Notre Dame University (NDU)
Shouf Campus
Ramez G.Chagoury Faculty of Architecture, Art, and Design

Future Technologies for Achieving Net-Zero Carbon Buildings

Lebanon | April 09, 2025

Prof. Dr. Shady Attia
Sustainable Building Design Lab, UEE,
Applied Sciences, University of Liège, Belgium
shady.attia@uliege.be

/in/shady-attia-14352a7
/www.shadyattia.org

LIÈGE université
SBD Lab

Acknowledgment

Al Shouf 09/04/2025

CLAUDINE CHAMOUN

Senior Lecturer
FAAD Coordinator, Shouf Campus.
Ramez G.Chagoury Faculty of Architecture, Art, and Design

Content

Cause of Climate Change

Climate Disruptions in Lebanon

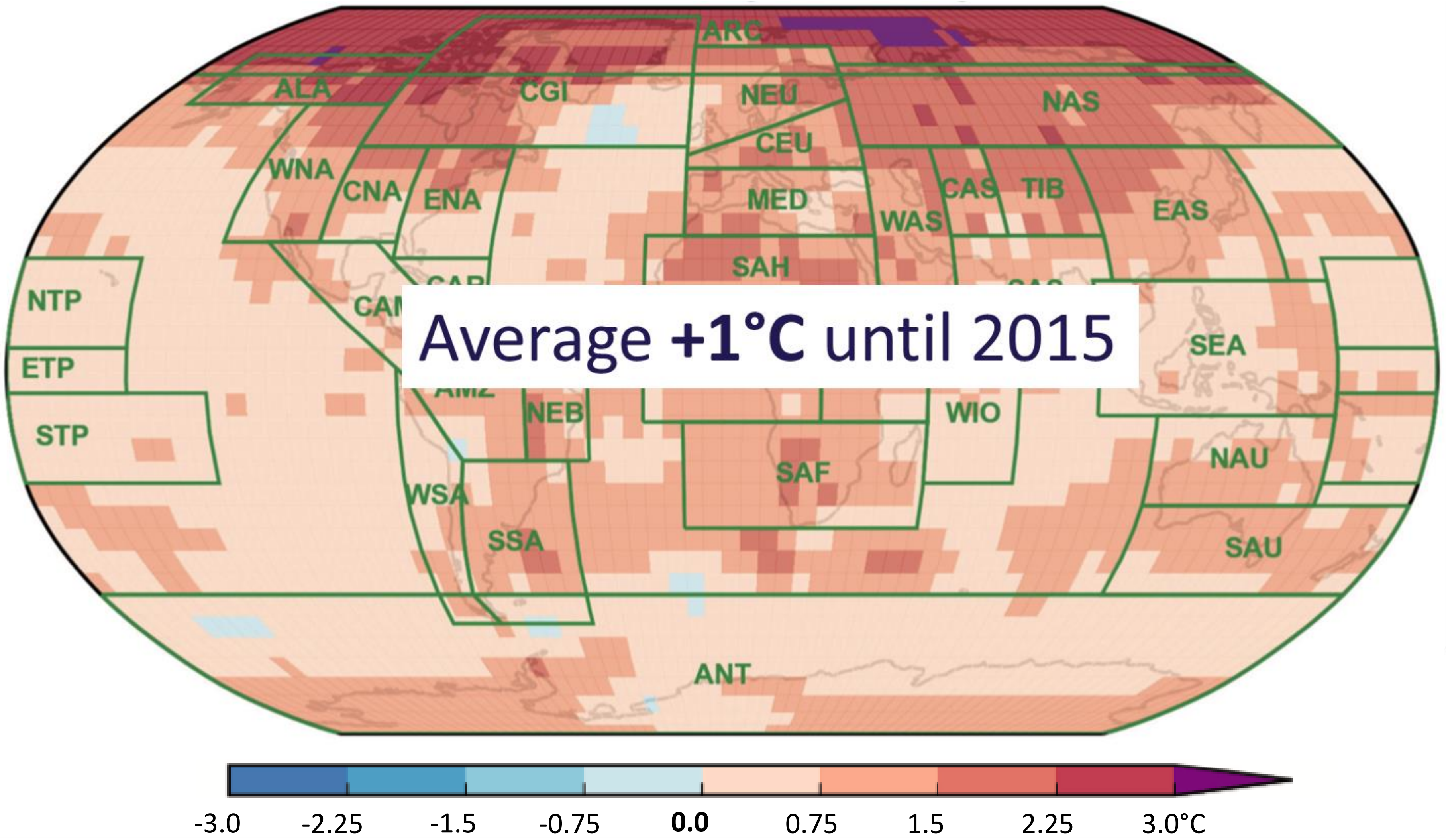
Al-Shouf Cedar Reserve

- **Floods**
- **Sea Level Rise**
- **Windstorms**
- **Heat Waves**
- **Fires**
- **Power outages**
- **Earthquakes**
- **Water Shortages**
- **Air Pollution**
- **Pandemics**

- **2024 Dubai**
- **2023 Darna**
- **2021 Beirut**
- **2019 Shouf** (Storm Norma)
- **2018 Jeddah**
- **2016 Kuwait**

Global Climate Change

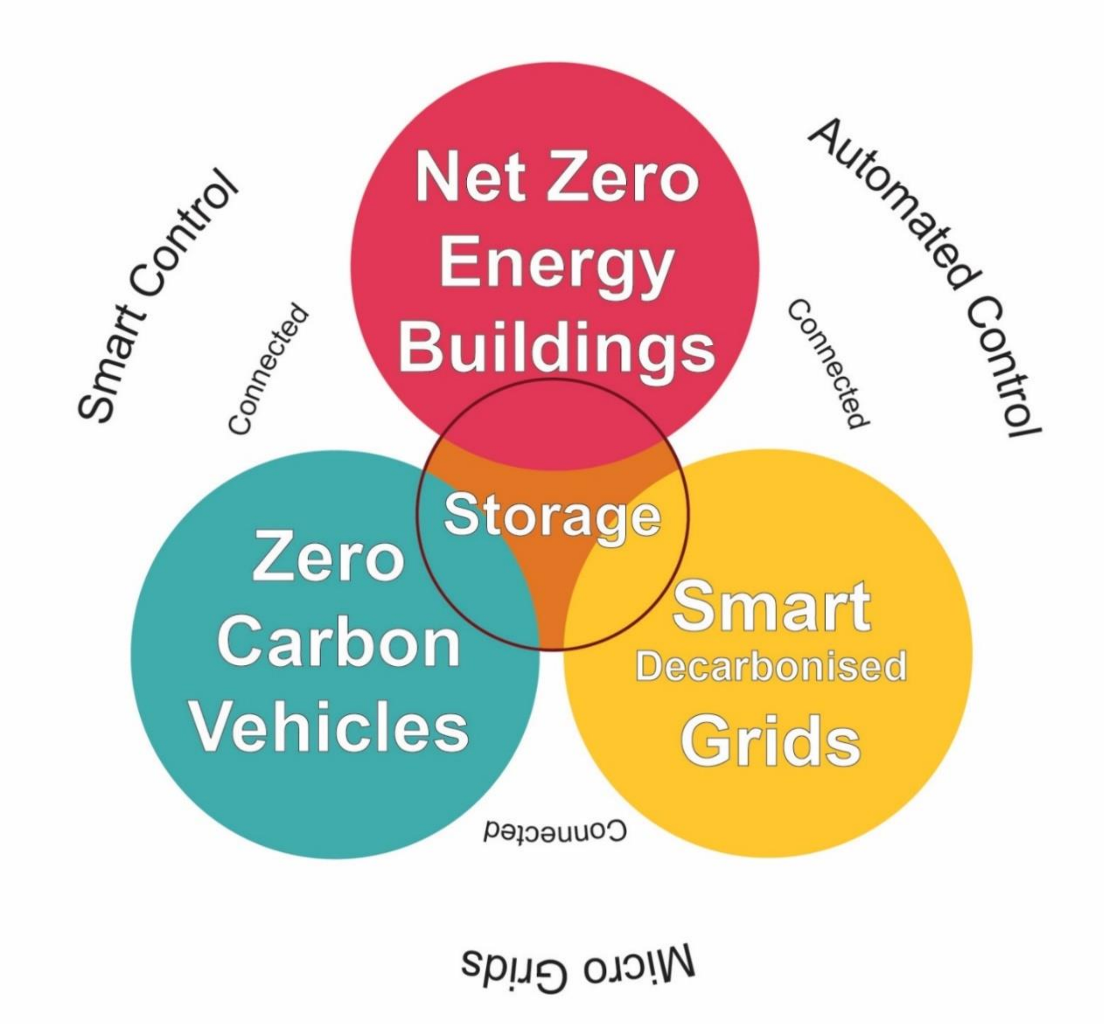
Paris Agreement 2015 Targets Compatibility

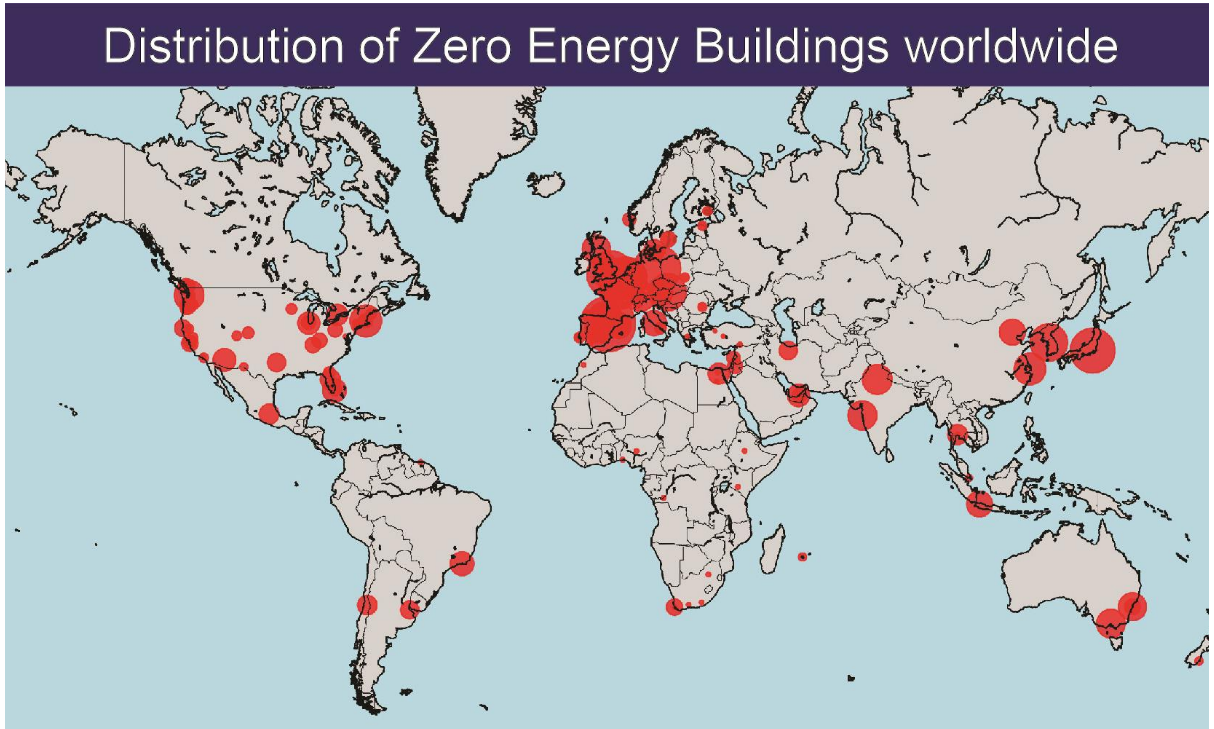


International Panel on Climate Change, 2019

Carbon Neutral Communities

Storage & Scale the Core of Carbon Neutrality

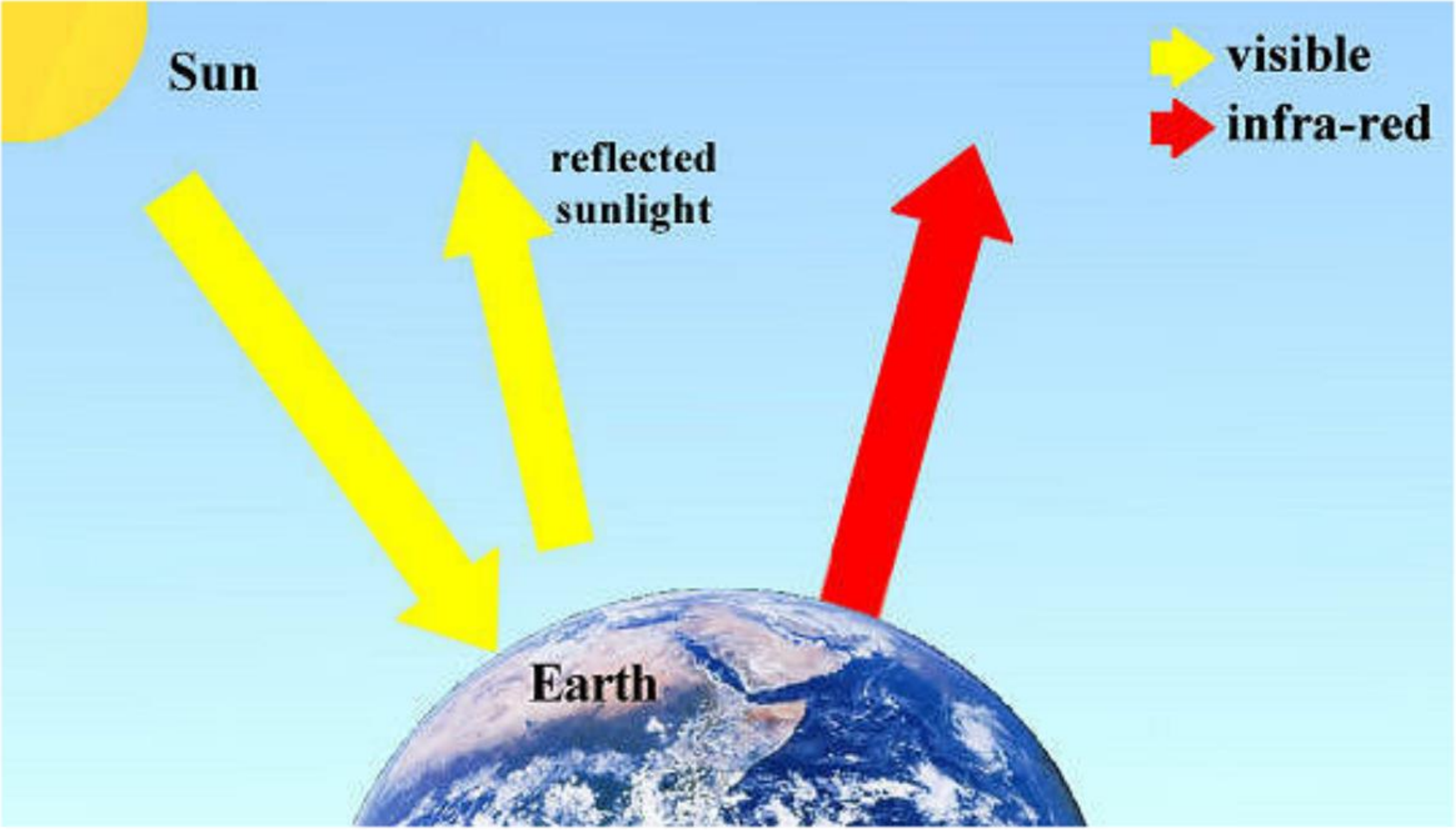




Source: Attia, S. (2025) **Net Zero Energy Buildings (NZEB)** , Elsevier, 2nd

What cause climate change?

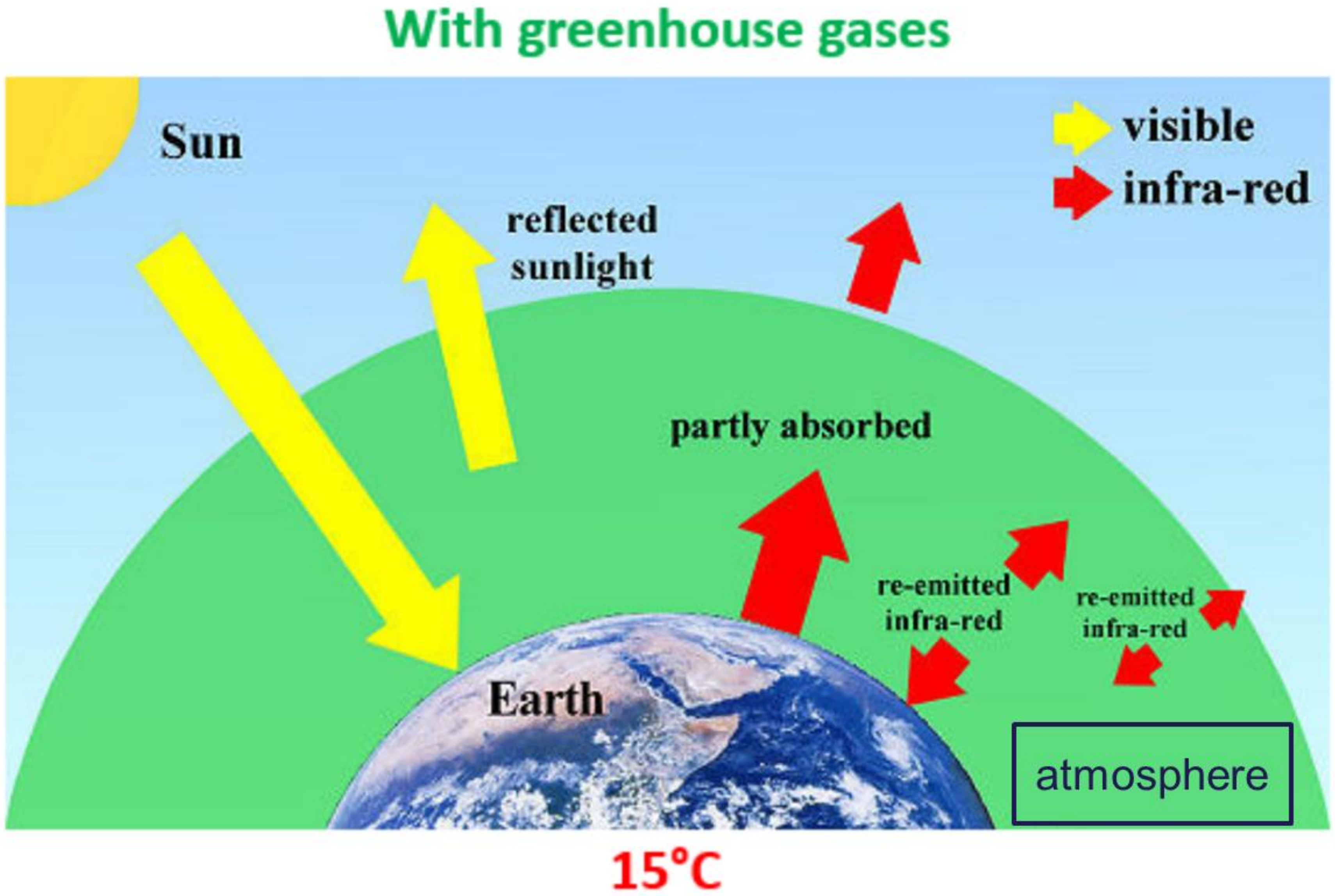
No greenhouse gases



-18°C

https://hklaureateforum.org/en/climate-change-and-its-impacts-to-hong-kong

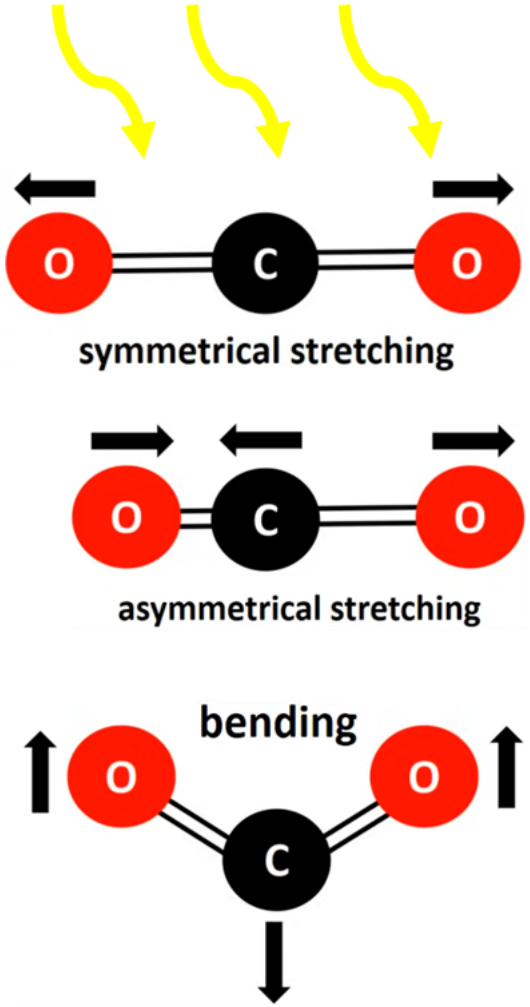
What cause climate change?



