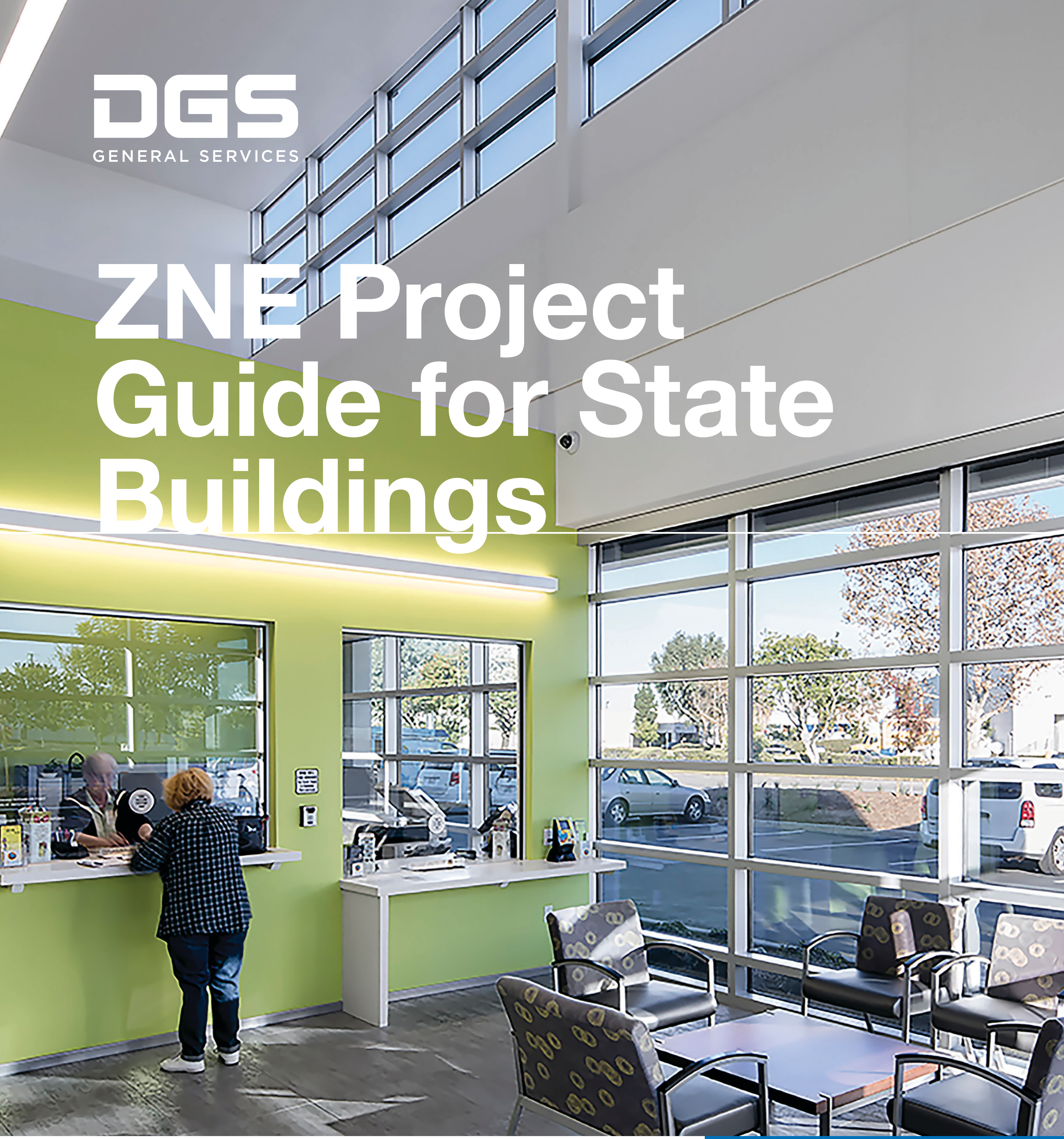

DGS
GENERAL SERVICES

ZNE Project Guide for State Buildings

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INTRODUCTION

Zero Net Energy (ZNE) is possible for many buildings and this ZNE Project Guide for State Buildings can help DGS and its agencies on the path to zero energy for new construction and major renovation projects.

A ZNE building is an extremely energy efficient building that is designed and operated to produce as much energy as it consumes over the course of the year. ZNE buildings are no longer solely demonstration projects and market outliers. NBI's 2018 Getting to Zero Status Update and Zero Energy Building List includes a wide-range of mainstream building and ownership types that reflect a universal trend toward ZNE adoption.

ZNE is feasible in both new construction and existing building renovation. Teams have found that ZNE buildings do not always cost more to build, especially when ZNE is a goal from the start. Plus, they provide exemplary spaces for their occupants. ZNE buildings are thermally and acoustically comfortable and offer glare-free daylighting, which creates a highly productive environment. They also have significantly lower operations and maintenance costs.

The steps to achieve ZNE are different from a traditional building planning process. This checklist and guide are intended to explain those differences and assist project teams in the development of a ZNE building, starting in the initial budget stages and following through construction to ZNE verification. Included are resources, checklists, and a worksheet to inform a process of gaining stakeholder support, selecting a qualified design team, managing the design and construction process, occupying a ZNE building, and verifying a ZNE result. While this guide is intended solely for new construction and major renovation projects, existing building operators may find helpful suggestions for minor retrofits and operational efficiencies.

The ZNE Checklist is broken into three sections and should be evaluated throughout the project and considered during predesign, design, and operations and verification. Each item on the checklist has a corresponding section in the ZNE Project Guide. Not all items on the checklist will apply to your project. The guide is not meant to be read cover-to-cover but rather should be used as a reference as you envision, design, build, and occupy the ZNE building. Use the guide to see recommendations and feed discussions during design, construction, and operations using considerations for each topic and review the resources for further research. The ZNE Project Reporting Tool at the end of this document should be used to describe how each item in the checklist was evaluated and to document the associated ZNE decision to assist future projects.

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TABLE OF CONTENTS

Pre-design

Design

Operations and Verification

ZNE PROJECT CHECKLIST FOR STATE BUILDINGS

The Checklist is intended to assist project teams in the development of a ZNE building. Project Managers can evaluate each section throughout each project phase, starting predesign, design, and continuing through operations and verification. Each item on the checklist has a corresponding section in the ZNE Project Guide that includes more information and resources on each topic.

Pre-design

Green Building and ZNE Requirements

- ❑ **Meet State ZNE Energy Efficiency Requirements**
  - ❑ Exceed Title 24 by at least 15%
  - ❑ Achieve or exceed the target energy use intensity (Source EUI) for existing buildings
- ❑ **Review other green buildings considerations**
  - ❑ Achieve LEED Silver certification, or higher
  - ❑ Or, California Green Building Standards Code (CALGreen Tier 1) measures (10,000 sf or less)
  - ❑ Incorporate monitoring-based commissioning
  - ❑ Use low water use fixtures, meeting or exceeding current code
- ❑ **Consider water reuse and recycling**
  - ❑ Use purple pipe for reclaimed water if available to, or near the site

Pre-design Process

- ❑ Include ZNE requirement in budget packages
- ❑ Identify a team ZNE champion
- ❑ Develop and refine Owners Project Requirements (OPR) to reflect ZNE
- ❑ Review contract structures and include ZNE
- ❑ Select qualified ZNE team
- ❑ Set building energy performance targets
- ❑ Hold design charrettes, as required
- ❑ Conduct early design phase energy modeling

Project Finance

- ❑ Conduct lifecycle costing analysis (LCCA) at various stages of design
- ❑ Evaluate on-bill financing (OBF) options including on-bill repayment (OBR), and GS $Mart
- ❑ Review opportunities for utilizing energy service companies (ESCOs) for existing buildings
- ❑ Consider power purchase agreements (PPAs) for onsite renewable energy
- ❑ Engage with utility incentive programs including Savings By Design

Site Analysis

- ❑ **Conduct bioclimatic analysis**
  - ❑ Evaluate solar access
  - ❑ Evaluate different building orientations to inform optimal layout
- ❑ **Analyze passive design and natural ventilation options**
- ❑ **Daylight spaces and incorporate glare control**
- ❑ **Evaluate water reuse and recycling opportunities**

Design

Building Envelope

- ❑ **Optimize exterior insulation levels**
  - ❑ Consider continuous exterior rigid insulation
  - ❑ Review construction details and evaluate to avoid thermal bridging
- ❑ **Install continuous air barriers and adequately seal penetrations to minimize leakage**
  - ❑ Seal all joints and seams, including sealing transitions at two or more materials
  - ❑ Seal envelope penetrations with caulk and/or gasket systems
  - ❑ Consider a blower door test to identify leaks
- ❑ **Model various window to wall ratios (WWR)**
  - ❑ Optimize WWR per orientation to minimize net energy use
  - ❑ Consider targeting overall WWR of 40% or less
- ❑ **Identify most effective high-performance glazing for each façade/orientation**
  - ❑ Select glazing that maximizes energy performance and daylighting
  - ❑ Select windows with low U-factor and SHGC
  - ❑ Identify the proper VLT for each space
- ❑ **Control glare with external and internal shading**
  - ❑ Shade the exterior side of window glazing
  - ❑ Provide interior shade control
  - ❑ Model daylight patterns
- ❑ **Specify cool and/or green roofs**

Space Conditioning

- ❑ **Evaluate passive cooling and heating options**
  - ❑ Incorporate thermal mass into the floor or walls
- ❑ **System type considerations**
  - ❑ Evaluate distribution and equipment efficiency options
  - ❑ Evaluate multiple high-performance conditioning systems
  - ❑ Reduce internal loads to reduce system size
  - ❑ Use refrigerant/chilled water/hot water/steam instead of air to transfer energy
  - ❑ Limit fan energy to ventilation only

Ventilation

- ❑ **Study separating ventilation from conditioning**
  - ❑ Evaluate passive ventilation
  - ❑ Consider dedicated outside air systems (DOAS)
- ❑ **Consider heat/energy recovery systems (H/EVR)**
  - ❑ Identify opportunities for other waste energy reuse
- ❑ **Evaluate demand control ventilation (DCV)**

Design (continued)

Controls and Metering

- ❑ **Consider controls automation, centralization, and feedback**
- ❑ **Add a controls integrator to the team**
- ❑ **Incorporate monitoring-based commissioning, where required**
- ❑ **Submeter HVAC, lighting, plug loads, PV**
  - ❑ Incorporate fault detection and diagnostics
  - ❑ Design circuiting systems to segregate end-use loads at the panel
- ❑ **Assess open source vs. proprietary monitoring systems**
- ❑ **Create new property profile in department's EnergyStar Portfolio Manager account**
  - ❑ Automate energy data transfers with utilities Provide profile access to DGS
- ❑ **Consider controls and communications to make the building energy systems (lighting, HVAC, energy storage) demand response (DR) capable**

Interior and Site Lighting

- ❑ **Reduce lighting power density (LPD) with 100% LEDs**
  - ❑ Specify high-efficacy task lighting
  - ❑ Tune lighting during commissioning
- ❑ **Evaluate direct and indirect interior lighting options**
- ❑ **Consider interior vacancy, photosensor, and dimmable lighting controls**
- ❑ **Consider exterior dimmable lights, photosensors, and motion sensors**

Renewables and Energy Storage

- ❑ **Evaluate solar budget and system size**
  - ❑ Balance cost of energy efficiency and renewables
- ❑ **Prepare for resiliency from natural disasters**
  - ❑ Consider microgrids or building islanding systems
- ❑ **Prepare for future solar**
  - ❑ Dedicate appropriate roof area and/or site area
  - ❑ Install or plan for future electrical wiring and panel controls
- ❑ **Evaluate on and off-site renewable options**
  - ❑ Retain or retire renewable energy certificates (RECs)
- ❑ **Evaluate battery and thermal storage options and benefits**
  - ❑ Consider current and future equipment space needs
- ❑ **Reduce peak energy use for grid integration**
  - ❑ Design for and participate in utility demand response (DR) programs
  - ❑ Evaluate opportunities to reduce peak energy use
  - ❑ Utilize electric vehicles (EVs) for storing over-generated PV power

Operations and ZNE Verification

Operations

- ❑ **Specify efficient office equipment for reduced plug loads**
  - ❑ Consider establishing plug load budget target
  - ❑ Specify plug load and workstation vacancy sensors
  - ❑ Develop and implement equipment purchasing policies
- ❑ **Commission the building systems during design, construction, and during occupancy**
  - ❑ Incorporate the commissioning agent at predesign
- ❑ **Conduct occupant training on building operation and energy use**
  - ❑ Teach occupants about how to use new equipment and controls
  - ❑ Develop and provide tenant guides
  - ❑ Train facilities and operations staff on how to operate new systems and monitor energy and water use
- ❑ **Create displays to share real-time energy use with tenants**

ZNE Verification

- ❑ **Benchmark energy performance with EnergyStar Portfolio Manager**
- ❑ **Verify ZNE performance after 1+ year**
  - ❑ Submit for third-party certification

PRE-DESIGN

Pre-design involves cross-departmental planning and collaboration to determine the necessary scope, budget, schedule, site, and design team to create a ZNE building. Foundational steps include selecting design and construction team members, budgeting, and securing financing.

GREEN BUILDING AND ZNE REQUIREMENTS

California has a history of leading the nation in environmental regulation and energy efficiency, committing to zero net energy (ZNE) buildings through policy, plans, and code. In 2009 the state adopted its first Long Term Energy Efficiency Strategic Plan with the goal that all new residential construction to be ZNE by 2020, all commercial buildings and half of existing commercial be ZNE by 2030, and half of existing state renovated buildings be ZNE by 2020 with the rest achieving ZNE by 2025. In 2010, Cal Green was introduced, spurring sustainable design and energy efficient buildings across the state. Two years later Governor Brown mandated ZNE for all state buildings. With the planned 2018 updated Long-Term Energy Efficiency Strategic Plan, ZNE is likely to advance further.

Third-party rating systems like US Green Building Council's LEED (Leadership in Energy and Environmental Design) provide a framework for sustainable design strategies. Focusing on energy, water, and waste can help meet the green building requirements and reduce operational costs.

Meet State ZNE Energy Efficiency Requirements

Executive Order B-18-12, signed in April of 2012 by Governor Brown, mandates ZNE requirements for new state buildings and major renovations started after 2025 must be constructed to be zero net energy, while 50% of existing square footage must be in the process of achieving zero net energy by 2025. Additional building mandates can be found in the executive order, the Green Building Action Plan and the State Administrative Manual (SAM), Chapter 1800. SAM Section 1815.31 outlines requirement that all new and major renovations building designs as well as build-to-suit leases beginning design after October 1, 2017, be designed and built following cost-effective energy efficiency strategies for achieving ZNE, including exceeding 2016 Title 24 energy requirements by 15%, or more, until December 31, 2019 and then 2019 Title 24 starting on January 1, 2020.

