Definitions of zero net energy

A zero net energy (ZNE) building is an energy-efficient building that produces as much energy as it consumes over the course of a year, usually by incorporating solar PV on-site.[1] There are many different definitions of ZNE. In general, any nomenclature such as ZNE or net zero energy (NZE) refers to the same concept. The definition refers to operational energy use only.

DEFINITIONS BY CLASSIFICATION

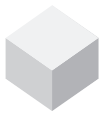
Ultra-low Energy / Nearly ZNE / ZNE Capable
A building that has demonstrated significant technical progress towards goals of energy use reduction, even though it may not have pursued a ZNE energy path by investing in on-site renewables[1]

Emerging projects
A building that has a publicly stated goal of ZNE but has not yet demonstrated achievement of that goal through 12 consecutive months of measured energy[1]

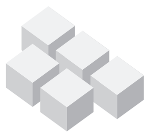
Verified projects
A building that has 12 months of metered data that show zero net or positive energy production over a given consecutive 12 months[1]

Net Positive
A building that produces more energy than it consumes over 12 consecutive months[1]

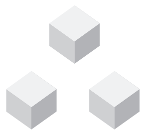
DEFINITIONS BY SCALE



ZNE Building
An energy-efficient building where the actual annual delivered energy is less than or equal to the on-site renewable exported energy[2]



ZNE Campus
An energy-efficient campus where the actual annual delivered energy is less than or equal to the on-site renewable exported energy[2]

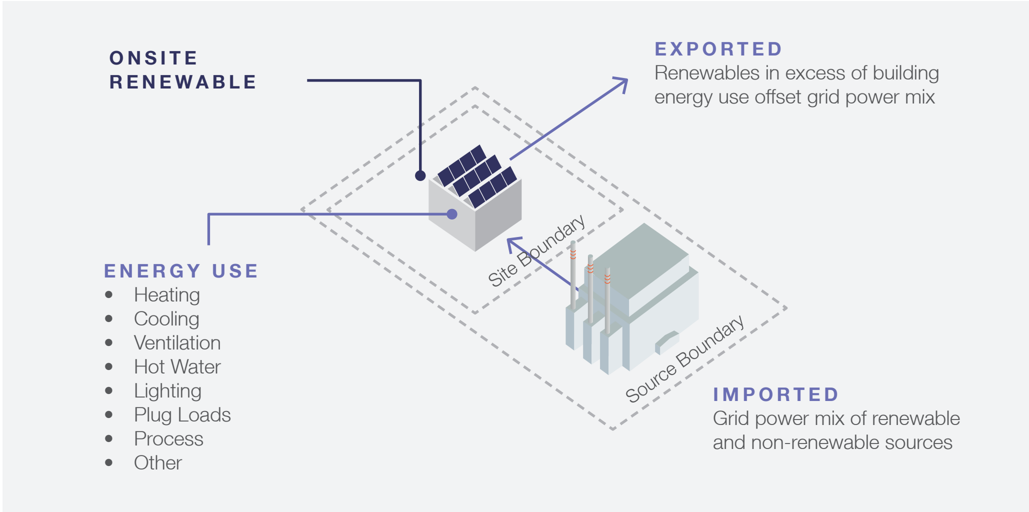


ZNE Portfolio
An energy-efficient portfolio where the actual annual delivered energy is less than or equal to the on-site renewable exported energy[2]

DEFINITIONS BY BOUNDARY

ZNE Site
A building that produces as much energy as it consumes over the course of a year, when accounted for within the building site boundary[3]

ZNE Source
A building that produces as much energy as it consumes over the course of a year, when accounted for at the energy generation source[3]



Site Boundary of Energy Transfer for Zero Energy Accounting[2]

Additional definitions

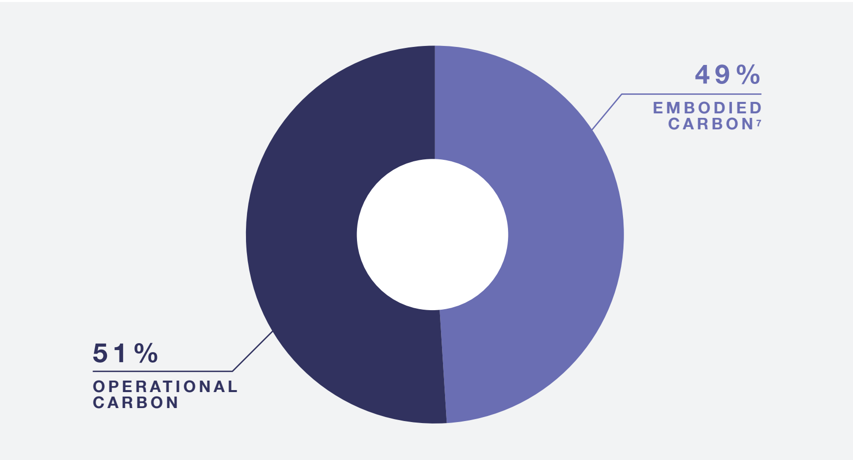
DEFINITIONS BY ZERO NET CARBON

The core distinction between zero net energy and zero net carbon (ZNC) is that ZNC or carbon-neutral buildings consume only carbon-free renewable energy, either produced on-site or procured. A ZNE and ZNC building can consume natural gas and offset that consumption through carbon offsets, however a zero carbon building would not consume natural gas at all. The definitions of ZNC and zero carbon are associated with operational energy only. However, some carbon certifications and international definitions also include embodied energy associated with the materials used in construction or end-of-life phases of the building.

