CEE 176A: ENERGY EFFICIENT BUILDINGS
STANFORD UNIVERSITY (SUMMER 2023)
MWF 1:30 – 2:20pm, Shriram 104 | 3 units

INSTRUCTOR:

Kyle Douglas (kyled@stanford.edu)
Office Hours: Tuesday & Thursday 11:00 am – 1:00 pm
The Blume Center (Bldg. 540), Room 123

COURSE ASSISTANTS:

Katie Wheeler (wheel2kl@stanford.edu)
Office Hours: Monday 12:00 – 1:00 pm
Friday 12:00 – 2:00 pm
Location: TBA

COURSE READER:

CEE176A Course Reader (from *Energy for Sustainability* by Randolph and Masters)
(Reader available online via the Stanford Bookstore, link via Canvas announcement)

CANVAS:

Lecture slides, handouts and homework will be posted on the CEE 176A Canvas website.

THE COURSE:

The general theme of this course is to introduce techniques that will help enable the design and evaluation of Zero Net Energy (ZNE) single-family homes. We start with energy-efficiency techniques to reduce heating and cooling loads, then we explore issues associated with building orientation and window overhangs to control solar gains. Having reduced energy demands, we then electrify everything, focusing on heat pumps to power heating, cooling and hot water demands. Finally, we figure out how to power it all, including an electric vehicle, with grid-connected rooftop solar photovoltaics, paying special attention to negative impacts of shading.

In this course you will learn how to do residential heating and cooling calculations, financial analysis of specific energy features, passive solar design techniques, and simple sizing of photovoltaics (PVs) for on-site electricity generation. Heating and cooling analysis techniques that apply to buildings of all sizes will be introduced, but our emphasis will be on residential-scale buildings. Small buildings are simpler to model (spreadsheets work fine) and the analysis used provides intuition into the more complex behavior of larger buildings. Residential buildings are also more important than commercial buildings, both in terms of total energy demand (20% more) and dollars spent on energy (35% more). Larger-building energy systems are covered in CEE 156/256 (Kolderup, Winter) and CEE 226E (Rumsey, Spring).

BACKGROUND EXPECTED:

There are no prerequisites for the course. While the course is quantitative, the math is basic. At most, you may be required to use a spreadsheet program (e.g. Excel) to do some of the homework problems.

COURSE LEARNING GOALS:

1. Identify building design concepts for residential homes that provide for the thermal comfort of its occupants, result in affordable energy bills, and properly integrate its systems with the local climate.
2. Evaluate the energy efficiency of a residential home and its systems using quantitative metrics.
3. Apply integrative design methods to develop a holistic model for a ZNE house in a given location.

COURSE REQUIREMENTS:

Homework will be handed out on Fridays and will be due by **midnight** the following Friday. We will be using Gradescope for homework submission and grading. Solutions to the homework sets will be made available to students within a week after their due date.

When submitting your homework to Gradescope, we ask that you follow the requirements below. These requirements are aligned with how professional engineers undertake analysis and present their work, improve your learning of the course concepts and analysis procedures, and facilitate better homework grading:

(1) **Work written problems** on plain paper, engineering paper, or on a tablet. If you use engineering paper, only write on the front side of each page (note that on the back side there is typically a dark grid that faintly shows through to the front side). If you use a tablet to complete your homework problems, we recommend using a grid option for the paper to keep your work organized.

(2) **Clearly label each homework** with your name and the homework assignment number in the upper right-hand corner of each page.

(3) **Show your work.** Keep in mind that an answer placed on paper is not an acceptable solution without your supporting work. Showing your work generally means including a drawing, assumptions, and supporting calculations.

(4) **Keep your work organized and neat.** Your work should be a document that is easy to read and follow. Write legibly, use headings for groups of calculations, and space out your work. It is preferable to start each problem on a new page.

(5) **Box your answers.** Place a box around your answers. For numerical answers, be sure to include units.

(6) **Scan your homework** and upload it to Gradescope. We don't recommend submitting pictures of your assignments because they are more difficult to manage and can be of poor quality. A few good (and free!) scanning apps are CamScanner, Adobe Scan, and Genius Scan.

(7) **Document collaboration.** You are encouraged to work with one another on your assignments. Collaboration is common practice in engineering and facilitates team learning. If you work with someone else on homework problems, provide their name on your assignment.

