# New Tool For Establishing Comprehensive Deep Energy Efficiency Retrofit Programs For The Multi-Tenant Light Commercial Building Sector

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## ABSTRACT

Current energy efficiency programmatic solutions addressing the Multi-Tenant Light Commercial (MTLC) market sector primarily rely on direct install programs and often, as a result, leave broad sets of retrofit opportunities unconsidered and unrealized. On the other hand, comprehensive, deep energy efficiency retrofits that rely on fully customized audits and implementation programs are too costly to justify for this market segment. To achieve comprehensive, deep energy retrofits within the MTLC building sector, program implementers would benefit by having the ability to customize recommendations for retrofit measures in a cost-effective fashion. A modeling tool that would enable comprehensive programs that offer customized, retrofit measure recommendations targeted at MTLC buildings would need to generate cost-effective measures specific to a building, based on its end use activity, geographic location, and available rebates.

The MTLC Toolbox is a new tool that combines the strength of EnergyPlus building modeling software with an easy to use functional front-end. The interface allows the user to perform simple, accurate, and easy to understand energy efficiency analysis and the ability to customize solutions for specific buildings and tenants. The tool adapts the existing EnergyPlus reference strip mall model to more adequately represent market conditions based on thorough market research of California's MTLC market. This paper demonstrates the capabilities of the tool and future implications in providing comprehensive energy conservation recommendations for MTLC buildings without the need of an engineering team, thus decreasing transaction cost.

## Introduction

Multi-Tenant Light Commercial (MTLC) buildings, commonly referred to as "strip shopping malls", encompass a wide variety of building types including single-story buildings with multiple tenants, and mixed-use, low-rise developments with offices, retail shops, and other spaces on various floors.

MTLC buildings include a wide variety of primary building activities, structural configurations, ownership and occupancy arrangements, and leasing structures. These buildings are classified as stand-alone buildings or complexes composed of a group of buildings, as in the case of a large shopping center or an office campus (Huppert et al. 2013; Kessler 2014). From an energy billing perspective, each of these buildings could have one or several utility meters; in some cases, a number of buildings might be aggregated under a single utility meter. It is easier to implement deep energy retrofits in some sub-sectors of the commercial market, such as owner-occupied, large office campuses; for other sub-sectors, such as MTLC buildings, it is much more difficult to implement deep energy retrofit projects, due to a variety of barriers and competing stakeholder interests (Huppert et al. 2013; Bell, Sienkowski, Kwatra 2013).

## Definition of MTLC buildings

It is difficult to create a universally accepted definition; a useful definition for the MTLC sector can be established based on the component terms: “multi-tenant” and “light-commercial”.

It is observed in the Commercial Building Energy Consumption Survey (CBECS) data that 99% of all multi-tenant commercial buildings (buildings with 2 or more tenants) in the U.S. have 38 or less tenants (EIA 2003). In order to narrow the focus, the research team considered 38 or fewer tenants as the cutoff to define MTLC buildings.

Light commercial, also referred to as “small commercial”, is often defined in the literature according to one of two variables: square footage (sq-ft) of the building, or peak electric demand (kW) of the building over a given year. Based on sq-ft, light commercial buildings are broadly defined as buildings under 50,000 sq-ft. One rationale that is often cited is that 95% of all commercial building stock in the U.S. is under 50,000 sq-ft. (Huppert et al. 2013) Some definitions limit the maximum sq-ft of small commercial to 30,000 sq-ft. (ICSC 2015).

When defining light commercial based on the peak load of the buildings (a definition usually employed by the utility providers), light commercial building accounts (which most MTLC buildings have) are defined as small and medium-sized business accounts with a peak demand under 200 kW; some utilities use a peak load under 499 kW (Stadler et al. 2010). The peak demand usage for light commercial buildings can be converted to a rough estimate of sq-ft using the value for non-coincidental peak load per sq-ft (3.06 watts per sq-ft) (CEUS 2002) averaged across all commercial buildings in California. A 200 kW peak load corresponds to 65,000 sq-ft and 499 kW corresponds to 163,000 sq-ft. It is observed in CBECS data that 99% of all commercial buildings in the U.S. have a gross leasing area of less than 160,000 sq-ft (EIA 2003). The 160,000 sq-ft is also consistent with the calculation of 163,000 sq-ft based on the 499 kW peak load condition. Therefore, 160,000 sq-ft was used as a cutoff for defining light commercial buildings.

