TVA TENNESSEE VALLEY AUTHORITY

REGIONAL GRID TRANSFORMATION

Initiative Progress Report

VERSION TWO: 05/2024


START UP
TESTING IN
PROGRESS

Acknowledgments

The Tennessee Valley Authority (TVA) would like to thank the following organizations for their committed work to define and pursue the implementation of grid transformation within the TVA service region.

Their leadership will help the region build a resilient, flexible and integrated electric system that meets regional customer needs of the future.

Bowling Green Municipal Utilities

BrightRidge

Cleveland Utilities

East Mississippi Electric Power Association

EPB

Harriman Utilities Board

Huntsville Utilities

Jackson Energy Authority

Knoxville Utilities Board

Middle Tennessee Electric

Memphis Light, Gas, Water

North East Mississippi Electric Power Association

Nashville Electric Service

Pickwick Electric

Pennyrile Rural Electric Cooperative Corporation

Scottsboro Electric Power Board

Starkville Utilities

Tennessee Valley Authority

Tennessee Valley Public Power Association

Glossary

Conservation voltage reduction (CVR)

The reduction or replacement of energy sources that produce carbon emissions, such as coal, oil and natural gas, with energy sources that emit less or no carbon, such as wind, solar and nuclear energy.

Decarbonization

The reduction or replacement of energy sources that produce carbon emissions, such as coal, oil and natural gas, with energy sources that emit less or no carbon, such as wind, solar and nuclear energy.

Demand voltage reduction (DVR)

This is a strategy to lower the system operating voltage during the forecast peak window, thus reducing the energy delivered, which results in lower demand.

Digitalization

Enabling or improving processes by leveraging digital technologies and digital data.

Distributed energy resources (DER)

Small, modular, energy generation and storage technologies, such as solar panels and batteries, that provide electric capacity or energy where you need it.

Electrification

The process of replacing technologies that use fossil fuels, such as coal, oil and natural gas, with technologies that use cleaner electric energy sources.

Extreme weather events

Occurrences of unusually severe weather or climate conditions that cause devastating impacts on communities and natural ecosystems (e.g., tornadoes, storms, extreme heat and cold).

Situational awareness

An understanding of the current conditions of grid operations and performance

ACRONYMS

AMI	Automated metering infrastructure
AMR	Automated meter reading
BIL	Bipartisan Infrastructure Law
DE	Duke Energy
DER	Distributed energy resources
DOE	Department of Energy
EPB	formerly Electric Power Board of Chattanooga
EPRI	Electric Power Research Institute
ESG	Environment, society and governance
HU	Huntsville Utilities
IIJA	Infrastructure Investment and Jobs Act
IRA	Inflation Reduction Act
ISOP	Integrated System Operations Planning
KUB	Knoxville Utilities Board
LPC	Local Power Company
NES	Nashville Electric Service
ORNL	Oak Ridge National Laboratory
TVA	Tennessee Valley Authority
T&D	Transmission and distribution

Introduction

The Need for Grid Transformation

In today's energy landscape, significant trends are changing how we use energy. Remote work and smart home technologies continue to prosper, leading to increased reliance on cloud computing, web-based tools and energy-efficient appliances for improved productivity and quality of life. Businesses of all sizes are adopting technology advancements and sustainable practices to meet consumer demands, regulatory standards and energy conservation goals. The growing popularity of distributed energy resources (DER), such as solar panels and battery storage, reflects a move toward cleaner energy solutions in an increasingly electrified world.

These trends are transforming power supply dynamics, signaling the need for proactive planning and innovative solutions to meet future demands. According to the Department of Energy (DOE), **investments in grid expansion and modernization are essential**, given the aging infrastructure and increasing frequency of extreme weather events. To participate in and benefit from clean energy sources, the TVA service region must take action now to build a grid that supports a resilient, sustainable and prosperous future.

DOE INDEPENDENT ESTIMATES

Electricity transmission systems

NEED TO EXPAND BY

60%

by 2030 and may need to triple by 2050[1].

Extreme weather events

in the TVA service region make it clear that America's existing energy infrastructure will not endure their continuing impacts[1].

- 2022 **Winter Storm Elliott**
- 2021 **Texas Freeze**
- 2021 **Western Kentucky tornado**

Deploying advanced grid solutions

can increase the capacity of the existing grid to support

20-100 GW

of incremental peak demand when installed individually[2].

AT LEAST

91 GW

of peak demand growth expected within the next decade[2].

The number of clean energy generation and storage projects

slated to be added to the grid is growing and with the investments from the Bipartisan Infrastructure Law (BIL), even more clean energy sources will join the queue for grid integration[1].

Most solutions could be deployed on the existing grid in under

3-5 years

and at lower cost and greater value than conventional approaches[2].

For more information, explore the DOE Liftoff Report[1].

Aligning with the Vision

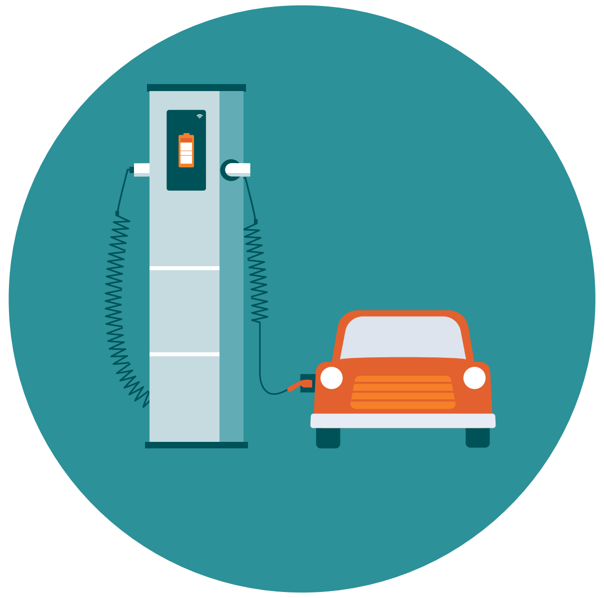
With a vast service territory spanning parts of seven southeastern states, the Tennessee Valley Authority (TVA) and its network of 153 local power company (LPCs) partners provide electricity to approximately 10 million residents and businesses. To ensure a thriving, resilient future for all, the region must work together toward a shared goal.

Valley Vision 2035 serves as a strategic framework, detailing key trends, challenges and opportunities shaping the future of the energy industry for the region. Outlined through a 24-month planning process involving a Collaboration Group representing regional stakeholders, Valley Vision 2035 addresses the emerging energy landscape and aims to create value for the entire region amidst evolving trends and uncertainties. This collaborative approach enables LPCs to tap into a wealth of collective knowledge and expertise, empowering them to make informed decisions and drive meaningful progress.

Exploring key drivers such as decentralization, electrification and decarbonization equips LPCs with the insights needed to anticipate future challenges and opportunities. By identifying key areas for investment and development, such as DER, smart grid technologies and customer engagement initiatives, LPCs can prioritize their resources and initiatives to maximize impact.

KEY DRIVERS

1. Decentralization



2. Electrification

3. Decarbonization

Transforming the Regional Grid

Valley Vision 2035 set the strategic direction for TVA and its partners to align, collaborate, leverage new technologies, create value for the region and prepare for the energy future. The Regional Grid Transformation (RGT) initiative aims to partner with LPCs to address regional challenges and pave the way for that future.

At the heart of RGT lies a commitment to empower LPCs with the tools, resources and expertise necessary to thrive in a dynamic energy marketplace. By integrating advanced technologies, optimizing grid operations and fostering collaboration between TVA and LPCs, RGT enables LPCs to enhance their capabilities in line with the objectives outlined in Valley Vision 2035 and collectively drive grid transformation across the region.

Valley Vision 2035 and the Regional Grid Transformation initiative have a shared goal to future-proof the power grid.

The Value of Grid Transformation

The long-term financial benefits of grid transformation improvements are more than double the initial investments, representing a significant return on investment for LPCs and business across the TVA service region. Envision an estimated $4-7 billion in net benefits across the region, with positive returns anticipated in less than a decade.

As we collectively invest in a dynamic grid system, these benefits echo throughout the entire region.

ESTIMATED

$4-7B **in net benefits**
across the TVA service region

GREATER THAN

2:1
benefit-to-cost ratio
yielded by investment

TIMEFRAME OF

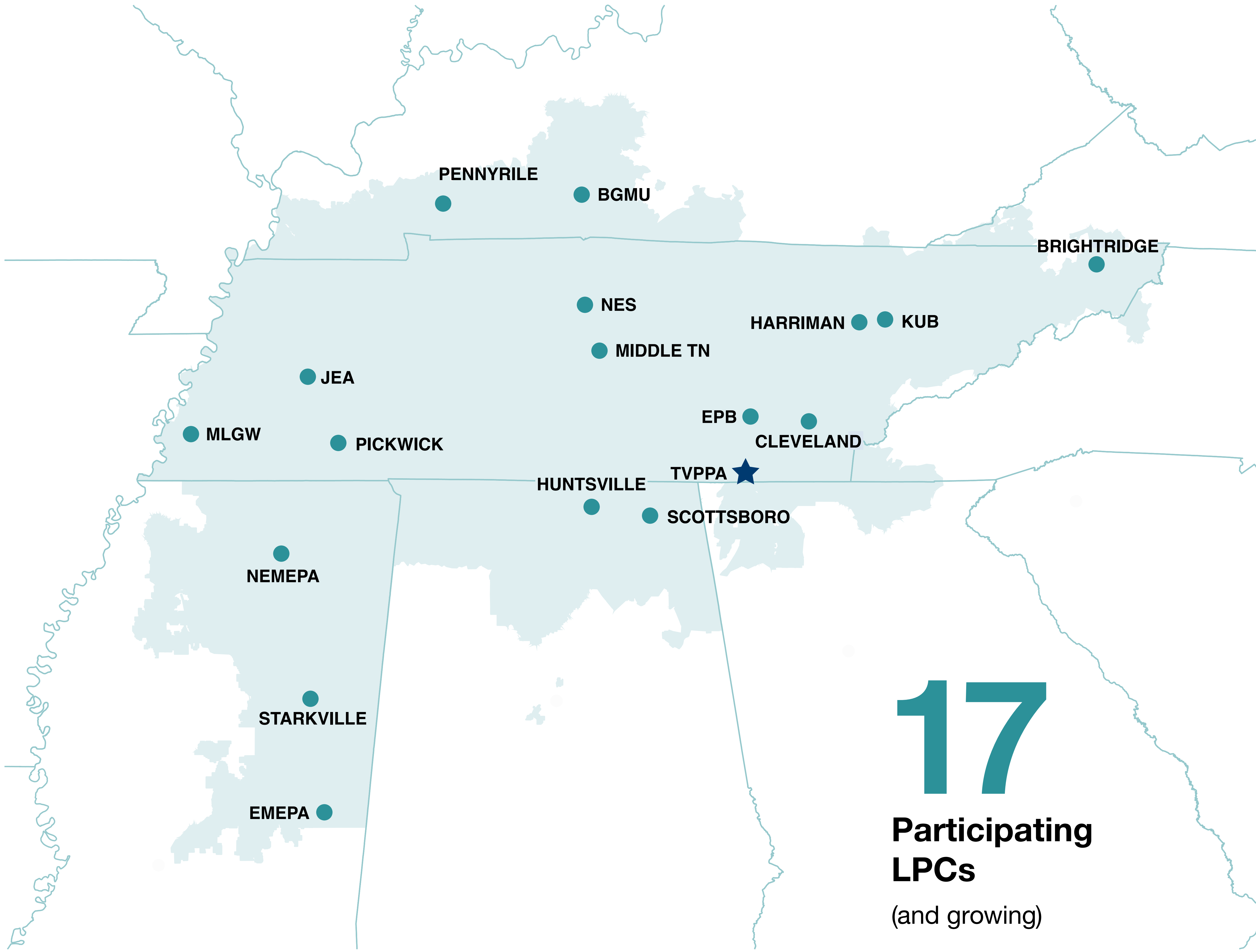
6-8
years
for net benefits to turn positive

Collaborative Approach

A major component of the RGT initiative is the creation of a new integrated planning model for LPCs and TVA to partner throughout the process of developing and maintaining an integrated grid.

The strength of the partnership between TVA, LPCs and other stakeholders is foundational in achieving an interconnected grid that builds a resilient, flexible and integrated electric system that meets customer needs of the future. The Working Team—the Electric Power Research Institute (EPRI), Tennessee Valley Public Power Association (TVPPA), TVA and 17 LPCs—outlined actions to implement, deploy and scale that will drive greater efficiencies, provide overall cost savings and deliver broad value for the region.

Transforming the regional grid will maximize value to communities and drive shared benefits by enhancing customer satisfaction and preserving energy affordability, resiliency and reliability.