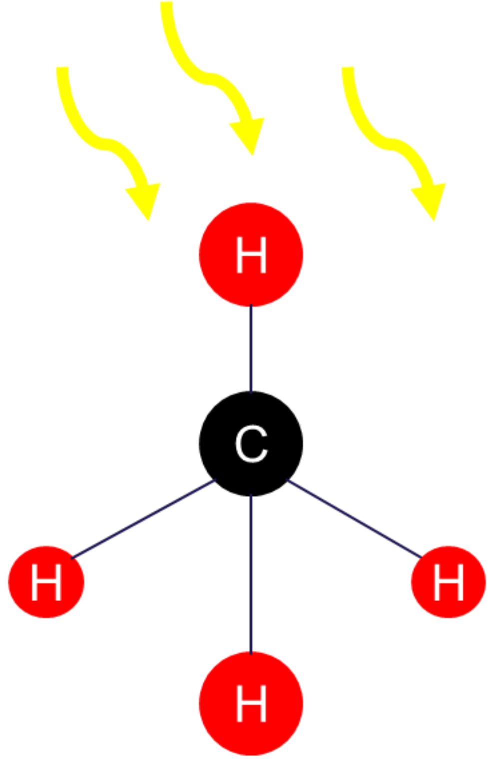
https://hklaureateforum.org/en/climate-change-and-its-impacts-to-hong-kong

What cause climate change?

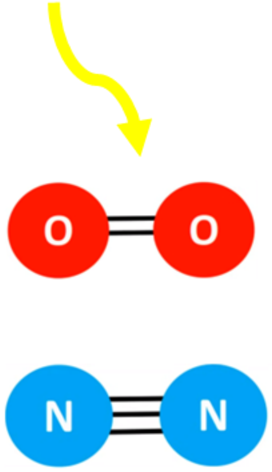
LIÈGE université
SBD Lab



burning of fossil fuels such as coal, oil, natural gas, and deforestation



Methane is emitted by livestock, agricultural practices, decay of organic waste in municipal solid waste landfills and during processing of coal, oil, and natural gas. It traps the heat.



No GHG

https://www.youtube.com/watch?v=AF1JPg20amY

What cause climate change?

LIÈGE université SBD Lab

Molecule	x or %	µmol mol^{-1} (ppmv)[a] (2014)	µmol mol^{-1} (ppmv) (1750)
N_2	0.78 or 78%	780 900	780 900
O_2	0.21 or 21%	209 400	209 400
H_2O	0.03 (100% humidity, 298 K)	30 000	31 000
H_2O	0.01 (50% humidity, 298 K)	10 000	16 000
Ar	0.01 or 1%	9300	9300
CO_2	3.8×10^{-4} or 0.038%	393	280
Ne	1.8×10^{-5} or 0.002%	18	18
CH_4	1.77×10^{-6} or 0.0002%	1.80	0.72
N_2O	3.2×10^{-7} or 0.00003%	0.32	0.27
O_3[b]	3.4×10^{-8} or 0.000003%	0.034	0.025
All CFCs[c]	8.7×10^{-10} or 8.7×10^{-8}%	0.0009	0
All HCFCs[d]	1.9×10^{-10} or 1.9×10^{-8}%	0.0002	0
All PFCs[e]	8.3×10^{-11} or 8.3×10^{-9}%	0.00008	0
All HFCs[f]	6.1×10^{-11} or 6.1×10^{-9}%	0.00006	0

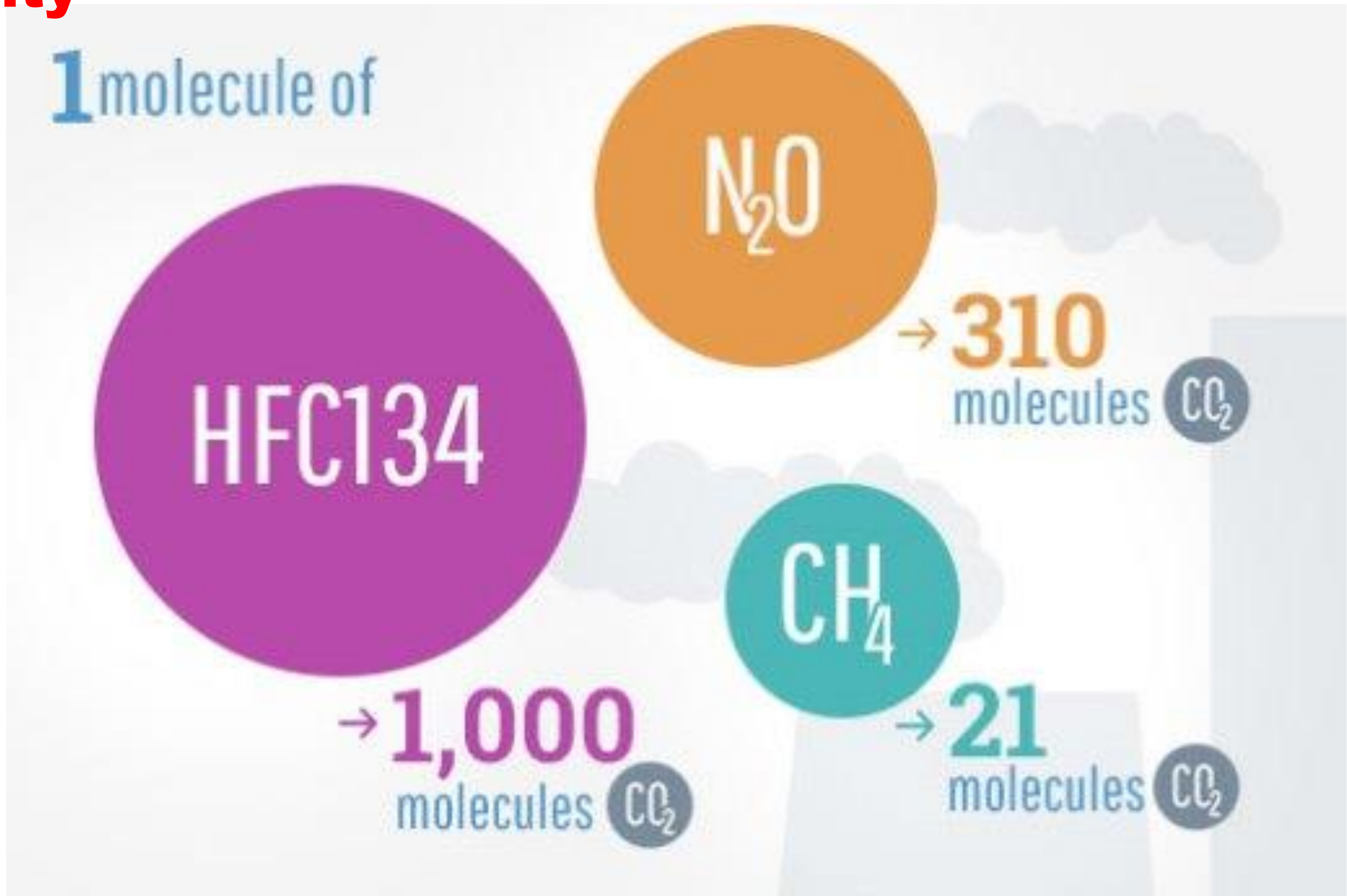
ISBN: 9780444635242

Climate change indicator?

1. GHG Emissions Intensity

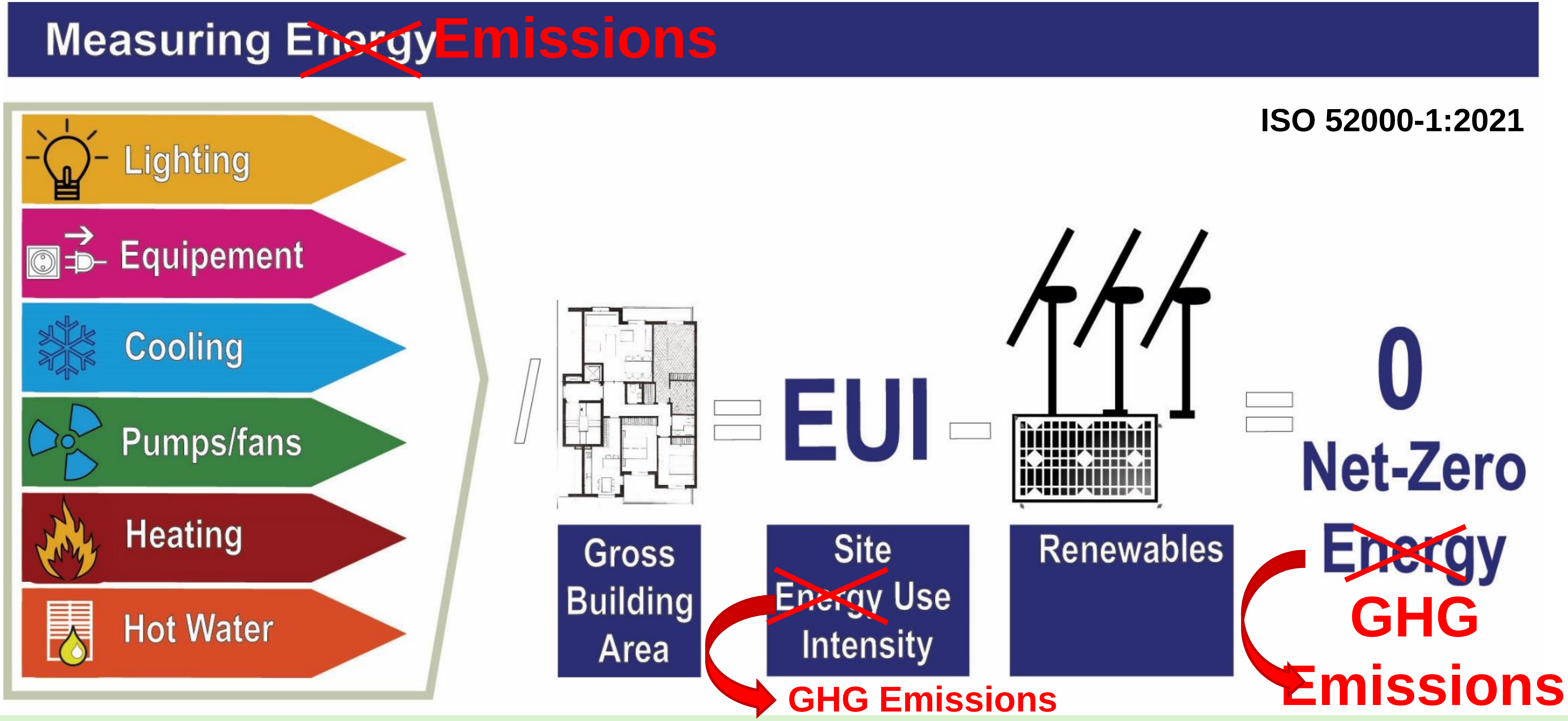
~~EUI~~
~~Energy Use Intensity~~
~~kWh/m /year~~

GWP
$kgCO_{2.e}/m^2/year$



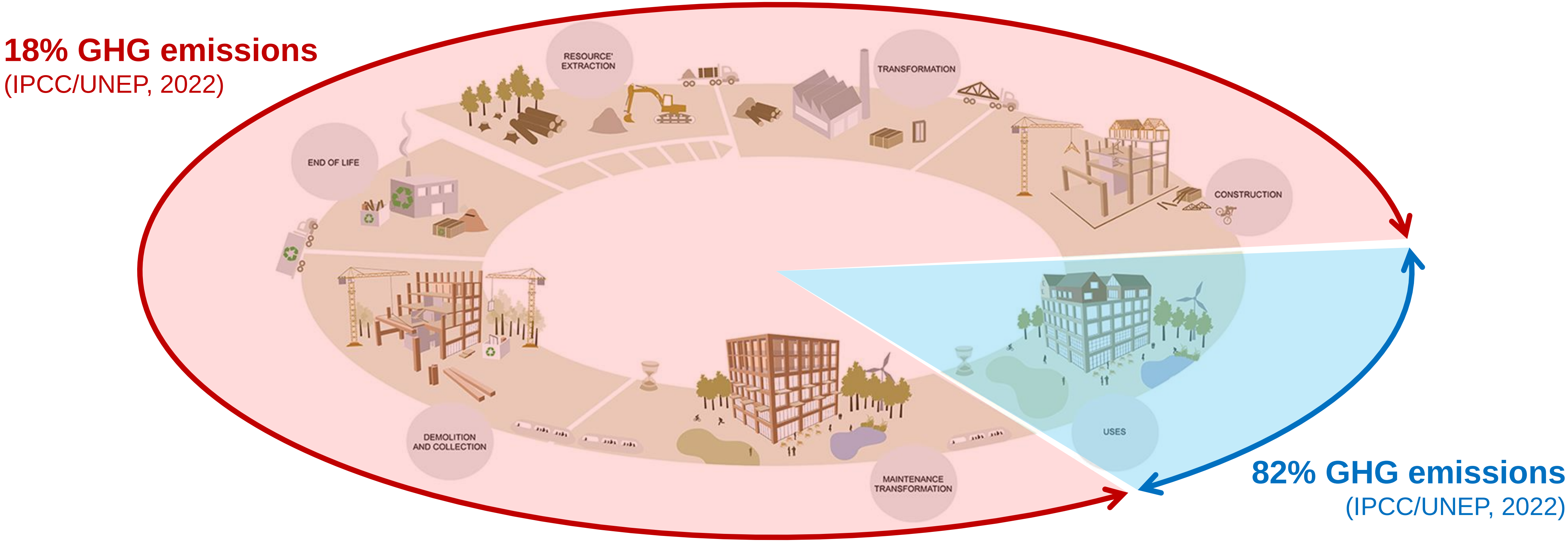
Zero Net Carbon Buildings

From Energy Use Intensity to GHG Emissions Intensity



Why Whole-Life Carbon Buildings

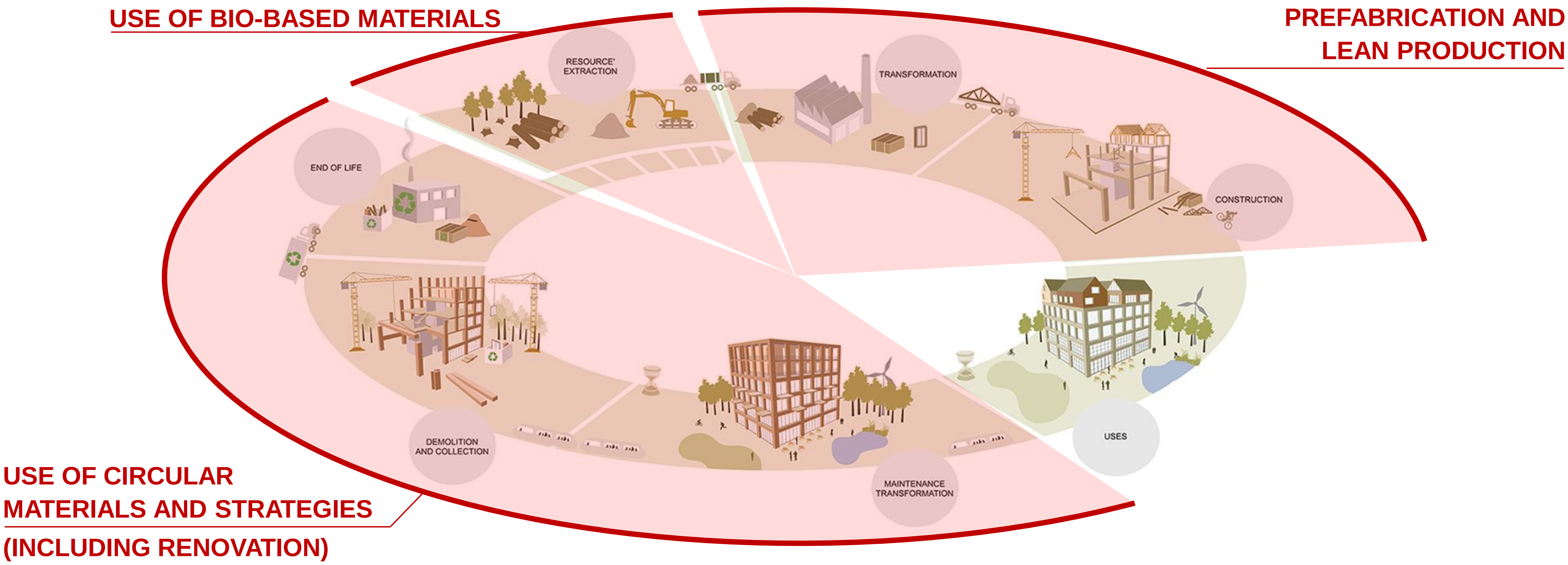
‘Embodied’ and ‘operational’ impacts



Life cycle phases of buildings

Source: https://www.smartlivinglab.ch/en/infrastructures/smart-living-building/

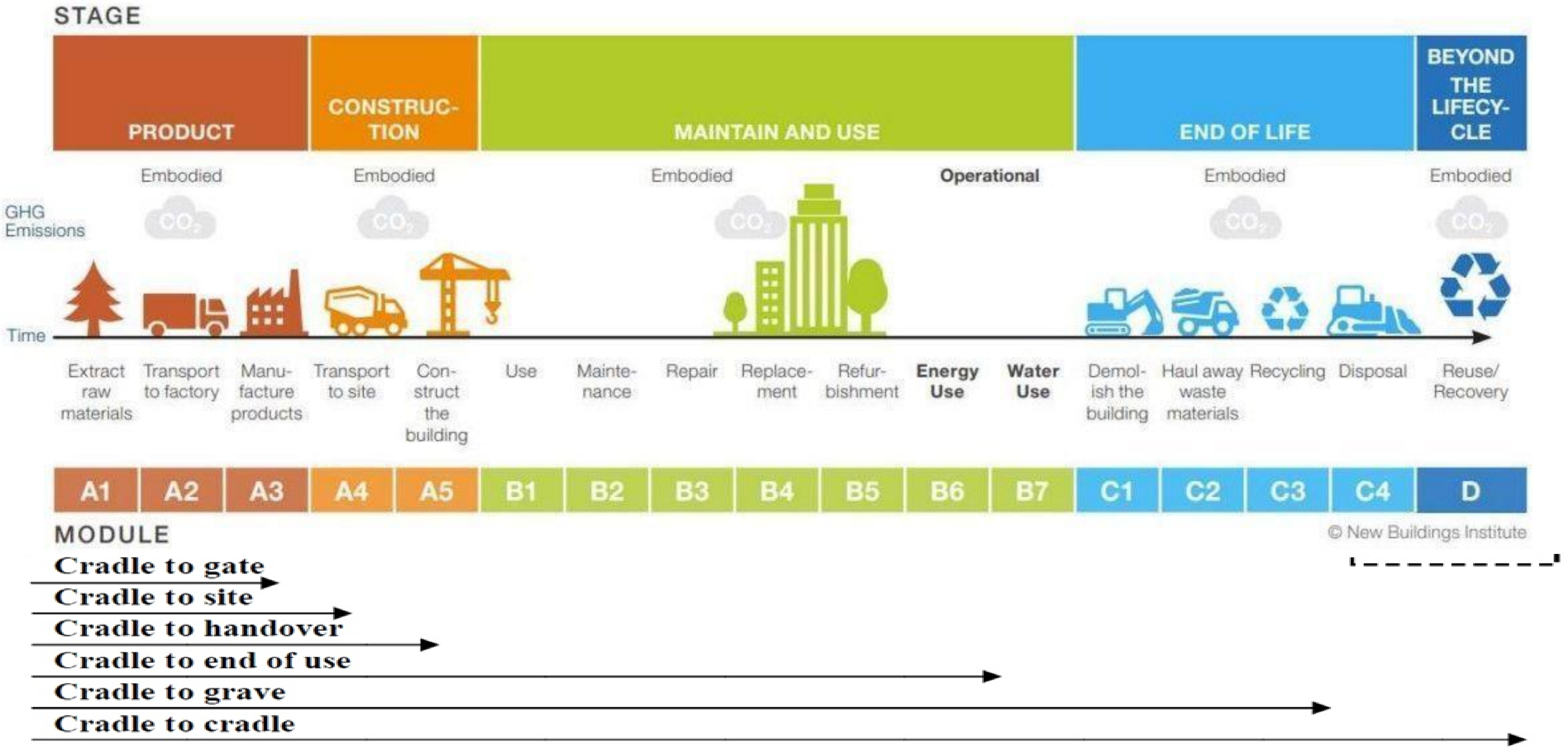
Reducing 'embodied' impacts



Life cycle phases of buildings

Source: https://www.smartlivinglab.ch/en/infrastructures/smart-living-building/

Lifecycle Stages of Buildings: ISO 14040



Why whole life cycle carbon?

