CARIBBEAN CENTRE FOR RENEWABLE ENERGY & ENERGY EFFICIENCY

AN INSTITUTION OF CARICOM

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NREL Transforming ENERGY

Resilient Energy Platform

ICF

Data Collection to Support Resilience Planning

Integrated Resource and Resilience Planning Workshop Series

March 4, 2021

Speakers

Gerald Lindo
Renewable Energy unit Lead
CCREEE

Nate Blair
Distributed Systems and Storage Analysis
NREL

Juanita Haydel
Senior Vice President
ICF

Erick Conde
Project Management Specialist SEED Office
USAID

Gail Mosey
Senior Researcher
NREL

Sertaç Akar
Systems Engineer
NREL

James Elsworth
Research Engineer
NREL

The USAID-NREL Partnership

USAID and NREL partner to deliver clean, reliable, and affordable power to the developing world. The USAID-NREL Partnership addresses critical aspects of deploying advanced energy systems in developing countries through:

- Policy, planning, and deployment support.
- Global technical toolkits.

www.nrel.gov/usaid-partnership

Global Technical Platforms

The USAID-NREL Partnership's global technical platforms provide free, state-of-the-art support on common and critical challenges to scaling up advanced energy systems.

REexplorer MAPPING OUR ENERGY FUTURE — www.re-explorer.org

Greening the Grid — www.greeningthegrid.org

I-JEDI — www.i-jedi.org

Resilient Energy Platform — www.resilient-energy.org

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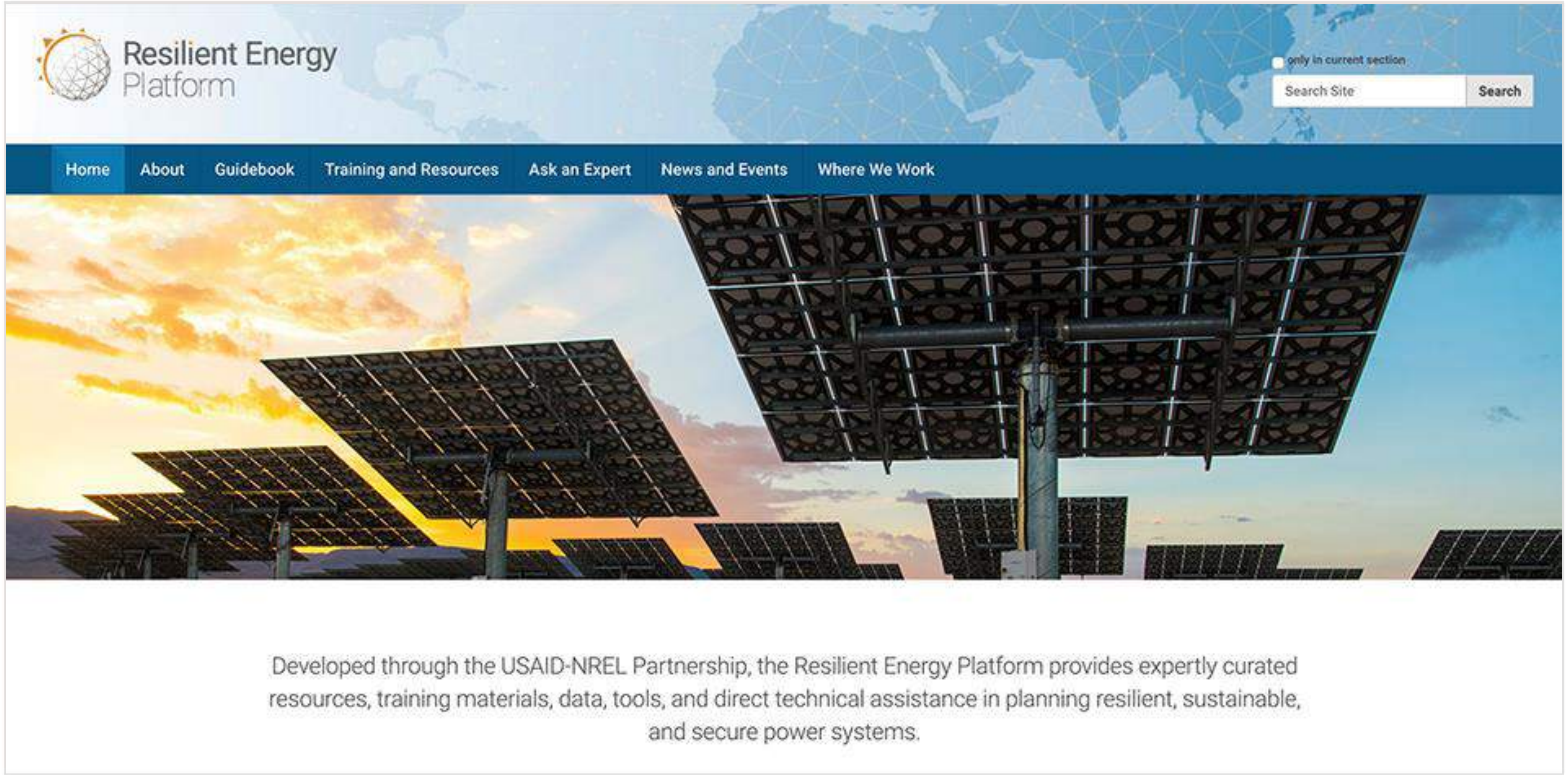
Resilient Energy Platform

Developed through the USAID-NREL Partnership, the Resilient Energy Platform provides expertly curated resources, training materials, tools, and technical assistance to enhance power sector resilience.

The platform enables decision makers to assess power sector vulnerabilities, identify resilience solutions, and make informed decisions to enhance power sector resilience at all scales.



https://www.resilient-energy.org

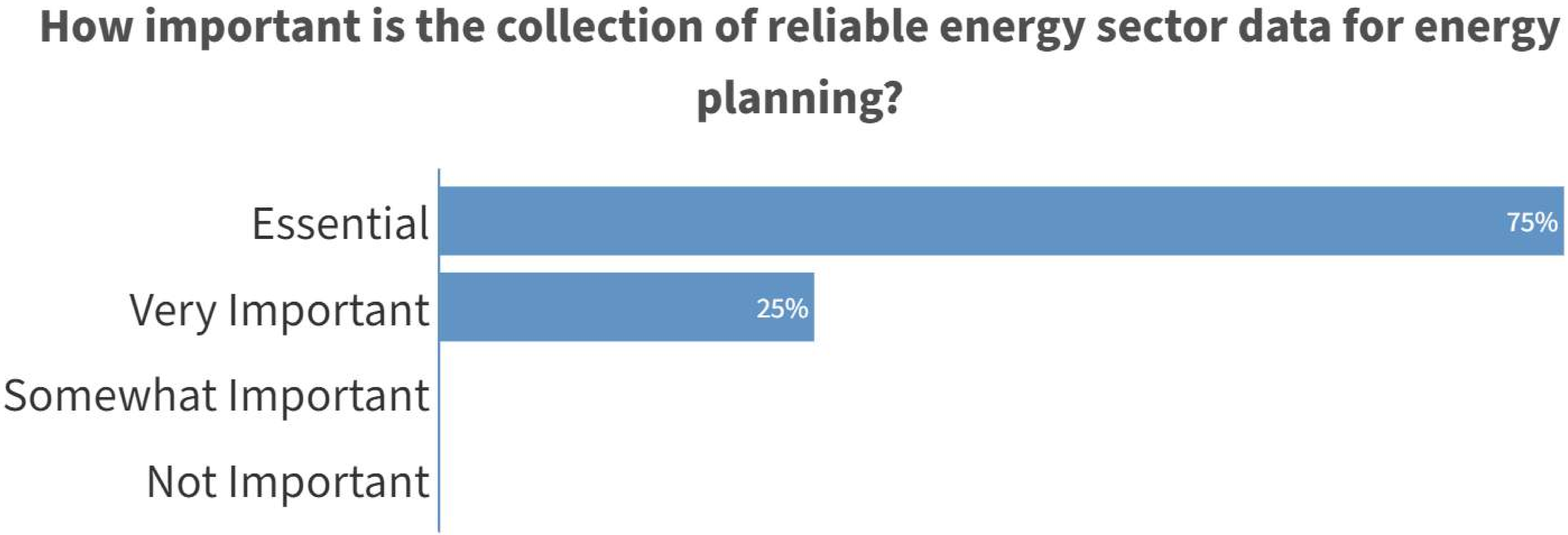
Polling


What country do you or does your organization represent?
Antigua and Barbuda
Barbados
25%
Belize
Dominican Republic
13%
Dominica
Haiti
Grenada
Guyana
Jamaica
13%
Saint Lucia
Suriname
13%
Trinidad and Tobago
25%
United States
13%
Other

Polling

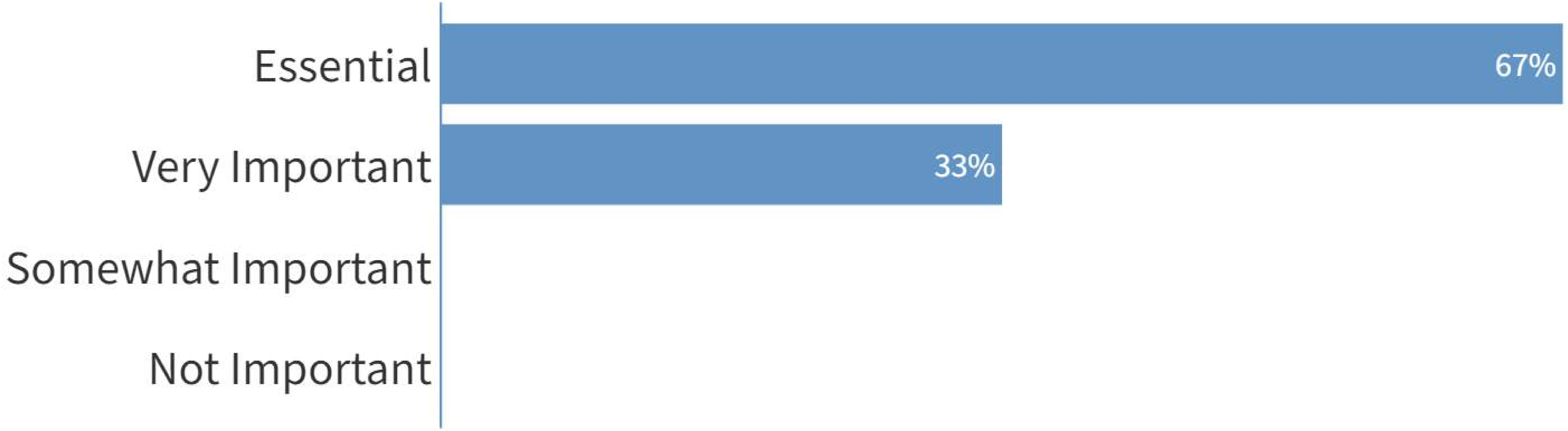

What type of organization or agency do you represent?
Utility
Regulator
Energy agency/ministry
25%
Environmental Group
13%
Academia
13%
USAID
13%
Other
38%

Polling


How important is the collection of reliable energy sector data for energy planning?
Essential
75%
Very Important
25%
Somewhat Important
Not Important

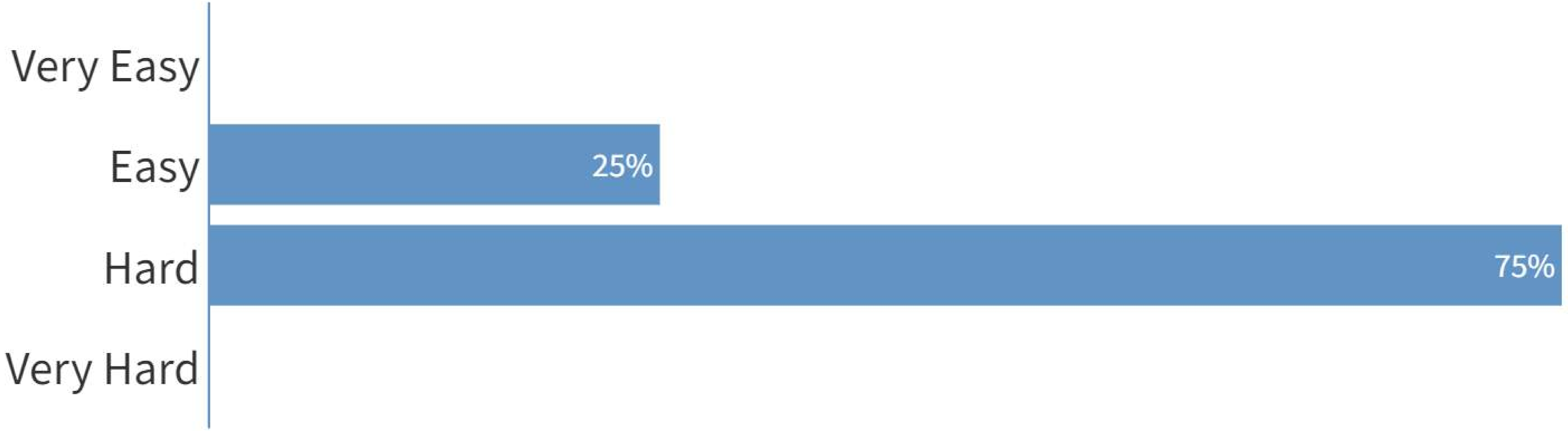
Polling

How important is the collection of reliable energy sector data for your work?



Polling

How easy is it to get data from stakeholder agencies in the energy sector?



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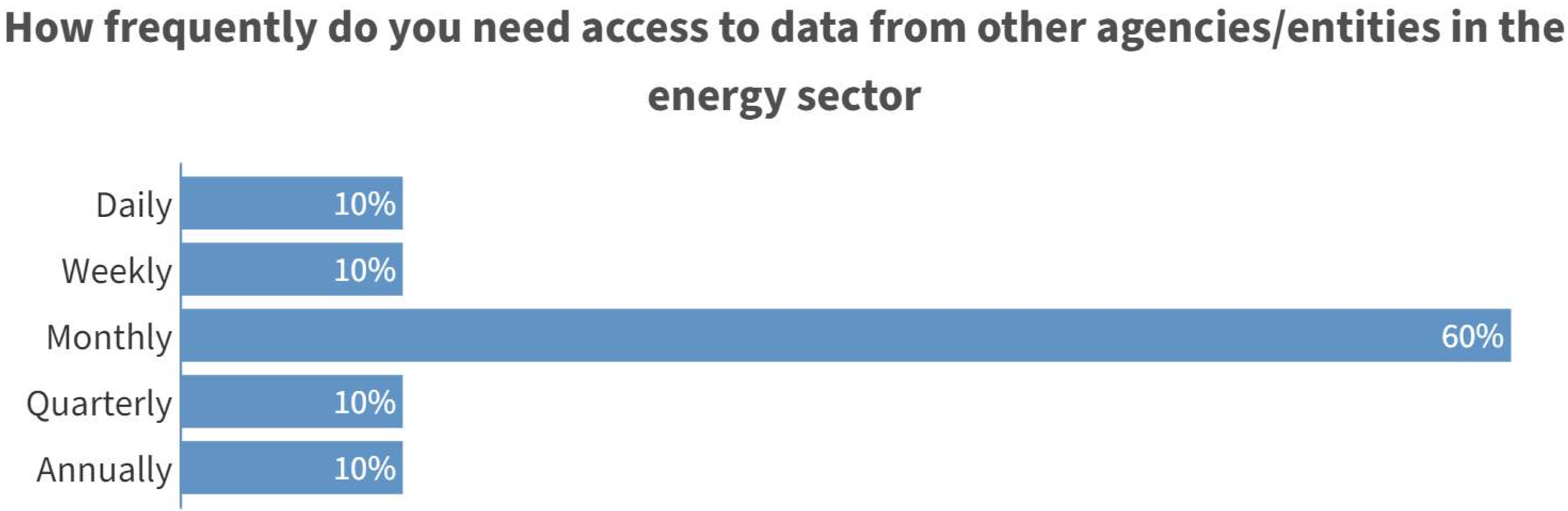
How frequently do you need access to data from other agencies/entities in the energy sector
Daily
10%
Weekly
10%
Monthly
60%
Quarterly
10%
Annually
10%

Polling

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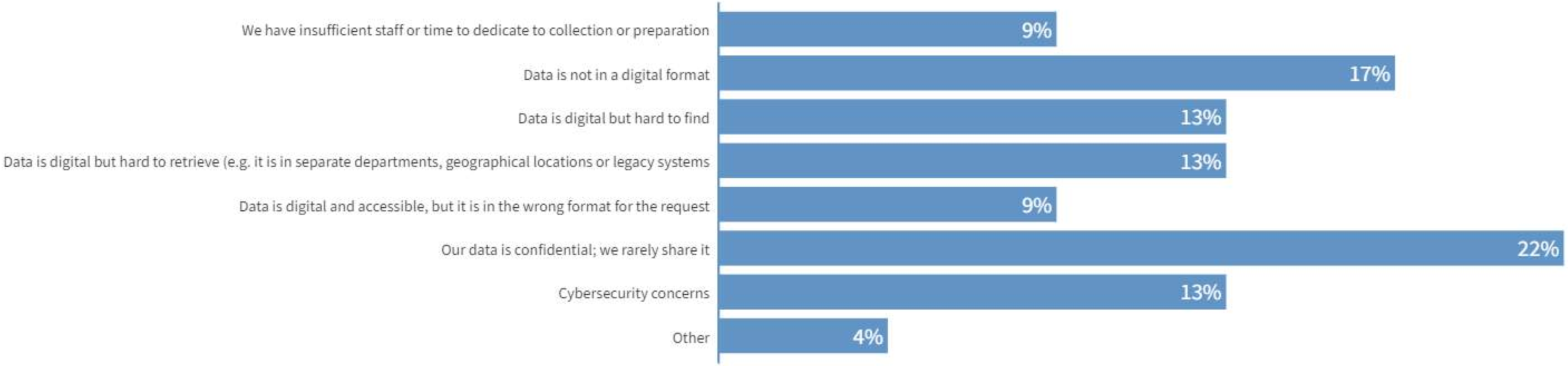
What are the biggest challenges you face when fulfilling data requests? (Choose all that apply)



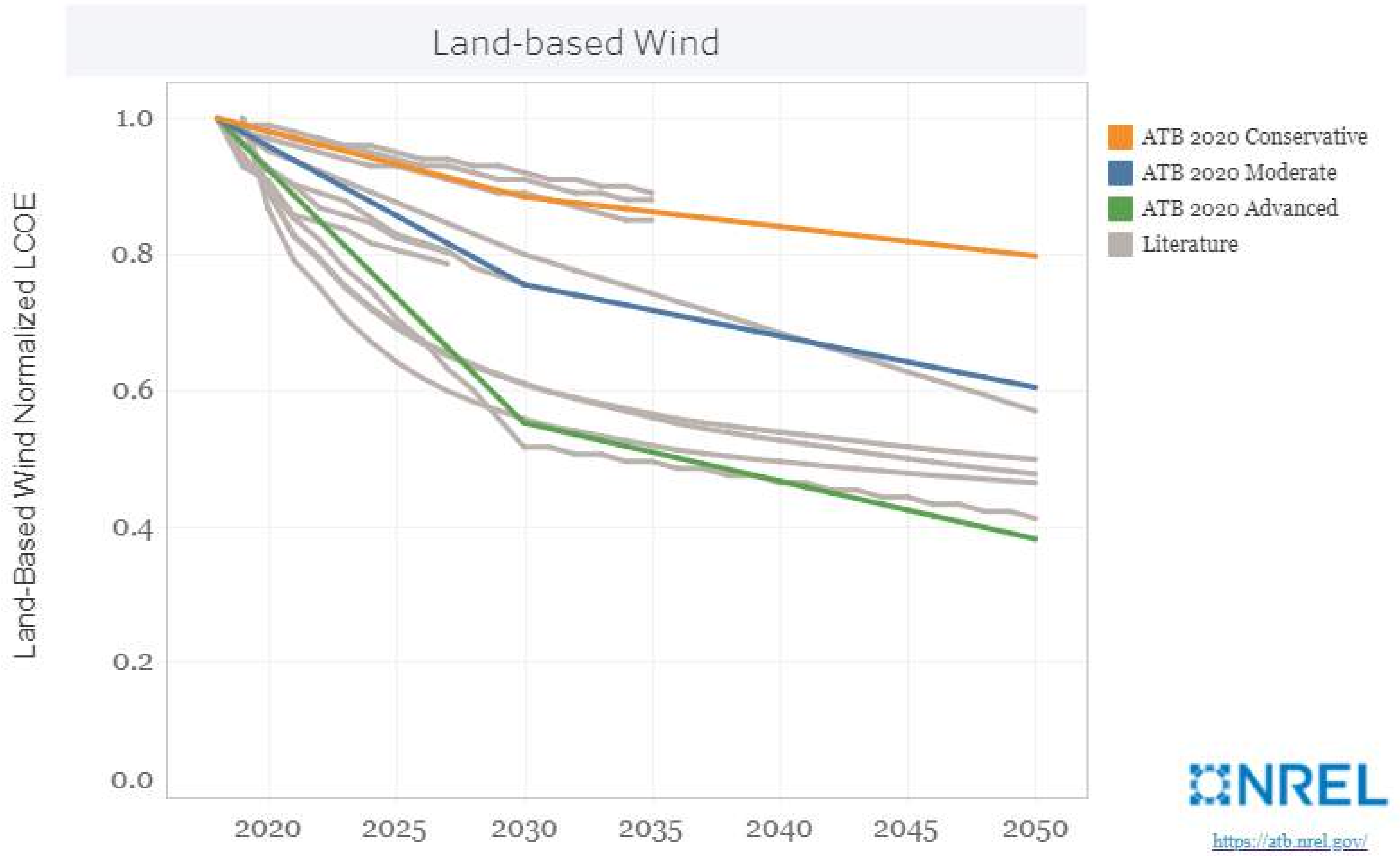
NATIONAL RENEWABLE ENERGY LABORATORY

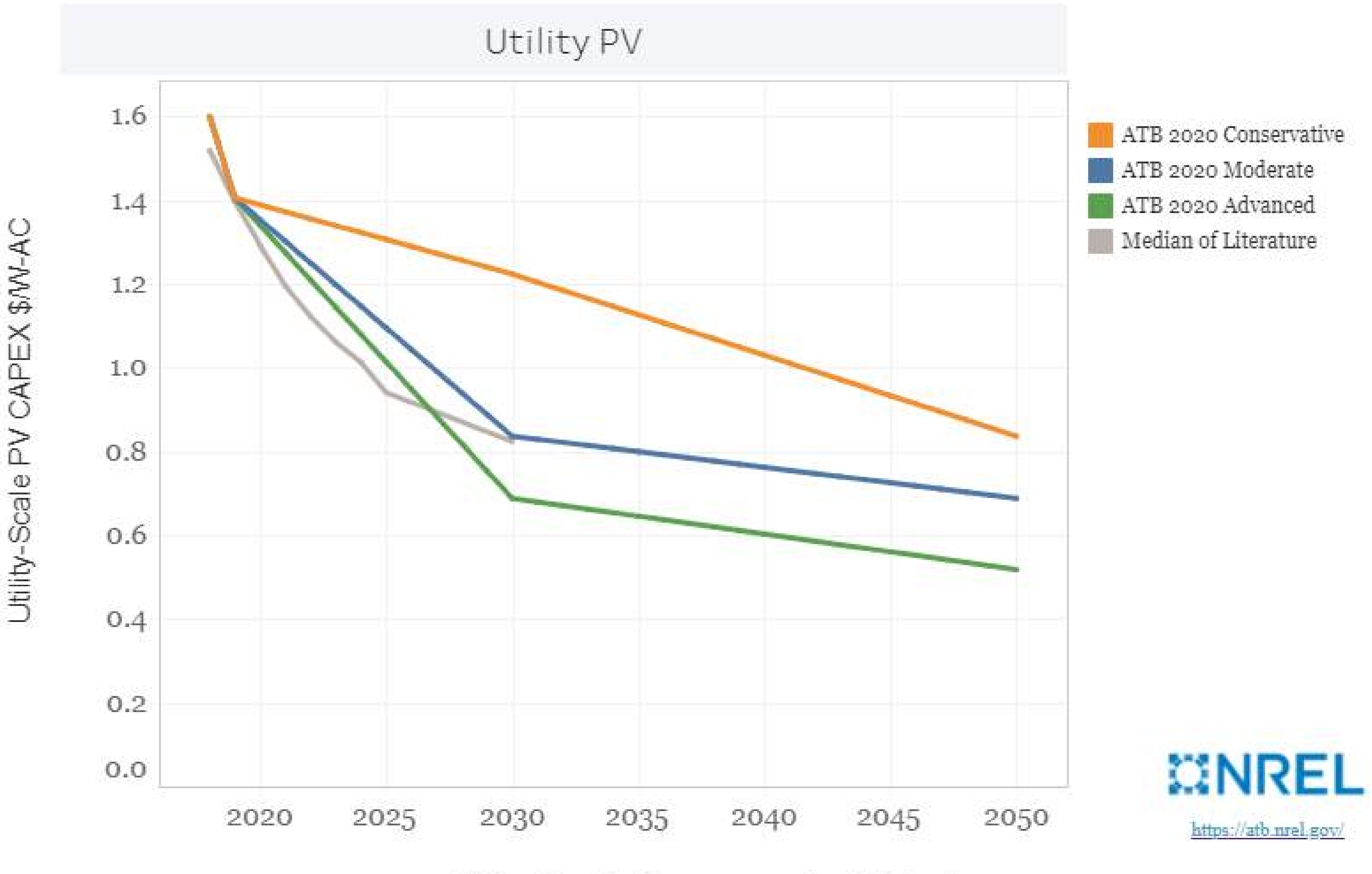
Data Needs for an IRRP Process

Nate Blair
Strategic Energy Analysis Center

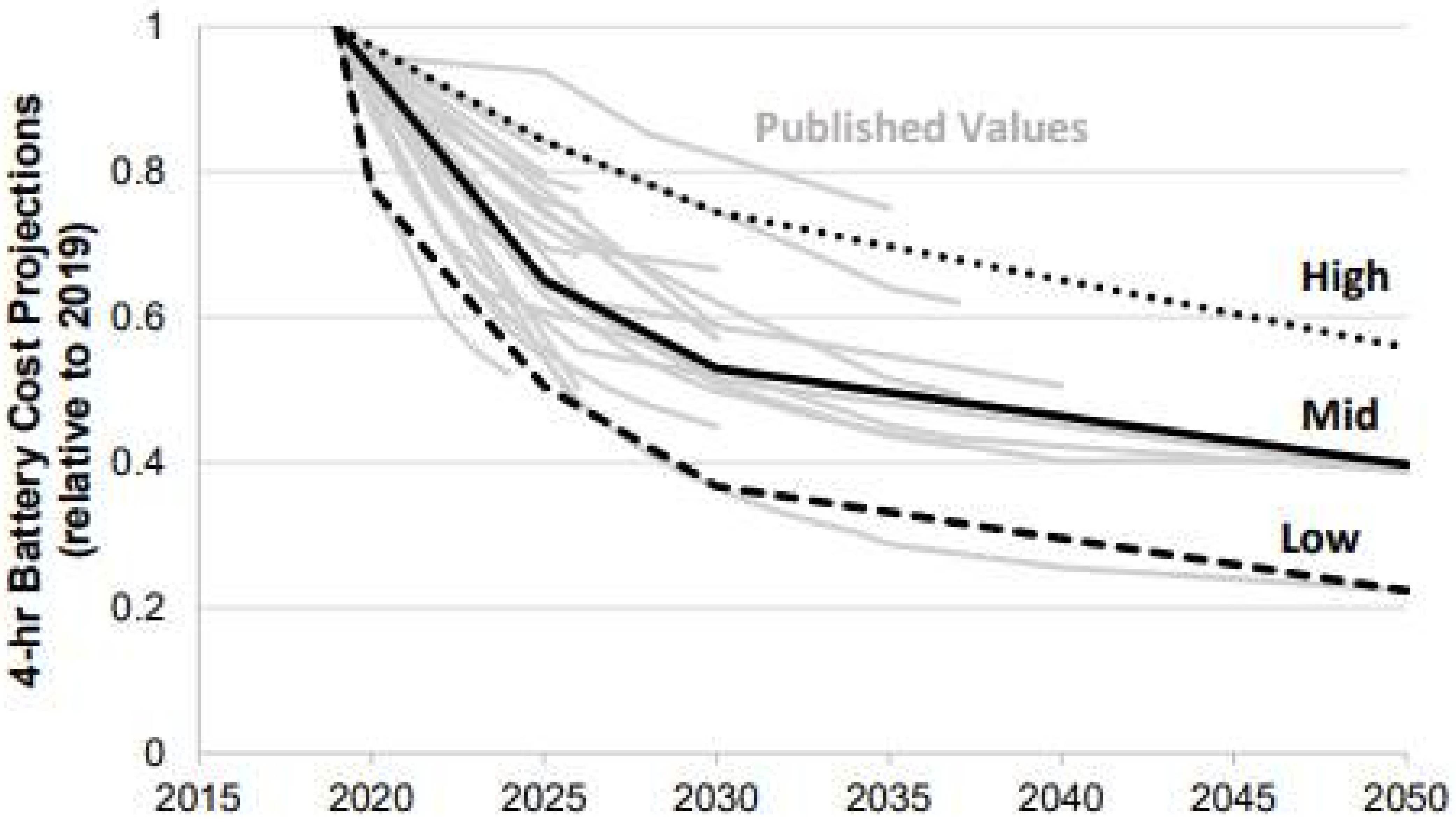
Generation Technology Price Forecasts

- Solar PV, land-based wind and batteries have all been dropping in costs and are anticipated to drop further
- Other generation technologies more site-specific and not likely to have cost reductions (geothermal, biopower, diesel generators, etc.).



