



# Utility and Grid Operator Resources for Future Power Systems Webinar Series

## Integrated Distribution Planning

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National Renewable Energy Laboratory  
Grid Planning and Analysis Center

NREL Webinar series

July 24, 2025

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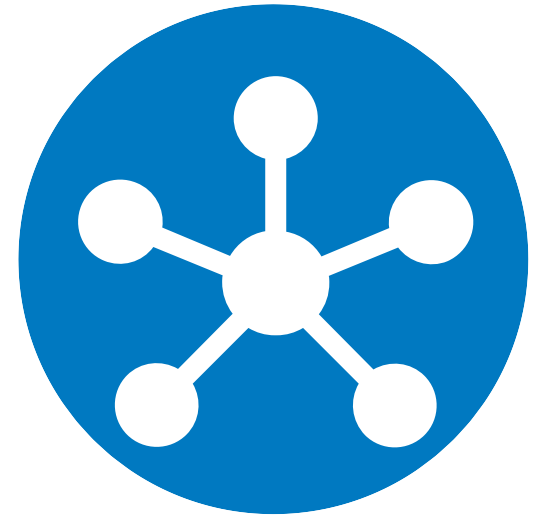
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**Integrated Distribution  
Planning**

# 1. Overview

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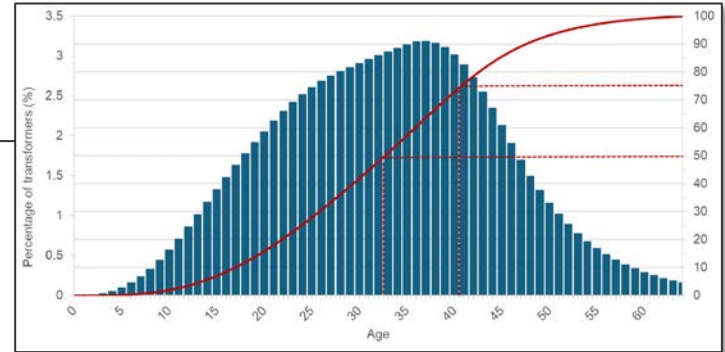
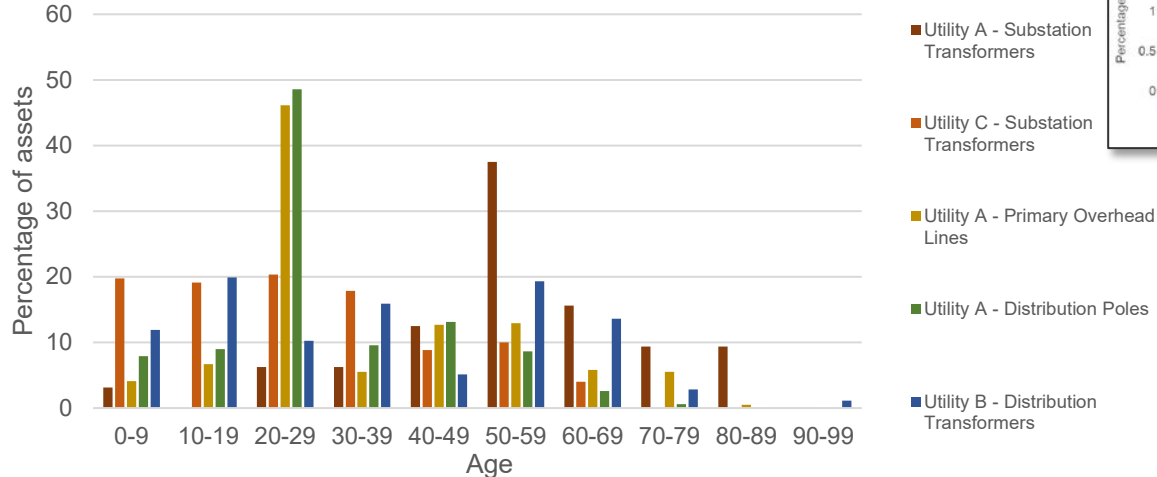
# Motivations for Integrated Distribution Planning

Overview | Industry Status | Emerging Practices | NREL Resources

Generational opportunity to address:

- aging infrastructure

### Age of Utility Equipment



Source: NREL. 2024. *Distribution Transformer Demand: Understanding Demand Segmentation, Drivers, and Management Through 2050.* <https://www.nrel.gov/docs/fy25osti/92076.pdf>.

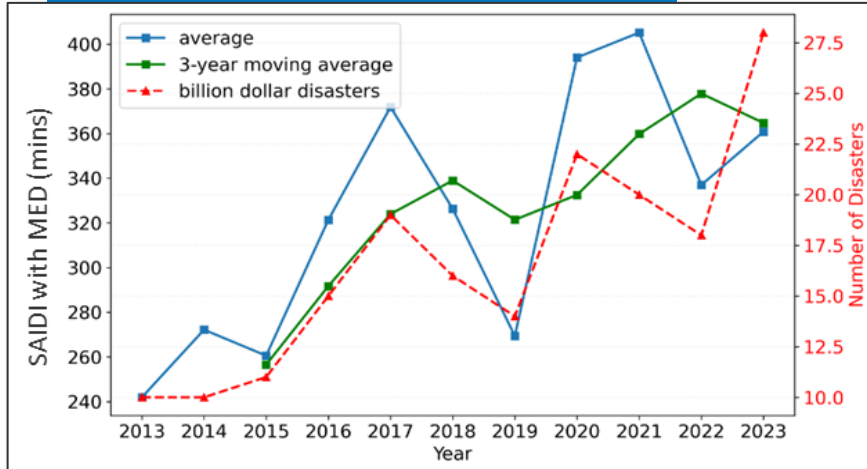
Source: NREL. 2025. *NREL Analysis of Distribution Utility Asset Data.*

# Motivations for Integrated Distribution Planning

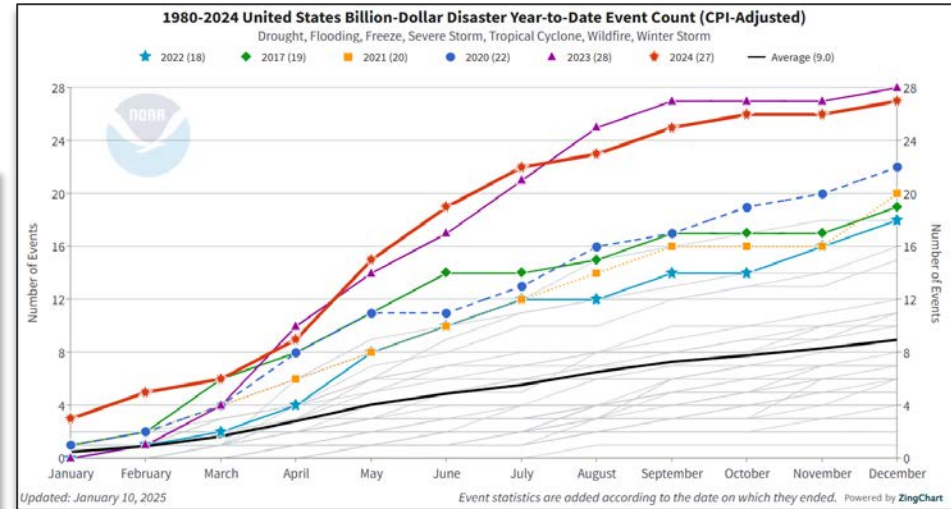
Overview | Industry Status | Emerging Practices | NREL Resources

Generational opportunity to address:

- aging **infrastructure**
- increasing **reliability and resilience** challenges



[1] Source: NREL. 2025. EIA 861 Form Analysis.



