CLIMA 2019
Built environment facing climate change
REHVA 13th HVAC World Congress
26 - 29 May, Bucharest, Romania
BUILT ENVIRONMENT FACING CLIMATE CHANGE
Diamond sponsors

Costs and benefits of antibacterial filter and its effects on energy saving, human health and worker productivity

Cristina Becchio

Politecnico di Torino

28-05-2019

Scenario

Revised EPBD 2018/844

Multiple benefits at economic, societal and environmental levels; improvement of the **quality of life**, **health and performance of occupants**

Establishment of a **Smart Readiness Indicator (SRI)**

Total score is based on average of total scores on 8 IMPACT CRITERIA:

Scenario

PROBLEMS

40%
Total energy consumption of buildings in Europe

90%
Time spent in enclosed environments

50 %
Outdoor pollutants carried into building

24%
Diseases in the world due to environmental factors

SOLUTION

Air filtration in HVAC system has the potential to reduce the outdoor to indoor transport of pollutants and to improve health, comfort and productivity of occupants

NEW TECHNOLOGIES

ANTIBACTERIAL FILTER
in HVAC system

Research Goal

To demonstrate that the antibacterial filter cost, in HVAC system, is totally repaid by **socio-economic benefits**

COSTS

Costs related to the air filtration

BENEFITS

ENERGY SAVINGS

HUMAN HEALTH

WORKER PRODUCTIVITY

COMPARISON WITH REFERENCE FILTER FROM LITERATURE

Impacts of pollutants on human

Case studies

	11 l/s per person	67
	11 l/s per person	67
	5 l/s per person	140 students + 10 teachers
	16.5 l/s per person	43 students + 2 teachers
	11 l/s per person	67

Methodology

AIR' SUITE FILTER vs REFERENCE FILTER

Features and antibacterial capability

COSTS → FINANCIAL VALUATION

Approach used to evaluate the costs associated with air filtration

BENEFITS → SOCIO-ECONOMIC EVALUATION

Benefits of Air'Suite filter in terms of human health effects and reduction of employees' productivity loss

RESULTS → COST-BENEFIT ANALYSIS

Reference Filter VS Air'Suite Filter

Reference Filter		Outdoor pollutants		Air' Suite Filter
	50% «	PM 1	» 50%	
	80% «	PM 2.5	» 90%	
	95% «	PM 10	» 95%	
	0% «	SO_2	» 20%	
	0% «	NO_2	» 5%	
	0% «	CO_2	» 1%	
		Bacteria		
	0% «	Gram+	» 98%	
	0% «	Gram-	» 53%	

