TENNESSEE VALLEY AUTHORITY

Capability Progression Model

Contents

Introduction

The **Capability Progression Model** (CPM) is a framework designed to help local power companies (LPCs) identify which capabilities are necessary to operate the grid of the future and self-assess their progress toward each of these capabilities.

The CPM is designed for and with LPCs to meet the needs of our communities across the region. To benefit from the value and cost savings grid modernization offers, LPCs need to be able to identify the capabilities and technologies that will have the greatest impact on their operations and infrastructure. By outlining capability progression and example technologies, TVA ensures LPCs have what they need to make meaningful, measurable advancements that can lead to a sustainable future for their organizations and those they serve.

LPCs are driving progress; TVA is just helping them navigate with Valley Vision in mind.

THE CAPABILITY PROGRESSION MODEL

Establishes Minimum Capability Levels

considered must-haves for all LPCs

Supports LPCs

in maturing capabilities and recognizing achievements

Outlines an Investment Path

related to each capability area

Assessing Progress Across the Region

Recognizing that each LPC has unique needs, the current state of regional grid transformation was assessed to provide value for every LPC, no matter where they stand on the path to grid modernization.

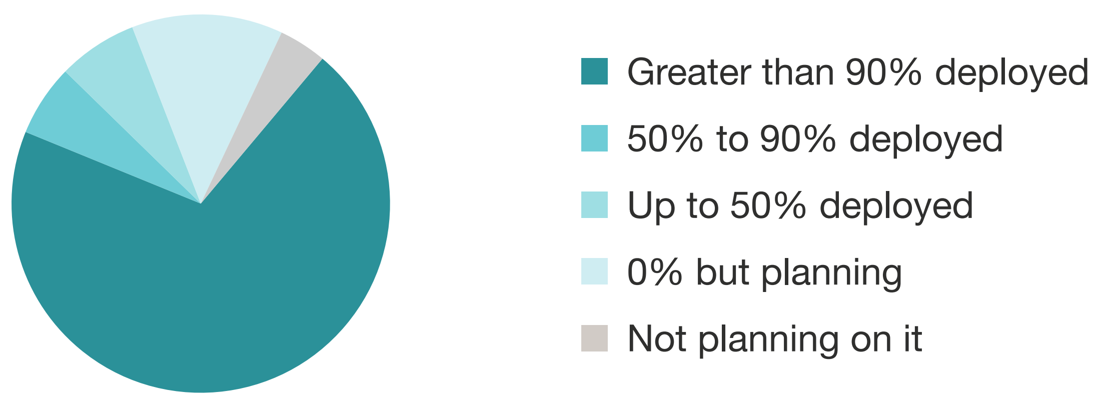
The Valley-wide LPC Capability Assessment survey deployed in 2022—which had a 96% response rate from LPCs—directly informed the capability standards and supporting technologies of the CPM.

96%

response rate from LPCs

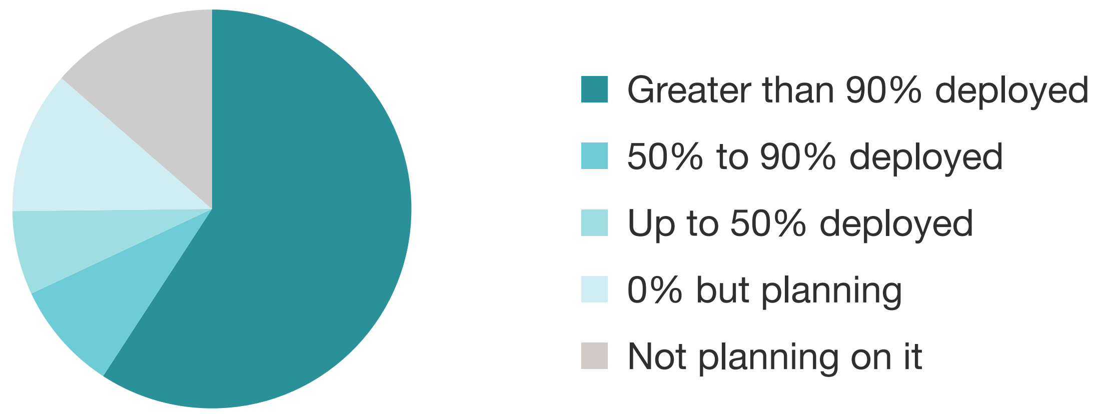
directly informed the capability standards and supporting technologies of the CPM.

AMI DEPLOYMENT



SCADA USE

FIBER OPTICS DEPLOYMENT



The Four Stages of Grid Modernization Progression

The CPM features 18 capabilities that fall under one of four stages of progression: **Enabling**, **Planning and Assessing**, **Value Generating** and **Enhancing**.

As LPCs build enabling capabilities, achieving capabilities in the following three stages will become easier. For example, grid situational awareness is an **enabling** capability and refers to the ability of LPCs to monitor and report on their distribution system in real-time. Grid optimization, a **value-generating** capability, uses the information uncovered and sourced through grid situational awareness to optimize the performance and efficiency of the grid. To accomplish grid optimization, LPCs must first have achieved some level of grid situational awareness.

The CPM is an evolving framework, and TVA is working diligently with LPCs and other stakeholders to provide guidance and resources around these capabilities.

18 capabilities in the CPM → **4** stages of progression

STAGES OF PROGRESSION

1

Enabling

Enabling capabilities are foundational to a utility. They help “unlock” more advanced capabilities, leading to added benefits and value for the utility and its end-use customers. For example, telecommunications is a critical enabler of a modern and efficient grid that can restore power during outage events rapidly, and it also supports the growth in EVs and new solar and storage resources.

2

Planning and Assessing

Planning and assessing capabilities help a utility better understand and plan its system. For example, system modeling improves the ability to adapt to extreme weather events, understand options for alternatives and enable locational elements of DER and load.

3

Value Generating

Value generating capabilities enable a utility to better optimize and control their system to provide better service to the end-use customers as well as support the bulk electric system.

4

Enhancing

Enhancing capabilities provide the opportunity for LPCs to extract more value out of the existing operational systems and capabilities across the enterprise.

Capability Areas

Each of the areas are comprised of a variety of individual capabilities, which represent the technologies, projects and applications related to that area. Short descriptions of these capability areas are below, with more in-depth explanations in the RGT Strategic Roadmap.

The CPM is comprised of five capability areas, each playing a distinct role in the development of a modernized grid.

Integrated Planning

Integrated planning is needed to determine best practices, manage region-wide efforts and optimize investments.

Regional Guidelines

To assist the advancement of the grid transformation process, regional guidelines should be used for facilitating partnership and collaboration around common standards, architecture, information sharing and stakeholder alignment.

Enhanced Transmission & Distribution Operations

This capability area utilizes situational awareness to provide transmission and distribution (T&D) operators with the ability to operate the grid with coordination and resiliency.

Exceptional End-User Experience

Developing meaningful tools and services with an intentional customer focus supports the work of grid transformation. By establishing strong relationships with end-use customers, TVA and LPCs can help manage energy use and costs while setting up clear lines of communication for increased transparency and understanding.

Grid Transformation Enabling

The grid transformation enabling capability area is the groundwork for this process as it outlines the foundational capabilities and technologies to implement grid transformation successfully.

Standards for Maturing in a Capability

The TVA working team and LPC focus groups worked to establish maturity levels for each of the capabilities within the CPM to help LPCs measure their progress toward maturity in each capability and ensure alignment with their utility peers in TVA's service area. While there are five levels of maturity through which LPCs can progress, the following two have been identified as benchmarks for the region:

VS

Valley Standard

The VS establishes a minimum recommended threshold for each LPC capability.

VTL

Valley Transformational Level

The VTL details activities and objectives that optimize a capability, enabling stakeholders to benefit more from the value it offers.

EVERY LPC IS DIFFERENT

Each LPC is at a different starting point for every RGT capability, varying by service territory population and number of meters serviced, geography and terrain, infrastructure, financial constraints and customer needs. To transform the regional grid, all LPCs must move toward greater grid resiliency, efficiency and flexibility by first achieving the VS before striving for the VTL.

Achieving grid modernization at a regional level will take several of the largest LPCs making concerted efforts to modernize and achieve VTL status and beyond. By achieving the VTL, LPCs and stakeholders will see enhanced benefits for their business and customers.

The VTL is not the finish line; roadmaps will continue to evolve to reflect regional learnings, ensuring the most effective and efficient path to a resilient and flexible grid for the region.

LPCs must satisfy all requirements listed under the maturity level before that level has been achieved, including specifics listed under the penetration level.

Progress Starts Here

Self-assessment empowers LPCs to identify best practices, pinpoint areas for growth and strategically chart their course toward a more resilient future. Defining and prioritizing areas for action ensures that resources are allocated efficiently and efforts are focused on the most impactful activities.

TVA, LPCs and other stakeholders have worked for several years to develop the information in this report and outline the importance of the VS and VTL. Capability progress and the associated benefits do not happen overnight—it will take collaboration and time to reach the next level within the capabilities.

Begin your journey to grid modernization by exploring each of the capabilities, supporting technologies and potential investments outlined in the following content.

Capability Progression Model

DIGITAL NAVIGATION

Click on each capability in the model to jump to a detailed breakdown of the definition, importance, maturity levels, supporting technologies and stakeholder benefits of each capability.

1 Enabling

CAPABILITIES

- Cybersecurity
- Grid Situational Awareness
- Telecommunications
- Advanced Customer Metering
- Workforce Enablement
- Data Management
- Data Analysis and Analytics

2 Planning and Assessing

CAPABILITIES

- System Modeling
- DER Interconnection
- Load and DER Forecasting (Planning)

3 Value Generating

CAPABILITIES

- Grid Optimization
- Self-Healing Grid
- Impact Assessment
- Alternatives Assessment
- Customer Experience Management

4 Enhancing

CAPABILITIES

- Resource Co-Optimization
- Load and DER Forecasting and Operationalization
- DER Incorporation and Optimization

CAPABILITY AREAS

- Integrated Planning
- Regional Guidelines
- Enhanced T&D Operations
- Exceptional End-User Experience
- Grid Transformation Enabling

Enabling | Planning and Assessing | Value Generating | Enhancing

- Cybersecurity
- Grid Situational Awareness
- Telecommunications
- Advanced Customer Metering
- Workforce Enablement
- Data Management
- Data Analysis and Analytics

Cybersecurity

CATEGORY	STAGE
Grid Transformation Enabling	Enabling

CYBERSECURITY

Overview

DEFINITION

Protection against online threats by employing technologies, workforce development and processes that safeguard systems and data against criminal or unauthorized use of networks, devices and data.

SUPPORTING TECHNOLOGIES

- Security information and event management (SIEM) system
- Data backups (cloud or server)
- Intrusion Prevention Systems (IPS)
- Advanced threat protection solutions
- Data encryption (both in transit and at rest)
- Multi-factor authentication
- Regular (at least annually) penetration testing and vulnerability assessments
- Network segmentation
- Incident response plan and tools
- Patch management tools and procedures

CAPABILITY IMPORTANCE

As more technologies and devices are connected to the grid, the risk of cybersecurity incidents increases, with threats becoming more common and impacts more severe.

Cybersecurity measures protect digital and physical infrastructure, sensitive data and operations from unauthorized access and threats due to hacking, malware and data breaches. By safeguarding their systems, assets and information, LPCs can maintain the reliability and integrity of their services, ensure customer privacy and avoid costly disruptions or damages caused by cyberattacks.

CYBERSECURITY

Frameworks

The National Institute of Standards and Technology (NIST)[1] and the Department of Energy (DOE)[2] have developed frameworks that offer guidance to organizations of all sizes and sectors in managing cybersecurity risks.

When seeking to mature cybersecurity abilities, LPCs should utilize one or both frameworks to ensure coverage of the necessary factors for comprehensive and effective defense against cyber threats.

Please note that NIST Cybersecurity Framework (CSF) targets have been provided with the intention for LPCs to cross-reference those benchmarks with the DOE Cybersecurity Capability Maturity Model (C2M2), should they choose to use that framework instead of the NIST CSF.

Mapping of C2M2 elements to CSF elements and an indication of their relationship (e.g., subsets of, intersects with or equal to) can be found in the National Institute of Standards and Technology, "DOE-C2M2-V2.1-to-NIST-CSF-V1.1-Mapping"[3].

These frameworks provide a flexible approach, allowing organizations to understand, assess, prioritize and communicate their cybersecurity efforts, with online resources for additional guidance on implementing specific practices.

1 National Institute of Standards and Technology, "NIST Cybersecurity Framework", Version 2.0, https://www.nist.gov/cyberframework

2 Department of Energy, "Cybersecurity Capability Maturity Model (C2M2)", Version 2.1, https://www.energy.gov/sites/default/files/2022-06/C2M2%20Version%202.1%20June%202022.pdf

3 Mapping of C2M2 elements to CSF v1.1 elements and an indication of their relationship (e.g., subsets of, intersects with or equal to) can be found in National Institute of Standards and Technology, "DOE-C2M2-V2.1-to-NIST-CSF-V1.1-Mapping" https://www.nccoe.nist.gov/sites/default/files/2023-07/CSF-DOE-C2M2V2_1-mapping.xlsx. Relationship refers to the logical comparison between a Reference Document Element (in this case CSF v1.1) and a Focal Document Element (in this case C2M2). Relationships are described using one of five cases derived from a branch of mathematics known as set theory: subset of, intersects with, equal, superset of, or not related to.

CYBERSECURITY

Maturity Levels

	Level 1	Level 2	Level 3	Level 4 VS	Level 5 VTL
Est. Time at Level	**0-1 Years**	**1-3 Years**	**1-3 Years**	**1-3 Years**	**N/A**
Framework Target	None	LPC should be in accordance with NIST CSF[1] v2.0 Tier 1: Partial or equivalent in DOE C2M2[3]	LPC should be in accordance with NIST CSF[1] v2.0 Tier 2: Risk Informed or equivalent in DOE C2M2[3]	LPC should be in accordance with NIST CSF[1] v2.0 Tier 3: Repeatable or equivalent in DOE C2M2[3]	LPC should be in accordance with NIST CSF[1] v2.0 Tier 4: Adaptive or equivalent in DOE C2M2[3]
Awareness and Preparedness	Limited cybersecurity tools, capabilities and workforce skillsets.	Partially implemented cybersecurity capabilities, people and tools are in place. LPC uses traditional and limited IT and OT protections, such as vendor-proprietary protocols, passwords, etc. This reduces initial outages that typically result in immediate losses.	Organizations are aware of risks but not fully prepared to proactively protect the enterprise and grid operations. LPCs may experience cost avoidance through risk management and benefit from better prioritization of cybersecurity funding based on risks identified.	LPC has implemented their cybersecurity framework (based on NIST) standards companywide, including both corporate and OT grid functions, and can repeatedly respond to events. This operational efficiency leads to fewer outages, reduced incident response costs, maintenance cost savings and better utilization of staff.	LPC is prepared at an enterprise level including corporate, IT/OT and grid operations. The LPC can proactively detect risks and react accordingly. Benefits include predictive maintenance savings, reduced downtime costs, regulatory and legal cost savings, reputation protection, optimized staffing and lower insurance premiums.

1 National Institute of Standards and Technology, "NIST Cybersecurity Framework", Version 2.0, https://nvlpubs.nist.gov/nistpubs/CSWP/NIST.CSWP.29.pdf

2 Department of Energy, "Cybersecurity Capability Maturity Model (C2M2)", Version 2.1, https://www.energy.gov/sites/default/files/2022-06/C2M2%20Version%202.1%20June%202022.pdf

3 Department of Energy, "C2M2 Cybersecurity Framework Tiers Mapping". Version 2.1, https://www.nccoe.nist.gov/sites/default/files/2023-01/DOE-C2M2-CSF_Tiers-mapping.xlsx

VS Valley Standard VTL Valley Transformational Level

CYBERSECURITY

Potential Benefits

Strong cybersecurity safeguards the grid by preventing and minimizing service interruptions and data breaches that can lead to costly outages. By enhancing resilience and ensuring faster response and recovery times, LPCs can maintain reliable operations and protect customer trust. Cybersecurity measures can lower insurance and incident costs, shorten downtime and strengthen the overall security of critical energy infrastructure.

Strong cybersecurity improves overall grid resilience by preventing and minimizing the impacts of cyberattacks.

TVA Benefits

TVA Benefits	VS	VTL
Reduced customer outage frequency	●○○○○ (Quantitative)	●●●○○ (Quantitative)
Reduced service interruptions, breaches or data losses	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)
Reduced response times to cyber incidents	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)
Increased coordination between TVA and LPCs	●○○○○ (Qualitative)	●●●●● (Qualitative)

LPC Benefits

LPC Benefits	VS	VTL
Reduced customer outage frequency	●○○○○ (Quantitative)	●●●○○ (Quantitative)
Reduced cost of cybersecurity event response	●○○○○ (Quantitative)	●○○○○ (Quantitative)
Reduced downtime costs	●○○○○ (Quantitative)	●●○○○ (Quantitative)
Lower insurance premiums	●○○○○ (Quantitative)	●●●○○ (Quantitative)
Reduced service interruptions, breaches or data losses	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)

Customer Benefits

Customer Benefits	VS	VTL
Reduced customer outage frequency	●○○○○ (Quantitative)	●●●○○ (Quantitative)
Increased resiliency	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)
Reduced risk of service disruptions	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)
Reduced duration of impacts from cyber incidents	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)

●●●●● Amount of potential benefits on a scale of 1-5

- Quantitative
- Semi-quantitative
- Qualitative

VS Valley Standard

VTL Valley Transformational Level

CYBERSECURITY

Implementation Considerations

People Who May Be Impacted

- All staff must be trained and aware of potential threats
- IT/OT personnel should have specialized cyber defense knowledge and skills

Processes That May Be Impacted

- Cybersecurity training via drills and exercises will need to be developed and deployed to all staff, including leadership, to ensure awareness of potential threats and knowledge of how to respond to threats when they occur.
- Asset identification and incident response techniques, processes and exercises will need to include contingencies and plans for cyber threats, including those associated with the supply chain, SCADA communications, segmentation, patch management and any instance of physical and cyber convergence.
- Organizational planning will include details on cyber defense and event recovery regarding resiliency, predictive maintenance, real-time grid monitoring, external collaboration, advanced threat intel and regulatory compliance.

Challenges of Implementation

- Initial buy-in for investment may be a challenge, as there may be concerns with justifying the expense to defend against unknown future threats.
- The initial and continuous training of staff and leadership on current and emergent cyber threats may prove to be a significant time and capital investment.
- With the introduction of new supporting processes and technologies, internal staff skills may need to be augmented with external staff during periods of transition. As higher levels of maturity are achieved, LPCs may find value in a dedicated internal staff with the skills and knowledge to manage cybersecurity measures.

Enabling | Planning and Assessing | Value Generating | Enhancing

- Cybersecurity
- **Grid Situational Awareness**
- Telecommunications
- Advanced Customer Metering
- Workforce Enablement
- Data Management
- Data Analysis and Analytics

Grid Situational Awareness

CATEGORY	STAGE
Grid Transformation Enabling	Enabling

GRID SITUATIONAL AWARENESS

Overview

DEFINITION

Grid situational awareness is the ability for an LPC to have accurate awareness of their distribution system's electrical network connectivity, voltage and power levels, outage locations and related performance indicators.

SUPPORTING TECHNOLOGIES

- DSCADA in substation
- Fiber or broadband to substations
- DSCADA monitored cap banks, reg stations, switches and reclosers
- Distribution management system to support state estimation
- Increased use of field area network (FAN)
- Cellular networks

CAPABILITY IMPORTANCE

Remote and real-time visibility into the grid conditions enables optimal management of the power supply.

By investing in grid situational awareness technologies, LPCs ensure they have the information they need to make educated, data-driven decisions about how to best operate the grid and support the grid of the future.

GRID SITUATIONAL AWARENESS

Potential Benefits

Grid situational awareness enhances real-time visibility, enabling LPCs to respond quickly to capacity reductions, improve near-term planning and optimize grid operations. By reducing truck rolls, crew patrolling time and service interruptions, it minimizes outages and leads to shorter, less frequent disruptions. These efficiencies improve reliability and communication and lower medium-term costs, ensuring a more resilient and responsive grid.

Grid situational awareness enhances real-time visibility, reduces response time and improves operational reliability.

TVA Benefits

TVA Benefits	VS	VTL
Reduced time to restore outages	●○○○○	●●○○○
Reduced customer outage frequency	●○○○○	●●○○○
Improved near-term planning	●○○○○	●●○○○
Better visibility into LPC storm event response	●○○○○	●●○○○
Increased coordination between TVA and LPCs	●○○○○	●●●●● (graded shading)

LPC Benefits

LPC Benefits	VS	VTL
Reduced reliability-related truck rolls	●○○○○	●●○○○
Increased revenue from decreased outages	●○○○○	●●○○○
Reduced crew patrolling time	●○○○○	●●○○○
Reduced time to restore outages	●○○○○	●●○○○
Reduced customer outage frequency	●○○○○	●●○○○
Enhanced grid awareness to support internal communications	●○○○○	●●○○○
Increased efficiency of grid operations	●○○○○	●●○○○
Real-time operational visibility	●○○○○	●●●○○

Customer Benefits

Customer Benefits	VS	VTL
Reduced time to restore outages	●○○○○	●●○○○
Reduced customer outage frequency	●○○○○	●●○○○
Improved reliability	●○○○○	●●○○○

●●●●● Amount of potential benefits on a scale of 1-5

● Quantitative
● Semi-quantitative
● Qualitative

VS Valley Standard
VTL Valley Transformational Level

GRID SITUATIONAL AWARENESS

Activities for Advancement

Visibility

Real-time visibility of voltage, power and outages of distribution system infrastructure (i.e., substations and circuits/feeders downstream).

Reliability Metric Reporting

Tracking and acting on distribution system reliability information enables LPCs to identify trouble areas on the system and improve end-use customer's experience.

Alarm Philosophy Development

Create a clear plan for when something goes wrong. Think of it like having a rulebook for alarms—decide in advance what actions to take when there's a problem with our electricity system.

Alarm Reporting

Change the way we show alerts about the system's status. Instead of using many colors, we simplify it to show only when something isn't normal. It's like turning complex signals into easy-to-understand warnings, making it clearer when something needs attention.

Grid Situational Awareness means knowing what is happening on the distribution grid to ensure the electric grid remains reliable, efficient and secure—now and in the future.

GRID SITUATIONAL AWARENESS

Maturity Levels

	Level 1	Level 2	Level 3 VS	Level 4 VTL	Level 5
Est. Time at Level	N/A	2-3 Years	3-5 Years	3-5 Years	3-5 Years
Visibility	Zero to partial visibility at substations. (i.e., manual readings).	Remote visibility to most (51-75%) substations and some or many (1-50%) downstream devices.	Remote visibility to almost all (76-95%) substations and some or many (1-50%) downstream devices.	Remote visibility to almost all (76-95%) substations and most (51-75%) downstream devices.	Remote visibility at all (96-100%) substations—high frequency, high fidelity— down to the end of the line on almost all (76-95%) circuits.
Reliability Metric Reporting	No reporting of reliability metrics.	Limited reporting of any reliability metrics.	EIA required reliability metrics calculated with some (1-25%) automation assistance and reported annually.	EIA required reliability metrics calculated largely automatically with minimal manual adjustments and reported annually.	Detailed reliability metrics (beyond EIA requirement) calculated regularly and used internally for tracking purposes.
Alarm Philosophy Development	No formal alarm philosophy.	Informal efforts made to eliminate nuisance alarms.	Formal alarm philosophy has been established.	Alarms in production are fully aligned with the alarm philosophy.	Governance to ensure consistency in alarming for future needs.
Alarm Reporting	No alarm reporting.	Using basic status alarming interfaces that may include excessive or similar colors without effort to streamline.	Incorporation of more advanced status alarming user interface where additional efforts have been undertaken to appropriately reserve alarm colors in displays.	Status alarming displays have been re-engineered to reduce the use of color to only abnormal conditions.	Status alarming displays incorporate “widgets” to present analog values in context.

VS Valley Standard VTL Valley Transformational Level

GRID SITUATIONAL AWARENESS

Implementation Considerations

People Who May Be Impacted

- Control center personnel
- Field crews
- IT/operational technology crew for management of the OT network
- Planning personnel
- Customer service

Processes That May Be Impacted

- Fault diagnosis can be done from the control room using remote sensing instead of through field observations.
- Recovery processes become more streamlined and targeted. Knowing where and what is faulty helps field crews load the repair materials on their trucks before they drive to the location, preventing unnecessary trips.
- Planning becomes easier as personnel can more precisely identify loading, voltage and outages on the distribution system, enabling data-informed decisions on where to focus capital upgrades to improve reliability, service and more.
- Customer service is more proactive and satisfactory when providers know an end-use customer's power is out before they call to report the outage.

