A Framework for Integrated Distribution System Planning

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Presentation for Ameren Illinois workshop
September 23, 2024

This work was funded by the U.S. Department of Energy, Office of Electricity, under Contract No. DE-AC02-05CH11231.

Berkeley Lab's activities in integrated distribution planning

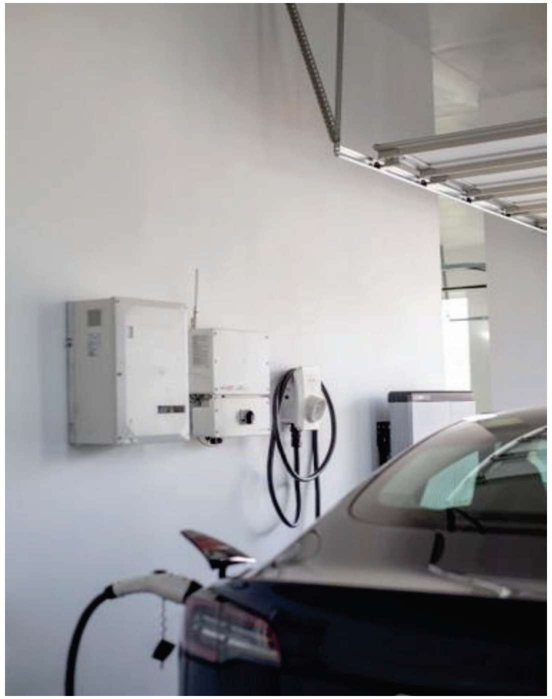
In partnership with NARUC, NASEO, NASUCA, and other national and regional organizations, Berkeley Lab conducts training, technical assistance, and research and develops tools to advance distribution system planning.

Training	Technical Assistance	Research & Tools
We **offer educational opportunities** that provide foundational information, address cutting-edge issues, disseminate advanced planning practices and new DOE-funded research, and facilitate peer-sharing.	We **provide unbiased technical expertise and research-based information** to help states address key institutional issues related to advancing distribution system technologies, investing in grid infrastructure, and applying robust planning methods and processes.	We conduct research and provide tools focused on three areas: **current IDSP practices and gaps, emerging best practices, and planning guidance.**

Website: https://emp.lbl.gov/projects/integrated-distribution-system-planning

Integrated Distribution System Planning

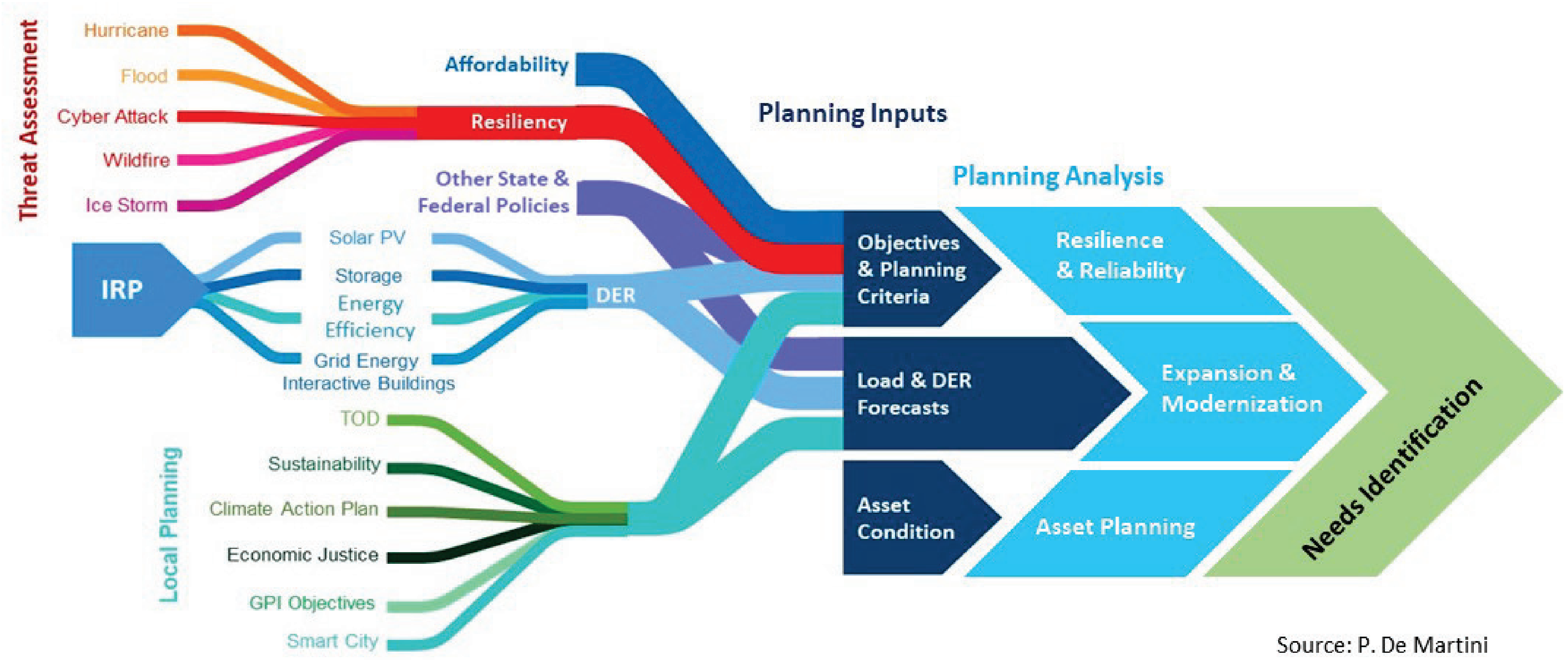
- States set goals, objectives, and priorities that define **long-term, high-level outcomes** for grid planning.
- Integrated distribution system planning (IDSP) provides a **decision framework to enable the formulation of long-term grid investment strategies** that address state and local policy goals, objectives, and priorities, consumers' needs, and evolution at the grid edge.
- **Shared understanding among stakeholders of strategies** for addressing goals, objectives and priorities in grid planning is essential.
  - Goals for grid planning include **traditional regulatory aims** (e.g., safety, reliability, and affordability) **and newer policy goals** (e.g., transportation electrification, more renewable resources, and emissions reductions) and related outcomes such as greater asset utilization and improved integration and utilization of distributed energy resources (DERs).
  - Grid planning objectives also reflect the importance of **transparency and stakeholder engagement**.



Source: Sunrun

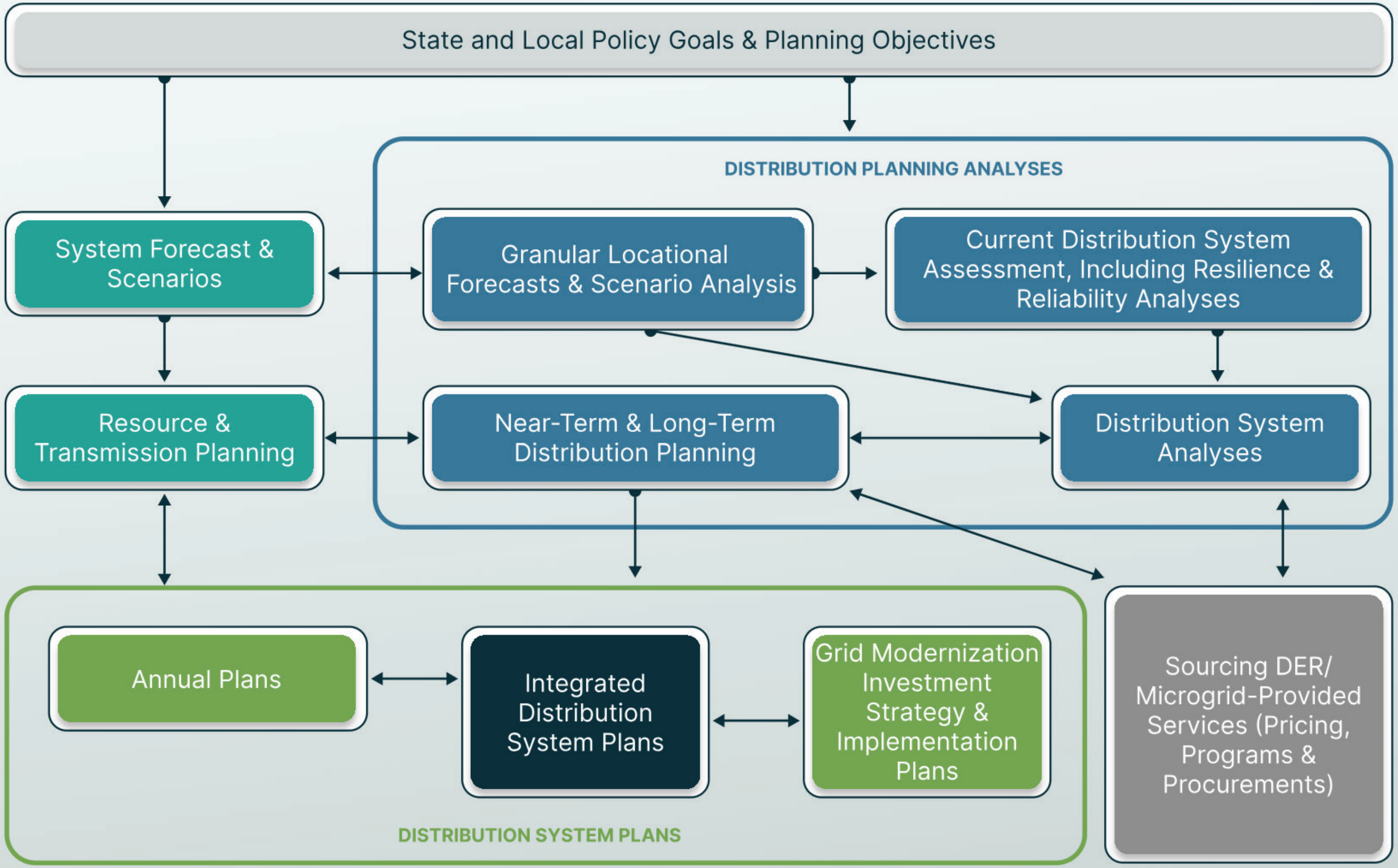
Expanding distribution system planning inputs

Distribution planning is increasingly dependent on resilience planning, bulk power system planning, local planning, and using DERs.



