

Lecture E3

The Economics of Healthy Buildings

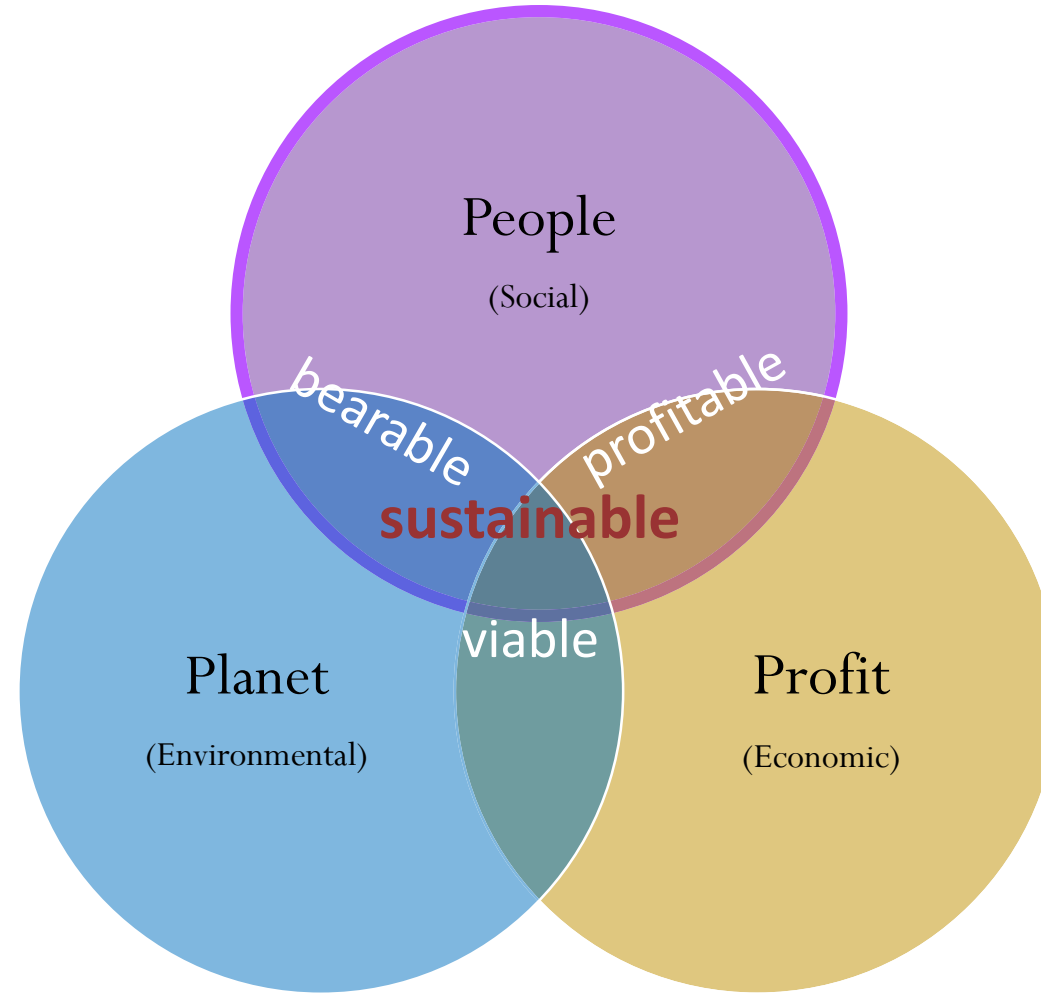
The role of buildings in shaping human health

Juan Palacios

Feb 2023

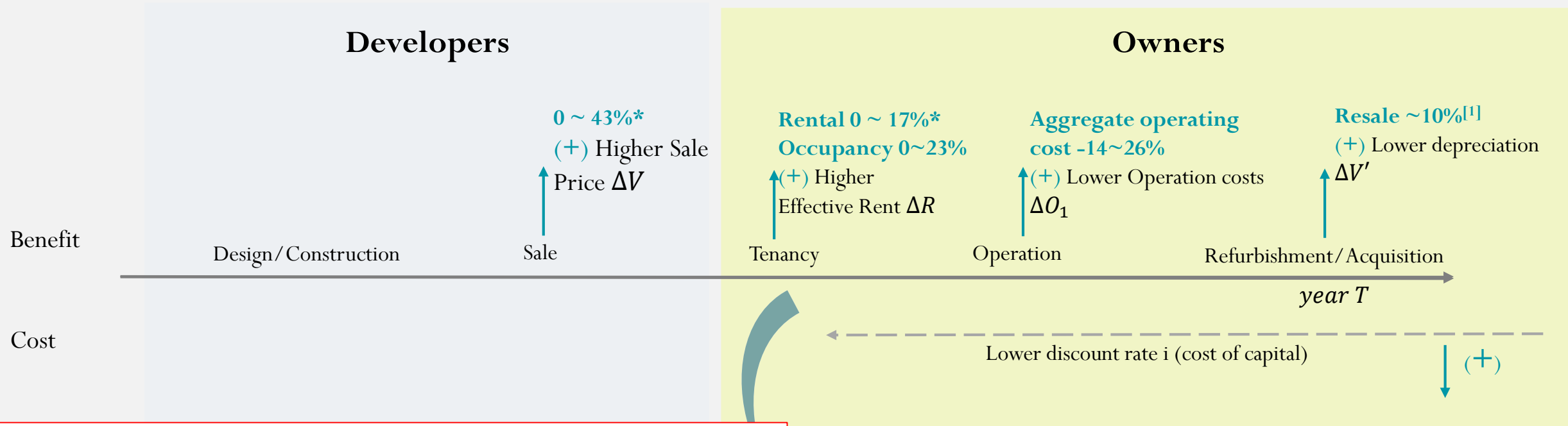
(MIT Center for Real Estate)

Triple Bottom Lines



← Lecture today

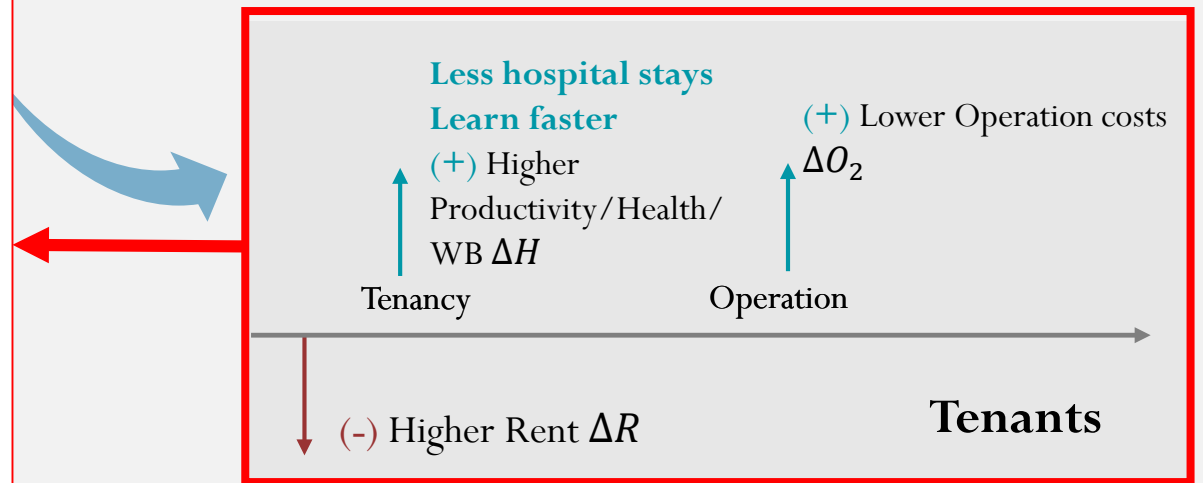
Is There a Business Case for Green Buildings?



Why are tenants willing to pay higher rent for being in a green certified building?

- Lower energy costs and lower operation costs
- Lower environmental damages
- More productive employees
 - Employees sick less often than in conventional buildings
 - Employees are more productive

