The AREN laboratories offer state-of-the-art facilities to test a wide range of operational and control strategies for lighting and HVAC systems and subsystems. Indeed, several control projects have been carried out in the Larson HVAC laboratory including demand-ventilation controls, optimal chiller and thermal energy storage controls, outdoor air intake controls, and optimal operation of evaporative systems. In addition, fault diagnostic algorithms have been tested in the laboratory for specific HVAC equipment including for heating and cooling coils, chillers and outdoor air intake dampers.

**Master’s Degrees**
- Architectural Engineering - Master of Science (MS) (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/architectural-engineering/architectural-engineering-master-science-ms)

**Doctoral Degree**
- Architectural Engineering - Doctor of Philosophy (PhD) (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/architectural-engineering/architectural-engineering-doctor-philosophy-phd)

**Faculty**
While many faculty teach both undergraduate and graduate students, some instruct students at the undergraduate level only. For more information, contact the faculty member’s home department.

Amadei, Bernard (https://experts.colorado.edu/display/fisid_105978) Distinguished Professor; PhD, University of California, Berkeley

Amy, Gary L. Professor Emeritus

Baker, Kyri A. (https://experts.colorado.edu/display/fisid_159754) Assistant Professor; PhD, Carnegie Mellon University

Balaji, Rajagopalan (https://experts.colorado.edu/display/fisid_118480) Professor; Chair, PhD, Utah State University

Bielefeldt, Angela R. (https://experts.colorado.edu/display/fisid_110322) Professor; PhD, University of Washington

Brandemuehl, Michael J. Professor Emeritus

Chinowsky, Paul (https://experts.colorado.edu/display/fisid_125496) Professor; PhD, Stanford University

Cook, Sherri M. (https://experts.colorado.edu/display/fisid_154773) Assistant Professor; PhD, University of Michigan Ann Arbor

Corotis, Ross B. (https://experts.colorado.edu/display/fisid_100942) Professor; PhD, Massachusetts Institute of Technology

Crimaldi, John P. (https://experts.colorado.edu/display/fisid_115733) Professor, Associate Chair; PhD, Stanford University

Dashti, Shideh (https://experts.colorado.edu/display/fisid_148493) Associate Professor, Faculty Director; PhD, University of California, Berkeley

Diekmann, James E. Professor Emeritus
DiLaura, David L.  
Professor Emeritus

Dow, John O.  
Associate Professor Emeritus

Frangopol, Dan M.  
Professor Emeritus

Goodrum, Paul M. (https://experts.colorado.edu/display/fisid_151965)  
Professor; PhD, University of Texas at Austin

Gooseff, Michael N. (https://experts.colorado.edu/display/fisid_155922)  
Professor; PhD, University of Colorado Boulder

Gupta, Vijay  
Professor Emeritus

Halek, Milan F.  
Senior Instructor Emeritus

Hallowell, Matthew Ryan (https://experts.colorado.edu/display/fisid_146163)  
Associate Professor; PhD, Oregon State University

Hearn, George (https://experts.colorado.edu/display/fisid_101059)  
Associate Professor; PhD, Columbia University

Henze, Gregor P. (https://experts.colorado.edu/display/fisid_146496)  
Professor; PhD, University of Colorado Boulder

Hernandez, Mark T. (https://experts.colorado.edu/display/fisid_107635)  
Professor; PhD, University of California, Berkeley

Hubler, Mija H. (https://experts.colorado.edu/display/fisid_155134)  
Assistant Professor, Faculty Director; PhD, Northwestern University

Javernick-Will, Amy N. (https://experts.colorado.edu/display/fisid_146430)  
Associate Professor; Associate Professor, Associate Faculty Director; PhD, Stanford University

Kasprzyk, Joseph R. (https://experts.colorado.edu/display/fisid_151506)  
Assistant Professor; PhD, Pennsylvania State University

Klees, Rita C. (https://experts.colorado.edu/display/fisid_145391)  
Associate Faculty Director, Scholar in Residence; PhD, University of Colorado

Ko, Hon-Yim  
Professor Emeritus

Korak, Julie Ann (https://experts.colorado.edu/display/fisid_155070)  
Assistant Professor; PhD, University of Colorado Boulder

Krarti, Moncef (https://experts.colorado.edu/display/fisid_104154)  
Professor; PhD, University of Colorado Boulder

Scholar in Residence; PhD, University of Colorado Boulder

Liel, Abbie B. (https://experts.colorado.edu/display/fisid_146431)  
Associate Professor, Faculty Director; PhD, Stanford University

Linden, Karl G. (https://experts.colorado.edu/display/fisid_143747)  
Professor; PhD, University of California, Davis

