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FACULTY OF ENGINEERING AND ARCHITECTURE

DEPARTMENT OF ARCHITECTURE AND URBAN PLANNING
BUILDING PHYSICS, CONSTRUCTION AND SERVICES RESEARCH GROUP

EVALUATION METHODS FOR DEMAND-CONTROLLED VENTILATION SYSTEMS:

THE PERSISTENCE OF THE EQUIVALENCE PRINCIPLE

ASC/AIVC 2024 Workshop Singapore

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This assumption of exact physical equivalence makes it impossible for us to speak of the absolute acceleration of the system of reference, just as the usual theory of relativity forbids us to talk of the absolute velocity of a system; and it makes the equal falling of all bodies in a gravitational field seem a matter of course.

— *Albert Einstein, 1911*

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Demand-controlled ventilation

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Ventilation
Information
Paper
n° 38
March 2018

International Energy Agency's
Energy in Buildings and Communities
Programme

Air Infiltration and Ventilation Centre

What is smart ventilation?

François Durier, CETIAT, France
Rémi Carrié, ICEE, France
Max Sherman, LBNL, USA

1 Introduction

In March 2017, AIVC identified smart ventilation for buildings as a new and important topic to be addressed.

Several actions were defined by AIVC Board about this topic in order to exchange and disseminate information on this topic. A working group of AIVC experts from several countries was created. One of its tasks was to agree on a definition of smart ventilation.

The purpose of this paper is to present and illustrate this definition of "smart ventilation".

2 What is smart ventilation?

2.1 Definition

The definition given by AIVC for smart ventilation in buildings is:

"Smart ventilation is a process to continually adjust the ventilation system in time, and optionally by location, to provide the desired IAQ benefits while minimizing energy consumption, utility bills and other non-IAQ costs (such as thermal discomfort or noise).

A smart ventilation system adjusts ventilation rates in time or by location in a building to be responsive to one or more of the following: occupancy, outdoor thermal and air quality conditions, electricity grid needs, direct sensing of contaminants, operation of other air moving and air cleaning systems.

In addition, smart ventilation systems can provide information to building owners, occupants, and managers on operational energy consumption and indoor air quality as well as signal when systems need maintenance or repair.

Being responsive to occupancy means that a smart ventilation system can adjust ventilation depending on demand such as reducing ventilation if the building is unoccupied.

Smart ventilation can time-shift ventilation to periods when a) indoor-outdoor temperature differences are smaller (and away from peak outdoor temperatures and humidity), b) when indoor-outdoor temperatures are appropriate for ventilative cooling, or c) when outdoor air quality is acceptable.

Being responsive to electricity grid needs means providing flexibility to electricity demand (including direct signals from utilities) and integration with electric grid control strategies.

Smart ventilation systems can have sensors to detect air flow, systems pressures or fan energy use in such a way that systems failures can be detected and repaired, as well as when system components need maintenance, such as filter replacement."

"Smart ventilation is a process to continually adjust the ventilation system in time, and optionally by location, to provide the desired IAQ benefits while minimizing energy consumption, utility bills and other non-IAQ costs (such as thermal discomfort or noise)."

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UDC : 697.3

Belgische norm

NBN D 50-001
1e uitg., oktober 1991

Ventilatievoorzieningen in woongebouwen

Dispositifs de ventilation dans les bâtiments d'habitation

Lüftungssystemen von Wohngebäuden

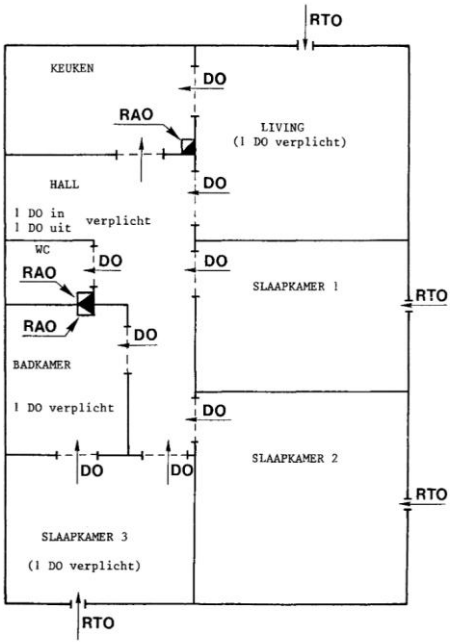
Ventilation systems for housings

Toelating tot publikatie : 1 oktober 1991.

Commissie : Ventilatie

Belgisch Instituut voor normalisatie (BIN), vereniging zonder winstoogmerk
Brabançonnelaan 29 - 1040 BRUSSEL - telefoon (02) 734 92 05 - prk. 000-0063310-66

Prijsgroep : 15



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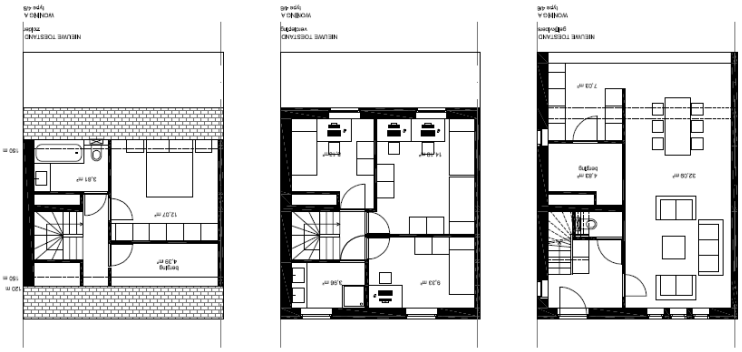

