CEN/TC 247

Date: 2006-08

prEN 15232

CEN/TC 247

Secretariat: SNV

Energy performance of buildings — Impact of Building Automation Control and Building Management

Energieeffizienz von Gebäuden — Einfluss der Gebäudeautomation und des Gebäudemanagement

Performance thermique des bâtiments — L'impact de l'automation et de la régulation du bâtiment et de la gestion technique du bâtiment

Old Title :	E:Calculation methods for energy efficiency improvements by the application of integrated building automation systems
	F: Méthodes de calcul pour l'amélioration de l'efficacité énergétique par les systèmes d'automatisation intégrée du bâtiment
	D: Methode zur Kalkulation der Energieeffizienzverbesserung beim Einsatz von integrierten Gebäudeautomationssystemen

ICS:

Descriptors: Energy performance, BACS, TBM, control functions, integrated functions, energy saving functions

Date: 2006-08-05

Doc No: CEN/TC 247 N 665

Formal Vote draft for work item 00247046 (prEN15232) for CEN/TC247 approval

Document type: European Standard
Document subtype:
Document stage: Formal Vote
Document language: E

D:\CEN\EPBD\FV-15232\FV-Draft-prEN15232_for_TC247_approval.doc STD Version 2.1c

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Foreword

This document prEN 15232 has been prepared by Technical Committee CEN/TC 247 "Building automation, controls and building management", the secretariat of which is held by SNV.

This document is currently submitted to the Formal Vote.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive, see informative Annex ZA, which is an integral part of this document.

The standards under the mandated are aimed at European harmonization of the methodology and an overview of the whole set of EPBD standards is given in the TSxxxxxx(UD).

Introduction

This European standard was devised to establish conventions and methods for estimation of the impact of building automation, control systems (BACS) and technical building management (TBM) on energy performance and energy use in buildings.

This standard also provides guidance for taking BACS and TBM functions as far as possible into account in the standards prepared under the mandate M343. Therefore it is coordinated between CEN/TC247 and CEN/TC 89, TC 156, TC 169, TC 228 to support these TC's by strong cooperation in specifying how the impacts of the BACS and TBM functions are taken into account in their standards. The results about BACS and TBM contained in these interrelated standards of M343 are summarized in chapter 5.

This standard should be used for existing buildings and for design of new or renovated buildings.

1 Scope

This standard defines:

— A structured list of control, building automation and technical building management functions which have an impact on the energy performance of buildings

— A method to define minimum requirements regarding the control, building automation and technical building management functions to be implemented in buildings of different complexities.

— Detailed methods to assess the impact of these functions on a given building. These methods enable to introduce the impact of these functions in the calculations of energy performance ratings and indicators calculated by pr EN 15203, prEN15217.

— A simplified method to get a first estimation of the impact of these functions on typical buildings.

This standard can be used by:

— building owners, architects or engineers defining the functions to be implemented for a given new building or for the renovation of an existing building

— public authorities defining minimum requirements for control, building automation and energy management function for new buildings as well as for renovation as defined in prEN 15217, Annex D.3

— public authorities defining inspection procedures of technical systems as well as inspectors applying these procedures to check if the level of control, building automation and technical building management functions implemented is appropriate

— public authorities defining calculation methods which take into account the impact of control building automation and technical building management functions on the energy performance of buildings as well as software developers implementing these calculation methods and designers using them

— designers checking that the impact of all control building automation and technical building management functions are taken into account when assessing the energy performance of a building.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

2.1 General

UD	Explanation of the general relationship between various CEN standards and the Energy Performance of Buildings Directive (EPBD) ("Umbrella Document")

2.2 BAC produced and system standards

EN 215: 2004	Thermostatic radiator valves - Requirements and test methods
EN 12098-1: 1996	Controls for heating systems - Part 1: Outside temperature compensated control equipment for hot water heating systems
EN 12098-2: 2001	Controls for heating systems - Part 2: Optimum start-stop control equipment for hot water heating systems
EN 12098-3: 2002	Controls for heating systems - Part 3: Outside temperature compensated control equipment for electrical heating systems
EN 12098-4: 2005	Controls for heating systems - Part 4: Tariff compensated optimum start-stop control equipment for electrical
EN 12098-5: 2005	Controls for heating systems - Part 5: Start-stop schedulers for heating systems
EN ISO 16484-2: 2004	Building automation and control systems (BACS) — Part 2: Hardware
EN ISO 16484-3: 2005	Building automation and control systems (BACS) — Part 3: Functions
prEN 15500: 2006	Electronic Individual Zone Control Equipment

2.3 Energy performance of building

EN 832: 2002	Thermal performance of buildings - Calculation of energy use for heating - Residential buildings
EN 13363: 2003	Solar protection devices combined with glazing - Calculation of solar and light transmittance - Simplified method
EN ISO 13790	Thermal performance of buildings - Calculation of energy use for space heating
prEN ISO 13790:	Energy performance of buildings – Calculation of energy use for space heating and cooling
EN 13971: 2003	Carbonate liming materials - Determination of reactivity - Potentiometric titration method with hydrochloric acid
prEN 15217	Energy performance of buildings – Methods for expressing energy performance and for energy certification of buildings
prEN 15203	Energy performance of buildings — Assessment of energy use and definition of ratings

2.4 Energy performance of Heating and Domestic hot water

prEN 15315	Heating systems in buildings - Energy performance of buildings - Overall energy use, primary energy and CO2 emissions
prEN 15316-1	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 1: General
prEN 15316-2-1	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 2-1: Space heating emission systems

prEN 15316-2-3	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 2-3: Space heating distribution systems
prEN 15316-3-2	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-2: Domestic hot water systems, distribution
prEN 15316-3-3	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-3: Domestic hot water systems, generation
prEN 15316-4-1	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-1: Space heating generation systems, combustion systems
prEN 15316-4-2	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-2: Space heating generation systems, heat pump systems
prEN 15316-4-3	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-3: Space heating generation systems, thermal solar systems
prEN 15316-4-4	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-4: Space heating generation systems, the performance and quality of CHP electricity and heat
prEN 15316-4-5	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-5: Space heating generation systems, the performance and quality of district heating and large volume systems
prEN 15316-4-6	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-6: Space heating generation systems, the performance of other renewables heat and electricity
prEN 15316-4-7	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-7: Space heating generation systems, biomass combustion systems
prEN 15378	Heating systems in buildings — Inspection of boilers and heating systems

2.5 Ventilation and air conditioning

prEN 13779	Ventilation for non-residential buildings - Performance requirements for ventilation and room-conditioning systems
prEN 15239	Ventilation for buildings - Energy performance of buildings - Guidelines for inspection of ventilation systems
prEN 15240	Ventilation for buildings - Energy performance of buildings - Guidelines for inspection of air-conditioning systems
prEN 15241	Ventilation for buildings - Calculation method for energy losses due to ventilation

	and infiltration in commercial buildings
prEN 15242	Ventilation for buildings - Calculation methods for the determination of air flow rates in buildings including infiltration
prEN 15243	Ventilation for buildings - Calculation of room temperatures and of load and energy for buildings with room conditioning systems

2.6 Energy performance of lighting

prEN 15193-1	Energy performance of buildings - Energy requirements for lighting – Part 1: Lighting energy estimation

3 Terms and definitions

This clause presents the vocabulary used in this standard.

The terms and definitions listed in this standard but defined by other relevant ISO/IEC International Standards and/or European standards are repeated below for convenience in most cases.

NOTE Other language versions may contain an alphabetical index in National Annexes.

For the purposes of this standard, the following terms and definitions apply.

3.1
auxiliary energy
electrical energy used by heating, cooling and/or domestic water systems to transform and transport the delivered energy into the useful energy
[UD]

NOTE 1 This includes energy for fans, pumps, electronics, etc., but not the energy that is transformed. Pilot flames are considered as part of the energy use by the system.

NOTE 2 In EN ISO 9488, *Solar energy – Vocabulary*, the energy used for pumps and valves is called "parasitic energy".

3.2
building automation and control
BAC
description for products, software, and engineering services for automatic controls, monitoring and optimization, human intervention, and management to achieve energy – efficient, economical, and safe operation of building services equipment

NOTE The trade designation and the industry branch are also referred to as building automation and/or building control.

3.3
building automation and control system
BACS
comprising all products and engineering services for automatic controls (including interlocks), monitoring, optimization, for operation, human intervention and management to achieve energy – efficient, economical and safe operation of building services

NOTE 1 The use of the word ‘control’ does not imply that the system/device is restricted to control functions. Processing of data and information is possible.

NOTE 2 When a Building Control System, Building Management System or Building Energy Management System is in compliance with the requirements of the EN ISO 16484 standard series, it should be designated as a Building Automation and Control System (BACS).

3.4
building management
BM
the totality of services involved in the management operation and monitoring of buildings (including plants and installations). Building management can be assigned as part of Facility Management.
[CEN/TS15339]

3.5
building management system
BMS
cf. building automation and control system

NOTE 1 Building services is divided in technical, infrastuctural and financial building services and energy management is part of technical building management.

NOTE 2 building energy management system is part of a BMS.

NOTE 3 Building energy management system comprising data collection, logging, alarming, reporting, and analysis of energy usage, etc. The System is designed to reduce the energy consumption, improve the utilization, increase the reliability, and predict the performance of the technical building systems, as well as optimize energy usage and reducing its cost.

3.6
delivered energy
total energy, expressed per energyware, supplied to the building through the system boundary from the last market agent, to satisfy the uses taken into account (heating, cooling, ventilation, domestic hot water, lighting, appliances etc.)
[UD)

NOTE 1 For active solar and wind energy systems the incident solar radiation on solar panels or the kinetic energy of wind is not part of the energy balance of the building. The losses resulting from the transformation of these renewable energy carriers into heat or electricity are also not taken into account. Only the energy delivered by the generation devices and the auxiliary energy needed to supply the energy from the source (e.g. solar panel) to the building are taken into account in the energy balance and hence in the delivered energy.

NOTE 2 Delivered energy can be calculated for defined energy uses or it can be measured

3.7
energy carrier
substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes
[ISO 13600:1997].

NOTE The energy content of fuels is given by their gross calorific value.

3.8
energy demand
energy to be delivered by an ideal energy system (no system losses are taken into account) to provide the required service to the end user (e.g. to maintain the internal set-point temperature of a heated space)

3.9
energy use for space heating or cooling or ventilation or domestic hot water or lighting
energy input to the heating, cooling, ventilation, hot water or lighting system to satisfy the energy need for heating, cooling, ventilation, hot water or lighting respectively. It is the sum of the energy needs and the non-recovered technical system thermal losses

3.10
energy ware
tradable commodity used mainly to produce mechanical work or heat, or to operate chemical or physical processes, and listed in Annex A of ISO 13600
[ISO 13600]

NOTE Examples are oil, gas, coal, grid electricity, district heating. Energywares form a proper subset of energy carriers. The set of energy carriers is open. Solar radiation is an energy carrier that is not an energyware.

3.11
function
<BACS> effect of programs and parameters
[EN-ISO 16484-2:2004]

NOTE 1 Functions within a BACS are referred to as control functions, I/O, processing, optimization, management and operator functions. Listed in the BACS FL (function list) for a specification of work
[EN-ISO 16484-2:2004]

NOTE 2 Function is a program unit that delivers exactly one data element, which can be a multiple value (i.e. an array or a structure). Functions can be an operand in a program.
[IEC 1131-3:1993]

3.12
integrated building automation and control systems
a BACS designed to be interoperable and with the ability to be connected to one or more specified 3rd party building automation and control devices/systems through open data communication network or interfaces performed by standardized methods, special services and permitted responsibilities for system integration

Examples Interoperability between 3rd party BAC devices/systems for HVAC, domestic hot water, lighting, electrical power distribution, energy metering, elevators and escalators, other plants, as well as systems for communications, access control, security, life safety, etc.

3.13
integrated function
‹BACS› effect of programs, shared data points and parameters for multi-discipline interrelationships between various building services and technologies

3.14
measured energy rating
energy rating based on measured amounts of delivered and exported energy.

NOTE The measured rating is the weighted sum of all energywares used by the building, as measured by meters or other means. It is a measure of the in-use performance of the building. This is particularly relevant to certification of actual energy performance.

NOTE Also known as "operational rating".

3.15
technical building management
TBM
the process(es) and services related to operation and management of buildings and technical building system through the interrelationships between the different disciplines and trades

NOTE The disciplines and trades comprise all technical building services for the purpose of optimized maintenance and energy consumption.

EXAMPLES Optimization of buildings through interrelationships ranging from heating, ventilation and air conditioning (HVAC) to lighting and day lighting to life safety and security to electric power systems and energy monitoring and metering; to its services, including communications and maintenance; and to its management.

3.16
technical building system
technical equipment for heating, cooling, ventilation, domestic hot water, lighting and electricity production [UD]
NOTE A technical building system is composed of different subsystems

3.16
set-point temperature of a conditioned zone
internal (minimum) temperature, as fixed by the control system in normal heating mode, or internal (maximum) temperature, as fixed by the control system in normal cooling mode [AD]

Note corrected value of a temperature set point to be used for the calculation of energy performance. It enables to take into account simply the impact of the accuracy of the control system on the energy performance.

4 Abbreviations and acronyms

For the purposes of this document, the following abbreviations and acronyms apply.