Source: P. De Martini

Berkeley Lab Interactive IDSP Framework



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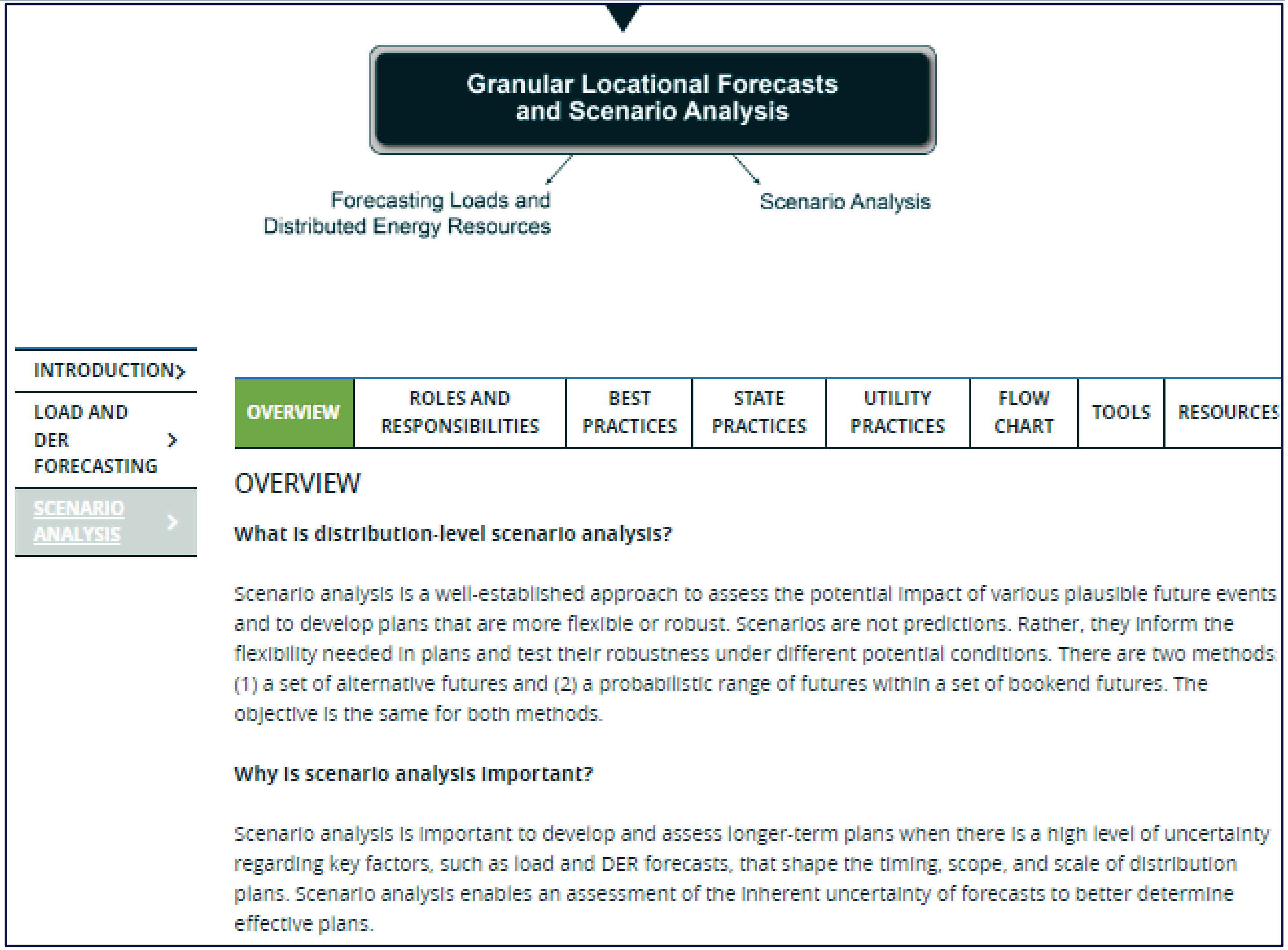
What’s included

- Overview
  - What is it?
  - Why is it important?
  - Key questions (Q&A)
- Roles and Responsibilities
- Best Practices
- State Practices
- Utility Practices
- Flow Chart (e.g., inputs/outputs)
- Tools
- Annotated Resources List



Topics

1. Stakeholder Engagement
2. Equity Considerations
3. Forecasting Loads and DERs
4. Scenario Analysis
5. Threat-Based Risk Assessment
6. Worst-Performing Circuits Analysis
7. Asset Management Strategy
8. Cost-Effectiveness Framework for Investments
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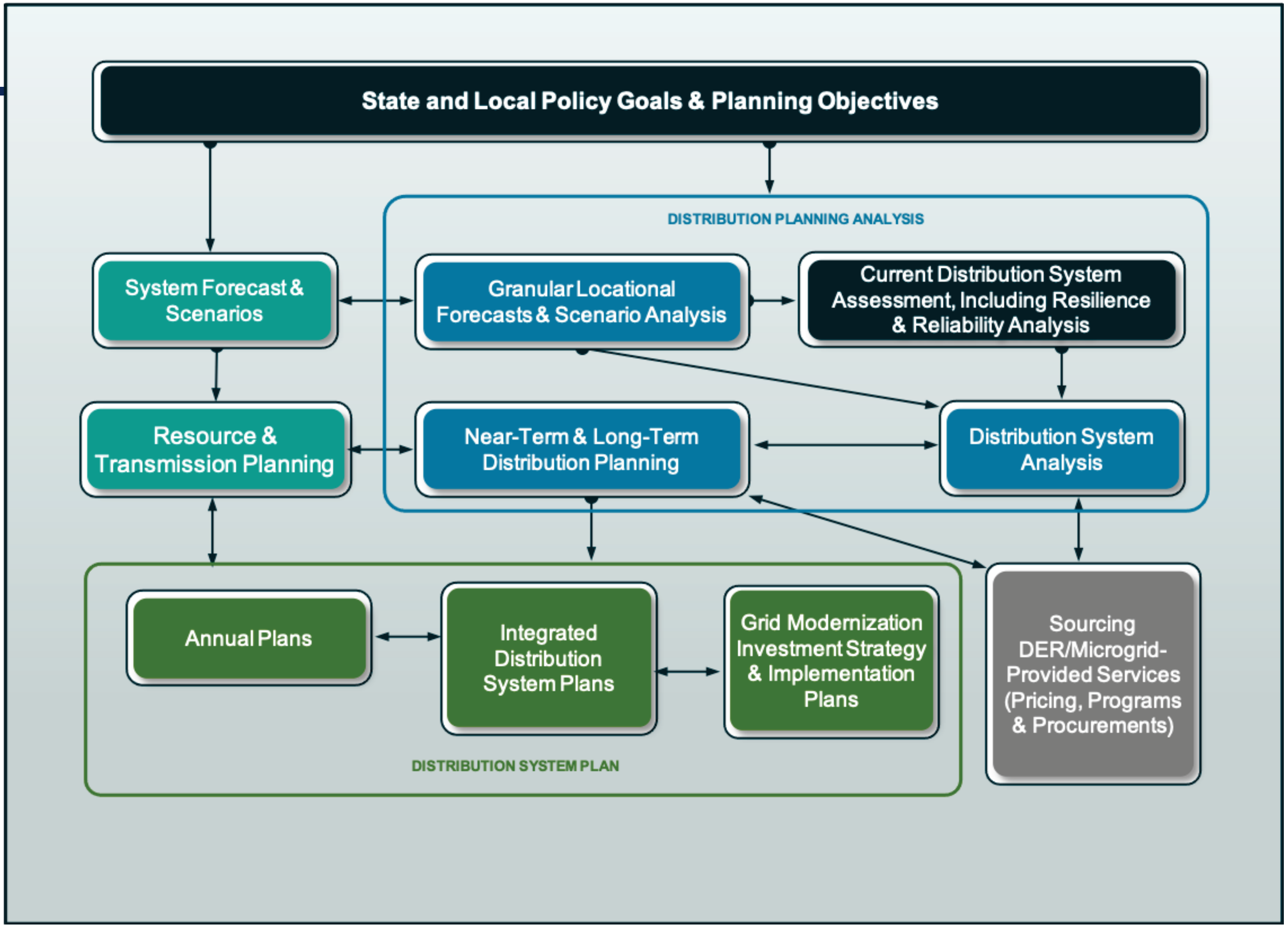
17. Procurements



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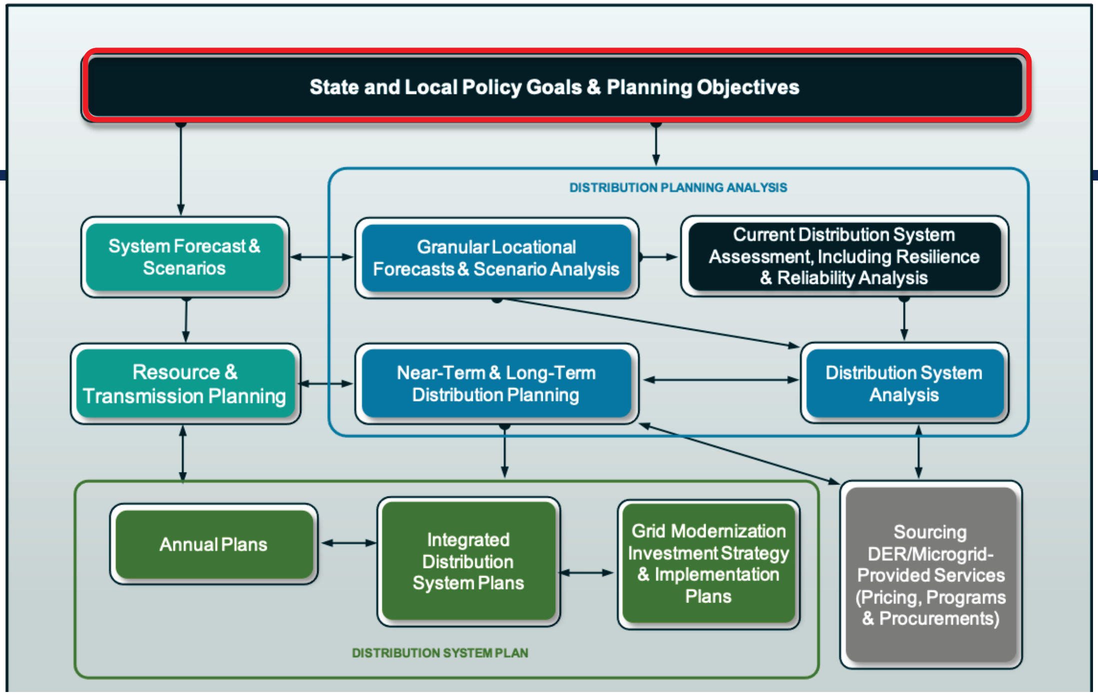

State and local policy goals and planning objectives are key IDSP inputs. Planning objectives and priorities originate from these goals, as well as input from communities and stakeholders.

- **Stakeholder engagement** involves participation by a wide variety of interested or concerned parties to provide feedback on planning objectives, inputs, methods, scenarios, and priority investments.
- **Equity considerations** aim to fairly distribute the benefits and burdens of grid investments across different customer groups.