The definition of an MTLC building for the research at hand is as follows:

- Commercial end-use with tenant types including retail, food store, offices, restaurants, mercantile, etc.
- Between 2 and 38 tenants.
- Leasable area size of less than 160,000 sq-ft.
- Power load less than 499 kW.

## Size and Economic Importance of the MTLC Sub-Sector

As listed in the table below, there are a total of approximately 910,000 MTLC buildings in the U.S. Those buildings account for approximately 20% of all commercial buildings, 21% of all commercial building sq-ft, and 25% of all electricity used by commercial buildings. This was calculated by comparing all US CBECS commercial data relative to buildings for 2 to 38 tenants, and less than 160,001 sq-ft.

Of all US MTLC buildings, 90,000 MTLC buildings are in California, accounting for roughly 2% of all US commercial buildings, 2% of all US commercial sq-ft (1.5 billion sq-ft), and 2% of all US commercial electricity consumption (20 billion kWh). Furthermore, the MTLC market in California accounts for 22% of California commercial buildings, 26% of California commercial sq-ft, and 26% of California commercial building electricity consumption. California approximations were calculated by isolating for buildings labeled in the West-Pacific census region, and then each building was weighted for climate zones. For example, we estimated that roughly 95% of climate zone 4 buildings within West-Pacific were in California, and thus a building labeled West-Pacific and climate zone 4, counted 95% towards California statistics. These statistics clearly show the scale of MTLC buildings in California.

Table 1. Scale of California MTLC Buildings.

| | Number of CBECS Records | Total Number of Buildings | Total Number of Buildings (% of total US) | Total Area (Millions of SQ FT) | Total Area (% of total US) | Annual Electricity Usage (GWh) | Annual Electricity Usage (% of total US) |
|---|---|---|---|---|---|---|---|
| Commercial Buildings (All US) | 5100 | 4,600,000 | 100% | 70,000 | 100% | 1,000,000 | 100% |
| Multi-Tenant Buildings (All US) | 1600 | 940,000 | 20% | 24,000 | 34% | 410,000 | 41% |
| Multi-Tenant Light Commercial Buildings (All US) | 1200 | 910,000 | 20% | 15,000 | 21% | 250,000 | 25% |
| Commercial Buildings (CA-specific) | -- (Calc.) | 410,000 | 9% | 5,700 | 8% | 76,000 | 8% |
| MTLC Buildings (CA-specific) | -- (Calc.) | 90,000 | 2% | 1,500 | 2% | 20,000 | 2% |

*Source:* EIA 2003.

## Problem Definition and Motivation

### Current Audit and Retrofit Limitations in MTLC Buildings (Problem Definition)

As the focus of this paper is to discuss a tool that can help improve accessibility and cost-effectiveness of audits and deep energy retrofits to the MTLC sector, it is important to discuss the current approaches toward energy efficiency. The current process for implementing energy efficiency retrofits is diagrammed in Figure 1. There are five main steps to the retrofit process which include: solicitation (customer is engaged by auditor to participate in a building or tenant space audit), on-site audit (auditor collects data for understanding how the space is consuming energy), follow-up analysis (auditor analyzes measurements from on-site audit to measure how space is consuming energy and where improvements and retrofits can be implemented), retrofit (auditor or subcontractor performs building system maintenance and may replace equipment to match occupant needs and realize energy savings), and energy measurement and verification (auditor or sub-contractor quantifies and verifies the energy and cost savings resulting from improvements in energy-consuming systems, determined by comparing energy use before and after the installation of energy saving measures and making appropriate adjustments for changes in conditions such as weather)[1] (Webster et al. 2015). In addition to describing the process, we briefly describe the limitations of auditing in two extremes: direct install (DI) programs and ESCOs.

