Trade Introduction of a New Building Code with Requirements for Energy Performance

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ABSTRACT

A new version of the Swedish Building Code (BBR) that introduced requirements for the energy performance of buildings has applied since 2006, with restrictions on energy performance for buildings heated with electricity applying since 2009. Requirements are set for the energy performance of buildings with the effect of ensuring that energy calculations are performed at the planning stage and that energy performance is verified by measurements within 24 months of building completion. This is a major change from the previous codes. It is the building proprietor's responsibility to ensure that the regulations set by the authority are followed. The building proprietor may sue the contractor if the requirements are not fulfilled. The contractor, in turn, may sue the designer, installer, etc. In order to avoid future conflicts, a cooperation project between building proprietors, contractors, and consultants has been initiated.

The cooperation is called SVEBY (Standardize and Verify Energy Performance in New Buildings) and it consists of 17 subprojects. The aim is to develop guidelines for contracts, calculations, measurements, and verifications to ensure that the requirements for energy performance are fulfilled.

SVEBY will facilitate cooperation between actors to avoid disputes caused by unclearness in building codes, methods, trade agreements, and contracts. So far, five subprojects have been successfully completed, and the results are supported standard contracts, trade rules, and guidelines.

Introduction

As a consequence of the European Building Performance Directive (EPBD, 2002), the Swedish National Board of Housing, Building and Planning introduced a new building code that sets requirements for energy performance of the building. The new building code gained legal force in 2006, and further restrictions for electrically heated buildings gained legal force in 2009. The transitional period for the old building code ended on 1 January 2010. The requirements not only set maximum energy use per square meter, but also cover installed electric power for heating and a mean coefficient for thermal transmittance. Furthermore, the new building code sets requirements for the energy performance to be verified by measurements within 24 months of building completion. Consequently, the building sector has to change its traditional way of working in order to meet these new requirements. This applies to the building proprietor who needs to learn how to set new requirements when ordering a new building, the contractor who needs to change his work with a new way of quality assurance, and the consultants who take on new assignments.

The new building code only sets the overall requirements. It does not give details of how they should be followed. According to the law, the building proprietor is responsible for making sure that the requirements of the building code are followed. The building proprietor is also responsible for energy performance being measured and reported within 24 months of completion of the building. If the requirements are not met by measurements after 24 months, there will be a conflict between the contractor and the building proprietor. The contractor will have major difficulties taking measures for the construction, as all the consultants will be working on other projects. In order to avoid future conflicts, a cooperation project between the building proprietors, contractors, and consultants has been initiated. The cooperation is called SVEBY (Standardize and Verify Energy Performance in New Buildings) and it consists of 17 subprojects. This paper describes the subprojects that have been completed so far. SVEBY develops agreements, guidelines and routines for contracts, calculations, measurements, and verifications to ensure that the designed energy use will comply with the measured energy use.

The New Building Code

The new building code set by the National Board of Housing, Building and Planning has requirements for the building's energy performance. The requirements are described in terms of specific energy use (kWh/m^2 A_{temp}) and are shown in Table 1. A_{temp}, the temperate area, is defined as the area on the inside of the building envelope, on all floors, that is supposed to be heated to more than 10ºC. The area of interior walls, openings for stairs, shafts, and similar are included. The area of the garage is not included.

The building's energy use is defined as the energy that needs to be delivered to the building (often called "bought energy" in Sweden and "site energy" in the U.S.), at normal use and during a normal year, for heating, comfort cooling, hot tap water, and electricity for the operation of the building. Electricity for domestic purposes or business activities is not included (definitions of electricity for different appliances are shown in Table 3).

The requirements differ depending on: in which climate zone the building is placed (Sweden is divided into three climate zones, see Figure 1), if the building has an occupant activity of living (dwellings) or business activities (premises), and if the building is heated by electricity or in another way. All premises are treated equally, independent of business activity, such as hospitals, restaurants, offices, schools, grocery stores, shopping centers, etc. The reason is that only energy for heating, comfort cooling, hot tap water, and electricity for the operation of the building is included. Electricity for business activities is not included.

