# Beyond counting widgets: Evaluation of the maturity of grid transformation capabilities in the Tennessee Valley

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## ABSTRACT

The more than 150 local power companies (LPCs) in the Tennessee Valley represent a diverse group of public power distribution utilities in both type and size. Since the beginning of grid transformation initiatives in the Valley in 2018, the team made up of TVA, Guidehouse and EPRI has observed large variances in grid modernization technology and system deployment. These differences in operational maturity among the LPCs cannot be attributed solely to utility type, size or density of customers. With additional Distributed Energy Resources (DERs) coming online and a focus on energy efficiency and demand response, grid operational and planning maturity will play a larger role moving forward. Starting in 2021, the team set out to evaluate the current and future state of maturity of grid modernization capabilities of the Valley LPCs. Gathering a common set of operational, planning, and customer-focused capability information from as many LPCs as possible deepened the understanding of what key investments are needed. This information on capabilities provided strategic guidance to the utilities as they collectively seek to develop and operate a more modern and integrated power system.

To support maturity progression in the Valley, the team worked with a set of LPCs to develop a "Capability Progression Model" (CPM) that specifies a detailed maturity model of 18 capabilities important for the grid as technology evolves over the next 10 years. The CPM addresses the issues of technology models that struggle to adequately capture the different nuances of LPCs or provide an approach for achieving greater levels of grid functionality. The CPM aims to capture the nuances and potential pathways for LPCs with varying starting points and limitations on plans for modernization. The CPM does this by allowing for multiple technology pathways to improve overall maturity. The 18 different capabilities in the CPM span four categories: Enabling, Planning and Assessing, Value Generating, and Enhancing. The CPM leverages five levels of functionality, starting with basic "ad hoc" at Level 1, and advancing through "world class" at Level 5 for each capability. The CPM includes definitions of "Valley Standard" and "Valley Transformational" levels of attainment for each capability to set a minimum target and a stretch goal for LPCs to achieve.

To evaluate the maturity of LPCs within the framework of the CPM, the team developed the Valley-wide LPC Capability Assessment. The information collected provided a defined snapshot of current maturity and plans for maturity improvement. The information also provided feedback to justify the need for ongoing investments into grid modernization capabilities. The objective is for LPCs to make more informed decisions when developing future strategic and tactical plans, have greater insight into their current state as an electric provider, close gaps, and achieve their goals. LPCs understand how important it is to advance grid capabilities to maintain affordability and meet customer electric demand as more demand response products, EVs and DERs are deployed across the Valley and the customers require a resilient grid to withstand the impacts of extreme weather events. Future work will investigate the impacts of the CPM and the LPC's specific feedback from the assessment on utility operations and planning within the Tennessee Valley.

## Introduction

The electric grid needs to be transformed and modernized to accommodate current energy trends. First, there is increased development and interest in distributed energy resources that are smaller and more sparsely located. Second, electrification of energy use in transportation and primary end-uses such as space conditioning and food preparation are increasing electric demand. Finally, end customers are requiring a more resilient grid to balance the increased impacts of severe weather and extreme events. Utilities are adapting their operations and adding functionality in unique ways to meet these changing requirements. The team observed a large variance in the technology and operational maturity of LPCs that is not fully driven by size or density of customers, which, along with regulatory pressure, tend to be the primary drivers seen nationwide. This finding is based on a review of readily available data (e.g., EIA data, results of a technology based LPC Assessment completed in 2022). The review of available data also found that there is limited detail on specific capabilities, on the LPCs. It is also becoming increasingly important to understand how to approach integrated system planning and operations in response to market trends.

Within the Tennessee Valley Authority (TVA) service territory, multiple characteristics such as service territory population distribution, number of meters serviced, geography and terrain, financial constraints, state regulations, and customer requirements led to the observed heterogeneity in the current grid modernization capabilities of the more than 150 LPCs. The Tennessee Valley Authority is the nation's largest public power supplier, delivering energy to more than 10 million people across seven southeastern states. TVA works in partnership with 153 individual LPCs to keep reliable, affordable, safe, and clean public power flowing to homes and businesses throughout the seven-state Tennessee Valley region (Figure 1). These LPCs — both municipal utilities and regional cooperatives — purchase power from TVA and distribute it to end-use consumers.

