TENNESSEE VALLEY AUTHORITY

CONNECTED COMMUNITIES

Get Connected: A Technology Landscape

for Communities in the TVA Region

VERSION TWO: JANUARY 2024

Note to Readers

This report was developed by the Tennessee Valley Authority's (TVA) Connected Communities team, an initiative of TVA's Innovation and Research group. This report provides an overview of key technologies and applications of relevance to the Connected Communities initiative. The contents of the report should not be interpreted as a recommendation for any particular community to pursue a specific technology or vendor, but rather as an introduction to options that may warrant further consideration depending on a community's unique circumstances.

For more information on this report, please email:
connectedcommunities@tva.gov

Executive Summary

Through the Connected Communities initiative, the Tennessee Valley Authority (TVA) is helping communities located in its service territory leverage tech- and data-driven solutions to improve quality of life, deliver environmental benefits and scale economic opportunities in an effort to become more connected. TVA, in conjunction with a variety of stakeholders, is working to jumpstart innovative pilot projects to make progress toward Connected Communities milestones, which are outlined in the initiative's roadmap.[1] The information presented here can serve as a starting point to inform TVA's planning around process and technology gap analysis and horizon mapping, as well as supporting stakeholders engaging in Connected Communities efforts.

This report provides an overview of 42 key technology solutions that can support progress in the TVA service region. Innovative technologies considered in this report have seen limited deployment but offer promise in addressing community challenges identified in the Connected Communities four focus areas. The report highlights key barriers, drivers, market players and technology deployment in the TVA service region to date and can help inform priorities for projects.

Several technologies summarized in this report face a variety of adoption barriers, like lack of education and awareness. The barriers presented suggest that several forms of support will be necessary, including financing, education, technical support, facilitation and creation of viable business models. TVA's Connected Communities initiative supports advancement of the types of technologies highlighted in this report by sharing information and experience, and helping communities foster stakeholder collaboration, set goals and identify resources to make progress..

The information in this report aims to make it easier for local power companies (LPCs), governments, community groups and other stakeholders to identify and begin to evaluate the technology applications that make sense for their communities. Each community is unique in its needs and existing infrastructure, but by working together, communities can make progress in achieving Connected Communities goals.

Introduction

Selected Technologies

With the endless possibilities of technology solutions available today, how did we come up with a list of just 42? The main objective was to identify and characterize solutions that may serve as a catalyst for innovation across the region or technologies with the potential to advance Connected Communities concepts within TVA's programs or operations.

KEY QUESTIONS

- What technologies are aligned with the Connected Communities vision?
- What technologies are already supported by one of TVA's initiatives?
- Are companies leading the research, testing and deploying relevant technologies and is the technology commercially available?
- How are these technologies applied?
- Are there barriers to implementing these technologies in TVA's territory?
- What activity is happening in TVA's territory regarding these technologies and which jurisdictions are leading in this space?

80+

technologies researched

that relate to the Boyd Cohen Smart City Framework.

42

technologies selected

to focus efforts on for Connected Communities.

Shortlist Development

Using the key questions as a guideline, our team reviewed over 80 technologies related to the Boyd Cohen Smart City Framework (smart people, smart economy, smart government, smart environment, smart mobility and smart living), drawing on sources such as federal departments, national laboratories, industry organizations, TVA subject matter experts, Guidehouse Insights and others.[2] To create a shortlist of technologies on which to focus efforts, the research team evaluated potential applications for current or near-term TVA activities and categorized each technology into the appropriate Connected Communities focus area(s). Technologies that have the potential to enhance grid or community resiliency were prioritized, along with those that have a higher potential for positive or transformational impact.

After compiling a smaller list of technologies, the team used case studies, use cases, vendors and any potential information on current market adoption for each technology for further investigation. Research results led to a narrower focus on 42 technologies that are well-suited for the various communities TVA serves.

This Technology Landscape Report builds on the previous 'Emerging Technologies Report' by adding 18 new technologies and expanding on the research developed in the previous report. While many of these additions may be more technologically mature and often overlap with the competencies of other TVA initiatives, the expanded scope of this report represents a focus on technologies that can enhance the resiliency of the grid and communities. This version also includes additional details surrounding specific technology applications and examples, lists federal funding programs that could potentially support projects deploying these technologies and draws connections between the technologies and the 2035 milestones outlined in the Connected Communities Roadmap.

Introduction

About the Report

The technologies highlighted in this report offer opportunities to enhance progress in the Connected Communities four focus areas. Each community is unique, and some technologies may be better suited to meet one community's needs than another. While some technologies are related, each technology included serves a specific purpose in the Connected Communities vision. The following sections provide a description of each of the identified technologies, how they align to Connected Communities Roadmap milestones, the value the technology offers, regional case studies, barriers to adoption and potential funding opportunities offered by the federal government. The selection accounts for the technology's readiness for deployment and its transformative potential following widespread adoption.

The technologies are listed by focus area and beneficiaries of the technologies (sectors of the economy).

Implementation of these technologies will require collaboration across TVA and various external stakeholders. This research highlights the importance of stakeholders working together to bring these solutions to life.

13

technologies

support **Enhanced Community Resiliency** and are flagged in the sidebar using the below graphic:

Supports Enhanced Community Resiliency

This report highlights potential funding sources that were available during the research phase. However, the future availability of these funding sources is uncertain.

Introduction

Focus Areas and Milestones

When TVA introduced the Connected Communities initiative as an innovative approach to address resource planning challenges it engaged over 30 organizations from across the service region. This collaboration led stakeholders to identify four focus areas based on the significant challenges communities face and the potential for technology-related solutions to benefit communities in those areas.

The Connected Communities team developed a Roadmap to set milestone outcomes for the TVA service region in each of the four focus areas (see the Connected Communities Roadmap for further details). There is also a Community Assessment Tool that sets community-level milestones for each focus area. Communities can use this tool, together with the Connected Communities Guidebook, to inform their goal setting and project planning.

In the sections that follow you will see references to “milestones” in the summary of each technology. This is intended to flag the Connected Communities milestone that each technology could help your community achieve.

FOCUS AREAS

Broadband and Digital Literacy

Goal: Everyone in the TVA service region has access to services through broadband, modern technology and the knowledge and empowerment to use it.

Economic Empowerment

Goal: Everyone in the TVA service region is economically secure and can contribute to a modern, 21st century economy to the best of their ability.

Energy and Environmental Justice

Goal: Everyone in the TVA service region has access to a healthy environment (natural and built) and reliable affordable and clean energy.

Enhanced Community Resiliency

Goal: Communities in the TVA service region have plans and resources to minimize the impacts of events like natural disasters and cyberthreats, to endure them safely and to recover quickly.

Broadband and Digital Literacy

The following technology applications can help improve equity in access to digital and online services, furthering progress toward achieving the milestones established for the region in the Connected Communities Roadmap 2.0.

INCLUDED TECHNOLOGIES:

- 5G
- Wi-Fi 6
- Public Wi-Fi Kiosks
- Edge Computing
- Smart Poles
- Fiberoptic Broadband
- Fixed Wireless Broadband
- Low-Earth Orbit (LEO) Satellite

Broadband and Digital Literacy

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

High market growth anticipated

SECTOR

Community-wide

MILESTONES

Increase urban-rural internet access parity

5G

Fifth-generation wireless (5G) is now standard for many broadband cellular networks in the U.S., particularly in major urban and suburban areas, and it provides faster and more accessible internet. Broad deployment began in 2019 and was rolled out quickly across the United States by major telecommunication companies, with continued deployment to less populated areas. 5G data transfer is between 10 and 100 times faster than other network options available today. Since 5G requires numerous towers, deployments are most effective in more densely populated areas such as downtowns and large suburbs. Thus, it may not be available in some communities, limiting their ability to leverage 5G for connectivity. Additionally, the use of 5G also requires 5G-enabled products, which may present a cost barrier for some community members. Greater understanding and awareness of 5G use cases can support further deployment. In particular, local government support of 5G adoption can help bridge the digital divide, support local economic expansion, improve services and increase public involvement.

Barriers to adoption vary. Local governments may lack the resources needed to manage and benefit from 5G connectivity,[3] and due to strict FCC requirements, communities have limited time to review proposals from service providers and identify locations for equipment. The initial upfront cost, financial risk or lack of clear financial benefits may be barriers to municipalities improving public internet access. There are also public concerns over health risks and aesthetics for 5G; however claims of negative health impacts are largely unsupported by scientific literature, and visually, 5G towers are virtually the same as third-generation (3G) or fourth-generation (4G) equipment.[4,5]

Technologies and Use Cases

- 5G-enabled smartphones and tablets, laptops, smart TVs, virtual reality via smartphones

Benefits

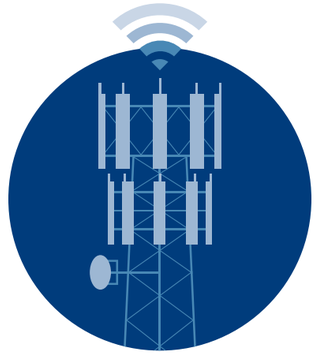
- Access to high-speed internet
- Host Internet of Things (IoT) devices

Regional Deployment

Local Project: Knoxville is partnering with telecommunications company CNX to deploy 5G. To deploy these services more quickly across Knoxville, CNX completed an inventory on city-owned assets.[6]

Additional Resources

Ongoing research into 5G is conducted by national laboratories, like the National Renewable Energy Laboratory (NREL) and the Pacific Northwest National Laboratory (PNNL), in conjunction with large communications companies. 5G infrastructure technologies are mature and deployment now is focused on bringing 5G to more rural areas.



POTENTIAL FUNDING

- None identified

Broadband and Digital Literacy

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate market growth anticipated

SECTOR

Residential, commercial and institutional

MILESTONES

Increase household broadband access

Wi-Fi 6

Sixth-generation Wi-Fi (Wi-Fi 6) technology, or high-efficiency Wi-Fi, is an Institute of Electrical and Electronics Engineers (IEEE) standard for wireless local area networks. Wi-Fi 6 aims to improve data rates in high-density areas, allowing it to support more devices at once and use less battery power. This technology also provides faster speeds for residences, businesses, educational facilities and public Wi-Fi applications such as smart poles or public Wi-Fi kiosks.[7]

The intensive data capabilities Wi-Fi 6 offers make it very useful in denser population centers. Although Wi-Fi 6 may require cabling upgrades, networking equipment is largely the same as other generations. While many new products support Wi-Fi 6, it is inaccessible to older devices and requires upgraded hardware on the consumer side and upgraded Wi-Fi network hardware.[8]

Technologies and Use Cases

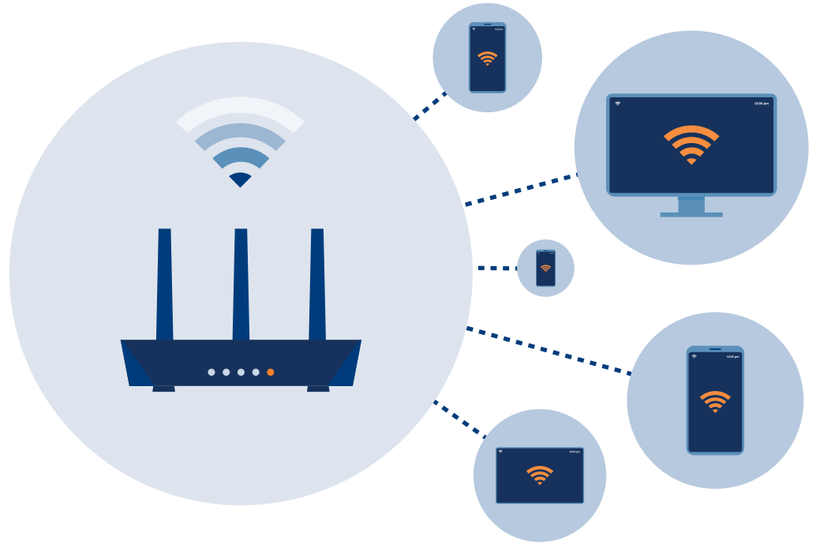
- Wi-Fi 6-enabled devices: routers, laptops and smart devices

Benefits

- Access to high-speed internet
- Can increase access to internet when paired with a broadband equity effort

Regional Deployment

Local Project: Numerous internet providers throughout the region offer Wi-Fi routers that support Wi-Fi 6 for residential and commercial customers. This is a mature technology deployed across the United States, with many players in this space.



Additional Resources

Many key players exist in the Wi-Fi 6 market including Cisco Systems, NETGEAR, Intel, Linksys Holdings and others.

POTENTIAL FUNDING

- None identified.

Broadband and Digital Literacy

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

Increase public Wi-Fi

Public Wi-Fi Kiosks

Public Wi-Fi kiosks are placed in public spaces and provide free Wi-Fi. These kiosks can also have a screen that shares details on community events, provides maps of the area, offers device charging, displays advertisements to support local businesses and a host of other capabilities.

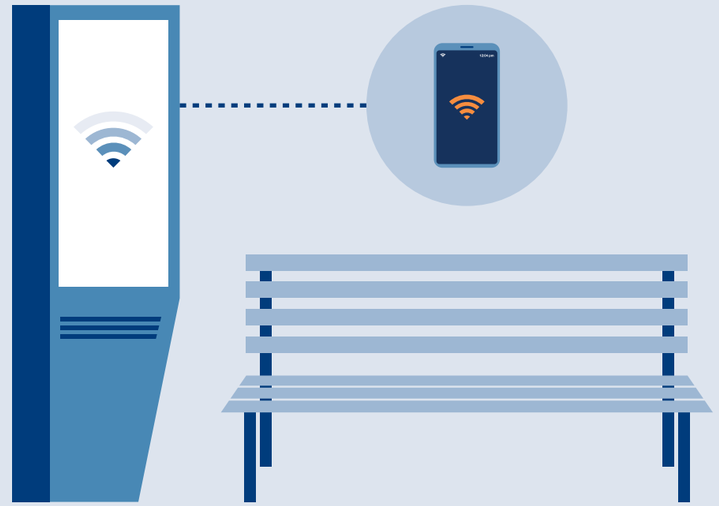
The growing necessity of the internet for daily life and the need for equitable access are driving the advancement of these kiosks, and advertising can provide revenue to fund the kiosks. When deploying public Wi-Fi kiosks, be mindful of privacy concerns about both data collection and the security of internet access, as the networks offered by the kiosks are often less secure than others.[9]

Technologies and Use Cases

- Kiosk infrastructure, routers

Benefits

- Access to high-speed internet



The internet is more than just entertainment now. It is increasingly important for everyday life - telemedicine, telebanking, job interviews and more. Public Wi-Fi kiosks help more people access this necessary tool.

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Broadband and Digital Literacy

PUBLIC WI-FI KIOSKS CONTINUED

Regional Deployment

TVA Initiative: Through the Connected Communities initiative, TVA is piloting this technology in Giles County. Pulaski Electric System (PES) is the electric provider for much of Giles County, Tennessee, and its subsidiary, PES Energize, has been a broadband provider in some portions of Giles County since 2007. PES installed public Wi-Fi hotspots in Lynnville, Elkton and Minor Hill, providing rural residents access to quality internet service.

Additional Resources

Link and IKE Smart City are companies that have experience with public Wi-Fi kiosks.

POTENTIAL FUNDING

- BIL - Digital Equity Competitive Grant Program
- BIL - Rural Utilities Service—Distance Learning, Telemedicine and Broadband Program
- BIL - State Digital Equity Capacity Grant Program

Broadband and Digital Literacy

AT A GLANCE

TECH READINESS

Limited commercial deployment but growing

POTENTIAL

High market growth anticipated

SECTOR

Commercial, institutions, state and local government

MILESTONES

Increase household broadband access

Edge Computing

Edge computing pulls together solutions that process data at or near the source of data generation. This generally happens using Internet of Things (IoT) devices rather than in a central location like a data center or the cloud. This allows for faster processing, more efficient data delivery and a reduction in necessary bandwidth to share data to the cloud or end users. Other benefits include reduced operational costs due to lessened data storage needs, improved system resiliency and flexible scalability.[10] Edge computing has applications in many sectors, including the power sector with grid monitoring using IoT devices, the farming sector with agricultural IoT devices, for higher education and research institutions and for municipalities for sensors and data collection including traffic, air quality monitoring, safety alert systems and more.

Open-source IoT/edge computing platforms are increasingly popular due to their flexibility, customization options and cost advantages.[11] However, the lack of awareness of this technology and cybersecurity concerns are barriers to greater adoption.[12]

Technologies and Use Cases

- Analysis of data from distributed devices and sensors (e.g., traffic data from sensors on traffic poles, monitoring air quality sensors placed on smart lighting poles and issuing alerts based on particulate levels identified)
- Real-time data processing, enhanced data security for supply chain and asset management by moving computing away from cloud processing

Benefits

- Improved computing to enable analytics
- Increases processing speeds

POTENTIAL FUNDING

- None identified.

Regional Deployment

Local Project: AT&T has partnered with University of Tennessee, Knoxville (UTK) to expand 5G coverage and edge computing on campus.[13] Additionally, TVA, Oak Ridge National Laboratory (ORNL) and the University of Tennessee are collaborating to help startups focused on the "industries of the future," including edge computing, through the Techstars Industries of the Future Accelerator program.[14]

Additional Resources

Dell, Microsoft and Amazon Web Services have all created edge computing platforms, and many large telecommunication providers have already implemented edge computing for their cellular networks.

Broadband and Digital Literacy

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

Increase urban-rural parity internet access

Supports Enhanced Community Resiliency

Smart Poles

Smart poles integrate connected lighting, wireless connectivity (Wi-Fi or cellular) and Internet of Things (IoT) sensors into one cohesively designed unit.[15] This technology, typically on streetlight poles, can provide public connectivity, charging for phones or electric vehicles (EVs) and reduce energy use from better managed connected lighting. Smart poles can also offer data via IoT sensors for air quality, noise, traffic movement, gunshot detection and more. They can also host public Wi-Fi access points or the small cells needed for mobile broadband networks, allowing for network space on poles that can be leased to third-party internet service providers for municipal revenue.[16]

Smart poles are part of a larger technological shift toward increased public connectivity and safety combined with smart city sensor infrastructure.[15] Some of the current challenges that decision-makers need to consider when implementing smart poles include the high cost per unit, data privacy concerns, ownership model and the use of cameras on smart poles.