ISO 14040

1. **Comprehensive Carbon Footprint Assessment**
2. **Long-term Sustainability Goals**
   Climate-neutral by 2050.
3. **Regulatory Efficiency**
   Resources efficiency
4. **Market Transformation**
   accelerate the adoption of green technologies
5. **Holistic Environmental Impact**:
   circular economy

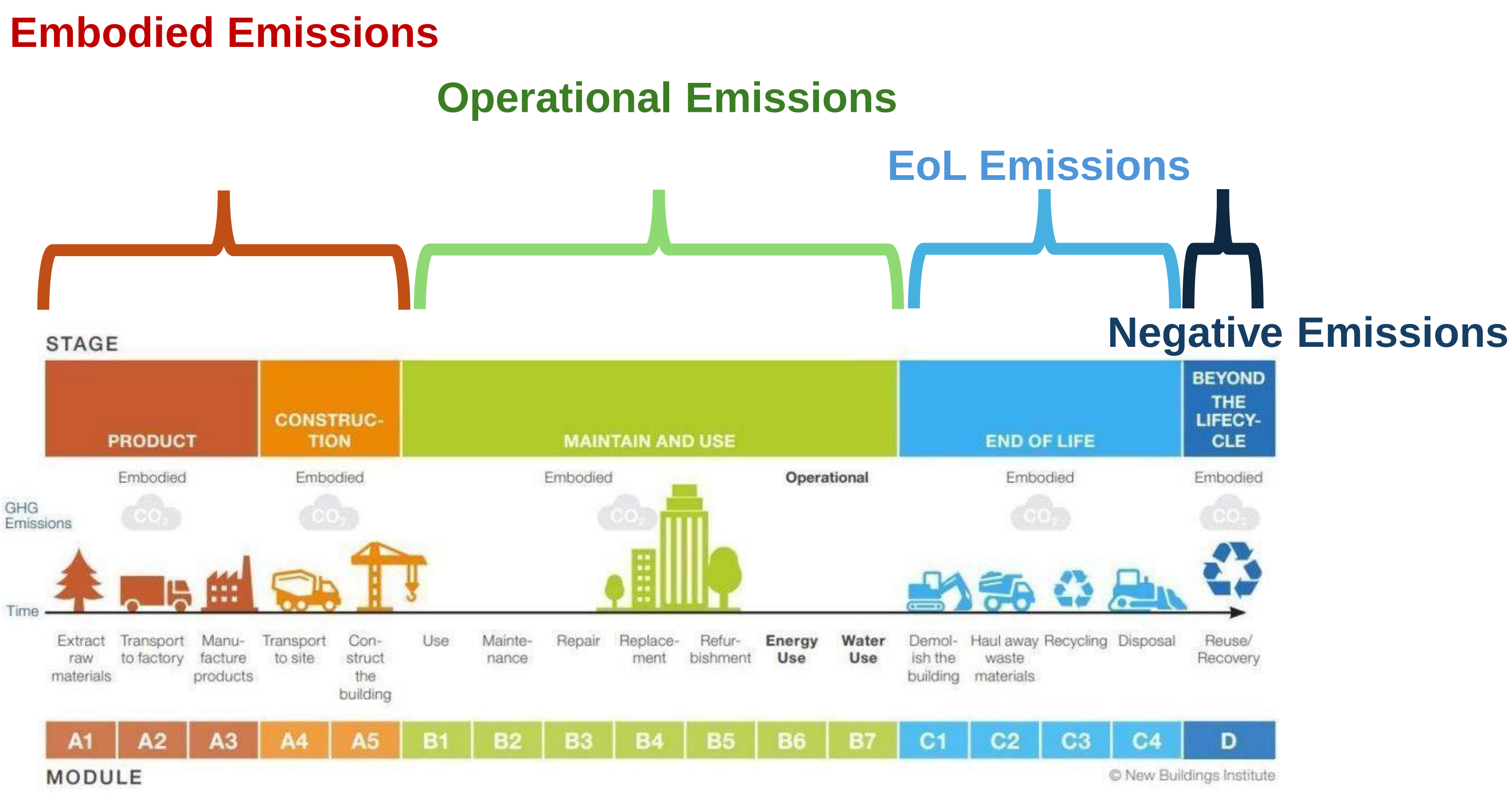
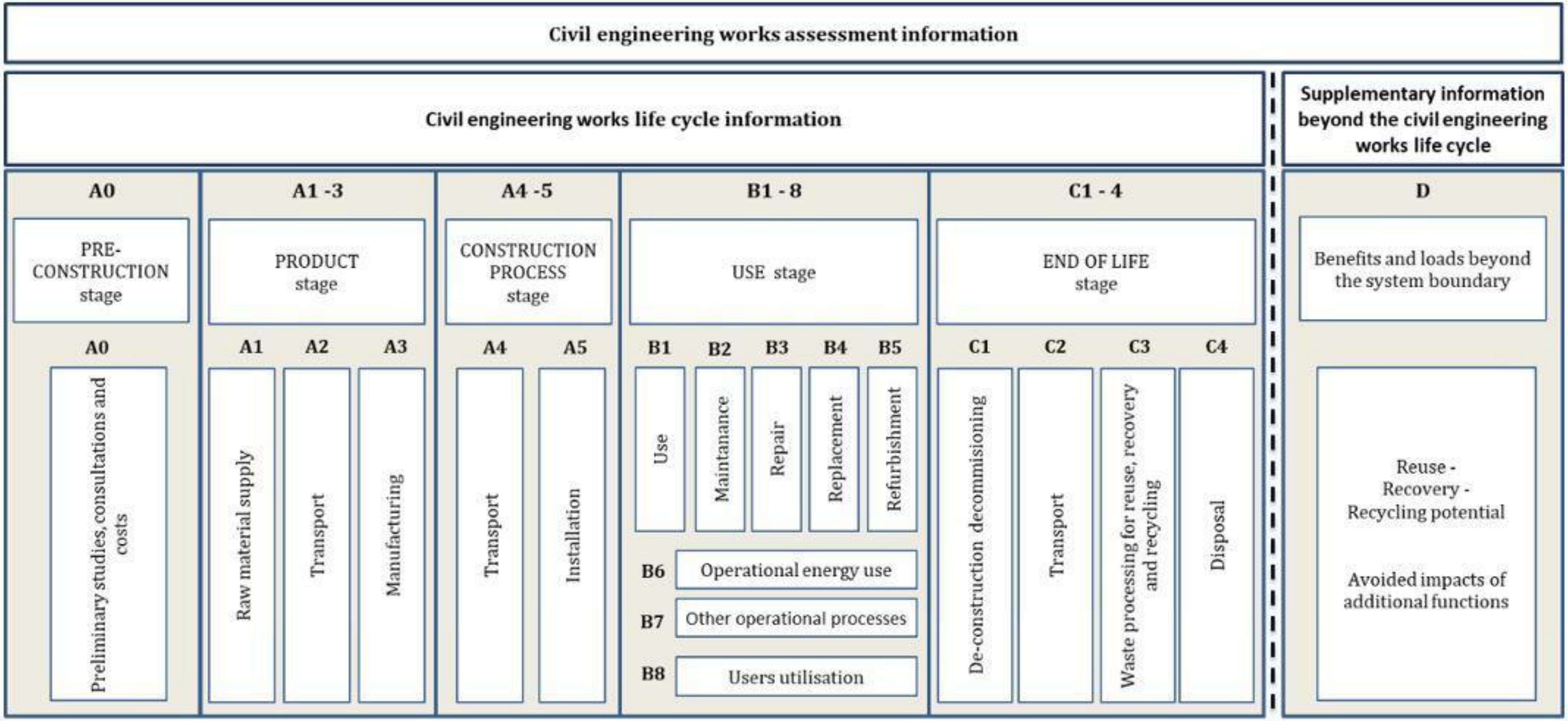


Figure 1: Lifecycle stages of building carbon. Data source: BS EN 15978:2011
Source: Bowles, Cheslak, and Edelson 2022

Lifecycle Stages of Buildings: EN 15643

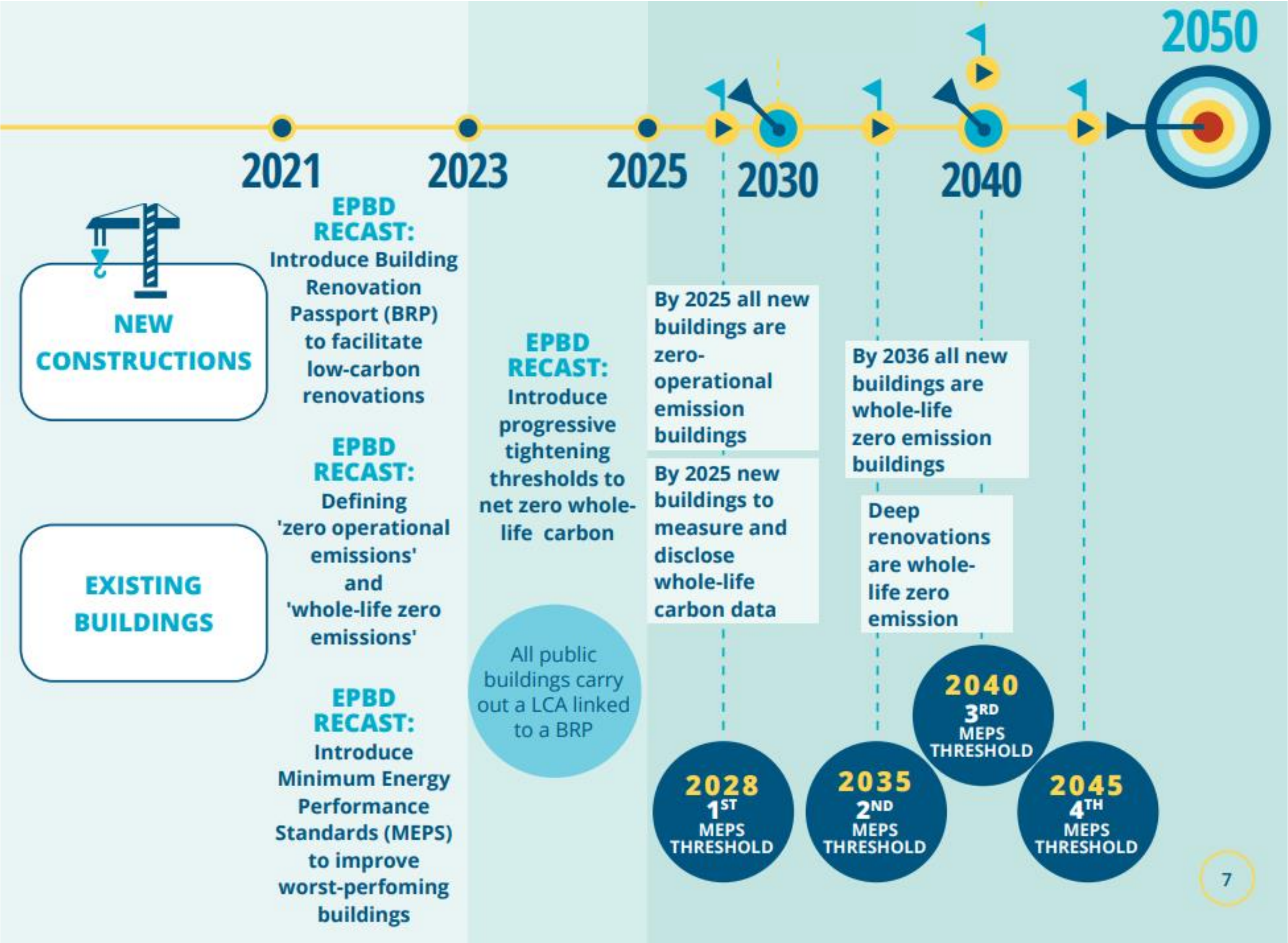


Net-Zero Whole-Life Carbon Buildings

LIÈGE université

EU Carbon Neurality 2050

1. All-electric buildings
2. Low carbon buildings
3. Decarbonization of heating & cooling
4. Decarbonization of Energy Mix
5. Low carbon building services



Why whole life cycle carbon?

Denmark

- regulation year: 2023
- all new buildings > 1000 m_2
- system boundary: A1-A3, B4, B6, C3-C4
- lifespan: 50 years
- from 2025: max. 7,1 kg $CO_{2\text{-eq}}$ /m_2 / year
- 1,5 kg $CO_{2\text{-eq}}$ /m_2 / year: A4-A5

France

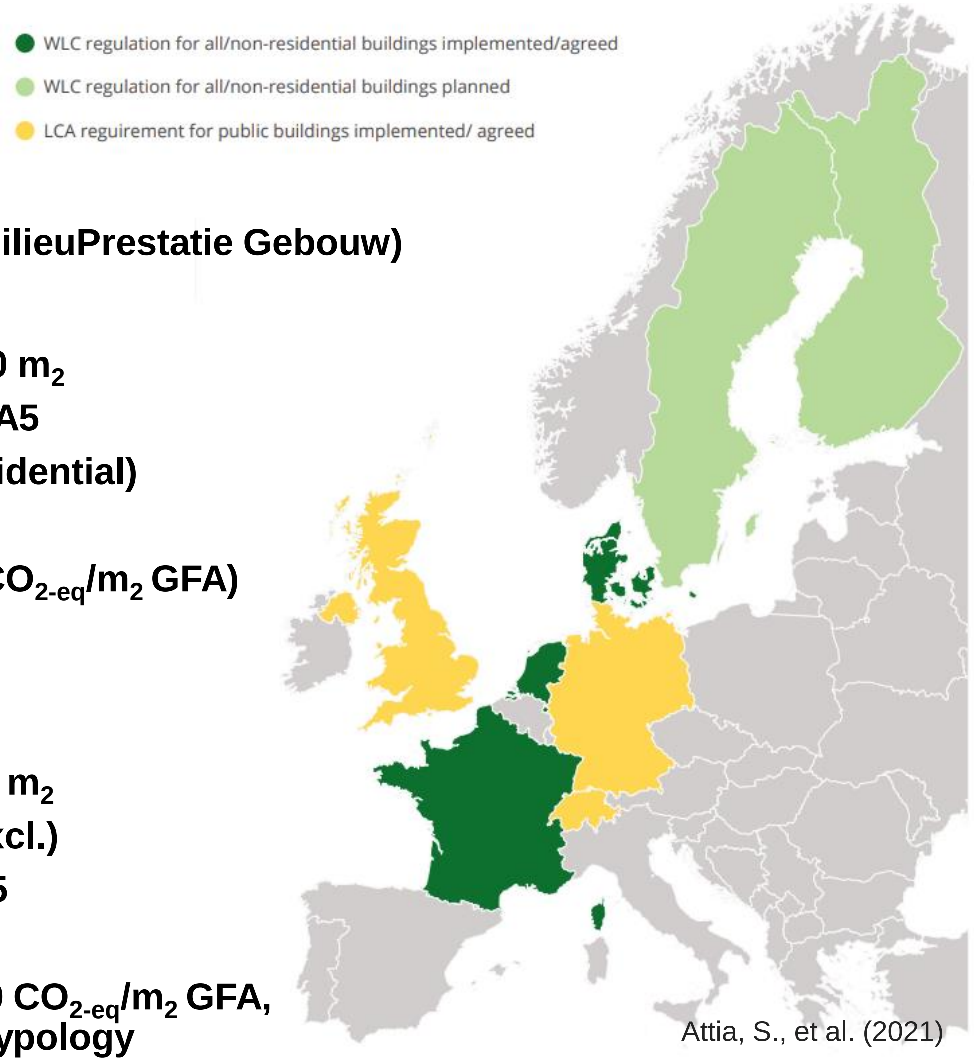
- regulation year: 2022
- all new buildings > 50 m_2
- system boundary: A1-A5
- lifespan: 50 years
- from 2022: max. 640-980 kg $CO_{2\text{-eq}}$ /m_2,
- depending on building typology

The Nederlands (MilieuPrestatie Gebouw)

- regulation year: 2017
- all new buildings > 100 m_2
- system boundary: A1-A5
- lifespan: 75 years (residential)
- from 2021: ≤ 0.8
- (DGBC max. 200-260 $CO_{2\text{-eq}}$/m_2 GFA)

Sweden

- regulation year: 2022
- all new buildings > 1000 m_2
- (single-family houses excl.)
- system boundary: A1-A5
- lifespan: 50 years
- from 2025: max. 180-460 $CO_{2\text{-eq}}$/m_2 GFA, depending on building typology



Attia, S., et al. (2021)

Operational vs Embodied emissions

Embodied Emissions

Operational Emissions

EoL Emissions

Negative Emissions

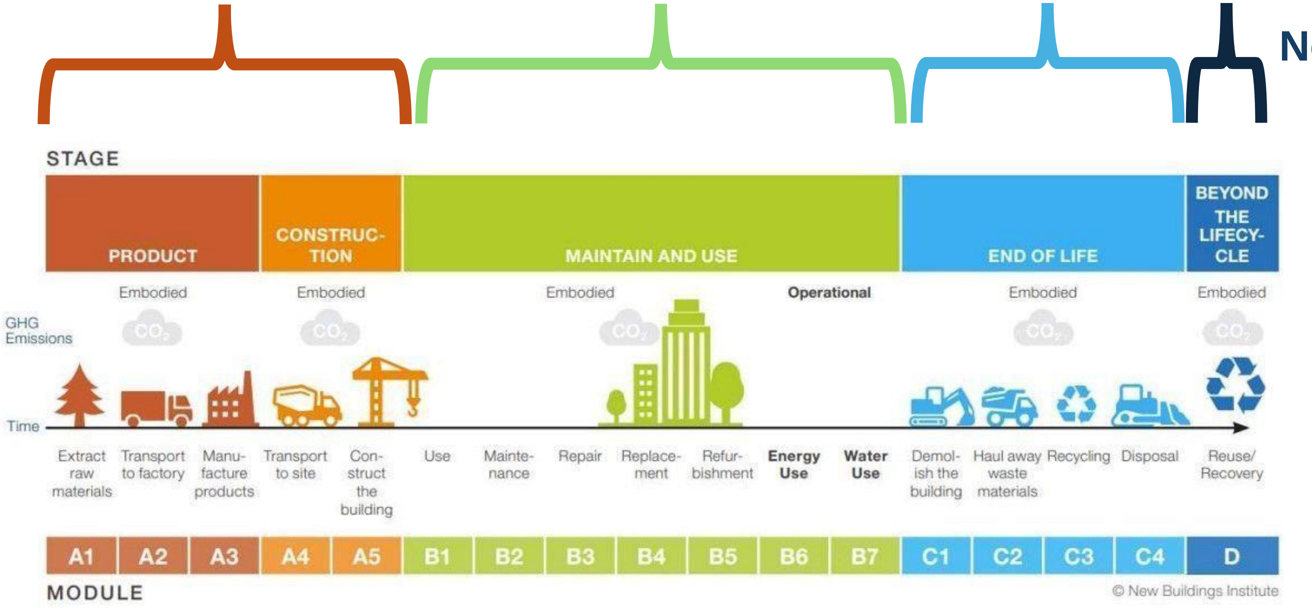
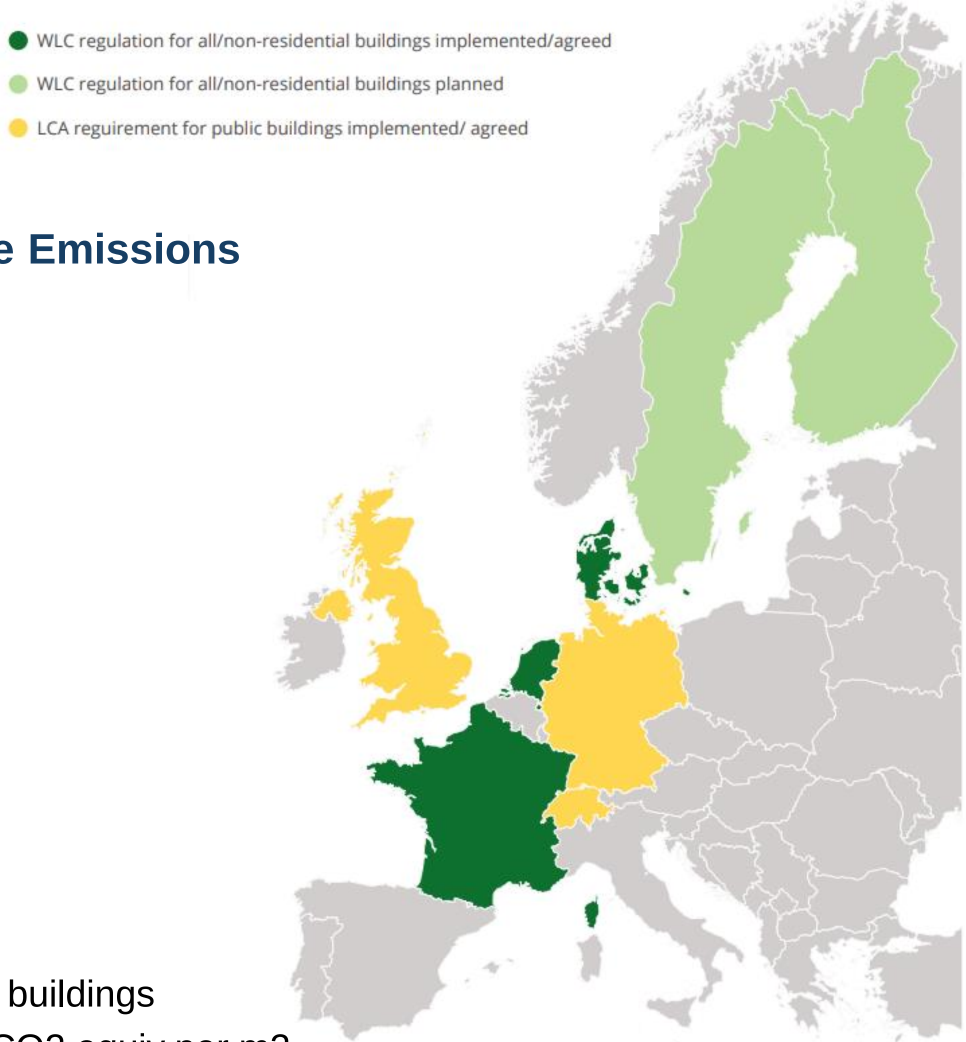


Figure 1: Lifecycle stages of building carbon. Data source: BS EN 15978:2011
Source: Bowles, Cheslak, and Edelson 2022



