CIVIL-407
Energy and Comfort in Buildings

Introduction:

Energy concepts and fundamentals

The value of human-centric buildings

September 11, 2025

HOBEL
HUMAN-ORIENTED BUILT ENVIRONMENT LAB

Human-Oriented Built Environment Lab
Website: hobel.epfl.ch
Twitter: @licinadusan

EPFL

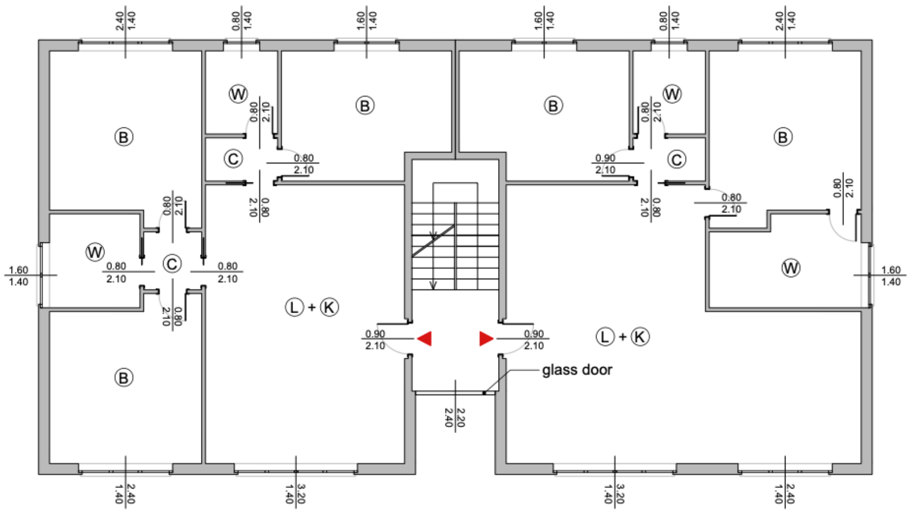
Assoc. Prof. Dusan Licina, Ph.D.
School of Architecture, Civil and Environmental Engineering
École polytechnique fédérale de Lausanne
dusan.licina@epfl.ch

Today's learning objectives (9h15 – 12h00)

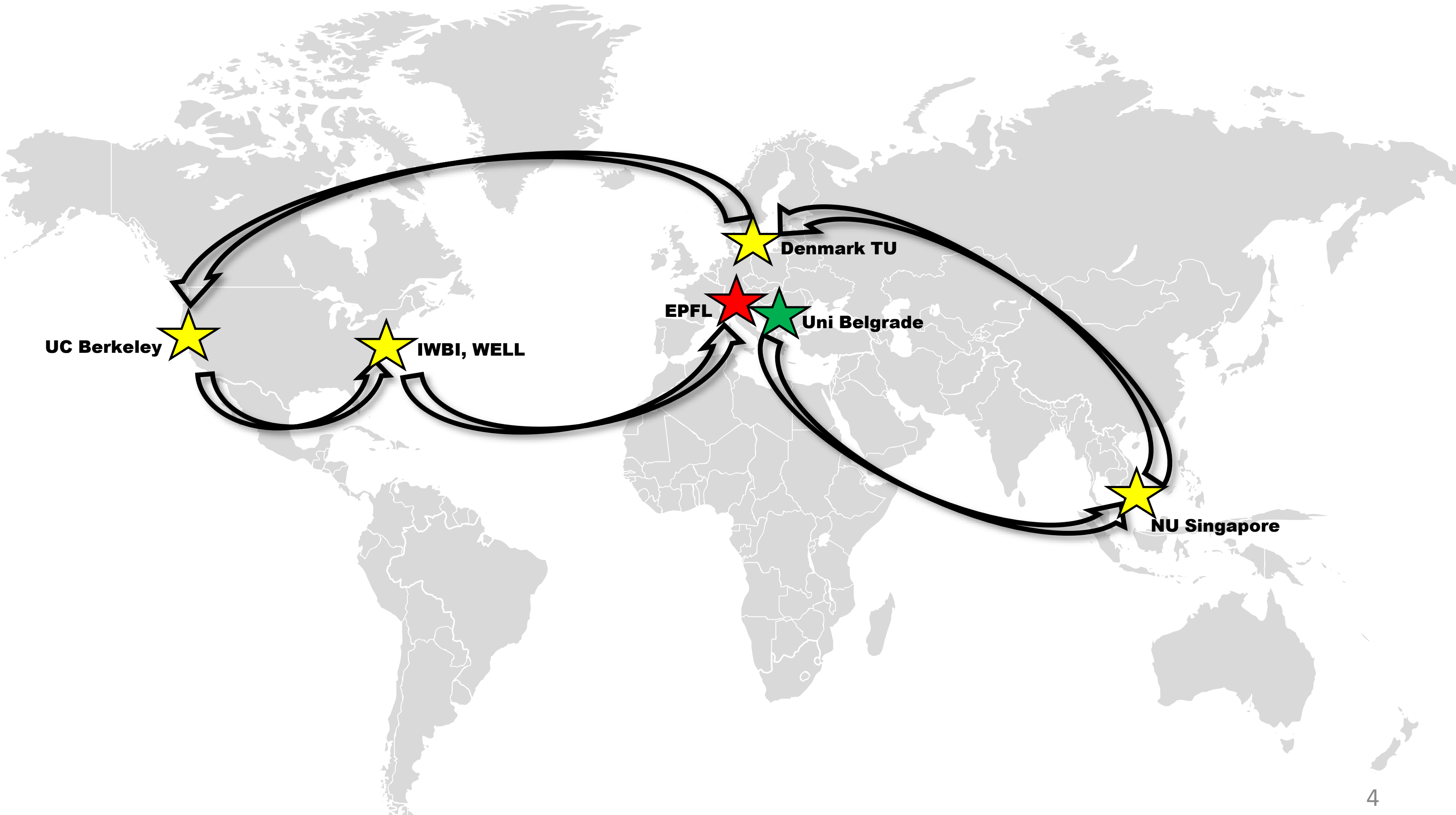
- Introduce ourselves and yourselves
- Discuss the course syllabus
  - Course information, outline, schedule, ground rules
  - Why are we all here?
- Introduce the field of building energetics
  - Energy and climate crisis
  - Energy use in buildings
- The value of human-centric buildings
  - Why does it matter?
- Quiz on climate change
- Bonus slides (on your own if needed)
  - Brush-up (units, heat transfer, psychometrics)

Today's project objectives (12h30 – 14h00)

- Scheduled time: Thursday 12:30-2:00 (see course schedule)
  - Tutorials some weeks
  - Free work some weeks
- Energy modeling of a building
- Part 1: individual modeling of a single apartment + energy performance strategies
- Part 2: group work on building modeling + design



My carbon footprint trajectory…



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Indoor air quality (IAQ)

Exposure science

Building environmental monitoring

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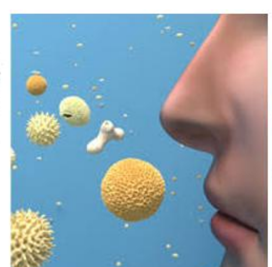
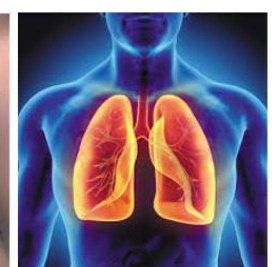
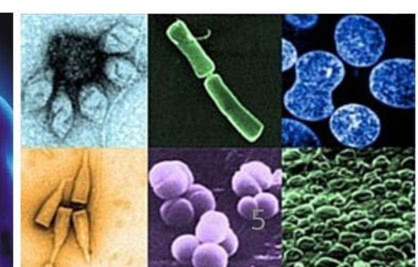
Smart ventilation systems

Indoor environment and building energy nexus



Human-Oriented Built Environment Lab

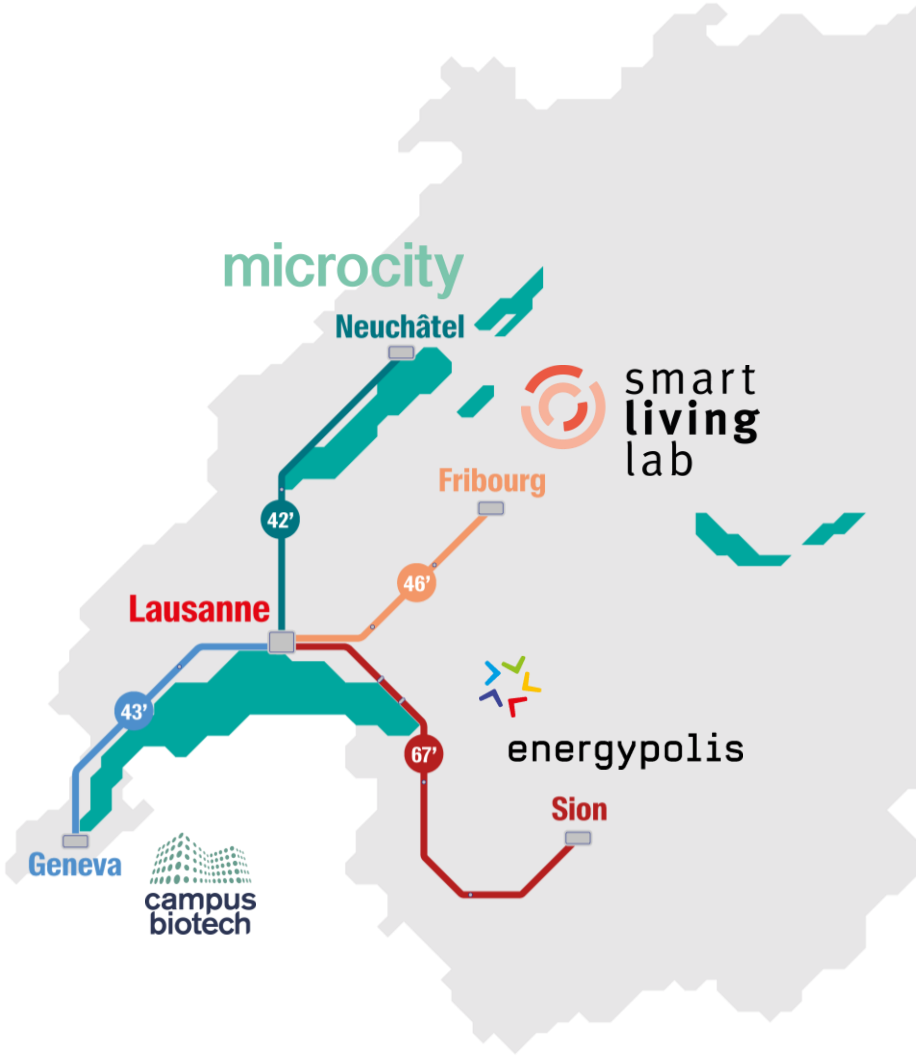
Lausanne – Main Campus

Fribourg – Smart Living Lab

Neuchâtel – Microcity

Sion – Energypolis Campus

Geneva – Campus Biotech

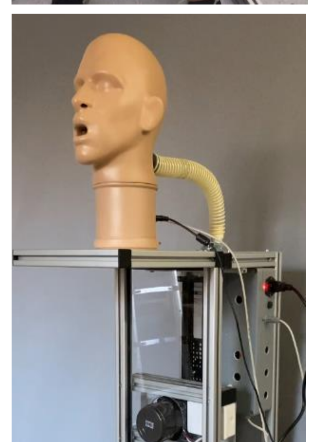


Unique laboratory facilities…

FULL-SCALE CHAMBER

SMALL-SCALE CHAMBERS

BREATHING & COUGHING THERMAL MANIKINS



HIGH-END INSTRUMENTS

Available MSc / semester projects at HOBEL

Some examples:

1. The impact of occupant behavior on ventilation rates in residential buildings
2. Building and testing a low-cost air cleaner for enhanced indoor air quality
3. Exploring the limits of building ventilation by means of air cleaning devices
4. Indoor air quality and thermal comfort assessment at university campus building
5. Building and testing a low-cost thermal manikin
6. Assessment of air quality and thermal comfort on public transport
7. Human inhalation exposure to carbon dioxide and particulate matter in built environment
8. A novel camera-based method for estimating perceived indoor air quality and environmental satisfaction
9. Calibration of an building energy simulation model based on actual data
10. Exploring the Global Thermal Comfort Database
11. Analyzing building energy and indoor environmental data in a Swiss residential building

If interested, please send email me at dusan.licina@epfl.ch

Dolaana Khovalyg

- **Assist. Professor** in **Energy** and **Building Systems Engineering** at **ENAC** since 2018
- Head of **the Laboratory of Integrated Comfort Engineering (ICE)**
- **Research focus**: thermal conditioning of buildings, building physics, well-being and comfort of building occupants
- **Teaching activities**:
  - *Urban Thermodynamics* (CIVIL-309)
  - *Energy & Comfort in Buildings* (CIVIL-407)
  - *Thermodynamics of Comfort in Buildings* (CIVIL-450)

EPFL

smart living lab

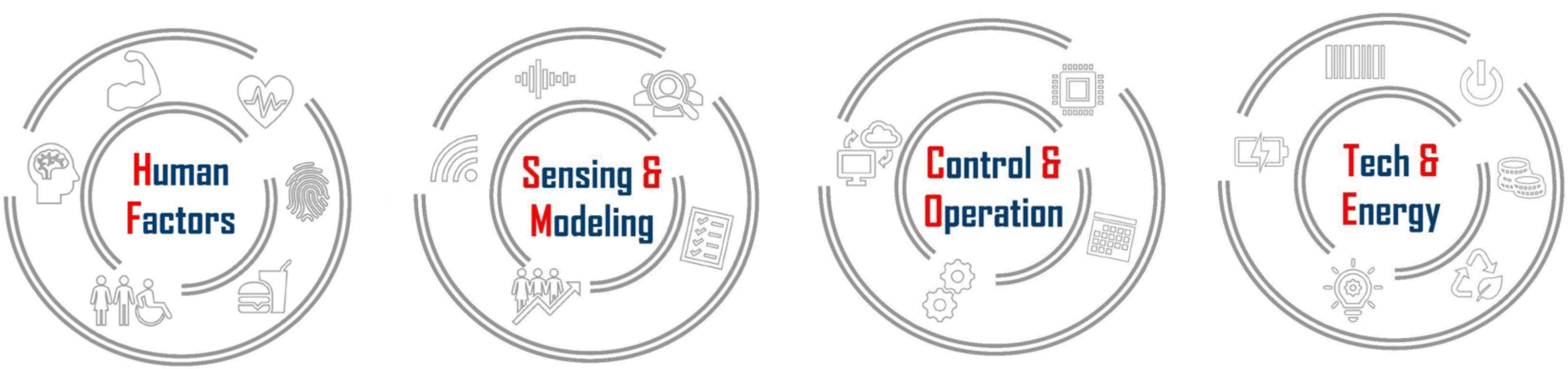
Integrated Comfort Engineering Laboratory

Advancing human comfort studies and the design and control of occupant-centered buildings

PURPOSE:

- **Promote the well-being and thermal comfort of building occupants**
- **Reduce the carbon footprint of thermal conditioning in buildings**

RESEARCH TOPICS:



More details on our website: https://www.epfl.ch/labs/ice/

Andrew Sonta

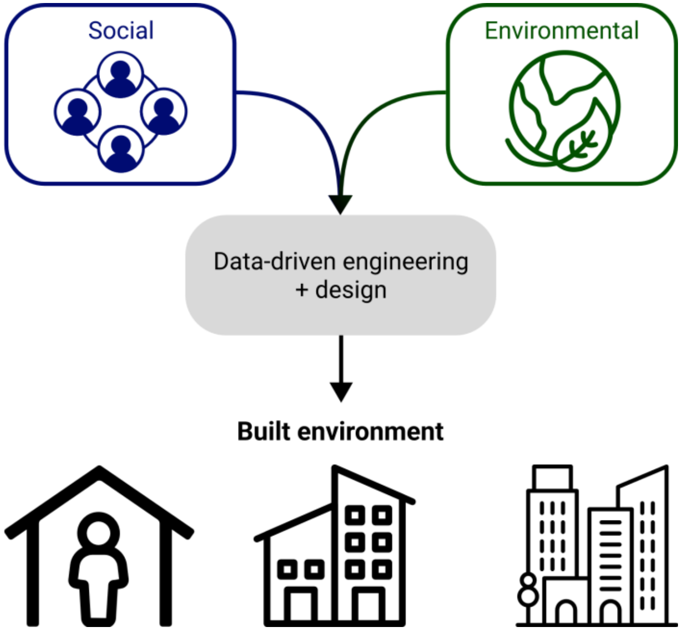
Tenure-Track Assistant Professor
September 2022 – present

Previously:

- Postdoc, Columbia University,
  Data Science Institute
- PhD, Stanford University, Civil and Environmental Engineering

ETHOS Lab

Engineering and Technology for Human Oriented Sustainability



Research vision
Using **data**, **engineering**, and **design** to create interventions in the built environment that integrate our **social** and **environmental** goals.

Current projects

- Occupant-centric building design and management
- Socio-environmental analysis of urban form

Your project instructor + guest lecturer

Matteo Favero

PostDoctoral Researcher | Engineering and Technology for Human-Oriented Sustainability (ETHOS Lab) | EPFL

Education
- BSc and MSc in Building Engineering **@ Politecnico di Milano, Italy**
- PhD in Civil and Environmental Engineering **@ NTNU, Norway**

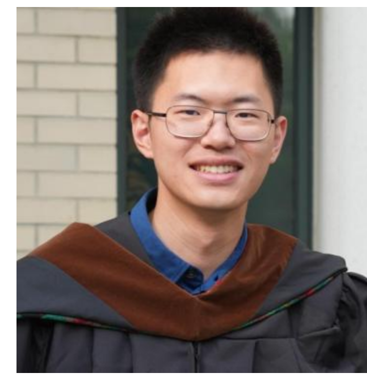
Past research projects
- PhD Research Fellow within **WP4 Energy flexible neighbourhoods @ FME ZEN Centre**
- **IEA EBC Annex 79** on 'Occupant behaviour-centric building design and operation'

Ongoing research projects
- **Human-building interaction** and **occupant-centric models** for thermal comfort in buildings
- **IEA EBC Annex 87** on 'Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems'

Your teaching assistants this semester…

Yufei Zhang is a doctoral student in the ETHOS Lab. He earned his MSc in Integrated Building Systems at ETH Zurich, focusing on simulation and data-driven design of urban energy systems, and his BSc at Tongji University, China, on energy in the built environment. He enjoys street workouts and is fascinated by video games.

Tianqi Liu is a doctoral student in the HOBEL Lab. He holds an MSc in Building Performance and Diagnostics from Carnegie Mellon University (2023) and a BEng in Building Environment and Energy from Tianjin University (2021). His research interests include sensing optimization and advanced HVAC controls to enhance well-being and reduce energy use.



Maitreyee Saini is a doctoral student at the ICE Lab, EPFL. She obtained her MSc in Mechanical Engineering at TU Delft (2024), focusing on urban thermal energy networks, and her BTech in Mechanical Engineering at Vellore Institute of Technology, India. She is interested in energy transition, thermal comfort, and green energy integration at district and building scales.

About you…

Background

- Class profile (56 students):
  - 5xAR, 1xCGC_ING, 8xEL_ENG, 14xGC, 18xGM, 2xMTEE, 8xSIE
- Any experience from work or studies in related fields?

Just for fun

- 🌍 Who has lived outside Switzerland?
- 🌍 Who has lived in more than 3 different countries?
- 🧀 Who has tried fondue?
- 😴 Who has ever fallen asleep in a stuffy classroom?
- 🏀 Who will be EuroBasket champion?

Course information: CIVIL-407

Classroom and Meeting Time

- Thursdays, 09h15 – 12h00 & 12h30 – 14h00; Room: CHB331

Office and hours – Prof. Dusan Licina

- Thursdays, 14h to 15h
- Office GC A1 354

Office and hours – Prof. Dolaana Khovalyg

- Thursdays, 14h to 15h
- Office GC A1 344

Office and hours – Prof. Andrew Sonta

- Tuesday, 14h to 15h
- Office GC G1 484

Prerequisites

- Elementary building physics
- Familiarity with heat transfer, HVAC systems, comfort and indoor climate and energy demand in buildings is a plus

Course information: CIVIL-407

Course Content Official Description

- Energy use in buildings
- Human-centric buildings
- Thermal comfort requirements
- IAQ and ventilation requirements
- Importance of human behavior

1st half of semester

- Solar geometry and heat gain
- Building envelope
- Heating & cooling demand
- Heating and cooling systems
- Green building standards

2nd half of semester

Course learning outcomes

By the end of the course, you will be able to:

- **Apply** human comfort requirements when designing and operating building energy systems.
- **Explain** how building energy demand, indoor air quality, and thermal comfort interact with occupants.
- **Analyze** energy flows in buildings and **perform** heat balance calculations.
- **Use** basic building energy simulation tools to model performance.
- **Recognize and compare** major green building standards.

Course resources

Purchasing a textbook is **not compulsory** for this course

The reference textbooks from which we will draw information, for your consideration:

- Edward Allen. How Buildings Work: The natural Order of Architecture, 3rd ed. (*downloadable from Moodle*)
- Claude-Alain Roulet. Energétique du bâtiment - Tome 1 and 2. PPUR.
- Y. A. Çengel; A. J. Ghajar, Heat and Mass Transfer: Fundamentals and Applications. McGraw Hill Education, 5th edition
- ASHRAE Handbook of Fundamentals, 2018
- Different building standards such as ISO 17772, ISO 6946, ASHRAE 55, ASHRAE 62.1, SIA 380/1, SIA 2024.
- Peer-reviewed papers and websites – it will be provided throughout the semester.

Course deliverables and grading

• Exam 1 (1st half of the course)	30 pts
• Exam 2 (2nd half of the course)	30 pts
• Individual project report	20 pts
• Group project presentation	20 pts
Total	100 pts

Grading scale:

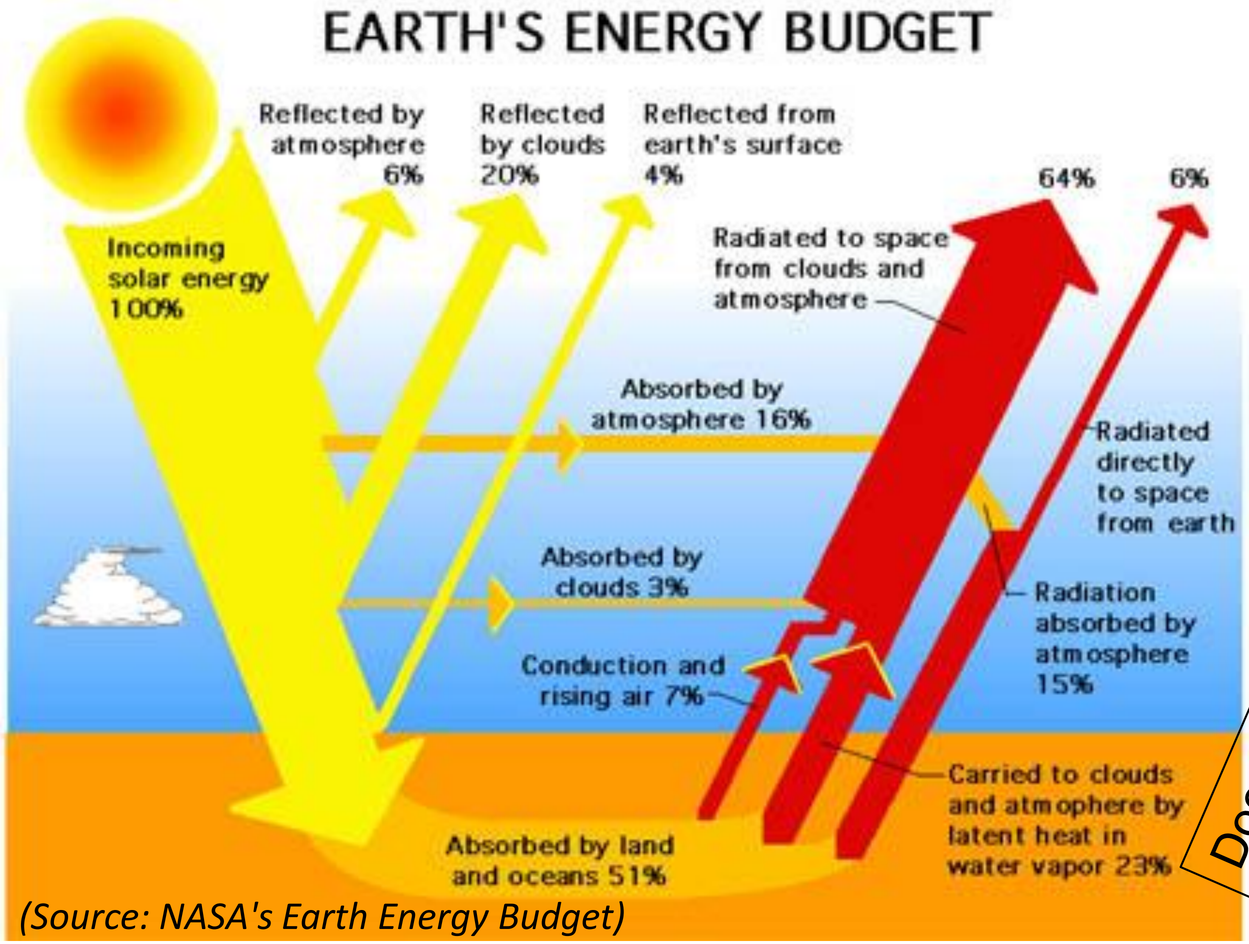
• 5.50 - 6.00	≥ 90%
• 5.00 - 5.49	80-89.9%
• 4.50 - 4.99	70-79.9%
• 4.00 - 4.49	60-69.9%
• 0.00 - 3.99	< 59.9%

Other relevant details…

- I will post lecture notes and updated syllabus on Moodle
  - I will do so usually 1-3 days before class
- I will generally communicate with the class via email
  - Don’t let me go into your spam folder
  - Do you have a different email address that you prefer?
    - If so, email me at dusan.licina@epfl.ch
- Please make sure to:
  - ask when you have a question or when you want to share a comment / experience
  - participate in discussions whenever given an opportunity
  - participate in all pooling sessions, quizzes and debates

Any questions so far?