NO molecular filtration power

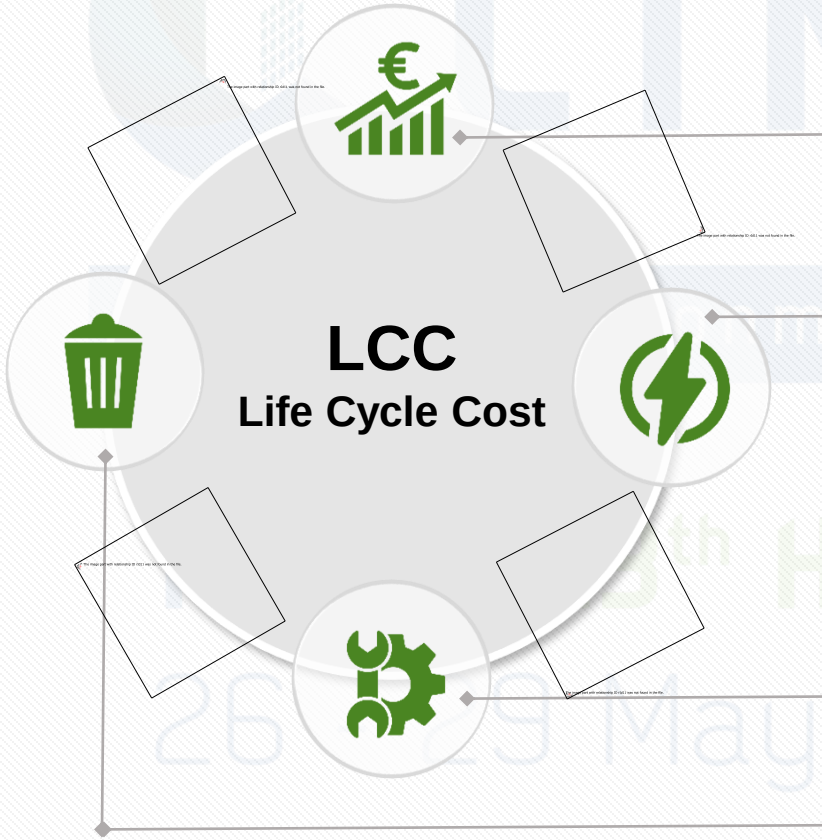
INEFFECTIVE against gaseous substances

Can remove these pollutants in a range **from 1% to 20%**, compared to a reference one

Staphylococcus Aureus

Escherichia Coli

Life Cycle Cost Analysis



Investment Cost

Energy Cost

Maintenance Cost

Disposal Cost

LCC_{TOTAL} =

$I_{investment}$
+
LCC_{energy}
+
$LCC_{maintenance}$
+
$LCC_{disposal}$

Life Cycle Cost Analysis

	AIR' SUITE FILTER	REFERENCE FILTER
Investment Cost (MEDIUM size)	150 €	65 €
Maintenance Cost	40 €/year	
Disposal Cost	4 € (increase 5% per year)	
Energy Cost	156 €	244 €
Initial – Final Pressure	70 Pa – 250 Pa	80 Pa – 450 Pa
Average Pressure Drop	130 Pa	203 Pa

Air flow Rate: **1 m³/s**
Calculation period: **10 years**
Cost of energy: **0.10 €/kWh**
Interest Rate: **6%**
Ventilation Efficiency: **50%**

