U.S. DEPARTMENT OF ENERGY

Identifying Grid Needs and Evaluating Investment Options

Training for States on Distribution System and Distributed Energy Resources Planning

Presented by Samir Succar, ICF

November 29, 2023

Agenda

Planning objectives vs criteria

Utility budgets

Investment evaluation

Returning to this morning's discussion…

Baseline information on current state of distribution system

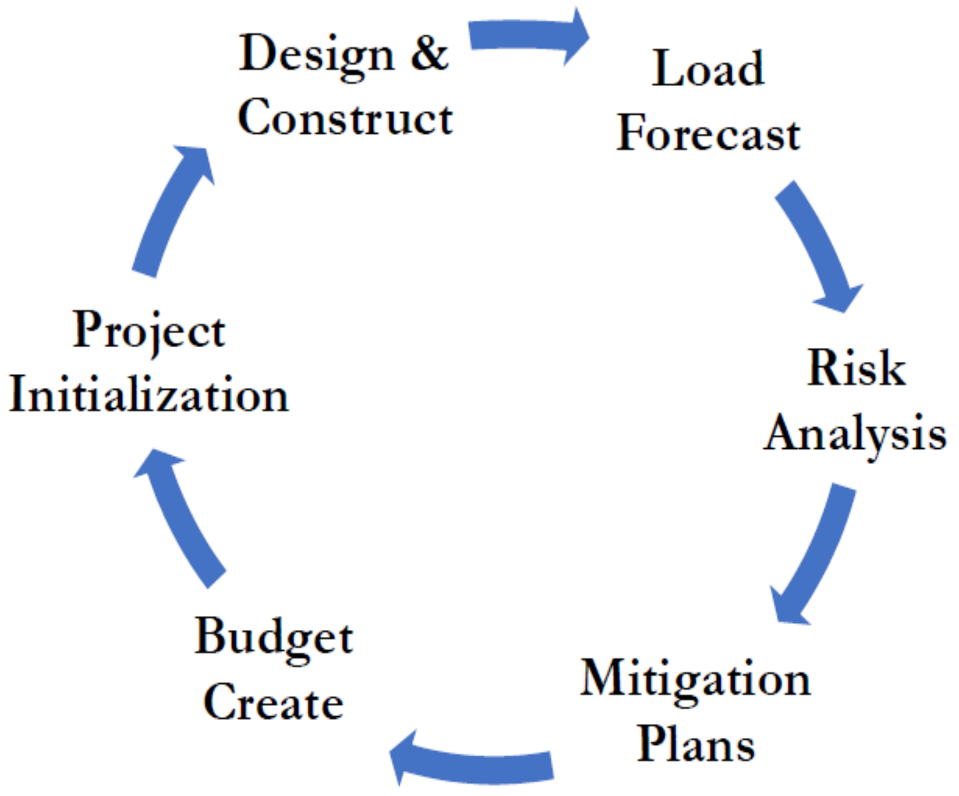
- Such as system statistics, reliability performance, equipment condition, historical spending by category

Description of planning process

- Load forecast – projected peak demand for feeders and substations
- Risk analysis for overloads and plans for mitigation
- Budget for planned capacity projects
    - Asset health analysis and system reinforcements
    - Upgrades needed for capacity, reliability, power quality
    - New systems and technologies
    - Ranking criteria (e.g., safety, reliability, compliance, financial)

Distribution operations

- Vegetation management
- Event management



Source: Xcel Energy

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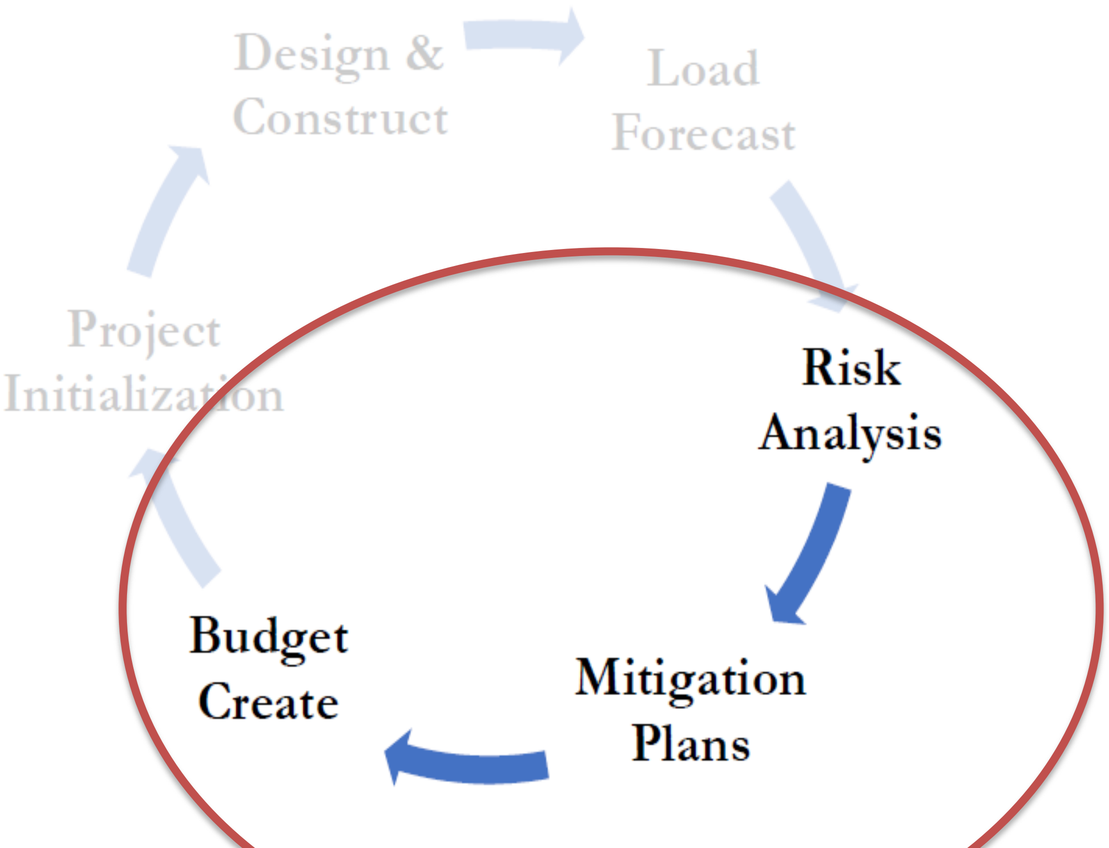


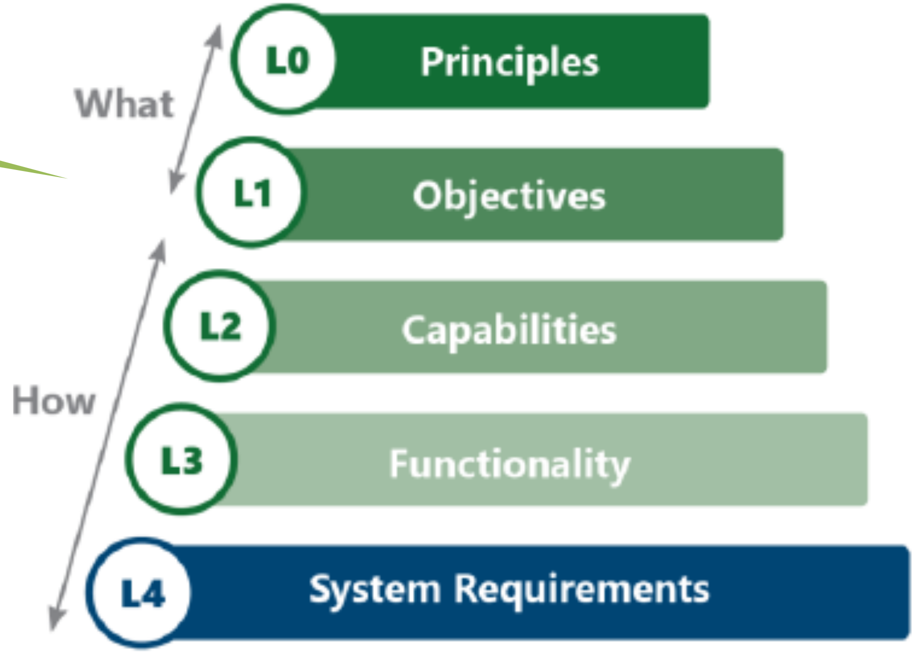
Source: Xcel Energy

Grid Modernization Strategy & Implementation Planning

Objective: an envisioned or desired result or attribute

?

