CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

ENERGY RESEARCH AND DEVELOPMENT DIVISION

FINAL PROJECT REPORT

Palm City Transit Village – Zero Emission Affordable Housing Design

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National Community Renaissance would like to extend gratitude to the project partners who rose to the occasion and brought the best of their respective expertise to the project. Every aspect is better for the collaboration that underpinned this work. Thank you to Arup US, Inc., Studio-E Architects, Build Momentum, Inc., the University of Southern California, and Enterprise Community Partners.

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PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission, and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solutions, foster regional innovation, and bring ideas from the lab to the marketplace. The EPIC Program is funded by California utility customers under the auspices of the California Public Utilities Commission. The CEC and the state's three largest investor-owned utilities — Pacific Gas and Electric Company, San Diego Gas and Electric Company, and Southern California Edison Company—were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The CEC is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

For more information about the Energy Research and Development Division, please visit the CEC's research website (www.energy.ca.gov/research/) or contact the Energy Research and Development Division at ERDD@energy.ca.gov.

ABSTRACT

Palm City Transit Village is an affordable housing project in San Diego, led by National Community Renaissance in collaboration with Studio-E Architects, Arup US, Inc., Build Momentum, Inc., and the University of Southern California. Addressing California's housing and climate challenges, the team proposes 288 all-electric, transit-oriented units in a mixed-use development. The project emphasizes low-carbon technologies and advanced materials to set new standards in building decarbonization and energy efficiency, focusing on resident comfort and sustainability. Notable features include smart energy management systems, heat pump water heaters, responsive thermostats, automated lighting controls, a microgrid with energy storage and solar photovoltaics, and passive high-insulative construction materials. This design phase of the project demonstrates the cost-effectiveness and feasibility of advanced energy technologies in affordable housing, highlighting environmental benefits and aiding policy advancements through knowledge transfer. The proposed implementation strategy encompasses pre-installation and design review, procurement of materials and technology, construction, installation, commissioning, performance testing, technology efficacy verification, community and resident engagement, project benefit evaluation, and dissemination of findings.

Keywords: Affordable housing, sustainable building, decarbonization, energy efficiency, zero net energy

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Background

California is simultaneously confronting a decades-long housing shortage while making strides in rapidly decarbonizing the world's fifth-largest economy to abate climate change. As residential developers and builders rush to add high-quality housing units, the adoption of high-energy efficiency design strategies, all-electric builds, and advanced clean energy technology in multifamily housing has lagged. While the anticipated decarbonization benefits of these approaches are evident, a post-COVID economy with high material and labor costs, coupled with a lack of sector knowledge and the complex economics of building housing, has heightened real and perceived risk toward embracing new approaches and technologies.

These risks and challenges are especially acute in affordable housing development, which is the type of housing most needed to ameliorate the multifaceted challenges of the housing crisis. Demonstrations of successful affordable housing projects built with advanced energy technologies and design approaches are needed, along with practical knowledge of their implementation, costs, performance, and effective integrations. The results of such a demonstration will catalyze implementation and drive decarbonization in multifamily housing, ultimately fostering more sustainable and cost-effective housing across California.

National Community Renaissance received California Energy Commission funding in 2022 to design and plan the project, "Zero Emission Affordable Housing Design: Palm City Transit Village." Palm City Transit Village is envisioned as a zero-net-carbon, live-work-play, transit-oriented affordable housing community in San Diego that will have 288 apartment homes, a childcare facility, a retail area, and convenient access to the San Diego Metropolitan Transit System. In partnership with Studio-E Architects, Arup US, Inc., Build Momentum, Inc., and the University of Southern California, National Community Renaissance conducted extensive planning, design, and research to accelerate the pace of change in California's housing sector while demonstrating alignment with the state's climate goals.

Project Purpose and Approach

This project enabled the design and planning of cutting-edge, low-carbon technologies and advanced materials to enhance understanding of building decarbonization practices and accelerate the pace of change in California's housing sector along with the achievement of the state's climate goals. Validation of performance, costs, and deployment experience for these technologies, individually and integrated into a single building, is crucial to catalyze market shift and hasten adoption. Knowledge transfer activities ensure these research results arrive in the hands of policymakers, academics, builders, and others. Further, the project will offer residents a high standard of comfort and modernity, while reducing burdens on individual, community, and regional health through emissions reduction.

Beyond full electrification, each Palm City Transit Village residential unit will have smart and connected home energy management systems, offering residents control and insight into energy use. Heat pump water heaters and thermostats will respond to time-of-use rates, maintaining comfort and avoiding high energy prices. Lighting controls turn off lights in daylit or empty rooms. A building-integrated microgrid will include stationary energy storage coupled with solar photovoltaic to reject heat and generate energy. To support resilience and safety, residential units and common areas will have assigned Tier 1 (critical loads), Tier 2 (priority loads), or Tier 3 (discretionary loads) designations. Tier 2 and 3 circuits may be turned off to allow for indefinite, renewables-driven backup power of Tier 1 critical loads during power outages. This will "island" the building during an outage to keep residents safe and critical services running. These solutions join passive design approaches such as shade fins and advanced, prefabricated, sustainable, high-insulative construction materials to make each building ultra-low-carbon.

Design and energy performance modeling of the Palm City Transit Village residential units yielded impressive energy performance and cost savings for residents and management. In addition, many quality of life and living improvements were identified. These savings and improvements included:

- A 93-percent reduction in energy costs for residents, delivering 30-year lifecycle cost savings of $124,906 for an average residential unit.
  - A 100-percent reduction in energy costs for non-residential space.
  - These reductions were in comparison to a "Standard Design" that includes the minimum size requirements of photovoltaic and battery energy storage systems by the 2022 California Building Energy Efficiency Standards (Title 24).
- A 22-percent reduction in overall energy use intensity when comparing the Proposed Design to a Title 24 Standard Design baseline building.
- A 14-percent reduction in grid carbon emissions.
- Load shifting, peak shaving, and demand response during peak demand.
- Futureproofing for dynamic, real-time pricing of the electricity market.
- Cooler spaces and better indoor air quality thanks to heat pump driven water heating, space conditioning, and clothes drying.
- Electric vehicle charging, still uncommon in multifamily homes.
- Enhanced aesthetics through functional design thanks to shading fins and facade-mounted photovoltaic panels.
- A more resilient residence supportive of better safety and health outcomes as units will be able to rely on the microgrid to power the homes during outages, ensuring critical loads are served.
- Greater awareness of energy and water use and costs thanks to an integrated smart home system.

The design phase further revealed challenges inherent in deploying these technologies in a dense multifamily application, including:

- Lack of clarity regarding safety and fire standards, and scarcity of examples for installing and operating a battery energy storage system of this scale in this building type.
- Challenges with complex electricity tariffs and allowable interconnection behaviors for charging and discharging the battery using grid power and onsite generation.
- Poor initial cost performance of most of the building features and construction methods and all of the energy features, when compared with a Title 24 Standard Design model.
    - Proposed building features, such as phase change technologies, exterior shade fins, a cool roof and more, added a total cost of $667,800 to the project, resulting in a per unit additional cost of $8,348.
    - Proposed energy features such as heat pump water heaters, a building microgrid, smart home features, and more added a total cost $4,129,985 to the project, resulting in a per unit additional cost of $51,625.
- Financing schemes for affordable housing projects are complex and often leave little room for deviation or the implementation of features and technologies not considered the market standard or necessary for code compliance.

Knowledge Transfer and Next Steps

The project team prepared, submitted, and approved a biphasic Case Study Plan. The Case Study Plan outlines knowledge transfer goals, objectives, and priorities for the Design Phase (on which this document reports) and the Build Phase that will follow. Design Phase lessons will be combined with lessons from the Build Phase to be disseminated upon completion and occupancy of the Palm City Transit Village residential units. This approach captures more meaningful findings from the construction, commissioning, measurement/verification, and operations phases. During Phase I (Design Phase), the project team submitted a Case Study outlining all meaningful findings from this phase.

The project team is proud to be considered for a proposed award of Phase II (Build Phase) funding in the Next EPIC Challenge, which would bring the Design Phase proposal to life. Completing the Build Phase will deliver a bevy of results and data for California and the building and development sector, helping to bring the buildings of the future into existence without subsidy. Further, the results of building, operating, and validating the proposed project will be indispensable to addressing the challenges identified in the previous section.

The team looks forward to capturing and reporting results of the Build Phase and supporting the California Energy Commission’s charge to advance the state of the energy sector, improving lives, and protecting the natural world.

Design Phase Findings and Recommendations

Community and Resident Engagement

Finding: Effective engagement requires dedicated resources and incentives for staff to ensure participation from communities. Initial budgeting overlooked these necessities.

Recommendation: Increase budget flexibility to accommodate the costs of engaging community members and residents. Integrate engagement strategies early in the project planning phase.

Policy Barriers and Workforce Development

Finding: Decarbonization policies and priorities are fragmented, creating challenges for cohesive, systemic action. There's a noticeable gap in technical expertise among professionals and a high demand for skilled labor in zero-carbon technologies.

Recommendation: Advocate for a state-led initiative to streamline and centralize decarbonization policies, enhance technical education, and support workforce development to bridge policy and practical application gaps.

Team Composition

Finding: The ambitious goals of the project necessitate a diverse team of specialists, especially for achieving advanced energy efficiency standards.

Recommendation: Ensure project plans include specialists in advanced energy to guide research and implementation.

Market Cost and Adoption of Advanced Energy Technologies

Finding: Advanced technologies add significant costs despite efficiency gains, which pose a barrier to wider adoption.

Recommendation: Implement incentives to lower initial costs and encourage market adoption while updating building codes to create initiative for new technologies.

Market Availability of Advanced Energy Technologies

Finding: Limited suppliers and technological maturity restrict the availability and increase the costs of cutting-edge technologies.

Recommendation: Incentivize broader deployment and adoption of these technologies to stimulate market demand and lower costs.

Navigating Utility Interconnection and Grid Interaction

Finding: Slow and complex interconnection processes with utilities like San Diego Gas & Electric Company hinder the deployment of microgrids, affecting project timelines and economics.

Recommendation: Streamline interconnection processes, provide dedicated support for microgrid projects, and apply regulatory pressure to facilitate quicker, more efficient procedures.

Tariff Structures and Microgrid Economics

Finding: Current tariff structures limit the financial viability of microgrids by restricting their ability to leverage grid energy economically.

Recommendation: Reform tariffs to accommodate microgrid capabilities and ensure fair net metering guidelines, enhancing the economic rationale for microgrid deployment.

Design Phase Lessons

This project highlights the complexities of integrating carbon-free technologies into affordable housing, underscoring the need for comprehensive planning, community engagement, policy reform, and market incentives. Successful implementation requires addressing both technical and policy barriers, ensuring economic viability, and fostering collaborative efforts across sectors. These insights can guide future projects aiming to achieve similar sustainable development goals.

CHAPTER 1: Introduction

Context and Project Purpose

National Community Renaissance (National CORE) received California Energy Commission (CEC) funding in 2022 to design and plan the project, "Zero Emission Affordable Housing Design: Palm City Transit Village." Palm City Transit Village (PCTV) is envisioned as a zero-net-carbon, live-work-play, transit-oriented affordable housing community in San Diego that will have 288 apartment homes, a childcare facility, a retail area, and convenient access to the San Diego Metropolitan Transit System (MTS). In partnership with Studio-E Architects (Studio-E), Arup US, Inc. (Arup), Build Momentum, Inc. (Momentum), Enterprise Community Partners, and the University of Southern California (USC), National CORE conducted extensive planning, design, and research to accelerate the pace of change in California's housing sector while demonstrating alignment with the state's climate goals.

As residential developers and builders rush to add high-quality housing units, the adoption of high-energy efficiency design strategies, all-electric builds, and advanced clean energy technology in multifamily housing (MFH) has yet to become common practice. While the anticipated decarbonization benefits of these approaches are evident, a post-COVID economy with high material and labor costs, coupled with a lack of sector knowledge and the complex economics of affordable housing, has heightened real and perceived risk toward embracing new approaches and technologies.

These risks and challenges are especially acute in affordable housing development, which is the type of housing most needed to ameliorate the multifaceted challenges of the housing crisis. Demonstrations of successful affordable housing projects built with advanced energy technologies and design approaches are needed, along with practical knowledge of their implementation, costs, performance, and effective integrations. The results of such a demonstration will catalyze implementation and drive decarbonization in MFH, ultimately fostering more sustainable and cost-effective housing across California.

Innovative high-efficiency design strategies have a slower rate of adoption in residential MFH projects. Both cost and barriers in incorporating advanced construction techniques and technologies in this sector have led to an increased sensitivity to the risk associated with new techniques and technologies in affordable housing. This project leveraged and improved National CORE’s advanced approaches in building 100 percent affordable, all-electric, zero net energy (ZNE) mixed-use projects in California and across the nation through a three-pillared approach:

1. Early Upward Market Adoption: Evaluated design strategies and measures for early upwards market adoption with a downward cost trajectory producing rapidly competitive business-as-usual measures.
2. Design Adaptability: Evaluated innovative design strategies and measures.
3. Energy Equity: Explored energy equity within affordable housing in California.