BAC **Building Automation and Control**

BACS **Building Automation and Control System**

BM **Building Management**

EUBAC **European Building Automation Controls Association**

HVAC **Heating, Ventilation and Air Conditioning**

TBM **Technical Building Management**

5 Impact of BACS and TBM on the energy performance of buildings

5.1 General

Building Automation and Control (BAC) provides effective automation and control of heating ventilating cooling, hot water and lighting appliances etc. that leads to increase operational and energy efficiencies. Complex and integrated energy saving functions and routines can be configured on the actual use of a building depending on the real user needs to avoid unnecessary energy use and CO2 emissions.

Building Management (BM) especially Technical Building Management provides information for operation, maintenance and management of buildings especially for energy management - Trending and alarming capabilities and diagnose of unnecessary energy use. Energy management is a requirement about controlling, monitoring, optimisation and determination of energy performance of buildings.

5.2 BAC Efficiency Class

Functions having an impact on the energy performance of buildings are listed in Table 1.

They are split in three groups: functions for automatic control, function for building automation, function for technical building management

Four different BAC efficiency classes (A, B, C, D) of functions are defined either for non – residential and residential building.

- Class D corresponds to non energy efficient BACS. Building with such systems shall be retrofitted. New buildings shall not be built with such systems.
- Class C corresponds to standard BACS
- Class B corresponds to advanced systems BACS and BMS
- Class A corresponds to high energy performance BACS and BMS.

Table 1 defines the list of functions corresponding to each level

To be in class C minimum functions defined in table 1 shall be implemented. In addition the hydraulic system shall be properly balanced.

To be in class B **Building automation function** plus some specific functions defined in table 1 shall be implemented in addition to class C. Room controllers shall be able to communicate with a building automation system.

To be in class A **Technical building management function** plus some specific functions defined in table 1 shall be implemented in addition to class B.

One is in class D If the minimum functions to be in class C are not implemented.

5.3 BAC and BM functions having an impact on the energy performance of buildings

Table 1 shall be used by:

a) building owners, architects or engineers defining the functions to be implemented for a given new building or for the renovation of an existing building

b) public authorities defining minimum requirements for control, building automation and energy management function for new buildings as well as for renovation as defined in prEN 15217, Annex D.3

c) public authorities defining inspection procedures of technical systems as well as inspectors applying these procedures to check if the level of control, building automation and technical building management functions implemented is appropriate

d) public authorities defining calculation methods which take into account the impact of control building automation and technical building management functions on the energy performance of buildings as well as software developers implementing these calculation methods and designers using them

e) designers checking that the impact of all control building automation and technical building management functions are taken into account when assessing the energy performance of a building

Table 1 shall be used in the following way.

a) building owners, architects or engineers defining the functions to be implemented for a given new building or for the renovation of an existing building

- They shall put an x in front of each of the functions they want to be implemented. They will use the shaded boxes as an help tool to determine in which category A, B, C, D the function they have specified are located. To achieve for example category B the x shall all be put in a shaded box for category C.

- A simplified alternative especially for specification at an early stage of a project will be to specify only the category of function A, B, C, D.

f) public authorities defining minimum requirements for control, building automation and energy management function for new buildings as well as for renovation as defined in prEN 15217, Annex D.3

- they can define the minimum category to be achieved. Unless differently specified by public authorities this category is C

b) public authorities defining inspection procedures of technical systems as well as inspectors applying these procedures to check if the level of control, building automation and technical building management functions implemented is appropriate

- Public authorities can request to use the table to inspect the control system in place
- Inspectors shall put an x in front of each of the functions which are implemented
- They will then be able to determine the category A,B, C, D of functions already implemented. To be in a given category all the X shall correspond to shaded boxes for this category

g) public authorities defining calculation methods which take into account the impact of control building automation and technical building management functions on the energy performance of buildings as well as software developers implementing these calculation methods and designers using them

- Public authorities can request that the impact of the control functions defined in the list is taken into account
- Software developers shall develop software user interfaces enabling to input the list of functions which are implemented according to table 1. They can provide a simplified input mode based on the category of functions A, B, C, D.

h) designers checking that the impact of all control building automation and technical building management functions are taken into account when assessing the energy performance of a building

- Designers will only have to input either the category of functions (A, B, C, D) or the detailed list of function in the software enabling to assess the energy performance of a building.

All functions defined in table 1 are not applicable to all types of hvac systems. prEN15243 indicates in table 5a for different categories of HVAC system the function which have the main impact on energy consumption.

		Definition of classes							
		Residential				Non residential			
		D	C	B	A	D	C	B	A
AUTOMATIC CONTROL									
HEATING AND COOLING CONTROL									
Emission control									
	The control system is installed at the emittor or room level, for case 1 one system can control several rooms								
0	No automatic control								
1	Central automatic control								
2	Individual room automatic control by thermostatic valves or electronic controller								
3	Individual room control with communication between controllers								
Control of distribution network water temperature (supply or return)									
	Similar function can be applied to the control of direct electric heating networks								
0	No automatic control								
1	Outside temperature compensated control								
2	Indoor temperature control								
Control of distribution pumps									
	The controlled pumps can be installed at different levels in the network								
0	No control								
1	On off control								
2	Variable speed pump control with constant Δp								
3	Variable speed pump control with proportional Δp								
Intermittent control of emission and/or distribution									
	One controller can control different rooms/zone having same occupancy patterns								
0	No automatic control;								
1	Automatic control with fixed time program;								
2	Automatic control with optimum start/stop.								
Interlock between heating and cooling control of emission and/or distribution									
0	No interlock;								
1	Partial interlock (dependant of the HVAC system)								
2	Total interlock.								
Generator control									
0	Constant temperature								
1	Variable temperature depending on outdoor temperature								
2	Variable temperature depending on the load								
Sequencing of different generators									
0	Priorities only based on loads								
1	Priorities based on loads and generator capacities								
2	Priorities based on generator efficiency (check other standard)								

		Definition of classes							
		Residential				Non residential			
		D	C	B	A	D	C	B	A
VENTILATION AND AIR CONDITIONING CONTROL									
Air flow control at the room level									
0	No control								
1	Manual control								
2	Time control								
3	Presence control								
4	Demand control (e.g. counting the number of people)								
Air flow control at the air handler level									
0	No control								
1	On off time control								
2	Automatic flow or pressure control with or without pressure reset.								
Heat exchanger defrost control									
0	Without defrost control								
1	With defrost control								
Heat exchanger overheating control									
0	With overheating control								
1	Without overheating control								
Free mechanical cooling									
0	No control								
1	Night cooling								
2	Free cooling								
3	H,x- directed control								
Supply Temperature control									
0	No control								
1	Constant set point								
2	Variable set point with outdoor temperature compensation								
3	Variable set point with load dependant compensation								
Humidity control									
0	No control								
1	Supply air humidity limitation								
2	Supply air humidity control								
3	Room or exhaust air humidity control								

		Definition of classes							
		Residential				Non residential			
		D	C	B	A	D	C	B	A
LIGHTING CONTROL									
	Occupancy control								
0	Manual on/off switch								
1	Manual on/off switch + additional sweeping extinction signal								
2	Automatic detection Auto On / Dimmed								
3	Automatic detection Auto On / Auto Off								
4	Automatic detection Manual On / Dimmed								
5	Automatic detection Manual On / Auto Off								
	Daylight control								
0	Manual								
1	Automatic								
BLIND CONTROL									
0	Manual operation								
1	Motorized operation with manual control								
2	Motorized operation with automatic control								
3	Combined light/blind/HVAC control (also mentioned above)								
BUILDING AUTOMATION									
0	No building automation function								
1	Adapting the operation of the building and technical systems to users needs								
2	Optimizing the operation by the tuning of the different controllers								
3	Standard alarming functions								
4	Standard monitoring function								
TECHNICAL BUILDING MANAGEMENT									
0	No technical building management function								
1	Detecting faults of building and technical systems and providing support to the diagnosis of these faults								
2	Reporting information regarding energy consumption, indoor conditions and possibilities for improvement								

Table 1 - Function list and assignment to energy performance classes

5.4 Reference BAC functions

A reference list of BAC functions is defined in Table 2 - Reference BAC functions.

Unless differently specified this list shall be used for the following used:

— To specify the minimum functions to be implemented for a project

— To define the BAC function to take into account for the calculation of energy consumption of a building when the BAC functions are not defined in details.

Unless differently specified by public authorities the minimum level of functions to be implemented corresponds to the functions defined in Table 2 - Reference BAC functions. Public authorities wishing to modify the minimum requirements shall adapt this table.

		Residential	**Non residential**
AUTOMATIC CONTROL			
HEATING AND COOLING CONTROL			
	Emission control		
	The control system is installed at the emittor or room level, for case 1 one system can control several rooms		
2	Individual room automatic control by thermostatic valves or electronic controller		
	Control of distribution network water temperature (supply or return)		
	Similar function can be applied to the control of direct electric heating networks		
1	Outside temperature compensated control		
	Control of distribution pumps		
	The controlled pumps can be installed at different levels in the network		
1	On off control		
2	Variable speed pump control with constant Δp		
	Intermittent control of emission and/or distribution		
	One controller can control different rooms/zone having same occupancy patterns		
1	Automatic control with fixed time program;		
2	Automatic control with optimum start/stop.		
	Interlock between heating and cooling control of emission and/or distribution		
1	Partial interlock (dependant of the HVAC system)		
	Generator control		
1	Variable temperature depending on outdoor temperature		
	Sequencing of different generators		
1	Priorities based on loads and generator capacities		
VENTILATION AND AIR CONDITIONING CONTROL			
	Air flow control at the room level		
1	Manual control		
2	Time control		

		Residential	Non residential
Air flow control at the air handler level			
0	No control		
1	On off time control		
Heat exchanger defrost control			
1	With defrost control		
Heat exchanger overheating control			
1	Without overheating control		
Free mechanical cooling			
0	No control		
1	Night cooling		
Supply Temperature control			
1	Constant set point		
Humidity control			
1	Supply air humidity limitation		
LIGHTING CONTROL			
Occupancy control			
0	Manual on/off switch		
Daylight control			
0	Manual		
BLIND CONTROL			
0	Manual operation		
BUILDING AUTOMATION			
0	No building automation function		
TECHNICAL BUILDING MANAGEMENT			
0	No technical building management function		

Table 2 - Reference BAC functions

6 Calculation procedures of BAC efficiency

6.1 General

The calculation of the impact of building automation, control and management functions on the building energy performance can either be done by a detailed method or a BAC Factor method. The following figure illustrates how to use the different approaches.

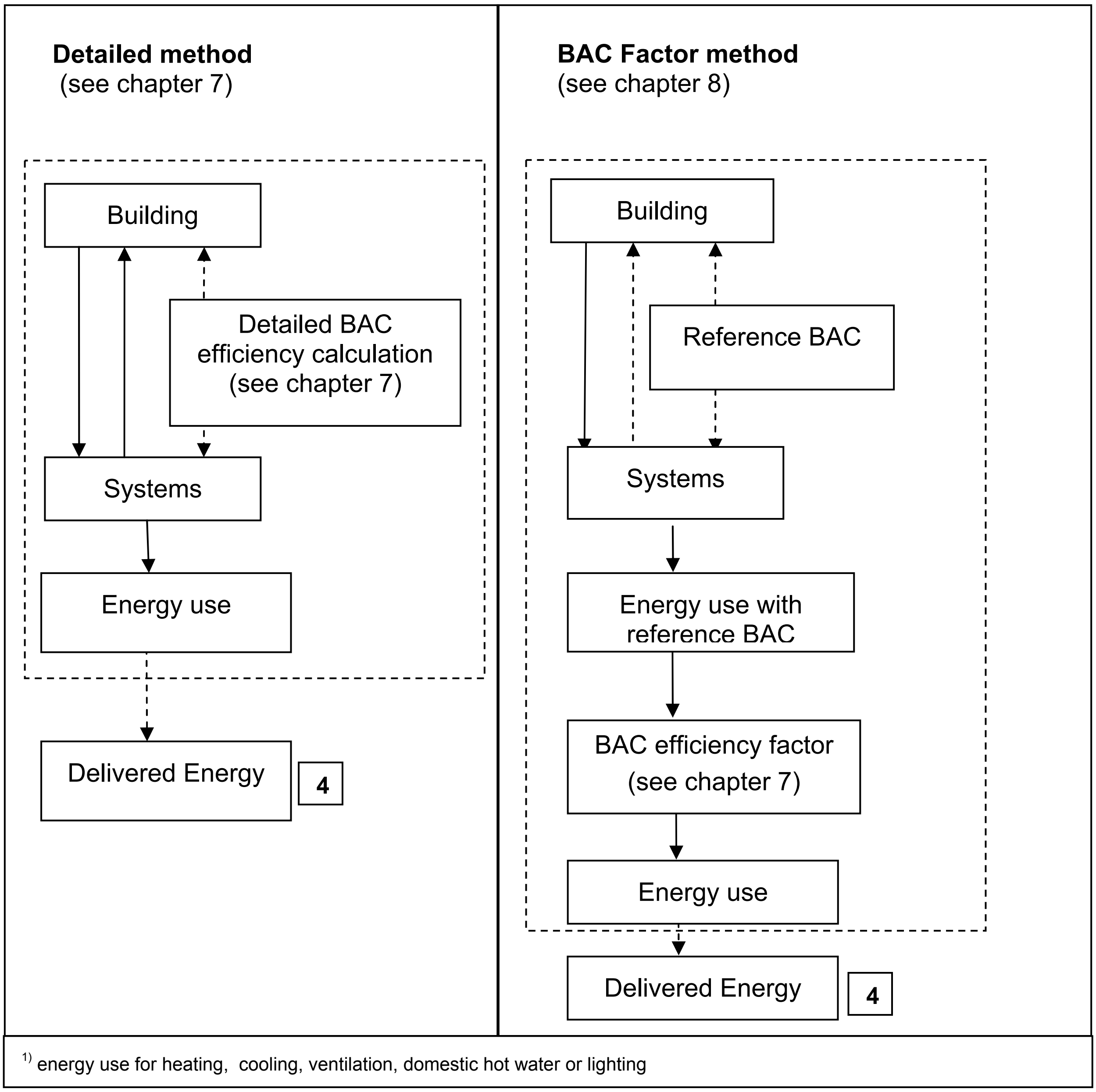

Figure 1: Difference between Detailed and BAC Factor method methods

[4] represents the delivered energy, represented separately for each energy carrier, inclusive of auxiliary energy, used by space heating, cooling, ventilation, domestic hot water and lighting systems, taking into account renewable energy sources and co-generation. This may be expressed in energy units or in units of the energyware (kg, m³, kWh, etc). See Figure 2 – Schematic illustration of the calculation scheme in TS xxxx

The detailed method should be used only when a sufficient knowledge about automation, control and management functions used for the building and the energy systems is available. The application of the detailed calculation procedure implies that all automation, control and management functions that have to be account for the operation of a building and its energy systems are known. Chapter 7 gives a general survey of those functions and declares how to use them in the context of energy performance calculations.

