Energy and Sustainable Design

Fall 2022

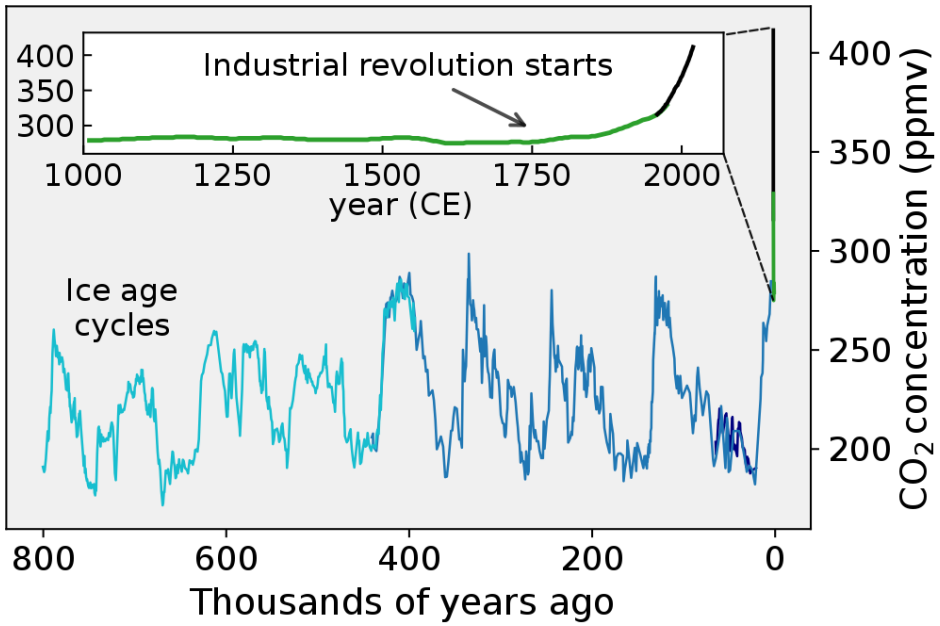
Overview and Syllabus

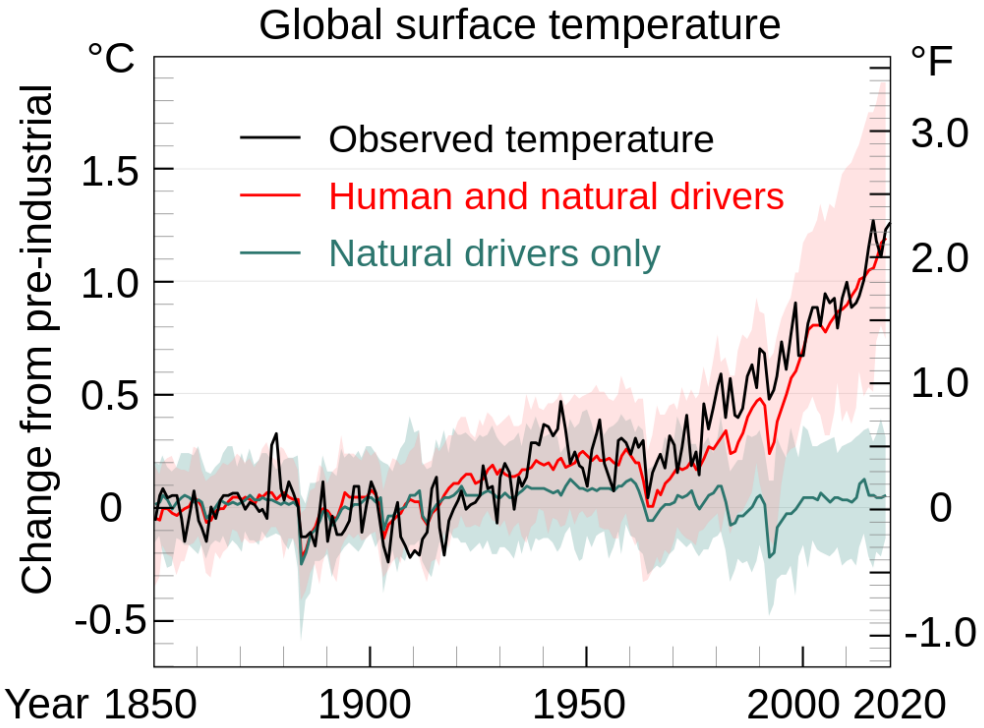
An *Incomplete* List of Environmental Problems!