Project Goals and Objectives

The goals of this project were to:

- Evaluate and implement innovative technologies and building-level enhancements to deliver a carbon-free, affordable, and mixed-use development.
- Develop approaches to influence residents' and building manager's decision-making and encourage energy-efficient behaviors that result in smaller carbon footprints.

The key objective of this project was to deliver a complete and scalable design for carbon-free, urban infill, mixed-use, transit-oriented development that makes use of under-used land around transit lines. In pursuit of these goals and objectives, the project team evaluated the following performance metrics throughout the project:

- Energy use intensity
- Peak load curtailment percentage
- Islanding capability duration
- Construction cost per unit
- Operational greenhouse gas intensity
- Total number of attendees engaged in community workshops
- Percent of electric vehicle (EV) charging stations

Project Team

National CORE has built nearly 10,000 housing units in its nearly 30 years of history and has certified its projects using the U.S. Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) for Homes standards since the rating system was first launched in 2007. National CORE was the developer of Vista Dunes, the first LEED for Homes multifamily Platinum project, and winner of the USGBC Home Depot award for excellence in affordable housing in 2009. The project helped chart the course for ZNE and carbon-neutral affordable housing, one that National CORE continues to this day. Including Vista Dunes, National CORE has certified 12 projects through the USGBC's LEED for Homes program. National CORE continues to lead by example and was named a USGBC Power Builder two years running, the lone nonprofit developer to achieve this distinction.

Arup is the carbon-free concept design consultant at the forefront of the most ambitious and challenging design and engineering projects for over seven decades. Arup routinely ideates and initiates grant-funded projects and supports clients to implement the resulting scope of work. Arup's low-energy and low-carbon consulting project examples include Beddington Zero Energy Development (BedZED), a mixed-income neighborhood constructed in 2002 on a brownfield site. BedZED is the United Kingdom's first and largest ZNE residential community and is widely considered to be an early flagship example for inclusive ZNE residential development. Arup consulted on energy design for PCTV. The Arup team was responsible for all deliverables on Task 4: Innovative Low-Emission Design, Technology, and Strategy Implementation deliverables, as well as some deliverables on Task 2: Project Development and Community Engagement and Task 9: Build Phase Application.

USC's team, led by Dr. Burçin Becerik-Gerber, Professor of Civil and Environmental Engineering at USC, focused on interactions between the built environment and its users with aims to understand then predict interaction. The research team developed several novel approaches that aim to model and change behavior within the building energy efficiency domain. USC was responsible for the deliverables on Task 5: Customer Interface Assessment.

Studio-E is a San Diego-based design collaborative led by principals Eric Naslund, John Sheehan, Maxine Ward, and Mathilda Bialk. Practicing throughout the Southwestern United States, the firm's varied portfolio—housing, mixed-use, civic, educational, institutional, and urban planning projects—is recognized with numerous design awards, including three National Honor Awards from the American Institute of Architects. Studio E was responsible for the deliverables on Task 3: Architecture Integration and Constructability.

Momentum is one of California's most successful commercialization partners. Since 2005, Momentum successfully developed and managed $5.5+ billion in funded cleantech projects in collaboration with more than 1,000 partners, including water agencies, utilities, equipment manufacturers, commercial, and industrial customers. Through these projects, Momentum helps clients research, demonstrate, commercialize, and operate transformative advanced energy technologies. Momentum supported National CORE through the transparent, efficient completion of all the grant requirements, communications of project benefits, and reporting. Momentum was responsible for all deliverables on Task 1: General Project Tasks, Task 7: Evaluation of Project Benefits, and Task 8: Technology/Knowledge Transfer Activities, as well as some deliverables on Task 9: Build Phase Application.

Enterprise Community Partners (Enterprise) is a 501(c)(3) nonprofit organization. Enterprise is a proven and powerful nonprofit that improves communities and the lives of the people who live there by making well-designed homes affordable. Enterprise brings together nationwide know-how, partners, policy leadership, and investment to multiply the impact of local affordable housing development. Enterprise is also recognized by the California Strategic Growth Council as the primary technical assistance provider of the Strategic Growth Council's Affordable Housing and Sustainable Communities (AHSC) Program. Currently, Enterprise is under contract with the Strategic Growth Council to provide technical assistance for Round 6 and Round 7 of AHSC. In that role, Enterprise is providing technical assistance to AHSC applicants throughout the entire state. Enterprise was responsible for deliverables on Task 6: Programs and Policy Changes to Support Market Transformation.

Project Site

The PCTV project site is to be located on the existing four-acre surface parking lot of the Palm Avenue Trolley Station (Figure 1). The project site is adjacent to the MTS transit line. The site consists of several parcels, each of which will host one of the new MFH buildings. The proposed development is sited in an already developed area (urban infill) and is consistent with the city's General Plan and all permitting requirements.

Figure 1: Palm Avenue Trolley Station Project Site

An aerial view of the existing parking lot that will become PCTV

Source: National CORE

PCTV will deploy transit and sidewalk improvements that will provide benefits to all residents of the nearby community, including those from the disadvantaged community about 0.3 miles north of the project site. Transit improvements may increase bus frequency or improve the riders' comfort at the transit stops while sidewalk modifications provide increased safety for bicyclists and pedestrians.

CHAPTER 2: Project Approach

Overall Design Approach and Strategies

The project team at National CORE took a human-centric approach to the design of PCTV, seamlessly integrating state-of-the-art energy technologies to elevate the aesthetics and functionality of the building. Designed by Studio-E and built by National CORE, PCTV will be sleek, modern, high-quality housing that offers an excellent living experience while breaking down stereotypes associated with affordable housing. It will exude a pride of place as a walkable, bikeable, transit-oriented community. On the exterior, PCTV showcases roof and facade solar photovoltaic (PV) panels along with vertical and horizontal shading. Electric vehicle service equipment (EVSE) will be highly visible for use by residents and visitors. On the interior, residents will enjoy more usable living space thanks to the compact nature of the energy innovations, such as smaller footprints for water heaters, quieter common and home spaces thanks to heat pumps, and efficient lighting. Building fit and finishes will follow a modern, human-focused aesthetic. By showcasing these emerging technologies and design strategies, PCTV will look as advanced as it is, serving as a vivid demonstration that a sustainable, all-electric future is achievable today.

Architectural Designs, Aesthetics, and Functionality

The construction of the PCTV will make use of several advanced design elements (Figure 2), including:

- Prefabricated structural panels
- Phase change materials
- External building shades

Analysis and modeling from Arup, the project's engineering partner and expert on building decarbonization strategies, showed that these elements will enhance building energy savings by 5 percent annually.

Figure 2: PCTV Advanced Design Elements

A PCTV building being erected using BamCore prefabricated structural panels

Source: BamCore

Prefabricated Structural Panels by BamCore offer low embedded carbon, leveraging the strength, flexibility, and renewability of bamboo. They are hollow core, ready for blow-in insulation of nearly any kind. Engineered for superior structural integrity, these panels are lighter than traditional materials with better strength-to-weight ratios. They are faster to assemble and have resistance to mold and pests, thanks to the inherent properties of bamboo. Use of these panels will significantly reduce construction time and labor costs. Moreover, they offer excellent thermal performance, leading to lower energy costs for heating and cooling a building. Buildings constructed with BamCore's panels have shown excellent structural stability, energy efficiency, and weather resistance.[1] These panels are a practical, sustainable, and eco-friendly solution to modern construction challenges.

Phase Change Materials, specifically the ENRG Blanket, will incorporate phase change material technology into PCTV's ceilings and walls (Figure 3). It absorbs, stores, and releases thermal energy as it changes states of matter, creating a thermal buffer within the building's interiors, mitigating temperature fluctuations, and reducing reliance on mechanical space conditioning. Stabilizing indoor temperatures reduces energy consumption, thereby lowering utility bills. This improves indoor comfort by minimizing temperature swings, contributing to a more constant indoor climate. The ENRG Blanket maintains comfort levels while reducing the need for mechanical heating and cooling.[2] The material's capacity to quickly absorb and release thermal energy makes it exceptionally adaptive to varying environmental conditions, optimizing its energy-saving potential.

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[1] BamCore. 2023. "Professional Resources". Global Bamboo Technologies Inc. Available at https://www.bamcore.com/professional-resources.

[2] Phase Change Solutions. 2023. *ENRG Blanket®, PRECISE TEMPERATURE CONTROL FOR BUILDING ENERGY EFFICIENCY, Using BioPCM® Engineered Smart Material*. Available at https://phasechange.com/wp-content/uploads/2023/03/ENRG-Blanket-Brochure-6.pdf.

Figure 3: ENRG Blanket Phase Change Material

An example of the exterior of the ENRG Blanket Phase Change material to be used in the construction of the walls and ceilings of the PCTV

Source: Phase Change Solutions

External Building Shades will be installed on PCTV's exterior. This includes vertical fins on the east and west facades and overhangs on the east, west, and south facades. These physical barriers will be made of metal and will filter sunlight, particularly when it is most intense during mornings and afternoons. The shades will be fixed and mounted vertically to complement the building's sleek architecture. The shades will significantly reduce solar heat gain without interfering with PV generation and will reduce the need for space conditioning in residences and common areas.

Design Strategies for Integrating Conventional and Emerging Energy Technologies

National CORE is committed to creating advanced energy communities and has built a track record of high-quality, energy-efficient, 100 percent electric communities. This foundation of routinely meeting and exceeding the most advanced energy design codes and practices enabled the project team to set a high bar for selecting and modeling emerging technologies and advanced design strategies for PCTV. These selections (described below) are individually a blend of market readiness—some are newly market-ready while others are established but yet-to-scale in multifamily homes—and represent a sincere and well-designed approach to near-ZNE building. Each selection is a departure from common and established practices in the development of mixed-use MFH, especially in 100 percent affordable developments. Demonstrating these emerging and established energy technologies and design strategies in this scale of building is critical to changing standard practice to favor higher energy efficiency. Demonstration of these technologies and strategies in concert, fully integrated and fine-tuned, shows the promise and benefits of an all-electric, low-carbon future that is possible today.

End-Use Energy Efficiency

Advanced Heat Pump Water Heaters

PCTV will use innovative, high-efficiency, demand response enabled heat pump water heating technology, largely uncommon in multifamily homes, to displace conventional resistive electric and natural gas combustion solutions (Figure 4). Water heating is one of residential buildings' most intense energy end uses, second only to space conditioning. Data from the 2020 Residential Energy Consumption Survey — as conducted by the U.S. Energy Information Administration — shows that, in California, domestic hot water accounts for 30 percent of all energy usage and 81 percent of water heating in the state is fueled by fossil fuels.[3,4] The remaining domestic hot water share in California is largely resistive electric heating, which, while less carbon-intense given the state's energy mix, is notoriously energy inefficient (Table 1).

Figure 4: Rheem's Heat Pump Water Heaters

A Sampling of Rheem's heat pump water heaters, including some that use a standard 120v outlet

Source: Rheem

Electrifying domestic hot water heating represents a pivotal avenue for advancing decarbonization, particularly in multifamily homes. Traditional natural gas and resistive electric heaters dominate the current domestic hot water market but have various drawbacks: natural gas systems are less safe, require complex installations, and emit greenhouse gases, while resistive electric heaters are more inefficient. In contrast, modern heat pump water heaters offer a more efficient, safe, and flexible alternative. Though initially more expensive, they are easy to install and enable significant energy savings over time. Utilizing a closed-loop refrigerant system, heat pump water heaters transfer heat from the ambient air to heat water, thereby also cooling the surrounding space. Their variable rate compressors allow for precision in energy use. For PCTV, these heat pump water heaters will be smart grid integrated, serving as a thermal "battery" that can respond to energy pricing and demand signals, thereby

[3] U.S. Energy Information Administration. 2023. *CE3.1ST Annual household site end-use consumption in United States homes by state—totals and averages, 2020*. Available at https://www.eia.gov/consumption/residential/data/2020/state/pdf/ce3.1.st.pdf.

[4] U.S. Energy Information Administration. 2023. *Highlights for water heating in U.S. homes by state, 2020*. Available at https://www.eia.gov/consumption/residential/data/2020/state/pdf/State%20Water%20Heating.pdf.

conserving electrical resources and saving consumers money without compromising usability. Table 1 illustrates the vast performance and cost difference between these technologies. The comparison assumes the California state-wide energy mix for emissions calculations and uses industry averages for Uniform Energy Factor.[5]

Table 1: Energy and Cost Performance Comparison for Heat Pump Water Heaters

Metric	Heat Pump	Electric Resistive	Natural Gas
Uniform Energy Factor (UEF)[6]	4.0	0.95	0.7
Energy Source	Electricity	Electricity	Natural Gas
Energy to Heat 60 Gallons	2.5 kWh	9 kWh	13 kWh (equiv.)
CO2 Emissions (kg) to heat 60 gallons of water[7]	.34	1.43	2.097
Operating Cost to heat 60 gallons ($0.52/kWh)[8]	$1.30	$4.68	$6.76

Source: Arup

Heat Pump Dryers

Clothes drying is an energy-intensive, inefficient process. Most consumers use natural gas or resistive electric dryers. Heat pump dryers offer a high-efficiency solution, particularly well-suited for communal laundry. Heat pump dryers are up to 60 percent more energy-efficient than traditional dryers. They need no external venting and reduce installation costs. These advantages also make them environmentally friendly, quieter, and less heat intensive. Residents will enjoy superior performance without sacrificing efficiency or safety.