Resources:

California Long-Term Energy Efficiency Strategic Plan

Executive Order B-18-12

CEC Approved and Pending Local Ordinances

CAL Green

State Administrative Manual (SAM) Chapter 1800

SAM Management Memo 17-04

SAM Management Memo 1815.31 – Zero Net Energy for New and Existing Buildings

ZNE for New and Existing State Buildings 1815.31

California Green Building Action Plan

DGS ZNE Website

EPA Water Reuse Guidelines

California Recycled Water Policy

ZNE Frequently Asked Questions and Terminology

ZNE Case Studies

ZNE Case Study Buildings

ZNE Communications Toolkit

2016 Getting to Zero List

State of California ZNE Calculator

A growing number of cities have adopted additional efficiency, cool roof, and solar photovoltaic (PV) requirements, some which may have even higher performance targets than the state. While the State of California projects are exempt from local requirements, efforts should be made to meet local requirements if higher than state requirements, when cost effective.

Review Other Green Building Considerations

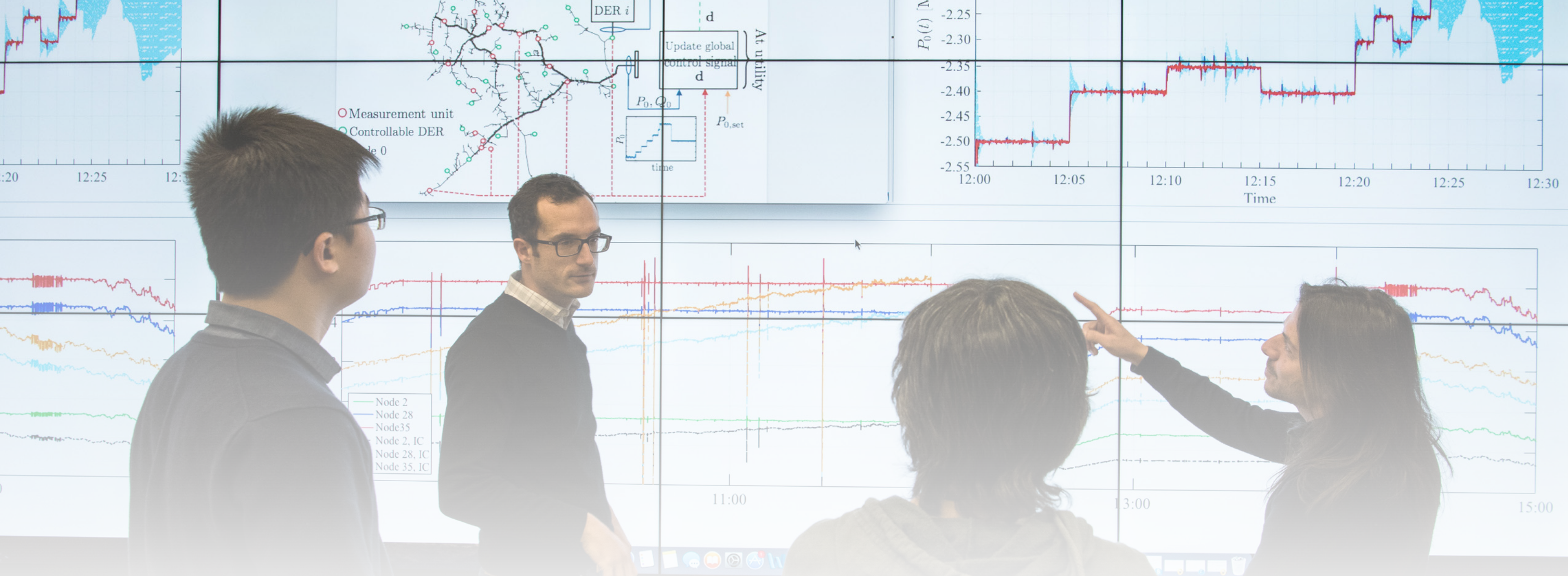
Executive Order B-18-12 also mandates numerous other requirements including the following:

- New buildings or major renovations larger than 10,000 square feet and existing buildings larger than 50,000 square feet must earn the "Silver" level of LEED (Leadership in Energy and Environmental Design) certification and incorporate on-site renewable energy if economically feasible.
- Buildings smaller than 10,000 square feet shall meet applicable California Green Building Standards Code Tier 1 measures.
- State agencies shall pursue monitoring-based commissioning for state-owned buildings in accordance with SAM Section 1815.3.
- Utilize low water use fixtures meeting or exceeding code requirements, and incorporate requirements of SAM Section 1835.

Consider Water Reuse and Recycling

Consider capturing, treating, and reusing greywater and/or rainwater, or using available recycled water to reduce potable water use for both building toilet and urinal flushing as well as irrigation. Evaluate the maximum cistern size based on the available water from indoor plumbing such as handwashing, showers, and laundry as well as outdoor rainwater and stormwater opportunities. Compare available recycled water against the demand from toilet and urinal flushing and irrigation purposes to identify the proper system size. When water reuse is not immediately possible, prepare for future water reuse opportunities by providing a cistern and/or dual piping during initial design and construction. Follow code requirements for independent recycled water conveyance, commonly referred to as "purple pipe."

Early in design, evaluate potential on-site storage locations to minimize piping and energy use from water filtration systems and pumps. Recycled water must be treated to local quality standards by reducing the total suspended solids and thoroughly treating bacteria, pathogens, and other contaminants, if not already done so by municipal suppliers.



PRE-DESIGN PROCESS

Successful ZNE projects start with early planning and goal setting. Team leads engage with finance teams, contracting, scheduling, and other departments to ensure stakeholders understand and are committed to the goal. Documents such as the Owner Project Requirements record project goals and targets and help coordinate with outside agency team members. Meetings and early design sessions can educate and inform the team, often reducing time later in the project.

Budget Packages

Requirements for ZNE and other green building requirements must be integrated into budget packages for building projects in order to fund all phases adequately. Additional design services and studies may be necessary, increasing the design budget; on the other hand, this may result in lower construction costs due to reduced equipment needs.

ZNE Champion

One of the key ingredients to success in developing a ZNE project is an internal champion or someone who is fully committed to the ZNE vision and goal and encourages others to advance their capabilities to develop a ZNE building. This may be a project team member, department manager, architect, engineer, or another committed individual. The ZNE champion brings their excitement, raises awareness, and educates other stakeholders and decision-makers to gain widespread support for a ZNE project. Other responsibilities may include managing the ZNE for State Building checklist and required reporting.

Owners Project Requirements

Design and construction team commitment is necessary for ZNE project success during the development of the budget package. Be clear about the ZNE requirement in the Request for Proposals (RFP), Owners Project Requirements (OPRs), and contract documents incorporate the target EUI.

Resources:

ZNE Project Guide

San Diego ZNE RFP

SF USD OPR Example

How to Guide for Energy Performance-Based Procurement

ZNE Decision Making Matrix for State Agencies

DGS Source EUI Energy Targets for State Buildings

ZNE Charrette Toolkit

PV Watts® Solar Calculator

The Owners Project Requirements (OPR) define project goals, the building program, operational parameters, sustainability and energy goals, and financial expectations. OPRs should detail the requirements of the building envelope; lighting, heating, cooling, and ventilation; hot water; controls; and other energy using systems. OPRs should be clear about specific programmatic requirements; operational patterns and schedules; plug load assumptions; and other activities in the building that influence the energy consumption. “Template” language in an OPR should be modified for individual projects, and teams should carefully track changes over time.

Contract Structures

Consideration should be given to the contractual approach selected, whether it be design-build, design-bid-build, lease-leaseback, or energy service company (ESCO). Each has its own unique set of benefits and drawbacks for a ZNE project. Once a team has been selected and is committed to a ZNE result, consider incorporating an EUI target range into the contractual documents. This “performance-based procurement” approach sets a clear expectation with the design team and the building occupants on how the building should perform once it is occupied.

State of California Energy Efficiency Targets for Existing State Buildings

State of California Energy Efficiency Targets for Existing State Buildings Pursuing Zero Net Energy (ZNE)
October 3, 2017
The flollowing energy efficiency targets for existing state buildings represent the top quartile (75%) of energy efficiency
Metric for energy efficiency used is Source Energy Use Intensity (Source EUI)**

State Building Type	Source EUI Targets for State Climate Zones***																
	CA Ave	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Conversion Factors for Zones	1.00	0.99	1.01	0.92	0.97	0.95	0.94	0.90	0.95	0.97	0.99	1.06	1.02	1.05	1.06	1.09	1.12
Adult Education - CCC	54	53	55	50	52	51	51	49	51	52	53	57	55	57	57	59	60
College/University	142	141	143	131	138	135	133	128	135	138	141	151	145	149	151	155	159
Data Center	100	99	101	92	97	95	94	90	95	97	99	106	102	105	106	109	112
Fire Station - CALFIRE	65	64	66	60	63	62	61	59	62	63	64	69	66	68	69	71	73
K-12 School	85	84	86	78	82	81	80	77	81	82	84	90	87	89	90	93	95
Laboratory	261	259	264	240	254	248	246	235	248	254	259	277	267	274	277	285	293
Library	114	113	115	105	111	108	107	103	108	111	113	121	116	120	121	124	128
Mixed Use Property (CALFIRE)	49	48	49	45	47	46	46	44	46	47	48	52	50	51	52	53	55
Multi-family Housing	133	132	134	122	129	126	125	120	126	129	132	141	136	140	141	145	149
Non-Refrig. Warehouse	37	37	37	34	36	35	35	33	35	36	37	39	38	39	39	40	41
Office - Average All Types	81	81	82	75	79	77	77	73	77	79	81	86	83	85	86	89	91
Office - Large >50K sq. ft.	128	127	129	118	124	122	120	115	122	124	127	136	131	134	136	140	143
Office - Small <50K sq. ft. - CHP	201	199	203	185	195	191	189	181	191	195	199	213	205	211	213	219	225
Office - Small <50K sq. ft. - CMD	30	30	30	28	29	29	28	27	29	29	30	32	31	32	32	33	34
Office - Small <50K sq. ft. - DMV	162	160	164	149	157	154	152	146	154	157	160	172	165	170	172	177	181
Office - Small <50K sq. ft. - EDD	132	131	133	121	128	125	124	119	125	128	131	140	135	139	140	144	148
Office - Small <50K sq. ft. - Others	114	113	115	105	111	108	107	103	108	111	113	121	116	120	121	124	128
Other - Maintenance DOT/DWR	71	70	72	65	69	67	67	64	67	69	70	75	72	75	75	77	80
Other - Caltrans TMC	567	561	573	522	550	539	533	510	539	550	561	601	578	595	601	618	635
Other - CDFA	249	247	252	229	242	237	234	224	237	242	247	264	254	262	264	272	279
Other - CDFW ecolog. reserve	22	22	22	20	21	21	21	20	21	21	22	23	22	23	23	24	25
Other - CDFW fish hatchery	118	117	119	109	114	112	111	106	112	114	117	125	120	124	125	129	132
Other - CDFW wildlife area	55	54	56	51	53	52	52	50	52	53	54	58	56	58	58	60	62
Other - DPR park structures	27	27	27	25	26	26	25	24	26	26	27	29	28	28	29	29	30
Other - HCD migrant centers	30	30	30	28	29	29	28	27	29	29	30	32	31	32	32	33	34
Other - Education	54	53	55	50	52	51	51	49	51	52	53	57	55	57	57	59	60
Other - Entertainment public	17	17	17	16	16	16	16	15	16	16	17	18	17	18	18	19	19
Other - Lodging/Residential	189	187	191	174	183	180	178	170	180	183	187	200	193	198	200	206	212
Other - Specialty Hospital (DSH)	426	422	430	392	413	405	400	383	405	413	422	452	435	447	452	464	477
Outpatient Rehab/Phys - (DSH)	113	112	114	104	110	107	106	102	107	110	112	120	115	119	120	123	127
Prison/Incarceration - CDCR	187	185	189	172	181	178	176	168	178	181	185	198	191	196	198	204	209
Residence Hall/dorm - CALFIRE	112	111	113	103	109	106	105	101	106	109	111	119	114	118	119	122	125
Senior Care Facility – CalVet	161	159	163	148	156	153	151	145	153	156	159	171	164	169	171	175	180

* Based upon the following sources:

1. Historic 2015 state building energy use as recorded in Energy Star Portfolio Manager
2. California Commercial End-Use Survey (CEUS)
3. ASHRAE Standard 100 Data

** Source EUI can be extracted from Energy Star Portfolio Manager report, or calculated ZNE calculator inputing annual energy data

*** California Climate Zones - see http://www.energy.ca.gov/maps/renewable/building_climate_zones.html
or by zip code http://www.energy.ca.gov/maps/renewable/BuildingClimateZonesByZIPCode.pdf

Team Selection and Integrated Approach

Since energy consumption in a building is a function of both design and operations, discussion about ZNE and the EUI target with the design team is a critical part of the team selection and contracting process. Sharing the goal puts teams on notice of the goal and encourages them to think about energy performance even before putting pen to paper.

During the team interviews, consider asking for EUI of previous buildings and experience designing ZNE buildings, as well as information about sustainable design goals, predicted EUIs, and actual performance in completed projects. See the interview questions within the ZNE Project Guide for State Buildings to gauge team experience and fit for the project.

Energy Targets

Successful ZNE champions and project managers have set clear energy and sustainability goals for their project before design begins. New projects or major renovations shall exceed energy code requirements by at least 15%, but it is helpful to establish absolute energy target – called an Energy Use Intensity (EUI) expressed in kBtu/sf/yr. Energy targets vary slightly depending on building type, occupancy, and climate. Existing state buildings pursuing ZNE should work to achieve EUI targets or lower in the top quartile of historic state building energy use. These targets are posted by building type and occupancy and adjusted for all 16 California climate zones. New construction projects should target whole-building EUI targets as shown in the following table (derived from NBI's analysis of successful ZNE building energy usage). These targets are for overall gross energy consumption, before including the contribution from on-site renewables.

Design Charrette

Shortly after the project team has been selected, a charrette is beneficial to align the ZNE vision among all stakeholders. This can be combined with a charrette to plan approach to LEED certification. A charrette is an interactive, facilitated discussion where relevant team members, including owners, architects, engineers, contractors, building occupants, and facility maintenance staff, review priorities and agree on shared project goals. Time on the agenda should allow for a focused discussion about achieving ZNE and energy targets.

Integrated design charrettes build consensus, streamline the design process, and set the team up for success. They are most effective when they happen early in preliminary or schematic design to allow stakeholders to share their perspective and ideas about the project at a time when their feedback can still be easily – and inexpensively – incorporated into the design. The charrette also provides design team members an opportunity to share their early design schematics and experiences on other projects. Post charrette, the facilitator should provide a summary of the event, including next steps. At that time, the owner may want to update the OPR with any new performance goals or include additional details such as thermal comfort ranges that might have been agreed to during the charrette.

Early Design Phase Modeling

Early design is also the appropriate time for the design team to collect bioclimatic site data such as solar access, wind availability, and rainfall amounts. Early analysis can help calculate the renewable energy generation and rainwater harvesting potential on the site. This is a function of the location, available space, production capability of photovoltaics, turbines, cistern systems. PV Watts™ is a tool from the National Renewable Energy Lab that helps define the solar potential on a particular site.