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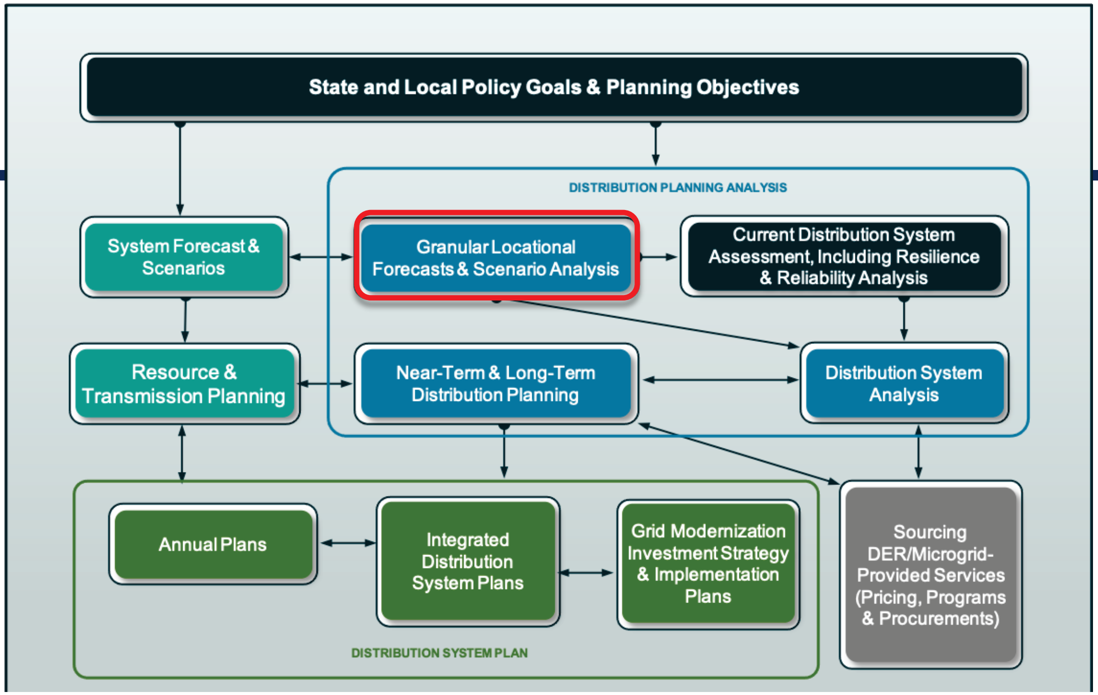
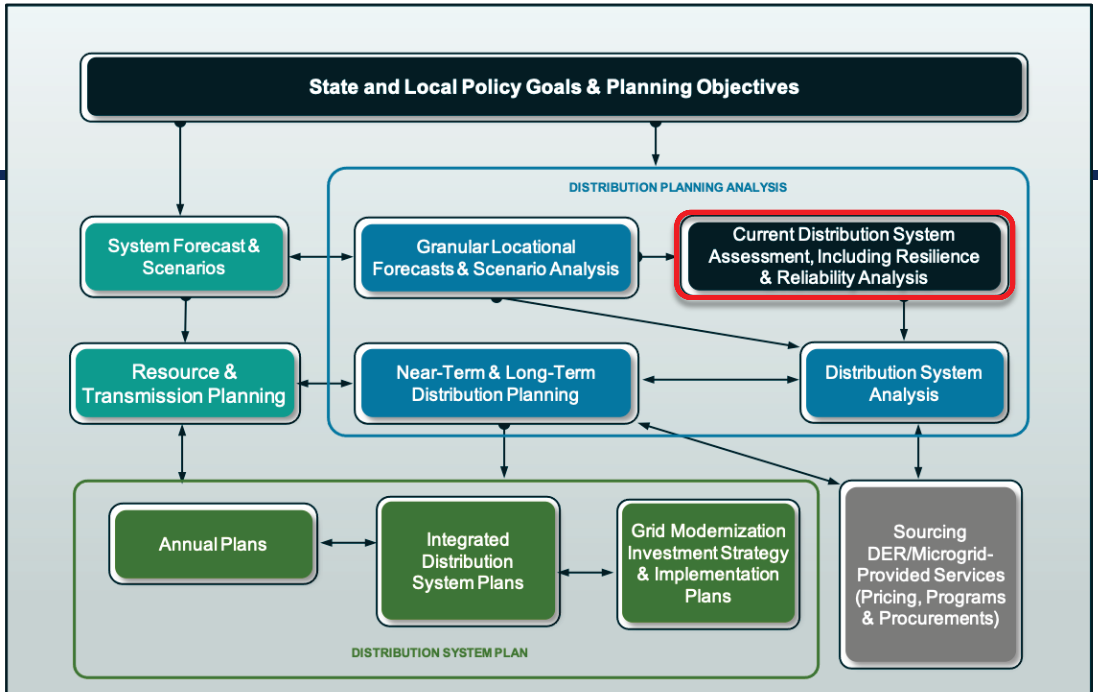


- **Granular locational forecasts** are projections of loads and DERs at the distribution substation and feeder levels that provide locational and temporal information to inform the type and timing of distribution system investments needed. The forecasting process considers potential changes to loads due to load modifiers such as various types of DERs.
- **Scenario analysis** assesses the potential impact of various plausible future events to inform the flexibility needed in grid plans and test their robustness under different potential conditions.

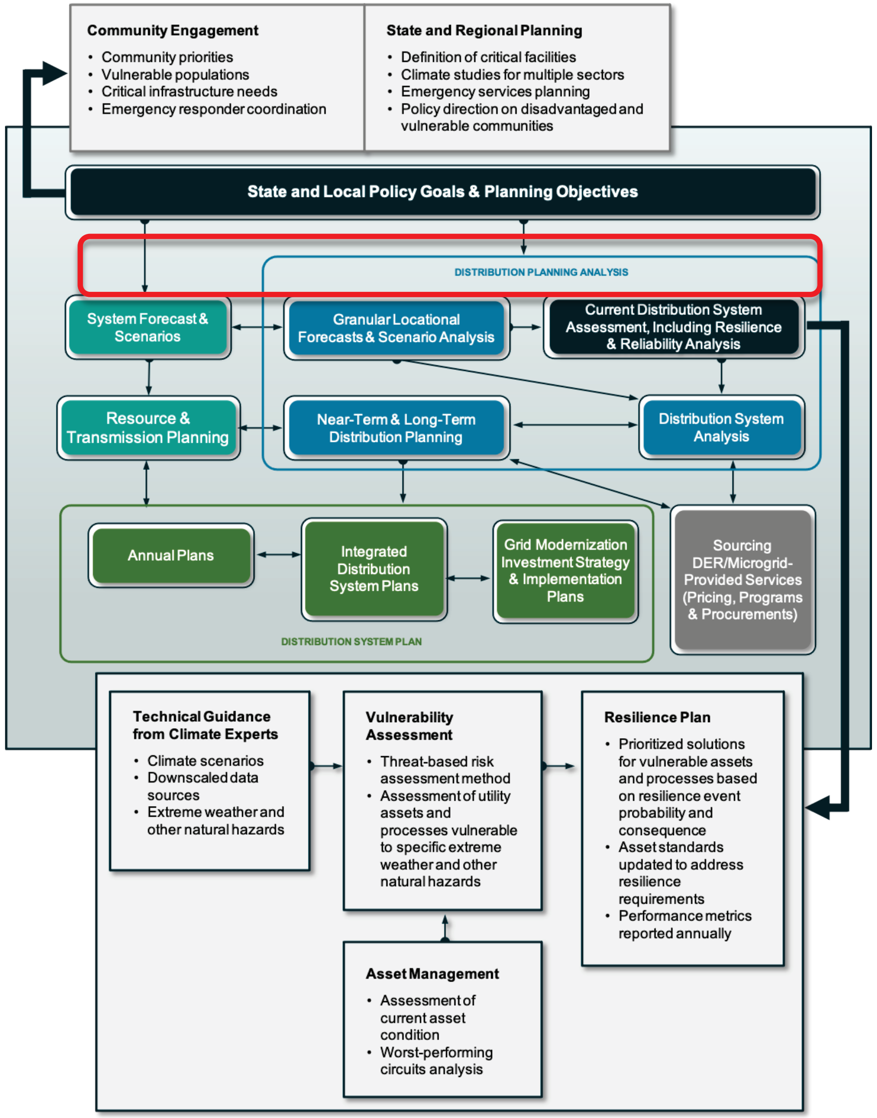
Topics



Current distribution system assessment evaluates asset condition and operational performance with respect to planning criteria and service standards, *including for reliability and resilience*.

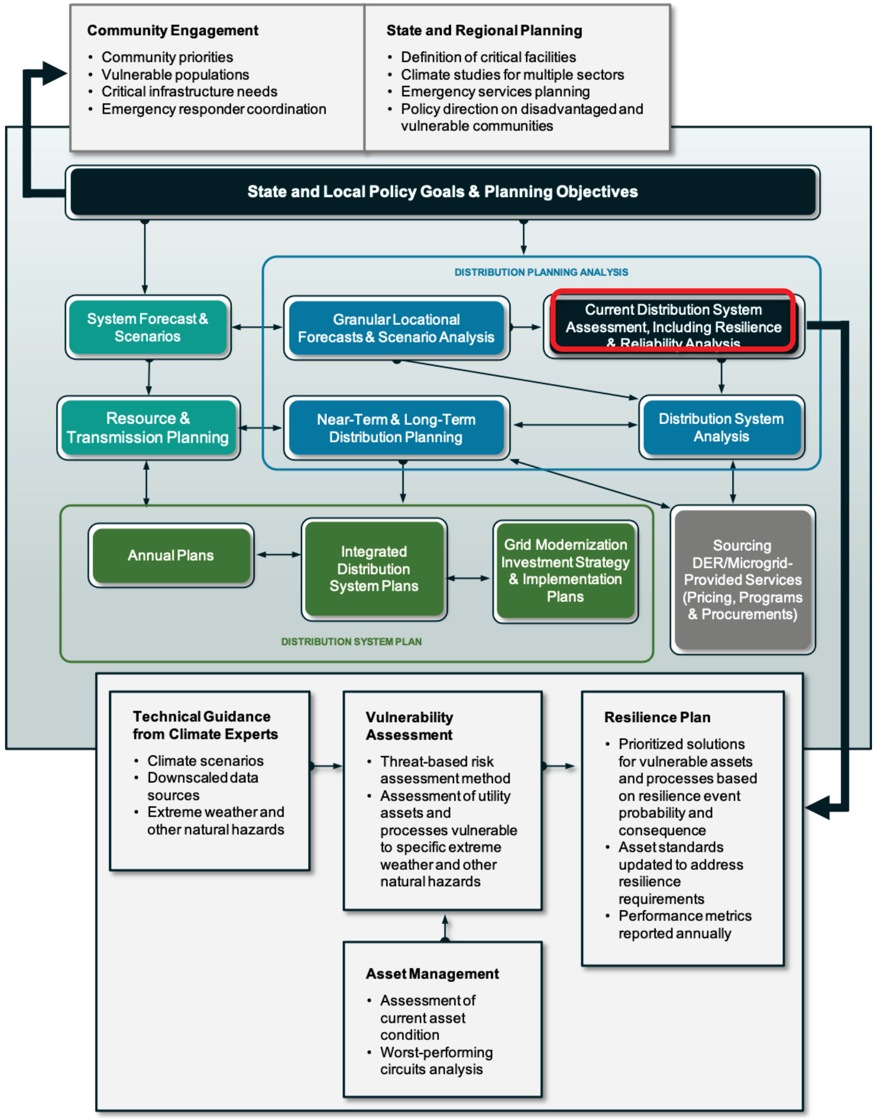
- **Asset management strategy** is the process of managing physical infrastructure for delivering electric service, including a systematic analysis of the condition and performance of physical grid assets.
- **Worst-performing circuits analysis** examines outage data to develop a list of circuits with the worst reliability performance and assess potential root causes to develop a remediation plan to reduce the duration and/or frequency of interruptions.
- **Threat-based risk assessment** identifies specific threats to assets and processes and categorizes vulnerability levels based on consequences (e.g., customer interruptions, grid damage).