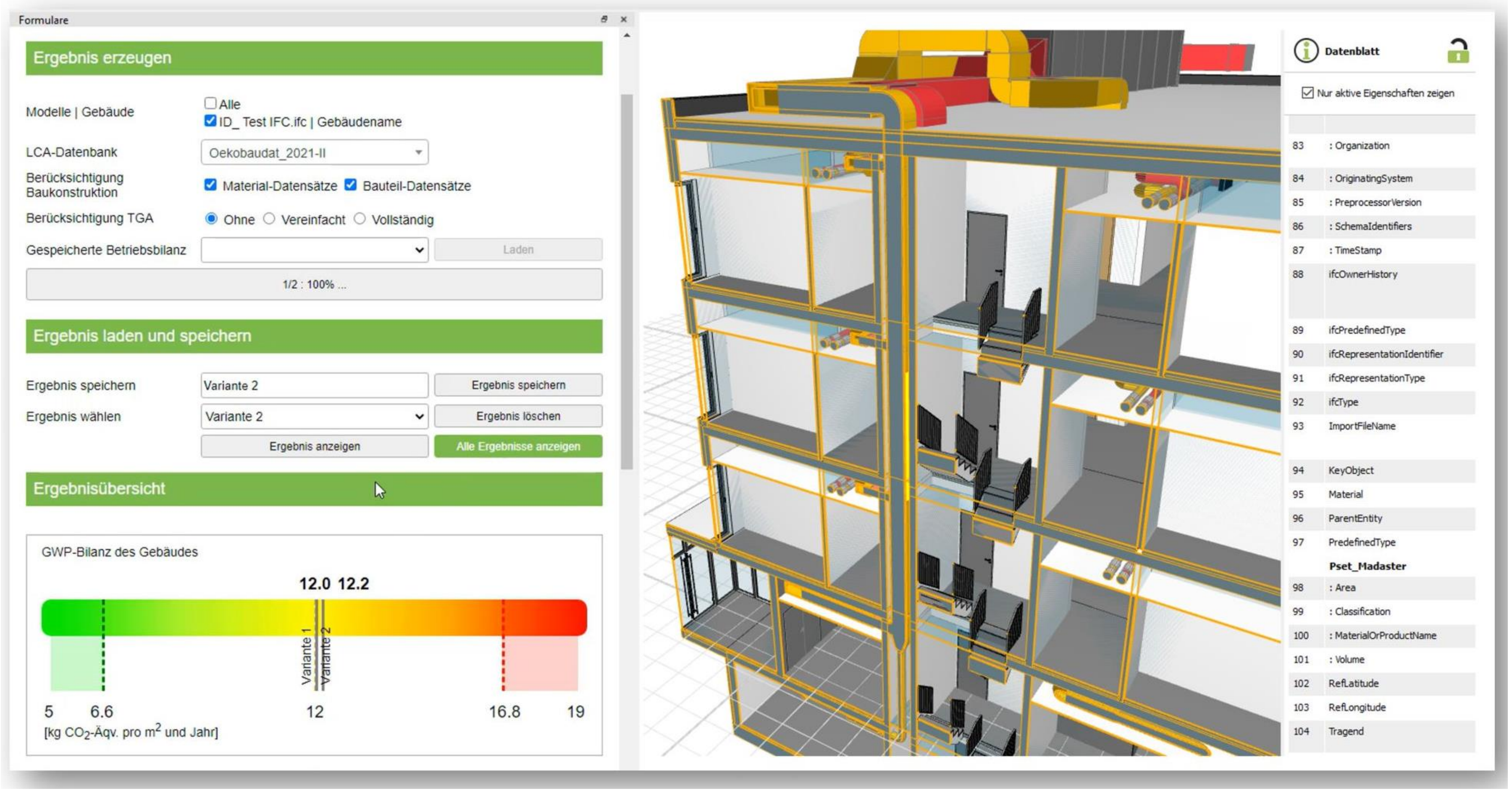
- RE2020 threshold of 4 kgCO2.equiv. operational emissions per m2 for new residential buildings
- Dynamic LCA calculation method + threshold for embodied carbon emission of 100 kgCO2.equiv per m2

Attia, S., et al. (2021)

GHG Emissions

LIÈGE université SBD Lab

Embodied and Operational Emissions



Source: DGNB, Sebastian Theißen, BIM-based emissions modeling

- 2023, Operational emissions:

4 kgCO2.equiv. per m2 for new residential buildings

- 2023, Embodied emissions (Office)

24 kgCO2.equiv per m2

- 2025 Operational + Embodied emissions:

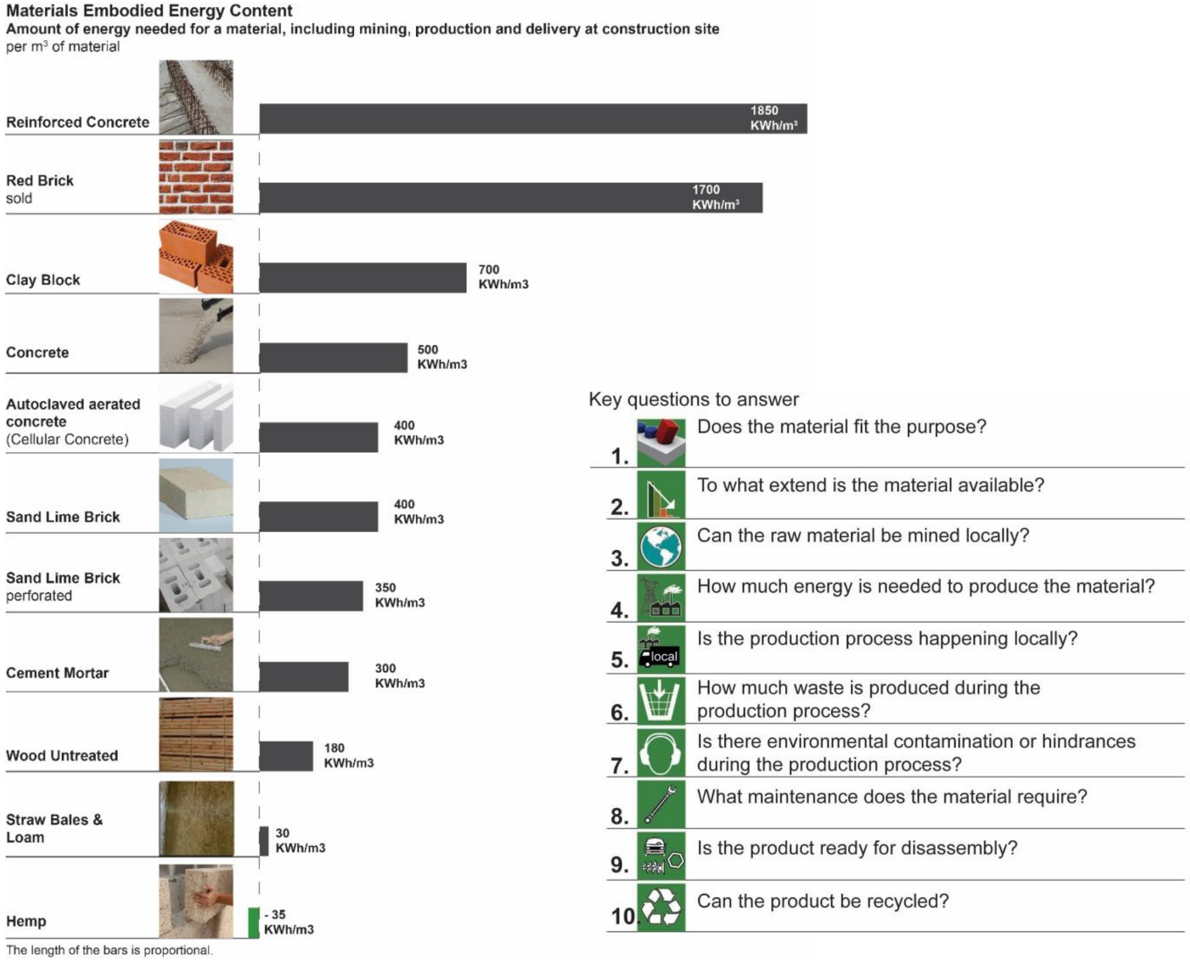
7,1 kgCO2.equiv. per m2 for new residential buildings: A1-A3, B4, B6, C3-C4

1,5 kg CO2-eq /m2 / year: A4-A5

Embodied GHG Emissions

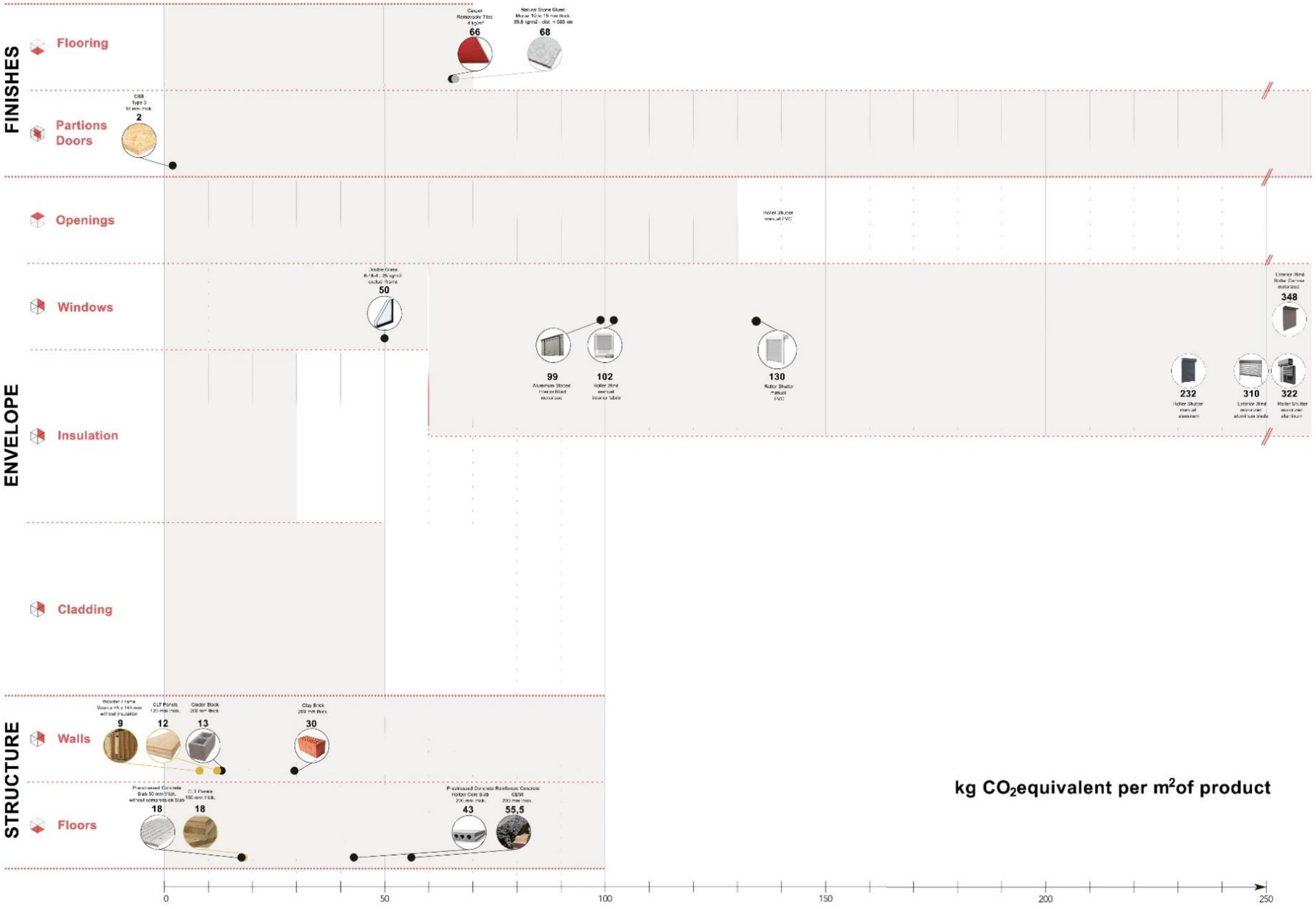
Many of the mostly widely used construction materials are from carbon-intensive heavy industries

Source: https://materialepyramiden.dk/



Embodied GHG Emissions

- Taking a Broader View of Carbon
- Whole life carbon Assessment
- Environmental Product Declarations



Embodied GHG Emissions

Categories of carbon negative materials & potential of negative emissions


Timber


Straw


Cork


Hemp


Biochar

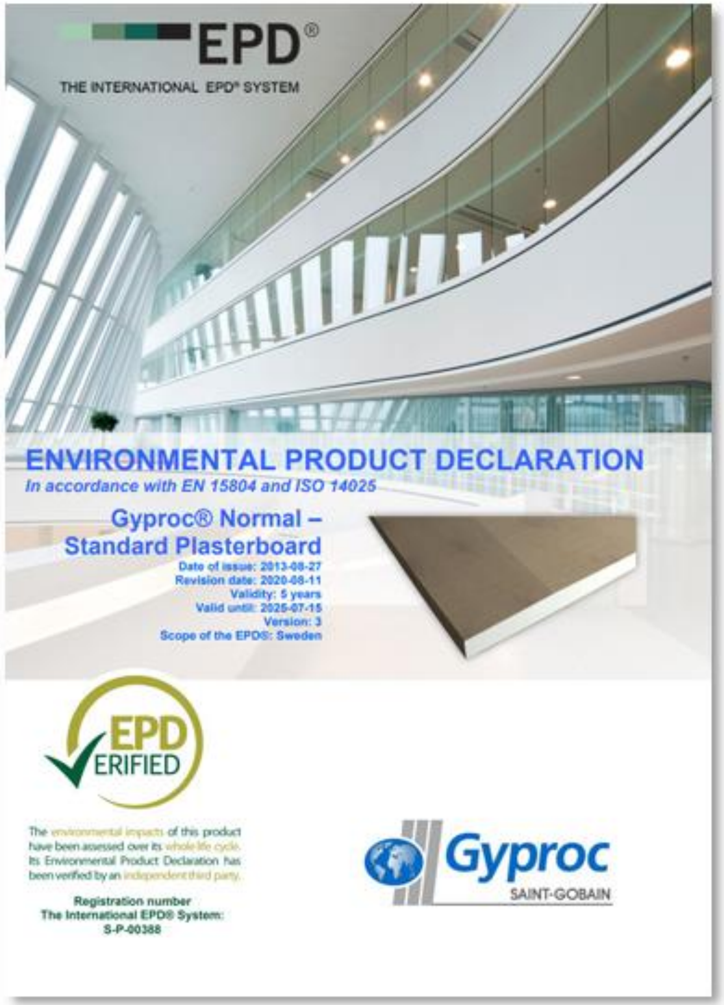

Captured carbon


Biomineralization (Low carbon aggregates)

Potential of negative emissions	
Biobased Materials	10-50%
Charcoal Concrete	2-10%
Carbonized Concrete	2-3%

Environmental Product Declaration

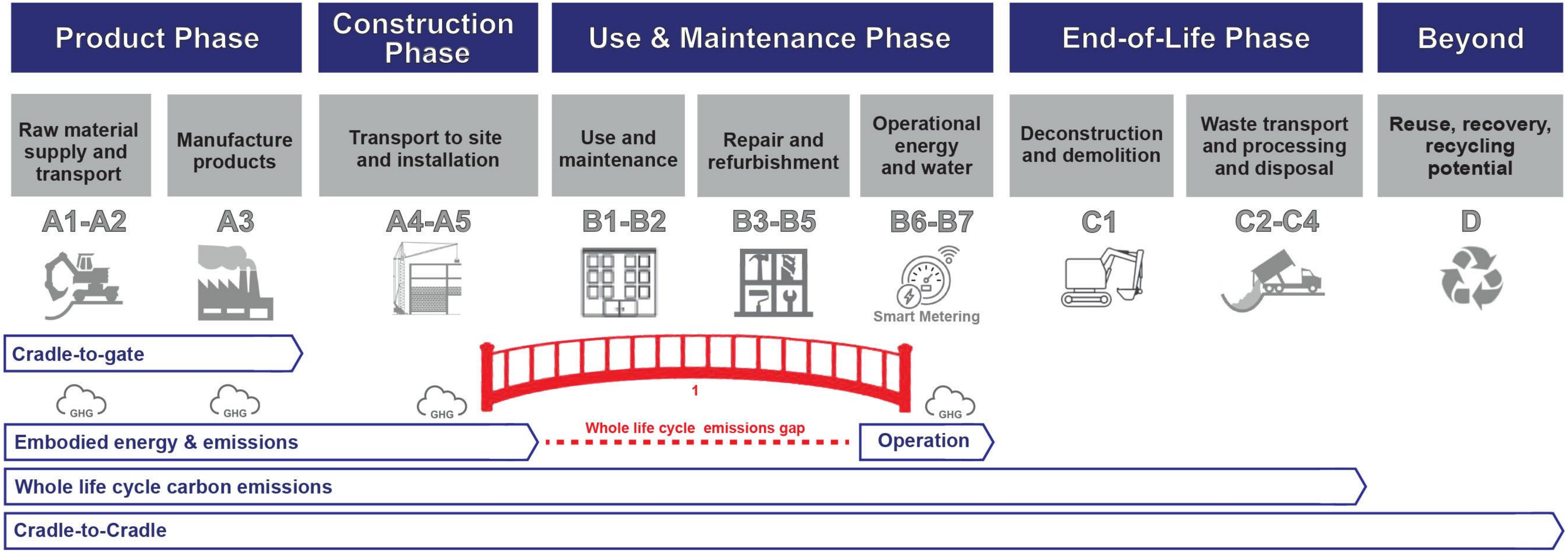
Life Cycle Impact Assessment of Building Materials and Products



ENVIRONMENTAL IMPACTS															
Parameters	Product stage	Construction process stage		Use stage							End-of-life stage				D Reuse, recovery, recycling
	A1 / A2 / A3	A4 Transport	A5 Installation	B1 Use	B2 Maintenance	B3 Repair	B4 Replacement	B5 Refurbishment	B6 Operational energy use	B7 Operational water use	C1 Deconstruction / demolition	C2 Transport	C3 Waste processing	C4 Disposal	
Global Warming Potential (GWP 100) - *kg CO_2 equiv/FU*	2,14E+00	1,24E-01	1,52E-01	0	0	0	0	0	0	0	4,10E-02	1,34E-02	1,54E-03	1,24E-01	-2,18E-02
	The global warming potential of a gas refers to the total contribution to global warming resulting from the emission of one unit of that gas relative to one unit of the reference gas, carbon dioxide, which is assigned a value of 1.														
Ozone Depletion (ODP) *kg CFC 11 equiv/FU*	5,52E-08	1,90E-17	2,76E-09	0	0	0	0	0	0	0	5,59E-18	7,03E-15	2,47E-12	6,94E-16	9,80E-05
	Destruction of the stratospheric ozone layer which shields the earth from ultraviolet radiation harmful to life. This destruction of ozone is caused by the breakdown of certain chlorine and/or bromine containing compounds (chlorofluorocarbons or halons), which break down when they reach the stratosphere and then catalytically destroy ozone molecules.														
Acidification potential (AP) *kg SO_2 equiv/FU*	8,24E-03	4,95E-04	5,54E-04	0	0	0	0	0	0	0	1,44E-04	5,48E-05	1,74E-05	7,08E-04	1,82E-05
	Acid depositions have negative impacts on natural ecosystems and the man-made environment incl, buildings. The main sources for emissions of acidifying substances are agriculture and fossil fuel combustion used for electricity production, heating and transport.														
Eutrophication potential (EP) *kg $(PO_4)^{3-}$ equiv/FU*	1,51E-03	1,21E-04	9,33E-05	0	0	0	0	0	0	0	8,38E-06	1,38E-05	3,2E-06	8,03E-05	-3,45E-01
	Excessive enrichment of waters and continental surfaces with nutrients, and the associated adverse biological effects.														
Photochemical ozone creation (POPC) *kg Ethylene equiv/FU*	3,03E-04	1,81E-05	5,11E-05	0	0	0	0	0	0	0	9,68E-06	2,25E-06	2,14E-06	5,84E-05	0
	Chemical reactions brought about by the light energy of the sun. The reaction of nitrogen oxides with hydrocarbons in the presence of sunlight to form ozone is an example of a photochemical reaction.														
Abiotic depletion potential for non-fossil ressources (ADP-elements) - *kg Sb equiv/FU*	1,96E-06	1,65E-09	1,99E-06	0	0	0	0	0	0	0	1,02E-09	1,15E-09	8,46E-10	4,22E-08	0
Abiotic depletion potential for fossil ressources (ADP-fossil fuels) - *MJ/FU*	3,66E+01	1,73E+00	2,29E+00	0	0	0	0	0	0	0	5,11E-01	1,81E-01	1,64E-02	1,65E+00	0
	Consumption of non-renewable resources, thereby lowering their availability for future generations.														