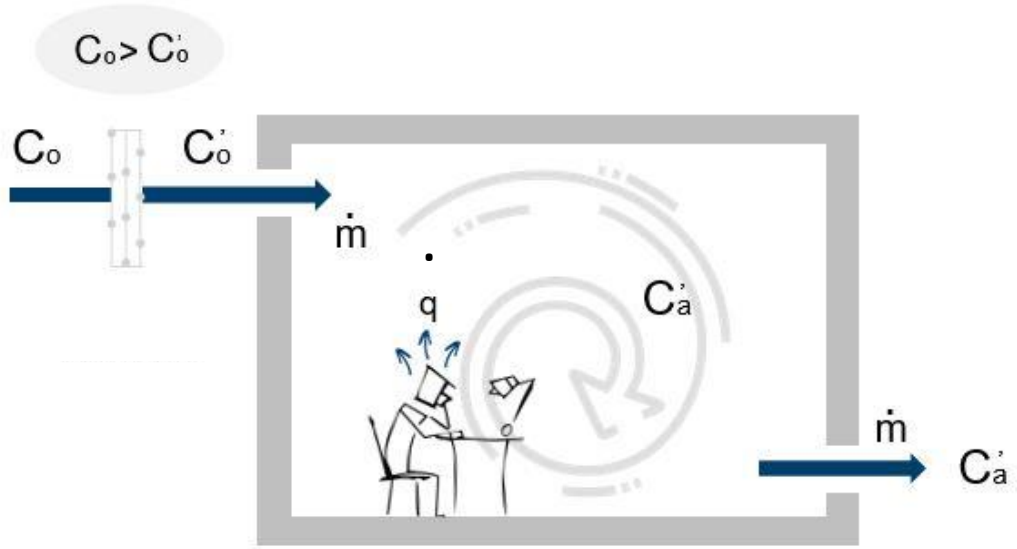
LCC RESULTS

REFERENCE FILTER	**2,682 €**
AIR' SUITE FILTER	**1,934 €**

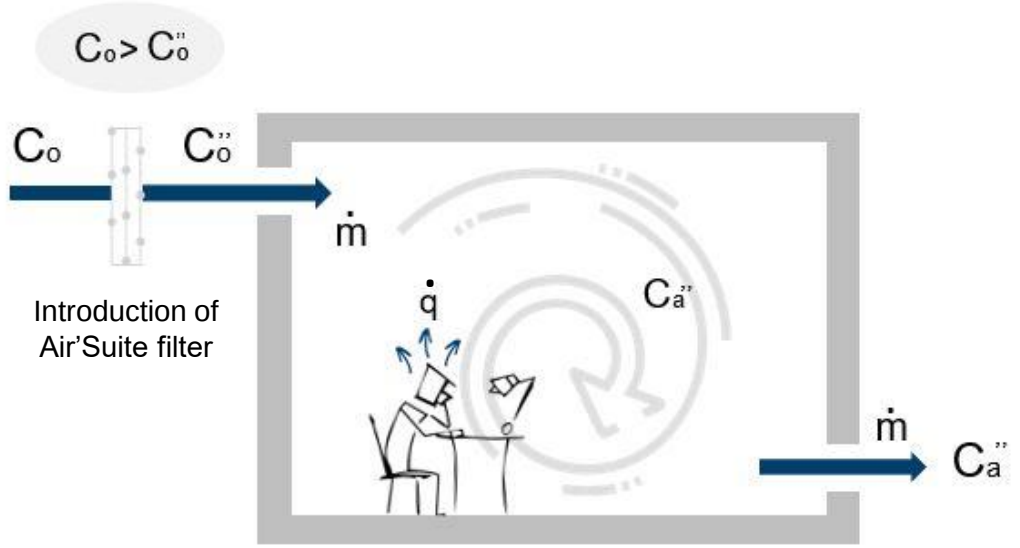
Socio-economic evaluation: HEALTH

- CONSTANT external air flow
- Medium size filter (both Reference filter and Air'Suite filter)

REFERENCE FILTER



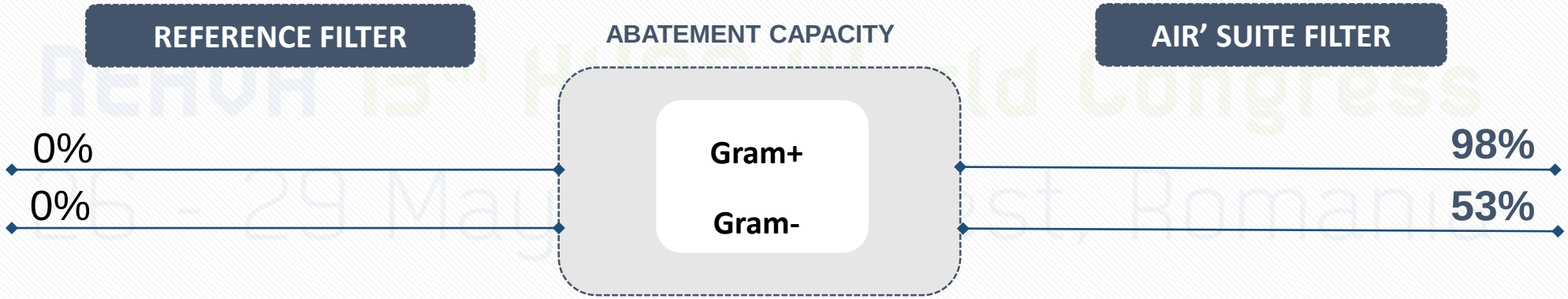
AIR' SUITE FILTER



Contaminants and Diseases

BACTERIA
STAPHILOCOCCUS AUREUS (Gram +) and ESCHERICHIA COLI (Gram -)

DISEASES
PNEUMONIA and MENINGITIS



Evaluation Method: Cost of Illness

The COI technique evaluates benefits of antibacterial filter as avoided costs: *direct and indirect costs*

DIRECT COSTS

Medical care costs

- Hospitalization
- Antibiotic treatment

INDIRECT COSTS

Human Capital Approach (HCA)

- Loss of working days

For each day of absence is attributed an economic value that corresponds to the loss of productivity

