CONNECTED COMMUNITIES

Emerging Technologies

VERSION ONE: 12/2022

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 technology 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, 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

Emerging Technologies Research

Through the Connected Communities initiative, the Tennessee Valley Authority (TVA) is helping communities throughout its service territory (the Tennessee Valley) leverage tech- and data-driven solutions to improve quality of life, deliver environmental benefits and scale economic opportunities. Connected communities are towns, main streets, neighborhoods and cities that use data and technology-driven innovations to offer new and improved services to people and businesses. We are working together with a variety of stakeholders to jumpstart innovative pilot projects and programs to deliver on Valley-wide Connected Communities' goals. The information presented here can serve as a starting point to inform TVA's planning, as well as efforts by the range of stakeholders engaging.

This report provides a high-level overview of 24 key technology applications that can support progress toward the region's connected community mission and vision. The report highlights barriers, drivers, market players and experience with deployment in the Valley to date. This information can help inform our decision-making as we clarify priorities for the ways in which we will advance the Valley-wide Connected Communities mission and vision. While many of the identified technologies are mature enough for pilot projects or even programs, there are a variety of adoption barriers. The barriers presented suggest that several forms of support will be necessary, including financing, education, technical support, facilitation and building viable business models to name a few. One of the most prevalent barriers across many technologies is the lack of education and awareness. We can support Connected Communities' progress by sharing knowledge, experiences and lessons learned in the Valley. Easy access to high-quality information is a first step toward increasing adoption of Connected Communities technology applications.

We hope this information makes it easier for our 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 we can all work together to achieve our Connected Communities goals.

Introduction

Research Methodology

With the endless possibilities of technology solutions available today, how did we come up with a list of just 24? To start, our main objective was to identify and characterize options that may serve as a catalyst for innovation across the Valley or emerging technology applications with the potential to advance Connected Communities concepts within our own programs or operations.

Key Questions

1. What emerging technologies are currently being tested within the Connected Communities space?

2. What activity is happening in TVA's territory regarding these technologies, and which jurisdictions are leading in this space?

3. How are the technologies applied?

4. Which companies are leaders in the research, testing and deployment of these relevant technologies?

Shortlist Development

Using the key questions as a guideline, our team started by looking at over 80 technologies that relate 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 Guidehouse Insights, federal departments, national laboratories, industry organizations and others. To create a shortlist of technologies on which to focus efforts, the research team filtered the original 80+ options looking at the potential applications for current or near-term TVA activities, how each of those technologies may fit into one of the focus areas of Connected Communities, potential impact and whether the technology is already a focus of another initiative (e.g., electric vehicles (EVs) and EV charging were excluded as they are heavily researched under TVA's EV initiative).

Once a smaller list was compiled, the team expanded the research to investigate case studies, use cases, vendors and any potential information on current market adoption of those technologies. This enabled us to find 24 technology applications that may be well-suited for the various communities we serve.

80+

technologies researched

that relate to the Boyd Cohen Smart City Framework.

24

technologies selected

to focus efforts on for Connected Communities.

Introduction

Findings

Based on our research, applying the following technologies can help the Tennessee Valley to meet its Connected Communities goals. Each community is unique, and some technologies may be better suited in one community while a different set of technologies is a better fit in another community. While some may be related, each of these technology applications serves a specific purpose in the Tennessee Valley's Connected Communities vision. In the following pages, you'll see a description of each of the identified technologies, the value it presents, current examples, as well as barriers to adoption.

Many of these technology applications require collaboration across multiple stakeholders and require input from various departments here at TVA, as well as external stakeholders. This highlights the importance of various entities working together to bring forward the shared vision of Connected Communities. Every stakeholder plays a role in bringing these solutions to light.

TECHNOLOGIES

Building-Scale Energy
(e.g. lighting, heating)

Energy Analytics
(e.g., energy modeling)

Community-Scale Energy
(e.g., community solar, microgrids)

Connectivity
(e.g., Wi-Fi kiosks)

Other Analytics
(e.g., smart water management)

Agriculture
(e.g., agrivoltaics)

Economic Development
(e.g., virtual reality for workforce development)

Emerging Technologies

Building-Scale Energy

These technologies can be found in homes, multifamily buildings, commercial buildings and industrial complexes and often involve enhancements to or integration of existing technologies such as thermostats, HVAC systems, lighting and windows.

INCLUDES

- Connected Lighting
- Behind the Meter Storage
- Building Thermal Storage
- Smart Heating Solutions
- Smart Ventilation
- Smart Windows & Glass
- Grid-Interactive Efficient Buildings

Emerging Technologies

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

High market adoption anticipated in education and retail buildings

FOCUS AREA

Energy and Environmental Justice

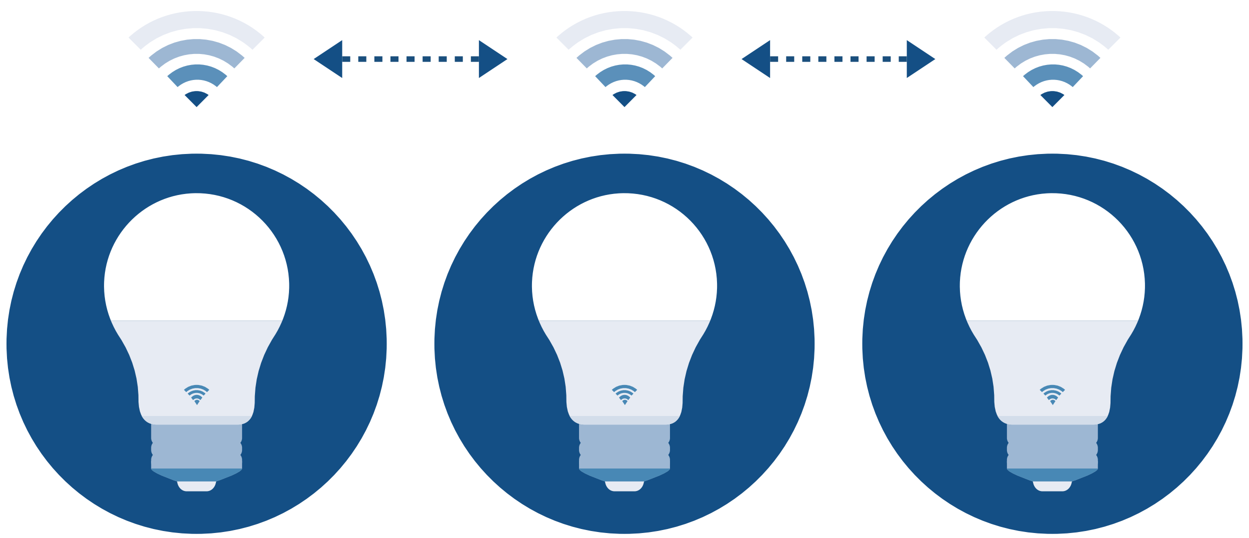
Connected Lighting

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 make decisions about lighting in individual rooms.[1]

What is driving this type of lighting? Things like energy efficiency, the savings that come from reduced energy use, utility incentives and rebates and popularization of smart building management systems all encourage the wider adoption of smart lighting systems in commercial buildings.[2] Smart lighting systems face barriers to greater adoption, including higher costs compared to basic lighting systems, a small pool of knowledgeable professionals in this space, lack of awareness and no standardization in smart lighting system setup.[2]

Benefits

- Improved energy efficiency
- Reduced peak electric load
- Reduced energy costs



EXAMPLES & RESOURCES

In the Tennessee Valley

The state of Tennessee partnered with Osram, a smart lighting company, to retrofit lighting systems in state buildings, reducing their consumption by an expected amount of 60-80%. Updates included daylight harvesting and occupancy sensors. Osram also completed projects for other Tennessee buildings, including the Tennessee Supreme Court, East Tennessee Fire Services and Codes Enforcement and East Tennessee Regional Health Office, all using advanced lighting controls and LED lights.[3] TVA's Consortium for Energy Efficiency (CEE) group is also involved in connected lighting work.

Beyond the Valley

Signify and Enlightened are two smart lighting companies that can provide smart lighting solutions.

