Inspection and audit of air conditioning facilities
AuditAC

“Field benchmarking and Market development for Audit methods in Air Conditioning”

Is a project:

Supported by

The sole responsibility for the content of this publication lies with the authors. It does not represent the opinion of the European Communities. The European Commission is not responsible for any use that may be made of the information contained therein

AuditAC web site: http://www.eva.ac.at/projekte/auditac.htm
AuditAC participants:

France (Project coordinator)
Armines - Mines de Paris

Austria
Austrian Energy Agency

Belgium
Université de Liège

Italy
Politecnico di Torino

Portugal
University of Porto

Slovenia
University of Ljubljana

UK
Association of Building Engineers

BRE
(Building Research Establishment Ltd)

Welsh School of Architecture

Eurovent-Certification

AuditAC training package
What is air conditioning audit for?

1) Detect the source of degradation of the performance (the system doesn’t stop operating but use more energy and/or is not able to guarantee the comfort)

2) Find profitable improvements in money and energy savings.
General Structure

Session 1: Air conditioning systems
Session 2: The Inspection of the air conditioning systems
Session 3: Definitions for air conditioning facilities audit and benchmarking
Session 4: Energy conservation opportunities for an air conditioning plant
Session 1
Air conditioning systems

AUDITAC training package
Air conditioning systems

- Air conditioning fundamentals and classification
- A simple method for air conditioning recognition
- The air conditioning market in Europe: facts and figures
Basic function and components

A system based on vapour compression cools a fluid vector (refrigerant, air or water) in order to cool a building or a zone of a building transferring the heat extracted from the inside to the outside, spending work of compression.
Different levels of air conditioning

**Partial Cooling**, which is obtained with air conditioning equipment that provides partial control of the temperature and none of moisture. For instance, the rooms are cooled, but the fresh air is introduced without having been cooled and dried. In such cases also, the installed cooling capacity of the AC system may be insufficient for all circumstances, as a result the internal air cannot be kept at a constant temperature.

**Total Cooling**, wherein the AC system provides full temperature control and includes the provision of the minimum rate of ventilation air changes required for hygienic purposes at an adequate temperature. This type of equipment allows a degree of dehumidification consequent to the cooling effect– it is a very frequent level of comfort today.

**Total Air Conditioning**, which includes full control of temperature and humidity as well as provision of the minimum ventilation rate required for hygienic purposes but is not capable of attaining air purity conditions for specific IAQ (Indoor Air Quality) levels.

**Advanced Air Conditioning**, same as TAC but with a full control of IAQ. These systems are particularly applied in hospitals or clean rooms in the electronic industry.
Different levels of air conditioning

Air conditioning can also:

- Provide heating: reversible systems can supply cooling and heating in winter and summer or, for some system types, cooling and heating at the same time to different zones.

- Provide controlled ventilation: the ventilation is integrated with the A/C system and the overall system introduces the fresh air and treats it. Heat and coolth recovery from the extracted air is possible.

A large variety of system and technologies exist with different possibilities.
General classification

AUDITAC training package
LOCAL OR CENTRAL

? -> LOCAL
  - ROOM BY ROOM
    - RAC
  - SERIES OF ROOMS
    - PACKAGE
      - Rooftop
  - BUILDING
    - Other
      - CAC

FLUID: AIR ONLY
  - A.H.U.s and DUCTWORK

FLUID: AIR AND WATER
  - INDUCTION UNITS
  - FAN-COIL UNITS
  - MIXING
    - Displacement
    - CAV
    - VAV
  - Chilled ceiling
  - 2 pipes
  - 3 pipes
  - 4 pipes

FLUID: REFRIGERANT
  - MULTI-SPLIT
  - VRF

WLHP
Primary System

- Boilers
- Compression or absorption Chillers
- Air or water cooled condenser
- Dry/wet, with/without direct contact cooling towers
- Condenser heat recovery
- Stratified or ice cold storage
- Solar energy
HVAC System Overview

All-air systems
- Single duct system (including multi-zone)
- Dual duct system
- Single duct, terminal reheat
- Constant volume (with separate heating)
- Variable Air Volume (with separate heating)

DX systems
- Direct expansion (DX) single split system
- Direct expansion (DX) multi split system
- Water loop heat pump
- VRF

DX systems
- Fan coil system
  - 2-pipe
  - 3-pipe
  - 4-pipe
- Two pipe ceiling system change over (includes passive beams)
- Four-pipe ceiling system
- Embedded systems
- Air handling unit

Induction system
- Active beam ceiling system
- 2-pipe non change over
  - 2-pipe change over
  - 3-pipe
  - 4-pipe

Water-based systems
- Room unit & Single duct ventilation
- Water loop heat pump
Different air conditioning components and systems in an office building

- AHU with heat recovery
- Fan Coils Units
- Chilled beams system
- Boilers
- Cooling tower
- All air system with mixing box
- Split system
- Water cooled Chillers
Systems description

Packaged units
Split systems and variable refrigerant flow
Chillers
Water loop heat pump
Cooling towers
Mechanical ventilation and air handling units
Packaged units

AUDITAC training package
Zone equipped with a mobile packaged unit
Zone equipped with a window unit
Air cooled packaged system

Conditioned air

Building with grilles

Vivitiated air

Air condenser integrated (A) or not (B)

Air cooled packaged unit

LEGEND

- Water
- Air
- Refrigerant
- Expansion valve
- Compressor
- Condenser
- Evaporator
- Cooling tower

AuditAC training package
Water cooled packaged system (water from network or natural source)

Legend:
- Water
- Air
- Refrigerant
- Expansion valve
- Fan
- Compressor
- Condenser
- Evaporator
- Cooling tower

Network (G) or natural source (F)

Conditioned air

Building with grilles

Vivitiated air

Water cooled packaged unit
Water cooled packaged system
(with cooling tower)

LEGEND

- Water
- Air
- Refrigerant

- Expansion
- Valve
- Fan
- Compressor
- Condenser
- Evaporator
- Cooling
tower

AuditAC training package
Rooftop: source
www.trane.com

Packaged unit: source
www.liebert-hiross.com
Split systems and variable refrigerant fluid (VRF)
Zone equipped with a split unit
Zone equipped with a multi-split unit
Zone equipped with a variable refrigerant flow system

LEGEND

- Water
- Air
- Refrigerant
- Expansion valve
- Fan
- Compressor
- Condenser
- Evaporator
- Cooling tower
- 4-ways valve
Split system example:
source  www.airwell.com
Chillers

AUDITAC training package
Air cooled chiller with fan coil units (FCU)

LEGEND

- **Water**
- **Air**
- **Refrigerant**

- **Expansion valve**
- **Fan**
- **Compressor**

- **Condenser**
- **Evaporator**
- **Cooling tower**

Air condenser integrated (A) or not (B)

Air cooled chiller
Air cooled chiller with air handling unit (AHU)

LEGEND

- Water
- Air
- Refrigerant

- Expansion valve
- Fan
- Compressor
- Condenser
- Evaporator
- Cooling tower

Air condenser

Air cooled chiller

AHU

Building with grilles

Vitiated air
Air cooled chiller with chilled ceiling

Chilled ceiling

Building

AuditAC training package
Air cooled chiller with passive beams

Legend:
- Water
- Air
- Refrigerant
- Expansion valve
- Fan
- Compressor
- Condenser
- Evaporator
- Cooling tower