Otherwise the BAC factor method (Chapter 8) allows a rough estimation of the impact of BAC and BM according to the efficiency classes A, B, C and D (defined in chapter 5). The BAC factor method is specially appropriated to the early design stage of a building.

7 Detailed calculation procedure of BAC efficiency

7.1 Introduction

This chapter describes approaches to take into account the impact of control, building automation and technical building management function in the assessment of energy performance indicators defined in pr EN 15127 , pr EN 15203 and connected standards.

It defines:

- In § 7.2 description of the main approaches used in these standards to take into account the impact of the control, building automation and technical building management functions
- In § 7.3 an overview of links between these standards and the control, building automation and technical building management functions
- In § 7.4 to 7.10 a detailed description of the ways each control, building automation and technical building management function can be dealt with in connection with the relevant standards. Especially when the relevant standard does not describe explicitly how to deal with control, building automation and technical building management function, this standard provides this explicit description.

7.2 General principles of calculation / Main approaches for the calculation of the impact of BACS functions

The standards enabling to calculate the impact of control, building automation and building management functions on energy consumption use different approaches to calculate this impact.

5 approaches are common to different standards:

- The direct approach;
- The operating mode approach;
- The time approach;
- The temperature approach;
- The correction coefficient approach.

7.2.1 Direct approach

When the calculation of energy performance is performed using detailed simulation method or even hourly simulation method as described in pr EN 13790 it is possible to calculate directly the impact of a number of functions e.g. impact of intermittent heating, varying temperature between heating and cooling set points, movable solar shadings…

This approach is not relevant when monthly methods are used.

Even with detailed simulation method the direct approach can not be used when the impact of control leads to time variations which are quicker than the simulation time step.

In these cases the other approaches shall be used.

7.2.2 Operating mode approach

Automatic control enables to operate climate systems under different operating mode e.g.: for ventilation system: occupied mode /unoccupied mode, for intermittent heating normal mode, no heating mode, set back mode, peak power mode.

The approach to calculate the impact of the automatic control on the energy consumption is to calculate the energy consumption sequentially for each operating mode. The total energy consumption is obtained by summing the energy consumption during each operating mode.

Each operating mode corresponds to a given state of the control system. The calculations are performed for each operating mode by considering the relevant state of the control system: e.g. fan on / fan off.

7.2.3 Time approach

This approach can be used when the control system has a direct impact on the operating time of a device (e.g. control of a fan, a luminaries)

The energy consumption for a certain time period is given by a formula (1) which has the following shape:

$$E = P.t.F_c \qquad (1)$$

where

— E is the energy consumption for the time period;

— P is the input power of the controlled system;

— t is the duration of the time period;

— F_c is a characteristic coefficient which represents the impact of the control system. It is the ratio between the time where the control switches the system on and the duration of the time period.

By extension the time approach can be used if the control system modulates the operation of the system instead of switching it on and off. Fc represents in this case an equivalent operating time ratio.

7.2.4 Room temperature approach

This approach can be used when the control system has a direct impact on the room temperature.

It consists in taking into account in the calculation of the energy needs according to prEN ISO 13790 a corrected room temperature which takes into account the impact of the control system.

The following impacts shall be taken into account:

— Emission control of heating and cooling

— Intermittent control of emission and or distribution

— Optimizing the operation by the tuning of the different controllers

— Detecting faults of building and technical systems and providing support to the diagnosis of these faults.

The impact of the room controller

The impact of the intermittent heating controller

The calculation of the energy used is performed by a formula (2) which has the following shape

$$E = L.\left(\left(\theta_{sp} + \Delta\theta_c\right) - \theta_r\right).t \quad (2)$$

where

- E is the energy demand or consumption of the time period;
- L is a transfer coefficient;
- θ_{sp} is the set point which shall be maintained by the control system;
- $\Delta\theta_c$ represents the impact of the actual control system, it will be equal to 0 if the control system was perfect, and will be positive in case of heating and negative in case of cooling;
- θ_r is a reference temperature e.g. the outdoor temperature;
- t is the duration of the time period.

In this approach:

- θ_{sp} depends on the control system type used. It can be constant or variable;
- $\Delta\theta_c$ is a characteristic of the quality of the control system itself and of the controlled system. It can be defined by a product standard or a product certification provided this standard takes into account not only the controller but also the controlled system;
- L enables to take into account the influence of the plant or of the building controlled;
- θ_r enables to take into account the boundaries conditions, such as for example the climate.

$\theta_{sp} + \Delta\theta_c$ is called the equivalent temperature set point.

7.2.5 Correction coefficient approach

This approach is used when the control system has a more complex impact such as for example a combined effect on time, temperature etc,

The calculation of the energy demand or consumption is performed by a formula (3) which has the following shape

$$E = E_{pc}.x_c \quad (3)$$

where

- E is the energy demand or consumption;
- E_{pc} is the energy consumption in the reference case, e.g. if the system is controlled ideally, or if a BACS or TBM function is not present, or if the system is assumed to be controlled such that it is simple to calculate the energy performance;
- X_c is the correction coefficient which represents the increase or decrease of energy consumption as compared to the energy consumption E_{pc} of the reference case.

The values of x_c depend on the control type but vary also with the climate, building type…. Table or formula should be provided for example in national annexes to determine the impact of these parameters on x_c.

7.2.6 Equivalence between the different approaches

The parameters of the operating mode approach, time approach (F_c) and of the temperature approach ($\Delta\theta_c$) can generally be determined from the description of the control system and of the user profile.

The parameter of the correction coefficient approach X_c shall be determined by prior simulations. These simulations enable to define the tables or formulas giving the value of x_c in function of relevant parameters: building type, system type, user profile, climate….

7.3 Approach to take into account the different function in the calculation procedure

The control functions defined in table 1 shall be taken into account when applying the following standards.

Function		Standard
Automatic control		
HEATING AND COOLING CONTROL		
	Emission control	prEN 15316-2-1, §6.5.2 and annex B pr EN 15243§14.3.2.1 and annex G prEN 15316-2-1, §6.5.1 and annex A prEN ISO 13790 § 13
	Control of distribution network water temperature	prEN 15316-2-3, pr EN 15243
	Control of distribution pump	Pr EN 15316-2-3
	Intermittent control of emission and/or distribution.	prEN ISO 13790 §13.1.2 prEN 15316-2-3, prEN 15243
	Interlock between heating and cooling control of emission and/or distribution	pr EN 15243
	Generation control and sequencing of generators	prEN 15316-4, pr EN 15243
VENTILATION AND AIR CONDITIONING CONTROL		
	Air flow control at the room level	prEN 15242, prEN 13779
	Air flow control at the air handler level	prEN 15241
	Heat exchanger defrost and overheating control	
	Free mechanical cooling	
	Supply temperature control	prEN 15241
	Humidity control	prEN 15241 ?
LIGHTING CONTROL		Pr EN 15193
	Combined light/blind/HVAC control (also mentioned below)	none
BLIND CONTROL		prEN ISO 13790
Building automation		
Adapting the operation of the building and technical systems to users needs		None
Optimizing the operation by the tuning of the different controllers		None
Standard alarming functions		None
Standard monitoring function		None
Technical building management with energy efficiency functions		
Detecting faults of building and technical systems and providing support to the diagnosis of these faults		None

Function	Standard
Reporting information regarding energy consumption, indoor conditions and possibilities for improvement	prEN 15203

Table 3 control, building automation and technical building management function links to the EPBD standards

7.4 Heating and cooling control

7.4.1 Emission control

One shall differentiate at least the following types of room temperature control:

0) No automatic control of the room temperature.

1) Central automatic control: There is only central automatic control acting either on the distribution or on the generation. This can be achieved for example by an outside temperature controller conform to EN 12098-1 or EN 12098-3.

2) Individual room control is performed by thermostatic valves conform or not conform to EN215.

3) Individual room control is performed by an electronic controller conform or not conform to pr EN 15500

The impact of the control system type is taken into account by considering an equivalent internal temperature set point.

$$\theta_{ei} = \theta + \delta\theta \qquad (4)$$

Where:

θ_{ei} is the equivalent internal temperature which takes into account control inaccuracies

θ is the set point temperature of the conditioned zone

$\delta\theta$ is the control accuracy which depends on the control and controlled systems.

The set point is increased by $\delta\theta$ for heating and decreased by $\delta\theta$ for cooling. $\delta\theta$ depends on the control system and on the emitter type.

This approach is described in

- pr EN 15316-2-1 § 5.3 for heating systems
- pr EN 15243 § 14.3.2 for air conditioning systems
- pr EN ISO 13790 §13

For electronic controllers $\delta\theta$ is equal to the “control accuracy” determined according to prEN 15500.

Values of the control accuracy are the following table 4:

	Standard	Certification	Control accuracy $\delta\theta_{vt}$ (K)	
			Heating	Cooling
Direct electric emitter with built in controller	NF EN 60 675	NF Performance catégorie C	0,9	
Thermostatic radiator valve	NF EN 215	CENCER	0,45*(hysteresis+ water temperature effect)[1]	
Individual zone control equipment	Pr EN 15500	EUBAC cert	Cah defined in the standard and certified	Cac defined in the standard and certified
Other controller if emission can be totally stopped			1,8	1,8
Other controllers if emission can not be totally stopped			2	2

NOTE 1 pr EN 15316-2-1 defines also a method using control efficiency approach in § 5.3.2 and a method using an energy performance factor in § 5.3.3

NOTE 2 Set points for heating and cooling should be configured so that there is always a minimum dead band between heating and cooling

Table 4 - Control accuracy

7.4.2 Control of distribution network water temperature

One shall differentiate at least the following types of supply temperature control:

0) No automatic control;

1) Outside temperature compensated control;

2) Indoor temperature control.

Two effects shall be taken into account when assessing the impact of the supply (and/or return) temperature control:

— The presence of an automatic control lowered the mean flow temperature. This leads to a decrease of distribution losses. These losses shall be calculated according to prEN 15316-2-3 § 6. The temperature being calculated according to prEN 15316-2-3 § 8.

— If there is no automatic control of the supply and/or return temperature the room controller actions leads generally to a decrease of the flow rate. This enables to reduce the auxiliary energy consumption. This shall be calculated according to prEN 15316-2-3 § 5.3.2 through the correction coefficient for flow temperature control f_v defined in prEN 15316-2-3 § 5.3.3.1

NOTE This flow temperature control correction coefficient shows that the flow and the auxiliary energy consumption are lower if there is no temperature control. Indeed a reduction of the supply an/or return temperature in the heating case or an increase of it in the cooling case reduces the temperature difference between the supply and the return temperature, which requires a higher mass flow in order to supply the same flow of heat or cold (which is proportional to the product of the temperature difference and the mass flow) to the emitters.

7.4.3 Control of distribution pumps

One shall differentiate at least the following types of pump control:

0) No control;

1) On off control;

2) Variable speed pump control with constant Δp;

3) Variable speed pump control with variable Δp.

The impact of pump control on auxiliary energy demand is taken into account according to prEN 15316-2-3 § 5.3.4 through the correction coefficient for control f_R .

7.4.4 Intermittent control of emission and/or distribution

One shall differentiate at least the following types of intermittent control of emission and/or distribution:

0) No automatic control;

1) Automatic intermittent control without optimum start in conformity with EN12098-1 or EN 12098-3 or EN 12098-5 or EN-ISO 16484-3

2) Automatic intermittent control with optimum starts in conformity with EN12098-2 or EN 12098-4.

The impact of intermittent control of emission and/or distribution is split in two aspects:

— An impact on the energy needs of the building due to indoor temperature reduction;

— An impact on the energy use of the HVAC system due to lower operating times.

c) Impact on the energy needs of the building

The impact of the intermittent occupation is calculated according to pr EN ISO13790 § 13.1.

This approach takes into account the fraction of the number of hours in the week with a normal heating or cooling set point (e.g. 5*14/7/24), this fraction is defined by the coefficient $f_{N,H}$ for heating and $f_{N,C}$ for cooling.

The approach described in this standard does not differentiate the different types of controls.

In order to differentiate the different types of control the following procedure shall be applied:

In the equations (48) and (49) of prEN ISO 13790 replace:

— $f_{N,H}$ by $f_{N,H,C} = f_{N,H} * X$

— $f_{N,C}$ by $f_{N,C,C} = f_{N,C} * X$

where X is given in the following table 5

	X
No automatic control	0,5
Automatic intermittent control without optimum start	0,8
Automatic intermittent control with optimum starts	1

Table 5 – Factor x

i) impact on the energy use of the HVAC system

The impact of the control system on the operating time of the HVAC system is calculated according to a reduction of the auxiliary energy demand for heat distribution calculated according to prEN 15316-2-3 § 5.3.5.

