Target Improves Efficiency in New Construction

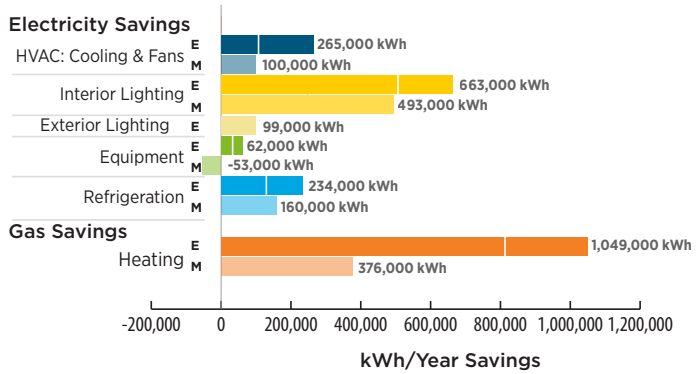
Target Corporation partnered with the U.S. Department of Energy (DOE) to develop and implement solutions to reduce annual energy consumption in new stores by at least 50% versus requirements set by ASHRAE/ANSI/IESNA Standard 90.1-2004[1] as part of DOE's Commercial Building Partnership (CBP) program.[2] The National Renewable Energy Laboratory (NREL) provided technical expertise.

The result was a Target store in Brookfield, Wisconsin, a single-story, 133,000-ft^2 building completed in July 2012. Target engineers and NREL staff brought new energy efficiency measure (EEM) ideas to the table starting with the DOE Advanced Energy Design Guide and Advanced Energy Retrofit Guide recommendations.[3] Model-based expectations of energy savings are shown in the "Expected and Measured Energy Reductions" graph below. From October 2012 (when the store's electrical submetering system was completed) through May 2013 (8 months), total savings were estimated at 34% versus ASHRAE 90.1-2004. This was lower than the project goal, mainly because of higher than expected natural gas use, caused by an programming issue with one of the store's main air handling units.

Since the 1990s, an in-house engineering team has steadily tested and implemented energy-saving features in Target's new store designs. NREL used EnergyPlus modeling software[4] to simulate EEMs for the building envelope, lighting, HVAC, refrigeration, and plug loads to estimate energy savings. Target subjected the EEMs to rigorous economic analysis informed by the energy simulations to ensure they met the company's business criteria.

During the Brookfield project, Target gained a deeper understanding of how energy is used in its stores and committed to testing new technologies in the field; DOE learned lessons about the process of designing, building, and operating buildings to share with the broader industry.

Expected and Measured Energy Reductions



E: EXPECTED 12 MONTHS, WHITE LINE MARKS 8 MONTH POINT IN EXPECTED
M: MEASURED 8 MONTHS

NREL engineers check light levels in a refrigerated display case at a Target store, to compare the performance of LED and fluorescent case lights. *Photo by Dennis Schroeder, NREL19510*

Project Type	General merchandise with some food sales, new construction
Climate Zone	ASHRAE Zone 6A, cold and humid
Ownership	Owner occupied
Barrier Addressed	Lack of trustworthy performance data for new EEMs needed to establish a business case
Square Footage of Project	133,000 ft^2
8 Months Measured Energy Savings (Versus ASHRAE 90.1-2004)	34% total 700,000 kilowatt-hours (kWh)/yr of electricity 13,000 therms/yr of natural gas
Simple Payback Period	< 5 years
8 Months Carbon Dioxide Emissions Avoided[5]	600 metric tons/yr
Construction Completion Date	July 2012

[1] ASHRAE 90.1: https://www.ashrae.org/resources--publications/bookstore/standard-90-1-document-history#2004

[2] CBP is a public/private, cost-shared initiative that demonstrates cost-effective, replicable ways to achieve dramatic energy savings in commercial buildings. Companies and organizations, selected through a competitive process, team with DOE and national laboratory staff who provide technical expertise to explore energy-saving ideas and strategies that are applied to specific building projects and that can be replicated across the market.

