Sustainable Building 2030: Creating an Effective Climate Change Program for Buildings.

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ABSTRACT

The Sustainable Building 2030 (SB 2030) is a progressive energy conservation program designed to show how state funded buildings can be a model for the reduction of energy and carbon in Minnesota buildings. Initially based on the national Architecture 2030 program, SB 2030 was adapted to Minnesota's buildings, climate and policies, but could serve as a model for climate change programs anywhere. All state funded projects designed after 2010 must use 60 percent less energy than an "average building". The target improvement increases by 10 percent every 5 years until net zero energy is reached in 2030 for new buildings. Renovated portions of buildings must meet half of the reductions required by new buildings. 93 diverse buildings have participated in the program and are representative of the broader building stock of the state. This creates the potential to serve as a pilot program for more progressive energy codes. In addition, SB 2030 is integrated with an operations and benchmarking program to track the actual performance of completed projects and provide a feedback loop to policy makers and the building industry. Data from the first five years shows SB 2030 as a code would be one of Minnesota's most cost effective climate strategies. The next five years are critical as the research investigates the optimization of energy efficiency, validation of ongoing operation of early SB 2030 projects, the integration of on-site renewable energy, and the transformation of the state's energy grid to achieve net zero buildings for all state buildings by 2030.

Introduction

Operating and maintaining buildings in Minnesota involves the consumption of large amounts of energy. In 2013, residential and commercial buildings consumed 41.6% of the total energy in the state – the residential sector at 22.4% and the commercial consumed 19.2% (EIA) . Buildings are a critical part of the state's energy action plan. Energy efficiency combined with the production of renewable energy needs to be dramatically increased.

The state has made many strides. (Union of Concerned Scientists. 2009) On May 25, 2007, Minnesota Governor Tim Pawlenty signed into law the Next Generation Energy Act. The legislation increased energy efficiency, expanded community-based energy development, and established statewide green house gas (GHG) emission reduction goals of 15% by 2015, 30% by 2025, and 80% by 2050, based on 2005 levels. The bill charged the Governor's previously formed Climate Change Advisory Group with developing a comprehensive GHG emission reduction plan to meet these goals.. One of the policy recommendations in the Next Generation Energy Act was to "adopt green building guidelines for all commercial and residential buildings consistent with Architecture 2030 targets." (NGEA 2007)

In the spring of 2008, the Minnesota Legislature passed a bill assigned the Center for Sustainable Research at the University of Minnesota to develop a Minnesota program reflecting the goals of Architecture 2030. This program was named Sustainable Buildings 2030 (SB 2030).

It was created to show how state funded buildings could be a model for the creation of net zero carbon buildings by 2030. However, SB2030 was also seen as a way to test the feasibility of transitioning the "lead by example" program into a code for all buildings to scale the GHG reductions. To become a code that is integral to the climate change action plan for the state, SB2030 needed to include some key aspects:

- The energy guideline needed to move from a relative performance improvement (30% better than code) to an absolute performance (net zero)
- A clear target that is tailored to the actual climate, building type and program must be set. (see SB2030 Tool – D'Souza et al.)
- Design targets need to be verified with actual performance over time to prove that real energy reduction is occurring.

In the first 8 years of the program, the approach has worked well and has shown to be a cost effective approach for GHG reductions. The development team is now looking at ways to modify the International Green Construction Code to make SB2030 apply to all buildings. The code development is in the early stages, but shows promise and important details for a building code that integrates a pathway to net zero for new buildings and major renovations.

Architecture 2030

The Next Generation Energy Act expanded the state's sustainable building program to include development of green building guidelines mandatory for all major renovations receiving funding from the bond proceeds fund after January 1, 2009. The legislation defined major renovations as at least 10,000 square feet and included the replacement of the mechanical, ventilation, or cooling systems of the building or a section of the building. The energy efficiency requirement based on Architecture 2030 and adapted to Minnesota became Sustainable Building 2030 (SB2030).

The legislature passed the Sustainable Building 2030 standards to create quantitative measures of total building energy use and associated carbon dioxide emissions per square foot for different building types and uses that allow for accurate determinations of a building's conformance. The energy-efficiency performance standards must be updated every three or five years to incorporate all cost-effective measures and reflect the reductions in carbon dioxide emissions per square foot resulting from actions taken by utilities to comply with the renewable energy standards. New buildings must meet the following performance reductions measured against energy consumption by an average building in 2003:

- 60 percent in 2010
- 70 percent in 2015
- 80 percent in 2020
- 90 percent in 2025
- 100 percent in 2030

Renovation projects have targets that are 50% of the new building targets

According to the legislation, the guidelines for both new buildings and major renovations must:

- Research, development, and demonstration of new energy-efficiency technologies and techniques suitable for commercial, industrial, and institutional buildings.
- Analyze and evaluate practices in building design, construction, commissioning and operations that influence the energy use in the commercial, industrial, and institutional sectors.
- Analyze and evaluate the effectiveness and cost-effectiveness of Sustainable Building 2030 performance standards, conservation improvement programs, and building energy codes.
- Develop and deliver of training programs for architects, engineers, commissioning agents, technicians, contractors, equipment suppliers, developers, and others in the building industries.
- Analyze and evaluate the effect of building operations on energy use.