Embodied GHG Emissions

Coupling of Embodied and Operational GHG Emissions Modeling



Source: Attia, S. (2025) **Net Zero Energy Buildings (NZEB)** , Elsevier, 2nd

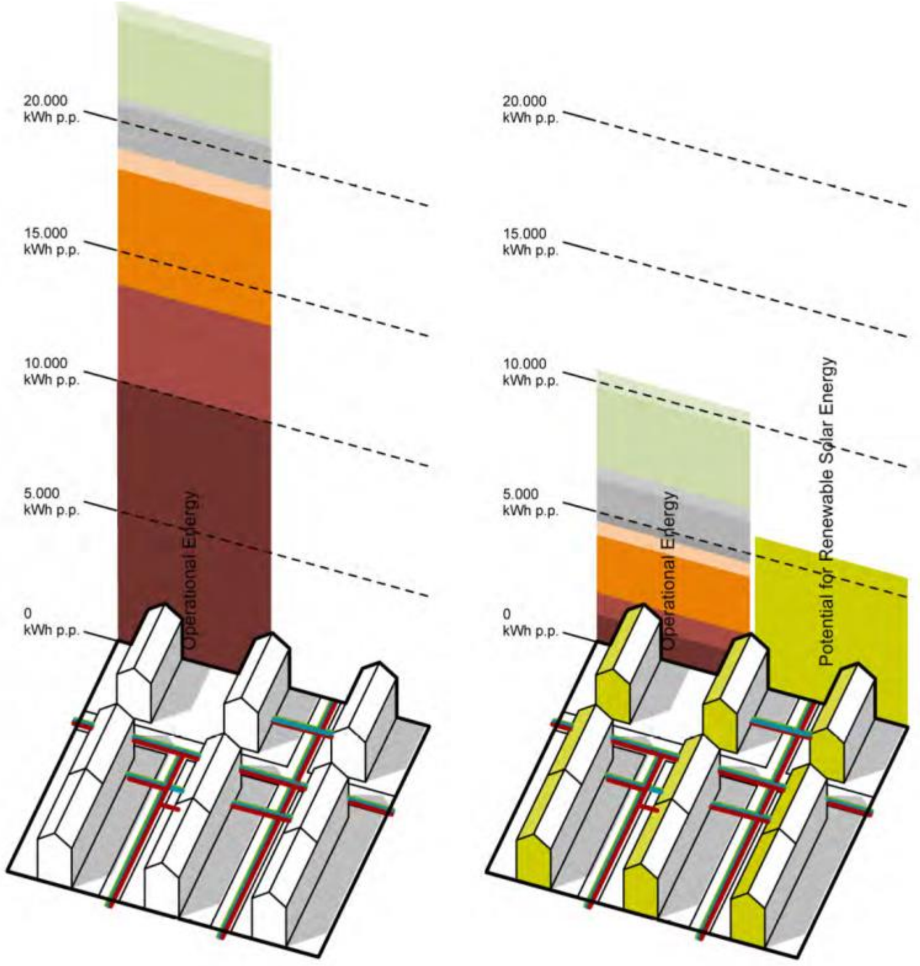
Embodied GHG Emissions

Some low carbon solutions

Nr.	Low carbon solutions	Category
1	Renovate instead of building new	Circularity principles and downsizing in the conceptual design stage
2	Design for flexibility, resilience and extended lifespan	
3	Design for disassembly	
4	Re-use existing materials in construction	
5	Optimize the use of space in offices, residential buildings	
6	Design based on light construction method instead of massive construction	
7a	Use industry by-products instead of cement	Carbon reduction in material selection and sourcing
7b	Use recycled concrete and other by-products as aggregate for new concrete	
8	Reduce concrete demand through material use optimization in (structural) design	
9	Offsite construction and design for less waste on-site	
10	Use of locally sourced materials and clean transportation	
11	Use timber structures in new construction	Carbon reduction in material selection and sourcing – bio-based materials
12	Use hybrid (concrete + timber) structures in new construction	
13	Use timber roof elements in standard structure	
14	Use other bio-based materials	

Building Stock Renovation

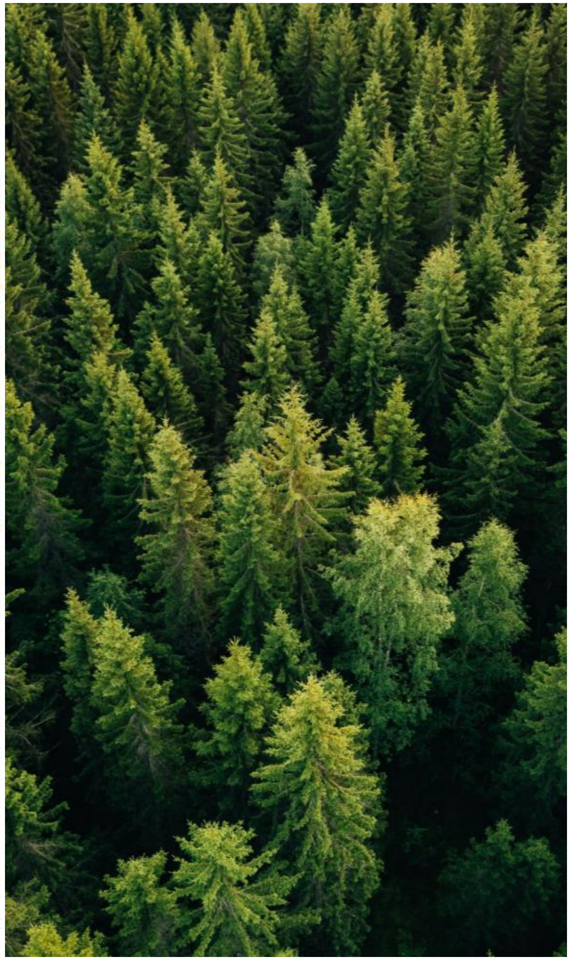
Evaluate systematic strategies to increase the deep renovation rate before implementation to gain time, money and energy.



Zero Net Carbon Buildings

De Tippe Zwolle (F6), The Netherlands

LIÈGE université
SBD Lab



Zero Net Carbon Tall Buildings

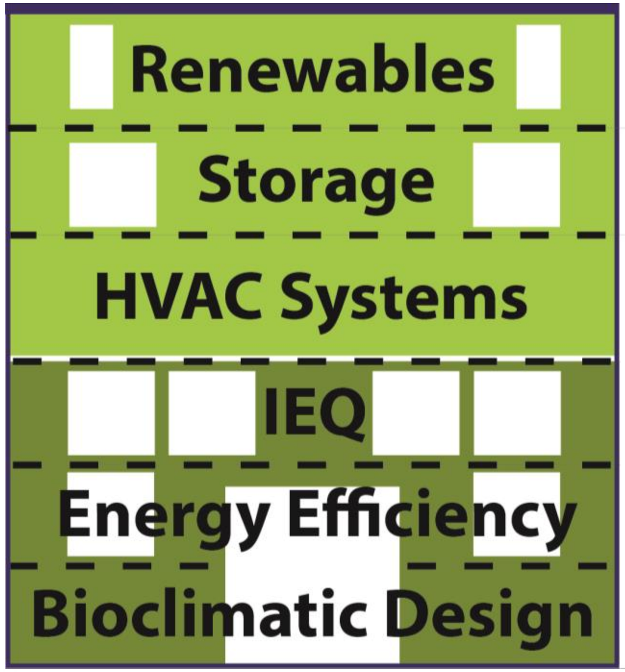
HAUT, Arup, Amsterdam, The Netherlands

Pathways and Solutions

Zero Net Carbon Buildings

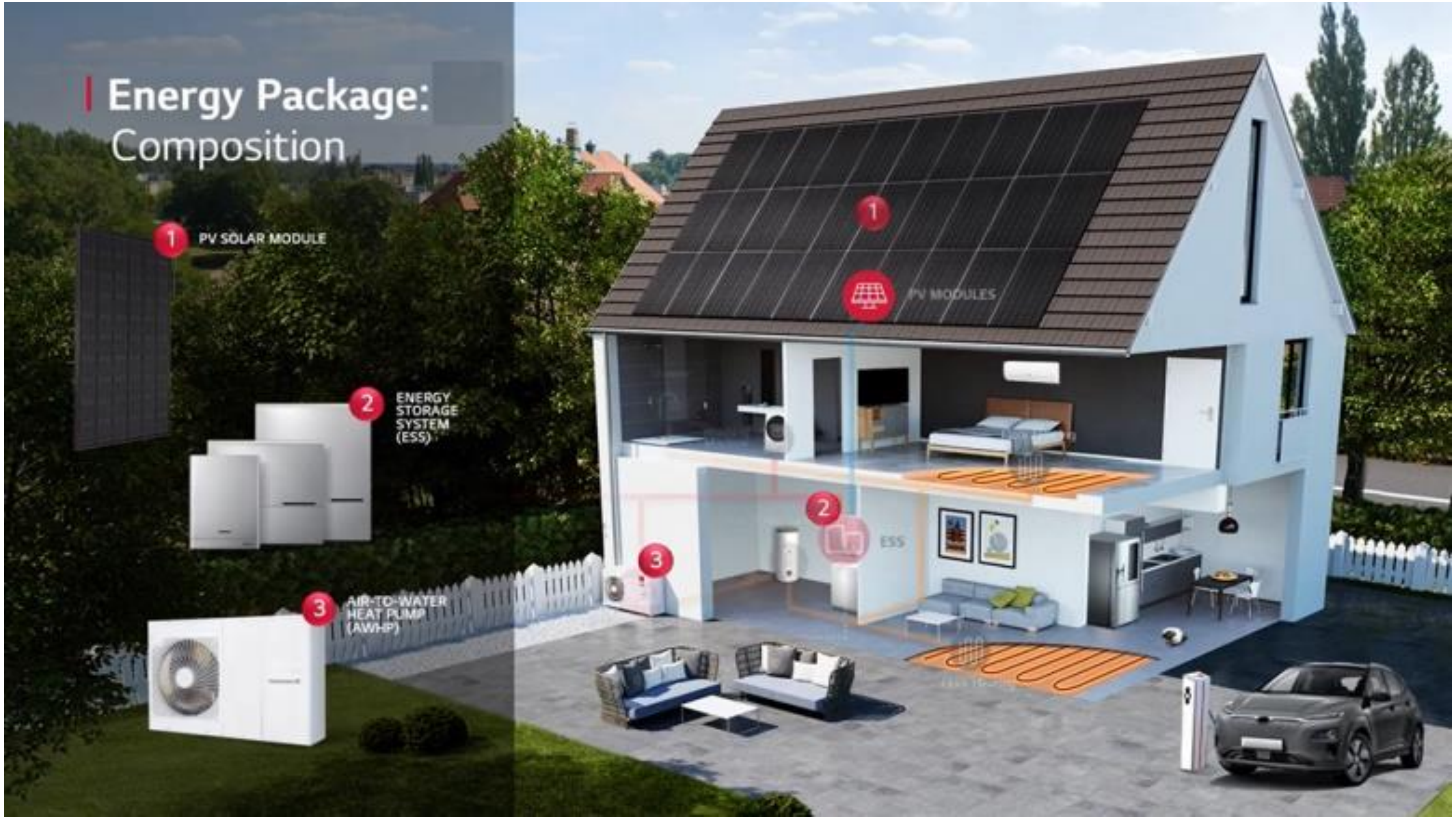
Definition

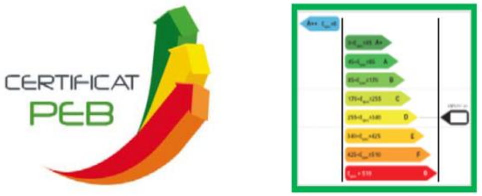
An ZNC is a grid-connected, carbon-efficient building **that balances its total annual carbon emissions by on-site generation.**
A ZNC building is a **highly energy efficient** building that produces on-site, or **procures, enough carbon-free renewable energy** to meet building operations energy consumption annually.



Source: Attia, S. (2025) **Net Zero Energy Buildings (NZEB)** , Elsevier, 2nd

Technology Portfolio in 2050





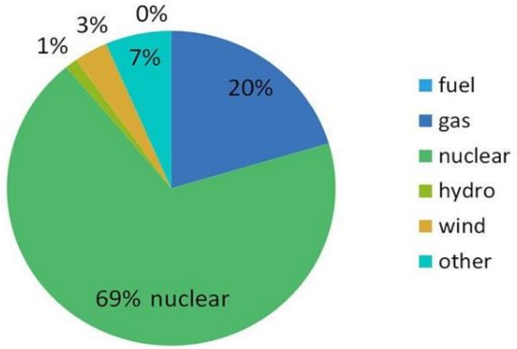
Carbon Neutral Buildings

AC unit with environmental Friendly refrigerant

PV with increase efficiency

Belgian Energy Mix:

Current and Future Scenarios

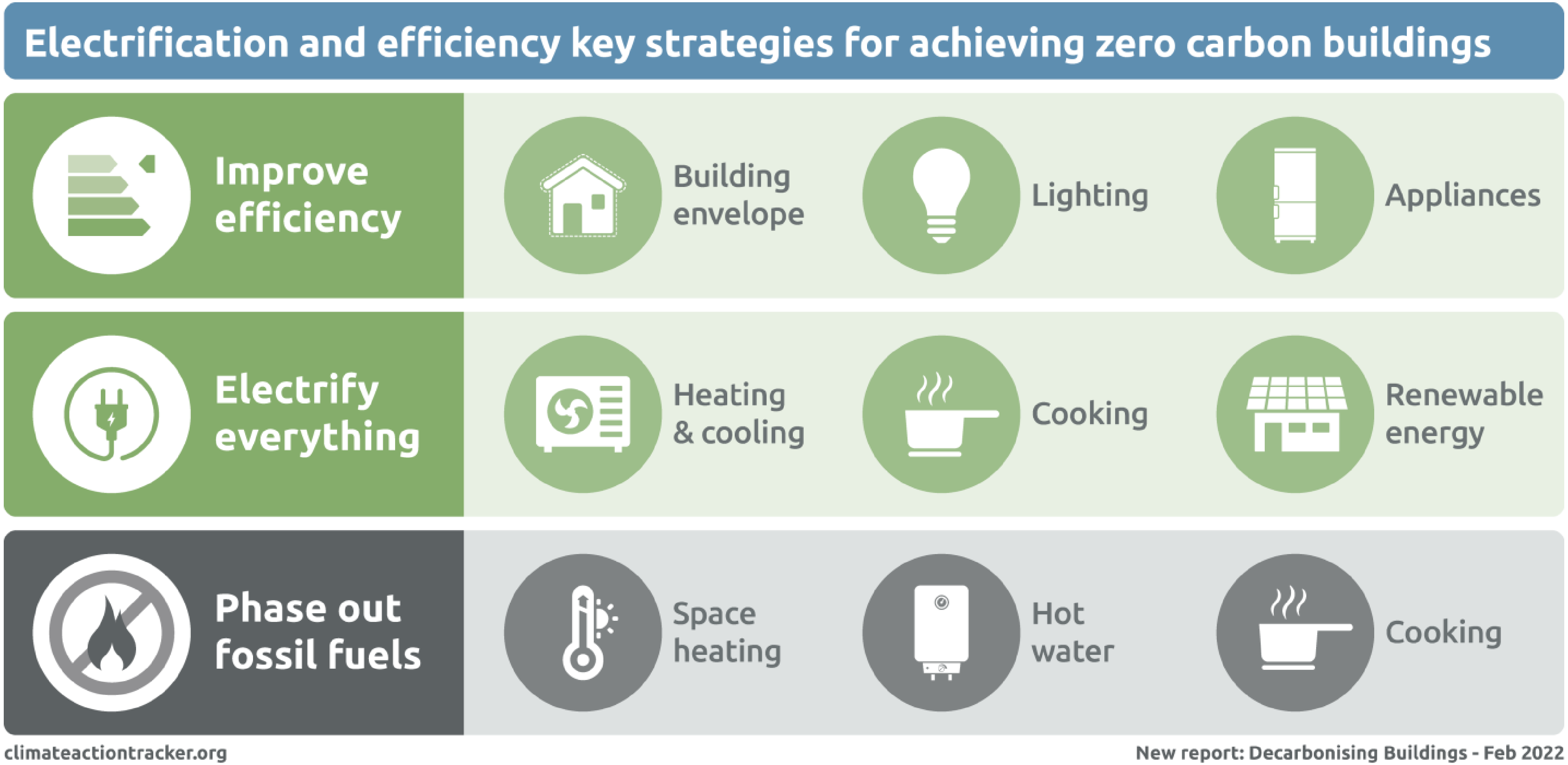


De Belgische energiemix van februari 2017 (bron : ELIA)