Technologies and Use Cases

- Loudspeakers and visual alarms for music or emergency announcements
- Environmental sensors, such as flooding and air quality sensors
- Pedestrian count sensors
- Insights into energy usage of the poles

Smart poles serve a variety of functions - community safety, entertainment and connectivity. Cities and towns can choose from these functions to determine the right type of smart pole for their community.

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Broadband and Digital Literacy

SMART POLES CONTINUED

Benefits

- Access to high-speed internet
- Host IoT devices
- Access to data from a variety of sensors
- Energy savings from smart controls that adjust lighting level in response to brightness changes
- Revenue from allowing internet service providers to transmit through smart poles

Regional Deployment

TVA Initiative: Johnson City, Tennessee partnered with TVA, BrightRidge and the Electric Power Research Institute (EPRI) to install smart poles in downtown Johnson City. The poles include lights, cameras, speakers, pedestrian counters, parking kiosks and a Wi-Fi hotspot.[17]

Additional Resources

Several companies have experience with smart poles, such as Siemens, GE, Signify, ENE, HUB, Nokia and others.

POTENTIAL FUNDING

- BIL - Digital Equity Competitive Grant Program
- BIL - Rural Utilities Service — Distance Learning, Telemedicine and Broadband Program
- BIL - State Digital Equity Capacity Grant Program

Broadband and Digital Literacy

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Widely available but not in all areas

SECTOR

Community-wide

MILESTONES

Increase household broadband access

Fiberoptic Broadband

Fiber optic technology transmits data via light waves through transparent glass fibers about the diameter of a human hair. Fiber transmits data at speeds far exceeding current digital subscriber line (DSL) or cable modem speeds and currently has the highest capacity and distance capabilities of any transmission medium.[18] Fiber optic cables can either be installed aerially or underground, with underground installation providing resilience benefits for areas exposed to extreme weather conditions. However, this can make underground fiber a more expensive option for "last mile" service (from the core network to the home) than alternatives. Installing underground fiber to existing buildings can also involve significant logistical considerations, requiring coordination and approvals for right-of-way access, among other things. Nevertheless, the cost and logistics of installing fiber may be justified due to its resilience and overall performance benefits.

Technologies and Use Cases

- Cloud computing
- Enabling smart grid development
- Enabling video conferencing, streaming, smart home devices

Benefits

- Faster speeds, more scalability
- Higher reliability than other internet connections, including wireless
- Improved durability and resiliency in the event of a natural disaster

Regional Deployment

TVA Initiative: TVA has a 30-year Dark Fiber Program through which they lease surplus fiber in areas where economics may otherwise limit deployment for local entities.

Local Project: Chattanooga started offering fiber optic broadband in 2009 after receiving a $111 million grant from the Department of Energy (DOE). The network developed by EPB contributes to high-speed internet access for residences as well as the development of a smart grid. Review the Broadband Chattanooga case study to learn more.

Additional Resources

The University of Tennessee at Chattanooga (UTC) released a study outlining the significant benefits of fiber optic infrastructure for smart grid applications and economic development in Hamilton County.[19]

POTENTIAL FUNDING

- BIL - Digital Equity Competitive Grant Program
- BIL - Rural Utilities Service—Distance Learning, Telemedicine and Broadband Program
- BIL - State Digital Equity Capacity Grant Program

Broadband and Digital Literacy

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Widely available but not in all areas

SECTOR

Community-wide

MILESTONES

Increase household broadband access

Fixed Wireless Broadband

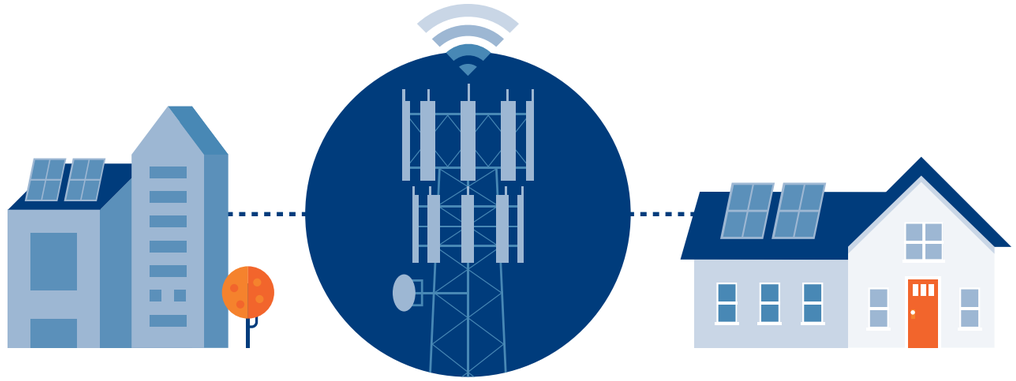
Fixed wireless broadband deployment involves attaching radios to two or more vertical assets to transmit signals. This technology uses longer-range directional equipment and can provide broadband service in remote or sparsely populated areas where other types of broadband would be too costly to provide. Fixed wireless offers internet speeds slower than other types; however, it requires minimal investment if vertical assets already exist. Additionally, fixed wireless broadband is a mature technology, with many commercial deployments and providers across the United States but has yet to be readily available in all areas. While fixed wireless does not face cost barriers as high as fiber, it does present technical feasibility challenges where the built environment, natural environment or weather can impact the signal.

Technologies and Use Cases

- Point-to-point microwave
- 5G fixed wireless
- WiMAX for providing internet to a wide area, such as a city or suburb
- Wireless mesh networks

Benefits

- Mature technology with deployments across the United States
- Less cost-intensive than other emerging internet technology



Regional Deployment

TVA Initiative: TVA's Antenna Collocation Program supports the licensing of space on existing structures for antennas, including those for fixed wireless broadband.

Local Project: BrightRidge provides a limited amount of fixed wireless broadband service to customers in upper East Tennessee. However, deployments are limited to special circumstances for shorter-term service provision in areas where traditional service is less feasible. Much of this type of broadband has been replaced by fiber and in the long term will largely act as a bridge to fiber deployment in difficult areas.

POTENTIAL FUNDING

- BIL - Digital Equity Competitive Grant Program
- BIL - Rural Utilities Service—Distance Learning, Telemedicine and Broadband Program
- BIL - State Digital Equity Capacity Grant Program

Additional Resources

The Federal Communications Commission (FCC), Wireless Internet Service Providers Association (WISPA) and Rural Utilities Service (RUS) websites are good resources for understanding and identifying funding sources for fixed wireless broadband.

Broadband and Digital Literacy

AT A GLANCE

TECH READINESS

Limited commercial deployment

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

Increase urban-rural internet access parity

Low-Earth Orbit (LEO) Satellite

Low-Earth orbit (LEO) satellite internet uses a constellation of small satellites closer to Earth to provide internet services. LEO satellite internet offers increased coverage in remote or undeveloped areas. A company must deploy thousands of satellites to maintain LEO satellite internet coverage, requiring large upfront investments for providers. This type of internet must also support competitive pricing and speeds comparable to other options to attract users – additional characteristics will be clarified as the technology develops.

While there is not a clear path for communities to be involved in the build-out of LEO satellite internet infrastructure and technology, customers should be aware of the costs and benefits of utilizing these services as the industry develops and costs decline. Although LEO satellite internet has yet to reach commercial scale, it is currently offered by Starlink, with additional companies pursuing other LEO satellite offerings.

Technologies and Use Cases

- Small, portable LEO satellite receivers placed in remote areas as an alternative to constructing broadband infrastructure

Benefits

- Lower latency and faster speeds (50+ Mbps for upload, 10+ Mbps for download) for internet
- Increased coverage for remote areas

Regional Deployment

Local Project: Starlink offers service to many remote areas in the United States and is likely to expand to most of the country in the future. It is currently available throughout some areas in the TVA region with plans to expand service to the Nashville area, potentially offering connectivity to those in more rural areas and those lacking adequate conventional broadband infrastructure. While the upfront cost is expected to be relatively high, certain plans may be a more viable long-term option for some businesses and residences.[20]

POTENTIAL FUNDING

- None identified.

Additional Resources

Companies such as Starlink, Amazon's Project Kuiper, Iridium Certus and Blue Origin are developing satellite internet services.

HIRING

Economic Empowerment

Technologies detailed in this section support economic security to help people in TVA's service region contribute to the modern economy. These emerging technologies support educational and entrepreneurial goals in line with the Connected Communities Roadmap milestones below.

INCLUDED TECHNOLOGIES:

- Virtual Reality for Work Force Development
- Artificial Intelligence (AI) for Small Businesses

Economic Empowerment

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

Increase training program availability

Virtual Reality for Work Force Development

Virtual reality (VR) and augmented reality (AR) can provide digital spaces for workforce development and training. VR and AR can provide immersive and interactive training, simulating environments and scenarios that mimic real-world work situations. This allows trainees to learn and practice their skills in a controlled and safe virtual setting. These applications could be beneficial to mitigate costs, maintain social distancing or avoid safety concerns in training.

VR training for workforce development is becoming more common and necessary due to the declining cost of VR technology, increasingly realistic and advanced experiences and the need to train employees remotely.[21] As with many digital technologies, there are data privacy concerns with this technology. Other barriers include virtual fatigue, as VR may be uncomfortable or disorienting after long periods, and the lack of accessibility for visually impaired trainees.[21]

Technologies and Use Cases

- AR and VR wearable headsets
- Remote assistance
- Accelerated training for industrial and critical infrastructure-related roles

Benefits

- Decreased time for workforce training
- Increased ability for remote training

Regional Deployment

Local Project: TRANSFR is a company based in Alabama that offers hands-on simulation-based training for workforce development. TRANSFR has collaborated with Alabama Industrial Development Training (AIDT) on a pilot study by offering VR training to a major defense manufacturer, which saw increased job retention.[22]

POTENTIAL FUNDING

- None identified.

Additional Resources

Some of the commercial players in this space are Oculus, STRIVR, HTC Vive and Quest for Business.

Economic Empowerment

AT A GLANCE

TECH READINESS

Limited commercial deployment but growing

POTENTIAL

High market growth anticipated

SECTOR

Commercial

MILESTONES

Decrease unemployment

Artificial Intelligence (AI) for Small Businesses

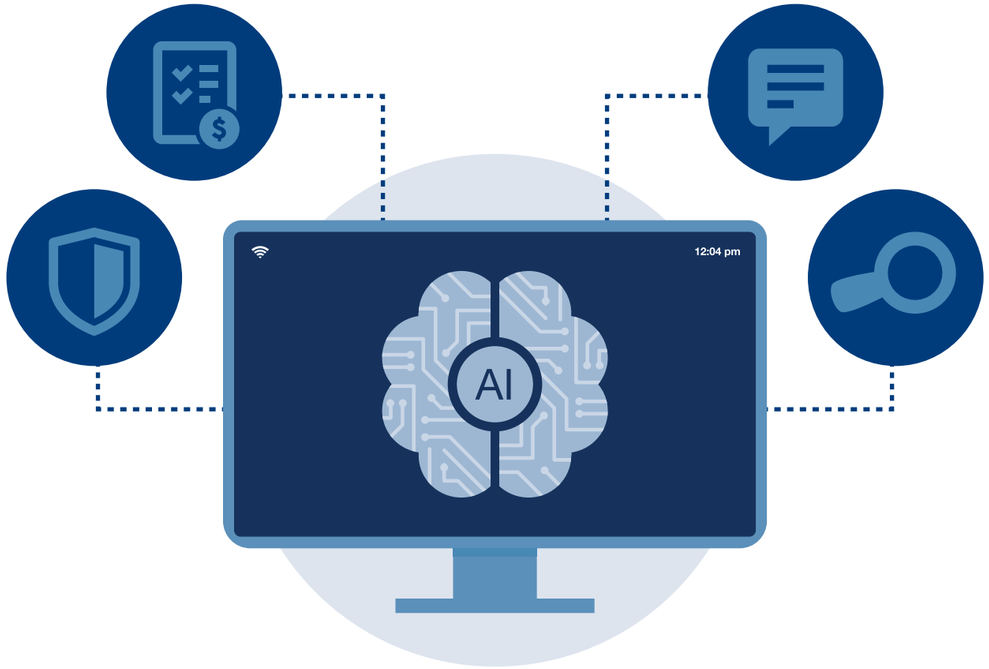
Artificial intelligence (AI) programs focus on performing tasks that typically require human cognition, such as problem-solving and decision-making. Machine learning (ML) is a subset of AI that involves developing algorithms and models that enable computers to learn from data and make decisions on their own. AI and ML can be used to augment financial reporting, customer service and experience, cybersecurity, CRM systems, market research and other critical business functions. While AI can be a service product, implemented as easily as other software, barriers could include awareness and familiarity with the technology among business owners, cybersecurity, change management and implementation challenges. Data ownership and governance is another important consideration with the use of AI, given that there can be opacity surrounding how AI models generate specific results from the data they are trained on, with some models requiring large amounts of data from various sources.

Technologies and Use Cases

- Open AI GPT-4, Google Bard
- AI customer service software, such as Intercom

Benefits

- Streamlined processes and tasks for small business owners
- Reduced costs, greater competitiveness in local markets
- Can support small businesses



Regional Deployment

None identified.

Additional Resources

The United States Chamber of Commerce offers guidance on ways that small businesses can leverage AI.

POTENTIAL FUNDING

- None identified.

Energy and Environmental Justice

Promotes access to healthy natural and built environments and reliable, affordable, clean energy for everyone in the TVA service region. These emerging technologies support energy and environmental justice goals in line with the Connected Communities Roadmap milestones below.

INCLUDED TECHNOLOGY SECTORS:

- Smart and Clean Energy Solutions
- Buildings
- Agriculture
- Mobility

Energy and Environmental Justice

Smart and Clean Energy Solutions

These community-wide technologies apply to anyone in the community: residents, businesses, institutions and industry.

INCLUDED TECHNOLOGIES:

- ✓ Smart Energy Community
- ✓ Microgrids
- ✓ Community Solar
- ✓ Virtual Power Plants
- ✓ Energy Load Disaggregation
- ✓ Digital Twin Modeling

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

In demonstrations

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

Increase non-utility owned solar and ownership options

Smart Energy Community

A smart energy community combines distributed energy and demand response resources to provide lower energy costs and higher levels of resilience, flexibility and control for a community. These communities may combine various technologies, including virtual power plants, distributed power generation, energy storage, smart inverters, smart meters, demand side management devices and vehicle-to-grid (V2G) systems.

Environmental regulations and energy consumers' desire for more reliable, controllable, inexpensive and locally generated energy is driving interest in smart energy communities. However, more widespread deployment faces barriers such as slow policy change, technology adoption, hesitation from residents, difficulty organizing within residential groups and costs associated with planning, constructing and operating a smart energy community.[23]

Technologies and Use Cases

- Virtual power plants – platforms that allow dispatch of energy flexibly and automatically utilizing software and smart devices
- Smart inverters and meters, demand side management (DSM) devices
- Bidirectional electric vehicle (EV) charging
- Energy storage and renewable generation such as wind, solar or geothermal
- Small modular reactors for district heating and electricity

Benefits

- Reduced energy costs and peak electric load

Regional Deployment

Local Project: In partnership with the Department of Energy (DOE), Oak Ridge National Laboratory (ORNL) implemented Smart Neighborhoods in Alabama and Georgia that manage energy for dozens of homes. The Alabama Smart Neighborhood, completed in 2017, has a microgrid and utilizes transactive energy. The Georgia Smart Neighborhood, opened in 2019, is powered by solar and battery energy.[24, 25]

Additional Resources

DOE has a series of "Connected Communities" projects (separate from TVA's Connected Communities) that highlight other smart energy communities.

POTENTIAL FUNDING

- BIL - Sec. 40107 Deployment of Technologies to Enhance Grid Flexibility - Smart Grid Program
- IRA - Sec. 45(Y) Clean electricity production tax credit
- IRA - Sec. 48(E) Clean electricity investment tax credit
- IRA - Sec. 30C Alternative fuel refueling tax credit

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

In demonstrations

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

Increasing non-utility owned solar and ownership options

Supports Enhanced Community Resiliency

Microgrids

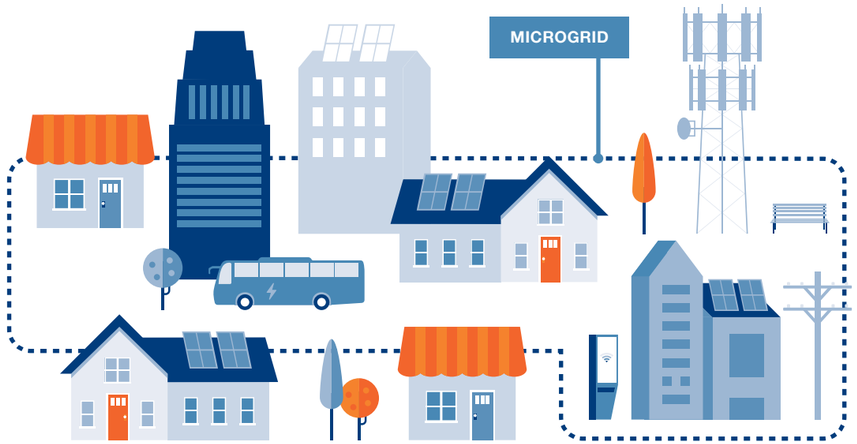
Microgrids utilize similar technologies as smart energy communities and can be implemented as a part of a smart energy community. However, microgrids enable a community or a piece of critical infrastructure to isolate completely from the grid by providing greater energy resilience and reliability for a small area (e.g., community areas, military bases, colleges, hospitals or commercial campuses) in times of grid instability. Increased frequency of extreme weather events, more favorable regulations and decreasing technology costs are all drivers behind an increase in microgrid activity, with business and industrial customers leading adoption. Community microgrids, serving residential and commercial customers, are the most difficult to deploy and have the slowest adoption due to upfront costs, regulatory challenges, varying public input requirements, participation and collaboration among several entities.[26]

Technologies and Use Cases

- Virtual power plants – platforms that allow dispatch of energy flexibly and automatically utilizing software and smart devices
- Smart inverters and meters, demand side management (DSM) devices
- Incorporation of energy storage and renewable generation such as wind, solar or geothermal
- Incorporation of small modular reactors for district heating and electricity

Benefits

- Improved resilience and reliability
- Reduced peak electric load and energy costs



Regional Deployment

TVA Initiative: TVA is exploring opportunities to support industries and federal customers around resiliency.

