DDL753 Design of sustainable habitats

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IIT Delhi

Course Overview

27th July, 2023

Bhutan
(Land of the Thunder Dragon)

- Gross National Happiness
- 70% of area under forests
- 1st carbon negative country in the world

Source: https://www.earthtrekkers.com/bhutan-land-thunder-dragon/

Valley of Flowers Trek (July 2021)

Have you had any sustainable habitat experiences?

Introductions

- Name
- Program
- Interests and background related to Design of Sustainable Habitats

POOJA AGARWAL

Design for Indoor Air Quality | Built Environment | Health and Wellnes | Prototyping | Building Modelling | Airflow Simulations

Supervisor: Prof. Jay Dhariwal **Year of Joining:** 2021

E-mail: pooja.agarwal@design.iitd.ac.in
Portfolio link: https://www.linkedin.com/in/pooja-s-agarwal/

SONAL GANGRADE

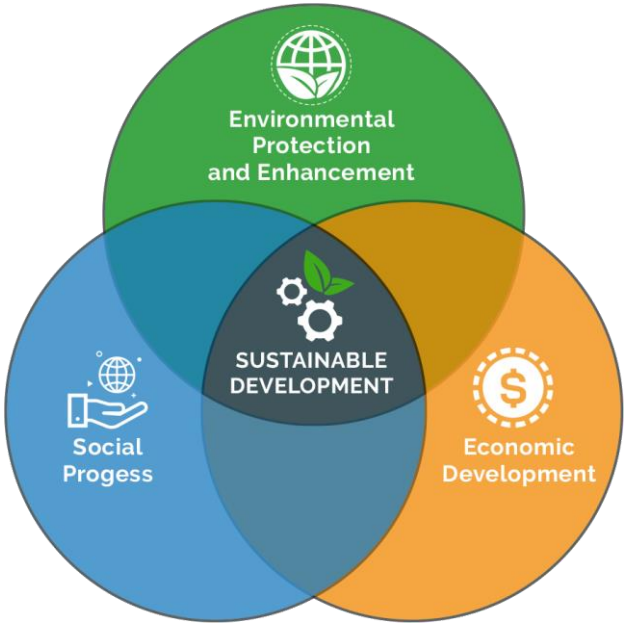
Design for Health and Wellnes | Thermal Comfort | Building Design | Design for Sustainability

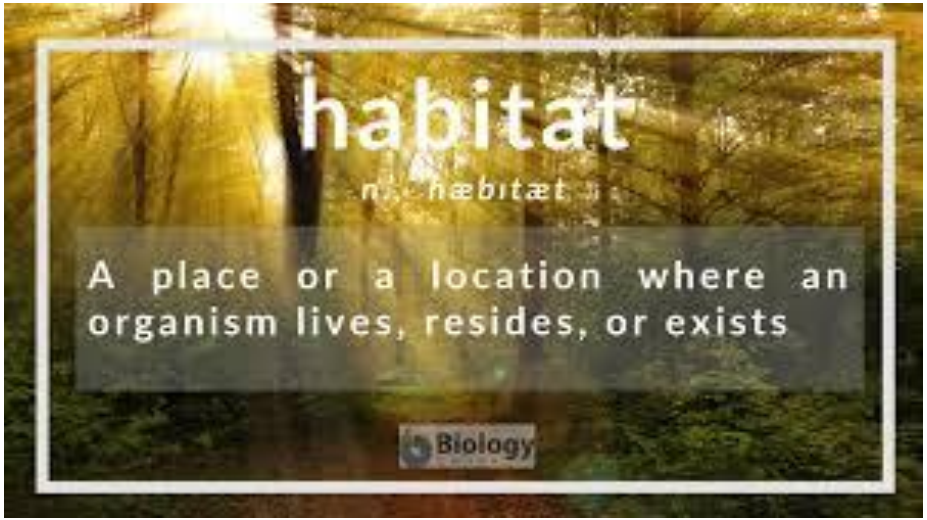
Supervisor: Prof. Jay Dhariwal **Year of Joining:** 2021

E-mail: sonal.gangrade@design.iitd.ac.in
Portfolio link: www.linkedin.com/in/sonal-gangrade-094

TAs for the course

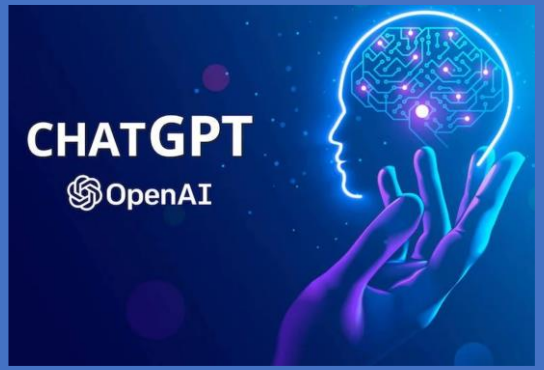
Design of Sustainable Habitats





Source: https://www.arenasolutions.com/resources/glossary/sustainable-development/
https://sustainability-success.com/social-sustainability-examples/#google_vignette


SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS



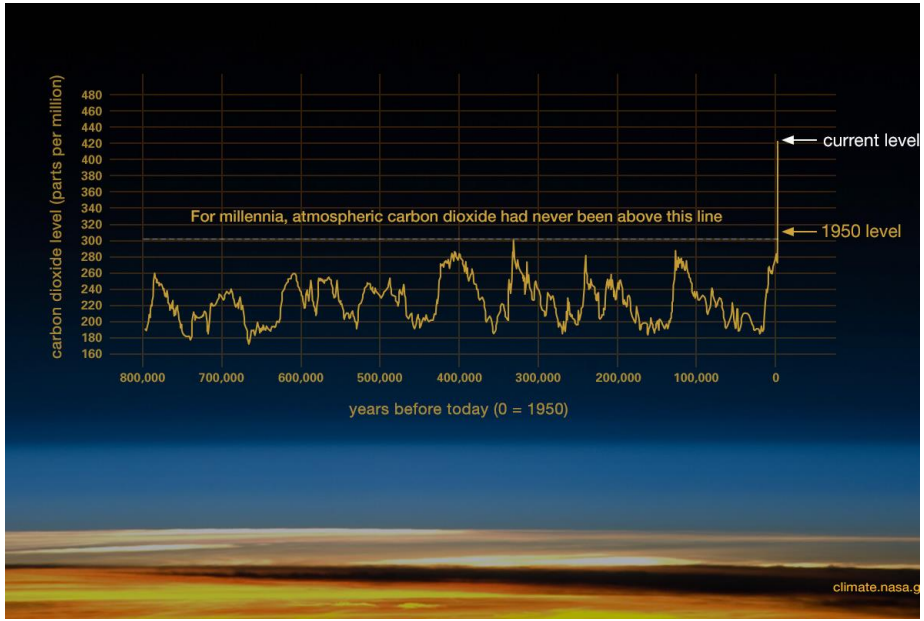
World's major challenges

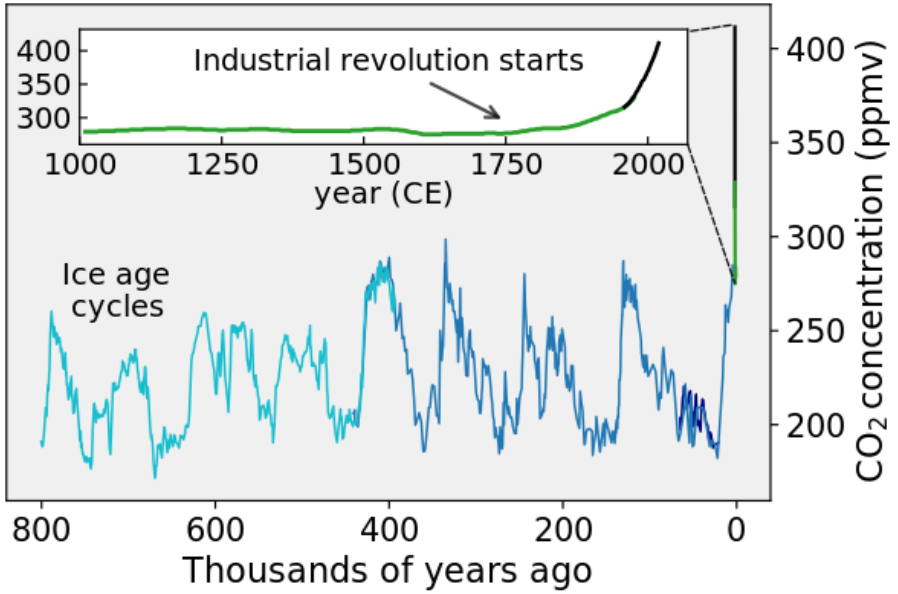
As of my last update in September 2021, the world faced several major challenges, and it is likely that many of these challenges persist in 2023. Some of the key global challenges include:

1. Climate Change: The Earth's climate continues to be a pressing concern, with rising temperatures, extreme weather events, and the depletion of natural resources. The need to transition to clean energy sources and reduce greenhouse gas emissions remains critical.
2. Global Health Pandemics: The ongoing COVID-19 pandemic demonstrated the vulnerabilities of the global health system. There's a continuous need to improve pandemic preparedness, enhance healthcare infrastructure, and address emerging infectious diseases.

The effects of Climate Change

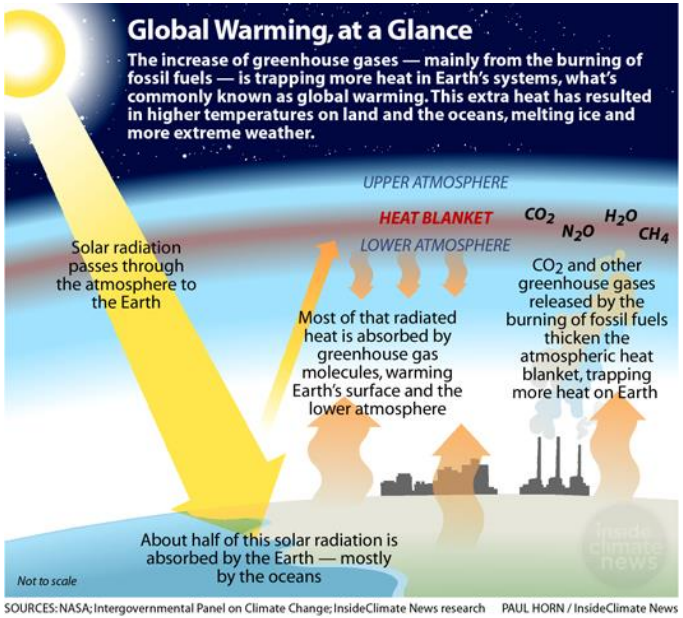
Source: https://climate.nasa.gov/effects/

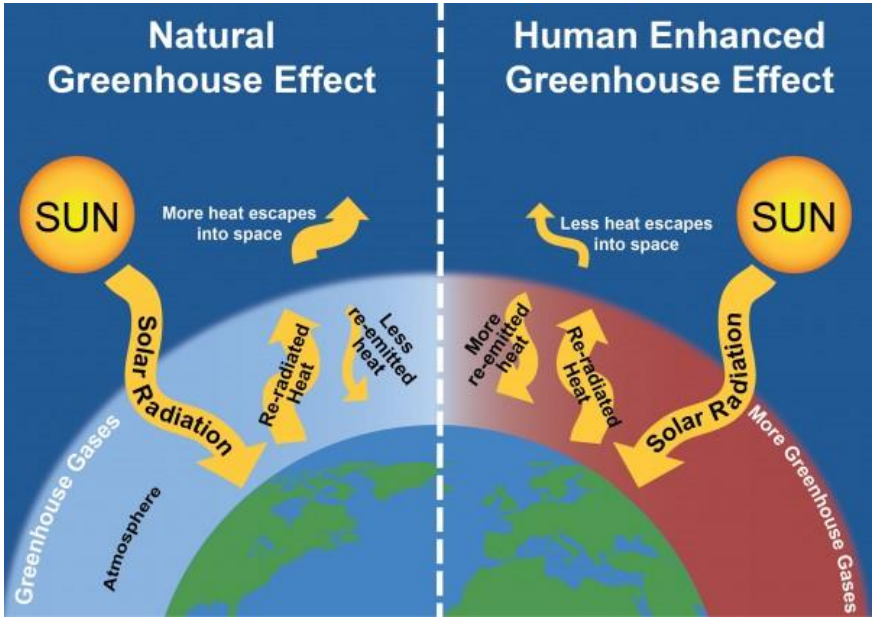




Evidence for Climate Change

Source: https://climate.nasa.gov/evidence/, https://en.wikipedia.org/wiki/Carbon_cycle
Prof Yama Dixit, IIT Delhi "Learning from the Past"





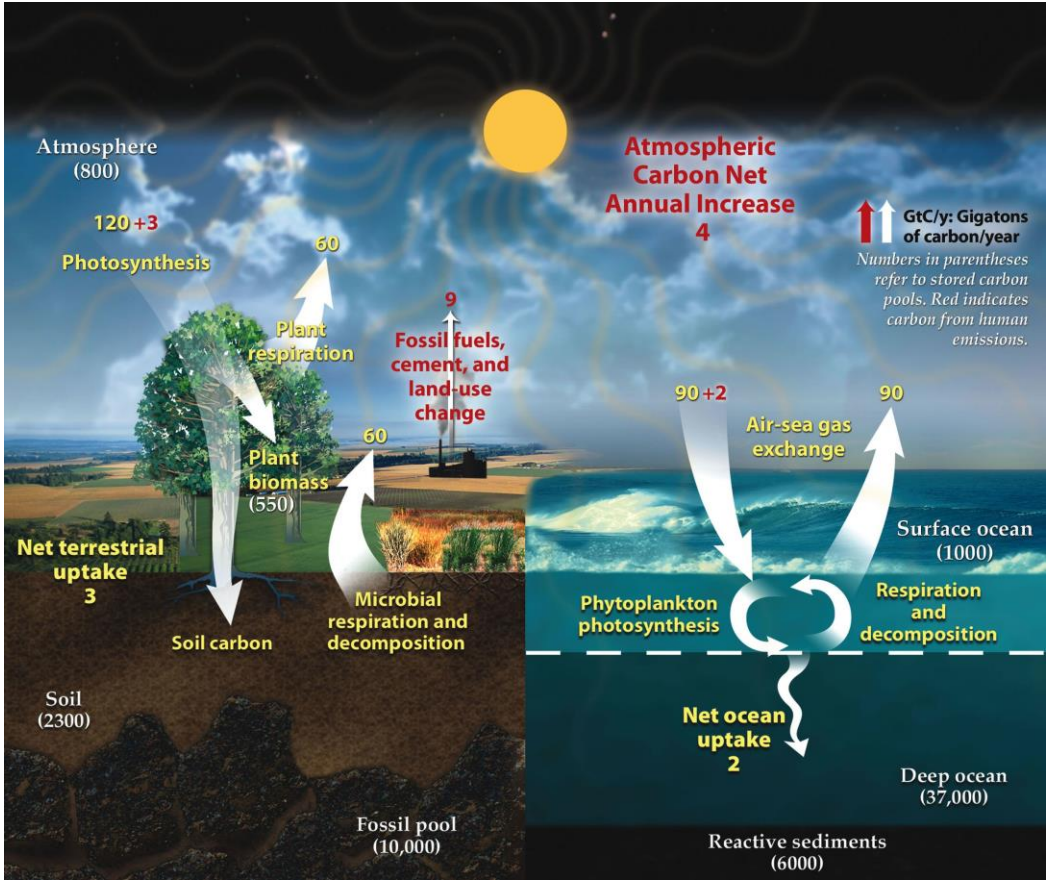
What is causing Global Warming?