Reason behind everything: GHG

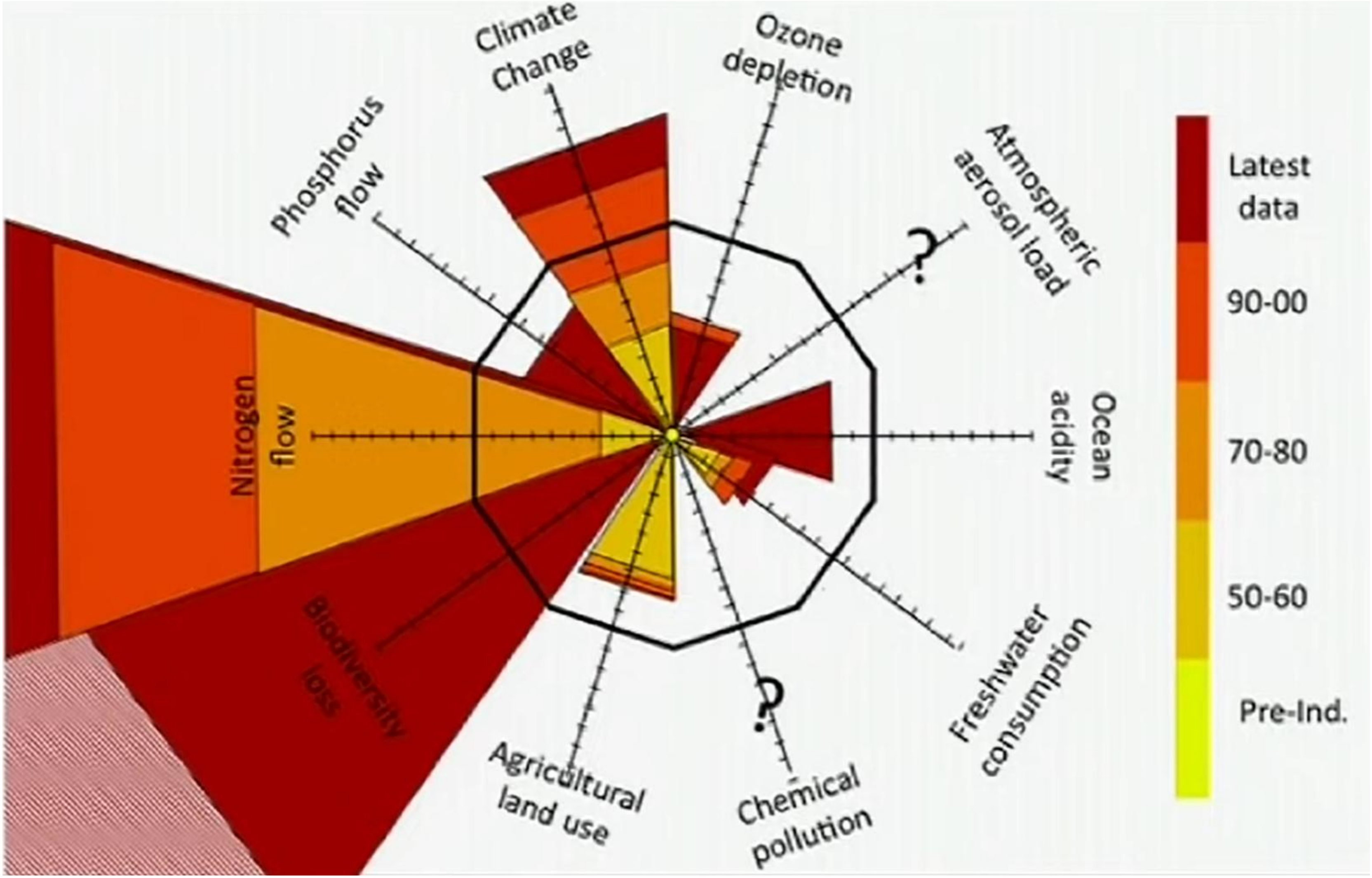


(Source: NASA's Earth Energy Budget)

Does +1.1 °C matter?
Yes! >1 °C of fever already indicates an illness in the human body (compared to normal temperature of +37 °C)

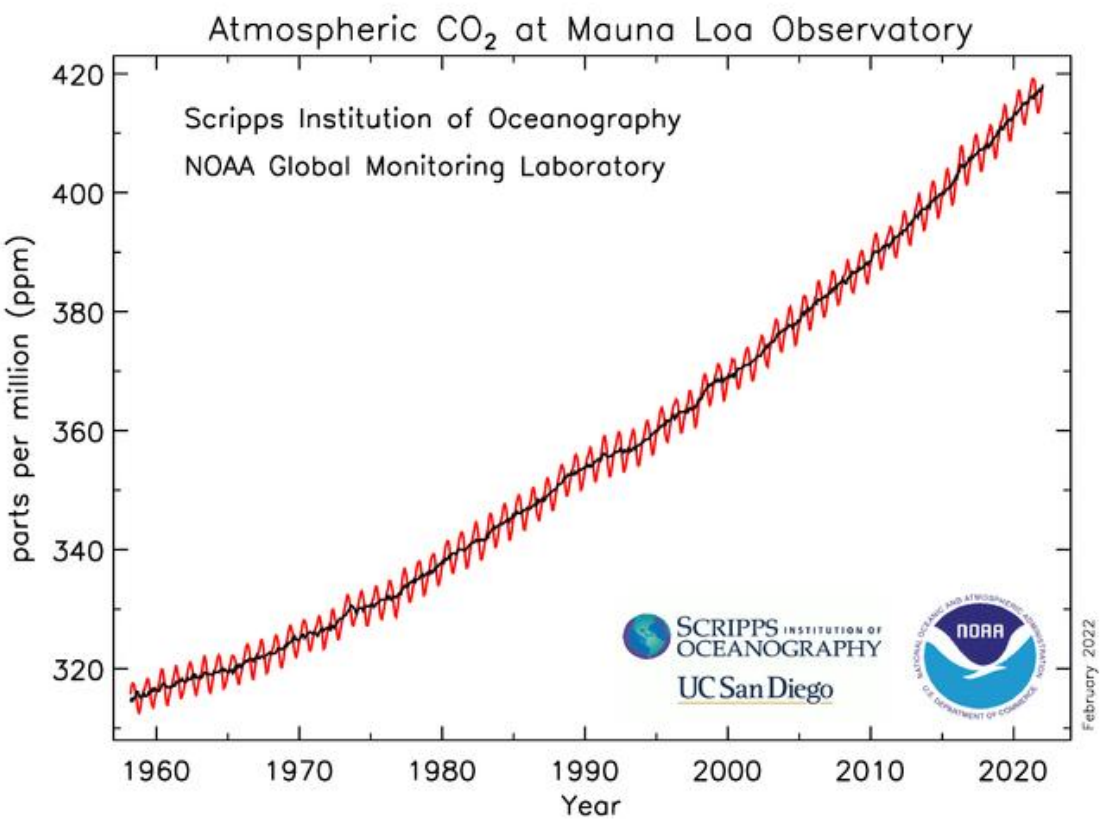
- Without GHG: Mean global temperature would be 33 °C lower!
- Man-made GHG: Additional warming since pre-industrial time = = +1.1 °C during last decade (IPCC AR6).

The 10 limits of our planet



(Science article: https://www.science.org/doi/10.1126/sciadv.adh2458
Newspapers article: https://ideas.ted.com/the-9-limits-of-our-planet-and-how-weve-raced-past-4-of-them/)

Staggering facts



- The atmospheric abundance of CO_2 has risen from its pre-industrial level of 280 ppm to a level of 420 ppm today.
- "Planetary boundary" already exceeded (350 ppm).
- The CO_2 level continues to increase at a rate of a few ppm per year.

(Sources: IPCC reports, Nazaroff, 2008)

Staggering facts

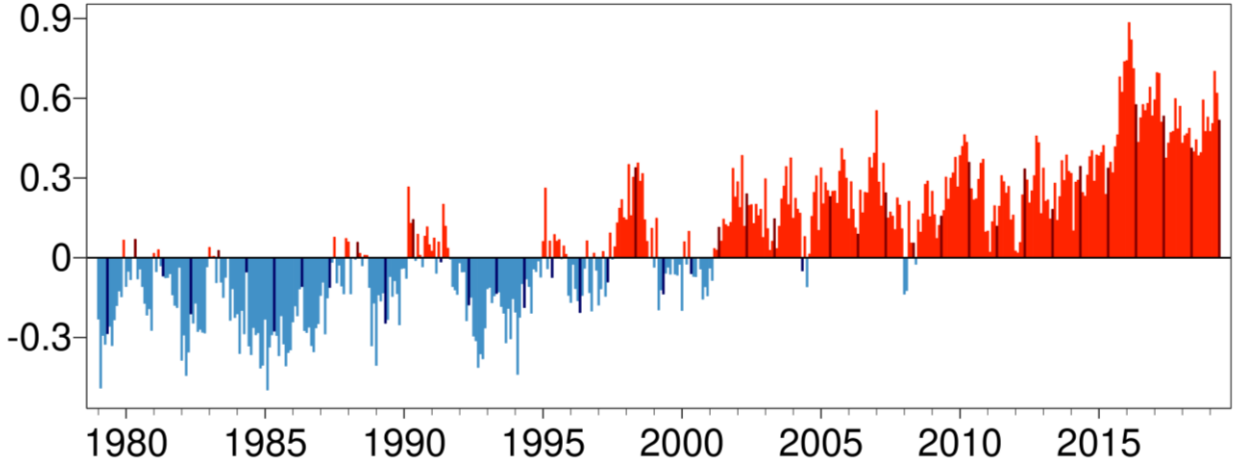
- CO_2 concentrations are increasing unabatedly no matter how much scientific information is produced, thought, shared, discussed…
- "Business as usual" trajectory will bring us to a rise in atmospheric CO_2 to 500 – 1000 ppm by 2100!

What are the implications?

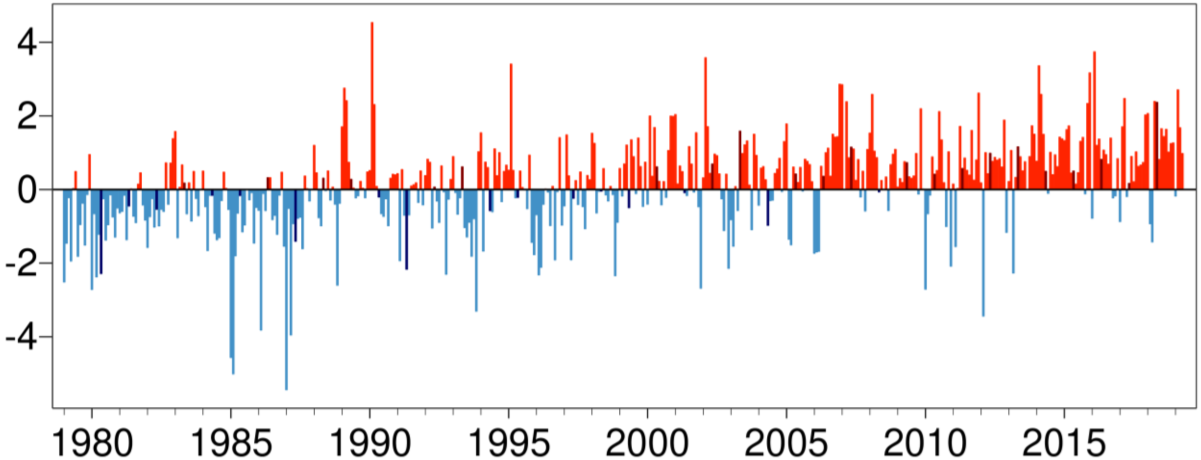
(Source: Intergovernmental Panel on Climate Change)

(Source: Nazaroff, 2008)

Global surface air temperature change

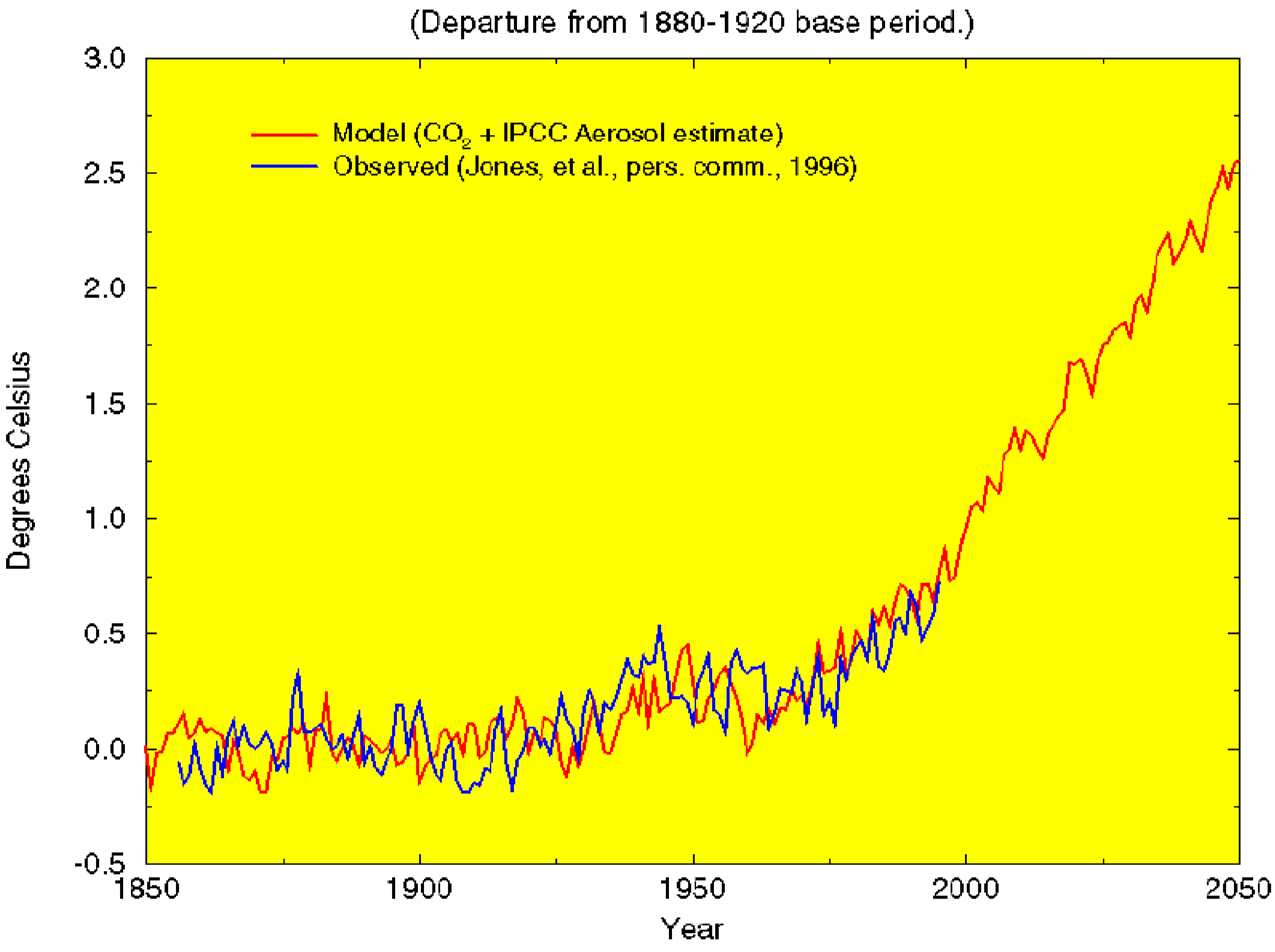


Global monthly (ºC)
1981 - 2010

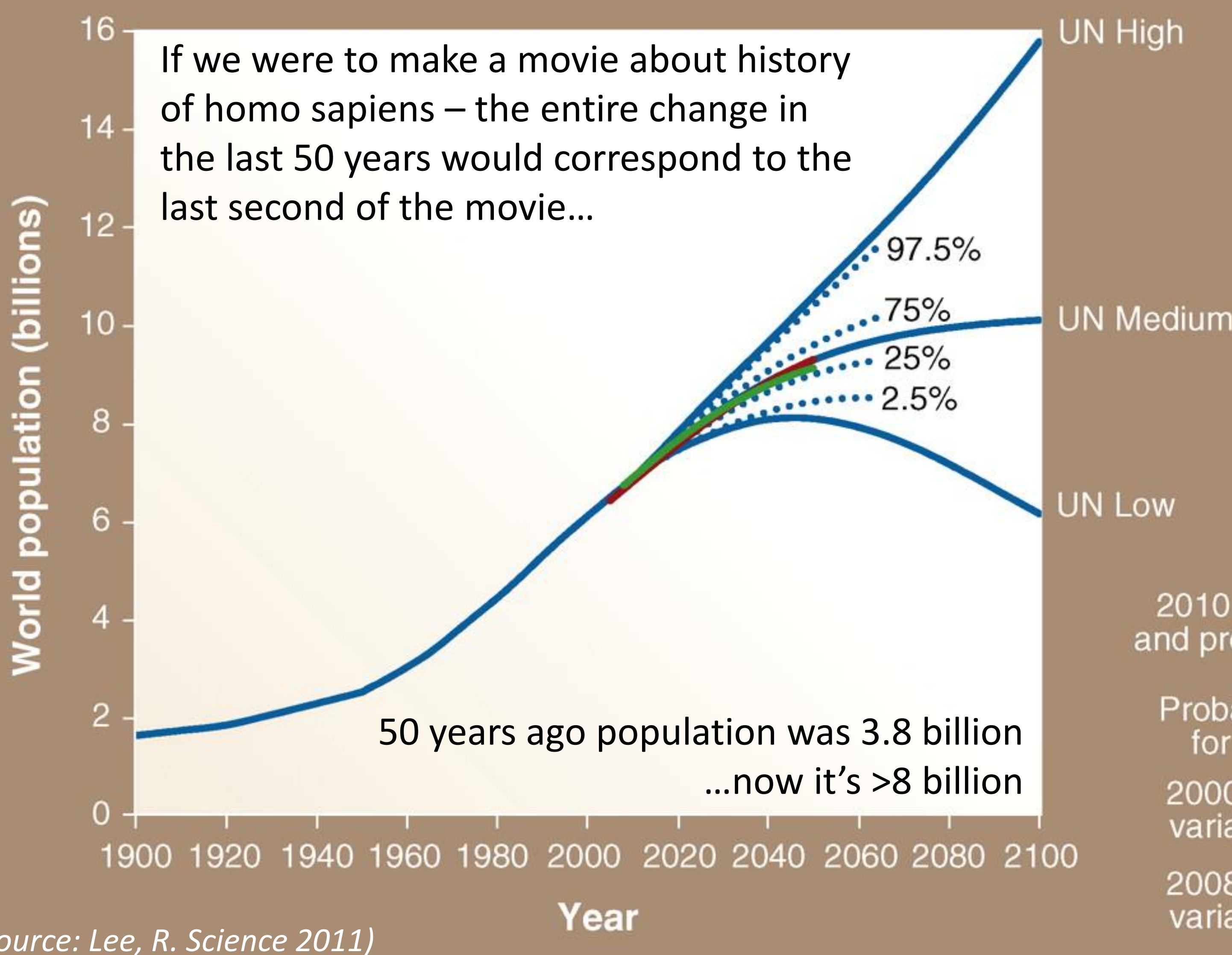


European monthly (ºC)
1981 - 2010

Global surface air temperature prediction



The Outlook for Population Growth

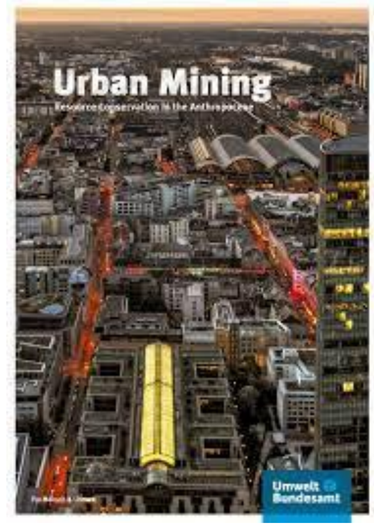


If we were to make a movie about history of homo sapiens – the entire change in the last 50 years would correspond to the last second of the movie…

50 years ago population was 3.8 billion
…now it's >8 billion

(Source: Lee, R. Science 2011)

Tremendous increase in urbanization



Urban Mining and Recycling

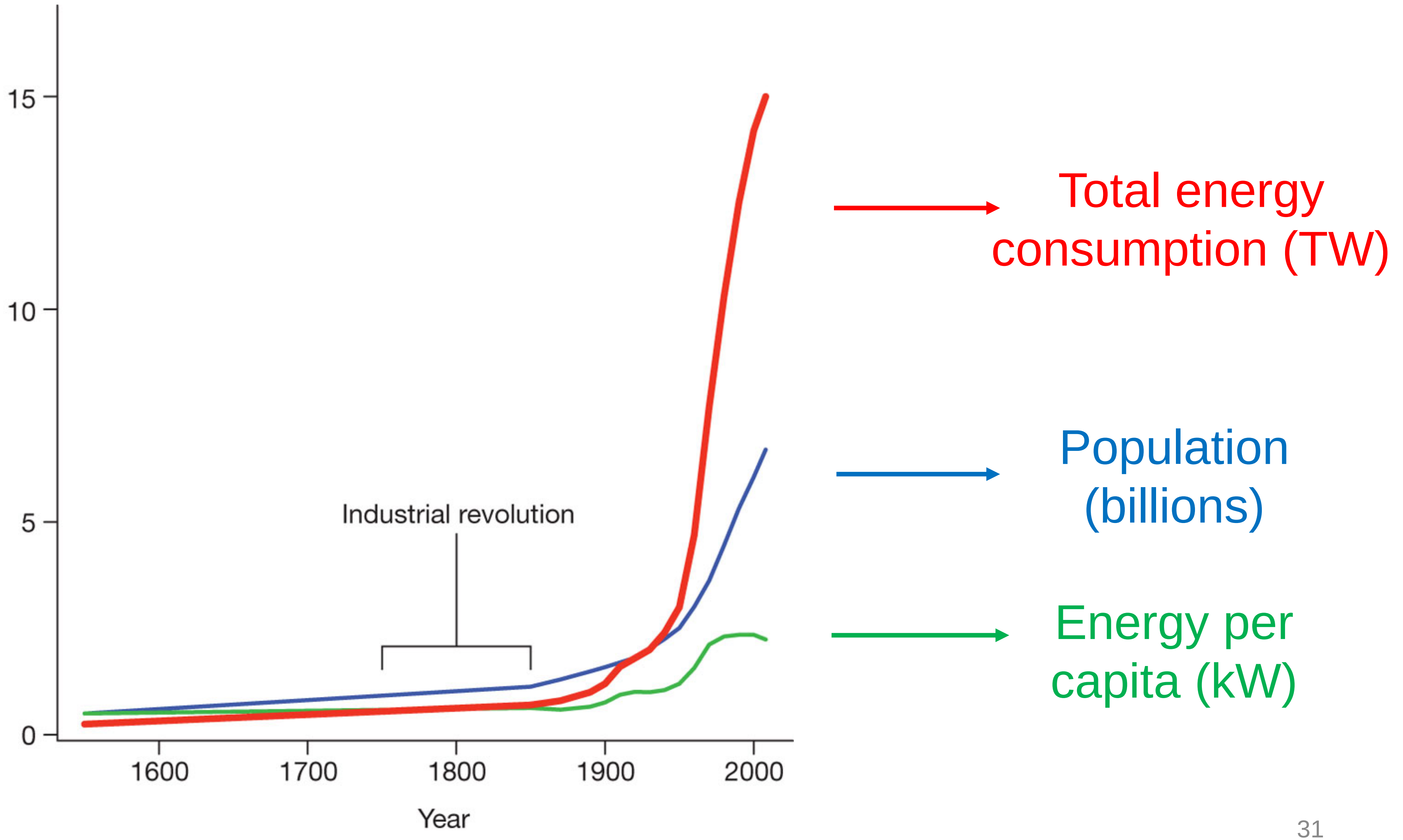
Situation 2025:

• World population	8.1 billion
• Births per second	4.2
• Deaths per second	2.0
• Population growth per second	2.2
• Building materials needed	1’078 *

* tons per second !!!