Challenges of Implementation

- Deploying substation equipment could prove challenging due to long lead times on equipment, confusing standards, number of vendors and other factors.
- Control room acceptance may be difficult, including concerns for safety. Historically manual processes are well understood, and any change will require time for personnel to accept and adapt to.
- Implementation of supervisory control and data acquisition (SCADA) may require additional system upgrades which could increase overall cost and impact. Implementing IT systems requires resources in areas the utility has not previously required them, including new skills, positions and added costs to running the distribution system.

With a clear understanding of their grid's condition and potential risks, LPCs can make informed decisions and implement strategies to ensure a resilient and sustainable energy infrastructure for years to come.

Enabling | Planning and Assessing | Value Generating | Enhancing

- Cybersecurity
- Grid Situational Awareness
- **Telecommunications**
- Advanced Customer Metering
- Workforce Enablement
- Data Management
- Data Analysis and Analytics

Telecommunications

CATEGORY	STAGE
Grid Transformation Enabling	Enabling

TELECOMMUNICATIONS

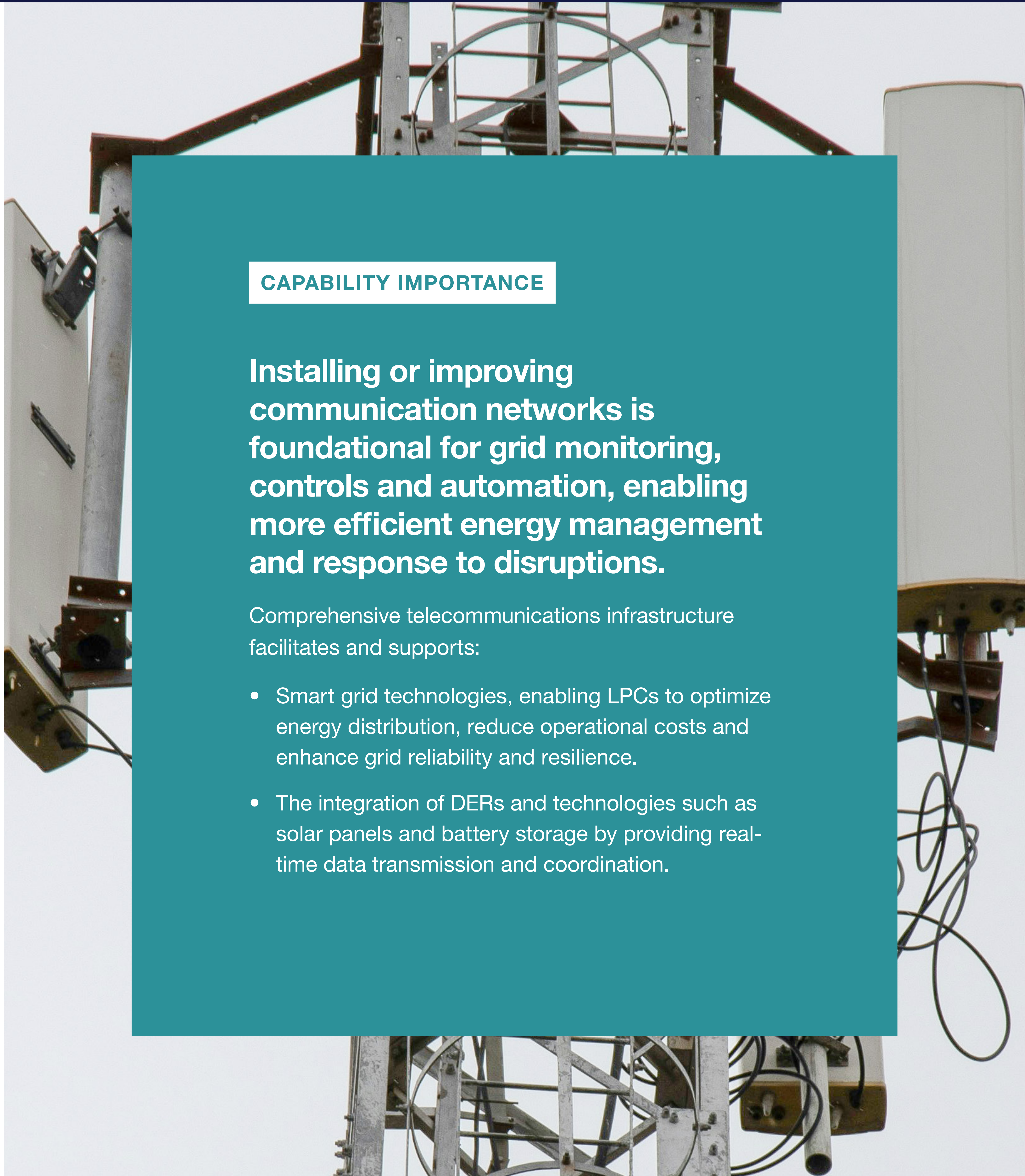
Overview

DEFINITION

Technologies used to transmit and coordinate information throughout the utility—as well as between the utility, business partners and customers—that support internal operations and enterprise objectives.

SUPPORTING TECHNOLOGIES

- Leased private internet provider-based communications
- RF Mesh (e.g., 900 MHz)
- LTE 3G/4G/5G Cellular
- Zigbee or low-power local network broadband
- Fiber to substations (e.g., using MPLS connectivity)
- Secure Wi-Fi available in substation buildings and yard



CAPABILITY IMPORTANCE

Installing or improving communication networks is foundational for grid monitoring, controls and automation, enabling more efficient energy management and response to disruptions.

Comprehensive telecommunications infrastructure facilitates and supports:

- Smart grid technologies, enabling LPCs to optimize energy distribution, reduce operational costs and enhance grid reliability and resilience.
- The integration of DERs and technologies such as solar panels and battery storage by providing real-time data transmission and coordination.

TELECOMMUNICATIONS

Maturity Levels

	Level 1	Level 2	Level 3 VS	Level 4 VTL	Level 5
Est. Time at Level	N/A	2 Years	3 Years	4 Years	4 Years
Communication Connectivity	Communication links are only used for critical connections that are required for business and operational continuity. Lack of these connections would cause business and/or service disruption.	Communication links deployed to key substations and facilities. **PENETRATION LEVEL:** Broadband between all (96-100%) data center(s) and control center(s). Narrowband wired to some or many (1-50%) substations.	Communication links deployed to almost all (76-95%) substations and facilities, as well as to critical distribution line devices. **PENETRATION LEVEL:** Level 2+ Broadband to some or many (1-50%) substations. Narrowband wired to most (51-75%) substations. The focus should be on substations providing the majority of load and those most closely integrated to TVA delivery points. Narrowband wireless to devices on some (1-25%) feeders. LPC enabled narrowband connectivity to some (1-25%) larger customer loads and some (1-25%) larger capacity DERs.	Communication links deployed to all (96-100%) substations, facilities and many (26-50%) key distribution devices. Redundant communications are used on key substations and facilities. **PENETRATION LEVEL:** Level 3+ Broadband to most (51-75%) substations, narrowband to almost all (76-95%) substations. Narrowband to devices on many (26-50%) feeders. Devices serving smaller loads now have communication links. LPC enabled narrowband connectivity to many (26-50%) customer loads and many or most (26-75%) DERs (above 500kW nameplate).	Communication links deployed to all (96-100%) substations, facilities and almost all (76-95%) distribution devices and control and coordination of third party DERs. **PENETRATION LEVEL:** Level 4+ Broadband wired to almost all (76-95%) substations. Narrowband wireless to devices on most (51-75%) feeders. Narrowband wireless to almost all (76-95%) key DERs (above 500kW nameplate).

Broadband: Frequency range of 500kbps to 45Mbps. E.g., T1 (1.544Mbs), Fiber (channelized and/or carrying MPLS or other backbone protocol), 900MHz or Microwave pt-pt connections, Ethernet LAN. Cellular LTE (in some cases) and 5G.

Narrowband: Frequency range of 9600 bps to 500kbps. E.g., traditional copper wire, DS0 (64kbps), 900MHz mesh (AMI configuration with limited bandwidth/meter), cellular 3G, LTE (in some cases).

VS Valley Standard VTL Valley Transformational Level

TELECOMMUNICATIONS

Potential Benefits

Telecommunications play a critical role in modernizing the grid by enabling real-time monitoring, self-healing networks and dynamic pricing, which improve overall grid performance and resilience. By supporting advanced technologies and optimizing smart grid assets, the grid accommodates growing energy demands and minimizes service disruptions, helping drive economic growth and strengthen community resilience.

Telecommunications supports advanced technologies and optimizes smart grid assets, accommodating growing energy demands.

TVA Benefits

TVA Benefits	VS	VTL
Increased ability to respond to supply shortfalls during capacity, emergency or storm events	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)
Improved customer satisfaction	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)
More resilient telecommunications networks for the region	●○○○○ (Qualitative)	●●●●● (Qualitative)
Increased coordination between TVA and LPC	●○○○○ (Qualitative)	●●●●● (Qualitative)

LPC Benefits

LPC Benefits	VS	VTL
Improved grid performance and resilience	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)
Increased ability to integrate and optimize smart grid technologies	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)
Increased ability to support deployment of advanced technologies	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)
Improved customer satisfaction	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)

Customer Benefits

Customer Benefits	VS	VTL
More effective solutions to outages	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)
Increased resiliency	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)
Improved customer satisfaction	●○○○○ (Semi-quantitative)	●●○○○ (Semi-quantitative)
Increased ability to accommodate growth of DER	●○○○○ (Qualitative)	●●●●● (Qualitative)
Increased economic development opportunities	●○○○○ (Qualitative)	●●●●● (Qualitative)

●●●●● Amount of potential benefits on a scale of 1-5

● Quantitative
● Semi-quantitative
● Qualitative

VS Valley Standard
VTL Valley Transformational Level

TELECOMMUNICATIONS

Implementation Considerations

People Who May Be Impacted

- Operations personnel
- Field crews
- Planning personnel
- IT/OT technologists
- Customer service

Processes That May Be Impacted

- Operations are improved as telecommunications enables real-time monitoring and control of the system, improving response times and facilitating more efficient operations.
- IT/OT processes are impacted by telecommunications through improved system interoperability and enablement of more effective coordination between IT/OT systems.
- Planning processes are enhanced from increased telecommunication by providing more accurate and timely data with decreased delays to support operations and a more resilient electric service.
- Customer program processes are affected by increased telecommunications by enhancing customer engagement, providing real-time updates on energy usage and awareness into service disruptions.

Challenges of Implementation

- Implementation of new technology may potentially cause changes in the reliability of service, which would require mitigation, problem-solving or additional communications to customers and stakeholders.
- The initial cost of deployment may be substantial, and once implemented, maintenance costs will need to be factored into budgeting and capital planning.
- Additional workforce or training of the existing workforce will be needed to implement, operate and maintain infrastructure.
- The monitoring and management of the communication network will be an additional consideration, as higher maturity levels (Level 4+) require near real-time monitoring to function optimally.

Cybersecurity
Grid Situational Awareness
Telecommunications
Advanced Customer Metering
Workforce Enablement
Data Management
Data Analysis and Analytics

Advanced Customer Metering

CATEGORY
Grid Transformation Enabling

STAGE
Enabling

ADVANCED CUSTOMER METERING

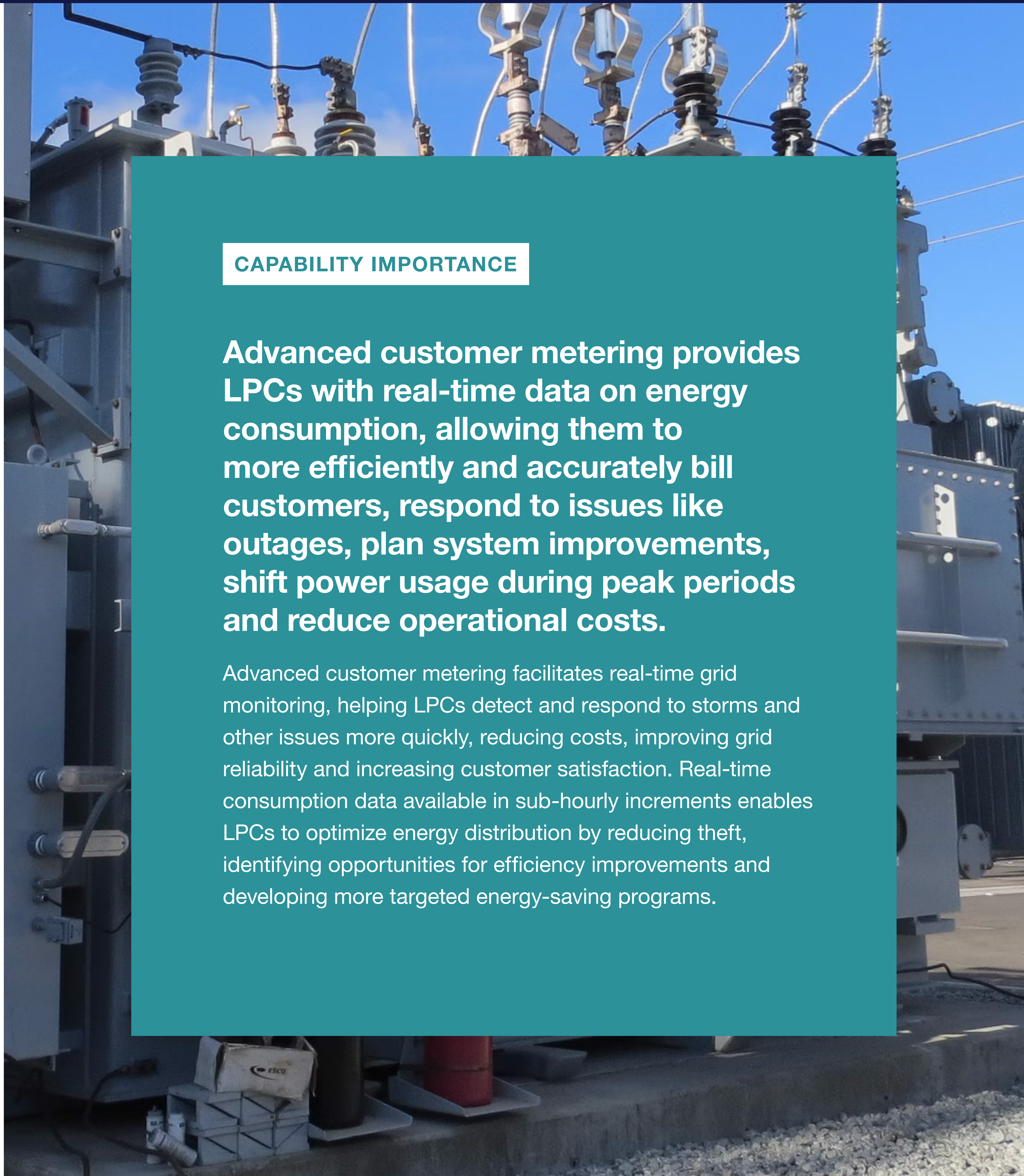
Overview

DEFINITION

An integrated system of smart meters, communication networks and data management systems that provides faster and more reliable two-way communication between utilities' back-office and customer meters.

SUPPORTING TECHNOLOGIES

- AMI interval capable meters to support variable pricing
- Meter data management platforms (MDMS)
- Broadband communication technology (for example, mesh network, cellular, radio, fiber, ethernet)



CAPABILITY IMPORTANCE

Advanced customer metering provides LPCs with real-time data on energy consumption, allowing them to more efficiently and accurately bill customers, respond to issues like outages, plan system improvements, shift power usage during peak periods and reduce operational costs.

Advanced customer metering facilitates real-time grid monitoring, helping LPCs detect and respond to storms and other issues more quickly, reducing costs, improving grid reliability and increasing customer satisfaction. Real-time consumption data available in sub-hourly increments enables LPCs to optimize energy distribution by reducing theft, identifying opportunities for efficiency improvements and developing more targeted energy-saving programs.

ADVANCED CUSTOMER METERING

Maturity Levels

	Level 1	Level 2	Level 3 VS	Level 4 VTL	Level 5
Est. Time at Level	N/A	1-2 Years	1-2 Years	3-5 Years	1-2 Years
Advanced Customer Metering	Traditional manual meter reading, typically using electro-mechanical meters. Meter data is used reactively, not proactively.	AMI broadly implemented for at least 51% of customers and used primarily for improved billing and ad-hoc for other purposes. This can help improve billing accuracy, reduce meter reading costs and support customer inquiries more easily. **PENETRATION LEVEL:** AMI deployed to most or almost all (51-95%) customers.	AMI fully deployed to all (at least 96%) customers and data used for billing, detailed customer feedback, enabling new rates, reduced operational costs and basic analysis. The system needs to support outage reporting, high/low voltage alarms and variable rate pricing (e.g., TOU pricing). **PENETRATION LEVEL:** AMI deployed for all (96-100%) customers.	AMI data is used in some (1-25%) operational decision-making and more broadly for analysis and most (51-75%) processes. The system must enable near real-time voltage monitoring to support voltage optimization. Process integration assists in fault awareness, reducing outage response time and efficiency. **PENETRATION LEVEL:** AMI deployed for all (96-100%) customers and data used for most (51-75%) processes.	AMI data leveraged in almost all (76-95%) grid and customer programs, used both proactively and holistically. When fully integrated, data supports advanced customer programming and improves efficiency across nearly all operations. **PENETRATION LEVEL:** Advanced AMI deployed for all (96-100%) customers and data used comprehensively across the enterprise.

AMI: Recent generation (past 10 years) of Automated Metering Infrastructure that is more capable than early power line carrier and other implementations with limited bandwidth and that require ping, pull.

Advanced AMI: Current generation of Advanced Automated Metering Infrastructure with capabilities beyond ping and pull with functions and bandwidth to support variable rate pricing, outage notifications, capture and report voltage readings in near real time.

VS Valley Standard VTL Valley Transformational Level

ADVANCED CUSTOMER METERING

Potential Benefits

Advanced customer metering reduces the cost in meter reading and increases the speed at which energy consumption data is available to the end-customer and the utility. This capability enhances the quick detection of and response to outages, reducing both downtime and operational costs through remote meter management. This capability enables innovative rate structures, such as time-of-use pricing and managed EV charging, optimizing load management across the region while giving customers greater control over their energy use.

Advanced customer metering leads to operational cost savings which can be passed on to the end customer.

TVA Benefits

TVA Benefits	VS	VTL
Reduced time to restore outages	●○○○○	●●●○○
Increased awareness of customer outages	●○○○○	●●○○○
Improved customer satisfaction	●○○○○	●●○○○
Optimized load management	●○○○○	●●●●●

LPC Benefits

LPC Benefits	VS	VTL
Reduced meter services labor	●○○○○	●○○○○
Increased revenue from avoided theft/tampering	●○○○○	●●●○○
Reduced time to restore outages	●○○○○	●●●○○
Improved customer satisfaction	●○○○○	●●○○○

Customer Benefits

Customer Benefits	VS	VTL
Reduced customer outage restoration time	●○○○○	●●●○○
Lower monthly bills	●○○○○	●●●○○
Improved customer satisfaction	●○○○○	●●○○○
Increased customer services (e.g., TOU rates, managed EV charging, etc.)	●○○○○	●●●●●
Increased customer services (e.g., TOU rates, managed EV charging, etc.)	●○○○○	●●●●●
Increased accessibility for customers to their data	●○○○○	●●●●●

●●●●● Amount of potential benefits on a scale of 1-5

- Quantitative
- Semi-quantitative
- Qualitative

VS Valley Standard

VTL Valley Transformational Level

ADVANCED CUSTOMER METERING

Implementation Considerations

People Who May Be Impacted

- Operations personnel
- Billing and accounting departments
- Meter data management department
- Field crews
- Customer programs and communications

Processes That May Be Impacted

- Operations are streamlined as AMI enables utilities to monitor and engage with the grid in real-time, quickly identifying outages and issues, leading to faster response and restoration times and improved reliability.
- Metering becomes automated, as AMI deployment eliminates the need for manual meter readings and provides highly accurate and detailed usage data, reducing billing errors and disputes.
- Planning is more effective and comprehensive as the data collected helps utilities better understand consumption patterns, aiding in more accurate load forecasting, effective DER integration and enhanced capacity planning.
- Customer service and program design become more user-friendly, as AMI empowers customers with real-time alerts and detailed information about their energy usage, promoting energy-saving behaviors and enabling personalized programs and incentives.
- Engineering has more insights into energy use across customers and can provide innovative solutions for identified challenges.

Challenges of Implementation

- Leaders may be hesitant to deploy advanced customer metering capabiliites becuase it is a new technology.
- Workforce flexibility and repurposing will be needed to support AMI deployment.
- Once maturity level 3 is reached and the system has been largely deployed, maintenance costs and budgeting for updates will be essential.
- At maturity level 3 and above, LPCs may experience operational system integration difficulties as the AMI vendor platform may not integrate seamlessly with operational systems. AMI platforms are not currently standardized across vendors, which can limit LPC's future options once one vendor is selected.

● Enabling ○ Planning and Assessing ○ Value Generating ○ Enhancing

- Cybersecurity
- Grid Situational Awareness
- Telecommunications
- Advanced Customer Metering
- **Workforce Enablement**
- Data Management
- Data Analysis and Analytics

Workforce Enablement

CATEGORY	STAGE
Grid Transformation Enabling	Enabling

WORKFORCE ENABLEMENT

Overview

DEFINITION

The processes and programs that support and enable a skilled and empowered workforce by identifying needs, improving skills and retaining talent.

SUPPORTING PROCESSES TO REACH VALLEY STANDARD

- Skill gap and job role assessments
- Educational and training opportunities
- Mentorship and apprenticeship programs
- Competitive benefits, compensation and incentives
- Collaborative partnerships for employee pipeline creation

CAPABILITY IMPORTANCE

Integration of more advanced grid technologies is driving the demand for skilled workers in the energy sector. In addition, with the integration of distributed renewable energy sources, energy storage and electric vehicles, workers need to be trained with new qualifications and skills to manage the evolving grid.

Investing in workforce enablement ensures LPCs have qualified personnel with the necessary expertise to design, install, operate and maintain the advanced grid technologies and infrastructure associated with grid modernization initiatives. Communities can foster economic growth, create job opportunities and remain competitive into the future.

WORKFORCE ENABLEMENT

Activities for Advancement

Skill Gap and Job Role Assessments

EXAMPLES

- **Regular Skills Audits:** Conduct audits to identify employee capability gaps and compare internal skill levels with industry benchmarks.
- **Job Role Analysis:** Analyze roles to align with industry trends and technological advancements, developing a competency framework to map required skills.
- **Employee Surveys:** Use surveys and feedback to understand perceived skill gaps and areas for improvement.

Educational and Training Opportunities

EXAMPLES

- **Incentivize Upskilling:** Offer educational opportunities and tuition reimbursement for further education, certifications or credentials.
- **Technical Training:** Provide specialized training on new technologies, such as smart grids and renewable energy systems.
- **Accessible Learning:** Partner with online platforms for courses and organize workshops and seminars with industry experts.

Developing a skilled and capable local workforce ensures LPCs are prepared to meet evolving operational needs as additional technologies are integrated into the grid.

Mentorship and Apprenticeship Programs

EXAMPLES

- **Mentorship Program:** Pair new hires with experienced mentors for guidance and provide training to mentors on effective coaching.
- **Apprenticeships:** Develop programs for technical roles, including rotational opportunities in different departments.
- **Feedback Mechanisms:** Establish regular feedback sessions between mentors and mentees to ensure progress.

Competitive Benefits, Compensation and Incentives

EXAMPLES

- **Comprehensive Benefits:** Offer health insurance, retirement plans, wellness programs and flexible work hours.
- **Performance Bonuses:** Provide bonuses based on individual and team performance and recognition programs for outstanding contributions.
- **Market Research:** Conduct regular market research to keep compensation packages competitive.

Robust Performance and Promotion Process

EXAMPLES

- **Regular Reviews:** Conduct regular performance reviews with constructive feedback.
- **Goal Setting:** Implement a goal-setting process where employees set and review goals with managers using objective performance metrics.
- **Career Mapping:** Create clear career paths and progression plans for various roles.