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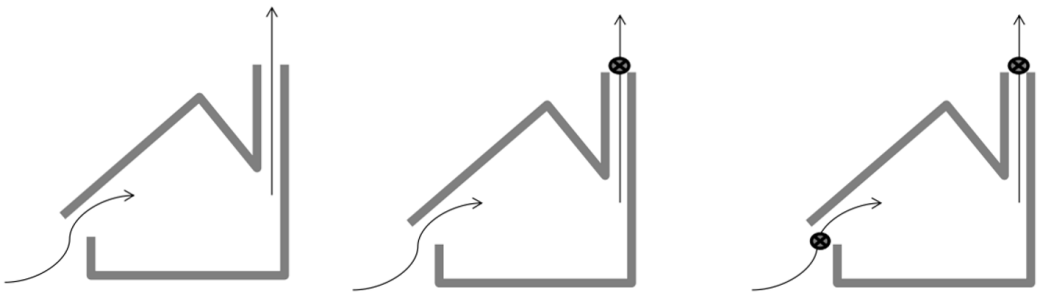

A C D

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Tabel 1 - Nominale ventilatiedebieten

Woonkamer	1l/s per m^2 vloeroppervlakte (3,6 m^3/hm^2) met een minimum van 21 l/s (75 m^3/h). Men moet de 42 l/s (150 m^3/h) niet overschrijden.
Slaapkamer Studeerkamer Speelkamer	1 l/s per m^2 vloeroppervlakte (3,6 m^3/hm^2) met een minimum van 7 l/s (25 m^3/h). Men moet de 10 l/s en per persoon (36 m^3/h persoon) niet overschrijden.
Keuken (1) Badkamer Wasplaats, Droog-plaats + analoge ruimten	1 l/s per m^2 vloeroppervlakte (3,6 m^3/hm^2) met een minimum van 14 l/s (50 m^3/h). Men moet de 21 l/s (75 m^3/h) niet overschrijden.
W.C.	7 l/s (25 m^3/h).
Gangen, trapzalen Nacht- en daghall en analoge doorgangsruimten	1 l/s per m^2 vloeroppervlakte (3,6 m^3/hm^2).
(1) Voor keukens met een open doorgang naar andere kamers of ruimten is het minimaal ventilatie-debiet 21 l/s(75m^3/h).	

7) De toevoeropeningen en afvoeropeningen kunnen worden uitgerust met een automatisch regelsysteem als funktie van de luchtkwaliteit of van de winddrukken of van de CO2- of waterdampconcentratie.

"Supply or exhaust openings can be equipped with an automatic control system as a function of air quality or wind pressure or CO_2- or water vapor concentration"

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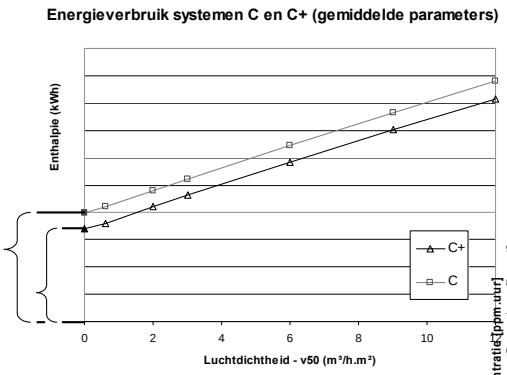
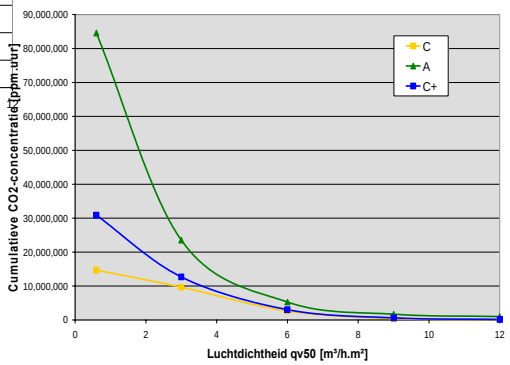
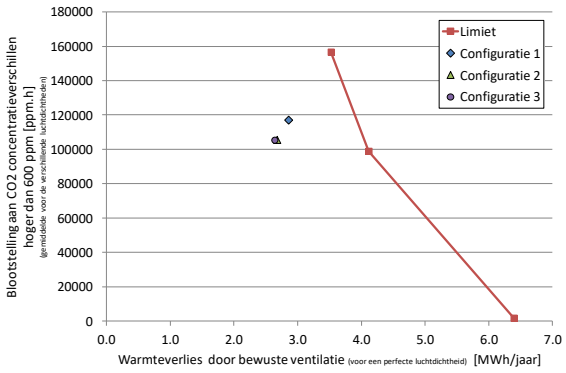
1st generation equivalence

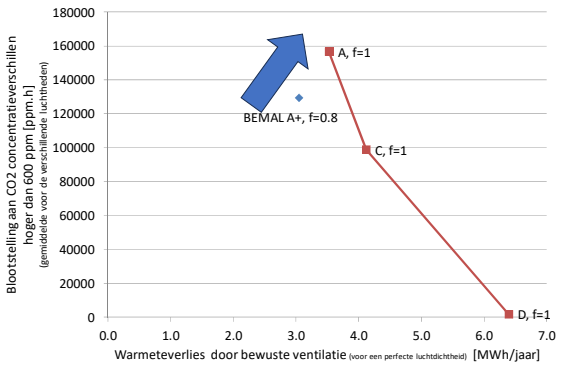
$Q_{v,C}(\sim \dot{V}_{dedic,C})$

$Q_{v,C+}(\sim \dot{V}_{dedic,C+})$






Blootstelling aan CO2 concentratieverschillen hoger dan 600 ppm [ppm.h]
(gemiddelde voor de verschillende luchtdichtheden)
Warmteverlies door bewuste ventilatie (voor een perfecte luchtdichtheid) [MWh/jaar]
Limiet
Configuratie 1
Configuratie 2
Configuratie 3


