Enabling Local Building and Cross-Sector Solutions Through the E2C Program

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ABSTRACT

The Energy to Communities (E2C) program connects local entities, Tribes, and utilities with national laboratory experts and customized, cutting-edge analysis to achieve abundant, reliable, affordable, and secure energy systems that reflect local and regional priorities. E2C brings together innovative technologies, state-of-the-art modeling, and unique laboratory validation capabilities to help close the gap between energy ambitions and real-world action. This paper describes the E2C program's technical approach and highlights buildings-related affordability and reliability technical findings from the E2C In-Depth Partnership projects, where local partner teams work alongside national laboratory staff to apply robust modeling and analysis tools and validate hardware or system performance under local conditions. Examples of innovations include conducting advanced regional residential building stock analysis to identify opportunities for improved energy affordability (Delaware Valley), leveraging national laboratory evaluation and validation platforms to de-risk utility solutions (Colorado Springs), and applying innovative integrated distribution planning methods using national laboratory simulation capabilities to investigate the affordability and reliability of building-grid solutions (Pittsburgh). Finally, the paper discusses how the innovations piloted through E2C could be applied to address emerging

challenges and opportunities, including enabling data center load growth through integrated cross-sector solutions that consider various objectives, such as reliability and affordability.

Introduction

Buildings are where people live and work. They are hubs for economic activity and productivity. Ensuring the provision of reliable and affordable energy supplies, combined with buildings that use that energy to maximize benefits to occupants and businesses while keeping costs low, are key strategies being pursued across local, regional, and national scales. Buildings also consume approximately 75% of the electricity in the United States (DOE 2026). They are a key driver of electric peak demand (Langevin et al. 2021) and thus electric infrastructure and electricity reliability needs in the United States. In addition to its connection to the electricity system, the buildings sector is tightly linked to the oil and gas, transportation, and other sectors. These interdependencies are becoming more complex as building loads grow, including energy-intensive uses such as data centers, and as more devices behind the utility meter become controllable and flexible. As a result, advanced building and energy infrastructure projects increasingly require integrated energy solutions that account for cross-sector interactions while also addressing practical risks related to technology controls, interoperability, and security.

While many of these concepts can be discussed at a high level, building and infrastructure projects are ultimately implemented in local contexts. Each place brings distinct challenges and opportunities shaped by resident needs and preferences, local energy resources and costs, building stock conditions and construction practices, and the characteristics of existing grid infrastructure and utility ownership. At the same time, local conditions are influenced by upstream factors such as regional energy markets, state policy, technology availability, and broader economic trends. For example, a building-grid infrastructure solution for a marine or coastal city in the northwest United States with relatively low electricity costs may differ from a solution for a cold-climate city in the northeast with higher electricity costs. Developing advanced building and infrastructure projects therefore requires a tailored, place-based approach, working closely with local partners.

A key challenge facing some of the most advanced and ambitious cross-sector building and infrastructure projects is that, although they are local in nature, these projects often require cutting-edge analytical, modeling, and validation capabilities that are distributed across the United States at national laboratories and other research institutions. Various U.S. Department of Energy (DOE)-funded programs have helped bridge this gap by making advanced national laboratory capabilities accessible to local jurisdictions through technical assistance partnerships. These programs allow communities to leverage specialized expertise, tools, and facilities that would otherwise be difficult to access locally. This paper describes how the Energy to Communities (E2C) program, funded by the U.S. DOE, provides an innovative technical assistance model designed to meet communities at their specific point of need. By leveraging the world-class research capabilities of the U.S. national laboratory system, E2C enables local governments, Tribes, and community organizations to access three distinct offerings tailored to different timelines and technical requirements. The E2C program is managed by National Laboratory of the Rockies (NLR), with critical support from Argonne National Laboratory

(ANL), Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL).

Key contributions of this paper include: 1) Presenting the first cross-program presentation of the E2C approach and findings *for buildings-related work*, including an emphasis on affordability, reliability, and resilience topics. 2) Documenting how the E2C program approach is being applied to emerging challenges and opportunities. The approach combines various depths of program support and includes U.S. national laboratories working with local partners to analyze, de-risk, and validate building and infrastructure projects prior to actual implementation.

The remainder of the paper is organized as follows: First, the E2C program technical approach is described for each of the three main program offerings. Next, the E2C In-Depth Partnership program findings are presented for five In-Depth Partnership projects with buildings-related affordability and reliability elements; descriptions of each project's background, technical approach, and key innovations, findings, and next steps are included for the applicable projects. The subsequent section discusses how the E2C approach is being applied to address the following emerging challenges and opportunities: 1) energy reliability and the growth of data centers and other large loads; 2) increased interest in energy resilience and backup power solutions, especially the creation of building-level, campus-level, and other microgrids; and 3) greater emphasis on energy affordability. Finally, the paper ends with concluding remarks.