[2] Source: NOAA National Centers for Environmental Information (NCEI). 2025. "U.S. Billion-Dollar Weather and Climate Disasters." <https://www.ncei.noaa.gov/access/billions/>.

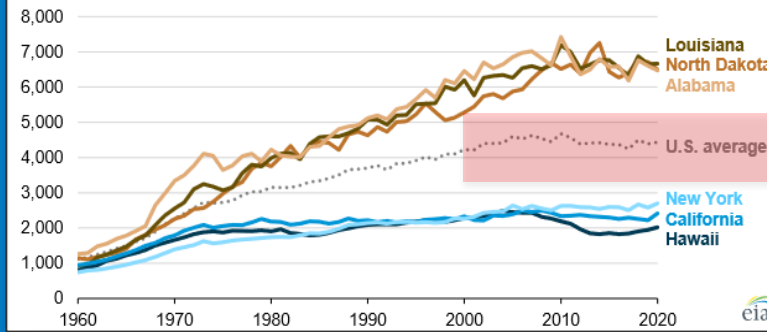
# Motivations for Integrated Distribution Planning

Overview | Industry Status | Emerging Practices | NREL Resources

Generational opportunity to address:

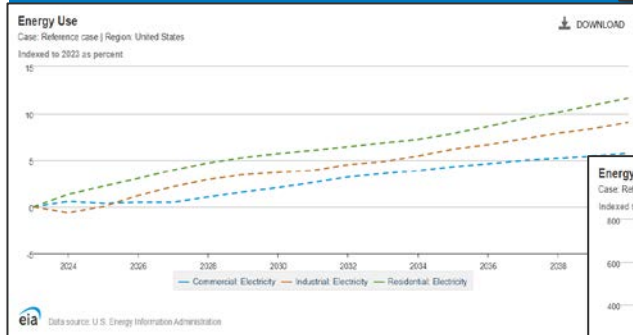
- aging infrastructure
- increasing reliability and resilience challenges
- record capacity expansion for electrification and new loads
- integration and capturing the value of distributed energy resources (DERs)

Annual residential electricity retail sales per capita, selected states (1960–2020)  
kilowatthours (kWh) per person

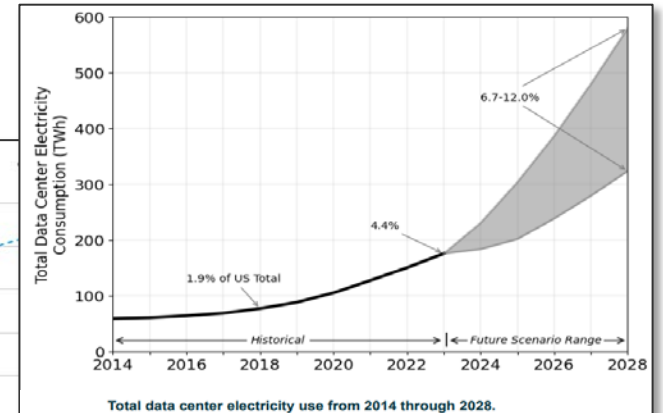
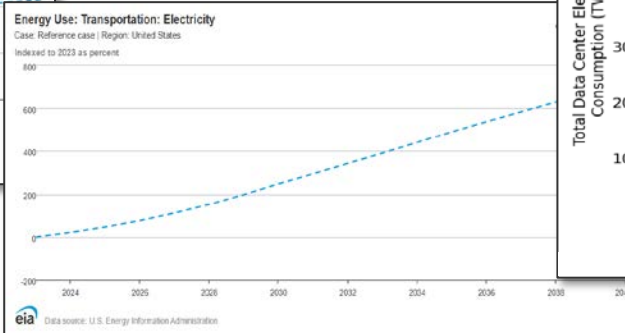


Source: EIA. 2021. *Per Capita U.S. Residential Electricity Use Was Flat in 2020, But Varied by State, 2021.* <https://www.eia.gov/todayinenergy/detail.php?id=49036>.

Source: Berkely Lab. 2024. 2024 United States Data Center Energy Usage Report. <https://www.lbl.gov/berkeleylab/publications/2024-01-24-United-States-Data-Center-Energy-Usage-Report.pdf>



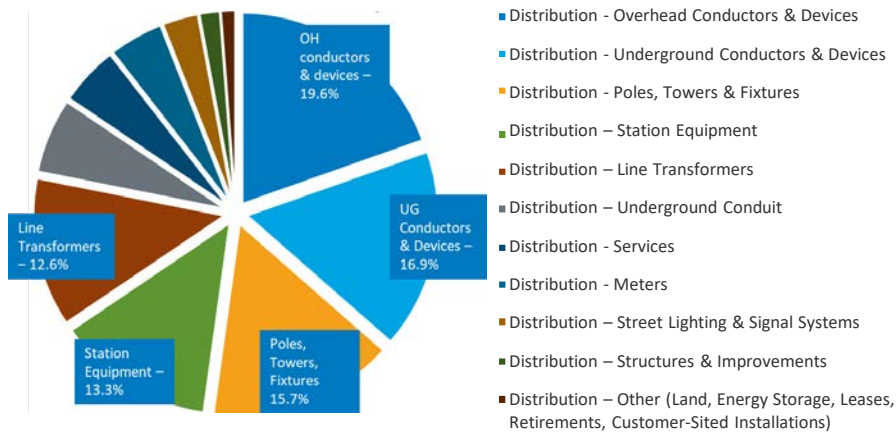
Source: EIA. 2023. *Annual Energy Outlook. U.S. Energy Information Administration - EIA - Independent Statistics and Analysis*



# Motivations for Integrated Distribution Planning

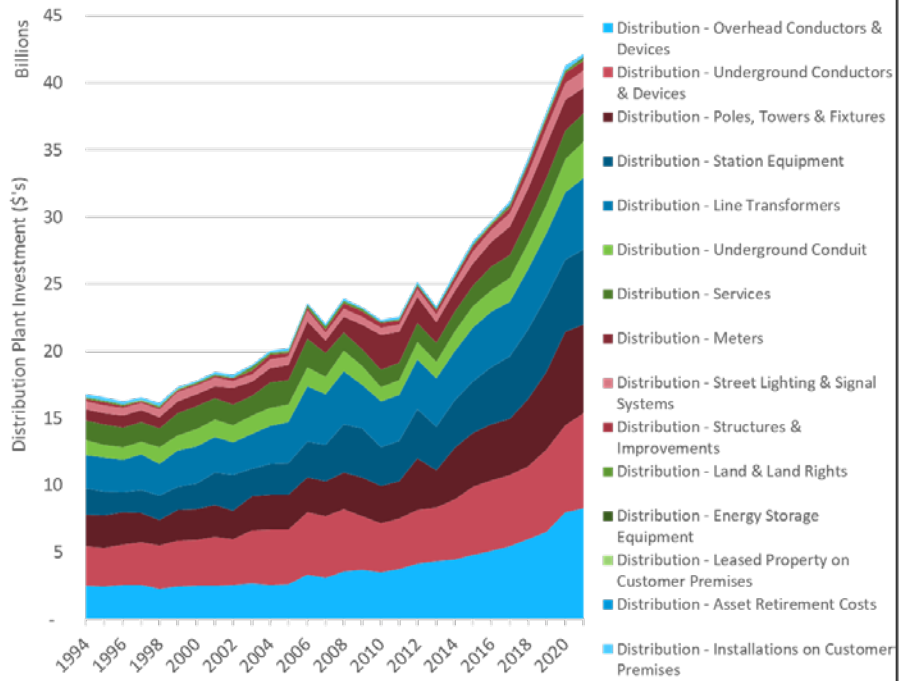
Overview | Industry Status | Emerging Practices | NREL Resources

Generational opportunity to address:



- all while ensuring **affordable** electricity to power economic growth; **reliable, resilient** energy to drive manufacturing, transportation, agriculture; at **just, reasonable,** and **nondiscriminatory** rates.

