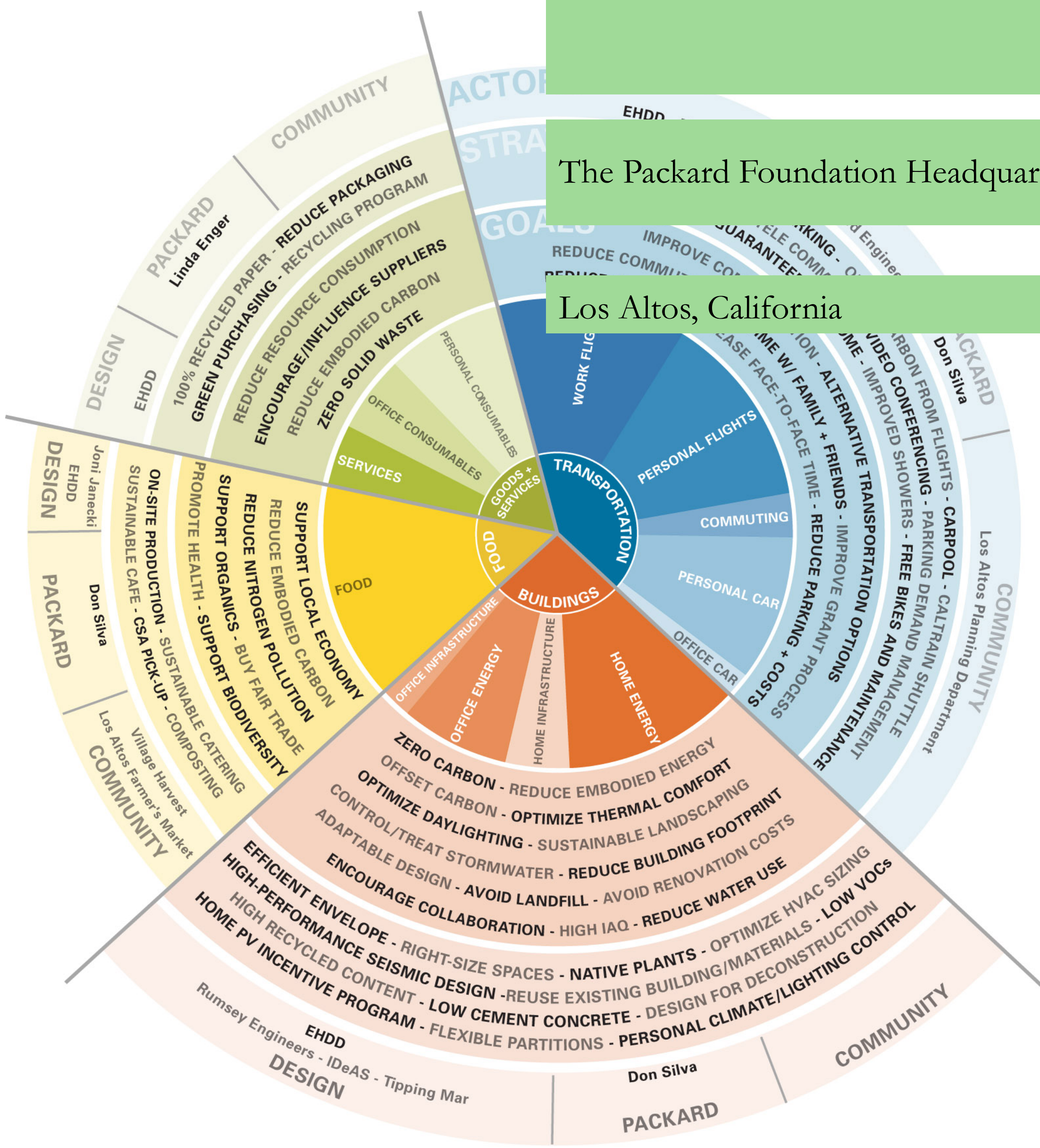
Sustainability in Practice
Building and Running 343 Second Street



The Packard Foundation Headquarters

Los Altos, California

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October 2013

Acknowledgments

People of the Packard Foundation and the design team have been extraordinarily generous with access and time. At the Foundation: Carol Larson, Craig Neyman, Susan Orr, Don Silva, Juan Uribe, Linda Enger, Curt Riffle, Minna Jung, and my main contact and guide, Amelia Hayter. At RhodesDahl: Linda Rhodes and Vickie Dahl. At EHDD Architecture: Brad Jacobson and Marc L'Italien. At Integral Group: Eric Soladay, Dave Maino and Andrew Martinez. At DPR Construction: Mike Humphrey and Mike Messick. I hope they and all others who contributed to this building project will find their hard work fairly reflected here.

I am also in debt to the sources of images used. I have tried to credit each image appropriately; any oversights I learn of will be corrected quickly.

photo: Jeremy Bittermann

About This Study

As a case study, this work is part history, part analysis, and part interpretation. It rests on documents and interviews made available by the participants in the making of 343 Second Street. It highlights key features of this project, and it makes no claim to provide general principles for others to follow. Instead, it invites others to see a project they might be planning as if it were this one, and to let any similarities and differences serve to sharpen a sense of direction and their instincts for what to pursue and commit to. If, as they say, the devil is in the details, I hope an understanding of these details and these devils will help others see their own devils and details more clearly.

Pages 1-3 summarize the study; the main text's table of contents is on page 4.

Sustainability in Practice

The Buddhist scholar and deep ecologist Joanna Macy frequently says to her audiences, "Hope isn't something you *have*; it's something you *do*." The same goes for sustainability. This much-voiced, multi-faceted, contentious term refers to a pattern of living and working, not a gadget, device or trophy. Sustainability isn't something you *have*, it's something you *do*. Few American efforts of the last decade embody this as deeply as the design, construction and operation of the David and Lucile Packard Foundation's new headquarters building in Los Altos, California.

photo: Jeremy Bittermann

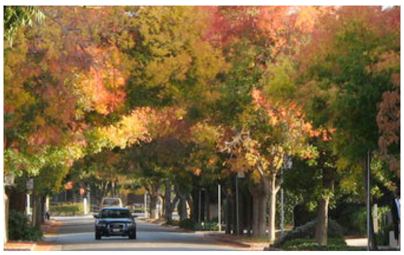
Known inside the foundation by its address, 343 Second Street, the new Packard headquarters represents not only a physical structure but also a living organization, to which professionals and support staff devote many waking hours and through which they pursue the multiple goals of their working lives. The story of the new headquarters is one of recognizing that hopes for a sustainable place of work require ongoing engagement of all staff. The Packard project's achievement lies in devising not only a fine physical setting but also modes of engagement that are truly manageable and satisfying for the long term.

The present document is a careful case study of this project—what happened, how, and how much, in the context of related building projects over the past 15 years in the US. I have considered the main readership to be professionals and leadership in organizations which are contemplating new buildings of their own, and I have therefore emphasized the process of formulation and decision-making. New-built workplaces do not drop fully formed from the skies, nor are they lined up ready-made in some catalog. They emerge, like gardens—originally untended places where ideas have grown, strongly conditioned by accidents of soil and climate, strongly but not wholly shaped by husbandry, into habits and structures which support an organization's life (or fail to). What were the seeds, the soil and climate and the husbandry that have led to 343 Second Street?

A summary

The Packard Foundation describes its headquarters project as "a conscious decision to live the values we support," which it articulates for this project as a threesome:

> *a physical manifestation of our long-term commitment to conserving the Earth's natural resources; a comfortable, healthful space for our employees to work collaboratively; support for a vital downtown in the community which has been the Foundation's home for over 45 years.*[1]



City of Los Altos (left); EHDD Architecture (center); Packard Foundation (right)

This study centers on sustainability, and will show how all three Packard value streams have mixed and reacted to generate the particular embodiment of sustainability which is the present headquarters.

Getting from the earliest discussions to moving in was a six-year process (2006-2012), including a 12-month halt due to the 2008 financial crisis. The building, 343 Second Street, stands on a roughly triangular 1.8 acre site at the south-east edge of Los Altos' business district. The building has room for about 120 professionals and staff, in two long, relatively narrow two-story wings (250 ft by 45 ft) about 45 feet apart, and two short perpendicular wings which bridge the gap and define a generous internal courtyard. The roofs of the long wings are mostly covered with the photovoltaic (PV) panels which provide the building's energy. These are not visible from the street, where the impression is a quietly varying facade of wooden walls, balcony projections, and frequent windows, set a little back from the sidewalk by sheltering foliage—ground cover, bushes, trees.

Results

The project set itself two major sustainability standards, LEED Platinum status and net zero energy operation, and the first year of operation, July 2012-July 2013, has seen both achieved. Equally important, 97% of its inhabitants report general satisfaction with the building, a proportion that puts it in the top 5% of a national database of building occupant surveys.[2] As this study will show, these results arise from a merging of very good work by design and construction professionals with a

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[1] Packard Foundation, www.packard.org/about-the-foundation/our-green-headquarters/ (accessed Oct.2, 2013)

[2] Center for the Built Environment (University of California, Berkeley) Post-Occupancy Evaluation administered April 17-28, 2013.

very steady commitment within the Packard Foundation staff, leadership, and Board to an understanding and practice of sustainability much wider than just the building. All participants have strong reason to be proud of what they have achieved so far. At the same time, operational success and inhabitant satisfaction are qualities that need continued attention and effective action. For Packard and for any who follow these footsteps, sustainability will remain something to be done, not had. Time will be sifting the lasting ideas and practices from the temporary and the fashionable. There are decades of learning and practice ahead for all American organizations as sustainability becomes understood and embedded in the ways we work.

Preview of Conclusions

In this study, the process by which 343 Second Street came about is more important than the physical specifics of the building, persuasive as they are. The significance of Packard's process for sustainability is its intimate, judicious merging of technical possibilities with organizational priorities and values. Especially noteworthy are the adaptability and resilience of the participants to the opportunities and challenges that came along. The project experienced two stock market crashes, a "sustainability wheel" and its great expansion of vision, a mid-course design shift, a target cost commitment. Moments like these arrive in many projects, but the steadiness of the response by all participants in 343 Second Street is not so common. The basic goals remained well in view even as the path toward them showed itself to be different from expected.

The wide engagement of Packard staff in pursuing in-house sustainability has been vital to reaching this point. Attaining the net zero energy goal is an effort that reaches right to individual desks, and calls on initiative as well as cooperation. This is both challenge and opportunity. Through the creation of an active and effective in-house Sustainability Task Force and in less formal ways, Packard staff and leadership rose to it, as this study recounts in detail.

The importance of beauty to the project's success is a third noteworthy element. For inhabitants to be committed to sustainability in the workplace, connecting with their sense of beauty is commonly overlooked but profoundly important. The Packard process was able to recognize this and to find effective, broadly appealing ways of implementing it, true to the personalities and the practicalities of its situation.

As other organizations consider green buildings of their own, this threesome of steadiness, wide engagement, and beauty must of course be joined by a technical element. The individual technologies used at 343 Second Street are well established. The technical achievement, and it is considerable, is to have deployed them in a sensitively integrated fashion. The tools for doing this, such as energy modeling, are widely available. Good results in other locations await only the competent use of available technology and tools.

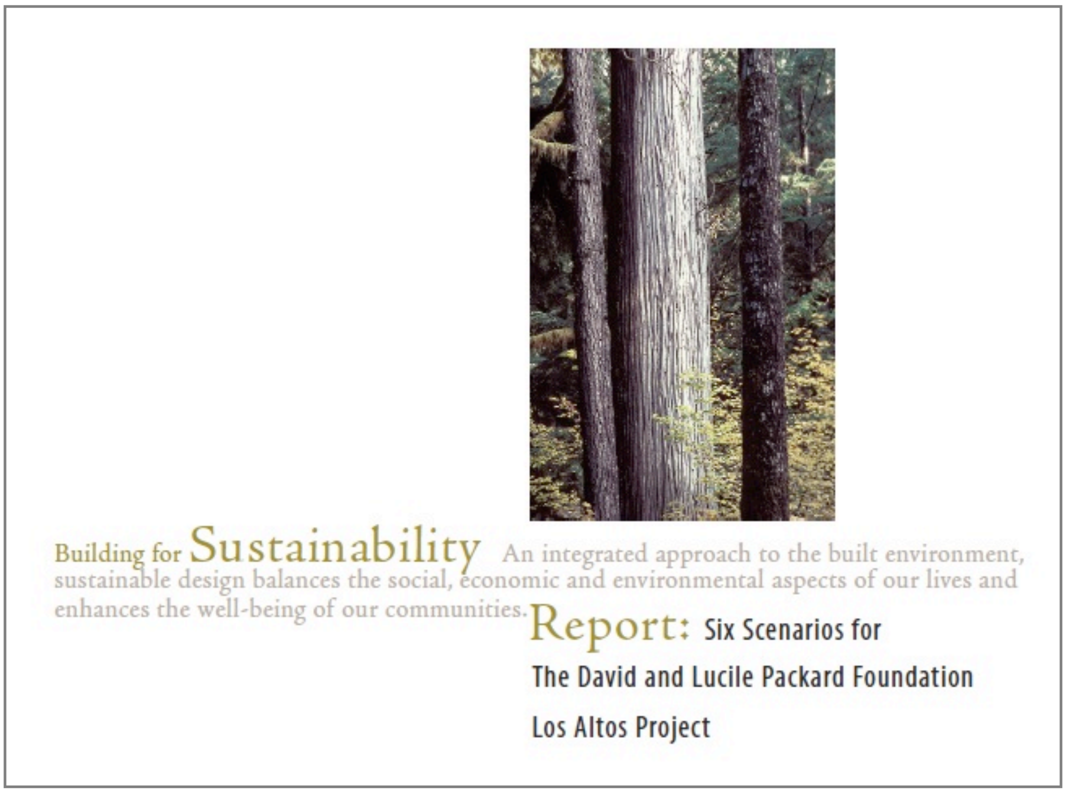
This all bears on the question of replicability. This has been in Packard's rhetoric and on the minds of Packard people from the start. My view on this is nuanced in many respects, but unwavering in one general way: the means are now available for a very wide range of organizations to house themselves in high-performing buildings at reasonable cost. The specific goal of net zero operation is more subject to local circumstance, but the information below about workable reductions in energy demand indicates that local solar energy will permit net zero low-rise offices in many locations. If an organization can bring steadiness, wide engagement, and internally authentic forms of beauty to a project, and if it teams up with a design team that understands integrating systems into harmonious wholes, the chances of joining the Packard Foundation's league are excellent.

photo: Jeremy Bittermann

2—A HISTORY OF THE PROJECT

Packard's discussions about a new headquarters began about 1999, centering on a goal of consolidating the staff, at that time scattered through five Los Altos sites, into a single building. The story of this building is very much a story of shifting and sharpening of goals and options. Techno-rational accounts describe design processes as starting with precise goals and moving to choices between clear-cut options for arriving at them. Packard's good results did not arrive by this route, nor should others expect anything different.

A first round: 1999-2002



Packard Foundation

The image is from the cover of a 2001-02 study of sustainable offices. It testifies to the presence of sustainability in Packard's culture for a long time. Environmental conservation has been a major area for the foundation from the start in the 1960's, and climate-related issues, including energy policy and energy efficiency, have seen significant grant-making by Packard since at least 1997.[3] When discussion of a possible new headquarters building or campus started in 1999-2001, green building was one of the explicit themes. The site on which 343 Second Street now stands was purchased at that time, and BNIM Architects of Kansas City, Missouri was hired to

[3] Packard Foundation, http://www.packard.org/what-we-fund/conservation-and-science/ (accessed Sept. 28, 2013)

generate a master plan and building design. Planning ended with the stock market crash of 2000-2001, the bursting of the so-called "dot-com bubble," which cut the value of Packard's portfolio nearly in half. But the foundation wound the process down constructively, allowing BNIM to organize its preliminary research into a report, "Building for Sustainability," that became nationally influential.[4]

BNIM's research had tackled a question of scope: how far is it reasonable to go in pursuing sustainable buildings? Its strategy was to develop very preliminary designs for six progressively more ambitious buildings, using the Packard site and its specific climate, topographic and municipal conditions. These "Six Scenarios for the David and Lucile Packard Foundation Los Altos Project" were informed by close and quite detailed consultations with a first-rank engineering firm (Keen Engineering) and cost consultant (Oppenheim Lewis) to maintain solid engineering feasibility and realistic costing. The report's digest of its findings was a table of vsual comparisons which became known among American sustainability-oriented architects as the Packard Matrix, and will be discussed further below. The comparison of the Six Scenarios of 2002 with what 343 Second Street became by 2012 is instructive. Both continuity and change are evident in the ensembles of physical features and technologies.

Returning to the question: 2006

When the Packard Board reopened the question of a new headquarters in the summer of 2006, however, sustainability was not a defining feature at first. Board minutes state a lack of consensus on this, though energy efficiency was generally agreed desirable.[5] Of equal or greater weight were the values of consolidating staff, maintaining the emotional bond to the existing headquarters (300 Second Street, designed about 1987 with very strong Packard family involvement), improving facilities for large meetings, parking, and resale potential. By November of 2006, when both staff and board had begun to consider building alternatives actively, sustainability had regained prominence in discussions. However, it was never, then or later, a sole priority. The foundation was building a home for its work, not a demonstration building.

[4] "Building for Sustainability," David & Lucile Packard Foundation, 2002

[5] "Chronology of New Building Activities" digest from Board and Committee meeting minutes, President's Office, Packard Foundation (confidential internal document)

When the first nationally circulated Request for Qualifications (RFQ) went out to 35 architecture firms in June 2007, sustainability was one of six "general design parameters."[6] Other considerations mentioned included compatibility with local context, parking, ADA accessibility, and "appropriate use of modern design principles." Sustainability itself, true to its action-oriented nature, was not defined directly.

The page on "Sustainable Design Objectives" starts as follows, "The Foundation values approaches and technologies that address the following considerations," and then lists 14 unranked, disparate topics which represent the full range of the national discourse on possible eco-improvements to building. In effect, the RFQ was an invitation: "Dear Design Firm, define sustainability for this project—propose a persuasive framing of the problem, and show us what you would put in that frame." The selection would not go according to tightness of fit to precise, pre-existing criteria, but rather to a proposal's coherence and promise of substantial progress.

A key point of process from April 2007, after staff and board committee were well engaged in the new headquarters question, but several months before selecting the design team, was Packard's decision to employ a project management firm to provide the specialized, detailed tracking, problem-solving and decision support functions which are vital to the success of a complex project like a full-scale headquarters building. Its role is often called "owner's representative," to distinguish it from the buyer-seller relationship an owner typically has with architects, engineers, and builders. The firm chosen was RhodesDahl of Charleston, South Carolina. It had a strong track record in complex exhibit and museum projects, including the Monterey Bay Aquarium, where they had worked closely with the Packard family almost 25 years before. This long acquaintance put the firm's principals in an unusually good position to balance the professional and personal aspects of the headquarters project.

Personal values and inclinations are a time-honored, legitimate part of the actions of a private foundation like Packard, but I believe they have a potentially deeper importance than commonly recognized. It is to provide character, that elusive but essential quality. Consider this possible thumbnail hotel review: "A perfectly adequate place to stay but lacking character and any sense of a personal touch." What does the writer find missing? Consider, as an alternative, one dictionary's definition of "character": "the mental and moral qualities distinctive to an individual."[7] My suggestion, in considering the Packard headquarters project in the light of sustainability, is that buildings, like people, need to have a degree of distinctiveness

[6] The David and Lucile Packard Foundation, "Request for Qualifications – Architectural and Engineering Services" (June 2007)

[7] Apple Dictionary, version 2.1.3

or individuality about them if they are to be sustained. As I am describing the events that led to 343 Second Street, readers should be alert for ways that the project did or did not acquire character. I suggest that personal inclinations, preferences, intuitions can be a means for character to emerge, and this happens precisely because they are personal and not generic.

From a green building to a sustainable organization

By the end of June 2007, 22 architecture firms had responded to the RFQ and RhodesDahl had overseen a winnowing process which asked 8 of them to respond to a second RFQ by the third week of July. All did, and further review led to three being invited to interviews with the Packard board and staff. There ensued one of the two main defining moments of the design process. Each candidate firm was to make a presentation and respond to questions. According to everyone I interviewed who was there, the proposal and presentation by EHDD Architecture rang like a bell with the Board and staff. It not only won them the job, it redefined the work in a transformative way. A passage in the "Sustainable Design Philosophy and Practices" section of EHDD's written proposal captures the essence:

> *What is the most appropriate sustainable vision for the Packard Foundation? The current de facto standard for an exceptional green building would be LEED Platinum. . . . The 'Living Building' approach articulated in the Packard Matrix in 2002, goes a step further to make the building largely self sustaining. . . . And a Zero Carbon building would be a third laudable approach.*
>
> *All of these options however are focused primarily on creating a green building, rather than a sustainable organization. As better tools help us quantify resource use and impacts, we are learning that buildings are just one slice of a much larger pie. The Ecological Footprint analysis for the Thames Gateway project . . . illustrates resource use for several different scenarios including everything from building energy use to food, waste, and transportation. It shows how broadly resource use is distributed through our lives, and the broad range of actions needed to achieve "One Planet Living." We believe this suggests a shift away from looking at green buildings in isolation, constrained by the artificial property lines and trying to understand impacts and solutions in a more integrated, holistic manner.*[8]

A slightly later diagram (next page) makes the same point visually.[9] It became known as the "sustainability wheel," and appeared in a variety of forms in Packard and design team documents. It is also the cover image for this study, because it dramatizes the relation of the 343 building project to the full range of sustainability questions faced by the Packard Foundation and similar organizations.

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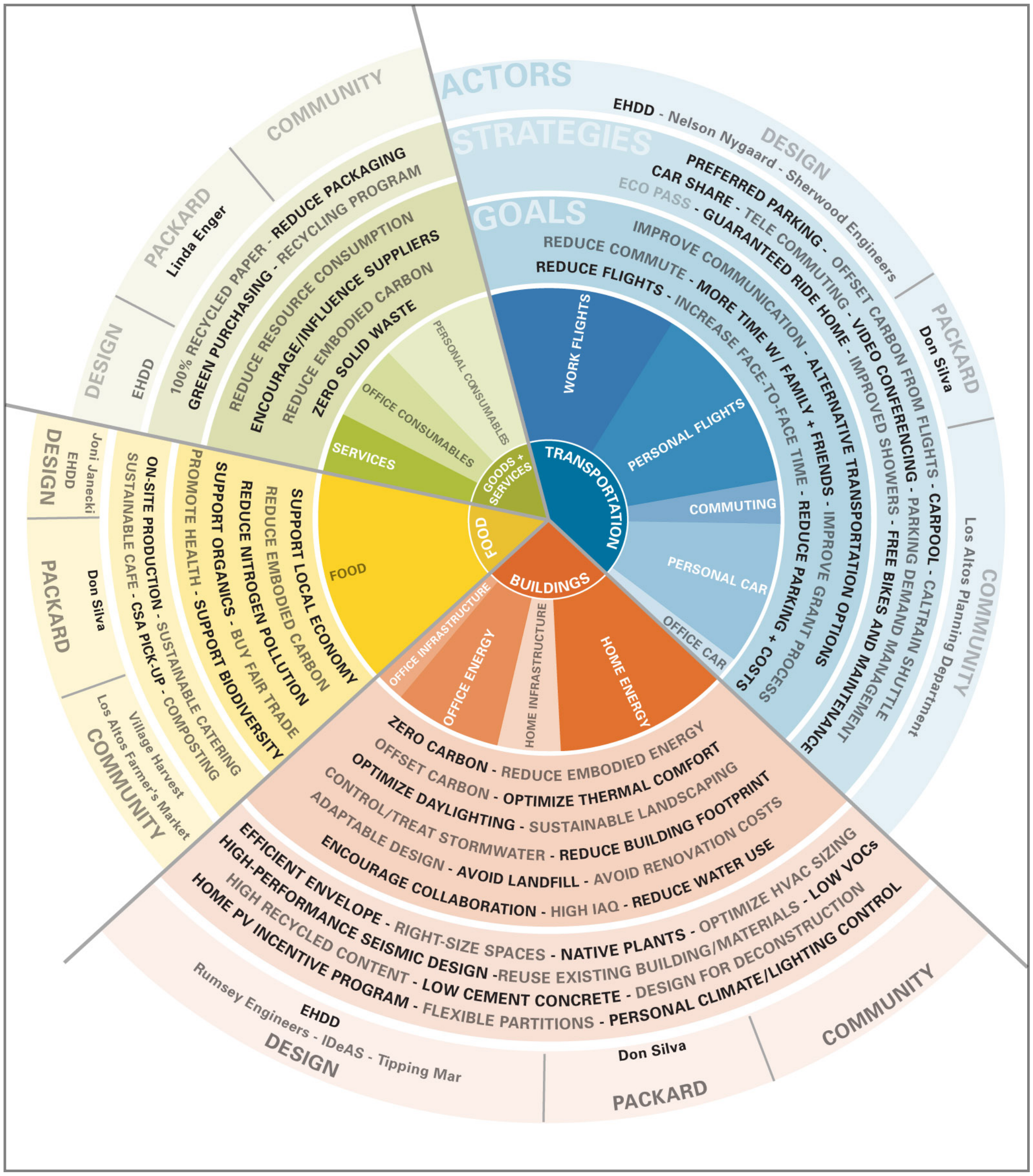
[8] EHDD Statement of Professional Design Qualifications, The David & Lucile Packard Foundation 343 Second Street Building (July 23, 2007)

[9] 343 Second Street Building Program Document, p. 24



The Sustainability Wheel (EHDD Architecture)

The red sector indicates the portion of Packard-related carbon emissions due to buildings, employees' homes as well as the office.[10] EHDD was proposing that the organization see itself as responsible, or at least implicated in the full 360 degrees of emissions, not just the building portion. That stance would involve all staff, not just the facilities people and the design/engineering experts, in assessing their impacts and considering how to soften them. It would make them actors, not just spectators.