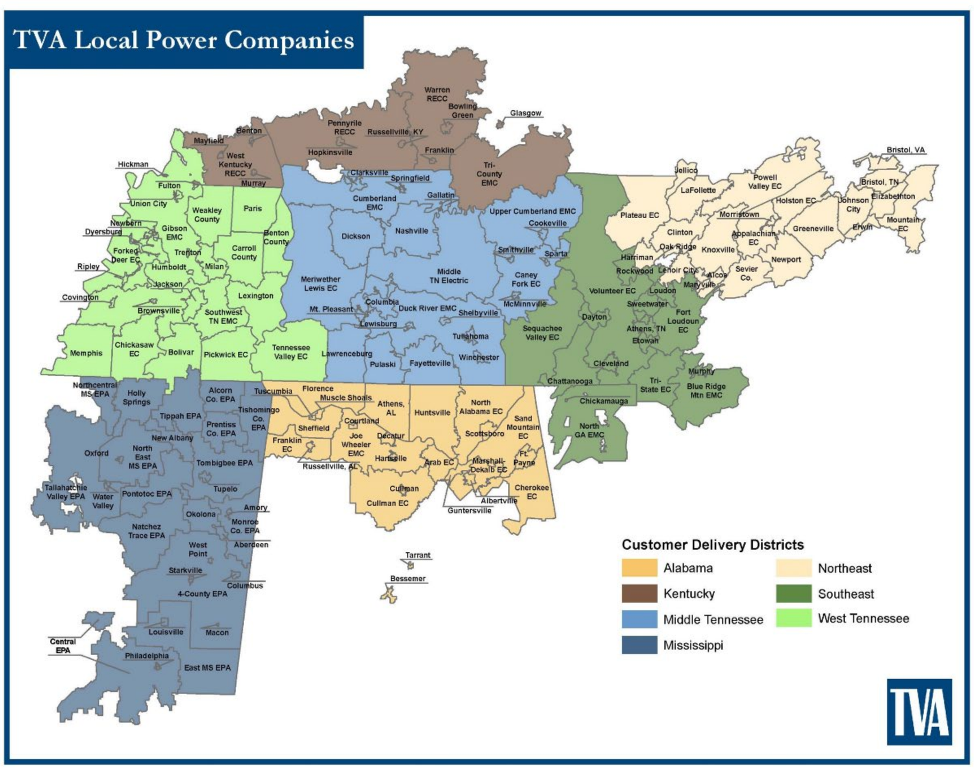


**Figure 1.** The 153 Local Power Companies served by the Tennessee Valley Authority *Source:* TVA 2025.

The LPCs range in size from 884 customers in Courtland Electric Department to 448,062 customers in Nashville Electric Service. Almost half of the LPCs serve less than 15,000 customers with 58% of customers served by municipal utilities and 42% served by cooperative utilities (see Figure 2 for a scatter plot of size vs density that distinguishes between municipal and cooperative ownership structures). The team developed six peer groups based on number of customers [Small ≤15k, Medium <15k and ≤60k, Large > 60k] and customer density (Low Density ≤20 customers/line-mile, Medium to High Density >20 customers/line-mile).

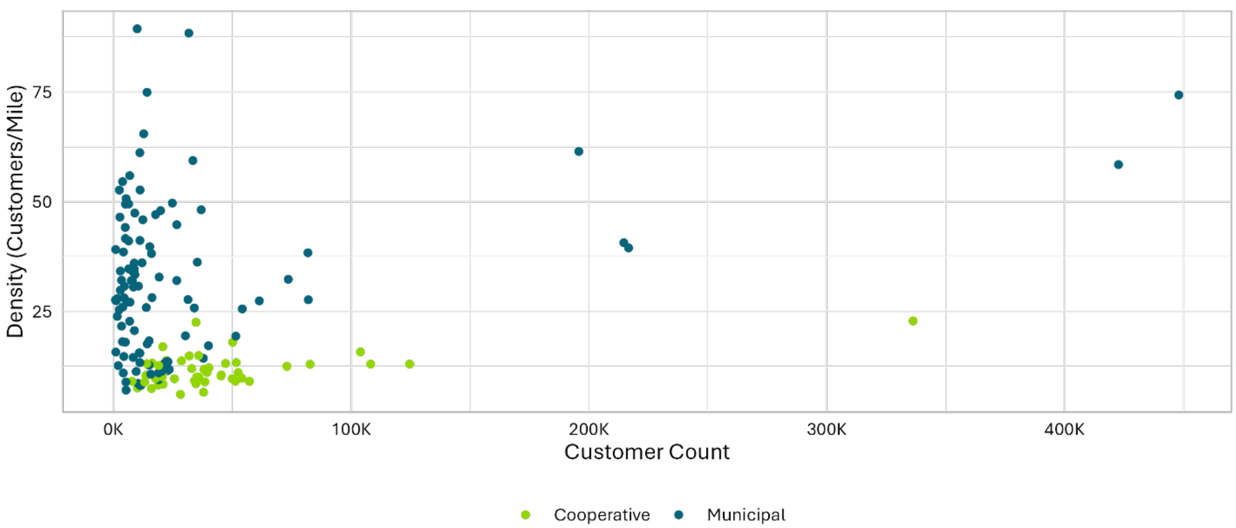


**Figure 2.** LPC customer counts and density, color coded by ownership *Source:* TVA 2025.

To support LPCs in identifying a path to transform their grid to meet the needs of the future, TVA is collaborating with a subset of LPCs as part of the Valley Vision initiative. The Valley Vision initiative is focused on moving towards a dynamic two-way power system where energy will move from generation sources to end-use customers and back. Accommodating this new two-way power flow will require innovative advancements across the grid by TVA and LPCs. A key initial step in the process of grid transformation in the region is identification of the current capabilities of all the LPCs. To develop this understanding, TVA and technical leaders from representative LPCs on a working team identified the need for a common framework to assign current status and gauge progress. In response, TVA, LPCs, TVPPA, and subject matter experts from EPRI and Guidehouse developed the capability progression model.

