Modeling for Energy Systems
ENVIRON 716 (ENERGY 716)
Duke University—Nicholas School of the Environment
Fall 2014

Lecture: Tuesday and Thursday, 8:30 to 9:45 in Gross Hall 107
Lab (Help) Sessions: Friday, 8:30 to 9:45 or 10:05 to 11:20 in LSRC A153 (you must attend the section for which you are registered)

Instructor:
Tim Johnson, Associate Professor of the Practice in Energy and the Environment, and Energy and Environment MEM Program Chair
tjohns@duke.edu | 919-681-9339 | Environment Hall 3113
Office hours Monday 1:30 to 3:00 and Wednesday 9:30 to 11:00, or by appointment

Teaching Assistants and Grader:
Rubenka Bandyopadhyay and Eric Williams will serve as TAs, and Xin Li will be the primary grader for the course. The TAs should be your first point of contact with questions about the assignments and course material.

Rubenka Bandyopadhyay  |  rb171@duke.edu
Office hours: Tuesday and Thursday 10:30 to 11:30 in Environment Hall 3100

Eric Williams  |  e.l.williams@duke.edu
Office hours: Monday and Wednesday 8:30 - 9:30 in LSRC A141

Course Description and Objectives
This course provides an introduction to modeling for energy system analysis. While the class begins with an overview of static spreadsheet modeling, the core of the course focuses on the application of optimization and simulation methods to understand, design, and predict the behavior of energy systems. Optimization and simulation lie at the heart of Operations Research (OR), a field that evolved out of the need to improve public and private decision making as it relates to complex socio-technical systems. In particular, the suite of OR tools provides valuable analytical support to decision processes involving significant sources of uncertainty and conflicting objectives. Transmission network design, vehicle routing, investment planning, facility siting, plant dispatch, financial risk assessment, and environmental resource management are all energy-related problems that have benefitted from the availability of OR analytical frameworks and, in turn, have provided impetus for the further development of these methods. Optimization, simulation, and other OR methods are therefore an important part of the analytical toolkit for anyone interested in the transition to a more sustainable energy system at a time when changes in technological, economic, and policy drivers are uncertain and the pressure to meet growing energy demands must be balanced with the need to mitigate the negative environmental impacts of its supply and use.
By the end of the course, you will be able to:

- Explore and analyze large datasets using advanced Excel features (including user defined functions and simple Visual Basic programming)
- Set up and solve (using Excel) basic energy-related optimization problems, as well as more advanced network and mixed-integer problem formulations
- Apply probability theory to generate random variables and characterize the distribution of empirical data, and use both in Monte Carlo studies to support decision making under uncertainty
- Demonstrate good modeling practice, including the need to assess sensitivity to assumptions and design models that are as transparent and accessible as possible to others

Prerequisites
Prerequisites include college-level calculus (including partial derivatives of functions of several variables), probability theory, and basic linear algebra (i.e. how to write and solve systems of linear equations in matrix form). You should also be familiar with capital-sigma (\( \sum \)) notation for compactly representing summation of similar terms. Finally, you should know at least the basics of Excel.

Coursework and Grading
Your grade will be based on the following:
Assignments: 90% (9 assignments at 10% each)
Class Participation: 10% (including attendance at both lecture and lab sessions)

The assignments will give you practice applying the concepts and tools covered in class. I encourage you to work in study groups and help each other learn. However, the work you submit must be your own. An example of appropriate collaboration would be for Student A to explain the procedure used in a problem to Student B, who then goes off by himself or herself to complete the problem and write up his or her own explanation. It would be inappropriate for the students to complete the assignment together, and even less appropriate for Student B to simply copy the math or the explanation/interpretation from Student A. Note that study groups are most effective when each member attempts to do the problem sets BEFORE meeting as a group. Only if you really try to solve the problem on your own will you realize whether you understand the problem and its solution. It is very easy to hear someone’s explanation and think you understand the problem, but you will often not. This will also help insure that you are using study groups in ways that are consistent with the Nicholas School Honor Code.

The assignment topics and due dates (which are subject to change) are as follows:

**Assignment 1**
Excel modeling and dealing with large data sets in excel  
Due 9/12

**Assignment 2**
Simple macros and functions  
Due 9/19

**Assignment 3**
More on VBA and an intro to LP  
Due 9/26
Assignment 4  
Formulation of mathematical programs, graphical and Excel solution to LP programs  
Due 10/03

Assignment 5  
Formulation of multi-period problems; formulation and solution of transportation problems  
Due 10/17

Assignment 6  
Networks, logical constraints, unit commitment problem  
Due 10/31

Assignment 7  
Review of probability theory  
Due 11/07

Assignment 8  
Probability analysis  
Due 11/21

Assignment 9  
Monte Carlo simulation  
Due 12/02

Class participation will be based on attendance (including Friday help sessions), contribution to all class discussions, and evidence of having prepared for class.