This bold expansion of the conceptual horizon spoke immediately and powerfully to the Packard selectors, and seems to have been decisive in their choosing EHDD. Let me be clear that rhetoric alone, however stirring, would not have been enough.

[10] The size of each sector is in accurate proportion to its contribution to total carbon emissions.

EHDD had to present a strong record of completed work and a strong team of energy and structural engineers, as well as a coherent, comprehensible approach to the building itself, the specific problem at hand, and a reasonable fee structure. All three finalists had indeed done this, and it is fair to say that any would have generated a good result, if chosen. What is important for this case study is not to speculate about what *might* have happened, but to clarify and interpret the consequences of what *did* happen. EHDD's call to Packard to be a sustainable organization played out over the succeeding years of design, construction and initial operation in the multi-sided, broadly engaged approach that makes this project genuinely worth attention among American organizations, designers, engineers, and activists committed to advancing sustainability.

There followed 12 months of intense design activity, in which the net zero goal became firmly established, the physical outline and the key technical choices for the building were settled, the Packard organization began overt efforts to become sustainable, and the project came to its second defining moment, a key shift in aesthetics. Then, in September 2008, the recession hit. Though the impact on Packard's finances was milder than in 2000-2001, the project went on a year's hold in January 2009. As before, the organization acted in an orderly way, and work could resume basically from where it halted. And so it did, in January 2010.

With this outline of chronology in mind, let us look into the design as it emerged before 2009.

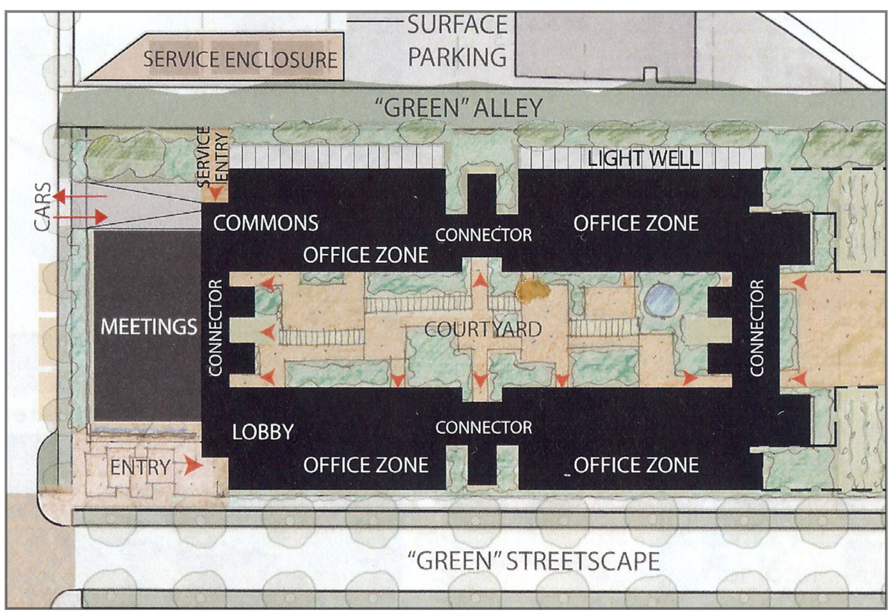
Programming, Sustainability Task Force, Conceptual Design

For the building itself, the months up to January 2008 were a combination of programming and conceptual design. Architectural programming is the activity of exploring needs and functions and deciding what spaces will suit them in the contemplated building. This is a more fluid process than one might think. A major new building is a chance to consider changing an organization's work patterns. Two examples: How can the new building's spatial layout support collaboration? And what kinds of privacy are needed? EHDD surveyed the Packard staff extensively about their work styles and environmental preferences and patterns. RhodesDahl brought in a workplace consultant to inform staff about what the zeitgeist had to say about hot-desking, hotelling and other alternatives to the familiar closed private office.

In parallel, the call for a sustainable organization had materialized in a Sustainability Task Force (STF) of Packard staff. Packard leadership was clear that staff engagement was very important to the integrity and the effectiveness of any efforts toward organizational sustainability. To that end, the STF needed to be staff-led and represent staff from all segments of the organization. This conviction paid off handsomely.

By January 2008, the STF had started its own lines of information gathering, especially through commissioning a carbon footprint analysis. It, too, was probing work styles, about such possibilities as sharing printers, converting to 100% recycled paper, and taking its grant "paperwork" to digital form. These topics overlapped significantly with the building design team's investigations. All these questions had energy implications, and all proposed outcomes had spatial consequences, too.

Conceptual design is an activity of unearthing consequences and implications and resolving them harmoniously. Buckminster Fuller used to say that no one can build a boat in general, only specific boats—this long, this deep, curved this way, powered that way, and so on. The process is an interplay of vision and feasibility. Once hired, in July 2007, the architects and engineers on the design team could set about gathering enough specifics about Packard's needs and preferences to make judgments about whether the wishes for LEED Platinum or carbon neutrality or other attributes could be achieved with good working conditions and reasonable cost. By October, the team could advise that the multiple tests for Platinum and the more demanding energy test of net zero operation were achievable, and Packard agreed. Two months later, a conceptual design could be rolled out. Two long, narrow wings, a large central courtyard, a large meeting room, a certain mix of open workspaces and closed offices, an overlapping mix of work zones, "connector" spaces (for shared activities like printing or rest rooms) and common areas.



EHDD

This was the specific boat as it would be seen by its crew—many details not yet worked out, modifications possible as need or insight might indicate, a number of informed guesses to be confirmed, but already a design which incorporated the majority of desired features to date. As such, it was accepted by the Packard Finance Committee at the end of January 2008 and embodied in a booklet prepared by EHDD, "343 Second Street Building Program Document, February 2, 2008."

sustainability

- Organizational Sustainability
  - o Challenge is to develop new models for living and working within the earth's capacity
  - o This project is a catalyst for a broader organizational sustainability initiative, in which the Foundation is developing a new model for sustainable organizations
    - › Buildings are one slice of the pie, but Transportation, Goods/Services and Food are large contributors to the Foundations carbon footprint.
    - › The Organizational Sustainability Wheel is a draft document to be developed through a comprehensive environmental assessment currently pursued through a staff Sustainability Task Force **(Fig. 39)**
    - › Feedbacks between the design project and operational initiatives will multiply the power and speed of change
      - Advancement of commuting options and incentives may reduce the amount of required parking, saving money and materials
      - Integration of videoconferencing may tip the balance and allow reduction in flights – a major contributor to climate change
  - o Goal is to engage staff in making the Foundation a premier example of an organization focused on continually improving its business practices

The booklet's section on sustainability opens with language confirming the interweaving of architectural and organizational sustainability in this project:

"The challenge is to develop new models for living and working within the earth's capacity."[11]

In addition to energy, which I have emphasized so far, the sustainability section covered several other important topics, including indoor air quality, which historically had been one of the sore spots which motivated sustainable design, and site water strategies, which proposed reducing potable water demands by a combination of low-flow fixtures and collection of rainwater for irrigating the plantings. One possibly surprising inclusion is a segment on acoustics. How are "sound isolation" and "sound masking systems" and the like related to protecting the planet? The answer springs from the attempts to develop new models. Opening interior spaces to allow daylight and natural ventilation also opens them to sound, which has definite impacts on the kinds of work a foundation like Packard exists to do. So there is indeed an acoustic dimension to sustainability.

Building structure also received attention beyond the usual. A brief comparison of structural materials for environmental effects moved on to mention the three structural systems under consideration for the building. For Packard, sustainability had come to include earthquake resilience, the ability for the primary structure to remain sound in a major earthquake. Relative cost-effectiveness was left as a question for the next phase, but the project was already strongly inclined to go well beyond code requirements in this area.

Technical investigations were an important part of the conceptual work. Heating, cooling, and lighting are major energy uses in any office. The technical leads, Rumsey Engineers (later merged into Integral Group) assembled information on climate, likely wall and window materials, hours of building use, and performance of different ventilation and air conditioning equipment into estimates of energy need. The net zero goal would require photovoltaic (PV) panels on the roof, so estimates for what they might be able to generate were also developed at this time.

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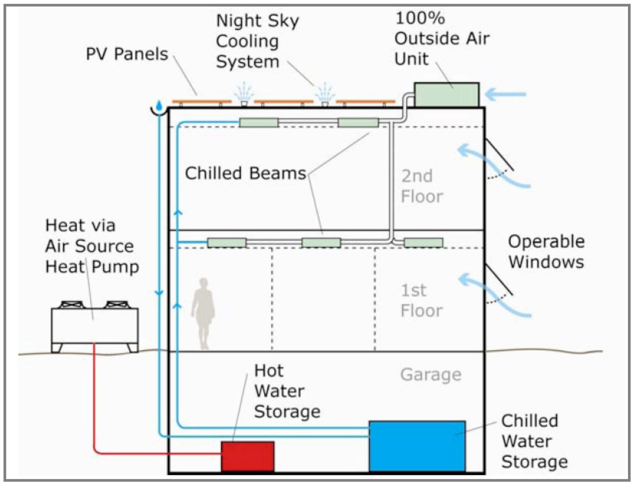
[11] 343 Second Street Building Program Document, p.25



Integral Group

The technology considered for 343 Second Street was all quite familiar to engineering firms committed to energy efficiency. "No new technology" was a de facto Rumsey/Integral slogan for this project, though never quite voiced this way. All systems had been used in previous installations in the Bay Area. Their limitations were understood, as well as their potential.

The question for the Packard project was whether efficient equipment and patterns of use could result in energy demand so much lower than a typical office's—65% or more lower—that solar electricity from the rooftop panels could supply it. A later section will discuss the specific options and choices, but the basic answer in January 2008 was yes. It would take great care with equipment details, a very complex control system, and attentive choices and work patterns by the users, but it was within reach.

One major unresolved question was parking. The city of Los Altos had a regulatory formula for minimum allowable parking provision; early thinking about the new headquarters had assumed one or more underground parking levels; these would cost real money; organizational sustainability was already stimulating thought about reducing car use generally and commuter use in particular. The eventual resolution—no underground garage, an incentive program for trip reduction, and monitoring of parking impact—is less eye-catching than the net zero goal or ample office daylighting, but is one of the genuine sustainability achievements of the project. It is also another example of sustainability as ongoing attention and work.

Schematic Design

With the approval of the conceptual design in January 2008, the building work began to be called "schematic design." Often this term covers programming and conceptual design as well, but in this case it really meant taking the conceptual elements into enough detail to be able to settle the outstanding questions, such as parking and the structural system, and make a detailed cost estimate. With one major exception, the process moved steadily forward. The city's response to a parking proposal was encouraging. Relative costs settled the structure question: the highest performance approach (base isolation) would be too expensive, so a system which would preserve primary structure (rocking braced frame) was chosen. Discussion of cooling and heating alternatives led to firm recommendations for system types. The assembled cost estimates raised no significant problems.

EHDD Architecture

Aesthetics in play

The major exception concerned the building's aesthetics. During June and July, a feeling grew in the decision-making group that the design as presented thus far was simply not beautiful enough, and not beautiful in ways that conveyed the right spirit or character for a Packard headquarters. Though the Board had expressed general approval for the design in mid-June, members had asked for further study of the roof and large wall at the main entry, the exterior sun shades, and materials. By mid-July 2008, the design was at its second defining moment. The lead project manager from RhodesDahl made the judgment that the design was not yet aligned with the Foundation's aesthetics. After discussion, EHDD agreed to bring an additional architect, their director of design, into the project with the understanding that the project's environmental goals were shaping up nicely, but beauty needed to be improved. Thereafter, he worked with Packard's president and two Board members, each from a different generation of the Packard family, as a kind of subcommittee for the look and feel of the building, outside and in. The original designers and engineers continued to develop their aspects of the project, and a full design committee covering all aspects continued to meet throughout this period.

From the point of view of long-term sustainability, active involvement by owner-occupiers like Packard on topics other than cost is desirable. It indicates a desire by owners to get a building they believe in and will pay attention to. In this specific case, it represents one more way sustainability was something to be performed, not just possessed.

Second, the active business of sustainability, the finding of "new models for living and working within the earth's capacity," cries out for the emotional engagement that beauty brings. There are plenty of difficulties. Beauty is a slippery quality, which makes many of the actors in building projects uncomfortable, from accountants to CEO's to city planners and politicians. Architects, who of all groups are expected to look out for beauty, have mostly found it hard to articulate it persuasively in community settings. Lawyers and judges, who are pressed into service when push comes to shove, have found it all too easy to dismiss beauty as undefinable and therefore unenforceable.

Neutra House, Los Altos: one of the reference points for the design of 343 Second Street. (Image by permission of Los Altos Neutra House Project)

Nevertheless, we will sustain what we love, and the presence of beauty, powerful even if hard to define, is an enormous help. The great variations between people in what seems beautiful are all the more reason to make use of building owners' tastes and feelings, when they are articulate and coherent, as in the present case.

The new design committee, with the agenda of focusing on beauty, produced a revised design over the six weeks before the September Finance Committee meeting, and it was warmly received, discussed in lively fashion, and unanimously approved. Details appear below, in the subsection on the building shell. The changes included increased glazing to render the building more transparent, nearly complete concealment of the building services, more vertical proportions to be reminiscent of residential rather than commercial buildings, and materials with warmer, less "technological" textures. These clearly moved toward the qualities Board and staff members had voiced as desirable: "classy, tasteful, warm, understated, a good fit to California culture, part of the neighborhood, doesn't stand out,"[12] and so on.

Costs, approval, and hold

Costs were a final key part of the schematic phase. Cost figures are intensely interesting and highly charged. Buildings are expensive, so the amounts are large and hard to keep in perspective. Published amounts do not always refer to the same things: is a number just for construction, or are design fees included? what about furniture? or insurance? and so on. The numbers here only give a partial idea; readers with real interest in this project's costs will find more detail later.

Estimates in 2008 were laid out in a customary way, with "hard" costs (building construction, site works, and owner's contingency (10%)) separated from "soft" costs (furniture, fixtures and equipment (or FFE), architectural and other fees, and permits and insurance). Added together, they formed the total project cost. A June 2008 estimate of total cost at $56.5-$59 million rose to $61-$62.6 million in September, after the design changes. This figure included the photovoltaic array, at $2 million.

As a way of comparing this to similar projects, the industry custom is to divide project costs by the square footage of the building, as if the costs are evenly spread over the area. The main reason for this is that real estate rentals get quoted on the same basis, so much per square foot. With both expenses and revenues on the same basis, a building's financial balance is easy to grasp. The square-foot basis also

[12] from digest of Finance Committee minutes, Packard Foundation (confidential internal document)

roughly controls for the fact that bigger buildings have more floor, wall, and roof, and to that extent cost more for the same level of services and finishes. So two buildings with the same cost per square foot can generally and roughly be regarded as giving the same value for money.

The Packard Finance Committee had gathered square foot cost information for projects with related functions, such as the Hewlett Foundation's headquarters, some university buildings, and a hotel. After taking account of the higher energy and environmental goals of the 343 project, and becoming satisfied with the revised design, they were satisfied that its costs were reasonable, and approved it both physically and financially.

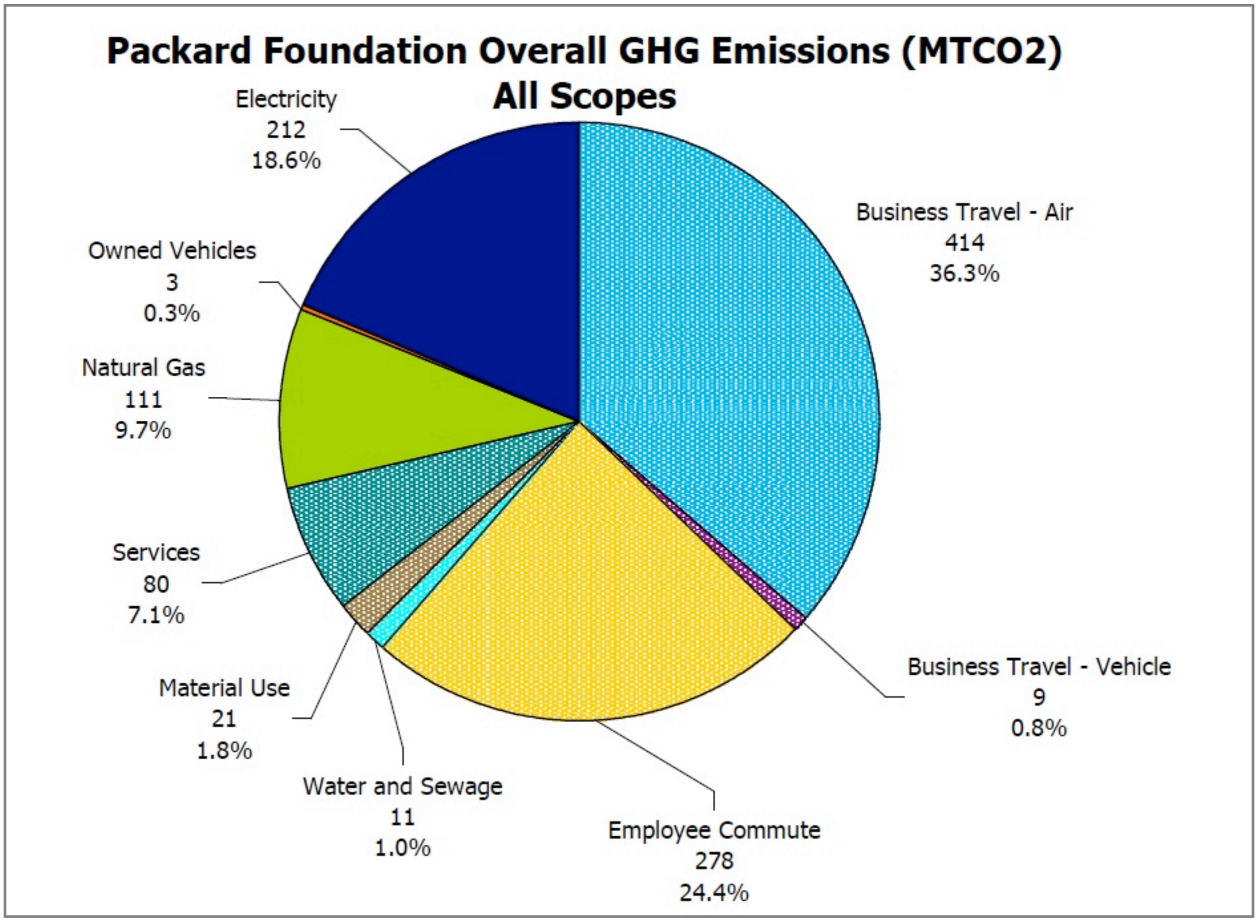
Two weeks later, Lehman Brothers declared bankruptcy, the US financial world shook to its core, and Packard was again faced with the need to consider the viability of its building project. Proceeding with the same prudence as previously, the Board decided to get design documents completed and the permitting process started, but to hold back on breaking ground for at least one year.

STF Progress

The Sustainability Task Force had been active during the same period. It commissioned an analysis of Packard's carbon emissions by the San Francisco office of HDR, Inc., a large international architecture/engineering/consulting firm which had been involved early in sustainability issues. Even before the HDR report confirmed it, the Task Force judged that transportation was Packard's area of greatest energy and carbon impact, and it began soliciting and pursuing ideas for alternatives to single-occupant commuting by car, California's notoriously dominant mode. Recycling policies and practices also came under discussion. Office uses of electricity, already flagged by the Building Program Document as one-third of the organization's demand, began to receive the detailed attention required to find possible reductions in the burden to be serviced by on-site photovoltaics in reaching net zero energy. There was a tally of office printers, and the beginnings of a more inclusive study of all "plug loads," i.e. office equipment. Recognizing that awareness is a critical factor in doing sustainability, the STF also started an ongoing practice of making and distributing information graphics, like a "what to recycle" poster for staff kitchen areas.

The HDR report on carbon emissions arrived in July 2008. It conveyed a careful set of estimates, based on data which the STF helped collect, of carbon emissions from the various functions directly and indirectly connected with the Packard Foundation's work during 2007. They provide an important overall perspective on the state of sustainability for the Packard Foundation at this time. I discuss them in some detail.

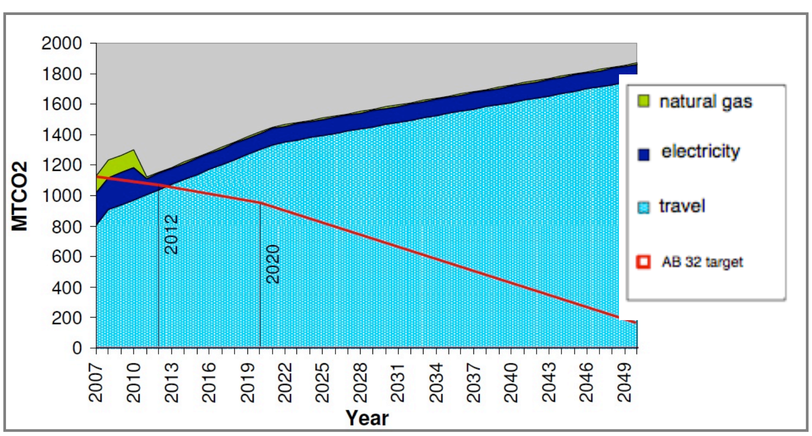
By far the largest three contributors were electricity use (dark blue in the graphic), employee commuting (yellow), and business travel (light blue). The last was easily the



HDR

largest and most challenging to consider reducing, as Packard is actively involved with a global portfolio of environmental and health efforts. Site visits and face-to-face consultation are central to its practice. Commuting, the next largest category, has intractable features of its own, starting with the nearly universal American fact that employers take no direct responsibility for how their people get themselves to work.

The two travel categories together accounted for 61% of Packard's carbon emissions for 2007. Only with the third largest category, electricity, did one reach an area where meaningful reductions were being pursued actively, in the form of the new building, with its net zero goal. A second graphic from the HDR report put this in sobering perspective, by showing how the new building's improvements would factor in the total picture over a forty-year time span. 2050 is the target year for California's ambitious AB 32 legislation, which mandates a statewide reduction to 1990 emission



HDR

levels. The red line in the graphic shows the steady reductions called for by AB32. The colored areas, which I have relabeled for quicker understanding, represent the year-by-year contributions, direct and indirect, of Packard operations. Light green is carbon from natural gas used on Packard grounds, i.e. for heating and cooling equipment in any of Packard's buildings. Dark blue is carbon emitted in generating electricity, again covering all Packard properties. Light blue is carbon from both business travel and employee commuting. The shapes of these areas come from a "business-as-usual" assumption—that the projected building would be built and would perform as projected, and that otherwise Packard would continue operating as it then did, including a pattern of adding a few employees each year out to 2020, and slower but continued growth in employment from 2020 to 2050.