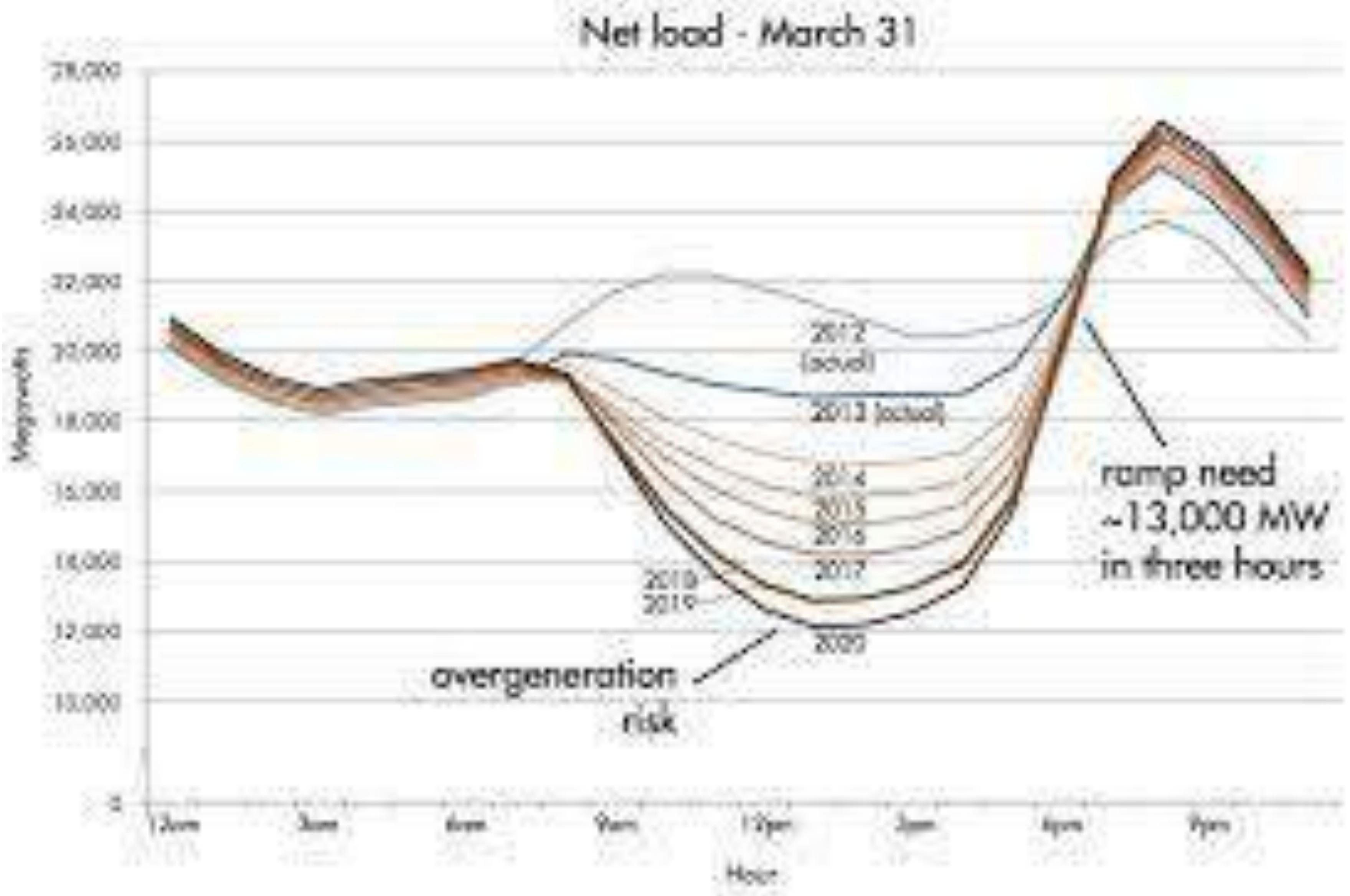


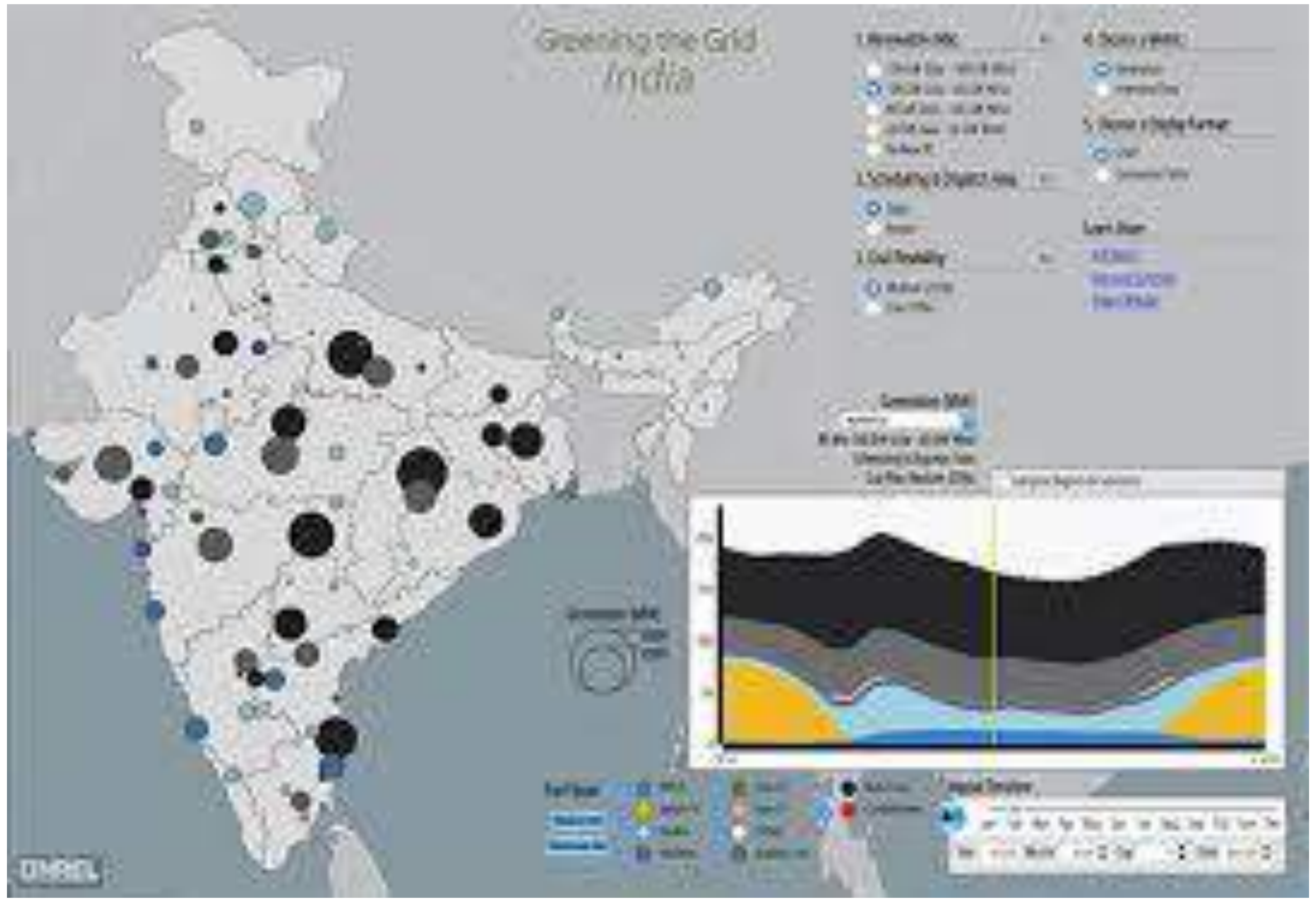
ATB cost projections compared with literature



Historical Load Data

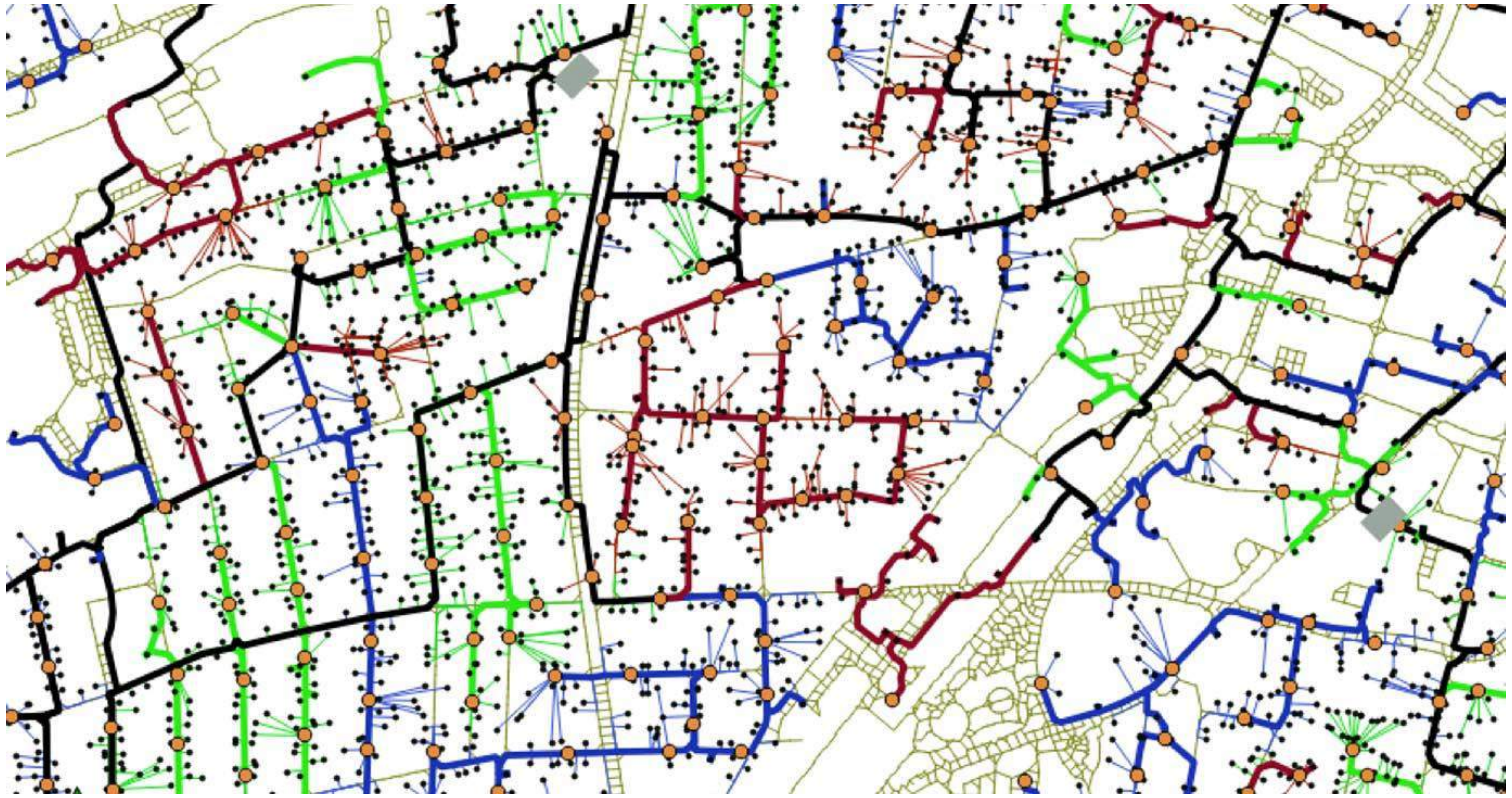
- Collecting aggregate load data for the system is critical for modeling.
- Load growth forecasting is also critical – growth due to electrification (EV's, heat pumps, etc.) should be estimated.
- For small systems, planned industrial load growth will also be critical.
- Note that net load can also be a function of distributed generation (likely rooftop PV).

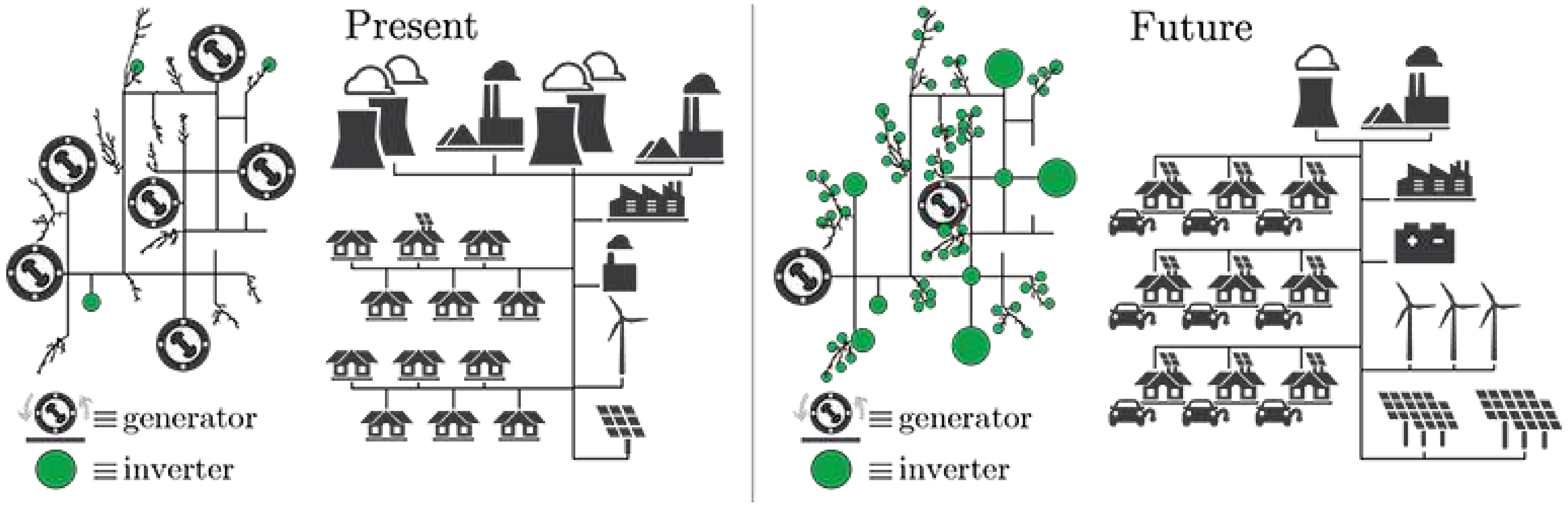


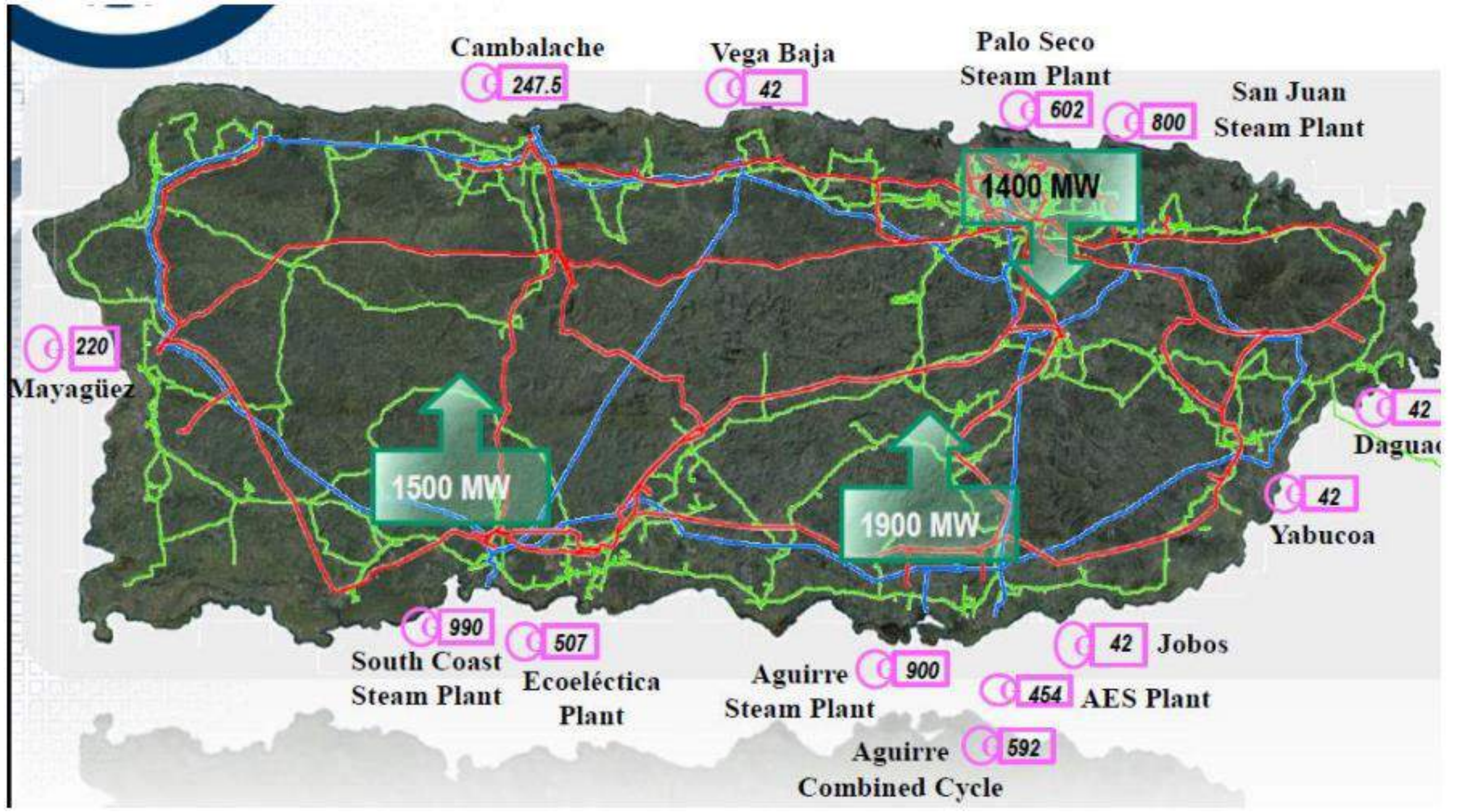


Transmission and Distribution Maps and Data

- This data needs to be collected and fed into the grid modeling software for the IRRP
- This data is typically complex and stored in a database.
- There is typically some significant effort to enter this data into grid modeling software if not already in that format.





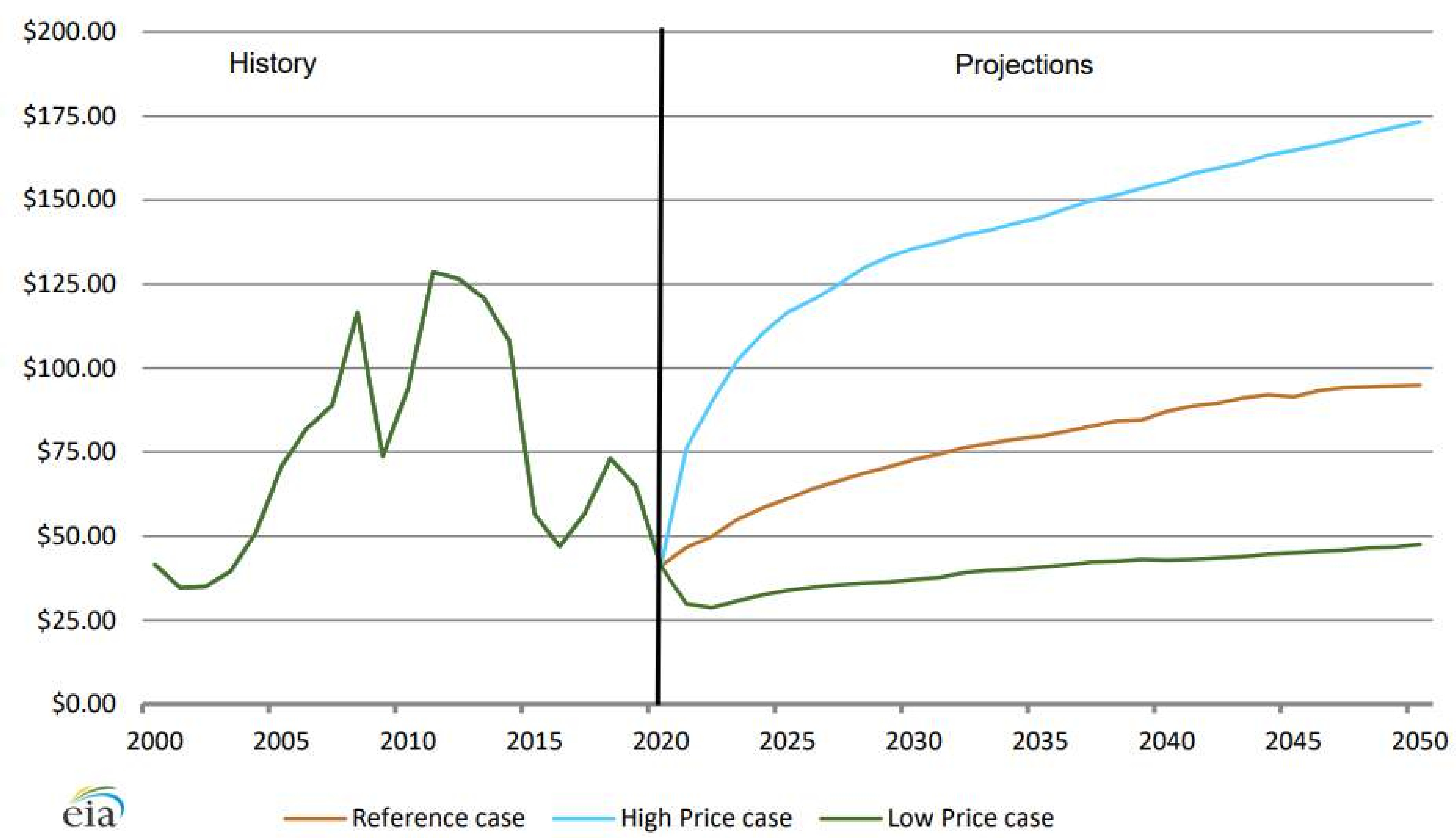


Fuel Price Forecasts

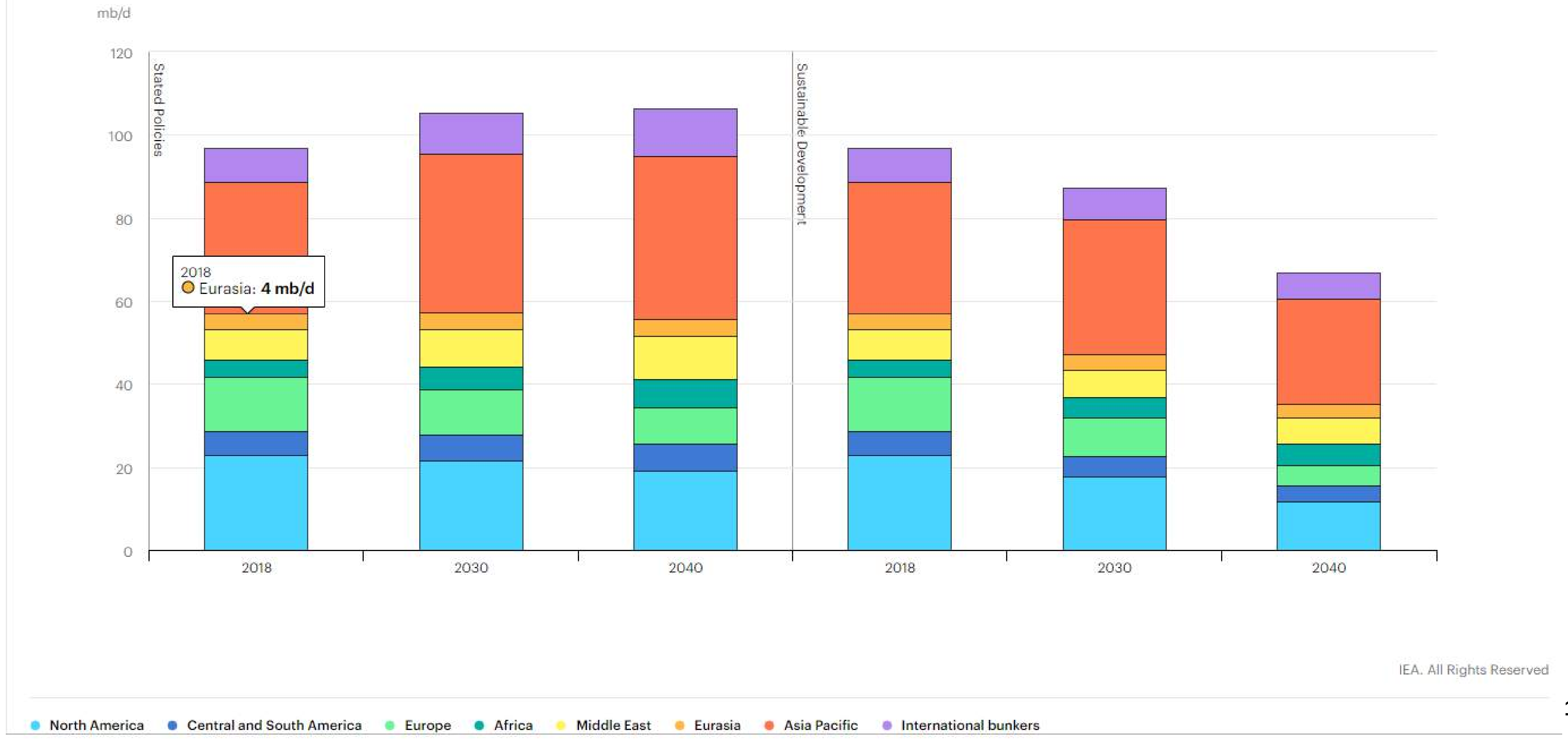
- Fuel prices are often very local and difficult to extrapolate from US or other data sources.
- Fuel costs are impacted strongly by subsidies or delivery costs.
- Some sources for Fuel Price Forecasts:
  - US EIA Annual Energy Outlook Data
  - US EIA Short-Term (next few years)
  - IEA Global Oil Forecast

