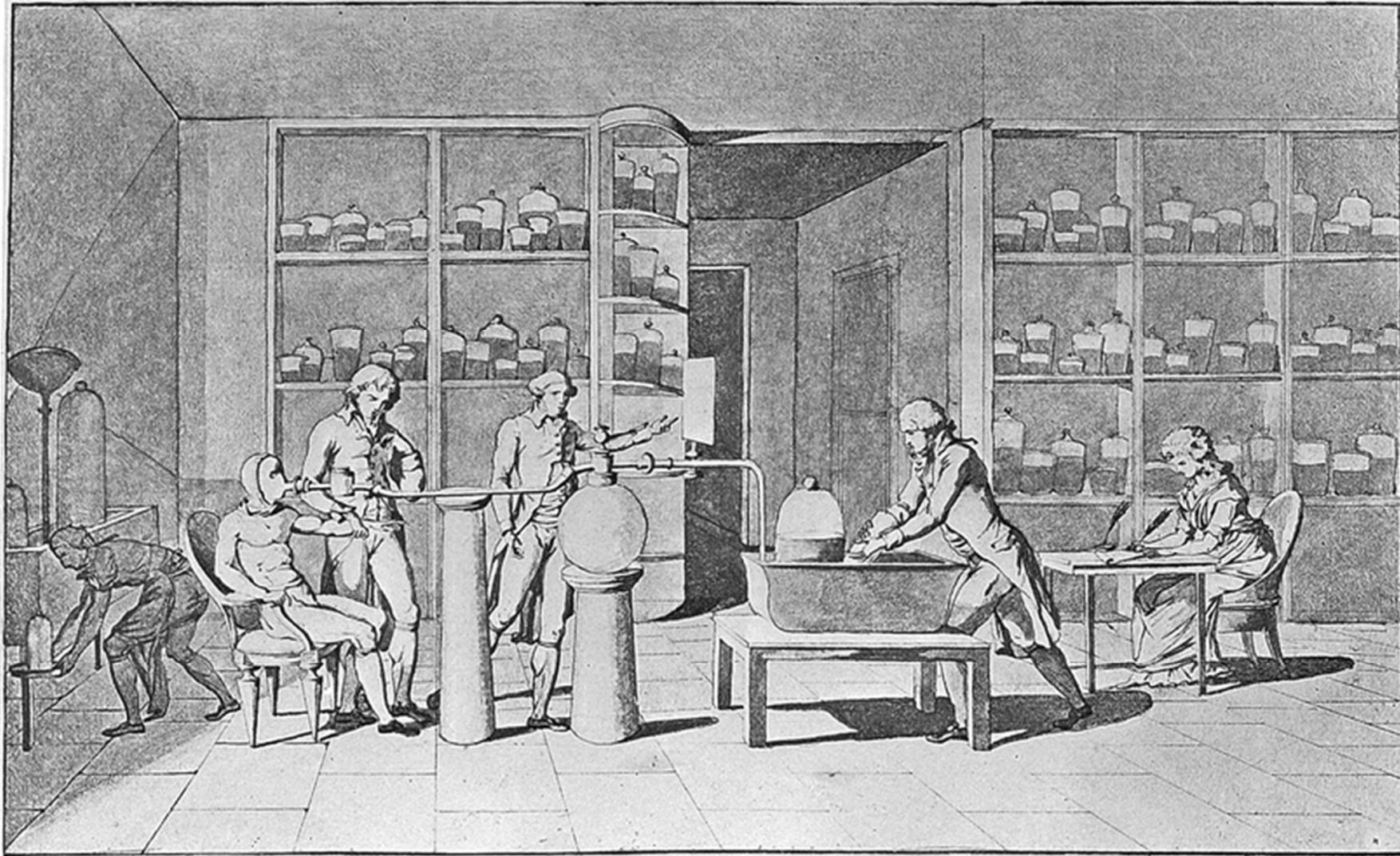


Sufficient **indoor airquality** in hospitals and low energy consumption

archipelago



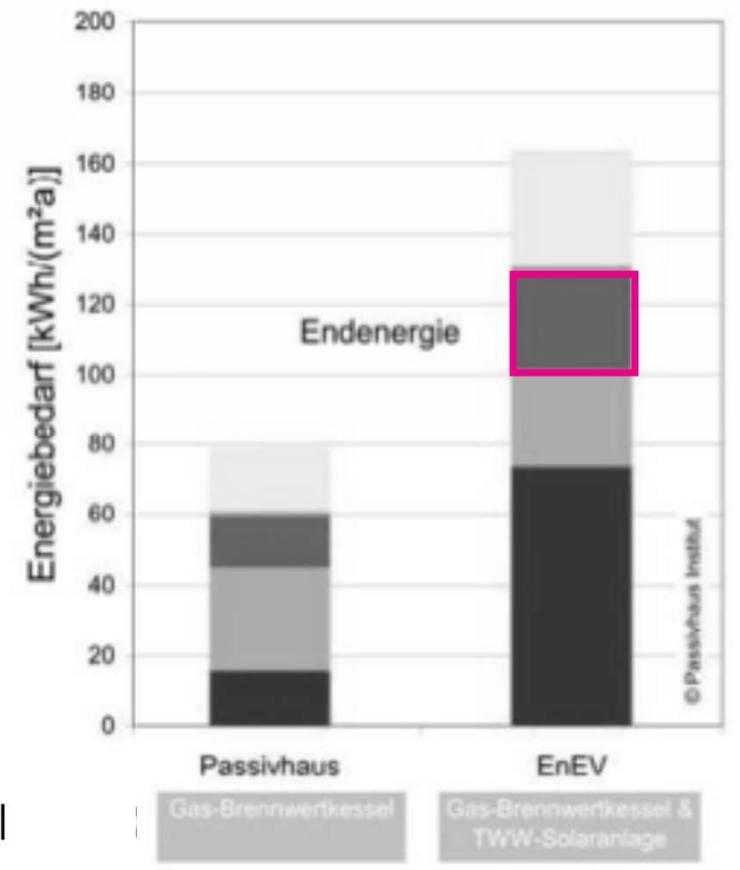
Héliog Arents

*Lavoisier dans son laboratoire
Expériences sur la respiration de l'homme au repos*

*In Belgium 5% of the carbon emissions are caused by healthcare. Hospitals are responsible for **55%** and hygienic ventilation can easily be responsible of **20%** of the carbon emissions of the hospitals.*

*The key question of this workshop is: “Which **ventilation rates** are **sufficient** taking into account the epidemiological and hygienic challenges?”*

15 à 20%
 of end energy demand of a hospital
 is related to mechanical ventilation