Air condenser
Air cooled chiller
Air cooled chiller with active beams

Fresh air from an AHU

Active beams

AuditAC training package
Screw air cooled chiller, courtesy of Carrier
Water cooled chiller with fan coil units (FCU) (water from network or natural source)

LEGEND

- Water
- Air
- Refrigerant
- Expansion valve
- Fan
- Compressor
- Condenser
- Evaporator
- Cooling tower

Network (G) or natural source (F)

Water cooled chiller

FCU
Screw chiller water-cooled (source: www.carrier.com)
Water cooled chiller with air handling unit AHU (water from network or natural source)
Water cooled chiller with air handling unit AHU (with cooling tower)
Water cooled chiller with air handling unit AHU (with cooling tower)

LEGEND

- dotted line: Water
- solid line: Air
- solid line with arrow: Refrigerant

- diamond: Expansion valve
- circle: Fan
- square: Compressor
- cross: Condenser
- rectangle: Evaporator
- square with diagonal line: Cooling tower

Water cooled chiller

AHU

Building with grilles

Vivitiated air
Water loop heat pump

AUDITAC training package
Water loop heat pumps

Legend:

- Water
- Air
- Refrigerant

Expansion valve
Fan
Compressor
Condenser
Evaporator
Cooling tower

Cooler
(cooling system, cooling tower…)

Heater
(heat exchanger, boiler…)

AuditAC training package
The cooling towers
Dry cooling tower

Water cooled air-conditioning system

LEGEND

- Water
- Air
- Refrigerant
- Expansion valve
- Fan
- Compressor
- Condenser
- Evaporator
- Cooling tower

Air/water heat exchanger
Water cooled air-conditioning system

Wet cooling tower

LEGEND

- Water
- Air
- Refrigerant
- Expansion valve
- Fan
- Compressor
- Condenser
- Evaporator
- Cooling tower

Droplet filter
Spray
Heat exchanger
Collection basin
### Water cooled air-conditioning system

#### Wet/Dry cooling tower

- **Expansion valve**
- **Fan**
- **Compressor**
- **Condenser**
- **Evaporator**
- **Cooling tower**

#### LEGEND

- **Water**
- **Air**
- **Refrigerant**

#### Diagram Details

- **Droplet filter**
- **Spray**
- **Heat exchanger**
- **Collection basin**
Cooling tower: source
www.arctichill.com
Mechanical ventilation and air handling units (AHU)
Ventilation system with CO2 detector without cooling

Legend:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>⃣→</td>
<td>Water</td>
</tr>
<tr>
<td>←�</td>
<td>Air</td>
</tr>
<tr>
<td>←⃣</td>
<td>Refrigerant</td>
</tr>
<tr>
<td>⮔</td>
<td>Valve</td>
</tr>
<tr>
<td>⮧</td>
<td>Damper</td>
</tr>
<tr>
<td>⮕</td>
<td>Filter</td>
</tr>
<tr>
<td>⮜</td>
<td>Fan</td>
</tr>
<tr>
<td>⮜</td>
<td>Pump</td>
</tr>
<tr>
<td>⮤</td>
<td>Command</td>
</tr>
</tbody>
</table>

Outdoor intake → Filter → Supply air

Exhaust to outdoor → Filter → Extract air

CO₂ sensor
Air Handling Unit – Constant Air Volume

Legend:
- Water
- Air
- Sensor
- Valve
- Fan
- Pump
- Damper
- Filter
- Command
- Temperature

Outdoor intake

Mixing box

Exhaust to outdoor

Supply air

Water from chiller

Extract air

AuditAC training package
### Air Handling Unit
- **Variable Air Volume**

**Legend**
- Water
- Air
- Sensor
- Valve
- Fan
- Pump
- Damper
- Filter
- Command

**Diagram Description**
- **Outdoor intake**
- **Mixing box**
- **Supply air**
- **Exhaust to outdoor**
- **Extract air**
- **Water from chiller**

---

AuditAC training package 51
AHU: source
www.hydronic.com
How to recognize the installed system
Two methods to recognise the systems

A 5-STEP METHOD TO DETERMINE THE TYPE OF INDOOR HEAT REMOVAL OF AN AIR-CONDITIONING SYSTEM
Type of system

Fluid link between systems

One air conditioning system per room

Refrigerant (low diameter pipes)

Carrier between the building and the plant room?

Water (medium diameter pipes)

Chiller

Carrier?

Water

Chilled water

Chiller + FCU

Cooled water

Ceiling systems/ beams

VRF

Multisplit

Water loop heat pump system

Single split system

Window (fixed packaged unit)

Mobile packaged unit

One air conditioning system treating several rooms

Air (direct or indirect by high diameter ducts)

Packaged unit

Location of the chiller system?

Inside

Roof

Packaged unit

Rooftop

AuditAC training package
Two methods to recognise the systems

A 4-STEP METHOD TO DETERMINE THE TYPE OF HEAT REJECTION OF AN AIR-CONDITIONING SYSTEM
Fan integrated in the cold generating equipment:

- Yes
  - Refrigerant (low diameter pipes)
  - Fluid link between the system and the outside?
    - Yes
      - Collection basin under the cooling tower?
        - Yes
          - Cold generating equipment
        - No
          - Origin of the sprayed water?
            - Wet cooling tower
            - Integrated air condenser
          - Independent circuit
          - Non-integrated air condenser
          - Wet/dry cooling tower
          - Network water condenser
          - Dry cooling tower
          - Natural water condenser
    - No
      - Open
      - Type of water loop?
      - Lake, river
      - Water network
      - Water network condenser

- No
  - Closed (cooling tower)
  - Type of water loop?
    - Yes
      - Collection basin under the cooling tower?
        - Yes
          - Cold generating equipment
        - No
          - Origin of the sprayed water?
            - Wet cooling tower
            - Integrated air condenser
          - Independent circuit
          - Non-integrated air condenser
          - Wet/dry cooling tower
          - Dry cooling tower
          - Network water condenser
          - Natural water condenser
The air conditioning market in Europe: facts and figures

AUDITAC training package
Figures from EECCAC project
Energy Efficiency and Certification of Central Air Conditioners

A “SAVE” project ended in 2001
13 participants from 8 countries including the EU manufacturers' association Eurovent gathered to identify measures to achieve a better Energy Efficiency of chillers and A/C systems (> 12 kW).