Source: http://css.snre.umich.edu/factsheets/climate-change-science-and-impacts-factsheet

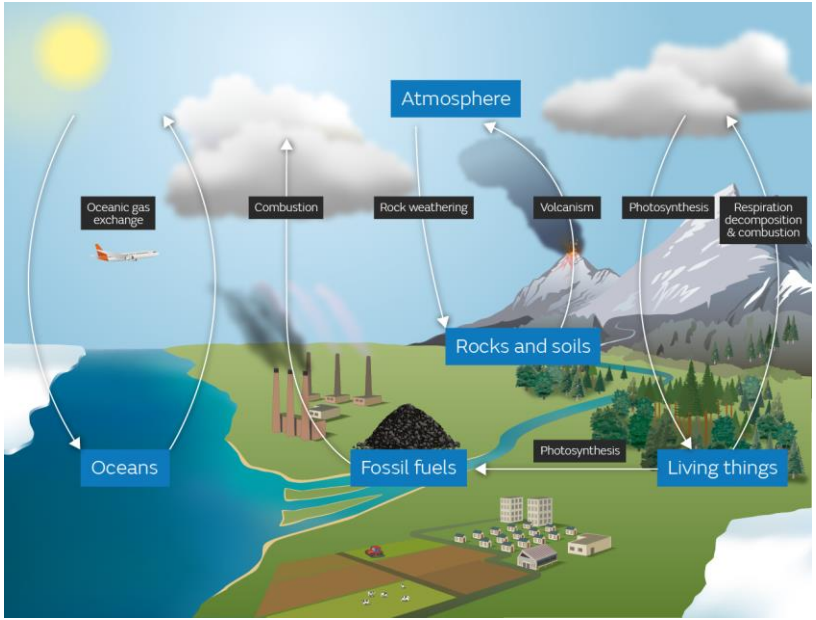
Carbon is backbone of life on Earth

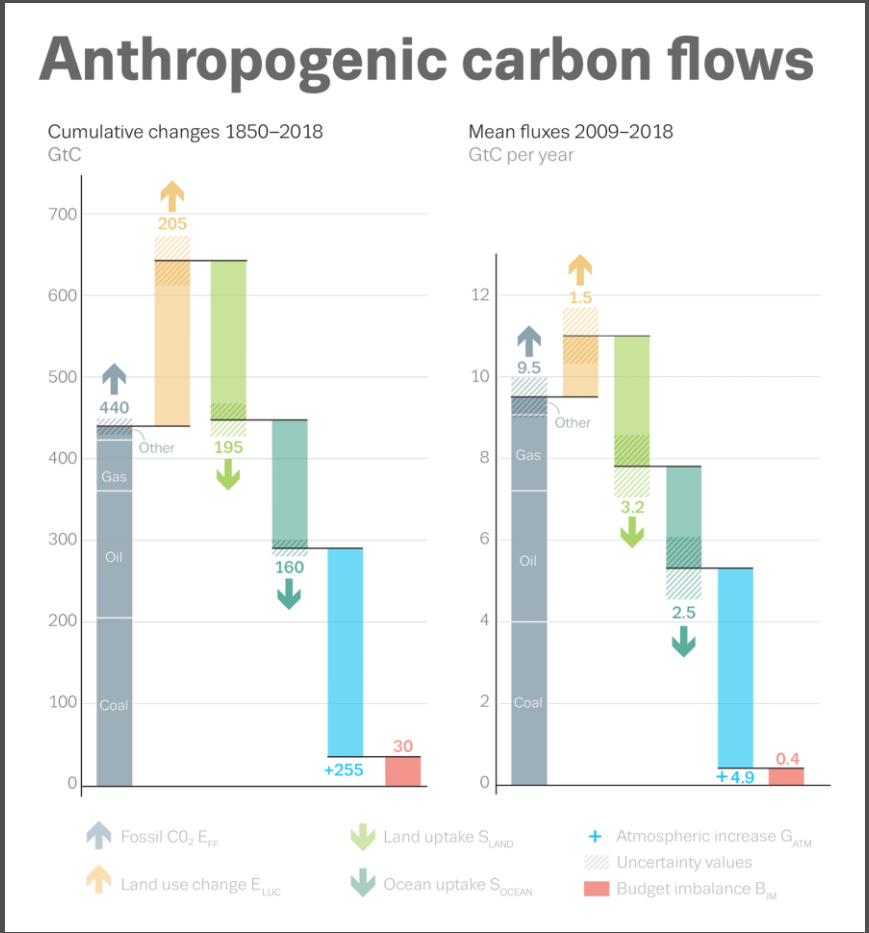
Source: [Photographs ©2007 MorBCN (top) and ©2009 sarahluv (lower).]

Carbon Cycle



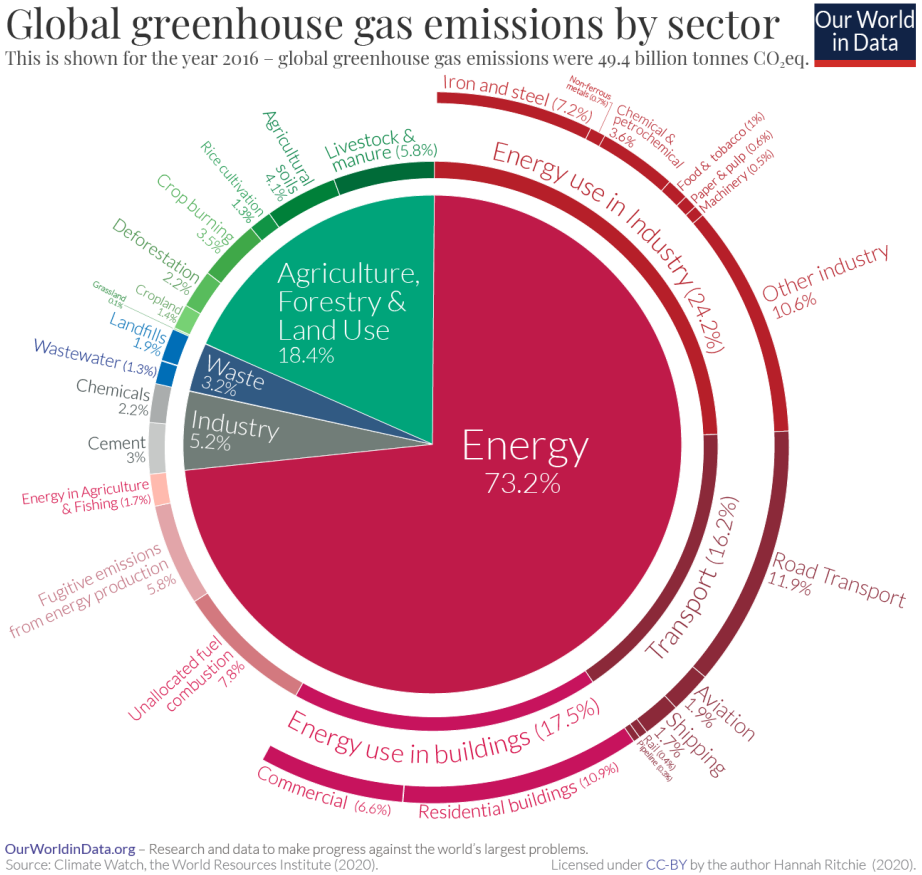
Source: https://earthobservatory.nasa.gov/features/CarbonCycle





Source: https://www.metoffice.gov.uk/weather/climate/climate-explained/carbon-cycle
https://essd.copernicus.org/articles/11/1783/2019/

Manmade emission sources



How do these numbers relate to each one of us?

Basis 1 for calculation: from fuel consumption per flight

One way to calculate CO_2 emissions is from fuel consumption per flight.

A **Boeing 737-400** jet is typically used for short international flights.

For a distance of 926 km, the amount of fuel used is estimated to be 3.61 tonnes [1], including taxiing, take-off, cruising and landing.

Using a seating capacity of 164 [Wikipedia, viewed 28.2.08] and an average seat occupancy (or 'load factor') of 65% [2], this gives a fuel use of 36.6 g per passenger per km.

CO_2 emissions from aviation fuel are 3.15 grams per gram of fuel [1], which gives CO_2 emissions from a Boeing 737-400 of 115 g per passenger per km.

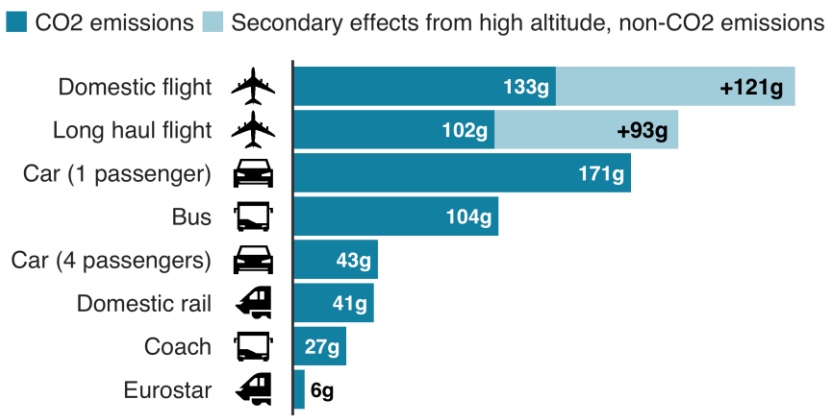
At a cruising speed of 780 km per hour [Wikipedia, 28.2.08], this is equivalent to 90 kg CO_2 per passenger per hour.

You can relate 90 kg CO_2 eq per person per hour to 50 billion tons CO_2 eq per year for planet!
What would be the CO_2 emissions if you use a car/public transport/bike ride?

Source: https://www.carbonindependent.org/22.html#:~:text=CO2%20emissions%20from%20aviation%20fuel,CO2%20per%20passenger%20per%20hour.

Emissions from different modes of transport

Emissions per passenger per km travelled



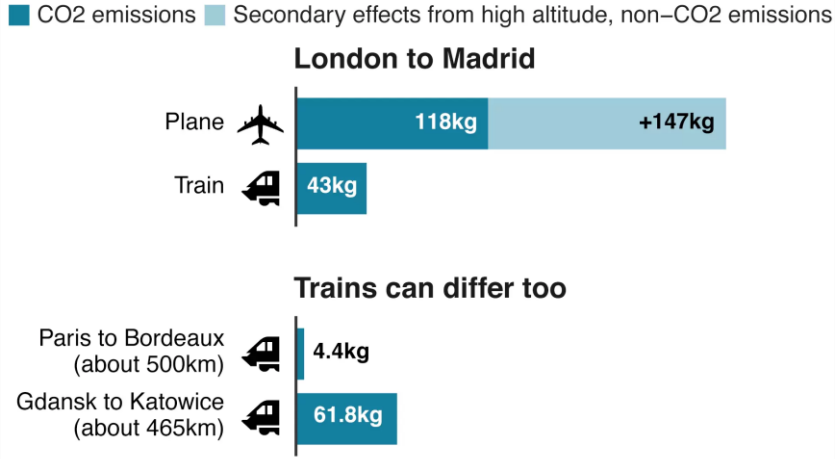
Note: Car refers to average diesel car

Source: BEIS/Defra Greenhouse Gas Conversion Factors 2019

BBC

Emissions from different journeys

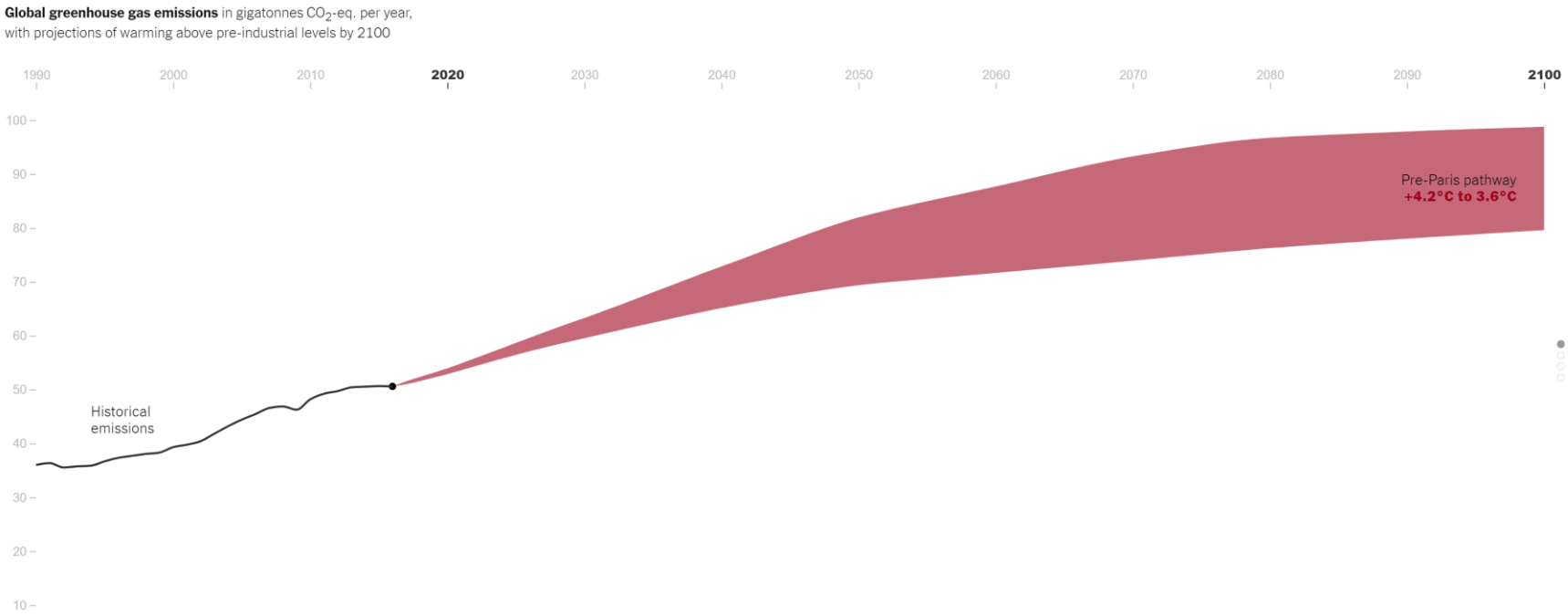
Emissions per passenger for journey



Source: EcoPassenger

BBC

GHG emissions and Global Warming



Source: https://www.nytimes.com/interactive/2021/10/25/climate/world-climate-pledges-cop26.html?auth=login-google1tap&login=google1tap

Energy Swaraj Foundation
Energy by Locals for Locals

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We are running out of **time!**

The IPCC report affirms that temperature rise beyond 1.5 degree celsius will start **irreversible climate change**. The 1.5 degree celsius is the most important number for every human being. It is the number that all climate scientists are keeping an eye on. Did you know how much time is left before global warming touches the 1.5 degree celsius limit?