One significant problem is how follow-up analysis is currently done (highlighted in light orange). As seen in Figure 1, there are two extremes to follow-up analysis in the auditing and retrofit process. In one extreme, DI programs only implement measures with known savings based on the Database for Energy Efficiency Resources (DEER) or other sources, which provides an incomplete picture of potential savings. As such, DI programs focus on the most cost-effective measures that can help utilities gain cumulative savings in the aggregate. This is a good first step in approaching energy efficiency and the measures are provided for free or at little cost by the utility, but it falls short of realizing deep energy savings for individual tenants and building owners. At the other extreme, engineers at ESCOs can provide a better understanding of energy saving opportunities and deeper savings, but this is very expensive as ESCOs require costly engineering resources and analysis. ESCOs thus generally target larger buildings (understood to be 50,000 sq-ft and above) with a single point of responsibility for energy payments as there is a larger energy savings opportunity to generate the necessary revenue to recoup the cost of the project and profit; popular markets including office buildings and the MUSH market (municipal and state governments, universities and colleges, K-12 schools, and hospitals). Thus, the current options are low-cost with little energy savings, or high-cost with high energy savings.

Currently there are no available solutions that can provide cost-effective, deep energy savings to the small and medium commercial building sector (Stuart et al. 2013), especially not in MTLC buildings (Huppert et al. 2013). Implementing deep energy retrofits are easier in some sub-sectors of the commercial market, such as owner-occupied, large office campuses, while deep energy retrofits are inhibited in MTLC spaces is inhibited by the high cost of the retrofit process; ineffective packaging of technologies; savings is spread out among the different tenants, as is the case in multi-tenant buildings; and incomplete understanding of savings through retrofit packages.

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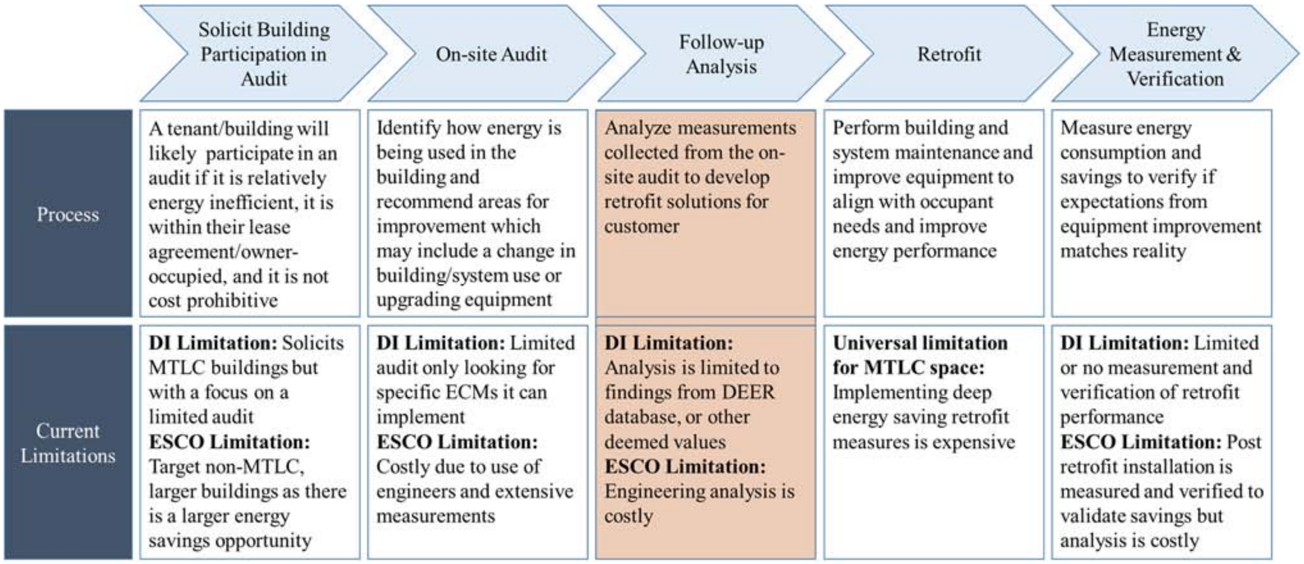
[1] energy service companies (ESCOs) business model guarantees energy savings and that requires measuring building or tenant space post-installation measurement to verify estimated savings, while energy measurement and verification is not always done in a direct install program