RESULTS
Definitions of all CAC systems found on the EU market given.
Chillers based systems as the main element of the stock
Present Energy Efficiency efforts have been reviewed
Optimisation of a chiller to improve its EER on the basis of capacity cost only
Optimisation of a chiller for its least LCC (Life Cycle Cost)
Packaged units can also be improved a lot
Part load performance quantified for the first time in Europe
The air conditioned surface in Europe: estimation of the stock to 2020 from EECCAC

COOLED AREA IN Mm²

AuditAC training package 60
A few key figures -1

• Chillers and Room Air Conditioners represent some 45% and 36% of the market respectively in 1998.
• Spain and Italy were the largest national central air conditioning markets in the EU in 1998 with 24% and 25% of the EU market respectively.
• France, Germany and the UK each had about 10% of the EU market.
A few key figures -2

- USA and EU are not the same market
A few key figures -3
European market shares for centralised technologies in 1998

- Chillers: 71%
- Packages: 8%
- Rooftops: 7%
- VRF: 3%
- Splits >12kW: 11%

AuditAC training package
Subsystems on the market with chillers

- Chillers: 71%
- Splits >12kW: 11%
- Packages: 8%
- Rooftops: 7%
- VRF: 3%

- Air (AHU): 39%
- Classic (FCU): 58%
- Nat, Water: 1%

Two loops: 2%
Offices and trade are the largest users of A/C in general.
Sectors and systems: chillers are the most spread

AuditAC training package
Primary equipment efficiency

The best on market is always 20-50% better than the average

Ex: Rooftops
The market confirms: no size effect on EER but types – note distinct temperature regime for testing

![Graph showing EER vs. Cooling capacity with linear trendlines for air and water cooled systems. The R² values for air cooled and water cooled are 0.0003 and 0.0073 respectively.](image-url)
Optimisation of equipment for its least LCC (Life Cycle Cost)
Packaged units can also be improved a lot. Systems built around chillers have even more improvement margins.
Concentration of efforts on Air based distribution systems

ALCC Euros/m²/year

SPECIFIC CONSUMPTION

kWh/m²/YEAR

AuditAC training package
Indicating the SEER in the Eurovent directory

It is proven that each set of outside conditions (for each sector, climate, type of chiller, type of secondary system) can be reduced to four or five external conditions without loss of accuracy.

The ESEER index is a set of 4 conditions given for E.U. as a whole, but there are as many similar indices as specific demands: sector, country, etc.
Perspectives of market transformation

• Provision of information (labelling, grading, efficiency ratings) based on EER and very soon on ESEER

• Removing less efficient models from the market (MEPS in building codes or Eurovent voluntary agreements)

• Encouraging higher efficiency levels through negotiated agreements (e.g. fleet-average efficiency targets)

• Public buildings and general market transformation programmes

• The development of an EU model building code that addresses air conditioning amongst other energy end-uses. (an EU equivalent to ASHRAE 90.1)
Session 1
Air conditioning systems

Back to main

AUDITAC training package
Session 2
The Inspection of the air conditioning systems
• Main aspects of the European Energy Performance of Buildings Directive (EPBD)
• Articles of the European Energy Performance of Buildings Directive
• The CEN standard on AC inspection
Main aspects of the European Energy Performance of Buildings Directive

⇒ To respond to the Kyoto objectives of reduction of CO$_2$

EU Member States (MS) shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive at the latest on 4 January 2006

MS may ask for an additional period of three years to apply fully the provisions of Articles ⇒ 2009.
What does the Directive require?

The EPBD impacts on the energy auditing of air-conditioning systems in two ways:
• directly, a mandatory inspection ("pre-audit" in the terminology of Auditac)
• indirectly, through a separate requirement to provide recommendations for improvements to energy efficiency

The latter requirement implicitly calls for the analysis that both mandatory pre-audits and more comprehensive energy audits can provide.
Compulsory inspection: why?

The compulsory inspection of air-conditioning systems is clearly targeted at improving the energy efficiency of systems. Its main impact is likely to be on those systems that are not already subject to effective operation and maintenance procedures. This does not mean that more detailed (and more expensive) energy audits may not be justified - indeed, inspection may identify situations where this seems likely to be worthwhile.

The underlying purpose of Article 9 is to initiate a continuous improvement process that will set up higher quality standards in air conditioning: either diagnosis and correction of existing systems operation (in the short term) or audits followed by investments and improvement works (in the longer term). It should provide a sound basis for the work of professionals: operators, auditors, and contractors.
**Compulsory inspection: what does it cover?**

Article 2 of the EPBD - definition of an “air conditioning system”:
“a combination of all components required to provide a form of air treatment in which the temperature is controlled, possibly in combination with the control of ventilation, humidity and air cleanliness.”

The inspection includes:
- all types of comfort cooling and air conditioning systems that provide a total cooling output for the building above the specified 12 kW
- the associated water and air distribution and exhaust systems
- the controls that are intended to regulate the use of the systems.

It excludes:
- mechanical ventilation
Compulsory inspection: how?

Member States have freedom to define detailed ways of complying with the Directive, but work is in hand (including the Auditac project) to establish agreement on recommendations for essential minimum requirements, and on what constitutes good practice.

The CEN draft standard prEN 15240 is an important part of this effort. It was published in 2005 for "enquiry" - that is, for comments to be received from Member States' standardisation bodies. The draft has been revised in the light of comments received and is expected to be published for voting during 2007.
Compulsory inspection: how?


This draft standard gives details for inspection of air conditioning systems, and of the associated air distribution and exhaust systems. It comprises a "normative" (mandatory) standard plus several "informative" annexes that describe recommended procedures, checklists etc.
**Certification of the energy performance of a building : why?**

For sale or rental of new buildings:
- Energy efficiency from design in comparison between benchmark values
- Can be based on an integrated calculation that is also used to set minimum standards for new buildings.

For existing buildings:
- Can be based on measured consumptions,
- Or use measured consumptions to identify those poorly-performing buildings that justify further assessment.

The certificate is accompanied with recommendations for improvements.

Different interests of owners and occupants: the renter normally pays the energy bill, the owner’s interest to invest in energy efficiency is weak.

If renters and owners have clear and visible information about the energy efficiency of the buildings that they rent or own, they can negotiate rents that reflect this. This in turn should encourage investment in energy-saving measures where this is beneficial.
Certification of the energy performance of a building: why?

In the case of public authority buildings and certain privately owned or occupied buildings frequented by the public, energy certificates must be prominently and permanently displayed for the public.

Many of these buildings are rarely sold or rented, and so may not need certificates under the "sale or rent" rule. Another reason for them to have visible performance certificates is that public authority buildings and buildings frequented by the general public can be used to demonstrate efficient technology and to set examples by incorporating energy efficiency measures into renovations.
Articles of the European Energy Performance of Buildings Directive
Article 7: Energy performance certificate (1/2)

1. Member States shall ensure that, when buildings are constructed, sold or rented out, an energy performance certificate is made available to the owner or by the owner to the prospective buyer or tenant, as the case might be. The validity of the certificate shall not exceed 10 years.

Certification for apartments or units designed for separate use in blocks may be based:
— on a common certification of the whole building for blocks with a common heating system, or
— on the assessment of another representative apartment in the same block.

Member States may exclude the categories referred to in Article 4(3) from the application of this paragraph.
Article 7: Energy performance certificate (2/2)

2. The energy performance certificate for buildings shall include reference values such as current legal standards and benchmarks in order to make it possible for consumers to compare and assess the energy performance of the building. The certificate shall be accompanied by recommendations for the cost-effective improvement of the energy performance. The objective of the certificates shall be limited to the provision of information and any effects of these certificates in terms of legal proceedings or otherwise shall be decided in accordance with national rules.