**The Capability Progression Model**

The Capability Progression Model (CPM) is a strategic and actionable framework developed to help LPCs in identifying and maturing the capabilities necessary to operate the grid of the future. Developed collaboratively with LPC representatives with subject matter expertise on capability specific focus groups, the CPM ensures that utilities across the region have an identified pathway to modernize operations, optimize infrastructure, and ultimately contribute to a more resilient and efficient energy system, key objectives of the Valley Vision initiative. The CPM is built on top of an inventory of typical utility, grid, and customer capabilities developed by Guidehouse and EPRI and based upon TOGAF (The Open Group 2025) and the Smart Grid Maturity Model (SGMM) (The SGMM Team 2011). The team believes that the CPM meets a critical need within the public power utility segment and is broadly applicable beyond LPCs in the Tennessee Valley. The team reviewed other maturity models and considered their limitations when developing the CPM to best fill a gap.

The CPM outlines 18 capabilities grouped into four stages of progression: Enabling, Planning and Assessing, Value Generating, and Enhancing. (see Figure 3). The 18 capabilities are grouped by five capability categories: Integrated Planning, Regional Guidelines, Enhanced Transmission & Distribution (T&D) Operations, Exceptional End-User Experience, and Grid Transformation Enabling (see Appendix for definitions of capabilities). At the heart of the CPM is the recognition that foundational, or "Enabling," capabilities, are essential prerequisites for more advanced grid functions. These Enabling capabilities—such as Telecommunications and Grid Situational Awareness—form the foundation upon which more complex capabilities like Grid Optimization and DER Incorporation and Optimization can be built. Without these foundational elements, LPCs cannot effectively monitor, manage, or optimize systems in real-time, which is critical for many advanced capabilities such as leveraging the full potential of Distributed Energy Resources (DERs).

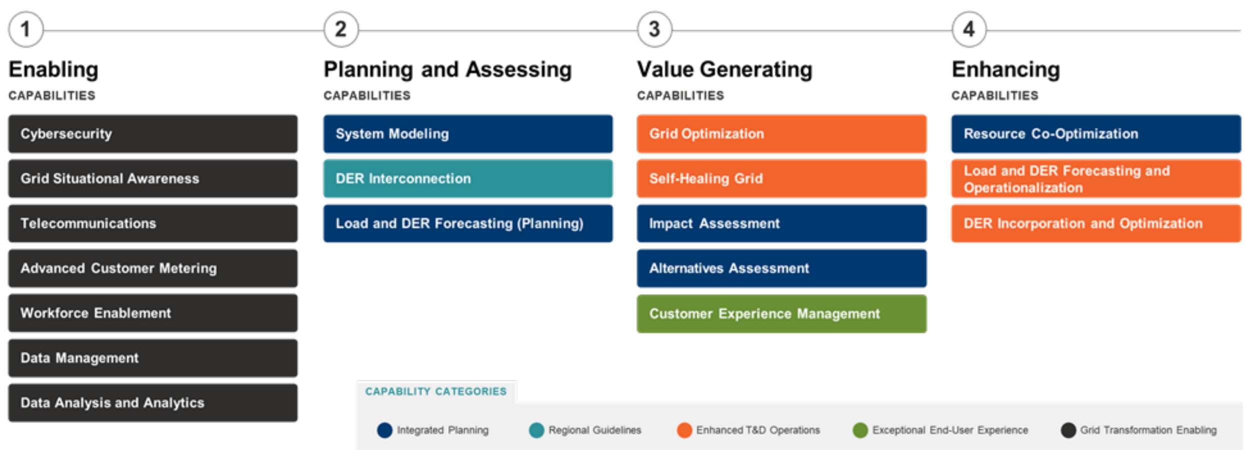


**Figure 3.** The 18 capabilities in the CPM grouped by stage of progression. *Source:* TVA 2025.

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

As LPCs build Enabling capabilities, achieving capabilities in the following three stages will become more straightforward. 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 by 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 outlined five levels of capability maturity, starting with basic "ad hoc" at Level 1, and advancing through "world class" at Level 5 for each of the 18 capabilities. The CPM also introduced two key recommended benchmarks: the Valley Standard (VS) level, which sets the minimum recommended threshold for each capability, and the Valley Transformational Level (VTL), which details activities and objectives that optimize a capability, enabling stakeholders to benefit more from the value it offers (see Figure 4). Achieving the Valley Standard is a critical first step for all LPCs, regardless of size, geography, or financial constraints. It ensures a consistent baseline across the region, enabling coordinated progress and shared benefits.