| | Solicit Building Participation in Audit | On-site Audit | Follow-up Analysis | Retrofit | Energy Measurement & Verification |
|---|---|---|---|---|---|
| Process | A tenant/building will likely participate in an audit if it is relatively energy inefficient, it is within their lease agreement/owner-occupied, and it is not cost prohibitive | Identify how energy is being used in the building and recommend areas for improvement which may include a change in building/system use or upgrading equipment | Analyze measurements collected from the on-site audit to develop retrofit solutions for customer | Perform building and system maintenance and improve equipment to align with occupant needs and improve energy performance | Measure energy consumption and savings to verify if expectations from equipment improvement matches reality |
| Current Limitations | **DI Limitation:** Solicits MTLC buildings but with a focus on a limited audit<br>**ESCO Limitation:** Target non-MTLC, larger buildings as there is a larger energy savings opportunity | **DI Limitation:** Limited audit only looking for specific ECMs it can implement<br>**ESCO Limitation:** Costly due to use of engineers and extensive measurements | **DI Limitation:** Analysis is limited to findings from DEER database, or other deemed values<br>**ESCO Limitation:** Engineering analysis is costly | **Universal limitation for MTLC space:** Implementing deep energy saving retrofit measures is expensive | **DI Limitation:** Limited or no measurement and verification of retrofit performance<br>**ESCO Limitation:** Post retrofit installation is measured and verified to validate savings but analysis is costly |

Figure 1. Diagram of audit and retrofit process.

### Motivation

The focus of the tool is to improve how follow-up analysis is currently done (the highlighted portion of Figure 1). As discussed before, there are no cost-effective solutions that yield a comprehensive understanding of energy use and path to deep energy savings. While this tool cannot achieve the breadth and depth of an ESCO analysis, we hope to achieve a middle-ground solution that seeks to capture a deeper understanding of savings in a DI audit by developing this tool.

This tool provides more energy professionals, beyond costly engineers, the ability to analyze building energy use and identify retrofit technologies specifically identified as suitable for MTLC-buildings that can be implemented to reduce their overall energy consumption. The proposed tool takes a more extensive look at possible measures than a DI program and can be implemented in an MTLC building, while not requiring the time and analysis of engineering staff at an ESCO firm or utility. Thus, the tool provides a wide breadth of energy conservation measures to achieve deeper energy savings while also minimizing the cost requirements.

In broader terms, this tool can play a significant role for small and medium building audit program development. As we stated before, implementing energy efficiency retrofit projects in MTLC spaces is inhibited by the high cost of the retrofit process, ineffective packaging of technologies, and incomplete understanding of savings through retrofit packages. This tool would facilitate deep energy retrofits by encouraging more extensive data collection, directly provide a way to analyze building energy consumption, and thus provide better and more extensive recommendations without the cost of a custom-fit ESCO program.

## Multi-Tenant Light Commercial Building Toolbox

The goal of the MTLC toolbox is to develop a tool for MTLC buildings that wouldn’t go as far as providing a fully tailored solution, but would seek to implement retrofit measures that go further than current direct install programs. The program would implement more measures than direct install programs, account for interactive effects, and also reduce costs for, and increase access to, more expensive measures such as more extensive energy audits and HVAC by reducing the associated costs in modeling and labor.

