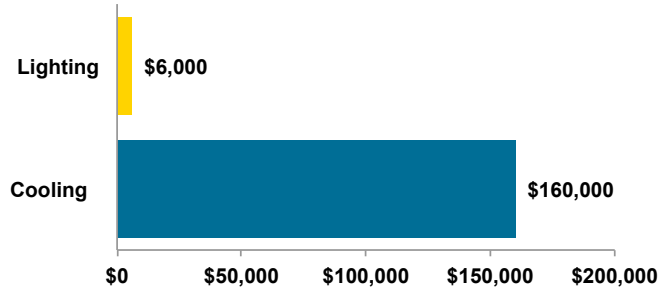
Lights, Cameras, Action… and Cooling – The case for centralized low carbon energy at Fox Studios

Overview

Fox Studios partnered with the U.S. Department of Energy (DOE) to develop and implement solutions to retrofit two production stages and one of its central cooling plants, to reduce energy consumption by at least 30% as part of DOE's Commercial Building Partnerships (CBP) Program. Although this case study reports expected savings arising from proposed design recommendations for a unique building type and the unusual load characteristics associated with its use, the EEMs implemented for the central plant are applicable to any large campus, office and higher education facility. The intent is that by making the energy-efficiency measures (EEMs) set that were assessed as cost-effective from this project applicable to a larger number of buildings on the campus Fox Studios will be able to implement an integrated campus-wide energy strategy for the long term.

The significant challenges for this project in the design phase included identifying how to assess and analyze multiple system types, develop a coherent strategy for assessment and analysis, implement the measurement and verification activities to collect the appropriate data (in terms of capturing 'normal' operating characteristics and granularity) and determine the best approach to providing cooling to the site buildings based on the nature of existing systems and the expected improvement in energy performance of the central cooling plant. The analytical framework adopted provides a blueprint for similar projects at other large commercial building campuses.

Expected Whole-Campus Annual Energy Cost Reductions



Overhead view of Fox Studios site.

Source: Fox Studios

Project Type	Film Studios Production Stages and Central Plant, Retrofit
Climate Zone	ASHRAE Climate Zone 3B, Warm and Dry
Ownership	Private
Barriers Addressed	• Existing energy management practices • Lack of measured energy data • Visual and functional performance needs in a constrained environment
Square Footage of Project	~265,000
Expected Energy Savings (vs. existing energy use)	~28% (Large Stage) ~6% (Medium Stage) ~50% (Central cooling plant)
Expected Energy Savings (vs. ASHRAE 90.1-2007)	• Not available
Actual Energy Savings (to be verified)	~1,300,000 kWh / yr electricity
Expected Cost Savings[2]	~$28,000 (Large Stage) ~$2,000 (Medium Stage) ~$130,000 (Central cooling plant)
Project Simple Payback	~18 years (Large Stage) ~4 years (Medium Stage) ~3 years (Central cooling plant)
Actual Cost Reductions	To be verified
Expected Carbon Dioxide Emissions Avoided	~917 metric tons per year[3]
Construction Completion Date	October 2013

1. The Commercial Building Partnerships (CBP) program is a public/private, cost-shared initiative that demonstrates cost-effective, replicable ways to achieve dramatic energy savings in commercial buildings. Through the program, companies and organizations, selected through a competitive process, team with U.S. Department of Energy (DOE) and national laboratory staff who provide technical expertise to explore energy-saving ideas and strategies that are applied to specific building project(s) and that can be replicated across the market.
2. Cost reductions based on an average blended utility rate of $0.13/kWh.
3. Emissions calculated using the Greenhouse Gas Equivalencies Calculator.

Fox Studios worked with Lawrence Berkeley National Laboratory (LBNL) and its consultants that were part of the CBP program to determine appropriate energy-efficient designs and operations. The majority of energy reductions are expected to come from a reduction in cooling and house lighting energy, with projected energy reductions of approximately 28% at the large production stage, approximately 6% at the medium production stage from the proposed house lighting EEM, and approximately 50% for the central cooling systems.

Fox Studios is the television and feature film production arm of 21st Century Fox, and is located in west Los Angeles, California. The Fox Studios campus is unique, and consists of a large complex of 15 production stages and several others that range in age (dating back to the 1920s). The studio buildings are large single-zone spaces, typically do not have windows, and have an interior height of 40–50 feet. These physical characteristics and the unpredictable patterns of use associated with production facilities present a particular challenge in meeting energy needs. Similar challenges may arise at other large multi-building campuses, such as conference centers, entertainment venues, and large health-sector facilities. The need for particularly powerful, high-quality production lighting drives the studio's overall energy demands, particularly for cooling to offset the heat produced by that lighting.