One can in addition consider the impact of an optimum stop function. Nevertheless no standard already enables to assess this impact.

7.4.5 Interlock between heating and cooling control of emission and/or distribution

For air conditioned buildings this function is one of the most important regarding energy savings.

The possibility to provide at the same time heating and cooling in the same room depends on the system principle and on the control functions. Depending on the system principle a full interlock can be achieved with a very simple control function or can request a complex integrated control function.

0) One shall differentiate at leastNo interlock: the two systems are controlled independently and can provide simultaneously heating and cooling;

1) Partial interlock: The control function is set up in order to minimize the possibility of simultaneous heating and cooling. This is generally done by defining a sliding set point for the supply temperature of the centrally controlled system;

2) Total interlock: The control function enables to warranty that there will be no simultaneous heating and cooling.

A total interlock can be achieved in different ways:

- By the system principle which avoids any risk, for example
- heating and cooling are generated by a reversible heat pump which can not provide at the same time heating and cooling;
- a single distribution network provide either heat or cool (e.g. 2 pipes fan coils with change over).
- By a single controller acting in sequence on heating and cooling. This is applicable to systems where heating and cooling can both be totally controlled at the room level, for example 4 pipes fan coils.

System including a control of heating (respectively cooling) at the building level and a control of cooling (respectively heating) at the room level raised specific problems regarding interlock of heating and cooling. They include for example system composed of:

- a central ventilation system serving different rooms with a preheating coil in the central Air handling unit, and a central control of the supply air temperature;
- a cooling (or heating and cooling) device in each room with its local control.

In such systems one can reach the three levels of interlock:

- No interlock : the supply air temperature set point is fixed to a constant value;
- Partial interlock : the supply air temperature set point varies with the outdoor temperature;
- Total interlock: the supply air temperature set point is automatically reset depending on the cooling request in the different zones (this requests and integrated control system).

Example of methods to calculate this impact through a correction factor approach are given in pr EN 15243 § E.1.2.4

7.4.6 Generation control

The generation control depends on the generator type. Nevertheless the goal consists generally in minimising the generator operating temperature. This enables to limit the thermal losses. For thermodynamic generators this also enables to increase the thermodynamic efficiency.

Details regarding specific systems are given in the following standards:

- Combustion systems : PREN 15316-4-1;
- Heat pump systems: pr EN 15316-4-2 ??;
- Solar heating systems: pr EN 15316-4-3;
- Quality district heating systems : pr EN 15316-4-5 ??;
- Other renewable systems : pr EN 15316-4-6
- Biomass generation system: pr EN 15316-4-7 ??;

Three main types of temperature control can be differentiated:

0) Constant temperature control;

1) Variable temperature depending on the outdoor temperature;

2) Variable temperature depending on the load (this includes control according to room temperature).

7.4.7 Sequencing of generators

If different generators are available one can differentiate at least the following types of sequence control:

0) Without priorities;

1) Priorities based on loads and generator capacities

2) Priorities based on generator efficiencies

This is calculated according to Pr EN 15316-4-1 § 5.3.3.

7.4.7.1 Boilers

The impact of the control system is calculated according to prEN 15316-4-1.

This standard includes three calculation methods: typology, case specific boiler efficiency method, boiler cycling method.

The “case specific boiler efficiency method” describes explicitly how to asses the impact of the control system.

This is dealt with in §5.3.8 running temperature of the generator and Annex H

7.4.7.2 Biomass generation system

The impact of the generator control system is calculated according to PREN 15316-1 part 2.2.7.

The method is similar to the “directive method” described in prEN 15316-4-1.

The generator operating temperature shall be calculated in the same way as in prEN 15316-4-1 running temperature of the generator.

7.4.7.3 Quality district heating systems

The impact of the generator control system is calculated according M 343 PREN 15316-1 part 2.2.5.

The losses are calculated in §5.2.2 “Heat Loss”. The loss depend on the mean temperature of the dwelling station.

This temperature depends on the mean water temperature of the secondary circuit of the dwelling station which shall be calculated in the same way as in prEN 15316-4-1 § 5.3.8 running temperature of the generator.

7.4.7.4 Heat pump systems

The impact of the control system is calculated according to PREN 15316-1 part 2.2.2.

This standard includes 2 calculation methods: a simplified method based on system typology and a detailed case specific method.

The simplified methodology when existing, is the subject of a national annex. It is developed by applying the detailed case specific method to cases representative of a national typology. The way to deal with control in this simplified methodology does then depend on the national annex.

d) Operating temperature

The application of the detailed specific method takes into account in § 5.2.2 the controller setting of the heat emission system. One shall at minimum differentiate the following control types of the distribution:

0) Constant temperature control;

1) Variable temperature depending of the outdoor temperature;

2) Variable temperature depending on the load (this includes control according to room temperature).

From the type of control used one can define the operating temperature according to prEN 14335-2 §5.2.5 running temperature of the generator. This temperature is taken into account in §5.2.6.11 of mandate M 343 WI9 part 2.2.2.

Back up heater

i) The operation of back up heaters depends on the following values of outdoor temperature: A cut off temperature θ_{ltc}: below this temperature the heat pump is switched off and the back up operates alone;

ii) A balance temperature θ_{bp}: below this temperature the back up is started. This temperature is in all cases equal or higher than the cut off temperature.

The following mode shall be taken into account:

— Alternate mode: the cut off temperature and the balance point are equal. At this temperature the heat pump is stopped and the back up operates alone;

— Parallel mode: there is no cut off temperature. Below the balance temperature the back up is started and operates in parallel with the heat pump which operates at it's full power;

— Partly parallel mode: Above the balance temperature the heat pump operates alone. Between balance and cut off temperature back up is and heat pump operate in parallel with the heat pump at it's full power. Below the cut off temperature the back up operates alone.

7.4.7.5 Solar heating systems

The calculation method defined in PREN 15316-1 part 2.2.3 does not distinguish between different types of control systems.

7.4.7.6 Cogeneration systems

The calculation method defined in PREN 15316-1 part 2.2.4 does not differentiate different types of control systems.

7.5 Ventilation control

7.5.1 Air flow control at the room level

The type of control to use shall be specified according to prEN 13779. One shall at least differentiate the following types of local (room or zone) flow control.

0) No control: The system runs constantly;

a. Manual control: The system runs according to a manually controlled switch;

b. Time control: The system runs according to a given time schedule;

c. Presence control: The system runs dependent on the presence (light switch, infrared sensors etc.);

1) Demand control (counting the number of people) : The system runs dependent on the number of people in the space (counting of occupants);

d. Demand control (gas sensors): The system is controlled by sensors measuring indoor air parameters or adapted criteria (e.g. CO_2, mixed gas or VOC sensors). The used parameters shall be adapted to the kind of activity in the space.

The impact of the control type is calculated according to prEN 15242 § 6.2.3 and 6.2.5. This impact is calculated by multiplying the air flow by two characteristic coefficient called Cuse and C_{cont} in pr EN 15242.

The coefficient value depends on :

— The control type;

— The use profile of the building.

7.5.1.1 Air flow control at the air handler level

One shall differentiate at least the following types of control:

0) No control;

1) On off time control.

2) Automatic flow control with or without pressure reset.

The impact of the control type is calculated according to prEN 15242 § 6.2.3 through the Cuse coefficient. Which represents the fraction of time where the fan is on.

The impact of an automatic flow control on the energy consumption is highly dependant on the actuator used to modulate the flow (dampers, blade angles for axial fan, speed control). It is calculated according to prEN 15241 § 5.3.3 through the Ccont coefficient. Nevertheless the impact of automatic fow control with pressure reset is not dealt with in this standard.

7.5.1.2 Heat exchanger defrost and overheating control

The impact of the control system of a heat exchanger for heat recovery is calculated according to PREN 15241 § 6.3.4.

When applying this standard one shall differentiate the following case:

e) Defrost control

1) Without defrost control : there is no specific action during cold period;

e. With defrost control: during cold period a control loop enables to warranty that the air temperature leaving the heat exchanger is not too low to avoid frosting.

This impact is considered in prEN 15241 in § 6.3.4.3.

1) Overheating control

2) Without: there is no specific action during hot or mild periods;

3) With overheating control: during hot periods where the effect of the heat exchanger will no more be positive a control loop stops modulates or bypass the heat exchanger.

This impact is considered in prEN 15241 in § 6.3.4.4.

7.5.1.3 Free mechanical cooling

This control function enables to use the cooler outdoor to cool down the buildings internal fabric and inside air.

One shall differentiate the following types of free cooling:

0) No control

1) Night cooling: the amount of outdoor air is set to its maximum during the unoccupied period provided: 1) the room temperature is above the set point for the comfort period, 2) the difference between the room temperature and the outdoor temperature is above a given limit;

2) Free cooling the amount of outdoor air and recirculation air are modulated during all periods of time to minimize the amount of mechanical cooling. Calculation is performed on the basis of temperatures;

3) H,x- directed control: the amount of outdoor air and recirculation air are modulated during all periods of time to minimize the amount of mechanical cooling. Calculation are performed on the basis of temperatures and humidity (enthalpy).

Night cooling is defined in EN ISO 16484-3 § 5.5.3.5.8. It's impact can be calculated according to prEN13790, section 5.2 and 9.4.3

H,x- directed control is defined in EN ISO 16484-3 § 5.5.3.5.2.

The impact of the function shall be calculated by determining for each calculation period an equivalent air flow rate.

7.5.2 Supply temperature control

If the air system serves only one room and is controlled according to indoor temperature of this room one shall use §7.4 even if the control acts on the supply temperature.

In the other cases one shall differentiate at least the following types of control:

0) No control : no control loop enables to act on the supply air temperature;

1) Constant set point : a control loop enables to control the supply air temperature, the set point is constant and can only be modified by a manual action;

2) Variable set point with outdoor temperature reset: a control loop enables to control the supply air temperature. The set point is a simple function of the outdoor temperature (e.g. linear function);

3) Variable set point with load dependant reset: a control loop enables to control the supply air temperature. The set point is defined as a function of the loads in the room. This can normally only be achieved with an integrated control system enabling to collect the temperatures or actuator position in the different rooms.

This temperature control shall be considered with a particular attention is the system principle does not prevent simultaneous heating and cooling. See § 7.4.5 Interlock between heating and cooling control of emission and/or distribution.

The impact of this supply temperature control shall be calculated according to prEN 15241 § 6.3.6 and § 6.3.7. To apply this standard it is necessary to define precisely the set point of the supply temperature: Ts, sp.

7.5.2.1 Humidity control

One shall differentiate at least the following types of control:

0) No humidity control: no control loop enable to act on the supply air humidity;

1) Minimum supply air humidity control : a control loop enables to avoid the supply air humidity to go below a threshold value;

2) Supply air humidity control: a control loop enables to keep the supply air humidity at a constant value

3) minimum room air humidity control: a control loop enables to avoid the room air humidity to go below a threshold value

4) room air humidity control: a control loop enable the room air humidity to be kept at a constant value

The impact of the humidity control shall be calculated according to prEN 15241 § 6.3.8.

7.6 Lighting control

One shall differentiate at least the following types of control

a) Daylight control

1) Manual: There is no automatic control to take daylight into account

a. Automatic: An automatic systems takes daylight into account

b) Occupancy control

0) 'Manual On / Off Switch': the luminaire is switched on and off with a manual switch in the room;

1) 'Manual On / Off Switch + additional automatic sweeping extinction signal': the luminaire is switched on and off with a manual switch in the room. In addition, an automatic signal automatically switches off the luminaire at least once a day, typically in the evening to avoid needless operation during the night.

2) 'Auto On / Dimmed': the control system switches the luminaire(s) automatically on whenever there is presence in the illuminated area, and automatically switches them to a state with reduced light output (of no more than 20% of the normal 'on state') no later than 5 minutes after the last presence in the illuminated area. In addition, no later than 5 minutes after the last presence in the room as a whole is detected, the luminaire(s) are automatically and fully switched off.

3) 'Auto On/Auto Off': the control system switches the luminaire(s) automatically on whenever there is presence in the illuminated area, and automatically switches them entirely off no later than 5 minutes after the last presence is detected in the illuminated area.

4) 'Manual On / Dimmed': the luminaire(s) can only be switched on by means of a manual switch in (or very close to) the area illuminated by the luminaire(s), and, if not switched off manually, is/are automatically switched to a state with reduced light output (of no more than 20% of the normal 'on state') by the automatic control system no later than 5 minutes after the last presence in the illuminated area. In addition, no later than 5 minutes after the last presence in the room as a whole is detected, the luminaire(s) are automatically and fully switched off.

5) 'Manual On / Auto Off': the luminaire(s) can only be switched on by means of a manual switch in (or very close to) the area illuminated by the luminaire(s), and, if not switched off manually, is automatically and entirely switched off by the automatic control system no later than 5 minutes after the last presence is detected in the illuminated area.

The impact of the control system can be performed according to PREN 15193. It is calculated by a time approach according to § 7.2.3. The time during which the light is on is obtained by multiplying the occupation time of the building by reduction coefficient according to equations 7 and 8 of prEN15913.

The coefficient F_D takes into account the impact of daylight. The coefficient F_O takes into account the impact of occupation.

The impact of daylight control is determines according Annex C of prEN 15193.