Zero Net Carbon (ZNC)
A highly energy-efficient building that produces on-site, or procures, enough carbon-free renewable energy to meet building operations energy consumption annually.[4]

Embodied Carbon
The carbon emitted when materials are mined, manufactured, and transported.[5]

International Living Future Institute Zero Carbon Standard
One hundred percent of the operational energy use associated with the project must be offset by new on or off-site renewable energy. Also, one hundred percent of the carbon emissions impacts associated with the construction and materials of the project must be disclosed and offset.[6]



Total Carbon Emissions of Global New Construction from 2020 to 2050 (Business as Usual Projection)[7]

INTERNATIONAL DEFINITIONS OF ZNE+C

Both ZNE and ZNC are concepts employed around the globe, with different definitions in each country. Below are excerpts from the European Union, Japan and Canada. Interestingly, the policies adopted in the European Union do not include plug loads in the calculation of energy use, while Canada is specifying carbon-free emissions in its green building code.

European Union
A nearly zero-energy building means a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby. Energy performance includes heating, cooling, ventilation, hot water, and lighting.[8] This definition excludes plug loads.

Japan
A net zero energy building has high energy saving through load reduction, natural energy use and high efficient systems and appliances without decreasing the environmental quality both indoors and outdoors.

With the introduction of on-site renewable energies, the on-site energy generated will be equal to or greater than the actual energy consumed within the building in the course of a year.[9]

Canada
A zero carbon building is defined as one that is highly energy efficient and produces on-site, or procures, carbon-free renewable energy in an amount sufficient to offset the annual carbon emissions associated with operations.[10]

Why ZNE+C?

RUNNING OUT OF FOSSIL FUELS

2018 reserve-to-production ratios[11] suggest if reserves are used at the rate they are now, they would last until...

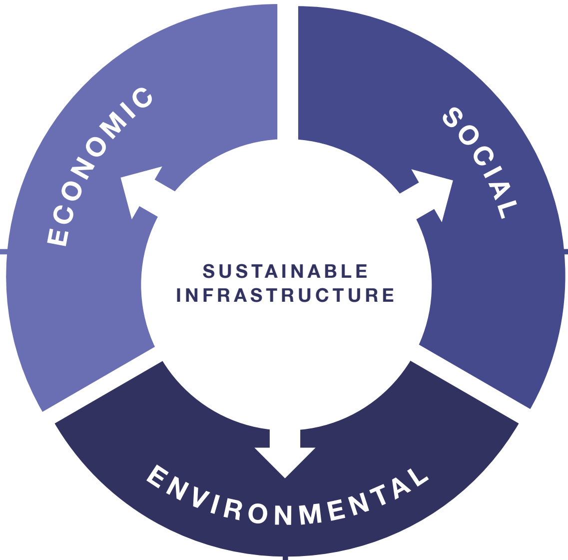
Oil: 2067 - Gas: 2070 - Coal: 2151

RISING ENERGY COSTS

As supply decreases, energy costs will rise. The U.S. Energy Information Administration predicts the nominal dollar spot price will quadruple, triple and double by 2050 for oil, natural gas and coal, respectively.[12]

CLIMATE FINANCE

Emerging form of green finance available for projects in developing countries that help reduce emissions or adapt to climate change.



AIR POLLUTION

Buildings impact air quality, killing half a million people globally each year by polluting the air from the energy they consume.[13]

NEED FOR HEALTHIER BUILDINGS

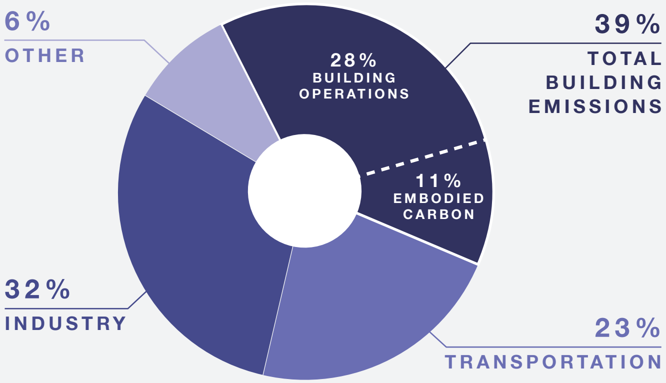
Inherent to ZNE+C building design is healthier building design. Daylighting, natural ventilation, and improved envelopes for more uniform temperature distributions are a few examples of how ZNE+C buildings improve occupant comfort.

GLOBAL CLIMATE GOAL

The Paris Agreement is an international treaty that aims to keep global temperature rise below 2°C, and 1.5°C where possible. The 1.5°C pathway calls for zero net anthropogenic greenhouse gas emissions by 2050. Achieving the aims of the Paris Agreement requires immediate, drastic reductions in all energy sectors, including buildings.

WHAT ROLE DO BUILDINGS PLAY?

The building sector is the largest emitter, accounting for 39% of global emissions.[14]



Global CO_2 Emission by Sector[14]

WHY ARE ZNE+C BUILDINGS NEEDED NOW?

We cannot meet climate goals without eliminating building operations emissions and embodied carbon emissions by 2050.

Two-thirds of today's buildings will still be standing by the 2050 deadline.[15] Intermediary steps to building reduction will not suffice; a 100% reduction of emissions in the building sector means ZNE+C buildings are a must.

Benefits of ZNE+C

DEVELOPERS

Why build a ZNE+C building?

Increased consumer- and policy-driven demand for highly efficient and sustainable homes.

ESTABLISH EXPERTISE FOR INNOVATIVE DESIGN

Improve your company's brand by delivering buildings that achieve both comfortable living and exceptional architectural, mechanical and environmental performance.

GROWING MARKET

Public interest and demand for ZNE+C is growing globally and will continue to rise as more mandated ZNE+C policies are adopted. Increase profits by getting ahead of the buying movement and securing a position in the market now.

INEVITABLE POLICY PUSH

As ZNE+C policies are rapidly evolving, developers should grow the skills and operational capacity needed to supply ZNE+C buildings now. This will allow them to avoid the costs of rushed training to comply with future codes, while gaining recognition as early innovators.

