
Cleanrooms and associated controlled environments —

**Part 16:
Energy efficiency in cleanrooms and
separative devices**

Salles propres et environnements maîtrisés apparentés —

*Partie 16: Efficacité énergétique dans les salles propres et les
dispositifs séparatifs*

Document Preview

[ISO 14644-16:2019](https://standards.iteh.ai/catalog/standards/iso/b18b7600-d2c0-4a06-908d-df84e2552827/iso-14644-16-2019)

<https://standards.iteh.ai/catalog/standards/iso/b18b7600-d2c0-4a06-908d-df84e2552827/iso-14644-16-2019>



iTeh Standards
(<https://standards.itih.ai>)
Document Preview

[ISO 14644-16:2019](https://standards.itih.ai/catalog/standards/iso/b18b7600-d2c0-4a06-908d-df84e2552827/iso-14644-16-2019)

<https://standards.itih.ai/catalog/standards/iso/b18b7600-d2c0-4a06-908d-df84e2552827/iso-14644-16-2019>



COPYRIGHT PROTECTED DOCUMENT

© ISO 2019

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

	Page
Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
3.1 General terms.....	1
3.2 Terms related to installation.....	3
3.3 Terms related to energy efficiency.....	4
3.5 Abbreviated terms.....	4
4 Energy reduction evaluation and implementation process	5
4.1 General.....	5
4.2 New or existing cleanrooms.....	6
4.3 Energy performance comparison.....	7
4.3.1 General.....	7
4.3.2 Compare energy performance.....	7
4.3.3 Determine the business case.....	7
4.3.4 Monitor and review.....	7
4.4 Existing cleanroom retrofit or renovation.....	7
4.5 Process for existing cleanrooms.....	8
4.5.1 Select project team.....	8
4.5.2 Review user requirements and project scope.....	8
4.5.3 Collate information on cleanroom performance criteria.....	9
4.6 Process for design/construction of new build or updating cleanrooms.....	9
4.6.1 Review user requirements and project scope.....	9
4.6.2 Undertake energy performance design review.....	9
4.7 Comparative review of cleanroom environmental performance.....	9
4.8 Identify energy reduction opportunities.....	10
4.9 Assess the impact of energy reduction opportunities.....	10
4.10 Select energy reduction opportunities for implementation.....	10
4.11 Implementation.....	10
4.12 Monitor, review and feedback.....	11
4.13 Decommissioning.....	11
5 Impact of user requirement specification (URS) on energy consumption	11
5.1 Principle.....	11
5.2 Garment levels.....	11
6 Airflow volume and compensating factors	12
6.1 Fresh air supply.....	12
6.2 Airflow volume rate.....	12
6.3 Source strength and airflow rate calculation for non-unidirectional rooms.....	12
6.3.1 Determining air volume flow rate.....	12
6.3.2 Ventilation effectiveness index.....	13
6.3.3 Compensation factors (C_f).....	13
6.4 Flexible procedure for airflow rate estimation in non-UDAF rooms.....	14
6.4.1 General.....	14
6.4.2 Design stage.....	14
6.4.3 Testing stage.....	15
6.4.4 Operational stage.....	15
6.5 Air velocity reduction for unidirectional air flow systems.....	15
7 Power management: turn-down, turn-off and recovery	15
7.1 Turn-down.....	15
7.2 Turn-off.....	16

8	Adaptive control	16
9	Heating and cooling loads	17
10	Fan and filter selection	17
	10.1 Air movement fans.....	17
	10.2 Selection of air filters.....	17
11	Lighting levels	18
12	Training	18
13	Operation	18
14	Maintenance	19
15	Decommissioning	20
	Annex A (informative) Source strength: Air volume and worked example	21
	Annex B (informative) Energy saving opportunities	26
	Annex C (informative) Impact assessment	32
	Annex D (informative) Benchmarking: Energy performance indicators for cleanrooms	33
	Annex E (informative) Useful measures to minimize excess heating and cooling losses or gains	38
	Annex F (informative) Critical area reduction example	40
	Bibliography	42

iTeh Standards
(<https://standards.itih.ai>)
Document Preview

[ISO 14644-16:2019](https://standards.itih.ai/catalog/standards/iso/b18b7600-d2c0-4a06-908d-df84e2552827/iso-14644-16-2019)

<https://standards.itih.ai/catalog/standards/iso/b18b7600-d2c0-4a06-908d-df84e2552827/iso-14644-16-2019>

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 209, *Cleanrooms and associated controlled environments*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

A list of all parts in the ISO 14644 series can be found on the ISO website.