Historic Systems and Performance Needs Create Challenges

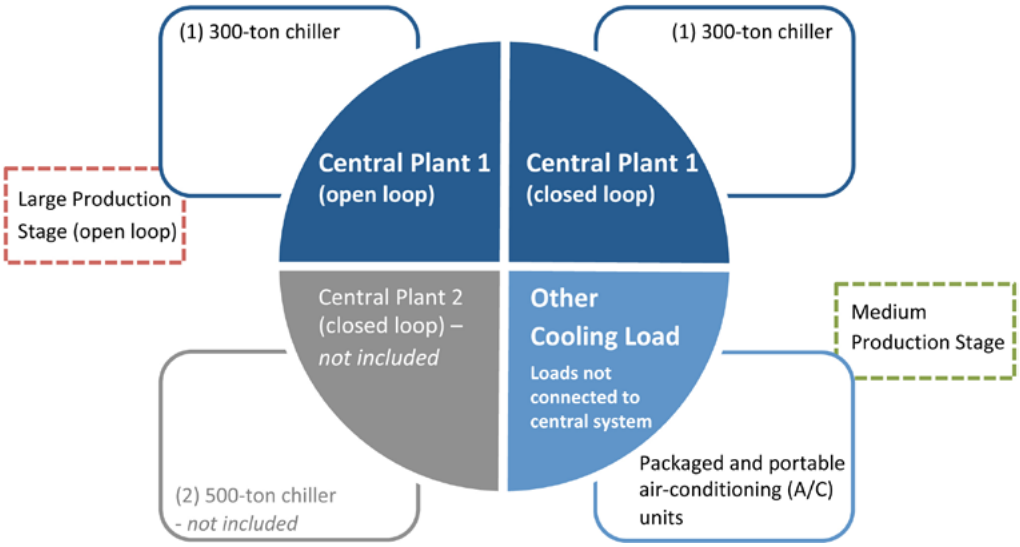
The current heating, ventilating and air conditioning (HVAC) systems deployed across the campus can be grouped into four categories:

- Central Plant 1 (CP1): 1 open loop
- Central Plant 1 (CP1): 1 closed loop
- Central Plant 2 (CP2): 1 closed loop
- Other Cooling Plant (decentralized technologies, such as portable chillers)

Because improving the energy efficiency of the heating systems would only yield negligible energy benefits, these categories only represent cooling systems. This is a result of the predominantly warm climate and the ongoing need for cooling due to the frequent, year round operation of the production lighting.

The challenge for the CBP project team in addressing central plant efficiency was to identify how to modify the existing design and operations of CP1 to have the best impact. The longer-term objective of consolidating the numerous cooling systems into one central plant system was not considered in this part of the design phase, due to the anticipated high costs of trenching to connect the different plant facilities and the buildings on campus. While this case study focuses just on improvements to CP1, future work will revisit this longer-term objective.

The concept diagram below highlights the different cooling systems, how they relate to the supplied production stages and to this project. Central Plant 1 provides cooling and heating to four of the fifteen production stages and eight other buildings, with cooling from two 300-ton chillers via two separate chilled water loops: one open-loop system, which is also supplied from a chiller-fed buffer tank, and one closed loop. The large production stage is currently fed from the open loop portion of this system. Buildings that only receive part of their cooling from central cooling, or as in the case of the medium production stage, are not supplied with central cooling at all, have dedicated in-building cooling systems, and in some cases use portable units that are deployed as required. Of the systems not currently included in the project, CP2 provides cooling and heating to numerous other campus production stages and buildings, with cooling from two 500-ton chillers on a closed loop system.



A set of EEMs were proposed for the CP1 retrofit based on an analysis of the plant's pre-retrofit energy use. The first is to replace the single-speed controls for the chillers and pumps with variable-speed controls, which would allow the plant to run more efficiently at part-load operation. Next, by upgrading and updating the open chilled water loop with direct-evaporative cooling from CP1, some of the stage coils within the open loop would transition to a closed chilled water loop, increasing load on the CP1 chillers and allowing them to operate more efficiently.

Another proposed EEM is to implement staging and temperature reset controls for the condenser water pumps, to improve their efficiency by limiting operation to efficient zones of their performance curves. Last but not least, a proposed increase in chiller capacity accomplished through adding a new 750-ton chiller would be added to the CP1 plant room, providing a welcome level of system redundancy.

To support decision making related to the analysis and implementation of energy-efficiency measures across the campus, representative production stage building types were identified, which shared common characteristics in terms of geometry, construction, internal loads, and HVAC system type. The assessment of the production stages focused on two types: a large production stage and a medium production stage. One representative production stage for each type was selected based on the ability for their production schedules to accommodate installation of monitoring equipment and evaluation of EEMs while still providing filming activities during the baseline energy measurement period. The performance data gathered during this period was essential to not only understanding the energy consumption of the production stages, but also how the production stages influenced the central plant.

Production stage energy loads are typically dominated by production lighting, both in terms of their contribution to the overall lighting energy load and their impact on the cooling load. Despite this seemingly obvious opportunity for energy saving, requirements placed on the output characteristics of production lighting are such that to date no acceptable energy-efficient alternative has been identified, and replacement was not an option for the project. However, house lighting, which is used when staging activities between filming, does not have these requirements and showed energy-saving potential.

Consequently, cooling systems offered the greatest potential for energy savings, but in this case they are the most difficult to analyze and evaluate due to the multiple central plants and subsequent multiple separate chilled water loops currently servicing different production stages and buildings on the campus. To manage this level of complexity an analysis approach was developed that started with the two types of production stages. For each of the types of production stages the first step was to determine the heat gain that arises from both production and house lighting. Even among the different stage types there is significant variance according to size, the

Central plant chilled water pumps and pipes prior to insulation.

