CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

ENERGY RESEARCH AND DEVELOPMENT DIVISION

FINAL PROJECT REPORT

The Living Empowerment House Project

July 2024 | CEC-500-2024-087

PREPARED BY:

Becky Constantine
Alfonso Ceja
Innovative Housing Opportunities

Marc Costa
Amy Whitehouse
The Energy Coalition

Robert Fortunato
ForStrategy Consulting
Primary Authors

Molly Mahoney
Project Manager
California Energy Commission

Agreement Number: EPC-21-022

Anthony Ng
Branch Manager
TECHNOLOGY INNOVATION & ENTREPRENEURSHIP BRANCH

Jonah Steinbuck, Ph.D.
Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

Drew Bohan
Executive Director

DISCLAIMER

This report was prepared as the result of work sponsored by the California Energy Commission (CEC). It does not necessarily represent the views of the CEC, its employees, or the State of California. The CEC, the State of California, its employees, contractors, and subcontractors make no warranty, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the CEC, nor has the California Energy Commission passed upon the accuracy or adequacy of the information in this report.

ACKNOWLEDGEMENTS

Innovative Housing Opportunities would like to thank individuals and institutions that made this concept design phase possible. The project team thanks all contributing members at Innovative Housing Opportunities, ForStrategy Consulting, The Energy Coalition, Community Electricity, Arup, Winston Engineering, and the countless residents at Innovative Housing Opportunities properties who engaged in feedback, as well as numerous community-based organizations in Santa Ana engaged during the project. Innovative Housing Opportunities would also like to thank the following Technology Advisory Committee members for their time and insight during the design phase: Baird Brown of eco(n)law, Phil Friedl of Jones Lang LaSalle, Kay Aikin of Dynamic Grid, Nick Brown of Build Smart Group, Sean Armstrong of Redwood Energy, Timothy McDonald of Onion Flats, Gary Klein of Klein and Associates, Mike Steffen of Walsh Construction, and Marcela Oliva of Los Angeles Community College District/Los Angeles Trade Technical-College.

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

The Living Empowerment House marks a groundbreaking venture in urban development, creating the world's premier zero-carbon, affordable, replicable, grid-responsive, and equitable multifamily living space centered around transactive energy. Comprising two mid-rise mixed-use buildings housing 237 units, the project employs wood-framed modular construction and subterranean parking, integrating with the Santa Ana community's main thoroughfare.

This visionary project incorporates cutting-edge sustainability features, including 2.5 megawatt hours of battery storage and 945 kilowatts of solar photovoltaics. With a remarkable 22 percent reduction in peak demand, the development achieves island-able functionality from 4:00 p.m. to 9:00 p.m. on high-demand days. The design budget, initially projected at $177 million, was optimized to $151 million through modular construction and decentralized mechanical systems.

The Living Empowerment House represents a harmonious convergence of regulatory expertise and innovative engineering solutions, adeptly navigating the complexities of mixed-use development. Achieving 100 percent on-site self-consumption during peak demand hours underscores the success of passive load reduction strategies, decentralized mechanical equipment deployment, and creative use of subterranean parking for oversized batteries. Modular footprints and strategic use of state and federal incentives enhance the cost-effectiveness.

Addressing regulatory and operational intricacies, the project employs master metering for the building and private metering for units. Large, distributed energy resources, streamlined billing, and tenant rewards contribute to operational efficiency. Prioritizing community engagement, especially with low-income residents, through informational programs, data initiatives, and an electric vehicle program fosters inclusivity. Revenue generation via a microgrid controller connected to a virtual power plant program ensures financial viability.

The Living Empowerment House, led by Innovative Housing Opportunities, and involving Studio One Eleven, Arup, Winston Engineering, Community Electricity, ForStrategy Consulting, The Energy Coalition, and the Technical Advisory Committee, exemplifies a transformative approach to sustainable, economically viable, and community-centric urban living. This pioneering project sets a new standard for environmentally conscious urban development.

Keywords: decentralized energy, multifamily housing, virtual power plants, disadvantaged communities, distributed energy resources, energy efficiency, transactive energy, building decarbonization

Please use the following citation for this report:

Ceja, Alfonso, Becky Constantine, Marc Costa, Amy Whitehouse, and Robert Fortunato. 2023. *The Living Empowerment House Project* . California Energy Commission. Publication Number: CEC-500-2024-087.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Executive Summary

The Living Empowerment House Phase I project's purpose is to design the world's first zero-carbon, affordable, replicable, grid-responsive, and equitable multifamily development that is designed for transactive energy. This project developed designs for 237 residential units in two mid-rise mixed-use buildings, using wood-framed modular construction, subterranean parking, and space programming to embrace the main thoroughfare of the Santa Ana community. The project design includes 2.5 megawatt hours of battery storage and 945 kilowatts of solar photovoltaics on the roof and facades of the building, plus 22 percent of peak demands curtailed to produce an island-able project between peak demand hours of 4:00 p.m. and 9:00 p.m.

This project embodies a unique integration of regulatory knowledge with innovative architecture and engineering approaches, to overcome multiple challenges related to mixed-use development. The Innovation Housing Opportunities team proved that a mid-rise building with a small roof footprint and no outdoor space for renewables can achieve 100 percent on-site self-consumption from 4:00 p.m. to 9:00 p.m. on the highest peak demand day. To lower costs and make roof space available for solar power, passive strategies were used to lower the base load, including decentralizing all mechanical equipment, undergrounding parking areas to house "oversized" batteries, planning efficient modular footprints, and stacking state and federal incentives. By opting to master meter the building and privately meter the units, connecting large, distributed energy resources behind the meter, managing billing and tenant rewards through their rental bill, and avoiding complex and unfavorable energy tariffs, the Innovation Housing Opportunities project team addressed regulatory and ongoing operational challenges. Further, the Innovation Housing Opportunities project team continues to engage low-income residents through information, data, and electric vehicle program offerings, and provide revenues through a microgrid controller connected to a virtual powerplant program.

This combination of strategies will result in lowering the first costs of construction, lowering operating costs for the developer and residents, ensuring serviceability of the equipment by maintenance staff, and empowering the residents to interact with the building and transportation systems through education and technology programs offered by the developer.

CHAPTER 1: Introduction

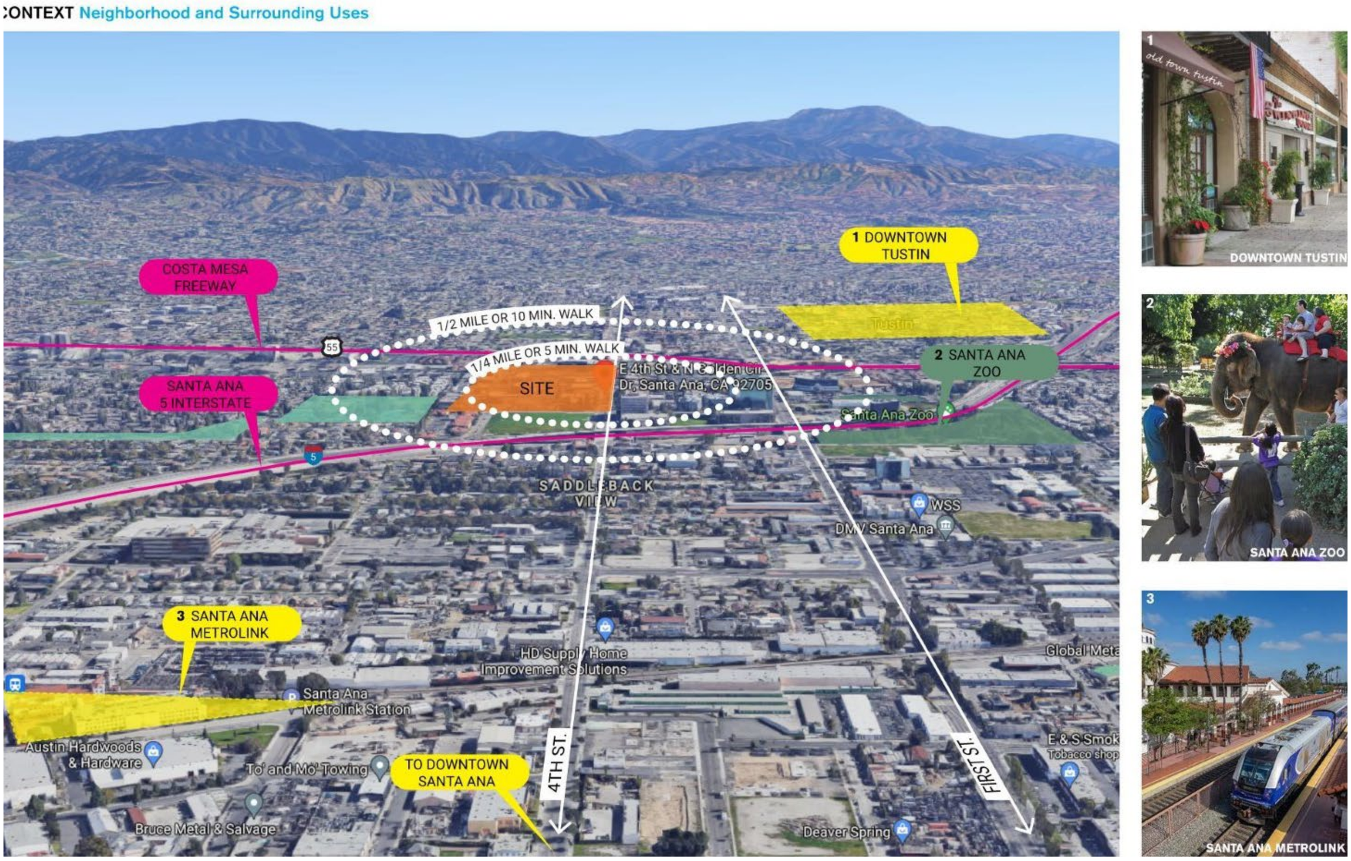
The content of this report is the summary of efforts in the first phase of Grant Funding Opportunity (GFO-20-305), the NEXT EPIC Challenge. The purpose of this solicitation is to fund a design-build competition that will challenge multi-disciplinary project teams to design and build a mixed-use development – using cutting-edge energy technologies, tools, and construction practices - that is affordable, equitable, emissions-free, and resilient to climate change impacts and extreme weather events.

