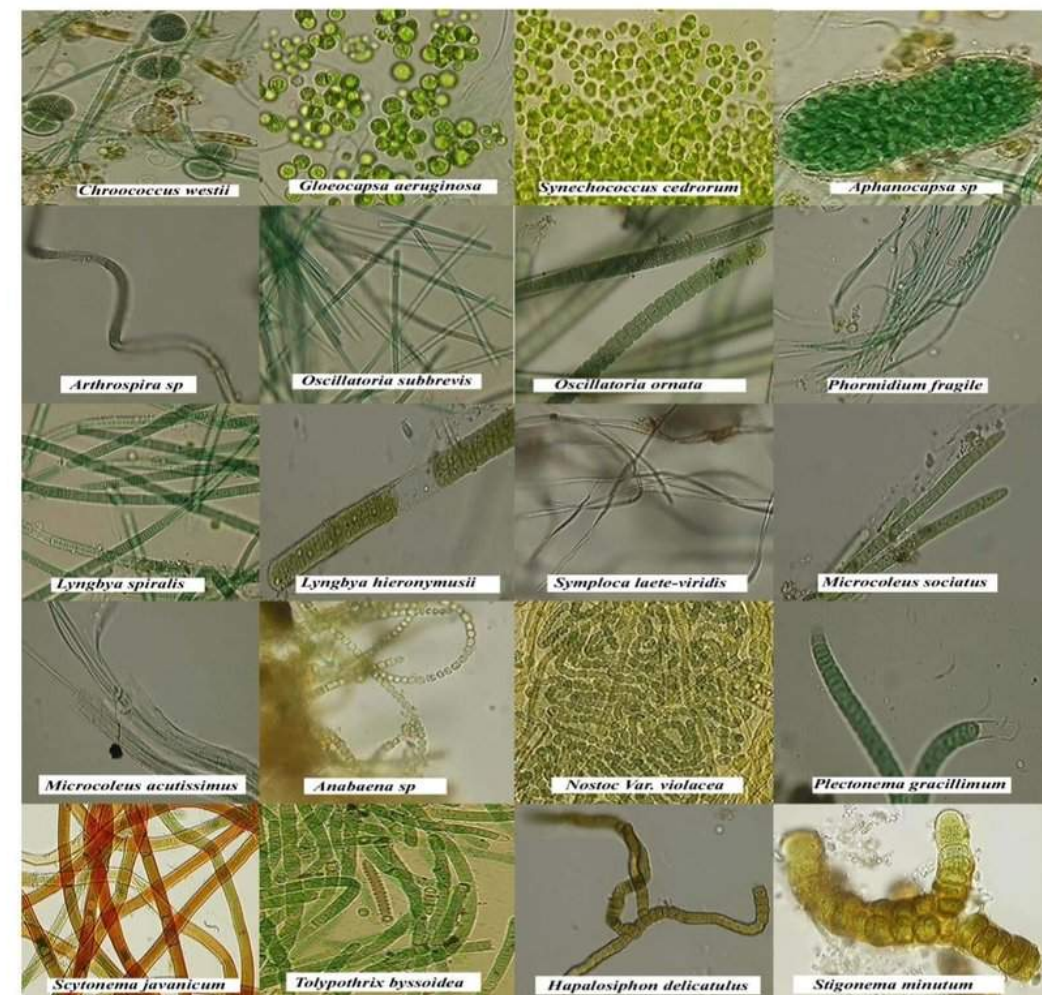
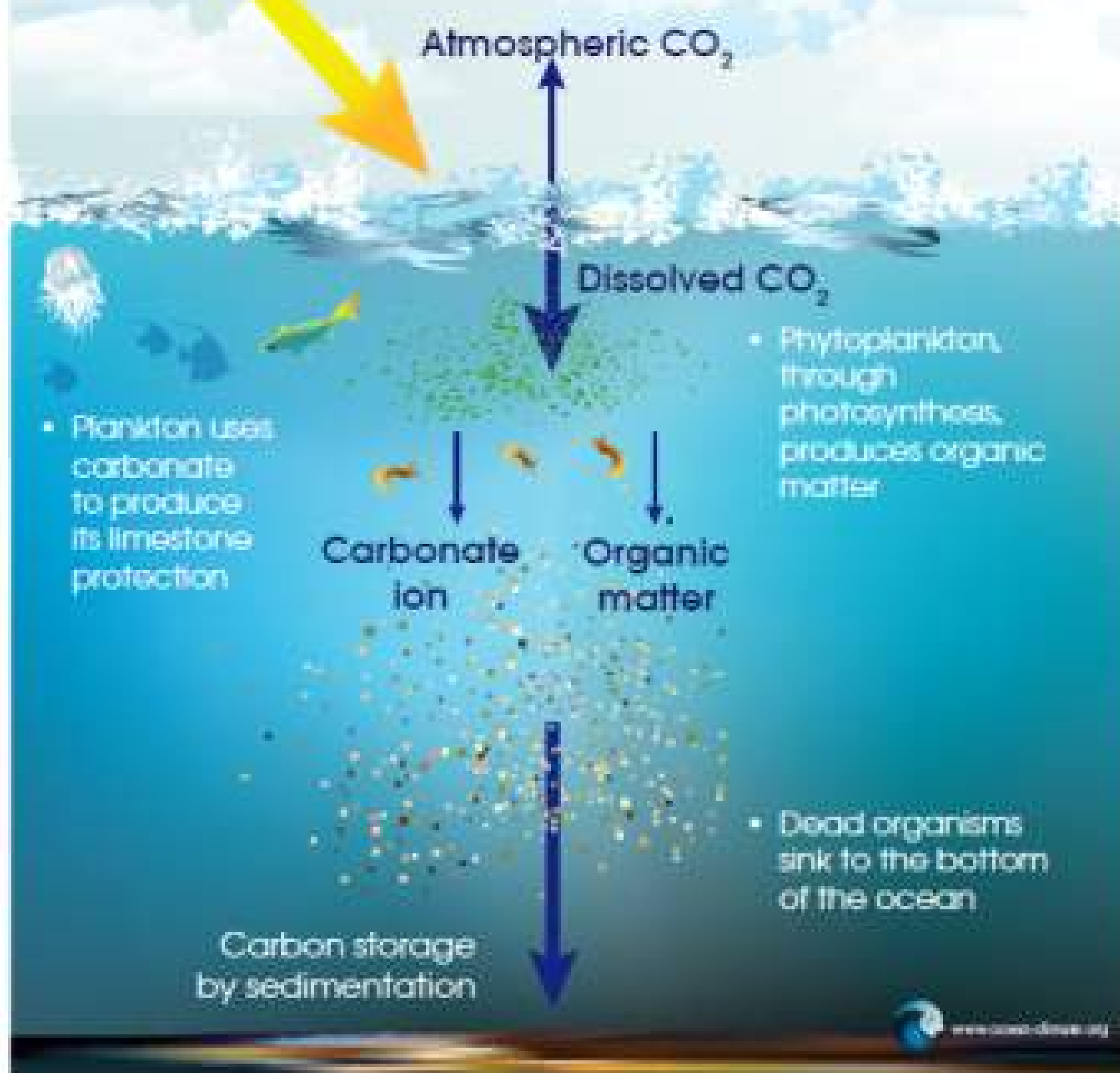
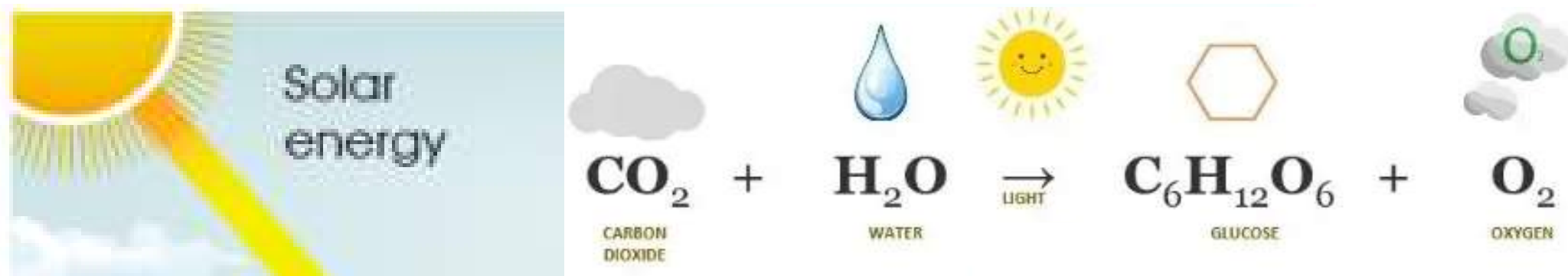


The Atmosphere and Embodied Carbon

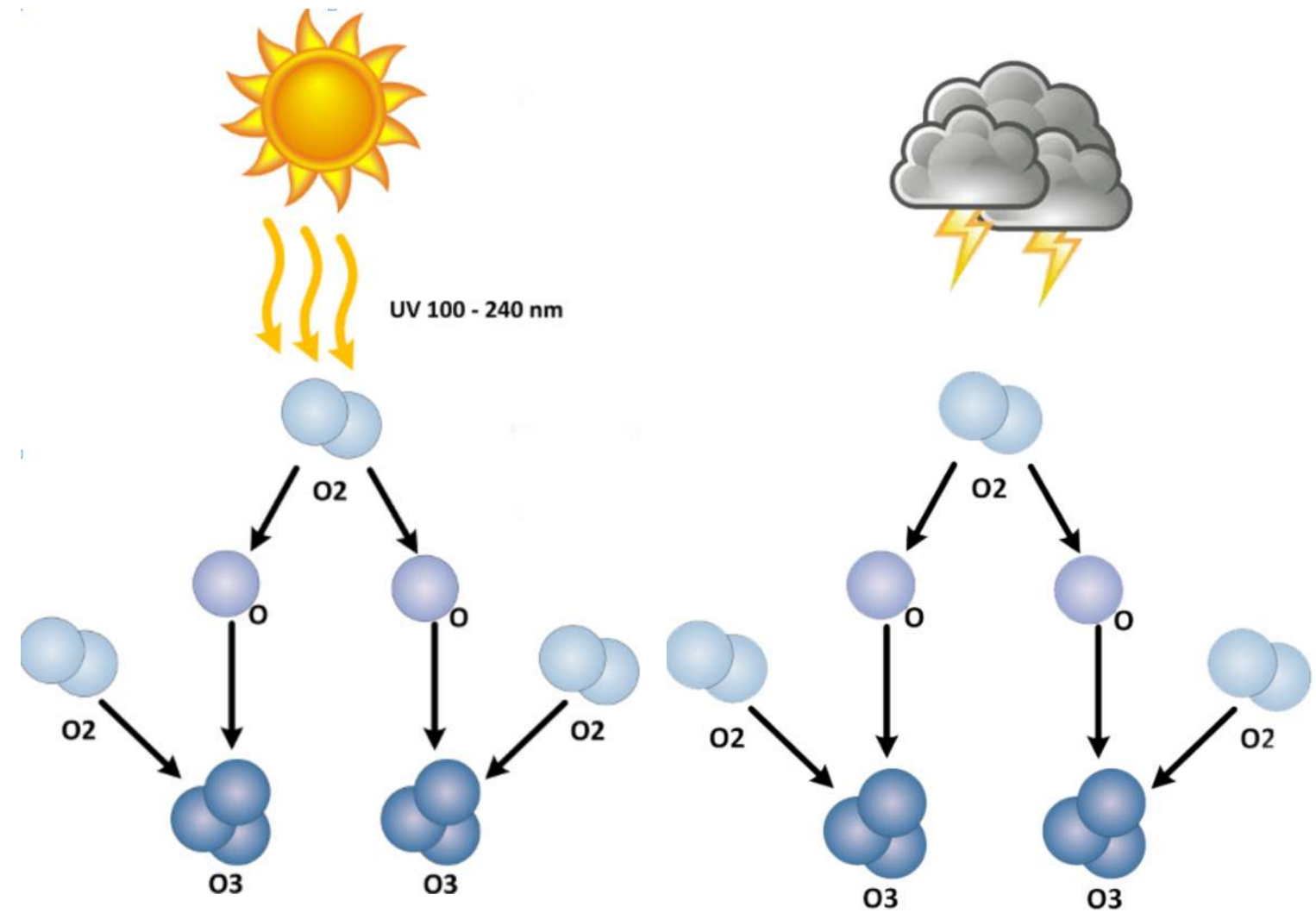
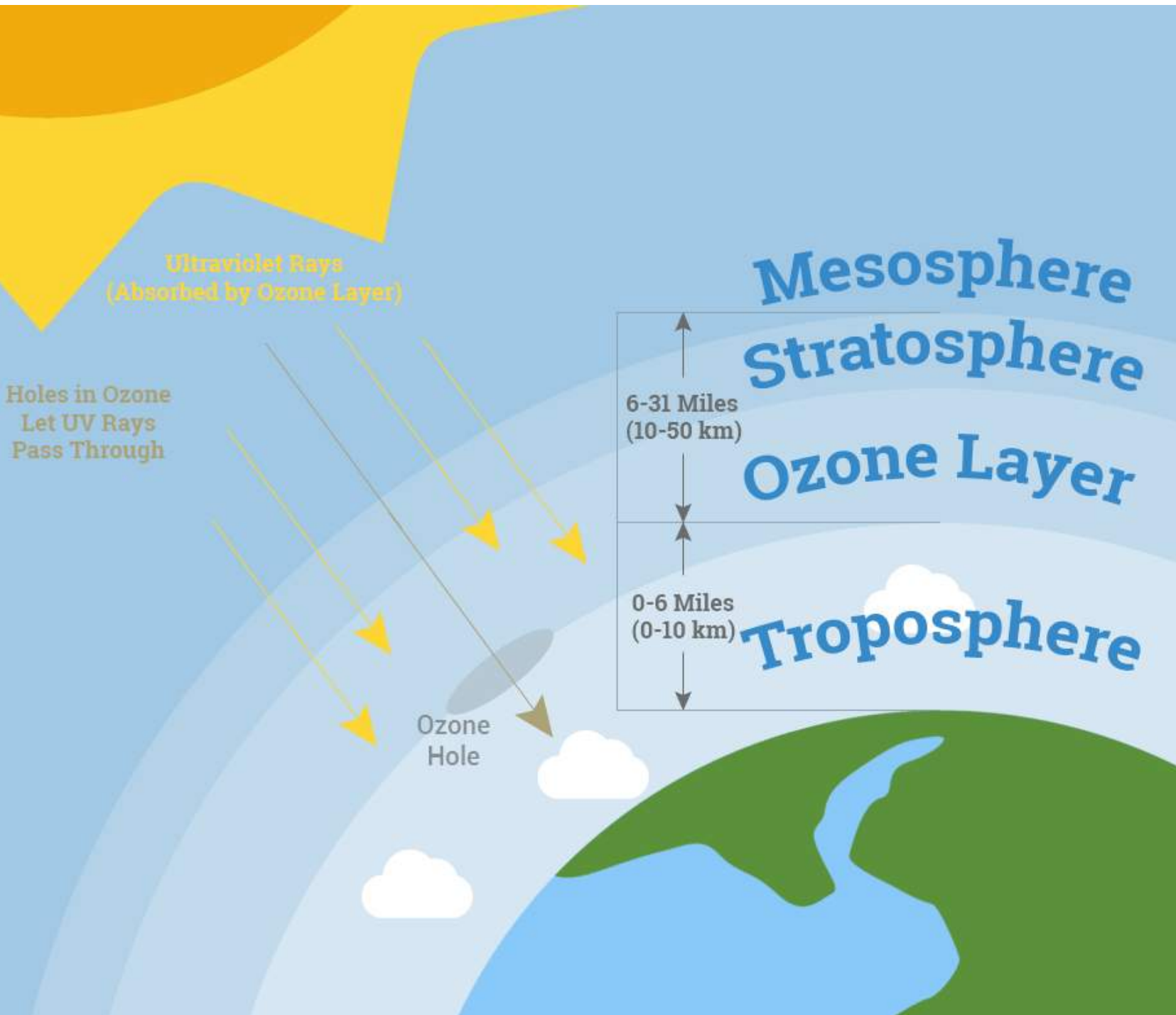
THE ATMOSPHERE

The image is a composite background featuring a view of Earth from space. The top half shows a dark, star-filled sky. The bottom half shows the Earth's horizon with a blue atmosphere and white clouds. The title 'THE ATMOSPHERE' is centered in white, bold, sans-serif font. There are several lens flare effects, including a large one on the left and several smaller ones on the right.