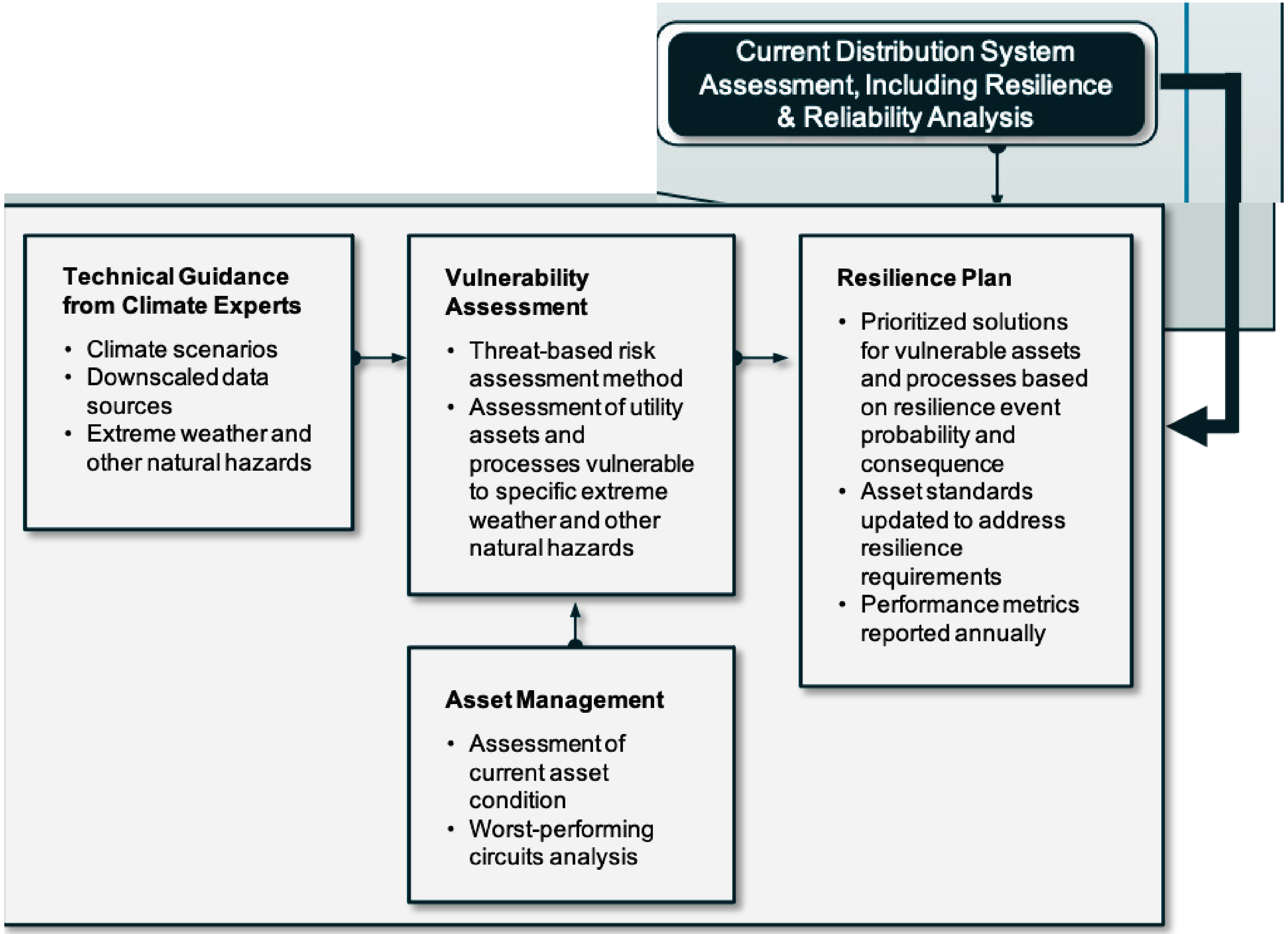
Integrating resilience planning and distribution planning (1)



Source: Berkeley Lab, *Grid Resilience Planning: State Requirements, Utility Practices, and Utility Plan Template*

Integrating resilience planning and distribution planning (2)





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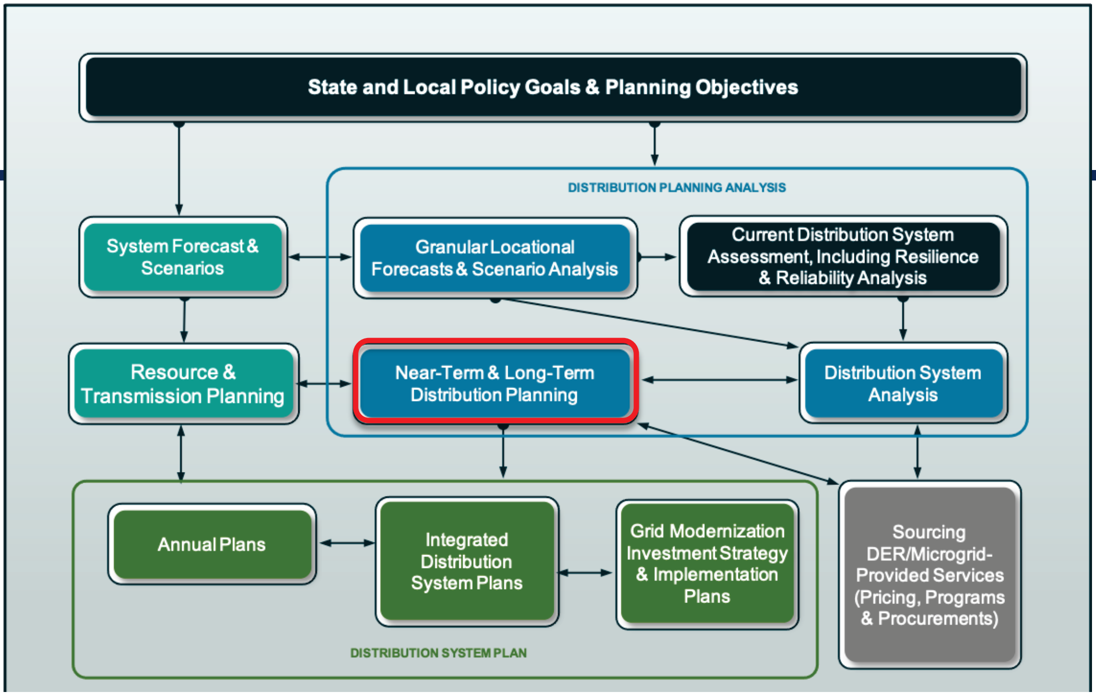

Long-term plans establish the utility's strategy for capital investments and other expenditures to address identified grid needs, typically over a 10-year period. **Near-term plans** identify expenditures with greater specificity over the next 3–5 years.

- **Cost-effectiveness evaluation** assesses benefits and costs of grid investments and qualitative factors to determine an optimal course of action to meet identified grid needs.
- **Multi-objective decision-making** is a set of methods to prioritize expenditures that provide the greatest value for meeting state goals, customer needs, regulatory requirements, and utility criteria.
- **Coordinated planning** harmonizes outputs from traditionally siloed planning processes (e.g., transmission and distribution planning) by enhancing consistency in assumptions and methods. **Integrated planning** unifies processes to streamline analyses, mitigate misalignment, and increase resource efficiency.

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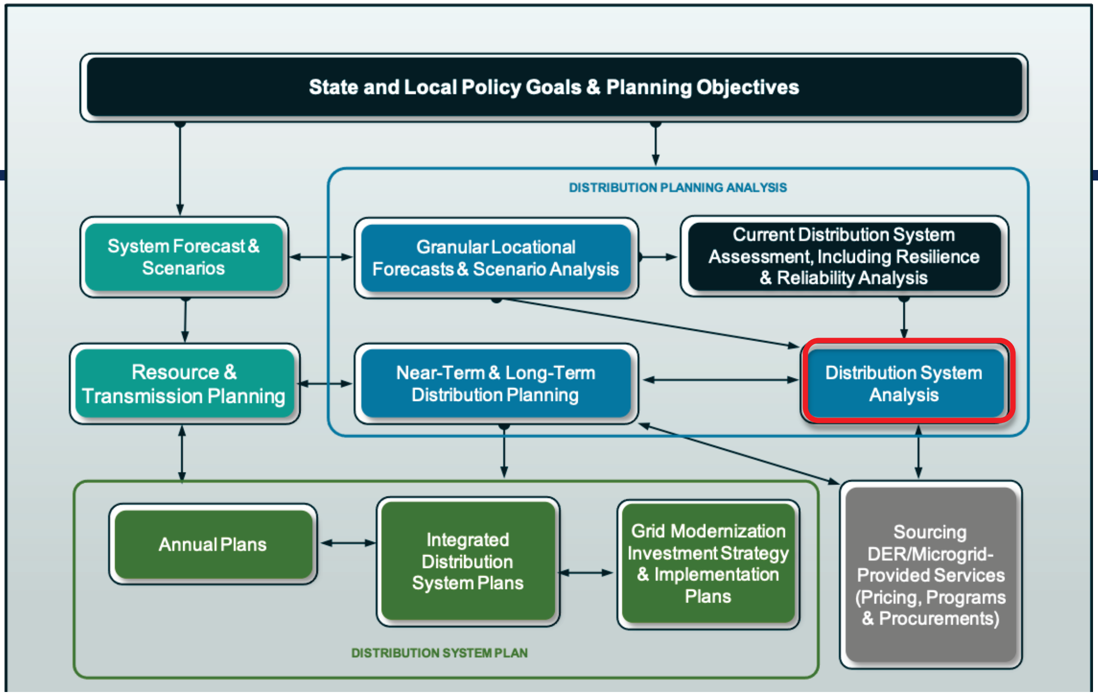
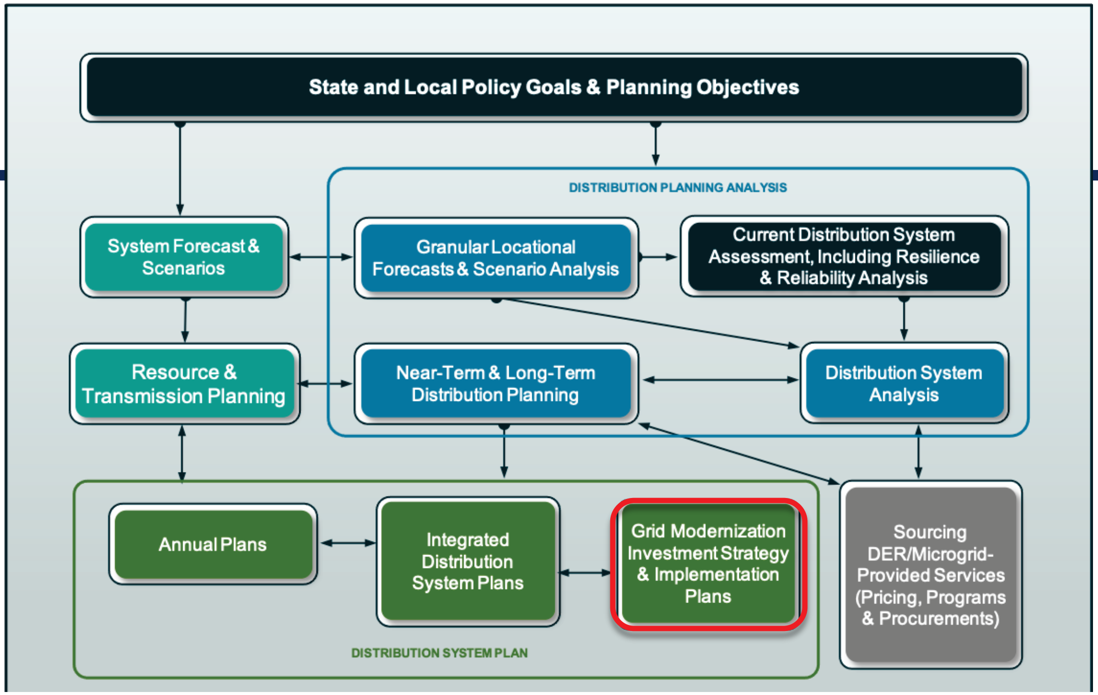


Distribution system analyses include engineering, economic, and other technical studies necessary for an effective planning process for local grids.