Source: Fox Studios

lighting requirements specified by the studio user and the studio's operating schedules, depending on the production being filmed. The operating schedule was one of the key criteria for selection of each production stage as continued use over the course of the monitoring period was essential in providing insight into energy use of each stage type. By selecting a representative production stage for each type, launching monitoring equipment, and gathering actual measured data for a period of time (in this case two months), the larger set of production stages can be characterized and more educated input values can be developed for the energy model and other analysis models. By using results of the energy and heat gain analysis in energy modeling, plus additional measurement and verification efforts, the project team was able to prioritize methods for improving efficiencies of water-side and air-side cooling systems in the production stages. In addition they were able to analyze the impact of different efficiency measures related to cooling at the production stage type level and to begin to analyze the impacts at the chilled water loop level relating to the central plant, once an analysis approach was designed.

Improving design of air-side distribution systems was also an important element in maximizing the impact of the improvements.

The retrofits for the production stages needed to be flexible to effectively meet the requirements of a space that is frequently reconfigured, support air stratification in the stage area to keep generated heat out of the occupied zone, and keep people cool in specific locations, especially at floor level. So, in addition to the house lighting efficiencies, the production stage EEMs being considered included air handler upgrades, air distribution measures, and an improved relief air system. Where air handlers were upgraded, these were fitted with automatic airside economizers. The improvement to air distribution included taking return air from medium level (and therefore is lower temperature return air due to stratification than that currently taken at high level) and installing flexible supply ducts that hang to low level to take supply air to where it is needed. This both reduces the degree of cooling necessary for the return air and overcomes the challenge presented by the studio floor partitions — which obstruct free air flow at floor level — and enables cooling requirements to be met when and where they arise. The relief air system, which had relied on natural stratification to push warm air out, would utilize fans to more effectively remove warm air by mechanical means. The production stage EEMs were only a part of the puzzle to develop a high-efficiency central cooling system for the whole site, which provides the greatest potential for leveraging the inherent scale economies, and could achieve greater energy savings.

In a similar fashion as the approach taken with the production stages, the central plants were assessed to identify the best opportunity to establish a series of models that could effectively capture the dynamics of the central plant, and analyze what efficiency measures provided the greatest potential for energy savings. However, as with the production stages, the closer the team looked, the greater the degree of complexity discovered. In addition to the multiple central plants, multiple chilled water loop types (open and closed), and the various types of equipment, the age of the equipment was a factor as well, since it was discovered some of the air handling units date back to the 1930s. To manage the complexity the team decided the focus would be on CP1 for the two chilled water loops, one which was open and the other closed. To develop useful models to effectively represent this complexity the team again used a combination of M&V and different types of models to refine, evaluate and calibrate the models. Numerous discoveries were made along the way, which led to approaches like comparing kW/ton across the load range to assess if it is beneficial to connect air cooled and/or portable systems to the central plant.

The outcome of the team's creative analysis approach demonstrated that energy reductions for the large and medium production stages are expected to be lower than those from the central plant, but still significant: for the large production stage, whole-building savings were projected to be approximately 28% in cooling and lighting, and for the medium production stage, whole-building savings in cooling and lighting were projected to be approximately 22%.

Decision Criteria

The EEMs selected for the Fox Studios sample set, which included a central cooling plant and the two production stages, went through several iterations before a preferred set of EEMs were identified. The technical expert team of ARUP and Constructive Technologies Group (CTG) studied CP1 and the production stage loads and operations, utilizing the measured performance data, to identify packages of EEMs with energy-saving potential that were collectively in line with the projects goals. The results of production stage energy modeling were used in parametric analysis of multiple stage energy efficiency measure scenarios and in the analysis of different central plant design options, incorporating different technologies, designs, and control strategies. The proposed EEMs had to be cost-effective.

Maintenance and Operations

Many of the cooling systems and the buildings in which they are utilized are not centrally monitored or controlled—in these cases, cooling supply and central plant chiller operation are not efficiently matched with demand. This situation results in suboptimal cooling distribution and leads to challenges with providing cooling where required. There was also a significant labor burden associated with the existing approach to controls and maintenance of adequate system capacity. To increase cooling supply to a stage maintenance staff has to walk to the mechanical room of each stage to open the chilled water supply valves. When it appeared that distributed cooling capacity from the plant was maximized and additional cooling was needed, portable equipment, consisting of portable packaged air-conditioning units and portable cooling towers with connected fan coil units, were deployed to the required site. Implementation of centralized control and connection of an additional chiller aims to remove both of these issues.

Economic

Fox Studios' payback criteria of positive net present value in less than ten years, using a discount rate of 8 percent (plus 10% escalation in electricity prices) are similar to other private sector institutions. However, since some of its current building energy systems have reached the end of its useful life—without these improvements, future labor and operating costs, such as those from procuring and operating more portable, inefficient a/c units threaten to become prohibitive. The target discounted payback for efficiency measures was therefore less stringent than it might otherwise have been, due to the cost associated with continuing to operate the current systems, and given forecast growth in the studio's requirement for cooling capacity.

The following economic conclusions were drawn:

- Measures that did not require purchasing new equipment, such as re-commissioning or implementing new control strategies and optimizing existing sub-systems, were preferred.
- EEMs targeting the central plant were prioritized over those targeting the production stage because they would produce savings across the current plant as well as for buildings added to the system in the future.