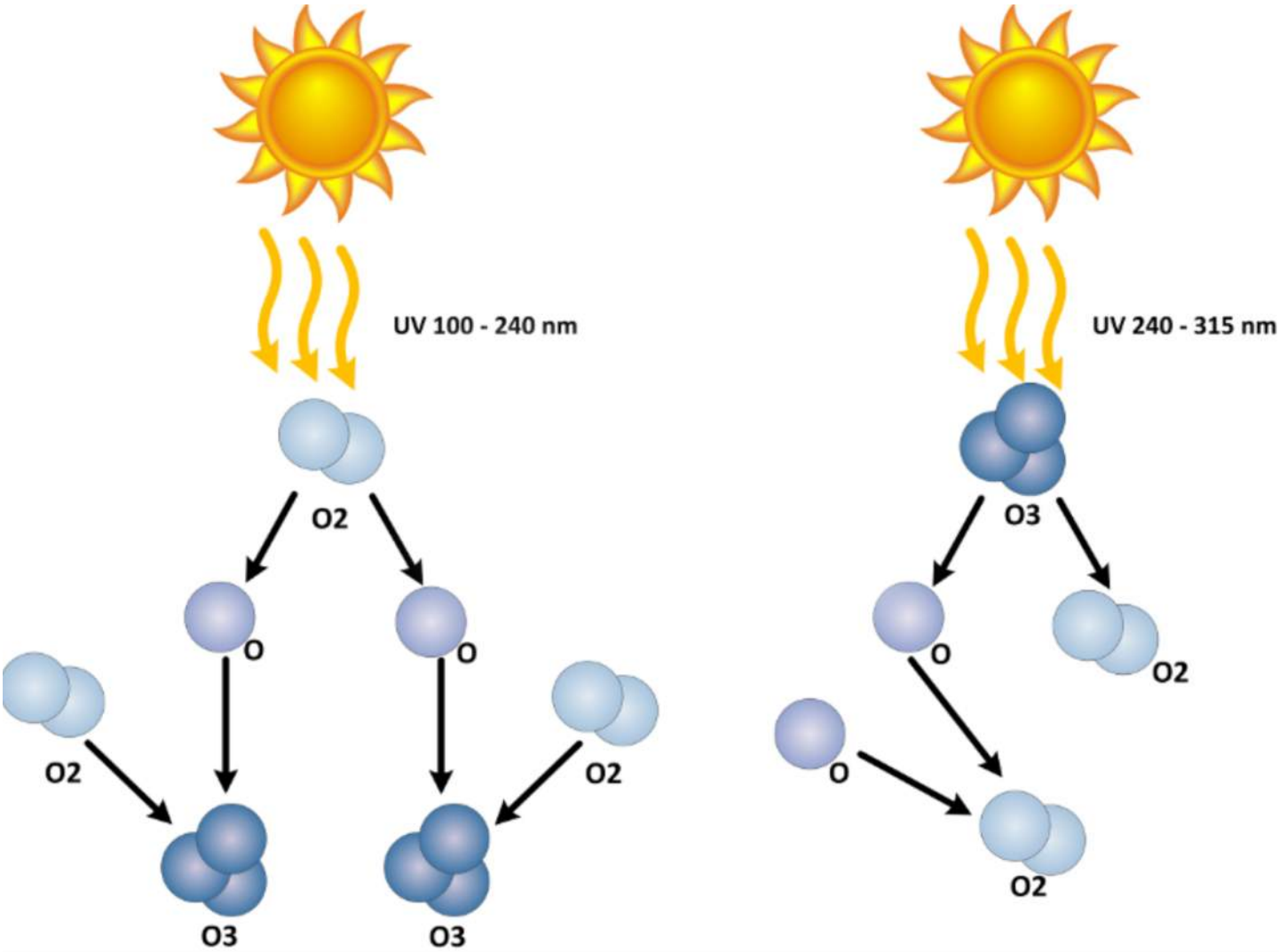
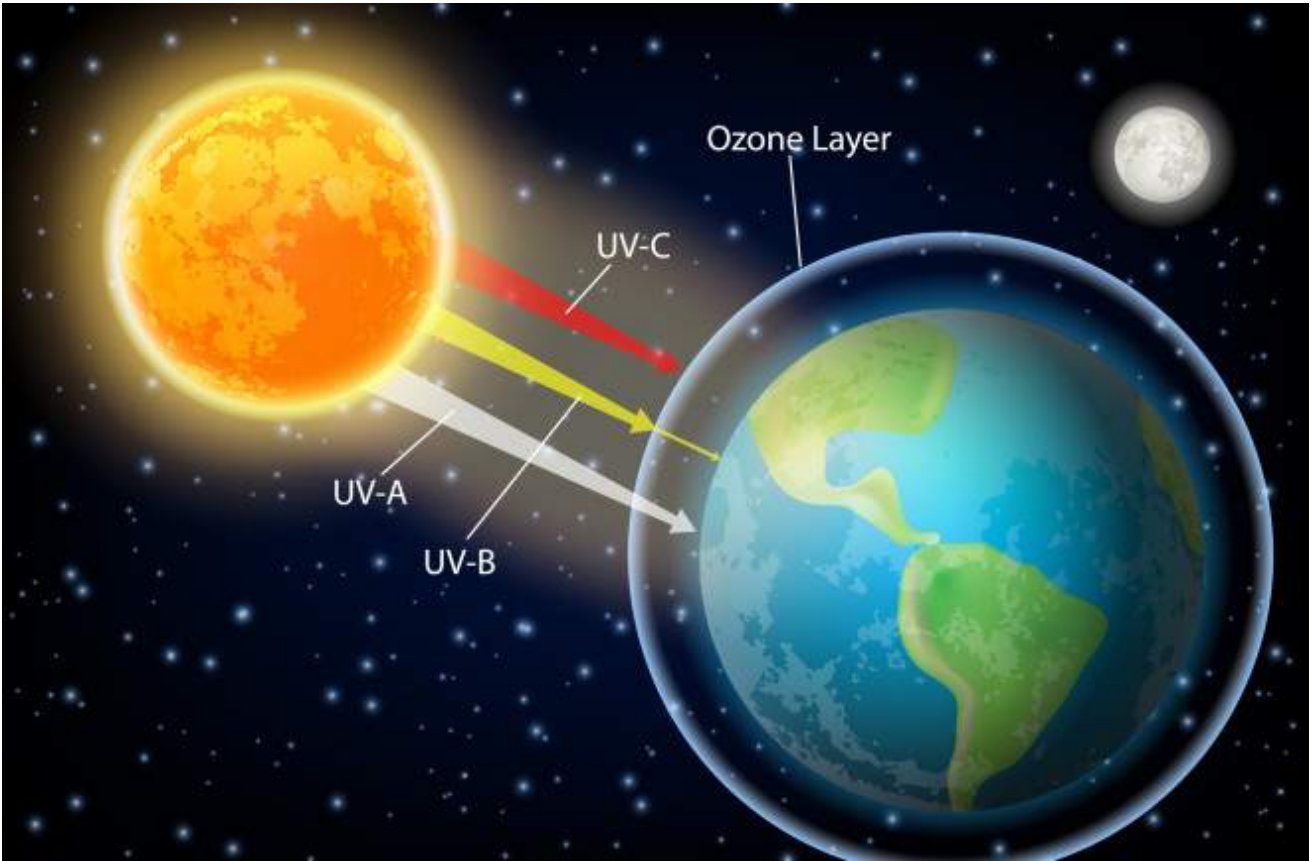
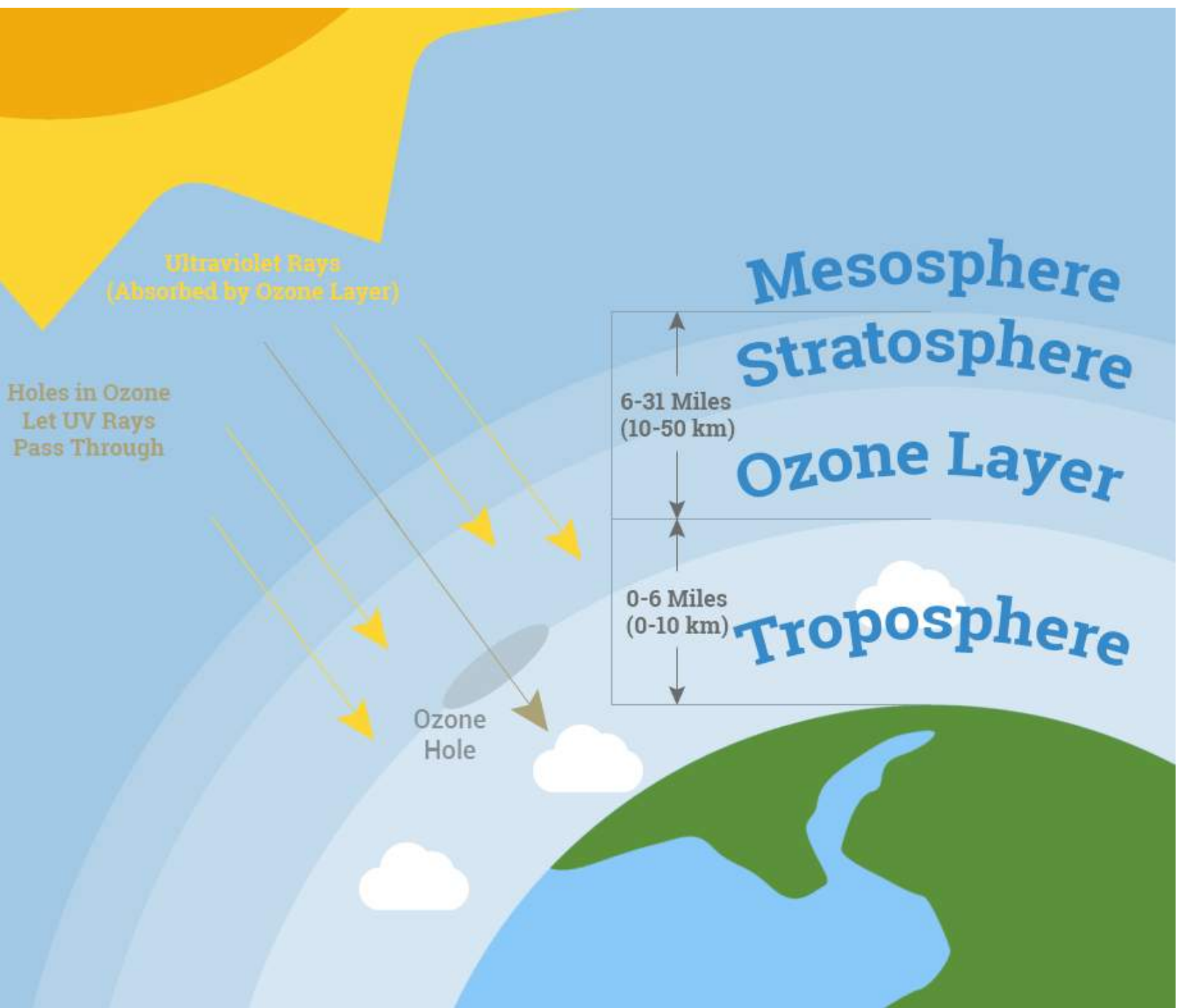


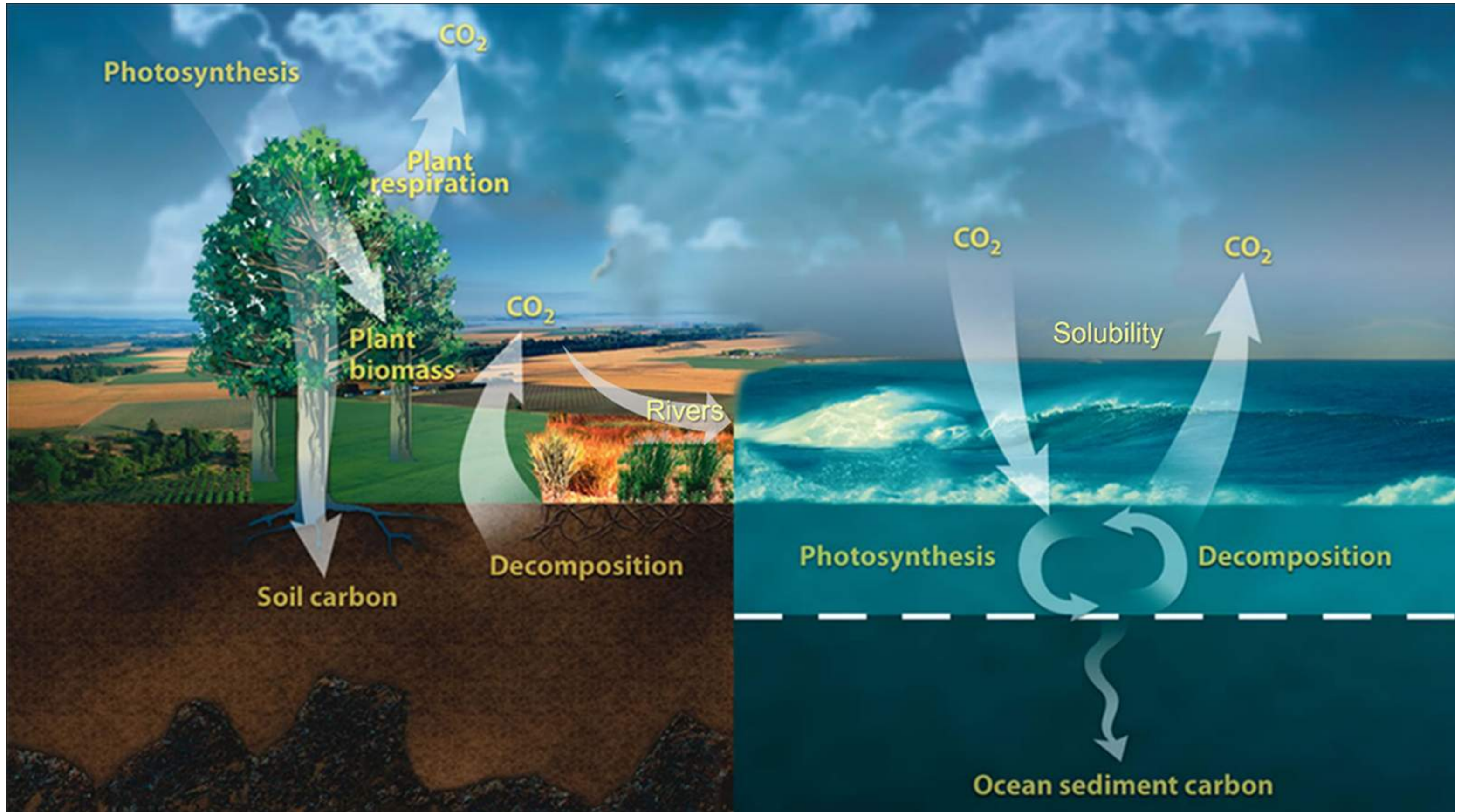


OZONE

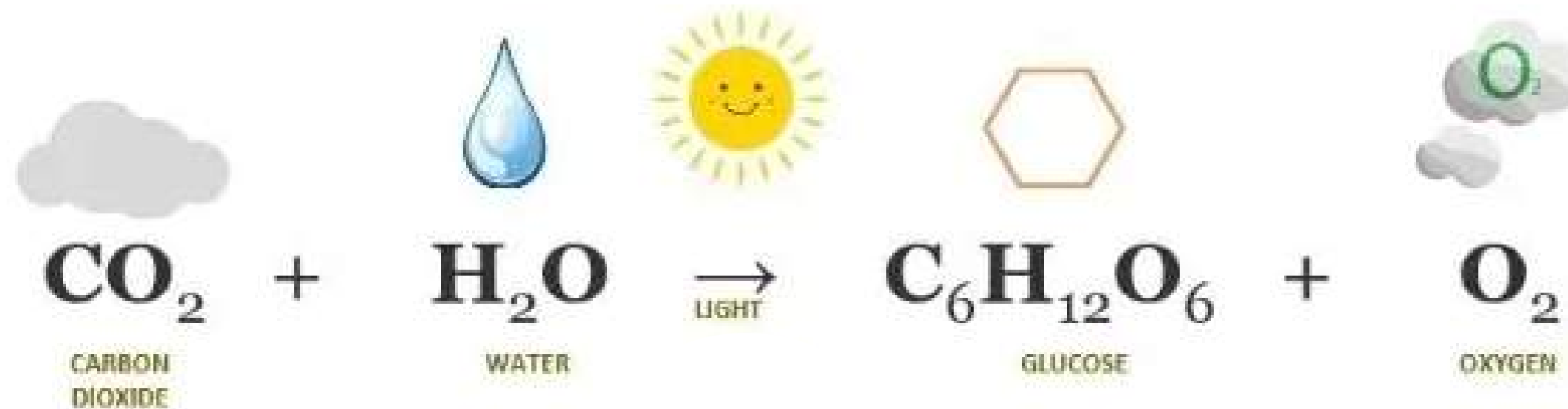


OZONE

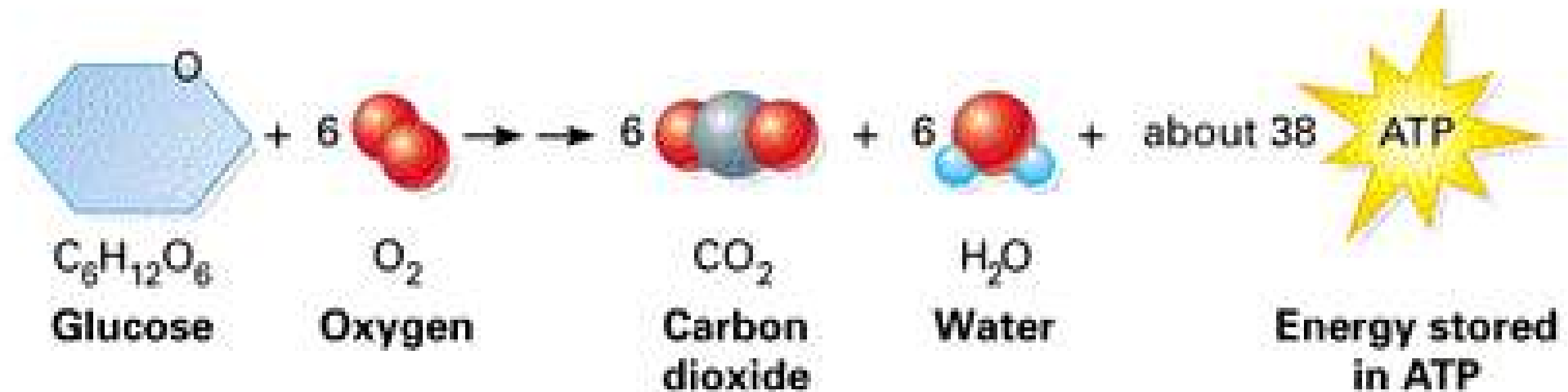


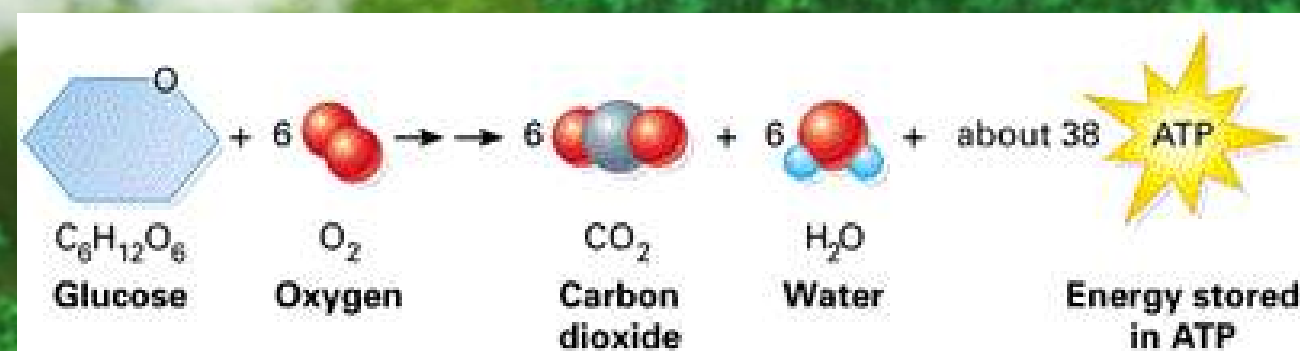


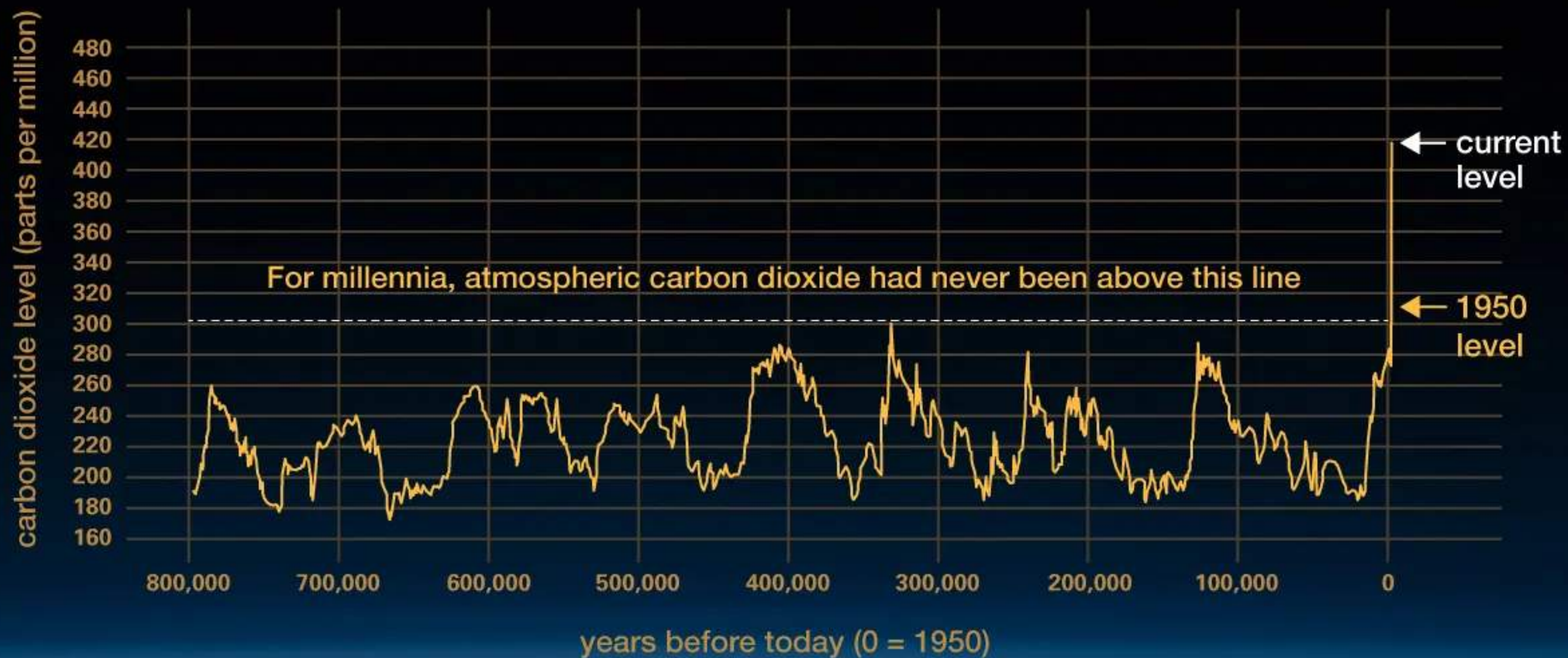
PHOTOSYNTHESIS



CELLULAR RESPIRATION

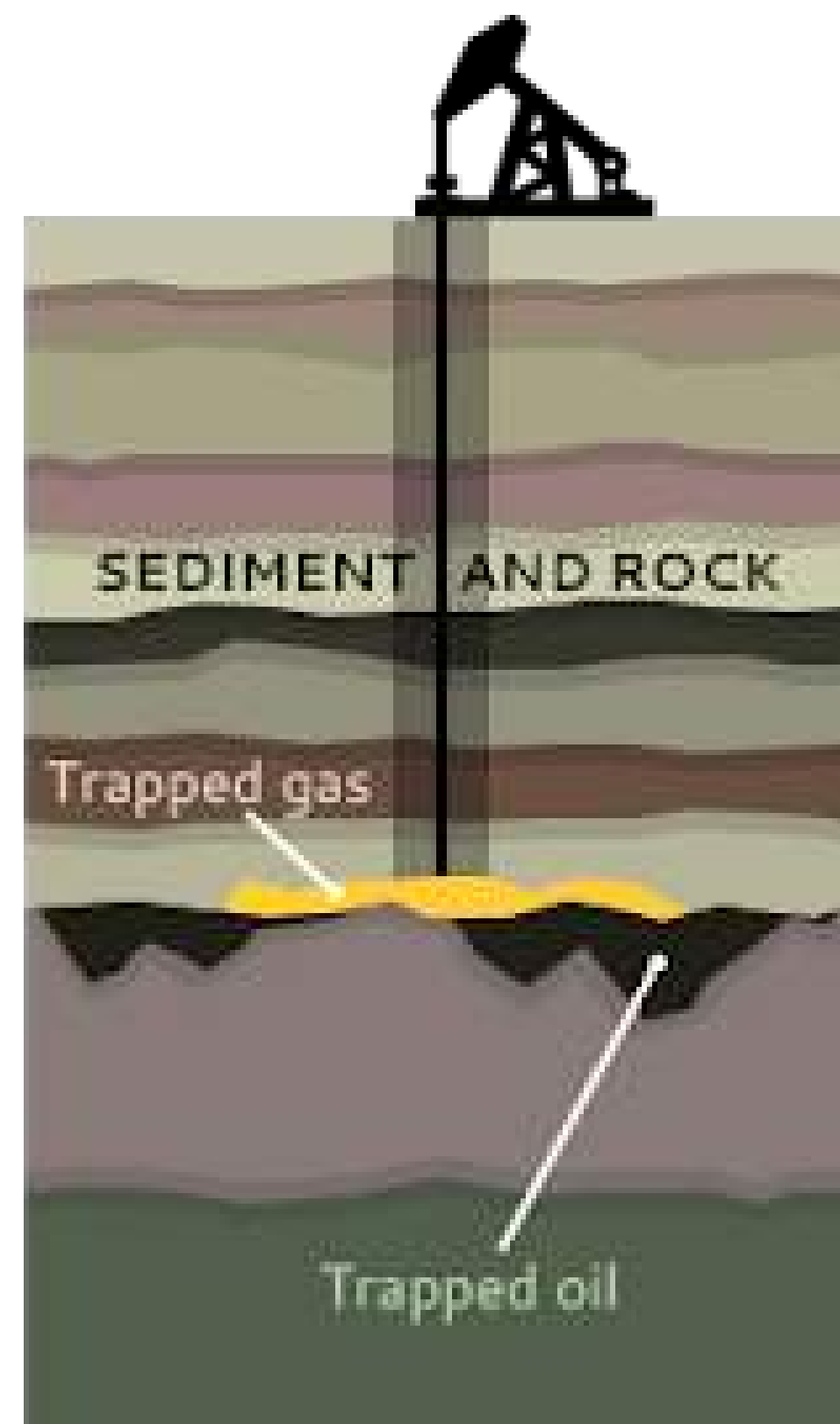
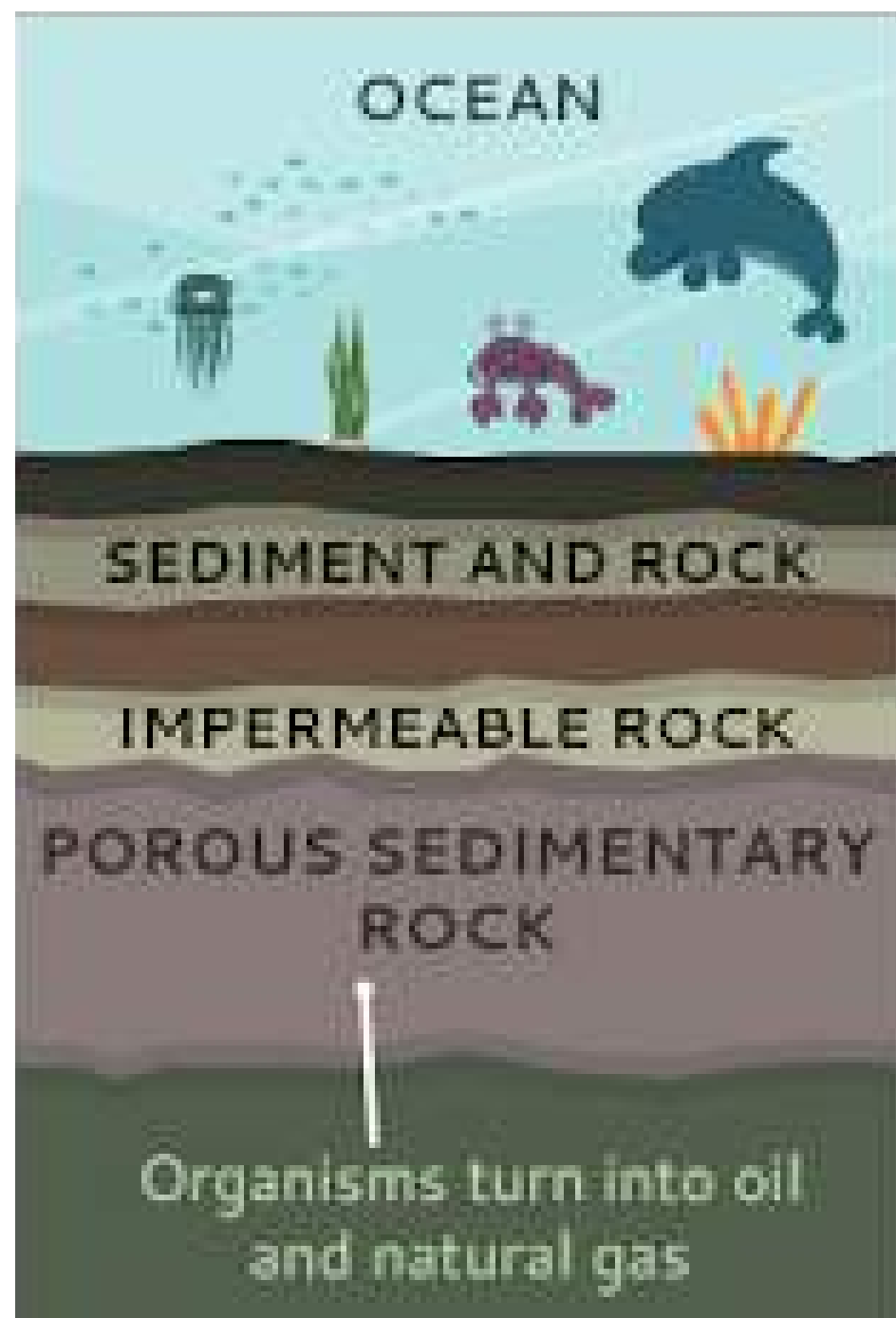