## Advantages over Previous Commercial Building Tools

The developed tool uses a “MTLC model” building that represents a typical tenant space found in California, and it can be modified in terms of operation and equipment, to represent a variety of different tenant types (e.g. instead of generic retail, more specific tenant types include: Mercantile, Office, Food Service, Food Store, Salon Service). Previous studies that have addressed the MTLC sector have focused only on general retail spaces (DOE 2016a; DOE2016b; HMG 2012). In addition, the tool tailors specific business operating and equipment characteristics to each of these tenant types. The MTLC tool includes customized hours of operation, equipment power densities, lighting power densities, occupancies, wall construction, roof construction, and HVAC systems, creating more representative tenant and construction types beyond a generic retail space with no specificity. These parameters are based on historical California building code requirements, engineering evaluation, and industry expertise.

The MTLC tool addresses a second shortcoming not done by previous work: the lack of tools for MTLC stakeholders to modify designs to meet their individual needs, and the inability to examine the impact of individual energy retrofit technologies on energy consumption along with the impact of retrofit packages cumulatively. The tool was developed primarily for entry-level energy auditors to lower the cost of building analysis. It provides the user with the opportunity to analyze building energy use, and identify steps to reduce overall energy consumption.

## Capabilities

The MTLC Toolbox is a user-interface that uses the U.S Department of Energy-created EnergyPlus as the simulation engine. EnergyPlus is an open-source building energy simulation software, which is typically used for a comprehensive and customized building energy analysis. The level of detail and customization required to develop an accurate model for a building makes the software difficult for the average user. The developers of EnergyPlus did not create the software for people to use directly. They designed it primarily to function with an externally developed user-interface, which is the precisely the purpose of the MTLC Toolbox. The functional combination of the MTLC Toolbox and EnergyPlus allows for a simple, accurate, and easy to understand energy efficiency analysis.

The MTLC Toolbox utilizes the analytical strength of EnergyPlus by using a comprehensive building model developed by the California Lighting Technology Center and the Western Cooling Efficiency Center (Alley et al. In Review). Through their extensive research in the MTLC building sector, the centers developed a more relevant market model for MTLC buildings in California by tweaking the DOE reference model building to reflect characteristics closer to the audited buildings. The existence of this open-source, easy to use, tool is an important and unique contribution of this project to the body of research dedicated to building simulation and energy efficiency in the MTLC segment.

**Inputs.** The MTLC Toolbox has been developed to allow the user to explore potential energy savings through technology and construction retrofits. The toolbox will develop a current, or baseline, model for the user based on their current equipment specifications. Although the general model is an accurate representation of a typical MTLC building in California, several parameters in the model can be modified based on certain specifications of the building or tenant space being analyzed. Variable factors that influence these parameters include lighting specifications, HVAC equipment, exterior envelope characteristics, geographical location, etc. To achieve that level of customization, the MTLC Toolbox contains short user-forms, which ask the user to make specific selections regarding the equipment and characteristics of their tenant space with said variable options and baseline values indicated in Table 2. The MTLC Toolbox adds the customized information to the building model, and runs simulations based on the specified selections.

After selecting parameters such as tenant type, building orientation, window-wall-ratio, and climate zone to build a model of their existing building, users may then compare its energy performance against its performance with one of more than 3000 possible ECM packages. Packages may be composed of lighting power density reductions, HVAC efficiency improvements, and the addition of energy-efficiency technologies such as cool roofs, skylights and daylight harvesting controls.