FERC Form 1 Distribution Plant Investment (1994-2021 Using 2022 GDP Deflators)

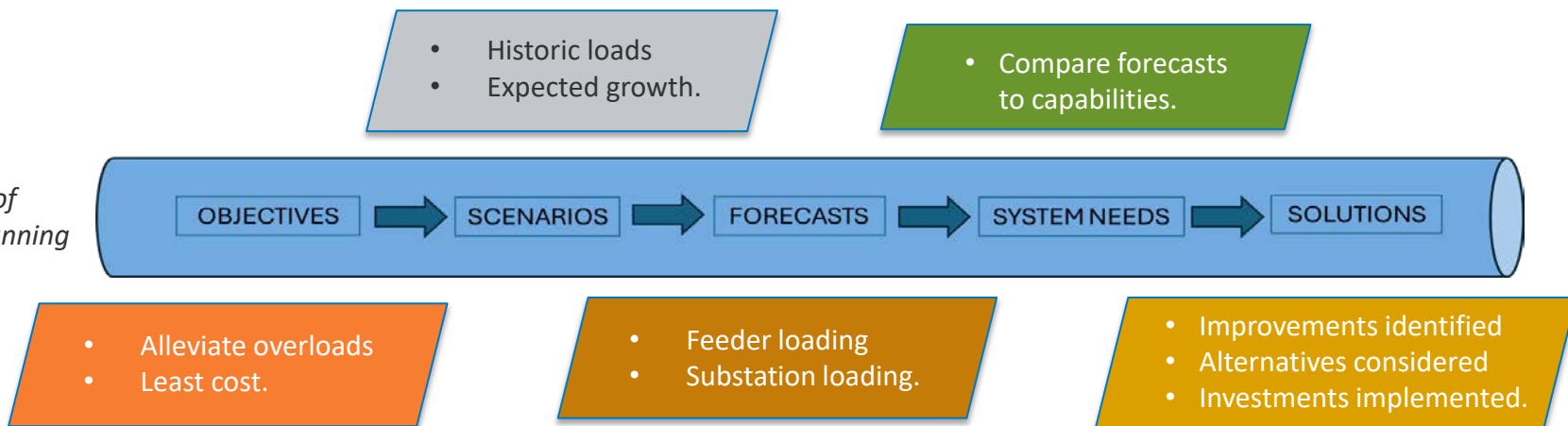


Source: NREL. 2024. Analysis of FERC Form 1. Data accessed from Hitachi Energy's Velocity Suite.

# Diagram of Traditional Distribution Planning

Overview | Industry Status | Emerging Practices | NREL Resources

*Core activities of  
Distribution Planning*



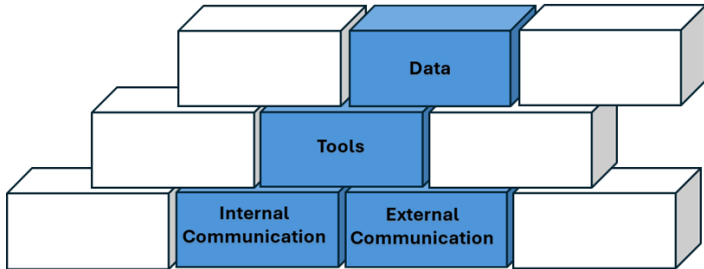
# Diagram of Integrated Distribution Planning

Overview | Industry Status | Emerging Practices | NREL Resources

Integrating **Stakeholders' Expectations** Into Distribution Planning:

Integrating **Grid Modernization** Into Distribution Planning:

Core activities of  
Distribution Planning



Building Blocks of Distribution Planning

Integrating **Transmission and Generation** Into Distribution Planning:

# Definition

Overview | Industry Status | Emerging Practices | NREL Resources



“For decades, traditional distribution planning practices have helped utilities meet core requirements for providing safe, reliable and affordable delivery of electricity. However, advancements in technologies, trends in customer distributed energy resource (DER) adoption, and expanding clean energy goals are prompting reevaluation of current distribution planning practices.”

Source: Smart Electric Power Alliance (SEPA). 2020. “Integrated Distribution Planning: A Framework for the Future.”  
<https://sepapower.org/resource/integrated-distribution-planning-a-framework-for-the-future/>.



**NARUC**  
National Association of  
Regulatory Utility Commissioners

“Emerging technologies, decreasing costs, consumer preferences, new energy service providers, and state and local efforts are driving significant growth in distributed energy resources (DERs) such as solar, storage, energy efficiency, demand management, and microgrids. These investments increasingly require regulatory and policy innovation and a greater emphasis on planning to overcome system complexities and avoid unnecessary costs associated with operating the grid.”

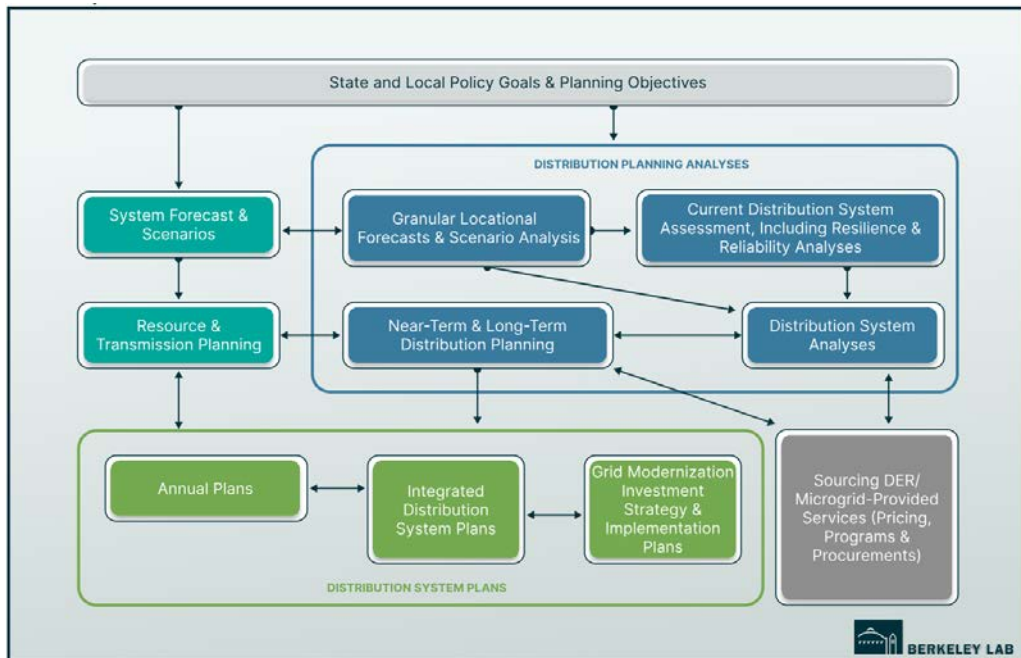
Source: National Association of Regulatory Utility Commissioners (NARUC). 2021. “Task Force on Comprehensive Electricity Planning.”  
<https://www.naruc.org/committees/task-forces-working-groups/retired-task-forces/task-force-on-comprehensive-electricity-planning/resources-for-action/roadmaps/>.