[3] Available through the DOE Resource Database: http://apps1.eere.energy.gov/buildings/commercial/resource_database

[4] EnergyPlus: http:// apps1.eere.energy.gov/buildings/energyplus/

[5] EPA Greenhouse Gas Equivalencies Calculator: http://www.epa.gov/cleanenergy/energy-resources/calculator.html

Decision Criteria

At Target, EEMs needed to meet the same criteria as any investment of capital to meet the company's obligation to its shareholders. Brookfield was selected for the project because it offered a good mix of weather conditions, allowing Target to test heating and cooling efficiency strategies.

Economic

EEMs were judged based on net present value (NPV), taking into account tax incentives, utility rebates, climate, capital costs, installation costs, operations and maintenance (O&M) costs, and energy costs. In addition:

- Positive NPV was the primary economic criterion, but measures that were estimated to pay back within 5 years (when all factors such as O&M costs were accounted for) were viewed favorably.
- Target allocates some of its construction budget to innovation. The decision process involves a number of groups, including engineering, financial, and construction. The team weighs potential savings for a pilot store and for portfolio rollout against the cost when deciding whether to pursue a new technology. Target recognizes that additional investment in pilot projects may not meet financial hurdles, but it will pursue testing if economics of a wider roll-out of technology will be economical based on economies of scale.
- Target aggressively pursues utility rebates where they are available and takes the availability and terms of rebate programs into account when considering where to invest in efficiency.

Branding

Customer experience was also a primary consideration. Any EEM that potentially impacted that experience was closely scrutinized from a branding and merchandising perspective. Although an EEM such as putting doors on medium-temperature refrigerated cases (containing seafood, packaged produce, cheese, beverages, meat, and deli goods, to name a few) was projected to save significant energy, concerns about the impact of the doors on the customer experience (and hence, sales) prevented their deployment in this project.

The look and feel of the sales floor were major considerations. Target uses a drop (suspended) ceiling with recessed fluorescent lights on a regular grid, giving a uniform feeling. Changes to the lighting system or any prospective daylighting technologies had to take this consideration into account.

Operational

Target emphasizes simplicity when saving energy. For example, insulation generally performs for decades as expected. Other EEMs, although impactful, depend on moving parts or controls working properly to realize savings. Examples of Target's approach included:

- Maintenance and energy costs were reduced by installing long-lived solid-state lighting fixtures to spotlight merchandise.
- Ventilation airflow and associated energy use were optimized and good indoor air quality was maintained by bringing in a continuous 0.08 cfm/ft^2 of outdoor air.

Policy

Sustainability is a focus of Target's business practices, in terms of waste reduction, water conservation, and energy use in its stores and distribution chain. Reducing energy use in buildings supported the following company goals for 2016:

- Reduce greenhouse gas emissions by 10% per ft^2 and 20% per dollar of retail sales.
- Earn the ENERGY STAR® label (top 25% in energy performance among comparable buildings nationwide) for at least 75% of its buildings.

Energy Efficiency Measures

The table starting on page 3 includes the full range of EEMs considered during the design process, some of which Target included in the Brookfield store. Target used the information in this table when screening EEMs against the compay's economic criteria. Only the installed EEMs were included in the calculations of whole-building energy savings for each building system. HVAC savings were modeled by adding EEMs in a cumulative fashion rather than individually or as a package. Energy savings included electricity and natural gas. EEMs that are not applicable in all climates are marked with an asterisk (*). Climate-dependent EEMs should be evaluated to check whether they are a good match for a project's climate zone. EEMs are listed in order from greatest to least savings. HVAC EEMs are exceptions, because of the way they were modeled. The EEMs shown in the table represent measures to create a store that reduces total energy use by 50% versus ASHRAE 90.1-2004.