After initial modeling, the design team should finalize of the Basis of Design (BOD). The BOD translates an owner's needs into specific building approaches such as building envelope, mechanical, electrical, plumbing, security systems, building automation system, etc. Essentially, this is the design team's response to how the details in the OPRs will be actualized.

Use energy modeling during design to determine the benefits of each measure. The results may show that the added cost does not exceed the benefits or it may help to reduce the size of the HVAC system and area needed for photovoltaics.

PROJECT FINANCE

Resources:

Washington State LLCA Spreadsheet

Cost Control Strategies for Zero Energy Buildings

CPUC Statewide Finance Program

Savings By Design

SMUD Incentives

NREL ZE Cost Study

GS $Mart

State Financial Marketplace

DSIRE

Federal solar tax credits

California Solar Initiative

Commercial PACE

Community Choice Aggregation in California

DGS Clean Energy Generation Program

ZNE buildings have been constructed for the same first costs as conventional buildings. Studies suggest that zero net energy is a cost-effective investment. Success requires a committed team, a clear energy goal, and a whole-building, integrated design process. Early in design, evaluate opportunities for utility incentives, low-interest energy efficiency loans, power purchase agreements for solar, and other sources to lower initial construction costs. Existing buildings have a unique opportunity for additional financing through on-bill financing and repayment. With any project, the ongoing cost of the building operations and maintenance should be evaluated to ensure the most cost-effective options.

Lifecycle Costing Analysis (LCCA)

Once system loads have been reduced with passive strategies, carefully investigate the occupancy and use patterns to ensure that electrical and mechanical equipment is sized appropriately. Reducing loads leads to smaller mechanical systems which can save first and ongoing operational costs and can reduce the size of mechanical rooms, increasing rental or usable space. Remaining loads can be balanced with renewable energy, also managing the first costs of the photovoltaic system.

Setting the EUI target during the budgeting phase will help size the PV array and help set the project budget. During the design phase, utilize lifecycle cost analysis (LCCA) tools to review the upfront and long-term operation and maintenance costs to evaluate the total project cost to support healthy construction and operations budgets. Using the tool early, along with energy modeling, can facilitate selection of the best equipment for the project by evaluating the initial costs comparing to the operating and replacement costs. The analysis supports integrated design by considering the trade-offs with all team members, including future building operator and finance departments. Failure to consider lifecycle costs may result in unnecessarily large systems or equipment that demands high energy use, more maintenance, or even early replacement.

On-bill Financing (OBF)

On-bill financing (OBF) is a finance program for existing buildings funded by California utility customers and administered by the state's investor-owned utilities under the auspices of the CPUC. OBF provides eligible existing state customers with zero-interest loans of up to $1,000,000 per meter for financing energy efficiency projects that receive IOU rebates or incentives. OBF loan terms are up to 10 years and monthly repayment amounts are determined by the energy savings achieved. Once the loan is repaid, all energy savings that result from the new energy efficient equipment installed will translate into lower energy costs – savings the state can keep. New construction projects are not eligible for this program.

On-bill Repayment (OBR)

On-bill repayment (OBR) will be a regulated CPUC program for existing buildings, post-2017. OBR programs typically offer the benefit of a private, low-interest rate loan that is repaid through the utility, covering the cost of energy efficiency measures. Similar to OBF, OBR will allow building owners to fund the up-front cost of energy improvements allow repayment by a familiar billing process, often for a lower interest rate than traditional loans. Similar to OBF, new construction projects are not eligible for this program.

GS $Mart

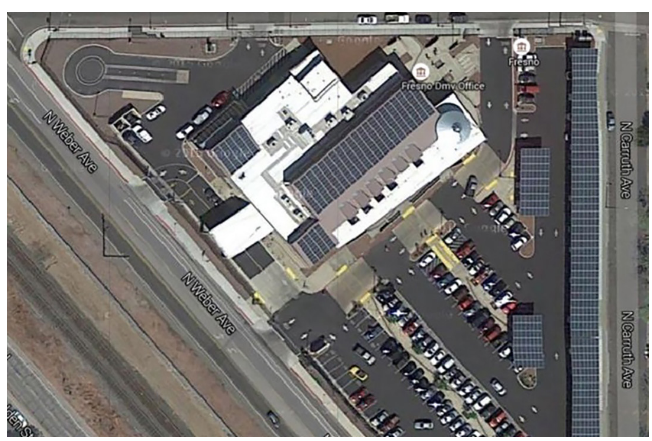
Pronounced "G S Smart," GS $Mart is California's award-winning, innovative concept for government financing. GS $Mart loans are used to finance energy savings projects. The GS $Mart program is managed by the California Department of General Services' Procurement Division. Private lenders provide financing. There is no pre-payment penalty. As with other types of financing for energy performance contracts, loan terms and monthly repayment amounts are determined by the energy savings achieved. Potential lenders review the energy savings audits for financial feasibility. For more information on this financial resource, see the State Financial Marketplace website.

Energy Service Companies (ESCOs)

ESCO is an acronym for "Energy Service Company." ESCOs develop, design, build, and fund projects that reduce energy consumption and costs, and decrease operations and maintenance costs at their customers' facilities. The State of California is researching possibilities for ESCOs to provide financing for state government energy savings projects. ESCOs provide financial assurance to lenders that the energy savings generated will cover the debt service. Project financing terms typically range between seven and fifteen years depending on the types of measures installed.

Power Purchase Agreements (PPAs)

A power purchase agreement (PPA) is a financial agreement a developer uses to design, permit, finance, and install a renewable energy system using solar, wind, or other renewable energy sources on a customer's property at little to no cost. The developer sells the power generated to the host customer at a fixed rate that is typically lower than the local utility's retail rate. This lower electricity price serves to offset the customer's purchase of electricity from the grid while the developer receives the income from these sales of electricity as well as any tax credits and other incentives generated from the system. PPA benefits can include no up-front cost to the interested agency and guaranteed energy prices for the term of the contract, often 20-25 years. DGS has a program that assists departments in acquiring on-site renewable energy through PPAs. See the Renewables and Storage section for more information about PPAs.



Aerial view of Fresno DMV.
Source: Google Maps.

Incentive Programs

Energy efficient and ZNE buildings can unlock financial incentives not available to other projects. Sources of additional funding may include utility energy efficiency programs, Community Choice Aggregator (CCA) programs. Financial incentives constantly evolve so every project team should investigate the opportunities for technical assistance, energy efficiency, on-site renewables, battery, and demand response measures to maximize incentives.

The Database of State Incentives for Renewables & Efficiency® (DSIRE) database can help policies, tax credits, and financial incentives by state. California IOU efficiency programs are offered through Savings By Design. Non-IOU and CCAs may have programs and should be researched early in design. These can provide energy modeling and other technical assistance, as well as financial incentives for both owners and design professionals. Often utility programs must be involved early in design to qualify for financial incentives. Even if they do not have ZNE specific programs, other programs may be available for the project.

California Lottery Southern Distribution Center. Source: LPAS Arch + Design

SITE ANALYSIS

Site analysis evaluates the unique characteristics of a property to evaluate what elements will support or hinder the building goals. Designers can utilize solar access, natural shading, air movement, available water, soil conditions, etc. to optimize the building location, orientation, massing, and consider other green building elements that could support energy and water performance. Decisions about passive heating, cooling, and ventilation solutions must occur early in design to minimize design time.

Bioclimatic Analysis and Orientation

The interrelationships between the building and its systems, surroundings, and occupants should make efficient and effective use of resources by considering climate as a resource. During the conceptual and schematic design phases, evaluate the major climatic variables that impact the energy performance of buildings including temperature, wind patterns and orientation, solar exposure, and humidity. Assess local topography or adjacent properties that would impact access to sunlight and passive solar heating. Characterize the local climate using annual seasonal metrics such as annual solar radiation, cooling degree days (CDD), heating degree days (HDD), dew-point design temperature and design wet-bulb temperature. Use the psychometric chart to provide a quick overview of the number of hours in which heating, cooling, humidification or dehumidification are likely to be needed. Use this information to prioritize mechanical system design response.

Many resources are available to designers to help analyze your micro-climate and building configuration. Early design analysis software and other evaluation tools can be used to analyze site characteristics and compare design alternatives without significant investment in energy modeling.

Solar Access

Shade cast from surrounding trees and buildings can reduce solar access, minimizing available on-site energy production potential from

Resources:

Daylight Pattern Guide

Urban Heat Islands Compendium

NBI ZNE Design Fundamentals Fact Sheet

Deep Savings in Existing Buildings

NBI Technical Resource Guides:

- Daylighting Pattern Guide
- Daylighting Guide for Office Interiors
- Plug Load Guide
- Indirect Evaporative Cooling
- Luminaire Level Lighting Control
- Radiant Heating and Cooling + Dedicated Outdoor Air Systems
- ZNE Building Controls: Characteristics, Energy Impacts, and Lessons

Sensitivity Analysis Using Key Performance Indicators for Building Performance photovoltaics. Use bioclimatic analysis to select the best array location, keeping in mind that new and future buildings or design elements such as awnings, cooling towers, and other architectural and mechanical elements that could hinder the future production of energy. When siting options are limited, or an existing building shades the roof area, ground or vertically mounted PV arrays may be the best opportunity before researching to off-site generation.

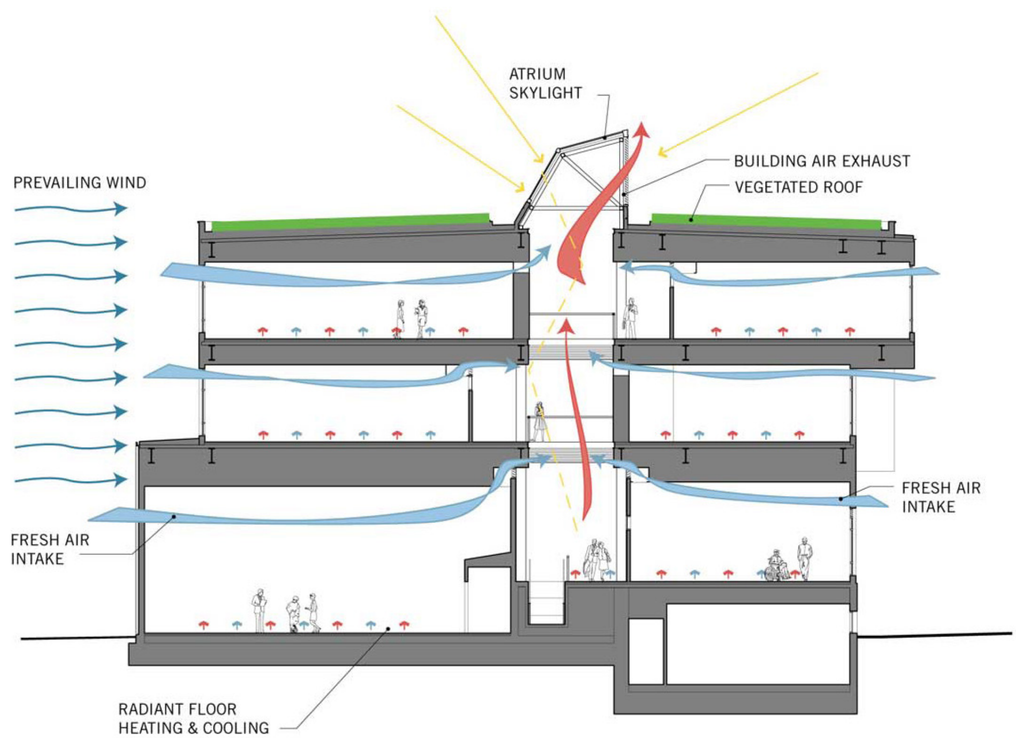
Passive Design

Passive systems take advantage of the natural elements on the site to reduce building energy demands, be more energy efficient, and potentially require a smaller on-site renewable energy system. The major climatic variables that can be utilized for optimum building performance include air and ground temperature, wind, solar energy, and moisture. Deep roof overhangs, exterior window shades, and vegetation can block the sun during the hottest times of the day. Window placement and thermal mass can heat and cool the building without mechanical means. Perform a site study to identify these opportunities.

Natural Ventilation

Ventilation can be provided solely through operable windows in smaller buildings or in breezy climates that take advantage of seasonal winds. Natural ventilation and cooling can minimize or eliminate mechanical ventilation in taller buildings by utilizing nature's propensity to move air through pressure differences, such as the stack effect. The greater the air temperature differential and the taller the vertical path in the building, the more pronounced the stack effect will be. Stack effect can reduce the energy consumption of a roof-mounted central exhaust-only system as it can help draw the air out, but it will increase the energy consumption of a similar system providing supply air since the fans will have to overcome the stack effect. Since stack effect has a greater impact toward the top and the bottom of the building, designs will need to account for different pressure impacts at different stories of the building.

Use Computational Fluid Dynamics (CFD) modeling software early in design to simulate air movement through the building, or site, throughout the day and different seasons to assist with the natural ventilation design. Consider CFD modeling in buildings over 50,000 sf and complex buildings over 20,000 sf.



San Francisco City College Multi-Use Building. Credit: CCSF Multi Use Building, VBN Architects and Pfau Long Architects.

Daylight Harvesting

During building programming, consider daylighting opportunities to reduce electric lighting as much as possible. Locate rooms that require ample lighting near windows to use daylight to its fullest effect. Narrow floor plates and high windows in large, deep rooms can more evenly distribute daylight into the space. Corridors require lower light levels so hallways can be interior spaces or have shared light from other spaces. Skylights can provide even daylight to centrally located spaces, but there are trade-offs with losing roof space for equipment or PV panels.

The main shortfall of daylight is that it is not readily available at all hours of the day. Additionally, direct daylight can cause discomfort from glare and heat gain, so window and skylight blinds or exterior shading strategies are encouraged. Horizontal overhangs and vertical fins on the building exterior, on the proper orientation, can shade windows, reducing the solar heat gain and internal glare. Interior light shelves can reduce glare for tasks near windows and may move light deeper into a space when the right techniques are used. Surface material color and texture selection are also an important consideration for glare reduction and adding an element of brightness the space. Daylighting simulation software can be used to optimize daylight in the design by modeling exterior shading options for each elevation and internal design characteristics to map the distribution of diffuse daylight, while results will quickly show direct sunlight patterns with shadow casting.

Other Site Considerations

Beyond building orientation and the existing site environmental factors, future regional development can impact building energy consumption and maintenance requirements. Consider how the future development or expansion of surrounding sites will impact solar access, wind, and rainfall amounts.

San Francisco MUB roof. Credit: Bruce Damonte.

DESIGN

Once a design team is identified, the project is described in three dimensions with building massing and programmatic arrangement. As building-site synergies are considered, systems and materials are specified, and design decisions are made, the building becomes progressively more defined.