System requirements: technology solutions that can meet specific business
and technical requirements



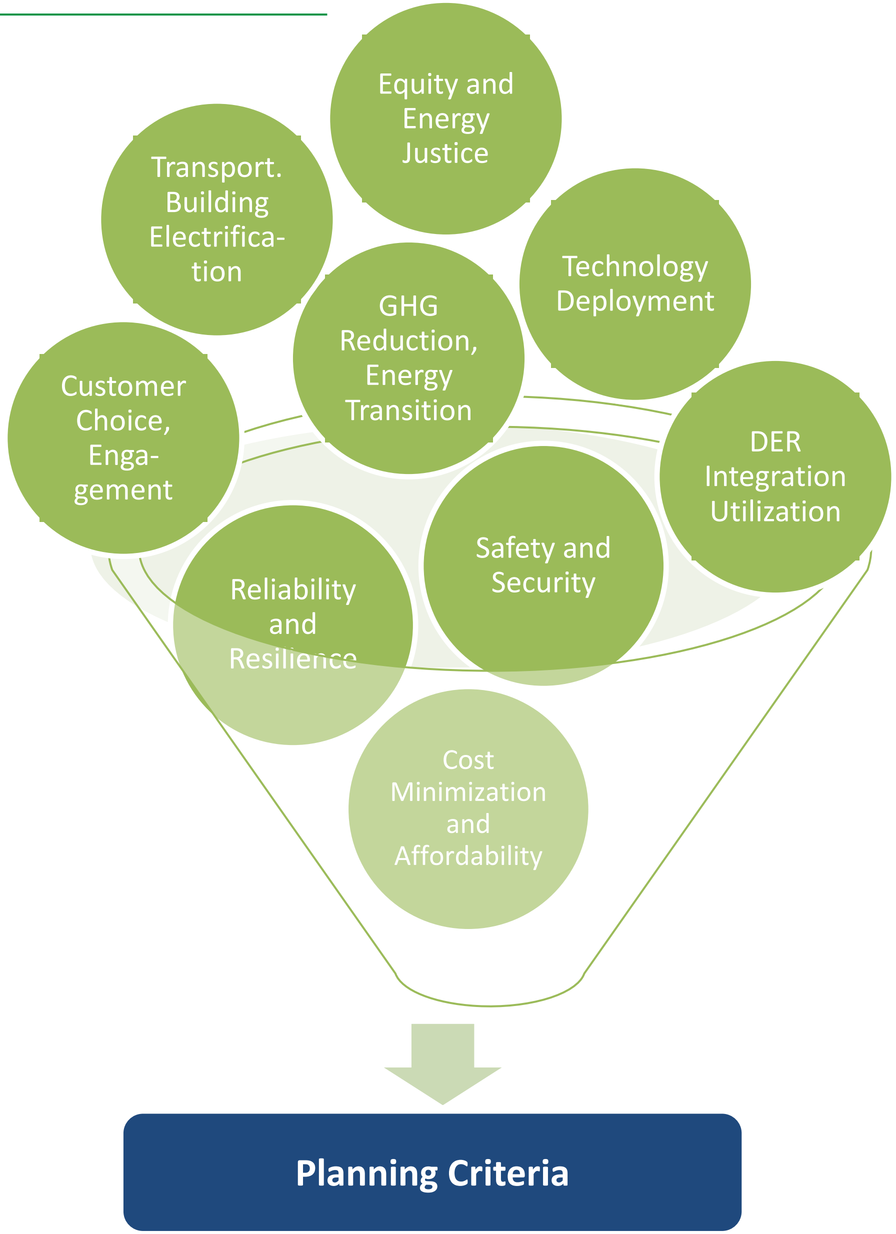
Source: *Modern Distribution Grid Guidebook, Strategy & Implementation Planning Guidebook*, Version 1.0 Final Draft, DOE Office of Electricity, June 2020; [Modern-Distribution-Grid_Volume_IV_v1_0_draft.pdf (pnnl.gov)]

Mapping Technologies to Objectives (Example)

Objective	Capability	Function	Technology
Reliability improvement by reducing customer unplanned outage durations Achieve 2nd quartile CAIDI performance by 2025	Improve outage identification and customer service restoration	Fault Identification Fault Location Fault Isolation Service Restoration	Fault Current Indicators Outage Notification from Meters Outage Management System Geospatial Information System Distribution Management System and/or SCADA Automated Switches Work Management System

Source: *Modern Distribution Grid, Volume I: Customer and State Policy Driven Functionality, DOE, 2017;* Available online at: https://gridarchitecture.pnnl.gov/media/Modern-Distribution-Grid_Volume-I_v1_1.pdf

Translating Objectives into Criteria



Objectives: Goals for desirable system characteristics or attributes

Criteria: Principles or standards by which system risks or solutions may be evaluated or prioritized

Based on survey of state planning objectives, Schwartz, Berkeley Lab

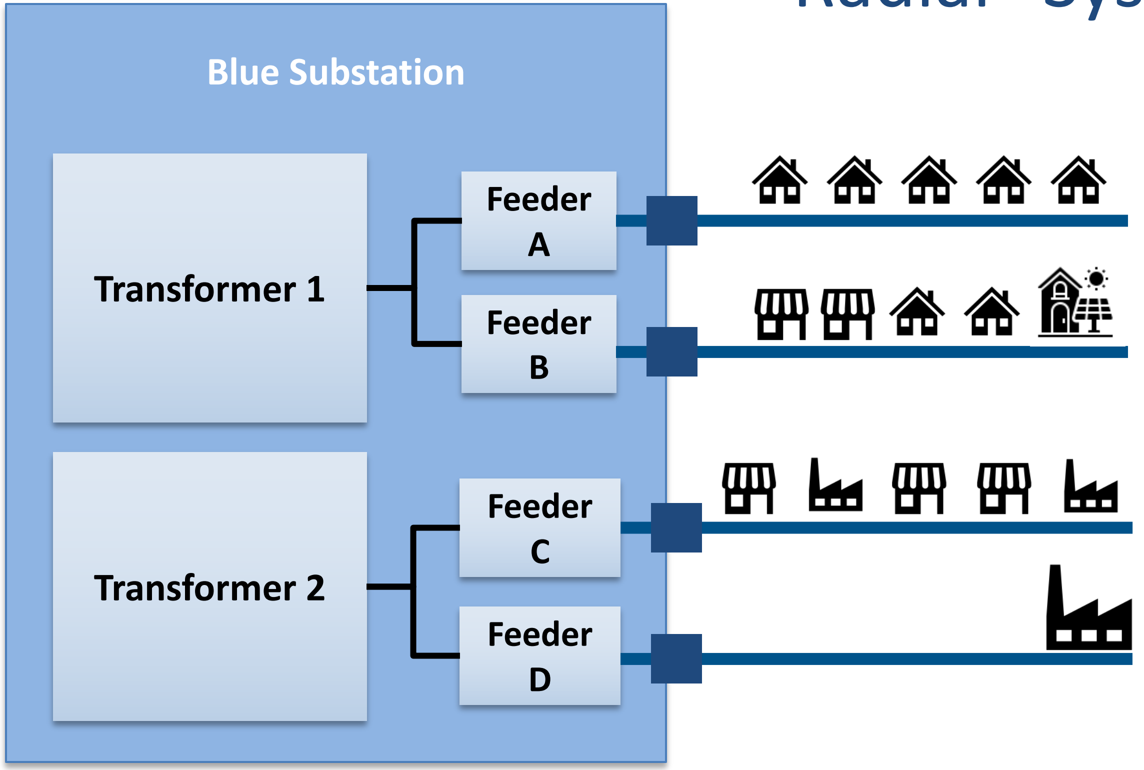
Planning for Electric Capacity

Normal Operations

Safety

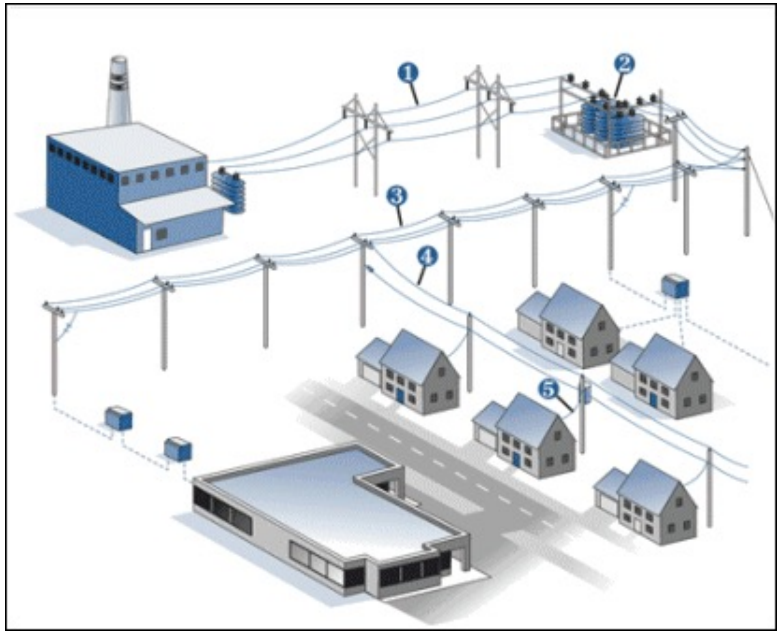
Reliability

“Radial” System



Residential (~500 – 1,500 customers)

Commercial and Industrial



Credit: Ameren
https://www2.ameren.com/common/DistributionSystem.aspx

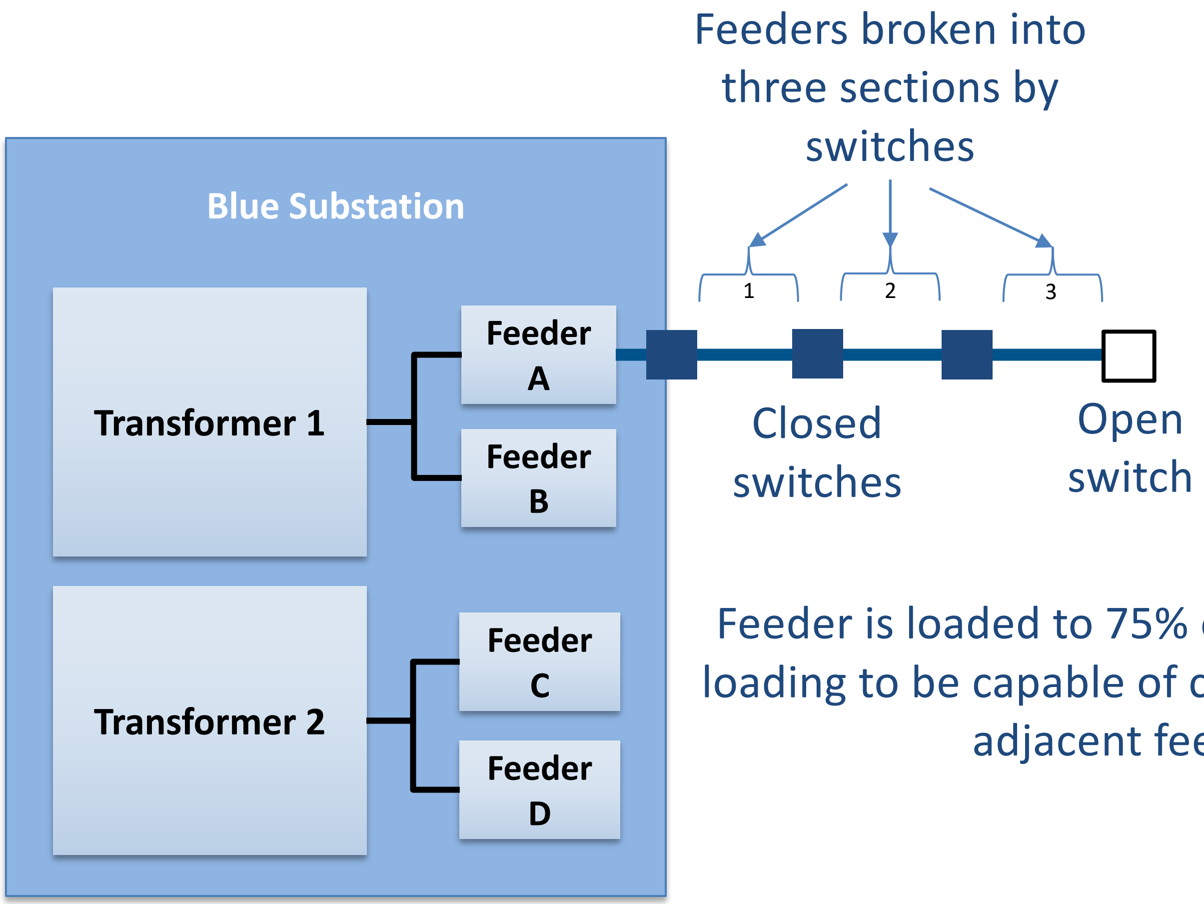
DER is analyzed for system normal configuration