The effect of the new building shows at the left edge of the chart. Natural gas use disappears in 2011, the projected completion date. (Actually small amounts of natural gas would continue to be used by other Packard buildings, but the amounts are so small compared to the major sources of carbon that they do not show on this graphic.) Electricity drops by about half at the same time. In relation to the total, these are significant and valuable changes, but leave untouched the much larger emissions due to travel.

The 2008 HDR report contained a variety of additional suggestions about how Packard could reduce its emissions, and framed them with a strong caution: "No distinct measures were identified for meeting the 2050 target as it will take all currently technologically feasible measures just to meet the 2020 target."[13]

The purpose of a business-as-usual chart like this is to dramatize the consequences of inaction. Its effect is to separate out the faint-hearted. Though it is getting ahead of the story, this is a moment to acknowledge Packard's achievements as an organization, i.e. as a group of human individuals coherently organized. Not only did Packard complete its new building, albeit with a year's delay, but the efforts stimulated by the STF have made a noticeable dent in the trends presented above, such that Packard's total emissions now fall underneath the 2013 AB 32 target.

The year's hold on construction did not mean a cessation of work on sustainability. The action log of the Sustainability Task Force for 2009 shows a regular rhythm of meetings and a steady flow of topics—questions about turning off computers when not in use, a plug load study, a tentative list of carbon abatement actions, a series of "green tips" disseminated over the internal computer network, Earth Day activities, guidelines for printer/copier use, the rollout of smart power strips, construction of a web tool for ride-sharing, discussion of vendors for carbon offsets, a change to more efficient water purifiers, paper reduction. None of the measures were transformative

[13] (HDR 2008)

in themselves, but their number and their steady flow throughout 2009 show how sustainability was becoming a practice. EHDD's call for a sustainable organization had taken root.

Several of the STF efforts were directly related to the building project. Printers, copiers, power strips, purifiers—all these are energy users whose large number multiplies small individual impacts into a large total. As mentioned above, in typical offices these "plug loads" add up to one-third of total energy use. If Packard was to achieve net zero, i.e. reduce its electricity demands to 30% of their 2007 levels, plug loads would have to do their share of this major shrinkage. The STF's probing of this question in 2009 grew during the next year into a comprehensive study of uses and potentials for greater efficiency.

Discussions were also happening with Los Altos city staff and council about the fit between the proposed building and city policies and desired directions of change. Considerations included parking, of course, but also compatibility of the building's physical size and placement with the existing and desired character of its part of downtown Los Altos, the state of the existing building at 343 Second Street, and general conformance with planning requirements like setbacks, location of refuse collection areas, and maximum floor area for given site size. The available documents show no sign of significant difficulties arising, nor of milestones being passed, only indications that needed presentations and discussions were moving steadily forward.

The situation as the 12 months of holding pattern drew to a close is admirably captured in a memorandum and information packet prepared for the December Board meeting.[14] Signed by the Foundation's president and the vice president/chief financial officer, and by the two principals of RhodesDahl as well, the packet aims to provide solid information on aspects of the building question that had been unclear, and to focus the Board's attention on a single central question, whether the various advantages of the new building—"enhanced sustainability, improved convening space, and co-located staff with the possibility for growth"—would be worth its extra cost. Clearly the foundation's leadership had concluded that the external financial situation had stabilized enough for definite information and projections to be possible once again, and the time was ripe for an up or down decision on the new building. It is also clear from the care with which information was assembled that they did not regard the decision as already made.

The cost calculation was framed as a comparison between acquiring the new building (and selling one of the two existing buildings in use) and foregoing the new building in favor of significant upgrades to both existing buildings. It aimed to take full account of reduced energy costs for a net zero energy building, and the costs of required upgrades and extra maintenance for the existing buildings. The conclusion, expressed cautiously, was that the new building would cost the foundation $10-$20

[14] Board memorandum, Dec. 4, 2009 (confidential internal document)

million more over the next 20 years than would the upgrade scenario. Reduced energy and avoided upgrade costs would balance most of the cost of the building approved in schematic a year before, but would not cover all. The price tag was now clearly defined.

A number of non-cost issues had been on the table, and the memo addressed them squarely. Both scenarios would provide enough space to house foundation staff, the new building scenario for somewhat longer, even with growth. Putting Foundation money into sustainable practices, and specifically into energy efficiency and renewable energy, had been happening at various levels for more than ten years, and support for climate change work had become a long-term grant commitment in 2008. In this and other ways, having a net zero energy building would be consistent with the Foundation's mission.

Committing to a price

The project pause in 2009 had a powerful effect on its construction history. During the period of high momentum in 2008, DPR Construction had come fully on board the project team. Starting in June, a series of "load-up" meetings worked through the implications of the schematic design and made provisional resolutions. The resulting modified plans went to two separate cost estimators, one inside DPR and one outside the design/construction team (Davis Langdon, now merged with Aecom), with a second item-by-item reconciliation meeting in each round to agree on which estimate to accept.

The pause ordered by the Board in December 2008 provided for a continuation of document preparation through the design development phase, i.e. to the point where the design was fully agreed and could be costed accurately enough for the eventual start-construction decision to be well grounded. Such preparatory work continued through May 2009. Then the full hold went into effect. It ended in December of that year, with the Board agreeing to move forward again.

There was an important proviso, however. The estimated construction cost was too high for a Board which had seen its investment portfolio drop drastically a year before. There had been considerable recovery of value, but also a considerable increase in caution. Cost had been a constant point of attention from the beginning, as one might expect. The foundation had plenty of assets, in a certain sense, but the board and leadership were aware that money spent on a building might look self-indulgent and would certainly reduce total spending on grants to some degree. A figure around $35-37 million dollars appears repeatedly in discussions up to mid-2008 as the hard cost, i.e. the actual construction of the building, not including its furnishings and office equipment, or the soft costs of design fees, permits, insurance, and so forth, or indeed the usual owner's contingency of 10% against unforeseen complications. The hard cost estimate went up to $39-41 million at the September 2008 board meeting which approved the modified schematic design that emerged from the summer efforts of EHDD's director of design and the active Board members.[15]

Fifteen months later, in December 2009, with the project in gear again, DPR Construction and RhodesDahl, builder and owner's representative, sat down for a hard, clear-eyed look at the results of the load-in and reconciliation meetings in relation to the Board's new stance of relative caution. There was a gap. The costs really looked like $42.4 million, and the Board looked very firm on not exceeding $39.5 million.[16] This was not an official decision meeting, but it was a tipping point moment for the project, with cancellation a real possibility. Some discussion of the visible points of cost reduction reduced the gap somewhat, but not entirely. The estimates had been carefully worked up in the load-in/reconciliation process, and little evident uncertainty was left.

DPR made the critical move. They committed to finding a further 5% reduction, about $2.5 million, in total hard costs, without knowing at that time how they would do it. A formal letter from DPR to RhodesDahl on January 14, 2010 sealed the arrangement. The building would go up with a Guaranteed Maximum Price of $38.7 million, based on the June 2009 design documents (called "100% Design Development"). Construction would start in the fall of 2010.

Cost as an elastic leash

The cost of a building project is an oddly elastic business, as one may gather from the events sketched above. There is an undeniable definiteness to the amounts of money handed over to suppliers of building materials and workmen who assemble them, and the same for amounts actually paid to architects, engineers, insurance companies, city building departments, and other providers of services. Woe betide the owner who fails to provide those payments. But this definiteness does not translate easily into answers to two questions of great importance: how much *will* the building cost (in the future, when we build it), and how much *did* the building cost (in the past, taking all payments together).

The second question, which sounds almost trivial (why not just add up all the payments?), is the more straightforward, but has considerable subtlety. Usually one asks because one wants to compare the given project with something—a similar building elsewhere, or a building one thinks of building. But unlike mass produced products like cars or breakfast cereal, each building project has unique features. The rock and soil conditions at the site are different, and so are local regulations, prevailing labor rates, easy points of access, weather, the scope for landscaping, and the owner's taste in lobby furniture. There are no standard costs for ingredients like

[15] Packard Foundation, TPB for Board-0908 v.2 (confidential internal document)

[16] Mike Humphreys (DPR), personal communication

these, nor for basic building materials. So to get a useful answer, one has to pose a carefully delineated question, very definite about what is to be included and excluded.

How much did 343 Second Street cost? Few questions come quicker to mind. Formulating a good answer, however, does not happen so quickly. It has been a recurrent point of discussion among Packard people and their design/construction team. The Packard Foundation's preferred answer at the time of writing is two-fold:

> *Among builders and developers, a common term is "replicable warm shell" (variants include "vanilla shell," "cold shell" or even "warm shell"). In our case, the costs of replicable shell are $23.5 million ($477 per sq. ft.) and include such things as the roof, walls, windows, heating, cooling, plumbing, elevator, solar panels, etc. We expect that this replicable shell would attain net zero energy and LEED certification.*
> *Added to this replicable shell are a variety of tenant improvements, including Packard-specific external and internal finishes, as well as site-specific preparations (e.g., rain gardens along Second Street to help capture storm water runoff), and deconstruction activities (e.g., recycling approximately 95 percent of the materials from the previous buildings). Taken together, these building construction costs total $37.2 million ($756 per sq. ft.), an approximate estimate of how much it could cost for a builder to re-create our facility in a similarly-situated location.*[17]

Packard is saying, in effect, that one might be asking what getting their exact building would cost or one might be asking what a largely but not totally complete building would cost that would perform as well as theirs. It gives answers to both questions.

I will comment later on this and other points relevant to the foundation's hope to have made a replicable building. Here, as we trace the history of the Packard design, the question in play is the future-facing one: how much will our building cost? The answer varied from meeting to meeting during 2009. The location, program, layout, and other large features of the design were not changing, but the devils were at work in the details.

This stage of the process is called "design development," and the task is to look hard at how to embody the agreed large features in specifically shaped and located physical materials. This may be easier or harder than the educated guesses of the schematic design phase, and inevitably the costs come out different, sometimes up, sometimes down. At no stage can such estimates provide granite-hard numbers. They do have firmness, but of a more elastic kind, perhaps stiff rubber instead of granite. Not only may the next feature to be examined introduce further small changes, but there is an element of negotiation in all the numbers. It is instructive to read how DPR approached this. Their letter committing to the 5% reduced cost has the following passage (text in brackets are my comments):

> *Net Zero Energy Usage buildings are rare. . . . It takes very careful coordination between the thermal envelope [the shell], the mechanical systems [HVAC etc], and the photovoltaic system. [See below for more on each of these.] It is a process with multiple iterations to get it*

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[17] Packard Foundation website, http://www.packard.org/about-the-foundation/foundation-faq/#headquarters (accessed Aug.21, 2013)

> *right. The effects of these decisions then trickle through the architecture in the details. We must layer on top of this the aesthetic criteria that must be achieved. . . . It is very difficult to write "instructions to bidders" for design/build trades, especially in this hungry marketplace. An early buyout [i.e. commitment] would certainly produce great numbers , but it could also create a team that prioritizes self-imposed market constraints over quality of performance or sustainability goals.*[18]

In other words, the various providers of building goods and services would very likely reduce their prices by 5%, in order to get the work. But if one asks for this early, before one has completely worked out how to harmonize all the technical, architectural, and owner preference issues, one may well end up with goods and services that meet the price but don't do a good job of it. The letter states a three-part alternative approach (my paraphrases are in brackets):

> *– allow the design team to run through the full construction document process [i.e. harmonize everything]*
>
> *– hold DPR responsible for identifying budget increases and developing recovery plan [i.e. make DPR find savings which balance any cost increases while gaining agreement from the whole design team]*
>
> *– lock in the Subcontractors based upon fully vetted documents [i.e. not ask for bids until one knows exactly what to ask for]*[19]

DPR refers to this approach as "target cost design." The general idea, fixing a cost and insisting that design stay within it, had considerable attention and a certain amount of use in American manufacturing from the 1990's on, and from much earlier in Japan.[20] It was sometimes used in construction in the years under discussion, but it was far from standard. In fact, it reversed the firmly established standard pattern for large buildings, in which budget works to set only rough limits until a design is complete, after which the parties expect to negotiate over both cost and features until a final design at an acceptable cost is arrived at.

The plug load study

If 2010 opened with a breakthrough on the construction front, it continued well on another important front, plug loads. Recall that this unlovely term covers the very large area of office equipment and appliances, ranging from fax machines to water coolers to network servers. Plug loads are the third major category of energy uses in offices, alongside heating/cooling and lighting. As such, Packard was going to have to find substantial efficiencies all across this disparate collection of gear.

The notion of a plug load study had come up in the Sustainability Task Force already as it was getting underway in 2008. It came to pass over the next two years, partly at the hands of the design team's engineers and partly through the reactions and comments of Packard staff collected by the STF. The subject requires both

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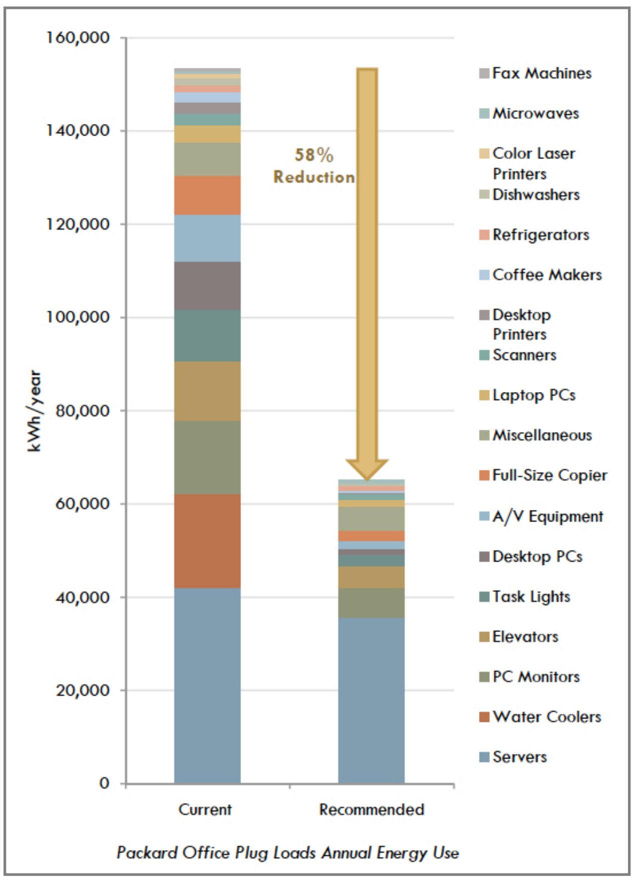
[18] DPR Construction Inc to RhodesDahl LLC, January 14, 2010

[19] Ibid.

[20] (Feil, Yook, and Kim 2004), (Zimina, Ballard, and Pasquire 2012)

engineers and building users. It reaches intimately into the working life of offices, and it calls for specialized sensors and recorders to track use patterns and electric energy demand. It also calls for a willingness to cross longstanding contractual and psychological boundaries in design and construction. Three participants in the Packard project put it this way in a 2010 paper,

> *In conventional building design practice, a solid line is drawn between the physical building elements and equipment specified by the design team, and portable plug in electrical equipment moved in by the building tenants. This is reinforced by many features of the project delivery process. Contracts define strict boundaries around scope of services. Energy compliance rules and modeling programs separate "regulated" from "unregulated" loads and focus on the former over the latter. Most fundamentally, architects and engineers follow a libertarian code of conduct in which any whiff of sacrifice, limits on lifestyle or "telling the client how to live" is anathema.*[21]



Integral Group

The final plug load report appeared in July 2010. As the graphic shows, it found that plug loads could come down by 58%. The graphic does not show that much of this could happen by using equipment already commercially available. Efficiencies had been creeping steadily upward for years. 63% energy savings in computers, 25% savings in copiers, 48% in printers, all available off the shelf. Further substantial savings could be found in turning off machines when not in use. The monitoring of use patterns in Packard's old headquarters showed audio-visual equipment left on all day, and the same for scanners, laser printers, copiers and the like. The stand-by energy use of all these machines turned out to be considerable and avoidable. Timers or occupancy sensors were inexpensive and effective. Once again, "no new technology" was proving a sound slogan.

Finally, the graphic does show the largest remaining problem, for which neither Packard nor anyone so far has dramatic solutions. Servers are indispensable workhorses for digital information, and our current appetites for the latter eat up any gains in efficiency or speed advances in chip technology. The engineers were able to identify a possible 15% reduction, but no more. In fairness, this was partly due to Packard's already having moved to higher-than-average efficiency servers and power supplies.

[21] (Kaneda, Jacobson, and Rumsey 2010)

Transportation and Parking

Discussion so far has been heavily weighted toward energy, but as mentioned above, from quite early the Packard staff and design team had been aware that taking the organization as a whole, the biggest energy uses and the biggest carbon emissions were coming not from the building, but from transportation. The STF had been at work promoting awareness of this point, and doing what it could to encourage changes.

City of Los Altos

The transportation question that bore most directly on the building project was parking. Like most cities, Los Altos had experienced enough parking controversies to have imposed regulations requiring each new building in town to provide a certain quota of parking spaces for every thousand square feet of building. For reasons of both sustainability and project cost, Packard was hopeful that this requirement could be softened for 343 Second Street. The rationale would be provided by a careful survey of staff commuting and daytime business travel patterns. No one expected to do without parking, but the foundation already owned several small lots and had underground space at 300 Second Street, another foundation workplace. The hope was that this existing capacity, together with an active program for reducing commute needs, would prove acceptable.

It is noteworthy how big a change in stance this represented from the foundation's assumptions in the first round of headquarters planning in 2000-2001, and indeed from the start of the present round. At that time, one or two levels of underground parking were taken for granted as needs. But with the sharpening of project goals, and the call for a sustainable organization, reduced parking seemed desirable and attainable.

Initial explorations of the parking issue with the city encountered an obstacle to change which often springs up—the anxiety that accepting Packard's argument and reducing the required provision would create an appearance of unequal treatment. There had been no relief for other developers up to that time. And relief to Packard would make it harder to press future developers to provide adequate parking.

Packard's counter was to commit to a formal Transportation Demand Management program, which would include spot-check monitoring of street parking to see if Packard staff were in fact using up the city's spaces. The city was generally receptive. It added some fail-safe conditions and requested a cash payment in lieu of providing the 84 spaces which its regulations would have required. The amount was significant, about $3 million. Its use was not to be confined to parking-related spending. Presumably the rationale was simply that Packard should experience a cost burden of the same size as any other developer. Looked at from a sustainability point of view, spending this money for something other than expanses of asphalt seems a potential step forward in the quality of city life, which is one of the general benefits hoped for by advocates of reduced car use.

Moving in and post-occupancy

Actual construction of the building started with ground-breaking in November 2010, and proceeded smoothly in the large, and intensely in the small. DPR had the substantial task of making good on its maximum guaranteed price, which included the 5% reduction from the careful cost estimates of 2009. They approached this by looking for reductions across the board, in all the very many subcomponents of the job, rather than by making major cuts in one or two areas. As proposed in their commitment letter, this began with detail-by-detail work with the design team as the plans went into the phase of construction documents. This is when the developed design generates the dimensioned drawings and specific instructions on materials and equipment that will directly guide construction. Often, this phase is in the design team's hands, and the sheaf of construction documents is the information base for various builders to make bids. But in this case, builder (DPR) and design team had already joined hands, with client approval, so construction documents were formed by much more integrated discussions than usual.

The customary hands-off system has conceptual advantages in opening the construction process to competition, with conceptual promise of reduced costs. This is not the place to enter a detailed discussion of the pros and cons of different contract forms. However, a few things should be said. The conventional system is hands-off in both directions. Once designers have said what they want, they are to leave the actual choices of how to do this, the so-called "methods and means," in hands of the builder. Conceptually this is very clean, especially in assigning blame for mistakes and shortcomings. Did the builder do what the document asked? If not, then the builder is at fault. If yes, then the designer. But present-day buildings are so complex that even conventional designs often come out faulty. The conceptual clarity of the contract is then no guard against legal disputes over who should provide relief.

Frontier projects are even more exposed to this problem. The structures are less familiar, and, as we have seen, the interaction between aspects of the design is consequential. There has been a good deal of discussion of possible alternative contract approaches, and some experimentation with them. A prominent theme is "integrated delivery," which refers to arrangements in which designers and builders work together from the beginning of the project.

The advantages and disadvantages of integrated delivery are the reverse of the conventional design-bid-build approach. There is no competition for lowest cost (or most efficient) bid for the completed design, but that design may do a better job of balancing its aspects, and even ending up costing less, because a builder has been able at any early stage to bring into the project experience in what works well or badly in construction.

The Packard project was legally structured in a conventional way, but there was a considerable integration in the actual flow of work. The construction documents were jointly developed. DPR then put them into action over the 20 months between November 2010 and moving-in early in July 2012.

Meanwhile, three highly significant steps were taken to prepare for the first year of occupation. First, an experienced controls engineers was added to the Packard staff as a full-time facility manager for the new building. A second move was an agreement to use unspent money from the contingency amounts to pay for a small team from the architectural/engineering/construction team to stay with the project for a full 12 months after Packard moved in. Third, an in-house "Tiger Team" was constituted to coordinate the move-in and serve as a link between Packard staff and the designers/builders during the very important commissioning period.

Commissioning

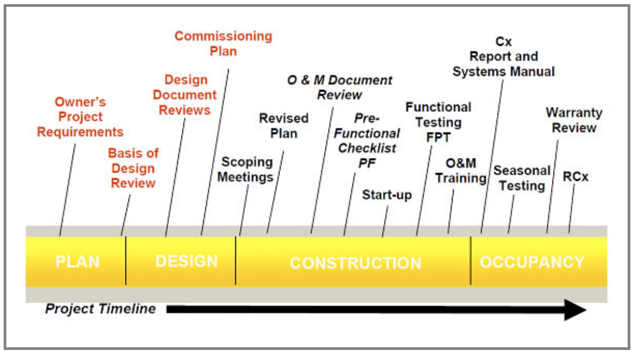
The notion of commissioning comes from shipbuilding. In the words of Wikipedia's current entry,

> *Ship naming and launching endow a ship hull with her identity, but many milestones remain before she is completed and considered ready to be designated a commissioned ship. The engineering plant, weapon and electronic systems, galley, and multitudinous other equipment required to transform the new hull into an operating and habitable warship are installed and tested. The prospective commanding officer, ship's officers, the petty officers, and seamen who will form the crew report for training and intensive familiarization with their new ship.*[22]

Commissioning recognizes a theme of this report: building a complex structure and running it should not be entirely separate, but should overlap. Navies have recognized this for a long time, the building professions only recently. During the 1980's, American HVAC engineers began to take seriously the possibility that newly constructed buildings might contain numerous malfunctioning or misfitting parts, even after energetic post-installation checking by reputable builders. One compilation

[22] "Ship Commissioning," http://en.wikipedia.org/wiki/Ship_commissioning (accessed Sept. 10, 2013)

of reports from the 2000's found problems with thermal distribution, heating and cooling plants, lighting, and controls in 20-40% of buildings, depending on the category.[23] Some were small and almost laughable, like installing a key switch upside down. Others were subtler and more encompassing, like settings on linked equipment which cause them to switch on and off frequently, rather than settling into a stable state. All were creating discomfort and costing money. Such things were largely accepted as regrettable facts of life. The arrival of the commissioning idea suggested a better way: instead of regarding a building as fully functioning on the day of handover, owners (and designers and builders) should arrange a transition phase of testing, training, and monitoring in which the building would be brought up to full functioning. This changed the framing of installation mistakes and malfunctions from regretted and ignored to expected and fixable.