Blootstelling aan CO2 concentratieverschillen hoger dan 600 ppm [ppm.h]
(gemiddelde voor de verschillende luchtdichtheden)
Warmteverlies door bewuste ventilatie (voor een perfecte luchtdichtheid) [MWh/jaar]
BEMAL A+, f=0.8
A, f=1
C, f=1
D, f=1

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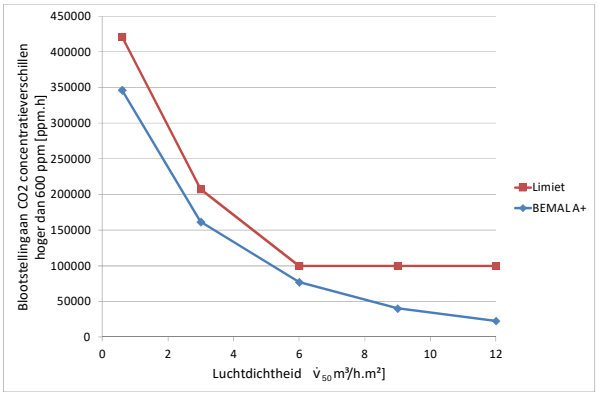
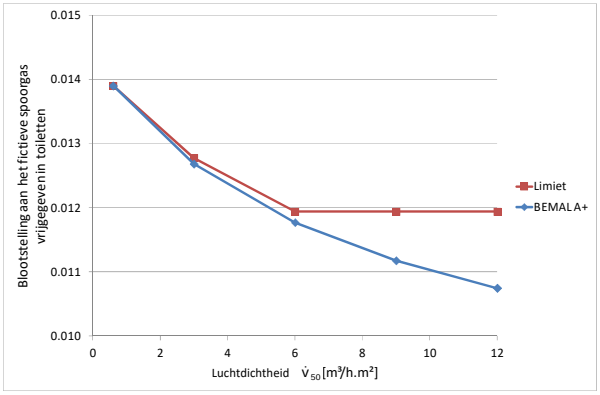

Blootstellingaan CO2 concentratieverschillen hoger dan 600 ppm [ppm.h]
Luchtdichtheid v̇50 m³/h.m²]
Limiet
BEMAL A+


Blootstelling aan het fictieve spoorgas vrijgegeven in toiletten
Luchtdichtheid v̇50 [m³/h.m²]
Limiet
BEMAL A+

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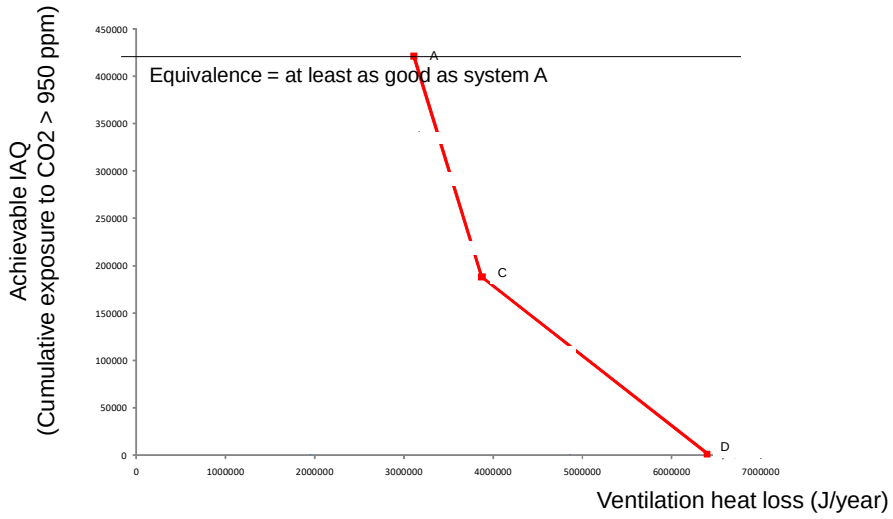
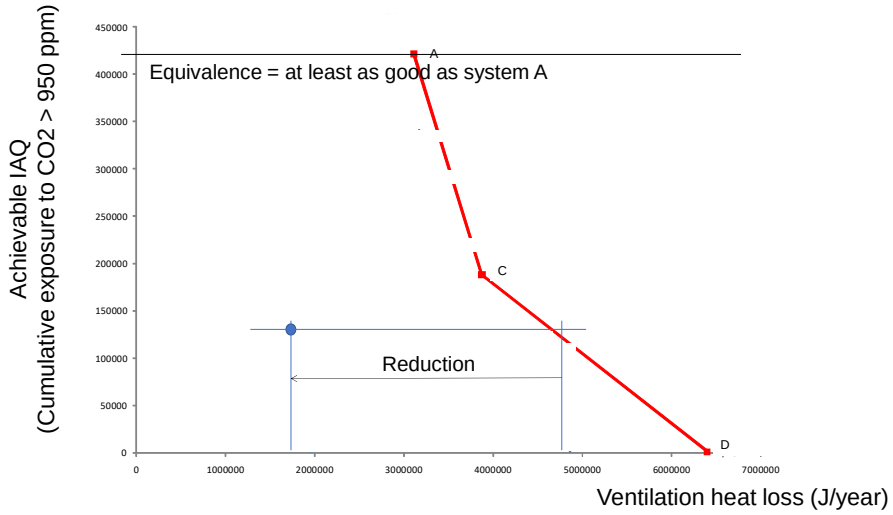
2nd generation equivalence





