Syllabus as of 9/11/2017. Please see Sakai for updates.

Energy Systems Modeling Fall 2017 ENV 716L.001

Nicholas School of the Environment Duke University

Time **Location**
TuTh 8:30 – 9:45 Environmental Hall 1112

Lab sessions
F 10:05-11:20
F 11:45-13:00 Environment Hall 1104

Instructor (lectures)
Dalia Patiño-Echeverri
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Phone: 919-613-7461
Office hours: Tuesdays 9:45-10am (outside of classroom) - Thursdays 9:45-11:00 (EH 3118) – Fridays 13:00-14:30 (EH 3118)

Lab sessions instructor
Tim Johnson
Timothy.l.johnson@duke.edu
Phone: 919-681-9339
Office hours: Mondays and Wednesdays from 13:30-15:00 – EH 3113

Teaching Assistants and graders
Bella Tan
Kaifeng Xu
Jun Zhang

Responsibilities of Teaching Assistants and Graders
-Grading the assignments in a timely manner
-Answering the claims about grading
*Please communicate with the graders and TAs, exclusively through Sakai, by submitting your assignments and grade disputes there. For general questions please use the Sakai forum.

Course Description
This course is an introduction to the use of computer models and the methods of optimization and simulation for students interested in the analysis of energy systems. The course makes emphasis in the formulation of optimization problems and simulation models, and in the identification of the available methods to solve them.
Our goal is to enable students to formulate, implement, and use their own quantitative model to puzzle out problems related to private and public decision making in the context of the U.S. energy system and the environment. The applications and case studies presented, deal with problems of energy systems, their externalities, and the government policies that affect them.

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

Readings
Readings as indicated in class schedule below, many available on the internet or via Duke library, and others available via Sakai. Required readings begin with RR. Optional readings begin with OR.
You may want to purchase a copy of the "Excel Bible" by John Walkenbach that corresponds to the version of Excel you will be using (i.e., Excel 2013 or Excel 2016). A number of optional readings recommended below come from this book and are not posted on Sakai. You may read online Duke's library digital copy, but there is a limit on the allowed number of concurrent viewers.

Sakai and PC compatibility
Readings, class announcements, schedule changes, grades, power point slides and working files (excel) will all be posted to the course Sakai site. Students are also encouraged to use Sakai's discussion boards to continue the discussion of course issues beyond the classroom. Anyone having trouble working with the Sakai site should seek help from their fellow students, or contact Information Technology (http://sakai.duke.edu/home.do). For this class students will be required to use software that can only be installed on a windows platform. Mac users may work in the computer clusters or make other arrangements.
Excel files with examples of quantitative analysis and macros will occasionally be posted on Sakai. These are all developed on a windows PC with MS Office 2016 (with solver add-in) and it is the students responsibility to solve all the compatibility issues that may arise.

Course Assignments
Written assignments should be presented using Times Roman 12 pt font, single-spaced text, 1" margins. Most assignments are to be submitted via Sakai. When an assignment asks for a hardcopy, students should print on both sides and **not** use a cover sheet. Problem sets can be hand-written and then scanned only if the text and math are written clearly and neatly. Points will be deducted for confusing or disorganized submissions.

There will be 9 assignments (Assignment 8 has two parts). The assignments ask to apply concepts and tools learned in class. Students are encouraged to work in study groups of up to three people on these problem sets and help each other learn. However, each student must submit his or her own copy of the assignment and it is a violation of the Nicholas School Honor Code to directly copy another student's work. An example of appropriate problem set collaboration would be for Student A to explain the procedure used in the problem to Student B. Then Student B goes off by himself and completes the problem again and writes up his own explanation. It would be inappropriate for Student B to directly copy the math or the explanation/interpretation from Student A. Study groups are most effective when everyone attempts to do the problem sets

BEFORE meeting as a group. Only those who really try to solve the problem on their own will realize whether they understand the methods and their application.