DEADLINE TIME LEFT TO LIMIT GLOBAL WARMING TO 1.5°C

6YRS **001**DAYS **04:23:52**

LIFELINE WORLD'S ENERGY FROM RENEWABLES

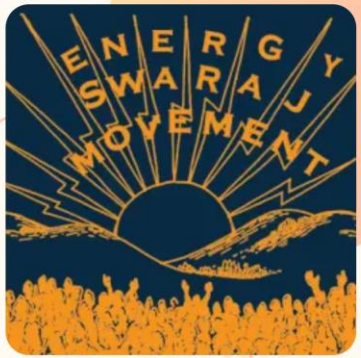
13.690071561%

RATE FELL 29% IN 2022 | US GOVERNMENT TO INVEST $300M IN MONITORING AGRICULTURAL EMISSIONS | QUEENSLAND ID

#ActInTime

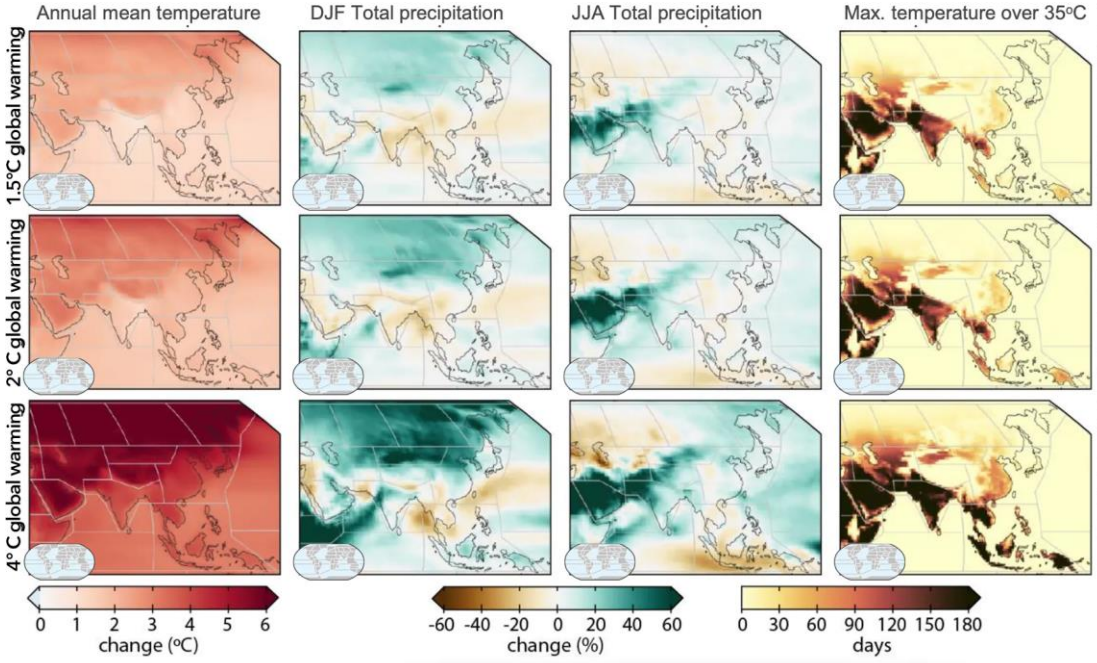
There is a need for a **Public Movement!**

Energy Swaraj as a public movement!



Source: https://energyswaraj.org/

Global Warming leading to intense heat waves in India



Projections at 1.5°C, 2°C, and 4°C global warming

Changes relative to the 1850–1900 in annual mean surface temperature, total precipitation (Dec–Feb, DJF), and total precipitation (Jun–Aug, JJA). Last column shows the total number of days per year with maximum temperature exceeding 35°C.

Source: IPCC

Rising intensity of heat waves of India

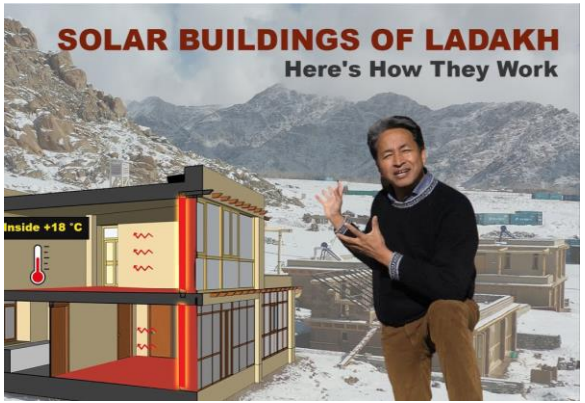
- Severe heat waves increasing in frequency
- Higher temperatures arrive earlier and stay far longer
- They may break human survivability limit
- 2/3rd Indian population can't afford an AC
- 38 crore people depend on heat exposed labour in India.
- By 2030, 3.4 (8) crore in India (global) job losses due to heat stress

Source: World Bank. 2022. Climate Investment Opportunities in India's Cooling Sector. www.worldbank.org

https://www.hindustantimes.com/cities/mumbai-news/11-dead-50-hospitalized-after-maharashtra-bhushan-award-function-in-navi-mumbai-questions-raised-over-organization-and-lack-of-shade-and-water-101681673928462.html

How should we bring down the CO_2 emissions?

What could you do?
What if we do that on scale?



https://www.theguardian.com/environment/2019/jul/04/planting-billions-trees-best-tackle-climate-crisis-scientists-canopy-emissions

AMG approach (Prof Chetan Singh Solanki, IITB)

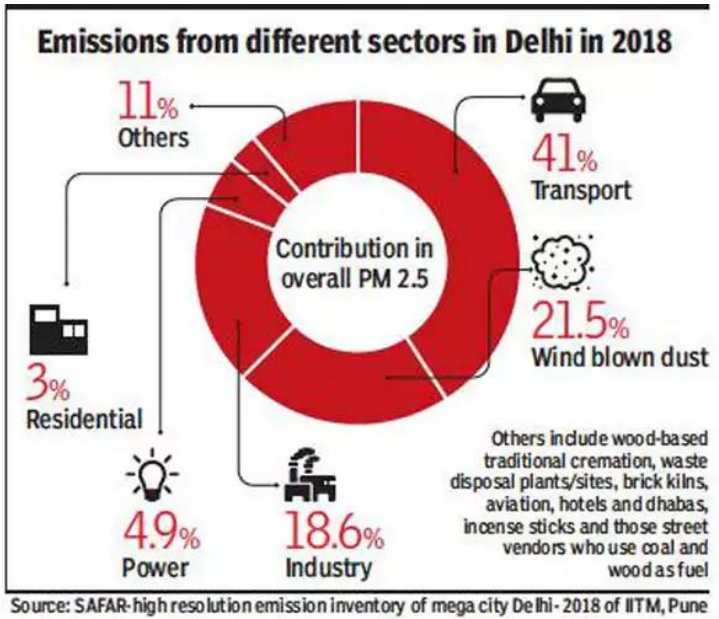
*First **'Avoid'** use of energy by **1/3rd**, even if solar energy,*

*Then **'Minimize'** use of energy by another **1/3rd**, using energy efficient appliances, and*

*At last, **'Generate'** only remaining **1/3rd** energy locally using renewable sources.*

Source: https://energyswaraj.org/aboutourteam/amgapproch

Sectoral contribution to ambient air pollution in Delhi



Do you see any overlap between the sectors that cause CO_2 emissions and air pollution? Would it help if Delhi switches to Electric Vehicles?

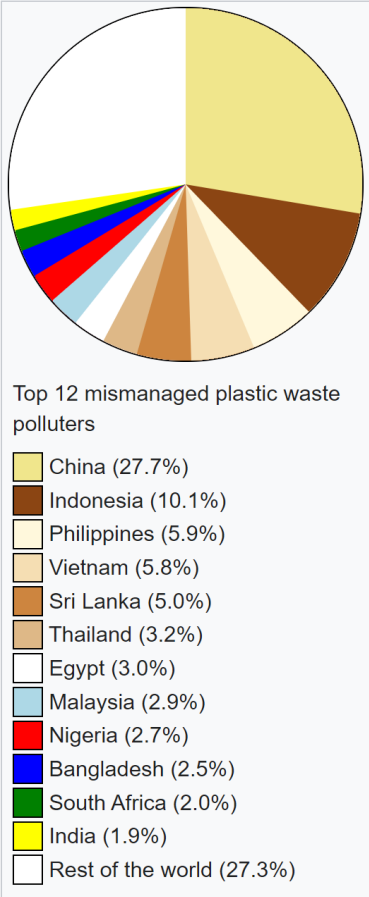
Source: [Delhi air pollution: Smaller sources add up to 11% of PM2.5 emission | Delhi News - Times of India (indiatimes.com)]

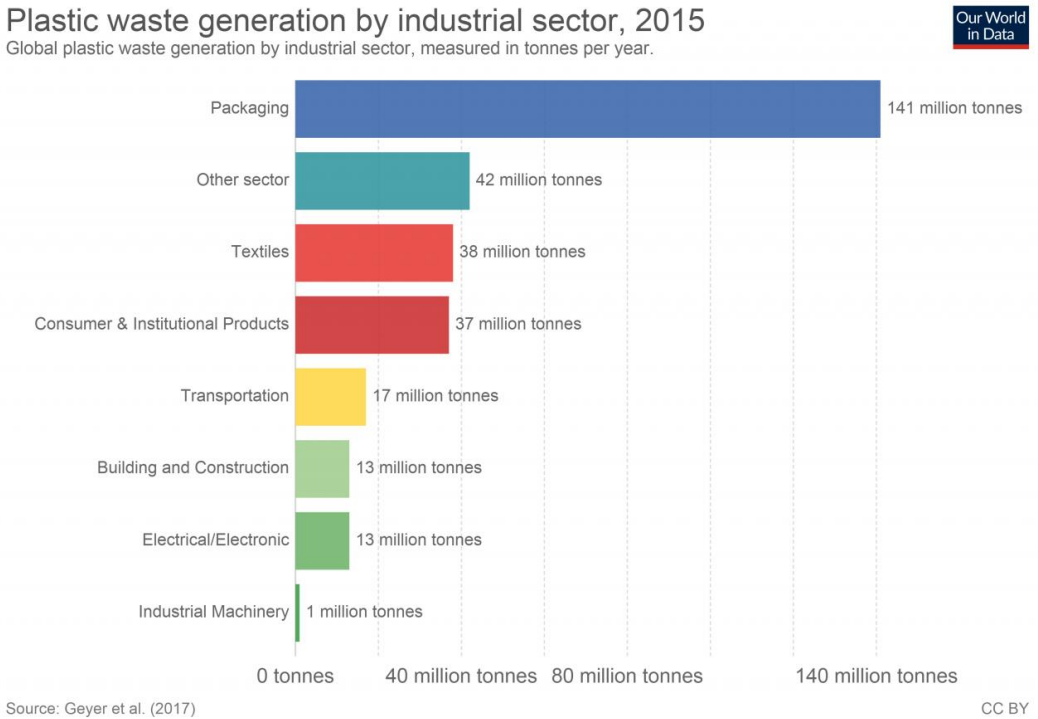
a Plague of Plastics

From the Arctic to Antarctica, ocean debris is killing marine wildlife—but we still have the power to stop plastic pollution.

This albatross carcass was one of scores recently found packed with plastic trash on Midway Island, where scientists estimate 99 percent of the birds have some plastic in their stomachs.

CHRIS JORDAN



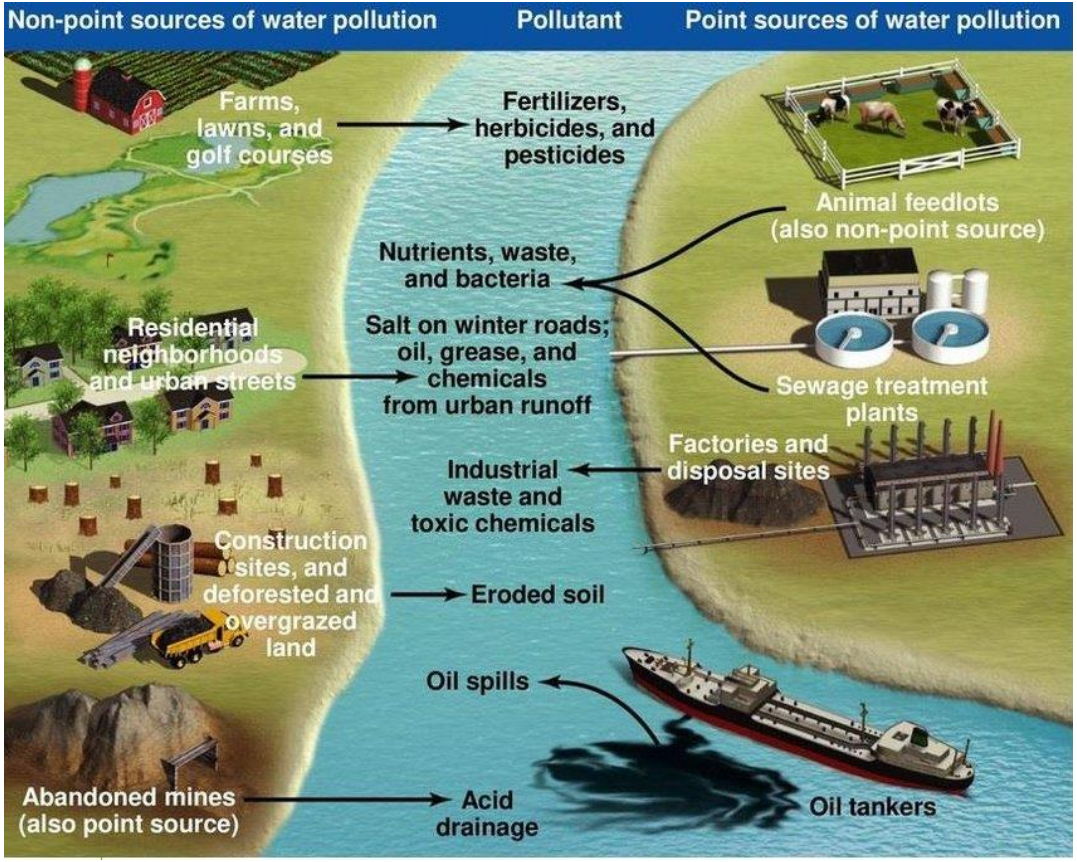


Source: https://en.wikipedia.org/wiki/Plastic_pollution

Water pollution in Yamuna

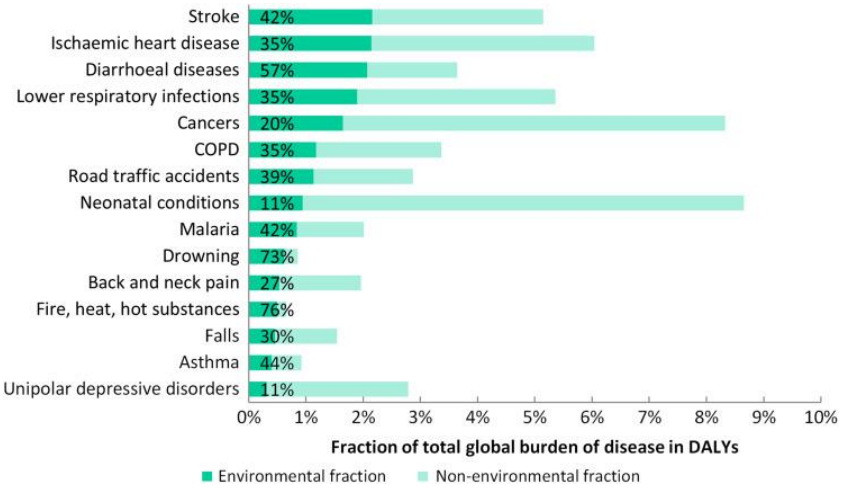
Source: https://www.indiatoday.in/cities/agra/story/polluted-yamuna-mars-taj-mahal-up-govt-yet-to-take-measures-1857552-2021-09-26