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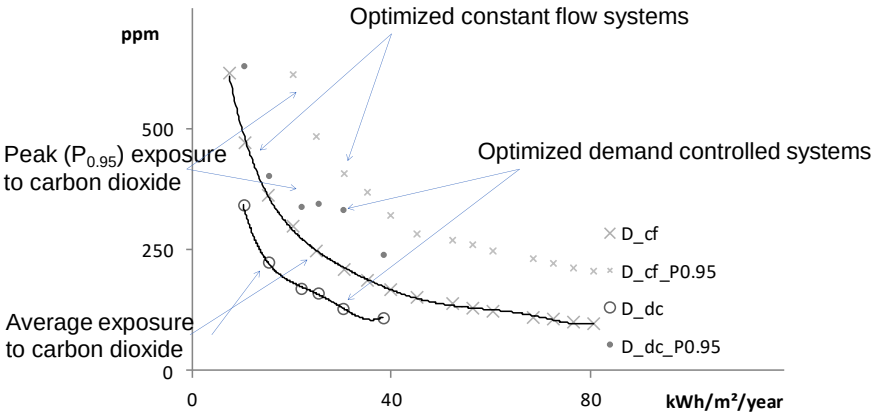
Investigating the potential…



Ventilation and infiltration heat loss
for mechanical supply and exhaust systems

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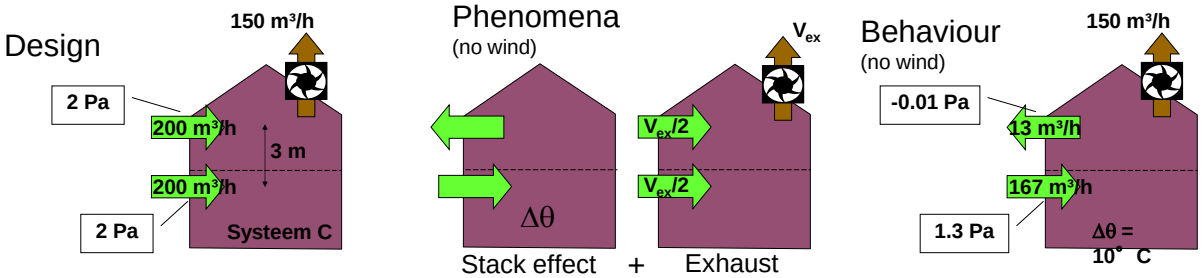
Exploring the real behaviour

example: interaction mechanical exhaust and natural supply



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'Smartzone'

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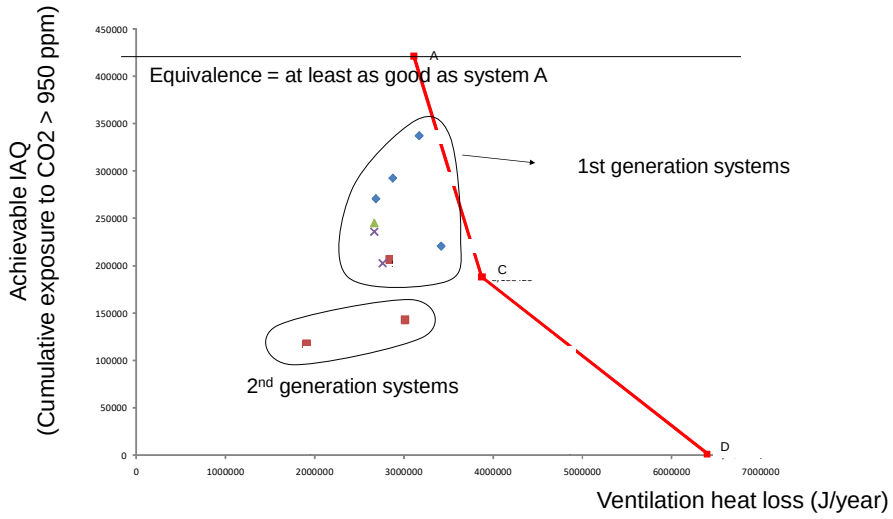

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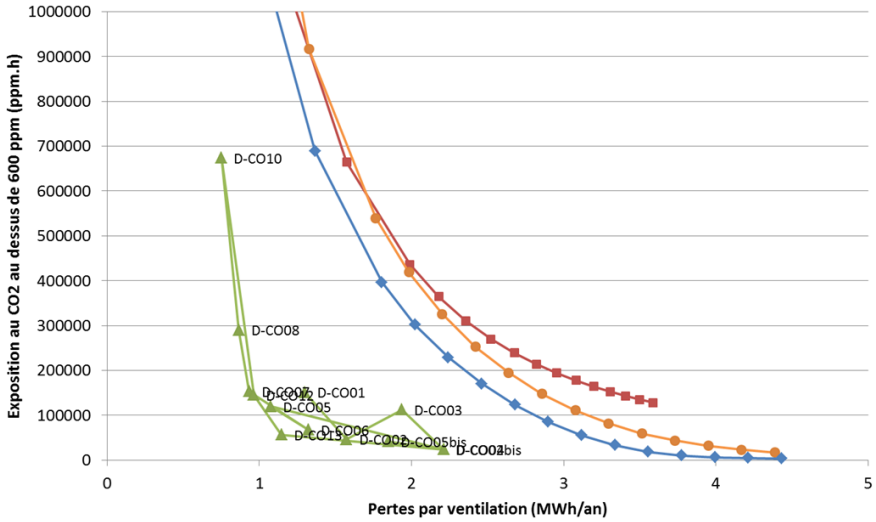