BUILDING ENVELOPE

A well-insulated and sealed envelope can minimize heat transfer between conditioned and unconditioned spaces, reducing heating and cooling energy. Attention to the details and transitions during construction can maximize comfort and cut energy use. Teams should work collectively and conduct early and iterative energy modeling to identify the optimum building performance, cost, and occupant comfort for the project.

Insulation Levels

Reduce building heating and cooling demand through the design and construction of an extremely well-insulated, contiguous thermal building envelope. Focus on maximizing envelope efficiency while still providing daylight access for the occupants. Control lighting systems to respond to the presence of daylight. Compare the upfront costs of insulation with long-term savings through energy modeling and lifecycle costing analysis and install as much insulation as is cost-effective. Super-insulated envelopes need to pay special attention to ventilation and humidity control within the building.

Thermal Bridging

Thermal bridges make it easier for heat to travel in or out of the building, impacting the heating and cooling loads of the building, as well as on the perceived comfort of space occupants. Review detail to eliminate thermal bridges that penetrate all the way from the exterior to the interior of the building and those that only partially penetrate the thermal envelope. Implementing design details like continuous insulation can go a long way toward minimizing thermal bridges in the assembly by enclosing the entire assembly within an insulating material and allow for cladding opportunities such as rainscreen assemblies.

Resources:

Transition to Sustainable Buildings: Strategies and Opportunities to 2050

Building Envelope Thermal Bridging Guide

Enhanced Thermal Performance Spreadsheet

Thermal Bridges Redux

Windows for High-Performance Commercial Buildings

Daylighting Pattern Guide

Daylighting Guide for Office Interiors

Cool Roof Rating Council

Investigation of the Impact of Commercial Building Envelope Airtightness on HVAC Energy Use

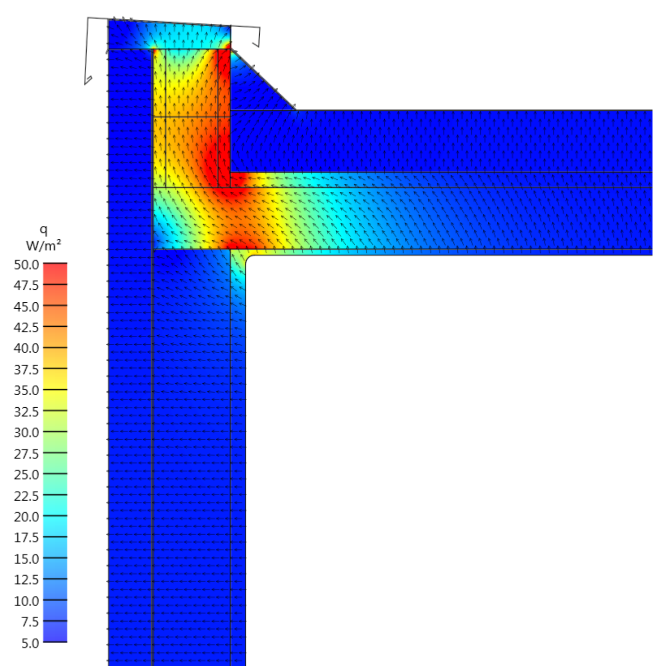
Reach Code Cost Effective Report

Air Infiltration

The building envelope should include a continuous air barrier system to control air leakage into or out of the conditioned space. Select an air barrier with permeability not exceeding 0.004 cfm/sf under a pressure differential of 0.3 inches of water (1.57 psf) (0.02 L/m^2/s @ 75 Pa) when tested in accordance with ASTME 2178. When neighboring conditioned spaces are designed with temperature or humidity levels that differ by more than 50%, provide an air barrier between the two spaces.

Seal all joints and seams, including sealing transitions in places and changes in materials. Consider the joints at foundation, walls, material transitions, windows, doors, roof, control and expansion joints, pipe, and duct penetrations. Penetrations of the air barrier and paths of air leakage should be caulked, gasketed, or otherwise sealed in a manner compatible with the construction materials and location. Joints and seals shall be sealed in the same manner or taped or covered with a moisture vapor-permeable wrapping material.

Buildings less than 20,000 sf should conduct a whole-building blower door test to determine that the infiltration rate does not exceed 0.4 cfm/sf of envelope area when tested at 75 Pa, or as required by code.

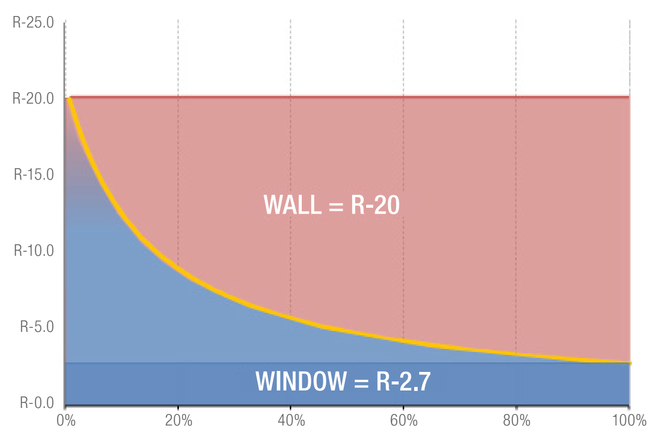


Thermal bridging at the parapet.
Source: OgreBot/Uploads by new users/2015 July 06 12:00

Window to Wall Ratio

A commonly accepted overall limit for the window-to-wall ratio (WWR) for commercial buildings is 30%, including top lighting. In some cases, this can increase to 40% for buildings in temperate climates when 50% of the conditioned floor area is within a daylit zone and includes automatic daylighting controls. When energy modeling is being conducted, as with most large buildings, each orientation's WWR should be optimized to minimize net energy use. Evaluate available daylighting with appropriate daylighting controls to turn off or dim electric lights when there is sufficient daylighting in the zone. Modeling will also help optimize solar heat gain and conductive/convective/radiative heat losses for the most efficient elevation WWR.

Through energy modeling evaluation of the envelope components, the WWR can be increased and still achieve an efficient envelope by finding the right a balance between a high R-value solid surface, a high U-rating window, and the needs of the building occupants, such as daylight and views. Also consider the window orientation, exterior shading, window attachment thermal bridging, visual light transmittance (VLT), solar heat gain, etc. See the Window Types section for more information.



R-value decreases as the WWR increases.
Source PAE Engineers

Window Types

Windows can both benefit and hinder energy efficiency in buildings, and their benefits must outweigh their drawbacks for an overall efficient envelope. The National Fenestration Rating Council rates glazing performance through the U-factor, Solar Heat Gain Coefficient (SHGC), Visible Light Transmittance (VLT), and air leakage rate. Fenestration assemblies should also consider thermal bridging, waterproofing, and interior and exterior shading. The U-factor is a measurement of the overall rate of heat transfer for the fenestration assembly (including framing) – a lower U-factor indicates a better insulator. SHGC describes how solar radiation is admitted through a window (specifically the glass) from sunlight exposure – the lower the value, the less heat transfer. While lower SHGCs are desirable to reduce solar radiation into the space, it will also reduce the amount of daylight entering the space with current technologies. Best practices specify windows with a VLT rating of no less than 1.5 times the assembly SHGC to balance the benefits of reduced solar radiation and incoming daylight. A lower window air leakage rating means less air will pass through cracks in the window assembly.

Title 24 regulates the U-factor, relative SHGC (RSHGC) and VLT for various fenestration types, such as a fixed window, curtainwall, skylights, and storefront windows. Title 24 prescriptively requires fixed window performance of 0.36 U-factor, 0.25 SHGC, and 0.42 VLT. To improve performance, projects in cooling-dominated climate zones can consider windows with lower U-factors and SHGC. SHGC is a characteristic of the glass while U-factor is of the entire assembly; therefore SHGC can be a relatively less expensive measure. Additionally, RSHGC takes into account shading on the window from overhangs or other permanent exterior shading devices. A window with SHGC of 0.22 is a feasible design option that maintains an acceptable VLT while providing benefits from reduced solar radiation. Adding permanent exterior shading to achieve an RSHGC of 0.20 will increase the performance of the window and allows daylight to enter the space without causing glare.

Since window glazing typically has poor insulating characteristics, increasing the number of panes of glass, adding coatings, tints, and filling the air space with specific gases can increase the fenestration assembly U-factor. Like other efficiency measures, the benefits of each must be weighed against cost and the efficiency impacts. Identify the best window system for each building elevation as it relates to the site, keeping in mind that each elevation could have a different WWR, U-factor, SHGC, and VLT.

External and Internal Shading

External window shades fully or partially block the entry of direct daylight during the cooling season, significantly reducing cooling loads. Buildings can limit their East-West direct sun exposure and on south-facing windows, make use of horizontal and vertical overhangs, fins, or shades to minimize solar heat gain. Daylight modeling will assist design teams with understanding the seasonal shading opportunities presented for each orientation with various designs. Horizontal shades can be combined with PV panels to serve a dual function. Detail exterior shades to limit thermal bridging. Window and façade maintenance may become more difficult with protruding elements, so coordinate with facilities and maintenance to fully understand the financial and logistic impacts.

Account for the impacts of internal glare and solar heat gain associated with windows and skylights, by selecting interior blinds, shades, and proper interior finishes. Balance visual comfort and ample daylight by locating occupants away from direct daylight through shielding, shading, and diffusing the light for more even distribution. A multitude of interior window shades are available including various opacities of fabric shades and manually and mechanically operated blinds. Manually operated blind systems can be very effective. However, they rely on and require constant user attention to maintain complete glare control while achieving maximum daylight performance. Mechanical blinds have the distinct advantage of being deployed only when needed and retracting without user intervention when direct sunlight is no longer present to allow for unimpeded diffuse daylight.

Cool and Green Roofs

Cool roofs not only have a positive effect by reducing building loads and the air temperature of the roof level air intake, but they also reduce the heat island impact of the building on its surroundings. Cool roof requirements in Title 24 are specific to roof slope and building type. Cool roof products are widely available for all types of commercial roofs in California because it is a code requirement in many areas. Title 24 requires an aged solar reflectance index (ASRI) of 0.63 and a thermal emittance (TE) of 0.85 for low-sloped roofs. Increasing the ASRI, such as an ASRI of 0.70 can be achieved with all types of low-sloped roofing products and can be beneficial especially in climate zones with large cooling loads. Based on currently available products, some types of cool roofs can be less expensive than their non-cool roof counterparts, depending on the roofing material type. See the performance values of roofing products at the Cool Roof Rating Council website.

An important consideration in cool roof design is the potential for condensation and ice to build up under the roof membrane in cold climates. Ice can be addressed by ensuring proper roof construction and drainage, maintaining appropriate relative humidity, and adding insulation above the roof deck.

Green (or vegetated) roofs have many of the same benefits of cool roofs, plus added insulation of the thermal mass and a desirable aesthetic. They also offer reduced and/or improved quality of stormwater runoff and can serve as a public space. In some climates, however, they may require irrigation which would impact water use unless recycled water could be utilized. Designers should consider the additional weight and structural impacts of a green roof as well as leak detection. Consider how much roof area will not be covered by PV panels, due to shading, or other constraints, before evaluating cool and green roofs.

SPACE CONDITIONING

When the building envelope has been optimized with insulation and air sealing, and with the addition of shading from overhangs, fins, and improved glazing, the size of the HVAC system can be minimized, shrinking both upfront and operating costs. Common strategies for ZNE buildings include separating heating and cooling from ventilation, using thermal storage to shift energy demand, and optimizing passive strategies. Similar to optimizing the envelope, iterative energy modeling can assist with evaluating and selecting high performance, cost-effective equipment.

Resources:

Passive Solar Home Design

Radiant Heating and Cooling + Dedicated Outdoor Air System

Indirect Evaporative Cooling

NBI Sensitivity Analysis Report

Passive Strategies

Thermal mass is essential for passive building design and must be coupled careful with coordination of windows, walls, and floors to control, collect, store, and dissipate or reject solar heat. Concrete is a common thermal mass, but as phase change materials advance, these products may provide a more flexible approach to passively controlling temperature. Night ventilation strategies for cooling using thermal mass and solar shading are the most common strategies used in commercial buildings. Thermal mass, in a passive strategy context, is not common in commercial buildings due to the need for a dedicated storage space that can fluctuate in temperature outside of the comfort zone. Work with the interior design team to ensure that the space designated for thermal mass is not obstructed so it can perform as designed.

Manage HVAC loads at the source. The most efficient system is the one that's off.

System Type Considerations

Four key strategies that should be considered when first considering HVAC selection options are:

1. Reduce internal heating and cooling loads to reduce equipment size and minimize first costs. Use passive strategies such as night flushing, glazing shading, and thermal storage.
2. Select inherently efficient system types. Consider multiple options such as those discussed in this section. Use Lifecycle Cost Analysis (LCCA) to evaluate system repair and replacement costs when evaluating costs and benefits at the system type level.
3. Select and design an efficient distribution system. Using refrigerant or water instead of air to transport heating and cooling energy, as in a VCHP system (see below), is inherently a more efficient distribution strategy. Consider whether it is possible to decouple heating and cooling from ventilation.
4. Select the most efficient equipment available within the system type selected.

Right size the equipment. Perform analysis of HVAC load requirements, continue to evaluate opportunities to reduce internal loads to minimize equipment size. Optimize the design to reduce internal heating and cooling loads through shading glazing and better glazing, efficient equipment, and less electric lights. Consider incorporating thermal storage (chilled water, ice, and phase change materials) to shift energy use when energy is less expensive and/or when there is an excess of renewable energy to take advantage of reduced rate grid-energy. Ensure that the systems and components are not significantly oversized (which can lead to increased energy consumption, short cycling, wasteful short-duration temperature swings, and equipment maintenance problems) or undersized (which can lead to excessively long runtimes, thermal discomfort due to unmet loads, and equipment maintenance problems). Right-sizing equipment will lower first costs of the HVAC system and distribution system and reduce operating costs.

When comparing systems during early design energy modeling, consider these and other variables: climate and geological considerations, building orientation, building function and occupancy, floor-to-floor ceiling heights, desired temperature set points and responsiveness, and zoning and control considerations.

Variable Capacity Heat Pump (VCHP) Systems (Variable Refrigerant Flow, Variable Refrigerant Volume)

Variable speed compressors with multiple-capacity control VCHP systems achieve high efficiencies by varying the amount of refrigerant provided to each zone as loads fluctuate.

This system is best suited to buildings in temperate climates and those with a wide variety of conditioning needs but it not well suited to those with 100% outside air applications. VCHP systems are particularly suitable for buildings with diverse loads, where some spaces might need heating while others need cooling. Buildings with high hot water loads, such as kitchens and housing, can integrate VCHP systems with hot water systems. Utilizing the heat rejected by the space cooling function for water heating results in higher combined energy savings. For buildings with low floor-to-floor heights, as in many existing buildings, the small refrigerant piping is convenient.