Direct and Indirect Costs = Benefits of Air'Suite Filter

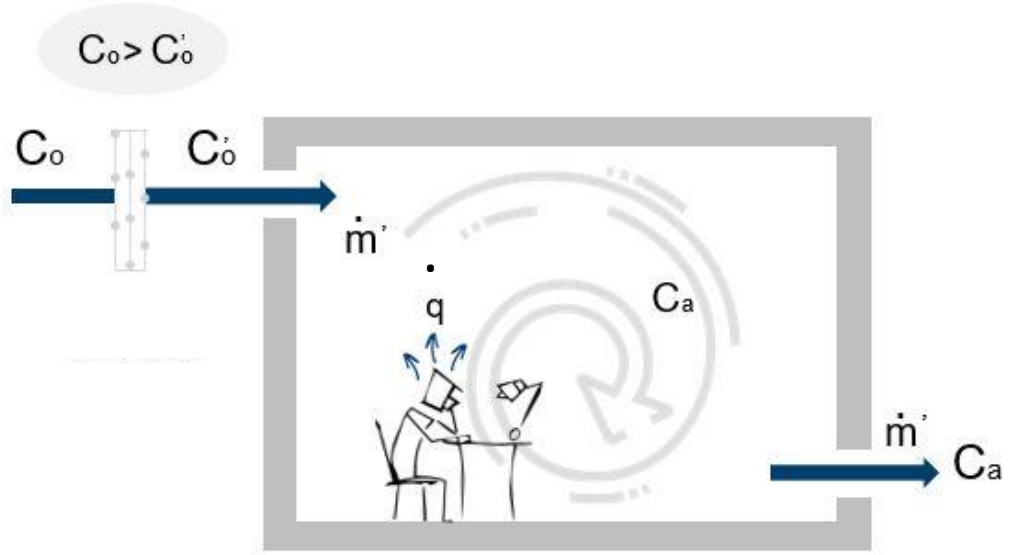
DIRECT COSTS per patient	€
Cost of antibiotic treatment for **pneumonia**	**37.50**
Cost for outpatient management for pneumonia	**182**
Daily cost of hospitalization for pneumonia with complications (CC) in adults (> 17 years)	**3,558**
Daily cost of hospitalization for pneumonia without complications (CC) in adults (> 17 years)	**2,291**
Daily cost of hospitalization for **meningitis**	**8,067**

INDIRECT COSTS per patient	€
Average gross daily wage NOT received in the tertiary sector **(OFFICE)**	**125**

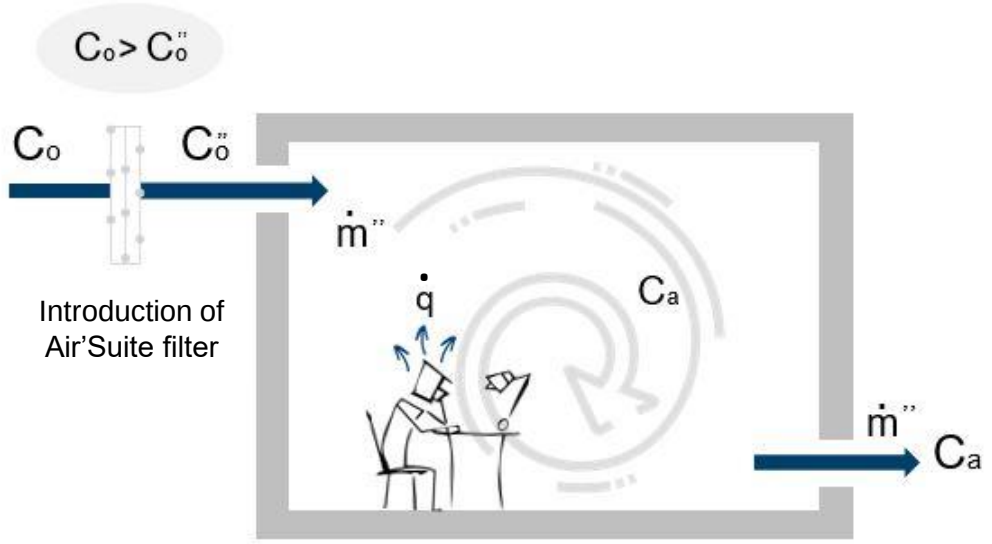
Socio-economic evaluation: PRODUCTIVITY

- CONSTANT concentration of pollutants
- Large size for Reference filter and Medium size for Air'Suite filter

