Project Report—
Deep Energy Efficiency: Getting to Scale (Lighting)

University of California
Carbon Neutrality Initiative
Global Climate Leadership Council

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Executive Summary

Energy Efficiency is a primary strategy component for achieving carbon neutrality, reducing life-cycle costs as well as the costs of de-carbonizing residual energy use.

2004-2014 UC retrofits in conjunction with the UC/CSU/Utility Partnership and Statewide Energy Partnership (SEP) have avoided as much as an additional 12% of total scopes 1 and 2 CO_2e emissions relative to a total 2014[1] baseline. Interior and exterior lighting efficiency avoided as much as 1.3% of total scopes 1 and 2 CO_2e emissions relative to a total 2014 baseline.

This project and the 2014 Deep Energy Efficiency and Cogeneration (DEEC) Study, have identified an additional 29-36+% of potential for avoided emissions through energy efficiency including 7-8% from lighting retrofits alone. This is a high scenario but not an upper bound. Application of similar methodology to the Smart Lab and Deep HVAC efficiency estimates in the DEEC study will likely result in identification of additional potential (e.g., including buildings under 40,000 gsf).

The potential suggests the pace of retrofits will need to increase substantially in order to capture the full potential of energy efficiency at scale toward reducing the cost of carbon neutrality by 2025. Some campuses are pursuing energy efficiency at a faster pace. The Irvine main campus in particular is on track with a least-cost carbon neutrality path fully utilizing energy efficiency retrofits. This exemplar demonstrates the necessary scale for energy efficiency is achievable and suggests some important directions.

Several initiatives over the last decade have set the stage for getting to scale with energy efficiency. In addition to the Utility Partnership and SEP, the State Partnership for Energy Efficient Demonstrations, the California Higher Education Sustainability Conference and the UC Davis Smart Lighting Initiative have all helped increase the pace and depth of energy efficiency retrofits.

This study builds on these efforts to identify strategies to fully scale deep energy efficiency for one major end-use (lighting), analyze related issues, and make recommendations for implementation. This work is applied to a business plan template and two example business plans for deep energy efficiency at scale.

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[1] 2013 emissions used for one campus.

Scope

This study includes:

- analysis of the UC Davis Smart Lighting Initiative,
- development of a streamlined planning process in conjunction with a Bren School of Environmental Science and Management master's thesis on technological and financial strategies for achieving carbon neutrality at UCSB by 2025, and
- detailed analysis of LED lighting reference projects at UC campuses.

The results include:

- lighting retrofit planning metrics,
- lighting retrofit planning designs
- reference project costs, design, and performance information
- assessment of financing options including the existing bond-based loan program and a new re-investment spin-up model, and
- recommendations for necessary staffing.

Planning-Level Project Design

The nominal deep lighting retrofit project design identified by this study is:

1) full rebuild of fixtures with LED technology and new optics, removing fluorescent ballasts and lamp holders, and
2) fully tunable networked lighting controls—with an average of 3 fixtures per zone in most areas.

This nominal project design can typically reduce lighting energy use and associated GHG emissions to less than 20% of a typical aggregate baseline. The typical baseline for lighting intensive campus buildings (excluding storage, parking, and other space with low energy use) is around 4 kilowatt-hours (kWh) per year per gross square foot (gsf) of floor area. The typical average residual use after retrofit is around 0.5 kWh per year per gsf.

New LED fixtures or fixture-level control granularity are variations on the nominal deep lighting retrofit project design seen in some reference projects. Some reference projects use local controls in some scenarios, particularly private offices.

Ballast compatible plug-in LED lamps are being employed in limited scenarios around the UC system including CFL-based fixture types for which fuller retrofit options are less mature or when buildings have less than five years remaining life. This option is also the predominant choice in at least one campus' comprehensive retrofit program for housing. Ballast compatible plug-in LED lamps do not reduce maximum power, offer as much control potential, or promise as much durability as do full fixture replacement or rebuild options. However first costs that are lower by an order of magnitude sometimes make them a compelling choice[2].

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[2] Retrofit options that rewire existing lamp holders are not commonly seen around the UC system. These options are not recommended because they create complex safety protocols.

Financing

Loans

The nominal deep lighting retrofit project design is typically financeable with UC general-purpose revenue bond-based loans for most space types (excluding private offices) at electricity prices above $0.105 per kWh. Debt constraints are currently limiting this scenario for some campuses. Other types of UC bonds are being explored as possible alternatives that may not be as limited by debt-constraints. This discussion is ongoing.

Utility on-bill financing has also been used on a limited basis. This scenario may not impact campus debt in the same way as general-purpose bond-based loans. This option has been subject to per-account limits that have been somewhat restrictive for large main campus master-meter accounts. Relaxation of these limits may allow more on-bill financing in the future.

Subsidies

Substantial subsidies for energy efficiency retrofits continue to be available to most campuses through the UC/CSU/Utility Partnership[3]. Utility incentives can allow incrementally deeper energy savings from more efficient LED fixture rebuilds or replacements, more granular controls or more tunable controls, or integration with control of other energy end-uses. Utility incentives can also allow incrementally more energy savings through application of the nominal project design to more space-types (e.g., private offices) or to more buildings in cases when financing is constrained.

Spin-up Reinvestment

Spin-up reinvestment of energy budget surplus is another financing method that can be used either in conjunction with loan scenarios, or where debt constraints preclude loan financing. In this scenario, unrestricted seed funding or loan financing, often in conjunction with incentives, is used to fund an initial portfolio of energy efficiency projects. The utility surplus created by these projects, net of any debt service, is then re-invested in more energy efficiency projects. Compounding re-investment can multiply seed funding by factors of two-to-three in the timeframe of the 2025 Carbon Neutrality Initiative.

Sources of seed funding could include proceeds from campus sale of excess Cap and Trade permits, donor funding, or utility budget surplus resulting from energy price decreases[4]. The spin-up scenario is different from common revolving fund scenarios that attempt to preserve capital. Compounding re-investment is possible only with no expectation of repayment of seed funding. The full utility budget surplus created by the projects is then available as a windfall once

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[3] The UC/CSU/Utility Partnership has recently expanded to include the Los Angeles Department of Water and Power, providing electricity service to the UCLA main campus. Subsidies are expected to endure, despite some recent complexity around project eligibility.

[4] Allocation of Cap and Trade proceeds (i.e., 2016-2017 proposed California State Budget) have not materialized

additional reinvestment is no longer required (e.g., 2025 for a plan timed around the Carbon Neutrality Initiative), earlier than for new debt service.

Planning

Planning for energy efficiency retrofits at scale is enabled by a streamlined early analysis methodology that produces cost and value estimates suitable for planning purposes, but defers precision of detailed project design to implementation stages.

Timing of Detailed Project Design

Detailed project design steps are an integral part of retrofit project implementation. These steps need to be identified and budgeted for as a part of planning to scale. However, getting to scale will often require putting a plan in place, establishing requisite staffing, and securing initial funding before these steps are executed.

Expediency

Creating a plan for efficiency retrofits at scale can and should often be implemented with modest available staff and student resources. An example of this is at UC Santa Barbara—where this project and a parallel student effort resulted in an analysis of all energy efficiency retrofit opportunity for the campus (Bart et al 2016), as well as forming much of the basis for the Business Plan template in this report (Chapter BP).

This effort worked with sample audits in eight buildings and one in-progress campus reference project—planning around just a few predominant fixture types, general building types and space categories. Campus information was supplemented with reference project information from other campuses.

UC Riverside is directly using planning metrics from the Business Plan template, adding a short-term scenario for buildings scheduled for demolition in 3-5 years.

Lawrence Berkeley National Laboratory (LBNL) is proceeding with similar planning, but going further along into the implementation process. This effort is using additional resources including past comprehensive audits and consultant effort to identify specific solutions for more fixture types, obtain higher precision performance estimates, and create information suitable for bid packages for pilot projects. LBNL is considering maintenance savings and integration with HVAC controls in a broad assessment of operational costs.

Staffing

The most frequently articulated barrier to ramping up efficiency retrofit activity is availability of staffing for project development and management. On the order of 1.2 full time equivalent (FTE) professionals per million gsf of floor area is appropriate for a retrofit portfolio capturing the full potential of energy efficiency in all end-uses by 2025. Roughly one-quarter of this is typically commensurate with lighting projects. This perspective is based on the experience of campuses already achieving some scale with energy efficiency, as well as the typical percentage of total project costs going toward the in-house staffed aspects of retrofit activities. Some of the necessary staffing for project management is often shared with capital projects units.

Economies of scale should be sought, but are challenging to achieve because of the highly granular nature of campus energy using systems, the uniqueness of virtually every building, the diversity of space types and business functions, and the granularity of documentation required for securing subsidies, especially for lighting. Some outsourcing of project development and management is being explored by some campuses, but with limited success. Some of the project functions, such as contract management and liaison with building and department managers, are difficult to outsource in a university campus environment. In addition, energy efficiency retrofit (especially LED lighting retrofit) is a fast moving field, with the consultant community struggling to keep up with cost trends and critical applications information. In-house energy management staffing, with the peer-group interactions and technology expertise available within the UC system, may be the best way to achieve the best possible project designs.

Necessary staffing scale-up may be bold, but on the same scale as capital projects staffing and not unusual for a major campus initiative. Project development and management staffing is fundable as a component of energy efficiency retrofit projects. There are few other opportunities that have as straightforward a value proposition, with substantial avoided costs net of project financing.

Embedded barriers to scaling of energy management staffing can include assessments of potential that are self-limited by perceived constraints of existing staffing levels and recruiting in a job market with significant demand for energy management professionals.

The following strategic approaches are suggested for overcoming barriers associated with staffing needed for project development and management of energy efficiency retrofit projects at scale:

- Develop a staffing proposal within an overall business plan for energy efficiency retrofits at scale, including the value proposition.

- Evaluate the opportunity from a high level. The combined sustainability (including CNI) and financial value proposition spans multiple campus units including budget and sustainability offices. Part of the necessary staffing may be best located in larger self-funded units such as housing. The existing energy or project management function may matrix into several units, needing coordination. Decisions to expand staffing are typically initiated from above in a top-down university budgeting environment. These factors point toward consideration of staffing initiatives and the overall business plans for energy efficiency at the Vice-Chancellor for Administration level.

Alignment with Carbon Neutrality Planning and Other Campus Planning

Planning for energy efficiency retrofits at scale should be fully integrated into 2025 carbon neutrality planning and other campus planning. Integrated planning will ensure the opportunity is fully valued and the necessary pace is recognized. Consideration of renovation scheduling in retrofit portfolio planning can provide economies of coordination.

Analysis should illustrate baseline and residual energy use and GHG emissions (e.g., not just "savings"). It is also desirable to characterize baseline, residual, and avoided energy use and GHG emissions for the systems being retrofit as percentages of overall campus or unit amounts (e.g., not just absolute values). It is also helpful to provide the context of the overall retrofit portfolio to-date, to provide perspective on the scale and pace of required efforts.

1. Background

Energy Efficiency is a primary strategy component for achieving carbon neutrality, along with de-carbonization of the residual energy supply. Electrification can sometimes support both these strategies, especially in the development of new facilities. The bulk of Scope 1 and 2 greenhouse gas (GHG) emissions are the result of campus building energy use. Energy use for site lighting also contributes a significant amount of emissions.

Impressive system wide energy efficiency initiatives have already resulted in significant avoided GHG emissions, providing leadership in climate stabilization and helping to set the stage for the 2025 Carbon Neutrality Initiative. There remains significant efficiency potential at a depth and scale perhaps three times again that already achieved. The pace of necessary project activity—to achieve this potential in the timeframe necessary to stabilize the climate or meet the 2025 goal—is beyond that achieved by most campuses or by most organizations in a broader context.

The traditional incremental planning of building energy efficiency retrofits often fails to address barriers associated with organizational resources, and lacks tools to mange depth and scale. The project “Deep Energy Efficiency—Getting to Scale” (the “Project”) seeks to inform a systematic, even strategic, approach to planning building energy efficiency retrofits at depth and scale.

The Project has identified a manageable scope to explore a systematic approach to deep energy efficiency at scale—one major end-use (lighting) on four campuses.

1.1 UC Achievements in UC/CSU/Investor-Owned Utility Partnership 2004-2014

In 2004-2014 the UC/California State University/Investor-Owned Utility (IOU) Partnership incentivized UC retrofits, including monitoring-based commissioning, that have avoided 240 million kWh per year of electricity use and 14.7 million therms per year of natural gas use (Table 1). Interior and exterior lighting retrofits accounted for 58 million kWh per year (Table 2). In later years, UC bond-funded loans (Statewide Energy Partnership) provided much of the balance of funding for these projects through the Statewide Energy Partnership (SEP), enabling the portfolios to move toward scale.

This Project takes steps toward integrating energy efficiency planning with 2025 Carbon Neutrality Initiative planning. The impact of avoided energy use from 2004-2014 retrofits can be expressed as avoided CO_2e emissions and compared with system-wide total CO2e emissions from natural gas, steam, and electricity purchases or with total 2014 Scope 1 and 2 CO_2e emissions[5][6].

2004-2014 UC retrofits in conjunction with the UC/CSU/IOU Partnership have avoided an additional 10-13% of CO_2e emissions from natural gas, steam and electricity use, and 10-12% of total scopes 1 and 2 CO_2e emissions relative to a total 2014 baseline. Interior and exterior lighting efficiency accounted for 1.1 – 1.3% of CO_2e emissions from natural gas, steam and electricity use, and 1.0-1.3% of total scopes 1 and 2 CO_2e emissions relative to a total 2014 baseline (Table 2).

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[5] From Climate Action Plan (CAP) Annual Inventories.

[6] 2013 emissions used for one campus.