Planning for Capacity

System Flexibility

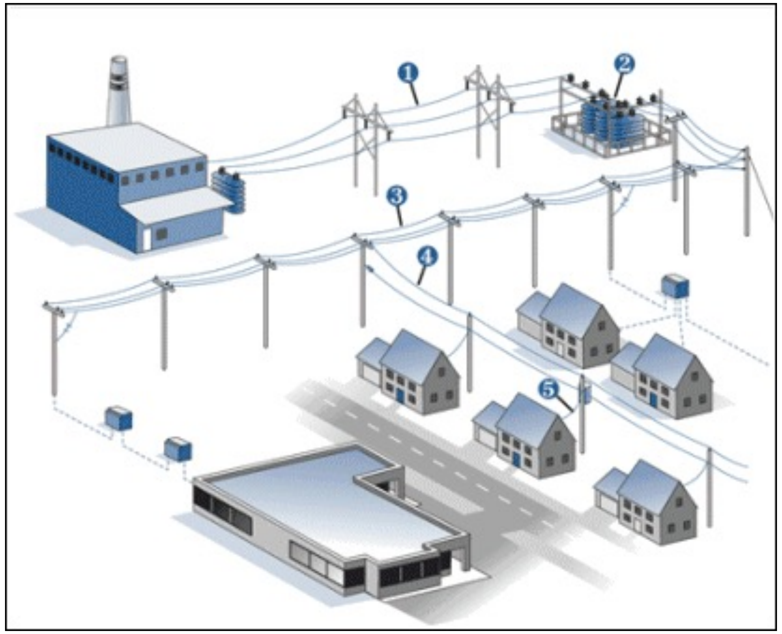
Safety

Reliability



Each section carries 25% of feeder capacity

Feeder is loaded to 75% of capacity at full loading to be capable of carrying section of adjacent feeder

