Technische Universiteit Eindhoven University of Technology

# Concentration versus $m^3$ air per hour

*The battle of the assessors?*

Marcel Loomans – Building Performance Group
Department of the Built Environment, Eindhoven University of Technology

## Performance Based Building

Technische Universiteit Eindhoven University of Technology

Performance approach

- Work with the **end result** in mind, not the means.
- Performance is about what a building has **to do**, not how it is built.
- A building needs to be **assessed** on its performance in an **objective** manner.

Design → Construction → Use → Demolition

Alternative: Prescriptive approach…

# What is the difference?

Technische Universiteit Eindhoven University of Technology

Prescriptive versus Performance

"Turn left at the next traffic lights, then take the fourth street to the right, go right ahead at the first roundabout, turn to the right at the second roundabout and keep the left lane, then turn ……."


Spekkink, D. 2005. Key note presentation on PeBBu, CIB Conference, Helsinki, 2005

# What is the difference?

Technische Universiteit Eindhoven University of Technology

Prescriptive versus Performance

**"To the airport!"**


Spekkink, D. 2005. Key note presentation on PeBBu, CIB Conference, Helsinki, 2005

# Room ventilation

Air change per hour (ACH), $m^3/h$ ($q_v$), supply conditions, …

**Prescriptive**


"Turn left at the next traffic lights, then take the fourth street to the right, go right ahead at the first roundabout, turn to the
right at the second roundabout and keep the left lane, then turn ……."

Assumes a certain performance from the ventilation system for the room.

# Room ventilation

Health, Comfort, Productivity, Energy, …

**Performance**


**"To the airport!"**

Needs performance indicators related to, e.g.,
Air quality, Thermal comfort, Energy demand, …

# Room ventilation

Technische Universiteit Eindhoven University of Technology

## Performance indicators

**Concentration contaminants, PM2.5, PMV, kWh/m$^2$, local air change index, contaminant removal efficiency,…**

Ventilation (for air quality) is one of the design solutions to fulfill the requirements…

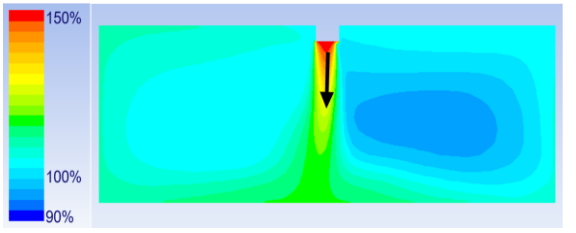
…source control

…filtering, photocatalytic oxidation, …

# System versus Room

Technische Universiteit Eindhoven University of Technology

**ACH** or $\mathbf{q_v}$ is a performance at **system level**




Local Air Change Index

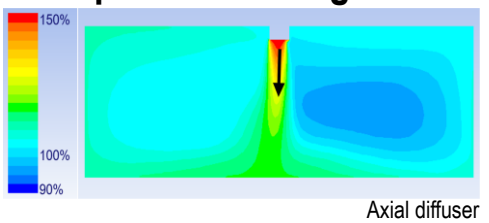
**Ventilation efficiency** is a performance at **room level**

Dijkstra, D., Loomans, M.G.L.C., Hensen, J.L.M. & Cremers, B.E. (Bart) (2016). Ventilation efficiency in a low-energy dwelling setting – a parameter study for larger rooms. Proceedings of the 14th International Conference on Indoor Air Quality and Climate (Indoor Air 2016), 3-8 July 2016, Ghent, Belgium: Ghent University

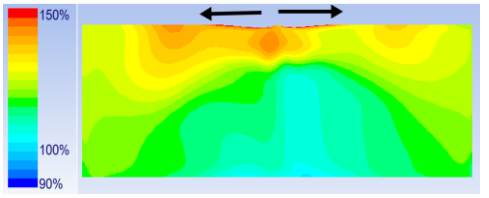
# System versus Room

## Example for dwelling

Local Air Change Index ($\varepsilon_p^a = {}^{\tau_n}/_{\bar{\tau}_p} \cdot 100\%$)