E2C Program Technical Approach

The E2C program offers three different but synergetic opportunities to support local entities. To address immediate, specific hurdles, E2C Expert Match provides support over two to three months, delivering the actionable data needed to resolve near-term energy questions. For those seeking broader strategic development, E2C Peer-Learning Cohorts convene participants for six months to focus on a common energy topic, with subjects evolving based on participant feedback and current energy trends. For more complex, large-scale initiatives, E2C In-Depth Partnerships offer immersive, multiyear collaborations that use high-fidelity modeling and hardware validation to de-risk infrastructure projects before real-world deployment.

In-Depth Partnerships

The In-Depth Partnership offering represents E2C's most robust form of support. This multiyear model bridges the gap between local planning and real-world deployment by pairing community coalitions with national laboratory experts to rigorously test energy strategies in simulated environments—helping communities de-risk projects before breaking ground. E2C launched the first six in-depth partnerships in 2023, followed by three more in 2024.

E2C equips In-Depth Partnership teams with a sophisticated suite of laboratory capabilities tailored to their unique infrastructure needs. For many communities, this involves high-fidelity modeling through tools like ResStock™ and ComStock™, which can analyze how specific interventions—such as advanced building technologies—affect localized costs and grid demand. Other teams leverage advanced emulation via the Advanced Research on Integrated Energy Systems (ARIES) platform to create "digital twins" of community grids and energy infrastructure, allowing them to simulate hundreds of scenarios, including extreme weather and high-load growth. Further, linking facilities like FLEXLAB® with ARIES provides the opportunity to test real-world hardware, such as microgrid controllers and building systems, ensuring they reliably respond to grid signals without service interruption.

The impact of these technical capabilities is evident in how communities address reliability and long-term infrastructure security. In Colorado Springs, Colorado, the team is validating an advanced grid control solution using a controller-hardware-in-the loop setup for a water treatment site, demonstrating that heating, ventilating, and air-conditioning (HVAC) systems could shed 50% of their load during peak periods to ensure essential services remain operational. Similarly, in Sitka, Alaska, the team is using lidar-based grid models to protect a $500 million hydropower investment, ensuring the community's primary energy source remains stable.

These partnerships also prioritize energy affordability and the management of regional growth. In the Delaware Valley, Pennsylvania, an analysis of 800,000 homes revealed that "light-touch" retrofits are modeled to reduce energy utility bills for nearly all applicable homes and show a positive modeled net present value in ~45% of occupied single-family-households (Present et al. 2026), providing a data-driven roadmap to reduce energy costs for residents. Meanwhile, in Chicago, Illinois, and Nashville, Tennessee, laboratory experts are modeling the impacts of rapid metropolitan growth. These efforts ensure that aging infrastructure can support evolving electric vehicle charging demands—projected to reach 91 gigawatt-hours in Chicago by 2050—while maintaining the high level of service required by residents and businesses.

Peer-Learning Cohorts

While In-Depth Partnerships provide deep technical support, E2C Peer-Learning Cohorts facilitate the exchange of strategies and best practices among peers across the country or within regions with shared energy challenges. These six-month engagements provide timely information to support decision-makers in initiating energy projects. Rather than providing site-specific analysis, cohorts focus on high-level thematic education reinforced by peer exchange and guided activities. By convening up to 15 participants in a virtual environment, this E2C offering allows leaders to workshop challenges and develop strategies alongside national laboratory researchers and apply the learnings to their local context. Nearly 300 participants from more than 35 states and Tribes have joined E2C Peer-Learning Cohorts.

Buildings-related cohorts have covered topics such as 1) evaluating and prioritizing municipal buildings for energy efficiency investments, 2) designing and enhancing energy efficiency programs for residential buildings, and 3) navigating electricity load growth and associated utility grid impacts. For example, in the cohort on designing and enhancing energy efficiency programs for residential buildings, 15 participants (municipalities, Tribes, nonprofits, and utilities) convened in a series of six workshops to learn best practices and lessons from peers related to this topic. Some specific workshop session topics for this cohort included building a strong foundation for a residential energy efficiency program, planning community outreach strategies, and measuring program success and expanding beyond energy efficiency.

A critical feature of the E2C ecosystem is the intentional path from the general to the specific. The cohort model builds local capacity and serves as a vital "on-ramp" for participants who wish to transition into the Expert Match offering for customized, near-term technical support.

Expert Match

Expert Match serves community stakeholders who hold decision-making power but require specialized expertise to inform upcoming and time-sensitive decisions and address near-term energy questions and challenges. This offering targets the specific technical or economic hurdles that often stall local progress. Since its launch, Expert Match has provided a direct line to national laboratory researchers for nearly 250 participants, delivering site-specific insights through approximately 40–60 hours of support per request over a two- to three-month period.

National laboratory experts use a variety of specialized tools to provide these rapid answers. For instance, in Westminster, Colorado, the REopt® platform modeled a resilience hub at a recreation center, providing the analysis needed to move forward with a 200-kilowatt solar and 150-kilowatt storage system. Additionally, researchers conducted thermal simulations for projects such as Hope Village in Detroit, Michigan, and Tranquility Estates in Raymond, New Hampshire to identify the most efficient heat pump options for their unique regional climates.