3



The Roadmap of Green Building Certifications

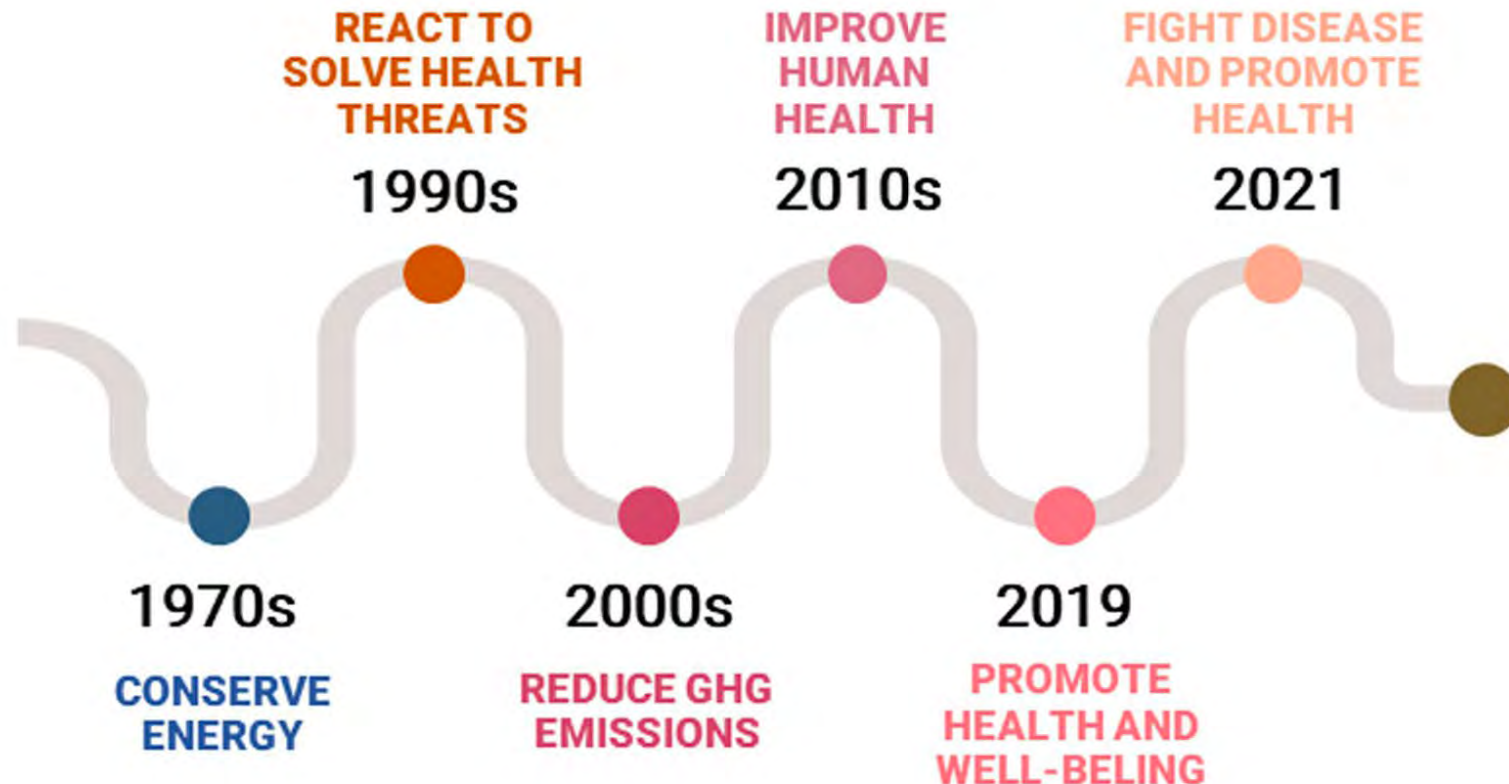
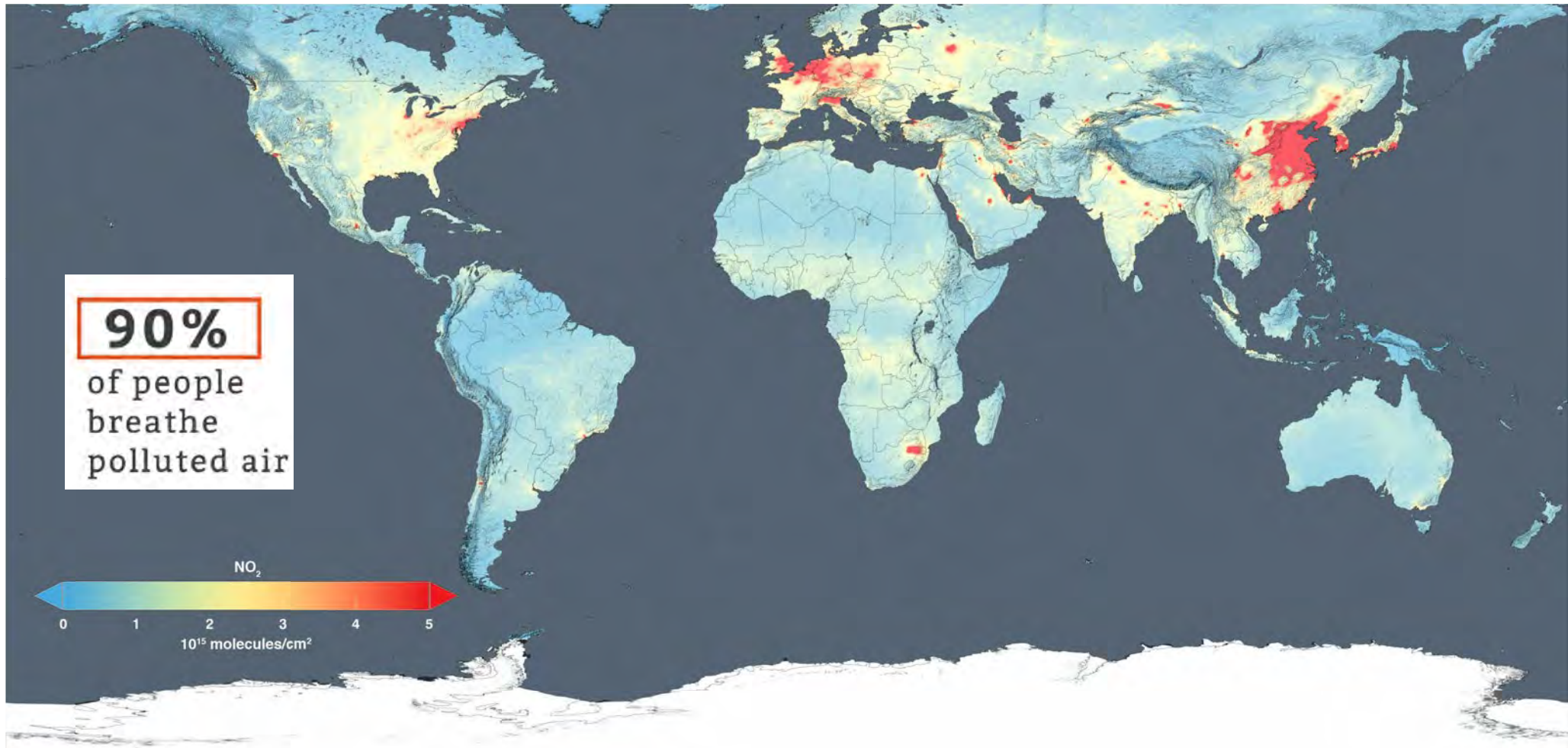


Figure courtesy of Licina, Wargocki, et al. Used with permission. License: CC BY.

Source: Licina, D., Wargocki, P., Pyke, C., & Altomonte, S. (2021). The future of IEQ in green building certifications. *Buildings and Cities*, 2(1), pp. 907–927. DOI: <https://doi.org/10.5334/bc.148>

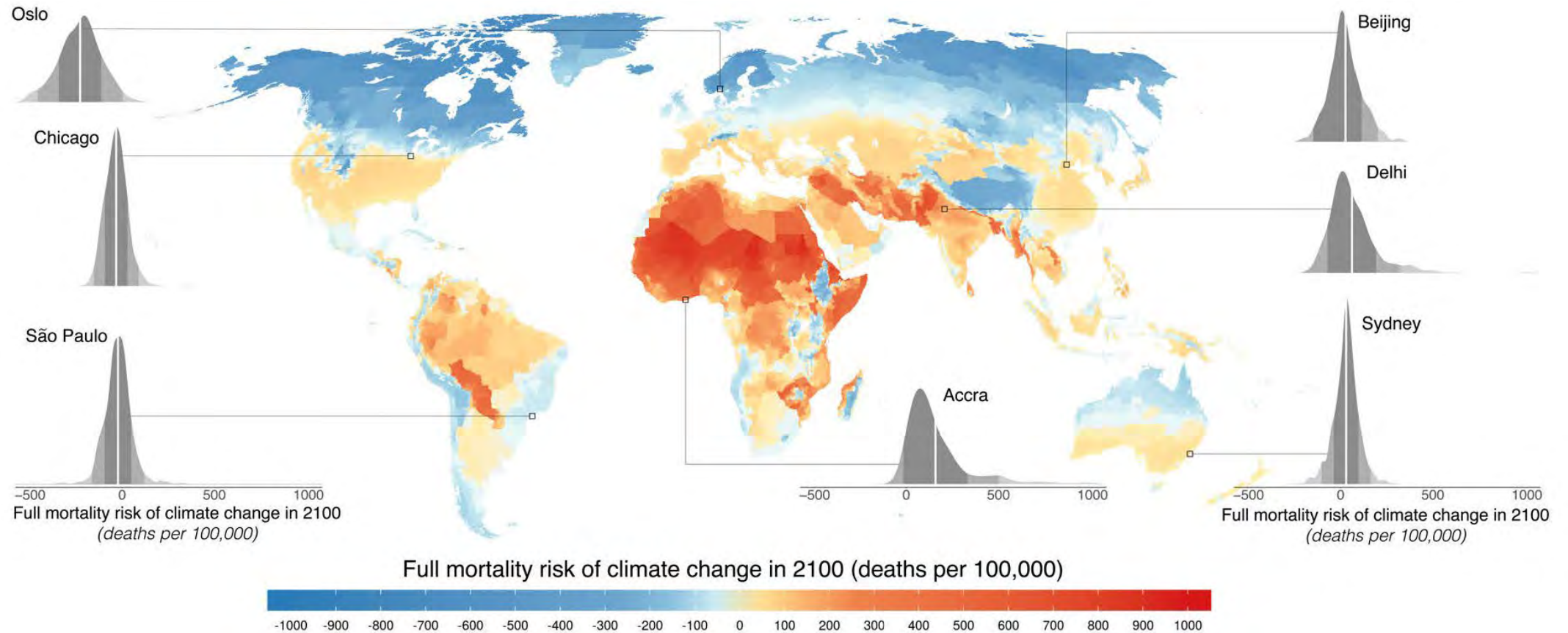
Environment & Health: Air Pollution

Air pollution causes 4.2 million premature deaths worldwide (WHO)