The coefficient dealing with daylight control $F_{D,C,n}$ is given in table C.9 of prEN15193. It's values depends on:

— the control type manual /automatic

— The level of daylight penetration in the building: weak/medium/strong.

This coefficient is combined with a second coefficient dealing with daylight supply to obtain the F_D the approach is described.

The impact of occupancy control is determined according to annex D of prEN15293.

First the coefficient F_{oc} which depends only on the control type is read in in table D.1 of prEN15193.

This coefficient is combined with the proportion of the time that the space is unoccupied to obtain F_o.

7.7 Blind control

One shall differentiate at least the following control types:

0) Manual;

1) Motorized;

2) Automatic control;

3) Combined light/blind/HVAC control.

The impact of blind control on solar gains shall be taken into account according to prEN13790 §11.4.3 movable shading provisions.

The impact of blind control on thermal losses during night shall be taken into account according to pr EN 13790 §8.3.2 Effect of nocturnal insulation.

7.8 Building automation system

A building automation and control systems enables the following functions in addition to standard control functions:

— Adapting the operation of the building and technical systems to users needs

— Optimizing the operation by the tuning of the different controllers

— Standard alarming functions

— Standard monitoring function.

A BAC system enables to adapt easily the operation to the user needs.

One shall check at regular intervals that the operation schedules of heating, cooling, ventilation and lighting is well adapted to the actual use schedules and that the set points are also adapted to the needs.

Attention shall be paid to the tuning of all controllers this includes set points as well as control parameters such as PI controller coefficients

Heating and cooling set points of the room controllers shall be checked at regular intervals. These set points are often modified by the users. A centralised system enables to detect and correct extreme values of set points due to misunderstanding of users.

If the Interlock between heating and cooling control of emission and/or distribution is only a partial interlock (see § 7.4.5) the set point shall be regularly modified to minimise the simultaneous use of heating and cooling

Standard alarming functions and standard monitoring functions will support the adaptation of the operation to user needs and the optimization of the tuning of the different controllers. This will be achieved by providing easy tools to detect abnormal operation (alarming functions) and by providing easy way to log and plot information (monitoring functions).

7.9 Technical building management functions

These functions are especially useful to achieve the following requirements of the energy performance in buildings directive:

Article 7: Establishing an energy performance certificate;

Article 8: Boiler inspection;

Article 9: Air conditioning system inspection.

These functions are dealt with in the following standards:

PrEN 15217: Energy performance of buildings – Methods for expressing energy performance and for energy certification of buildings.

PrEN 15203: Energy performance of buildings — Assessment of energy use and definition of ratings.

PR EN 15378: Energy performance of buildings – Systems and methods for the inspection of boilers and heating systems.

PrEN 15240: Energy performance of buildings – Guidelines for the inspection of air-conditioning systems;

PrEN 15239: Inspection of ventilation systems.

7.9.1 Detecting faults of building and technical systems and providing support to the diagnosis of these faults

Specific monitoring functions shall be set up to enable to detect quickly the following faults:

a) Improper operation schedules

This is especially necessary in buildings which are not permanently occupied such as offices, schools

The monitoring function shall include at the minimum a graph or an indicator highlighting the time where: Fans are on, cooling system is running, heating system is in normal mode, lighting is on.

b) Improper set points

Specific monitoring functions shall be set up to enable to detect quickly improper set points of room temperature.

The monitoring function shall include a graph or an indicator enabling to have a global view of the different set points of room temperature for heating and cooling.

c) Simultaneous heating and cooling

If the system can lead to simultaneous heating and cooling monitoring functions shall be set to check that simultaneous heating and cooling is avoided or minimized.

Fast switching between heating and cooling shall also be detected.

d) Priority to generator(s) having the best energy performance

When several generation systems having different energy performances are used to do the same function (e.g. heat pump + back up, solar system + back up) a monitoring function shall be set to verify that the systems having the best energy performances are used before the others.

7.9.2 Reporting information regarding energy consumption, indoor conditions and possibilities for improvement

Report shall be set to report information regarding energy consumption and indoor conditions.

These reports can include

a) Energy certificate for the building

b) The monitoring function shall be used to obtain a calculated rating as defined in Pr EN 15203 § 8.

Using the on line monitoring function enables to obtain a rating fully in conformity with requirements of prEN 15203. Measurements of the meters can be done for an exact year according to § 8.2. If sufficient number of meters is installed the measurements can be done for each energy ware. Energy used for other purposes than heating, cooling, ventilation, hot water or lighting can be measured separately according to § 8.3. The measurement of outdoor temperature enables to perform the correction for outdoor climate defined in § 8.4.

The rating can be used to prepare an energy performance certificate designed according to prEN 15217.

c) Assessing the impact of improvement of building and energy systems

This assessment can be done according to prEN 15203 by using a validated building calculation model as defined in § 9.

Using the monitoring functions enables to take into account the actual values regarding climatic data, internal temperature, internal gains, hot water use, lighting use, according to prEN 15203 § 9.2 and 9.3.

d) Energy monitoring

The TBM monitoring function can be used to prepare and display the energy monitoring graphs defined in prEN 15203 Annex G.

e) Room temperature and indoor air quality monitoring

Monitoring function can be used to provide report regarding air or room operative temperature in the rooms as well as indoor air quality. For buildings which are not permanently occupied these functions shall differentiate occupied and non occupied buildings. For buildings which are heated and cooled the report shall differentiate cooling and heating periods.

The reports shall include the actual value as well as reference values such as set points for example.

7.10 Assessing the impact of BAC and TBM function

The impact of the BAC and TBM functions is highly dependant on the system complexity, the user behaviour and on the ways the BAC and TBM functions are used by the operating team. So the assessment of the energy impact of these functions shall be considered as a conventional assessment.

The assessment shall be performed using the detailed calculation procedure with modified input data. Unless differently specified the modified input data will be the following table 6.

	Without BAC and TBM functions	**With BAC functions**	**With Bac and TBM functions**
	Class C	Class B	Class A
Set point for heating	reference	-0,5K	-1K
Set point for cooling	reference	+0,5K	+1K
Operating time	reference	Reduced by 5%	Reduced by 10%
Simultaneous use of heating and cooling	reference	Reduced by 50%	Reduced by 80%

Table 6 - Input data

8 Calculation procedures based on BAC efficiency factors

8.1 Description of BAC Factor method

This method gives the opportunity to simply evaluate the impact of BACS and TBM functions by using BAC efficiency factors related to the annual energy use of a building including

- energy input to the heating system, calculated according to prEN 15316,
- energy input to the cooling system, calculated according to prEN 15255,
- energy input to the lighting system, calculated according to prEN 15193, and
- energy input to the ventilation system, calculated according to prEN 15241.

The BAC efficiency factors were obtained by performing transient pre-calculations for different building types as mentioned in prEN 15217. Thereby each building type is characterized by a significant user profile of occupancy and internal heat gains due to people and equipment, respectively. The BAC efficiency classes A, B, C and D as defined in chapter 4 were represented by different levels of control accuracy and control quality.

Finally, two sets of BAC efficiency factors $f_{BAC,hc}$ and $f_{BAC,e}$ were extracted from the results of these energy performance calculations. They are available for the assessment of

- energy for heating and cooling ($f_{BAC,hc}$ according to Tables 8 and 9, and
- electric energy for lighting and auxiliary devices ($f_{BAC,e}$ according to Tables 10 and 11).

The energy input to the building energy systems (energy use) accounts for building energy demand, total thermal losses of the systems as well as auxiliary energy required to operate the systems. Each of the energy systems installed in a building has to be assessed with the right BAC factor taking into account the correlations given in table 7.

Energy use		Energy demand		System losses	Auxiliary energy	BAC factor	Notes
Heating	=	Q_{NH} prEN13790	+	$Q_{H,loss}$ prEN15316		$f_{BAC,hc}$	
			+		$W_{h,aux}$ prEN15316	$f_{BAC,e}$	
Cooling	=	Q_{NC} prEN13790	+	$Q_{C,loss}$ prEN15255		$f_{BAC,hc}$	
			+		$W_{c,aux}$	$f_{BAC,e}$	
Ventilation	=				$W_{V,aux}$ prEN15241	$f_{BAC,e}$	

Lighting	=				W_{light} prEN15193	$f_{BAC,e}$	The impact of lighting control has to be evaluated separately with prEN15193.

Table 7 - Relations between building energy systems and BAC efficiency factor

The whole calculation sequence of the BAC efficiency factor method is depicted in Figure 2. As to be seen one of the BAC efficiency classes as described in Table 1 has to be defined as a reference case first. Normally class C which corresponds to a standard building automation and control system is set as reference. Based on this reference case the annual energy use of the building energy systems must be calculated. The use of the BAC efficiency factors now allows to easily estimate the energy use for others than the reference case. Therefore the relevant efficiency factors have to be set in relation against each other.

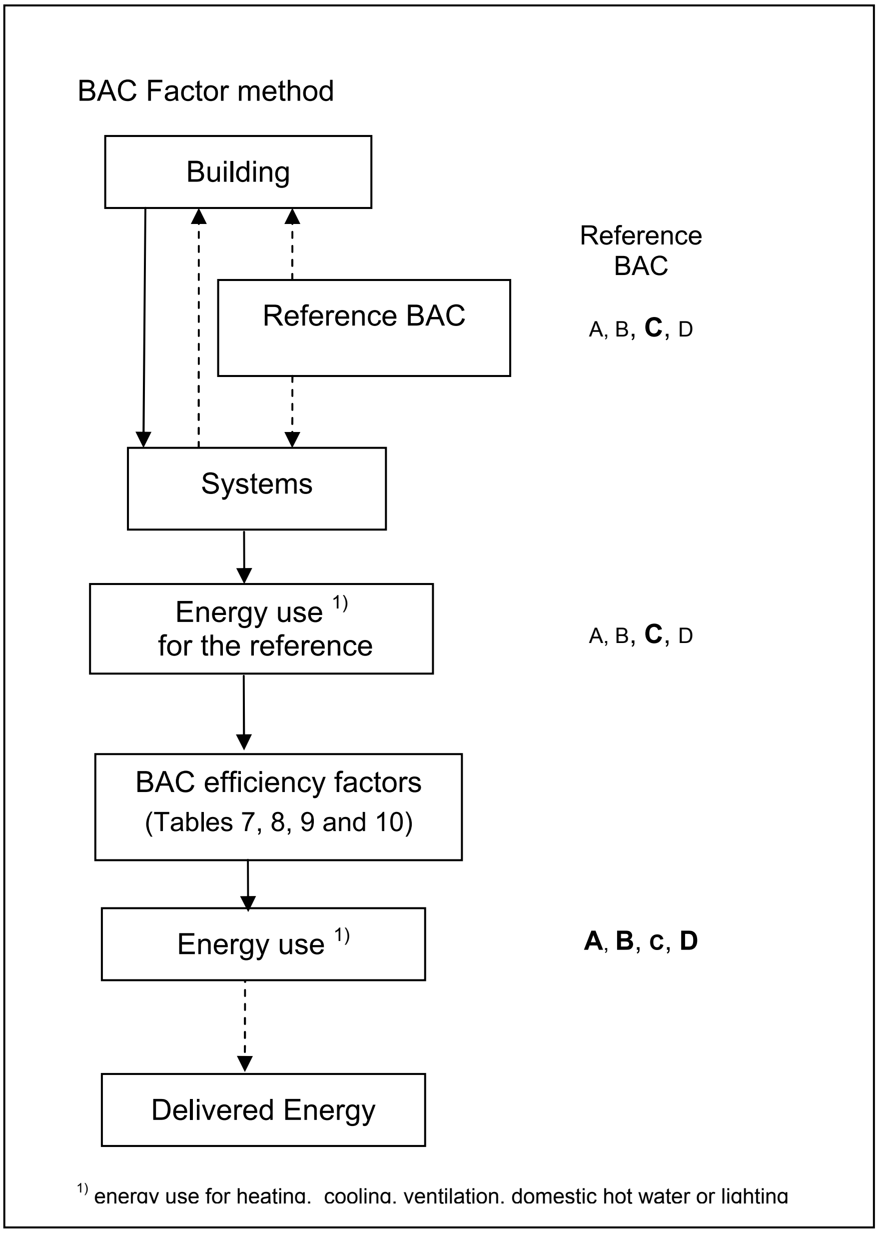

Figure 2: Calculation sequence of BAC efficiency factor method

The BAC efficiency factors are then to be used for different building energy systems as illustrated in the following equations to calculate the BAC assessed energy input to the systems.

- Heating system

$$Q_{f,h,BAC} = \left(Q_{NH} + Q_{H,loss}\right) \times \frac{f_{BAC,hc}}{f_{BAC,hc,Ref}} \quad (5)$$

$$W_{h,aux,BAC} = W_{h,aux} \times \frac{f_{BAC,e}}{f_{BAC,e,Ref}} \quad (6)$$

- Cooling System

$$Q_{f,c,BAC} = \left(Q_{NC} + Q_{C,loss}\right) \times \frac{f_{BAC,hc}}{f_{BAC,hc,Ref}} \quad (7)$$

$$W_{c,aux,BAC} = W_{c,aux} \times \frac{f_{BAC,e}}{f_{BAC,e,Ref}} \quad (8)$$

- Ventilation System

$$W_{V,aux,BAC} = W_{V,aux} \times \frac{f_{BAC,e}}{f_{BAC,e,Ref}} \quad (9)$$

- Lighting System

$$W_{light,BAC} = W_{light} \times \frac{f_{BAC,e}}{f_{BAC,Ref}} \quad (10)$$

with

$f_{BAC,hc}$, $f_{BAC,e}$	BAC efficiency factors for thermal energy and for electric energy
$f_{BAC,hc,Ref}$, $f_{BAC,e,Ref}$	BAC efficiency factors as before but for Reference BAC

8.2 BAC efficiency factor for thermal energy $f_{BAC,hc}$

The BAC efficiency factors for thermal energy (heating and cooling) are classified depending on the building type and the efficiency class the BAC/TBM system is related to. The factors for efficiency class C are defined to be 1 as this class represents a standard automatic control system. The use of efficiency classes B or A always leads to lower BAC efficiency factors, i.e. an improvement of building performance.