Emerging Technologies

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

High anticipated market growth

FOCUS AREA

Energy and Environmental Justice

Behind the Meter Storage

Small-scale battery storage (serving residential and small commercial consumers) can help reduce peak load, support adoption of renewable energy and provide resilience. 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.[4]

Several drivers are increasing interest and use in this technology, including declining battery costs, high solar penetration, demand for resilience and more favorable incentives and rate structures.[5] Some barriers of behind the meter battery storage include the lack of net energy metering, storage incentives and favorable rate structures.[6]

Benefits

- Improved energy efficiency
- Reduced peak electric load
- Reduced energy costs

EXAMPLES & RESOURCES

In the Tennessee Valley

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 U.S. battery manufacturer, material supplier, equipment manufacturer or battery end user.[7]

Beyond the Valley

National laboratories conduct various types of research into behind the meter battery storage projects including PNNL, ORNL and NREL. Some states, like California, New York and Vermont, have crafted state policies that either incentivize or encourage the adoption of battery storage.

AT A GLANCE

TECH READINESS

Limited commercial deployment

POTENTIAL

Limited anticipated market growth

FOCUS AREA

Energy and Environmental Justice

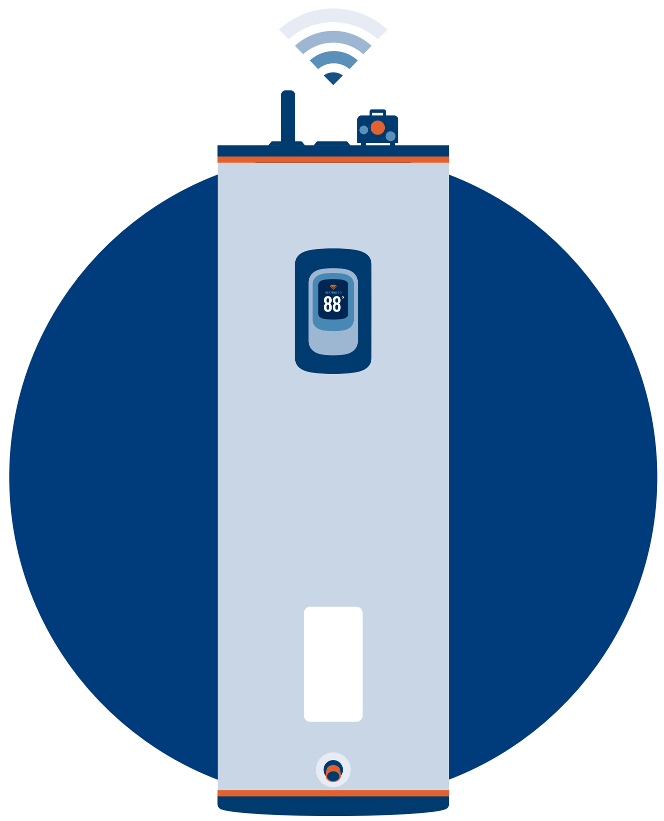
Building Thermal Storage

Thermal energy storage (TES) at the building level can be used for heating and cooling as well as reducing energy usage.[8] Building-scale TES traditionally uses large tanks of hot or cold water as the storage, but current research is exploring phase-change materials that can be used as a layer of the building's walls.

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

Benefits

- Improved energy efficiency
- Reduced peak electric load
- Reduced energy costs



EXAMPLES & RESOURCES

In the Tennessee Valley

Identified current activity in TVA's service area is limited to water heaters. However, ORNL is actively researching this technology and its applications.

Beyond the Valley

Various national laboratories such as NREL, LBNL and ORNL conduct research on this topic. Due to the limited commercial deployments of this technology, there are few commercial companies.

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

High anticipated market growth

FOCUS AREA

Energy and Environmental Justice

Smart Heating Solutions

Smart heating solutions include heat pumps, water heaters, thermal energy storage and heating control systems (e.g., thermostats), that are capable of being internet connected for remote monitoring and control. Remote control of such devices allows them to be coordinated for grid management needs and to better accommodate home preferences.

There are many reasons to adopt this technology, including potential energy savings, improved environmental regulations and increased comfort. Smart thermostats allow users to remotely adjust settings, pre-condition a space and monitor status via an app – saving an average of 10-12% of heating usage in homes, with additional savings potential in more extreme climates.[9] Tax incentives, updated energy standards and subsidies help encourage utilities and consumers to use more efficient heating systems.[10] Challenges facing smart heating solutions involve detailed planning. Systems must have interoperability with other building and utility systems to work seamlessly. For those who rent, there is a smaller incentive for the landlord to install these items – especially items with high upfront costs, as the landlord does not pay the electricity bill. However, renters who pay the electricity bill would benefit from such improvements.[9,11]

Benefits

- Improved energy efficiency
- Reduced peak electric load
- Reduced energy costs

EXAMPLES & RESOURCES

In the Tennessee Valley

TVA has a variety of experience in this space. TVA conducted a smart water heater demonstration project with EPRI and Bristol Tennessee Essential Services in 2009.[12] For customers, TVA's EnergyRight Marketplace helps direct people to smart thermostats for purchase. TVA continues to research this topic with their Advanced Heat Pump group.

Beyond the Valley

Other utilities across the nation have experience with smart heating solutions, particularly smart thermostats. PNNL also focuses research on this topic.

Emerging Technologies

AT A GLANCE

TECH READINESS

Limited stand-alone commercial options

POTENTIAL

High anticipated market growth

FOCUS AREA

Energy and Environmental Justice

Smart Ventilation

Similar to other smart technologies, smart ventilation uses air quality sensors and smart vents to maintain indoor air quality and to support more efficient heating and cooling of buildings. Smart ventilation may be part of a larger smart heating, ventilation and air conditioning (HVAC) solution and/or a larger set of controls for a grid-interactive building.

Advanced smart ventilation systems are becoming more commonly commercially available, spurred by the COVID-19 pandemic, though adoption is not widespread. Prior to COVID-19, there was less awareness regarding indoor air quality concerns, which led to slow adoption of this technology.[13]

Benefits

- Improved energy efficiency
- Reduced peak electric load
- Reduced energy costs

EXAMPLES & RESOURCES

In the Tennessee Valley

At this time, no smart ventilation projects were identified as active in the TVA area, though EnergyRight continues to have an incentive for ultraviolet germicidal irradiation (UVGI) systems. UVGI systems, which can operate year-round, may help reduce and deactivate certain airborne pathogens.

Beyond the Valley

NREL and PNNL have both conducted research on this topic.

Emerging Technologies

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate anticipated market growth

FOCUS AREA

Energy and Environmental Justice

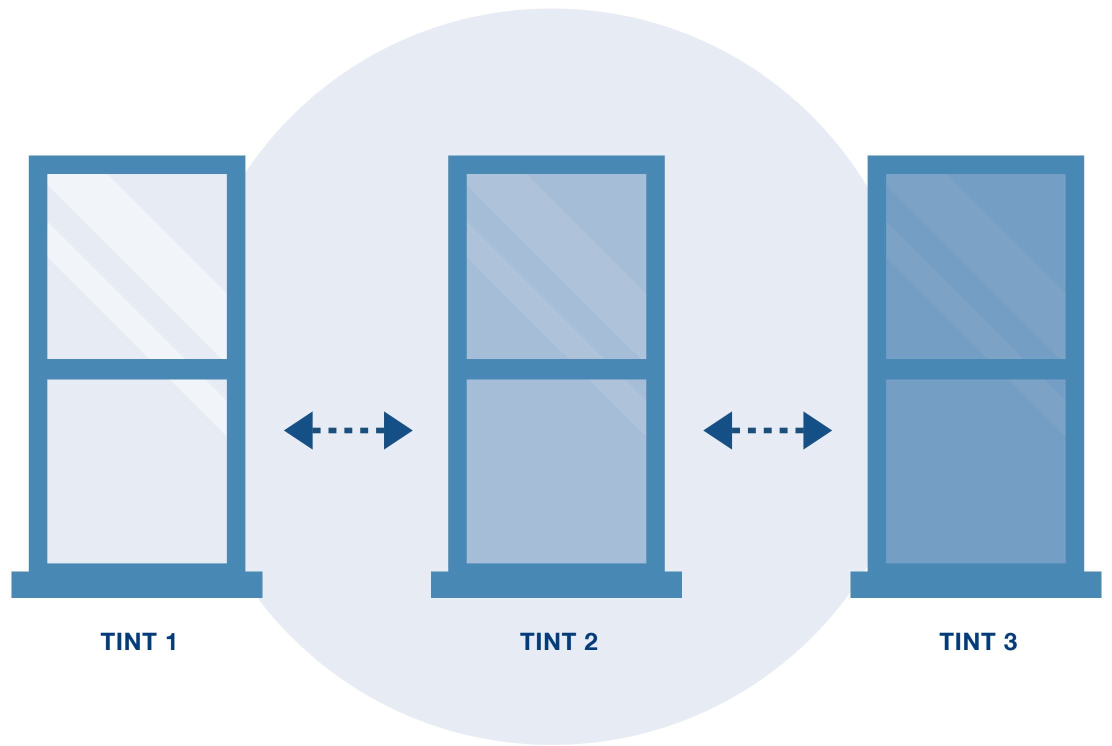
Smart Windows & Glass

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.[14]

Driving increased use of smart windows and glass is smart windows' ability to integrate into smart buildings, enabling all smart devices to be connected. Another driver is the desire to improve occupant comfort levels inside buildings.[14] Growth has been slower than expected due to both a lack of stakeholder education on smart windows and the expensive 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.[14]

Benefits

- Improved energy efficiency
- Reduced peak electric load
- Reduced energy costs



EXAMPLES & RESOURCES

In the Tennessee Valley

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.[15,16]

Beyond the Valley

View, SageGlass, Halio, PHYSEE, PowerWindows and EControl-Glas are all smart lighting companies across the globe. NREL also researches applications of this technology.