Home Energy Management System

PCTV will integrate a smarter, greener, modern approach to energy across the property and in every residential unit. The last decade has seen the emergence and rapid scaling of smart home technologies. Consumers are interested in automating and engaging in energy efficiency and energy management and the data behind it. Offering simple, accessible, comprehensible, reliable, and interoperable tools is key to driving behavior change and automating these processes. Ultimately, this access could ease concerns about ceding a level of control to utilities as demand response and load flexibility become more common. These technologies are also a quality-of-life enhancement that adds convenience and makes domestic life easier and more manageable. Residents of PCTV will have a Home Energy Assistant, which acts as a hub to report information on energy use and an interface to control smart devices. The information will be granular, down to individual loads, offering knowledge about managing energy use and costs, providing residents the answer to the question, "Where is my energy

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[5] CEC (California Energy Commission), Energy Assessments Division. "2021 Total System Electric Generation." Available at https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2021-total-system-electric-generation.

[6] PennState Energy Conservation, Energy Efficiency of Water Heaters

[7] assumes155 gCO2/kWh for electricity and 166.9 gCO2/kWh for natural gas

[8] https://www.sdge.com/residential/pricing-plans/about-our-pricing-plans/whenmatters

being used?" Beyond communicating with the macro system of the PCTV microgrid, the Home Energy Assistant offers control or integration with:

- *Lighting controls* (aligned with Title 24 requirements) coupled with vacancy sensors in bathrooms, dimmable light switches, and smart switch outlets.
- *Smart thermostats* help operate space conditioning more efficiently, offer back-end building management control during emergencies, and respond to grid signals.
- *Smart water valves* give insight into water use and watch for catastrophic leaks.
- *Smart water heaters* to engage in demand response.
- *A smart electrical panel* integrates the home into the larger building's dynamic energy system and microgrid and offers information on every load in the home, including cooking, lighting, and plug loads.

Load Flexibility, Grid interactions, and Residents' Engagement

PCTV embraces energy management and load flexibility under normal conditions as well as during grid outages or peak demand events. The PCTV microgrid and its energy management systems will integrate through smart panels and a suite of smart devices, allowing control over all loads. This will allow for the microgrid to assume all residential loads from 4:00 to 9:00 p.m. through onsite generation, stored energy, and load management. The energy management system will curtail at least 20 percent of the building's peak load in response to utility signals for grid emissions and real-time pricing, assuming alignment between the two. The microgrid controller will manage the PV and battery integration in response to curtailment or flexible usage needs. This will demonstrate the scaled performance of advanced building automation; advanced lighting controls; advanced heat pump water heater demand and pricing response; microgrid controllers; smart inverters with California's Rule 21 Phase II[9] advanced inverter functionality; energy storage lithium-ion batteries; and vehicle-to-grid/vehicle-to-building integration. This approach will deploy future-proof EV infrastructure and ensure that residents are prepared for California's transportation transformation.

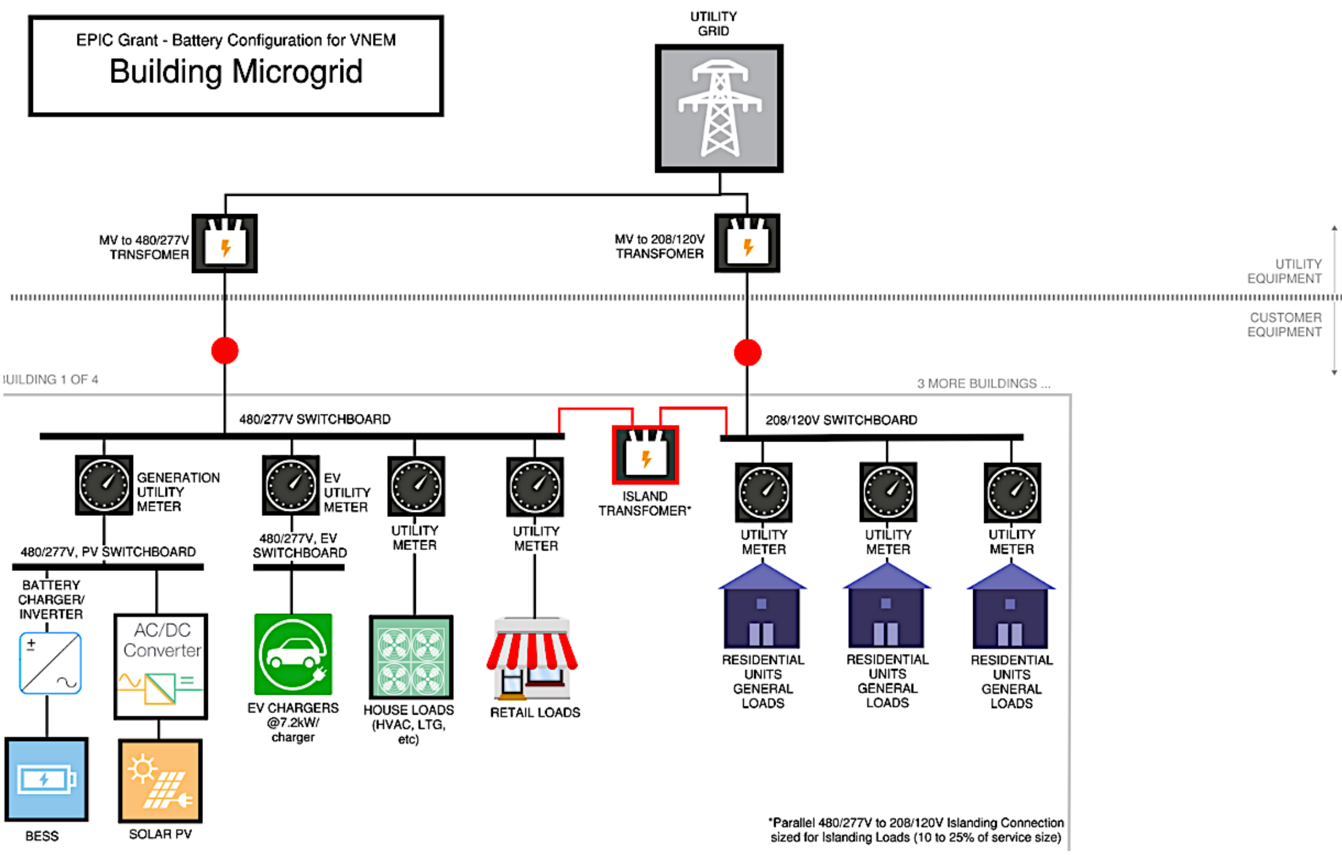
Residents can opt in or out of automated demand response and load management to reap economic benefits from participation. They will receive comprehensive outreach, engagement, and education on the use and functionality of their smart home systems and advanced energy technologies. Control is based on (1) turning off or reducing circuits connected to noncritical lighting, water heating, plug loads, or appliances, and (2) increasing/lowering heating, ventilation, and air conditioning (HVAC) setpoints in response to grid signals. When residents opt-in to the proposed energy platform, they will have the option of enabling deep reductions in energy usage from appliances, equipment, thermostats, and other noncritical circuits during peak hours or outages.

[9] CPUC (California Public Utilities Commission). 2024. "Electric Rule 21: Generating Facility Interconnections." State of California. Available online at https://www.cpuc.ca.gov/Rule21/.

Microgrid Design Strategy

PCTV will incorporate an in-building microgrid as a cutting-edge approach to energy management that offers myriad benefits to residents during routine operations and during times of crisis. The microgrid will consist primarily of PV panels installed on the building roof and facade. Onsite generation will power the community directly — both residential and mixed-use elements — and also feed into a battery energy storage system (BESS). When PV generation drops off during peak pricing or during periods of peak demand, this stored energy can be dispatched to meet the community's electricity needs. Additionally, the microgrid will be equipped with smart grid management technology that constantly monitors energy production, consumption, and storage, allowing for an optimized and cost-effective energy use cycle. This same system integrates into the residential home energy management system to ensure energy during outages. In the event of a larger grid failure, the microgrid will island, isolating itself to prevent back feeding onto the grid and continuing to provide electricity to the community. This ensures a high level of resilience, safeguarding residents from the frequent inconveniences and potential dangers associated with power outages. Figure 5 shows the basic design of the microgrid.

Figure 5: Architecture of the PCTV Microgrid



An overview of the PCTV Microgrid, including its external interconnection, the loads served within the development, and key enabling hardware

Source: Arup

Beyond basic electricity generation, the microgrid will provide essential services, including demand response and peak load shaving. Energy management systems will adjust larger building loads to help regulate consumption during high-demand periods from 4:00 to 9:00 p.m., assuring resource availability and thereby lowering energy costs. Additionally, the system will contribute to maintaining a consistent and high-quality power supply, which will minimize instances of power surges or outages. In addition, the microgrid can provide vital grid services, such as frequency regulation and voltage support, when connected to the main grid.

The system will have a comprehensive microgrid management software that integrates the BESS and enhances system efficiency. It will employ a modular, AI-infused architecture facilitating real-time dynamic configuration of microgrid resources, encompassing all loads. The system's cloud-based platform, certified by UL[10] and OpenADR2.0b[11], features machine learning for predictive analytics and load management, offering granular control over energy dispatch. It supports seamless transition between grid connected and islanded modes, ensuring uninterrupted power during outages and optimizing for demand response and peak load shifting.

Table 2 provides the load distribution of the PCTV Microgrid, broken down by Tier 1 and Tier 2 electrical loads, to satisfy the CEC Design Phase requirements.

Table 2: Load Tiering in the PCTV Microgrid

Tier 1 loads	Minimal lighting in tenant spaces and egress paths, community room refrigerators, select 120V outlets in community room, community room USB charging and Wi-Fi, building fire-life-safety subsystems, sewage pumping infrastructure
Tier 2 loads	Tenant unit refrigerators and in-wall USB charging

Source: Arup

As proposed, the PCTV microgrid system will meet the following CEC's Design Phase requirements:

- **Design requirement one:** *The building's residential load during peak demand hours, 4:00–9:00 p.m., must be met through a combination of onsite renewables, onsite storage, and load management.*
    - No utility power is purchased between 4:00–9:00 p.m. The electrical load of the proposed design with a peak of 114 kilowatt (kW) is supplied by onsite solar PV generation if available and BESS discharge between 4:00–9:00 p.m. The BESS is charged by the solar PV during the daytime hours, and the remaining solar PV serves first the electrical load during the day, then exports to the utility grid. Utility power is purchased outside of 4:00–9:00 p.m. when solar PV generation is not available.

[10] UL Solutions. 2024. Product Certification. Available at https://www.ul.com/services/certification/product-certification.

[11] openADR Alliance. 2024. "OpenADR2.0b". Available at https://openadr.memberclicks.net/index.php?option=com_mcform&view=ngforms&id=24297#!/.

- **Design requirement two:** *The building(s) must be able to island from the main grid during an outage and be able to shed discretionary loads to provide power to Tier 1 critical loads (10 percent of peak load) and Tier 2 priority loads (25 percent of peak load).*
  - A one-day outage is simulated with the Tier 1 and Tier 2 electrical load. Solar PV supplies that electrical load when available during the daytime hours and is used to charge the BESS. Excess solar is curtailed because the grid is unavailable. BESS discharges to supply the electrical load when the solar is not available.
- **Design requirement three:** *The microgrid must be sized for indefinite renewables-driven backup power of Tier 1 critical loads using any combination of onsite renewables, onsite storage, and load management.*
  - An indefinite outage is simulated with the Tier 1 load. Solar PV supplies that electrical load when available during the daytime hours and is used to charge the BESS. Excess solar is curtailed because the grid is unavailable. BESS discharges to supply the electrical load when the solar is not available.

In addition to resilience and reliability benefits, the PCTV microgrid will offer environmental and economic advantages. The use of renewable PV energy significantly lessens the community's carbon footprint. Coupled with fully electrified, high-efficiency end uses, the building will be near ZNE. Residents stand to benefit from reduced energy costs, thanks in part to intelligent demand management and the ability to store and use energy internally. Furthermore, the microgrid will foster a sense of community engagement by allowing residents to be actively involved in their energy usage, monitored in real-time for greater awareness. Its modularity and scalability mean that the system can easily adapt to evolving community needs or technological advancements. Demonstration of this microgrid will provide insight into the economics of such a system, leading to lessons learned, and ultimately be a case study for the scale of deployment. Working as a living case study will maximize the impact of the public interest investment in the system. By de-risking this project, risk is better understood for all future deployments, which will be more cost-effective, impactful, and deploy more rapidly in a market that understands the solution.

In incorporating the microgrid into the design, the PCTV team encountered numerous obstacles. Given the relative newness and novelty of a microgrid serving a medium-density MFH, this was not unexpected, but the challenges would be all the bigger were it not for Electric Program Investment Charge (EPIC) funding to defray associated costs. The cost performance of advanced energy technologies in today's market is poor — the largest cost of which is the microgrid and its assorted components. This high cost is exacerbated by a complex tariff structure and needlessly bogged down interconnection.

