General Course Information:

ELEN E6906, Topics Course, FUTURE ENERGY: ECONOMICS, SYSTEMS, POLICIES

Instructor Information

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Course Prerequisite, Description
Students must have either taken ELEN 6767, "Internet Economics, Engineering and the Implications for Society", or have sufficient knowledge of the course content, to be verified by instructor. In particular, incoming students will have knowledge of the following economic concepts: social welfare maximization; elasticity; competitive, oligopoly, monopoly markets; subadditivity in cost functions with large fixed cost; first and second best pricing; average cost pricing; Cournot & Bertrand pricing; Ramsey pricing; Price of Anarchy; Pigovian taxes; Coasian bargaining; externalities.

It is assumed that students will be able to read and understand on their own the first four chapters of D.S. Kirschen and G.Strabac's "Fundamentals of Power System Economics", 2nd edition ("Introduction", "Basic Concepts from Economics", "Markets for Electrical Energy", "Participation in Markets for Electrical Energy"). The course will largely bypass electricity markets and related optimizations, which are covered well in texts and other courses.

The course will consist primarily of reading, discussing and researching contents of the papers listed below. Students will take turns at presenting papers, and leading class discussions.

Course requirements: Active participation; homework; two papers; project with oral presentation.

Grading policy:
35% active participation
15% homework
15% mid-term paper
15% project and oral presentation
20% final exam paper

Themes & Reading:

1. **Fundamentals of Energy Production and Use, True Cost of Energy**

   (i) Fundamentals of Renewable Energy
   Basic characteristics of biomass, hydropower, wind, solar, geothermal energy sources; their intermittency and environmental externalities; policies for the renewable energy

transition.

D. Timmons, J.M. Harris, B. Roach, “The Economics of Renewable Energy”, Global Development and Environment Institute, Tufts University

(ii) Social Cost

C. Olson, F. Lenzmann, “Bringing the Social Costs and Benefits of Electric Energy from Photovoltaics Versus Fossil Fuels to Light”, MRS Energy and Sustainability: A Review Journal”, Materials Research Society, pp 1-29, 2016

(iii) Hidden Costs and Externalities of Energy Production

National Research Council, “Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use”, Chapter 1-Introduction, The National Academies Press, Washington DC, 2010

(iv) Economics of Renewable Energy

National Research Council, “Electricity for Renewable Resources: Status, Prospect and Impediments”, Chapter 4 – “Economics of Renewable Electricity”, National Academic Press, Washington, DC, 2010

2. **Connection to Climate Change**

W.D. Nordhaus, “Revisiting the social cost of carbon”, PNAS, vol. 114, no. 7, Feb. 14, 2017, 1518-1523

W.D. Nordhaus, J. Boyer, “The Structure and Derivation of RICE-99”, chapter 2 in “Warming the World, Economic Models of Global Warming”, MIT Press, 2000

3. **Power Sector Economics and Pricing under High Penetration of Renewable Energy**

Y. Matsuo et al., “Investigating the Economics of the Power Sector under High Penetration of Variable Renewable Energy”, Applied Energy, vol. 267, 113956, 2020

L. Hirth, “The Market Value of Variable Renewables: The Effect of Solar Wind Power Variability on their Relative Price”, Energy Economics, vol. 38, 2013, pp 218-236

4. **Regulators’ Problems**

Regulators, notably in California, have the problem of setting prices and subsidies for centralized, stable grid power, which is subject to high sunk and fixed costs, and decentralized, variable power from PV/solar panels, which is further complicated by

contrasting societal impacts.

F.A. Wolak, “The Evidence from California on the Economic Impact of Inefficient Distribution Network Pricing”, National Bureau of Economic Research Working Paper 25087, Sept. 2018

R. Braeutigam, “Optimal Policies for Natural Monopolies”, Chapter 23 of “Handbook of Industrial Organizations”, Vol. 2, Ed. R. Schmalensee and R. Willig, North Holland, 2007

S. Borenstein, “The Private Net Benefits of Residential Solar PV: The Rise of Electricity Tariffs, Tax Incentives, and Rebates”, National Bureau of Economic Research Working Paper 21342, July 2015

5. **Future Energy Systems & Networks**

(i) Implications of Significant Wind Generation Penetration

GE Energy, “Analysis of Wind Generation Impact on ERCOT Ancillary Services Requirements”, Executive Summary, March 2008

M. A. Ortega-Vazquez, D.S. Kirschen, “Estimating the Spinning Reserve Requirements in Systems with Significant Wind Power Generation Penetration”, IEEE Trans. Power Systems, vol. 24 (1), February 2009, 114-124

(ii) Demand Response with Intermittent Renewable Energy

H. Ballouz, J. Mathias, S. Meyn, R. Moye, J. Warrington, “Reliable Power Grid: Long Overdue Alternatives to Surge Pricing”, arXiv:2103.06355v2 [math.OC], 26 March 2021

(iii) Economies of Scale in Storage and Transmission for Renewable Energy Sources

V.Duelkar, J. Nair, A.A. Kulkarni, “Statistical Economies of Scale in Battery Sharing”, arXiv:1912.00462v1, Dec. 1, 2019, also in J. Energy Storage, 2021

(iv) Risk-Aware System Design with Stable and Variable Energy Sources

D. Mitra, Q. Wang, “Stochastic Traffic Engineering for Demand Uncertainty and Risk-Aware Network Revenue Management”, IEEE/ACM Trans. Networking, vol.13(2), 2005

(v) Energy System Expansion Design Optimization

C. Skar, R. Egging, A. Tomasgard, “The Role of Transmission and Energy Storage for Integrating Large Shares of Renewables in Europe”, International Association for Energy Economics, Q1, 2016

C. Skar, G. Doorman, A. Tomasgard, “The future European power system under a climate policy regime”, ENERGYECON 2014, May 2014, 318-325

6. **Case Study of Design Optimization of Hybrid Wind-PV Microgrids in Bangladesh**

M. Nurunnabi, N.K. Roy, E. Hossain. H.R. Pota, “ Si**ze** Optimization and Sensitivity Analysis of Hybrid Wind/PV Micro-Grids – A Case Study for Bangladesh”, IEEE Access,vol.7, Oct. 2019