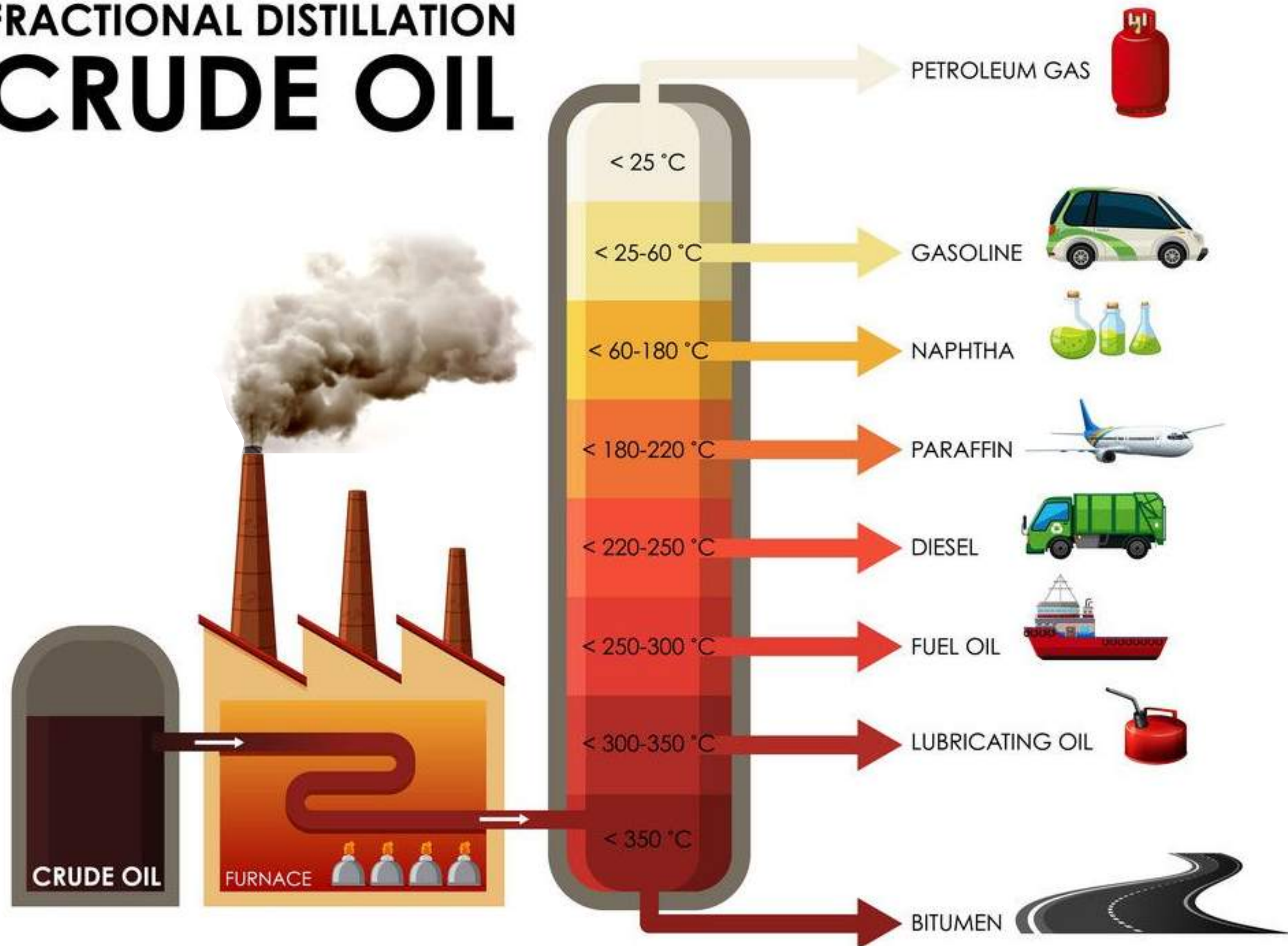


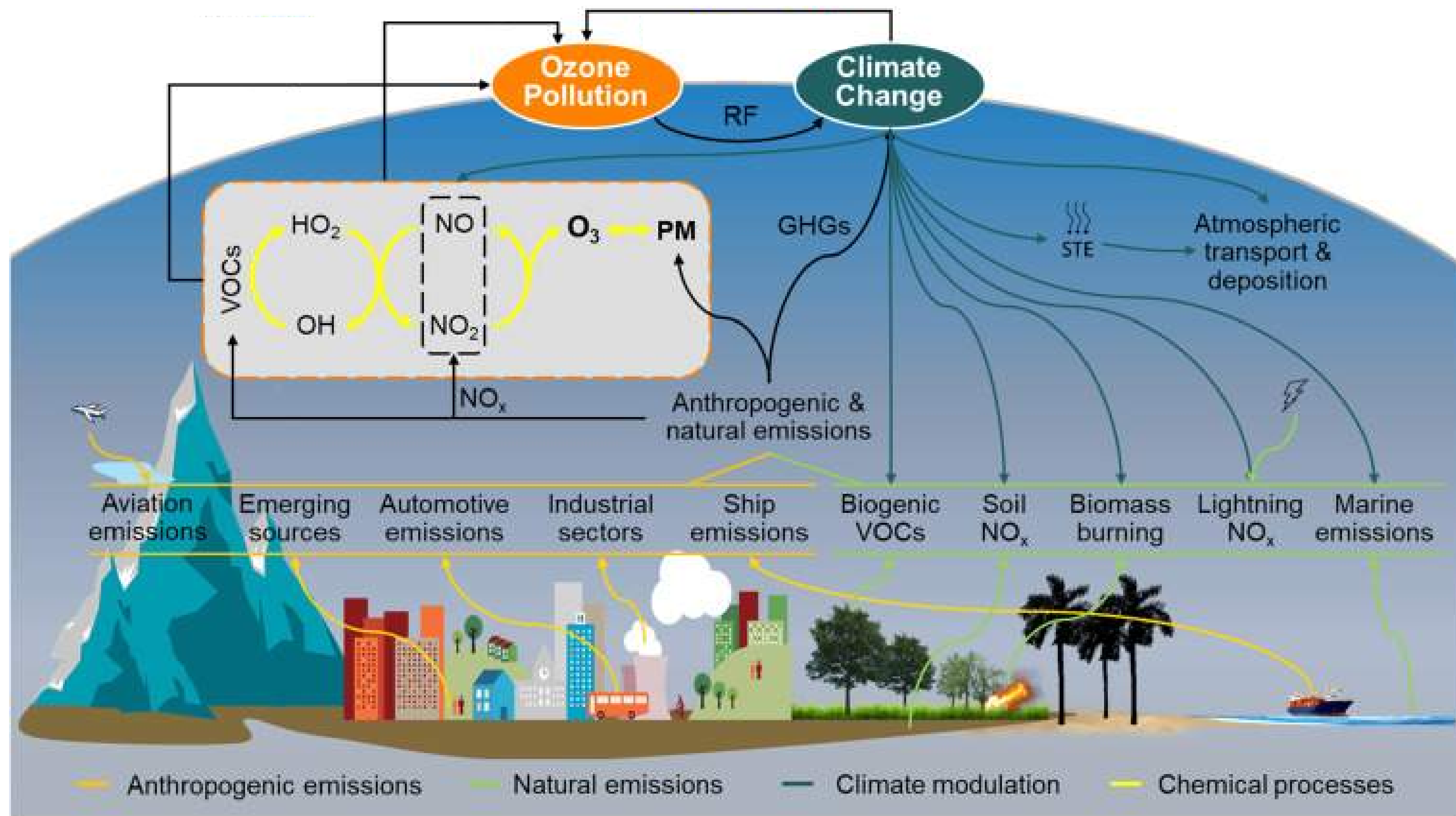


HUMAN ACTIVITY



FRACTIONAL DISTILLATION CRUDE OIL

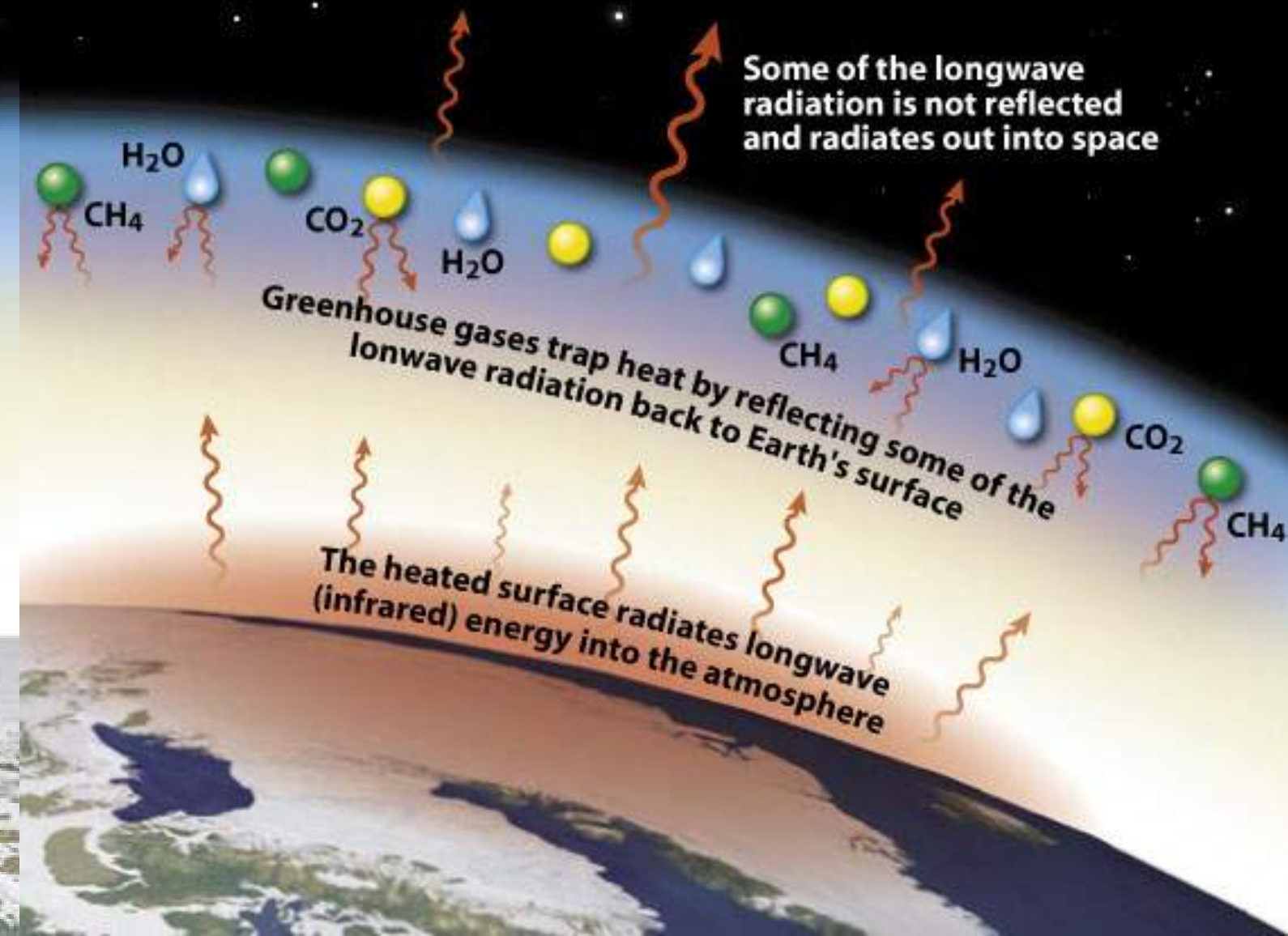
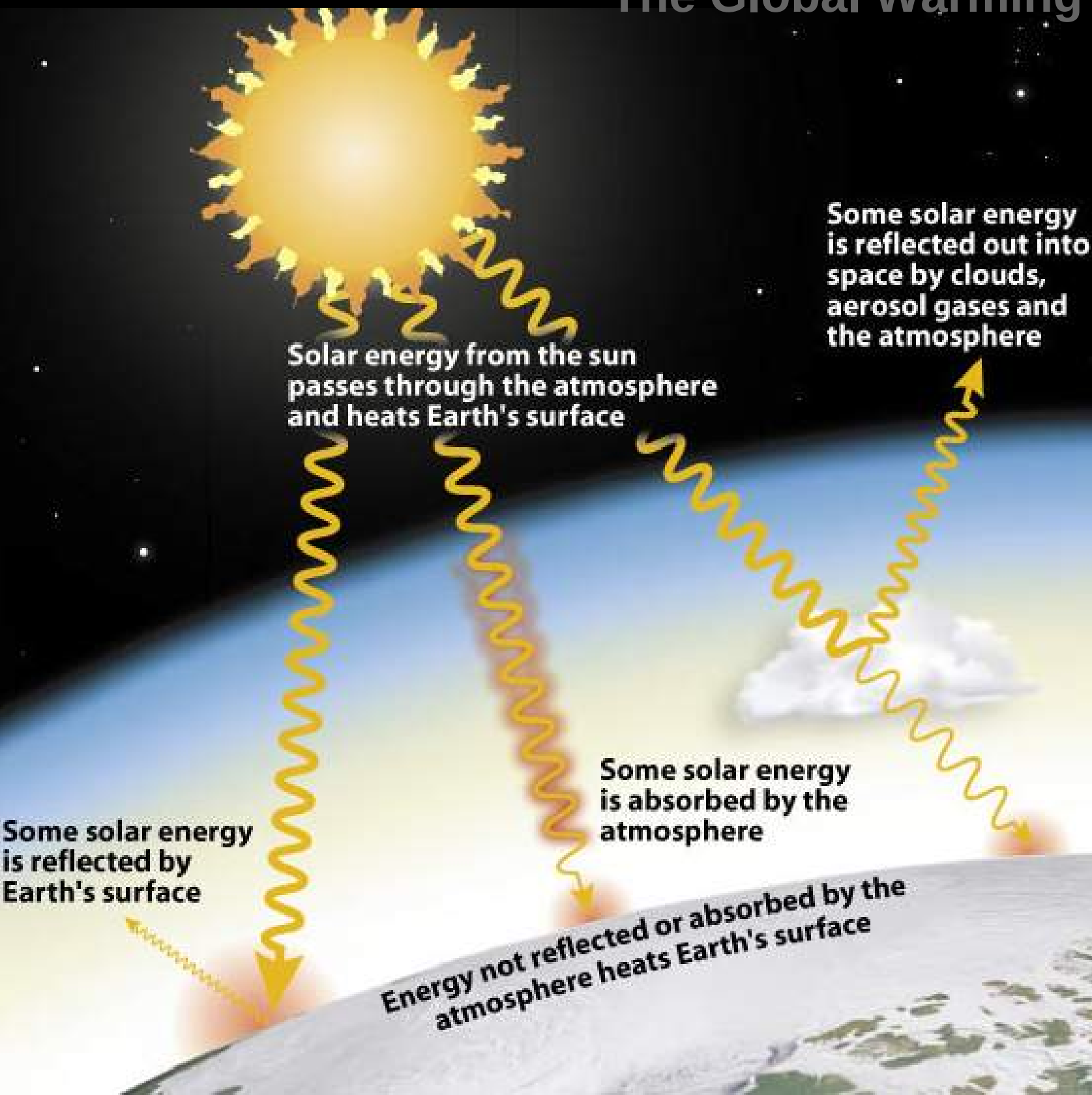




Greenhouse Gases (GHG's)

The Global Warming Potential (GWP)

Carbon dioxide (CO_2)
Methane (CH_4)
Nitrous oxide (N_2O)
Fluorinated gases
Water (H_2O)

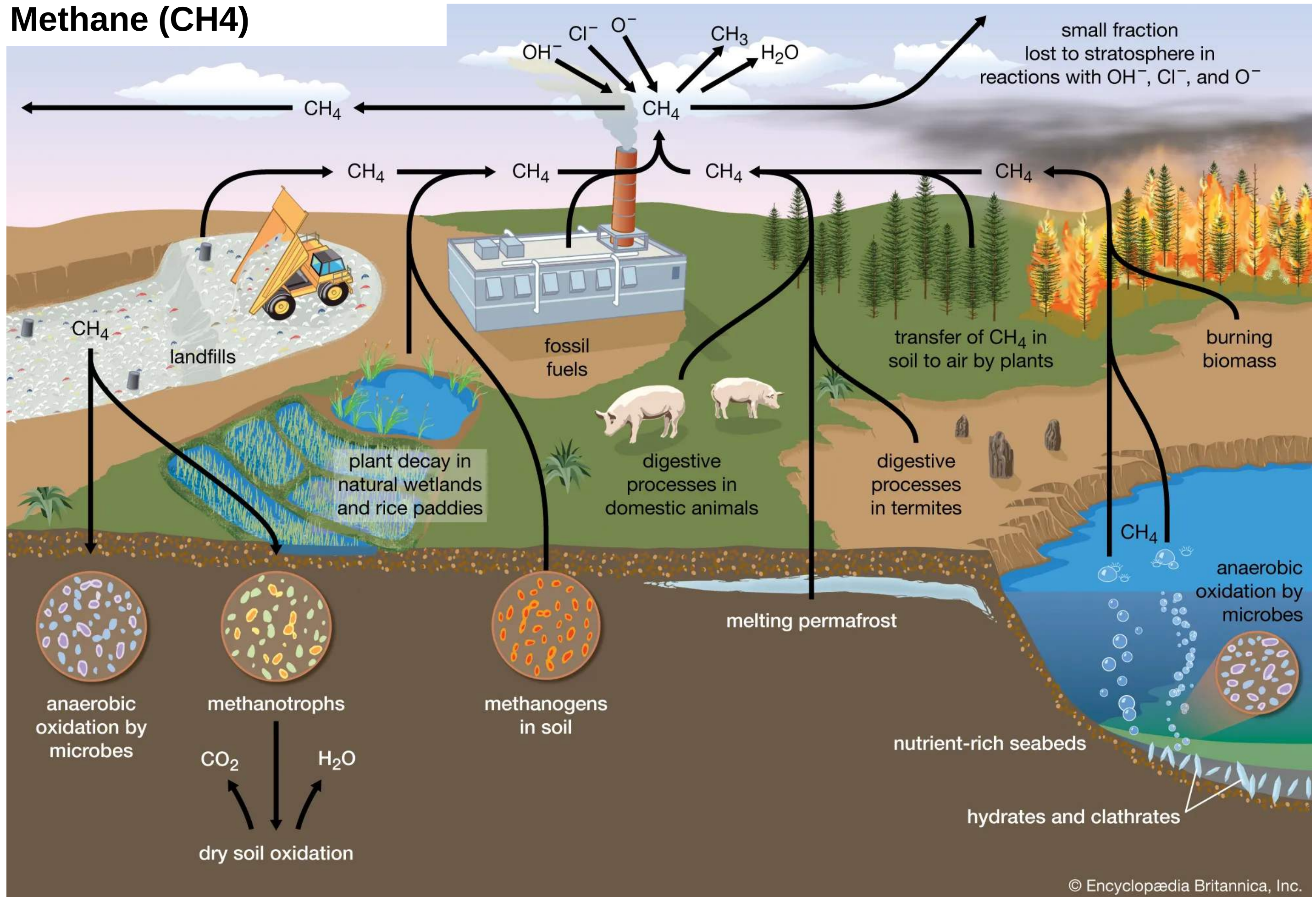


Carbon dioxide (CO₂)

