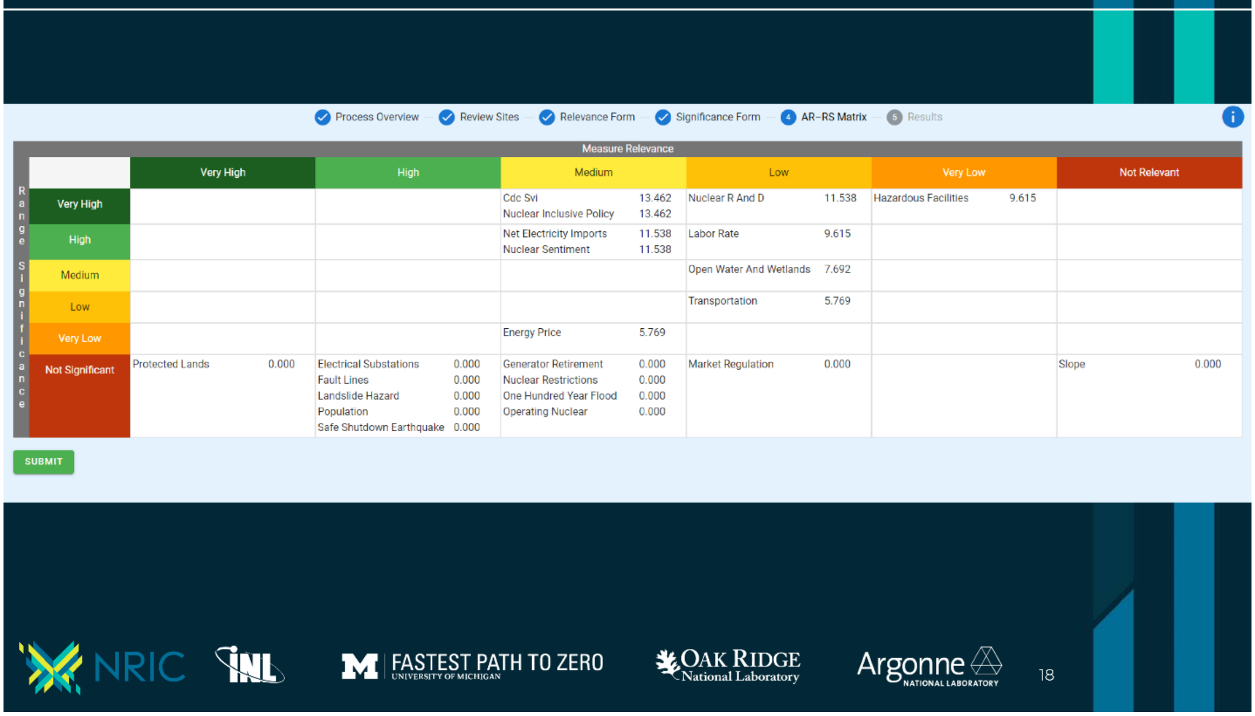
Process Overview
Review Sites
Relevance Form
Significance Form
4 AR–RS Matrix
5 Results
Measure Relevance
Very High
High
Medium
Low
Very Low
Not Relevant
Range Significance
Very High
Cdc Svi 13.462
Nuclear Inclusive Policy 13.462
Nuclear R And D 11.538
Hazardous Facilities 9.615
High
Net Electricity Imports 11.538
Nuclear Sentiment 11.538
Labor Rate 9.615
Medium
Open Water And Wetlands 7.692
Low
Transportation 5.769
Very Low
Energy Price 5.769
Not Significant
Protected Lands 0.000
Electrical Substations 0.000
Fault Lines 0.000
Landslide Hazard 0.000
Population 0.000
Safe Shutdown Earthquake 0.000
Generator Retirement 0.000
Nuclear Restrictions 0.000
One Hundred Year Flood 0.000
Operating Nuclear 0.000
Market Regulation 0.000
Slope 0.000
SUBMIT
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Appendix C

