THE POWER OF

ZERO

OPTIMIZING VALUE FOR NEXT GENERATION GREEN

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1 EXECUTIVE SUMMARY 2

2 BACKGROUND 4

3 CONSTRUCTION COST STATISTICAL ANALYSIS 8

4 ENERGY ANALYSIS 14

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5 COST MANAGEMENT STRATEGIES AT THE BUILDING SCALE 16

6 COMMUNITY SCALE 26

7 CASE STUDIES 28

8 BIBLIOGRAPHY/ LITERATURE SURVEY 50

1

EXECUTIVE SUMMARY

Sustainability appears to have come into its own; green design is accepted, embraced, and even expected in most building sectors and regions. The cost of building green, however, remains a question and often a matter of debate.

The industry has been changing quickly, and buildings that were at the leading edge in terms of sustainability just a few years ago are now more standard. Just a decade ago[1], regenerative buildings seemed a worthy yet almost unattainable goal. Today, there are quite a few buildings that produce at least as much energy as they use. The State of California's energy code, in fact, is intended to require buildings to produce at least as much energy as they consume by 2030.

Despite this transformation, the market continues to question the cost implications of building green. And while the market is relatively familiar with building to LEED Certified, Silver, and even Gold, there remain questions about the costs of building to the next levels of green. This study looks at the cost implications of building to "next generation green" standards. For the purposes of this study, "next generation green" refers to buildings that achieve: LEED Platinum certification, Living Building Challenge (LBC) certification, AIA COTE Top Ten recognition, Architecture 2030, and/or are Net Zero Energy.[2]

The firms involved in this study work at the forefront of sustainability, and have contributed both data and wisdom of firsthand experience, in an attempt to develop a realistic evaluation of the cost implications of building to the highest green standards. The cost analysis itself uses a benchmarking, rather than comparative, analysis approach; the results are in terms that are readily understandable without being falsely precise.

This study also begins to look at long-term costs and savings associated with building green. Predicted and actual energy use data was available for a sizable number of projects. Water use predictions and data were also requested, but were largely not available. Given growing water scarcity, water prices are likely to rise and the industry will begin targeting, achieving, and tracking water use strategies and numbers in the near future.

This report includes: a brief discussion of cost analyses to date, presentation of statistical analysis of cost and energy data, case studies, discussion of community scale approaches to sustainability, lessons learned, and a literature survey/bibliography.

The findings of this study can be summarized as follows:

- High-performance, “next generation green” buildings are being designed and constructed now. This is not about the fure.
- There are two distinct types of “next generation green” project. The “demonstration projects” remain valuable in leading the industry forward, while the ”mainstream projects” are becoming a growing cohort. The latter tend to emphasize cost control, with project teams that are successfully attempting to achieve high-performance goals within normal budget constraints.
- Design teams are reaching high levels of sustainability by reducing consumption, rather than simply adding onsite renewable power generation.
- Design teams are controlling costs by focusing first on passive design and an integrated approach.
- As energy associated with architecture and building systems is reduced, plug loads become the lion’s share of energy use, and occupant behavior and procurement become essential elements of high-performance design.
- Costs for “next generation green” buildings are approaching those of conventional buildings.
- Where the budget is limited, projects with aggressive and absolute high-performance goals, such as Net Zero Energy, tend to do a good job of controlling costs.
- Scale is a major cost driver, and community or campus scale projects are able to manage costs by working at an infrastructure scale, and by integrating across building types.
- Values and determination continue to be the major differentiator for project teams that successfully, and cost effectively, attain the highest levels of green design.

The authors intend to continue to gather data, with the intention of updating findings and adding sorely needed energy and water use data. Potential contributors are encouraged to volunteer data and information.[3]

[1] A regenerative building, by definition, is one that has a net positive impact on the environment rather than most buildings, which have a negative impact environmentally-speaking.

[2] This report uses ILFI’s definition of Net Zero Energy, and therefore also uses ILFI’s designation “Net Zero Energy” or “NZE” as opposed to “Zero Net Energy” or “ZNE.”

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2

BACKGROUND

Building owners, real estate developers, and design teams have been questioning the "cost of green" since the beginning of the modern sustainability movement. Though there are many factors that go into the decision to "think green," it is crucial to consider the value of green design, not just to the project at hand, but to society at large. Several credible organizations have performed "cost of green" studies over the past decade; this study builds upon those and adds a new dimension to the conversation.

As noted, and for the purposes of this study, "next generation green" refers to buildings that achieve: LEED Platinum certification, Living Building Challenge (LBC) certification, AIA COTE Top Ten recognition, Architecture 2030, and/or Net Zero Energy. We define "next generation" this way because the earlier "Cost of Green" studies were published at a time when the LEED Platinum pool was not yet substantial, and when there were very few Living Buildings or Net Zero Energy buildings – too few for meaningful analysis. Studies upon which this one builds include the following.

Building for Sustainability Report: Six Scenarios for The David and Lucile Packard Foundation, Los Altos Project (2001, 2002)

The David and Lucile Packard Foundation requested this study as they were considering how far to push the design of their new headquarters in Los Altos, California in terms of sustainability, in both design and construction. Their steering committee asked appropriate questions at a time when there were still many unknowns regarding sustainable design strategies: What will it look like? How much energy will it consume? Will the design and construction schedule be affected? Can we measure predicted external costs to society, such as the impacts of pollution on health care costs? How much will it cost in terms of first cost as well as in terms of 30-, 60-, and 100-year net present value cost models?

The team that participated in this study included BNIM, Hawley Peterson Snyder, Keen Engineering, and Oppenheim Lewis as cost estimator, along with a substantial peer review team including DPR Construction as the cost reviewers. This exercise comprised the costing of a hypothetical building. In fact, it was based on six conceptual designs for the same building program representing a market-rate building, the four levels of LEED, and a "living building" (back when the team was still defining "living building", prior to the creation and codification of the Living Building Challenge). And so, this study included hypothetical costs for hypothetical designs.

Key takeaways from this study were many, but two in particular stood out. The first was that the net present value of the six designs, when evaluated over the long-term, demonstrated that within 28 years the costs of all six models converged to be equal and, from there on out, the "living building" would yield substantial operational and replacement cost savings over time.

The second takeaway came from the peer review process. The initial estimate indicated that first costs for a "living building" exceeded the market rate building by 25%. By the time the peer review was complete, approximately one year later, the difference between market rate and living building reduced to a 10% cost premium. The team concluded that this was due primarily to the environmental awareness within the estimating and construction industry of strategies/systems/materials associated with sustainability, such that what was new and innovative – and therefore

pricier – one year earlier no longer warranted large contingencies in the pricing. It appeared that this market shift occurred during this 2001-2002 period when the acceptance of "green" into the market began gaining traction.

Cost of Green Reports

Davis Langdon performed two studies: "Examining the Cost of Green" (2004) and "The Cost of Green Revisited" (2007). The first study clearly demonstrated that the costs for buildings that pursued LEED certification were scattered throughout the range of construction costs for non-LEED buildings. In essence, one could not statistically support the notion that, on average, green design and construction cost more. The report clarified that there are many reasons the cost per square foot of one building of a certain project type might cost more than a similar building of the same project type; LEED may be just one of the cost drivers, and a minor one at that.

The follow-up report of 2007 made similar findings, this time using substantially higher levels of LEED (Gold and Platinum) as compared to the 2004 study (Certified and Silver). Again, there was no statistical evidence that LEED buildings cost more, on average. During this period, construction costs rose dramatically, but LEED was not a factor in this. The report also acknowledged that the perception that green is an added feature (as opposed to integrated design) remained intact within the industry and general market. These two reports were different from the Packard report in that they were based on actual costs of built projects as reported by project teams, not hypothetical designs or estimated costing. They also used a benchmarking approach.

Living Building Financial Study (2009)

Similar to the Packard study, this effort analyzed the additive costs for green, and was conducted by a multi-disciplinary team – in this case, Cascadia Region Green Building Council, SERA Architects, Skanska USA Building, Gerding Edlen Development, Interface Engineers, and the New Buildings Institute. Its goal was to offer information on incremental first costs between LEED Gold and Living Buildings (projects certified through the Living Building Challenge[4]) and report on expected payback. Additionally, the team explored variations in cost based on geography, building scale, and project type. Project types were: University Classroom, K-8 Schools, Low-Rise Office, Mid-Rise Office, Mixed-Use Renovation, Single-Family Residence, Multi-Family Residential, High-Rise Mixed-Use, and Hospital. The four distinct climate-cities were Portland *(temperate)*, Atlanta *(hot-humid),* Phoenix *(hot-arid)*, and Boston *(cool)*, which determined base case energy and water use.

The team determined that four of the sixteen Living Building Challenge (LBC) prerequisites (v. 1.3) would have the greatest impact on design and therefore costs: 4 – Net Zero Energy, 10 – Net Zero Water, 11 – Sustainable Water Discharge, and 12 – A Civilized Environment. Prerequisites related to materials (5 - Materials Redlist and 8 – Appropriate Materials / Service Radius) were not addressed in depth by the team because they were deemed more difficult to quantify. The team found other prerequisites to have minimal impact on first cost.

Next, the team took eight actual buildings (one per project type listed above) and extrapolated the actual design to reflect LBC requirements. Similar to the Packard study, this exercise used hypothetical costs for extrapolating from LEED Gold to Living Building Challenge certification and across four climate types. And, as did the Packard study, this study compared a base building against itself with sustainability added.

The analysis showed that there are six discernable factors that substantially drive costs on a given project:

Client Type:

Whom the building is developed for, and their goals and priorities, greatly affect the initial budget for the base building, which in turn affects the first cost premium for Living Buildings. (Public buildings had lowest cost premiums, while speculative buildings cost the most.)[5]

[4] http://living-future.org/lbc

[5] This study essentially has the same findings in terms of the crucial importance of the building owners and tenants. By contrast, however, this report finds speculative projects to enjoy lower cost premiums for "next generation green" as well.

Climate:
Climate exerts a significant influence on the cost premium to create a Living Building. (The milder the climate, the more can be done with architectural solutions, and the less energy is needed. The climate of a building's location impacts availability of water and renewables as well.)

Scale:
The scale of the building, both in absolute size and the ratio of floor area to roof area, affects the cost premium to build a Living Building. (Costs for systems necessary to achieve LBC on smaller buildings, such as Single Family Residences, are greater compared to larger building base costs vs. premiums.)

Building Use:
The primary and secondary uses of a building greatly affect its energy and water usage, which in turn affects the cost premium to build a Living Building. (Building Use determines base energy and water consumption, which effect probability of achieving net zero targets.)

Incentives:
The availability of incentives for green building projects can dramatically decrease the first cost of a project. (Portland, for example, goes from most expensive place to build Living Buildings to least expensive place based on available incentives.)

Cost of Energy and Water:
The cost of energy and water affects the payback. (Cost of energy is lowest in Portland. Phoenix has the lowest cost for water; Atlanta the highest. Boston has the highest energy rate, and a high water rate as well.)

DEFINING "NEXT GENERATION GREEN"

This study defines "next generation green" to include Net Zero Energy, certification under either of the International Living Futures Institute (ILFI) standards, LEED Platinum certification, Architecture 2030, and/or AIA/COTE Top 10 recognition. The following table describes the performance criteria upon which each of these green standards is based. Each referenced standard has a rigorous energy requirement, which may range from a minimum predicted energy reduction from baseline to measured net zero energy use. Several of the standards include additional criteria that address other aspects of environmental and social sustainability.

Performance Metrics for Next Generation Green Buildings

Standard		Overview and Performance Criteria
Net zero site energy	Energy	A performance-based metric requiring annual site energy use to be offset by onsite renewable energy generation.
Net zero source energy	Energy	A performance-based metric requiring annual primary energy use to be offset by onsite renewable energy generation; accounts for transmission losses from source to site.
Net zero capable	Energy	A performance -based metric requiring an EUI of 35 kBtu/sf/yr, at maximum. Net zero capability does, in practice, also depend on factors such as climate, area for PV, and budget (NBI 2012)
A performance-based standard requiring typology-specific targets defined within seven performance areas (petals). Petals are further subdivided into a total of 20 imperatives.		
ILFI Living Building Challenge Certification	Energy	Must Demonstrate net zero site energy use.
	Water	Must demonstrate net zero site water use; all storm water must be managed on site.
	Materials	No red-listed chemicals may be used on site; materials must be regionally sources; carbon offsets equivalent to the project's embodied energy must be purchased
	Site	Must be built on a greyfield or brownfield site; must integrate agriculture, habotat exchange, and minimal site paving; may not excessively shade adjacent buildings.
	Health	Total VOC concentration and respirable suspended particles must be measured nine months post-occupancy.
	Other	The project must encourage the use of alternative transportation, be ADA compliant, and integrate biophilia and beauty.
A performance-based standard requiring net zero site energy. The project must also meet site and systems integration requirements of Living Buildings.		
ILFI Net Zero Energy Certification	Energy	Must demonstrate net zero site energy use.
	Site	Must be built on either a greyfield or brownfield site; may not excessively shade adjacent buildings.
	Other	Must educate and inspire occupants and integrate onsite renewable technologies.
Projects in the "next generation green" category included LEED projects earning platinum certification, which requires achievement of at least 80 out of 110 possible points across six categories. The following describe criteria for points that may or may not have been pursued on each of the included projects.		
LEED v.2009 Platinum	Energy	Points are awarded for modeled energy performance improvement over baseline, responsible refrigerant management, onsite renewables, and commissioning.
	Water	Points are awarded for demonstrated water performance improvement over baseline, water-efficient landscaping and innovative wastewater technologies.
	Materials	Points are awarded based on commitment to: building reuse and construction waste management; materials reuse, recycled, rapidly renewable, third-party certified, regionally sourced materials; onsite recycling.
	Site	Points are awarded for encouraging alternative transportation, brownfield redevelopment, density and connectivity and by reducing heat island effect, light pollution, erosion, and runoff.
	Health	Points are awarded for measured IAQ performance, outdoor air delivery monitoring, and construction IAQ management, low-VOC adhesives and finishes, systems controllability, thermal comfort, daylighting, and views.
	Other	Projects earn additional points from innovation in design and regionally specific credit incentives.
A green building design competition in which built work is judged using ten sustainable design metrics.		
AIA/COTE Top Ten	Energy	Projects are evaluated for energy use reduction, systems integration, onsite renewable and/or alternative energy generation, peak demand reduction, and passive survivability.
	Water	Projects are evaluated for water conservation, onsite recycling, and rainwater capture measures.
	Materials	Winning projects evaluate materials' lifecycle health/environmental impacts and encourage occupancy waste reduction.
	Site	Projects are evaluated for their ability to respond to ecological context, wildlife/habitat preservation, and their response to local density/ site conditions [infill, greyfield, brownfield, etc.].
	Other	Projects are evaluated for their bioclimatic design, adaptability, community integration, project right-sizing, and efficient program organization.