In addition, the legislature supported the SB 2030 program with a requirement for utilities to develop and implement conservation improvement programs that are expressly designed to achieve energy efficiency goals consistent with the Sustainable Building 2030 performance standards. These utility programs support publicly bonded buildings required to comply with SB 2030 as well as private buildings that are voluntarily pursuing energy efficiency beyond the state energy code. These programs must include offerings of design assistance and modeling, financial incentives, and the verification of the proper installation of energy-efficient design components in new and substantially reconstructed buildings. A utility making an expenditure under its conservation improvement program that results in a building meeting the Sustainable Building 2030 performance standards may claim the energy savings toward its energy savings goal. (SF2706)

Adaptation of 2030 to Minnesota

The Architecture 2030 program has galvanized interest in low energy design in the architecture and engineering industries. (Architecture 2030) The SB 2030 design team comprised of the Center for Sustainable Building Research (CSBR) at the University of Minnesota, the Weidt Group and LHB were tasked by the state of Minnesota in 2008 to revise the state green building guidelines to adapt Architecture 2030 to Sustainable Buildings 2030 (SB 2030). It has been tailored to the needs of an enforceable guideline program for Minnesota buildings. ASHRAE and AIA have both adopted Architecture 2030, as well as hundreds of design firms. AIA has provided a reporting mechanism for design firms to report progress towards the goals. As all of these efforts have been voluntary, mandating the goals creates additional challenges that must be addressed. Architecture 2030 relies EPA's Target Finder and the Commercial Building Energy Consumption Survey (CBECs) from 2003 to a national average baselines for different building types. Figure 1 compares the Net Site Energy Targets between Architecture 2030 and SB2030.

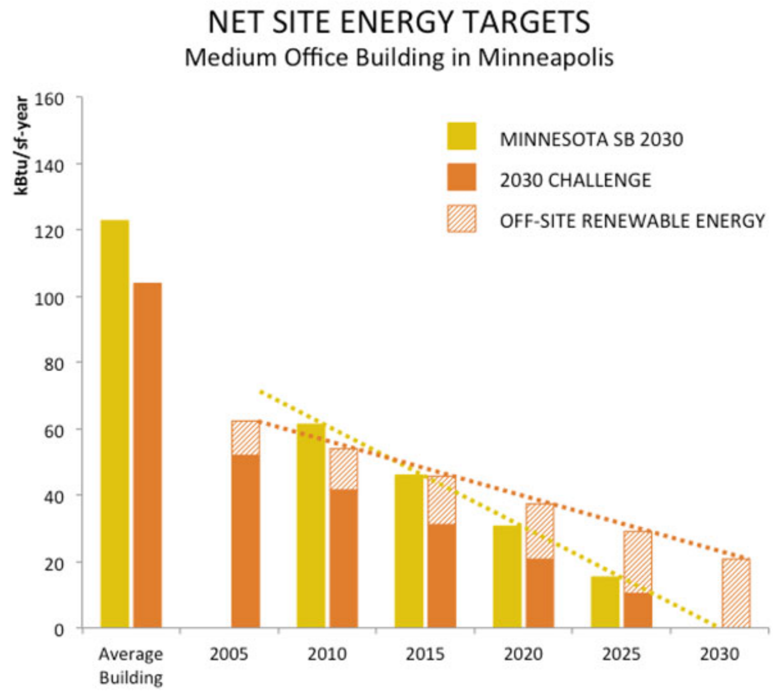


Figure 1 - Comparison of SB2030 and Architecture 2030

Target Finder and the Commercial Building Energy Consumption Survey (CBECs) from 2003 set national average baselines for different building types. Target Finder adjusts targets for eligible building types for occupant density, hours of use, local weather, and other operational parameters. For building types not eligible for Target Finder, projects can use national average numbers published by CBECs. Through benchmarking all public buildings in Minnesota, it was determined that only 20-25% of the building types in the public portfolio were eligible for Target Finder and Portfolio Manager scores. The team anticipated the mix of new construction projects would be similar to the existing building stock of public buildings. This meant that SB 2030 would either need to rely on national average EUI goals that were not adjusted for climate, fuel mix, hours of use, or occupancy, or on a percent reduction from the energy code. Many design attributes of a building are not regulated by the energy code and are the same in the baseline as the design, which means that two design teams with the same owner requirements could have different EUI goals.