COMMERCIAL REAL-ESTATE OWNERS

Why own a ZNE+C building?

Improved bottom line from lower operational expense and higher employee retention and productivity.

ENERGY RESILIENCE

As ZNE+C buildings typically have on-site renewables, property owners can be protected from rising energy costs and grid vulnerabilities through low to zero utility bills.

LOWER OPERATIONAL COST AND HIGHER RENT/RESALE

ZNE+C buildings tend to have lower operational costs, adding to higher rent and resale value.

EMPLOYEE RETENTION AND PRODUCTIVITY

Strategies used in ZNE+C buildings make them healthier and more liveable, reducing employee turnover and increasing work productivity.

MEDIA ATTENTION

Capitalize on brand promotion now while public interest continues to grows.

AVOID LEGISLATIVE RESTRICTIONS

Reap the benefits of current tax incentives while avoiding future carbon penalties. Staying ahead of codes may also avoid expensive retrofits down the line.

BUILDING OCCUPANTS

Why occupy a ZNE+C building?

Increased comfort from exceptional indoor environment quality, all the while reducing your building's carbon footprint to zero.

EXEMPLIFY SUSTAINABLE LIVING

Combat climate change through lower energy consumption that is offset by clean renewable energy.

NATURAL DAYLIGHTING AND VENTILATION

Designed and built using passive solar and ventilation design principles where possible, ZNE+C buildings make the most of natural daylight and fresh air breezes.

IMPROVED CONTROLS, IMPROVED COMFORT

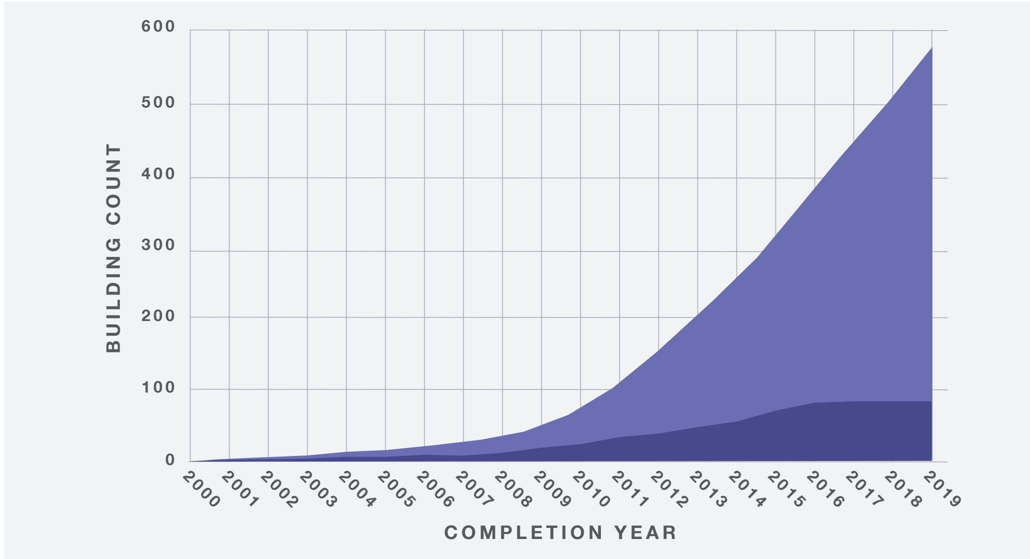
ZNE+C buildings often use smart HVAC and lighting controls to minimize unnecessary consumption. These controls have direct benefits for occupant comfort (eg, energy-saving LED lights can vary brightness to best suit occupant needs).

EXEMPLAR TECHNOLOGY

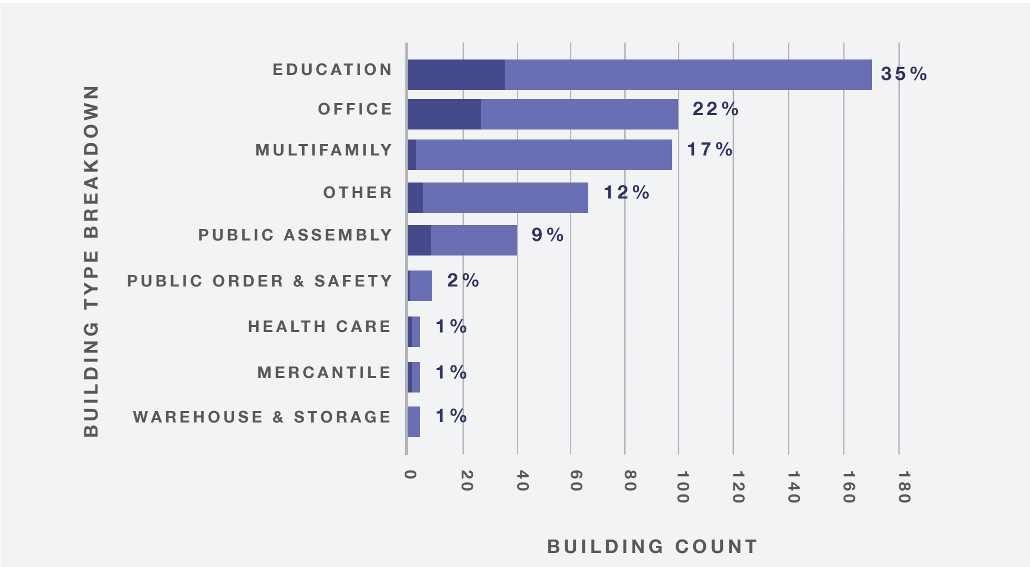
Live or work on the cutting edge of building design with the newest technology integrated into your building.