Climate change and housing affordability present two of the most significant challenges facing California. The deadly and destructive fires of the past few years, as well as findings from California's Fourth Climate Change Assessment (CEC, 2018), highlighted the dire impacts expected) from climate change on California if greenhouse gas emissions are not dramatically reduced. To avoid the most severe impacts of climate change, Senate Bill 100 set aggressive policy goals to decarbonize its energy sector by 2045. Building decarbonization – primarily achieved through energy efficiency, on-site renewable generation and storage, and full end-use electrification – is a key strategy for realizing the state's goals to reduce greenhouse gas emissions. Many of California's local governments are already pursuing ordinances that would require all new and existing buildings to be zero-emission by 2030 and 2050, respectively.

The main challenges faced in this project were meeting the on-site energy resilience metrics, given the form factor of the buildings, while also keeping the project financially viable. The requirement to be energy self-sufficient between 4:00 p.m. and 9:00 p.m., even on the most extreme design day, was a challenge. The solutions included locating generously sized battery energy storage systems in the at-grade and sub-terranean parking, using facade solar photovoltaic (PV) in addition to the roof, and selecting highly efficient and flexible demand appliances. Financial barriers were overcome by specifying a master metered building to hedge utility tariff uncertainty, stack various ratepayer and federal incentives, and lastly, participate in a virtual power plant to earn grid service revenue to buy down the enhanced distributed energy resources (DER).

Figure 1 illustrates the context and location of this project. Situated between major freeways and adjacent to both a major transit line and downtown corridor, the Living Empowerment House sits in a highly viable location within the City of Santa Ana.

Figure 1: Areal View of Project Site



Source: Innovative Housing Opportunities

This project blends the opportunities to transform the community, the lives of future residents, and the multifamily housing industry through innovative aesthetic design combined with replicable energy features.

CHAPTER 2: Project Approach

Innovative Housing Opportunities (IHO) served as the prime recipient for the grant and worked with Studio 111 through the architectural design process. Arup provided conceptual and design engineering, as well as energy and emissions analysis. Winston Engineering supported Arup and contributed to civil and overall project engineering. Community Electricity managed the strategy and partner development of energy assets. The Energy Coalition and ForStrategy served as general advisors.

The specific objectives included:

- All building end-uses must be electric (no gas consumption allowed).
- A minimum of 20 percent of the building's peak load must be available to be temporarily managed or curtailed to respond to grid conditions.
- The building's residential load during peak demand hours, 4:00 p.m. to 9:00 p.m., must be met through a combination of on-site renewables, on-site storage, and load management.
- All residential end uses must be controllable through the home energy management system and be capable of responding to real-time pricing signals.
- The microgrid controller(s) must be interoperable with DER aggregation platforms such as Virtual Power Plants.
- 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).
- The microgrid must be sized for indefinite renewable-driven backup power of Tier 1 critical loads using any combination of on-site renewables, on-site storage, and load management.
- 20 percent of all parking spaces associated with the development must have electric vehicle (EV)-charging stations that can respond to grid- and building signals.
- All remaining parking spaces must be EV-ready, meaning they must have a dedicated electrical circuit with the capacity to eventually become a charging station.

To the fullest extent possible, every active and passive energy-generating and consuming component of the building was selected based on its ability to contribute to transactive energy, lower energy bills for occupants, and maximize grid benefits. The team also interviewed the building owner and maintenance staff and found a strong preference for equipment they can self-service, easily replace, and with warranties of 10 years or longer. From the outset of the project, the team considered a mix of both technologies and holistic approaches, such as PassiveHouse, Leadership in Energy and Environmental Design (LEED), and Net Zero Energy certification systems. The overall goal was to specify a technology mix that lowered the buildings' energy consumption during the 4:00 p.m. to 9:00 p.m. peak as required in the grant, and that enabled solar and storage to meet the on-site resilience requirements.

Overall Design Approach and Strategies

A literature review and project team experience working with the U.S. Department of Energy, National Laboratories, and the International Energy Agency, pointed to a suite of interconnected technologies that contribute to the occupants, environment, and the grid.

To meet the grant's specified objectives, the team hosted a design charrette to create a vision statement for the project. This resulted in the following guiding language:

> "The Living Empowerment House will create the first zero carbon, affordable, replicable, and equitable multifamily development that is designed for transactive energy. In planning and execution, this project will unite residents, buildings, and businesses through interactive, people-powered technology that invites the industry to create more connected energy communities."

With this vision established, the team further developed an owner's project requirements document. It outlined a shared strategy that served as a basis for decision-making on the technology selection, architectural layout, engineering specifications, and tenant engagement strategies. The owner's project requirements included the following four main criteria:

1. A healthier, safer, and more durable building for the tenants and the broader community
2. Lower first costs
3. Lower operation and maintenance costs
4. A more replicable, scalable system for affordable housing

The next phase in developing the project strategy included a series of in-depth focus groups with residents in two of IHO's existing properties. These meetings informed the project team that residents deeply care about their energy bills but have experienced difficulties in interacting with modern technology. Some residents were previously unhoused and stated that training and engagement programs would be greatly appreciated.

The team also engaged the maintenance staff to gather feedback on the feasibility of maintaining an all-electric building. The staff indicated a strong preference for simple, familiar air conditioning equipment, as opposed to large centralized mechanical equipment, which they did not have a working knowledge to service on-site.

The culmination of the design charrette, resident focus groups, and maintenance staff interviews led to the creation of the following guiding principles:

- IHO is the long-term holder and operator of these buildings. All projects must strive to reduce operational and maintenance expenses in addition to reducing capital expenditures.

- Building systems should be simplified and streamlined to maximize efficiency and be easily replaceable. Focus on first-time, operational, and ongoing maintenance costs.
- Materials should be selected to maximize the product warranty and reduce replacement costs.
- The buildings should maximize opportunities for passive heating/cooling ventilation, and natural daylight.
- The buildings should maximize renewable energy opportunities and the roof should be seen as "the engine of the building" where roof obstructions and shading are minimized.
- The buildings should be designed and built so they don't use natural gas.
- The building should be master metered, with all living units and end uses individually metered. The ability to have real-time and simple visualizations of energy consumption is paramount to creating the residents' sense of ownership in efficiency and conservation.

Architectural Designs, Aesthetics, and Functionality

Given the aggressive energy design requirements of the grant, the team performed an in-depth analysis of the form factor, orientation, and configuration of the two buildings. A multi-story building with an all-electric design points to the need to maximize the roof space for solar photovoltaics, and any available space for battery electric storage systems. The team addressed the fact that this is a tall building with a small footprint, by decentralizing all equipment and freeing up the roof for maximum solar use. Parking area served as the location to fit the large energy storage batteries, because there was no other available open space for the storage system. The team integrated facade solar into the shading strategy for the south- and west-facing windows, which were reduced and inset into the building to add a texturing effect while adding an aesthetic design feature. The image below (Figure 2) depicts the result of the building orientation and roof space utilization.

Figure 2: Living Empowerment House Isometric Rendering

Source: Innovative Housing Opportunities

To complement this highly technical exterior shell of the building, the team carefully designed an interior courtyard to serve the residents as an outdoor living space. The landscape design in the image below for the North and South buildings enhances sustainability and energy efficiency by incorporating raised commercial patios and strategically selected tree species to reduce heat gain and energy consumption (Figure 3).

Figure 3: Interior Courtyard Rending of the South Building

Source: Innovative Housing Opportunities

Design Strategies for Integrating Conventional and Emerging Energy Technologies

The IHO project team performed preliminary energy and emissions modeling at the conceptual design stage to determine how different technology mixes would perform compared to a design that is simply code-compliant. The modeling was completed in four stages using different tools to benchmark the proposed design and various design alternatives against the grant criteria. The stages are described as follows:

- **Solar radiation study:** Arup used a proprietary tool to evaluate incidental radiation on the buildings to understand their cooling loads. This tool was used to compare different building massing and exterior shading strategies to reduce cooling, anticipated to be a large energy driver because of the buildings' climate zone. It also enabled the team to determine the optimal places for PV on the buildings.
- **IES energy analysis:** Arup built a conceptual energy model in Integrated Environmental Solutions Virtual Environment (IESVE) 2023 Feature Pack 1[1] to estimate site energy performance. This tool provided information on the annual energy consumption, hourly consumption, as well as utility costs for each of the design options explored. It was also used to benchmark the proposed design against a Title 24 standard design representing a code-compliant building (CEC, 2022).

[1] IES is a software provider for building energy modeling tools. The Virtual Environment is a suite of integrated analysis tools for the design and optimization of buildings. https://www.iesve.com/software/virtual-environment

- **Microgrid spreadsheet analysis:** Arup placed the hourly data from the IES energy model into a spreadsheet tool to size the microgrid. For each design option evaluated, an optimized microgrid size was calculated.
- **First Cost Analysis:** Arup provided the cost estimator with design details for each design option. With this information, they provided first costs, which helped the design team weigh energy efficiency and grid management ability against capital costs when deciding on the proposed design.

Sequencing this approach ensured that the design grew and evolved towards the aspirational goals of the project. These studies provided the project team with the information to optimize the design and achieve greater energy performance well beyond what is typically seen in affordable housing.

End-Use Energy Efficiency

Several design alternatives were evaluated to meet the performance and operational goals. The measures were developed and selected during a series of design charrettes with the project team. Each of the measures was assessed for annual energy performance, peak electrical demand, energy consumption between 4:00 p.m. to 9:00 p.m., ability to load-shift, and life cycle cost benefits. The team's approach was to select proven technologies for the appliances and use emerging technologies for the microgrid and demand flexibility controls.

The following energy efficiency measures (EEM) were evaluated for annual energy consumption impacts:

1. **EEM – 1, Basis of Design (BOD):** represents the design base case, specifically, the starting point. It consists of standard residential wood construction, in-line fans for continuous ventilation, bathroom, and kitchen exhaust fans for local source ventilation, a one-to-one split system for space conditioning, and individual heat pump water heaters.
2. **EEM – 2, Passive House Envelope:** Replace the envelope of the BOD with a high-performance envelope built to passive house standards.
3. **EEM – 3, Energy Recovery Ventilator:** replace the inline fan for continuous ventilation and the bathroom exhaust fans in the BOD with an energy recovery ventilator for heat recovery.
4. **EEM – 4, Packaged Terminal Heat Pump:** incorporates packaged terminal heat pumps for space conditioning and energy recovery ventilation in place of 1:1 split systems and inline fans.
5. **EEM – 5, Water Source Heat Pump:** replace the split systems with water-to-air heat pumps for space conditioning. In addition, water-to-water heat pumps replace the air source heat pumps used in the BOD for domestic hot water heating. These water source heat pumps are connected to a central ambient water loop that serves as a heat source during the winter and a heat sink in the summer for heat rejection. A

central air-to-water heat pump as well as a cooling tower are provided to regulate the temperatures in the central ambient water loop.