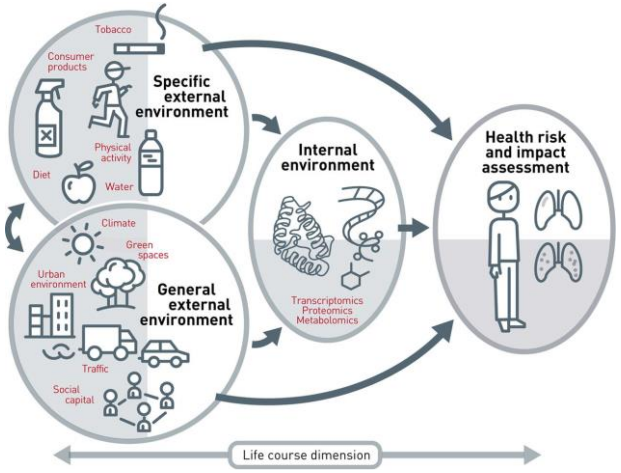
Sources of Water Pollution

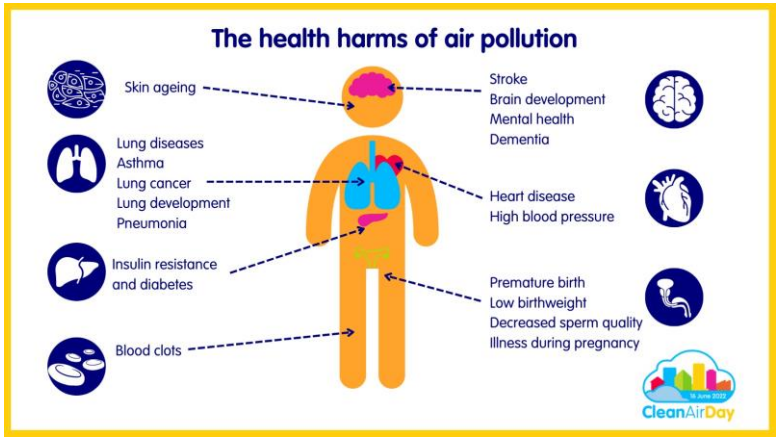


Source: https://www.researchgate.net/figure/Sources-of-Water-Pollution_fig1_335207701

Health effects of environmental causes







- Prüss-Ustün, A., Wolf, J., Corvalán, C., Neville, T., Bos, R., Neira, M. (2017). Diseases due to unhealthy environments: an updated estimate of the global burden of disease attributable to environmental determinants of health. Journal of Public Health, 39(3), 464–475. https://doi.org/10.1093/pubmed/fdw085

[Green Trails Initiative](), Indiahikes

[Recycling shredded plastic]()

8 ACTS OF EMERGENCY

1. SOUND THE ALARM

Acknowledge and raise awareness of the climate and ecological crisis - including its roots in systems of oppression - in our organisations and our practice.

2. START THE JOURNEY

Invest in educating ourselves and our teams on methods of sustainable and regenerative design and show leadership by making measurable change to our practice.

3. BRING CLIENTS WITH US

Meaningfully consider environmental and social impacts as part of every pitch, proposal, and production process. Not every design output will be carbon neutral or fully climate friendly, but every project is an opportunity to make real progress.

4. MEASURE WHAT WE MAKE

Measure the environmental and social impact of our work and design projects and hold ourselves to account for what we find out.

5. REDEFINE 'GOOD'

Encourage, recognise and reward sustainable and regenerative design excellence in our industry through media and awards.

6. EDUCATE, ACCELERATE

Build and foster intra- and cross-discipline knowledge networks to share tools, resources, and best practice to accelerate progress in our industry.

7. DESIGN FOR JUSTICE

Create with and for the people who are disproportionately affected both by climate change and by the transition to a lower-carbon world.

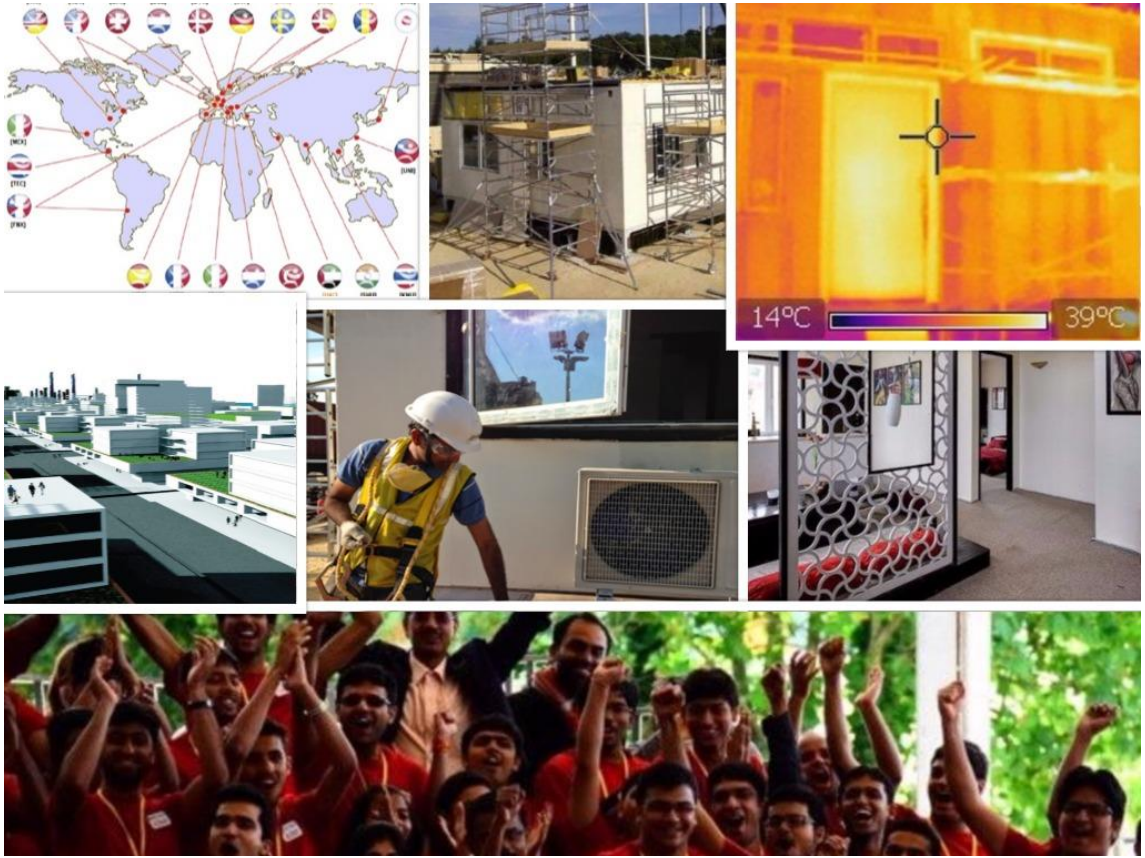
8. AMPLIFY VOICES FOR CHANGE

Enable systemic change by working alongside policymakers, campaigners, ecologists, scientists, activists, and others to strengthen local and national movements for change.

#DESIGNDECLARES

Design studios in UK aim to reduce envt. footprint

Team S.H.U.N.Y.A.



Solar Decathlon Europe 2014

Fab Bhutan Challenge

5 challenges - 5 areas of intervention

There will be four areas of intervention in the challenge, and through them it will be possible to outline the course of the program.

The theme of the Fab Bhutan Challenge, as well as the overall theme of the event, is **“designing resilient futures.”**, an acknowledgement of the changes and transformation that Bhutan is currently undertaking.

The Challenge, following this theme, will bring together local and global innovation communities to propose meaningful interventions that enrich, scale and invest in Bhutan’s resilient economy from the bottom up following these four pillars:

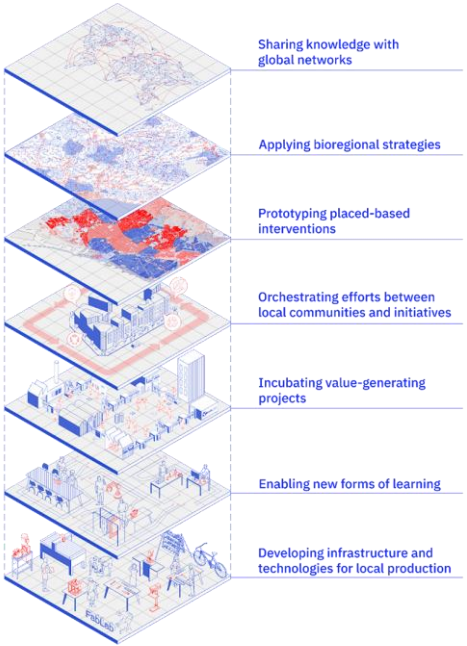
- Youth & Education
- Technology
- Innovation, Sustainability and Community
- Economic Opportunity

1. Climate Adaptive Agriculture
2. Water Conservation
3. Human Wildlife Conflict
4. Cultural Preservation
5. Assistive Technology

society composter

Vigyan Ashram: self sufficient village

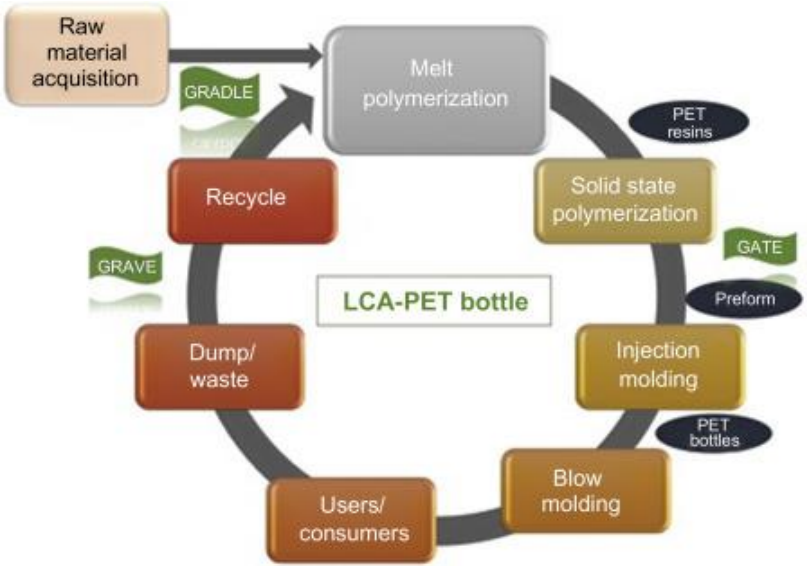
Fab City Network



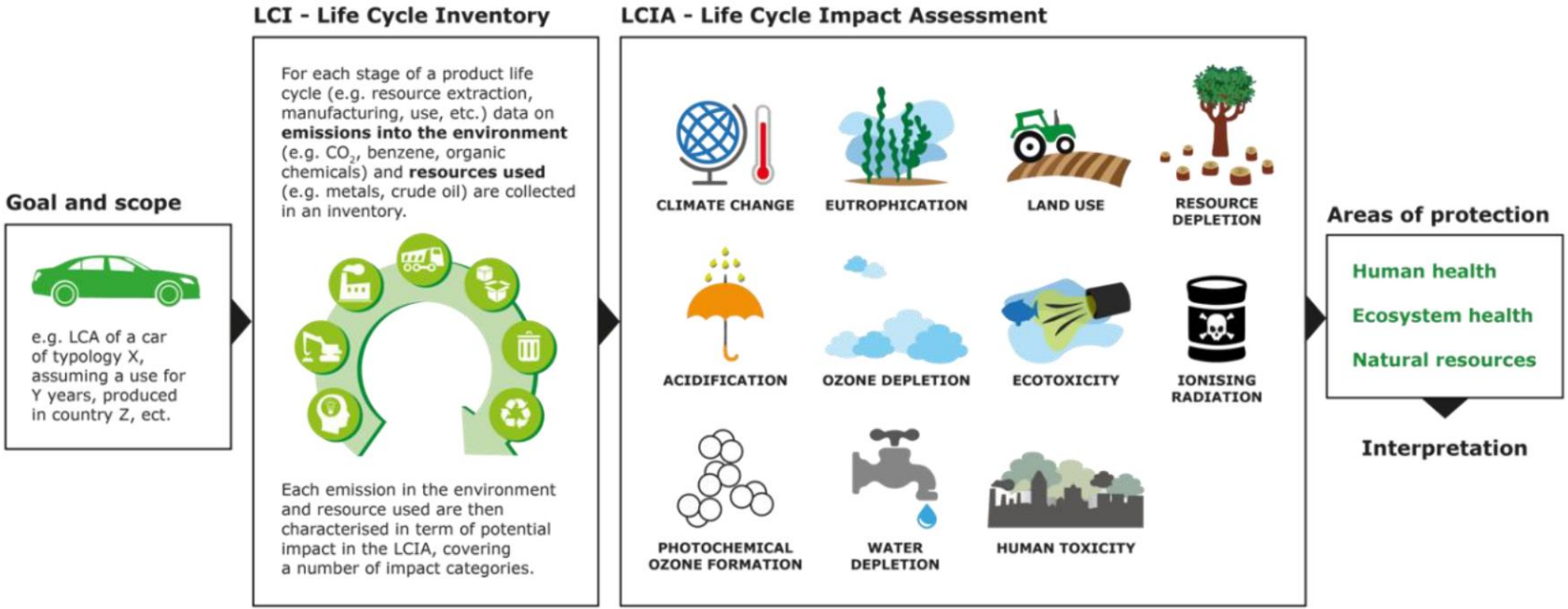
What have we learnt so far?

