European Commission

Technical assistance for ensuring optimal performance of technical building systems under the new Energy Performance of Buildings Directive (EU) 2018/844

Final Report with the technical guidelines for an effective understanding of Building Automation and Control System (BACS) capabilities under Articles 14&15

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Technical assistance for ensuring optimal performance of technical building systems under the Energy Performance of Buildings Directive

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AC	air-conditioning
AHU	air-handling unit
API	application programming interfaces
AUDITAC	IEE Project name
BAC	building automation control
BACS	building automation and control system
BAPV	building attached photovoltaics
BAT	best available technology
BBSR	German Federal Institute for Reseach on Building, Uraban Affairs and Spatial Development
BC	base case
BEG	Bundesförderung für Effiziente Gebäude
BEM	building energy management
BEMS	building energy management system
BESS	battery energy storage systems
BIM,	Building Information Modelling
BIPV	building integrated photovoltaics
BMWi	Federal Ministry for Economic Affairs and Energy
CA	Concerted Action (of the EPBD)
CAV	constant air volume
CB	chilled beams
CE	"Conformité Européenne" (European conformity marking)
CEN	French: Comité Européen de Normalisation; English: European Committee for Standardization
CENELEC	French: Comité Européen de Normalisation Électrotechnique; English: European Committee for Electrotechnical Standardization
COP	coefficient of performance

CTI	Italian Thermotechnical Committee
DC	direct current
DCV	demand-controlled ventilation
DE	Deutschland; Germany
DG	Directorate-General
DHW	domestic hot water
DIN	German standards organisation
DR	demand response
DX	direct expansion
EBPD	Energy Performance of Buildings Directive
EC	European Commission
ECO	energy conservation opportunity
ED	Ecodesign Directive
EEA	European Economic Area
EED	Energy Efficiency Directive
EEI	energy efficiency index
EEOS	Energy Efficiency Obligation Scheme
EER	energy efficiency ratio
ELR	Energy Labelling Regulation
EMS	energy monitoring system
EN	European norm
ENER	Directorate-General for Energy
EPATEE	Evaluation Into Practice to Achieve Targets for Energy Efficiency
EPB	Energy performance of Buildings (Directive)
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
EPREL	European Product Database for Energy Labelling
ESCO	energy services company
EU	European Union
EU27	27 Member countries of the EU

EU28	the former 28 Member countries of the EU
eu.bac	European Building Automation Controls Association
EUR	Euro (currency)
FCU	fan coil unit
FM	facility manager
FP	flue pipe
GEG	German Energy Saving Ordinance for Buildings
GHG	greenhouse gas [appears once in table]
H2020	Horizon 2020
HARMONAC	HARMONAC IEE project
HBES	home and building electronic systems
HIU	heat interface
HP	heat pump
HR	heat recovery
HRS	heat recovery system
HVAC	heating, ventilation and air-conditioning
HVAC&R	heating, ventilation, air-conditioning and refrigeration
IAQ	indoor air quality
ICT	Information and communications technology
IEA	International Energy Agency
IEC	International Electrotechnical Committee
IEE	Intelligent Energy Europe
INTAS	INTAS H2020 project
iSERV	iSERV IEE project
ISO	International Organization for Standardization
IT	information technology
KEYTV	thermostatic radiator valves
KPI	key performance indicator
LED	light emitting diode
LENI	lighting numerical indicator

LPHE	liquid-to-liquid plate heat exchangers
Lx	lux
MFH	Multi-family housing
MID	Only appears once
MISE	Ministry of Economic Development
MS	Member State
MSA	market surveillance authority
MURE	MURE II database
NF	Norm Francais
NGO	non-governmental organisation
NZEB	nearly zero-energy building
O&M	operation & maintenance
OJ	Official Journal (of the EU)
PDI	lighting power density
PICS	Protocol Implementation Conformance Statement
PI	Performance indicator
POA	plane-of-array
PR	performance ratio
PSFP	average specific fan power
PSFP	average specific fan power
PV	photovoltaic
PVGIS	Photovoltaic Geographical Information System
QR	QR code
RAC	Room air conditioner
RE	renewable energy
RES	renewable energy systems/sources
RT	rooftop
SEDBUK	seasonal efficiency of a domestic boiler in the UK
SEER	seasonal energy efficiency ratio
SFP	specific fan power

SK	solar keymark
SME	small or medium enterprise
SRI	Smart Readiness Indicator
STC	standard test conditions
TBS	technical building systems
TC	technical committee
TES	thermal energy systems
TIM	installation and maintenance technician
TR	as in CEN/TR
TS	technical specification
TW	terawatt
TWh	terawatt hours
US	United States
VAV	variable air volume
VOC	volatile organic compound
VRF	variable refrigerant flow

INTRODUCTION

Introduction/background

Energy performance of buildings is key to achieving the EU's Climate & Energy 2020 objectives and long-term targets. The Energy Performance of Buildings Directive[1] (EPBD) sets minimum requirements for the energy performance of new and retrofitted buildings, requires certification of building energy performance and declaration via energy performance certificates, and requires inspection of building heating and air conditioning systems. In 2018[2] the EPBD was amended to address the following aims:

- accelerate the cost-effective renovation of existing buildings, with the vision of a decarbonised building stock by 2050
- mobilise investments in building renovation
- support electromobility infrastructure deployment in building car parks
- introduce new provisions to enhance smart technologies and technical building systems, including automation.

In consequence, new provisions to enhance technical building systems were introduced.

Background: technical building systems under the EPBD

Technical building systems are defined in the EPBD as 'technical equipment for space heating, space cooling, ventilation, domestic hot water, built-in lighting, building automation and control, on-site electricity generation, or a combination thereof, including those systems using energy from renewable sources of a building or building unit' (Article 2(3) of the EPBD).

Article 2 of the EPBD also provides additional definitions for 'building automation and control system'(BACS) (Article 2(3a)); 'air-conditioning system' (Article 2(15)); and 'heating system' (Article 2(15a)).

The performance of technical building systems has a significant impact on overall building energy performance, therefore, one of the aims of the EPBD is to ensure that technical building system performance is optimised. In particular:

- Article 8(1) requires Member States to set system requirements on overall energy performance, proper installation, appropriate dimensioning, adjustment and control of technical building systems
- Article 8(9) require Member States to ensure that when a technical building system is installed, replaced or upgraded, the overall energy performance of the altered part or (where relevant) of the complete altered system is assessed

[1] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings, OJ L 153 of 18.6.2010, p. 13. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF

[2] 6 Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency, https://eur-lex.europa.eu/eli/dir/2018/844/oj

- Article 14 and 15 require Member States to establish regular inspections of heating systems, air-conditioning systems, and combined ventilation and heating/air conditioning systems above an effective rated output of 70 kW.

It is clear that the performance of these technical building systems have a major impact on overall building energy efficiency and can be equally important as the energy efficiency measures set at the component level (which are regulated via the Ecodesign Directive and Energy Labelling Regulation). Therefore, they merit being the recipients of sufficient policy attention and related regulatory requirements to ensure that the systems - when being installed, retrofitted, operated and maintained - are as efficient as is technically and economically justified within the broader context of EU energy policy.

Despite the establishment of such system requirements, it has become clear that the understanding, interpretation and enforcement of these requirements would benefit from greater standardisation and that there is a need for further clarification by means of technical guidelines to help Member States put these provisions into practice and increase the their impact in the EU building stock.

Aims and objectives of the project

The objectives of this project are to develop and disseminate technical guidelines for the further establishment and enforcement of technical building system requirements and to support the effective assessment and documentation of overall system performance.

In order to achieve these objectives and to establish a reference, the current regulations on technical building system requirements applied in the different EU Member States and their enforcement have been investigated. All technical building systems and aspects referred to in Article 8(1) of the EPBD are covered.

Project activities and report structure

This project addresses these objectives via the conduct of five specific tasks listed below:

Task 1: Review of technical building system requirements (definition and enforcement) and other relevant measures and initiatives, identification of good practices

Task 2: Identification and assessment of possible technical building system requirements

Task 3: Possible approaches for enforcement of technical building system requirements and assessment and documentation of system performance

Task 4: Technical guidelines for establishing and enforcing technical building system requirements, and for system performance assessment and documentation

Task 5: Technical guidelines for an effective understanding of BACS capabilities under the EPBD

The Task 1 to 3 reports served as inputs to this Task 4 report, and are included in the second interim report and are summarised in the presentation delivered at the stakeholder meeting.

The Task 4 report which concerns guidance on implementing EPBD Article 8, is published as a separate report.

This document is the final Task 5 report which is concerned with supporting implementation of EPBD Articles 14(4) and 15(4).

TASK 5. TECHNICAL GUIDELINES FOR AN EFFECTIVE UNDERSTANDING OF BACS CAPABILITIES UNDER THE EPBD

5.1 Objectives

This task has two objectives:

i) review and understanding of BACS capabilities

ii) provision of technical guidance for an effective understanding of BACS capabilities under the EPBD.

These guidelines will be directed to authorities in charge of the implementation of the provisions of Article 14 (4) and 15 (4) of the EPBD and the professionals in the buildings sector who will have to ensure compliance.

5.2 Task approach and proposed methodology

The methodological activities foreseen under Task 5 are:

- review and understanding of BACS capabilities
- provision of technical guidance for an effective understanding of BACS capabilities under the EPBD.

5.3 Activity 1: Review and understanding of BACS capabilities

5.3.1 Introduction to EPBD Articles 14 (4) and 15 (4)

The aim of this Task is to support an effective understanding of BACS capabilities under the EPBD within Article 14 and Article 15 on inspection of heating and cooling systems, more in particular:

Article 14 (4) requires that Member States lay down requirements to ensure that, where technically and economically feasible, non-residential buildings with an effective rated output for heating systems or systems for combined space heating and ventilation of over 290 kW are equipped with building automation and control systems by 2025. The building automation and control systems shall be capable of:

- continuously monitoring, logging, analysing, and allowing for adjusting energy use
- benchmarking the building's energy efficiency, detecting losses in efficiency of technical building systems, and informing the person responsible for the facilities or technical building management about opportunities for energy efficiency improvement
- allowing communication with connected technical building systems and other appliances inside the building and being interoperable with technical building systems across different types of proprietary technologies, devices, and manufacturers.

The article also suggests that it is optional for residential buildings to be equipped with:

- the functionality of continuous electronic monitoring that measures systems' efficiency and informs building owners or managers when it has fallen significantly and when system servicing is necessary
- effective control functionalities to ensure optimum generation, distribution, storage and use of energy.

Article 15 (4) on inspection of cooling systems is similar to Article 14.

The focus of the subsequent analysis is on the benchmarking requirement of Article 14 (4) and Article 15 (4) part b on benchmarking.

5.3.2 Review of standards or guidelines for benchmarking heating and cooling systems

EN 15232-1: Energy Performance of Buildings – Energy performance of buildings – Part 1: Impact of Building Automation, Controls and Building Management

EN 15232 is the key EPBD standard that describes BACS functions and was already described in the Task 1 report. It contains the key functional descriptions of BACS.

Within this, benchmarking is part of Function group 7.

Function 7.4 on reporting information regarding energy consumption, indoor conditions:

- Level 0: indication of actual values only (e.g. temperatures, meter values)
- Level 1: trending functions and consumption determination
- Level 2: analysing, performance evaluation, benchmarking of indoor environment and energy.

Class D and C BACS require Level 0 of function 7.4.

Class B BACS require Level 1.

Class A BACS require Level 2.

Related to benchmarking, the following gaps were reported and recommended for the next review (source: Ecodesign Preparatory Study for BACS[3]).

- It did not cover all BACS functions that have an impact on the real in use HVAC energy consumption because they mainly serve to support the EPC calculation that only uses pre-defined user or occupancy profiles (ISO 17772-1). For example, this does not include the benefits of window contacts. Note, the eu.bac BACS System Certification scheme Part 2 with technical recommendations contains a more extensive list referred to as EN 15232+ and this could be considered. Also, in residential buildings, night-time set-back temperatures can result in additional savings, but this is not included in EN 15232 and yet it is worth considering it.
- For historical reasons, the current version is focused on modelling the impact of BACS on new building EPCs; which in principle cannot be based on metered data. When considering existing buildings, aspects and requirements for monitoring could be added and further elaborated. This work could support the

[3] https://ec.europa.eu/energy/studies_main/preparatory-studies/ecodesign-preparatory-study-building-automation-and-control-systems_en

new EC Renovation Wave strategy[4] and also help to improve the data sources used to model the impact of BACS.

- Also connected to the previous remark, the requirements for monitoring or KPIs could be more detailed.

Key conclusion

Benchmarking belongs to class A BACS. It is a functional requirement, but the standard itself does not contain the technical details to elaborate this.

Eu.bac certification scheme[5] requirements for certifying energy efficiency of building automation and control systems, at first delivery and during their lifetime Part 4: Specification of Key Performance Indicators

Performance indicators (PIs) are values out of operational data of a BACS that indicate information about the energy efficiency of a specific part of the BACS component/function. An evaluation of those values over a certain observation period shall be used to "score" the efficiency of the observed BACS component/part. Key Performance Indicators (KPIs) are a selection of performance indications that define the most energy-relevant PIs including a scoring of either one or a combination of several PIs. The structure in the document basically follows Table 2 of EN 15232.