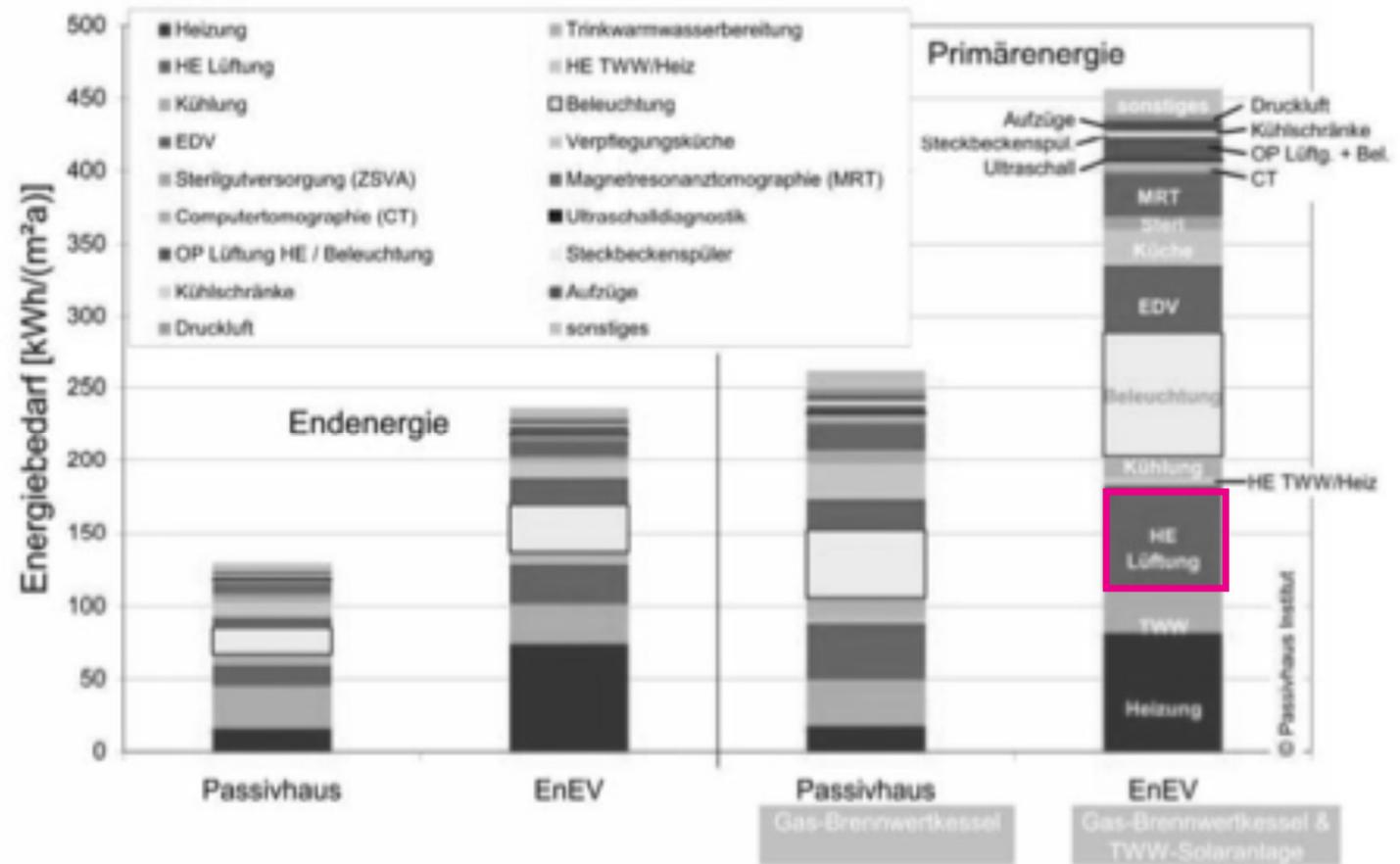


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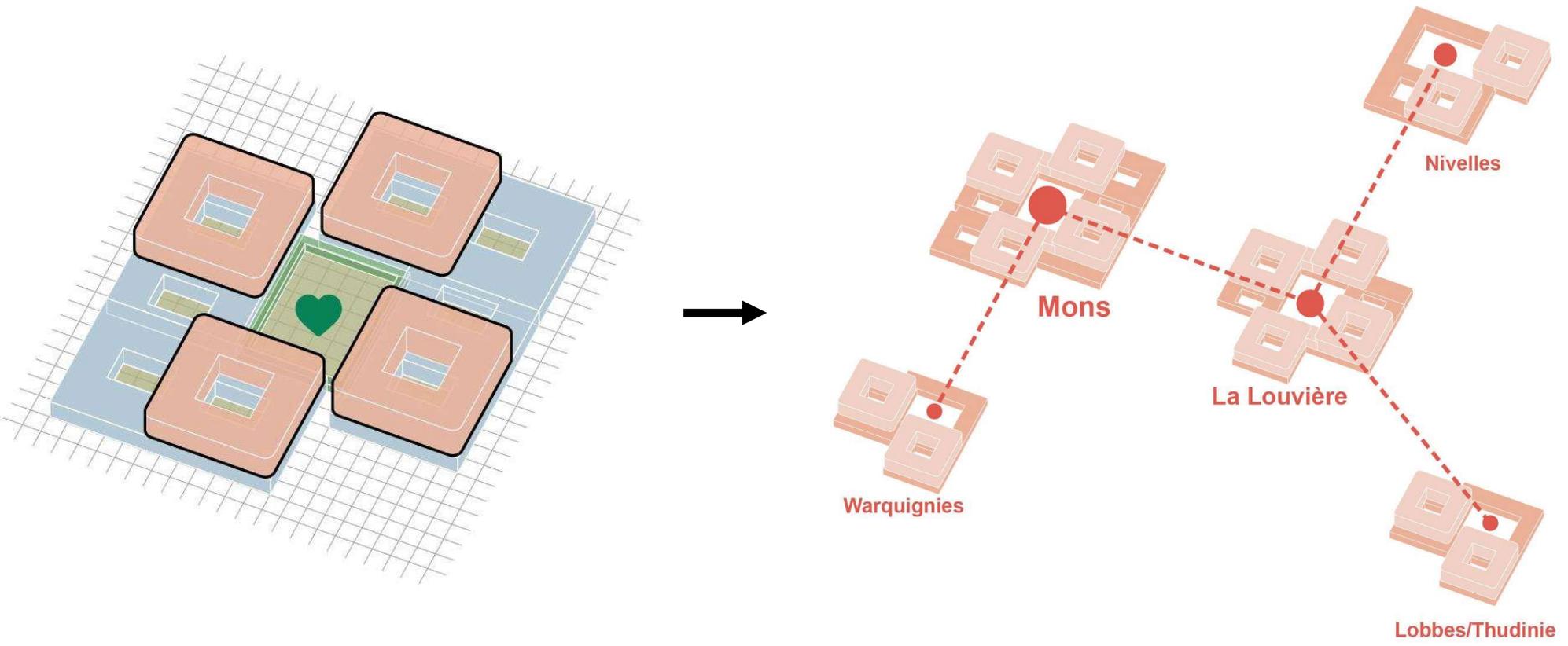
15 à 20%

of end energy demand of a