Growth trends

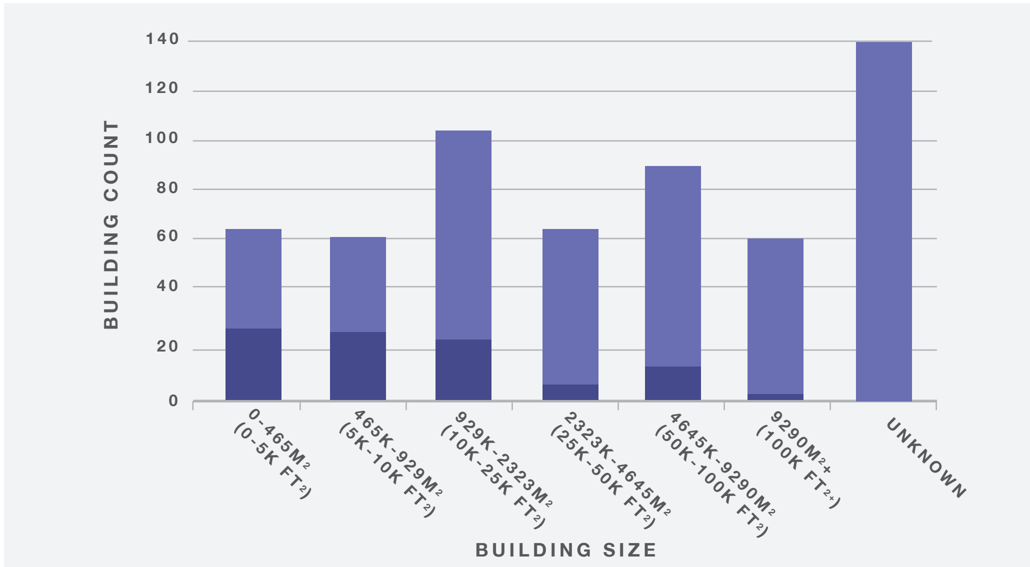
The adaptation of stricter policies has driven the exponential growth of ZNE+C buildings across the world since the early 2000s. Areas where policies have been passed see a higher number of ZNE+C buildings compared to areas with no policy. For example, in the US, California has one of the strictest building codes, and almost half of all ZNE+C buildings in the US are located there. As policies expand, ZNE+C buildings are encompassing a wider range of building types and sizes.



ZNE Building Growth in the US[16]



ZNE building type breakdown[16]



ZNE Buildings by size[16]

Pioneering policies around the world

A combination of prescriptive and performance codes, initiatives and plans to reach goals set by countries, states and cities has been driving the development of ZNE buildings across the globe. Each region has pilot policies that are the first to take aggressive steps towards ZNE. Most countries have made pledges to take these types of steps towards sustainable development. There are also many non-mandatory programs available to certify buildings.

Today's landmark policies and initiatives

Individual countries and cities are implementing policy that provides a roadmap towards ZNE in the near future. Below are some of the original pioneering policies around the world that are still in effect today, with revisions every few years. Other countries and cities are gradually following suit. Non-mandatory drivers like program initiatives and global pledges are also becoming more prominent in the industry and public spheres.

Carbon Reduction

Energy Efficiency

Renewable Energy

2007 CALIFORNIA LONG TERM ENERGY EFFICIENCY STRATEGIC PLAN

- New residential construction ZNE by 2020
- New commercial construction ZNE by 2030
- 50% commercial buildings retrofitted to ZNE by 2030
- 50% new major renovations of state buildings ZNE by 2025

2010 EUROPEAN UNION'S ENERGY PERFORMANCE OF BUILDINGS DIRECTIVE

- New public buildings nearly ZNE by 2018
- New construction nearly ZNE by 2020
- Include energy performance certificates in sales
- Set minimum energy performance requirements for new and renovated buildings

2007 THE BC ENERGY PLAN, CANADA

- Electricity self-sufficiency by 2016
- Reduce greenhouse gas emissions by 33% from 2007 levels
- New government buildings meet LEED Gold standards
- Funding to help with retrofits
- Support 100,000 solar roofs

2014 JAPAN'S BASIC ENERGY PLAN

- New public building construction ZNE by 2020
- Average net zero emissions in new construction by 2030

LEED (LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN)

- Developed in 1993 by the US Green Building Council
- 83,000+ LEED registered and certified buildings globally
- Many US federal agencies, states, and local government require LEED certification
- Each new version released is more stringent

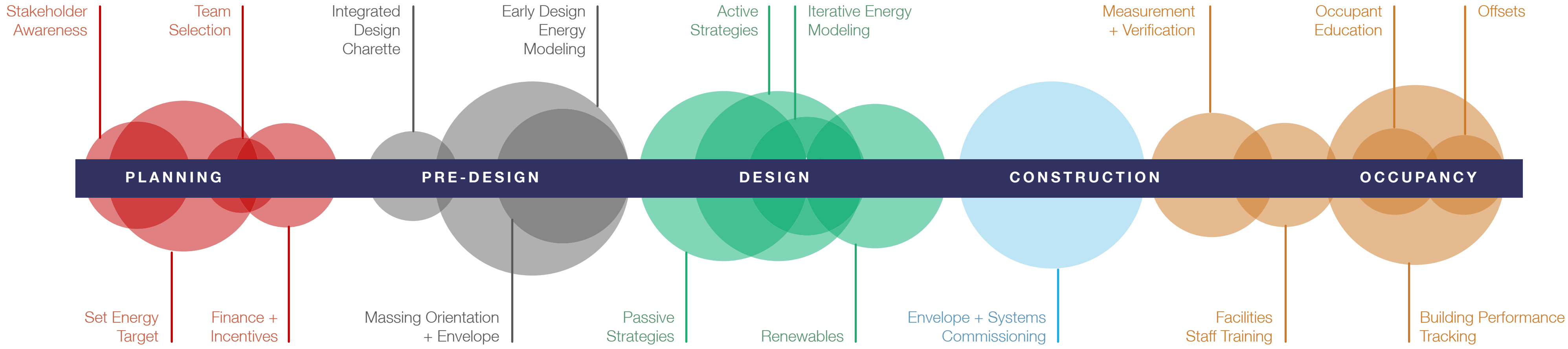
2016 PARIS AGREEMENT

- Keep global average temperature to well below 2°C above pre-industrial levels
- Nationally determined contributions (NDC) for each individual country
- 185 parties

Approach to ZNE+C

A ZNE+C building requires integrated whole-building design from planning through to occupancy. At each stage of the project from early conceptual design to operation, ZNE+C minimises loads, maximises efficiencies and optimises renewable generation.