- Climate change; extreme weather, flooding, and drought
- Pollution: air, water, soil
- Destruction of natural habitats and deforestation
- Biodiversity loss
- Natural resource depletion
- Soil degradation, erosion, and desertification
- Sea level rise and melting ice caps
- Ocean acidification/acid rain
- Food scarcity and insecurity
- Overfishing
- Waste disposal and unsustainable waste
- Water: supply and management
- Equity: local and international

Energy and Carbon

We will accept the overwhelming scientific consensus that climate change is real and is due primarily to human activity, such as fossil fuel energy use, that is increasing the atmospheric of so-called greenhouse gases (GHG) including CO_2, CH_4, and N_2O.





Although the *global average* increase in temperature may seem small, the main effect is (and was predicted to be) extreme weather and climate variations.

drought and crop failures

flooding

wildfires

severe weather events

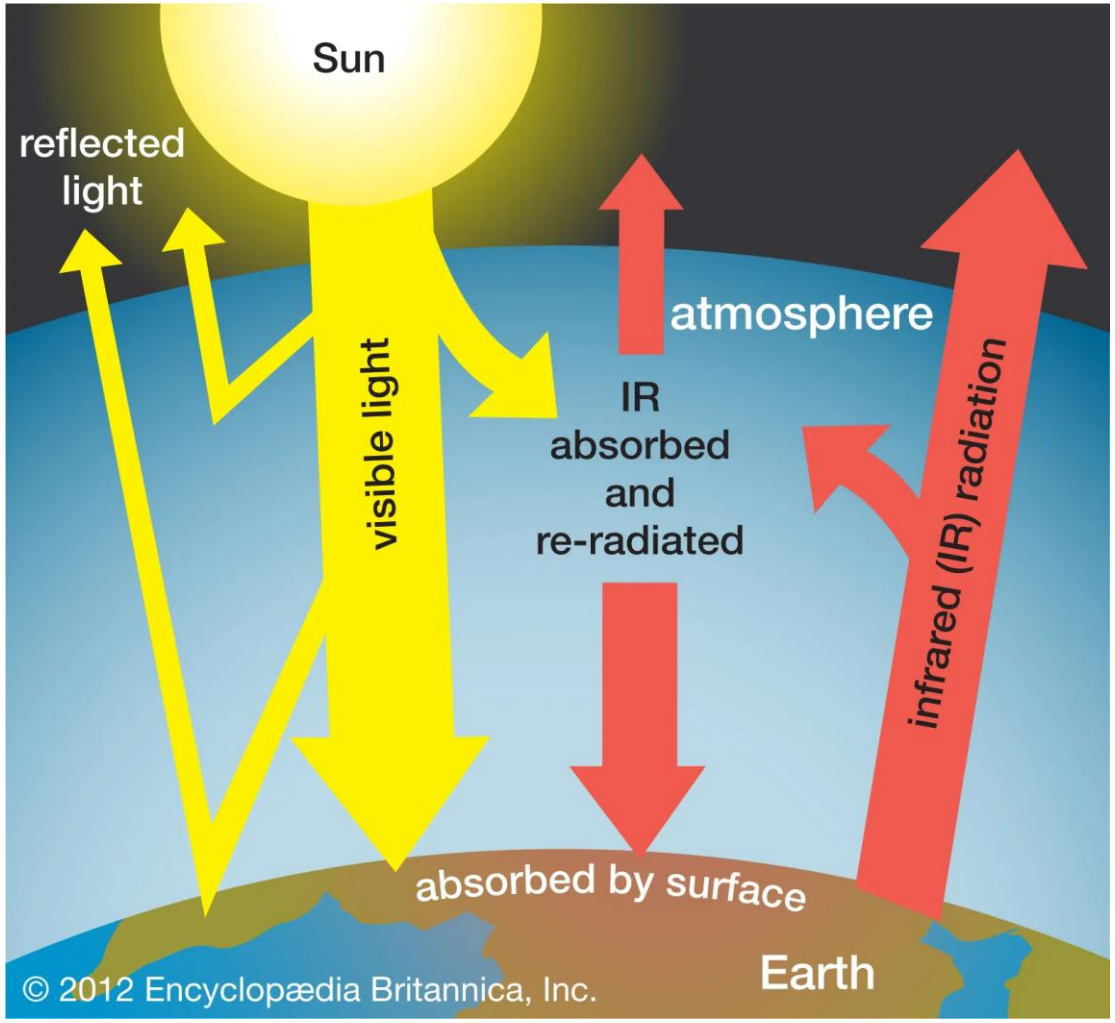
The “Greenhouse Effect”