hospital is related to mechanical ventilation

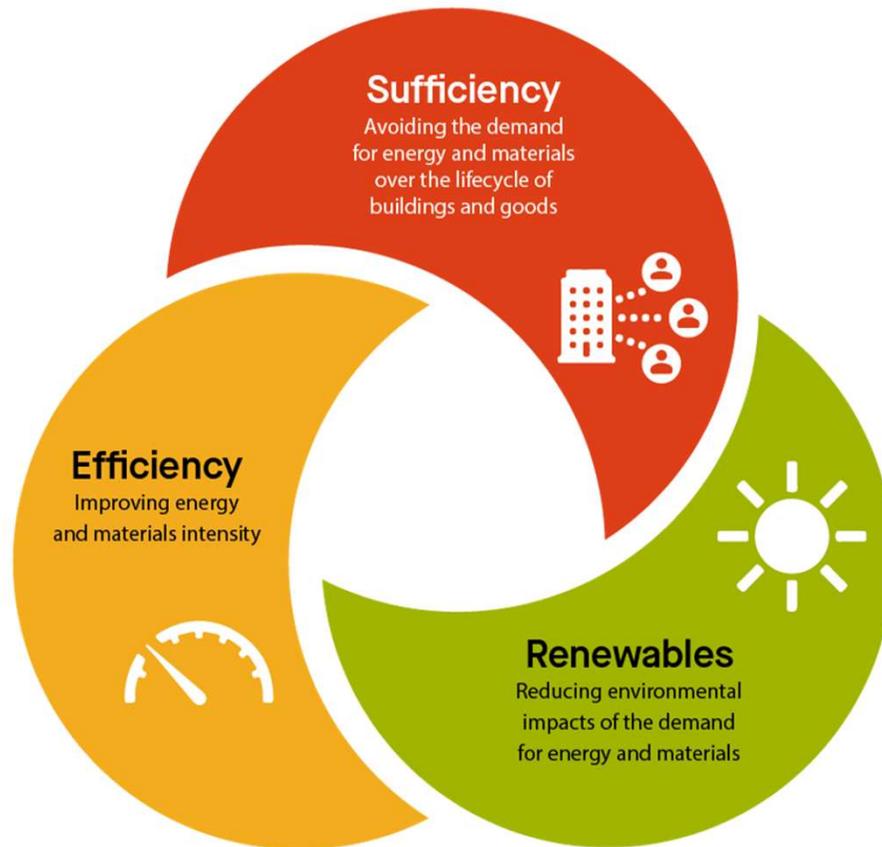
- ▶ patient rooms
- ▶ hot floor
- ▶ consultation
- ▶ offices
- ▶ public
- ▶ logistics