17

Participating LPCs

(and growing)

Roadmaps

Roadmaps

TVA and LPCs have an opportunity to leverage data and technology to proactively prepare for more cost-effective and efficient operations while supporting technology, customer and societal needs. The Working Team realized the importance of building roadmaps that would support LPCs on their grid transformation journey.

Strategic Roadmap

By examining the electric power system holistically across generation, transmission and distribution, the Working Team carefully assessed the current grid through the lens of the trends and pain points facing the energy industry. The RGT Strategic Roadmap is the product of that collaboration and outlines the recommended capability areas and goals for advancement that support TVA's overarching strategy for pursuing grid transformation.

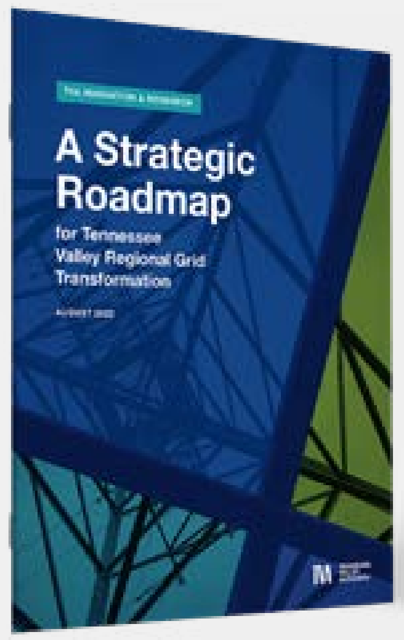
These capabilities are organized into five categories—referred to as Capability Areas, as defined in the RGT Strategic Roadmap.

5 Capability Areas

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

LPCs and communities can use the Strategic Roadmap to understand regional priorities and the actions needed to progress capability areas toward regional grid transformation.

Investments in these areas will result in benefits to LPCs, TVA, end-use consumers and the region. Regardless of their starting point, LPCs can review the Strategic Roadmap to understand the capabilities needed for grid transformation and how to accelerate, expand and create new value throughout the process.



Explore the RGT Strategic Roadmap to identify where your organization is on the path to grid modernization.

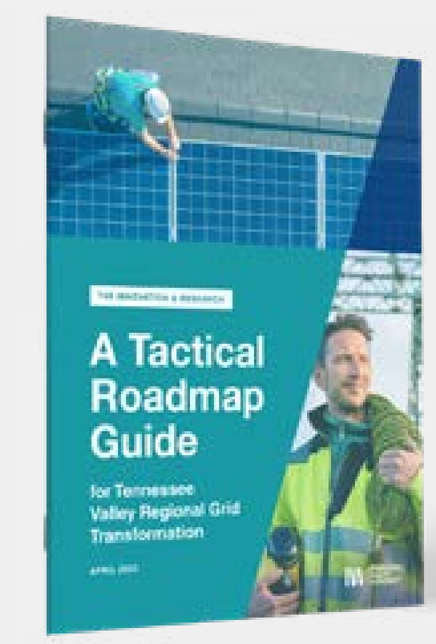
Tactical Roadmaps

While the Strategic Roadmap provides a high-level guide, it lacks detail on what the tactical, prescriptive process might look like for a specific LPC. That's where the RGT Tactical Grid Transformation Roadmaps come in.

Developed by the Working Team, the Tactical Roadmaps each feature a specific regional grid transformation plan, highlighting technologies or capabilities deployment for nine respective LPCs and TVA. The purpose of the Tactical Roadmaps is to provide more detailed information and insights about the individual actions of each participating LPC; each roadmap details the unique capabilities, needs, opportunities and challenges of a specific LPC, providing an in-depth look at an actionable RGT plan at the community level.

The wide range of roadmaps can help LPCs interested in RGT examine the approach another LPC with similar characteristics may be taking to transform their own grid. The variation in LPC Working Team members and their individual roadmaps demonstrate that every community can implement grid transformation projects, no matter size, current progress or priorities.

By outlining the technologies being explored or implemented and the estimated timelines for deployment, other LPCs can consider the activities and technologies that provide the most value and best help them prepare their grid for the future.



Explore the RGT Tactical Roadmaps to identify which activities and technologies best fit your organization's needs.

LPC TACTICAL ROADMAP

Huntsville Utilities

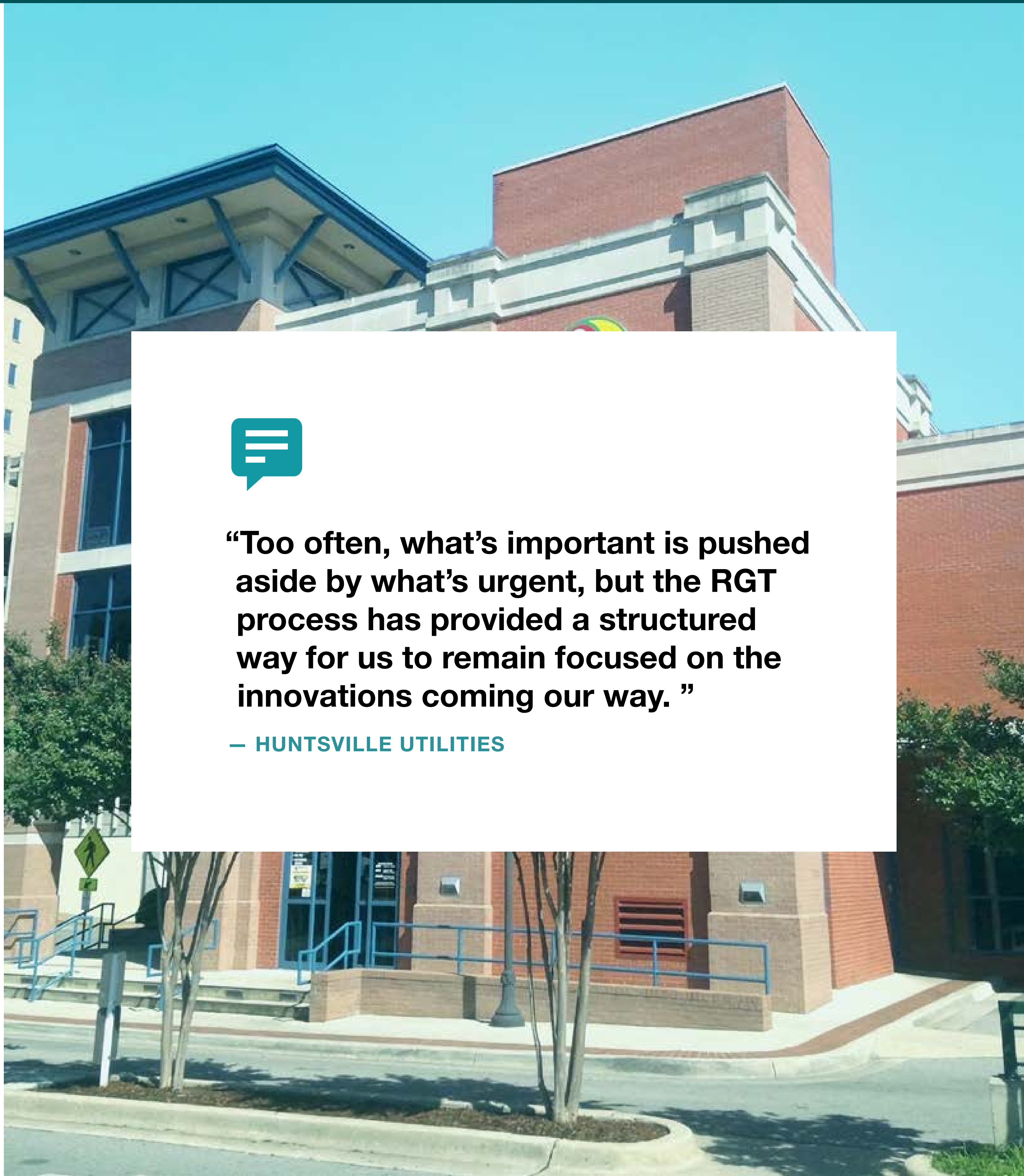
ALABAMA

200,000
Customers

HIGH
customer density

Huntsville Utilities' (HU) desire to increase reliability and resiliency for their customers led to their participation in the RGT initiative. To meet current and future customer expectations, HU plans to prioritize grid and operational improvements while maintaining electric rates at an affordable level. It also continues to evaluate other drivers, like local business development, new load growth and environmental considerations when assessing overall needs for grid improvements.

LEARN MORE



"Too often, what's important is pushed aside by what's urgent, but the RGT process has provided a structured way for us to remain focused on the innovations coming our way. "

— HUNTSVILLE UTILITIES

LPC TACTICAL ROADMAP

Bowling Green Municipal Utilities (BGMU)

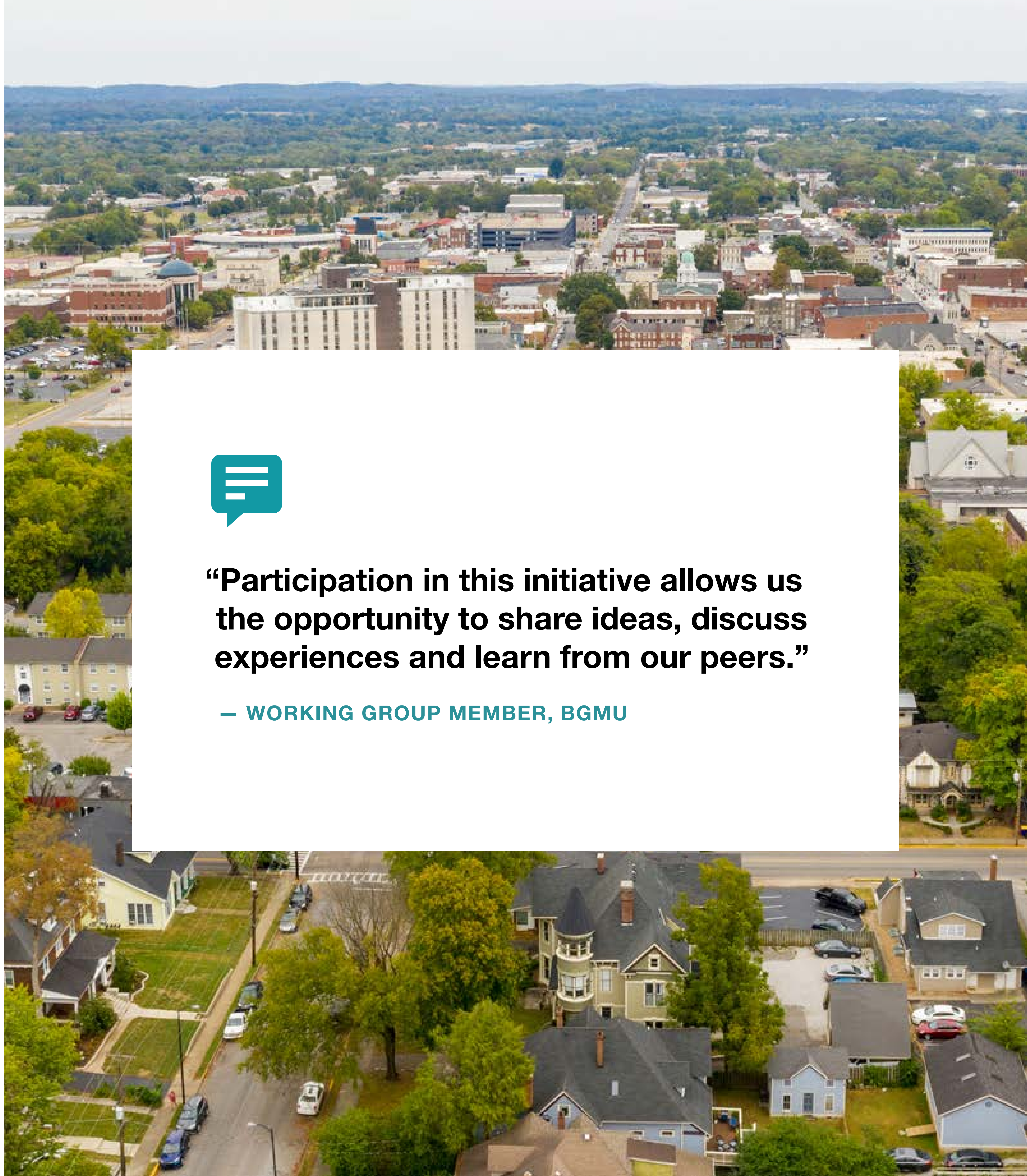
KENTUCKY

30,000
Customers

HIGH
customer density

BGMU joined the Working Team LPCs of the RGT initiative to provide the best service possible to their customers by working with TVA and LPCs to better prepare for industry changes. BGMU is a smaller utility and their participation in the Working Team and their perspective on grid transformations helps ensure RGT is reflective of all Valley LPCs. BGMU benefits from the interest and support of local leadership, enabling them to take part in this collaborative effort to help promote progress across the region.