Radiant Heating and Cooling

Radiant heating and cooling limits fan energy to ventilation only and relies on the mean radiant temperature rather than just air temperature to meet conditioning needs. Radiant systems are particularly well-suited to spaces that require or experience higher levels of air changes, or those that rely on natural ventilation. But radiant systems are less appropriate for spaces with unpredictable schedules or load characteristics where responsiveness is required and/or desired. Radiant options include slabs, and wall panels, and chilled beams.

Ceiling and floor slabs work well in spaces with stable occupancy density and standard ventilation rates and not responsive to rapid temperature changes. When cooling, ceiling slabs are often more effective than floor slabs. Chilled beams work well in spaces that require high ventilation rates, high ceilings, and can be combined with radiant slabs to meet large sensible cooling loads.

Ceiling and radiant wall panels offer a faster thermal response than slabs, making them more effective in spaces with frequently changing thermal demands or for cooling-dominated applications and work well in a retrofit application.

Humidity can be a significant concern for radiant cooling applications. Air-based cooling systems dehumidify the air as a function of their normal operation. Radiant cooling systems require separate humidity control in some climates or else the cooling surfaces can cause condensation that can lead to problems ranging from mold and mildew growth to dripping water and slip hazards. In climates that require humidity control, proper design of the ventilation (Dedicated Outside Air System, or DOAS) system so that it adequately controls humidity is essential. When combined with natural ventilation in a humid climate, this also creates the need for a system lock-out for when the natural ventilation system is active and bringing humid air into the building.

Circulation pumps should not run constantly but should be equipped with controls that shut them down when circulation is not needed. Some chilled beams rely on active induction and require airflow in order to meet the cooling needs. Depending on the design parameters of the application, this can be resolved by oversizing the DOAS in order to provide sufficient airflow, at the expense of additional fan-energy consumption.

Ground Source Heat Pumps (GSHP)

Ground source heat pumps, also called geo-exchange systems, use the ground itself as a heat sink or a heat source to increase the thermal conversion efficiency of the refrigerant loop. A water/glycol mix flows through tubes, either drilled vertically down into the earth or laid down horizontally in loops and buried, to pull heat from the ground in winter or pump heat to the ground in summer. GSHPs are a relatively common strategy in ZNE new construction but are rarely used in existing buildings due to cost, access, and land use concerns. Consider whether the site characteristics and plans will allow for horizontal tubing: more space is required, but the installation cost can be significantly lower for horizontal tubing. When evaluating whether to install a GSHP system, consider lifecycle costs and benefits and include air-source heat pumps as well as other system types in the comparison.

Evaporative Cooling

Evaporative coolers work by adding water vapor to hot, dry air which, through the process of evaporation, removes sensible heat from the air and effectively lowers its temperature. Indirect evaporative cooling (IEC) systems are typically used in modern construction, rather than the direct-effect “swamp coolers” of yesteryear. In an IEC system, the supply air is passively cooled before it enters the space by passing over a medium that has been directly evaporatively cooled on an adjacent but isolated side. The IEC’s advantage over traditional evaporative cooling is that no moisture is added to the supply air stream, providing improved indoor air quality. IEC systems are suitable for buildings with cooling towers because they can precool ventilation air, reducing the use of mechanical cooling.

Consider the estimated water use when comparing different evaporative approaches and equipment. Many systems meet California Energy Commission (CEC) water-use-level recommendations for evaporative units of 0.15 gallons per minute per ton (gpm/ton). When located on the roof, consider the structural implications of the unit’s water weight.

Radiant Ceiling Panels.

VENTILATION

Resources:

Radiant Heating and Cooling and Dedicated Outdoor Air Systems

ASHRAE Standard 62.1

The Impact of Ventilation on Productivity

Research on Displacement Ventilation Systems

Optimizing Radiant Systems for Energy Efficiency and Comfort

Space conditioning and ventilation is responsible for 41-51% of the total energy load in conventional California office; design teams are selecting radiant systems to cut this energy use in half. Decoupling the ventilation system from the heating and cooling systems(s) (taking the “V” out of HVAC.) can provide deep energy efficiencies. Therefore, ventilation system design decisions need to be made in tandem with the space conditioning system selection. Further reducing ventilation energy use, reduce ventilation flow rates based on occupancy, providing ventilation only when necessary.

Separating Ventilation from Conditioning

Many radiant systems use pipes, most commonly filled with water, to provide heating and/or cooling while ventilation and any humidity control requirements are efficiently met by a separate system. The savings come in large part because using water or a refrigerant to move and remove heat in a building is inherently more efficient than using air. A common solution for both radiant heating and cooling system and VCHP systems (both of which are covered in more detail above) uses a Dedicated Outdoor Air System (DOAS) to provide 100% of the code ventilation requirements separately from heating and cooling systems. DOAS configurations are available as manufactured packaged units or built-up on-site, depending on the application. Most systems bring outside air across a filter and then through a tempering coil to supply cool dehumidified air directly to the space. Exhaust air is then sent back through the DOAS and may include heat recovery, depending on the climate, before being exhausted to the outside. Energy or Heat Recovery Ventilation (ERV/HRV; see below) may also be incorporated into a DOAS to reduce the radiant system load. Consider system options based on the climate and building characteristics, such as dehumidification, the use of pre-cooling (which may allow some downsizing of the radiant system), and heat recovery.

Heat and Energy Recovery Systems (HRV and ERV)

Energy Recovery Ventilation (ERV) and Heat Recovery Ventilation (HRV) systems transfer energy between the supply and exhaust airstreams. When there is a cooling load, heat in the supply airstream is transferred to the cooler exhaust airstream, lowering the temperature of the supply air, requiring less energy to reduce the air to the design temperature. When there is a heating load, heat in the exhaust airstream is transferred to the cooler supply airstream, raising the temperature of the supply air, again requiring less energy to raise the air to the design temperature. This system works well for larger buildings in climate zones with relatively high space conditioning requirements. Compact contained HRV systems may be appropriate for smaller spaces.

Unlike its simpler HRV cousin, an ERV system can transfer both sensible and latent heat through transferring moisture between the exhaust and supply air streams with an enthalpy wheel. This makes ERVs far more effective in transferring heat under cooling loads than HRVs. In hot, dry climates, it is more cost effective to utilize HRV than ERVs. In these climates, the efficiency gains of ERVs are reduced, even though the price is higher. The design of ERVs systems must account for several additional design and air quality concerns. Avoid cross-contamination of the make-up and exhaust airstreams. This is one reason that the pressure drop on the supply and exhaust side needs to be limited. The design should also account for frost protection in cold climates. ERVs save energy, but those savings are offset somewhat by the energy needed to run the ERV system itself and the pressure drop created by the ERV unit. As a result, it is essential for ERVs to have a bypass that allows the ERV to be powered down and the airstreams to be routed around the ERV unit.

David Brower Center | Berkeley, CA

Demand Control Ventilation (DCV)

Demand control ventilation reduces ventilation flow rates, based on occupancy, reducing the need for heating and cooling outside air while maintaining high indoor air quality. CO^2 controls identify areas where occupancy is variable or irregular, such as meeting rooms, studios, theaters, educational facilities, etc. CO^2 control should allow for both a reduction of outside air flow when occupancy is low and an increase in outside air flow beyond minimum set points when occupancy is high.

DCV will not provide substantial energy savings when occupancy schedules are consistent and predictable, such as an open office, and are better suited for large meeting spaces, cafeterias, and other assembly areas. Other spaces where DCV may not be suitable include: systems where the total supply air flow is less than 1000 cfm, systems with exhaust air energy recovery and an exhaust air flow rate of less than 1000 cfm, and in space types with specific contaminants (such as retail applications with VOC from retail stock), where occupant density may not be an appropriate basis for control of ventilation rate.

CONTROLS AND METERING

Resource:

Zero Net Energy Building Controls: Characteristics, Energy Impacts, and Lessons Learned

State Administrative Manual

ASHRAE Guideline 36: High-Performance Sequences of Operation for HVAC Systems

SAM 1815.3 – Requirements for New, Existing and Leased Buildings

Large buildings often contain many controls: lighting, temperature, humidity, occupancy, security, monitoring, etc. In smaller, less complicated buildings, simpler standalone (not centralized) controls systems can be implemented. Designing successful controls systems for ZNE buildings is a balancing act between the number and depth of control systems, automation, and tenant engagement. When deciding what type of control systems to implement, consider who will be using the controls systems and the necessary overrides. Buildings in which occupants will play a significant role in operating controls can rely more on end-use level controls, but there must be engagement and training opportunities for tenants to ensure success.

Controls Automation, Centralization, and Feedback

Building operators need data and actionable feedback to run a building efficiently, and in many cases, the occupant is the operator. If the occupants take a hands-off role, controls automation will be important to reduce energy demand.

Cost-effectiveness is a useful lens through which to view controls system selection options: what are the costs and benefits of controls systems integration and whole-building controls? Consider if there will be a dedicated building operator able to view building operation feedback in a centralized manner. When specifying a whole-building control system, be sure to install a system that can both monitor and track building performance trends to ensure that this feedback is available.

Building systems that have the capability for demand response (DR), such as HVAC and lighting, should be linked to the central control system, which will respond when DR events are dispatched. See the Grid Integration section for more information about DR.

Controls Integration

It is critical to the success of the building's controls (themselves important to achieving ZNE goals) to bring both controls professionals and building operators into the design process early to discuss controls. Include a dedicated "controls integrator" professional to improve operational sequencing efficiencies, avoid late-stage controls problems, and ensure on-the-ground diagnostic capabilities through the proper inclusion of energy sub-meters. The person responsible for this can be a new team member, or existing team member, like the commissioning agent. The professional can assist with the layout, access, and format of the lighting, HVAC, plug load meters, and control considerations as well as the startup and controls commissioning process, and can serve as the first point of contact, advisor, or decisionmaker for controls questions that impact multiple systems and/or require multiple subcontractors. Information on optimized sequences of operation for heating, ventilating, and air-conditioning (HVAC) systems to maximize HVAC system energy efficiency and performance can be found in ASHRAE Guideline 36.

Monitoring-Based Commissioning

Monitoring-based commissioning (MBCx) is the process of installing permanent metering equipment to provide ongoing building system monitoring by building staff. The Owner's Project Requirements (OPR) indicates if there are any specific submetering or software reporting requirements. Staff should be trained to analyze the monitoring data, understand specific alarms and deviations, as well as how to diagnose basic issues. Deviations from the baseline will indicate opportunities for operational improvements and equipment repairs, helping operators stay on top of energy usage as well as maintenance issues due to equipment faults. Refer to the operations and verification section for information about design and construction phase building systems commissioning. For requirements and criteria for MBCx, refer to SAM 1815.3.

Submetering

Design for meterability. It is much easier to reduce energy use in building systems if the building operator can track the energy consumption of those systems over time. Good metering and feedback systems deliver opportunities for significant energy savings that can pay for these features. Evaluate the LCCA and benefits of installing submetering systems on all major end-uses: space conditioning, ventilation, water heating, lighting, plug loads, and process equipment (such as data centers or pumping.)

Open Source vs. Proprietary Control Systems

Successful ZNE buildings have been built and operated using both open source and proprietary control systems. When evaluating building management systems (BMS) and similar control systems, consider how the management of this building will overlap with others in the same agency or portfolio. A decision made now can lock you into a particular system for many years to come, consider whether existing control systems and vendors can deliver the kinds of monitoring and control features needed for a successful ZNE building, and consider adopting new systems if they cannot.

Reporting / Energy Dashboard

Interactive energy data displays, such as touchscreen dashboards and smartphone applications, can help familiarize occupants with the impacts of their behaviors on energy use and help educate visitors about sustainability goals and achievements. Similarly, online platforms allow occupants to see, in real-time, the effects their behaviors have on building energy consumption. Such tools can help engage occupants and remind them to use building systems as designed. Many building control and monitoring systems now provide similar functionality, so there may be opportunities to integrate this capability into building control systems. The project team should consider the best way to provide building performance feedback to occupants so that they can be engaged in efforts to maintain energy performance goals.

Plan to create a physical or digital energy dashboard and report building energy performance metrics in larger ZNE buildings. Physical dashboards should be installed in the building lobby or another area accessible to both building occupants and visitors. Digital dashboards may include a website or a smartphone application. Consider the balance between granularity and simplicity when selecting a system. Incorporate the energy consumption and generation dashboards into tenant education. Refer to the Operations and Verification section for more information about occupant education programs and EnergyStar Portfolio Manager under the Benchmarking Performance subcategory.

California Lottery Santa Fe Springs District Office.

INTERIOR AND SITE LIGHTING

Decisions made early in the design phase can have a significant impact on a building's potential for using daylight or the need for electric light. Site analysis combined with building programming can encourage daylighting in frequently used spaces, while exterior and interior shading can help with the lighting levels for comfort, avoiding glare and high contrast. When electric light is needed, LED lamps combined with controls sensing daylight, occupancy, and vacancy can provide the most efficient options. Both energy and daylight modeling can support teams to find a balance between daylight and optimized building performance.

Lighting Power Density (LPD)

Title 24 sets allowable watts per square foot based on the lighting needed for the space function. Spaces that need a higher level of attention to detail, such as an equipment repair station, are allowed a higher lighting power density. Below code, LPDs will reduce operational costs associated with connected lighting energy use. One option to achieve below code LPDs is with LED lighting, which can provide the appropriate illuminance to the space at a lower total wattage, depending on lighting design goals. An LPD of 0.65 W/sf can be achieved in an open office layout using LED fixtures. LED office lighting can use 0.10 W/sf less than the prescriptive code requirement while providing the same lighting levels.

A second option to reduce overall LPD is to reduce total space lighting levels and consider high-efficacy task lighting that directs the light precisely to the work surface, giving the occupant control of the light level. Vacancy controls, or overrides, should be considered for task lights, so they are not left on when they are not needed. Photometric plans can illustrate LPD at work surfaces, and this data should be cross-referenced with daylight models to identify potential areas of glare. Controlling glare from direct light or high contrast areas will improve occupant comfort.

Resources:

Saving Energy Through Lighting and Daylighting Strategies

Advanced Lighting

Whole Building Design

International Dark-Sky Association

Luminaire Level Lighting Control

Illuminating Engineering Society of North America

Reach Code Cost Effective Report

California Lighting Technology Center

Illumination Levels

TYPE OF AREA	FOOTCANDLES	
	Horizontal	Vertical
General and Private Office Reading # 3 pencil or softer, ball-point pen, photocopies, keyboard, 8 and 10 point type	30	
Open plan office Intensive VDT use	30	5
Classrooms Reading # 2 pencil or softer	30	
White Boards		5
Chalk Boards		50
Machine Rooms – Active Operation	30	
Mail Sorting, machine equipment service	50	
Stairways and corridors	5	
Toilets and Washrooms	5	3

Title 24 limits lighting level density levels. Illumination Levels from the DGS Standard Operating Efficiency Procedures. Adapted from: IESNA Lighting Handbook 9th edition – 2000 IESNA Lighting Design Guide, Chapter 10

A third option to reduce LPD is through institutional tuning, which is the process of adjusting (or tuning) lighting levels in a space during commissioning to compensate for lighting designs that provide higher illuminance than required. This measure works in conjunction with dimmable ballasts, which were adopted as a requirement in the 2013 Title 24 Standards. Based on space factors and normal lighting design practices, lighting designers often over-illuminate the space to ensure adequate lighting is provided. Institutional tuning sets the maximum light levels in a space at a lower yet acceptable level than the fully installed light levels (e.g., tuning a 65 footcandle design down to 50 footcandles). The result is to reduce the installed energy draw of luminaires, therefore, lowering the LPD while maintaining adequate lighting levels. It is important to maintain initial light levels above the minimum requirement to account for depreciation in lamp efficacy over time.