3

CONSTRUCTION COST STATISTICAL ANALYSIS

To evaluate the cost of "next generation green" for this study, the authors collected detailed project information on almost 200 high-performing projects, including, where possible, full cost estimates, predicted and actual energy usage, and a host of relevant project characteristics. Of these, 88 included sufficient cost data to support detailed analysis; the other 100 plus projects were used for statistical analysis, but not mined for more detailed information.

In order for the statistical analysis to be meaningful, comparisons were done between similar buildings, and construction costs were normalized. These two strategies mitigate differences that would result due to scale, program, location and time, building type, and other such characteristics.

"Next generation green" projects from the following four categories were analyzed: Community Centers, K-12 Schools, Low-rise Office Buildings, and Wet Laboratories.[6] Data was also collected for "control" projects within each category – buildings that are similar in program but do not have the same high-performance goals.[7]

In order to bring the population of projects to a common basis, we normalized the data based on a single location and point in time. For this study, the location was set to Kansas City, Missouri, and the time to mid-2013.[8]

THERE ARE MANY WAYS OF ANSWERING THE QUESTION "WHAT DOES GREEN COST?"

Often, this actually means, "Does green cost more?" closely followed by "More than what?" Some studies compare costs for a green building to a comparable building without the green elements. These comparisons may yield a higher cost for building green because the assumption is that sustainability can be added on – that it can be separated from the rest of the building – and that sustainable strategies when integrated do not reduce expected costs. It is, in fact, very difficult to extract costs that are strictly associated with sustainability, and the difficulty becomes greater with high performing projects.

In addition, comparative cost studies tend to come up with a hard number or percentage increase for an answer. This can be misleading in that the audience tends to take that number as definitive and predictive. In truth, the ultimate cost of sustainability on a given project will be particular to that project, and to that team and client.

The Cost of Green studies take a benchmarking approach to the question of cost. These results do not tell the reader how much they should expect to add for green; rather, the reader learns whether projects are achieving high-performance goals within budget parameters for lower performing projects. Both approaches – additive and comparative – provide useful information to a hungry market, and are in fact not contradictory.

[6] Additional categories were created, and may be explored further at a later date. These include: Healthcare Centers (non-acute), High-rise Office Buildings, Office Tenant Improvements, and Libraries.

[7] Note that most of the control projects achieved some level of sustainability, typically LEED Certified or Silver or their equivalent. This fact shows that the industry has become comfortable with sustainable design, and is incorporating it into everyday projects and budgets.

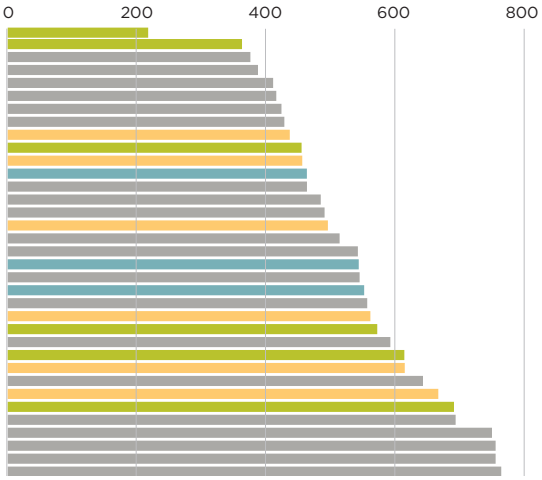
[8] Note that the costs presented may seem inaccurate for particular locations; this disparity is due to the wide variety in construction costs by location and over time. Normalizing eliminates these differences, but the reader is cautioned not to assume that the construction costs given are true for his/her particular location.


WORDS OF
WISDOM
COSTS AND DESIGN INTELLIGENCE WILL ONLY IMPROVE, BECOMING MORE MAINSTREAM
COST DRIVERS INCLUDE: SCALE, PROGRAM, CLIMATE, TEAM, OWNER

The following images graph the comparison of “next generation green” to “business as usual” control buildings within each of the four categories. The unit of comparison is dollars per square foot, exactly as would be used for a typical cost benchmarking exercise. This approach is familiar to the industry and allows one to compare projects of dissimilar size.

Wet Laboratories

In this graph, the blue bars represent the Net Zero Energy and Living Building Challenge projects that fall under the Wet Laboratories category.[9] Statistically speaking, the high performing laboratories are scattered throughout, and are generally indistinct within that population, while the most expensive laboratories are actually some of the control buildings. This does not mean that green buildings are always cheaper than the most expensive non-green buildings; labs just happen to have a wide variety of cost ranges. That said, within the laboratory population, teams are clearly creating very high-performance laboratory buildings within the same cost range as the general population.



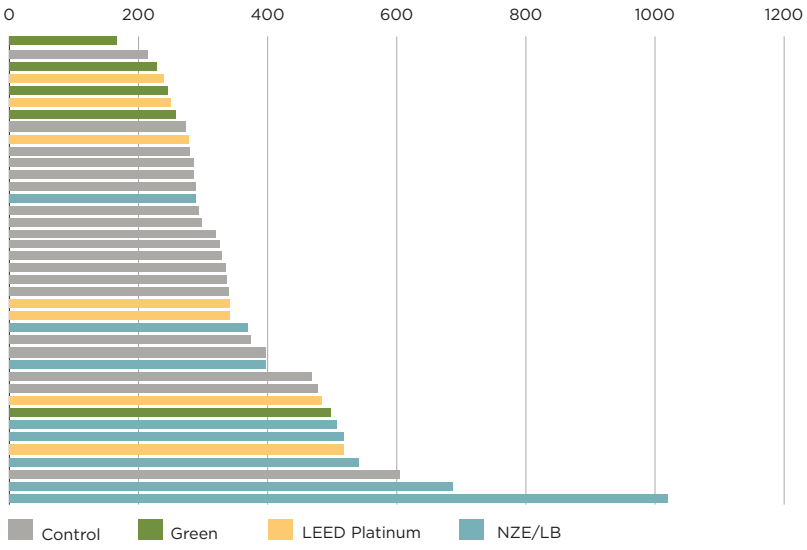
K-12 Schools

This graph compares cost per square foot for K-12 Schools, and demonstrates some interesting distinctions. Schools tend to be much more constrained than labs in terms of cost. In this graph, variations in cost between projects are not as pronounced as for laboratories, and the average costs are much lower.[10]

There are two Living Building projects in the K-12 Schools analysis. At the bottom of the graph, there is a school coming in at about a thousand dollars a square foot, an unusually high budget for this building type. In this particular case, the project team was creating a demonstration project to find what might really be possible for a school that meets the Living Building Challenge. The second is a developer-led childcare center where client cost was a definite constraint. In this case, the goal was to build to next-generation standards within a very competitive budget. This goal was achieved because of a very integrated and focused approach with all team members pulling together to achieve a Living Building within standard cost parameters.

For K-12 Schools, this study suggests that, while high-performance schools are being built within standard costs, a project team wishing to build a “next generation green” school should anticipate taking a very disciplined and integrated approach in order to keep costs down.

It might be fair to say that in the K-12 Schools cost analysis, the industry is beginning to shift towards high-performance buildings.

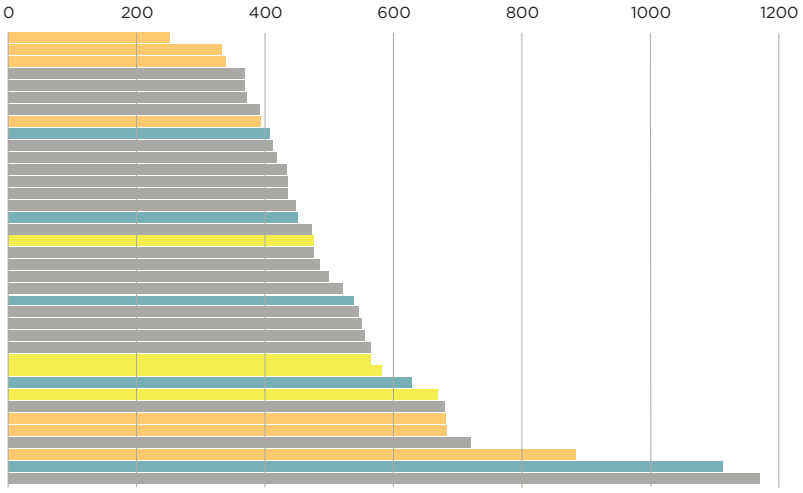


[9] These two levels of green are not synonymous, but we group them together to say “these are buildings that might represent within the population a reasonable claim of being a next-generation high-performance building.”

[10] Within the United States, K-12 Schools can be built quite inexpensively. Constraints on education budgets are tight and even onerous. It could be said that construction costs have been driven down to the absolute minimum. One might even want to question whether school design has been commoditized to the point that it is difficult to build high-quality schools within standard budgets, much less high-performance school buildings.

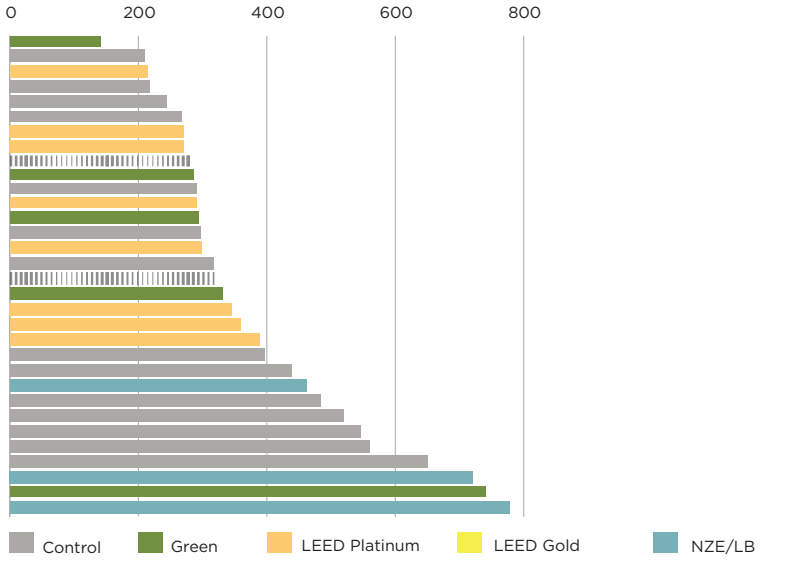
Community Centers

The data for Community Centers display a hybrid of the patterns shown for Wet Laboratories and K-12 Schools analyses. Much like with the K-12 Schools analysis, the population of high-performing buildings includes several demonstration projects, which tend to be very small buildings (7,000 to 10,000 square feet) where design teams have spent tremendous effort to design to the highest green standards. And similar to the Wet Laboratories analysis, the graph shows that high-performing Community Centers are scattered throughout the whole cost range, indicating that, again, "next generation green" buildings are well within the cost range for non-green buildings. Statistically, this does not mean that high-performing buildings are necessarily the cheapest buildings; there are some expensive ones and some inexpensive ones. However, the analysis does suggest that high-performance buildings can be built at a lower cost per square foot than some standard buildings.



Low-rise Office Buildings

The Low-rise Office Buildings analysis shows some of the highest performing buildings starting to move down the curve a little bit.[11] In this population, even some of the standard developer buildings are really starting to reach for Net Zero Energy, within competitive cost parameters. LEED Gold is now becoming the norm, with LEED Platinum achievable within normal cost ranges. Statistically, however, it would not be possible to say that, on average, high-performance buildings are costing predictably more or less than other buildings.

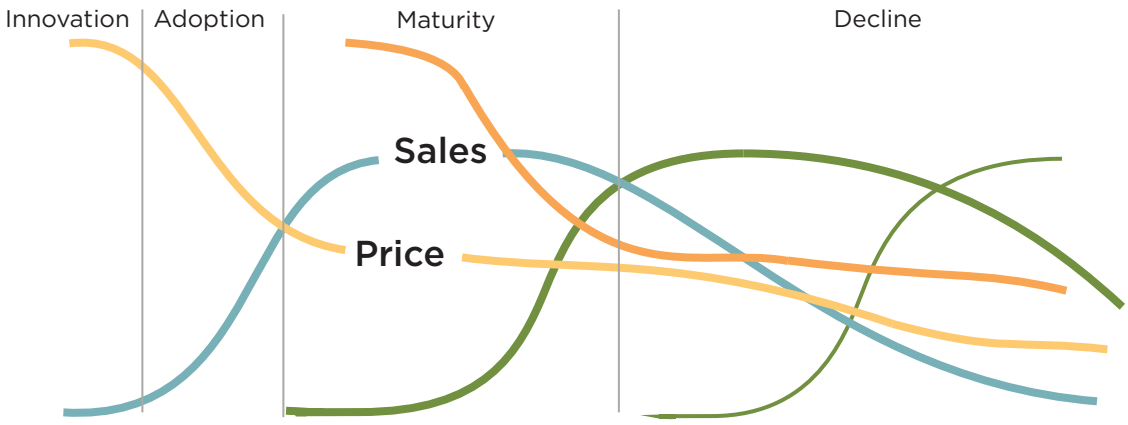


[11] The striped bars on the graph represent core-and-shell developer projects, which arguably have lower cost targets than other projects in the analysis and which include some tenant improvements.


WORDS OF
WISDOM
A HARMONIZED
TEAM, IN SYNC
WITH EACH OTHER,
INCREASES CHANCES
FOR SUCCESS

Statistical Analysis Findings

- High-performance, "next generation green" buildings are being designed and constructed; they are not in the future, but are here now.
- There are two distinct types of "next generation green" project. The "demonstration projects" are very valuable in leading the industry forward, while the "mainstream projects" are the growing cohort. The latter tend to emphasize cost control; project teams are successfully attempting to achieve high-performance goals within normal budget constraints.
- Design teams are reaching high levels of sustainability by reducing consumption, rather than simply adding onsite renewable power generation.
- Design teams control costs by focusing first on passive design and an integrated approach.
- Costs for "next generation green" buildings are approaching those of conventional buildings.
- Where the budget is limited, projects with aggressive and absolute high-performance goals, such as Net Zero Energy, tend to do a good job of controlling costs.
- Values and determination continue to be the major differentiator for project teams that successfully, and cost effectively, attain the highest levels of green design.



This image represents the life cycle of a product in terms of sales and price; this would typically describe the life of a product, but it also presents a realistic story about the history and trends of green building.

During the innovation period, when a product is first introduced and brought to market, there are only a few that are sold and demand is not high. Conversely, the price is high since the market is unfamiliar with the new product and it costs more to produce.

The product goes through an adoption period where sales increase, then a maturity phase and eventually a decline phase. Price follows an inverse curve, starting high during the adoption stage, and then falling and stabilizing when the market becomes saturated. The price falls again as the product is retired from the market, and as the next generation product comes into the market, the cycle begins again.