These brand new checkout stands and registers feature a standby mode and turn off during unoccupied hours. *Photo by Rois Langner, NREL 27647*

Energy Efficiency Measures	Implemented in This Project	Will Consider for Future Projects	Expected Annual Savings (kWh/yr)
Envelope: 5% Whole-Building Savings Expected Versus ASHRAE 90.1-2004			
*Increase roof insulation to R-25.	Yes	Yes	135,000
*Increase wall insulation to R-12.3.	Yes	Yes	57,000
*Reduce infiltration in cart vestibule area.	Yes	Yes	19,000
Lighting: 8% Whole-Building Savings Expected Versus ASHRAE 90.1-2004			
Upgrade 114-W sales floor fixtures to 59-W fixtures.	Yes	Yes	265,000
Remove neon decorative lights throughout sales area.	Yes	Yes	
Remove all backlighting from panels in the electronics section.	Yes	Yes	
Upgrade display and vendor lighting to light-emitting diode (LED) or higher efficacy fluorescent lamp/ballast combinations.	Yes	Yes	
Upgrade valance (concealed) accent lighting to lower wattage, higher efficacy linear fluorescent lamps on the sales floor.	Yes	Yes	
Balance illuminance y changing 32-W T8 lamps to 25-W T8 lamps in offices and storage areas.	Yes	Yes	
Reduce the number of auxiliary lighting fixtures, such as those installed above refrigerated cases.	Yes	Yes	
Improve distribution and reduce the number of fixtures in the back-of-house and office areas.	Yes	Yes	
Use vacancy sensors (manual on, automatic off) in offices, stockrooms, walk-in coolers and freezers, and restrooms.	Yes	Yes	
Improve distribution and reduce the number of exterior lighting fixtures.	Yes	Yes	99,000
Manage lighting schedules on the sales floor by turning off all lights during unoccupied hours.	Yes	Yes	53,000
Use daylight sensors to dim or switch electric lighting in vestibules and food service areas.	Yes	Yes	4,000
HVAC: 29% Whole-Building Savings Expected Versus ASHRAE 90.1-2004			
1) Ventilate using a constant 0.08 cfm/ft^2 of outdoor air.	Yes	Yes	662,000
2a) Add to 1: increase HVAC fan efficiency and control by changing from constant air volume to variable air volume and increase rooftop HVAC unit energy efficiency ratio (EER) to 11.6.	Yes	Yes	1,047,000
2b) Add to 1: widen temperature deadband set points throughout the store.	Yes	Yes	
*3) Add to 2: energy recovery ventilators to the rooftop units that bring outside air into the building in the main sales, checkout, and grocery areas.	Yes	Yes	1,332,000
*4a) Add to 3: evaporative condensing for the HVAC system.	Yes	Yes	1,341,000
*4b) Add to 3: operate the grocery section at the traditional 53°F dew point temperature and the rest of the store at 55°F to 57°F dew point temperature.	Yes	Yes	
4c) Add to 3: desiccant system to the grocery zone for dehumidification.	Yes	Yes	

Energy Efficiency Measures	Implemented in This Project	Will Consider for Future Projects	Expected Annual Savings (kWh/yr)
Refrigeration: 7% Whole-Building Savings Expected Versus ASHRAE 90.1-2004			
Allow suction and condensing temperatures to float in response to ambient and store conditions.	Yes	Yes	99,000
Add doors to open medium-temperature cases.	No	Yes	99,000
Replace all existing evaporator fan motors in cases with electronically commutated motors.	Yes	Yes	84,000
Add LED fixtures in all low- and medium-temperature refrigerated cases and walk-in freezers.	Yes	Yes	51,000
Use anti-sweat control strategies that modulate power based on sales floor dew point.	Yes	Yes	47,000
Add night curtains to open produce cases.	No	Maybe	47,000
Remove condensing units.	No	Yes	34,000
Add variable frequency drives to condensers.	Yes	Yes	19,000
Include strip curtains on all walk-in cooler and stocking doors.	Yes	Yes	3,000
*Add evaporative condensing for the refrigeration system.	Yes	Yes	3,000
Plug Loads: < 1% Whole-Building Savings Expected Versus ASHRAE 90.1-2004			
Set all computers to standby mode when not in use.	Yes	Yes	9,000
Reduce electric loads associated with drink machines by using a load-managing device and turning off at night.	Yes	Yes	
Eliminate personal printers, copiers, fax machines, and scanners. Replace with one or two multifunction print stations.	No	No	
Replace desktop computers with laptop computers.	No	No	
Identify energy efficiency strategies for stockroom charging stations.	No	No	
Choose checkout stands and registers with standby mode and turn off cash registers and checkout stands during unoccupied hours.	Yes	Yes	
Manage plug loads on the sales floor by turning off electronic products during unoccupied hours.	Yes	Yes	
Use liquid crystal display monitors throughout store.	Yes	Yes	
Kitchen: < 1% Whole-Building Savings Expected Versus ASHRAE 90.1-2004			
Consider close-proximity exhaust hood designs and temperature and particulate driven control strategies to lower exhaust flow rates.	Yes	Yes	19,000
Use high-efficiency kitchen equipment and turn off equipment at night.	Yes	Yes	7,000