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Packard hired Constructive Technologies Group (CTG, later merged with Cadmus Group) to be its commissioning agent. This accorded with the building profession's consensus that commissioning should be managed by a party outside the design and construction team, so as to minimize the blindness of familiarity and the chances of cover-ups. The intent, though, is not to have the agent operate completely independently. It should coordinate with the existing team and with building staff to put the building through its paces and deal with any problems.

Commissioning is far from universal in present-day building projects,[24] but the idea is in fairly wide circulation in the US, since the LEED system makes a basic level of commissioning a prerequisite for any certification. The arrangement in the Packard project went beyond the familiar in a significant way. The foundation took some of the contingency money which appears in all construction budgets, and allocated it to a year's involvement, after occupancy, of the design, engineering and construction firms in the commissioning process. This extended the scope of commissioning, from checks and adjustments to be finished before the building began to operate to include monitoring and problem-solving during the early operational period. And it ensured that this extended work would have ready and regular access to the professionals most familiar with the in's and out's of the design. Committing to post-occupancy services of this kind was very rare at the time, though the idea was in circulation as a desirable but unlikely option.

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[23] (Mills 2011)

[24] (Mills 2011)

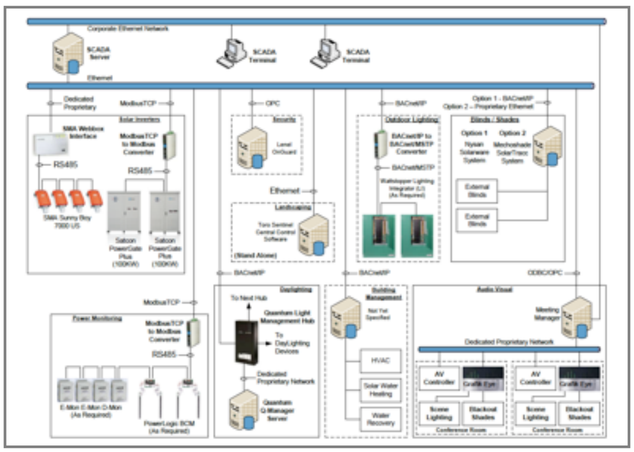
Packard's decision was made easier by the relative smoothness of the construction to date and DPR's deep commitment to its target cost contract. The contingency money had not been seriously tapped. Even if it had been, setting up post-occupancy services would likely have paid for itself in quicker and more effective problem solving during the commissioning period.

A commissioning issue that was very present in this project is the tradeoff between independence of perspective and understanding of the design. One wants fresh eyes (and uncommitted egos) so as to get problems recognized and addressed. But one needs the real problems, not apparent or partially observed ones. 343 Second Street had a highly integrated, finely balanced design. The performance of the whole would not be the simple sum of the performances of the parts. So testing, tuning and training required an unusual degree of understanding of the ways the different systems—heating/cooling, lighting, ventilation and so on—were supposed to interact with each other. One example: at one point, exterior doors with automatic (mechanical) closers were not closing reliably, apparently because of slightly elevated air pressure in the building; air pressure is governed both by the ventilation system and by the proportion of operable windows that are open; when doors stood open, security alarms would be triggered and a human check required. The needed whole-building understanding, in this case, was to recognize the interaction of systems at the root of the problem, and then to ensure that one system's performance was not unduly compromised by changes in another one. Both security and ventilation need to work in the end.

The project's way of dealing with the independence/understanding tradeoff issue could be called "all of the above." CTG/Cadmus did not replace the design team, but joined it, in effect, for the commissioning period. When it came to post-occupancy services, the working group initially had representation from all the original players (EHDD, DPR, Rumsey/Integral, RhodesDahl, and Packard staff), as well as the new player (CTG/Cadmus), but before long Rumsey had taken over the latter's scope of work. Inside the foundation, the Tiger Team of key staff also came into being. In this project, familiarity and developed understanding had immediate payoffs in problems found and solved, and independence had less to contribute.

The Foundation also took the step mentioned above, creating the new staff position of Building Engineer. Such a job title is common in quite large organizations, with office towers or multiple buildings to manage. It is less common for organizations at Packard's relatively small size, where the equipment side of running a building (HVAC, utility interfaces, pumps and filters, etc) is often contracted out.

It is even less common to define the building engineer's job as Packard did. According to one public source of career information, "Sometimes called building porters or building superintendents, building engineers are maintenance personnel in the employ of a building owner who carry out maintenance tasks along with some cleaning tasks in a building's common areas, such as lobbies and elevators."[25] This is very far from what Packard had realized they would need. 343 Second Street would be a complicated building relying on an equally complicated control system for monitoring and automatic management. Reaching the net zero goal would require heating and cooling to respond to weather conditions, time of day, the number of people in the building, the demands of individual locations for fresh air and daylight, and the existence of special events. Power production from the photovoltaic array, the raising and lowering of sunshades, irrigation of the plantings—all these and more were to run automatically, yet enable individuals to modify conditions at their desks or meeting areas to suit themselves, and also to keep them informed on how their actions were affecting the building's performance. The building engineer would need deep experience with controls and a well developed set of skills of the kind found in the chemicals or nuclear industry, together with the flexibility to deal with an evolving set of equipment and approaches in the field of building controls. (To preview a later section, the area of controls is the one in which 343 Second Street departs from its general stance of using only tried-and-true technology. The control system is not unprecedented, but American controls technology for buildings is still far from settled into standard procedures.)



Pipeline Systems Inc.

To Packard's credit, they recognized the set of skills and experience they needed, and found an energetic, resourceful individual to fill the position. This is not a trivial step from the point of view of costs. For the foreseeable future, the salary and benefits of this position will be part of the foundation's annual operating budget. It lies in the area which is tempting to trim when money appears to be tight, yet at this stage in the pursuit of sustainability, this expense is needed for this and probably any similar building to operate successfully.

From six months before to one year after

The internal Tiger Team first convened in December 2011. The roster included the chief financial officer, the building engineer, the facilities manager, the information technology lead, and a representative from RhodesDahl, the project managers. The group's assignment was coordination of the move into the new building and the first year of inhabiting it. Minutes of the roughly biweekly meetings mainly show a succession of relatively small items—signage of electric car charging stations,

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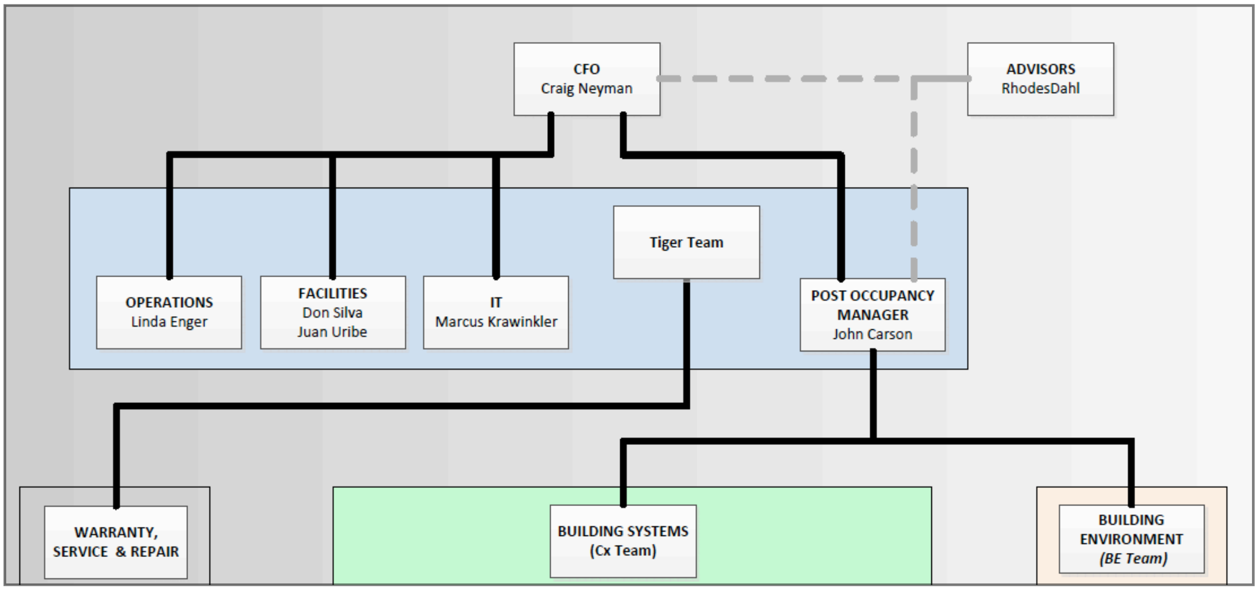
[25] Houston *Chronicle* Careers web page, http://work.chron.com/duties-building-engineer-16285.html (accessed Sept. 10, 2013)

software maintenance agreements, timing of training videos, a few nonfunctioning occupancy sensors—raised and eventually dealt with. The pace was not particularly fast, the drama not particularly high. A few major events did occur. Two of the four heating units failed unexpectedly in early January. The remaining two seemed capable of meeting basic heating needs at that time, but the margin was slim and their reliability, as clones of the failed units, was obviously in question. Packard had to



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arrange for a backup heating unit in case there was more trouble. Only a propane-fueled unit was available, and its use would interrupt the planned net zero year, because the certifying body, the International Living Future Institute, had a ground rule of no on-site fuel use of any sort during the 12 consecutive months considered for net zero operation. A period of backup propane would not taint the building forever, the 12 month clock would just need to be restarted, but obviously this would be a great disappointment. In the event, the backup did not have to be used, and the clock continued to run. The causes of the heating unit failures remained mysterious, but replacement units were duly installed. The episode did have a noticeable effect on the first year's energy performance, pushing it above the design estimates for the few months of malfunction. Fortunately, other aspects of energy performance exceeded expectation, and the design had included a contingency margin of nearly 20%, so the net zero goal was not seriously threatened, even by a mishap of this size.

Some of the mundane seeming items on the Tiger Team agenda were of a kind with subtle, long-lasting effects on sustainability in a building. The boardroom had periods of stale-seeming air. Some occupancy sensors, used to turn off lighting in empty offices, were not working. Lighting in the employee parking area was not coming on properly. The temptation in such cases is for quick fixes, such as keeping ventilation systems permanently on or disabling occupancy sensors. The accumulated effect of such fixes, however, is a slow but steady degradation in energy efficiency and a much quicker decline in occupants' trust in the building's equipment and satisfaction with their experience in the building,[26] which translate to a loss of connection to the sustainability goals.

The point of a cross-departmental body like the Tiger Team is to maintain high expectations for the building. Packard's group managed to achieve this. Having the building engineer on staff was very helpful at this stage. As someone routinely in the building all day, he could easily try various corrective measures, such as temporary changes in ventilation start times, to find improvements with small effects on overall energy use. This is far more effective than the usual practice, which is to call in the equipment supplier's maintenance people, who can make changes but cannot usually observe their effects over hours or days, and who cannot easily understand the building system as a whole.

Another fine example of the usefulness of a knowledgeable onsite troubleshooter came with temperature control. In a few spaces, thermostats had been mounted in places which were systematically hotter or colder than the rest of the room, which consequently was colder or hotter than desirable. These are not home thermostats adjustable by the occupant turning a dial. The engineer could, however, adjust them for a few degrees of "offset" either way, and trial and error could pretty quickly find settings that made the rooms comfortable.

During this period, the post-occupancy services team was devoting considerable time to getting accurate energy use readings. The net zero goal assumes that one can tell how much energy is produced and consumed in a building like this one, but that did not prove straightforward. The commercially available meters chosen to track individual circuits in the building were unreliable. The team needed circuit-by-circuit information to understand use patterns in the building, but decided the risk of bad data was too great to use them as the base for claiming of a net zero year. A mundane alternative was available—the monthly bills from Pacific Gas & Electric, the local utility. PG&E is the only supplier of energy to the building, and the only purchaser of energy it produces, both of which have cash consequences, always a motivator for reliable measurement. The needed numbers would come from master meters under PG&E's control, as recorded in twelve months of bills.

(Time does not permit any detailed description, but Packard staff also kept at their other sustainability related efforts during this period. For example, significant reductions in paper use occurred, as did consideration of the transportation issue. The Sustainability Task Force gave way to a more distributed set of responsibilities, with the building engineer and a communications staff member tasked with tracking progress.)

[26] (Leaman and Bordass 2005)

The energy meter episode illustrates the adolescent state of building sensors and controls. Reliability, usability, and costs are improving all the time, but when it came such a seemingly straightforward as measuring the electric energy used in a circuit, difficulty arose. The measurement presents no conceptual problems to an electrical engineer, but finding an affordable, reliable meter in the market was another matter. Over time, demand for such meters is likely to rise and operating experience will generate the many tiny engineering improvements that make reliability and reduce cost in this area, as well. As of the year 2012, this had clearly not happened yet.

Another post-occupancy event was a classic of the kind that justifies commissioning as a distinct step in making a building. It involved the power inverters for the photovoltaic array. These convert the DC power generated by the array into the AC power that is required for machinery, appliances, lights, and indeed all normal uses, as well as for sending power to the grid. They are critical components. About two months after moving into the building, one of the two power inverters for the main rooftop array failed, taking half the array's power offline. Investigation showed that one electrical connection had been reversed on installation, so the overload that caused the failure was bound to happen sooner or later. Two wires, two screws—what could be simpler than getting the right wire under the right screw? But when hundreds of connections of all kinds have to be made in a building, a few errors of this kind are inevitable, and most of them only show themselves when real operation is in progress. The justification for commissioning is to get those faults to show themselves at a time when people are systematically looking for them and in a position to fix them.

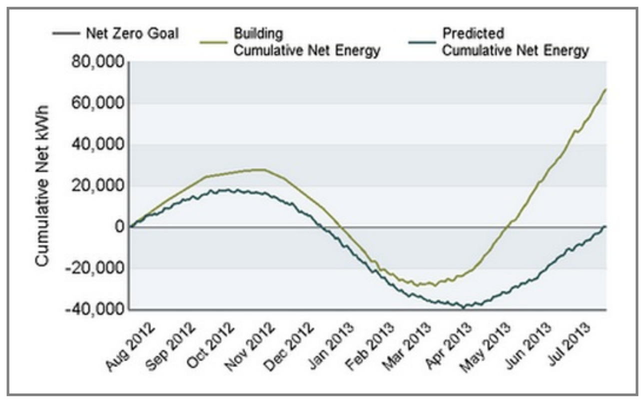
Informing the inhabitants

The post-occupancy group also worked on ways to provide information to Packard's people about energy and water use. This is a frontier zone for building projects with high sustainability goals. Up to the 1990's, commercial buildings aimed to be seen but not heard, so to speak. They were to be visually attractive, but as unobtrusive as possible in their functioning. Machinery was to be hidden and silent, and operate without needing attention from users. There would be a maintenance staff, ideally invisible and silent as well. Office users should expect their spaces to have optimal, unvarying lighting and thermal comfort. No one should need or want to know how much energy or water is being used. The resulting user experience may have been rather flat and generic, but the convenience of inattention was real enough, and the seen-but-not-heard paradigm was firmly in place for most of the post-1945 period.

The emergence of sustainability as an issue called this into question, at least for those concerned about energy use and environmental impacts. The reigning paradigm was energy intensive, and the search for efficiencies and reductions led, among other places, to the habits and behaviors of users. Such things as lights left on, summer indoor cooling, winter clothing, and use of laser printers are significantly linked to a building's energy consumption. This implies that users are important players in pursuing sustainability. With their cooperation, one could somewhat vary heating, cooling, ventilation, lighting, and equipments toward lower energy demand. Most users are not willing to shiver or swelter in the cause of sustainability, but are willing and sometimes even delighted to have some variation in temperature, light level or clothing during a day, or from season to season.

Information plays a key role in this, though not one that is fully understood as yet. It is clear that a project like Packard's, with its net zero goal, will benefit if users are in touch with how their building is performing. They are willing to pay closer attention and consciously reduce energy more if the place is falling short, and are pleased to relax somewhat if things are ahead of plan. So finding the right ways to communicate with users becomes important.

Jeremy Bittermann



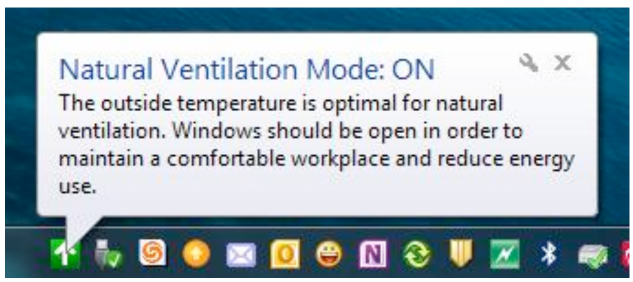
Packard Foundation

This is an area of active work across many current building projects. The notion of a "building dashboard," which presents key information the way a car does to a driver, is widely discussed, and there are businesses which specialize in the hardware and software involved. Unlike cars, however, we are far from having a settled, widely understandable set of dashboard gauges and readings for buildings. So the Packard communications staff, like their counterparts elsewhere, have been trying to find the right channels of communications and the right balance of clarity, accuracy, detail, and interpretation for them. As usual on frontiers, progress has been mixed.

The Tiger Team settled on four main goals, but their greatest success has been in a fifth area. The goals are: a display on computer desktops to give real time information on building performance; a foyer display to give similar information adapted for visitors to the building; a web-accessible version of the same information; and a comprehensive data system (called SCADA in the trade, for "supervisory control and data acquisition") for building management staff to have complete access to environmental variables and equipment settings in the building. Despite hopes to have these all achieved by the beginning of the 12-month validation period for net zero energy, development has gone slowly. Versions of the displays have been tried, SCADA is well along, but work continues on all of these as of the writing of this report.

On the other hand, there has been quite complete success in the fifth area, which the staff's own account (from a post-occupancy team report) describes as follows:

> *Prompts for Opening and Closing Windows – One criterion for successfully operating a naturally ventilated building is that in order to actively participate the staff needs to know when it's OK to open windows and doors, and even more importantly, when to close them. The initial approach was to display the "open" or "closed" information on the four displays in the break rooms. Because the staff spends most of the time in their offices or workstations - working, the displays did not communicate the information in a timely manner accessible to all. The IT department developed an icon that resides on each staff member's computer that is linked to the open or closed command, so each person now can see when to open or close their windows and/or doors as the command is issued. It's amazing how this simple device has allowed the staff to participate in the effort to reduce energy use.*[27]



This account shows all the ingredients of genuine progress in a frontier area—homing in on a specific need, trial and error in meeting it, and recognition of the wider benefits of meeting the specific need. The latter is quite important. Having Packard staff participate directly in reducing energy use is vital to achieving the net zero goal. *Active* cooperation, direct contributions to the effort, however small, is far more satisfying and effective than passive cooperation, mere acceptance of conditions imposed by others.

[27]"Preparation for the Start of the Net Zero Year," Packard Foundation internal document (July 2012)

3—SUSTAINABILITY AND BUILDINGS: A CAPSULE HISTORY TO 2007

Before delving further into various important details, some background on American thought and action about buildings and sustainability over the past generation will be helpful, especially to show the significance of Packard's process, the ways in which sustainability here has been a matter not of having but of doing.

It is often forgotten that sustainability was launched into global use as a political idea, not a technical or spiritual one. In 1980, a time when global environmentalists and promoters of Third World economic development had been at each other's throats for a decade or more, the International Union for Conservation of Nature (IUCN) put forward the notion of sustainable development.[28] Their insight was that destructive economic and social developments in the Third World were equally threatening to environmental and developmental prospects. The political intent was simple but potentially powerful—identification of common ground where cooperation between erstwhile adversaries might be possible. The relevance for the present study is that sustainability began as an action-oriented idea, and part of the Packard Foundation's leadership as exemplified by its new headquarters, is a return to this orientation.

Sustainability continued as a political rallying point through the 1980's, but moved away during the 1990's. As material interests in the industrialized status quo became evident (and seemed threatened), the politics of sustainability turned back toward adversarial lobbying and campaigning. Simultaneously, the "deep ecology" movement[29] and its relatives offered spiritual avenues for expressing concern for the Earth, which attracted significant participation. What relates most closely to the Packard project, however, is the budding of interest by certain organizations and established architecture/engineering firms in showcase building projects at the commercial or institutional scale.

The energy crises of the 1970's had sparked considerable interest in solar energy for buildings, but this materialized almost entirely in houses, not offices, meeting halls, schools, or malls. The countercultural spirit of that period had neither the interest nor the leverage to disturb the inertia of established organizations or unlock the sizable funds that sizable building projects require. By the early 1990's, however, the continued looming of environmental problems moved a few pioneer businessmen and established designers to take the first steps toward "big green." A good history of this period has yet to be written, but a few things are clear.

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[28] (Resources 1980)

[29] The various strands of deep ecology share the belief that all forms of life, not just humanity, have a profound right to live and flourish, and human ethical, legal and political systems need thorough transformation to move toward this value.

First, large buildings with mainstream functions could also have substantial green ambitions. The Commerzbank tower in Frankfurt, the Inland Revenue Center in Nottingham, England, the National Audubon Society's renovated headquarters in New York, the Osaka Municipal Gymnasium in Japan and other projects from as early as 1992 incorporated elements of passive solar design, natural ventilation, daylighting, green roofs, and high-performance enclosure, technologies still in wide use. These buildings stood as massive instances of economist Kenneth Boulding's dictum, "What exists, is possible."

Wikimedia Commons (left and center); Global Environment Centre Foundation (right)

Second, the character of this work was functional and technical. The goal was to make buildings that were sustainable in themselves, without needing to involve their users. The key actors were the architects and engineers, whose assignment was to work out specifically how to achieve low energy use, passive ventilation, good indoor air quality and other green goals, without interfering with the operations of the client organization, and then to oversee construction so that the final building would be high performing and highly visible, a shining testament to client values and designer/builder skill, while remaining essentially unobtrusive to its occupants.

This was a natural merger of then-current approaches to design and to organization,[30] and truly opened the way to the past two decades of "big green" building. (The Packard Foundation was an active participant in 2000-2002, as we have seen.) The explosion of cheap computing, the framing of the LEED rating system, the prompt engagement of the relevant professional societies, as well as the persistence of major environmental problems and the growing evidence for climate change—all these assisted the intrinsically conservative building industry to move much further forward than might have seemed possible. While this kind of green building is not yet the norm, it is no longer confined to situations where exceptional commitment joins with rare technical skill.

[30] see Howard Davis' excellent *The Culture of Building* {Davis:2006to}

. . . and yet . . .

The same two decades have provided a good chance for the limitations of the functional-technical approach to become apparent. 343 Second Street marks a significant step forward in the ways it has transcended these limitations. Before going into any detail, let me be clear that high levels of technical-functional analysis and execution remain essential to buildings in which sustainability can be done. I hope the description and assessment in the following sections of this case study will make clear how essential they have been to 343 Second Street. But more is required than that, as I hope this case study also makes clear.

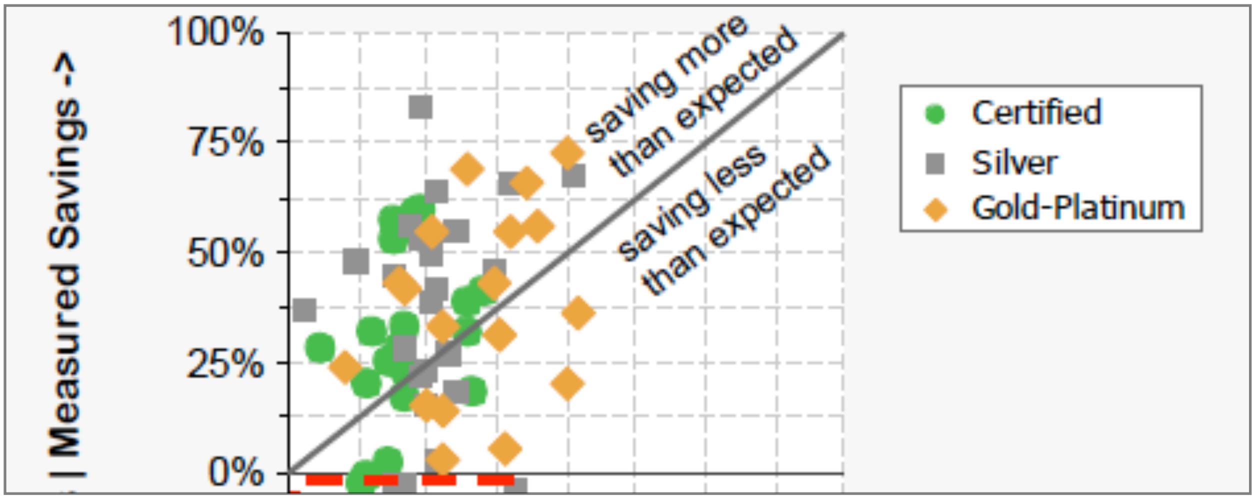
The most evident limitation in "big green" American practice of the past two decades is that it addresses the design and construction phases of projects, but not the phase of actual use. The clearest illustration of this, and one close to the heart of the Packard project, is energy. Buildings as sheltering envelopes and activities that take place inside buildings together account for roughly 43% of total US energy use, and construction of buildings runs to 6% more. Between extracting energy from its sources, converting it to useful forms, and emitting CO_2, methane, and various pollutants, energy use at America's huge scale has enormous effects on sustainability. Reducing those effects is a major priority of any approach to green building, somehow to be harmonized with the ways our life patterns depend on energy use—light, warmth, "coolth," computers, appliances, and all the rest.