The 2030 Challenge has two different compliance options, using Target Finder to find a median EUI, or reaching a specified percent better than several different energy codes. Minnesota preferred the target EUI method because it allows for greater flexibility in meeting the requirement. From the previous work in benchmarking public buildings, we knew that only 20% of the public buildings were eligible for setting a goal in Target Finder. To be able to set an EUI goal for all public buildings, we needed to create a target calculation method that could be extended to additional building types. The Architecture 2030 program uses national average EUIs, but these are not adapted for local weather or occupancy. In order to provide a target calculation method for all buildings that accounted for local weather, occupancy, and did not vary based on the design solution, the SB 2030 team decided to create an online SB 2030 Energy Standard Tool. The goal of the tool was to match the Target Finder goals for the 16 building types supported by Target Finder, but with a method that was extensible to additional building types. During a research phase of the project, the team discovered that the CBECs and Target Finder numbers were similar to the energy consumption of a baseline building defined by ASHRAE 90.1-1989. Additional rules and interpretations were applied to a single baseline for each building program, including baseline geometry for each building type. By having a single standard, design teams have a single clear performance goal, and cannot compare multiple baselines to choose the least stringent target.

The team performed an engineering analysis to establish a methodology to achieve the SB2030 performance standard. In order to establish the average Minnesota building Energy Use Intensity (EUI), the SB 2030 team evaluated several of the existing systems:

- Target Finder/Portfolio Manager which contained 15 different building types, including 5 hotel types
- Architecture 2030 National Average EUI's which contain 18 different building types
- Minnesota B3 Benchmarking Typical Buildings which contain 40 different building types
- Using 3 different National Energy Codes 1989, 2004, and 2007
- DOE Commercial Reference Buildings which contain the same building types as Target Finder, based on ASHRAE 90.1 2004 Energy Code

The evaluation determined:

- The ASHRAE 90.1 1989 code requirements yields similar EUI results to the CEBCS 2003 average building for the 15 building types in CBECS.
- Later energy codes rule sets resulted in energy consumption that was lower than the CBECS 2003 average
- Target Finder is difficult to extend to a larger range of building types because a statistically significant sample of buildings must be surveyed for each building type
- The National Average EUI's developed by the Architecture 2030 team are not accurate for running a program in Minnesota because they do not allow weather or occupancy adjustments

By basing the SB 2030 methodology on ASHRAE 90.1 1989 with additional interpretations the team could create a single EUI goal for each building's design criteria that was fuel neutral, but otherwise independent of the design decisions made. This meant that two different design teams with the same owner requirements would be held to the same EUI goal. With the energy code, each unique design is compared to a unique baseline building derived from the design. Minnesota wanted an EUI goal that took into account the heating and cooling fuel (i.e. district energy, electricity, or natural gas), but was otherwise independent of the design decisions. That way there was a common standard for all projects.

By creating an online tool that calculated the EUI goal the rule set could be consistently applied. This method also avoided the challenge of survey base methods that each additional building type added represents a smaller portion of the building portfolio but requires a similar sample size to be statistically significant. A modeling based approach allows each new building type to be added with incrementally less effort. The first version of the tool launched with 19 building types tailored to the anticipated projects. The next version of the tool will expand that to nearly 50 building use types that can be combined into 100 building types.

The SB 2030 Energy Standard is adjusted for local climate within the state, building types, type of occupancies, number of floors, time of day usage, ventilation rates, plug loads, fuel type and other special characteristics of the building. Each building energy use is modeled as it would be in 2003 and reduced by the appropriate percentage. Table 1 further compares Architecture 2030 and SB2030.

Table 1. Comparison of Architecture 2030 and SB2030

	Architecture 2030	SB2030
Baseline(s)	CBECs 2003 Target Finder % Reduction from code	SB 2030 Standard Tool
Occupancy adjustments	Only available for Target Finder and % reduction from code buildings	Consistent for all buildings
Design or Operations Standard	Design Standard, no operational verification	Design and operational standard tracked over first 10 years of operations
Offsite renewables	Up to 20%	Not allowed

Source: Architecture 2030 *Source*: B3mn.org

SB2030 legislation required utilities to develop and implement conservation improvement programs that are expressly designed to achieve energy efficiency goals consistent with the Sustainable Building 2030 performance standards. These programs must include offerings of design assistance and modeling, financial incentives, and the verification of the proper installation of energy-efficient design components in new and substantially reconstructed buildings. The utility support provided by utility programs for SB 2030 is currently being studied under a research grant from the state of Minnesota.

A utility making expenditures under its conservation improvement program that results in a building meeting the Sustainable Building 2030 performance standards may claim the energy savings toward its energy savings goal. Currently, two state utilities are employing the SB 2030 Energy Standard within the Energy Design Assistant program and incentivizes project to reach higher energy conservation goals of SB 2030 program.

In addition to the utility programs, the SB2030 program was required to create other supporting program elements including a case study database to track building performance, a training program for design professionals, an energy efficient operations program and a tool for setting SB 2030 Energy Standard targets and meeting them in design.

SB 2030 Energy Standard Tool

The SB 2030 Energy Standard Tool (D’Souza et al.) allows a project team member to set an EUI Standard for their building at Predesign, and update that Standard as occupancy requirements are refined throughout design and operations of the building. This provides a consistent EUI requirement for all projects with the same owner’s program, and adjusts that target if the expected or actual occupancy of the building changes over the design or occupancy of the building.