► patient rooms



► sufficient airquality



- ▶ patient rooms
reference ventilation rate?

inquirey Belgian engineering offices:

75 → 280 m³/h.room

▶ patient rooms

NF S 90-351

AIA – CDC – ASHRAE 170

norme française

ISSN 0335-3931
NF S 90-351
6 Avril 2013
Indice de classement : S 90-351
ICS : 11.080.01

**Établissements de santé —
Zones à environnement maîtrisé —
Exigences relatives à la maîtrise
de la contamination aéroportée**

E : Health care institutions — Controlled environment areas —
Requirements for airborne contamination control
D : Einrichtungen des Gesundheitswesens — Zonen aus kontrolliertem Bereich —
Anforderungen an die Lenkung von luftgetragener Kontamination

Norme française homologuée
par décision du Directeur Général d'AFNOR.
Remplace la norme homologuée NF S 90-351, de juin 2003.

Correspondance À la date de publication du présent document, il n'existe pas de travaux de normalisation internationaux ou européens traitant du même sujet.

Résumé Le présent document précise les exigences de sécurité sanitaire pour la conception, la construction, l'exploitation, la maintenance, le contrôle et l'utilisation des installations de traitement et de maîtrise de la qualité de l'air dans les établissements de santé.

Descripteurs **Thésaurus International Technique** : salle propre, atmosphère maîtrisée, établissement sanitaire, bloc opératoire, exigence définition, risque, contamination, conception, planification, installation, caractéristique de construction, matériau, conditions d'exploitation, air, qualité, classification, contrôle de propreté, contrôle contamination atmosphérique, qualité bactériologique, maintenance, qualification.

Modifications Par rapport au document remplacé, mise à jour et compléments techniques : en particulier le domaine d'application a été étendu et précisé notamment concernant les zones concernées et les niveaux de risque.

Corrections

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Version de 2013-04-F

2007 EDITION

**GUIDELINES FOR
DESIGN AND
CONSTRUCTION OF**

**HOSPITAL
AND
HEALTH CARE
FACILITIES**

The American Institute of Architects Academy
of Architecture for Health
The Facility Guidelines Institute
With assistance from the U.S. Department of
Health and Human Services

AIA

➔ 6 volumes/h

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► patient rooms

DIN 1946-3

Room use	Requirements	Measures
2.3 Radiation therapy and x-ray diagnostics	Depending on heating and cooling loads and equipment used	Outdoor air $\geq 40 \text{ m}^3/\text{h}$ per person, taking radiation protection requirements (air filters) into account, where necessary
2.4 Physical therapy Tub baths, kinotherapeutic baths, swimming pools		As in VDI 2089 Part 1
3 Intensive care	Temperature stabilization is to be ensured at least for cardiology, neurosurgery and neo-natal patients	
3.1 Wards (intensive care)		Outdoor air $40 \text{ m}^3/\text{h}$ per person or $> 100 \text{ m}^3/\text{h}$ per patient Room air temperature $22 \text{ }^\circ\text{C}$ to $26 \text{ }^\circ\text{C}$ Room humidity 30 % to 60 %
3.2 Isolation rooms, including anterooms (intensive care)	See: Table 1 line 5.3, in special cases lines 5.1 and 5.2	Outdoor air $40 \text{ m}^3/\text{h}$ per person or $> 100 \text{ m}^3/\text{h}$ per patient Room air temperature $22 \text{ }^\circ\text{C}$ to $26 \text{ }^\circ\text{C}$ Room humidity 30 % to 60 %
3.3 Other rooms, corridors (intensive care)		Outdoor air $5 \text{ m}^3/\text{m}^2 \text{ h}$
4 Supply and waste disposal areas		
4.1 (Central) medical product sterilization unit	Outdoor air flow depends on thermal loads, contamination level, number of persons	
4.2 Bed and bedding treatment, laundry	Outdoor air flow depends on thermal loads, contamination level, number of persons	
4.3 Pathology, autopsy rooms		Room air temperature $\leq 22 \text{ }^\circ\text{C}$
In rooms 2.1 to 2.4, 3.1 to 3.3, 4.2 and 4.3 insect screens are necessary where windows will be openable.		

➔ **40 m³/h**
per pers.

➔ **30 m³/h**
per pers.
(icw operable windows)

► patient rooms

R³ Nordic Guideline for Hospital Ventilation (2023)

Table 2 Requirements for indoor environment for general room types

Room Type	Ventilation class	Amount of outdoor air (ODA)*	Relative Humidity*** %	Temperature °C
Patient room with occupancy of permanent nature **	CL5	0,010 m ³ /s,patient and 0,001 m ³ /s,m ² ****	Air humidification is not required	Heating season: 20-24 Cooling season: 23-26
Rooms for Staff, and other general areas**	CL4	0,007 m ³ / s,person and 0,000,7 m ³ /s,m ² *****	Air humidification is not required	Heating season: 20-22 Cooling season: 23-26

* Additional ventilation may be required by local regulations or for microbiological and chemical dilution and heat gains and losses etc.