The innovative structure of E2C ensures that, regardless of a community's starting point, stakeholders have access to the expertise required to build a more abundant, affordable, and reliable energy future. By connecting foundational learning with rapid technical answers and deep-dive validation, E2C creates a robust framework for local energy success.

E2C In-Depth Partnership Program Findings: Buildings-Related Affordability and Reliability

This section presents the E2C In-Depth Partnership program findings for five projects with buildings-related affordability and reliability elements. Descriptions of the project background, technical approach, key innovations, findings, and next steps are included for the applicable projects. The first three projects are part of the first round of E2C In-Depth Partnership projects, which are in the second half of the national laboratory technical assistance phase/timeline; the last two projects are part of the second round of E2C In-Depth Partnership projects, which are in the early stages of technical assistance, and thus more emphasis is placed on the planned technical approaches, instead of the findings, for those projects.

Delaware Valley, Pennsylvania

Background. The Delaware Valley E2C In-Depth Partnership was led by the Delaware Valley Regional Planning Commission to support the planning and launch of a Southeast Pennsylvania Regional Innovation Center serving Bucks, Chester, Delaware, and Montgomery Counties. The goals of the Regional Innovation Center are to 1) facilitate collaboration to reduce residential utility costs through coordinated home retrofit delivery; 2) expand the capacity of local governments to manage energy use, performance, and costs; and 3) advance regional visioning and convening to sustain long-term affordability, resilience, and reliability outcomes.

To operationalize these goals, the partnership brought together home repair and weatherization providers, county and municipal governments, the local utility (PECO), technical experts, and national laboratory partners to align programs, data, and decision-making processes around measurable building-level outcomes.

Technical approach and key innovations. The national laboratory teams worked with the community team to develop a housing stock analysis focused on single-family houses to inform other areas of the work plan, including analyses of funding needs, workforce capacity, and the region's supply chain. This housing stock analysis covered the existing housing's characteristics, their energy use, and the associated energy utility bills. It also covered the potential of retrofit measure packages through the aforementioned metrics, plus first costs and net present value. Additionally, an analysis of the electrical panel constraints and other readiness obstacles associated with the retrofit measure packages was performed. Key innovations include:

1. **Comprehensive building stock analysis presented for many different audience types**. Combining off-the-shelf ResStock data with select project-specific inputs enabled results scaled to meet the needs of different stakeholders—from a 100-page report (Present et al. 2026) and a conference paper and presentation (Present, Compitello, and Pawlowski 2025) to a three-slide summary—and one of the more comprehensive housing stock analyses found in the literature search for a project focused on under 1 million houses.
2. **Analysis of retrofit obstacles**
   Including analysis of the prevalence, cost, and options for addressing obstacles (e.g., inadequate electrical panels, asbestos, lead paint, knob and tube wiring, and moisture).

Findings and next steps. The housing stock analysis[1] reported that the nearly 800,000 single-family houses in the study area, as modeled by ResStock, use approximately 31 billion kWh of site energy annually—42% of that being natural gas, 33% electricity, 21% fuel oil, and 4% propane. It showed that 64% of that site energy use is for heating, and approximately 30% of houses heat primarily with fuel oil or propane. The analysis of the retrofit obstacles found that approximately 35–40% of the homes assessed for DOE Weatherization Assistance Program services are deferred due to repair needs that must be addressed prior to weatherization.

The retrofit measure package analysis found that the modeled envelope retrofit package reduces site energy use from each fuel, showing energy utility bill reductions for every occupied house (as seen in Figure 1) and a positive net present value in 45% of occupied houses. The other measure packages each included a heat pump and showed increased electricity use, decreased site use of each other fuel, and decreased site energy use overall. They showed more houses with positive net present values if there was an original heating fuel of electricity or both existing central air conditioning and an original heating fuel of fuel oil or propane.

[1] Note: See Present et al. 2026 for detailed results; results here are summarized findings and are also updated relative to Present, Compitello, and Pawlowski 2025.

The next phase will operationalize these findings through a coordination pilot between home repair and weatherization providers designed to reduce deferrals and improve delivery sequencing. It will establish shared workflows, data-sharing protocols, and defined operating procedures to support more holistic retrofit outcomes. Lessons learned will inform replicable coordination models that can be expanded across the region.