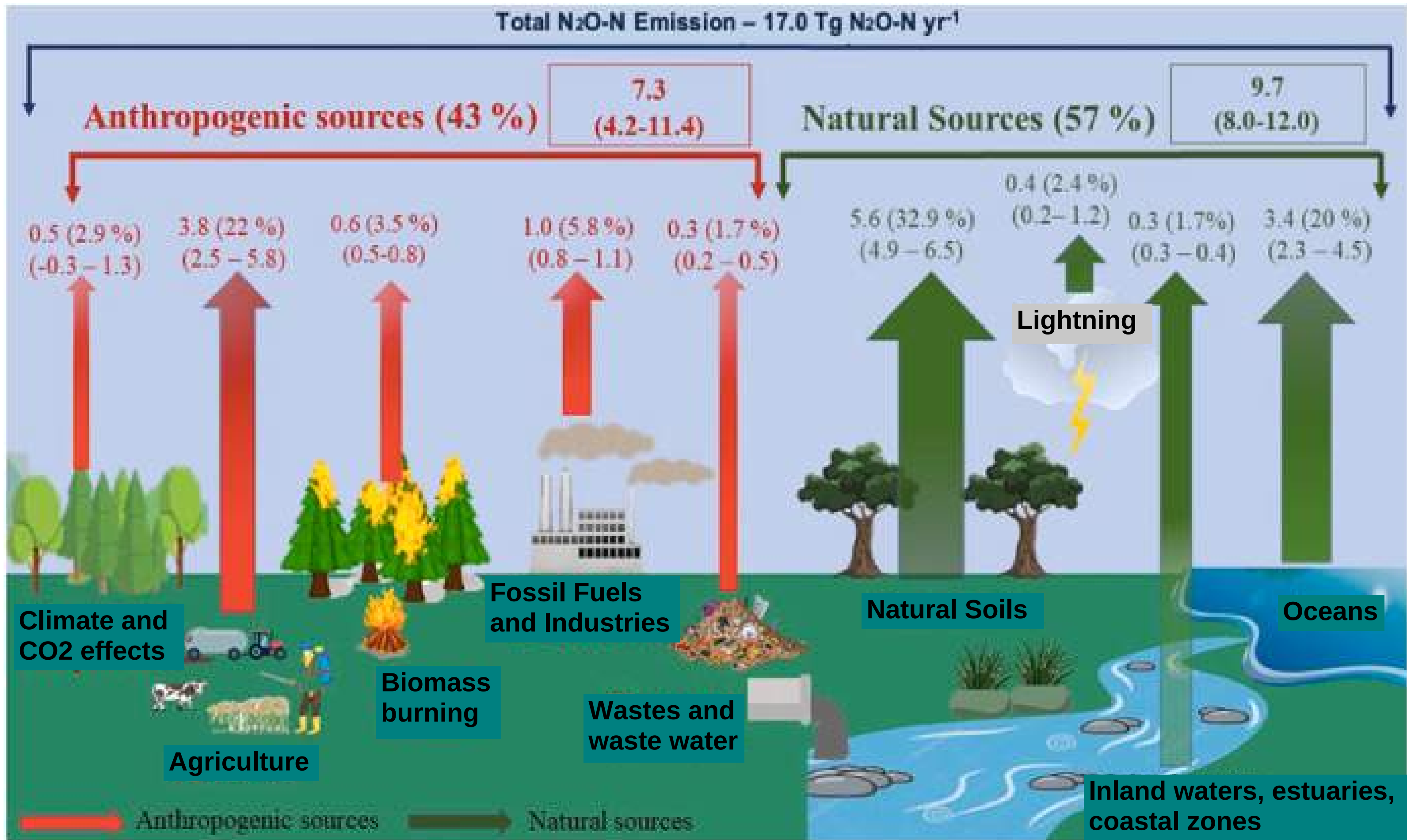
Carbon dioxide (CO₂): Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees and other biological materials, and also as a result of certain chemical reactions (e.g., cement production). Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.



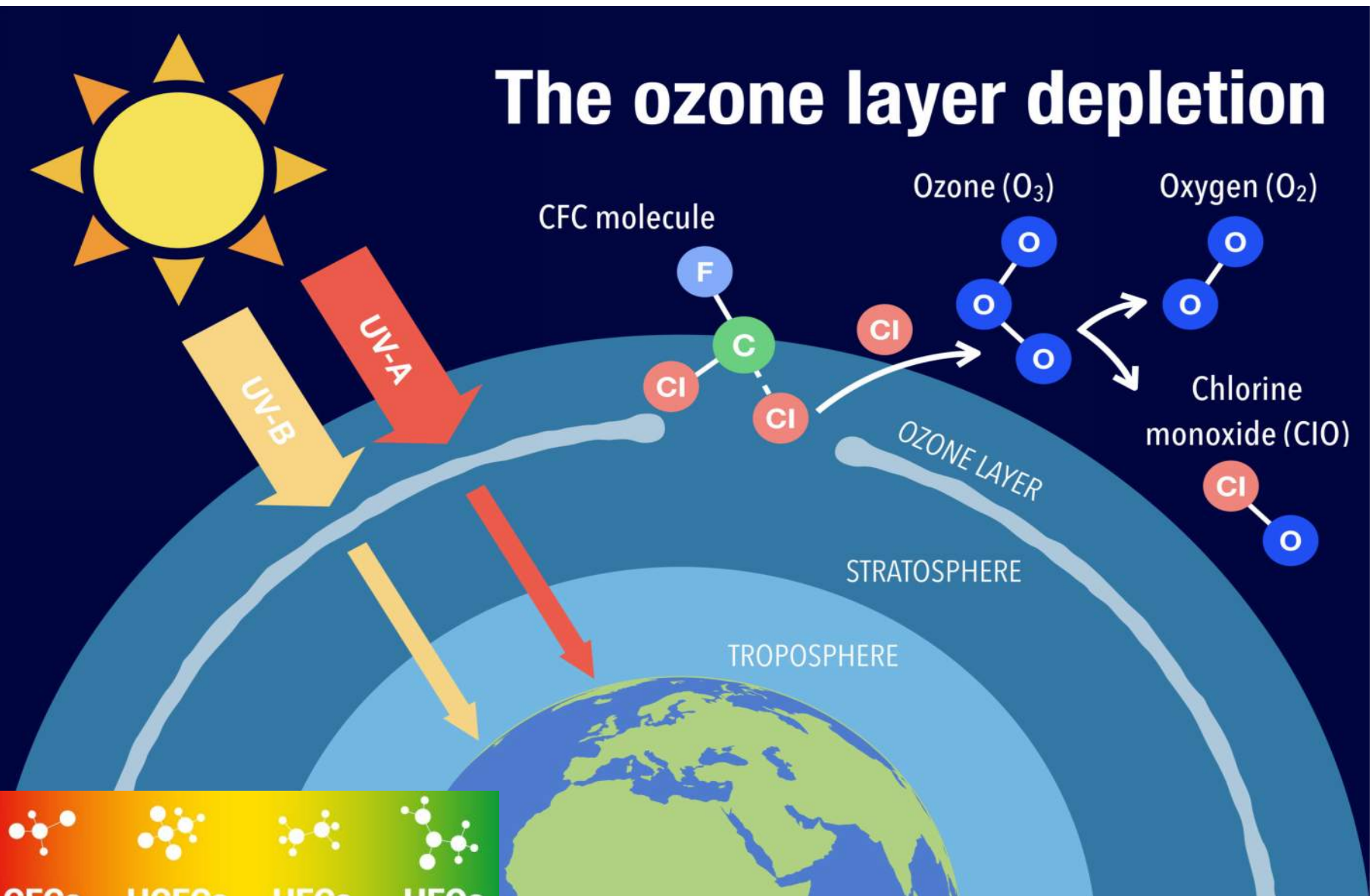
Methane (CH₄)



Nitrous oxide (N₂O)



Fluorinated gases



CFCs	HCFCs	HFCs	HFOs
High ODP High GWP	Low ODP High GWP	Zero ODP High GWP	Zero ODP Very Low GWP

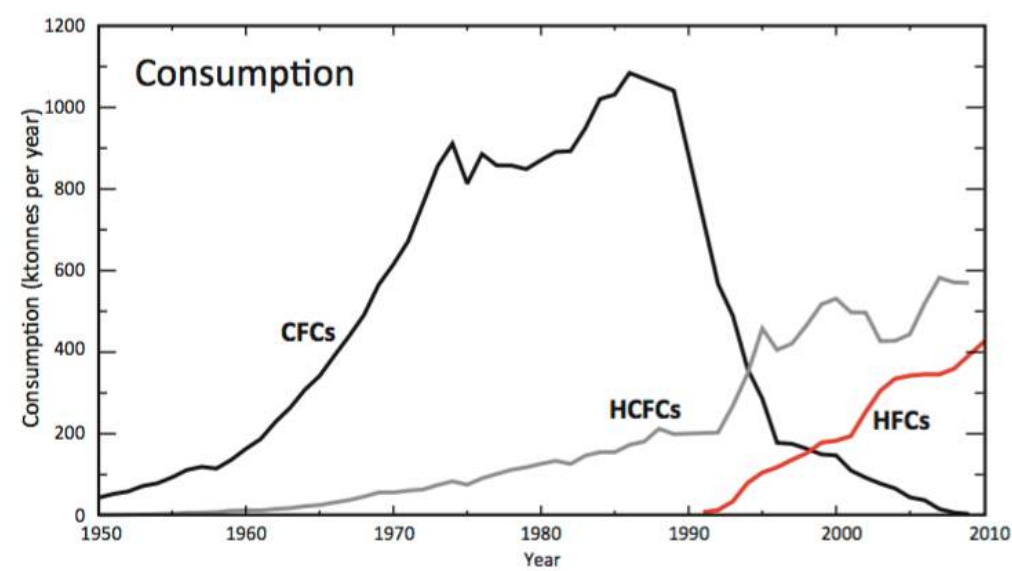
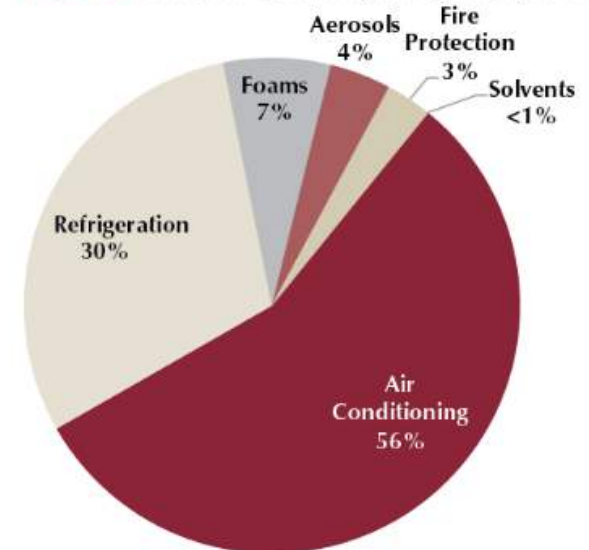
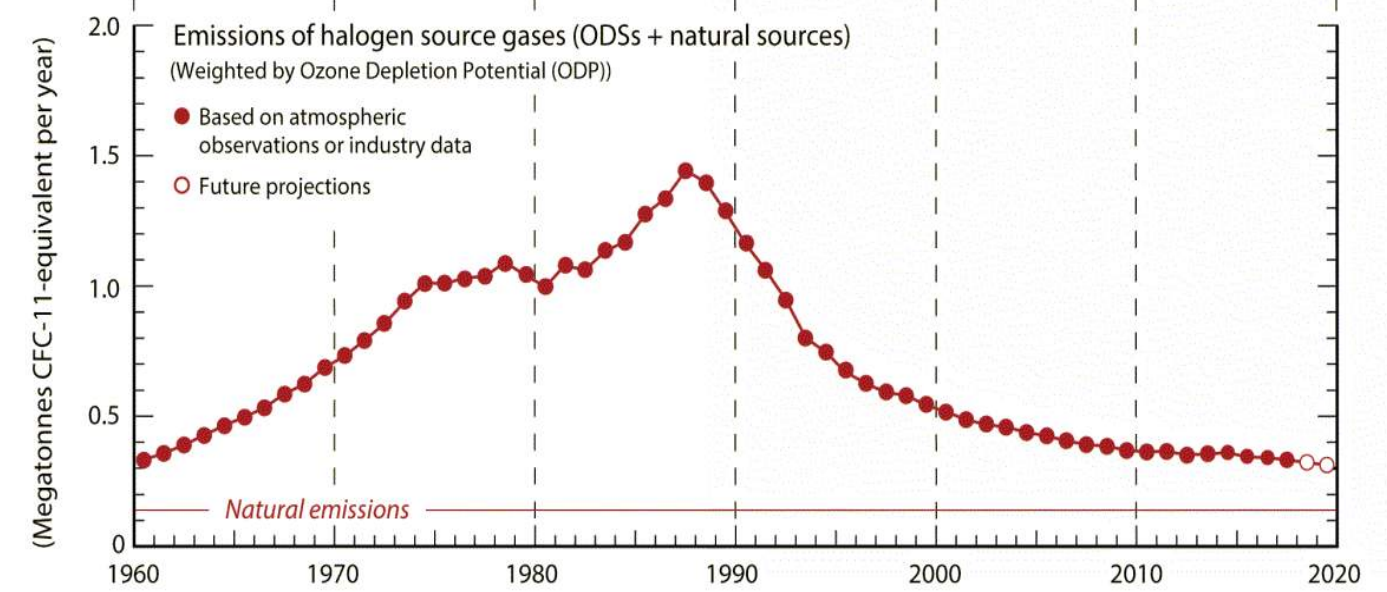
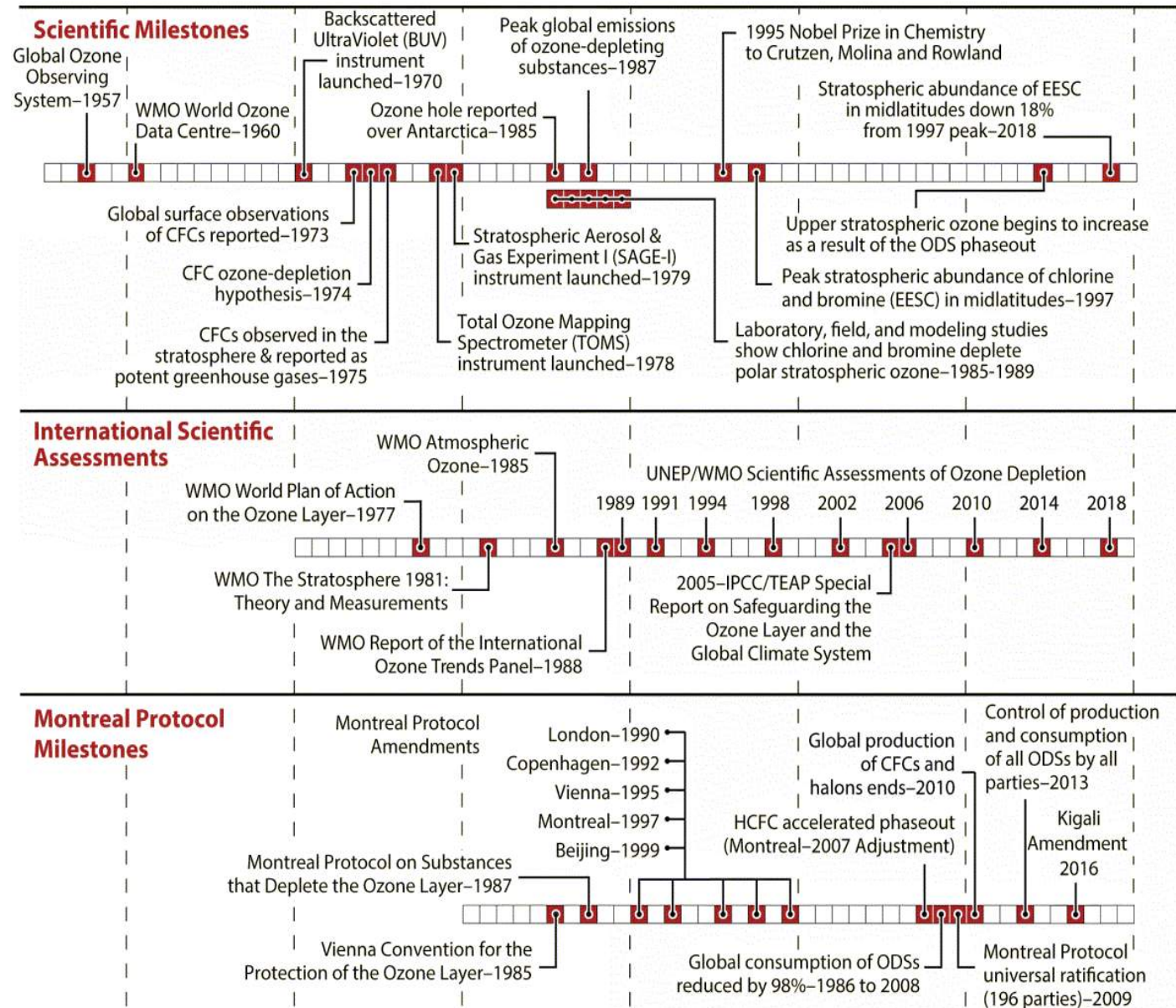


FIGURE 2: Global HFC Consumption by Sector, 2012 (tonnes CO_2 -eq)



Milestones in the History of Stratospheric Ozone Depletion



Embodied Carbon

Embodied carbon—also known as embodied greenhouse gas (GHG) emissions—refers to the amount of greenhouse gas emissions associated with upstream—extraction, production, transport, and manufacturing—stages of a product's life.

DEFINITIONS AND ACRONYMS

GWP - Global Warming Potential - as developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO₂).

PCR - Product Category Rules - are a set of specific guidelines that provide a standardized method for assessing the environmental impact of a product or service throughout its lifecycle.

LCA - Life Cycle Assessment - is a tool to assess potential environmental impacts throughout a product's life cycle, i.e., from natural resource acquisition, via production and use stage to waste management (including disposal and recycling). The term 'product' includes goods, technologies, and services.