Local Project: EPB has three microgrids in its service territory that are used for research and are supported by the Department of Energy (DOE) funding. Additionally, Oak Ridge National Laboratory (ORNL) researchers use artificial intelligence (AI) and test bed “Commanders” to create simulations and perform research on secure controls and hardware using these research microgrids.[27]

Additional Resources

ComEd has a natural gas microgrid that incorporates solar and batteries, with Honeywell and Duke, both located close to TVA’s service region, also having experience with microgrids. Several private companies provide design, procurement and construction of microgrids, including Siemens, Enel Green Power, Ameresco, Bloom Energy, etc.

POTENTIAL FUNDING

- BIL - Sec. 40107 Deployment of Technologies to Enhance Grid Flexibility - Smart Grid Program
- IRA - Sec. 45(Y) Clean electricity production tax credit
- IRA - Sec. 48(E) Clean electricity investment tax credit
- IRA - Sec. 30C Alternative fuel refueling tax credit

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

Decrease energy burden and energy poverty and increase non-utility owned solar and ownership options

Community Solar

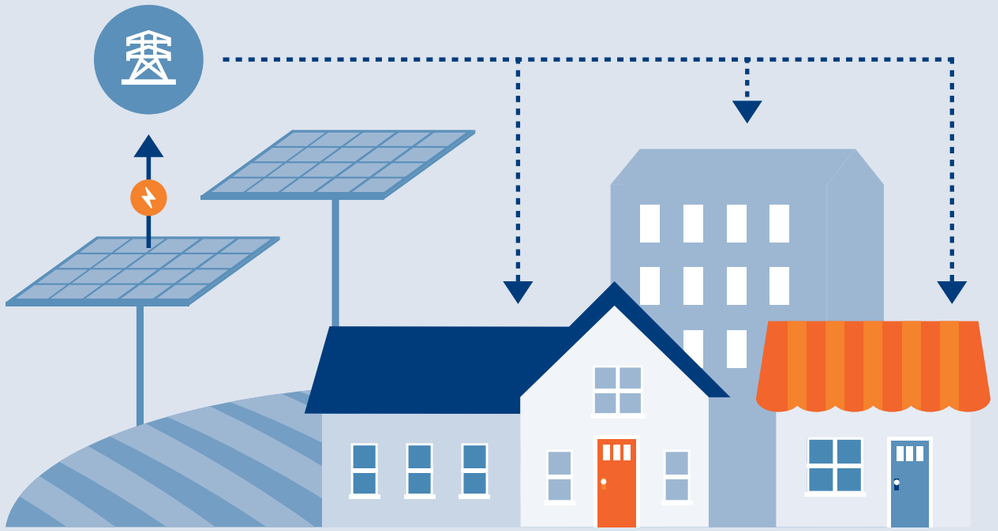
A solar project or power purchasing program within a geographic area in which the benefits of the solar project flow to multiple customers is called community solar. Community solar customers can either buy or lease a portion of the solar panels in the array, typically receiving a credit on their electricity bill for electricity generated by their share of the community solar system. This technology is more beneficial than individual solar systems because it allows a wide variety of customers to access renewable energy without needing to install solar systems themselves, providing the electric grid with additional generation capacity and resiliency. TVA's flexibility option allows local power companies to meet five percent of their power needs through local generating sources, including the option to offer community solar. These projects are driven by rising fuel costs, the desire to reduce carbon emissions, advances in solar technology and increased energy independence.[28] Community solar must be done in coordination with the local power company and requires significant up-front investment. However, there are many financing options available to communities, in addition to state and federal grants and tax incentives.

Technologies and Use Cases

- Community solar systems in conjunction with agrivoltaics
- Community solar systems installed on covered parking lots or local brownfield site remediation

Benefits

- Reduced energy costs and renewables adoption



Community solar allows for more diverse groups of people, like those living in apartments and condos, to participate in the clean energy transition.

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Energy and Environmental Justice

COMMUNITY SOLAR CONTINUED

Regional Deployment

TVA Initiative: TVA's Tennessee Valley Renewable Energy programs have provided access to community solar to over one million people.[29]

Local Project: Several local power companies and their communities offer community solar programs including Nashville Electric Services (NES), the city of Chattanooga and Middle Tennessee Electric (MTE). Partnering with TVA and the city of Knoxville, Knoxville Utilities Board (KUB) launched its community solar program, providing its customers with a simple way to support local solar generation.[30]

Additional Resources

The Department of Energy's (DOE) National Community Solar Partnership is a coalition of stakeholders working to expand access to community solar and help communities realize additional benefits, such as resilience and workforce development.[31]

POTENTIAL FUNDING

- IRA - Sec. 45(Y) Clean electricity production tax credit
- IRA - Sec. 48(E) Clean electricity investment tax credit

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

Decrease energy burden and energy poverty and increase non-utility owned solar and ownership options

Supports Enhanced Community Resiliency

Virtual Power Plant (VPP)

The term virtual power plant (VPP) is sometimes used to describe various approaches to supplement power plants, such as energy efficiency and demand response programs. In the context of emerging technologies, VPP is more narrowly defined as a system that relies on software and a smart grid to dispatch distributed energy resource (DER) flexibility services remotely and automatically to a distribution or wholesale market via an aggregation and optimization platform.[32, 33] VPPs can be managed by a utility or third-party provider. These systems focus on dispatching DERs to meet market needs, while DER management systems (DERMS) focus on grid reliability. Electrification, policies supporting DER adoption (which lead to an increase in DER penetration) and the adoption of time-of-use electricity pricing all play a role in driving the use of VPPs.[29] The complexity and cost of a system, privacy and cybersecurity concerns and customer outreach and education are just some of the hurdles for increasing the deployment of VPPs.[29]

Technologies and Use Cases

- Time of use pricing
- Real-time energy transactions
- DER, DERMS, distributed energy software platforms

Benefits

- Improved resilience and reliability
- Reduced peak electric load
- Reduced energy costs

Regional Deployment

TVA Initiative: Energy Services & Programs is exploring opportunities at large locations with backup power.

Local Project: In 2019, TVA awarded a research project to the University of Kentucky to study VPPs for DER aggregation and demand response controls to evaluate the impact of coordinated operation of appliances.[34] Kentucky's Glasgow Electric Plant Board also partnered with Sunverge for a three year storage VPP pilot in 2016, leveraging time-of-use electricity rates to reduce peak demand and support frequency regulation and voltage optimization.[35]

Additional Resources

Many utilities outside of the region have experience with VPPs, including Pacific Gas & Electric (PG&E), Con Edison and Green Mountain Power. Private companies such as AutoGrid, Swell, Sunverge, Sunrun and Tesla also have experience with VPPs.

POTENTIAL FUNDING

- BIL - Sec. 40107 Deployment of Technologies to Enhance Grid Flexibility - Smart Grid Program
- IRA - HOMES and HEEHRA home electrification and energy efficiency rebate programs
- IRA - Sec. 25D Residential clean energy tax credit
- IRA - Clean electricity Investment and Production tax credits (45Y and 48E)

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Commercially available and growing rapidly

POTENTIAL

Very high market adoption potential

SECTOR

Community-wide

MILESTONES

Increase energy efficiency program participation

Energy Load Disaggregation

Load disaggregation is the use of analytics and other data to identify individual electricity loads. This data can be useful for residential and small commercial customers to help them better understand their energy use and take action to improve energy efficiency. Increased data understanding can aid in reducing peak demand without requiring additional hardware to be installed. This data can also help utilities identify customers who already have or could benefit from certain technologies, such as distributed energy resources (DERs), heat pumps, electric water heaters or electric vehicles (EVs). While load disaggregation using smart meter data is a utility-driven solution, end-use customers can also purchase in-home energy management devices that monitor loads directly and in real time.

Smart meters are driving the implementation of load disaggregation. As utilities install smart meters, load disaggregation becomes feasible as the meter can now collect data.[36] However, the amount of data collected and processed may be a barrier to widespread adoption.[37]

Technologies and Use Cases

- Software analytics that provides appliance-level energy consumption from smart meter data without requiring hardware

Benefits

- Better understanding of how customers use electricity, enhancing opportunities to reduce and manage consumption
- Customer outreach and supporting the adoption of behind-the-meter (BTM) opportunities
- Enables more clean energy deployment

Regional Deployment

Local Project: The Middle Tennessee Electric (MTE) myMTE app allows all members to view and report outages, see usage, pay bills and more. MTE recently rolled out new app enhancements to give members even more control of their energy usage with load disaggregation technology. Members can now see how their home's energy efficiency compares to similar homes, get relevant energy-saving tips and look at a detailed breakdown of energy usage.

POTENTIAL FUNDING

- BIL - Sec. 40107 Deployment of Technologies to Enhance Grid Flexibility - Smart Grid Program

Additional Resources

Oracle, Bidgely, Uplight and Itron OpenWay are all resources for utilities interested in load disaggregation. For residential or commercial customers, Sense may be a good tool for load disaggregation as well.

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Multiple demonstration projects

POTENTIAL

High market growth anticipated

SECTOR

Community-wide

MILESTONES

Enhance community plans to further address Connected Communities focus areas

Digital Twin Modeling

Digital twin models are one-to-one digital recreations of real-world objects or systems with many applications. Digital twins are a visual tool for monitoring present conditions and simulating future scenarios, allowing for the possible use of machine learning or artificial intelligence (AI).[38] Depending on the sensors and available data, digital twins can inform municipal operations, flood planning, heat islands, water treatment, building efficiency, traffic management, air quality and more.[37]

Basic digital twin models (i.e., those without sensors to track real-time conditions) are relatively low-cost compared to those needed for testing on real-world infrastructure, allowing communities to create basic digital twins with easily accessible, open-source data such as Geographic Information System (GIS) data or satellite imagery.[37]

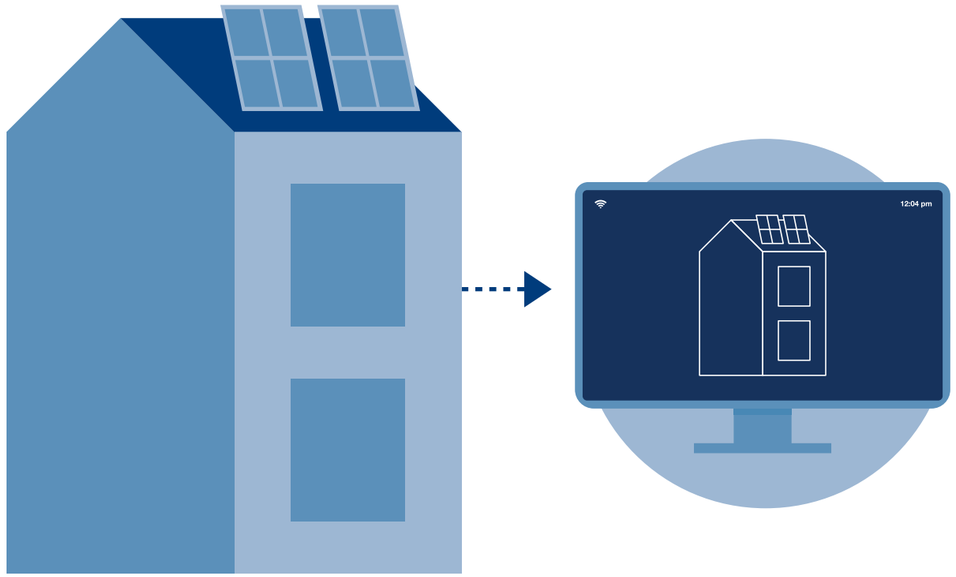
While digital twins present valuable use cases to various sectors, there is a knowledge gap about their applications and benefits. Utilities and municipalities, which may benefit from this technology, will need employees to be comfortable with and knowledgeable about working with digital twins.[37] There is also a general lack of digitized data, Internet of Things (IoT) sensors, data for the digital twins and proper data security and privacy.[37]

Technologies and Use Cases

- Modeling for resiliency and disaster preparedness

Benefits

- Better informed planning for electric and water infrastructure, buildings, transportation systems, etc.
- Increased ability to preemptively take action based on observations and changing conditions



Regional Deployment

Local Project: Oak Ridge National Laboratory (ORNL) has done significant work in this space, including creating a modeling program called Automatic Building Energy Modeling (AutoBEM), developing a digital twin for the power grid and working with Departments of Transportation on a digital twin model looking at traffic congestion.[39, 40, 41]

POTENTIAL FUNDING

- None identified.

Additional Resources

ORNL leads research and development on this topic.

Energy and Environmental Justice

Buildings

Technologies that can be applied to residential, commercial, institutional and industrial buildings or a combination of building types.

INCLUDED TECHNOLOGIES:

- ✓ Battery Storage for Reliability and Resilience
- ✓ Smart Heating, Ventilation and Air Conditioning (HVAC) and Water Heating
- ✓ Grid-Interactive Efficient Buildings
- ✓ Building Energy Modeling and Artificial Intelligence
- ✓ Building Thermal Storage
- ✓ Smart Windows and Glass
- ✓ Connected Lighting
- ✓ Smart Water Management
- ✓ Smart Wastewater Management

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

High market growth anticipated

SECTOR

Community-wide

MILESTONES

Decrease energy burden and energy poverty

Supports Enhanced Community Resiliency

Battery Storage for Reliability and Resilience

Small-scale battery storage (also known as "behind-the-meter" storage) serving residential and small commercial consumers can help reduce peak load, support the adoption of renewable energy and provide resilience. Given that generation from wind and solar can be variable based on weather conditions, batteries can help absorb excess energy and dispatch it when needed, improving the value proposition for renewables. Batteries can also improve resiliency by providing backup power in the event of an outage. Community energy storage, which is similar to community solar, is an uncommon but growing opportunity. Currently, most community energy storage projects are "front-of-the-meter" and utility-owned.[42]

Several drivers are increasing interest and use of this technology, including declining battery costs, higher market penetration, demand for resilience and more favorable incentives and rate structures.[43] Storage related incentives, new policies and processes for interconnecting battery storage and more favorable rate structures can help increase battery storage adoption in the region.[44]

Technologies and Use Cases

- Lithium-ion batteries
- Electric vehicles (EVs) and bidirectional charging

Benefits

- Improved energy efficiency
- Reduced peak electric load and energy costs
- Access to electricity during a power outage
- Potential for additional revenue streams for homeowners from energy markets
- Enables more clean energy deployment and increases resilience

Regional Deployment

TVA Initiative: Energy Services & Programs is exploring this technology.

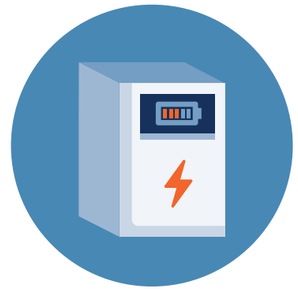
Local Project: Oak Ridge National Laboratory (ORNL) operates the country's largest open-access battery manufacturing R&D center, supporting manufacturing efficiency and a domestic supply chain for batteries by providing access to any United States battery manufacturer, material supplier, equipment manufacturer or battery end user.[45]

Additional Resources

National laboratories conduct various types of research on behind-the-meter battery storage projects including Pacific Northwest National Laboratory (PNNL), ORNL and National Renewable Energy Laboratory (NREL). Some states, like California, New York and Vermont, have crafted state policies that either incentivize or encourage the adoption of battery storage.

POTENTIAL FUNDING

- BIL - Sec. 41001 Energy storage demonstration projects
- BIL - Sec. 40207 State and local battery collection, recycling, and reprocessing programs
- IRA - Sec. 48 Environmental Justice for Solar and Wind Capacity
- IRA - Sec. 48E Clean Electricity Investment Credit
- IRA - Sec. 25D Residential Clean Energy Credit



Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Limited stand-alone commercial options

POTENTIAL

High market growth anticipated

SECTOR

Community-wide

MILESTONES

Decrease energy burden and energy poverty and increase energy efficiency program participation

Supports Enhanced Community Resiliency

Smart Heating, Ventilation and Air Conditioning (HVAC) and Water Heating

Smart heating, ventilation and air conditioning (HVAC) and residential water heaters are internet-connected devices that support an integrated approach to more efficient heating and cooling of buildings and water. They use smart thermostats, sensors and vents to provide more control to homeowners and also help maintain healthy indoor air quality (IAQ). Smart HVAC and water heating systems allow for a holistic approach to building energy monitoring and management, helping realize energy savings and, with the appropriate platform, enabling grid interactivity. These systems allow for remote monitoring and control, leading to increased learning, adaption and optimization of user preferences and needs.

Remote control of such devices allows for coordination aligned with grid management needs, better accommodation of household preferences and increased comfort. Smart thermostats allow users to remotely adjust settings, preemptively heat or cool a space when energy is cleaner or less costly and monitor status via an app – saving energy and money.[46] Systems must have interoperability with other buildings and the local power company's systems to work seamlessly.[47, 48] Commercial availability of advanced smart ventilation systems is increasing, spurred partly by the COVID-19 pandemic, though adoption is still not widespread.

Having an app to control your thermostat is not just convenient. It can also help save money by reducing energy costs.