** Visitors and staff should be taken into account separately based on variable usages. There may be elevated airborne exposure risk in close contact with the patient, Kalliomäki et al (2020)

***Condensation of moisture on components or surfaces is not allowed. If humidification is needed for specific purpose, it should be defined in URS.

**** Category I and low polluting building according to EN16798-1

***** Category II and Low polluting building according to EN16798-1

Note 1: Bold indicates the range over which the parameter may float.

→ 36 m³/h
per patient
+
58 m³/h
per room
(16m² room)

Dr. Meinhard Stalder
Independent Consultant
Am alten Bahndamm 3
23923 Schönberg

To whom it may concern

Subject: Formal objection concerning DIN EN 16798

Groß Bünsdorf, 15th of Jan 2025

Dear Ladies and Gentlemen,

while reviewing DIN EN 16798 I noticed an inconsistency in the ventilation part of the document. One of the formulae for calculating the air-volume-flow seems to be wrong.

Specifically, the mistake is in the formula used in „method 1“ (section 6.3.2.2) on the top of p.22:

$$q_{\text{tot}} = n \cdot q_p + A_R \cdot q_B$$

Which should correctly read:

$$q_{\text{tot}} = \max [n \cdot q_p ; A_R \cdot q_B]$$

Accordingly in the calculated example (see Table NA.8) for the category II office with 10 m² and one person not 14 + 14 =28 l/s but only 14 l/s is needed. One of the two contributions -more correctly the larger of the two, but they are equal in this example- would suffice. Both pollutants are removed with the same parcel of exhaust-air synchronously.

Explanatory statement:

Section NA.5, subsection NA.5.1.1 (p.11) makes the assumption that the air is well mixed throughout the whole room. This means that every liter of exhaust air contains the same amount of pollutants (CO₂, VOCs,...). Every liter of exhaust air removes not only CO₂ but the same proportion of all other substances. The CO₂ and the other substances are not separated from one another. Thus, the larger of the two summands in the above equation suffices to keep both concentrations below their respective limits.

Maybe an example with different values can exemplify this:

- Let us take the same 10 m² room with two persons. This room would require 28 l/s, 14 l/s for each person. No extra ventilation for the VOC-component (in the wrong formula another 14 l/s) is needed. VOCs levels would be already at a value two times better (i.e. lower) than demanded.

- Let us take a larger room (20 m²) with one person. This room would also require 28 l/s, this time for removing the VOCs. But no further ventilation for the person (in the wrong formula another 14 l/s) is needed. Due to the already good ventilation the level of the CO₂-excess would reach only half of the allowed limit (i.e. 275ppm instead of 550ppm).

The **wrong formula** will increase the ventilation, and the additional ventilation will just cause a **waste of energy**. This should be unacceptable amid all the struggle to conserve as much energy as possible.

Notice: We are talking about **energy saving** legislation!

Further comments:

The above described context is put in correct wording in section 6.3.2.2., directly in front of the incorrect formula (English retranslation from the German Text):

*„The necessary dilution ... of a given pollutant is independently ... to evaluate. The **highest** of these values of the exhaust air volume flow is to be used for the design.“*

Whereas in section NA.5.1.2 the wording is different and thus as **wrong** as in the formula (English translation from the German Text):

*„The calculated exhaust air volume flow is given by two components: (a) ... (b)... The ventilation for each category is the **sum** of both of these components ...“*

Additionally, I must observe that some other parts of this standard are somewhat clumsy and confusing. For example "method 3" is redundant (see section 6.3.2.4) when it states a method on the grounds of „given“ minimum air volume flow. Where does such a "given" value come from? Of the following five dashes the first three refer to contributions from method 1. Dash four and five introduce an arbitrary air change rate (ACH) with no connection to the previously derived values. Is this an "emergency exit" to ignore carefully motivated air change requirements and take "traditional" values if convenient?

Please consider this letter as a formal objection to correct/ rephrase the DIN EN 16798. At least the formula in section 6.3.2.2. should be corrected. Please also consider to slim down "method 3" which after scrutinizing boils down to taking an arbitrary/traditional ACH.