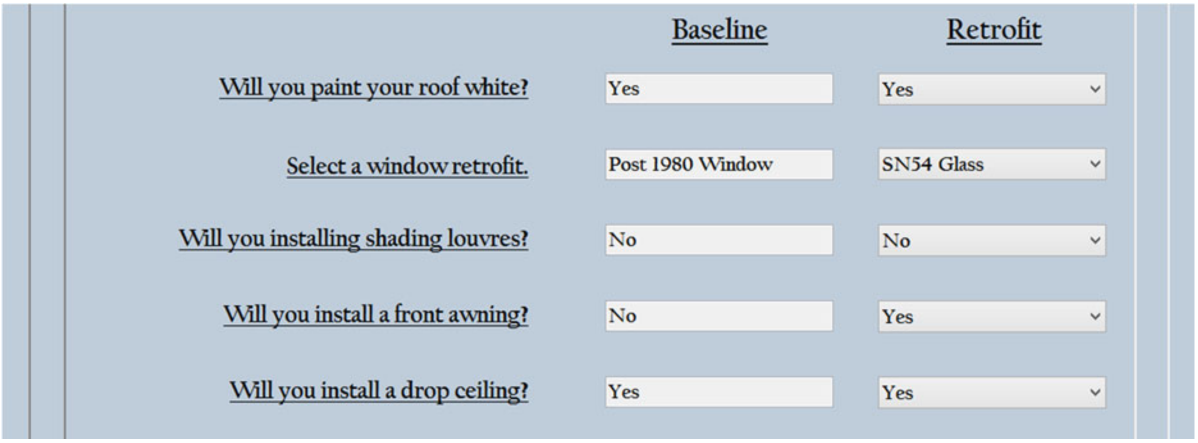
Table 2. Key variable used for MTLC toolbox parameters.

| Parameter | Variables | Baseline Value |
|---|---|---|
| Business Type | Mercantile; Office; Food Service; Food Store; Salon Service | Mercantile (retail) |
| Building Location | 1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11; 12; 13; 14; 15; 16 | Climate Zone 12 |
| Building Orientation | North; South; East; West | West |
| Tenant Space Location | Left End Unit; Right End Unit; Center Unit | Center Unit |
| Roof<br>DOE reference building (circa 1980-2003, updated to comply with Title 24, Part 6 requirements for R-value) | Standard Roof; White Roof | Standard Roof |
| Drop Ceiling | No Drop Ceiling; Drop Ceiling with R-value = 14 | No Drop Ceiling |
| Window-Wall Ratio | 50%; 80% | 50% |
| HVAC | COP = 2.9; 4.1; 5; 6<br>Standard Cooling; Evaporative Precooling<br>No Economizer; Economizer<br>Automatic Fan Control; On | COP = 2.9<br>Standard Cooling<br>No Economizer<br>Automatic Fan Control |
| Duct Leakage | Leaky = 18%; Tight = 3% | Leaky = 18% |

| Parameter | Variables | Baseline Value |
|---|---|---|
| Envelope Leakage | $4.5 \cdot\ 10^{-5}\ kg/(s \cdot ft^2)\ at\ 1\ Pa$ | $4.5 \cdot\ 10^{-5}\ kg/(s \cdot ft^2)\ at\ 1\ Pa$ |
| Skylights | None; Skylights (compliant with T24-2013 requirements) | None |
| Awnings | None; Awning on Front-Façade Windows | None |
| Window Louvers | None; Exterior Horizontal Window Louvers, 0° tilt | None |
| Windows | Pre-1980: [U-factor = 6.927, SHGC = 0.54]; Post-1980: [U-factor = 4.088, SHGC = 0.38]; Post-2004: [U-factor = 3.236, SHGC = 0.25]; SN54: [U-factor = 1.65, SHGC =0.25]<br>VLT: 0.6 for all<br>Diffuse (top window in 80% WWR only): [U-factor=1.02, SHGC = 0.13, VLT = 0.1] | Post-1980: DOE reference building (circa 1980-2003); U-Factor (W/m2*K): 4.088; SHGC: 0.38; VLT: 0.6 |
| Horizontal Louvers (outdoor) | None; Fixed Louvers with 0° Downward Inclination | None |
| Indoor Lighting | Linear Fluorescent T8; LED lighting; T12 lighting<br>LPD Based on Business Type | Linear Fluorescent T8<br>LPD (retail) = 1.14 |
| Indoor Lighting Controls | Manual Switches Only, Daylight Harvesting Controls | Manual Switches Only |
| Outdoor Lighting (not modeled in MTLC tool) | N/A | N/A |