Radiation from the sun arrives at earth in primarily visible wavelengths.

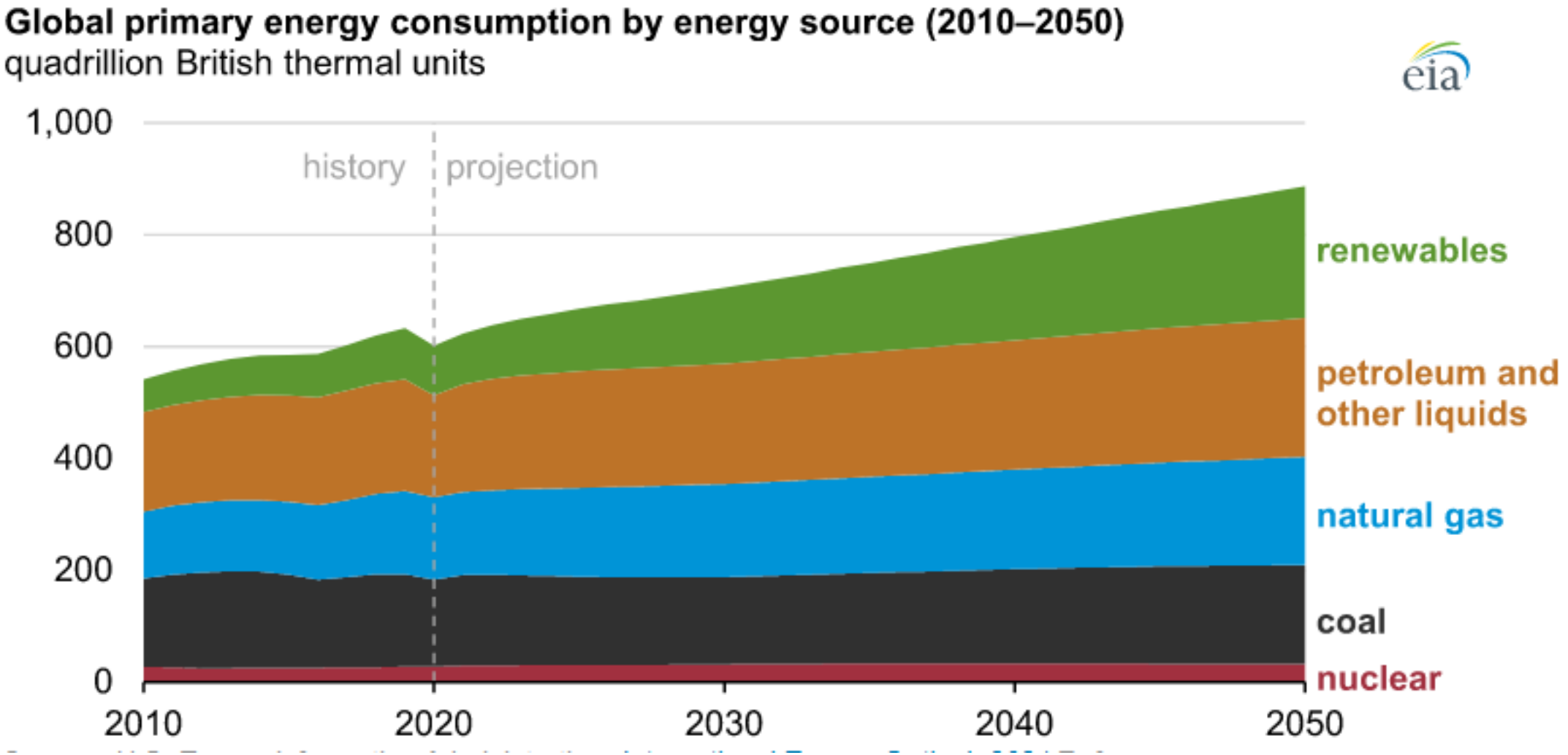
Some of this radiation is reflected and some is absorbed by the earth’s surface. The absorbed radiation is re-emitted as infrared (IR) “black body” radiation.