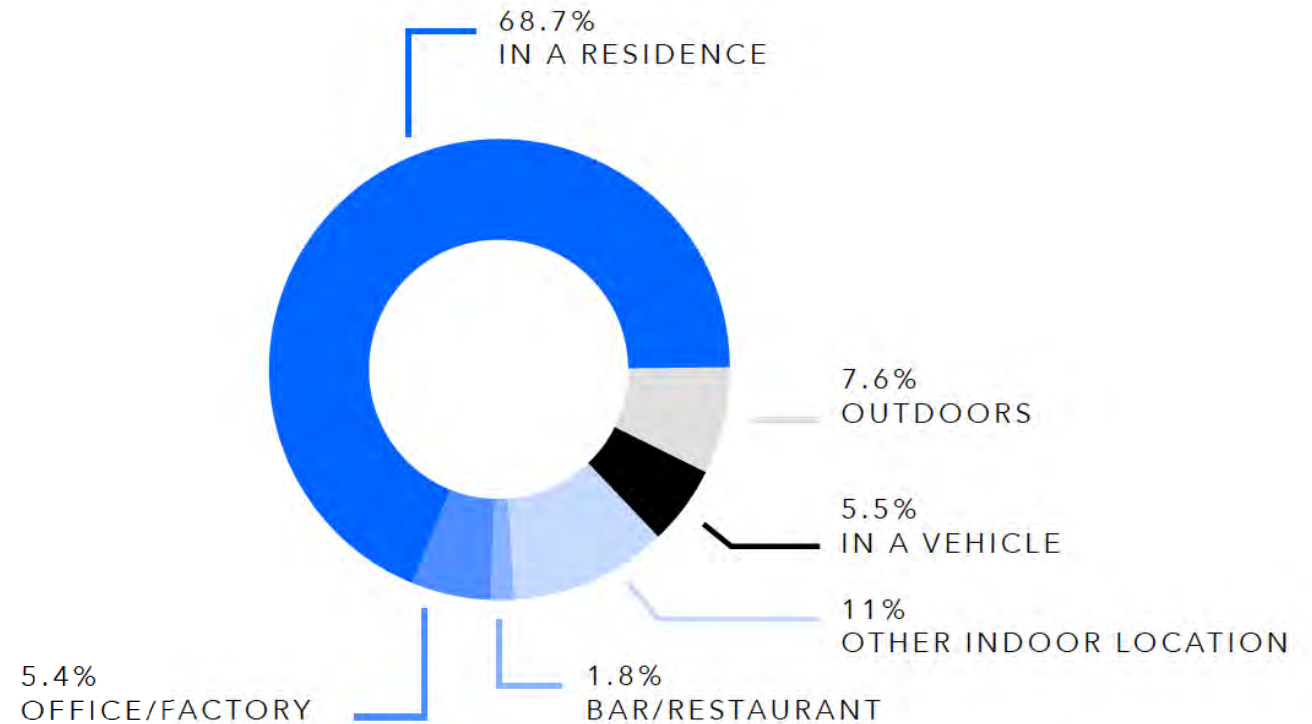
Environment & Health: Heat & Cold

Temperature stress causes **5 million premature deaths a year**



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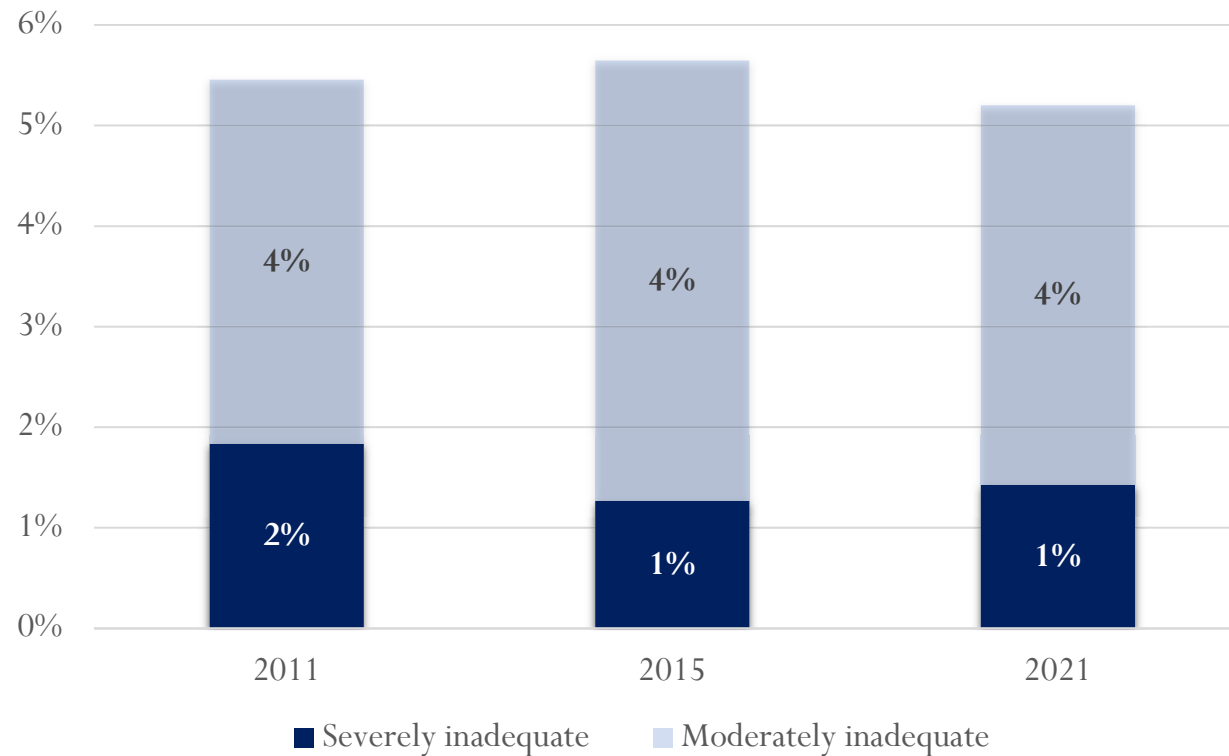
The Role of Buildings: 90% Time Indoors



Source: Klepeis et al. (2001)

...and “indoor” isn’t always so great

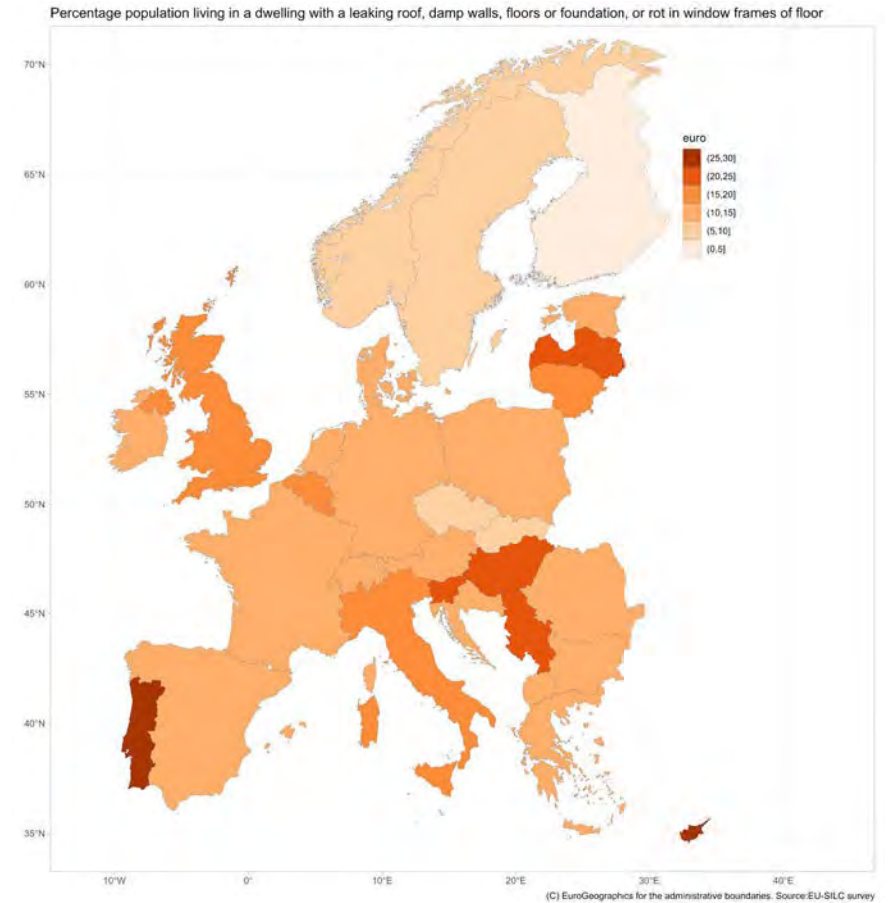
Percentage of Population with Housing Quality Issues in the U.S.