Zero Net Carbon Buildings

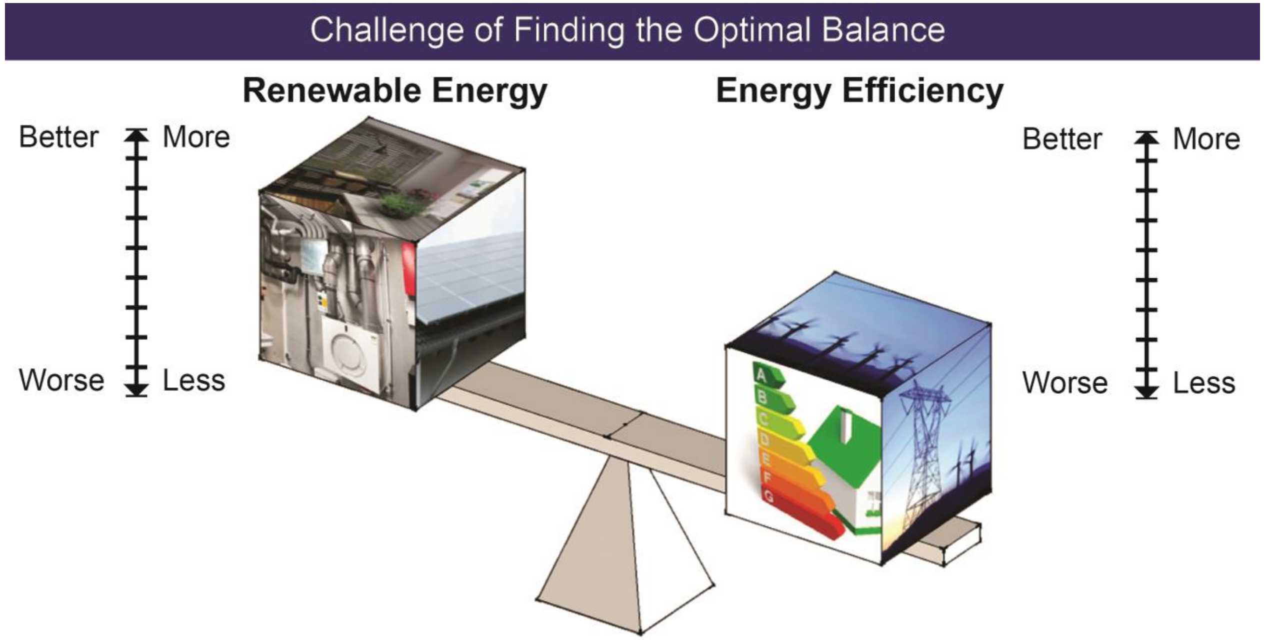
Electrification + Decarbonization

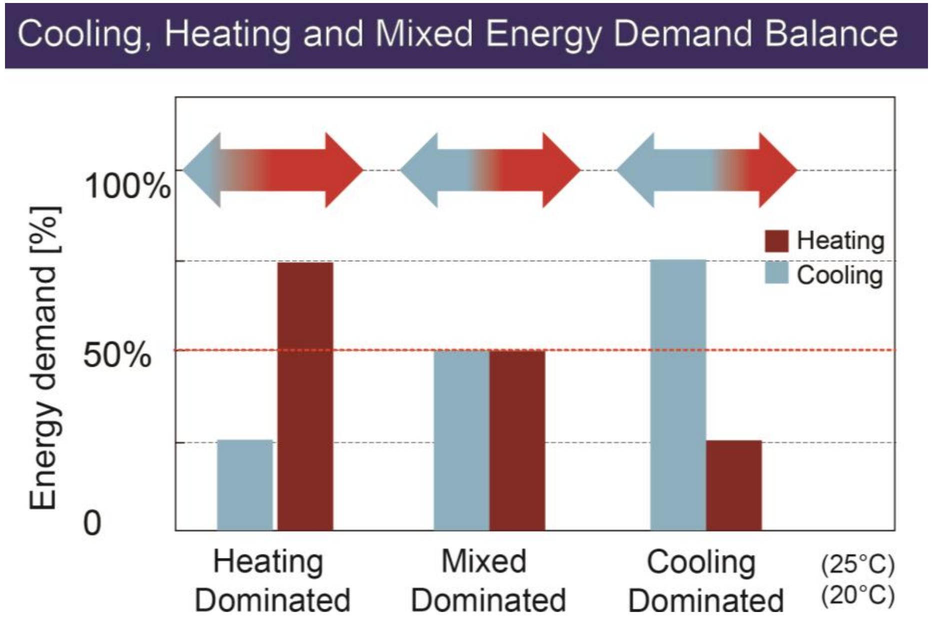
ASHRAE Standard 189.1, 2020



Zero Net Carbon Buildings

IEQ, Energy Efficiency and RES Balance

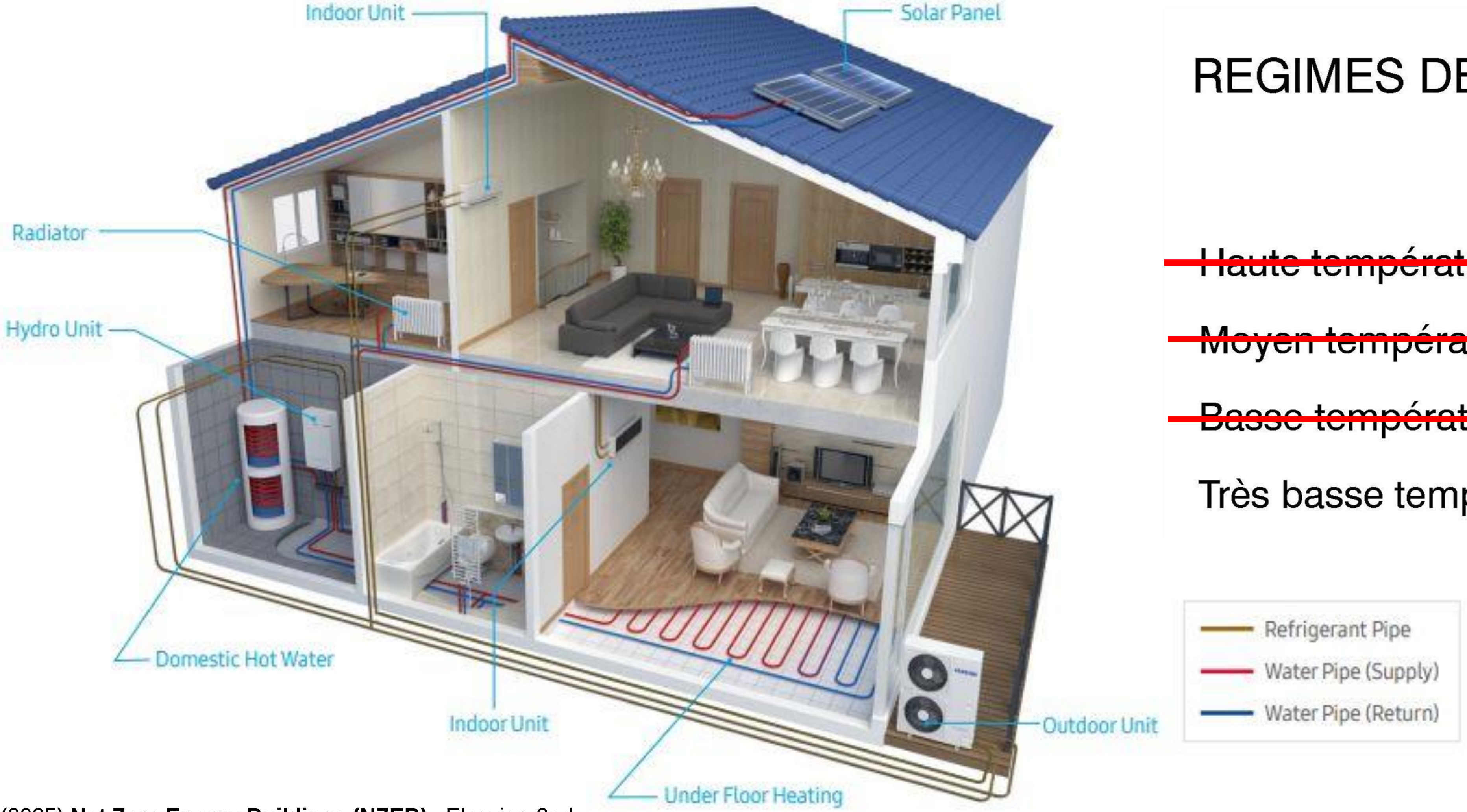




Attia, S. (2025) **Net Zero Energy Buildings (NZEB)** , Elsevier, 2nd

Zero Net Carbon Buildings

Decarbonization of Heating



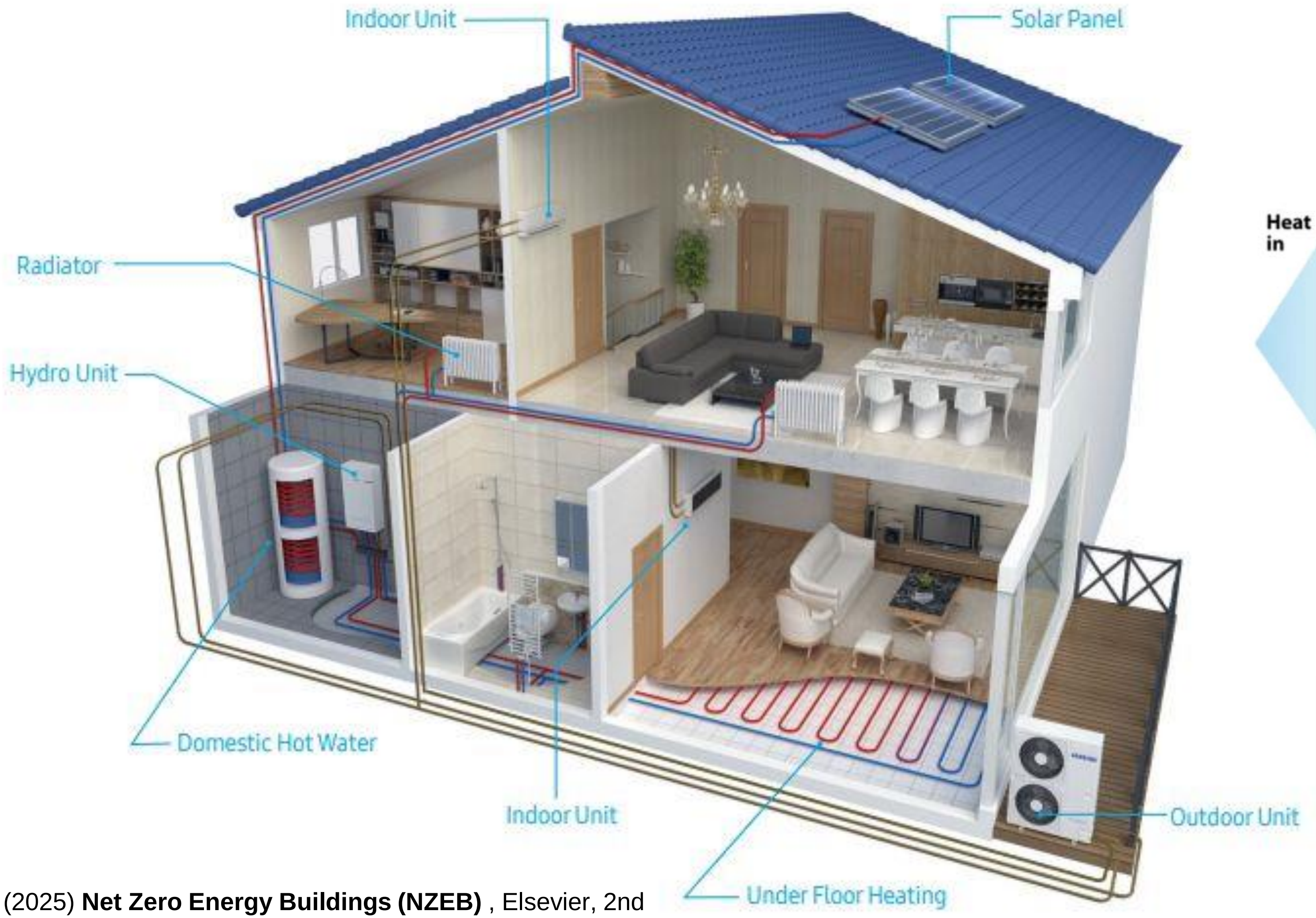
REGIMES DE TEMPERATURE

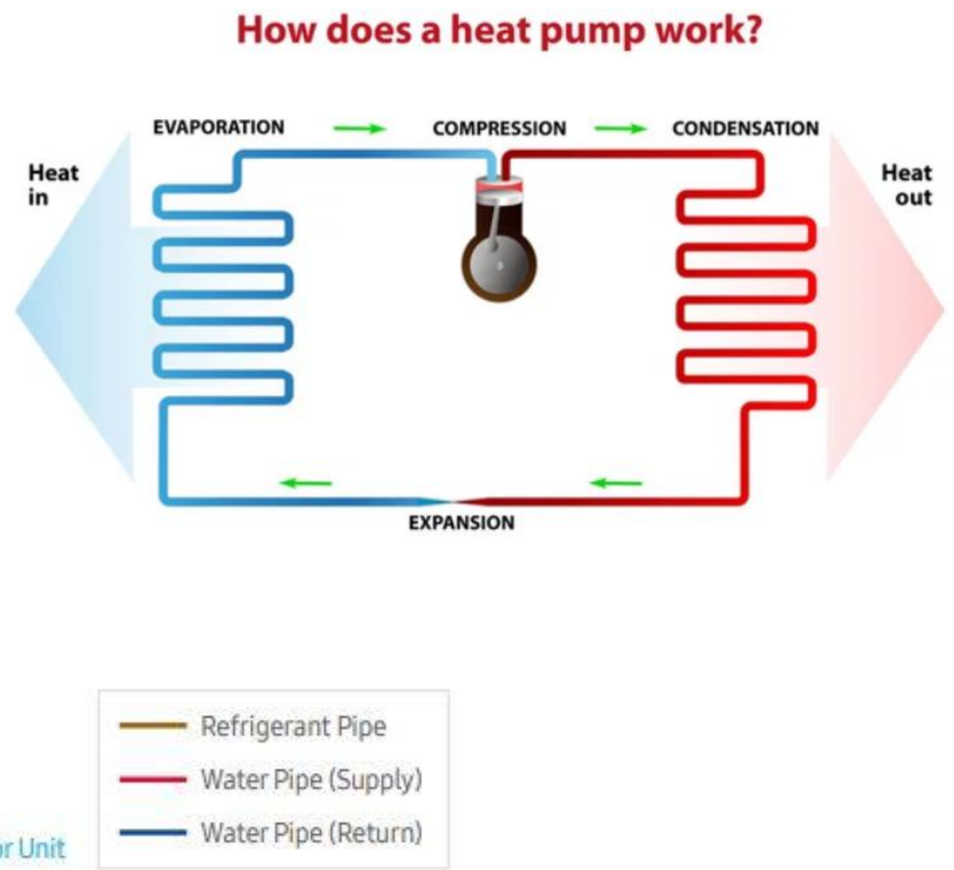
	T aller
~~Haute température~~	~~90°C~~
~~Moyen température~~	~~70°C~~
~~Basse température~~	~~55°C~~
Très basse température	30°C

Attia, S. (2025) **Net Zero Energy Buildings (NZEB)** , Elsevier, 2nd

Zero Net Carbon Buildings

All Electric with Heat Pumps





Attia, S. (2025) **Net Zero Energy Buildings (NZEB)** , Elsevier, 2nd

Zero Net Carbon Buildings

Worlds largest heat pump to be installed in Helsinki, Finland.

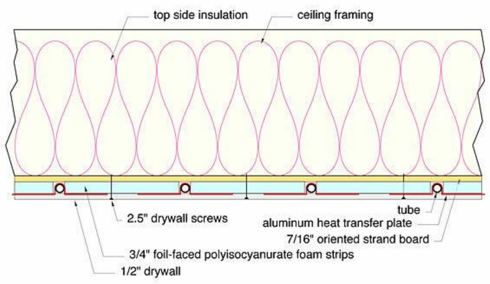
1. Full heating production capacity ranges from 20-33 MW, depending on the air temperature,
2. Can help deliver heat up to 90 degrees Celsius (194 Fahrenheit) while operating at temperatures as low as -20 degrees Celsius (-4 Fahrenheit).
3. The heat pump will provide heat for 30,000 homes in Helsinki annually, roughly saving 26,000 tonnes of CO_2 emissions.

Source: MAN Energy Solutions

Zero Net Carbon Buildings

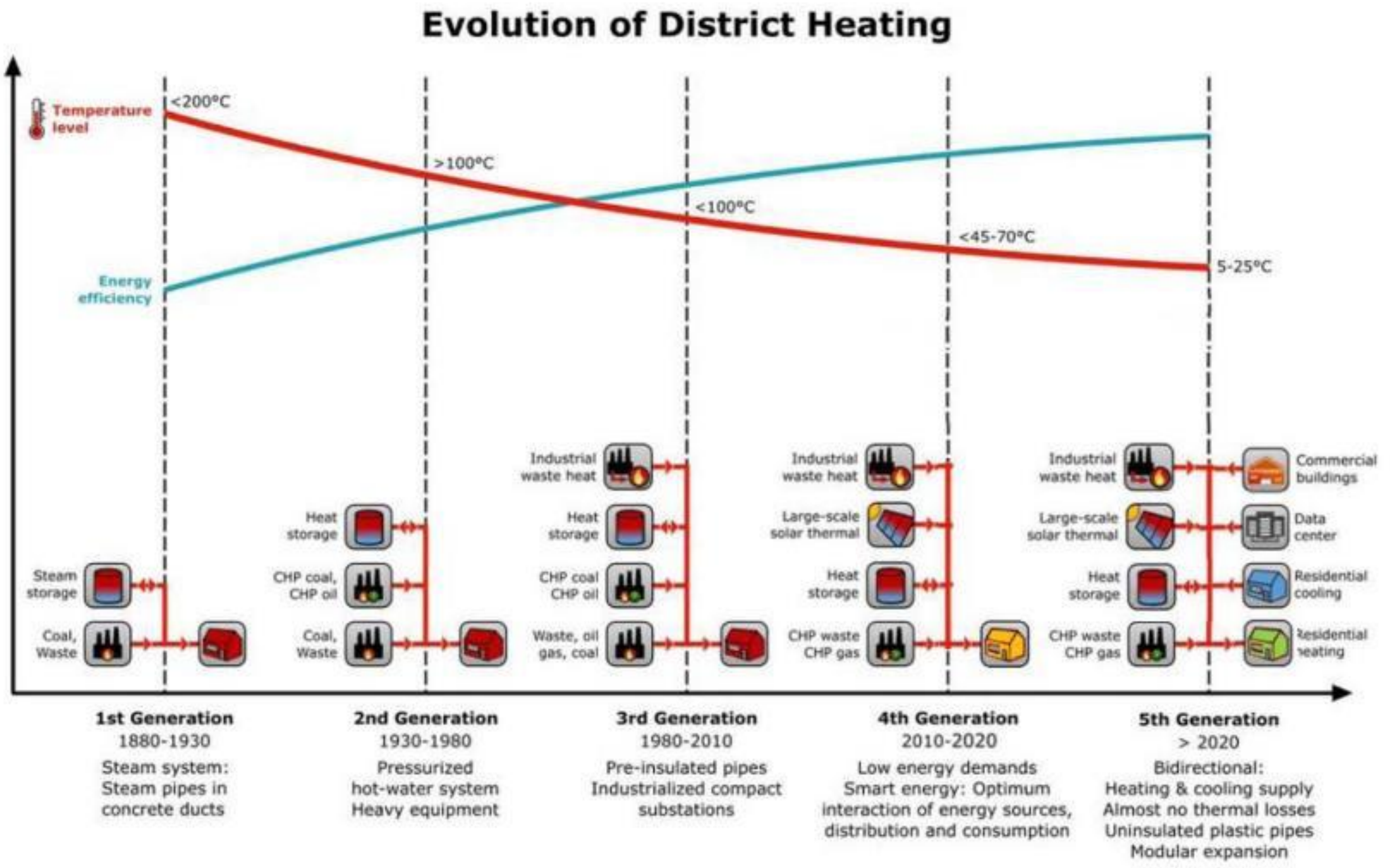
Floor Heating and Cooling

Hydronic radiant ceiling cooling/heating



District Heating & Cooling

LIÈGE université
SBD Lab

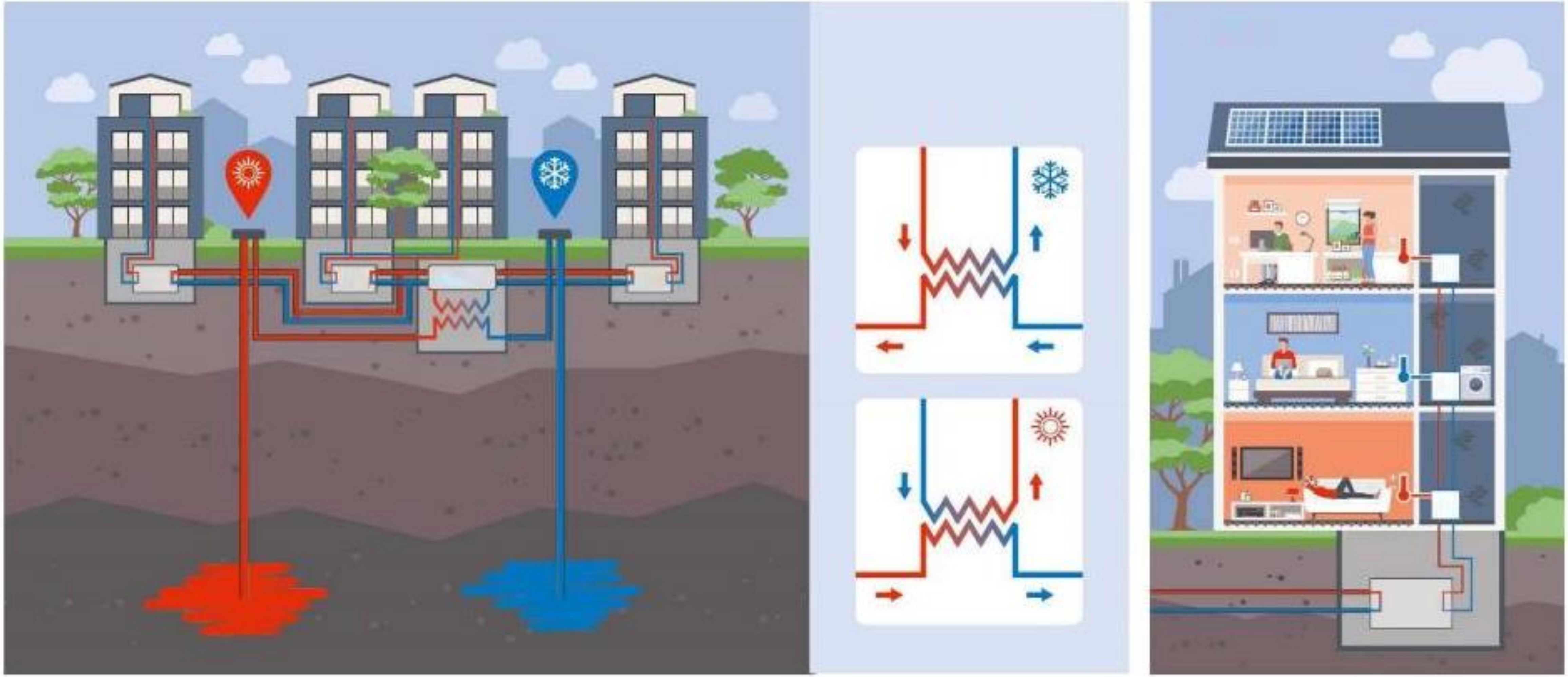


4th Generation:
District heating grid with a collective source

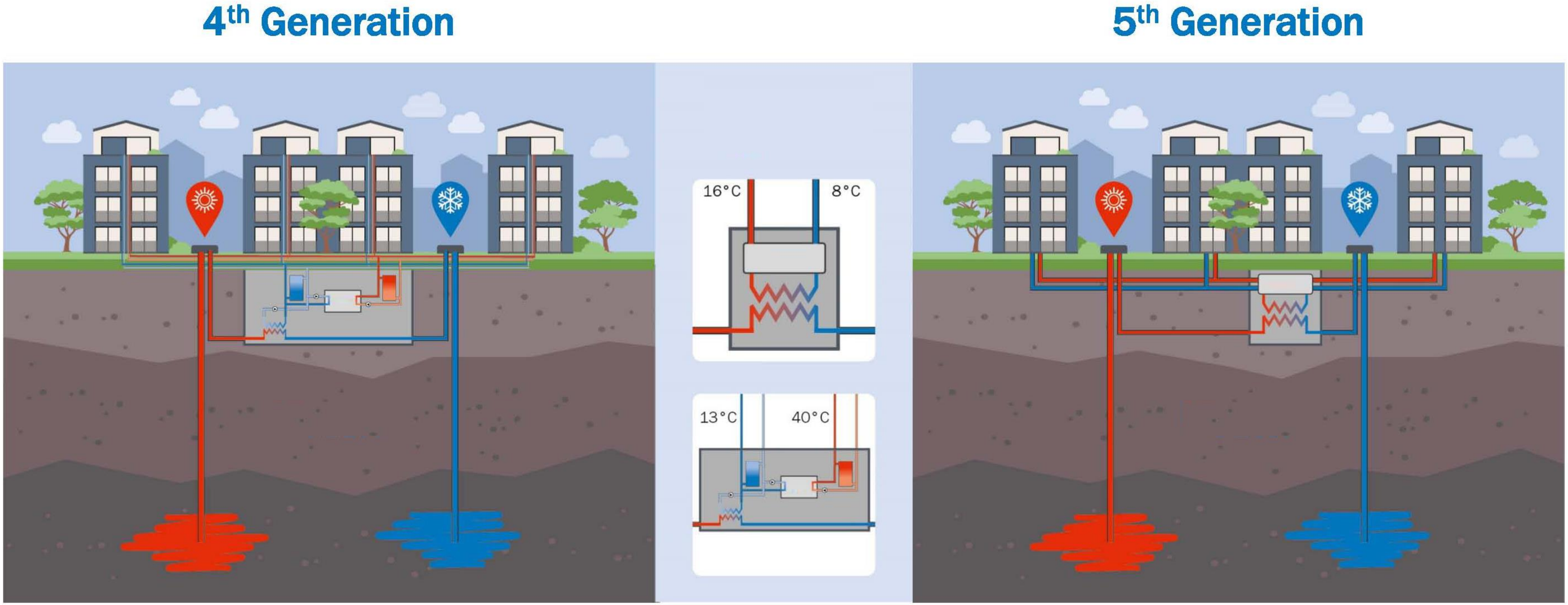
5th Generation:
Thermal energy directly from the subsurface
(T 5 – 25 °C)