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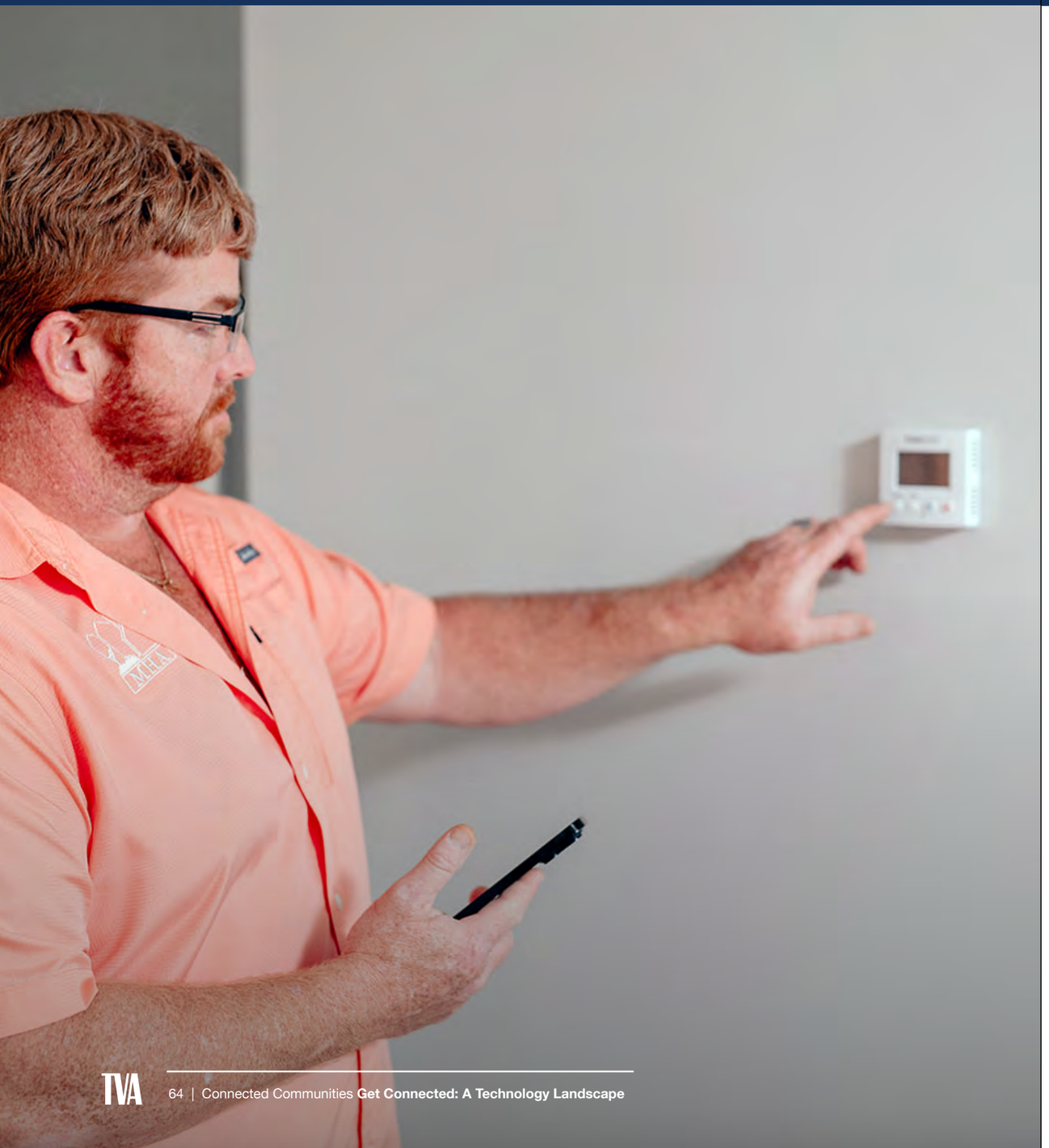
Energy and Environmental Justice



SMART HVAC AND WATER HEATING CONTINUED

Technologies and Use Cases

- Smart controls associated with geothermal systems, heat pumps or heat pump water heaters
- Thermal energy storage
- Air quality monitoring technology
- Connected HVAC devices

Benefits

- Improved energy efficiency, reduced energy costs
- Improved comfort and convenience
- Reduced peak electric load

Regional Deployment

TVA Initiative: Energy Services & Programs is exploring this technology.

Local Project: TVA has a variety of experience in this space. TVA conducted a smart water heater demonstration project with the Electric Power Research Institute (EPRI) and Bristol Tennessee Essential Services in 2009.[49] Additionally, TVA's EnergyRight Marketplace helps direct people to smart thermostats for purchase. TVA continues to research this topic with their Advanced Heat Pump group.

Additional Resources

The National Renewable Energy Laboratory (NREL) and Pacific Northwest National Laboratory (PNNL) have both researched smart ventilation while utilities across the nation have experience with smart heating solutions, particularly smart thermostats. PNNL also focuses research on smart heating.

POTENTIAL FUNDING

- BIL - Sec. 40502 Energy Efficiency Revolving Loan Fund Capitalization Grant Program
- IRA - HOMES and HEEHRA home electrification and energy efficiency rebate programs

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

In demonstrations

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

Decrease energy burden and energy poverty

Grid-Interactive Efficient Buildings

Grid-interactive efficient buildings (GEBs) use smart building controls, sensors and analytics to communicate with the grid. GEBs reduce the amount of energy required by appliances, heating, ventilation and air conditioning (HVAC) systems, water heaters and more during periods of peak demand. This capability is used to optimize buildings and distributed energy resources (DERs) to maintain the comfort of the building occupants, lower utility bills and reduce grid system costs. For buildings to be effectively integrated with the grid, local power companies will be critical partners for planning, data and integration studies.

GEB adoption receives large support from the Department of Energy (DOE) with the National Roadmap for GEBs released in May 2021 and the announcement of 10 projects through the Connected Communities DOE grant for coordinating multiple GEBs in October 2021.[43, 50] Challenges faced by GEBs include the interoperability of various systems in the building (e.g., HVAC, water heater, lighting, solar, storage and electric vehicle (EV) charging), high upfront costs associated with smart controls, distributed generation and storage and the lack of consumer understanding and awareness for adoption.

Technologies and Use Cases

- Smart lighting, HVAC, shades and windows

With the availability of so many smart appliances, there is an opportunity for more deployment of GEBs across the country.

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Energy and Environmental Justice

GRID-INTERACTIVE EFFICIENT BUILDINGS CONTINUED

Benefits

- Improved resilience and reliability of the energy system due to buildings' ability to reduce demand as needed
- Reduced energy costs and peak electric load
- Enables more clean energy deployment and increases resilience

Regional Deployment

TVA Initiative: Through Connected Communities, TVA is piloting this technology through one of its pilot projects in Murfreesboro, Tennessee.

Local Project: Oak Ridge National Laboratory (ORNL) is very involved with GEB technology, having deployed VOLTTRON, an open-source communications platform, and a microgrid for the DOE Alabama and Georgia Smart Neighborhood projects.[22, 51] ORNL is also involved in the Building Operations Testing Framework project.[52] TVA is involved with GEBs by working with the Electric Power Research Institute (EPRI) to better understand the technical feasibility of this technology to then provide lessons learned to local power companies.

Additional Resources

Various national laboratories, including ORNL, the Pacific Northwest National Laboratory (PNNL), the National Renewable Energy Laboratory (NREL) and DOE conduct research on GEBs. There are also some private companies in the GEB space, like GridOptimal.

POTENTIAL FUNDING

- IRA - HOMES and HEEHRA home electrification and energy efficiency rebate programs
- IRA - Sec. 25D Residential clean energy tax credit

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

Decrease energy burden and energy poverty

Building Energy Modeling and Artificial Intelligence (AI)

Building energy modeling (BEM) is a physics-based software simulation used for building and heating, ventilation and air conditioning (HVAC) design, allowing for the creation of performance assessments and development of energy codes and standards. BEM projects provide valuable support for the development and adoption of grid-interactive efficient buildings (GEBs) and GEB controls.[53] Integrating AI into current BEM methods can provide more accurate energy modeling at facilities, enhanced data and results visualization and improved system operations for energy savings.

BEM software is mature, widely used and commercially available. However, the increasing complexity of building energy systems and controls needs is driving the development of more complex BEM solutions to support urban planning, energy codes, energy efficiency and demand response efforts and building controls development. There are also limited educational offerings. Using AI for energy modeling and building control is an emerging technology that offers great promises but has not yet been widely verified.

Technologies and Use Cases

- AI for building HVAC optimization, fault detection and remediation, continuous building commissioning
- Advanced metering infrastructure (AMI) pump monitoring (commercial, industrial, municipal, agricultural)

Benefits

- Better informed planning for energy efficiency
- More accurate data and energy use forecasting for connected DERs and smart devices
- Enables more clean energy deployment and increases resilience

Regional Deployment

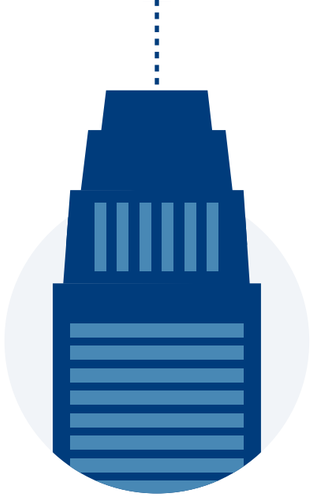
Local Project: Oak Ridge National Laboratory (ORNL) developed the modeling software suite AutoBEM, which uses satellite imagery to develop large-scale models across many buildings at once and enables the creation of digital twins of a community's buildings. ORNL is testing the accuracy of AutoBEM by comparing its outputs for an analysis of over 178,000 buildings across Chattanooga against actual energy data from EPB and other data sources.[54, 55]

Additional Resources

Both the Department of Energy (DOE) and national laboratories across the United States produce BEM research and tools. Additionally, there are some open-source software for use including EnergyPlus, OpenStudio and OptiMiser (specifically residential-focused). Several public and private sector services can be found on DOE's website.[52]

POTENTIAL FUNDING

- None identified.



Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Limited commercial deployment

POTENTIAL

High market growth anticipated

SECTOR

Commercial

MILESTONES

Improve air quality

Supports Enhanced Community Resiliency

Building Thermal Storage

Thermal energy storage (TES) at the building level can be used with heating and cooling systems and can help reduce energy usage.[56] Building-scale TES traditionally uses large tanks of hot or cold water or ice for storage. Current research is exploring phase-change materials that can be used as a layer of the building's walls or in refrigeration systems.

TES shows promise for reducing building heating and cooling costs, which propels ongoing research. However, drivers for commercialization are currently limited. Adoption requires buy-in from many stakeholders, including utilities, building owners, designers, architects and engineers, slowing TES implementation on a broader scale.

Technologies and Use Cases

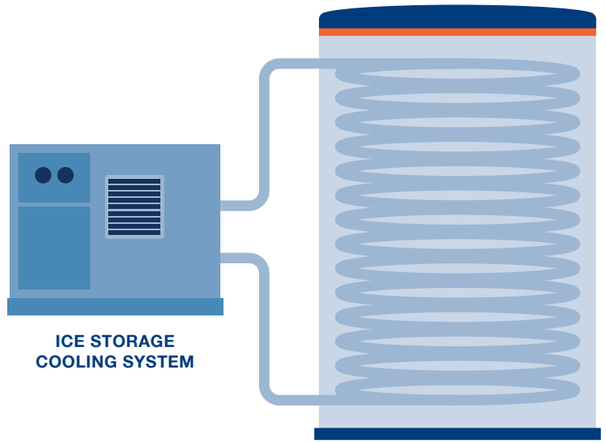
- Phase change material including ice storage in containers to shift energy consumption to low-cost or non-peak hours
- Thermal storage tanks to increase energy delivery capacity and enable shifting energy demand away from peak hours, electrifying industrial loads with an electric boiler for example

Benefits

- Improved energy efficiency
- Reduced peak electric load
- Reduced energy costs
- Reduce baseload and peak energy demand

Regional Deployment

None identified.



Additional Resources

Various national laboratories, like the National Renewable Energy Laboratory (NREL), the Lawrence Berkeley National Laboratory (LBNL) and the Oak Ridge National Laboratory (ORNL), conduct research on this topic. Due to the limited commercial deployments of this technology, there are few commercial companies.

POTENTIAL FUNDING

- BIL - Sec. 41001 Energy storage demonstration projects
- IRA - Sec. 48 Environmental Justice for Solar and Wind Capacity
- IRA - Sec. 48E Clean Electricity Investment Credit
- IRA - Sec. 25D Residential Clean Energy Credit

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

High market growth anticipated

SECTOR

Community-wide

MILESTONES

Decrease energy burden and energy poverty

Smart Windows and Glass

Any glass or windows that can automatically change their properties to reduce heat and glare in a building are considered smart windows or glass. These smart windows can also provide privacy to those inside the building. This, combined with the reduced heating and glare, improves the comfort levels of the occupants of the building and can help reduce energy costs.[57]

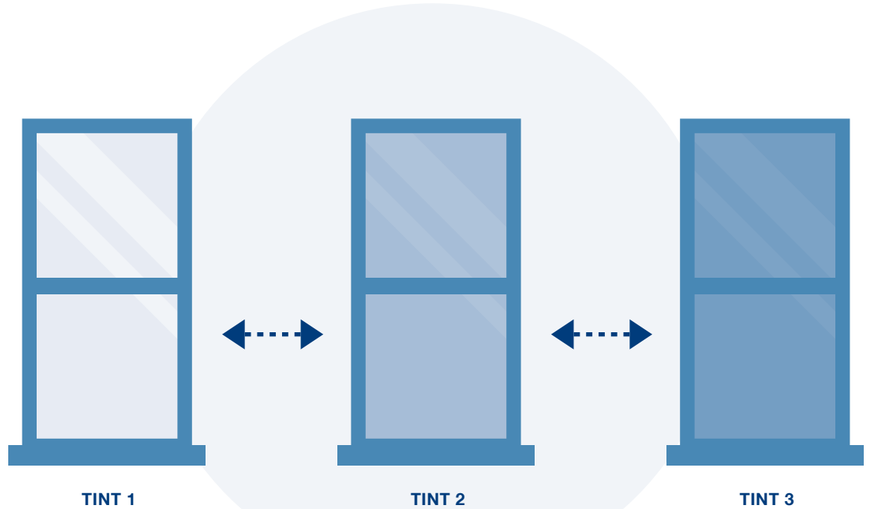
The desire to improve occupant comfort levels in addition to the ability to pair their functionality with smart buildings is driving increased adoption of smart windows and glass.[56] Growth has been slower than expected due to a lack of stakeholder education on smart windows and the higher price in comparison with traditional windows and glass. There is currently a lack of market competition that would cause the price of these products to decrease.[56]

Technologies and Use Cases

- Electrochromic and thermochromic windows that change color based on electric current or heat
- Photochromic windows which adjust darkness or opacity based on ultraviolet (UV) levels

Benefits

- Improved energy efficiency
- Reduced peak electric load and energy costs
- Improved comfort and convenience



Regional Deployment

Local Project: View, a private smart glass company, installed their smart windows at three locations in Tennessee: Methodist University Hospital, Erlanger Children's Hospital Outpatient Center and the Memphis International Airport.[58, 59]

POTENTIAL FUNDING

- IRA - HOMES and HEEHRA home electrification and energy efficiency rebate programs

Additional Resources

View, SageGlass, Halio, PHYSEE, PowerWindows and EControl-Glas are all smart window companies across the globe. The National Renewable Energy Laboratory (NREL) also researches applications of this technology.

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

High market growth anticipated in education and retail buildings

SECTOR

Community-wide

MILESTONES

Decrease energy burden and energy poverty

Connected Lighting

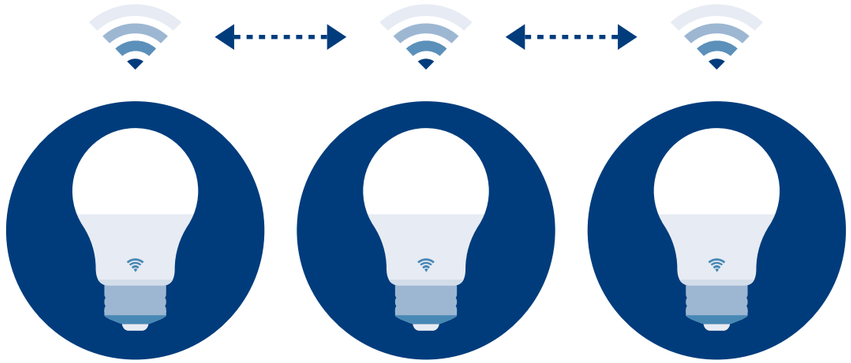
Internet-connected lighting systems, or smart lighting systems, are used to increase energy efficiency and occupant controls. This is done by using sensors or controllers that allow for the lights to communicate with each other and transmit data to help make decisions about lighting in individual rooms.[60] The savings that come from reduced energy use, utility incentives and rebates and popularization of smart building management systems encourage wider adoption of smart lighting systems in commercial buildings.[59, 61] Smart lighting systems face barriers to greater adoption, including higher costs compared to basic lighting systems, a limited pool of knowledgeable professionals in this space and the lack of awareness and standardization in smart lighting system setup.

Technologies and Use Cases

- Smart bulbs, switches and plugs
- Control hardware such as bridges
- Control software

Benefits

- Improved energy efficiency
- Reduced peak electric load and energy costs
- Improved comfort, light quality and convenience



Regional Deployment

TVA Initiative: Energy Services & Programs is involved in energy efficiency initiatives and programs which may involve connected lighting.

Local Project: The state of Tennessee partnered with Osram, a smart lighting company, to retrofit lighting systems in state buildings, reducing their consumption by an expected 60-80%. Updates included daylight harvesting and occupancy sensors. Osram also completed projects for other Tennessee buildings, including the Tennessee Supreme Court, East Tennessee Regional Health Office and East Tennessee Fire Services and Codes Enforcement, all using advanced lighting controls and LED lights.[62]

Additional Resources

Signify and Enlightened are two smart lighting companies that can provide the services described above.