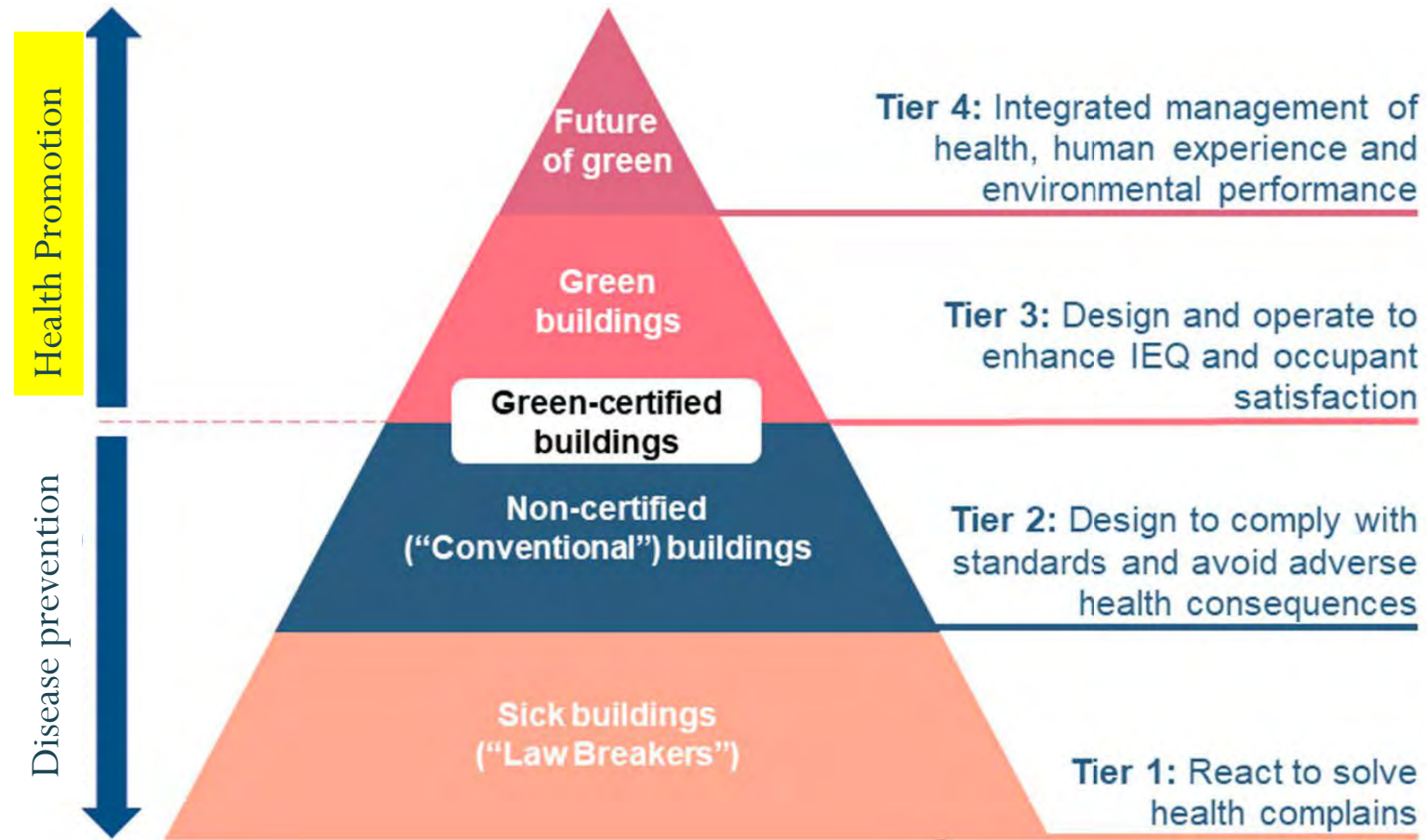
Source: American Housing Survey

...and “indoor” isn’t always so great

- 13% of households in the European Union live in deficient dwellings
- Energy poverty: ~ 34 million Europeans unable to afford to heat their homes properly (pre Ukraine crisis)
- Large body of evidence associating temperature shocks to cardiovascular problems and other risk factors
- Putting pressure on health care systems. Rising costs of health care in most OECD countries (~10% GDP)



The Roadmap of Green Building Certifications



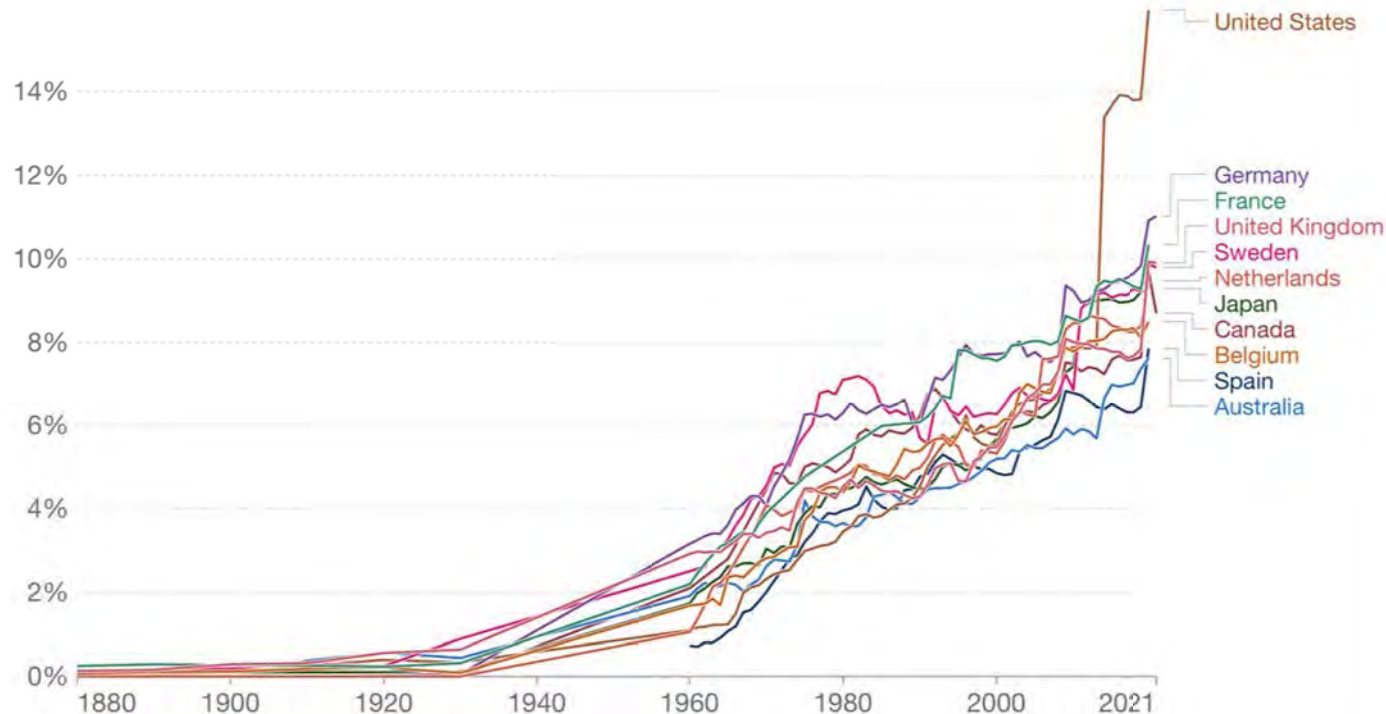
Source: Licina, D., Wargoeki, P., Pyke, C., & Altomonte, S. (2021). The future of IEQ in green building certifications. *Buildings and Cities*, 2(1), pp. 907-927. DOI: <https://doi.org/10.5334/bc.148>. Figure courtesy of Licina, Wargoeki, et al. Used with permission. License: CC BY.

Role of Health for Public Sector and Business

Government health expenditure as a share of GDP, 1880 to 2021

This metric captures spending on government funded health care systems and social health insurance, as well as compulsory health insurance.

Our World
in Data



Source: Our World In Data based on Lindert (1994), OECD (1993), OECD Stat
 Note: Health spending includes final consumption of health care goods and services (i.e. current health expenditure). This excludes spending on capital investments.

OurWorldInData.org/financing-healthcare • CC BY

Harvard
Business
Review

Presenteeism in the
United States:
+\$150 billion/year

Productivity

Presenteeism: At Work—But Out of It

by Paul Hemp

From the Magazine (October 2004)

Summary. Reprint: R0410B Employers are beginning to realize that they face a nearly invisible but significant drain on productivity: presenteeism, the problem of workers' being on the job but, because of illness or other medical conditions, not fully functioning. By some estimates,... [more](#)

For years, Amy Farler, who designs transmission components for International Truck and Engine, suffered in silence. Once in a while, when an allergy-related sinus headache escalated into a full-blown migraine, she missed a day of work. But most of the time, she went to the office and quietly lived with the congestion and discomfort of her seasonal allergies. "Sometimes, it's like you wouldn't mind if your head rolled off your body," says the 31-year-old engineer, who spends



Learning Outcomes

1. The bottom line in healthy building investment strategies:
 - a) Impacts on occupant health and productivity
 - b) The role of health in tenants' income statements
2. Owner and developer perspective on healthy building strategies:
 - a) Barriers to adoption
 - b) Life cycle analysis of healthy buildings
3. Healthy & green buildings

Healthy-Building Strategies

What can MIT CRE do to this classroom to promote health and performance of students?