Figure 1. World oil prices in three cases, 2000–2050

2020 dollars



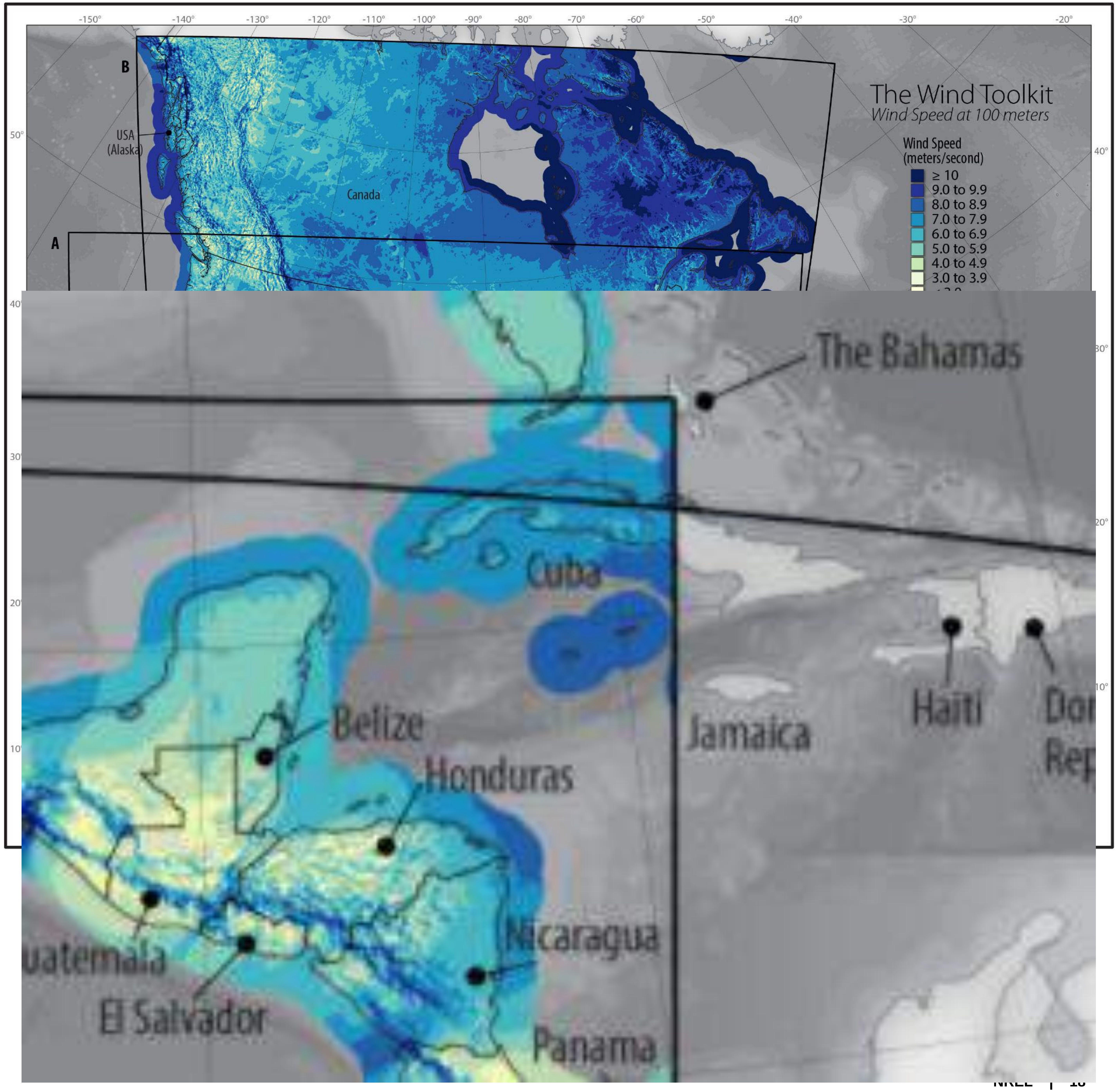
Source: U.S. Energy Information Administration. *Annual Energy Outlook 2021*, National Energy Modeling System runs REF2021.D113020A, HIGHPRICE. D113020A, LOWPRICE. D113020A



Wind Resource Data

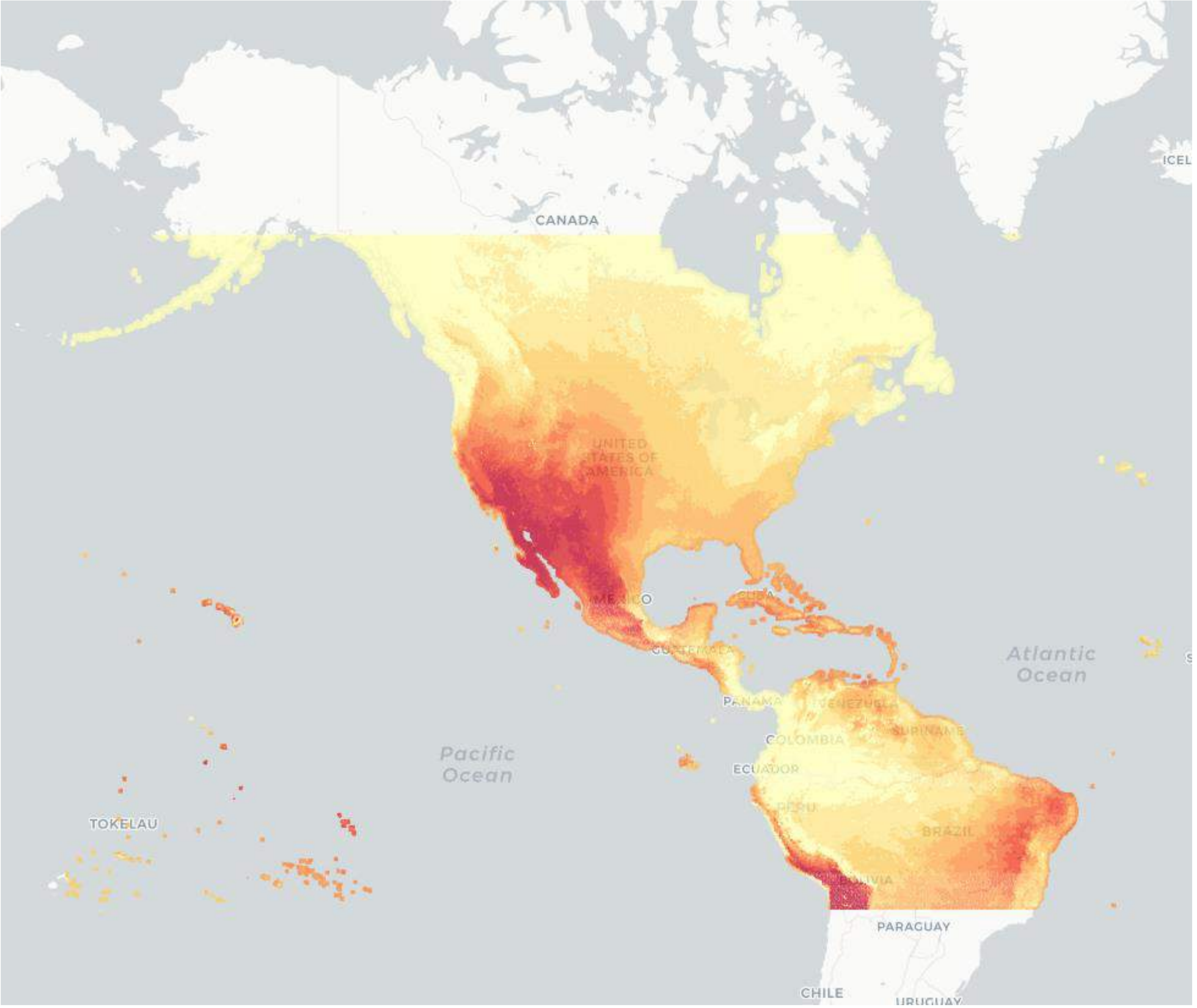
- Key to understanding both land-based and offshore (more likely in the future)
- Need Hourly or sub-hourly wind data
  - available for much of Caribbean at NREL Wind Toolkit
  - https://www.nrel.gov/grid/wind-toolkit.html
  - Wind Prospector interactive tool
  - https://maps.nrel.gov/wind-prospector

- DOE Wind Maps and Data
  - https://windexchange.energy.gov/maps-data



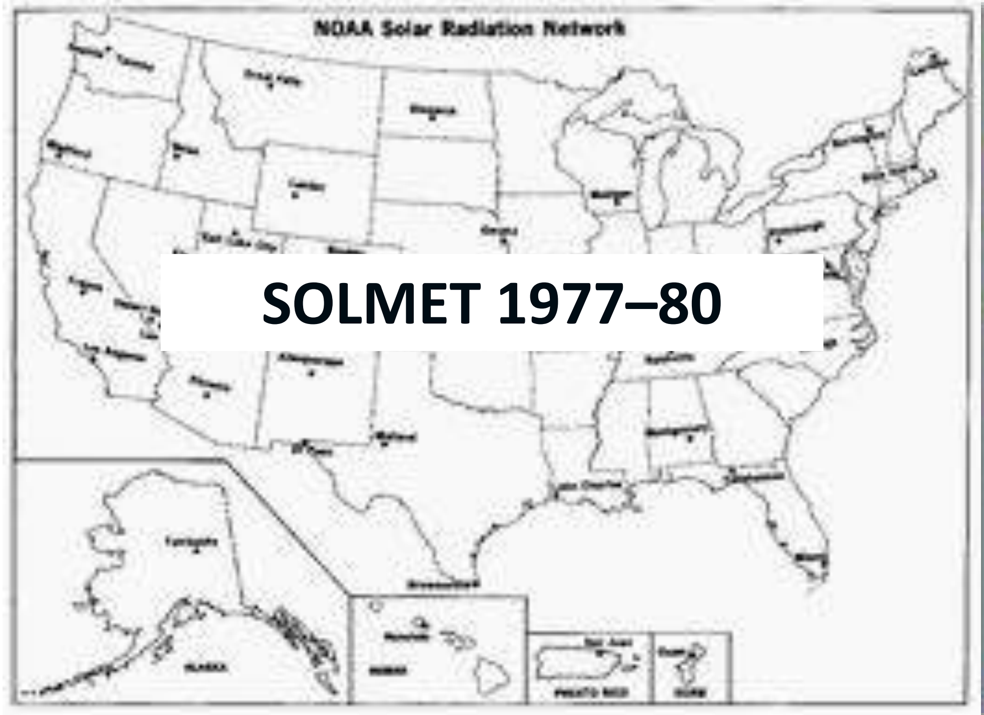
Weather Data- NSRDB

- NREL National Solar Radiation Database
- Free 30-min data on a 4km x 4km grid for most of the Western hemisphere and a square surrounding India
- Ongoing effort to create new, more precise data and for a larger extent
- 20+ years (and TMY) data
- https://nsrdb.nrel.gov/

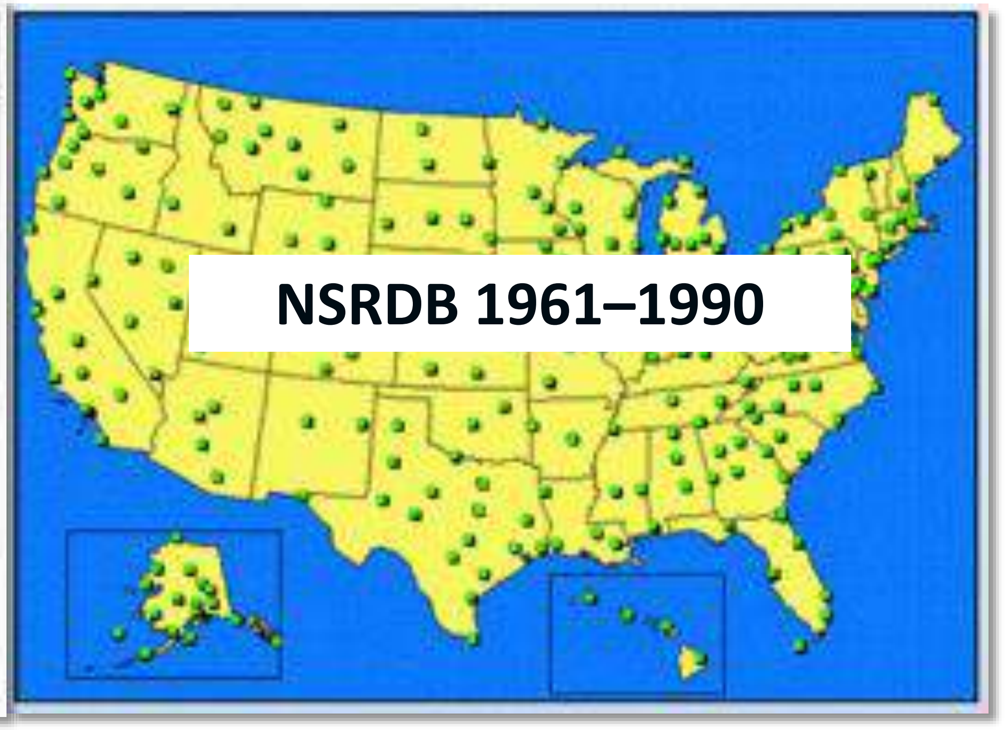


Available via automatic download in both SAM and REopt

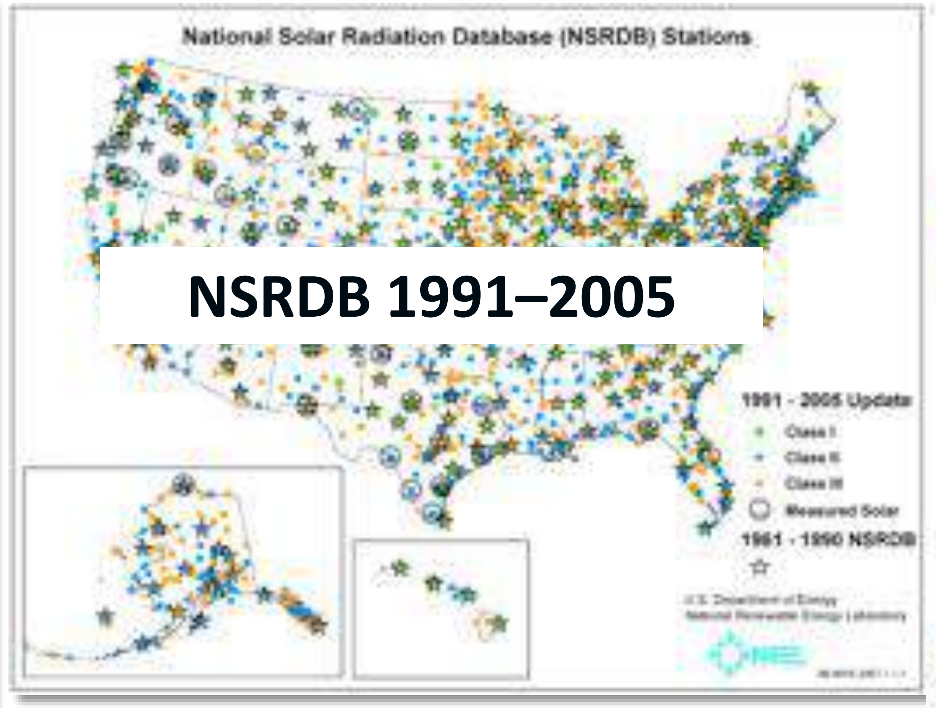
Evolution of the National Solar Radiation Database (NSRDB)



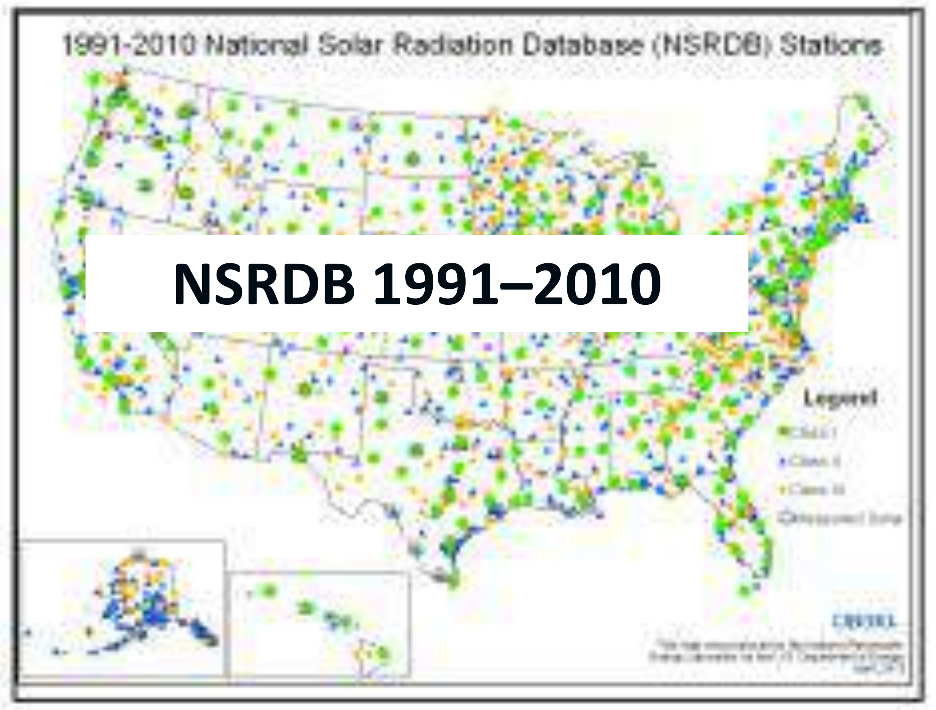
248 weather stations with 26 ***Solar measurement*** stations [ERDA, NOAA, 1979]



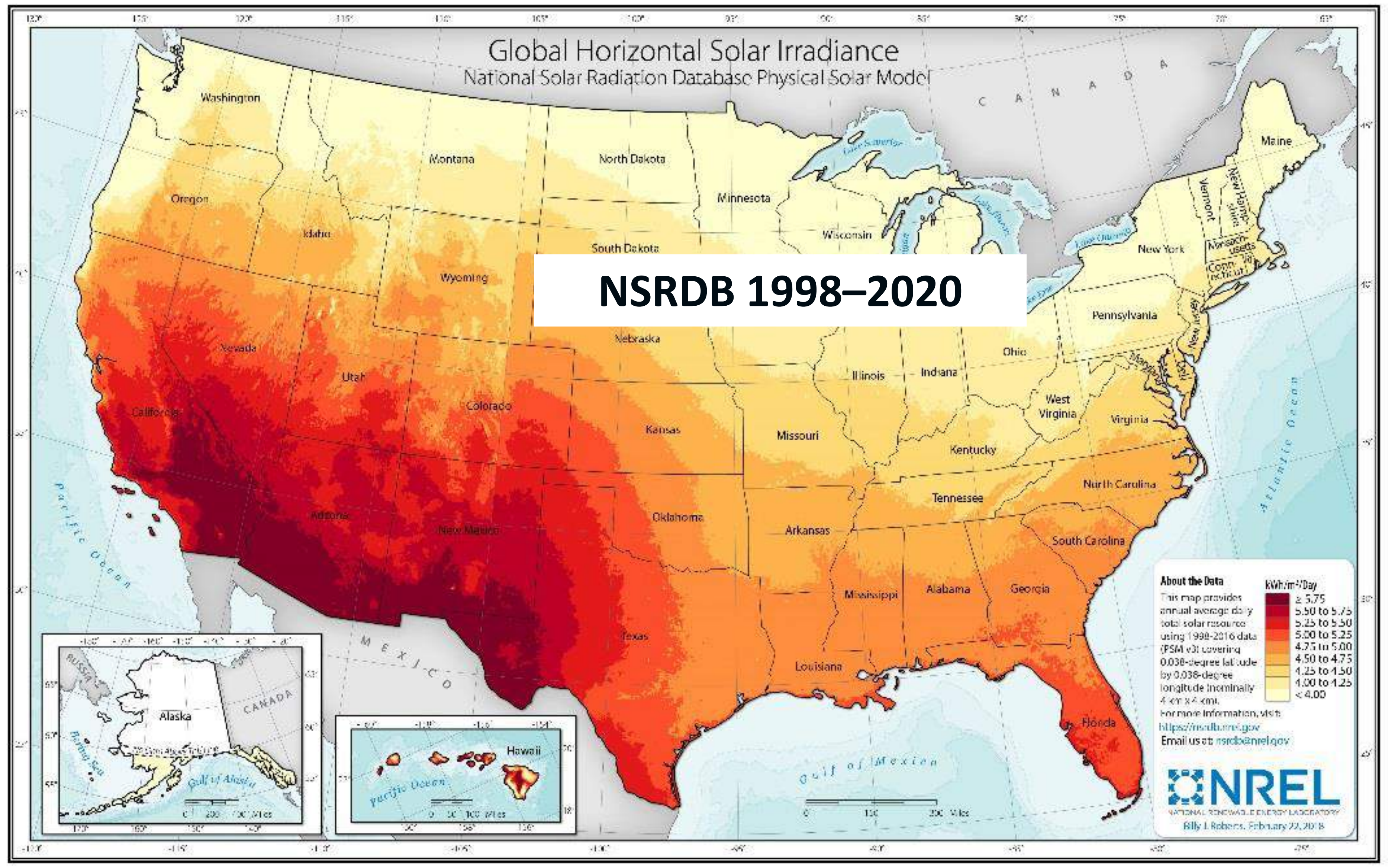
239 ***modeled*** stations with 56 partial measurement stations [DOE, NOAA, 1994]