Table 1: Avoided Energy Use & CO_2e Emissions from Energy Efficiency Retrofits—
Achieved by UC in Conjunction with **2004-2014 UC/CSU/IOU Partnership**
All Efficiency Retrofits (including monitoring-based commissioning)

Avoided Energy Use	240 million kWh per year	
	14.7 million therms per year	
Aggregate CO_2 Emission Factor (electric IOU campuses)	0.000295 MT/kWh	
Aggregate CO_2 Emission Factor (all campuses)	0.00538 MT/therm	
Total UC 2014 CO_2e Emissions— from Natural Gas, Steam, and Electricity Purchases	1,121,000 MT per year	
Total UC 2014 CO_2e Emissions— Scope 1 and 2	1,178,000 MT per year	
Bounding Scenario	All avoided use is directly purchased energy	All avoided use is cogenerated energy
Avoided CO_2e Emissions	141,000 MT per year	114,000 MT per year
CO_2e Avoided Relative to 2014 Natural Gas, Steam & Electricity	13%[7]	10%
CO_2e "Wedge" Relative to Total 2014 Scope 1 & 2 Emissions	12%	10%

Table 2: Avoided Energy Use & CO_2e Emissions from Energy Efficiency Retrofits—
Achieved by UC in Conjunction with the **2004-2014 UC/CSU/IOU Partnership**
Interior and Exterior Lighting

Avoided Energy Use—Interior Lighting	49 million kWh per year	
Avoided Energy Use—Exterior Lighting (incl. parking garages)	9 million kwh per year	
Avoided Energy Use—Interior and Exterior Lighting	58 million kWh per year	
Aggregate CO_2e Emission Factor (electric IOU campuses)	0.000258 MT/kWh	
Total UC 2014 CO_2e Emissions— from Natural Gas, Steam, and Electricity Purchases	1,121,000 MT per year	
Total UC 2014 CO_2e Emissions— Scope 1 and 2	1,178,000 MT per year	
Bounding Scenario	All avoided use is directly purchased energy	All avoided use is cogenerated energy
Avoided CO_2 Emissions	15,000 MT per year	12,000 MT per year
CO_2e Avoided Relative to 2014 Natural Gas, Steam & Electricity	1.3%	1.1%
CO_2e "Wedge" Relative to Total 2014 Scope 1 & 2 Emissions	1.3%	1.0%

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[7] The avoided fraction of total CO2e emissions from natural gas, steam, and electricity purchases is lower than the avoided fraction of $ expenditure (~18% in the directly purchased energy scenario).

1.1.1 UC Irvine Exemplar

UC Irvine has achieved the greatest scale of energy efficiency retrofit relative to campus size for lighting as well as for overall retrofits. Avoided CO_2e emissions from all retrofits total 23-28% of natural gas, steam and electricity use, and 21-26% of total scopes 1 and 2 CO_2e emissions relative to a total 2014 baseline (Table 2a).

Table 2a: Avoided Energy Use & CO_2e Emissions from Energy Efficiency Retrofits—
Achieved by UC Irvine[8] through the **2004-2014 UC/CSU/IOU Partnership**
All Efficiency Retrofits (including monitoring-based commissioning)

Avoided Energy Use	60 million kWh per year	
	2.3 million therms per year	
CO_2 Emission Factor	0.000275 MT/kWh	
CO_2 Emission Factor	0.00534 MT/therm	
Total UC Irvine 2014 CO_2e Emissions— from Natural Gas, Steam, and Electricity Purchases	103,000 MT per year	
Total UC Irvine 2014 CO_2e Emissions— Scope 1 and 2	108,000 MT per year	
Bounding Scenario	All avoided use is directly purchased energy	All avoided use is cogenerated energy
Avoided CO_2e Emissions	29,000 MT per year	23,000 MT per year
CO_2e Avoided Relative to 2014 Natural Gas, Steam & Electricity	28%	23%
CO_2e "Wedge" Relative to Total 2014 Scope 1 & 2 Emissions	26%	21%

1.1.2 Methodology for Reporting Avoided Emissions

This analysis provides a new basis for reporting combined impacts of natural gas, steam, and electricity consumption—by CO_2e emissions—an alternative to the traditional combinations by site energy use, source energy use, or $ expenditures. Tracking of the avoided use by energy type should be maintained, but comprehensive reporting by CO_2e emissions proves useful, especially for characterizing overall impact in the context of campus cogeneration plants.

Methodology was also created to enable rough estimation of avoided emissions from partially cogenerated energy—establishing a bounding scenario assuming all avoided energy is cogenerated.

Bounding Scenario Discussion:

- **All avoided use is directly purchased energy**—avoided energy use is concurrent with and less than direct energy purchases. This is the scenario for non-cogeneration campuses, and as a bounding scenario could approximate the scenario for peak energy use on cogeneration campuses.

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[8] Figures include the Medical Center. Over 95% of the emission reduction has been on the main campus.

- **All avoided use is cogenerated energy.** This bounding condition is not at all applicable to the campuses without cogeneration. It is also perhaps unlikely to be reached for cogeneration campuses if cogeneration is preferentially operated to avoid direct energy purchase. This scenario is presented to allow estimation of the likely scenarios in which avoided use is a blend of cogenerated and purchased energy. The factor used to convert emissions of directly purchased energy to emissions of cogenerated energy is 0.81. This assumes:
    - aggregate electricity and natural gas emission factors of 0.000295 MT/kWh and 0.053 MT/MMBtu
    - heat rate of 9,215 Btu/kWh
    - cogeneration heat recovery efficiency ~ boiler efficiency
    - idealized cogeneration operation utilizes all waste heat, avoided use energy mix is the same as cogeneration production mix (these assumptions minimize the factor)

Because of the high fraction of de-carbonization of directly purchased electricity, the difference between the bounding scenarios is not as large as it once was. This suggests a simplified analysis when the fraction of avoided energy that is cogenerated is uncertain or too complex to analyze. Applying a factor of 0.9 to the bounding scenario of all directly purchased energy provides an estimate with uncertainty due to cogeneration only plus or minus 10%.

1.1.3 Other Steps Toward Scale

Other provisions for getting to scale have been part of the implementation of the UC/CSU/ IOU Partnership and SEP. Introduction of, and strategic planning for, the monitoring-based commissioning delivery mechanism have enabled a significant degree of scale for this UC/CSU/IOU Partnership element (Meiman et al 2012). Along with the California Higher Education Sustainability Conference Series, the Training and Education element of the UC/CSU/IOU Partnership has enabled sharing of best practices. Collaboration with the California Energy Commission through the State Partnership for Energy Efficient Demonstrations (SPEED) program, including demonstrations and development of business cases, has set the stage for getting to scale, especially for LED and adaptive lighting technology (Johnson et al 2012).

1.2 Overall Energy Efficiency Potential— Deep Energy Efficiency and Cogeneration Study

In 2014 UCOP commissioned an ambitious, insightful, and informative Deep Energy Efficiency and Cogeneration (DEEC) Study for UC campuses from ARC Alternatives (ARC Alternatives 2014). This analysis followed some precedents from previous energy efficiency scoping projects[9], providing information for planning of efficiency retrofits. This study took more steps toward scale by focusing on deep efficiency measures and considering all UC buildings with floor area over 40,000 gross square feet[10]. The deep efficiency focus meant that the most comprehensive financeable measures were prioritized over incremental measures. Campuses with municipal electricity providers and medical centers were included.

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[9] e.g., Strategic Energy Plans by Newcomb Anderson McCormick in 2008

[10] Strategic Energy Plans emphasized buildings with over 50,000 gross square feet of floor area.

This study used simple models that proved useful—for planning and moving forward to identify the resources needed to achieve deep efficiency at some scale. Projects were characterized in three categories: smart labs, deep HVAC and smart lighting. Monitoring-based commissioning was considered as one major delivery mechanism for deep HVAC. Results are summarized in Table 3.

Table 3: Avoided Energy Use & CO$_2$e Emissions from Energy Efficiency Retrofits—
Projected by Deep Energy Efficiency and Cogeneration (DEEC 2014) Study

Avoided Energy Use (Low-High Estimate)	369-485 million kWh per year	
	13-18 million therms per year	
Aggregate CO$_2$e Emission Factor (all campuses)	0.000295 MT/kWh	
Aggregate CO$_2$e Emission Factor (all campuses)	0.00538 MT/therm	
Total UC 2014 CO$_2$e Emissions— from Natural Gas, Steam, and Electricity Purchases	1,121,000 MT per year	
Total UC 2014 CO$_2$e Emissions— Scope 1 and 2	1,178,000 MT per year	
Bounding Scenario	All avoided use is directly purchased energy	All avoided use is cogenerated energy
Avoided CO$_2$e Emissions from Deep Energy Efficiency in DEEC Study (Low-High Estimate)	178,000-242,000 MT per year	144,000-196,000 MT per year
CO$_2$e Avoided Relative to 2014 Natural Gas, Steam & Electricity	16-22%	13-18%
CO$_2$e "Wedge" Relative to Total 2014 Scope 1 & 2 Emissions	15-21%	12-17%

1.2.1 Smart Lighting in DEEC

Potential lighting savings in the DEEC study are 67-79 million kWh/year out of a total 369-485 million kWh per year for smart lighting, smart lab, and deep HVAC retrofits (Table 4). The DEEC study accounted for interior lighting retrofits in laboratory building in "smart lab" measure totals. The DEEC study did not include garage, exterior, or site lighting.

Table 4: Avoided Energy Use & CO$_2$e Emissions from Energy Efficiency Retrofits—
Projected by Deep Energy Efficiency and Cogeneration (DEEC 2014) Study
For Smart Lighting (Interior)

Avoided Energy Use (Low-High Estimate)	67-79 million kWh per year	
Aggregate CO$_2$e Emission Factor (all campuses)	0.000295 MT/kWh	
Total UC 2014 CO$_2$e Emissions— from Natural Gas, Steam, and Electricity Purchases	1,121,000 MT per year	
Total UC 2014 CO$_2$e Emissions— Scope 1 and 2	1,178,000 MT per year	
Bounding Scenario	All avoided use is directly purchased energy	All avoided use is cogenerated energy
Avoided CO$_2$e Emissions from Deep Energy Efficiency in DEEC Study (Low-High Estimate)	20,000-23,000 MT per year	16,000-19,000 MT per year
CO$_2$e Avoided Relative to 2014 Natural Gas, Steam & Electricity	1.8-2.1%	1.4-1.7%
CO$_2$e “Wedge” Relative to Total 2014 Scope 1 & 2 Emissions	1.7-2.0%	1.4-1.6%

1.3 This Project

This one-year applied research effort was initiated to explore planning methodology—for capturing the potential of comprehensive energy-efficiency retrofits system-wide toward the 2025 carbon neutrality goal—or deep energy efficiency at scale[11]. A manageable scope for the Project was achieved by focusing on lighting retrofits on four campuses—Santa Barbara, Riverside, Los Angeles, and Davis; along with the Lawrence Berkeley National Laboratory.

Lighting was selected as the end-use because, in comparison with other end-uses, the transformational technology advance, to light emitting diode (LED) and adaptive lighting controls, is already relatively complete. The Project focused almost exclusively on LED technology. The UC “living laboratory” experience with LED and adaptive lighting technology is enabling expansion of the scope from remaining technical issues to the issues of getting to scale.

LED technology is one of the most important innovations supporting climate stabilization. UC has played a key role in basic research, as well as technology integration and technology transfer, to accelerate adoption of LED lighting. The UC living laboratory for advanced lighting technology has included extensive demonstrations and best practice projects by UC facilities. UC research units have supported these efforts, most prominently the Solid State Lighting and Energy Electronics Center (SSLEEC) at UC Santa Barbara, the California Lighting Technology Center (CLTC) at UC Davis, and the California Institute for Energy and Environment (CIEE).

The Project has refined estimates for the potential of additional lighting efficiency retrofits at depth and scale and seeks to align this analysis with planning for 2025 carbon neutrality. It has

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[11] Carbon Neutrality Initiative/Global Climate Leadership Council Project—Deep Energy Efficiency: Getting to Scale (Lighting)

also developed planning methodology—exploring financial issues and crafting business cases. The planning methodology is intended to be replicable by other campuses and for other end-uses for which technology transition is more complex.

1.3.1 This Report

This is a Review DRAFT of the complete Project Report. This report includes a business plan template as Chapter BP. Two campus-specific Business Plans are attached—from UC Riverside and Lawrence Berkeley National Laboratory

2. Initial Assessment of Avoided $C0_2e$ Emissions from Deep Energy Efficiency at Scale—Lighting

The Project initially assessed the size of the CO2e emissions wedge[12] from deep lighting energy efficiency at scale—to inform the other elements. This effort built on some excellent previous steps toward planning for depth and scale around the UC system: the Smart Lighting Initiative (SLI) at UC Davis, the 2014 Deep Energy Efficiency and Cogeneration (DEEC) Study, and the UC Irvine exemplar. The Project augmented this informative work with initial planning and sample audits at Santa Barbara and Riverside, as well as SLI Phase II project evaluation at Davis.

2.1 UC Davis Smart Lighting Initiative (2007-present)

The UC Davis campus took a major step to depth and scale—by extending planning for retrofit of CLTC-enabled lighting technology campus-wide with the Smart Lighting Initiative. (SLI). This was the first publicly described campus planning for efficiency retrofit at full scale, with the intent of comprehensively upgrading one energy use subsystem—lighting—with all appropriate retrofit measures. This was expressed in the primary goal of the SLI—to reduce campus electricity use for lighting by 60 percent from a 2007 baseline[13]. The initiative has already met this goal for exterior and site lighting (including parking garages), with significant use of LED and adaptive technology. The initiative has made significant progress toward that goal for interior lighting.

2.1.1 Baseline Modeling

The CLTC developed baseline models to inform SLI planning. The exterior lighting model used a detailed luminaire (lighting fixture) inventory and straightforward assumptions about operating hours to establish a 2007 baseline for exterior lighting energy use. Parking garages are included in the exterior model with 24/7 operation (8,760 hours per year). Operation of pathway, road and other exterior lighting is assumed to correspond to dark hours (excluding dawn and dusk) at 4,075 hours per year. (This methodology may result in a conservatively low number in some scenarios.) Estimated hours of use for recreational fields are much lower. The total exterior and garage lighting energy use was estimated at 4.5 million kWh per year.

Assessing interior lighting baseline conditions presents a number of challenges. The SLI baseline model for interior lighting took a simple approach that proved useful in setting targets and moving forward expeditiously. A sample set of 20 buildings was selected for assessment. The process used sample audits and plan take-offs to assess baseline lighting power density (LPD). Sample light and occupancy logging, logging from previous audits, and assigned values from the Database For Energy Efficient Resources were used to assess operating hours (DEER 2015). Results were

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[12] Planning wedge concept by Socolow et al graphically breaks down solutions to multifaceted problems like climate stabilization into component parts.

[13] This target closes the loop on an RD&D- and technology-driven California Public Utilities Commission Lighting Action Plan (CPUC 2010) with a similar goal.

aggregated into an estimated campus-wide average for LPD and effective full load hours (EFLH). The average LPD is estimated at 1.18 Watts per gross square foot (gsf) of floor area. The average EFLH is estimated at 3,504 hours per year. The resulting estimate for average lighting energy intensity is 4.13 kWh per year per gsf.

