

CARLETON UNIVERSITY
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
BLDG 5301 – FALL 2024
BUILDING ENERGY MANAGEMENT AND OPTIMIZATION

Instructor: Burak Gunay, PhD, PEng

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Office Hours: Monday 4 pm to 5 pm

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Lectures on Monday 6:05 pm to 8:55 pm

Learning Objectives:

1. Conduct analysis on building energy management systems data
2. Perform optimization for decision making
3. Perform model selection and validation
4. Understand and develop inverse models
5. Understand classification and clustering techniques
6. Use coding to perform energy management tasks

Supplementary textbook: Reddy, A., 2011. Applied data analysis and modeling for energy engineers and scientists. Springer.

Software: Matlab; Python

Course Plan:

Lecture 1: Introduction (Sep 9)

- Energy sector landscape
- Building energy systems
- Challenges in managing energy use in buildings
- Methods to optimize energy use in buildings
- Energy audits

Lecture 2: Inverse modelling - part 1 (Sep 16)

- Multiple linear regression models
- Change point models
- Matlab tutorial - 1 (estimating retrofit energy savings through multiple linear regression and change point model-based baselines)
- Case study

Lecture 3: Inverse modelling - part 2 (Sep 23)

- Neural network models
- Regression trees

- Matlab tutorial - 2 (estimating retrofit energy savings through neural net and regression tree model-based baselines)
- Case study

Lecture 4: Remote envelope characterization (Sep 30)

- Estimating building envelope properties through inverse modelling
- Matlab tutorial - 3 (estimating R value and air permeance)
- Case study

Lecture 5: Fault detection and diagnostics - hard faults (Oct 7)

- Detecting hard faults affecting HVAC systems
- Matlab tutorial - 4 (detecting hard faults in VAV AHU systems)
- Case study

Lecture 6: Fault detection and diagnostics - soft faults (Oct 28)

- ASHRAE Guideline 36 and best practice sequences of operation
- Approaches to detect and interpret sequencing logic faults
- Matlab tutorial - 5 (detecting soft faults in VAV AHU systems)
- Case study

Lecture 7: Virtual metering and end-use disaggregation (Nov 4)

- Inverse modelling applications to complement existing submetering network
- Matlab tutorial - 6 (disaggregating end-uses in VAV AHU systems)
- Case study

Lecture 8: Load forecasting (Nov 11)

- Time-series modelling and decomposition approaches
- Matlab tutorial - 7 (arima models for short-term electricity demand forecasting)
- Case study

Lecture 9: Optimization (Nov 18)

- Optimization algorithms for data-driven building energy management
- Matlab tutorial - 9 (boiler plant equipment sequencing optimization)
- Case study

Lecture 10: Model-based predictive controls (Nov 25)

- Controls-oriented modelling, RC thermal networks
- Real-time optimization of control decisions
- Matlab tutorial - 10 (optimal start time optimization)
- Case study

Lecture 11: Demand response (Dec 2)

- Critical and coincident system electricity demand
- Sequences of operation for demand management
- Comfort and rebound considerations in demand management
- Matlab tutorial - 11 (Simulating the indoor temperature and demand profile of a building)

- Case study

Lecture 12: Project presentations (Dec 6)

Grade Distribution:

Assignment 1 – Change point models 10%

Assignment 2 – Multiple linear regression and artificial neural networks 10%

Assignment 3 – Load forecasting 10%

Assignment 4 – Optimal sequencing for plant equipment 10%

Assignment 5 – Optimal start of AHUs 10%

Project – Establish an energy use baseline and identify anomalies 50%

Letter Grade Distribution:

≥ 90.00	A+
85.00 - 89.99	A
80.00 - 84.99	A-
77.00 - 79.99	B+
73.00 - 76.99	B
70.00 - 72.99	B-
67.00 - 69.99	C+
63.00 - 66.99	C
60.00 - 62.99	C-
57.00 - 59.99	D+
53.00 - 56.99	D
50.00 - 52.99	D-
≤ 49.99	F

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Learning and Working Environment

The University and all members of the University community share responsibility for ensuring that the University’s educational, work and living environments are free from discrimination and harassment. Should you have concerns about harassment or discrimination relating to your age, ancestry, citizenship, colour, creed (religion), disability, ethnic origin, family status, gender expression, gender identity, marital status, place of origin, race, sex (including pregnancy), or sexual orientation, please contact the Department of Equity and Inclusive Communities at equity@carleton.ca We will strive to create an environment of mutual respect for all through equity, diversity, and inclusion within this course. The space which we work in will be safe for everyone. Please be considerate of everyone’s personal beliefs, choices, and opinions.