WBLCA - Whole Building Life Cycle Assessment - method studies the totality of products present in a building,

Baseline - the counterfactuals against which we compare the selected case – for example the fuel, food, clothing and building material that would otherwise have been used if the functional unit were not. **OR** an overview of the already available data as well as the current applications of LCA in a country

PCR Product Category Rules

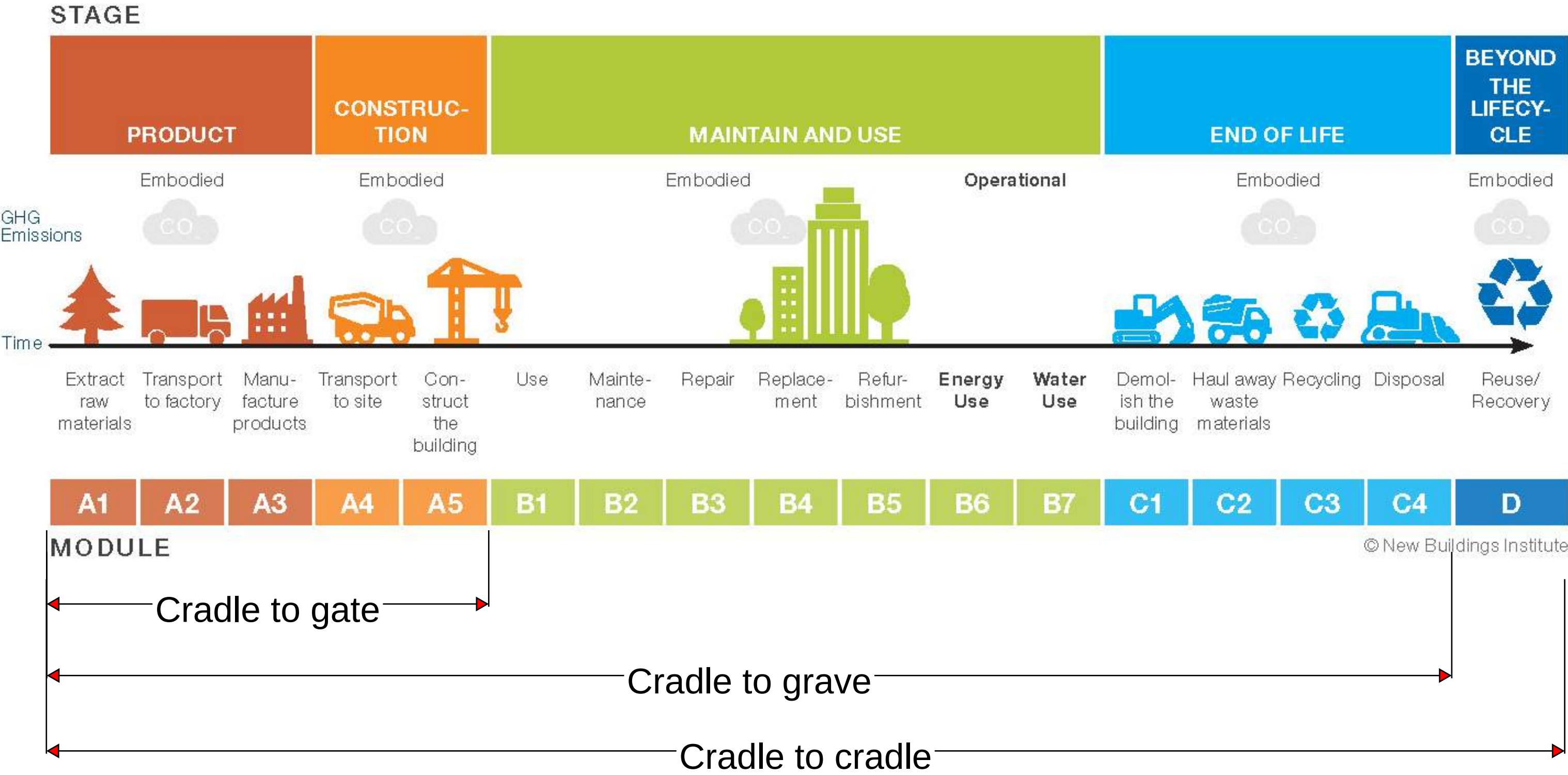
Environmental impact													
Parameter	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4
GWP	kg CO ₂ -eqv	2,34E+2	8,76E+1	3,66E+0	0	0	0	0	0	9,16E+0	2,48E+0	0	1,44E+0
ODP	kg CFC11-eqv	1,23E-5	1,45E-5	4,56E-7	0	0	0	0	0	1,14E-6	3,92E-7	0	3,04E-7
POCP	kg C ₂ H ₄ -eqv	5,44E-2	1,54E-2	7,21E-4	0	0	0	0	0	1,80E-3	3,02E-4	0	2,96E-4
AP	kg SO ₂ -eqv	6,27E-1	4,41E-1	2,81E-2	0	0	0	0	0	7,03E-2	9,50E-3	0	9,33E-3
EP	kg PO ₄ ³⁻ -eqv	2,91E-1	1,05E-1	6,56E-3	0	0	0	0	0	1,64E-2	2,53E-3	0	2,26E-3
ADPM	kg Sb-eqv	8,25E-4	3,09E-4	5,80E-7	0	0	0	0	0	1,45E-6	6,84E-6	0	1,42E-6
ADPE	MJ	2,51E+3	1,39E+3	5,06E+1	0	0	0	0	0	1,27E+2	3,66E+1	0	2,76E+1

GWP Global warming potential; **ODP** Depletion potential of the stratospheric ozone layer; **POCP** Formation potential of tropospheric photochemical oxidants; **AP** Acidification potential of land and water; **EP** Eutrophication potential; **ADPM** Abiotic depletion potential for non fossil resources; **ADPE** Abiotic depletion potential for fossil resources

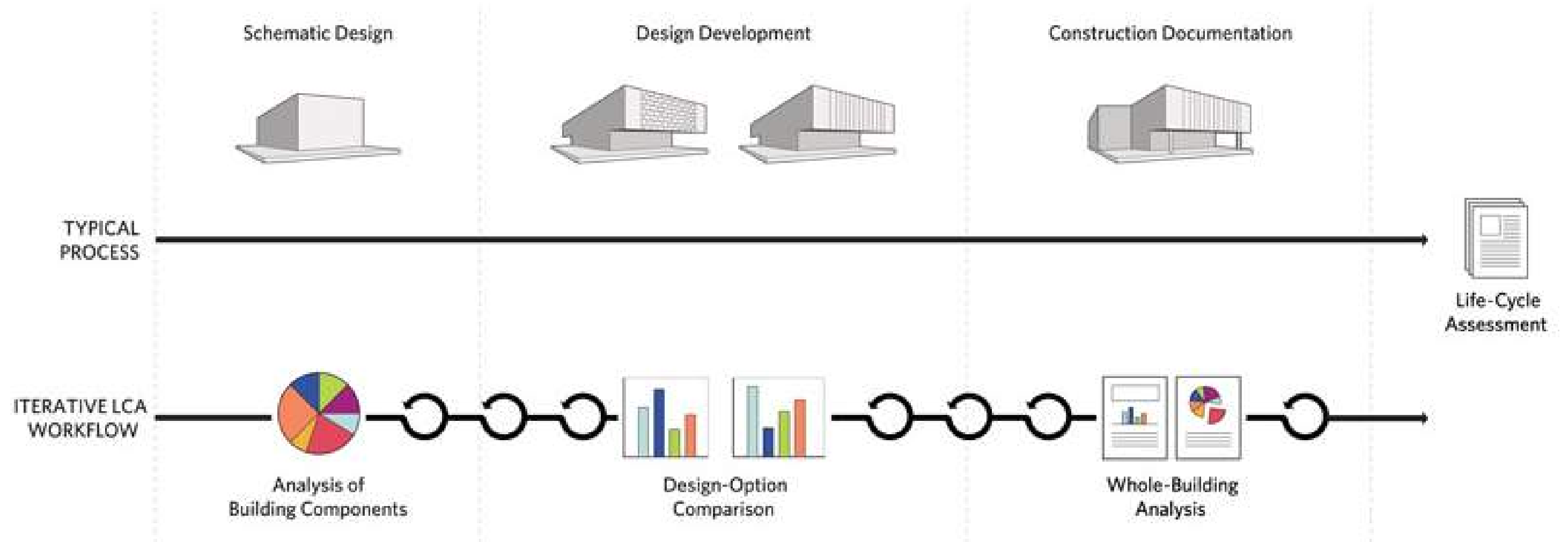
Resource use													
Parameter	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4
RPEE	MJ	1,27E+2	2,24E+1	2,11E-1	0	0	0	0	0	5,26E-1	5,29E-1	0	2,17E-1
RPEM	MJ	3,29E+0	0,00E+0	0,00E+0	0	0	0	0	0	0,00E+0	0,00E+0	0	0,00E+0
TPE	MJ	1,30E+2	2,24E+1	2,11E-1	0	0	0	0	0	5,26E-1	5,29E-1	0	2,17E-1
NRPE	MJ	2,89E+3	1,49E+3	5,17E+1	0	0	0	0	0	1,29E+2	3,90E+1	0	2,86E+1
NRPM	MJ	0,00E+0	0,00E+0	0,00E+0	0	0	0	0	0	0,00E+0	0,00E+0	0	0,00E+0
TRPE	MJ	2,89E+3	1,49E+3	5,17E+1	0	0	0	0	0	1,29E+2	3,90E+1	0	2,86E+1
SM	kg	5,46E+1	0,00E+0	0,00E+0	0	0	0	0	0	0,00E+0	0,00E+0	0	0,00E+0
RSF	MJ	0,00E+0	0,00E+0	0,00E+0	0	0	0	0	0	0,00E+0	0,00E+0	0	0,00E+0
NRSF	MJ	0,00E+0	0,00E+0	0,00E+0	0	0	0	0	0	0,00E+0	0,00E+0	0	0,00E+0
W	m ³	4,98E+0	8,43E-1	1,42E-2	0	0	0	0	0	3,55E-2	1,82E-2	0	2,27E-2

RPEE Renewable primary energy resources used as energy carrier; **RPEM** Renewable primary energy resources used as raw materials; **TPE** Total use of renewable primary energy resources; **NRPE** Non renewable primary energy resources used as energy carrier; **NRPM** Non renewable primary energy resources used as materials; **TRPE** Total use of non renewable primary energy resources; **SM** Use of secondary materials; **RSF** Use of renewable secondary fuels; **NRSF** Use of non renewable secondary fuels; **W** Use of net fresh water

Life Cycle Assessment (LCA)

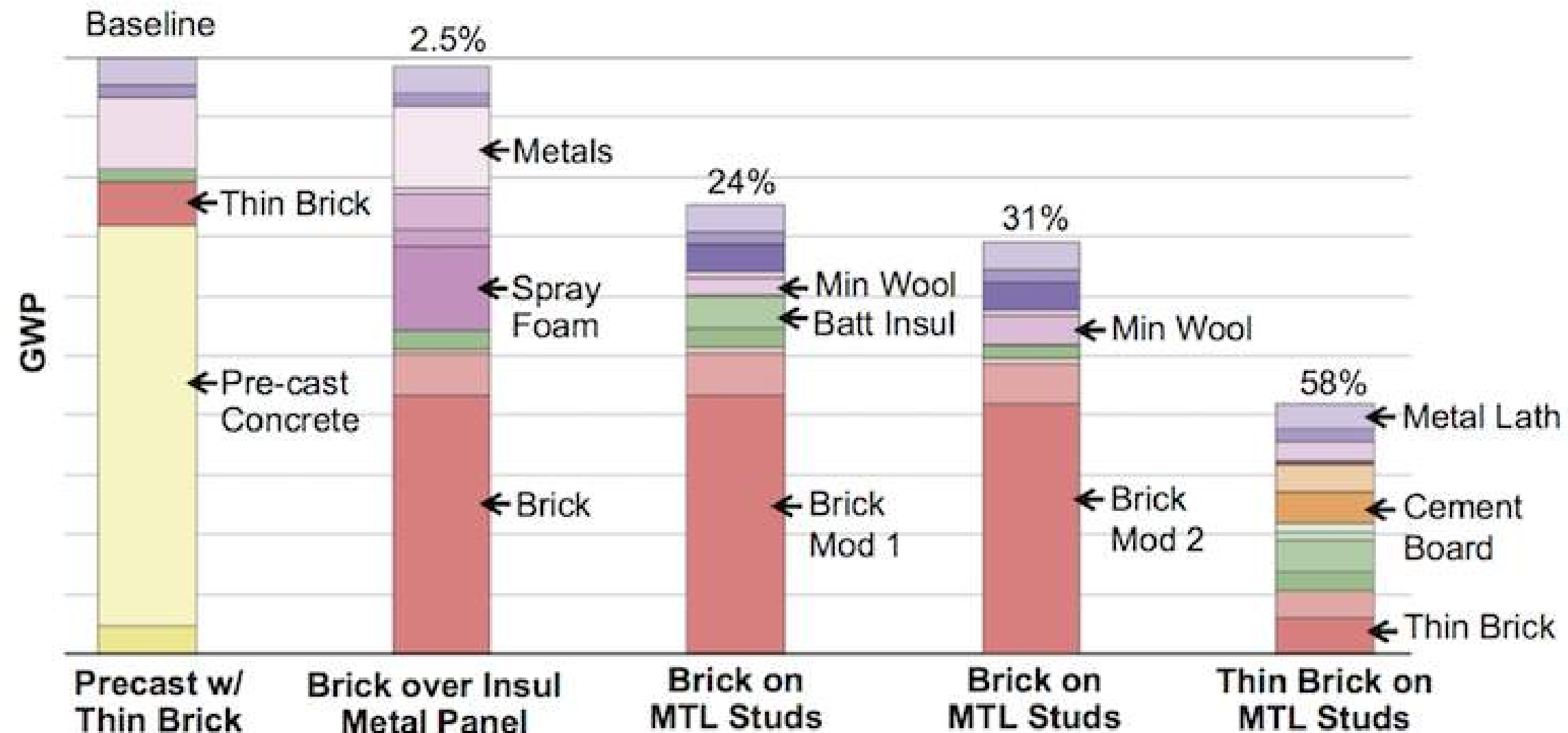


Design process implementation

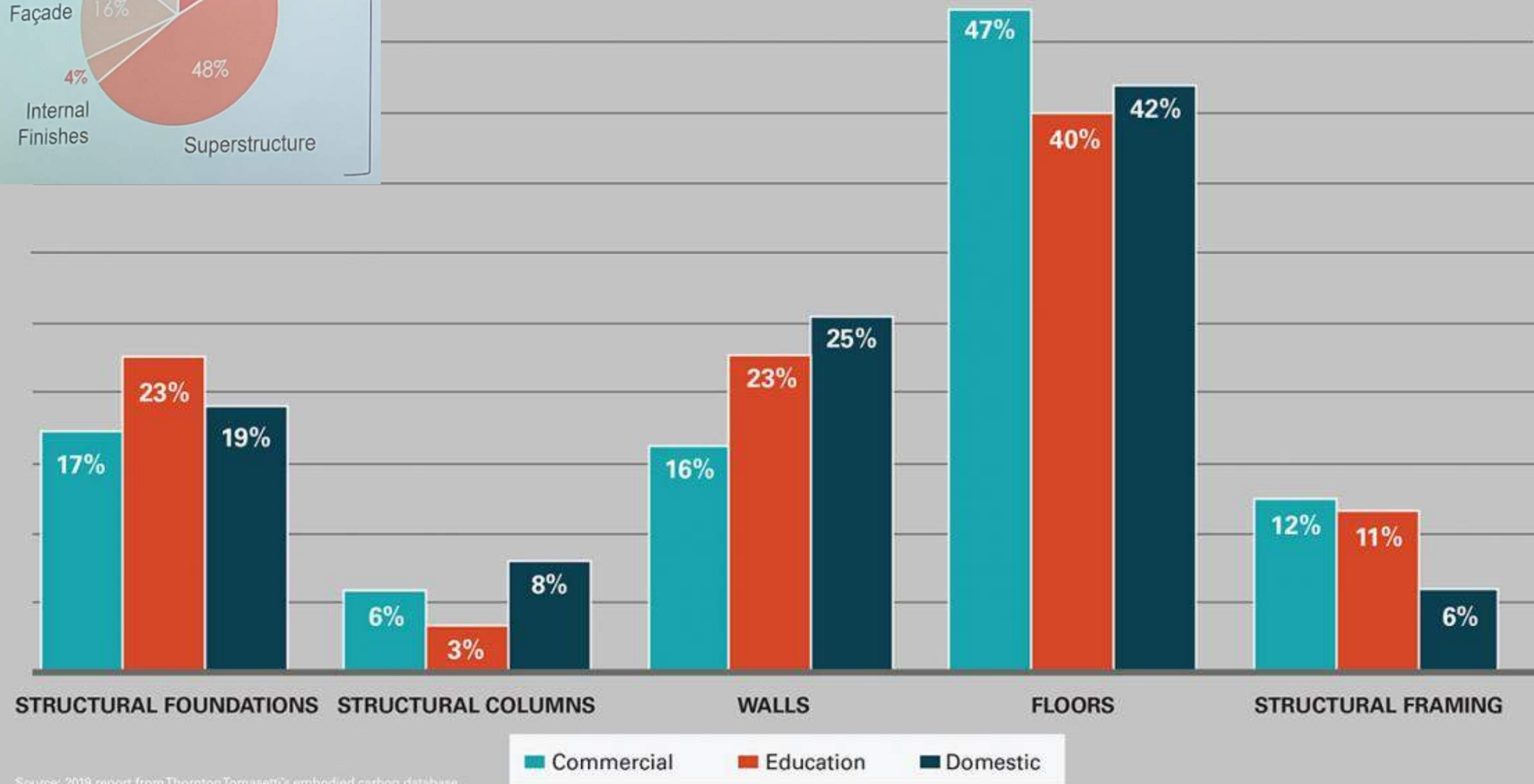
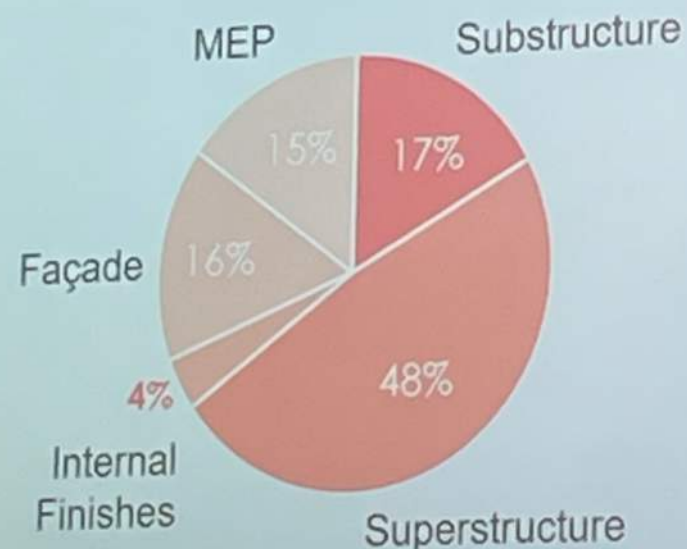


Baseline / Design Studies

A Tale of Five Bricks



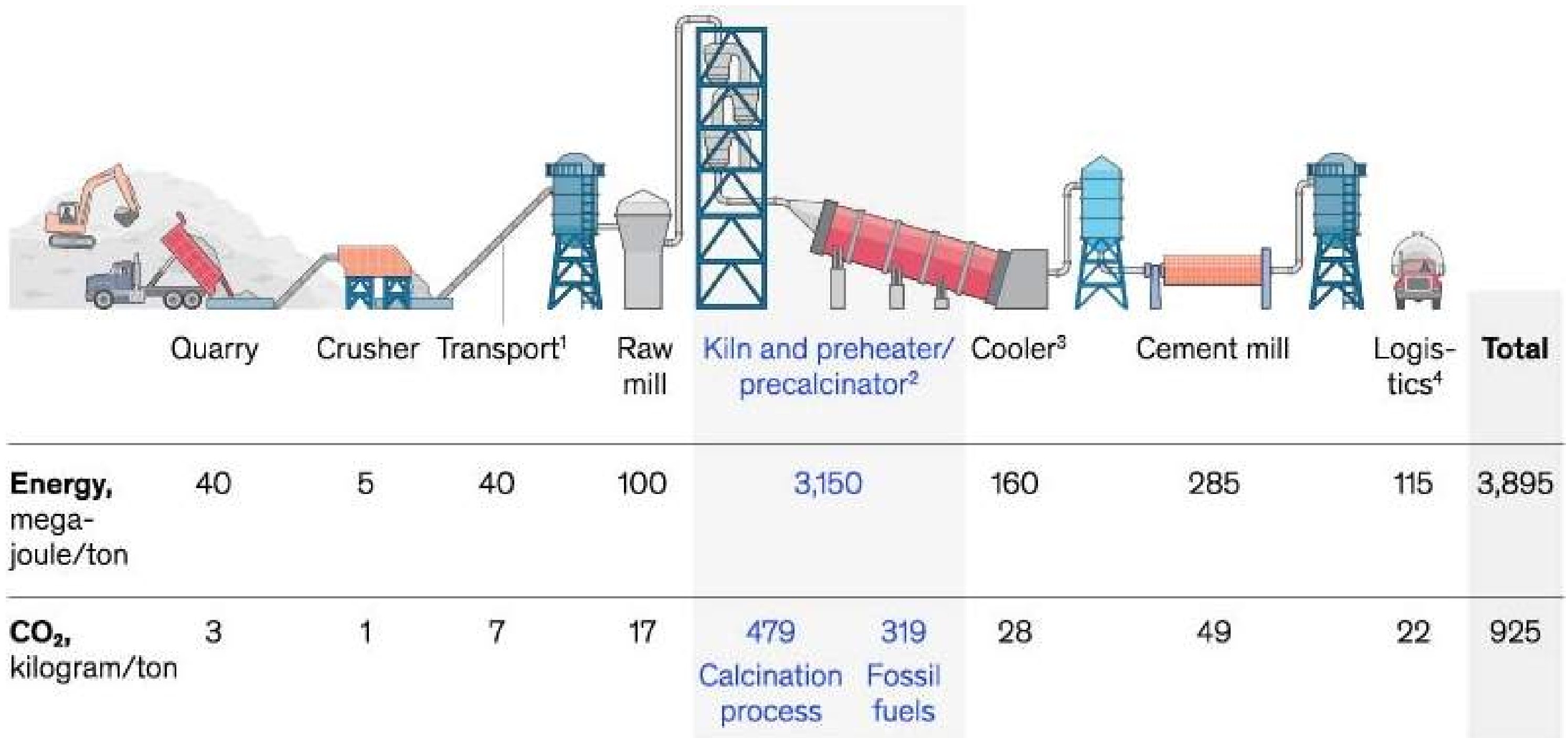
Where is the Embodied Carbon?