- Causes of Climate Change
- Sectoral contribution of Climate Change
- CO_2 emissions for an individual
- Global Warming and Heat Waves
- Air, Plastic and Water Pollution
- Health effects of environmental degradation
- Initiatives in design, architecture and engineering communities

Topic 1: Life Cycle Assessment



LCA steps


Goal and scope
e.g. LCA of a car of typology X, assuming a use for Y years, produced in country Z, ect.
LCI - Life Cycle Inventory
For each stage of a product life cycle (e.g. resource extraction, manufacturing, use, etc.) data on emissions into the environment (e.g. CO_2, benzene, organic chemicals) and resources used (e.g. metals, crude oil) are collected in an inventory.
Each emission in the environment and resource used are then characterised in term of potential impact in the LCIA, covering a number of impact categories.
LCIA - Life Cycle Impact Assessment
CLIMATE CHANGE
EUTROPHICATION
LAND USE
RESOURCE DEPLETION
ACIDIFICATION
OZONE DEPLETION
ECOTOXICITY
IONISING RADIATION
PHOTOCHEMICAL OZONE FORMATION
WATER DEPLETION
HUMAN TOXICITY
Areas of protection
Human health
Ecosystem health
Natural resources
Interpretation

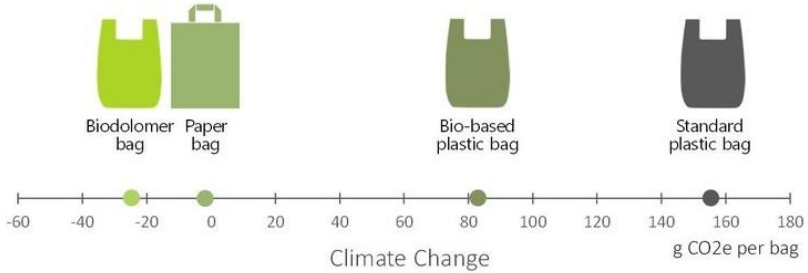
LCA software use

Name	Hairdryer *1 pc* Impact in kg CO2 eq	Hairdryer Eco *1 unit* Impact in kg CO2 eq
PWB SMD		
Powercord		
Polycarbonate		
Nylon PA6		
ABS		
Electricity		
Motor		
Chromium steel		
Switch		
Copper		
Polypropylene		
Ceramic		
PET recycled		
Total impact	7.85 kg CO2 eq	6.8 kg CO2 eq

Source: https://ecochain.com/knowledge/5-ways-to-use-your-lca/

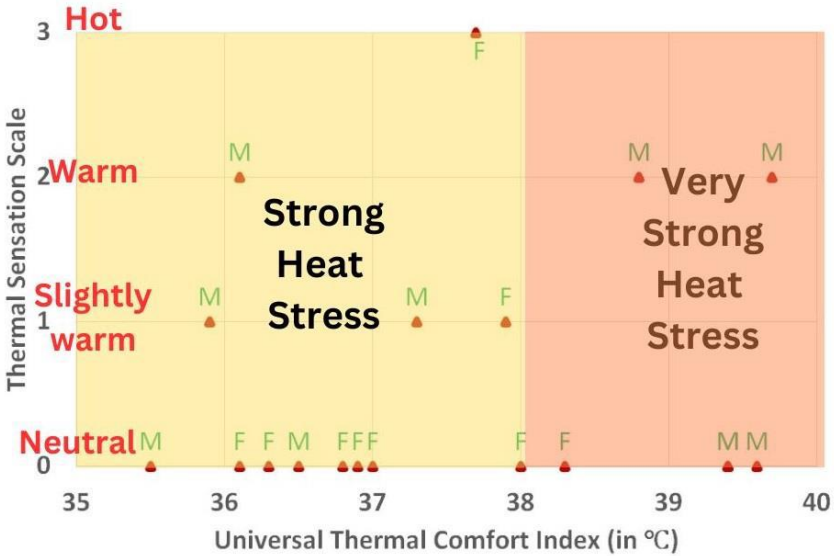
Impact of our choices on our and our planet's health

- Bike ride vs. public transport vs. a car
- AC vs. natural ventilation
- Local foods vs. Foods with ingredients from far off places
- Online order vs. Eating at a restaurant
- Biofuel vs. Petrol



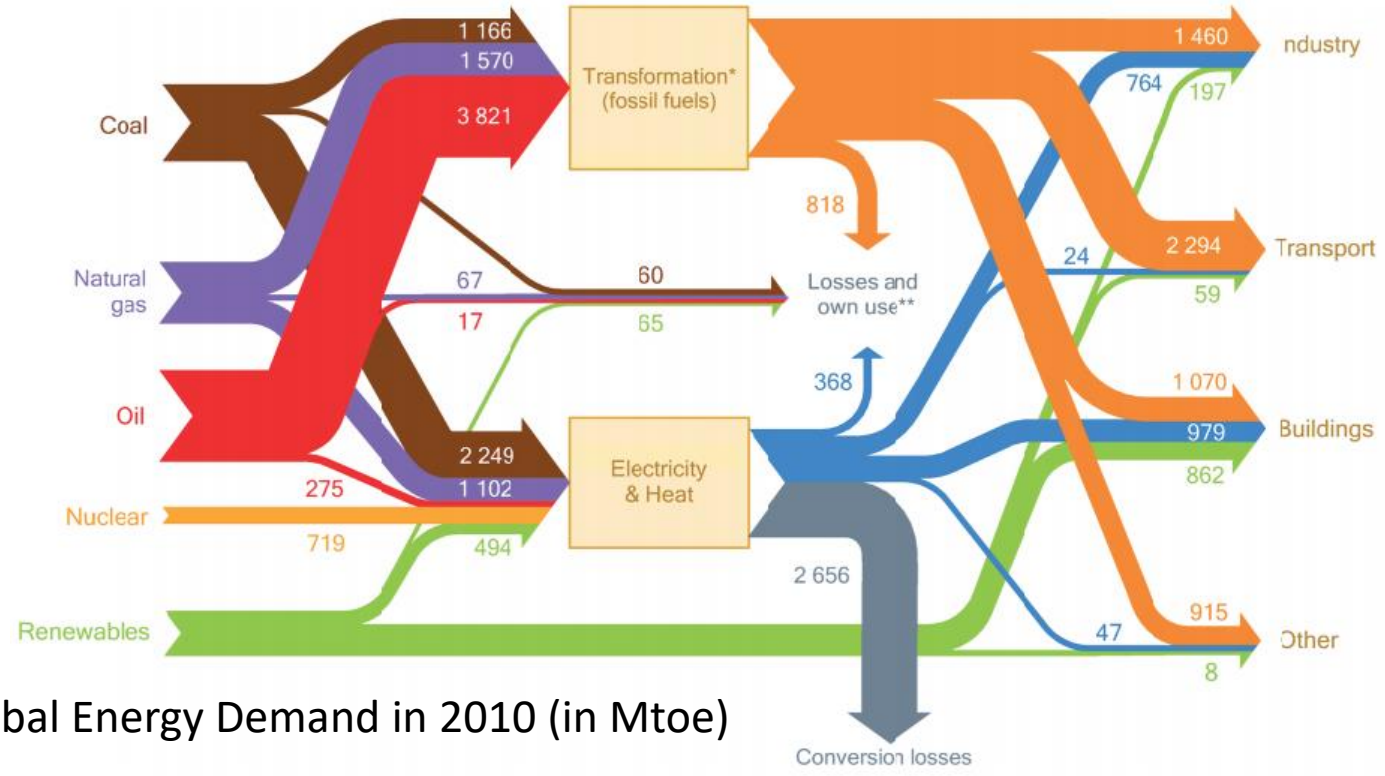
Source: https://biodolomerforlife.se/lca-comparing-biodolomer-fossil-pe-bio-pe-september-1-2019/

Immersion 1: Communities living a low carbon lifestyle



Source: Dhariwal, J., Gangrade, S. (2023). Learnings from thermal comfort adaptation of Jain ascetics during heat waves. Energise India Conference.
The 'Perfect Ascetic' - Jainpedia

Topic 2: Energy

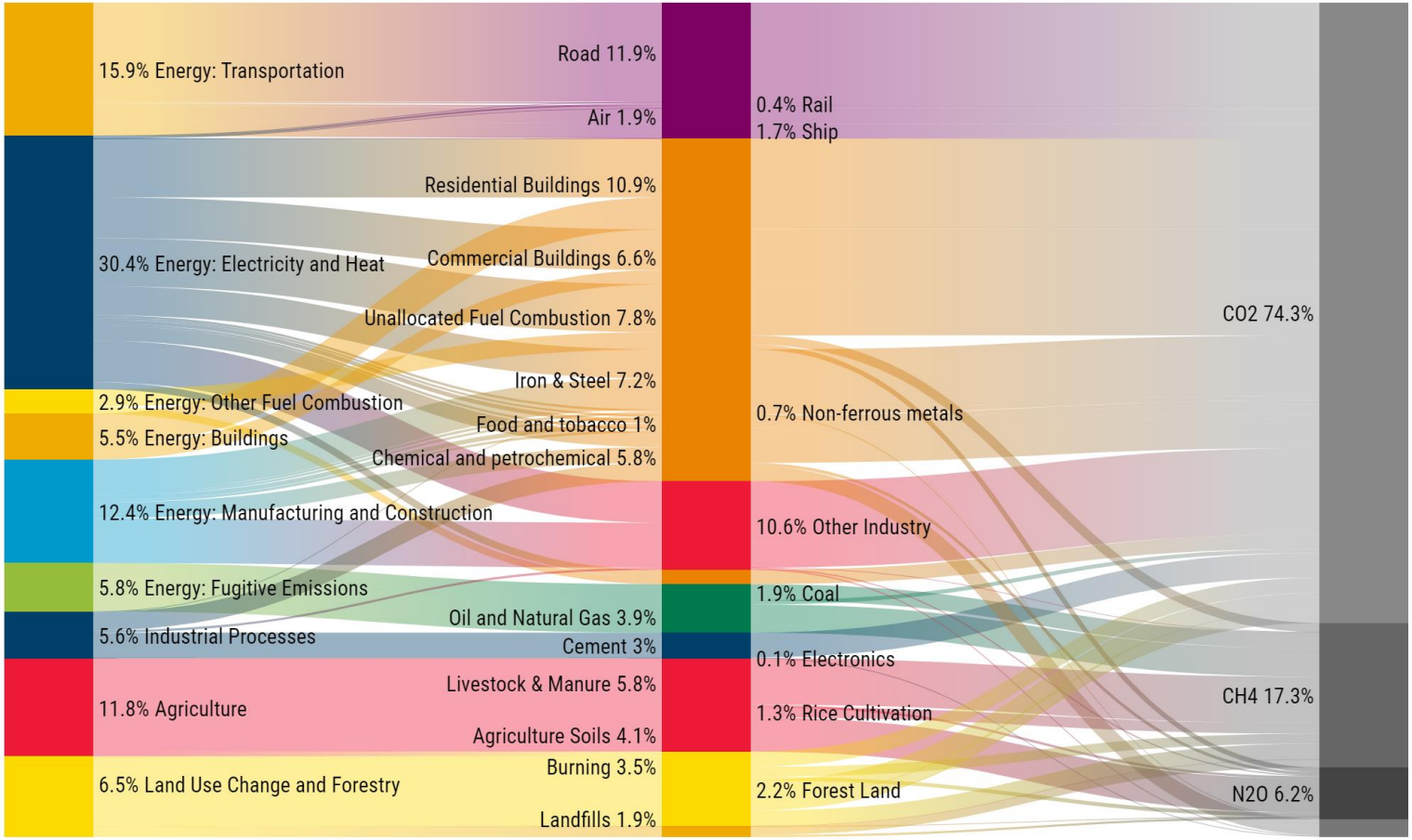


Global Energy Demand in 2010 (in Mtoe)

Source: https://www.sankey-diagrams.com/world-energy-flows-2012/

World Greenhouse Gas Emissions in 2016 (Sector | End Use | Gas)

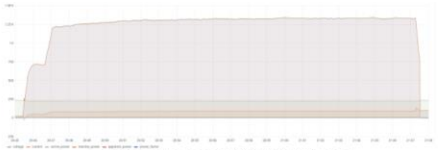
Total: 49.4 GtCO2e



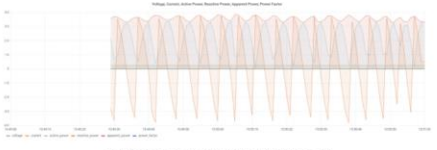
Source: Climate Watch, based on raw data from IEA (2018), CO2 Emissions from Fuel Combustion, www.iea.org/statistics; modified by WRI.

WORLD RESOURCES INSTITUTE

Energy measurements using Energy Monitors



data from a new AC : 1.25 kW max

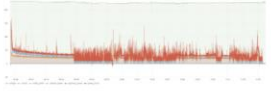


data from a old AC : 3 kW max

Fan : 80 W

9 Fin oil Heater : 2 KW max

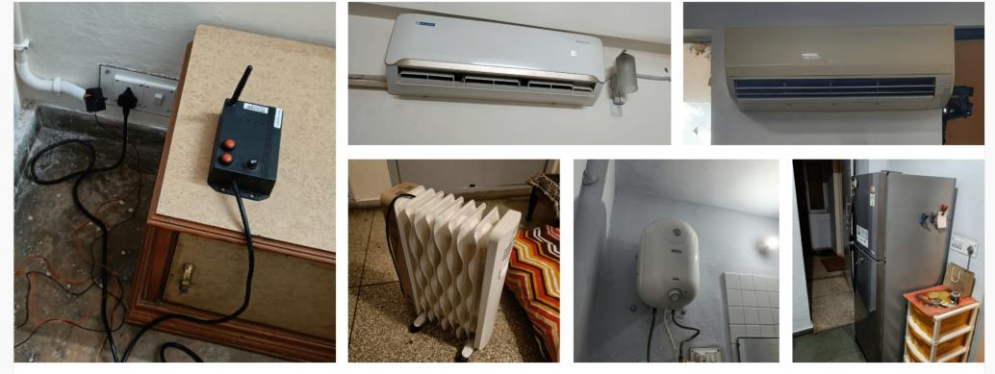
Geyser : 2 KW max



Laptop : Fluctuating (100 W max)

Light : 10 W max

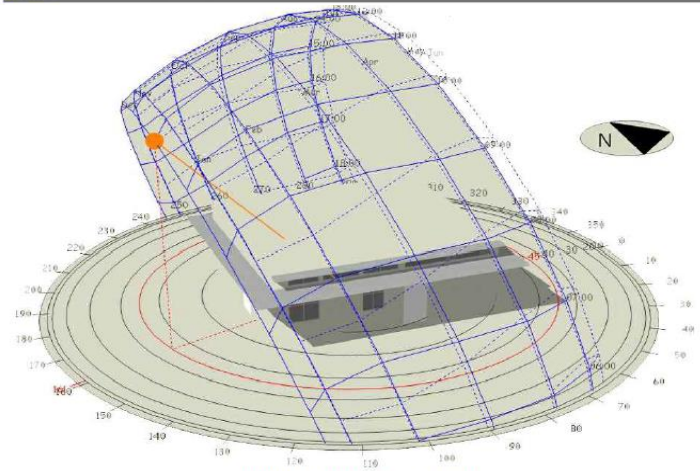
Fridge : 80 W max



Topic 3: Health and Wellness in Built Envt

Source: https://www.metrohealth.org/transformation/transformation-blog/well-building-means-a-healthy-building

House Design: Passive Solar Architecture



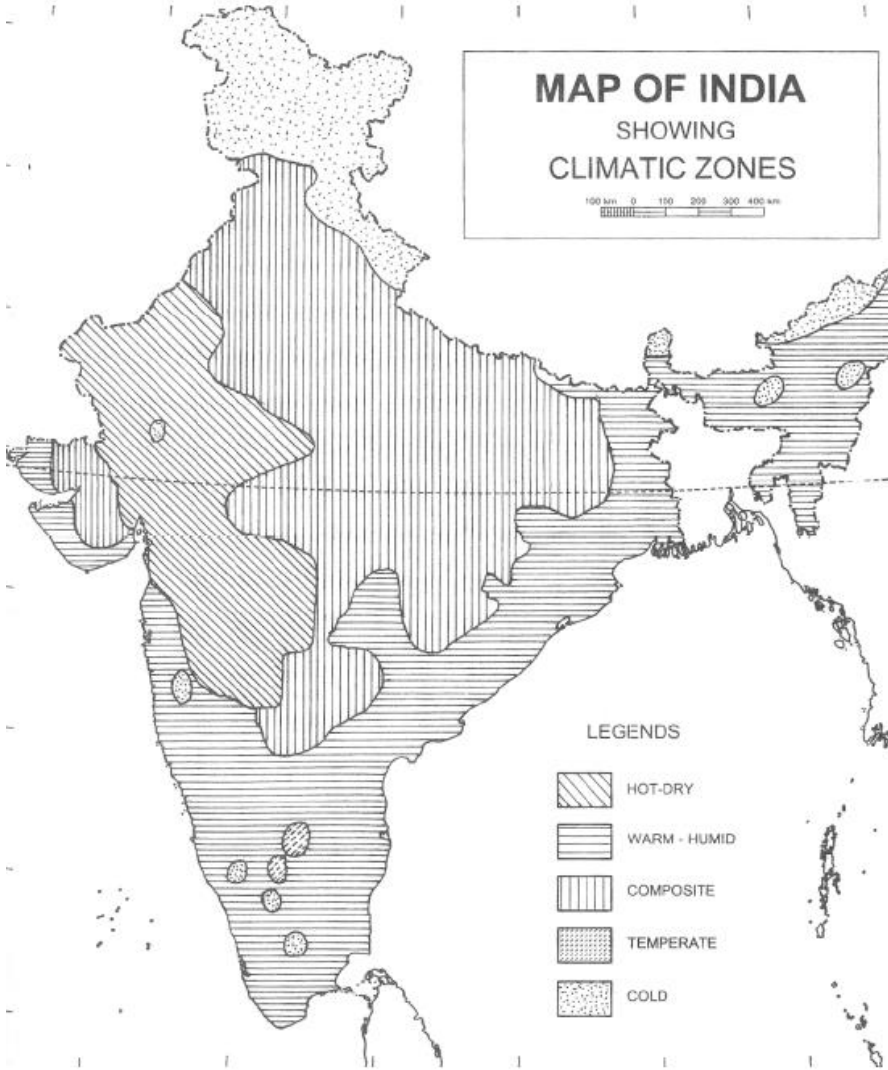
SUN PATH ANALYSIS FOR MUMBAI

Climatic zones of India

- Nayak, J.K., and J.A.Prajapati. 2006. *Handbook on Energy Conscious Buildings* IIT Bombay and Solar Energy Centre, Ministry of Non-conventional Energy Sources, Government of India: R & D project no. 3/4(03)/99-SEC.