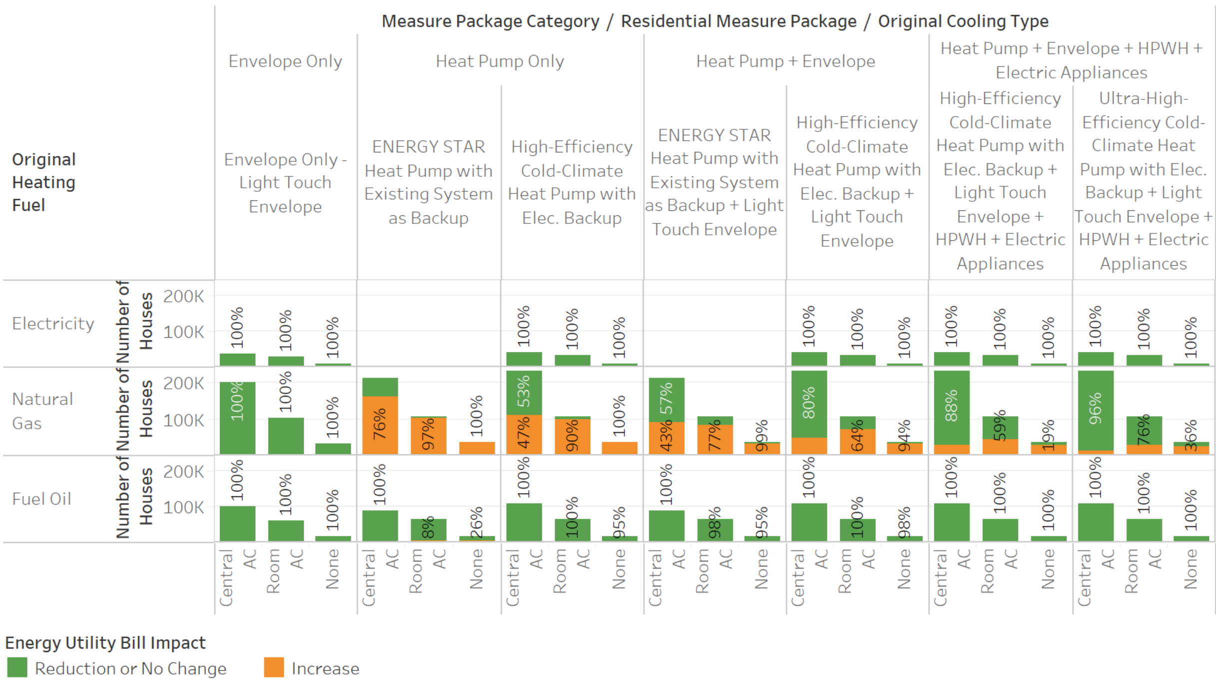

Figure 1. Number of occupied single-family houses by modeled annual energy utility bill impact direction by retrofit measure package, original heating fuel, and original cooling type[2]

Pittsburgh, Pennsylvania

Background. In coordination with the Green Building Alliance, Pittsburgh's Department of City Planning, and Duquesne Light Company (DLC), the national laboratories are developing an integrated distribution planning framework to inform future investments in the grid. In traditional distribution planning processes, DLC is limited to a narrow set of solutions it can use to address constraints on its system and a limited set of criteria it can use to evaluate such solutions. This narrow perspective has historically limited to what extent utilities can consider investments in the building stock. The developed integrated distribution planning framework will allow DLC to evaluate a broader set of technology solutions, including customer-sited investments, such as building energy efficiency; assess future distribution challenges with greater feeder-level and local building details; and compare investments using a wider set of criteria aligned with local energy priorities. The effort is grounded in strong partnership between the community coalition

[2] Note that the heat pump measures that use existing heating systems as a backup are not applied to houses with original heating fuel of electricity in ResStock 2024 Release 2. HPWH = Heat Pump Water Heater.

and the national laboratories, with close coordination and data sharing from DLC and significant involvement from all parties in key decision-making.

Technical approach and key innovations. This study employs an integrated, replicable modeling framework that combines community needs assessment, technology prioritization, and advanced metering infrastructure (AMI) analytics and tax assessor data to model the building-grid nexus from the bottom up. AMI data and building models are combined with distribution modeling efforts and feeder-level load forecasting to simulate DLC's potential future challenges and possible solutions, including investments in the building stock. These modeling efforts are informed by place-based insights on local energy priorities to determine which solutions result in the best outcomes for the community.

1. <u>Community engagement and technology prioritization.</u>

A data-driven approach leveraging local building, environmental, socioeconomic, and grid datasets was adopted to characterize and prioritize neighborhoods in areas where DLC anticipates future grid constraints. Combined with the communities' willingness to engage, two neighborhoods were selected for granular housing stock modeling. Additional in-person activities, questionnaires, and interviews with local developers assessed energy-related challenges and technology solution interests, further informing the building modeling process.

2. <u>AMI data translation to building simulation models.</u>

To model the selected neighborhoods, building information was extracted from building polygons, tax assessor data, and AMI data within neighborhood boundaries. Each meter was associated with the relevant metadata, and its load profile was then analyzed and mapped to a dwelling model from the ResStock 2024.1 dataset relevant to the greater Pittsburgh region (Parker and Speake 2024). The mapped ResStock models were converted to building models in the City Buildings, Energy, and Sustainability (CityBES) platform, recalibrated using additional years of AMI data to capture post-COVID-19 pandemic (2020–2022) shifts, then aggregated from dwelling units to whole buildings for the energy retrofit analysis. Prioritized retrofit measures were then applied to the calibrated baseline models in CityBES to evaluate their energy savings and cost-effectiveness. To capture the impacts from energy retrofits to buildings outside the neighborhood of interest but on the same substation, simulation results were extrapolated based on building characteristics.