ZNE+C WORKFLOW



ZNE+C APPROACH

To maximise the return on investment of building measures, follow this six-step approach to cost-effective ZNE+C design.

1. Load reduction
Reduce building energy demands through passive strategies.
Example measure: improved insulation

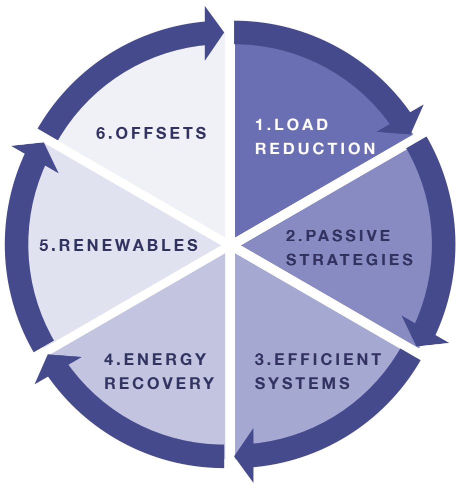
2. Passive strategies
Implement passive design measures that harness environmental conditions to meet building loads.
Example measure: natural ventilation

3. Efficient systems
Reduce energy losses by increasing energy efficiency of active systems (ie, systems that use energy).
Example measure: heat pump with a high coefficient of performance

4. Energy recovery
Supply energy by recovering energy from existing energy losses.
Example measure: wastewater heat recovery system

5. Renewables
Supply demands of energy consumption with renewable energy generation.
Example measure: solar thermal panels

6. Offsets
Offset remainder of the energy budget if necessary.
Example measure: energy efficiency project investment



ZNE+C must-haves

ENERGY TARGET

An energy target is an annual, whole-building energy-use limit that guides design and operation. It should be specific, measurable on-site with minimal data manipulation, inclusive of all loads and aggressive. Research the energy consumption of a comparative average building. Then, establish an ambitious but feasible budget.

Try to break down the energy target by system. This will help when there are discrepancies in design versus actual energy consumption, as systems that are not behaving as predicted can be identified and adjusted.

ENERGY INFORMATION SYSTEM

An energy information system allows operators to analyse current and historical energy performance, and to view normalized energy demand and consumption (from utility meter to sub-system).

Through normalizing data by external variables like weather and occupancy, an energy information system has an advantage over a building automation system by more accurately detecting anomalies and measuring the impact of energy conservation measures. However, it is not a substitute for a building automation system.

BUILDING PERFORMANCE TRACKING

While ZNE+C buildings are designed to be most efficient buildings, most buildings fail at operating efficiently. Achieving the ZNE+C goal requires regular check-ins and troubleshooting to stay on track. Typically buildings' performance deteriorate up to 30% in the first four years of operation and commissioning or retro-commissioning can reduce that performance decay.

PLUG & PROCESS LOAD

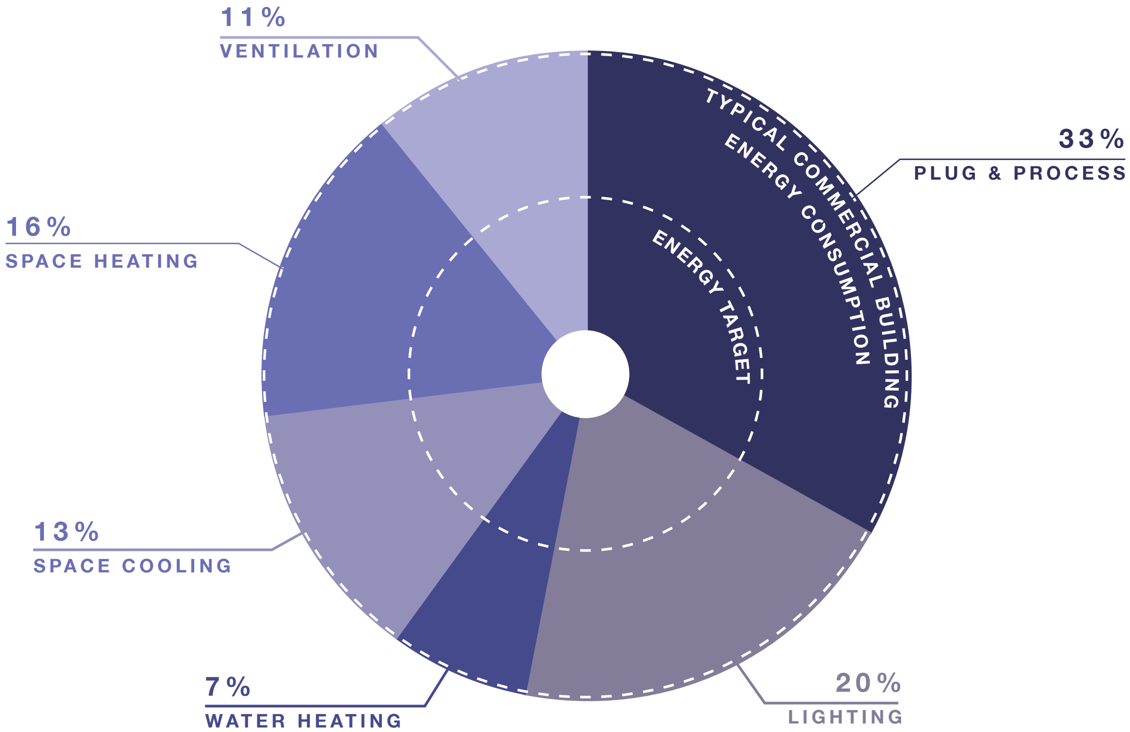
Plug and process loads (PPL) account for 33% of US commercial building energy consumption.[17] They are crucial in reducing the energy consumption of a ZNE+C building. There are several tips to successful PPL management:

- Eliminate unnecessary PPLs, and meet those that are essential efficiently.
- Automatically turn PPLs off when not needed.
- Restrict or standardize procurement to ensure only high-efficiency appliances are purchased.
- Educate occupants of PPL's impact.