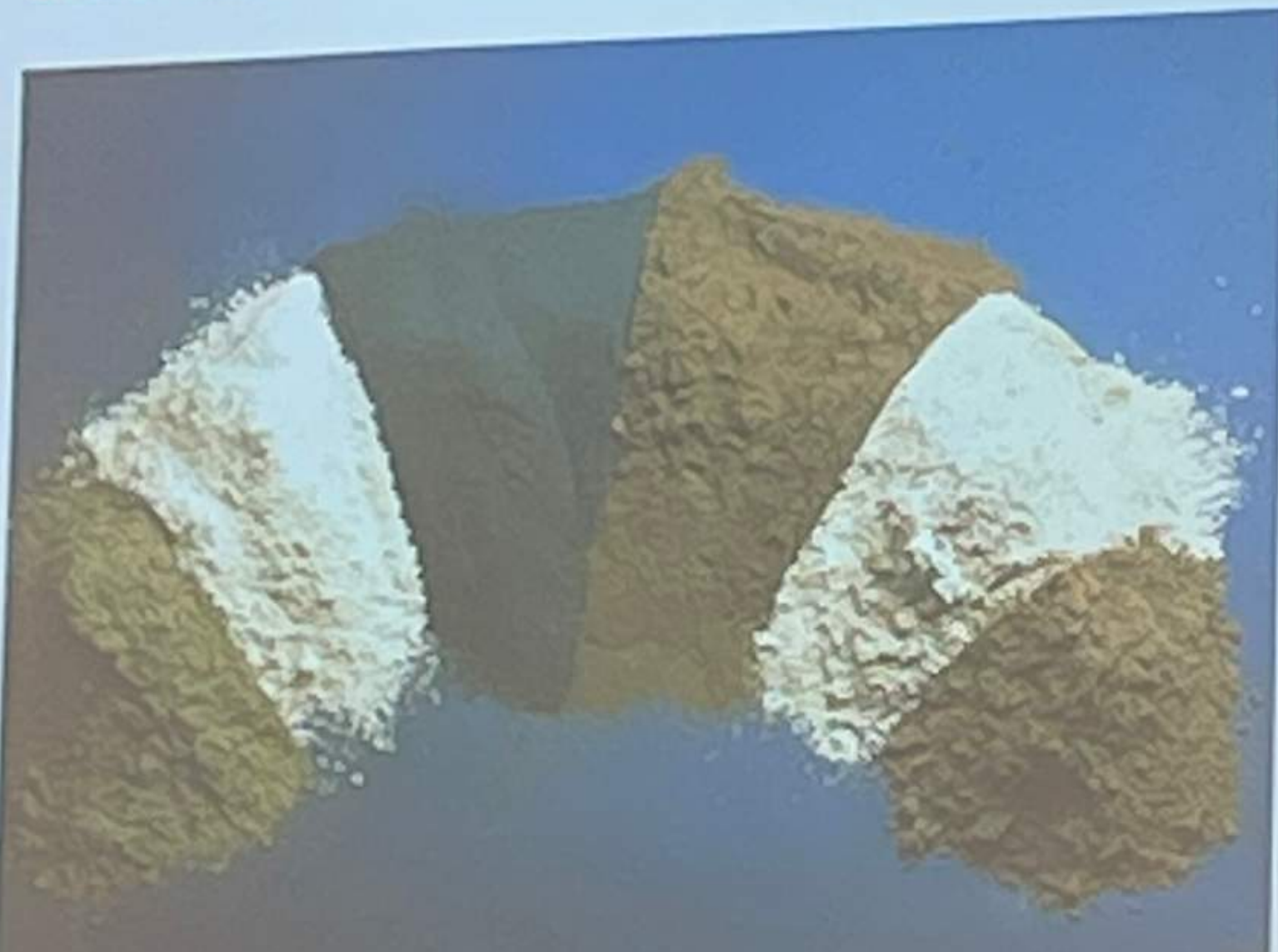
Source: 2019 report from ThorntonTomasetti's embodied carbon database.

Kg of CO₂ created (or stored) to create each tonne of building materials





Less cement = less embodied carbon



4000psi NW Concrete		
NRMCA Industry Average LCA		
Cement Replacement	GWP kgCO2e/cy	GWP Reduction
0%	293	
20% FA	252	-14%
30% FA	229	-22%
40% FA	205	-30%
50% FA/SL	182	-38%

Embodied Carbon Estimator

Material	Structural Component	Quantity	Unit	Total Impact (lb CO2e)	Total Impact (kg CO2e)	
Concrete	2,500 PSI	1	Cubic Yards	407.3	184.75	← -27%
	3,000 PSI	1	Cubic Yards	452.4	205.21	← -18%
	4,000 PSI	1	Cubic Yards	554.8	251.68	← Baseline
	5,000 PSI	1	Cubic Yards	676	306.63	← +22%
	6,000 PSI	1	Cubic Yards	771.3	322.64	← +28%
	8,000 PSI	1	Cubic Yards	825.4	374.4	← +49%
	3,000 PSI LW	1	Cubic Yards	803.5	367.19	
	4,000 PSI LW	1	Cubic Yards	934.8	424.02	← +68%
	5,000 PSI LW	1	Cubic Yards	1,032.8	468.49	

OPTIMIZATION – COMPOSITE FLOORS

Slab System – Typ. 40% of Struct EC

18 GA. = 3.0 kgCO₂e/sf

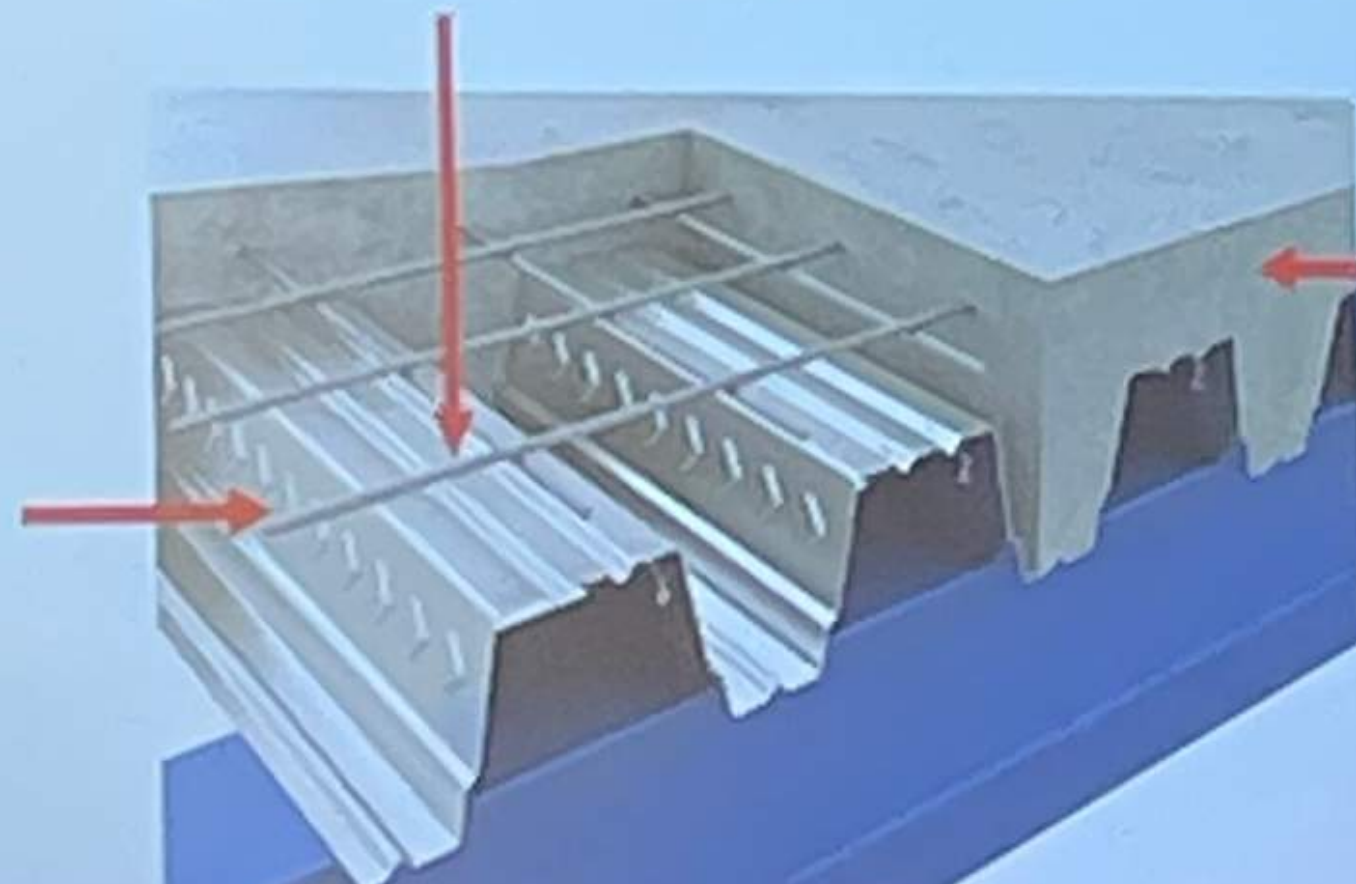
20 GA. = 2.3 kgCO₂e/sf

NW 2" 7.8 kgCO₂e /sf

LW 3" 12.2 kgCO₂e /sf ← 56% Increase!

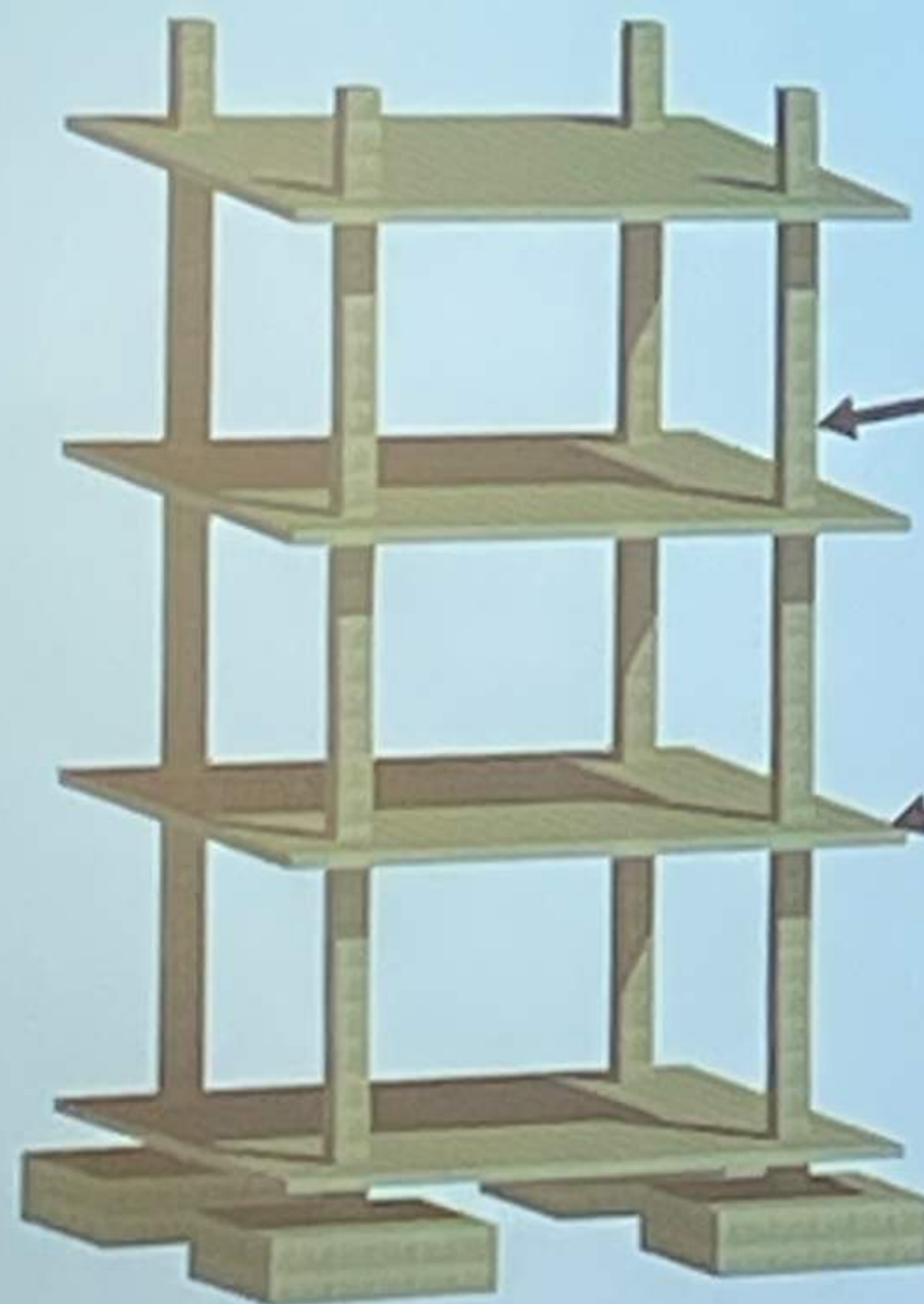
2" Deck = 2.7 kgCO₂e/sf

3" Deck = 3.8 kgCO₂e/sf



4.5" NW Topping = 4.5 kgCO₂e/sf

3.25" LW Topping = 5.6 kgCO₂e/sf



Element

Revised

Reduction

18" col, 6ksi / 46 kg/ft

21" col, 4ksi / 37 kg/ft

20%

7" slab, 6ksi / 12 kg/sf

9" slab, 4ksi / 9 kg/sf

25%

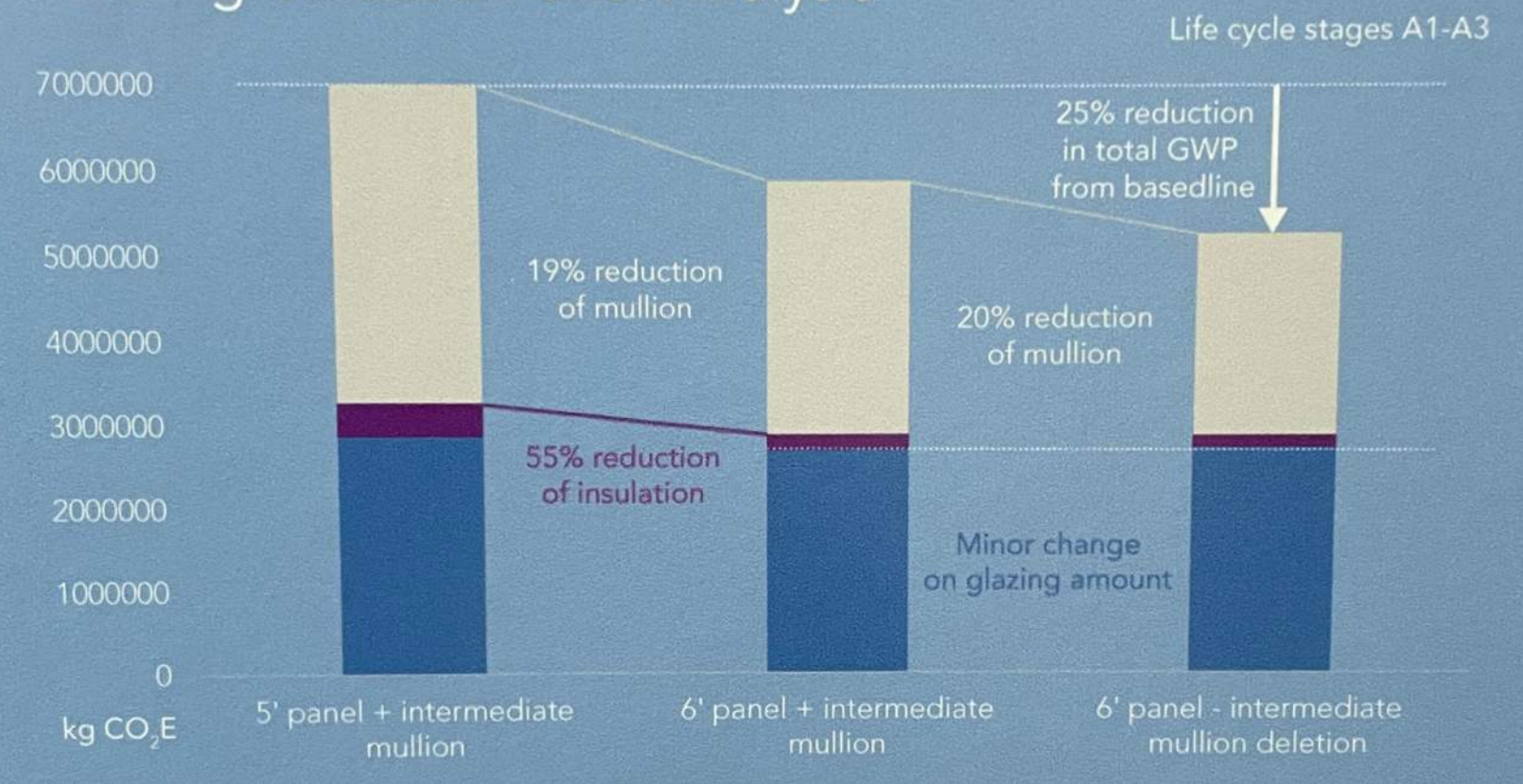
30" ftg, 4ksi / 30 kg/sf

32" ftg, 3ksi / 26 kg/sf

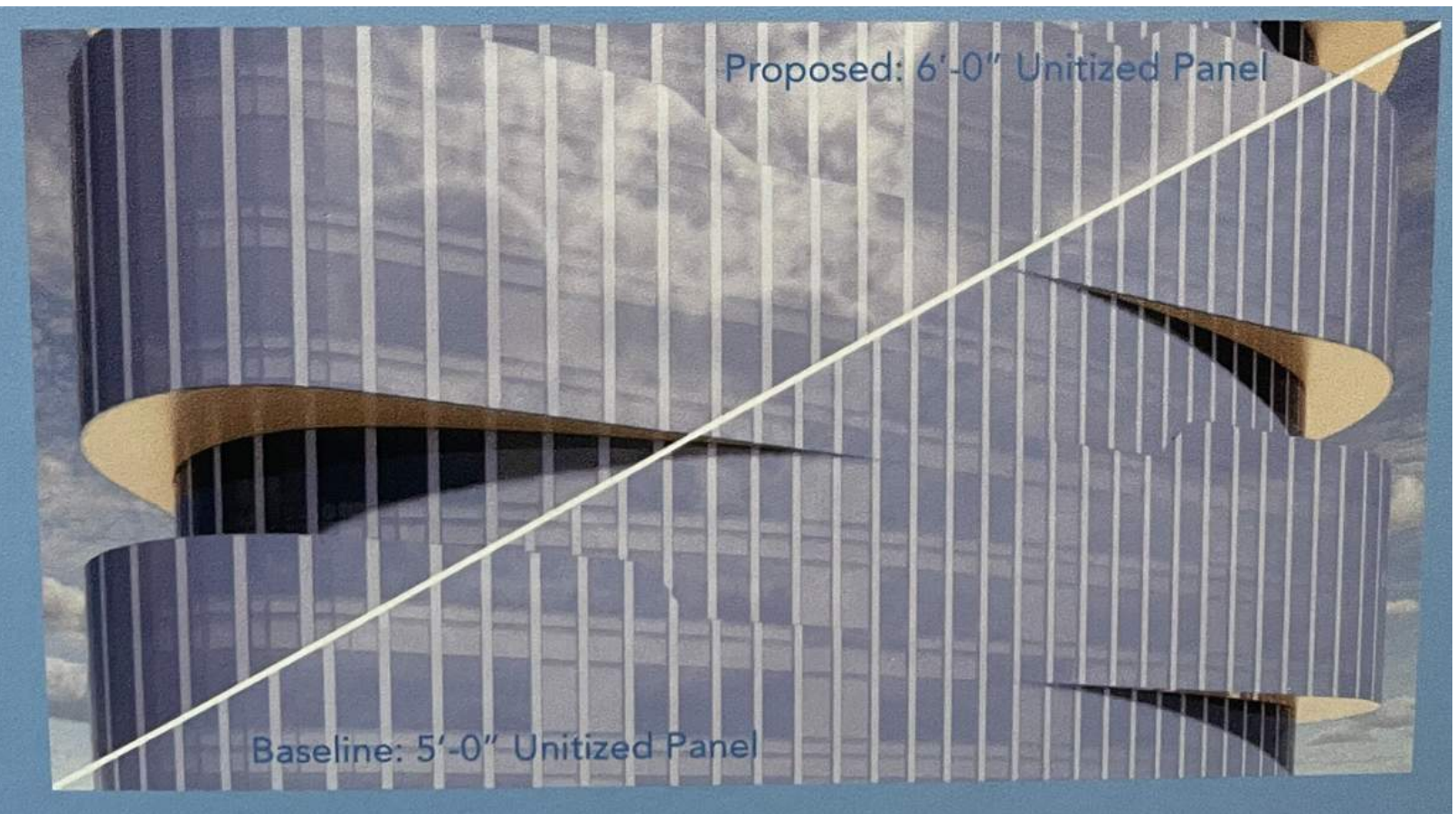
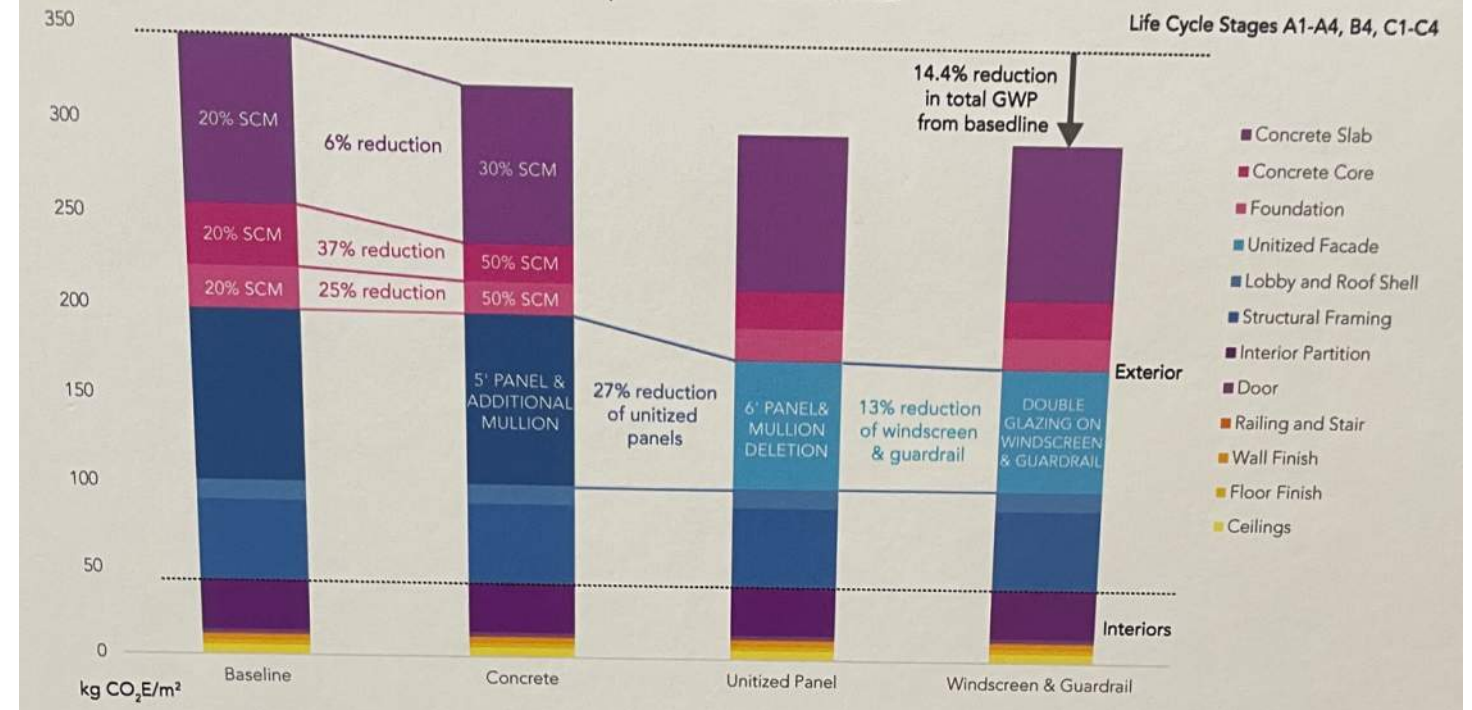
14%