With kind regards,



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▶ patient rooms

CEN/TC156/WG18 Ventilation in Hospitals

work in progress

at the moment focus on operating theatres

cfr. lecture Roberto Traversari

archipelago



► patient rooms

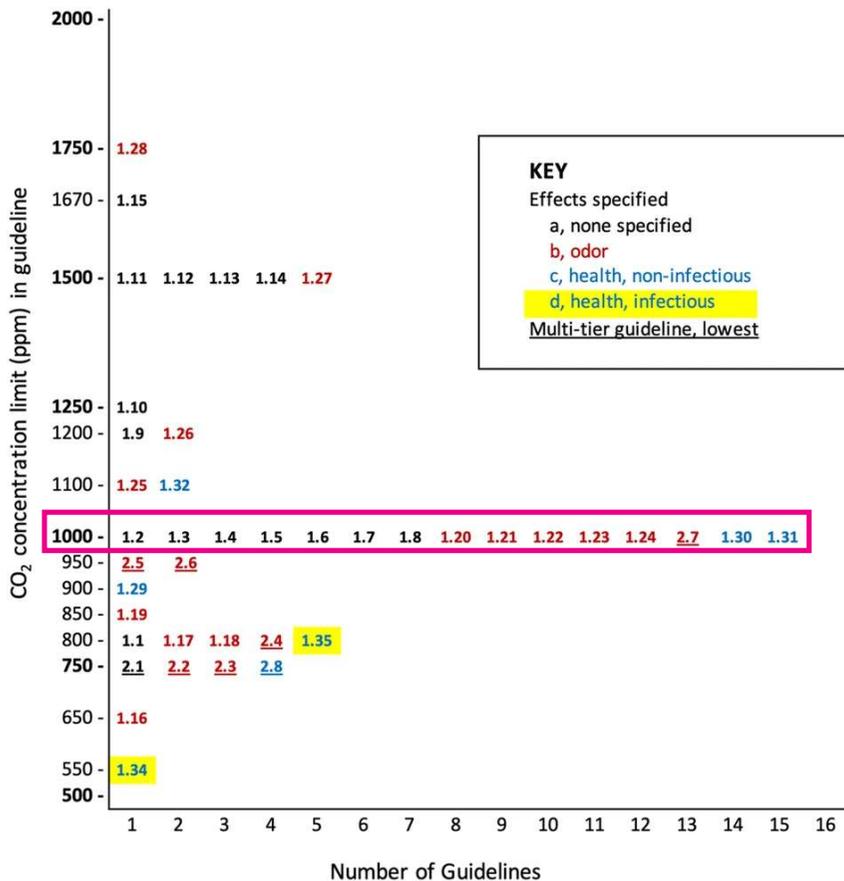
impact of ventilation rate on energy demand

hospitalroom single room (47,5 m3)	GRO 2025	47,5 m3 2 fresh ACH	DIN 1946-4 (100m3/h.patient) common practise	4 fresh ACH	6 fresh ACH		
fresh air changes/hour (ACH)							
m3/h.pp		75 m3/h.room	95	100	125	190	285
m3/h		75	95	100	125	190	285
ACH		1,58	2	2,11	2,63	4	6
indoor airquality							
ppm		620	580	570	530	490	460
ppm with 2 visitors (2h)		1020	870	870	790	670	580
energy demand							
Fans (kWh/year)		353	432	452	552	810	1190
AHU Heating (kWh/year)		0,8	6	8	33	177	667
AHU Cooling (kWh/year) (*)		197	247	258	317	460	655
Local Heating (kWh/year)		0	0	0	1,3	106	315
Local Cooling (kWh/year)		97,5	31	20	0,5	0	0
Heating + Cooling (kWh/year)		295,3	284	286	351,8	743	1637
Heating + Cooling + Fans (kWh/year)		943,6	1000	1024	1255,6	2296	4464

944 → 4464 kWh/room.y
x 4,7

► patient rooms

is there an optimal airflow rate, based on *epidemiological and hygienic criteria*?



Conclusion : “For all these reasons, and also because it is difficult to measure VR accurately in many buildings, it has been difficult to quantify the relationships between VRs and specific exposures, and the specific human health risks, and thus to set health-protective VR airflow guidelines.”

Source : Mendell MJ, Chen W, Ranasinghe DR, Castorina R, Kumagai K. Carbon dioxide guidelines for indoor air quality : a review. J Expo Sci Environ Epidemiol. 2024 Jul;34(4):555-69.

► patient rooms

is there an optimal airflow rate, based on *epidemiological and hygienic criteria*?

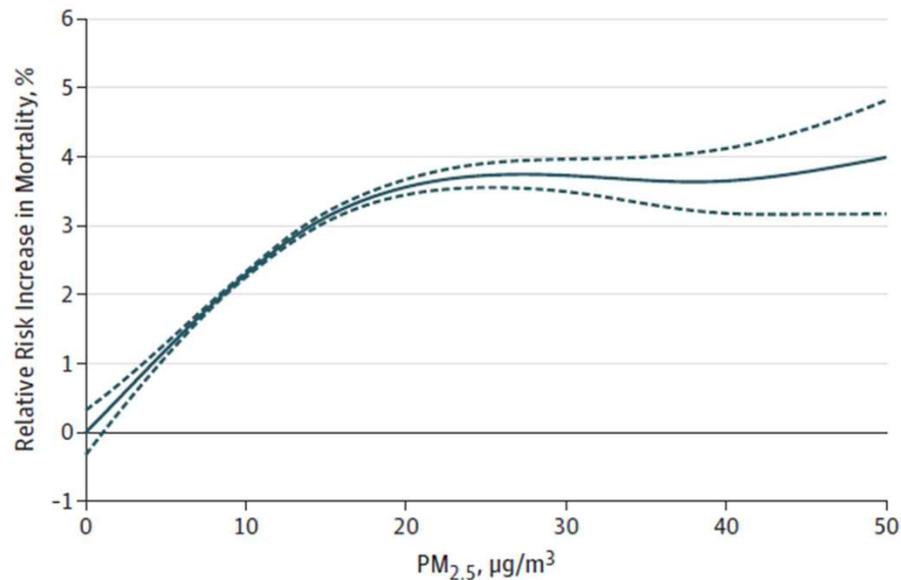


Figure from article by Qian et al. regarding the exposure response curve for the concentration PM. (hourly average) with the relative increase in the risk of mortality.

Conclusion : “(...)The relationship found in it shows that there is no threshold value for PM_{2,5} and that a choice must therefore be made regarding **what is considered acceptable**. (...)”