6. **EEM – 6, Central Plant:** delivers space heating and cooling to the apartment units through central chilled and hot water. A reversible heat pump generates both hot water in the winter and chilled water in the summer, delivered to hydronic fan coil units in each residence to provide conditioning. An additional air-cooled chiller is provided for top-off cooling.

Load Flexibility, Grid Interactions, and Residents' Engagement

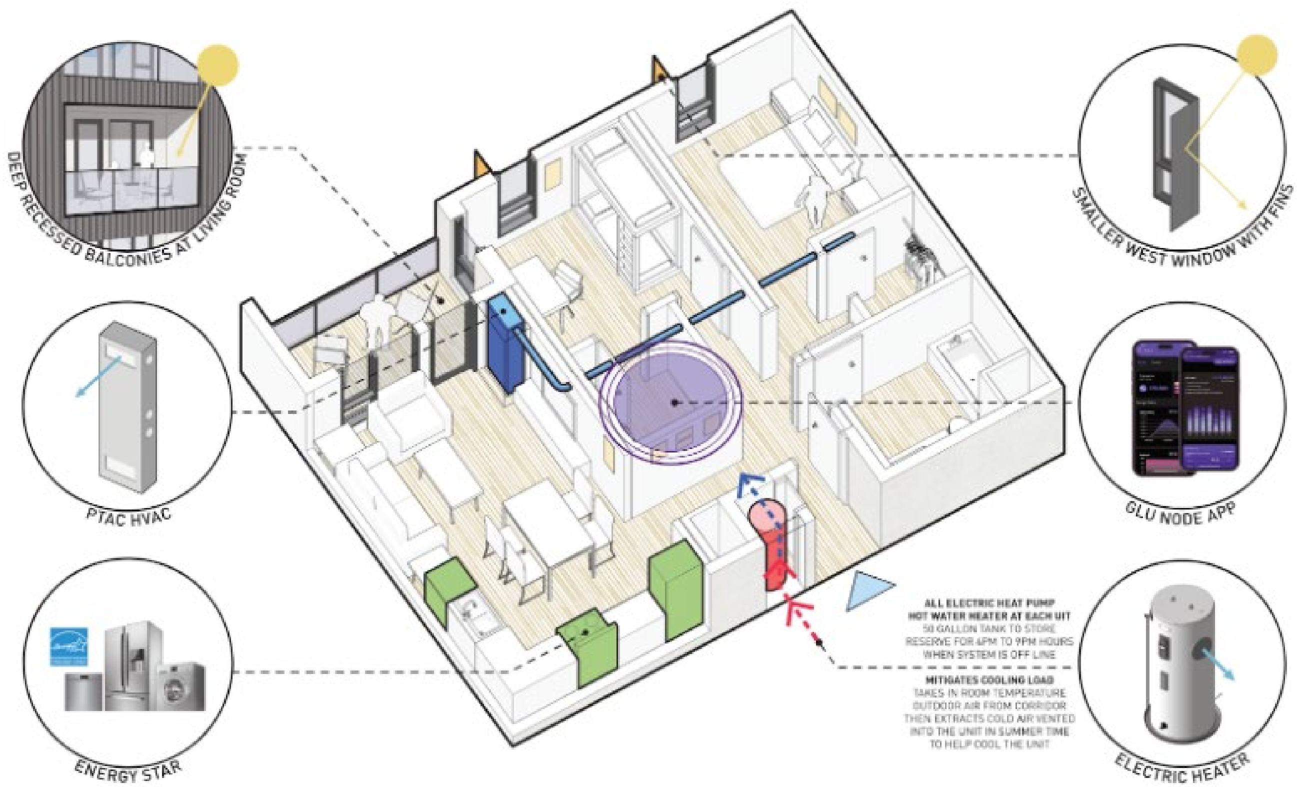
The technologies just described served as the suite of options the team evaluated during the technical analysis phase of the grant. The team's technical experience was complemented by interviews with IHO's portfolio of residents. This customer-centric approach informed the final selection of the team's design alternatives. This provided the team with an approach to a deep level of customer engagement. A key feature of that customer engagement included a transactive energy program, visual feedback platforms, and financial rewards for participating in the energy features of the buildings.

The overarching goal is to reduce costs by reducing or eliminating loads (for example, recirculation pumps) and installing smart, efficient equipment. Due to Southern California Edison Rule 18 (CPUC, 2009) for master metering, tenant rent must be billed equally to each tenant regardless of consumption; however, the strategy is to allocate rewards to tenants to encourage smart energy actions and demand flexibility. This approach is enabled through solar, storage, and bi-directional charging that are included in the virtual power plant. Although there will only be a master meter, each tenant will have their dwelling unit third-party metered, and all end-uses will be disaggregated via smart panels and cloud-based application programming interfaces. Through meticulously designed, smart contracts in the energy management system, the team's operations strategy will offer diverse scenarios of customer preference for thermal comfort, optimization of financial gains, carbon reduction, and load flexibility. The transactive energy rewards program would include:

- A microgrid controller that relays price signals between a virtual power plant platform and end-use devices.
- Heating, ventilation and air conditioning (HVAC), water heating, and plug load appliances that will be controlled (through OpenADR3, CTA2045, and IEEE 2030.5) and optimized for bill reduction, grid exports, and carbon reduction.
- A tenant-facing mobile application to visualize current and forecasted energy bills and rewards associated with smart energy actions.

Figure 4 illustrates a typical living unit's floor plan along with the final energy measures depicted in the bubbles surrounding the image. The common theme of the selected measures is that the equipment is decentralized. Rather than specifying large, centralized equipment, typically located on the roof of the building, the image shows the individual water and space conditioning equipment located inside the living units. The team also included features related to the building envelope, which minimized summer heat gains, and minimized winter heat loss through careful orientation of the building and sizing of the windows. Lastly, the energy appliances are all connected to a smart mobile application that visualizes daily energy consumption, so the residents can understand and control their energy according to their personal preferences.

Figure 4: Typical Living Unit Floorplan and Energy Technologies



Source: Innovative Housing Opportunities

Final Design Strategies

Based on the team's development of the owner's project requirements, design charrette, interviews with residents and staff, engineering analysis, architectural design iterations, and coordination with project advisors, the team reached consensus on a suite of measures that met the intent of the grant and satisfied multiple strategic objectives for the project. This subsection describes each aspect of the building's energy systems that shall be included in the final construction drawings and cost estimates.

Domestic Hot Water

The design approach to decentralize all energy equipment and preserve open space on the roof led the project team to select a water heating technology that would be installed inside each living unit. The project team selected the Rheem Proterra water heater. This air-to-water heat pump uses surrounding air to heat the domestic hot water (DHW) electrically. The proposed design provides each unit with its heat pump water heater to avoid large losses in energy from recirculating hot water throughout the building. Moreover, it would be configured to capture excess heat from the apartments during the summer – providing space cooling – to heat the DHW. This heat recovery benefit has not been captured in the energy model.

With a built-in tank and smart controls, this system can preheat – enabling load shifting. This benefit was critical to the project given the grant criteria around curtailing load and minimizing energy use between 4:00 p.m. to 9:00 p.m.

The specified appliance has an efficiency of 3.5 Uniform Energy Factor (UEF) which is much higher than the 2.2 UEF efficiency required by code. No code compliance credit is being taken for a reduction in DHW loads, because the standard design and proposed design assume the same plumbing fixtures.

Cooking

Although no equipment has yet to be specified, the team agreed to use all EnergyStar equipment. The stove will be induction, which is more efficient at heating food than electric-resistant ranges. Studies have shown that these systems require less exhaust as well as space cooling than their counterpart electric resistance stoves. They also enhance occupant safety because the cooking surface does not get as hot as an electric resistance cooktop. It is anticipated that 120-volt models may be available by the time of construction; however, 240-volt induction ranges were used for energy modeling purposes.

Demand Flexibility (Load Shedding & Load Shifting)

The team diligently analyzed technologies that are manufactured with demand flexibility capabilities that include software protocols meeting the latest industry standards for communication and data interoperability. A hallmark feature of this project is that nearly all appliances shall be able to be controllable and share data on common data platforms compatible with the microgrid, virtual power plant and prosumer mobile application. The buildings will have batteries with smart inverters on IEEE 2030.5 (IEEE SA, 2024) and/or OpenADR3.0 (OpenADR Alliance, n.d.) that will be used for load shifting and discharging energy from 4:00 p.m. to 9:00 p.m. In addition, the DHW heat pump water heaters will be configured via the CTA (Consumer Technology Association) 2045 standard for preheating to heat water in the tanks in the morning and early afternoon, so that energy spent on DHW heating is minimized during 4:00 p.m. to 9:00 p.m. (CTA, 2024). Tenants will also have the ability to opt into a program where their thermal setpoints can be adjusted to respond to grid conditions and demand response events. The project team is exploring time-of-use pricing for laundry to encourage laundry use outside of peak hours.

Electric Vehicle Charging & Vehicle-to-Grid (V2G)

Approximately 21.3 percent of the total parking spots (70 out of 329) will have EV charging stations. Among these, 10 charging stations will be Tritium 75 kilowatt (kW) fast chargers, 45 Level 2 Chargers, and 15 will be bi-directional (V2B) 22 kW chargers equipped with a backup battery system. The bi-directional chargers use a 20-foot container housing a 250-kW power inverter and a 645-kilowatt-hourkWh storage capacity, enabling bidirectional power flow between the PV, grid, and vehicles (V2G). The remaining parking spots, which are approximately 78.7 percent of the total (259 out of 329), will be EV-ready. This means that they are designed with the necessary electrical infrastructure to accommodate future installation of EV charging equipment, all with IEEE 2030.5 compatibility.

Envelope

To minimize the negative effects of unwanted summer heat gains, and winter heat losses through the envelope assemblies, the team specified enhanced products and performance features of the wall and roof components. The modeled envelope constructions are provided in Tables 1 and 2. Both the opaque and the transparent envelope assemblies perform better than what is required by Title 24. The design opted for a higher R-value batt insulation in the exterior walls rather than continuous exterior rigid insulation so that the insulation could be applied in the factory as part of the modular construction. Standard airtightness is assumed: maximum 0.4 cfm/ft² (facade area) at 75 Pa[2]. This airtightness can be achieved through applying a standard house wrap/weather barrier.