Emerging Technologies

AT A GLANCE

TECH READINESS

In demonstrations

POTENTIAL

Moderate anticipated market growth

FOCUS AREA

Energy and Environmental Justice

Grid-Interactive Efficient Buildings

Grid-interactive efficient buildings (GEBs) use smart building controls, sensors and analytics to communicate with the grid, reducing the amount of energy required during periods of peak demand. This capability is used to optimize buildings and DERs to maintain the comfort of the building occupants, lower utility bills and reduce grid system costs.

GEB adoption is receiving large support from the DOE with the National Roadmap for GEBs released in May 2021 and the Connected Communities DOE grant (separate from TVA's Connected Communities) for coordinating multiple GEBs, which announced 10 projects in October 2021.[17,11]

Challenges faced by GEBs include the interoperability of various systems in the building (like HVAC, water heater, lighting, solar, storage, EV charging), high upfront costs of GEBs and the lack of consumer understanding and awareness for adoption.

Benefits

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

EXAMPLES & RESOURCES

In the Tennessee Valley

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.[18,19] ORNL is also involved in the Building Operations Testing Framework project.[20] TVA is involved with GEBs by working with EPRI to better understand the technical feasibility of this technology to then provide lessons learned to LPCs. TVA also launched a related pilot project testing an open-source home energy management system that can connect to and control multiple electric devices in a home. Learn more here.

Beyond the Valley

Various national laboratories, including ORNL, PNNL and NREL, conduct research related to GEBs as well as the DOE. There are some private companies in the GEB space like GridOptimal and VOLTTRON.

Energy Analytics

The technologies found in this category are often software tools that use advanced analytical models to provide greater insights into energy usage. Using data, LPCs and customers can make more informed decisions about their energy use.

INCLUDES

- **Building Energy Modeling**
- **Energy Load Disaggregation**

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate anticipated market growth

FOCUS AREA

Energy and Environmental Justice

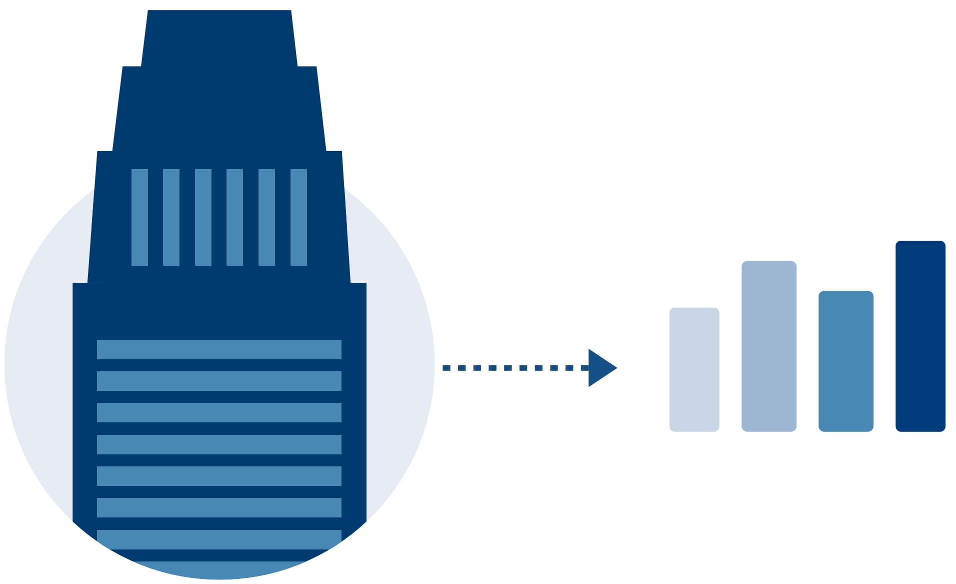
Building Energy Modeling

Building energy modeling (BEM) is a physics-based software simulation used for building and HVAC design, building performance assessment and development of energy codes and standards. BEM projects will provide valuable support to development and adoption of GEBs and GEB controls.[21]

BEM software is mature, widely used and commercially available. However, the increasing complexity of building energy systems and controls needs is driving development of more complex BEM solutions to support urban planning, energy codes, energy efficiency and demand response efforts, and building controls development. However, adoption difficulties come up in building business cases that support energy cost savings as well as limited educational offerings.

Benefits

- Better informed planning for energy efficiency
- BTM DER



EXAMPLES & RESOURCES

In the Tennessee Valley

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 for the community.[22,23]

Beyond the Valley

Both the DOE and national laboratories across the US produce BEM research and tools. Additionally, there are some open-source software for use including EnergyPlus and OpenStudio and OptiMiser (specifically residential focused).

AT A GLANCE

TECH READINESS

Commercially available & growing quickly

POTENTIAL

Very high market adoption potential

FOCUS AREA

Energy and Environmental Justice

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 or reduce peak demand without requiring additional hardware to be installed. This data can also help utilities identify customers that have or could benefit from certain distributed energy resources (DER), such as 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 helping to enable the implementation of load disaggregation. As utilities install smart meters, load disaggregation becomes feasible as the meter can now collect data. However, the amount of data collected and processed may be a barrier for widespread adoption.[24]

Benefits

- Customer outreach and support for behind the meter (BTM) opportunities

EXAMPLES & RESOURCES

In the Tennessee Valley

In creating this report, no load disaggregation projects were identified in TVA's service area. Let us know if your community is exploring or implementing load disaggregation.

Beyond the Valley

Oracle, Bidgely, Uplight and Itron OpenWay are all resources for utilities interested in load disaggregation. For residential or commercial customers, Sense is a good resource for this topic.

Community-Scale Energy

Community-scale energy includes technology applications applied to energy use at the community level. Some of these technology applications improve resilience and reliability for a community, while others aggregate energy across an entire community to use as a shared resource.

INCLUDES

- **Community Solar**
- **Microgrids**
- **Smart Energy Community**
- **Virtual Power Plant**

Emerging Technologies

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate anticipated market growth