Design

The current CP1 cooling system is a mixture of types and eras spread across four production stages and eight other buildings. The evaluation of scenarios that connect more buildings to this system is a primary factor in the development of a new campus energy strategy. The first stage in developing this strategy was to 1) reduce cooling load at stages (and subsequently load on the central plant), 2) examine the options for improving cooling plant efficiency in CP1 and reducing the use of open loop systems by transitioning to closed coil strategies, and 3) evaluate HVAC system designs at the stage level against the efficiency of the improved central plant design to come up with a cost-benefit analysis of connecting stages to the central plant and reducing reliance on portable, inefficient equipment. Identifying complementary approaches at the central plant and the production stages is crucial to overall energy performance and realizing the potential cost savings.

The final design also needed to be sufficiently flexible to meet different filming arrangements, while also operating very quietly and with very little vibration.

Policy

Fox Studios' parent company, 21st Century Fox, is committed to reducing its climate impact through reduction in energy use, carbon emissions, and use of renewable energy where economically feasible.

For carbon emissions, the goal is to reduce emissions by 15% per shoot-day for feature films and 10% per episode for television productions with an overall goal of reducing emissions intensity per unit revenue by 25% by the year 2020. Establishing a transparent methodology and tools to calculate reductions is part of this goal. Reducing energy use is a key element for delivering on the carbon reduction goals.

Renewable energy projects are judged on a case-by-case basis according to the characteristics of the site and the key economic criteria, such as implementation costs and local utility rates.

Energy Efficiency Measures Snapshot

The following table summarizes the EEMs considered for the medium and large production stages and Central Plant 1, along with their expected savings, costs, simple payback, and cost of conserved energy. This analysis used the following considerations and assumptions:

- Energy-savings estimates were based on known and historical production schedules. Further assumptions about annual production needs were made in order to estimate annual energy savings. Production schedules and the lighting power used in film production typically vary considerably, making the use of historical production records of great value to the analysis.
- To calculate the cooling savings for the production stage EEMs, a central plant cooling efficiency of 0.89 kW/ton was utilized—this is equivalent to the proposed central plant efficiency and ensured that the retrofit energy reductions were appropriately allocated.
- The HVAC energy efficiency measures at the production stages were selected from a range of potential options, and the upgrade of CP1 was developed as an option during pre-design. The option of upgrading CP2 or connecting the two central plants will be investigated in detail during the project's next design phase.
- Payback periods for some EEMs proposed for the Large Production Stage were higher than the 10 year threshold—in contrast to EEM's for the Medium Production Stage, these were adopted as replacement was necessary due to equipment end-of-life.

Energy Efficiency Measures for the Fox Studios Central Plant and Production Stages

	Implement at Fox	Will Consider for Future Projects	Expected Annual Savings		Expected Improvement Cost, $	Simple Payback, Years	Cost of Conserved Energy (CCE),[4] $/kWh
			kWh/year	$/year			
Central Plant (50% Central Cooling Energy Savings)							
Install variable frequency drives and variable valve controls on chilled water pumps	Yes	Yes	280,000	$39,000	27,000	0.7	$0.01
Implement staging controls for condenser water pumps	Yes	Yes					
Implement condenser water temperature reset control based on outside air temperature *	Yes	Yes					
Retrofit chillers with variable frequency drives	Yes	Yes	230,000	$32,000	230,000	7.3	$0.1
Convert chilled water system from open-loop to closed-loop	Partial	Yes	530,000	$74,000	160,000	2.1	$0.03
Large Production Stage (28% Energy Savings)							
House Lighting (~4% of Energy Savings)							
Replace existing lighting with light-emitting diode (LED) fixtures	Yes	Yes	30,000	$3,900	34,000	8.8	$0.11
HVAC (~24% of Energy Savings)							
Replace existing air-handling unit and include automatic air-side economizer	Yes	Yes	81,000	$11,000	290,000	27.5	$0.33
Redesign air distribution system	No	Yes					
Install rooftop exhaust with make-up air	No	Yes					
Replace direct-evaporative cooling with closed circuit chilled water coil	Yes	Yes	100,000	$13,000	180,000	13.4	$0.16
Medium Production Stage (22% Energy Savings)							
House Lighting (6% of Energy Savings)							
Replace existing lighting with compact fluorescent lamp (CFL) fixtures	Yes	Yes	17,000	$2,200	8,500	3.9	$0.05
HVAC (16% of Energy Savings)							
Redesign air distribution system and connect to chilled water network**	No	No	45,000	$5,800	92,000	16	$0.19
Install rooftop exhaust with make-up air**	No	No					

* A climate-dependent EEM.
** Assumes incremental capital costs, as some plant capacity increase would be required.
Cost savings are based on an average blended utility rate of $0.13/kWh.
4. The CCE was evaluated with 8% discount rate for 25 years (Meier, 1984).
Note that in some cases, expected energy savings are shown for multiple HVAC technologies implemented together, as their operation is interdependent.

Energy Use Intensities by End Use

The technical expert team, led by Arup and CTG, studied central plant load operating characteristics, measured data, and historical production scheduling data to estimate peak and average daily cooling loads. The average cooling load data were then correlated to outdoor air temperature, and the correlation was applied to the local weather data to generate an hourly cooling load profile for use in the model simulations—not only for the central plant, but also for the production stages. The intent is to develop and implement a coherent campus-wide strategy to focus resources in terms of developing integrated technical solutions, and to standardize and streamline operations and maintenance practices. With regards to reducing overall cooling loads, the possible use of LEDs for production lighting was assessed, but it was clear that the technology does not yet produce light at the required color temperature or intensity.