District Heating Grid: 5th Generation

The Neutral Grid: Centralized Heat Pumps

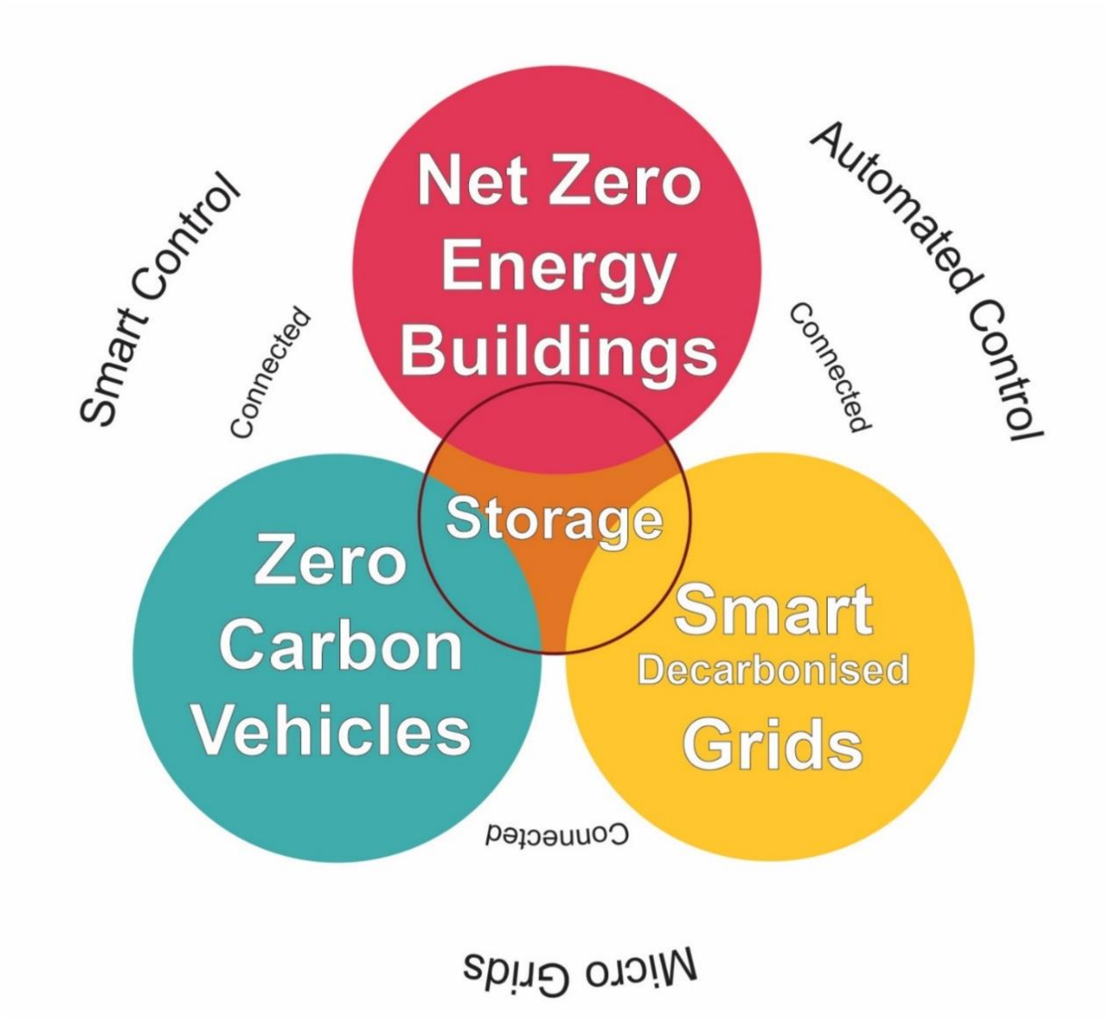


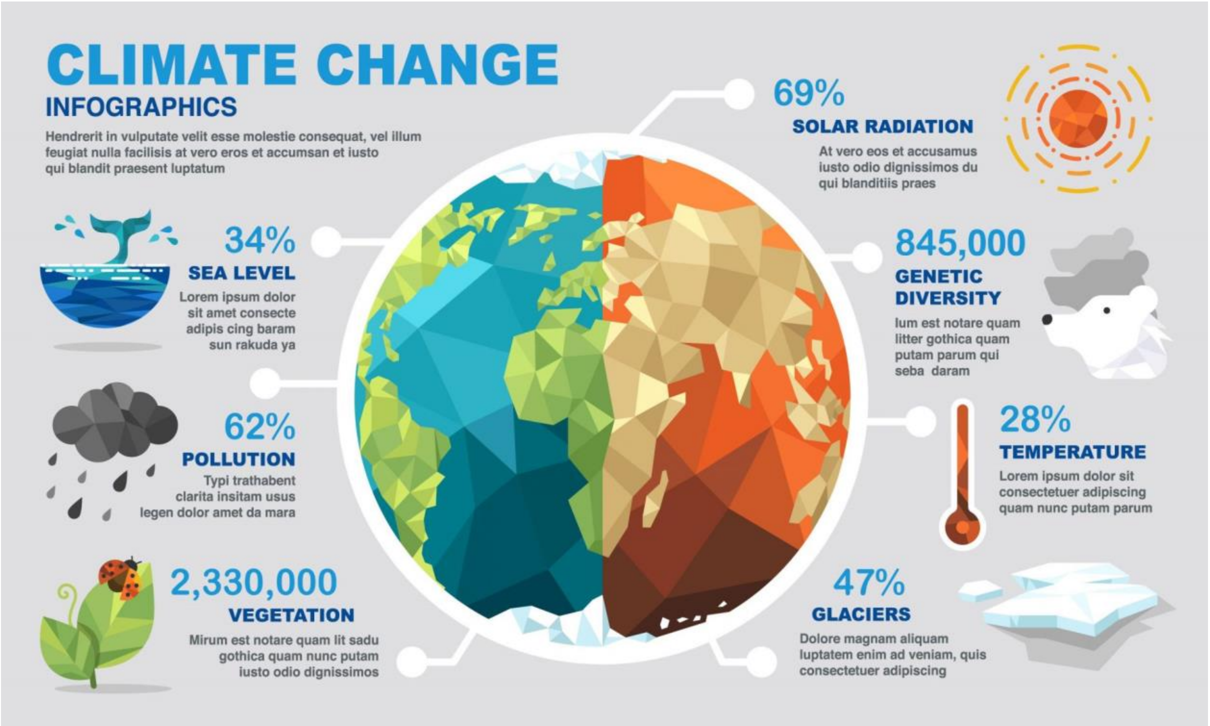
4th Generation vs. 5th Generation



Carbon Neutral Communities

Storage & Scale the Core of Carbon Neutrality



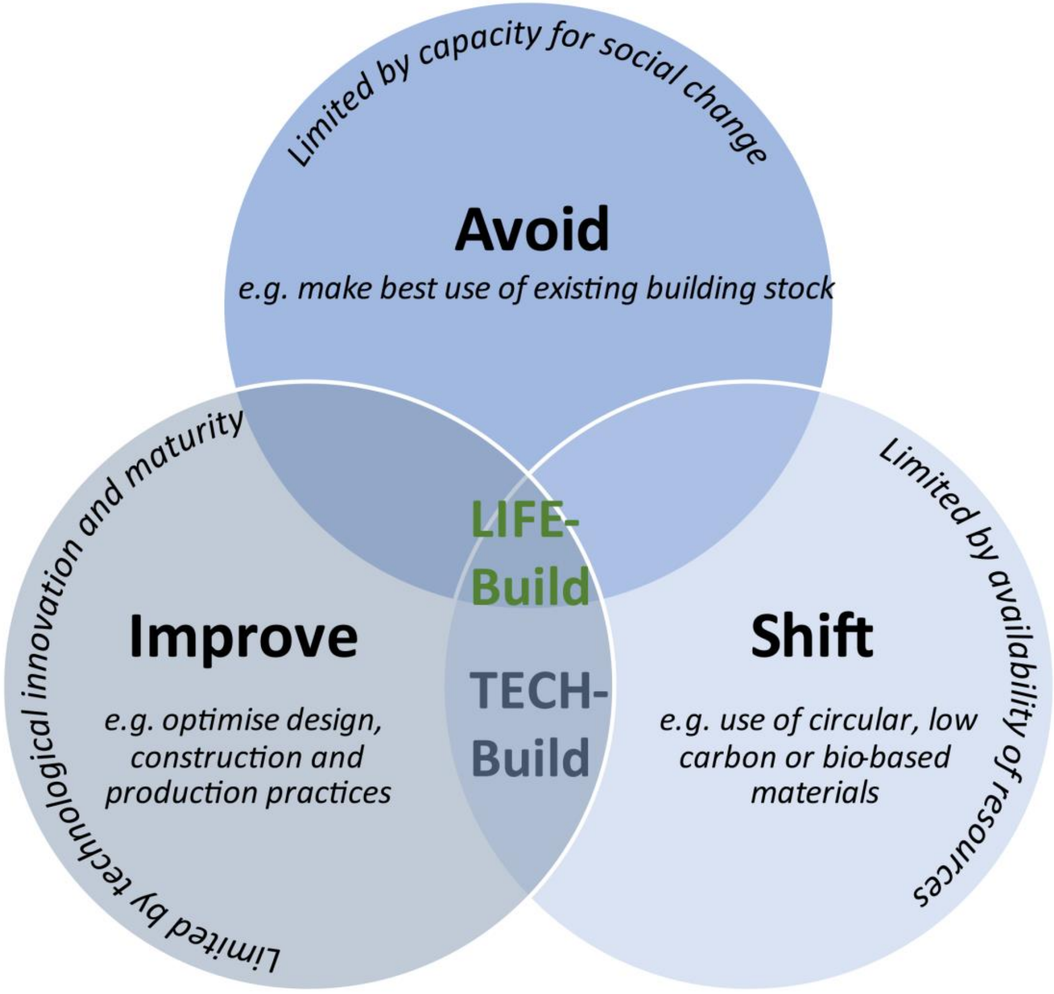


Resilience

Source: Attia, S. (2025) **Net Zero Energy Buildings (NZEB)** , Elsevier, 2nd

Carbon Neutral Communities

Storage & Scale the Core of Carbon Neutrality

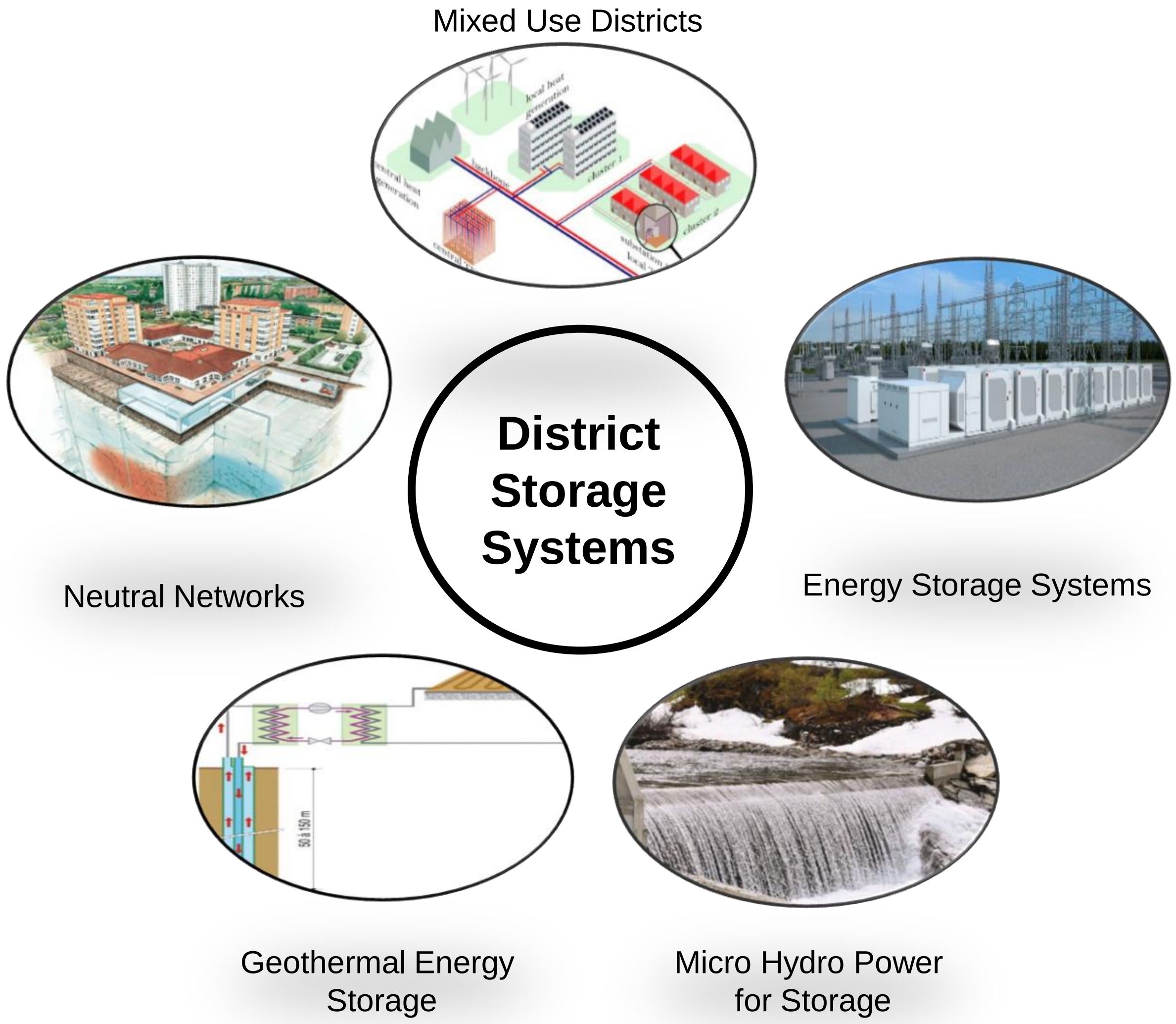


Resilience

Source: Le Den, X. et al. (2023). Towards an EU roadmap for reduction of whole life carbon in buildings. Brussels, Belgium.

Energy Storage Systems

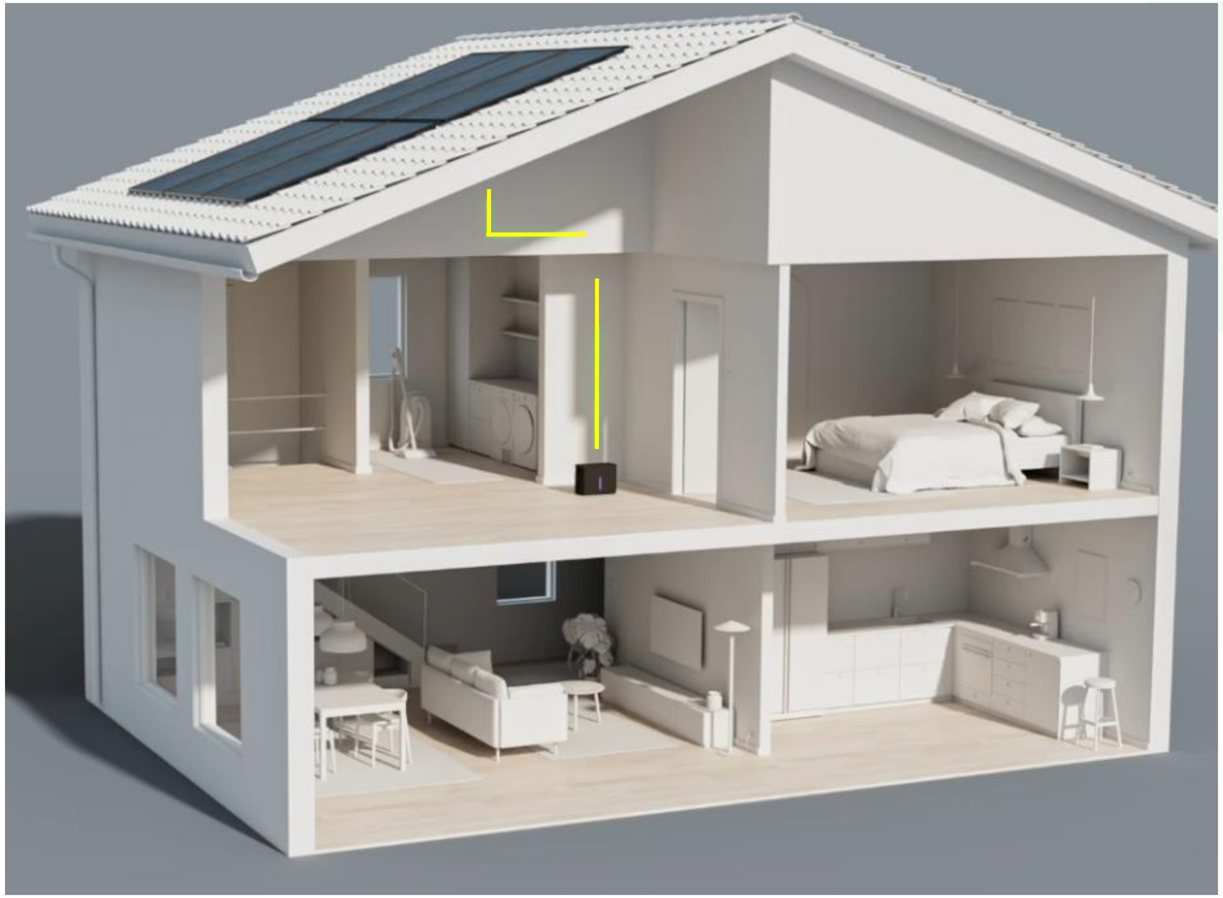
The Core of Carbon Neutrality



Zero Net Carbon Buildings

Plug-In Battery

2 kWh and 5 kWh cover all households equipments and appliances



Source: https://www.homewizard.com/

Zero Net Carbon Buildings

Regulations on Refrigerants

ISO 817

1. EU Directive introduced in 2006 on the direct impact of air conditioning systems
2. February 2024: EU set a steeper schedule for phasing down fluorinated gases
3. Prohibition of product categories: Chillers, Heat Pumps and Split Air Conditioning systems

Split Air-to-Water		
X <= 12 kW at 150 GWP	➡	1st January 2027
X <= 12 kW full F Gas prohibition	➡	1st January 2035
X > 12 kW at 750 GWP	➡	1st January 2029
X > 12 kW at 150 GWP	➡	1st January 2033

Time period	Updated EU phase down adopted in February 2024
2021 - 2023	
2024 - 2026	23.6%
2027 - 2029	10.1%
2030	5%
2048	2.38%

Zero Net Carbon Buildings

New refrigerants – new rules

ISO 817

Refrigerant	GWP	Safety class ISO 817; PED (EU)
R718 (Water)	0	A1 (non-flammable)
R744 (CO2)	1	A1 (non-flammable)
R290 (Propane)	3	A3 (higher flammability)
R1234yf	4	A2L (mildly flammable)
R1234ze	7	A2L (mildly flammable)
R454b	466	A2L (mildly flammable)
R513A	631	A1 (non-flammable)
R32	675	A2L (mildly flammable)
R410A	2088	A1 (non-flammable)

Future influences:

- Achieving low-carbon buildings
- Growth of hydronic technologies and low GWP- refrigerants
- Advanced control and monitoring systems
- Retrofit balance
- Balance what’s possible and what’s practical

Zero Net Carbon Buildings

LIÈGE université
SBD Lab

Smart Meters & Grid Mix Emission Factors

ISO 52000-3:2023

- Net-Zero Energy ≠ Net-Zero Carbon
- Belgium has a 15 min – grid mix factor

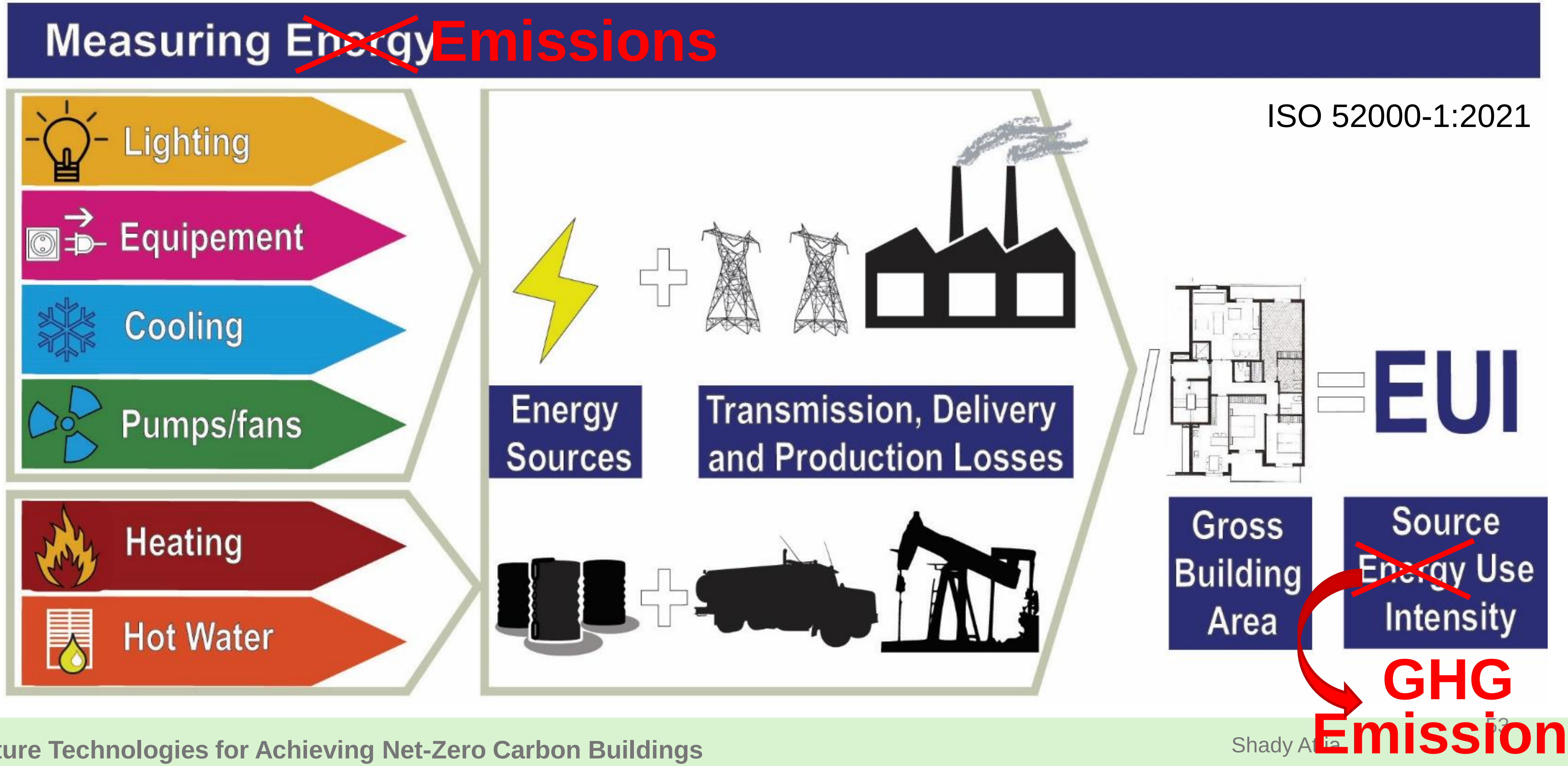
- Annual operational emissions calculations based on dynamic factors and export/import fluctuations