This model was applied to 11.1 million gross square feet of 2007 floor area to estimate total interior lighting energy use at 46 million kWh per year. Uncertainty in this number was estimated to be plus or minus 16% with a 95% confidence level. Preliminary review and insights from other campus planning indicates the energy use estimate may be too high—because residence halls and low lighting intensity buildings may have been underrepresented in the sample building set.

2.1.2 Implied Planning Metrics

The planning goal of 60% reduction in energy use implies an average avoided use of 2.48 kWh per year per gross square foot and 1.65 kWh per year per gross square foot residual (post-retrofit) use.

2.2 SLI Progress To-date

2.2.2 Exterior Lighting

The SLI has met its goal for exterior lighting (including garages). Campus records indicate 2.8 million kWh per year of energy use reduction by retrofits through 2014 or a 62% reduction from the 2007 baseline. Projects with another 0.4 million kWh of energy use reduction have been proposed. (UC/CSU/IOU Partnership records indicate 2.5 million kWh per year of incentivized savings through 2014, with another 0.16 million KWh per year in 2015. Some projects may not have been done in conjunction with the UC/CSU/IOU Partnership or may not have been eligible for incentives.) The technology portfolio used to accomplish this included LED and networked adaptive controls (Bedwell 2012). Davis is an existence proof for deep light efficiency retrofits at scale for exterior (including garage) lighting.

2.2.3 Interior Lighting

The SLI has made significant progress toward its goal for interior lighting. SLI projects through 2013 included UC/CSU/IOU incentivized projects with 2.8 million kWh per year of savings plus major renovation projects in baseline space with 1.3 million kWh per year of avoided use. A 'Phase 2' of projects was completed in 2014-2015, which targeted 5.6 million kWh per year of savings in four Areas. The projected savings assessment was adjusted to 4.8 million kWh per year to align with some incentive rules that conservatively estimate savings from adaptive controls. At the end of the project some 'deemed savings' rules were applied to parts of the projects, further reducing the incentivized savings to 3.7 million kWh per year. This illustrates an issue facing deep energy efficiency retrofits at scale. All avoided energy use—reductions that may be eligible to fund loan debt service and may be associated with avoided CO_2e emissions—may not be eligible for incentives.

Phase 2 Area 1 projects with 0.6 million kWh per year of savings are in the overall 2004-2014 UC/CSU/IOU Partnership totals reported earlier. Areas 2-4 of Phase II are in a supplementary accounting of lighting projects including 2015. Additional phases of projects with projected savings of 11.3 million kWh per year of savings are envisioned, bringing the projected savings estimate to ~20 million kWh.

2.3 Lighting in the Deep Energy Efficiency and Cogeneration Study (2014)

The Deep Energy Efficiency and Cogeneration (DEEC) study identified potential for 67-79 million kWh/year of avoided energy use from interior lighting retrofit in all UC campus buildings above 40,000 gross square feet of floor area. This did not include laboratory buildings as potential was included in "smart lab" measure totals. (Please see Section 1.2.1 and Table 4 for more information.)

The DEEC study used UC Davis SLI planning metrics and UC campus information—to partially identify UC system-wide potential for smart lighting retrofits, accompanied by similar analysis for smart lab retrofits and heating, ventilation and air conditioning retrofits.

The DEEC study identified 3.3 to 3.8 million kWh of potential lighting energy efficiency retrofits at the UC Davis main campus. Exclusion of buildings with floor area under 40,000 gross square feet and laboratory buildings from the lighting retrofit savings totals in DEEC study are the two primary reasons why the DEEC study numbers for the main Davis campus are only about one-third that projected for future phases of the Smart Lighting Initiative. Reconciling this gap was an important initial goal of the Project.

2.4 Analysis of Lighting Retrofits by the UC/CSU/IOU Partnership

Progress toward scale for interior lighting can be assessed through an analysis of the UC part of the 2004-2014 UC/CSU/IOU Partnership project portfolio, supplemented with 2015 results and other results from the UC Davis SLI. For campuses with electricity service from IOUs and full access to UC/CSU/IOU Partnership, the average avoided use per year per gsf (normalized to 2014 gross floor area) is 0.56 kWh per year per gsf. Including 2015 projects brings this to 0.65 kWh per year per gsf. Considering the size of the UC system, this is a very large amount of lighting retrofit activity, but not yet approaching the scale of ~2+ kWh per year per gsf that the SLI planning suggested is possible, and not at a pace that could get to that scale in the timeframe of the 2025 Carbon Neutrality Initiative.

2.4.1 UC Irvine Exemplar

The Irvine campus has achieved 1.4 kWh per year per gsf of avoided use from interior lighting retrofits for the combined campus and medical center, including over 1 kWh per year per gsf for the medical center[14]. Including 2015 projects brings the Irvine total to 1.5 kWh per year per gsf

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[14] Based on a rough estimate of floor area split between the campus and medical center.

for the combined campus and medical center. The Irvine campus is implementing interior lighting energy efficiency retrofits at scale, at a pace that may complete all appropriate retrofits well within the timeframe of the 2025 Carbon Neutrality initiative, making it an existence proof for deep energy efficiency retrofits at scale for interior lighting.

Retrofit projects for exterior lighting (including parking garages) at the Irvine campus have a total avoided use of 5.3 million kWh per year through 2015, again with significant reductions at the medical center as well as at the campus. The Irvine campus and medical center join the Davis campus as existence proofs for deep energy efficiency retrofits at scale for exterior lighting. Some other campuses are approaching 1 million kWh per year of energy use reduction from exterior lighting retrofits[15].

2.5 Planning to Scale

“Deep Energy Efficiency—Getting to Scale” Project planning efforts included sample audits at UC Santa Barbara and UC Riverside (Ulloa et al 2015), and identification of preliminary retrofit project scenarios based on best practices at UC campuses,

2.5.1 Planning Metrics

Analysis discussed in previous sections has focused on the metric of avoided energy use (a.k.a. energy savings) per gross floor area (exterior walls). Project accounting often focuses on avoided use, for understandable reasons, as traditional incentives are based on avoided use and debt service for loans is based on avoided cost. Program and project design often excludes from publication the pre- (baseline) and post- (projected residual) retrofit use analysis, even if those are estimated or measured as a part of project accounting. The SLI used a (60%) savings target as the primary metric, with the post (projected residual) use implied. The DEEC study followed suit with the savings metrics from the SLI. UC /CSU/IOU Partnership project databases track only savings.

Using savings metrics exclusively can lead to difficulties in applying metrics to planning in scenarios with different baseline conditions. Also, the savings metric does not completely inform carbon neutrality planning—as it is the amount of post-retrofit residual use that is critical for planning of de-carbonization.

Planning to scale by the Project will strive to analyze baseline and projected use, with avoided use being the derived quantity. While avoided use (savings) will be reported for comparison purposes with previous planning and projects, the Project will strive to report pre- and post-retrofit energy use, and stress the value of reporting in this manner in future case studies.

Energy intensity for interior lighting is traditionally reported using metrics normalized to gross floor area (exterior walls). Though counter-intuitive for a system inhabiting interior space, this follows the precedent of the California Title 24 Building Efficiency Standard representation of lighting power density, and facilitates planning in conjunction with other building metrics most commonly normalized against gross floor area.

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[15] Exterior lighting does not lend itself as well to comparative metrics as does interior lighting.

There are several different ways of calculating gross floor area. OGSF50 is the most commonly used space reporting metric, including for CAP Annual Inventories. Project efforts will strive to normalize intensity metrics to OGSF50, and to label metrics when they deviate from this protocol. In Project reports, unless otherwise noted, floor area is OGSF50.

Comparative metrics for previous and new planning are presented in Table 5.

2.5.1 UC Santa Barbara

The Project used sample audits on representative buildings to develop an initial estimate of baseline and anticipated performance of retrofit systems for three general building types: laboratory, academic/administrative, and housing. The aggregate baseline estimate for these lighting-intensive building types is 3.9 kWh per year per gsf[16] (see Table 5). This is consistent with the Davis SLI baseline.

The Project created retrofit scenarios for the space types—projecting the performance of the retrofit systems and deriving the post-retrofit or residual energy use. This is an advance in planning methodology from the previous studies that used savings as the primary planning metric. Using baselines and residual use as the primary planning metrics will improve the predictive ability of planning models and help ensure best practices are employed in retrofit design, as well as allow the estimation of the residual energy use needing to be de-carbonized.

At Santa Barbara, the project crafted preliminary retrofit scenarios for the space types and occupancy scenarios. The project assumed fixture replacement or full fixture rebuild taking full advantage of LED technology in most applications, with aggressive adaptive control scenarios suggested by best practice demonstration and retrofit projects. For example, occupancy rates of ~23% for corridors were assumed, in the range regularly observed in demonstrations and projects, as opposed to traditional assumptions of ~80%.

The aggregate anticipated performance estimate for the retrofit systems is 0.7 kWh per year per gsf, assuming an aggressive controls implementation. This estimate is supported by a 2013 demonstration of edge-lit LED fixtures with luminaire-level controls at UCSB in 2013. The derived aggregate savings estimate is 3.2 kWh per year per gsf, potentially applicable to 6.7 million gsf out of the total 8.0 million gsf at Santa Barbara (see Table 5).

2.5.2 UC Davis

The Project did limited analysis of the SLI Phase II projects. This included categorization and metrics for retrofit measures by space-type and measure (please see Table 5).

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[16] This preliminary assessment excludes a small amount of energy use in low-lighting intensity spaces.

Table 5: Comparative Interior Lighting Energy Efficiency Retrofit Planning Metrics

	Metric Domain	Floor Area gsf (definition)	Baseline Use kWh/yr/gsf	Retrofit Performance Residual Use kWh/yr/gsf	Reduction kWh/yr/gsf
UC Davis Smart Lighting Initiative (SLI) Baseline Model	Main Campus Average 2007	11.1 million (1)	4.13	1.65 (derived)	2.48 60% target
UC Davis SLI Baseline Model	Main Campus Average 2014	~12.2 million (OGSF50)	3.64	1.46 (derived)	2.18 60% target
UC Davis SLI Phase II	Project	~2.5 million (basic gross)	3.71	1.69	2.02
UC Davis SLI Phase II	Circulation/ Lobby (Corridors)	~0.4 million (basic gross)	4.90	1.85	3.05
UC Davis SLI Phase II	Laboratories	~0.7 million (basic gross)	3.98	1.85	2.13
UC Davis SLI Phase II	Offices	~0.6 million (basic gross)	2.00	1.03	0.97
UC Davis SLI Phase II	LED Retrofits	~0.8 million (basic gross)	4.12	1.04	3.08
UC Davis SLI Phase II	Non-LED Retrofits	~0.9 million (basic gross)	2.49	1.16	1.33
UC Davis SLI Phase II	Excluding “No Action”	~1.7 million (basic gross)	3.25	1.10	2.15
DEEC Study Low Estimate		(basic gross)			1.8
DEEC Study High Estimate		(basic gross)			2.2
UCSB Planning Laboratory Bldgs	Sample Buildings	(OGSF50)	3.76	0.74	3.02
UCSB Planning Admin/Academic Bldgs	Sample Buildings	(OGSF50)	4.80	0.73	4.01
UCSB Planning Housing Bldgs	Sample Buildings	(OGSF50)	2.54	0.61	1.94
UCSB Planning Aggregate	Lighting Intensive Building Types	~6.7 million (OGSF50)	3.87 (3)	0.71 (3)	3.16
UCSB Planning Campus	Total Inventory	~8.0 million (OGSF50)	3.22 (4)	0.59 (4)	2.63
UC Irvine Exemplar 2004-2014	Main Campus and Medical Center	~10.8 million (OGSF50)			1.4
UC Irvine Exemplar 2004-2015	Main Campus and Medical Center	~10.8 million (OGSF50)			1.5
UC/CSU/IOU Elec IOU 2004-2014 Average	Campuses and Medical Centers	~89 million (OGSF50)			0.56
UC/CSU/IOU Elec IOU 2004-2015 Average	Campuses and Medical Centers	~89 million (OGSF50)			0.65

Notes: (1) Gross space definition may be non-standard
(2) Conservative ~80% occupancy level assumptions
(3) Excludes low-lighting intensity space (e.g., storage)
(4) Excludes usage from low lighting intensity buildings (including garages in exterior analysis)

2.6 Initial Assessment

To achieve an initial assessment of CO$_2$e emission reduction potential from deep energy efficiency lighting retrofits at scale, the Project synthesized planning information from UC/CSU/Utility Partnership records, the SLI baseline model, SLI Phase II project records, the DEEC Study, sample audits, and preliminary scenario development.

Low Estimate—Interior and Exterior Lighting

The low estimate uses:

1) the low estimate from the DEEC Study for interior lighting, adding lighting savings from smart lab projects back into lighting totals, and
2) an extrapolation of the UC Davis exterior lighting savings to 10 campuses, less savings achieved to-date[17].

High Estimate—Interior and Exterior Lighting

The high estimate uses:

1) 90% of the planning-level project design scenario in Chapter, normalized to all campus floor area, applied to all floor area in the UC system, less savings achieved to-date[18], and
2) an extrapolation of the UC Irvine exterior lighting savings to 10 campuses, less savings achieved to-date.

Table 6: Avoided Energy Use & CO$_2$e Emissions from Energy Efficiency Retrofits—
Projected for Interior & Exterior Lighting Deep Energy Efficiency Retrofits to Scale

Avoided Energy Use—Interior Lighting	115-280 million kWh per year	
Avoided Energy Use—Exterior Lighting (incl. parking garages)	19-44 million kWh per year	
Aggregate CO$_2$e Emission Factor (all campuses)	0.000295 MT/kWh	
Total UC 2014 CO$_2$e Emissions— from Natural Gas, Steam, and Electricity Purchases	1,121,000 MT per year	
Total UC 2014 CO$_2$e Emissions— Scope 1 and 2	1,178,000 MT per year	
Bounding Scenario	All avoided use is directly purchased energy	All avoided use is cogenerated energy
Avoided CO$_2$e Emissions from Deep Energy Efficiency in DEEC Study (Low-High Estimate)	39,000-96,000 MT per year	32,000-77,000 MT per year
CO$_2$e Avoided Relative to 2014 Natural Gas, Steam & Electricity	4-9%	3-7%
CO$_2$e “Wedge” Relative to Total 2014 Scope 1 & 2 Emissions	3-8%	3-7%

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[17] Adjustment for reductions already achieved to-date does not include lighting retrofit projects not in UC/CSU/IOU Partnership records (for instance, at the campuses served by municipal electricity providers).