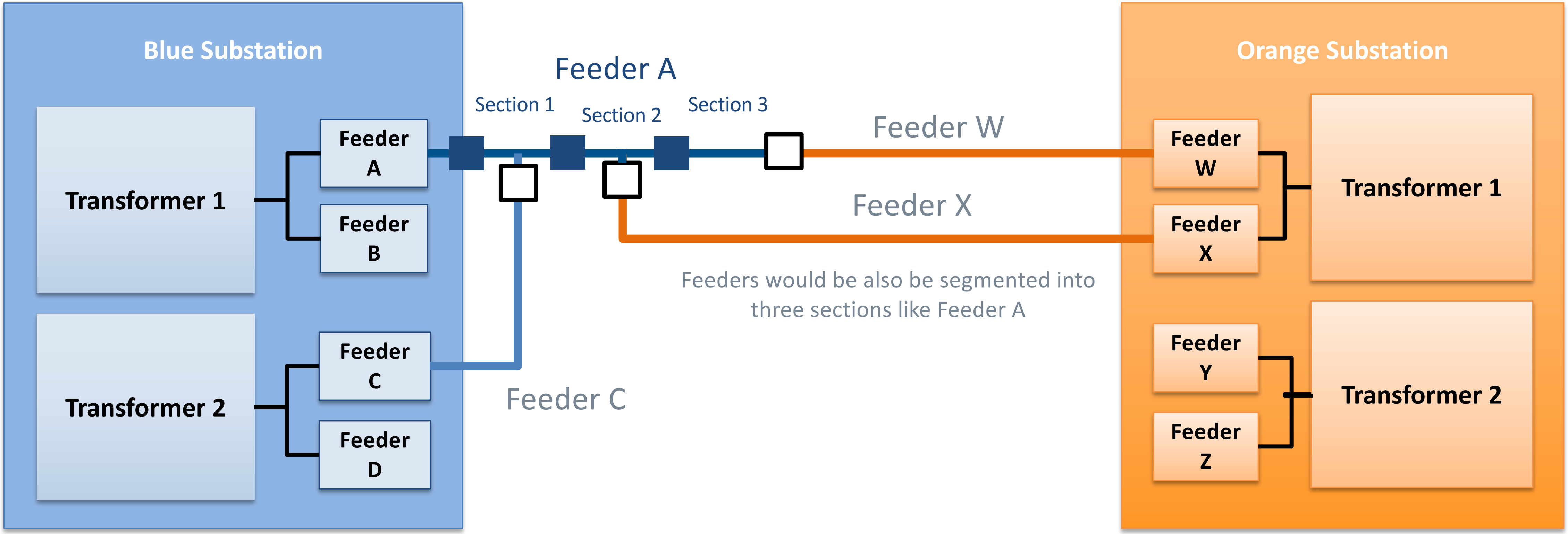


Credit: Ameren
https://www2.ameren.com/common/DistributionSystem.aspx

Planning for Capacity

Contingency Operations

Safety Reliability

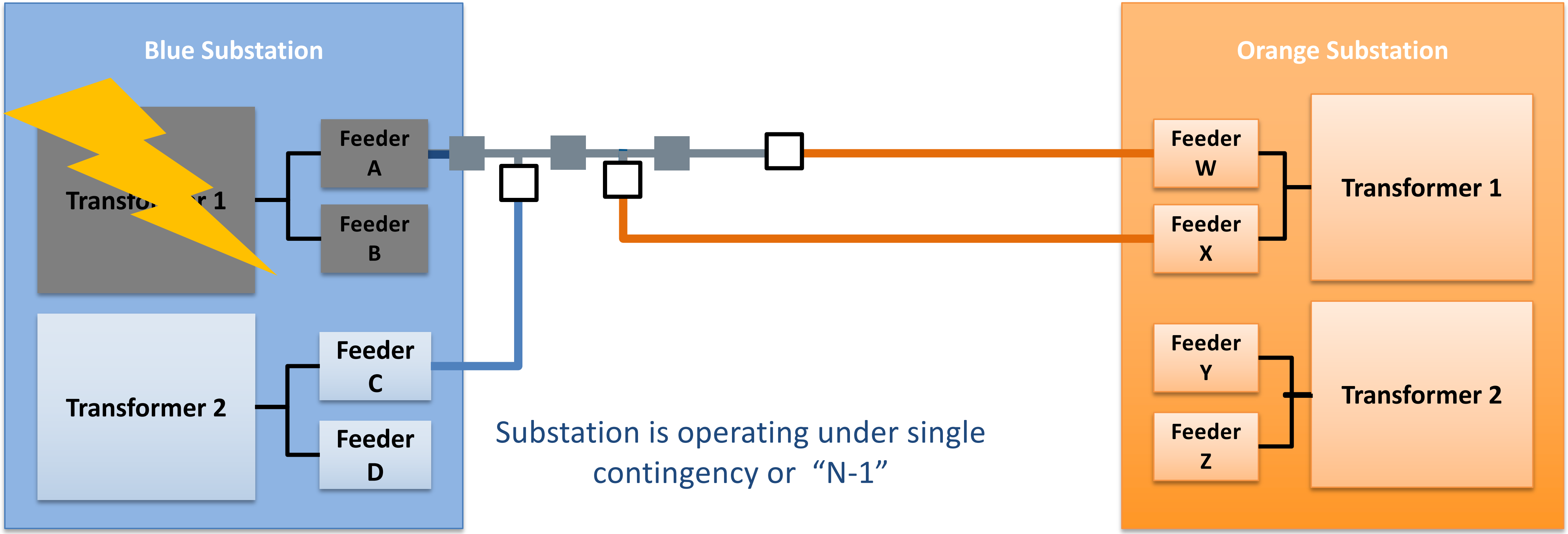


DER may <u>not</u> be studied for abnormal or contingency configurations

Contingency Capacity Criteria

Safety Reliability

Example: Substation Transformer Outage

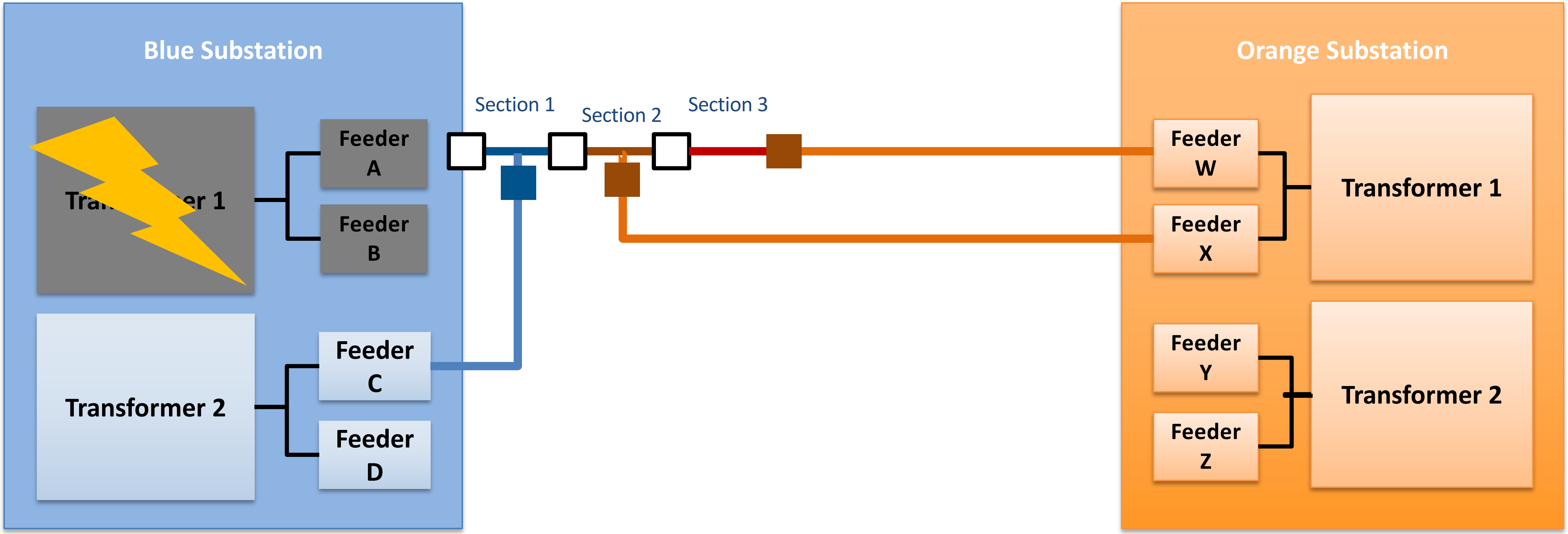


Substation is operating under single contingency or "N-1"

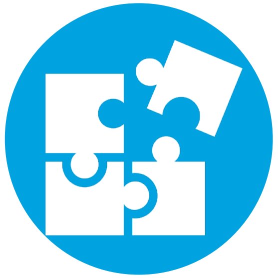
Contingency Capacity

Safety

Reliability



Distribution Planning Criteria – Capacity Constraints and EVs



Electric Capacity
- Normal
- Contingency

Voltage
Reliability

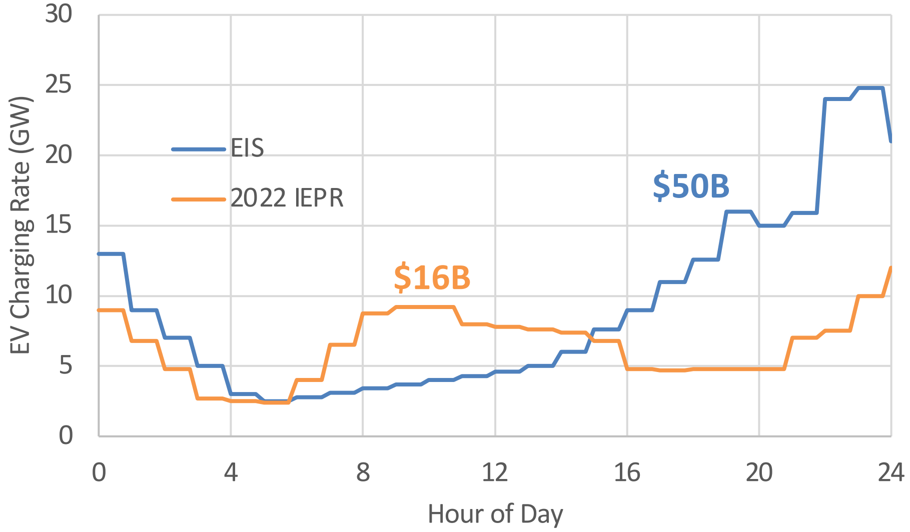
Source.Energy Systems Integration Group; data courtesy of Kevala, 2023; Public Advocates Office, 2023.

Transformer Replacement

Exegol Utility District
When equipment is a candidate for replacement, the utility replaces legacy designs with similar design standards that may become overloaded with incremental EVs.

Tatooine Cooperative
When equipment is a candidate for replacement, either at end of life or when doing things like pole replacement, the utility replaces legacy designs with future-ready solutions.

Smart Charging



Differences in charging assumptions can have a large impact on the cost of distribution upgrades. Smart charging can adjust the charging profile.

Distribution Planning Criteria – Voltage Violations and PV

Safety

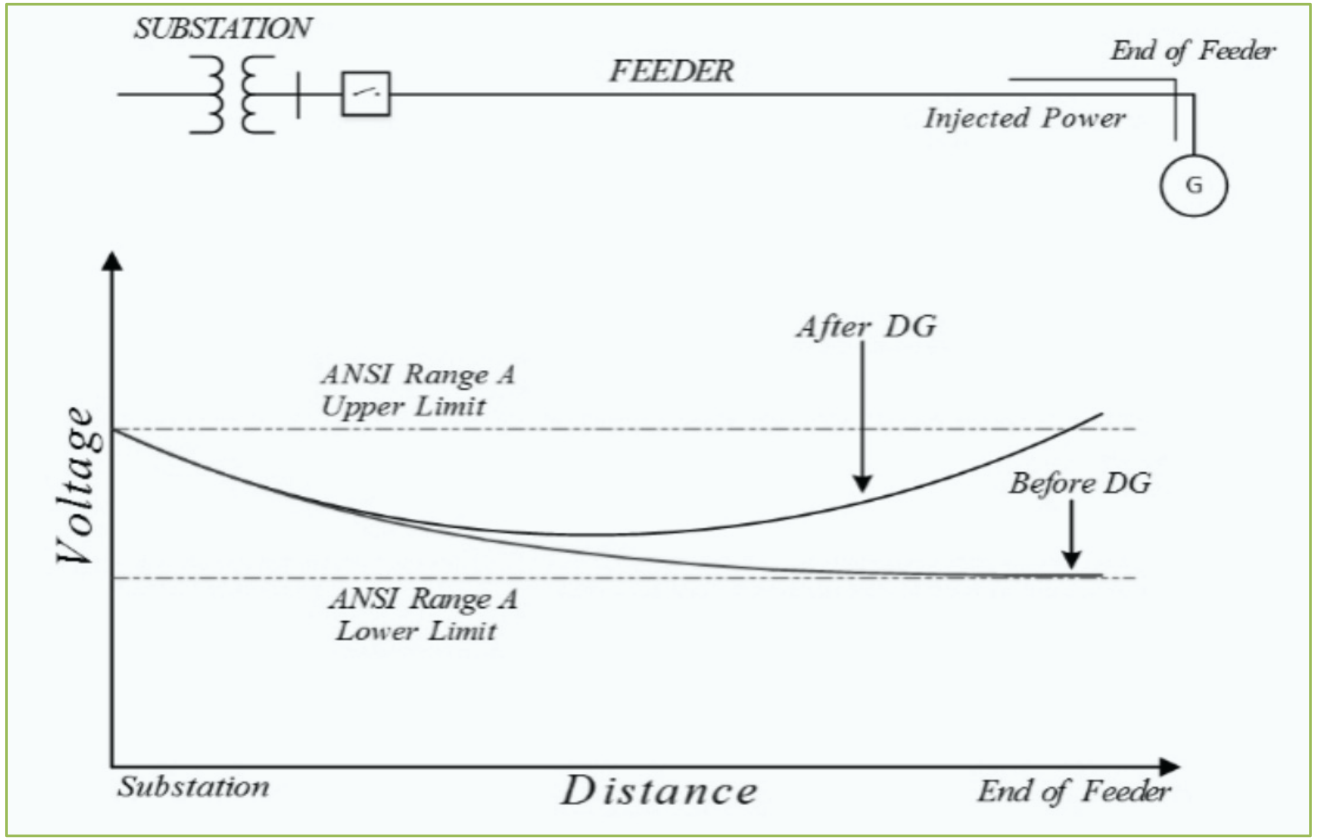
Reliability

Electric Capacity
- Normal
- Contingency

Voltage

Reliability

Illustration of Voltage Criteria



Sahito, Anwar & Memon, Zubair & Buriro, Ghulam & Memon, Sarwan & Jumani, Muhammad. (2016). Voltage Profile Improvement of Radial Feeder through Distributed Generation. SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES). 48. 497-500.