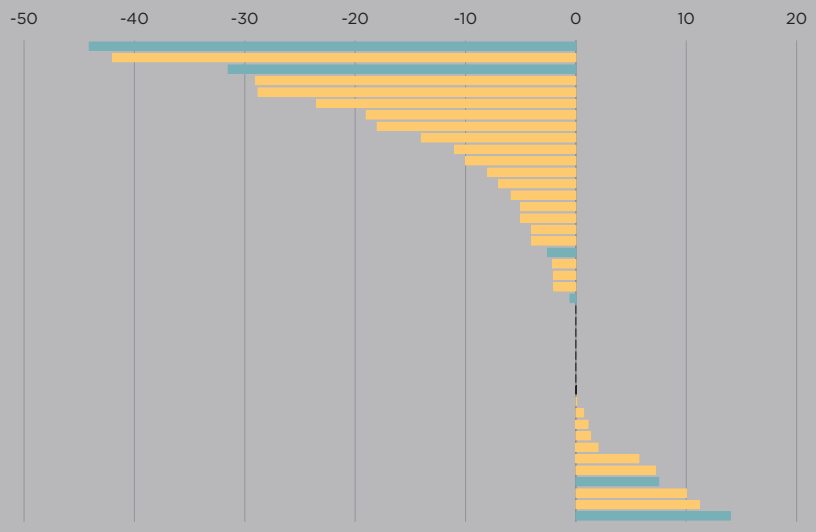
This sales/price curve can also describe the history and future of green building costs very nicely. When LEED first came on the market, projects were few and far between, and teams expended time and money learning how to deliver this newly defined level of green. As LEED was refined and the market grew to understand how to design and build green, the market adjusted and costs fell.

The data analyzed for this study suggest that the market is on a similar trajectory with "next generation green" buildings.

4

ENERGY ANALYSIS

This graph plots predicted versus actual energy performance.[12] The data suggests that the highest performing buildings are producing more energy than predicted and/or their actual energy demand is lower than modeled.

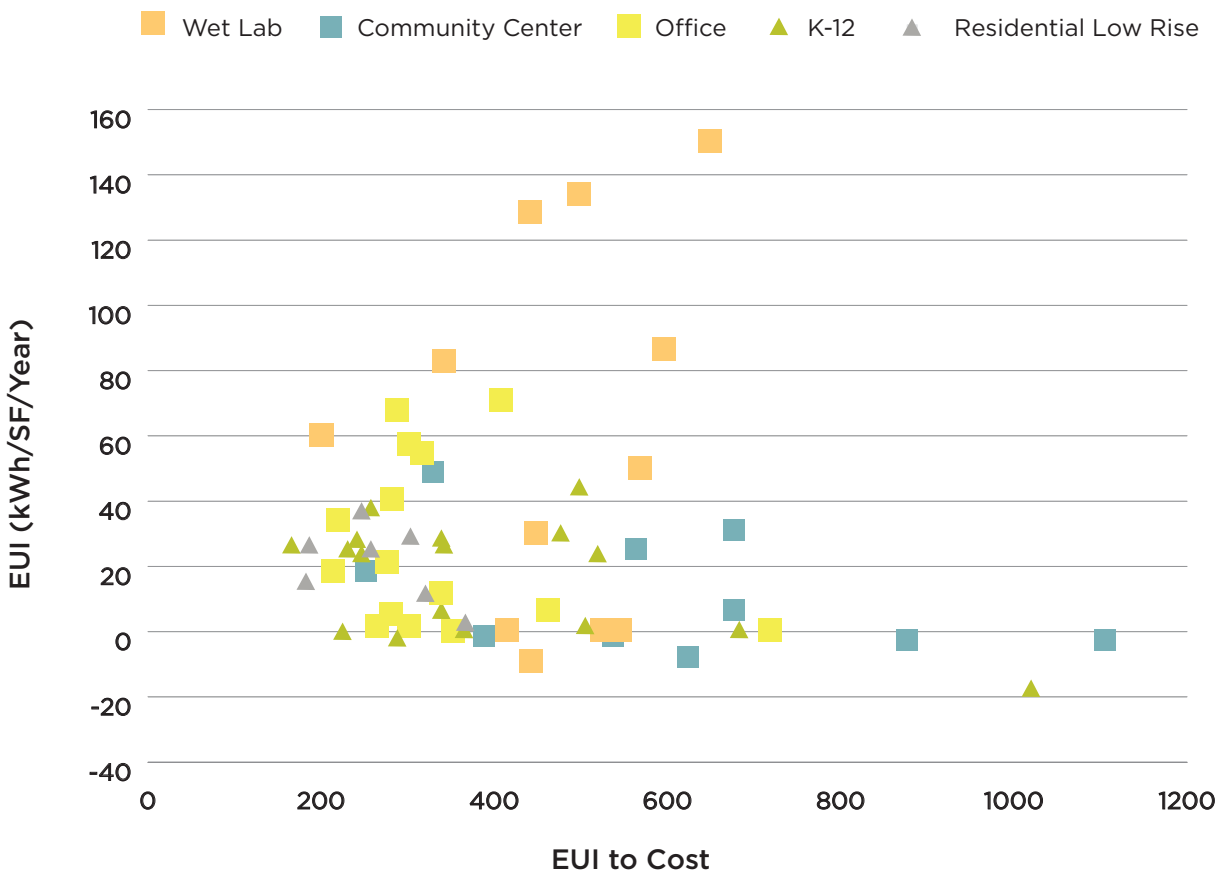


[12] There is an ongoing discussion in our industry about predicted versus actual energy use, as energy models typically do not accurately predict actual energy usage for a given building.

[13] Note that these numbers do not include onsite generation; if they did, most of these projects would have an EUI of zero or less.

The industry is moving away from using energy models simply to predict building systems performance as compared to code; now, teams are starting to model process loads (e.g. plug loads), and are taking very seriously whole building energy performance. It is possible that the findings of this comparison are because these project teams are holding themselves to a very strict and potentially costly standard – Net Zero Energy. The models are therefore conservative and, in general, buildings are exceeding predicted performance.

This chart compares energy use intensity (EUI)[13] to construction cost. The Wet Laboratories are projects with very high energy intensities, while the K-12 Schools, Community Centers, and Office Buildings have lower EUI's.



If indeed green costs more, than one might expect the buildings with highest energy use to cost more; however, the opposite appears to be true. This graph demonstrates that teams are creating projects with very low EUIs in a wide range of building project types, with no significant cost increase. If there is a correlation between cost and energy intensity, one would expect to see a correlation line going from the top left of the chart down to the lower right; the lower the energy intensity, the higher the cost.

In general, we found that projects with aggressive and hard performance goals tend to do a better job of cost control. When all of the energy used in a building must be generated onsite, using costly technologies and perhaps with space restrictions, design teams tend to do a good job of finding less expensive ways to reduce energy demand, and a more accurate job of predicting both demand and generation.

5

COST MANAGEMENT STRATEGIES AT THE BUILDING SCALE

Statistical analysis shows that "green" does not have to be the major cost driver for a given project, even for cutting edge high-performance projects or "next generation green". In fact, there are a host of other factors – program, location, aesthetic goals, and budget – that typically drive costs.

Given the multiplicity of factors, how can a project team manage costs associated with high-performance design?

This section comprises case studies for several high performing projects, with an emphasis on exploring how the project teams managed costs, looking both at strategies for success, and areas of concern. These projects include:

- new construction of the first ever Net Zero Energy lab building;
- retrofit of an historic and iconic structure to house labs, while achieving LEED Platinum and 70% energy use reduction;
- tenant fit out of an existing tilt-up structure, targeting Net Zero Energy within a standard developer pro-forma; and
- new construction of the first certified Living Building.

Several key points emerge from this analysis:

- Owner commitment is absolutely necessary.
- Commitment and experience on the part of all team members is required.
- Green goals must be included in the program and budget from project conception.
- Design and delivery processes are usually different for "next generation green" projects.
- For costs to remain low, cost containment must be a priority.

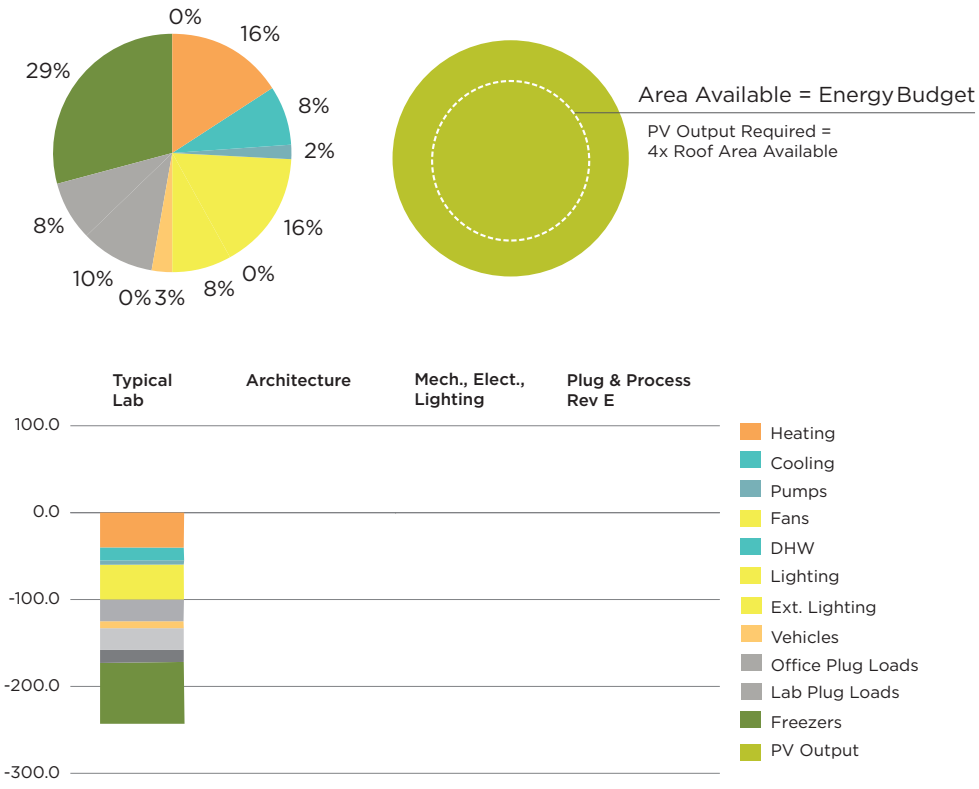
Certain design strategies emerge in the case studies:

Use energy production capacity as a design boundary. With a Net Zero Energy building, the team knows from the start that all power used in the building must be generated onsite.[14] The most straightforward response to this requirement is to determine how much power can in fact be generated on the site. However, the amount of power that can be generated is often dramatically less than the power needed. This boundary therefore sets a challenge; the power budget has effectively been set, and it is now the team's job to figure out how to meet it. This turns out to be a very effective cost management strategy; projects in the study that had tight sites and a set goal of net zero energy in fact did a better job at containing costs than those without a specific goal.

The following graphs describe the design process for a Net Zero Energy building. This example focuses on energy use and generation; a similar process can be used for water systems.[15]

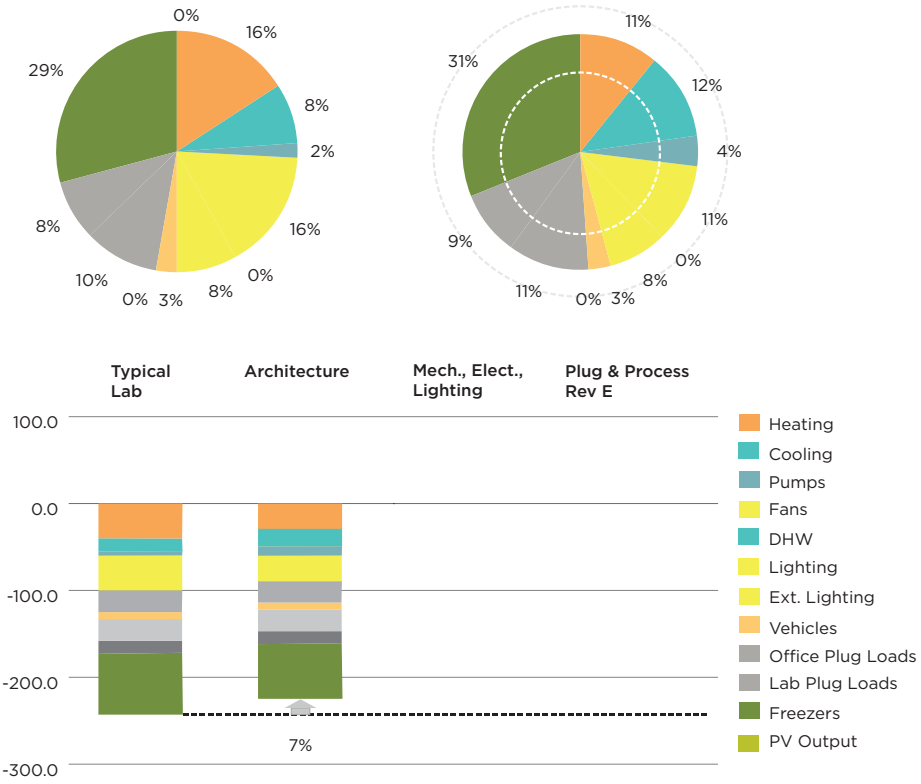
[14] A standard approach might be to calculate the amount of power needed for a particular project, and then to design power generation to meet that need; for Net Zero Energy, the approach is reversed.

[15] Note that the building in question is a laboratory; the load distribution shown is particular to this building type. Other building types will have different load distributions, but the approach to energy use reduction remains the same.



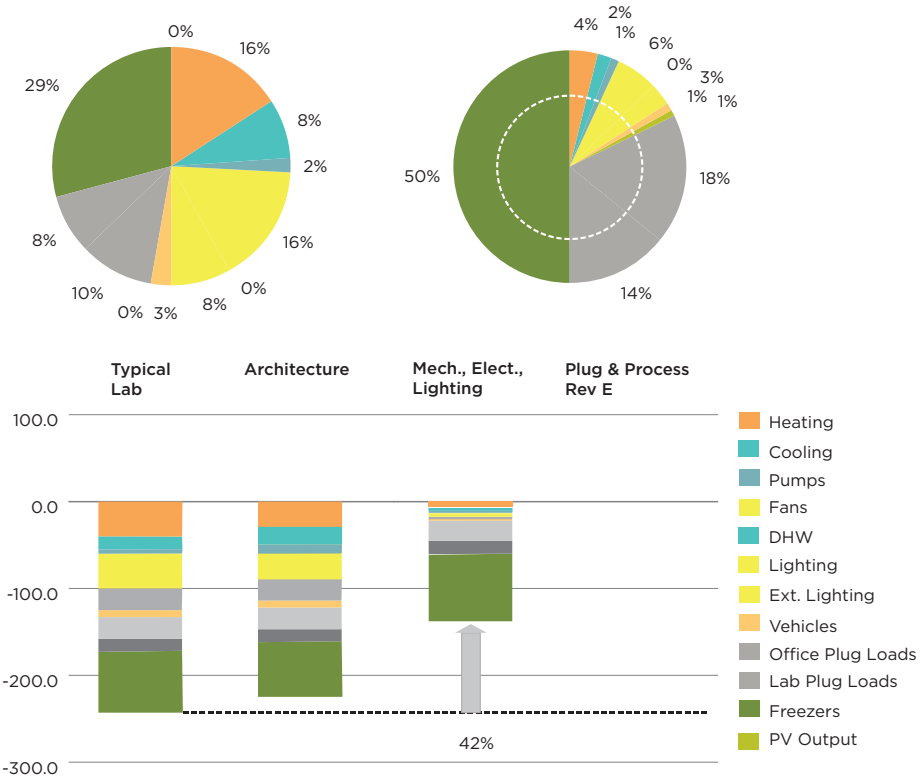
Step 1:
Develop energy use predictions. Calculate available energy generation.