[18] This is a conservative assumption because preliminary indications are that some previously retrofitted space can be included in new deep retrofits, using current conditions as the baseline.

For deep energy efficiency lighting retrofits at scale, potentially implemented in conjunction with other deep efficiency retrofits, previous assumptions about all avoided use being directly purchased energy may not hold. The bounding scenario of all avoided use as cogenerated energy is presented to enable analysis of avoided use when it is partially cogenerated energy. Please see details in the discussion of bounding scenarios in Section 1.1.2.

2.7 Update of Overall Energy Efficiency Potential with Lighting Efficiency at Scale

Increases in low and high estimates for lighting energy efficiency have been added to the estimates by the DEEC Study to result in an update of overall estimates of energy efficiency as a wedge toward carbon neutrality. Also added are estimates of potential from Deep HVAC and Smart Labs in buildings less than 40,000 gsf, as well as remaining potential from monitoring-based commissioning (MBCx)[19]. The increased potential estimate is presented in Table 7. (Lighting efficiency is extracted from smart lab estimates to avoid double-counting.)

Additional emphasis on natural gas efficiency measures can be expected given the relative difficulty of decarbonizing this energy source. Table 7 remains a partial estimate of potential. The high estimate is not an upper bound.

Table 7: Avoided Energy Use & CO_2e Emissions from Energy Efficiency Retrofits—
Projected by Updating Interior and Exterior Lighting to Scale and Combining with Deep Energy Efficiency and Cogeneration (DEEC 2014) Study

Avoided Energy Use	394-852 million kWh per year	
	13-33 million therms per year	
Aggregate CO_2e Emission Factor (all campuses)	0.000295 MT/kWh	
Aggregate CO_2e Emission Factor (all campuses)	0.00538 MT/therm	
Total UC 2014 CO_2e Emissions— Natural Gas, Steam, and Electricity Purchases	1,121,000 MT per year	
Total UC 2014 CO_2e Emissions— Scope 1 and 2	1,178,000 MT per year	
Bounding Scenario	All avoided use is directly purchased energy	All avoided use is cogenerated energy
Avoided CO_2e Emissions	186,000-427,000 MT per year	150,000-346,000 MT per year
CO_2e Avoided Relative to 2014 Natural Gas, Steam & Electricity	17-38%	13-31%
CO_2e “Wedge” Relative to 2014 Total Scope 1 & 2 Emissions	16-36%	13-29%

Please see discussion of scenarios for Table 6 in Section 2.7 and for Tables 3 and 4 in Section 1.2.

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[19] These estimates took into account the probability of less potential in smaller buildings and less potential from MBCx in the balance of buildings.

3. Value Proposition

3.1 GHG Emission Reduction with Net Cost Avoidance

Already "bending the curve" on campus GHG emissions, energy efficiency retrofit is the carbon neutrality strategy component that also has a straightforward financial value proposition. Energy efficiency retrofits in the era of the UC/CSU/IOU Partnership and Statewide Energy Partnership have annual avoided costs of over $20 million net of debt service, considering only energy cost savings.

Maintenance cost reduction is also sometimes attributed to LED lighting retrofits. Can this avoided cost be quantified with enough rigor to be considered along side avoided energy costs in financing analysis?

3.2 Net Avoided Maintenance Costs?

3.2.1 Planned Short-Cycle Maintenance for Incumbent Systems

Many cost benefit analyses for LED lighting retrofit note maintenance costs savings associated with elimination of planned short-cycle maintenance—lamp (and sometimes) ballast replacement for incumbent lighting systems. Evaluation of this avoided cost is relatively straightforward, but some questions arise when considering its impact on the overall financial value proposition, or the ability for this avoided cost to contribute to debt service for loans financing LED lighting retrofits or to spin-up of re-investment.

The general question is:
What are other costs of ownership and do they factor into ability to service debt or spin-up re-investment?

3.2.2 Long-Cycle and Unplanned Maintenance?

What about the long–term fixture replacement cycle and unplanned maintenance?

Some analyses of "maintenance costs" try to be comprehensive including consideration of the long-term fixture replacement cycle. This might be appropriate for a "new" fixture or a "replacement at end-of–lifetime" decision considering total cost of ownership. However, retrofit projects are in a different context—an "intervention" generally somewhere in the middle of the actual useful lifetime of the incumbent fixture.

A retrofit intervention "resets" the fixture replacement cycle, as well as unplanned maintenance and any planned long-cycle maintenance. This reset defers any of these costs to a timeframe after the warrantee period on the new fixture, and delays costs in a way that is likely to reduce the rate of expenditure under almost any set of assumptions about the relative life of LED and other fixtures.

Assuming the retrofit fixture is of high quality and carries a 10-year or longer warrantee; long-term fixture replacement, unplanned maintenance, and planned long-cycle maintenance costs are almost certainly reduced in the timeframe of debt service or spin-up of re-investment. At the same time, given uncertainty about fixture lifetime and long-term maintenance, this avoided cost is almost impossible to quantify, especially in a "deferred " maintenance environment.

One possible conclusion is that these long-cycle costs are not possible to quantify and capture, but can be safely omitted from a financing analysis as it is relatively certain that they do not increase in a well-managed "intervention" scenario.

3.2.3 Other Planned Short-Cycle Maintenance? Controls?

Are there planned short-cycle maintenance costs associated with lighting controls?

Considering warrantees, one possible conclusion is that these maintenance costs are actually long-cycle costs. It may be a reasonable assumption that these costs can be considered together with other long-cycle costs, will not move these overall costs from net savings to a net increase, and can be omitted from a financing analysis.

3.2.4 Operational Costs for Lighting Controls?

How do day-to-day operational costs change with the more capable controls often accompanying LED lighting?

It is arguable that there are significant potential ongoing operational costs incurred for effort that enables automatic lighting controls to optimize operation and capture energy anticipated (e.g., monitoring and tuning of controls on ongoing basis, wireless sensor battery replacement for some controls options). Networked controls may mitigate these costs with operational efficiency associated with remote monitoring and control.

There is not yet enough campus experience to directly estimate these operational costs. An upper bound estimate can be obtained by applying a vendor quote for all-in networked controls support ($28 per year per zone). This is the same order of magnitude as re-lamping/ballasting costs for incumbent fluorescent systems. This indicates short-cycle maintenance costs will not go up with LED/adaptive controls, and might be managed to create a net reduction. Recent requirements for lighting controls in building standards will make lighting controls more ubiquitous, perhaps driving innovation that minimizes operational costs.

3.2.5 Quantification

The following is a limited quantification of planned short-cycle lighting maintenance costs (e.g., fluorescent and HID lamp replacement):

- Interior Lighting— maintenance costs at UC Davis are estimated at $0.11 per gsf per year based on work orders. Of this, $0.07 per gsf per year can be attributed to lamp and ballast replacement. If this cost savings could be added to the $0.21 per gsf per year energy cost savings for SLI Phase 2 LED and controls retrofits[20] it would increase debt service capacity or ROI by roughly one-third.
- Exterior Lighting— At LBNL annual lamp replacement cost for incumbent lighting fixtures is estimated at 26-40% of the annual energy costs savings from LED and controls and retrofits, potentially increasing the ROI by as much as one-third[21]. (Estimates of planned short-cycle controls (e.g., sensor) maintenance costs for the new fixtures and controls negated much of this savings. These estimates need further analysis as they may not account for expected warrantees on new lighting controls, nor account for maintenance of some components of the controls that are also present for the incumbent systems.)

The development of the Business Plan for LBNL included analysis of short and long-cycle maintenance costs (see Attachment B). This analysis is informative but not ready for generalization to application at other campuses. Generalizations about accounting for and capturing maintenance costs in financing proved beyond the scope of the Project.

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[20] 3 kWh per gsf per year of energy savings @ $0.07 per kWh

[21] For a range of fixture types, excluding highest and lowest values, blended energy cost of $0.086 per kWh.

4. Barriers and Opportunities

4.1 Staffing of Project Development and Management

The most frequently articulated barrier to ramping up efficiency retrofit activity is availability of staffing for project development and management. What is the level of staffing needed to achieve deep energy efficiency at scale? Preliminary investigation in conjunction with the Carbon Neutrality Financial and Management Task Force indicates that an ideal level of energy management staffing may be 0.6 to 1.0 full time equivalents (FTE) per million gsf of campus floor area (UCOP 2016). This is the level of energy management staffing that has enabled UC Irvine to achieve energy efficiency retrofits at scale—on track toward capturing the full potential of energy efficiency by 2025 or earlier.

This analysis is consistent with an extrapolation of efficiency retrofit project experience to the scale of efficiency retrofit activity being contemplated in conjunction with the 2025 carbon neutrality goal[22]. Over $1 billion in projects has been identified by the DeepEE2014 study and this investigation. 14% is a typical fraction of total project costs going toward in-house project development and management at scale, including contract management. If this is undertaken in a period of 8 years, around $20 million per year will be expended, implying a staff of 150 professionals[23]. This is equivalent to roughly 1.2 professionals for every million gross square feet of campus floor area[24].

This assumes limited economies of scale and limited outsourcing. Economies of scale should be sought, but are challenging to achieve because of the highly granular nature of campus energy using systems, the uniqueness of virtually every building, and the diversity of space types and business functions. Economies of scale are further limited by the granular nature of documentation required for securing subsidies, especially for lighting.

Some outsourcing of project development and management is being explored by some campuses, but with limited success. Some of the functions such as contract management and liaison with building and department managers are difficult to outsource in a University campus environment.

4.1.1 Perspective

For energy efficiency staff accustomed to thinking in limited terms, the prospect of such a staffing scale-up may seem bold or daunting. Compared to other campus enterprises, it is neither. On the academic side new research or curricular initiatives often occur at this scale. On the facilities side,

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[22] General staffing for energy management overlaps with, but is not entirely synonymous with staffing for energy efficiency retrofit project development and management. The former typically includes staffing for some activities other that retrofit projects. The latter typically includes some project management staffing that may be drawn from other campus units.

[23] Assuming salary plus benefits of $130k per year per professional.

[24] For the 128 million gsf of UC floor area in 2014.

capital projects staffing can typically be at this scale on an ongoing basis, and occasional upgrade programs such as seismic retrofits can have the same scale over a similar timeframe.

Project development and management staffing is fundable as a component of retrofit projects. There are few other opportunities that have as straightforward a value proposition, net of required funding.

4.1.2 Embedded Barriers

Even with an apparent opportunity like deep energy efficiency at scale, the initiative to expand staffing is unlikely to come from within an existing energy management staff. Such a unit may not yet exist at all. The top-down budgeting prevalent in a university system is not conducive to such bottom-up initiatives. The vision of energy management staff as to what is possible may be self-limited by the perceived constraints of current staffing levels. Existing staff may be wary of getting into a scenario where expectations are out in front of the ability to increase staff.

The energy management or retrofit project management function may matrix into sustainability, utility, maintenance, and project management units. While such a distributed team approach has advantages, there may be challenges to expanding nimbly in response to an imperative/opportunity—such as deep energy efficiency at scale toward carbon neutrality.

Recruiting is another potential embedded barrier in a job market with significant demand for energy management professionals. This becomes even more of a challenge for the diverse skill set needed in campus and team scenarios.

4.1.3 Summary Approaches

The following approaches are suggested for overcoming the barrier of staffing needed for project development and management of efficiency retrofit projects at scale:

Business Plan

Develop a staffing proposal within an overall business plan for energy efficiency retrofits at scale, including the value proposition.

Economies of Scale

Seek economies of scale in project design.

Evaluate the Opportunity from a High Level

The combined sustainability (including CNI) and financial value proposition spans multiple campus units including budget and sustainability offices. Part of the necessary staffing may be best located in larger self-funded units such as housing. The existing energy or project management function may matrix into several units, needing coordination. Decisions to expand staffing are typically initiated from above in a top-down university budgeting environment.

These factors point toward consideration of staffing initiatives and the overall business plan at the Vice-Chancellor for Administration level.

Energy Efficiency Program Approach

Addressing staffing needed for energy efficiency retrofits at scale is inherently interrelated with the overall approach to a campus energy efficiency program. As an example, Irvine campus success in getting to scale is enabled by the strategic approach to energy management outlined in Figure 1.

Figure 1. UC Irvine Approach to Energy Efficiency[25]

Elements of an Exemplary Energy Efficiency Program

Get the organizational culture ready
Adopt a challenging goal
Understand true potential of "smart" buildings
Develop a scalable strategy
Pilot new concepts initially
Use "information layer" to verify and sustain performance
Foster breakthrough thinking
    Challenge status quo
    Question accepted limits
    Think comprehensively: re-engineer whole systems
    That is, whole building energy retrofits
Prioritize "deep" energy efficiency projects (i.e., >50% savings)
Build team with technical and leadership skills
Apply a simple project justification/approval process

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[25] Courtesy Wendell Brase, UC Irvine Vice Chancellor for Administration

4.2 Procurement

Installation

Economies of scale, continuity, and competition are important and achievable to control installation costs. One approach that can capture all of these economies—achievable with campus-wide scale and an increased pace of retrofits—is a multiple vendor process. Multiple (e.g., three) vendors are qualified to operate on campus simultaneously, then bid against each other for increments of project scope. Mobilization (scale) and familiarization (continuity) costs are limited while still reducing costs through competition.

Materials

Much of the available economies of scale for materials are already captured from typical building-scale projects, or from installation vendor aggregation of purchases. Still, coordination may be able to reduce costs by aggregating materials purchases within other phasing constraints. This is difficult to address in the context of this study, but can be explored in the process of detailed project design.

Some lighting equipment incentives, specifically recess mount LED rebuild kits or replacement fixtures are, at least in the short term, being shifted by some utilities to distributors (mid-stream). This requires coordination with vendors to capture these incentives.

4.3 Learning Curve

Energy efficiency retrofit (especially LED lighting retrofit) is a fast moving field, with the consultant community struggling to keep up with cost trends and critical applications information. Conventional cost estimation sources have not been able to keep up with recent reductions in LED lighting and controls equipment costs, nor with reductions in installation labor time spurred by innovation and the growing experience base.

Much of the performance increment of LED technology results from optical design advantages. There is a corresponding shift of performance metrics emphasizing fixture output as opposed to light source output. Not fully tracking the advantage or metrics shift can result in underestimation of performance of LED retrofits. The potential for overestimation of costs and underestimation of performance results in a significant risk of financially viable projects being rejected.

In this fast evolving environment, it is possible for in-house energy management staffing, with the peer-group interactions and technology expertise available within the UC system, to be out in front of much of the consultant community. Emphasizing development of in-house expertise may be the best way to achieve the best possible project designs.