San Diego Gas & Electric's (SDG&E) tariff structure for microgrids significantly limits their usability, benefits, and cost-effectiveness, primarily because it restricts the ability to charge the microgrid from grid energy, thereby curtailing opportunities for rate arbitrage and other functionalities essential for optimizing energy costs and usage. This limitation essentially forces the microgrid to rely heavily on its own generation capabilities, which may not always be the most economical or efficient method, especially during periods when grid electricity prices are lower. Furthermore, there is considerable confusion regarding the extent to which net metering is allowed under these tariffs. Net metering, a mechanism that credits solar energy system owners for the electricity they add to the grid, is crucial for the financial feasibility of renewable energy investments. However, the introduction of Net Energy Metering 3.0 (NEM 3.0) has compounded this confusion by changing the rules and reducing the compensation for solar energy that is fed back into the grid. This lack of clarity and the restrictive nature of the tariff structure hinder the full potential of microgrids to provide cost savings, sustainability benefits, and enhanced energy resilience, particularly undermining the economic rationale for deploying microgrid solutions in communities served by SDG&E.

This poor economic performance underpinned by limited ability to draw grid energy to battery storage drastically increased the needed onsite PV to make the system sufficiently productive. Given the limited parking inherent in this modern urban design, solar canopies were not an option, and the roof deployment was not enough. This led to the facade PV design — a more complex, costly, uncommon, and still-to-be-vetted deployment type.

Further challenges are foreseen when the microgrid is complete and ready to begin operation because of a slow, duplicative, and delayed interconnection processes, taking from six to twelve months. This presents significant challenges to the deployment, usability, and benefits of a microgrid in a multifamily home like PCTV but also substantially increases the risk for developers and builders. These bureaucratic hurdles exacerbate the uncertainty and financial strain associated with such projects, making them less appealing and more hazardous from an investment perspective. This risk becomes acute and bordering on intolerable, especially for developers of affordable housing like National CORE, who operate with thinner margins and are often reliant on tight schedules to meet funding and regulatory requirements. The prolonged timelines and increased costs due to these interconnection challenges can jeopardize the feasibility and sustainability of affordable housing projects, ultimately impacting the availability of cost-effective, resilient, and sustainable housing solutions for lower-income communities. Therefore, the inefficiencies in SDG&E's interconnection process not only delay the adoption of innovative energy solutions like microgrids but also undermine efforts to provide equitable access to affordable and sustainable housing.

While designing the microgrid for PCTV, direct ownership was considered along with leasing and a purchase power agreement arrangement. The former is the current strategy due to the poor economic performance of the service area’s utility market for this type of deployment. Microgrid developers and designers who offer such an arrangement don’t imagine a return on investment before needing to replace major components.

Electric Mobility Strategy

Twenty percent of PCTV parking spaces will be equipped with next-generation EVSE, including an equal amount of Level 2 (L2) 40A and L2 20A spaces, and will be integrated into the PCTV microgrid, leveraging their demand response capability. One hundred percent of parking spaces associated with this project will be ready for future EVSE installation. L2 EVSE will have permanently attached SAE J1772 charging connectors. EVSE will be weatherized and vandal resistant. EVSE will have signage and labeling with clear and comprehensible operating instructions, customer support contact information, and all other information as required by applicable laws, ordinances, regulations, and standards. EVSE will be future-ready, compliant with California's robust existing and known forthcoming EVSE standards, including full certified support for the latest Open Charge Point Protocol (currently version 1.6), being ISO 15118 ready, and Title 24 compliant. Selected equipment will be ready for broader adoption of bidirectional power solutions, including vehicle-to-building and vehicle-to-grid. All EVSE deployed as a part of this project will meet standards as described in Senate Bill 454, the California Air Resources Board EVSE Standards, and the California Department of Food and Agriculture Division of Measurement Standards.

Advanced Construction Planning and Practices

PCTV was designed, and will be built, using integrated planning, design, and construction systems. Harmony between workstreams and leveraging of existing connections within the sector will deliver a condensed project timeline to enhance economic viability and demonstrate replicability. The project team's approach will allow design and construction to be examined and adjusted in tandem, eliminating extensive revisions and enabling constructability from the onset. Layering on the grant-funded systems in an existing, proven approach, the team will be empowered to adjust project priorities and design as needed to ensure design minimums are preserved while costs are managed. As a well-established project developer and owner, National CORE will leverage its acumen and resources to enable this deep integration while also assuming the risk necessary to allow the designers and contractors to pursue new techniques and technologies. National CORE and Arup will use energy simulation tools from the earliest phases of design to identify and better understand challenges related to Title 24 compliance and ZNE targets.

For this project, Arup used three software: IES VE, a building performance modeling software; Helioscope, a solar design tool; and Xendee, a microgrid optimization software. These tools assess energy conservation and demand response scenarios that are not supported by the 2022 California Building Energy Code Compliance engine. The first step was to develop a model using IES VE of a Title 24-compliant project. The model uses architectural drawings as the reference for the 3D geometry. All inputs into the Title 24 model follow the 2022 Multifamily Alternative Calculation Method Reference Manual along with all of its appendices and references to the Single-Family Alternative Calculation Method Reference Manual (SF ACM). Arup refers to the Title 24 standard model as the "Standard Design." These reference manuals provide the framework and rules to calculate the Standard Design for Title 24 compliance and develop a compliant "Proposed Design." Arup used the SF ACM's annual energy and load profiles for process loads for residential dwelling units. The SF ACM Appendix E provides the process loads for interior and exterior lights, ovens, stove tops, refrigerators, dishwashers, miscellaneous electrical loads, TVs, cable boxes, clothes washers, and clothes dryers. After Arup completed the Standard Design, a new iteration was developed to perform analysis of energy conservation interventions.

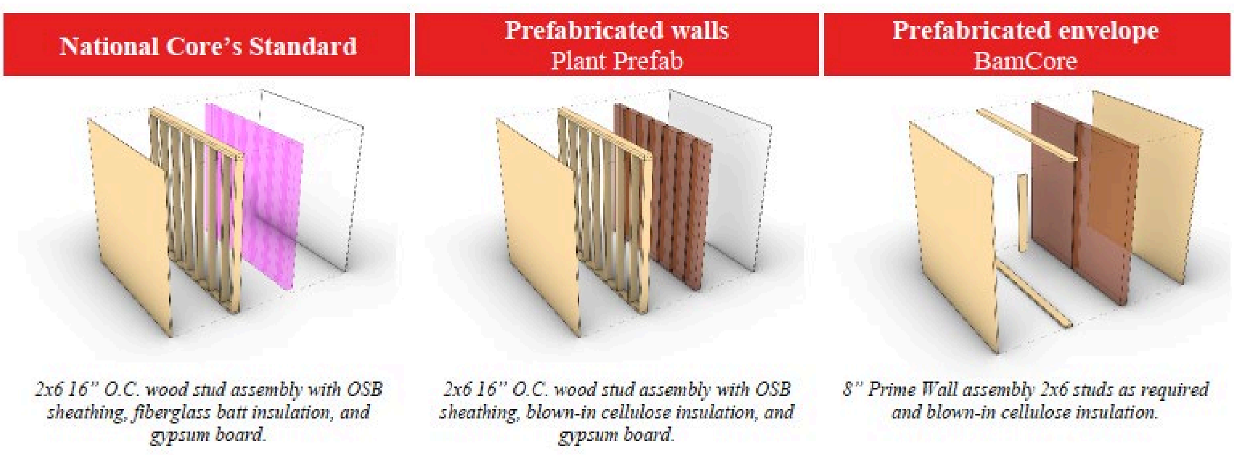
National CORE is an expert in controlling costs through standardization and leverages extensive connections with labor, suppliers, and vendors. Given the razor-thin margins in building and administering affordable housing, they are best suited to deliver the project cost effectively. As a primary cost reduction strategy, National CORE proposed using new building systems that hold the potential to reduce both construction costs and the time to build, as well as optimize long-term operating costs. At the center of this strategy is the use of BamCore, a panelized bamboo system that creates a cavity wall that can be fully insulated, improving thermal performance and reducing energy consumption while offering the potential to save time and money in framing. National CORE elected to prototype the BamCore system by building a 3,000-square-foot community building in Cathedral City. The prototype was successful in saving both time and money. Deploying BamCore at a low-rise building for the first time will allow subcontractors to better understand how to erect, assemble, and deploy other building systems including plumbing, electrical, and insulation. Like any innovative system, National CORE sets out to study and fully understand both the possibilities and the pitfalls, enabling developers and builders to confidently commercialize this innovative approach to larger applications.

Reduction of Embedded Emissions

As buildings become more energy-efficient, the proportion of embodied carbon contribution over the building's lifetime emissions will become greater. Arup's analysis showed that, for a low-emission residential development, the split between operational and embodied carbon is 50 percent/43 percent with the remainder associated with construction activities and end-of-life disposal. The project team focused on solutions to reduce embedded carbon and construction waste, increase productivity, and incorporate circular economy principles with potential for early upward market adoption and design adaptability in affordable housing.

Two solutions were considered: BamCore bamboo-based modular walls, a highly renewable, sustainable, and strong material that reduces energy use to create materials and construct a building; and, as an alternative, Plant Prefab, a prefabricated wall material (Figure 6).

Figure 6: Assessed Wall Assemblies



(") = inches
Source: Arup

Design Phase analysis indicated both options do not offer significant reductions in emissions when compared to the Title 24 baseline. However, the PCTV team continues to research and evaluate the financial feasibility of less market-ready solutions such as carbon-impregnated concrete. Other technologies that may be evaluated include structural timber, rapidly renewable construction materials, and other alternative concrete technologies.

Market Transformation

The PCTV project aims to be a catalyst for change in California's MFH, focusing on cost-effective, energy-efficient building and operation. The project will serve as a hands-on model for transforming the state's housing landscape. A detailed Knowledge Transfer Plan was crafted to document and share insights from the planning, design, construction, and operation stages through a comprehensive Case Study. This study will be disseminated during Phase II (Build Phase) to a diverse range of stakeholders via various outreach tactics such as industry publications, webinars, and direct meetings. The team's goal is to provide a replicable, cost-efficient blueprint for sustainable mixed-use development that details successes and challenges encountered to provide actionable solutions for overcoming barriers. Ultimately, the aim is not only to fulfill the needs of the PCTV project but to also influence the industry to adopt more sustainable, equitable, and efficient building practices.

To finance the comprehensive infrastructure required for the entire project, National CORE plans to tap into specific funding programs such as the Infill Infrastructure Grant Catalytic (IIGC) Program and the Regional Early Action Planning (REAP) Grants such as the REAP 2.0 Higher Impact Transformative (HIT) Awards. Construction of the PCTV development was designed to unfold in three or four distinct phases, each of which will be underpinned by local gap subsidies as well as long-term, low-interest loans, spread over a 55-year term. Funding for these phases is expected to come from three main avenues: the "Bridge to Home" initiative by the City of San Diego Economic Development Department, the San Diego Housing Commission, and the County of San Diego Innovative Housing Trust Fund (IHTF). Upon securing these local funds, subsequent financial backing will be sought through competitive applications to the State of California Department of Housing and Community Development (HCD). The funding could come from various channels, including Infill Infrastructure Grants, Transit-Oriented Development loans or grants, as well as state and federal Low-Income Housing Tax Credits, in addition to private sector equity and construction loans or mortgages. Table 3 details the development funding summary planned to date.

Table 3: Total Development Funding Summary

Name of Lender or Grant Provider	Source	Status	Date of Approval/ Expected Approval	Amount of Funds	Purpose
9% TC Equity	equity	Plan to apply	9/1/25	$27,302,606	Building
CEC Design Phase	grant	Secured	6/1/22	$1,000,000	Energy
CEC Build Phase	grant	Applied	6/1/24	$8,000,000	Energy
City of San Diego	loan	Secured	11/17/23	$6,229,266	Building
Private Lender	loan	Secured	11/17/23	$3,820,702	Building

Name of Lender or Grant Provider	Source	Status	Date of Approval/ Expected Approval	Amount of Funds	Purpose
State of CA HCD REAP HIT/IIGC	loan	Secured	6/5/23	$5,965,790	Building
County of San Diego IHTF	loan	Plan to apply	11/1/24	$4,000,000	Building
San Diego Housing Commission	loan	Applied	4/1/24	$4,000,000	Building
Deferred Developer Fee	developer	Secured	11/1/24	$692,587	Building

Source: National CORE

Interoperability is a foundational necessity for smart grids and seamless integration of distributed energy resources as incorporated in the PCTV zero-emission mixed-use development concept. The project will use new and updated standards and protocols such as OpenADR, SunSpec Modbus, CTA-2045, and IEEE 2030.5, which have established methods of communication between customer-owned equipment (for example, water heater and HVAC) and systems (for example, microgrid controller, building energy management system, and digital twin); the local Distributed Energy Resources Management System; virtual power plant; and the grid operator. Manufacturers are already releasing residential-scale products into the market with communications capability, which can receive dispatch commands from a grid operator or aggregation service to provide frequency response, regulation, ramp-rate control, and Volt-VAr support, among others (for example, water heaters with CTA-2045 port, or OpenADR Compatibility).[12]

The project team will coordinate with the Open Distributed Energy Management (OpenDEM) from Amzur technologies, the winner of U.S. Department of Energy's Plug and Play distributed energy resource (DER) challenge. OpenDEM seeks to reduce the cost and complexity of DER integration for utilities, manufacturers, grid service providers, energy managers, and asset owners. OpenDEM builds on the success of OpenADR to develop a bi-directional, low-cost, and low-complexity interface to support secure energy communication/interaction between entities inside and outside of a customer boundary for auto-enrollment, distributed coordination, resource aggregation, and optimization across a wide and dynamically evolving range of devices and energy systems.[13]

[12] Obi, Manasseh, Tylor Slay, Robert Bass. 2020. "Distributed energy resource aggregation using customer-owned equipment: A review of literature and standards." *Energy Reports*, Volume 6, Pages 2358-2369, ISSN 2352-4847. https://doi.org/10.1016/j.egyr.2020.08.035.