FOCUS AREA

Energy and Environmental Justice

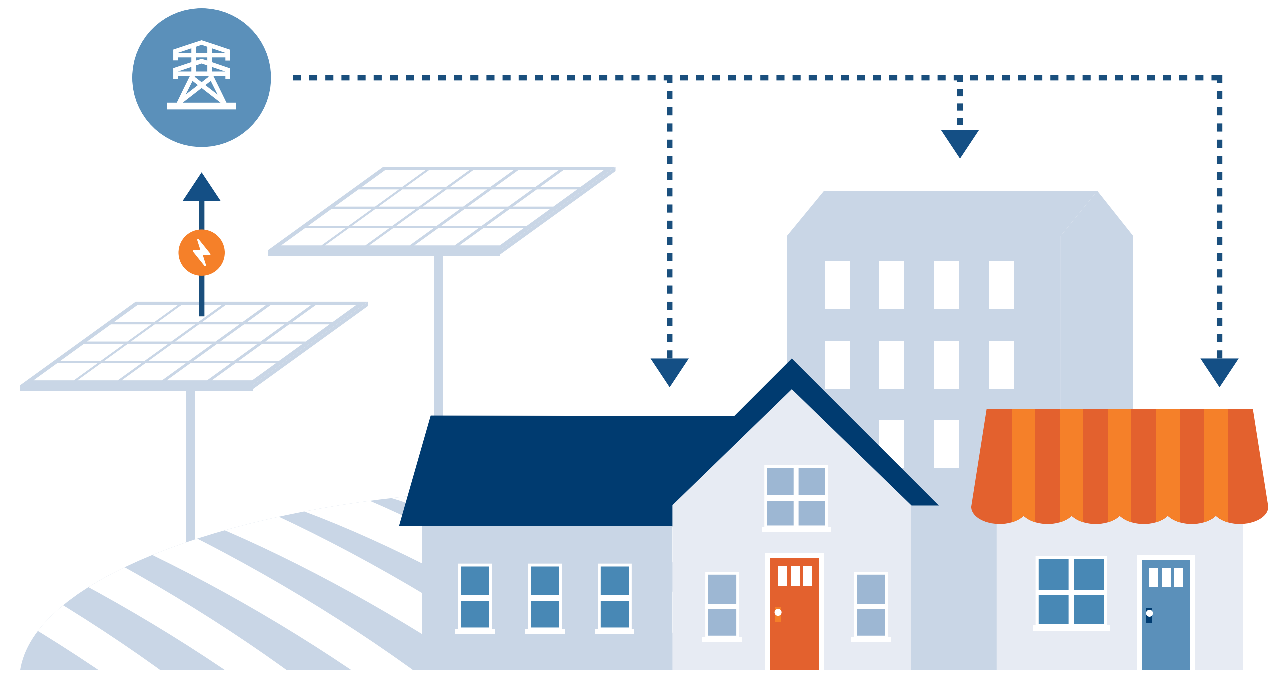
Community Solar

Community solar is any solar project or purchasing program, within a geographic area, in which the benefits of a solar project flow to multiple customers. Community solar customers can either buy or lease a portion of the solar panels in the array and typically receive a credit on their electricity bill for electricity generated by their share of the community solar system. The benefit of this over rooftop solar systems is that it allows a wide variety of customers to access renewable energy without needing to install solar themselves, while providing the grid additional generation capacity and resilience.

Community solar projects are driven by rising fuel costs, advances in solar technology, an increase in federal and state tax incentives and a desire to reduce carbon emissions and increase energy independence.[25] Community solar must be done in coordination with the local utility and requires significant up-front investment, which may hinder widespread adoption.

Benefits

- Reduced energy costs
- Renewables adoption



EXAMPLES & RESOURCES

In the Tennessee Valley

Several LPCs and their communities have community solar programs including Nashville Electric, the City of Chattanooga and Middle Tennessee Electric. Knoxville Utilities Board will soon begin construction on Knoxville's first community solar project in summer 2022.[26] In total, TVA's Valley Renewable Energy programs have provided access to community solar to over one million people.[27]

Beyond the Valley

The DOE's Solar Energy Technologies office is a great resource for community solar as well as NREL.

COMMUNITY-SCALE ENERGY

Emerging Technologies

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate anticipated market growth

FOCUS AREA

Energy and Environmental Justice

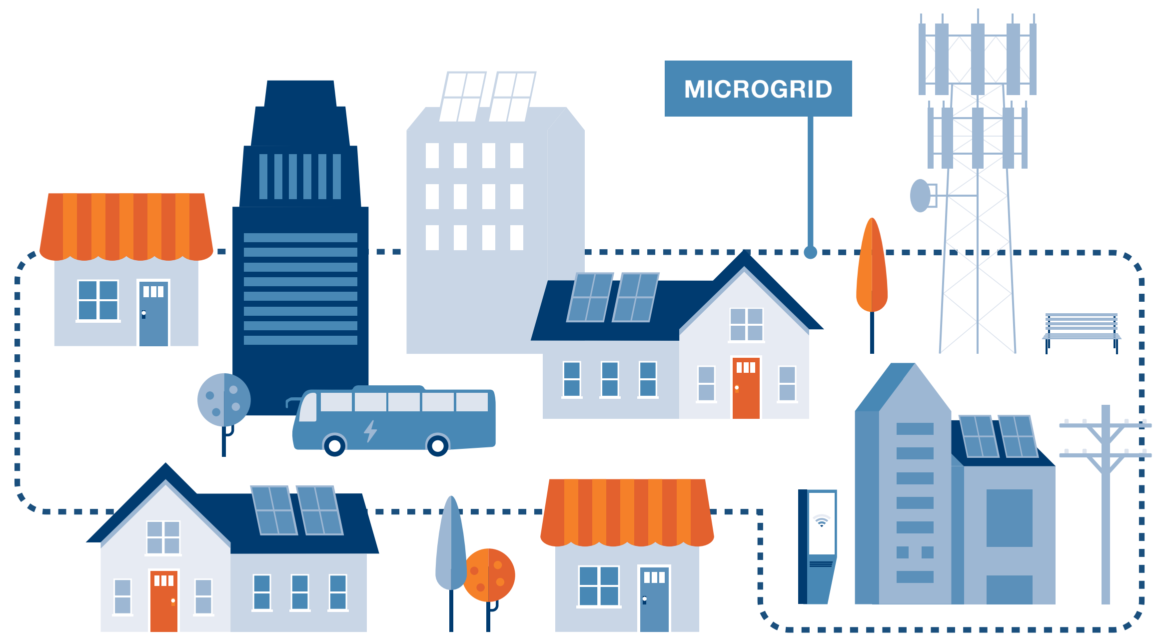
Microgrids

Microgrids control and optimize parts of the electric grid, including distributed energy resources (DERs) and loads that can isolate from the larger overall electric grid to provide greater energy resilience and reliability for a small area (e.g., community area, military base, college, hospital or commercial campus) 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. Business and industrial customers are the leading adopters. Community microgrids, serving residential and commercial customers, are most difficult to deploy and have the slowest adoption due to upfront costs, regulatory challenges and varying or required public input and collaboration.[28]

Benefits:

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



EXAMPLES & RESOURCES

In the Tennessee Valley

EPB of Chattanooga has three microgrids in its service territory that are used for research and are supported by DOE funding. Additionally, ORNL researchers use AI and a test bed named “Commander” to create simulations and perform research on secure controls and hardware using these research microgrids.[29]

Beyond the Valley

Honeywell and Duke are both located close to TVA’s service area and have experience with microgrids. There are several private companies that provide design, procurement and construction of microgrids, including Siemens, Enel Green Power, Ameresco, Bloom Energy, etc.

AT A GLANCE

TECH READINESS

In demonstrations

POTENTIAL

Moderate anticipated market growth

FOCUS AREA

Energy and Environmental Justice

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 use a variety of other technologies, including microgrids, virtual power plants, distributed power generation, energy storage, smart inverters, smart meters, DSM devices and vehicle-to-grid (V2G) systems.

Environmental regulations as well as energy consumers' desire for more reliable, controllable, inexpensive and locally generated energy are driving interest in this technology application. However, more widespread pursuit of smart energy communities faces slow policy change and technology adoption as well as hesitation from some residential groups.[30]

Benefits

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

EXAMPLES & RESOURCES

In the Tennessee Valley

ORNL, in partnership with the DOE, 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.[31,32]

Beyond the Valley

ComEd has a natural gas microgrid that incorporated solar and batteries. Additionally, the DOE has a series of "Connected Communities" projects (separate from TVA's Connected Communities) that highlights other smart energy communities.