*Climate-dependent EEM

Project Notes

As a matter of corporate policy, Target does not share the capital cost of individual technologies or express energy savings in terms of dollar equivalent. Therefore, the business cases for the EEMs are not included in the table on page 3. Additional notes for each building subsystem include:

Lighting

- The sales floor lighting upgrade from 114-W to 59-W fixtures is also being implemented in existing stores as a retrofit measure.
- Target worked with vendors to identify options for LED or higher efficacy fluorescent ballast/lamp combinations for lighting its displays.

HVAC

- Target followed its standard practice of continuously ventilating at a reduced 0.08 cfm/ft^2 of outdoor air.
- The increase in HVAC fan efficiency and shift from constant volume to variable volume fan control was applied in the grocery area.

Refrigeration

- Open produce cases did not feature night curtains because Target had not finished weighing energy cost savings against O&M costs.
- Medium-temperature refrigerated display cases did not include doors because of concerns about the impact of the doors on sales.
- Condensing units were not removed because it was decided that further testing and analysis were required.

Plug and Process Loads

- Target was combining some office devices to save energy at the time of the project. Therefore, the savings from this EEM was not included in the project total.
- Energy consumption was not the main criterion in Target's choice of laptop versus desktop computers. Target decided to stay with desktop computers.
- Stockroom chargers (for lifts, etc.) were not included in the energy savings calculation because of the insignificant savings potential.

NREL researchers examine HVAC units on the roof of a Target store. *Photo by Dennis Schroeder, NREL 19507*

Target installed daylight sensors in the vestibules of its store to dim or turn off electric lighting when there is sufficient daylight. *Photo by Rois Langner, NREL 27646*

Energy Use Intensities by End Use

Energy modeling using EnergyPlus software was an integral part of the design process for the Brookfield store from the outset. Each design decision was evaluated in the context of how it impacted the store's energy performance. If savings did not reach the goal, more work was done to identify additional opportunities.

For some building systems such as lighting, modeling a package of EEMs was appropriate for Target's decision-making needs. In other cases, such as HVAC, the business case was assessed by taking the current prototype system and adding strategies in a cumulative fashion. In refrigeration,Target asked that EEMs be simulated individually.

The energy model of the store was based on Target's design development documents, construction drawings, and knowledge about its occupant density, plug load diversity, real efficiency curves for HVAC systems, and other factors specific to its stores.

To assess whole-building savings for this case study, three energy models were created, as described below. The energy consumed annually by each model normalized by floor area (called energy use intensity or EUI) is shown in the graph at the bottom of the page. All models were run with observed weather.

Although not presented here, an additional model was built to explore the impacts of EEMs that Target was not yet ready to roll out because of cost, maintenance, or merchandising concerns. The goal was to help Target look ahead to possible future strategies. See "Lessons Learned" on page 8 for a brief discussion of the results.

Code Baseline

The first energy model represented minimal compliance with the prescriptive specifications of ASHRAE 90.1-2004 for building envelope, lighting, and mechanical systems and ASHRAE 62.1-2004 for ventilation. Additional work was done to develop a refrigeration baseline to capture the impact of energy-saving innovations. The code baseline had an EUI of 111 kBtu/ft^2.