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Tabel [1]: $f_{reduc,vent,heat,zone\ z}$ voor ventilatiesystemen A, B, C et D met een regeling op de toevoer in functie van de behoefte in de droge ruimten en/of een regeling op de afvoer in functie van de behoefte in de natte ruimten

Type detectie in de droge ruimten	**Type regeling van de toevoer in de droge ruimten**	**Type detectie in de natte ruimten**		
		Lokale detectie in de natte ruimten		**Andere detectie** of **Geen detectie**
		Lokale regeling van de afvoer	**Centrale regeling** van de afvoer	
CO_2 - lokaal: één of meerdere sensoren in elke droge ruimte	Lokaal	0,35	0,38	0,42
	2 (dag/nacht) of meer zones	0,41	0,45	0,49
	Centraal	0,51	0,56	0,61
CO_2 - semi-lokaal: één of meerdere sensoren in elke slaapkamer	Centraal	0,60	0,65	0,70
CO_2 - semi-lokaal: één of meerdere sensoren in de belangrijkste woonkamer en één of meerdere sensoren in de belangrijkste slaapkamer	2 (dag/nacht) of meer zones	0,43	0,48	0,53
	Centraal	0,75	0,81	0,87
CO_2 - centraal: één of meerdere sensoren in het afvoerkanaal of de afvoerkanalen	Centraal	0,81	0,87	0,93
Aanwezigheid - lokaal: één of meerdere sensoren in elke droge ruimte	Lokaal	0,54	0,60	0,64
	2 (dag/nacht) of meer zones	0,63	0,67	0,72
	Centraal	0,76	0,82	0,88
Aanwezigheid - semi-lokaal: één of meerdere sensoren in elke slaapkamer	Centraal	0,87	0,93	1,00
Aanwezigheid - semi-lokaal: één of meerdere sensoren in de belangrijkste woonkamer en één of meerdere sensoren in de belangrijkste slaapkamer	2 (dag/nacht) of meer zones	0,66	0,72	0,78
	Centraal	0,87	0,93	1,00
Andere of **geen detectie** in de droge ruimten	Geen, lokaal, per zone of centraal	0,90	0,95	1,00

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3rd generation equivalence

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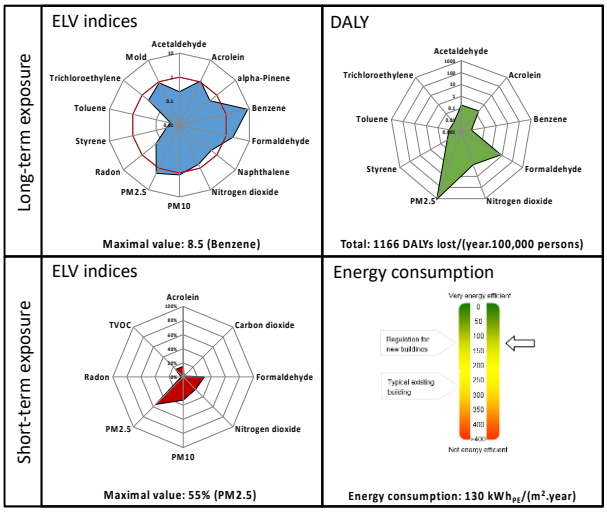
Rating?

3 cases

Comparing cases
Ranking options / engineering case
Accrooss buildings / generic options



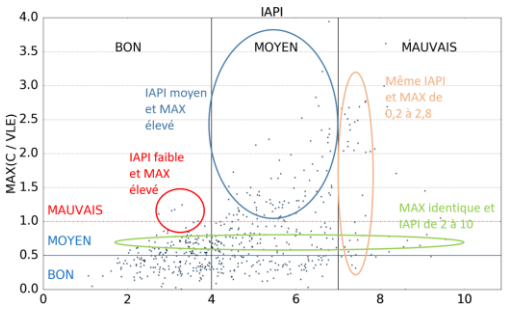


Figure 15 : Détection des masques d'information et des incohérences – Exemple pour l'indice IAPI.

Tableau 20 : Synthèse de la distribution de la population en fonction des interprétations respective de chaque indice.

Liste des indices étudiés	Résultats (% population)		
	Bon	Moyen	Mauvais
IAPI	38	48	14
LHVP	94	0	6
CLIM2000	100	0	0
BILGA	80	18	2
GAPI	33	33	34
IEI	59	38	3
Quad-BBC	95	3	2
DALY	33	33	34

Tableau 21 : Synthèses des forces et faiblesses pour chaque indice, partie 1.

Liste des indices étudiés	Avantages							
	Discriminant	Nombre de polluants	Facilité de mise en place	Facilité d'interprétation	Valeurs bornées	Effets sanitaires	Cohérence avec l'indice MAX	Perte information
IAPI	++	+	++	++	++	+	-	-
LHVP	--	--	++	++	--	-	++	--
CLIM2000	---	--	++	++	--	-	+	--
BILGA	--	+	++	++	+	+	-	-
GAPI	+	++	+	---	--	-	--	---
IEI	-	+	+	++	++	-	-	+
Quad-BBC	-	+	+	-	-	+	+	-
DALY	+	+	-	-	--	+++	++	-

Tableau 22 : Synthèse des forces et faiblesses pour chaque indice, partie 2.