There were two goals to improving the central plant design—improve energy performance and increase capacity to enable redundancy. Overall, it was seen that with relatively simple energy efficiency upgrades to the central plant, it would be much preferred from an energy standpoint to make greater use of the plant, and retire less efficient portable plant equipment. The proposed central plant design provides site-wide energy security and enables chilled water to be dispatched with greater flexibility to the location of demand as required. Proceeding with the anticipated connection of CP1 and CP2 would further support such a strategy.

Determining the cooling load profile of the central plant and buildings—as well as the resulting opportunities for energy savings—was achieved through a combination of both modeled and empirical data. Complicating the modeling and data gathering process was the presence of multiple sources of chilled water—both the open loop and closed loops on CP1—and the monitoring challenges they presented. In particular, using the available monitoring points, it was not possible to accurately characterize the cooling load profile for the open loop system, as it was also supplied from a buffer tank lacking the needed trend data. The challenge of this missing data was overcome by characterizing secondary pumping flow (within the production stages) as a function of loop flow conditions, which subsequently enabled characterization of the cooling load profile of the open loop. These results supported the technical team's estimates for total open loop flow and had a strong positive correlation with outside air temperature, thus reinforcing confidence in the methodology and the results.

Central plant energy modeling was based on as-built drawings of the existing plant and the hourly load profiles developed from the data analysis described above. The proposed improvements to CP1 were accounted for in analysis of the large production stage; a revised energy baseline adjusted for the estimated reduction in CP1-supplied cooling energy intensity to ensure that only energy savings from EEMs at the production stage were represented.

For the production stages, energy models were used to analyze and compare the impacts of the proposed EEMs. Packages of complementary EEMs were modeled together to assess their performance in terms of energy savings and return on investment, which resulted in a focus on cooling and lighting. Even though there is minimal insulation in the production buildings, reducing heating energy is not considered a priority—this is due to the favorable local winter climate and that heat gain from house and production lighting offsets the need for heating energy. The proposed cooling retrofits focused on upgrading of existing internal HVAC systems—both water-side and air-side.

For the large production stage, proposed modifications to the water-side systems comprised the replacement of the local open-loop direct evaporative cooling system with a closed chilled water coil, transferring this load from the open loop chilled water system to the closed loop chilled water system, thereby increasing load on the closed loop chiller and consequently its increasing operating efficiency. Improving chiller utilization in this way also enables improving staging strategies as rather than always having two chillers operating at part load, the second chiller is only enabled once cooling requirements exceed the capacity of the primary chiller. Air-side modifications included the retrofit of a 100% outside air economizer to the air handler and adding high-level air exhaust and mid-level return air. Within high stage areas there is significant stratification in the spaces: returning air that is closer to the occupant level and relieving the hottest air at a high level lowers the energy needed to cool the space. At floor level, stages are densely partitioned, limiting air circulation. Therefore cooling air has to be precisely supplied to the needed location. Noise and vibrations must also be minimized for film production and current systems were being turned off during 'red light' filming events; consequently heat would build up in the occupied spaces. Resolving this issue was a key performance criterion for the proposed design. The proposed flexible cooling duct solution supports each of the requirements, with maximum duct static pressure settings and air supply dampers located in high level fixed ducts providing the necessary protection against excess noise.

For the medium production stage, proposed modifications included connecting air handling systems that had been connected to stand alone evaporative direct-expansion (DX) systems to the central plant chilled water system, which would remove the need to deploy portable cooling systems when they had insufficient capacity. Similar to the large production stage, proposed HVAC modifications to the air side systems included installing mechanical fan for exhaust air and implementing an air-distribution solution similar to that described for the large production stage.

Lighting EEMs focused on house lighting lamp replacement: installing compact fluorescent (CFL) and light-emitting diode (LED) fixtures for the medium and large production stages, respectively, in place of incandescent bulbs.

Modifications to the medium production stage were ruled out at this stage. In contrast, although payback periods for retrofits proposed for the large production stage were longer than for measures at the medium production stage, end-of-life issues with the

equipment meant that replacement and upgrades were essential and so were approved.

The central plant and production stage retrofits together contribute approximately 37% combined average energy savings for the cooling and lighting systems. The proposed designs target the most energy-intensive elements of the site, apart from production lighting, which is installed as needed by each film production crew, and therefore outside of the studio's scope.