EMISSION FACTOR [g/kWh] — 2023, HOUR of the day × MONTH

HOUR of the day	1	2	3	4	5	6	7	8	9	10	11	12
1	411	517	487	484	500	543	580	544	512	470	480	383
2	406	516	484	473	474	534	561	532	509	472	479	380
3	402	516	478	467	475	534	563	529	506	472	479	379
4	400	517	483	464	480	533	566	529	506	473	480	380
5	403	519	485	467	487	533	570	533	509	476	483	383
6	415	523	493	477	498	536	573	540	518	486	489	391
7	429	529	500	487	502	535	568	542	527	492	499	402
8	441	531	498	479	489	518	545	524	521	497	505	411
9	447	522	483	454	463	487	508	493	494	486	498	415
10	446	501	462	422	426	451	467	457	461	462	486	414
11	440	481	441	389	390	421	434	421	425	439	476	408
12	434	466	426	365	365	400	410	393	396	418	471	404
13	432	458	420	351	350	387	396	378	376	404	470	404
14	437	460	420	344	345	379	389	371	368	401	479	409
15	447	473	430	344	348	379	391	372	372	411	495	420
16	460	494	448	356	360	389	401	384	391	433	516	429
17	468	521	473	381	383	408	420	408	424	466	520	430
18	469	540	499	425	416	440	456	450	475	505	511	426
19	464	540	513	478	459	481	498	498	526	521	502	421
20	457	530	512	517	497	519	541	540	549	513	495	415
21	448	523	505	522	518	546	572	562	547	502	491	407
22	440	520	500	511	511	556	580	563	537	493	486	399
23	434	520	500	500	499	551	575	554	529	487	486	396
24	425	518	496	487	489	540	570	545	519	477	482	386

Zero Net Carbon Buildings

Converting the primary energy use intensity to GHG emissions



Carbon Neutral Communities

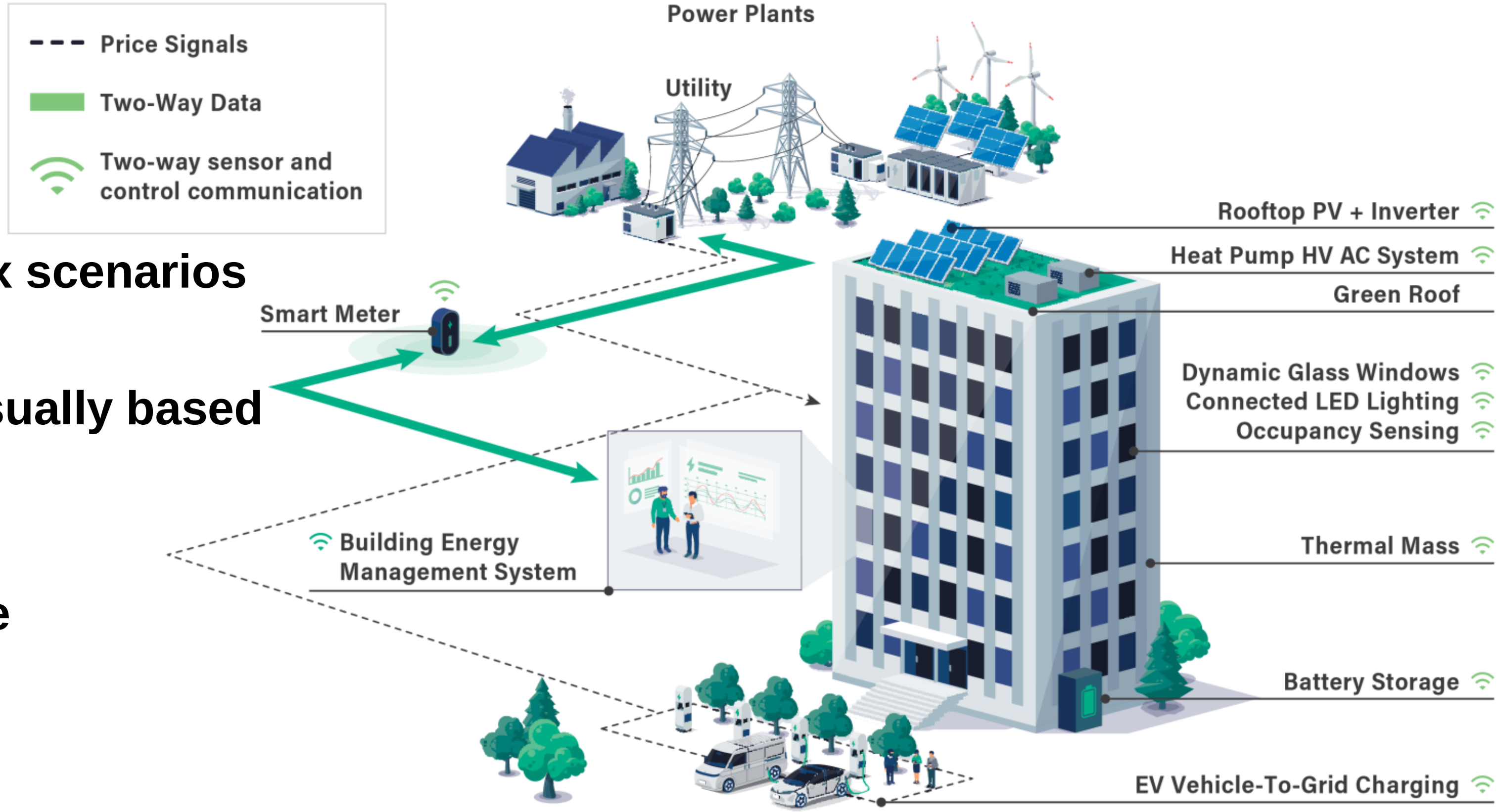
LIÈGE université SBD Lab

From Single Building to Community

Carbon Neutral Communities

From Single Building to Community

1. Either average or marginal grid mix scenarios are typically adopted
2. Environmental data sources are usually based on averages:
   - Real-time Generation Mix Data
   - Carbon Intensity of Each Source
   - Power Demand and Grid Load
   - External Data Sources
   - Emissions Factor Calculation
   - Updating the Signals through smart grids



Source: NREL.

WORLD RESOURCES INSTITUTE

Source: https://trellis.net/article/health-economic-and-community-benefits-zero-carbon-buildings/

Conclusion

LIÈGE université

The transition towards zero-emission buildings

PAST | TRANSITION | FUTURE

2021
nearly Zero-Energy
low renovation rates

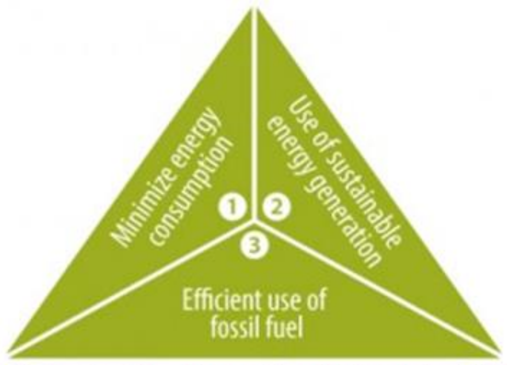


Figure 1a: Trias Energetica (Duijvestein, 2010)

2030
nearly Zero Emission
massive deep renovation

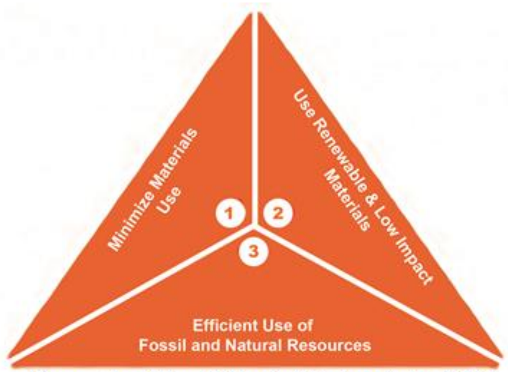


Figure 1a: Trias Materia (Duijvestein, 2010)

2050
zero-emission built environment

The transition towards Zero-emission buildings

PAST | TRANSITION | FUTURE

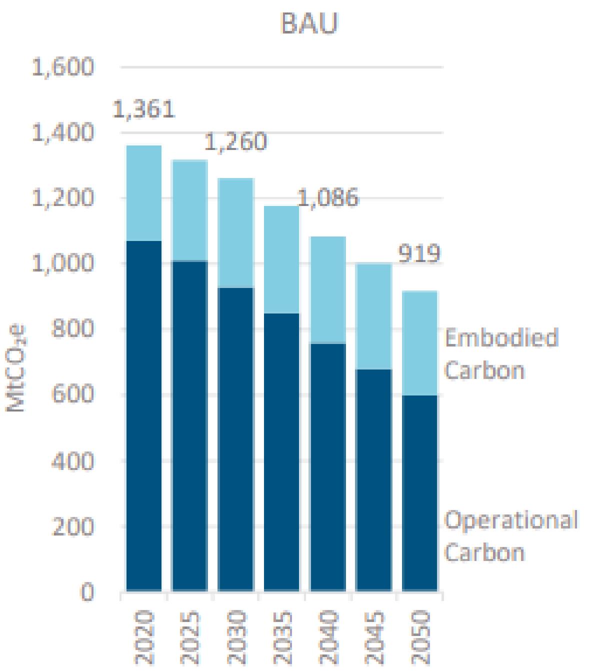


Figure 2 Development of WLC emissions in a business-as-usual scenario

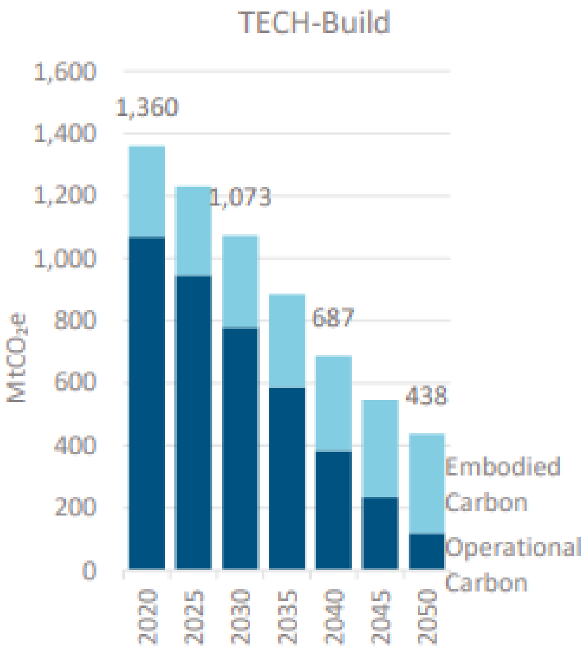


Figure 3 Development of WLC emissions in the TECH-Build scenario

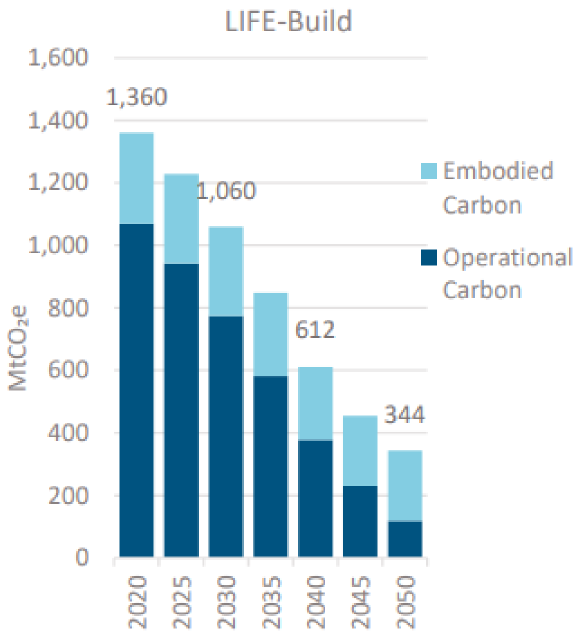


Figure 4 Development of WLC emissions in the LIFE-Build scenario

Le Den, X. et al. (2023). Towards an EU roadmap for reduction of whole life carbon in buildings. Brussels, Belgium.

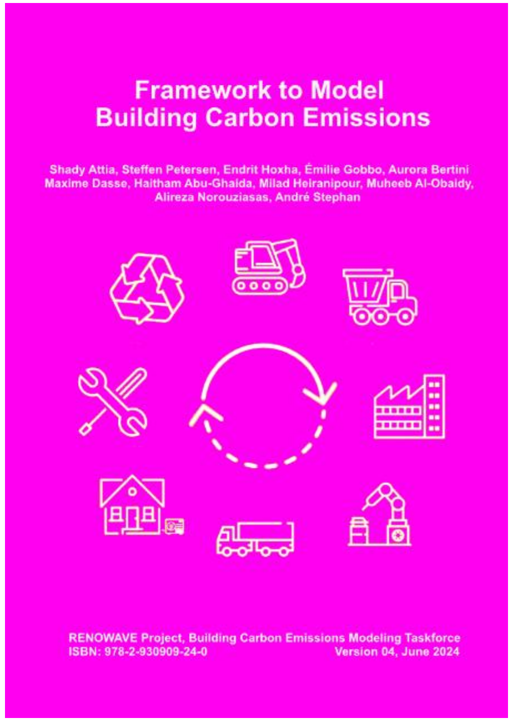
Framework for Building Modelling

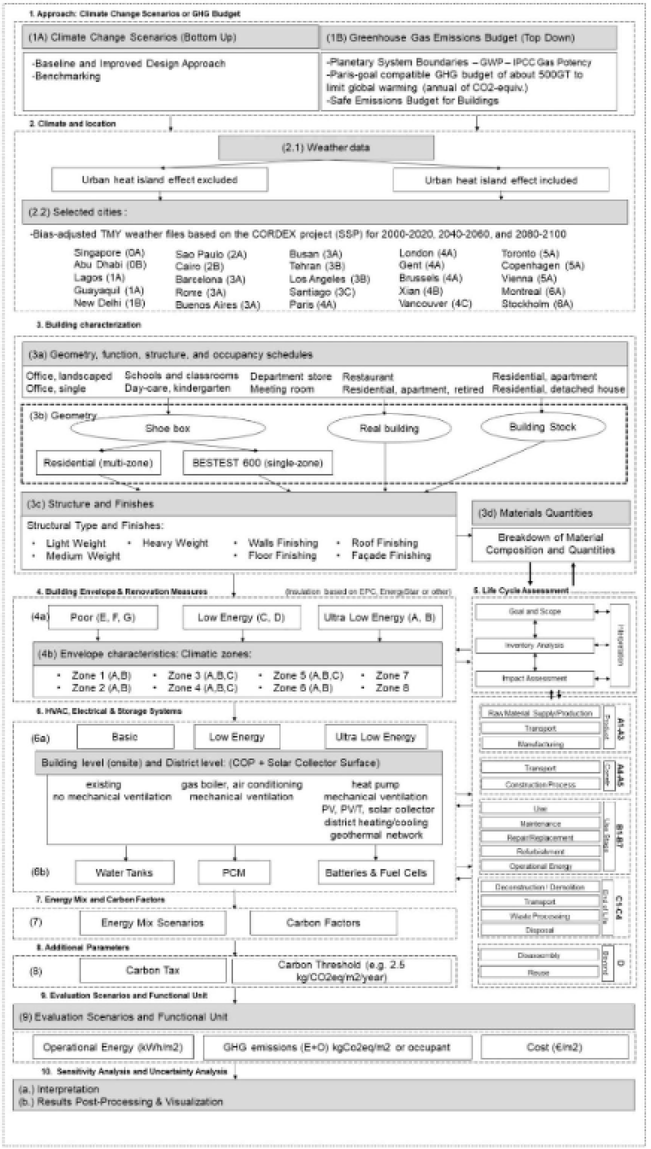
For Zero Carbon Buildings

10 Modules

Paris-goal-compatible assessment method

- evaluate the assessment methods proposed or required by current climate policies, aiming to check their compatibility with meeting the science-based carbon targets and budgets





Attia, S., Petersen, S., Hoxha, E., Gobbo, E., Bertinit, A., Dasse, M., et al. (2024) Framework to Model Building Carbon Emissions, Report, Sustainable Building Design Lab, Liege University, Liege, Belgium. DOI: 10.13140/RG.2.2.15338.73925/3

Conclusion

What should be focused on:

- ➢ Adopt the new indicators of GWP and Module A-B-C + (D)
- ➢ Get experienced with carbon numbers through EPDs (databases)
- ➢ Use consistent methodology and software

Zero Carbon Emissions Buildings Ingredients:

> Reduced building area
> Minimized car parking
> High-Performance envelope
> Electric heating & cooling
> Biogenic materials
> 40% window-to-wall ratio
➢ Plug-in batteries
> Solar PV on roof and facades

Category	Embodied carbon reduction solution
Avoid	Optimize/reduce the use of space in offices and residential buildings
Avoid	Use existing assets that are currently unused instead of new buildings.
Avoid	Renovate instead of build new
Improve	Design for adaptability, resilience and extended lifespan
Improve	Design for disassembly
Improve	Design based on light construction methods instead of massive construction
Improve	Reduce concrete demand by use of void formers in concrete slabs
Improve	Use carbon cured concrete
Improve	Implement carbon capture in cement production
Improve	Implement carbon capture in steel production
Shift	Re-use existing building components and materials
Shift	Use industry by-products instead of clinker in cement
Shift	Use alternative cementitious materials instead of cement in concrete
Shift	Use recycled concrete and other by-products for new concrete
Shift	Full timber construction
Shift	Hybrid (concrete + timber) structures in new construction
Shift	Use other bio-based materials
Shift	Use recycled steel in steel production
Shift	Use recycled glass in glass production
Shift	Use renewable energy in cement production
Shift	Use renewable energy in steel production and other metals
Shift	Use renewable energy in glass production

Le Den, X. et al. (2023). Towards an EU roadmap for reduction of whole life carbon in buildings

Directions:
Begin by setting a decarbonization performance goal and limit for your project. Start by mixing the smallest building area with the minimal parking. Next, add a high-performance building envelope alongside an electric heating and cooling system. Add a pinch of solar PV and a large scoop of biogenic materials and run the energy and life cycle impact assessment simulations.

Questions?

Notre Dame University (NDU)
Shouf Campus
Ramez G.Chagoury Faculty of Architecture, Art, and Design

Future Technologies for Achieving Net-Zero Carbon Buildings

Lebanon | April 09, 2025

Prof. Dr. Shady Attia
Sustainable Building Design Lab, UEE,
Applied Sciences, University of Liège, Belgium
shady.attia@uliege.be

/in/shady-attia-14352a7
/www.shadyattia.org

LIÈGE université SBD Lab

References

Attia, S., Petersen, S., Hoxha, et al. (2024). Framework to Model Building Carbon Emissions. (Version 5). Liege, Belgium: Sustainable Building Design Lab. doi:10.13140/RG.2.2.15338.73925/4;
Attia, S. (2025) Net Zero Energy Buildings (NZEB), Elsevier, 2nd Edition, Camridge, UK

Alaux, N., Saade, M. R. M., Hoxha, E., Truger, B., & Passer, A. (2023). Future trends in materials manufacturing for low carbon building stocks: A prospective macro-scale analysis at the provincial level. Journal of Cleaner Production, 382, 135278.

An, J., Wu, Y., Gui, C., & Yan, D. (2023). Chinese prototype building models for simulating the energy performance of the nationwide building stock. Building Simulation, 16(8), 1559–1582. https://tinyurl.com/3z8kyzwu

ASHRAE, S. (2021). Standard 189.1- Standard for the Design of High-performance Green Buildings. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 66.

Attia, S. (2023). DynamicRenowave: Life Cycle Assessment and Energy Simulation of Building Renovation Strategies. https://www.sbd.uliege.be/dynamicrenowave

Attia, S., & Petersen, S. (Directors). (2024, April 24). Building Carbon Emissions Modeling Framework (Webinar 1). https://www.youtube.com/watch?v=5OfzJ9yCAkA

Bertini, A., & Dasse, M. (Directors). (2024, April 24). Building Carbon Emissions Modeling Framework (Webinar 2). https://www.youtube.com/watch?v=4B3Cs4ewIVc&t=1662s

CEN (2019). 15804:2019+A2 sustainability of construction works—Environmental product declaration—Core rules for the product category of construction products. European Committee for Standardization, Brusssles, Belgium.

CEN (2021). EN 15643:2021 - Sustainability of construction works - Framework for assessment of buildings and civil engineering works, European Committee for Standardization, Brussels, Belgium.

Le Den, X. et al. (2023). Towards an EU roadmap for reduction of whole life carbon in buildings. Brussels, Belgium.