Assignment #1 ***Posted on Sakai 8/31; Due 9/9***
Spreadsheet modeling

Assignment #2 ***Posted on Sakai 9/7; Due 9/16***
Analyzing large data sets in excel.

Assignment #3 ***Posted on Sakai 9/14; Due 9/23***
Simple macros and functions.

Assignment #4 ***Posted on Sakai 9/21; Due 9/30***
Formulation of mathematical programs, graphical and excel solution to lp programs

Assignment #5 ***Posted on Sakai 9/28; Due 10/7***
Formulation and solution of linear programs.

Assignment #6 ***Posted on Sakai 10/5; Due 10/16***
Multi-period problems. Networks. Logical constraints. Unit commitment problem

Assignment #7 ***Posted on Sakai 10/12; Due 10/21***
More on Networks

Assignment #8a ***Posted on Sakai 10/19; Due 10/28***
Review of probability theory

Assignment #8b ***Posted on Sakai 11/2; Due 11/11***
Probability analysis

Assignment #9 ***Posted on Sakai 11/16; Due 12/2***
MonteCarlo Simulation

Grading
Each assignment will be evaluated using a numbered grade (0-100) and your overall numbered grade will be determined using the following weights:

Assignments (9):	90% (10% each)
*Quizzes:	10%
Total:	100%

Letter grades of A+, A, A-, B+, B, B-, C+, C, C-, or F will be assigned according to numbered grades in the following way:

Above 100:	A+

(95-100]	A
(90-95]	A-
(85-90]	B+
(80-85]	B
(75-80]	B-
(70-75]	C+
(65-70]	C
(60-65]	C-
60 or below	F

***Quizzes*.** The first 5-20 minutes of the lab session will be devoted to complete a quiz on the material covered in previous classes and assignments. Tim will solve the quiz immediately after students finish but there will **not** be graded feedback on the quizzes. At the end of the semester, the quizzes grade may be raised for those students who attended all labs and lectures and participated actively and constructively for their own benefit and the benefit of others. Students must remain in silence and looking only at their quiz until all students have finished and Tim starts to discuss the solution. We will not have makeup quizzes for **any reason (please do not ask)** but we will not have into account your two worst quizzes**.**

Sakai Forum. Questions related to the assignments are to be posted in Sakai using the forum tool. In this way all students will benefit from the answers and help others get when asking questions.

Policy on late assignments. All assignments are due by 11:55PM on the posted due date. **Assignments submitted after the due date will lose 0.5 points per minute.** Please do not ask for exceptions. If you are ill or have a family emergency that prevents you from being able to complete the assignment on time, please submit the web-based short-term illness form *prior* to the due date. The short-term illness form can be found at: http://trinity.duke.edu/undergraduate/academic-policies/illness.
You are governed by the Nicholas School Honor Code in completing this form (see below). An assignment that is not submitted because of illness or family emergency will be excluded from your grade calculation (so the 80% of assignments will be based on 7 instead of 8 assignments). If your illness or family situation prevents you from completing more than one assignment please communicate this in a timely fashion. We may recommend that you drop or withdraw the class, or may require a test at the end to make up for the missed assignments.
An answer key for all assignments will be posted no later than 72 hours after the due date. Please take the time to review the answer key and identify any mistakes you may have in your assignment and any remaining questions you may have about the material.

Bonus points. Occasionally there will be opportunities for getting bonus points by attending and writing short commentaries on seminars, lectures and extracurricular activities. Some of you might be unable to participate and that is ok. Because this class uses an absolute grading system (e.g. your grade is unaffected by the performance of your classmates) you should not feel it is unfair that others can get bonus points and you can't.

Grade disputes. Students will be informed of the grade received in each assignment no later than 12 days after the assignment has been submitted. Students who consider there has been a mistake in the grading process should upload to Sakai a written document, no later than 7 days after the grades have been released. Please do not talk to or send emails to the TAs, regarding your grades. There will be a separate grade dispute folder for each assignment under the "Assignments" tab in Sakai.
The grade dispute document should contain the following information
1. The type of problem you found
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 students)
c) an interpretation dispute (you think you should have gotten more points)
2. A short description of the issue.
2a.Possibly including why 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 digital Dropbox and it is named *.xls"...).