5. Financial, Phasing, and Logistical Scenarios

5.1 Finance Precedents

The groundbreaking scope and scale of energy efficiency retrofits described in section 1.2.1 was achieved primarily with a unique combination of: 1) incentives through the UC/CSU/Utility Energy Efficiency Partnership[26] and 2) UC bond-funded loans through the Statewide Energy Efficiency (SEP) Program[27].

In 2004-2014, the cost of UC energy efficiency retrofit projects implemented in conjunction with the Utility Partnership totaled around $247 million[28], with around $65 million being offset by utility incentives. The net costs, approaching $200 million, have been financed primarily by SEP loans (Table 8). These projects have resulted in about $36 million in annual avoided energy costs[29].

The Utility Partnership incentives preceded the SEP loans, with a limited amount of funding available to fund full project costs for MBCx and up to full project costs for retrofits in the pilot years of the program 2004-2005. Energy use was reduced by around 12 million kWh per year and 0.8 million therms per year in 2004-2005.

In 2006-2008, the program shifted to partial incentives of $0.24 per kWh/yr and $1.00 per therm/yr, but with more overall incentive funding available. This resulted in reduced energy use of around 48 million kWh per year and 4 million therms per year.

The bond-funded loan program was introduced in 2009 to fund the balance of project costs after incentives. This resulted in a significant acceleration of the pace of retrofits for 2009-2014 to reduce energy use by 180 million kWh per year and 10 million therms per year. The pace of electricity savings increased more than natural gas savings, partly because there was an emphasis placed on Natural gas savings by the Utilities during part of the 2006-2008 program cycle.

From 2004-2014, the cost of retrofit energy efficiency projects at UC Irvine was around $57 million[30], offset by around $16 million in utility incentives, with net project costs financed primarily by bond-funded loans. This has been sufficient to fund a comprehensive retrofit program that has avoided an amount of GHG emissions roughly one-quarter above the campus

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[26] Subsidies of $0.24 per kWh/year and $1.00 per therm/year, subject to evolving limitations, are available for energy service through investor-owned utilities—not including UC Davis medical center electricity served by Sacramento Municipal Utility District, and Riverside electricity served by Riverside Public Utilities. Availability of electricity subsidies to UCLA is pending the imminent joining of the UC/CSU/Utility Partnership by Los Angles Department of Water and Power.

[27] For planning purposes loan terms are 5% interest, 15-year duration, and maximum 85% debt service ratio (debt service can be no more than 85% of the avoided energy cost).

[28] As tracked by the Utility Partnership.

[29] With nominal energy prices of $0.100-0.109 per kWh and $0.684-0.800 per therm.

[30] As tracked by the Utility Partnership.

total 2014 GHG emissions from purchased electricity and natural gas[31]. UC Irvine is well on its way to achieving a least-cost strategy for 2025 carbon neutrality, utilizing Utility Partnership incentives and SEP loans for deep energy efficiency at scale.

At UC San Diego, there have been even greater expenditures that have led to more absolute GHG emission reduction, again financed primarily by bond-funded loans. However, these savings are smaller on a per square foot basis, as UC San Diego has roughly double the floor area of Irvine. There has also been comparable expenditure on the Davis campus, also primarily financed by bond-funded loans, but again, resulting reductions in energy use and emissions are lower than those achieved at Irvine on a per square foot basis.

Debt financing using UC-bond funded loans has the potential to provide the core funding for comprehensive energy efficiency retrofits because it fully accesses the future value of the avoided energy use.

Table 8. UC Energy Efficiency Accomplishments in the 2004-Present UC/CSU/IOU Partnership Era

	Electricity Use Reduction (million kWh/yr)		Natural Gas Use Reduction (million th/yr)		Incentives ($Millions)		Project Costs Retrofit+MBCx Partnership Records (2,3) ($Millions)	
	Retrofit+ MBCx (1)	NC	Retrofit+ MBCx	NC	Retrofit+ MBCx	NC	Total	Net of Incentives
2004-2005	12	N/A	0.8	N/A	$ 5M	N/A	$ 6M	N/A
2006-2008	48	N/A	3.7	N/A	$14M	N/A	$ 30M	$ 16M
2009-2014	180	23	10.4	1.7	$46M	$9M	$211M	$165M
2004-2014	**240**	**23**	**15.0**	**1.7**	**$65M**	**$9M**	**$247M**	**$181M**
2015 (est)	18	0.95	0.7	0.014	$ 5M	$0.3M	$ 37M	$ 32M
2016 (pre)	27		1.3		$ 7.9M		TBD	TBD

Notes:

1) Monitoring-Based Commissioning
2) May not reflect all costs
3) Not including Los Angeles projects without incentives (~$20 million total project cost?)

5.2 Scale of Needed Financing

The 2014 DEEC report and this study have identified appropriate energy efficiency retrofits going forward that can reduce UC GHG emissions by as much as 25% relative to 2014 levels. More potential is likely to be identified when the methodology used in this study for lighting is applied to HVAC and laboratory end-uses (i.e., addressing buildings less that 40,000 gsf in floor area).

The funding required to achieve the high scenario reductions identified in the 2014 DEEC report is on the order of $800 million. Additional funding will be associated with the additional potential identified by this study and likely to be identified using this studies more comprehensive methodology. Going forward funding in excess of $1 billion for energy efficiency is likely part of the least-cost strategy toward UC carbon neutrality in 2025.

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[31] Figures include the Medical Center. Over 95% of the spending and emission reduction has been on the main campus.

5.3 Prospects for Additional Debt Financing

Some campuses, including Irvine and San Diego, are proceeding to extend their debt financing of energy efficiency, as manifested in the $50 million of loan proposals approved by the Regents in the in the first phase of 2016-2025 Statewide Energy Plan financing (Table 9). However, some campuses are observing that their debt models will not allow more debt financing of energy efficiency. As a result, only four campuses made proposals to that first phase of 2016-2025 SEP financing.

Table 9. Statewide Energy Partnership—Bond-Funded Loan Authorization

Approval Date	Nominal Period	Amount ($Millions)	Cumulative Amount ($Millions)	Campuses
January 2009	2009-2011	$178M	$178M	B, D, I, LA, R, SD, SF, SB, SC
September 2010	Augmentation to 2012	$ 16M	$194M	D, SF
January 2013	2013-2014 (and 2015)	$ 74M	$268M	B, D, I, SD, SF, SB, SC
January 2016	2016-2025 (1st Phase)	$ 50M	$318M	I, LA, SD, SC

5.3.1 Changes to the SEP Bond-funded Loan Program

The GCLC Financing Pillar has identified possible changes in the bond-funded SEP loan program —that could potentially expand ability of campuses to debt finance deep energy efficiency at scale:

1) an option for 30-year loan term for certain applicable projects,
2) a clear path for using loan financing that is independent of UC/CSU/Utility Partnership incentives, and
3) use of Limited Project Revenue Bonds (LPRB) as an alternative to the traditional General Revenue Bonds (GRB).

30-year loan term

A 30-year loan term may be applicable to long-lifetime components such as chillers or boilers. Given the evolution of lighting toward solid state LED technology that resembles a durable appliance, some are asking if longer-term loans might be applicable to some types of lighting.

Loan financing independent of utility incentives

In the past, applications for bond-funded loans were generally linked to applications for UC/CSU/Utility Partnership incentives as the project evaluation and M&V process performed by the utilities provided a due diligence step important to loan approval. There are at least two scenarios where the utility process does not suffice, in service territories not in the UC/CSU utility partnership (i.e. Riverside and UC Davis Medical Center electricity), and when regulated utility savings accounting diverges from the accounting of actual savings appropriate for loan service calculations. There are now provisions for due diligence independent from utility incentive applications.

Limited Project Revenue Bonds

Limited Project Revenue Bonds are being explored for financing energy efficiency projects because there are some indications that the financial obligations created by these bonds may be accounted for differently with respect to campus financing benchmarks in campus Debt Affordability Models. The differences are thought to allow more financial obligation without running up against restrictions on exceeding some measures of debt. This might allow a campus to make prudent decisions about incurring more financial obligation without running up against arbitrary limits that might have been exceeded by General Revenue Bonds (GRBs).

However, if a campus is concerned about more financial obligations independent of the measures of debt in Debt Affordability Models, then LPRBs do not appear to offer advantage, as the actual financial obligation is essentially the same as with GPBs. Also, LPRBs ostensibly need to have specific revenue sources funding repayment of the debt obligation. While avoided energy costs are accepted as a means of repayment of GRBs, this revenue source has not been vetted as a means of repayment of LPRB obligations.

No campuses opted to pursue LPRBs in proposals to the first phase of 2016-2025 SEP funding.

5.3.2 Relevant Perspectives on Campus Energy Utility Budgets

Some campuses, such as Santa Barbara, observe that unpredictable variability in energy utility costs poses budgeting challenges. For this reason, the UCSB Office of Budget and Planning (OB&P) has described the utility budget as being encased by a “firewall” in order to provide a cushion for year-to-year fluctuation. Managers of the utility budget currently allow surplus funds to be used for “one time” capital investments in energy efficiency projects, but are wary of assuming an annual surplus in the utility budget and obligating it as a recurring source of debt financing for energy efficiency.

This Santa Barbra perspective both illustrates the issues posing a challenge to applicability of the debt-financing model and suggests a second core-funding model—spinning-up a variation of a revolving fund.

5.4 Need for a Second Core Financing Mechanism?

On the order of $1 billion additional investment in energy efficiency is likely to be required for the least-cost strategy toward 2025 UC carbon neutrality. Debt financing on the order of $200 million has been an effective core mechanism to fund the significant energy efficiency efforts to-date. It will likely play a major role going forward for some campuses, perhaps providing a significant fraction of core financing.

If the Irvine main campus’ utilization of bond-financed loans supplemented with utility incentives over the last decade could be replicated on each of the other campuses in the next decade—at a scale commensurate with each campus size—it would be sufficient to approach the potential of energy efficiency toward 2025 carbon neutrality.

However, because various issues including concerns over debt capacity may limit the replication of the Irvine main campus model, identification of a second core funding mechanism may be needed.

5.5 Potential Alternatives for Funding Energy Efficiency Retrofits

Potential alternatives for funding energy efficiency retrofits can be classified into two types, those that create an ongoing financial obligation, and those that do not. Funding sources that create ongoing financial obligations include—

- commercial-grade investment vehicles aggregating energy efficiency projects[32]
- revolving funds seeded with otherwise obligated funds
- energy service companies (ESCOs)

These options do not alleviate the concern over incurring ongoing financial obligations, perhaps actually raising more concern as the obligations are to external entities as opposed to a UC bond-funded loan program. There are additional disadvantages to some of these options, with no basis for preference of these options over UC bond-funded debt financing [33].

Funding alternatives that do not create ongoing financial obligations include:

- spin-up reinvestment[34] seeded with otherwise un-obligated funds
- allocation of Cap and Trade GHG emission permit sale proceeds to UC[35]
- proceeds from resale of excess Cap and Trade GHG emissions permits
- various types of donor-funding

With the potential exception of revolving funds, the size of the funding sources without obligations is either too small to directly make a significant impact, un-predictable, or un-knowable without extensive development efforts.

5.5.1 On-Bill Financing

On-bill financing is in a grey area with respect to long-term ongoing financial obligations. It is effectively re-payment of a loan from the energy utility. This new financial obligation appears alongside and is balanced by avoided energy costs on the utility bill. However, it may not typically

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[32] A potentially interesting variation would seek to replicate the Insurance Company Contract fund fixed-income option that is no longer available as an investment option in the UC Retirement Savings Program.

[33] ESCOs have been proposed from time-to-time by some campuses as an alternative financing path. UCOP has not supported these proposals, with strong justification. Compared with debt-financing, agreements with ESCOs at the same time pose greater financial and legal risks while providing poorer financial performance. Transaction costs are high as vendor contracts cannot be agreed to by UC, necessitating extensive negotiation of contract terms. UCOP has not supported use of sole sourcing exceptions sought by ESCOs.

[34] This is a variation on "revolving fund" internal financing. Unlike most revolving funds, there is no intent to preserve capital, allowing compounding re-investment to achieve investment levels that are multiples of 2-3 in the timeframe of the 2025 CNI.

[35] Tentative allocations have not materialized.

be included in a debt capacity analysis. This illustrates that energy expenditures and debt service on energy efficiency project loans have an "interchangeability" that is not recognized by traditional debt capacity analysis.

UC campuses have used utility on-bill financing on a limited basis. This option has been subject to per-account limits that have been somewhat restrictive for large main campus master-meter accounts. Relaxation of these limits may allow more on-bill financing in the future.

5.5.2 Variations on Revolving Funds

Tentative allocations of California Cap & Trade proceeds have not materialized. However, the active discussion about the allocation of these funds within UC suggests a potential long-term strategic use for similar funding.

Guiding principles under discussion for the use of the tentative allocation of Cap and Trade funding to UC were: achieving high *leverage* for the funds toward reduction of GHG emissions, and achieving reduction in GHG emissions that is *incremental* over reductions that are otherwise possible. A short-term strategy aligned with these principles is use of these funds in combination with utility incentives and other funds such as debt-financing (leverage), to implement projects with payback periods longer than otherwise pursued (incremental).

A long-term strategy aligned with these guiding principles is to use otherwise unobligated funds to seed a variation on "revolving funds", which leverage cash infusions from various sources and aggressively re-invest avoided energy cost streams in order to spin-up funding dedicated to energy efficiency. This enables the funding of both an initial portfolio and a large portfolio over time (leverage), as well as expanding the size of the efficiency portfolio beyond what is possible with other available funding mechanisms (incremental)[36].

Green revolving funds are being widely adopted as a mechanism for funding campus energy efficiency retrofits. The Association for the Advancement of Sustainability in Higher Education (AASHE) has complied information on 81 campus sustainability revolving loan funds (AASHE 2016). The Caltech fund, with a total investment of $18 million in 2014, stands out relative to the size of the campus. (Caltech 2016). There is crossover with the 57 campuses participating in the Billion Dollar Green Challenge—which include both Caltech and UCLA (BDGC 2016).

Discussion of metrics for green revolving funds typically includes *ROI* or *simple payback period*, and less often *total return on investment* or *time to recover initial investment*. (Sustainable Endowments Institute 2013). Seed funds are often "borrowed" from dormant fund sources, with the obligation to ultimately preserve the capital. From this standpoint, revolving funds often create ongoing obligations little different from classic debt financing.