The chart on the left represents the predicted energy use of the building, designed to meet or exceed code. Energy demands are broken out by system; this approach allows the design team to see where to focus demand reduction efforts. The chart on the right represents the total energy that must be supplied in order to reach the Net Zero Energy target. The inner dashed line represents the total energy that can be generated on site. In this case, the roof was designed to maximize area for photovoltaic arrays – and still it is only possible to generate about 25% of the total energy needed.



Step 2:
Maximize passive design/architectural energy reduction solutions.

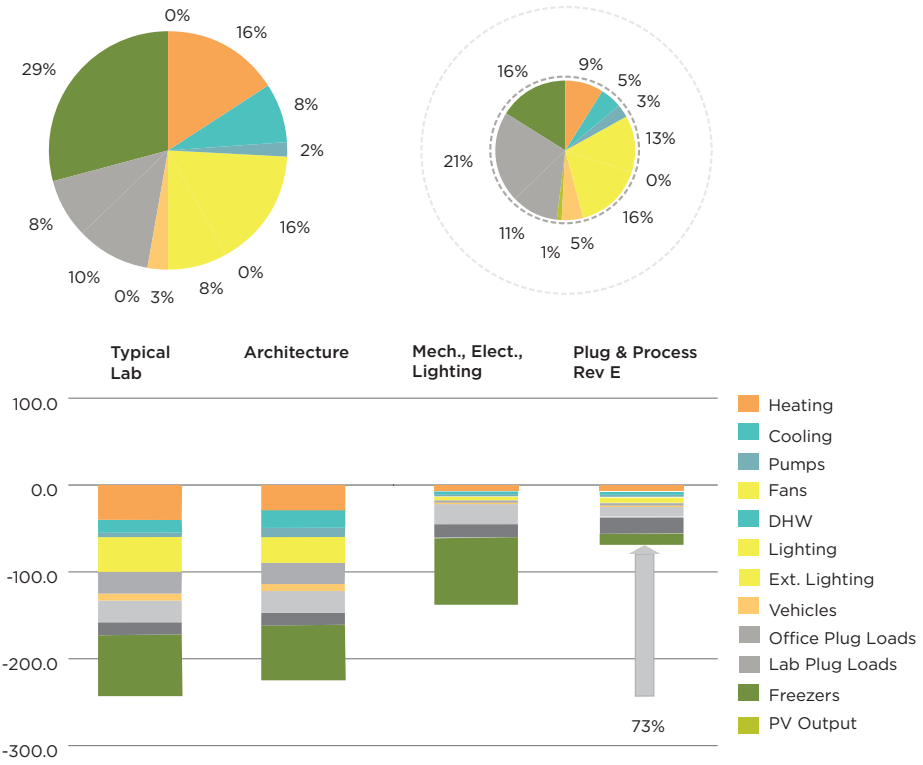
The design team begins searching for energy demand reductions. The first step is to look at passive design opportunities. In this case, the building's orientation was shifted a few degrees, to maximize sunlight on the photovoltaic array. Program areas were separated, so that areas that can accept natural ventilation are separate from those that need to be closed. The building footprint is narrowed so that daylight can effectively penetrate. These moves result in a 7% energy demand reduction. Major cost implications include: increase in façade costs, reduction in HVAC costs.



Step 3: Maximize active systems energy use reduction.

Next, the team looks as opportunities with the active systems in the building, in this case including: lighting, thermal storage, chilled beams, split system, and more. The energy savings here are substantial, but the project is still a good distance from being able to generate all energy onsite. Cost implications are complicated and include: reduction in plant size (offset, however, by the need to meet peak demand), reduction in ducting, additional systems.

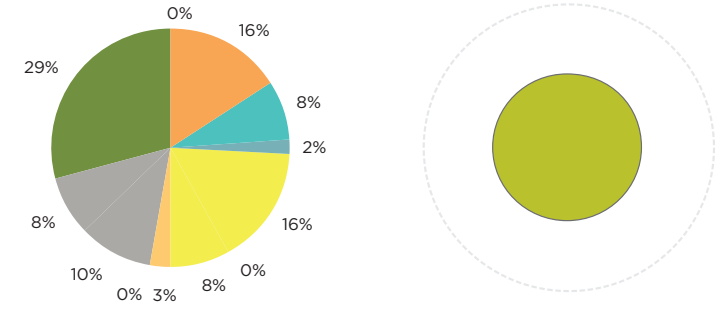
The chart on the right now shows an interesting shift: energy required for building systems has been drastically reduces, and now the lion's share – about 82% - of energy demand is for equipment and

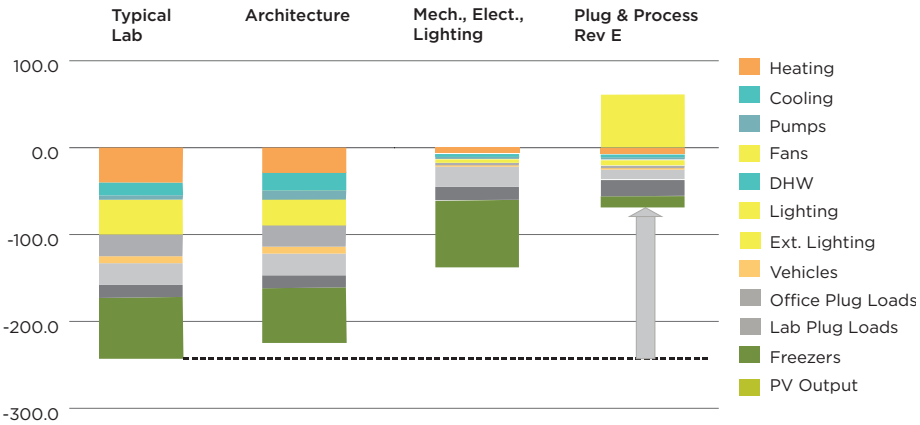


Step 4: Reduce plug load energy use.

The team now turns to working with the building occupants to find ways to reduce energy use consumption for plug loads. In this case, solutions included: colocation of systems-heavy equipment in a single room, automatic shutoff of at electrical panels of power to all non-essential equipment.

This study finds that projects with high performance goals, like Net Zero Energy, focus on occupant behavior as a necessary strategy. While this can be a daunting task, it fosters occupant engagement which ultimately helps the project to succeed.





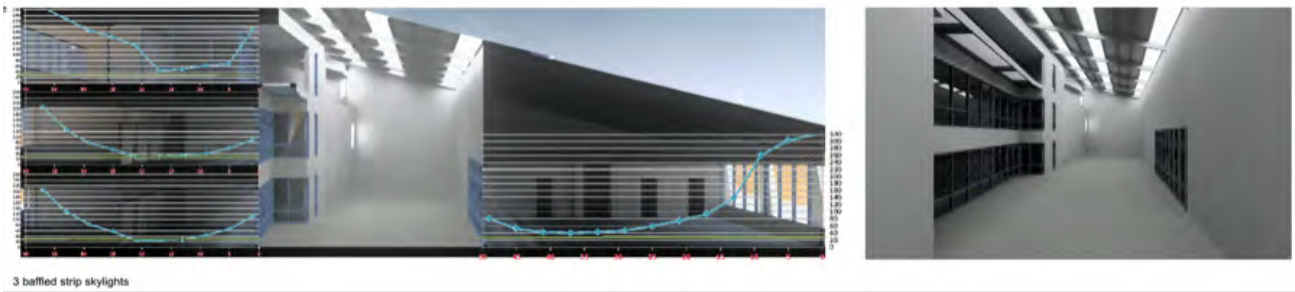
Final Step 5:
Add renewable energy.

Model early, consistently, and intensively. The successful "next generation green" projects in this study implemented a rigorous integrated design process, predicated on the use of extensive design analysis. Project teams built computer models early in the design process, and used them to test and inform the development of passive design systems (the use of orientation, massing, and envelope design to maximize natural ventilation and daylight, and to control solar impacts). Design teams then used modeling to design and fine tune active mechanical systems.

While a rigorous analysis process implies a more intensive early design process, with associated fees, this process creates efficiencies that result in streamlined construction documentation and construction phases, and in cost reductions unrealized in a conventional process.

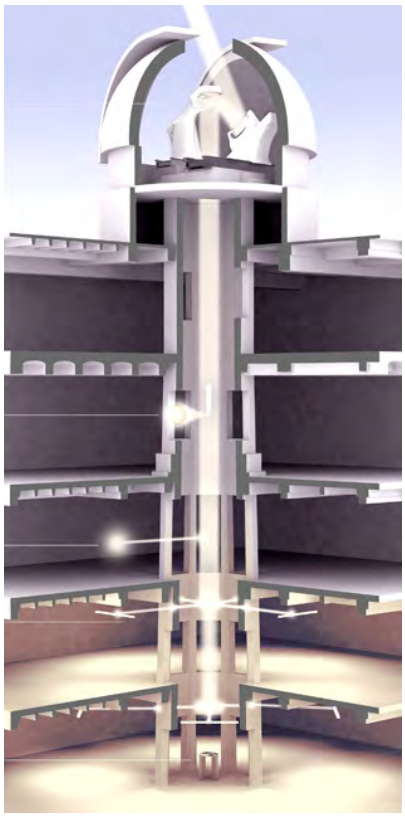
+ $75,000 glazing
- $150,000 perimeter heating deleted
- $300,000 reduced photovoltaics
= $375,000 savings

These images showcase the intensive energy and cost modeling used for an office building, in Palo Alto, that achieved Net Zero Energy. One might assume that triple glazing would be costly and ineffective in the moderate Palo Alto climate. However, energy analysis showed that the use of high-performance glazing allowed the elimination of perimeter heating AND a reduction in photovoltaics; rigorous modeling enabled the design team to add one costly element and subtract two.



The team for the first Net Zero Energy laboratory used daylight modeling to fine tune the central skylight, reducing the need for electrical lighting and thereby reducing cooling loads and downsizing the cooling system, resulting in reductions to both construction and long-term operational costs.

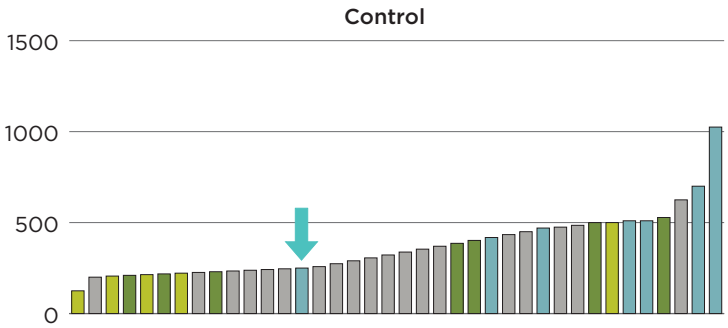
Take advantage of project specifics, and look for opportunities to turn a challenge into an advantage. Every project is unique, and cost-effective high-performance opportunities can often be found in what appear to be problematic conditions.



(top) Unstable soil conditions required the provision of a crawl space under the NREL Research Support Facility. The design team recognized this condition as an opportunity; the crawl space functions as part of the HVAC system, precooling and preheating air year round to reduce energy demand and therefore costs.

(right) The coloestat (solar telescope) in the Linde + Robinson building could have been a useless liability during renovation. Instead, the design team used the shaft to drive light deep into the building. This would have been a costly design move if the shaft did not already exist; instead, it became an opportunity to reduce first costs while increasing performance.

Include high-performance goals in initial cost budget and identify cost-containment as a priority. Projects that include high-performance goals within the original programmatic goals stand a much better chance of achieving those goals without breaking the budget. And when the stated goal is to achieve "next generation green" within a given budget, project teams have a much better chance to contain costs. This requires a rigorous approach with full commitment by all team members and a willingness to trade other design elements for high-performance ones.



WORDS OF WISDOM

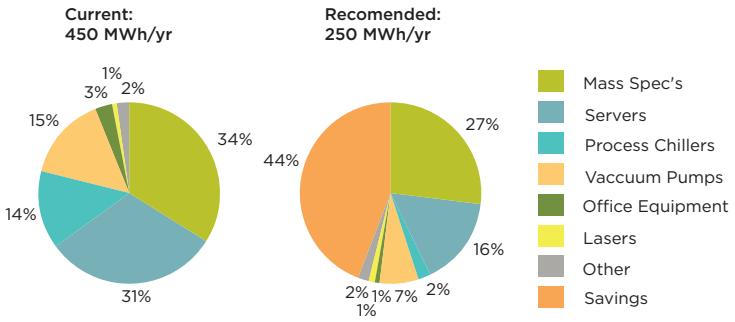
ROOM FOR EXPLORATION IS REQUIRED

THERE MUST BE A WILLINGNESS TO RISK NEW THINGS (MANAGED/ CALCULATED RISK)