Collaborative Partnerships for Employee Pipeline Creation

EXAMPLES

- **University Partnerships:** Partner with universities to develop relevant curricula and offer internship programs for practical experience.
- **Industry Associations:** Collaborate with associations for training and certification programs.
- **Career Fairs:** Participate in career fairs to attract young talent and promote the industry as a viable career option.

WORKFORCE ENABLEMENT

Maturity Levels

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-2 Years	1-2 Years	1-3 Years	1-3 Years
Processes and Programs	Limited changes to traditional worker and skill acquisition	Has developed an understanding of the near-term impacts that achieving grid transformation will have on the organization. Has completed identification of the required skills, workforce needs and programs that will be required to improve employee satisfaction and retention.	Internal initiatives implemented that promote cultures of collaboration, cybersecurity and advanced data collection and review. Begin forming relationships with external entities (universities, TVPPA) to shape resources, skills and incoming employee pipeline.	Proactive engagement with internal resource pipelines to shape the training of resources, including benefits and robust training programs.	Coordination with universities in TVA's service region to uplift resource skills that generate a pipeline of skilled workers, fill identified gaps and create a collaborative and positive work culture.
Internal Needs Assessment	No formal assessment process or structure in place.	Assessment of 5-year skills needs for most (51-75%) significantly impacted employee areas (key operational and business areas). Succession plans in place to address some, many or most (1-75%) of the most important gaps identified.	Assessment of 5-year skills needs for impacted employee areas beyond those significantly impacted. Succession plans in place to address almost all (76-95%) of the most important gaps identified, with some (1-25%) plans in the process of implementation.	Assess 5-year skills needs for almost all (76-95%) employee areas (operational and business areas). Succession plans in place to address all (96-100%) gaps identified, with many or most (26-75%) plans in the process of implementation.	Assessment of 5-year skills needs for all (96-100%) employee areas. Almost all (76-95%) gaps have been addressed and an action plan to address almost all (76-95%) gaps is being implemented.

VS Valley Standard VTL Valley Transformational Level

WORKFORCE ENABLEMENT

Potential Benefits

Workforce enablement enhances efficiency by improving processes, reducing operational risks and ensuring a safer, more productive work environment. By empowering employees with the skills and tools needed for modern grid operations, it boosts engagement, retention and overall service reliability. These improvements help the region keep pace with evolving customer demands while supporting local economic development and community growth.

Workforce enablement helps the industry keep pace with evolving energy demands and supports local economic development.

TVA Benefits

TVA Benefits	VS	VTL
Increased opportunities for implementation of new technologies	●○○○○	●●●●○
Increased economic development opportunities regionwide	●○○○○	●●●●○
Improved collaboration between TVA and LPC to implement technologies to benefit the regional grid	●○○○○	●●●●○

LPC Benefits

LPC Benefits	VS	VTL
Increased retention of workforce	●○○○○	●●○○○
Reduced risk of operational issues	●○○○○	●●○○○
Increased productivity	●○○○○	●●○○○
Reduced risk to implementation of strategic goals and operational plans	●○○○○	●●○○○
Improved worker safety	●○○○○	●●○○○

Customer Benefits

Customer Benefits	VS	VTL
Increased support of local economic development and community growth	●○○○○	●●●○○
Increased hiring and retention in LPC community	●○○○○	●●○○○
Increased prevention of utility services falling behind on customer demands	●○○○○	●●○○○

●●●●● Amount of potential benefits on a scale of 1-5

● Quantitative
● Semi-quantitative
● Qualitative

VS Valley Standard
VTL Valley Transformational Level

WORKFORCE ENABLEMENT

Implementation Considerations

People Who May Be Impacted

While all staff may be impacted by workforce enablement activities and processes, the following personnel will be instrumental in the planning and implementation of programs:

- Human resources
- Organizational planning
- Field operations
- Operations personnel
- Executive leadership

Processes That May Be Impacted

- Implementation of a skill gap and job role analysis, mentorship programs and leadership training ensure enhanced mobility for employees, both through promotions and lateral movement to departments that better fit their skills and career aspirations.
- After completing market analyses, adjust and improve employee benefits and compensation to align with the industry value, ensuring improved retention and satisfaction.
- At Level 3+, LPCs coordinate with external organizations to establish a pipeline of entry-level employees.
- At Level 4+, LPCs begin working collaboratively with local universities and organizations to provide career growth opportunities for employees and facilitate a pipeline of incoming skilled employees.

Challenges of Implementation

- Implementing employee development programs and initiatives requires ample research, evaluation and planning, which may cause strain on current employee workloads and competing priorities.
- Cultural resistance to change from leadership and staff may necessitate change management techniques and additional resources from external organizations or subject matter experts.
- When initiating external partnerships with industry organizations or educational institutions, external coordination may prove to be a challenge and processes may require redesign and additional buy-in.

Enabling | Planning and Assessing | Value Generating | Enhancing

- Cybersecurity
- Grid Situational Awareness
- Telecommunications
- Advanced Customer Metering
- Workforce Enablement
- **Data Management**
- Data Analysis and Analytics

Data Management

CATEGORY	STAGE
Grid Transformation Enabling	Enabling

DATA MANAGEMENT

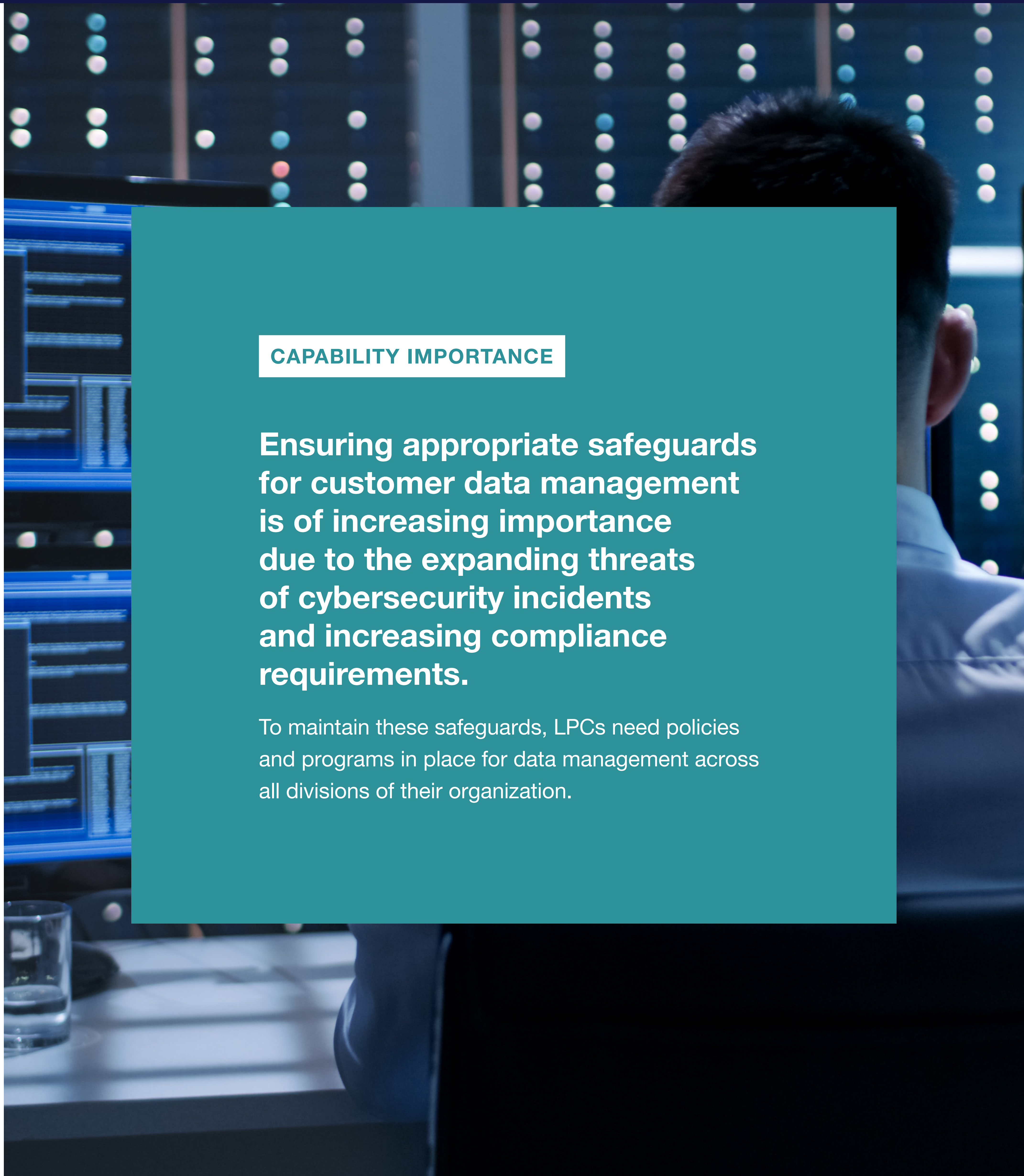
Overview

DEFINITION

The development, execution and supervision of plans, policies, programs and practices that deliver, control, protect and enhance the value of data and information assets throughout their lifecycles.[1]

SUPPORTING PROCESSES

- Data stewardship
- Data quality profiling, monitoring and analysis



CAPABILITY IMPORTANCE

Ensuring appropriate safeguards for customer data management is of increasing importance due to the expanding threats of cybersecurity incidents and increasing compliance requirements.

To maintain these safeguards, LPCs need policies and programs in place for data management across all divisions of their organization.

[1] Data Management Body of Knowledge, 2nd Edition (DMBOK). Data Management Association International (DAMA). Technics Publications, 2017.

DATA MANAGEMENT

Maturity Levels

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-2 Years	2-5 Years	Indefinite	Indefinite
Characteristics of Maturity Levels	**Initial**[1] Processes are unpredictable, poorly controlled and reactive.	**Managed**[1] Processes are characterized and is often reactive.	**Defined**[1] Processes are characterized for the organization and is proactive.	**Quantitatively Managed**[1] Processes are measured and controlled.	**Optimizing**[1] Focused on process improvement.
Data Governance	**DATA STRATEGY** There is no formal data strategy and little if any documentation on data management processes and procedures. **OVERSIGHT** Oversight of data management is ad-hoc and informal.	**DATA STRATEGY** Senior leadership has taken steps to establish a vision for data management and high-level plan for implementing capabilities over time. Some initial data management processes and tools have been formally established for one or more key business processes. **OVERSIGHT** A basic data governance structure is in place to oversee data management efforts and enforce standards and expected data behaviors.	**DATA STRATEGY** A Chief Data Officer or Director of Data Management is named; benefits realization for strategic data initiatives is tracked according to formal business cases per implementation plan. **OVERSIGHT** Data communities are formed along business functional / divisional areas to further mature oversight and derive additional business value from an added decentralized approach.	**DATA STRATEGY** Data strategy has become a board level focus for the organization (both opportunities and risks) and executive staff report on beneficial results of data strategy implementation (e.g., “return on data assets”) as well as risk planning & mitigation. **OVERSIGHT** A multi-level data governance operating model is in place, consisting of an executive data governance steering committee and functional data governance council, who oversee all data governance efforts and the daily operations of a data governance office.	**DATA STRATEGY** Data is measured as a financial asset and monetized as a core competency for competitive advantage. **OVERSIGHT** Data governance operations are an embedded aspect of all new & ongoing development (DevOps) and daily business functions.

1 The seven attributes that this maturity applies to are People, Process, Technology, Culture, Analytic Opportunities, Data and Analytic Techniques. Social Security Administration Analytics Center of Excellence, “Advanced Analytics Capability Maturity Model (A2CM2)”. February 6, 2020. https://www.ssa.gov/data/data_governance_board/ACE_A2CM2_for_DGB.pdf

VS Valley Standard VTL Valley Transformational Level

DATA MANAGEMENT

Maturity Levels (continued)

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-2 Years	2-5 Years	Indefinite	Indefinite
Data Governance (continued)	**DATA CULTURE** There is little to no shared awareness or recognition of how data management & usage behaviors relate to daily business functions.	**DATA CULTURE** Organizational culture begins to value and adopt data proficiency, with basic data governance policies, formal communications and individual behaviors (e.g., cross-functional collaboration, identifiable data stewardship, use of sharing agreements).	**DATA CULTURE** Basic data literacy (proficiency and vocabulary) is typical within the organization giving a commonly accepted identity as a data driven organization (e.g., scorecard on data governance KPI's such as data quality improvement, # of certified data sets documented with policies, % of data catalogued).	**DATA CULTURE** Organizational culture has undergone full digital transformation, where all business processes, daily activities and most formal communications are digitized & automated as part of workflow applications and other digital. platforms around core systems.	**DATA CULTURE** The culture has common understanding, acceptance and enthusiasm for the expectation that business decisions are supported by valid data insights. Data organization drives all enterprise data health. Culture is harmonized between centralized and decentralized data governance.
Lifecycle Management	**DATA STORAGE & OPERATIONS** Maintenance & support of core application databases is minimal and / or understaffed, supporting only basic business function. Data issues may be common, and system performance may be sometimes lacking. There are few if any data repositories dedicated for analytics purposes.	**DATA STORAGE & OPERATIONS** All core application databases are well maintained & supported according to documented service level agreements (SLAs) for system performance. There are also one or more databases dedicated for analytics purposes, also subject to SLAs for performance. Emphasis on developing and executing strategy for archiving and retention.	**DATA STORAGE & OPERATIONS** A variety of fit-for-purpose data storage technologies are developed and implemented to meet specific requirements of data analytics platforms & tools (e.g., data lake, data warehouse, in-memory storage, NoSQL databases) on-premises and / or in the cloud, all subject to documented SLAs for performance. Completed implementation of strategy for archiving and retention.	**DATA STORAGE & OPERATIONS** Specialized storage capabilities are implemented, configured, optimized and managed to accommodate specialized and / or compute-heavy workloads (e.g., image processing, natural language processing, geospatial computation, time series analysis, math optimization solvers, etc.) on-premises or in-cloud. This also incorporates use of data virtualization / logical data fabric. Full automation of retention & archiving strategy.	**DATA STORAGE & OPERATIONS** Data storage & operations capabilities represent best-in-class standards across managed data centers / cloud and are offered as a service to 3rd parties.

VS Valley Standard VTL Valley Transformational Level

DATA MANAGEMENT

Maturity Levels (continued)

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-2 Years	2-5 Years	Indefinite	Indefinite
Lifecycle Management (continued)	**DATA MODELS & ARCHITECTURE** There is limited understanding of the data models (logical data structures, a.k.a. "schemas") within core application databases. Enterprise level systems architecture is undocumented and poorly understood.	**DATA MODELS & ARCHITECTURE** The data models for core applications and dedicated analytics data repositories are documented, understood, maintained and supported by appropriate staff. Enterprise systems architecture is accurately documented at a high level to support strategic technology planning for key business processes & functions.	**DATA MODELS & ARCHITECTURE** Data models, systems architectures and integrations are developed and implemented in an ongoing fashion (e.g., DevOps / Agile) to accommodate specific requirements of data analytics efforts. Data modeling standards (such as conformed dimensions like business entities) are established, governed and enforced. Schemas are optimized for sharing and reuse for operational analytics. Enterprise architecture, integration and interoperability are continually evaluated for strategic business opportunities and risk mitigation, both in terms of core systems performance and innovative value from analytics.	**DATA MODELS & ARCHITECTURE** Data models and architectures are more easily evolved with changing business processes and operational needs by leveraging partial automation and AI-assisted data model mapping technologies. There is a well-defined master data & reference data process that determines how conformed dimensions are defined. Total enterprise value is enhanced and recognized as an asset as a result of "top quartile" data modeling & architecture competencies.	**DATA MODELS & ARCHITECTURE** Data models and architectures are best-in class standards, potentially licensable / monetizable for 3rd parties.
Foundational Activities	**DATA SECURITY & COMPLIANCE** Little or no user access credentialing or compliance controls are in place.	**DATA SECURITY & COMPLIANCE** Data user access is effectively administrated using an enterprise class identity access management platform. Data security and compliance policies are established, governed and enforced.	**DATA SECURITY & COMPLIANCE** Data asset attribution is enhanced such that there is better granularity of data control for only intended users under specified conditions (e.g., timeframe, device). Data security information enables improved confidence in external audit and compliance, reducing risk and further ensuring proper data use.	**DATA SECURITY & COMPLIANCE** Data user history / logs enable notification of security & compliance violations to improve enforcement and further reduce risk, while optimizing data & IT resources.	**DATA SECURITY & COMPLIANCE** Best-in-class data security & compliance programs.

VS Valley Standard VTL Valley Transformational Level

DATA MANAGEMENT

Maturity Levels (continued)

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-2 Years	2-5 Years	Indefinite	Indefinite
Foundational Activities (continued)	**DATA DEFINITIONS & METADATA** Business data definitions have been documented in few if any areas and are informally understood. **DATA QUALITY** Data quality is not recognized as an important capability to consider, and informal, if any data quality efforts have been identified.	**DATA DEFINITIONS & METADATA** Data dictionaries are in place for certain critical business processes, and under development in others, so users can access and understand the meaning of key data elements. Technology staff have documented metadata and metadata management procedures for core applications to support basic data governance operations. Named individuals begin to take ownership of data elements and associated quality. **DATA QUALITY** Investments have been made in training and launching data quality programs for one or more critical business processes. Named resources are responsible for driving future data quality efforts and education.	**DATA DEFINITIONS & METADATA** Data definitions & metadata Data catalog(s) are in place with detailed inventory of key data assets across the organization; metadata management policies, procedures and platforms are formalized and standardized across the enterprise; data stewards are named for priority business processes and take ownership of data definitions, guide data lifecycle improvements and serve as knowledge clearinghouse for data users. **DATA QUALITY** Data quality tools and / or platforms are in place, with named resources to profile and monitor data quality for all key business processes according to documented data quality rules and standards.	**DATA DEFINITIONS & METADATA** Data communities are established within priority business domains (e.g., distribution operations) to advise and operationalize data governance core team activities within their domains, driving additional value & operational excellence. **DATA QUALITY** Data quality processes are increasingly automated and leverage a continuous improvement model under a data quality manager role.	**DATA DEFINITIONS & METADATA** Excellence in data governance and management supports integration with external data exchanges for strategic purpose, e.g., economic development agencies, consumer groups or value-added customer product & service offerings (i.e., data monetization). **DATA QUALITY** Data stewardship and data quality adopt a distributed organizational structure with capabilities embedded in business departments while best practices are shared in an enterprise center of excellence (CoE).

VS Valley Standard VTL Valley Transformational Level

DATA MANAGEMENT

Potential Benefits

Effective data management is an expectation for all LPCs, and it improves data quality, completeness and accuracy for better planning and decision-making. By enhancing analytical productivity, data management increases the value of insights while strengthening regional resiliency and long-term economic growth. A well-managed data strategy supports improved system design, positioning LPCs for smarter investments and more efficient operations.

Effective data management supports improved system design, enabling smarter investments and more efficient operations.

TVA Benefits

TVA Benefits	VS	VTL
Reduced risk of data breach	●○○○○ (semi-quantitative)	●●○○○ (semi-quantitative)
Reduced risk of data loss	●○○○○ (semi-quantitative)	●●○○○ (semi-quantitative)
Reduced risk of unauthorized use of data	●○○○○ (semi-quantitative)	●●○○○ (semi-quantitative)
Improved informed planning and decision making	●○○○○ (qualitative)	●●●●● (qualitative)

LPC Benefits

LPC Benefits	VS	VTL
Reduced risk of unauthorized use of data	●○○○○ (semi-quantitative)	●●○○○ (semi-quantitative)
Increased analytical productivity	●○○○○ (semi-quantitative)	●●○○○ (semi-quantitative)
Improved data quality and use	●○○○○ (qualitative)	●●●●● (qualitative)

Customer Benefits

Customer Benefits	VS	VTL
Improved reliability	●○○○○ (quantitative)	●●○○○ (quantitative)
Deferred rate increases	●○○○○ (semi-quantitative)	●●○○○ (semi-quantitative)
Increased attraction of new commercial and industrial customers	●○○○○ (qualitative)	●●●●● (qualitative)

●●●●● Amount of potential benefits on a scale of 1-5

- Quantitative
- Semi-quantitative
- Qualitative

VS Valley Standard

VTL Valley Transformational Level

DATA MANAGEMENT

Implementation Considerations

People Who May Be Impacted

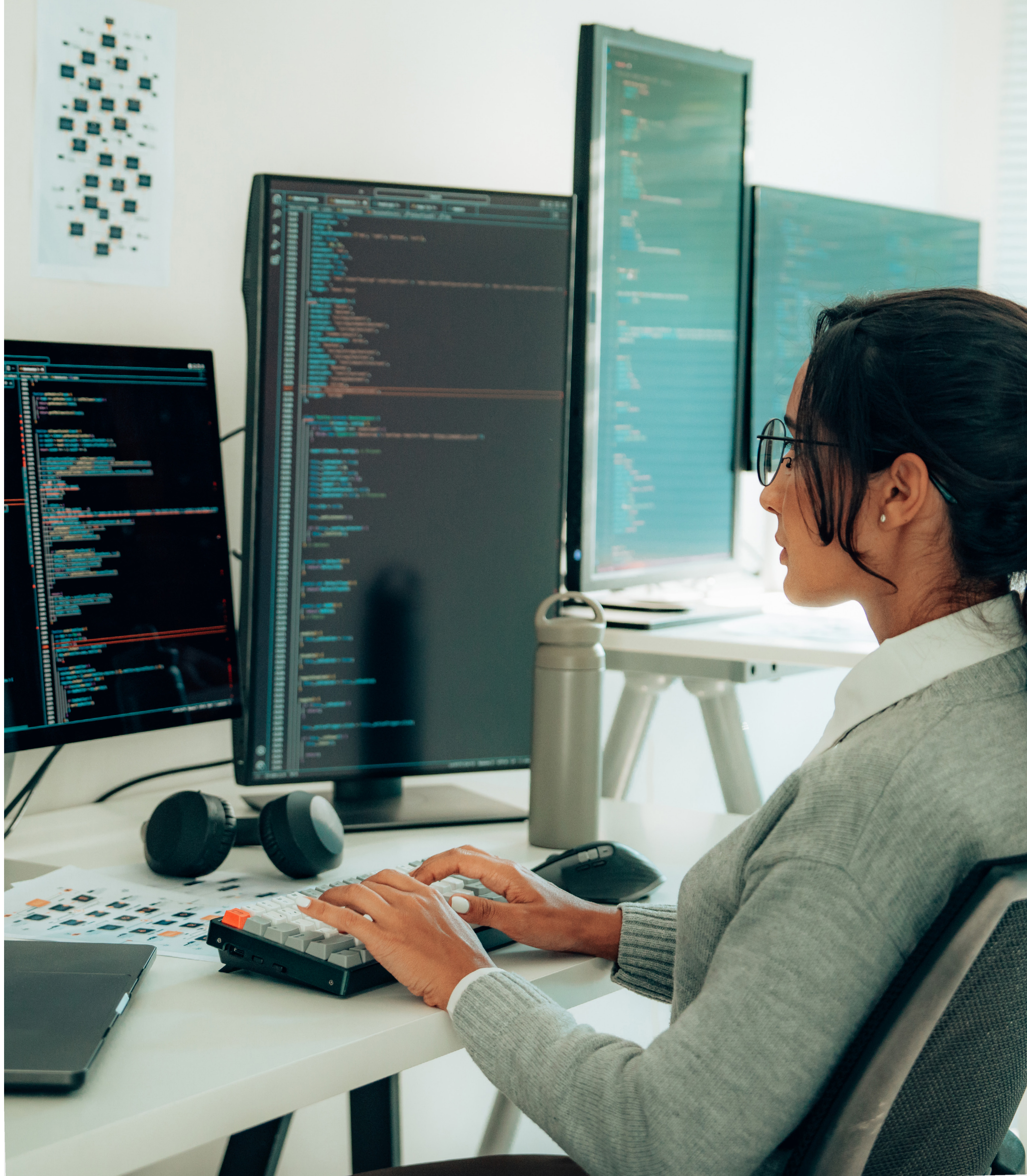
- Business domain experts (likely to become data stewards)
- IT/OT data source support staff (database developers)
- CIO (strategic)
- Business strategy
- Director software applications
- Enterprise architect
- Distribution system operations
- External parties (e.g., cloud/SaaS/consultants)
- Finance division
- Risk management team
- External affairs

Processes That May Be Impacted

- Management report generation processes for operations and planning can lead to more informed planning and decision-making.
- IT application support processes for metadata gathering standardize data access, use and quality.
- Software development and integration processes for data use and process transparency increase analytical productivity and value of insights and decisions.
- Application support processes for data governance and data quality improvement processes and tasks enhance system modeling and planning capabilities.
- Distribution system operations processes are impacted by increased data management capabilities, enhanced control and quality of critical operations data.
- Financial processes see improved quality, use and benefits of data assets, enabling quantifiable revenue and cost tracking for reporting.
- Risk management processes can better identify potential areas of risk through implementation of data security and compliance measures.
- Sales and economic development processes are prepared to support integration of external data exchanges for strategic purposes.
- External affairs processes are better equipped with a common set of data across the enterprise to offer to external stakeholders.