A user specifies up to three building types, the area, number of floors, and whether they are new construction, or renovations. A default space type allocation is set for each building type, as well as typical operational parameters such as expected plug loads, people density, schedules, and ventilation requirements. These may either be accepted, or edited. The tool then creates and runs a DOE2 file on the central server. The EUI of the typical building is multiplied by the current required reduction percentage, and the EUI and CO_2 requirements for projects are shown and fed into the B3 tool. Figures 2, 3 and 4 show and example of the SB2030 tool results.

EUI goals must be updated at four design phases, and each of the first ten years of occupancy to account for any changes in building use, or schedule.

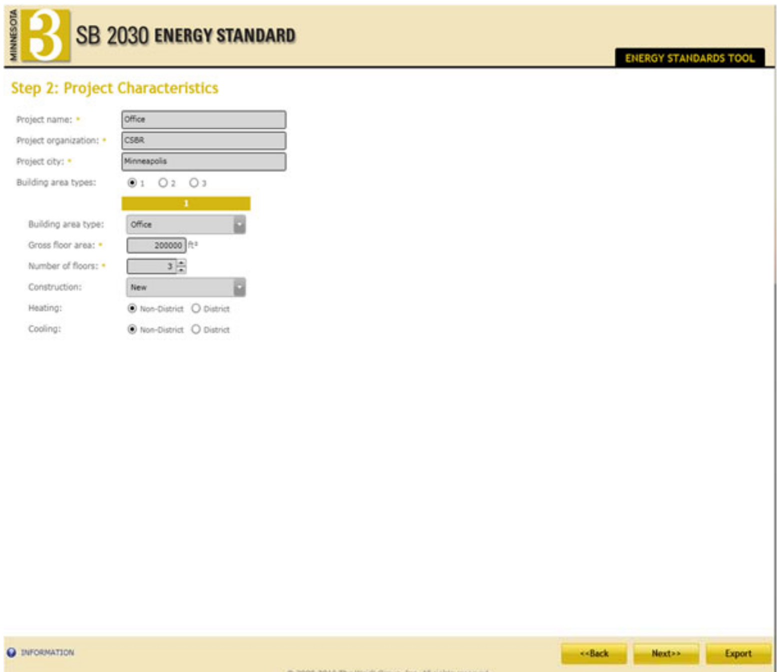
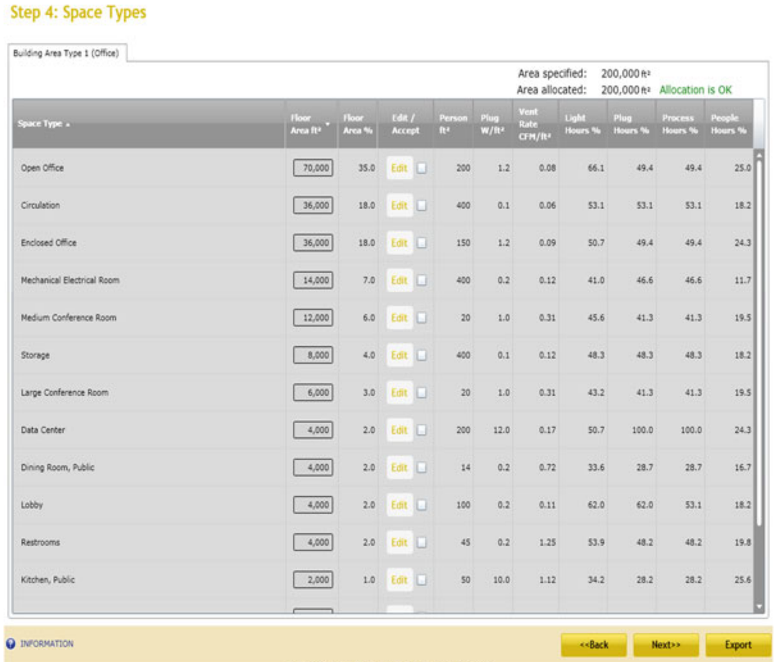