Axial diffuser



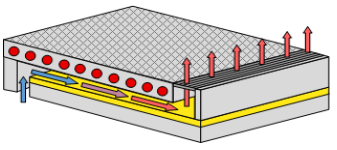

Radial diffuser

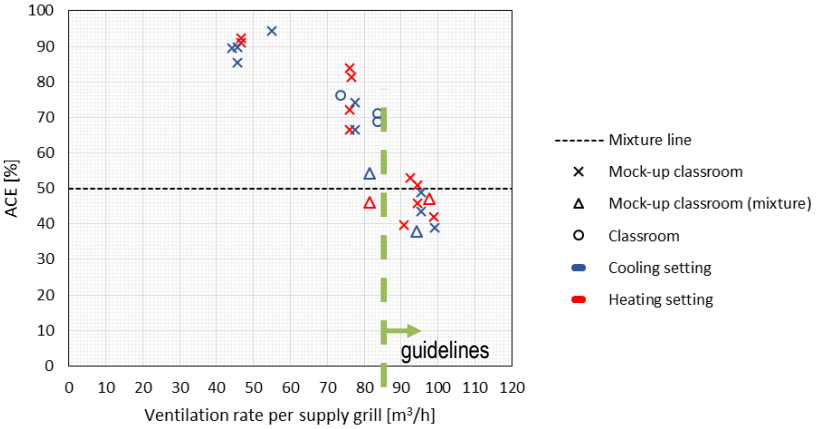
Dijkstra, D., Loomans, M.G.L.C., Hensen, J.L.M. & Cremers, B.E. (Bart) (2016). Ventilation efficiency in a low-energy dwelling setting – a parameter study for larger rooms. Proceedings of the 14th International Conference on Indoor Air Quality and Climate (Indoor Air 2016), 3-8 July 2016, Ghent, Belgium: Ghent University

# System versus Room

## Example for classroom ventilation

Air Change Efficiency



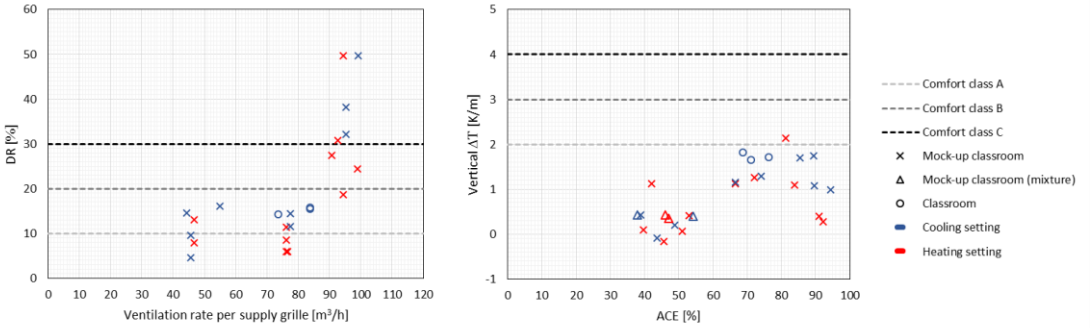



Steen, J. vd, Loomans, M., Schellens, N. & Hensen, J.L.M. 2017. Full-scale performance assessment of an innovative climate system for a classroom environment. Submitted for Healthy Buildings 2017 Europe, Lublin (Pl), 2-5 juli 2017.

# System versus Room

## Example for classroom ventilation

Draught rate + temperature gradient




Steen, J. vd, Loomans, M., Schellens, N. & Hensen, J.L.M. 2017. Full-scale performance assessment of an innovative climate system for a classroom environment. Submitted for Healthy Buildings 2017 Europe, Lublin (Pl), 2-5 juli 2017.

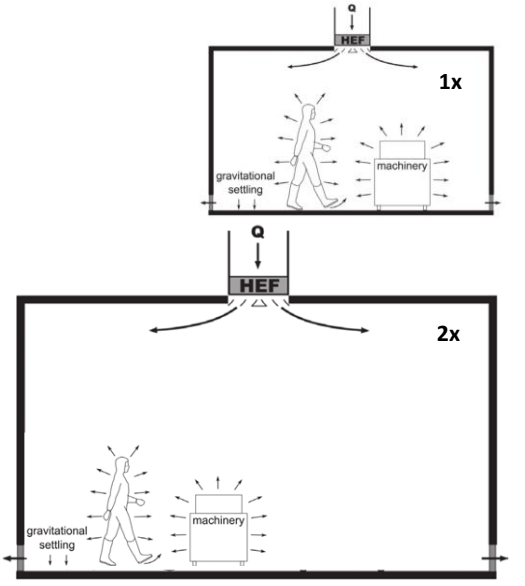
# Rules of thumb…

## Example for clean rooms

| EU-GMP Class | ACH |
|---|---|
| Grade D | 6-20 |
| Grade C | 20-40 |
| Grade B | 40-60 |