The IR radiation can be absorbed greenhouse gases and re-emitted.

Some of this re-emitted IR radiation returns to the earth to further warm it.

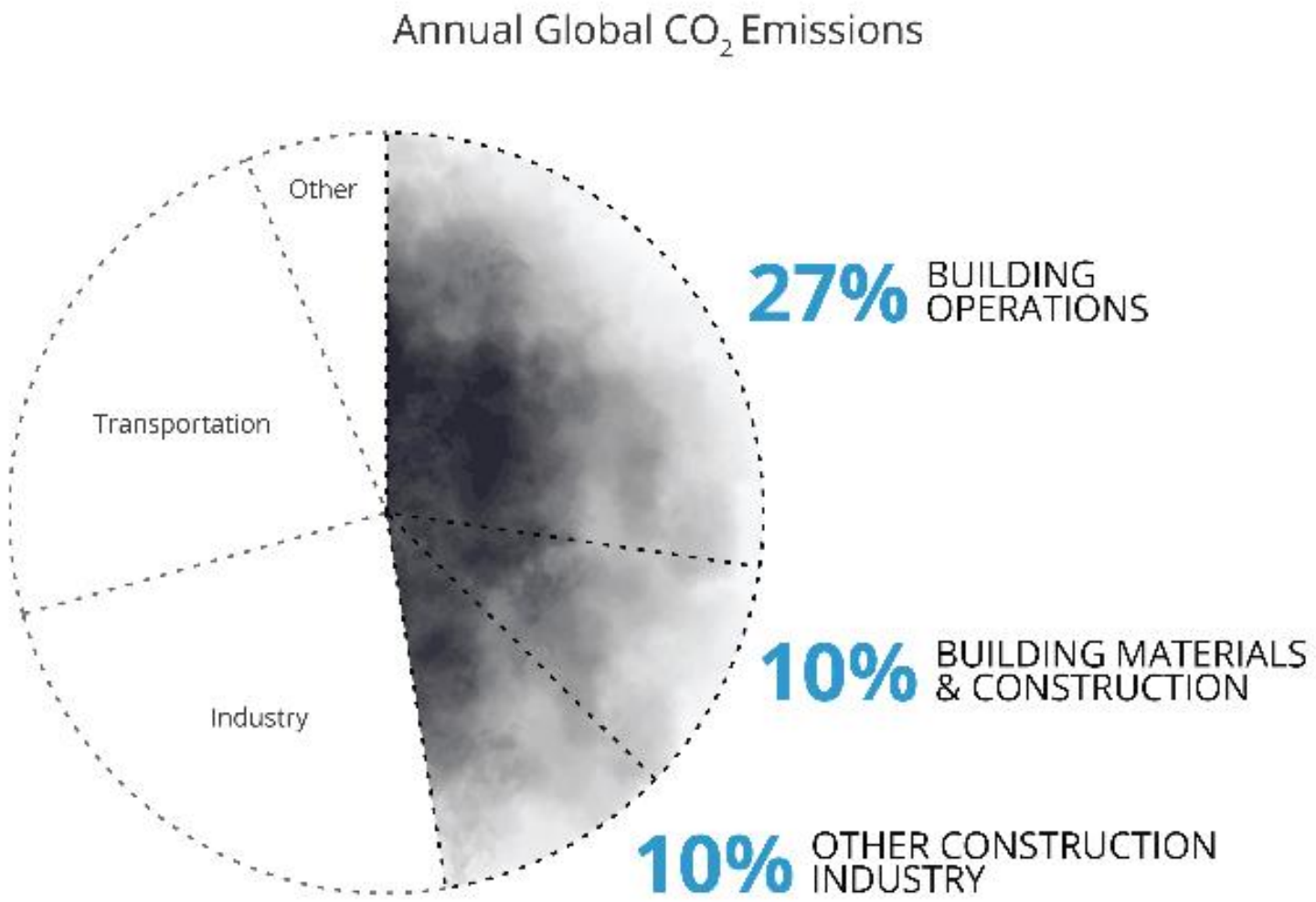


Where does our energy come from?



Built Environment: *human-made structures, features, and facilities viewed collectively as an environment in which people live and work. (OED)*

THE BUILT ENVIRONMENT



Climate Change is Not the Only Problem!

10 million people worldwide die each year from the acute and cumulative effects of air pollution (1 in 6 of total deaths)

Nearly one in three people in the world (2.37 billion) did not have access to adequate food in 2020

2.3 billion people face water stress (drought) annually

25 per cent of the world's land has been rendered unusable due to degradation and desertification

Over the last 10,000 years the world has lost one-third of its forests. An area twice the size of the United States. Half occurred in the last century. Due primarily to agriculture.

etc.

What are we doing in this class?

Nothing less than an attempt to address the question:

*How do we transition material civilization (energy, cities, buildings, transportation, etc.) to be as environmentally friendly, carbon-free, and healthy as possible, and do so in a **sustainable** way?*

What is Sustainability?

A famous definition:

> *Sustainability or sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs."*

1983 UN Commission on Environment and Development

Sustainability is commonly thought of as having three dimensions or aspects:

- Environmental
- Economic
- Social

"planet, prosperity, and people"

Aspects of Sustainability

- Environment: Minimize **pollution** of air, water, and land; transition to **fossil-free energy** to mitigate **climate change**; protect **habitat** and **biodiversity**; minimize **extraction** from natural **ecosystems**; low environmental impact **agriculture**; minimize **waste** and **water** use