A comparison with Danish building regulations is that they also include lighting where appropriate and that the requirements for premises are depending on heated gross floor area. Norwegian building regulations include lighting and appliances, and the requirements for premises are different for different business activities (Andresen et al. 2010).

Figure 1. Sweden Divided into Three Climate Zones

Table 1: Requirements for Specific Energy Use in the National Building Code (kWh/m^2 A_{temp})

Climate zone	I	II	III
Premises that are heated in a way other than with electricity	140	120	100
Dwellings that are heated in a way other than with electricity	150	130	110
All buildings heated with electricity	95	75	55

The ventilation system in dwellings and premises should be designed for an outdoor ventilation rate of 0.35 liter per second and square meter. Empirical investigations during the 1980s have showed that 0.35 liter per second and square meter will not cause any medical inconvenience for the occupants (Abel, 2010).

If, for hygienic reasons, the outdoor ventilation flow is greater than 0.35 liter per second and square meter in premises, an addition may be allowed to the energy performance requirement according to Table 2. There is no corresponding addition for dwellings.

The code provides the option to demand -control the ventilation rate. For dwellings, however, the ventilation rate may not be lower than 0.10 liter per second in a non-occupied area.

Table 2: Addition of Energy Performance for Premises

Climate zone	I	II	III
Premises that are heated in a way other than with electricity	$110*(q_{mean} -0.35)$	$95* (q_{mean} -0.35)$	$70* (q_{mean} -0.35)$
Premises heated with electricity	$65*(q_{mean} -0.35)$	$55* (q_{mean} -0.35)$	$45* (q_{mean} -0.35)$

Where q_{mean} is the mean specific outdoor flow during the heating season. q_{mean} is only allowed to be counted for up to 1.00 liter per second and square meter.

The building's energy performance should be measured during a continuous period of 12 months and completed, at the latest, 24 months after the building has been taken into use.

Corrections of energy performance, according to a normal year, and possible corrections from the designed use of the building (indoor temperature, hot tap water use, airing, and suchlike) should be accounted for in a special report.

Previous Energy Performance

In Sweden, the first building regulation to include energy performance requirements came in the late 1970s (SBN75 1977 and SBN80 1982). These requirements for energy performance were written as requirements with regard to insulating properties of the building envelope. In fact, even before this, indirect requirements regarding the insulating properties of the building envelope had been in force, but these were from a health point of view to prevent draughts and condensation on walls, etc. Requirements were also set for heat recovery. The new building code includes major changes, as the requirements are set for the building's energy performance with verification by measurements within 24 months of building completion.

The new building code will also require improvements in energy performance. Figure 2 shows the energy demands for apartment buildings by various energy carriers and as a function of the year of construction (SCB 2006). It can be seen that older apartment buildings have demand levels in the range 150-200 kWh/m2, and that a noticeable improvement occurred around 1980. One explanation for this improvement can be found in the revised building regulations of that period. The specific heat demand has essentially remained constant since, with a value of over 130 kWh/m^2 for buildings built in the 2000s. No buildings heated by oil or direct electric heating have been built in the 2000s. Table 3 shows the energy demands for premises divided into different categories and construction years (SCB 2006). A noticeable improvement also occurred for premises around 1980, and since then the average has been fairly constant. There is a big difference in energy performance for different building categories.

Figure 2. Average Heating Use Year 2005 for Apartment Houses per Construction Year and Energy Carrier