Guidelines values for air change rate (ISPE 2011)

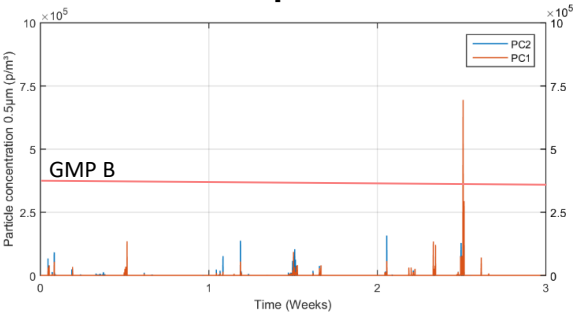
**Overdesigning…**



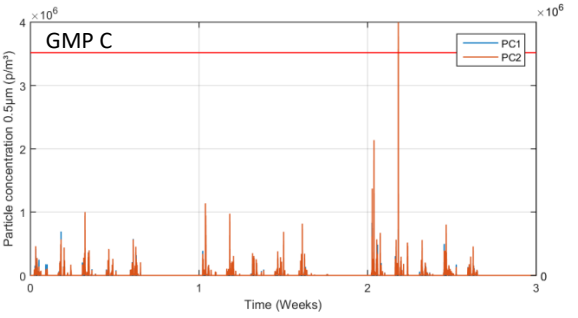

Molenaar. P.C.A. 2017. Ventilation efficiency improvement in pharmaceutical cleanrooms for energy demand reduction. Final Master thesis. Eindhoven University of Technology, Eindhoven.

# Rules of thumb…

## Example for clean rooms




0.5 µm particle concentration in two cleanroom facilities




GMP* C demand: 3,520,000 particles/m³ in operation
99.9% complying with GMP B…

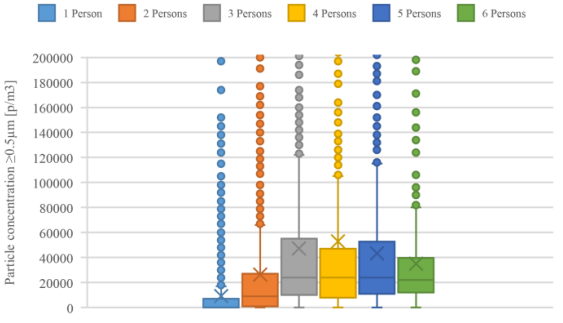
**Overdesigning…**

* GMP: Good Manufacturing Practice

Molenaar. P.C.A. 2017. Ventilation efficiency improvement in pharmaceutical cleanrooms for energy demand reduction. Final Master thesis. Eindhoven University of Technology, Eindhoven.

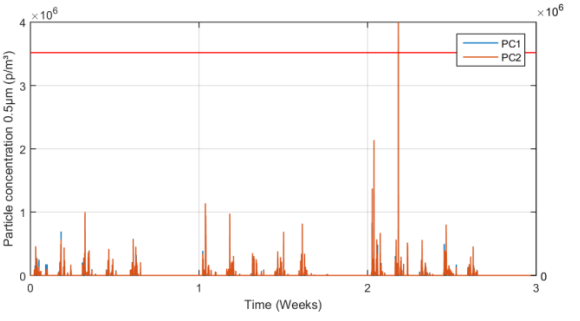
# Rules of thumb…

## Example for clean rooms




Sources

Particle sources




Molenaar. P.C.A. 2017. Ventilation efficiency improvement in pharmaceutical cleanrooms for energy demand reduction. Final Master thesis. Eindhoven University of Technology, Eindhoven.