The full document is 36 pages long and is available for their members and on request. The study team are not allowed to disclose the full document, but it could form the basis for the next review of EN 15232 or its international ISO successor (if any). The document has 46 KPIs, DHW is not considered.

*For **heating and cooling energy consumption monitoring**, the following KPIs and PIs are defined:*

- KPIEH.c: Total heating energy consumption (of, for example, an entire building)
    - EN 15232: 7.2 – class A
    - KPI explanation: total heating energy consumption (of, for example, an entire building) in relation to outside air temperature
    - KPI function: daily consumption measured/calculated
    - KPI Evaluation: evaluate in x–y presentation versus average outside temperature (energy signature)
    - reason for KPI: detection of odd energy usage (e.g. air tightness of a building)
- KPIEH.d: Total heating energy consumption (of, for example, an entire building) HDD compensated
    - EN 15232: 7.2 – class A
    - KPI explanation: total heating energy consumption (of, for example, an entire building) in relation to outside air temperature
    - KPI function: = KPIEH.c/(HDDActual/HDDNormal)

[4] https://ec.europa.eu/energy/sites/ener/files/eu_renovation_wave_strategy.pdf

[5] https://www.eubaccert.eu/

- KPI Evaluation: evaluate value plus/minus tolerance band
- reason for KPI: detection of odd energy usage (e.g. air tightness of a building)

- PIEH.c: Heating consumption of a building per total area
  - PI explanation: heating consumption of a building per total area
  - PI function: KPIEH.c/total building area
  - reason for PI: benchmark for building/space
  - PIEH.d: heating consumption of a building per total area HDD compensated
  - PI explanation: heating consumption of a building per total area HDD compensated
  - PI function: KPIEH.d/total building area
  - reason for PI: benchmark for building/space.

Similar KPIs are defined for individual heat distribution networks (KPIEH.a, KPIEH.b) and for cooling systems (KPIECs). Also, similar PIs are defined for individual heat distribution networks (PIE.a, PIE.b) and for cooling systems (PIRCs). While these are clearly the benchmark values that should be under consideration for this study actual reference values for typical buildings are not included.

This certification also includes *benchmarks* ***for room or zone controllers****, for example (only a few* of *the most relevant):*

- KPIR.c: room/zone air temperature (overheating comfort supervision)
  - EN 15232: 1.1 Class A, B, C
  - KPI explanation detects "temperature" condition (e.g. overheated, too few heating supply) of room/zone – in relation to actual set-point (+ 0.5 K) and "heating controls output >0"
  - KPI function: = (PIRh.i + PIRh.j)/PIRh.a
  - daily evaluation: (daily value valid, day counts if "in use" (if (PIRh.i+PIRh.j) >0) occurred)
  - KPI evaluation: number of days where ((daily values >0.1) >20% of supervision period
    - "green" = else ()
    - "red" = number of days where (daily value >0.1) >20% of supervision period
    - "yellow" = number of days where (daily value >0.1) >10% of supervision period
  - reason for KPI: monitor room/zone temperature against actual set-point [in band, out of band] KPI might be applied without appropriate control function. Make a comment on the morning boost – for all KPIs that might be affected by any type of boost function or window draft.
- KPIR.f: room/zone air temperature control after OSC (optimal start/stop)
  - EN 15232: 1.5.2, 3.5.2 Classes A, B

- KPI explanation: monitor room/zone (cold – or warm water supply) temperature against reaching in target temp. range [within time, out of time]
- KPI function: = PIRh.g /1h; daily evaluation: (daily value valid, day counts if "OSC" occurred): daily values of (zero if no value):
  - green: value ≤0.25
  - yellow: value between ">0.25 and ≤0.5"
  - red: value >0.5
- KPI evaluation: number of days where ((daily values >(0.25)) >20% of supervision period:
  - "green" = else ()
  - "red" = number of days where (daily value >0.25) >20% of supervision period
  - "yellow" = number of days where (daily value >0.25) >10% of supervision period.

- PIRh.a: cumulates daily use of room/zone
  - PI explanation: cumulates hours of use during a day (might be several time spans during a day).
  - PI function: cumulate daily time "in use" (e.g. if "OSC" occurred).
- PIRh.g: maximum of daily time of absolute deviation of space temperature reaching set-point within OSC function
  - PI explanation: while OSC is on (that day) maximum daily time of absolute deviation of space temperature reaching set-point within OSC
  - PI function: maximum daily difference abs (tTARGET – tset-point – 0.5 K(case heating), +0.5 K(case cooling)).
- PIRh.i: heating: comfort supervision upper limit
  - PI explanation: cumulates hours of temperature above comfort band (heating) during "in use" of a day
  - PI function: while "in use": cumulated daily time while (room/zone temp. (J) > (heating set-point + 0.5 K) AND "heating controls output >0").

Similar KPIs are defined for air supply (KPIR.a, KPIE.b) and for cooling systems on overcooling (KPIE.c).

A selection of KPIs/PIs for ***heating emission groups*** *(e.g. radiators, AHU heating coils, supplementary heaters):*

- KPIHS.b: monitor function of variable speed pump controls
  - EN 15232: 1.4.3 Class A
  - KPI explanation: KPI determines relation of average pump speed vs. heating demand total
  - KPI function: = PIHSh.b/PIRh.c; Daily:
    - green: value ≤0.1

        - yellow: value between “>0.1 and ≤0.2”
        - red: value >0.2
    - KPI evaluation: number of days where ((daily values > (0.1)) >20% of supervision period
        - “green” = else ()
        - “red” = number of days where (daily value >0.1) >20% of supervision period
        - “yellow” = number of days where (daily value >0.1) >10% of supervision period.
    - reason for KPI: hydraulic balancing and sizing.
- PIHSt.a: supply water temperature: monitor temperature while demand (at least one room):
    - PI explanation: provide evidence of function of heating curve: Calculate average supply
    - temperature while at least one supplied room/zone is “in use”.
    - PI function: daily average of supply water temperature while demand >0
    - reason for PI: indicator of heat curve function together with PIHSt.b.

There are numerous others in the guideline.

The specifications also *contain KPIs/PIs for AHU, lights and blinds.*

Key conclusions

The standard focuses mostly on KPI/PI which benefits from the BACS functions themselves. What is missing and a potential gap for future policy is:

- more specific measurement methods to monitor the heat generation efficiency, e.g. efficiency benchmarking (KPIs) and indicators (PIs) of heat generation such as measured seasonal performance factor for heating/cooling with HP (SPFh/SPFc) to compare ErP SCOP/SEER
- monitoring and benchmarking heating/cooling distribution losses
- the typical building benchmark data [kWh/m²/year] are not included, see also LEED requirements and approaches for benchmarking (p. 184)
- monitoring of interlocks between heating and cooling
- monitoring of window and door contacts to directly identify sources for heating and cooling losses.

It might, however, be ambitious to implement all this, considering that only a few demonstration buildings are known, and no reference data is disclosed. As a minimum policy requirement, it might be necessary to narrow down the extensive set of parameters proposed to what is cost-effective and can be easily implemented in existing buildings.

Eu.bac compliance verification checklist[6]

To support Member States implementing the revised Energy Performance of Buildings Directive (EPBD), eu.bac has created a compliance checklist for building automation and control system (BACS) requirements related to Article 14 and Article 15.

First, it should be noted that eu.bac previously already published a generic guideline[7] on transposing Articles 8/14/15.

The checklist, in essence, includes several steps.

1. In the first step a guideline is provided on how to check if the heating or cooling is over 290kW and within scope.
2. Check if there is sufficient coverage of BACS. It does not explicitly require class B BACS[7] but have a more pragmatic and reduced requirement.
3. A checklist is proposed to verify compliance with the following minimum BACS requirements:
   a) continuously monitoring, logging, analysing, and allowing for adjusting energy use, meaning:
      i) having implemented the EN 15232 class B function 7.4.1 for trending and consumption determination
      ii) demonstrate that for HVAC a BACS function is in place with monitoring and data recording to detect recurring energy wasting deviations and to trigger respective corrective actions
      iii) show that a BACS set-point (fixed or calculated) management system in place for all relevant supplying HVAC plants to optimise demand driven operation
      iv) show that there is a runtime management as per EN 15232 Class A: 7.2.2 Individual setting following a predefined time schedule; adaptation from a central point
      v) have a set-point adjustment or reset from a central point for individual spaces according to EN15232 function 7.1.2
   b) benchmarking the building's energy efficiency, detecting losses in efficiency of technical building systems, and informing the person responsible for the facilities or technical building management about opportunities for energy efficiency improvement, meaning:
      i) check if the building's HVAC plant energy consumption data is recorded at least once a day and benchmarked for the building
      ii) check if there is monitoring and benchmarking for HVAC sub-systems relative to their defined benchmarks, for example for a heat pump the seasonal performance factor (SPFh/SPFc) should be monitored and compare it to the ErP SCOP/SEER product data and available benchmark (ErP)
      iii) check if there is automatic detection of HVAC equipment running in manual override/exception mode logged and flagged centrally

[6] https://www.eubac.org/news/eu.bac-publishes-bacs-compliance-verification-checklist-.html

[7] https://www.eubac.org/cms/upload/eu.bac_guidelines_on_revised_EPBD_June_2019.pdf

iv) check if there is automatic detection of faults in HVAC equipment that is logged and flagged centrally

v) check if there is automatic detection of loss in efficiency in the HVAC-related TBS with central indication of detected faults and alarms/diagnostic functions that are used to derive corrective actions and fix recurring suboptimal energy performance

vi) check the awareness of the facility manager in charge

c) allowing communication with connected technical building systems and other appliances inside the building and being interoperable with technical building systems across different types of proprietary technologies, devices and manufacturers. A method is provided to check compliance for this.

Key conclusions
This is a good checklist for enforcement.

For what matters with regard to benchmarking, the most useful suggestion is to require benchmarking of HVAC sub-systems relative to their defined benchmarks, for example a heat pump's Seasonal Performance Factor (SPFh/SPFc) needs to be monitored and compared to the ErP SCOP/SEER product data and available benchmark (ErP).

Specific benchmark data for building level benchmarking are not provided.

LEED requirements[8] v4 for building operations and maintenance related to benchmarking (US)

Requirements for minimum energy performance are:

- metering the building's energy use for a full 12 months of continuous operation and achieving the levels of efficiency set forth in the options below. Each building's energy performance must be based on actual metered energy consumption for both the LEED project building(s) and all comparable buildings used for the benchmark
    - Case 1: an EPC is available that satisfies compliance with minimum benchmark (in the US ENERGY STAR Rating of at least 75)
    - Case 2: when no EPC is available:
        - Option 1: benchmark against typical buildings
            - Path 1: national average data available; demonstrate energy efficiency performance that is 25% better than the median energy performance of similar buildings by benchmarking against the national source energy data provided in the portfolio manager tool
            - Path 2: national average data not available; if national average data are unavailable for buildings of similar type, benchmark against the building site energy data of at least three similar buildings, normalised for climate, building use and occupancy. Demonstrate a 25% improvement
        - Option 2: benchmark against historical data; if national average source energy data are unavailable, compare the building's site energy data for the previous 12 months with the data from three contiguous years of

[8] https://www.usgbc.org/resources/leed-v4-building-operations-and-maintenance-current-version

the previous five, normalised for climate, building use, and occupancy. Demonstrate a 25% improvement.

Key conclusions

The LEED requirements give some good guidance on how benchmarking can be performed in Case 2 which are benchmarks against typical buildings or historical data.

In Case 1 it is permitted to omit benchmarking when the building already has a low energy building EPC; however, this is not recommended by the study team, because the scope is buildings with over 290 kW and one should be aware that low energy buildings have often been reported to suffer from performance gaps.

OPERAT digital platform[9] for collecting and benchmarking of non-residential building data

In October 2019 the Tertiary Decree (Décret tertiaire[10]), also called the Tertiary Renovation Decree, was adopted in France; according to the terms in Article 175, all buildings that have 1000 m² of floor area or more used that are used for tertiary purposes must declare their energy consumption on a yearly basis and ensure they reduce it. Companies should collect the energy data of their buildings and submit the yearly consumption values to the digital platform OPERAT, operated by ADEME. Hereby it should be noted that according to the Tertiary Decree Article L111-10-3[11], all existing buildings in scope for the years 2030, 2040 and 2050 will have to reduce their final energy demand respectively by 40%, 50% and 60% compared to a reference energy demand which cannot be prior to 2010.

Key conclusions

Having noted that building benchmark data itself was often missing in previous proposed methods such a platform clearly provides a potential solution. In addition, for BACS it requires that building energy data are collected in an open standard format that allows it to be fed into the benchmarking system. It also requires that BACS can read out the provided benchmark. It is a clear and ambitious benchmark that can easily be verified.