Table 1: Envelope Assembly Summary

Assembly Type	Insulation	U-value	Construction Details
Exterior Wall	R-19 batt	U-0.071	2″ x 6″ wood framing 24″ on center with R-19 cavity insulation (5.5″ fiberglass batt)
Exterior Roof	R-38 continuous	U-0.026	R-38 insulation entirely above deck (6.5″ polyisocyanurate)
Exposed Floor	R-11 batt	U-0.071	2″ x 6″ wood framing 16″ on center with R-11 cavity insulation (3.5″ fiberglass batt)
Slab on Grade	Uninsulated	F-0.73	Uninsulated concrete

U-value = the rate of transfer of heat through a structure
R-value = a measure of how well a two-dimensional barrier, such as a layer of insulation resists the conductive flow of heat.
Source: Innovative Housing Opportunities

Table 2: Transparent Constructions Summary

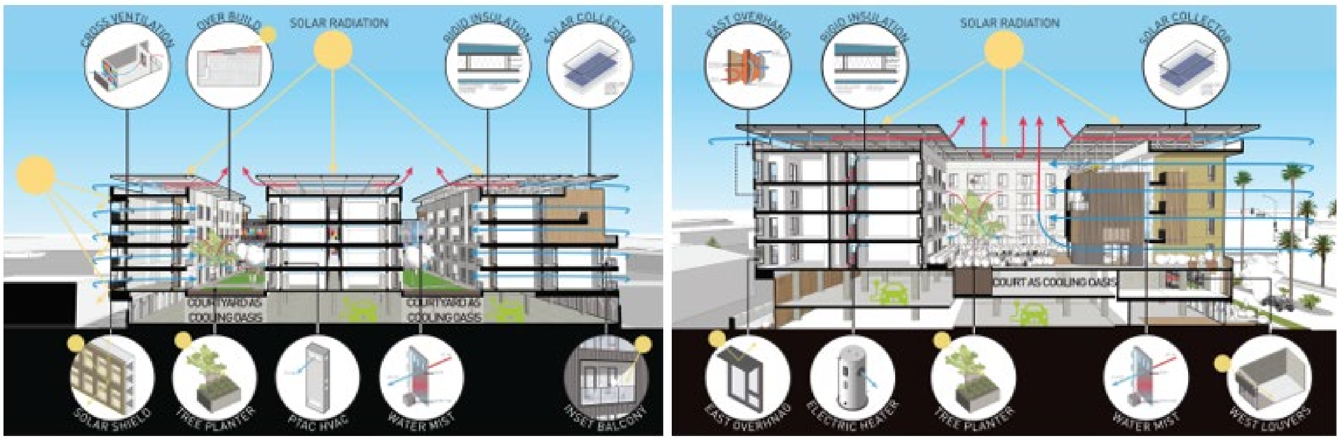
Assembly Type	U-Value	SHGC	Construction Details
Operable Windows	0.34	0.23	Operable double pane low-e coated, argon-filled insulated glass units with thermally broken vinyl frames
Storefront Windows	0.41	0.26	Double pane low-e coated, air-filled insulated glass units with thermally broken vinyl or aluminum frames
Glazed Doors	0.34	0.23	Operable double pane low-e coated, argon-filled insulated glass units with thermally broken vinyl frames

SHGC = solar heat-gain coefficient ratings for windows.
Source: Innovative Housing Opportunities

[2] Represents the air leakage rate in cubic feet per minute per square foot (cfm/ft²) at a pressure of 75 pascals (Pa).

Figure 5 illustrates the high-performing features of the envelope. Solar gains, air infiltration, moisture control, and passive design of windows and shading, along with optimized natural airflows all played a role in the final strategy.

Figure 5: High Performing Envelope Features



Source: Innovative Housing Opportunities

Heating, Ventilation, and Air Conditioning

Based on the maintenance staff's preference for 'easy-to-service' equipment, and systems that would not result in a total space conditioning outage, the team selected a packaged terminal air conditioning unit located in each living unit. The design includes a packaged terminal heat pump with a built-in energy recovery ventilation by Ephoca (or equivalent). The energy recovery ventilator makes this unit extremely efficient and will have an air return in each of the bathrooms. By design, this system will provide bathroom source ventilation and whole dwelling unit ventilation. In addition, this unit contains a highly efficient air filter, with a rating of a MERV 13 filter. It should be noted that the cooking range will need its own dedicated exhaust range hood vented outdoors to preserve the hygienic conditions required to separately filter cooking exhaust containing cooking particulate matter.

Key assumptions are provided in Table 3. As shown, the cooling and heating efficiencies of this system are in line with Title 24. It, however, achieves higher efficiency than the standard design HVAC systems due to built-in heat recovery and electrically commutated fan motors, which offer three-speed operation of the indoor terminal units.

Table 3: Residential HVAC System Comparison

Building Element	Proposed Design	Title 24 Standard Design
Conditioning type	packaged terminal heat pump	single-zone system heat pump
Cooling Efficiency	10.96 EER, 13.92 IEER	SEER 14
Heating Efficiency	3.30 coefficient of performance	direct exchange heat pump: HSPF 8.2 electric resistance supplemental heat: 100% AFUE.

Building Element	Proposed Design	Title 24 Standard Design
Supply Fan Power	0.25 with cfm cycling	0.75 with cfm cycling
Minimum Air Flow Ratios	50%	100%
Exhaust Fan Power	0.20 with cfm	Included in supply fan power
Economizer	No	No
Heat Recovery	No	No

AFUE = Annual Fuel Utilization Efficiency
cfm = cubic feet per minute
EER = Energy Efficiency Ratio
HSPF = Heating Seasonal Performance Factor
IEER = Integrated Energy Efficiency Ratio
SEER = Seasonal Energy Ratio
Source: Innovative Housing Opportunities

Process and Miscellaneous Load

A large percentage of annual site energy consumption is attributed to the miscellaneous equipment category. This category primarily consists of residential plug loads, including residential cooking (separate from the commercial cooking category), laundry, and other residential electric demands. This load is restricted given that residential plug load demand is outside the scope of controllable design factors. However, the project has specified smart receptacles and switches that can be hardwired into the units. This gives the residents and building owner additional opportunities for voluntary load-shedding capabilities through the prosumer network program envisioned as part of the project. In this scenario, power will be managed through smart outlets. Certain outlets that host non-critical equipment have the option to be controlled through the prosumer mobile application, microgrid controller, and/or virtual power plant (VPP) software to allow residents to choose to shut off electricity usage during demand response events. The loads were modeled identically between the standard design and the proposed design.

Renewables and Storage

As a benefit of selecting decentralized water and space conditioning equipment and locating those appliances within the living units, the roof space on the buildings is completely open for maximum coverage of solar arrays. However, even with this open space on the roof, more solar capacity was needed to meet the design criteria of the grant. Therefore, the buildings include both rooftop solar PV and building-integrated PV on the facades. To further meet the design challenge, more capacity outside the productive hours of the solar was needed. This resulted in both buildings having a generously sized battery energy storage system (BESS) on site. These systems were designed and sized to meet the buildings' entire energy demand between 4:00 p.m. to 9:00 p.m. every day throughout the year. As such significantly more PV is provided than what is required for Title 24; the battery is also much larger than the code minimum as seen in Tables 4 and 5.

Table 4: Solar Photovoltaic Requirements

Building Element	Proposed Design	Title 24 Standard Design
PV Array Rated Power (kW)	945 kW	555 kW

Source: Innovative Housing Opportunities

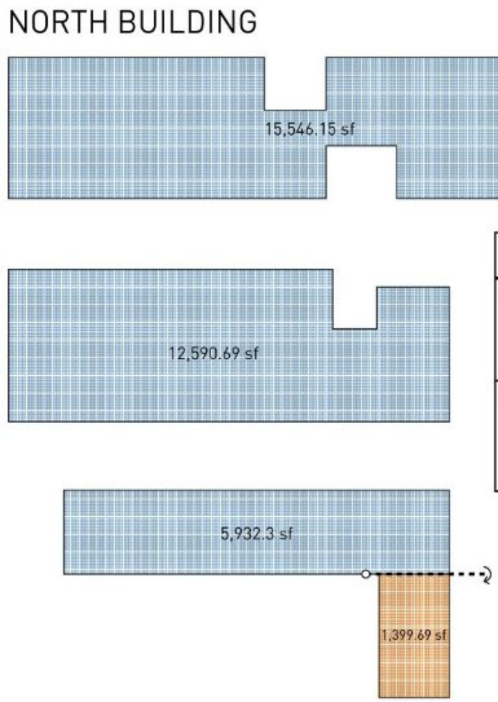
Table 5: Energy Storage Requirements

Building Element	Proposed Design	Title 24 Standard Design
Battery energy storage capacity (kWh)	2,575 kWh	520 kWh
Battery power capacity (kW)	649 kW	131 kW

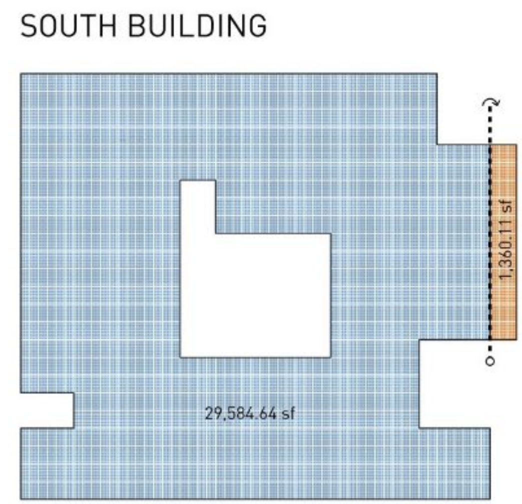
Source: Innovative Housing Opportunities

Figures 6 and 7 below illustrate how the roof space was maximized, yet additional facade space was needed to meet the solar capacity, which satisfied the ability to island the building from the grid.