NRIC STAND Quickstart Tool Guide

Appendix C

NRIC STAND Quickstart Tool Guide

Appendix A

Data Availability by Geography

Layer	Variable	CONUS	AK	HI	Source
EJ40	CEJST Climate	x	x	x	Council on Environmental Quality (CEQ)
	CEJST Energy	x	x	x	
	CEJST Health	x	x	x	
	CEJST Housing	x	x	x	
	CEJST Pollution	x	x	x	
	CEJST Transit	x	x	x	
	CEJST Water	x	x	x	
	CEJST Workforce	x	x	x	
Construction Mean Annual Wage By State		x	x	x	Bureau of Labor Statistics
Electric Energy Generators		x	x	x	EIA
Electricity Market Type By State		x	x	x	EPA
Electric Retail Service Territories		x	x	x	Homeland Infrastructure Foundation Level Data (HIFLD)
Electric Substations		x	x	x	Homeland Infrastructure Foundation Level Data (HIFLD)
Energy Intensive Facilities	Food Industry	x	x	x	HSIP GOLD 2015
	Manufacturing	x	x	x	
	Mining	x	x	x	
Fault Lines		x	x	x	USGS Quaternary Fault and Fold Database
Hazardous Facilities	Airports	x	x		HSIP GOLD 2015
	Biodiesel Plants	x			
	Biological Products Manufacturing	x	x	x	
	Chemical Manufacturing	x	x	x	
	Ethanol Plants	x			
	Explosives Manufacturing	x	x	x	
	Liquified Natural Gas Import Terminals	x	x		
	Lubricating Oils and Grease Plants	x	x	x	
	Natural Gas Compressor Stations	x			
	Natural Gas Import/Export Locations	x			
	Natural Gas Processing Plants	x			
	Natural Gas Storage Facilities	x			
	Nitrogenous Fertilizer Plants	x	x	x	
	Nuclear Fuel Plants	x			
	Oil Refineries	x	x	x	
	Petroleum Pumping Stations	x	x	x	
	Pharmaceutical Preparations Manufacturing	x	x	x	
	Phosphatic Fertilizer Plants	x	x	x	
	POL Terminals, Storage Facilities, Tank Farms	x	x	x	
Landslide Hazard		x			USGS, Source from report
NERC Regions		x			Homeland Infrastructure Foundation Level Data (HIFLD)
Net Electricity Imports By State		x	x	x	EIA Net Interstate Flow of Electricity, EIA Electricity Net Imports
Nuclear Facility Summary By County		x	x	x	EIA
Nuclear Inclusive Policy By State		x	x	x	NCSL, DSIRE
Nuclear R And D By County		x	x	x	FPTZ
Nuclear Restriction By State		x	x	x	NCSL
Nuclear Sentiment By County		x			University of Oklahoma Center for Risk and Resilience & FPTZ
One Hundred Year Flood		x		x	ORNL collected from state and county level floodplain data.
Open Water And Wetlands		x	x	x	NLCD 2016 Land Cover (CONUS)

Continued..

Population	2018	x			ORNL Landscan data and US Census data
	2020		x	x	
	2030	x			
Protected Lands	American Indian reservations	x	x		USFWS Critical Habitat, Wild and Scenic River Lines (ArcGIS), USFWS National Cadastral Data, US Census, HIFLD Hospitals, HIFLD Prison Boundaries, HIFLD Colleges and Universities, USDA 2001 Roadless Rule GIS Data, BLM Navigator
	Correctional facilities	x	x		
	Critical habitat	x	x		
	Forests	x	x		
	Hospitals	x	x		
	National monuments	x	x		
	National, state, and local parks	x	x		
	Schools/colleges	x	x		
	Wild and scenic rivers	x			
	Wilderness areas	x			
	Wildlife refuges	x			
Retail Energy Price By State		x	x	x	EIA
Retiring Generator Summary By County		x	x	x	EIA
Safe Shutdown Earthquake	0.3g	x			USGS National Seismic Hazard Mapping data
	0.4g	x			
	0.5g	x			
	0.6g	x			
	6.5g			x	
	10g			x	
	15g		x		
Slope	12%	x	x	x	Digital Terrain Elevation Dataset National Geospatial Intelligence Agency
	18%	x	x	x	
Social Vulnerability Index By County		x	x	x	CDC
Streamflow	15kgpm	x			Low-flow statistics (7-day, 10 year) calculated from USGS National Water Information System (NWIS) and USGS/EPA National Hydrologic Dataset Plus
	20kgpm		x		
	50kgpm	x			
	65kgpm	x			
	84kgpm		x		
Transmission Lines		x	x	x	Homeland Infrastructure Foundation Level Data (HIFLD)
Transportation	Major Roads	x	x	x	HSIP GOLD 2015
	Navigable Waterways	x	x	x	
	Rail Lines	x	x	x	
Utility Nuclear Experience By County		x	x	x	EIA augmented by additional FPTZ research. See documentation for more information.