The iSERV benchmarking project and method

To provide its benchmarks, the iSERVcmb project requires details on the physical composition of buildings in terms of utility meters, floor areas, activities undertaken and the building services components installed. Initial experience within iSERVcmb of collecting the data required for the process from the participating buildings, meters and sub-components quickly established that a standardised format was required to ensure comparability between systems across the EU. The project therefore established an active Excel spreadsheet[12] to both collect AND collate information about HVAC systems, activities and areas served in buildings. This can be downloaded from the iSERVcmb website and enables anyone wishing to collate and benchmark information on their HVAC systems to do so.

[9] https://operat.ademe.fr/#/public/home

[10] https://www.legifrance.gouv.fr/loda/id/JORFTEXT000038812251/

[11] https://www.legifrance.gouv.fr/codes/article_lc/LEGIARTI000037671213/

[12] https://iservcmb.info/the-iservcmb-spreadsheet/index.html

The logic of the iSERVcmb process requires the following input information to be provided (Table 15):

- floor area and activities, on a room-by-room basis
- HVAC system components, sensors and utility meters installed in the building
- hours of use of areas by activities (schedules)
- how these all connect, to provide the relationship between activities, HVAC components and utility use.

Table 1: ISERVcmb input data spreadsheet.

CUBRIC Building IT Suite - Example of Single Space Configuration

Heating, Ventilation and Air Conditioning System Details

Building

Building Name*	Description	Organization Name*	Site Name*	Sector*	Address*	Town*	Postcode*	Country*	Control of HVAC Temperature*	Construct Month*	Data Starts From	End Month
CUBRIC		Cardiff University	Cathays Park	Further Education / Universities	Park Place	Cardiff	CF10 3AT	United Kingdom	Exhaust Air Temperature	01/2006	04/2006	<Ctrl-;>

Utility Meter

Name*	Description	Meter Type*	Unit Type*	Multiplier	Space Where Located	Unique Meter Id*	Data Starts From	End Month	Parent Meter Name
IT Suite AC Electricity Meter	Power supply separate from main building supply	Electricity	kWh			MET_CUBRIC_73578000	04/2006	<Ctrl-;>	<Ctrl-;>
IT Electric Lighting and Power Meter	Power to the computing equipment and room lighting	Electricity	kWh			MET_CUBRIC_73578001	04/2006	<Ctrl-;>	<Ctrl-;>

HVAC Sensor

Name*	Description	Sensor Type*	Unit Type*	Duct/Pipe Area m2	Unique Sensor Id*	Data Starts From	End Month
IT Suite room air temperature		Room air temperature sensor	Centigrade		SEN_CUBRIC_73578002	10/2011	<Ctrl-;>

HVAC System

Name	Description	Main HVAC System	HVAC Type	System Classification	System Sub-classification	Data Starts From	End Month	Sensor Name(s)	Meter Name(s)	Control Of Flow Temperature
DX Splits		N	Full Air Conditioning(no RH control)	Non-centralised System	Split Packaged Unit	04/2006	<Ctrl-;>	None	IT Suite AC Electricity Meter	Return/flow temperature

HVAC Component

Name	Description	Component Type	Component Sub-type	Serves which HVAC System(s)	Space Where Located	Nominal Electrical Power Input (KW)	Meter Name(s)	Sensor Name(s)	Data Starts From	End Month	Parent Component	Nominal Heat R… Capacity (…
						Or* but preferably both if available						Please check H…
DX Split 1 Outdoor Unit		Heat Rejection	Forced air condensers	DX Splits		0.28	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	15.5
DX Split 2 Outdoor Unit		Heat Rejection	Forced air condensers	DX Splits		0.28	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	15.5
DX Split 3 Outdoor Unit		Heat Rejection	Forced air condensers	DX Splits		0.28	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	15.5
DX Split 4 Outdoor Unit		Heat Rejection	Forced air condensers	DX Splits		0.28	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	15.5
DX Split 1 Chiller		Cold Generators	Screw Liquid Chillers	DX Splits		5.90	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	
DX Split 2 Chiller		Cold Generators	Screw Liquid Chillers	DX Splits		5.90	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	
DX Split 3 Chiller		Cold Generators	Screw Liquid Chillers	DX Splits		5.90	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	
DX Split 4 Chiller		Cold Generators	Screw Liquid Chillers	DX Splits		5.90	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	

Schedules of Setpoint and Occupation

Name	Description	Range 1 - Applies From	Range 1 - Applies To	Range 2 - Applies From	Range 2 - Applies To	Range 3 - Applies From	Range 3 - Applies To	Range 4 - Applies From	Range 4 - Applies To
Schedule 1 - Whole Building		01/01	31/12						
Schedule 2 - IT Suite		01/01	31/12						

Space

Name*	Description	Floor Area (m2)*	Height (m)	Sector*	Activity*	Served By HVAC(s)	Utility Meter(s)	Schedule of Setpoints, RH and Occupancy	Sensor Name(s)	Data Starts From	End Month	Control of HVAC Temperature
CUBRIC IT Suite [AR00-V006] IT Frame Room		27.00		Further Education / Universities	IT: Server Room	DX Splits	IT Electric Lighting and Power Meter	Schedule 2 - IT Suite	IT Suite room air temperature	04/2006	<Ctrl-;>	Exhaust Air Tempera…

Once the physical assets in the building are described and entered the spreadsheet, it can be sent to an email address where it is then automatically loaded and configured in the HERO database. Once loaded, a set of blank benchmark ranges can be produced which are tailored to the building, systems and activities described.

The HERO Reporting Module automatically generates two standard reports per building. The first is a high-level report that shows a summary of the building, its consumption and any potential savings that can be made (Table 16). The second report is highly detailed and shows a breakdown at the services level for the building along with heat maps at the meter level where sub-hourly data is available (Figure 2).

Table 2: Example iSERVcmb benchmark report: HVAC system performance summary.

HVAC Summary – Performance Relative to Benchmarks

HVAC - Electricity			Annual kWh/m2				
Status	HVAC System Name	Year To	Measured	Benchmark Min	Benchmark 25%	Benchmark 75%	Benchmark Max
	Main system (AHU1 and AHU2)	31-12-2013	3,542.40	9.70	114.27	325.00	430.41
	Kitchen Storage Split 1	31-10-2013	103.35	1.00	36.70	179.50	358.00
	LAN Room AC System	31-10-2013	93.21	1.00	20.90	100.50	200.00
	Servery Split	31-10-2013	103.35	1.00	36.70	179.50	358.00
	System AHU 10	31-12-2013	77.41	0.06	54.81	164.99	220.14
	System AHU 11	31-12-2013	77.37	0.00	54.91	165.42	220.73
	System AHU 5	31-12-2013	109.11	16.57	96.07	265.02	350.17
	System AHU 6	31-12-2013	121.67	14.64	61.64	163.94	213.54
	Training Room Splits	31-10-2013	158.82	1.00	36.70	179.50	358.00
	Domestic Hot Water System	31-10-2013	3.54	9.61	26.65	64.43	82.43

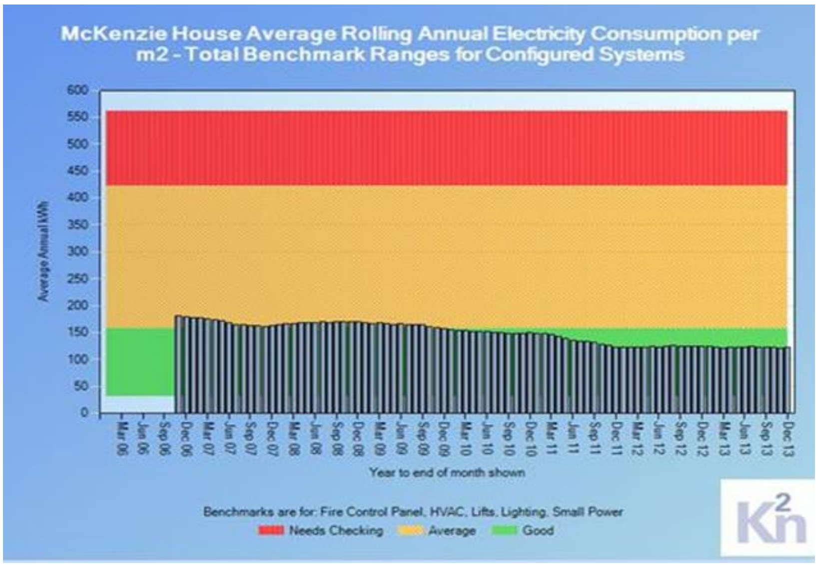

Figure 1: Example iSERVcmb benchmark report: whole building level.

Key conclusions

This is a predecessor and similar approach to what will be implemented on the OPERAT digital platform[13]. Both approaches are still in early implementation and will benefit from data being entered in the databases to define the top edge of benchmark. The disaggregated approach of iSERV gives more insight about in which HVAC domains and by which measures savings can be obtained.

[13] https://operat.ademe.fr/#/public/home

Using the reference values for final heating demand (kWh/m²/year) from EPCs for existing buildings

Most countries have reference data for their EPCs, e.g. those published by the German Ministry for Economy and Energy[14] (Table 17)

Table 3: German reference final heating demand (kWh/m²/year) values for use in EPCs of existing buildings.

Lfd. Nr.	Nutzungsgruppe	Nutzung	Schreibweise für die Angabe „Gebäudenutzung" im Energieausweis	Vergleichswerte Wärme $[kWh/(m^2_{NGF} \cdot a)]$	Vergleichswerte Strom $[kWh/(m^2_{NGF} \cdot a)]$
1	2	3	4	5	6
1.1	Hotel, Beherbergung	Hotels ohne Stern, Pensionen, Gasthäuser, Hotels garni	Hotel/Pension, einfach	150	50
1.2		Hotels mit 1 und 2 Sternen	Hotel, 1 und 2 Sterne	85	55
1.3		Hotels mit 3 Sternen	Hotel, 3 Sterne	95	60
1.4		Hotels mit 4 und 5 Sternen	Hotel, 4 und 5 Sterne	105	65
1.5		Jugendherbergen, Gästehäuser, Ferien-, Vereins-, Schullandheime	Herberge, Ferienheim o. ä.	90	20
2.1	Gaststätten	Ausschankwirtschaften	Ausschankwirtschaft	240	70
2.2		Speisegaststätten/Restaurants	Speisegaststätte/Restaurant	205	95
2.3		Kantinen/Mensen	Kantine/Mensa	120	75
3.1	Veranstaltungs-gebäude	Kinos	Kino	55	80
3.2		Opernhäuser, Theatergebäude	Opernhaus, Theater	110	40
3.3		Saalbauten, Stadthallen	Saalbau, Stadthalle	110	40
3.4		Freizeitzentren, Jugendhäuser, Gemeindehäuser	Freizeitzentrum, Gemeindehaus o. ä.	105	20
4	Laborgebäude		Laborgebäude	Ermittlung der Vergleichswerte: nach Nummer 6.4	
5.1	Sportanlagen	Sporthallen	Sporthalle	120	35
5.2		Mehrzweckhallen	Mehrzweckhalle	240	40
5.3		Schwimmhallen, Hallenbäder	Schwimmhalle, Hallenbad	385	105
5.4		Sportheime (Vereinsheime)	Sport-, Vereinsheim	80	20
5.5		Fitnessstudios	Fitnessstudio	100	120
6.1	Handel/Dienst-leistung	Handel Non-Food, sonstige persönliche Dienstleistungen bis 300 m^2	Handel Non-Food o. ä. bis 300 m^2	135	45
6.2		Handel Non-Food über 300 m^2	Handel Non-Food o. ä. über 300 m^2	75	60
6.3		Handel Food bis 300 m^2	Handel Food bis 300 m^2	125	75
6.4		Handel Food über 300 m^2 sowie Metzgerei mit Produktion	Handel Food über 300 m^2	95	265
6.5		Kaufhäuser, Warenhäuser, Einkaufszentren (Food und Non-Food)	Kaufhaus, Einkaufszentrum	70	85
6.6		Geschlossene Lagerhäuser, Speditionen	Lagerhaus	30	35
6.7		Kosmetik/Friseur	Kosmetik/Friseur	155	65
7.1	Gesundheitswesen	Krankenhäuser bis 250 Betten	Krankenhaus bis 250 Betten	145	84
7.2		Krankenhäuser von 251 bis 1 000 Betten	Krankenhaus 251 bis 1 000 Betten	175	80
7.3		Krankenhäuser mit über 1 000 Betten	Krankenhaus über 1 000 Betten	200	80
7.4		Freiberufliches Gesundheitswesen, Praxen	Gesundheitswesen, Praxen	200	35
8.1	Verkehrsinfra-struktur	Flughafen, Terminal	Flughafen, Terminal	135	205
8.2		Flughafen, Frachthallen	Flughafen, Frachthalle	120	70
8.3		Flughafen, Wartung/Hangar	Flughafen, Wartung/Hangar	270	65
8.4		Flughafen, Werkstätten	Flughafen, Werkstatt	155	150
8.5		Bahnhof (inklusive Vermarktungsbereich) < 5 000 m^2	Bahnhof bis 5 000 m^2	120	30
8.6		Bahnhof (inklusive Vermarktungsbereich) ≥ 5 000 m^2	Bahnhof über 5 000 m^2	115	100
9.1	Bürogebäude	Bürogebäude, nur beheizt	Büro, nur beheizt	105	35
9.2		Bürogebäude, temperiert und belüftet	Büro, temperiert und belüftet	110	85
9.3		Bürogebäude mit Vollklimaanlage, Konditionierung unabhängig von der Außentemperatur	Büro mit Vollklimaanlage	135	105

14 https://www.bundesanzeiger.de/pub/publication/aw0alBTBco6yYzcam0E;wwwsid=A5F5A6B0864256EB8D675984C41169C4.web06-pub?0

Key conclusions

With regard to the total final heating or cooling demand of a building, in principle the respective reference values which should be available from the regional EPCs could be used as benchmarks. In principle all countries should have this for buildings within the scope of the EPBD.