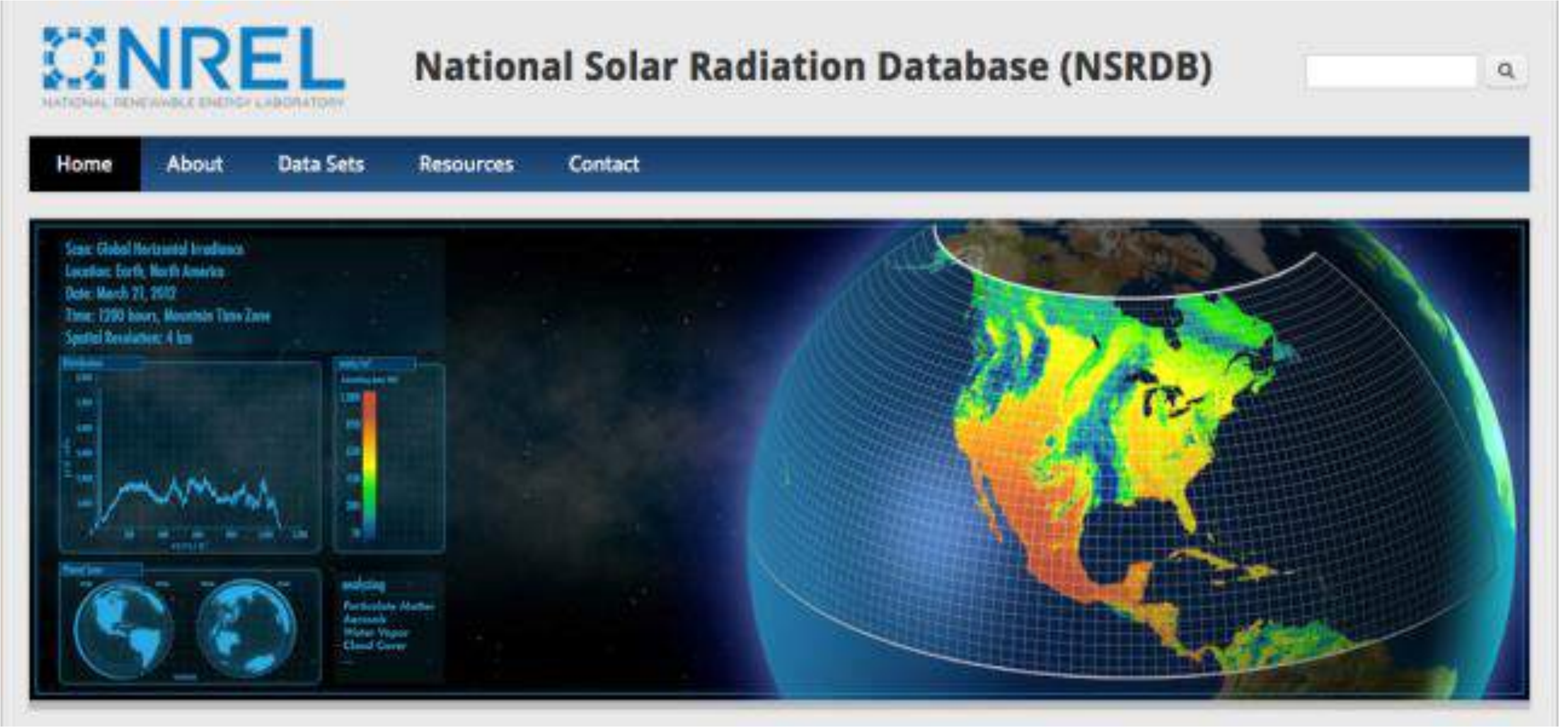
1,454 ***modeled*** locations [DOE, SUNY-A, NOAA, 2007]



1,454 ***modeled*** locations [DOE, CPR, 2012]



Satellite-based, gridded, 4 km x 4 km, half-hourly [DOE, NOAA, UW, SCS 2016]



http://nsrdb.nrel.gov

Other Resource Data

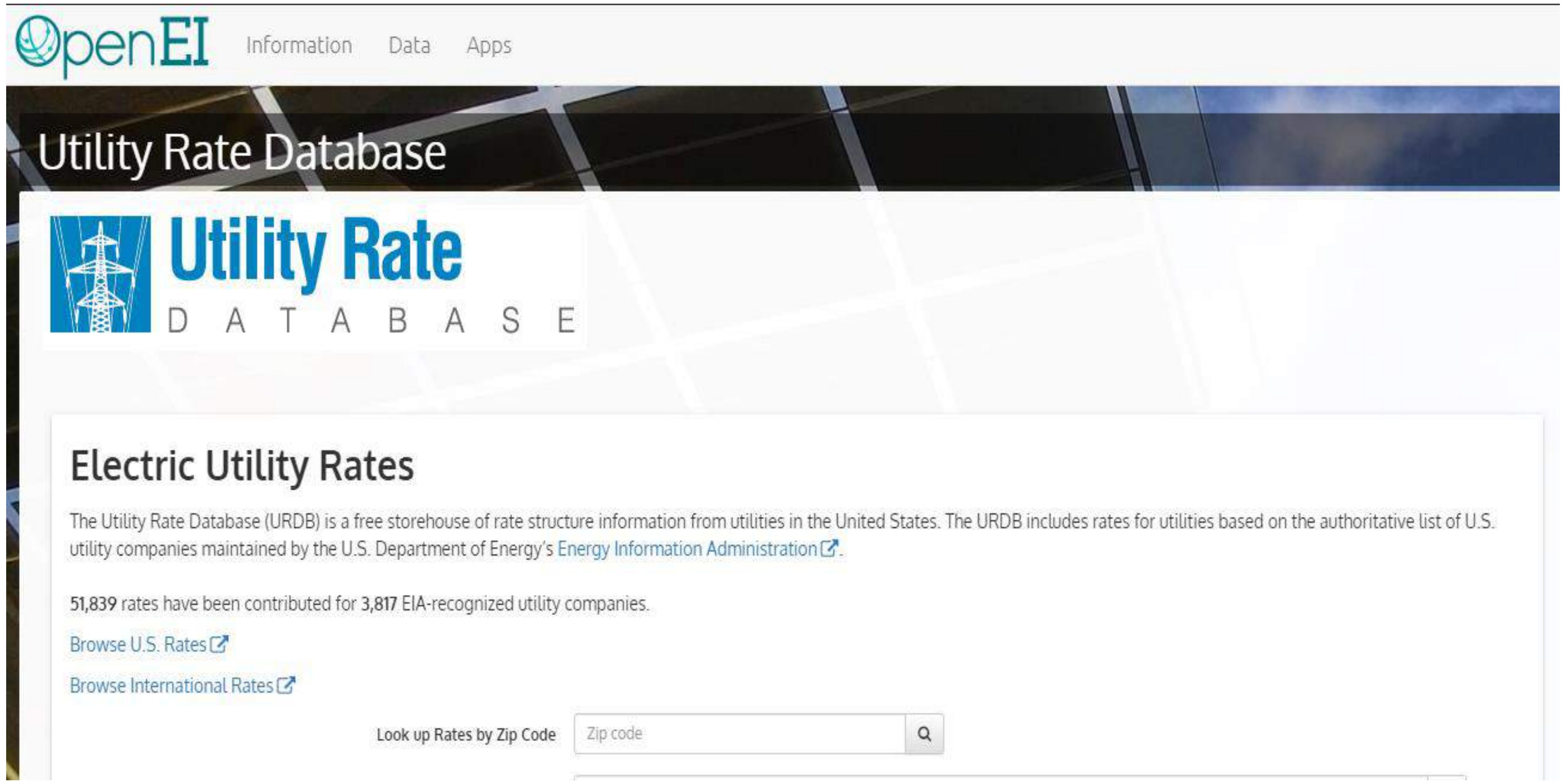
- Geothermal
  - Geothermal resource is very local. If available, likely worth pursuing.
  - IRENA https://www.irena.org/geothermal

Hydro

- Very local data unfortunately
- Very important to confirm hydro changes (rainfall) over last 10 years and forecasted into the future.

Utility Rates for Behind-the-Meter-URDB

- Utility rate database hosted on Open Energy Information (OpenEI) with utility rates for the United States & some international locations
- 70%+ of US load captured via NREL updates every year.
- International Rates can be added and are included currently at a low level.



Available via automatic download in several NREL tools.

Current URDB capabilities

Can accurately represent:

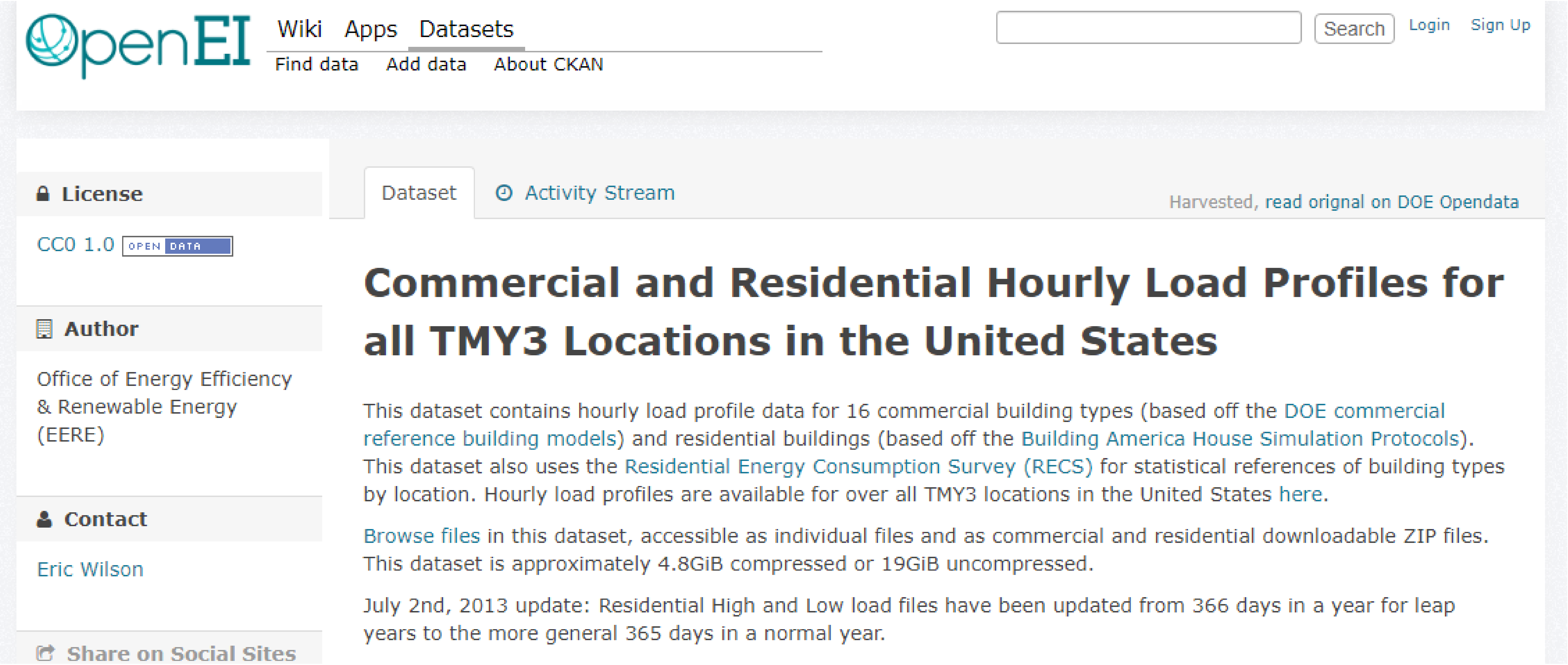
Residential and Commercial Rates, including
1) Time-of-Use rates
2) Tiered rates
3) Seasonal rates
4) Flat rates
4) Rates with applicability rules

Cannot accurately represent:

1) Nested tier rates
2) Racheting tier blocks
3) Excess demand charges

Electric Load Information

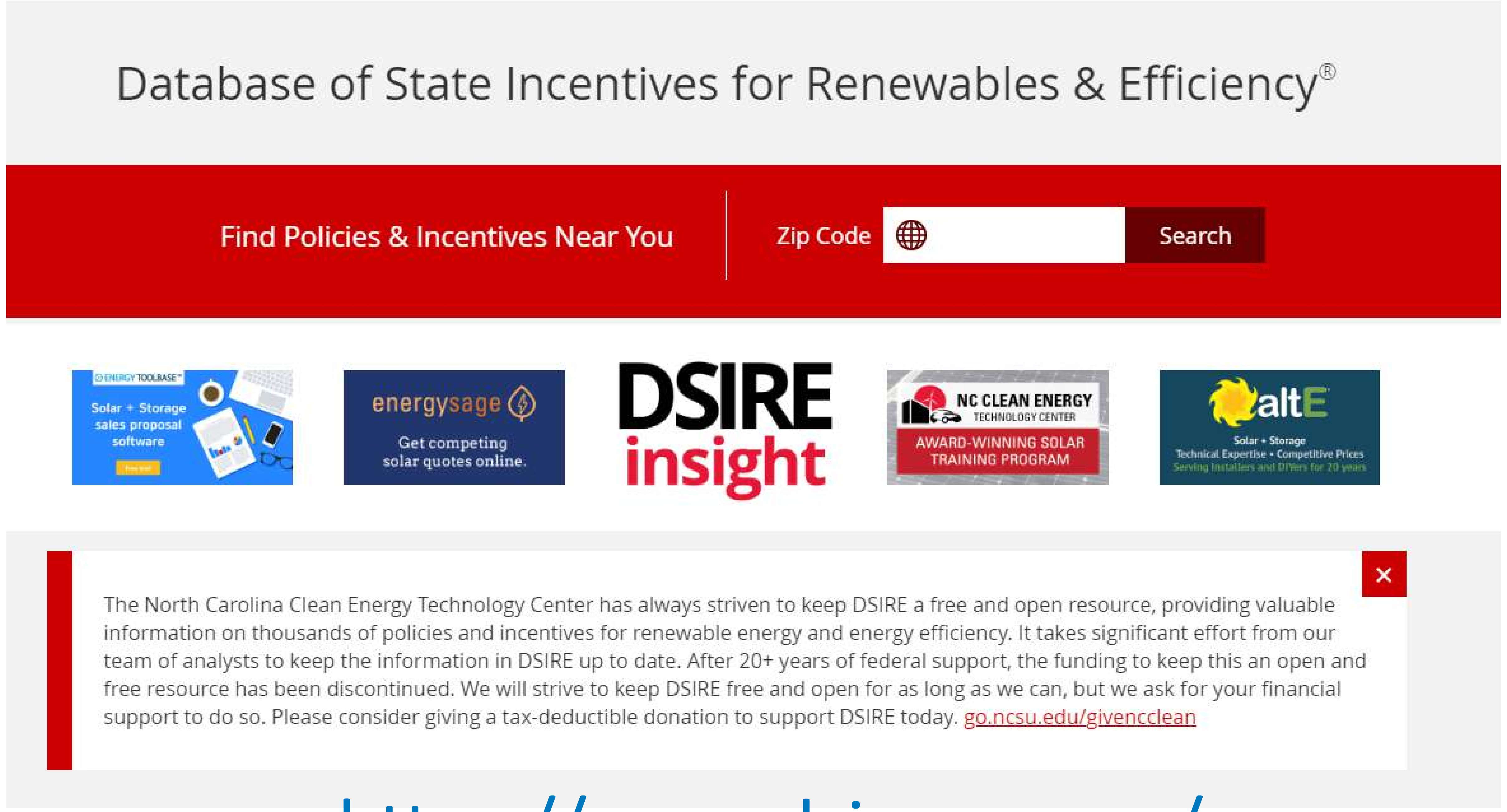
- OpenEI also contains typical electric loads for three levels of residential usage and many different types of commercial buildings and various locations



Available via automatic download in both SAM and REopt

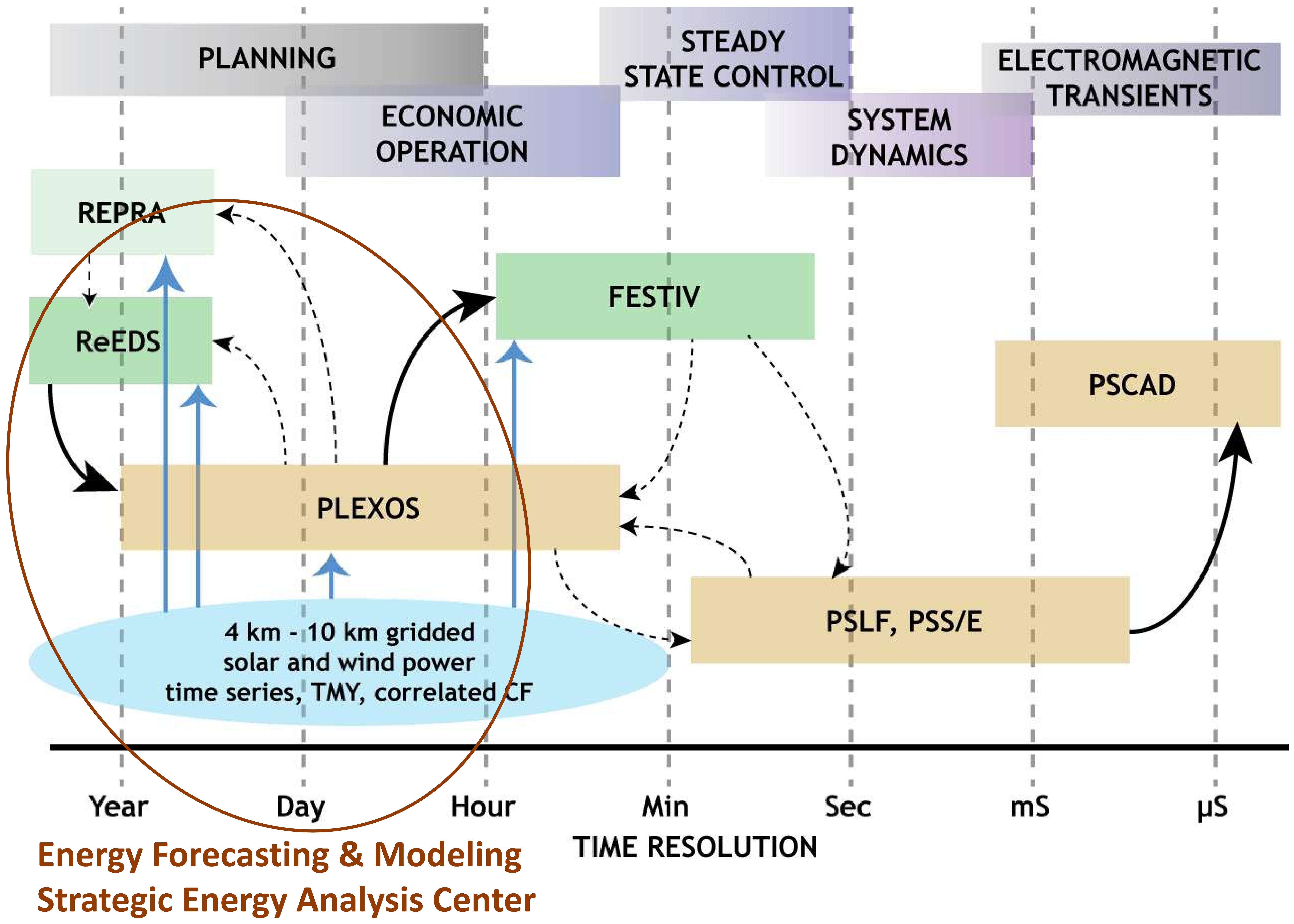
Incentive Information

- Incentives, subsidies and import taxes are all critical to planning.
- For example, DSIRE USA catalogs many US federal, state, and local incentives- not always up to date