Investment categorization

Cost

- **Distribution investments are frequently lumped together in grid modernization proceedings, but for cost-effectiveness evaluation and cost allocation it's important to categorize investments according to type and drivers.**
- **In terms of type, a high-level taxonomy of investments might include:**
  - Existing infrastructure replacements and upgrades (e.g., 4 kV to 12 kV upgrades)
  - Line extension and service upgrades (e.g., new service requests, amperage upgrades)
  - Distribution capacity expansion (e.g., substation upgrades)
  - Hardening (e.g., undergrounding, steel/concrete poles, raising equipment)
  - Grid technology (e.g., grid management and monitoring hardware and software)
  - Administrative (e.g., meters and backend software, billing software)

Source: Kahrl (3rd Rail) and de Martini (Newport)

Capacity Planning

Process to plan for adequate system capacity under normal and contingency operations

Capacity Planning is typically an annual process to address load growth or movement of load around the system

System analyzed for normal and contingency conditions

Solutions identified and proposed to address constraints

Asset Health

Programs to plan the replacement of aging assets

Asset health programs contribute to system reliability and the customer experience

Different approaches to asset health

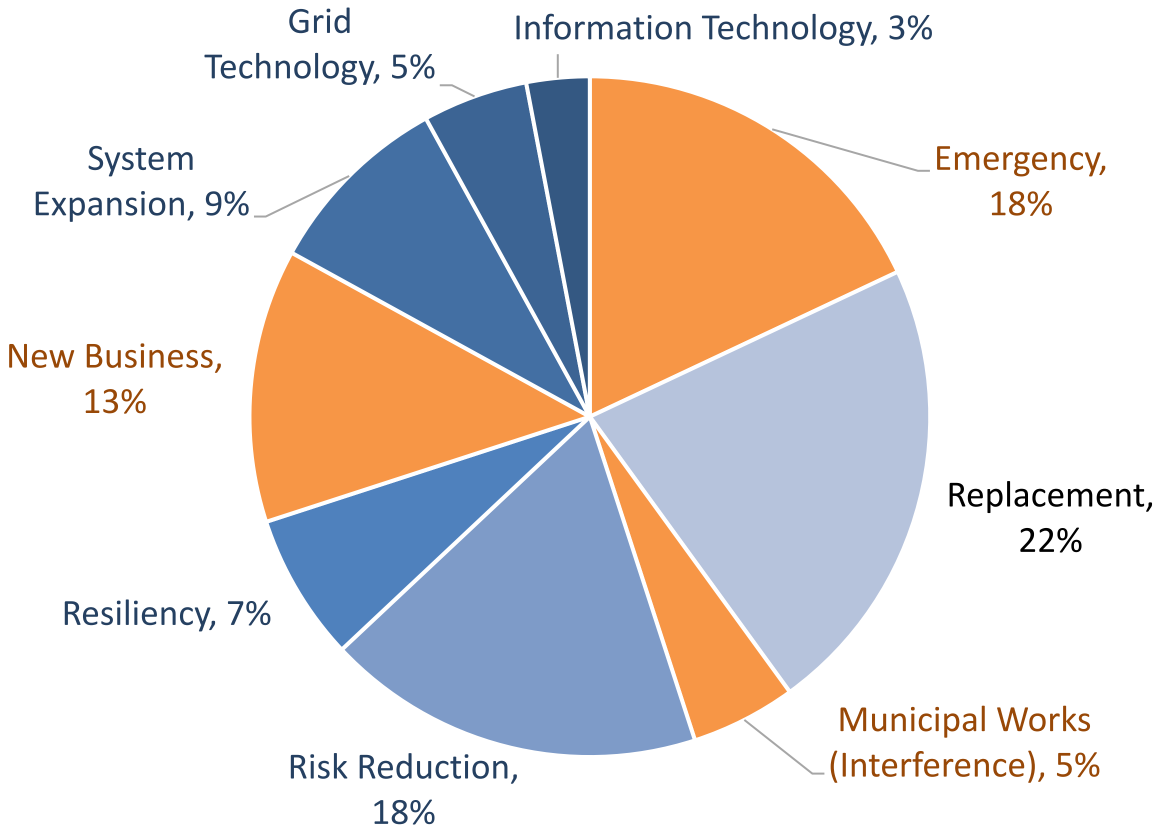
- Corrective Maintenance – replacing failed assets
- Preventative Maintenance – replacing assets prior to failure
- Reliability-Centered Maintenance – replace assets based on historic reliability records
- Condition-based Predictive Maintenance – proactive and situational based

Utility Budgets: Discretionary vs Non-Discretionary

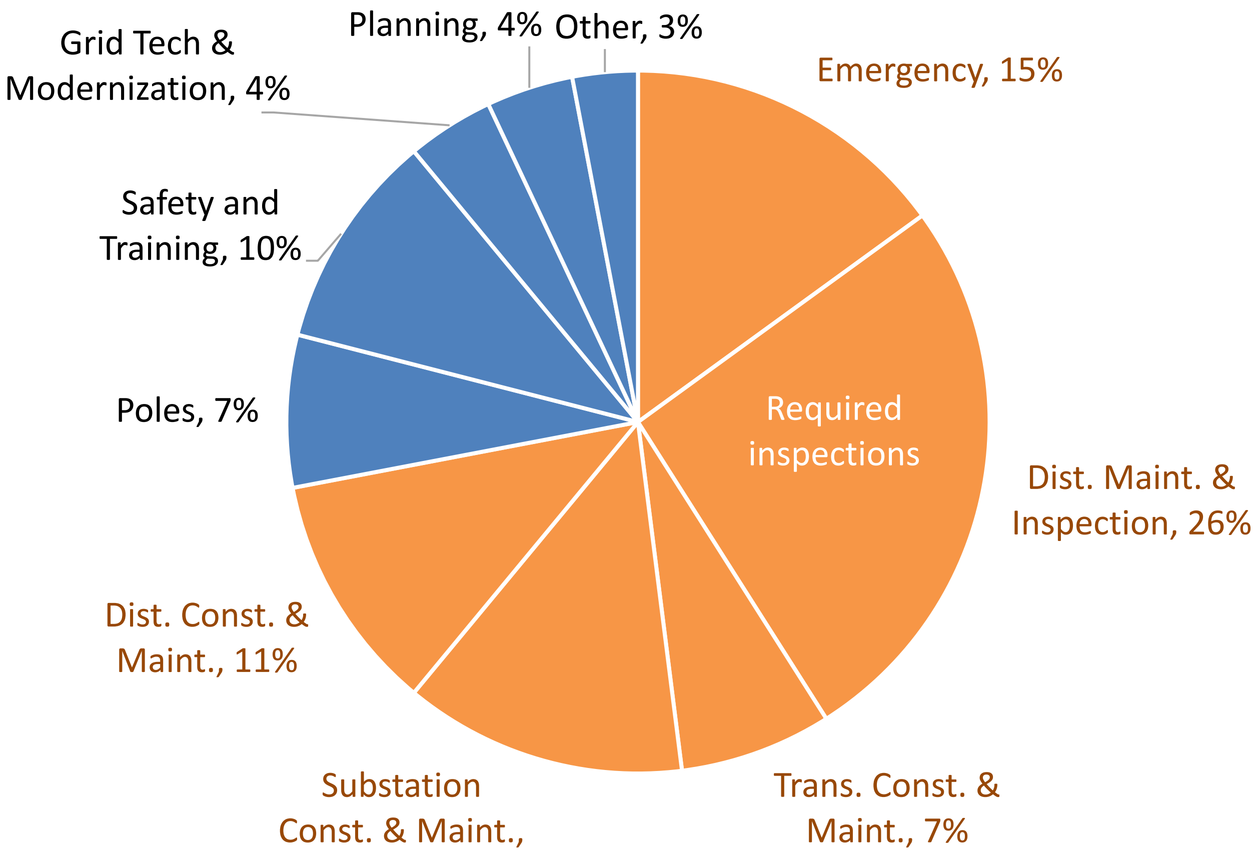
Cost

Utility capital and O&M expenditures can be discretionary or non-discretionary.

Capital



Operations and Maintenance



Development of multi-objective distribution plans

Integrated distribution planning should address the development of prioritized and optimized multi-year distribution plans.

Determine Grid Need
Assess grid health, resilience risks, customer load and DER growth needs

Identify Potential Solutions
Develop grid & non-wires solutions that address more than one objective

Evaluate C-E of Potential Solutions
Assess cost-effectiveness of grid & non-wires solutions

Develop Multi-year Plan
Prioritize & optimize expenditures with given financial and resource constraints

Planning Objectives

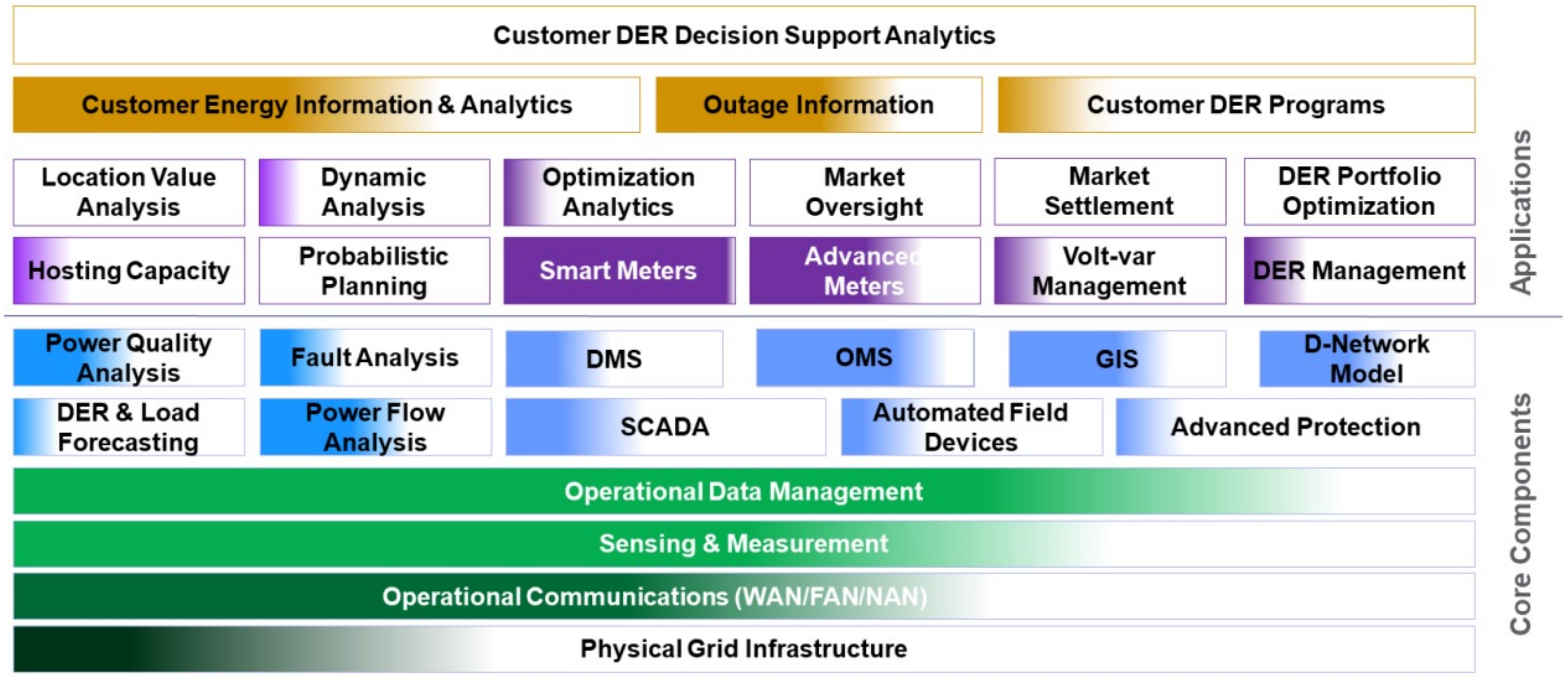
Improve Asset Health & Safety	Improve Reliability	Increase Capacity	Improve Resilience	Promote Equity
Address asset conditions that lead to failure	Reduce frequency & duration of outages	Expand capacity to address load growth & DER adoption	Address climate threat risks to critical grid infrastructure	Ensure benefits of the grid are fairly distributed