The indicative benchmarks from the respective Ecodesign Regulations or other data sources for HVAC sub-systems

Much of the Ecodesign Regulations have indicative benchmarks included in their annexes, which can also be used on the condition that they can be monitored.

Annex V of Regulation (EU) No 813/2013 for space heaters and combination heaters contains the following benchmark:

- Benchmark for seasonal space heating energy efficiency in medium-temperature application: 145%
- Benchmarks for water heating energy efficiency of combination heaters: Declared load profile 3XS, XXS, XS, S, M, L, XL, XXL, 3XL, 4XL Water heating energy efficiency is 35%, 35%, 38%, 38%, 75%, 110%, 115%, 120%, 130% and 130%, respectively.

Annex V of Regulation (EU) 2016/2281 provides the benchmarks for seasonal space heating or cooling energy efficiency or air heating products and cooling products and seasonal energy performance ratio of high temperature process chillers (Table 18).

Table 4: Benchmarks for seasonal space heating or cooling energy efficiency of air heating products and cooling products and seasonal energy performance ratio for high temperature process chillers

Warm air heaters	Using gaseous or liquid fuels	84 %
	Using electricity	33 %
Comfort chillers	Air-to-water, $P_{rated,c}$ < 200 kW	209 %
	Air-to-water, $P_{rated,c}$ ≥ 200 kW	225 %
	Water/brine-to-water, $P_{rated,c}$ < 200 kW	272 %
	Water/brine-to-water, $P_{rated,c}$ ≥ 200 kW	352 %
Air conditioners	Electric, air-to-air air conditioner	257 %
Heat pumps	Electric, air-to-air heat pump	177 %
High temperature process chillers	Air-cooled, P_A < 200 kW	6,5 SEPR
	Air-cooled, 200 kW ≤ P_A < 400 kW	8,0 SEPR
	Air-cooled, P_A ≥ 400 kW	8,0 SEPR
	Water-cooled, P_A < 200 kW	8,5 SEPR
	Water-cooled, 200 kW ≤ P_A < 400 kW	12,5 SEPR
	Water-cooled, 400 kW ≤ P_A < 1 000 kW	12,5 SEPR
	Water-cooled, P_A ≥ 1 000 kW	13,0 SEPR

Key conclusion

For heat/cold generation the efficiency benchmarks can be sourced from the indicative benchmarks included in the respective Ecodesign regulations.

So far Ecodesign does not include the efficiency benchmarks for heat/cold distribution and emission, which are also important HVAC sub-systems that can be benchmarked. Therefore, these benchmark values should be collected from the input cited in Tasks 1 and 2.

5.3.3 Expert interviews

This input was based on the data gathered from the Ecodesign BACS study and the interactive session organised by eu.bac with their manufacturers before they launched their proposal (27/10/2020).

In order to avoid interfering with the policy-making process related to the Ecodesign BACS proposal the study team preferred not to organise expert interviews with stakeholder organisations in 2021 and based the analysis on the information already collected and their own expertise.

Considering the data collected, the team think that an expert interview with a facility manager could be useful (for example Imtech) and/or an engineering expert to check for more practical approaches to benchmark heat/cold distribution with measured data (could also be Imtech or Priva).

5.4 Activity 2: Provision of technical guidance for an effective understanding of BACS capabilities under the EPBD

Aim:

Drawing from the findings of Activity 1, the study team will prepare a set of technical guidelines to support an effective understanding of BACS capabilities under the EPBD. The principal target audiences for these guidelines will be:

- *professionals of the buildings sector who will have to ensure compliance of BACS deployed with these capabilities*
- *Member States or other Authorities in charge of the implementation of the provisions of Article 14 and 15 of the EPBD*

The study team will derive these guidelines so as to include a mapping of BACS capabilities specified under Article 14(4) and 15(4) to BACS functions and configurations as available on the market. In so doing they will pay attention to detailing which functions and configurations can ensure adequate benchmarking capabilities (e.g. scope and frequency of data collection from technical building systems, type and number of sensors, software for data processing, analysis and feedback to building manager, etc.)

The team will further include an indicative list of products available on the market (ensuring a balanced representation of system suppliers) that feature such functions.

In addition, these guidelines will be established to include:

- *recommendations for building sector professionals to support their understanding and ensuring BACS deployed comply with the required capabilities*
- *recommendations for Member States or other Authorities in charge of the implementation of the provisions of Article 14 and 15 of the EPBD on the effective enforcement of BACS capabilities required under Article 14(4) and Article 15(4).*

The results of this activity will be summarized in a (10-15) pages report supplemented by two -pagers designed to support the dissemination of guidelines with building professionals and Member States or other Authorities in charge of the implementation of the provisions of Article 14 and 15 EPBD. This are included in this final report and the two pager is a separate document.

5.4.1 Mapping of the BACS functions relevant to Articles 14 (4) and 15(4) to allow for continuously monitoring, logging, analysing and allowing for adjusting energy use

How do BACS functions of EN 15232 map to heating and cooling

All the functions apart from hydronic balancing (see Annex F) are included in the standard EN 15232. An overview of the most relevant functions for heating/cooling is included in Table 19 with their potential relationship with Articles 8/14/15 and other EU policy. The functions in blue text are those which were identified as the most relevant in previous tasks.

Table 5: Listing of the most relevant BACS functions EN 15232 for heating/cooling and mapping on EPBD Article 8/14/15 and other EU potential policy instruments

system boundary									EPBD policy								EU regulation				
									art. 8(1)												
overall parameter	subsystem parameter	product parameter	item (short description of characteristic TBS parameter)	Symbol or EN15232 function #	Unit	min.	typ.	max.	overall perf.	dimensioning	installation	adjustment (to needs)	proper control	art. 14/15 checklist	TBS data for an EPC	EPC data for dimensioning	ELD installer label	ErP product regulation	art. 114 TFEU(free market)	RED	EED metering
Overall system level, key BACS functions related to heating and SHW																					
	✓		Heating and/or Cooling Control	**1 & 3**																	
	✓		Room or zone heating or cooling emission control	1.1 & 3.1	level	0	2	4			✓	✓	✓	✓	✓	✓	✓	✓	✓		
	✓		Control of the temperature of the heating and cooling distribution network, typically water in a hydronic network For heat pumps in hydronic systems: it is control of the	1.3 & 3.3	level	0	1	2				✓		✓	✓		✓	✓	✓		
	✓		Control of distribution pumps(circulator pump) in heat or cold distribution networks	1.4 & 3.4	level	0	1	4			✓			✓	✓		✓	✓	✓		
	✓		Intermittent control of heat or cold emission and distribution	1.5 & 3.5	level	0	0	3			✓	✓		✓	✓		✓	✓	✓		
	✓		Control of the heat or cold generators (e.g. gas boiler, heat pump, etc ..)	1.6 & 1.7 or 3.7	level	0	1	2			✓	✓		✓	✓		✓	✓	✓		
	✓		Sequencing of different heating and/or cooling generators in the case that multiple generators are used	1.8 & 3.8	level	0	1	2			✓			✓	✓		✓	✓	✓		
	✓		Interlock control between heating and cooling emission and/or distribution systems	3.6	level	0	1	2			✓	✓		✓	✓		✓	✓	✓		
	✓		Domestic hot water supply control	**2**																	
	✓		- Control of water storage tank with electrical heater and/or integrated heat pump - indirect tanks connected to external heater	2.2	level	0	0	2			✓	✓			✓		✓	✓			
	✓		Control of DHW storage charging with solar collector and supplementary heat generation	2.3		0	1	2			✓	✓			✓		✓	✓			
	✓		Control of DHW circulation pump	2.4		0	0	1			✓	✓			✓		✓	✓			
	✓		Technical home and building management	7																	
	✓		Setpoint management	7.1		0	1	3				✓	✓				✓	✓	✓		
	✓		Runtime management	7.2		0	1	2				✓	✓				✓	✓	✓		
	✓		Detecting faults of technical building systems and providing support to the diagnosis of these faults	7.3		0	0	2				✓	✓				✓	✓	✓		
	✓		Reporting information regarding energy consumption, indoor conditions	7,4		0	1	2	✓				✓				✓	✓	✓	✓	✓
	✓		Hydronic efficiency and automatic balancing(EN15316-2)	Not available							✓	✓					✓	✓	✓		
		✓	Control accuracy for room controllers, product documentation and demonstrated performance (see all proposals in ED BACS study)	Ind. Standards											✓			✓			
✓			**the electrical auxiliary energy for heating, BACS;**	**W H, aux, B**	kWh/(m².y)	TBD?			✓				✓		✓						
✓			Know the performance of your BACS (EN 15232- class A/B/C/D)	all	class	D	C	A	✓		✓			✓	✓		✓				

Generic Article 14/15 compliance checklist on scope

This can be sourced from the eu.bac Article.14/15 compliance checklist[15].

What is a suitable proposal for minimum requirements on BACS functions and how can the verification be done?

This could be based on the Dutch minimum BACS requirement based on EN 15232 class C requirements[16],[17] who proposed EN 15232 class C for most relevant H/C functions and class A for function (7.4) on 'Reporting information regarding energy consumption, indoor conditions'.

Putting forward only class C instead of class B came out of a technical/economic analysis that reported that there are two main barriers:

1. Some buildings have meters or sensors in places that make communication with the BACS difficult, e.g. in the basements or technical rooms with reinforced concrete. Relocating and/or adding measuring devices via new cabling and/or gateways could lead to unreasonably high costs.
2. The second limitation concerns communication or lack of interoperability between installations for heating and cooling and BACS. This was found to occur because much of the existing heating and cooling equipment cannot easily be connected to the BACS.

In line with the Dutch requirement a clear checklist for compliance is added in Table 20 and a recommendation for verification methods is added in Table 21.

Also note that:

- For deeply renovated buildings these limitations obviously should not apply, and class B could be required as a minimum (which is the case in Italy, for example). Class B compliance can also be required under Article 8 when an important part of the heating or cooling system is replaced (e.g. the heat generator or emitters/building fabric).
- In order to stimulate the uptake of higher class BACS a full assessment to know the performance of your BACS (EN 15232- class A/B/C/D) is put forward as a requirement, e.g. a free online tool is available at: https://www.igt-institut.de/tool-gebaeude-inspektor/ (in German). It is also important building documentation.
- The class A requirement for reporting information regarding energy consumption and thus benchmarking in EN15232 is still very generic in both the Dutch requirement and the EN 15232 itself. Therefore, a proposal for more detailed benchmarking requirements is elaborated in a later section.