Healthy-Building Strategies

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EIGHT FEATURES THAT MAKE HEALTHIER AND GREENER OFFICES

1. INDOOR AIR QUALITY & VENTILATION

Healthy offices have low concentrations of CO₂, VOCs and other pollutants, as well as high ventilation rates.



101%

WHY? Increase in cognitive scores for workers in a green, well-ventilated office.¹

2. THERMAL COMFORT

Healthy offices have a comfortable temperature range which staff can control.



6%

WHY? Fall in staff performance when offices are too hot and 4% if too cold.²

3. DAYLIGHTING & LIGHTING

Healthy offices have generous access to daylight and self-controlled electrical lighting.



WHY?

46 minutes

more sleep for workers in offices near windows.³

4. NOISE & ACOUSTICS

Healthy offices use materials that reduce noise and provide quiet spaces to work.



66%

WHY? Fall in staff performance as a result of distracting noise.⁴

5. INTERIOR LAYOUT & ACTIVE DESIGN

Healthy offices have a diverse array of workspaces, with ample meeting rooms, quiet zones, and stand-sit desks, promoting active movement within offices.



WHY?

Flexible workspaces help staff feel more in control of their workload and engenders loyalty.⁵

6. BIOPHILIA & VIEWS

Healthy offices have a wide variety of plant species inside and out as well as views of nature from workspaces.



7-12%

WHY? Improvement in processing time at one call centre when staff had a view of nature.⁶

7. LOOK & FEEL

Healthy offices have colours, textures, and materials that are welcoming, calming and evoke nature.



WHY?

Visual appeal is a major factor in workplace satisfaction.⁷

EMPLOYEE ENGAGEMENT



Healthy offices have employees that are regularly consulted and that feedback is used to drive continuous improvement.⁸

8. LOCATION & ACCESS TO AMENITIES

Healthy offices have access to public transport, safe bike routes, parking, and showers, and a range of health food choices.



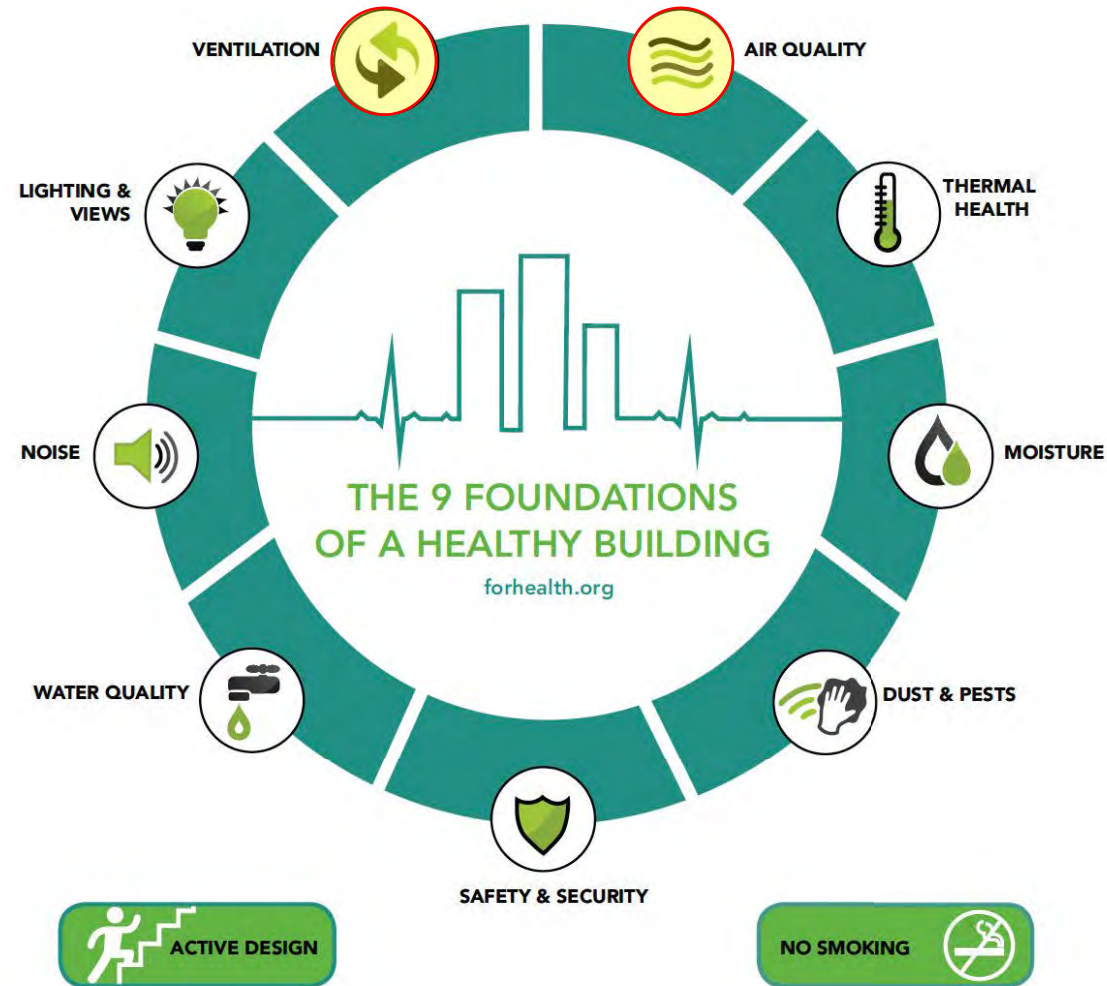
€27m

WHY?

savings through cutting absenteeism as a result of Dutch cycle-to-work scheme.⁹

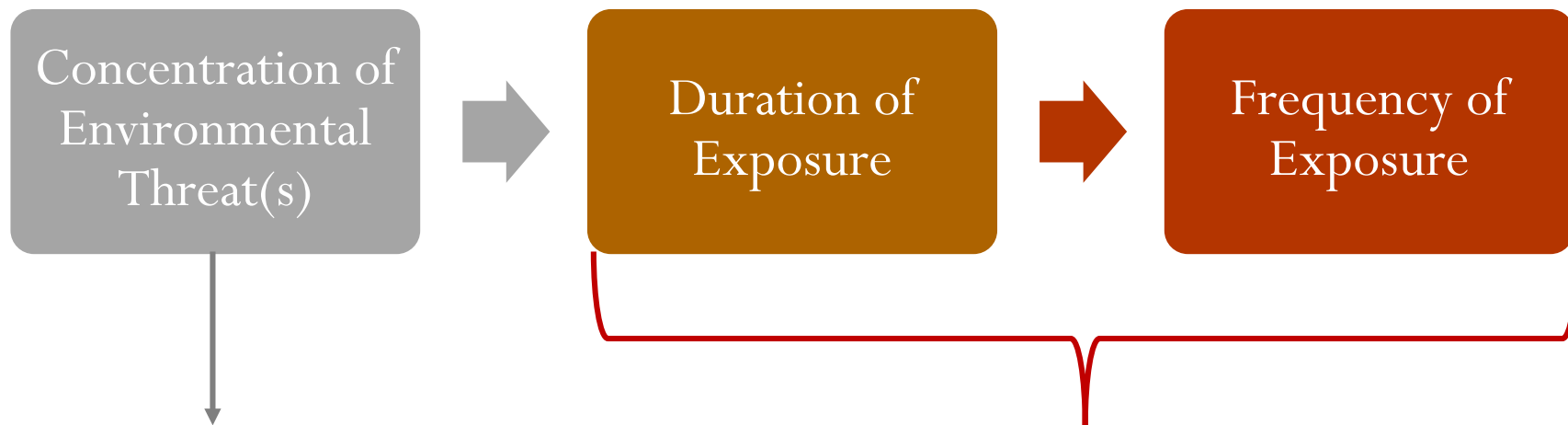


Healthy-Building Strategies



Evaluating Impact Healthy Building Strategies

What influences the appearance of meaningful/costly health impacts in buildings?