Figure 2 - SB2030 Energy Standards Tool: Project Characteristics



Space Type	Floor Area ft²	Floor Area %	Edit / Accept	Person ft²	Plug W/ft²	Vent Rate CFM/ft²	Light Hours %	Plug Hours %	Process Hours %	People Hours %
Open Office	70,000	35.0	Edit	200	1.2	0.08	66.1	49.4	49.4	25.0
Circulation	36,000	18.0	Edit	400	0.1	0.06	53.1	53.1	53.1	18.2
Enclosed Office	36,000	18.0	Edit	150	1.2	0.09	50.7	49.4	49.4	24.3
Mechanical Electrical Room	14,000	7.0	Edit	400	0.2	0.12	41.0	46.6	46.6	11.7
Medium Conference Room	12,000	6.0	Edit	20	1.0	0.31	45.6	41.3	41.3	19.5
Storage	8,000	4.0	Edit	400	0.1	0.12	48.3	48.3	48.3	18.2
Large Conference Room	6,000	3.0	Edit	20	1.0	0.31	43.2	41.3	41.3	19.5
Data Center	4,000	2.0	Edit	200	12.0	0.17	50.7	100.0	100.0	24.3
Dining Room, Public	4,000	2.0	Edit	14	0.2	0.72	33.6	28.7	28.7	16.7
Lobby	4,000	2.0	Edit	100	0.2	0.11	62.0	62.0	53.1	18.2
Restrooms	4,000	2.0	Edit	45	0.2	1.25	53.9	48.2	48.2	19.8
Kitchen, Public	2,000	1.0	Edit	50	10.0	1.12	34.2	28.2	28.2	25.6

Figure 3 - SB2030 Energy Standards Tool: Space Types

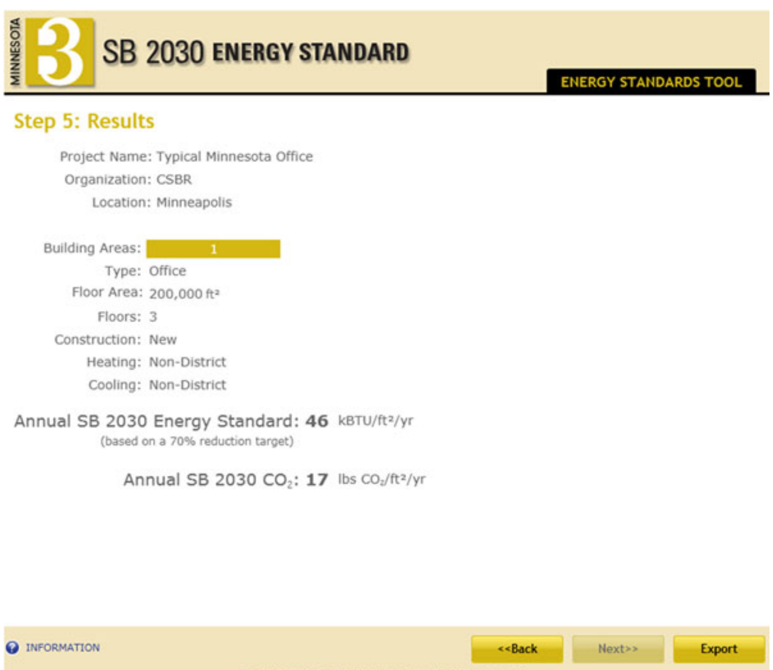


Figure 4 - SB2030 Energy Standards Tool: Goal Results

SB 2030 Application and process for required projects.

All projects for new or substantially renovated buildings receiving funding from the state of Minnesota from General Obligation (GO) bonds that began Schematic Design after August 1, 2009 are required to meet the SB 2030 energy standard targets. This includes:

- New projects of any size that are considered buildings under the state building code must meet the requirements.
- Building additions that contain new HVAC systems
- All renovations over 10,000sf or that include replacement of HVAC systems in all or part of the building.

Once a SB 2030 project is identified, an online Tracking Tool file is set up. This is typically done as part of the larger B3 program requirements, though the system was designed to support SB 2030 compliance independent of other requirements. Using the tool allows team members to be assigned roles, for the design team to compile information in a single location accessible by both the design team and the reviewers, to complete individual guidelines and to submit phases for review by the State Agency and by the SB 2030 Review Team. The tool requires several phase submissions intended to coincide with design process. For the SB 2030 program there are significant milestones at the Predesign, Schematic Design, Design Development and Construction Documents, along with annual reporting during operation of the building.

The SB 2030 process starts with the pre-design submission of a preliminary SB 2030 Standard EUI. As specifics needed to establish a target EUI are likely not known completely at this early phase, default attributes are used with the building's basic program to allow an early energy target to be created. As the project progresses and specifics are known, the target EUI will shift accordingly.

During the Schematic Design and Design Development phases, the project team submits both an updated Energy Standard along with a list of building strategies to be used and the simulated monthly energy consumption to verify that the design is anticipated to meet the SB 2030 Standard.[1] These early design submissions are reviewed by the SB 2030 Review Team and either approved or sent back to the design team for further information or for revision.

At the Construction Document phase the Energy Standard Tool is updated with the finalized design information and the design simulation is submitted with related construction documents and a metering plan that verifies that the project includes appropriate sub-metering. The review team either approves the Construction Document Submission or sends it back to the design team for clarification or revisions.

Tracking of the energy consumption is required for SB 2030 projects for 10 years; actual consumption data compliance with the SB 2030 target is required every year after two years of operations. This allows the project teams a one-year grace period to work out any seasonal operational start up that might arise with bringing a new set of systems on-line.

[1] The margin for projects is 15% at SD, 10% at DD and 5% at CD and operation.