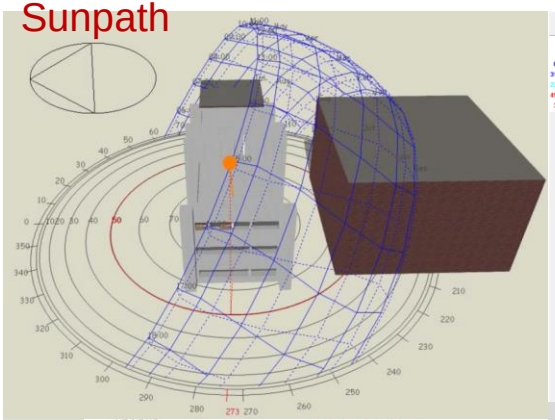
5)Composite Region

OBJECTIVES	PHYSICAL MANIFESTATION
1)Resist heat gain in summer and Resist heat loss in winter	
- Decrease exposed surface area	Orientation and shape of building. Use of trees as wind barriers
• Increase thermal resistance	Roof insulation and wall insulation
- Increase thermal capacity (Time lag)	Thicker walls
• Increase buffer spaces	Air locks/ Balconies
• Decrease air exchange rate	Weather stripping
• Increase shading	Walls, glass surfaces protected by overhangs, fins and trees
• Increase surface reflectivity	Pale colour, glazed china mosaic tiles, etc.
2)Promote heat loss in summer/ monsoon	
• Ventilation of appliances	Provide exhausts
• Increase air exchange rate (Ventilation)	Courtyards/ wind towers/ arrangement of openings
• Increase humidity levels in dry summer	Trees and water ponds for evaporative cooling
• Decrease humidity in monsoon	Dehumidifiers/ desiccant cooling

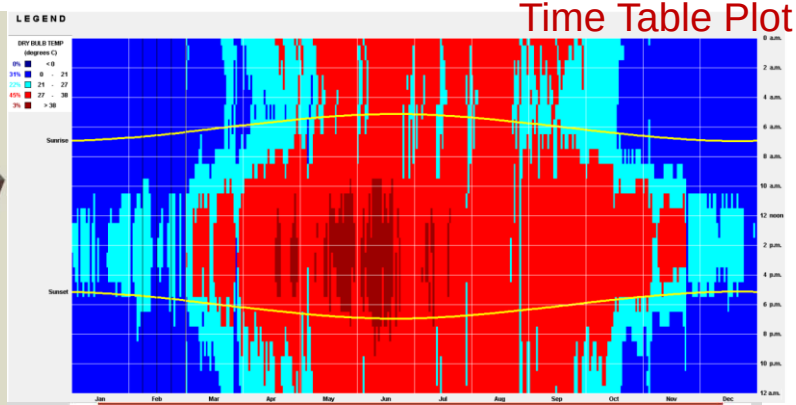


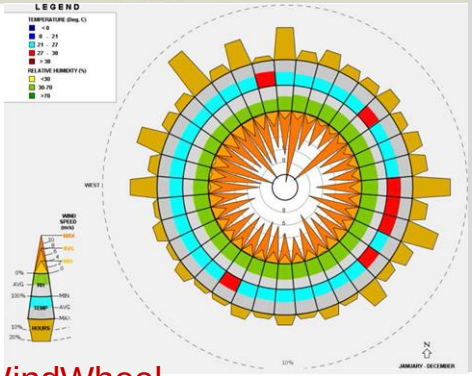
Climate Analysis

Sunpath

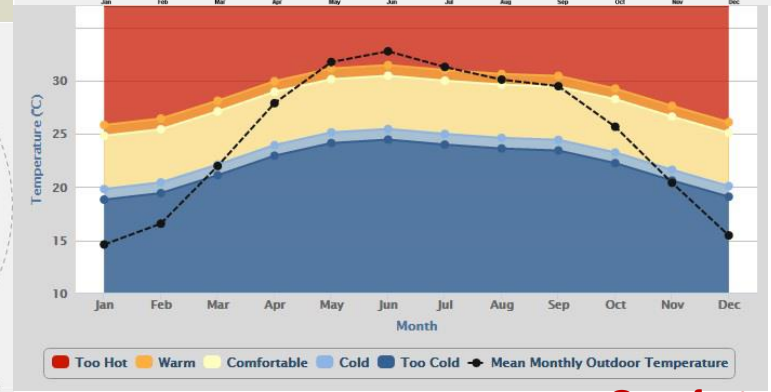


Time Table Plot



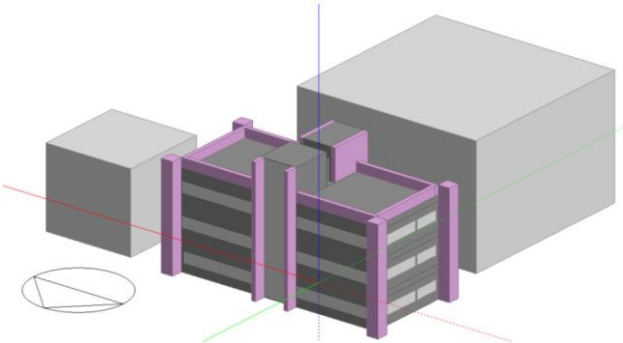


WindWheel

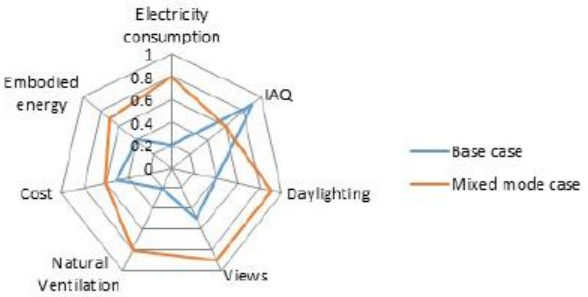


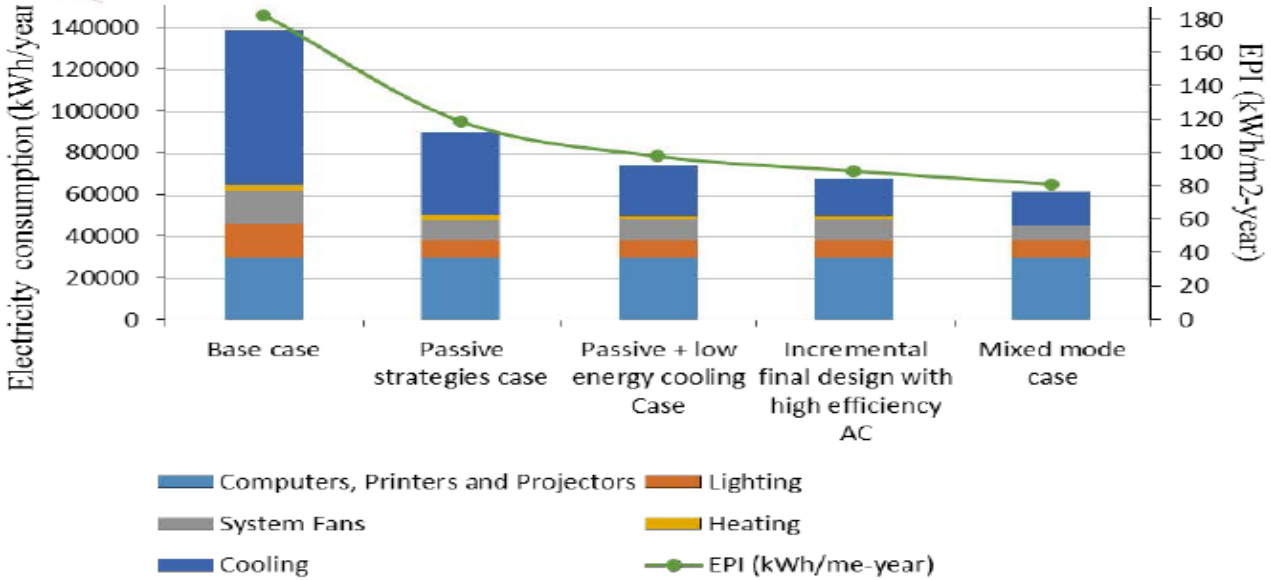
Comfort

Software: DesignBuilder, Climate Consultant, CARBSE tools



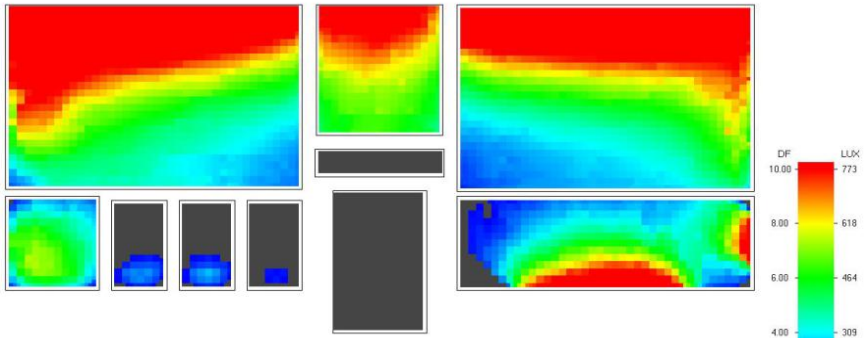
New Delhi climate



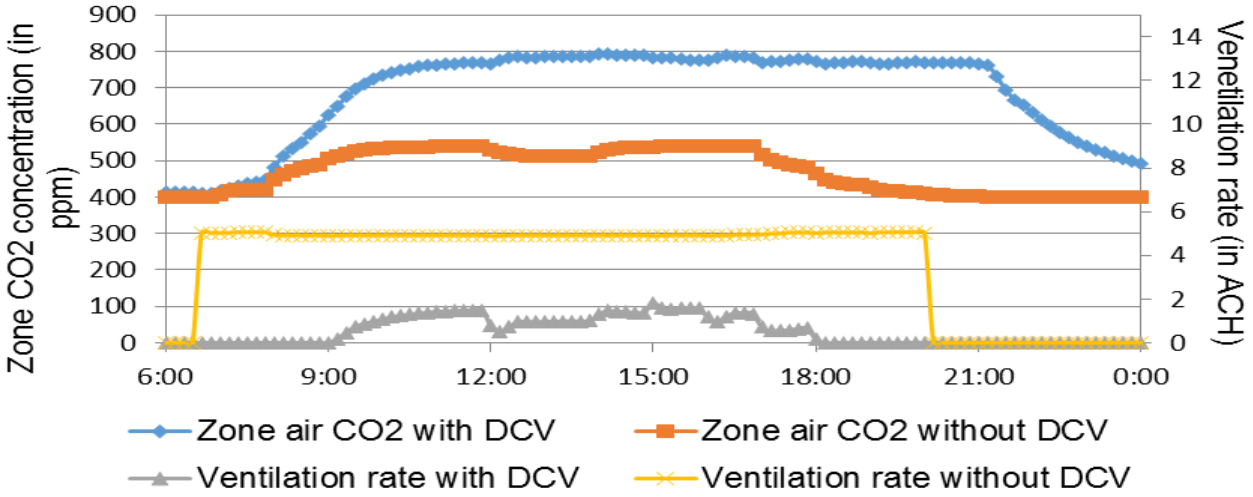


Dhariwal J., 'Design and simulation of a mixed-mode office building', *BS2015, 14th International Conference of International Building PerformanceSimulation Association (IBPSA),* Dec 2015. Winner of the student modelling competition for this entry.

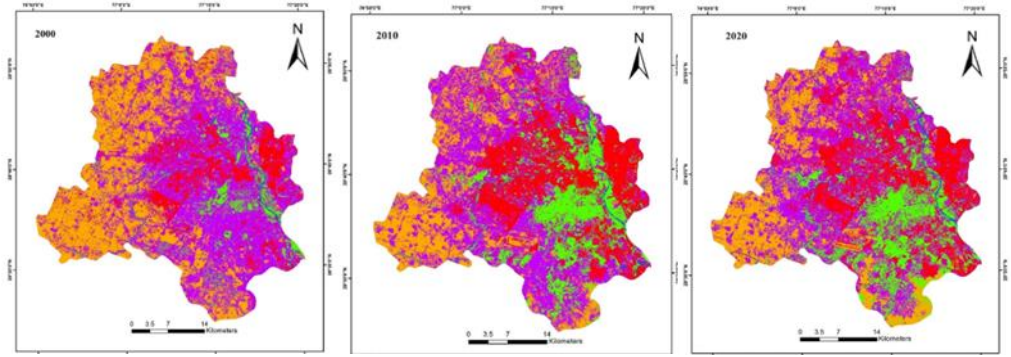
Daylighting simulation



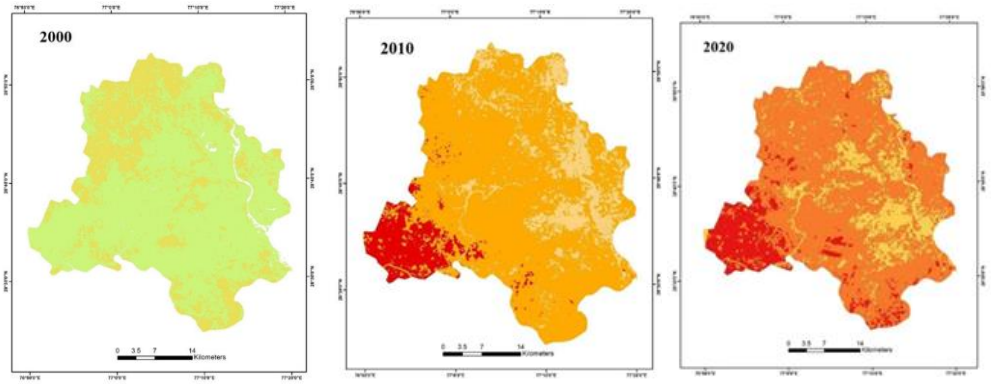
Demand controlled ventilation

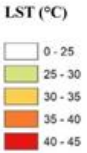


Heat stress assessment & mitigation



LULC map of Delhi – 2000, 2010 and 2020





Land Surface Temperature (LST) Distribution Delhi 2000, 2010, and 2020.