Energy Model Results

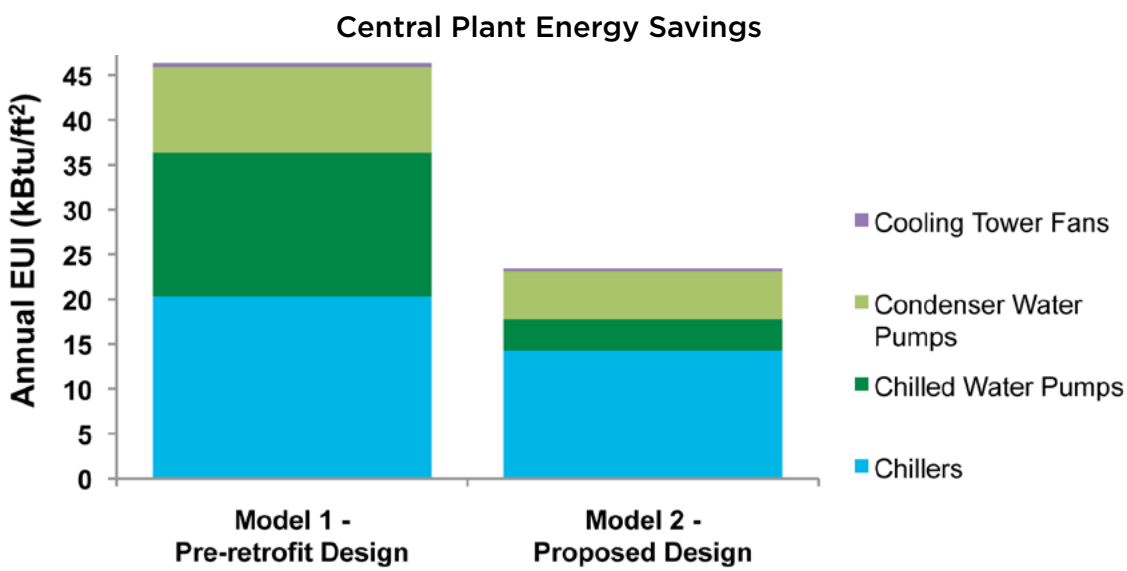
Models 1 and 2, described below, show energy savings from the central cooling plant EEMs.

Model 1: Pre-retrofit Design, Central Plant

Model 1 represents the pre-retrofit operation of the CP1, which is assumed for connection to four of the large production stages, one scoring stage and 7 other production buildings (not assessed as building types for this project). This model hasan annual energy use intensity (EUI) of about 26.9 thousand Btu per square foot (kBtu/ft^2).

Model 2: Proposed Design, Central Plant

Model 2 represents the proposed CP1 design, which incorporates variable-speed control on the chilled water pumps, condenser water pumps, and chiller compressor. Also proposed are staging controls for the condenser water pumps, outside air temperature-based chilled water temperature reset, and a conversion of a portion of the open-loop chilled water system to a closed-loop design. Improvements in chiller staging will ensure that the multiple chillers of different capacities are appropriately prioritized to maximize part load efficiency. This model has an annual EUI of about 13.6 kBtu/ft^2.



Central Plant Energy Use Intensity

End Use Category	Model 1 – Pre-retrofit Design	Model 2 – Proposed Design	
	Annual EUI (kBtu/ft^2)	Annual EUI (kBtu/ft^2)	Percent Savings Over Existing
Chillers	11.8	8.3	30%
Chilled Water Pumps	9.3	2.0	78%
Condenser Water Pumps	5.6	3.2	43%
Cooling Tower Fans	0.2	0.1	50%
Total	**26.9**	**13.6**	**50%**

Models 3 through 5 were created to assess energy savings for the large production stage. Model 3 is the large production stage pre-retrofit design baseline, representing existing performance. Model 4 represents energy saved at the large production stage as a result of the EEMs implemented at the central cooling plant. This model revises the baseline energy of the large stage due to the increased efficiency of chilled water production due to the improvements at the central plant. Model 5 is the proposed design for the large production stage and includes the stage EEMs applied after the CP1 efficiency improvements have been taken into account.

Model 3: Pre-retrofit Design, Large Production Stage

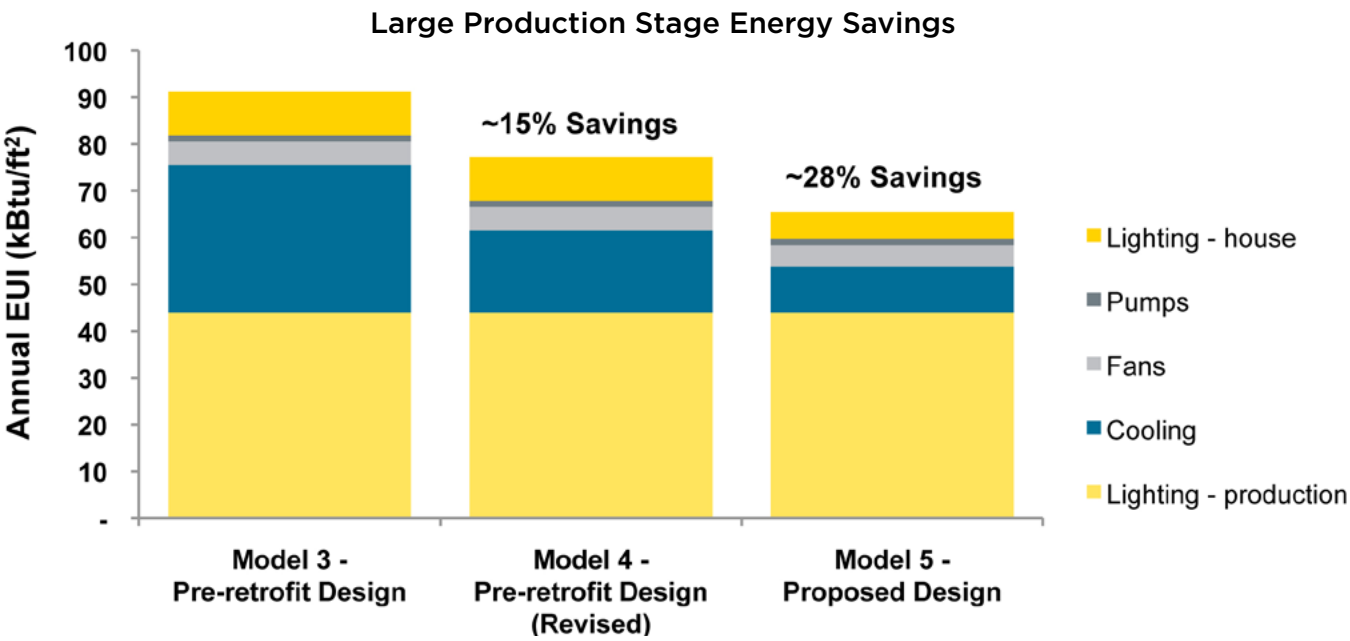
Model 3 represents the existing operation of the large production stage. This model has an annual EUI of approximately 91.3 kBtu/ft^2.