Emerging Technologies

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate anticipated market growth

FOCUS AREA

Energy and Environmental Justice

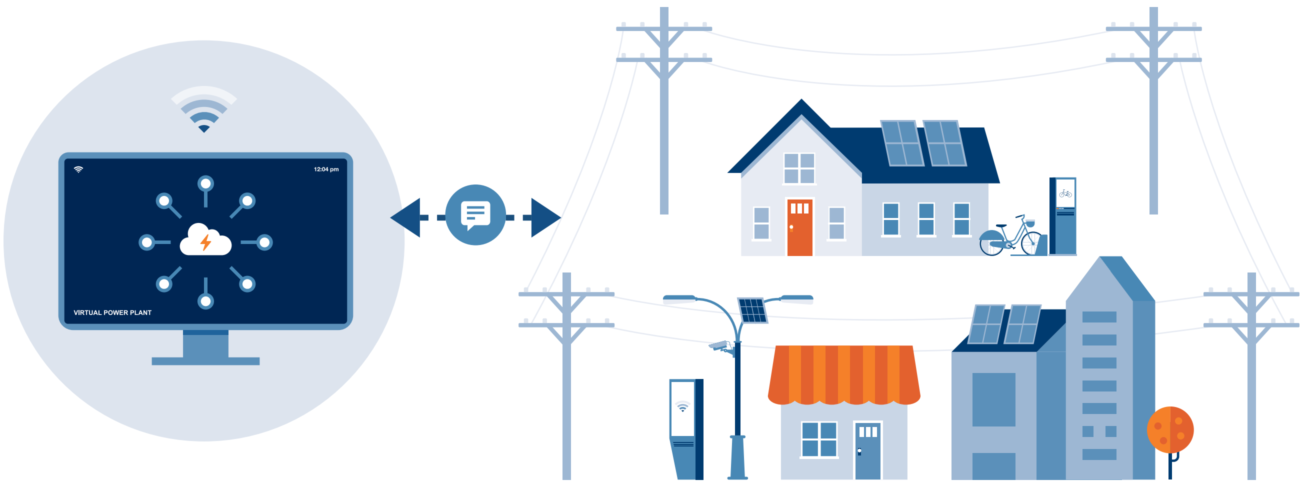
Virtual Power Plant

A virtual power plant (VPP) is 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.[33] VPPs can be managed by a utility or third-party provider. These systems focus on dispatching DERs to meet capacity, energy or ancillary service needs defined by market signals, while DER management systems (DERMS) focus on grid reliability defined by utility system operations.

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.[33] The complexity and cost of a chosen system, convolution of labels, privacy and cybersecurity concerns and customer outreach and education are just some of the hurdles for increased deployment of VPPs.[33]

Benefits

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



EXAMPLES & RESOURCES

In the Tennessee Valley

In 2019, TVA awarded a research project to University of Kentucky to study VPPs for DER aggregation and demand response (DR) controls, which would evaluate the impact of coordinated operation of appliances on future distribution systems for communities.[34] Also, Kentucky's Glasgow Electric Plant Board partnered with Sunverge for a 3-year solar plus storage VPP pilot project in 2016 that leveraged time-of-use electricity rates to reduce peak demand and support frequency regulation and voltage optimization.[35]

Beyond the Valley

Other utilities that have experience with VPPs include PG&E, Con Edison and Green Mountain Power. There are also private companies such as AutoGrid, Swell, Sunverge, Sunrun and Tesla that have experience with VPPs.

Connectivity

Connectivity technologies allow for more accessible and higher quality forms of communication between various entities. This includes technologies that provide connectivity services, like internet access, in public areas rather than just at home.

INCLUDES

- 5G
- Edge Computing
- Public Wi-Fi Kiosks
- Smart Poles
- Wi-Fi 6

Emerging Technologies

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

High anticipated market growth

FOCUS AREA

Equitable Access to Digital Services

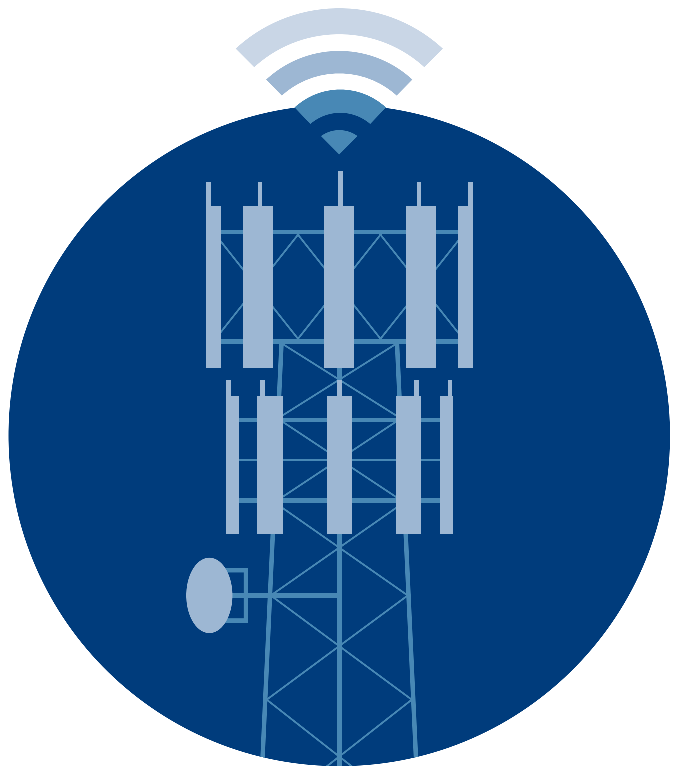
5G

Fifth generation wireless (5G) is now standard for broadband cellular networks. 5G provides faster and more accessible internet for consumers and other internet-connected devices. Broad deployment began in 2019 and was rolled out quickly across the U.S. by major telecom companies, with deployment to less populated areas continuing. Greater understanding and awareness of 5G use cases can support further deployment.

Local government support of 5G adoption can help to bridge the digital divide, support local economic expansion and improve services and public involvement. 5G faces cybersecurity and data privacy risks and concerns. Local governments may also lack the resources and skills needed to manage and benefit from 5G connectivity. The initial upfront cost, financial risk or lack of clear financial benefits may be barriers to municipalities improving public internet access. There are also unresolved public concerns over health risks and aesthetics for 5G.[36]

Benefits

- Access to high-speed internet
- Host IoT devices



EXAMPLES & RESOURCES

In the Tennessee Valley

Knoxville is partnering with telecommunications company CNX to deploy 5G. To deploy 5G services more quickly across Knoxville, CNX completed an inventory on city-owned assets.[37,38]

Beyond the Valley

Ongoing research into 5G is conducted by national laboratories, like NREL and PNNL, in conjunction with large communication companies. 5G infrastructure technologies are mature and deployment now is focused on bringing 5G to more rural areas.

AT A GLANCE

TECH READINESS

Limited commercial deployment but growing

POTENTIAL

High anticipated market growth

FOCUS AREA

Equitable Access to Digital Services

Edge Computing

Edge computing pulls together solutions that process data at or near the source of data generation, generally Internet of Things (IoT) devices, rather than in a centralized location such as a cloud or data center. This allows for faster processing and more efficient data delivery, as well as reducing the bandwidth necessary to share data to the cloud or end users. Other benefits include reduced operational costs due to reduced data storage needs, improved system resiliency and flexible scalability.[39]

Open source IoT/Edge Computing platforms are becoming increasingly popular due to their flexibility and customization options as well as the cost advantages.[40] However, the lack of awareness of this technology and cybersecurity concerns are barriers to greater adoption.[41]

Benefits

- Improved computing to enable analytics

EXAMPLES & RESOURCES

In the Tennessee Valley

AT&T has partnered with University of Tennessee, Knoxville to expand 5G coverage and Edge Computing on Campus.[42] Additionally, TVA, ORNL and 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.[43]

Beyond the Valley

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.

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate anticipated market growth

FOCUS AREA

Equitable Access to Digital Services

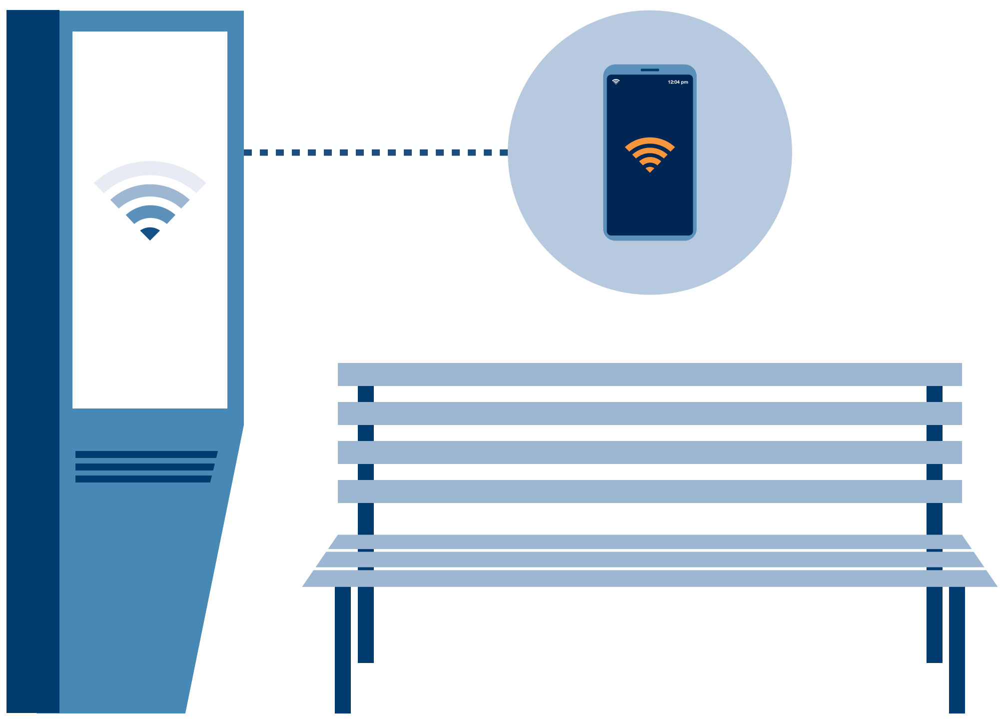
Public Wi-Fi Kiosks

Public Wi-Fi kiosks are placed in public spaces and provide free Wi-Fi. These kiosks can have a screen that shares details on community events, provide maps of the area, offer device charging, display advertisements to support local businesses, etc. Advertising can provide revenue to fund the kiosks.