Source: Kahrl (3rd Rail) and de Martini (Newport)

State of the grid and gap analysis

- Determine the status of current tools and capabilities
- Track progress in each area and identify where investment is most needed
- Grid modernization status provides a gap analysis according to **functionality and capability**
- Next: Prioritize investments delivering joint and interdependent benefits according to **objectives**

DTE Grid Modernization Status (2023)



Reference U.S. Department of Energy Modern Distribution Grid Project Volume 3 Figure 8: https://gridarchitecture.pnnl.gov/modern-grid-distribution-project.aspx

Source: DTE DGP 2023

Prioritizing Utility Investments

Goal: develop a list of **prioritized solutions** given **practical constraints**, such as budget limitations.

Steps:

1. Ranking planning objectives w/stakeholder input
2. Normalizing the value contribution of each solution in relation to one or more objectives
3. Developing a prioritized list

See example: DTE Electric Company's 2021 Distribution Grid Plan, pp. 82-90; https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t000000Uc0pkAAB.

Illustrative Value-Spend Efficiency Method

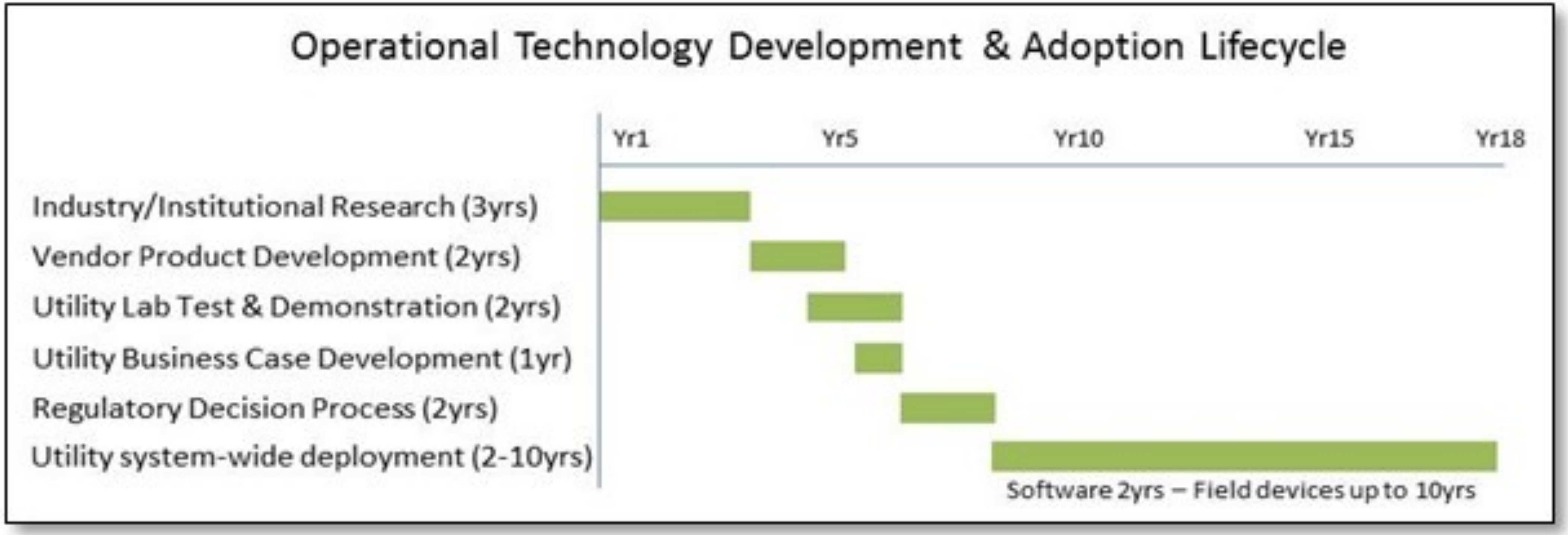
	Planning Objectives Ranked (1-5)									
Specific Projects	Safety (5)	Service Compliance (5)	Reliability (3)	Resilience (4)	Electrification (3)	DG/DS Integration (3)	Equity (4)	Score	Cost ($mm)	Spend Efficiency (S/C)
Tree Trimming[1]	5		3	3				11	$2.5	4.4
Undergrounding[2]	3		3	4	1	1	2	14	$5.0	2.8
Pole/Tower Hardening	2	2	3	4			1	15	$2.0	7.5
4kV Voltage Upgrade Conversions	4	4	2	3	3	3	3	22	$10.0	4.5
Substation Breaker Replacement[2]	5	5	3		1	1		15	$2.0	7.5
ADMS		3	3	3	2	3	1	15	$2.5	6.0
Field Automation[2,3]	3	3	3	3		1	2	15	$3.0	5.0
Advanced Metering	1	2	2	1	1	3	1	11	$2.5	4.4

1. Improved reliability & resilience supports greater consumer reliance on electrification
2. If program involves using larger conductor or higher capacity equipment
3. Improved reliability and resilience of grid improves the availability for DER to provide bulk power & grid services

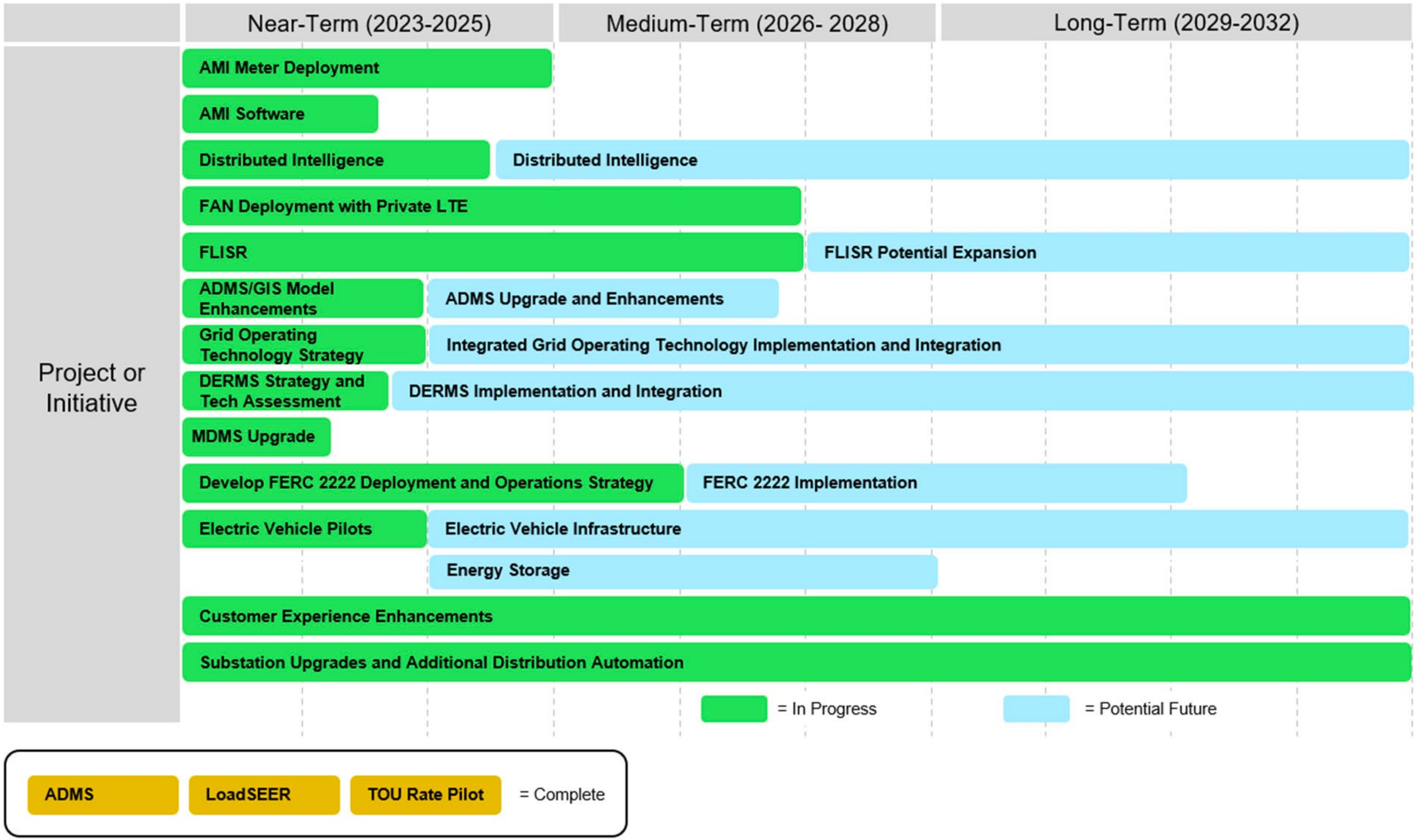
Source: Integrated Resilient Distribution Planning, by P. De Martini, J. Taft, A. De Martini, and M. Hall, PNNL-32883, May 2022. Available at: https://gridarchitecture.pnnl.gov/media/advanced/Integrated_Resilient_Distibution_Planning.pdf.