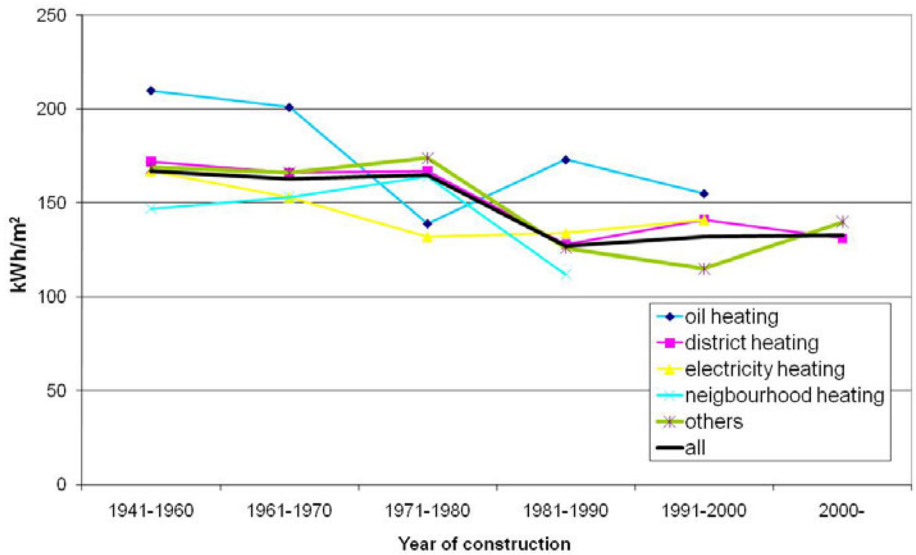

Table 3: Average Energy Use (Including District Heating and/or Electricity for Comfort Cooling) for Heating and Tap Water Heating per Area in Premises, Divided into Different Categories and Construction Year (kWh/m^2)

Year of construction	1941- 1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-	All
Apartments	160	160	181	148	143	83	149
Hotels etc.	140	150	158	152	166	142	156
Restaurants	132	153	167	194	204	162	168
Offices etc.	129	135	123	116	113	126	127
Food trades	147	150	154	140	176	138	150
Other trades	128	140	120	125	117	96	125
Hospitals, 24 hours	163	163	162	136	149	110	156
Hospitals, daytime	138	152	137	130	111	96	136
Schools	151	144	138	130	123	113	139
Bath and sports arenas	112	173	170	107	144	69	153
Churches, chapels	93	83	108	100			126
Theater, cinema, concert	133	113	126	120	132	114	130
Heated garages	147	150	126	117	124	111	139
Others	123	189	142	145	166	95	145
All	**141**	**147**	**138**	**127**	**129**	**129**	

The areas related to energy performance in Figure 2 and Table 3 are the living area for rent or the premises area for rent within the building, called BOA and LOA. The tempered area within the new building code (A_{temp}) is approximately 1.25 times BOA and LOA for apartment houses with heated basements and 1.15 times BOA and LOA for apartment houses without heated basements. Furthermore, the energy performance in Figure 2 and Table 3 does not include electricity for the operation of the building. For apartment houses, the electricity for operation is often between 10 and 25 kWh/m^2A_{temp}. For premises, the variation is greater and often between 15 and 40 kWh/m^2A_{temp} (Bröms and Wahlström 2008). This means that most building categories need improvements in energy performance with the new building code, and some premises almost need to halve their energy performance.

The SVEBY Project

The aim of the SVEBY project is for building proprietors, contractors, consultants, and local housing committees to cooperate in the work to meet the requirements for the buildings' energy performance, and to avoid disputes due to unclearness within the building code. The SVEBY cooperation will develop and conclude agreements for this purpose, for new trade rules and methods for contracts, calculations, measurements, and verifications in order to quality assure the buildings' operational energy performance. The verification of energy performance after 24 months of operation will not only mean that the requirements of the law are fulfilled, but also, at the same time, check that the delivered building meets the building proprietors' order. It is therefore very important to have guidelines and trade rules on how the energy performance should be met during the building process, the amount of deviation that may be accepted between the ordered and verified energy performance, and how the reasons for the deviation should be analyzed.

Table 4: Subproject within the SVEBY Program

No.	Title
1	Definitions and terminologies
2	Case studies
3	Input data of occupants' use in dwellings for energy calculations
4	Input data of occupants' use in offices for energy calculations
5	Validation of energy calculation methods
6	New contracts between the building proprietor and consultants
7	Additional contract between the building proprietor and the contractor
8	Guidance for follow -up of energy performance during the building process
9	Rules for measurements of energy performance
10	Cost -effective measurement methods and follow –ups
11	Verification of energy performance while considering airing of building moisture
12	Prediction of energy performance at delivery and final inspection
13	Deviation analyses between measured and contracted energy performance
14	The building proprietor's quality assurance of energy performance during operation
15	Responsibilities and economic sanctions of high -energy performance
16	Requirement specification for design and buying of part contractors and products
17	Normal year correction for cooling

The SVEBY project is extensive and has therefore been divided into several subprojects in which different trade representatives are working together to agree on methods and rules. Together, all the subprojects will cover all obscurities for the whole building process, from the program stage to 24 months of operation. So far, subprojects numbers 1, 3, 7, 8, and 9 have been carried out and are described in more detail in this paper. Subprojects numbers 2, 5, 13, and 17 are ongoing. Table 4 lists the titles of all 17 subprojects.