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[36] The context of the discussion about distribution of C&T funds included both a base amount to each campus and medical center and an amount that would be distributed on a merit basis. The guidelines for the merit-based distribution considered scenarios for seeding aggressive spin-up re-investment scenarios funds as part of the decision criteria.

A more aggressive strategy is possible when seed funding is purposed toward spinning-up investment in energy efficiency retrofits, with limited or no requirements to maintain a cash reserve (e.g., seeding with allocation of proceeds from the Cap and Trade program). For this strategy, funds that become available through avoidance of energy use are re-invested as fully and as soon as possible. Re-investment continues after proceeds from any investment accrue to the original amount of the investment. With this strategy, an investment "compounds" and the ideal investment performance resembles that of compound interest. An important metric is the *multiple* of the original investment achieved in a target time period.

This aggressive "compounding" reinvestment strategy for revolving funds is not fully explored in much of the literature on green revolving funds. Some of the funds may be pursuing such a strategy, but it is not prominent in reporting.

We suggest that an aggressive "compounding" reinvestment strategy for energy efficiency retrofits may have the potential to create the core funding mechanism needed as an alternative or complement to debt financing when limits on ongoing financial obligations come into play. This strategy has the potential to provide the core funding for comprehensive energy efficiency retrofits because, like debt financing, it fully accesses the future value of the avoided energy use.

5.5.3 Spinning-up Re-investment Toward a Second Core Financing Mechanism

Additional Perspectives on Campus Utility Budgets

Returning to the Santa Barbara perspective introduced in 5.3.2—OB&P is currently allowing Utility & Energy Services (U&ES) to utilize surplus from the utility budget (itself a product of historical efficiency projects and low natural gas prices) for energy efficiency retrofits in the following year. This is in lieu of more debt financing.

If this strategy were pursued on an ongoing basis, concerns about managing the risk of variable energy costs might be balanced with climate protection imperatives through establishment of risk management guidelines to enable a reasonable buffer or reserve to accrue. Reserve guidelines might be lower for proceeds resulting from investment of purpose-driven funding (e.g., seeding with allocation of proceeds from the Cap and Trade Program) than those resulting from variation in energy prices.

5.5.4 Compounding Re-investment

A strategy to maximize spin-up reinvesting of avoided energy costs could have the goal—in the timeframe between now and 2025—of creating investment of multiples of the amounts of seed funding from sources such as Cap and Trade allocations. The compounding of these multiples is increased by:

- A longer investment timeframe
- Higher frequency of re-investment (shortened compounding period)
- Higher return on investment (ROI)

The ideal compounding scenarios in Table 10 illustrate the non-linearity of the effect of these parameters in the classic compounding function.

The compounding would be dampened by

- Delay in onset of proceeds (e.g., time to commission projects and achieve increased energy performance)
- Some proceeds directed to reserve funds or other priorities

The straw compounding scenarios in Table 10 illustrate the impact of realistic dampening effects in actual implementation.

Table 10. Ideal and Straw Compounding Scenarios for Aggressive Spin-up Re-Investment

Scenario		Compounding	Multiple in 4th Year	Multiple in 8th Year
Ideal 1[37]	10% ROI	Yearly/Quarterly	1.46/1.48	2.14/2.20
Ideal 2	20% ROI	Yearly/Quarterly	2.07/2.18	4.3/4.8
Ideal 3	40% ROI	Yearly/Quarterly	3.8/4.6	15/21
Straw 1	• 20-40% ROI weighted toward 20% • higher ROI investments loaded 1st • 6 month accrual delay • no reserve	Yearly	2.9	7.6
Straw 2	• 20-40% ROI weighted toward 20% • higher ROI investments loaded 1st • 6 month accrual delay • front-loaded reserve 3.6% of accrued savings at 8 years	Yearly	2.6	6.2
Straw 3	• 10-40% ROI weighted toward 10% • higher ROI investments loaded 1st • 6 month accrual delay • no reserve	Yearly	2.2	4.6

5.5.5 Deep Energy Efficiency Project Portfolios

Some assessments of the remaining energy efficiency potential on UC campuses have postulated that most high ROI projects have already been implemented. This may have some validity on campuses already approaching the full potential of deep energy efficiency as a least-cost measure (e.g., Irvine). However, we suggest there remains a significant portfolio of "deep" energy efficiency projects with high ROI on most campuses. We observe a significant cohort of deep efficiency high ROI projects in the portfolio of projects proposed by Santa Barbara for the 2016-2017 Cap and Trade allocation, many of which might have even higher ROI once utility incentives are accounted for. Also at Santa Barbara we observe a significant potential for high ROI deep lighting efficiency projects for corridors and similar spaces.

5.5.6 Potential to Create Core Financing

Preliminary analysis indicates it may be possible to compound an initial investment by a factor of 4 or more over 8 years in realistic scenarios (Table 10). This spin-up of re-investment provides a means to significantly leverage a one-time infusion of funds. A modest amount of seed funding

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[37] Ideal compounding is synonymous with compound interest calculations.

could be multiplied into an amount that could be an alternative or supplement to debt financing. This might provide a significant fraction of the core funding needed to implement a comprehensive energy efficiency retrofit program as a least-cost strategy toward 2025 carbon neutrality.

5.6 Hard Choices

It has been said that hard choices will need to be made for UC to achieve operational carbon neutrality in 2025. For some campuses, one of those hard choices may be whether to incur substantially greater ongoing financial obligations, in the form of debt financing, to implement comprehensive energy efficiency retrofits.

An easier choice for some campuses may be to pursue the strategy of aggressively spinning-up reinvestment of budget amounts made available through avoided energy costs. The choice in this case can be framed as deciding to forgo using the immediate financial benefits of energy efficiency projects for any purpose other than re-investment in energy efficiency and associated risk management. In this scenario other priorities are not usurped as they might be with debt financing, rather other priorities simply do not immediately benefit from energy efficiency.

In the long term, other priorities will actually benefit from energy efficiency, once the carbon neutrality goal has been met (or additional investment in energy efficiency is no longer the least-cost option). At that time the benefits to other priorities could be multiples of what they might have otherwise been, in roughly the same magnitude and timeframe as the benefits appearing from eventual relief of debt service.

A commitment to make aggressive but prudent re-investment decisions yearly or perhaps even quarterly, prioritizing energy efficiency, may be seen as preferable to a hard obligation to debt service. Both debt financing and aggressive spin-up of re-investment effectively access the future value of energy efficiency. Debt financing does this with more certainty and the fundamental advantage of earlier reductions in energy use. Aggressive spin-up of re-investment avoids incurring hard long-term financial obligations, but with more uncertainty and with some dependence on a significant fraction of deep high ROI projects in a campus retrofit efficiency portfolio.

The two approaches are not mutually exclusive. Aggressive spin-up of re-investment can be implemented with avoided energy budget in excess of debt service for existing or future portfolios of debt-funded projects.

5.7 Summary Strategy

The following strategies are suggested for developing, managing, and accessing traditional and alternative sources of funding:

Statewide Energy Partnership, UC Bond-Funded Loans— System Wide

Continue to improve the UC bond-funded loan program (Statewide Energy Partnership or SEP). For those campuses inclined to use debt financing, nothing can match the access to the future value of energy efficiency that the SEP provides as core financing for deep energy efficiency retrofits. This is demonstrated in the success of campuses like UC Irvine.

Continue to adapt the SEP and support M&V protocols to be independent of application of utility subsidies. Campuses will increasingly want to access the SEP independently of subsidies because of evolving limitations to subsidies, either by utility service territory (i.e., Riverside or UC Davis Medical Center) or by shifts to the availability of subsidies themselves.

Utility Incentives—System wide

Continue to pursue statewide utility subsidies through the Utility (IOU with addition of LADWP pending) Partnership. These subsidies can deepen the efficiency projects pursued through debt financing or accelerate the aggressive spin-up of re-investment. The pending expansion of the Partnership to include LADWP is an important accomplishment.

Utility Incentives—Campuses

Plan project implementation to take advantage of subsidies that will be phasing out, as well as anticipated new program offerings.

Spinning-up Aggressive Re-investment (Variation on Revolving Fund)

Regardless of level of debt financing used, consider committing to use budget surplus resulting from energy efficiency exclusively for re-investment in energy efficiency projects and associated risk management.

Consider using any infusions of funding for energy efficiency—including proceeds from campus sales of unneeded GHG emission permits, donor funds or utility budget surpluses from price decreases—as seeding for aggressive spin-up of re-investment of energy efficiency (a.k.a. aggressive management of a revolving fund). Seek new sources of seed funding.

Avoid low-cost projects that "trap" future value of energy efficiency (e.g., T12 to T8 conversions), even when pursuing high ROI projects to spin-up aggressive re-investment.

Prioritize utility incentivized measures for early implementation toward spin-up of re-investment.

6. Planning Methodology

Planning for energy efficiency retrofits at scale is enabled by a streamlined early analysis methodology that produces cost and value estimates suitable for planning purposes, but defers precision of detailed project design to implementation stages. For lighting, planning-level information for retrofits includes predominant fixture types, fixture density estimates, reference costs, representative operation and occupancy information, and reference project designs. This planning–level information typically comes from previous survey information, sample audits, and reference projects—previous project on a campus, or other campuses. This report provides one source of reference project information. Other sources include best practice project documentation, California Higher Education Sustainability (CHES) Conference presentations, or professional society conferences and journals.

6.1 Reference Projects

Reference project costs, design, and performance information can be found in Appendix 1. Application of this information is illustrated in the Business Plan template in Chapter BP.

The deep lighting retrofit project design that forms the basis of the business plan template is:

1) full rebuild of fixtures with LED technology and new optics, removing fluorescent ballasts and lamp holders, and
2) fully tunable networked lighting controls. with an average of 3 fixtures per zone in most areas.

Some reference projects are using LED fixture replacements or fixture-level control granularity in some scenarios. Some projects are using local controls in some scenarios, particularly private offices. These variations are all good alternatives to the basic project design.

Private spaces tend to have the widest variety of control approaches. This is due to typically lower baseline lighting energy use, along with some of the most interesting scenarios of integration with HVAC controls. The need for flexibility in control of private offices, including the scenario of no automatic control at all, is reflected in the revision of California Title 24 building energy efficiency standards effective in 1 January 2017, relaxing of control requirements for private offices with less than two fixtures.

Some campus projects are employing ballast compatible plug-in LED lamps in limited scenarios. These scenarios include down light or wall sconce fixture types for which replacement or complete rebuild options are less mature, or for buildings with limited remaining life. In the case of one campus housing unit, ballast compatible plug-in LED lamps are the predominant choice for a comprehensive retrofit program that is more than half complete.

Ballast compatible plug-in lamps do not reduce maximum power, offer as much control potential, or promise as much durability as full fixture replacement or rebuild. However first costs that are lower by an order of magnitude sometimes make them a compelling choice[38].

6.2 Timing of Detailed Project Design

Detailed project design steps are an integral part of retrofit project implementation. These steps need to be identified and budgeted for as a part of planning to scale. However, getting to scale will often require putting a plan in place, establishing requisite staffing, and securing initial funding before these steps are executed.

Creating a plan for efficiency retrofits at scale can and should often be implemented with modest available staff and student resources. An example of this is at UC Santa Barbara where this project and a parallel student effort resulted in an analysis of all energy efficiency retrofit opportunity for the campus (Bart et al 2016) and the Business Plan template in the report (Chapter BP).

This effort worked with sample audits in 8 buildings and one in-progress reference project; planning around 2 predominant fixture types, 3 general building types and 5 space categories. Campus information was supplemented with reference project information from other campuses.

UC Riverside is directly using planning metrics from the Business Plan template, adding a short scenario for buildings scheduled for demolition in 3-5 years (Attachment A). LBNL is proceeding with similar planning, but going further along into the implementation process. This effort is using additional resources including past comprehensive audits and consultant effort to identify specific solutions for more fixture types, obtain higher precision performance estimates, and create information suitable for bid packages for pilot projects (Attachment B).

6.3 Alignment with Carbon Neutrality Planning and Other Campus Planning

Planning for energy efficiency retrofits at scale should be fully integrated into 2025 carbon neutrality planning and other campus planning. Integrated planning will ensure the opportunity is fully valued and the necessary pace is recognized. Consideration of renovation scheduling in retrofit portfolio planning can provide economies of coordination.

Analysis should illustrate baseline and residual energy use and GHG emissions (e.g., not just "savings"). It is also desirable to characterize baseline, residual, and avoided energy use and GHG emissions for the systems being retrofit as percentages of overall campus or unit amounts (e.g., not just absolute values). It is also helpful to provide the context of the overall retrofit portfolio to-date, to provide perspective on the scale and pace of required efforts.

Examples of this characterization and context can be found in Chapter 1 Background and Chapter 2 preliminary analysis of to-date and planned retrofit energy efficiency savings and avoided CO2 emissions—relative to Climate Action Plan 2014 Inventories.

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[38] Retrofit options that rewire existing lamp holders are not commonly seen around the UC system. These options are not recommended because they create complex safety protocols.

BP. Business Plan for Lighting Retrofits in Academic, Administration, and Laboratory Buildings

This Chapter is a business plan template for deep energy efficiency lighting retrofits at scale in academic, administration, and laboratory buildings. The value proposition and financing analysis, including metrics on the basis of *per million gross square feet* of buildings, may be applicable to campus planning or can be adapted to local metrics. Planning is based on representative space-types and reference projects within the UC system**. Application to any campus should include assessment of the validity of assumptions for planning purposes. More detailed surveys and space-specific project designs will eventually be necessary—potentially completed as a part of the project development step of implementation.**

This planning methodology enables acceleration of retrofit efforts to scale by allowing consideration of a comprehensive portfolio of retrofits, while planning for and financing detailed project design as a part of project implementation.

Analysis is based on an electricity price of $0.105 per kWh.

Campus Business Plans

Campus-specific Business Plans are provided as attachments to this report. Both of these campuses have an applicable electricity price lower than $0.105 per kWh. These plans illustrate planning alternatives for lower electricity prices.

BP.1 Title Page

BUSINESS PLAN FOR DEEP ENERGY EFFICIENCY AT SCALE— INTERIOR LIGHTING RETROFITS IN ACADEMIC, ADMINISTRATION, AND LABORATORY BUILDINGS

UNIVERSITY OF CALIFORNIA, _______________

UC CARBON NEUTRALITY INITIATIVE

BP.2 Executive Summary

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- This plan can reduce greenhouse gas emissions (GHG) from interior lighting in University of California academic, administration, and laboratory buildings by 70-80+%.