[13] Smart Electric Power Alliance. 2018. "Plug & Play Phase 1 Final Submission. Open Distributed Energy Management ESI (OpenDEM), Lead Organization Amzur Technologies." Available at https://sepapower.org/thank-plug-and-play-phase-1-final-submissions/.

Community Engagement

PCTV is envisioned as a community unto itself while also integrated into the Palm Avenue neighborhood and greater San Diego area. It focuses on living, working, and playing at or near homes or in areas reachable by transit. It will offer mixed-uses such as a childcare center along with retail and dining options. Importantly, it offers indoor and outdoor "third places," social environments separate from home ("first place"), and work ("second place"). The loss of third places in the United States is a growing concern.[14] Social spaces have traditionally served as crucial sites for social interaction, community building, and civic engagement. The transformation of third places into less social, more transactional spaces, often due to economic pressures or technological changes, weakens community ties and reduces social capital. PCTV creates abundant space to form new community connections.

PCTV's use of advanced clean energy technologies and zero-carbon strategies will significantly improve local air quality, thereby reducing health impacts associated with pollution. Additionally, PCTV will chip away at the housing affordability crisis in the area by providing 288 affordable apartment homes. Its strategic location next to the MTS will reduce the need for car trips, mitigating traffic and lowering carbon emissions. The development will transform a largely unproductive lot into a bustling community space, thus better integrating the neighborhood. Enterprise Community Partners and USC have taken active steps to understand and address resident needs through community outreach, engagement, and research, thereby underpinning alignment with community goals. The project team aims to demonstrate how sustainable, affordable housing can be achieved, setting a precedent for future developments. These efforts make PCTV a model that tackles both the climate and housing crises in a way that benefits the local community.

Community and Stakeholder Engagement

The development team began robust community engagement in early 2020, prior to receiving public funding, with numerous stakeholder groups, elected officials, interested parties, and others. To date, this engagement work has yielded numerous support letters and no opposition.

Furthermore, National CORE continued to engage general community members and stakeholders during the Design Phase as it relates to the EPIC-funded project. Project partners targeted more specific topics and groups for further engagement. Enterprise Community Partners held two policy workshops to engage project partners, stakeholders, and influential policymakers on the policy implications of, and barriers to, the zero-net-carbon elements of the project. USC also conducted resident surveys and interviews to understand resident needs and barriers and prepare education and outreach materials for PCTV residents during the Build Phase. Finally, Momentum held the Technical Advisory Committee meeting for the EPIC project to engage technical and jurisdictional stakeholders.

The project team, led by National CORE, solicited extensive community input through multiple avenues as the team wanted a deep understanding of the opportunities and challenges

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[14] McPherson, Miller, et al. 2006. "Social Isolation in America: Changes in Core Discussion Networks over Two Decades." *American Sociological Review*.

presented by developing the Palm Avenue site. One of these avenues were meetings with members of the community and stakeholders:

- City of San Diego – Attended various meetings: Mayor Todd Gloria
- Then Council President Pro Tem Monica Montgomery Steppe
- Councilmembers: Joe LaCava, Jennifer Campbell, Stephen Whitburn, Marni von Wilpert, Chris Cate, Raul Campillo, Vivian Moreno, Sean Elo-Rivera
- San Diego County Board of Supervisors – Attended various meetings:
    - Then Chairman of the Board of Supervisors Nathan Fletcher
    - Supervisor Joel Anderson
    - Supervisor Jim Desmond
    - Supervisor Nora Vargas
    - Supervisor Terra Lawson-Remer
- San Diego Metropolitan Transit System Board of Directors: Otay Mesa Nestor Community Planning Group
- San Diego Regional Economic Development Corporation
- Greater San Diego Chamber of Commerce Board of Directors and the Chamber Land Use and Housing Committee
- San Diego Building and Construction Trades Council
- San Diego Climate Action Campaign
- San Diego Foundation
- City of San Diego Sustainability Department
- Imperial Beach Collaborative Neighborhood Center
- San Diego Association of Governments Board and Staff
- Imperial Beach Job Corporation
- U.S. Department of Transportation

Throughout various stages of engagement, stakeholders provided feedback on workforce development, public dissemination of project information, and potential for a climate resilience network. The USC team devised, implemented, and evaluated the outcomes of an online questionnaire aimed at 120 residents across four distinct low-income housing properties in Southern California. The purpose of the survey was to investigate:

- Energy use
- Conservation behavior
- Requirements for focused resident engagement
- Educational opportunities among affordable housing residents

To gain deeper insights into occupant behavior, the team carried out semi-structured interviews involving 20 low-income residents of these properties. Through these investigations, the team identified crucial factors influencing energy consumption patterns and underscored potential pathways for targeted interventions aimed at enhancing energy efficiency.

In August 2023, the Enterprise team developed and ran two Development Advisory Group workshops to support National CORE and the CEC seeking to scale and replicate carbon-free, mixed-use affordable housing. In each meeting, Enterprise gathered feedback from decarbonization experts for National CORE's PCTV project. During these meetings, the Development Advisory Group members commented on current decarbonization policies and regulations and proposed solutions to address existing barriers. The set of barriers was organized into the following broad categories:

- Planning/code/regulatory approvals and requirements
- Costs/funding/financing
- Limitations from the buildings/utilities side
- Designer/tenant know-how (capacity building/technical assistance)

The project team identified the need to prioritize changes in zoning to allow for Transit-Oriented Developments and mixed-use buildings around high-quality transit stops and the need to streamline approvals at local, county, and metropolitan planning organization levels. Additionally, the team identified the need for statewide legislation that sets aside public dollars for decarbonization — so that first costs are allocated for regulated affordable housing (covenanted affordable housing) and increased costs aren't passed on to tenants. Advanced solar, battery, and energy management designers will be needed to help developers, and there is a need for collaboration with labor. Lastly, there is a need to advocate for community-based organization involvement in grant administration and expanded opportunities for technical assistance.

The Technical Advisory Committee (TAC) is a requirement for most CEC-funded projects. The TAC was brought together for one or more meetings to discuss key technical pieces of a funded project with the project team. Momentum developed and facilitated a virtual TAC meeting spanning three main topics: Community Engagement, Technology Considerations, and General Project Questions. The discussion focused on community engagement, particularly with community-based organizations, and the strategies employed to ensure equitable and active participation in energy-saving initiatives. TAC members made suggestions to leverage existing marketing campaigns and partner with public utilities for broader outreach.

Workforce Development

PCTV will create hundreds of temporary construction jobs paying prevailing wages and will create hundreds of permanent jobs. Additional specialized trade labor will be needed to deploy the advanced energy technologies. The project team is partnering with the San Diego Building Trades Council under a Project Labor Agreement to ensure a highly skilled and trained workforce on the project buildout. This Project Labor Agreement will be the first-ever on any residential project in San Diego County. Permanent opportunities related to the development itself include maintenance, groundskeeping, operations, and tenant relations staff. Contracts for special maintenance needs will generate jobs, including elevator, solar PV, and BESS maintenance. The mixed-use nature of the project will create job opportunities for the childcare center as well as the retail and restaurant spaces.

Addressing Affordability and Gentrification

One method to address and minimize gentrification is to build deed-restricted affordable housing with rental rates not exceeding 80 percent of the area's median income.[15] The 100 percent affordable and energy-efficient units in PCTV will decrease costs for residents, giving them greater financial flexibility while increasing standards of living and establishing a thriving community. Building deed-restricted housing forever shelters the land from the negative aspects of gentrification. California requires millions more affordable rental units; U.S. Census data indicate over 45 percent of renters in San Diego County pay more than 35 percent of their income on housing.[16,17] National CORE partnered with MTS to create PCTV as MTS is not subject to typical development limits on certain lots, reducing the regulatory burden on the project and allowing for higher density. PCTV does not displace any existing housing and does not displace any existing residents. Given that it is a 100 percent affordable development, it will add economic diversity to an area dominated by market-rate housing, offering low- and moderate-income San Diegans more variety and higher-quality housing in areas previously out of reach.

[15] NLIHC (National Low Income Housing Coalition). 2019. "Gentrification and Neighborhood Revitalization: WHAT'S THE DIFFERENCE?" Available at https://nlihc.org/resource/gentrification-and-neighborhood-revitalization-whats-difference#:~:text=Preserving%20the%20subsidized%20housing%20in,through%20new%20construction%20and%20acquisition

[16] California Housing Partnership. 2023. *CALIFORNIA Affordable Housing Needs Report*. Available at https://chpc.net/wp-content/uploads/2023/03/HNR_CA_CHPC-Master2023-FINAL.pdf.

[17] U.S. Census Bureau. 2021. "SELECTED HOUSING CHARACTERISTICS." American Community Survey, ACS 1-Year Estimates Data Profiles, Table DP04. Available at https://data.census.gov/table/ACSDP1Y2021.DP04?g=050XX00US06073.

CHAPTER 3: Energy, Emissions, and Cost Performance

Design Challenges

In the Design Phase, the project team established "layerability" as a fundamental criterion for including a given technology in the final design. That is, can a given technology, system, or part of a system be replaced, omitted, or otherwise changed; to what degree and how quickly; and at what cost? The proposed innovative design strategies currently "designed-in" can also largely be "designed-out" of the deployment, if necessary. This builds flexibility in construction costs and adjusts for unexpected funding challenges often managed by affordable housing developers. Table 4 indicates identified risks, relative impacts, and proposed mitigation strategies.

Table 4: Risk Assessment and Mitigation

Risk Type	Risk Description	Likelihood	Severity	Contingency Plan
Technical	Failure of Home Energy Management System and other grant-funded equipment	Low	Medium	Ensure robust support and maintenance contracts, and ensure onsite staff is trained to service and remediate when feasible.
Regulatory	Non-compliance with standards or codes	Low	High	Consult regularly with legal and compliance teams; keep abreast of updates to local and national codes.
Financial	Budget overruns due to cost of new technology	Medium	Medium	Stay abreast of pricing changes and market movement; explore additional funding or grants focused on green technologies.
Operational	Difficulty in integrating systems	Low	High	Pilot testing of microgrid and other systems; integration with dummy loads before full-scale implementation.
Adoption	Resistance to new technology by residents	Medium	Low	Engage residents through workshops, training, and real-time feedback on energy savings.
Cybersecurity	Data breaches affecting Home Energy Assistant	Low	High	Employ robust encryption and multifactor authentication; regular security audits.
Supply Chain	Delays in getting materials of any type	High	Medium	Identify multiple suppliers; keep a buffer stock of essential materials.
Communication	Miscommunication between technology providers and construction team	Low	Medium	Regular meetings between all stakeholders, with minutes and action items circulated.
Resilience	Failure of microgrid during grid failure or extreme weather	Low	High	Conduct stress tests on microgrid under simulated conditions.

Source: Arup

Energy and Emissions Performance

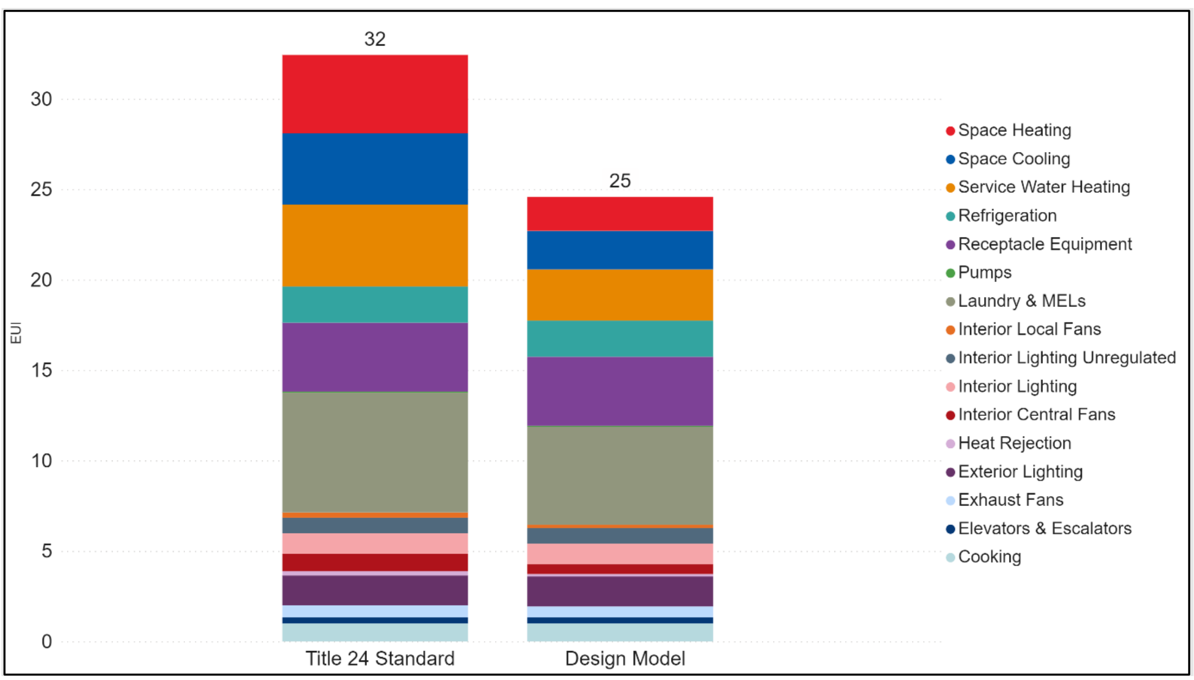
The PCTV design team used advanced software to go beyond California's standard building energy requirements, aiming to reduce energy consumption, costs, and greenhouse gas emissions. Arup created a Title 24-compliant baseline model, incorporating various household appliances and energy loads for comparison with the Proposed Design. Building on National Core's existing all-electric construction approach, the team analyzed which emerging technologies would be most effective for the project's specific climate and operational profile, identifying eight key energy conservation measures to optimize energy usage and electrical demand.