3. Member States shall take measures to ensure that for buildings with a total useful floor area over 1 000 m² occupied by public authorities and by institutions providing public services to a large number of persons and therefore frequently visited by these persons an energy certificate, not older than 10 years, is placed in a prominent place clearly visible to the public. The range of recommended and current indoor temperatures and, when appropriate, other relevant climatic factors may also be clearly displayed.
Field of application

Art. 4.3: Member States may decide not to set or apply the requirements referred for the following categories of buildings:

- buildings and monuments officially protected as part of a designated environment or because of their special architectural or historic merit, where compliance with the requirements would unacceptably alter their character or appearance,
- buildings used as places of worship and for religious activities,
- temporary buildings with a planned time of use of two years or less, industrial sites, workshops and non-residential agricultural buildings with low energy demand and non-residential agricultural buildings which are in use by a sector covered by a national sectorial agreement on energy performance,
- residential buildings which are intended to be used less than four months of the year,
- stand-alone buildings with a total useful floor area of less than 50 m2.
Article 9: Inspection of air-conditioning systems

“With regard to reducing energy consumption and limiting carbon dioxide emissions, Member States shall lay down the necessary measures to establish a regular inspection of air conditioning systems of an effective rated output of more than 12 kW. This inspection shall include an assessment of the air-conditioning efficiency and the sizing compared to the cooling requirements of the building. Appropriate advice shall be provided to the users on possible improvement or replacement of the air-conditioning system and on alternative solutions.”
Status of implementation in some countries

- Austria/ Germany
- France
- Netherlands
- Portugal
- Sweden
- UK
The CEN (European Committee for Standardization) standard on AC inspection

AUDITAC training package
The CEN standard

In the frame of the TC 156 Ventilation for buildings, two standards are in preparation (for spring 2007):

1. Energy performance of buildings – Guidelines for inspection of ventilation (prEN 15239)

Although the inspection is not compulsory

The CEN standard Guidelines for inspection of air-conditioning systems

The standard is made of 8 parts:

1. Scope
2. Normative and references
3. Terms and Definitions
4. Energy impacts of AC, justification of inspection improvements
5. Inspection methodology
6. Advice on alternative solutions and improvements
7. Frequency of inspection
8. Annexes
The CEN standard

Annexes

- Annex A Checklist of pre–inspection information
- Annex B Checklists indicating observations and appropriate actions or advice
- Annex C Example of categories of documentation and information about the system
- Annex D Energy impacts of air conditioning, justification of inspection and improvements
- Annex E Features affecting the frequency and duration of inspection
Point 4: Energy impacts of air conditioning, justification of inspection and improvements

1) Reduction of the cooling needs of the building
2) Improving the system efficiency on the various stages:
   - emission
   - distribution
   - generation

In the inspection, attention should be paid also on the possibilities to save energy by other measures than those related to the system (⇒ annex D).

Ventilation issues are presented in prEN 15239, and heating issues in prEN EPBD WI 5.
Point 5: Inspection methodology

General
5.1 Pre-inspection and document collection
5.2 Methodology
   5.2.1 Inspect refrigeration equipment
   5.2.2 Inspect for effectiveness of outdoor heat rejection
   5.2.3 Inspect for effectiveness of heat exchange to the refrigeration system (indoor units of split and distributed systems)
   5.2.4 Inspect cooled air, and independent ventilation air, delivery systems in treated spaces
   5.2.5 Inspect cooled air, and independent ventilation air, delivery systems at air handling units and associated ductwork
   5.2.6 Inspect cooled air, and independent ventilation air, delivery systems at outdoor air inlets
   5.2.7 Inspect building system controls and control parameters
   5.2.8 Energy consumption metering
   5.2.9 Reporting
Inspection methodology: general

The introduction of the standard contains:

Instructions for measurements method, calibrated measurement instruments

Compare the installed cooling capacity to the estimated cooling needs (Annex B)

Estimate Specific Fan Power (standards EN 12599 and EN 13779)
Inspection methodology: general
5.1 Pre-inspection and document collection

There is a minimum content for the information described in Annex A.
5.1 Pre-inspection and document collection

Inspector has to check visually as far as possible to ensure that the equipment described is present and according to system specification.
Annex A: Checklist of pre-inspection information

<table>
<thead>
<tr>
<th>Information required</th>
<th>Present Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Itemised list of installed refrigeration systems, with locations of the indoor and outdoor components of each system..</td>
<td></td>
</tr>
<tr>
<td>2 Description of system control zones.</td>
<td></td>
</tr>
<tr>
<td>3 Description of method of control of temperature.</td>
<td></td>
</tr>
<tr>
<td>4 Description of method of control of periods of operation.</td>
<td></td>
</tr>
<tr>
<td>5 Records of maintenance to refrigeration systems, including cleaning indoor and outdoor heat exchangers, refrigerant leakage tests, repairs to refrigeration components or replenishing with refrigerant.</td>
<td></td>
</tr>
<tr>
<td>6 Records of maintenance to air delivery systems, including filter cleaning and changing, and cleaning of heat exchangers.</td>
<td></td>
</tr>
<tr>
<td>7 For relevant air supply and extract systems, commissioning results of measured absorbed power at normal air delivery and extract air rates, and commissioning results for normal delivered delivery and extract air flow rates (or independently calculated Specific Fan Power for the systems).</td>
<td></td>
</tr>
<tr>
<td>8 An estimate of the design cooling load for each system (if available). Otherwise, a brief description of the occupation of the cooled spaces, and of power consuming equipment normally used in those spaces.</td>
<td></td>
</tr>
<tr>
<td>9 Energy consumption counters; location, target values for consumption, records of consumption, compared measured vs. target consumption</td>
<td></td>
</tr>
</tbody>
</table>
5.2.1 Inspect refrigeration equipment

- Plant environment: clean?
- Compressors: can be brought in operation?
- Recording of measurements
- Operating temperatures
- Refrigerant charge: if exist a visible liquid sight glass: no bubbles, no distinct liquid level line
- Refrigerant leak test: examine the documentation if periodic detection is done, if not, leak detection has to be considered
- Checking of the insulation of the refrigerant lines (especially for multi split)
- Vibration and noise level
5.2.1 Inspect refrigeration equipment

Expansion valve covered of ice

Damaged insulation of the refrigerant lines
5.2.2/3 Inspect for effectiveness of outdoor and indoor heat exchangers

- 5.2.2 Of outdoor heat rejection
- 5.2.3 Of heat exchange to the refrigeration system (indoor units of split and distributed systems)
  
  • **Locate** and check the condition and operation of the heat exchanger units
  
  • Check that nothing **obstruct** the flow of air
  
  • Check that all **heat exchanger surfaces** are free from debris and grease and that the fins are undamaged
  
  • Check the condition of intake air **filters**
  
  • Check for **oily staining** on direct expansion heat exchanger surfaces that might indicate refrigerant leakage
  
  • In operation, ensure the **correct rotation and control** of fans
5.2.2/3 Inspect for effectiveness of outdoor and indoor heat exchangers

Example of a damaged finned condenser surface
5.2.4/5 Inspect cooled air, and independent ventilation air, delivery systems in treated spaces and at air handling units and associated ductwork.