# Rules of thumb…

## Example for clean rooms

Energy savings Demand Control Filtration

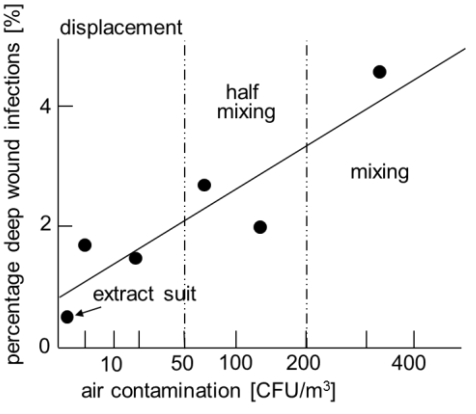
| Cleanroom | % of time occupied | ACR setback % of time | Overall fan speed energy Savings [%] |
|---|---|---|---|
| Facility H: Room B | 1.8 | 96.1 | 93.6 |
| Facility H: Room C | 3.2 | 88.9 | 86.8 |
| Facility R: | 22.5 | 70.0 | 68.1 |

Molenaar. P.C.A. 2017. Ventilation efficiency improvement in pharmaceutical cleanrooms for energy demand reduction. Final Master thesis. Eindhoven University of Technology, Eindhoven.

# Operating room ventilation

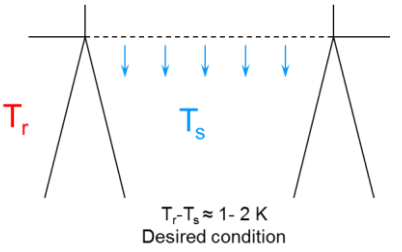
## Requirement at system level (old guideline)

http://www.uhn.ca/



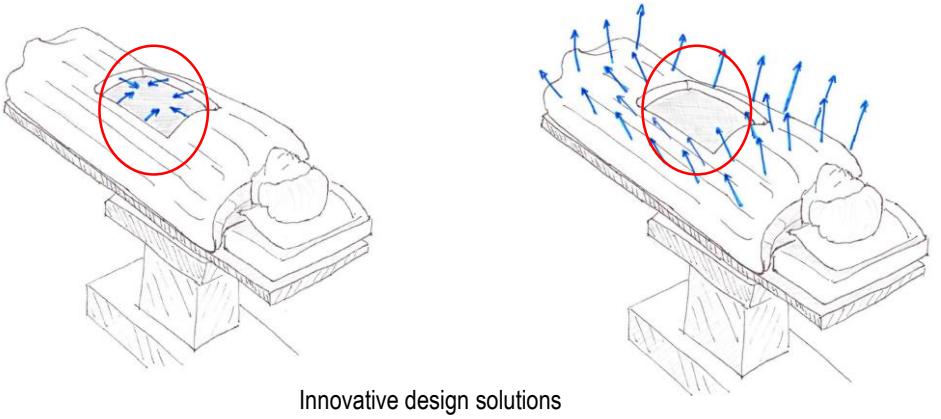

Lidwell, O.M., e.a. 1987. Ultraclean air and antibiotics for prevention of postoperative infection, Acta Orthop. Scand. 58, pp. 4-13.

UDF system
(minimum supply velocity)



# Operating room ventilation

## Requirement at wound level (new guideline)

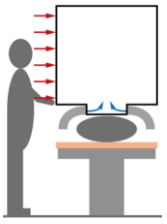


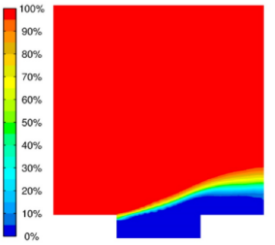
Innovative design solutions

Loomans, M.G.L.C., de Visser, I.M., Loogman, J.G.H. & Kort, H.S.M. (2016). Alternative ventilation system for operating theaters: parameter study and full-scale assessment of the performance of a local ventilation system. Building and Environment, 102, 26-38.

# Operating room ventilation

## Performance assessment






6-15% air change rate compared to UDF system

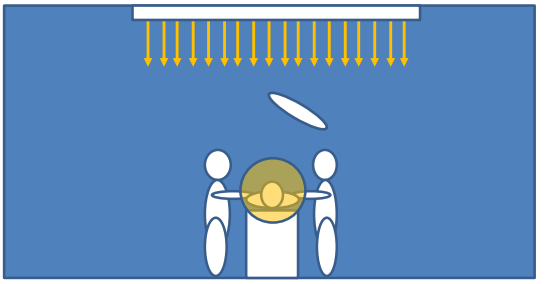
Loomans, M.G.L.C., de Visser, I.M., Loogman, J.G.H. & Kort, H.S.M. (2016). Alternative ventilation system for operating theaters: parameter study and full-scale assessment of the performance of a local ventilation system. Building and Environment, 102, 26-38.