Case Studies

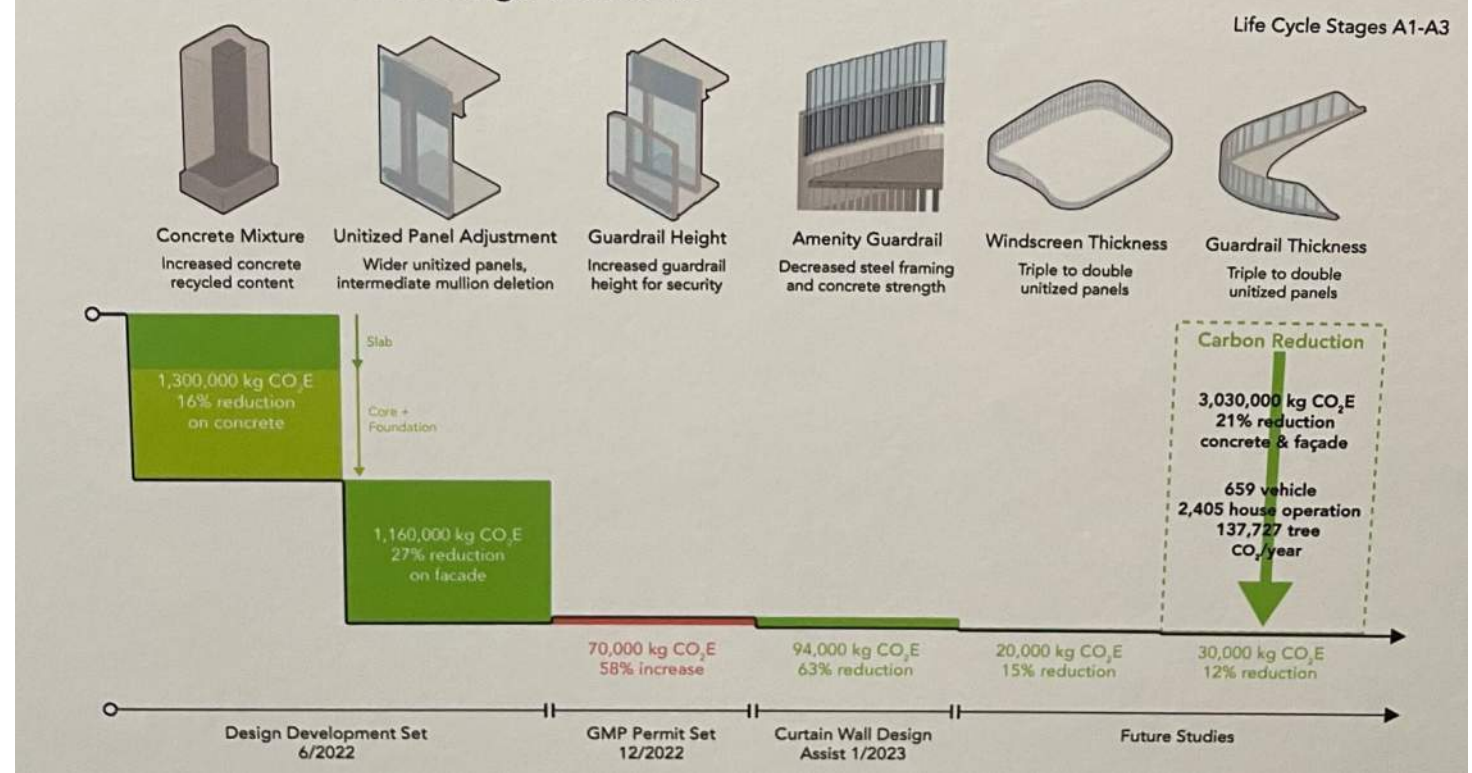
Building Unitized Panel Analysis



Stacked Bar Chart - Baseline vs. Proposed in GWP/m2



Embodied Carbon and Design Decisions



PARAPET FRAMING DESIGN

2.0 Design Lighter - Shorter, balloon-framed parapets reduce carbon by 1.7t CO₂e eliminating kickers and insulation in the concealed space



ACOUSTIC CEILING TILES

Plant-based ceiling tiles in corridors have 33% of the carbon of typical ACT



CEMENTITIOUS UNDERLAYMENT

2.0 Specify Specifically - Using a low carbon alternative specification saves 35% more carbon



WOOD FRAMED PARTITIONS

Cost effective, low carbon alternative to cold-formed steel framing



COMPOSITE CARPET TILE

Red List free and only 50% of the carbon of conventional carpet tiles



UNDERSLAB INSULATION

2.0 New Technologies - Replacing 2" XPS insulation with insulated foam-glass aggregate saves 55 metric tons of CO₂e



CONTINUOUS INSULATION

2.0 When More is Less - Although 50% thicker than Polyiso(PIR), mineral wool board has 65% less carbon



CAVITY INSULATION

Cellulose insulation has 50% less carbon than conventional glass fiber insulation



TRIPLE-PANE UPVC WINDOWS

Higher embodied carbon than double-pane; 1.45% operational carbon savings pays back in 2-5 years Presented for further discussion



BIO-BASED RESILIENT FLOOR

42% less carbon than conventional LVT flooring, and promotes PVC-free interiors



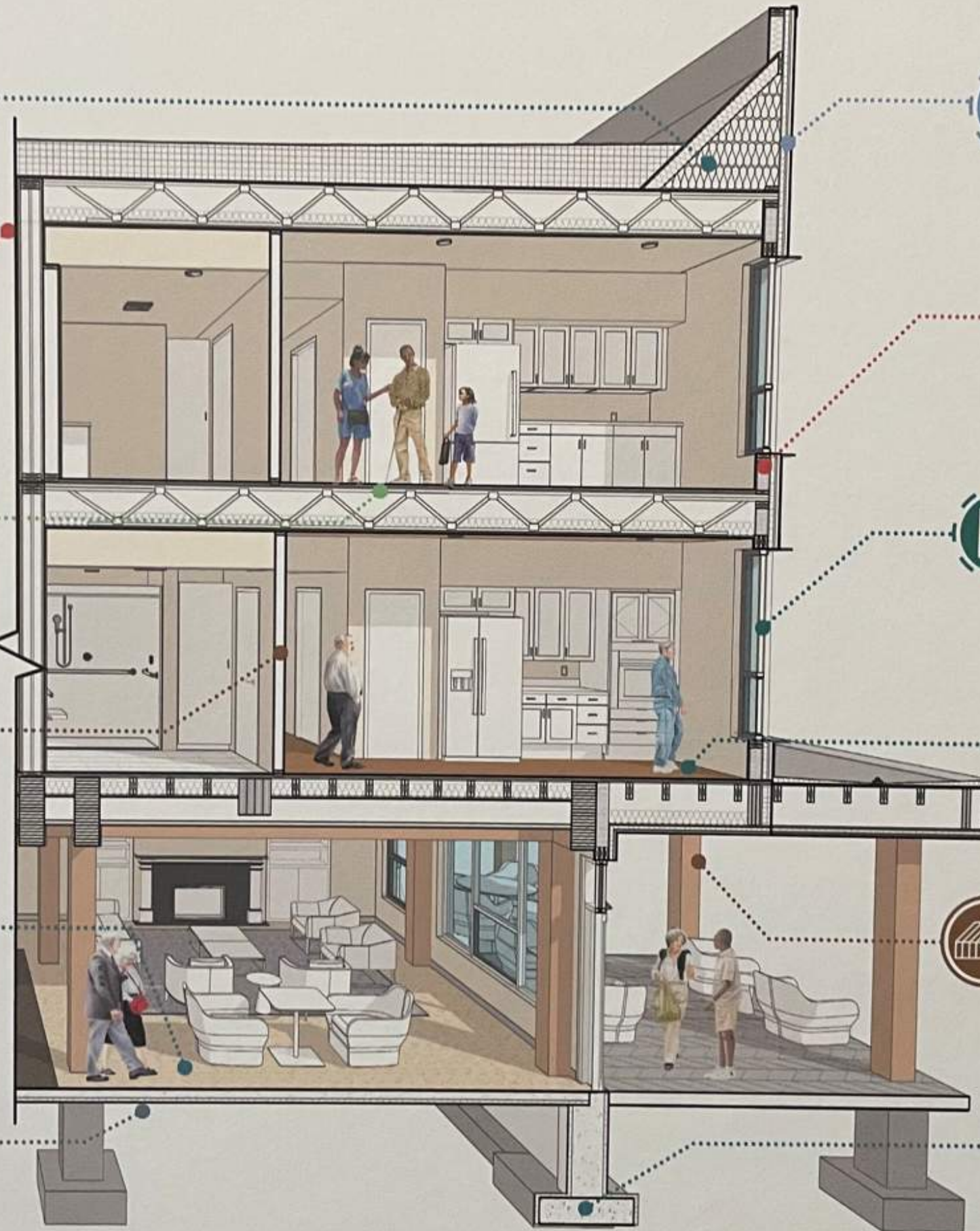
MASS TIMBER FRAMING

42% less carbon than structural steel and added biophilia benefit to the community

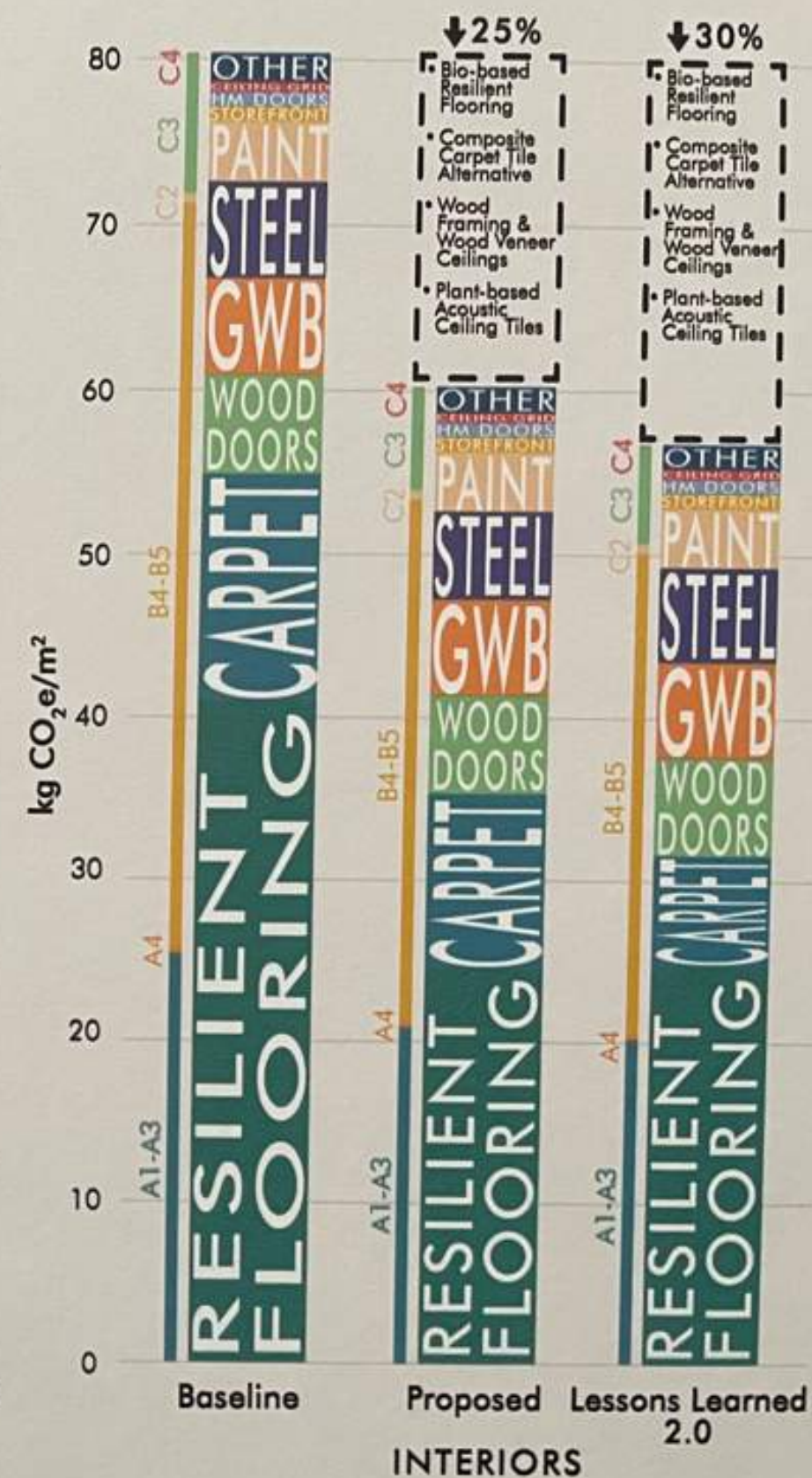
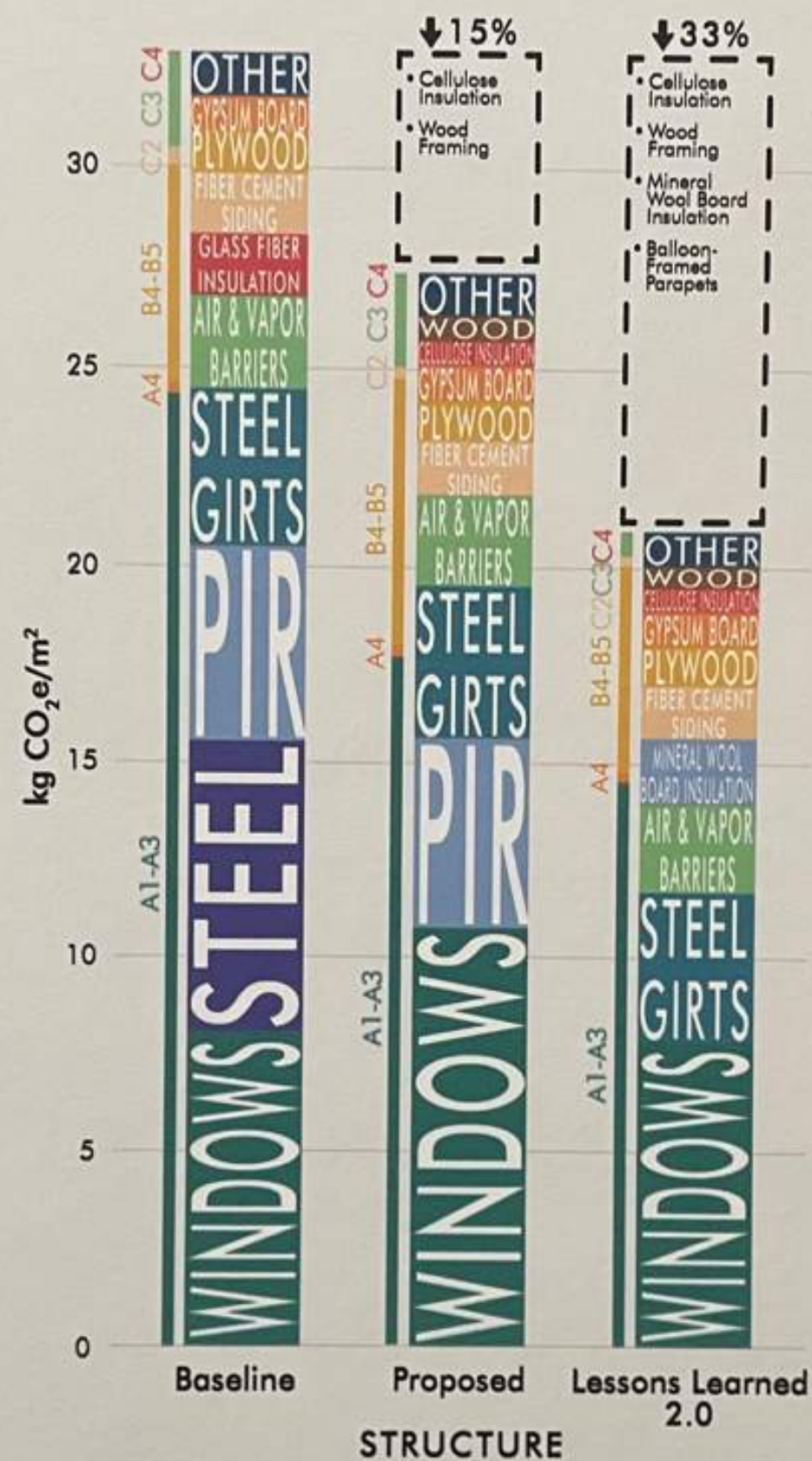
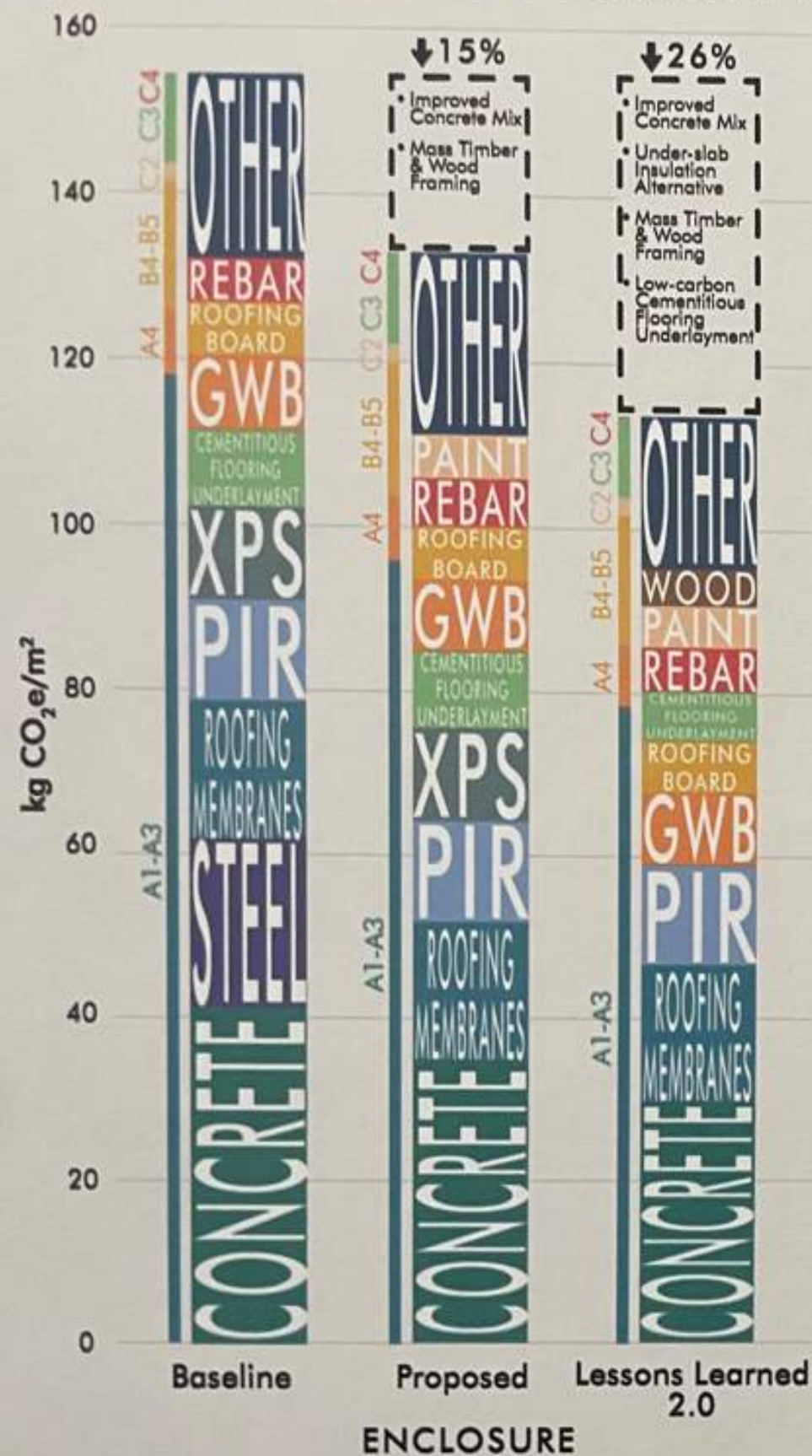