- **Hosting capacity analysis** identifies the amount of DERs that can be interconnected without adversely impacting power quality or reliability under existing control and protection systems and without infrastructure upgrades.
- **Value of DERs** derives from their capability to provide load relief, reduce power interruptions, address voltage issues, enhance resilience, or meet local energy needs. The potential value depends on capability to provide needed grid services at specific locations and times.
- **Interconnection** is the result of adding a DER to a distribution system. The term may refer to the technical, procedural, and legal requirements of the interconnection process or the physical location at which the DER provides certain electrical and interoperability capabilities.

Topics



Grid modernization strategy & implementation plans establish a technology roadmap for capital investments, programs, and other expenditures. Grid modernization plans are informed by the IDSP and, ideally, are filed together.

- The **distribution investment strategy and implementation plan** provides the utility's roadmap for meeting multiple planning objectives in an affordable way over the planning horizon. It demonstrates how the utility translates planning objectives into expenditure decisions and describes near-term needs in the context of long-term goals.
- **Functional requirements analysis** is a business process that identifies potential changes to utility organizational activities involving people, processes, and technologies to address specific grid needs.

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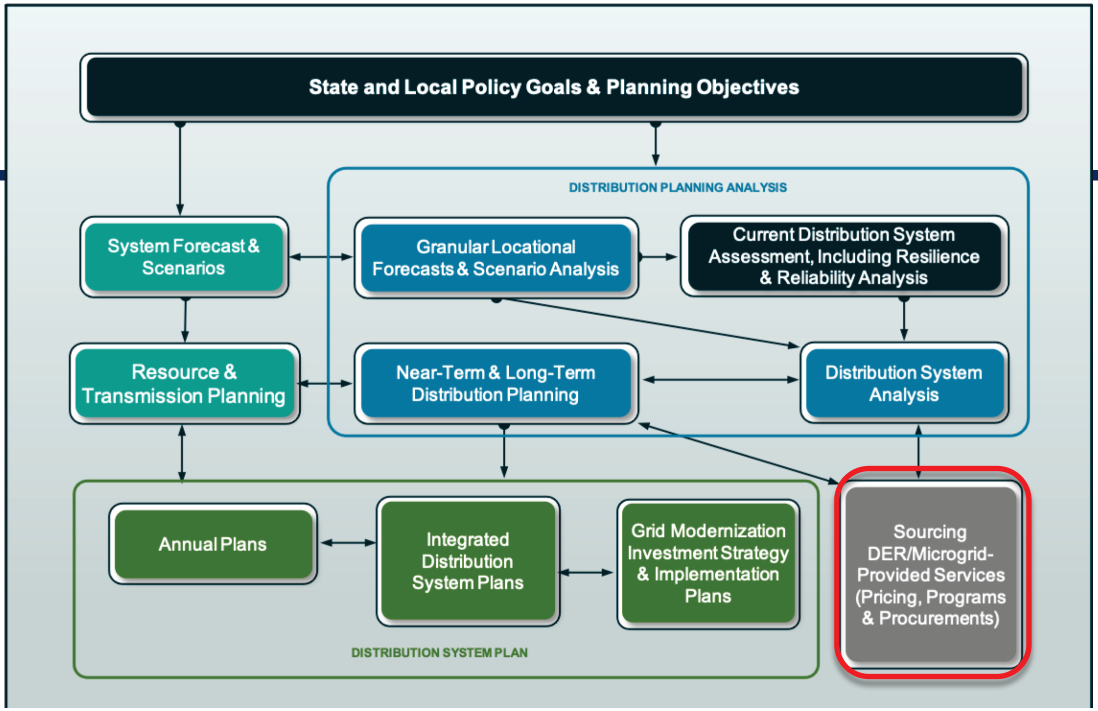
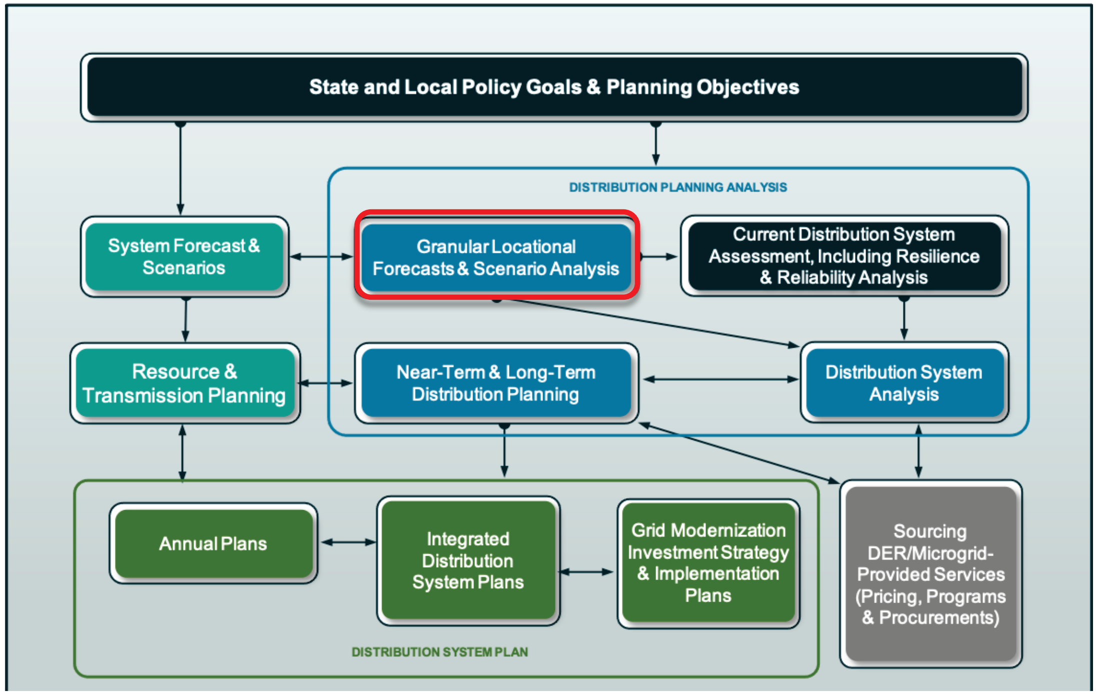


Sourcing DER/microgrid-provided services includes programs, procurements, and pricing to meet some distribution system needs with DERs.

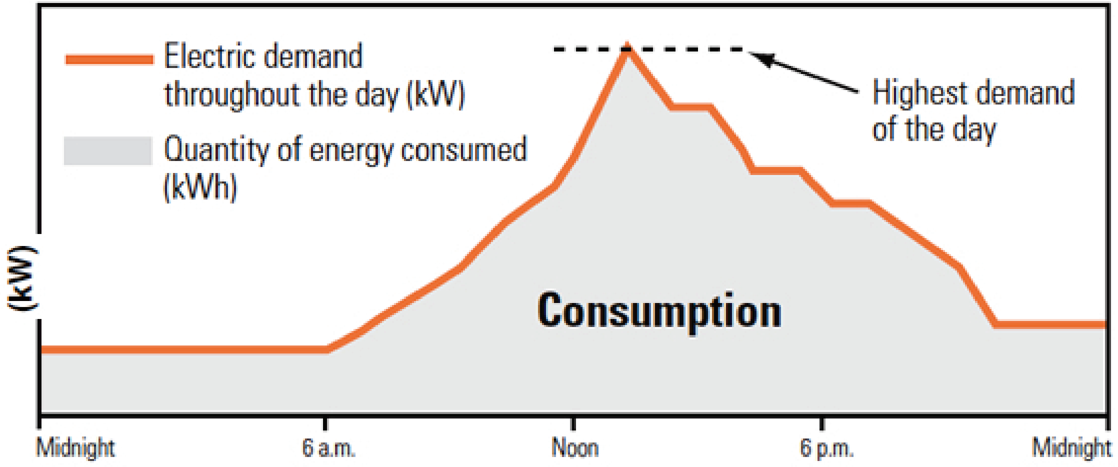
- **Geotargeting programs** includes focusing incentives by grid location or providing higher incentives to address a specific locational grid need through DERs.
- **Procurements** are solicitations for non-wires alternatives to defer traditional distribution system investments, such as feeder and substation upgrades, by acquiring DERs to provide specific grid needs — e.g., to provide load relief, reduce power interruptions, or improve resilience.
- ***Pricing*** *includes designing new or adapting existing tariffs for utility customers to include location- and time-sensitive distribution system benefits of DERs. See [Carvallo and Schwartz 2023](#).*

Example Section:
Load and DER Forecasting

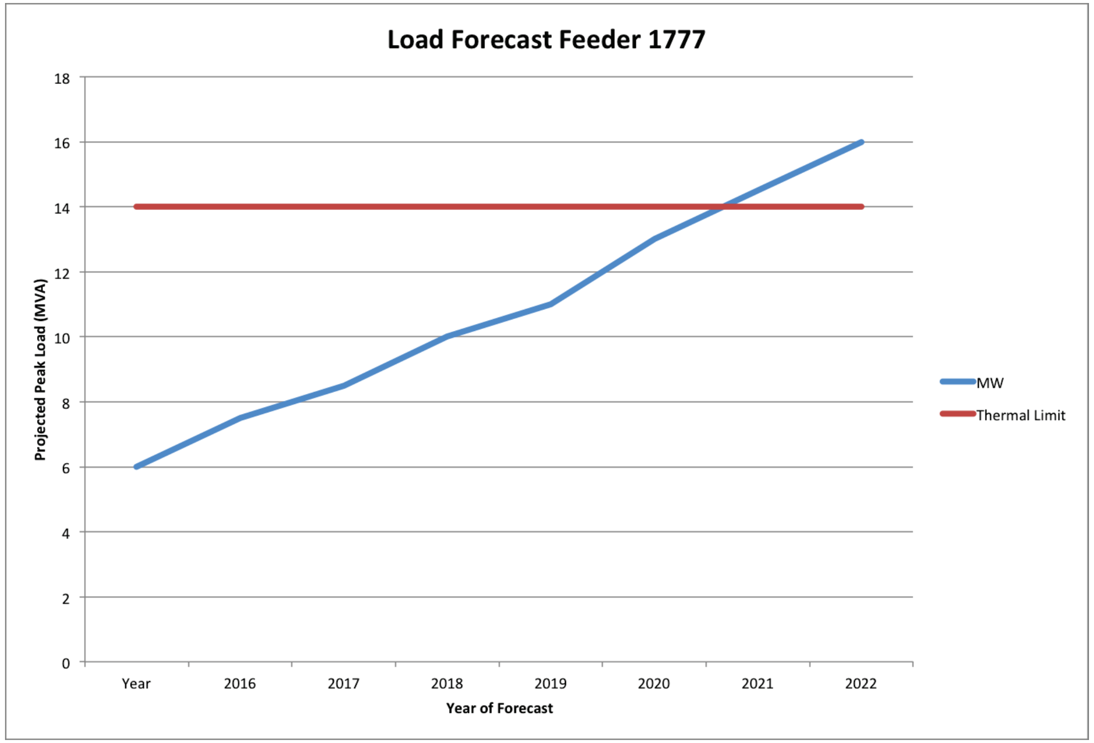


Why is load and DER forecasting important?