POTENTIAL FUNDING

- BIL - Sec. 40502 Energy Efficiency Revolving Loan Fund Capitalization Grant Program
- BIL - Sec. 40552 Energy Efficiency and Conservation Block Grant Program
- IRA - Sec. 30002 Green and Resilient Retrofit Program
- IRA - HOMES and HEEHRA home electrification and energy efficiency rebate programs

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

Increase energy efficiency program participation

Supports Enhanced Community Resiliency

Smart Water Management

Smart water management uses sensors and data to inform better overall management and monitor water quality. The analysis can be done using historical and/or sensor data for applications such as detecting water leaks, checking water quality and enabling predictive maintenance. Another possible application of smart water management is to narrow the search for lead in water service pipes so that cities can replace them; this has traditionally been difficult due to a lack of installation records.[63]

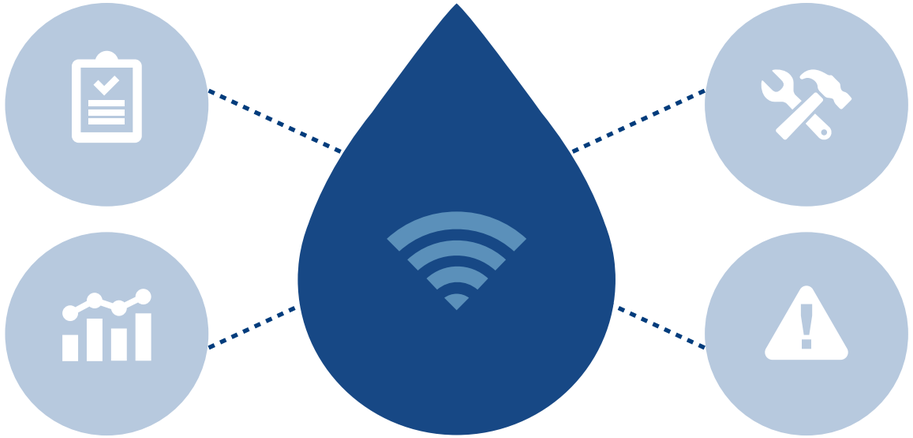
Climate change and increasingly scarce freshwater resources are driving forces for more smart water management implementation.[64] However, implementing smart water management technology can be difficult with required collaboration between city departments, limited funding opportunities and data integrations that may not yet exist.[65]

Technologies and Use Cases

- Water level and pressure sensors
- Smart water metering and Internet of Things (IoT) devices

Benefits

- Improve water and wastewater management, efficiency and contamination monitoring
- Cost savings
- Enhance resource stewardship



Regional Deployment

Local Project: The White House Utility District (WHUD), located in White House, Tennessee, implemented a leak detection program in collaboration with Esri, a software company. Data from smart water meters throughout the district is pulled into geographic information system (GIS) maps in real-time. WHUD also installed high- and low-flow alarms that trigger if water flow goes below or above a certain threshold.[66]

POTENTIAL FUNDING

- BIL - Delta Regional Authority Community Infrastructure Fund

Additional Resources

Smart water management research and implementation are conducted by the United States Geological Survey (USGS). There are also some private companies that have experience in this space, including Optiqua, ZWEEC and AquaTEC.

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate market growth anticipated

SECTOR

Community wide

MILESTONES

Increase energy efficiency program participation

Supports Enhanced Community Resiliency

Smart Wastewater Management

Smart wastewater management focuses on using sensors to monitor wastewater contents, the presence of chemicals in water and system capacity. Sensors can also detect leaking pipes and the impact of rainfall on sewage systems. Internet of Things (IoT) technology provides insights into wastewater issues by assessing the patterns of leaks, floods and contamination and enables quick reaction times and problem solving.[67]

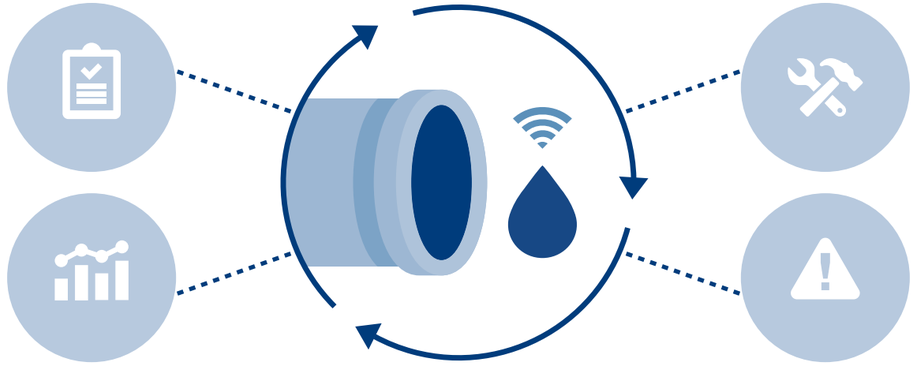
The sensors for smart wastewater management are easy to use and have a fast response time.[68] Using sensors for remote monitoring also eliminates the need for maintenance staff to check pipes as regularly or collect samples for lab monitoring. This may save time as some industries, such as manufacturing, are required to use devices to monitor wastewater quality to ensure wastewater does not contain trace metals or chemicals.[69] A challenge to implementing sensors across a system is that it requires significant build-out, and companies may be unwilling to spend large sums to accomplish this.[68]

Technologies and Use Cases

- Smart water metering and IoT devices

Benefits

- Improve water and wastewater management, efficiency and contamination monitoring
- Enhance resource stewardship



Regional Deployment

Local Project: Spencer, Tennessee partnered with Electroc Scan Inc. and implemented a sensor system to detect leaks in the city's primary raw water pipeline after receiving a grant in 2019 under the Water Infrastructure Improvements for the Nation Act.[70] Additionally, the city of Memphis implemented a smart sensor monitoring system for industrial wastewater discharge. The system monitors water quality for more than 100 industrial sampling sites in the city's wastewater service area. City staff can use the data collected by these sensors to see information about discharge in real-time.[71]

POTENTIAL FUNDING

- BIL - Delta Regional Authority Community Infrastructure Fund

Additional Resources

The United States Geological Survey (USGS) Upper Midwest Water Science Center is testing smart waste water technology by using optical sensors to detect sewage contamination in the Great Lakes. The sensors will be able to identify sources and timing of contamination.

Agriculture

The following technologies are applicable on farms and other agricultural applications.

INCLUDED TECHNOLOGIES:

- Internet of Things (IoT) for Agriculture
- Controlled Environment Agriculture – Smart Controls
- Agrivoltaics

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate market growth anticipated

SECTOR

Community wide

MILESTONES

Improve air quality

Internet of Things (IoT) for Agriculture

Internet of Things (IoT) for agriculture includes using sensors and drones to monitor and manage farms more accurately. These allow for precision farming, smart greenhouses, livestock tracking and remote, smart technologies for irrigation, fertilization and field monitoring.

Three key sectors are driving the adoption of IoT across farming and agriculture: smart greenhouses, precision agriculture and livestock tracking and monitoring.[72] Upfront costs and connectivity/bandwidth needs are the main barriers to adoption. IoT networks require many sensors and consistent, reliable internet connectivity to be effective, both of which can be difficult for interested parties to obtain.[71]

Technologies and Use Cases

- Precision farming using analysis of crop growth, soil conditions, weather patterns and other variables
- Automated irrigation systems
- Drones with cameras and sensors
- Livestock monitoring

Benefits

- Reduced operational, water/electricity use and costs
- Potential to reduce food costs
- Enhance resiliency by supporting local agriculture
- Reduce baseload and peak energy demand
- Support local agriculture

Regional Deployment

Local Project: The University of Tennessee, Knoxville (UTK) offers a precision livestock farming research initiative.[73] UTK also has a Smart Agriculture Laboratory researching sensors, robots and IoT networks for farming applications.[74] Outside of the university setting, AgLaunch is a non-profit based in Tennessee that works to support start-ups focused on agriculture technology and supporting farmers looking to modernize.[75]

POTENTIAL FUNDING

- IRA - Sec. 22002 Rural Energy for America Program

Additional Resources

Some large companies in the agriculture space, like Farmers Edge, Bayer and John Deere, are good additional resources for this topic.

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

High market growth anticipated

SECTOR

Agriculture

MILESTONES

Improve air quality

Supports Enhanced Community Resiliency

Controlled Environment Agriculture – Smart Controls

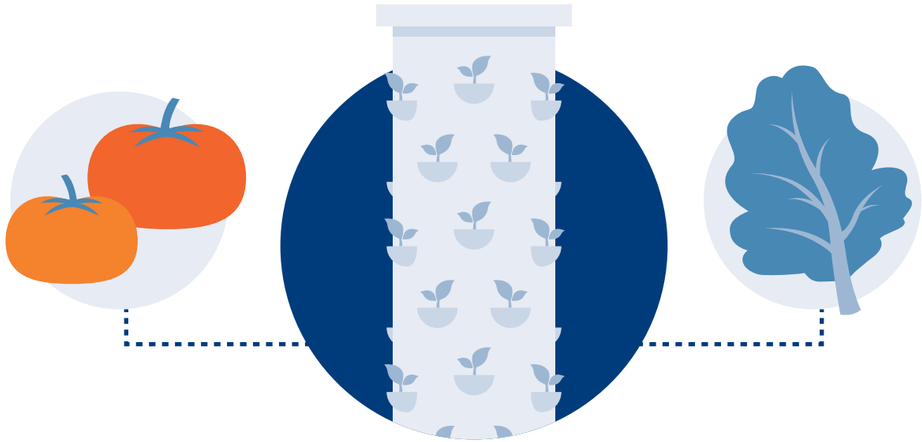
Controlled environment agriculture (CEA) is an advanced and intensive form of indoor agriculture where plants grow in enclosed structures, like greenhouses or indoor facilities, with light, temperature, fertilizers and humidity closely controlled. CEA can increase crop yields and quality, help conserve resources like fertilizer and water, reduce land requirements by allowing vertical farming and minimize the impact of pests and diseases. This method also allows the production of locally grown, fresh produce that can be harvested at peak ripeness, and it is commonly used for crops such as leafy greens, strawberries, other types of produce and ornamentals.

Technologies and Use Cases

- LED grow-lights
- Heat recovery
- Automation and Internet of Things (IoT) for smart and connected lighting and ventilation controls
- IoT for smart irrigation and nutrient delivery

Benefits

- Better informed decisions to maximize production and minimize usage of energy, water and fertilizers
- Smart controls enabling flexible load management and reduce peak electric demand
- Enhanced resiliency by creating a local food supply chain and protecting crops from weather and storms



VERTICAL FARMING

Regional Deployment

TVA Initiative: TVA has partnered with the Electric Power Research Institute (EPRI), Knoxville Utility Board (KUB) and the University of Tennessee Institute of Agriculture to develop a containerized indoor agriculture project in Knoxville. The project is one of 22 farms intended to collect data on the impact of various parameters on indoor food production – including power, temperature, humidity, airflow, water use and more. This data will help inform electric load planning, water impacts, rate design, workforce development and sustainability considerations. The food produced at this farm is donated to the Second Harvest Food Bank of East Tennessee.[76]

Additional Resources

The Department of Energy (DOE) integrated lighting campaign initiative offers information on integrated lighting in greenhouses.

POTENTIAL FUNDING

- BIL - Sec. 40109 State Energy Program
- BIL - Sec. 40502 Energy Efficiency Revolving Loan Fund Capitalization Grant Program
- BIL - Sec. 40552 Energy Efficiency and Conservation Block Grant Program
- IRA - Sec. 179D Energy Efficient Commercial Buildings Deduction

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Demonstration pilots

POTENTIAL

Moderate market growth anticipated

SECTOR

Community wide

MILESTONES

Decrease energy burden and energy poverty and increase non-utility owned solar and ownership options

Agrivoltaics

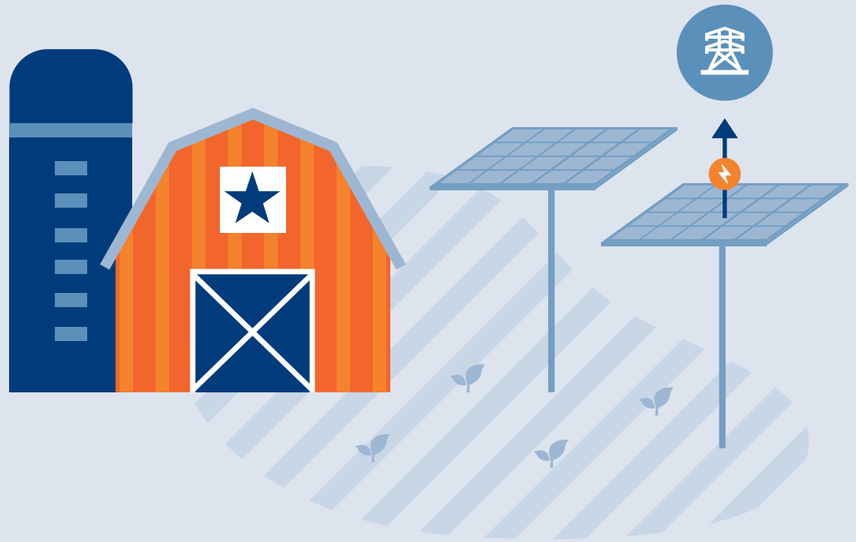
Solar panels can require a large area for use, and sometimes there is limited building rooftop space available in certain locations. Agrivoltaics involves the co-location of solar photovoltaics and agriculture that can lead to water savings, increased food production and improved energy production. Current research into agrivoltaics indicates increased solar panel efficiency and crop yields, particularly for shade-tolerant and temperature-sensitive crops.[77] Using this approach retains and potentially enhances agricultural land use and soil quality. While the National Renewable Energy Laboratory (NREL) does not believe agrivoltaics will likely be feasible for large-scale, single-crop farms, it has benefits in hotter areas or where farmland is limited.[78] Applications also include grazing from smaller animals such as sheep. Regulations regarding land use and project siting can cause challenges for interested farmers, as regulations often restrict uses on agricultural land.[76]

Technologies and Use Cases

- Animal grazing and shade for plant growth below elevated solar panels
- Solar powered irrigation systems, grain drying and other electrified farm equipment
- Floating solar panels over ditches and ponds to reduce evaporation

Benefits

- Reduced water/electricity use and costs
- Reduced operational costs
- Potential to reduce food costs
- Increase value and revenue streams for farmers



Agrivoltaics provide another option for solar deployment, especially in locations where roofs may not be suitable but farmland is available.

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Energy and Environmental Justice

AGRIVOLTAICS CONTINUED

Regional Deployment

Local Project: The Tennessee Department of Environment and Conservation (TDEC) has offered funding opportunities to farmers interested in on-farm renewable energy projects.[76] TVA, along with the University of Tennessee, Knoxville (UTK), is exploring a grant for agrivoltaics involving soybeans and sheep, with three potential locations in Kentucky. The University of Tennessee at Chattanooga (UTC) also works on a pilot project in central Tennessee.

Additional Resources

At the national level, NREL and the U.S. Department of Agriculture (USDA) are good resources for more information on agrivoltaics, with a recent NREL publication on the InSPIRE project.[79] University of Massachusetts and Oregon State University are two universities that provide additional information on this topic.

POTENTIAL FUNDING

- IRA - Sec. 48 Environmental Justice for Solar and Wind Capacity
- IRA - Sec. 48E Clean Electricity Investment Credit
- IRA - Sec. 25D Residential Clean Energy Credit
- IRA - Sec. 22002 Rural Energy for America Program
- IRA - Sec. 22004 Empowering Rural America New ERA Program
- The proposed federal "Pollinator Power Act" and "Agrivoltaics Research and Demonstration Act", if passed, would also support this approach and offer federal grants for agrivoltaics.[80]

Energy and Environmental Justice

Mobility

The emerging technologies detailed in this section support the transition from fossil-fuel-based transportation.

INCLUDED TECHNOLOGIES:

- ✔ Electric Vehicles (EVs) and Charging Infrastructure
- ✔ Managed Charging and Vehicle Grid Integration
- ✔ Community Electric Vehicle (EV) Charging Plazas
- ✔ Electric School and Transit Buses
- ✔ Micromobility

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

High market growth anticipated

SECTOR

Mobility

MILESTONES

Increase public EV access, charging stations and programming

Electric Vehicles (EVs) and Charging Infrastructure

Electric vehicles (EVs) offer great promises to shift the transportation sector to cleaner fuel sources. Gas and diesel vehicles are the biggest sources of CO_2 emissions in the United States, and switching to EVs reduces air pollutants.[81] Charging at times of low energy use, like overnight, also helps keep rates low. However, the benefits of switching to EVs go beyond the tailpipe. Running off power from the electrical grid, EVs are designed for optimal efficiency. With no heavy engine under the hood, EVs can be safer in head-on collisions, and battery-powered motors also make for smoother, stronger acceleration. Driving an EV is much easier regarding maintenance schedules, with fewer maintenance checks needed. The batteries in EVs are generally designed to last for the expected lifetime of the vehicle, with most manufacturers offering 8-year/100,000-mile warranties. While many EVs have ranges of a few hundred miles, the need for charging infrastructure is currently a barrier to the widespread adoption of EVs.

Technologies and Use Case

- Replacing municipal and company fleets with EVs
- Electric shuttles or vans for housing complexes
- Car-share and rideshare with EVs
- A network of public EV charging stations (level 2 and direct current (DC) fast chargers)

Benefits

- Easier maintenance and lower emissions
- EVs can serve as a backup battery during peak electric demand and power outages, enhancing resiliency

Regional Deployment

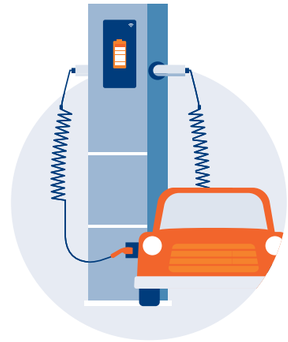
TVA Initiative: TVA is working with a broad coalition of partners to increase the number of EVs in the region. TVA's shared goal is to pave the way for more than 200,000 EVs on Valley roads by 2028. Energy Services & Programs is exploring EV charging to enable and prepare for large-scale electric transportation and develop a fast charging network (e.g. Fast Charge TN Network).

Additional Resources

TVA has created a strategic plan for developing a fast-charging EV network across the region, making it easier for drivers to make the switch to EVs.[82] In November 2020, the TVA Board approved the development of a new EV policy with an optional EV rate. Together, the policy actions and rate options can spur the development of public charging infrastructure across the TVA region. TVA is building a coalition of automakers, cities, transit agencies, rideshare companies and fleet operators committed to bringing EVs and investment to the region. More info can be found on the EnergyRight website.