*Source:* Alley et al. In Review

After the baseline model is developed, the user will run through a similar user-form, seen in Figure 2, and select new, recommended equipment for each parameter they customized in their baseline model. The MTLC Toolbox will use the retrofitted selections to create a retrofit building model. The retrofit model will run through an EnergyPlus simulation, and the energy consumption outputs of the retrofit model will be compared to the outputs of the baseline model to determine the energy savings resulting from the equipment retrofits.



| | Baseline | Retrofit |
|---|---|---|
| Will you paint your roof white? | Yes | Yes |
| Select a window retrofit. | Post 1980 Window | SN54 Glass |
| Will you installing shading louvres? | No | No |
| Will you install a front awning? | No | Yes |
| Will you install a drop ceiling? | Yes | Yes |

Figure 2. Portion of retrofit questionnaire in MTLC toolbox

The MTLC Toolbox allows the user to create as many retrofit combinations as desired. For example, if the user wanted to view energy savings based only on HVAC retrofits, they can create a model which contains only retrofitted HVAC equipment, with all of the other equipment remaining the same. Similarly, they can view a model with only lighting upgrades, envelope upgrades, or any combination of upgrades they regard as viable for their building.

**Outputs.** Once the simulations for all the retrofit models are finished, the user can compare the outputs of up to three retrofit models at one time, view the savings for each retrofit model, and identify the model with the retrofits most viable to implement in their building tenant space.

The output page contains all of the results, represented through various charts. The first chart, seen here as Figure 3, is an annual, overall energy consumption reduction plot, which contains the differences in energy consumption between each retrofit model as compared to the baseline model. The next two plots are also energy reduction plots based on the difference between the retrofit models and the baseline, but split into two categories: Lighting and HVAC. The final plot consists of the maximum possible demand reduction, which is based on power usage values.

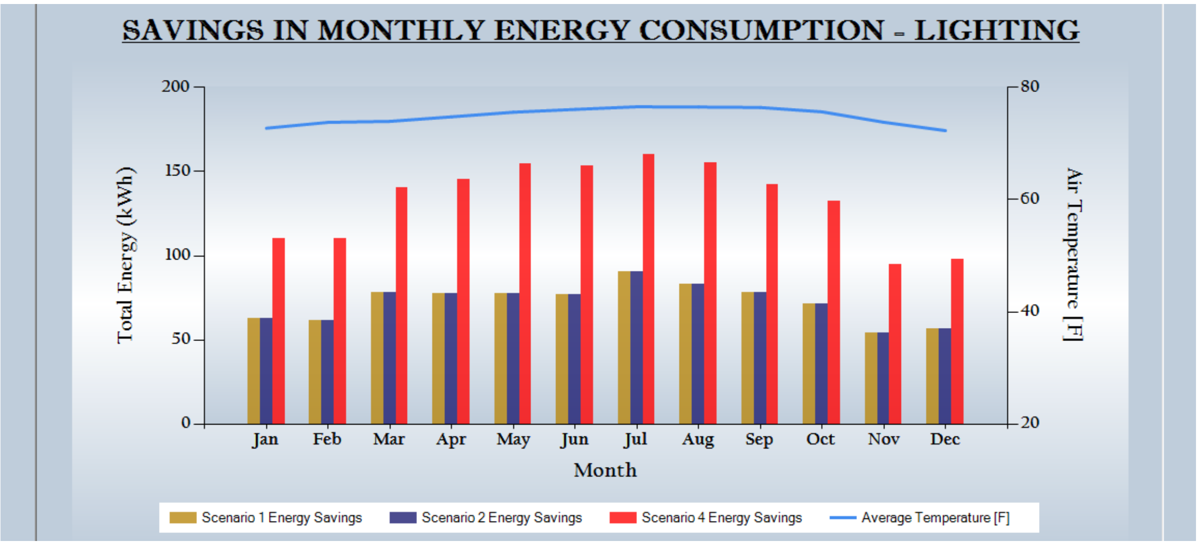


Figure 3. Savings chart for lighting-only from MTLC toolbox

Finally, a detailed flowchart of the user-interface experience is shown below in Figure 4.