Figure 6: Top View of Solar Photovoltaic Systems

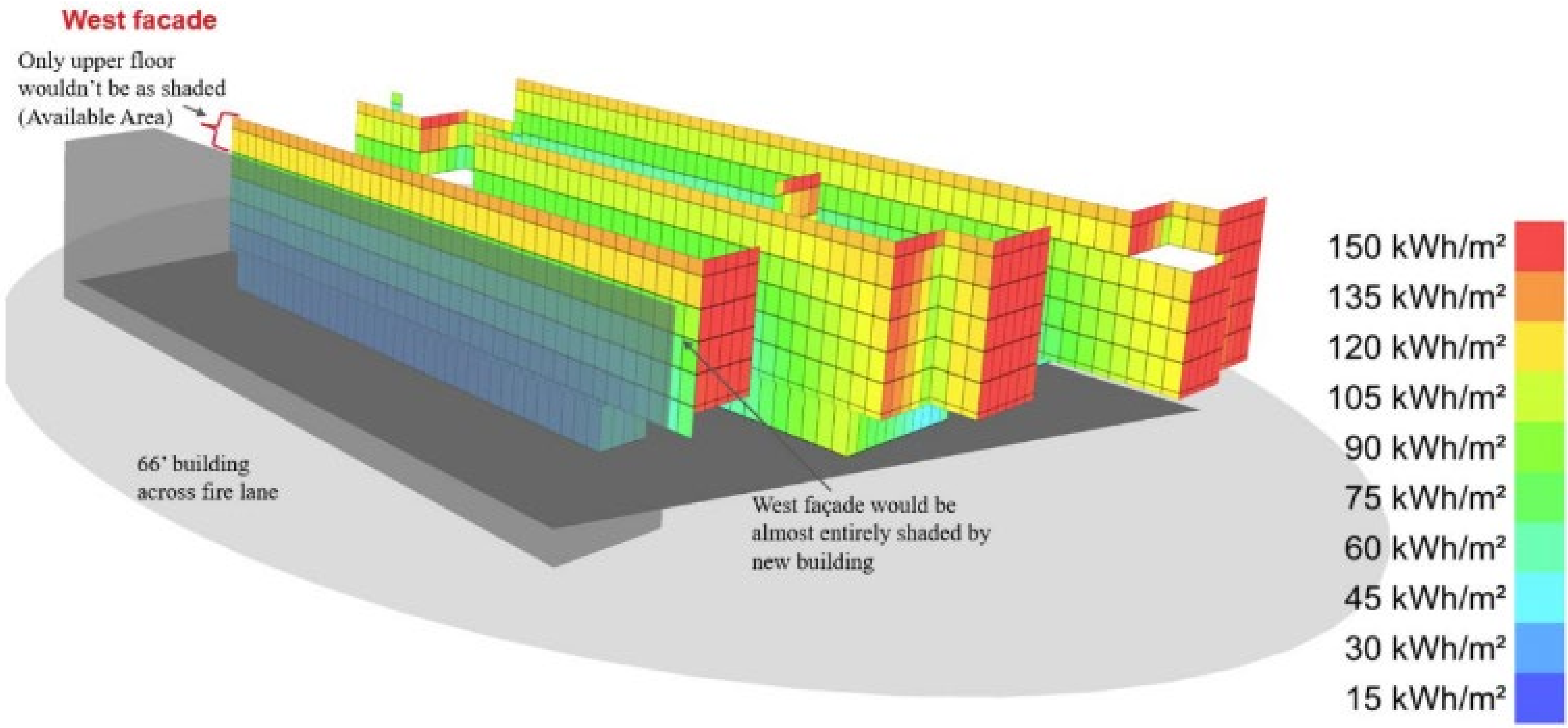


	Roof top PV	Facade PV	Total
North Building	34,000 SF area for PV 476 kW 1322 panels 23,186 panel area	2,800 sf area for PV 40 kW 111 panels 1,917 panel area	36,800 sf area for PV 516 kW 1433 panels 25,133 panel area
South Building	29,500 sf area for PV 412 kW 1144 panels 20,064 panel area	1,300 sf area for PV 18 kW 50 panels 877 panel area	30,800 sf area for PV 430 kW 1194 panels 20,941 panel area



Source: Innovative Housing Opportunities

Figure 7: Rendering of North Site Facade PV Potential



Source: Innovative Housing Opportunities

Microgrid Design Strategy

A typical building would not participate in a VPP or have a microgrid controller. The team recognized that an all-electric building that must be able to island from the grid would require an unusually large solar and battery system. However, such a system would significantly over-produce power at times when the building is not consuming the maximum electrical loads. This results in a large amount of standby power that would otherwise sit passively in the battery system. This excess power presented an opportunity to be put to work in the form of electrical grid market participation.

The paragraph provides a technical summary of the microgrid and VPP approach. A unique feature of this property is that the annual peak load (547kW) is twice the average demand (244kW) of the building, and the EPIC grant requires the annual peak load to be fully offset with on-site renewable energy generation and storage. With 946kW of solar PV and 2.575MW of battery storage, this building operates the same in short- and long-duration outages while dispatching demand flexibility modes in the heat pump water heater (HPWH) and HVAC. This project can 'afford' such a large DER system because the VPP vendor, Autogrid, estimates $530,000 in annual revenues from the master metered net exporting system. These revenues come from two strategies. The first is to dispatch excess energy from the battery to the grid. Autogrid monitors and manages this power and selects an appropriate wholesale market program of 'off-taker' for energy sales. The second opportunity for grid sales is to leverage the smart appliances in the buildings and send a control signal to the equipment to pre-heat, pre-cool, or turn off, among other demand flexibility strategies. The key strategy is that a micro-grid controller and VPP software both communicate with each other, the building, and the grid.

The paragraph summarizes the technical requirements and operations of the microgrid and VPP strategy. To support the microgrid, Schnider will provide a microgrid controller, and the AutoGrid Flex™ platform, and Predictive Controls™ Technology[3] will be used to co-optimize across site-specific and portfolio value streams. The microgrid controller and VPP platform will work together as a layered hardware and software architecture by incorporating market rules, rate regulatory requirements, and device specifications. The microgrid controller ingests load information and weather forecasts to create forecasts of building loads and solar production. These forecasts are then used by the VPP's advanced optimization algorithms to generate optimal plans for DERs such as energy storage and generators. During normal operations, the microgrid controller focuses on energy self-consumption, and loads will be optimized to lower energy bill costs; and as a secondary objective, maximize grid export revenue. During both temporary and longer outages, the microgrid controller optimizes energy load, and maximizes the hours of energy self-consumption from on-site power. By incorporating different value streams into the optimization function, the microgrid solution ensures resiliency and reliability of power to the sites, while simultaneously monetizing additional value streams of the microgrid assets. This will ultimately lower electricity bills and deliver additional grid services. It allows revenue stacking from energy bill arbitrage plus grid export proceeds to be delivered to tenants. The on-site DERs will include demand charge management, time-of-use arbitrage, and maximum use of renewable generation. Portfolio value streams from aggregating energy

[3] https://www.auto-grid.com/solution/derms/

flexibility across these on-site DERs include grid services (peak load shifting, frequency regulation, and non-wire alternatives valuation via dynamic rates) and market value streams (capacity markets and ancillary services). The microgrid will interact with VPP aggregation software to react to the Emergency Load Reduction Program, Proxy Demand Resource, and Demand Side Grid Support.

EV Charging and/or Electric Mobility Strategy, V2B and/or V2G capability

One hundred percent of the EV charging stations are equipped with the ability to respond to signals from the utility or grid. EVCS, an EV charging network provider, will provide a software package installed on the charging stations. The ability to monitor and throttle down kW output is available by adjusting a few simple settings within the software administrative web portal to lower peak demand when needed. All the Level 2 AC (alternating current) and DC (direct current) coupled charging stations have a 97 percent uptime rating. All equipment installed meets UL certifications and Energy Star requirements.

Approximately 21 percent of the total parking spots (70 out of 329) will have EV charging stations. Among these, 10 charging stations will be Tritium 75 kW fast chargers, 45 will be Level 2 chargers, and 15 will be bi-directional (V2B) 22 kW chargers equipped with a backup battery system. The bi-directional chargers use a 20-foot container housing a 250-kW power inverter and a 645-kWh storage capacity, enabling bidirectional power flow between the PV, grid, and vehicles (V2G).

The remaining parking spots, which are approximately 79 percent of the total (259 out of 329), will be EV-ready. This means that they are designed with the necessary electrical infrastructure to accommodate future installation of EV charging equipment.

The integration of Smartcar technology enhances the functionality of the EV charging infrastructure by including managed charging, a vehicle-sharing program for residents, and integrations to the IHO rental billing and energy rewards system to lower the barriers to accessing and paying for vehicles.

The vehicle-sharing program demonstrates that the team’s vision extends beyond housing, encompassing a transformative approach to transportation. By embracing vehicle-to-everything “V2X” technologies, the project is poised to redefine the concept of EVs. Pre-owned EVs will be leased by the property owner and seamlessly integrated into a virtual power plant, bolstering energy storage capacity and resilience (V2G). This pioneering initiative will enhance community connectivity and contribute to improved employment opportunities, underscoring the team’s commitment to holistic sustainability.

Advanced Construction Planning and Practices

Given these advanced technologies, the project team recognized that the financial viability of the project would depend on saving financial resources wherever possible. One major area for cost savings presented itself in the strategy to pursue modular construction. The main consideration of modular construction was that it significantly accelerates the construction time because various building assemblies, primarily floor, wall, and roofs are pre-built to specification before arriving on-site. This saves approximately six months of construction time, which includes labor, land holding costs, and ultimately an expedited time to receive a certificate of occupancy and collect rental agreements. Therefore, modular construction is the proposed construction method for this project. An integrated design process included close coordination between the architect, engineers, and Plant Prefab - the modular construction vendor. Those coordination efforts yielded "modifications to the massing" as the buildings were broken down into components and brought forward the most advanced centralized and decentralized mechanical systems for evaluation.

According to the Modular Building Institute, the modular building saves time, materials, and cost because it minimizes material waste and air pollution given that the units are built inside a factory setting (MBI, 2023). This reduces worker heat exposure, an increasingly troubling issue. Furthermore, since the modules are built in a controlled setting, they can be built safer and faster with fewer on-site accidents. This approach reduces the amount of on-site work and introduces an enhanced level of quality assurance by building the assemblies off-site. The team anticipates a reduction in: construction noise on-site (because 70 percent of the building is done off-site), reduced construction parking, traffic, and congestion, reduced site trash (because 70 percent of the build is off-site), and construction time on-site would be 20 to 40 percent shorter, and most importantly, quality housing is made available to the community in less time. Due to the selection of HPWHs and packaged terminal air conditioners (PTAC) in each rental unit, a 22 percent reduction is estimated in costs directly related to plumbing, HVAC, and electrical; the elimination of water, duct, and refrigerant lines otherwise needed in centralized water and space conditioning equipment.

To limit embodied carbon emissions, the project team explored mass timber and other options but opted for a modular wood frame construction, which has a much lower embodied carbon footprint than a steel or concrete structure.