Verification of Results

The SB 2030 program relies on a third-party review of information during the Construction Documents phase from the design team to compare three main items: 1) the inputs to the Energy Standard Tool, which creates an estimate of a 2003 building given certain project characteristics such as schedule, space types, certain equipment and lighting loads, etc.; 2) the documentation of the energy simulation, which may be outputs from a number of types of allowed software; and the 3) construction documents, which verify that the building characteristics are identical to those modeled in the Energy Standard Tool and the design model. This approach allows flexibility for the design teams to work with the tools that they are the most comfortable with. This approach also builds capacity among energy modeling professionals; their outputs are validated for appropriate methods, completion of simulation and for accuracy in comparison to the construction documents.

In operations the SB 2030 project is required to verify that the SB 2030 Standard is being met annually. The energy consumption data is compiled through the B3 Benchmarking program (an online water and energy tracking and benchmarking tool) and data is automatically reported to the annual operations portion of the Tracking Tool. If the project has any changes to operation or other building characteristics these can be reflected in changes to the SB 2030 Standard Tool, which will result in a change to the Target EUI and which may trigger a brief review by the SB 2030 Review Team. The SB 2030 Standard is weather normalized to remove variations due to annual changes. If the project is not meeting the SB 2030 Standard in Operation there are a set of steps to remediate the project including verification of equipment, validation of the standard and eventual participation in the Energy Efficient Operations program.

Project information is also accessible on the B3 Case Study Database. Annual energy and water consumption is displayed for projects, alongside the weather normalized SB 2030 standard to document which projects are achieving compliance with the program in operation. Several years of operation data is reported.

Results of Projects in Design and Operations

SB 2030 has been used by a wide variety of projects from the new stadium for the Minnesota Vikings to camper cabins in state parks for the Minnesota Department of Natural Resources. This is challenging for the program to create tools and strategies to achieve very aggressive energy efficiency targets across diverse building types, design teams, programs and occupancy. However, this diversity of building types is representative of the broader building industry.

From 2010 through the end of 2015, 93 projects had submitted design models indicating compliance with the 60% energy reduction goal.[2] (Figure 3) All but nine of the projects had design models that were better than the SB 2030 Energy Standard target. In fact, over half (53) of the projects beat the target by over 25% and would comply with a 70% reduction.[3] These projects are transitioning into operations and the program is tracking actual energy use. 42 projects have reported at least one year of actual operations data to compare to the SB 2030 and Design model.

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[2] Projects beginning schematic design after January 1, 2015 are targeting a 70% reduction.

[3] These results are much better than the AIA 2030 commitment nationally that has only 40% of the projects submitting energy models and only 14% achieving the goal. (USDOE)

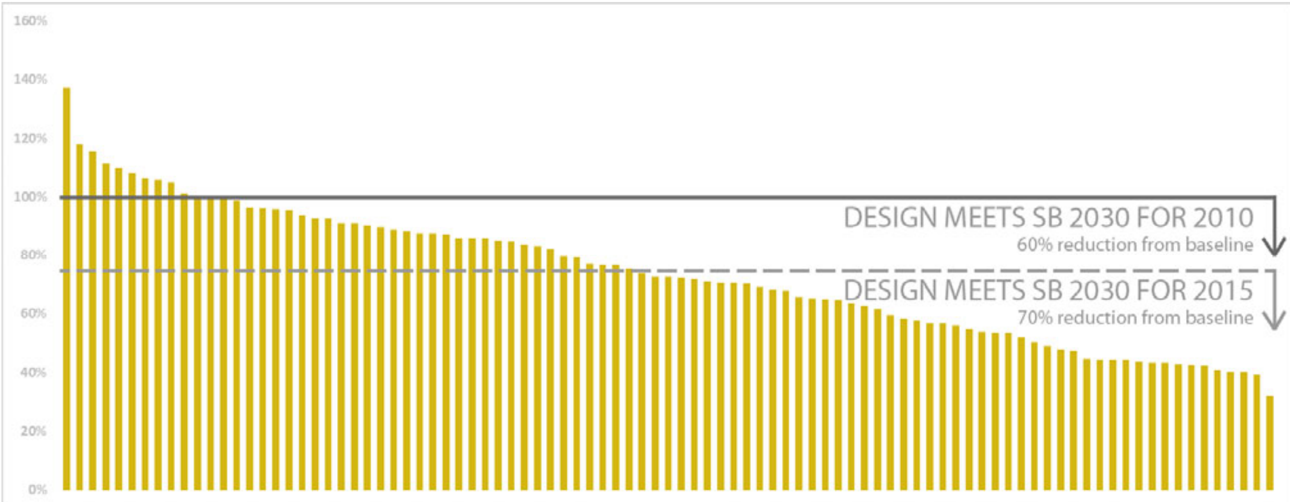

Figure 3 - Designs of 93 projects to meet SB 2030

Table 2 shows the performance of six of these projects selected for further examination as they have three years of data to review and no significant changes to their programs. First year operations are averaging below the design predictions, but are increasing in the second and third year of operations. Tracking the actual operation data has uncovered a number of important questions and challenges:

Table 2. Comparison of SB 2030 Standards, Designs and Operations Data for Six Projects

Project	Area (sf)	SB 2030 Standard	Design	Year 1	Year 2	Year 3
UMTC Akerman Hall	65,425	139	106	83	91	99
Minnesota National Guard Hastings Armory Renovation	18,487	85	73	87	99	103
Camp Ripley COE Training Facility	22,100	74	71	57	72	75
Kendall's ACE Hardware	14,594	53	42	50	50	44
Prairie Horizons Townhomes	12,151	59	59	59	57	55
Big Bog State Recreation Area	3,040	81	37	36	35	38

Source: SB 2030 Case Studies Database

- Inconsistent data between the design and the benchmarking software is entered for things like the area of building that could lead to inaccuracies in the EUI comparisons.
- Program changes occur that modify the occupancy or operational character of the building and therefore change the energy use. These changes require rerunning the SB 2030 standard for the building.
- Operations data needs to be normalized for the weather.

Two projects from the Minnesota Department of Military Affairs are interesting examples of the SB 2030 program. The first is a new training center for emergency operations at Camp Ripley in Little Falls, Minnesota. At 22,000 square feet, the building includes two large training rooms, administrative offices, storage, and equipment rooms. According to the SB 2030 Energy Standard Tool, an "average" building like this training center would have an EUI of 185 kBTU/sf/year. The 60% reduction goal was an EUI of 74 kBTU/sf/yr and the submitted design forecasted energy use of 71 kBTU/sf/yr. The first three years of operations were 57, 72 and 75 kBTU/sf/yr respectively and the last year of data was 66.2 kBTU/sf/yr. In general, buildings for this state agency are very tightly operated so the variation in energy performance relates primarily to changes occupancy and weather. This is particularly true on the Camp Ripley campus. The systems installed in this project were not exotic – this reduction in energy consumption was achieved mostly by envelope improvement and heat recovery, and illustrates the improvement achievable by working with performance metrics.

The second project is a renovation of an armory in Austin, Minnesota. It is also a 22,000 square foot building, but was originally built in 1964. The building was renovated with interior updates, roof replacement and new lighting and mechanical systems. According to the SB 2030 Energy Standard Tool, an "average" building like this armory would have an EUI of 126kBTU/sf/year. The SB 2030 reduction goal was an EUI of 88 kBTU/sf/yr because the project is a renovation. The goal would have been 50 kBTU/sf/yr if it were a new building. The submitted design forecasted energy use of 47 kBTU/sf/yr. The first two years of operations were 66 and 54 kBTU/sf/yr respectively. The Austin Armory shares some of the same questions about the variation of actual performance data from design as the training center at Camp Ripley. In both this cases, the training schedules of the individual units could play a significant role in energy use. In addition, it calls into question the assumption that renovation projects are harder than new buildings and therefore the reduction targets are cut in half. Both projects show the necessity to link design with the benchmarking of actual energy performance to have a feedback loop of energy performance to inform and integrate the disparate areas of design, operations and occupancy. This project, similar to the other Military Affairs project achieved high performance through envelope, some mechanical improvement and heat recovery.

Impact of the Program to Date

93 buildings with an area of 9,370,336 sf have been designed to the SB 2030 Energy Standard are predicted to save approximately 534 million kBtus/year. 90% of all buildings projects enrolled in the SB 2030 program have documented designs that met or exceeded the SB 2030 Energy Standard. These projects are predicted to save the building owners $8.3 million per year assuming an average cost of $15.54 per kBtu. SB 2030 Buildings anticipate a reduction in carbon emissions of 58,000 tons of CO_2e annually. Operation data is now coming in for projects for the first 5 years of the program, we currently have a year or more data for 42 projects, though this needs to be validated to ensure that accurate comparable data is being reported.

SB2030 and the Building Code

One goal of the SB 2030 program since the beginning was to use the pilot program of state funded buildings to develop a pathway to Net Zero Energy for all buildings in Minnesota using the building code. In 2014, the Center for Climate Strategies, analyzed the cost and potential impact of transitioning the SB 2030 program into a code for residential, commercial and industrial buildings. (CSEO) A SB 2030 energy code would potentially save over 10 million metric tons of annual CO_2e savings in 2030 with about 58 million metric tons of CO2e savings between 2015 and 2030. The costs of implementing the program were determined to be less than the direct economic benefits in avoided energy and other costs. Figure 5 (CSEO)

Table F-2.16 RCII-2 - Estimated Net GHG Reductions and Net Costs or Savings

	2030 GHG reductions ($MMtCO_2e$):	2015 – 2030 cumulative reductions ($MMtCO_2e$):	Net present value of societal costs, 2015 – 2030 (million $2014):	Cost effectiveness ($2014/ t CO_2e):
Zero Energy Building Implementation in the Residential Sector	4.73	24.61	$(823.49)	$(29.59)
Zero Energy Building Implementation in the Commercial Sector	4.56	28.89	$(1,226.73)	$(37.69)