OCCUPANT ENGAGEMENT

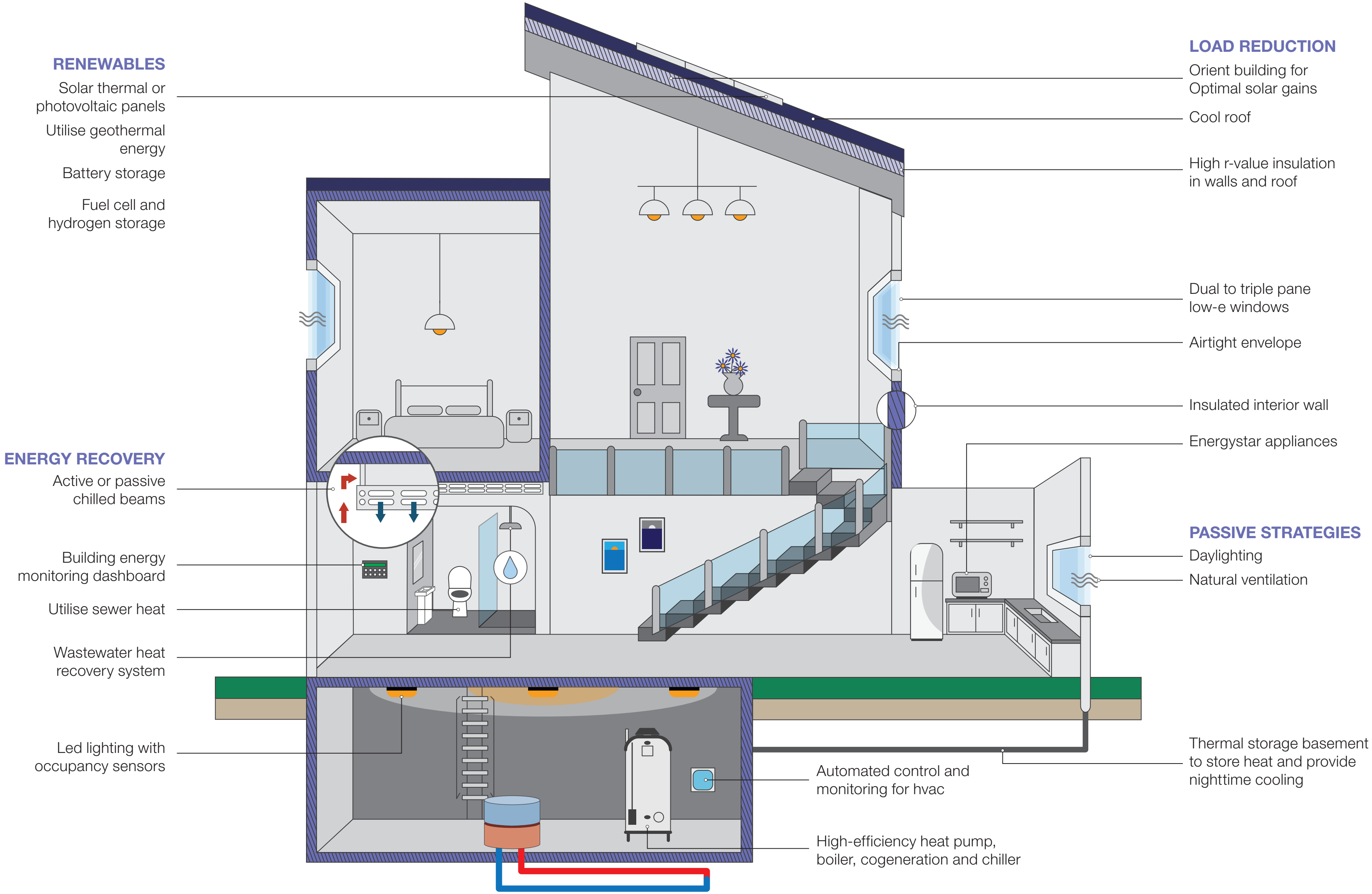
A ZNE+C building must have a focus on occupant engagement to prevent unexpected behaviour. Occupants need to have an awareness of how much energy they use and its impact on building operations. They should also be well-informed of what controls are available to them that improve comfort in addition to energy performance.Some integral steps of occupant engagement are:

- Evaluate occupant patterns.
- Prompt occupants with reminders of what are ideal behaviours.
- Create a communication system between facility operators and occupants.
- Develop move-in and ongoing trainings.



Typical Commercial Building Energy Consumption[17]

Example ZNE+C strategies



Performance metrics

Several metrics and rating systems contextualize energy performance for ZNE+C buildings.

TIME DEPENDENT VALUATION (TDV)

Time dependent valuation is a metric used in California for the Title 24 code. It is ultimately an economic metric and is expressed in dollars. The concept behind TDV is that energy-efficiency measure savings should be valued differently depending on which hours of the day and year the savings occur, to better reflect the actual costs of energy. The TDV method encourages building designers to design buildings that perform better during periods of high energy cost and is relatively easier to achieve compared to other ZNE metrics.