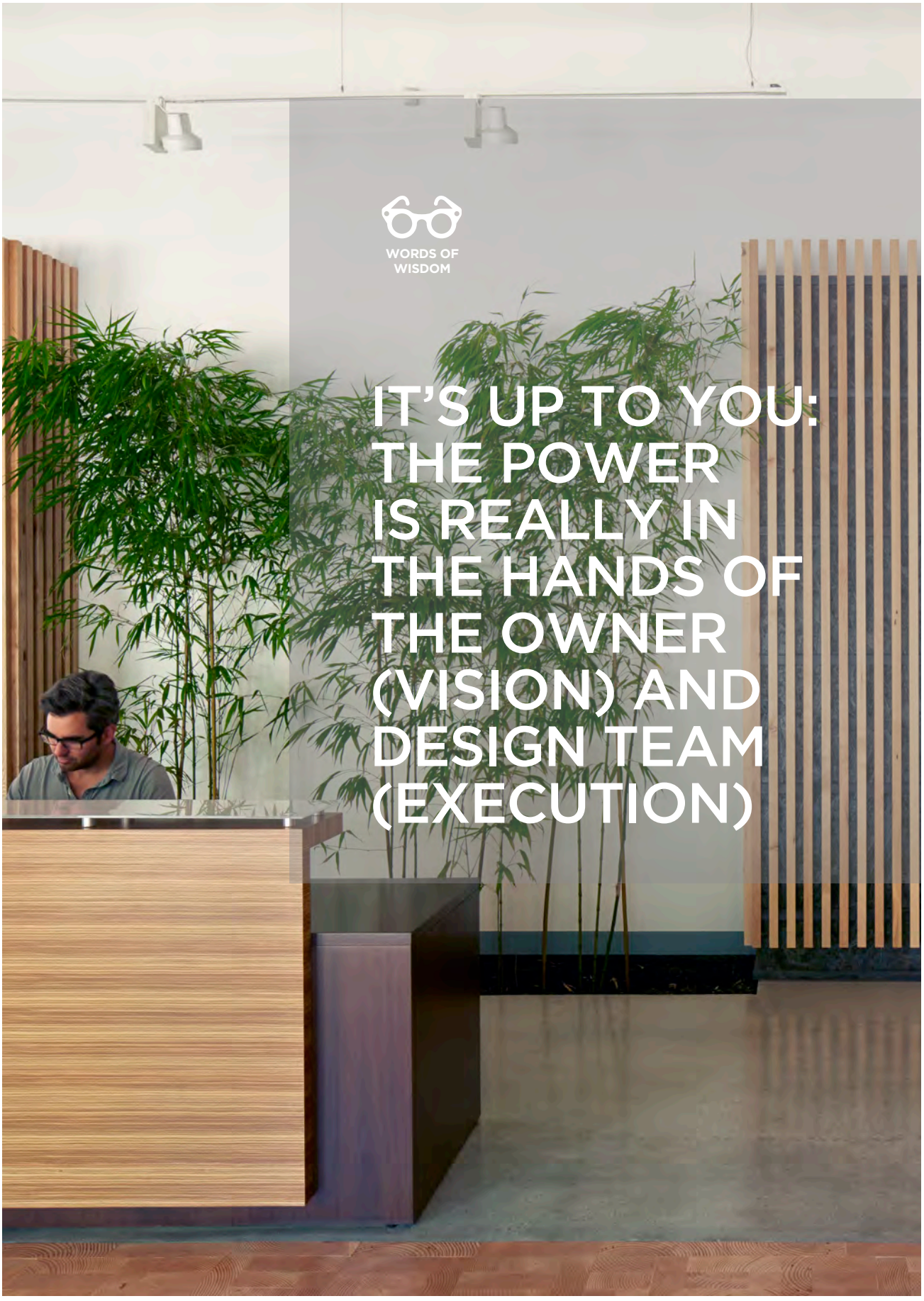
UniverCity Childcare is a developer-led Living Building Challenge project. The owners set cost containment as a fundamental goal early in the process. The team worked hard and collaboratively to create a building that achieves LBC requirements within a stringent and very competitive budget.

Reduce plug loads; occupant buy-in is essential. Once energy use associated with heating, cooling, and lighting the building has been reduced, plug loads become a major opportunity for further reductions. To reduce plug loads, building occupants and operators must be engaged; this brings the added benefit of a knowledgeable and committed tenant.

The Linde+Robinson design team collaborated with building occupants to identify opportunities to substantially reduce plug load energy. These savings created occupant engagement without adversely impacting program and performance.



Team collaboration and commitment are non-negotiable requirements. Interviews with successful "next generation green" teams reveal that active participation on the part of all team members is absolutely necessary. The entire project team – including owners and occupants – must be ready, willing and able to work collaboratively to pursue high-performance goals. The process can be daunting, with plenty of detours and unwelcome challenges; one weak link can sabotage the process.


WORDS OF
WISDOM
IT'S UP TO YOU: THE POWER IS REALLY IN THE HANDS OF THE OWNER (VISION) AND DESIGN TEAM (EXECUTION)

6

COMMUNITY SCALE

Relevant Strategies

As one spends any amount of time within the challenge of designing a next generation green building, it is readily apparent that in order to truly deepen the impact of building design, the industry must consider strategies that are often more appropriate to address at the community scale. There are obvious advantages to looking beyond the scale of an individual building towards a larger system. This is particularly true for issues related to water, energy, resources, waste, transit, food, and so on. These are issues that may be more naturally addressed at the community scale and sometimes at both – building and community scales. For example, an owner may set up a recycling program in a building to reduce trips to the landfill, but if the municipality can change how waste is handled systemically at a community scale, greater (positive) impact is achieved. Similarly, a design team can develop a rainwater collection system to handle point-source loads at the building scale, yet could have a tremendous impact if given the opportunity to design or redesign the stormwater system for an entire city. Though not mutually exclusive by any means, it quickly becomes apparent how the shift in scale readily results in a dramatic shift in impact.

As Donella Meadows suggests in her compelling treatise, *Leverage Points: Places to Intervene in a System*, there are points in a system that we can touch to "slow the damage", others to "change the structure", and others still to "change consciousness."[16]

To that end, listed here are several strategies that are relevant to consider at the community scale:

- District energy
- District water
- Green streets
- Smart electricity grid
- Demand management
- Resource sharing
- Renewable energy infrastructure
- Zero waste program
- Stormwater management
- Comprehensive transit system
- Food hub / sustainable agriculture

Further, by working at this larger scale, there are more opportunities to impact larger scale issues that a single building would have little influence over. Climate change mitigation, for example, is being addressed at the scale of some of the larger U.S. cities. Energy security can be addressed at multiple scales, with proportional capacity for impact. Resource conservation, while certainly controllable at the building scale, can be more strategic at a community, regional or industry scale. Other opportunities at the community-scale include job creation, long-term resilience, and quality-of-life (or healthy community) improvements.

Opportunities

In addition to increased capacity to impact positive change at the community-scale, there are other key opportunities available to us. For example, there is an efficiency of scale for some issues, such as a waste management system as noted above or food, transit, and energy. Also, a community can begin to see an effective interplay of constructed, social, economic, and natural systems. A well-integrated framework for constructed systems may help alleviate the burden on natural systems, and economic policies may boost opportunities for stronger social systems.

[16] Meadows, Donella. *Leverage Points: Places to Intervene in a System.* Sustainability Institute. December 1999.

Community-scale thinking has a strong capacity to strengthen a community through a common vision. The time and effort spent creating this vision – one that works diligently towards common ground – will inevitably strengthen the community in a way that guides more strategic actions, ones that may be implemented at either the individual building or community scale. As a corollary, longer term strategies are often more digestible. Who wouldn't want a healthier community? Once this bigger vision is identified and agreed upon, it becomes easier to see how the smaller moves support that vision with increased buy-in. Feasibility is questioned less; instead the community begins looking for solutions.

Though the list of opportunities and benefits is much more extensive than these examples, it is clear that the potential for higher performing buildings is greater if the team is able to tap into a more robust infrastructure.

Barriers to Overcome

Given all the opportunities, it is important to note that there are some very real barriers to overcome at the community-scale. Often this means, for example, that larger-scale cultural shifts are required for follow-through. Considering how difficult it may be to change one person's behavior, how much more difficult might it be to change a community's behavior? Though not impossible – the authors of this study have seen tremendous change occur in the minds of many communities – there is a lot of time and energy and savvy required in the work of aligning all key stakeholders. This comes in the form of in-person one-on-one meetings, focus group conversations, all-inclusive public dialogue, strategic meetings with community leaders, strategic use of social media, a good dose of quantitative and qualitative data, and a whole host of precedents that help a community envision a new and better future within their place. Then, even if minds are changed and alignment is achieved, next steps often require a compelling mix of positive incentives and sound regulations.

Dramatic change has been observed in communities that have suffered through extreme natural disasters, when those communities are able to balance a real and immediate desire to build back to "normal" with the opportunity to build back to "better than normal". Catalyzing change in a natural disaster zone is challenging enough, yet somehow it takes a whole other kind of energy and momentum to catalyze change in a slow disaster zone, ones caused by slow disinvestment, social injustices, and so on. The potential, however, is the same.

Resources

There are a few places to go for information to operate at this larger-than-building scale:

- Ecodistricts Framework - One of the most powerful resource as of this writing is the work being done with ecodistricts across the U.S. Their website (ecodistricts.org) highlights communities that are doing the hard work of mining the details, and coming up with compelling community-based solutions.
- The Public Interest Design Institute and their SEED Network (www.publicinterestdesign.org) has an interesting framework for community-engagement as it relates to community-based design solutions.
- One Planet Communities (oneplanetcommunities.org) has a ten-principle framework that guides communities through topics ranging from energy, water, and material use to cultural heritage, health, and happiness, all focused on achieving community metrics that fall within the capacity of one planet to support.

Other resources include the Living Building Challenge scale jumping guidelines, principles of biomimicry, and the Clinton Climate / Global Initiatives (C40).

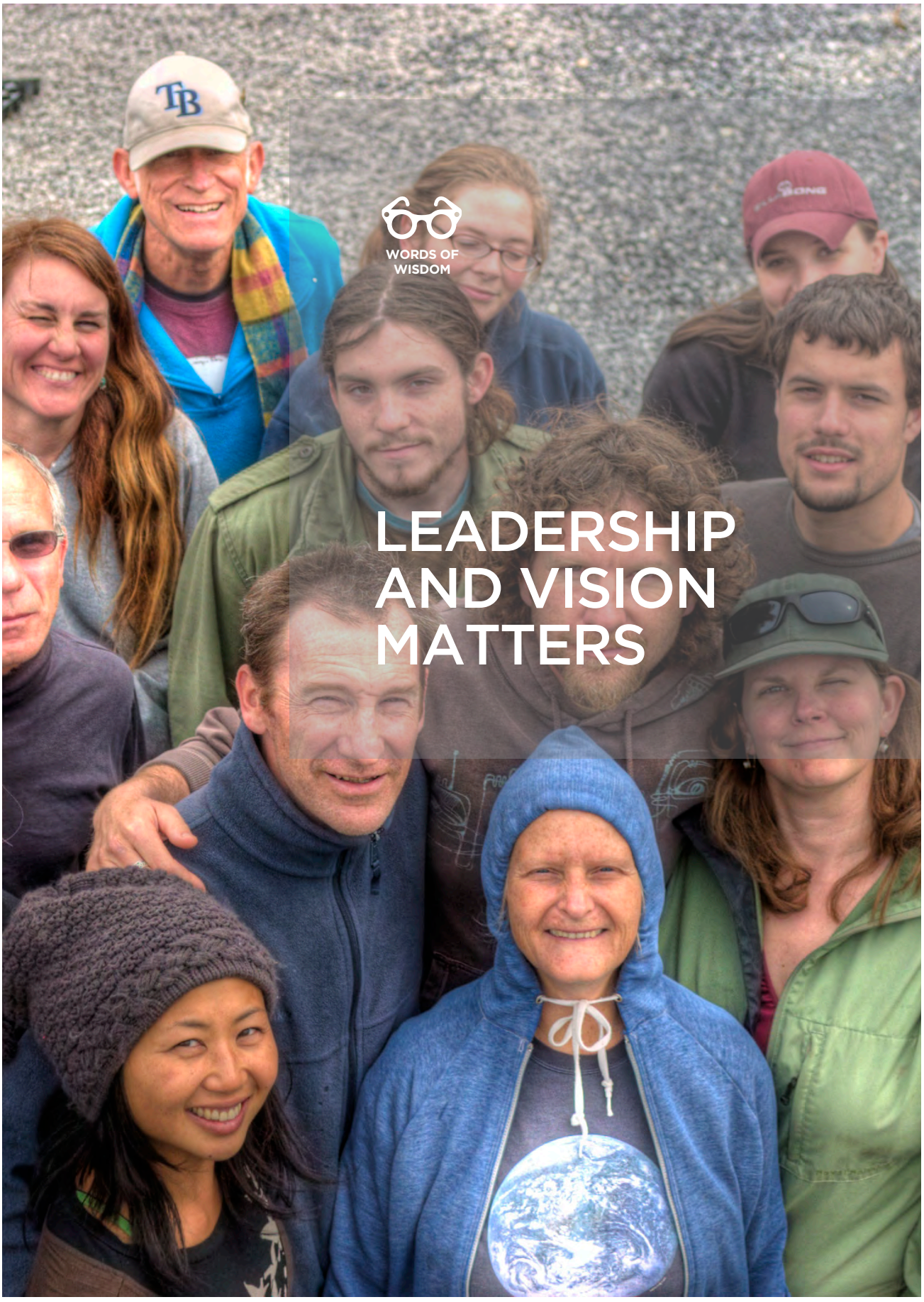
More Work To Do

While there is clear and compelling potential for communities to impact change at a larger scale than individual buildings, there is more work to do. The design and construction industry needs more metrics surrounding the benefits of integrated systems. A better connection needs to be drawn between energy and water systems. We could all stand to see more built examples of what it would take to de-centralize our massive central systems into digestible local systems. We also require a shift in thinking – from a concept of "carrying capacity" to a more biomimetic principle of "ecological performance standards". This framework would allow us to begin to truly work with nature (by mimicking her principles) to slow and halt destruction of ecological services given to us for free towards maintenance and support of these services. Finally, in many of our cities and rural areas, we still need to imagine how to awaken many of our communities that are in slow disaster mode into one of recovery and healthy rebirth.

7

CASE STUDIES

FIVE CASE STUDIES


WORDS OF
WISDOM
LEADERSHIP
AND VISION
MATTERS

CASE STUDY #1

OMEGA CENTER FOR SUSTAINABLE LIVING

In 2006, the Omega Institute of Holistic Studies decided to accept the Living Building Challenge for their planned alternative wastewater treatment facility, designed to meet the regulatory requirements of a growing campus. Such were the simple beginnings of the first building in the world to achieve both Living Building and LEED Platinum certification.

At little more than 6200 sf, this is an educational wastewater treatment facility for a 200-acre campus treating the wastewater from more than 100 buildings on their campus. Both the owner and the design team took on the Living Building Challenge head-on, and stuck with it, along with the contractor, through to the last day of construction and verification. It was critical that all team members were on board, believed it could be done, and worked through every detail to achieving net zero energy, net zero water, and strict material requirements.

The entire team had to think differently throughout the project, changing from the paradigm of "take, use, and throw away" to one of "capture, use, recirculate," essentially creating closed loops for each system.

Each piece of the building puzzle needed to be integral with the other decisions … as the team carefully wrapped the flows of air, water, and energy around each other.

Surprisingly (at least at the time), the most difficult challenge was not the net zero energy or net zero water requirements, but rather the material sourcing: all wood was to be FSC-certified or salvaged; no materials from the prescribed Red List were allowed; materials were to be sourced within 250, 500, 1000 miles based on weight. Given all those constraints, the next critical challenge was the one not mentioned by LBC, the challenge of affordability.

Omega began the effort to parse out the costs of this building to share with the green building community, but has stopped short of completing this effort. They did go far enough to ask whether or not it may be merely an academic exercise since the more tightly you wrap different flows, systems, components around each other, the harder it is to pull them back apart, to dissect them in a perhaps futile attempt to understand the individual pieces. What is a site cost versus the building cost if you are talking about the concrete of a constructed wetland that treats building wastewater? How do you categorize the lagoon costs: educational classroom finish material or wastewater treatment system? What part of the treatment counts towards the building and what counts to the overall campus, since it is treating all campus water?