The growing necessity of the internet for daily life and the need for equitable access are driving the advancement of these kiosks. When deploying these kiosks, be mindful of privacy concerns about both data collection and the security of the internet access, as the networks offered by the kiosks are often less secure than others.[44]

Benefits

- Access to high-speed internet



EXAMPLES & RESOURCES

In the Tennessee Valley

Public Wi-Fi has been deployed in some cities, but no use of Wi-Fi kiosks was identified through this research. Chattanooga's NoogaNet is one such public Wi-Fi network that is accessible at locations such as libraries, recreation centers and parks.[45]

Beyond the Valley

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

Emerging Technologies

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate anticipated market growth

FOCUS AREA

Equitable Access to Digital Services

Smart Poles

Smart poles integrate connected lighting, wireless connectivity (Wi-Fi or cellular) and Internet of Things (IoT) sensors into one cohesively designed unit, typically on streetlight poles. This technology can provide public connectivity, charging for phones or EVs, reduced energy use from better managed connected lighting, as well as data via IoT sensors for air quality, noise, traffic movement, gunshot detection, etc. Poles can host public Wi-Fi access points and/or the small cells needed for mobile broadband networks, or space on poles can be leased to third parties for municipal revenue.[46]

The overall technological shift of our world is leading towards increased public connectivity and safety, and smart city sensor infrastructure. The high cost per unit, data privacy concerns, ownership model and use case justification are some of the current challenges smart poles need to overcome for broader implementation. The use of cameras on smart poles also has caused public concern in the past due to privacy concerns.

Benefits

- Access to high-speed internet
- Host IoT devices

EXAMPLES & RESOURCES

In the Tennessee Valley

Johnson City, Tennessee is partnering with TVA and Brightridge to install smart poles in downtown Johnson City. The poles include lights, cameras, speakers, pedestrian counters, parking kiosks and a Wi-Fi hotspot.[47]

Beyond the Valley

There are several companies that have experience with smart poles, such as Siemens, GE, Signify, ENE.HUB and Nokia.

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate anticipated market growth

FOCUS AREA

Equitable Access to Digital Services

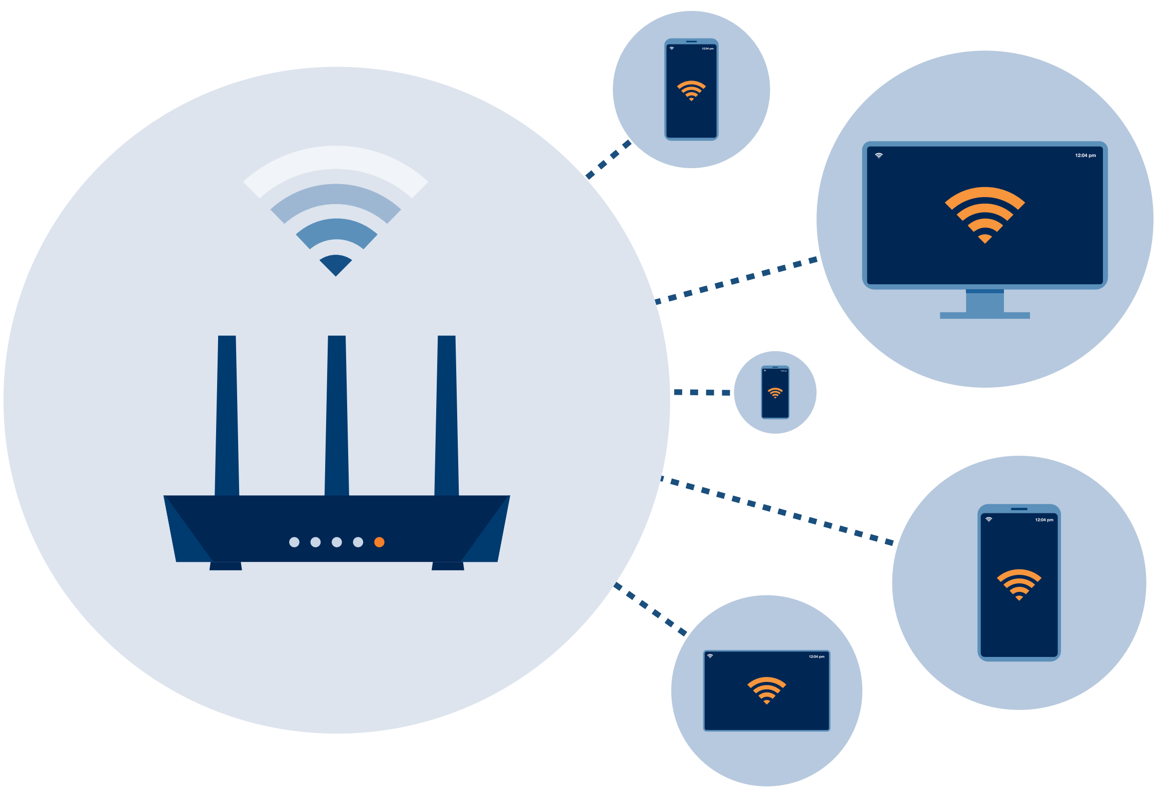
Wi-Fi 6

Sixth generation Wi-Fi (Wi-Fi 6) technology, also known as high-efficiency Wi-Fi, is an Institute of Electrical and Electronics Engineers (IEEE) standard for wireless local area networks aimed at improving data rates in high-density areas, allowing it to support more devices at once, use less battery power from connected devices and provide faster speeds.[48]

Wi-Fi 6 can support more data-intensive uses which makes this very useful in denser population centers. While many new products support Wi-Fi 6, it is inaccessible to older devices and requires upgraded hardware on the consumer side as well as upgraded Wi-Fi network hardware.[49]

Benefits

- Access to high-speed internet



EXAMPLES & RESOURCES

In the Tennessee Valley

Numerous internet providers throughout the Tennessee Valley offer Wi-Fi routers that support Wi-Fi 6 for residential and commercial customers. This is a mature technology deployed across the United States, and there are many players in this space.

Beyond the Valley

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

Emerging Technologies

Other Analytics

Similar to energy analytics, these tools allow users to gain more information about existing systems, like wastewater treatment, allowing for more informed decision-making from advanced data analytics.

INCLUDES

- Digital Twin Modeling
- Smart Water Management
- Smart Wastewater Management

Emerging Technologies

AT A GLANCE

TECH READINESS

Multiple demonstration projects

POTENTIAL

High anticipated market growth

FOCUS AREA

Energy and Environmental Justice

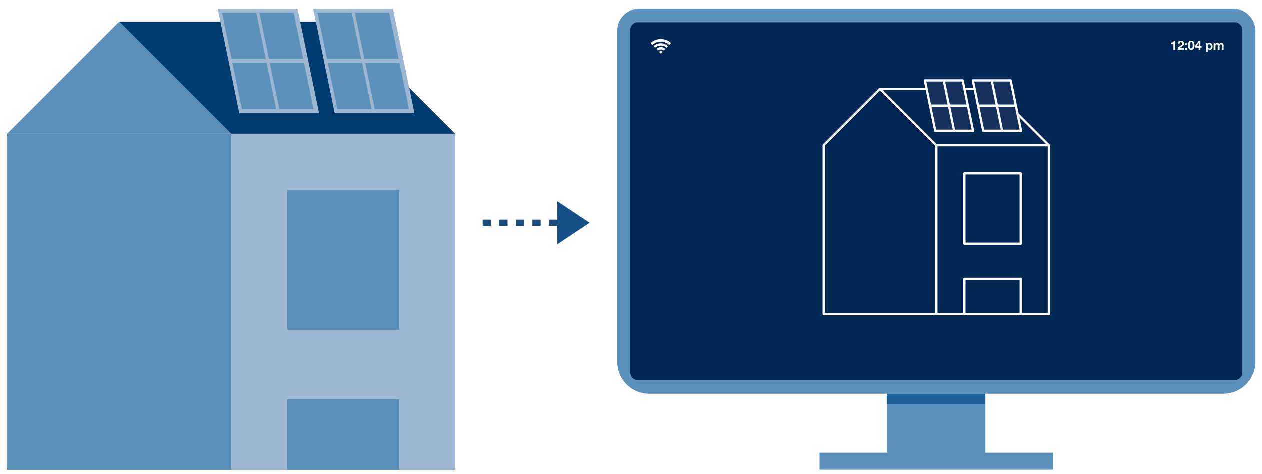
Digital Twin Modeling

One-to-one digital recreations, or digital twin models, of real-world objects or systems and have many applications. Digital twins are a visual tool for monitoring present conditions and simulating future scenarios and may use machine learning or artificial intelligence (AI).[50] Depending on the sensors and data available, digital twins can inform municipal operations, flood planning, heat islands, water treatment, building efficiency, traffic management, air quality and more.