- Projecting peak demand at specific locations on the distribution system informs the timing, need, and type of investments.
  - For example, to address capacity shortfalls, power factor and voltage issues, thermal overloads



Source: We Energies



Source: Distribution System Planning 101

Load forecasting process

Inputs

Utility

- Substation/feeder name
- Peak load/hourly load
- Monthly energy consumption/Advanced Metering Infrastructure (AMI) hourly load
- Customer count
- Customer class
- Customer load shapes
- Known large customer load interconnection requests

Vendor or Public Data

- Historical weather
- Forecast weather
- Economic indicators (gross domestic product, demographics, prices, financial markets, etc.)
- Land use

Methods & Tools

Methods

- Weather Normalization
- SCADA Data Manipulation
- Trend Analysis (Regression, Neural Networks)
- Geospatial Analysis

Tools

- SCADA
- Geographic Information System (GIS)
- Customer Information System (CIS)
- AMI
- Statistical Software
- Vendor Software

Outputs

Substation / Feeder load forecast

- Circuit/substation name
- Base year load
- 1-in-10 (90^{th} percentile) base year load
- Annual load growth rate
- Known large customer loads
- 5- or 10-year peak load/hourly load forecast

DER forecasting process

Inputs

Utility

- Substation/feeder name
- Monthly energy consumption
- AMI hourly load
- Customer count
- Customer class
- DER historical counts, capacity, savings
- DER load shapes
- Existing and planned DER programs/tariffs

Vendor, Consultants and Public Data

- Historical weather
- Land use
- Building stock, parcel data
- Customer socio-economics
- Vehicle registration
- Vehicle miles traveled
- Building permits
- DER technology characterization, efficiency and behavior

Federal and State Policies and Regulations

- DER targets
- DER programs
- DER incentives
- DER technology characterization and efficiency

Methods & Tools

Methods

- Allocation
- Bottom-up Adoption
- Adoption Propensity
- Geospatial Analysis
- Target-setting or "Back-casting"

Tools

- NREL EVI-Pro
- GIS
- NREL D-Gen
- CIS
- NREL SAM/ PVWatts
- Vendor Software
- Statistical Software

Outputs

Substation/ Feeder DER forecast

- Circuit/substation name
- Annual DER contribution to peak load forecast
- Annual DER 8,760 forecast

Roles and responsibilities

Public utility commissions

- Provide guidance to regulated utilities on developing forecasting scenarios consistent with state policies.
- Require reporting on forecast error metrics and forecast improvements to avoid utility over- or under-investment to meet loads.

Utilities

- Develop spatial load forecasts annually for distribution substations and circuits.
- Revise forecasts continually based on error metrics and emerging load drivers.

State energy offices, utility consumer advocates and other stakeholders

- Participate in technical meetings and regulatory proceedings to provide feedback on forecasting inputs, methods, DER adoption propensity models, and scenarios to meet state and local policies and priorities.

Best practices

- Adopt **scenario or probabilistic forecasting techniques** to better capture uncertainty and manage risk — and update decision-making processes to use these inputs.
- Incorporate **risk analysis**, including to account for forecast bias.
- **Revise forecasts to address errors** in key data sources and **add information** not included in the original forecast.
- Choose the right type of function for **load-temperature relationships**.
- Consider **price elasticity** to electricity rates.
- Conduct **sensitivity analysis** to understand how economic forecast errors translate into load forecast errors.
- Adopt **hourly forecasts**, such as 8,760 (every hour of the year) or 576 (one 24-hour weekend day and one weekday for each month of the year).
- Adopt **longer-term forecasting horizons** (>15 years) that align with policy goals.
- Incorporate **adoption propensity models** for DERs and electrification.
- Create **spatial load forecasts** with customer-level resolution.
- **Align forecasts** across utility departments.
- **Reconcile forecasts** — distribution-level, bottom-up forecast and corporate.

Example state practices

- **California** - Energy Commission (state energy office) develops system-level, demand-side forecasts
  - Baseline demand, BTM distributed generation, transportation, additional achievable energy efficiency, additional achievable fuel substitution, and long-term demand scenarios (see Demand Side Modeling web page)
- **Hawaii** - The Public Utilities Commission (PUC) directed Hawaiian Electric Companies to convene stakeholder groups to discuss development of integrated grid plans.
  - Topics addressed by the Distribution Planning Working Group include circuit-level forecasts and forecasting tools.
- **Colorado** - The PUC requires utilities to develop forecasts under at least two load scenarios: load growth associated with existing state policy and a "high" growth scenario
- **Vermont** - The Department of Public Service requires that load forecasts account for levels of building and transportation electrification that result from compliance with state climate policy.
  - Requirements also specify that utilities forecast peaks for both summer and winter and springtime minimum load.
- Some states require load forecasts to account for DER growth (e.g., **CA, CO, MI, MN, NV, VT**).
- Some states require load forecasts to include new building and transportation electrification loads (e.g., **CO, HI, MN, NY, NV, VT**).

Example utility practices

- **Duke Energy (SC)** - The utility developed a "Morecast" for its Integrated System Operations Plan.
  - *The Morecast is a 10-year, hourly distribution system forecast at the circuit level describing the aggregate load at the beginning of the primary voltage feeder. The model was developed in-house by Duke Energy. Forecasts for load, electric vehicles (EVs), DER, and customer programs are used to build circuit-level net load forecasts.* (reference)

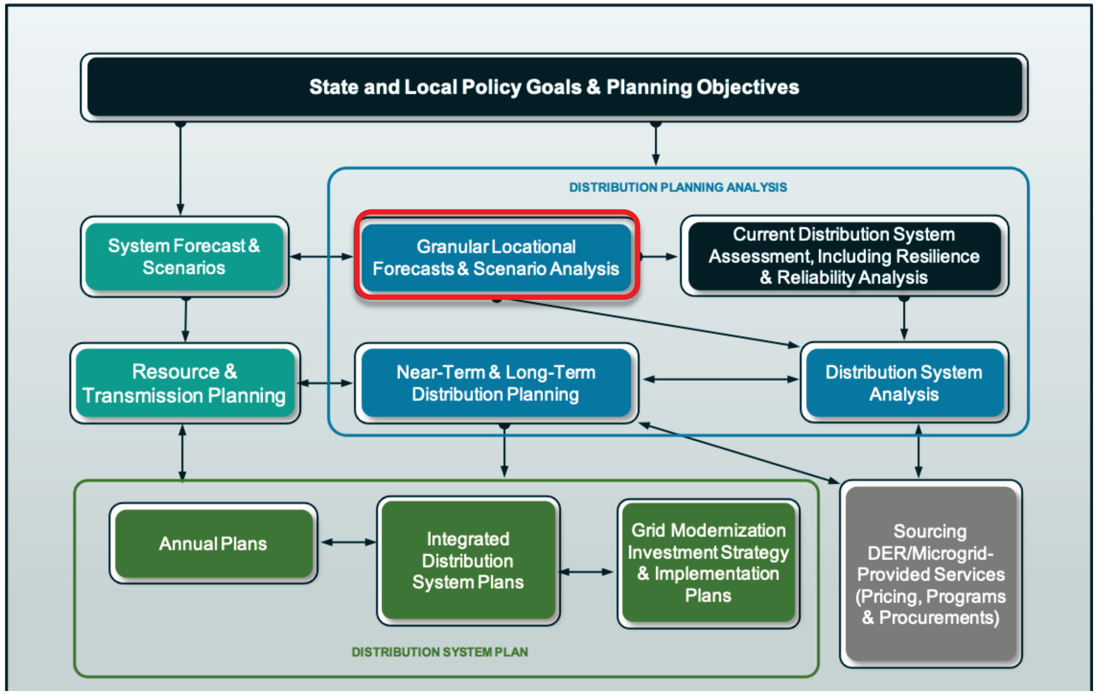
- **Hawaiian Electric Companies** - The utility convenes a Forecast Assumptions Working Group for its Integrated Grid Planning stakeholder engagement process.

- **Eversource Energy (MA)** - Forecasting and Electric Demand Assessment Methodology and this presentation describe how forecasting fits into the utility's overall distribution planning process

Load Forecasting: Tools

- LoadSeer - Scenario management, load growth, and capacity analysis
- Kevala's platform - Load and DER forecasting and DER adoption propensity modeling
- ITRON's forecasting analytics website includes MetrixIDR (short-term automated forecasting), MetrixND (statistical modeling), and MetrixLT (load shape modeling)
- SAS Energy Forecasting
- Eviews - Econometric analysis, forecasting, and simulation
- Clean Power Research PowerClerk Analytics - DER adoption scenarios and PV production
- AdopDER - Portland General Electric used this tool to estimate technical, economic, and achievable potential for more than 50 DER technologies and program measures
- NREL's Distributed Generation Market Demand (dGen^{TM}) model - Customer adoption of DERs
  NREL's TEMPO model - Long-term scenarios for transportation
- NREL's EVI-X Modeling Suite - EV charging infrastructure needs
- NREL's End-Use Load Profiles for the U.S. Building Stock - Represents all major end uses, building types, and climate regions in the U.S. commercial and residential building stock. Berkeley Lab and NREL published practical guidance on using the database.
- EPRI's Load Shape Library - Publicly-available dataset of end-use building load profiles
- Energetics' EV Watts - Data and analysis on vehicle electrification

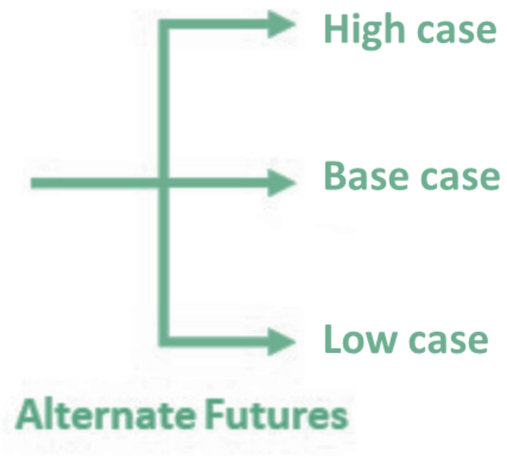
Example Section: Scenario Analysis



Scenario analysis for forecasting

- Distribution system studies beyond a five-year horizon introduce greater uncertainty, given the reliance on forecasts for system changes (e.g., load, DER adoption, electrification).