The de facto industry standard for assessing how green a project is the Leadership in Energy and Environmental Design (LEED) system. One of 343 Second Street's claims to excellence is its Platinum rating, LEED's highest category. This rating, like all LEED ratings for new construction,[31] is based on design documentation, because LEED's goal is to influence the design stage. For energy, sustainable design primarily means the choice of heating, cooling, lighting and information systems for efficient, coordinated function, not using more energy than really needed to get the job done. It can also mean choosing to supply some energy from sun, wind, or other renewable sources available at the site.

LEED awards its energy points according to estimates of how low the energy demands of the building will be, and what proportion of its energy will come from on-site renewables. These are estimates, not measurements. Estimates are based on assumptions. Good engineers know how to make reasonable assumptions, and their estimates are reasonable in turn. But there is a distance between the dock and the ship. When actual measurements of energy use in LEED-rated buildings began to appear in the mid-2000's, their averages met the averages of design estimates pretty well, but results for individual buildings were widely scattered around the average, by

[31] The LEED ratings discussed here are for new construction, LEED-NC for short. There are also LEED ratings for existing buildings (LEED-EB), commercial interiors (LEED-CI), "core and shell" buildings, i.e. speculative commercial rentals (LEED-CS), and so on. Caution: the terminology has changed as LEED has gone through its periodic revisions. The version used for 343 Second Street is v2009.

as much as a factor of two either way. Though controversy swirled, and a degree of cynicism emerged around the underperforming cases, it is important that there were almost equal numbers of *over-performing* buildings.



New Buildings Institute

Later sections will discuss important details of all this.[32] The conclusion may already be obvious: design-phase energy estimates may allow good comparisons between different designs, but they cannot make reliable predictions of operational energy use. This is because they assume usage patterns that cannot be guaranteed, and because they can take no account of the wide variations in training and competence of operational staff. Thus energy ratings as practiced during 1990-2010 cannot be relied on, despite the best efforts of designers and engineers. Good design does not guarantee good performance. The happy side of this coin is that attentive, astute building managers can save energy well beyond the designers' estimates. Over-performance has been as common as underperformance. Part of the Packard achievement has been to understand this and act decisively on it.

Net zero: a return to engagement

The Packard headquarters aimed at a more dramatic energy goal than even LEED's highest level. It aimed for net zero annual energy use, i.e. keeping energy use in the building down to the level that could be generated from the rooftop photovoltaics. Adopting this goal changes the character of the task profoundly. Obviously, the organization must acquire means of generating energy, instead of simply connecting to energy networks provided by some utility company. More profoundly, the organization must move from cruise passengers to sailing crew, i.e. from treating its workplace as a comfortable yet unobtrusive shell to accepting active, ongoing engagement in its operation.

[32] There will also be discussion of the other aspects of sustainability addressed by the LEED system, and how the Packard project dealt with them.

Generating energy for offices like Packard's is conceptually simple these days: everything in the office can be done electrically, electric energy can be generated reliably and straightforwardly by solar photovoltaic (PV) panels, and the panels can go on the roof of the office building. However, the number of panels required depends on the energy needed, and conventional office usage in the US would require far more panels than will fit on any roof. Net zero is only possible if offices can reduce their energy needs a great deal, i.e. the energy they use for light, heat, cooling, computing, communicating, and appliances. This is where engagement comes in.

The people in buildings are generally interested in what energy makes possible, not energy itself. From the roaring fires of old, to twentieth-century cool air, to information-age e-mail—one could say that the multi-branched history of technology is about channelling energy from its natural sources (wood, water, coal, oil, sun) to focussed, controlled human uses. We present-day Westerners get our lives lived and our work done by flipping switches and turning dials to actuate often invisible devices. In workplaces like American offices, this has been carried beyond the conscious. Extreme ingenuity and effort have gone into making things automatic. One sets a thermostat, and heating and cooling come on and off by themselves to achieve the desired temperature. A timer locks doors at night and opens them in the morning. A server collects and presents e-mail. Toilets flush as one moves away, and faucets flow when one gets near the sink.

Getting to net zero annual energy, as best current practice approaches it, requires both automation and awareness. The installations in 343 Second Street subdivide the building into 29 zones for heating and cooling, manage electric lighting room by room according to occupancy and brightness of outside light, put the computer servers on reduced activity for nights and weekends, and generally act to use energy only when needed and only as much as needed.

Automatic function cannot do the whole job. The building's inhabitants need to be engaged, at several levels. They need to understand the energy-using systems well enough to notice malfunctions, they need to agree with the goal of energy saving enough not to bypass or disable them, and they need to work constructively with each other to iron out problems and deal with unforeseen circumstances.

From impacts to benefits

Why would anyone want to put effort into helping their workplaces run? Avoiding glitches in out-of-sight machinery is not enough. Two histories—of conventional American offices and recent green workplaces—both confirm this, but in two divergent ways. The conventional history is one of dead end. The green history points an encouraging way forward.

The conventional US office, as of the end of the 20th century, aimed to be unobtrusive. Unlike homes, public gathering places, or malls, conventional offices make little attempt to inspire pride, belonging, or sense of ownership, at least as regards the physical place. In the words of workplace consultant Franklin Becker, "Rarely do conventional offices endanger our health on a daily basis. Few of the places where we do office work horrify us; occasionally they energize us. Typically, they simply bore us to tears."[33] In certain respects, this condition has been hard won, and represents significant achievement in safety and basic comfort. But it generates little motivation for close attention, much less active engagement.

As regards our theme of energy, this condition arises importantly from the agenda of its designers and engineers, "who favor a controlled and rational system, a building that is so integrated with its mechanical services that it becomes a machine itself and is controlled by technical authority."[34] Owners and employees alike have been quite willing to leave energy and related matters to experts. Their only real requirement was a way to complain about discomfort. In turn the experts, from building operators right up to the engineers' professional society, were satisfied with balance of complaints as the criterion of comfort. If "hot calls" and "cold calls" were equal, that was the best one could do. As argued above, this situation is not up to the demands of net zero energy.

Though this pattern of expertise is thoroughly self-limiting, this was not evident as serious efforts to make green offices began in the 1990's-2000's. Green building cannot do without real expertise, and expertise at that time was technical-functional. (It still is, in many projects.) The problems were framed as primarily physical ones, calling for physical solutions.

The notion that a building is a shell, perhaps helpful to the activities inside but not responsive to them or much affected by them, was convenient in this regard. If buildings were heavy energy users, one should seek lower-energy materials and equipment—better insulation, window glass that allowed visible light to pass but kept heat inside, more efficient air conditioning, and so on, always with an eye on cost. During the 1990's there was considerable technical development of this kind. Chillers became much more efficient. A great variety of curtain wall systems were conceived and tried. New glass coatings and precision assembly allowed windows to transmit visible light, reject heat radiation, and generally improve their thermal performance radically. However, the human side was largely not questioned. Activities were surveyed and taken as inputs to engineering study, but not much studied for their relation to the effectiveness of technical improvements, nor indeed much considered as involving human persons possessed of agency, values, or

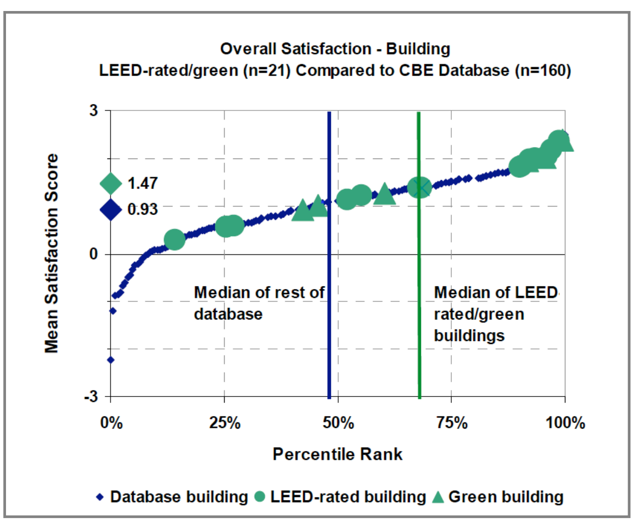
[33] (Becker 2005)

[34] (Cooper 2002)

autonomy. Building inhabitants were represented only as behavioral statistics. They in turn were allowed to go on expecting a certain generic comfort which neither required nor invited their participation.

Once up and running, the green offices of this period began to acquire history, and it has illuminated a way forward for occupant engagement. The reason is somewhat surprising: claims of sustainability encountered predictable resistance, one form of which was a call for detailed data on their actual performance. We have already heard how this has generated salutary data on energy performance. The same general pressure for data led to detailed surveys, called post-occupancy evaluations, of building inhabitant attitudes. Conventional practice had not really wanted to know what inhabitants thought about their buildings, but now did want proponents of change to prove their way was better. The results contain good news and bad news for current sustainable design, but definitely point to avenues of progress.

Perhaps the most active US post-occupancy evaluation group is the Center for the Built Environment (CBE) at the University of California, Berkeley. Starting in 2000, CBE has data for over 500 buildings, both conventional and hopeful-green. Respondents are asked to rate characteristics of their indoor environment, such as thermal comfort, acoustics, lighting, office layout, or maintenance quality, on a 7-point scale from "very satisfied" to "very dissatisfied", and are offered a chance to comment in writing on any aspects of dissatisfaction. 343 Second Street has been the subject of a CBE survey. As mentioned earlier, the building received very strong general approval from staff. In fact, 97% said they were satisfied or very satisfied with the building in general. Individual aspects of the building, such as acoustics or daylighting, had lower but still very substantial approval, and indeed one strong index of the building's success with its inhabitants is that a degree of dissatisfaction with one or another detail of its functioning does not translate into disapproval in general.



(Abbaszadeh et al. 2006)

Returning to the whole population of CBE-studied buildings, a 2006 review of the full database by CBE staff[35] showed that the LEED-rated buildings in their sample generated far better satisfaction on thermal comfort and indoor air quality than conventional buildings. This was no doubt very gratifying to the designers/engineers involved, but the most important implication is that green buildings can reward their inhabitants. The place of work can be

[35] (Abbaszadeh et al. 2006)

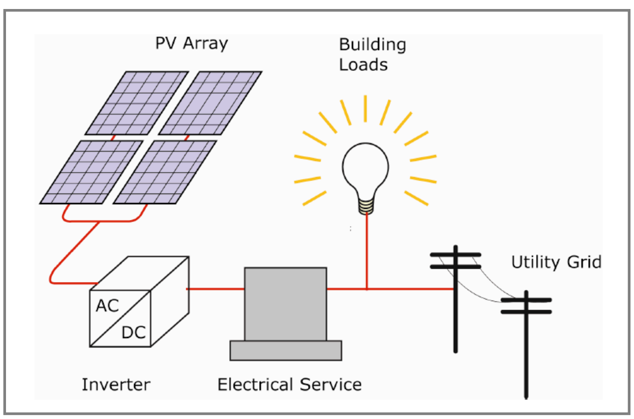
satisfying in direct and immediate ways, not just through the more abstract knowledge of benefiting the planet as a whole. With proper sustainable design and engineering, one can be more thermally comfortable, breathe better air, and (we now know) enjoy much more daylight, views of the outdoors, and more adaptable work environment than conventional approaches. Thus, when design and engineering need the partnership of building inhabitants, as with the net zero goal, the latter have the prospect of positive, strong satisfactions from working in such a setting.

4—THE SYSTEMS OF 343 SECOND STREET

Achieving the net zero goal in an office building calls on both equipment and behavior. In this section, I discuss the ingredients of 343 Second Street's successful recipe in some detail. I aim the discussion particularly at non-technical professionals who may be considering or already involved in a major green building project. Please bear with the detail, and with my attempts to explain technical reasons, not just results. I hope this will unfold some of the unavoidable complexities of present-day buildings in a useful way. The technically knowledgeable may already know much of what follows; please skim ahead freely.

Energy: a hard upper limit

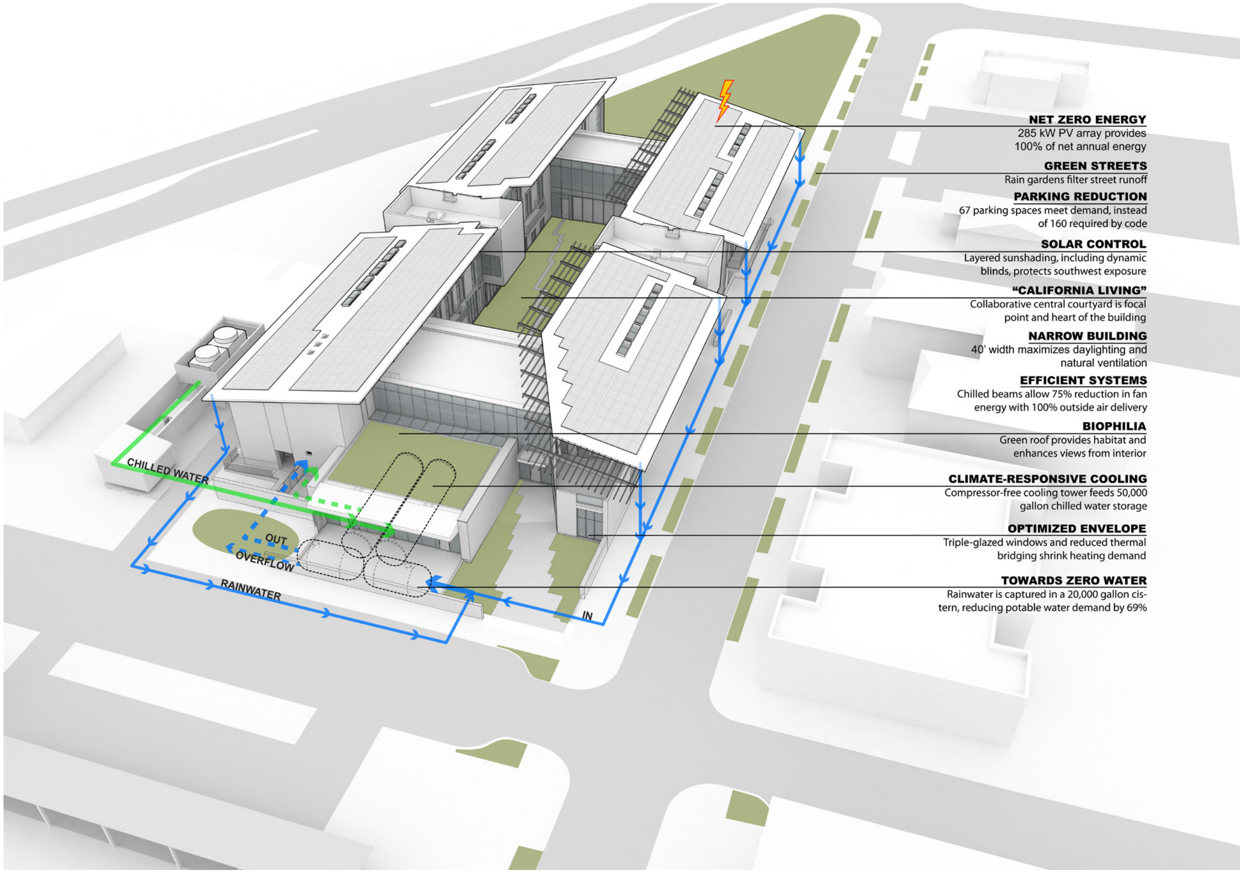
From the start, it was clear that the building would need electric energy in multiple ways. This was to be supplied by a photovoltaic array, as indicated by a diagram that appeared in all reports from the engineers:



Integral Group

The light bulb stands for all the various uses of electricity (called "loads" by the engineers). The link to the utility grid allows the building to export or import energy when the PV supply exceeded or fell short of demand. Net zero performance literally means that exports and imports balance over the course of a year: the building produces as much energy in a year as it uses. The most important implication of this approach is not apparent in the diagram, though the engineers were fully aware of it: the PV array would have to go on the roof, and the layout of the building therefore determined the upper limit to the building's total energy use.

Let us work through the numbers in a simplified way. The building would have two stories about 49,000 square feet of total space, and thus about 24,000 square feet of roof. (The actual numbers are somewhat messier.) One actually can only use 60% of this, or 12,000 square feet, because one has to allow for walkways, safety margins at



EHDD Architecture

edges and so on. When sunlight reaches the roof, it falls equally on every square foot, so all solar panels are able to generate equally. Each panel can only generate so much over the course of an average year, however—the maximum is about 22 kilowatt-hours per square foot of panel in this part of California[36]. Multiply by 12,000, and you have the yearly energy budget for the building, 276,000 kilowatt-hours. That's all you get, use it wisely.

22 kilowatt-hours is not very much. It would keep a small lamp, say an Exit sign, burning night and day all year, or provide a computer or printer's standby power (but not operating power) for a year of working hours. Office work as typically done requires much more than this. An average California office of 40,000 square feet in 2006 consumed something like 940,000 kilowatt-hours.[37] The implication for design is very clear. To stay within what the rooftop PV could reasonably provide, energy use should not exceed 30% of typical California amounts.

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[36] All the quantities at this point are realistic, but approximate. The design process makes more solid estimates, based on information about the specific panels to be used, weather at the specific location, and so on.

[37] California Energy Commission sample study

Energy efficiency

The energy budget thus had to come down by over two-thirds. And this without compromising the organization's ability to do its job. The key notion is efficiency, getting the same or better result with lower resource use, rather than reduction in itself. The challenge is much more varied and intricate than energy supply. Electricity is used in many different ways, to support both general conditions like room temperature and multiple specialized uses like water coolers, telephones, and exit signs. There is no single technology, dial adjustment, or tolerance level that can properly address all these functions at once.

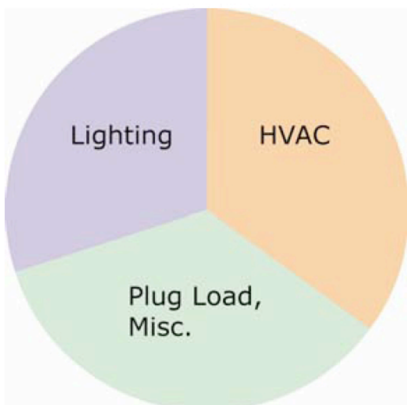

Figure 1: Typical Office Building Energy End-Use

Integral Group

A second simple diagram from the engineers provided a starting point: one groups all the uses in three main categories—heating/ventilating/air conditioning (HVAC), lighting, and plug loads/miscellaneous. Rumsey/Integral chose to portray them as roughly equal; statewide data for 2006 put HVAC at about twice the other two, for a 50:25:25 breakdown. The exact proportions matter less than the fact that each of these quite distinct areas are heavy users of energy, so each requires close attention if the tight overall energy budget is to be met. Rumsey/Integral initially approached this in the most straightforward way: every identifiable function should aim for the same percentage reduction. This was unlikely to be the result across the board. Some reductions would probably be easier than others. But the target was very demanding, so all options had to be considered with equal seriousness. The "no new technology" inclination gave further direction: one should look at how to get very high efficiency from the equipment available. I will discuss each major building system in turn.

HVAC

American office workers are used to arriving in their workplaces and finding them adequately warm (or cool) and the air adequately breathable. Compared to the unwholesome workplaces of the earlier industrial era, the common standard is high. Surveys show it is rarely fully satisfactory, but that is another story.[38] Workers are also used to having these conditions provided by hidden means. The air is just there and it is warm or cool enough. American engineers are used to achieving this with centralized boilers or chillers and a system of channels (ducts or pipes) that serve the

[38] A British organization, Usable Buildings Trust, has a website with a wealth of information on this point: http://www.usablebuildings.co.uk/

individual occupied spaces. This pattern arose for a fascinating mix of technical, historical, and commercial reasons,[39] but as with many American habits sustainability concerns have stimulated a search for adaptations and alternatives. For the Packard project, this was the assignment of Rumsey/Integral, the project's mechanical, electrical and plumbing (MEP) engineers throughout, responsible both for engineering design and for monitoring construction related to their specialties.

Rumsey/Integral were at the forefront of building energy efficiency in California and nationally.[40] True leaders are in front, but not so far as to be isolated voices. Rumsey's practice accepts the conventional starting points for HVAC design, and aims to sift the flow of research results and new equipment for insights that can be applied in new configurations to demanding jobs, like Packard's, with its net zero goal. They aim to get the most out of equipment and information that already exist ("no new technology"). So the established engineering definition of thermal comfort—a range of acceptable temperatures and humidities—was the natural starting place. The actual choice reflects the slowly growing understanding that most people change their preferred temperatures with the seasons: the basic targets for 343 Second Street were to be 74-78 F in summer and 68-72 F in winter.[41] The installation also needed to supply outside air to meet the national standard—about 0.1 cubic feet per minute for each square foot, or 4,000 cubic feet per minute to the building as a whole.

The engineering task, then was to find equipment and controls that would do this. Actually, there was one more key component, the building shell, whose ability to retain heat (or keep it out) is a critical variable. The medieval castle required baronial fireplaces to provide any warmth, while the best shells of the present can stay warm with just the body heat of their occupants. So architectural needs, priorities, and values are entangled in the goal of energy efficiency.

The shell: function and aesthetics

The key points of entanglement have to do with windows. It is not hard to make an opaque wall or roof that insulates very well. That is largely a question of cost. Windows are another matter. From the perspective of thermal comfort, they are holes in the protective shell, which are closed by glass, a good conductor of heat, which has to be held in place by frames which can all too easily provide thermal bridges, i.e. easy paths for heat to flow between outside and inside. As large, flat surfaces, windows readily transfer heat to air that contacts them, and moreover they

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[39] Cooper's *Air Conditioning America* gives an excellent account.

[40] As one example, three of this project's principals have published an incisive article on plug loads: Kaneda, Jacobson, and Rumsey 2010)

[41] Rumsey Engineers, Mechanical and Plumbing Design Narrative (November 7, 2008). It is not clear whether the final operating schedule has stayed with this seasonal variation in targets.

effectively radiate heat (or cold) directly to any other surfaces in the space—walls, ceiling, human bodies, furniture. In engineering terms, windows are a problem, perhaps a welcome problem for adventurous engineers, but a problem nonetheless.

Of course thermal comfort is not the only kind of comfort in play, nor is comfort the only consideration in choosing the size, placement, framing, or functioning of windows. One example: people like having operable windows. They may or may not open them often, but if asked, people place quite a high value on being able to. Indeed, it seems from a variety of research that simply having possibilities for adjusting one's air increases one's tolerance for variations in temperature, humidity or freshness.[42] This has good effects on building energy use, by allowing HVAC equipment to run less often. But it makes the engineer's life more difficult. It is harder to estimate performance in advance, and harder to interpret performance results as they come in.