Market Transformation

This project demonstrates that all-electric multifamily affordable housing can be built to encompass the latest technologies while remaining economically viable. The guiding principles for the project included demonstrating that first and operating costs, would be competitive or better than average construction costs. Through the selection of decentralized equipment, and by choosing smart appliances, as well as modular construction, the team found advantages to this approach. The team also identified an innovative business model for the energy systems by creating entirely new revenue streams from accessing the energy wholesale market to amortize excess energy production. Furthermore, by partnering with a microgrid developer and VPP provider, the solar, storage, and vehicles are financed off-balance sheet and paid back over time through the proceeds from the electrical power grid sales revenues. This amortization of the energy system is further accelerated by stacking multiple public funding opportunities ranging from ratepayer programs, grant funds, and federal tax incentives. The main takeaway for stakeholders looking to replicate this model is to understand how valuable it is to stack multiple programs, and how to size and operate the DERs and demand flexibility to gain the most value from them. Typically, building components are sunk costs that passively serve the purpose of creating a habitable place to live. However, energy systems are a revenue-generating asset that serves the residents and creates shared economic benefits for the residents, owner, and systems developers.

This project would add a new dimension to the design of affordable mixed-use housing - it would introduce the need to work with, or at least follow, IHO's lead on bringing a regulatory perspective to the team. Average contractors and developers completely miss the opportunity to go beyond the standard practice DER sizing dictated by traditional economics and minimum code requirements. VPPs and grid participation overcome this barrier and carry enormous financial benefits that are traditionally only thought of (if ever), once the building is built. However, recently energy prices have risen sharply, and gas and electricity price spikes occur. This project shows that maximizing roof and facade solar, with 'oversized' batteries, can pay themselves back, and the next 10 years of guaranteed Inflation Reduction Act (IRA) Investment Tax Credits (ITC) can stand on their own feet. This building has a difficult form factor, no outdoor ground space for the battery system, and a temperate climate limiting extreme demand flexibility.

This project focused on the affordable, replicable, and scalable challenge established by the CEC. The team worked through a highly complex set of analyses and design options and emerged with simple, affordable, decentralized solutions that are less expensive than standard construction to build, maintain, and operate. The technologies are proven, off-the-shelf, and tested. The replicable innovation is the 'cookbook' for how to put the ingredients together, how to leverage grid-interactive buildings as a resource, and how to navigate the regulatory environment. Others can do this if there is an example in the market to follow.

The team anticipates stacking three program opportunities to reduce the project costs. First, the CEC Next EPIC Challenge grant will provide up to $9 million in grant funding related to the scope of the energy systems and strategies in the Phase II application. Second, the team is pursuing up to $2 million from the CEC's Building Initiative for Low-Emissions Development (BUILD) program (CEC, 2024) which incentivizes all-electric technologies in multifamily buildings. Third, IHO as a non-profit can now apply for the ITCs via the newly created direct pay option created in the IRA (IRS, 2024). Under the ITC guidelines, IHO would be able to apply for a 40 to 70 percent tax incentive on capital costs related to various clean energy equipment, with higher incentives for serving low-income populations, using domestic content goods, and using organized labor. This will set a precedent for California ratepayers to maximize CEC funds without Internal Revenue Service (IRS) penalties, demonstrating how developers and nonprofits can amplify the effects of ratepayer and federal funding.

Residents will be part of a transactive energy prosumer network. The project will follow California Public Utility Commission/Southern California Edison Rule 18 and be master metered, but also have individual electrical panels in their unit. Under Rule 18, energy costs will be embedded in the tenants' monthly rental costs. Also, each unit will be metered, and in this case, they will be third party-owned meters. Outside of the cost accounting design of the prosumer network, the rewards tracking for customers avoiding energy use and receiving proceeds from solar generation and battery dispatch, and any other net exports from demand reduction, will be returned to the residents. These rewards will be in the form of a rent reduction, not interfering with the Rule 18 specification. From a behavior standpoint, it is anticipated that customers will better respond to 'carrots' in the form of rent reduction, rather than 'sticks' in the form of higher electric bills. The team will also conduct an Energy Internet Network pilot that will innovate with smart contracts to boost utility electricity transaction efficiency. Community Electricity's protocol, originating from a separate CEC grant, encompasses hardware, software, and monitoring and will be tested through a simulation. The trial will evolve to demonstrate the protocol's value by comparing long-term purchase power agreement contracts with flexible short-term ones while monitoring and quantifying potential arbitrage and hedging opportunities.

For technologies or strategies that do not have extensive demonstrations or deployment, the team will have backup design features to ensure that the design objectives are met. Most of the design innovations will come from strategies rather than technologies. The team feels that the technology exists to implement the energy and emissions goals of the multi-use building, but new strategies and controls are needed to implement the concept. Most technologies will be off the shelf, which will help with the replicability of the design.

Community Engagement

The project team used a comprehensive and multifaceted approach to solicit community input and incorporate community feedback into the project design, particularly for the purpose of the non-residential space. The following steps and actions were taken, and are planned to ensure alignment with the needs and vision of the community:

Community Engagement Through Meetings with Residents:

- The team conducted meetings with residents of existing housing buildings, including El Verano (housing seniors and formerly homeless individuals) and Park Derian (home to young working families), during which it gathered insights into residents' unique needs, aspirations, and concerns related to gentrification.
- Residents provided feedback on energy conservation, heating concerns, digitalization, energy monitoring, energy usage and billing, and the use of commercial space.
- These meetings highlighted the importance of energy conservation, backup generators, and affordable childcare facilities within the non-residential space.
- The team plans to create a group consisting of approximately 15 residents from managed properties and the project vicinity. This group would provide continuous feedback throughout the project's development, ensuring that the community's perspectives are incorporated.

Engagement with Property Managers:

- The team conducted interviews with local property managers to gain insights into maintenance, management processes, and long-term building systems.
- Valuable feedback was obtained regarding uniformity, preventive maintenance, mental health, and safety concerns, parking facilities, and energy cost reduction.

- The team plans to establish a "Property Managers Influence Group" to partner with experienced managers to optimize maintenance and management processes.

Collaboration with Local Organizations:

- The team collaborated with local organizations like Thrive and Cielo to understand the community's needs. Insights were gained into challenges related to childcare, food business incubation, transportation justice, and affordable amenities.
- Strategies to counter gentrification included resident involvement, ongoing community input meetings, multilingual accessibility, and collaboration with local organizations.

Expert Insight from SoCal Climate Action:

- The team gained expert insights from Jack Eidt, urban planner, and co-founder of Wild Heritage Planners, focusing on equitable development practices and urban planning.
- Key learnings emphasized open space, pedestrian access, community trust, and addressing neighborhood needs.

Collaboration with Santa Ana Active Streets:

- The team plans to collaborate with Santa Ana Active Streets to enhance accessibility and inclusivity in public transportation systems.
- Strategies included reducing reliance on personal vehicles, prioritizing dedicated bus lanes, constructing safer infrastructure, and promoting alternative modes of transportation.
- Collaboration with this organization aimed to combat gentrification and improve transportation accessibility.

Through ongoing engagement and collaboration, the team aimed to align the project design with the needs, aspirations, and vision of the community while mitigating potential gentrification effects.

The project team proposes the formation of a "Residents Influence Group" based on the community engagement just described. This represents an innovative approach to mitigate gentrification by ensuring that the project remains aligned with the needs and aspirations of the community. This initiative strives to foster shared ownership and collective empowerment, ultimately leading to a more meaningful and successful project outcome. This group of engaged residents will play a vital role in shaping the project's trajectory by offering their unique perspectives, insights, and opinions. Their firsthand experiences and local knowledge will serve as invaluable assets, helping the team make informed decisions and refine the project as it evolves. Participants will be monetarily compensated to recognize and appreciate their contributions and create a mutually-beneficial partnership. Additionally, sustained engagement with community-based organizations will help build collaborative opportunities for residents to take advantage of alternative transportation, business incubation, and community trust, fortifying the neighborhoods.

The development is poised to have a range of positive impacts on the local community. It responds to housing needs and environmental concerns through affordable housing and climate readiness. Its electric, fossil-gas-free approach, improves indoor air quality, while shared EV mobility supports both workforce development and transportation options. The Glu mobile app introduces subscribers to a virtual power plant, enabling local and cost-effective energy participation. This empowers residents to be prosumers, fostering conscious energy use and rewarding energy efficiency efforts. Lower electricity bills and clean energy sources underscore sustainability. The app further enhances community interaction, facilitating dog walking, and parking sharing. Residents will be equipped with energy awareness tools, and on-site innovations will be showcased. With green spaces, pedestrian-friendly paths, and an affordable daycare center, the development prioritizes community well-being. The allocation of specific solar power and storage units, engaged in local energy markets, cements a commitment to conscious energy consumption and a sustainable future.

At the heart of the team's strategy lies the empowerment of community residents. If awarded, all on-site labor will be at the prevailing wage, and the team will work with contractors to source local labor. The team also worked with the modular prefabrication vendor, Plant Prefab, to source all materials within California. The anticipated construction costs are nearly $132 million across both buildings, which will provide an abundance of work in the Santa Ana community.

In the operation phase of the project, the resident car-sharing program, centered around EVs, holds the potential to revolutionize access to employment opportunities and delivery jobs. By providing residents with convenient and eco-friendly transportation, it is envisioned that a direct pathway to income generation will be created. Through this EV car-sharing initiative, individuals within the community can tap into a range of work and delivery opportunities that might have previously been less accessible due to transportation limitations. This innovative approach not only enhances economic empowerment but also aligns with the team's commitment to sustainability.

Moreover, throughout the team's community engagement efforts, the recurring need for affordable daycare facilities surfaced. This requirement is especially critical in enabling mothers to participate in the workforce. Recognizing this shared necessity, one of the commercial spaces is designated for an affordable childcare facility. This endeavor not only supports working mothers but also contributes to the overall well-being and harmony of the community. By offering a solution that aids women in securing employment while addressing a community-wide need, their economic prospects and social cohesion are enhanced.

CHAPTER 3: Results

Key results included the identification of replicable strategies that can be adopted in the affordable multifamily developer community. These focused on technology configuration, technology selection, business models, and financing strategies.

Technology configuration in this project pointed to decentralizing both HVAC and DHW systems. The benefits of doing so yielded two outcomes. One was lowering the first costs by avoiding additional piping and electrical infrastructure. This also allowed the existing maintenance staff to have confidence that they could maintain familiar equipment and quickly replace individual equipment with minimal disruption to all tenants. The second outcome is that locating the packaged terminal air conditioner units and HPWHs inside the units freed up roof space to maximize the necessary solar PV to meet the peak energy demand.