“(...) That could argue in favor of making the requirements stricter. However, given the limited substantiation that is available and the side effects that can occur, such as **increasing energy consumption**, it does not seem opportune to make extreme demands. (...) »

Source: Boerstra et al. Onderzoek naar eisen voor het binnenklimaat in de langdurige zorg, april 2023

Right-tech : how to balance cost with what's considered acceptable?



*“Thanks to the possibility of additional ventilation through windows in patient rooms, it is possible to **reduce the demand for fresh air to just 30 m³/h per person for a specific project.**”*

Source : Passive House Institute (2022), Implementation of the Passive House concept in hospitals.



architectes : wörner traxler richter

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And if we go back to the origin of the modern hospital...

NOTES
ON
"HOSPITALS."

BY
FLORENCE NIGHTINGALE.

Third Edition,
Enlarged and for the most part Re-written.

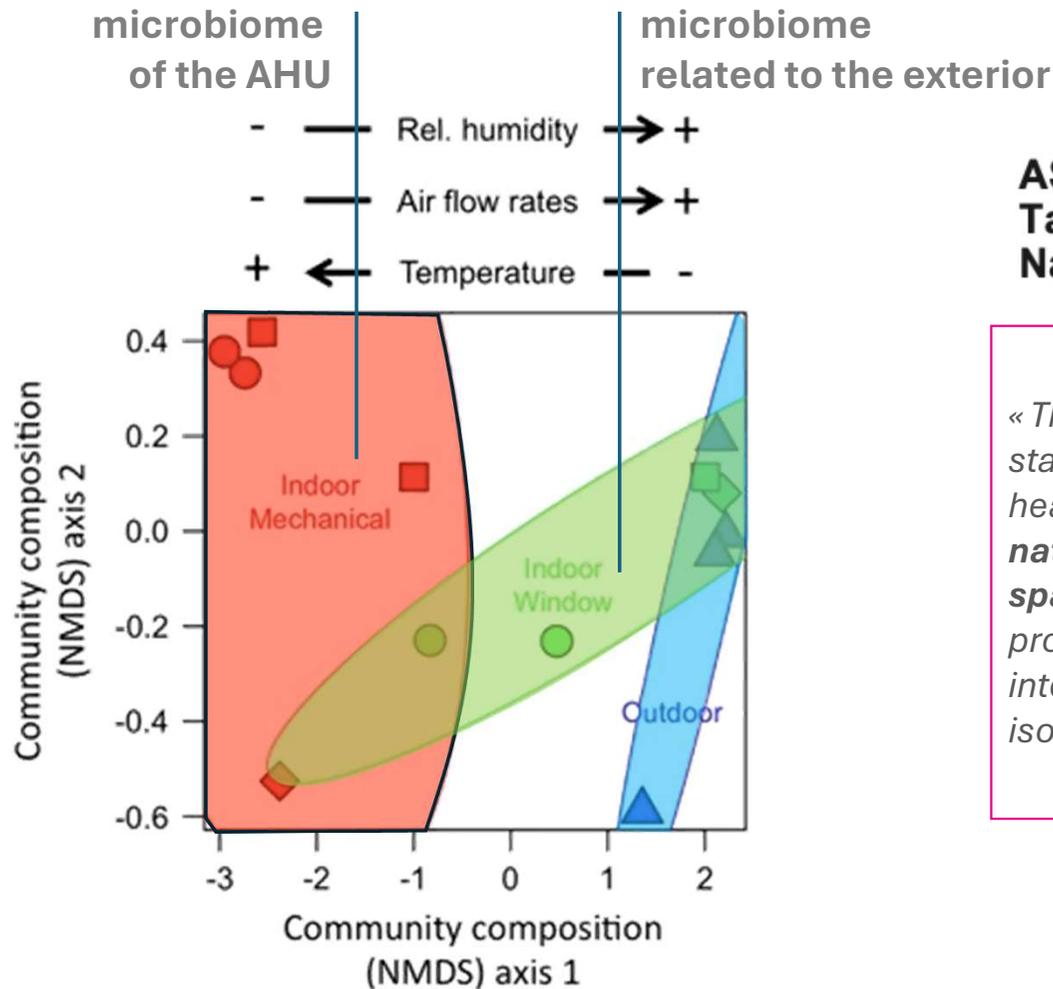
LONDON:
LONGMAN, GREEN, LONGMAN, ROBERTS, AND GREEN.
1863.



Florence Nightingale



Right-tech : What about **fresh air**?



ASHRAE SSPC 170 Natural Ventilation Task Group: Position Paper on Natural Ventilation in Health Care Facilities

« The current version of the ANSI/ASHRAE/ASHE 170 standard only allows mechanical ventilation in healthcare facilities. This task force suggests that **natural ventilation be allowed in most healthcare spaces**, with the exception of operating rooms, procedure rooms, sterile central areas, interventional radiology or cardiology spaces, air isolation areas, and protected environments. »

Right-tech : Should **humidity** be regulated in patientrooms?

DIN 1946-4

When **natural ventilation** is an alternative, **humidification is not necessary**, even in the case of basic mechanical ventilation. Problems related to electrostatic charges on people and equipment and their dissipation must be solved by proper grounding of floors, building elements and equipment users (see also DIN EN 60601 and DIN EN 61010).