(1) Assessment:

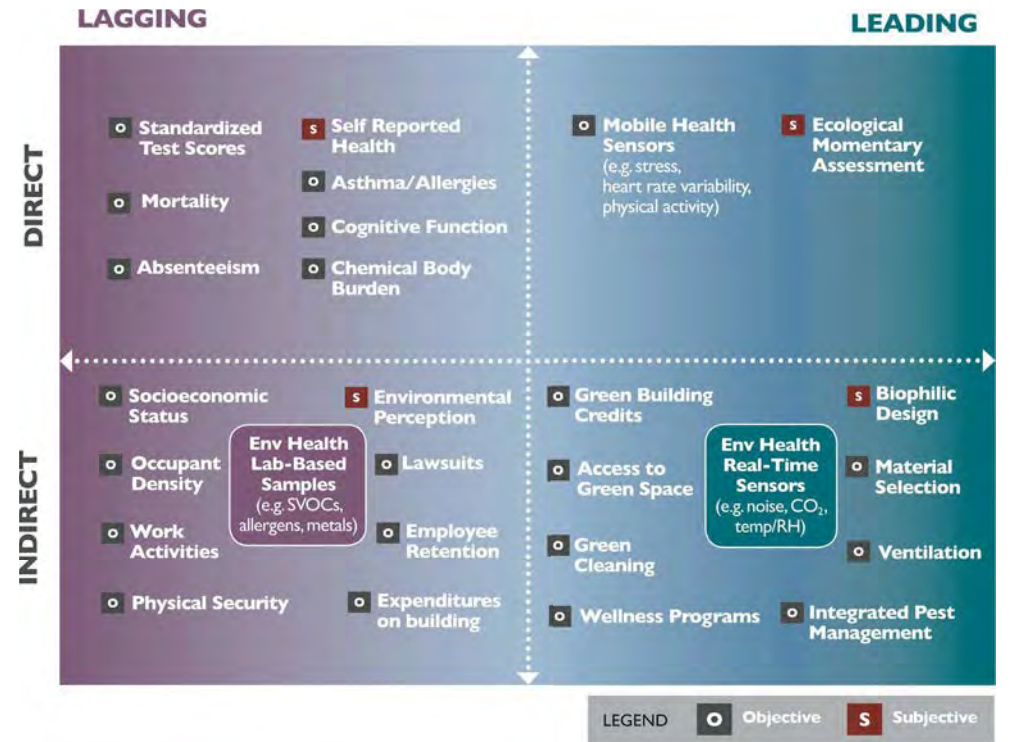
- Measurement of environmental hazards
- Evaluating exposure against industry standards

(2) Attribution:

- Occupancy measurements:
 - How long and how often are occupants exposed?
- Establishing fair comparison groups: “Apple to apple” comparisons

Assessment: Smart & Healthy Buildings

- Sensor technology and the increase in digitalization of buildings give us the opportunity to create the data to evaluate interventions
 - Data from buildings: Indoor environmental quality sensors
 - Data from people: Wearables, surveys, movement sensors, smartphone data, ...
- How do we design studies to evaluate impacts of healthy building attributes?
 - To assess the impact of healthy-building aspects, we need to think carefully about how we establish **fair benchmarks** in our building



Source: Allen, J.G., MacNaughton, P., Laurent, J.G.C., Flanigan, S.S., Eitland, E.S. and Spengler, J.D., 2015. Green buildings and health. *Current environmental health reports*, 2(3), pp.250-258. © Joseph G. Allen, corresponding author Piers MacNaughton, Jose Guillermo Cedeno Laurent, Skye S. Flanigan, Erika Sita Eitland, and John D. Spengler (Source: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4513229/>). CC-BY License (<http://creativecommons.org/licenses/by/4.0/>)

Attribution: Challenge to Estimate Impact

Easier to monitor / manipulate
Less connected to the bottom line
(occupants/tenants)

Difficult to monitor / manipulate
More connected to the bottom line
(occupants/tenants)

OWNER/BUILDING-MANAGER

TENANT

ENVIRONMENT

1. Indoor Air Quality
2. Thermal Comfort
3. Daylighting & Lighting
4. Noise & Acoustics
5. Interior Layout & Active Design
6. Biophilia & Views
7. Look & Feel
8. Location & Access to Amenities

EXPERIENCE

Perception of the occupants' experience in the building, as measured by a survey.

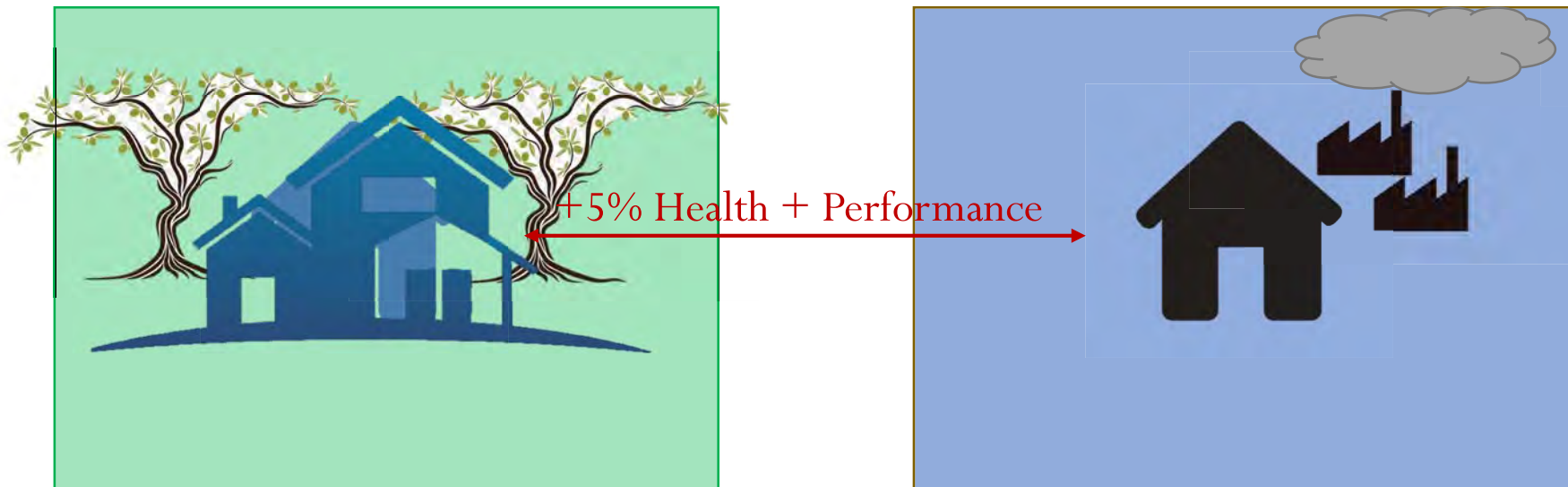
ECONOMICS

1. Absenteeism
2. Staff turnover / Retention
3. Medical Costs
4. Revenue
5. Medical Complaints
6. Physical Complaints

Attribution: “Apple-to-apple” comparisons

Challenges to assessing impacts of health in buildings:

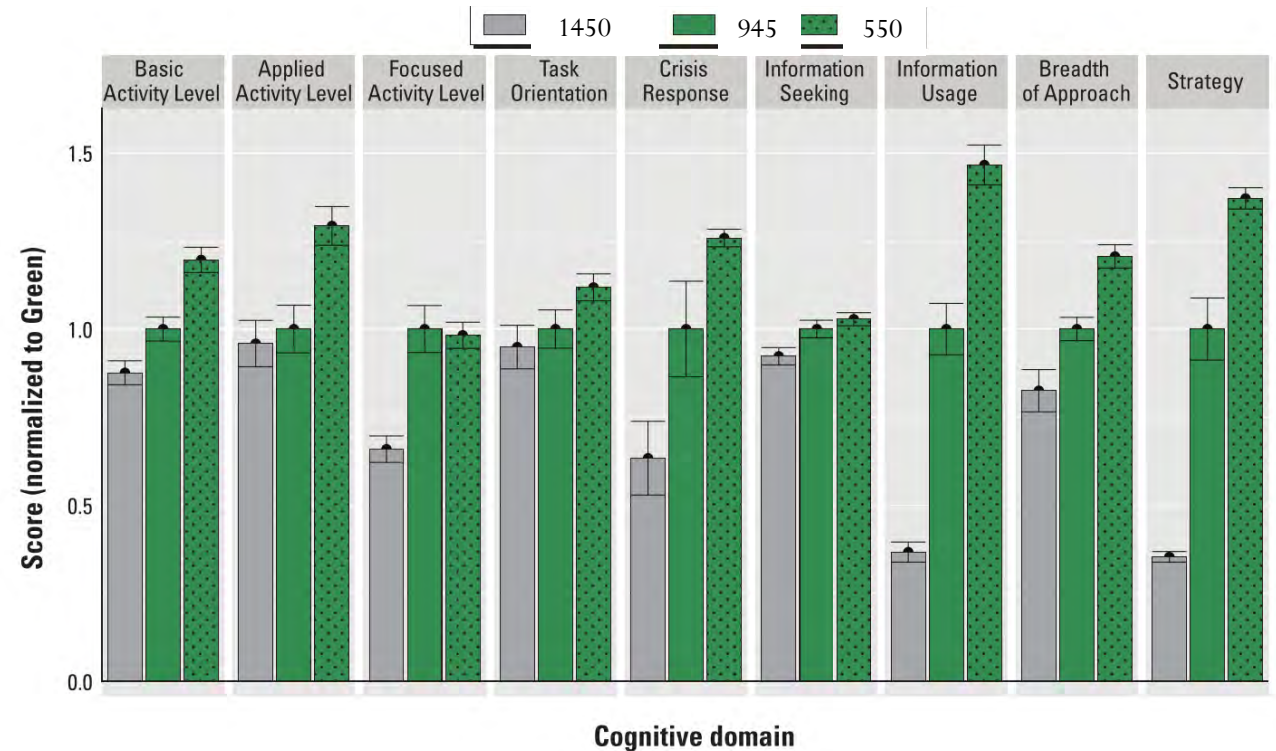
- **Outdoor factors**: Indoor environmental quality is the result of multiple factors: outdoor amenities, design of homes, ...
- **Occupants are different** in income, education, value of health, ... across buildings, introducing challenges to compare health or performance outcomes



Indoor Air Quality & Cognitive Performance

- Twenty-four participants spent **6 full work days** (0900-1700 hours) in an environmentally controlled office space, blinded to test conditions.
- On different days, they were exposed to artificially elevated carbon dioxide (CO_2) levels independent of ventilation.
- On average, cognitive scores were **61% higher** on the day with 945 in the room and **101% higher** on the two days with 550 in the room than with 1450 ppm
- Similar effects found in school settings, where students score lower in tests after exposure to high levels of CO_2 during semester (Palacios et al., 2023)

Cognitive Performance / Decision Making




Source: Allen, J.G., MacNaughton, P., Satish, U., Santanam, S., Vallarino, J. and Spengler, J.D., 2016. Associations of cognitive function scores with carbon dioxide, ventilation, and volatile organic compound exposures in office workers: a controlled exposure study of green and conventional office environments. *Environmental health perspectives*, 124(6), pp.805-812. This image is in the public domain.