# Room to system performance

Case: operating room ventilation

*System performance*

$q_v$ [$m^3$/h]



CFU/$m^3$

*Room performance*

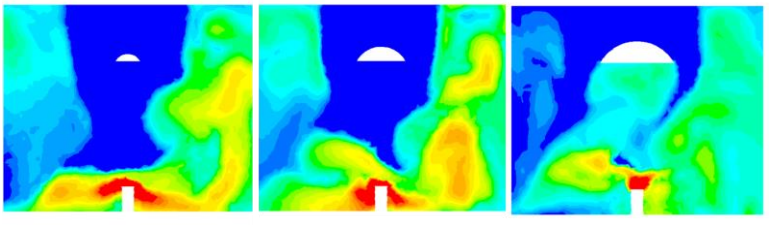
Variation:

- #personnel

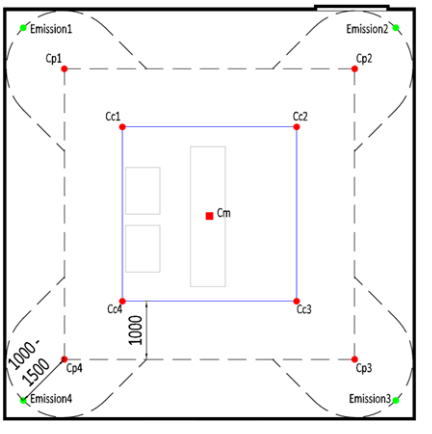
- #equipment
- type

# Operating room ventilation

## Scenario's – use cases - …

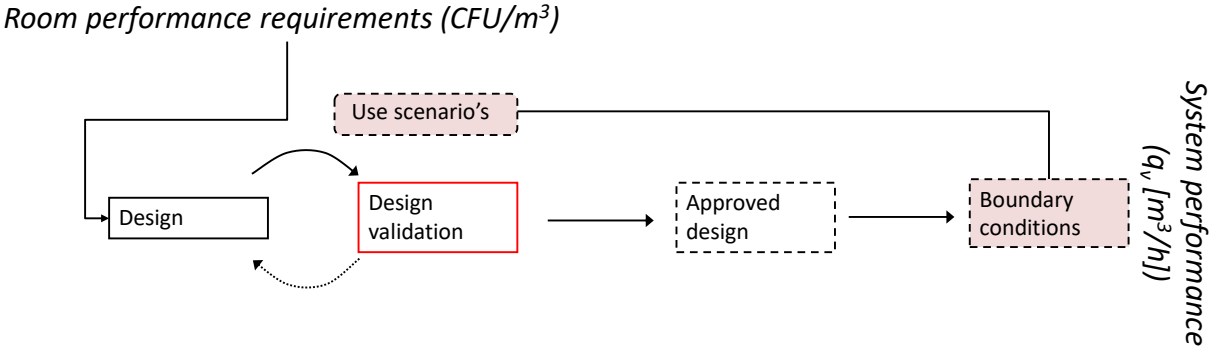


Zoon, W. *personal communication*



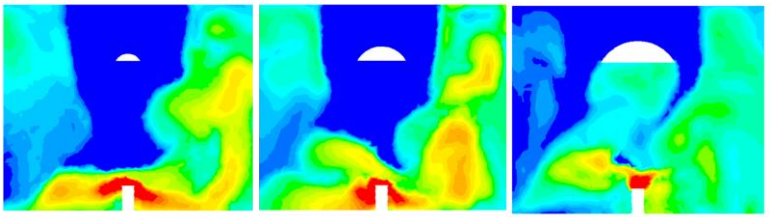

VCCN RL7 (2014)

# Room to system performance



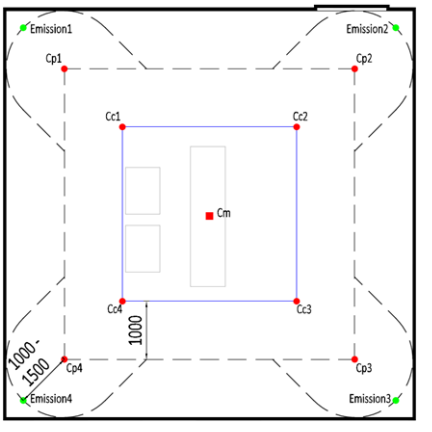

Adapted from Zoon, W. *personal communication*

# Operating room ventilation



Determine supply boundary constraints within which a solution can work.