Non-residential Building Types	BAC efficiency factors $f_{BAC,hc}$			
	D	C (Reference)	B	A
	No automatic control	**Standard automatic control**	Advanced automatic control TBM level highlighted	Advanced automatic control TBM all function
Offices	1,51	1	0,80	0,70
Lecture Hall	1,24	1	0,75	0,35
Education buildings (Schools)	1,20	1	0,88	0,80
Hospitals	1,31	1	0,91	0,86
Hotels	1,31	1	0,85	0,68
Restaurants	1,23	1	0,77	0,68
Wholesale and retail trade service buildings	1,56	1	0,73	0,47
Other types: - Sport facilities - Storage - Industrial buildings - etc.		1		

Table 8 **BAC/TBM Efficiency factors $f_{BAC,hc}$ – Non-residential buildings**

Residential Building Types	BAC efficiency factors $f_{BAC,hc}$			
	D	C (Reference)	B	A
	No automatic control	**Standard automatic control**	Advanced automatic control	Advanced automatic control + HM
Single family houses Apartment block Other residential buildings	1,10	1	0,88	0,81

Table 9 BACS/TBM efficiency factors $f_{BAC,hc}$ – residential buildings

8.3 BAC efficiency factor for electric energy $f_{BAC,e}$

The BAC efficiency factors for electric energy including auxiliary devices are classified depending on the building type and the efficiency class the BAC/TBM system is related to. The factors for efficiency class C are defined to be 1 as this class represents a standard automatic control system. The use of efficiency classes B or A always leads to lower BAC efficiency factors, i.e. an improvement of building performance.

Non-residential Building Types	**BAC efficiency factors $f_{BAC,e}$**			
	D	**C (Reference)**	**B**	**A**
	No automatic control	**Standard automatic control**	Advanced automatic control TBM level highlighted	Advanced automatic control TBM all function
Offices	1,10	1	0,93	0,87
Lecture Hall	1,06	1	0,94	0,89
Education buildings (Schools)	1,07	1	0,93	0,86
Hospitals	1,05	1	0,98	0,96
Hotels	1,07	1	0,95	0,90
Restaurants	1,04	1	0,96	0,92
Wholesale and retail trade service buildings	1,08	1	0,95	0,91
Other types: - Sport facilities - Storage - Industrial buildings - etc.		1		

Table 10 BAC/TBM Efficiency factors $f_{BAC,e}$ – Non-residential buildings

Residential Building Types	**BAC efficiency factors $f_{BAC,e}$**			
	D	**C (Reference)**	**B**	**A**
	No automatic control	**Standard automatic control**	Advanced automatic control	Advanced automatic control + HM
Single family houses Apartment block Other residential buildings	1,08	1	0,93	0,92

Table 11 BACS/TBM efficiency factors fBAC,e – residential buildings

8.4 Sample calculation for the BAC factor method

Table 12 gives an example on how to use BAC efficiency factors for calculating impact of BAC/TBM on the total energy performance of a office building. The efficiency class C was chosen as reference BAC system. The improvement of energy efficiency when changing to BAC efficiency class B will be calculated.

				Heating	Cooling	Ventilation	Lighting
Energy demand	1		kWh/ period	100	100		
System losses Reference Case	2		kWh/ period	33	28		
Thermal Energy input Reference Case (Class C)	3	$\sum 1+2$	kWh/ period	133	128		
BAC factor $\mathbf{f_{BAC,hc}}$ Reference Case (Class C)	4			1	1		
BAC factor $\mathbf{f_{BAC,hc}}$ Case of interest (Class B)	5			0.80	0.80		
Thermal Energy input Case of interest (Class B)	6	$3\times\frac{5}{4}$	kWh/ period	106	102		
Auxiliary energy	7		kWh/ period	14	12	21	34
BAC factor $\mathbf{f_{BAC,e}}$ Reference Case	8			1	1	1	1
BAC factor $\mathbf{f_{BAC,e}}$ Case of interest	9			0.93	0.93	0.93	0.93
Auxiliary energy Case of interest	10	$7\times\frac{9}{8}$	kWh/ period	13	11	20	32

Table 12 - Example for BAC factor method

Annex A
(informative)

The impact of innovative integrated BAC functions (Examples)

A.1 General

The use of building automation and control systems leads in general to an improved energy performance of buildings. The automation of control devices gives an opportunity to save energy compared to a manual non-automated intervention of the occupants. The energy saving effect due to the application of BACS can be intensified if also integrated and complex control functions are taking into consideration. Furthermore the implementation of a technical building management is recommended to get a deeper knowledge about the energy consumption of a building and to optimise the operation of its energy systems. The energy consumption for running the building automation and control system has always to be taken into account.

For building automation and control functions in specific processes and for different energy systems whose impact is calculated through the general procedure defined in the umbrella document for the mandate M 343: For detailed calculations national calculation methods can be applied.

A.2 Examples of integrated Functions

A.2.1 Overview

The integrated building automation and special control functions which are considered here are not yet covered by other standards under the mandate M 343. Nevertheless they are important and widely used. Their impact on the energy performance of buildings is not yet covered by other standards of the EPBD mandate M 343. These functions can be described as follows:

a) Individual room temperature control in heated zones
   Calculation of the efficiency improvement by the use of window contacts affecting radiator valves.

b) Blind and Lighting Control
   The interaction of lighting, blind and HVAC control systems dependent from the occupancy of the building coordinated by the building automation leads to higher energy efficiency.

.

A.2.2 The use of window contacts in individual room temperature control in heated zones

The individual room temperature control in heated zones provides an opportunity to improve the energy efficiency by the use of an integrated function between heating control and window contacts. The functionality is as follows: When the windows will be opened by the occupants the heating system in the room is switched off automatically and no additional heat is supplied into the room. That reduces heating energy losses through open windows by preventing unnecessary heat supply into the roorm. After closing the window the heat supply is switched on again. To realise this operating mode an integrated building automation system is required. It is assumed that there is no interoperation between window contacts and the central management of the heating system, e.g. control of supply temperature or pump.

As an effect of the functionality as described before the room temperature during the period the window is opened decreases faster compared to a continuously operating heating system. The transient deviation of room temperature from the desired temperature set point is accepted by the occupant but could also encourage the occupant to close the window as soon as the room is sufficiently infiltrated.

The energy efficiency improvements due to the application of window contacts in conjunction with a BACS can easily be summarized in an energy saving factor f_{W}. If no building automation system with such integrated functions is available the factor f_{W} is 1. On the other hand the application of automation systems that allows the interoperation of window contacts and individual room temperature control in a heated zone leads to values $f_{\mathrm{W}} < 1$.

The heating energy demand of a building energy system can that way be calculated with equation (A1)

$$Q_h' = Q_h \cdot f_{\mathrm{W}} \qquad \textbf{(A1)}$$

Q_h' Heating energy demand with application of window contacts

Q_h Heating energy demand without application of window contacts (prEN13790)

f_{W} Energy saving factor due to the use of window contacts

The conventional case is the non-use of window contacts. Thus the heating energy demand without application of window contacts has to be calculated first as standardised in prEN13790. After that it is possible to assess the energy saving effect due to the use of window contacts with the help of f_{W}.

The energy saving factor f_{W} can be read from Figure A1 and Figure A2. It depends on the temperature difference ΔT_{m} between the averaged interior (room) and the exterior (outdoor) temperatures as calculated with equation (A2).

$$\Delta T_{\mathrm{m}} = \overline{T}_{\mathrm{int}} - \overline{T}_{\mathrm{ext}} \qquad \textbf{(A2)}$$

$\overline{T}_{\mathrm{int}}$ Average interior temperature during the period under consideration

$\overline{T}_{\mathrm{ext}}$ Average exterior temperature during the period under consideration

The mass of the building as well as the heat transmittance U also have an impact on the energy saving effect that can be reached by the use of window contacts. The amount of internal loads does not have a significant effect on f_{W} but on the total heat energy consumption.

It is possible to interpolate missing data from the graphs given in Figure A1 and Figure A2. For high mass buildings a linear interpolation in dependence on the average U-value of the envelope is feasible whereas for new buildings with a low U-value a linear interpolation in dependence on the building mass could be performed.

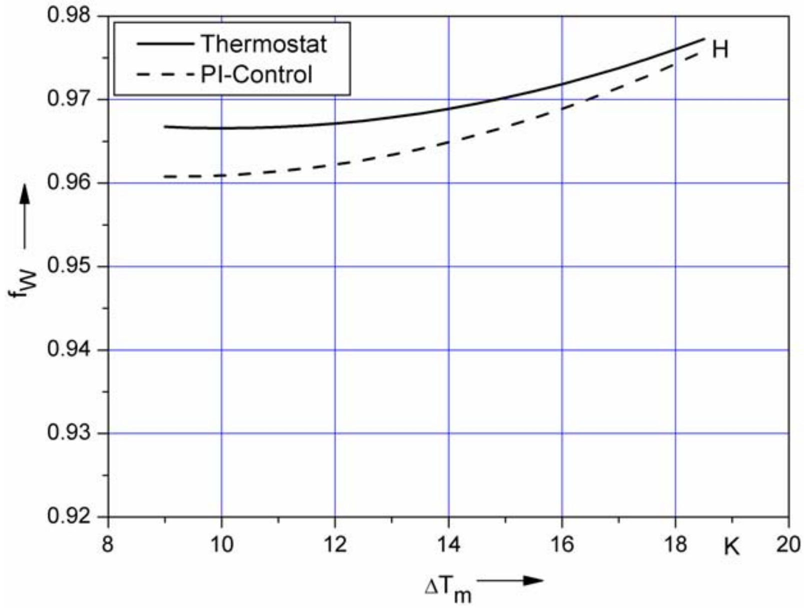

Figure A1: Efficiency factor for the use of window contacts; old buildings (U=1.48 W/m²K); H-high mass building (~900 kg/m²)

Note: The graphs were derived from the comparison of a huge number of simulation results for both cases: systems with and without window contacts.[1])

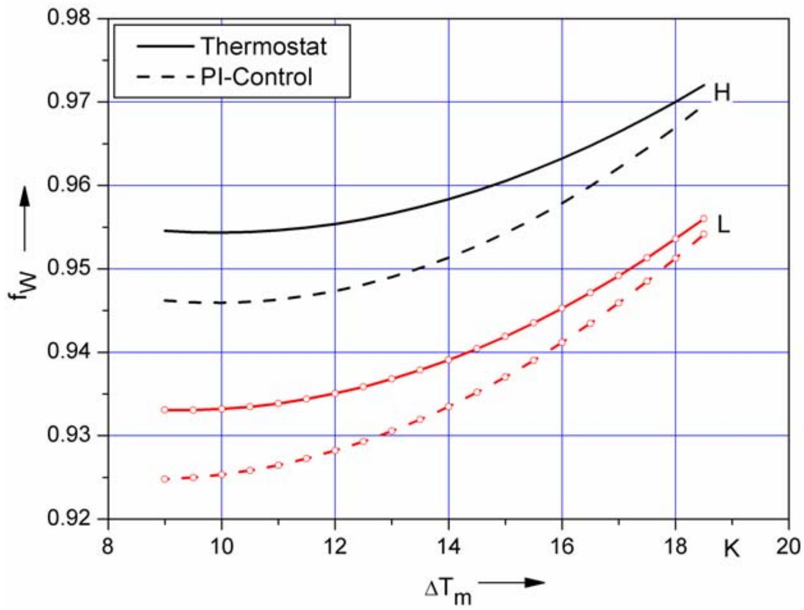

Figure A2: Efficiency factor for the use of window contacts; new buildings (U=0.61 W/m²K); H-high mass building (~900 kg/m²), L-low mass building (~120 kg/m²)

The factor f_W takes into account [1]:

— Weather conditions change during the heating period and differ about various climate zones. That is why f_W is affected by the average exterior temperature.

— The duration for opening a window is dependent on exterior temperature Figure A3 as known from measurements carried out at residential buildings [2]. In addition prEN15242 [4] defines a ratio of opening of a given window. The potential side effects of the use of window contacts stopping the heating which would lead to shorter periods of opening due to lower room temperatures or the prevention of permanent infiltration through opened windows are not considered because reliable and generally accepted information about user behaviour are neither available nor standardised. That is why it is assumed that daily time periods when windows will be opened are identical for both cases with and without window contacts.