Model 4: Pre-retrofit Design, Large Production Stage (Revised)

Model 4 represents energy use after implementation of central plant EEMs. This model has an annual EUI of approximately 77.7 kBtu/ft^2.

Model 5: Proposed Design, Large Production Stage

Model 5 takes the revised baseline (Model 4) and incorporates energy savings from the EEMs selected for the building. These include replacement of incandescent house lighting with LED fixtures and a combination of HVAC measures: retrofitting the air-handling unit with a 100% outside air economizer, adding rooftop exhaust, redesigning the air distribution infrastructure, and replacing the direct-evaporative cooling with a closed chilled water coil. This model has an annual EUI of approximately 65.5 kBtu/ft^2.



Large Production Stage Energy Use Intensity

End Use Category (electricity)	Model 3 – Pre-retrofit Design	Model 4 – Pre-retrofit Design (Revised)		Model 5 – Proposed Design	
	Annual EUI (kBtu/ft^2)	Annual EUI (kBtu/ft^2)	Percent Savings Over Existing	Annual EUI (kBtu/ft^2)	Percent Savings Over Existing
Cooling	31.5	17.5	44%	9.8	69%
Fans	5.0	5.0	0%	4.5	9%
Pumps	1.3	1.3	0%	1.3	3%
Lighting - house	9.4	9.4	0%	5.8	39%
Lighting - production	44.0	44.0	0%	44.0	0%
Total	**91.3**	**77.7**	**15%**	**65.5**	**28%**

Models 6 through 8 were created to assess energy savings for the medium production stage. The respective models show energy performance of the medium production stage corresponding with the pre-retrofit, revised baseline, and proposed designs as described above.

Model 6: Pre-retrofit Design, Medium Production Stage

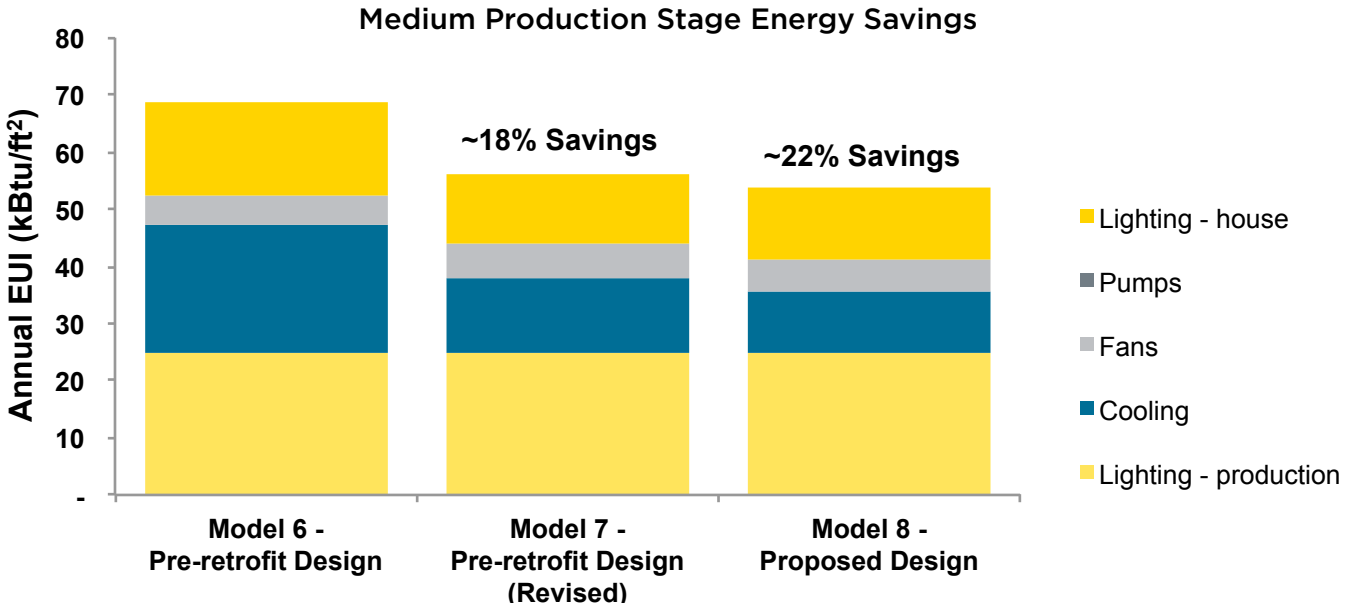
Model 6 represents the existing (pre-retrofit) operation of the Medium Production Stage. This model has an annual EUI of approximately 68.6 kBtu/ft^2.