# Definition

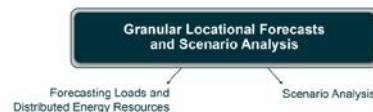
Overview | Industry Status | Emerging Practices | NREL Resources



BERKELEY LAB



“Integrated Distribution System Planning (IDSP) provides a systematic approach to satisfy customer service expectations and state and utility objectives for grid planning and design. It addresses grid reliability, resilience, safety, operational efficiency, and integration and utilization of distributed energy resources and includes a grid modernization roadmap.”



INTRODUCTION >

LOAD AND DER FORECASTING >

SCENARIO ANALYSIS >

OVERVIEW	ROLES AND RESPONSIBILITIES	BEST PRACTICES	STATE PRACTICES	UTILITY PRACTICES	FLOW CHART	TOOLS	RESOURCES
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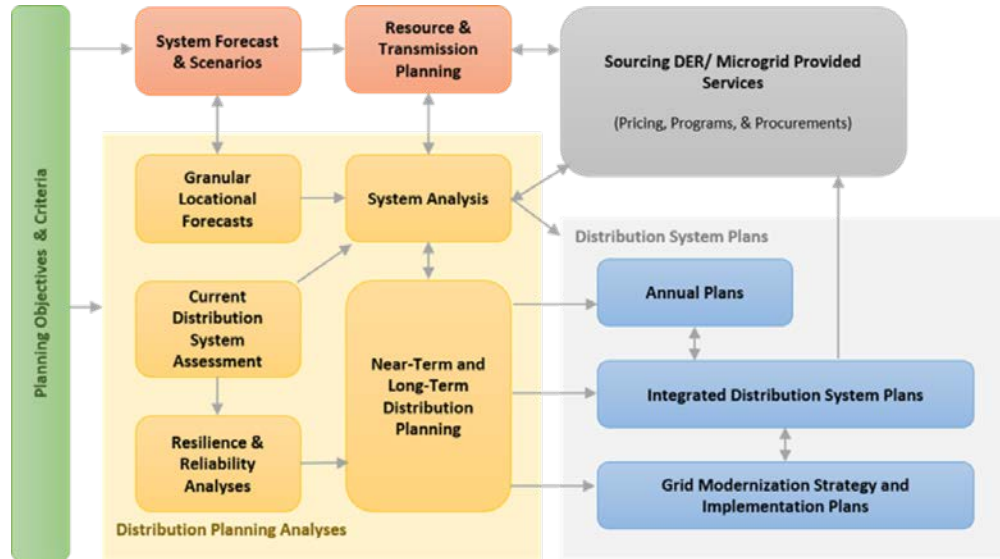
Source: Berkely Lab. 2025. “Integrated Distribution System Planning.” <https://emp.lbl.gov/projects/integrated-distribution-system-planning>.

# Definition

Overview | Industry Status | Emerging Practices | NREL Resources



Office of Electricity



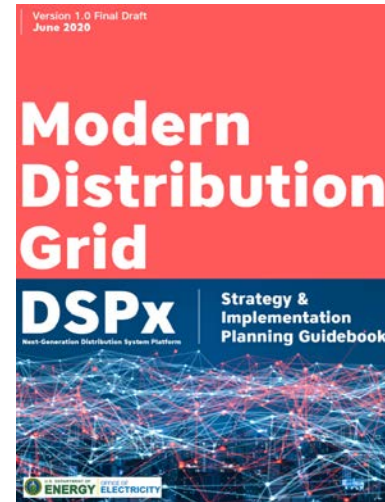
“An Integrated Distribution System Planning (IDSP) process provides a decision framework for developing holistic infrastructure investment strategies for local electricity grids. The planning process involves the determination of grid system requirements that are needed to achieve reliability, resilience, safety, affordability, and other objectives, such as equity and decarbonization.”

# Overview—DSPx

Overview | Industry Status | Emerging Practices | NREL Resources

- Developed in consultation with more than 40 industry experts, including utilities, regulators, trade groups, and vendors
- Helps utilities develop long-term investment strategies with increasing levels of complexity
- Serves as a guide for investment decisions based on systematic mapping of objectives to specific technology functions
- Enables improved communication between utilities and regulators (or other oversight organizations)
- Describes different investment prioritization tests (e.g., cost effectiveness or cost-benefit) tests.

Source: Pacific Northwest National Laboratory. 2022. “Modern Distribution Grid Project.”  
<https://gridarchitecture.pnnl.gov/modern-grid-distribution-project.aspx>.



# Diagram of Integrated Distribution Planning

Overview | Industry Status | Emerging Practices | NREL Resources

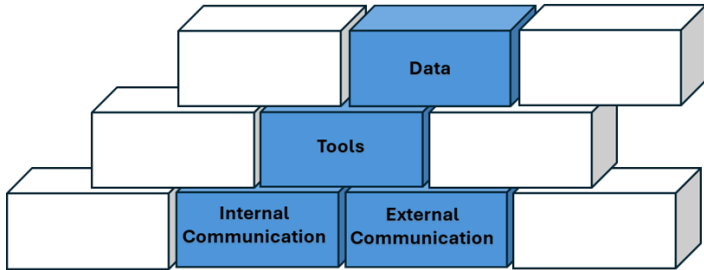
## Integrating **Stakeholders' Expectations** Into Distribution Planning:

- Reliability
- Resilience
- Affordability
- Just, reasonable, and nondiscriminatory
- State decarbonization goals.

## Integrating **Grid Modernization** Into Distribution Planning:

- Aging infrastructure
- Systems and sensors
- Technology adoption
- Microgrids
- Distribution automation.

Core activities of  
Distribution Planning



Building Blocks of Distribution Planning

## Integrating **Transmission and Generation** Into Distribution Planning:

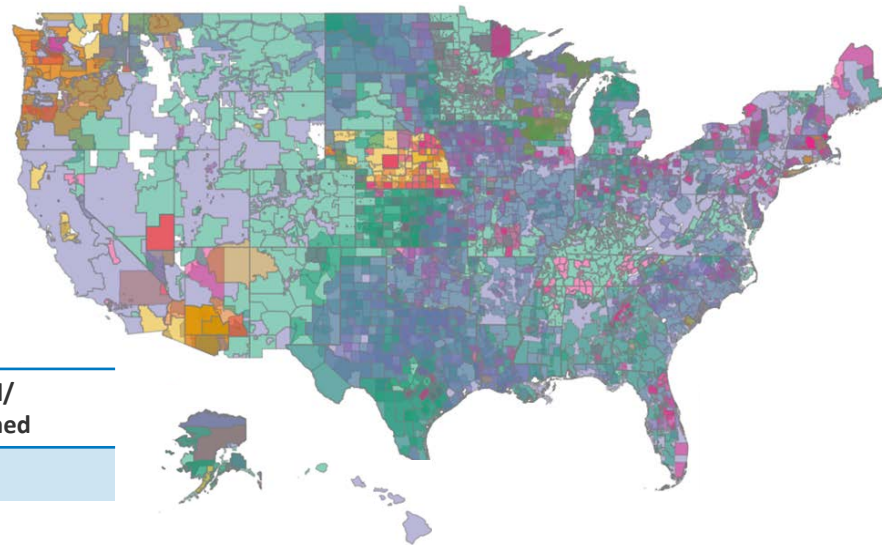
- Harmonized forecasting
- Optimal solution development
- Integrated Resource Planning
- Distribution contingencies.

## 2. Industry Status

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# Regulation and Distribution Utilities

- More than 3,000 diverse investor-owned utilities (IOUs) and municipal and cooperative distribution utilities
- Massive patchwork of regulation across 50 states and with different regulation paradigms for IOUs, munis, and co-ops
- With a range of resources, and utilities that range from serving a handful of customers to millions of customers.