LEARN MORE



"Participation in this initiative allows us the opportunity to share ideas, discuss experiences and learn from our peers."

— WORKING GROUP MEMBER, BGMU

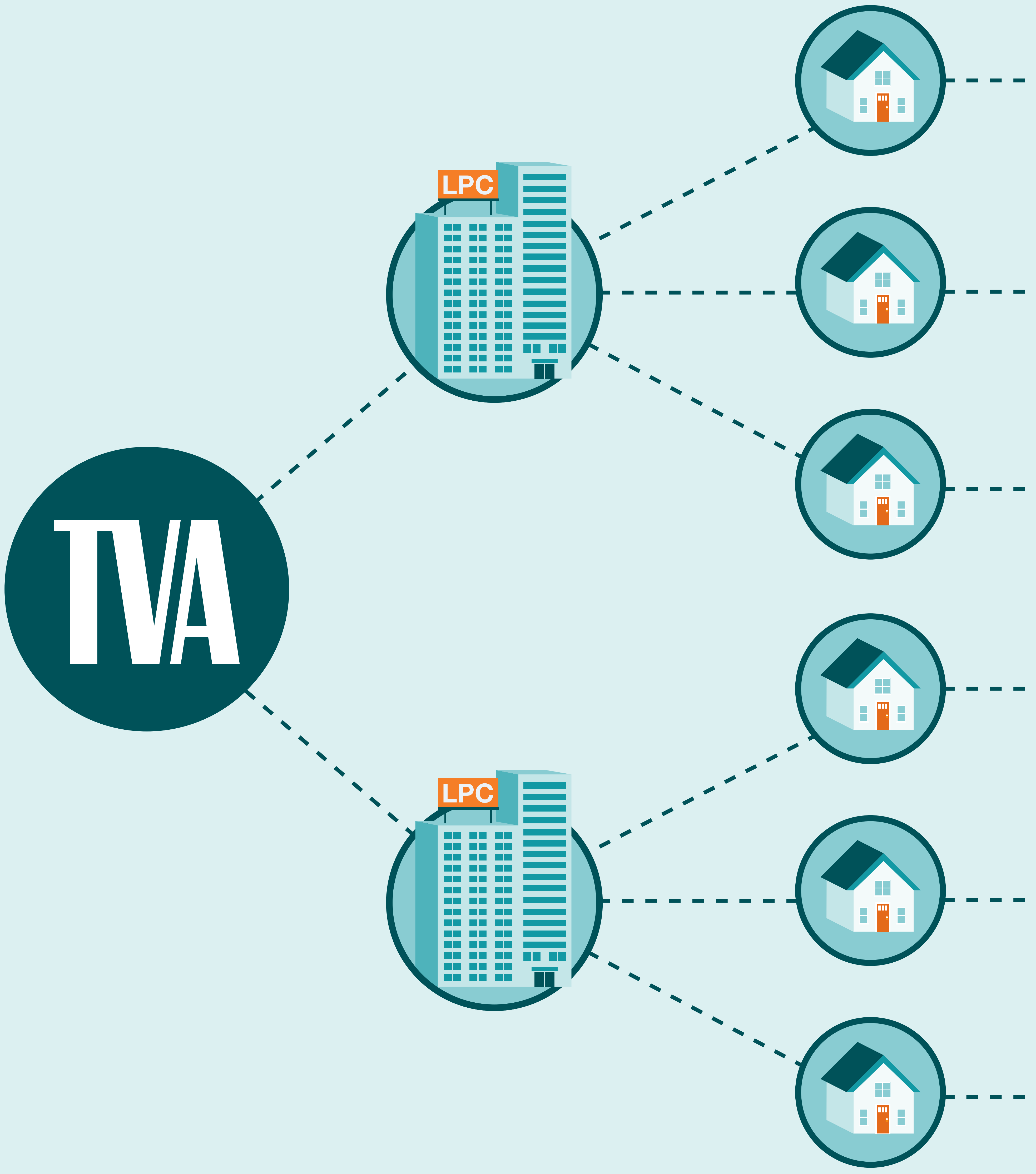
Taking Action

Taking Action

Transforming the regional grid will take stakeholders across the region working together to make progress in meaningful, substantial ways. LPCs and TVA can leverage their respective expertise and resources to develop comprehensive plans that address the unique needs and challenges of the TVA service region. Whether through collaborative pilot projects between LPCs and TVA or case studies highlighting individual LPCs making strides to modernize their grid, sharing of lessons learned and successful strategies ensures collective growth, action and advancement of Valley Vision 2035's focus areas.

"By sharing our resources, we can accomplish much greater things than any of us can accomplish individually."

— WORKING TEAM MEMBER, NASHVILLE ELECTRIC SERVICE (NES)



Pilot Projects

TVA is committed to helping LPCs make progress in areas that are most meaningful and valuable for their communities, organizations and end-use customers. To support advancement, RGT partners with select LPCs to pilot projects that produce scalable processes and repeatable results to better facilitate growth across the region.

This collaborative approach ensures alignment with Valley Vision 2035 and fosters a culture of innovation and continuous improvement across the TVA service region.

LPC PILOT

DER Interconnection

The DER Interconnection Pilot Project, a collaboration between TVA and ten LPCs, aimed to address challenges arising from the increasing deployment of DER like solar panels and battery storage in the TVA service area.

Through educational workshops, a maturity assessment and harmonization efforts, the pilot developed 82 recommendations for advancing interconnection practices across the region. This collaborative effort represents a significant step toward standardization and cooperation in DER interconnection processes, ultimately benefiting grid reliability and supporting the clean energy transition in the region.

LEARN MORE

LPC PILOT

Integrated Planning

In collaboration with TVA, HU participated in an Integrated Planning Pilot Project initiative to enhance their planning capabilities in alignment with the RGT strategic roadmap. Faced with challenges such as increased solar and combined heat and power (CHP) projects, growing loads and EV adoption, HU recognized the importance of integrated planning to address these issues effectively.

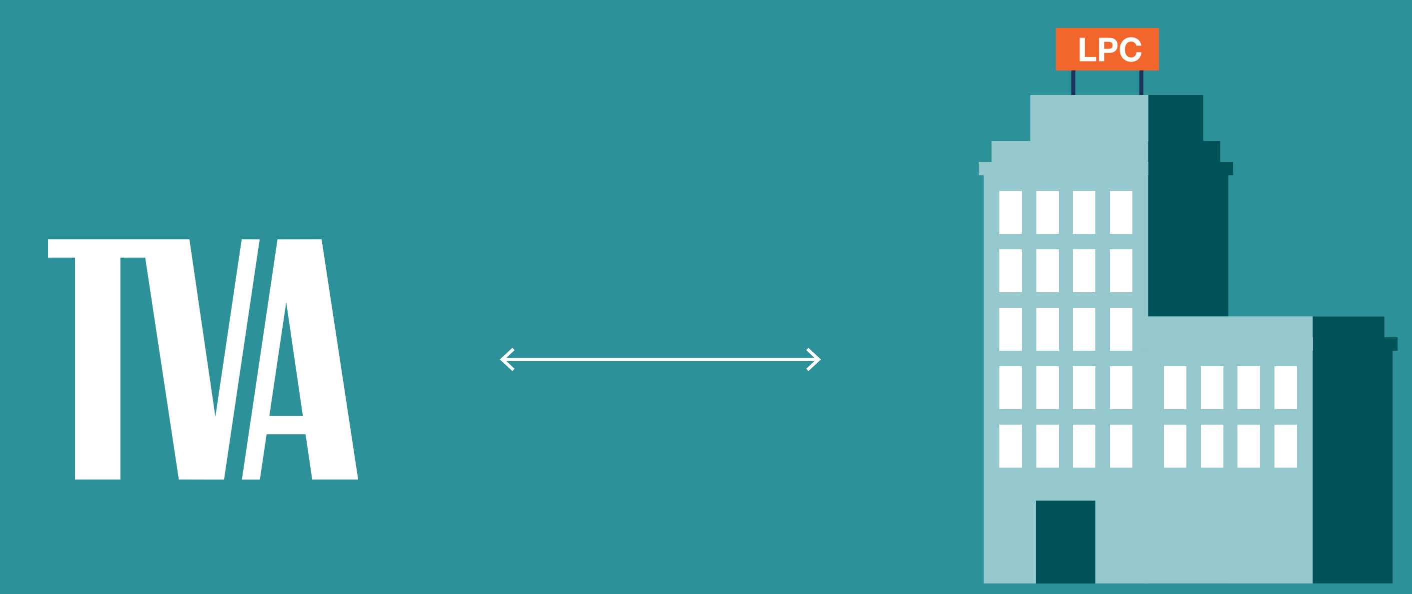
By applying Wide Area Distribution Analysis techniques and proactive planning for solar/storage and system upgrades, HU can now better anticipate and address future needs strategically. The pilot project not only benefited HU and its customers but also sought mutual benefits for TVA and regional LPC peers through holistic, outcome-based planning.

LEARN MORE

PROGRESS WITH PILOTS

The Integrated Planning Pilot Project provided measurable value and insight for the RGT initiative.

The team is building on this progress and momentum with the 2.0 Integrated Planning Pilot kicking off in 2024, providing additional learnings as the region continues on the path to collective grid modernization.



Case Studies

While pilot projects offer the opportunity for TVA and LPCs to partner on initiatives, LPCs are also making meaningful strides toward grid modernization on their own. LPC investments into new technologies and capabilities make their operations more efficient, customer-focused, reliable and resilient. The RGT team developed a series of case studies highlighting LPCs in pursuit of RGT goals. These resources offer lessons learned and recommendations for other LPCs that are exploring or already undertaking similar projects.

Case studies are published on the RGT website as they are developed, so keep an eye out for updates.

The energy future depends on projects, investments and upgrades that support grid modernization.

Case studies of successful initiatives provide vital insights that help other LPCs make progress in tangible, meaningful ways.

As RGT continues to evolve to meet the needs of our LPC partners, more case studies and lessons learned will be shared.

LEARN MORE

CASE STUDY

Investing in Advanced Metering Infrastructure (AMI)

PROJECT	TECHNOLOGY
Harriman Utility Board AMI Deployment	AMI

OBJECTIVE

Deploy smart meters throughout its distribution system to improve operational efficiency and expand customer offerings. Harriman Utility Board has not only improved its operational efficiency but also unlocked the ability to offer more tailored services to its customers.

Explore more about how Harriman Utility Board gained board approval and funding to invest in AMI.

CASE STUDY

Private LTE Network Trial:

PROJECT	TECHNOLOGY
West Kentucky Rural Electric Cooperative Corporation (WKRECC)	Private LTE Network

OBJECTIVE

Establishing a private LTE network enables WKRECC to integrate and optimize smart grid initiatives and enable several key functions for the utility, including SCADA, dynamic pricing, real-time monitoring and control of devices behind the meter—such as solar panels, batteries and appliances—and enhanced workforce capabilities for laptop users and truck drivers.

Explore more about how West Kentucky Rural Electric Cooperative Corporation (WKRECC) accelerated the modernization of its electric distribution system.

Capability Progression Model

Introducing the Capability Progression Model

The **Capability Progression Model** (CPM) is a framework designed to help LPCs identify which capabilities are necessary for 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 stakeholders 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 2035 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 Working Team wanted to assess the current state of transformation of the regional grid to provide value for every LPC, no matter where they stand on the path to grid modernization.

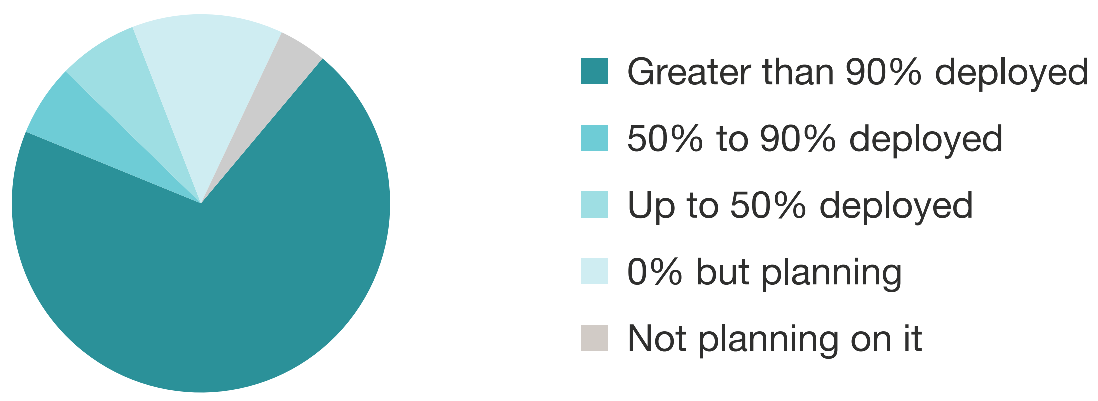
The Valley-Wide LPC Capability Assessment survey—which had a 96% response rate from LPCs—directly informed the capability standards and supporting technologies of the CPM. The CPM began as a technology-focused pyramid based on feedback from this assessment, and the results helped TVA and LPCs categorize capabilities as foundational or more advanced, setting proper expectations for LPC implementation.