Introduction

Cleanrooms and associated controlled environments are widely used in many industries, such as life-sciences (including pharmaceutical, medical device), micro-electronics, aerospace, food processing, nuclear and hospitals. Operational size ranges from tens to thousands of square metres, most with unique design and operational characteristics based on their function. Their development has involved rapid expansion and progress for several decades, mirrored by an increasing energy demand. This document embraces the accumulated experiences and practices in cleanroom design, operation and maintenance, formulated to reduce their energy consumption and the global impact of this dramatic growth.

Users are also referred to ISO 50001 for energy management.

Although varying greatly in function and size, the energy consumption of cleanrooms can be over 10 times higher than that for offices of similar size. A considerable amount of energy is required to provide large amounts of filtered and conditioned air to achieve specific levels of air cleanliness. Air movement fans can account for 35 % to 50 % of the HVAC consumption of cleanrooms due to the power required to overcome the high pressure differentials needed to operate high-efficiency filters and other circulation components in the cleanroom system. Production of this type of high-quality air can consume up to 80 % of the total energy used in a typical manufacturing facility.

Additional energy is also used to achieve temperature and relative humidity control for processes in the cleanroom, for personnel comfort and to achieve the requisite pressurization of the cleanroom space. There is therefore significant potential for energy saving by diligent design in the installation of new cleanrooms, and by retrofit improvements and upgrades to existing facilities. This document sets out the measures that can be taken to introduce these techniques and applies to the full spectrum of “cleanroom technology”, from cleanrooms to clean air devices, including isolators, glove boxes and mini-environments as described in ISO 14644-7[1]. This document is based on actual experience, practice and tests supported by theoretical calculations for the purpose of clear and scientific description of the effects of energy saving.

The energy saving methods and techniques used in this document are all general ones applicable to varied environments and situations. They are not process-specific and exclude related production processes such as water treatment, and oven, autoclave and stress cycling operations. Their specific application depends on the actual conditions of cleanroom operation as agreed between the customer, the supplier and the installation engineers.

At each stage in the cleanroom life cycle, opportunities exist to optimize system performance and reduce energy consumption. Energy saving measures implemented at the design stage achieve the most effective results for new cleanrooms, but similar energy savings can also be achieved for those currently in operation. Cleanrooms can be used singly or as a group, based on practical conditions on site.

During design, when information about the finished building and process is at its minimum, conservatism can dictate the oversizing of systems and the mandating of overly tight specifications. At this stage, challenging these specifications and design considerations is valuable for energy efficiency.

When setting the system to work and executing performance testing, there is an opportunity to adjust the system to accommodate the actual conditions as built to optimize the system performance and minimize energy usage.

During the operating life of the facility, analysis of monitoring data can and should be used to further optimize system performance and minimize energy usage.

Cleanrooms and associated controlled environments —

Part 16:

Energy efficiency in cleanrooms and separative devices

1 Scope

This document gives guidance and recommendations for optimizing energy usage and maintaining energy efficiency in new and existing cleanrooms, clean zones and separative devices. It provides guidance for the design, construction, commissioning and operation of cleanrooms.

This document covers all cleanroom-specific features and can be used in different areas to optimize energy use in electronic, aerospace, nuclear, pharmaceutical, hospital, medical device, food industries and other clean air applications.

It also introduces the concept of benchmarking for the performance assessment and comparison of cleanroom energy efficiencies, while maintaining performance levels to ISO 14644 requirements^[2]^[3].

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 50001, *Energy management systems — Requirements with guidance for use*

3 Terms and definitions

ISO 14644-16:2019

<https://standards.iteh.ai/catalog/standards/iso/b18b7600-d2c0-4a06-908d-df84e2552827/iso-14644-16-2019>

For the purposes of this document, the terms and definitions given in ISO 50001 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 General terms

3.1.1

air-handling unit

AHU

unit or plant, comprising fan, filtration, heating, cooling and mixing of fresh air and recirculated air, that delivers conditioned air to a room or facility

3.1.2

classification

method of assessing level of cleanliness against a specification for a *cleanroom* (3.1.4), *clean zone* (3.1.5), controlled zone or a defined location therein

Note 1 to entry: Levels should be expressed in terms of an ISO Class, which represents maximum allowable concentrations of particles in a unit volume of air.