Windows—energy and aesthetics

Windows had a large role in the mid-2008 design shift at 343 Second Street. Generally, that second defining moment in the design was about the role of beauty in sustainable buildings, though the participants were not putting it that way. They were just trying to make the right building. By its nature, beauty is not available as a spray-on treatment, but has to be worked out through the physical possibilities and human perceptions present in the project. When the project, like this one, is about creating an environment for work, the building is not just a walk-in sculpture but a setting in which day to day functions and personal interactions are supported, and enhanced if possible. Beauty in such a building should be negotiated, not imported or imposed. That is what happened at 343 Second Street. The Packard Board had become increasingly uneasy about the visual character of the design; their point person, the lead owner's representative, had detected this and made the call for a shift in direction; and the architects responded by bringing new eyes and instincts into the process, in the person of the EHDD design director.

The connection to the goal of replicability is this: what is one trying to replicate? The Packard building is a careful, balanced blend of ingredients. Is one just after the energy performance, the measured sustainability functions of other kinds as well, or some of the experience of working in or using the building? Just as the Packard participants had to work closely to find the blend that suited them well, others will have to go through a similar clarifying process.

What happened to the design as a result of the owner's representative's intervention is the return side of the connection between function and form. Form should not merely follow function. Function should enable form, or more accurately, feeling and form. These things form a loop, which should be followed completely around.

[42] (Nicol, Humphreys, and Roaf 2012)

DPR's commitment letter had touched on this, in trying to convey how the delicate balances of technical function were also interwoven with the look and spirit of the building: *"The effects of these decisions then trickle through the architecture in the details. We must layer on top of this the aesthetic criteria that must be achieved."* Now the design subcommittee would prioritize feeling and form, and make changes that would "trickle through" the engineering arrangements.

The building remained two long, narrow wings connected by two short bridges. The alignment with the Los Altos grid remained, as did the workspace organization into neighborhoods and connectors. The roof slope was already much shallower than the PV optimum of 30 degrees, because 30 degrees would look uncomfortably steep from ground level looking up. The changes now were in proportions, sightlines, surface materials, placement of windows, placement of spaces. The specific moves originated in an architect's eye for changes that make a difference, but the needed differences emerged from the owners.

For some time, discussions about EHDD's sketches of the building and images they showed about similar projects had been eliciting comments hoping for more warmth, less visible services and structure, more exposed wood, a more tactile feeling, something more like 300 Second Street (the previous headquarters), and so on. The goal of the design shift was to find modifications and ways of communicating them that both responded to and reached out ahead of this kind of reaction.

There was definitely room for maneuver. The work area had been divided into neighborhoods and connectors, but these had not been what architects call "detailed," i.e. these spaces were areas on the plan, but window location, trim, door height, light placement, and so on had not been decided. Similarly for the large meeting room, for which exterior details such as roofline were undecided, as well as the interior. When architects discuss "details," they often do not mean small refinements. The word for them refers to any specific decisions about how elements will function or relate to each other. So several hundred square feet of roof and a door handle may both be "details."


Jeremy Bittermann

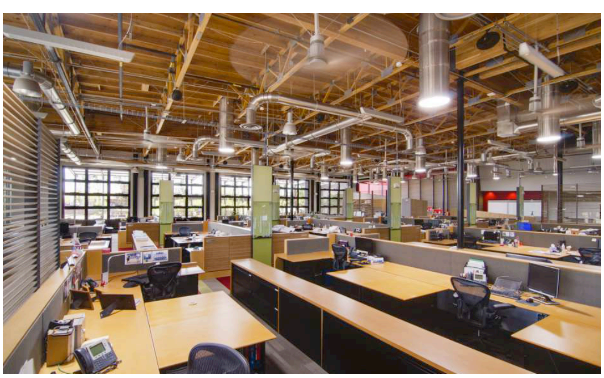
One set of moves went toward making the building feel more like a residence than a typical office. Changes that make this difference included making the proportions of windows and similar elements more vertical than horizontal and placing windows off-center in their walls, so their light would wash adjoining partitions rather than appearing as a bright opening in a dark wall.

Jeremy Bittermann

Proportions and presence were very much in play with the meeting room placement and roof. In schematic design, the large meeting room had been placed at the end of one of the long wings, but now it was moved to align with the center of the bridging wings, which allowed large windows looking through into the courtyard and also out to the side street past the front of the building. Its roof became an active element, too, by becoming a planted surface which serves as part of the view from the Boardroom on the second floor.

The choice of surface materials is closely connected to the feel of a building, directly through the sensory experiences of textures and colors but also indirectly, through the associations of different materials with other buildings and uses. For this project, the difference between residential and office associations was important, but also between them and retail settings like motels or restaurants. It would not really be enough just to use exposed wood, fabric, or stone. These moves have all been made in certain ways in generic California offices and commerce. The design committee had to work in surprisingly fine detail to get the desired quiet refinement into 343 Second Street. This process continued into the construction phase, where full-scale mockups of wall segments revealed the need for adjustments in such things as mortar technique in the stonework.

A more straightforward move, made early on, was to get all services hidden. Ducts, pipes, wiring, and any steel structure have often been left exposed in offices of the last two decades, and sometimes have been handled as elements of visual interest in their own right. But in this project they were all to be out of sight, boxed into linear elements that could read as beams or ceiling profiles. These projected into the individual offices spaces somewhat more than exposed services would have, and reduced the penetration of daylight somewhat, but this cost was not large and the increase in warmth and hospitable feeling was considerable.



services exposed—DPR Phoenix office (Greg Matstorakos)

services hidden—343 Second Street (Jeremy Bittermann)

Transparency

Other moves had to do with seeing into and even through the building. The desire to be a good neighbor in Los Altos suggested that allowing views into the building from the street would keep the foundation from being a faceless presence. The narrowness of the wings with good daylight in them from both sides also made it possible to arrange views right through to the leafy plantings in the courtyard. The organizing of the interior into neighborhoods and connectors helped to balance the provision of views with adequate privacy for people's work. The connectors could be more transparent and the neighborhoods less so, and the resultant alternation of ample with limited views would lighten up the street presence of the building.


Jeremy Bittermann

The result for 343 Second Street was a wall which is 47% glass. This is not unusually high for present-day commercial buildings, but it raises energy performance questions which a net zero building must attend to. Glass is a poor insulator in bulk, and of course is used in very thin sheets, which make the insulating value even less. Compared to the insulated solid walls used in this building, a single sheet of glass transmits heat 35 times faster. Windows have received extensive research and development over the past 30 years. Light carries heat, so a transparent surface is intrinsically less insulating than an opaque one. However, much of the heat is carried by infra-red light, which is invisible. A key development in windows has been coatings which reflect infra-red light but allow visible light to pass through. Those selected for 343 Second Street are almost six times better than a single sheet of glass. They consist of two sheets of glass, separated by a gap in which a sheet of very thin plastic is stretched. All surfaces have heat-reflecting coatings, and the inner gap is filled on both sides of the plastic with argon gas, which transmits heat much more slowly than air. And though expensive compared to other windows, they perform so well that the building could forego the normal need for supplementary perimeter heating.

Six times better than a sheet of glass is about six times worse than the solid wall. If energy were everything, window area would be much, much smaller. But to repeat the theme of this study once again, this building is a working home for an organization which pursues sustainability but whose primary mission is elsewhere. To make a sustainable world, it is this kind of organization which must be served by its buildings. 343 Second Street is exemplary because it shows that demanding benchmarks in sustainability can be achieved without giving the whole organization over to it. The organization must be engaged and aware. It cannot afford a tunnel vision that ignores sustainability in its ongoing conduct of business. But it does not need an opposite tunnel vision, in which sustainability is the only goal.

How then does one decide how much window to have? This question can serve as a model for the many similar ones which come up in sustainable office design. Insulation thickness, surface colors, covered or bare floors—these and many others fall outside the common accounting frame, in which dollar costs get set alongside dollarized benefits for each option being considered, and one chooses the numerically best one. Numerical measures, like dollar cost, do figure importantly, but not as the final measure.

Instead, the numbers set boundaries. The Packard project has already presented two good examples, the DPR guaranteed maximum price (GMP) and the annual PV output estimate. If proposed materials and construction methods exceeded the GMP, some other way would have to be found. And if one is comparing energy-using alternatives, as in the questions of which windows and how much window to install, one only considers options that use less energy than the photovoltaics provide in a year.

Taken together, these two screens narrow the field considerably. But they do not specify a single, well-defined set of choices. Of particular importance are the very aesthetic elements that the design committee was working on—proportions, surfaces, and so on. The guaranteed cost and energy budget approach allowed exploration for the right tactile qualities or the right window trim and size in terms of feeling and spirit. The moves just had to stay in bounds.

Heating

A given building shell in a given location imposes a quite well defined demand for heating. Weather records for most local areas in the US can give hour-by-hour outdoor temperatures and humidities, the chosen comfort zone gives the desired indoor conditions, and the physical properties of the shell can then predict how much heating will be needed. Actually, to choose equipment, one wants to know what extreme conditions one might have to meet, as well as energy usage during more average periods. This can call for compromise. Equipment sized for peak demands may operate inefficiently when only part-way on. In previous times of cheap, unproblematic energy, inefficiency mattered little, but a net zero building needs all the efficiency it can get.

The actual plan at 343 Second Street is to supply heat largely during a morning warm-up period, the building having been allowed to cool off overnight. After a time, temperatures should be back in the comfort zone and the workday can begin. After that, the "internal heat gains," i.e. the heat given off by occupants and office equipment, were expected to be enough to maintain temperatures as desired. The thermal quality of the building shell thus greatly reduces the demand for heating; it may also allow a smaller heating unit, with consequent cost savings.

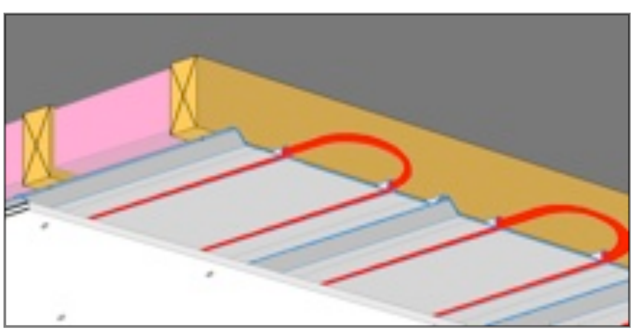
Though much reduced, there remains a heating demand which should be served efficiently. At Los Altos, the key was to use thermal energy already available at the location—the atmosphere itself contains abundant thermal energy, which can be captured for heating.

The required device, the so-called heat pump, is a familiar option for residential heating, and even more familiar by a different name and context—refrigerator. The mechanics of the building heat pump and the household fridge are basically the same. A special fluid absorbs heat in one place, gets its temperature raised in an electrically operated compressor, travels in this hot state to a second place where it gives up heat, and finally returns to the first place via an expansion process which lowers its temperature enough to be able to absorb heat again. The net effect is a transfer of heat from a cooler place—outdoors in the air or inside the refrigerator case—to a warmer place—inside the building, or outside the refrigerator. The electrical energy of compression also shows up in the output, so it adds to the total heating effect.

Heat pumps are not free. The one installed for heating at 343 Second Street requires a reliable supply of electric energy, so it is one of the demands which must fit within the budget limit set by the building's PV panels. The advantage is in leverage: it delivers 3.5 heat energy units for every unit of electric energy used. This goes some way toward balancing the additional cost of equipment.

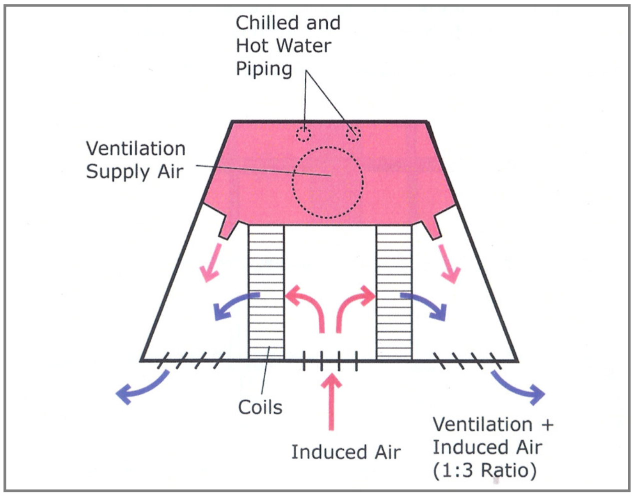
Distributing Heat

Once heat has been gathered by the heat pump, it needs to be distributed to where it is needed. The customary approach in offices has been to convey room air back to the central plant, heat it there, mix in the desired amount of outside air, and return the heated mix to the various rooms. The appeal of this approach is a certain simplicity of concept: one takes air, treats it and brings it back. Heating (or cooling) and ventilation are taken care of together. Disadvantages have become apparent over time, primarily that a great deal of air must be moved, which requires large ducts and lots of fan energy.



xLath

Rumsey/Integral considered two alternatives—radiant panels and the misleadingly named active chilled beams. Both are "hydronic," which means heat is distributed by piping hot water to points of use. Old-fashioned "radiator" heating is a hydronic system. Radiant panels use the water to heat large flat plates in the ceiling or walls. The diagram shows one specific way of doing this. Ventilation air is handled completely separately.



Integral Group

Active chilled beams were named for their original use as means of cooling, but the device also works for heating. Ventilation air is jetted along the sides of a ceiling cavity, and the high speed flow drags the other air in the cavity along with it, which in turn draws room air up past an array of heating tubes and then back out into the room with the ventilation flow.

Both candidate systems were capable of doing the heating/cooling job, and both embodied the energy advantage of moving small volumes of water rather than large volumes of air. The choice went to chilled beams, for architectural rather than engineering reasons. The radiant surfaces need to be metal or dense industrial material, and are quite large, at least several square feet apiece, and much more for situations like the building's second floor, where the overhead surfaces are quite high. This would have undercut the interior aesthetic of warm, tactile surfaces too much.

The piping for chilled beams is so much smaller than conventional air ducts that Rumsey/Integral was able to use some of the saved space for a further energy saving move. It takes energy to move water through a pipe. The faster the flow, the greater the energy to be supplied by the pumps, and much more than proportionately so. Getting the needed flow to happen at slower speeds is a big energy advantage, and a simple way to do this is with fatter pipes.

Ventilation

Ventilation for workplaces is more than a matter of bringing outside air into a space. One legacy of the unwholesome workplaces of the earlier industrial era has been a strong body of law and expectation that workplace air will be clean and healthy. Physically, this means it needs to be filtered and its humidity managed.

All US commercial/institutional buildings are required to supply rooms with outside air, and the minimum flows are set down in regulations. The chilled beam system does this with air ducts that fan out to the occupied spaces and utility rooms from centralized "air handlers." The air handlers draw in outside air, adjust its humidity if necessary, and propel it into the ducts. Sometimes a parallel set of ducts return room air to the air handler to be expelled, but at Packard this "relief" function only occurs in the meeting rooms. (Spaces with potential hazards, like machine rooms, are always ducted back.) Generally, the Packard design relies on gentle flows throughout the building to get return air back outside. In conditions when outside windows can be opened, relief happens that way.

The Packard ventilation system is described as "100% outside air." This term needs explanation. Conventional HVAC systems, as described above, bring all room air back to the central plant and mix it with outside air there. Thus the conditioned air returned to the rooms is part outside air and part air that has already been inside, in use, so to speak. The air that flows back to a given room may be 25% outside or some other proportion. It must, however, contain the amount of outside air prescribed by the regulations.

In the chilled beam system, the amount of outside air is no different, but because it is not mixed with inside air before it gets to a given room, it can be described as 100% outside. The air emerging from the active chilled beam unit is not, however, usually 100% outside air. The jet action of the nozzles in the unit draws in room air, past the heating or cooling coils, as described above. This mixes with the outside air to form the blend which flows back into the room.

At times when neither heating nor cooling are needed, the ventilation flow can be slowed, and then the jet action no longer draws in room air. At such times, "100%" is straightforwardly true. At other times, it is true that the air in a given room is not mixed with air from other rooms, so smells or airborne contaminants are not carried through a building, so the system is "100% outside" in that limited sense.

Cooling

Cooling is needed more than one might think in commercial space occupied for a full working day, because even when it is cool outside, the human beings and their equipment indoors can generate enough heat for discomfort. Even with its eventual efficiencies, the Packard building needs cooling at least some of the time between April and the end of October. The atmosphere around Los Altos could not only provide a large amount of fuel-free heat, Rumsey/Integral realized it could also provide free cooling to a much greater extent than conventional HVAC practice recognized.

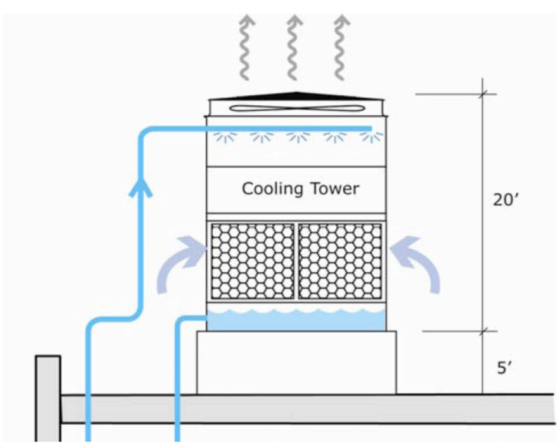


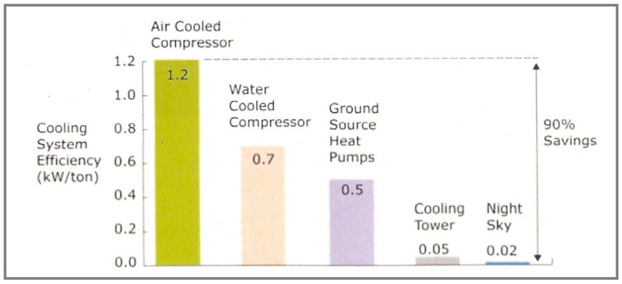
Figure 6: Cooling Tower

Integral Group

Already by 2008, the so-called "economizer" was well known to engineers, and even required in some codes. One could take advantage of favorable outdoor temperature and humidity to shut down the main heating/cooling equipment and basically just use outside air. One could do this directly, funneling outside air though the ductwork. Or one could do it indirectly, using a cooling tower, in which a water spray falls through an upward stream of air and evaporation cools the falling water significantly.

The extra equipment is not free, but in many places around the country, the right conditions happen often enough to make an economizer worth while.

Rumsey/Integral's insight was that night-time cool temperatures could in effect be put to work during the day. One chills water at night with the cooling tower, stores the water in a large insulated tank until cooling is needed during working hours, and circulates it then to the occupied spaces. The right night-time conditions happen very often during the April-October period, and daytime cooling needs are not overly severe. Enough cooling could in fact be gained this way that the building could dispense with a normal, compressor-based cooling system entirely. The energy savings are very great, on the order of 90%. Not buying a regular compressor saves significant money. Finally, the components are all standard—cooling tower; large storage tank; and a system for distributing the chilled water for use.



Integral Group

Photovoltaics—energy and community presence

The PV system is another place where architecture and energy efficiency are tangled together. The panels naturally go on roofs, but the best placement there for energy is often different from the best placement for appearance and structure. At 343 Second Street, a solar panel will produce the most energy in a typical year if it is tilted up 30 degrees from the horizontal, and aimed due south. The natural compass direction of roofs on this long, narrow site is quite different. To align with the existing street directions, it points about 60 degrees away from south to the west (or 120 degrees away to the east, depending on which way the roofs slope). And a roof slope of 30 degrees would be much greater than usual for large buildings. For some engineers and some designers, this presents an all-or-nothing situation: either maximize the solar energy, or forget about it. A more sophisticated approach is to inquire how big is the energy penalty, and how big are the aesthetic penalties for various possible directions and tilts, and then consider options.

In this case, the aesthetics penalties bulked large. An announced goal from the beginning had been to support the Los Altos downtown, and a quieter parallel one had been for the foundation not to seem imposing or flamboyant. Quiet elegance, warmth, hospitality had been aesthetic goals. For the architects this made alignment with the existing streets a high priority, and the same for keeping the total height modest rather than imposing.

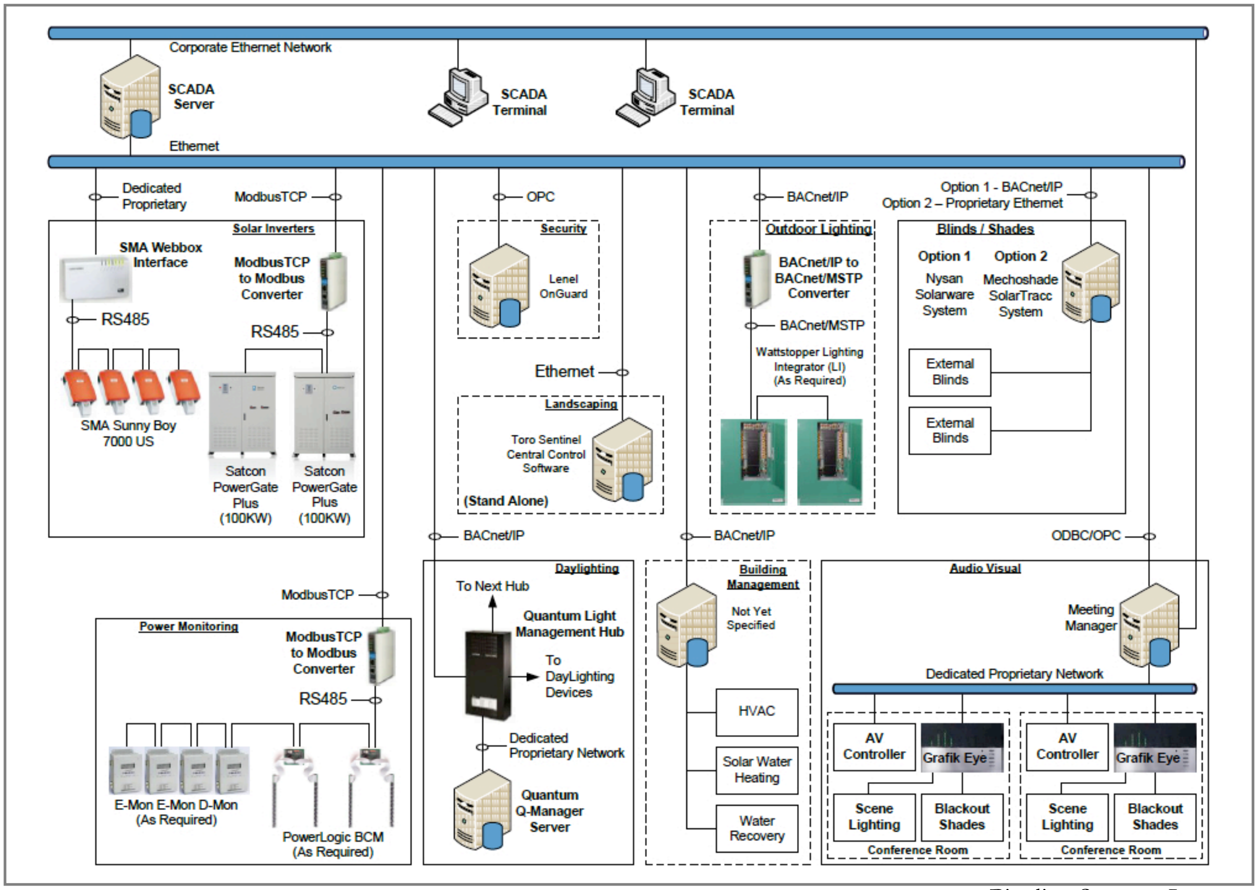
On the other hand, the energy penalties were real but not overwhelming. Simulation studies of different directions and tilts are easy to run on computers, and fairly reliable. They showed that a southwest facing roof of the architects' preferred slope would collect 3% less energy; facing northeast, the other possibility, was worse, as one might expect, with a total penalty of 10%. 3% felt entirely manageable to the engineers, but there was considerable debate over the architects' strong preference to have the roofs slope oppositely. Their position was that this would help the two wings seem part of a single entity, two halves that fit together, rather than a side by side placement of two repetitions of a shape.