3. <u>Building-to-grid integrated simulation and impact assessment.</u>

To quantify the impacts on grid operations, node-level baseline load forecasting is coupled with the simulated demand-side load shape changes under technology adoption scenarios (e.g., electric load growth, HVAC upgrades, demand flexibility), enabling the end-to-end simulation of feeder and system performance for any building-grid upgrade measure. Developed for DLC, the machine-learning-based annual peak load forecasting framework fuses high-resolution AMI data, advanced weather indicators, and feeder-level characteristics to deliver robust real-world accuracy (≤4% error vs. up to 46% for conventional utility methods), supporting less overbuilt capacity and more reliable, affordable infrastructure planning (Choi et al. 2026).

Findings and next steps. Recognizing the challenges of developing a detailed building stock model for an entire utility territory, this framework balances effort and results by leveraging national laboratory simulation capabilities and machine learning methods to approximate ground truth building information. It balances scale and granularity by modeling key neighborhoods in detail, then extrapolates the results to the wider analysis boundary. Next steps of this analysis include finalizing the residential measure selection, simulating the measures, developing the demand-side load changes and the adoption propensity model for integration into the distribution grid model, and repeating a similar process for the commercial sector. The modeled building investments will then be compared to traditional grid investments across a range of community priority criteria in an optimized capacity expansion framework developed in CADET.[3]

Colorado Springs, Colorado

Background. Colorado Springs Utilities (CSU) is collaborating with NLR and LBNL on a pioneering project to boost the resilience of its power grid. This partnership focuses on validating advanced grid and building controls for CSU's Mesa Water Treatment Plant. By using the ARIES and FLEXLAB simulation platforms (Figure 2), the project aims to address challenges like regional load growth, wildfire threats, and rising energy costs, ultimately creating a scalable framework to enhance grid reliability and service quality across all of CSU's utility sectors.

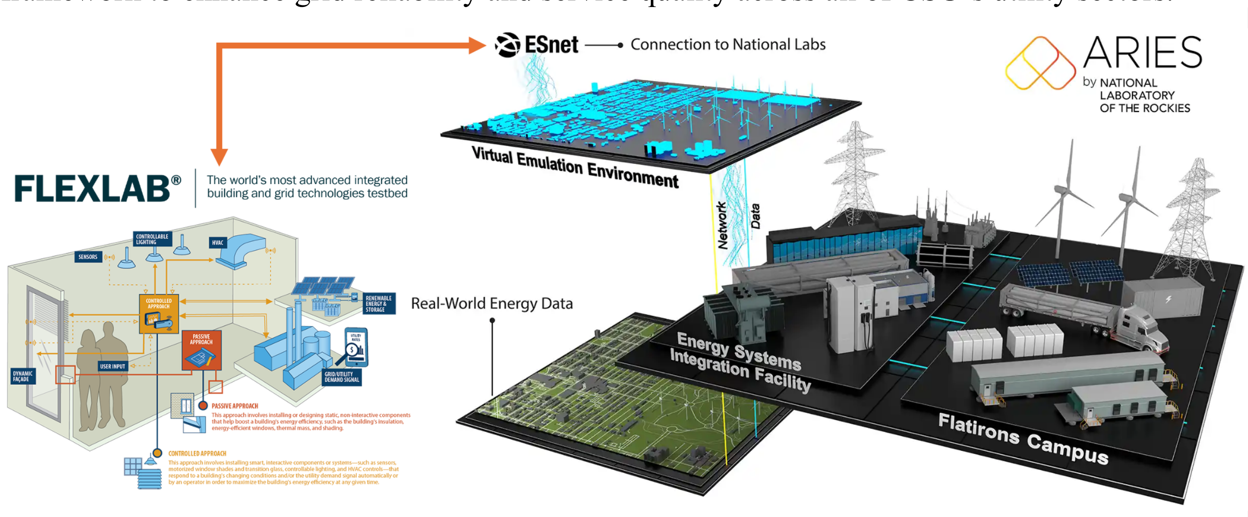

Figure 2. ARIES-FLEXLAB simulation setup for de-risking advanced grid control solutions.

Figure credit: Includes figures originally developed by Cristen Farley, LBNL and Josh Bauer, NLR

Technical approach and key innovations.
Laboratory validation and simulation. To lay the groundwork for the project, LBNL conducted controlled load response tests at its FLEXLAB facility. The team emulated one of the office building's HVAC systems to measure its load reduction response to demand-response signals. By testing various cooling set point adjustments, they were able to characterize how the building sheds electrical load during peak demand periods. This initial testing validated the load-shedding mechanism and provided essential data for further testing the coordinated energy performance of the full, integrated grid control strategies including on-site generation, energy storage and flexible building loads.

[3] For more information on CADET see: https://www.nlr.gov/grid/cadet.

Meanwhile, the NLR team developed a high-fidelity digital twin of the site's power assets, including loads, local generation, and battery storage. Using NLR's ARIES platform in a controller-hardware-in-the-loop setup, the team ran real-time digital simulations of grid operations. These simulations, which incorporated the site's actual load data, helped identify the most effective strategies for fulfilling the facility's power needs under various scenarios in both grid connected and islanded modes of operations.