Current Prototype

The second model represented a store built and operated to Target's current new store prototype specifications and had an annual EUI of approximately 63 kBtu/ft^2, 43% below code. Savings resulted from lower lighting power density, improved envelope, and more efficient HVAC equipment than ASHRAE 90.1-2004 required.

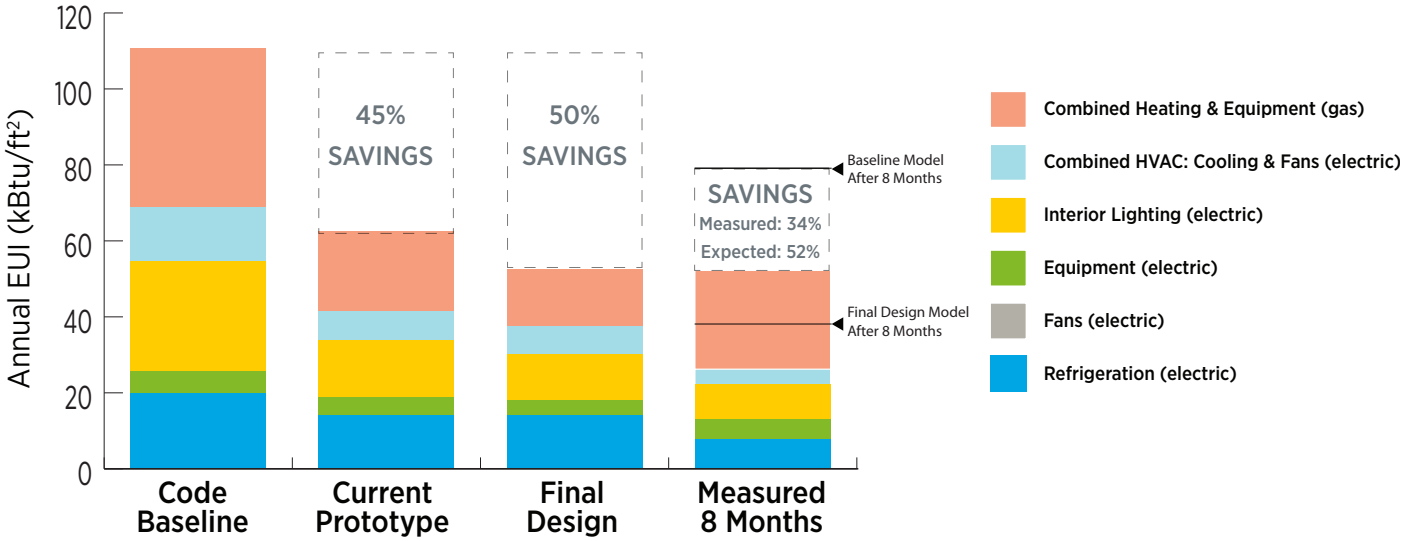
Final Design

The third version incorporated the EEMs selected for the Brookfield design. This model had an EUI of about 53 kBtu/ft^2 and annual energy savings of 52% versus ASHRAE 90.1-2004.

Measured Energy Use

In 8 months, the store used 52 kBtu/ft^2, 34% below the ASHRAE 90.1-2004 model run for the same amount of time with the real outdoor temperature and humidity. Performance fell below the project goal because of natural gas use above the model expectation and nighttime lighting, plug load, and fan power that exceeded design assumptions. Plug loads in general were higher than expected.

Comparing EUI of Energy Models and Measured Energy Use



Annual Energy Use and Percentage Savings by End Use

	Code Baseline	Current Prototype		Final Design		Measured (8 months)	
End Use Category	Annual EUI (kBtu/ft²)	Annual EUI (kBtu/ft²)	Percent Savings Versus Code Baseline	Annual EUI (kBtu/ft²)	Percent Savings Versus Code Baseline	8 Month EUI (kBtu/ft²)	Percent Savings Versus Code Baseline (8 months)
Heating & Equipment (gas)	42	21	50	15	64	26	27
Cooling and Fans (electric)	14	7.6	46	7.6	46	4	39
Interior Lighting (electric)	29	15	48	12	59	9.3	58
Equipment (electric)	5.7	4.9	14	4.1	28	5.1	-36
Refrigeration (electric)	20	14	30	14	30	7.8	35
Total	**111**	**63**	**43**	**53**	**52**	**52**	**34**