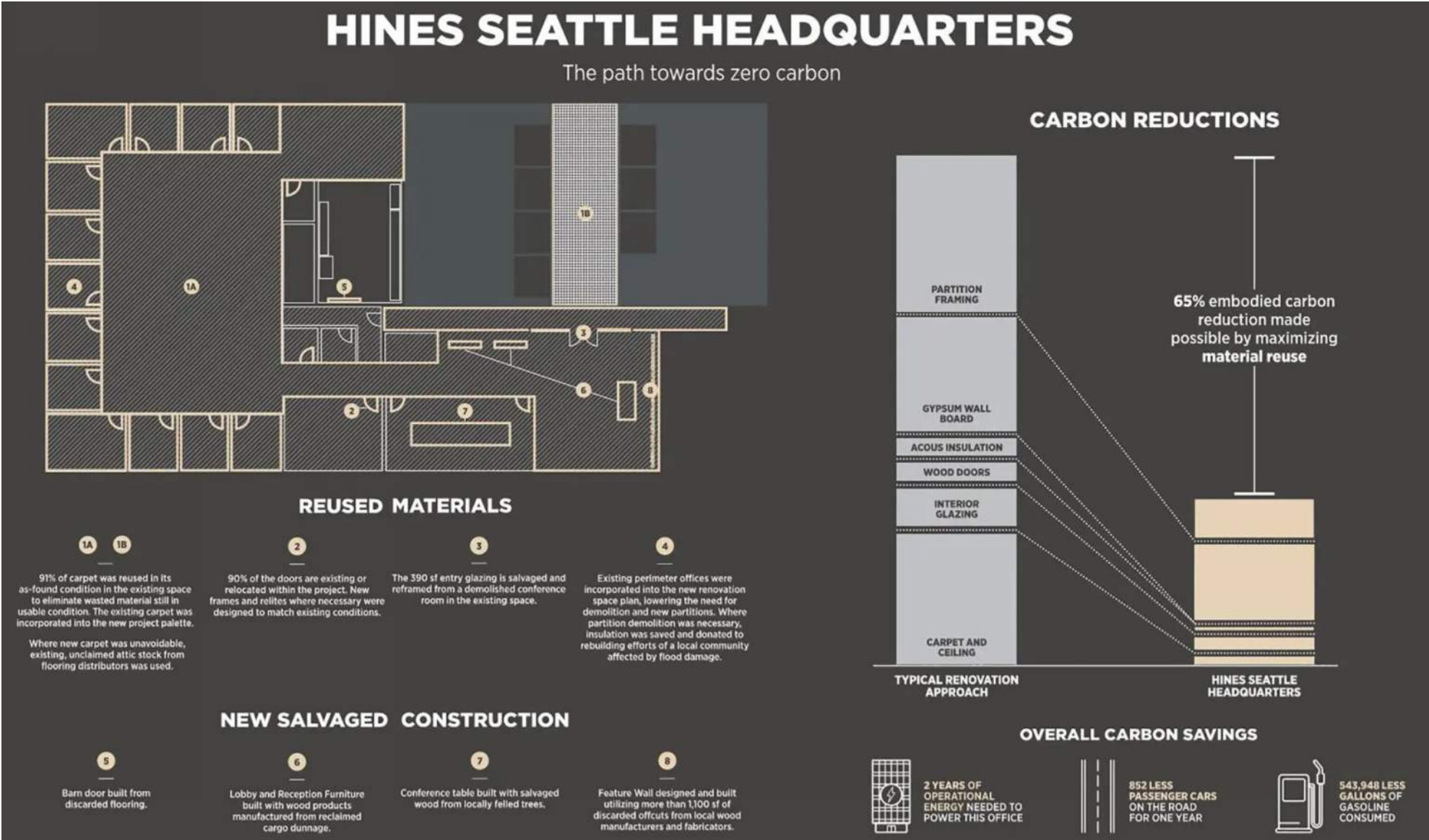
IMPROVED CONCRETE MIX

2.0 Specify Specifically - Requiring performance-based Supplemental Cementitious Materials (SCMs) saves 35 metric tons of carbon

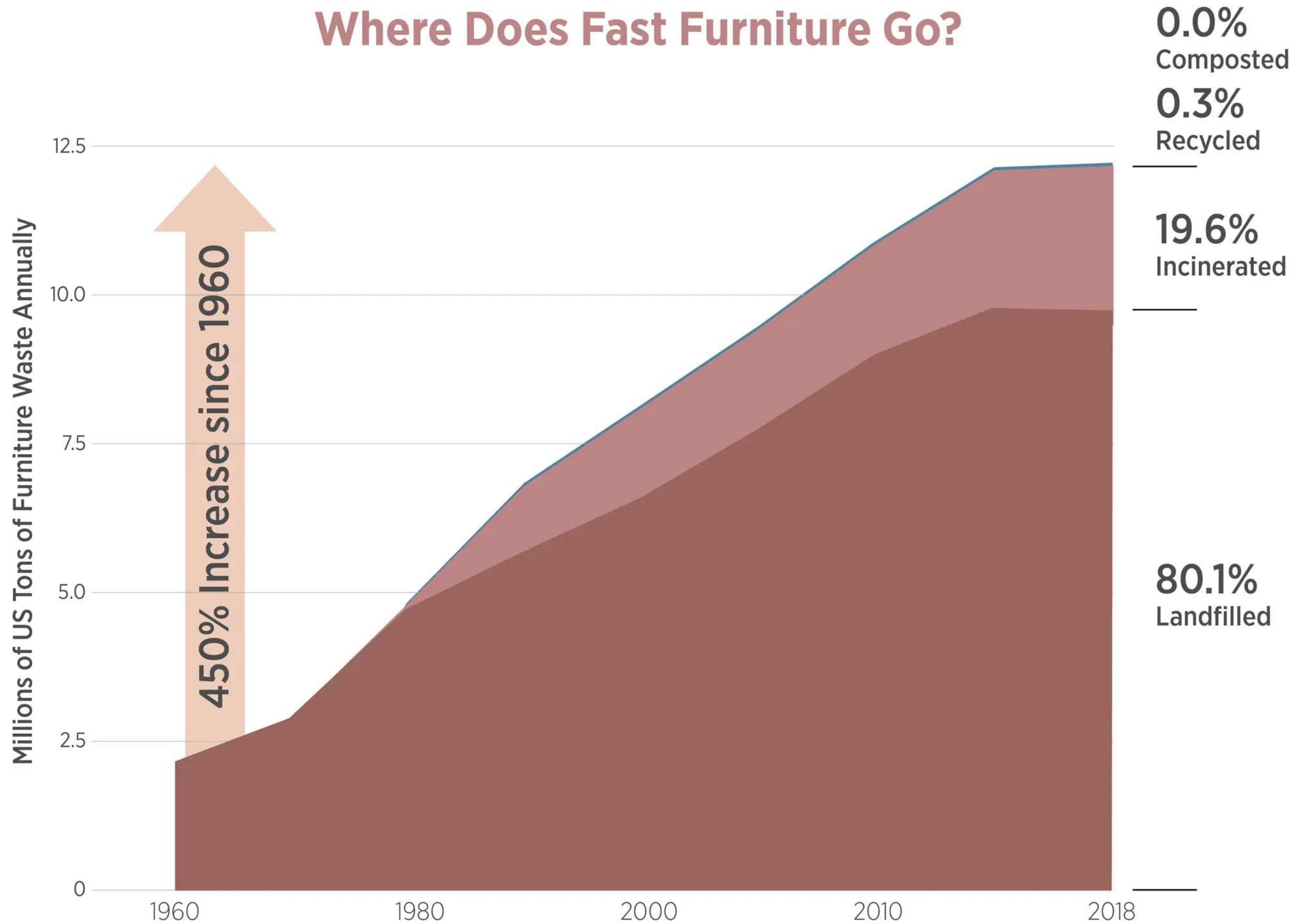


GLOBAL WARMING POTENTIAL BY LIFE CYCLE STAGE AND RESOURCE TYPE





Where Does Fast Furniture Go?

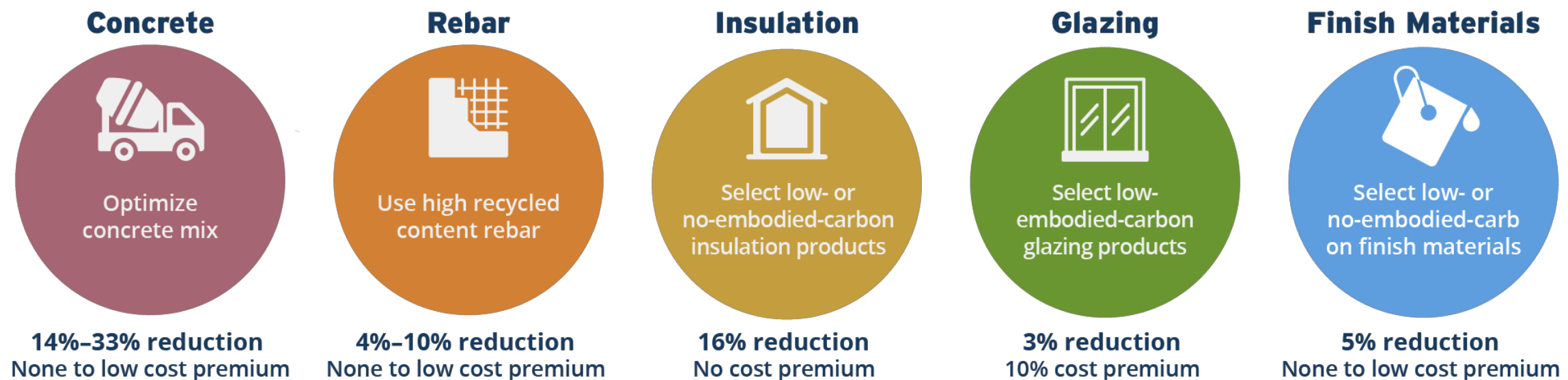


Office Implementation

From today to carbon neutral

Start with Simple Steps (Inflate your tires)

- Push structural our engineers
- Consider simple design choice that lower embodied carbon
- Start becoming comfortable using LCA applications and begin looking at product LCA's and PCR's
- Implement strategy for marketing purposes
- Simply ask ourselves "how much embodied carbon does this take?"



Professional LCA Software (flexible)



- GaBi
- SimaPro
- OpenLCA
- Brightway

Whole Building LCA & Whole Life Carbon (A-C/D + B6)



- Tally
- OneClick
- Athena Impact Estimator
- epic

Upfront Carbon Calculators (A 1-3) GWP only



- BEAM
- CARE
- TallyCAT
- BHoM
- Beacon
- ...

Material, Assembly or Component tools (Highly variable)

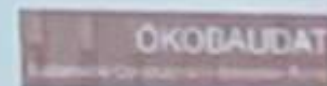


CARBON CONSCIENCE

climatepositive
designchallenge

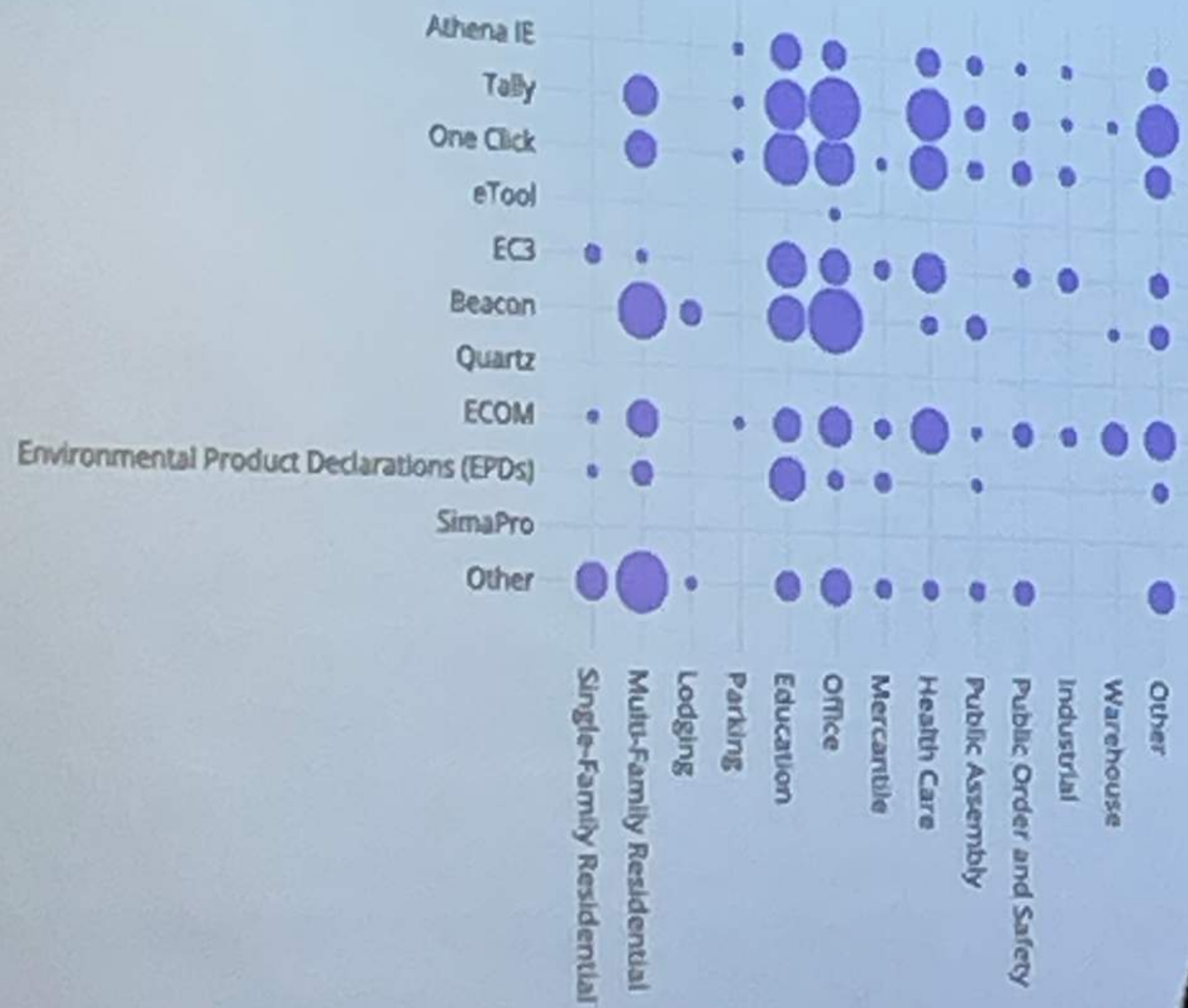
- Kaleidoscope
- Upstream
- MEP 2040 Refrigerant Calculator
- Pathfinder
- Carbon Conscience

Product Selection / Procurement (EPDs)



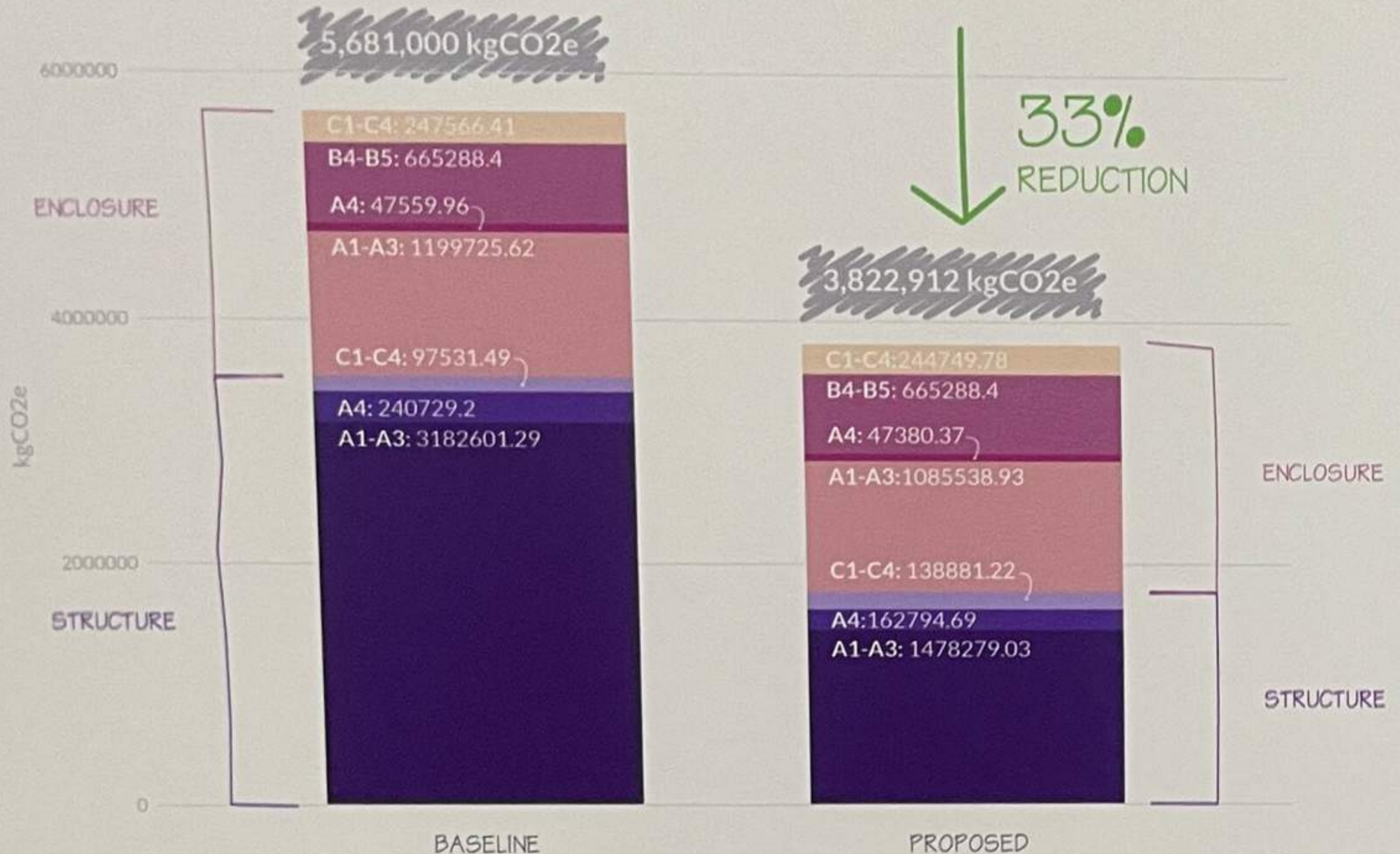
- EC3
- PHANOS*
- Okubaudat*
- BECD*

* presently focused on EU data, other datasets are in development



TOTAL CARBON (kgCO₂e) BASELINE VS PROPOSED

CRADLE TO GRAVE







Personal choices to reduce your contribution to climate change

* Cumulative emissions from descendants; decreases substantially if national emissions decrease.

Average values for developed countries, based on current emissions.

Annual climate savings (tCO₂e)

Upgrade light bulbs

Hang dry clothes

Recycle

Wash clothes in cold water

Replace typical car with hybrid

Eat a plant based diet

Switch electric car to car free

Buy green energy

Avoid one transatlantic flight

Live car free

Have one fewer child

Low Impact

< 0.2 tCO₂e

Moderate Impact

0.8-0.2 tCO₂e

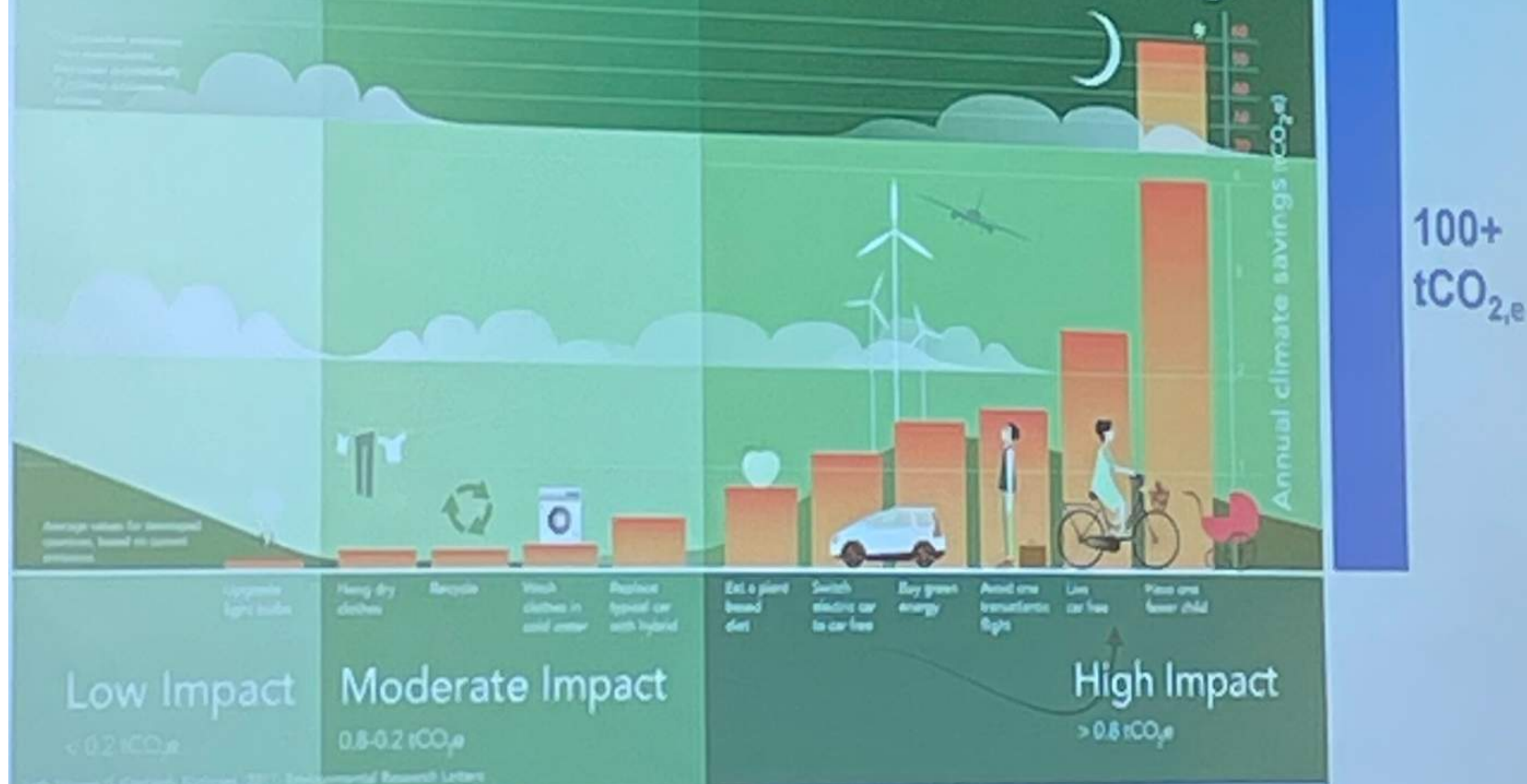
High Impact

> 0.8 tCO₂e

Seth Wynes & Kimberly Nicholas, 2017, Environmental Research Letters

Reduce large Boston commercial building EC by 1%

Personal choices to reduce your contribution to climate change



thank you