Potential Challenges of Implementation

- Identification and availability of data governance leads and/or potential data stewards if there is a lack of qualified personnel to oversee and manage data management efforts.
- Competing demands on required IT staff resources may arise when there are other critical IT initiatives, such as cybersecurity or ongoing maintenance tasks.
- Identification and budget for business lead or manager who can make informed and strategic decisions for analysis and analytics investments.
- Ability to obtain, implement and train on new analytics capabilities or platforms my be hindered if staff lack the specialized knowledge to select, integrate and effectively use those platforms.
- Lack of resources to fund and participate in more advanced data capability developments that integrate into real-time operational processes.
- Executive education, buy-in and sponsorship of data valuation/ monetization concepts.
- Financial staff will require education on implemented data governance and compliance requirements when utilizing data leveraged in LPC financial systems.
- Adoption of methodologies to value data as assets/risk drivers.



Enabling | Planning and Assessing | Value Generating | Enhancing

- Cybersecurity
- Grid Situational Awareness
- Telecommunications
- Advanced Customer Metering
- Workforce Enablement
- Data Management
- **Data Analysis and Analytics**

Data Analysis and Analytics

CATEGORY	STAGE
Grid Transformation Enabling	Enabling

DATA ANALYSIS AND ANALYTICS

Overview

DEFINITION

The ability to acquire the data necessary to support decisions, the skills to leverage data analytics tools and the expertise to generate actionable insights based on analytics to improve business performance in a measurable and demonstrable way.

SUPPORTING TECHNOLOGIES AND PROCESSES

- More advanced spreadsheet toolkits and/or add-ins
- Business intelligence dashboards with improved value and efficiency insigths
- Reports are generated by a core analysis team for targeted business user groups

CAPABILITY IMPORTANCE

To improve utility operational efficiency and customer satisfaction from additional data availability, it is essential LPCs have the appropriate skills and tools to analyze the data.

By prioritizing acquiring and expanding data analysis capabilities, LPCs can improve a multitude of grid operational functions that reduce costs and staff requirements.

DATA ANALYSIS AND ANALYTICS

Maturity Levels

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-3 Years	3-5 Years	2+ Years	1-3 Years
Data Collection and Application	**DATA** Data is manually acquired and processed using informal and undocumented methods. **METHODS** Analyses are ad hoc, generated manually and typically report historical information or basic forward-looking trends. **INSIGHTS** Insights are descriptive, i.e., relating past information and trends for learning and improvement.	**DATA** Data is acquired using manual or scripted methods. Includes development of repeatable query logic and established data refresh methods. **METHODS** Analyses are structured and include business intelligence dashboards refreshed on standard intervals as appropriate to the task objective (e.g., daily, monthly or as requested). **INSIGHTS** Insights are characterized as descriptive and "recent" (e.g., daily, monthly or as requested) information based on data refresh cycles.	**DATA** Data is acquired and processed for specific use cases and automated "data pipelines"[1]. **METHODS** Analyses use deployable analytics for users and "data store"[2] developers. **INSIGHTS** Insight maturity is diagnostic, offering possible or highly certain explanations or evidence of business performance.	**DATA** Automated data access tools, platforms and callable services allow data pipelines to be developed on premise, in the cloud, or across both. **METHODS** Analyses use commonly accepted data science methods, techniques and patterns such as machine learning and predictive modeling. **INSIGHTS** Insight maturity is predictive and / or prescriptive and uses available data to offer future outcomes and/or recommendations for business performance.	**DATA** Data acquisition and analytics development lifecycles and workflows are automatable and modularized. **METHODS** Analyses use generative AI methods. **INSIGHTS** Insight maturity involves use of available data, predictions and recommendations to automate future courses of action to manage and improve business performance.

1 Data pipelines refer to the method in which data is ingested from various data sources, transformed and then ported to a data store.

2 Data store refers to a repository for storage, management and distribution for collections of data (e.g., a data warehouse or data lake).

VS Valley Standard VTL Valley Transformational Level

DATA ANALYSIS AND ANALYTICS

Potential Benefits

Data analysis and analytics enable enhanced reporting, optimize power flow economics and improve revenue by providing deeper insights for smarter decision-making. Advanced analytics streamline grid management and planning, offering greater certainty around future demand and customer behavior. By enabling faster, data-driven decisions, LPCs can improve efficiency, see operational gains, defer rate increases and enhance overall service reliability.

Data analysis and analytics enhance grid management and planning, enabling faster, data-driven decisions.

TVA Benefits

TVA Benefits	VS	VTL
Improved LPC reporting and analysis	1 (Quantitative)	2 (Quantitative)
Improved power flow economics and revenue	0	1 (Quantitative)
Improved customer satisfaction	1 (Semi-quantitative)	2 (Semi-quantitative)
Greater insights and decision making	1 (Qualitative)	1–5 (Qualitative)

LPC Benefits

LPC Benefits	VS	VTL
Improved grid management	1 (Semi-quantitative)	2 (Semi-quantitative)
Reduced uncertainty around range of future grid conditions	1 (Semi-quantitative)	2 (Semi-quantitative)
Reduced decision making time	1 (Semi-quantitative)	2 (Semi-quantitative)
Improved customer satisfaction	1 (Semi-quantitative)	2 (Semi-quantitative)
Increased insights into current and expanded customer behavior and demand	1 (Qualitative)	1–5 (Qualitative)

Customer Benefits

Customer Benefits	VS	VTL
Deferred rate increases	1 (Semi-quantitative)	2 (Semi-quantitative)
Improved customer satisfaction	1 (Semi-quantitative)	2 (Semi-quantitative)
Increased attraction of new commercial and industrial customers	1 (Qualitative)	1–5 (Qualitative)

Amount of potential benefits on a scale of 1-5

- Quantitative
- Semi-quantitative
- Qualitative

VS Valley Standard

VTL Valley Transformational Level

Implementation Considerations

People Who May Be Impacted

- Business analysis staff
- Business domain experts
- IT/OT data source support staff (database developers)
- Cybersecurity/information security
- CIO
- Business domain directors/managers
- Director of software applications
- Enterprise architects
- Executive leadership
- Distribution system operations
- Analytics project teams
- Finance
- Risk management
- Board of directors
- External affairs
- Community stakeholders

Challenges of Implementation

- There may be a shortage of skilled personnel who can effectively handle the increased demand and focus on data analysis and analytics.
- Competing demands on required IT staff resources may arise when there are other critical IT initiatives, such as cybersecurity or ongoing maintenance tasks.
- Identification and provisioning for a leader or manager to make analysis and analytics investment decisions may arise when there is a lack of clear ownership for the strategic direction and justification of investments.
- Ability to obtain, implement and train on new analytics capabilities or platforms my be hindered if staff lack the specialized knowledge to even select, integrate and effectively use those platforms.
- Availability of OT resources and funding for advanced analytics tools and resources that integrate into real-time operational processes.
- Executive education, buy-in and sponsorship of data valuation/monetization concepts.
- Education and involvement of external-facing leadership and staff.

Processes That May Be Impacted

- Operations and planning reports can be provided to targeted business groups to make informed decisions based on anlaytic insights.
- Improved IT application support processes for data extract, transform load (ETL) and query management allow for user-defined, interactive management reporting dashboards.
- Software/applications budgeting, licensing, request, installation, admin and support should be factored into capability implementation strategy.
- Query development and management can support more advanced spreadsheet toolkits, add-ins, dashboard platforms and data science workbench products.
- Technology training and education processes will allow for gathering and preparing data, performing advanced analysis and providing insights into more granular load forecasts, grid events and customer behavior analysis.
- Software development, along with application support and integration, is needed to define and support analytics data requirements, advise on business processes and support solution development.
- IT/business planning and budgeting for technology platform investments will shift to acquiring and integrating advanced data tools and analytics solutions.
- Enterprise architecture planning will require the integration of advanced data systems, analytics tools and infrastructure into the overall IT architecture.
- Technology strategy and innovation will focus on adoption of advanced technologies and platforms that enable robust data analysis. This focus requires a more agile and forward-thinking approach to innovation, ensuring emerging technologies are evaluated for their ability to enhance data-driven decision-making.
- Project management/PMO will have a greater emphasis on data-driven project execution.
- Distribution system operations processes will incorporate proactive maintenance and optimization of asset management to ensure more reliable operations.
- Outage management will be enhanced through the use of analytics to predict potential failures of equipment and optimize maintenance resources for faster restoration.
- Data analytics to support key utility processes, including operation technology, metering, financial planning, risk management, sales and customer relations and external data exchange.

System Modeling

CATEGORY	STAGE
Integrated Planning	Planning and Assessing

SYSTEM MODELING

Overview

DEFINITION

Modeling of an LPC's power network that considers how much electricity is used, the impact of renewable energy sources and how different parts of the network behave, such as high- and low-voltage areas.

SUPPORTING TECHNOLOGIES

- Static Power Flow Modeling Tools (e.g. CYME, Synergi, PSSE, Milsoft)
- AutoCAD

CAPABILITY IMPORTANCE

Detailed and accurate digital representations of their distribution system help LPCs anticipate future needs, plan upgrades and ensure the reliability and efficiency of their network.

System modeling is instrumental for managing the power network efficiently and deciding where to invest money for improvements. It can support activities such as acquiring equipment and land and enables LPCs to efficiently allocate capital and maintain high-quality and reliable service for their customers.

SYSTEM MODELING

Maturity Levels

	Level 1	Level 2 VS	Level 3	Level 4 VTL	Level 5
Est. Time at Level	N/A	1-2 Years	1-2 Years	1-2 Years	1-2 Years
Processes and Programs	Limited and infrequent system models using available historical data.	System is modeled based upon extension of historical load data using static power flow tools. Modeling dependency upon load actuals from historical (SCADA + metering). **PENETRATION LEVEL:** Most (51-75%) of the Medium Voltage (MV) system model is reviewed annually based on current state and historical data to confirm foundational assumptions and inputs are still valid.	Power flow of the system is statically modeled using standard processes and tools. The system model leverages a 3-year view of future load and DER forecast developed using linear regression from historical data. **PENETRATION LEVEL:** Almost all (76-95%) MV system models including load and DER reviewed annually using standard tools	System is modeled using static power flow and transient stability analysis. The system model leverages a 5-year view of future load and DER forecast developed using predictive methods from periodic data. **PENETRATION LEVEL:** Almost all (76-95%) MV and LV systems are modeled based on the current state and analytical models and are updated after modifications to the grid occur.	System is modeled and optimized using innovative load flow tools. The system model leverages a 10-year view of future load and DER forecast developed using an analytical model from recent data. **PENETRATION LEVEL:** All (96-100%) load, DER and systems are modeled and optimized using agile and innovative tools and current data.
Implementation Considerations	No formal assessment process or structure in place.	Level 2 applies if LPC's objectives are limited to meeting traditional planning needs (aging infrastructure, minimal load growth and standard planning guidelines).	Pursuit of levels 3-5 is recommended if the LPC's goal is to modernize its grid to meet higher levels of load growth and new customer demands (e.g., incorporating DERs, EVs) or other strategic priorities.		

Medium Voltage: refers to voltages between 1kV to 35 kV according to the International Electrotechnical Commission.

VS Valley Standard VTL Valley Transformational Level

SYSTEM MODELING

Potential Benefits

System modeling enhances resource planning by providing deeper insights on power quality, reliability and operational efficiency. It supports economic growth by accommodating higher load demands and enabling new opportunities for local development. With more informed decision-making, LPCs can optimize grid performance and rate design, better meeting customer needs while maintaining a more reliable and resilient grid.

System modeling enhances resource planning and informed decision-making, helping optimize grid performance and rate design.

TVA Benefits

TVA Benefits	VS	VTL
Reduced generation reserve requirement	●○○○○ (quantitative)	●●●●○ (quantitative)
Reduced overall cost of providing capacity from the transmission system	●○○○○ (quantitative)	●●○○○ (quantitative)
More effective and comprehensive resource planning	●○○○○ (qualitative)	●●●●● (qualitative, graded shading)

LPC Benefits

LPC Benefits	VS	VTL
Lower capital and operational costs	●○○○○ (quantitative)	●●○○○ (quantitative)
Improved grid utilization	●○○○○ (semi-quantitative)	●●○○○ (semi-quantitative)
Increased operational efficiency	●○○○○ (semi-quantitative)	●●○○○ (semi-quantitative)
More informed decision making	●○○○○ (qualitative)	●●●●● (qualitative, graded shading)

Customer Benefits

Customer Benefits	VS	VTL
Improved power quality	●○○○○ (semi-quantitative)	●●○○○ (semi-quantitative)
Improved rate design	●○○○○ (qualitative)	●●●●● (qualitative, graded shading)
Increased economic development opportunities	●○○○○ (qualitative)	●●●●● (qualitative, graded shading)
Increased community employment opportunities	●○○○○ (qualitative)	●●●●● (qualitative, graded shading)
Improved ability to perform non-wires analysis and incorporate DER into grid	●○○○○ (qualitative)	●●●●● (qualitative, graded shading)

●●●●● Amount of potential benefits on a scale of 1-5

● Quantitative
● Semi-quantitative
● Qualitative

VS Valley Standard
VTL Valley Transformational Level

SYSTEM MODELING

Implementation Considerations

People Who May Be Impacted

- Operations center personnel, including system operators
- IT personnel
- Organizational planners

Processes That May Be Impacted

- System operations benefit from a greater ability to adapt to extreme weather events and a better understanding of strategic options for resource deployment.
- Data transfer planning will need to be facilitated across internal departments.
- Planning can be enhanced by developing a system modeling data transfer plan across internal departments, enabling more effective DER, transmission and system planning, with the introduction of grid model management (GMM) coordination at Level 5.
- Customer service is streamlined through more effective resource and load planning, delivering more consistent service and power quality.
- Establish protocols/procedures for aggregated data exchange across the T&D interface

Challenges of Implementation

- Additional training for staff on modeling tools and technologies requires additional financial resources. This is especially true for the skills required for transient stability analysis, a component of the VTL.
- There will need to be increased communication and integration with the IT department.
- Data quality needs are expensive, which may be difficult for some LPCs to manage.
- The grid model management (GMM) coordination and upkeep can be challenging for smaller LPCs that have outsourced system model development and lack the skills to provide continued monitoring and maintenance.
- Internal coordination across different utilities that may exist for a municipality or cooperative (water, gas, electric, waste) may prove challenging. One solution may not work for all utilities, and alternative approaches may prove necessary.

Enabling | Planning and Assessing | Value Generating | Enhancing

System Modeling

DER Interconnection

Load and DER Forecasting (Planning)

DER Interconnection

CATEGORY	STAGE
Regional Guidelines	Planning and Assessing

DER INTERCONNECTION

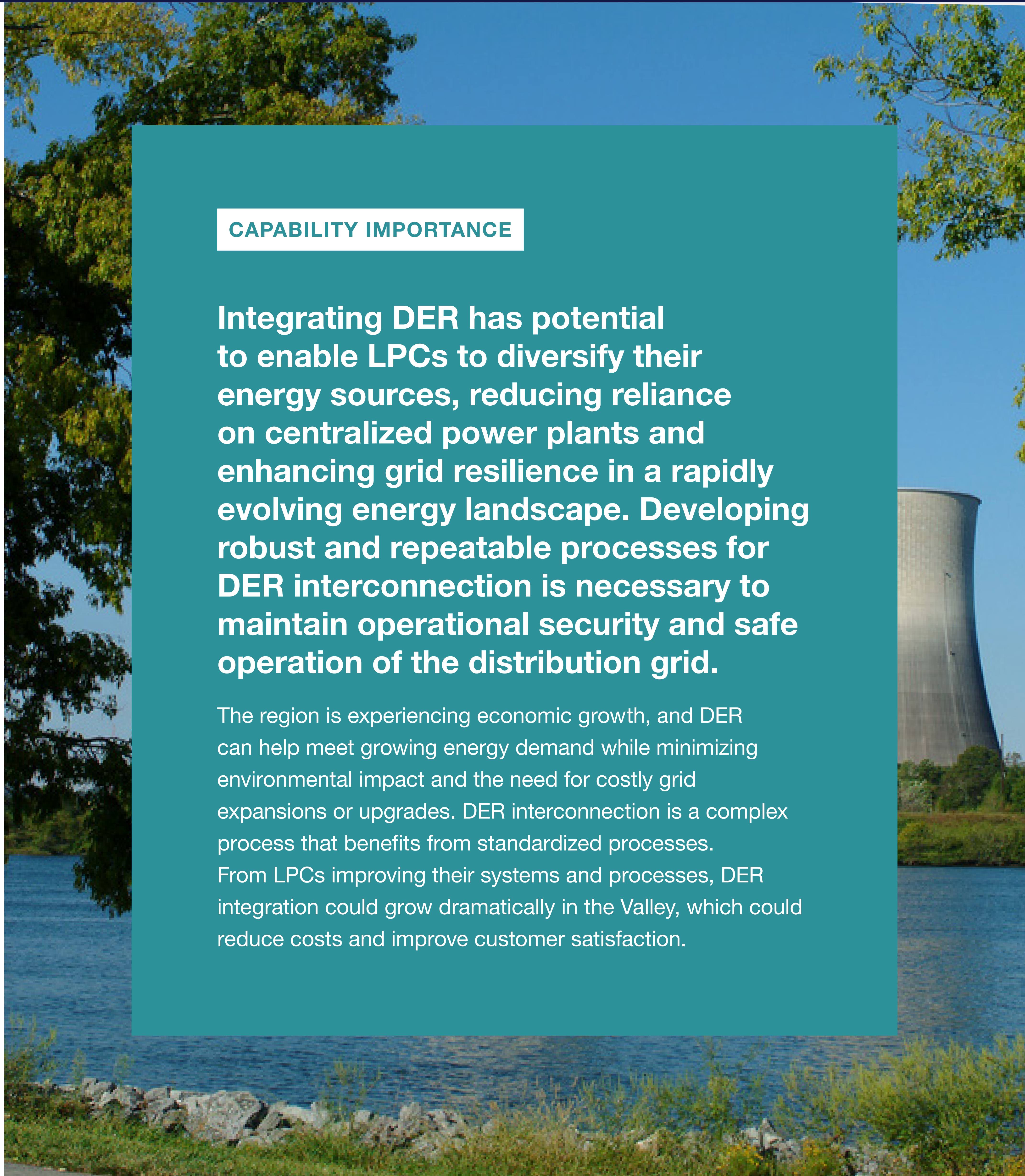
Overview

DEFINITION

The processes, requirements, standards and technical reviews that allow safe and efficient connection of distributed energy resources (DER) to the distribution grid, helping establish and increase hosting capacity for DER while ensuring operational security.

SUPPORTING TECHNOLOGIES

- Internal hosting capacity assessment
- Interconnection request tracking tool (online platform for tracking of Interconnection studies) updated for battery energy storage systems, network grid connections, power quality meters and reclosers.



CAPABILITY IMPORTANCE

Integrating DER has potential to enable LPCs to diversify their energy sources, reducing reliance on centralized power plants and enhancing grid resilience in a rapidly evolving energy landscape. Developing robust and repeatable processes for DER interconnection is necessary to maintain operational security and safe operation of the distribution grid.

The region is experiencing economic growth, and DER can help meet growing energy demand while minimizing environmental impact and the need for costly grid expansions or upgrades. DER interconnection is a complex process that benefits from standardized processes. From LPCs improving their systems and processes, DER integration could grow dramatically in the Valley, which could reduce costs and improve customer satisfaction.

DER INTERCONNECTION

The RGT DER Interconnection Standards Project

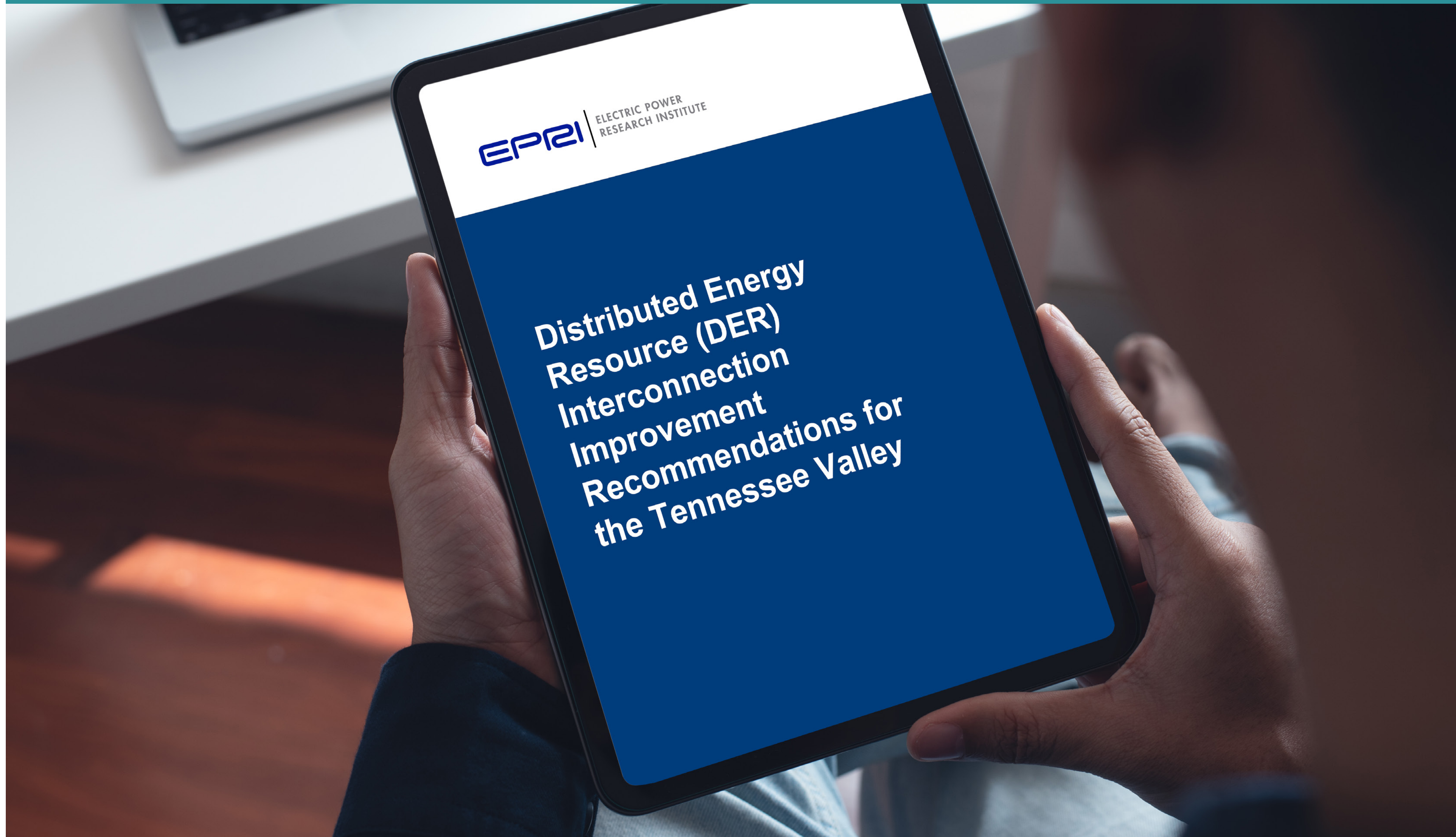
Defined and documented interconnection administrative and technical review processes are critical to integrating DER on LPC distribution systems. A systematic DER interconnection process with study- and size-specific guidance provides greater consistency and transparency based on industry-leading practices.

In the RGT DER Interconnection Pilot, TVA and 10 partnering LPCs aligned interconnection processes and standards to ensure regional progress across the holistic system. For more information on comprehensive maturity in the DER Interconnection capability, refer to the recommendations found in the RGT *DER Interconnection Standards* project report.

The maturity benchmarks and standards in the DER Interconnection pilot project are highlighted in the VS and VTL on the following page.

Explore the *DER Interconnection Standards* project report for more detailed information on standards.