Grading disputes: There will be a separate grade dispute folder for each assignment under the "Assignments" tab in Sakai. If you have questions about grading, please upload a written document in the relevant sub-folder containing the following information:

1. The type of problem you found, for example:
   a) a factual error (like adding up the numbers wrong or referencing something that is not there)
   b) an inconsistency error (standards were inconsistently applied between papers)
   c) an interpretation dispute (you think you should have gotten more points)
2. A short description of the issue, including why you feel you should get more points
3. References that explain where to find the supporting material (e.g. "I put the graded document in your mailbox," or "My Excel model is in the Sakai dropbox and it is named *.xls")

The grade dispute document needs to be uploaded no later than 7 days after the graded assignments are returned. However, discrepancies occurring when there is an error in adding up points for an assignment, or when the wrong grade has been uploaded (i.e. points appearing in your “Gradebook” on Sakai are different from points you actually received) have no expiration date; let us know anytime (by e-mail or in person during TA office hours) if you see such errors.

Late assignments: All assignments must be uploaded to Sakai by 6:00pm on the posted due date. Assignments handed in after 6:00pm but before 11:00pm on the posted due date will lose 25 points. Assignments submitted after 11:00pm on the posted due date will receive a grade of zero. Please do not ask for exceptions.
If you know of conflicts with the course schedule that will affect a majority of the students, please let me know as soon as possible. I will make exceptions only for serious illnesses and personal emergencies. If you are sick, you will need to complete the Short-Term Illness Notification Form (STINF) at: [http://trinity.duke.edu/academic-requirements?p=policy-short-term-illness-notification](http://trinity.duke.edu/academic-requirements?p=policy-short-term-illness-notification). The website provides instructions, but note the following text:

“Definition of Incapacitation:
An incapacitating illness or injury is one in which a student is hospitalized, under medical care for a short-term condition, or otherwise sufficiently debilitated as to be unable to perform basic academic tasks. Colds, headaches, or other such mild complaints that result in your feeling less than 100% are not considered incapacitating, and you should not use the STINF in such instances.

Appropriate uses of the STINF might include such conditions as influenza, migraine, sinus infection, and strep throat.”

In the event of something even more serious, of course, I will make every effort to accommodate your situation.

Readings
All course readings are available on Sakai or via web links to public documents and information resources. We will not be using a separate textbook, though I highly recommend purchasing a copy of the “Excel Bible” by John Walkenbach that corresponds to your version of Excel (e.g., the “Excel 2010 Bible” or the “Excel 2013 Bible,” both of which are available new for around $30). Duke’s Library has a digital copy that you may read online, but limits the number of concurrent viewers. The book will continue to serve you well after this class. The schedule below lists required reading assignments, which must be completed prior to each day’s class (see the note above under Coursework and Grading). Optional readings are occasionally provided for those that want additional information. I may also assign additional readings based on your interest in particular topics.

Sakai
If you are registered for the class, you should have complete access to our Sakai website. All course materials, including assignments and readings, are available on Sakai. Students are also encouraged to use Sakai’s discussion boards to continue the discussion of course issues beyond the classroom.

Computing
I will often post Excel files with examples of quantitative analysis and macros. I use a Windows PC with MS Office 2010 and it is your responsibility to resolve any compatibility issues in order to keep up with the course material.

My Expectations of You
This is your course. At minimum, I expect you to attend and be an active participant, which, in turn, requires that you arrive prepared, having completed the readings and other assignments before class.
Please be on time and refrain from checking email and websurfing while we are together. I also expect you to have an open mind, but to think critically and use what we learn in making your own judgments.

In addition, if you have suggestions on how to improve the course, please let me know. Feedback received midstream can be more useful (to you and me) than end-of-term evaluations, and I am happy to make reasonable changes if a majority concurs.

**What You Can Expect From Me**
I’m here to help you learn. I understand and appreciate the diversity in your backgrounds, interests, and analytical strengths, and have tried to design the course to accommodate these differences while providing opportunities to help you develop in new areas. Again, feedback is appreciated. I’m available during office hours (see first page) if you have questions about the class (or anything related), and am happy to find mutually-agreeable times outside of these windows to meet. Just let me know what works best for you.