The interpretation disputes may require faculty input and may only be resolved at the end of the semester. Others disputes will be resolved no more than 3 weeks after being submitted.

Although the grade dispute document needs to be uploaded no later than 7 days after the graded assignments are returned, 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/in person during office hours) if you see such errors.

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, 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 all assignments and sign your name beside it: *"I have adhered to the Duke Community Standard in completing this assignment."*

Class etiquette
1. Please make sure you do everything you can to make our classroom culture a comfortable learning environment for everyone. We will likely have people from many different backgrounds in this class and you should all feel comfortable and make each other comfortable while

participating.
2. Please take responsibility for making the class successful. What you learn in the class will be largely dependent on your attitude and work. Ask yourself what you can do during each class to move the course forward in a positive way.
3. If you must enter the class late, please do so quietly. If for any reason the door is locked please knock. It is preferred to have a short disruption than a student missing an entire class.
4. Please try your best to focus in class and **keep laptops and cellphones outside of the classroom**. Take notes on a notebook, not on your laptop.

Green Classroom Certification

"This course has achieved Duke's Green Classroom Certification. The certification indicates that the faculty member teaching this course has taken significant steps to green the delivery of this course. Your faculty member has completed a checklist indicating their common practices in areas of this course that have an environmental impact, such as paper and energy consumption. Some common practices implemented by faculty to reduce the environmental impact of their course include allowing electronic submission of assignments, providing online readings and turning off lights and electronics in the classroom when they are not in use. The eco-friendly aspects of course delivery may vary by faculty, by course and throughout the semester. For more information on the Green Classroom Certification, visit: sustainability.duke.edu/action/classroom."

Class Topic and Readings Schedule

Please try to complete the required readings (RR) before the class on which they are listed. Other readings (OR) offer supplementary material and/or an alternative presentation of similar information.

1. Tuesday August 29 - Class Overview and introductions

- OR1-Excel 2016 Bible: Chapters 1 through 4, review if needed

2. Thursday August 31 - Spreadsheet modeling: A simple cost model

Good modeling practices. Form Controls.

- RR2-EIA Levelized Cost of Electricity and Levelized Avoided Cost of Electricity Methodology Supplement.
- RR2- Rubin Ch 13 FinancialEng.pdf (Chapter on Economics and the Environment)
- OR2-Excel 2016 Bible: Chapter 10

Friday September 1 – Review of basic energy terms and units

3-4. Tuesday September 5 - Spreadsheet modeling: Analysis of large data sets with Excel. eGrid database.

If, count, countif, sum, sumif, indirect, tables, Pivot tables, Lookup, vlookup, data analysis (descriptive statistics, correlation, histograms)

- RR3- egrid_faq.pdf (eGRID FAQ: https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid-questions-and-answers)
- OR3-Excel 2016 Bible: Chapters 13, 14, 17, 33, 34

Friday September 8 -

- OR4- -Excel 2016 Bible: Chapter 42

5. Tuesday September 12 - VBA Macros in Excel I

VBA Excel Macros for Beginners.

- RR5- Excel and VBA class notes.docx (Notes on Excel and Visual Basic)

6. Thursday September 14: VBA Macros in Excel II

- OR6- Excel 2016 Bible: Chapters 39-40

Friday September 15: No lab with Tim or office hours with Dalia due to NSOE retreat. There will not be a quiz. Optional help session with the TAs during lab hours

7. Tuesday September 19 – Continuation of Macros (Dalia out of town – Tim give the lecture)

- If Then statements, Loops, Functions and Sub routines
- OR7- Excel 2016 Bible: Chapter 44

8. Thursday September 21 - Introduction to mathematical programming

Feasible region, feasible solution, objective function, decision variables, binding and non-binding constraints. Linear and non-linear programming. Assumptions of lp. Graphical method for lp problems with two decision variables

- RR8-Energy modeling for policy studies.pdf (Hogan, W.W. (2002). Energy Modeling for Policy Studies. Operations Research, (50) 1, 2002, pp.89-95.)
- OR8-Using graphical methods-LP.pdf (Reeb,J. and Leavengood (1998). Using graphical methods to solve linear programs.)