[15] https://eubac.org/news/eu-bac-publishes-bacs-compliance-verification-checklist/

[16] 'Onderzoek inzetbaarheid en uitwerking van Building Automation and Control Systems (BACS) onder de EU richtlijn 2018 aangaande energiebesparing in utiliteitsgebouwen (EPBD III)'(9/2019)

[17] Handreiking Energieprestatie Installaties in gebouwen (EPBD III) (12/2020)

Table 6: Verification check list for EN 15232 minimum class C requirements for most relevant Heating/Cooling functions

Symbol or EN15232 function #	Unit	min.	typ.	max.	min. proposal level	belong to class	short description of typical requirement: not allowed	short description of typical requirement: required
1 & 3								
1.1 & 3.1	level	0	2	4	2	C	no control of room temperature with heating	- If mechanical ventilation is installed then 1 controller per ventilation zone is required. - If no mechanical HRV ventilation is installed then 1 controller per room is required.
1.3 & 3.3	level	0	1	2	1	C	no control of water distribution temperature	- control of water distribution temperature depending on outdoor temperature and/or heat demand
1.4 & 3.4	level	0	1	4	1	C	no control of the distribution pump (also check spanish proposal)	- on/off control of the distribution pump - stepwize control of the distribution pump - variable speed distribution pump
1.5 & 3.5	level	0	0	3	1	C	no automatic control of start/stop of the heat generator	- on/off control of heat generator with the timer - on/off control with optimization of start and stop - on/off control of the heat generator based on heat demand
1.6 & 1.7 or 3.7	level	0	1	2	1	C	No automatic control in the heat generator	- variable return temperature (gas) or exit temperature (heat pump) in function of outdoor temperature - variable return or exit temperatures in function of heat demand
1.8 & 3.8	level	0	1	2	1	C	Fixed sequence	- priority control based on loads - priority control based on efficiency characteristics - control based on multiple parameters (demand, ..)
3.6	level	0	1	2	1	C/B	Individual control of H/C in large(>500 m²) non residential buildings	Intergrated H/C room temperture controllers that have a dead band between H/C larger than 2 °C
2								
2.2	level	0	0	2	1	C/B	on/off set point temperature only	- automatic control combined with a time clock
2.3		0	1	2			TBD	TBD
2.4		0	0	1	1	C/B/A	no control or allways on	timer based control
7								
7.1		0	1	3	1	C	Manual control for each room or zone (in large buildings > 500 m²)	Set Point management from a central point in large buildings (>500 m²) Regular reset of individual set points in large buildings (>500 m²)
7.2		0	1	2	1	C	No runtime management or no night time set back from comfort to economy temperatures No requirements for small buildings (< 500 m²) with underfloor heating and mechanical heat recovery ventilation	- schedules per room or ventilation zone based on predefined time events - schedules per room or ventilation zone variable in time - no requirements for small buildings (< 500 m²) with underfloor heating and mechanical heat recovery
7.3		0	0	2	0+	D+	No detection	Detection as requested per manufacturer
7,4		0	1	2	2	A	Only indicating values	See monitoring and benchmarking proposal elaborated in this study
Not available					-	NA		These guidelines for installers are included in the NL implementation
Ind. Standards					-	NA	Use of BACS products that are not compliant with proposed Ecodesign regulation	Use of BACS products with CE Label or better with CEN Keymark for TRVs or EU.BAC certified room controllers
W H, aux, B	kWh/(m².y)	TBD?			-	NA	No measured data	measured data
all	class	D	C	A	C		No inventory and assessment of the BACS functior	Digital record with implemented BACS functions and class (e.g. use https://www.igt-institut.de/tool-

Table 7: Recommended verification method for list for EN 15232 minimum class C requirements for most relevant H/C functions (DOH means Declaration of Honour)

item (short description of characteristic TBS parameter)	Symbol or EN15232 function #	Unit	min.	typ.	max.	min. proposal level	belong to class	how to check requirements	Benhmarking proposed PI or KPI for monitoring
Overall system level, key BACS functions related to heating and SHW								**how to check**	
Heating and/or Cooling Control	**1 & 3**								
Room or zone heating or cooling emission control	1.1 & 3.1	level	0	2	4	2	C	DOH of installer, check rooms	KPIR.c, KPIR.f, PIRh.a
Control of the temperature of the heating and cooling distribution network, typically water in a hydronic network For heat pumps in hydronic systems: it is control of the supply water temperature For condensing gas heaters: it is control of the return water temperature	1.3 & 3.3	level	0	1	2	1	C	For large installations(290kW), a temperature record should be supplied else can be DOH from installer	PIHSt.a, PICSt.a
Control of distribution pumps(circulator pump) in heat or cold distribution networks	1.4 & 3.4	level	0	1	4	1	C	Only required in lage installations (>70 kW): Log of the pump power energy consumption in large buildings andcheck if the quaterly min/max value recorder per year should be below 0,2.	
Intermittent control of heat or cold emission and distribution	1.5 & 3.5	level	0	0	3	1	C	- Log of energy consumption for heating in large buildings - Else, installer DOH	PIHSt.a, PICSt.a
Control of the heat or cold generators (e.g. gas boiler, heat pump, etc ..)	1.6 & 1.7 or 3.7	level	0	1	2	1	C	- Log of return heat water temperature for heating in large buildings - Else, installer DOH	PIHeff.a, PICeff.a
Sequencing of different heating and/or cooling generators in the case that multiple generators are used	1.8 & 3.8	level	0	1	2	1	C	Log file of energy consumption of the different generators	PIHSt.a, PICSt.a
Interlock control between heating and cooling emission and/or distribution systems	3.6	level	0	1	2	1	C/B	Installer DOH	
Domestic hot water supply control	2								
- Control of water storage tank with electrical heater and/or integrated heat pump - indirect tanks connected to external heater	2.2	level	0	0	2	1	C/B	Installer DOH	
Control of DHW storage charging with solar collector and supplementary heat generation	2.3		0	1	2			Installer DOH	
Control of DHW circulation pump	2.4		0	0	1	1	C/B/	Installer DOH	
Technical home and building management	7								
Setpoint management	7.1		0	1	3	1	C	Building owner DOH	KPIR.c, KPIR.f, PIRh.a
Runtime management	7.2		0	1	2	1	C	Building owner DOH	KPIR.c, KPIR.f, PIRh.a
Detecting faults of technical building systems and providing support to the diagnosis of these faults	7.3		0	0	2	0+	D+	Installer DOH and manufacturer data sheet	
Reporting information regarding energy consumption, indoor conditions	7.4		0	1	2	2	A	See monitoring and benchmarking proposal elaborated in this study	KPIEH.c, KPIEC.c,
Hydronic efficiency and automatic balancing(EN15316-2)	Not available					-	NA	Monitoring of dT, see proposal for installers DoH	PIHhyd.a
Control accuracy for room controllers, product documentation and demonstrated performance (see all proposals in ED BACS study)	Ind. Standards					-	NA	can be implemented in conjuction with ED	KPIR.c, KPIR.f, (PIRh.a
the electrical auxiliary energy for heating, BACS;	**W H, aux, B**	kWh/(m².y)	TBD?			-	NA	check measured data	
Know the performance of your BACS (EN 15232- class A/B/C/D)	all	class	D	C	A	C		check assessment report and declared EN 15232 class	

5.4.2 Proposal for a more detailed minimum BACS Energy Monitoring System (EMS) requirements to support the benchmarking

How to set the overall benchmark value for the energy demand for heating or cooling in existing buildings

To date the simplest approach is to put requirements directly on the final energy demand (gas, heating oil, electricity) for heating and cooling. This approach was found in most of the examples and BACS EMS guidelines[22],[24]. As an alternative, using primary energy will add more complexity; while, in principle the full set of EPBD EN standards would allow for this it is not essential for what is proposed hereafter.

Benchmarking can be done by providing two options to the building owner similar to the French Tertiary Building Decree (Article L111-10-3)[18]:

Option 1, to provide **absolute final energy demand values for heating/cooling** for a representative reference building. In France those values are not published yet but as a source of example values a reference for those of Germany (2019) can be consulted (see Figure 3). Note that they may need to be corrected for abnormal absence/occupancy.

Tabelle 25: Zonenflächebezogene Teilenergiekennwerte der Energieaufwandsklasse „gering“ unterschiedlicher Gewerke in kWh/(m²·a)

Nutzungs-nummer	Standard-Nutzungseinheiten	Hauptnut-zung	Heizung	Warmwasser	Beleuchtung	Luftförde-rung	Kühlkälte	Hilfsenergie-Kälte	Be- u. Ent-feuchtung	Arbeitshilfen
1	Einzelbüro	X	40,9	12,7	19,1	9,0	7,6	5,9	15,3	4,5
2	Gruppenbüro (zwei bis sechs Arbeitsplätze)	X	41,7	12,7	17,2	9,0	7,3	5,6	15,3	4,5
3	Großraumbüro (ab sieben Arbeitsplätze)	X	40,9	12,7	25,6	13,5	10,2	7,2	23,0	6,0
4	Besprechung, Sitzung, Seminar	X	69,1	3,6	18,2	33,9	11,3	8,5	57,5	1,0
5	Schalterhalle	X	46,5	3,6	11,0	4,5	4,8	3,2	7,7	2,3
6	Einzelhandel / Kaufhaus	X	43,8	7,3	21,4	11,7	9,1	7,0	19,8	3,6
7	Einzelhandel / Kaufhaus (Lebensmittelabteilung mit Kühlprodukten)	X	47,5	7,3	23,5	11,7	10,3	7,7	19,8	20,4
8	Klassenzimmer (Schule), Gruppenraum (Kindergarten)	X	45,8	35,1	5,2	12,5	6,9	4,5	21,2	2,0
9	Hörsaal, Auditorium	X	68,4	3,6	8,8	37,5	16,5	9,0	63,7	1,8
10	Bettenzimmer	X	59,5	180,4	40,6	31,0	14,3	19,8	52,6	4,4
11	Hotelzimmer	X	39,3	158,3	6,9	11,6	6,3	5,1	23,2	8,0
12	Kantine	X	48,2	149,0	6,1	19,1	11,3	7,2	37,1	1,3

Figure 2: Extract of German reference final energy demand values [kWh/(m².y)] per type of activity for different services including heating (Heizung) and cooling (Kuhlkälte) for the low energy building class ('gering' or low)

Option 2, set an **energy saving target versus historical data for existing buildings.** For example, in France an energy savings reduction objective of -40% compared to 2010 or more recent values must be achieved by 2030 if option 1 is not used.

In addition, it is also possible to set more specific targets in performance indicators of the subsystem, especially if they can be easily monitored and verified. This is discussed later in the document.

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[18] https://www.legifrance.gouv.fr/codes/article_lc/LEGIARTI000037671213

__Overall energy consumption minimum requirement__

These requirements can be set to all type of buildings within scope (>290 kW). Note that the selection hereafter is a proposal for a minimum requirement that could be implemented cost effectively, license free and in a technology neutral manner. Obviously as could be concluded from the previous review tasks much more advanced BEMS exist, it can be hoped that this minimum requirement will trigger building owners with high consumption to go for more advanced solutions available on the market.

- **KPIEH.c and KPIEC.c: Total heating energy consumption (of, for example, an entire building)**
    - EN 15232: 7.2 – class A
    - KPI explanation: total heating energy consumption (of, for example, an entire building) in relation to outside air temperature. The annual hourly peak load and also average load for heating and cooling must be calculated, to support the appropriate heat/cool generator dimensioning in case of replacement[19] and thus comply with the Article 8 'dimensioning' requirements.
    - KPI function: hourly consumption measured/calculated.
    - KPI Evaluation: evaluate in x–y presentation versus average outside temperature (energy signature). The annual hourly peak load and average load for heating and cooling must also be calculated to support Article 8 on dimensioning in case of a replacement. Try to exclude the gas or heat demand for DHW from the monitoring because this will complicate the interpretation.
        - For medium to inefficient buildings with a measured EPC of class C or worse check that:
            - there is no energy use for heating with outdoor temperatures above 20 °C.
            - no large scattering(high/low) occurs which could indicate on/off cycling and considering better heating curve to be tuned
            - there is no hourly disproportional high (+30 %) energy consumption which might indicate air-tightness issues (doors open, etc.).
            - For buildings with heating and cooling be informed that a low spill-over temperature from heating to cooling (e.g. 8 °C) indicates a low energy building with good insulation and airtightness.
            - For buildings with heating and cooling also check that the range in which there is simultaneous heating and cooling requirements is not too large (e.g. <6 °C)

[19] https://www.epeeglobal.org/wp-content/uploads/EPEE-EPBD-Implementation-Guidelines-2019.pdf

        - For a combined system for heating and DHW the measured curve will remain flat at high outdoor temperatures (see Figure 4) needs to be corrected or properly interpreted.
    - For low energy buildings with an EPC class B or A:
        - Be aware that other internal heat gains apart from the outdoor temperature will drive heating demand and therefore the interpretation of this curve is more complex.
        - Check annually if the average spill-over temperature between heating and cooling, which should be typically low for these types of buildings (e.g. 8-10 °C).
- reason for KPI: detection of odd energy usage, e.g. air tightness of a building, such as windows/doors left open or H/C demand when not in use. Also support with data for the dimensioning of the heat or cold generators for any future replacement.
- Note, the following input is required:
    - Energy for heating recorded per hour [kWh] (source: smart energy meter as required per EED)
    - Outdoor temperature recorded per ¼ hour (°C)
    - Optional for buildings with low EPC: Disproportional energy consumption relative to the curve (+30 %) should be signalled per hour on a visible location.
- Examples: See Figure 4 and Figure 5.

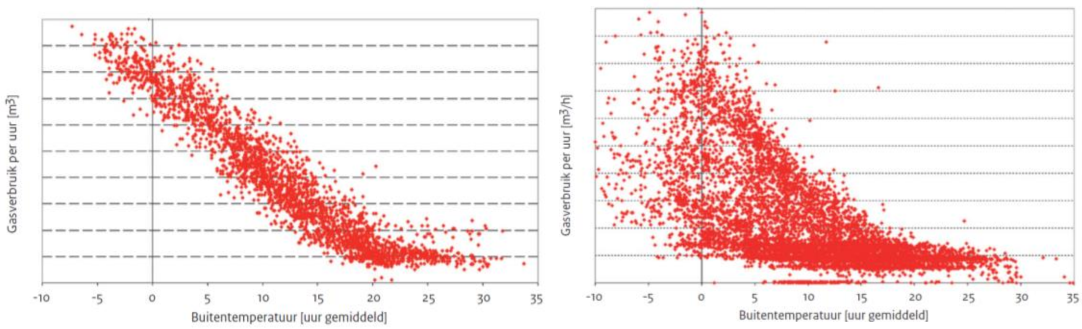

Figure 3: KPIEH.c measured for a building with incorrect functioning of gas installation (right) and correct functioning (source: Agentschap NL[20])

[20] https://openarchivaris.nl/blob/56/ca/a19cf061e2614a19b751ebd93e75.pdf

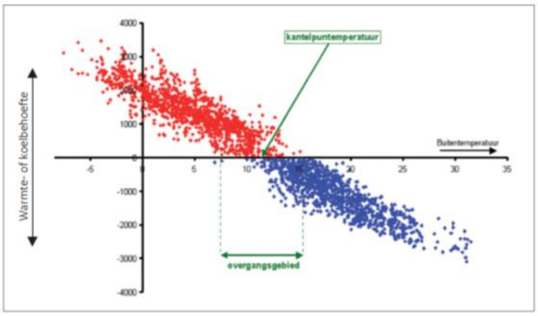

Figure 4: KPIEH.c and KPIEC.c measured for a correct working installation with heating and cooling (source: Agentschap NL[21])

- **PIEH.c: Heating consumption of a building per total area**
  - PI explanation: heating consumption of a building per total area
  - PI function: KPIEH.c/total building area
  - reason for PI: benchmark for building/space, this value is directly linked to the primary metric of an EPC.
  - Note, the following input required is:
    - Final energy for heating recorded per hour [kWh] (source: smart energy meter as required per EED)
    - Floor area from EPC
    - It might be necessary to consider multiple areas and therefore add additional calorimeters to attribute consumption to the heating demand of the area
    - EPC data on final Energy for heating for a class B or low energy reference building alike per month[kWh/m²/month].
  - Example: See Figure 6.