As John Muir once said, "Once you tug at anything in nature, you will find it hitched to the entire universe." Maybe that is the true test of our up and coming Living Buildings, or a great compliment to the Challenge itself.

PROJECT NAME
Omega Center for Sustainable Living

LOCATION
Rhinebeck, New York

BUILDING / SITE AREAS
Building: 6250 SF; Site: 4.5 Acres

PROJECT TYPE
Wastewater Treatment Facility and Education Center - New Construction

DELIVERY METHOD USED
Negotiated Contract with local builder

VISION
Omega Institute: Through innovative educational experiences that awaken the best in the human spirit, Omega provides hope and healing for individuals and society.

CONSTRUCTION COST
$2.8 million

COST DRIVER(S)
Alternative wastewater treatment, Living Building Challenge, Vision

EUI
13.2

LEED/LBC/OTHER RATING
Living Building and LEED Platinum

WEBLINK
http://www.eomega.org/omega-in-action/key-initiatives/omega-center-for-sustainable-living

WORDS OF WISDOM
Anticipate hurdles (many) and take one at a time; Believe you can do it; Owner as champion is key; Vision drives everything

CASE STUDY #2

INDIO

The retrofit of the Indio building—an existing 30,000-square-foot, uninsulated office building in Sunnyvale, CA —to a Net Zero Energy building is the first project of its kind. Because of the economics of the approach, this retrofit proves that the development of Net Zero Energy buildings can be profitable.

This core and shell 1970s building has notably gone from Class C- to Class B+, in real estate terms, and the developer now has a savvy business case for future net zero retrofits. The project focused on incorporating as many sustainable strategies as possible within the developer budget, primarily through upgrading the envelope and greatly reducing the mechanical loads. The building is 100% daylit and 100% naturally ventilated. These elements not only allow the building to track toward net zero and carbon neutrality but they also make the space more attractive to tenants; Indio has leased out in record time during the spring of 2014.

The airy open space is surprisingly beautiful, for what was once merely a large boxy office. Now cool air and soft light comes in from rows of tall operable windows made of dynamic glass. It features indirect light from skylights, polished concrete floors, slowly spinning ceiling fans, a white fabric ceiling—as acoustical buffer—and exposed ductwork.

Indio's developer, Kevin Bates, President of Sharp Development, put together an economic model for the project that shows how it is profitable to retrofit for net zero in Silicon Valley. Now he wants appraisers to take a look at this model and begin to improve the way they value sustainable design. The business model focuses on driving down operating costs. If the building performs as designed, the PG&E bill is zero at the end of the year.

Another aspect of the business case has to do with turnover costs. Because of the nature of the design of this building, it lends itself well to open landscape, inetrior environment and tenants drawn to this building are looking for that open environment. This means fewer hard walls being demolished and landfilled, fewer walls being built, less electrical rework and less rezoning of mechanical systems when there is tenant turnover, and less cost.

"Everybody looks at payback and that's not how I look at it," Bates said. "I look at, 'What does it mean for the value of the building today if we were to sell it today. Am I better off or worse off than if I had done a standard retrofit? And what does it mean if I hold it long-term from a cash flow standpoint. Am I better or worse off, and how long does that cash flow take to pay back the expenses?' Just the rent we will get in that 15 months by leasing it sooner alone almost pays for the additional costs."

The developer ran all the numbers as if the team did the design the old way and then ran all the numbers for what was actually done. It costs about $44 per square foot more to do it this way. According to Bates, the building is bringing in a little bit of premium on rent, but the main way it pays off is a higher overall building value as it generates additional revenue from reduced operating costs and faster lease up time.

"The business model proves you are $2 million better from doing it this way if you sold it," Bates said. "If you don't sell it, it pays for itself in 3-4 months. It's a pretty strong economic case for a building of this size."

PROJECT NAME
Indio

LOCATION
Sunnyvale, California

BUILDING / SITE AREAS
30,000 SF

PROJECT TYPE
Net Zero Energy Retrofit of Existing Building

DELIVERY METHOD USED
Design Build

VISION
"Hopefully we're keeping a lot of the old building stock out of the landfill and renovating in a way that's going to be a lot healthier for people to work in. And, hopefully, we're making some additional profit for those that are willing to renovate in this way."
Kevin Bates, Developer

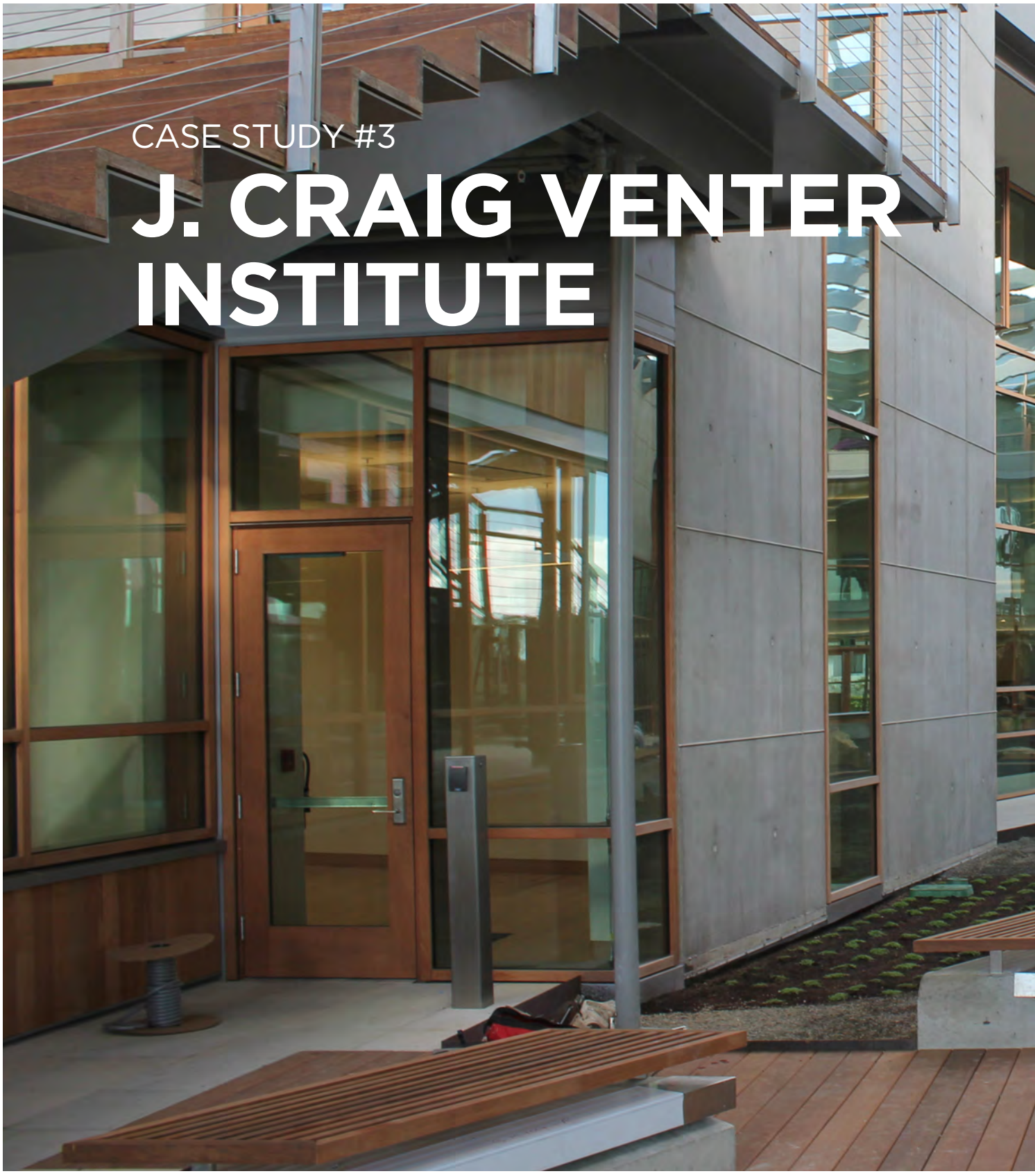
CONSTRUCTION COST
$44/SF over standard (includes solar panels without recognizing rebates/ incentives)

COST DRIVER(S)
Photovoltaics

EUI
22.5

LEED/LBC/OTHER RATING
Net Zero Energy targeted, LEED Platinum

WORDS OF WISDOM
"The performance of the building was of foremost importance; the architecture defers to the engineering. This is the reason we were able to reach this level of performance cost effectively."
Kevin Bates, Developer



CASE STUDY #3

J. CRAIG VENTER INSTITUTE

The 45,000-square-foot J. Craig Venter Institute (JCVI) lab on the University of California, San Diego campus, which opened in November 2013, is the first Net Zero Energy lab in the United States, and possibly the world.

The JCVI is a not-for-profit, genomic research organization with approximately 300 scientists and staff dedicated to human, microbial, plant, synthetic and environmental genomic research, and the exploration of social and ethical issues in genomics.

J. Craig Venter, Ph.D., founder and CEO of JCVI, a scientist most known for sequencing the first draft human genome, had the vision to pursue a carbon neutral design for his new laboratory.

Though the building's setting above the ocean is spectacular, the design team resisted the temptation to orient the building for optimal views of the ocean in favor of orienting for passive and active solar gain. The architecture follows a passive design approach, relying on the orientation and architecture—including skin, insulation, natural ventilation, and daylight— as the first stage of energy reductions.

The building is separated into two zones, with biology labs in one zone and offices in another zone, because the offices can be naturally ventilated whereas labs typically have stringent and high-energy HVAC requirements. The narrow footprints of the two wings make it possible to bring in natural ventilation and daylight, and the building is optimally oriented for photovoltaics. The design team optimized building design by using energy modeling and analysis up front.

Careful choices for the mechanical systems reduced energy by 42%. Heating and cooling are decoupled from ventilation, with separate air handlers for office and laboratory wings. Induction diffusers deliver air to each space, and contain heating/cooling coils, which deliver either hot water or medium-temperature water to heat or cool the building.[17] To meet the International Livign Future Institute's definition for Net Zero Energy, no on-site combustion is allowed. The solution at JCVI is a water-to-water heat pump. One side of the unit is used to cool the building, while the other is used for heating loads such as domestic and industrial hot water. For much of the year, the building charges two 25,000 gallon thermal storage tanks by running its cooling towers at night, storing up chilled water to be discharged through the induction diffusers the next day. In rare cases when supplemental chilling is required, the water-to-water pump can take up the slack.

Mechanical system loads in this high-performance building are so low, and the envelope is so tight, that the greatest energy savings left to be found is the electrical plug load. The building relies on a number of innovative power-saving measures. All electrical panels in the offices automatically shut off at night. In the labs, the building uses a "green plug" system. Lab users simply plug nonessential equipment into specific plug strips, which are colored green for ease of identification. These strips automatically shut off every night.

To combat one of the most pernicious energy drains of a typical genomics lab, most of the freezers are co-located in a single room, and that room is treated differently than any other part of the lab. Instead of using air-cooling equipment, the freezer room uses a more efficient water-cooled system that consumes less energy.

The building and site also value water. Rainwater and air handler condensate are collected and stored in a cistern, filtered, and then reused for non-potable purposes. The building includes waterless urinals and high-efficiency plumbing.

[17] These induction diffusers are sometimes called "chilled beams," but that term belies the dual heating/cooling nature of this technology, and the term is going out of fashion.

This project was designed to meet 100% net zero water, but because of code issues this target could not be met at this time.[18] Though net zero water in southern California seems improbable, the designs for Venter show it is technically possible, if codes allow for it.

The client's goal was to achieve industry-leading energy and water use reductions, with minimal cost increases. Underground parking was required by the University, and when the costs for parking are removed, the construction costs for JCVI are in alignment with projects of similar scale and program.

JCVI exemplifies a key finding of this study: Project teams that are tasked with evry rigid or strict energy reduction goals often handle cost management very well. On-site renewable energy (photovoltaics) is typically a major cost driver and requires a substantial amount of space. Project teams respond by reducing energy demand as much as possible, through passive and active systems, as well as occupant behavior. This approach tends to increase costs for architecture, while reducing costs for mechanical and renewable energy systems. The rigor of the energy goal provides incentive for a robust integrated design approach.

PROJECT NAME
J. Craig Venter Laboratory

LOCATION
University of San Diego, California

BUILDING / SITE AREAS
45,000 SF

PROJECT TYPE
Research lab and office - New construction

DELIVERY METHOD USED
Design Bid Build

VISION
"The building is a unique design that will meld the environmental philosophies of our genomics research with the sustainability goals that I believe must be part of all of our lives."
J. Craig Venter

CONSTRUCTION COST
Confidential

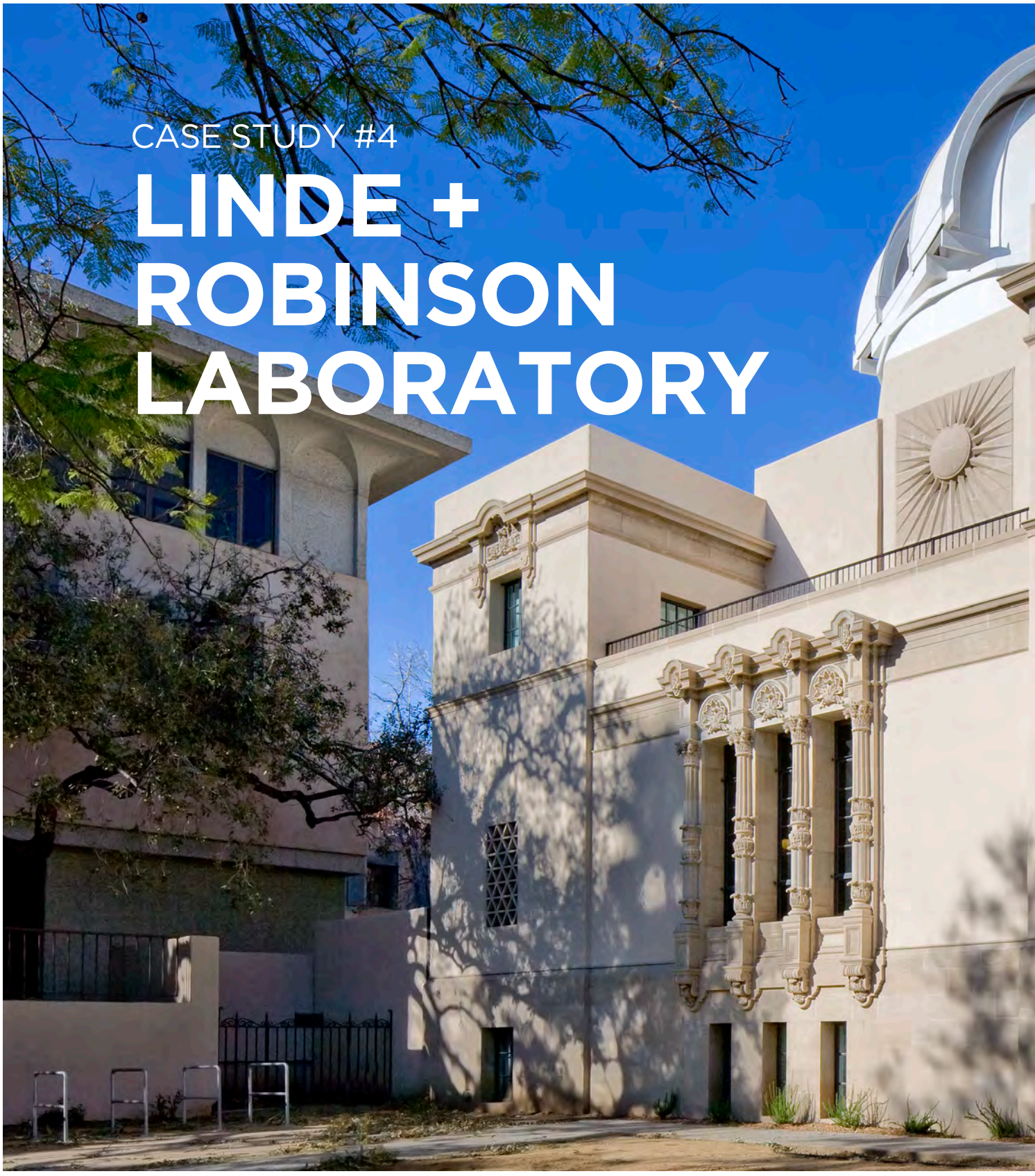
COST DRIVER(S)
Biology lab requirements, Passive design arppoach