Academic Accommodations

You may need special arrangements to meet your academic obligations during the term. For an accommodation request the processes are as follows:

Academic Accommodations for Students with Disabilities: The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca . You should request your academic accommodations in the Ventus Student Portal, for each course at the beginning of every term. For in-term tests or midterms, please request accommodations at least two (2) weeks before the first test or midterm. Please consult the PMC website for the deadline to request accommodations for the formally-scheduled exam (if applicable).

Accommodation for Student Activities: Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to stu-

dents who compete or perform at the national or international level. Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, see the Senate Policy on Accommodation for Student Activities (PDF).

Pregnancy Obligation: Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, please review the Student Guide to Academic Accommodation (PDF).

Religious Obligation: Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, please review the Student Guide to Academic Accommodation (PDF).

Survivors of Sexual Violence: As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit the Sexual Violence Prevention & Survivor Support.

Engineering Academic Advising

The Engineering Academic Support Service assists undergraduate engineering students with course selection, registration, and learning support from first-year through to graduation. Academic Advisors Contact can be found here: <https://carleton.ca/engineering-design/current-students/undergraduate-academic-support/undergraduate-advisors/>.

Student Mental Health and Wellness

As a university student you may experience a range of mental health challenges that can significantly impact your academic success and overall well-being. Carleton's Wellness Services Navigator is designed to help students connect with mental health and wellness resources. If you need to talk to someone from the department for more information and support with connecting to resources, you can contact the following faculty members, depending on your program.

Here is a list of on-campus and off-campus resources:

1. Carleton's Wellness Desk: Located at 204A MacOdrum Library, is a space for students to learn about resources, connect with our Wellness Coordinator, and decompress during stressful times of the year. You can pop into the Wellness Desk any time during its hours of operation – no appointments necessary! <https://wellness.carleton.ca/mental-health/wellness-desk/>
2. Carleton's Health and Counselling Services: To book an appointment contact the main clinic by calling (613) 520-6674. If urgent, let the Patient Care Coordinator know or go in person to the main clinic (2500 Carleton Technology and Training Centre Building) and indicate that they are in crisis and need to speak to someone right away. <https://carleton.ca/health/>
3. Residence Counselling and Wellness Service: Counselling services specifically for students in residence. <https://carleton.ca/health/residence-counselling/>
4. Therapy Dogs: Carleton's therapy dogs are around campus with their owners (who are Carleton University staff and faculty) to comfort and provide support to help you thrive as a university student. <https://carleton.ca/wellness/dogs/>
5. Emergencies and Crisis and Emergency Numbers
6. Good2Talk (1-866-925-5454): Good2Talk is a free, confidential helpline providing professional counselling and information and referrals for mental health, addictions and well-being to post-secondary students in Ontario, 24/7/36 <https://good2talk.ca/>
7. Empower Me: Undergraduate students have access to free counselling services in the community through Empower Me, either in person, by telephone, video-counselling or e-counselling. This free

service is accessible 24/7, 365 days per year. Call 1-844-741-6389 (toll free) to make an appointment with a counsellor in the community. More information is available <https://students.carleton.ca/services/empower-me-counselling-services/>

8. The Walk-In Counselling Clinic (off-campus community resource): The walk-in Counselling Clinic have offices in various locations across Ottawa and the greater Champlain region that are open 7 days a week. Individuals will be assisted, with no appointment, on a first-come, first-serve basis during the Walk-in Counselling Clinic hours. The Walk-in Counselling Clinic offers services in many languages and is free and confidential. More information can be found at: <https://walkincounselling.com/>

9. Distress Centre of Ottawa and Region: Available 10am-11pm, 7 days/week, 365 days/year. Distress Line: 613-238-3311, Crisis Line: 613-722-6914 or 1-866-996-0991, Text: 343-306-5550. <https://www.dcottawa.on.ca/>

10. Distress and Crisis Ontario, Available for chat 2 pm – 2 am EST. <https://www.dcontario.org/>

11. BounceBack Ontario (Toll-Free: 1-866-345-0224) is a free skill-building program managed by the Canadian Mental Health Association (CMHA). It is designed to help adults and youth 15+ manage low mood, mild to moderate depression and anxiety, stress or worry. Delivered over the phone with a coach and through online videos, you will get access to tools that will support you on your path to mental wellness. <https://bouncebackontario.ca/>.