[SOURCE: ISO 14644-1:2015, 3.1.4, modified — In the definition, the part after “clean zone” has been added.]

3.1.3

clean air device

stand-alone equipment for treating and distributing clean air to achieve defined environmental conditions

Note 1 to entry: Clean air devices include certain *separative devices* (3.1.7) as defined in ISO 14644-7[1], for example, clean air hoods, containment enclosures, gloveboxes, isolators and mini-environments.

[SOURCE: ISO 14644-4:2001, 3.2, modified — Note 1 to entry has been added.]

3.1.4

cleanroom

room within which the number concentration of airborne particles is controlled and classified, and which is designed, constructed and operated in a manner to control the introduction, generation and retention of particles inside the room

Note 1 to entry: The class of airborne particle concentration is specified.

Note 2 to entry: Levels of other cleanliness attributes such as chemical, viable or nanoscale concentrations in the air, and also surface cleanliness in terms of particle, nanoscale, chemical and viable concentrations are also specified and controlled subject to application.

Note 3 to entry: Other relevant physical parameters can also be controlled as required, e.g. temperature, humidity, pressure, airflow, vibration and electrostatic.

[SOURCE: ISO 14644-1:2015, 3.1.1]

3.1.5

clean zone

defined space within which the number concentration of airborne particles is controlled and classified, and which is constructed and operated in a manner to control the introduction, generation and retention of contaminants inside the space

Note 1 to entry: The class of airborne particle concentration is specified.

Note 2 to entry: Levels of other cleanliness attributes such as chemical, viable or nanoscale concentrations in the air, and also surface cleanliness in terms of particle, nanoscale, chemical and viable concentrations might also be specified and controlled.

Note 3 to entry: A clean zone(s) can be a defined space within a *cleanroom* (3.1.4) or can be achieved by a *separative device* (3.1.7). Such a device can be located inside or outside a cleanroom.

Note 4 to entry: Other relevant physical parameters can also be controlled as required, e.g. temperature, humidity, pressure, airflow, vibration and electrostatic.

[SOURCE: ISO 14644-1:2015, 3.1.2]

3.1.6

pre-filter

air filter fitted upstream of another filter to reduce the challenge on that filter

[SOURCE: ISO 14644-4:2001, 3.8]

3.1.7

separative device

equipment utilizing constructional and dynamic means to create assured levels of separation between the inside and outside of a defined volume

Note 1 to entry: This equipment can be used as a *clean zone* (3.1.5).

Note 2 to entry: Some industry-specific examples of separative devices are clean air hoods, containment enclosures, glove boxes, isolators and mini-environments.

[SOURCE: ISO 14644-7:2004, 3.17, modified — Note 1 to entry has been replaced, and former Note 1 to entry has been renumbered accordingly.]

3.2 Terms related to installation

3.2.1

adaptive control

capability of the system to modify its own operation parameters automatically to achieve the best possible performances in various modes operations year-around

3.2.2

air change rate

rate of air exchange expressed as number of air changes per unit of time and calculated by dividing the volume of air delivered in the unit of time by the volume of the *cleanroom* (3.1.4) or *clean zone* (3.1.5)

[SOURCE: ISO 14644-3:2005, 3.4.1, modified — In the definition, “space” has been replaced by “cleanroom or clean zone”.]

3.2.3

diffuser

device placed on inlet air supply terminal to improve distribution of incoming air with room air

Note 1 to entry: A mesh grille or a perforated screen is not considered to be a diffuser.

3.2.4

non-unidirectional airflow

non-UDAF

air distribution where the supply air entering the *clean zone* (3.1.5) mixes with the internal air by means of induction

[SOURCE: ISO 14644-4:2001, 3.6]

3.2.5

contaminant removal effectiveness

CRE

ratio of particle concentration measured in the exhaust/return to the average of particle concentration in the room, when particles entering from filtered supply air are ignored

[SOURCE: REHVA Guidebook No. 2]

3.2.6

air volume flow rate

supply airflow rate

air volume supplied into an installation from final filters or air ducts in unit of time

[SOURCE: ISO 14644-3:2005, 3.4.5, modified — “air volume flow rate” has been added as main term.]