- Understanding the potential impact of several potential forecasts can improve strategic decisions for longer-term distribution system planning.



Create 3 possible future scenarios

Develop a base case, a high and low case from the DER, load, and other related forecasts

Create a range of potential future scenarios

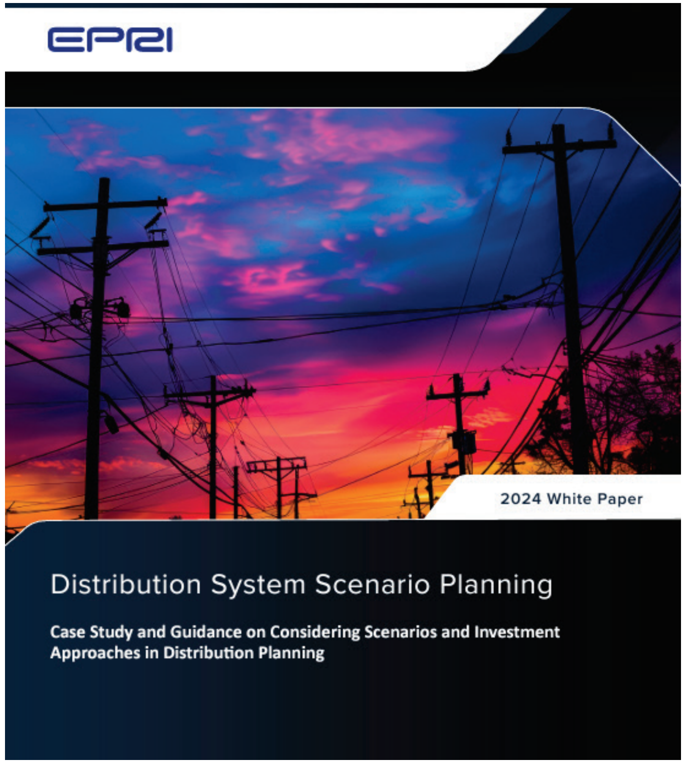
Requires probabilistic techniques and detailed information to develop sensitivities

Scenario analysis for implementation planning

- Applying plausible high-impact scenarios to stress-test implementation plans is a well-established approach to assess plan flexibility needed and test plan robustness under different potential conditions.
- The process helps identify least-regret investments.

Approach	Description
No regrets	Proceed with actions necessary on all/most scenarios
Most likely	Apply "likelihood factors" to move forward with initiatives that are more likely to be necessary
Worst case	Address the full range of risks that develop in any of the scenarios
Leveraged	Proceed with actions with a higher operational risk (No regrets/ Most likely); scale project to address worst-case scenario
Staged	Proceed with worst case actions but advance the necessary elements in multiple phases

Source: EPRI, 2024, Distribution System Scenario Planning, adapted from Table 2



Best practices

- Translate systemwide or statewide load, DER, and climate forecasts into distribution-level forecasts that combine bottom-up information.
  - Bottom-up information may include localized DER adoption data and demographics.
- Determine the scenario analysis method to inform long-term planning based on the degree of uncertainty with planning forecasts and implementation factors.
- Use scenarios to understand the impact on timing, scope, and scale of grid needs to determine the plan flexibility required.
- Develop longer-term strategies and implementation plans that identify least-regrets and on- and off-ramps to address uncertainty.
- Apply scenarios to stress-test whether plans have sufficient flexibility to change as needed and are robust with respect to least-regrets investments.

Example state and utility practices

- State examples
  - OR (PUC staff's proposed revised guidance) - High, medium, and low DER and EV adoption scenarios for feeder-level forecasts of DER and EV adoption
  - VT - Load forecasts account for building and transportation electrification to comply with state climate policy

- Utility examples
  - DTE (MI) - Planning scenarios include electrification, catastrophic storms, and behind-the meter distributed generation and distributed storage
  - Eversource (MA) - Developed low/high DER saturation scenarios to support planning and identify capacity upgrades

DTE (MI) 2023 DSP Grid Modernization Scenarios

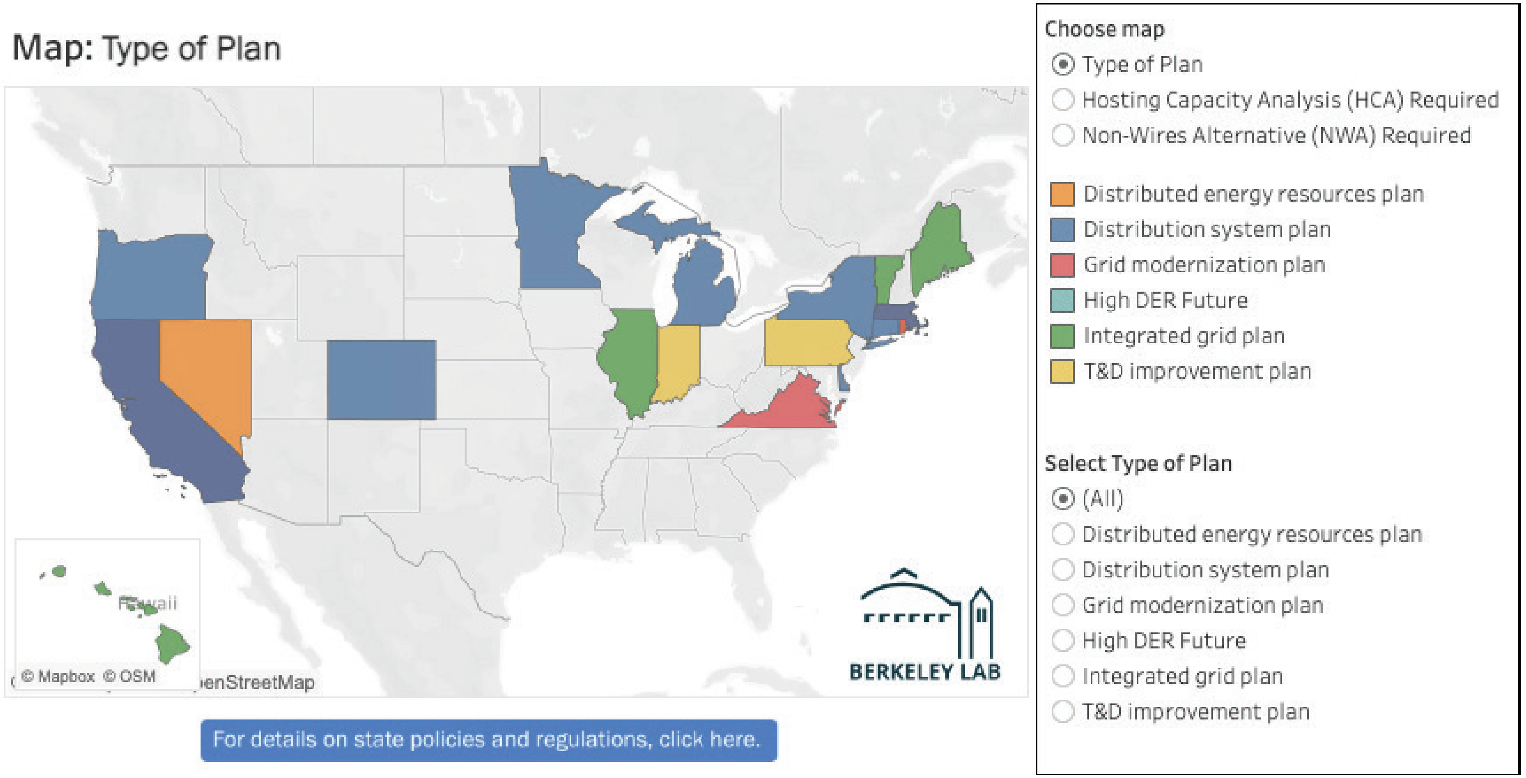
Scenario	Description
Electrification	High electrification of transportation, buildings, and industrial processes
Increasing CAT Storm	Increased frequency and intensity of catastrophic (CAT) storm threats to electric infrastructure
DG/DS	High adoption of distributed generation (DG) solar PV and distributed storage (DS) as batteries behind the meter (BTM)

Source: DTE 2023 Distribution System Plan

Other Resources

State requirements for electric distribution planning

- Data visualization, online catalog, and document library summarize legislative and regulatory requirements for electric utilities to file some type of distribution system plan in 20 jurisdictions
- **Interactive interface** to identify state-by-state requirements
  - Types of distribution plans filed
  - Filing frequency
  - Planning horizon
  - Non-wires alternatives
  - Hosting capacity analyses
- Details by state
  - Proceedings, orders
  - Filed utility plans
  - Type of regulatory action
  - State goals and objectives
  - Term of action plan
  - Stakeholder engagement and equity provisions



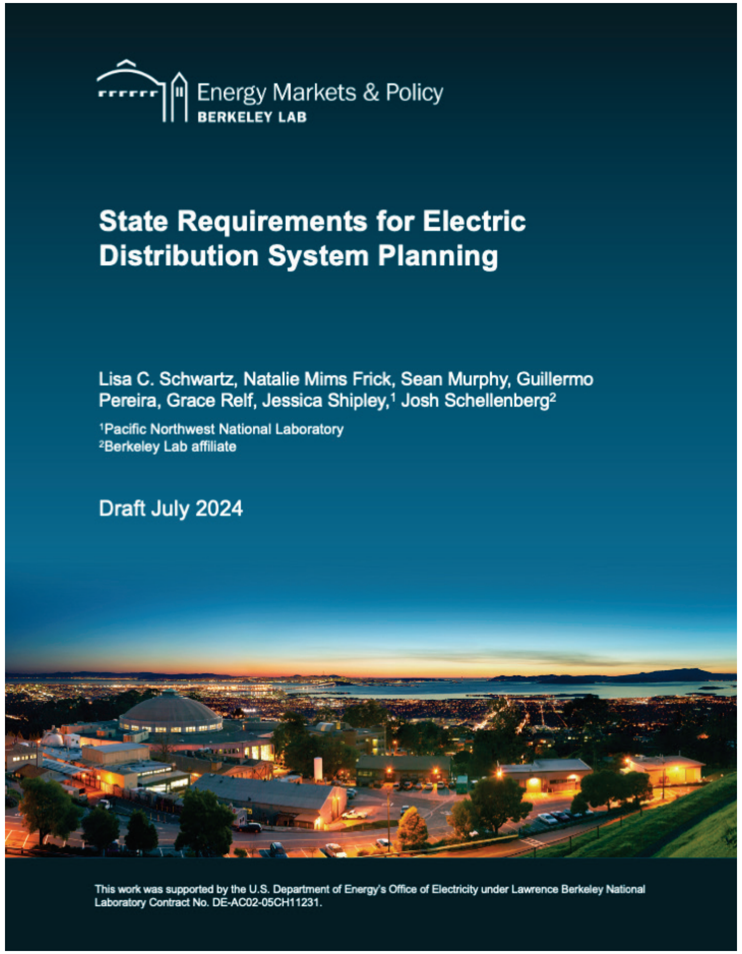
https://emp.lbl.gov/state-distribution-planning-requirements

State requirements for electric distribution planning (forthcoming)

- State goals and objectives
- Procedural requirements
- Stakeholder engagement
- Forecasting loads and DERs
- Hosting capacity analysis
- Baseline information requirements
- Grid modernization strategy
- Grid needs assessment
- Non-wires solutions
- Reliability and resilience analyses
- Equity
- Pilots
- Coordination with other planning processes

Reviews state requirements and utility approaches and offers best practices.