ZERO ENERGY PERFORMANCE INDEX (zEPI)

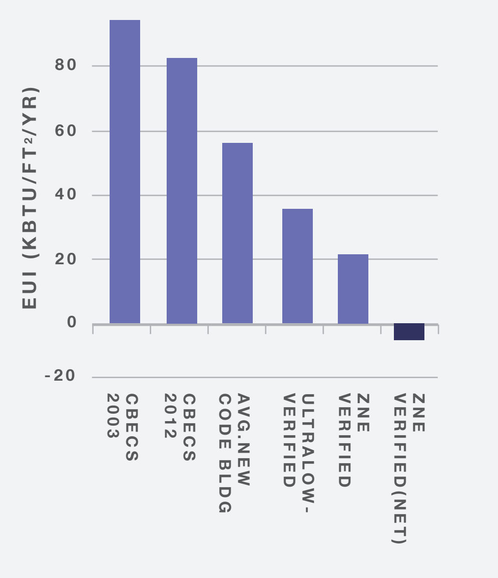
zEPI provides a common and fixed scale for measuring commercial building energy performance. zEPI normalizes scores by building type, square footage and climate, and sets a fixed, universal baseline. The zEPI scale marks key energy measurement milestones as well as the performance of individual projects or policies. It permits direct comparisons in order to understand the relative performance of each of these elements in the measurement of energy performance.

ENERGY USE INTENSITY (EUI)

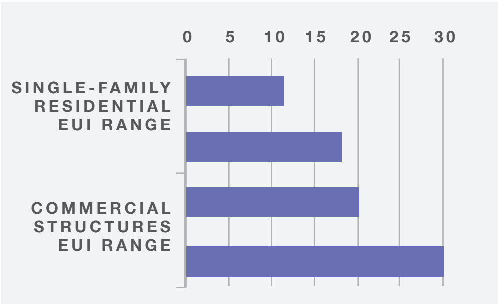
EUI is a common expression of a building's energy use as a function of its size. It is expressed as energy use in kBtu per square foot per year. Buildings that have been verified as ZNE have either a zero net building EUI or a negative net building EUI as the renewable production exceeds the energy use. This EUI can be source or site, depending on the definition of zero net energy by boundary used. The median EUI of a ZNE building is 22.6 and should be the target energy performance for most buildings.[18]

EMBODIED CARBON EMISSIONS/FT²

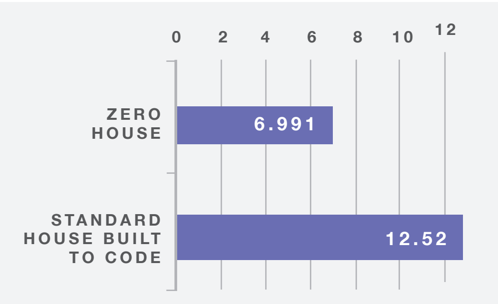
Embodied carbon is a key metric to quantify zero-carbon buildings. Embodied carbon calculations require an understanding of all of the materials, or ingredients, within your products, and all activities related to those materials, such as processing and transport. It is expressed in emissions per square feet of the building.



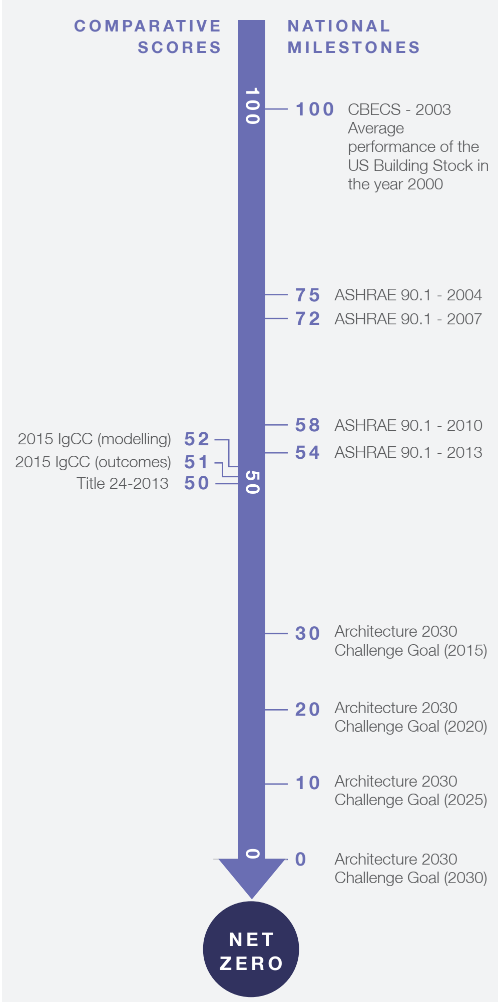
Average Site EUI Comparison[19]



Typical Site EUI for ZNE Building (kBtu/ft²)[1]