3.2.7

air change effectiveness

ACE

ratio between the recovery rate at a location or locations in a *cleanroom* (3.1.4) and the overall recovery rate of the cleanroom after a contamination event

Note 1 to entry: The recovery rate is defined and measured in accordance with ISO 14644-3[6].

3.2.8

turn-down

controlled reduction of airflow velocity in *unidirectional airflow* (3.2.9) *cleanrooms* (3.1.4) and *clean air devices* (3.1.3) or airflow rates in *non-UDAF* (3.2.4) cleanrooms in order to save energy during periods when the cleanroom is not in operation

**3.2.9
unidirectional airflow
UDAF**

controlled airflow through the entire cross-section of a *clean zone* (3.1.5) with a steady velocity and approximately parallel airstreams

Note 1 to entry: This type of airflow results in a directed transport of particles from the clean zone to exit.

[SOURCE: ISO 14644-4:2001, 3.11, modified — In the definition, “streamlines” has been replaced by “airstreams”, and “to exit” has been added at the end of Note 1 to entry.]

**3.2.10
emission**

amount of contaminants that is discharged from objects into the *cleanroom* (3.1.4) air

**3.2.11
source strength**

rate describing the number of particles or colony-forming units emitted from an object per time unit

Note 1 to entry: A source can be a person, equipment or an object.

**3.2.12
microbe-carrying particle**

particle on which a microorganism is carried, normally dispersed into room air by personnel as a skin cell, or fragment of skin cell, on which a skin microbe(s) is carried

3.3 Terms related to energy efficiency

**3.3.1
benchmarking**

comparative evaluation and/or analysis of similar operational practices

**3.3.2
energy cost**

total financial cost of the energy consumed, related to the area being investigated

**3.3.3
power**

time rate at which work is done or energy is transferred

Note 1 to entry: The SI unit of power is the watt (W) or joule per second (J/s).

3.5 Abbreviated terms

CFD	computational fluid dynamics
EMS	environmental management system
FFU	fan filter unit
HSE	health, safety and environment
HVAC	heating, ventilation and air conditioning
RH	relative humidity

<i>SFP</i>	specific fan power
URS	user requirement specification
VE	ventilation effectiveness

4 Energy reduction evaluation and implementation process

4.1 General

The energy consumption of cleanrooms, clean zones and separative devices can be reduced in accordance with [4.2](#) to [4.13](#), following the process shown in [Figure 1](#).

[Figure 1](#) summarizes the process that can be used for a typical cleanroom including its airflow system shown in [Figure 2](#). It covers existing cleanrooms in operation, existing cleanrooms that are being modified and new build cleanrooms in the design phase.

iTeh Standards
(<https://standards.iteh.ai>)
Document Preview

[ISO 14644-16:2019](#)

<https://standards.iteh.ai/catalog/standards/iso/b18b7600-d2c0-4a06-908d-df84e2552827/iso-14644-16-2019>