The loss of energy from a northeast orientation was worrying enough that the team agreed to expand the PV area by adding a roofed enclosure over part of the visitor parking, across the side street (Whitney St.) from the entry end of the building. The additional area, about 7% more, would roughly balance the shortfall. In the end, the energy demand of the building was reduced enough that the extra panels were not needed. But this did not become clear until after the PV system was installed.[43]

The photovoltaic system provides a good illustration of another key point. I mentioned earlier that one cannot cover an entire roof with solar panels. The Packard installation used about 15,500 square feet out of about 27,000 available in the final design. That means about 40% of the area did not have panels. Why? Because of access needs. People maintaining the panels or washing them have to have somewhere to stand. Even more important, in case of fire, firemen need to be able to work on the roof, to create smoke openings, among other things. It is a general principle that not all of a resource is usable, be it oil in the ground or roof area under the sun. One always needs to ask what fraction of a resource is actually available.

Jeremy Bittermann

[43] David Maino (Integral), personal communication and simulation results



Pipeline Systems Inc.

Control systems

All of the building services and functions discussed so far involve a high degree of automatic control, and the system of controls is correspondingly complicated. The diagram above shows nine distinct subsystems, from the solar panels to heating/cooling to landscape irrigation. Each of these may have its own sub-subsystems.

The ideal adopted in the Packard design is to have all of this under unified control, the SCADA system mentioned earlier. This approach offers the typical benefits of the digital world, and typical difficulties as well. The main benefit is unification, which is a considerable advantage once achieved. The subsystems have all grown up independently of each other. Drip irrigation, solar panels, and the others are quite different businesses. All grew by different, disconnected paths. Their original markets often involved quite different client and user groups. HVAC engineers stand in an industrial tradition of large mechanical equipment, pumps or motors that were switched on and off by hand, and much hand adjustment of valves and settings. Electric matters, such as lighting or solar panels, have quite different safety demands, units of measurement, and standards of good performance. The same goes for each category of specialized equipment. When a building incorporates all of them, the potential confusions from multiple switch and meter panels make knowing and managing the state of the building very difficult.

The digital dream is that signals from all the different systems could be brought through a central server which presents them in an integrated way, in a single visual language and a simple, consistent mode of action. From a single workstation, one should be able to see the current state of every building subsystem, take appropriate actions, and see their effects. Alarms and reminders should all appear at the same place. And all routine actions, such as warming up the building in the morning, should be automated, so that building managers do not need to memorize complicated sequences and functions take place reliably. A side benefit should be that the building's performance history is recorded and preserved, which greatly helps any troubleshooting.

There are two kinds of difficulty in the way. The first is programming. Data does not automatically flow into the central server, it has to be acquired though carefully arranged steps, and each subsystem has its own coding conventions and quirks. Many of the functions require very detailed choices, for example exactly which lights will come on at which preset times. The very flexibility of digital systems imposes a burden of choice. And the layout of the central control screens poses its own set of choices and coding demands. This may eventually become a plug-and-play affair, but it is far from that at this stage of development. The Packard system has something like 15,000 monitoring and control points, so the programming load is substantial.

The second difficulty lies in a tradeoff between visibility and convenience. Older systems, which have to be adjusted by hand at the individual items of equipment, can give the operator direct, rich information about their state of operation, through sounds, vibration, heat, and so forth. Much of this direct information is lost when translated into digital codes, to the hindrance of troubleshooting and informed intuition. The gain in convenience is real and considerable, so one faces real tradeoffs and real issues in commissioning.

Packard has largely finessed these difficulties by having a full-time engineer on the staff. This allows ongoing real-time observation of both the real building and its digital portrayal on the control screens, and both speeds and improves the fit between them. As acknowledged previously, this shifts the costs from the performance zone to the salary and benefits zone.

Complex controls are the standard approach to green commercial buildings at this time. Packard's system is good of its kind, but not qualitatively different from others in use. Over time, one can expect things to get simpler, as patterns become more settled and predictable. One British building was able to reduce its HVAC monitoring system from hundreds of points to a single one, as the building manager discovered that a single temperature measurement at the right point gave him all the forewarning he needed to keep the building comfortable.[44]

[44] Martyn Newton, personal communication. The building is the Elizabeth Fry Building at the University of East Anglia.

The rest of sustainability

Energy has been the primary concern so far in this study, because net zero energy was the furthest-reaching of the project's goals. But it is important to let the 2002 Scenarios remind us that the step before this goal, the step assumed to be in place, was the LEED Platinum standard. This concerns much more than energy, and we should now review what this project did in these other areas to measure up to Platinum.

The LEED rating names five areas of sustainability—sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality. Within each, it presents a number of distinct clearly defined tests. Water efficiency, for example, has three—water use reduction, water efficient landscaping, and innovative wastewater technologies. Indoor environmental quality has fifteen, materials and resources has eight, and so on. Success on a test is worth between one and six points, depending on the test. Projects seeking a LEED rating can choose which tests to try passing, and the rating level depends on how many points they gain. The lowest level, Certified, requires 40 points, while Platinum, the highest, requires 80. The total possible for the five areas is 100 points, and ten extra credit points are possible for extra achievement on regionally important topics or innovative approaches within the five sustainability areas.

Of the resulting maximum of 110 points, 343 Second Street received 94, a hefty margin about the Platinum threshold. To do this, the design needed to do very well in all five areas, and did:

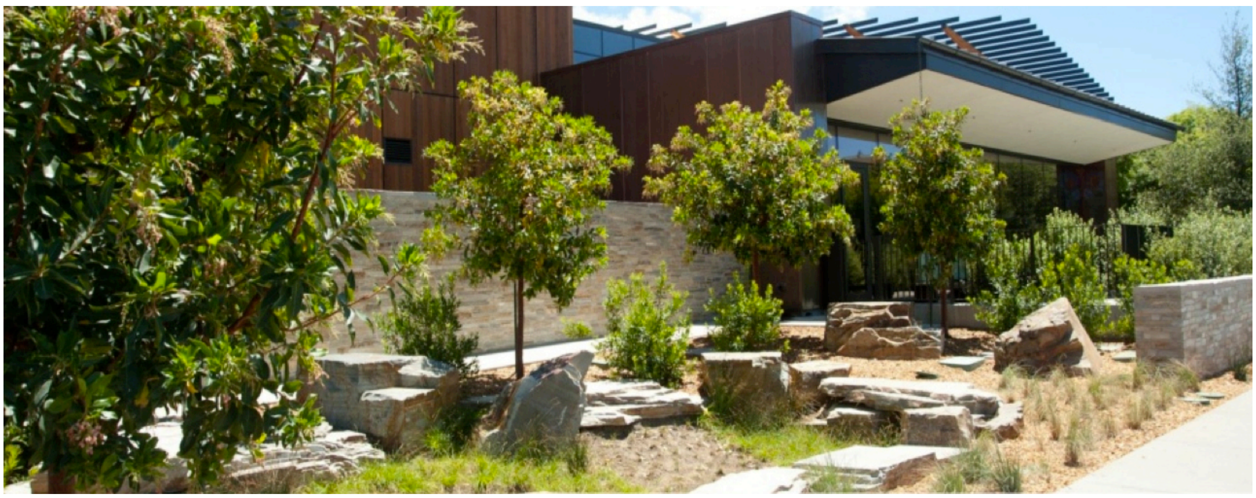
- § 24 of 26 points in Sustainable Sites
- § 8 of 10 in Water Efficiency
- § 33 of 35 in Energy and Atmosphere
- § 6 of 14 in Materials and Resources
- § 13 of 15 in Indoor Environment
- § 6 of 6 in Innovation in Design
- § 4 of 4 in Regional Priorities

The individual tests run from electric car charging stations and low-emitting paints to use of local materials and construction waste management, 46 distinct tests in all, of which 343 Second Street gained points on 37. Of particular note are the provisions for water and the recognition of on-going processes.

Water

Water is a perennial concern for California's urban areas, sited as they are where local supplies are radically insufficient. Sustainable designers recognized early on that water is a key issue, but it has often taken a back seat to energy, perhaps because it is neither a global commodity nor linked at its sources to highly distasteful pollution. In any case, the LEED system allocates 10% of its points to water measures. 343 Second Street pursued those points with success, by what is now a familiar combination—high efficiency at points of use, and mobilization of unregarded local resources.

The main unregarded water resource in Los Altos, and throughout the Bay Area is rainfall. American building and city planning has largely treated it as a nuisance, to be barred from any entry into buildings and instead to be conveyed away as invisibly as possible. In fairness, considerable damage can be done by badly managed rainwater in climates capable of intense rain, which is all climates. And carelessly stored rainwater can accumulate hazards to public health. Nevertheless, rainwater is real water, and good ways of using it in big buildings have gradually been spreading over the past ten or twenty years.



Terry Lorant

The dominant onsite use of water in California is for irrigating landscape plantings. For the average office building, this can be almost 70% of the total, or something like 540,000 gallons of fresh water per year. When supplied through municipal systems, all this water has been pumped, filtered, sanitized, and purified to the very high standards of officially sanctioned drinking water. Plants are neither as sensitive as humans, nor as likely to file lawsuits. Rain falling directly on them is generally clean enough, though the history of acid rain from coal power plants shows this should not be taken completely for granted. The difficulty in a place like California is mismatched amounts. It is common for rain to be too intense to be usefully absorbed on site, and just as common for dry spells to be too long for the kinds of plants favored for commercial/institutional landscaping.

Efficiency in irrigation starts with choosing drought-tolerant plant varieties. The landscape design is an important component of the appearance of the finished building, and also of its meaning to staff and Board. The courtyard is divided into grassland and woodland sides, with plant choices aiming to convey the spirit of these contrasting ecologies. The main street frontages try to convey a gently varying, treeshaded experience which allows passersby a lightly screened sense of what the interiors and courtyard are like. In all, this program took 51 plant varieties to execute. Of these two-thirds are drought-tolerant. Here again, as so often in this project, one can sense the interplay of environmental and organizational values, both present, neither in sole command.

The other key ingredient of efficient water use is judicious application of water to plants, supplying their needs while losing as little as possible to evaporation and runoff. The building uses drip irrigation, accepting the additional materials and labor costs of its network of tubing, rather than conventional sprays. Irrigation is also under "smart," i.e. digital control. At present this means programmable timing, but not sensing of soil conditions.

The plant choice and watering system provide the biggest reductions in this building's landscape water needs. The design documents estimate they allow a 75% smaller than average water need. An important increment comes from storing rainwater for dry spells. A 10,000 tank under the building collects rain from the roofs and is the first supplier of the irrigation system, for further reduction of perhaps 9%. "Smaller than average" is a somewhat slippery index, of course. For a large state like California, such an average sweeps together buildings of many different sizes, settings, and purposes. Perhaps a better index of water efficiency, and certainly the one relevant to the Platinum rating, is LEED's own, in which the Packard design is compared to a carefully defined baseline case. The baseline is a hypothetical building of the same size and site coverage, conventional plantings, and standard good practice in applying water to them. The same estimating procedure, using the same hourly climate information, is used for both buildings. This approach estimates that 343 Second Street needs 57% less landscaping water than the baseline, taking plant selection, irrigating system, and rainwater storage all together.

The next largest office building water use is sewage conveyance (toilets and urinals). One of the most hopeful developments in sustainability over my lifetime has been increasing willingness to consider this topic thoughtfully instead of consigning it to a kind of untouchability. If purifying water to high standards is needless for irrigation, it is absurd for toilets. So in addition to choosing low-flush fixtures, Rumsey/Integral specified a second 10,000 gallon rainwater storage tank for supplying toilets. Finally, an even less-regarded resource, urine itself can be used. Properly designed urinals require no added water to get their waste into the sewage system, and such fixtures have been installed at 343 Second Street. LEED's approach estimates an 87% reduction in potable water use for conveying sewage in this building.

Landscape and sewage are not the whole story on office water, but they are the bulk of it. The other main use, sinks and showers, needed only the choice of readily available low-flow fixtures for the total potable water use to meet the LEED test of 65% reduction.

Recognizing on-going processes

While most of LEED's 46 tests bear on physical features of the building in question, a few recognize that buildings only achieve high performance if they are inhabited in ways that keep the physical features doing their job. As one more example to join the many in this report, the physical provision of space for recycling office waste is helpful, but not decisive in getting recycling to occur. It happens that LEED does not have a test for actual recycling, but it does have tests for some other points of ongoing process:

§ Fundamental Commissioning of the Building Energy Systems
§ Enhanced Commissioning
§ Measurement and Verification
§ Construction Waste Management
§ Construction IAQ Mgmt Plan-During Construction
§ Construction IAQ Mgmt Plan-Before Occupancy

Commissioning is no surprise. The discussion above about setting up commissioning for 343 Second Street introduced the idea, its rationale, and some of its results. The practice is very much a recognition of benefits arising from routines for paying attention to patterns emerging from the actual running of a building. This is especially true of what LEED calls enhanced commissioning. The test here calls for engaging the commissioning agent with building management in significant ways. The agent is to be hired before construction documents are complete, to generate manuals and training routines for the different building systems, and to review building performance after 8-10 months of operation.

Measurement and Verification also reaches past the builder-owner handover. It asks for a definite monitoring plan to be in place during the first year, along with suitable measurement gear, so that the energy model for the building can be checked against observed performance under the actual weather that prevails. This task promotes collaboration between building staff and the design engineers, which is highly desirable. It has a dual potential. Not only can it help building staff become truly familiar with the complexities of their systems and possibly reveal trouble spots in the building, but it can also lead to improvements in energy-use computer models.

The tests relating to construction waste management and air quality have been present in LEED almost from the start. They reach into the day-by-day activities of the construction phase, and thereby help to connect designers and builders in real time. Waste Management refers to getting as much as possible of the waste material generated during construction reused, rather than simply dumped in some landfill. Construction IAQ (Indoor Air Quality) has two tests, one about maintaining air quality during construction, and one about establishing a good starting condition for air in the building as occupation begins. The construction phase has the potential for many kinds of smoke, dust, and fumes to circulate in the building. These can be health risks to the construction workers, and they can also become lodged in the ductwork or surface finishes of the building to be released later, in the use phase. With good planning and attentive work, however, air problems of this kind can be drastically reduced.

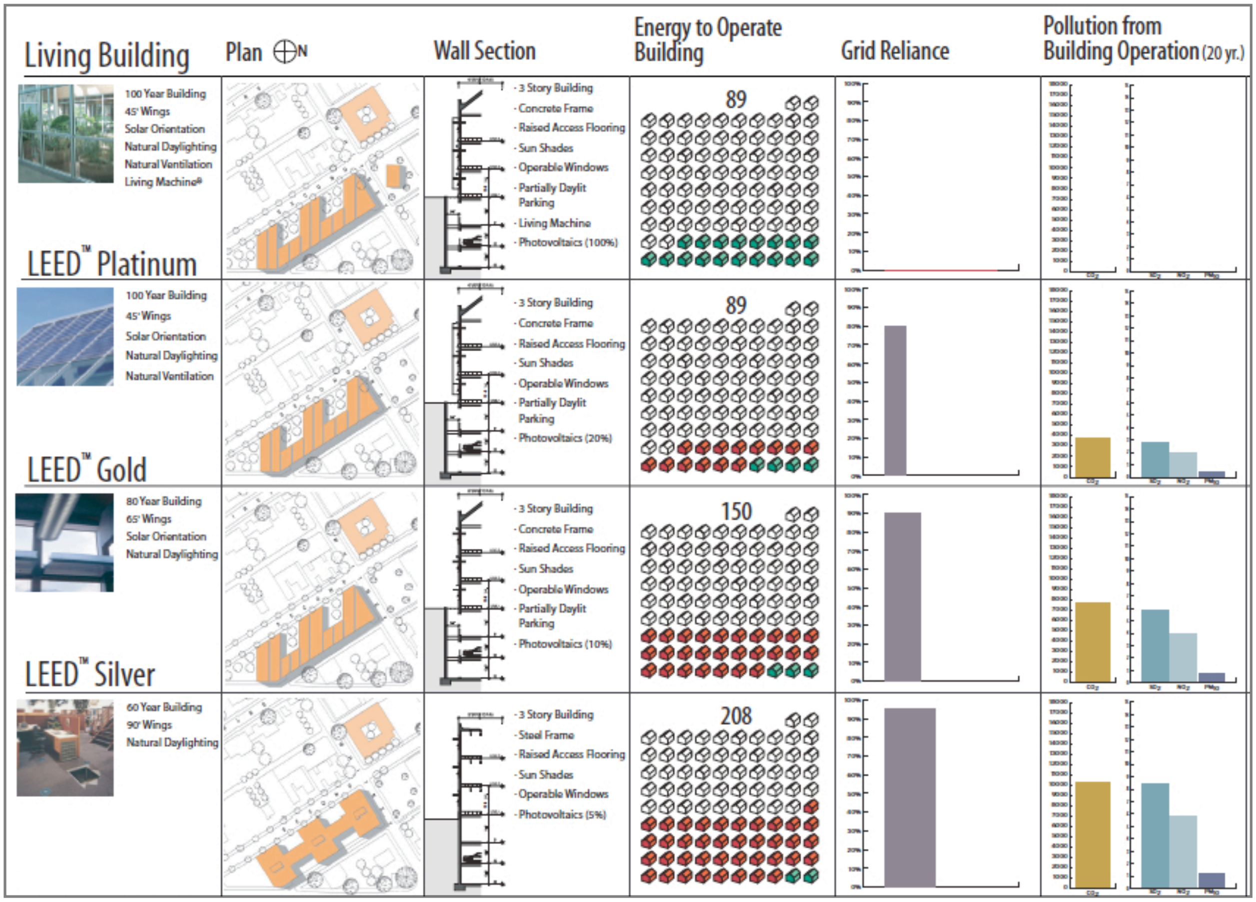
The Before Occupancy test aims to confirm the good results of construction-phase air management. One can conduct a stringent set of air samples, or one can flush the building thoroughly with clean outdoor air. The Packard project chose the latter path, and ran into one of its few genuine hitches. The formula LEED uses to specify the amount of air to be put through the building to flush it out did not account well for the amount of natural air circulation in the building, and was in fact so large that staff became acutely uncomfortable. In the end, Packard chose not to apply for this credit.

This discussion of on-going processes has been more about LEED than about Packard's ways of meeting these parts of the standard. The fact is that Packard's wide staff engagement and interest in the entire sustainability wheel meant that these tests were routine business, in effect.

LEED in general

The LEED system has attracted controversy in recent years. Is it reliable? Is it worth the effort and expense? Can it be gamed? These and other questions circulate in the hallways of professional meetings and on the Internet. This report is not at all the place for an extended discussion, but a few observations emerge from the Packard experience at 343 Second Street. Looking at the multi-year trajectory of the project, one can see that the LEED's main effect was just what its originators intended. It provided a defined scale of ambition. It put an organization like Packard in a position to judge concretely how far it wanted to go in pursuing sustainable design.

Such was the approach in the Six Scenarios of 2002. Four of the six appear in the portion of the "Packard Matrix" shown below. The visual indices for energy, grid reliance, and pollution from operation indicate the progressively greener alternatives from below to above. The plan and wall section columns show what professionals at that time considered sensible layout, structural, and technical choices for achieving each given level. In passing, one can note that the eventual choices for 343 Second Street had interesting similarities and differences. Drastically reduced energy use was central then as much as now for the greener end of the scale, as it must be, given the energy budget imposed by the amount of sunlight falling on the site. Natural lighting and ventilation, operable windows, solar shading, and narrow wings appear both then and now, while the underground parking, due south orientation, raised floor ventilation, and concrete frame structure of 2002 all yielded, for the reasons described above, to alternatives.



Packard Foundation

It was the LEED structure that provided the targets around which each set of definite choices could organize itself. That set of landmarks in the sea of possibilities has been of enormous value nationally, as well as in the defining stages of the Packard project. And in Packard's case it did not define ceilings, only steps upward. There has been concern that LEED would limit progress, that projects would accumulate only enough points to just qualify for the level of their choosing, and would not explore ways to go further. The Packard project did not do this. It used the Platinum level to define the floor of its ambition, not the ceiling. At 94 points instead of 80, and even more in adopting the net zero goal, the foundation went well beyond minimums.

Working through the LEED process is indeed laborious. This is the shadow side of one of the system's great attractions, the insistence on clear criteria for each of its tests. A LEED test typically asks whether a certain quantifiable aspect of a project, such as an air flow, the distance to a supplier, or a light level, reaches a certain quantifiable level. The goal is to have no argument about whether the test is passed or not. This is a direct and sensible defense against wishful thinking and convenient half-truths, two endemic patterns in American self-promotion. Unfortunately, the complexity and variability of big buildings, and the large number of LEED's tests, mean a large number of fine details to be tracked, organized, and concretely documented. The important feature of access to daylight, for example, turns out to require mapping sightlines from 42 inches above every square foot of building space, to see if one can see out from 90% or more of them. Not roughly 90%, but exactly.

Moreover, as the Packard experience with air flushing indicates, highly detailed test specifications can fail to connect with unforeseen ways that projects address different aspects of performance. They then lose points for not meeting the letter of the law, even if they meet its basic goals.

LEED's complexity mirrors the complexity of the buildings it rates. Both complexities have real costs in time, effort, and money. For now, the system's wide acceptance indicates that those costs are generally tolerable because the system meets a real need, the gauging of greenness in buildings. As the US pursues sustainability over the next decades, it will be interesting to see how these factors develop. There is reason to believe that greenness will become part of the assumed background of organizational life, the way public health largely has. There may be accustomed provisions in buildings that are taken for granted, the way the presence of toilets now is. If so, there will be a largely hidden apparatus of regulation at work, with its own paperwork. But the need to verify each claim in painstaking detail may recede.

Costs, again—what was the question?

Costs matter to the pursuit of sustainability. They bear heavily on replicability, which has been a goal of the Packard project from the start. Bost replicability and cost are notions which spring quickly to mind but are not easy to pin down.

As pointed out earlier, there is more than one cost question. Packard currently answers two. If one is asking what getting their exact building would cost, the answer is $37.2 million ($756 per square foot). If instead one is asking the cost of a building with equal performance aside from the cost of the interior fittings (cabinets and so forth), the answer is $23.5 million ($477 per square foot). In this subsection, I want to unfold those numbers somewhat, to indicate what they do and do not cover. Then I will comment on an often neglected topic, running costs.

First, one more relevant question about a building: what is the total cost, the so-called "project cost"? Here we get into some terminology. "Construction" is not the whole story. In the building industry, that term refers only to the hard costs—labor and materials that go into putting the building up and landscaping the site. It does not include fees to the design team (architects, engineers, and consultants), all the furniture, fixtures and equipment (FF&E) to be installed, and the costs of permitting and insurance.

Fees are the largest of all these soft costs, running to 25% or so of the construction cost. FF&E will be another 10-15%. Permits and insurance are a much smaller percentage, but still significant dollar amounts. The total outlay for a project, soft as well as hard costs, may be 50-70% greater than the construction cost. The project cost for 343 Second Street is about $55 million.

Also omitted from the construction cost number are the contingency amounts, which the prudent owner must have available, though hoping not to use them. Thus the budget for a project shows a number typically 10% larger than the projected cost.

I go into all these distinctions because cost figures available at large are sometimes one, sometimes another of them. The larger of Packard's published numbers is a construction or hard cost, not a project cost and not a budget total. When asking about costs, one needs to be clear what one wants to know.

For a sustainability oriented building like 343 Second Street, the real question on people's minds is often about the impact of sustainability on hard costs. How much does it cost to be green? The lower of the two Packard numbers ($23.5 million, or $477 per square foot) is Packard's answer to this question. The design team went through the construction budget item by item and took out three kinds of cost they considered unrelated to the sustainability features of the project—the contingency amounts, the amounts related to special features of this particular project (primarily demolition of existing structures on the site, and installing an extensive audio-visual installation for Packard conferences), and "tenant improvements." This term comes from commercial real estate, where many buildings go up as only floors, outer walls, and basic services like water, toilets, and elevators, leaving tenants to fit out their rented space as they see fit.

What is left in the budget after these subtractions is known in the building industry as a "warm shell." If one completed this much of the building, one would have the structure, the envelope (walls, windows, and roof), the building mechanical systems (heating, cooling, ventilation, plumbing), and the photovoltaic array. This would not be a building one could work in. There would need to be tenant improvements of some kind, if only low-end carpeting, paint and cubicles. For a building the size of 343 Second Street, done in a very generic way, this might come to $2.5 million ($50 per square foot) to be added to the warm shell amount. There might also be special features of one's own to pay for. But the completed warm shell by itself would contain all the physical elements of the high-performing building that is 343 Second Street.