9. Thursday September 21 –Introduction to linear programming. Lp solutions using excel solver. Lp post-optimality and sensitivity analysis both graphically and in excel.

- RR9- Optimization_Technology_for_Energy_and_Power.pdf. (Bloom, J. 2008). Optimization Technology for Energy and Power. Power Point Slides, ILOG 2008.

Friday September 22: LP in Excel

- Formulating linear equations in Excel
- Excel's Built-in Solver
- RR9-AvoidingSolverMistakes.pdf (Evans, J, 2008) Teaching Note—Some Practical Issues with Excel Solver: Lessons for Students and Instructors. James R. Evans, (2008) INFORMS - Transactions on Education 8(2):89-95. http://dx.doi.org/10.1287/ited.1070.0006

10. Tuesday September 26 –More on Lp post-optimality

- RR10-Vector and Matrix Algebra.pdf. pp1-10.(Excerpts from the books of Johnson &Wichern (Applied Multivariate Statistical Analysis)

11. Thursday September 28 - Formulation of lp programs.

Formulating LP problems in canonical and standard form. Lp formulation using sigma-capital notation and in matrix form. Assumptions of lp. Example: Gasoline blending problem.

- RR11-Bazaraa Ch-1.pdf. (Bazaraa M.S.; Jarvis, J.J.; Sherali, H.D. (1990) Linear Programming and Network Flows. Second Edition. New York: John Wiley & sons. Chapter 1: Introduction. pp1-24.)

Friday September 29: Basic Matrix Operations with Excel and Matlab

- Addition, Subtraction, Multiplication, Transposition, and Inversion
- Solving Systems of linear equations
- OR11-using simplex methods LP.pdf (Reeb,J. and Leavengood (1998). Using the Simplex Method to Solve Linear Programming Maximization Problems.)

12. Tuesday October 3 - Multi-Period lp programs. Handling inventories

13. Thursday October 5 - Network flow models problems. Transportation networks.

- RR13-NetworkFlowModels_JensenBarnes.pdf (Jensen, P.A. & Barnes, J.W. (1980). Network Flow Programming. New York: John Wiley and Sons, Inc. Chapter 1: Network Flow Models. pp.1-50)

Friday October 6: No lab – Tim will offer help to those interested during regular lab hours. Fall break begins at 7pm

Tuesday October 10: Fall Break

13. Thursday October 12- Networks: Trans-shipment

Expressing formulation in terms of vectors and matrices.

Friday October 13: Quick review of elementary matrix algebra and quiz on elementary vectors and matrices algebra. (Adding, subtracting and multiplying vectors and matrices)

14. Tuesday October 17- Networks: Shortest path

15. Thursday October 19 - Networks: Maximum flow - Networks as an abstract representation of planning problems: Planning trucks replacement

- OR15- Applications of Network Problems.pdf. M.O. Ball et al., Eds., Handbooks in OR & MS, Vol. 7, Chapter 1 – *Applications of Network Optimization*. Ahuja, R.K. et al. 1995.