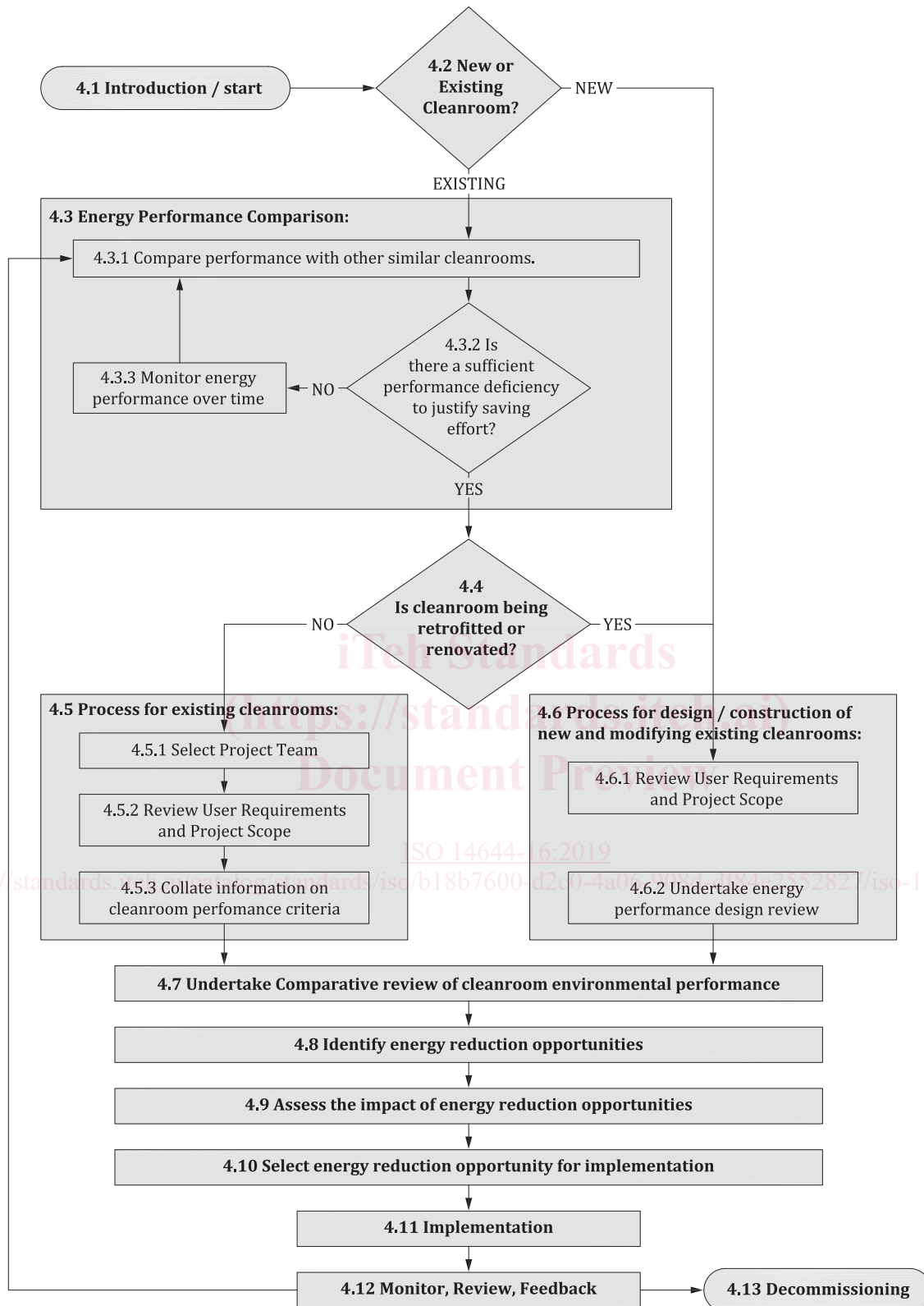


Figure 1 — Systematic approach to energy saving — Project work flow

4.2 New or existing cleanrooms

The process of reducing energy consumption of new and existing cleanrooms differ because the starting point and data available are different.

The recommendations of 4.5 and 4.6 should be followed if a new cleanroom is being designed or an existing cleanroom is being assessed for energy reduction purposes.

If an existing cleanroom is planned to be refurbished, then there might be other opportunities to reduce energy consumption that can be incorporated in the modifications.

4.3 Energy performance comparison

4.3.1 General

The process of reducing energy consumption in existing cleanrooms can require the time involvement of many resources and there is a cost associated with this activity. For this reason, it is important to establish the cleanroom significant energy use (SEU) that justifies the reduction activity (see ISO 50001).

4.3.2 Compare energy performance

Assess the current energy performance of the cleanroom and compare to a suitable comparator or benchmark. Example comparators can include another similar cleanroom facility, previous commissioning data where energy performance had previously been optimized, or a calculated comparator-based on previous experience. Guidance on benchmarking energy performance is given in [Annex D](#).

4.3.3 Determine the business case

Establish if the difference between the current cleanroom energy consumption and energy cost, and the comparator or benchmark is significant and would justify further investment of time and resources.