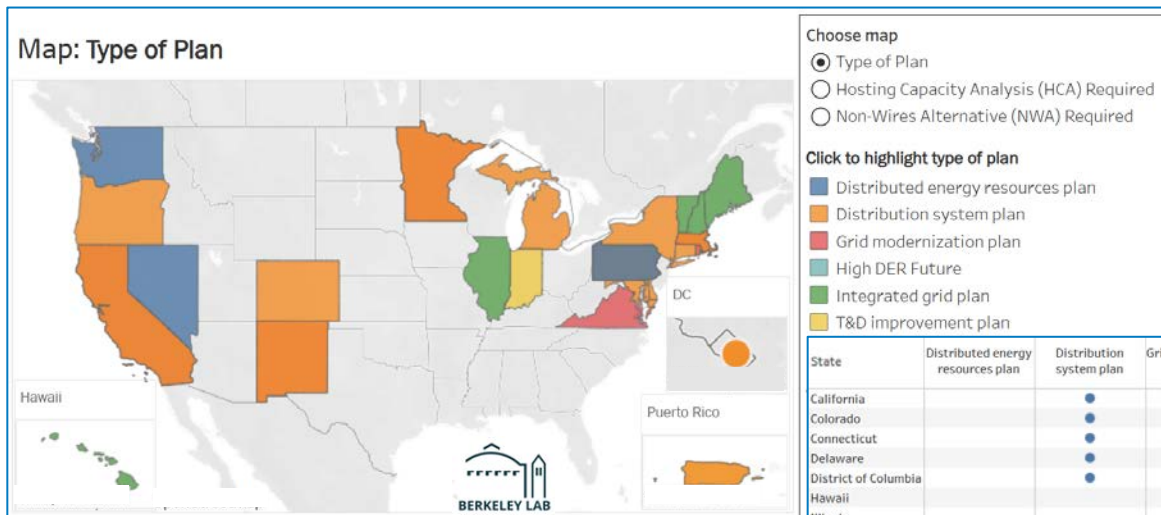
	Investor-Owned	Cooperative	Municipal/ Public-Owned
# of companies <sup>1</sup>	225	917	1,880
% of customers <sup>1</sup>	71%	14%	15%
<b>Structure</b>	Private, for-profit	Public, non-profit	Private, non-profit
<b>Ownership</b>	Shareholders	Members	Local government
<b>Business model</b>	Provide return on investment	Provide at-cost electricity rates	Provide at-cost electricity rates
<b>Regulation</b>	Public Service Commission	Co-op board of directors	Public Service Commission (Partial/state dependent)

Type of Utility	Count	Customer %	Load %
Cooperative	917	14%	13%
Federal	9	0%	1%
Investor Owned	225	71%	69%
Municipal	1760	11%	11%
Municipal Mktg Authority	3	0%	0%
Political Subdivision	92	3%	3%
State	15	1%	2%
Wholesale Power Marketer	1	0%	0%

Source: NREL. 2025. EIA 861 Form Analysis.

# State of the Industry—IDP Activity

Overview | Industry Status | Emerging Practices | NREL Resources



Many states and individual utilities are currently in the process of adopting various IDP processes.

State	Distributed energy resources plan	Distribution system plan	Grid modernization plan	High DER Future	Integrated grid plan	T&D improvement plan	NWA	HCA
California		•	•	•			•	•
Colorado		•					•	•
Connecticut		•					•	•
Delaware		•					•	•
District of Columbia		•					•	•
Hawaii					•		•	•
Illinois					•		•	•
Indiana						•		
Maine					•		•	•
Maryland		•					•	•
Massachusetts		•	•			•	•	•
Michigan		•					•	•
Minnesota		•					•	•
Nevada	•						•	•
New Mexico			•					
New York							•	•
Oregon		•					•	•
Pennsylvania						•		
Rhode Island			•			•	•	
Vermont					•		•	•
Virginia			•				•	
Washington	•						•	

Source: Lawrence Berkeley National Laboratory. 2025. "State Requirements for Electric Distribution System Planning."

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





# RFI Results—Example Question

Distribution  
planning  
includes  
non-wire  
alternatives

Fluency			
Not At All Fluent	Somewhat Fluent		Fluent
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Importance		
Not Important	Somewhat Important	Important
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Implementation Timeline			
No Plans	Soon (1-3 years)	Immediate (0-12 months)	Already Implemented or In Progress
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Easiness		
Not Hard	Somewhat Hard	Hard
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

# RFI Results—How To Interpret

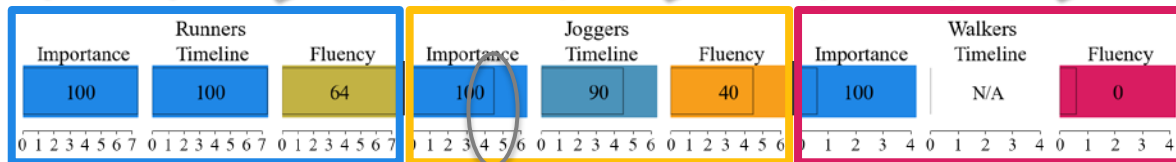
Importance  
Timeline  
Fluency

Importance  
Timeline  
Fluency

Importance  
Timeline  
Fluency

Distribution planning includes non-wire alternatives

Number of Respondents



5 out of 6  
respondents

- 7 runners
- 6 joggers
- 4 walkers



# RFI Results—Load Forecasting

[PRELIMINARY]

The load forecast includes probabilistic forecasts

The load forecast includes electrification of industrial processes

The load forecast includes high load factor enterprises (e.g., grow houses, data centers, or crypto-currency)

The load forecast includes time series (e.g., 8760) load forecasts, as opposed to yearly or seasonal peak forecasts

Distribution load forecasts are used to inform transmission planning

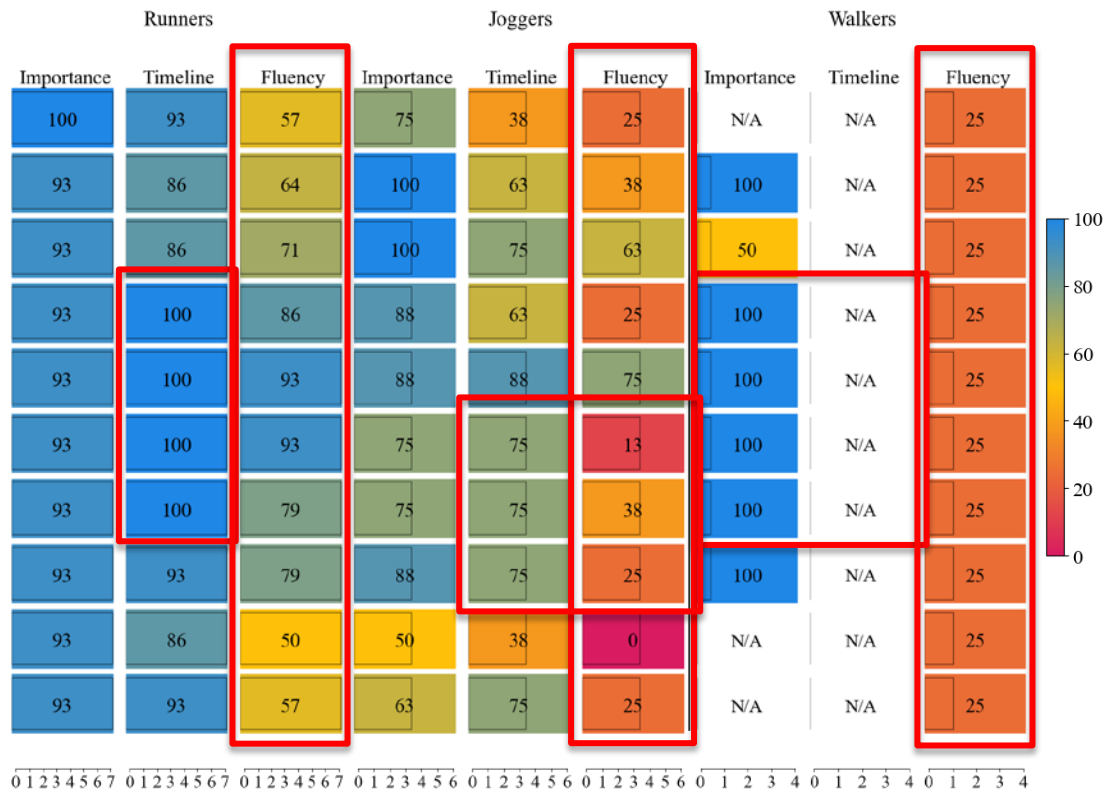
The load forecast includes PV adoption propensity