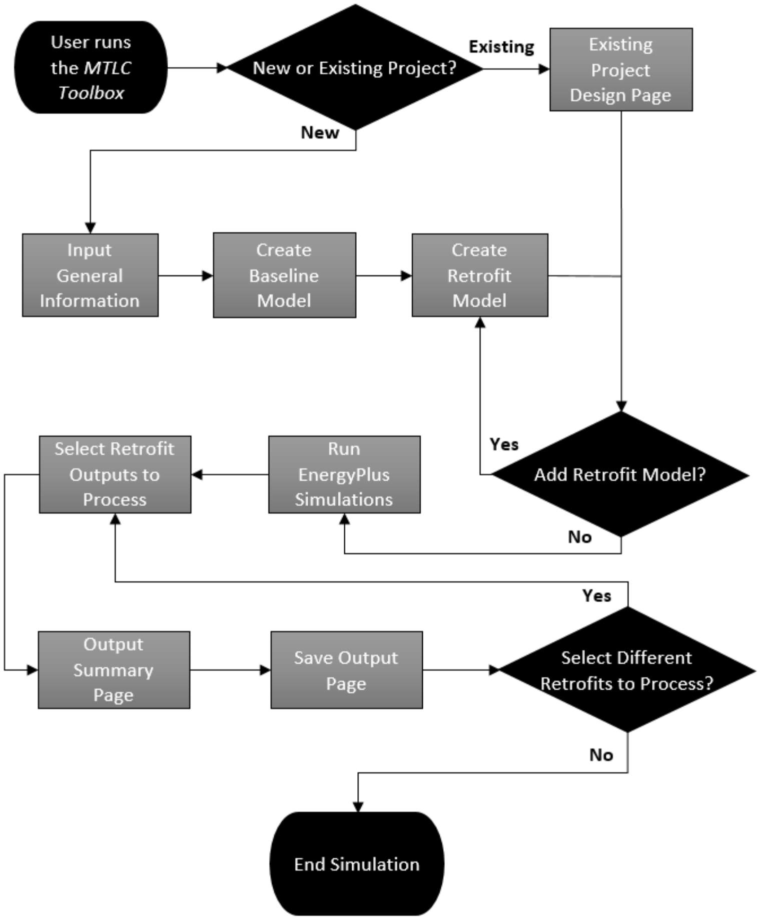


Figure 4. User-interface experience flowchart for MTLC toolbox

## Program Development

The broader goal of the tool is to develop lower cost building energy audit analysis. As the cost of analysis is currently prohibitively high, there is a little incentive to collect the relevant data, thus inhibiting the realization of deep energy savings. We envision the possibility of utilizing trained entry-level energy auditors (instead of high-cost engineers), coupled with standardized collection methodologies and tools and automated analytic engines, can provide a market accepted, cost effective energy audit service for some portion of building inventories, decreasing the overall cost of energy audits and expanding the reach of current programs.

The case study that points to the possibility of such a program is that in 2013, the California Conservation Corps (CCC) developed a new low-cost model for effective auditing and retrofitting of commercial buildings. The CCC trained its workforce of "at risk" youth, veterans, and other entry-level professionals in basic energy auditing and retrofit skills, putting them to work on auditing and retrofitting millions of square feet of K-12 schools across the State of California. The CCC coupled this workforce with automated tools and analytics as well as partnership with industry to provide a cost effective way to conduct data collection and retrofits for simple energy consuming equipment. The CCC can currently generate simple audit reports; the next step would be to provide the CCC or a similar program with tools to recommend deeper energy savings. Although this program would not be perfect, it does provide a more cost-effective solution than an ESCO program while providing deeper savings than a DI program.

## Conclusions

The MTLC Toolbox is a new tool that allows users to perform simple, accurate, and readily understood energy efficiency analysis and the ability to customize solutions for specific buildings and tenants. The tool adapts the existing EnergyPlus reference strip mall model to more adequately represent market conditions based on market research of California's MTLC market. We have shown that the tool can facilitate more comprehensive energy conservation recommendations for MTLC buildings without highly tailored and costly engineering analysis.

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