EUI
55

LEED/LBC/OTHER RATING
LEED NC Platinum, Net Zero Energy, Net Zero Carbon

WEBLINK
http://www.jcvi.org/cms/sustainable-lab/overview

[18] California state code does not address blackwater reclamation at the building scale; the proposed treatment system at Venter was therefore defined as a treatment plant. The code requires treatment plants (which typically serve entire communities) to provide daily on-site testing of water produced from the plant. These requirements do not make sense at a small scale, and daily testing is cost prohibitive at such a small scale. Net Zero Water was dropped as a goal due to building codes and operational costs associated with implementation.



CASE STUDY #4

LINDE + ROBINSON LABORATORY

A retrofit of a historic (1932) astrophysics lab, Linde+Robinson became the first historic LEED Platinum laboratory building. The design really took advantage of what the existing building offered, including turning an old coelostat telescope into a light source for dark basement lab rooms.

A key story on Linde+Robinson is the plug loads. Amory Lovins, when meeting with the team and Caltech to review the project, suggested to President Chameau that a portion of the donor funding should be earmarked for efficient lab equipment. A plug load study with the design team and occupants found opportunities for greater efficiency in how equipment was used, and found more energy-efficient equipment. These simple and readily available strategies brought the plug loads down by 50 percent, resulting in costs savings in construction and operation.

The success of the design and great reduction of plug loads in an energy intensive environment happened in large part because the design team closely collaborated with the tenants (Caltech scientists) and equipment-makers during the design.

The design team also capitalized on existing features in inventive ways. The coelostat telescope, mounted on the building's roof, consists of mirrors that track the sun. The designers reconditioned it so it no longer serves an astronomical purpose, but is a pathway for sunlight to light basement labs. The underground pit that was originally part of the coelostat experimental apparatus was reconfigured into a thermal energy storage tank. Creative approaches to cost transfer, especially breaking down the institutional barrier between facilities and research equipment, enabled Caltech to realize incredible energy savings not otherwise attainable.

PROJECT NAME
Linde+Robinson Laboratory for Global Environmental Science, California Institute of Technology

LOCATION
Pasadena, California

BUILDING AREA
49,000 SF

PROJECT TYPE
Renovation of 1932 Astrophysics Lab

DELIVERY METHOD USED
Design-Bid-Build

VISION
Create the most energy efficient laboratory possible.

CONSTRUCTION COST
$25 million

COST DRIVER(S)
Historic retrofit of concrete building with 11.5 feet floor-to-floor into multidisciplinary lab including fume hoods, clean room, wet lab, and instrument labs with thermal energy storage, heat recovery, radiant ceiling panels and fume hood stack exhaust wind control.

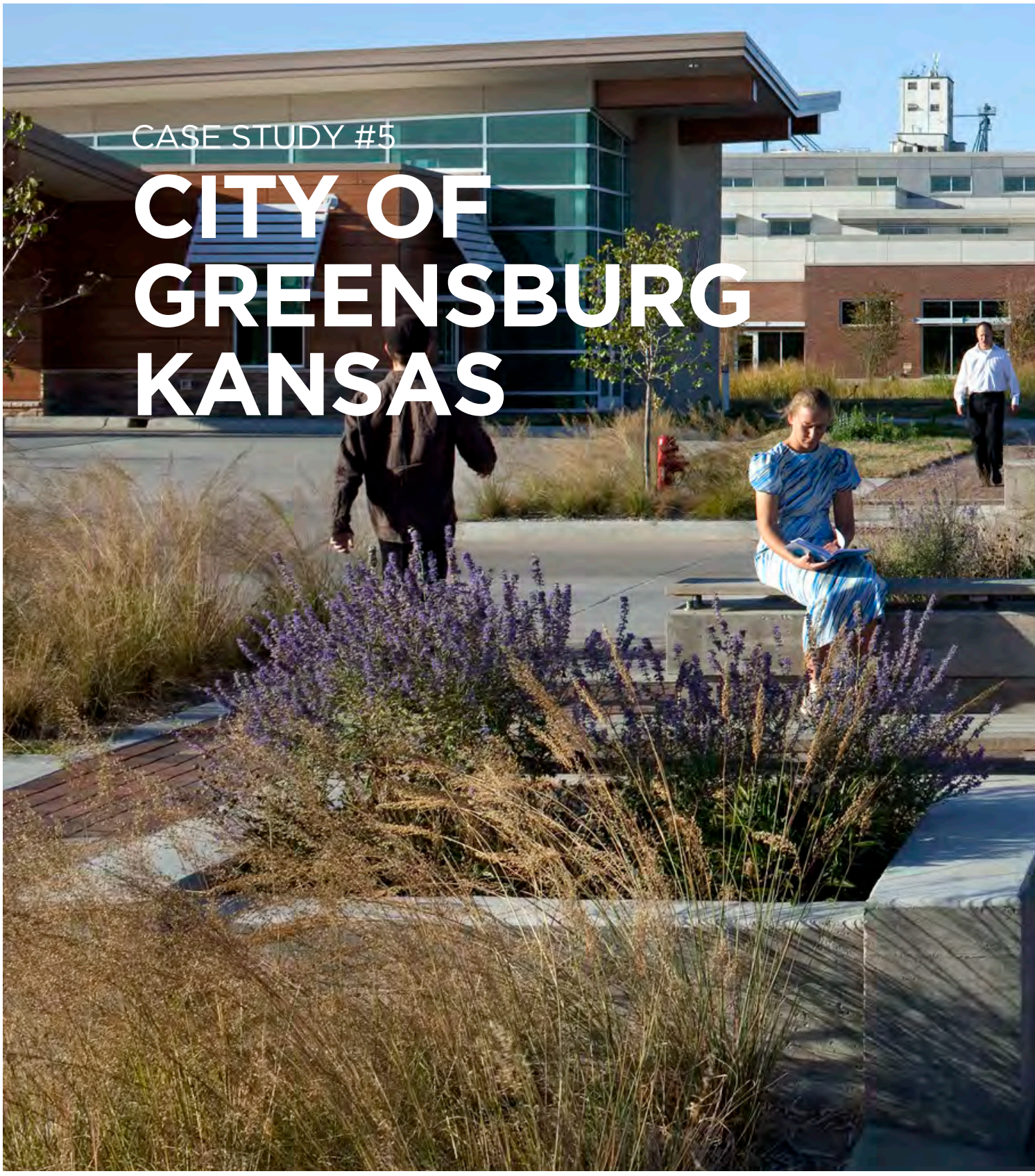
EUI
55

LEED/LBC/OTHER RATING
LEED Platinum

WEB LINK
http://www.lindecenter.caltech.edu/building/green-design

WORDS OF WISDOM
Don't take on more than the entire team can handle, including maintenance staff.

If users are getting funding for more efficient lab equipment, also give funds for maintenance of special systems not found elsewhere on campus.



CASE STUDY #5

CITY OF GREENSBURG KANSAS


FLORIDA 100 W
STOP

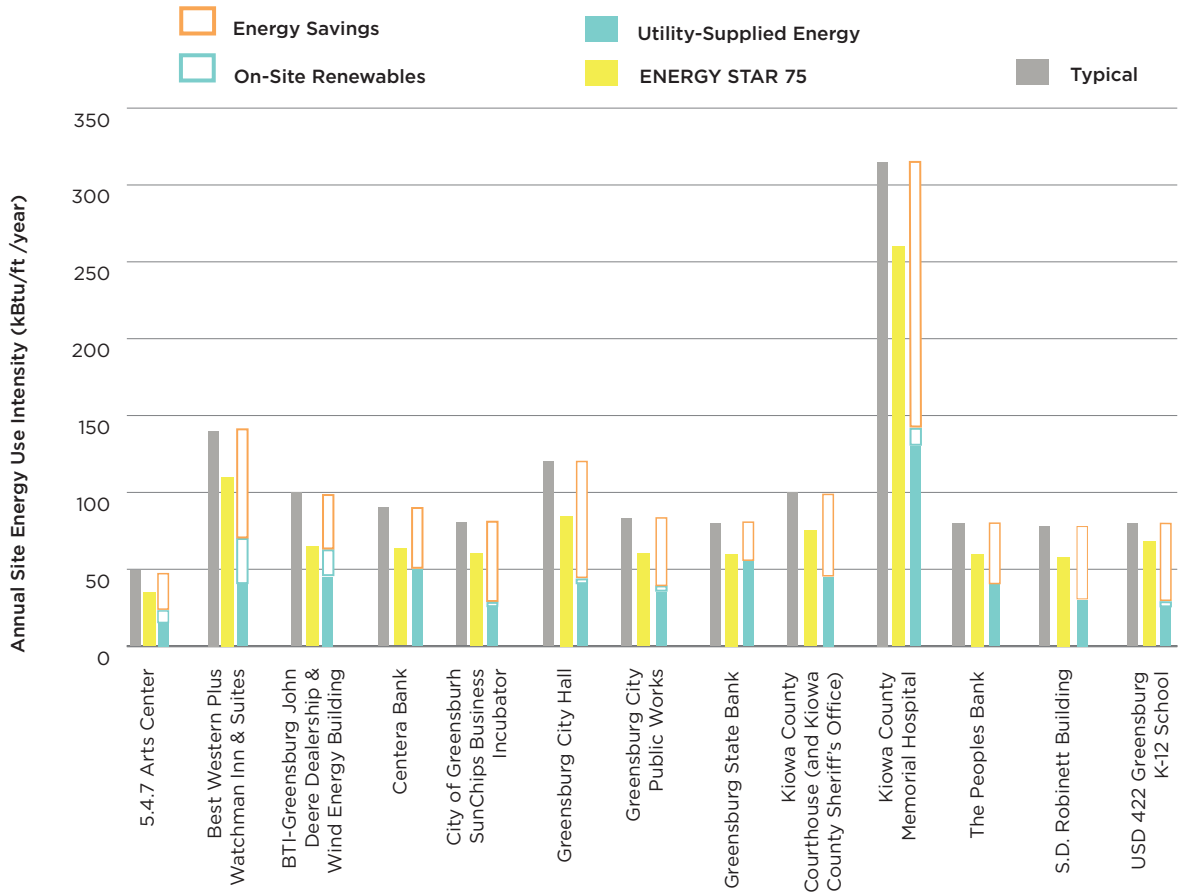
This is the story of a small rural town in Central Kansas that withstood the devastating effects of an EF-5 tornado on May 4, 2007, killing 11 individuals and destroying 95% of the structures. The tornado was as wide as the town, literally, and ran through its center, right down Main Street.

In an incredible gesture to rebuild, and rebuild strong, the community imagined a new future and captured it in their vision statement:

"BLESSED WITH A UNIQUE OPPORTUNITY TO CREATE A STRONG COMMUNITY DEVOTED TO FAMILY, FOSTERING BUSINESS, WORKING TOGETHER FOR FUTURE GENERATIONS."

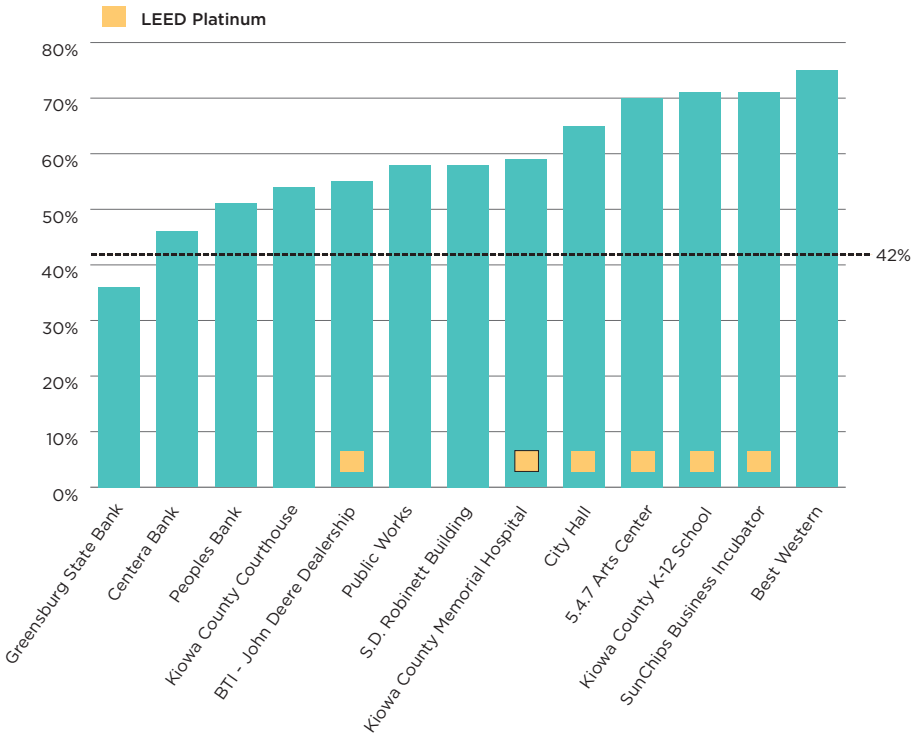
For the first time in the nation, a community mandated LEED Platinum certification for all their buildings, with a minimum of 42% energy savings. Once again, we see that a strong vision becomes the foundation for "next generation green" being realized. This time the "owner" is the community.