Defined common standards across the Valley for DER Interconnection provide a foundation for a sustainable future and seamless integration of DERs, providing operational security, grid resilience and interoperability.



DER INTERCONNECTION

Maturity Levels

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	3 Years	1-3 Years	1-3 Years	1-3 Years
Integrating DER	Basic DER interconnection approach for processing/technical review; done on an as-needed, ad hoc basis.	Defined and documented manual interconnection admin and technical review processes for DERs on the distribution system. *IEEE 1547-2018 Adoption and Implementation (incremental)* per TVA/LPC DER Interconnection Study recommendations. Refer to L2 recommendations from *RGT DER Interconnection Standards* project.[1] **TRIGGERING NEED[2]:** Initial applications (>250* kW and <5 MW) for DER interconnection have been received.	Systematic DER interconnection process with study- and size-specific guidance, greater transparency based on industry-leading practices. Refer to L3 recommendations from *RGT DER Interconnection Standards* project.[1] **TRIGGERING NEED[2]:** Recommended for systems encountering >50 apps/year and/or if circuits have >1% DER penetration.	Self-service data-driven DER interconnection process and approvals, with emerging automation. Refer to L4 recommendations from *RGT DER Interconnection Standards* project.[1] **TRIGGERING NEED[2]:** When and where there is sufficient LPC interest in increasing process efficiencies, improving customer satisfaction and optimizing interconnection queue management.	Largely automated and targeted DER interconnection process with granular interconnection support. Refer to L5 recommendations from *RGT DER Interconnection Standards* project.[1] **TRIGGERING NEED[2]:** When and where there is sufficient LPC interest in further increasing process efficiencies, improving customer satisfaction and optimizing interconnection queue management (e.g., trigger could be an increasing number and volume of interconnection requests or the need to reduce staff time.

1 For additional information, refer to the RGT DER Interconnection Standards Project Report

2 **Triggering Need** refers to the level of DER interconnection requests or level of interest in improving processes that would trigger the need to move to the next capability level of DER Interconnection.

VS Valley Standard VTL Valley Transformational Level

DER INTERCONNECTION

Potential Benefits

Streamlining DER interconnection improves efficiency by simplifying application processing, enhancing grid planning, enabling load sharing and better energy utilization. By improving DER interconnection processes, LPC can facilitate increasing the number of DER interconnections and the amount of DER on their distribution system. Also, LPCs can reduce complaints, improve responsiveness and more efficiently interconnect new DER.

Streamlining DER interconnection can increase DER in the Valley and reduce the need for expensive capital improvement projects to address growth

TVA Benefits

TVA Benefits	VS	VTL
More streamlined evaluation and processing of interconnection applications	●○○○○	●●○○○
Increased grid planning, load sharing and energy utilization benefits	●○○○○	●●○○○
Enhanced efficiency of data gathering efforts	●○○○○	●●○○○
Improved customer satisfaction	●○○○○	●●○○○

LPC Benefits

LPC Benefits	VS	VTL
Decreased behind-the-meter solar integration costs	●○○○○	●●●●○
Decreased front-of-the-meter solar integration costs	●○○○○	●●●○○
Improved customer satisfaction	●○○○○	●●○○○
Increased preparedness for interconnection applications	●○○○○	●●●●●

Customer Benefits

Customer Benefits	VS	VTL
Improved customer satisfaction	●○○○○	●●○○○
Increased economic development	●○○○○	●●○○○
Greater consistency and transparency of interconnection process and requirements	●○○○○	●●●●●

●●●●● Amount of potential benefits on a scale of 1-5

● Quantitative
● Semi-quantitative
● Qualitative

VS Valley Standard
VTL Valley Transformational Level

DER INTERCONNECTION

Implementation Considerations

People Who May Be Impacted

- Planning departments, including engineering, management and directors
- Field operations personnel, including planning and technical crews
- Operations department, including operators and supervisors
- Executive leadership of operations and planning

Processes That May Be Impacted

Please see the DER Interconnection Standards Project Report for more detailed requirements.

- Interconnection processes, including the interconnection application, standard written documents, interconnection training, and field support for interconnection (see DER study requirements[1]).
- Update and streamline documentation and data collection, including field/customer research and data on DER management, maintenance and performance.
- Determine preferred utility settings from adoption of IEEE Std. 1547-2018

DISTRIBUTION, TRANSMISSION, AND STAKEHOLDER COORDINATION

- Communicate/coordinate with the multiple Authorities Governing Interconnection Requirements (AGIRs) in the Valley about lead times for for making necessary updates to templates, including the need for a stakeholder process
- Initiate a stakeholder process to determine interconnection and interoperability capability and, if needed, the preferred functional settings in advance of, or in conjunction with, adopting IEEE standard 1547-2018

Potential Challenges of Implementation

- The integrated nature of DER interconnection requires external expertise, which may create resistance and potential delays in progress.
- Staffing resources or lack of staff experience and knowledge in this capability will require additional training, communications and capital to support individuals and departments.
- This capability will require process redesign and change management to ensure alignment and adoption, including some back-office integration (e.g., GIS) at maturity Level 4 and more extensive integration (e.g., DERMS) at Level 5.

[1] For additional information, refer to the RGT DER Interconnection Standards Project Report

System Modeling

DER Interconnection

Load and DER Forecasting (Planning)

Load and DER Forecasting (Planning)

CATEGORY	STAGE
Integrated Planning	Planning and Assessing

LOAD AND DER FORECASTING (PLANNING)

Overview

DEFINITION

Predicts load and load offset due to models of customer behavior, predicted load growth, modeled distributed energy resources (DER) adoption, future weather and other forward-looking factors to produce spatially and temporally granular load forecasts[1] that account for scenarios and sensitivities.

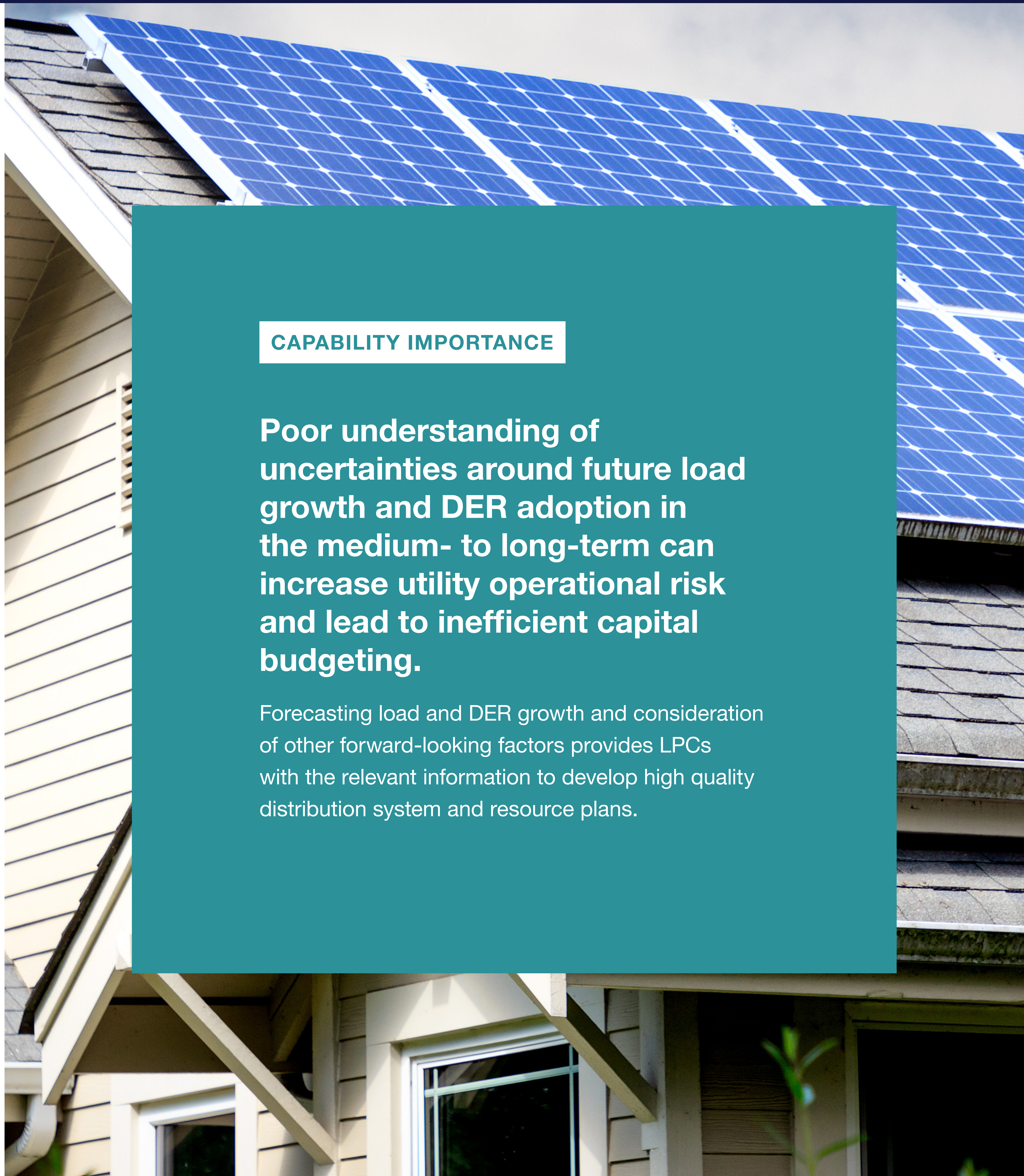
These forecasts support development of a future Distribution Resource Plan (DRP) and Distribution System Plan (DSP)[2]. Planning forecast includes the following forecast horizons: (a) medium-term (1 month to 1 year) and (b) long-term (1 to 20 years).

SUPPORTING TECHNOLOGIES

- Spreadsheet with more advanced tools (e.g., use of pivot tables)
- Load data input from OT systems and mostly manual tracking

1 Forecasts developed may include negative, zero, or positive growth.

2 The development of the DRP and DSP support the creation of the Integrated System Plan (ISP) as identified in the Valley Vision initiative.



CAPABILITY IMPORTANCE

Poor understanding of uncertainties around future load growth and DER adoption in the medium- to long-term can increase utility operational risk and lead to inefficient capital budgeting.

Forecasting load and DER growth and consideration of other forward-looking factors provides LPCs with the relevant information to develop high quality distribution system and resource plans.

LOAD AND DER FORECASTING (PLANNING)

Maturity Levels

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	**N/A**	**1-2 Years**	**1-2 Years**	**1-3 Years**	**1-3 Years**
Load Forecasting Methods	Load forecasting methods use estimated seasonal extremes (peak and valley) for the entire system.	Load forecasting methods use trend analysis for system-level forecasting methods.	Load forecasting methods that calculate both an average value and a range of possible outcomes based on a probability distribution of peak load events (e.g., 1-in-5, 1-in-10, 1-in-20)[1]. The system level forecasts are validated by at least one sub-component forecast (e.g., substation or geographic area).	Load forecasting methods reconcile disaggregated load component forecasts with substation level forecasts to improve forecast results.	Load forecasting methods use statistical forecast and machine learning methods to complement trend analysis. The methods are also complemented by all available forecasting techniques to maximize the accuracy of the forecasts. Forecasting methods using actual end point load data.
Load Forecasting Scenario Analysis	None.	Load forecasting scenario analysis done by adjusting key load forecast factors (e.g., new service account trend, weather factors, etc.).	Load forecasting scenario analysis includes key load forecast factors plus the impact of long-run climate trends.	Load forecasting scenario analysis includes the impact of longrun climate trends and identified tipping point factors (e.g., level of penetration of variable energy resources and/or DERs).	Load forecasting scenario analysis includes the impact of long-run climate trends and identified tipping point factors and other non-technical factors (e.g., behavioral factors).
Spatial and Temporal Granularity of Load Forecast Application	Load forecast only applied to develop annual system-level outputs.	Load forecast applied to develop monthly system-level outputs.	Load forecast applied to substation-level 8760 hourly models as needed.	Load forecast applied to circuit-level 8760 hourly models as needed.	Load forecast applied to sub-hourly circuit-level models for medium term; 8760 hourly circuit-level models for long term; yearly/seasonal/monthly extremes (peak and valley) for 20 years.

[1] 1-in-5, 1-in-10 and 1-in-20, refer to peak demand under conditions that have a 20, 10, and 5 percent chance of being met or exceeded, respectively.

VS Valley Standard VTL Valley Transformational Level

LOAD AND DER FORECASTING (PLANNING)

Maturity Levels (Continued)

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	**N/A**	**1-2 Years**	**1-2 Years**	**1-3 Years**	**1-3 Years**
Load Forecasting Timeframe	Seasonal, updated at least annually.	Medium-term (1 month-1 year), updated at least seasonally and long-term (1-10 years), updated at least annually.	Medium-term (1 month-1 year), updated at least monthly and long-term (1-10 years), updated at least annually.	Load Forecasting Timeframe is maintained at Level 3.	Load Forecasting Timeframe is maintained at Level 3.
DER Forecasting	Includes none or minimal load offsets from DERs.	Identifies circuits with potential DER load offsets.	DER Forecasting includes load offsets from DERs.	Includes load offsets from DERs (other types of DERs included – solar PV, EVs). Weather impacts simulated.	Includes load offsets from DERs (other types of DERs included – solar PV, EVs). Sensitivity to weather and behavioral impacts considered.
Coordination with TVA[1]	Done in ad hoc manner related to delivery points.	Formalized around key inputs (including economic and demographic variables, the electricity rate forecast and other input assumptions) and outputs including distribution area coincident peak demand and energy use.	At Level 2 and above completed on an annual basis to reflect updated peak conditions during either summer or winter.	Maintained at Level 3.	Maintained at Level 3.

1 Coordination elements such as development of specific templates to be determined between TVA Planning and LPC Planning collaboration.

VS Valley Standard VTL Valley Transformational Level

LOAD AND DER FORECASTING (PLANNING)

Potential Benefits

Planning for load and DER forecasting improves capital decision-making by providing more accurate future scenarios and granular load forecasts, which can help optimize investments and reduce costs. By enhancing forecasting accuracy, stakeholders can better plan for DER integration, improve operational efficiency and potentially defer larger investments.

Load and DER forecasting to support planning improves capital decision-making and operational efficiency.

TVA Benefits

TVA Benefits	VS	VTL
Reduced uncertainty in future scenarios	1 (Semi-quantitative)	2 (Semi-quantitative)
More optimized and targeted capital decisions	1 (Semi-quantitative)	2 (Semi-quantitative)
Increased potential to defer transmission and generation capital investments	1 (Qualitative)	4 (Qualitative)

LPC Benefits

LPC Benefits	VS	VTL
Increased capital and operations planning	1 (Semi-quantitative)	2 (Semi-quantitative)
Improved load forecast accuracy	1 (Semi-quantitative)	2 (Semi-quantitative)
Increased load forecast granularity	1 (Semi-quantitative)	2 (Semi-quantitative)
Increased potential for reduced costs	1 (Qualitative)	4 (Qualitative)

Customer Benefits

Customer Benefits	VS	VTL
Reduced customer rates	1 (Quantitative)	3 (Quantitative)
Increased accuracy of plans for accommodating DER	1 (Semi-quantitative)	2 (Semi-quantitative)
Increased opportunities for economic development	1 (Qualitative)	4 (Qualitative)

Amount of potential benefits on a scale of 1-5

Quantitative
Semi-quantitative
Qualitative

VS Valley Standard
VTL Valley Transformational Level

LOAD AND DER FORECASTING (PLANNING)

Implementation Considerations

People Who May Be Impacted

- Distribution system planning
- Engineering

Processes That May Be Impacted

- Distribution system planning processes will be improved with more robust current and forecast system load information, enabling more effective capital decisions and plans for accommodating DER.
- Engineering design processes will be impacted by the need to account for more complex and dynamic system scenarios resulting from changes in load, DER and system forecasts.

Potential Challenges of Implementation

- Data acquisition may be difficult due to the complexity and scale of data generated, requiring robust data systems and infrastructure.
- Load and DER forecasting capabilities require advanced modeling knowledge and tools which utilities may currently lack.
- Incorporating/obtaining climate impact information can be challenging due to the need for reliable data on long-term weather patterns, extreme events and climate variability.

Grid Optimization
Self-Healing Grid
Impact Assessment
Alternatives Assessment
Customer Experience Management

Grid Optimization

CATEGORY	STAGE
Enhanced T&D Operations	Value Generating

GRID OPTIMIZATION

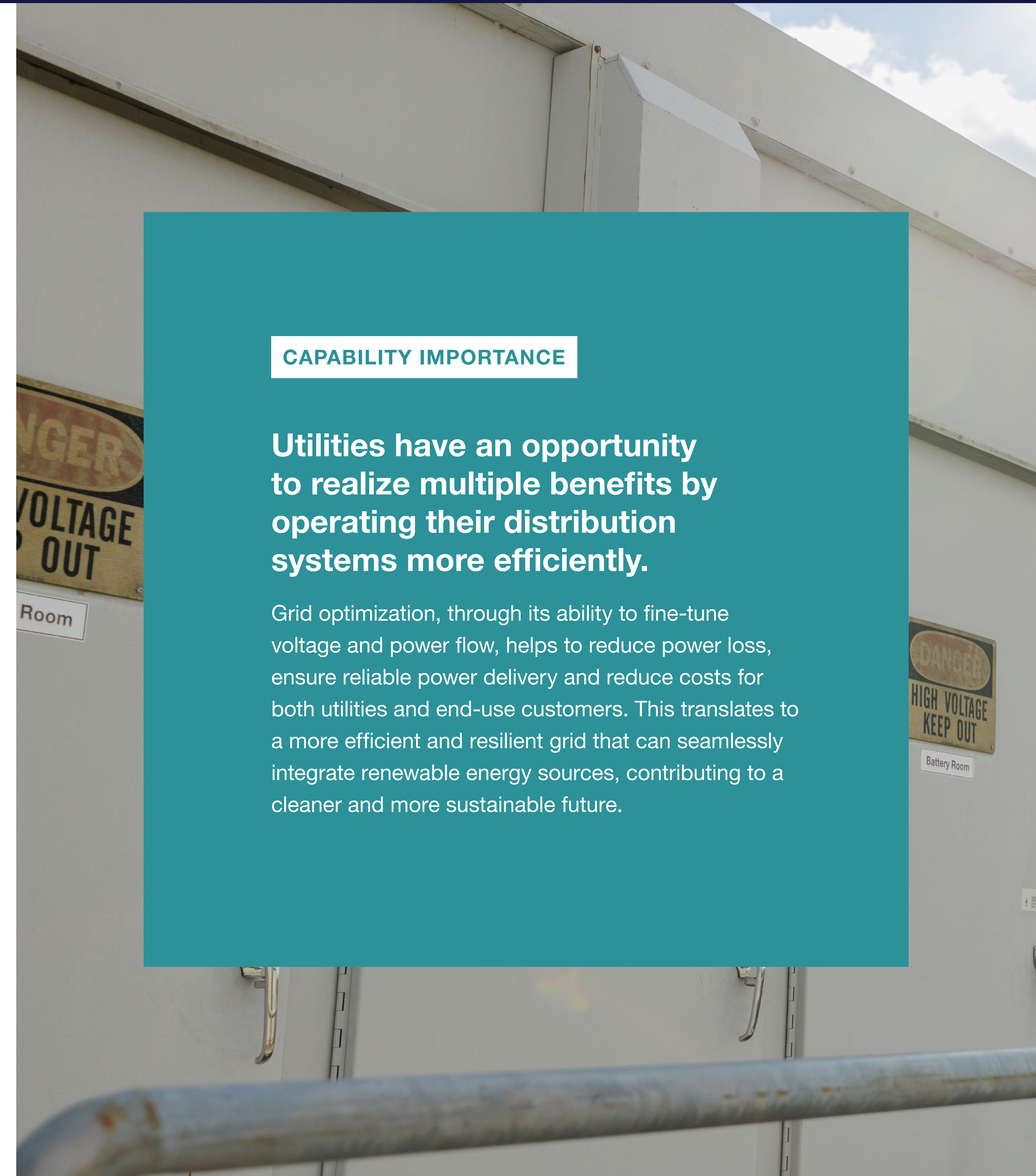
Overview

DEFINITION

Activities and technologies that allow grid operators to improve the performance and efficiency of the distribution system, including peak load management, optimizing power flow and ensuring voltage stability.

SUPPORTING TECHNOLOGIES

- Sensors and some automation devices
- Grid monitoring system
- Substation SCADA
- SCADA-controlled cap banks
- SCADA-controlled line regulators



CAPABILITY IMPORTANCE

Utilities have an opportunity to realize multiple benefits by operating their distribution systems more efficiently.

Grid optimization, through its ability to fine-tune voltage and power flow, helps to reduce power loss, ensure reliable power delivery and reduce costs for both utilities and end-use customers. This translates to a more efficient and resilient grid that can seamlessly integrate renewable energy sources, contributing to a cleaner and more sustainable future.

GRID OPTIMIZATION

Activities for Advancement

Remote System Management

Monitoring the power grid from afar and adjusting the voltage and power flow to make it more efficient on most circuits.

Remotely Controlled Voltage

The system autonomously adjusts the voltage to save energy and reduce demand across most circuits, based on system needs.

Renewable Energy Sources

To reach the Valley Transformational Level, LPCs will need to include additional renewable energy sources in large quantities in the process of optimizing voltage levels.

Grid Optimization means improving the performance and efficiency of the distribution systems. It involves managing peak load, optimizing power flow and ensuring voltage stability.

GRID OPTIMIZATION

Maturity Levels

	Level 1	Level 2 VS	Level 3	Level 4 VTL	Level 5
Est. Time at Level	N/A	1-5 Years	3-5 Years	3-5 Years	3-5 Years
Remote System Managing and Voltage Control	Engineering-centric grid monitoring and voltage / power flow optimization are manually dispatched. Voltage and power flow are determined using static engineering values and only modified seasonally, if at all.	Remote grid monitoring and manual voltage/power flow optimization with remote dispatch. Conservation voltage reduction or demand voltage reduction are manually dispatched. **PENETRATION LEVEL:** Optimization deployed in some or many (1-50%) of targeted circuits with conservation voltage reduction and/or demand voltage reduction used only on some (1-25%) circuits.	Remote grid monitoring and system voltage / power flow optimization with remote advisory dispatch.System conservation voltage reduction or demand voltage reduction are remotely dispatched. **PENETRATION LEVEL:** Voltage and power flow optimization consistently used in most (51-75%) circuits. Limited use of conservation voltage reduction and/or demand voltage reduction used on many or most (26-75%) circuits.	Remote grid monitoring and centralized system voltage/power flow optimization with remote autonomous dispatch and large DER (>500 kW) visibility. System conservation voltage reduction or demand voltage reduction are system determined and remotely dispatched. **PENETRATION LEVEL:** Voltage, power flow, conservation voltage, and/or demand voltage optimization used on almost all (76-95%) circuits.	Optimized voltage, power flow, conservation voltage reduction or demand voltage reduction including DER incorporation into voltage and power flow schemes. **PENETRATION LEVEL:** Voltage, power flow, conservation voltage and/or demand voltage optimization used on almost all (76-95%) circuits.
Distributed Energy Resources (DER)				Large FOTM DER incorporated into voltage optimization algorithm.	Most (51-75%) large FOTM (>500 kW) and larger BTM DER (>50 kW) comprehensively incorporated into optimization algorithm.

VS Valley Standard VTL Valley Transformational Level

GRID OPTIMIZATION

Potential Benefits

Grid optimization enhances resiliency by improving power flow, reducing transmission congestion and lowering generation fuel usage, which can lead to cost savings for both utilities and customers. By minimizing power losses and voltage issues, it ensures reliable power quality while boosting storm response and worker safety. These efficiencies strengthen grid reliability and customer satisfaction and support economic growth and lower energy costs for end-users.

Grid optimization enhances resiliency by improving power flow, minimizing power losses and voltage issues.