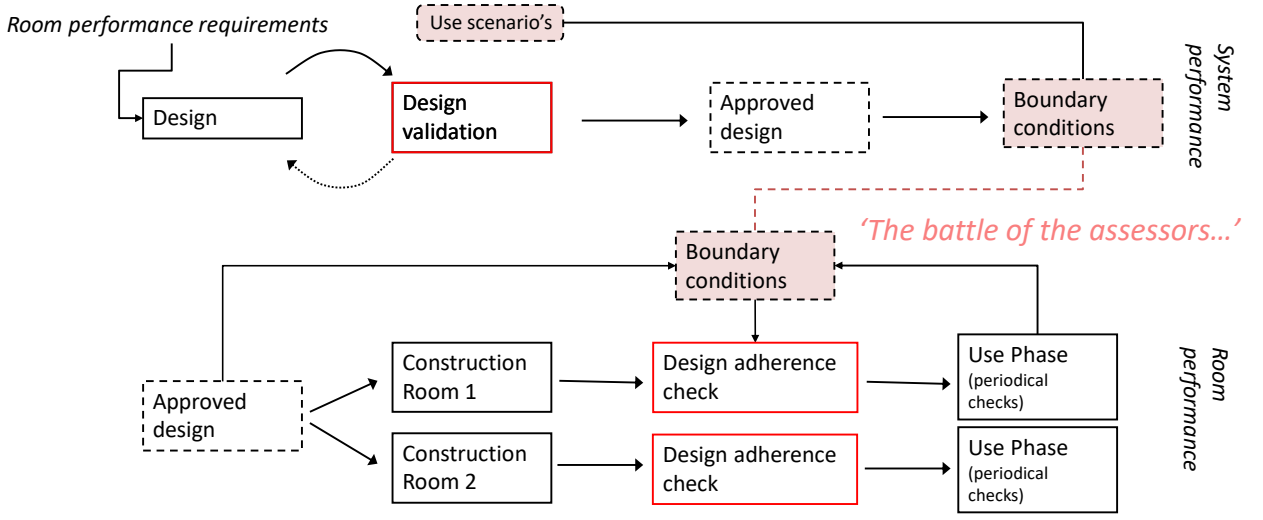
- Design variants
- Scenario's
- …




VCCN RL7 (2014)

Zoon, W. *personal communication*

# System to room performance




Adapted from Zoon, W. *personal communication*

# Prescriptive and Performance

*System level* *Room level*

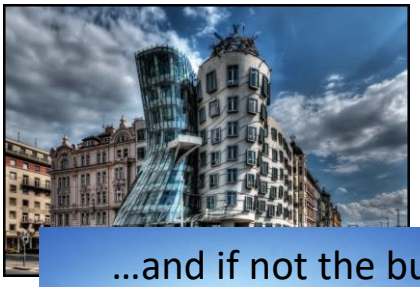
Air flow rate (ACH, $m^3/h$)

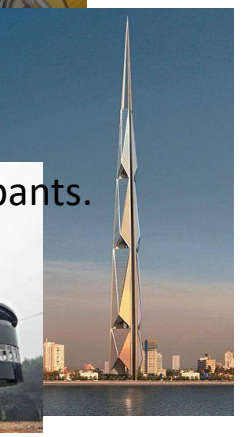
"Turn left at the next traffic lights, then take the fourth street to the right, go right ahead at the first roundabout, turn to the right at the second roundabout and [illegible] turn ……."


Contamination concentration (CFU/m3)

Potential for well defined cases, but buildings tend to be unique…

...





…and if not the buildings, then at least its occupants.

7S815

http://www.lifehack.org/articles/lifestyle/25-insanely-unique-and-mind-blowing-buildings-around-the-world.html