Locate the air delivery openings, grilles or diffusers, and locate the route by which air is extracted from the spaces.

Note if there is any evidence that occupants find the air delivery arrangement unacceptable positioning and geometry of air supply openings in relation to extract openings: potential to short-circuit from supply to extract?

Filters: correct record the frequency of changing or cleaning? Are they clean? Damaged? Blocked? Are they equipped with a differential pressure gauge? Fit and sealing? Housing in the duct?

Assess the condition of heat exchangers (significantly damaged, or blocked by debris or dust)

Note whether refrigeration heat exchangers have staining that could indicate refrigerant leakage

Note the fan type, and method of control.
5.2.4/5 Inspection methodology: inspect cooled air, and independent ventilation air, delivery systems in treated spaces and at air handling units and associated ductwork.

Example of dirty AHU filter
5.2.6 Inspect cooled air, and independent ventilation air, delivery systems at outdoor air inlets

- **Locate** the inlets for outdoor air.
- Note any significant **obstructions** or blockages to inlet grilles, screens and pre-filters.
- Note where **inlets** may be affected by proximity to local sources of heat, or to air exhausts.
5.2.7 Inspect building system controls and control parameters

Locate and inspect the controls and sensors.

Is the control set up for zones or room by room? Is it appropriate (for internal gains or exposure to solar radiation)? Analyse the possibility to move from zone control towards room by room control.

Control timers set to actual time? set times of on and off periods corresponding to use and occupation?

Determine the suitability of the timers and the set periods in use

Determine, if possible, the set temperatures in each heating and cooling zone in relation to the activities and occupancy of the zones and spaces.
5.2.7 Inspect building system controls and control parameters

If timing and set temperatures are included in the Building Management System (BMS), the building manager or his agent should interrogate the BMS to demonstrate these aspects. They shall also demonstrate provisions set up for energy reporting and comfort reporting.

Determine, if possible, the type and age of the refrigeration compressor(s) and method of refrigeration capacity control. It is good if compared to good current practice? Which method is used to set, modulate or control air flow rate in the air supply, recirculation and exhaust ducts? Compare to good current practice, including:

- time/occupancy /IAQ (Indoor Air Quality) control of air flow rate;
- use of air flow rate for night ventilation or free cooling;
- control of heat recovery according to heating/cooling needs
5.2.8 Energy consumption metering

Does it have energy input meters or hours run meters?

Are energy consumptions recorded on a regular annual basis? Is it possible to deduce the use of the system from the annual consumption record? Where more frequent records are available these may allow the onset and end of the cooling 'season' to be identified and compared with expectation. Such simple checks may help to identify whether controls are adequate or appropriate.

If meters are installed, but no consumption records are available, take and record any relevant meter readings, together with the time and date of the reading. This information should be provided to the building owner or manager, to be kept available for the next inspection. Advise to continue to take and record meter readings on a regular basis.

Where no such metering is in place, advice to the building owner or manager to review the scope to install appropriate metering at least to the more significant energy consuming air conditioning plant, and to record the consumption on a regular basis.
5.3 Reporting

- Details of the **property** inspected, and the **inspector**
- List of the **documents** provided
- Details of the **systems** inspected
- Details of the **results** of the inspection: measurements or calculations
- **Comments:**
  - on the likely **efficiency** of the installation and any suggestions made for improvement
  - on any **faults** identified during the inspection and suggested actions
  - On the **adequacy** of equipment **maintenance** and any suggestions made for improvement
  - On the **adequacy** of installed **controls** and control settings and any suggestions made for improvement
  - On the **size** of the installed system in relation to the cooling load and any suggestions for improvement
  - concerning **alternative** solutions
- **Summary of findings and recommendations** of the inspection
6. Advice on alternative solutions and improvements

- Significant opportunities to reduce cooling loads (low cost improvements)
- Improvements/renovation
- Or replacement!

More details in annex D on:
- Cooling load reduction
- Alternative cooling techniques
7. Frequency of inspection

The frequency is defined at national level, the default value is 3 years.

More or less frequent, depending on (details in annex E):

- type of building
- energy impact of the system
- type of equipment
- quality of maintenance
- result of the previous inspection
The EPBD inspection of the air conditioning facilities

END

Back to main

AUDITAC training package
Session 3
Definitions for the audit and benchmarking of air conditioning facilities

AUDITAC training package
Two procedures: preliminary audit and detailed audit

Preliminary audit (or pre-audit or walk-through Audit): short audit (1-2 days), to discover the actual building, its actual HVAC system, its actual use and its actual occupancy. Determination of the existence or not of faults or possible improvements through visual (non intrusive, punctual measurements) verifications, analysis of as built records, system manual, possible complaints and operating costs.

If pre audit show preliminary opportunities of improvement ⇒ audit is necessary to go further in the analysis in order to quantify the energy and economic savings.
Actions taking place during preliminary audit

- Checking the envelope use and structure
- Visual inspect the plant
- Check for the presence of O&M activities and contract

Considering a list of energy conservation opportunities (ECOs)

- Reduce internal loads
- Improve insulation
- Add solar shading
- Install BEMS
- Change the setpoint temperatures
- Use better filters
- Optimise the filter replacement frequency

Feasibility, need for details

- Calculate the savings from load reduction through replacement with EnergyStar facilities
- Assess the investment for envelope changes
- Assess the impact on solar loads reduction
- Calculate the investment
- Calculate the best investment with savings

Activating the detailed audit tasks

- Easy to implement actions, no need for detailed audit, Operational
The air conditioning preliminary audit procedure

1. Collection of documents and data analysis
2. Visit of the facilities
3. Definition of profitable solutions and actions
4. Reporting
Collection of information

Main information:
- Use of building, occupancy scenarios, internal loads
- IAQ requirements
- Original plans and modifications of installed plant
- Plant sizing calculations
- Energy bills (at least over two years)
- O&M contracts and bills
- Others…

If lack of equipment documentation: an inventory will be done by the auditor!
Analysing Energy Data

If the A/C system energy consumption is available separately, then a Cooling Energy Index (CEI) could be calculated:

\[ CEI = \frac{AC\_Annual\_Energy\_Consumption (kWh)}{Conditioned\_Floor\_Area (m^2)} \]

In order to compare

- energy consumption to similar building types (benchmark method would take into account different parameters (weather, sector, air control factors etc.) to be accurate)
- to track consumption from year to year in the same building.

By tracking the CEI using a rolling 12-month block, building performance can be evaluated based on increasing or decreasing energy use trends.

At least two years of energy consumption data are necessary to establish the trend line and values including weather correction.
Visit of the facilities

The visit of the facilities allows:

- To determine the consistency of the documents collected to the reality
- To visually detect first opportunities of improvement
- To define the possible measurements and sensor to use for the measurements campaign.