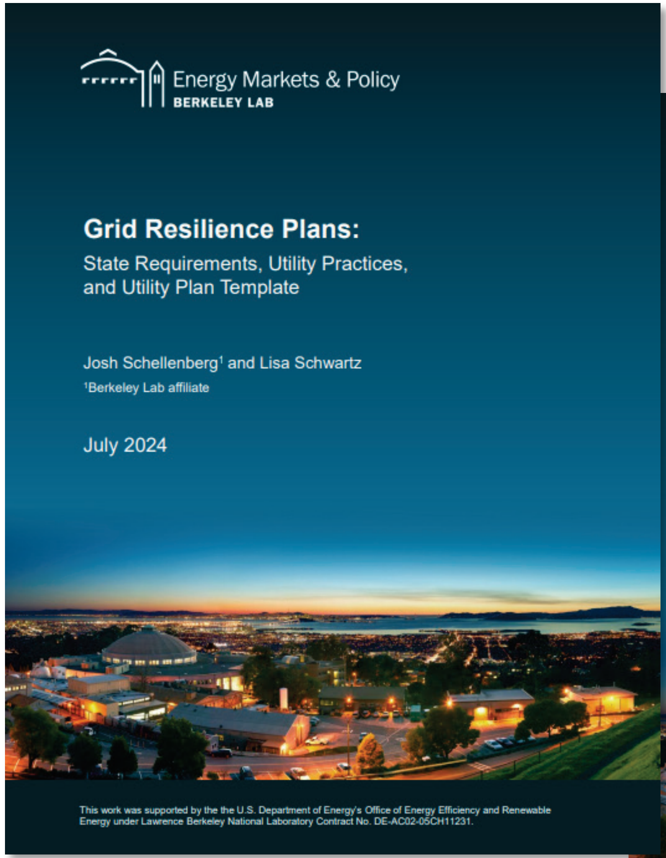
Includes links to legislation; regulatory requirements, proceedings, and orders; and filed utility plans.



Will be posted at https://emp.lbl.gov/publications/state-requirements-electric

Grid resilience plans: Report and template

- Overview of state requirements and emerging best utility practices for resilience planning
- Template that utilities and states can adapt
- Key template elements
  - A vulnerability assessment
  - Description of proposed resilience programs
  - Projected costs and rate impacts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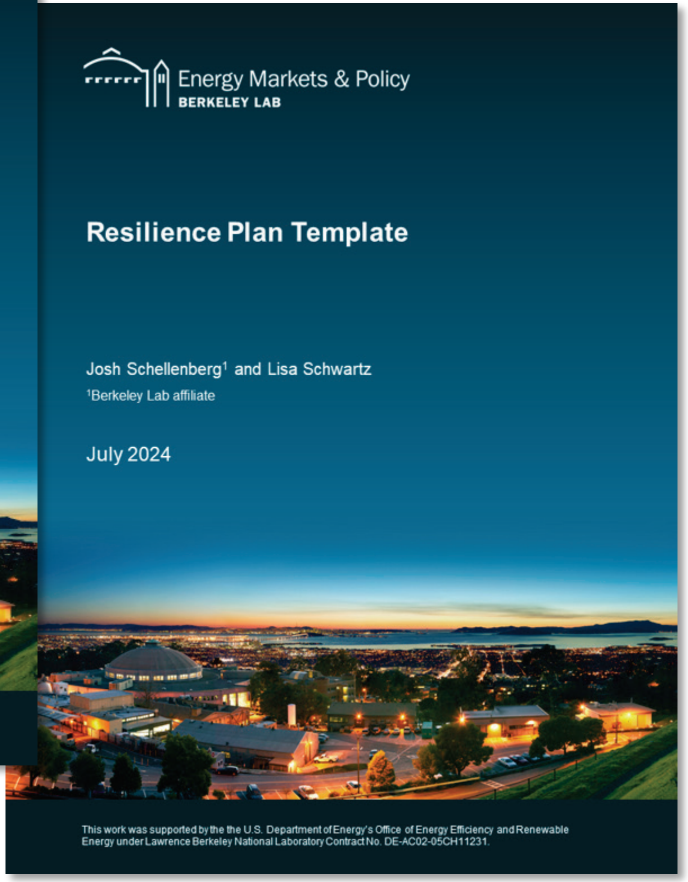
Grid Resilience Plans:
State Requirements, Utility Practices, and Utility Plan Template

Josh Schellenberg[1] and Lisa Schwartz
[1]Berkeley Lab affiliate

July 2024

This work was supported by the the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.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Resilience Plan Template

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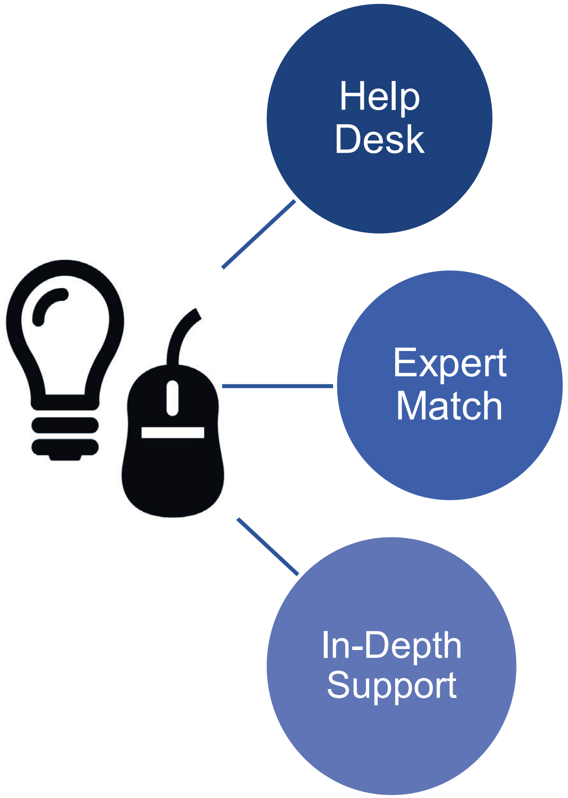
https://emp.lbl.gov/publications/grid-resilience-plans-state

Resources: Direct state technical assistance from National Labs

- **Distribution system planning** and **grid resilience planning**: Contact Lisa Schwartz: lcschwartz@lbl.gov
- **Other electricity topics**: [Resources and Assistance for State Energy Offices and Regulators program]



Help Desk
- Online intake form with rolling Lab screening
- Connect to PM within 2 business day to clarify request
- Connect to SME within 5 business days
- Up 4 person-hours of support

Expert Match
- Online intake form with rolling review by Labs
- Connect to PM within 2 business day to clarify request
- Connect to SME within 5 business days
- Up to 80 person-hours of support

In-Depth Support
- Detailed application form
- Planned 9-month work cycle by Labs & DOE
- 80+ person-hours of support
- ***Next application cycle anticipated in Fall***

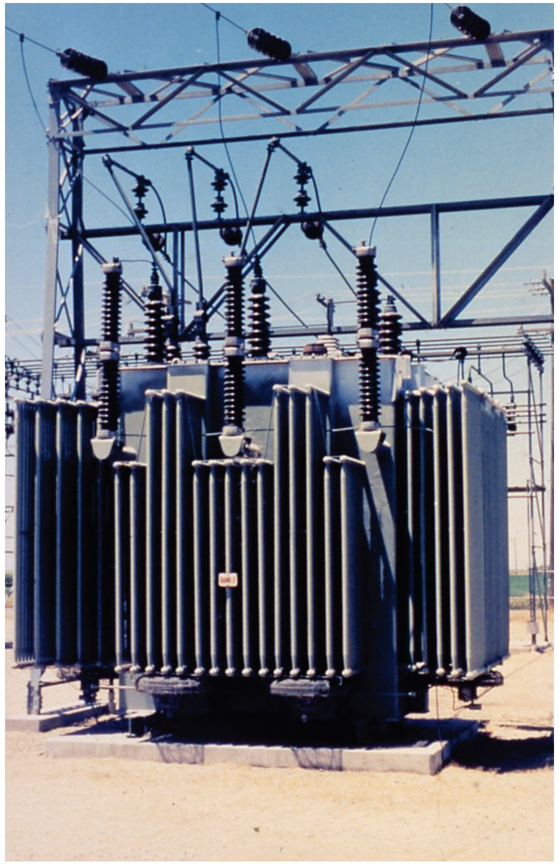
statetaprogram.lbl.gov

Other resources

- **Berkeley Lab's integrated distribution system planning website**
  - Including presentations and recordings for prior trainings (scroll below diagram to "Regional and state trainings")
  - Next round of IDSP trainings with NARUC and NASEO in December (East), March (Midwest) and April (West)
- **DOE's Distribution Grid Transformation website**
- U.S. Department of Energy, *Modern Distribution Grid* guidebooks
- S. Murphy, L. Schwartz, C. Reed, M. Gold, and K. Verclas, *State Energy Offices' Engagement in Electric Distribution Planning to Meet State Policy Goals*, National Association of State Energy Officials, 2023
- J. Carvallo and L. Schwartz, *The use of price-based demand response as a resource in electricity system planning*, Berkeley Lab, 2023
- J. Keen, E. Pohl, N. Mims Frick, J.P. Carvallo and L. Schwartz, *Duke Energy's Integrated System and Operations Planning: A comparative analysis of integrated planning practices*, Grid Modernization Laboratory Consortium, 2023
- Berkeley Lab, Pacific Northwest National Lab and NARUC, Peer-Sharing Webinars for Public Utility Commissions on Integrated Distribution System Planning, 2023
- N. Frick, S. Price, L. Schwartz, N. Hanus and B. Shapiro, *Locational Value of Distributed Energy Resources*, Berkeley Lab, 2021

Forthcoming resources

- Report on distribution system planning data, metrics and analyses
- Report on resilience planning data, metrics and analyses
- Cost-effectiveness evaluation for grid modernization investments
- Cost recovery challenges for grid modernization investments
- Interactive resource for best practices for grid codes
- ICE Calculator 2.0 (recent updates) to value reliability investments that reduce or avoid interruptions lasting up to 24 hours
  - Publicly available tool widely cited in support of utility regulatory filings
  - Updates will incorporate results of new surveys of residential and nonresidential customers on the cost of power interruptions throughout the U.S. and improve the tool's design and performance
    - Open, transparent, and peer-reviewed process to upgrade the ICE Calculator
  - Project Advisory Committee includes DOE, NARUC, NASEO, NASUCA, EEI, EPRI, NRECA and APPA
  - Funding from ~10 utilities and U.S. Department of Energy's Office of Electricity



Source: EPRI

Extra Slides

Contact

Lisa Schwartz, lcschwartz@lbl.gov

For more information

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Acknowledgements

This work was funded by the U.S. Department of Energy Office of Electricity, under Contract No. DE-AC02-05CH11231.

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