POTENTIAL FUNDING

- BIL - Sec. 11401 Grants for Charging and Fueling Infrastructure
- IRA - Sec. 30C Alternative Fuel Refueling Property Credit



Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Limited commercial deployment but growing

POTENTIAL

High market growth anticipated

SECTOR

Mobility and buildings

MILESTONES

Improve air quality

Supports Enhanced Community Resiliency

Managed Charging and Vehicle Grid Integration

Managed charging and vehicle grid integration require infrastructure for electric vehicle (EV) chargers that are connected to the internet via Wi-Fi or cellular to enable flexible load management. This includes chargers capable of discharging to the home or the electric grid in times of high electric demand or serving as an energy supply resource, known as vehicle-to-home (V2H) or vehicle-to-grid (V2G). EV charging is a mature technology with bidirectional charging equipment commercially available but faces barriers to widespread adoption in some markets, such as multifamily and low- to-moderate-income housing. Additionally, demand for this technology is limited both by the lack of vehicle models that enable V2H or V2G capabilities and EV adoption as a whole. The number of bidirectional-enabled EV models is expected to grow, with V2H capability as a key value proposition among new models. Full functionality for grid interaction is still nascent and relies partly on other developments in energy markets. EV charging equipment faces high costs for implementation and requires collaborative support for buildout, including support from EV manufacturers, electric utilities and federal funding.

Technologies and Use Cases

- Advanced multifamily EV load management system
- Connected residential level 2 chargers
- Bidirectional chargers for V2H and V2G
- Reduces the need for energy generation when it is most costly or polluting

Benefits

- Connected EV chargers enable shifting of charging to off-peak periods (periods when demand for electricity on the electric grid is lower and generally less costly)
- EVs can serve as a backup battery during peak electric demand or power outages, enhancing resiliency

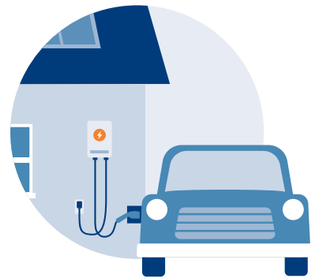
Regional Deployment

TVA Initiative: Energy Services & Programs is exploring EV charging.

Local Project: TVA, Middle Tennessee Electric (MTE) and Nashville Electric Service (NES) have collaborated on a two-year smart charging pilot with 200 chargers in the greater Nashville area that limit EV charging during times of peak demand for electricity.[83] TVA, in collaboration with Oak Ridge National Laboratory (ORNL), has also recently started testing bidirectional charging with the Ford F-150 truck at ORNL's Yarnell Station research house. The goal of this project is to power a home with the truck in the event of an outage and potentially integrate with home energy management systems.

POTENTIAL FUNDING

- BIL - Sec. 11401 Grants for Charging and Fueling Infrastructure
- IRA - Sec. 30C Alternative Fuel Refueling Property Credit



Additional Resources

The Department of Energy (DOE) and the Department of Transportation (DOT) offer a variety of training materials on EVs and EV charging equipment installation. Bidirectional charger manufacturers include Nuuve, Wallbox, Enphase and Mitsubishi.

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Limited commercial deployment but growing

POTENTIAL

High market growth anticipated

SECTOR

Mobility

MILESTONES

Increase public EV access, charging stations and programming

Supports Enhanced Community Resiliency

Community Electric Vehicle (EV) Charging Plazas

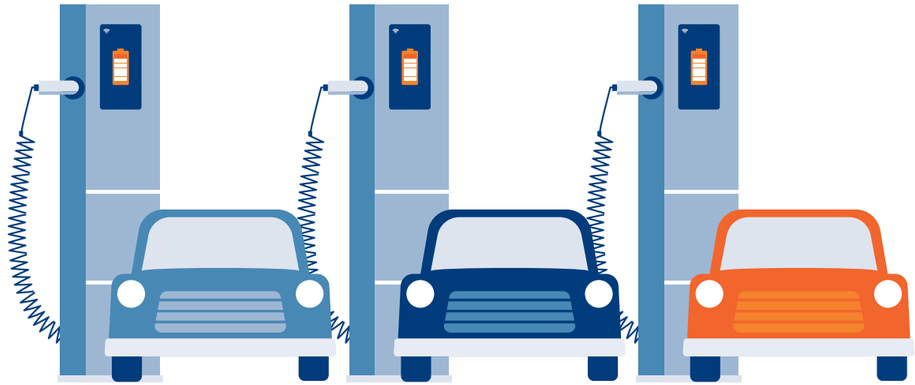
Community charging plazas are publicly accessible facilities with multiple electric vehicle (EV) charging stations in a central location. These plazas can feature shared ownership models within the community, offering subsidized charging rates similar to the concept behind community solar. Given the barriers associated with EV charging station implementation at multifamily and affordable housing units, community charging can help spur growth in EVs in underserved areas. While the technology associated with charging infrastructure is mature, upfront costs, grid infrastructure, land availability and regulatory challenges can make building community charging plazas difficult. Overcoming these barriers requires collaboration and partnerships between community leaders and members, EV charging station vendors and local electric utilities.

Technologies and Use Cases

- Direct current (DC) fast charging stations in publicly-owned locations
- Managed charging for fleets and vehicle-to-grid (V2G) infrastructure
- Integration with mobility services such as ride or car-sharing programs

Benefits

- Increased adoption of EVs leads to reduced localized air pollution in underserved areas
- Reduced economic burden of fuel costs and travel



Regional Deployment

TVA Initiative: Energy Services and Programs is exploring EV charging, and TVA's EnergyRight supports fast charging specifically through their fast charge program. This program aims to deploy 80 new DC fast charging sites in communities across the TVA region by 2026, filling gaps in access to fast charging. This program is currently available to local power companies.[84]

Local Project: Tennessee and several cities are applying for community charging grants from the Bipartisan Infrastructure Law (BIL), including more than $15M in grants specifically set aside for rural and underserved areas.

Additional Resources

The Joint Office of Energy and Transportation has released guidance and funding opportunities for community charging competitive grants.[85]

POTENTIAL FUNDING

- BIL- Sec. 11401 Grants for Charging and Fueling Infrastructure (Community Charging)
- BIL - Sec. 30018 Low or No Emission (Bus) Grants, Bus and Bus Facilities Grants
- BIL - Sec. 71101 Clean School Bus Program
- IRA - Sec. 30C Alternative Fuel Refueling Property Credit
- IRA - Sec. 45W Commercial clean vehicle credit
- IRA - Sec. 60101 Clean heavy-duty vehicles

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Limited commercial deployment but growing

POTENTIAL

High market growth anticipated

SECTOR

Mobility

MILESTONES

Improve air quality

Supports Enhanced Community Resiliency

Electric School and Transit Buses

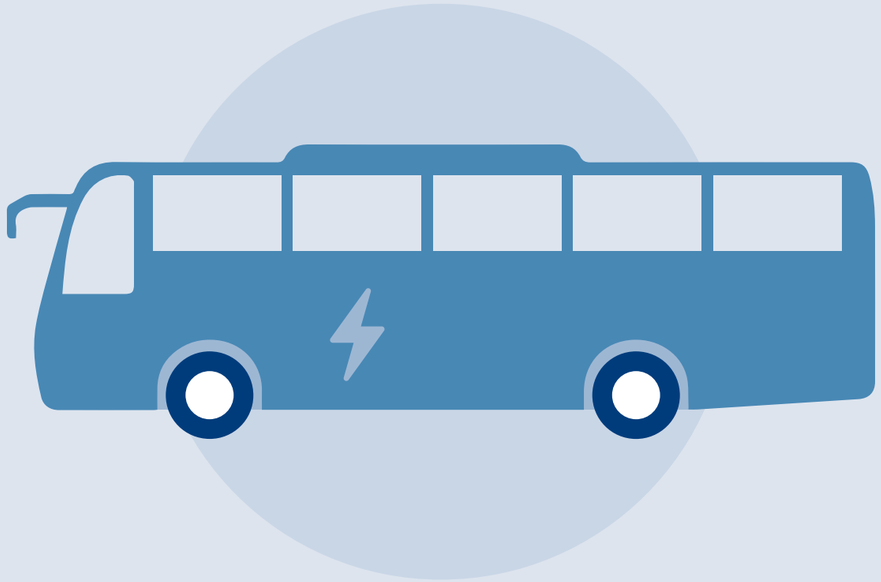
Electrifying school and municipal bus fleets can help reduce carbon emissions, improve air quality and create a more sustainable and efficient transportation system. Electric buses may also offer lower lifecycle costs associated with maintenance and replacement parts. An electric bus fleet can also provide valuable flexibility to the grid and load shifting capabilities for nearby facilities given the large battery capacities in the buses.[86] While the technology associated with electric buses exists and has been commercialized, widespread adoption is somewhat limited. In addition to the buses themselves, building out public networks would require charging infrastructure and distribution capacity to support a fleet of transit vehicles, likely requiring collaboration between the community or local government, charging equipment suppliers and the local electric utility.

Technologies and Use Cases

- Electric municipal and school buses
- Electric streetcars, light rail and ferries

Benefits

- Lifecycle costs can be lower than traditional buses due to reduced maintenance costs
- Lower localized air pollution for communities
- Improved reliability and rider experience
- Reduces the need for energy generation when it is most costly or polluting



Federal funding means that more school districts have the opportunity to deploy electric school buses. This helps increase electric school bus deployment and improves air quality around the nation.

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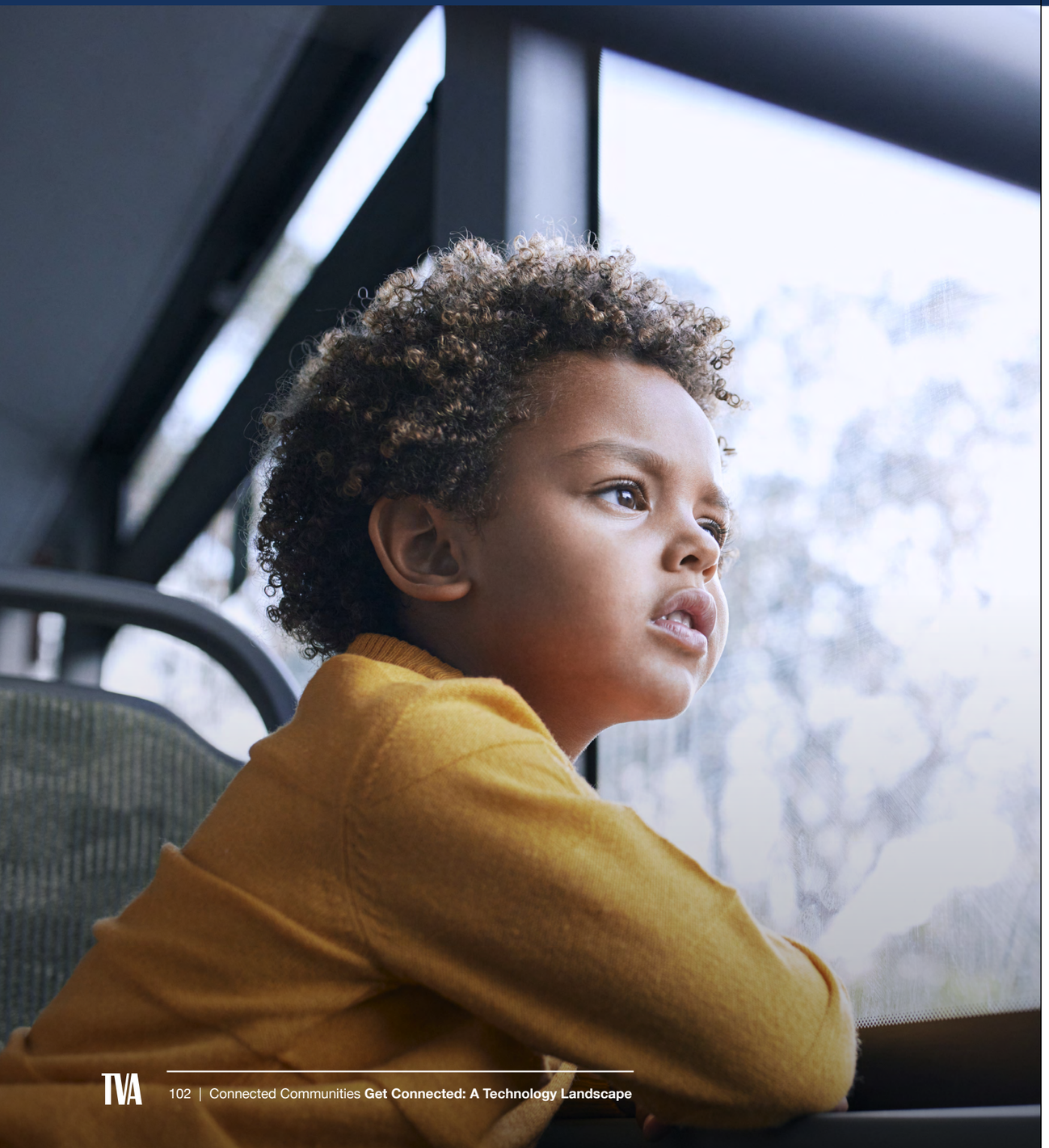
Energy and Environmental Justice



ELECTRIC SCHOOL AND TRANSIT BUSES CONTINUED

Regional Deployment

TVA Initiative: Energy Services and Programs is exploring EV charging and Innovation and Research's Electric Evolution initiative is helping facilitate funding for EV buses across the service territory, all in support of large-scale electric transportation. There is significant activity surrounding the acquisition of electric school buses in TVA's service region, with TVA acting as the supporter and convener for communities in the pursuit of Bipartisan Infrastructure Law (BIL) Clean School Bus grants, helping secure funding for several school districts.

Local Project: Several public transit agencies across Tennessee are expanding their electric bus fleets, including KATbus, CARTA and MATA.[87] Vanderbilt University is partnering with Lightning eMotors for electric shuttle buses in Nashville.

Additional Resources

Government programs such as the Federal Transit Administration's Low or No Emission Vehicle Program can provide funding and technical support for electric buses.

POTENTIAL FUNDING

- BIL - Sec. 30018 Low or No Emission (Bus) Grants, Bus and Bus Facilities Grants
- BIL - Sec. 71101 Clean School Bus Program
- IRA - Sec. 30C Alternative Fuel Refueling Property Credit
- IRA - Sec. 45W Commercial clean vehicle credit
- IRA - Sec. 60101 Clean heavy-duty vehicles

Energy and Environmental Justice

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate market growth anticipated

SECTOR

Mobility

MILESTONES

Improve air quality

Micromobility

Micromobility consists of transportation using lightweight vehicles for rent with quick accessibility, such as bicycles or scooters, that are often electrified. Multiple companies have commercial product offerings, with adoption increasing in major cities with multiple successful use cases. Minor infrastructure investment is required for charging stations. Additionally, investments in dedicated lanes or paths for scooters and bicycles reduce hazards to riders. Implementation of micromobility solutions requires thoughtful integration with the existing infrastructure and transportation system of a community to mitigate safety hazards, maximize use and ensure that the community captures the full benefits of the investment.

Technologies and Use Cases

- Electric scooters, electric bicycles

Benefits

- Enhances the experience of residents and visitors to downtown areas
- Enables flexible public transportation and alternative commute options
- Increases quality of life by enabling outdoor recreation opportunities for all
- Reduces need for parking capacity
- Improves air quality by displacing demand for internal combustion vehicles
- Enables sustainable transportation options for everyone

Regional Deployment

Local Project: Cycle LLC and the Nashville Downtown Partnership offer bike share to the city of Nashville with an upgraded, all-electric bike fleet. The Nashville bike share offers about 300 electric, pedal-assist bikes BCycle e-bikes that can check in and out of the city's 34 existing stations.[88]

Additional Resources

The National Association of City Transportation Officials (NACTO) is a nonprofit organization that provides guidance and resources for cities and communities looking to improve transportation systems.[89] Shared micromobility providers include Lime, Bird and Lyft.

POTENTIAL FUNDING

- BIL- Sec. 25005 Strengthening Mobility and Revolutionizing Transportation (SMART) Grant Program
- BIL - Sec. 11529 Active Transportation Infrastructure Investment Program

Enhanced Community Resiliency

Enhances community resiliency through plans and resources to help communities minimize impacts, effectively endure evolving challenges and strengthen recovery strategies for the future.

INCLUDED TECHNOLOGY SECTORS:

- ✓ Community Resiliency
- ✓ Power Grid Resiliency

Enhanced Community Resiliency

Community Resiliency

Community-wide technologies apply to anyone in the community: residents, businesses and institutions. There are additional technologies, listed to the right, with benefits that overlap focus areas and can be found in various sections throughout the report.

INCLUDED TECHNOLOGIES:

- ✓ Resiliency Hubs
- ✓ Emergency Response Apps

Included Technologies from Previous Chapters

- ✓ Smart Poles
- ✓ Microgrids
- ✓ Virtual Power Plants
- ✓ Battery Storage for Reliability and Resilience
- ✓ Smart Heating, Ventilation and Air Conditioning (HVAC) and Water Heating
- ✓ Grid-Interactive Efficient Buildings
- ✓ Building Thermal Storage
- ✓ Smart Water Management
- ✓ Smart Wastewater Management
- ✓ Controlled Environment Agriculture – Smart Controls
- ✓ Managed Charging and Vehicle Grid Integration
- ✓ Community Electric Vehicle (EV) Charging Plazas
- ✓ Electric School and Transit Buses

Enhanced Community Resiliency

AT A GLANCE

TECH READINESS

Commercially available, limited adoption

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

Communities develop robust community resiliency plans

Resiliency Hubs

Resiliency hubs are existing, trusted sites that are augmented to support residents and coordinate resource distribution and services before, during and after a natural hazard event. Resiliency hubs are ideally community-run facilities that operate year-round, such as community centers, recreation facilities, neighborhood grocery stores, restaurants, schools and more. Ensuring that hubs are readily accessible to all neighborhoods, so residents can quickly access the location in the event of an emergency, is a priority. Features of a resiliency hub include distributed energy generation and storage, robust operations and processes, emergency communications abilities and programs and services outside of emergency response to garner trust in the community.

While the components and technologies required are mature and readily commercially available, the model of a resiliency hub has not been adopted at scale by communities. Potential barriers to adoption include limited funding and community alignment in areas where resiliency hubs would be most effective.