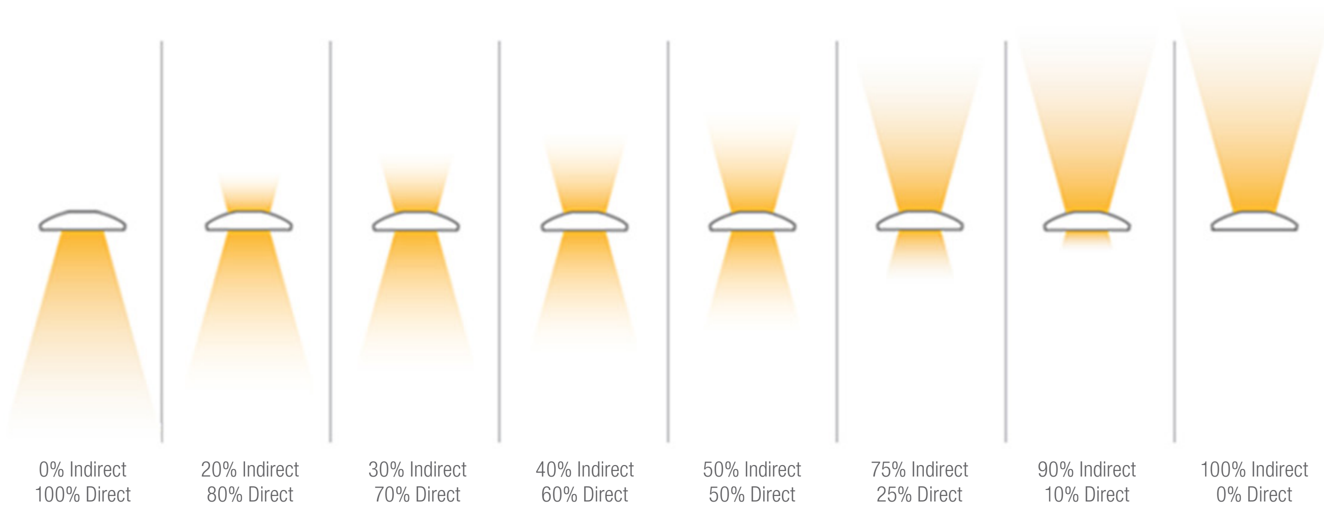
Interior Lighting Technology Type

Evaluate the two primary components for lighting performance – light source efficacy and their controls. LEDs deliver very high levels of efficacy but are not always compatible with all lighting controls. As the high-performance lighting market matures, these incompatibilities are becoming less common, but it is still important to ensure that the lighting control technologies chosen work with daylighting options and the lighting technologies chosen.

Evaluate the percentage of suspended indirect vs. direct lighting strategies depending on floor-to-floor height and ceiling surface and configuration. Tall ceilings with dark, matte surfaces don't allow for proper indirect light distribution while low, highly reflective surfaces can increase opportunities for glare.

Interior Lighting Controls

Manual controls are suited for workstation environments where detailed tasks take place and allow users to adjust the lighting in the space through on/off and dimmable switches. Automated lighting controls include sensors for daylight/photosensor, occupancy, and vacancy. Sensor placement is important to their energy savings potential and should be carefully considered. Photosensors send a signal to adjust the light output based on detected illuminance automatically and are best located near windows and doors. In spaces where Title 24 mandates photosensors, the requirements allow for lighting to be dimmed to 20% of full power. To go beyond Title 24 requirements in these spaces, photosensors can be set to turn the lighting completely off (0%) if adequate daylight is available. Occupancy sensors turn lights on and off by detecting motion within a space and should be in spaces with occasional or irregular use. Some sensors can be used in conjunction with dimming controls to keep the lights from turning off completely when a space is unoccupied. Vacancy sensors require users to manually turn lights on but will automatically turn lights off after preset duration without detected motion.



Indirect and direct lighting options

Occupancy and vacancy sensors can include infrared, ultrasonic, or a combination of both. Selection depends on the space type, surface texture, and desired sensitivity. Open office lighting layouts or other large spaces can be designed to allow control of sub-areas within the larger space. For instance, open office layouts can be sectioned into smaller areas that are controlled by individual sensors; therefore, allowing lighting in portions of an open office area to dim or turn off when unoccupied. A controls integrator can assist with coordinating the controls to the building automation system and the sequences of operation. During commissioning, test sensor functionality and ensure that surrounding elements such as reflections or neighboring sounds do not interfere with the device.

Site Lighting Type

The high-performance of LED light sources allows for significant energy savings in exterior applications, especially considering the long operating hours and large areas that often characterized many exterior lighting installations. The long service life and resulting lowered maintenance costs only contributed more cost savings. Beyond the lamp type, consider luminaire shielding, color temperature, high color rendering index (CRI) (90+) site light levels, and lighting controls for optimum exterior lighting performance.

Limit light trespass through luminaire shielding. Light shields are installed on luminaires to block the light in a specified direction. Many exterior luminaire manufacturers offer light shields specifically for their products, and third-party after-market solutions are also available for many luminaires. LEDs are intense light sources, so specifying luminaires with higher cut-off angles will help shield people from glare and even discomfort of having a direct line-of-site exposure to the LED light source.

Higher light levels of site lighting are often misperceived as increasing safety. However, if care is not taken, increases in luminaire brightness can have a negative impact on safety due to high contrast. The best strategy for security lighting is to design for lower, but uniform, light levels that avoid the creation of high-contrast dark zones.

Site Lighting Controls

Even highly efficient light sources like LEDs can benefit from good control strategies. The energy code requires controls that site lighting is turned off during daylight hours, but there are opportunities to turn site lighting off or down during nighttime hours. Most sites see a period with little to no activity each night. During these hours, site lighting can be turned down while landscape and accent lighting can be completely turned off. LED light sources are very well suited to dimming, making step down strategies very feasible.

RENEWABLES AND ENERGY STORAGE

Resources:

NREL Solar Ready Buildings Planning Guide

SAM Management Memo 1815.31 – Zero Net Energy for New and Existing Buildings

Federal On-Site Renewable Power Purchase Agreements

The Regulatory Assistance Project

State of CA ZNE Calculator for State Buildings

PV Watts

Find the right balance between energy efficiency and renewable energy. Minimize energy loads through passive systems and efficiency to minimize the capital cost of renewable systems. Evaluate the options for reducing upfront and long-term costs of on-site energy generation through purchasing or leasing photovoltaic panels. Overproduction of electricity is discouraged by net energy metering tariffs and time dependent value (TDV) calculations. Some buildings, particularly existing buildings, may not be capable of adding renewables right away so consider future renewable energy needs and design buildings to be solar ready. Consider whether and how the renewable system can generate energy for the building during a grid-wide power disruption, and how batteries can be used to minimize peak energy requirements and demand charges, reducing the simple payback.

Solar Budget and Sizing

When setting energy targets (early in the design process), calculate the project site's renewable energy budget: how much energy can be generated using on-site resources? Find the optimal cost-effectiveness balance point between energy efficiency investments and on-site renewable capacity to achieve ZNE. Solar PV is almost always the most cost-effective way to create energy on-site, usually followed by solar thermal systems. If the site allows, consider other renewables (small-scale wind, geothermal, micro-hydro, site-harvested biomass). Since the price of PV is reliant on the amount of energy generation needed, reduce the energy demand to minimize the upfront cost. Consider the effects of shading from trees and neighboring structures, including potential future buildings (check local zoning laws). DGS's State of California ZNE Calculator for State Buildings and the PV watts web tool can help estimate required renewable energy generation and PV array size to achieve ZNE.

Calculate the cost-effectiveness impacts of various solar panel siting options:

- The roof – usually the simplest and most cost-effective option
- Ground-mounted arrays or parking structures – these are common and effective but may incur additional costs due to additional structure needs
- The building façade – typically less cost-effective due to suboptimal panel orientation and higher mounting costs; may be suitable for some projects).

RESULTS **74,233 kWh/Year***

System output may range from 70,722 to 75,784kWh per year near this location.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Energy Value ($)
January	4.45	5,070	646
February	5.35	5,519	703
March	5.62	6,382	813
April	6.05	6,604	841
May	6.18	6,941	884
June	6.17	6,676	851
July	6.47	7,176	914
August	6.68	7,354	937
September	5.78	6,157	784
October	5.43	6,054	771
November	4.85	5,277	672
December	4.46	5,023	640
Annual	5.62	74,233	$ 9,456

PV Watts® | Long Beach, CA

Resiliency

During Superstorm Sandy (as well as various other natural and human events) many building owners were dismayed to learn that their solar panels did not provide power to the building when the grid went down. Consider resiliency benefits and evaluate costs for solutions such as microgrids or building islanding systems that can allow the building to operate, at least in some capacity, or can power critical systems when the grid is down. As a more affordable option, some PV system power inverters come with emergency plugs to provide grid-isolated power sources in emergencies. Consider the community benefits of these resiliency aspects in public buildings especially.

ZNE Ready Buildings

Some ZNE buildings will not install all solar panels before initial occupancy. Design the building so that additional solar panels can easily be incorporated after construction. Maximize the roof area available for solar panels by consolidating and minimizing rooftop equipment. Be sure that the structure can support the 2-6 psf that solar PV and thermal panels add. Install wiring that is capable of carrying electric current corresponding to the maximum predicted output of potential, not just currently installed, PV systems. Design the mechanical/electrical rooms to include space for future installation of inverters and additional electrical equipment. Install empty conduit from electrical rooms to the parking lot, and/or site locations where future on-site solar generation may occur. This will save much expense when adding future solar, and minimize disruption to building occupants and operations. Similarly, consider these systems when designing and specifying the controls and electrical panel. Install submetering equipment to track and record on-site energy generation trend data.

On-site and Off-site Renewables

Not all sites are suitable for on-site energy generation due to lack of solar access, and in larger buildings, there may not be sufficient roof or another area to produce enough energy to make it to ZNE through on-site resources alone. A portion or all energy may need to be generated off-site. Off-site renewable energy can be purchased through some utilities, Community Choice Aggregators (CCAs), or community renewable energy options. Owners can enter into long-term contracts with a utility or CCA programs to supplement on-site generation or offset all facility power needs with renewable energy generated off-site. Engaging in a local community solar program allows owners to utilize solar energy through a shared off-site solar power plant. In order to qualify for state ZNE classification, community renewable energy agreements need to be committed for at least 20 years and be based in California. For more information about Community ZNE definitions for renewable energy generation, see SAM 1815.31.

Be sure to ***retain or retire the Renewable Energy Certificate (RECs)*** from your renewable energy system to ensure that you can claim ZNE status. The federal government provides a 30% tax credit for renewable energy systems, but public buildings often need to partner with a tax-paying entity through a Power Purchase Agreement (PPA) to capture these benefits. Review contracts carefully to confirm See the Project Finance section for more information about PPAs.

Battery and Thermal Energy Storage (TES)

The price of battery storage has now fallen to the point that it is worth considering in many buildings. California Assembly Bill 2514, passed in 2013,, mandated the state's three Investor Owned Utilities (IOUs) to procure 1,325 MW of electricity storage (e.g., batteries) by 2020. In 2017, the California Public Utilities Commission ordered the IOUs to procure 500 MW of behind-the-meter storage, and some utilities have already had incentive programs in place to help finance energy storage. Base the size and operating parameters of the battery system on the applicable tariff for the facility, and consider the cost savings impacts of reducing peak demand charges.

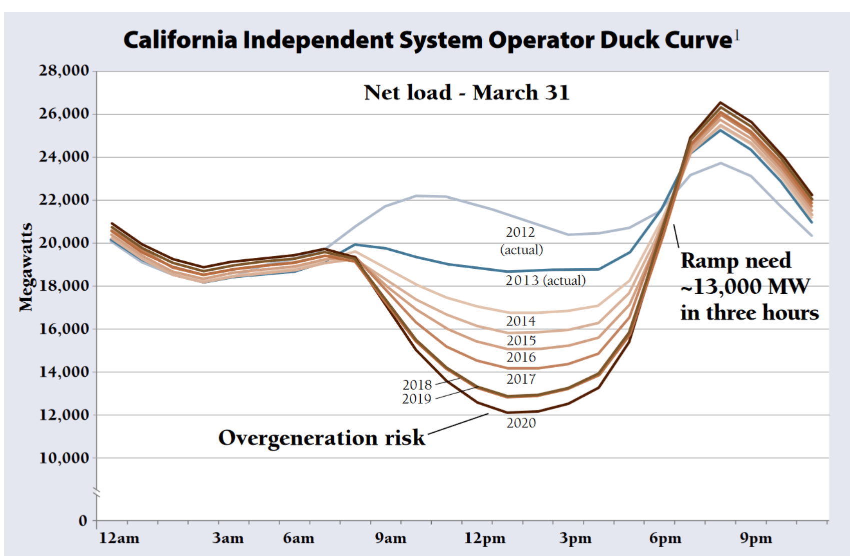
Thermal energy storage using ice, chilled or heated water, and phase change materials are well suited to new construction projects, especially larger projects and campuses using chilled water systems. TES systems have the potential to be more energy efficient as the chillers, and hot water tanks can operate at higher temperatures. Tank-type heat pump water heaters offer a low-cost energy storage option for facilities with high hot water loads. The avoided cost of chiller capacity reduction will often pay for the tank systems, and the utility cost savings are a bonus. Some large buildings and campuses are opting for longer-term energy storage systems: aquifer-based seasonal energy storage, in which water warmed with waste heat from the building in summer is stored underground and used in the winter for heating (and vice versa). Smaller buildings may find ice systems and phase change materials to fit the budget. Another energy storage system to consider: phase change materials which provide energy storage by melting and solidifying at certain temperatures to store or release a large amount of energy. These are relatively new and the technology is evolving fast.

Include these considerations when evaluating the cost-effectiveness of battery and thermal energy storage systems: mechanical system size reductions, demand charges, utility rate structures, and maintenance savings. Understand that all forms of energy storage have losses; batteries may have a round-trip efficiency of ~80%; especially when inverter efficiencies are included.