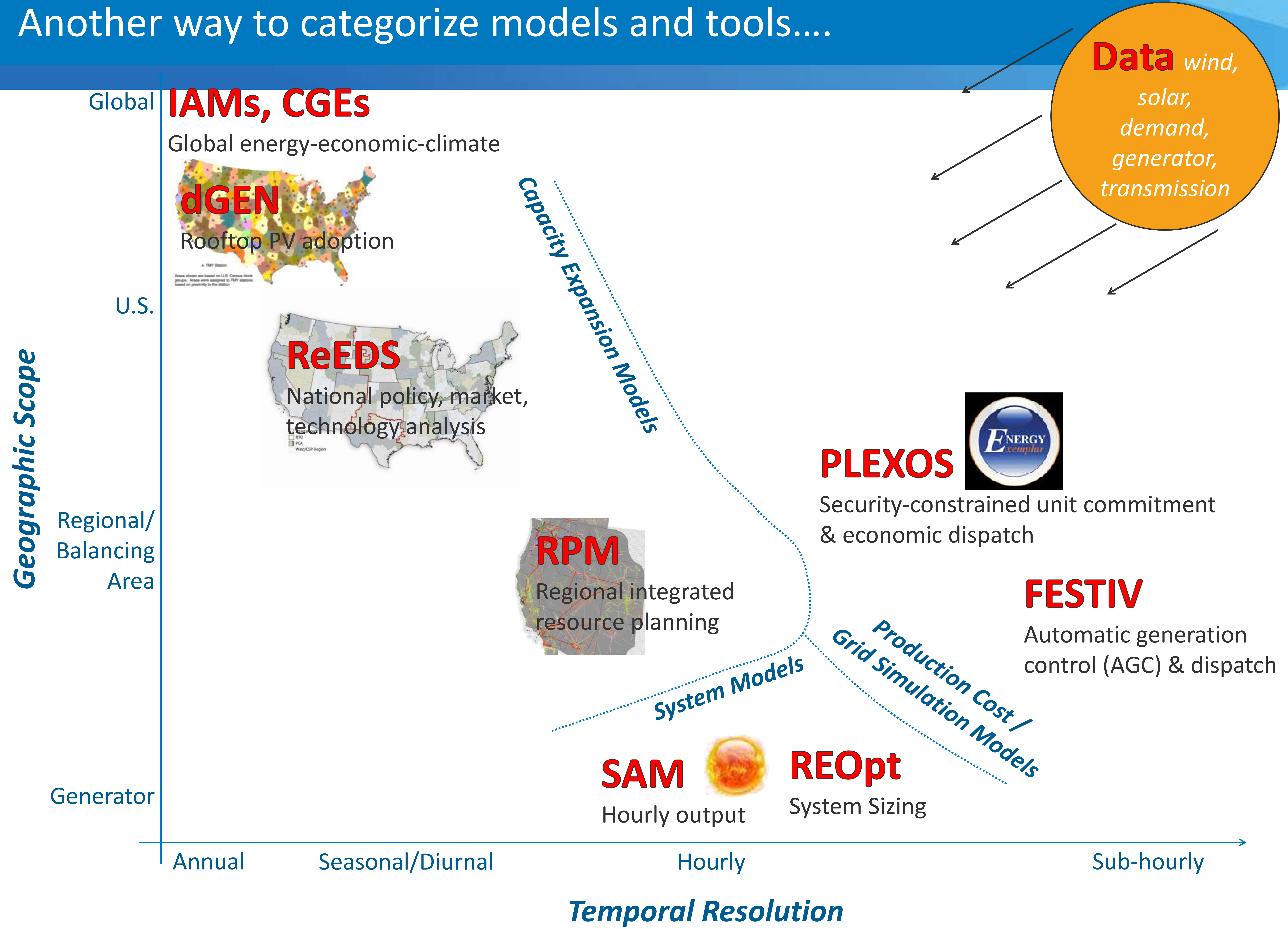


https://www.dsireusa.org/

NREL models designed for different timescales

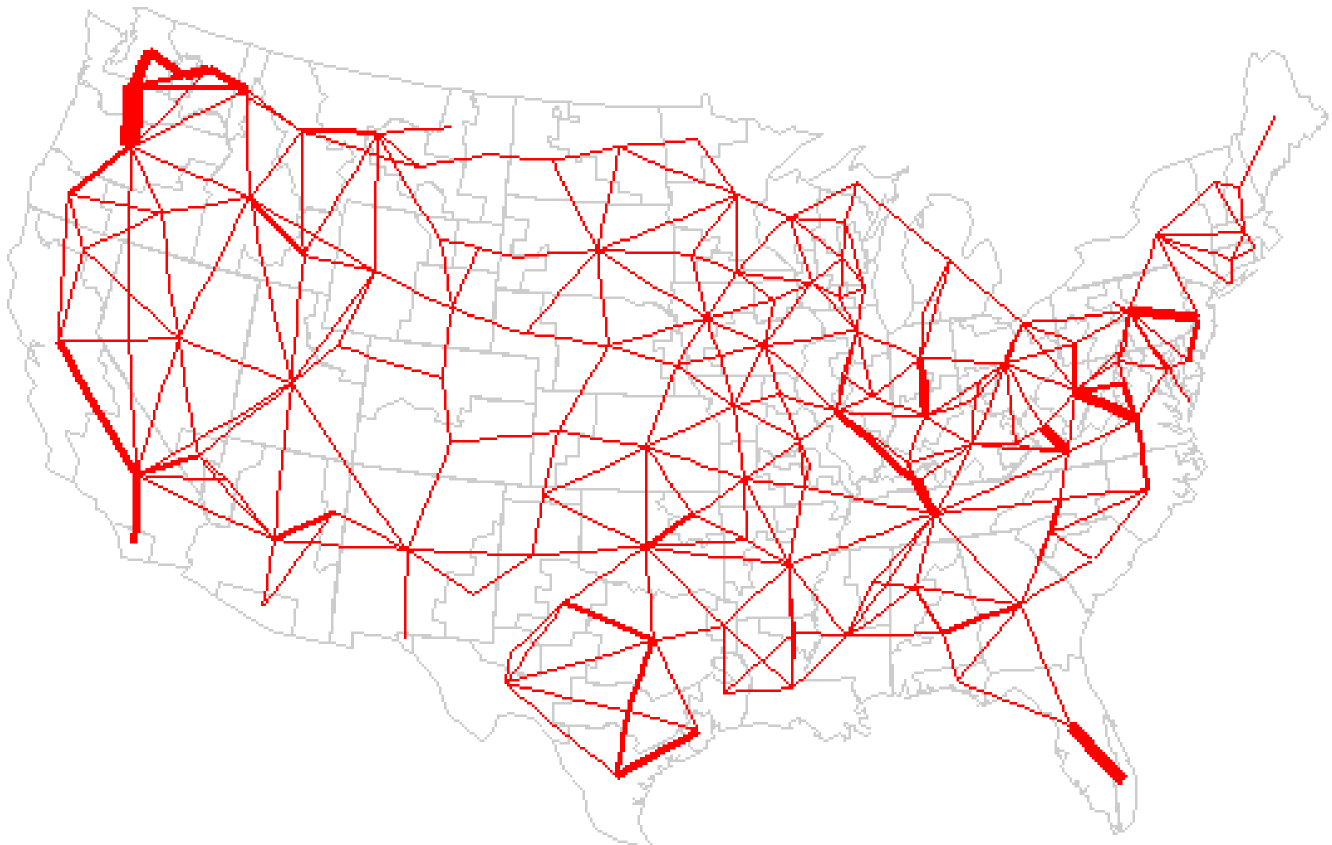


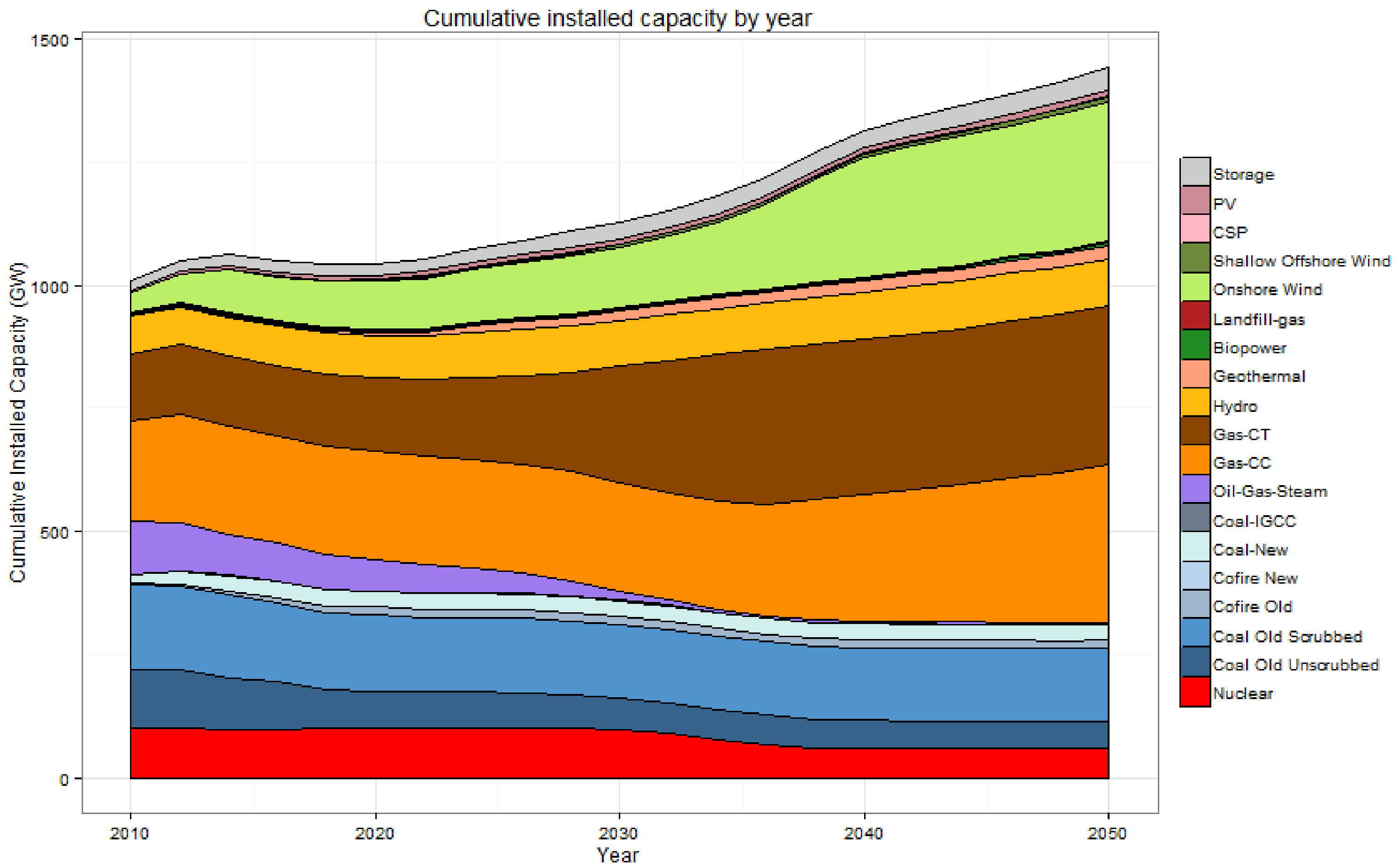
Another way to categorize models and tools….



Regional Energy Deployment System (ReEDS) Model

Contact: Wesley.Cole@nrel.gov





Brown, Maxwell, Wesley Cole, Kelly Eurek, Jon Becker, David Bielen, Ilya Chernyakhovskiy, Stuart Cohen, et al. 2020. *Regional Energy Deployment System (ReEDS) Model Documentation: Version 2019PDF*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-74111.

www.nrel.gov/analysis/reeds

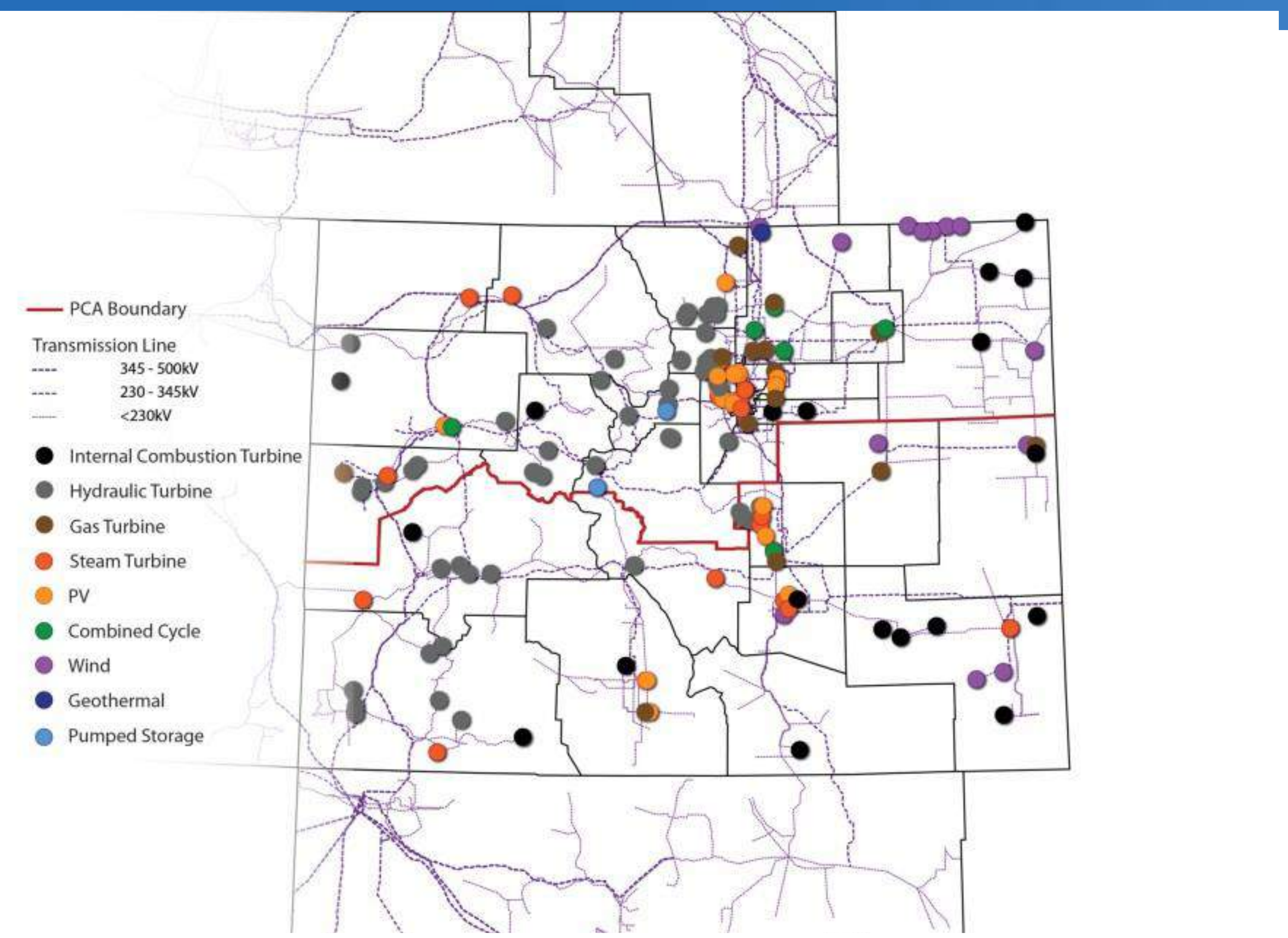
Purpose: Regional Energy Deployment System (ReEDS) is a linear optimization model of U.S. electricity investment and operation focused on issues of particular importance to developing renewable energy technologies (RETs).

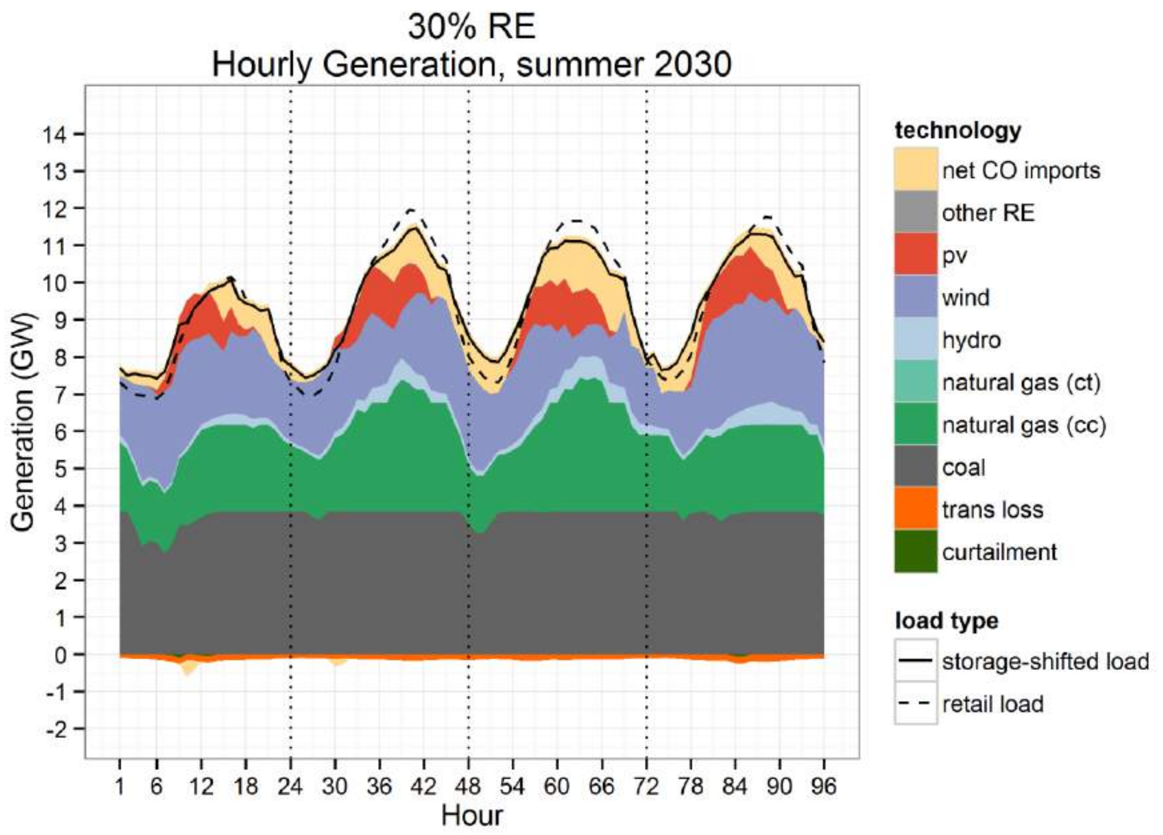
Key Features:

- Produces scenarios of electricity system development from 2010-2050 under a range of policy, technology, and economic conditions.
- Optimizes sequential 2-year tranches of investment and operation for least cost.
- Detailed spatial structure resolves patterns of load and resource distribution, allows representation of transmission needs.
- Full suite of electricity generating technologies: fossil, renewable, nuclear, and electricity storage systems.
- Reduced transmission system obeys Kirchoff's voltage law, distributes power from generators to loads realistically.
- RETs are supported by detailed resource assessments and supply curves.
- Statistical calculations describe how RETs contribute to system adequacy and affect operational reliability, assuring that ReEDS-developed electricity systems are robust.
- Results Viewer at: https://cambium.nrel.gov/

Resource Planning Model (RPM)

Contact: Trieu.Mai@nrel.gov





Mai, T.; Drury, E.; Eurek, K.; Bodington, N.; Lopez, A.; Perry, A. (2013). Resource Planning Model: An Integrated Resource Planning and Dispatch Tool for Regional Electric Systems. 69 pp.; NREL Report No. TP-6A20-56723.

Purpose: New capacity expansion model with high spatial and temporal resolution that can be used for mid- and long-term scenario planning of regional power systems. Developed with a flexible platform to model a large number of focus regions.

Key Features:

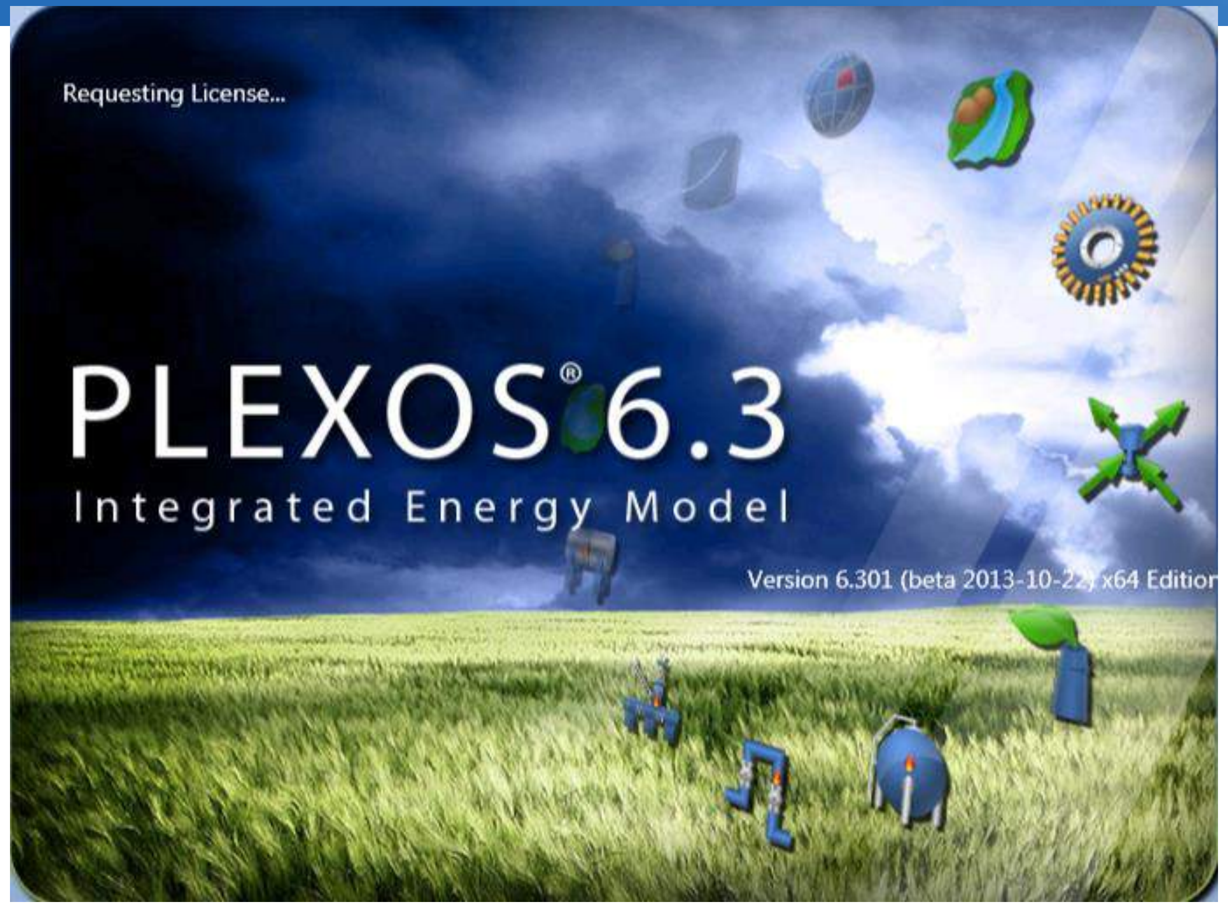
- Endogenously and dynamically considers grid integration of renewable resources, including transmission and interconnection availability and costs, renewable resource limits and output characteristics, and dispatch options for conventional generators, in its optimal decision-making.
- RPM is an hourly chronological model with a highly discretized regional structure, and includes unit commitment and economic dispatch modeling within its capacity expansion framework.
- Initial version was developed to model the power system in Colorado, but the model can be adaptable to other regions.

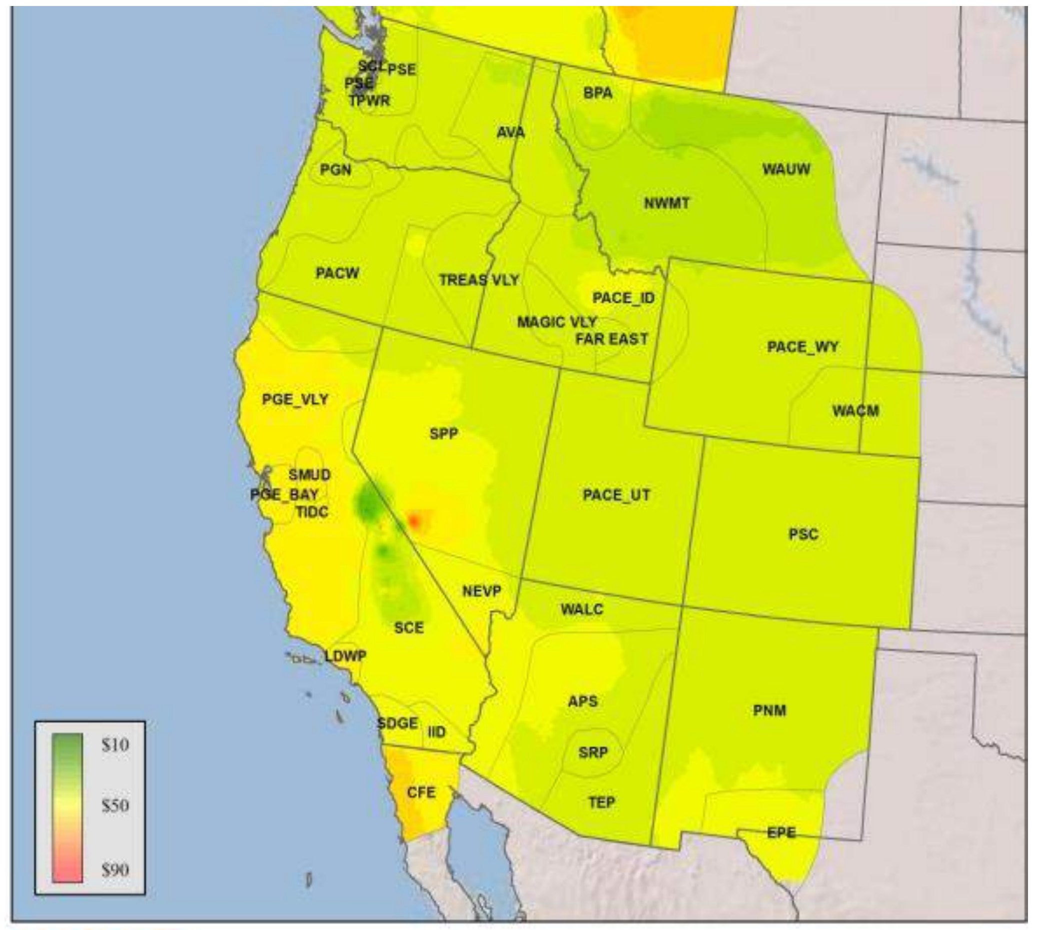
Current Developments:

- Inclusion of other BAs in the Western Interconnection to better represent boundary conditions and to enable modeling of other Western U.S. systems (e.g. Southwest)
- DC optimal power flow modeling
- Unit- and line-specific modeling within the focus study region
- Improved clustering methods developed to more rigorously aggregate solar, wind, and demand for model representation

PLEXOS Integrated Energy Model

Contact: Gregory.Brinkman@nrel.gov





Recent study:
Lew, D., et al. (2013). *The Western Wind and Solar Integration Study Phase 2*, NREL/TP-5500-55588. Golden, CO: National Renewable Energy Laboratory.

Purpose: Commercial electric power system simulation tool that can help understand the issues associated with integration of variable and uncertain generation technologies.

Key Features:
- Performs unit commitment and economic dispatch at nodal or zonal resolution at time steps as small as 5 minutes.
- Optimizes usage of enabling technologies, such as demand response, plug-in vehicle charging, and electricity storage.
- DC optimal power flow modeling
- Ability to model different types of ancillary services, market horizons, and forecast windows
- Databases available for the eastern and western interconnections in the U.S.
- Used for major studies including the Western Wind and Solar Integration Study (Phase 2) and the Eastern Renewable Generation Integration Study
- Mixed Integer Program
- Ability to model stochastic optimization

Current Developments:
- Integrated gas-electricity sector energy model
- Ability to run on a High Performance Computing cluster
- Refining database for the eastern interconnection

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Integrated Resource and Resilience Planning in the Energy Sector: Data for the 2nd R

ICF

Juanita Haydel, ICF
Senior Vice President – Energy Markets

04 March 2021

Integrated Resource and Resiliency Planning (IRRP)

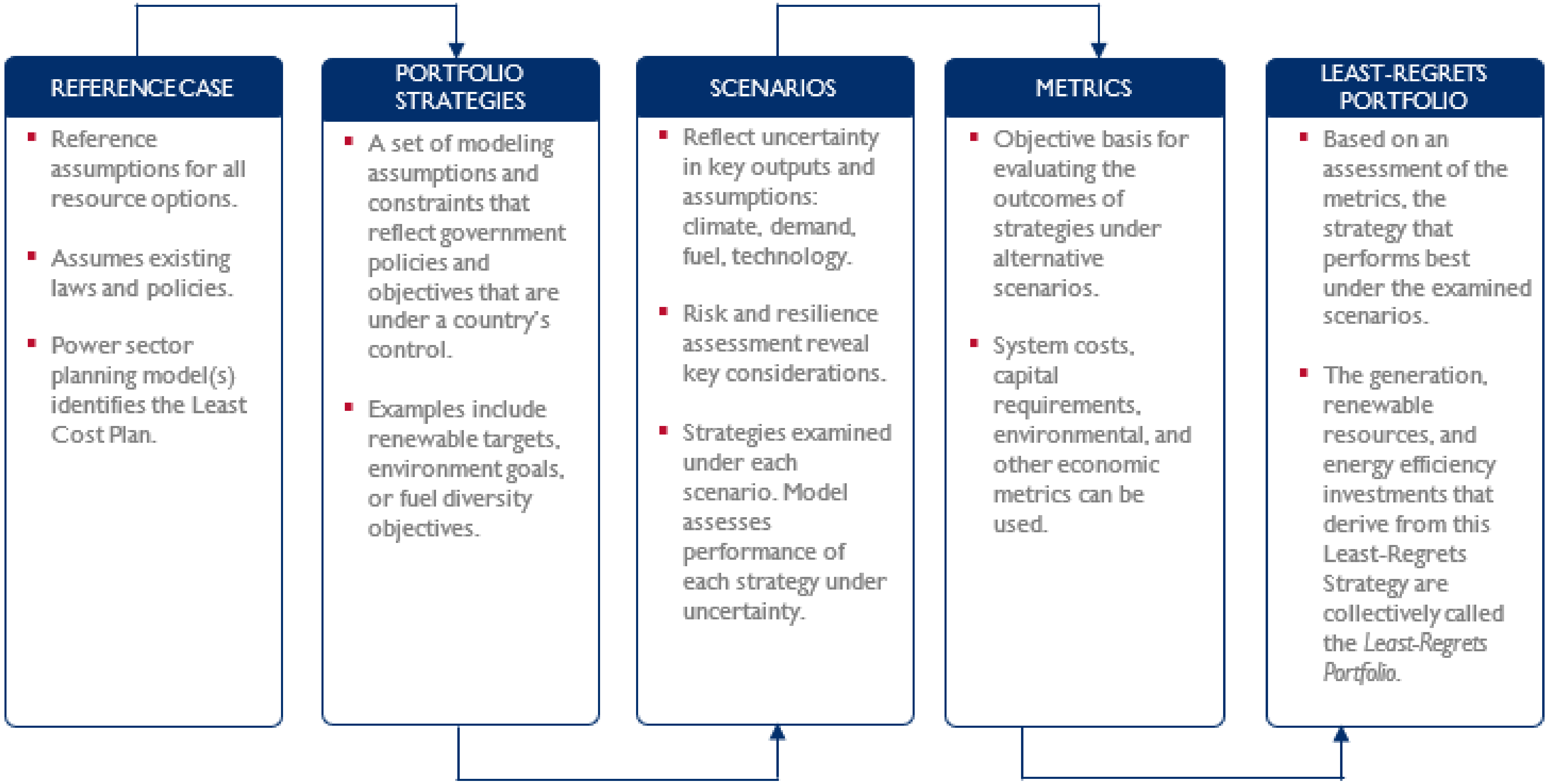
A method for developing a power system investment plan that explicitly addresses risks and resiliency concerns, including potential impacts from climate change.