Figure 5 - Estimated GHG Reductions and Net Costs or (Savings)

Merging the SB 2030 program with the Minnesota Energy Code requires the development of specific code language, mechanisms and other support. Initial data on costs for achieving SB 2030 show that is competitive with building less efficient buildings. The primary concern is in the architecture, engineering and building construction industries over delivering high-performance buildings. Further analysis is needed on the cost of buildings and delivery to meet the standard at higher levels of the program, the availability of technology and designs to meet the performance requirements, training for the building industry and measurement, verification and enforcement for the code.

The team has looked at a number of options to integrate SB 2030 with the Minnesota Energy Code and modifying the International Green Construction Code (IgCC) is currently the preferred option. IgCC 2015 includes an outcomes based compliance path based upon the Zero Energy Performance Index zEPI (Eley et al) with EUI goals by climate zone and building type. Code compliance is determined by achieving in operations an EUI at least 50% below the reference EUI. This code compliance path is in many ways similar to the Architecture 2030 and SB 2030 EUI reduction requirements. The SB 2030 team has proposed replacing Table 612. (Figure 6) in the IgCC with the SB 2030 Standard Tool. This will allow the EUI to reflect occupant density, unique plug loads, and schedules. An EUI metric that does not account for those measures would unfairly benefit lightly used buildings such as libraries with limited open hours, or office buildings with large private offices and few occupants. The 200,000 sf office building shown in the examples in figures 2,3, and 4 would have a 70% target of 100kBTU/sf/year if it included a 20,000 sf data center versus the 4,000 sf data center in the default. The goal from the IgCC table for the same office building would be 57 kBTU/sf/year.

Development of this code path for Minnesota is still in the early stages, but the work to date on the SB2030 buildings has provided important guidance on adjustments for the code to be successful.

TABLE 612.1 REFERENCE ANNUAL ENERGY USE INDEX (EUI_r)

CLIMATE ZONE	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7	8
Use and Occupancy[a]	Reference EUI_r skBtu/sf/yr														
Business (B)															
Office	154	159	154	151	140	137	167	144	152	179	155	190	176	208	282
Bank	154	159	154	151	140	137	167	144	152	179	155	190	176	208	282
Medical office (non-diagnostic)	115	118	115	113	104	102	125	108	114	134	116	148	131	156	210
Storage (S-2)															
Distribution/Shipping Center	105	67	69	66	64	55	75	70	66	87	81	104	95	119	186
Mercantile (M)															
Grocery/Food Store	448	476	452	484	450	473	522	479	514	554	511	592	561	633	758
Assembly (A)															
Library (A-3)	234	232	224	230	217	209	254	228	235	275	246	304	277	327	434
Educational (E)															
Elementary/Middle School	140	139	134	134	128	124	149	132	132	160	141	182	161	193	274
Institutional (I-2)															
Hospital/Inpatient Health	417	422	397	408	388	407	425	366	398	425	374	439	394	446	532

a. Use and occupancy as determined by Chapter 3 of the *International Building Code*.

Figure 6 – EUI Reference Table from IGCC 2015

CONCLUSIONS AND NEXT STEPS

SB2030 is not only one of the most cost effective strategies to reduce climate change emissions in the building sector in Minnesota, but also a pilot program for more progressive energy codes. Tools and standards are not enough to drive deep energy efficiency. The creation of the SB2030 Design Tool to adapt the broad goals of Architecture 2030 to a specific climate, building type and program is critical to setting a challenging, but achievable target for buildings. In addition, integration with operations and benchmarking programs to track the performance of completed designs and provide a feedback loop to policy makers and the building industry is essential. Designs of energy efficient buildings set the stage for potential energy savings in the future, but they must be informed and integrated with the demand, variability and complexity of future occupancy, and the range of expertise and skill level of management and operations.

The next five years are critical as the research investigates the optimization of energy efficiency, validation of ongoing operation of early SB 2030 projects, the integration of on-site renewable energy, and the transformation of the state's energy grid to achieve net zero buildings for all state buildings by 2030. As of January 1, 2015, all buildings in the SB2030 program are targeting a 70% reduction, which will jump to an 80% reduction in 2020. As the program targets increase there are a number of important areas of research:

- What is the limit of energy efficiency within the limits of a 15-year payback requirement of the program?
- How do you bridge design into operations to realize the potential performance if SB2030 buildings?
- Can the cost of solar in Minnesota come down and the efficiency increase fast enough to provide the power required to achieve net zero?
- How should the requirement of all energy to be generated on-site be modified to allow for a variety of building site and types? (Pless and Torcellini)
- Can all building types achieve net zero and is it the right goal for all projects? Should some projects be targeting net positive to make up for more challenging building types? (Griffith et al.)

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