Technologies and Use Cases

- Energy resilience through distributed power generation and storage
- Disaster response and coordination center, with emergency communications capabilities
- Long-term food storage and medical supplies for use as an emergency shelter
- Education and training services, as well as community-building activities

Benefits

- Enhanced community resilience and safety in the event of a disaster (e.g., access to food and refrigeration for medications during a power outage)
- Reduced burden on local emergency response teams
- Greater community cohesion

Regional Deployment

Local Project: While just outside of TVA's service region, Fulton County, Georgia has expanded their Metropolitan Library to serve as a resiliency hub. The goal of the hub is to allow those in surrounding neighborhoods to better prepare to react, respond and recover from emergencies and public health pandemics. In addition to distributing resources, this hub provides support to residents and business, coordinating communications and operations.[90]

POTENTIAL FUNDING

- IRA - Sec. 48 Environmental Justice for Solar and Wind Capacity
- IRA - Sec. 48E Clean Electricity Investment Credit
- IRA - Sec. 60103 Greenhouse Gas Reduction Fund
- IRA - Sec. 60201 Environmental and Climate Justice Block Grants

Additional Resources

The Urban Sustainability Directors Network Resiliency Hub Website has a multitude of resources available for understanding resiliency hubs and guides for planning and building.[91]

Enhanced Community Resiliency

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

Communities develop robust community resiliency plans

Emergency Response Apps

Emergency response apps can inform community members about occurrences of dangerous conditions, natural disasters and emergencies, helping people prepare for emergencies and communicate effectively during an event. Emergency response apps are often free to download and easily accessible by anyone with a smartphone.

Technologies and Use Cases

- Federal Emergency Management Agency (FEMA) hurricane monitor
- Air quality sensors and associated alerts

Benefits

- Increased awareness and communication in the event of a natural disaster
- More effective allocation of resources by emergency services

Regional Deployment

Local Project: Taking emergency alerts one step further by improving the health and wellness of under-resourced elders, Three3, Inc. is implementing strategies in Knoxville, Tennessee to improve resiliency to indoor and outdoor environmental health risks. Data from indoor and outdoor air quality sensors is being combined with weather conditions and weather forecast data to trigger alerts to elders and designated members of their networks in the case of extreme events. TVA supports this project via a Connected Communities grant.

Additional Resources

FEMA and the American Red Cross have developed apps that include information and updates about weather events, natural disasters based on zip code and educational materials about preparing for an event and what to do when one occurs. Many private companies also offer emergency response apps.

POTENTIAL FUNDING

- None identified.

Enhanced Community Resiliency

Power Grid Resiliency

Enhances community resiliency through plans and resources that help communities minimize impacts, effectively endure evolving challenges and strengthen recovery strategies for the future.

INCLUDED TECHNOLOGIES:

- Fiber for Grid Resilience
- Distribution Grid Self-Healing and Optimization
- Grid Predictive Maintenance
- Integrated Planning for Grid Optimization
- Advanced Grid Assessment
- Advanced System Modeling
- Front-of-the-Meter Battery Storage

Regional Grid Transformation

The technologies included in this section are relevant to local power companies. Many technologies available to local power companies support the Regional Grid Transformation (RGT) effort that TVA has underway. RGT helps TVA and local power companies protect the region from power disruptions while positioning local power companies to introduce cleaner and more efficient technologies, offering more value to customers in TVA's service territory.

Strategic deployment of advanced grid technologies will deliver the needed capabilities to realize new value for TVA's customers, communities and local economies. Value includes energy affordability, resiliency, regional innovation, optimized investing, environmental sustainability, resourcefulness, economic development and overall community vitality.

More information and videos can be found on the Regional Grid Transformation website.

Enhanced Community Resiliency

AT A GLANCE

TECH READINESS

Demonstration pilots

POTENTIAL

Moderate market growth anticipated

SECTOR

Community-wide

MILESTONES

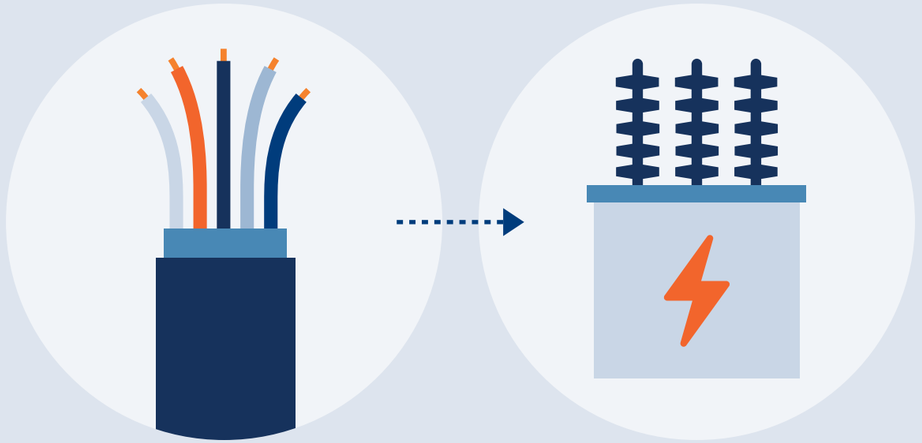
Communities develop robust community resiliency plans

Fiber for Grid Resilience

Using fiberoptic infrastructure for substation and grid connectivity can be a key enabler for grid resiliency. Fiber deployed for customer broadband connectivity could be extended to provide grid connectivity, and dark fiber (fiber that has been installed but is not currently in use or transmitting data) can sometimes be economically leveraged for grid connectivity as well. For grid resilience, fiber is used for smart grid controls, protection hardware and software, power electronics and sensors for security, flexibility and increased control for grid infrastructure. The use of fiber combined with increased field area networking (FAN) can extend communications out to line sensors, informing the network of grid conditions. Real-time data acquisition and secure communication enable operators to detect and address issues promptly, reduce outage time and improve overall grid resiliency. There has not yet been widespread adoption of this application of fiber, or fiber paired with FAN, for grid control, protection and resiliency. Barriers to the adoption of fiber include potential installation risks associated with construction execution. Additionally, fiber deployment is often high-cost, which can affect the feasibility of these types of projects unless they leverage existing dark fiber or existing plans to lay fiber.

Technologies and Use Cases

- Connecting supervisory control and data acquisition (SCADA) and advanced metering infrastructure (AMI)
- Distribution automation systems, advanced control centers and command hubs
- Fiber from operations center to substations and facilities and FAN



The internet is needed for more than just homes and businesses. Expanding internet for use by electric utilities can increase community resiliency.

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Enhanced Community Resiliency

FIBER FOR GRID RESILIENCE CONTINUED

Benefits

- Increased reliability, cybersecurity and resilience
- Enhanced monitoring and control
- Durable communications in the event of natural disasters or cellular outages

Regional Deployment

TVA Initiative: TVA has a strategic fiber initiative that launched in 2017 to meet the power system's growing need for bandwidth and accommodate the integration of new distributed energy resources (DERs).[94]

Local Project: Federal researchers are examining the fiber network that runs EPB's smart electric grid and high-speed broadband internet to learn approaches that will enhance the ability to defend the national power grid.[92] Oak Ridge National Laboratory (ORNL) is collaborating with utilities worldwide researching dark fiber for power grid cybersecurity with their DarkNet project.[93] The project is also aimed at developing new applications for dark fiber, such as monitoring power lines and controlling the flow of electricity.

Additional Resources

The University of Tennessee at Chattanooga (UTC) released a study outlining the significant benefits of fiber optic infrastructure for smart grid applications and economic development in Hamilton County.[17]

POTENTIAL FUNDING

- None identified.

Enhanced Community Resiliency

AT A GLANCE

TECH READINESS

Limited commercial deployment but growing

POTENTIAL

High market growth anticipated

SECTOR

Local power companies

MILESTONES

Improve electric system reliability and decrease energy burden and energy poverty

Distribution Grid Self-Healing and Optimization

This set of technologies includes software, switching equipment (to control, protect and isolate) and power electronics to quickly recover from line faults, optimize power flow on the grid, manage distributed resource use, balance feeder loads and more. By optimizing the distribution network, communities can reduce energy waste, improve voltage regulation and ensure better load balancing. Technologies to enable self-healing grid (e.g., fault location, isolation and system restoration - FLISR) fully deployed with an advanced distribution management system (ADMS), voltage optimization (VO) and advanced metering infrastructure (AMI) play significant roles in improving grid performance, reducing outage time and enhancing customer satisfaction. These technologies support grid reliability and hosting capacity by optimizing power flow on the grid and recovering from outages more quickly, resulting in a more sustainable, resilient and customer-centric power distribution system.

Technologies and Use Cases

- Distribution management systems (DMS) and ADMS allow utilities to automate outage restoration processes and optimize the electrical grid. DMS provide data at a more granular level along the distribution system that can inform new programs and projects. Distribution automation will reroute power around issues on its electrical grid system in the event of an outage.
- FLISR – also referred to as “self-healing grid” – uses distribution automation solutions to lower the frequency and duration of system interruptions by automating service restoration and converting sustained outages into momentary outages through intelligent switching operations.
- Voltage optimization is used to monitor and control load tap changers (LTC), voltage regulators and station and line capacitors.
- Demand response management systems (DRMS) provide the ability to control, operate and monitor energy-consuming assets.
- Distributed energy resources management system (DERMS) allow for better control over distributed energy resources (DERs) on the grid.
- A distribution system operator (DSO) model is an advanced concept – not a technology – that may present opportunities in the future for TVA and local power companies to coordinate system planning and operations. An example is aggregating DERs and demand response for system benefit.

POTENTIAL FUNDING

- BIL - Sec. 40101 Preventing Outages and Enhancing the Resilience of the Electric Grid
- BIL - Sec. 40103 Upgrading Our Electric Grid & Ensuring Reliability & Resiliency

Benefits

- Improve customer service reliability
- Provide additional capacity/energy on the system
- Improve grid visibility to anticipate and address problems more quickly
- Help mitigate local transmission congestion and constraints

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Enhanced Community Resiliency

DISTRIBUTION GRID SELF-HEALING AND OPTIMIZATION CONTINUED

Regional Deployment

TVA Initiative: TVA's Innovation and Research's Regional Grid Transformation (RGT) initiative dives deeper into this topic.

Local Projects: While TVA is responsible for the transmission side of the electric grid, local power companies in the region are working on pilot projects to help enhance the distribution side of the grid. Below are examples of utilities participating in RGT:[95]

- North East Mississippi Electric Power Association (NEMEPA) intends to deploy a DERMS and DRMS in the coming years.
- Knoxville Utility Board (KUB) and Middle Tennessee Electric (MTE) are exploring FLISR distribution automation solutions to reach their system reliability goals. KUB is actively installing this system in order to have a smart distribution network that could quickly and automatically isolate a power outage to impact as few customers as possible.
- Huntsville Utilities is currently deploying voltage optimization on its system and intends to deploy distribution automation.
- BrightRidge is currently implementing distribution automation, having deployed an alternative to conventional automatic circuit reclosers and designed to accommodate advanced distribution automation functions, provide SCADA functionality and offer significant benefits for radial line protection.
- KUB is evaluating a battery storage + solar pilot project and a smart thermostat DRMS pilot project.
- Jackson Energy Authority (JEA) is implementing targeted distribution automation to improve reliability.
- NES is deploying distribution automation to targeted areas on its system and has implemented numerous automatic throwover schemes for individual customers that require high reliability. This allows the grid to automatically reroute power in the event of a grid outage to specific customers. Building on an existing FLISR pilot project, Nashville Electric System (NES) also plans to use findings to continue deploying FLISR to targeted areas.

Additional Resources

The Department of Energy (DOE) offers information on approaches to modernize the electric grid. Resources are available on the Office of Electricity Delivery and Energy Reliability's website and on the SmartGrid.gov website. DOE has also published several reports that contain findings on these topics.

Enhanced Community Resiliency

AT A GLANCE

TECH READINESS

Limited commercial deployment but growing

POTENTIAL

High market growth anticipated

SECTOR

Local power companies

MILESTONES

Improve electric system reliability and decrease energy burden and energy poverty

Grid Predictive Maintenance

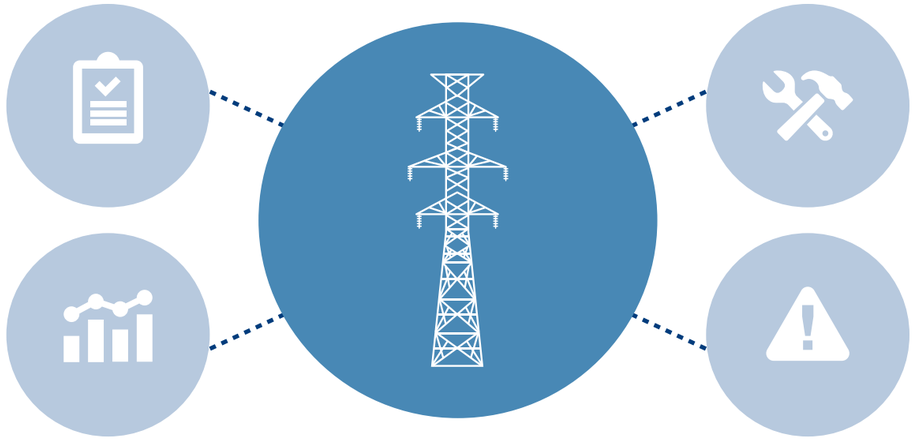
Grid predictive maintenance uses sensors, data and analytics to anticipate failures, determine grid infrastructure needs and proactively address maintenance areas to help keep the grid running smoothly and reduce costs. Advanced methods of applying artificial intelligence (AI) techniques for preventative grid maintenance can enhance and improve the overall reliability and resilience of smart grid systems.

Technologies and Use Cases

- Predictive maintenance of wire and poles
- Utilizing satellite imagery for maintenance
- Using light detection and ranging (LiDAR) remote sensing data to prioritize vegetation management locations

Benefits

- Enables long-term planning to get ahead of asset failing
- Reduces maintenance costs and reduced repair time
- Reduces unexpected failures
- Reduces spare part costs and inventory



Regional Deployment

TVA Initiative: TVA's Regional Grid Transformation (RGT) initiative explores this topic in depth.

Local Project: The North East Mississippi Electric Power Association (NEMEPA) is deploying monitoring as part of distribution automation to improve reliability on their grid. Asset analytics using this monitoring data will provide NEMEPA with asset health assessments, predictive maintenance analyses to help adjust proactively to problems on the grid and more effectively planning for capital improvements and software implementation.

POTENTIAL FUNDING

- BIL - Sec. 40101 Preventing Outages and Enhancing the Resilience of the Electric Grid
- BIL - Sec. 40103 Upgrading Our Electric Grid & Ensuring Reliability & Resiliency

Additional Resources

The National Renewable Energy Laboratory (NREL) investigates various approaches to assessing the grid's health in real-time and providing predictive analytics.[96]

Enhanced Community Resiliency

AT A GLANCE

TECH READINESS

Limited commercial deployment

POTENTIAL

Moderate market growth anticipated

SECTOR

Local power companies

MILESTONES

Communities develop robust resiliency plans

Integrated Planning for Grid Optimization

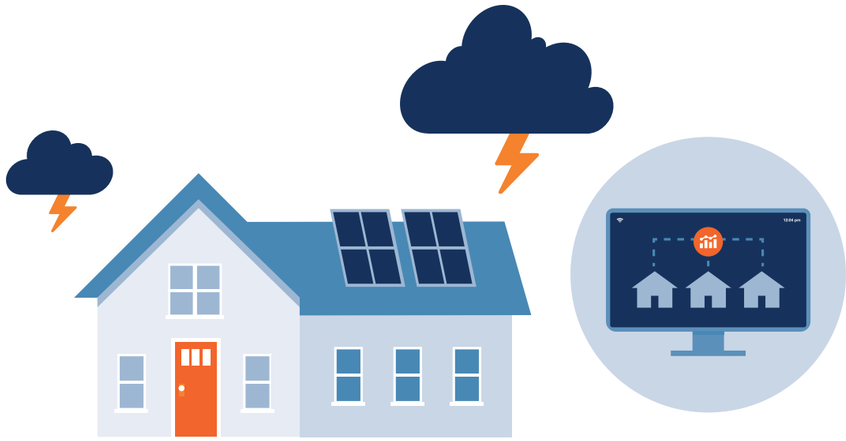
Modeling to simulate and study the impact of widespread outages, assess the benefits of distributed energy resources (DERs) and understand electric vehicle (EV) use can help address resiliency and aid in the planning of resilience hubs. These efforts have the potential to assess the social justice impact on residents and the economic impacts on businesses over different lengths of outages. Modeling can allow electric utilities to examine the potential grid impacts of an outage, risk mitigation from DER adoption and what is needed for optimal placement of DER to maximize benefits during outages. This information can help community groups better engage in resiliency planning.

Technologies and Use Cases

- Software modeling of outages and their impact
- Integrated transmission and distribution system modeling
- Load and DER forecasting
- Grid and customer impact assessment
- Non-wires alternatives analysis

Benefits

- Planning of optimal placement of DERs to maximize system resiliency
- Planning for more equitable resiliency to outages
- Better understanding of future grid impacts to help keep costs lower



Regional Deployment

TVA Initiative: RUNWITHIT Synthetics (RWI), in collaboration with the Electric Power Research Institute (EPRI), will apply synthetic modeling to forecast human impacts to help the city of Nashville and Nashville Electric System (NES) assess the outcomes of a widespread outage on residents and the benefits of DER deployments. The software will model the impacts of the first 24 hours, the first 72 hours and a full week of an outage.[97]

POTENTIAL FUNDING

- BIL - Sec. 41007 Solar Energy Research and Development (Solar Energy Technologies Office OPTIMA program)

Additional Resources

The National Renewable Energy Laboratory's (NREL) SMART-DS data sets provide standardized distribution network models that have been validated against thousands of real utility systems. SMART-DS users can test distributed automation algorithms, advanced distribution management system capabilities and other emerging distribution technologies on standardized, full-scale, synthetic distribution networks.[98]

Enhanced Community Resiliency

AT A GLANCE

TECH READINESS

Limited commercial deployment

POTENTIAL

Moderate market growth anticipated

SECTOR

Local power companies

MILESTONES

Improve electric system reliability

Advanced Grid Assessment

Grid maintenance has evolved by integrating advanced technologies such as drones, satellite imagery and light detection and ranging (LiDAR). Utilities can use drones to fly over and observe large areas of land for monitoring grid infrastructure for routine inspections, preventative maintenance for wildfire risk and assessments of damage after storms. This can reduce worker safety risks, save time and money and increase system resilience and reliability. Drones tend to be low-cost technologies that can save money and time for grid surveillance; however, drones can be vulnerable to cybersecurity attacks and require cybersecurity measures, particularly when used for critical infrastructure. Drones also require skilled operators, and some communities may restrict their use or require special permitting. Sophisticated satellite imagery provides utilities with a comprehensive view of assets including transmission and distribution lines, substations and the surrounding vegetation. LiDAR can be utilized by utilities to create models of the energy corridor, assess potential vegetation encroachments and optimize maintenance efforts. Utilizing these technologies enables utilities to prevent vegetation-related outages, reducing the need for emergency repairs and ensuring a more reliable energy supply.