- This plan is part of an overall portfolio of deep energy efficiency retrofits at scale that can reduce Scope 1 and 2 GHG emissions by one-third to one-half. Such a program is the foundation of an overall strategy to meet the goal of UC Carbon Neutrality Initiative goal of zero net GHG emissions from buildings and vehicle fleet by 2025

- This plan can be implemented between now and 2025.

- The $1.7-2.8 million cost (net of incentives) lighting energy efficiency retrofits (*per million gross square feet of buildings*) might be debt financed, or derived from as little as $0.7-1.3 million of seed funding (*per million gsf of buildings*) with a strategy of spinning-up re-investment[39].

- Seed funding may be available from utility budget surplus, allocation of cap and trade proceeds, green donors, or other sources.

- Utility incentives are likely to be available to subsidize a substantial fraction of costs, allowing incremental expansion of depth or breadth of scope.

- The avoided energy cost is $266,000 - $325,000 per year (*per million gsf of buildings*). This is fully available as budget surplus in 2025-2032, depending on financing strategy[40].

- Additional benefits include reduced maintenance costs, extended useful life of campus lighting systems, and improved lighting quality.

- Inclusion of service areas could add 10% to project costs and savings.

- Costs for in-house project development and project management staffing necessary to implement this retrofit program are included in cost estimates and financing strategies.

- In-house staffing of 0.3 FTE energy and project management professionals (*per million gsf of buildings*) between now and 2025 is commensurate with delivery of this lighting retrofit portfolio. This is in the context of a need for 1.2 FTE energy and project management professionals (*per million gsf of buildings*) for an overall deep energy efficiency retrofit portfolio.

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[39] Overall costs will be 4-14% higher in high prevailing wage areas (e.g., Northern California)

[40] Financing scenarios are for an applicable electricity price of $0.105.

BP.3 Context/Value Proposition

This business plan for deep lighting energy efficiency retrofits at scale is part of campus planning toward the UC Carbon Neutrality Initiative goal of net zero Scopes 1 and 2 greenhouse gas emissions by 2025.

[Optional]

Campus energy efficiency retrofits since establishment of the UC Policy on Sustainable Practices in 2004 are already avoiding xx% of electricity use, xx % of natural gas use, and xx% of Scopes 1 and 2 greenhouse gas emissions—relative to 2014 quantities of xx kWh per year, xx therms per year, and xx metric tons of CO2e per year.

Interior lighting retrofits in this plan are estimated to avoid electricity use of 2.5-3.1 million kWh per year and greenhouse gas emissions by 749-914 metric tons of CO2e per year (*per million gsf of building area*). These reductions are 70-80+% of the interior lighting baseline.

This plan is part of an overall portfolio of energy efficiency retrofits that can reduce Scope 1 and 2 GHG emissions by one-third to one-half. Such a program of energy efficiency retrofits is the foundation of an overall strategy to meet the goal of UC Carbon Neutrality Initiative goal of zero net GHG emissions from buildings and vehicle fleet by 2025 (Bart et al 2016).

There will be significant long-term financial benefits to the campus. The avoided energy cost is $266,000 - $325,000 per year (*per million gsf of buildings*). This will become fully available as budget surplus in 2025-2032, depending on financing strategy. Please see section BP.4 for financing scenarios.

In addition, lighting system maintenance and operational costs are anticipated to decrease on balance. The remaining useful life of campus lighting systems will be extended. Finer control of heating ventilation and air-conditioning systems may be enabled by occupancy sensors used as part of networked lighting controls. Campus lighting quality will be improved.

BP.4 Planning Assumptions and Metrics

This plan uses planning assumptions and metrics based on lighting retrofit projects implemented on this and/or other UC campuses[41].

Scope and Measures

Most linear fluorescent fixtures and compact fluorescent lamp-based downlight fixtures will be fully re-built with LED technology including elimination of existing ballasts and lamp holders and installation of new optics. Most other lighting fixture types will be fully re-built or replaced with LED technology. In some cases linear fluorescent fixtures will be completely replaced with new LED-based fixtures. Project costs for replacement fixtures will be higher on average. Avoided electricity use and GHG emissions for these fixtures will be higher on average.

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[41] In applying this template, assumptions should be checked for validity for planning purposes in the context of the campus application.

Most fixtures will get new networked lighting controls enabling the full tuning capabilities of LED lighting. Control granularity will average approximately 3 fixtures per zone. In some cases local controls with less capability may be employed, lowering project costs and resulting in less avoided electricity use and GHG emissions.

Inclusion and scope for private office space will be dependent on a number of detailed design factors including the availability of incentives[42]. Inclusion and scope for service spaces is dependent on the management approach to these spaces.

The estimates in this plan cover 90% of interior lighting fixtures in academic, administration, and laboratory buildings. Service areas could be added with rudimentary information about the management baseline and operations of these areas. For planning purposes service areas could be brought into the scope by increasing all planning amounts by 10%.

Space that will have major renovations between now and 2025—that will replace or substantially upgrade lighting systems—should be identified and designated for separate funding under that planning.

Project Design

For planning purposes, assumptions about nominal project designs are described in Table BP-1. These project designs are based on actual UC projects—representing a most-likely design within a wide range of design approaches. **Detailed surveys and space-specific project designs should be completed as a part of the project development step of implementation.**

Table BP-1 Assumptions for Nominal Project Designs

	Space-type	LED full fixture output (1) (fixture lumens)	LED full fixture power (Watts)	Average top-trim high level
4 ft linear	Circulation (e.g., corridors	4,200	37	80%
4 ft linear	General (e.g., open office, classroom)	4,200	37	60%
4 ft linear	Laboratory	4,700	42	65%
4 ft linear	Private	4,200	37	60%
Downlight	Circulation	1,800	20	90%
Downlight	General	1,800	20	90%

Notes: 1) LED fixtures or full LED re-build kits with optics are rated in terms lumens leaving the fixture (fixture lumens). This is as opposed to fluorescent lamps rated in terms of lamp output within the lighting fixture.

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[42] Networked fully tunable lighting controls are almost always appropriate in circulation and general space types. Several considerations make project design more situation dependent for private offices. Baseline energy use per fixture is low relative to other space types and task lighting approaches are highly applicable. Private office scenarios may be highly suitable for application of networked controls to heating, ventilation and air-conditioning control.

Baseline Power

The assumptions for the nominal base case power of incumbent fixtures are:

- 59 Watts ballast input for a 2 lamp x 4 foot linear fluorescent fixture with electronic ballast and F32T8 lamps, and
- 38 Watts ballast input for a 2 lamp x 18 Watt CFL down light.

Several other base cases will be encountered for linear fluorescent fixtures, most with higher power draw. Improvements in efficiency for these fixtures will generally be higher than planning assumptions.

Baseline and Controlled Hours of Operation

For planning purposes, estimates of nominal baseline and controlled hours of operation are listed in Table BP-2 for a variety of space types, along with the range encountered in various UC reference projects.

Table BP-2 Assumptions for Baseline and Controlled Hours of Operation

Space-type	Baseline hours/year	Controlled— Fully Tunable Networked Controls equivalent high output hours/year
	planning assumption (reference range)	
Circulation (e.g., corridors)	8,423 (2,182-8,760)	1,752 (946-5,471)
General (including Laboratory)	5,598 (3,276-7,919)	2,400 (2,400-2,584)
Private	3,000 (992-4,554)	1,440 (555-3,188)

Space-type Distribution and Fixture Counts

The Building Type Distribution and nominal fixture counts *(densities per million gsf of buildings)* used for planning purposes are listed in Table BP-3. These planning assumptions are conservative because they are based on lamp counts and the assumption of two-lamp fixture equivalents. Other fixture types will be encountered, mostly 3- and 4- lamp fixtures. This will tend to lower the actual retrofit fixture count and project costs.

Table BP-3 Assumptions for Space Distribution and Nominal Fixture Densities

per million gsf of buildings	Interior 2’ x 4ft linear fluorescent 2-lamp equivalents			Interior 2x 18 W CFL downlight equivalents
	Buildings with Labs	Academic/Administration Buildings	Overall	
	70% floor area by building	30% floor area by building		
Corridors			2,250	330
General Non-Lab (1)	4600	2750	4,025	190
General Lab	0	3650	1,115	
Private	3750	4150	3,865	
Subtotal			11,255	520
Service			1,150	50
Total			**12,405**	**570**

Notes: 1) Total general fixture equivalent density (lamp count) is lower in laboratory buildings because lab buildings are on average newer with sharper lighting designs

2) Fixture density is based on surveys at UC Santa Barbara

Project Costs

Project cost assumptions are listed in Table BP-4. Cost assumptions are based on a synthesis of reference projects on UC campuses. A full LED re-build kit including optics for recess-mount fixtures (troffers) is the basis for planning assumptions. Other fixture types will tend to increase costs. This will be offset by conservatively high fixture count assumptions.

Installation costs will be 4-14% higher in high prevailing wage areas (e.g. Northern California).

Table BP-4 Assumptions for Project Cost Per Lighting Fixture

	Fixture Materials Cost (full LED re-build kit with optics for recess-mount)	Fixture Labor Cost (2)	Controls Materials Cost	Controls Labor Cost (2)	Project Development & Management Cost (1)	Total Cost
4' linear	$122	$31	$70	$33	$36	$292
4' linear private office	$122	$31	$105	$33	$41	$332
Downlight	$121	$28	$70	$33	$36	$287

Notes: 1) 14% project development and management cost

2) Labor Costs will be 10-56% higher in high prevailing wage areas (e.g., Northern California). Resulting overall costs will be 4-14% higher,

Project Performance

Project economic performance by fixture and space-type is summarized in Table BP-5. The threshold for improving a debt-finance portfolio is an ROI greater than 11%—corresponding to the overall debt finance portfolio maximum debt service of 85%. Considering space-types individually, circulation spaces meet this threshold without incentives while general spaces may meet the threshold with incentives. Bundling space-types as in a typical project design, circulation and general space types together meet the threshold without incentives while circulation, general and private space types together may meet the threshold with incentives.

Table BP-5 Summary Project Performance By Fixture and Space-Type

	Circulation	Project Cost per Fixture (without incentives)	Annual Energy Savings Per Fixture	Annual Cost Savings Per Fixture (1)	ROI (without incentives)
4' linear	Circulation	$292	445	$47	16.0%
4' linear	General	$292	277	$29	10.0%
4' linear	General Lab	$292	265	$28	9.5%
4' linear	Private Offices	$332	145	$15	4.6%
Downlight	Circulation	$287	289	$30	10.5%
Downlight	General	$287	170	$18	6.2%

Notes: With electricity cost of $0.1015 per kWh

BP.5 Financing Scenarios

Two primary financing options are debt financing with UC bond-funded loans (the Statewide Energy Partnership) and spin-up reinvestment (a form of "green revolving fund" seeded with otherwise unobligated funds), both utilizing the budget surplus created from the avoided energy cost resulting from the retrofits. Utility incentives may be available and should be sought to subsidize part of the projects costs. These incentives can incrementally expand the project scope: by increasing the efficiency and therefore the avoided energy use GHG emissions and energy costs, by increasing the number of buildings that can be retrofit within exiting financing constraints, and/or by extending the space-types that can be retrofit within financing constraints.

Financing scenarios are quantified in Table BP-6, including both debt and spin-up reinvestment options, with variations on use of incentives. Loans and spin-up reinvestment are considered separately, but can be combined.

Debt Financing

UC bond-funded loans have been used to finance the majority of UC campus energy efficiency retrofits to-date. The planning parameters are 5% interest rate for 15-years with a maximum 85% debt-service ratio. Retrofit of major space types excluding private offices can be accomplished with debt-financing alone at the 85% debt service ratio limit, reducing energy use and greenhouse gas emissions from major space types to 30% of baseline (70% reduction).

Incentives can incrementally expand scope by allowing more buildings to be retrofit within a given debt plan, with a debt service ratio of 61% (breadth). Or incentives can extend retrofits to include private offices, further reducing energy use and greenhouse gas emissions to 20% or less of baseline (80+% reduction) with an 84% debt service ratio (depth). Incremental increase in energy efficiency is also possible with even higher efficiency LED fixtures or more granular controls. This is not explored in this planning analysis, but should be investigated in the process of detailed project design.

Assuming 2017 project implementation, the full avoided energy cost resulting from retrofits becomes available as budget surplus in 2032 for debt financing scenarios.

Spin-up Reinvestment

A spin-up reinvestment version of revolving funds is an alternative or complement to debt financing. These scenarios can be considered if debt capacity is an issue. Seed funding is required for these scenarios. After the use of seed funding at the outset to finance first project phases, subsequent phases are funded out of the energy budget surplus created by the initial phases. Spin-up reinvestment scenarios can also take advantage of incentives. Incentives increase the return on investment and increase the multiplier on the seed funding. As with debt financing the incremental benefit of incentives can allow: expansion of scope to more buildings with a given amount of seed funding, expansion of scope to include private office space, or higher energy efficiency in project design.

Multipliers on seed funding of 2-3 are available, depending on the scenario. Seed funding of 0.7-1.3 million per million gsf will result in overall investment of $1.7-2.8 million dollars over 8 years.

For planning purposes spin-up reinvestment scenarios conservatively assume

- an annual reinvestment cycle,
- a delay of one year in capturing avoided energy costs flowing initial investment.
- a reserve maintained on the energy budget surplus, in each year corresponding to 4% of the first year surplus,

Higher multipliers and lower seed funding amounts may be achievable with: a shorter re-investment cycle, quicker project delivery resulting in a shorter delay in capturing avoided energy costs, and/or a lower reserve on the energy budget surplus.

With spin-up re-investment, avoided energy costs are fully available as energy budget surplus immediately when re-investment ends in 2025—assuming phasing resulting in completion of retrofits in conjunction with the carbon neutrality goal.

Combination of Debt and Spin-up Reinvestment Financing

Debt funding scenarios in Table BP-6 assume none of the avoided energy cost net of debt service is re-invested in new projects. Re-investing the 15-39% of avoided energy cost net of debt service creates a hybrid scenario that lowers the amount of debt required for a given portfolio scope, and delays the availability of these net proceeds as budget surplus until re-investment ends in 2025.