Given the repeated theme of this case study that sustainability comes from live, ongoing activity, not just an assembly of good equipment, I hope readers will take the warm-shell figures as honest but partial information about what it takes to achieve sustainability at the level of 343 Second Street. What it also takes is active engagement of building occupants. And tenant improvements, from wall colors to landscaping to information displays, play a key role in connecting occupants with the way the building uses energy and water, and generates waste. So green projects must not only add tenant improvements to their cost estimates, but must recognize in their specific design choices the potential encouragement or discouragement they can bring to sustainable performance.

There is not yet a guideline for how to make the right kind of improvements, nor how much they cost. 343 Second Street is the Packard Foundation's successful effort, but as we have seen, it has emerged from a process engaging all aspects of the foundation's work and spirit. Other organizations should expect to go through their own forms of such a process if they want to reach similar success.

Running costs

Once up, a building needs to run. In several ways, 343 Second Street will have different running costs from a conventional office. Energy costs will be almost zero. The building uses no natural gas, and generates as much electric energy as it uses. There are utility payments for having a connection to the power grid, which enables the building to draw energy during low production times and export when there is excess production. In a typical year, the building should export somewhat more than it imports, and thereby gain a small revenue stream. The first year of operation, for example, has seen a surplus of a little more than 60,000 kilowatt-hours,[45] which is worth a little over $8,000 at current electricity prices. However, the grid connection is not offered free by the utility. There is a monthly charge of $1,000-2,000. Moreover, current California policy restricts the amount of exported power that can be sold by utility customers.[46]

Compared to a conventional building's energy costs, this is very small, though not quite zero. One in-house "life-span" estimate made during the post-occupancy period comparing a hypothetical conventional building with the 343 Second Street estimates showed annual costs of the former starting at ten times higher and escalating steadily over the building's life.[47]

On the other side of the ledger, we have seen that the complexity of the building calls for a full-time engineer with controls experience on staff, at least at first. Salary and benefits for this person will be an annual charge, and so will the upkeep of the controls system. One indication of how building controls of this kind are still young as a field is that little information circulates at large about their ongoing maintenance.

Does all this balance out over time? One simple way of framing this question comes from Packard's chief financial officer. He suggests thinking of the building's costs in three parts—shell, photovoltaics, and internal operations. Roughly speaking, one can

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[45] http://www.packard.org/about-the-foundation/our-green-headquarters/energy-reports/ (accessed Sept. 12, 2013)

[46] http://www.cpuc.ca.gov/NR/rdonlyres/C085BDE6-7DC1-4FD8-8208-52300A082672/0/FAQs_NSC_91411.pdf (accessed Sept. 29, 2013)

[47] "Lifespan Costs," Packard Foundation (confidential internal document)

then see the shell as cost-neutral, the extra costs of construction balanced by much reduced energy needs. The PV array can be seen as the power plant that supplies that energy, so its cost in an investment that is paid back in avoided payments to the outside utility. The avoided costs would balance the investment sooner than the useful life of the array, and much sooner than the time Packard might leave. So there is basic cost neutrality in this segment as well. Operations is not so well balanced. The dedicated staff position has definite, predictable costs. The on-staff engineer has definite potential for finding additional cost-saving efficiencies, but it is hard to estimate their size.

This framing appeals because it breaks the question of balance into manageable parts. There are pitfalls, however. Compared to a conventional building of its size, 343 Second Street may well avoid enough utility charges to balance the cost of the PV system in less than 10 years.[48] However, this is only possible because of the building's highly efficient shell and the operational efficiencies that go on inside it. The biggest reductions in utility charges come from efficiency, the two-thirds reduction in use, not the PV system. If one asks how quickly the PV system recovers its cost when the avoided charges are just the retail costs of power used by 343 Second Street, the answer is more like 27 or 28 years. That still meets the test of expected system lifetime, though more narrowly.

Meanwhile, attempts to separate out the costs of the efficient shell quickly stall in a tangle of imponderables. For example, how much should a given window frame be charged to efficiency and how much to aesthetics? or what is the energy effect of operable windows in offices? Numbers can of course be generated for questions like these, but they always hang from a tenuous chain of assumptions.

For me, these considerations confirm the thoroughly integrated nature of the project. As this study has repeatedly shown, engineering, aesthetics, and inhabitant work patterns are all essential to what has been achieved. The best approach to cost recovery is that actually taken in the life-span exercise just mentioned, namely to set the expected operational savings of the actual building against its full cost, and see how long it takes to overcome the difference in initial cost between it and a completely generic conventional building. If the length of time is acceptable, then the real criteria for decision, the quality of organizational life in the building and the contributions it may make to the organization's mission, can take their rightful place in guiding design, construction, and operation.

[48] "Lifespan Costs"

5—THE PROJECT IN NATIONAL CONTEXT

343 Second Street's place among American green buildings can be gauged partly by comparing it with other front-line projects at this point in time. The starting point must be that the front line is crowded. The map shows a recent compilation of net zero projects around the world.[49] This includes buildings of all types—houses, apartment blocks, schools, visitor centers, health centers, as well as offices. The Packard project's significance is not that it is in a class by itself, but rather that its very sound base (the sustainable organization) and excellent implementation qualify it to be a leader in its class.

Eike Musall

Net Zero offices are flagged in green, and when one restricts the map to net zero office projects in the continental US, as below, one sees that the class is small.

adapted from Eike Musall

Of the seven projects on the map (at this scale, the Packard flag hides one other which is very near by), I have marked two as instructive comparison—the National Renewable Energy Laboratory (NREL) Research Support Facility in Golden, Colorado and the Bullitt Center in Seattle, Washington. Both buildings are complete, and both have net zero energy as a major goal, but neither has yet completed a full year of both full use and full energy production, whereas the Packard building has. The three projects together show that a useful breadth of motivations, and circumstances can be congenial to net zero and high performance building.

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[49] Eike Musall, Bergische Universität Wuppertal; accessed via http://batchgeo.com/map/net zero-energy-buildings, accessed Aug. 27, 2013

NREL Research Support Facility

The Research Support Facility is a Federal office building, housing about 800 professional and support staff. (A second RSF building, completed in late 2011, houses an additional 500.) NREL's mission is to develop innovative approaches in renewable energy production and energy efficiency into market-viable technologies and practices. The site in Golden has been the home of a variety of computation and laboratory facilities, and the purpose of the Research Support building was to bring staff out of leased office space and into close proximity to the labs. The design and performance of such an office is intimately related to its organization's mission and work, and from the beginning the general goal was to demonstrate the effectiveness of present-day approaches and create an ongoing living laboratory.

A programming phase in 2007 led to a February 2008 Request for Proposals (RFP) which conveys the building's goals in prioritized form: the LEED Platinum level was deemed mission-critical; an energy use target of 25 kBtu/year per square foot was highly desirable; net zero capability was to be achieved if possible. These goals were shaped by local factors, as they should be. The building was to house a data center serving the entire Golden site. This energy-intensive function is essential to research support, but accounts for about one-third of the building's total energy use.[50] The local climate is laconically described as "cool, dry" in one standard classification scheme: though summer days can be very hot, heating is the dominant need over the year, consuming ten times as much energy as cooling.

As often happens, early design work modified the goals somewhat. The occupant capacity went up, from 650 to 800, and a data center was added, serving the intensive scientific computing needs of the entire NREL location. These moves sharply raised the energy demands of the project, so the energy target was raised to 35.1 kBtu/year per square foot. This is about twice the Packard level, and that of the Bullitt building described below.

The business side of the project was noteworthy from the start. The owner, NREL, adopted the fixed-budget approach, and found its way to the actual amount by a two-stage selection process. A first sounding for interest asked to hear from design-build teams, in which design and construction firms would jointly apply for the job. Three finalist teams were selected and asked to propose conceptual designs and budgets which would meet the RFP goals as fully as possible. The selection would go to the most convincing combination of high performance and low cost. The eventual winner, a team led by architects RNL and builders Heselden Construction,

[50] data from a December 2011 presentation: Shantih Pless et al, "NREL's Research Support Facility: An Energy Performance Update" available from http://www.nrel.gov/sustainable_nrel/pdfs/rsf_operations.pdf (accessed Aug. 27, 2013). (Hootman 2013) provides extensive information about the design and construction phases.

quickly concluded in their initial studies that the net zero goal was not only achievable at reasonable cost, but essential to a successful proposal.

The supply/demand balance for energy was approached differently from Packard and Bullitt. Packard essentially committed to holding its demand down to match the supply available from photovoltaics on its roof. NREL could not do this, once the decision to have four stories, high occupant density, and a data center. Twice Packard's number of floors and twice the energy demand for each square foot of floor was more than RSF's roof could supply, even in the good solar conditions of Golden, Colorado. Fortunately, the RSF project also involved parking for staff. Installing an additional PV array as a cover to the parking lot would provide the needed extra capacity.


National Renewable Energy Laboratory

NREL's net zero at the RSF, then, is somewhat different from Packard's at 343 Second Street. But it is well within the intuitive meaning of net zero, namely that a site generate as much energy as it uses over a year. Packard's design team in fact added an array over its visitor parking area at a point when it seemed the building roof alone would not provide enough extra capacity to deal with bad solar years.

The building design centered on daylighting. As at 343 Second Street, the form was two long, narrow wings, joined in this case by a single bridging wing. All rise four stories. The interior largely consists of open-office workstations, with only a few private offices. The latter are fully partitioned off from the open space, but are open above, as heating/cooling comes from radiant panels in the ceiling that spans the whole floor.

The building is cooled efficiently, with a chiller-plus-economizer system. It does not use the night-to-day storage found at 343 Second Street, but cooling is only 5% of the building's energy use, even leaving out the data center. Heating is closer to 40%, and gets closer attention. The building makes heavy use of passive solar technique, which amounts to using daylight for heating as well as lighting. Sunlight certainly carries energy, as any beach-goer knows. It heats up anything which absorbs it. Passive solar technique is the judicious management of this heating: one admits plenty of sun, but gets the heat distributed and absorbed in ways that avoid overheating.

Passive solar does part of the heating job. A variety of active heating features do the rest. The most unusual is the "transpired" solar collector. This produces heated air, not electricity. A perforated metal skin over parts of the south-facing wall gets heated by the sun. Fans draw outside air in through the perforations. It is warmed by the heated metal and passes on into the building, bringing warmth needed there. During any part of the day when this heat is not needed, the warm air is directed to a basement full of carefully arranged masonry blocks. These store the heat until needed, perhaps late in the day. Then the transpiration is turned off and building air is cycled through the masonry maze to be heated and returned to the occupied spaces. The building gets hot water and some assist to space heating from a wood chip fueled boiler.

The construction budget agreed in the end was $57.4 million (hard costs, including interior improvements). This does not include the photovoltaic array, which was acquired separately, in a partly private-sector way which leaves some of the array direct costs confidential and substitutes payments for power generated. An estimate based on then-current array costs indicated the RSF installation costing about $8 million. Together, this makes a construction cost of about $295 per square foot. Given the Denver area's generally lower construction costs, this is equivalent to about $385 in the Bay Area.

Bullitt Center

Under the leadership of its executive director, Denis Hayes, the Bullitt Foundation set itself truly pathbreaking goals when it decided on new construction for its offices in Seattle. Hayes, an energy visionary of long experience, convinced his board to make its new headquarters an icon of deep sustainability. The project thus differs in key organizational ways from the Packard project. High visibility is a goal, whereas at Packard the hope is to set a persuasive example in a low intensity way that diverts staff attention relatively little from the foundation's main business of grant-making. In addition, the Bullitt building's presence in the world will be importantly connected with Hayes' high personal visibility, whereas the Packard approach is more about the collaborative effort of many than about individual talents and personalities.

The Bullitt project fits a common idea of how major change takes place. A visionary leader sees opportunity and seizes it, mobilizing support and driving forward by force of personality. Talented people rally around the clarity and decisiveness that a single strong leader can provide, and great obstacles are overcome.

Packard, on the other hand, has followed a different path, and one perhaps more accessible to the general run of organizations. Steady leadership has been quite important to the making of 343 Second Street, but it has shown itself in the nurturing of collaboration and consensus, making it possible for momentum to accumulate throughout the organization and thus be able to carry sustainability forward without continued need to be rallied from above.

The Bullitt Center does break important new ground. A much smaller organization than Packard, at $104 million in assets vs $5.8 billion, Bullitt only needs about 4,000 square feet for its operations. Whereas Packard and NREL are both owner-occupiers, Bullitt would largely be a landlord, renting space to commercial tenants at viable rates. The location is Seattle's general business district, and the site is typical—about 10,000 square feet on the ground, and a height limit which allows six stories. The finances in such building call for building all six, with strong consequences for the other half of the Bullitt agenda, the environmental program.


bustler.net

Bullitt aimed its building at the most stringent standard in existence, the Living Building Challenge.[51] This requires buildings to demonstrate through a year of actual performance that they meet or exceed specific targets in seven areas—site impacts, energy, water, health, equity, and beauty. The energy standard is no surprise—net zero. But alongside it go nineteen other requirements, of which the most stringent are net zero water (all water supplied by precipitation), and no materials from a "red list" of toxics.

Net zero energy in a six-story building makes the energy budget very tight. Recall that Packard's two-story building, with 13,400 square feet of usable roof, in comparatively sunny California, needed thoroughgoing attention to efficiency to get its energy needs in balance. The Bullitt Center would have about the same floor space, but spread over six stories on a much smaller site, offering perhaps 9,000 total square feet. And it would be located in notoriously cloudy Seattle.

As these constraints played out through a multi-stage design process, Bullitt's design team pursued efficiency with equal energy and roughly equal success. The building would require 236 MWh/year, compared to Packard's 247 MWh/year. To get this out of 30% less area of solar panels in a cloudier climate, Bullitt's engineers had to push very hard. They successfully lobbied for city permission to extend the panel array out over the sidewalk, normally not allowed. They raised the array on a steel framework rather than attaching it directly to the roof. This is not unusual: Packard had rejected the framework for architectural reasons, as part of the desired low-key, non-industrial appearance. At Bullitt, the framework allowed much more of the roof

[51] consult http://living-future.org/lbc for additional information

to be used for panels, as maintenance and fire access could happen underneath the raised panels.

The Bullitt design also profited from advances in panel output of perhaps 25%. Finally, the design accepted a smaller safety margin than at Packard, 12% instead of 19%. The building has not completed its first year of operation yet, so one has yet to see how these choices play out. But at this point, photovoltaics and climate patterns are well enough understood that one can have good confidence that the array will perform as planned.

The demand side of the budget, with its needs for efficiency, shows differences from Packard and comes out slightly lower, at 16 kBtu/year per square foot versus 17. The Packard building uses much more energy to run its heating and cooling equipment, while Bullitt uses much more to operate pumps. This is a consequence of Bullitt's using a different source of heat.

As at 343 Second Street, Bullitt use electrically powered heat pumps to capture thermal energy from the environment for heating the building. But unlike Packard, the Bullitt building uses ground it stands on as the source of thermal energy (hence "ground source"). This requires a major extra step. Whereas simple fans can draw outside air through air-source equipment and send it away again, the ground stays where it is. To access its heat, one has to insert a pipe carrying water which absorbs the heat and brings it back to the heat pump. At Bullitt, this is done underneath the building, i.e. vertically in deep holes. Quite a large number are needed, and considerable pumping energy is required to move all that water through all that length of pipe. The same equipment is used in reverse when cooling is required, capturing heat from the building and transferring it back to the environment, and similar amounts of pumping are required for that.

Even if all of Bullitt's pumping energy is ascribed to heating and cooling, the building's total for this function is markedly less than Packard's. Possibly differences in climate account for this, though both locations are relatively temperate. Los Altos has more hot weather, Seattle has more cold, but the Bullitt building seems to need less energy for managing its internal climate in both seasons. Possibly it is the difference in heating/cooling delivery. Packard uses active chilled beams, as described earlier. Bullitt uses radiant floor slabs, where tubes carrying hot or cold water are embedded a floor made of concrete. This delivers heating or cooling directly to the zone where it is needed, i.e. the lower 6-8 feet of the space. This is a very efficient in itself. However, it does require more pumping, as the hot or cold water must be moved a long way through relatively narrow tubing. Moreover, the system needs the floor slab largely uncovered with carpeting, cork tiles, or other coverings, which would slow down heat transfer. The resulting appearance is much more congenial to the Bullitt Center's general aesthetic than to Packard's.

Ventilation is another area where Bullitt uses much less energy, 60% less.[52] This may also reflect a difference in aesthetics. The Bullitt building makes use of very large, slow-rotating ceiling fans for much of its air circulation. These are extremely efficient, but not even considered for the Packard building, because of the priority on keeping services and structure out of view. The active chilled beams used here are very efficient of their kind, but not in the same league as the large ceiling fans.

The energy use picture is reversed when it comes to plug loads and other miscellaneous equipment. The Bullitt Center estimates show it using 75% more energy in this category than 343 Second Street. Both totals include their respective server rooms. Both organizations worked very hard on defining and reducing plug loads, but came up with quite different totals. The difference probably comes from the differing numbers of expected regular occupants: the Bullitt Center expects about 60% more people to work there than in the 343 Second Street.

The two buildings are very close in their energy use for lighting and domestic hot water. As a minor difference, Bullitt has an elevator serving six stories rather than Packard's two, though considerable effort in the design went toward making an "irresistible stair," whose character and views would get people to walk up rather than ride the elevator, if they were at all able.

Finally, engagement of the users. The two buildings are very close in their need for users to understand, believe in, and actively support the sustainable goals embodied there. They are very different in the engagement process. Packard is an owner-occupier. Many of its users are staff who participated in the formulation of the project, and in the wider work on sustainability led by the Sustainability Task Force. The Bullitt building is basically commercial rental property. The Bullitt Foundation is an occupier, but most of the building users will be tenants.

Normally, as mentioned above, design teams hate any appearance of "telling the client how to live." When it comes to rental space, commercial landlords have the same attitude. But the Bullitt Center's performance hopes call for the same low levels of energy use as at Packard, and also make similar demands in several other sustainability areas. As landlords, the Bullitt Foundation has not shied from building these demands into its leases. This is genuinely frontier work. Tenants need to agree to keep their energy and water use within challenging limits, not use furniture that contains certain toxic materials, such as formaldehyde, and position their workers within 30 feet of a window.[53] Rents are set at Seattle Class A levels. There are penalties if tenants exceed their budgets, but rent rebates if their consumption falls under budget. There is also a provision for a kind of trading among tenants. Those

[52] "CCSDC_Energy_Performance_FINAL," internal report, Bullitt Foundation (no date)

[53] http://seattletimes.com/html/businesstechnology/2020481293_bullittleasesxml.html (accessed Sept. 15, 2013); interestingly, The Bullitt Center web page on leases does not mention energy and water budgets and other green constraints, but the leases do contain them.

who can operate under the building's energy or water budgets can trade some of their allotment with tenants who need more. It is the whole building's performance which must meet the net zero goals, not each individual tenant.

The cost of the building was $18.5 million ($355 per square foot; hard costs), which is said to be about $50 per square foot above the Seattle Class A average.[54] This figure includes neither tenant improvements nor soft cost items.

Net Zero Energy as a Transformative Goal

The stories of other large and small net zero projects are beginning to emerge, for example in the recent Getting to Zero National Forum,[55] and the frequently updated inventory of world projects compiled by Eike Musall of Wüppertal whose maps headed this section. The brief case studies and keynote overviews of the Getting to Zero Forum confirm a number of the themes in this study. I mention just a few. Net zero and similar performance goals both demand and reward integrated effort by designers, builders, and owners, starting early in design and extending well into the operational phase. Firm energy budgets, of the kind set by needing to operate within what one's rooftop PV system can provide, spur design teams to go the extra mile in finding energy efficiency. Great energy efficiencies are needed for net zero, and can be found. Contrary to the casual assumption that efficiencies cost more, there is considerable evidence that projects cost less if efficiencies are pursued from the beginning. Many of these efficiencies do need the engagement of building occupants, or inhabitants as they are beginning to be called, in recognition that they are meaningful actors, not just passive presences in the operation of offices and other workplaces. Lastly, what is acceptable as cost to turns out to be much more variable than facile bottom-line thinking would have it. Just as organizations and businesses have always varied in how much they would spend to present their chosen face to the world and to support their internal culture, public, private and non-profit entities also vary in how they conceive sustainability—how the state of the planet intersects with their interests and values now and in the future.

[54] http://www2.buildinggreen.com/blogs/americas-greenest-office-building

[55] September 17-18, 2013; Denver, Colorado; sponsored by the National Association of State Energy Officials (NASEO) and the New Buildings Institute.

6—BRIEF CONCLUSIONS AND NEXT STEPS

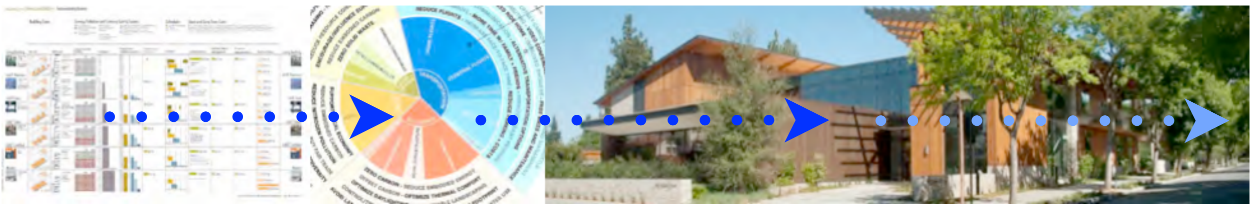
As I stated at the outset, the importance of 343 Second Street for sustainability is the character of the process by which it came about—intimate, judicious merging of technical possibilities with organizational priorities and values. It was conducted with remarkable steadiness, wide staff and leadership engagement, and a recognition that beauty matters and can be achieved in ways that are true to the personalities and the practicalities in play.

As other organizations consider green buildings of their own, this threesome of steadiness, wide engagement, and a place for beauty will need to consort with technical expertise. The individual technologies used at 343 Second Street are well established. The technical achievement of 343 Second Street, and it is considerable, is to have deployed well established technologies in sensitively integrated fashion.

Packard's very clear achievement, alongside the strong promise of projects like the Bullitt Center and the NREL Research Support Facility, show that net zero energy for low-rise offices is within reach in a fairly wide range of climate conditions. If an organization can bring steadiness, wide engagement and a self-aware recognition of beauty to a project, and if it teams up with a design team that understands integrating systems into harmonious wholes, the chances of joining the Packard Foundation's league are excellent.

In architecture and construction, the client is most often called "the owner." The term accurately enlarges one's understanding of the stakes. The owner does not just take advice, or receive services of an ephemeral kind. The owner ends up with a large, heavy, expensive, inertia-laden physical object, and with serious ongoing responsibilities that this object imposes. The doing of sustainability will increasingly become such a responsibility. It is the owner's people, then, who most need to understand how a good project like 343 Second Street came about. As you have seen, the Packard story has no great melodrama, but it has important twists and turns, shifts and sharpening of goals, emergent costs and benefits, many of which occurred among Packard's people, the owner's people. It is these people I am mainly writing for.

Finally, if sustainability is something you do, not something you have, then the Packard Foundation has continuing work in front of it. In addition to maintaining its level of cooperation and initiative at the desk level, even as the freshness of the new building fades, the foundation faces additional choices. Transportation, both commuting and business travel, remains much the largest contributor to the organization's carbon footprint, and new ideas, effort, and commitment are sorely needed. Closer to the building itself, the foundation needs to consider what standards to adopt for its ongoing operation. 343 Second Street is LEED Platinum as well as net zero in energy. The LEED system addresses much in addition to energy, as we have seen. It also has a standard, LEED-EB, which applies to existing buildings and calls for high performance in a similarly wide-ranging way. The Foundation should specifically consider adopting LEED-EB as a guide to its future performance.



Packard Foundation (left); EHDD Architecture (center); Jeremy Bittermann (right)

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