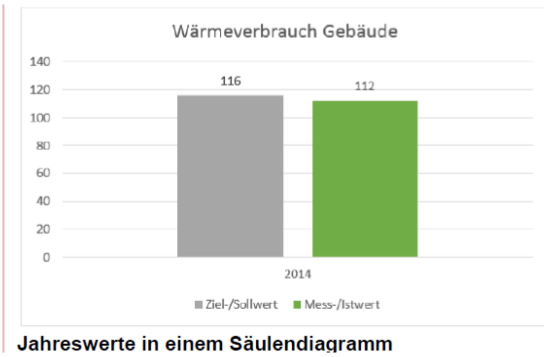

Figure 5: Comparison of annual final energy demand for heating with the benchmark (source: AMEV Empfehlung Nr. 158[22])

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[21] https://openarchivaris.nl/blob/56/ca/a19cf061e2614a19b751ebd93e75.pdf

[22] https://www.amev-online.de/AMEVInhalt/Planen/Monitoring/TechnischesM/2020-08-01_Technisches_Monitoring_2020.pdf

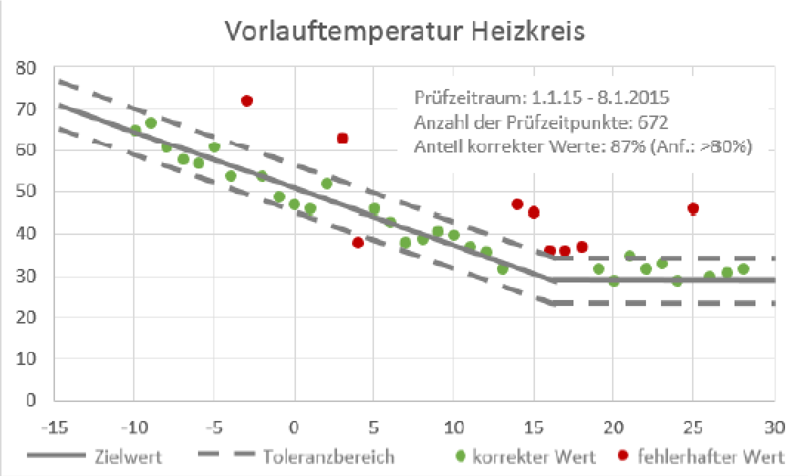
- **PIEH.d: Monthly heating consumption of a building per total area HDD compensated**
    - PI explanation: heating consumption of a building per total area HDD compensated
    - PI function: KPIEH.d/total building area
    - reason for PI: benchmark for building/space.
    - Notes, the following input required is:
        - the same data as PIEH.c
        - the normal or reference Heating Degree Days (HDD) as used in the EPC for calculating the monthly benchmark values
        - the measured HDD as provided by the local gas distribution company[23] or a meteorological station.

Monitoring and benchmarking of Heating/Cooling generation

These requirements can be set to all buildings that have not monitored the EPC label A or B benchmark.

- **PIHSt.a or PICSt.a: supply water temperature: monitor temperature while demand (for all the heat and generators and at least three rooms/zones):**
    - PI explanation: provide evidence of function of heating curve: Calculate average supply
    - temperature while at least one supplied room/zone is "in use".
    - PI function: daily average of supply water temperature while demand. For the heating curve, it should also be compared with the outdoor temperature or for low energy buildings other forecast that drive the heat demand.
    - reason for PI: indicator of heat curve functioning, for gas heaters the lower supply water temperature will increase condensation and gas heater efficiency and for heat pumps their efficiency or coefficient of performance. The lower temperature will also decrease the losses in the heat distribution systems.
    - Notes:
        - It is possible to introduce maximum supply temperature limits in the local EPBD requirements for certain types of buildings, e.g. 65 ° C). Therefore, this curve can serve as a monitoring tool for this.
        - Excessive supply temperatures can also be related to poor hydronic balancing (see distribution requirements) and under-dimensioning of radiators (see emission requirements).
    - Example: See Figure 7.

[23] For example in Belgium



Soll- und Messwerte in einem Punktdiagramm mit Bewertung der Messwerte (grün/rot)

Figure 6: Monitored supply water temperature versus the outdoor temperature (source: AMEV Empfehlung Nr. 158[22])

- **PIHeff.a and/or PICeff.a: monitor and benchmark the efficiency of the heat/cool generators:**
  - PI explanation: provide evidence of efficiency of the heat or cool generators
  - Measured when in "in use" and this measurement can only be done for hydronic heating or cooling systems and requires in that in addition flow or calorimeters to be installed.
  - PI function: Compare sub-systems relative to their defined benchmarks from Ecodesign or EPCs, for example for a heat pump the seasonal performance factor (SPFh/SPFc) should be monitored and compare it to the ErP SCOP/SEER product data and available benchmark (ErP).
  - reason for PI: indicator if the heat or cool generator is efficiently working (proper control settings, clogged heat exchanger/fan) and/or has up to date performance.
  - Notes:
    - it is possible and recommended to put a minimum heat generation efficiency in the local EPBD requirements for certain types of buildings or heaters and therefore this monitoring can be used.
    - this PI is not included in the current version of eu.bac handbook 4.
  - Example: See Figure 8.

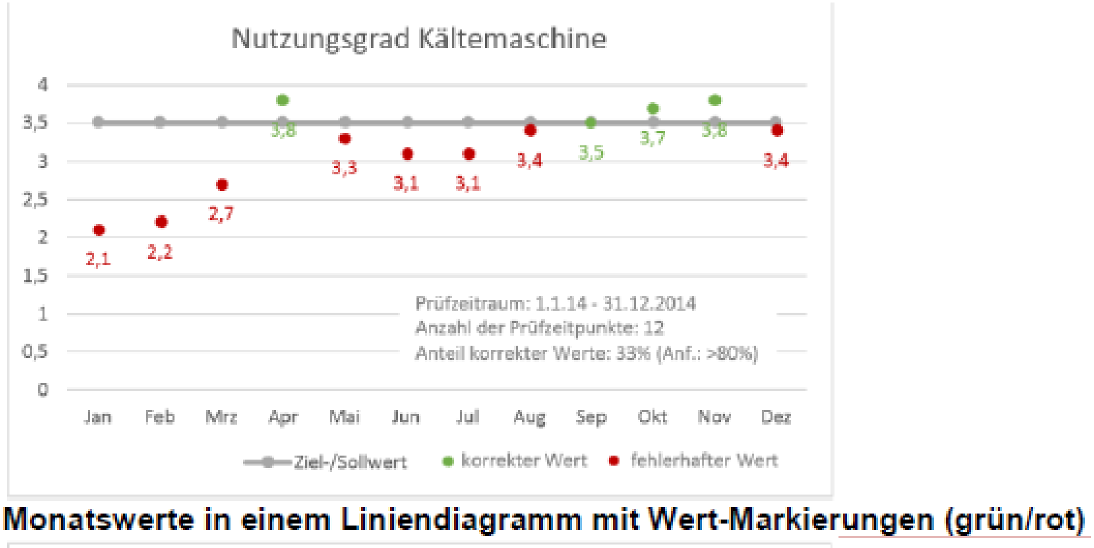


Figure 7: Monthly monitoring of the coefficient of performance of a chiller for cooling (source: AMEV Empfehlung Nr. 158[22])

Monitoring and benchmarking of Heating/Cooling distribution

These requirements can be set to all buildings that have not monitored the EPC label A or B benchmark.

- **PIHhyd.a: monitor the heating system insufficient hydronic balancing effects:**
    - PI explanation: This PI aims to monitor insufficient hydronic balancing effects and complements PIHSt.a, for more information see Annex D. Better performance can be achieved with automatic balancing, see Annex F.
    - Measured when in "in use" the proposed measurement is simple,
    - PI function: Monitoring of the hydronic health of a system by ΔT (or dT). ΔT is the difference between supply and return, either to an emitter or at a heating/cooling generator. Potential dT benchmarks are included in Annex E.
    - reason for PI: Poor hydronic balancing can cause a rise in return temperatures making the system less efficient and/or also increase the flow rate to compensate which results in more circulation pump energy consumption.
    - Notes:
        - This PI is not included in the current version of eu.bac handbook 4 and is only introduced within this study, future examples and experiences are highly welcome. The requirement was designed for simple implementation in the monitoring and benchmarking.
        - This a new proposal and method and this also means that the proposed dT limits will have to be experimentally validated in the field.

Monitoring and benchmarking of Heating/Cooling emission

These requirements can be set to all buildings that have not monitored the EPC label A benchmark.

- **KPIR.c: room/zone air temperature (overheating comfort supervision)**
  - EN 15232: 1.1 Class A, B, C
  - KPI explanation: detects "temperature" condition (e.g. overheated, too few heating supply) of room/zone – in relation to actual set-point (+ 0.5 K) and "heating controls output >0"
  - KPI function : = (PIRh.i + PIRh.j)/PIRh.a
  - daily evaluation: (daily value valid, day counts if "in use" (if (PIRh.i+PIRh.j) >0) occurred)
  - KPI evaluation: number of days where ((daily values >0.1) >20% of supervision period
    - "green" = else ()
    - "red" = number of days where (daily value >0.1) >20% of supervision period
    - "yellow" = number of days where (daily value >0.1) >10% of supervision period
  - reason for KPI: monitor room/zone temperature against actual set-point [in band, out of band] KPI might be applied without appropriate control function. Make a comment on the morning boost – for all KPIs that might be affected by any type of boost function or window draft.
  - Notes:
    - for large buildings (>290 kW) consider at least 5 zones/rooms and/or 1 per 500 m².
    - this also covers overheating thus can be combined with cooling.
    - the difference between the heating and cooling set point should be at least 4 °C.
- **KPIR.f: room/zone air temperature control after OSC (optimal start/stop)**
  - EN 15232: 1.5.2, 3.5.2 Classes A, B
  - KPI explanation: monitor room/zone (cold – or warm water supply) temperature against reaching in target temp. range [within time, out of time]
  - KPI function: = PIRh.g /1h; daily evaluation: (daily value valid, day counts if "OSC" occurred): daily values of (zero if no value):
    - green: value ≤0.25
    - yellow: value between ">0.25 and ≤0.5"
    - red: value >0.5
  - KPI evaluation: number of days where ((daily values >(0.25)) >20% of supervision period:

        - "green" = else ()
        - "red" = number of days where (daily value >0.25) >20% of supervision period
        - "yellow" = number of days where (daily value >0.25) >10% of supervision period.
    - Notes:
        - for large buildings (>290 kW) consider at least 5 zones/rooms and/or 1 per 500 m²
        - this monitoring can be combined with KPIR.c.
- **PIRh.a: cumulates daily use of room/zone**
    - PI explanation: cumulates hours of use during a day (might be several time spans during a day)
    - PI function: cumulate daily time "in use" (e.g. if "OSC" occurred). Produce for each season some graphs per day of week and compare to the planned occupancy
    - reason for KPI: Internal heat gains from occupants, ICT and lighting can have important impact on measured heating and cooling demand. Therefore, this parameter needs to complement KPIEH.c and KPIEC.c. This monitoring can also help for other energy savings related to other electrical loads monitored.
    - Notes:
        - this can be done by occupancy sensors (method 1), it is recommended to consider at least 5 zones/rooms and/or 1 per 500 m²
        - this should also be done by measuring the electrical power of office equipment, elevators and or lighting and compare per season a typical week from electrical power demand with heat/cool demand. Typical unoccupied offices use less than 25 % of the peak demand which can be used as a simple monitoring tool for occupancy
        - this parameter can be used to correct the benchmark values when provided by the local authorities.
    - Example: See Figure 9.