96%

response rate from LPCs

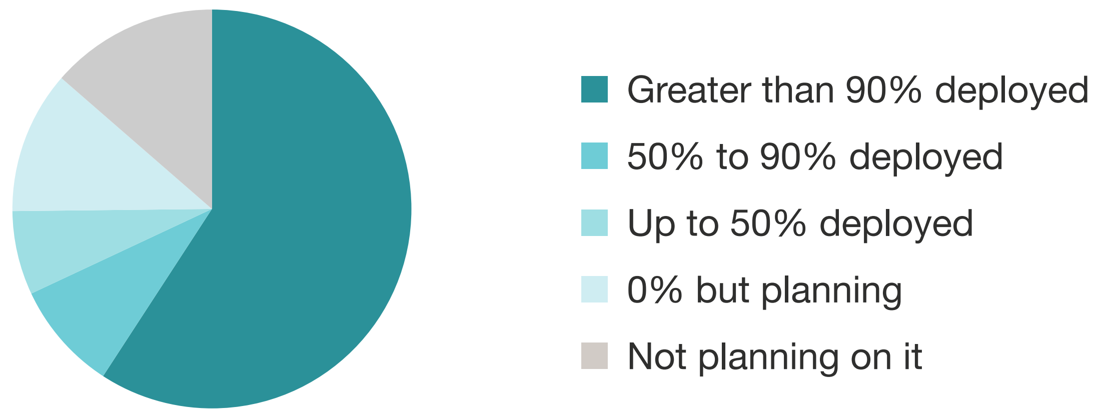
directly informed the capability standards and supporting technologies of the CPM.

AMI DEPLOYMENT



SCADA USE

FIBER OPTICS DEPLOYMENT



The 3 Stages of Capability Progression

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

As LPCs build **enabling** capabilities, achieving capabilities in the following two 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 → **3** 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 accommodates 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.

Capability Progression Model

1 Enabling

CAPABILITIES

- ✓ Cybersecurity
- ✓ Grid Situational Awareness
- ✓ Telecommunications
- ✓ Advanced Customer Metering
- ✓ Workforce Enablement
- ○ Data Governance
- ○ Data Analysis and Analytics

2 Planning and Assessing

CAPABILITIES

- ✓ System Modeling
- ✓ DER Interconnection
- ○ Load and DER Forecasting (Planning)
- ○ Load and DER Forecasting (Operations)

3 Value Generating

CAPABILITIES

- ✓ Grid Optimization
- ✓ Self-Healing Grid
- ○ Impact Assessment
- ○ Non-Traditional Alternatives Assessment
- ○ Traditional Resource Co-Optimization
- ○ Customer Experience Management
- ○ DER Incorporation and Optimization

CAPABILITY CATEGORIES

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

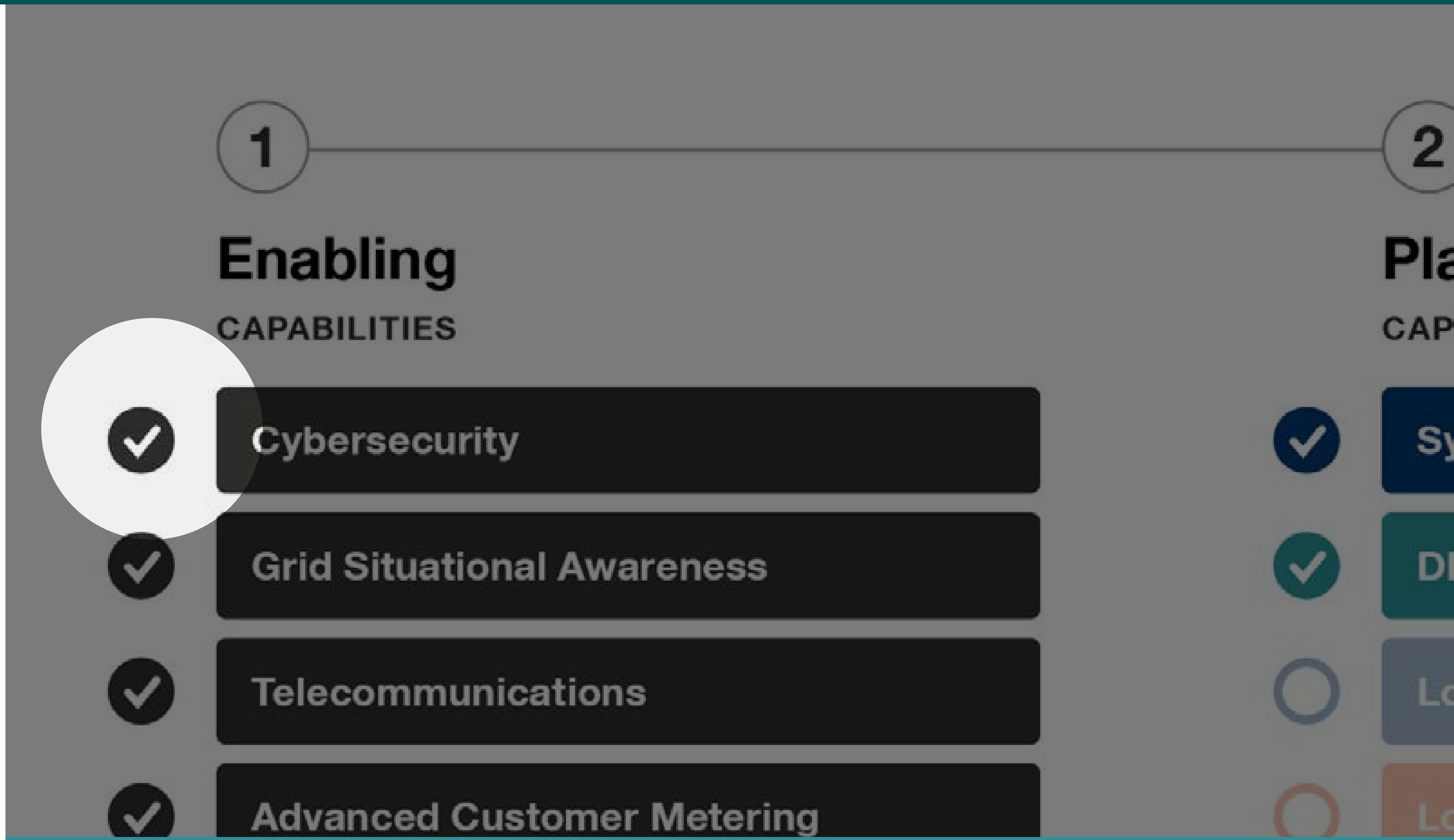
*Please note only the capabilities indicated with a checkmark have been researched and are included in this guide. All others are currently being explored and will be further defined in future updates.

- ✓ Initial Capabilities
- ○ Capabilities To Be Developed

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. Fortunately, the path forward is not linear; LPCs should plan to invest in the capabilities that have the highest value for their business and customers, today and in the future.

The path to achieving these goals will vary by LPC.



FOUNDATIONAL CAPABILITIES

Capabilities indicated with a check mark have been explored and are achievable by the majority of LPCs today. These priority capabilities have been researched with standards and supporting technologies detailed in this guide. All remaining capabilities are currently being explored and will be further defined in future updates.

Standards for Capability Progression

The RGT Working Team established 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

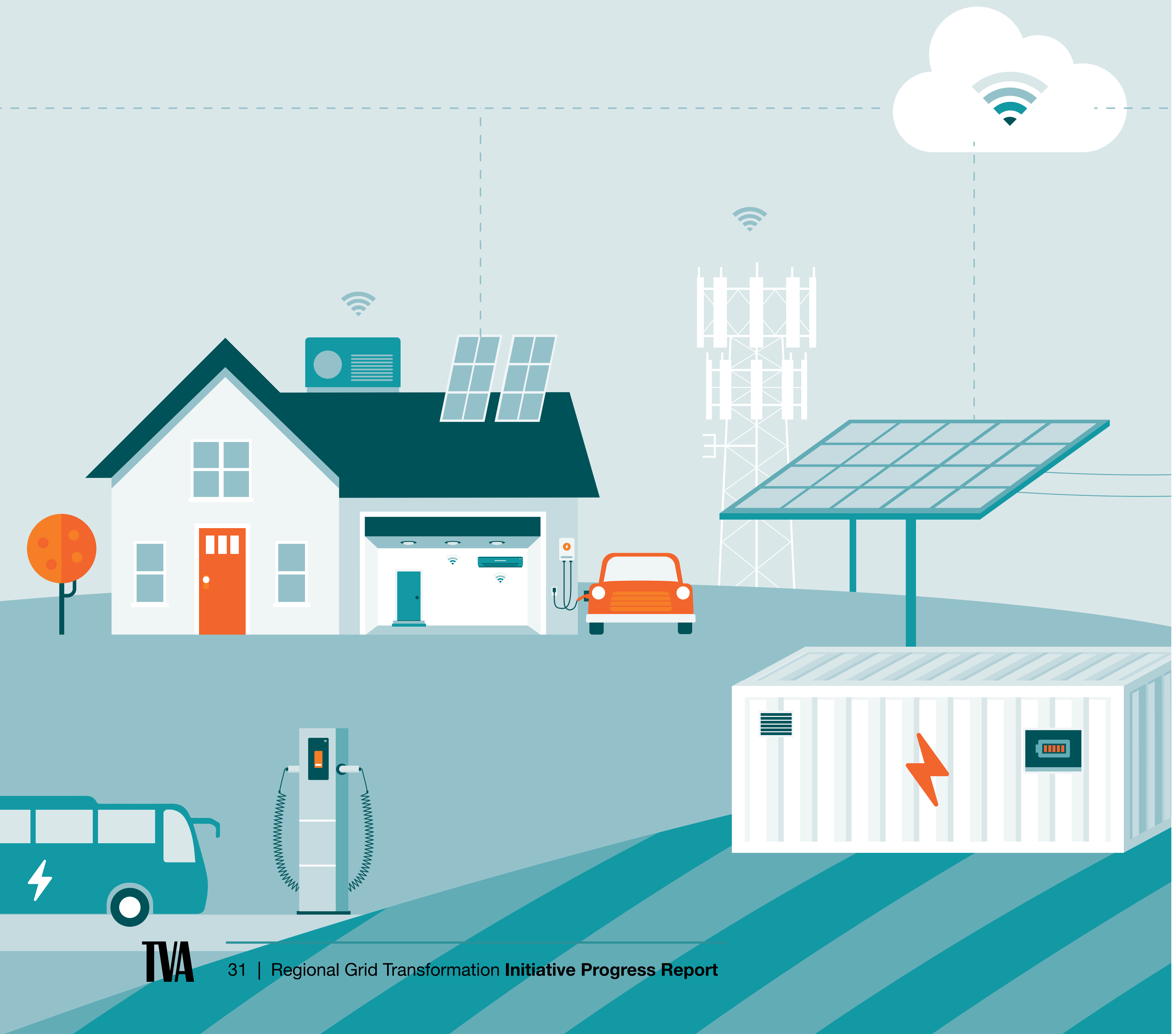
Valley Transformational Level

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

MOVING BEYOND THE VALLEY TRANSFORMATIONAL LEVEL

Grid modernization is a journey, and every LPC has a different starting point on the journey from achieving the VS to reaching the VTL. By achieving the VTL, LPCs and stakeholders will see benefits for their business and customers, and they will help other LPCs learn how to approach different investments and overcome challenges along the way. To achieve grid modernization at a regional level, several of the largest LPCs will need to make concerted efforts to modernize and achieve VTL status and beyond. 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.

Where is *your* organization on the path to grid modernization?



Progress Starts Here

Self-assessment empowers LPCs to identify best practices, pinpoint areas for growth and strategically chart our 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.

Begin your journey to grid modernization by exploring the Capabilities Model Index found at the end of this report to identify your organization's status and potential upgrades for the nine indicated capabilities.