Building Energy Savings From Implemented EEMs by End Use

Electricity End Use Category

	12 Months Expected Savings (kWh/yr)	8 Months of Measured Savings (kWh/8 mo)
Cooling and Fans	265,000	100,000
Interior Lighting	663,000	493,000
Equipment	62,000	-53,000
Refrigeration	234,000	160,000
Electricity Total	**1,224,000**	**700,000**

Natural Gas End Use Category

	12 Months Expected Savings (therms/yr)	8 Months of Measured Savings (therms/8 mo)
Heating	36,000	13,000
Natural Gas Total	**36,000[6]**	**13,000**

[6] Equivalent to 1,055,000 kWh/yr

Notes: Natural gas consumption for service hot water was relatively small and not considered in the study. Kitchen equipment was powered entirely by electricity.

Lessons Learned

As part of the CBP work on the Brookfield store, Target and DOE learned lessons that can help other companies achieve similar results. Some examples are included below.

Focus on continuous improvement

By pursuing an incremental, continuous improvement process that included energy savings goals and careful energy modeling throughout the design process, Target was able to refine its new store prototype to save significant energy cost-effectively. Target maintains a 20-year institutional memory in the form of best practices for store design, operation, and monitoring that have evolved based on measured evidence.

Image of the newly constructed Target store. *Photo by Rois Langner, NREL 27648*

Leverage data

Target maintains a company-wide energy management system with detailed energy submetering for refrigeration and HVAC systems in its stores. Data are sent to a central location at Target headquarters; control changes can also be made from there, even down to the level of checklane coolers on controllable "smart" circuit breakers. Target has built automated fault detection and diagnostics into its monitoring system, allowing the company to identify equipment issues before failure and to catch operational problems such as overridden lighting or HVAC controls that would waste substantial energy if not addressed promptly.

Recognize the value of an in-house team

Target realized that because building systems interact through the heat they absorb or release, experts in building envelope, lighting, HVAC, refrigeration, plug loads, commercial kitchens, and energy modeling must sit at the same table and communicate regularly. Also, even if an EEM is technically promising, it may not be implemented unless a company's merchandising and branding experts are consulted and their concerns addressed. Maintaining a multidisciplinary internal team to focus on saving energy led by a company champion for efficiency may appear at first to be an unaffordable luxury. However, the improved communication, knowledge of building details, and continuity provided by a strong internal team can quickly yield enough energy savings to pay for itself.

Save on capital costs, too

Common wisdom dictates that deep energy savings cost a lot of money up front and are recouped gradually over time. Because different building systems interact, EEMs in systems such as the building envelope and lighting can lead to mechanical system cost savings. These savings can then be used to improve the business case for the entire energy efficiency project.

> "Many energy efficiency strategies can actually reduce capital and operating costs, particularly in new construction."
>
> —Scott D. Williams
> Group manager of mechanical engineering, Target Corporation

Look ahead

Additional measures not selected for inclusion in the Brookfield store because of cost, merchandising, or maintenance concerns were also modeled with EnergyPlus for future consideration. They included further lighting power reductions, plug load reductions, doors on all medium-temperature refrigerated display cases except produce, night curtains on produce cases, and HVAC equipment designed to meet the specifications of the DOE High Performance Rooftop Unit Challenge.[7] Including these EEMs reduced annual EUI to 49 kBtu/ft^2, 58% lower than ASHRAE 90.1-2004.

Check operation on an ongoing basis

Sometimes HVAC and lighting schedules differ from design intent. The impact on energy use can be significant, especially in a location such as Wisconsin where winter temperatures can be extremely low. Seek automated solutions to check building automation system (BAS) schedules and set points regularly as Target has done on a large scale.

[7] DOE High Performance Rooftop Unit Challenge: http://www1.eere.energy.gov/buildings/commercial/m/bba_rtu_spec.html

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