Friday October 20 – Review of Probability theory

- RR15- Basic concepts of probability theory.pdf Ross, S.M. (1998). A first course in probability. New Jersey: Prentice Hall. Chapter 4: Random variables. Sections 4.1-4.6. pp.126-144.
- RR15-Ross, S.M. (2002) Simulation. San Diego: Academic Press.
  Chapter 2: Elements of probability. pp.5-36. (At least try to skim. Can skip section 2.7)

16. Tuesday October 24 - MILP - Ontario Hydro optimal investment and operating strategy I

- RR16-power planning ontario.pdf (Muller, R.A.&Geroge, P.J.(1985). *Northern Hydroelectric Development in and Optima Expansion Program for Ontario Canada.* Canadian Public Policy-Analyse de Politiques, XI:3, pp.522-532)

17. Thursday October 26 - MILP - Ontario Hydro optimal investment and operating strategy II

Another example of an optimal investment problem:

- OR17-Plugging ships in ports.pdf (Vaishnav, P et al. (2015). Shore Power for Vessels Calling at U.S. Ports: Benefits and Costs. Vaishnav, P, et al. Environmental Science and Technology 2015)

Friday October 27 – Review of Probability Theory II

18. Tuesday October 31 - Probability Analysis and Introduction to MonteCarlo simulation

- OR18- Morgan and Henrion Chapters.pdf (Chapter 5 and an excerpt from Chapter 8 of Morgan and Henrion's book Uncertainty. Chapter 5 reviews the material covered in RR15)

19. Thursday November 2 - MC: Fitting and generating random variables in Excel I

20. Friday November 3 - generating correlated random variables in Excel II

21. Thursday November 9 – Simulating wind power
Markov Chain Monte Carlo Simulation

22. Tuesday November 13: Simulating wind power II
Markov Chain Monte Carlo Simulation

- OR22- MCMC for wind power simulation.pdf (Papaefthymiou et. al (2008). MCMC for Wind Power Simulation)

23. Thursday November 17: Simulating wind power III
More on Markov Chain Montecarlo

Friday November 18: Quiz on all material covered until November 8

23. Tuesday November 21 - Fitting and generating random variables using @risk

Thursday November 23: Thanksgiving Break

24. Tuesday November 28 - Intro to optimization under uncertainty

- OR24-Reading meters for SOCAL (Wunderlinch, J.; Collette, M.; Levy, L.; Bodin, L. (1999) Scheduling Meter Readers for Southern California Gas Company. Interfaces pp.22-30.)
- OR24-Implications of generator siting for CO_2 pipeline infrastructure.pdf (Newcomer, A. & Apt, J. (2008). Implications of generator siting for CO_2 pipeline infrastructure. Energy Policy 36, 1776–1787.)

25. Thursday November 30 - Optimization under uncertainty II - stochastic programming

- OR25-Energy Planning Multistage stochastic optim.pdf (Li et. al (2010). Regional-scale electric power system planning under uncertainty - A multistage interval-stochastic integer linear programming approach. Energy Policy 38, 475–490)
- OR25-The people's Gas Light and Coke Company Gas Supply.pdf (Knowles, T.W. & Wirick, J.P. (1998) The Peoples Gas Light and Coke Company Gas Supply. Interfaces 28:5, pp.1-12.)
- OR25-China's coal and electricity delivery system.pdf (Kuby et. al (1995), Planning China's Coal and Electricity Delivery System. Interfaces. pp. 41-68)

Friday December 1 – Help session as needed at regular lab times

26. December 6 - There may be regular class with Dalia if we have not finished covering all the course material. Class will be at regular class hours and in the same room

We do not cover dynamic systems thinking and modeling in this course but you may want to explore this topic and the software Stella. Here are a few interesting readings:
*Ford, Andrew. *Modeling the Environment (Review Draft).* Island Press. 2009. Chapter 1 Introduction.
*Ford, A. *Modeling the Environment (Review Draft).* Island Press. 2009. Chapter 2. Software: Getting Started with Stella and Vensim
Optional readings: -Ford, Andrew. *Modeling the Environment (Review Draft).* Island Press. 2009. Appendix A and Appendix C. -Ruth, M. & Hannon, B. Modeling Dynamic Economic Systems.
*Ford, A. *Modeling the Environment (Review Draft).* Island Press. 2009. Chapter 16. Case #5 Managing a Feebate Program for Cleaner Vehicles.
Optional reading: Ford, Andrew. Simulating patterns of power plant construction with the CEC model. Summary report to the California Energy Commission. November 14 2000.