TVA Benefits

TVA Benefits	VS	VTL
Avoided energy costs from reduced demand and transmission losses	●○○○○	●●●○○
Avoided generation capacity costs from reduced demand and transmission losses	●○○○○	●●●○○
Increased end-customer reliability	●○○○○	●●○○○
Improved end-customer satisfaction	●○○○○	●●○○○

LPC Benefits

LPC Benefits	VS	VTL
Reduced LPC wholesale purchases from energy savings	●○○○○	●●●●○
Reduced LPC wholesale purchases from demand savings	●○○○○	●●●●○
Reduced power losses and voltage issues	●○○○○	●●○○○
Improved worker safety	●○○○○	●●○○○
Increased grid resiliency	●○○○○	●●○○○
Improved operational efficiency	●○○○○	●●○○○
Improved customer satisfaction	●○○○○	●●○○○

Customer Benefits

Customer Benefits	VS	VTL
Lower monthly bills	●○○○○	●●●●○
Improved power quality	●○○○○	●●○○○
Improved customer satisfaction	●○○○○	●●○○○

●●●●● Amount of potential benefits on a scale of 1-5

● Quantitative
● Semi-quantitative
● Qualitative

VS Valley Standard
VTL Valley Transformational Level

GRID OPTIMIZATION

Implementation Considerations

People Who May Be Impacted

- Operations
- Planning personnel
- Field crews
- Asset management
- Customer service operations

Processes That May Be Impacted

- Power quality processes are simplified and later become an "in the office" and proactive role with remote monitoring at the VTL and above.
- Grid voltage is better managed at all levels with primarily automated management at Level 5 with exceptions and issues flagged for operation intervention.
- Switching processes will change due to the increase in the number of SCADA connected control points on the system. This will increase efficiency in operations and maintenance of the grid.

Potential Challenges of Implementation

- Training to sufficiently and effectively support automation.
- Gird optimization requires investment to train staff before implementing infrastructure.
- Moving from manually approved control schemes to autonomous operation takes time to build trust in the system.
- Customers may feel the necessary investments are not justified.
- DMS model training and maintenance may be a new skillset for utilities.
- DERMS implementation to support DER integration and control is an additional cost for utilities.

Additional challenges of implementation at the VTL and beyond include Distribution Management System model creation and maintenance and DERMS implementation to support DER integration and control.

○ Enabling ○ Planning and Assessing ● Value Generating ○ Enhancing

- Grid Optimization
- **Self-Healing Grid**
- Impact Assessment
- Alternatives Assessment
- Customer Experience Management

Self-Healing Grid

CATEGORY	STAGE
Enhanced T&D Operations	Value Generating

SELF-HEALING GRID

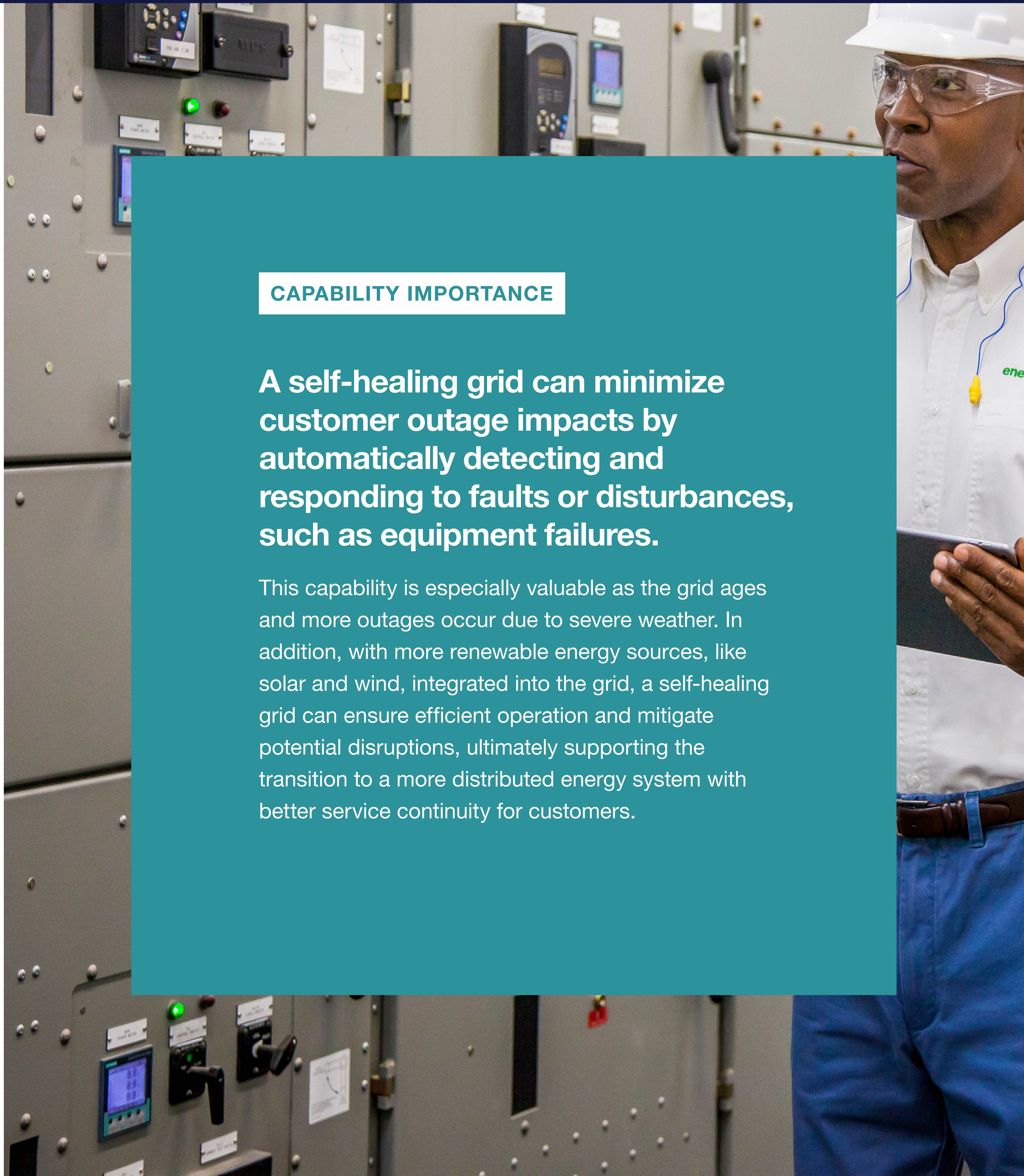
Overview

DEFINITION

A self-healing grid that is capable of automatically anticipating and responding to power system disturbances, including the isolation of failed sections and components, while optimizing grid performance and service to customers.

SUPPORTING TECHNOLOGIES

- Substation SCADA
- SCADA breakers, switches and reclosers
- Basic OMS



CAPABILITY IMPORTANCE

A self-healing grid can minimize customer outage impacts by automatically detecting and responding to faults or disturbances, such as equipment failures.

This capability is especially valuable as the grid ages and more outages occur due to severe weather. In addition, with more renewable energy sources, like solar and wind, integrated into the grid, a self-healing grid can ensure efficient operation and mitigate potential disruptions, ultimately supporting the transition to a more distributed energy system with better service continuity for customers.

SELF-HEALING GRID

Maturity Levels

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-5 Years	3-5 Years	3-5 Years	10 Years
Automated System Managing	Primarily manual switching and manual customer call-based outage identification and outage restoration.	Significant use of remote switching; call-based system outage identification and outage restoration. **PENETRATION LEVEL:** Many or most (26-75%) circuit breakers and switches/reclosers have SCADA monitoring and control. Must have call-based system outage identification and restoration.	Primarily remote switching augmented with limited automated reclosing. Call-based predictive outage management with limited monitoring integration. **PENETRATION LEVEL:** Almost all (76-95%) circuit breakers and switches/reclosers have SCADA monitoring and control. Some or many (1-50%) automated coordinated reclosing. Must have call-based system predictive outage management (including identification and restoration). Some or many (1-50%) integration of SCADA monitoring into outage management system or equivalent system.	Comprehensive remote switching and automated reclosing. Automated switching deployed using advisory mode. Extensive monitoring integration into call-based outage management. **PENETRATION LEVEL:** Almost all (76-95%) circuit breakers and switches/reclosers have SCADA monitoring and control. Automated coordinated reclosing and advisory fault location, isolation and service restoration (FLISR) switching present on most (51-75%) circuits with ties. Integration of SCADA monitoring into outage management system present for most (51-75%) circuits.	Full remote switching and automated reclosing. Automated switching deployed using autonomous mode. Integrated outage management with full monitoring, call incorporation and web/mobile integration. **PENETRATION LEVEL:** Level 4+ Automated coordinated reclosing and autonomous FLISR are present on almost all (76-95%) circuits with ties. Must have advanced outage capture and communication with text/web/mobile channels.

VS Valley Standard VTL Valley Transformational Level

SELF-HEALING GRID

Potential Benefits

A self-healing grid minimizes downtime by automatically detecting faults and restoring service, reducing the need for manual intervention and truck rolls. This improves operational efficiency, lowers costs and enhances customer satisfaction by shortening restoration times and reducing outage impacts. With remote device access and automated responses, critical services like hospitals experience fewer disruptions, ensuring greater resilience during storms and other outage events.

A self-healing grid improves operational efficiency, lowers costs and boosts customer satisfaction by reducing restoration times and outage impacts.

TVA Benefits

TVA Benefits	VS	VTL
Reduced customer outage frequency	●○○○○ (1, Quantitative)	●●○○○ (2, Quantitative)
Reduced time to restore outages	●○○○○ (1, Quantitative)	●●○○○ (2, Quantitative)
Improved customer satisfaction	●○○○○ (1, Semi-quantitative)	●●○○○ (2, Semi-quantitative)

LPC Benefits

LPC Benefits	VS	VTL
Reduced reliability-related truck rolls	●○○○○ (1, Quantitative)	●●○○○ (2, Quantitative)
Reduced crew labor	●○○○○ (1, Quantitative)	●●●●● (5, Quantitative)
Reduced outage frequency	●○○○○ (1, Quantitative)	●●○○○ (2, Quantitative)
Reduced time to restore outages	●○○○○ (1, Quantitative)	●●○○○ (2, Quantitative)
Improved operational efficiency	●○○○○ (1, Semi-quantitative)	●●○○○ (2, Semi-quantitative)
Improved customer satisfaction	●○○○○ (1, Semi-quantitative)	●●○○○ (2, Semi-quantitative)

Customer Benefits

Customer Benefits	VS	VTL
Reduced time to restore outages	●○○○○ (1, Quantitative)	●●○○○ (2, Quantitative)
Reduced outage frequency	●○○○○ (1, Quantitative)	●●○○○ (2, Semi-quantitative)
Reduced outages for business and essential services (e.g., hospitals) during weather and other extreme events	●○○○○ (1, Semi-quantitative)	●●○○○ (2, Semi-quantitative)
Improved customer satisfaction	●○○○○ (1, Semi-quantitative)	●●○○○ (2, Semi-quantitative)

●●●●● Amount of potential benefits on a scale of 1-5

● Quantitative
● Semi-quantitative
● Qualitative

VS Valley Standard
VTL Valley Transformational Level

SELF-HEALING GRID

Implementation Considerations

People Who May Be Impacted

- Operations personnel
- Field crews
- Organizational planning
- Customer service

Processes That May Be Impacted

- Outage identification, response and restoration will be streamlined and automated through self-healing capabilities, reducing the need for manual troubleshooting and response.
- Switching is streamlined through the quick identification and isolation of faults to minimize outages. The self-healing grid dynamically reroutes power to maintain service continuity and reduces the need for manual intervention.
- Customer service becomes more proactive and efficient, leading to a more responsive, reliable and customer-focused service experience.
- Reclosing strategies will be developed based on the type of fault and current grid conditions, optimizing the balance between reliability and equipment protection.
- Distribution management is enhanced through real-time monitoring, predictive analytics and dynamic load balancing.

Potential Challenges of Implementation

- As with any new technology, field workers, operators and other key personnel may lack initial trust in the abilities of self-healing technologies and processes. Automation must be proven and deployed incrementally to accommodate.
- The technology requires complex integration and testing to work properly—even sophisticated large utilities can have implementation and integration problems.
- At Level 4+, a fully autonomous grid operation requires trust, track record and experience that is hard won and easily lost, so maintaining the system and ensuring efficiency is critical to long-term success.

○ Enabling ○ Planning and Assessing ● Value Generating ○ Enhancing

- Grid Optimization
- Self-Healing Grid
- **Impact Assessment**
- Alternatives Assessment
- Customer Experience Management

Impact Assessment

CATEGORY	STAGE
Integrated Planning	Value Generating

IMPACT ASSESSMENT

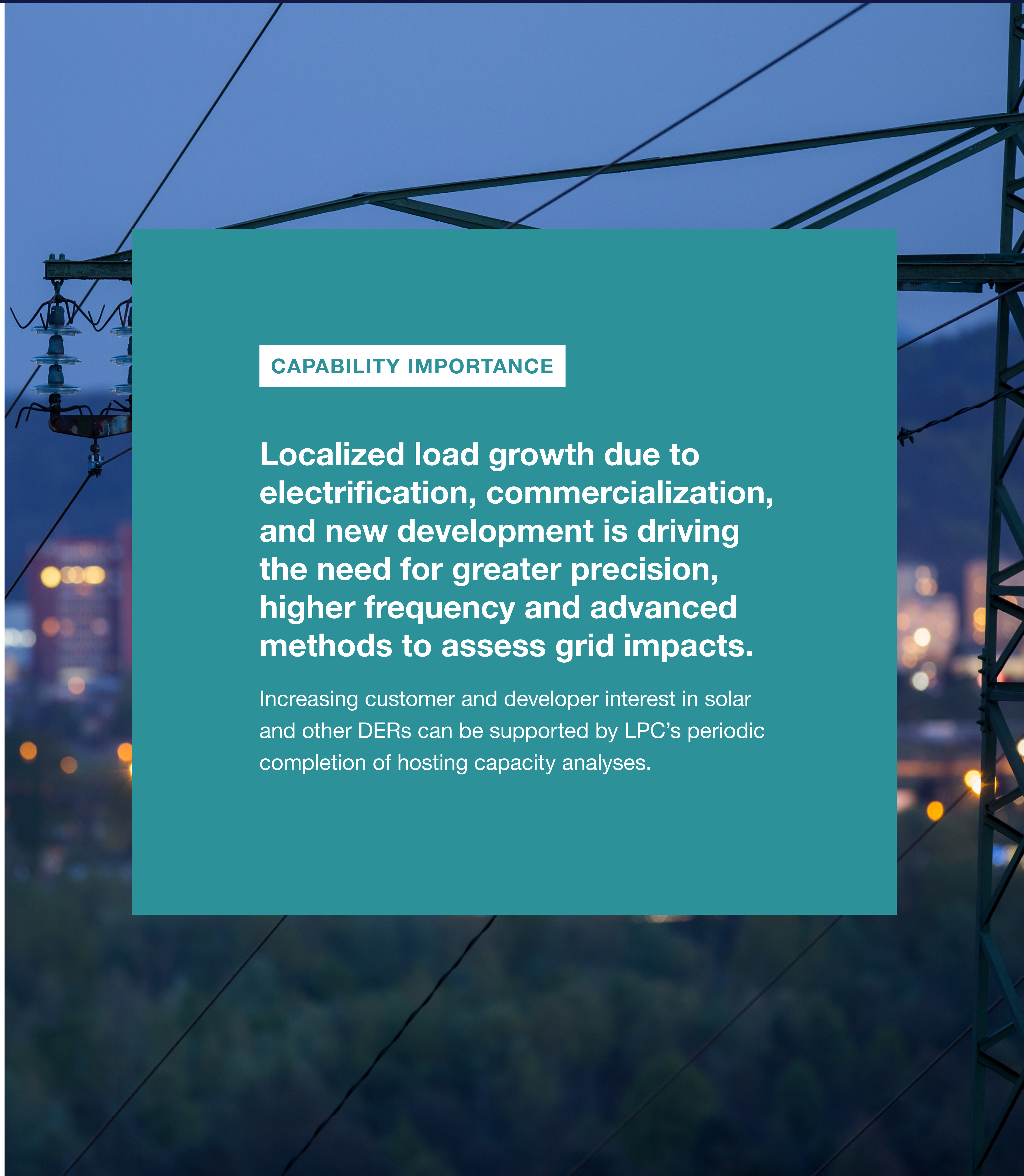
Overview

DEFINITION

Impact assessment[1] consists of identification of system constraints and issues (capacity, reliability and resilience) resulting from scenarios based on load, DER and system forecasts. Data on customer and developer DER[2] projects are leveraged to support hosting capacity analysis.

SUPPORTING TECHNOLOGIES

- Power flow tools (e.g. CYMDIST)
- Forecast loading model



CAPABILITY IMPORTANCE

Localized load growth due to electrification, commercialization, and new development is driving the need for greater precision, higher frequency and advanced methods to assess grid impacts.

Increasing customer and developer interest in solar and other DERs can be supported by LPC's periodic completion of hosting capacity analyses.

1 Impact Assessment Valley Standard and Valley Transformational Levels build off of the System Modeling capability progression model Valley Standard and Valley Transformational Levels. See System Modeling details for specific details of levels.

2 DER refers to both behind the meter (BTM) and front of the meter (FoTM) including but not limited to PV, BESS, EV, distributed backup generation, etc.

IMPACT ASSESSMENT

Maturity Levels

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	**N/A**	**1-2 Years**	**1-2 Years**	**1-3 Years**	**1-3 Years**
Impact Assessment Method	Use engineering or as-built diagrams.	Use load flow analysis tool(s) to develop models for subset of feeders identified as highly impacted in load, DER and system forecasts.	Use load flow analysis tool(s) on models for all distribution feeders.	Level 3 plus consideration of operational flexibility in the impact assessment.	Level 4 plus quantitative assessment of risks on all distribution feeder models.
Operating Characteristics Considered	Distribution system analysis including protection, thermal and voltage.	Consideration includes protection, capacity, thermal, voltage, power quality, customer DER and the reverse power flow from DER	Level 2 characteristics considered using both static and simple time-series analysis for multiple power flow conditions (e.g., minimum and peak).	Level 3 characteristics plus advanced time series analysis, such as 8760.	Level 4 plus additional focus on customer power quality and customer experience.
Grid Assets Assessed	Done in ad hoc manner related to delivery points.	Formalized around key inputs (including economic and demographic variables, the electricity rate forecast and other input assumptions) and outputs including distribution area coincident peak demand and energy use.	At Level 2+ completed on an annual basis to reflect updated peak conditions either summer or winter.	Maintained at Level 3.	Maintained at Level 3.

VS Valley Standard VTL Valley Transformational Level

IMPACT ASSESSMENT

Maturity Levels (Continued)

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-2 Years	1-2 Years	1-3 Years	1-3 Years
Assessment Frequency	Completed infrequently.	Completed at least once every three years or on an as needed basis for specific projects.	Completed at least annually or on an as needed basis for specific projects.	Completed at least quarterly or on an as needed basis for specific projects.	Completed near real time.
Hosting Capacity Analysis	Hosting Capacity Analysis are not consistently available or generated.	Hosting Capacity Analysis for DER interconnection purposes are completed as needed, used for internal planning and shared with external stakeholders on a need-to-know basis or upon request.	Hosting Capacity Analysis for DER interconnection purposes are completed periodically, at least annually and used for internal planning and external stakeholders. Hosting capacity maps are shared with external stakeholders on a need-to-know basis or upon request.	Hosting Capacity Analysis for DER interconnection purposes are updated automatically based upon grid changes and immediately available for internal use and for external stakeholders on a need-to-know basis or upon request.	Maintained at Level 4.

VS Valley Standard VTL Valley Transformational Level

IMPACT ASSESSMENT

Potential Benefits

Consistent and high quality impact assessments can strengthen grid reliability and resiliency by improving planning precision. Through development of a clearer outlook on system needs, impact assessments enable more targeted capital investments and may help defer or eliminate costly distribution or transmission upgrades. Hosting capacity analysis can improve decision-making, ensuring a more efficient, adaptable, and cost-effective approach to grid modernization.

Impact assessments provide a clear outlook on system needs, enabling more targeted capital investments.

TVA Benefits

TVA Benefits	VS	VTL
Increased precision in transmission outlook	●○○○○	●●○○○
Increased opportunities for deferral of transmission investments	●○○○○	●●○○○
Increased coordination between TVA and LPCs	●○○○○	●◐◐◐◐

LPC Benefits

LPC Benefits	VS	VTL
More robust current and forecasted system load conditions	●○○○○	●●○○○
Improved planning information	●○○○○	●●○○○
Improved granularity and resolution of load impact analysis	●○○○○	●●○○○
Improved planning for locational capital allocation	●○○○○	●●○○○

Customer Benefits

Customer Benefits	VS	VTL
Improved reliability	●○○○○	●●○○○
Earlier identification of system needs for upgrades	●○○○○	●●○○○
Reduction in the number of system overloads	●○○○○	●●○○○

●●●●● Amount of potential benefits on a scale of 1-5

● Quantitative
● Semi-quantitative
● Qualitative

VS Valley Standard
VTL Valley Transformational Level

IMPACT ASSESSMENT

Implementation Considerations

People Who May Be Impacted

- Distribution system planning
- Engineering
- AMI resources
- Operations/construction management
- Large customer sales/economic development
- Corporate communications

Processes That May Be Impacted

- Distribution system planning process will be improved with more robust current and forecast system load information based on AMI summary data, additional study scenarios and network modeling representations.
- Engineering design processes will be impacted by the need to account for more complex and dynamic system scenarios resulting from changes in load, DER and system forecasts.
- AMI data management process improvements will provide greater analytical details and resolution to provide near real-time system insights.
- Construction management process will be simplified through having a variety of system improvement alternatives at potentially lower cost and shorter/simpler construction in communities.
- Customer relations process for large customers is improved by having customer experience information during planning.
- Economic development process is improved by enabling targeted customer power quality improvements.
- Customer communications process is enhanced by providing more accurate information regarding the needs of customers in relation to system constraints and issues.
- Community affairs process is improved through the periodic generation of hosting capacity maps, outlining to communities where the system can support additional DER to support project development.

Potential Challenges of Implementation

- Acquisition and management of AMI data for use due to the complexity and scale of data generated, requiring robust data systems and infrastructure.
- Development and implementation of network models can be a challenge, considering the integration of DER, variable loads and evolving system constraints.
- DER data and modeling can be a challenge due to the variability of DER, and their characteristics, performance and interactions with the grid.
- Expertise and data for development of hosting capacity maps may be a challenge as these maps require specialized knowledge of grid dynamics, advanced analytical tools and high-quality, detailed data.
- Utilities may not have expertise in OT and non-wires alternatives projects to design, implement and integrate these solutions effectively.
- Economic data and modeling for grid impact analysis is essential for assessing financial impacts. Challenges may arise from limited access to detailed cost data, inconsistencies in data quality and complexity in building models that accurately capture economic trade-offs.
- It may be difficult to acquire or develop the knowledge and tools for dynamic approaches to distribution system modeling to account.
- Sharing arrangements and policies for hosting capacity maps could be challenging due to privacy concerns, data ownership issues and regulatory requirements.