**Teaching Assistant Responsibilities**
The teaching assistants are here to help, and should be the first place you look for assistance. Particular TA responsibilities include:
- Holding regular office hours
- Facilitating the Friday help sessions
- Answering questions posted on the discussion forum (Sakai)
- Recording grades
- Responding to grading disputes
- Helping design assignments
- Posting the assignment answer keys

**Nicholas School Honor Code and the Duke Community Standard**
All activities of Nicholas School students, including those in this course, are governed by the Duke Community Standard ([http://integrity.duke.edu/standard.html](http://integrity.duke.edu/standard.html)), which states:
“Duke University is a community dedicated to scholarship, leadership, and service and to the principles of honesty, fairness, respect, and accountability. Citizens of this community commit to reflect upon and uphold these principles in all academic and nonacademic endeavors, and to protect and promote a culture of integrity. To uphold the Duke Community Standard:
- I will not lie, cheat, or steal in my academic endeavors;
- I will conduct myself honorably in all my endeavors; and
- I will act if the Standard is compromised.”

Please add the following affirmation to the end of each assignment and sign your name beside it: “I have adhered to the Duke Community Standard in completing this assignment.”
### Topic and Reading Schedule

The schedule below is subject to change, and I may modify it as we go along if extra time is needed (or desired!) for particular topics. I’ll provide updates to the schedule in class and via email, and will let you know through regular announcements which readings correspond to which class days.

<table>
<thead>
<tr>
<th>Date</th>
<th>Schedule</th>
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<tbody>
<tr>
<td>August 26</td>
<td><strong>Class overview; Introduction to modeling</strong></td>
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<tr>
<td>August 28</td>
<td><strong>Spreadsheet modeling; Analysis of large data sets with Excel</strong></td>
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<td>September 2</td>
<td><strong>Macros and Visual Basic (VBA) programming in Excel</strong></td>
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<td>September 4</td>
<td><strong>Introduction to mathematical programming; Linear Programing (LP) problem formulation and solution; Use of Excel’s Solver; LP Sensitivity analysis; Blending problems</strong></td>
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#### Readings

- eGRID FAQ: [http://epa.gov/cleanenergy/energy-resources/egrid/faq.html](http://epa.gov/cleanenergy/energy-resources/egrid/faq.html)
- Excel 2010 Bible: Chapters 1 through 4, review if needed
- Excel 2010 Bible: Chapters 14, 34, and 35
- How to Use the Forms Controls on a Worksheet in Excel: [http://support.microsoft.com/kb/291073](http://support.microsoft.com/kb/291073)
- Excel 2010 Bible: Chapters 39 and 40
- Excel and VBA class notes.docx
- Programming 101.docx
- Optional Excel 2010 Bible: Chapter 44
- Optional VBA Excel macros for beginners.docx
- Optional Visual Basic in 12 easy lessons. Available at [http://members.tripod.com/acha_ean/vb_12_lesson/velfm.htm](http://members.tripod.com/acha_ean/vb_12_lesson/velfm.htm)
- Excel 2010 Bible: Chapter 37
- Optimization Technology for Energy and Power
- Some Basics of Matrix and Vector Algebra, review if needed
- Some Practical Issues with Excel Solver: Lessons for Students and Instructors
- Using the Graphical Method to Solve Linear Programs
- Optional Energy Modeling for Policy Studies
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<tr>
<th>Date</th>
<th>Topic</th>
<th>Readings</th>
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<tr>
<td>October 9</td>
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<td>October 14</td>
<td>Fall Break (no class)</td>
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<td>October 16</td>
<td>Network flow problems (continued): trans-shipment, shortest path, and maximum flow models; Networks as an abstract representation of the planning process; Mixed Integer LP (MILP) models; Large-scale optimization models</td>
<td>• Using the Simplex Method to Solve Linear Programming Maximization Problems&lt;br&gt;• Fossil Electricity and CO₂ Sequestration&lt;br&gt;• Additional readings from the applied literature may be assigned</td>
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<td>October 21</td>
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<td>November 20</td>
<td>Markov Chain Monte Carlo simulation; Simulating wind power</td>
<td><strong>Reading</strong>&lt;br&gt;• First And Second Order Markov Chain Models for Synthetic Generation of Wind Speed Time Series&lt;br&gt;• MCMC for Wind Power Simulation</td>
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<td>Thursday</td>
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<td>November 25</td>
<td>Optimization under uncertainty: Stochastic Programming; Course wrap-up</td>
<td><strong>Reading</strong>&lt;br&gt;• An Introductory Tutorial on Stochastic Linear Programming Models</td>
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<td>Tuesday</td>
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<td>November 27</td>
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