Technologies and Use Cases

- Aerial inspections and thermal imaging
- LiDAR mapping
- Satellite imagery
- Vegetation management

Benefits

- Save time and money to assess and maintain the electric grid
- Enhance ability to do preventative maintenance and reduce power disruptions

Regional Deployment

TVA Initiative: TVA is exploring solutions in this area as part of its Regional Grid Transformation (RGT) initiative.

Local Project: TVA is conducting research into drones for beyond visual line of sight inspections, as well as “drone-in-a-box technology” for wireless, remote or automated drones with embedded charging for grid purposes. In addition, TVA, EPB, the University of Tennessee at Chattanooga (UTC), Middle Tennessee Electric (MTE) and North Georgia Electric Membership Corporation (NGEMC) are partnering to examine drones for advanced, automated distribution line inspection.

Additional Resources

Popular drone manufacturers for commercial use include DJI, Parrot and Yuneec. The Federal Aviation Administration (FAA) also provides guidelines and regulations for flying drones for commercial purposes.

POTENTIAL FUNDING

- BIL - Sec. 40101 Preventing Outages and Enhancing the Resilience of the Electric Grid

Enhanced Community Resiliency

AT A GLANCE

TECH READINESS

Limited commercial deployment

POTENTIAL

Moderate market growth anticipated

SECTOR

Local power companies

MILESTONES

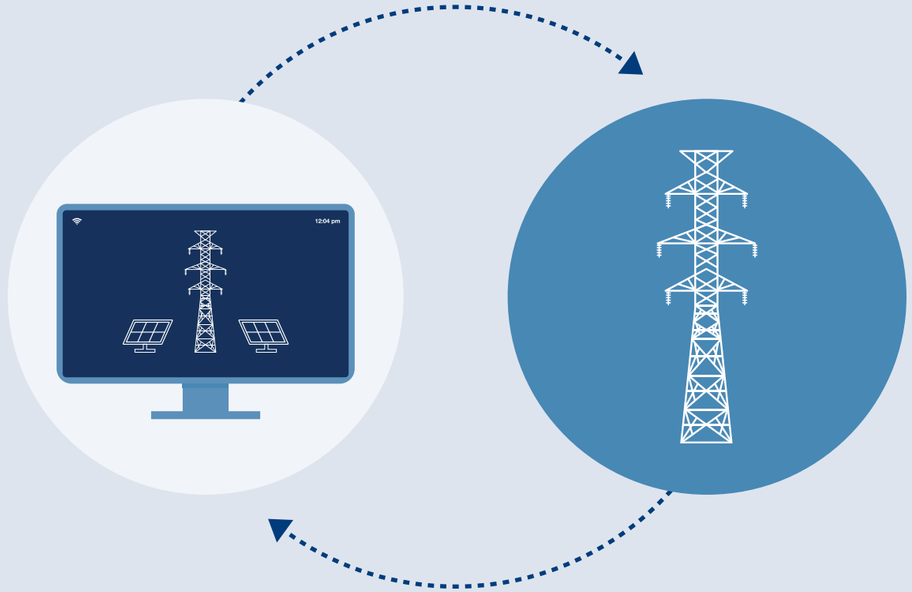
Improve electric system reliability

Advanced System Modeling

Advanced modeling concepts use modern computing power and data-centric tools to go beyond traditional utility modeling. For example, power hardware-in-the-loop (HIL) simulation is a tool that can connect physical control devices to simulated environments to test their functioning. Large-scale power HIL simulations can bring this testing to real-time grid simulations without exposing the grid to risk, allowing for the testing of distribution operations management, automation and optimization of emerging technologies. HIL simulation testing has use cases across various industries, with power being a more recent use case. Grid-scale simulation approaches, those that integrate transmission and distribution level analysis, are still being refined with limited commercial availability. This technology will become more valuable as the need for testing energy-related technologies increases. These advanced approaches can also provide insight and decision support for enhancing grid resiliency through renewable energy resources integration. Deployment of advanced modeling allows utilities to optimize system planning, understand impacts due to the integration of renewables and help ensure a reliable grid.

Technologies and Use Cases

- Inverter testing and characterization
- HIL testing
- Grid-scale storage and microgrid modeling
- Electric vehicle (EV) charging forecasting and impact modeling



Newer modeling options allow grid operators to test scenarios to better learn about impacts without harming the grid.

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Enhanced Community Resiliency

ADVANCED SYSTEM MODELING CONTINUED

Benefits

- Allows real distribution system assets to be connected to the simulated grid in a closed loop for safe and comprehensive testing — and optimization — before deployment.
- Verify the secure operation of distribution automation systems, improve their performance and decrease deployment time.
- Allow more distributed energy resources (DERs) safely onto the grid and in a faster timeframe

Regional Deployment

TVA Initiative: Demonstration projects are being conducted.

Local Project: Modeling was performed when EPB developed a microgrid at the Chattanooga Metropolitan Airport, consisting of a 2.6 MW solar PV array and a 500kW natural gas generator. EPB also installed two batteries to the solar PV to provide voltage and frequency reference when islanding. TVA also conducted an Advanced Planning demonstration project with Huntsville Utilities.

Additional Resources

The National Renewable Energy Laboratory (NREL) has been testing and evaluating the performance of distributed energy management systems (DERMS) and HIL.[99]

POTENTIAL FUNDING

- BIL - Sec. 40125 Modeling and Assessing Energy Infrastructure Risk
- Other - Operation and Planning Tools for Inverter-Based Resource Management and Availability for Future Power Systems (OPTIMA) program

Enhanced Community Resiliency

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate to high market growth anticipated

SECTOR

Local power companies

MILESTONES

Improve electric system reliability

Front-of-the-Meter Battery Storage

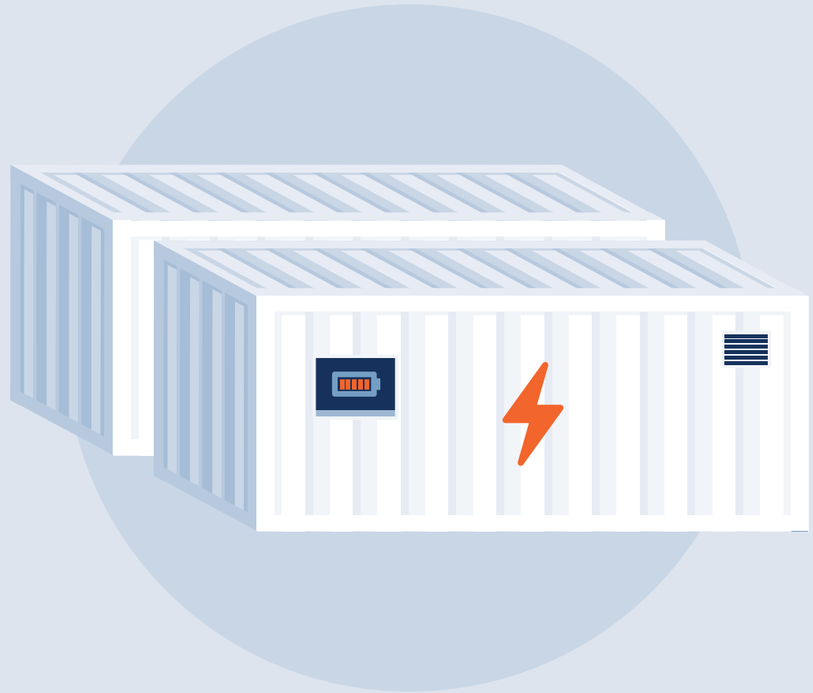
Front-of-the-meter batteries are directly connected to the distribution or transmission network. These batteries are often intended to participate in grid balancing mechanisms to maintain the network's resilience, selling power when the electric grid needs it, absorbing power when there is excess renewable power, helping balance the electric grid with ancillary services and increasing utilization of renewable power. These systems are often associated with renewable energy generation systems, such as solar farms, but can also be stand-alone.

Technologies and Use Cases

- Bidirectional power flow batteries, typically lithium-ion chemistry but other chemistries are also used, on the utility side of the meter between the distribution substation and the load (facilities or homes)

Benefits

- Grid stability and grid services
- Reduced greenhouse gas emissions by facilitating greater use of renewable generation sources
- Potential for microgrid and islanding, adding resiliency
- Potential to alleviate grid congestion issues



Battery storage has many uses and is one of the most flexible assets for an electric utility.

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Enhanced Community Resiliency

FRONT-OF-THE-METER BATTERY STORAGE CONTINUED

Regional Deployment

TVA Initiative: TVA's Storage Integration initiative supports several projects and is also examining two delivery point batteries for demonstration projects in TVA's service region. In 2020, TVA announced plans to install TVA's first owned and operated, grid-scale, battery energy storage system (BESS) near an industrial complex in Vonore, Tennessee, about 35 miles southwest of Knoxville.[100] TVA is also exploring a pilot project that involves a BESS to support the bulk electric system in a specific area. This pilot project will help provide insights to TVA on the operation of this type of energy storage system for future storage projects. Learnings from this project can also be used to inform local power companies on beneficial use cases for energy storage.

Additional Resources

The Department of Energy's (DOE) Electricity Advisory Committee has a subcommittee that focuses on energy storage and collaborates with the Electric Power Research Institute (EPRI). The University of Michigan also provides summarized information on energy storage options.[101]

POTENTIAL FUNDING

- BIL - Sec. 41001 Energy storage demonstration projects
- BIL - Sec. 40207 State and local battery collection, recycling, and reprocessing programs
- IRA - Sec. 48 Environmental Justice for Solar and Wind Capacity
- IRA - Sec. 48E Clean Electricity Investment Credit

Conclusion

Strengths

Current activity in the TVA service region demonstrates strengths in deploying some of the identified emerging technology applications. While broadband access across communities in the region has room for development, there are strong case studies regarding fiber, fixed wireless and smart pole deployment among some cities and municipalities. The region also exhibits a strong research, development and pilot program environment for energy technologies with the presence of Oak Ridge National Laboratory (ORNL), which actively partners with TVA, local power companies and cities. By leveraging the knowledge gained from these projects and the research provided by ORNL, the National Renewable Energy Laboratory (NREL) and others, communities can create their own pilot projects or programs with these four technologies and applications.

There are strong case studies regarding fiber, fixed wireless and smart pole deployment.

Opportunities

Identifying areas of strength also highlights the current gaps in other technologies in TVA's service region. The research did not identify regional examples for projects focused on artificial intelligence (AI) for small businesses or thermal energy storage, highlighting opportunities for TVA and others to showcase these options in the region. These technologies have been tested or piloted in other areas around the United States, and communities in TVA's service region may benefit from learning from those projects when pursuing their own related projects. By leaning on the experience of others, TVA and local power companies have the potential to create successful pilot projects or programs highlighting some of these technologies. If you have a planned or current project in any of these areas, please let us know by reaching out at:

connectedcommunities@tva.gov

There are opportunities for TVA to showcase new technologies in the region including AI for small businesses and thermal energy storage.

Conclusion

Next Steps

The technology applications presented in this report have varying degrees of market maturity and barriers to adoption. While some technologies present in the TVA service territory could benefit from increased deployment, others present an opportunity for TVA, communities and local power companies to test pilot projects and gain a better understanding of how these technology applications operate in the region. By working together with national laboratory experts, universities and private companies, these emerging technologies can be implemented to help achieve Connected Communities goals.

Appendix

Milestones

The following tables present a streamlined version of the Connected Communities Roadmap progress indicators and milestones, as well as a summary of current state conditions for each.

BROADBAND AND DIGITAL LITERACY

Current State *Where stakeholders are today*	**2025 Milestones** *Stakeholders lay the foundation*	**2035 Milestones** *Establish a long-term trajectory*
There are significant inequities in internet access within the region between disadvantaged communities and non-disadvantaged communities.	Increase household broadband access	Community broadband access parity
There is a significant urban-rural divide in internet subscriptions.	Increase urban-rural internet access parity	Urban-rural parity in internet subscriptions
There is a perception of community dispersion of public Wi-Fi locations as inconsistent, and the quantity of locations is low.	Increase public Wi-Fi	Readily available public Wi-Fi
Less than 70% of residents in the region own an connected device (one that connects to the internet).	Increase internet device ownership	Parity with national internet device ownership levels
There is no current regional or national tracking program for digital education.	Establish digital education measurement program	Digital literacy across service region

ECONOMIC EMPOWERMENT

Current State *Where stakeholders are today*	**2025 Milestones** *Stakeholders lay the foundation*	**2035 Milestones** *Establish a long-term trajectory*
There are high school graduation rate disparities between the TVA service region as a whole and its disadvantaged communities.	Increase high school graduation rates	Community graduation parity
There are income disparities between the TVA service region as a whole and its disadvantaged communities.	Decrease low-income population	National average parity
There are unemployment disparities between the TVA service region as a whole and its disadvantaged communities.	Decrease unemployment	National average parity
There is room for improvement in TVA and LPC tracking of supplier diversity.	Establish contract award tracking system	Increase contract awards to disadvantaged communities
Economic empowerment programs are not available to all in TVA service region.	Increase program prevalence	Complete service area coverage
Tech-related job training program locations are inconsistent, and the quantity is low.	Increase training program availability	Complete service area coverage
Communities remain unaware or are not engaging with U.S. federal funding opportunities.	Increase community federal funding applications	Increase community federal funding applications
22% of TVA households are housing burdened.	Increase housing partnerships, coordination and pilots	Increase affordable housing opportunities in each TVA region

Milestones Continued

ENERGY AND ENVIRONMENTAL JUSTICE

Current State *Where stakeholders are today*	**2025 Milestones** *Stakeholders lay the foundation*	**2035 Milestones** *Establish a long-term trajectory*
There are disparities in energy poverty and access across the TVA service region, with disadvantaged communities experiencing the greatest challenges.	Decrease energy burden and energy poverty	Energy burden and access equity
There are disparities in solar adoption based on geography and market segment among the four regions of TVA's service region.	Increase non-utility owned solar and ownership options	Increase solar power market penetration and non-utility owned solar
Community plans do not always address all Connected Communities focus area topics and goals.	Enhance community plans to further address Connected Communities focus areas	Complete service region coverage
TVA and LPC energy efficiency program offerings are varied with wide-ranging outcomes.	Increase energy efficiency program participation	Very high energy efficiency program participation
TVA and LPCs have limited offerings of time of use (TOU) rates.	Increase TOU rates and programming	Comprehensive rates and programming
Electric vehicle (EV) programs vary by state across the TVA service region.	Increase public EV access, charging stations and programming	Ready access to affordable EV opportunities
Distributed energy project financing access is not tracked by TVA and LPCs.	Establish financing tracking program	Promote greater financing options
There are disparities in air quality across the TVA service region, with disadvantaged communities experiencing the greatest challenges.	Improve air quality	Air quality community equity
TVA and LPCs do not track service disconnections patterns.	Establish service disconnection task force	Decrease service disconnections
TVA and LPCs language offerings currently vary by region and by organization	Increase language offerings	Increase language offerings and public speaking options
The TVA service region currently has 396 "disadvantaged communities" as defined by U.S. Department of Energy	Develop disadvantaged community engagement and reduction plan	Further reduce disadvantaged communities

Appendix

Milestones Continued

ENHANCED COMMUNITY RESILIENCY

Current State *Where stakeholders are today*	**2025 Milestones** *Stakeholders lay the foundation*	**2035 Milestones** *Establish a long-term trajectory*
SAIFI and CAIDI performance varies by LPC across the TVA service region.	Improve electric system reliability	National system reliability equity
Not all LPCs have cybersecurity trainings, response teams, certifications or system design standards.	LPCs develop cybersecurity programs	LPC cybersecurity programs achieve high performance
Community plan development quality and evaluation frequency varies throughout TVA service region.	Communities develop robust disaster plans	Communities integrate advanced solutions for dynamic disaster planning
TVA communities have some situational awareness of their standby generation needs.	Identify and prioritize standby generation investments	A majority of backup generation is emission-free
Some TVA communities have microgrids and/or have conducted microgrid studies.	Identify optimal microgrid opportunities	Implement microgrid plans
Communication capabilities are inconsistent, vary substantially and are lacking in many rural areas.	Initiate communications technology or strategy pilot project in each TVA region	Deployment of communication systems in every county to ensure outage-resilient communication system availability

Acronyms

5G	Fifth-generation wireless
AI	Artificial intelligence
AIDT	Alabama Industrial Development Training
AR	Augmented reality
BIL	Bipartisan Infrastructure Law
BEM	Building energy modeling
BTM	Behind the meter
DER	Distributed energy resources
DERMS	Distributed energy resource management systems
DOE	Department of Energy
DRMS	Demand Response Management Systems
DSM	Demand side management
EPB	Electric Power Board of Chattanooga
EPRI	Electric Power Research Institute
EV	Electric vehicle
GEB	Grid-Interactive Efficient Buildings
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
IRA	Inflation Reduction Act
KUB	Knoxville Utilities Board
LBNL	Lawrence Berkeley National Laboratory
MTE	Middle Tennessee Electric
NES	Nashville Electric Services
NREL	National Renewable Energy Laboratory
PNNL	Pacific Northwest National Laboratory
ORNL	Oak Ridge National Laboratory
TDEC	Tennessee Department of Environment & Conservation
TVA	Tennessee Valley Authority
USGS	United States Geological Survey
UTC	University of Tennessee at Chattanooga
UTK	University of Tennessee Knoxville
V2G	Vehicle to grid
VPP	Virtual power plant
VR	Virtual reality
WHUD	White House Utility District

Appendix

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