Technology Adoption Timing Considerations

Required efforts to develop, demonstrate, test, and deploy new technologies are incorporated into an IDSP grid modernization strategy



Example technology roadmap



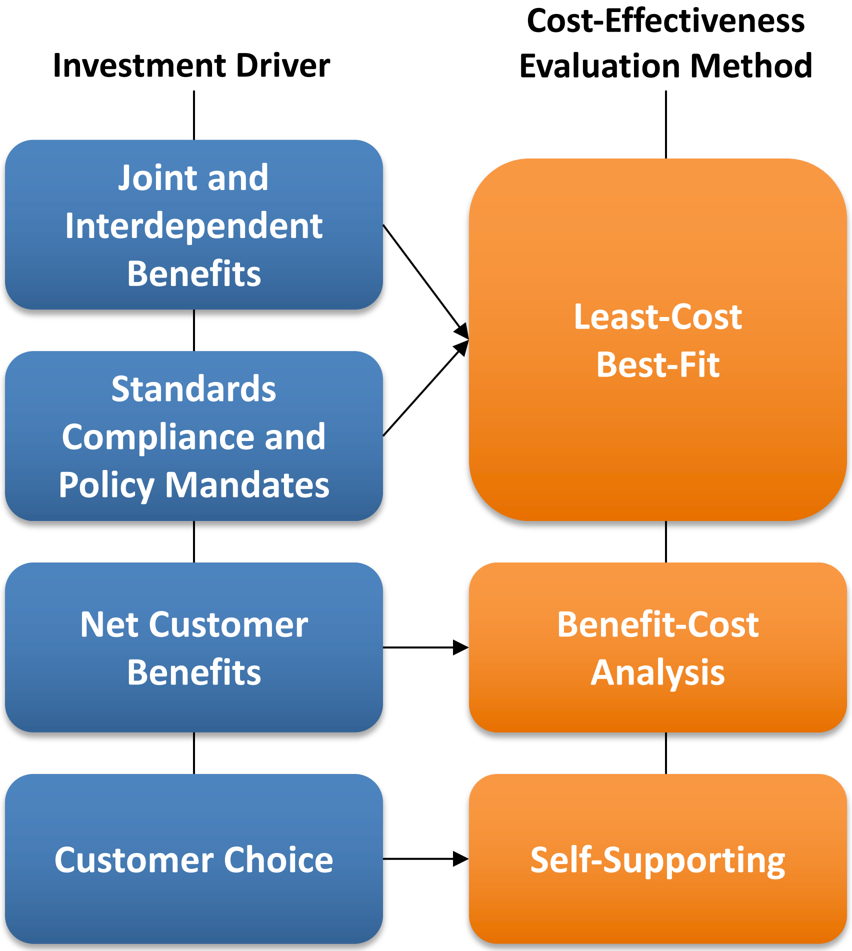
Source: Xcel Energy (2023)

Investment drivers and cost-effectiveness evaluation methods

Investments can be grouped under four key drivers:

1. **Joint and interdependent benefits** — core platform investments that are needed to enable new capabilities and functions in the distribution grid (e.g., distribution management systems)
2. **Standards compliance and policy mandates** — utility investments that are needed to comply with safety and reliability standards or to meet policy mandates for proactive investments to integrate DER (e.g., replacements and upgrades)
3. **Net customer benefits** — utility investments from which some or all customers receive net benefits in the form of bill savings (e.g., advanced metering infrastructure)
4. **Customer choice** — utility investments triggered by customer interconnection, opt-in utility programs, and customer-driven reliability improvements, paid for by individual customers (e.g., line extensions, hardening)

The investment driver points toward an appropriate cost-effectiveness evaluation method (right side of figure).



Source: Kahrl (3rd Rail) and de Martini (Newport)

Applying economic evaluation methods

Least-cost best-fit (LCFB) and benefit-cost analysis (BCA) are used in different situations and answer different questions.

LCBF – used for most distribution infrastructure investments and platform software investments

- *Given that we want some functionality/capability on the distribution system or that we want to meet some safety, reliability, or regulatory goal, what is the lowest cost way to do so?*

BCA – used for investments in advanced meters (often but not always), non-wires alternatives, utility resource procurement and programs

- *Will an investment enhance welfare (benefits > costs) for all or a subset of customers?*

There may be an overlap between BCA and self-supporting investments, which historically have been addressed through cost-sharing mechanisms (e.g., free footage allowances in line extension).

Source: Kahrl (3rd Rail) and de Martini (Newport)

Project vs. portfolio cost-effectiveness

Project cost-effectiveness is the first step to evaluate an overall distribution plan.

However evaluation of individual grid modernization projects is insufficient to determine whether an overall distribution expenditure plan is reasonable.

It is also necessary to consider whether the proposed portfolio of expenditures:

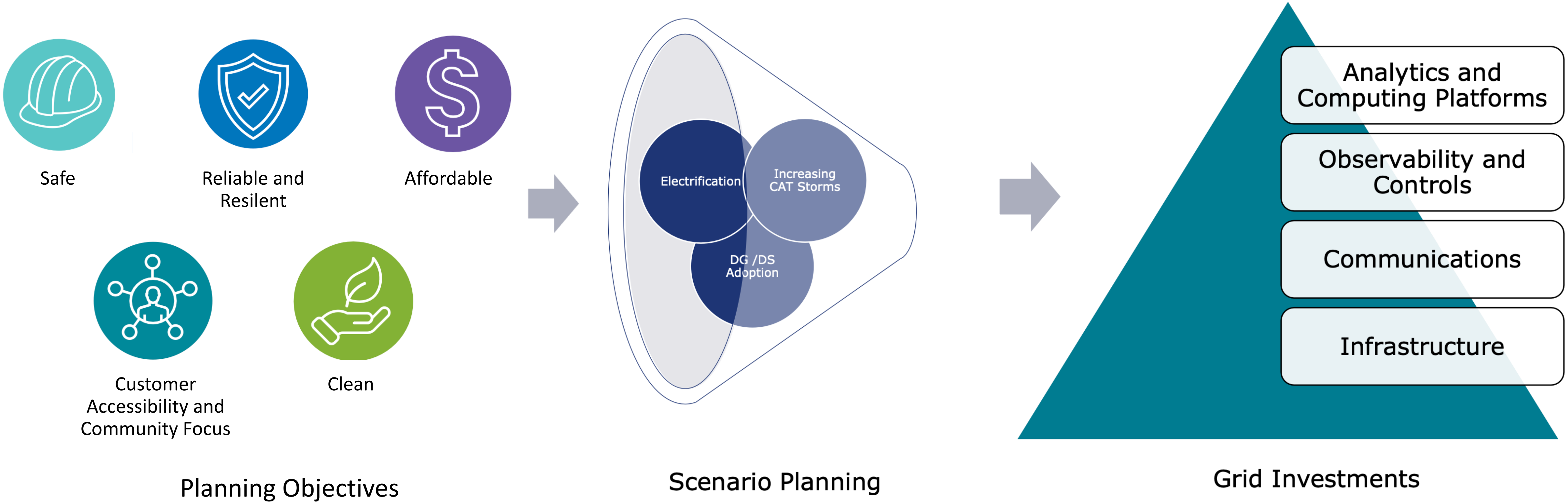
- Clearly addresses more than one identified statutory or regulatory objective
- Represents an integrated set of projects that are complementary
- Represents a set of projects that are part of a series of expenditures to address identified statutory or regulatory objectives
- Represents a prioritized set of expenditures given the urgency of grid needs that address identified statutory or regulatory objectives and utility financial and resource constraints
- Represents an optimized set of expenditures respecting customer affordability and equity considerations

Distribution expenditure plans require a multi-objective decision-making framework to evaluate these considerations.

The objective is to achieve the highest value per dollar expended – "value-spend efficiency"