- Economic: Promote "**decoupling**" i.e. increasing **economic output** while reducing the **environmental impact** of resources; include environmental "**externalities**" when assessing **economic costs**; Explicitly recognize **resource limitations** in economic planning;

- Social: Maintaining or improve the **well-being of people** in this and future generations; Consideration of **social justice**, particularly equity between **rich and poor** both within and between countries; Re-define notion of **"progress".**

What is *Sustainable Design*?

Sustainable design seeks to produce buildings and communities (the **built environment, human-made structures**) that

- reduce negative impacts on the environment, including **carbon footprint**
- improve building energy performance
- promote **health**, **comfort,** and **productivity** of building occupants,
- **reduce consumption of non-renewable resources**
- **responsible water use**
- **minimize waste**

Integrated, holistic *approach that encourages* ***compromise*** *and* ***tradeoffs*** *to positively impacts* ***all phases*** *of a building's* ***life-cycle****, including* ***design****,* ***construction****,* ***operation*** *and* ***decommissioning*** *without compromising the* ***bottom line****.* (GSA)

Some Specific Sustainable Design Topics

- Energy consumption, production, efficiency, renewable
- Life Cycle Analyses (LCA)
- Carbon footprint and de-carbonization
- Building heating and cooling, ventilation, lighting, aesthetics
- Building and community air, water, and soil quality
- Transportation (electrification, bike/walk friendly communities)
- Water supply, quality, and management
- Waste management and minimization
- Recycling/Re-use/Re-purpose
- Sustainable and healthy food production
- Biophilia

Some Basic Questions for Us

What is the **feasibility** of a complete transition to **renewable** and **carbon-free energy**?