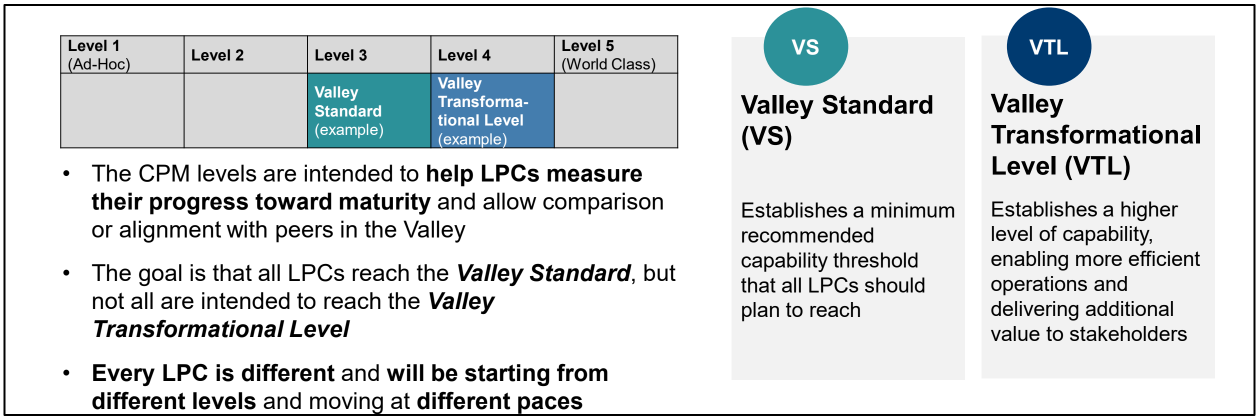


**Figure 4**. Description of Valley Standard (VS) and Valley Transformational Level (VTL) as it relates to the five maturity levels for each capability. *Source*: TVA 2025

To transform the regional grid, all LPCs must move toward greater grid resiliency, efficiency and flexibility by first achieving the Valley Standard before working towards the Valley Transformational Level. Achieving grid modernization at a regional level will take the majority of the largest LPCs making concerted efforts to modernize and to achieve Valley Transformational Level status. LPCs that achieve Valley Transformational Level will see enhanced benefits for their business and customers and are more prepared to participate in TVA programs that reduce costs for their customers.

The CPM provides structured pathways for LPCs of all sizes to modernize operations:

- Small LPCs (<15k Customers): These LPCs face unique challenges such as limited budgets and fewer technical staff. For these utilities, foundational capabilities like Telecommunications and Grid Situational Awareness are critical enablers. These allow even the smallest LPCs to monitor their systems in real-time, respond to outages efficiently, and begin integrating DERs like rooftop solar or community storage.

- Medium-sized LPCs (≥ 15k & <60k Customers): Typically straddle the line between rural and urban service areas, requiring a flexible approach to capability development. For example, System Modeling and other Planning and Assessing capabilities help medium LPCs adapt to extreme weather, optimize DER placement, and manage load growth. Achieving the Valley Transformational Level in key areas like Grid Optimization or Customer Experience Management enables these LPCs to deliver more value to their communities while supporting regional grid stability.

- Larger LPCs ( ≥ 60k Customers): Often are at the forefront of grid modernization and DER integration due to customer interests and localized load growth leading to grid constraints. With more resources and complex infrastructure, they are well-positioned to lead the way in achieving Valley Transformational Level across multiple capabilities. However, even these utilities, which are mostly municipal utilities, must ensure that foundational capabilities are in place to support advanced functions like real-time grid control, DER orchestration, and customer-facing energy tools. The CPM encourages large LPCs to serve as regional anchors—demonstrating best practices, piloting new technologies, and sharing insights that benefit smaller peers. Their progress is essential to achieving Valley-wide transformation, as their scale can drive significant improvements in grid resiliency, efficiency, and flexibility.

The CPM considers that capability progress and the associated benefits will not happen overnight. Instead, it will take collaboration and time to reach the next level within the capabilities. The CPM is an evolving framework, and TVA continues to work with LPCs and other stakeholders to provide guidance and resources around these capabilities. In addition, TVA is considering approaches for incentivizing LPCs to advance in maturity levels.

Assessment of the capability maturity can empower LPCs to pinpoint areas for growth to strategically chart their course toward a more resilient future grid. After identifying strategic objectives, an LPC is better prepared to start implementing specific tactical initiatives and create a tactical roadmap (see example in Figure 5). A tactical roadmap can also be used as a communication tool to outline existing grid modernization plans and projects. The roadmap also helps identify opportunities to prioritize initiatives that will increase maturity across multiple capabilities, leading to the greatest benefits.

To evaluate the maturity of LPCs within the framework of the CPM, the team launched the Valley-wide LPC Capability Assessment in June 2025. The information collected provides a defined snapshot of current maturity and plans for maturity improvement to characterize advancement to either the Valley Standard or Valley Transformational Level. The information also provides justification for the need for ongoing investments into grid modernization capabilities within the Tennessee Valley.

**The 2025 Valley-wide Capability Assessment**

The goal of the Valley-wide LPC Assessment is to gather information about the current and future state of grid modernization capabilities of LPCs across the Tennessee Valley. The primary objective of completing the Valley-wide assessment of capability maturity is to enable LPCs to make more informed decisions when developing future strategic and tactical plans, have greater insight into their current state as an electric provider, to close gaps, and achieve their goals. LPCs understand how important it is to advance grid capabilities to ensure affordability, support a generational increase in electric load due to economic development and electric vehicles, and reduce demand where possible with demand response and distributed energy production while additional gas generation is brought on-line.

**The Assessment Methodology**

The 2025 LPC Assessment focused on understanding the 15 capabilities within the first three stages of progression: Enabling, Planning & Assessing, and Value Generating in the CPM. Based on discussions with advanced LPCs, three capabilities, those included in the fourth Enhancing category, have limited current penetration in the Valley and it is unlikely that any LPCs have moved beyond the initial maturity level. Therefore, they were not included in the 2025 LPC Capability Assessment. However, those capabilities may be included in future assessments. To cover all the sub-capabilities within the 15 capabilities included and to address future plans, the assessment includes 114 questions and takes approximately 2 hours to complete. Select LPCs reviewed the questions for clarity and for general applicability for LPCs valley-wide.