Liste des indices étudiés	Avantages						
	Présence de sous-indices	Valeurs de référence	Cohérence de l'information transmise	Poids des sous-indices	Cohérence de la formule	Agglomération des sous-indices	Précision d l'information
IEI	++	+	++	++	++	+	-
LHVP	--	--	++	++	--	-	++
CLIM2000	---	--	++	++	--	-	+
BILGA	--	+	++	++	+	+	-
GAPI	+	++	+	---	--	-	--
IEI	-	+	+	++	++	-	-
Quad-BBC	-	+	+	-	-	+	+
DALY	+	+	-	-	--	+++	---

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- Martin Luther King, Jr.

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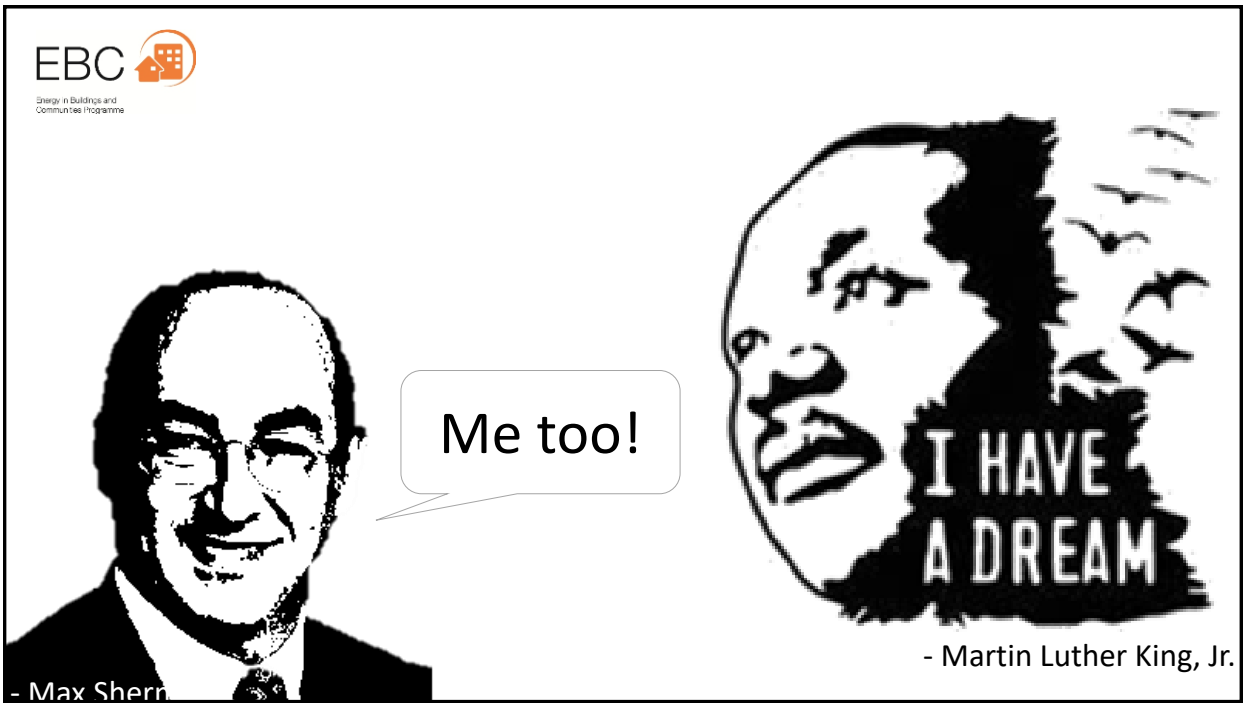
EBC
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Me too!
I HAVE A DREAM
- Martin Luther King, Jr.
- Max Shern

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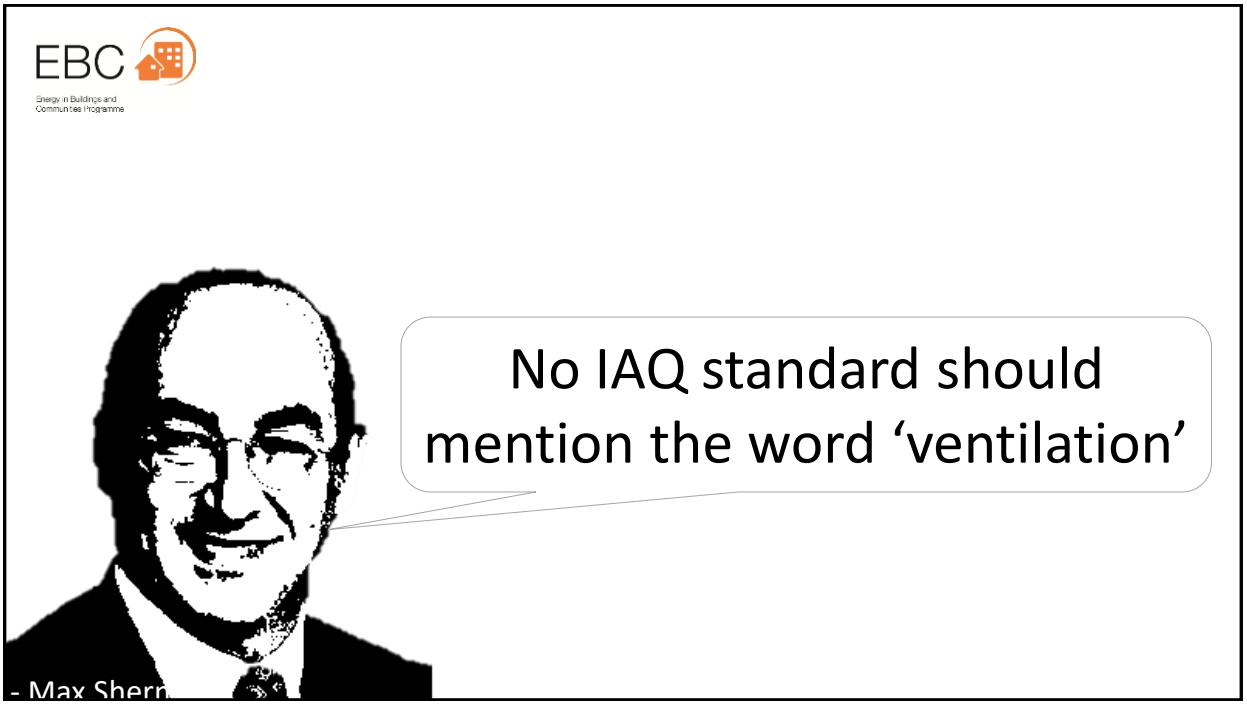
EBC
Energy in Buildings and Communities Programme
No IAQ standard should mention the word ‘ventilation’
- Max Shern