The load forecast includes residential electric vehicle adoption propensity

The load forecast includes energy efficiency adoption propensity

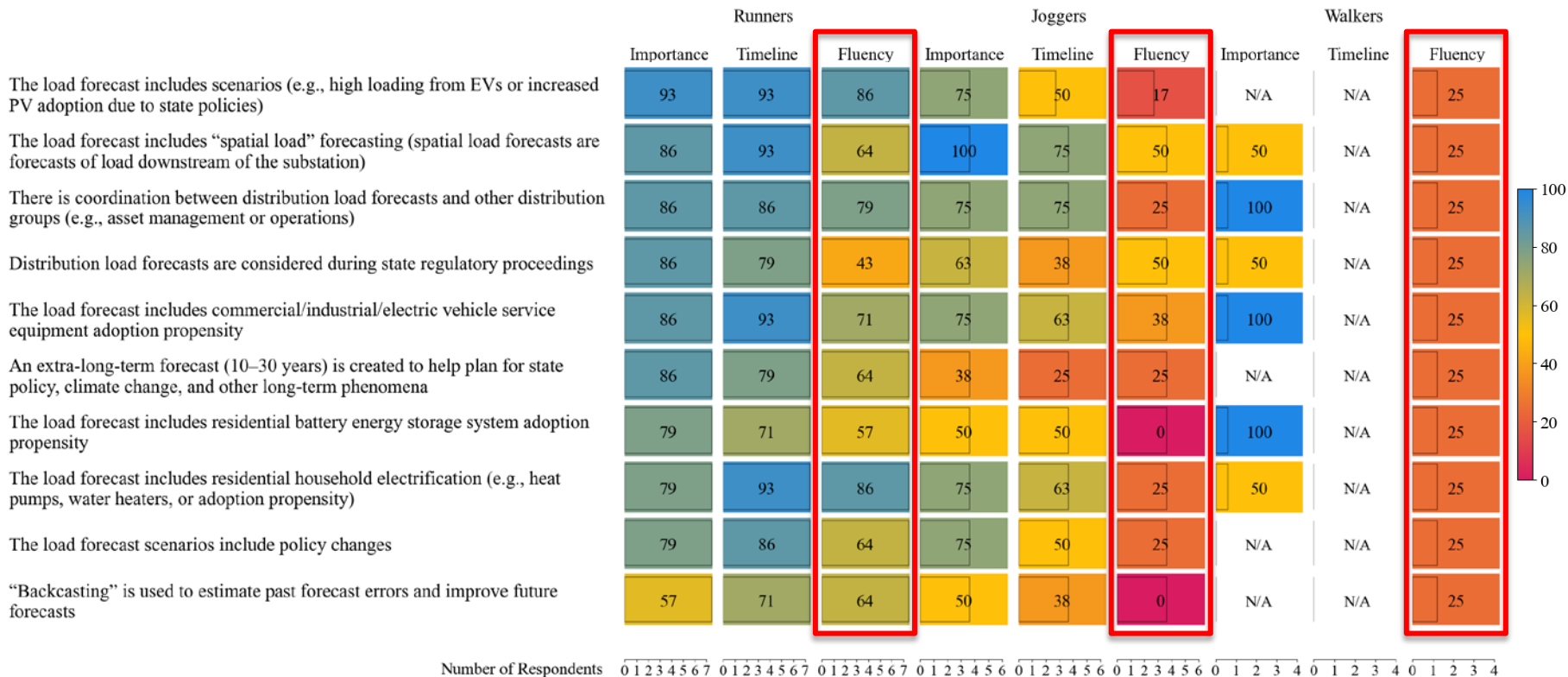
The load forecast includes demand response adoption propensity

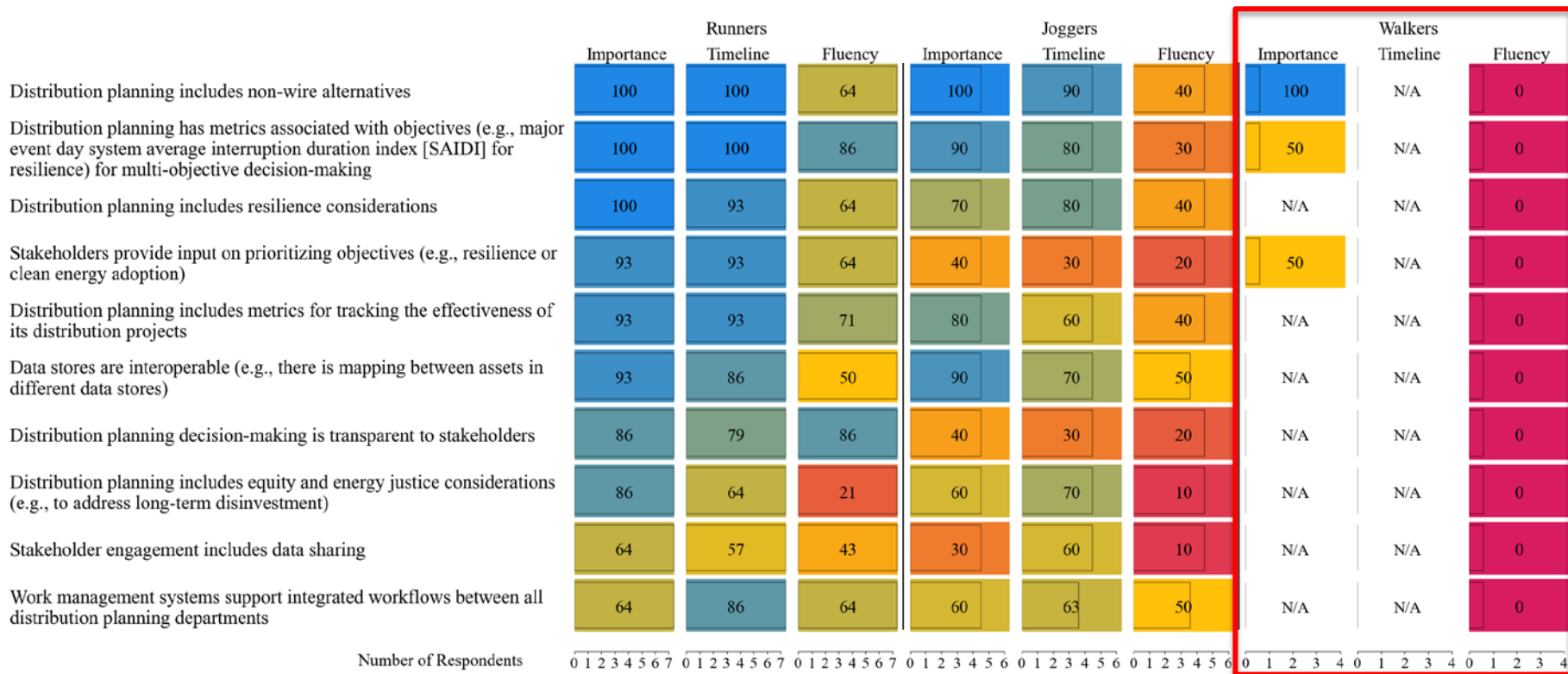
The load forecast includes impacts from variable pricing programs (e.g., time-of-use [TOU] or seasonal rates)