- Identifies and evaluates a range of investment portfolios using a set of criteria, including cost, reliability, and environmental impacts.
- Assesses portfolio resiliency against uncertain variables, such as climate change, regulatory changes, etc.
- Generates a "least-regrets" plan that is robust and resilient under a range of possible futures that reflect inherent risks and uncertainties
- Insurance against worse outcomes
- Leads to better outcomes and informs decision making

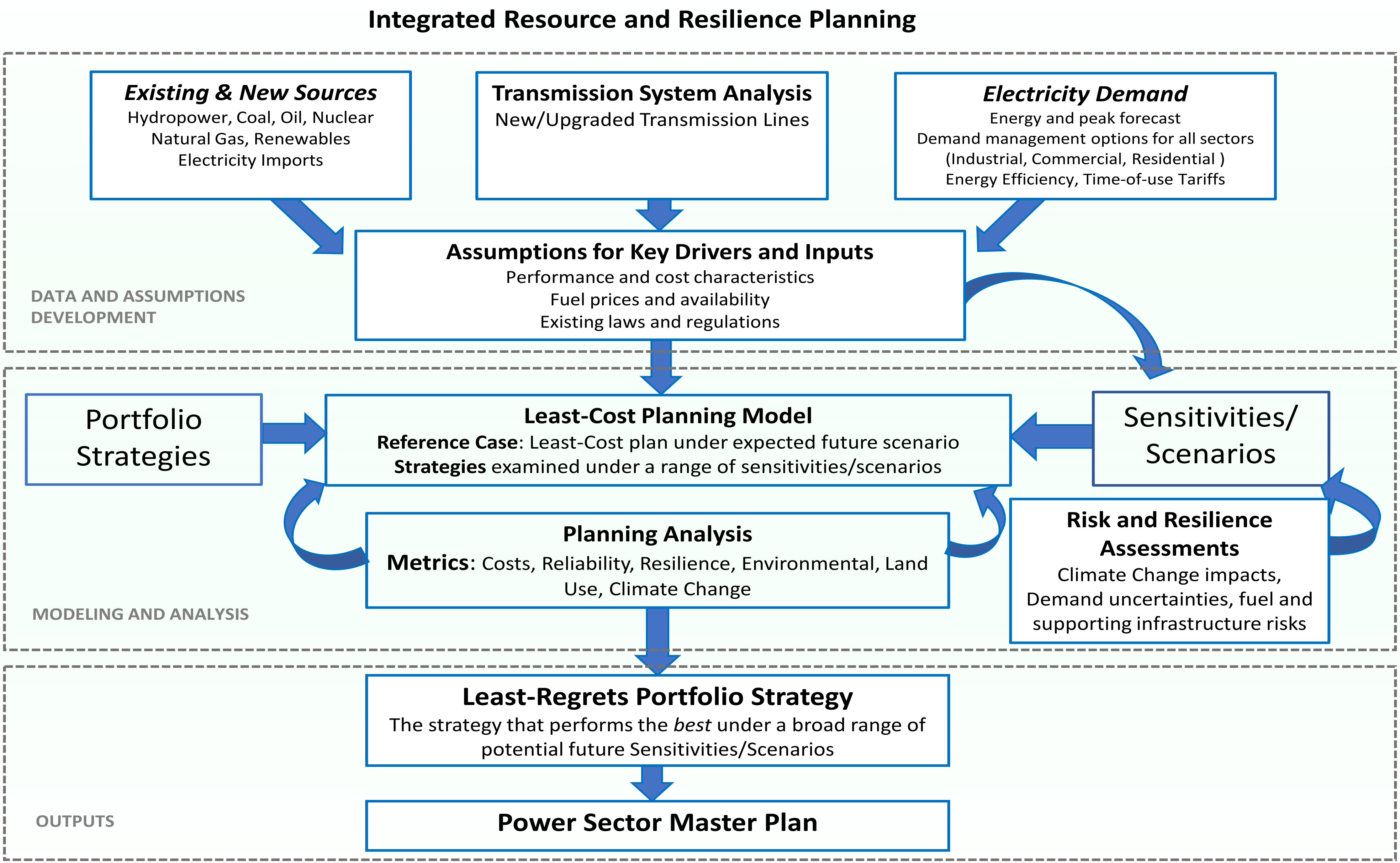
Traditional Power Sector Planning vs. IRRP

Traditional Planning	Cost	Cumulative investment; system costs
	Reliability	Unserved energy; unserved peak demand; transmission congestion
Added by IRRP	Resilience	**Ability to prepare for and adapt to changing conditions and recover from disruptions**
	Local Environment	Air quality (SOx, NOx emissions); ash production
	Land Use	Land area used for power plants
	Climate Change	Greenhouse gas emissions

A **Resilient Power System** can resist, adapt to, and recover quickly from low-probability, high-risk extreme events, including extreme natural disasters and human-caused attacks. It can provide reliable and secure power as longer term climate changes occur and affect the power system.



REFERENCE CASE
Reference assumptions for all resource options.
Assumes existing laws and policies.
Power sector planning model(s) identifies the Least Cost Plan.
PORTFOLIO STRATEGIES
A set of modeling assumptions and constraints that reflect government policies and objectives that are under a country's control.
Examples include renewable targets, environment goals, or fuel diversity objectives.
SCENARIOS
Reflect uncertainty in key outputs and assumptions: climate, demand, fuel, technology.
Risk and resilience assessment reveal key considerations.
Strategies examined under each scenario. Model assesses performance of each strategy under uncertainty.
METRICS
Objective basis for evaluating the outcomes of strategies under alternative scenarios.
System costs, capital requirements, environmental, and other economic metrics can be used.
LEAST-REGRETS PORTFOLIO
Based on an assessment of the metrics, the strategy that performs best under the examined scenarios.
The generation, renewable resources, and energy efficiency investments that derive from this Least-Regrets Strategy are collectively called the Least-Regrets Portfolio.



Integrated Resource and Resilience Planning
Existing & New Sources
Hydropower, Coal, Oil, Nuclear
Natural Gas, Renewables
Electricity Imports
Transmission System Analysis
New/Upgraded Transmission Lines
Electricity Demand
Energy and peak forecast
Demand management options for all sectors
(Industrial, Commercial, Residential)
Energy Efficiency, Time-of-use Tariffs
Assumptions for Key Drivers and Inputs
Performance and cost characteristics
Fuel prices and availability
Existing laws and regulations
DATA AND ASSUMPTIONS DEVELOPMENT
Portfolio Strategies
Least-Cost Planning Model
Reference Case: Least-Cost plan under expected future scenario
Strategies examined under a range of sensitivities/scenarios
Sensitivities/ Scenarios
Planning Analysis
Metrics: Costs, Reliability, Resilience, Environmental, Land Use, Climate Change
Risk and Resilience Assessments
Climate Change impacts, Demand uncertainties, fuel and supporting infrastructure risks
MODELING AND ANALYSIS
Least-Regrets Portfolio Strategy
The strategy that performs the best under a broad range of potential future Sensitivities/Scenarios
Power Sector Master Plan
OUTPUTS

IRRP requires a toolbox of models and approaches to support analysis and decision making

Demand forecasting approaches, which may range from econometric approaches to sector and end-use based models, should be capable of assessing climate impacts.

Energy efficiency assessment methods, including end-use load monitoring and analysis data to represent load, load shapes, and load shape impacts; building stock and usage data; and economic evaluation approaches.

Transmission planning models to examine load flows under alternative conditions and set limits in the long-range planning model, and conduct grid integration analyses.

Distribution planning tools to assess losses, optimize new connections, and improve collections.

Resilience assessment methods, including water resource modeling tools.

Financial analysis tools to assess revenue requirements, capital requirements, and rate impact analysis tools.

A long-term power sector planning model to assess future optimal investment decisions under a range of policy, economic, and technical inputs. A model should cover 20 to 30 years, examine capacity expansion and dispatch decisions, track environmental outcomes, represent transmission limits, and represent the characteristics of all resources.

IRRP in Tanzania: *Considering Climate and Other Risks*

Key Uncertainties are Considered in Scenarios

- **Fuel and Investment Risks**: Heavy dependence on a single fuel can increase volatility of supply and costs.
  - *IRRP can increase fuel diversity*
- **Climate Risks**: Frequent drought in Tanzania has reduced hydro-electricity generation and increased cost of service
  - *IRRP can help optimize the hydro contribution to the portfolio*
- **Demand-side Risks**: Rapid demand growth and poor load factor increases load shedding, resulting in customer dissatisfaction
  - *IRRP can manage demand growth, improve load factor, increase revenue and improve customer satisfaction*

The Telegraph

HOME » NEWS » WORLD NEWS » AFRICA AND INDIAN OCEAN » TANZANIA

Tanzania turns off hydropower as drought bites

Low water levels mean power cuts as electricity crisis bites in East African nation

By Our Foreign Staff

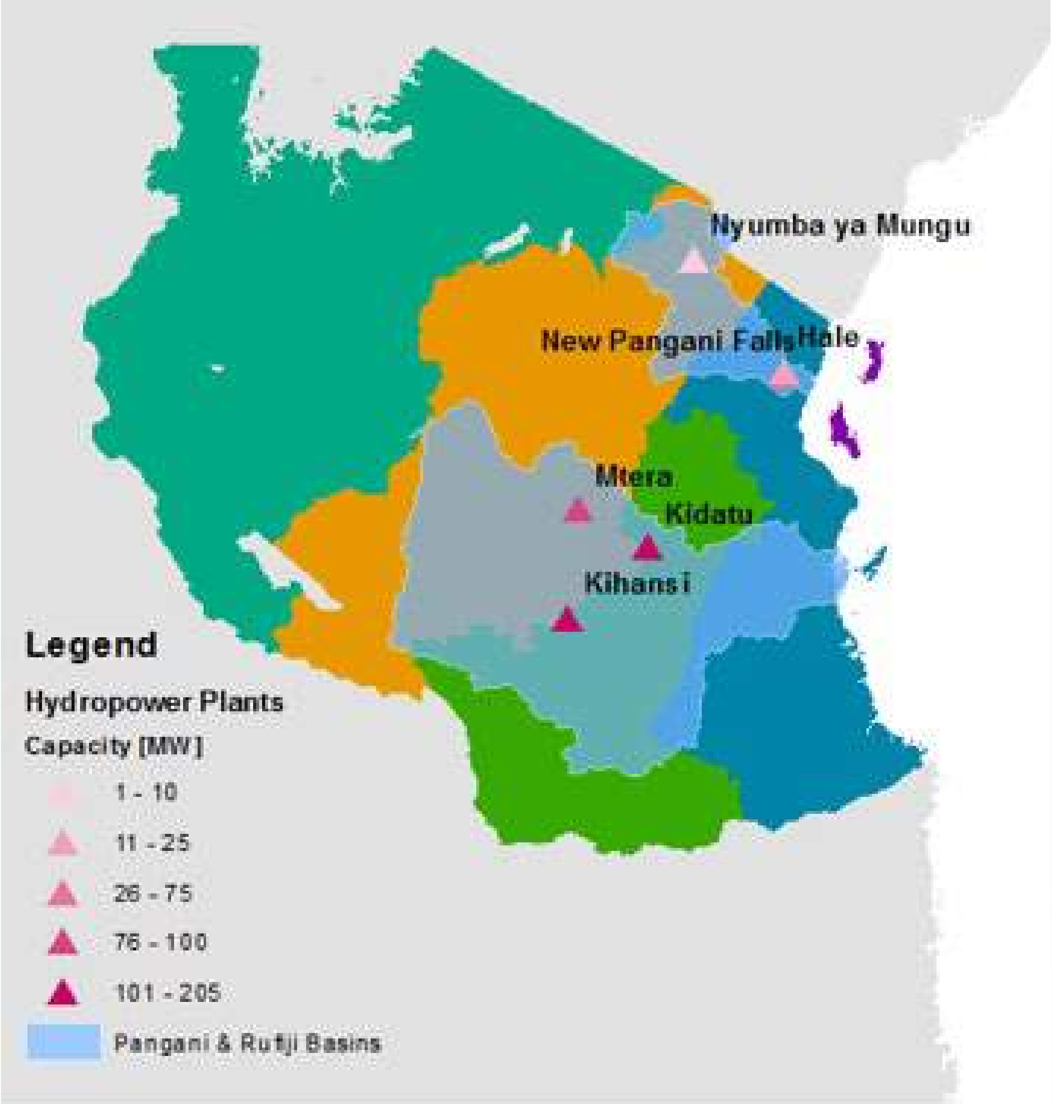
11:32PM BST 09 Oct 2015

Tanzania is shutting down all its hydropower plants because drought is causing low water levels in its dams, plunging the country deep into an electricity crisis.

The East African nation relies on water to produce more than a third of its power.

Tanzania IRRP

Goal: Identify least-regrets power sector plan that is robust and resilient in that performs the best under a broad range of potential techno-economic futures that reflect inherent risks and uncertainties

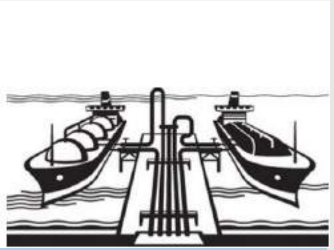


Application of IPM in IRRP

- IPM, along with other key tools, is used to examine a limited number of **portfolio strategies** under a range of scenarios
- A **portfolio strategy** reflects a possible future resource mix that reflects company or governmental policy
  - Focus on small non-hydro renewables
  - Natural gas as a primary fuel source
  - Large scale hydro investment
- These alternative portfolios are examined under a range of **scenarios** that reflect uncertainty in fact ors outside a planner's control (e.g., fuel price or demand growth).
  - Using IPM, we examined 3 portfolios under 7 different scenarios for 21 unique IPM runs.
- **Recommended portfolio strategy** is that strategy that performs well under a broad range of scena rios reflecting uncertain policy and economic futures.
  - Performance is determined by quantitative metrics to measure how plans rank against a baseline and one a nother.

Data Requirements for IPM®

- A combined production cost and capacity expansion simulation model
- A bottom-up partial equilibrium model of the electric sector
- A scenario driven forecasting tool to support decision making

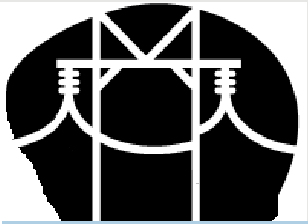


Resource Supply
- Gas Supply
- Coal Supply
- Hydro Supply
- Biomass Supply
- Renewable Potential

Existing Power Plant Variable Cost
- Fuel Transportation
- Fuel Costs
- Heat Rates
- O&M Costs

New and Existing Power Plants
- Coal
- Oil & Gas Steam
- Combustion Turbine
- Combined Cycle
- Geothermal
- Nuclear
- Hydro
- Renewables
- Cogeneration

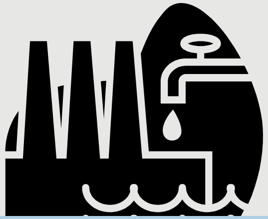
Retrofit Technology
- SCR, SNCR, and new NO_X control options
- Wet and Dry FGD
- ACI and Fabric Filter
- Cobenefits for Hg



Transmission
- New FERC Policies
- Long-term tradeoffs with Generation
- Grid operation

Electric Demand
- Hourly Demand
- Peak & Energy Growth
- Reserve Margin
- Steam Demand

Power Plant Dispatch and Grid Operation
- Economic dispatch



Air Policy Specifications
- NO_X, SO_2, Hg and CO_2
- MACT vs. Cap and Trade
- Banking and Progressive Flow Control
- National, Regional and State Programs
- Renewable Portfolio Standards

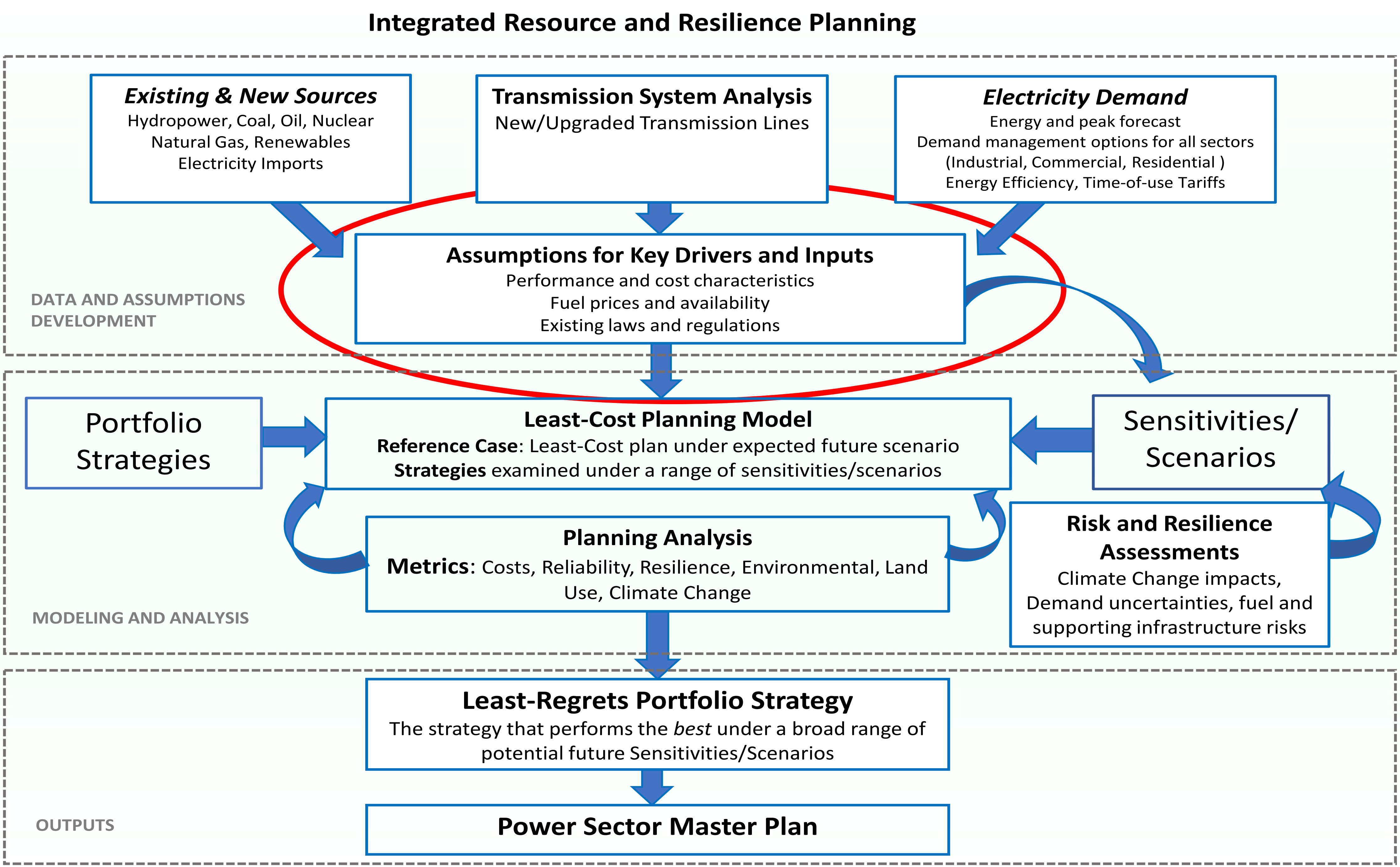
Operation
- Maintenance
- Outages
- Must Run

OPTIMIZATION

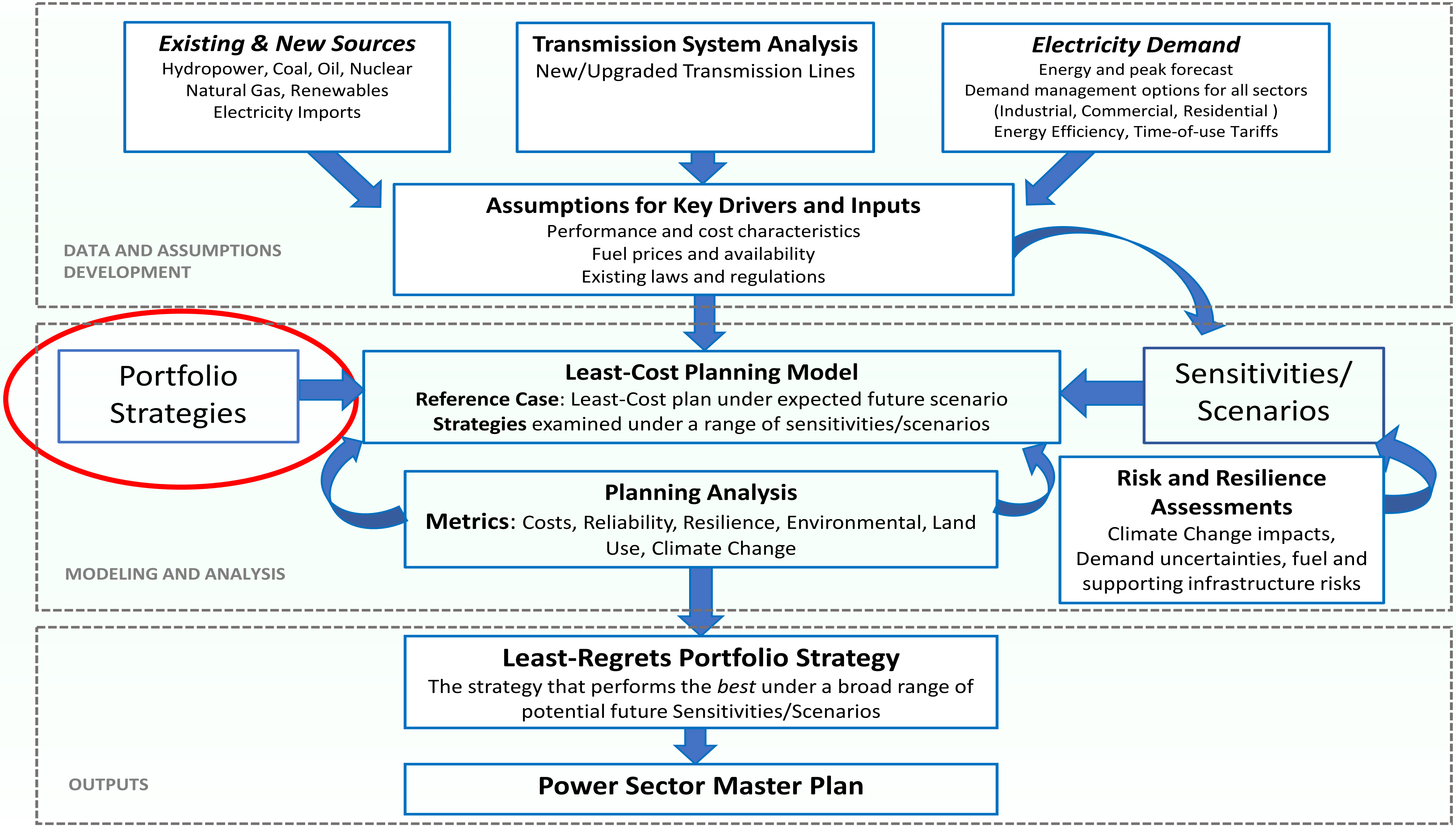
Projections

Power Prices
Fuel Prices
Allowance Prices
Asset Values
Dispatch Decisions
Capacity Build Decisions
Emissions
Compliance Costs
Compliance Decisions
Plant Retirement Decisions

IPM's Inputs and Outputs


Integrated Resource and Resilience Planning
Existing & New Sources
Hydropower, Coal, Oil, Nuclear
Natural Gas, Renewables
Electricity Imports
Transmission System Analysis
New/Upgraded Transmission Lines
Electricity Demand
Energy and peak forecast
Demand management options for all sectors
(Industrial, Commercial, Residential)
Energy Efficiency, Time-of-use Tariffs
Assumptions for Key Drivers and Inputs
Performance and cost characteristics
Fuel prices and availability
Existing laws and regulations
DATA AND ASSUMPTIONS DEVELOPMENT
Portfolio Strategies
Least-Cost Planning Model
Reference Case: Least-Cost plan under expected future scenario
Strategies examined under a range of sensitivities/scenarios
Sensitivities/ Scenarios
Planning Analysis
Metrics: Costs, Reliability, Resilience, Environmental, Land Use, Climate Change
Risk and Resilience Assessments
Climate Change impacts, Demand uncertainties, fuel and supporting infrastructure risks
MODELING AND ANALYSIS
Least-Regrets Portfolio Strategy
The strategy that performs the best under a broad range of potential future Sensitivities/Scenarios
Power Sector Master Plan
OUTPUTS

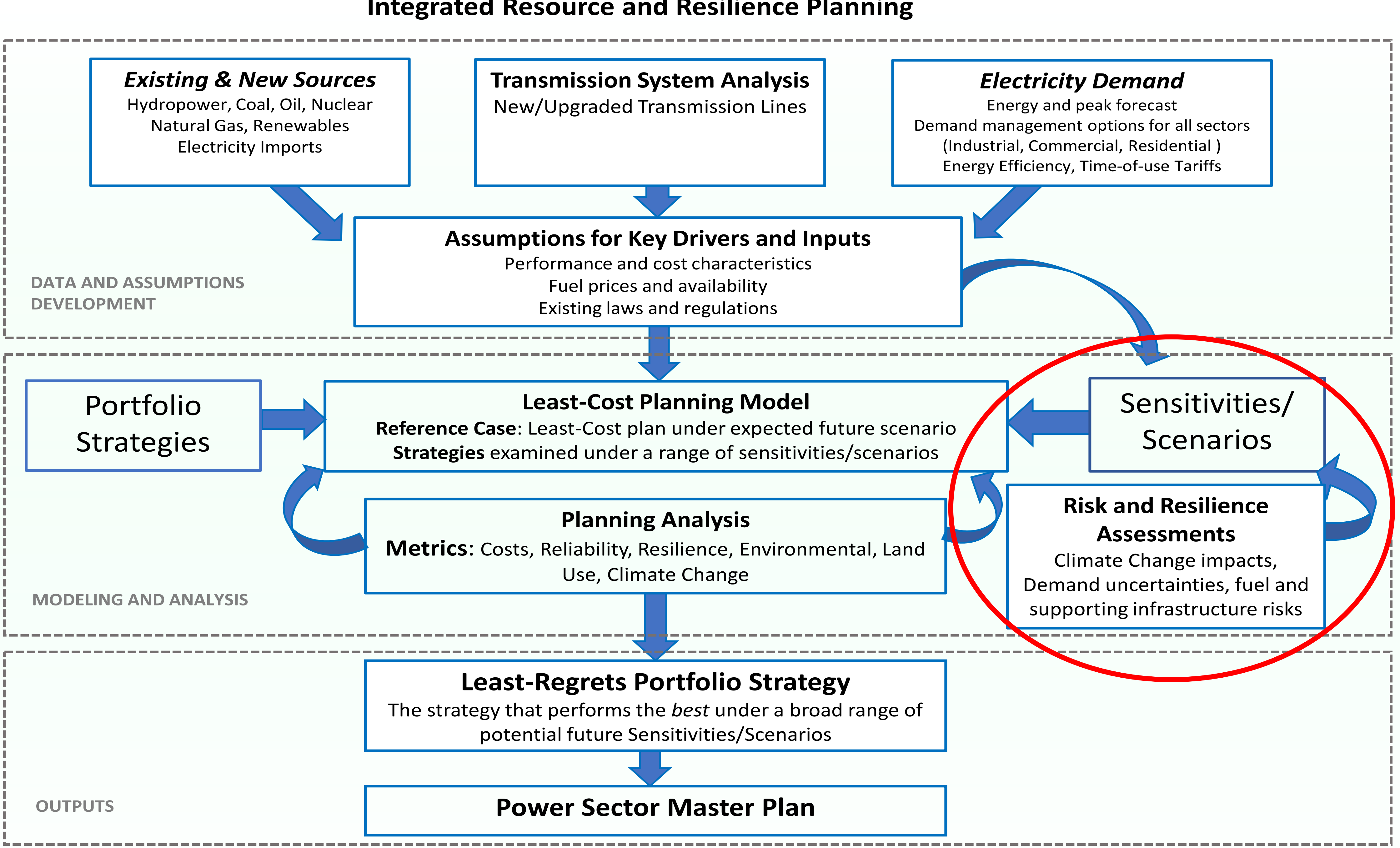
Integrated Resource and Resilience Planning