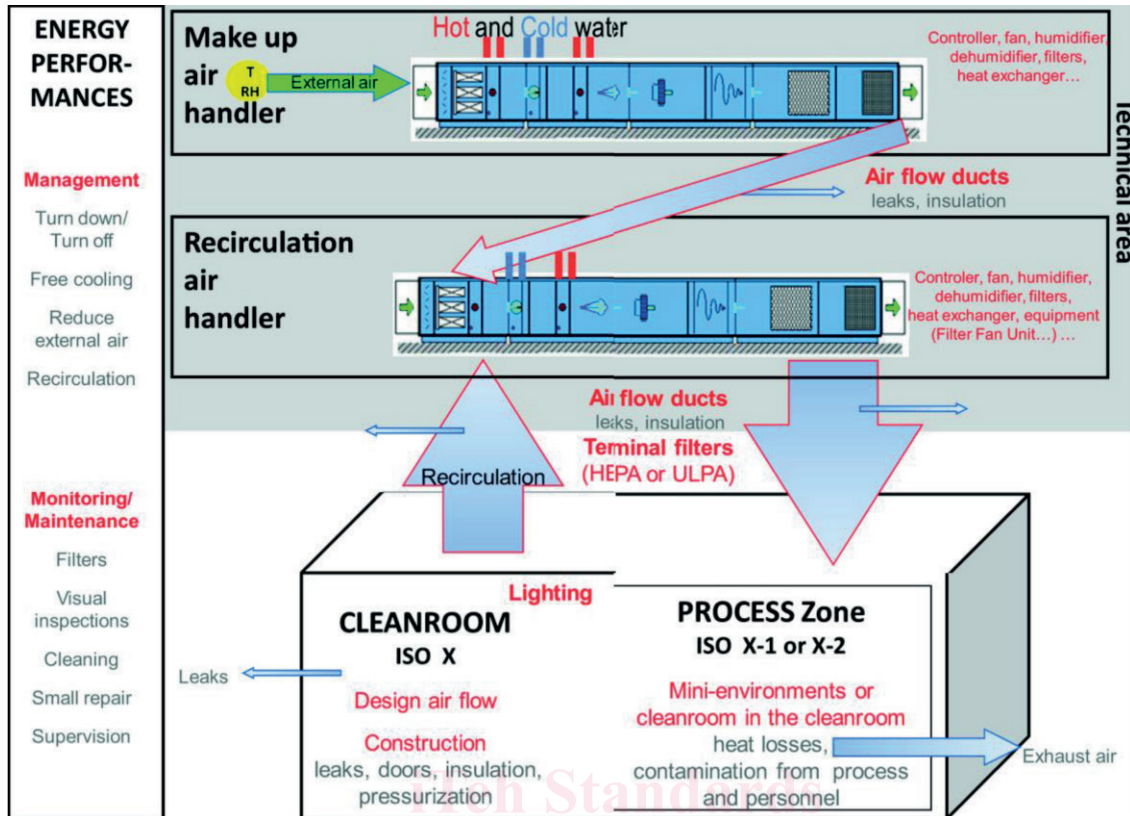
4.3.4 Monitor and review

If there is no justification at the current point in time, continue to monitor energy performance at regular intervals and reassess the energy performance in comparison to the benchmark. Over time, a number of variables can change which can change this assessment:

- cleanroom energy performance and efficiency can degrade;
- the unit cost of energy and project implementation costs can change, which will change the project economics; and
- new technologies can become available or more viable.

4.4 Existing cleanroom retrofit or renovation

The design of the cleanroom to be refurbished should be reviewed to ensure energy efficiency is considered in the design. The air handling and distribution system for a typical room is shown below.



SOURCE ASPEC-ADEME-EDF. Energy performance in clean zones (cleanrooms, controlled environments, contained areas)[5], reproduced with the permission of ASPEC France.

Figure 2 — Illustration of typical cleanroom air handling and distribution

The design should enable future regulation and optimization of cleanroom energy performance, for example, installation of variable speed drives for fan motors.

4.5 Process for existing cleanrooms

4.5.1 Select project team

Those selected for the project team should be sufficiently knowledgeable to provide expertise on the following aspects: engineering and maintenance of cleanroom equipment/utilities, cleanroom energy consumption, product quality, equipment/process validation, production operations, and health and safety.

The team can consist of any number of members.

4.5.2 Review user requirements and project scope

The project team should understand the cleanroom operation and document the scope of the energy reduction project. This can include:

- overall objective of the cleanroom (its purpose);
- critical process parameters required to be maintained within the cleanroom.

EXAMPLE Temperature and relative humidity ranges, room cleanliness requirement, recovery time and pressure differentials between adjacent rooms of different classification.