Enabling | Planning and Assessing | **Value Generating** | Enhancing

- Grid Optimization
- Self-Healing Grid
- Impact Assessment
- **Alternatives Assessment**
- Customer Experience Management

Alternatives Assessment

CATEGORY

Integrated Planning

STAGE

Value Generating

ALTERNATIVES ASSESSMENT

Overview

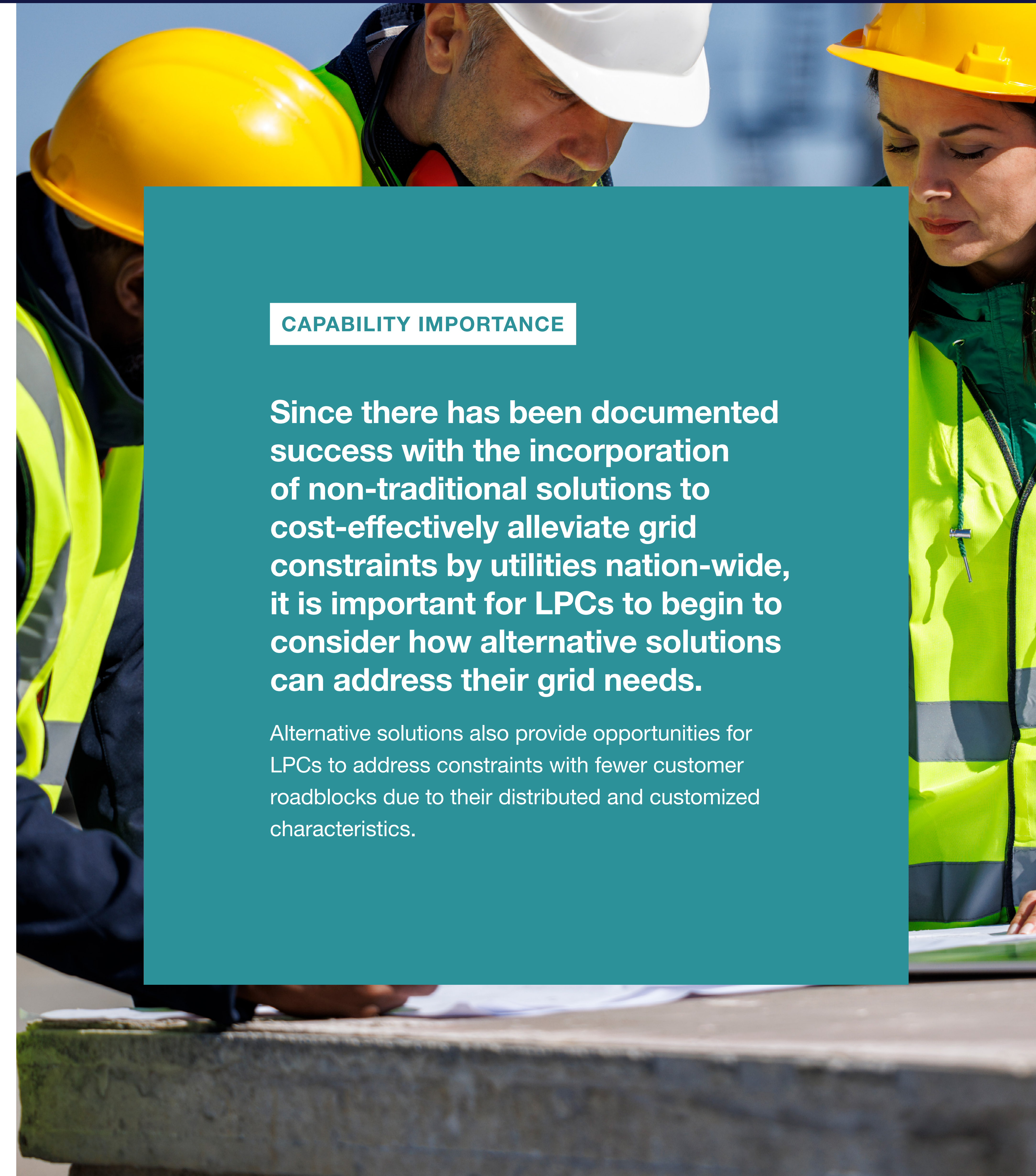
DEFINITION

Consists of a techno-economic evaluation by the LPC of solutions to address constraints on their transmission and distribution system with the incorporation of non-traditional mitigations (DER, load management, non-wires alternatives, etc.) to optimize utility capital expenditures, reduce project lead time and increase operational flexibility and resiliency.

Sub-capabilities include the increasing ability to consider additional types of mitigation alternatives for longer timeframes and for additional sites with different types of needs and concerns. The identification of the specific site with needs or concerns is covered in the Impact Assessment capability upon which this capability builds.

SUPPORTING TECHNOLOGIES

- Planning tool (e.g. Cyme, Synergi)
- Extract from asset management system
- Spreadsheet(s)



CAPABILITY IMPORTANCE

Since there has been documented success with the incorporation of non-traditional solutions to cost-effectively alleviate grid constraints by utilities nation-wide, it is important for LPCs to begin to consider how alternative solutions can address their grid needs.

Alternative solutions also provide opportunities for LPCs to address constraints with fewer customer roadblocks due to their distributed and customized characteristics.

ALTERNATIVES ASSESSMENT

Maturity Levels

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-2 Years	1-2 Years	1-3 Years	1-3 Years
Sites Assessed	Include those with aging infrastructure and existing overloading conditions.	Include those with aging infrastructure and existing or forecasted overloading.	Include Level 2 plus distribution planning capacity criteria, thermal limits, voltage criteria, power quality, customer DER limits and reverse power flow impacts.	Include all those from Level 3+ sites impacted by load shaping incentive programs (e.g., an EV TOU rate).	Include all impacts listed in Level 4+ consideration of reliability and resiliency.
Planning Horizon	Immediate.	Immediate to the next two years.	Immediate to the next three years.	Immediate to the next five years.	Immediate to the next ten years.
Evaluation of Solutions for Mitigating Impacts at the Sites Assessed	Include traditional asset replacement and upgrades.	Include traditional asset replacement and upgrades, and at least one non-traditional mitigation (e.g., utility-scale battery storage) as applicable[1].	Include asset replacement and upgrades, and both FoTM and BTM mitigations (e.g., DER or energy efficiency programs) as applicable[1].	Include Level 3+ integration of alternative identification and assessment into formalized planning process.	Leverages analytics powered to identify mitigation options for consideration.
Mitigation Prioritization	Based upon historical costs and ability to address identified needs.	Based upon historical costs with inflation, ability to address needs and concerns and consideration of implementation lead times. Alternative mitigations, at a minimum, meet planning needs, and are compared to the traditional mitigation(s) on a net present value/least cost basis.	Based upon historical and current costs, considering future cost escalations. Risk analysis considers project delivery and resource performance. Alternative mitigations are compared to traditional mitigations leveraging a benefit-cost analysis model.	Based upon Level 3+ consideration of external stakeholder objectives. Alternative mitigations are compared to traditional mitigations leveraging a benefit-cost analysis model with consideration of societal benefits.	Based upon Level 4+ including flexibility and resiliency objectives. Alternative mitigations are compared to traditional mitigations at Level 4+ consideration of benefits including flexibility and resiliency.

[1] Site applicability for evaluation of non-traditional mitigations is based on engineering considerations of project type, timing, cost, and other constraints.

VS Valley Standard VTL Valley Transformational Level

ALTERNATIVES ASSESSMENT

Potential Benefits

Alternatives assessment improves grid reliability and cost efficiency by including non-traditional solutions into utility planning to reduce constraints, lower energy costs, optimize capacity and enhance flexibility. This approach not only enhances customer satisfaction but also attracts new commercial and industrial investment, strengthening the region's energy and economic resilience.

Alternatives assessment improves grid reliability and cost efficiency by exploring non-traditional solutions to reduce constraints and optimize capacity.

TVA Benefits

TVA Benefits	VS	VTL
Reduced LPC capacity and energy requirements	●○○○○	●●○○○
Reduced overall system capital costs	●○○○○	●●○○○
Lower energy rates	●○○○○	●●○○○
Increased grid flexibility	●○○○○	●●○○○
Improved customer satisfaction	●○○○○	●●○○○
Increased attraction of new commercial and industrial customers to the region	●○○○○	●●●●●

LPC Benefits

LPC Benefits	VS	VTL
Improved reliability	●○○○○	●●○○○
Optimized capital cost expenditures	●○○○○	●●○○○
Increased operational flexibility	●○○○○	●●○○○
Improved customer satisfaction	●○○○○	●●○○○
Increased attraction of new commercial and industrial customers	●○○○○	●●●●●

Customer Benefits

Customer Benefits	VS	VTL
Lower monthly bills	●○○○○	●●○○○
Improved customer satisfaction	●○○○○	●●○○○
More grid solutions that align with community goals	●○○○○	●●●●●
Increased attraction of new commercial and industrial customers	●○○○○	●●●●●

●●●●● Amount of potential benefits on a scale of 1-5

● Quantitative
● Semi-quantitative
● Qualitative

VS Valley Standard
VTL Valley Transformational Level

ALTERNATIVES ASSESSMENT

Implementation Considerations

People Who May Be Impacted

- Distribution system planning
- Engineering
- Large customer sales (for DER information)
- Rates/market research

Processes That May Be Impacted

- Distribution planning processes, either annual or biannual, to address grid constraints will need to be modified to allow for consideration of alternative solutions
- Procurement of traditional assets such as mobile transformers or substation banks may change given shift in solution focus
- Solution cost comparison approach will need to be updated to account for additional benefit streams from alternative solutions
- Data collection of alternative solution performance to support further refinement of planning activities

Potential Challenges of Implementation

- Change management is critical when implementing a capability like this, as it involves complex technical, financial and operational changes. This shift often faces resistance due to entrenched practices and preferences to traditional approaches. Effective change management can address these challenges by fostering openness to new technologies, providing necessary training to close skill gaps and aligning diverse stakeholders across planning, operations, finance and regulatory groups.
- Employees will need to learn both basic and more advanced modeling tools required for techno-economic evaluations. Building this skillset requires training programs that cover foundational modeling techniques and tools, as well as ongoing support to build confidence and expertise.
- Data acquisition is a significant challenge in implementing this capability, as it requires extensive, accurate and often real-time data from various sources to evaluate both traditional and non-traditional mitigation solutions effectively. LPCs need comprehensive data, which can be difficult to acquire due to outdated metering infrastructure, inconsistent data formats and data silos across departments.
- Once maturity Level 3 is reached, LPCs will need to focus on customer communications, especially around DER. As DER increasingly impact grid planning, effective communication with customers who own or operate these resources is essential. Developing effective communication strategies is crucial for building trust, encouraging cooperation and ensuring a smooth integration of DER as viable mitigation alternatives.
- For Level 4 and 5, LPCs will have to implement new training, tools and methodologies to develop societal Benefit-Cost Analysis (BCA) and will need to develop management practices for the orchestration system.

Enabling | Planning and Assessing | **Value Generating** | Enhancing

- Grid Optimization
- Self-Healing Grid
- Impact Assessment
- Alternatives Assessment
- **Customer Experience Management**

Customer Experience Management

CATEGORY	STAGE
Exceptional End-User Experience	Value Generating

CUSTOMER EXPERIENCE MANAGEMENT

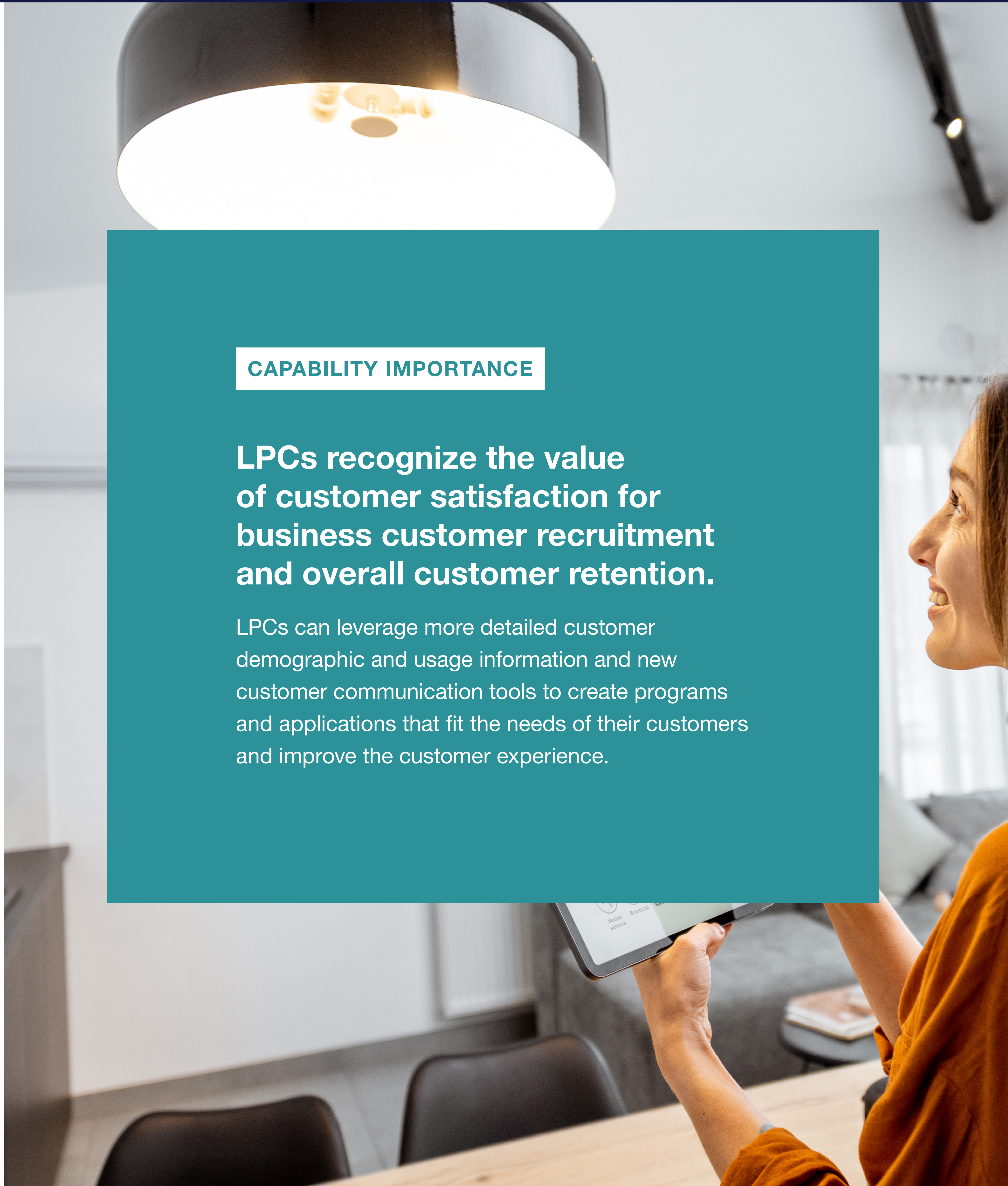
Overview

DEFINITION

Approaches for leveraging customer information (e.g., customer, meter and demographic data) using analysis and analytics to gain insights and design customer metrics to better enable customer service and programs.

SUPPORTING TECHNOLOGIES

- Targeted customer communications based on data analytics



CAPABILITY IMPORTANCE

LPCs recognize the value of customer satisfaction for business customer recruitment and overall customer retention.

LPCs can leverage more detailed customer demographic and usage information and new customer communication tools to create programs and applications that fit the needs of their customers and improve the customer experience.

CUSTOMER EXPERIENCE MANAGEMENT

Maturity Levels

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-2 Years	1-2 Years	1-3 Years	1-3 Years
Data Collection	Ad-hoc/manual processes to obtain, process and extract customer data.	Documented and standardized manual processes to obtain, process and extract customer data.	Minimal automated processes to obtain, process and extract customer data for core customer service operations (call center, billing, meter data).	Some automated data collection processes for analysis of all customer experience functions (programs, customer targeting).	Fully automated processes to obtain, process and extract customer data.
Metric Tracking	Customer Service KPIs (e.g., first response time[1], average resolution time and average handle time) are inconsistently tracked. Aggregated system-wide data is used in developing insights on customer experience.	Customer Service KPIs (e.g., first response time, average resolution time and average handle time) are tracked on a standardized monthly refresh cycle. Aggregated feeder level data is used in developing insights on customer experience.	Customer Service KPIs are tracked on a daily refresh cycle. Disaggregated customer data (meter level) used in targeting and providing customer information.	Customer Service KPIs are tracked on a daily refresh cycle. Disaggregated customer data (meter level) used in customer segmentation and targeting for programs & plans including TOU and DVR.	Customer Service KPIs are tracked on a daily refresh cycle. Disaggregated customer data (meter level) used in customer segmentation and targeting for programs & plans including TOU and DVR.

[1] Examples of first response times include time to settle member dispute, time to resolve an outage, etc.

VS Valley Standard VTL Valley Transformational Level

CUSTOMER EXPERIENCE MANAGEMENT

Maturity Levels (Continued)

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-2 Years	1-2 Years	1-3 Years	1-3 Years
Programs/ Plans	LPCs offer some (1-25%) of TVA programs + few (1-2) offerings of customer plans[1]. Some (1-25%) customers participating in customer programs/plans.	LPCs offer many (26-50%) TVA programs + some (3-4) offerings of customer plans. Some (1-25%) customers participating in customer programs/ plans.	LPCs offer most (51-75%) of TVA programs + many (5+) offerings of customer plans. Many (26-50%) customers participating in customer programs/plans.	LPCs offer almost all (76-95%) of TVA programs + many (5+) offerings of customer plans. Most (51-75%) customers participating in customer programs/plans.	LPCs offer almost all (76-95%) of applicable TVA programs + many (5+) offerings of customer plans. Almost all (76-95%) customers participating in customer programs/plans.
Accessibility	Aggregate customer energy usage is available on a monthly generated bill.	Online customer portal provides bill view, bill payment, request for management of services (start/stop/ transfer) and interval energy usage.	Online customer portal provides rate options comparison and access to customer's historical data. Mobile application is available and provides bill view, bill payment and generates bill alerts.	Online customer portal provides targeted rate option recommendation and recommendations on participation in LPC or TVA customer plans or programs. Mobile application provides outage notifications and alerts of service restoration.	Online customer portal provides advanced functionality such as service transfers and termination service. Mobile application provides outage notifications and alerts of service restoration.

[1] Examples of customer plans can include pre-pay, levelized billing, heat pump financing, residential storage incentives, etc.

VS Valley Standard VTL Valley Transformational Level

CUSTOMER EXPERIENCE MANAGEMENT

Potential Benefits

Customer experience management strengthens the utility-customer relationship by improving customer service and issue resolution, reducing outage restoration times and optimizing program targeting. By engaging customers more effectively, LPCs can lower service costs, improve customer satisfaction scores and improve the facilitation of DER adoption.

Customer experience management strengthens the utility-customer relationship by improving service, response times and program targeting.

TVA Benefits

TVA Benefits	VS	VTL
Avoided generation costs from peak demand reduction	1 (Quantitative)	2 (Quantitative)
Reduced time to restore outages	1 (Quantitative)	2 (Quantitative)
Reduced capital cost expenditures	1 (Semi-quantitative)	2 (Semi-quantitative)
Improved end-use customer satisfaction	1 (Semi-quantitative)	2 (Semi-quantitative)

LPC Benefits

LPC Benefits	VS	VTL
Reduced LPC wholesale demand charges	1 (Quantitative)	2 (Quantitative)
Reduced LPC wholesale purchases	1 (Quantitative)	2 (Quantitative)
Reduced time to restore outages	1 (Quantitative)	2 (Quantitative)
Improved customer satisfaction	1 (Semi-quantitative)	2 (Semi-quantitative)

Customer Benefits

Customer Benefits	VS	VTL
Reduced time to restore outages	1 (Quantitative)	2 (Quantitative)
Improved customer satisfaction	1 (Semi-quantitative)	2 (Semi-quantitative)
Increased potential to reduce carbon emissions	1 (Semi-quantitative)	2 (Semi-quantitative)

Amount of potential benefits on a scale of 1-5

Quantitative
Semi-quantitative
Qualitative

VS Valley Standard
VTL Valley Transformational Level

Implementation Considerations

People Who May Be Impacted

- Customer relations managers
- Customer service representatives (call center, front desk, etc.)
- Billing
- Sales team
- IT
- Program managers
- Operations/supply planning (e.g., in the case of a demand response program)
- Dedicated "experience" or service team or department (organization)

Processes That May Be Impacted

- Customer outreach is improved by using multiple communications channels to distribute targeted communications based on data analysis.
- Data analytics rely on fully automated data collection, allowing for analysis of all customers experience functions, which can lead to predictive premise-level demand forecasting based on anticipated customer behavior.
- Customer support will be improved through an overall better customer experience due to providing self-service capabilities and better call center experience, leading to reduced calls to service center, walk-ins and average time for customer issues resolution.
- Billing is improved through a web-enabled customer portal that includes features such as bill view, bill payment, notification of outages and service restoration.
- New customer onboarding will be streamlined with more robust customer communications, pricing options comparison and improved program and plan targeting.
- Regulatory filings are enhanced by having access to more accurate and detailed customer data, justifying program proposal and meeting customer-centric mandates.
- Program management would be improved through better data-driven insights, enabling more targeted and effective customer programs that align offerings with customer needs and enhancing overall program performance.
- Rates and Pricing could be better tailored to customers using detailed data and analytics. This can lead to offering pricing option comparisons and automated rate plan recommendations.
- Load forecasting is improved through leveraging more granular customer data, such as usage patterns and demographic insights, to create more accurate and dynamic demand projections.

Potential Challenges of Implementation

- Staffing resources are needed to assist in customer service and implementation processes.
- Lack of clear priorities, leading to competing initiatives between departments that may be pursuing overlapping or contradictory projects. Clear prioritization and alignment across teams are essential to ensuring a coordinated approach.
- Absence of skillsets needed to implement changes in this capability will require additional training for staff to gain the ability for necessary data analysis and analytics.
- The cost of deployment to implement changes may be substantial and will need to be factored into budgeting and capital planning.
- **At maturity Level 3 and above:**
    - Too little implementation planning without organizational owners may lead to misalignment between departments and gaps in accountability and strategic direction of this capability. This may lead to delays, missed opportunities and fragmented execution.
    - Significant investment in technologies or initiatives that are displaced by new, better technologies or initiatives can lead to wasted resources, sunk costs and skill development misalignment.

Customer experience management presents challenges for implementation in integrating customer data, aligning cross-functional teams, and maintaining consistent customer interactions.

Enabling | Planning and Assessing | Value Generating | Enhancing

Resource Co-Optimization

Load and DER Forecasting and Operationalization

DER Incorporation and Optimization

Resource Co-Optimization

CATEGORY

Integrated Planning

STAGE

Enhancing

RESOURCE CO-OPTIMIZATION

Overview

DEFINITION

Collaborative development of an integrated resource plan (IRP)[1] combining generation, transmission, distribution and distributed energy to better leverage resources and opportunities[2] for both local and bulk system objectives.

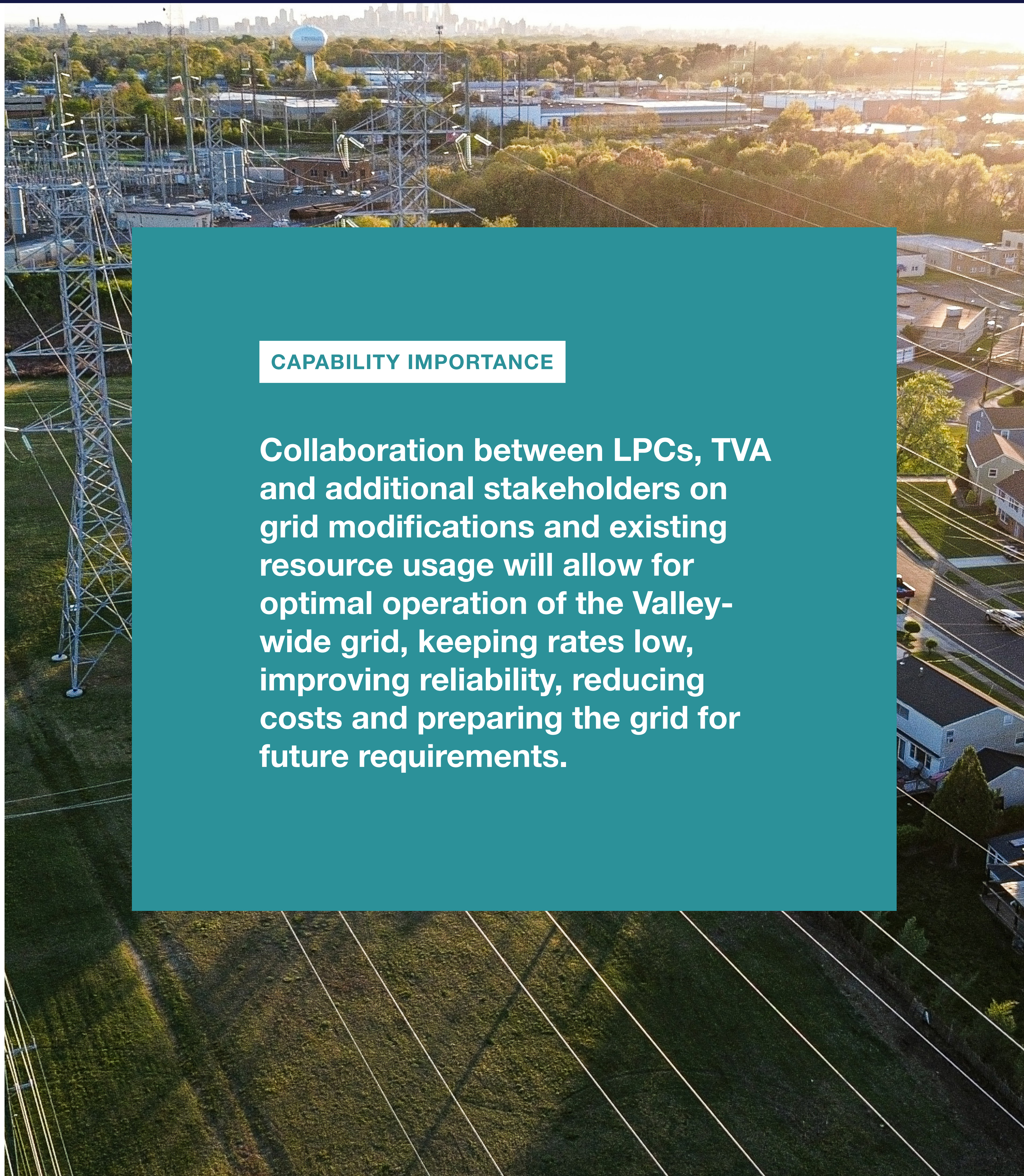
Sub-capabilities of resource co-optimization include stakeholder management, collaborative solution ranking/optimization and frequency.