Grid Integration

California is facing real and growing energy problems stemming in large part from a mismatch between when renewable energy is available and when peak demand on the electric grid occurs. All state buildings are required to participate in demand response (DR) power supply programs to modify peak electrical loads except when such programs adversely affect state agency building operations, occupant performance, or indoor

The "Duck Curve"
Source: Lazar, J. (2016). Teaching the "Duck" to Fly, Second Edition. Montpelier, VT: The Regulatory Assistance Project. Available at: http://www.raponline.org/document/download/id/7956]



environmental quality. Demand response is not only for load reduction; it can also be used to productively use energy during low-net-demand hours (e.g. when there is excessive solar on the grid). Renewable energy generation typically peaks around noon. However, peak energy use hours are shifting later: peak load now often occurs between 4-7 pm and in the future they may shift later. This leads to curtailment of renewable energy, steep ramp-up rates for power plants, and other grid problems. This issue is often referred to as the "duck curve." Some strategies to help minimize these problems and protect the building owner from future changes in rate structures or demand charges are:

- Focus on energy efficiency measures that have greater savings impacts during peak hours.
- Keep control zones in office space lighting small and automated, and provide task lighting, so that large spaces need not remain lit for a small number of workers staying late.
- Evaluate the costs and benefits of battery and thermal storage (consider demand charges and rate structures).
- Face the solar panels more toward the west wherever possible to minimize over-generation during low-net-demand hours (e.g., noon).
- Consider the use of on-site energy storage to capture midday energy production for use during peak hours, while maximizing on-site generation with optimum orientation.
- Install electric vehicle (EV) charging stations and use EV charging as a strategy for absorbing excess generation during low-net-demand hours, as well as to offset energy use from natural gas and district energy used. Electrical loads from EV charging does not count against building loads and can be excluded in calculating facility ZNE, so this is an effective way to use over-generated renewable energy and avoiding having to export at wholesale rates.

Simpliphi Hawaii Batteries

OPERATIONS AND VERIFICATION

After construction is complete, building operators enable the building to achieve its ZNE design intent. Engaging occupants is key to maintaining performance. Third-party organizations can verify the building's ZNE status and provide recognition.

OPERATIONS AND VERIFICATION

Resources:

Title 20 Appliance Efficiency Program

DGS Standard Operating Efficiency Procedures

Plug Load Guide

ICC Guideline for Commissioning

Whole Building Design Guide Building Commissioning

Building Commissioning Association

California Commissioning Collaborative

Gamified Energy Efficiency Programs

ZNE Verification FAQ

Getting to Zero Database and Registry

ILFI Net Zero Certification

Northeast Energy Efficiency Partnership Operations and Maintenance Guide

The Path to Net Zero: A Shout Out to Building Operators

Discovery School Energy Dashboard

State Administration Manual, Section 1805.3 Standard Operating Efficiency Procedures

State Administrative Manual (SAM) Chapter 1800 – Energy and Sustainability

PG&E Energy Storage and Generation Incentives

Major building systems are not the only energy uses to consider during design. Occupant energy use behavior can make or break ZNE goals so education and training should not be overlooked. Building occupants and facility staff may not be familiar with passive approaches, new equipment, or controls, yet these individuals must understand the systems, and how their interaction with these systems drives energy consumption, to achieve a ZNE result. For example, if the building is naturally ventilated, the occupants should know when to and when not open or close windows. The same holds true for daylighting strategies that can easily be disabled by occupants. Maintenance staff should also be trained to turn off systems, such as lighting, when their work is done, or be made aware of how to temporarily override controls, in emergencies.

Equipment Specifications, Purchasing, and Plug Loads

Even in very efficient buildings, plug loads can represent 50% or more of total annual energy use. The main culprits are computers, televisions, server rooms, and charging devices associated with personal electronics, all of which draw power even when not being used or are fully charged. Tile 24 addresses plug load management by requiring some outlets to be on, or be capable of, a timer/BMS for plug loads that only need to be energized during work hours. Consider developing a plug load budget and share with occupants, so they understand their allowed energy use. Select energy efficient equipment and appliances, and add plug load controls, like switched outlets or vacancy sensors, in master specifications. Additionally, require efficient equipment purchase through an energy efficiency procurement policy. Specify equipment with a higher tiered equipment for increased energy performance. CEE Tier 2, 3, 4 and CEE Advanced Tier is preferred over CEE Tier 1 products. Choose plug load sensors that sense when the device has not been in use, or the occupant has left the workpace. Create equipment power management plans and train staff to enable electronic to drop into a “sleep” mode and consume less power when they've been left idle for a pre-specified amount of time. Refer to Standard Operating Efficiency Procedures for further guidance and requirements to reduce plug loads.

California's Appliance Efficiency Regulations under Title 20 creates standards for 15 categories of appliances, but project teams can select more efficient appliances with additional research. EnergyStar rated equipment may not be available for all plug load appliances and equipment, such as commercial kitchen equipment so that specialty equipment may be required. Work with the manufacturer to identify the anticipated energy use and incorporate into the energy model for accurate on-site energy production sizing.

Building Systems Commissioning

Building systems commissioning ensures that a building is delivered according to the OPR. Commissioned buildings operate more efficiently, are more comfortable, and have lower operations and maintenance costs. Commissioning is also a requirement of CAL Green, as well as LEED certification. Commissioning Agents should be incorporated into the team during the design phase to act as the owners representative and review contract documents against the OPRs. During construction, the controls integrator and commissioning agent will test the installed systems to ensure they are working together according to the OPR. This can help identify any operational issues, hopefully before occupancy. The commissioning agent can also assist to resolve any issues uncovered in this process. Within the commissioning agent's scope also include building operator training and on-going commissioning to train owners and occupants on the proper use of the systems for maximum efficiency and identify and resolve any unexpected operational issues after move-in.

Identify inefficiencies through the implementation of an ongoing operations and maintenance program. A strong quality control program will keep the building operating to ZNE. Ongoing building systems commissioning should be part of the program, whether done in-house or by an independent commissioning agent. Refer to the controls and metering section for information about monitoring based commissioning.

Occupant Training

Develop tenant guidelines to educate occupants and describe the unique features of the building. Provide information on efficiency measures that may be different from a traditional workstation. The guidelines can also include information about future renovation considerations to maintain ZNE and other green building goals. Incorporate these guidelines into the lease or employee welcome package and occupant feedback to ensure they understand the available energy data.

Facility operations and maintenance staff should meet with the design team and commissioning agent to learn about the building systems, controls, and automation systems before taking over maintenance responsibilities. It may be helpful for the design team to develop an operations manual that includes equipment cutsheets, warranties, product maintenance guidelines, commissioning results, among other information. ZNE performance can be incorporated into building operator job descriptions and performance reviews. Refer to the Controls and Metering section for more information on dashboards and displays.

Share Energy Use

An energy dashboard is a great opportunity to visually present building energy consumption and production by month, day, hour, or a minute and remind occupants and visitors of the role they play in reducing energy use. Displays can be interactive, educational, or motivating, depending on your audience and the data available. Some energy tracking programs allow occupants to track energy use from a website or their smartphones and will send educational messages and reminders about energy reduction at peak hours. In competitive environments, saving energy can become a game between individuals or departments. Gamification challenges individual with energy reduction and provides the occupant with progress in energy efficiency. Points and medals are awarded to individuals and teams to motivate users. Refer to the Controls and Metering section for more information about displays.

Benchmark Energy Performance

One full year of energy consumption and production data is necessary to verify ZNE performance. Research has shown that some ZNE buildings may not operate at ZNE during the first twelve months of occupancy. Instead, it may take longer to meet the target. Ongoing tracking and review of energy performance with a Building Management System, energy dashboard, or EnergyStar Portfolio Manager is helpful to understand energy performance and renewable energy production if incorporated. All state agencies and facilities are required to benchmark energy and water use in the EnergyStar Portfolio Manager. Enter a new building into the agency's EnergyStar Portfolio Manager account and provide access to DGS. Most electricity and natural gas utilities can automate data transfers. Arrange for departments to enter water use manually. Facility staff can compare actual energy consumption to predicted performance to identify if systems are operating as designed. Uncovering irregularities through frequent data review can help to correct the issue promptly. The state displays energy and sustainability metrics and performance data on a public website. This data displays information reported by departments as required by executive orders and in the State Administrative Manual (SAM) Chapter 1800.

ZNE Performance (after 1+ year) and Certification

Ultimately, achieving ZNE depends on occupant behavior and understanding of ZNE features. Providing best practices and information on a ZNE building can help occupants take full advantage of their new building. After one year of energy use, review the building energy use and generation data to identify if zero net energy was achieved. Submit the energy data to the NBI Getting to Zero Database or the International Living Future Institute (ILFI) for third-party verification. If your building came short of achieving a net EUI of 0, evaluate the opportunities for improvement. Work with the commissioning agent, calibrate the energy model, and engage the occupants, etc., to ensure the performance meets ZNE goals.

ZNE PROJECT TRACKING TOOL FOR STATE BUILDINGS

Use ZNE Project Summary to describe how each item in the checklist was evaluated. While not all measures are appropriate for all projects, indicate how the decision was made to adopt a checklist item or Include data to document the ZNE actions.

Examples:

Project Finance

- ❑ **Conduct lifecycle costing analysis (LCCA) at various stages of design**

LCCA Conducted by ABC Consultants after the first cost estimate came back.

- ❑ **Consider power purchase agreements (PPAs)**

PPA was not available in our region.

Space Conditioning

- ❑ **Evaluate passive cooling and heating options**

The Standard Operating Procedures and OPR included specific temperature and humidity set points that were not consistently available for all spaces. We incorporated passive cooling in the vehicle storage area to eliminate cooling in this space.

- ❑ **Evaluate multiple high-performance conditioning systems**

ABC Engineers compared HRV, evaporative cooling, and DOAS plus radiant cooling, and compared each to a code-compliant baseline system. To meet efficiency and comfort needs, we selected the DOAS plus radiant cooling.

Pre-design

Green Building and ZNE Requirements

- ❑ **Meet State ZNE Energy Efficiency Requirements**
  - ❑ Exceed Title 24 by at least 15%
  - ❑ Achieve or exceed the target Energy Use Intensity (Source EUI) for existing buildings

- ❑ **Review Other Green Building Considerations**
  - ❑ Achieve LEED Silver certification, or higher
  - ❑ Or, California Green Building Standards Code (CALGreen Tier 1) measures (10,000 sf or less)
  - ❑ Incorporate monitoring-based commissioning
  - ❑ Use low water use fixtures, meeting or exceeding current code

- ❑ **Consider water reuse and recycling**
  - ❑ Use purple pipe for reclaimed water if available to, or near the site.

Pre-design Process

- ❑ **Include ZNE requirement in budget packages**

- ❑ **Identify a team ZNE champion**

- ❑ **Develop and refine Owners Project Requirements (OPR) to reflect ZNE**

- ❑ **Review contract structures and include ZNE**

- ❑ **Select qualified ZNE team**

- ❑ **Set building energy performance targets**

- ❑ **Hold design charrettes, as required**

- ❑ **Conduct early design phase energy modeling**

Project Finance

- ❑ **Conduct lifecycle costing analysis (LCCA) at various stages of design**

- ❑ **Evaluate on-bill financing (OBF) options including on-bill repayment (OBR), and GS $Mart**

- ❑ **Review opportunities for utilizing energy service companies (ESCOs) for existing buildings**

- ❑ **Consider power purchase agreements (PPAs) for onsite renewable energy**

- ❑ **Engage with utility incentive programs including Savings By Design**

Site Analysis

- ❑ **Conduct bioclimatic analysis**
  - ❑ Evaluate solar access
  - ❑ Evaluate different building orientations to inform optimal layout

- ❑ **Analyze passive design and natural ventilation options**

- ❑ **Daylight spaces and incorporate glare control**

- ❑ **Evaluate water reuse and recycling opportunities**

Design

Building Envelope

- ❑ **Optimize exterior insulation levels**
  - ❑ Consider continuous exterior rigid insulation
  - ❑ Review construction details and evaluate to avoid thermal bridging

- ❑ **Install continuous air barriers and adequately seal penetrations to minimize leakage**
  - ❑ Seal all joints and seams, including sealing transitions at two or more materials
  - ❑ Seal envelope penetrations with caulk and/or gasket systems
  - ❑ Consider a blower door test to identify leaks

- ❑ **Model various window to wall ratios (WWR)**
  - ❑ Optimize WWR per orientation to minimize net energy use
  - ❑ Consider targeting overall WWR of 40% or less

- ❑ **Identify most effective high-performance glazing for each façade/orientation**
  - ❑ Select glazing that maximizes energy performance and daylighting
  - ❑ Select windows with low U-factor and SHGC
  - ❑ Identify the proper VLT for each space

- ❑ **Control glare with external and internal shading**
  - ❑ Shade the exterior side of window glazing
  - ❑ Provide interior shade contros
  - ❑ Model daylight patterns

- ❑ **Specify cool and/or green roofs**

Space Conditioning

- ❑ **Evaluate passive cooling and heating options**
  - ❑ Incorporate thermal mass into the floor or walls

- ❑ **System type considerations**
  - ❑ Evaluate distribution and equipment efficiency options
  - ❑ Evaluate multiple high-performance conditioning systems
  - ❑ Reduce internal loads to reduce system size
  - ❑ Use refrigerant/chilled water/hot water/steam instead of air to transfer energy
  - ❑ Limit fan energy to ventilation only

Ventilation

- ❑ **Study separating ventilation from conditioning**
  - ❑ Evaluate passive ventilation
  - ❑ Consider dedicated outside air systems (DOAS)

- ❑ **Consider heat/energy recovery systems (H/EVR)**
  - ❑ Identify opportunities for other waste energy reuse

- ❑ **Evaluate demand control ventilation (DCV)**

Controls and Metering

- ❑ **Consider controls automation, centralization, and feedback**

- ❑ **Add a controls integrator to the team**

- ❑ **Incorporate monitoring-based commissioning, where required**

- ❑ **Submeter HVAC, lighting, plug loads, PV**
  - ❑ Incorporate fault detection and diagnostics
  - ❑ Design circuiting systems to segregate end-use loads at the panel

- ❑ **Assess open source vs. proprietary monitoring systems**

- ❑ **Create new property profile in department's EnergyStar Portfolio Manager account**
  - ❑ Automate energy data transfers with utilities Provide profile access to DGS
  - ❑ Consider controls and communications to make the building energy systems (lighting, HVAC, energy storage) demand response (DR) capable

Interior and Site Lighting

- ❑ **Reduce lighting power density (LPD) with 100% LEDs**
  - ❑ Specify high-efficacy task lighting
  - ❑ Tune lighting during commissioning

- ❑ **Evaluate direct and indirect interior lighting options**

- ❑ **Consider interior vacancy, photosensor, and dimmable lighting controls**

- ❑ **Consider exterior dimmable lights, photosensors, and motion sensors**

Renewables and Energy Storage

- ❑ **Evaluate solar budget and system size**
  - ❑ Balance cost of energy efficiency and renewables

- ❑ **Prepare for resiliency from natural disasters**
  - ❑ Consider microgrids or building islanding systems

- ❑ **Prepare for future solar**
  - ❑ Dedicate appropriate roof area and/or site area
  - ❑ Install or plan for future electrical wiring and panel controls

- ❑ **Evaluate on and off-site renewable options**
  - ❑ Keep renewable energy certificates (RECs)

- ❑ **Evaluate battery and thermal storage options and benefits**
  - ❑ Consider current and future equipment space needs

- ❑ **Reduce peak energy use for grid integration**
  - ❑ Design for and participate in utility demand response (DR) programs
  - ❑ Evaluate opportunities to reduce peak energy use
  - ❑ Utilize electric vehicles (EVs) for storing over-generated PV power

Operations and ZNE Verification

Operations

- ❑ **Specify efficient office equipment for reduced plug loads**
  - ❑ Consider establishing plug load budget target
  - ❑ Specify plug load and workstation vacancy sensors
  - ❑ Develop and implement equipment purchasing policies

- ❑ **Commission the building systems during design, construction, and during occupancy**
  - ❑ Incorporate the commissioning agent at predesign

- ❑ **Conduct occupant training on building operation and energy use**
  - ❑ Teach occupants about how to use new equipment and controls
  - ❑ Develop and provide tenant guides
  - ❑ Train facilities and operations staff on how to operate new systems and monitor energy and water use

- ❑ **Create displays to share real-time energy use with tenants**

ZNE Verification

- ❑ **Benchmark energy performance with EnergyStar Portfolio Manager**

- ❑ **Verify ZNE performance after 1+ year**
  - ❑ Submit for third-party certification

RESOURCE WEB ADDRESSES

These resources mirror those listed within each chapter.