How do we design the **built environment** to be as sustainable (**environmentally, economically, and socially**) as possible?

How do we build in **resilience** to deal with the inevitable consequences of climate change?

What are the **barriers** and **limits** to these goals?

*Our focus will be on **technological, engineering, and economic** aspects, but **social/equity** issues cannot be ignored!*

Course Delivery Format

MWF Class 12:00-1:00 for lecture, group problem solving, and discussion, and “labs”

Lab Tuesday 1:20-3:20

- Experiments (first 4 labs)
- Field trips (next ~ 4 labs)
- Guest lectures (remainder)

Office hours TBA, individual meetings as arranged

Assignments

- Weekly problem sets (collaboration is *allowed and encouraged*) - **45%**
- Short (1 page) reading, field trip, and outside speaker reflections - **20%**
- Lab worksheets submitted at end of lab (no lab reports!) - **5%**
- Class participation – **5%**
- Final project (ppt presentation or poster, and 10 page paper) - **25%**

No exams!

Resources

No textbook!

Readings posted on Moodle.

PowerPoints will be posted on Moodle *before class*.

Math!

Prerequisite: a college level introductory calculus course (equivalent to Math 135 at Macalester).

We will not require *advanced* math in the course

However, we will *use math a lot*! All problem sets and most classes will involves various kinds of calculations, mostly "word problems" that don't require calculus. A few problems will require *simple* derivatives and integrals. A reference for basic calculus is on Moodle *CalculusReviewMerged.pdf.*

It is more important that you understand what a derivative *means* (slope of a curve, rate of change) and what an integral *means* (area under a curve, limit of a sum), than detailed knowledge of calculus techniques!

As with all assignments you can get help from the instructor or other students in the class if you are rusty on you math skills.

Software!

There is no computer programming pre-requisite for the course.

However, you are expected to be comfortable (or willing to get up to speed) with basic Excel. There will be a brief tutorial you will work through.

If you are rusty or relatively inexperienced in Excel you can consult the instructor and/or with other students in the class if you need help.

We will also use some pre-written software for energy modelling, but you are not be required to generate new code.

Final Project!

In small groups (2-3), you will plan and design a small community (neighborhood), including a detailed “typical” building, that maximizes sustainability!

Following a rubric you will consider **energy, carbon, water, waste, building design, transportation, food, aesthetics, biophilia, costs, social aspects**, and other issues in your design!

The final weeks of the course will be devoted to this project (with no other assignments other than guest speakers). Some class time will be used for progress updates and discussions.

Attendance Policy

Attendance is mandatory! Each unexcused absences from class will result 1.5% course point deduction. Labs cannot be make up without a very compelling reason (with no credit for the relevant assignment).

The most important thing about getting an absence excused: communicate with the instructor! Before if possible, ASAP in any case!

Tentative Course Outline

Part I: Fundamentals (8-10 classes)

- nature of energy
- essentials of thermodynamics
- electrical energy (mostly lab)
- the electrical grid and renewable energy
- heat flow and insulation
- nature of light
- life cycle analyses
- carbon footprint

Part II: Buildings and Transportation (10-12 classes):

- building design and materials
- heating and cooling, lighting, air quality
- energy efficiency
- carbon footprint
- water and waste management
- solar energy
- energy storage
- electric transportation

Part III: Integration and Community (8-10 classes)

- water and waste management (community level)
- recycling
- distributed energy and energy storage
- aesthetics and biophilia green space, bike/walk friendly
- food
- transportation, district energy
- microgrids
- social and equity Issues

Important dates

Friday Sept 2	No class
Tuesday Oct 18	No lab (Tuesday becomes Thursday)
Friday Oct 21	No class (Fall Break)
Wednesday Nov 23	No class (Thanksgiving Break)
Friday Nov 25	No class (Thanksgiving Break)
Tuesday Nov 29	No lab
Wednesday Nov 30	Zoom class
Friday Dec 2	Zoom class
Friday Dec 9	Last day of class