

TO: The Engineering Faculty

FROM: The Faculty of the School of Civil and Construction Engineering

RE: New graduate course – CE 51701: Smart Building Systems Modeling

The Faculty of the Lyles School of Civil and Construction Engineering has approved the following new graduate course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

FROM (IF ALREADY OFFERED WITH TEMPORARY NUMBER):

CE 59700 Sustainable Building Design, Construction and Operation

Fall or Spring

Three total credits; lectures

No Prerequisites

Previous offerings (with enrollment): Fall 10 (26); Fall 12 (24); Fall 13 (16); Fall 14 (21); Fall 15 (10); Fall 17 (14); Fall 18 (16); Fall 20 (12); Fall 21 (8); Fall 22 (26); Fall 23 (26).

TO:

CE 51701: Smart Building Systems Modeling

Fall or Spring


Three total credits; lectures

No Prerequisites

Course description: The course introduces environmental issues associated with buildings and presents concepts of performance indicators for improved energy efficiency and indoor environmental quality. Building systems modeling and simulation is the focus of the class. Students become familiar with forward (physics-based) and inverse (data-driven) modeling methods and use them for performance-based building design, benchmarking, and advanced model-based control. This sets the ground for an in-depth analysis of performance prediction for the evaluation of building components and systems and the use of building energy simulation tools. It is followed by topics on building systems integration using examples that include building-scale renewable energy generation and management, innovative energy and comfort delivery systems, as well as applications on smart buildings and connected communities.

RATIONALE:

The course is one of the required graduate courses in the emphasis area of architectural engineering within LSCCE. The course has been offered 12 times to a total of 190 students. The course introduces forward and data-driven modeling methods for building components and systems as well as energy analysis using state-of-the-art simulation tools. In addition, it introduces students to smart buildings and connected communities including building-integrated renewable energy systems, distributed comfort delivery, and model-based predictive control concepts.



Head/Director of the Lyles School of Civil and Construction Engineering

Link to Curriculog entry: <https://purdue.curriculog.com/proposal:33265/form>



Course Information

- **Course number and title:** CE 51701 Smart Building Systems Modeling
- **Instructional Modality:** Online and in person
- **Course credit hours:** 3 credit hours

Contact Information

- **Instructor:** Panagiota Karava, Professor in Civil and Construction Engineering
- **Office Location:** HAMP G167A, HLAB 2016
- **Purdue Email Address:** pkarava@purdue.edu

Course Description

The course starts with an introduction to environmental issues associated with buildings and presents concepts of performance indicators for improved energy efficiency and indoor environmental quality. Building systems modeling and simulation is the focus of the class. Students become familiar with forward (physics-based) and inverse (data-driven) modeling methods and use them for performance-based building design, benchmarking, and advanced model-based control. This sets the ground for an in-depth analysis of performance prediction for the evaluation of building components and systems and the use of building energy simulation tools. It is followed by topics on building systems integration using examples that include building-scale renewable energy generation and management, innovative energy and comfort delivery systems, as well as applications on smart buildings and connected communities.

Learning Outcomes

By the end of the course, students should be able to:

- Build energy models based on first principles (physics-based forward models); Heat balance method; Finite difference methods. Work on examples using teaching modules in Python/ Google Colab.
- Model building components and systems; evaluate standard and new technology. Work on examples using teaching modules in Python/ Google Colab.
- Conduct building energy modeling and analysis using computer simulation tools.
- Become familiar with data-driven building models (change point method), system identification based on state-space representation, and model-based control approaches. Work on examples using teaching modules in Python/ Google Colab.
- Become familiar with concepts for building energy consumption and statistics for decision making. Effectively utilize building performance indicators and assess building decarbonisation technology and use related standards.
- Become introduced to advanced topics related to smart buildings and connected communities including building-integrated solar energy systems, distributed comfort delivery, model-based predictive control.