Resource Portfolio Strategies Development

Three Portfolios Strategies were examined

Portfolio A: Reference	Portfolio B: Limited Large-Scale Investment	Portfolio C: Renewable-centric
▪ An optimal capacity expansion plan under the Base Scenario	▪ Focuses on baseload fossil resources in the near to mid term. ▪ Focus on small scale non-hydro renewables: No hydro resources above 100 MW prior to 2027	▪ Sustainable resources--10% of end-use demand is required to be served by non-hydro renewable resources. ▪ Relative to the Portfolio A, this portfolio has 406 MW more non-hydro renewables and 147 MW less oil in 2036



Integrated Resource and Resilience Planning
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Scenario Development

- **Fuel and Investment Risks**: Heavy dependence on a single fuel can increase volatility of supply and costs.
- **Climate Risks:** Frequent drought in Tanzania has reduced hydro-electricity generation and increased cost of service
- **Demand-side Risks**: Rapid demand growth and poor load factor increases load shedding, resulting in customer dissatisfaction

Screening Portfolios Using Risk Analysis

- Scenarios are used to evaluate the performance of selected Portfolio Strategies under alternate future conditions
- Scenarios should be designed to represent specific risks driving the electric power markets
- Scenarios may be defined by only one risk (e.g., high load growth) or by a combination of changes (lower capital costs result in increased development which then results in load growth)
- The risks captured in scenario analysis for Tanzania included:
  - Drought
  - Fuel Outages
  - Higher Load
  - Large Scale Outages
  - Development Delays
- Other risks may include *new technology cost and performance, existing unit performance, energy efficiency/DSM performance, regulatory/policy risks*

Seven Scenarios were examined

Baseline Scenario

- Assumes 6.3% annual average peak and energy demand increase (CAGR through 2036), and 7,411 km transmission from 2018 to 2021
- Financing for incremental generation need is unconstrained

Drought Scenario

- Portfolio capacity additions/retirements are fixed throughout the run horizon
- For hydropower output, the drought scenario assumes on average lower future generation capability due to drought, which is derived by WEAP simulation of historical drought pattern magnitude and frequency

High Load Scenario

- The High Load Scenario uses 2016 PSMP reference load forecast which has an 11.1% average annual growth
- Demand side resources are available to serve the energy load
- In addition to the portfolio under consideration, incremental capacity additions are allowed to meet load

Hydropower plants output is based on the Water Evaluation and Planning System (WEAP) model simulation for baseline weather conditions
Portfolio capacity additions/retirements included through the run horizon; additional capacity builds are allowed to meet the incremental load

Seven Scenarios, continued

Moderate Load

- Uses the average of Baseline and High Load Scenario load growth
- Demand side resources are available to serve the energy load
- Incremental capacity additions are allowed to meet load

Stiegler's Gorge Outage

- Assume equipment failure temporarily prevents hydropower output from Stiegler's Gorge

Gas Pipeline Outage

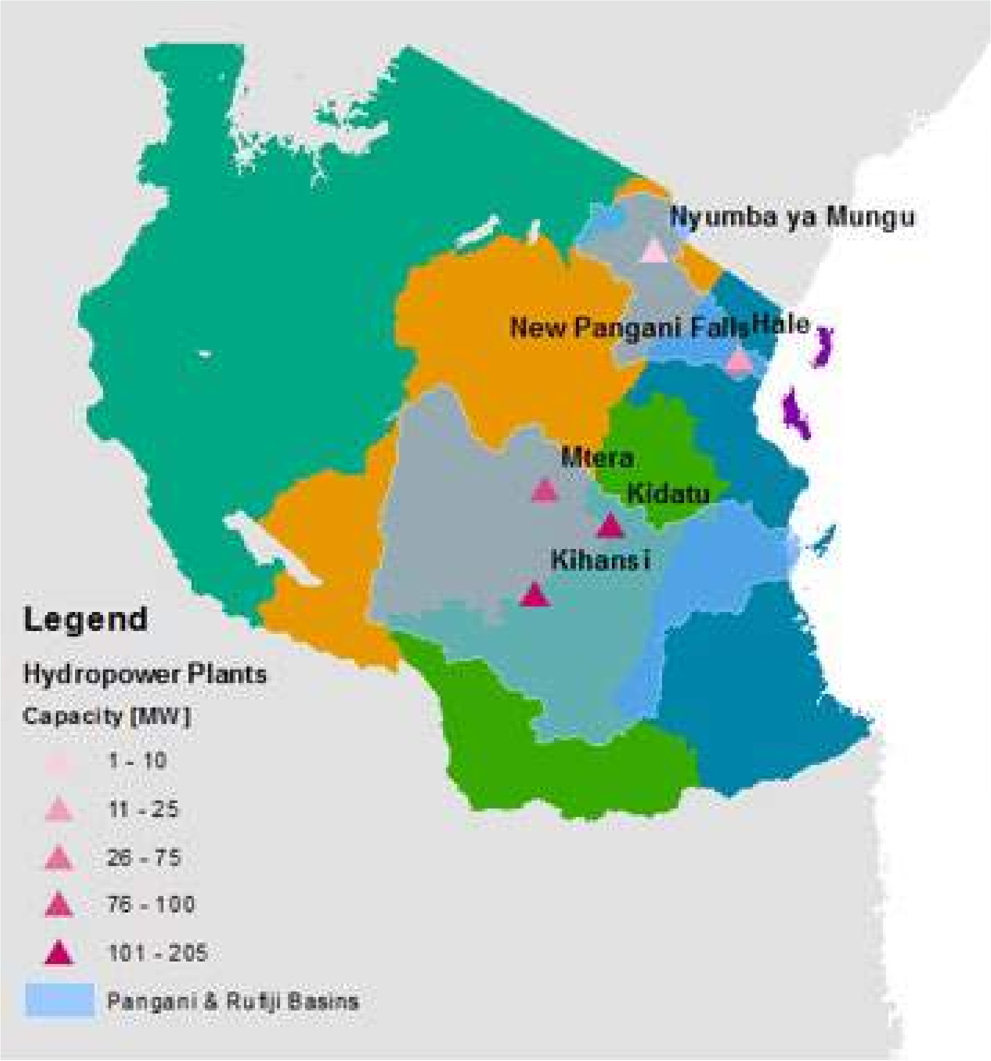
- Gas supply from Mtwara pipeline is limited in certain years due to assumed pipeline outage

Delayed Development Scenario

- Stiegler's is delayed by 3 years
- Northwest transmission grid update and the EKT transmission project are delayed by 3 years

Climate Risks to Hydropower Generation

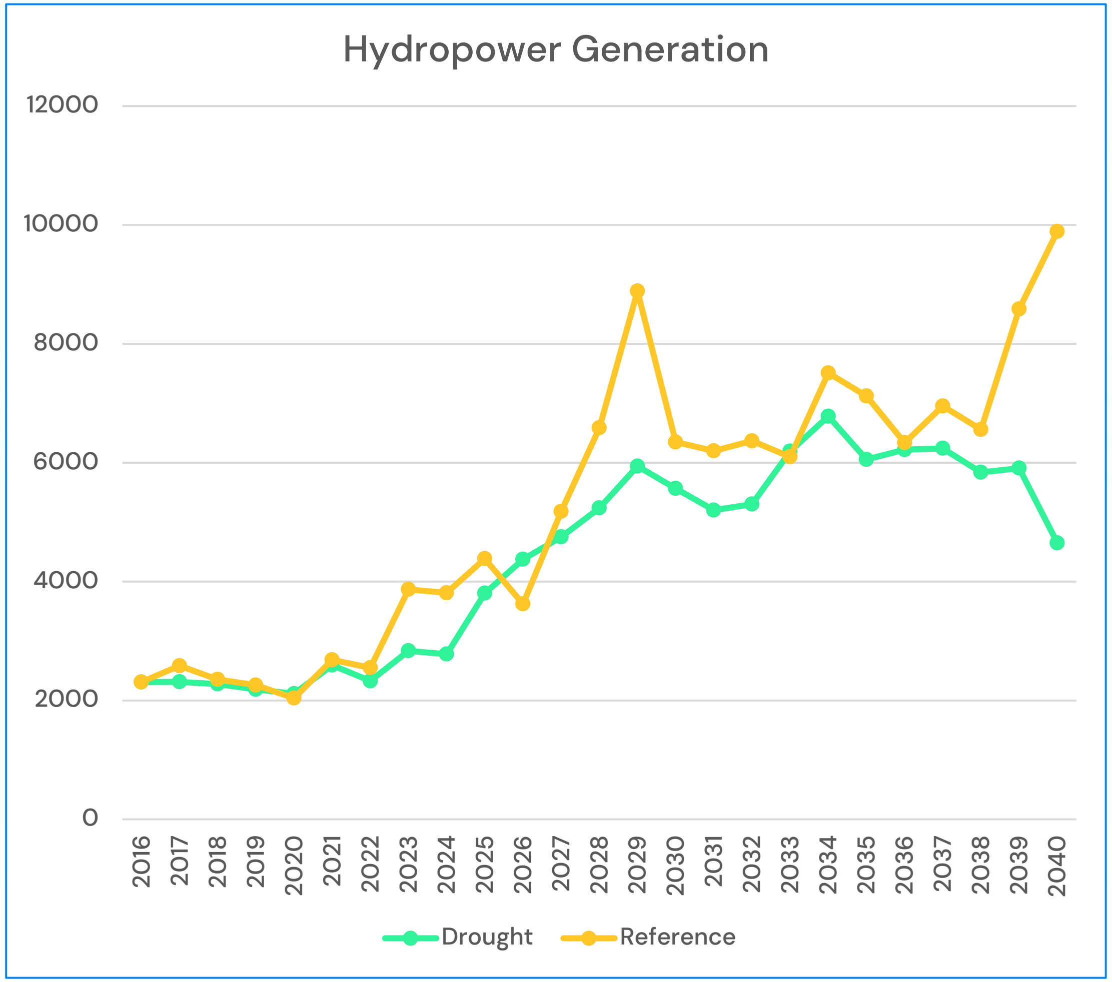
- Historically largest source of electricity
- Decline in hydropower reliability in recent years
- Currently 46% of generation capacity
- Changes in hydropower generation predominantly affected by changes in flow, which closely tracks rainfall
- Severe consequences as a result of drought:
    - High costs (~$70 million) from the use of incremental thermal generation plants, and reduced economic growth in drought years by more than 1% (Watkiss et al., 2011)



Model Selection and Data Collection

Models:

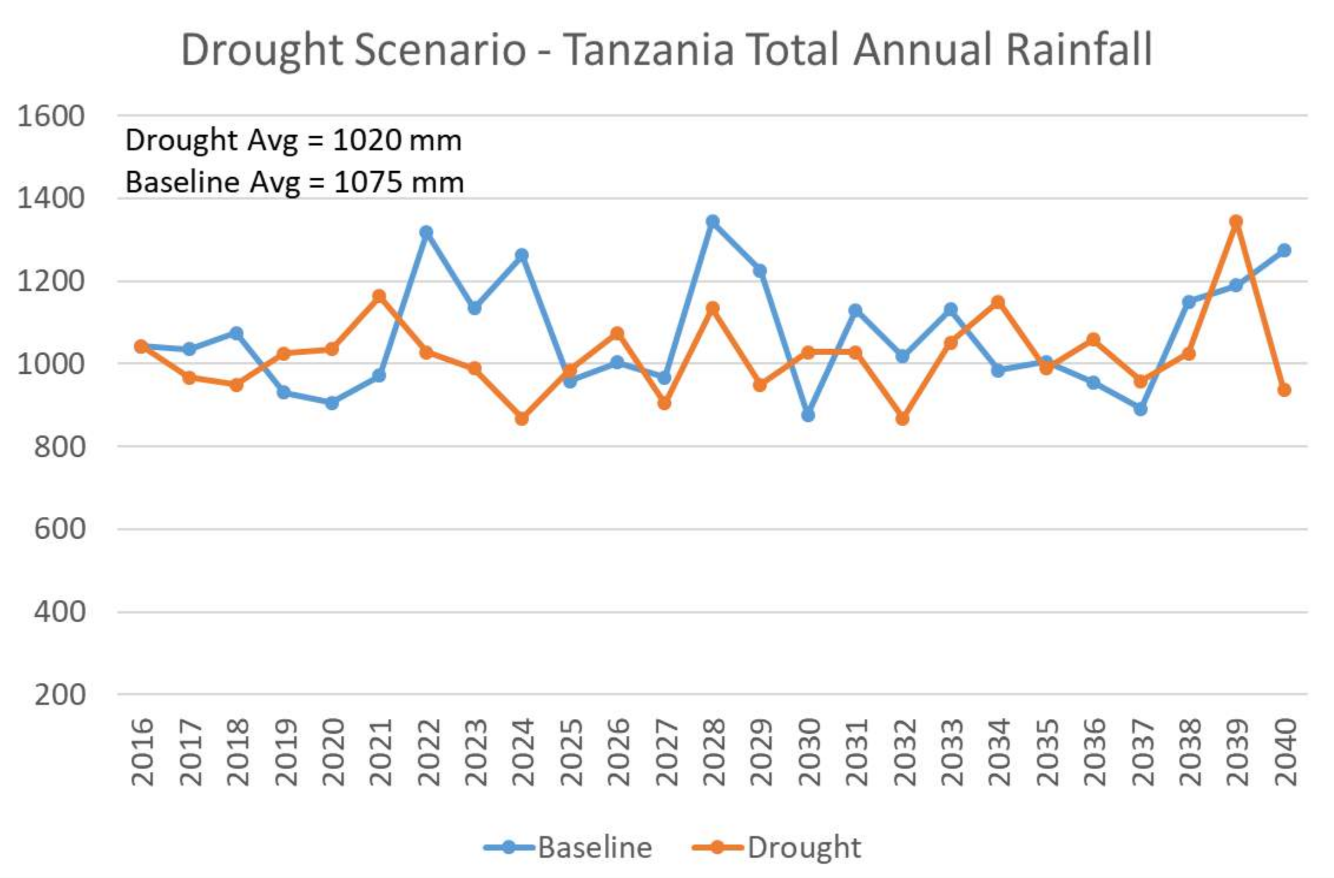
- Integrated Planning Model (IPM): used to examine a limited number of portfolio strategies under a range of scenarios
- Water Evaluation and Planning (WEAP): used to model hydropower output under drought and increasing temperature scenarios



Scenario Development & Key Uncertainties (Sensitivities)

Drought Sensitivity Assumptions:

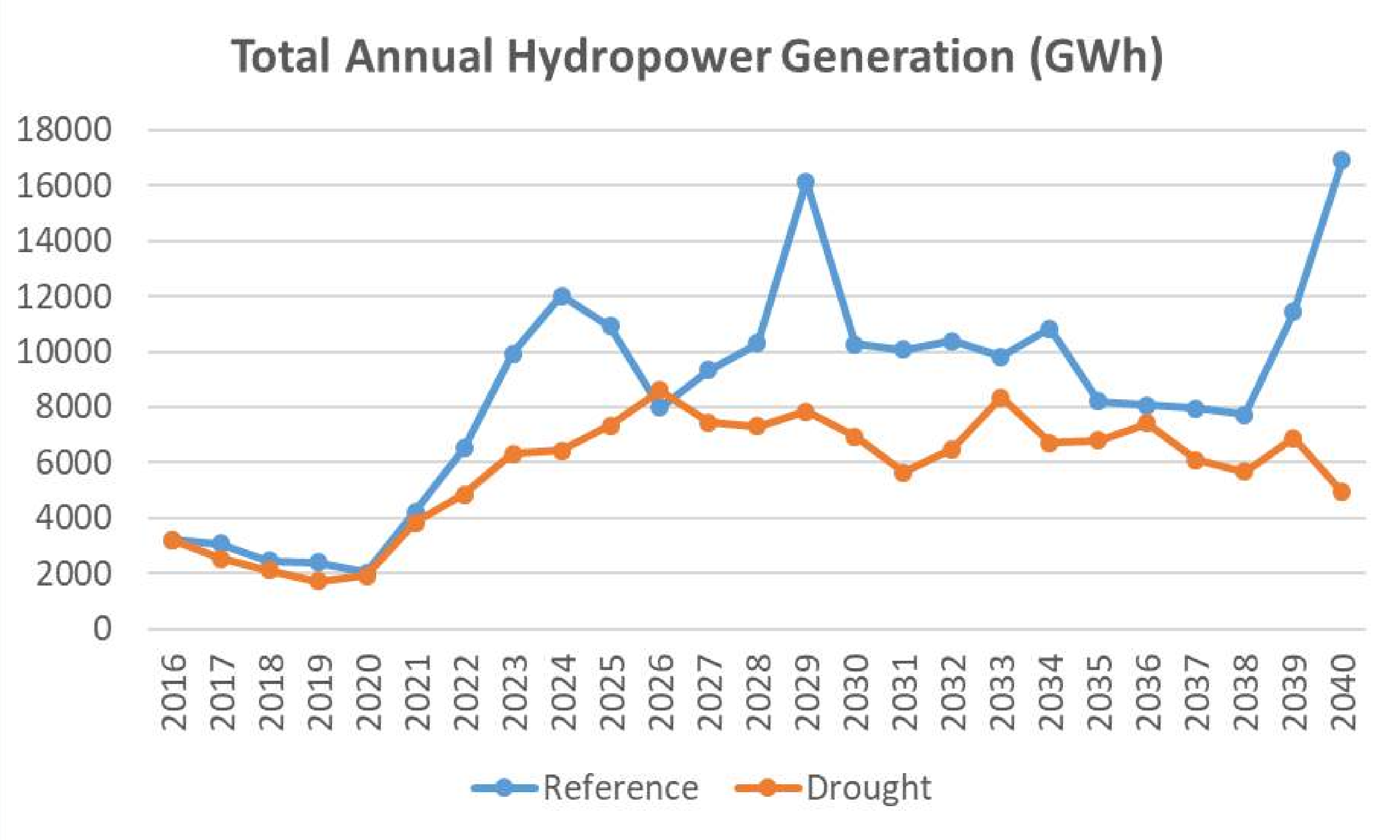
- Representative of power system performance under extended drought conditions that reduce amount of water available for power generation.
- Decline in annual average precipitation
- 5% for Tanzania, 8% for the Ruaha basin
- Increase in annual average temperature by 1.5°C relative to 1970 – 2000



Scenario Development & Key Uncertainties (Sensitivities)

Drought Scenario Results

- 30% reduction in streamflow
- 8% reduction in water supply delivered
- 12% reduction in hydropower generation



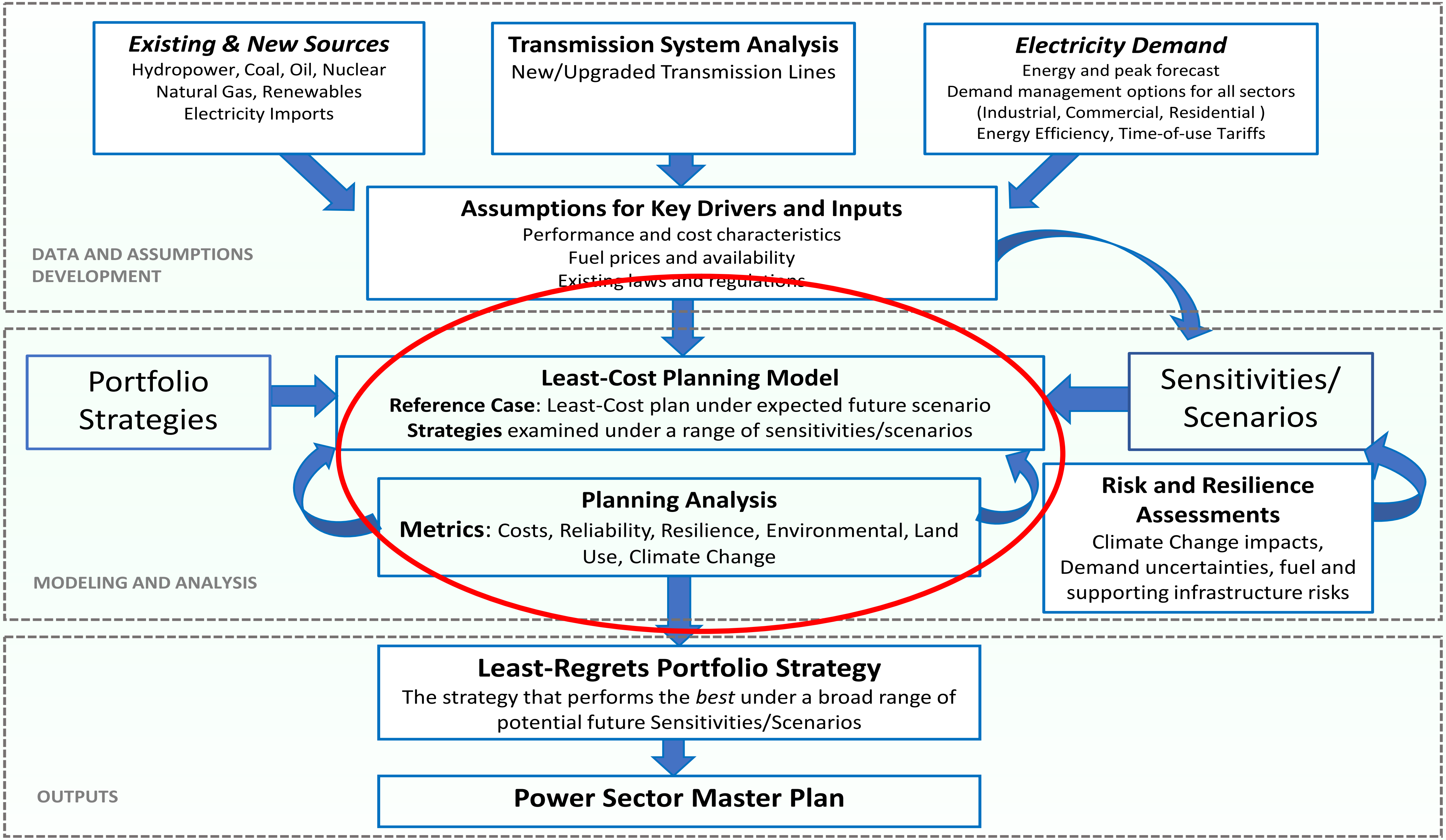
Details of the Other Scenarios

- The Pipeline Outage Scenario assumes that the Mtwara pipeline is unavailable to deliver gas from Mnazi Bay to any gas-fired generator north of Mtwara due to equipment failure.
- The outage on the Mtwara pipeline is assumed to result in the loss of natural gas delivery for one full year, and to occur every ten years.
- In this scenario, Songo Songo gas is still delivered to Somanga, Ubungo I, Tegeta, Songas, Somanga Fungu (IPP), and the Sumanga Fungu (TANESCO) plants.
- The first pipeline outage occurs in 2024 and the next outage occurs in 2033.

- The Stiegler's Gorge Outage Scenario assumes that the hydropower plant is unavailable due to equipment failure.
- The outage at the Stiegler's Gorge plant is assumed to result in loss of output for one full year, and to occur every ten years.
- This scenario is modeled with the first outage occurring in 2024 and the next outage occurring in 2033.