REFERENCE FILTER



AIR' SUITE FILTER

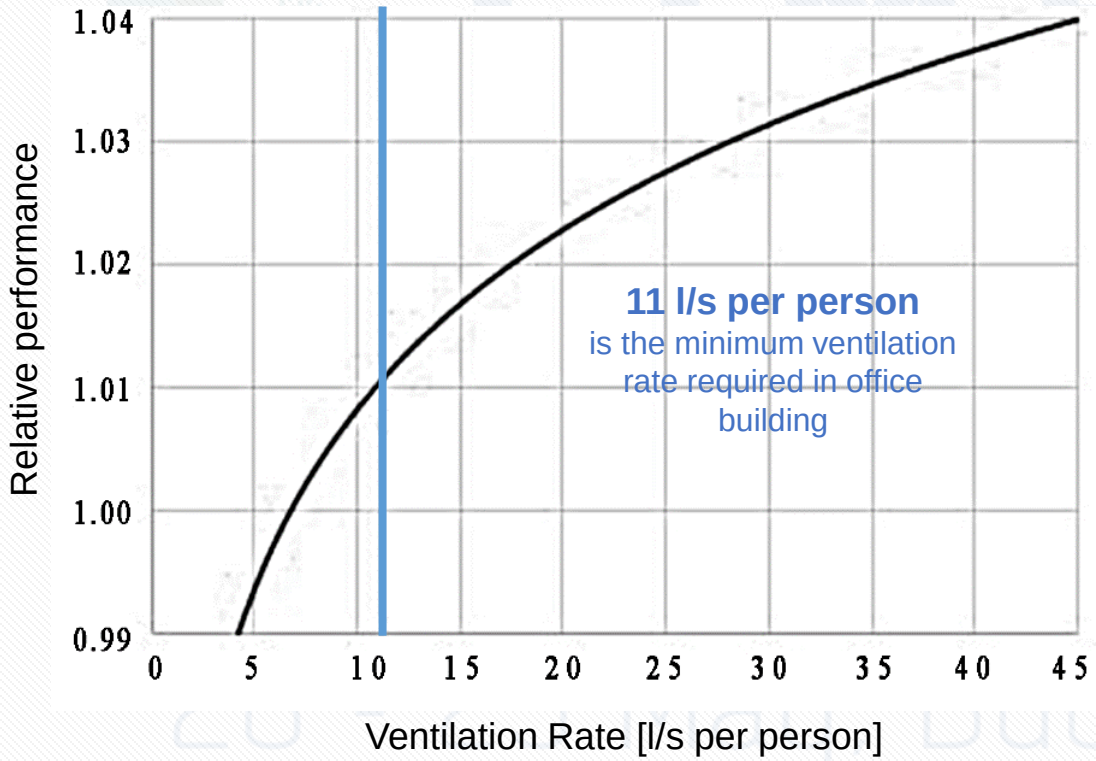


Main outdoor Pollutants

OUTDOOR POLLUTANTS:
PM 1, PM 2.5, PM 10, SO_2, NO_2, CO_2

REFERENCE FILTER	ABATEMENT CAPACITY	AIR' SUITE FILTER
50%	PM 1	50%
80%	PM 2.5	**90%**
95%	PM 10	95%
0%	SO_2	**20%**
0%	NO_2	**5%**
0%	CO_2	**1%**

Relation between ventilation rate and relative performance



Quantitative relationship of office work and ventilation rate

The graph shows that work performance will on average increase by about **1.5%** for each doubling of the outdoor air supply rate

$$RPv = (5.56 \times 10^{-8}) \times v^3 - (1.48 \times 10^{-5}) \times v^2 + (1.49 \times 10^{-3}) \times v + 0.983$$