Network of Initiatives

TVA is committed to supporting and facilitating a comprehensive approach to grid modernization that addresses the evolving needs of our communities and the energy landscape. The RGT initiative is making huge strides, and it's just one pathway TVA is exploring to progress toward a more resilient future.

The other TVA Innovation and Research initiatives below support RGT at the crossroads of the transmission and distribution systems to ensure a seamless regional experience. This holistic approach ensures that every aspect of grid modernization is addressed, from infrastructure upgrades to community engagement, ultimately delivering lasting benefits for all stakeholders.

Connected Communities

OBJECTIVE

Help communities embrace technology and data solutions to tackle local challenges and prepare to be a part of the energy system of the future.

LEARN MORE

Electric Vehicles (EVs)

OBJECTIVE

Prepare for and enable adoption of EVs across the TVA region in a way that creates benefits for communities and the grid.

LEARN MORE

Energy Storage

OBJECTIVE

Implement a long-term strategy to integrate energy storage for system flexibility and maximizing renewables.

LEARN MORE

Looking Ahead

Looking Ahead

The Working Team identified the goals, priorities and capabilities that will modernize the energy system; next, they will focus on the actionable steps LPCs and TVA can take to make it a reality.

Through the exploration of collaborative investments and strategic technical assistance, RGT seeks to maximize cost-savings and stakeholder benefits across the region.

By working closely with LPCs, TVA can help streamline efforts and increase efficiency to ensure collective progress toward shared goals.

RGT will continue to pursue regional advancement of grid modernization through the following activities:

1 Provide Funding Assistance

Infrastructure and technology investments can be expensive, and the federal funding landscape may be difficult to navigate. However, resources are available to help you along the way. TVA developed the Federal Funding Project Management Office (FFPMO) in April 2023 to help TVA and its LPCs secure federal funding in alignment with TVA's strategic priorities to bring more resources to the TVA service area.

Learn more about partnering with TVA on funding opportunities by contacting the FFPMO team.

2 Continue Capability Exploration

The path to regional grid modernization has just begun, and only the first nine capabilities have been explored. To ensure LPCs have detailed guidance and actionable recommendations, the Working Team will continue to explore the remaining capabilities to identify steps forward and refine resources accordingly.

3 Scale Case Studies

Transforming the regional grid will take intentional collaboration and the sharing of experiences. LPC partners across the region are already making progress in building a smart, automated, self-healing system. The capabilities, technologies and actions outlined by RGT enable LPCs to reduce disturbances and decrease maintenance costs, ensuring sustainability of not just the grid, but their businesses, as well. TVA is actively working to develop more case studies highlighting projects and initiatives that align with RGT technologies and capabilities.

4 Expand Integrated Planning

As we strive to make Valley Vision 2035 a reality, coordinating planning efforts across the region exposes stakeholders to new information about updated technologies, operational practices and load growth. The next integrated planning pilot project—beginning in 2024—will investigate processes and data sharing between TVA and LPCs to explore potential opportunities to optimize shared investments that result in meaningful change for the region.

A Beneficial Future

Valley Vision 2035 gave the region scenarios to consider, and RGT will help make them a reality. The region stands at the beginning of the journey to grid modernization, and TVA remains committed to partnering with LPCs and regional stakeholders every step of the way.

Once improvements and upgrades are successfully implemented to transform the grid, substantial benefits are realized at all levels. While there is an initial investment and associated costs, the advantages far exceed the original expense. A beneficial future is on the horizon for the region, but to realize it, we must act now.

Get Involved!

There is a place for every community alongside the RGT initiative. With your help, we will build a modern and sustainable infrastructure that powers our future.

Help define the energy future of our region.

If you, your LPC or your community are undertaking a project that aligns with an RGT technology or capability, contact your TVA customer relations manager or the RGT contacts below. There is opportunity for everyone and added benefits we can derive together as we prepare our communities for the future.

RGT CONTACTS

Jason Krupp

Sr. Project Manager,
Transformative Innovation
jakrupp@tva.gov
(615) 428-4849

Amy Henry

Director,
Transformative Innovation
abhenry@tva.gov
(865) 310-4839

Capability Model Index

As the RGT Working Team explores the remaining capabilities, this Index will be expanded to include maturity levels, implementation considerations and supporting technologies for all capabilities. Currently, this information has been included for Grid Situational Awareness and Grid Optimization, two critical capabilities that will unlock significant benefits across the region.

LPCs should feel empowered to use the information in this Index to develop their roadmap to achieve the Valley Standard and pursue the Valley Transformational Level for all grid modernization capabilities.

SCHEDULED UPDATES:

AUGUST 2024

Expanded details added for the following 2.0 capabilities*:

- Cybersecurity
- DER Interconnection
- Advanced Customer Metering
- Workforce Enablement
- Self-Healing Grid
- System Modeling
- Telecommunications

Q1 2025

Index entries added for 2.1 capabilities that have yet to be explored.

*These capabilities are indicated by a check mark in the CPM, as shown on the following page.

Capability Progression Model

TABLE OF CONTENTS*

CAPABILITY CATEGORIES

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

*Please note only the capabilities indicated with a checkmark have been researched and are included in this guide. All others are currently being explored and will be further defined in future updates.

✓ Initial Capabilities

○ Capabilities To Be Developed

Enabling | Planning and Assessing | Value Generating

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

Cybersecurity

CATEGORY	STAGE	STATUS
Grid Transformation Enabling	Enabling	Initial

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

- Data backups (Cloud or server)
- Intrusion prevention systems (IPS)
- Intrusion detection systems (IDS)
- Antivirus and malware solutions
- Securityinformation and event management (SIEM) system
- Data loss prevention (DLP) tools
- Advanced endpoint detection and response (EDR) solutions

CAPABILITY IMPORTANCE

As technology advances and more devices are connected to the grid, the risk of cyber threats increases.

Cybersecurity measures protect digital infrastructure, sensitive data and operations from cyber threats such as hacking, malware and data breaches. By safeguarding their systems 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

Cybersecurity Levels

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

	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] v2.1 Tier 1: Partial or equivalent in DOE C2M2[3]	LPC should be in accordance with NIST CSF[1] v2.1 Tier 2: Risk Informed or equivalent in DOE C2M2[3]	LPC should be in accordance with NIST CSF[1] v2.1 Tier 3: Repeatable or equivalent in DOE C2M2[3]	LPC should be in accordance with NIST CSF[1] v2.1 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

Enabling | Planning and Assessing | Value Generating

Grid Situational Awareness

CATEGORY	STAGE	STATUS
Grid Transformation Enabling	Enabling	✓ Initial

GRID SITUATIONAL AWARENESS

Overview

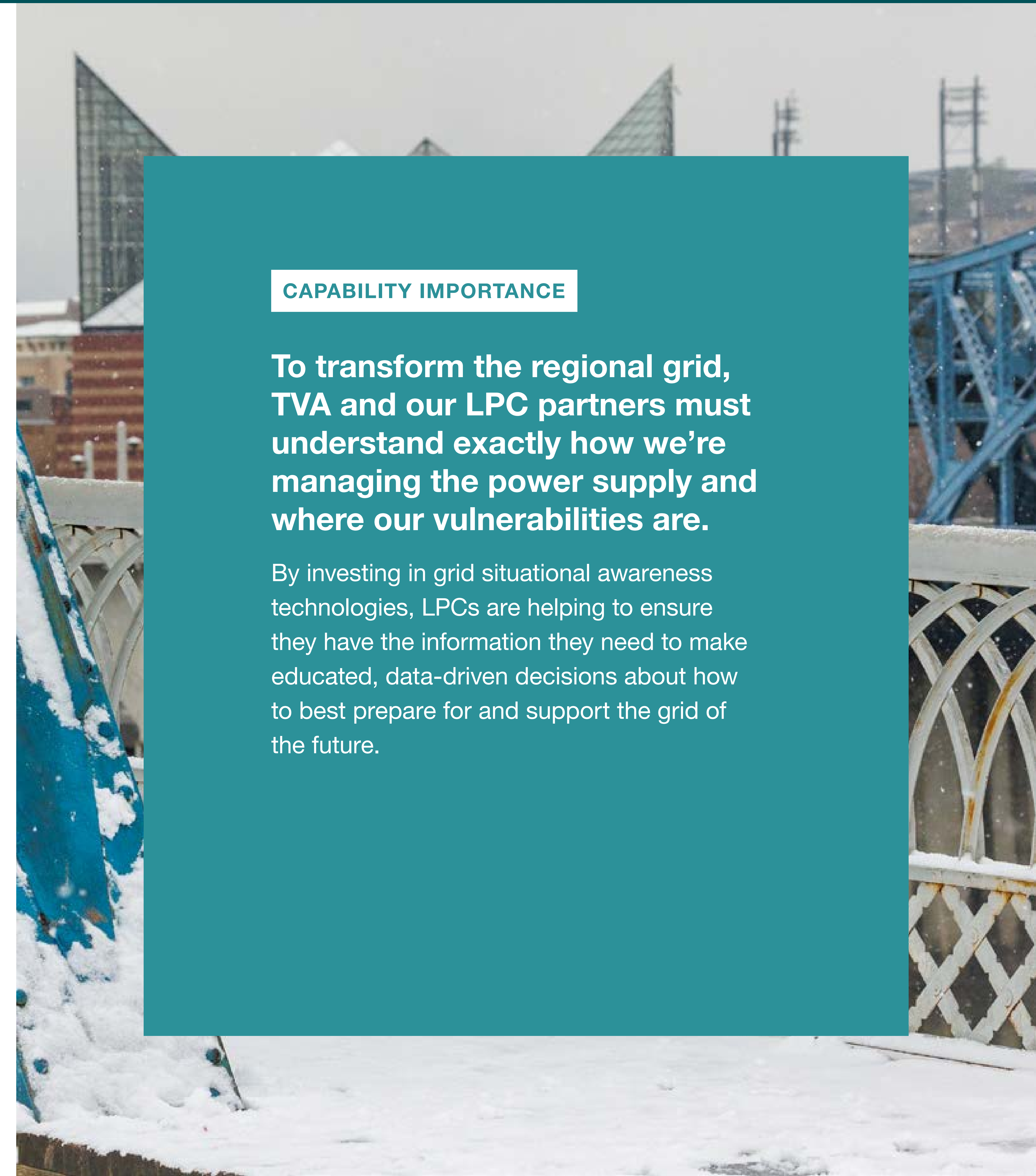
DEFINITION

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

SUPPORTING TECHNOLOGIES

- Fiber to substations
- Increased use of field area network (FAN)
- Cellular networks

Grid situational awareness is a critical capability for LPCs to prioritize and additional content has been provided to ensure stakeholders have the information they need to grow in this area.



CAPABILITY IMPORTANCE

To transform the regional grid, TVA and our LPC partners must understand exactly how we're managing the power supply and where our vulnerabilities are.

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

Potential Valley Stakeholder Benefits

TVA Benefits

Valley Standard (VS)

Grid Situational Awareness helps TVA respond to extreme weather by enabling LPCs to reduce capacity, improving near-term planning and ensuring reliable capacity reduction, while tracking EIA reliability metrics across the region.

Valley Transformational Level (VTL)

Optimized Grid Situational Awareness empowers LPCs to provide reliable, real-time capacity reductions for TVA during events, ensuring firm performance and enabling TVA to track impacts on EIA reliability metrics regionwide.

LPC Benefits

Valley Standard (VS)

Grid Situational Awareness uses cutting-edge technologies to empower LPCs with early visibility into disruptions, reducing truck rolls and enhancing communication through reliable data. This capability optimizes grid operations, minimizes outages, and provides comprehensive substation and line monitoring for informed, efficient maintenance planning.

Valley Transformational Level (VTL)

This level of Grid Situational Awareness provides LPCs with real-time fault location, reduces crew patrolling time and optimizes grid operations under N-1 and N-1-1 conditions, ensuring accurate substation and downline monitoring.

Customer Benefits

Valley Standard (VS)

Grid Situational Awareness benefits end-use customers by enabling power providers to identify service issues before customers even notice, resulting in shorter, less frequent interruptions and improved service reliability.

Valley Transformational Level (VTL)

Enhanced Grid Situational Awareness benefits customers by detecting most service issues early, reducing interruptions, improving reliability and providing better planning data to help lower medium-term costs.

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—we 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 remote visibility.	Remote visibility to **most (51-75%)** substations and s**ome (1-25%)** downstream devices.	Remote visibility to **almost all (76-95%)** substations and **some (1-25%)** downstream devices.	Remote visibility to **almost all (76-95%)** substations and **most (51-75%)** downstream devices.	Remote visibility to all substations and downstream devices.
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.	Status alarming displayed have been re-engineered to reduce the use of color to only abnormal conditions.	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.