Additional Contract between the Building Proprietor and the Contractor

In this subproject, the legal contracts between the building proprietor and the contractor have been studied. An additional standard contract has been developed to the valid Swedish standard contract for design and construct (ABT 06, 2007). The additional standard contract will assure the building proprietor that the requirements of energy performance will be fulfilled by the contractor. The meaning of "in a professional manner" in ABT 06 has been used to draw up the agreement on responsibilities in a relevant way.

The additional standard contract states that existing models for inspections should be supplemented with power and performance tests, and that the SVEBY measurement rules should be followed. The building proprietor is responsible for the measurements during operation and should report monthly to the contractor on the results of the measurements. Furthermore, the standard contract includes a model of compensation when energy performance is not fulfilled. Measures should be taken to correct the deviation of energy performance and/or the building proprietor should be compensated for the increased energy costs (Krohn 2009).

Rules for Measurements of Energy Performance

In this subproject, specifications have been agreed on site measurements and controls. The rules specify which parameters need to be monitored monthly and which only need to be measured once. It is important to have agreements on the required measurements and their accuracy in order to avoid unnecessary costs. The changes in user/occupant behavior compared with the designed values need to be determined in preparation for the verification of the building's energy performance.

The agreed rules for measuring apply to the building's measured energy performance, and the correction refers to the occupants' actual use of the building and a year of normal weather (a year of normal weather is a mean value of weather parameters over a period of 20-30 years). Corrections according to the deviations between the occupants' actual use of the building and the designed use are made according to standardized values taken forward within the subproject of input data on the occupants' use of the building. The rules for measurements will thereby directly form the basis of the account of energy performance deviation in a special report.

The rules for measurements are divided into three parts (Wahlström 2009). When a contract is signed, the parties can chose if measurements should only include Part 1, which is the base limit, or if Parts 2 and 3 should also be performed.

- Measurement Part 1: *The building's energy performance***.** The building's measured energy performance corrected with the occupants' actual use of the building and a year of normal weather. This part describes which measurements are necessary to perform and how the measured data should be analyzed in order to determine the building's energy performance. This part can be used directly as an appendix in a contract.

- Measurement Part 2: *Measurements as a basis when analyzing a deviation of energy performance.* This part describes what needs to be measured in order to analyze whether a deviation of energy performance has its explanation in a different use of the building by the occupants. These data are only analyzed in case of a deviation.
- Measurement Part 3: *Measurements as a preventive measure*. This part covers measurements that are recommended during the building process in order to avoid faults that may cause the building's predicted energy performance not to be reached.

Definitions and Terminologies

In this subproject, the project team has agreed on definitions and terminology for specifications of requirements, procurement, and verification. This work includes definitions of the necessary parameters for the building envelope, building services, occupant behavior, and climate. Furthermore, definitions have been drawn up for domestic and business electricity use, and electricity use for building operation (Stålbom 2009). Table 5 provides examples of these definitions.

Table 5: Examples of Definitions of Electricity for Different Appliances

Examples of energy appliances	Electricity for the operation of the building	Energy for domestic purposes or business activities
Electricity for appliances in domestic houses, e.g., dishwasher, washing machine, refrigerator, freezer, TV, computers		X
Electricity for appliances in premises, e.g., computers, copy-machines, cooling and freezing cabinets, stoves, dishwashers, washing machines		X
Floor heating intended for heating	X	
Floor heating intended for other purposes than heating. Heating performed with another heating system.		X
Towel dryer intended for heating	X	
Towel dryer intended for other purposes than heating. Heating performed with another heating system.		X
Infrared heating on balcony, glazed-in balcony, terrace, or other place outdoors		X
Common laundry for those living in the building		X
Outdoor lighting intended to light up common front doors	X	
Outdoor lighting intended to light up the yard		X
Outdoor lighting intended to light up front doors or balconies for separate apartments		X
Indoor lighting in dwellings and premises		X
Indoor lighting in stairwell and other common areas such as elevators, cellars, etc.	X	
Electricity heating in rain gutters etc. intended to prevent ice formation	X	
Heating cable in ground intended for snow melting		X