The following measures were packaged into a Proposed Design to include:

- Prefabricated Envelope
- Phase Change Material
- Improved Sealing for Infiltration
- External Shades
- Heat Pump Dryers
- Advanced Heat Pump Water Heaters
- High-Efficiency Mini-Split Heat Pumps
- High-Performance Cool Roof

Based on the Proposed Design's annual hourly outputs, Arup optimized the microgrid to meet the grant objectives of load management, demand response, and reacting to critical grid events. The packaged energy conservation measures exceeded energy and emissions reductions beyond what is required by Title 24. Figure 7 shows a column graph comparison detailed with the building end uses. The figure shows the Proposed Design energy use intensity (EUI) at 25 and Standard Design EUI at 32, a difference of 22 percent annually.

Figure 7: Energy Use Intensity between the Standard Design and Proposed Design



Source: Arup

Table 5 provides an itemized list of the end-use energy density and carbon emissions density. The Proposed Design emits 14 percent less grid carbon emissions than the Standard Design.

The primary savings come from the advanced heat pump technology in HVAC, domestic hot water, and clothes drying technology. The HVAC heat pump technology savings are improved through load reduction measures, which are the enhanced envelope measures of prefabricated walls, phase change materials, shading devices, and high-performing roofs.

Table 5: Site Energy and Greenhouse Gas Emission Comparison Table

End-Use	Site Energy Use Intensity (kBtu/sf/yr)			GHG Emissions Intensity (kg CO_2/sf/yr)		
	Standard Design	Proposed Design	% Improvement	Standard Design	Proposed Design	% Improvement
Space Heating [Non-Res]	3.90	1.43	**63%**	0.04	0.08	**-80%**
Space Heating [Res]	0.43	0.44	**-4%**	0.03	0.03	**1%**
Space Cooling [Non-Res]	1.36	0.95	**30%**	0.07	0.04	**39%**
Space Cooling [Res]	2.24	1.18	**47%**	0.11	0.06	**44%**
Indoor Fan [Non-Res]	0.95	0.61	**36%**	0.05	0.03	**44%**
Indoor Fan [Res]	0.30	0.11	**64%**	0.02	0.01	**61%**
Ventilation [Res]	0.67	0.62	**8%**	0.04	0.03	**8%**
Heat Rejection [Non-Res]	0.09	0.06	**31%**	0.00	0.00	**39%**
Heat Rejection [Res]	0.14	0.08	**47%**	0.01	0.00	**44%**
Domestic Hot Water	4.56	2.85	**38%**	0.23	0.15	**38%**
Pump	0.06	0.06	0%	0.00	0.00	0%
Indoor Lighting [Non-Res]	1.13	1.13	0%	0.05	0.05	0%
Indoor Lighting [Res]	0.86	0.86	0%	0.06	0.06	0%
Refrigeration [Res]	2.00	2.00	0%	0.11	0.11	0%
Dish Washing [Res]	0.29	0.29	0%	0.02	0.02	0%
TV/Entertainment [Res]	2.79	2.79	0%	0.16	0.16	0%
Miscellaneous Electrical Loads [Res]	3.91	3.91	0%	0.24	0.24	0%

End-Use	Site Energy Use Intensity (kBtu/sf/yr)			GHG Emissions Intensity (kg CO_2/sf/yr)		
	Standard Design	Proposed Design	% Improvement	Standard Design	Proposed Design	% Improvement
Cooking [Res]	1.00	1.00	0%	0.06	0.06	0%
Elevators	0.32	0.32	0%	0.01	0.01	0%
Outdoor Lighting	1.66	1.66	0%	0.12	0.12	0%
Laundry	2.41	1.21	50%	0.12	0.06	50%
Receptacles [Non-Res]	1.00	1.00	0%	0.05	0.05	0%
Total	**32**	**25**	**+22%**	**1.6**	**1.4**	**+14%**

Source: Arup

Costs and Benefits Performance

PCTV endeavors to improve residents' quality of life through high-quality, affordable housing. The San Diego area has some of the most, and at times the most, expensive energy in the country. Energy costs are a concern for everyone in the region, but as a percentage of income, high energy costs hit low- and moderate-income communities the hardest. They are also more likely to be burdened with energy-inefficient building stock and antiquated end-use equipment. PCTV will shift this reality. By leveraging the advanced technologies and designs in this proposal, PCTV can routinely offer residents over 90 percent savings on energy costs.

Lifecycle cost, from the residents' perspective, represents the net present value of the building experienced by the residents over its 30-year lifetime. The lifecycle cost savings of the Proposed Design compared to the Standard Design is $124,906 for an average residential unit. This represents the benefit of utility savings from the high efficiency of the design, the use of DERs, and demand response measures when comparing the Proposed Design to the Standard Design. The Standard Design includes the minimum size requirements of PV and BESS by the 2022 California Building Energy Efficiency Standards (Title 24). In the Standard Design, the analysis assumes the PV and BESS serve the non-residential portion of the building tied to the central house meter, meaning there are no utility cost savings from the residents' perspective assumed in the Standard Design for the DERs (for example, PV and BESS). The non-residential central house meter includes the domestic hot water heaters that are individually sized and located in each apartment. The developer will cover the cost of this domestic hot water heater end-use for each apartment by applying the utility savings from the onsite renewable generation. For the Proposed Design, the PV and BESS are assumed to benefit both the non-residential and residential spaces (specifically, the building operator and the residents) through a virtual net energy metering arrangement. SDG&E offers a tariff for this purpose, titled "Schedule NEM-V-ST Virtual Net Energy Metering for Multi-Tenant and Multi-Meter Properties Successor Tariff."

Overall, the incremental first cost per unit will benefit from the support of the grant because the technologies included are at early market adoption for the affordable housing sector. Any amount of additional capital is challenging to secure in addition to meeting all the other requirements for development along with the 2022 California Building Energy Efficiency Standards (Title 24). At almost $125,000, the lifetime savings for each resident are substantial, especially for low-income housing. These savings are detailed in Table 6 below. This outcome would have a dramatic effect on each resident's quality of life.

Table 6: Comparison of Two Cost Categories

	Incremental First Cost per Unit ($/Unit)			Resident's Lifecycle Cost Savings (based on utility rates) ($)		
	Standard	**Proposed**	**Cost**	**Standard**	**Proposed**	**Savings**
Rental	$25,190	$85,163	$59,972	$540,734	$415,828	$124,906

Source: Arup

Technology Transfer Plan

The project team submitted a Case Study Plan as part of this phase of the project. The Case Study Plan outlined goals for Phase I (Design Phase) and Phase II (Build Phase) of the project, with most of the technology and knowledge transfer occurring in Phase II to capture more meaningful findings from the construction, commissioning, measurement and verification, and operations phases. During Phase I, the project team submitted a Case Study that outlined all the meaningful findings from this phase.

Case Study Plan

The purpose of the project Case Study Plan was to outline National CORE's approach to document, record, analyze, and disseminate findings of the planning, construction, commissioning, verification, and operation of the PCVP for funding Phases I and II. The plan's key milestones are:

Planning and Design (Design Phase funding)

- Planning stage completion
- Completion of site design, layout, and engineering
- Commencing community engagement
- Completion of community engagement

Construction and Commissioning (Build Phase funding)

- Procurement of grant-funded equipment and systems
- Project groundbreaking
- Commencing installation of grant-funded equipment and systems
- Completion of installation of grant-funded equipment and systems
- Commissioning kick-off and completion
- Residents move in

Measurement and Verification (Build Phase funding)

- Initial measurement and verification findings
- Final measurement and verification findings

Operations (Build Phase funding)

- Any feasible early operations conclusions and findings
- Findings related to ongoing compliance with Phase II post-award reporting requirements

The outreach strategy is built on stakeholder analysis, ensuring each group benefits from unique outreach and information curated to their respective interests. Cultivating awareness, transferring knowledge, and building confidence in emerging decarbonization and energy efficiency solicitations is crucial for advancing the state of the industry. Each stakeholder group has diverse interests and varied desired lessons from the broad, multiyear, multidisciplinary project.

CHAPTER 4: Conclusion

The planning and design process for PCTV put into sharp relief the breadth and depth of the needs, challenges, and opportunities in developing next-generation, mixed-use, multifamily housing. The benefits of zero-net-carbon buildings are clear. California is addressing a decades-long housing crisis while simultaneously shifting the built environment from a climate change contributor to an ally in the fight to stem the change and adapt. The path to making this the standard in development and construction must be cleared, especially in the affordable housing sector. Even so, the challenges encountered in the project are not insurmountable and, with changes to the sector and policy, development could be accelerated and made economically feasible without subsidy.

In addition to the performance, cost analysis, and findings in the design process, the PCTV team identified key findings and recommendations that benefit the building and development of future projects. These findings relate to community and resident engagement; policy barriers and policy development; design team composition; emissions and cost modeling; market availability of advanced energy technologies; and utility interconnection and gird interaction.

- **Community and Resident Engagement**
  - **Finding – Resource Allocation**
    - The USC team, in the course of their work, highlighted the significance of allocating sufficient resources to support (1) meaningful incentives to spur and drive engagement, and (2) funding to deploy dedicated resident services staff to effectively engage residents. Because this work focused on a low-income community, any demand on their time and resources for the benefit of the project is felt acutely and can be unduly burdensome. It was observed that these elements were initially not included in the budget, necessitating an adjustment. Alternative funding was secured to address this oversight.
      - **Recommendation:** When conducting research involving human subjects, project planning should account for residents' greater needs and budget levels should have greater flexibility.
  - **Finding – Mechanisms for Innovative Incentivization and Recruitment**
    - Gift cards were distributed among the study population as a foundational form of incentivization and were well received.
    - A referral system was implemented in which residents were encouraged to motivate their neighbors to join the study, thereby improving participant recruitment.
    - The recruitment initiatives were strategically integrated with existing community programs, such as food distribution events and school-related

activities. This integration aimed to, and did, enhance the efficiency of the recruitment process and increase its relevance to the target demographic.

- **Finding – Engagement Timing**
  - The USC team encountered significant difficulties when arranging interview times, particularly with households headed by women. Despite efforts to offer flexible scheduling options, these challenges persisted.
    - **Recommendation**: Initiate engagement discussions at an earlier stage and consider alternatives to Zoom interviews, to better accommodate the scheduling constraints of participants.

- **Policy Barriers and Policy Development**
  - **Finding – Alignment in Policy Nexus of Decarbonization and Housing**
    - Enterprise Community Partners conducted policy workshops to understand varying perspectives and impacts of policies influencing this project. A full write up and overview of these can be found in the Community Benefits Plan.
    - Decarbonization is viewed, understood, and appreciated from a diverse multitude of paradigms, each with unique objectives and priorities, often connected to a professional interest but sometimes connected to a personal passion or interest.
    - Numerous policies and programs are already in place, encouraging decarbonization efforts. However, these policies are a patchwork with varying and often conflicting goals or otherwise unaligned and duplicative goals and efforts.
    - A significant number of professionals in the field are actively seeking practical solutions, and a growing interest in decarbonization is leading to a convergence of policymakers and industry professionals. Yet, a vast gap in technical expertise is evident, particularly in implementing new and maturing technologies, among current practitioners from all relevant industries and sectors connected to residential development.
    - There will be competition for tradespersons and professionals who know and understand these technologies, exacerbated by sky-high demand for labor of all types in building and development.
    - The economics of decarbonization are crucial, affecting both the financial viability for developers and cost implications for residents. There is a risk that a lack of understanding and education can build mistrust or delay adoption and incentives.
    - State funding programs are available, encouraging developers to include decarbonization strategies in their projects.
      - **Recommendations**
        - *State-Led Consolidation* – Implement a comprehensive, state-led initiative to unify and streamline decarbonization policies.

    - *Bridging Policy and Practice* – Foster a connection between policy frameworks and the tangible experiences of housing developers.
    - *Technical Knowledge Enhancement* – Develop programs to enhance technical knowledge among professionals, focusing on the latest decarbonization technologies.
    - *Economic Considerations* – Address the economic aspects of decarbonization, ensuring it is financially viable for developers and cost-effective for residents.
    - *Workforce Development* – Invest in workforce development to cater to the growing needs of the decarbonization sector.
    - *Leveraging Existing Incentives* – Use existing policies and programs as a springboard for expanded decarbonization initiatives.
    - *Enhancing State Funding Utilization* – Encourage the optimal use of state funding programs to support developers in integrating decarbonization into their projects.