Please note that an LPC must satisfy **all requirements** listed under the maturity level before that level has been achieved, including specifics listed under the penetration level.

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
- 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 etc.
- 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.

Pain Points That May Require Attention

- Deploying substation equipment could prove challenging due to long lead times on equipment, confusing standards, number of vendors etc.
- 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.

Telecommunications

CATEGORY	STAGE	STATUS
Grid Transformation Enabling	Enabling	✓ Initial

TELECOMMUNICATIONS

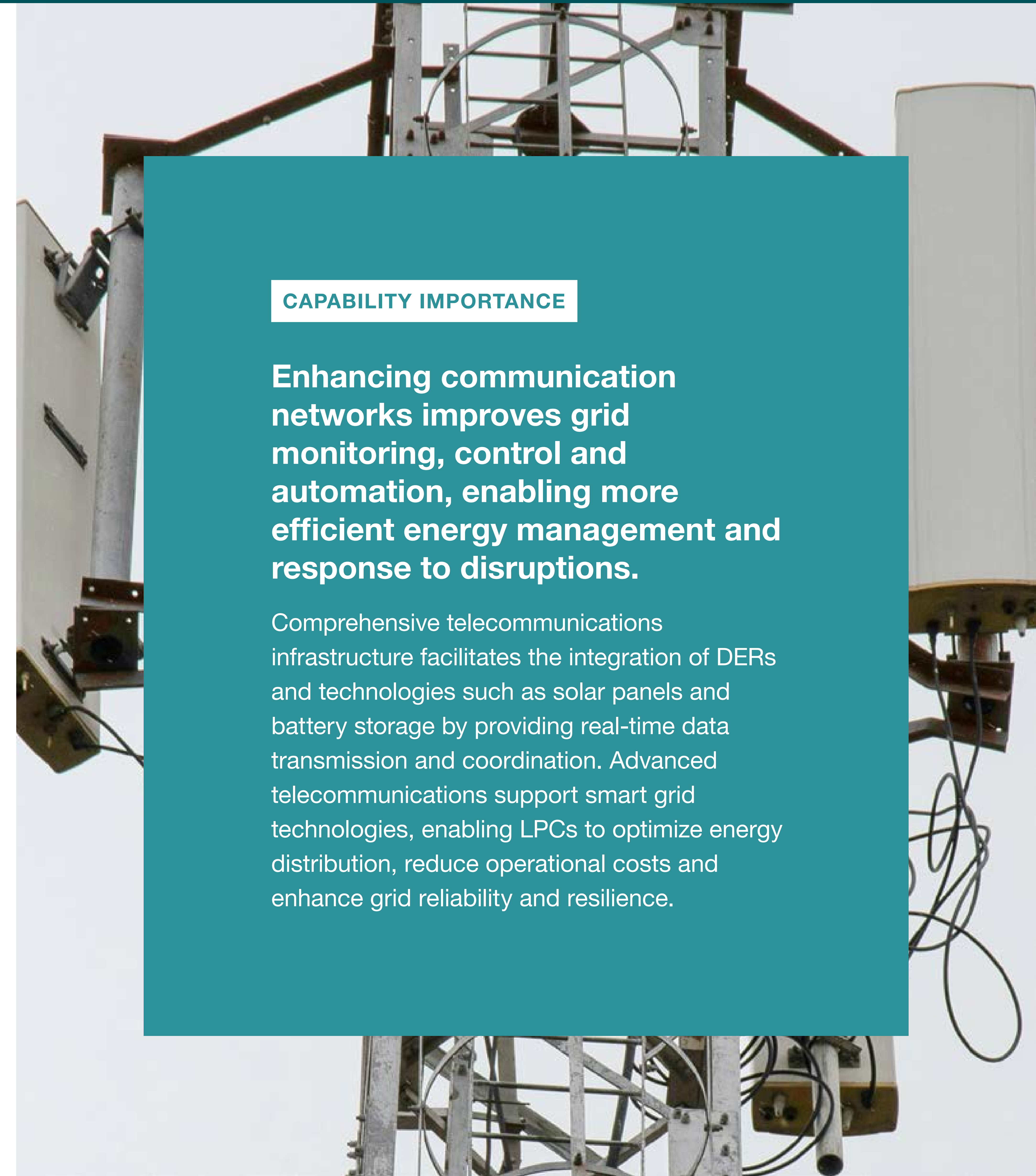
Overview

DEFINITION

Technologies used to transmit and coordinate information throughout the utility, supporting internal operations and enterprise objectives, and external communications with business partners and customers.

SUPPORTING TECHNOLOGIES

- Powerline communications (PLC)
- Copper wire (e.g., telecommunication leased lines)
- RF Mesh (e.g., 900 MHz)
- Zigbee or low power local networks
- Fiber, broadband, ethernet and WiFi
- LTE/5G for field area network (FAN)
- Software-defined networks (SDN)



CAPABILITY IMPORTANCE

Enhancing communication networks improves grid monitoring, control and automation, enabling more efficient energy management and response to disruptions.

Comprehensive telecommunications infrastructure facilitates the integration of DERs and technologies such as solar panels and battery storage by providing real-time data transmission and coordination. Advanced telecommunications support smart grid technologies, enabling LPCs to optimize energy distribution, reduce operational costs and enhance grid reliability and resilience.

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 (1-25%)** 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 (1-25%)** 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 connectivity to **some (1-25%)** larger customer loads and **some (1-25%)** larger capacity DERs.	Communication links are 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 (26-50%)** 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 is 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).

Please note that an LPC must satisfy **all requirements** listed under the maturity level before that level has been achieved, including specifics listed under the penetration level.

VS Valley Standard VTL Valley Transformational Level

Enabling | Planning and Assessing | Value Generating

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

Advanced Customer Metering

CATEGORY	STAGE	STATUS
Grid Transformation Enabling	Enabling	✓ Initial

ADVANCED CUSTOMER METERING

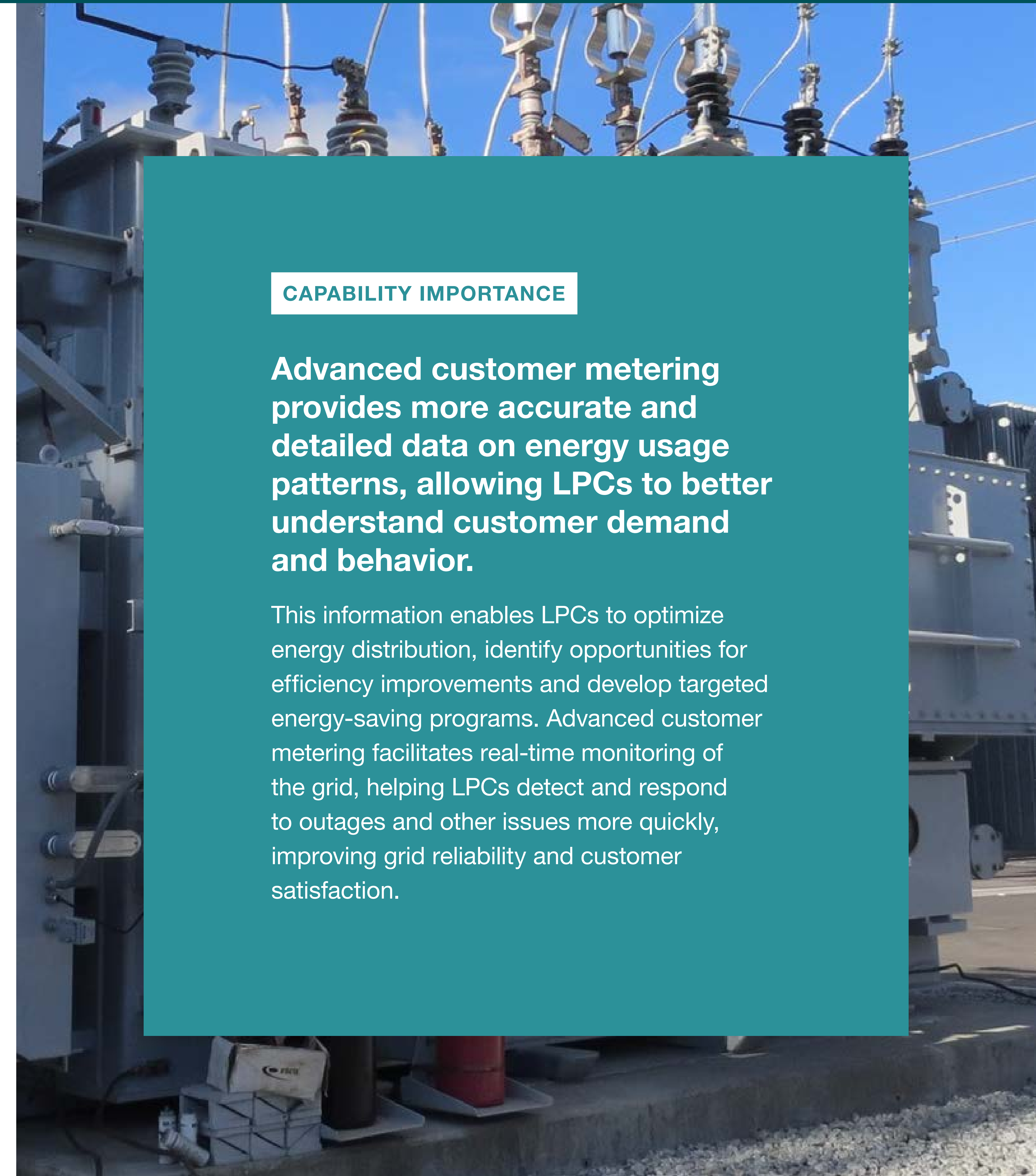
Overview

DEFINITION

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

SUPPORTING TECHNOLOGIES

- AMI meters
- Meter data management platforms (MDMS)
- Broadband communication technology (for example, mesh network, cellular, radio, fiber, ethernet)



CAPABILITY IMPORTANCE

Advanced customer metering provides more accurate and detailed data on energy usage patterns, allowing LPCs to better understand customer demand and behavior.

This information enables LPCs to optimize energy distribution, identify opportunities for efficiency improvements and develop targeted energy-saving programs. Advanced customer metering facilitates real-time monitoring of the grid, helping LPCs detect and respond to outages and other issues more quickly, improving grid reliability and customer satisfaction.

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 (51-75%)** or **almost all (76-95%)** 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.

Please note that an LPC must satisfy **all requirements** listed under the maturity level before that level has been achieved, including specifics listed under the penetration level.