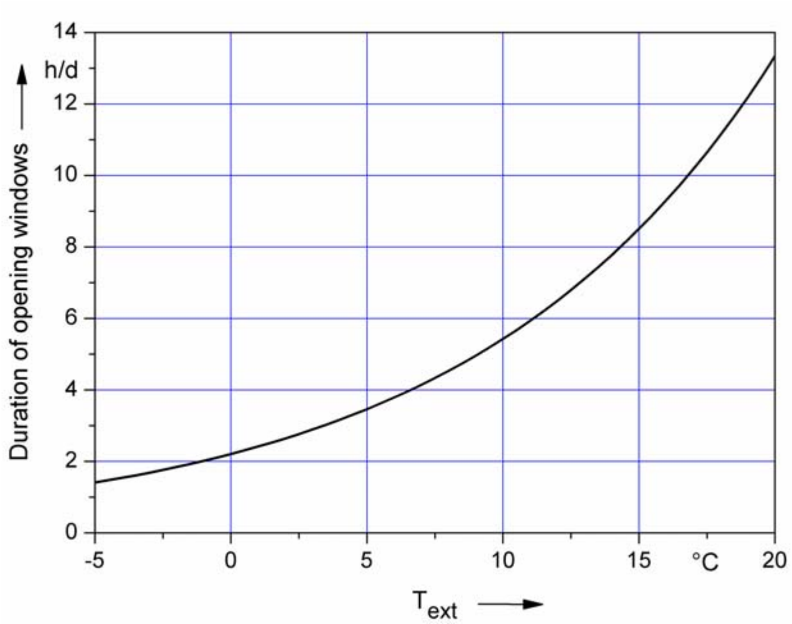

Figure A3: Duration of opening a window

— The air infiltration rate depends on the free cross-sectional area of an opened window. The daily profiles for ambient air infiltration rate distinguish between bottom hung and side hung windows.

— The infiltration rate depends on the inside-outside temperature difference.

— An individual room temperature controller is required. PI controller as well as thermostatic radiator valves was considered. The impact of the type of individual room temperature controller on the energy saving factor f_{W} is less than 1%.

A.2.3 Blind and Lighting Control

The daylight transmission into a room is controlled to reduce electric energy consumption for artificial lighting. This is done with blinds. The application of blinds for daylight control but also has an effect on heating or cooling energy because solar energy loads are correlated to the blind's position. For this reason the calculation procedure has to asses the efficiency of heating, cooling and lighting separately.

To estimate the impact of an integrated building automation system for blind and lighting control on the heating and cooling energy demand the solar gains and loads resulting from the blind's position have to be known. The blind control again depends on the availability of daylight as well as the part of the artificial lighting that is substitutable with day lighting. This part again can be calculated taking into account:

— operating time of artificial lights;

- specific energy consumption of lights;
- daylight efficiency as a function of shading effects of fixed external obstacles, transmittance of the windows and geometry of the room. (In a room only a part of the floor area can be provided sufficiently with daylight. The interaction of artificial lighting is therefore restricted to this limited area. For further details see Figure A4.

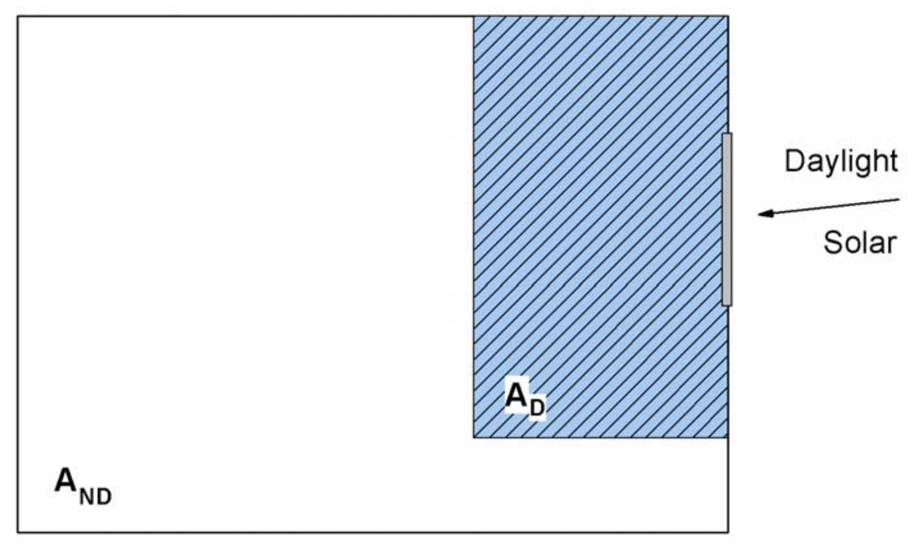

Figure A4: Definition of day lighting and non-day lighting areas in a room

(A_D- floor area with impact of daylight; A_{ND}- floor area with no impact of daylight)

The interaction between blind control, artificial lighting, heating and cooling is a very complex thing,.

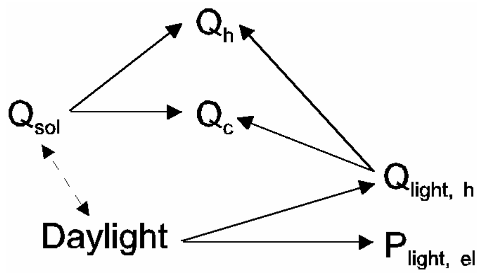

Figure A5: Interconnections between solar gains, heating, cooling and lighting energy

(Q_{sol}-Solar gains, Q_h-Heating energy demand, Q_c-Cooling energy demand, $Q_{light,h}$-Heat gains from artificial lighting, P_{light}-Electric energy demand for artificial lighting)

So in most cases it is necessary to use detailed simulation programs to get an impression on the building's energy performance. But there also are separate normative calculation procedures that allow to asses heating, cooling and energy demand for lighting in a building with a special regard to solar gains/loads and daylight respectively (EN832, EN13790, EN13791; EN 13363,…). Hence only some additional advice how to handle integrated building automation and control functions for a combined blind and lighting control should be given here.

a) Heating
During the winter period solar gains are highly welcome to reduce heating demand. Artificial lighting is necessary only if the amount of daylight depending on solar radiation does not match the requirements. The impact of BACS on the energy efficiency is therefore limited to the level of accuracy the artificial lighting fits the (intermittent) demands.

b) Cooling
If cooling is required the reduction of solar gains is a very simple method to reduce cooling energy demand. The impact of an integrated building automation system for blind and lighting control on the cooling energy can be estimated with equation (A3).

$$Q_c = \eta_{sh} Q'_c \qquad \textbf{(A3)}$$

Q_c Cooling energy demand (including solar gains reduced by the application of an automated shading control)

Q'_c Cooling energy demand (including solar gains not reduced by any shading)

η_{sh} Utilisation ratio of solar gains depending on type of shading and its control (see Equation (A3)

The utilisation ratio of solar gains depends on the type of shading and its control. That means the better the efficiency of the shading system the lower the utilisation ratio. It can be estimated with equation (A4).

$$\eta_{\mathrm{sh}} = 1 - \frac{Q'_{c,sol} - Q_{c,sol}}{Q'_c} \qquad \textbf{(A4)}$$

$Q'_{c,sol}$ Cooling energy demand due tue solar gains without any shading (see Equation A4)

$Q_{c,sol}$ Cooling energy demand due tue solar gains with shading (see Equation A4)

On the other hand reduction of solar gains by shading devices also reduces daylight entering the room. This could demand to switch on artificial lighting which in turn produces heat gains (additional cooling demands) as well as electric energy consumption, Figure A5. The dependencies between solar radiation, daylight and artificial lighting may be estimated with prEN15193 or DIN V 18599/4 [3].

Normally both shading as well as lighting processes are calculated separately. Here the application of a building automation and control system offers the opportunity to optimise the control of shading devises with a special respect to the artificial lighting and its electric energy consumption. An interaction between shading and artificial lighting is therefore required. In that way the minimisation problem (A5) should be solved.

$$Q_{c,lights} + Q_{c,\mathrm{sol}} + P_{light,el} =! \min \qquad \textbf{(A5)}$$

$Q_{c,lights}$ Cooling energy demand due tue heat gains from artificial lighting

The part of cooling energy demand caused by solar gains is given by:

$$Q_{c,sol} = \sum_{windows} (1 - \alpha_s \cdot f_{sh}) \cdot A_W \cdot (1 - F_f) \cdot g_{eff} \qquad \textbf{(A6)}$$

with

α_s Shaded fraction of the window

A_W Total window area

f_{sh} Efficiency factor for solar shading (Table A1))

F_f Ratio of frame area to total window area g_{eff} effective energy transmission of the window (glass)

$f_{sh} = 0$	No shading
$0 < f_{sh} < 1$	Variable (manual or automated) shading
$f_{sh} = 1$	Fully shaded; no solar gains

Table A1: Efficiency of solar shading

The efficiency factor for shading includes both variable shading devices as well as static shadings, i.e. overhangs or wing walls. The fraction of the window that is shaded as well as the factor for shading f_{sh} itself is depending on the sun's position and the time so that Eq.(**Fehler! Verweisquelle konnte nicht gefunden werden.**) is not a constant but has to be calculated during each time step.

c) Lighting
The use of daylight reduces the electrical energy demand and also the thermal gain of the lightings. Due to the maximum use of daylight the solar energy gains are also a maximum. Therefore the shading reduces the use of daylight and over the period of a year the energy demand varies. The part of cooling energy demand due to lighting including the use of daylight is given by Equation (A7).

$$Q_{c,lights} = (1 - \eta_{lights}) \cdot p \cdot [A_D \cdot (t_{act,D} + t_{act,N}) + A_{ND} \cdot (t_{act,ND} + t_{act,N})] \qquad \textbf{(A7)}$$

with

η_{lights} Efficiency of artificial light equipment

p Installed power of artificial lighting in W/m²

A_D Floor area with impact of daylight in m²

A_{ND} Floor area with no impact of daylight in m²

$t_{act,D}$ Actual time of use of daylight in daytime in h

$t_{act,N}$ Actual time of use of artificial light in nighttime in h

$t_{act,ND}$ Actual time of use of artificial light in daytime (if there is not enough daylight) in h

The terms in Eq. (A8) which contains the influence of the use of daylight are the effective time of use and the floor area with the impact of daylight. The effective time of use is given by:

$$t_{act,D} = t_{day} \cdot F_D \cdot F_P \qquad (A8)$$

with

t_{day} daytime (hours between sunrise and sunset)

F_D utilization factor of daylight

F_P factor for present users in the zone

The utilization factor of daylight depends on the orientation of the window as well as the relation of floor area with impact of daylight to the whole floor area ($A_D /(A_D + A_{ND})$. The kind of shading device as well as the shading due to overhang and wing wall has to be taken into account. Therefore the effective time of use of daylight and the floor area with impact of daylight are varies for each hour.

As an approximation over a wide range of the variable influences with the boundary conditions

- external shading device;
- shading control by bus system;
- minimum double glazing windows;
- window height appr. 2 m (0.25 m from the ceiling – room height 3 m);

is given in (A9) and Table A2.

The part of cooling energy demand due to solar gains and internal gains by lighting with impact of daylight each calculated by separate use of building automation system can be corrected by use of an integrated building automation system with a factor $f_{BAC,SD}$.

$$Q_{Sol.light} = \left(Q_{sol} + Q_{light}\right) \cdot f_{BAC.SD} \qquad (A9)$$

Correction factor for BACS	$f_{BAC,SD}$
integrated BACS (Blind and lighting)	0,94
Non integrated BACS (Blind and lighting)	1,00

Table A2 Correction factor for BACS (Blind and lighting)

Annex B
(informative)

Examples of how to use the BACS function list of EN 16484-3 to describe functions from prEN15232

B.1 General

Most of the BACS and TBM functions mentioned in the present standard prEN15232 may be represented by using the function list in EN16484-3. Some few of them correspond directly to a function defined in EN16484-3. Examples are given in A.2. For most of the functions however it is necessary to describe them by one or several rows of the EN16484-3 BACS function list accompanied by a control schematic. See A.3 for examples.

B.2 Direct representation by a function defined in prEN16484-3

B.2.1 Example 1

Considerer BACS or TBM Function in prEN15232:

- 5.5 Ventilation control
- 5.5.2 Supply temperature control
- 5.5.2.4 Free mechanical cooling
- i) Night cooling

Representation by using EN16484-3:

- This function is defied in section 5.5.3.5.8 Night cooling
- In the BACS function list it relates to the function 6.7 Night cooling.

B.2.2 Example 2

Considerer BACS or TBM Function in prEN15232:

- 5.5 Ventilation control
- 5.5.2 Supply temperature control
- 5.5.2.4 Free mechanical cooling
- iii) H,x- directed control

Representation by using EN16484-3:

- This function is defied in section 5.5.3.5.2 h,x-directed control strategy
- In the BACS function list it relates to the function 6.1 h,x-directed control.

B.3 Representation by a combination of functions defined in prEN16484-3

B.3.1 Example 1

Considerer BACS or TBM Function in prEN15232:

- 5.4 Heating and cooling control
- 5.4.1 Emission Control
- 4) Room by room control is performed by an electronic controller conform or not conform to WI 0247-017, WI 0247-018 or WI 0247-019.

Representation by using EN16484-3:
The function is described by one row of the EN16484-3 BACS function (Table B1), list and a control schematic (Figure B1), as shown in the following for the case of a PI controller. Analogously it can be represented for the case of a P controller.