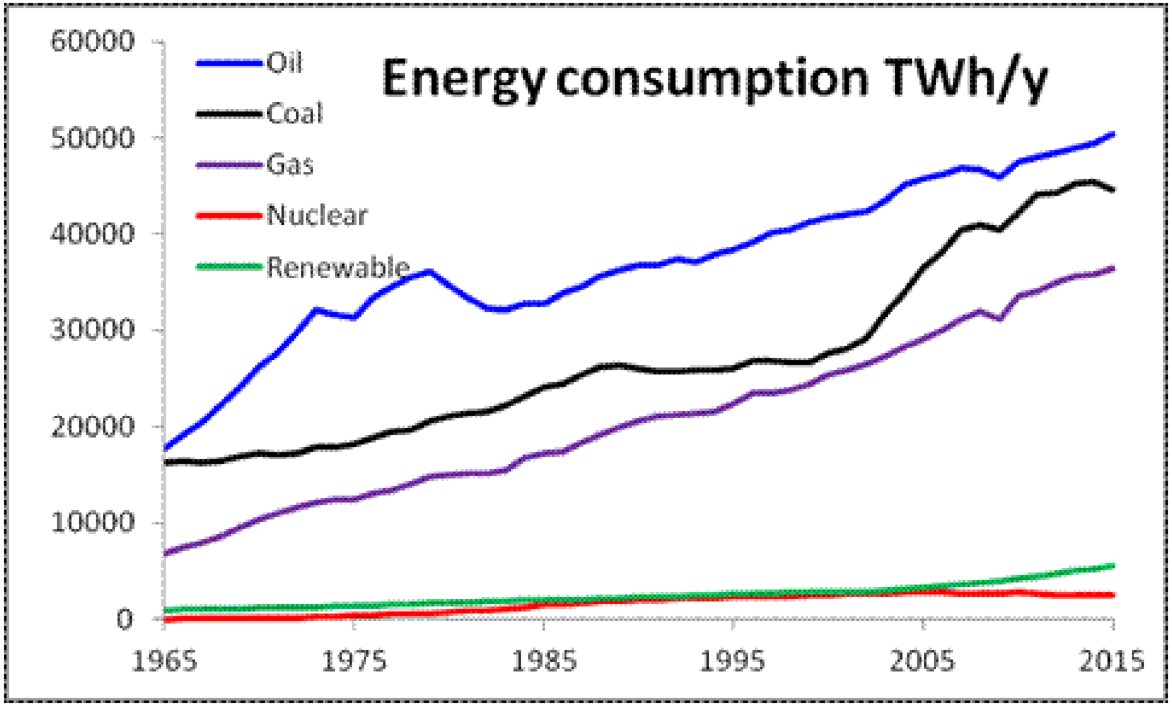
(German Standard, 490t per capita. This information is available for 2018 year)*

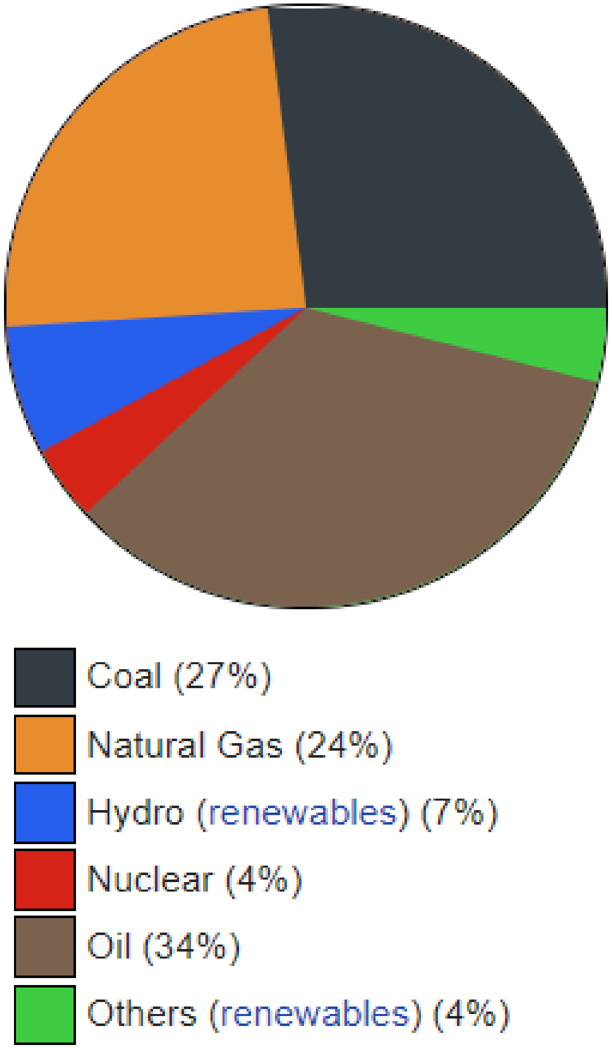
World population and Energy use



(Source: Ehrlich et al. 2012, Nature)

Sources of energy consumption in the world

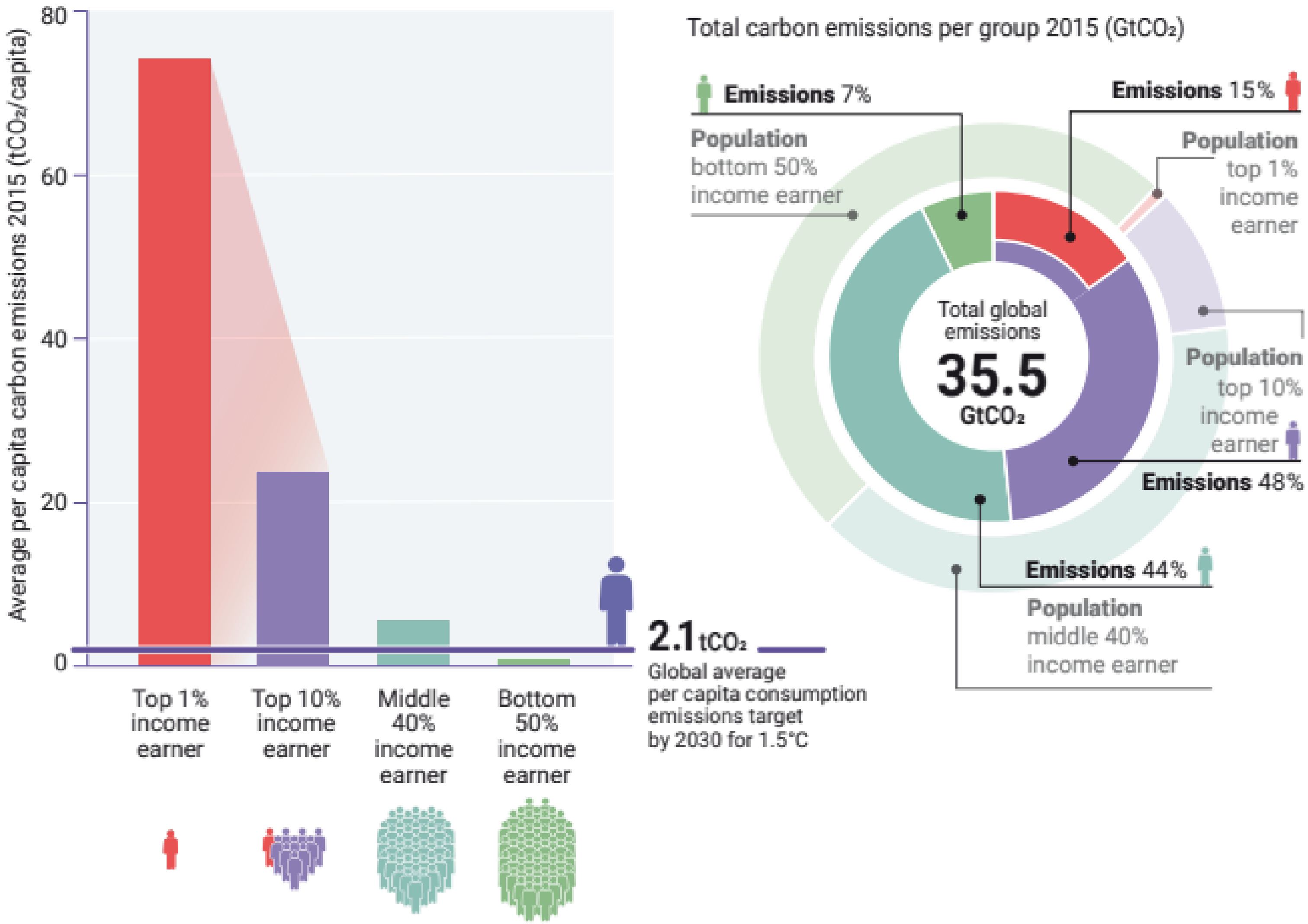




The world's energy consumption (2015)
Each 10000 TWh/y corresponds to an average value of about 1.142 TW

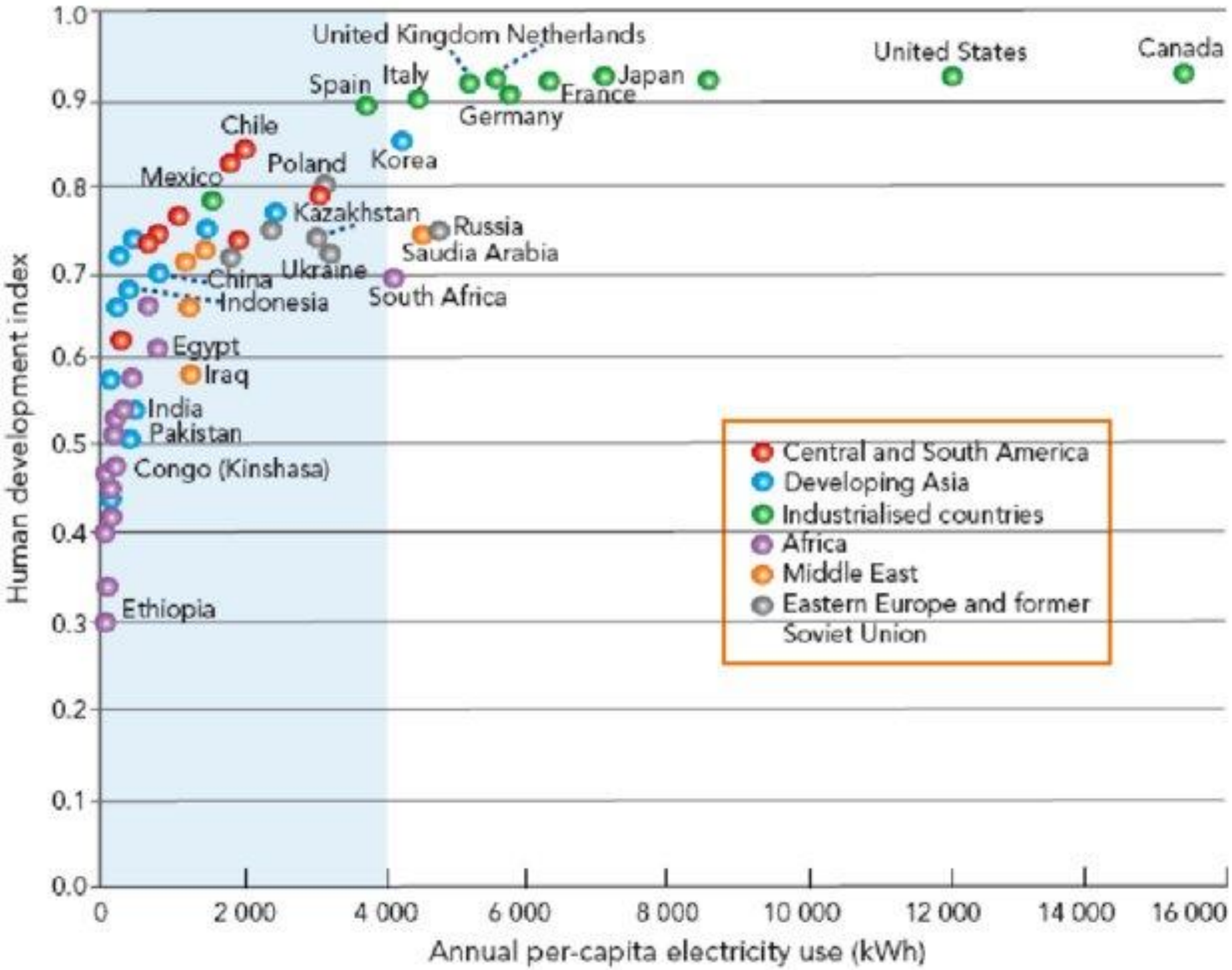
(Sources: Statistical Review of World Energy, 2016, 2019)

CO_2 emissions by 4 global income groups



(Source: Emission Gap Report, 2020)

Per-capita electricity consumption and Human Development Index



(Source: United States Department of Energy, 2000)

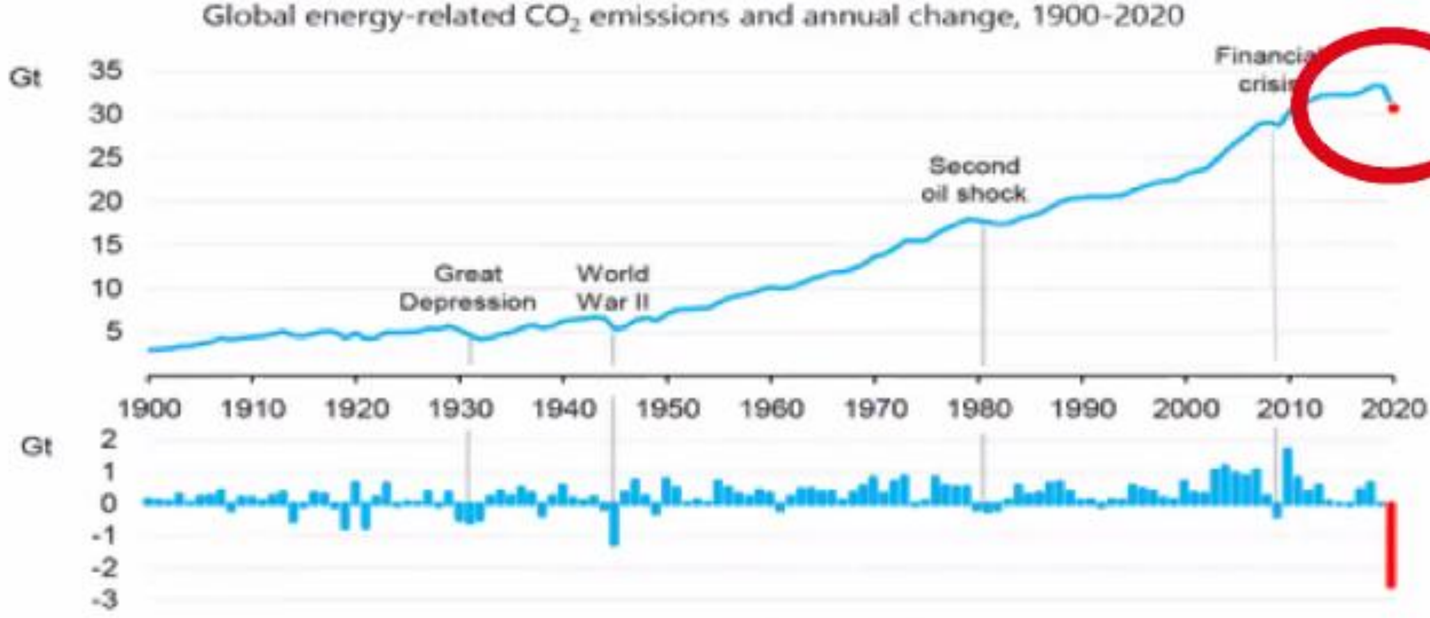
A day of great change is dawning

- 8 billion humans emit to the atmosphere ~8 billion tonnes of fossil carbon per year
- Population average emission rate is thus 1 tonne of C per person per year or about 3 kgC per person per day
- Rates vary *a lot* across populations!
  - US average emissions are 15 kgC per person / day (the highest)
    - 5x higher than the global average!
- Question: To let the CO_2 level rise to 450 ppm (inevitable) and global population growth to 9 billion, what average per-capita emission of C must be?
  - Answer: It must be reduced from 3 kgC to 1 kgC per person per day

(Source: Nazaroff, Indoor Air 2008)

Trend of CO_2 emissions

- CO_2 emission dropped the most ever due to the COVID-19 crisis



- Global energy-related CO_2 emissions fell nearly 8% in 2020 (lowers in a decade) mostly due to reduced coal use
- However, there was a large rebound soon after and is continuing during post pandemic

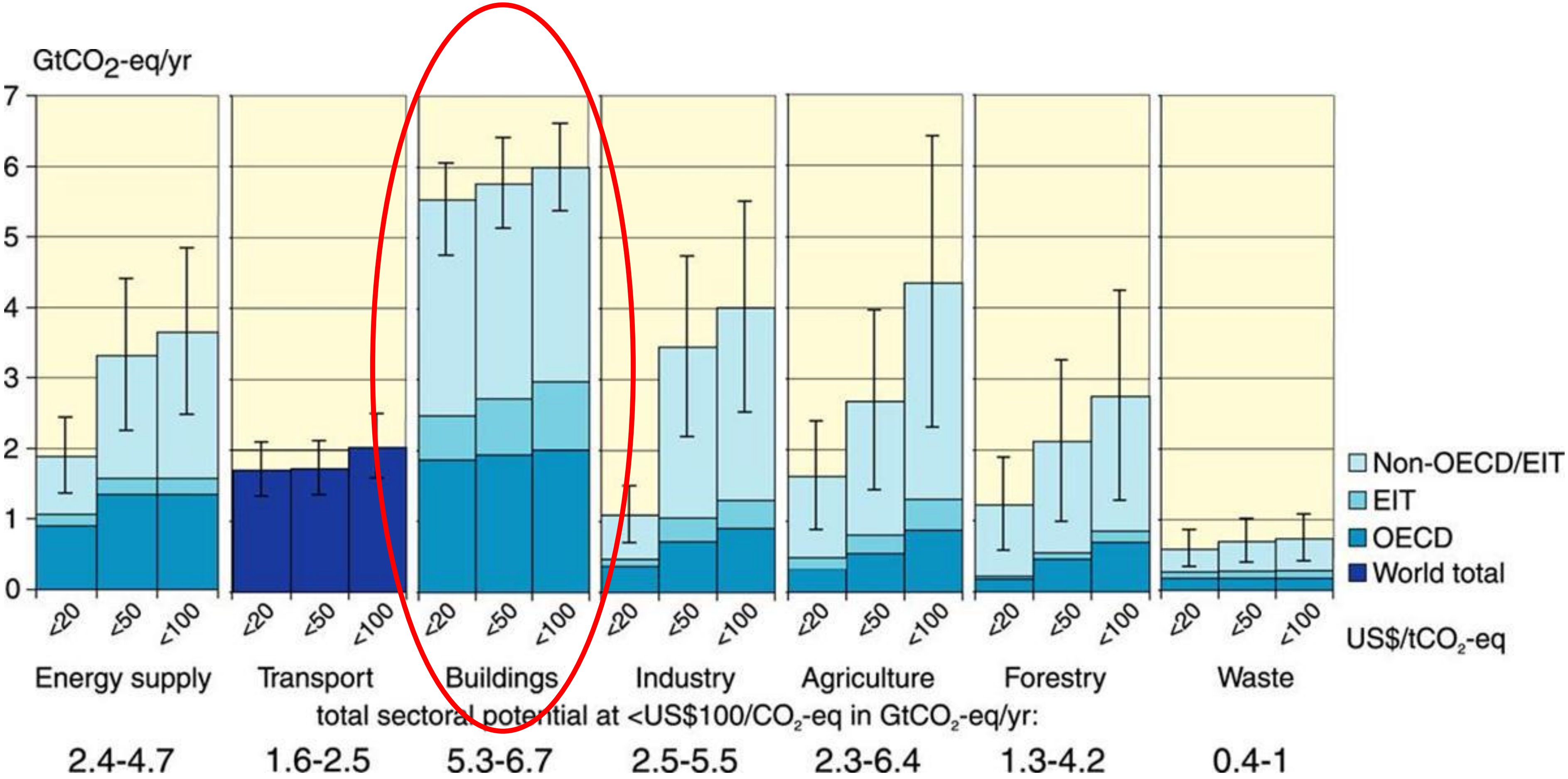
(Source: RA 2020. IEA)

A day of great change is dawning

How to get from 3 kgC to 1 kgC per person per day?

Where should we focus our efforts?

Where should we focus our efforts?



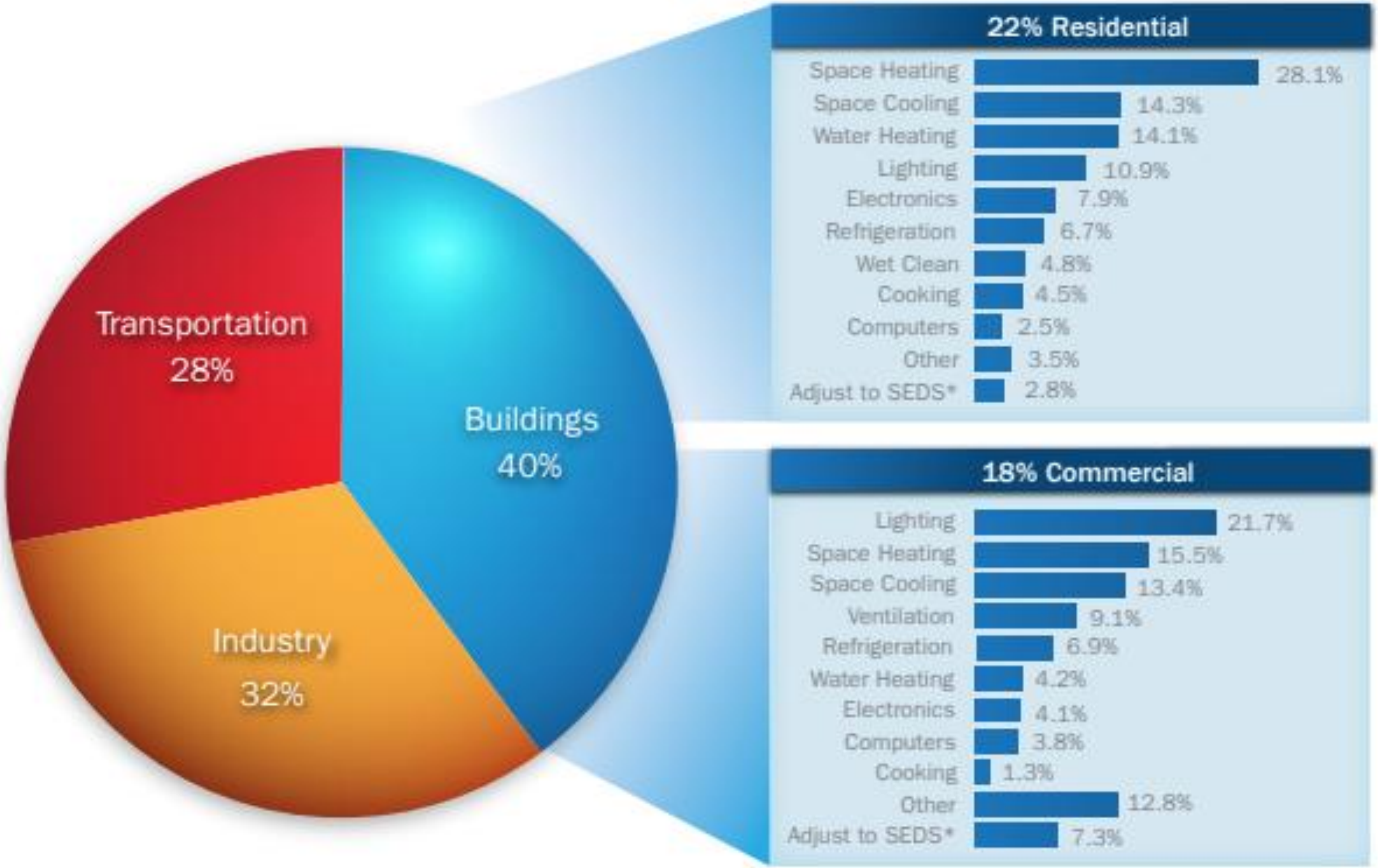
(Source: Climate Change 2007: Mitigation of Climate Change. Summary for Policymakers)

Any questions? See you in 15 mins…

Lets sum up a few key points so far:

- The climate is changing & the cause is human activity
- Impacts are obvious – air, soil and oceans started to send us invoices
- Energy use in buildings has the strongest (but not sole) influence
- The extent of future impacts depends on what we do now

US energy use in residential and commercial buildings, 2008



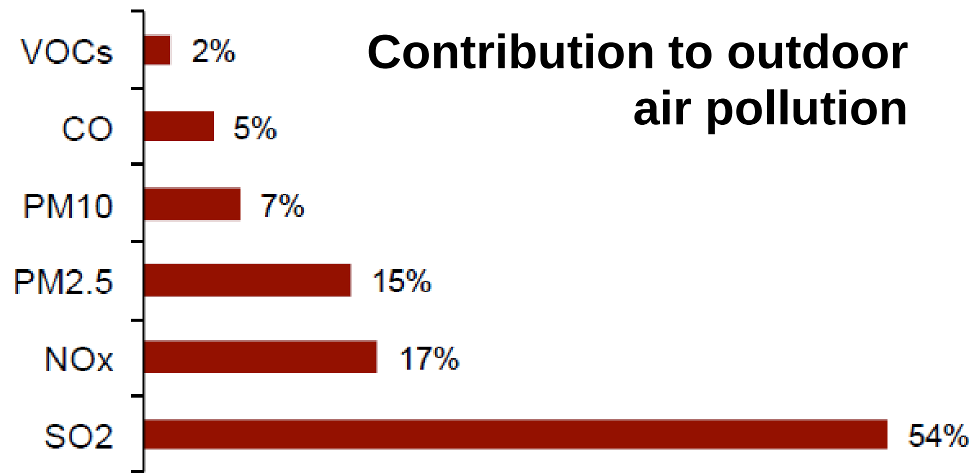
Building consume 40% of primary energy. Of that, 22% is consumed in residential buildings and 18% in commercial buildings

(Source: US DOE Quadrennial Technology Review)

Environmental impact of buildings (in the U.S.)

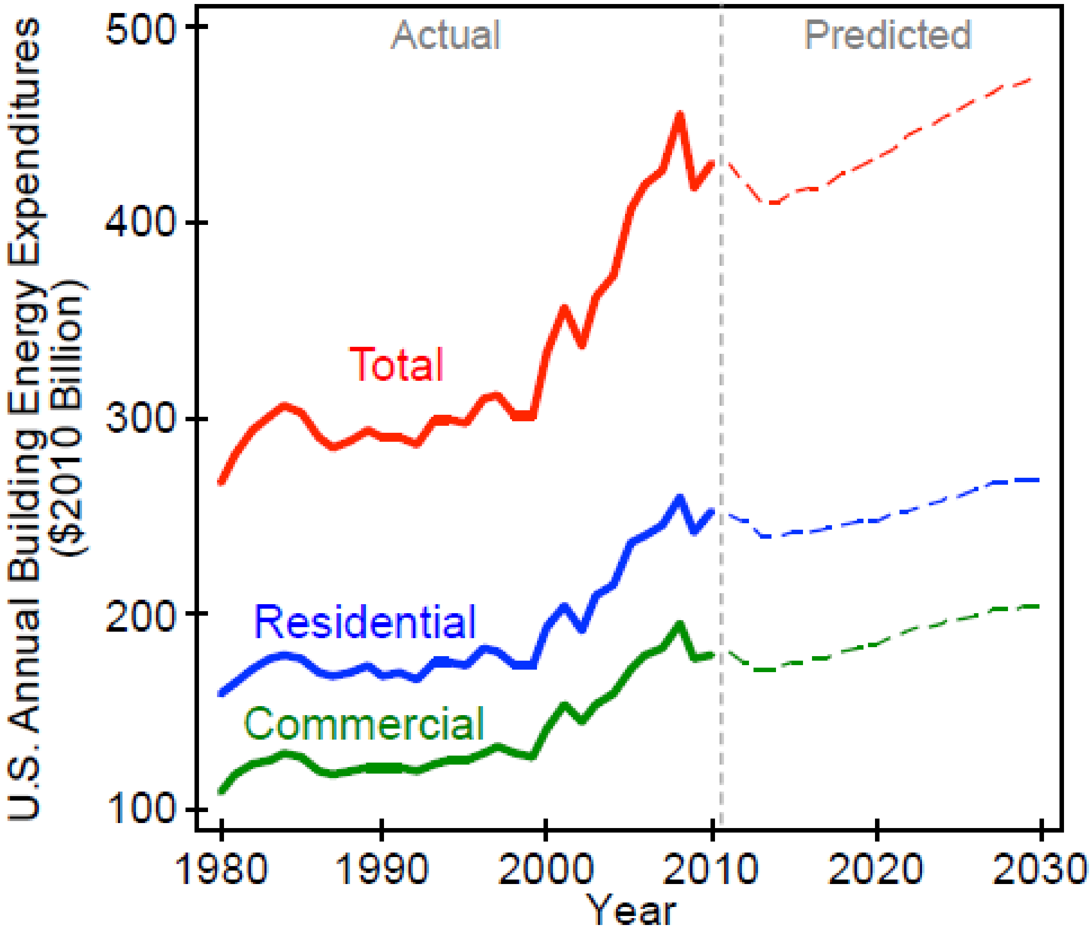
- 72% of total U.S. electricity consumption
- 38.9% of total U.S. primary energy use
- 39% of total U.S. CO_2 emissions
- 40% of landfill material in the U.S.
- 13% of potable water in the U.S.