Livneh, Ben (https://experts.colorado.edu/display/fisid_151999)  
Assistant Professor; PhD, University of Washington

McKnight, Diane Marie (https://experts.colorado.edu/display/fisid_110517)  
Professor; PhD, Massachusetts Institute of Technology

Molinaa, Keith Robert (https://experts.colorado.edu/display/fisid_102373)  
Professor; PhD, University of Colorado Boulder

Montoya, Lupita D. (https://experts.colorado.edu/display/fisid_148045)  
Assistant Professor; PhD, Stanford University

Morris, Matthew R. (https://experts.colorado.edu/display/fisid_150037)  
Senior Instructor, MS, University of Colorado Boulder

Neupauer, Roseanna M. (https://experts.colorado.edu/display/fisid_134747)  
Professor, Associate Chair; PhD, New Mexico Institute of Mining and Technology

Pak, Ronald Y.S. (https://experts.colorado.edu/display/fisid_105977)  
Professor; PhD, California Institute of Technology

Pfeffer, Tad (https://experts.colorado.edu/display/fisid_100207)  
Professor; PhD, University of Washington

Porter, Keith Alan (https://experts.colorado.edu/display/fisid_145182)  
Research Professor; PhD, Stanford University

Pourahmadian, Fatemeh (https://experts.colorado.edu/display/fisid_158562)  
Assistant Professor; PhD, University of Minnesota

Rajaram, Harihar (https://experts.colorado.edu/display/fisid_103246)  
Professor; PhD, Massachusetts Institute of Technology

Regueiro, Richard A. (https://experts.colorado.edu/display/fisid_134705)  
Associate Professor; PhD, Stanford University

Ren, Jason (https://experts.colorado.edu/display/fisid_153479)  
Professor; PhD, Pennsylvania State University

Rosario-Ortiz, Fernando L. (https://experts.colorado.edu/display/fisid_146165)  
Associate Professor; PhD, University of California, Los Angeles

Ryan, Joseph N. (https://experts.colorado.edu/display/fisid_101037)  
Professor; PhD, Massachusetts Institute of Technology

Salvinelli, Carlo (https://experts.colorado.edu/display/fisid_159846)  
Instructor; PhD, Missouri University of Science and Technology

Saouma, Victor E. (https://experts.colorado.edu/display/fisid_100429)  
Professor; PhD, Cornell University

Scheib, Jennifer G. (https://experts.colorado.edu/display/fisid_159887)  
Instructor; MS, University of Colorado Boulder

Silverstein, JoAnn (https://experts.colorado.edu/display/fisid_101482)  
Professor; PhD, University of California, Davis
Courses

AREN 5001 (3) Building Energy Systems: Thermal, Electrical & Lighting Sys
Prepares graduate students with general knowledge and skills that are required by advanced AREN technical courses. Covers three parts of materials: 1) building thermal systems, 2) building lighting systems, 3) building electrical systems.

Requisites: Restricted to graduate students only.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Building Systems Engineering

AREN 5010 (3) Energy System Modeling and Control
Engineering course devoted to building automation and control systems. Topics include HVAC control technology and strategies, measurement and device technologies, analysis and modeling of dynamic systems, simulation of conventional and advanced control approaches, assessment of control loop performance and hands-on direct digital control (DDC) programming exercises as used in current building control practice.

Equivalent - Duplicate Degree Credit Not Granted: AREN 4010
Recommended: Prerequisite AREN 4140.
Additional Information: Departmental Category: Building Systems Engineering

AREN 5020 (3) Building Energy Audits
Analyzes and measures performance of HVAC systems, envelopes, lighting and hot water systems, and modifications to reduce energy use. Emphasizes existing buildings.

Requisites: Restricted to graduate students only.
Recommended: Prerequisite AREN 3010.
Additional Information: Departmental Category: Building Systems Engineering

AREN 5050 (3) Advanced Solar Design
Predicts performance and analyzes economics of low-temperature, high-temperature, photovoltaic, and other innovative solar systems. Also includes performance prediction methods for solar processes. Taught intermittently.

Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Building Systems Engineering

AREN 5060 (3) Distributed Electricity Generation
Introduces basic distributed generation (DG) technologies including fuel-based systems and renewable energy technologies and overview approaches to conduct energy, economical, and environmental analysis of selected DG technologies using state-of-the-art analysis tools to evaluate optimal hybrid distributed generation systems to meet required electrical loads specific to urban centers, campuses, and residential communities.

Requisites: Restricted to graduate students only.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Building Systems Engineering

AREN 5070 (3) Thermal Analysis of Buildings
Examines response factors, conduction transfer functions and weighting factors for dynamic analysis of building envelopes. Also studies radiative and convective exchange in buildings, internal gains and infiltration analysis as modeled in hourly simulations. Taught intermittently.