In addition to the decentralized energy technologies, the team found that first costs could be reduced through modular construction. This accelerated the construction time, saving holding costs and labor costs. Off-site construction and on-site prevailing wage requirements are also positively impacted by this choice from the developer's cost standpoint.

The business model of master metering the buildings allows the developer to fully realize the net energy metering benefits of retail bill arbitrage, as well as appropriate sizing of the solar and storage systems. When paired with a microgrid controller and enrollment in a virtual power plant, the excess energy can be monetized, which is a severe oversight of today's building stock. It is estimated that nearly a quarter million dollars could be gained annually from this strategy.

Lastly, the financing strategies allow multiple capital offset opportunities to be leveraged together. While this is not new, it is rarely combined in this manner. Combining IRA incentives, grant funds, ratepayer funds, non-profit financing, and energy bill arbitrage, along with wholesale market participation, is a key element to driving demand for all-electric, grid-interactive buildings that all developers should become experts in navigating.

Design Challenges

The design challenges centered around the technical and financial feasibility of developing the two buildings. First, the form factor of the building leaves little room for solar PV to satisfy the peak demand - in both summer cooling, and winter DHW heating. The available open space to locate a battery system necessitated co-locating the BESS system with the parking, which is not only expensive but placed a major physical constraint on satisfying the local parking requirements. With these constraints, innovative demand flexibility strategies for tenant engagement through a prosumer network and mobile application were specified to maximize demand flexibility.

Second, the financial feasibility of generously sizing the batteries was, on its own, not financially feasible. As a non-profit, IHO is targeting the IRA investment tax credit stacking for 50 to 70 percent capital offset. This is complemented by the Next EPIC Challenge funding, the BUILD program funding, and the Self Generation Incentive Program incentives to lower capital costs.

Energy and Emissions Performance

The team used CalAdapt[4] with Arup's weather forecasting input files to explore multi-year extreme heat and cooling days. Passive house tools were used to explore enhanced envelope measures to reduce thermal demands, thermal bridging, and passive cooling strategies. In addition, Arup used their proprietary tool to evaluate incidental radiation on the buildings to understand cooling loads. The team also used IES energy modeling software[5] for a solar irradiation study to analyze thermal gain and loss reductions across the projected extreme weather scenarios.

This section of the report details the energy performance of the building with the final selected equipment and operations. The following describes the modeling assumptions and inputs that resulted in developing Tables 6 through 8, below.

Modeling Approach and Assumptions

Arup performed preliminary energy and emissions modeling at the conceptual design stage. The modeling was completed in stages using different tools to benchmark various design alternatives against the grant criteria. The stages are described as follows:

1. **Solar Radiation:** Arup used its proprietary tool Arup Solar to calculate the incident solar radiation falling on the buildings' exterior surfaces. This analysis was used to compare different massing and exterior shading options for the two buildings to limit cooling loads, anticipated to be large given the buildings' climate zone.
2. **Solar Photovoltaic Sizing:** To maximize renewable energy generation on-site, the project team explored siting PV panels on the façade. The Arup Solar tool was used to understand the effects of overshadowing on the facade that would hinder PV energy generation. This analysis helped to locate the facade PV so that it would be in direct sunlight even if new buildings were erected adjacent to the Living Empowerment House.
3. **Energy Efficiency:** After the solar radiation studies, Arup connected a whole building energy analysis in IESVE 2023 Feature Pack 1. This analysis estimated energy performance to benchmark against the CEC's project requirements. During this phase, several energy efficiency measures were developed and assessed in terms of their annual electricity consumption relative to the Title 24 standard design, representing a California Energy Code compliant design, as well as the BOD, representing the starting point for the project design – the business-as-usual case.

[4] https://cal-adapt.org/tools/local-climate-change-snapshot

[5] https://www.iesve.com/software/virtual-environment

4. **Grid Management:** Given the EPIC grant's requirements around demand response and islanding, Arup also developed several grid management measures in IESVE. These measures aimed to curtail and shift load away from the peak hours: 4:00 p.m. to 9:00 p.m. As such, they were assessed in terms of their peak energy demand and energy consumption between 4:00 p.m. to 9:00 p.m. throughout the year. The measures again were compared against the Title 24 standard design and BOD.
5. **Microgrid Sizing:** Using the results from the energy efficiency and grid management studies, Arup performed a microgrid sizing study to determine the optimal size of the PV installation and the BESS to meet the EPIC grant requirements. This analysis was conducted for each of the energy efficiency measures and grid management measures as well as for the Title 24 standard design and BOD.
6. **First Cost Analysis (not energy modeling):** From a cost narrative written by Arup, Lenax Construction Services created a cost estimate of the various proposed design options. Their cost estimate helped the team weigh the energy efficiency and grid management properties of each design option against their first costs to find a cost-effective solution.

Operating Assumptions

For this project, special attention was given to commonly overlooked inputs and values that would typically default to a code-compliant building. In particular, the operating schedules and equipment setpoints were individually specified within the energy models to reflect a highly optimized, transactive building that operates to arbitrage retail energy price avoidance, greenhouse gas (GHG) minimization, and grid sales maximization – all while being able to island from the grid, especially between 4:00 p.m. to 9:00 p.m.

Plug loads and domestic hot water loads were estimated using the Minimum Energy Performance Calculator for the LEED v4 credit Optimize Energy Performance. This calculator has a Multifamily Details tab that calculates the plug loads that need to be entered into an energy model. It makes use of EnergyStar assumptions for the power draw, water consumption, sensible gain, latent gain, and usage of different appliances inside a residence: refrigerators, dishwashers, cooking exhaust hoods, ranges, washers, dryers, miscellaneous devices, et cetera.

A combination of variation profiles and diversity schedules was used. These variation profiles came from Title 24, ASHRAE 90.1, and the LEED Multifamily Energy Modeling Guidance. They were approved by the project developer, Innovation Housing Opportunities.

The battery was modeled to discharge energy from 4:00 p.m. to 9:00 p.m. It was set to be charged by PV at all other daylight hours. No charging from the grid was modeled.

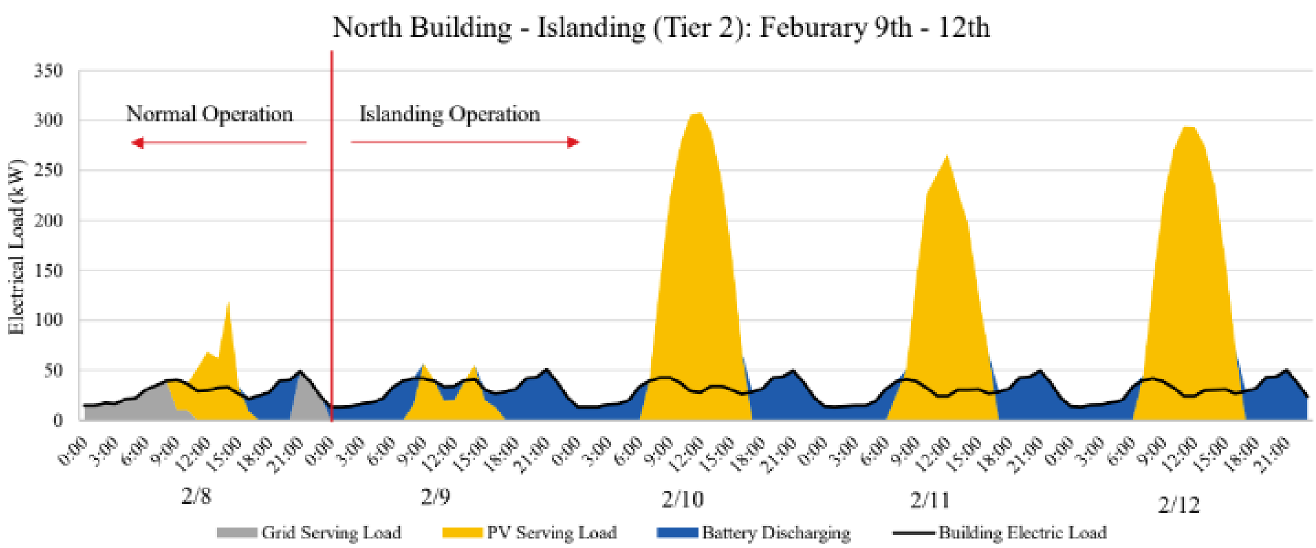
PV power generated during the 4:00 p.m. to 9:00 p.m. period was set to go directly to the building load. Any excess PV that could not be captured by the building, specifically, when the BESS is full and the building demand is lower than PV output, was modeled to be exported °back to the grid at 25 percent of its full value.

The DHW tank was modeled to be charged before the 4:00 p.m. to 9:00 p.m. period. Moreover, set points were modeled to be relaxed (80°F [27°C] for cooling; 68°F [20°C] for heating) during this peak period.

Energy and Emissions Performance Results

This project resulted in a robust sizing of DERs that were required to ensure that the building could operate during peak hours. This required significant solar PV arrays that were accompanied by significantly sized battery systems. This allowed the building to satisfy peak load in winter hours when the solar PV produces very little power or when the sun is not shining, but the grid is at peak conditions. The result of the DER sizing is illustrated in Figure 8, which shows the magnitude of the solar output in yellow, with the battery discharge in blue, and the building load in the solid black line.

Figure 8: North Building Islanding Mode Load Profile



Source: Innovative Housing Opportunities

The main output from the analysis (Table 6), and perhaps the most significant result, is that this building has zero grid purchases during peak hours, as seen in column 3 and column 6 in the table below. This represents the volume of energy purchased over the peak demand hours of the year.

Table 6: Volumetric Energy Consumption During Peak Hours

(1)	(2) = (3) + (4) + (5)	(3)	(4)	(5)	(6) = [(4) + (5)]/(2)
Annual electricity consumption (kBtu)	Annual consumption during peak hours (kBtu/year)	Annual grid purchase during peak hours (kBtu/year)	Annual load reduction from on-site solar and storage during peak hours (kBtu/year)	Annual load reduction from load management during peak hours (kBtu/year)	% Peak reduction from on-site solar, storage, and load management
7,284,826	1,532,315	0	1,291,096	241,220	100%

kBtu = thousand British thermal units
Source: Innovative Housing Opportunities

In terms of peak demand (Table 7), the project resulted in a similarly high-performing building. Between efficient technology selection, a generously sized solar and battery system, and aggressive demand flexibility strategies, this building can shed 100 percent of the peak demand energy load. The table below shows the highest predicted demand and the respective impacts between on-site renewables and demand response on achieving this 100 percent demand reduction.