Buildings in the U.S. account for ~7% of the total amount of energy used in the world



(Source: www.epa.gov/greenbuilding/pubs/gbstats.pdf)

Building energy use costs *a lot* of $$$



U.S. building energy expenditures totaled ~$430 billion in 2010

Objectives and climate strategy in Switzerland

- The climate policy of Switzerland aims at reducing the emissions of CO_2 by 20% by 2020 (interim target) by 50% by 2030 and by 70-85% on the horizon 2050 compared to emissions in 1990
  - Buildings: Reduction of GHG of 82% by 2040
  - Read about Energy Strategy 2050 here:

    https://www.bfe.admin.ch/bfe/en/home/policy/energy-strategy-2050.html#tab__content_bfe_en_home_politik_energiestrategie-2050_jcr_content_par_tabs
- Ambitious targets, but hey, we already know that it won't be enough!
- We need new building standards based on a life cycle approach.

Stock of buildings in Switzerland: Energy consumption and CO_2 emissions

Source: Bernard Nicod

Source: Echaffaudage-Vevey.ch

Source: Chantiers & Rénovation

- 1.7 million residential buildings in Switzerland in 2016
- Construction and operation of buildings: about 50% of the final energy consumption and the CO_2 emissions

(Source: Swiss Federal Office of Energy)

After-class thinking…

- *What do we do to reduce the consumption of energy to meet targets of Energy Strategy 2050?*
- *How to substitute the prevailing fossil fuels with renewable energies in buildings? Is reliance on renewables enough to overcome the challenge?*
- *Which are the economic and environmental implications?*

Embodied carbon: Construction practices

Bird's Nest
Beijing

1300 kg CO_2e/m^2

Olympic Stadium
London

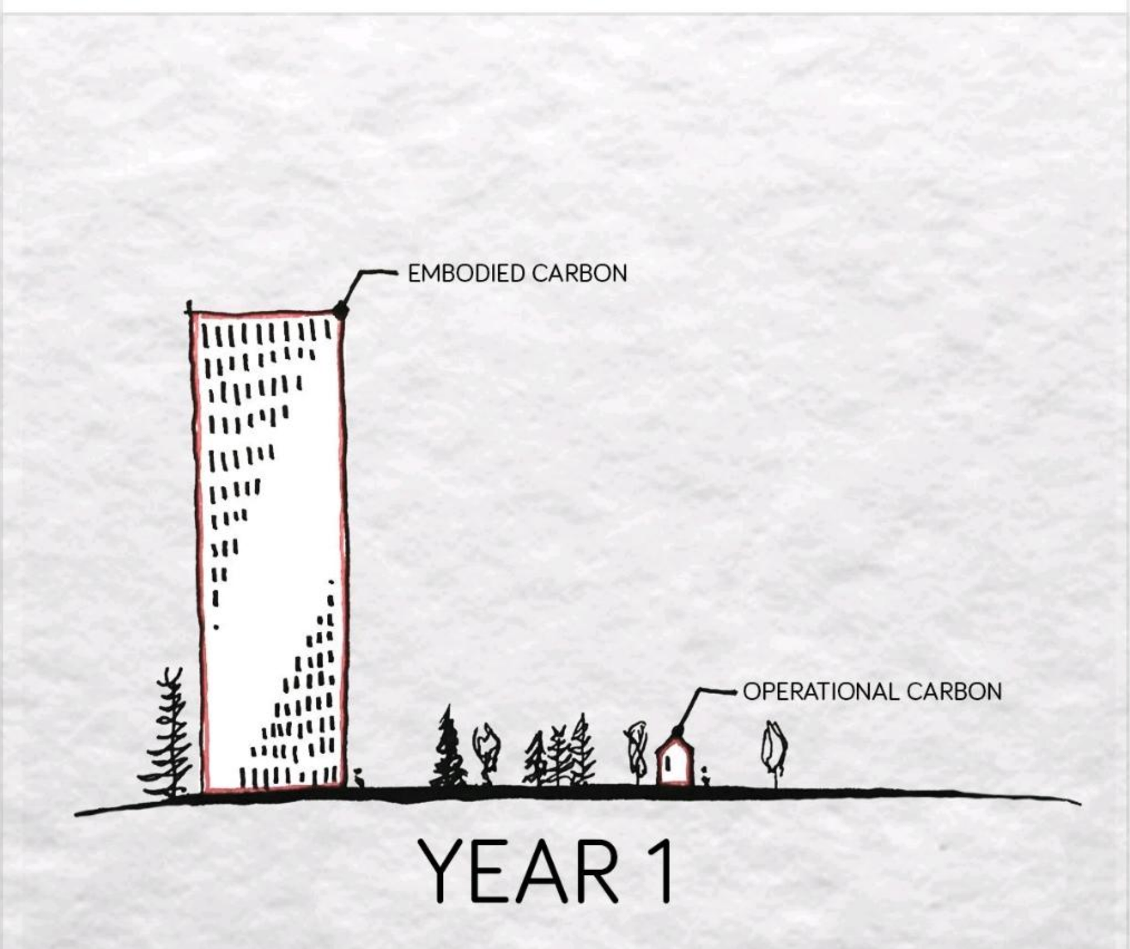
250 kg CO_2e/m^2

Mapungubwe Centre
South Africa

60 kg CO_2e/m^2

(Source: Catherine De Wolf)

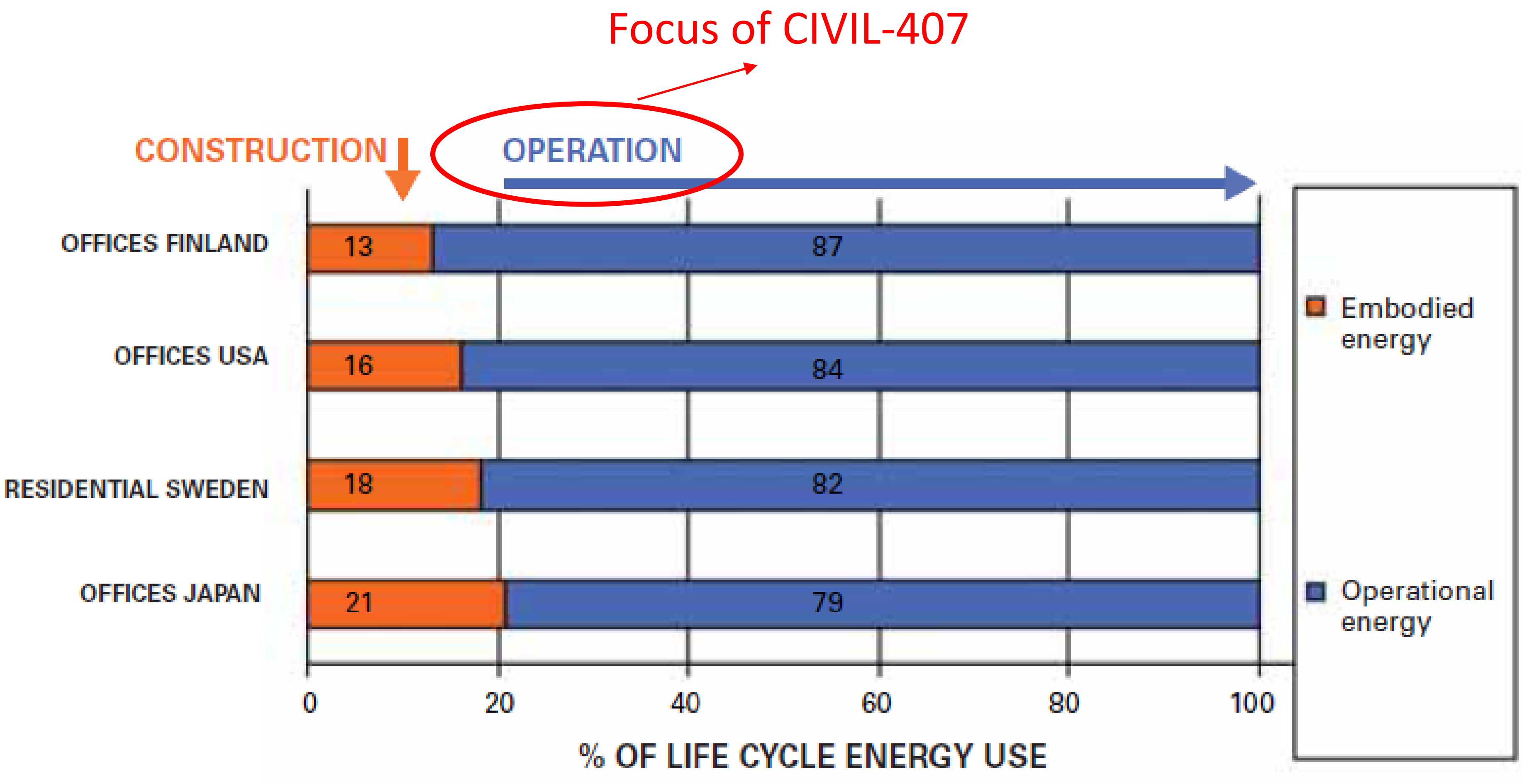
Embodied vs. Operational emissions…



In order to address climate emergency, we must focus both on **operational carbon**, which is the carbon load created by the use of energy to condition and power a building (focus of CIVIL 407), as well as **embodied carbon**, which is the carbon that is released in the manufacturing, production, and transportation of our building materials. In early building life, embodied energy could be large, although it's lower compared to operational energy overall

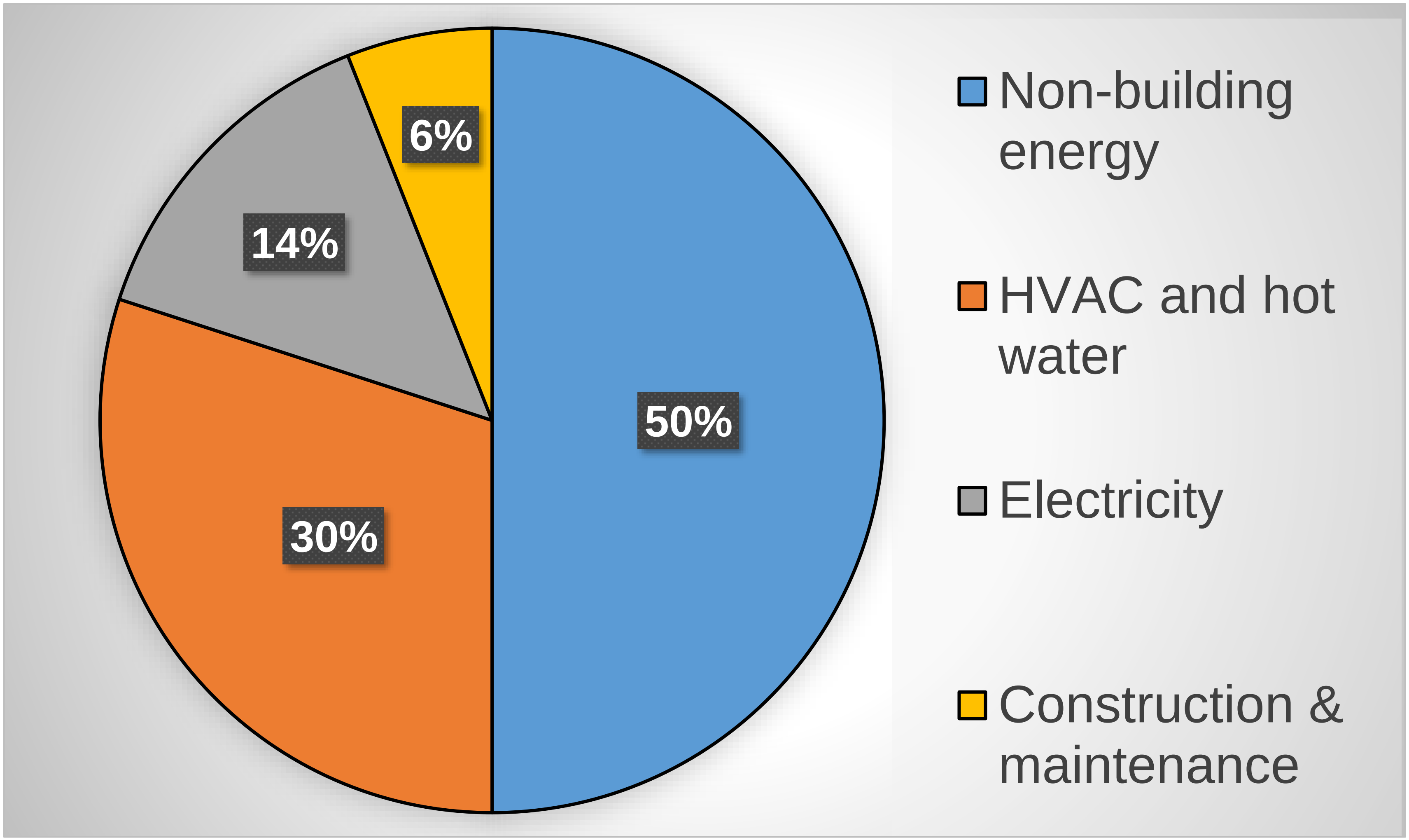
(Source: Steven Biersteker, LinkedIn)

Example of life cycle energy use of buildings



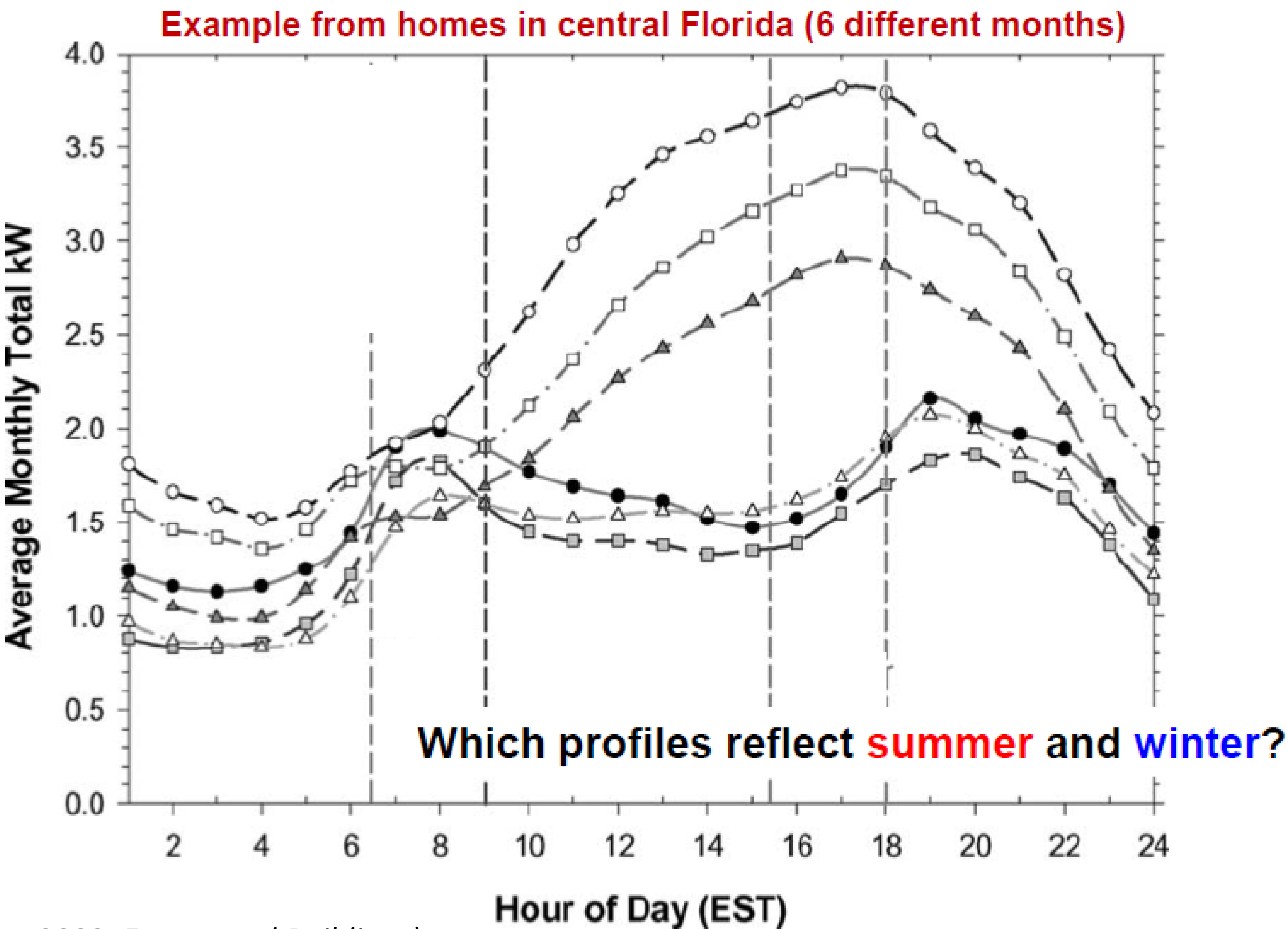
(Source: UNEP-SBCI, 2007)

Building energy use in CH: 50% !!!



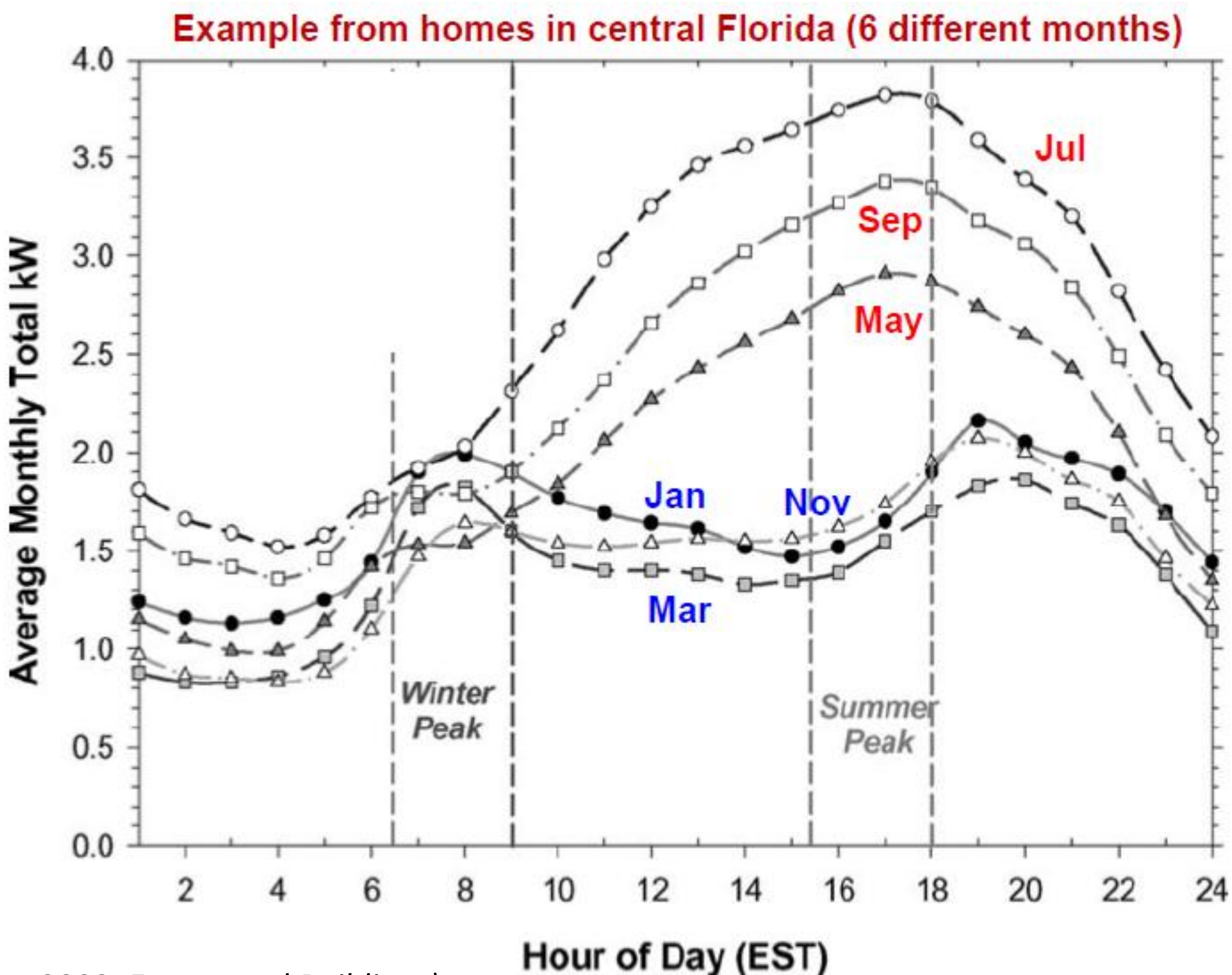
(Source: Swiss Federal Office of Energy)

Understanding energy use in buildings



(Source: Parker 2003, Energy and Buildings)

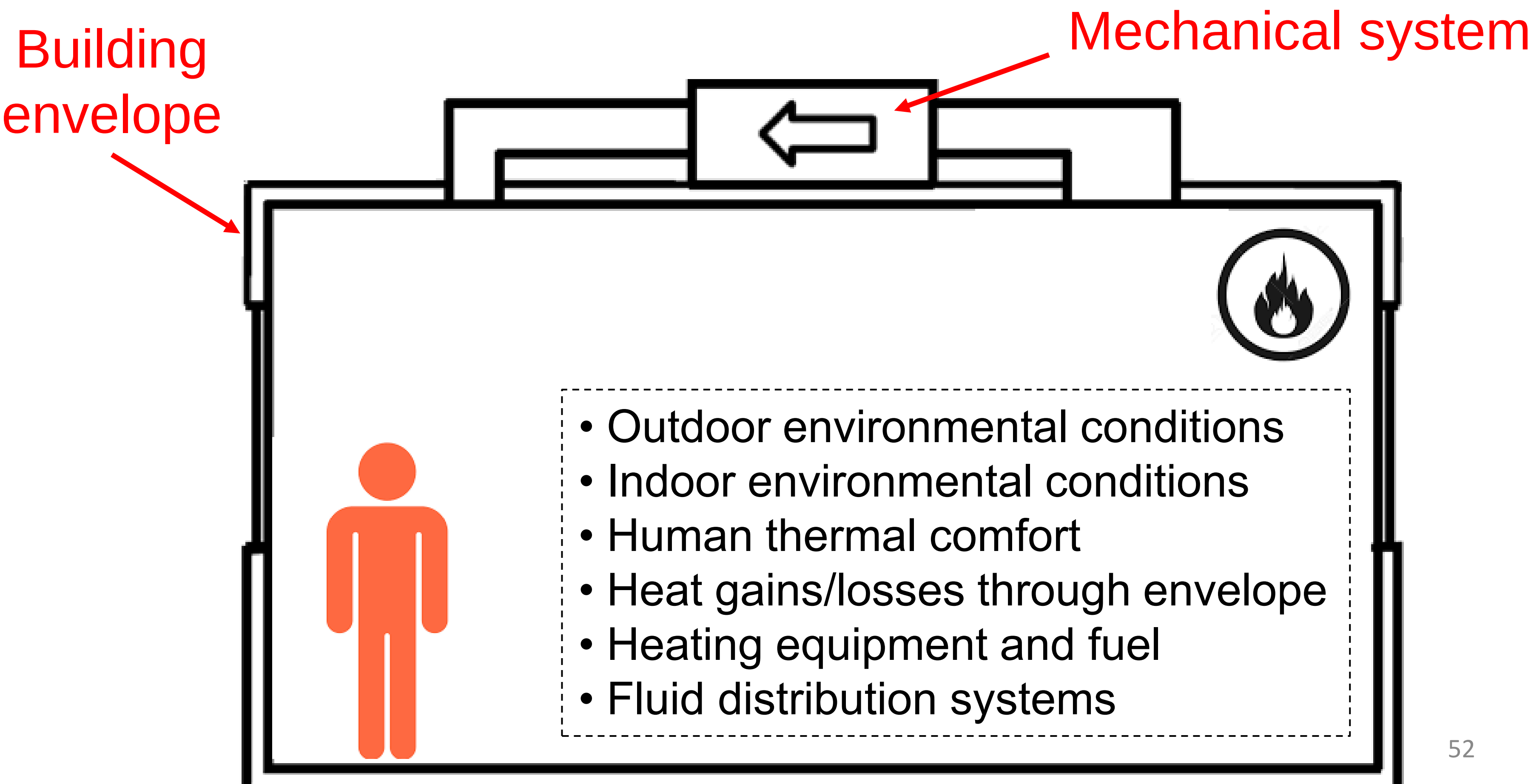
Understanding energy use in buildings



(Source: Parker 2003, Energy and Buildings)

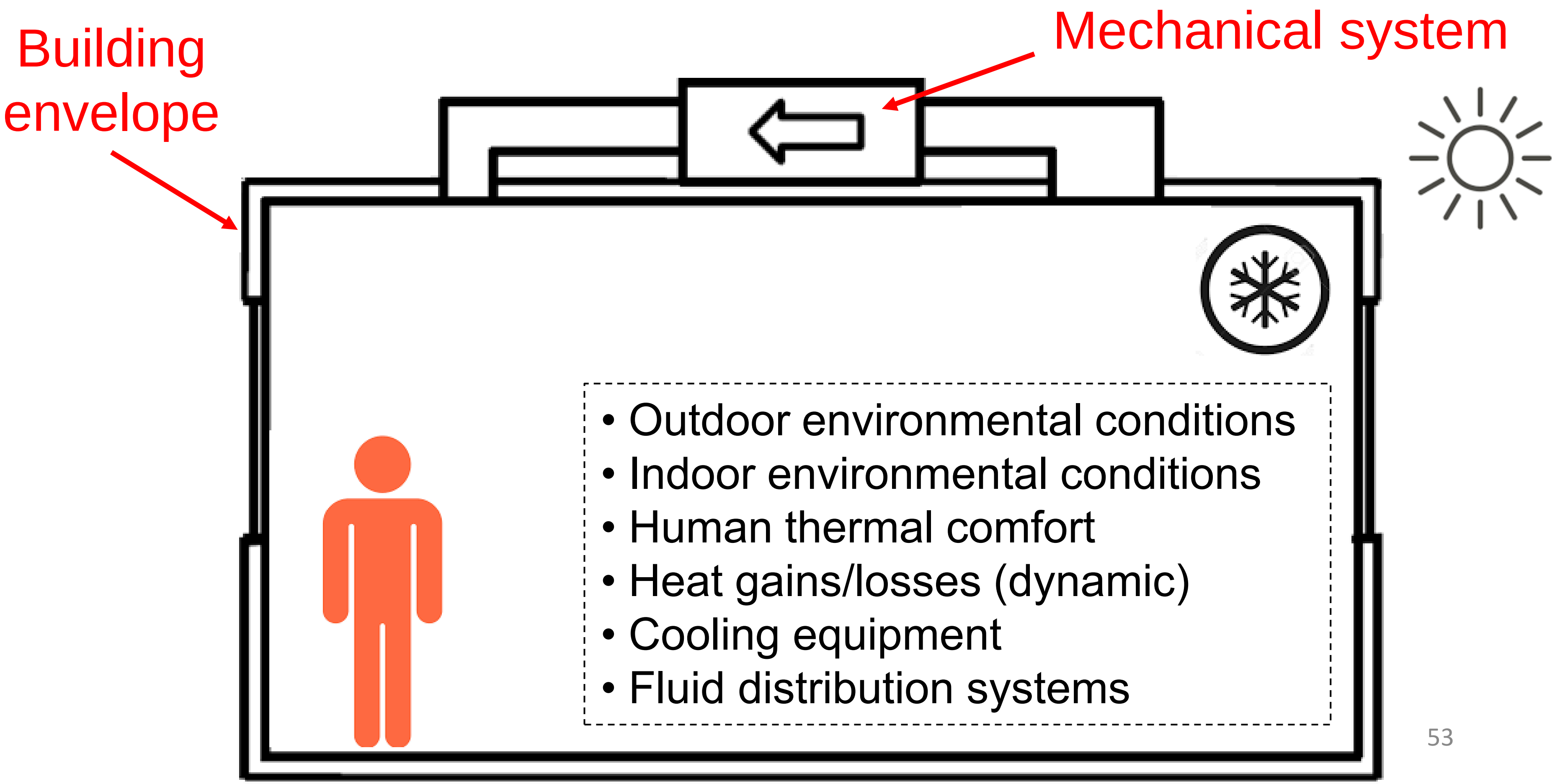
Building energy use for Heating

What are the key factors influencing energy use for **heating**?