On **28th June 2022** , the outdoor temperatures in Delhi was **40°C**, but because of high humidity, it felt like **58°C** & we had to use AC.

UTCI calculator

Urban heat island effect and vulnerable populations

Need for adequate ventilation (high CO_2 levels)

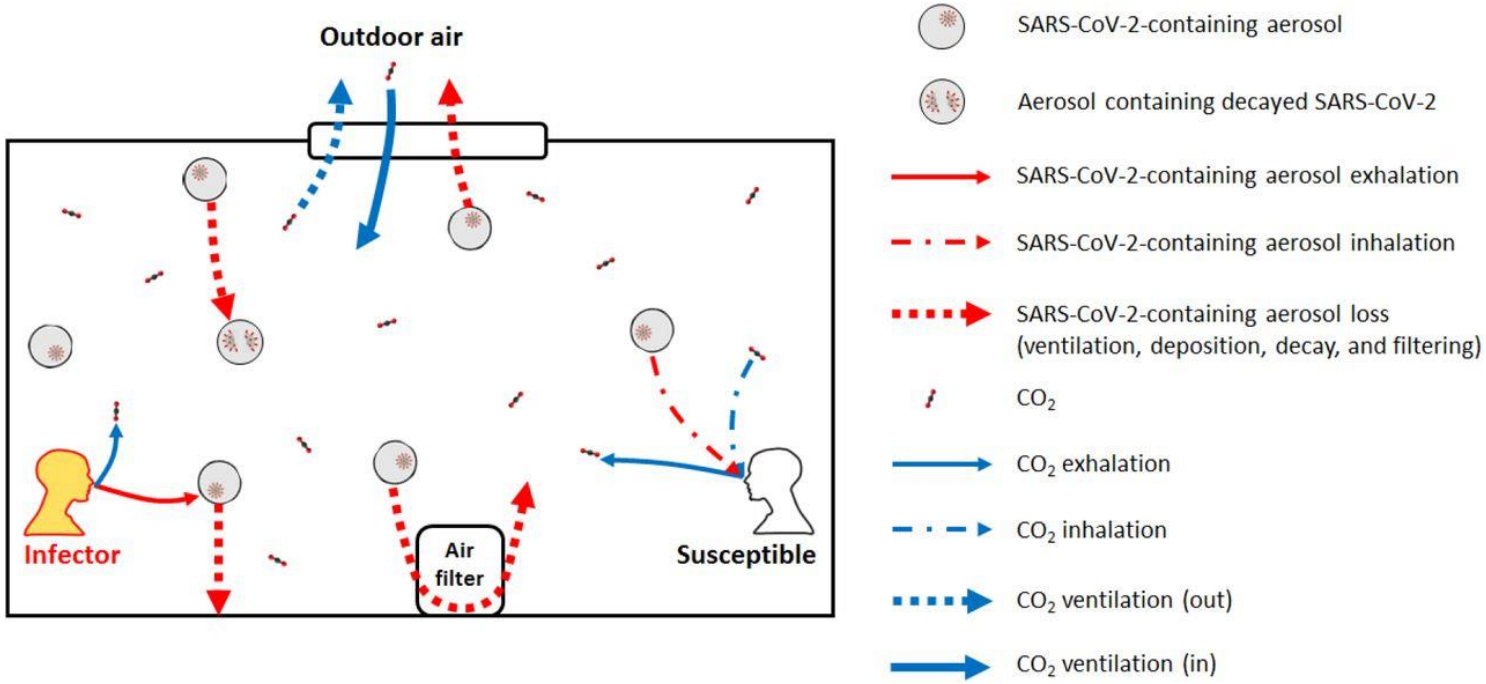
Table 1 | Overview of potential health effects

	CO_2 concentration (ppm)	Duration	Selected key references
Adverse health outcomes associated with acute CO_2 exposure			
CO_2 retention	1,000–5,000	<4 h	Zhang et al.[75]; Zhang et al.[73]; Vehvilainen et al.[77]; Shiraram et al.[76]
Inflammation	2,000–4,000	2 h	Thom et al.[80,81]; Schneberger et al.[82]
Cognitive effects	1,000–2,700	1–6 h	Kajtar and Herczeg[85]; Satish et al.[86]; Allen et al.[87,88]; Zhang et al.[75]; Zhang et al.[73,74]; Rodeheffer et al.[91]; Snow et al.[90]
Adverse health outcomes associated with chronic CO_2 exposure			
Chronic, low-grade systemic inflammation	~3,000	13 d	Zappulla[2,69]; Beheshti et al.[101]
Bone demineralization and kidney calcification	~2,000–3,000	60–90 d	Schaefer et al.[102,103]
Chronic, low-grade (sub-clinical) respiratory acidosis	Unknown	Decades	Carnauba et al.[109]; Robertson[61,106]
Behavioural changes and physiological stress	700–3,000	13–15 d	Beheshti et al.[101]; Wade et al.[104]; Martrette et al.[111]; Kiray et al.[112]
Hedonic feeding behaviours	Unknown	Ecological	Hersoug et al.[113]; Zheutlin et al.[1]
Oxidative stress and endothelial dysfunction	3,000–5,000	13 d to 6 months	Beheshti et al.[101]; Thom et al.[80,81]; Zwart et al.[119]

Exposure levels, including magnitude and duration, for which health effects may manifest. The selected key references are most relevant to the health end-point.

Jacobson, Tyler A, Jasdeep S Kler, Michael T Hernke, Rudolf K Braun, Keith C Meyer, and William E Funk. 2019. "Direct Human Health Risks of Increased Atmospheric Carbon Dioxide." *Nature Sustainability* 2 (8): 691–701. https://doi.org/10.1038/s41893-019-0323-1.

CO_2 levels as a proxy for Covid-19 transmission



Peng, Zhe, and Jose L. Jimenez. 2021. "Exhaled CO2as a COVID-19 Infection Risk Proxy for Different Indoor Environments and Activities." *Environmental Science and Technology Letters* 8 (5): 392–97. https://doi.org/10.1021/acs.estlett.1c00183.

Impacts of Sick Building Syndrome on well-being

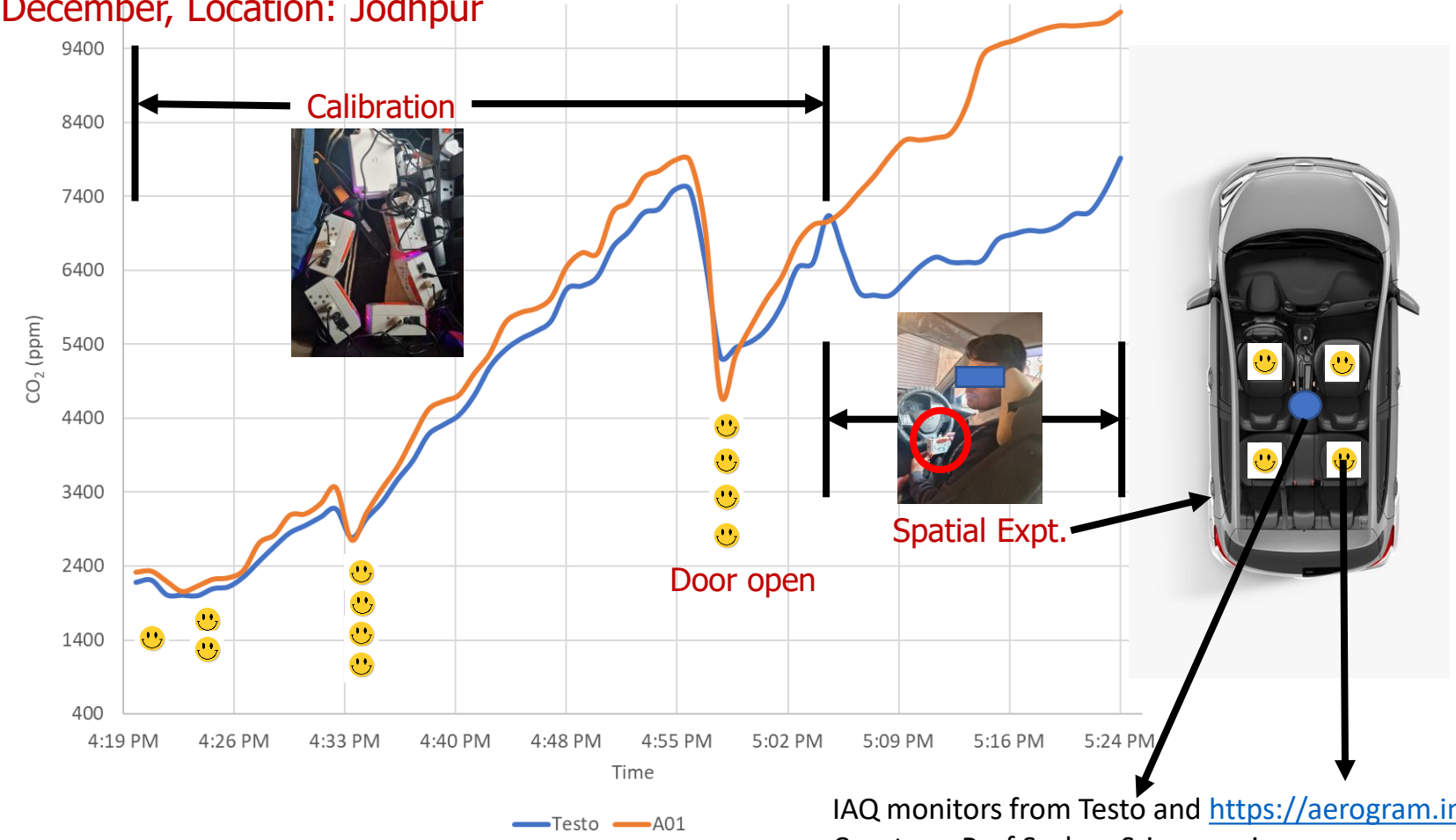
Author(s)	Country	Type of building	Identified symptoms associated with SBS
Magnavita (2015)	Italy	Companies	Anxiety, depression, environmental discomfort and job strain
Jafari et al. (2015)	Iran	Office buildings	Malaise, headache, throat dryness, cough, sputum, wheezing, skin dryness and eye pain
Zhang et al. (2014)	China	Schools	Skin symptoms, mucosal symptoms
Shan et al. (2016)	Singapore	Schools	Head and eye related issues
Norbäck et al. (2016a)	Malaysia	Schools	Ocular, rhinitis, throat symptoms, headache and tiredness, dermal symptoms
Lim et al. (2015)	Malaysia	University	Dermal, mucosal and general symptoms
Amin, Akasah, and Razzaly (2015)	Malaysia	University	Dry skin, runny nose, dry eyes, blocked/stuffy nose, tiredness and flu-like symptoms
Sun et al. (2013)	China	Dormitory	General symptoms of sick building, mucosal or skin problems and nose irritation
Sahlberg et al. (2013)	Sweden/Estonia/ Iceland	Residential Building	General signs of sick building (i.e. mucosal symptoms)
Takigawa et al. (2010)	Japan	Residential Building	Optical, nasal, and gular symptoms
Tsai, Lin, and Chan (2012)	Taiwan	Office building	Eye irritation and upper respiratory symptoms
Lukcso et al. (2016)	U.S.A.	Office building	Asthma and allergic disease
Gomzi et al. (2007)	Croatia	Office buildings	Fatigue, sore and dry eyes, and headache
Runeson-Broberg and Norbäck (2013)	Sweden	Office buildings	Headache, tiredness, nausea, and sensation of a cold

Ghaffarianhoseini, Amirhosein, Husam AlWaer, Hossein Omrany, Ali Ghaffarianhoseini, Chaham Alalouch, Derek Clements-Croome and John Tookey. 2018. “Sick Building Syndrome: Are We Doing Enough?” *Architectural Science Review* 61 (3): 99–121. https://doi.org/10.1080/00038628.2018.1461060.

Experiment 1: understanding CO_2 build up with occupancy in a closed car
Date: 17th December, Location: Jodhpur

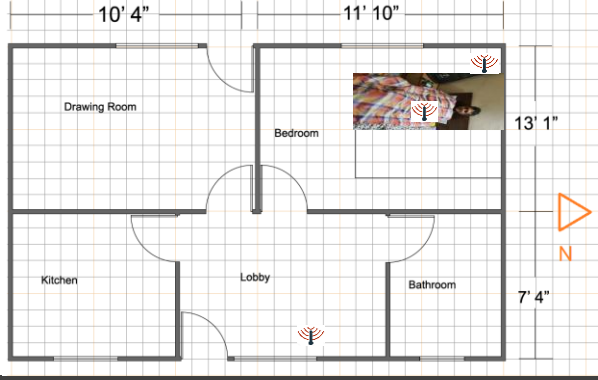
Insights:

1. CO2 levels can build up to unhealthy levels in less than an hour with just 4 people.
2. CO2 levels higher close to the people exhaling CO2 than in other parts of the car.
3. Have any of you been in such a situation in classes, offices, trains, etc.?