Table 7: Peak Demand Reduction Results

(1)	(2)	(3)	(4) = [(2)+(3)]/(1)
Highest Peak demand in a year (BOD) (kBtu/hr)	Peak clipping due to on-site solar and storage on the highest peak day in the year (kBtu/hr)	Peak clipping due to load management on the highest peak day in the year (kBtu/hr)	% Peak reduction from on-site solar, storage, and load management
1854.5	1449.5	405	100%

Source: Innovative Housing Opportunities

This project also achieved a significant emissions reduction over the building energy code baseline building (Table 8). Through the use of the solar PV system, as well as the operating schedule of the BESS system, significant GHG emissions were avoided from minimizing energy grid consumption. This building achieved a 43 percent reduction over the baseline design building.

Table 8: GHG Emissions Results

Technology Type	Rated Electricity Generation Output Capacity (kW)	Annual Electricity Generation (kWh)		Avoided Annual GHG Emissions (Metric ton CO2)		
		Baseline Design	Proposed Design	Baseline Design	Proposed Design	% improvement
Photovoltaic System	947	790,955	1,387,682	191	336	43%

Source: Innovative Housing Opportunities

Costs and Benefits Performance

The Living Empowerment House was designed as a customer-centric project with shared economic benefits to both the residents and the developer. The sections below show the results of the energy bill impacts to the residents, and the total economic impacts for the developer because of the project strategies.

Resident Benefits Results

The strategy of master metering the building afforded the project to fully maximize the benefits of solar and the ability to use the DERs to avoid retail energy costs while participating in wholesale power grid sales. Table 9 shows the resulting impacts on the tenant bills. A code-compliant building would have accrued nearly a quarter million dollars of utility bills. In this scenario, the annual savings over the baseline are a 50 percent reduction in the cost of all energy consumed on-site.

Table 9: Total Annual Estimate of Aggregated Residential Energy Bills

Baseline	Proposed Design		
First-Year Bill	First Year Bill	First-Year Saving	Percentage Reduction
$223,335	$112,385	$110,950	50%

Source: Innovative Housing Opportunities

Table 10 shows the lifecycle savings for the residents. This represents the cost savings from lower bills, and from lower rents that result from the capital cost savings of the modular construction and decentralized equipment, which lowered first costs and operating costs for the developer.

Table 10: Residents' Life Cycle Cost (Based on Utility Rates)

	Title 24 Standard	Proposed	Savings
Rental (1BR)	$351,496	$342,599	$8,897
Rental (2BR)	$562,393	$548,159	$14,235

	Title 24 Standard	Proposed	Savings
Rental (3BR)	$914,029	$890,897	$23,131
Per ft^2	$703	$685	$18
Total	$107,842,566	$105,113,034	$2,729,532

Source: Innovative Housing Opportunities

Developer Costs and Benefits Results

This cost-benefit analysis found that the proposed building costs more in up-front capital costs if the building owner were to pay for all DERs and own and operate them. However, the project strategy is to lease the systems and finance the system off-balance sheet. For a full accounting of the costs and benefits, the project team calculated the costs of owning the equipment to determine what strategy was most beneficial.

These incremental costs would be approximately $5.1 million more for the proposed building compared to a code-compliant building. These costs were driven by a DER system and enhanced building materials that totaled $7.1 million in incremental costs. However, the owner would save approximately $2 million by specifying lower-cost decentralized space and water heating systems.

When analyzing the life cycle benefits of the project, the team found a net benefit of $2.729 million compared to first-year incremental costs of $5.1 million. In terms of cost per square foot, this project would save $12.83/square foot over the life of the building. The benefits to the owner, combined with the immediate benefits to the tenants make for a compelling project to develop and replicate.

Technology Transfer Plan

The team will share the lessons learned through a variety of potential opportunities. These include:

- Publishing the project's final report on the CEC website
- Sharing the collective knowledge gained through the project with the IHO staff to replicate in new and existing developments.
- IHO staff to create, submit, and present the project design benefits at various conferences, industry organizations, and public-facing events as appropriate.

The intended audience includes:

- Internal IHO staff including management, project managers, and facilities teams.
- Fellow industry professionals
- City staff, community-based organizations, and other stakeholders impacted by the design strategies proposed in the project.

The information will be made available through:

- Speaking engagements
- Visual presentations
- Written reports and/or briefs and memos
- IHO website for summary documentation as appropriate
- Integrated into internal operating specifications where applicable.

CHAPTER 4: Conclusion

This effort has resulted in a Phase II submittal to the Next EPIC Challenge which demonstrates that an all-electric, mixed-use, low-income building is technically and financially feasible. However, there are risks associated with master metering and the regulatory uncertainty in tariffs that even the most generous incentive and tax credit stacking may not overcome. Key design features included decentralizing the HVAC and DHW systems to maximize rooftop area for solar PV and then adding facade solar. Financial strategies included master metering the property and using third-party metering to satisfy regulatory requirements that provide maximum value to avoid retail energy rates from DERs. At the same time, enrolling in a virtual powerplant, creating a microgrid, and rewarding customers with incentives, not penalties, for smart energy actions allow for demand flexibility and overall operating cost reduction. Simple, maintainable equipment, and prosumer network mobile applications, along with a carsharing program with ample EV charging infrastructure provide residents with the amenities needed for a desired place to live. Only with the CEC grant funds, is the technology procurement for peak electric demand autonomy possible with the sizing of generously sized battery systems. Finally, with an integrated design, the architects, engineers, and community engagement team were able to propose a welcoming space, not just for residents, but for the greater Santa Ana community.

It is recommended that the CEC consider how to further unlock the capabilities of demand flexibility and enhanced envelope technologies to create ultra-low energy, grid-interactive buildings that can contribute to the health of the local distribution grid as well as provide non-energy benefits to all stakeholders involved. As the state goals, and eventual strict mandates for the team’s climate goals approach, buildings such as these need to be replicable, achievable, and a de facto standard due to the value they provide, not the mandates they need to meet.

GLOSSARY AND LIST OF ACRONYMS

Term	Definition
AFUE	Annual Fuel Utilization Efficiency
BESS	Battery Energy Storage System
BOD	basis of design. It represents the design base case, specifically, the starting point.
BUILD	Building Initiative for Low-Emissions Development: A program that offers technical assistance throughout all phases of all-electric residential building design and construction
CEC	California Energy Commission
cfm	cubic feet per minute
CTA	Consumer Technology Association
DER	distributed energy resources: Technologies that can support local electrical generation, control, and storage
DHW	Domestic How Water System: Delivers hot water to fixtures used by people (sink, tower, tub, etc.)
EEM	energy efficiency measures
EER	Energy Efficiency Ratio
EPIC	Electric Program Investment Charge
EV	electric vehicle
GHG	greenhouse gas
HPWH	heat pump water heater: Devices used to efficiently heat and cool spaces by using electricity to move heat from one place to another (instead of generating heat directly)
HSPF	Heating Seasonal Performance Factor
HVAC	heating, ventilation, and air conditioning: The technology and systems used for controlling indoor climate, including temperature, humidity, and air quality in buildings and vehicles
IEER	Integrated Energy Efficiency Ratio
IES	Integrated Environmental Solutions
IESVE	Integrated Environmental Solutions Virtual Environment
IHO	Innovative Housing Opportunities
IRA	Inflation Reduction Act: A federal law signed by President Biden in 2022 that contained $500 billion in new spending and tax breaks and included significant federal spending for reducing carbon emissions
ITC	investment tax credits

Term	Definition
kBtu	thousand British thermal units
kW	kilowatt
LEED	Leadership in Energy and Environmental Design
PTAC	packaged terminal air conditioner: a type of self-contained heating and air conditioning system intended to be mounted through a wall
PV	photovoltaic
SEER	Seasonal Energy Ratio
SGIP	Self-Generation Incentive Program: A California Public Utility Commission program that provides incentives to support existing, new, and emerging distributed energy resources
UEF	Uniform Energy Factor: a metric developed by the Department of Energy to let the user see the energy efficiency of water heaters.
V2B	bi-directional charging or vehicle-to-building. It allows the EV to discharge electricity into the building.
V2G	vehicle-to-grid. It enables energy to be pushed back to the power grid from the battery
V2X	vehicle-to-everything
VPP	virtual power plant: a connected aggregation of DER technologies

References

CEC (California Energy Commission). 2018. *California Climate Change Assessment: Statewide Summary Report*. Available at: https://www.energy.ca.gov/sites/default/files/2019-11/Statewide_Reports-SUM-CCCA4-2018-013_Statewide_Summary_Report_ADA.pdf.

CEC. 2022. "2022 Building Energy Efficiency Standards." Available at: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

CEC. 2024. "Building Initiative for Low-Emissions Development Program – BUILD" Available at: https://www.energy.ca.gov/programs-and-topics/programs/building-initiative-low-emissions-development-program-build.

CPUC (California Public Utilities Commission). 2009. "Energy Division Resolution E-4238" Available at: https://docs.cpuc.ca.gov/published/Final_resolution/100132.htm#:~:text=SCE%27s%20tariff%20Rule%2018%2C%20Supply%20to%20Separate%20Premises,through%20a%20single%20meter%2C%20subject%20to%20certain%20provisions.

CTA (Consumer Technology Association). 2024. "Modular Communications Interface for Energy Management (ANSI/CTA-2045-B)." Available at: https://shop.cta.tech/products/https-cdn-cta-tech-cta-media-media-ansi-cta-2045-b-final-2022-pdf.

IEEE SA (Institute of Electrical and Electronics Engineers Standards Association). 2024. "IEEE Standard for Smart Energy Profile Application Protocol." Available at: https://standards.ieee.org/ieee/2030.5/5897/.

IRS (Internal Revenue Service). 2024. "Elective pay and transferability." Available at: https://www.irs.gov/credits-deductions/elective-pay-and-transferability.

MBI (Modular Building Institute). 2023. "Sustainability: Making the Case for Modular Construction." *Permanent Modular Construction annual report.* Available at: https://www.modular.org/sustainability/.

OpenADR Alliance. Nd. "OpenADR 3.0 Introduction and Certification Program." Available at: https://www.openadr.org/openadr-3-0.

Project Deliverables

Project deliverables, including interim project reports, are available upon request by submitting an email to pubs@energy.ca.gov.

- Project concept video (also available on the CEC's YouTube page)
- Conceptual Design and Engineering Report
- Energy Emissions Performance Report
- Emerging Technologies and Strategies Report
- Gentrification Report
- Zero Emission Cost-Benefit Analysis Report