Informing investment with cost-benefit analysis. To support CSU's investment decisions, the team also developed a set of critical operational scenarios and a structured cost-benefit analysis methodology framework. This analysis quantified the energy cost savings and other operational benefits such as resilience during power outages and continuity of maintaining critical utility service from implementing a pilot at the Mesa water treatment plant site with advanced grid controls orchestrating on-site energy generation, energy storage, and flexible building loads. Using LBNL's DER-CAM optimization tool, the analysis evaluates the benefit categories described in Table 1. This comprehensive methodology provides CSU with a technology-neutral and replicable framework to guide the scalable deployment of advanced grid controls across its entire service territory.

Table 1. Benefit categories analyzed in cost-benefit analysis for the Colorado Springs In-Depth Partnership

Benefit Category	**Details**
Reliability & Resilience	Avoided downtime and improved support for the critical water treatment plant systems during power outages caused by wildfires and other uncontrollable events
Financial Savings	Reduced energy costs including energy and demand charges, and potential revenue from new grid services
System Optimization	Determined the most cost-effective system size and coordinated dispatch strategies for both grid-connected and islanded (off-grid) operations

Next steps. Leveraging the ARIES-FLEXLAB interconnection shown in Figure 2, the next phase will execute end-to-end integrated testing in summer 2026 to demonstrate that local generation, combined with storage and flexible building loads can support critical loads on-site during outages, optimize energy costs with energy arbitrage, and provide additional grid support.

Nashville, Tennessee

Background. Nashville is growing quickly: Business is booming, the population is growing, and infrastructure systems—such as transportation, electricity, and buildings—all require significant expansion and updates and have become increasingly interdependent. Recognizing the need to coordinate these planning activities, Nashville Electric Service (NES) —one of the largest public power utilities in the United States—has partnered with local government, community-based organizations, and DOE's national laboratories to develop an integrated roadmap for meeting the city's future infrastructure needs.

Growth in the buildings sector is being driven by population increases, new industries including data centers, and the redevelopment of the East Bank in downtown Nashville. This growth also results in increasing electric demand and stresses the city's surface transportation network. The electric grid and the transportation system must grow together to make Nashville's vision a reality. These systems are increasingly mutually dependent. For example, modern traffic control systems make extensive use of electric grid dependent elements (e.g., traffic signals, cameras, sensors, communications systems, variable message signs, etc.) to maintain efficient operations. For its part, maintenance and repair of the electrical grid is reliant on the roadway network for movement of crews, heavy equipment, and supplies to where they are needed, especially under emergency conditions.

Technical approach and key innovations. An innovation central to this project is the integration of buildings, transportation, and electric grid models to create a roadmap that captures their interdependence. In 2025, key stakeholders provided input to inform the plan, and the national laboratories (led by ORNL in collaboration with ANL) began integrating key datasets from Nashville's government and NES into national laboratory-developed buildings, transportation, and electric grid models to create high-priority interconnected scenarios of future growth of and changes to transportation, building, and electricity needs. They also formed a Community Insights Team to help ensure that relevant stakeholders had a voice in the project.

Next steps. In 2026, the project will refine the priorities that define the future scenarios and complete the development of high-fidelity building, transportation, and electricity system models, followed by their systematic fusion into an integrated cross-sector simulation framework. These scenarios will include projected building and vehicle electric load growth, the expansion of energy-intensive industries, and extreme weather events. Integrating these three distinct sectors into a combined model will enable coordinated analysis of interdependencies, technology adoption pathways, and grid impacts under future scenarios.

The expected outcome of this project will be a better ability to forecast and coordinate across infrastructure sectors. Additionally, the project will identify possible infrastructure upgrades (such as grid feeders, building-to-grid integration, and road or transit options) that will reduce risks in extreme weather events and improve affordability and reliability throughout the city and the NES service territory.

Lane County, Oregon

Background. Lane County, Oregon, spans 4,620 square miles from the Pacific coastline to the foothills of the Cascade Mountains. The county is home to 12 cities and 37 unincorporated communities that range from rural to metropolitan. Forested areas make up almost 90% of the land in Lane County, putting wildfires and other natural hazard events top of mind for county and utility leaders in the region. In recent years, winter storms and wildfires have put significant strain on the electric system. Further, Lane County, like many coastal counties in Oregon, is working to boost their preparedness for a Cascadia Subduction Zone earthquake. Their susceptibility to natural hazards has led to technical assistance work supported by national laboratories (PNNL, LBNL, and NLR), focused on critical facilities within the county and load forecasting for local utilities.