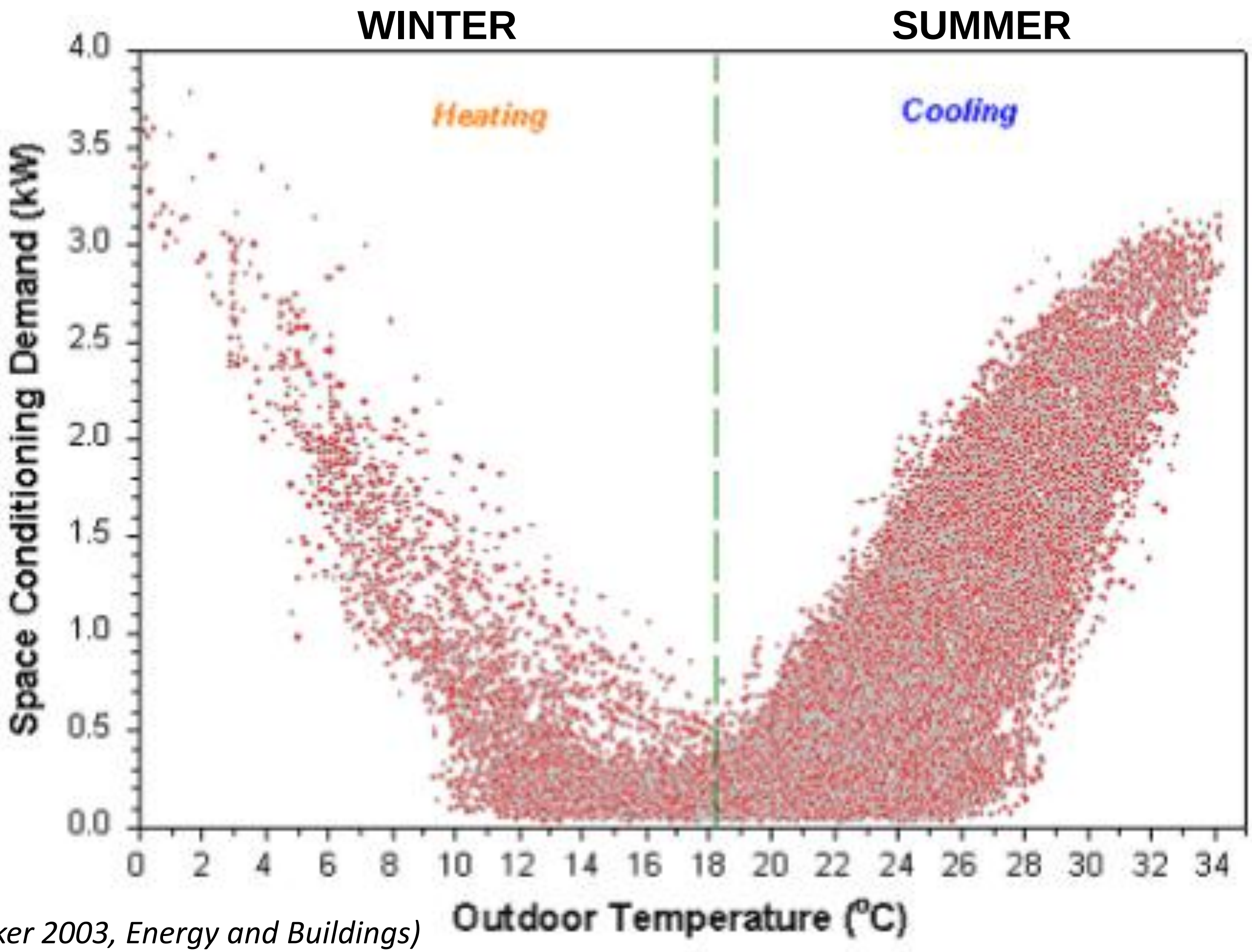


Building energy use for Cooling

What are the key factors influencing energy use for **cooling**?



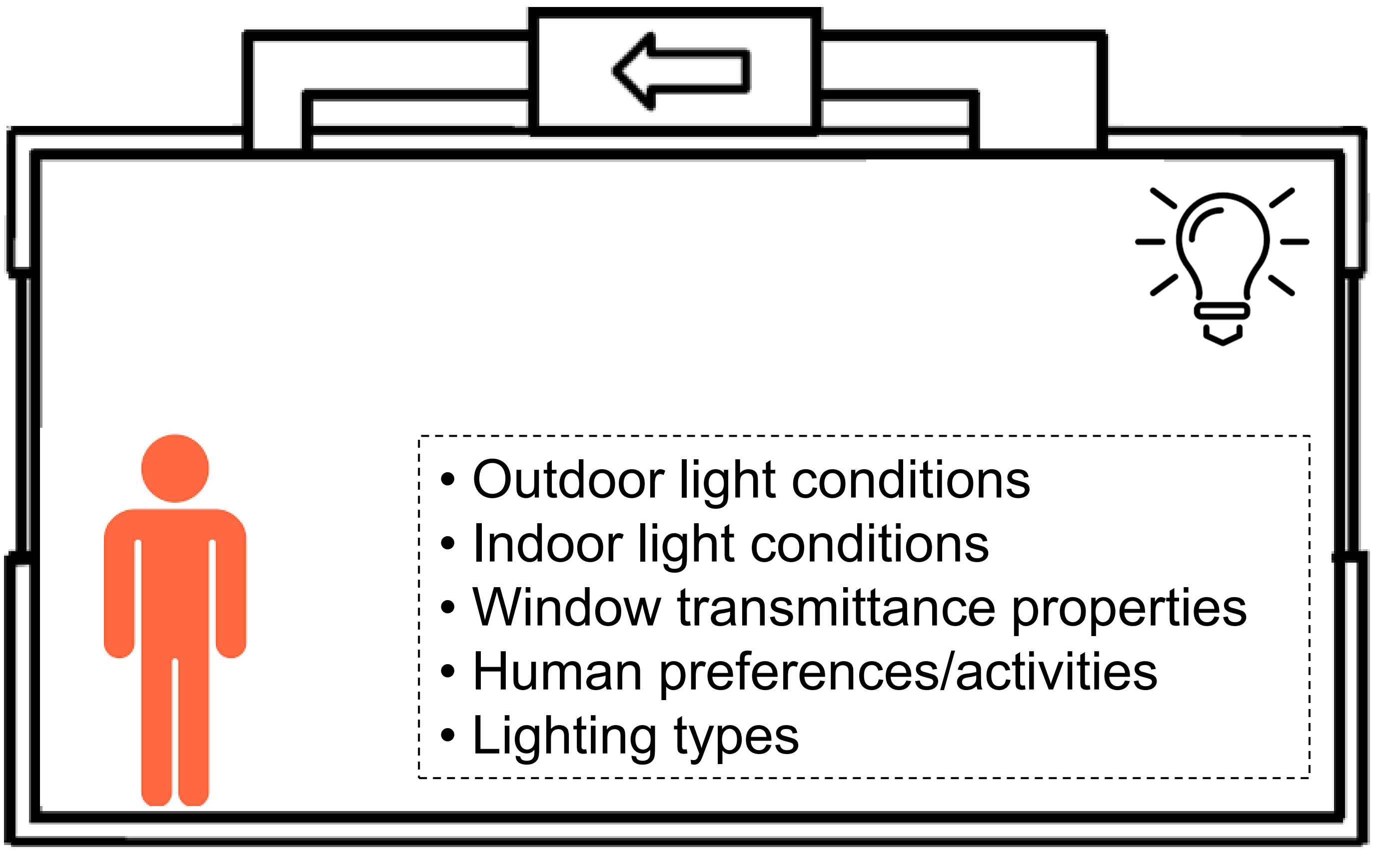
Understanding energy use in buildings



(Source: Parker 2003, Energy and Buildings)

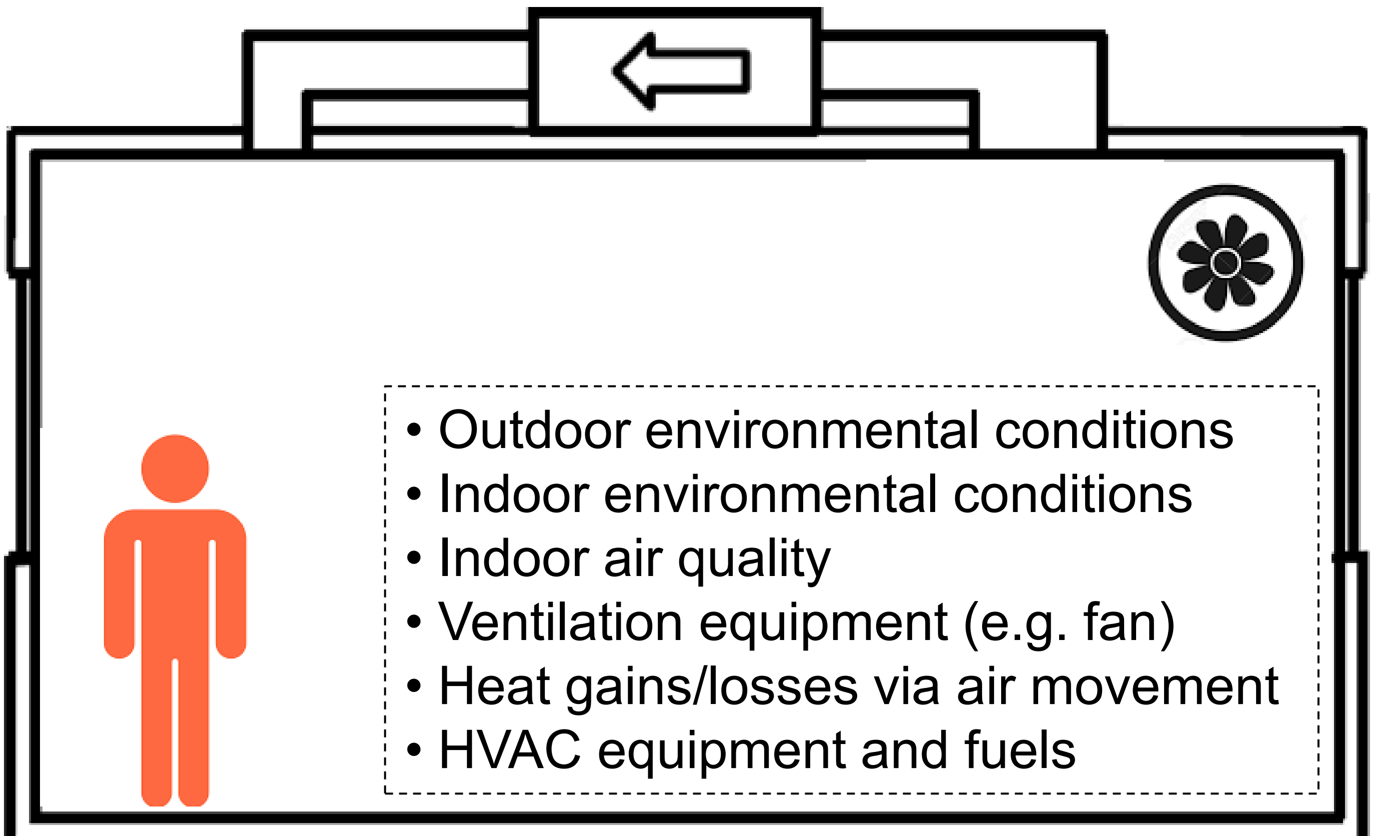
Building energy use for Lighting

What are the key factors influencing energy use for **lighting**?

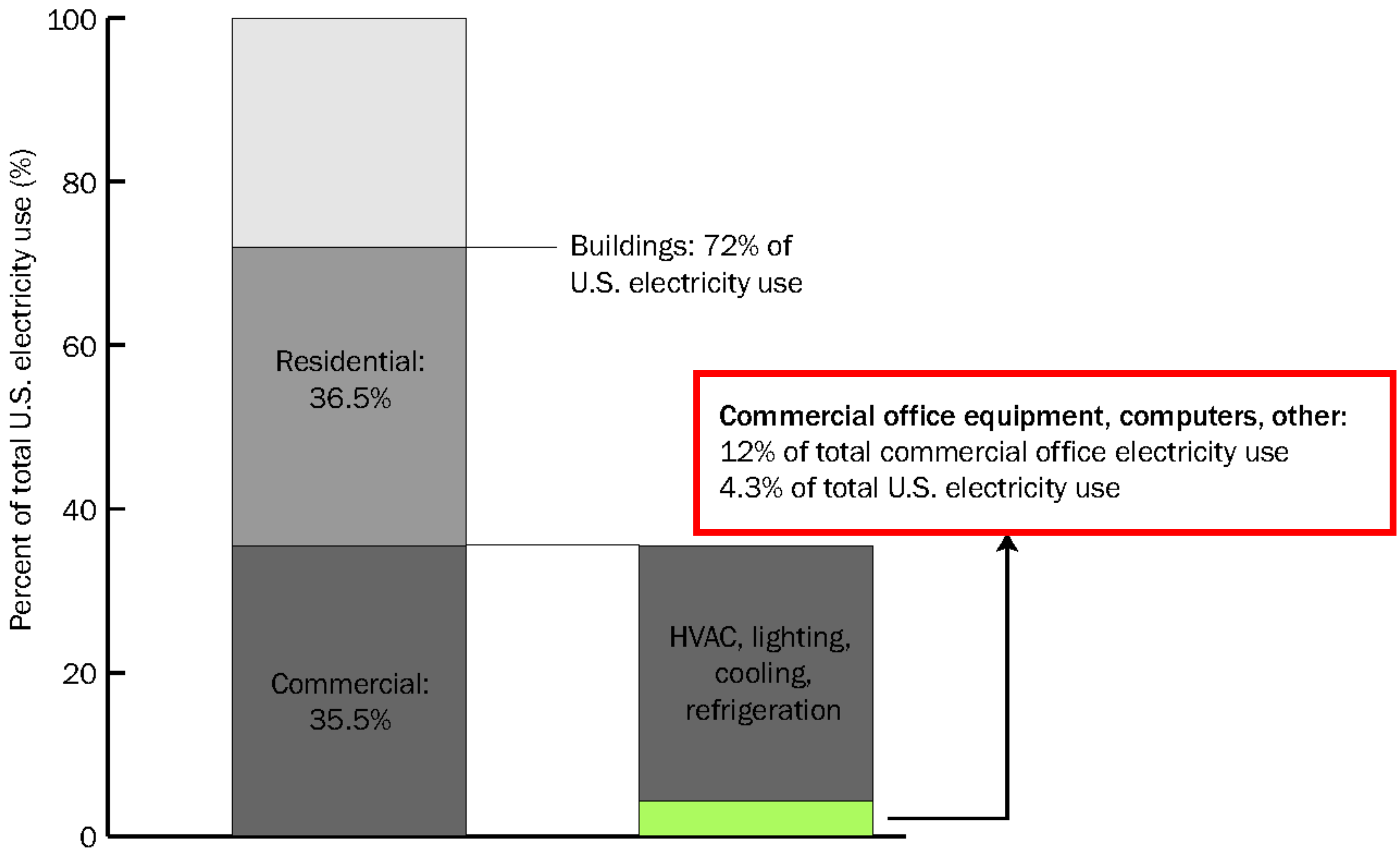


Building energy use for Ventilation

What are the key factors influencing energy use for **ventilation**?

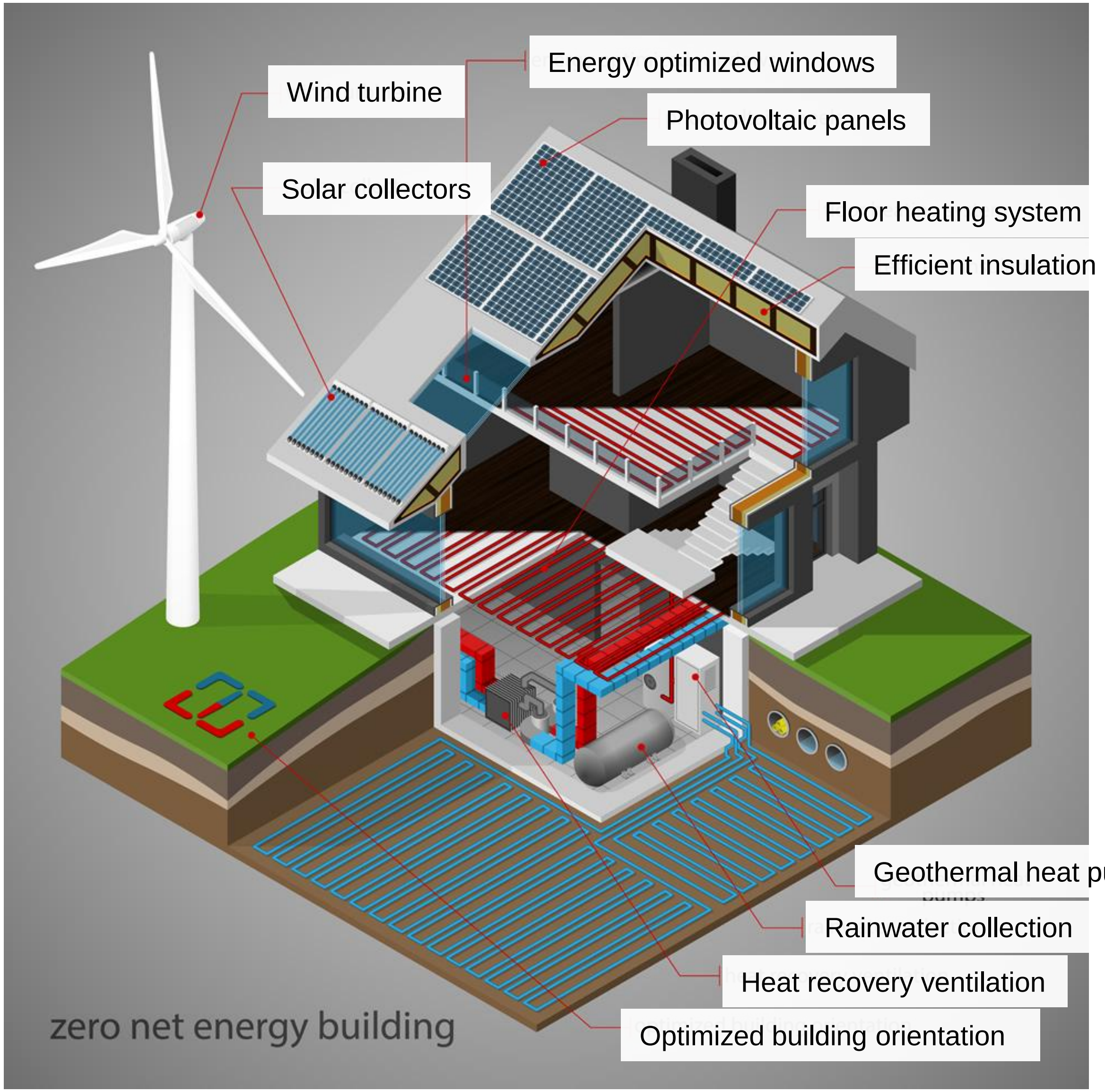


Building energy use: Plug loads



(Source: U.S. Energy Information Administration, Commercial Buildings Energy Consumption Survey)

What is a Net Zero Energy Building?



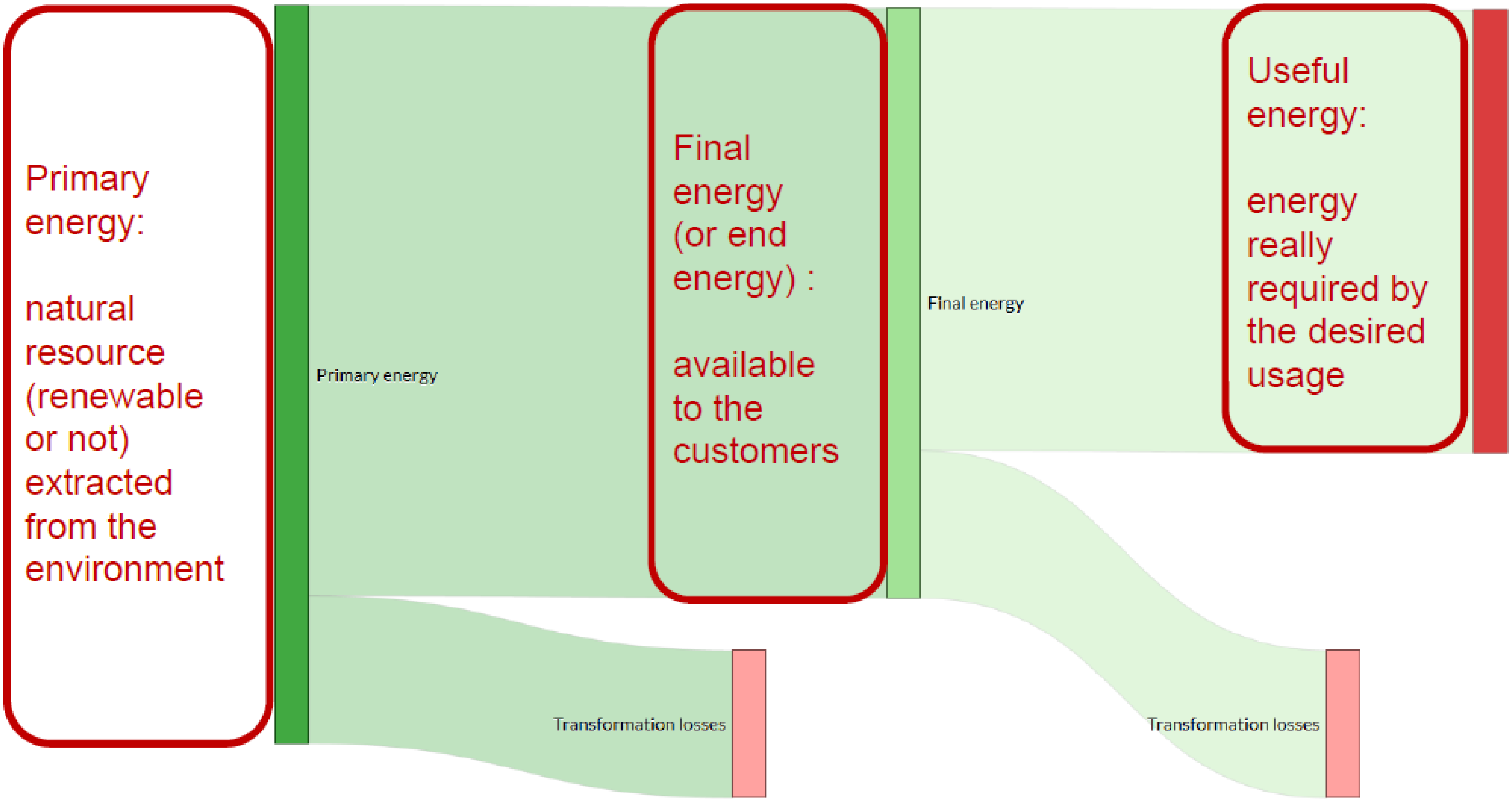
(Source: energyintime.eu)

Net Zero Energy Buildings: Definition

- **Net Zero Energy Building (ZEB) -** Energy use of **0 kWh/(m²a)** primary energy. Net ZEB is typically a grid connected building with very high energy performance
- **Nearly Net Zero Energy Building (ZEB) -** Technically reasonable achievable national energy use of **> 0 kWh/(m²a)** primary energy achieved with best practice energy efficiency measures and renewable energy technologies which may or may not be cost optimal
- **Primary (or Source) Energy** - Energy from *renewable* and *non- renewable* sources which *has not undergone* any conversion or transformation process
- **Delivered (or Site) Energy -** Energy, expressed per energy carrier, supplied to the technical building systems through *the system boundary*, to satisfy the uses taken into account (e.g. heating, cooling, ventilation, domestic hot water, lighting, appliances etc.) or to produce electricity.