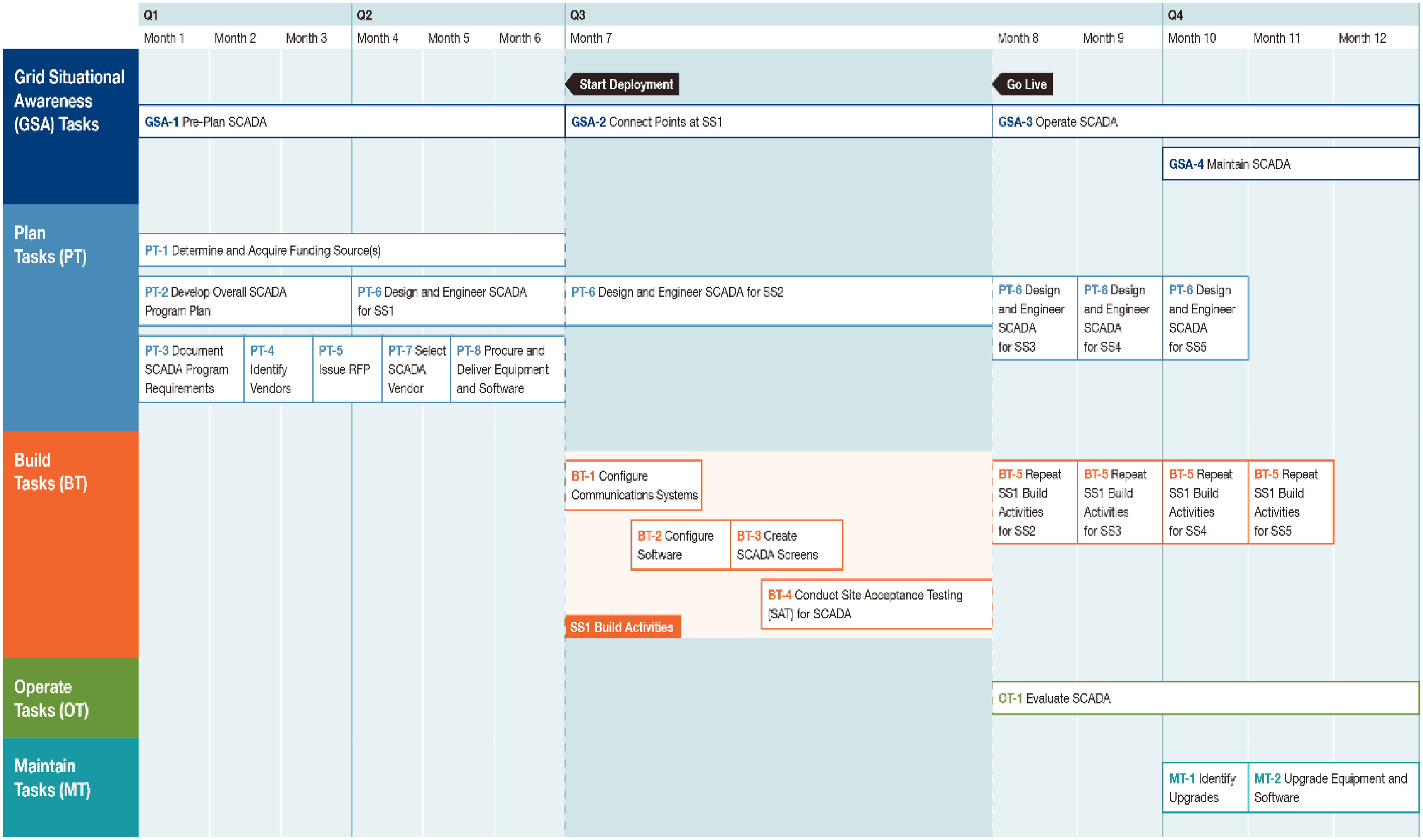


**Figure 5.** An example of a tactical roadmap developed for an LPC's deployment of Grid Situational Awareness. *Source:* TVA 2025

The questions that dictate maturity level assignment are structured in two different ways. Some ask about detailed sub-capability maturity within one of the CPM's capabilities and some focus on penetration of a sub-capability. Below are two example questions showing the distinction:

Example sub-capability maturity level question from Grid Situational Awareness:

*How do you calculate industry standard system and circuit reliability metrics (e.g., SAIDI, SAIFI) for your system?*

*a. Not calculated*
*b. Entirely manual calculation*
*c. Manual calculation supported by partial automation (1-25% automation assistance)*
*d. Automated calculation (26-75% of calculations are automated) with manual adjustments required in some cases*
*e. Almost entirely automated (>76% of calculations are automated)*

Example sub-capability penetration level question from Grid Situational Awareness:

*Please provide your best estimate of the percentage of substations in your territory that have remote monitoring with at least one point of visibility--note: a point of visibility could include substation internal (in front of circuit breaker) visibility or external (downstream of the circuit breaker) visibility and could range from health monitoring of a single data point to comprehensive voltage, current, temperature, etc. monitoring on the high-side and low side of individual feeders.*

*a. 0%*
*b. 1-25%*
*c. 26-50%*
*d. 51-75%*
*e. 76-95%*
*f. 96-100%*

**Results of the 2025 LPC Capability Assessment**

The primary output of the LPC Capability Assessment is a customized report with summary sections and supporting details for each LPC that completes the assessment. Leveraging an algorithmic approach using inputs from the LPC's unique responses, the team assigned each LPC to a CPM Level from 1 to 5 for all 15 capabilities. Also included in this report is information on how they compare valley-wide and to their own LPC peer- group based on their size and density (reference Figure 2). An example summary graphic is shown in Figure 6.