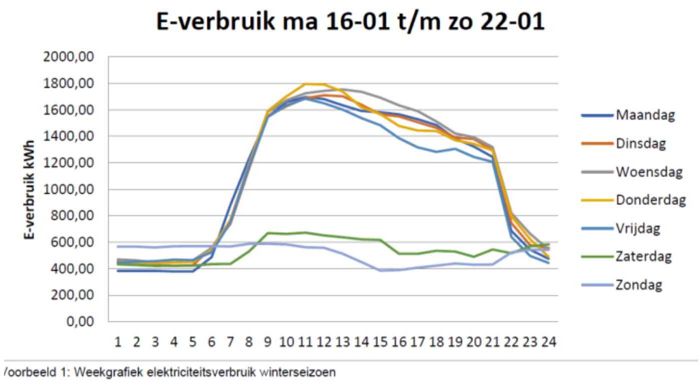


Figure 8: Hourly measured electricity use for 7 different days if the week to monitor building use (source: Dutch Government (RVO) – Guideline for BEMS (6/2020)[24])

Monitoring and benchmarking some more disaggregated parts of the HVAC system

It is possible to consider a more disaggregated approach for benchmarking, for example according to the iSERV project[25]. It addressed in more detail heating/cooling/ventilation auxiliary energy for various components of the system including some reference data with methods to detect anomalies. They identified[26] as 1st priority three energy conservation measures (ECO) with low capital cost and a short pay back, which were:

- O2.2 Shut off A/C equipment when not needed
- O2.3 Shut off auxiliaries when not required
- O3.1 Shut chiller plant off when not required

According to our review of the available iSERV benchmark data[27] in particular auxiliary electricity in heating/cooling terminal units can be significant (3-88 kWh/m²/y), in particular fan coils or DX indoor units. Also, ventilation electrical energy for air handling units (0.4-298 kWh/m²/y) has a large impact on heating and cooling demand and therefore monitoring could be justified.

Therefore, it is proposed to require as a minimum for buildings with H/C fan coils or DX indoor units or mechanical ventilation to monitor in addition:

- **PIHauxfc.a: monitor the auxiliary energy for fan coils or DX indoor units:**
    - PI explanation: This PI aims to monitor the shut off auxiliaries when not required.
    - This proposed measurement is in principle simple as it only requires an electricity submeter to be installed that covers this energy. It is only required when these units are used and when the electrical wiring allows for this.

[24] https://www.rvo.nl/sites/default/files/2020/06/handleiding-energieregistratie-en-bewakingssysteem-ebs-juni-2020.pdf

[25] https://www.iservcmb.info/iserv-results/index.html

[26] https://www.iservcmb.info/wp-content/uploads/sites/16/2018/07/Public-report-Algorithms-for-most-common-ECOs-from-measured-data.pdf

[27] https://www.iservcmb.info/wp-content/uploads/sites/16/2018/07/Total-EU-Measured-Consumptions-and-Power-Demands-by-HVAC-Component-and-Activity-Report.pdf

- PI function: Compare this energy consumption relative to the room/zone occupancy indicators (PIRh.a).
- reason for PI: Shut off auxiliaries when not required.
- Note: this PI is not included in the current version of eu.bac handbook 4, it includes other related PIs which requires different sensors. Also, iSERV provided a verification method[28] which is more sophisticated and requires more sensors. Therefore, alternative monitoring techniques can be used as provided by the sector.

- **PIHahu.a: monitor the electricity demand for the air handling units(AHU) in the building:**
  - PI explanation: Shut off H/C demand when not required.
  - This proposed measurement is in principle simple as it only requires an electricity submeter to be installed that covers this energy. It is only required when these units are used and when the electrical wiring allows for this.
  - PI function: Visualize the quarterly power demand for AHUs versus H/C demand (KPIEH.c and KPIEC.c) and occupancy indicators (PIRh.a)..
  - reason for PI: Verify for additional losses in heat or cold demand while not in use or decreased demand.
  - Notes: this PI is not included in the current version of eu.bac handbook 4, it includes other more sophisticated PIs which requires more and different sensors. Also, iSERV provided a verification method[29] which is more sophisticated and requires more sensors. Therefore, alternative monitoring techniques can be used as provided by the sector.

Heat Storage and demand response

These monitoring requirements can be set to all buildings that have a heat pump for heating. It can be required to comply with the related requirements proposed within the Ecodesign BACS study[30] for setting 'Specific minimum functionality requirements for packaged products: Minimum functionality requirements for TBS-related products with BAC functionality that claim Smart Grid capability' (see Task 7 reporting).

5.4.3 Proposal for variable inspection periods to replace the regular inspections related to Article 14/15 (6)

When the building has a measured energy consumption that is in line with the low energy building benchmark in principle it could be exempted from further inspections or audits.

[28] https://www.iservcmb.info/wp-content/uploads/sites/16/2018/07/Public-report-Algorithms-for-most-common-ECOs-from-measured-data.pdf

[29] https://www.iservcmb.info/wp-content/uploads/sites/16/2018/07/Public-report-Algorithms-for-most-common-ECOs-from-measured-data.pdf

[30] https://ec.europa.eu/energy/studies_main/preparatory-studies/ecodesign-preparatory-study-building-automation-and-control-systems_en

As a guideline the approach of Luxembourg (LU)[31] could be followed, which requires that:

- non-residential buildings: update an EPC every 3 year with measured data
- if an EPC > 140 % of the reference energy consumption then within 4 years an energy expert must draft a plan for an energy efficient renovation.

This could be applied to the proposed inspections for BACS as well, meaning that the energy expert responsible to draft a plan for an energy efficient renovation should also include the Article 14/15 audits presented in this document and thus calculate the BACS EN 15232 class and update the EPC digital data accordingly.

5.4.4 Indicative product listing and cost considerations

A selection of suitable equipment can be found in an overview of available AMEV attestations[32], from which the guidelines were also used to elaborate the performance indicators. Cost considerations are included in the Dutch Article 14/15 assessment report[33].

[31] https://guichet.public.lu/fr/entreprises/urbanisme-environnement/energie/energie/passeport-energetique.html

[32] https://www.amev-online.de/AMEVInhalt/Planen/Gebaeudeautomation/BACnet%202017/2021-01-22_Uebersicht_AMEV-Testate_Kurzuebersicht.pdf

[33] 'Onderzoek inzetbaarheid en uitwerking van Building Automation and Control Systems (BACS) onder de EU richtlijn 2018 aangaande energiebesparing in utiliteitsgebouwen (EPBD III)'(9/2019)

Annex D: Monitoring and benchmarking hydronic balancing: key performance indicators

eu.bac welcomes the interim report of the "Technical assistance study for ensuring optimal performance of technical building systems under the Energy Performance of Buildings Directive" and is grateful to the study team for the opportunity to provide feedback on the hydronic balancing aspects for ensuring optimal performance of technical building systems under the Energy Performance of Buildings Directive. We have based this feedback on both commercial and technical knowledge. Accordingly, we have considered current market conditions, design best practices and the state of the art of HVAC technology. The solutions proposed here are both technically and economically feasible. We begin by reviewing the types of system balancing, the relevant parts and types of distribution systems, possible segmentation of building types, Key Performance Indicators to verify hydronic balancing before setting out our recommendations for the different building segments. Please find our recommendations below.

DYNAMIC VS STATIC

When discussing hydronic balancing we first need to stress the importance of proper design practices. Standards for designing distribution networks for water-based cooling and heating systems specify the correct sizing of pipes and how these networks should be structured.

Two different approaches of hydronic balancing can be distinguished, static and dynamic.

Static balancing uses hand adjusted valves (manual balancing valves) to distribute the flows in the system. While this system has its uses in certain applications it is inferior when applied in systems that have varying flows.

Dynamic balancing uses valves that respond to the system conditions and loads. Commonly these valves use either mechanical or electronic compensation to ensure the pressure fluctuations in modern systems do not disrupt the temperature control. Typical valves that can be used to dynamically balance a system are differential pressure controllers, pressure independent control valves or electronic pressure independent valves. With today's technology, these types of valves are reliable, widely available, and cost-efficient. Therefore, any legislation should drive towards greater adoption of dynamic balancing where technically and economically feasible. Dynamic balancing improves both energy efficiency and temperature control stability. Nevertheless, static balancing is better than no balancing. Therefore, a general adoption of good hydronic balancing practices should be encouraged regardless of the approach.

DISTRIBUTION AND EMISSION LEVEL

Distribution in the system is generally understood to be the piping that brings the water from the generator, boiler, or chiller, to the terminal unit, for example, a radiator, fan coil unit or floor heating manifold.

Terminal units are where the energy is exchanged. These could be radiators, fan coil units, or radiant panels. The exchange is normally controlled through temperature control. To ensure the correct flow, terminal units are usually equipped with some form of balancing. This is referred to as "emitter level balancing".

The interaction between distribution and emission can be complicated. Changing loads in the system (distribution) might result in different conditions on the emitter level which could impact temperature controls. However, dynamic balancing can counter these fluctuations. Additionally, advanced balancing components, like pressure independent control valves, can independently compensate for these fluctuations. Therefore, they usually do not need balancing on the distribution level, which can result in significant cost savings.

SEGMENTATION OF BUILDINGS

In the shared Excel on heating systems, the buildings are grouped into residential, non-residential, small buildings and large buildings (column Y to AB). We would propose a different grouping as this would better reflect market conditions, solutions and how big the impact would be of any measures introduced.

Our grouping proposal would be as follows:

<u>Single-/two family houses:</u>

A single or semi-detached house equipped with an individual heating/cooling system. Typically, these would be privately owned.

The often-private ownership of this residential group means that legislation for upgrading the existing building stock will be difficult and costly to enforce. Information campaigns combined with subsidies might be the most effective approach together with putting forward requirements for new buildings.

<u>Multi-family residential:</u>

Apartment buildings or flat blocks that contain multiple apartments and have centralized heating- and/or cooling system. We recommend that when drafting legislation this group is limited to buildings with centralized systems of 70 kW and bigger, to stay in line with the EPDB. Apartment buildings have different ownership structures and therefore the incentives vary from one model to other. Where ownership is centralized, the legislation would be sufficient, however, where ownership is fragmented- access to finance, additional incentives and proper information distribution must be ensured based on local particularities.

Note: If an apartment building or flat block has individual heating- and/or cooling system per apartment, it would for all intents and purposes be a single-family house.

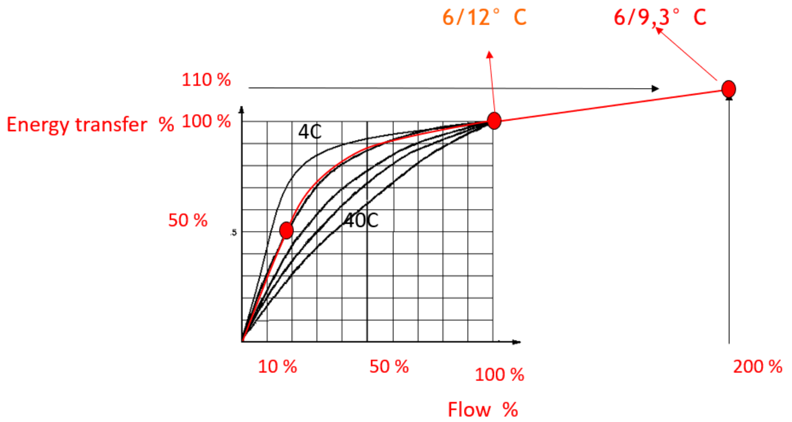
<u>Non-residential:</u>
We propose to split up non-residential in properties with systems <70 kW, properties with systems between 70 and 290 kW, and >290 kW, to stay in line with the EPDB. This group of course contains many different buildings with different purposes, like shops, schools, offices, workshops, hotels, factories, or airports, etc. Therefore, some granularity might be required when implementing measures to encourage energy efficiency. However, for this recommendation, we assume that the impact of proper hydronic balancing will be bigger and more meaningful if the system is larger and we assert that this generalization holds, regardless of function.

KEY PERFORMANCE INDICATORS:

eu.bac has been asked to give recommendations on how hydronic balancing could be verified during the operation of the building and how BACS could contribute to monitoring and maintaining proper water distribution in the system.

Fortunately, there is an easy to measure and monitor dimension that would be a good indication of the hydronic health of a system: ΔT and/or flow rate. Whilst flow rate is a clear and well-known parameter, ΔT is the difference between supply and return, either to an emitter or groups of them or at a heating/cooling generator. The simplified formula is $P(watt) = \frac{\Delta T(K) * Q(l/h)}{0,86}$

Considering emitters, increasing the flow only increases the output significantly if it is within the design specifications. In most cases doubling the flow through an emitter beyond those design specifications would increase the output by only about 10%. In simple terms, this is because the speed of the flow through the emitter is so high there is no time for energy to be efficiently transferred. Any additional flow through the emitter will serve mostly to reduce the ΔT. In summary, if we monitor the ΔT and the ΔT is smaller than the design parameters we know there is a flow in the system that exceeds design parameters.



Additionally, a high ΔT has an impact on the heating/cooling generators. If we consider boilers, then we can say that if the return temperature is higher than 60 °C the efficiency drops ~10%. Chillers generally operate more efficiently when the ΔT is higher. This means that usually supply and return temperatures for boilers and chillers are already monitored and maintained. Therefore, we can see that an installation is properly balanced if the ΔT is under control.