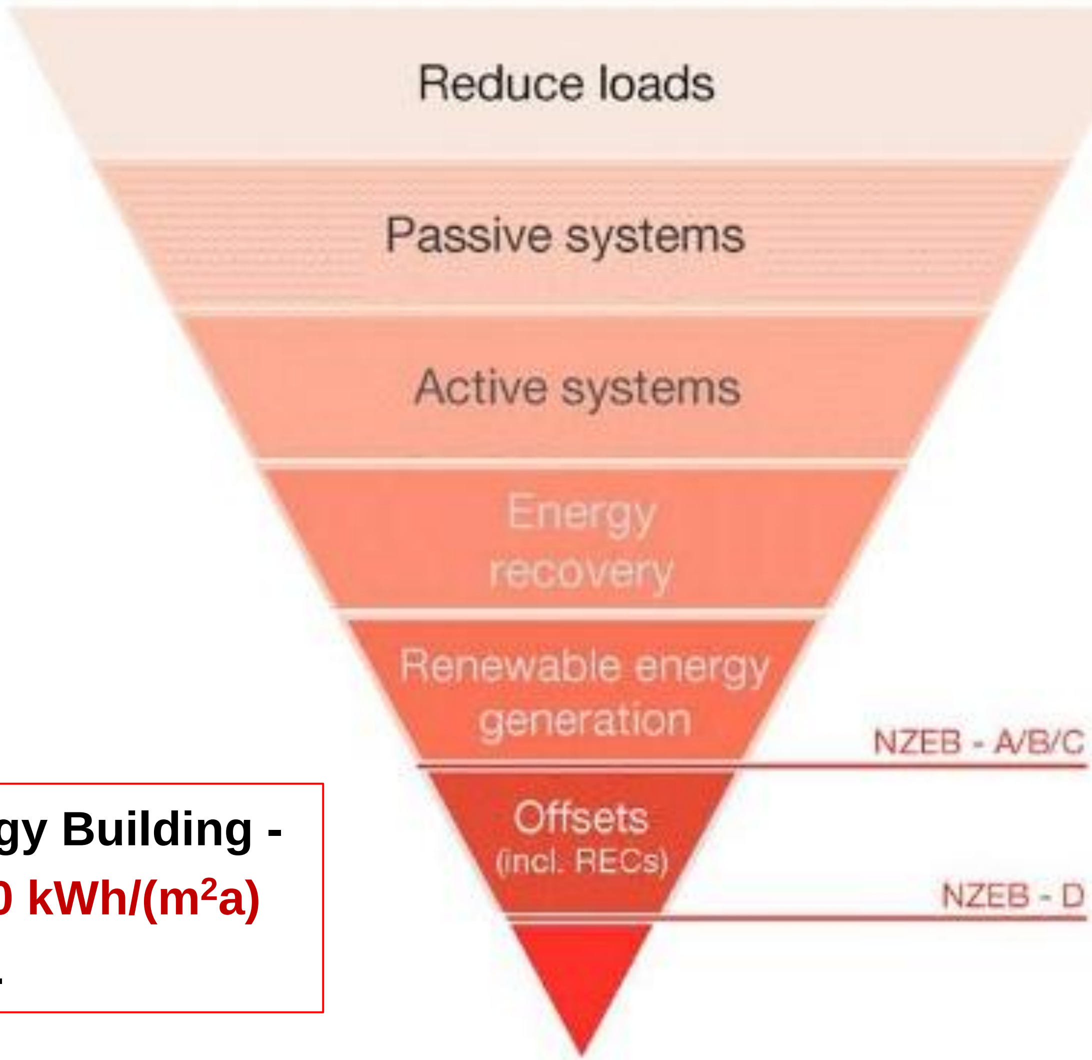
Kurnitski et al. (2012) *How to define nearly net zero energy buildings nZEB*

Primary / Delivered / Useful energy



- Coal or wind or waterfall or solar radiation or … (primary energy)
- Electricity (delivered energy)
- Light or heat or information & communication services or … (useful energy)

Net Zero Energy Buildings: Setting priorities



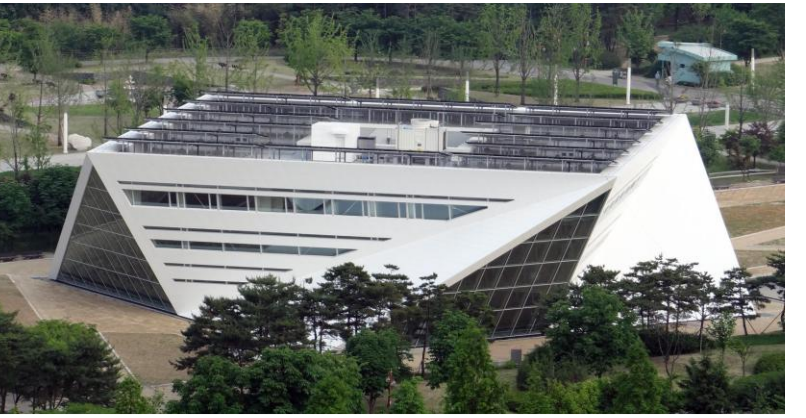
Net Zero Energy Building - Energy use of **0 kWh/(m²a)** primary energy.

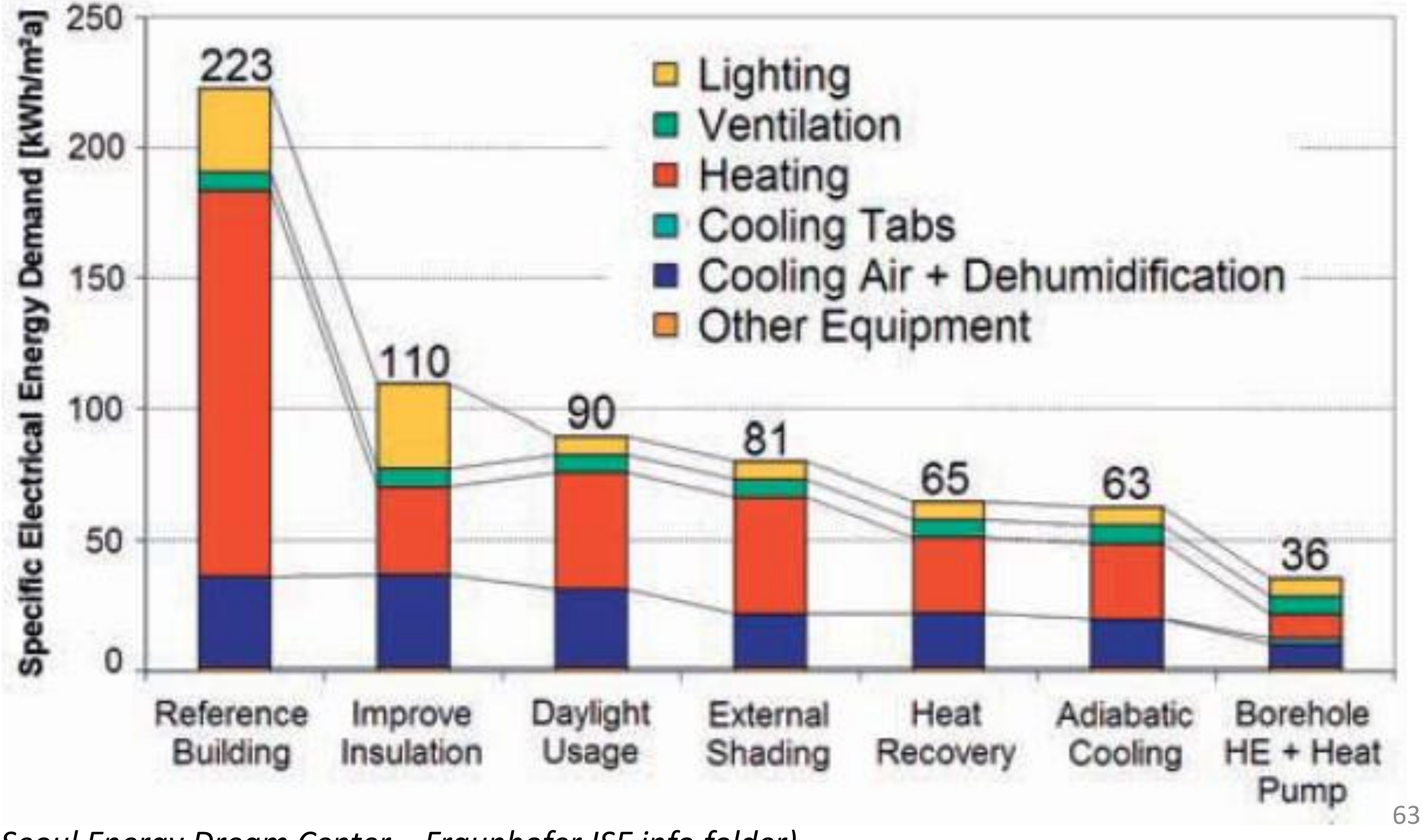
(Source: Two Degrees, Chap 6, McGregor, Roberts & Cousins)

What if we focus on renewable energy only?

Net Zero Energy Buildings

Energy Dream Center
Seoul (2012)





(Source: Seoul Energy Dream Center – Fraunhofer ISE info folder)

Consider: Sufficiency vs. Efficiency

Is technology sufficient to solve the issue?

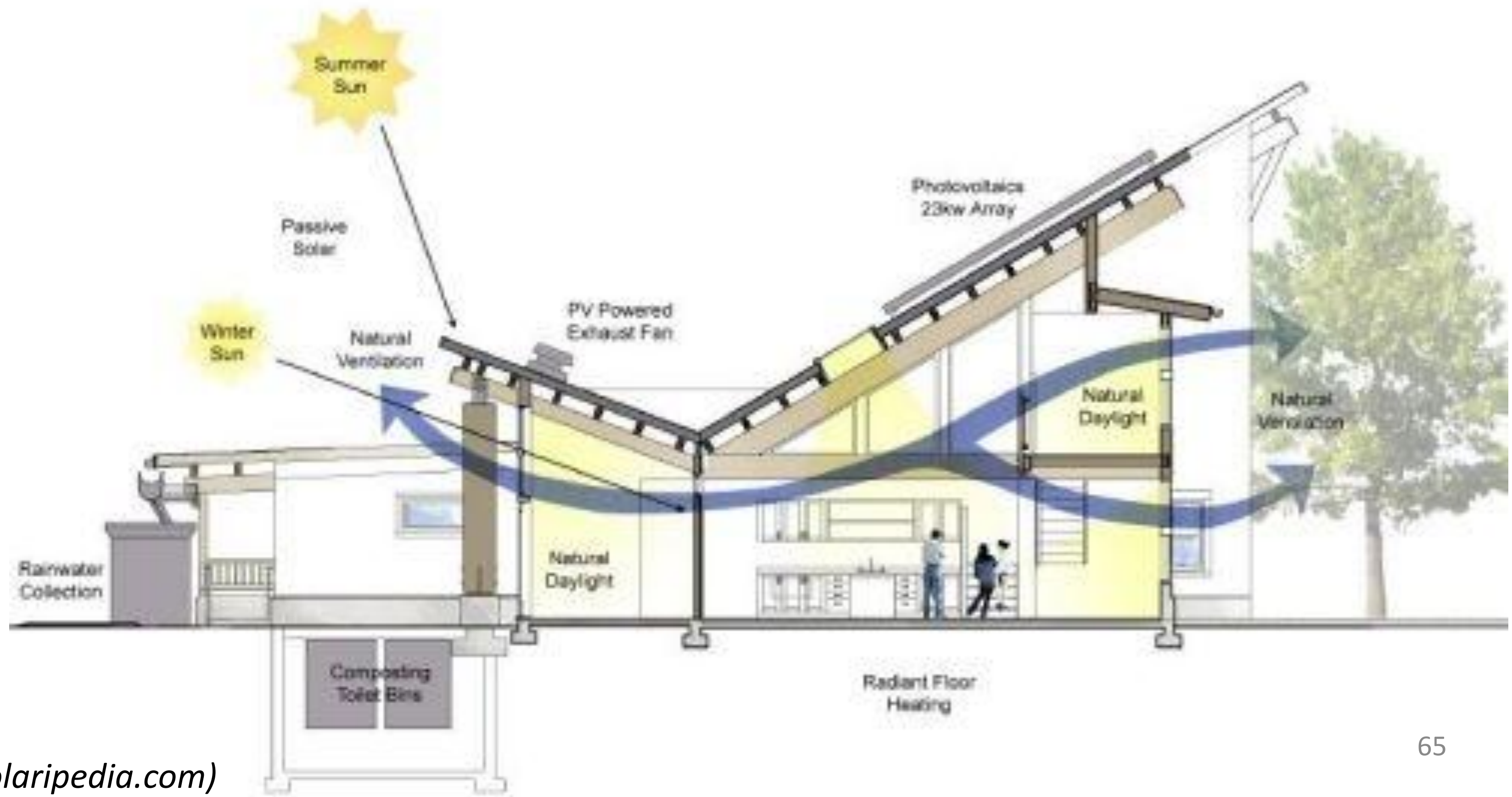
Sufficiency	**Efficiency**
Doing the right things	Doing things right
Tackles causes of climate change and the ecological crises	Tackles symptoms of climate change
Requires system change	Incremental improvement of individual technologies
Absolute reduction of the demand for all natural resources	At the best relative reduction of energy and materials consumption
The cost of climate neutrality is shared	Individuals bear the cost of efficiency improvement
Equity and fairness considerations	Competition and profits considerations

(Courtesy of Yamina Saheb)

Understanding building energy use

It all starts with understanding **building and material properties** and **heat and mass transfer processes**

- You will play with different parameters throughout the semester



(Source: solaripedia.com)

STRETCH !

What is comfort?

Human comfort in buildings

Human Comfort ≠ Thermal Comfort

Physical

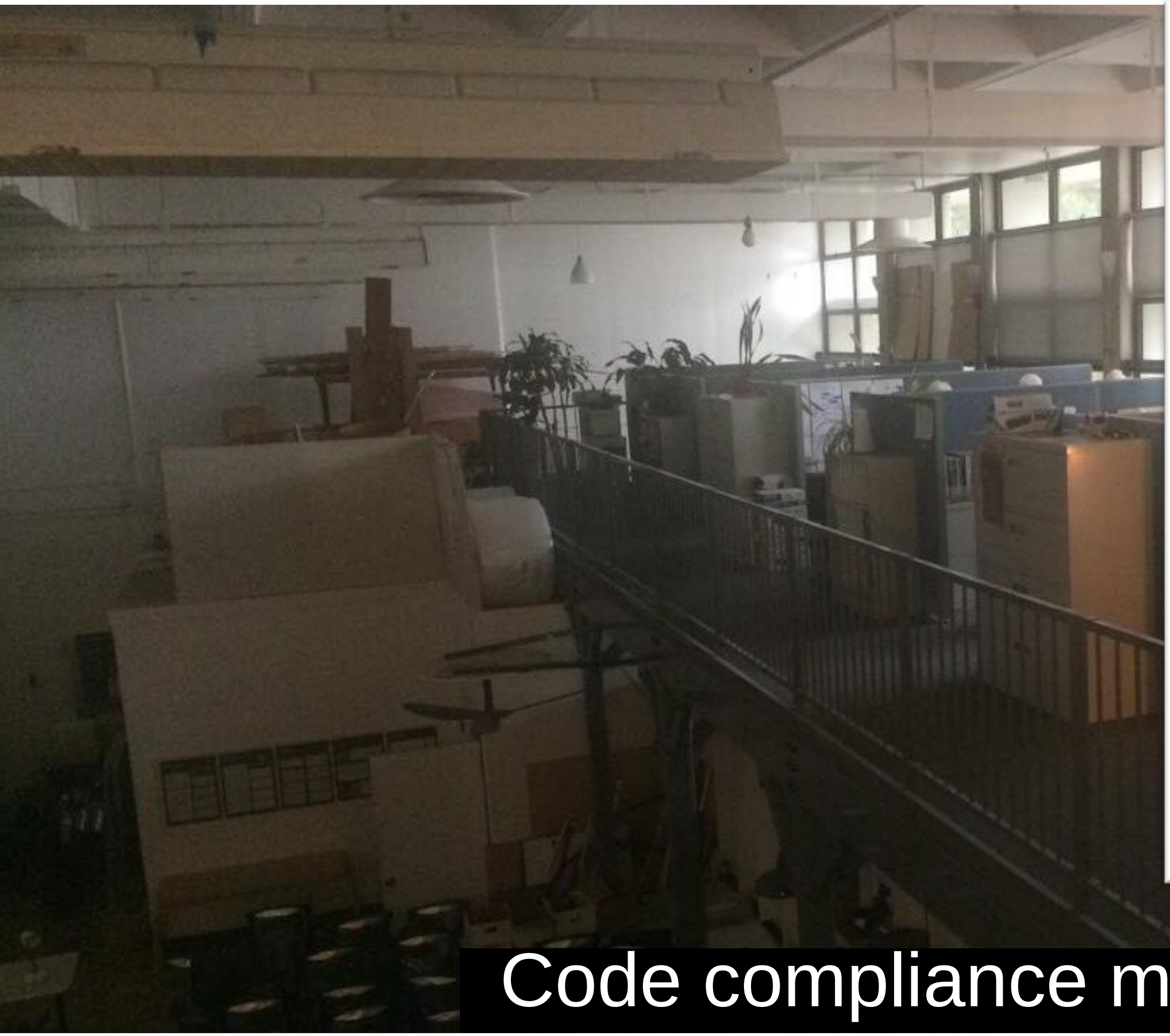
Age, Gender
Health and psychological status
Activity, Clothing
Access to food and drink
Safety, etc.

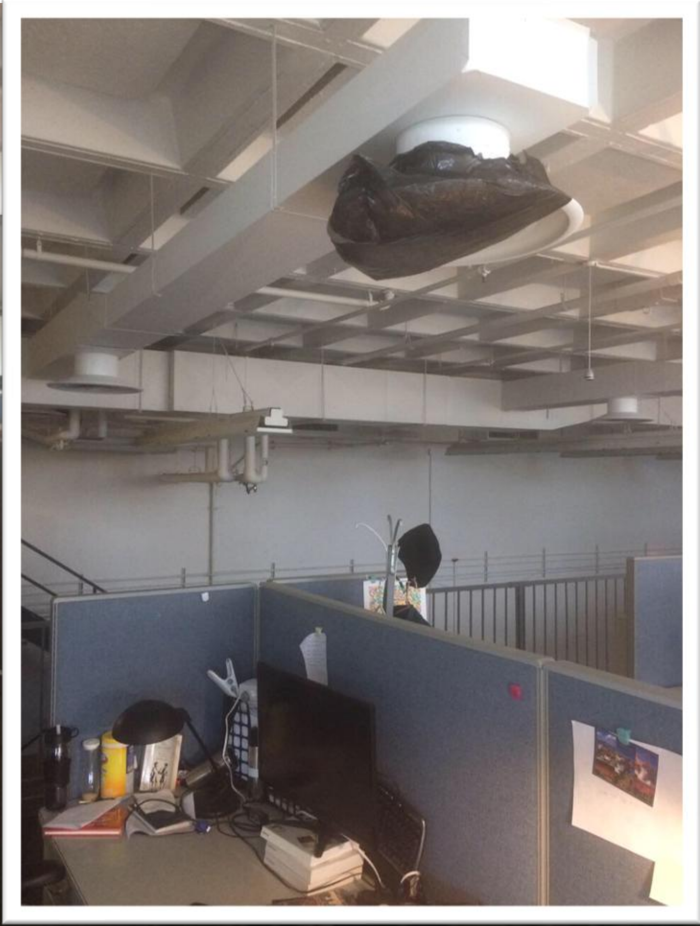
Personal

Comfort and the role of buildings

- Any building has primarily a protective role to occupants
- Occupied buildings should meet human comfort requirements
- Comfort depends on various aspects which should be considered as a whole
- What happens if comfort is not considered as a whole?

Comfort and buildings





Code compliance may not be sufficient

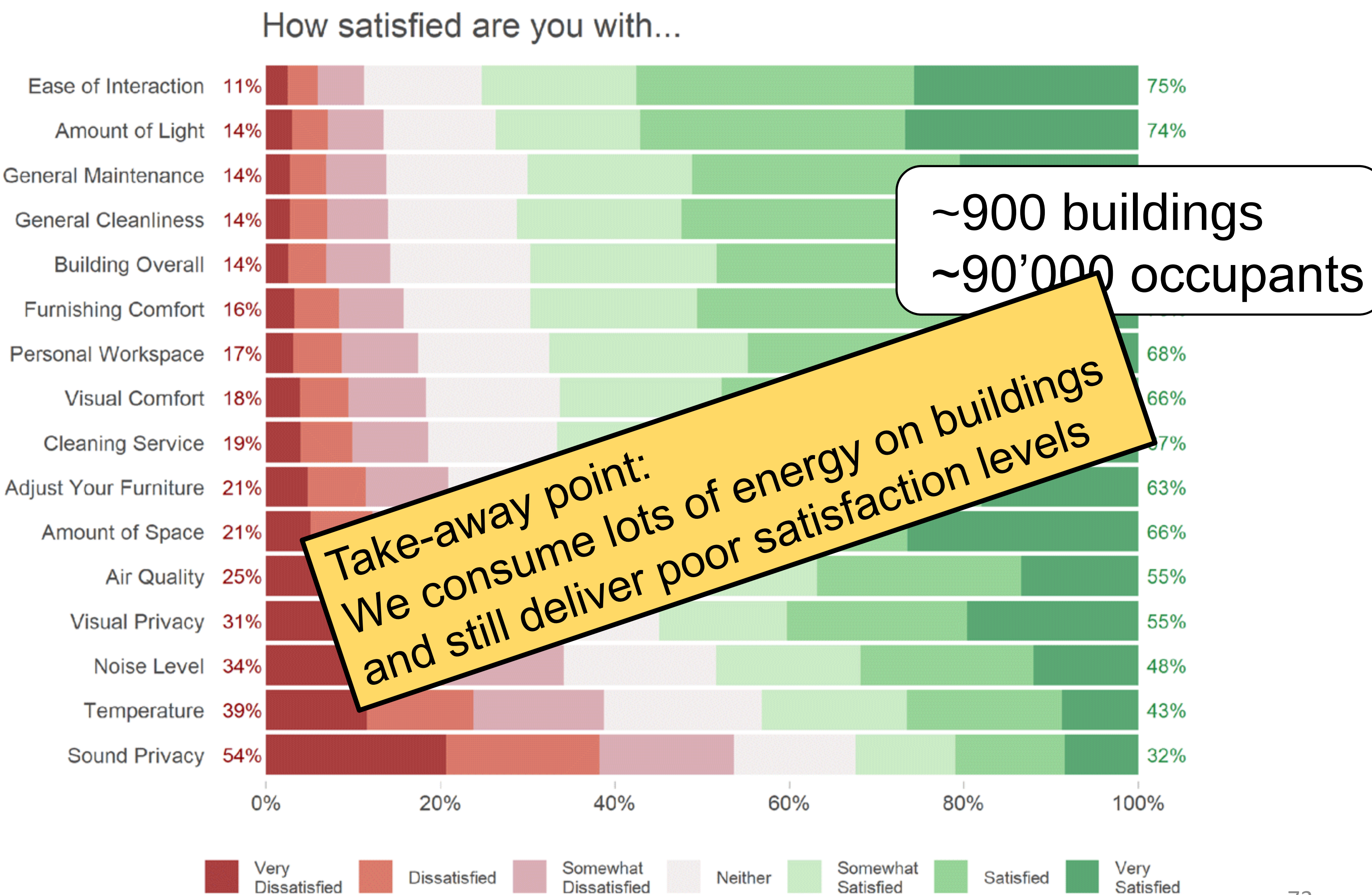
Comfort and buildings

Kresge Foundation HQ, Michigan, US

Comfort and buildings

Kresge Foundation HQ, Michigan, US

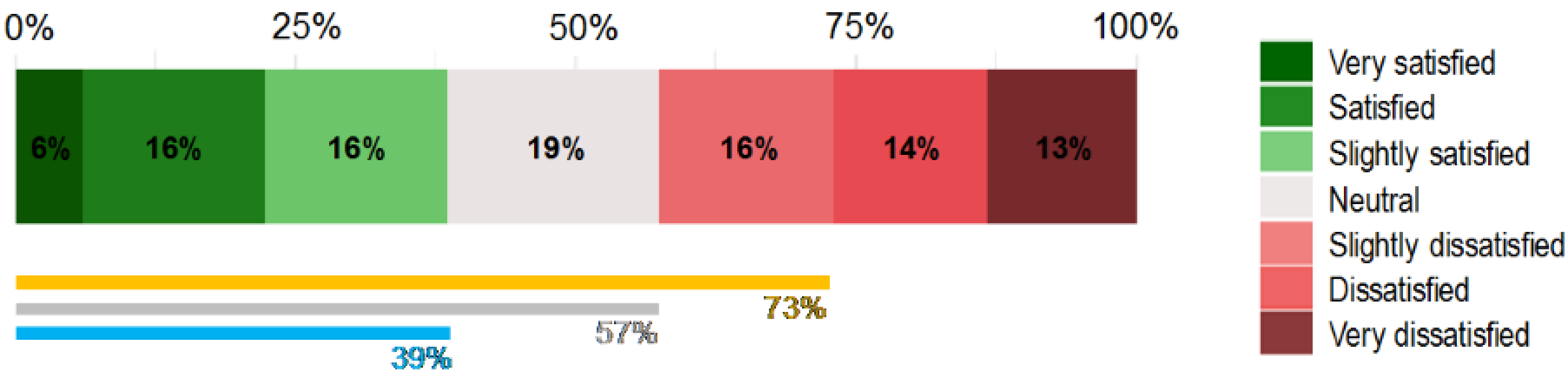
Occupant satisfaction in buildings



(Source: Graham et al 2021, Buildings and Cities 2:166-184)

Air temperature satisfaction in offices

351 buildings
52,980 occupants

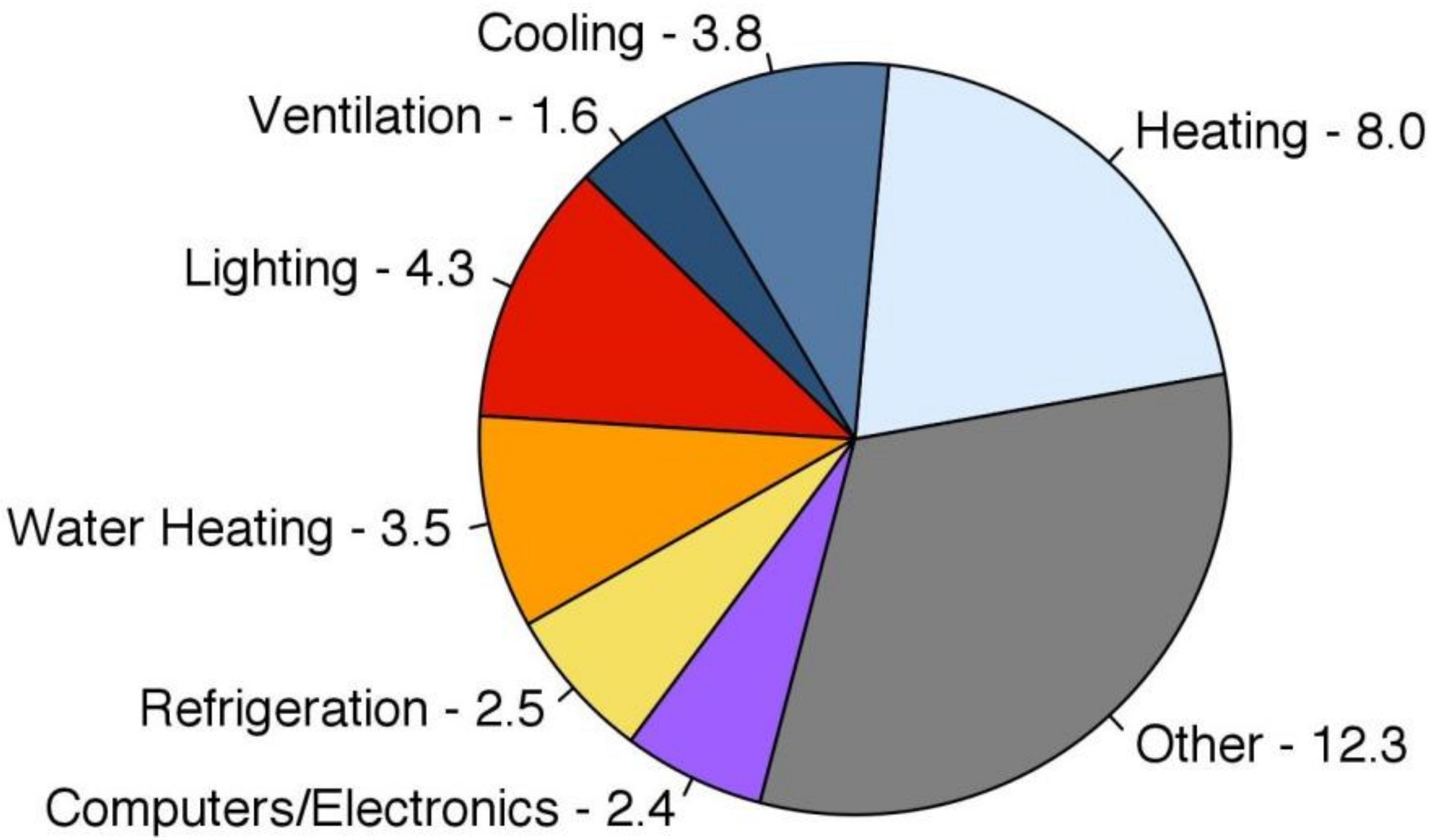


(Source: Karman et al 2018, Windsor Conference)

- ~40% of occupants are dissatisfied with air temperature
- ~40% of occupants are satisfied
- So we consume so much energy on buildings and still delivering such a poor performance -- what the heck can we do about it?