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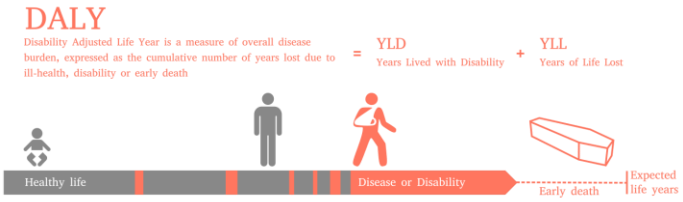
ST 1: indicators

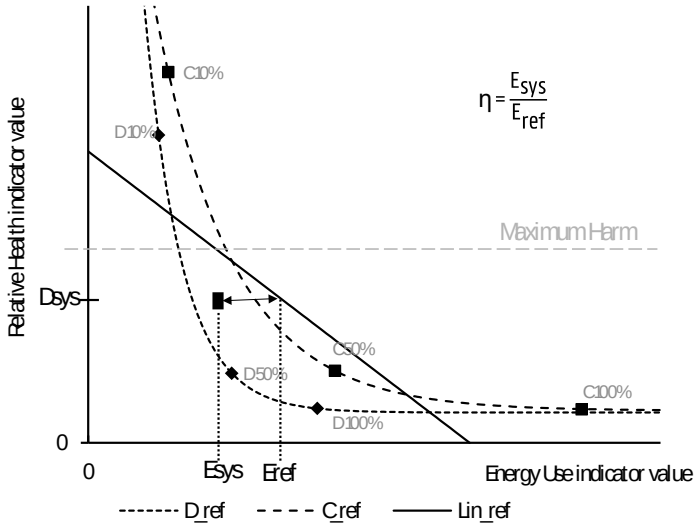
3 main IAQ goals

Avoid excessive harm to health

Avoid damage to building

Strive for acceptible PAQ





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- Material cost
- Maintenance
- Operation
- Installation cost

Hard costs

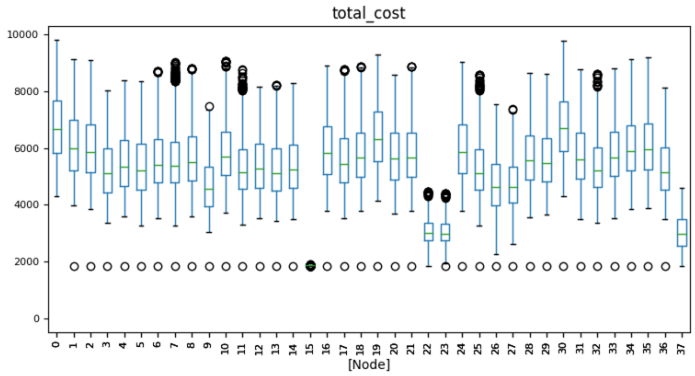
- Health cost
- Productivity loss
- Learning disturbance

Soft costs

- Willingness to pay

Not accounted yet

Update on total cost
<> Boulanger et al.



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4th generation equivalence

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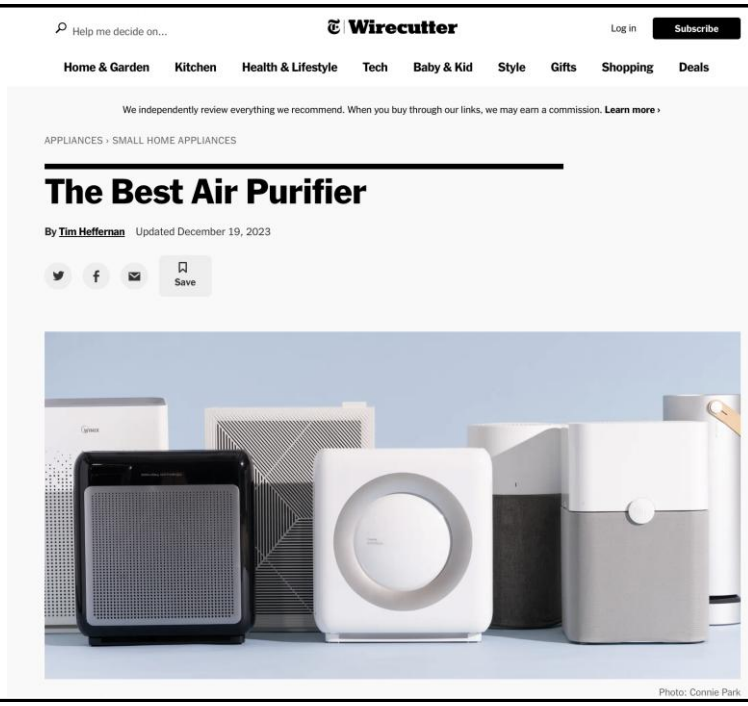