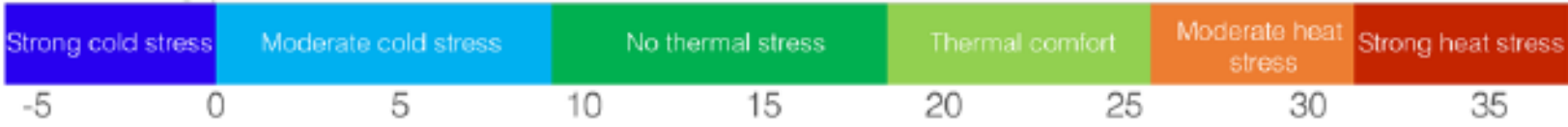
IAQ monitors from Testo and https://aerogram.in/
Courtesy: Prof Seshan Srirangarajan

Experiment 2: CO_2 levels in a bedroom (no heater)
Date: 25th December, Location: New Delhi

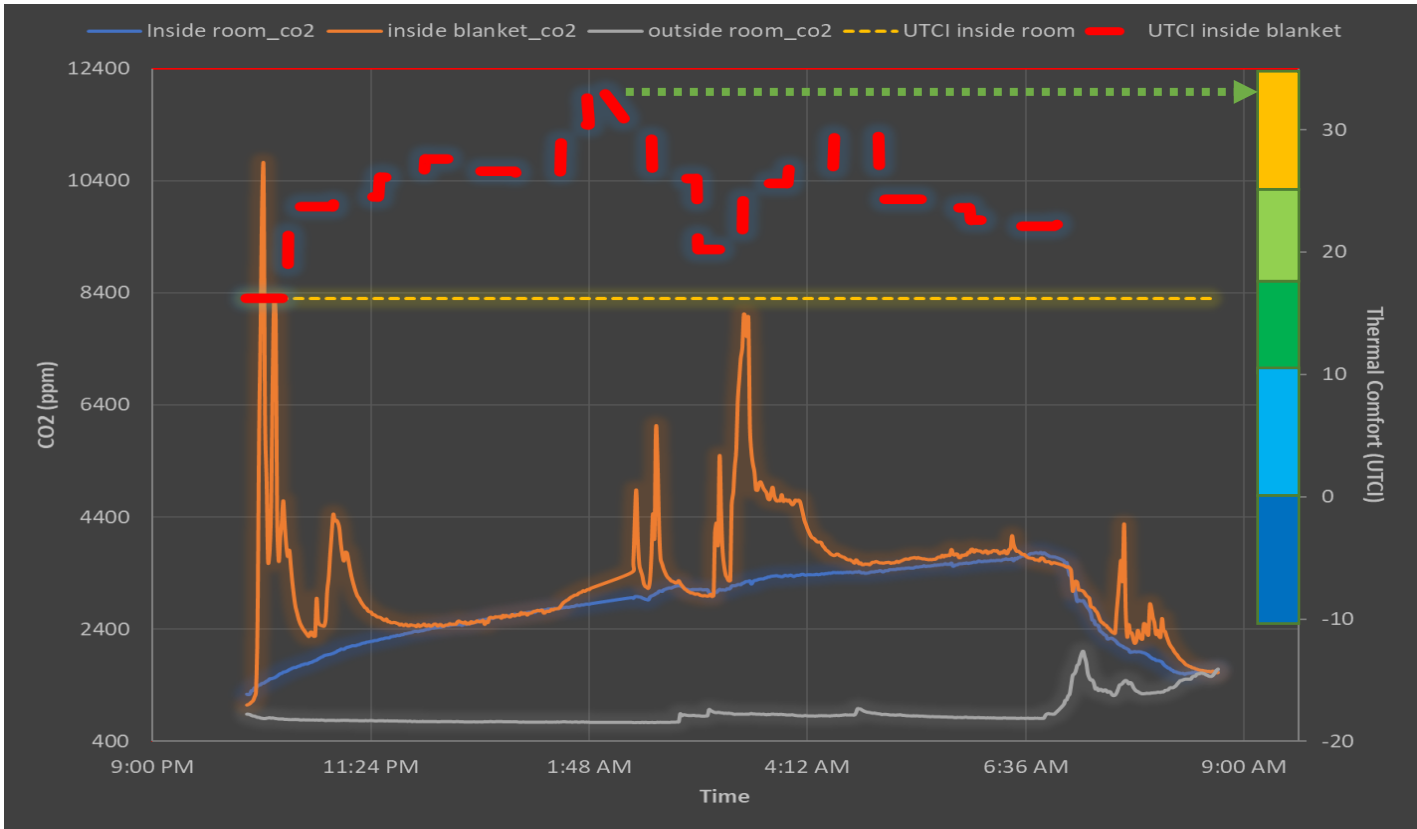


Insights:

1. Outside room CO_2 levels were around 800 ppm
2. Indoor room CO_2 levels reached 3500+ for two occupants. It's a fact as pointed out by the Nature paper.
3. CO_2 levels inside the blanket spiked to 10000+ ppm also. Its better to keep the face outside the blanket as we spend 1/3rd of our life sleeping. How many of you would want to put your face into the blanket as it is cold?
4. Door opening led to mixing of CO_2 levels for inside and outside of room.



Experiment 2: CO_2 levels vs. thermal comfort in a bedroom (no heater)
Date: 25th December, Location: New Delhi



Insights:

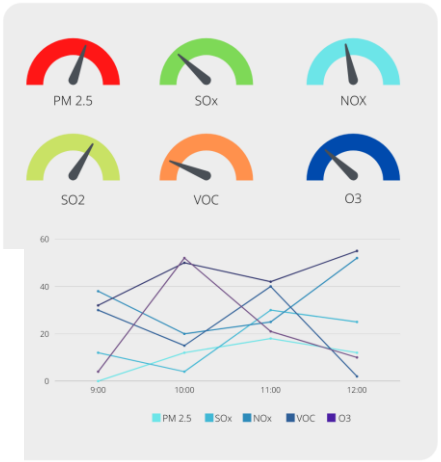
1. Outside and inside room UTCI was around 16 C
2. Inside blanket UTCI reached even 34 C
3. With no heater, it is better if the door can be kept open to have low CO_2 levels.

Data cloud

Calibration and Network Deployment of Low Cost Pollution Sensors

Network of low-cost sensors and network calibration

Sensor calibration

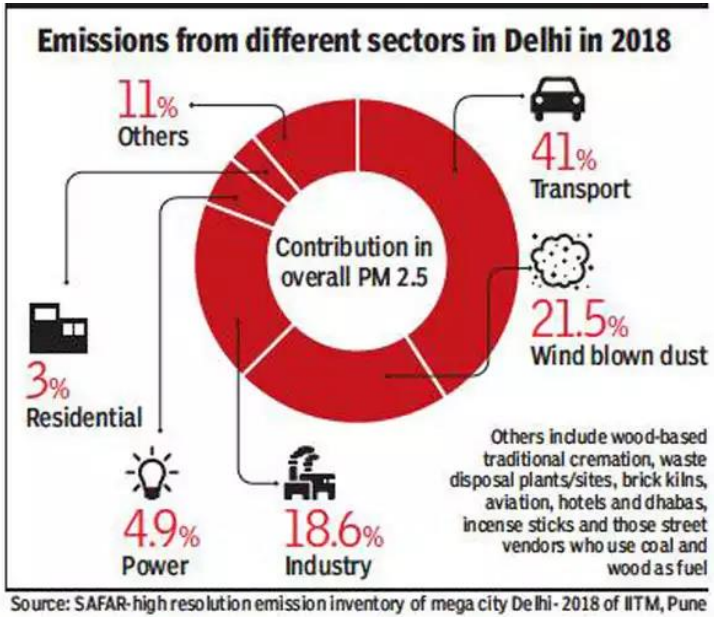


Pollution data analytics and dashboard

PIs: Prof. Seshan Srirangarajan & Prof. Jay Dhariwal, IIT Delhi

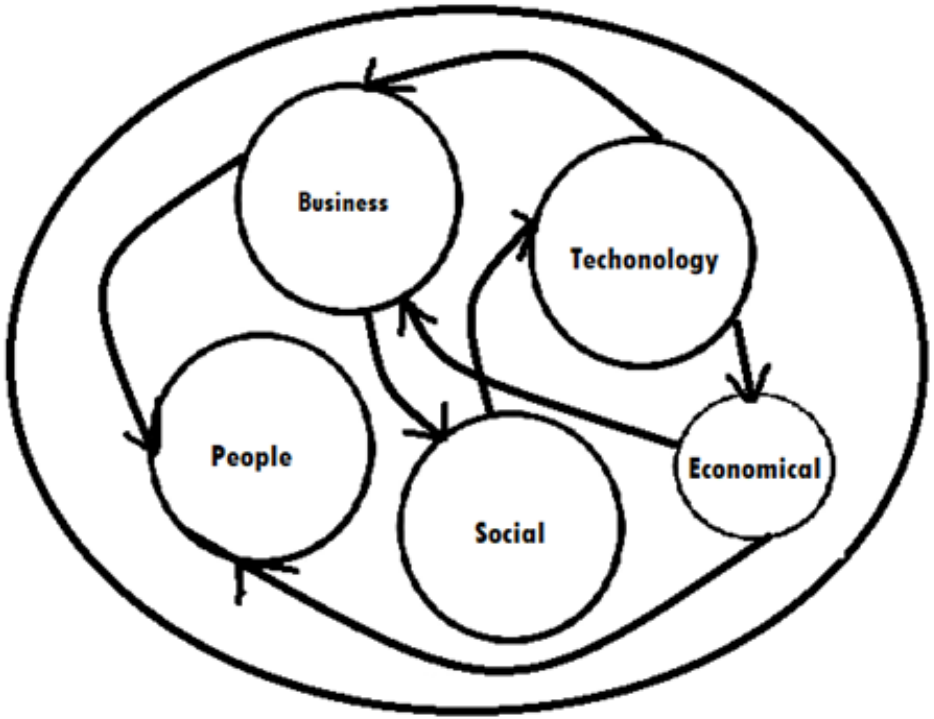
Air pollution mitigation

- Electric Vehicles
- Crop residue as insulation, eco-friendly plates, packaging
- Air purifiers
- Renewables



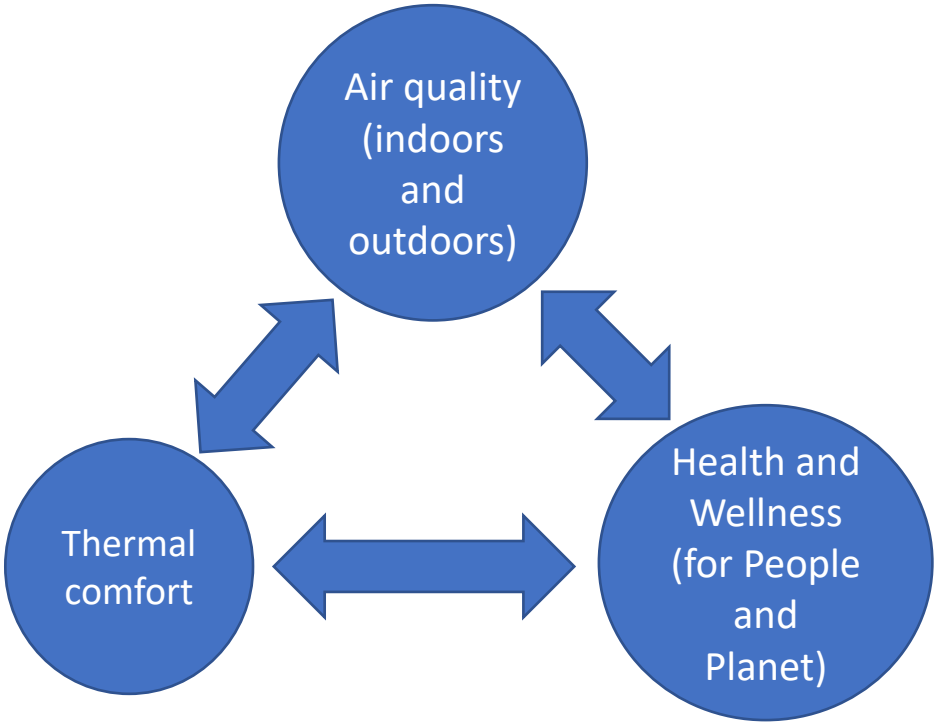
Source: [Delhi air pollution: Smaller sources add up to 11% of PM2.5 emission | Delhi News - Times of India (indiatimes.com)]

Systems Thinking



- What happens if we don’t use systems thinking?
- Was the invention of electricity, cars, plastics good from systems thinking point of view?

Design for Health and Wellness in a Delhi Classroom



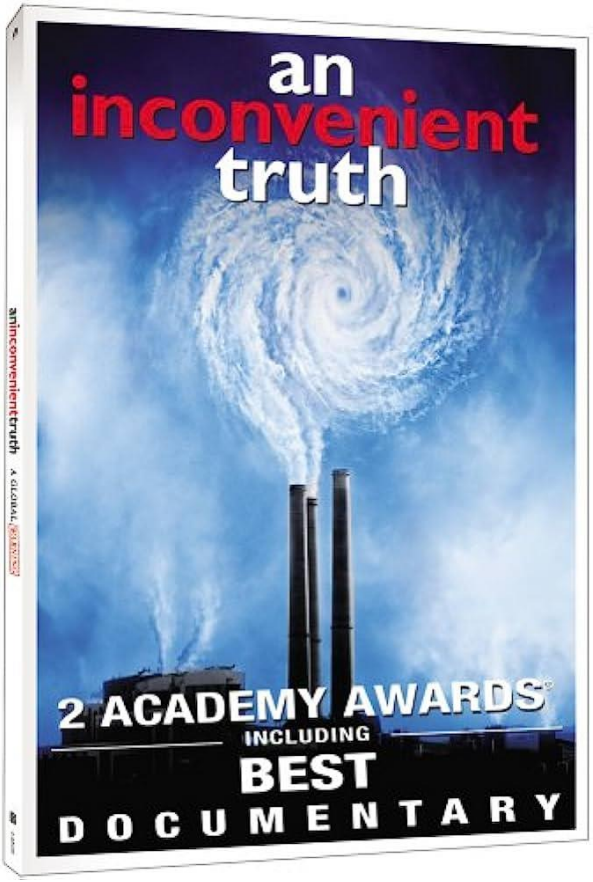
Maximize Health and Wellness for Class Occupants

Constraints:

1) Keep Thermal Comfort: < 32℃
2) Keep Air Quality: CO_2 < 800 ppm, PM2.5 < 50 µg/m3
3) Minimize Energy Consumption

Topic 4: Other fun things

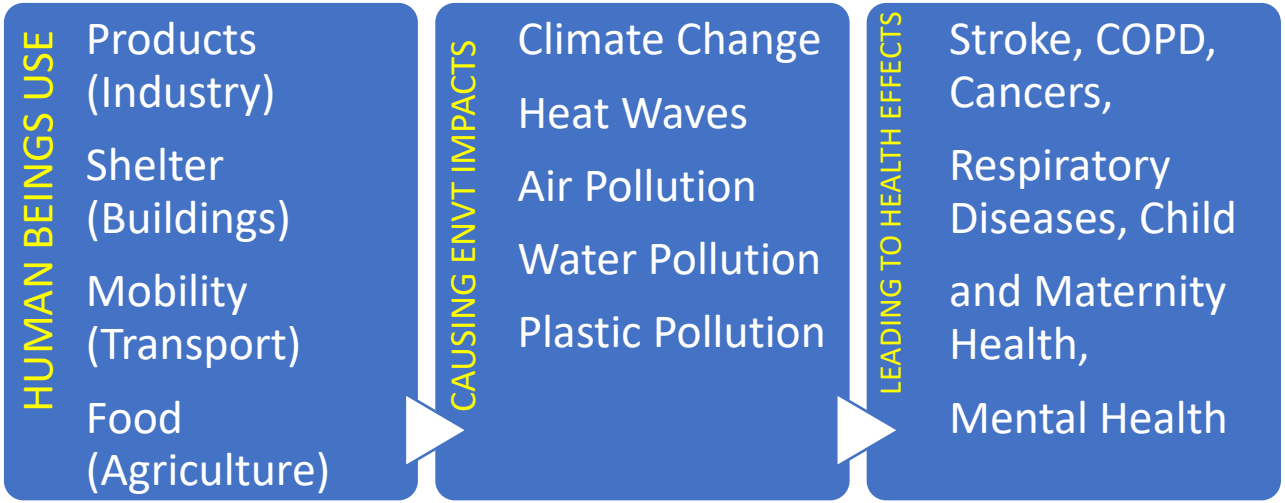
- Industry visit to understand plastic recycling
- Understand strategies to mitigate Water Pollution
- Documentaries related to environmental issues



Evaluation Policy

Evaluation mode	Weightage (%)
10 Assignments	50
Classroom Participation & Attendance	10
Project Proposal (5) + Project Presentation (20) + Project Display (5)	30
Exam and/or Viva	10
Other notes:	
Marks required for D grade	40
Marks required for Audit Pass	40
The student should do at least 5 assignments for Audit pass.	

The gist of the course: improve our and our planet's health



Thank you!