Input Data of Occupants' Use of Dwellings for Energy Calculations

In this subproject, the project team has agreed on input data for energy calculations that simulate standardized use of the building (Levin 2009). Input data for standardized use of living and other businesses are needed to:

- Provide a realistic and standardized way to describe different normal living and business activities and their corresponding effect on energy performance
- Facilitate, for the consultants, the calculation of energy performance for different business uses of the building
- Give a reasonable margin of energy performance for later fulfillment of measured values
- Be a help in order to correct deviations of energy performance caused by occupants using the building differently from its designed use

The agreed input data are intended to be used for the calculation of the building's expected energy performance for a normal year and are not intended to be used for the calculation of dimensioning power need. Input data are based on statistics and research investigations on the way energy and tap water are used in Sweden. Here, the agreed input data refer to representative values for new constructed buildings and new technologies used in new constructions. For example, new tap water devices, with energy -efficient user behavior techniques, will be installed to a much greater extent than in old buildings. The values are therefore not representative for mean use in Sweden. Examples of content and agreed values for living input data are given in Table 6.

Table 6: Examples of Input Data on Occupant Use of a New Apartment Building

Parameter	Description	Input data
Indoor temperature	Heating season	21^{o}C
Air flow	Demand controlled ventilation in kitchen	30 min per day
Air flow	Airing increase	4 kWh/m^2, year
Sun screening	Screening factor, total	0.5
Hot tap water	Yearly energy use	25 kWh/m^2, year
Hot tap water	Individual measuring and debiting	20 % decrease
Domestic electricity	Yearly energy use	30 kWh/m^2, year
Domestic electricity	Share of internal heat that can be assimilated for heating	70 %
Heat from persons	Power	80 W per person
Heat from persons	Presence time	14 hours per day and night and person (weekdays and weekends)

Guidance for Follow-Up of Energy Performance During the Building Process

Work is needed for quality assurance of energy performance during the complete building process. Mistakes must be discovered in time in order to take effective measures. Depending on the scale of the building project and the form of the contract, the need for follow-up actions will differ. All follow-up activities must still be planned with procedures and a budget however. The procedures must clearly describe who is responsible for measurements, analyses, and actions.

As quality assurance of the building's energy performance, the project team has agreed on guidelines to follow-up the building's energy performance during the complete building process. The guidelines aim to be a support for all actors during the building process and for the follow-up to take part, as far as possible, within the ordinary working routines. These general guidelines apply irrespective of the type of contractor and assume that the building proprietor gives all-embracing responsibility for energy follow-up to the building project management. The building project management will thereafter give other actors responsibility for the activities that should be performed. The guidelines (Wickman and Wahlström 2009) are described in Table 7, and they consist of:

- A **checklist** for energy performance follow-up during the building process. The checklist includes responsibilities for comprehensive follow-up activities and deliverables.
- **Energy verification** of documentation and results of activities performed according to the checklist and the verification action plan. The energy verification may be one of the account documents.
- **Energy calculations and the account of requirements for technical energy performance parameters,** which will be the basis for a more detailed follow-up with controls and performance tests of parameters. The account, together with information on the occupants' use of the building, will provide input for revised energy calculations. Revised energy calculations are recommended at the proposal stage, at the late project stage, and after the construction stage, including supplemented winter and summer tests.
- A **verification action plan** describes in detail which follow -up activities should be performed, when they should be performed, and by whom. It includes instructions on how the activities should be documented and communicated.
- A requirement that the existing model for inspections is supplemented with power and performance tests for different operation and climate conditions, i.e., supplementary **winter and summer tests**.