- **Team Composition**
  - **Finding – Need for Specialists in Advanced Energy**
    - The PCTV project team was composed of a robust range of specialists and subject matter experts. Because many of the goals of this project, especially goals related to building performance, were well outside of the standards accepted today, extensive work had to be done to understand how to achieve them or if they could work at all. PCTV would not exist as proposed without the human and financial resources to understand a path to the research goals. Outside of a demonstration setting, many of the same experts would be needed. Until common practice changes, developers and builders will need to enlist experts they may currently lack to scale beyond Title 24. For the Build Phase, the team will need additional expertise to design and build a microgrid.
      - **Recommendation:** Ensure project plans include specialists in advanced energy to guide research and implementation.
- **Emissions Reductions and Modeled Cost Comparison**
  - **Finding – Added Cost of Advanced Technologies Despite Efficiency Gains**
    - The Design Phase revealed poor initial cost performance of most of the building features and construction methods and all of the energy features when compared with a Title 24 model.
      - Proposed building features added a total cost of $667,800 to the project, resulting in a per unit incremental cost of $8,348.
      - Proposed energy features added a total cost $4,129,985 to the project, resulting in a per unit incremental cost of $51,625.

- Significant energy performance gains included:
  - A 93-percent reduction in energy costs for residents, delivering 30-year lifecycle cost savings of $124,906 for an average residential unit.
  - A 100-percent reduction in energy costs for non-residential space.
  - A 22-percent reduction in overall energy use intensity when comparing the Proposed Design to a Title 24 Standard Design baseline building.
  - A 14-percent reduction in grid carbon emissions
- **Recommendations**
  - Greater deployment incentives are needed to buy in a baseline of adoption of these technologies to create market momentum and demand and offset higher initial costs.
  - When costs stabilize, building codes and standards can give a final push for phasing in these solutions in lieu of legacy and combustion technologies.

- **Market Availability of Advanced Energy Technologies**
  - **Finding – Current Market Conditions Limit Availability and Keep Prices High**
    - **Limited Supplier Base for Cutting-Edge Technologies:** Some components, like phase change materials, large-scale BESS, and advanced smart electrical panels, have a limited number of suppliers which means higher costs coupled with longer lead times for procurement.
    - **Technological Maturity:** Many of the technologies have reached a market-ready technological maturity, but the market readiness is more like adolescence. In their initial iterations, the technology could become outdated or lack long-term performance and reliability data.
    - **Integration Complexity:** The capacity of new technologies to seamlessly integrate with existing building management system designs and technologies and other smart devices might be limited, posing challenges in ensuring interoperability and user-friendliness.
    - **Lack of Market Demand:** Because most of the technologies perform well above current building standards, they are simply less in demand. Cost-conscious builders and developers are risk averse and would not commonly elect to spend what amounts to nearly double on a given solution despite anticipated lower lifetime operating costs. This is especially true of some end uses such as water heating, the savings for which will not be passed to the owner but rather to the resident.
    - **Supply Chain Risks:** Global supply chains for advanced building technologies are vulnerable to disruption as they use materials for which the supply chains are new, delicate, and otherwise scaling. This impacts

the availability and price stability of these components, posing risks to project timelines and budgets and suppressing adoption rates.

— **Recommendations**
  - Greater deployment incentives are needed to buy in a baseline of adoption of these technologies to create market momentum and demand and offset higher initial costs.
  - When costs stabilize, building codes and standards will give a final push for phasing in these solutions in lieu of legacy and combustion technologies.
  - As advanced solutions overtake their predecessors in overall adoption and deployment, and trust is built in them by consumers, developers, and builders, many of these challenges will be corrected in parallel.

- **Utility Interconnection and Enabling Grid Interaction**
  - **Finding – Slow, Duplicative, and Delayed Interconnection Processes**
    - The slow, duplicative, and delayed interconnection process of SDG&E, taking from six to twelve months, not only presents significant challenges to the deployment, usability, and benefits of a microgrid in a multifamily home like PCTV but also substantially increases the risk for developers and builders. These bureaucratic hurdles exacerbate the uncertainty and financial strain associated with such projects, making them less appealing and more hazardous from an investment perspective. This risk becomes acute and bordering on intolerable, especially for developers of affordable housing like National CORE, who operate with thinner margins and are often reliant on tight schedules to meet funding and regulatory requirements. The prolonged timelines and increased costs due to these interconnection challenges can jeopardize the feasibility and sustainability of affordable housing projects, ultimately impacting the availability of cost-effective, resilient, and sustainable housing solutions for lower-income communities. Therefore, the inefficiencies in SDG&E's interconnection process not only delay the adoption of innovative energy solutions like microgrids but also undermine efforts to provide equitable access to affordable and sustainable housing.

— **Recommendation – Scale and Update Processes to Serve an Advanced, Electrified Economy**
  - *Streamline the Interconnection Process* – The utilities are largely doing business the way they always have yet the world that relies on them is speeding ahead. Processes that do not account for a dynamic, high-load, distributed energy future must be updated.

— **Recommendation – Dedicated Support and Guidance**

  - SDG&E should provide dedicated support teams for microgrid projects. These teams would offer technical guidance, assist with navigating regulatory requirements, and ensure a smoother, more predictable interconnection process.

— **Recommendation – Apply Regulatory Pressure**

  - Local and state regulatory bodies should adopt policies that facilitate quicker and more efficient interconnection processes for microgrids. In equal measure, there should be penalties for falling short of adequate service.

- **Finding – Tariff Structures making Microgrid Economics Challenging**
  - SDG&E's tariff structure for microgrids significantly limits their usability, benefits, and cost-effectiveness, primarily because it restricts the ability to charge the microgrid from grid energy, thereby curtailing opportunities for rate arbitrage and other functionalities essential for optimizing energy costs and usage. This limitation essentially forces the microgrid to rely heavily on its own generation capabilities, which may not always be the most economical or efficient method, especially during periods when grid electricity prices are lower. Furthermore, there is considerable confusion regarding the extent to which net metering is allowed under these tariffs. Net metering, a mechanism that credits solar energy system owners for the electricity they add to the grid, is crucial for the financial feasibility of renewable energy investments. However, the introduction of NEM 3.0 has compounded this confusion by changing the rules and potentially reducing the compensation for solar energy that is fed back into the grid. This lack of clarity and the restrictive nature of the tariff structure hinder the full potential of microgrids to provide cost savings, sustainability benefits, and enhanced energy resilience, particularly undermining the economic rationale for deploying microgrid solutions in communities served by SDG&E.

— **Recommendation – Revisit Tariff Structures with an Aim at Customer Benefit and Give Guidance on New Rates**

  - To mitigate the limitations imposed by SDG&E's tariff structure on microgrids, they should be reformed and specifically designed to accommodate the unique capabilities and benefits of microgrid systems. Such reform should include provisions that allow microgrids to charge from the grid when it is economically advantageous, enabling effective rate arbitrage and optimizing energy usage to reduce costs. Furthermore, there is a need for clear, fair, and favorable guidelines for net metering, especially in light of the complexities introduced by NEM 3.0. Ensuring that microgrids receive equitable compensation for the energy they supply to the grid is crucial for the financial feasibility of renewable energy investments and the broader adoption of microgrid technology.

- **Finding – Delayed Permission to Operate Disrupts Financing Agreements**
  - Delayed Permission to Operate for microgrids not only disrupts agreements but also significantly impacts the financial feasibility of projects like PCTV by undermining operating cost calculations. This uncertainty complicates and slows down the underwriting process, as the anticipated operational benefits and cost savings of the microgrid are not realized until after Permission to Operate is granted. Consequently, what should lower the operating budget is perceived by financiers as a liability, leading to increased borrowing costs and added complexities in financing arrangements. Furthermore, delays in obtaining Permission to Operate postpone the accrual of solar credits and exacerbate the situation with slow net metering billing, thereby negatively affecting the financial optics of the microgrid's benefits. These challenges highlight the need for more streamlined regulatory processes to ensure microgrids can be effectively integrated and financed as sustainable energy solutions.
    - **Recommendation** – See initial finding in this section.

GLOSSARY AND LIST OF ACRONYMS

Term	Definition
AHSC	Affordable Housing and Sustainable Communities
Arup	Arup US, Inc.
BedZED	Beddington Zero Energy Development
BESS	battery energy storage system
CEC	California Energy Commission
CO_2	carbon dioxide
DER	distributed energy resource
Enterprise	Enterprise Community Partners
EPIC	Electric Program Investment Charge
EUI	energy use intensity
EV	electric vehicle
EVSE	electric vehicle service equipment
GHG	greenhouse gas
HCD	State of California Department of Housing and Community Development
HIT	Higher Impact Transformative
HVAC	heating, ventilation, and air conditioning
IHTF	Innovative Housing Trust Fund
IIGC	Infill Infrastructure Grant Catalytic
kBtu	thousand British Thermal Units
kg	kilogram
kW	kilowatt
L2	Level 2
LEED	Leadership in Energy and Environmental Design
MFH	multifamily housing
Momentum	Build Momentum, Inc.
MTS	San Diego Metropolitan Transit System
National CORE	National Community Renaissance
NEM 3.0	Net Energy Metering 3.0
OpenDEM	Open Distributed Energy Management
PCTV	Palm City Transit Village
PV	photovoltaic
REAP	Regional Early Action Planning

Term	Definition
SDG&E	San Diego Gas & Electric
sf	square foot
SF ACM	Single-Family Alternative Calculation Method Reference Manual
Studio-E	Studio-E Architects
TAC	Technical Advisory Committee
Title 24	2022 California Building Energy Efficiency Standards
USC	University of Southern California
USGBC	U.S. Green Building Council
yr	year
ZNE	zero net energy

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Project Deliverables

The following deliverables were prepared and gathered for submission of this final report. Copies of the deliverables can be acquired by contacting the California Energy Commission at pubs@energy.ca.gov, requesting the deliverable, and providing the project agreement number.

The project team completed all standard CEC Task 1 deliverables:

- All Kick-off meeting deliverables
- All CPR meeting deliverables for one CPR meeting
- All final meeting deliverable (in progress)
- All progress reports and invoices (in progress)
- Final Report – Outline, Draft, and Final (in progress)
- Match funds status letter
- Permits letter
- Copies of subcontracts
- All TAC deliverables for one TAC meeting
    - Including TAC comments on project performance metrics (Memo)
- Project performance metrics

List of technical project deliverables:

- Stakeholder Working Group Member List
- Project Construction Timeline
- Advanced Construction Practices Plan
- Conceptual Design and Constructability report
- Submitted as one report:
    - Technology Standards and Protocols
    - Technology Contingency Plan
    - Blueprint for Future Projects
    - Standard Specification Sheets
- Lifecycle Cost Assessment Report
- Submitted as one report:
    - Customer Interface Best Practices Guidance
    - Decision-Making Model
    - Blueprint for Reducing Household Energy Consumption
- Development Advisory Group Member Information
- Initial Project Benefits Questionnaire
- Final Project Benefits Questionnaire
- Annual surveys
- Documentation of project and organization proles on EnergizeInnovation.fund
- Project Case Study Plan – Draft and Final
- Project Case Study – Draft and Final
- Summary of TAC Comments on Case Study (Memo)
- High Quality Digital Photos (captured in Conceptual Design and Constructability report)
- Full Build Phase Proposal Package

ENERGY RESEARCH AND DEVELOPMENT DIVISION

Appendix A: Energy Consumption of Baseline Design Versus Proposed Design

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APPENDIX A: Energy Consumption of Baseline Design Versus Proposed Design

Arup developed a Title 24 compliant model, referred to as the "Standard Design," in IES VE software. The inputs follow the 2022 California Building Energy Efficiency Standards (Title 24): Multi-family Alternative Calculation Method Reference Manual.[18] This source provides the process loads for interior and exterior lights, ovens, stove tops, refrigerators, dishwashers, miscellaneous electrical loads, TVs, cable boxes, clothes washers, and clothes dryers. The geometry is based on architectural drawings for Building A of the Palm City Transit Village, a six-story, mixed-use building with 79 residential units, a retail resident space, interior garage, community room, shared laundry services, and leasing office.

Arup then tested a variety of energy conservation measures to arrive at the best package for the Proposed Design. In close coordination with National CORE, the Proposed Design includes several energy conservation measures that National CORE has previously deployed in multifamily developments in Southern California. These include all-electric design, high-performance cool roof, and improved sealing for infiltration. Arup analyzed the high-performance cool roof and improved sealing for infiltration for the Proposed Design and verified they are effective measures, even in the mild climate of San Diego, at improving energy efficiency and reducing peak demand, thus they are included. The all-electric design National CORE typically builds includes high-efficiency heat pump water heaters for domestic hot water and high-efficiency mini-split heat pumps for space heating and cooling that exceed the minimum requirements of Title 24 as well as other features that align with the Standard Design for efficiency such as electric ovens and stovetops for cooking and electric dryers for laundry. Arup found the best opportunity to save energy consumption and lower peak demand was in laundry, which is why the Proposed Design includes heat pump clothes dryers. Arup explored additional energy conservation measures for the envelope to evaluate what was most effective for the climate and found that the following helped not only improve energy efficiency, but also lower peak demand: prefabricated envelope, phase change material, and external shades.