Late Homework: In general, **homework sets should be submitted to Gradescope by midnight on the date they are due.** However, the universe sometimes makes this impossible. For those times, you can turn in your assignment by midnight on the Sunday following the due date with no penalty. Extensions beyond Sunday must be approved by the teaching team. We cannot accept a homework assignment after the solutions have been posted.

GRADING:

Homework	55%
Midterm	15%
Literature Review	15%
Final Exam	15%

BUILDINGS BACKGROUND:

The energy required to operate our residential and commercial buildings is about 40 percent of total primary energy in the U.S., with more than half of that total being associated with the residential sector. When embodied energy in building materials—especially cement and steel—is taken into account, along with industrial buildings, the building sector is responsible for almost half of all U.S. energy demand.

In the process of providing energy to construct and operate our buildings we emit a significant fraction of total U.S. atmospheric pollutants, including nearly half of U.S. carbon emissions. Improvements in building energy efficiency offer major opportunities for reduced energy demand and carbon emissions, often at negative cost (more money saved in reduced energy than the cost of the improved technology and design).

In a "normal" year in the U.S., we build over 2 million housing units, including 1.4 million new single-family homes. Building codes such as California's Title 24 and appliance efficiency standards have dramatically reduced the energy required per square foot, but some of those gains have been offset by larger houses (roughly 2500 sq ft now versus 1700 sq ft 25 years ago). About one-third of households are rentals, which creates split incentives between landlords, who have little incentive to pay for efficiency improvements since they don't pay utility bills, and renters who pay the bills but can't perform retrofits. A typical U.S. household spends over $2000/yr for residential energy (about the same as is spent for gasoline), for a total of about $240 billion, with almost half of that being used for simple space heating and water heating. Energy for commercial buildings costs another $170 billion per year, with lighting, heating and cooling accounting for three-fourths of that demand. Most commercial buildings are not big skyscrapers—two thirds are just one to two-story buildings, and half are smaller than 50,000 square feet (roughly a Stanford dorm). These statistics and more can be found in the DOE (US Departmentt of Energy) *Buildings Energy Data Book*.

Students with Documented Disabilities:

Students who may need an academic accommodation based on the impact of a disability must initiate the request with the Office of Accessible Education (OAE). Professional staff will evaluate the request with required documentation, recommend reasonable accommodations, and prepare an Accommodation Letter for faculty. Unless the student has a temporary disability, accommodation letters are issued for the entire academic year. Students should contact the OAE as soon as possible since timely notice is needed to coordinate accommodations. The OAE is located at 563 Salvatierra Walk (phone: 723-1066, URL: https://oae.stanford.edu/). Please communicate with the course teaching team directly regarding your disability. We are happy to help in any way we can!

Tentative Schedule (subject to change)

Week	Date	Day	Lecture	Topic Covered	Assigned	Due	Reading
1	26-Jun	M	1	Introduction			6.1
	28-Jun	W	2	Heat Transfer			6.2
	30-Jun	F	3	R-Values	HW 1		6.2
2	3-Jul	M	4	Windows and Walls			6.3 - 6.4
	5-Jul	W	5	Walls			6.5
	7-Jul	F	6	Ceilings	HW 2	HW 1	6.5
3	10-Jul	M	7	Floors			6.5
	12-Jul	W	8	Infiltration			6.6
	14-Jul	F	9	Ventilation	HW 3	HW 2	6.6
4	17-Jul	M	10	Thermal Comfort			7.3.5
	19-Jul	W	11	The Whole House			6.7
	21-Jul	F	12	Solar Resource		HW 3	7.1
5	24-Jul	M	13	Suntempering	LIT REVIEW		7.2, 7.4.1
	26-Jul	W	14	Thermal Mass			7.4
	28-Jul	F	15	MIDTERM	HW 4		
6	31-Jul	M	16	Thermal Mass			7.4
	2-Aug	W	17	Passive Solar			7.2
	4-Aug	F	18	LCR Method	HW 5	HW 4	7.2
7	7-Aug	M	19	Heat Pumps			6.11
	9-Aug	W	20	Cooling			7.3
	11-Aug	F	21	Domestic Hot Water		HW 5	7.5
8	14-Aug	M	22	Economics			
	16-Aug	W	23	Solar PV			10.1 - 10.2
FINAL	**18-Aug**	**F**		**3:30 - 6:30 PM**		**LIT REVIEW**	