Indoor Air Quality & Decision Making

- Exposure to fine particulate matter:
 - Increases the probability that chess players make an error increases by 2.1 percentage points.
 - The magnitude of those errors increases by 10.8 percent.
- Implications for managers: finding a right move in chess is a complex cognitive task, where players need to find the optimal strategy across dozens of possibilities.
- Similar effects found in: Judges, call center workers, factory workers, students, baseball empires, etc.

MIT News
ON CAMPUS AND AROUND THE WORLD

 SUBSCRIBE

Chess players face a tough foe: air pollution

Study: Even chess experts perform worse when air quality is lower, suggesting a negative effect on cognition.

Peter Dizikes | MIT News Office
January 30, 2023



Estimating Building Impacts on Health

- Study to estimate the benefits of a move to healthy building by a real team of 1,400 employees



- Constructed in the 1980s
- No ventilation system

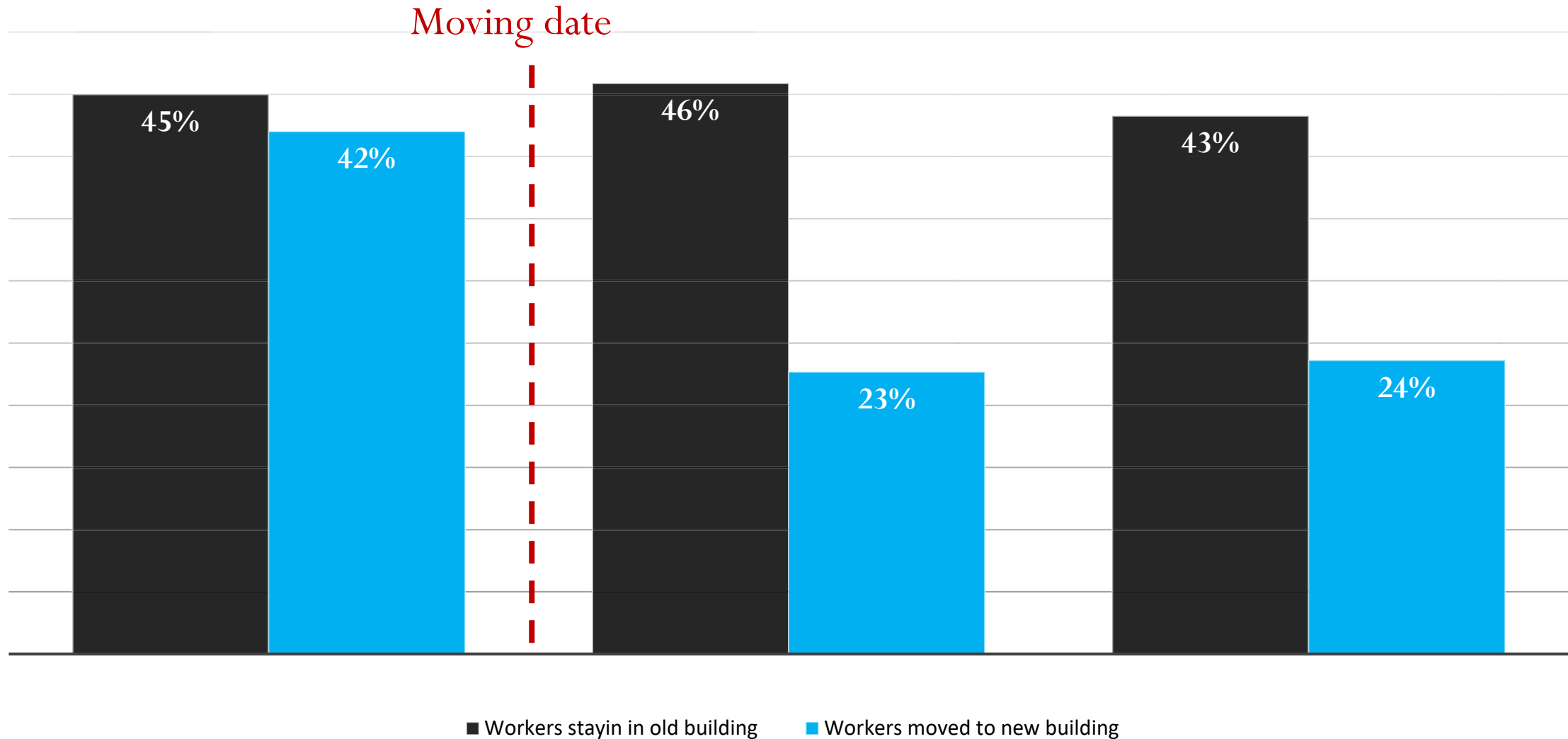
- Ventilation based on the principles of natural circulation
- Green wall

Source: Palacios J, Eichholtz P, Kok N (2020) Moving to productivity: The benefits of healthy buildings. PLoS ONE 15(8): e0236029. <https://doi.org/10.1371/journal.pone.0236029>. Photos © source unknown. All rights reserved. This content is excluded from our Creative Commons license. For more information, see <https://ocw.mit.edu/help/faq-fair-use/>.

Estimating Building Impacts on Health



Estimating Building Impacts on Health



Cost-Benefit Analysis

Is the building profitable for the tenant (municipality)?

Marginal benefit in building management and exploitation

€17 million

Marginal benefit in sick leave reduction:

Wages: €54 million/year
- 43% of FTEs sick at least once/year
- Average sick leave: 5 days
- 2% reduction in sick leave yields savings of €25,000/year

€2.5 million capitalized

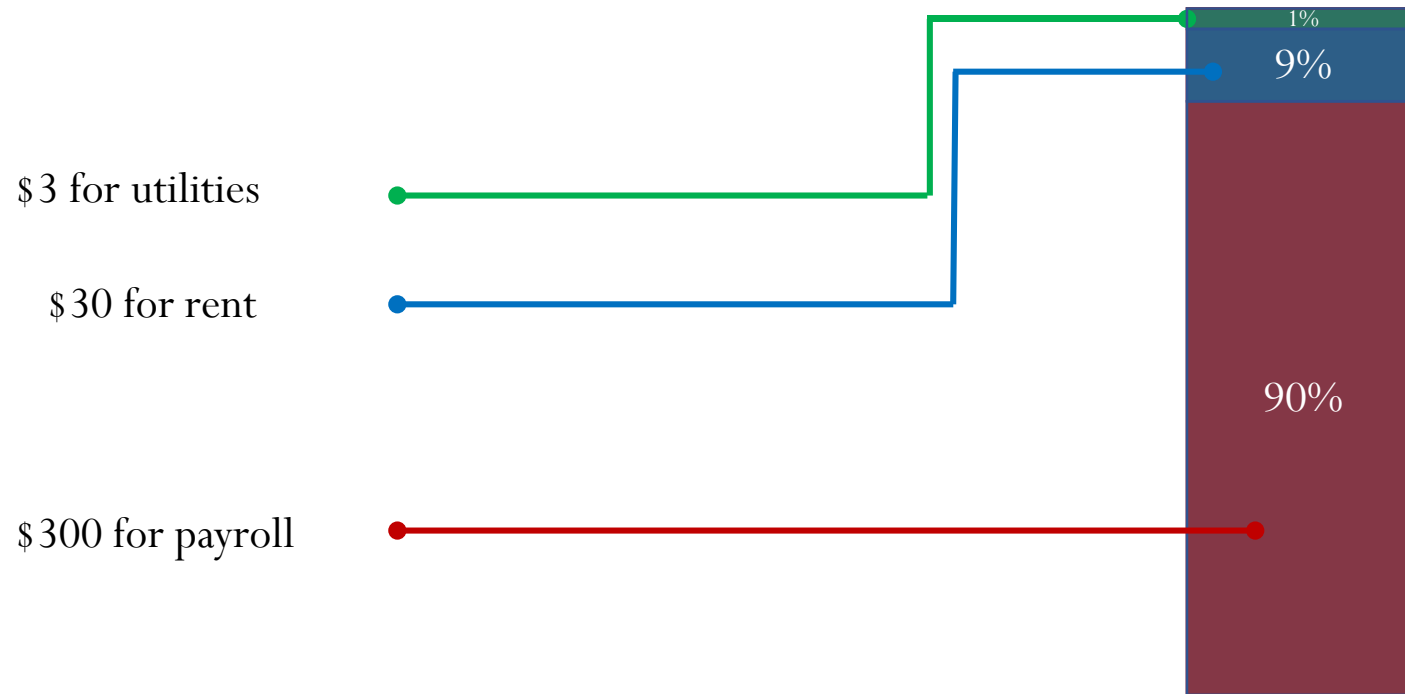
Extra costs for sustainable attributes (green + healthy):