Technical approach and key innovations. Anticipated work on this project includes data collection and mapping of critical facilities, followed by an analysis of critical building loads and backup power needs. Using these data, combined with data on existing local generation, the national laboratory experts will work with Lane County's emergency managers and planners and representatives from several of the 10 electric utilities serving within Lane County to identify areas for investment in backup power and/or microgrid technology. The types of critical facilities and the ways those facilities are used during disaster events widely vary. Laboratory experts will estimate backup power needs using two different approaches, applied to different critical facilities; Lane County emergency managers will lead surveys and interviews for the highest-priority facilities, while building energy modeling will be used for other facilities where sufficient data are available. Options will be explored for backup power solutions (e.g., solar-battery microgrid and/or fuel-based generators) and shared with Lane County as resources. The final product will be a GIS-based dataset of critical facilities containing available facility information; current backup power status, if available; and estimated backup power needs and suggested levels of priorities. The dataset will be adopted by Lane County in their emergency management data portal.

A second project focus area will be improving load forecasting for the local distribution utilities in Lane County. These utilities are small (3,800 to 97,500 customers), with most of their power purchased from Bonneville Power Administration (BPA). Historically, BPA has provided load forecasts for the utilities, and their need to conduct their own load forecasts to facilitate distribution system planning has been minimal; however, with distributed generation technologies, increasing electric end use loads, and community interest in residential and industrial development, geographically specific forecasts have become more important. The goal of this effort is to compile a tool kit that the partner utility can regularly use to inform their local system planning and to facilitate conversations with customers and partners in the region.

Next steps. The project team will continue with data collection and analysis for the critical facilities. A component of upcoming load forecasting analysis is expected to be projecting potential growth in areas with developable commercial and residential land and combining that with bottom-up building electricity consumption models for likely building types.

Discussion: E2C Approach for Emerging Challenges and Opportunities

E2C is grounded in being responsive to local energy challenges and opportunities. Prior to the launch of E2C in 2023, national laboratory staff spent more than a year conducting listening sessions with local stakeholders to understand both their energy challenges and how they would like to receive support from DOE. This work resulted in the creation of E2C's three programs, each of which is responsive to emerging energy challenges and opportunities.[4]

[4] www.nlr.gov/news/detail/program/2023/clean-energy-to-communities-program-launches-stakeholder-informed-program-meets-communities-where-they-are

First, Expert Match's rolling application process means that the requests coming into the program reflect evolving energy challenges. For example, when the program first started running, there were no requests on data centers or large loads. But in the last year, this topic has grown in interest. Similarly, technologies of interest have evolved—in the last year, more requests have come in related to geothermal heating and cooling than in previous years.

Second, Peer-Learning Cohort topics are developed by laboratory staff to be responsive to timely challenges and opportunities. Because new topics launch every six months, laboratory staff regularly track trends to ensure new topics will align with the needs of local organizations, including reviewing the technical assistance requests received in Expert Match. For example, in 2025, E2C ran a cohort on Navigating Electricity Load Growth and Associated Utility Grid Impacts. This cohort explored the potential impacts of, and strategies for, managing new and emerging demands on the electric grid, including new data centers, the expansion of domestic manufacturing, and changing building power sources and transportation fuels.

Last, through In-Depth Partnerships, teams work together over multiple years to address local energy challenges. The evolution of needs was also apparent during the In-Depth Partnership project scoping process—local teams may have applied to the program noting one particular challenge, but as they worked with laboratory staff over time, and energy challenges evolved and changed, and local teams began to prioritize emerging energy topics.

In addition to the program design being easily adaptable to evolving energy challenges and opportunities, the technical work done in the current portfolio has resulted in capabilities that prepare the laboratory teams to address new challenges that need utility and local stakeholder collaboration. Here, three of these emerging challenges and opportunities are highlighted: 1) energy reliability and the growth of data centers and other large loads; 2) increased interest in energy resilience and backup power solutions, especially the creation of building-level, campus-level, and other microgrids; and 3) greater emphasis on energy affordability.

In the **energy reliability and data center and large load growth category**, E2C has already begun working in this space with Cohort and Expert Match participants. As with any new topic, some of the fundamental questions local stakeholders have are around potential impacts (both positive and negative) as well as best practices on what they can do to address the challenges and opportunities. For example, in Indianapolis, Indiana, the local government wanted to understand the basics of data centers, potential impacts, and strategies for local governments to engage with data center developers.

One piece of the data center and large load growth challenge is making the best use of the grid's current infrastructure, and one component of this is to increase load flexibility. E2C is already working on load flexibility for individual buildings (in the Pittsburgh project) as well as advanced grid control solutions (in the Colorado Springs project). Combining load flexibility at different scales[5] (e.g., building, microgrid, data center, and large load flexibility), along with

[5] See Specian and Aquino 2006 for examples of technologies/program types that can support load flexibility.

potential grid infrastructure upgrades and controls, can be key strategies for helping to meet data center and large load growth while maintaining or improving grid reliability. However, technical approaches may require substantial de-risking and validation before actual implementation and could potentially benefit from E2C In-Depth Partnership project approaches that use national laboratory capabilities, including advanced analysis and modeling, emulation, and/or hardware-in-the-loop laboratory validation. With respect to buildings, this could include advanced modeling to quantify building demand flexibility potential in a grid region, laboratory de-risking of utility and microgrid control systems and their communication with building automation systems and other building devices that enable load flexibility (e.g., controllable thermostats), and data center design and optimization.