The Proposed Design included the following eight measures to reduce building energy usage and electrical demand:

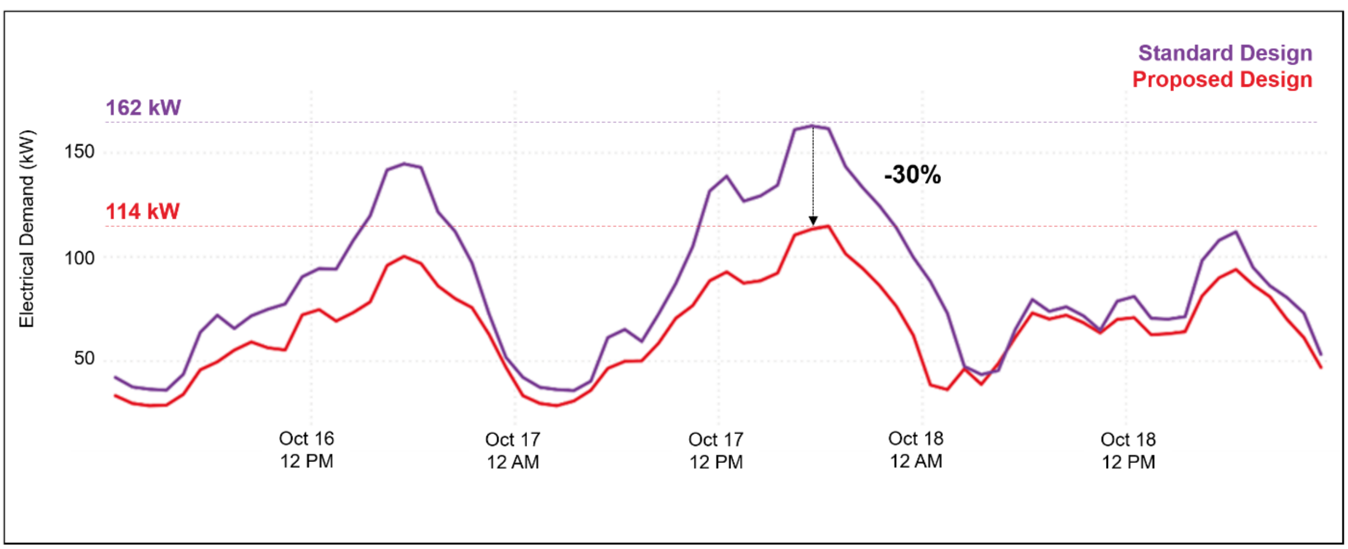
- Prefabricated Envelope
- Phase Change Material
- Improved Sealing for Infiltration
- External Shades
- High-Performance Cool Roof
- Heat Pump Dryers
- Advanced Heat Pump Water Heaters
- High-Efficiency Mini-Split Heat Pumps

[18] Bucaneg, Haile, Michael Shewmaker. 2022. "2022 Single-Family Residential Alternative Calculation Method Reference Manual: For the 2022 Building Energy Efficiency Standards Title 24, Part 6, and Associated Administrations Regulations in Part 1." California Energy Commission. Publication Number: CEC-400-2022-008. Available at https://www.energy.ca.gov/publications/2022/2022-single-family-residential-alternative-calculation-method-reference-manual

The Standard Design meets the minimum requirements of the 2022 California Building Energy Efficiency Standards (Title 24)[19] at a site EUI of 32 thousand British Thermal Units (kBtu) per square foot (sf) per year (yr). The Proposed Design exceeds those performance requirements through inclusion of the eight measures and has an EUI of 25 kBtu/sf/yr. These EUI estimates do not include offsets from onsite renewables. The EUI savings of 22 percent and a 14 percent savings of greenhouse gas (GHG) emissions intensity are shown in Figure 8 and Table B-1 of Appendix B, which break down the results by end-use. In Figure A-1, the Proposed Design has a 30 percent lower peak electrical demand than the Standard Design thanks to the energy efficient technologies. This enables right-sizing of the microgrid at 114 kW peak compared to a Standard Design peak at 162 kW. Designing a microgrid for a building that has a 30 percent lower peak demand relative to standard construction unlocks many benefits including reduced cost, smaller spatial allowances, and less embodied carbon. These savings primarily come from the following end-uses and the associated technologies:

- Space heating, space cooling, indoor fan, ventilation, and heat rejection
    - Prefabricated envelope, phase change material, improved sealing for infiltration, external shades, high-performance cool roof, and high-efficiency mini-split heat pumps
- Domestic hot water
    - Advanced heat pump water heaters
- Laundry
    - Heat pump dryers

Figure A-1: Peak Electrical Demand for Standard Design and Proposed Design



Source: Arup

[19] CEC (California Energy Commission). "2022 Building Energy Efficiency Standards". Available at https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency

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Appendix B: Emission Performance Calculation

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APPENDIX B:
Emission Performance Calculation

Table B-1: Site Energy Use Intensity and Greenhouse Gas Emission Intensity Between the Standard Design and Proposed Design

End-Use	Site Energy Use Intensity (kBtu/sf/yr)			GHG Emissions Intensity (kg CO_2/sf/yr)		
	Standard Design	Proposed Design	% Improvement	Standard Design	Proposed Design	% Improvement
Space Heating [Non-Res]	3.90	1.43	63%	0.04	0.08	-80%
Space Heating [Res]	0.43	0.44	-4%	0.03	0.03	1%
Space Cooling [Non-Res]	1.36	0.95	30%	0.07	0.04	39%
Space Cooling [Res]	2.24	1.18	47%	0.11	0.06	44%
Indoor Fan [Non-Res]	0.95	0.61	36%	0.05	0.03	44%
Indoor Fan [Res]	0.30	0.11	64%	0.02	0.01	61%
Ventilation [Res]	0.67	0.62	8%	0.04	0.03	8%
Heat Rejection [Non-Res]	0.09	0.06	31%	0.00	0.00	39%
Heat Rejection [Res]	0.14	0.08	47%	0.01	0.00	44%
Domestic Hot Water	4.56	2.85	38%	0.23	0.15	38%
Pump	0.06	0.06	0%	0.00	0.00	0%
Indoor Lighting [Non-Res]	1.13	1.13	0%	0.05	0.05	0%
Indoor Lighting [Res]	0.86	0.86	0%	0.06	0.06	0%
Refrigeration [Res]	2.00	2.00	0%	0.11	0.11	0%
Dish Washing [Res]	0.29	0.29	0%	0.02	0.02	0%
TV/Entertainment [Res]	2.79	2.79	0%	0.16	0.16	0%

End-Use	Site Energy Use Intensity (kBtu/sf/yr)			GHG Emissions Intensity (kg CO_2/sf/yr)		
	Standard Design	Proposed Design	% Improvement	Standard Design	Proposed Design	% Improvement
Miscellaneous Electrical Loads [Res]	3.91	3.91	0%	0.24	0.24	0%
Cooking [Res]	1.00	1.00	0%	0.06	0.06	0%
Elevators	0.32	0.32	0%	0.01	0.01	0%
Outdoor Lighting	1.66	1.66	0%	0.12	0.12	0%
Laundry	2.41	1.21	50%	0.12	0.06	50%
Receptacles [Non-Res]	1.00	1.00	0%	0.05	0.05	0%
Total	32	25	22%	1.6	1.4	14%

Source: Arup

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Appendix C: Cost Benefit Analysis

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APPENDIX C: Cost Benefit Analysis

This section provides an analysis of the estimated cost difference between the Proposed Design compared to the Standard Design (Tables C-1 through C-3). The Standard Design refers to the design that achieves minimum requirements for energy savings according to California's 2022 Building Energy Efficiency Standards (Title 24, Part 6), effective January 1, 2023.[20] It includes results that report two categories of costs for the residential units of the mixed-use developments: **incremental first cost**[21] and **lifecycle cost from the resident's perspective**. Eight energy conservation measures provided the best opportunities to reduce building energy usage and electrical demand:

- Prefabricated Envelope
- Phase Change Material
- Improved Sealing for Infiltration
- External Shades
- High-Performance Cool Roof
- Heat Pump Dryers
- Advanced Heat Pump Water Heaters
- High-Efficiency Mini-Split Heat Pumps

The following four grid-interactive measures provided the opportunity to further reduce building energy usage and electrical demand:

- Smart Thermostats
- Smart Electrical Panels
- Transactive Energy Platform
- Water Monitor Devices

The following three microgrid measures provided the opportunity to supply renewables-driven power:

- Onsite Battery Energy Storage System
- Onsite Solar Photovoltaics Roof- and Facade-Mounted
- Microgrid Components

The electric vehicle charging strategy measures included:

- Electric Vehicle Charging Stations
- Electric Vehicle Ready Infrastructure

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[20] CEC (California Energy Commission). "2022 Building Energy Efficiency Standards". Available at https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency

[21] Incremental first costs represent the additional costs for building features and energy equipment of the Proposed Design relative to the 2022 Title 24 minimum requirements. The cost for each building element includes materials, labor, and installation. Indirect costs — such as overhead, profit, project/construction management, and commissioning — are not included in the first cost analysis. Incentives are also not included.

Table C-1: Comparison of the Incremental First Costs of Building Features and Construction Methods, Standard Design Versus Proposed Design

Building Features and Construction Methods	Standard Design and Cost	Proposed Design and Cost	Incremental First Cost Increase (+) or Savings (-)
Prefabricated Envelope	16” OC Wood Frame R-21 batt insulation	Prefabricated walls with R-22 assembly	-$57,800
	$874,600	$816,800	
Phase Change Material	None	Dynamic thermal massing [56 btu/lbs*F per quarter inch layer]	+$533,300
	$0	$533,300	
Improved Sealing for Infiltration	T24 Prescriptive Requirements [No HERS Blower Door test Required]	HERS Blower Door Test	+$40,000
	$0	$40,000	
External Shades	None	External Shades	+$119,300
	$0	$119,300	
High-Performance Cool Roof	T24 Roof Insulation	High-Performance Roof Insulation + Cool-Roof	+$33,000
	$28,500	$61,500	
Total Incremental Cost Increase (+) or Savings (-) for the development			+$667,800
Incremental cost per residential unit ($)			+$8,348

Source: Arup

Table C-2: Comparison of the Incremental First Costs of Energy Features, Standard Design Versus Proposed Design

Energy Features	Standard Design and Cost	Proposed Design and Cost	Incremental First Cost Increase (+) or Savings (-)
Heat Pump Dryers	Electric Dryers	Heat Pump Dryers	+$43,000
	$16,300	$59,300	
Advanced Heat Pump Water Heaters	Heat Pump Water Heaters	Advanced Heat Pump Water Heaters	+$169,200
	$195,600	$364,800	
High-Efficiency Mini-Split Heat Pumps	T24 Efficiency for Heat Pumps	High-Efficiency Heat Pumps	+$47,300
	$163,300	$210,600	
Grid-Interactive Measures	None	Smart thermostats, smart electrical panels, transactive energy platform, water monitor devices	+$238,700
	$0	$238,700	
Solar Photovoltaics	T24 Requirements [Roof-mount at 115 kW_{DC}]	Proposed System [Roof-mount at 115 kW_{DC} and Façade-mount at 300 kW_{DC}]	+$1,560,500
	$420,000	$1,980,500	
Battery Energy Storage System	T24 Requirements [130 kWh / 30 kW]	Proposed System [870 kWh / 250 kW]	+$1,006,485
	$234,815	$1,241,300	
Microgrid Components	None	Electrical and Wi-Fi communication connections; system integration [microgrid controller included in BESS price]	+$968,600
	$0	$968,600	
EV Charging and EV Ready Infrastructure	T24 Requirements [Transformer at 150 kW, 4 L2 EV Charger, 18 receptacles at 208V-20A]	CEC Grant Requirements [Transformer at 250 kW, 14 L2 EV Charger, 7 Receptacles at 208V-20A]	+$96,200
	$82,100	$178,300	
Total Incremental Cost Increase (+) or Savings (-) for the development			+$4,129,985
Incremental cost per residential unit ($)			+$51,625

Source: Arup

Table C-3: Comparison of Incremental First Cost Per Unit, Standard Design Versus Proposed Design

	Incremental First Cost per Unit ($/Unit)		
	Standard	**Proposed**	**Savings**
Purchase	NA	NA	NA
Rental	$25,190	$85,163	-$59,972

Source: Arup

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Appendix D: List of Emerging Energy Technologies

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APPENDIX D:
List of Emerging Energy Technologies

The PCTV team included eight emerging energy technologies in the Proposed Design. They provided the best opportunities to reduce building energy usage and electrical demand. They are:

- Prefabricated Envelope
- Phase Change Material
- Improved Sealing for Infiltration
- External Shades
- High-Performance Cool Roof
- Heat Pump Dryers
- Advanced Heat Pump Water Heaters
- High-Efficiency Mini-Split Heat Pumps

The following four grid-interactive measures provided the opportunity to further reduce building energy usage and electrical demand:

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The electric vehicle charging strategy measures include:

- Electric Vehicle Charging Stations
- Electric Vehicle Ready Infrastructure