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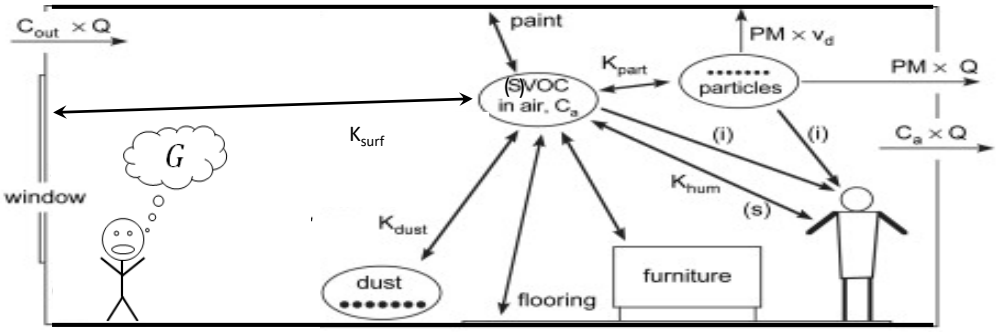

Mash-up of Weschler et al. & Dols, 2020, https://doi.org/10.6028/NIST.TN.2095

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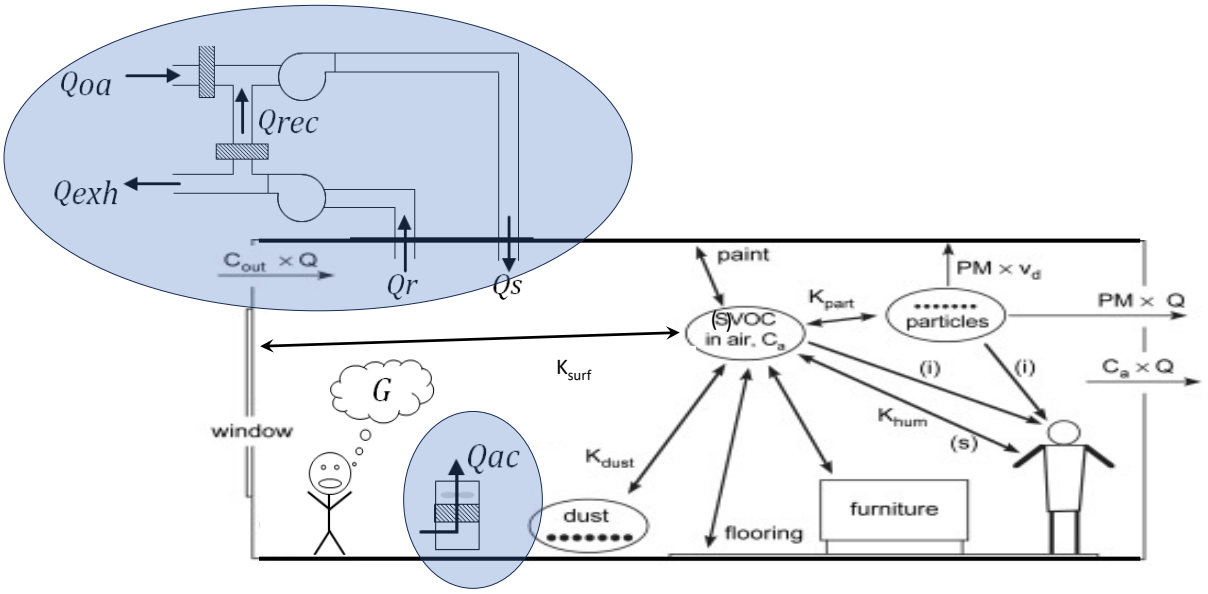
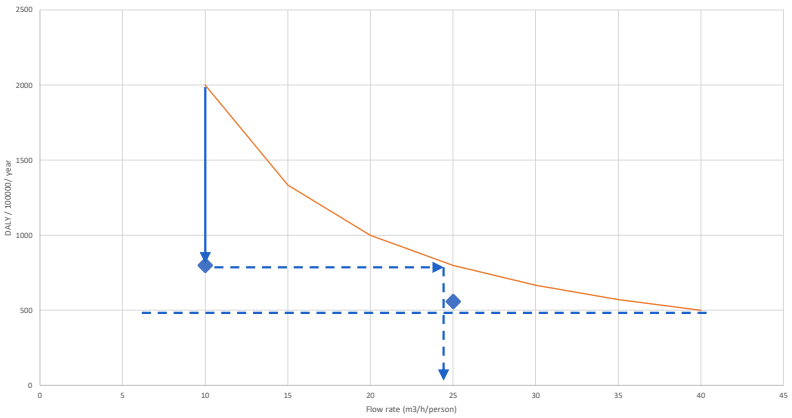


Mash-up of Weschler et al. & Dols, 2020, https://doi.org/10.6028/NIST.TN.2095

Equivalent impact of Air CLeaning



FACULTY OF ENGINEERING AND ARCHITECTURE

Jelle Laverge
Associate Professor

ARCHITECTURE & URBAN PLANNING

E jelle.laverge@ugent.be
T +32 9 264 37 49

architecture.ugent.be

Ghent University
@Jlaverge
Jelle Laverge

GHENT UNIVERSITY