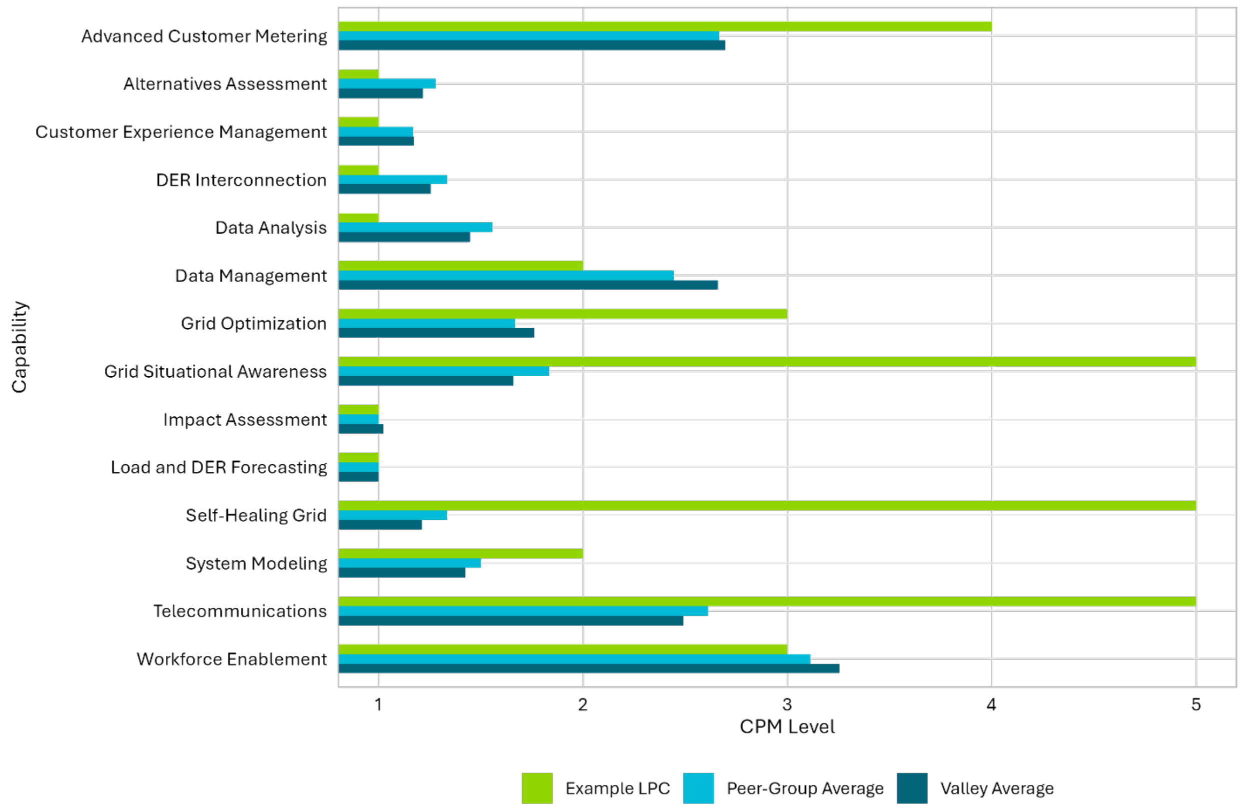


**Figure 6**. Example LPC CPM Levels Compared to Valley Average, and Peer- Group Average. Note: Results for the Cybersecurity capability are not reported due to data sensitivity and these results only include respondents through July 2025. *Source:* TVA analysis 2025.

For the example LPC represented in Figure 6, their report will highlight the capability areas where they are more advanced such as Self-Healing Grid and Grid Situational Awareness, and the capability areas where there is additional room for improvement as compared to their peers such as in Data Management and Workforce Enablement.

It will also be helpful for TVA and LPCs to understand the number of capabilities for which the LPCs are below Valley Standard or Valley Transformational Level. As is shown in Figure 7 and Figure 8, the majority of customers are served by LPCs that have at least 5 capabilities for which they are below Valley Standard and 12 capabilities below the Valley Transformational Level. This indicates that there is an opportunity for additional capability maturity growth over the next five to ten years from the LPCs.