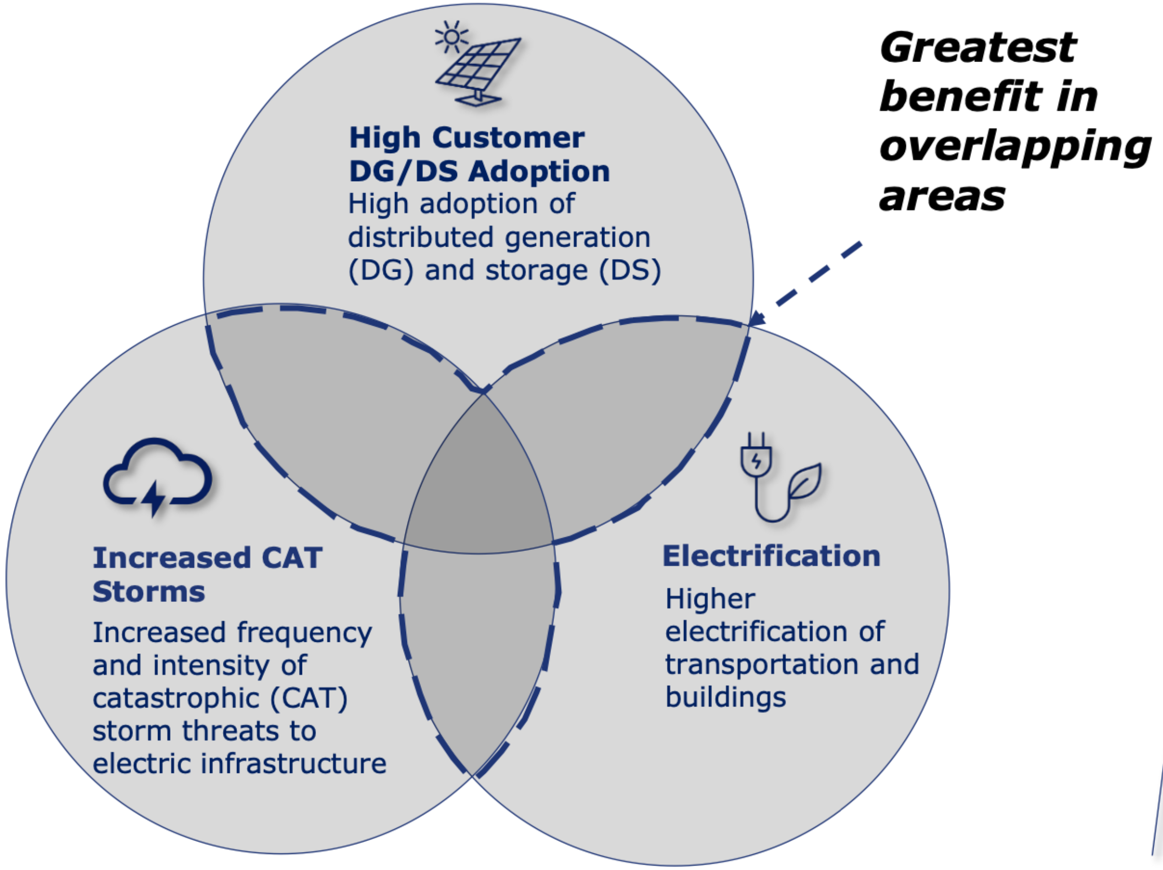
Source: Kahrl (3rd Rail) and de Martini (Newport)

DTE: Objectives, Scenarios, Investments



Source: DTE DGP 2023

Scenario Analysis: DTE Distribution Grid Plan

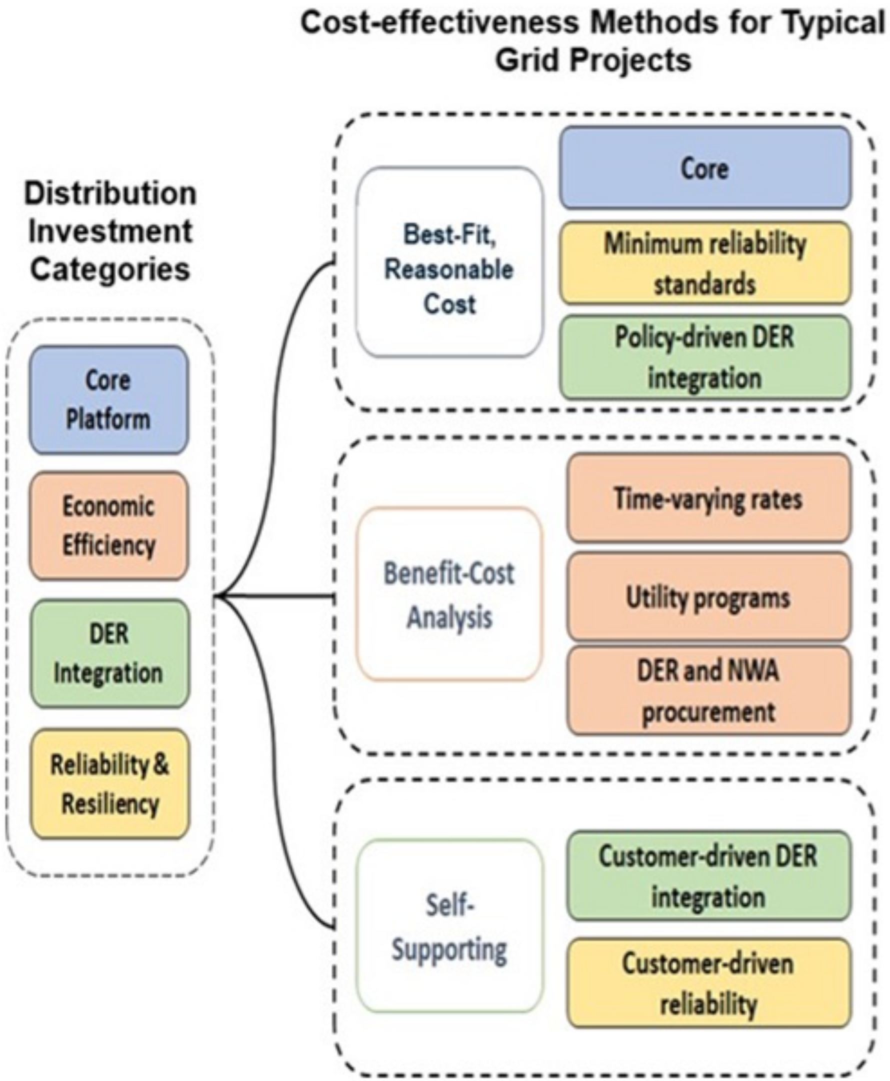


- Three scenarios were developed to analyze the range of potential impacts to the grid if one or multiple scenarios materialize
- Scenarios are driven by unique sets of drivers that are expected to impact the grid over the next 15 years and beyond
- Each scenario includes three components to determine the potential investments needed for the grid:
    1. Plausible forecasts
    2. Grid impacts
    3. Signposts

While the Company invests in projects and programs that support individual scenarios, the **greatest benefit** is achieved by **identifying investment opportunities across multiple scenarios**

Source: DTE DGP 2023

Grid Modernization Cost-Effectiveness Framework



Best-Fit, Most-Reasonable-Cost for core grid platform and grid expenditures required to maintain or reliable operations as well as integrate distributed resources connected behind and in front of the customer meter that may be socialized across all customers.

Benefit-Cost Analysis for grid expenditures proposed to enable public policy and/or incremental system and societal benefits to be paid by all customers. Grid expenditures are the cost to implement the rate, program or NWA. Various methods for BCA may be used.

Customer Self-supporting costs for projects that only benefit a single or self-selected number of customers and do not require regulatory benefit-cost justification. For example, DER interconnection costs not socialized to all customers. Also, undergrounding wires at customers' request.

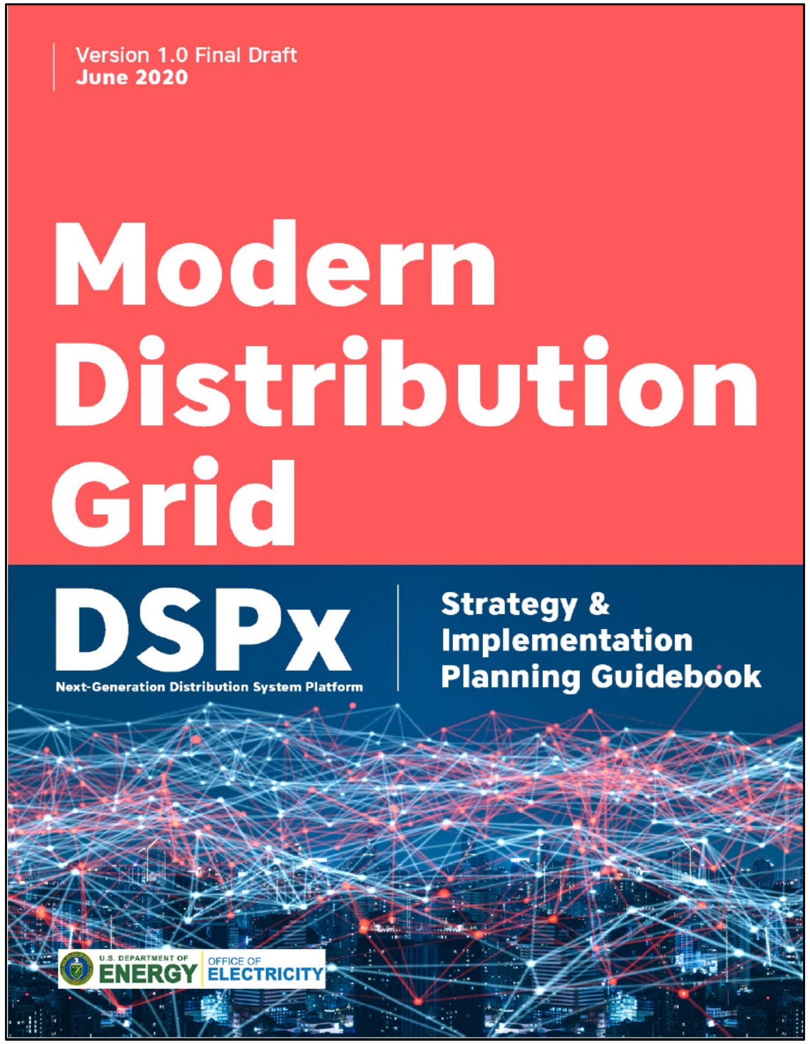
From Modern Distribution Grid Guidebook, DSPx Volume 4, June 2020; PNNL: Grid Architecture - Modern Distribution Grid Project

DOE's Modern Distribution Grid Guidebook

Volume IV of the guide includes an economic evaluation framework for grid modernization investments.

- Aims to inform approaches to evaluating economics and managing costs and risks of grid modernization investments

No textbook approach — multiple reasonable paths to achieving the same broad goals



U.S. Department of Energy. *Modern Distribution Grid Volume IV: Guidebook*

Questions to Ask

Have clear objectives been established in policy or regulation, or proposed by the utility?

What are the appropriate planning objectives and criteria for your distribution systems?

What is the utility's grid modernization strategy and roadmap, and how will they meet state objectives?

What is the appropriate investment prioritization model recognizing multiple objectives and multiple benefits?

What level of oversight and transparency is required to facilitate stakeholder buy-in and ensure objectives are achieved?

How does the plan address uncertainty in the pace and scope of change — e.g., in technologies and policies — over the planning period, and how do the grid mod strategy and roadmap address the needs?

Contact

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