- The Delayed Development Scenario assumes that a number of electric power projects are delayed in coming online. The projects that are delayed include:
- The Stiegler's Gorge hydro plant (delayed by three years from 2021 to 2024)
- NW Grid transmission line (delayed by three years from 2020 to 2023)
- The ECT import Phase 1 (delayed by three years from 2020 to 2023)
- New coal plants will not be available to be in service until 2024
- New geothermal plants will not be available to be in service until 2024

Integrated Resource and Resilience Planning

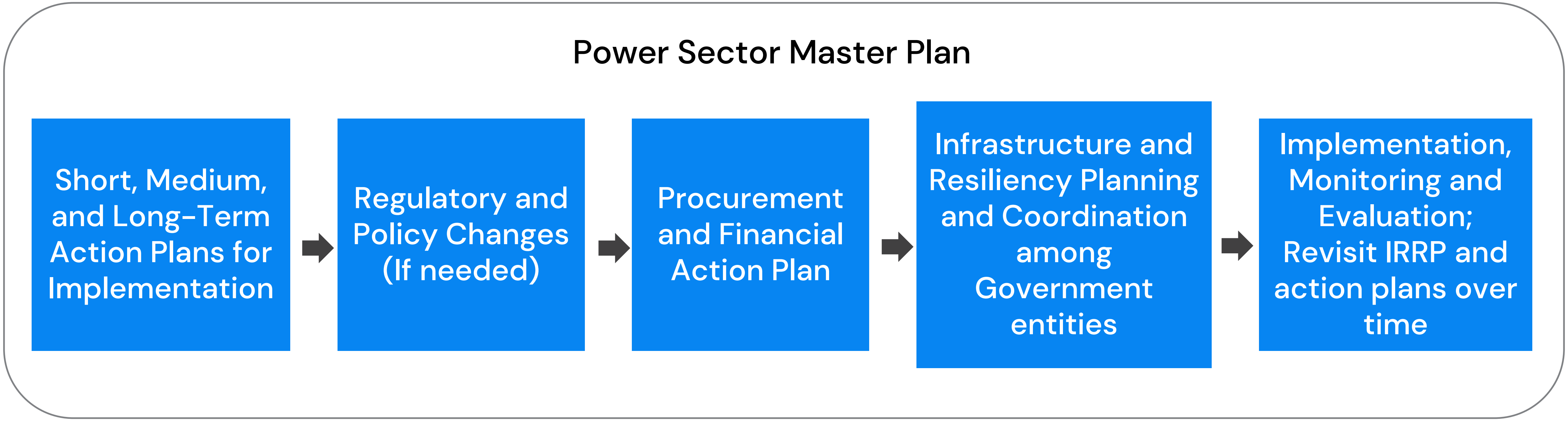


Metrics provide an unbiased means to evaluate the results of the IRRP analysis

Company Objective	Metric
Minimize cost	Levelized NPV ($/MWh) or $/MWh of generation portfolio costs
Rate stability/manage risks to ratepayers (Cost Resilience)	Range of $/MWh levelized costs or difference between base cost and highest cost scenario
Maintain reliability	Frequency and total MWh of loss of load events (Does the portfolio meet a one day in ten-year NERC requirement for reliability)
Environmental stewardship	% carbon reduction by 2030 period relative to the 2017 period
Minimize Renewable Curtailment	Renewable output/total available renewable generation
Achieve Diversity	% concentration on one type of asset or fuel
Minimize Land Use	Acres/MW of land utilized for each technology option

Interpret Results → Decision-Making

The Power Sector Master Plan supports decision-making:



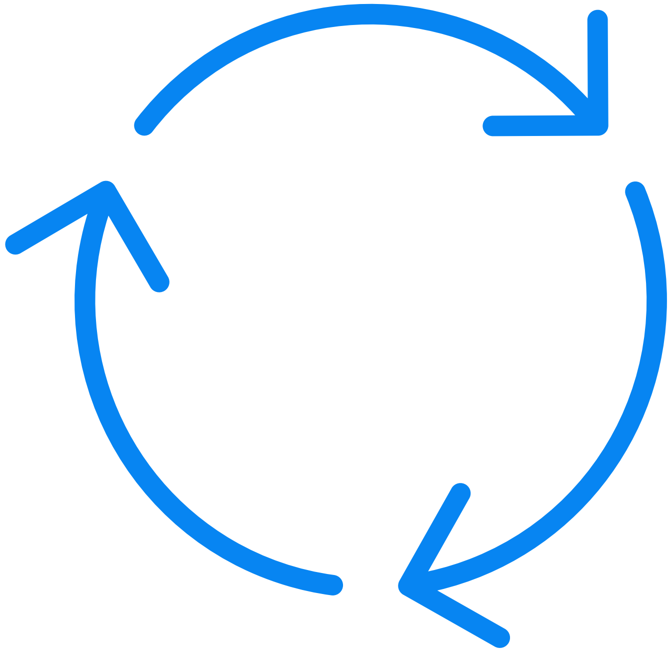
Lessons Learned: Enhance and institutionalize data collection and management

- Data management is critical to developing appropriate assumptions and robust analysis
- Limited information access and reliability needs to be corrected on an ongoing basis to improve data sets going forward
- Documenting source information and rationale for assumptions is critical to allow look-back and replication ("Assumptions Book")
- Develop standardized templates for data processing
- Continually improve modelling tools and collection of more granular data
- Perform after the fact performance assessments for input forecasts; maintain records of reasons for deviations of forecasts from actuals to assess how well the forecasting has performed so as to improve forecasting performance going forward
- Develop tracking of new customers through standardized interconnection surveys for smaller customers, and regular contact with regional development and economic growth agencies

Lessons Learned: Create a collaborative, sustainable process

Enhance data availability and planning outcomes through part icipation of key ministries

- Use stakeholder input to develop assumptions, inputs, and scenarios and same or similar tools, as much as possible, in order to ensure continuity of planning
- Institutionalize IRRP
- Best practices in IRRP is to repeat the analysis every 2 to 3 years
- Establish a requirement including a calendar/timetable for development, stakeholder engagement and review, and co mpletion of the IPSMP
- A framework for stakeholder input can be established over time
- Establish regulatory frameworks to support IRRP including key components (e.g., EE)



Any Questions?

Juanita.Haydel@icf.com

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NREL
Transforming ENERGY

Key Data Collection Process and Methodology

Gail Mosey and Sertaç Akar

National Renewable Energy Laboratory

4th March 2021

Resilient Energy Platform

IRRP
INTEGRATED RESOURCE AND RESILIENCE PLANS

Summary

- **What is the purpose of the key data collection framework?**
  - Standardizing data points gathered from communities based on key data requirements to run priority tools and models
- **Why do we prioritize data for tools and models?**
  - To ask communities in a more targeted way for data. We have a comprehensive list of data points which are being prioritized relative to the tools and models we often use with communities (e.g., Engage, SAM, REopt Lite)
- **What do we target for communities?**
  - The idea is to decrease the weight on communities for data collection and gather the necessary data and information to move forward in an organized and streamlined way
  - From a research perspective – as we continue to use the data template, we can see where communities seldom have the data needed and then integrate that into our tool and approach development
  - We have a comprehensive list of data needs with data for some communities already populated

Some of the Data Sources

Previously, NREL gathered data from various data sources to build a key data framework prioritized relative to the tools and models often use with communities.

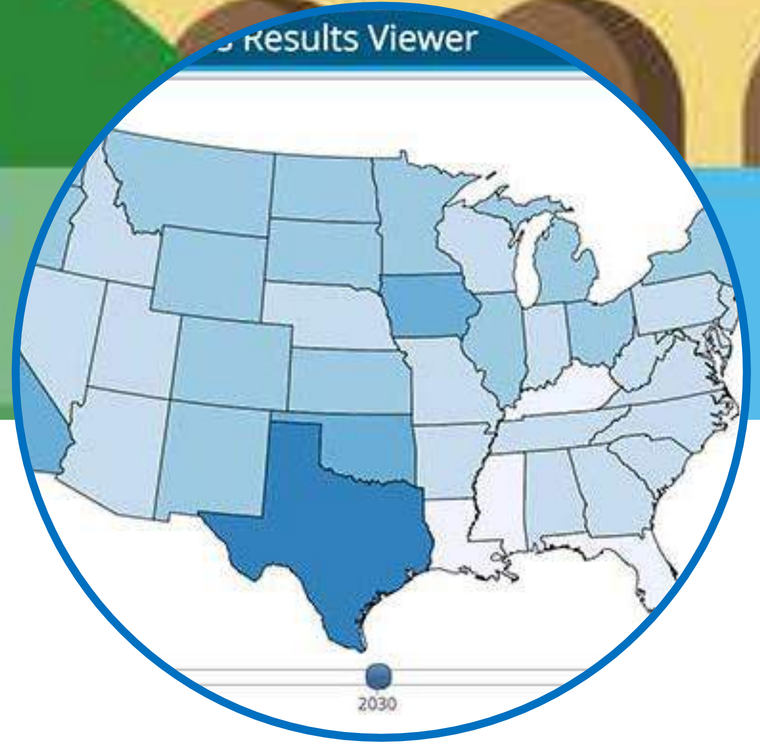
Some examples of data sources presented below:

- ETI Island Snapshot & Island Playbook
- Caribbean Center for Renewable Energy & Energy Efficiency (CCREEE)
- Alaska Energy Data Gateway (AEDG)
- Alaska Tribal Energy Data Book
- Hawaii Energy Transition Initiative (2008-2018)
- US Virgin Island Utility data (Provided by Dan Olis from previous studies)
- Guam Power Authority Annual Reports (2016, 2017, and 2018)
- EIA Territory Energy Profile Reports (2016, 2017, 2018, and 2019)
- Handbook on Conducting Grid Integration Studies (Created by the NREL International Team for USAID Grid Integration Data collection efforts; Katz, Cherminofsky, Zinaman)

NREL Tools & Models for Communities

Tier 1: High Level

- **Engage**: Cross-sectoral energy system planning and simulation



Tier 2: Regional Level

- Renewable Energy Integration and Optimization (**REopt**)
- The Regional Energy Deployment System (**ReEDS**)

Tier 3: Project Level

- System Advisor Model (**SAM**)
- **PVWatts** Calculator
- The Jobs and Economic Development Impact model (**JEDI**)

Key Data Structure

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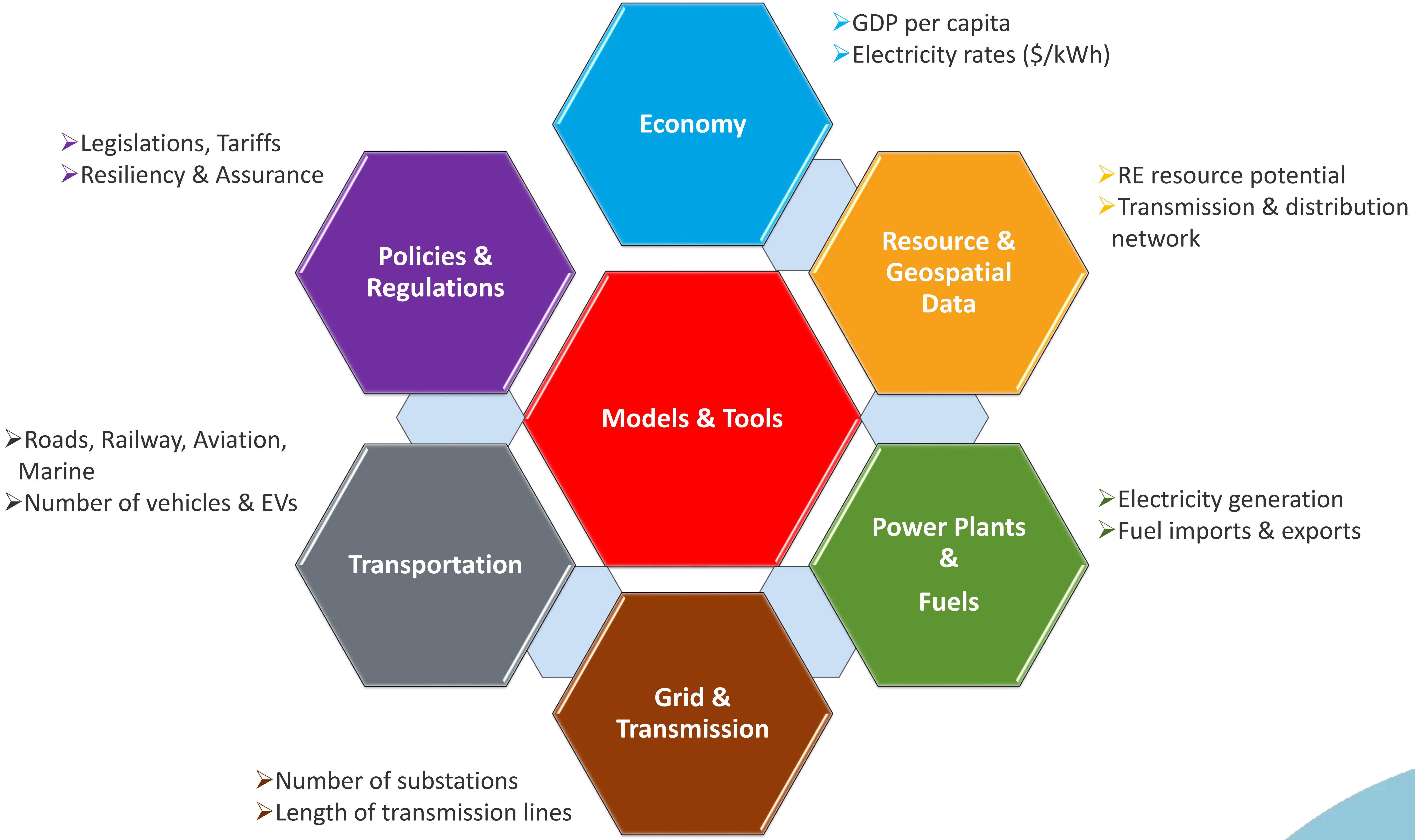

Key Data Form Snapshot

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Resource Data / Geospatial Data

- Resource
  - Solar
  - Wind
  - Geothermal
- Parcel Data
- Generation / Distribution locations

Power Plants

- Electricity generation mix
- Annual generation data
- Historic generation data
- Installed capacity by type
- Pipeline projects

Grid / Transmission

- Utility providers
- Independent Producers
- Number of customers,
- Number of substations,
- Total length of transmission lines

Fuels

- Fuel consumption
- Fuel production
- Fuel by sector
- Imports & exports

Transportation

- Roads
- Railway
- Aviation
- Marine
- Number of vehicles
- Number of EVs

Economy

- Total Area
- Population
- GDP, GDP per capita
- Human development index (HDI)
- Electricity rates ($/kWh)

Policies & Regulations

- Policies,
- Legislations
- Tariffs
- Resiliency & assurance

Demand

- Electricity demand
- Heat demand

Tier 1:
ENGAGE Model Structure

Supply	Storage	Conversion	Transmission	Demand
Biomass	Battery Storage	Natural Gas (NG) Turbine	AC Power Transmission	Electrical Demand
Coal	Thermal Storage	CC NG Turbine	Heat Pipes	Flat Load
Dispatchable	Water Reservoir	NG Boiler	Local (No Loss)	Heat Demand
Electric Grid	Natural Gas Storage	Hydropower Generator	Local Power Transmission	Hospital
Gas-CC		Combined Heat & Power (CHP)	Natural Gas Pipeline	Hotel (Large)
Gas-CT			Power Lines	Hotel (Small)
Geothermal				Midrise Apartment
Hydropower				Office (Large)
Nuclear				Office (Small)
Solar - CSP				Restaurant
Solar - PV Distributed				Retail
Solar - PV Utility				School
Wind - Offshore				Supermarket
				Warehouse

Tier 1:
ENGAGE Input Data Format

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Resilient Energy Platform

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Resource Constraints

- Available Resource
- Force all resource
- Minimum resource consumption (%/100)
- Resource scale factor
- Resource unit
- Ratio of resource area to energy capacit
- Installed area (m2)

Technology Constraints

- Energy capacity scale factor
- Energy efficiency (%/100)
- Plant Parasitic Efficiency (%/100)
- Export capacity (kW)
- Export carrier
- Installed Capacity (kW)
- Minimum operating capacity (%/100)
- Ramping rate (%/100)
- Technology Lifetime (yrs)

Monetary Costs

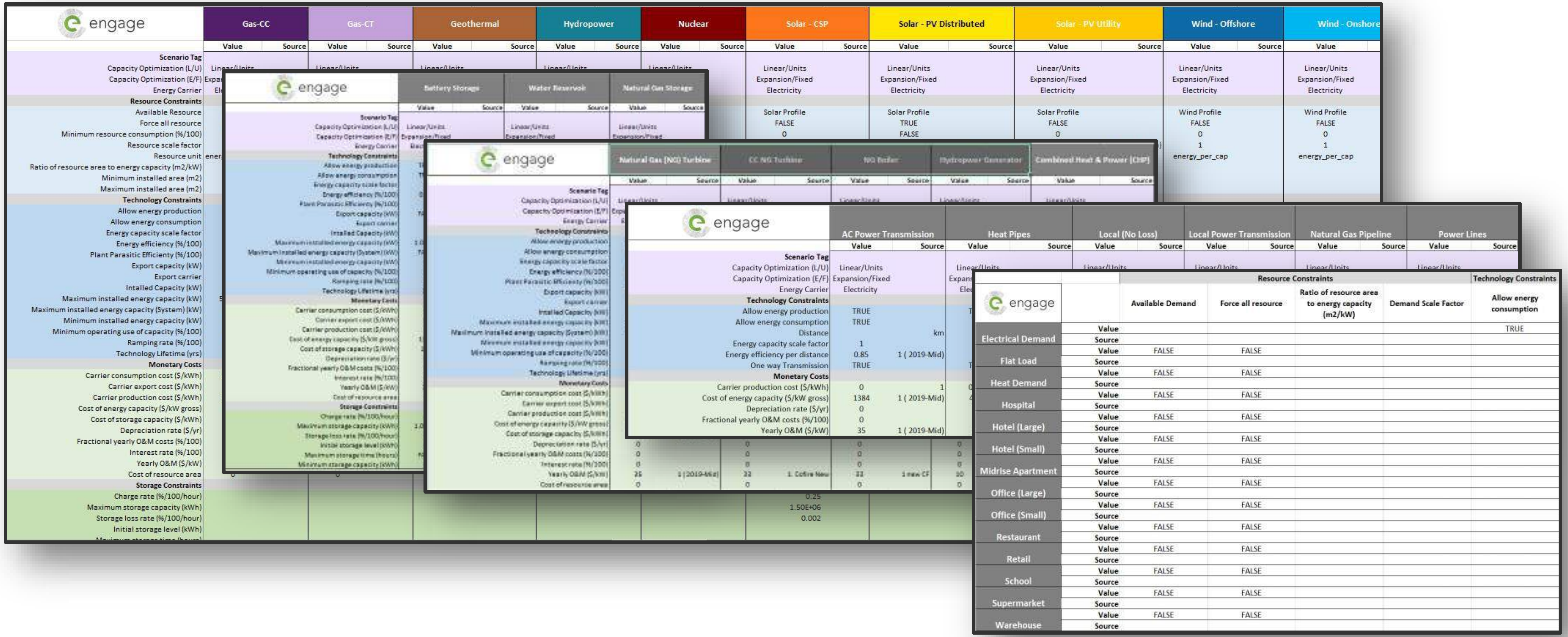
- Carrier consumption cost ($/kWh)
- Carrier export cost ($/kWh)
- Carrier production cost ($/kWh)
- Cost of energy capacity ($/kW gross)
- Cost of storage capacity ($/kWh)
- Depreciation rate ($/yr)
- Fractional yearly O&M costs (%/100)
- Interest rate (%/100)
- Yearly O&M ($/kW)
- Cost of resource area

Storage Constraints

- Charge rate (%/100/hour)
- Maximum storage capacity (kWh)
- Storage loss rate (%/100/hour)
- Initial storage level (kWh)
- Maximum storage time (hours)
- Minimum storage capacity (kWh)

engage

Tier 1:
ENGAGE Input Data Snapshot



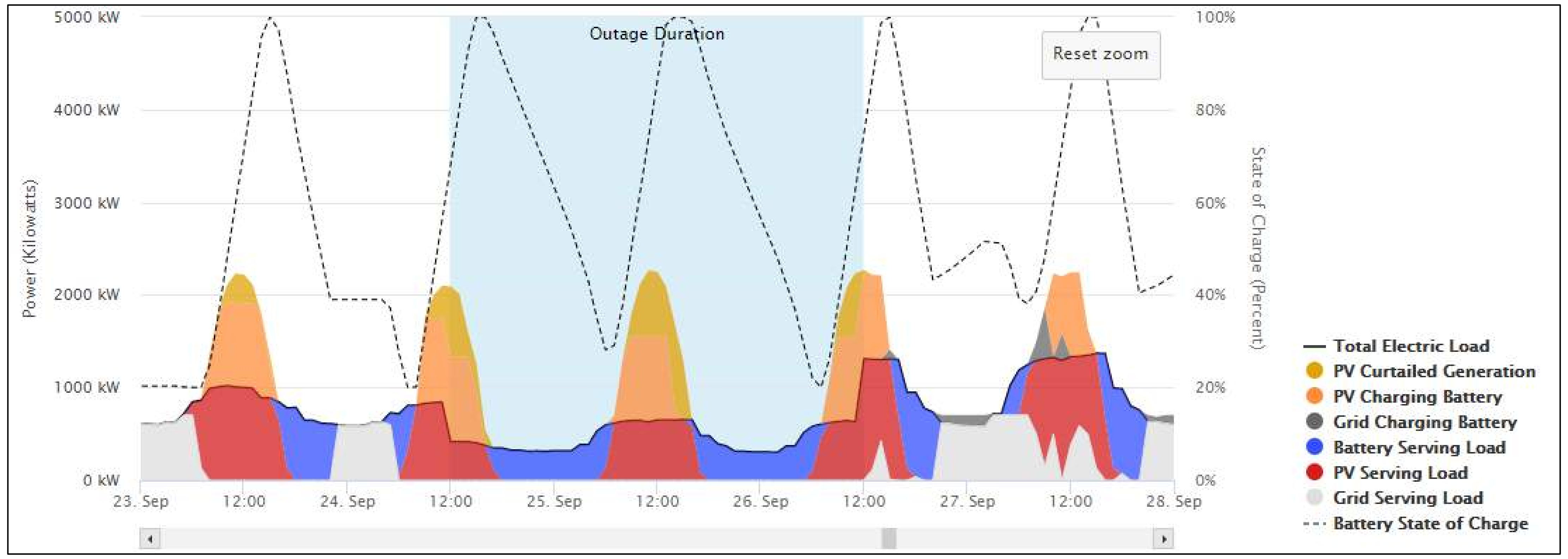
engage

Tier 2 and Tier 3 Models:

REopt Lite

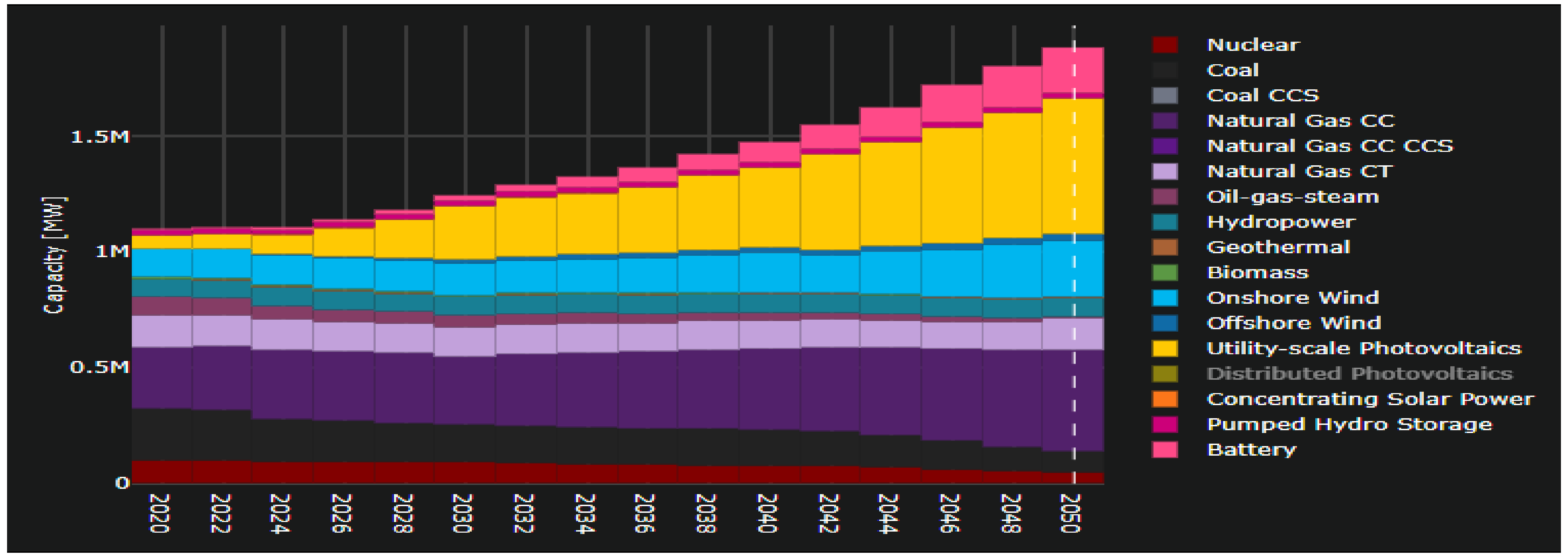
The REopt™ Lite web tool helps commercial building managers:

- Evaluate the economic viability of grid-connected PV, wind, battery storage, CHP, and thermal energy storage at an existing site,
- Identify system sizes and battery dispatch strategies to minimize energy costs,
- Estimate how long a system can sustain critical load during a grid outage.



ReEDS

The Regional Energy Deployment System (ReEDS) is NREL's flagship capacity planning model for the power sector. It simulates the evolution of the bulk power system—generation and transmission—from present day through 2050 or later.



SAM

The System Advisor Model (SAM) is a free techno-economic software model that can model many types of renewable energy systems and facilitates decision-making for people in the renewable energy industry.

SAM's financial model also calculates financial metrics for various kinds of power projects based on a project's cash flows over an analysis period.

JEDI

The Jobs and Economic Development Impact (JEDI) models are user-friendly screening tools that estimate the economic impacts of constructing and operating power plants, fuel production facilities, and other projects.

Data Collection Approach

- Align and prioritize data requirements relative to the tools that are often used with communities to identify critical data needs
- Gather data for pilot communities and run a sampling of tools/models to show effectiveness of data gathering strategy and methodology
- Identify gaps in available data for each community
- Create portfolios for each community with output from tools and models
- Based on data gaps identified, suggest areas where proxy (synthetic) data could be used and develop proxy data for the data gaps in a selected community
- Then use proxy data for a sample community plus current data to conduct a representative tool/modeling run to show effectiveness of proxy data

Thank You!

gail.mosey@nrel.gov

sertac.akar@nrel.gov

Q&A

Please enter your questions in the Q&A tab on the MS Teams Live Meeting.

Thank You!

Feedback Survey

https://www.surveymonkey.com/r/6DV8BYJ

Upcoming Workshops

- March 9: Climate Vulnerability Assessments with CIMH, NREL, ICF
- April – Date TBD: Storage for Resilience with NREL