# RFI Results—Load Forecasting (cont'd)


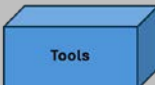

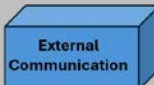
[PRELIMINARY]





# State of the Industry—NREL RFI Key Takeaways

Overview | Industry Status | Emerging Practices | NREL Resources

 <p>Data</p>	 <p>Tools</p>	 <p>Internal Communication</p>	 <p>External Communication</p>
<ul style="list-style-type: none"><li>• Data management is a fundamental first step</li></ul>	<ul style="list-style-type: none"><li>• Gap between importance and implementation timeline for topics and the fluency and hardness</li><li>• Attendees under pressure from expected increases in:<ul style="list-style-type: none"><li>• Load growth</li><li>• DER interconnections.</li></ul></li></ul>	<ul style="list-style-type: none"><li>• Importance of internal alignment on new processes and tools</li><li>• Need for ramping up workforce.</li></ul>	<ul style="list-style-type: none"><li>• Need for establishing mutual trust between stakeholders.</li></ul>
<ul style="list-style-type: none"><li>• Load forecasting topics ranked with higher importance than interconnection topics</li><li>• Opportunity for peer learning among utilities</li><li>• Even advanced utilities facing challenges with some IDP practices.</li></ul>			

## 3. Emerging Practices

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# Diagram of Integrated Distribution Planning

Overview | Industry Status | Emerging Practices | NREL Resources

## Integrating **Stakeholders' Expectations** Into Distribution Planning:

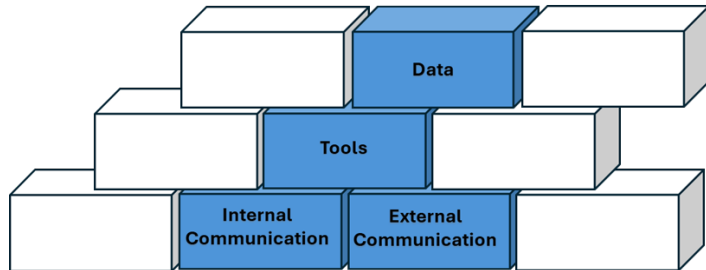
- Reliability
- Resilience
- Affordability
- Just, reasonable, and nondiscriminatory
- Stakeholder Decarbonization goals.

## Integrating **Grid Modernization** Into Distribution Planning:

- Aging infrastructure
- Systems and sensors
- Technology adoption
- Microgrids
- Distribution automation.



Core activities of  
Distribution Planning



## Integrating **Transmission and Generation** Into Distribution Planning:

- Harmonized forecasting
- Optimal solution development
- Integrated Resource Planning
- Distribution contingencies.

Building Blocks of Distribution Planning

# Duke ISOP (Integrated System and Operations Planning) example

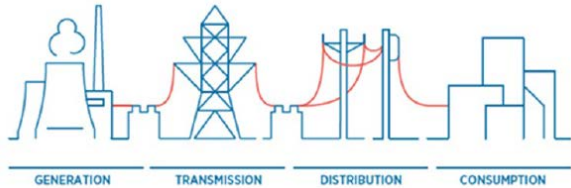
Overview | Industry Status | Emerging Practices | NREL Resources

The companies cited trends in these areas as contributing factors in a need to update planning tools:

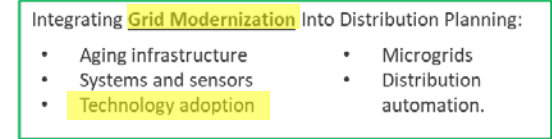
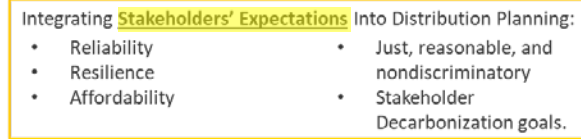
- technology development
- declining costs of resources
- customer preferences for distributed energy resources (DERs) such as solar and electric vehicles

Desired tools that:

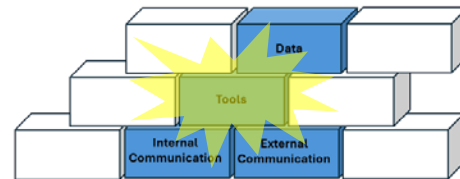
- better identify the locational value of distributed generation
- strengthen the link between distribution and bulk power plans.



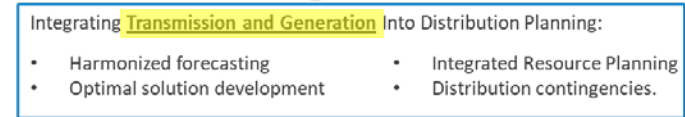
Power system domains included in the ISOP framework



Core activities of Distribution Planning



Building Blocks of Distribution Planning



Source: NREL. 2023. "Duke Energy's Integrated System and Operations Planning: A Comparative Analysis of Integrated Planning Practices." <https://research-hub.nrel.gov/en/publications/duke-energy-a-poss-integrated-system-and-operations-planning-a-comp>.

# Xcel Energy IDP for Minnesota (example)

Overview | Industry Status | Emerging Practices | NREL Resources

## Xcel Energy's IDP for Minnesota (Xcel Energy 2018)

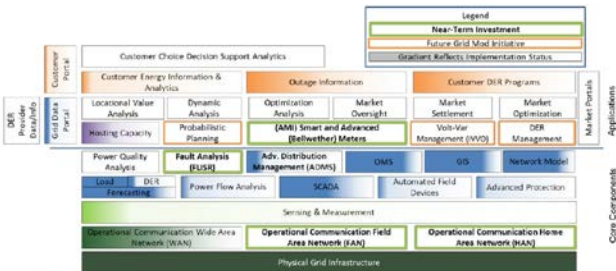
- Public Utility Commission (PUC) provided clear planning principles and objectives to guide IDPs.
- Xcel Energy defined three specific objectives: addressing aging assets, enabling clean energy transition, and modernizing the grid.
- PUC's decision on recent IDP filing requires discussion of how distribution planning is coordinated with the integrated resource plan, including:
  - Setting forecasts for DER consistently in its resource plan and its Integrated Distribution Plan
  - Conducting advanced forecasting to project the levels of DER deployment at a feeder level, using advanced planning tool
  - Proactively planning investments in hosting capacity and system capacity to allow DER and EV additions consistent with the forecast.

Integrating **Stakeholders' Expectations** Into Distribution Planning:

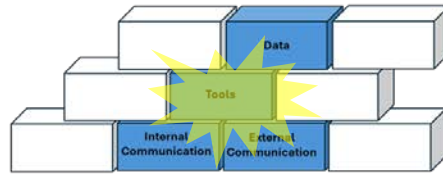
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Integrating **Grid Modernization** Into Distribution Planning:

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- Distribution automation.