€3.4 million

The Business Case for Corporate Tenants

How important is productivity for companies? Let's compare their annual costs:



Impacts of Health on Income Statements

- Consider a simplified example of a company that is considering whether to improve the indoor air quality in their buildings
 - Increased **air quality in the building** (i.e., ventilation rates + filtration)
- The company will need to evaluate the costs and benefits associated with the decision
 - Higher ventilation rates require higher energy expenditures
 - Indoor air-quality improvements have been associated in the medical literature with higher performance among employees driven by:
 - Lower sick leave (e.g., sick building syndrome)
 - Higher performance (e.g., higher cognitive performance)

Impacts of Health on Income Statements

- Consultancy company of 40 employees
- USD 75,000 per year

- Considers to double ventilation rate
 - From 20 cfm/person to 40 cfm/person
 - Increase in energy costs:
 - USD 40 per person per year

	Baseline situation
Revenue	\$6,000,000
Payroll	\$(3,000,000)
Rent	\$(300,000)
Utility	\$(30,000)
Other expenses	\$(1,000,000)

Source: Allen, J.G. and Macomber, J.D., 2020. Chapter 4. Healthy buildings: How indoor spaces drive performance and productivity. Harvard University Press.

Impacts of Health on Income Statements

	Baseline	Δ Energy costs	Baseline + Healthy Building
Revenue	\$6,000,000		
Payroll	\$(3,000,000)		
Rent	\$(300,000)		
Utility	\$(30,000)	\$ (1,600)	\$(31,600)
Other expenses	\$(1,000,000)		

Total increase in energy costs:

40 per person per year $\rightarrow 40 \times 40 = \$1,600$

Impacts of Health on Income Statements

	Baseline	ΔEnergy costs	ΔPayroll	Baseline + Healthy Building
Revenue	\$6,000,000			
Payroll	\$(3,000,000)		\$19,000	\$(2,981,000)
Rent	\$(300,000)			
Utility	\$(30,000)	\$(1,600)		\$(31,600)
Other expenses	\$(1,000,000)			

Benefits:

1. Fewer days of sick leave, on average:

1.6 days of sick leave associated with doubling ventilation rate → $1.6 / 250 = 0.64\%$

Increase in time that workers are able to work, due to less sick leave.

In monetary terms: $0.0064 \times 3,000,000 = 19,000$

Impacts of Health on Income Statements

	Baseline	ΔEnergy costs	ΔPayroll	ΔRevenue	Baseline + Healthy Building
Revenue	\$6,000,000			\$120,000	\$6,120,000
Payroll	\$(3,000,000)		\$19,000		\$(2,981,000)
Rent	\$(300,000)				\$(300,000)
Utility	\$(30,000)	\$(1,600)			\$(31,600)
Other expenses	\$(1,000,000)				\$(1,000,000)

Benefits:

2. Higher productivity:

Evidence literature: 2% higher productivity among employees

Translates to 2% higher production in the company → $0.02 \times 6,000,000 = 120,000$

Impacts of Health on Income Statements

	Baseline	ΔEnergy costs	ΔPayroll	ΔRevenue	Baseline + Healthy Building Scenario
Revenue	\$6,000,000			\$120,000	\$6,120,000
Payroll	\$(3,000,000)		\$19,000		\$(2,981,000)
Rent	\$(300,000)				\$(300,000)
Utility	\$(30,000)	\$(1,600)			\$(31,600)
Other expenses	\$(1,000,000)				\$(1,000,000)
Net income before tax	\$1,670,000				\$1,807,400
Change					\$137,400

Change in income statement (pre taxes):

$$\text{Healthy-Building Scenario} - \text{Baseline} = \$1,807,400 - 1,670,000 = 137,400$$

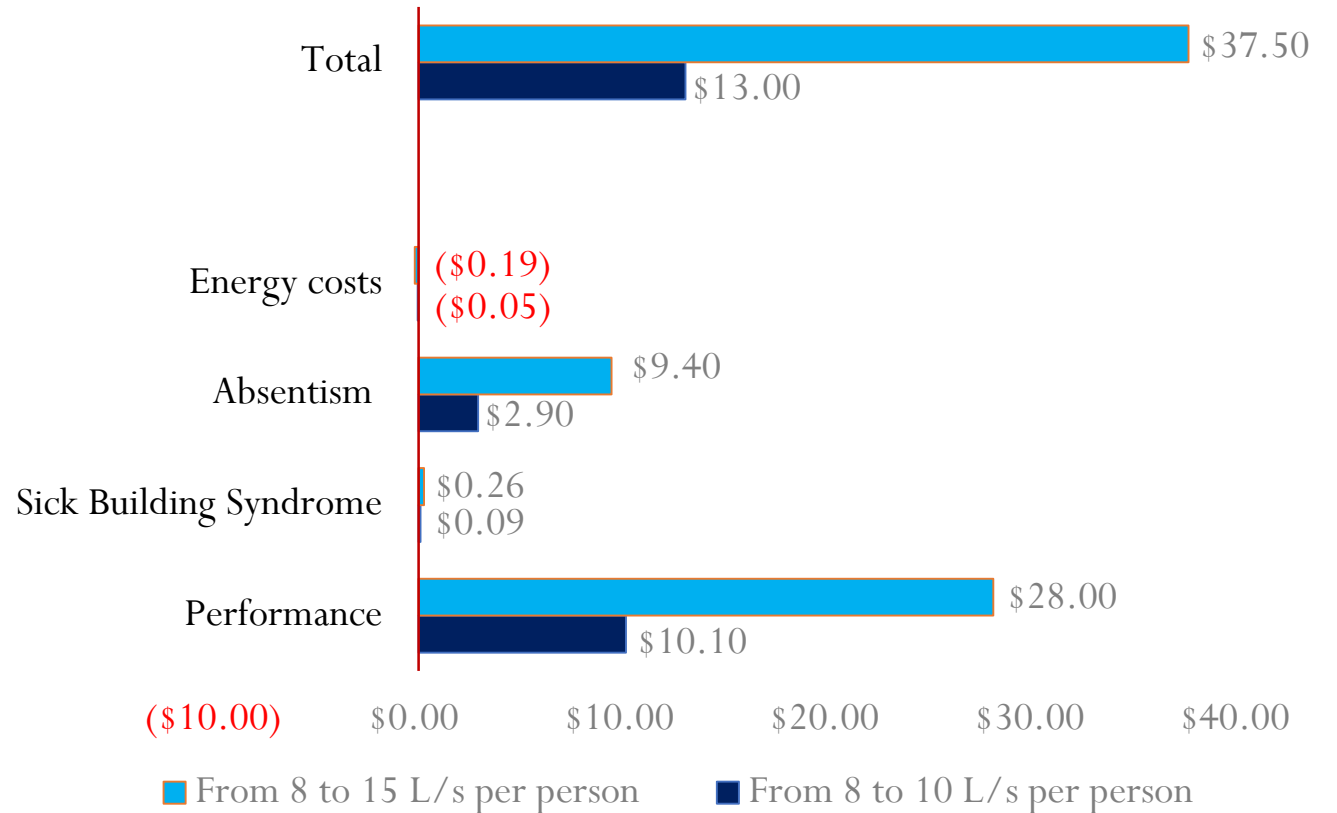
Impacts of Health on Income Statements

	Baseline	Δ Energy costs	Δ Rent	Δ Payroll	Δ Revenue	Baseline + Healthy Building Scenario
Revenue	\$6,000,000				\$120,000	\$6,120,000
Payroll	\$(3,000,000)			\$19,000		\$(2,981,000)
Rent	\$(300,000)		\$(51,000)			\$(351,000)
Utility	\$(30,000)	\$(1,600)				\$(31,600)
Other expenses	\$(1,000,000)					\$(1,000,000)
Net income before tax	\$1,670,000					\$1,756,400
Change						\$86,400

This increase in net income is larger than the largest rent increase documented in green building literature (17%, upper bound from green building lecture)

Projected Costs and Benefits for US Offices

- A study uses past academic estimates and energy models to provide projections of benefits and costs linked to providing more ventilation for the **entire U.S. office building portfolio**
- Three scenarios:
 - Baseline: Minimum ventilation rate recommended by ASHRAE
 - 25% above the baseline: **\$13B in economic benefits**
 - 87.5% above the baseline: **\$37B in economic benefits**



*Notes: Figures in billions of dollars

Source: Fisk, W.J., Black, D. and Brunner, G., 2012. Changing ventilation rates in US offices: Implications for health, work performance, energy, and associated economics. Building and environment, 47, pp.368-372.

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