EN ISO 16484-3

Annex A (normative)

BACS function list

1) Steady-state output, e.g.: 0,I,II=2 BO
Pulsed output, e.g.: 0,I,II=3 BO
Positioning outp. close-0-open=2 BO
Pulse width modulation output=1 BO

2) Active or passive

3) Only shared (networked) I/O data points from foreign systems for interoperable functions

4) Per input point address for a) collected, b) delayed or c) suppressed information

5) Per output point address

6) For cooling / heating use 2 x on / off conversions

7) Per input point address

8) E.g. device, schedule, life safety, loop, file (see EN ISO 16484-5)

9) If required, indicate whether applies to client devices "A" or server devices "B" (see BIBBs)

	Type of service (trade):	I/O functions										Processing functions																																Management functions				Operator functions				Remarks
		Physical					Shared 3), 9)					Monitoring						Interlocks					Closed loop control								Calculation / Optimization																					
Row No.	Plant	Binary output switching/positioning1)	Analog output positioning	Binary input state	Binary input counting	Analog input 2)	Binary value (output), switching	Analog value (output), positioning/setpt.	Binary value (input), state	Accumulated/totalized value (input)	Analog value (input), measuring	Fixed limit	Sliding / Floating limit	Run time totalization	Event counting	Command execution check	State processing 4)	Plant control	Motor control	Switchover 5)	Step control 5)	Safety / Frost protection control	P control loop	PI / PID control loop	Sliding / Floating / Curve setpoint	Proportional output stage	Proportional to on/off conversion 6)	Proportional to pulse width modulation	Setpoint / Output limitation	Switchover of parameters	h,x directed control 7)	Arithmetic calculation 7)	Event switching	Time schedule	Optimum start / stop	Duty cycling	Night cooling	Room temperature limitation	Energy recovery 7)	Backup power operation	Mains power recovery pogram	Peak load limitation	Energy tariff dependent switching	Input / output / value object types 9)	Complex object types 8), 9)	Event storage	Historical database	Graphic / static plant schematic	Dynamic display	Event instruction text	Remote messaging	NOTE For the definition of function types see EN ISO 16484-3. Indicate project-specific function descriptions in this column and in the points row, as e.g. row no., section no., column no., non standard function description no. BIBBs = BACnet Interop
	Data point Section no.	1					2					3						4					5								6													7				8				
	Point name or designation Column no.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	6	1	2	3	4	5	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	1	2	3	4	
1																																																				
2	room temperature					1																		1																													
3																																																				
4																																																				
5																																																				
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18																																																				
	Totals																																																			

Issue date	jj-mm-dd	Author	Approved	**Company:**	**Project:**	Location of controls (MER):	File: [table_A2-1-BACS FL template-050513.xls]
Rev. 1							
Rev. 2						Control diagram no.:	Page no. 1
Rev. 3						Interlocks description:	of:

Table 1 - Function list example 1

Fig B1 Control schematic to example 1

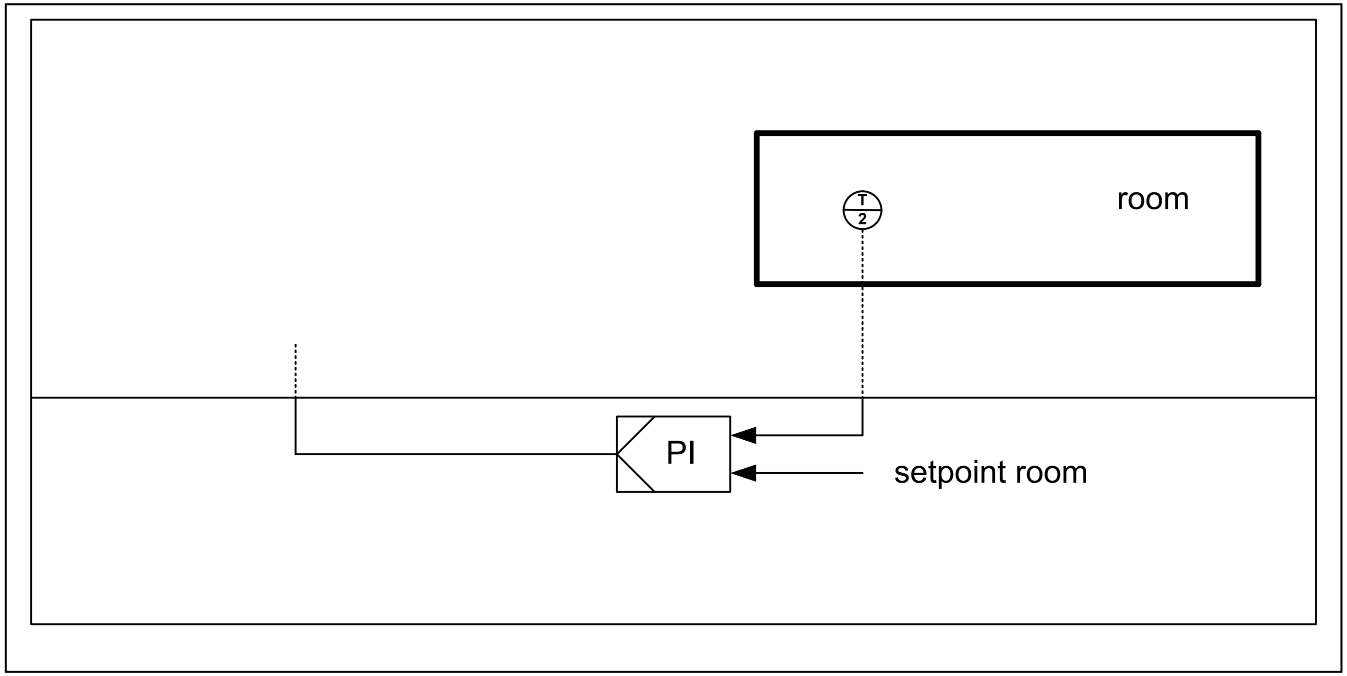

Figure B1- Control schematic to example 1

B.3.2 Example 2

Considerer BACS or TBM Function in prEN15232:

- 5.4 Heating and cooling control
- 5.4.2 Distribution control of water system
- 1) Supply temperature control of water system
- Outside temperature compensated control.

Representation by using EN16484-3:
The function is described by two rows of the EN16484-3 BACS function list (Table B2), and a control schematic (Figure B2) as shown in the following for the case of a valve drive with analog input.

EN ISO 16484-3

Annex A (normative)

BACS function list

1) Steady-state output, e.g.: 0,I,II=2 BO
Pulsed output, e.g.: 0,I,II=3 BO
Positioning outp. close-0-open=2 BO
Pulse width modulation output=1 BO
2) Active or passive
3) Only shared (networked) I/O data points from foreign systems for interoperable functions
4) Per input point address for a) collected, b) delayed or c) suppressed information
5) Per output point address
6) For cooling / heating use 2 x on / off conversions
7) Per input point address
8) E.g. device, schedule, life safety, loop, file (see EN ISO 16484-5)
9) If required, indicate whether applies to client devices "A" or server devices "B" (see BIBBs)

Row No.	Type of service (trade):	I/O functions									
		Physical					Shared 3), 9)				
	Plant	Binary output switching/positioning1)	Analog output positioning	Binary input state	Binary input counting	Analog input 2)	Binary value (output), switching	Analog value (output), positioning/setpt.	Binary value (input), state	Accumulated/totalized value (input)	Analog value (input), measuring
	Data point — Section no.	1					2				
	Point name or designation — Column no.	1	2	3	4	5	1	2	3	4	5
1											
2	supply water temperature sensor					1					
3	control valve		1								
4	outdoor air temperature					1					
5											
6											
	Totals										

Row No.	Type of service (trade):	Processing functions																		
		Monitoring						Interlocks					Closed loop control							
	Plant	Fixed limit	Sliding / Floating limit	Run time totalization	Event counting	Command execution check	State processing 4)	Plant control	Motor control	Switchover 5)	Step control 5)	Safety / Frost protection control	P control loop	PI / PID control loop	Sliding / Floating / Curve setpoint	Proportional output stage	Proportional to on/off conversion 6)	Proportional to pulse width modulation	Setpoint / Output limitation	Switchover of parameters
	Data point — Section no.	3						4					5							
	Point name or designation — Column no.	1	2	3	4	5	6	1	2	3	4	5	1	2	3	4	5	6	7	8
1																				
2	supply water temperature sensor													1						
3	control valve																			
4	outdoor air temperature														1					
5																				
6																				
	Totals																			

Row No.	Type of service (trade):	Processing functions												
		Calculation / Optimization												
	Plant	h,x directed control 7)	Arithmetic calculation 7)	Event switching	Time schedule	Optimum start / stop	Duty cycling	Night cooling	Room temperature limitation	Energy recovery 7)	Backup power operation	Mains power recovery pogram	Peak load limitation	Energy tariff dependent switching
	Data point — Section no.	6												
	Point name or designation — Column no.	1	2	3	4	5	6	7	8	9	10	11	12	13
1														
2	supply water temperature sensor													
3	control valve													
4	outdoor air temperature													
5														
6														
	Totals													

Row No.	Type of service (trade):	Management functions				Operator functions				Remarks
	Plant	Input / output / value object types 9)	Complex object types 8), 9)	Event storage	Historical database	Graphic / static plant schematic	Dynamic display	Event instruction text	Remote messaging	NOTE For the definition of function types see EN ISO 16484-3. Indicate project-specific function descriptions in this column and in the points row, as e.g. row no., section no., column no., non standard function description no. BIBBs = BACnet Interop
	Data point — Section no.	7				8				
	Point name or designation — Column no.	1	2	3	4	1	2	3	4	
1										
2	supply water temperature sensor									
3	control valve									
4	outdoor air temperature									
5										
6										
	Totals									

Issue date jj-mm-dd		Author	Approved	**Company:**	**Project:**	Location of controls (MER):	File: [table_A2-1-BACS FL template-050513.xls]
Rev. 1							
Rev. 2						Control diagram no.:	Page no. 1
Rev. 3						Interlocks description:	of:

Table 2 - Function list example 2

Control schematic to example 2:

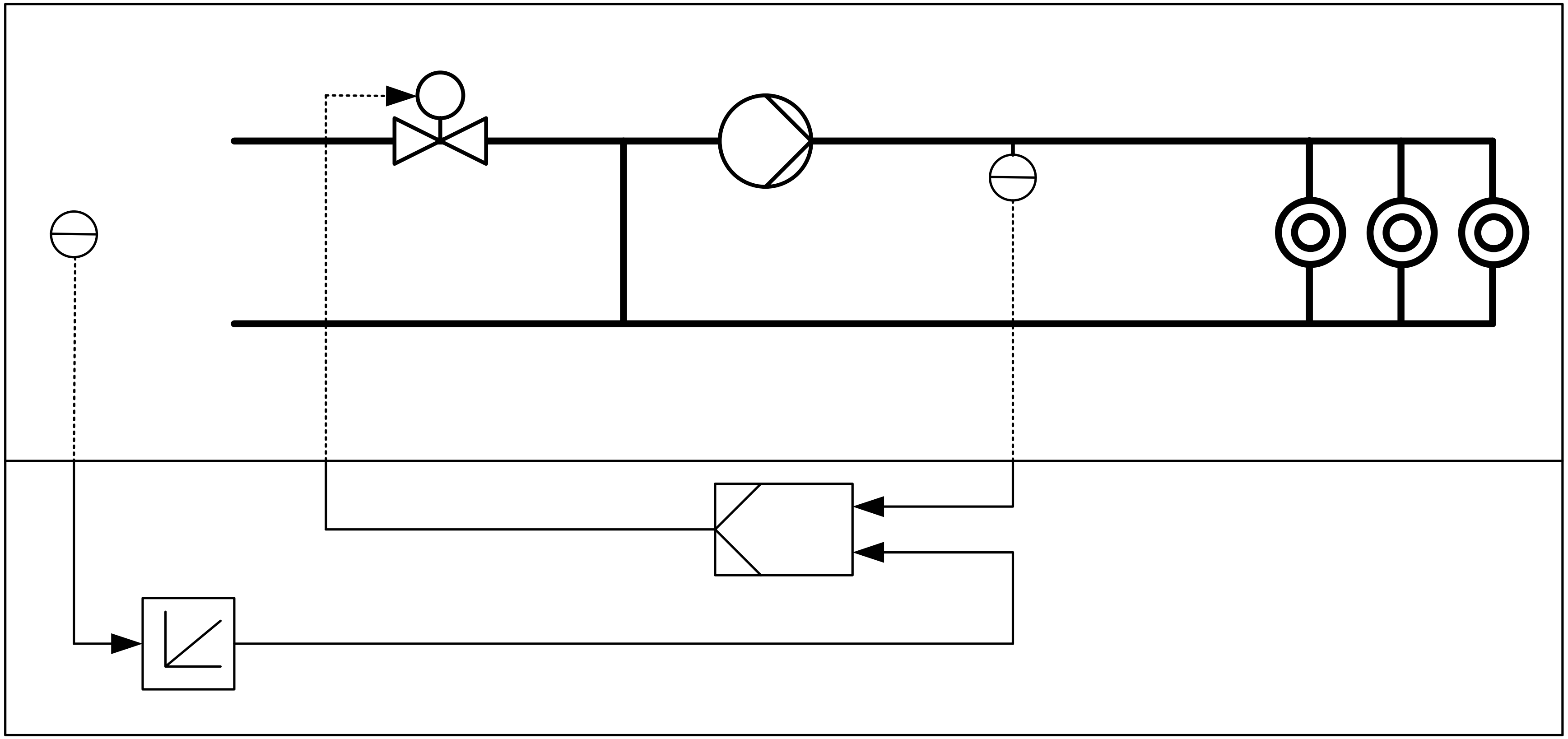

Figure B2 - Control schematic to example 2

3

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2002/91/EC of THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 2002 on the energy performance of buildings

This European Standard has been prepared under mandate M 343 given to CEN by the European Commission to provide a means of conforming to Essential Requirements of the New Approach Directive 2002/91/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL OF 16 December 2002 on the energy performance of buildings.

Once this standard is cited in the Official Journal of the European Communities under that Directive and has been implemented as a national standard in at least one Member State, compliance with the normative clauses of this standard confers, within the limits of the scope of this standard, a presumption of conformity with the relevant Essential Requirements of that Directive and associated EFTA regulations.

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Literature

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