Xcel Energy (Minnesota) Advanced Grid Intelligence and Security (AGIS): Core components, applications, and estimated implementation status (Xcel 2021)



Building Blocks of Distribution Planning

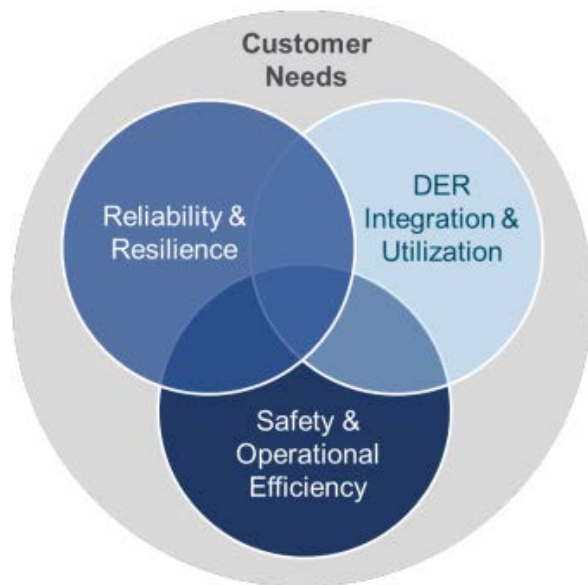
Integrating **Transmission and Generation** Into Distribution Planning:

- Harmonized forecasting
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Source: NREL. 2023. "Duke Energy's Integrated System and Operations Planning: A Comparative Analysis of Integrated Planning Practices." <https://research-hub.nrel.gov/en/publications/duke-energyaposs-integrated-system-and-operations-planning-a-comp>.

# IDP Benefits Beyond DER Complexities

Overview | Industry Status | Emerging Practices | NREL Resources



- Convergence of state energy policy objectives and priorities with utility/third-party planning processes
- Integration of customer and third-party systems with utility systems
- Improvements in reliability, resilience, and operational efficiency
- Leveraging advanced sensing, communications, control, information management, and computing technologies to enable the above
- Application of grid architecture and a focus on structure to ensure the building of a coherent system that is scalable
- Business process redesign and multi-jurisdictional coordination to effectively integrate planning, grid operations, and market design/operations.

Source: from U.S. DOE Office of Electricity. 2023. "Integrated Distribution System Planning Principles and Approaches."  
[https://www.energy.gov/sites/default/files/2023-11/IDSP%20Principles%2011%2004%20\\_optimized.pdf](https://www.energy.gov/sites/default/files/2023-11/IDSP%20Principles%2011%2004%20_optimized.pdf).

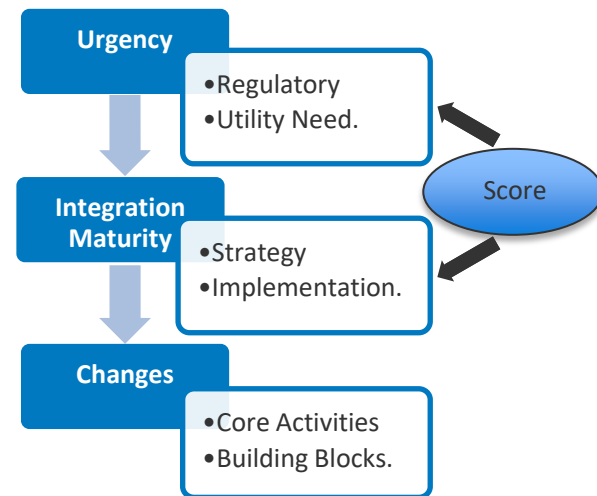
# IDP Self-Assessment Example

Overview | Industry Status | Emerging Practices | NREL Resources

Urgency		Integration Maturity	
Regulatory	Utility Need	Strategy	Implementation

Stakeholders' Expectations				
Reliability				
Resilience				
Affordability				
Energy efficiency				
Demand-side management				
Decrease technology costs—DER				
Decrease technology costs—EV				
Decrease technology costs—Building electrification				
Grid Modernization				
Aging infrastructure				
Systems and sensors				
Microgrids				
Distribution Automation (FLISR)				
Technology adoption—DER				
Technology adoption—EV				
Technology adoption—Building electrification				
Transmission and Generation				
Harmonized load forecasting—Energy efficiency				
Harmonized load forecasting—Demand-side management				
Harmonized load forecasting—DER				
Harmonized load forecasting—EV				
Harmonized load forecasting—Building electrification				
Optimal solution development				
DER as a resource - IRP				
DER as a resource - Distribution contingencies				

	Urgency	Maturity
Low	1	1
Medium	2	2
High	3	3



## 4. NREL Resources

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# NREL's Distribution Planning Suite

Overview | Industry Status | Emerging Practices | NREL Resources

## Datasets

[Synthetic Distribution System Models \(SMART-DS\)](#)

[Distribution Unit Cost Database](#)

Disaggregated Load profiles from [ResStock™](#), [ComStock™](#), and [EVI-Pro](#)

## Simulation

[Python Interface for OpenDSS](#)

[Python OpenDSS Wrapper for Power-Flow Analysis \(PyDSS\)](#)

[Building and EV Flexibility Modeling \(OCHRE™\)](#)

- NREL's distribution planning suite includes datasets and software tools that cover data analytics, scenario development, simulation engines, and applications.

## Data Analytics and Generation

Grid Data Model—distribution model representation

[Synthetic Distribution Model Creation \(SHIFT\)](#)

[Conversion of Distribution Modeling Formats \(DiTTo\)](#)

AMI Data Processing and Analytics

[Net Load Profile Evolution with DERs and Electrification \(EVOLVE\)](#)

## Application

Distribution capacity expansion planning—[CADET](#)

DER and EV hosting capacity—[Distribution Integration Solution Cost Options \(DISCO\)](#)

Risk Metrics for Power Flow—[EMERGE](#)

Energy Resilience Analysis for Distribution Power System—[ERAD](#)

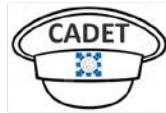
DER Interconnection—[PRECISE™](#)

Distribution System Protection Analysis and Relay Coordination—(D-SPARC)

# NREL's Distribution Planning Suite (cont'd)

Overview | Industry Status | Emerging Practices | NREL Resources

## Capacity Expansion Decision Support for Distribution Networks



### Long-term, Multi-objective Capacity Planning

- Affordability
- Reliability
- Resilience
- Energy Justice
- Hosting Capacity
- Equity
- Carbon Emissions .



### Integration with NREL Forecasting and Planning Tools

- dGen
- EVI-X
- ERAD
- PyDSS
- Sienna
- DISCO
- Distribution Unit Cost Database .

A flexible platform for developing distribution capacity planning strategies

Repeatable, defendable solution sets for engaging with stakeholders on decisions about wire solutions, non-wire solutions, customer programs, and EV charging.

### **Use Cases Under Development**

- Optimal switch placement and operation
- Right-sizing equipment for load management with
  - Managed EV charging
  - DER programs for buildings
  - NWAs.
- Capacity investments that impact resilience, reliability, and affordability.

### **Future Use Cases**

- Strategies for
  - Placing EV charging infrastructure
  - Voltage class upgrades.
- Cost-benefit analysis for the use of DERMS when using DER to manage load
- Cost and carbon emission trade-offs between non-wires alternatives (NWAs) and wire capacity
- The value of bridge-to-wire solutions.

Source: NREL. 2025. "CADET: Capacity Expansion Decision Support for Distribution Networks."

[CADET: Capacity Expansion Decision Support for Distribution Networks](#) | [Grid Modernization](#) | [NREL](#)

# Thank you!

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## 5. Q & A

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