Temperatures are also easy and cheap to measure with BACS which are perfectly suited for measuring, monitoring, logging, and maintaining temperatures. With these being some of the core functions of BACS many data points are already available and actively maintained.

We can also conclude that a more granular measuring of ΔT would result in a more precise view. Measuring only the central supply and return temperatures, can provide a general view of the hydronic health of the system. Meanwhile measuring the ΔT on the distribution level could identify which section of the system has an overflow. Finally measuring the ΔT on each emitter or group of them, can identify which emitter is problematic. Additionally, the ΔT can function as an indicator for several maintenance issues that can arise, such as the fouling of heat exchanger coils and filter pollution.

Notes:

1. The actual ΔT that needs to be maintained is dependent on the design of the system. There is a difference between cooling and heating, however also the terminal unit (emitter) can have a big impact on what the actual ΔT should be.

The ΔT for a radiator could be 20 k while for floor heating it could be only 2-3 K. It is therefore impossible to set a fixed value for the ΔT in legislation, but it would be possible to link it to design conditions.

2. Measuring ΔT in a more granular way is a market trend. This trend is fueled by the increasing adoption of green building standards, such as LEEDS and BREEAM which require ΔT management to guard efficiency. BREEAM encourages the charting of energy flows in buildings which requires knowing the ΔT(see formula above).
3. While a ΔT can be too small a deviation upwards is not an issue. When modulation is used (valves have not only the position open or closed but also many intermediate positions) in modern systems it is possible the ΔT will increase significantly. This should be accepted as a signal that the system is working properly.

VERIFICATION DURING PLANNING, CONSTRUCTION AND HANDOVER:

Changes during planning, errors in calculation, installation, and commissioning lead to the fact that in HVAC systems the generators, distribution and consumers are not optimally balanced. This leads to large energy losses and a loss of thermal comfort.

It is also a fact that the lack of thermal comfort caused by insufficient balancing could be solved in an unskilled way which would increase the energy use of the building. For example, an underflow in parts of the system that is caused by overflows in other parts should be solved by redistributing the water by balancing the system. However, it is not uncommon for it to be solved by increasing the setting on the pump or even mounting a bigger pump, causing additional excessive energy use, and potentially causing other problems like noise.

It is therefore crucial that during planning and construction the system is designed to allow hydronic balance and that when the project is handed over to the end-user proper documentation is handed over to report that shows that the settings on the valves are done properly and that any necessary measurements are executed.

RECOMMENDATIONS

Considering all the above we recommend that the following requirements will be put in place, grouped by the building segmentation mentioned above:

<u>One/two-family buildings:</u>

Phase 1: Planning/construction (new-built or major renovation of the technical system)

- it must be shown that all emitters have a provision for setting/limiting the flow required for that specific emitter

Phase 2: Handover

- A commissioning report must be handed over that specifies the flow per emitter and the setting used to achieve the design flow
- A calculation must be included with the handover to show the settings needed for each emitter, according to design conditions

Phase 3: Operation

- We do not propose further measurements during operation.

Notes:

1. When the system is heated by a condensing boiler additional measures could be considered to maintain a return temperature below the condensing temperature. However, most modern condensing boilers already contain an algorithm that lowers the supply temperature when the return becomes too high.
2. If the system is heated/cooled with a heat pump ΔT is a crucial dimension to maintain COP. However, also here usually these contain certain algorithms to ensure they don't become too small.

<u>Multi-family residential >70 kW:</u>

Changes in use, change of tenants, etc. always lead to changes in the thermal energy demand. This must be considered accordingly.

Phase 1: Planning/construction (new-built or major renovation of the technical system)

- It must be shown that all emitters have a provision for setting/limiting the flow required for that specific emitter
- The valves must be mounted in a place that is easily accessible for adjustments if necessary
- To allow for the wide load fluctuations which occur during operation, dynamic balancing methods should be strongly encouraged, therefore:
    - Dynamic (pressure-independent) valves should be used on each emitter or
    - The distribution should be dynamically balanced, for example by differential pressure controllers or,
    - A calculation must show that this is not economically feasible (payback time > 5 years)
- Flow rate and/or ΔT monitoring and logging must be included in the design on a central level (heating/cooling generation) to ensure efficiency

Phase 2: Handover

- A dimensioning calculation must be handed over that shows the proper flow and setting for each emitter as well as the expected ΔT
- A report specifying the settings made for each emitter and distribution balancing valve
- During the sizing and dimensioning the ΔT for that particular TBS needs to be determined by the designer using standard design practices, considering the design temperature regimes, the selected emitters and load variances.
- The circulation pump must be optimized either by:
    - Making a central measurement (total flow) with all the emitters on full load and reducing the pump setting until the right flow is achieved or
    - After opening all the emitters to full flow, the available differential pressure is measured at the furthest point in the system (longest pipe/highest resistance) and the pump setting reduced to achieve the correct differential pressure

Phase 3: Operation

- During operation ΔT on the system needs to be maintained at the specified value or higher. Lengthy and/or regular low ΔT should be signaled in the installation as an alarm and addressed

Notes:

1. In many cases, energy meters are installed per apartment to be able to bill individual tenants. In that case, the flow rate and ΔT per apartment is available since the energy meters need to measure it to determine the energy use of the apartment. In that case, central flow rate and/or ΔT measurement might not be needed since it can be done on a more granular level. It would still be necessary to monitor the ΔT and address any anomalies.

<u>Non-residential <70 kW</u>

We recommend that these buildings are treated the same as one/two-family buildings

<u>Non-residential >70 kW and < 290 kW:</u>

We recommend that these are treated the same as multifamily residential > 70 kW

<u>Non-residential >290 kW</u>

Changes in use, change of tenants, etc. always lead to changes in the thermal energy demand. According to EPBD2018 Art. 14 & 15 Abs.4, a) the energy consumption must be continuously monitored, logged, analyzed and its adjustment must be enabled.

Phase 1: Planning/construction (new-built or major renovation of the technical system)

- it must be shown that all emitters have a provision for setting/limiting the flow required for that specific emitter
- The valves must be mounted in a place that is easily accessible for adjustments if necessary
- To allow for the wide load fluctuations which occur during operation, dynamic balancing methods should be strongly encouraged, therefore:
    - Dynamic (pressure-independent) valves should be used on each emitter or
    - A calculation must be shown that such is not economically feasible (payback time > 5 years)
- Differential pressure sensors for adjusting the pump speed must be correctly placed in the installation. Either on 2/3 of the farthest unit or each branch should have their own pressure sensors
- Flow rate and/or ΔT monitoring and logging must be included in the design on emitter level or groups of emitters

Phase 2: Handover

- A dimensioning calculation must be handed over that shows the proper flow and setting for each emitter as well as the ΔT
- A report specifying the settings made for each emitter and distribution balancing valve
- The circulation pump must be speed controlled based on the pressure controllers and needs to be optimized so that at full load the lowest possible setting is realized

Phase 3: Operation

- During operation flow rate and/or ΔT on the system needs to be continuously monitored and logged for every emitter or groups of emitters and on the heating/cooling generation
- Procedures must be in place for signaling and responding to over/under flow and low ΔT situations

Annex E: Design supply and return temperatures – proposed minimum delta T requirements for hydronic balancing

Design temperature classes for the Dutch NTA 8800 (2020) (Table 9.14) and a proposal for minimum dT limits and maximum hours per year that they can be exceeded.

Due to the negative impact on system energy efficiency it is not recommended to allow design temperature classes 75/65, 80/60 and 90/70.

design temperature class	design supply T(°)	design dT(°)	dT(°) limit value	Max. h/y above limit
30/27	30	3	*1*	*120*
35/30	35	5	*1,5*	*120*
40/35	40	5	*1,5*	*120*
45/40	45	5	*1,5*	*120*
50/42	50	8	*2,5*	*120*
55/47	55	8	*2,5*	*120*
65/55	65	10	*3*	*120*
75/65	*75*	*10*	*3*	*120*
80/60	*80*	*20*	*3*	*120*
90/70	*90*	*20*	*3*	*120*

Note: values for dT and Max. hour per year (h/y) are indicative. These limits cannot be generalized and require considering multiple factors beyond design temperature class, supply T and dT. A method should be used to determine this limit considering the emitter type, time allowances for transgression (f. ex. during a reset) speed of the emitter, actual conditions and type of controls among others. Such methods should be further documented by the sector and build on field data. The designer of the building should use best practices to arrive at these values. .

Annex F: Types of hydronic balancing and assumed impact

When discussing hydronic balancing we first need to stress the importance of proper design practices. Standards for designing distribution networks for water-based cooling and heating systems specify the correct sizing of pipes and how these networks should be structured.

Two different approaches of hydronic balancing can be distinguished, static and dynamic.

Static balancing uses hand adjusted valves (manual balancing valves) to distribute the flows in the system. While this system has its uses in certain applications it is inferior when applied in systems that have varying flows.

Dynamic balancing uses valves that respond to the system conditions and loads. Commonly these valves use either mechanical or electronic compensation to ensure the pressure fluctuations in modern systems do not disrupt the temperature control. Typical valves that can be used to dynamically balance a system are differential pressure controllers, pressure independent control valves or electronic pressure independent valves. With today's technology, these types of valves are reliable, widely available, and cost-effective. Therefore, any legislation should drive towards greater adoption of dynamic balancing where technically and economically feasible. Dynamic balancing improves both energy efficiency and temperature control stability. Nevertheless, static balancing is better than no balancing. Therefore, a general adoption of good hydronic balancing practices should be encouraged regardless of the approach.

More information on the estimated impact of various types of hydronic balancing can be found for example in the Dutch standard NTA 8800:2020 in Table 9.2.

Annex G: AMEV monitoring requirements

Source:

https://www.amev-online.de/AMEVInhalt/Planen/Monitoring/TechnischesM/2020-08-01_Technisches_Monitoring_2020.pdf

Prüfgrößen Gebäude	**Zielwert**	**Messung [Einheit]**		**Anmerkung**
Elektr. Energieaufnahme aus dem Netz	Max. 450.000 kWh/a	Zählerstand	[kWh]	
	Max. 90 kWel	Momentane Wirklast	[kW]	
Einspeisung elektr. Energie in das Netz	Min. 100.000 kWh/a	Zählerstand	[kWh]	Netz-Einspeisezähler
Erzeugung elektr. Energie aus PV	Min. 180.000 kWh/a	Zählerstand	[kWh]	Einspeisezähler PV
Gasverbrauch	Max. 700.000 kWh/a	Zählerstand	[m³]	Wärmeäquivalent
Heizenergiebedarf	Max. 70 kWh/m²	Berechnung	[kWh/m²]	Bezugsfläche NRF
Trinkwasserverbrauch	Max. 250 m³/a	Zählerstand	[m³]	
Außenlufttemperatur		Messung	[°C]	
Prüfgrößen Gasbrennwertkessel	**Zielwert**	**Messung [Einheit]**		**Anmerkung**
Gasverbrauch	Max. 70.0000 m³/a	Zählerstand	[m³]	
Erzeugte Wärmemenge	Max. 700.000 kWh/a	Zählerstand	[kWh]	
Nutzungsgrad therm. (Mindestwert)	> 90%	Berechnung	[-]	Bewertung pro Tag, Bewertung im Probebetrieb
Betriebestunden	3.500 h/a	Zählerstand	[h]	
Betriebestarts	5.000 /a	Zählerstand	[Anzahl]	
Betriebestarts je Betriebestunde	< 1,5	Berechnung	[-]	Bewertung pro Tag, Bewertung im Probebetrieb
Vorlauftemperatur	75°C ± 3K	Messung	[°C]	80% korrekte Werte bei 96 Messwerten am Tag, Bewertung im Probebetrieb
Rücklauftemperatur	< 45°C	Messung	[°C]	80% korrekte Werte bei 96 Messwerten am Tag, Bewertung im Probebetrieb
Außenlufttemperatur		Messung	[°C]	Momentane Außenlufttemperatur und gleitender Mittelwert 24h
Prüfgrößen Heizkreis 1	**Zielwert**	**Messung [Einheit]**		**Anmerkung**
Betriebsmeldung der Umwälzpumpe	Freigabekriterium TAußen<18°C		[-]	Pumpe muss ausgeschaltet sein, wenn die Außenlufttemperatur über der Heizgrenztemperatur liegt, Bewertung im Probebetrieb
Vorlauftemperatur	Kennlinie TVL/TAußen: (70/-12:30/20); Toleranz: ± 2K	Messung	[°C]	80% korrekte Werte bei 96 Messwerten am Tag. , Bewertung im Probebetrieb
Rücklauftemperatur	Kennlinie TRL/TAußen: (50/-12:30/20); Toleranz: ± 5K	Messung	[°C]	80% korrekte Werte bei 96 Messwerten am Tag, Bewertung im Probebetrieb
Außenlufttemperatur		Messung	[°C]	Momentane Außenlufttemperatur und gleitender Mittelwert 24h

Tab. 1 Prüfgrößen für Gebäude und Anlagen (Beispiel)

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