One aspect of that vision addressed an aggressive energy goal, which emphasized energy goals for individual buildings as well as a plan to produce renewable energy for the whole community. Many conversations and details later, six years in fact, the National Renewables Energy Lab (NREL) – who provided significant support for the community as it rebuilt – went back to gather some data. NREL studied 13 buildings, as shown on the following chart.



By comparing the gray bars (typical energy use) with the blue bars (utility-supplied energy), one sees significant energy savings across the board. The dashed orange bars indicate overall energy savings, which reflect the rigorous design and construction required for each one.

The following chart shows energy savings for each building compared to the 42% energy savings targeted (all but one surpassing), and then how much is satisfied with renewables. It is interesting to see the correlation between those that targeted LEED Platinum and their actual energy savings achieved (typically higher).



Not included in the report are residences, but early reports showed 43% energy cost savings on average, in part achieved because of an on-site support person that reviewed plans and made recommendations to families as they were submitting for building permits.

Each of these individual building successes depended on the rigor of the owners, design teams, and builders to meet the "next generation green" goals. Simultaneously, the city worked at the community scale to support their strong vision with a strong community-scale goal: 100% renewable, 100% of the time, which they accomplished by building a wind farm outside of town, currently supplying all of the town's energy, or 25-33% of its capacity.

This is a perfect example of achieving sustainability with community-scale and building-scale goals and solutions. This is currently a net positive community, with plenty of room to grow.

PROJECT NAME
Multiple building projects

LOCATION
Greensburg, Kansas

BUILDING / SITE AREAS
Varies

PROJECT TYPE
Varies: Arts Center, Hotel, Bank (3), Business Incubator, City Hall, Public Works Building, County Courthouse, Hospital, Retail (2), K-12 School - All New Construction

DELIVERY METHOD USED
Design-Bid-Build

VISION
Blessed with a unique opportunity to create a strong community devoted to family, fostering business, working together for future generations.

CONSTRUCTION COST
Varies

COST DRIVER(S)
See Vision

EUI
Varies

LEED/LBC/OTHER RATING
Varies; LEED Platinum as a goal

WEBLINK
http://www.greensburgks.org/sustainability

WORDS OF WISDOM
Set Community-Scale Goals; Use an Integrated Design Approach; Incorporate Daylighting and Energy-Efficient Lighting; Invest in Simple Building Systems (NREL)

8

BIBLIOGRAPHY/ LITERATURE SURVEY

COSTING GREEN LITERATURE SURVEY

(opposite page) High-performance in buildings is often associated with cost premiums. These premiums are directly dependent upon approaches to delivery and cost management, and, more often than not, these premiums are perceived to be much higher than they really are [NBI 2012, WGBC 2013, Matthiessen and Morris 2004, 2007]. While research has been done to better understand cost premiums of green buildings, the existing literature remains somewhat limited. To add further confusion, the existing studies employ a wide range of methodologies and vary in depth, making it difficult to draw clear conclusions. Many of these studies are limited to LEED Certified projects, as the LEED scorecard is commonly used as a metric for green. Those few studies that explore beyond LEED are almost exclusively limited to hypothetical cases based on modeled buildings and have yet to be verified. Scope ranges from statistical analyses of several hundred projects to detailed case studies examining process, delivery, and budgeting methodologies for a small number of projects. The figure below summarizes reported cost premiums of seven of the seventeen papers reviewed. The papers included below were selected based on their relevance, as measured by citation count.

THE COST OF LEED – CONSTRUCTED BUILDINGS

The majority of existing studies use the LEED scorecard as a metric for green. The majority of these studies are based on constructed buildings.

Kats et al. examined cost premiums of 33 existing LEED office and school buildings in California and found that LEED cost premiums increase with the increasing rigor of the targeted certification level. This relationship is neither linear nor consistent across certification levels. LEED Certified buildings are reported to be 0.66% more expensive than the market cost, while LEED Platinum buildings are roughly 6% more expensive. Gold and Silver buildings are roughly equivalent, at about 2% above market cost. The majority of the increased costs were associated with the extra time required of the A/E team to integrate sustainable strategies. Financial benefits of LEED certification are, on average, over ten times the initial investment required for design/ construction [Kats, et al. 2003].

Mapp et al. report similar results, though with a much smaller scope. In its assessment of ten Colorado banks, the study finds cost premiums no higher than 2% for LEED Silver and LEED Certified banks. Additionally, the study finds that design team experience matters: soft costs for LEED projects without experienced designed teams were just above those of the non-LEED projects, while those of the experienced project teams were at the middle or low end of the range [Mapp et al. 2011]. Interestingly, though the study was published eight years after Kats, the cost of LEED does not appear to have diminished with increased A/E experience and market adoption.

In two separate studies of hundreds of existing LEED buildings, Matthiessen and Morris find no statistically significant difference between costs of LEED buildings versus those of non-LEED buildings [Matthiessen and Morris 2004, 2007]. The reported cost-per-square-foot of LEED buildings falls within the existing range for buildings of similar program type across all assessed LEED certification levels and program types. The authors note that a broad range of factors contributes to the feasibility and cost of construction for LEED

buildings, including location, climate, bidding climate, culture, local and regional design standards, including regulations and incentives, intents and values of the project team, and potential point synergies. As a result, there are low-cost and high-cost buildings in both the LEED and non-LEED categories, and the resulting data are skewed within each category: distributions are weighted toward the low end, with long high-end tails representing the few high-premium projects contained in the dataset.

THE COST OF LEED – MODELED BUILDINGS

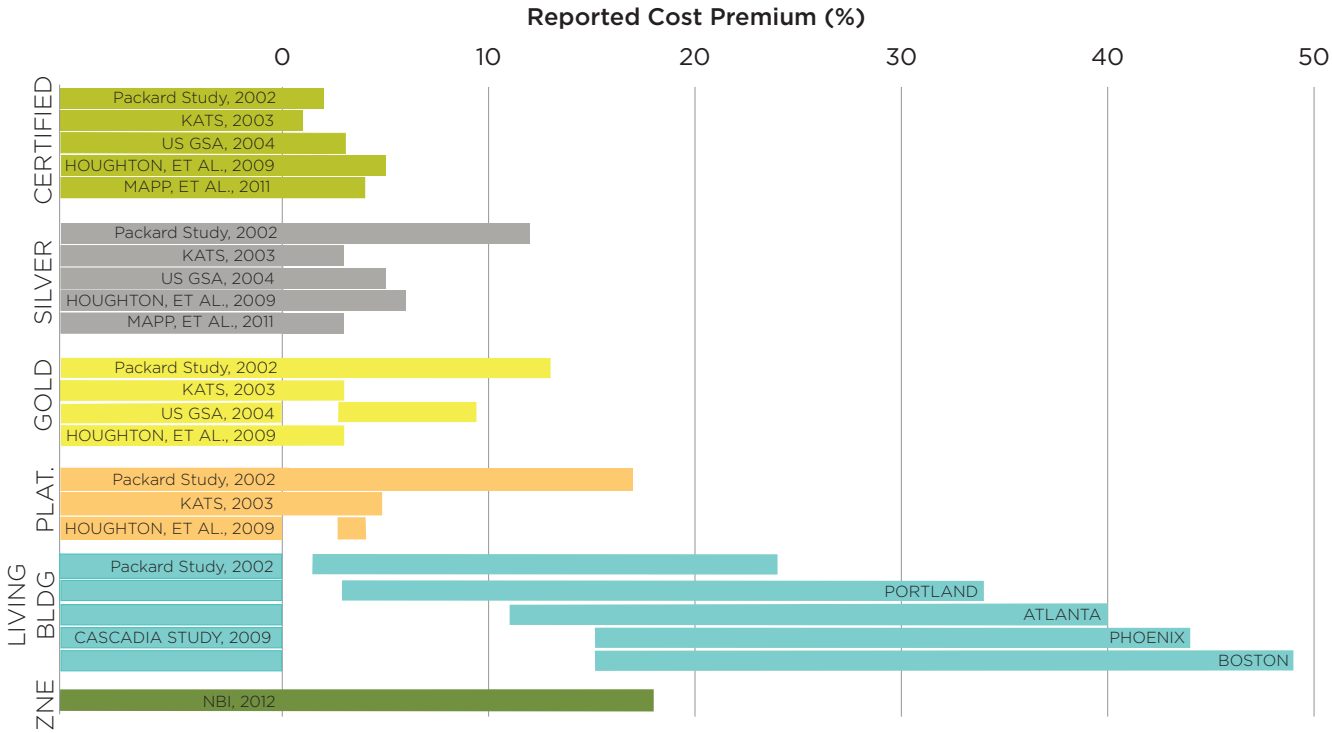
As mentioned earlier in this report, the Packard Foundation performed a feasibility study for a low-rise office building in California, evaluating the hypothetical cost premium for each LEED certification level, as well as for a "living building." The study included both capital costs and operations costs. They found that the hypothetical cost premium was directly proportional to the rigor of the targeted certification level, with the LEED Certified scenario 1% above the market cost, and the LEED Platinum scenario 17% above [Packard 2002]. Unsurprisingly, the scenarios requiring the highest capital costs demonstrated the lowest operating costs.

The United States General Services Administration (US GSA) assessed cost premiums for hypothetical office and courthouse modernization projects, creating low-cost and high-cost limits for each scenario by assuming low and high experience levels for each project team. The study found construction cost premiums ranging from 0-2% for LEED Certified projects to 1.5-8% for LEED Gold projects [US GSA 2004]. Platinum projects were not evaluated. When soft costs were included, costs increased considerably, depending on the experience of the project team.

THE COST OF NET ZERO – CONSTRUCTED BUILDINGS

There are very few published studies examining cost premiums beyond LEED. Of these studies, one examines cost premiums in existing zero net energy (ZNE) buildings, while the other two rely on modeled data to assess cost premiums of living buildings.

New Buildings Institute's (NBI) recent examination of hard cost premiums of 21 ZNE buildings across the country indicates cost premiums between 3 and 18% to achieve net zero energy buildings, without including the costs of photovoltaic arrays [NBI 2012]. The dataset



Summary of existing research examining cost premiums of high-performance buildings. There are relatively few studies, each employing a slightly different methodology, which perhaps contributes to the observed discrepancies.

primarily contained small commercial buildings, most of which were schools and demonstration buildings. All of the included projects use photovoltaic as their renewable energy source and all use readily available technologies to meet their energy performance targets. Cost premiums were found to depend on building type, location cost factors, and climate.

THE COST OF LIVING BUILDINGS – MODELED BUILDINGS

Two studies use multiple modeled scenarios to examine the cost premiums of hypothetical Living Buildings. The first, published in 2002 by the Packard Foundation, reports a cost premium of roughly 22% above the market cost for a 90,000 SF office building in California. The study also examined impacts to design, construction, and research schedules, societal costs, energy costs, and long-term costs for the project over three hypothetical building lifetimes (30-, 60-, and 100-year scenarios). For each modeled lifetime, though the capital costs were considerably higher across each of the metrics evaluated, the living building proved to be by far the best value and lowest impact over the lifecycle of the building [Packard 2002]. It is worth noting that the design of these hypothetical "living buildings" were done prior to the codified definition of the Living Building Challenge.

Cascadia published a follow-up study to the Packard Report in 2009, expanding the scope to consider twelve hypothetical building types in four climate zones They report a cost premium ranging from 4-49%, depending on climate zone and building type. The study finds a strong dependence upon parameters inherent to the project (i.e. owner involvement and clarity of goals, building type and size, site geometry] and parameters inherent to its location [climate, annual rainfall distribution, availability of local and regional incentives, and utility rates) [Cascadia 2009].

MANAGING THE COST OF GREEN

Many of the references above offer insight into cost-effective approaches and delivery strategies for green buildings. The US GSA study proposes a systematic approach to LEED, suggesting first examination of embedded points, second assessment of no-cost or low-cost credit opportunities, and finally well-researched selection of moderate- to high-cost credits. In all cases, evaluations should weigh the first cost against the long-term value. Matthiessen and Morris propose similar approaches, estimating that most buildings achieve up to 18 embedded LEED points. These embedded points can ensure a LEED Certified rating with little or no changes to the original design. Furthermore, integration of sustainable features results in considerable cost savings, both because a truly integrated feature will often satisfy many sustainable design goals and because "tacked-on" approaches are often inherently more expensive.

Cost management approaches to beyond-LEED projects are less prescriptive, though find similar dependencies between costs and project-specific characteristics. For example, the Packard study finds strong dependencies on location characteristics such as climate, annual rainfall distribution, local codes and cultures, and the availability of incentives, as well as project-specific characteristics such as client involvement, team experience, and project goals [Packard 2009]. Both the Packard and Cascadia studies find Living Buildings require considerably more research investment [Packard 2002, Cascadia 2009], which suggests a need for either providing additional funding for the added soft costs or more carefully controlling hard costs to accommodate the additional soft costs.

Federal organizations are testing different contract structures to deliver extremely high performance projects at the market rate [NREL 2012]. Based on previous research, DOE and NREL opted to implement a performance-based design/build approach for their recent Research Support Facility. The project was built in two phases, both of which met their cost and energy goals; the second phase achieved 17% higher efficiency at 11% lower cost. At roughly $14/sf, these additional savings were sufficient to cover the cost of the rooftop PVs, which would bring the project to net-zero energy. From the owner's perspective, NREL/DOE found that a two-stage competition with an extremely clear RFP resulted in selection of a well-integrated team. They incentivized the team to maximize team integration and project value through an award fee structure. (Curiously, this integration did not include the owner, as the team was tasked to use the RFP as the only/primary means of communication.) The design/build team was contractually required to achieve the energy performance goals. From the designer/builder's perspective, a metrics-based design approach using both energy and cost models to inform the design process resulted in considerable savings.


WORDS OF
WISDOM
AN INTEGRATED DESIGN PROCESS REALLY DOES MAKE A DIFFERENCE

In addition to the Words of Wisdom scattered throughout this document, the authors also gleaned the following DOs and DON'Ts during their research. Each of these relates to the taking on of a high-performance "next generation green" project.

DON'Ts

- Do not tolerate team members who are more obstacles than problem-solvers
- Do not be discouraged at each hurdle (there will be many)
- Do not forget that the community can be engaged in powerful ways and can be an important secondary tier of support

DOs

- Ensure owner buy-in
- Set clear project goals, including cost constraints
- Plan the work carefully
  - Set checkpoints for system integration
  - Design a careful flow of team meetings / decision-making
  - Perform regular cost checking, including timely small batch costing for decision-making
  - Hold early and regular meetings with regulatory officials
- Be willing to educate all constituents along the way
- Build a strong, resilient, next gen team
- Develop a spirit of exploration / inventiveness / problem-solving … willingness to push the envelope
- Build a diverse project team
- Get contractor, specialty subs, suppliers on-board early
- Assume the design will evolve and improve as the team moves through the process

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OPTIMIZING VALUE FOR NEXT GENERATION

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