Table BP-7: Financing Scenarios

All quantities are *per million gsf* of
Academic/Administration & Laboratory Buildings
Interior Lighting Retrofits ($0.105 per kWh)
Complete Re-build to LED Including Optics
Networked Fully-Tunable Controls
(average 3 fixture per zone granularity)
Major Space Types
(not including service spaces)
(inclusion of private offices depends on incentives)

Annual Interior Lighting Baseline	Annual Interior Lighting Baseline
3.6 million kWh $384.000	1,076 MT CO2e

Finance Scenario	Total Cost Scope	Incentives (3) Increment	Net Cost		Seed Funding Spin-up Reinvest Multiplier	Annual Residual Energy Use/ Cost Residual % of baseline	Annual Avoided Energy Use/ Cost Year fully available as budget surplus	Annual Residual GHG Residual % of baseline	Annual Avoided GHG	Debt Service Ratio (DSR) Annual Avoided Energy Cost Net of DSR
	$ million				$ million	kWh	kWh	MT CO2e		
Debt	$2.3 1	($0) N/A	$2.3		N/A	1.1 million $116,000 33%	2.5 million $267,000 2032	327 33%	749	83% $ 46,000
	$2.3 1	($0.6) Breadth	$1.7		N/A	1.1 million $116,000 33%	2.5 million $267,000 2032	327 33%	749	61% $103,000
	$3.6 2	($0.75) Depth	$2.85		N/A	0.5 million $ 57,000 <20%	3.1 million $325,000 2032	161 <20%	914	84% $ 73,000
Spin-up Reinvest Normal or Fast	$2.3 1	($0) N/A	$2.3	Norm	$1.2 1.9	1.1 million $116,000 33%	2.5 million $267,000 2025	327 33%	749	N/A
				Fast	$1.1 2.15	1.2 million $116,000 33%	2.5 million $267,000 2025	327 33%	749	N/A
	$2.3 1	($0.6) Breadth	$1.7	Norm	$0.7 2.3	1.1 million $116,000 33%	2.5 million $267,000 2025	327 33%	749	N/A
				Fast	$0.6 2.8	1.2 million $116,000 33%	2.5 million $267,000 2025	327 33%	749	N/A
	$3.6 2	($0.75) Depth	$2.85	Norm	$1.5 1.9	0.5 million $ 57,000 <20%	3.1 million $325,000 2025	161 <20%	914	N/A
				Fast	$1.3 2.1	0.5 million $ 57,000 <20%	3.1 million $325,000 2025	161 <20%	914	N/A

Notes:
1 Scope is all major space types except private offices
2 Scope is all major space types including private offices
3 When listed, incentives are at the full Utility Partnership level of $0.24 per kWh/year

BP.6 Implementation Plan

BP.6.1 Staffing

Plan to establish energy retrofit project delivery staffing levels commensurate with all anticipated retrofit project activity including but not limited to interior lighting:

- Necessary staffing is is estimated to be 0.3 FTE per million gsf of buildings for interior lighting (within a range of 0.2 to 0.4).
- This is typically in the context of an overall retrofit portfolio for all end-uses requiring 1.2 FTE per million gsf of buildings (within a range of 0.8 to 1.6).

Variability within the range can depend on the amount of survey work that is done in house and the amount of documentation required (e.g., for incentives). The effort required includes project development that typically draws from energy management staff, as well as project management that may also draw from other campus staff (e.g., capital projects).

Staff needs for project development and part of project management overlap with general energy management staffing. General energy management staffing needs are thought to be 0.6 to 1.0 FTE per million gsf. The fraction of this dedicated to retrofit portfolio delivery depends on the fraction of the comprehensive campus retrofit portfolio that has already been implemented and the fraction of portfolio delivery staff that is drawn from other campus departments.

The cost of this staffing is included in overall project cost estimates and financeable. If there is not currently a significant level of retrofit project activity, some seed funding may be necessary to initiate scaling-up of staffing. Start-up costs is minimized by the deferring of detailed project development to later stages of project development, using the planning-level metrics in this plan to secure initial allocations of funding.

These staffing estimates are based on:

- surveys of energy management staff at higher education universities including UC,
- 7-16% of overall project costs needed for project development and management (8-20% adder to materials and installation costs), and
- an eight-year timeframe to implement the portfolio in conjunction with the 2025 carbon neutrality goal.

Overall UC campus experience is that in-house staffing is the best way to deliver an energy efficiency retrofit portfolio. Installation and survey work may be successfully outsourced. However, efforts to outsource project development decisions or project management have met with limited success.

BP.6.2 Implementation Steps

- Select a scope/financing scenario
    - Building list (e., not slated for major renovation or demolition)
    - Commitment to plan

- Develop first phase project(s) based on the metrics in this plan.
    - Assess current availability of incentives
    - Pursue/allocate SEP loan, seed funding, incentives

- Develop detailed project documentation
    - Surveys
    - Detailed project design
    - Bid packages
    - Measurement and verification plans

- Implement projects including procurement and project management

- Implement measurement and verification including:
    - Analysis for debt service and /or spin-up reinvestment accounting,
    - Documentation for incentives, and
    - Improvement of project design for subsequent phases.

- Integrate upgraded lighting controls into operations
    - Shift maintenance resources from re-lamping to operations management
    - Integrate surplus into financial planning

- Develop and implement subsequent project phases

BP.6.3 Phasing Considerations

If the project portfolio is debt financed, phasing can be optimized to consider:

- integration into whole-building retrofit projects covering multiple end-uses
- capturing GHG reduction and cost reductions net of debt service as early as possible

If the project portfolio is fully or partly spin-up reinvestment financed, phasing needs to consider:

- timing of availability of energy budget surplus for project funding,
- possible scheduling of higher return-on-investment spaces or buildings early to maximize the multiplier on seed funding.

BP.6.4 Procurement Considerations

Installation

Economies of scale, continuity, and competition are achievable for to control installation costs. One approach consistent with campus-wide scale, that can capture all of these economies, is a multiple vendor process. Multiple (e.g., three) vendors are qualified to operate on campus simultaneously, then bid against each other for increments of project scope. Mobilization (scale) and familiarization (continuity) costs are limited while still reducing costs through competition.

Materials

Much of the available economies of scale for materials are already captured from typical building-scale projects, or from installation vendor aggregation of purchases. Still, coordination may be able to reduce costs by aggregating materials purchases within other phasing constraints.

Some lighting equipment incentives, specifically recess mount LED rebuild kits or replacement fixtures are, at least in the short term, being shifted by some utilities to distributors (mid-stream). This requires coordination with vendors to capture these incentives.

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Appendix I—Reference Project Information

LED Retrofit Project Design—Reference Projects and Planning Baseline/Occupancy Assumptions

Scenario	UC Project 1	UC Project 2	SPEED Adaptive Corridor Business Case Based on Multiple Demonstrations	SPEED 50 Corridor Study	UC Campus Planning Scenario 2	Planning
Corridors and Bathrooms Baseline No Controls	8,760 (hb)	7,274 – 8,760			7,000 (cb)	8,423 (24/7 less 2 wk winter break)
Corridors and Bathrooms Occupancy	2,716 – 4,818 (co)	2,182 – 5,471	1,752 (20%)	946(10.8%) (lo)	2,000	1,752 1,927 for less capable local controls
Open Spaces, Labs, Lecture Rooms, & Shared Offices Baseline No Controls	7,919 (hb) 5,147 (basic control)		UC Campus Planning Scenario 1—Lab 3,276-6,115 (cb) 5,304 typ		4,400	5,598 (avg of bounds)
Open Spaces, Labs, Lecture Rooms, & Shared Offices Occupancy	2,534 (co)				2,400 (lo)	2,400 2,640 for less capable local controls
Private Offices No Controls	4,554 (hb)	992 – (cb)			3,600	3,000
Private Offices Occupancy	3,188 (co)	555 – (lo)			2,800	1,440 1,584 for less capable local controls

Notes: **(cb)** Conservative baseline scenarios
(hb) High baseline scenario
(co) Conservative occupancy scenario
(lo) Low occupancy scenario

LED Retrofit Project Design—Reference Projects and Planning Design

Existing Scenario	UC Project 1	UC Project 2	UC Project 3	UC Project 4	UC Campus Planning Scenario 2	Planning
(3) 2' T8 lamp 2'x2' Recess Mount (Troffer) 3600 source lumens Nominal 51 Watts			Rebuild w Optics 3,200 fixture full lumens 29 Watts egress **(a)** no trim open office **(b)** top-trim to 40% (avg of 10-80%) private office **(b)** 2,361 fixture full lumens 23 Watts top-trim to 50% *$124 Mat **(f)*** *$41 Install* *Qty ~700*			
(2) 4' lamp 2'x4' Recess Mount (Troffer) 6000 source lumens Nominal 59 Watts (Elec Ballast) 64-71 Watts (Mag Ballast)	Replacement 4,000 fixture lumens 44 Watts *$120 Mat* *$61 Install* *Qty ~1500* Light Bar **(c)** Rebuild 4,500 source lumens 44 Watts *$103 Mat* *$36 Install* *Qty ~600* some spaces too bright **(a)**	**Lab Application** Rebuild w Optics 3,000 fixture lumens 33.3 Watts			Rebuild w Optics 4,200 fixture full lumens top-trim to 60% 37 Watt 22W @60% **(d)** *$122 Mat* *$31 Install* *Scale*	Rebuild w Optics 4,200 fixture full lumens 37 Watt top-trim to 60% 22W @60% **(d)** **Circulation** top-trim to 80% 30 W @ 80% **Lab Application** 4,700 fixture full lumens 42 Watt top-trim to 65% 25W @60% **(e)** *$122 Mat* *$31 Install* *Scale*
(3) 4' lamp 2'x4' Recess Mount (Troffer) 9000 source lumens Nominal 89 Watts				Replacement with Integrated Controls 4,000 fixture full lumens 40 Watts		

Notes:
(a) Low performance bound scenario
(b) High performance bound scenarios
(c) Also applicable to pendent and surface mount fixtures
(d) 11W per lamp replaced for (2) lamp fixture
(e) 13.5W per lamp replaced for (2) lamp fixture
(f) including return grill for through-the-lights return
All costs are per fixture, not including project development and management

Project Design—Reference Projects and Planning Design

Existing Scenario	Reference Projects and Planning Scenarios				**Planning**
	UC Project 1	UC Project 2	UC Campus Planning Scenario 1	UC Campus Planning Scenario 2	
CFLs in Down Lights or Other Fixtures					Reference project ratio of LED directional lamp lumens to non-directional CFL lamp lumens is 0.27-0.79 Ratio of LED Watts to CFL Watts is 0.29-0.58
(1) x 32 W CFL 34 W 2,400 lamp lumens	Plug-in/ballast compatible 15 W LED 970-1050 directional lamp lumens *$30 Mat* *$6 Install (no lift)*				
(2) x 26 W CFL 50 W 2 x 1,800 lamp lumens		Plug-in/ballast compatible 15 W LED 970-1050 directional lamp lumens **(b)** *$30 Mat* *$44 Install (lift)*			
(2) x 18 W CFL 38 W 2 x 1200 lamp lumens			Retrofit 20 W LED 1,800 fixture lumens $121 mat $28 install (no lift)	Plug-in/ ballast compatible non-dimmable (2) x 10.5 W LED 2 x 950 directional lamp lumens **(a)** *$18 Mat* *$18 Install* *(comb lift/no lift)*	Retrofit Downlight 20 W LED 1,800 fixture lumens $121 mat $28 install (no lift)
(1) x 26 W CFL 27 W 1 x 1,800 lamp lumens			Retrofit 20 W LED 1,800 fixture lumens $121 mat $28 install (no lift)	Plug-in/ ballast compatible 15 W LED 970-1050 directional lamp lumens *$18 Mat* *$18 Install* *(comb lift/no lift)*	
(1) x 18 W CFL 20 W 1 x 1,200 lamp lumens			(Based on larger fixture)		Retrofit Downlight 11 W LED 1,000 fixture lumens $68 mat $28 install (no lift)

Notes:		
	(a)	Low performance bound scenario
	(b)	High performance bound scenario

All costs are per fixture, not including project development and management.

LED Retrofit Project Design, Controls—Reference Projects and Planning Costs

Controls Scenario	UC Project 1	UC Campus Planning Scenario 1	UC Project 3	UC Project 4	UC Campus Planning Scenario 2	Planning
Advanced Lighting Control System Networked Top-Trim Fixture Granularity			*$107 Mat* *$61 Install* *Qty ~360*			
Advanced Lighting Control System Networked Top-Trim Less Granularity (~3 fixtures per sensor)		*$70 Mat* *Qty ~2,000*			*$66 Mat* *$33 Install* *Scale* *(Synthesized from Projects/Quotes)*	*$70 Mat* *$33 Install* *Scale* *Private Offices* *$105 Mat*
Local Controls Ceiling Occupancy Sensor	*$28 Mat* *$10 Install* *Qty ~740*					*$24 Mat* *$14 Install* *Scale*
Local Controls Wall Sensor	*$20 Mat* *$12 Install* *Qty ~200*		*$62 Mat* *$25 Install* *Qty ~290*			

Notes: **(a)** High bound scenario
(b) Low bound scenarios
All costs are per fixture, not including project development and management.

Reference Metrics
Retrofit Cost References and Assumptions

Project Development & Management

Type	Added Cost	Scope	Reference	Notes
Interior	19.4%	>200,000 gsf bldg / >10 fixture types	Project 1	
Interior	8%	>50,000 gsf bldg / 1 fixture type	Project 3	
Exterior	13.1%	> 2,000 fixtures / > 10 fixture types	Project 5	

Project Cost Factors

The DeepEE2104 Study (ARC Alternatives 2014) identified project cost factors for certain campuses. These factors are multipliers on base project costs to account for conditions that can increase costs.

For the main campuses (not acute care facilities at medical centers) cost factors were assigned based on feedback from campuses:
Campus A 1.25
Campus B 1.5

The study assumed Campus C would be similar to Campus A at 1.25

The reasons identified for the higher costs are:

- High cost of construction in urban areas
- High rise buildings
- Older buildings with greater presence of hazardous materials, such as asbestos
- Lack of space for student surge and project staging
- Complexity of research space at an all-graduate campus (San Francisco)

It is not clear the factors apply to campus lighting projects:

- Costs of construction can also be relatively high in a coastal location. There may be less of a difference if the cost references are from other UC campuses as opposed to general building stock.
- Extra costs in high-rise buildings may not apply to lighting projects as the work is virtually all accessed from the occupied space.
- Lighting fixture re-build kits are now often designed to allow all work to be done from within the existing fixture, without above ceiling access.
- Lighting retrofits are short duration projects for a given space, minimizing the need for re-location.
- Complexity of research space may impact lighting retrofits, but not to the degree it impacts HVAC retrofits.

Estimation of cost factors should be done specifically for lighting retrofits, considering that lighting projects can be designed for minimal interactions with the buildings and occupants.