Additional Information: Departmental Category: Building Systems Engineering
AREN 5080 (3) Computer Simulation of Building Energy Systems
Introduces major simulation programs for analysis of building energy loads and system performance. Focuses on one hourly simulation program to develop capability for analysis of multizone structure.
**Requisites:** Requires prerequisite course of AREN 4110 or AREN 5110 (minimum grade C). Restricted to graduate students only.
**Additional Information:** Departmental Category: Building Systems Engineering

AREN 5110 (3-4) HVAC System Design
Applies engineering principles to the design of heating, ventilating and air conditioning (HVAC) systems for buildings. Covers HVAC systems description, load estimation, psychometrics, coils and heat exchangers, air and water distribution systems and primary equipment and systems.
**Equivalent - Duplicate Degree Credit Not Granted:** AREN 4110
**Recommended:** Prerequisite AREN 3010.
**Additional Information:** Departmental Category: Building Systems Engineering

AREN 5130 (3) Optical Design for Illumination and Solid State Lighting
Covers the optical design process for illumination-based optics, emphasis on applications in architectural lighting. In-depth coverage of luminaire photometry, lamps, materials, manufacturing methods, product performance requirements. Projects utilize optical design software and include a variety of lamp types including LEDs using both reflector/lens optics.
**Equivalent - Duplicate Degree Credit Not Granted:** AREN 4130
**Recommended:** Prerequisite AREN 3540.
**Additional Information:** Departmental Category: Building Systems Engineering

AREN 5540 (3) Exterior Lighting Systems
Engages students in exploring and solving lighting problems for exterior environments. Provides an understanding of the design criteria and lighting equipment used in three primary exterior applications: parking lots and roadways, floodlighting of buildings, and sports facilities. Taught intermittently.
**Equivalent - Duplicate Degree Credit Not Granted:** AREN 4540
**Recommended:** Prerequisites AREN 3540 and AREN 4550.
**Additional Information:** Departmental Category: Building Systems Engineering

AREN 5650 (3) Forensic Engineering
Identify and explore the physical, chemical, mechanical, and biological deterioration mechanisms in the most common construction materials; concrete, masonry, metals, wood, polymers, and fiber-reinforced composites. Course topics include an introduction to failure analysis; materials science; ion diffusion; electrochemistry (corrosion); fracture, fatigue, and creep; and diagnostic, retrofit, and rehabilitation strategies for extended service life.
**Requisites:** Restricted to graduate students only.

AREN 5890 (3) Sustainable Building Design
Introduces green building design procedure/approach and provides insight into evolving design principles; explores aspects of building thermal/energy performance, indoor/outdoor environmental quality, occupant comfort and climate relevant to building design (structures not covered); emphasizes both comprehensive understanding and practical applications of sustainable building design strategies; applies prevailing simulation tools to assist green building design.
**Equivalent - Duplicate Degree Credit Not Granted:** AREN 4890
**Requisites:** Restricted to graduate students only.
**Recommended:** Prerequisite AREN 3010.
**Additional Information:** Departmental Category: Building Systems Engineering

AREN 5990 (3) Compu Fluid Dynamics (CFD) Analysis for Built/Natural Envmnts
Explores the fundamentals of simulating/analyzing civil and architectural environments with Computational Fluid Dynamics (CFD) method. Run with two parallel sessions: fundamentals and applications, with fundamental lectures presenting the principles of CFD technologies, and application sessions demonstrating the application of CFD for resolving building and environmental engineering problems (different than MCEN/ASEN) with hands-on exercises.
**Equivalent - Duplicate Degree Credit Not Granted:** AREN 4990
**Requisites:** Restricted to graduate students only.
**Recommended:** Prerequisites AREN 2120 and APPM 2360.
**Additional Information:** Departmental Category: Building Systems Engineering

AREN 6940 (1) Master's Candidate for Degree
**Grading Basis:** Pass/Fail
**Additional Information:** Departmental Category: Building Systems Engineering

AREN 6950 (1-6) Master's Thesis
**Repeatable:** Repeatable for up to 3.00 total credit hours.
**Additional Information:** Departmental Category: Building Systems Engineering

AREN 6960 (1-3) Master's Report
**Repeatable:** Repeatable for up to 3.00 total credit hours.
**Repeatable:** Repeatable for up to 3.00 total credit hours.

AREN 8990 (1-10) Doctoral Thesis
A minimum of 30 credit hours is required.
**Additional Information:** Departmental Category: Building Systems Engineering