Digital twin models are relatively low cost as communities can create basic digital twins with easily accessible, open source or low-cost data such as GIS data or satellite imagery.[50] While digital twins present valuable use cases to a variety of sectors, there is a knowledge gap about its applications and benefits. Utilities and municipalities, which may benefit from this technology, will need employees comfortable and knowledgeable about working with digital twins.[50] There is also a lack of digitized data, IoT sensors and data for the digital twin and proper data security and privacy.[50]

Benefits

- Better informed planning for electricity, water, buildings, etc.



EXAMPLES & RESOURCES

In the Tennessee Valley

ORNL has done a lot of work in this space, including creating a modeling program called Automatic Building Energy Modeling (AutoBEM), developing a power grid digital twin and working with multiple Departments of Transportation on a digital twin model looking at traffic congestion.[51]

Beyond the Valley

ORNL leads research and development on this topic.

Emerging Technologies

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate anticipated market growth

FOCUS AREA

Energy and Environmental Justice

Smart Water Management

Smart water management uses sensors and data to inform better overall management. It can apply analysis to historical data 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 water service pipes so that cities can replace them, which has traditionally been difficult due to a lack of installation records.[52]

Climate change and increasingly scarce freshwater resources are driving forces for more smart water management implementation.[53] However, implementing smart water management technologies requires collaboration between city departments, funding that may be difficult to gather and data integration that may not yet exist.[54]

Benefits

- Improve water and wastewater management, efficiency and contamination monitoring

EXAMPLES & RESOURCES

In the Tennessee Valley

Spencer, Tennessee implemented a sensor system to detect leaks in the city's primary raw water pipeline in partnership with Electro Scan Inc. after receiving a grant in 2019 under the Water Infrastructure Improvements for the Nation Act.[55] Additionally, White House Utility District (WHUD) implemented a leak detection program in collaboration with Esri. Data from smart water meters throughout the district is pulled into ArcGIS in real-time. WHUD also installed high- and low-flow alarms that trigger if water flow goes below or above a certain threshold.[56]

Beyond the Valley

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

Emerging Technologies

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate anticipated market growth

FOCUS AREA

Energy and Environmental Justice

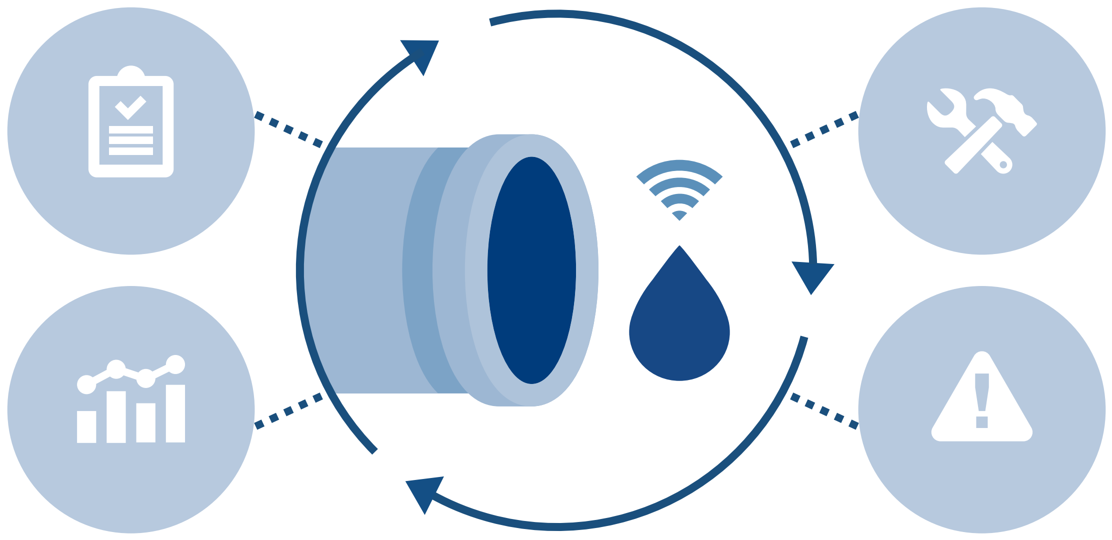
Smart Wastewater Management

Smart wastewater management focuses on using sensors to monitor water quality, presence of chemicals in water and system capacity. Sensors can also detect leaking pipes and the impact of rainfall on sewage systems. IoT technology in these applications grants insights into wastewater issues by looking at the patterns of leaks, floods and contamination, and can enable quick reaction times and problem solving.[57]

The sensors for smart wastewater management are easy to use and have a fast response time.[58] Using these for remote monitoring also removes the need for maintenance staff to check pipes as regularly, or to collect samples for lab monitoring. Some industries, such as manufacturing, are required to use devices to monitor wastewater quality to ensure wastewater does not contain trace metals or chemicals.[59] A challenge to implementing sensors across a system requires significant build out, and companies may be unwilling to spend large sums to accomplish this.[59]

Benefits

- Improve water and wastewater management, efficiency and contamination monitoring



EXAMPLES & RESOURCES

In the Tennessee Valley

The City of Memphis implemented a smart sensor monitoring system for industrial wastewater discharge. The system monitors water quality over more than 100 industrial sampling sites in the city's wastewater service area. The city staff can use the data collected by these sensors to see information about discharge in real-time.[60]

Beyond the Valley

The USGS Upper Midwest Water Science Center is testing 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 technology applications featured in this category connect the farming and energy industries to create a new intersection of opportunities for both of these sectors of the economy.

INCLUDES:

- **Agrivoltaics**
- **Internet of Things for Agriculture**

Emerging Technologies

AT A GLANCE

TECH READINESS

Demonstration pilots

POTENTIAL

Low anticipated market growth

FOCUS AREA

Energy and Environmental Justice

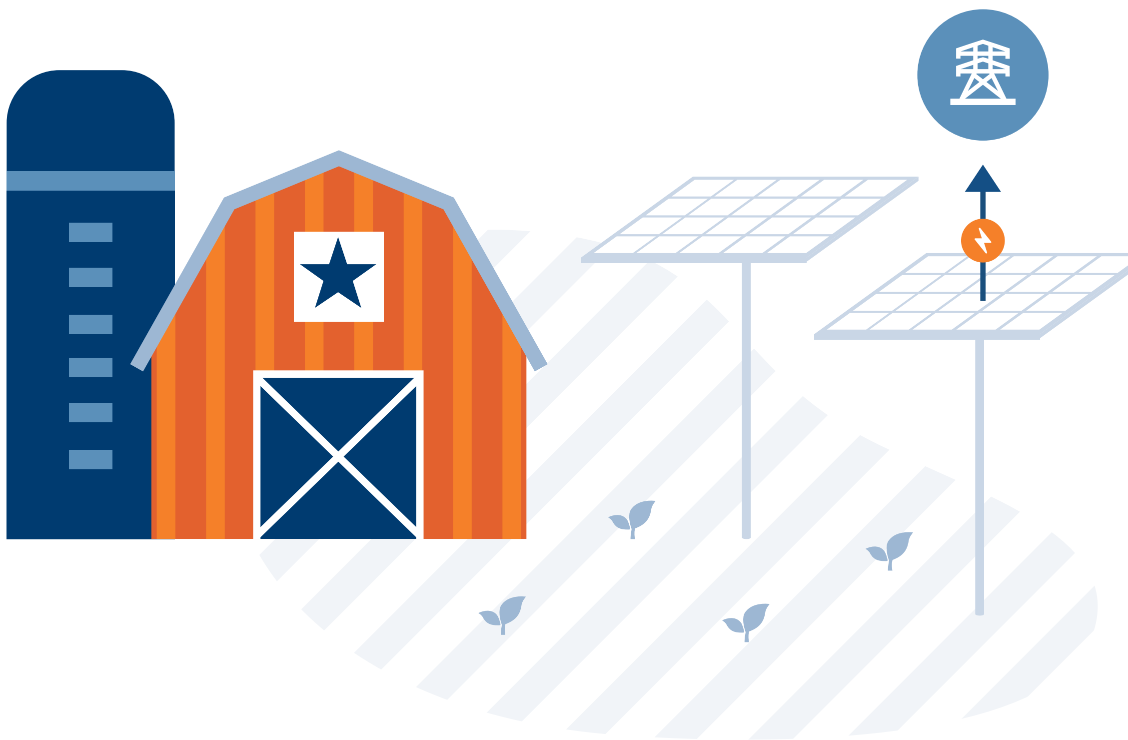
Agrivoltaics

Agrivoltaics involves the co-location of solar photovoltaics and agriculture (typically crops growing underneath elevated panels) 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 in shade-tolerant and temperature-sensitive crops.[61] Solar panels can require a large area for installation, and there is limited building rooftop space available. Using this approach retains and potentially enhances agricultural land use and soil quality.

While NREL does not believe agrivoltaics will likely be feasible for large scale, single crop farms, it has benefits particularly in hotter regions and regions with more limited farmland.[62] Regulations regarding land use and project siting can cause problems for interested farmers, as regulations often restrict uses on agricultural land.[61]

Benefits

- Reduced water/electricity use and costs
- Reduced operational costs
- Potential to reduce food costs



EXAMPLES & RESOURCES

In the Tennessee Valley

The Tennessee Department of Environment and Conservation (TDEC) has offered funding opportunities to farmers interested in on-farm renewable energy projects, though not specifically agrivoltaics.[61]

Beyond the Valley

At the national level, NREL and the U.S. Department of Agriculture (USDA) are good resources for more information on agrivoltaics. UMass and Oregon State University are two universities that provide additional information on this topic.

Emerging Technologies

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate anticipated market growth

FOCUS AREA

Energy and Environmental Justice

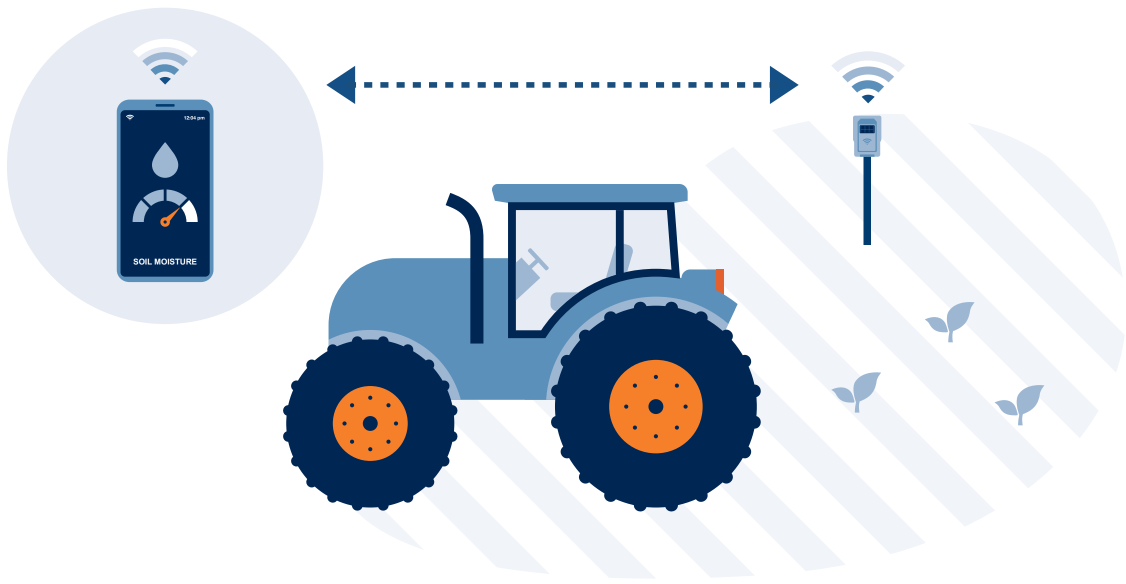
Internet of Things for Agriculture

The 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, as well as remote and 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.[63] 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.[63]

Benefits

- Reduced water/electricity use and costs
- Reduced operational costs
- Potential to reduce food costs



EXAMPLES & RESOURCES

In the Tennessee Valley

The University of Tennessee announced in July 2021 that it would be standing up a precision livestock farming research initiative.[64] The University of Tennessee Knoxville also has a Smart Agriculture Laboratory researching sensors, robots and IoT networks for farming applications.[65]

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.[66]

Beyond the Valley

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

Economic Development

The technology featured in this category focuses on reimagining workforce development in a virtual setting. Newly available technologies, such as virtual reality, are utilized for previously in-person requirements like training and orientations.

INCLUDES

- ✓ **Virtual Reality for Workforce Development**

AT A GLANCE

TECH READINESS

Commercially available

POTENTIAL

Moderate anticipated market growth

HIRING

FOCUS AREA

Economic Empowerment

Virtual Reality for Workforce Development

Virtual reality (VR) or augmented reality (AR) can provide digital spaces for workforce development and training. These applications could be particularly useful to mitigate cost, 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 for training employees remotely.[67] 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 of time, and the lack of applicability for visually impaired trainees.[67]

Benefits

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

EXAMPLES & RESOURCES

In the Tennessee Valley

Walmart has VR headsets in all stores for employee training, with headsets from Oculus and software from STRIVR.[68] TRANSFR is a company based in Alabama that offers hands-on simulation-based training for workforce development and 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.[69]

Beyond the Valley

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

Final Thoughts

Strengths

Current activity in the Valley demonstrates strengths in the deployment of some of the identified emerging technology applications: community solar, smart energy communities, digital twin modeling and behind the meter battery storage all have a strong presence in TVA's service area. By leveraging the knowledge gained from these projects as well as the research provided by ORNL, others have an opportunity to create their own pilot projects or programs with these four technologies and applications.

Opportunities

The identification of these four strength areas also highlights the current gaps in the Valley when it comes to the remaining 20 technologies previously outlined. This research did not identify projects in energy load disaggregation, smart ventilation or public Wi-Fi kiosks. Additionally, only limited activities were identified with virtual reality for workforce development, smart heating and building thermal storage. These technologies have been tested or piloted in other areas around the United States or the globe and communities in TVA's service area may benefit from learning from those projects in pursuing their own related projects. By leaning on the experience of others, TVA and LPCs have the potential to create successful pilot project or program 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

Considerations

TVA continues to evaluate ways to engage in projects that demonstrate the technologies described in this report. To do this there are a number of considerations, including prioritizing goals for Connected Communities, identifying available funding opportunities and assessing existing expertise and technical resources. Partnerships are an important aspect of continuing to explore the technologies listed above as well. By working together with stakeholders, Connected Communities can help demonstrate the ways in which technology and data can improve lives across the Valley.

Conclusion

The technology applications discussed have varying degrees of market maturity and barriers to adoption. While some technologies are well established in the Valley, others present an opportunity for TVA and LPCs 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 our Connected Communities goals.

4

selected technologies

currently have a strong presence in TVA's service area.

20

selected technologies

have been identified as having the potential for pilot project or program application in TVA's service area.

Resources

Acronyms

5G	Fifth generation wireless
AI	Artificial intelligence
AIDT	Alabama Industrial Development Training
AR	Augmented reality
BEM	Building energy modeling
BTM	Behind the meter
CEE	Center for Energy Efficiency
DER	Distributed energy resources
DOE	Department of Energy
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
KUB	Knoxville Utilities Board
LBNL	Lawrence Berkeley National Laboratory
LPC	Local power company
MTE	Middle Tennessee Electric
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
V2G	Vehicle to grid
VPP	Virtual power plant
VR	Virtual reality
WHUD	White House Utility District

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Emerging Technologies

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