Green Building and ZNE Requirements

California Long Term Energy Efficiency Strategic Plan: http://www.cpuc.ca.gov/General.aspx?id=4125

Executive Order B-18-12: https://www.gov.ca.gov/news.php?id=17508

CEC Approved and Pending Local Ordinances: http://www.energy.ca.gov/title24/2016standards/ordinances/

CAL Green: http://www.bsc.ca.gov/Home/CALGreen.aspx

State Administrative Manual (SAM) Chapter 1800: http://sam.dgs.ca.gov/TOC/1800.aspx

SAM Management Memo 17-04: https://www.documents.dgs.ca.gov/osp/sam/mmemos/MM17_04.pdf

SAM Management Memo 1815.31 – Zero Net Energy for New and Existing Buildings: https://www.documents.dgs.ca.gov/sam/SamPrint/new/sam_master/sam_master_file/chap1800/1815.31.pdf

ZNE for New and Existing State Buildings 1815.31: https://www.documents.dgs.ca.gov/sam/SamPrint/new/sam_master/sam_master_file/chap1800/1815.31.pdf

California Green Building Action Plan: http://www.climatechange.ca.gov/climate_action_team/documents/Green_Building_Action_Plan.pdf

DGS ZNE Website: https://www.dgs.ca.gov/dgs/Sustainability/ZeroNetEnergy.aspx

EPA Water Reuse Guidelines: https://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf

California Recycled Water Policy: http://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2013/rs2013_0003_a.pdf

ZNE Frequently Asked Questions and Terminology: http://newbuildings.org/sites/default/files/ZNE_CommsToolkit_FAQ_CA.pdf

ZNE Case Studies: https://newbuildings.org/case-studies/

ZNE Case Study Buildings: https://energydesignresources.com/media/19864463/zne_case_study_buildings-11.pdf?tracked=true

ZNE Communications Toolkit: https://newbuildings.org/resource/zero-net-energy-communications-toolkit/

NBI's 2016 Getting to Zero List: http://newbuildings.org/wp-content/uploads/2016/10/GTZ_2016_List.pdf

State of California ZNE Calculator: https://www.documents.dgs.ca.gov/os/ZNE/StateofCAZeroNetEnergyCalculator.xlsx

Pre-design Process

ZNE Project Guide: https://newbuildings.org/wp-content/uploads/2015/12/GtZ_ZNEProjectGuide2017.pdf

San Diego ZNE RFP: http://www.sandiegocounty.gov/content/dam/sdc/sdhcd/new-docs/PBV_VASH_RFP_2016.pdf

SF USD OPR Example: https://gettingtozeroforum.org/wp-content/uploads/sites/2/2017/08/OwnersProjectRequirements_SFUSD.pdf

How to Guide for Energy Performance-Based Procurement: https://www1.eere.energy.gov/buildings/publications/pdfs/rsf/performance_based_how_to_guide.pdf

ZNE Decision Making Matrix for State Agencies: http://www.documents.dgs.ca.gov/os/ZNE/ZNEDecisionMakingMatrix_1032017.docx

DGS Source EUI Energy Targets for State Buildings: http://www.documents.dgs.ca.gov/os/ZNE/California-StateBuildingEfficiencyTargetsforZNE_1032017.xlsx

ZNE Charrette Toolkit: https://newbuildings.org/resource/zne-charrette-toolkit/

PV Watts® Solar Calculator: http://pvwatts.nrel.gov/

Project Finance

Washington State LLCA Tool: https://des.wa.gov/services/facilities-leasing/energy-program/energy-life-cycle-cost-analysis

Cost Control Strategies for Zero Energy Buildings: http://www.nrel.gov/docs/fy14osti/62752.pdf

CPUC Statewide Finance Program: http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M183/K956/183956504.PDF

Savings By Design: http://www.savingsbydesign.com

SMUD: https://www.smud.org/en/business/save-energy/rebates-incentives-financing/

NREL ZE Cost Study: http://www.nrel.gov/docs/fy14osti/61365.pdf

GS $Mart: http://www.dgs.ca.gov/pd/Programs/StateFinancialMarketplace.aspx

State Financial Marketplace: http://www.dgs.ca.gov/pd/Programs/StateFinancialMarketplace.aspx

DSIRE: http://www.dsireusa.org/

Federal solar tax credits: https://energy.gov/savings/business-energy-investment-tax-credit-itc

California Solar Initiative: http://www.gosolarcalifornia.ca.gov/csi/index.php

Commercial PACE: https://naseo.org/data/sites/1/documents/publications/CLEAN_Master%20NASEO%20PACE%20Memo%202016-5-18%20FINAL.pdf

Community Choice Aggregation in California: https://www.pge.com/en_US/residential/customer-service/other-services/alternative-energy-providers/community-choice-aggregation/community-choice-aggregation.page

DGS Clean Energy Generation Program: http://www.dgs.ca.gov/dgs/Sustainability/CleanEnergyGeneration.aspx

Site Analysis

Daylight Pattern Guide: http://patternguide.advancedbuildings.net/

Urban Heat Islands Compendium: https://www.epa.gov/heat-islands/heat-island-compendium

NBI ZNE Design Fundamentals Fact Sheet: http://newbuildings.org/sites/default/files/ZNE_CommsToolkit_DesignFundamentals_CA.pdf

Deep Savings in Existing Buildings: http://newbuildings.org/resource/case-deep-savings-11-case-studies-deep-energy-retrofits/

NBI Technical Resource Guides:

- **Daylighting Pattern Guide:** http://newbuildings.org/resource/daylighting-pattern-guide/

- **Daylighting Guide for Office Interiors:** http://newbuildings.org/resource/daylighting-guide-office-interiors/

- **Plug Load Guide:** http://newbuildings.org/resource/plug-load-best-practices-guide/

- **Indirect Evaporative Cooling:** http://newbuildings.org/resource/zero-net-energy-technology-application-guide-indirect-evaporative-cooling/

- **Luminaire Level Lighting Control:** http://newbuildings.org/resource/zero-net-energy-technology-application-guide-luminaire-level-lighting-control/

- **Radiant Heating and Cooling + Dedicated Outdoor Air Systems:** http://newbuildings.org/resource/zero-net-energy-technology-application-guide-radiant-heating-and-cooling-dedicated-outdoor-air-syste/

- **ZNE Building Controls: Characteristics, Energy Impacts, and Lessons:** http://www.caba.org/CABA/Research/Zero-Net-Energy-Buildings.aspx

Sensitivity Analysis Using Key Performance Indicators for Building Performance: http://newbuildings.org/resource/using-kpis-better-energy-performance/

Building Envelope

Transition to Sustainable Buildings: Strategies and Opportunities to 2050: https://www.iea.org/publications/freepublications/publication/Building2013_free.pdf

Building Envelope Thermal Bridging Guide: https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/power-smart/builders-developers/building-envelope-thermal-bridging-guide-1.1.pdf

Enhanced Thermal Performance Spreadsheet: https://www.bchydro.com/content/.../BCHydro/.../betbg-enhanced-spreadsheet.xlsm

Thermal Bridges Redux: https://buildingscience.com/file/6931/download?token=ANRVCUt4

Windows for High-Performance Commercial Buildings: http://www.commercialwindows.org/

Daylighting Pattern Guide: http://newbuildings.org/resource/daylighting-pattern-guide/

Daylighting Guide for Office Interiors: http://newbuildings.org/resource/daylighting-guide-office-interiors/

Cool Roof Rating Council: www.coolroofs.org

Investigation of the Impact of Commercial Building Envelope Airtightness on HVAC Energy Use: http://ws680.nist.gov/publication/get_pdf.cfm?pub_id=860985

Reach Code Cost Effective Report: http://localenergycodes.com/content/performance-ordinances

Space Conditioning

Passive Solar Home Design: https://energy.gov/energysaver/passive-solar-home-design

Radiant Heating and Cooling + Dedicated Outdoor Air System: https://newbuildings.org/wp-content/uploads/2015/11/Radiant_ZNE_TAG1.pdf

Indirect Evaporative Cooling: http://newbuildings.org/resource/zero-net-energy-technology-application-guide-indirect-evaporative-cooling/

NBI Sensitivity Analysis Report: https://newbuildings.org/resource/sensitivity-analysis/

Ventilation

Radiant Heating and Cooling and Dedicated Outdoor Air Systems: https://newbuildings.org/wp-content/uploads/2015/11/Radiant_ZNE_TAG1.pdf

ASHRAE Standard 62.1: https://www.ashrae.org/resources--publications/bookstore/standards-62-1--62-2

The Impact of Ventilation on Productivity: https://www.cbe.berkeley.edu/research/briefs-ventilation.htm

Research on Displacement Ventilation Systems: https://www.cbe.berkeley.edu/research/dv.htm

Optimizing Radiant Systems for Energy Efficiency and Comfort: https://www.cbe.berkeley.edu/research/optimizing-radiant-systems.htm

Controls and Metering

Zero Net Energy Building Controls: Characteristics, Energy Impacts, and Lessons Learned: https://newbuildings.org/resource/zero-net-energy-building-controls-characteristics-energy-impacts-and-lessons-learned-research-report/

State Administrative Manual: https://www.documents.dgs.ca.gov/sam/SamPrint/new/sam_master/sam_master_file/chap1800/1815.3.pdf

ASHRAE Guideline 36: High-Performance Sequences of Operation for HVAC Systems: http://gpc36.ashraepcs.org/

SAM 1815.3 – Requirements for New, Existing, and Leased Buildings: https://www.documents.dgs.ca.gov/sam/SamPrint/new/sam_master/sam_master_file/chap1800/1815.3.pdf

Interior and Site Lighting Design

Saving Energy Through Lighting and Daylighting Strategies: https://app_gsagov_prod_rdcgwaajp7wr.s3.amazonaws.com/Lighting_and_Daylighting_Two_Pager_508_compliant_2-9-15.pdf

Advanced Lighting: http://algonline.org/

Whole Building Design: http://www.wbdg.org/resources/electric-lighting-controls

International Dark-Sky Association: www.darksky.org

Luminaire Level Lighting Control: http://newbuildings.org/resource/zero-net-energy-technology-application-guide-luminaire-level-lighting-control/

Illuminating Engineering Society of North America: https://www.ies.org/

Reach Code Cost Effective Report: http://localenergycodes.com/content/performance-ordinances

California Lighting Technology Center: https://cltc.ucdavis.edu/tags/led

Renewables and Energy Storage

NREL Solar Ready Buildings Planning Guide: https://www.nrel.gov/docs/fy10osti/46078.pdf

SAM Management Memo 1815.31 – Zero Net Energy for New and Existing Buildings: https://www.documents.dgs.ca.gov/sam/SamPrint/new/sam_master/sam_master_file/chap1800/1815.31.pdf

Federal On-Site Renewable Power Purchase Agreements: https://energy.gov/eere/femp/federal-site-renewable-power-purchase-agreements

The Regulatory Assistance Project: http://www.raponline.org/document/download/id/7956

State of CA ZNE Calculator for State Buildings: https://www.documents.dgs.ca.gov/os/ZNE/StateofCAZeroNetEnergyCalculator.xlsx

Operations and Verification

Title 20 Appliance Efficiency Program: http://www.energy.ca.gov/appliances/

DGS Standard Operating Procedures: http://www.documents.dgs.ca.gov/sam/SamPrint/new/sam_master/sam_master_file/chap1800/1805.3.pdf

Plug Load Guide: http://newbuildings.org/resource/plug-load-best-practices-guide/

ICC Guideline for Commissioning: http://shop.iccsafe.org/icc-g4-2012-guideline-for-commissioning-1.html

Whole Building Design Guide Building Commissioning: https://www.wbdg.org/building-commissioning

Building Commissioning Association: http://www.bcxa.org/

California Commissioning Collaborative: https://www.documents.dgs.ca.gov/green/commissionguidenew.pdf

Gamified Energy Efficiency Programs: http://aceee.org/research-report/b1501

ZNE Verification FAQ: http://newbuildings.org/resource/getting-to-zero-database-faqs/

Getting to Zero Database and Registry: http://newbuildings.org/resource/getting-to-zero-database/

ILFI Net Zero Certification: https://living-future.org/net-zero/certification

Northeast Energy Efficiency Partnership Operations and Maintenance Guide: http://www.sss.neep.org/sites/default/files/resources/OMG%20Update%20FINAL%20January%2018%202017_0.pdf

The Path to Net Zero: A Shout Out to Building Operators: http://newbuildings.org/the-path-to-net-zero-a-shout-out-to-building-operators/

Discovery School (Arlington, VA) Energy Dashboard: http://158.59.255.83/

State Administration Manual, Section 1805.3 Standard Operating Efficiency Procedures: http://www.documents.dgs.ca.gov/sam/SamPrint/new/sam_master/sam_master_file/chap1800/1805.3.pdf

State Administrative Manual (SAM) Chapter 1800 – Energy and Sustainability: http://sam.dgs.ca.gov/TOC/1800.aspx

PG&E Energy Storage and Generation Incentives: https://www.pge.com/sgip

DGS Clean Energy Generation Program: http://www.dgs.ca.gov/dgs/Sustainability/CleanEnergyGeneration.aspx

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New Buildings Institute (NBI) is a nonprofit organization driving better energy performance in buildings. We work collaboratively with industry market players—governments, utilities, energy efficiency advocates, and building professionals—to promote advanced design practices, innovative technologies, public policies, and programs that improve energy efficiency. We also develop and offer guidance and tools to support the design and construction of energy efficient buildings.

Throughout its 20-year history, NBI has become a trusted and independent resource helping to drive buildings that are better for people and the environment.