Influence of indoor environment: Energy

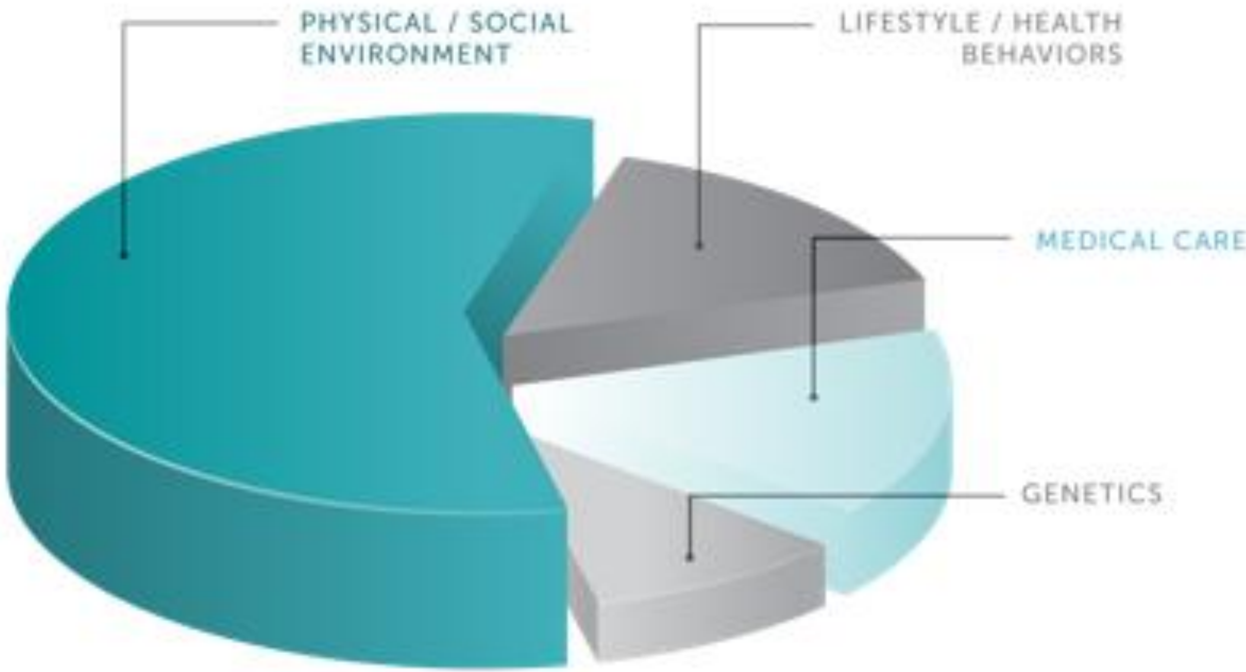
2014 Residential and commercial building primary energy use (%)



(Sources: 2013, 2014 EIA Annual Energy Outlook; 2010 Manufacturing Energy Consumption Survey)

Influence of indoor environment: Health

WHAT DETERMINES THE STATE OF HEALTH?



…BUT WHAT ABOUT THE ROLE OF BUILDINGS?

(Source: Center for Disease Control and Protection, FAQ 2014)

Role of indoor environmental quality (IEQ)?

Thermal comfort

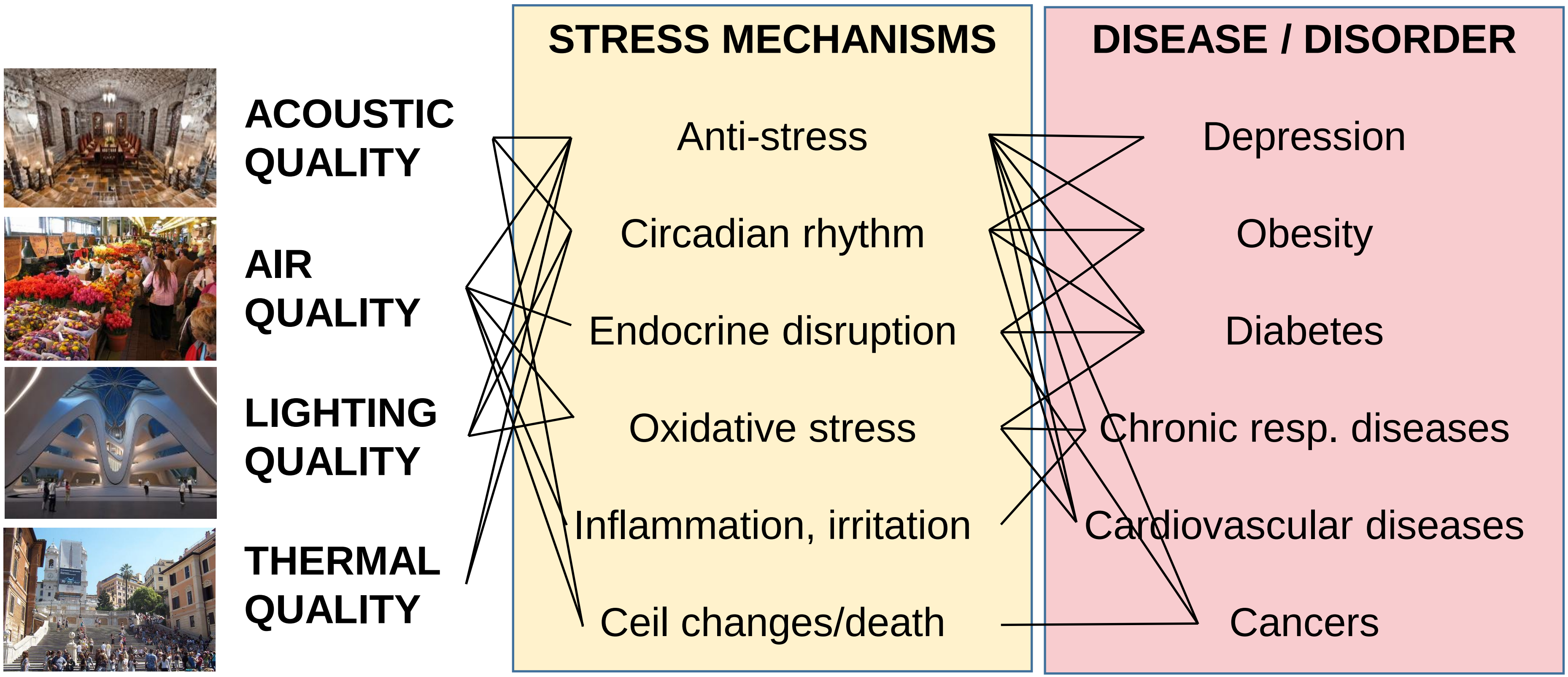
Lighting

Indoor air quality

Acoustics

(Source: Barbara Erwine)

IEQ, Stress mechanisms, and Human Health



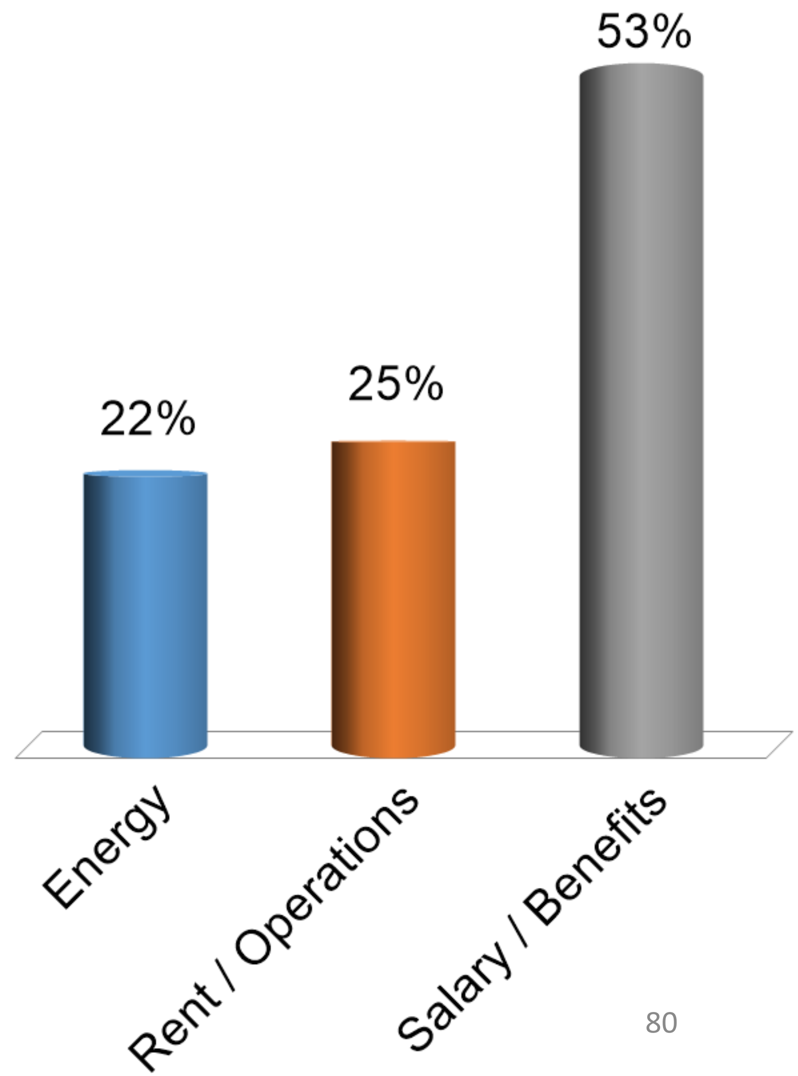
In class discussion…

Comfort and Health
vs.
Energy Use

1. What do we focus on primarily?
2. What matters more?
3. Are they often in conflict or not?
4. What costs more (assume you are a business owner)?

Commercial buildings: Which of the following operating costs is the highest?

A. Energy
B. Rent / Operations
C. Salary / Benefits



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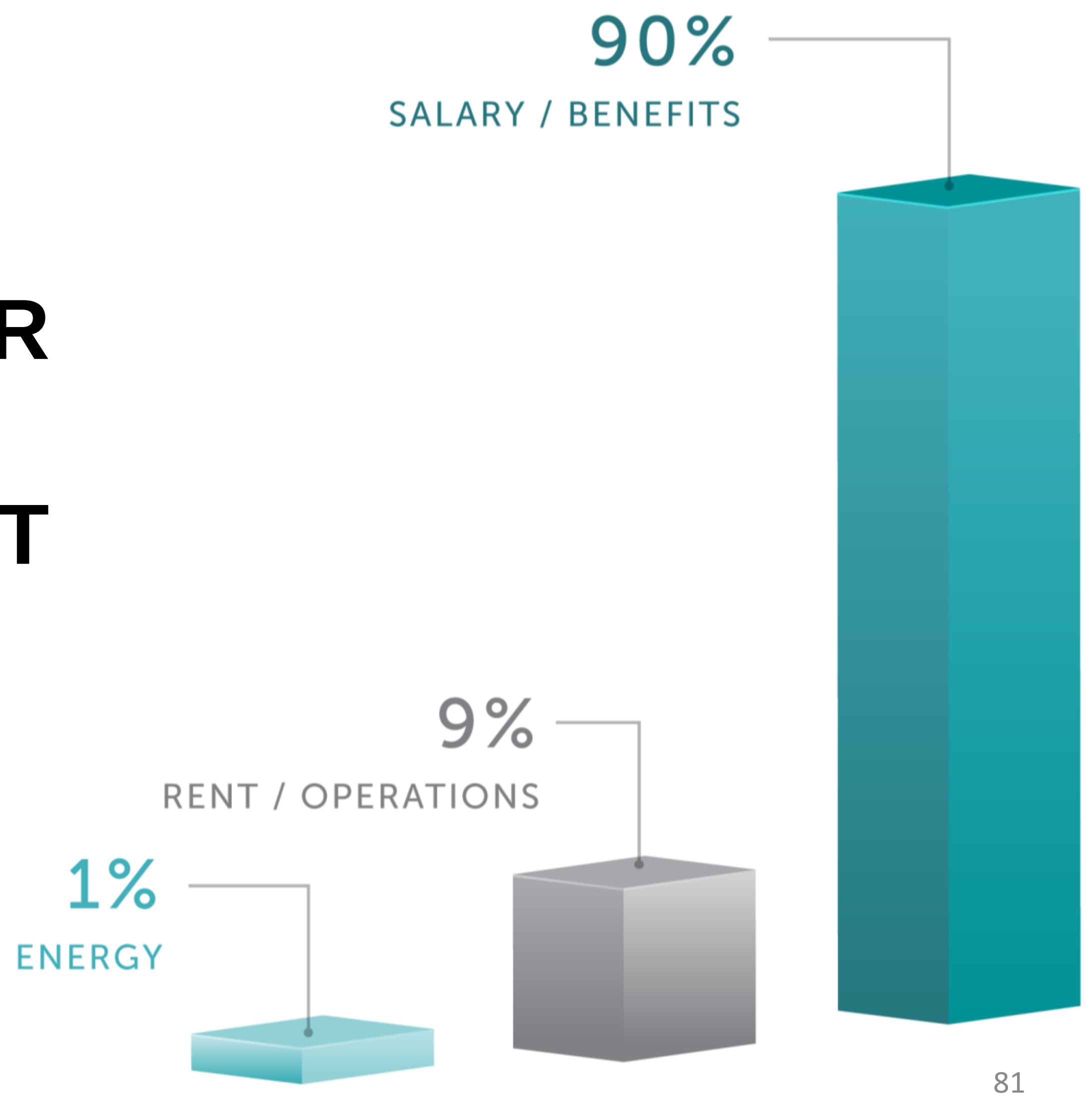
Operating costs disentangled

INVEST IN PEOPLE FOR RETURN ON INVESTMENT

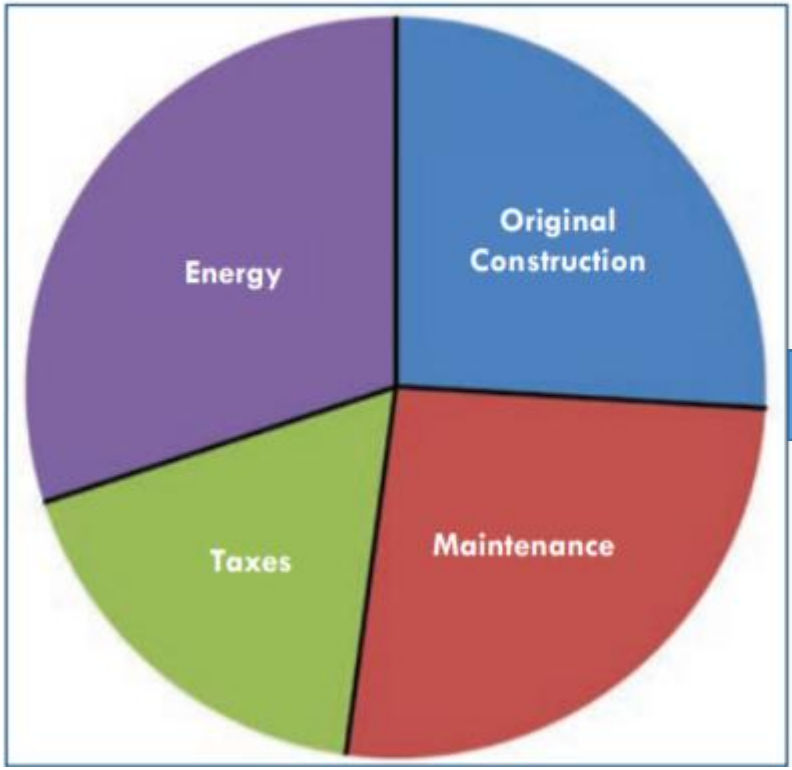


(Source: Knoll Workplace Research "What's Good for People, Moving from Wellness to Well Being")

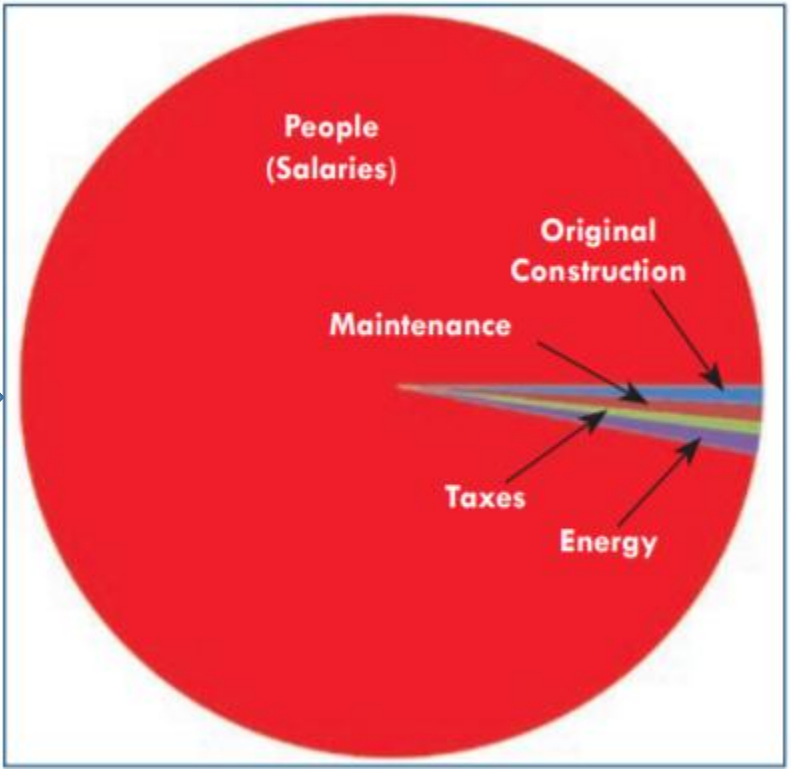
*(Source: Dan Int-Hout,
ASHRAE Journal, July 2013)*

Operating costs disentangled

Life-cycle building costs breakdown



Life-cycle building costs breakdown with people



- We can argue the numbers here, but not the orders of magnitude
- Reducing energy by 30% is negligible compared to the cost of people
- A net zero energy building (if possible) saves only 1% of salary costs!

Business case: Energy vs Health

Baseline Company Assumptions	
Number of Employees	40
Average Salary	CHF 75’000
Salaries as Percentage of Revenue	50%

	Baseline (CHF)	% of Revenue
Revenue	6’000’000	
Salaries	3’000’000	50
Rent	300’000	5
Utilities (energy)	30’000	0.5
Other expenses	1’000’000	16.7
Net income before taxes	1’670’000	27.8
Taxes (30%)	501’000	8.4
Net income after taxes	**1’169’000**	19.5

Business case: Energy vs Health

What if 1: Company invests in technology that will cause substantial energy savings of 20% (20% savings in utility bill)

(CHF)	**Baseline**	**Intervention**	**Baseline + savings**
Revenue	6’000’000		6’000’000
Salaries	3’000’000		3’000’000
Rent	300’000		300’000
Utilities (energy)	30’000	-20% (6’000 CHF)	24’000
Other expenses	1’000’000		1’000’000
Net income before taxes	1’670’000		1’676’000
Taxes (30%)	501’000		502’800
Net income after taxes	1’169’000		1’173’200
Change			**0.36%**

Conclusion: Change is <1%. High effort for small $$ savings

Business case: Energy vs Health

What if 2: Company invests in technology (increased ventilation rates) that will cause health improvement by having 2 fewer sick days per year (1% savings in salary) and productivity boost by 2%

(CHF)	Baseline	Intervention	Baseline + savings
Revenue	6’000’000	+2% (120’000 CHF)	6’120’000
Salaries	3’000’000	-1% (30’000 CHF)	2’970’000
Rent	300’000		300’000
Utilities (energy)	30’000	+1’600 CHF	31’600
Other expenses	1’000’000		1’000’000
Net income before taxes	1’670’000		1’818’400
Taxes (30%)	501’000		545’520
Net income after taxes	1’169’000		1’272’880
Change			**8.9%**

Conclusion: Substantial increase in revenue with simple strategy

IEQ impact on businesses & people: Huge!

Organizational outcomes

- Productivity loss
- Absenteeism
- Presenteeism (working while sick)
- Staff turnover/retention
- Revenue
- Medical costs
- Medical complaints
- Physical complaints
- Task efficiency & deadlines met, etc.

Comfort and health

- Headaches
- Eye strain/damage
- Dry throat and runny nose
- Skin irritation
- Infections
- Fatigue
- Seasonal Affective Disorder
- Asthma & breathing disorders
- Stress & depression
- Other serious disorders, including cardio-vascular, etc.

Value of comfort and well-being to real estate

LIVING BUILDING CHALLENGE

Paradigm shift from system-centric environmental design to human-centric approach

New principles reflected in dozen of languages

Where are we now?

High market penetration with exponential increase

Currently - Thousands of ongoing projects from 200 certification programs around the world

After-class thinking…

- *Do a detailed bullet point list of the tasks that you would do to assess the energy and indoor environmental quality of EPFL building*
- *Describe a strategy that may simultaneously increase energy efficiency and indoor environmental quality for that building*
- *Describe which steps would be needed to assess if the strategy is effective or not*

QUIZ

on climate change

Who will be today's climate change champion? 🏆

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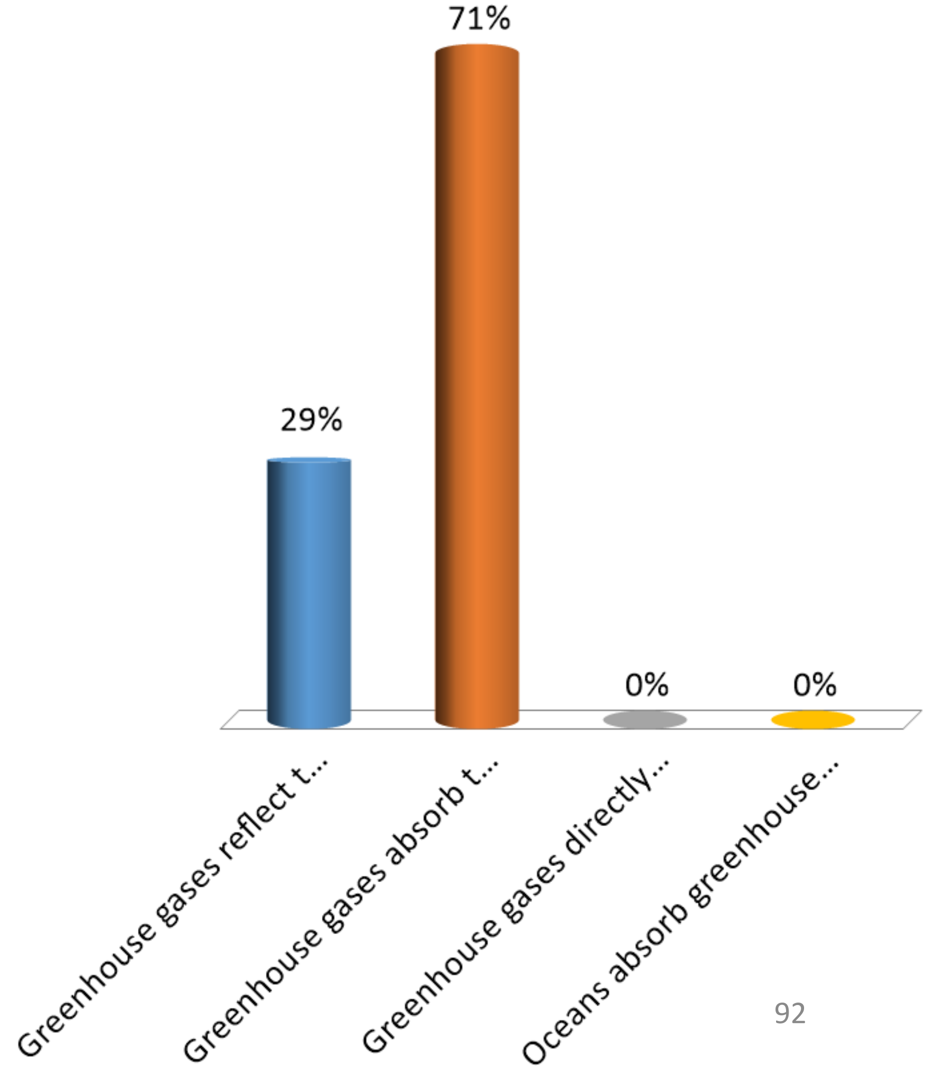
How does the greenhouse effect work?