The site visit will be spent inspecting actual systems and answering specific questions from the preliminary review. The amount of time required will vary depending on the completeness of the preliminary information collected, the complexity of the building and systems, and the need for testing equipment.
Visit of the facilities

Having several copies of a simple floor plan of the building will be useful for notes during the site visit. A separate copy should be made for noting information on locations of HVAC equipment and controls, heating zones, light levels, and other energy-related systems. If architectural drawings are not available, emergency fire exit plans are usually posted on each floor; these plans are a good alternative for a basic floor plan. Prior to touring the facility, the auditor and building manager should review the auditor's energy consumption profiles.
Reporting
Post-site work is a necessary and important step to ensure the preliminary audit will be useful. The auditor needs to evaluate the information gathered during the site visit, research possible Energy Conservation Opportunities (ECO’s), organize the audit into a comprehensive report, and make recommendations on improvements. The report from the audit, with possible ECO’s, should be used as the basic input for subsequent more detailed audits.
Definition of profitable solutions and actions

Reduce the consumption reducing the internal loads

They depend on:
- the climate (sun, temperature, humidity)
- the occupation rate
- the building envelope
- the air renewal rate
- artificial lighting and electrical appliances

Internal loads are difficult to treat because most actions towards the reduction of cooling consumptions in summer have opposite effects on heating consumptions in winter. If internal loads can be strongly reduced, the opportunity of replacement of the cooling equipment with a smaller capacity one should be evaluated.
Definition of profitable solutions and actions

Adapting the size of the A/C installation

A consequence of oversized cooling equipment is the operation of the system either continuously at very low capacity and therefore with poor performances, or for short ON/OFF cycles (many starting for very short time) and therefore with increased stress on the equipment, usually leading to a consequent reduction of equipment life time. Main reasons for oversizing are the need for comfort (acceptable temperature and humidity with quick response) even during peak load and possible future activity growth leading to an increase of cooling requirements.
Definition of profitable solutions and actions

Improving operation and maintenance activities

Technical improvements at one time cannot allow by itself high performances in the long term. O&M is indispensable because it allows to increase or at least maintain performances, availability, reliability and then operating costs of the installation.

Continuous follow-up of performances

The follow-up of performances based on a good metering is essential on an installation because it allows to detect technical defaults or energy drifts much quicker. Indeed, without measurement, problems are discovered far too late when a breakdown occurs. That follow-up can be included in a whole control system called “building energy management system” (BEMS) that allows to manage lighting, heating and A/C.
Session 4
Energy conservation opportunities for an air conditioning plant
Energy conservation opportunities (ECOs)

- Reducing the cooling load and improving the envelope
- Improving the components and the systems of air conditioning
- Performing efficient and energy savings oriented operation and maintenance activities
- Implement these actions by automated systems (BEMS) when possible
ENVELOPE AND LOADS

SOLAR GAIN REDUCTION / DAYLIGHT CONTROL IMPROVEMENT

- Install window film or tinted glass
- Install shutters, blinds, shades, screens or drapes
- Operate shutters, blinds, shades, screens or drapes
- Replace internal blinds with external systems
- Close off balconies to make sunspace/greenhouse
- Modify vegetation to save energy
- Maintain windows and doors
ENVELOPE AND LOADS

VENTILATION / AIR MOVEMENT / AIR LEAKAGE IMPROVEMENT

- Generate possibility to close/open windows and doors to match climate
- Ensure proper ventilation of attic spaces
- Optimise air convective paths in shafts and stairwells
- Correct excessive envelope air leakage
- Roll shutter cases: insulate and seal air leaks
- Generate possibility of night time overventilation
- Add automatic door closing system between cooled and uncooled space
- Replace doors with improved design in order to reduce air leakage
ENVELOPE AND LOADS

ENVELOPE INSULATION IMPROVEMENT

- Upgrade insulation of flat roofs externally
- Upgrade attic insulation
- Add insulation to exterior walls by filling cavities
- Add insulation to exterior wall externally
- Add insulation to basement wall externally
- Upgrade insulation of ground floor above crawl space
- Locate and minimize the effect of thermal bridges
- Cover, insulate or convert unnecessary windows and doors
- Use double or triple glazed replacement
ENVELOPE AND LOADS
OTHER ACTIONS AIMED AT LOAD REDUCTION

- Reduce effective height of room
- Use appropriate colour exterior
- Employ evaporative cooling roof spray
- Provide means of reducing electrical peak demand through load shedding
- Replace electrical equipment with Energy Star or low consumption types
- Replace lighting equipment with low consumption type
- Modify lighting switches according to daylight contribution to different areas
- Introduce daylight / occupation sensors to operate lighting switches
- Move equipment to non conditioned zones
- Generate possibility to close/open windows and doors to match climate
Energy conservation opportunities (ECOs)

- Reducing the cooling load and improving the envelope
- Improving the components and the systems of air conditioning
- Performing efficient and energy savings oriented operation and maintenance activities
- Implement these actions by automated systems (BEMS) when possible
PLANT

BEMS AND CONTROLS / MISCELLANEOUS

- Install BEMS system
- Define best location for new electrical and cooling energy meters
- Modify controls in order to sequence heating and cooling
  Modify control system in order to adjust internal set point values to external climatic conditions
- Generate the possibility to adopt variable speed control strategy
- Use class 1 electrical motors
- Reduce power consumption of auxiliary equipment
PLANT

COOLING EQUIPMENT / FREE COOLING

- Minimise adverse external influences (direct sunlight etc.) on cooling tower and air cooled condenser
- Reduce compressor power or fit a smaller compressor
- Split the load among various chillers
- Repipe chillers or compressors in series or parallel to optimise circuiting
- Improve central chiller / refrigeration control
- Replace or upgrade cooling equipment and heat pumps
- Consider feeding condenser with natural water sources
- Apply evaporative cooling
- Consider using ground water for cooling
- Consider indirect free cooling using the existing cooling tower (free chilling)
- Consider indirect free cooling using outdoor air-to-water heat exchangers
- Consider the possibility of using waste heat for absorption system
- Consider cool storage applications (chilled water, water ice, phase changing materials)
- Consider using condenser rejection heat for air reheating

AuditAC training package
PLANT

AIR HANDLING / HEAT RECOVERY / DISTRIBUTION

- Reduce motor size (fan power) when oversized
- Relocate motor out of air stream
- Use the best EUROVENT class of fans
- Use the best class of AHU
- Consider applying chemical de-humidification
- Apply variable flow rate fan control
- Consider conversion to VAV
- Exhaust (cool) conditioned air over condensers and through cooling towers
- Introduce exhaust air heat recovery
- Consider applying demand-controlled ventilation
- Generate possibility to increase outdoor air flow rate (direct free cooling)
- Replace ducts when leaking
- Modify ductwork to reduce pressure losses
- Install back-draught or positive closure damper in ventilation exhaust system
PLANT

WATER HANDLING / WATER DISTRIBUTION

- Use the best class of pumps
- Modify pipework to reduce pressure losses
- Convert 3-pipe system to 2-pipe or 4-pipe system
- Install separate pumping to match zone requirements
- Install variable volume pumping

TERMINAL UNITS

- Consider applying chilled ceilings or chilled beams
- Consider introducing re-cool coils in zones with high cooling loads
- Increase heat exchanger surface areas
- Consider displacement ventilation
- Install localised HVAC system (in case of local discomfort)

SYSTEM REPLACEMENT (IN SPECIFIC LIMITED ZONES)

- Consider water loop heat pump systems
- Consider VRF (Variable Refrigerant Flow) systems
Energy conservation opportunities (ECOs)