Learning Resources, Technology & Texts

- **Purdue Brightspace:** Class notes and handouts will be posted regularly.
- **Suggested Reference Books (Optional)**
 1. Principles of Heating, Ventilation and Air Conditioning in Buildings, by J.W. Mitchell and J.E. Braun, Wiley, 1st version, 2013.

2. Building Performance Simulation for Design and Operation by Hensen, Jan L.M. and Lamberts, Roberto, Spon Press, 2011.
3. Heating, Ventilating, and Air Conditioning by McQuiston, Parker, Spitler, 6th edition (2005), Wiley.
4. Energy Simulation In Building Design by Clarke, J.A., 2nd edition, Butterworth-Heinemann, Oxford, 2001.
5. Building Thermal Analysis by A.K. Athienitis, 3rd edition, 1998.
6. ASHRAE Handbook of Fundamentals. American Society of Heating Ventilating and Air Conditioning Engineers, Atlanta, Georgia, US.
7. Solar Engineering of Thermal Processes by John A. Duffie, William A. Beckman, 1991, ISBN: 0471510564.

Office Hours

Student Consultation hours, times, and location: Thursday, 2:45 pm-3:45 pm in the classroom or HLAB 2016 or virtually (Webex meeting invitations are on Brightspace). Friday 3:4 pm or virtually (Webex meeting invitations are on Brightspace). To schedule any other time please contact me by email.

Instructor's Email Availability and Policies

I will be available via email daily and try to respond as soon as possible (generally within 24-48) hours. When emailing me, please place the course number/section and the topic in the subject line of the email (*e.g.*, CE597 – Assignment 2 Question). This will help me tremendously in locating and responding to your emails quickly.

Virtual Office Hours

We will schedule virtual Office Hours as synchronous sessions (through WebEx) to discuss questions related to the course material and/or assignments. We will provide the schedule and WebEx link on Brightspace.

Assignments and Points

Your learning will be assessed through a combination of assignments, a project and a midterm exam spread throughout the semester. Details on these assignments and exams, including rubrics to guide evaluation, and guidelines on discussion participation and evaluation will be posted on the course website.

Weight	Assignment type	Assignment	Points
40%	Homework		
		Homework 1 (Finite Difference Wall Model)	100
		Homework 2 (Zone Finite Difference Model)	100
		Homework 3 (HVAC Model)	100
		Homework 4 (Building Simulation Model)	100
		Homework 5 (Data Driven Model)	100
30%	Exams		
		Exam 1	100
30%	Final project		
		Project Abstract	5
		Project Report	75
		Project Presentation	20

Schedule

Week	Dates	Content	Items To Be Working On	Items Due by Sunday 11:59ET at end of week
1	Aug 21-27	Introduction 1	Python/Google CoLab tutorials Hw#1 released	
2	Aug 28-Sep 3	Introduction 2	Python/Google CoLab tutorials	
3	Sep 4-10	Wall model Demo: Python & Wall model		Hw#1 due
4	Sep 11-17	Zone model	Hw#2 released	
5	Sep 18-24	Zone model Demo: Zone model	Continue working on HW #2	
6	Sep 25-Oct 1	Intro of HVAC	Continue working on HW #2	Hw#2 due
7	Oct 2-8	HVAC design & VAV example Demo: VAV example	Hw#3 released	
8*Fall break*	Oct 9-15	Building simulation principles/OpenStudio	Continue working on HW #3	Hw#3 due
9	Oct 16-22	Openstudio Demo: OpenStudio	HW#4 released	
10	Oct 23-29	Life-Cycle Cost Analysis & CO2 emission	Continue working on HW #4	Hw#4 due
11	Oct 30-Nov 5	Energy data analysis Demo: Change point analysis	Hw#5 released	Final project abstract due for feedback
12	Nov 6-12	Energy data analysis		
13	Nov 13-19	Exam	Continue working on HW #5	
14 *Thanksgiving Break*	Nov 20-26	Scenario discussions and final project preparation Demo: MPC		Hw#5 due
15	Nov 27-Dec 3	Project discussion		
16	Dec 4-10	Project discussion		Final project report and presentation due

Project

Students are required to submit a project report and prepare a project presentation. A project abstract will be due halfway through the semester for feedback. See Brightspace for project guidelines.