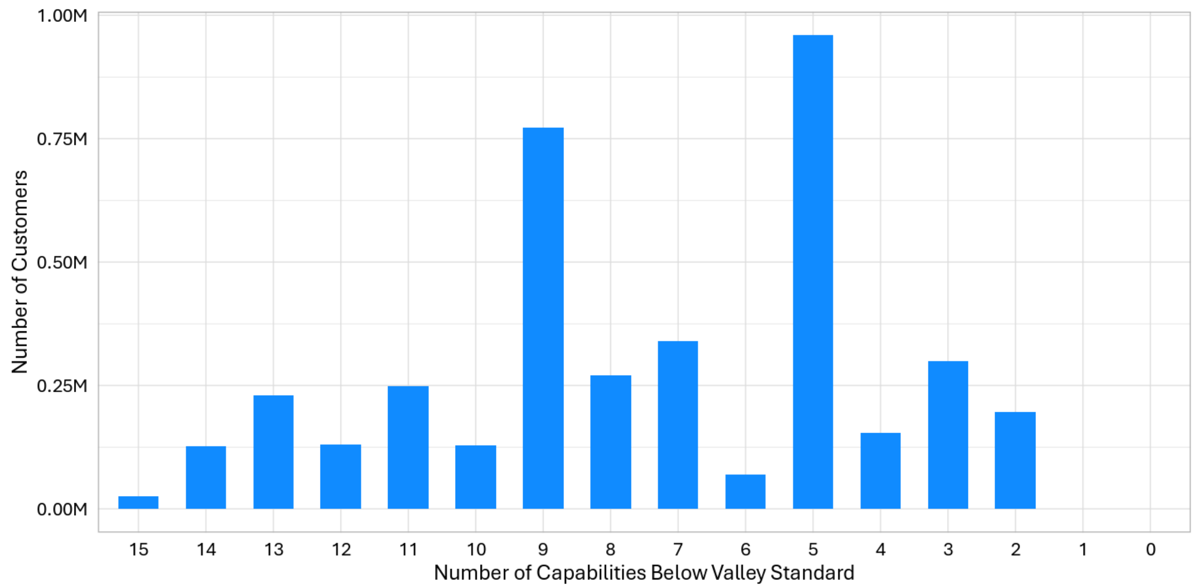


**Figure 7.** Distribution of Customers by LPCs' number of capabilities below Valley Standard level Note: These results only include LPC respondents through July 2025. *Source:* TVA analysis 2025.

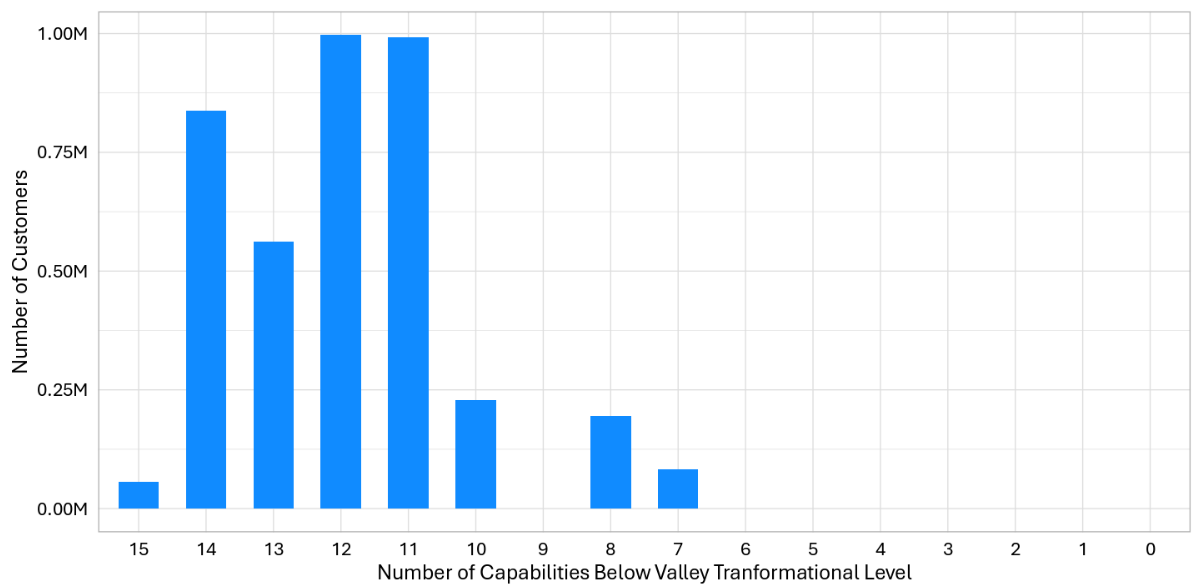


**Figure 8.** Distribution of Customers by LPCs' number of capabilities below Valley Transformational Level. Note: These results only include LPC respondents through July 2025. *Source:* TVA analysis 2025.

## Conclusions and Next Steps

The Capability Progression Model and the accompanying Valley-wide LPC Capability Assessment provided TVA and LPCs a snapshot of current maturity levels Valley-wide across 15 capabilities. The results indicate the need for ongoing investments into grid modernization capabilities since the majority of customers are served by LPCs with five or more capabilities below Valley Standard. The summary reports provided to the LPCs will help them make more informed decisions when developing future strategic and tactical plans, close gaps, and achieve their grid modernization goals. LPCs understand the importance of advancing grid capabilities to maintain affordability and meet customer electric demand and the increasing need for a resilient grid to withstand the impacts of extreme weather events.