RP_v represents the relative performance

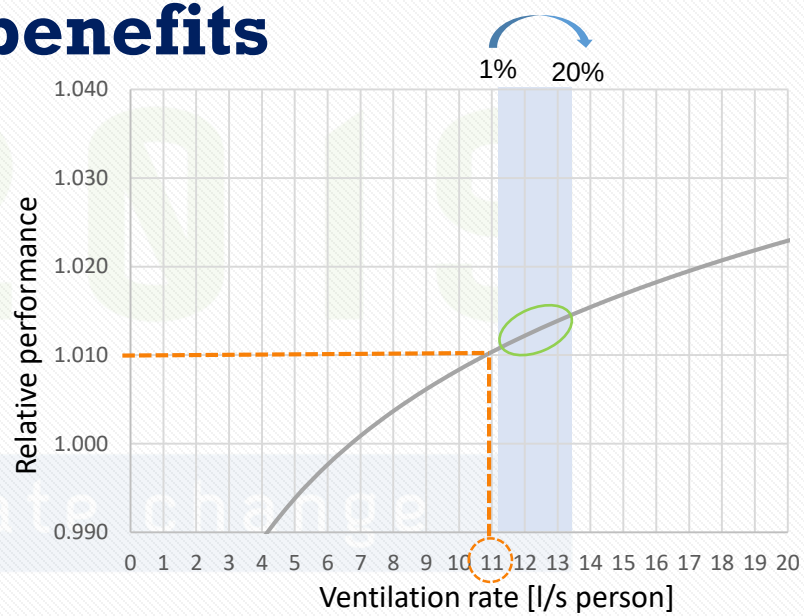
v is the ventilation rate (l/s per person)

Calculation of Air'Suite filter benefits

- **STATE OF ART**

  Q: 11 l/s per person

  Worker performance: 1.010



- **REFERENCE FILTER THAT WORKS AS THE AIR'SUITE FILTER = AIR'SUITE FILTER BENEFITS**

1%

Q: **11.1** L/s per person

Worker performance: 1.011

1.011 – 1.010 = 0.001 = **0.1%**

27.5 €/pers·year

20%

Q: **13.2** L/s per person

Worker performance: 1.014

1.014 – 1.010 = 0.004 = **0.4%**

110 €/pers·year

Results: Cost-benefit Analysis

The analysis **identifies, measures and compares:**

BENEFITS (achieved results)

COSTS (resources consumed)

$$\frac{B\,\alpha}{C\,\alpha} \quad \text{vs} \quad \frac{B\,\beta}{C\,\beta}$$

REFERENCE FILTER

AIR' SUITE FILTER

Incremental Analysis: impacts on human health

The evaluation method measures costs and benefits as **INCREMENTS** (as differences between alternative solutions):

$$\frac{B}{C} = \frac{B\,\beta - B\alpha}{C\,\beta - C\alpha}$$

se $\frac{B}{C} > 1 \Rightarrow \beta > \alpha$

Reference filter **(α)** ; Air'Suite filter **(β)**

Results - Office: Analysis on health

		REFERENCE FILTER	AIR' SUITE FILTER
COSTS	Investment cost	65 €	150 €
	Energy cost	244 €/year	156 €/year
BENEFITS	**Energy Savings**	-	**88 €/year**
	HEALTH	-	**83.33 €/year**

$$\frac{B}{C} = 17.85$$

$$\frac{B\beta - B\alpha}{C\beta - C\alpha} > 1 \Rightarrow \beta > \alpha$$

Reference filter **(α)**; Air' Suite filter **(β)**

For the analysis we considered the use of MEDIUM size filters. Health benefits are calculated in a office building with 67 occupants.

Comparative Analysis: Impacts on productivity

The analysis consists on the relationship between the flow of benefits and the flow of discounted costs, with the same discounted rate:

$$\frac{B}{C} = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+r)^t}}$$

se $\boldsymbol{\frac{B}{C} > 1}$ ⇨ **OK!**

Results - Office: Analysis on productivity

		REFERENCE FILTER	AIR' SUITE FILTER
COSTS	Investment cost	913 € (80 € + 833 €)	150 €
	Energy cost	244 ÷ 292.8 €/year	156 €/year
BENEFITS	**Energy Savings**	-	**88 ÷ 136 €/year**
	PRODUCTIVITY	-	**1,842.5 ÷ 7,370 €/year**

AIR' SUITE FILTER

$\frac{B}{C} = 22$ ✓

REFERENCE FILTER

$\frac{B}{C} = 0.06$

se $\frac{B}{C} > 1$ ⇨ OK!

To reduce the same percentage of outdoor pollutants (1%-20%), the reference filter requires an increase in costs due to the installation of a LARGE size filter (80€) + the cost of the air handling unit (833€). Productivity benefits are calculated in an office building with 67 occupants.

End of the presentation

cristina.becchio@polito.it

Politecnico di Torino

28-05-2019