Course Logistics

- (For asynchronous online students) You are encouraged to ‘mentally enroll’ in this course as if it occurred Tuesdays and Thursdays.
- Course requirements must be completed and posted or submitted on or before the specified due date and delivery time deadline. Due dates and delivery time deadlines are defined as that used in West Lafayette, Indiana).

- Assignments should be submitted on the due date. Late assignments will not be accepted, unless a specific arrangement has been made with the instructor prior to the due date.
- An assignment file should be appended by your username, such as “assignment1-kim53.doc.” This will make it easier for me to manage assignment files.

Incompletes

According to the [Grades and Grade Reports](#) section of Academic Regulations, “A grade of incomplete (I) is a record of work that was interrupted by unavoidable absence or other causes beyond a student’s control...” Further details on these circumstances and the process for assigning types of incompletes are outlined in the regulations. Please contact me as soon as you think an incomplete might be needed in this course and before final course grades are due.

Teaching Philosophy

As an instructor, it is my responsibility to maximize opportunities for every student in the class to learn, grow, and succeed in reaching both my own outcomes for the course and their personal goals and desires related to the class. To meet this responsibility, I draw on practices rooted in principles of collaborative learning and student-faculty partnership. I focus on student learning, which I define as a process of individual change. This means developing skills to view the world in new ways, and engaging in different types of discussions and dialogues.

How to Succeed in this Course

If you want to be a successful student:

- Be self-motivated and self-disciplined.
- Be willing to speak up if problems arise.
- Access the resources that are available to you; reaching out for assistance is essential.
- Be willing and able to commit adequate time for the course.
- Be able to meet the minimum requirements for the course.
- Accept critical thinking and decision making as part of the learning process.
- Take advantage of resources such as those listed in our course Brightspace.
- Review the University Policies content on our course Brightspace.

Copyright

Effective learning environments provide opportunities for students to reflect, explore new ideas, post opinions openly, and have the freedom to change those opinions over time. Students and instructors are the authors of the works they create in the learning environment. As authors, they own the copyright in their works subject only to the university’s right to use those works for educational purposes (Visit [Purdue University Copyright Office](#)). Students may not copy, reproduce or post to any other outlet (e.g., YouTube, Facebook, or other open media sources or websites) any work in which they are not the sole or joint author or have not obtained the permission of the author(s).

Violent Behavior Policy

Purdue University is committed to providing a safe and secure campus environment for members of the university community. Purdue strives to create an educational environment for students and a work environment for employees that promote educational and career goals. Violent Behavior impedes such goals. Therefore, Violent Behavior is prohibited in or on any University Facility or while participating in any university activity. See the Student Widget on our course Brightspace for more information on the Violent Behavior Policy.

Diversity, Inclusion & Belonging

1. In our discussions, structured and unstructured, we will explore a variety of challenging issues, which can help us enhance our understanding of different experiences and perspectives. This can be challenging, but in overcoming these challenges we find the greatest rewards. While we will design guidelines as a group, everyone should remember the following points:
 - We are all in the process of learning about others and their experiences. Please speak with me, anonymously if needed, if something has made you uncomfortable.