In the **resilience and microgrid category**, E2C has addressed building-level microgrids through Peer-Learning Cohorts on Enhancing Resilience at Critical Municipal Facilities Through Solar, Storage, and Microgrids held from January–June 2024 and Planning for Microgrids to Increase Energy Resilience from January–June 2025. Expert Match has also addressed questions for stakeholders about building- or campus-level microgrids. The City of Lander, Wyoming, participated in both a Microgrid Cohort and an Expert Match request to understand energy generation and storage options to provide redundancy and expand backup capacity for critical municipal facilities. In the In-Depth Partnership program, detailed microgrid modeling and validation work was completed for Moloka‘i, Hawaii. NLR researchers evaluated more than 500 grid scenarios for Moloka‘i using ARIES modeling to identify optimal energy project sizes and locations that will work with the existing grid (i.e., not require grid upgrades).

Additional E2C buildings work to address resilience could include bringing together validation capabilities from across DOE national laboratories using the Energy Sciences Network (ESnet). ESnet allows researchers at multiple national laboratories to conduct modeling and validation experiments in real time. For example, for a previous non-E2C project in Cordova, Alaska, researchers used ESnet to show how the local microgrid would be able to maintain power at critical facilities during an extreme weather event and the loss of some of its hydropower resources.[6] With respect to buildings, additional key modeling, validation, and de-risking activities could include modeling to estimate critical building loads and optimize the value of building energy efficiency and building load flexibility for reducing the costs of required microgrid generation and storage assets and/or extending the length of time critical loads can be met, as well as interoperability validation and de-risking of microgrid and building controls.

In the **affordability** category, many of E2C's Expert Match requests are focused on evaluating energy technologies (e.g., building efficiency measures, on-site generation/storage) for cost-savings potential. For example, the Department of Public Utilities in Columbus, Ohio, requested a techno-economic analysis for battery sizing to maximize energy bill reduction, as well as battery procurement and financing analysis for their wastewater treatment plant. Through In-Depth Partnerships, teams have focused on reducing energy costs at the building level as well via delivering streamlined energy efficiency services and minimizing grid infrastructure needs. For example, through the Delaware Valley In-Depth Partnership project, teams have identified

[6] docs.nlr.gov/docs/fy23osti/84972.pdf#:~:text=ESnet%20is%20a%20high%2Dperformance%2C%20unclassified,critical%20contributions%20not%20only%20for

building characteristics with the highest potential for energy savings and analyzed various potential building retrofit packages, including an analysis of up-front capital costs and estimated operational cost savings to understand potential impacts on affordability for residents. In addition, the project's implementation phase will include work to streamline the process of delivering energy services to households.

In future work, E2C could leverage the ability to assess household and commercial building energy bill savings and building energy affordability impacts at scale. The technical approaches applied for the Delaware Valley and/or Pittsburgh In-Depth Partnership projects could be expanded and applied for other locations and local partners and paired with bulk- or distribution-scale grid analysis to assess complex interactions and trade-offs between resident costs/affordability and grid-side costs and investments.

In summary, E2C is supporting these emerging areas and other topics through its different program offerings. E2C also plans to explore opportunities of artificial intelligence technologies to enhance the program and better support needs of local entities.

Conclusions

E2C provides an innovative technical assistance model designed to meet communities at their specific point of need. By leveraging the world-class research capabilities of the U.S. national laboratory system, E2C allows local governments, Tribes, and community organizations to access three distinct offerings tailored to different timelines and technical requirements. Although the program is cross-sector in nature, buildings-related technical assistance requests and activities are a major component of E2C across its In-Depth Partnership, Cohort, and Expert Match program offerings, and they have included a strong focus on affordability, reliability, and resilience. Within the E2C In-Depth Partnership projects, national laboratory experts have worked closely with local partners to apply advanced modeling and analysis capabilities, and they have leveraged national laboratory facilities to validate and de-risk building and infrastructure projects prior to actual implementation. Through its flexible program design, the E2C program approach is being applied to emerging challenges and opportunities, including energy reliability and the growth of data centers and other large loads; increased interest in energy resilience and backup power solutions, especially the creation of building-level, campus-level, and other microgrids; and greater emphasis on energy affordability.

For latest developments in the E2C program as well as how to get involved, please refer to the E2C web site (https://www.nlr.gov/state-local-tribal/energy-to-communities) for details.

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AI-assisted tools used: Copilot, Claude, ChatGPT, Gemini. Note: in some cases organization/enterprise versions were used. ***Used for:*** Drafting short project summaries in Program Technical Approach section; copy-editing prior to professional human copyedit (Pittsburgh section); editing author-drafted text for coherence and voice (Delaware Valley section); Drafting summary Colorado Springs project description based on author-developed materials. ***Extent:*** Drafting short (e.g., one sentence) project summaries; Light editing; Light editing; Drafting summary project description. ***Human review:*** The authors reviewed and verified all content, calculations, and citations.

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