Model 7: Pre-retrofit Design, Medium Production Stage (Revised)

Model 7 represents energy use after implementation of central plant EEMs. This model has an annual EUI of approximately 56.1 kBtu/ft2.

Model 8: Proposed Design, Medium Production Stage

Model 8 takes the revised baseline (Model 7) and incorporates energy savings from the EEMs selected for the stage. Similar to the Large Stage, this includes replacement of incandescent house lighting (but with compact fluorescent lamps), adding rooftop exhaust with make-up air louvers, and redesigning the air distribution infrastructure. It also proposes connection to the existing chilled water system. This model has an annual EUI of approximately 53.7 kBtu/ft2.



Medium Production Stage Energy Use Intensity

End Use Category (electricity)	Model 6 – Pre-retrofit Design	Model 7 – Pre-retrofit Design (Revised)		Model 8 – Proposed Design	
	Annual EUI (kBtu/ft^2)	Annual EUI (kBtu/ft^2)	Percent Savings Over Existing	Annual EUI (kBtu/ft^2)	Percent Savings Over Existing
Cooling	22.1	13.1	41%	10.6	52%
Fans	5.2	5.8	-10%	5.8	-10%
Pumps	–	–	0%	–	0%
Lighting – house	16.3	12.2	25%	12.2	25%
Lighting – production	25.0	25.0	0%	25.0	0%
Total	**68.6**	**56.1**	**18%**	**53.7**	**22%**

Expected Building Energy Savings from Implemented EEMs by End Use

Electricity End Use Category	Energy Savings
Lighting	46,000
Cooling	450,000
Pumping	750,000
Fans	13,000
Natural Gas Total	**~1,300,000**

Lessons Learned

From CBP work on the Fox Studios complex, the project team (Fox Studios, LBNL, Arup, CTG, Glumac, and DOE) each learned lessons that could be applied more widely to other facilities, such as office or higher education campuses that have a range of mechanical systems.

> "By partnering with the Commercial Building Partnership, we were able to demonstrate that our project goals did not have to change in order to meet energy efficiency targets. We increased the campus cooling capacity, created equipment redundancy while actually increasing energy efficiency and client comfort."
>
> Hal H. Haenel
>
> SVP & General Manager Studio Operations, Fox Studios

Grasping the Problem

In understanding how to address energy efficiency upgrades for complex, legacy mechanical systems with a number of system types and variations, it is vital to develop an appropriate strategy for undertaking such an assessment. Fox Studios' existing cooling system is of various ages, with many variations on how cooling was produced and supplied, so the priorities for refurbishment or outright replacement and connection to the central plant were not immediately clear. At the outset, the problem appeared messy and difficult—which to some degree it was. However, by defining a key set of metrics and criteria to evaluate each condition against, a process to evaluate cooling systems was possible. First, a representative metric for the efficiency possible for the central plant was assessed, both in terms of kW/ton along with an understanding of the loading conditions that were best suited to maximize chiller operation at part load. Next, each stage condition, whether it had an open direct evaporative coil, or made use of stand-alone or portable equipment, was evaluated and compared against the energy performance available from an improved plant. Finally, economic evaluations of options for modifying the stage cooling delivery were made to vet investment decisions. Strategic metering of specific equipment, including portable equipment and chilled water delivery on the open and closed loop systems enabled the level of energy analysis needed to make these decisions.

Unlocking Strategic Benefits

Design of new cooling systems should ensure that methods of cooling supply are effective, robust, and flexible to meet a wide range of future needs of the facility. An assessment of overall supply constraints is critical in identifying the system's pinchpoints, be it on the capacity side or air distribution, with evaluations done from the central plant to the local supply. For Fox Studios, this included identifying instances where cooling required supplementation, either because cooling capacity at the building load was insufficient, or because the cooling demand placed on the central plant was beyond its supply capacity.

Preferred Modes of Operation and Plant Configuration

The site energy load analysis completed suggested that the conventional practice of installing multiple identical chillers would not be the preferred approach. Due to the duration of various load conditions it was confirmed that a combination of small (300 ton), medium (500 ton) and large (750 ton) chillers provided the opportunity to meet energy requirements while utilizing chillers to maximize part-load efficiency (and capacity) through effective prioritization and chiller staging according to load condition.

The Enduring Value of a Data Collection Program

Without measured data, the risk/reward assessment associated with energy analysis and energy efficiency improvements is tilted towards the negative. To realize the full benefits of retrofits such as this, the ability of the site to have trend data that can support real energy savings estimation is crucial. Fortunately, Fox had trend capabilities in place for the chillers, and was able to be fully leveraged for this project. In addition to activating and storing existing trend points, more monitoring points were added at the medium and large production stages and trended separately to enable detailed energy assessments. For Fox Studios, these data were vital inputs to development of EEM, controls and operating strategies.

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