- Intention and impact are not always aligned, and we should respect the impact something may have on someone even if it was not the speaker's intention.
 - We all come to the class with a variety of experiences and a range of expertise, we should respect these in others while critically examining them in ourselves."
2. This course, as with every course offered at Purdue, plays a part in creating and sustaining a welcoming campus where all students can excel. There are many initiatives in ___ department and supported by the university focused on this goal, and this course is designed to take advantage of those resources. Learning experiences and assignments address diversity and inclusion, not because they are "topics," but because they are necessary to prepare students to be successful in a diverse, global environment.
 3. We strive for equity, providing equal access and opportunity, and working to maximize student potential. This requires both instructor and students to identify and remove barriers that may prevent someone from full access or full participation. You can help by:
 - Contacting me, anonymously if needed, if you see a potential barrier for someone or yourself in participating fully in the class. This might be a physical barrier such as access to technology or a personal situation.
 - Suggesting ways in which members of our class can support each other. Virtual study groups and discussion boards are examples, but I encourage you to be creative in your ideas.
 - Getting to know each other as contributing members of our learning community. Everyone has something to contribute, and while I designed the course to take advantage of the wealth of knowledge, expertise, and experience we bring together, I cannot do it well without your participation. There are many opportunities built into this course for this type of work. It is important we do it together.

Attendance Policy

Students are expected to be present for every meeting of the classes in which they are enrolled. Only the instructor can excuse a student from a course requirement or responsibility. When conflicts or absences can be anticipated, such as for many University sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible. For unanticipated or emergency absences when advance notification to an instructor is not possible, the student should contact the instructor as soon as possible by email. When the student is unable to make direct contact with the instructor and is unable to leave word with the instructor's department because of circumstances beyond the student's control, and in cases of bereavement, the student or the student's representative should contact the Office of the Dean of Students via [email](#) or phone at 765-494-1747.

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either [emailing](#) or by calling 765-494-8778. While information may be submitted anonymously, the more information that is submitted provides the greatest opportunity for the university to investigate the concern.

The [Purdue Honor Pledge](#) "As a boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue" .

For more information, please refer to Purdue's [student guide for academic integrity](#).

Netiquette

Your instructor and fellow students wish to foster a safe online learning environment. All opinions and experiences, no matter how different or controversial they may be perceived, must be respected in the tolerant spirit of academic discourse. You are encouraged to comment, question, or critique an idea, but you are not to attack an individual. Our differences, some of which are outlined in the University's nondiscrimination statement below, will add richness to this learning experience. Please consider that sarcasm and humor can be misconstrued in online interactions and generate

unintended disruptions. Working as a community of learners, we can build a polite and respectful course ambience. Please read the Netiquette rules for this course:

- Do not dominate any discussion. Give other students the opportunity to join in the discussion.
- Do not use offensive language. Present ideas appropriately.
- Be cautious in using Internet language. For example, do not capitalize all letters since this suggests shouting.
- Avoid using vernacular and/or slang language. This could possibly lead to misinterpretation.
- Keep an “open-mind” and be willing to express even your minority opinion.
- Think and edit before you push the “Send” button.
- Do not hesitate to ask for feedback.

Nondiscrimination Statement

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. More details are available on our course Brightspace table of contents, under University Policies.

Accessibility

Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247. More details are available on our course Brightspace under Accessibility Information.

Mental Health/Wellness Statement

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try [WellTrack](#). Sign in and find information and tools at your fingertips, available to you at any time.

If you need support and information about options and resources, please contact or see the [Office of the Dean of Students](#). Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc. sign up for free one-on-one virtual or in-person sessions with a [Purdue Wellness Coach at RecWell](#). Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is completely free and can be done on BoilerConnect. If you have any questions, please contact Purdue Wellness at evans240@purdue.edu.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact [Counseling and Psychological Services \(CAPS\)](#) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Basic Needs Security

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. There is no appointment needed and Student Support Services is available to serve students 8 a.m.-5 p.m. Monday through Friday. Considering the significant disruptions caused by the current global crisis as it related to COVID-19, students may submit requests for emergency assistance from the [Critical Needs Fund](#)

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructor via email or phone. You are expected to read your @purdue.edu email on a frequent basis.

Disclaimer

This syllabus is subject to change. You will be notified of any changes as far in advance as possible via an announcement on Brightspace. Monitor your Purdue email daily for updates.