- Reducing the cooling load and improving the envelope
- Improving the components and the systems of air conditioning
- Performing efficient and energy savings oriented operation and maintenance activities
- Implement these actions by automated systems (BEMS) when possible
O&M

FACILITY MANAGEMENT

- Generate instructions ("user guide") targeted to the occupants
- Hire or appoint an energy manager
- Train building operators in energy – efficient O&M activities
- Introduce an energy – efficient objective as a clause in each O&M contract
- Introduce benchmarks, metering and tracking as a clause in each O&M contract, with indication of values in graphs and tables
- Update documentation on system / building and O&M procedures to maintain continuity and reduce troubleshooting costs
- Check if O&M staff are equipped with state – of – the – art diagnostic tools
O&M

GENERAL HVAC SYSTEM

- Use an energy accounting system to locate savings opportunities and to track and measure the success of energy-efficient strategies
- Shut off A/C equipments when not needed
- Shut off auxiliaries when not required
- Maintain proper system control set points
- Adjust internal set point values to external climatic conditions
- Implement pre-occupancy cycle
- Sequence heating and cooling
- Adopt variable speed control strategy
O&M

COOLING EQUIPMENT

- Shut chiller plant off when not required
- Sequence operation of multiple units
- Operate chillers or compressors in series or parallel
- Track and optimize chillers operation schedule
- Maintain proper starting frequency and running time of (reversible) chillers
- Improve part load operation control
- Maintain proper evaporating and condensing temperatures
- Raise chilled water temperature and suction gas pressure
- Lower condensing water temperature and pressures
- Check sensor functioning and placement for (reversible) chillers
O&M

COOLING EQUIPMENT

- Check sensor functioning and placement for (reversible) chillers
- Maintain efficient defrosting (reversible chillers)
- Maintain proper heat source/sink flow rates
- Maintain functioning of (reversible) chiller expansion device
- Check (reversible) chiller stand-by losses
- Maintain full charge of refrigerant
- Clean finned tube evaporator / condenser air side and straighten damaged fins
- Clean condenser tubes periodically
- Repair or upgrade insulation on chiller
- Clean and maintain cooling tower circuits and heat exchanger surfaces
- Apply indirect free cooling using the existing cooling tower (free chilling)
Consider modifying the supply air temperature (all–air and air–and–water systems)
- Perform night time overventilation
- Shut off coil circulators when not required
- Replace mixing dampers
- Adjust fan belts (AHU, packaged systems)
- Eliminate air leaks (AHU, packaged systems)
- Increase outdoor air flow rate (direct free cooling)
- Adjust/balance ventilation system
- Reduce air flow rate to actual needs
- Check maintenance protocol to reduce pressure losses
- Reduce air leakage in ducts
- Clean fan blades
O&M

FLUID (AIR AND WATER) HANDLING AND DISTRIBUTION

- Maintain drives
- Clean or replace filters regularly
- Repair/upgrade duct, pipe and tank insulation
- Consider the possibility to increase the water outlet – inlet temperature difference and reduce the flow rate for pumping power reduction
- Balance hydronic distribution system
- Bleed air from hydronic distribution system
- Switch off circulation pumps when not required
- Maintain proper water level in expansion tank
- Repair water leaks
- Reduce water flow rates to actual needs
Energy conservation opportunities (ECOs)

- Reducing the cooling load and improving the envelope
- Improving the components and the systems of air conditioning
- Performing efficient and energy savings oriented operation and maintenance activities
- Implement these actions by automated systems (BEMS) when possible
Energy saving technical measures for building envelope: some examples

- Reduce sun exposure
  - Solar shading
  - Improvement of glazing
  - Control of solar input through openings

- Increase the thermal inertia of the building
  - Improve thermal insulation and reduce thermal bridges

- Reduce air infiltration
  - Access doors (automatic closing after passage)

Take into account the influence of the measures envisaged on the heating system!
Opportunities for replacement: an overview of efficiencies
Opportunities for replacement: an overview of efficiencies

Replacement can be an suitable option when the system is ageing and the opportunity should be evaluated in the audit.

The progress of the technologies of refrigeration make the action particularly interesting for the old systems.

We observe the savings possible due to higher efficiencies for different system types in the following slides, where EER* is the energy efficiency ratio:

Cooling Capacity(kW)/Absorbed power (kW)

measured at nominal conditions following the testing standard.

*in some text you can find EER as COP coefficient of performance, however we prefer to keep the COP notation for the efficiency of reversible system in heating mode and the EER for the cooling one
## Chillers efficiency

Summary of average and extreme EER values by chiller category on the EU market

<table>
<thead>
<tr>
<th>Categories</th>
<th>Type</th>
<th>Condenser</th>
<th>Application</th>
<th>EER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>min</td>
</tr>
<tr>
<td>Complete unit</td>
<td>cooling</td>
<td>air</td>
<td>conditioning</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>reversible</td>
<td>air</td>
<td>conditioning</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Floor</td>
<td>3.31</td>
</tr>
<tr>
<td></td>
<td>cooling</td>
<td>water</td>
<td>conditioning</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>reversible</td>
<td>water</td>
<td>conditioning</td>
<td>2.9</td>
</tr>
<tr>
<td>Remote Condenser</td>
<td>cooling</td>
<td>water</td>
<td>conditioning</td>
<td>2.76</td>
</tr>
</tbody>
</table>

The values used for testing the water and air cooled systems are somewhat arbitrary and it may be that the apparent benefit from water-cooling is not fully realised in practice.
Chillers efficiency

ARI data on evolution of centrifugal efficiency from 1975 to 2000
Packaged units efficiency

Rooftops with percentage of models on EU market for each EER class (from EUROVENT database 1998)
Room air conditioners (RAC) efficiency

Evolution of efficiency of split, non-ducted, air cooled Air conditioners up to 12kW on the EU market (EUROVENT CERTIFICATION)
How to retrieve the EER of an existing system

EUROVENT CERTIFICATION Database

On the site:

http://www.eurovent-certification.com/

Database of certified products directories since 1995

For non certified products there are links to all the certified manufacturers to request old documents

As a final resort you can refer to AuditAC « TG 6: How to benefit from the Eurovent- Certification database and to retrieve past equipment data in the audit process »
Energy conservation opportunities for an air conditioning plant

END

Back to main

AUDITAC training package
Thank you for your attention!