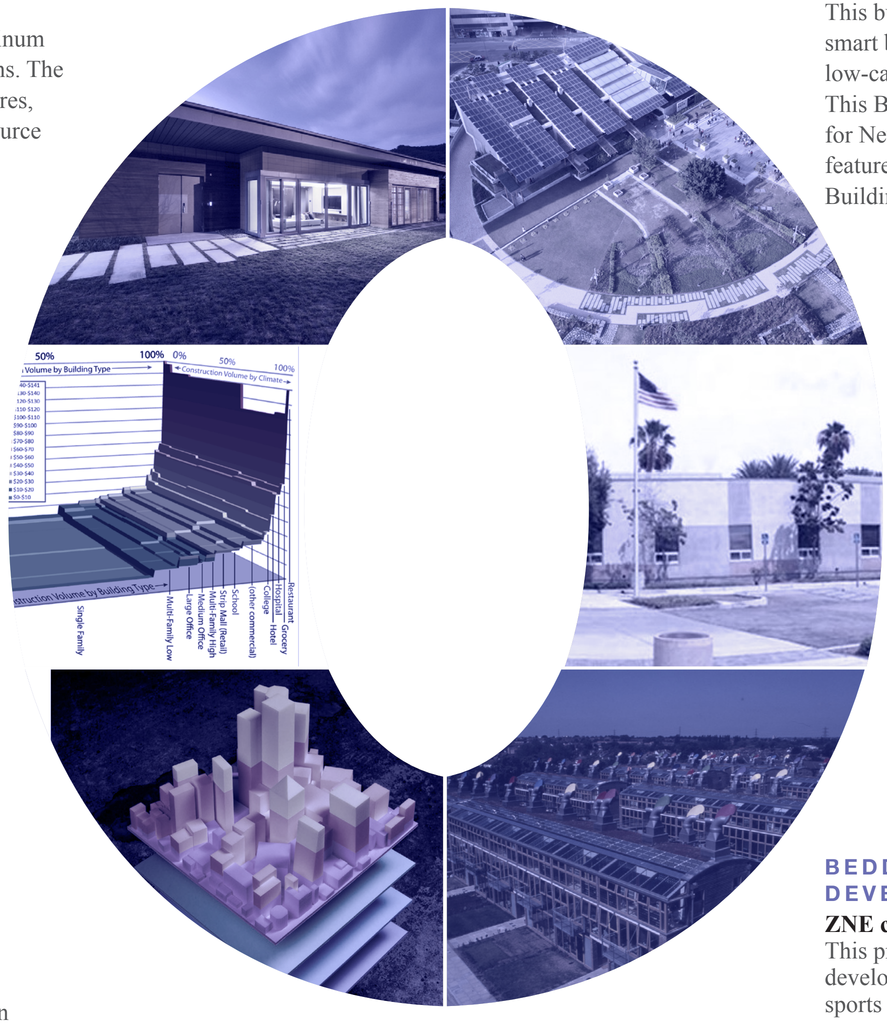
Embodied Carbon Footprint (kg CO_2-e emissions/ft²)[20]



*Commerical Building Energy Consumption Survey - U.S. Department of Energy

zEPI Scale to ZNE[21]

Reference projects



SAMSUNG ZERO ENERGY HOUSE/ GREEN TOMORROW AND ZERO ENERGY DEMONSTRATION BUILDING

Zero energy building

This project is East Asia's first USGBC LEED-Platinum certified building which also achieves zero emissions. The 423m² (4553 ft²) building has 68 green design features, including a high-performance façade and ground source heat pump with cooling tubes.

PG&E TECHNICAL POTENTIAL TO ACHIEVE ZERO NET ENERGY, CALIFORNIA, USA

Technical advisor to pacific gas and electricity company (PG&E)

This study used building simulation to quickly and easily investigate multiple designs and determine the optimum path for zero net energy for 12 commercial and residential prototypes in representative California climate zones.

ZNE HAS LEFT THE BUILDING: A ZERO NET ENERGY POLICY FRAMEWORK

State policy and design collaboration

This policy framework was designed to facilitate California State policy implementation and adoption of ZNE at the state level.

ZERO CARBON BUILDING, HONG KONG

Zero carbon building

This building incorporates 90 environmental strategies and is a smart building monitored by 2,500 sensing points. The building's low-carbon design and construction was completed in 14 months. This BEAM Plus Platinum-rated building also won the Grand Award for New Buildings in the Green Buildings Awards 2012. Design features include wind catchers, earth cooling tube, green walls and a Building Environmental Performance Assessment Dashboard.

DISTRICT OFFICE AND APPLIED TECHNOLOGY TRAINING CENTER AT SAN BERNARDINO COMMUNITY COLLEGE, CALIFORNIA, USA

Zero energy retrofit

This building retrofit is set to meet a target site EUI of 23 kBtu/ft²-yr through installation of a 174 kW solar carport canopy, 17 light pipes and upgrades of lighting and HVAC systems.

BEDDINGTON ZERO ENERGY DEVELOPMENT, LONDON, UK

ZNE community

This project is a prototype sustainable mixed-use development with 82 dwellings plus workspaces, shops, sports facilities and an exhibition centre.

It uses 100% renewable energy sources and an on-site wood-fueled combined heat and power plant to provide electricity and heat.

Future of ZNE+C

CHALLENGE

HIGH INTENSITY, HIGH DENSITY

There are a few scenarios where ZNE+C through on-site renewable energy generation is limited in its potential.[22]

- Buildings with high energy intensity
- Buildings with multi-stories, small roof footprints or small lot sizes
- Buildings in high-density areas where site area is shaded by surrounding environment
- Certain climates or geographical regions that have lower solar potential

OVERSUPPLY AND RAMPING

On-site renewables interconnect with the utility grid for most ZNE+C projects. Upon the widespread adoption of distributed energy resources, the export of renewables onto the grid can create a strain on the system, from ramp rate issues to voltage fluctuation.[23]

GRID MIX

ZNE+C definitions account for energy produced and energy consumed as an annual total. When investigating design strategies, the hourly profile has unique carbon implications specific to the project's location. For every project, it is highly recommended to research the following from the local utility:

- Grid mix (power content label)
- Rate structure
- Future developments

SOLUTION

COMMUNITY FRAMEWORK

Buildings with limited potential for on-site generation may consider the procurement of off-site renewables.[22] Financial models include:

- Power purchase agreements (PPA)
- Green power utility contracts
- Renewable energy certificates (RECs)

GRID HARMONIZATION

There are several grid harmonization strategies that the ZNE+C project could consider:[23]

- Share excess generation through agreements with other buildings nearby
- Install energy storage for load shifting
- Charge electric vehicle service equipment with excess energy

ELECTRIFICATION

Building electrification eliminates the use of natural gas, which is a carbon-emitting resource. If the utility grid increases its share of renewable sources, the carbon intensity of the building's electricity supply improves. The distinction with this approach is that the individual building is tied to the local, state and regional developments for decarbonization.