SUPPORTING TECHNOLOGIES

- Data platforms and modeling tools
- Basic communication processes and tools

1 The Resource co-optimization capability supports the immediate priority by the Valley Vision Collaboration Group of "Collaborative, System-Wide Planning and Operations", including integrated and iterative planning processes, roles and responsibilities and system-wide mapping of DER and other Valley service territory attributes. For example, development of an Integrated System Plan (ISP) will be supported by multiple efforts including the Integrated Transmission Plan (ITP), Distribution System Plans (DSP) and Distribution Resource Plans (DRP).

2 The customer experience management capability outlines resources and opportunities from the LPC perspective to benefit customers.



CAPABILITY IMPORTANCE

Collaboration between LPCs, TVA and additional stakeholders on grid modifications and existing resource usage will allow for optimal operation of the Valley-wide grid, keeping rates low, improving reliability, reducing costs and preparing the grid for future requirements.

RESOURCE CO-OPTIMIZATION

Maturity Levels

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-2 Years	1-2 Years	1-3 Years	1-3 Years
Stakeholder Management	Only system owners (G, T and D) are involved in modeling and decision making.	Stakeholders, included as applicable and appropriate, comment on the process and receive visibility of the outputs.	Stakeholders, included as applicable and appropriate, actively participate in the process with consideration of data, input assumptions and approaches and receive visibility into the processes and outputs.	Stakeholders, included as applicable and appropriate, actively co-develop models, scenarios and analyses and provide active inputs into the processes.	Systems owners (G, T and D) and stakeholders, as applicable and appropriate, work in active, timely and collaborative partnership.
Collaborative Solution Ranking/ Optimization	G, T and D solutions modeled independently using separate objective functions.	Solution prioritization based upon reliable and cost-efficient factors for all parties and coordinated by informal dialogue and sharing of assumptions.	Solution prioritization considers overall system reliability in addition to least cost and coordination is formalized around data and scenarios holistically and iteratively in a joint planning (tactical and strategic) cycle.	G, T and D optimization modeling performed together to optimize system reliability and resiliency with comprehensive system-wide scenarios and data considered in an ongoing manner according to a joint planning (tactical and strategic) cycle.	G, T and D optimization modeling performed to optimize system reliability and resiliency with consideration of environmental, climate and societal changes. Optimization completed in a regularly refreshed automated fashion according to a joint planning (tactical and strategic) cycle.
Frequency	Completed infrequently.	Completed at least once every three years or as needed.	Completed at least annually or as needed.	Maintained at Level 3.	Maintained at Level 3.

VS Valley Standard VTL Valley Transformational Level

RESOURCE CO-OPTIMIZATION

Potential Benefits

Resource co-optimization enhances coordination between TVA and LPCs, ensuring more efficient distribution planning and generation decisions. By improving information quality and stakeholder engagement, it enables systemwide investment strategies that reduce fuel costs and maintain lower rates. These efficiencies lead to more economical, data-driven decisions that strengthen grid reliability and long-term sustainability.

Resource co-optimization enhances coordination between TVA and LPCs, ensuring more efficient distribution planning and generation decisions.

TVA Benefits

TVA Benefits	VS	VTL
Improved reliability	●○○○○ (dark)	●●○○○ (dark)
Increased information sharing between TVA and LPCs for more optimal system-wide investment decisions	●○○○○ (orange)	●●●●● (orange, graded full to faint)
Increased regional stakeholder engagement	●○○○○ (orange)	●●●●● (orange, graded full to faint)

LPC Benefits

LPC Benefits	VS	VTL
Reduced LPC wholesale purchases	●○○○○ (dark)	●●○○○ (dark)
Increased ability to maintain low rates	●○○○○ (blue)	●●○○○ (blue)
Improved insights and coordination with TVA on regional planning	●○○○○ (orange)	●●●●● (orange, graded full to faint)
Improved reliability	●○○○○ (orange)	●●●●● (orange, graded full to faint)

Customer Benefits

Customer Benefits	VS	VTL
Improved reliability	●○○○○ (dark)	●●○○○ (dark)
Enhanced decision making for more economical decisions (e.g., keeping rates low)	●○○○○ (orange)	●●●●● (orange, graded full to faint)
Increased stakeholder engagement in decision making	●○○○○ (orange)	●●●●● (orange, graded full to faint)

●●●●● Amount of potential benefits on a scale of 1-5

- ● Quantitative
- ● Semi-quantitative
- ● Qualitative

- VS Valley Standard
- VTL Valley Transformational Level

RESOURCE CO-OPTIMIZATION

Implementation Considerations

People Who May Be Impacted

- Corporate communications
- Distribution system planning (LPC)
- Transmission planning (TVA)
- Generation planning (TVA)
- Finance
- IT (including cybersecurity)
- Forecasting groups
- Legal (confidentiality)
- Continuous improvement
- Customer program development groups
- Customer pricing
- Business development
- Data governance
- Data management
- Sustainability/environmental affairs

Processes That May Be Impacted

- Data and information inputs and outputs are more regularly shared among system owners (e.g., distribution load forecast from LPC to TVA is comprehensive and regular; as are demand point detail, timing, metrics, criteria from TVA to LPC) to ensure alignment in planning and operations, visibility across systems and coordinated decision-making.
- Data and information inputs/outputs are shared among system owners using a formal standardized process to streamline collaboration among system owners, ensuring consistency, accuracy and timeliness of exchanged information.

Potential Challenges of Implementation

- Shifting to a collaborative and co-optimized planning approach may encounter resistance to behavioral change requirements.
- Stakeholder management may be a challenge if there are varying priorities and objectives across stakeholders.
- Information-sharing processes and procedures can be challenging due to differing data standards, privacy concerns and system compatibility issues.
- Lack of trust between system owners and other stakeholders can hinder cooperation and the willingness to share critical data.
- Coordination and scheduling of multiple planning departments can be resource-intensive and prone to misalignment of schedules or priorities.
- Development of data flows and interfaces to integrate systems is a technical challenge, as systems must be reliable and secure to facilitate efficient and accurate resource co-optimization.

Enabling | Planning and Assessing | Value Generating | Enhancing

Resource Co-Optimization

Load and DER Forecasting and Operationalization

DER Incorporation and Optimization

Load and DER Forecasting and Operationalization

CATEGORY	STAGE
Enhanced T&D Operations	Enhancing

LOAD AND DER FORECASTING AND OPERATIONALIZATION

Overview

DEFINITION

Predicts load and load offset due to customer behavior, existing operating DER (demand response, energy efficiency, solar photovoltaic, battery energy storage systems, electric vehicles, etc.), near-term weather and other load drivers (economic and noneconomic) to produce spatially and temporally granular load forecasts accounting for scenarios and sensitivities (single to multifactor) and implemented within grid operations. Operational forecasting horizon is from real-time to up to ten days.

SUPPORTING TECHNOLOGIES

- SCADA (source of forecasting data and representation of DER)
- OMS (indicator of DER on the circuit)
- Spreadsheets (forecast tool)

CAPABILITY IMPORTANCE

High penetration of variable load and DER drives the need for multiple near-term scenarios and forecasts to reduce risks and prepare for new impacts to the grid.

By considering operational impacts from near-term forecasts, LPCs can move from a reactive to proactive operational state. The ability to be proactive can lead to more efficient operation and reduced maintenance costs.

LOAD AND DER FORECASTING AND OPERATIONALIZATION

Maturity Levels

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-2 Years	1-2 Years	1-3 Years	1-3 Years
Load Forecasting Methods	Load forecasting methods with no or minimal use of estimated seasonal extremes (peak and valley) to produce top-down system-level, substation-level, transformer-level or feeder-level load forecast results.	Load forecasting methods use trend analysis for system-level, substation-level, transformer-level or feeder-level load forecast results (usually based on historical trends of annual or seasonal data processed for operational needs).	Load forecasting methods that calculate both an average value and a range of possible outcomes based on a probability distribution of peak load events (e.g., 1-in-5, 1-in-10, 1-in-20)[1] to complement trend analysis to produce system-level, substation-level, transformer-level or feeder-level load forecast results.	Load forecasting methods reconcile disaggregated load forecasts (e.g., by end use and customer class) to validate top-down system-level, substation-level, transformer-level or feeder-level load forecast results. Combination of disaggregation results with top-down methods to optimize forecast results.	Load forecasting methods use statistical forecast and machine learning methods to complement trend analysis. The methods are also complemented by all available forecasting techniques to maximize the accuracy of the forecasts. Forecasting methods use actual end point load data.
DER Forecasting	Includes no or minimal use of load offsets from DERs.	Identifies circuits with potential DER impacts and is used for initial estimate of load offsets from DERs (curtailable load or demand response potential). Includes estimate of Energy Efficiency as part of load offset.	Includes data-supported (trend analysis) and/or model-based methods to forecast load offsets from DERs (curtailable loads and demand response potential, EE, PV, BESS, EV, etc.).	Includes data-supported (trend analysis) and/or model-based methods to forecast load offsets from DERs (curtailable loads and demand response potential, EE, PV, BESS, EV, etc.). In addition, weather impacts are simulated to adjust load offsets for operational use.	Includes data-supported (trend analysis) and/or model-based methods to forecast load offsets from DERs (curtailable loads and demand response potential, EE, PV, BESS, EV, etc.). In addition, weather impacts and behavioral impacts are simulated to adjust load offsets for operational use.

1 1-in-5, 1-in-10 and 1-in-20 refer to peak demand under conditions that have a 20, 10 and 5 percent chance of being met or exceeded, respectively.

LOAD AND DER FORECASTING AND OPERATIONALIZATION

Maturity Levels (Continued)

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-2 Years	1-2 Years	1-3 Years	1-3 Years
Grid Integration	Includes no or minimal integration of operational load forecasts to real-time grid analysis and/or generation dispatch tools.	Includes manual integration of operational load forecasts to real-time grid analysis and/or generation dispatch tools.	Includes some automatic integration of operational load forecasts to real-time grid analysis and/or generation dispatch tools.	Includes fully automatic integration of operational load forecasts to real-time grid analysis and/or generation dispatch tools.	Includes high fidelity operational load forecast results and key scenarios that are integrated to real-time grid analysis and/or generation dispatch tools.
Load Forecasting Scenario Analysis		Includes no or minimal use of operational scenario analysis based on adjusting key load forecast factors.	Includes operational scenario analysis based on adjusting key load forecast factors. Visualization of the increasing uncertainty over time for operational forecasts is available to operators.	Includes sensitivity analysis to load drivers such as economic and noneconomic (weather and behavior).	Includes operational scenario analysis based on operational level risk preference (conservative, normal, aggressive).
Load Forecasting Temporal Granularity		At a minimum, lead forecasts for monthly peaks at system-level, substation-level, transformer-level or feeder-level processed for operational needs.	At a minimum, load forecasts are derived from daily peak forecasts and scaled to hourly load forecasts by forecasted daily load shapes.	Developed for sub-hourly increments (15 minutes).	Based on sub-hourly increments (5 minutes)

VS Valley Standard VTL Valley Transformational Level

LOAD AND DER FORECASTING AND OPERATIONALIZATION

Potential Benefits

Incorporation of high-precision load and DER forecasting into operations enhances grid efficiency by improving short-term decision-making, optimizing available resources and reducing costs. More accurate hourly and sub-hourly forecasting enables better integration of demand-side management and DER resources, lowering reserve margins, fuel costs and maintenance expenses.

Operationalization of load and DER forecasting enhances grid efficiency by improving short-term decision-making, optimizing available resources and reducing costs.

TVA Benefits

TVA Benefits	VS	VTL
Reduced reserve margin	●○○○○	●●○○○
Reduced fuel costs	●○○○○	●●○○○
Improved hourly and sub-hourly operation of the G&T system	●○○○○	●●○○○

LPC Benefits

LPC Benefits	VS	VTL
Reduced maintenance costs	●○○○○	●●○○○
Reduced overall system costs	●○○○○	●●○○○
Improved ability to operate grid efficiently	●○○○○	●●○○○
Improved operational decision making	●○○○○	●●●●●

Customer Benefits

Customer Benefits	VS	VTL
Reduced customer costs	●○○○○	●●○○○
Improved utilization of customer DER	●○○○○	●●○○○
More optimal business cases for adding DER to the grid	●○○○○	●●●●●

●●●●● Amount of potential benefits on a scale of 1-5

● Quantitative
● Semi-quantitative
● Qualitative

VS Valley Standard
VTL Valley Transformational Level

LOAD AND DER FORECASTING AND OPERATIONALIZATION

Implementation Considerations

People Who May Be Impacted

- Distribution planning
- Distribution operations
- IT/OT
- Data science/analytics

Processes That May Be Impacted

- Forecasting processes will incorporate more granular, real-time data and advanced analytics to account for DER behavior, weather and customer activity.
- Load allocation processes will be impacted by the need to dynamically distribute load based on highly variable factors, such as DER output and customer demand patterns.
- Distribution planning processes will include more localized and temporally granular forecasts, integrating DER behaviors and scenario analysis.
- Business planning will need to align with new forecasting insights, incorporating DER projections, customer behavior and economic factors.
- Communications to TVA will be improved to ensure timely and accurate dissemination of forecast data across departments.

Potential Challenges of Implementation

- Technology implementation requires significant investment in forecasting tools, data integration systems and communication infrastructure. Interoperability with existing systems, managing deployment timelines and addressing cybersecurity concerns should be considered.
- Analytical training and skills for staff are necessary to develop, maintain and interpret complex forecasting models.
- Scenario development and management can be resource intensive and challenge to align with operational priorities.
- LPCs will need to develop robust strategies to incorporate and respond to weather impact information.

Enabling | Planning and Assessing | Value Generating | Enhancing

Resource Co-Optimization

Load and DER Forecasting and Operationalization

DER Incorporation and Optimization

DER Incorporation and Optimization

CATEGORY

Enhanced T&D Operations

STAGE

Enhancing

DER INCORPORATION AND OPTIMIZATION

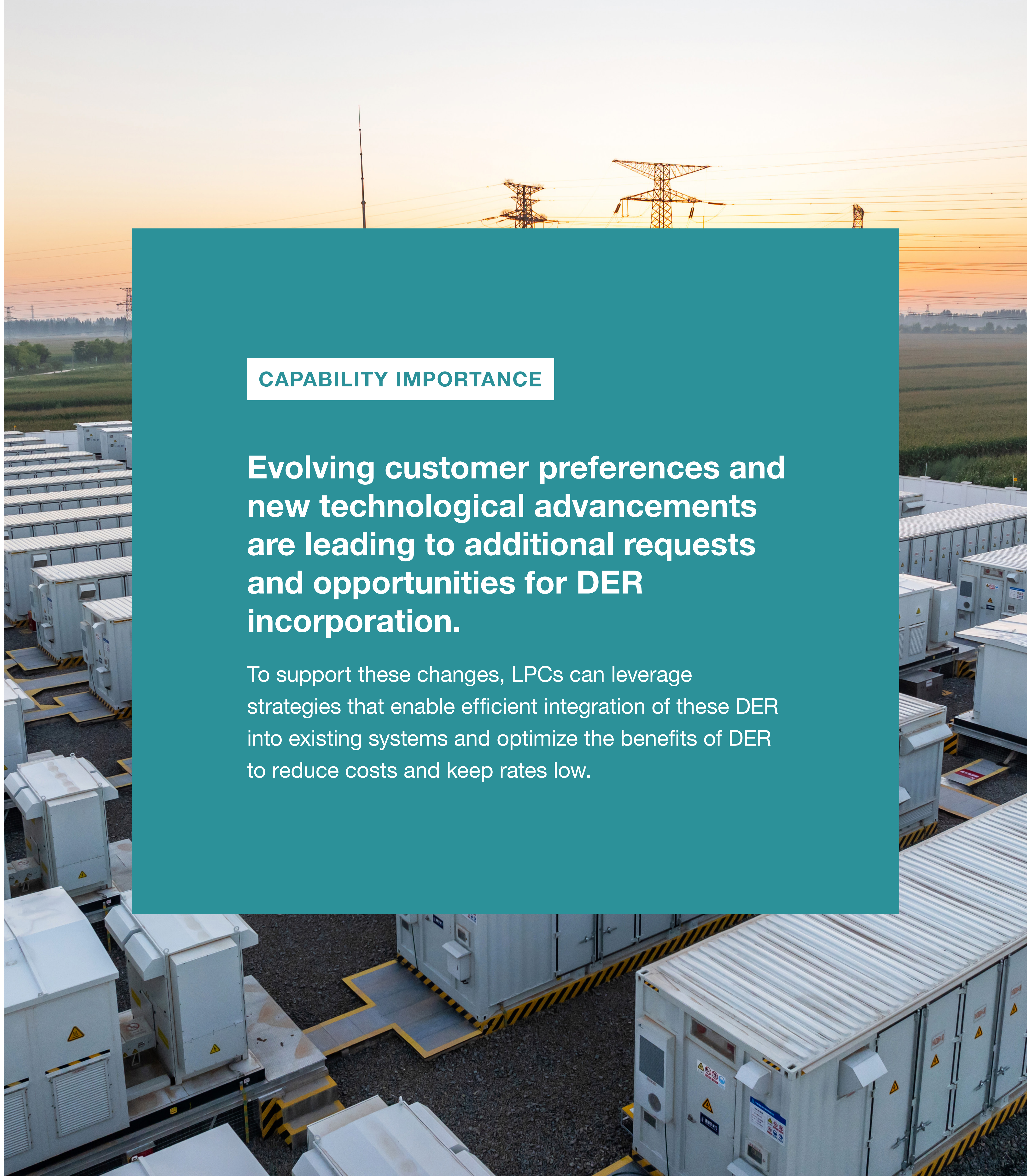
Overview

DEFINITION

The ability to include distributed energy resources (DER), such as battery energy storage systems, electric vehicles and photovoltaics, as part of overall demand and generation management operations.[1] Examples of optimization include operating and capital expenses.

SUPPORTING TECHNOLOGIES

- Communication technology for demand flexibility process (e.g., dedicated communication infrastructure with participating sites and communication channels with aggregators)
- Established reporting tools and dashboards



CAPABILITY IMPORTANCE

Evolving customer preferences and new technological advancements are leading to additional requests and opportunities for DER incorporation.

To support these changes, LPCs can leverage strategies that enable efficient integration of these DER into existing systems and optimize the benefits of DER to reduce costs and keep rates low.

[1] Grid flexibility is represented across multiple CPMs, including grid optimization, self-healing grid, customer experience management and DER incorporation and optimization.

DER INCORPORATION AND OPTIMIZATION

Maturity Levels

	Level 1	Level 2 VS	Level 3 VTL	Level 4	Level 5
Est. Time at Level	N/A	1-2 Years	2-3 Years	2-5 Years	2-5 Years
Load and DER Control Targets	Not calculated or used.	Manually calculated and available.	Calculated through a consistent process and is visible in the control center.	Calculated within an Operational Technology (OT) system and available.	Automated and optimized for the system.
DER Visibility	Limited (0-25%) visibility of DERs including manual (non-registered) summary by system, substation and feeder.	Some (1-25%) DERs are registered or estimated in OT system(s).	Many (26-50%) DERs are visible in OT system(s) with the ability to at least estimate real-time generation by installation.	Most (51-75%) DERs are modeled in the control system and there is visibility with DER metering capabilities/load disaggregation with real-time operational detail.	Almost all (76-95%) DERs are modeled in the control system and there is visibility with DER metering capabilities / load disaggregation with real-time operational detail.
Demand Flexibility	Not actively used.	Services can be manually triggered from the control center on a system-wide basis.	Events are manually triggered and coordinated with the operation of Demand Management System (DMS) functions. Flexible demand calculations are performed at the feeder level.	Events are partially triggered by automated requests and coordinated with the DMS functions. Flexible demand calculations can be performed down to the lateral level.	Service requests are fully automated as a mechanism to support the operation of advanced DMS functions. Flexible demand calculations can be performed down to the premise level.
Control	Control of DER is not present.	The organization has the awareness of potential benefits for control capability of loads and DER (>250 kW), including both emergency (e.g., ELCP) and economic signals.	Open-Loop control[3] can be performed for curtailing load and managing DERs (>250 kW) system-wide, by region, by substation or by feeder.	Closed-Loop control option performed for curtailing load with need for operator intervention to perform actions (suggest mode) and can be performed system-wide, by region, by substation, by feeder or by lateral.	Closed-loop control option can be performed down to the premise level. Autonomy and accuracy of controls enable full automation under normal operating conditions (i.e., excluding abnormal conditions). Flexibility is incorporated in the economic and load-frequency control.

VS Valley Standard VTL Valley Transformational Level

DER INCORPORATION AND OPTIMIZATION

Potential Benefits

Incorporating and optimizing DER increases diversity of energy supply, reduces fuel costs and improves the economic efficiency of distribution assets. By increasing grid capacity to accommodate load growth and streamlining DER integration, LPCs can support economic development and enable programs that may offer cost savings for end-use customers.

Incorporating and optimizing DER reduces fuel expenses and improves the cost efficiency of distribution assets.

TVA Benefits

TVA Benefits	VS	VTL
Reduced fuel costs	●○○○○	●●○○○
Avoided generation costs from optimized EV charging	●○○○○	●●○○○
Improved regionwide load curtailment	●○○○○	●●○○○

LPC Benefits

LPC Benefits	VS	VTL
Reduced LPC wholesale demand charges from greater DER capacity	●○○○○	●●○○○
Additional revenue from easier EV charging infrastructure interconnection	●○○○○	●●○○○
Increased capacity for load growth	●○○○○	●●○○○
Improved worker safety	●○○○○ (semi-quantitative)	●●○○○ (semi-quantitative)
Improved ability to streamline integration of solar and battery storage	●○○○○ (qualitative)	●●●●● (qualitative)

Customer Benefits

Customer Benefits	VS	VTL
Lower monthly bills	●○○○○	●●○○○
Improved reliability	●○○○○	●●○○○
Increased diversity of electric supply sources	●○○○○ (semi-quantitative)	●●○○○ (semi-quantitative)

●●●●● Amount of potential benefits on a scale of 1-5

- ● Quantitative
- ● Semi-quantitative
- ● Qualitative

- VS Valley Standard
- VTL Valley Transformational Level

DER INCORPORATION AND OPTIMIZATION

Implementation Considerations

People Who May Be Impacted

- Distribution operations
- Distribution forecasting groups
- DR team
- Sales
- OT department

Processes That May Be Impacted

- Distribution operations are impacted as DER is incorporated on the system and load and DER control targets are calculated.
- Peak load management is improved with better visibility into DER, and demand flexibility can be automated with DMS.
- Service restoration will use distribution capacity management with DER support for local load transfer, supporting both local and regional service restoration.
- Volt/VAR control will be gained with integrated DER control, reducing system losses and further increasing hosting capacity.
- Network maintenance will increase as more advanced technologies and tools are integrated into the system.

Potential Challenges of Implementation

- Significant investment in technologies or initiatives that are displaced by new, better technologies or initiatives can lead to wasted resources, sunk costs and skill development misalignment.
- Additional training for staff for new tools and technologies, such as DMS, grid model data management, DERMS, FLISR and more.
- Change management and communications to ensure alignment and adoption of abilities.
- Demand flexibility program development and implementation can be complex, as it involves coordinating diverse DER, integrating advanced metering and control systems, and engaging customers effectively.
- Regulatory alignment on the participation models, rates, incentives and capabilities can require navigating different regulatory frameworks, balancing competing stakeholder interests and developing rate design and incentives.
- Staffing resources to support growing functions will require additional training, communications and capital to support individuals and departments in developing staff experience and knowledge.
- Availability and integration of data from flexible resources can be a challenge as poor data availability and integration can limit the ability to optimize DER, reducing grid efficiency and undermine efforts to balance supply and demand.
- Quality models are essential for optimizing DER operations, predicting demand flexibility and managing grid stability. Maintaining model accuracy can be challenging due to the variability of DER outputs and customer behavior patterns.

Capability Progression Model

TENNESSEE VALLEY AUTHORITY

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