VS Valley Standard VTL Valley Transformational Level

Workforce Enablement

CATEGORY	STAGE	STATUS
Grid Transformation Enabling	Enabling	Initial

WORKFORCE ENABLEMENT

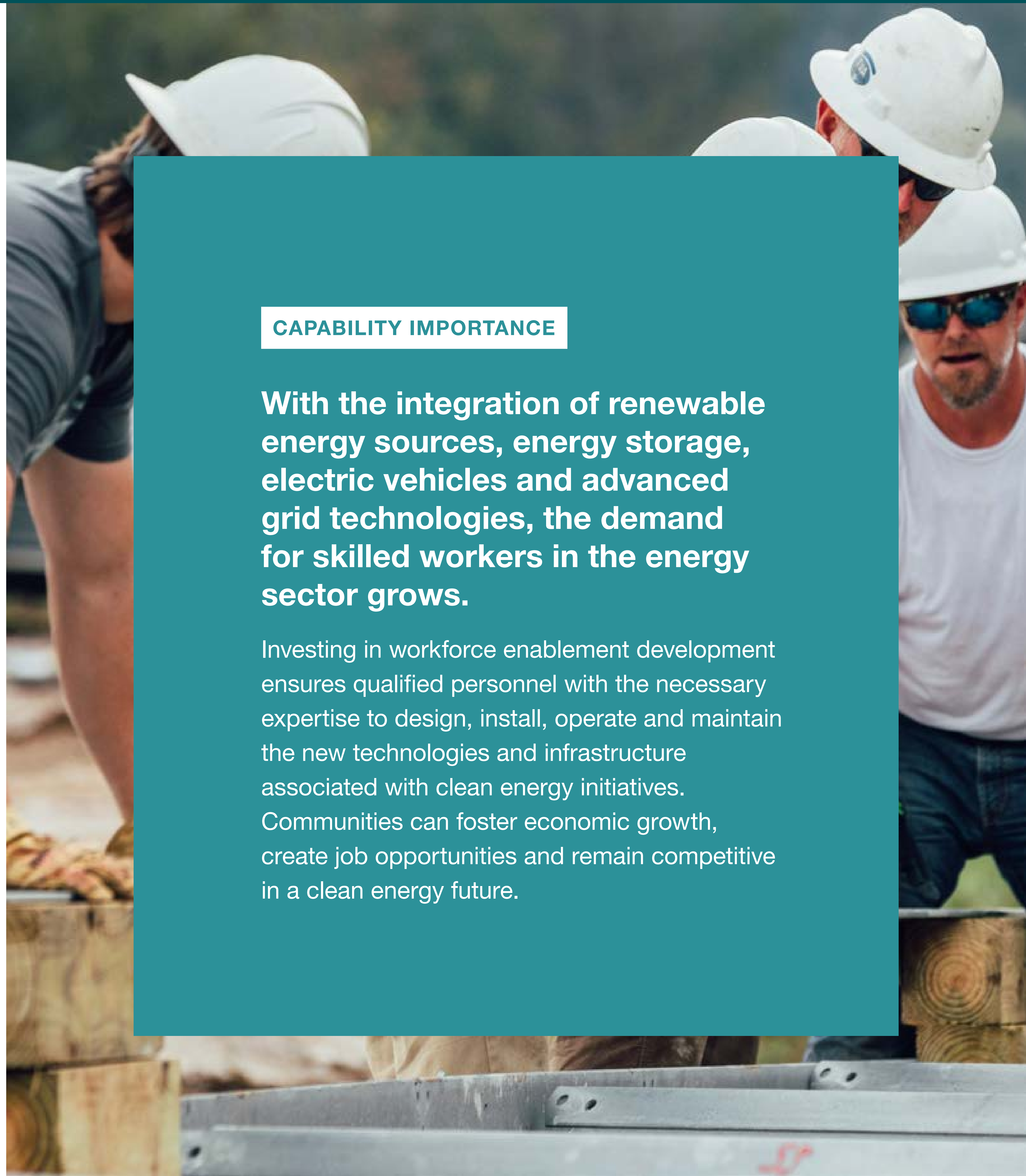
Overview

DEFINITION

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

SUPPORTING ACTIVITIES

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



CAPABILITY IMPORTANCE

With the integration of renewable energy sources, energy storage, electric vehicles and advanced grid technologies, the demand for skilled workers in the energy sector grows.

Investing in workforce enablement development ensures qualified personnel with the necessary expertise to design, install, operate and maintain the new technologies and infrastructure associated with clean energy initiatives. Communities can foster economic growth, create job opportunities and remain competitive in a clean energy future.

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 (1-25%)** of the most important gaps identified.	Assessment of 5-year skills needs for **all** 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 (26-50%)** 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.

Please note that an LPC must satisfy **all requirements** listed under the maturity level before that level has been achieved, including specifics listed under the penetration level.

VS Valley Standard VTL Valley Transformational Level

System Modeling

CATEGORY	STAGE	STATUS
Integrated Planning	Planning and Assessing	Initial

SYSTEM MODELING

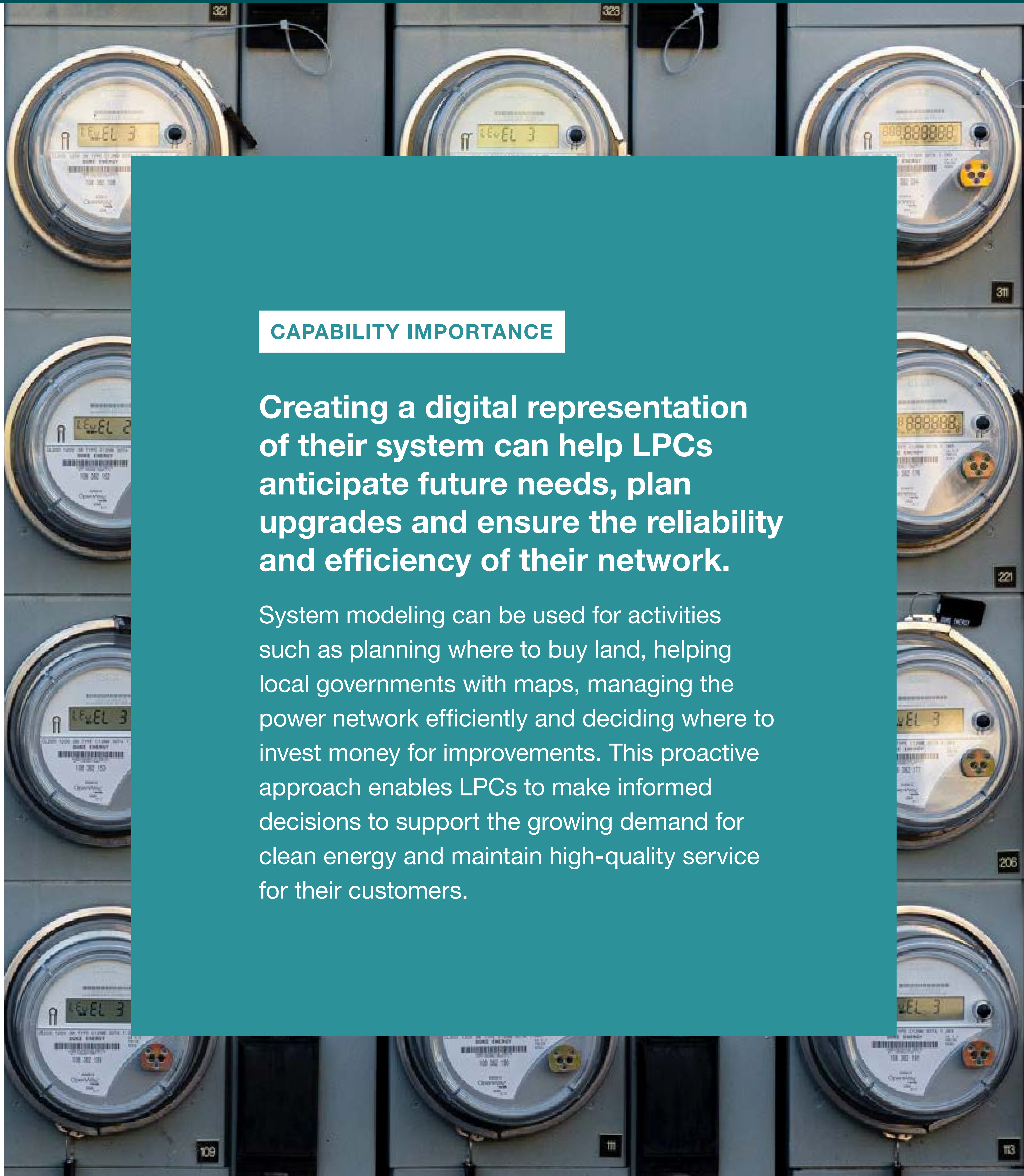
Overview

DEFINITION

Digital mapping 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, like high- and low-voltage areas.

SUPPORTING TECHNOLOGIES

- Static power flowmodeling tools (e.g., CYME, Synergi, PSSE, Milsoft)
- AutoCAD
- Enterprise GIS system
- Wide area distribution assessments (strategic studies)
- AMI granular meter data
- Load and DER forecasting
- Dynamic/transient power flow modules



CAPABILITY IMPORTANCE

Creating a digital representation of their system can help LPCs anticipate future needs, plan upgrades and ensure the reliability and efficiency of their network.

System modeling can be used for activities such as planning where to buy land, helping local governments with maps, managing the power network efficiently and deciding where to invest money for improvements. This proactive approach enables LPCs to make informed decisions to support the growing demand for clean energy and maintain high-quality 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.	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. **PENETRATION LEVEL:** **Most (51-75%)** of the 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:** **(76-95%)** MV system models including load and DER reviewed annually using standard tools	The 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.	The 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.		

Please note that an LPC must satisfy **all requirements** listed under the maturity level before that level has been achieved, including specifics listed under the penetration level.

VS Valley Standard VTL Valley Transformational Level

DER Interconnection

CATEGORY	STAGE	STATUS
Regional Guidelines	Planning and Assessing	✓ Initial

DER INTERCONNECTION

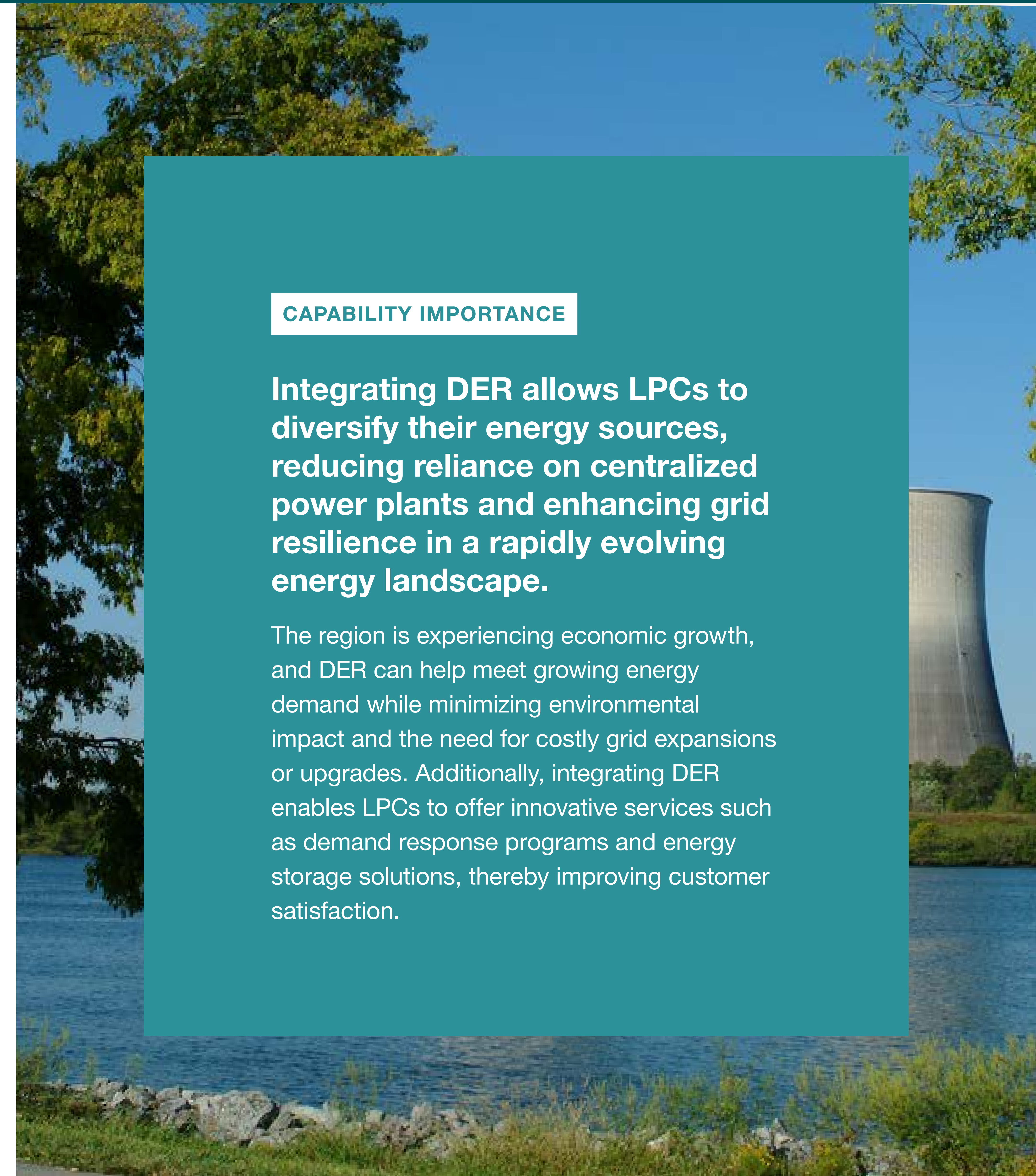
Overview

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

- DER tech review criteria
- Capacity tracking and assessment
- Mapping/GIS technology
- Non-wires alternative (NWA) assessment
- Integrate system planning (ISP)



CAPABILITY IMPORTANCE

Integrating DER allows LPCs to diversify their energy sources, reducing reliance on centralized power plants and enhancing grid resilience in a rapidly evolving energy landscape.

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. Additionally, integrating DER enables LPCs to offer innovative services such as demand response programs and energy storage solutions, thereby improving customer satisfaction.

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. **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]:** **(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.	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.

Please note that an LPC must satisfy **all requirements** listed under the maturity level before that level has been achieved, including specifics listed under the penetration level.