Immediate next steps will include gathering insights on the impact of the framework outlined in the CPM on LPC utility planning and collecting LPC feedback on the relevancy of the LPC specific Valley-wide Capability Assessment report findings. Results of the Assessment will support investment decisions to meet grid capacity constraints over the next 10 years. In addition, LPCs below Valley Standard may prioritize investing in grid modernization over the next five years to achieve the benefits outlined in the CPM. Subsequent Assessments launched every three years will support tracking LPCs progress towards achieving Valley Standard and Valley Transformational Levels and modernizing the grid to meet the challenges of a connected and transforming grid.

## Appendix

Table 1. CPM Capabilities and Definitions

| Capability | Definition |
|---|---|
| Cybersecurity | Technologies, workforce, and processes protecting against criminal or unauthorized use of networks, devices, and data. Sub-capabilities of cybersecurity include risk awareness, preparedness, and consistent processes. |
| Grid Situational Awareness | Grid Situational Awareness includes distribution system operation knowing three things in near real-time: electrical network connectivity including breaker and switch status, the system state characterized by current voltage and power levels across the grid, and location of outages affecting the grid and planned outages. Sub-capabilities of grid situational awareness include grid monitoring, alarming, and outage statistics. |
| Telecommunications | Technologies utilized to transmit and coordinate information throughout the utility, supporting operations and enterprise objectives, as well as between the utility and business partners and customers. Sub-capabilities include data-center and control center connectivity, as well as communications to and from substations, mainline feeders, customers and DERs. |
| Advanced Customer Metering | Advanced Customer Metering is 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, and can enable other capabilities such as variable rate pricing, better fault location, and more granular usage information for customers. Sub-capabilities include meter reading, proactive communication, voltage measurement, and outage alarming. |
| Workforce Enablement | Workforce Enablement consists of ensuring a pipeline of new and re-trained employees with skills to support the emerging needs of TVA and LPCs with a focus on IT, Data, Analytics, and OT technologies and tools. This can support employee satisfaction and empowerment, improve retention, and provide better compensation opportunities, all while ensuring a proactive health and safety-conscious culture. Sub-capabilities of workforce enablement include: workforce need identification, skill uplift, employee satisfaction, and employee retention. |
| Data Management | Data Management is 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. |
| Data Analysis and Analytics | Data Analysis & Analytics consists of the ability to acquire data necessary to support decision analysis tools, the necessary skills to leverage analysis and analytics tools, and the ability to generate actionable insights based on analytics to improve business performance in a measurable and demonstratable way. |
| System Modeling | System Modeling creates a representation of the LPC distribution system based on load, DER, and Medium Voltage/Low Voltage (MV/LV) behavior in current and future states based on incorporation of DER and load growth forecasts to support distribution planning, land acquisition, municipality support of maps and records, system management and capital investment processes. Sub-capabilities of system modeling include static power flow and transient stability analysis and incorporation of load and DER forecasts into system model. |
| DER Interconnection | DER Interconnection includes processes, requirements, standards, and technical reviews that allow safe and efficient connection of DER to the distribution grid and help establish and increase hosting capacity for DER while ensuring operational security. Sub-capabilities of DER interconnection include processes and standards. |

| | |
|---|---|
| Load and DER Forecasting (Planning) | Load and DER Forecasting (Planning) predicts load and load offset due to models of customer behavior, predicted load growth, modeled DER adoption (PV, BESS, EV, etc.), future weather, and other forward-looking factors (economic and noneconomic) to produce spatially and temporally granular load forecasts accounting for scenarios and sensitivities (single to multifactor) to support development of future Distribution Resource Plan (DRP) and Distribution System Plan (DSP). Planning forecast includes the following forecast horizons: (a) medium term (1 month to 1 year) and (b) long term (1 to 20 years). |
| Grid Optimization | Grid Optimization consists of activities and technology used by grid operators to improve the performance and efficiency of the distribution systems including peak load management, optimizing power flow, and ensuring voltage stability. Sub-capabilities of grid optimization include voltage optimization (VVO), power flow optimization, conservation voltage reduction (CVR), and demand voltage reduction (DVR). |
| Self-Healing Grid | Self-Healing Grid is one 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. Sub-capabilities of self-healing grid include outage identification, outage restoration, and switching. |
| Impact Assessment | Impact Assessment 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 projects are leveraged to support hosting capacity analysis. |
| Alternatives Assessment | Alternatives Assessment consists of a techno-economic evaluation by the LPC of solutions to address constraints on their transmission and distribution system with 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. |
| Customer Experience Management | Customer Experience Management describes 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 programs and service. |
| Resource Co-Optimization | Resource Co-Optimization is the collaborative development of an integrated system plan (ISP) combining generation, transmission, distribution, and distributed energy to better leverage resources and opportunities for both local and bulk system objectives. Sub-capabilities of resource co-optimization include stakeholder management, collaborative solution ranking/optimization, and frequency. |
| Load and DER Forecasting and Operationalization | Load and DER Forecasting and Operationalization predicts load and load offset due to customer behavior, existing operating DER (DR, EE, PV, BESS, EV, 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. |
| DER Incorporation and Optimization | DER Incorporation and Optimization is the ability for an LPC to include distributed energy resources (DERs), including Battery Energy Storage Systems, Electric Vehicles, Photovoltaics, etc., as part of overall demand and generation management operations. Examples of optimization can include operating expenses, capital expenses, etc. |

*Source*: TVA 2025

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