Passive House Concept Hospitals

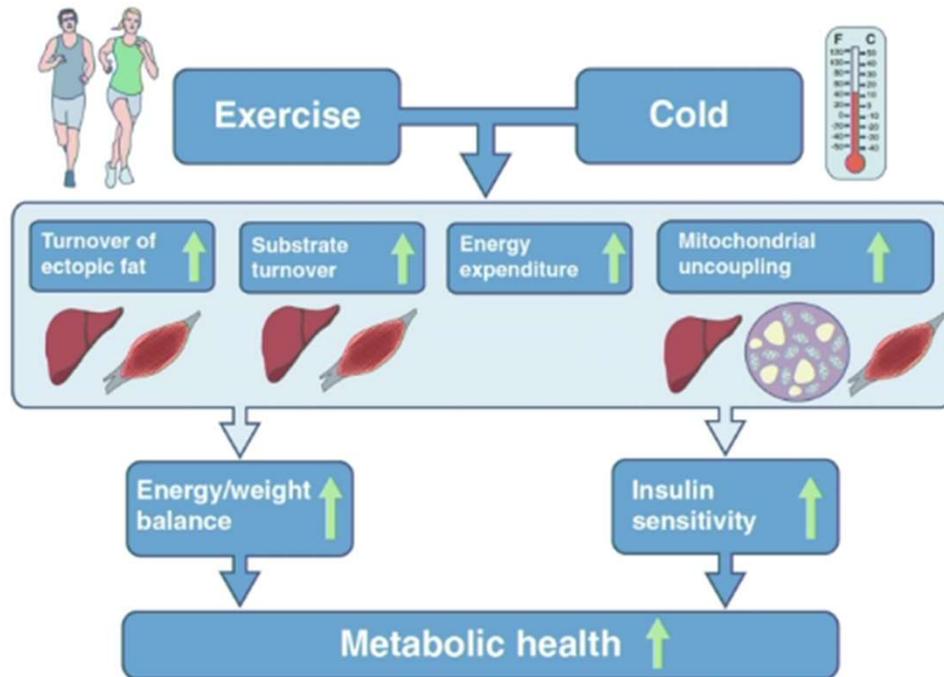
According to technical regulations for workplaces [ASR2012], indoor air should generally not be humidified. Humidification in winter is not necessary in most hospital rooms due to the good level of air filtration and the absence of dust in the indoor air. In areas where humidification is required, the target value may be limited to 30% relative humidity [L-DGKH]. In surgical wards, "humidification is only permitted with steam" for hygienic reasons [DIN 1946-4].

With the appropriate dimensioning of the volume of fresh air (9.1.2), the need for humidification in conventional care units should not even arise. The use of heat recovery systems that simultaneously allow moisture to be recovered can also contribute to a comfortable level of indoor air humidity.

Source : Passive House Institute (2022), Implementation of the Passive House concept in hospitals).

Can excessive comfort be harmful to health?

'Thermal Entrainment'



Source : Schrauwen & van Marken Lichtenbelt, Diabetologia 2016
Van Marken Lichtenbelt et al. Obesity Rev 2018

*“Indoor environments are becoming **more and more homogeneous** around the world.”*

*“Homogeneous indoor temperatures lead to **problems with metabolism, insulin sensitivity, as well as the cardiovascular and immune systems.**”*

Source : Van Marken Lichtenbelt, W., et al., Healthy excursions outside the thermal comfort zone. Building Research & Information, 2017. 45(7): p. 819-827.

Right-tech : our recommendations (work in progress)

Rooms in day hospitals

→ **40 m³/h.pers** (IDA 2 according to EN 16798-1)

Hospitalization rooms without contagious pathologies (maternity, etc.)

→ **75 m³/h per room for a single room with bathroom**

Rooms for patients with contagious pathology (isolation rooms) and intensive care rooms

The stricter value among the following 2 values*:

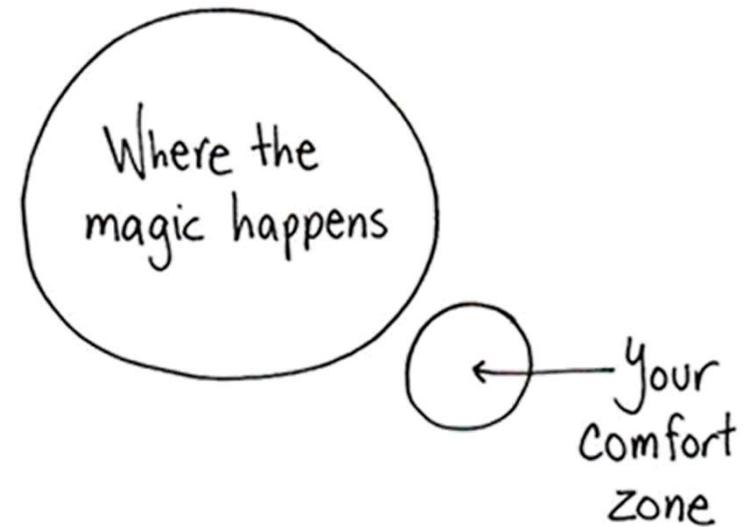
→ **Minimum 2 fresh air changes per hour**

(p.ex. for a room of 48,5 m³ (17,5 m² x 2,5 m) → **99 m³/h**)

→ **100 m³/h.patient** (according to DIN 1946-4)

*Excluding the use of anesthetic gases, in this case allow at least 150 m³/h.patient

Thanks !



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