END

of the AuditAC training package
Annexes

AUDITAC training package
Methods for estimating the cost-effectiveness of ECOs
Methods for estimating the cost-effectiveness of ECOs

The energy savings of a measure are not enough to guarantee its feasibility. The owner also requires to establish the « economic » feasibility in order to approve the action. Criteria are presented that allow estimation of whether the investment is profitable and allow comparison of different possibilities in order to define the most interesting in terms of money savings. The methods presented are:

- The net present worth
- The rate of return
- Benefit-Cost ratio
- Pay back return
Methods for estimating the cost-effectiveness of ECOs

Net Present Worth

The present worth of the cash flows that occur during the lifetime of the project is calculated as follows:

\[ NPW = -CF_0 + \sum_{k=1}^{N} CF_k \times SPPW(d, k) \]

SPPW (d,k) [Single Payment Present Worth after N years] = P/F = (1+d)^{-k} = value of the cash flow P needed to attain a needed cash flow F after k years

N = lifetime
d = discount rate
CF = cash flow

The initial cash flow is negative (a capital cost for the project), while the cash flows for the other years are generally positive (revenues). For the project to be economically viable, the net present worth has to be positive or at worst zero (\(NPW \geq 0\)). Obviously, the higher the is the NPW, the more economically sound is the project. This method is often called the net savings method since the revenues are often due to the cost savings from implementing the project.
Methods for estimating the cost-effectiveness of ECOs

Rate of Return

Once the rate of return is obtained for a given alternative of the project, the actual market discount rate or the minimum acceptable rate of return is compared to the ROR value. If the value of ROR is larger (d’>d), the project is cost – effective. In this method the first step is to determine the specific value of the discount rate, d’, that reduces the net present worth to zero. This specific discount rate, called the rate of return (ROR), is the solution of the following equation:

\[ N = \text{lifetime} \]
\[ d = \text{discount rate} \]
\[ CF = \text{cash flow} \]
\[ SPPW (d,k): \text{Single Payment Present Worth} \]

\[ -CF_0 + \sum_{k=1}^{N} CF_k \ast SPPW (d', k) = 0 \]
Methods for estimating the cost-effectiveness of ECOs

Benefit – Cost Ratio

The benefit – cost ratio (BCR) method is also called the savings – to investment ratio (SIR) and provides a measure of the net benefits (or savings) of the project relative to its net cost. The net values of both benefits (Bk) and costs (Ck) are computed relative to a base case. The present worth of all the cash flows are typically used in this method. The BCR is computed as follows:

\[
BCR = \frac{\sum_{k=0}^{N} B_k \times SPPW(d, k)}{\sum_{k=0}^{N} C_k \times SPPW(d, k)}
\]

The alternative option for the project is considered economically viable relative to the base case when BCR > 1.0.
Methods for estimating the cost-effectiveness of ECOs

Payback Period
In this evaluation method, the period \( Y \) (years) required to recover an initial investment is determined. \( Y \) is the solution of the following equation:

\[
CF_0 = \sum_{k=1}^{Y} CF_k \ast SPPW(d', k)
\]

If the payback period \( Y \) is less than the lifetime of the project \( (Y<N) \), then the project is economically viable and the obtained value of \( Y \) is called discounted payback period (DBP) since it includes the value of money. If, as in the majority of applications, the time value of money is neglected, \( y \) is called simple payback period (SBP) and is solution of the following equation:

\[
CF_0 = \sum_{k=1}^{Y} CF_k
\]

The methods described above provide an indication of whether or not a single alternative of a retrofit project is cost – effective. However, these methods cannot be used or relied on to compare and rank various alternatives for a given retrofit project. Only the life – cycle cost (LCC) analysis method is appropriate for such endeavour.
Thank you for your attention!

AUDITAC training package
Status of the implementation: Austria/ Germany

Not yet implemented.
Annual inspections by trained craftsmen (e. g. state of filters, proper function of controls...) combined with at longer intervals (3 years? 5 years?) inspection by expert engineers of the entire plant and focused on proper dimensioning and system performance
Status of the implementation: France

Not yet implemented.

The inspection is stated in the law (Code for construction and housing), but the application decrees are still in study.

The inspection would be probably developed as a technical inspection of the facilities and done by accredited bodies by Cofrac (French body for accreditation).
Status of the implementation:
Netherland

Inspection of air-conditioning systems with regard to the leakage of refrigerant exists out of the frame of the EPBD demands.

They started the development of a frame for the inspection of air-conditioning systems as a part of the EPBD implementation in the Netherlands.

The inspection is divided in two parts:

  - Optimizing the performance of the existing air-conditioning system. Good maintenance of the system will be a part of this approach.
  - Optimizing the performance by replacing (parts of) the air-conditioning system. And of course an advice on alternative ways of saving energy for cooling purpose.

The inspection will be based on CEN WI-6.
Status of the implementation: Portugal

The implementation of Article 9 has been done in Portugal and it’s waiting for governmental approval (included in the new RSECE - REGULATION ON HVAC SYSTEMS FOR BUILDINGS).

This regulation is applied to all HVAC systems with a power to be installed higher than 12 kW.

The main recommendations for HVAC systems inspections are the following:

- Air conditioning units with nominal capacity greater than 12 kW but lower than 100 kW – every 3 years
- Air conditioning units with nominal capacity greater than 100 kW – every 2 years

The commissioning tests are required for boilers, chillers (power and efficiency), cooling towers, pumps, hydraulic tests, heat exchangers, controllers, noise, and global functionality.
Status of the implementation: Sweden

The inspection is separate for the cooling production and distribution system:

- For the production system the technical inspection is associated to the annual inspection for the refrigerant charge (already mandatory with a refrigerant filling larger than 3 kg). This check is performed by accredited control bodies. Furthermore, there is a reporting duty for all plants larger than 10 kg filling, which has to be sent to the municipality together with an annual report.

- The distribution subsystem of the AC plants will be inspected as part of the energy certification process, and will be performed with the same intervals as the certification of the building (10 years).

No additional costs for the building owners as compared to today when having the mandatory annual inspection carried out, since this already exists. Inspectors (or energy experts) to carry out the energy certification of buildings is roughly expected to be around 700.
Status of the implementation: UK

- The UK procedures will be very close the CEN drafts. A drafting committee involving the parties affected exists, with a member of BRE leading the drafting.
- The article 9 implementation will be in the form of a regular inspection that will only require measurements that can be carried out without interference to plant operation. The probable inspection interval will be three years, but this may be dependent on the quality of the maintenance records.
Type de système

- Multisplit Chiller
- Chilled water
- Ceiling systems/ beams
- Chiller + AHU

- Split systems
- Chilled water
- Chiller + FCU

- Water loop heat pump system
- VRF
- Cooled water
- Ceiling systems/ beams
- Chiller + AHU

- Chiller
- Water loop heat pump system
- VRF

- Packaged unit
- Rooftop

- Roof Inside

- Fluid link : Water loop heat pump system

- Place of the cold generating system?

- One air conditioning system per room to treat
- One unit for a unique space

- Yes

- No

« Fluid link » between systems

- Small diameter pipes ⇒ refrigerant link

- Refrigerant (low diameter pipes)

- Air (direct or indirect by high diameter ducts)

- Water (mean diameter pipes)
One air conditioning system per room to treat

Type of system

One air conditioning system for several rooms to treat

« Fluid link » between systems

No

Yes

Refrigerant (low diameter pipes)

Fluid link between the building and the technical room?

Water (mean diameter pipes)

Air (direct or indirect by high diameter ducts)

Split systems

Chiller

Carrier?

Packaged unit

Place of the cold generating system?

Water

Chilled water

Cooled water

Ceiling systems/active-passive beams

VRF

Multisplit

Chiller + FCU

Chiller + AHU

Water loop heat pump system

Window (fixed packaged unit)

Mobile packaged unit

Single split system

Packaged unit

Roof Inside

Example n°2
Solar control glazing

Reflected energy
(Infrared rays)

Transmitted energy (Light)
Solar shading principle

Summer

Winter