A. Greenhouse gases reflect the Sun's energy, causing it to warm the Earth.

B. Greenhouse gases absorb the sun's energy, slowing or preventing heat from escaping into space.

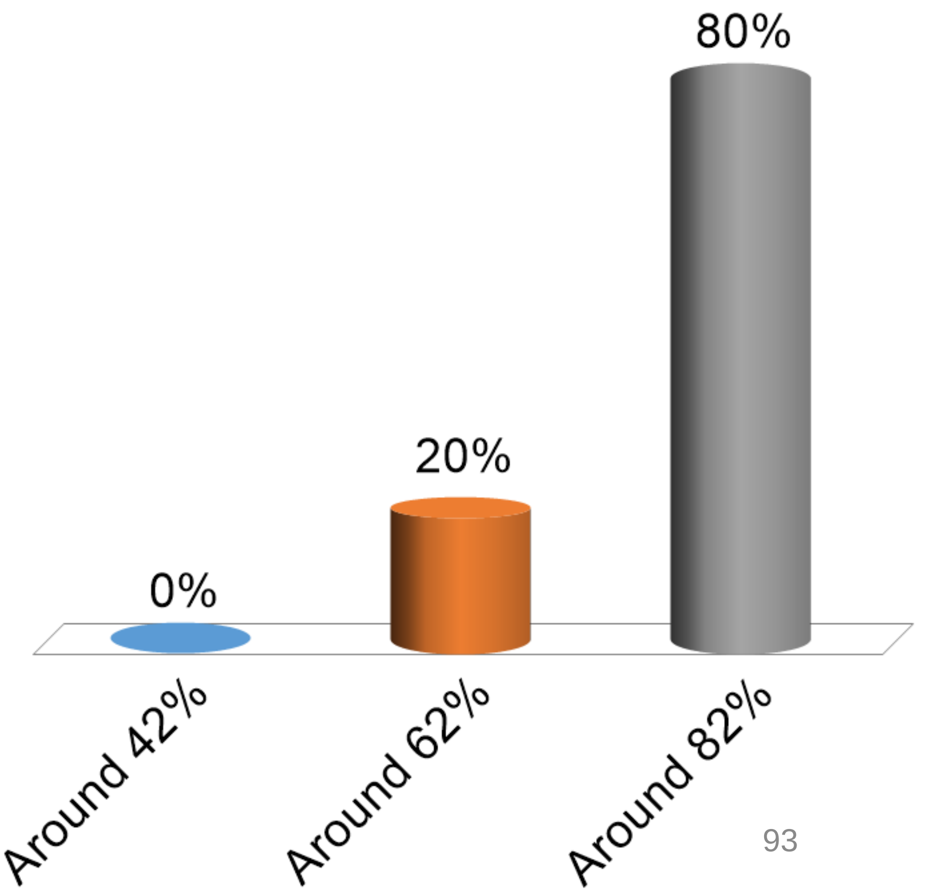
C. Greenhouse gases directly warm oceans and cause dramatic weather.

D. Oceans absorb greenhouse gases, which cause the Earth's temperature to rise.



Of all energy used in the world, how much comes from natural gas, coal and oil?

A. Around 42%
B. Around 62%
C. Around 82%



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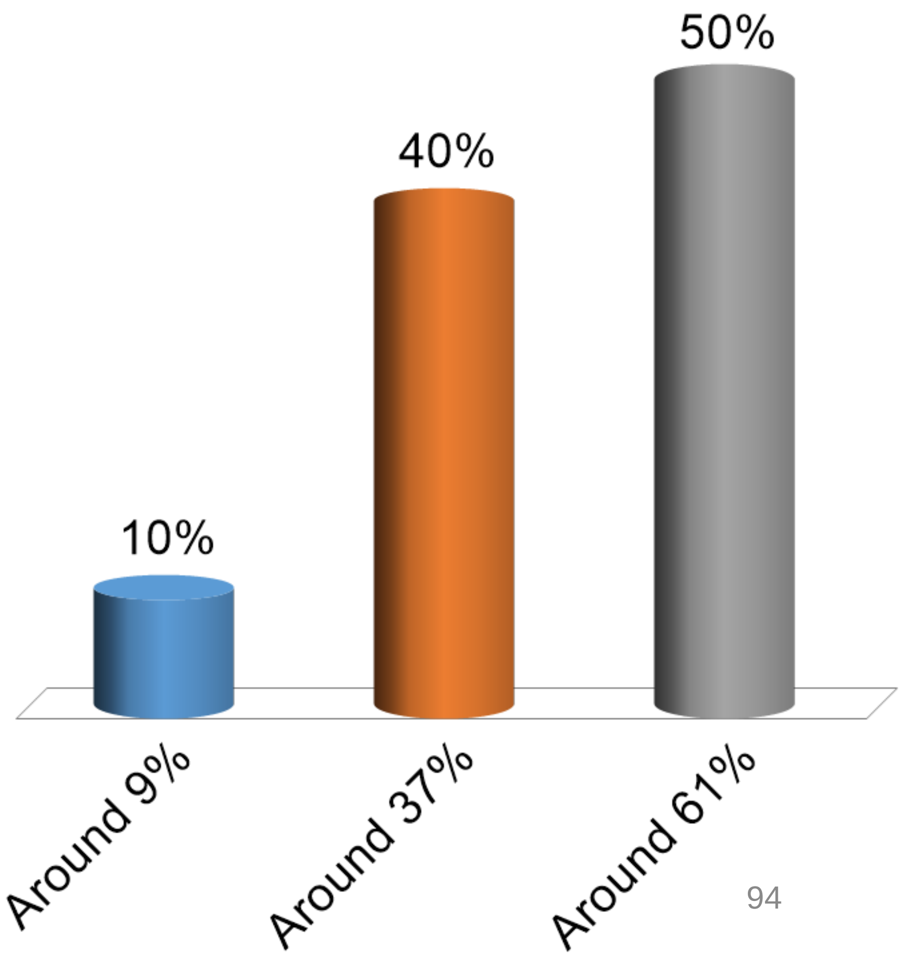
In 1990, 58% of the world's population lived in low-income countries. What is the share today?

A. **Around 9%**
B. Around 37%
C. Around 61%



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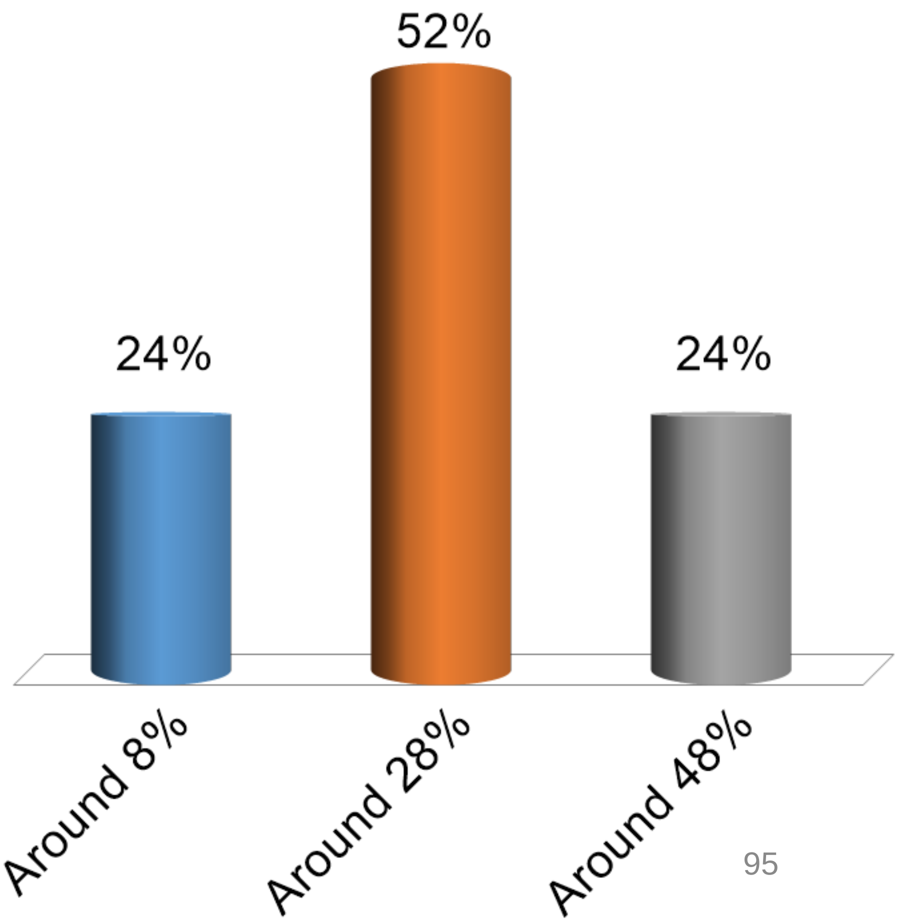
What share of the world's population lives in megacities (cities with at least 10 million people)?

A. **Around 8%**
B. Around 28%
C. Around 48%



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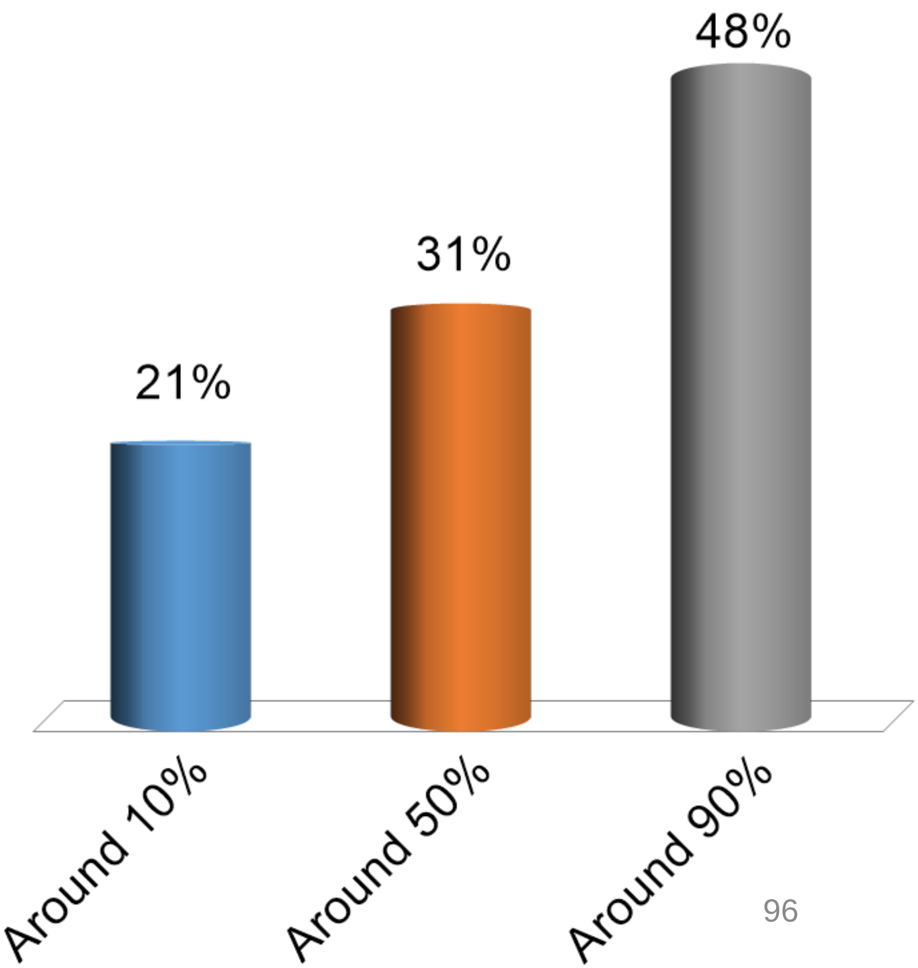
How much of the excess heat from global warming is captured in the oceans?

A. Around 10%
B. Around 50%
C. Around 90%



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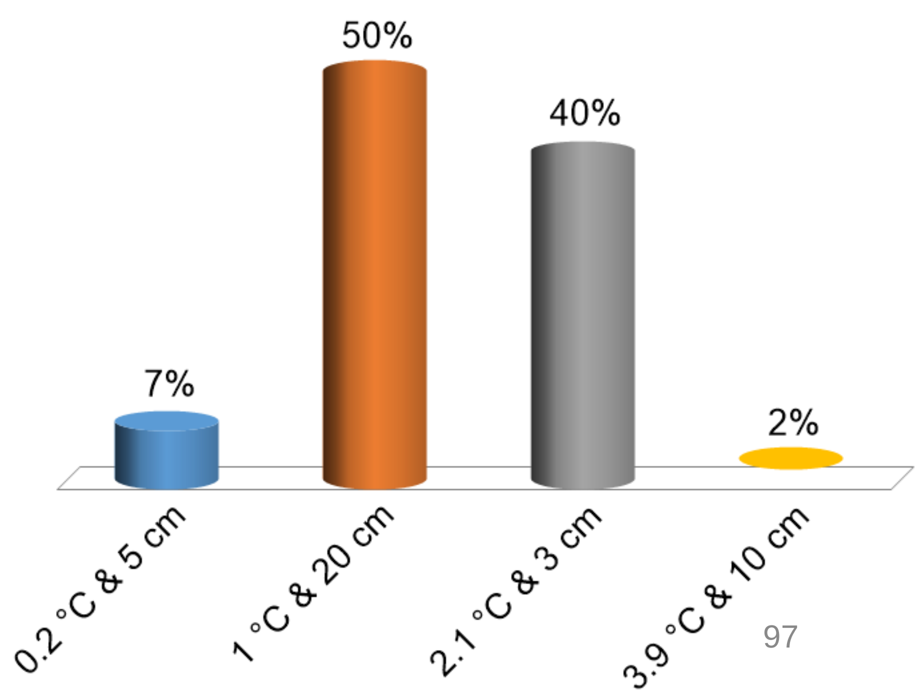
By how many degrees Celsius has the planet's average surface temperature increase & how many cm has global sea level rose since the late 19th century?

A. 0.2 °C & 5 cm

B. 1 °C & 20 cm

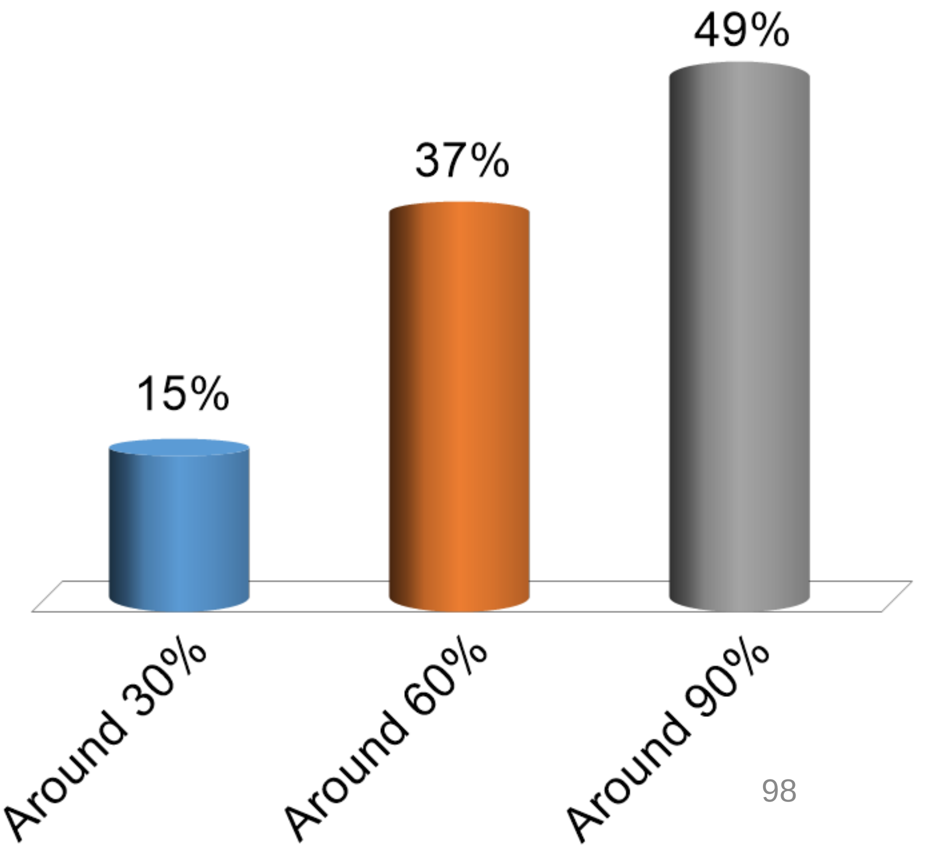
C. 2.1 °C & 3 cm

D. 3.9 °C & 10 cm



Biologists have evaluated the status of more than 140,000 species of plants and animals. How many are endangered or threatened?

A. **Around 30%**
B. Around 60%
C. Around 90%



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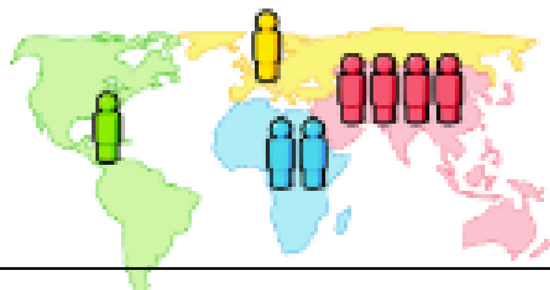
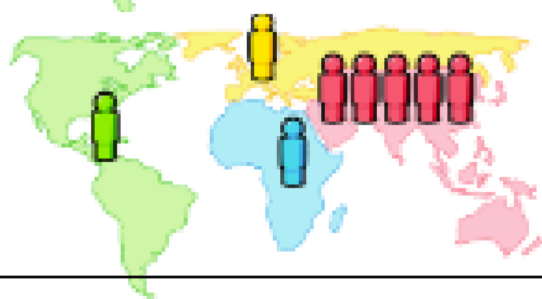
There are roughly eight billion people in the world today. Which map best shows where they live? (Each figure represents 1 billion people.)

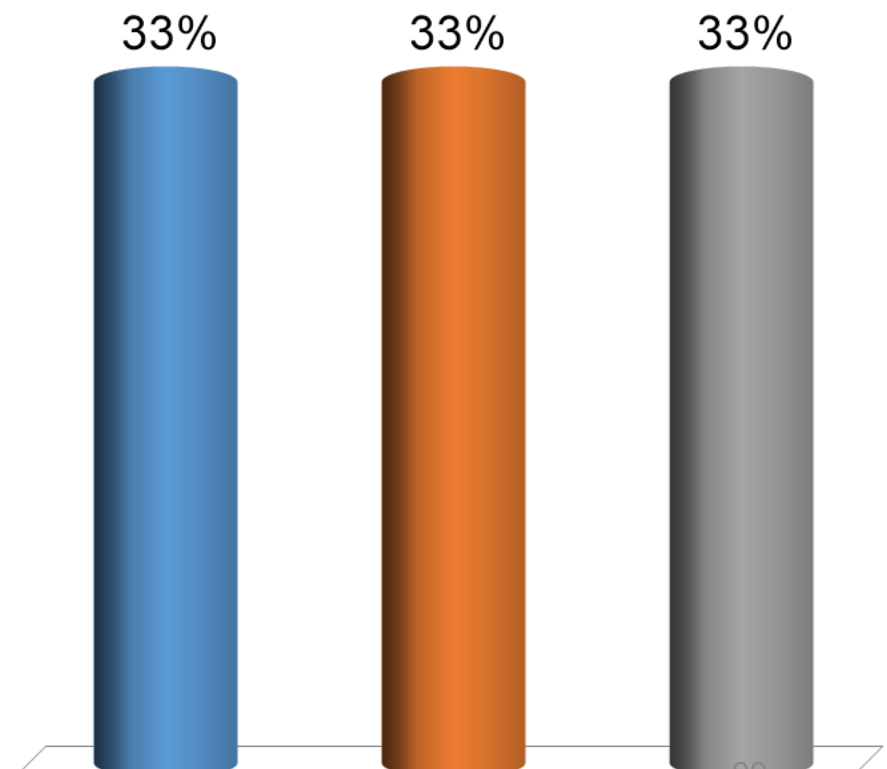
A.



B.

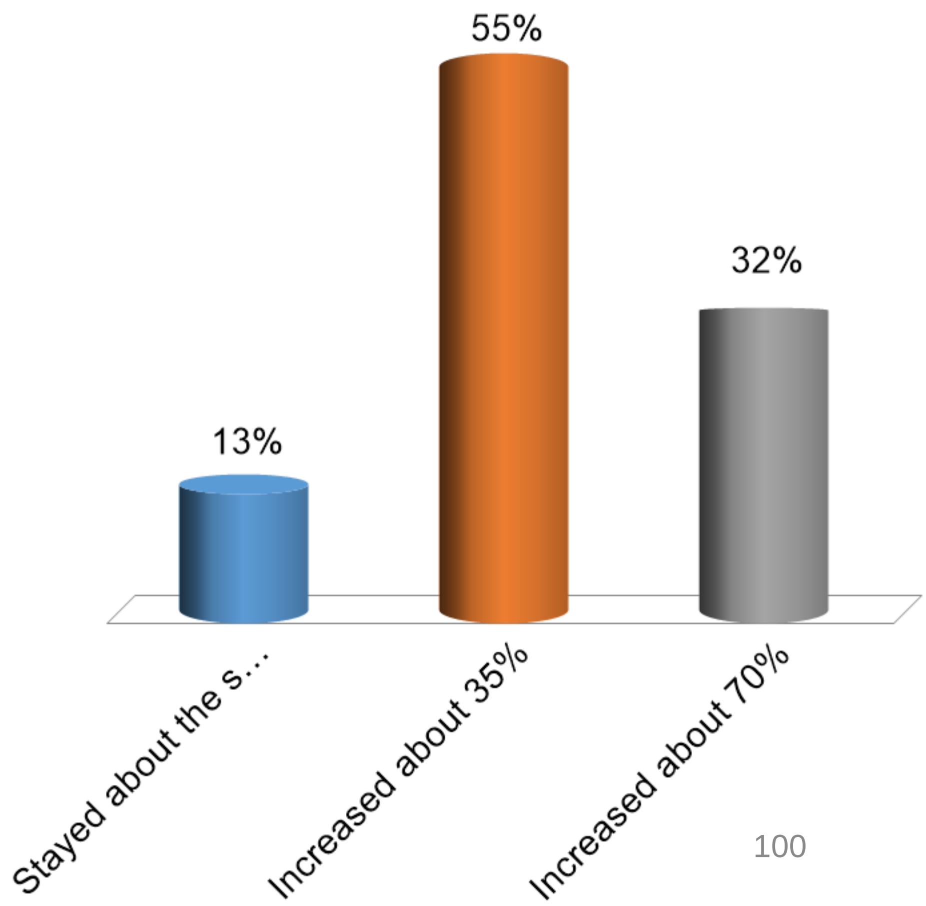


C.



What happened to the total amount of raw materials used across the world annually since 2000?

A. Stayed about the same
B. Increased about 35%
C. Increased about 70%



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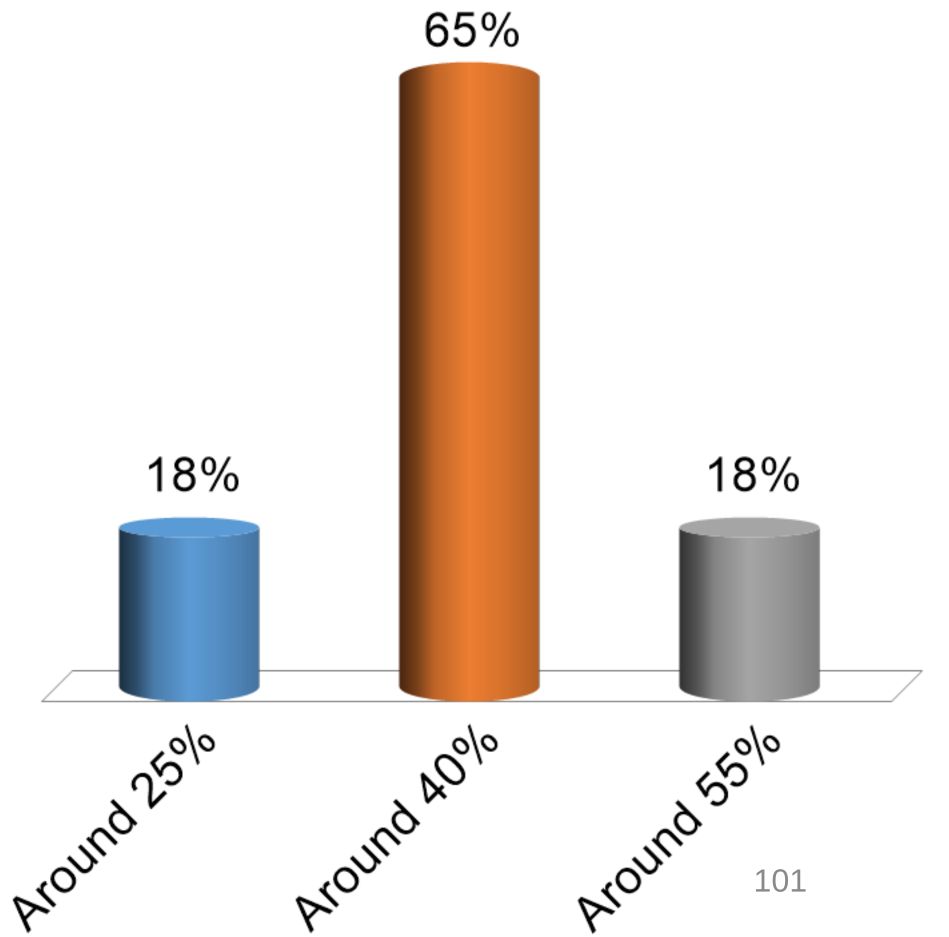
Buildings account for what percentage of GHG emissions?

A. Around 25%
B. Around 40%
C. Around 55%



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Summary of key concepts learnt today

- Human activity is the cause of increased GHG concentrations, and therefore climate crisis.
- Energy use in buildings has the strongest (but not sole) influence on our climate.
- Reducing building carbon footprint requires setting priorities and hierarchy of actions.
- Buildings shape human health, comfort and well-being in substantial ways, many which have been neglected by people who commission, design, manage and use buildings.
- Investment in healthy buildings presents a better business model relative to investment in energy saving measures. However, both are extremely important!
- There is a strong nexus between building energy use and indoor environmental quality. We will explore this in the first half of the semester.

Next time lecture on thermal comfort & energy

Thermal comfort & energy

- Thermal comfort (overview)
- Overheating of buildings
- Thermal comfort & energy efficiency
- Quiz

Note:
For those who want to get a quick brush-up on the fundamental concepts of energy and power units, heat transfer in buildings and psychrometric, please check out extra slides available on Moodle (within Week 01)