[1] The RGT DER Interconnection Standards Project report will be published soon. For additional information, contact your CRM for access to this 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

Enabling
Planning and Assessing
Value Generating

Grid Optimization
Self-Healing Grid
Impact Assessment
Non-Traditional Alternatives Assessment
Traditional Resource Co-Optimization
Customer Experience Management
DER Incorporation and Optimization

Grid Optimization

CATEGORY	STAGE	STATUS
Enhanced T&D Operations	Value Generating	Initial

GRID OPTIMIZATION

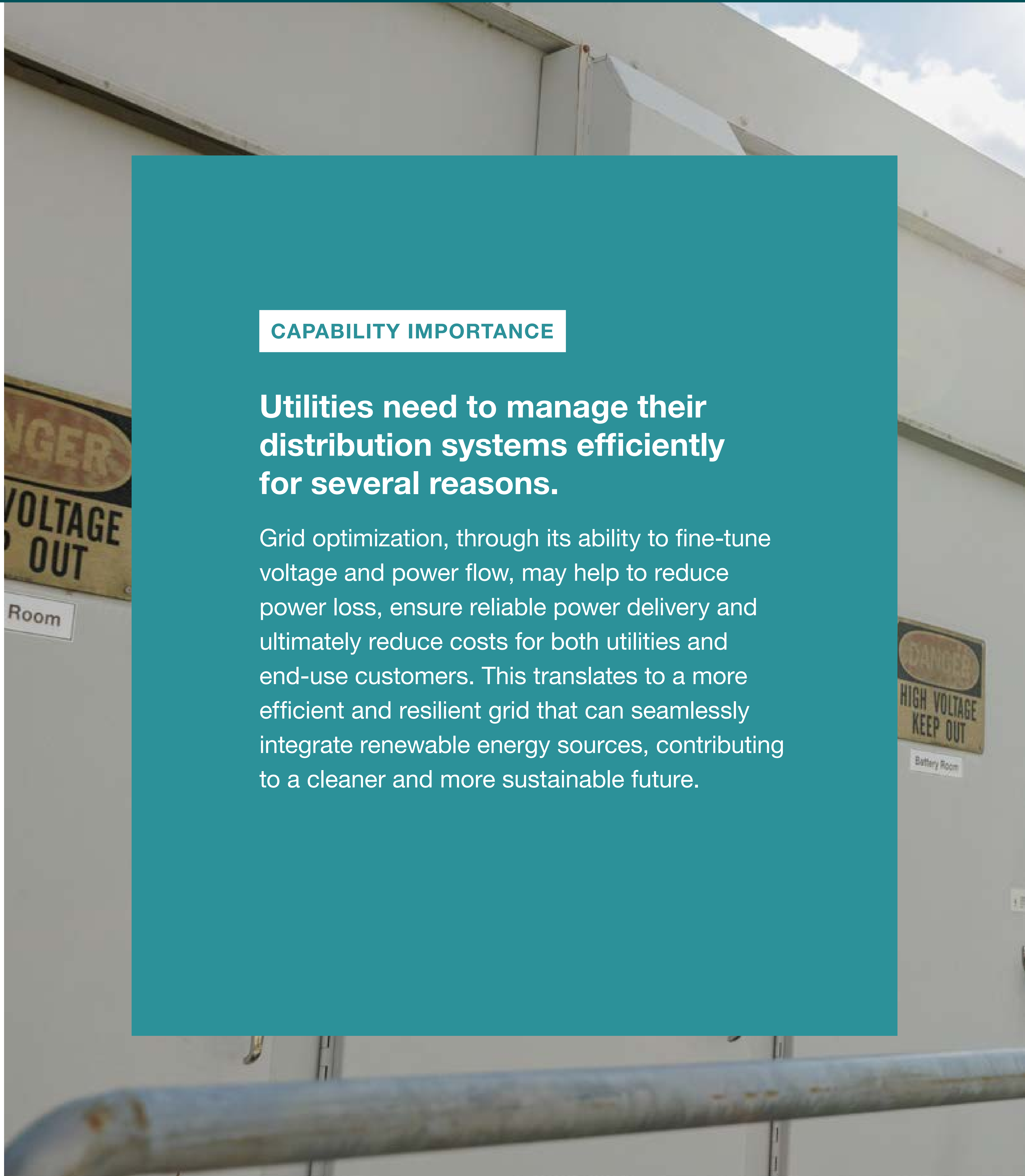
Overview

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

- Comprehensive voltage and current sensors
- Substation SCADA
- VO-FLISR integrated operations
- Advanced distribution management system (ADMS) integrated with advanced applications
- Distributed energy resource (DER) integration at more advanced levels



CAPABILITY IMPORTANCE

Utilities need to manage their distribution systems efficiently for several reasons.

Grid optimization, through its ability to fine-tune voltage and power flow, may help to reduce power loss, ensure reliable power delivery and ultimately 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

Potential Valley Stakeholder Benefits

TVA Benefits

Valley Standard (VS)

Grid Optimization benefits TVA by reducing distribution losses and improving power quality available across the region.

Valley Transformational Level (VTL)

TVA benefits from advanced Grid Optimization as it enhances customer resiliency, lowers generation fuel usage, extends time for new capacity build-out, reduces transmission congestion and improves power flow.

LPC Benefits

Valley Standard (VS)

Grid Optimization reduces power losses and voltage issues, enhances storm response, boosts worker safety and elevates LPCs to top-tier reliability, ultimately improving customer satisfaction.

Valley Transformational Level (VTL)

Grid Optimization at Level 3+ reduces power loss and energy bills, enhances voltage optimization, identifies DER voltage issues and results in a boost to grid resiliency, operational efficiency and customer satisfaction.

Customer Benefits

Valley Standard (VS)

Grid Optimization ensures end-use customers enjoy superior power quality with minimal flickering, enhancing satisfaction among commercial and industrial sectors. Tailored services foster economic growth, supporting diverse business needs seamlessly.

Valley Transformational Level (VTL)

Advanced Grid Optimization delivers cost savings to end-use customers while facilitating faster integration of DER, expanding clean energy accessibility throughout the region.

GRID OPTIMIZATION

Activities for Advancement

Remote System Managing

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

Automatic Voltage Reduction

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	Engineering-centric grid monitoring and voltage / power flow optimization are manually dispatched.	Remote grid monitoring and manual voltage / power flow optimization with remote dispatch deployed in some (1-25%) targeted areas.	Remote grid monitoring and system voltage / power flow optimization with remote advisory dispatch used in most (51-75%) locations.	Remote grid monitoring and centralized system voltage / power flow optimization with remote autonomous dispatch and large DER (>500 kW) visibility on almost all (76-95%) circuits.	Optimized voltage, power flow, conservation voltage reduction and demand voltage reduction including DER incorporation into voltage and power flow schemes used on almost all (76-95%) circuits.
Automatic Voltage Reduction	Voltage and power flow are determined using static engineering values and only modified seasonally, if at all.	Conservation voltage reduction and demand voltage reduction are manually dispatched on some (1-25%) circuits.	System conservation voltage reduction and demand voltage reduction are remotely dispatched. Limited use in many (26-50%) targeted areas.	System conservation voltage reduction and demand voltage reduction are system determined and remotely dispatched on almost all (76-95%) circuits.	Optimized voltage, power flow, conservation voltage reduction, and demand voltage reduction including DER incorporation into voltage and power flow schemes used on almost all (76-95%) circuits.
Renewable Energy Sources				Large front of the meter (FOTM) distributed energy resources (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

Implementation Considerations

People Who May Be Impacted

- Operations
- Planning
- 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 Valley Transformation Level and above.
- Grid voltage is mostly managed automatically at Level 5 with exceptions and issues flagged for operation intervention.

Pain Points That May Require Attention

- Ensuring training is done sufficiently and effectively to support automation.
- Large 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 that the necessary investments are not justified.

Additional pain points at the Valley Transformational Level and beyond include Distribution Management System model creation and maintenance and DERMS implementation to support DER integration and control.

Self-Healing Grid

CATEGORY	STAGE	STATUS
Enhanced T&D Operations	Value Generating	✓ Initial

SELF-HEALING GRID

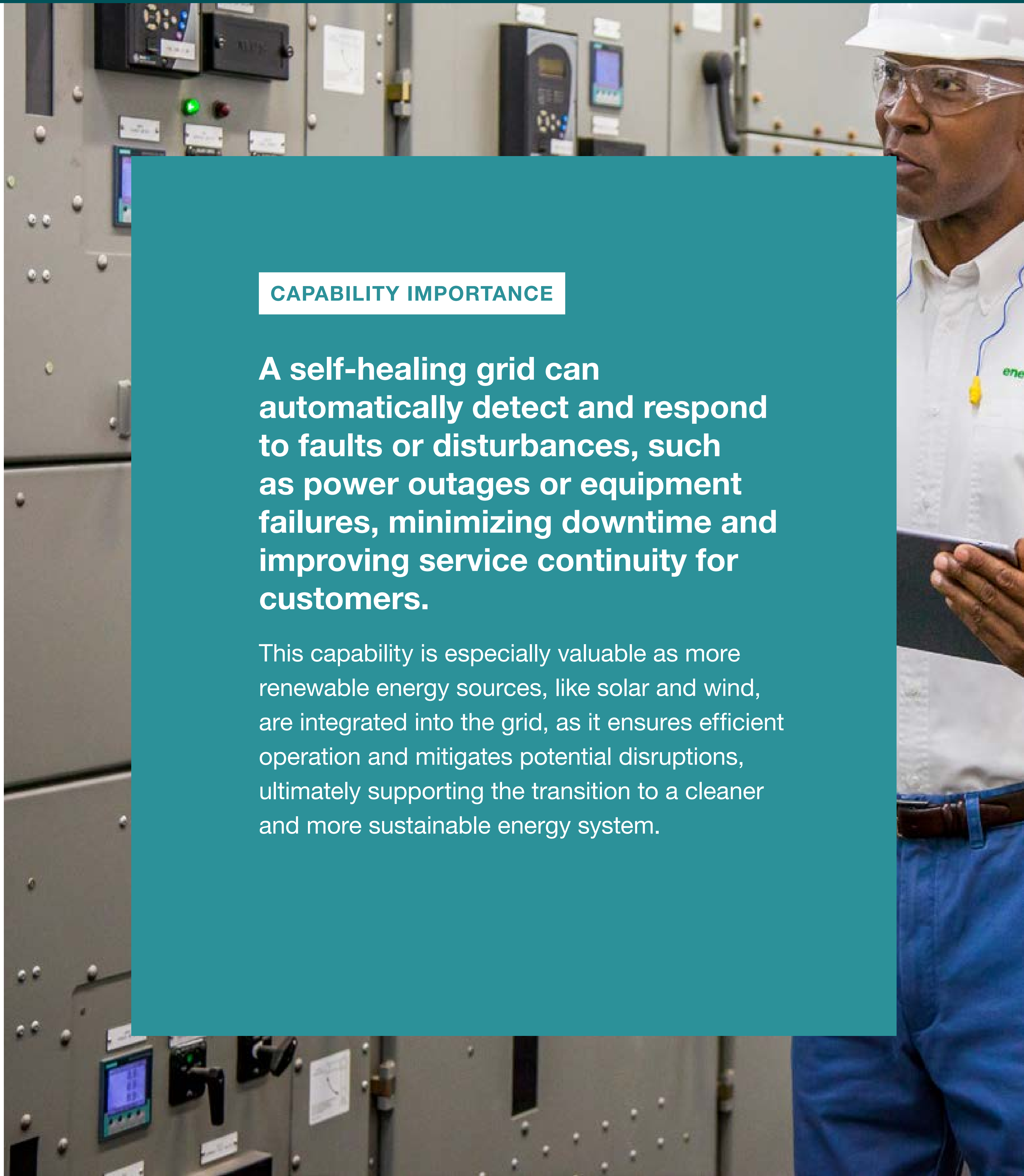
Overview

DEFINITION

The grid 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

- Distribution automation
- Supervisory control and data acquisition (SCADA) breakers, switchers and reclosers
- Outage management system (OMS)
- Advanced distribution management system (ADMS) integrated with advanced applications
- Fault location, isolation and service restoration (FLISR)



CAPABILITY IMPORTANCE

A self-healing grid can automatically detect and respond to faults or disturbances, such as power outages or equipment failures, minimizing downtime and improving service continuity for customers.

This capability is especially valuable as more renewable energy sources, like solar and wind, are integrated into the grid, as it ensures efficient operation and mitigates potential disruptions, ultimately supporting the transition to a cleaner and more sustainable energy system.

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 (26-50%)** 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 (1-25%)** automated coordinated reclosing. **Must** have call-based system predictive outage management (including identification and restoration). **Some (1-25%)** 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.

Please note that an LPC must satisfy **all requirements** listed under the maturity level before that level has been achieved, including specifics listed under the penetration level.

VS Valley Standard VTL Valley Transformational Level

REGIONAL GRID TRANSFORMATION

Initiative Progress Report

TVA TENNESSEE VALLEY AUTHORITY

tva.com/energy/technology-innovation/regional-grid-transformation