Table 7: Activities for Energy Performance Follow -Up

Person involved	*Stage*	*Content*	*Activities for energy performance follow -up*
Building proprietor Project leader	Planning and programming stage	Targets and requirements are set based on the building's specific conditions.	Energy targets are set. Responsibilities for overall follow -up are set.
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Building proprietor Project leader Quality manager	Proposal stage	Alternative systems for architecture, technique, and construction are evaluated. Descriptions of the building's installation systems are documented.	An account of requirements for technical energy performance parameters is set. Energy calculations are performed (proposal stage). A template for Energy Verification is made. A control plan concerning energy use is drawn up according to the planning and building law. The control plan is based on the checklist of energy performance follow -up and it includes resources and timetables.
	↓		
Project leader Designer/constructor Inspector	Project stage	Detailed description of the systems, construction, operational conditions and dimensioning of the building. The account documentation from the proposal stage is revised.	The designer/constructor describes how testing and control should be performed. The designed technical energy performance parameters are updated and revised energy calculations performed (project stage). A more detailed verification action plan is set.
	↓		
Project leader Inspector Contractor Operation staff	Construction stage	The building is constructed and the final inspection is performed.	The contractor performs self -inspections and tests the subsystems. The inspector follows the inspection plan, checks that the self -inspections and testing of the subsystems have been performed, and coordinates the inspection of operation and performance tests. Cooperation with the operation staff during running adjustments and handover of the operation. Final inspection is approved with exceptions.
	↓		
Building proprietor Project leader Inspector Operation staff	Guarantee stage	The building is approved and delivered	Winter and summer tests are performed and the final inspection can be fully approved. Constructed technical energy performance parameters are updated, and revised energy calculations are performed (construction stage). The building's energy performance is verified with measurements. Experiences and energy documentation are completed in the Energy Verification.
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Building proprietor Operation staff	Operation stage	The building is in operation	The Energy Verification serves as a tool during operation optimization by the operation staff.

Results, Discussions, and Further Work

The SVEBY project guidelines and templates have been developed for contracts, calculations, measurements, and verifications to ensure that requirements for energy performance are fulfilled. The deliverables will be compiled and published in the forthcoming "Guide to

Standardize and Verify Specific Energy Performance in New Buildings" together with the results from forthcoming subprojects. It is hoped that the guide will reach the main part of the construction and real estate business. So far, the results from the five completed subprojects have been very successful. Close cooperation and time for discussions within the Sveby project have resulted in five guidelines with decisions supported by both sides of a building contract.

First, an additional standard contract between the building proprietor and the contractor, including a model of compensation when energy performance is not fulfilled, is supported. The standard contract will be the main basis for avoiding expensive, future conflicts.

Second, rules for the measurement of energy performance will not only give a clear guide on which energy meters should be installed but also provide agreed rules on how to correct the measured energy performance when the tenants have used an extremely large amount of hot tap water.

Third, definitions and terminologies have been agreed that will be an important help during further work on guidelines on how to implement the new building code. The guide for different appliances and their electricity use divided into electricity for operation and electricity for domestic or business activities has been carefully collaborated with the National Board of Housing, Building and Planning. The building code does not include requirements for electricity use for domestic or business activities. The reason may be that in Sweden, these electric appliances are normally used and paid for by the tenants. It would be difficult legally for the building proprietor to demand this information from the tenants during verification of energy performance. Electricity use for domestic and business activities has a big impact on the building's total energy performance, however, and some choice of appliances could be influenced by the building proprietor during the construction. Examples include choice of refrigerator and freezer in apartment buildings, and choice of lighting in premises. Future work by the Sveby project could carry forward standardized figures for different appliances and promote the use of more low-energy products.

Forth, the agreement on the input data for living activities for energy calculations will facilitate a reasonable margin of energy performance during the building design.

Fifth, the agreed guidance on following up energy performance will provide clear rules on who is responsible for the follow -up, reasonable activities for follow-up during the planning, design, construction, and operation phases, and guides for documenting the follow-up activities.

The developed guidelines are now ready to be tested and improved in practice in a real building project of new constructions. This work will start in mid 2010.

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