UCC 501 – SUSTAINABLE ENERGY

Course Title	Sustainable Energy
Course Code	UCC501
Credit Hours	3
Pre-requisites (if any)	N/A
Co-requisites (if any)	N/A
Name of Faculty	Dr. Alejandro Rios G. (ARG) – Course Coordinator ariosg@masdar.ac.ae Dr. Nicolas Calvet (NC) ncalvet@masdar.ac.ae Dr. Taha Ouarda (TO) touarda@masdar.ac.ae Dr. Talal Rahwan (TR) trahwan@masdar.ac.ae plus several invited faculty members
Course Timing	Mondays and Thursdays, from 4:15 PM to 5:30 PM
Office hours	Tuesdays: 15-17 hrs or open door for minor issues
Teaching Assistants	Ashot Mnatsakanyan amnatsakanyan@masdar.ac.ae Vikas Kumar vkumar@masdar.ac.ae Latifa Yousef layousef@masdar.ac.ae Mahmoud Alzoubi malzoubi@masdar.ac.ae Oghare Victor Ogidiama oogidiama@masdar.ac.ae Ilia Papakonstantinou ipapakonstantinou@masdar.ac.ae
Brief Course Description	Assessment of current and potential energy systems, covering extraction, conversion, and end-use, with emphasis on meeting regional and global energy needs in a sustainable manner. Examination of energy technologies in each fuel cycle stage for fossil (oil, gas, synthetic), nuclear (fission and fusion) and renewable (solar, biomass, wind, hydro, and geothermal) energy types, along with storage, transmission, and conservation issues. Focus on evaluation and analysis of energy technology systems in the context of political, social, economic, and environmental goals.
Course Objectives	1. Learn and use sustainability concepts as they pertain to energy 2. Develop a broad knowledge of the currently available energy sources with a focus on renewable energy 3. Learn to assess real-world energy-related problems from a variety of angles including their scientific merit, sustainability, scaling, regulatory requirements, etc. 4. Develop a functional understanding of the fundamentals of energy conversions
Learning Outcomes of the Course	Students will: • be able to apply sustainability definitions and concepts in real-life problems relating to energy generation and consumption • learn how to handle the scale, scope and availability of different energy resources and the relative effort needed to extract and distribute them

- learn and use key terms (e.g. energy, power, energy density, Energy-Return-On-Energy-Invested, Capacity Factors, etc.) as they apply to real energy conversions
- calculate the efficiencies of energy conversion processes based on thermodynamic laws and the merit (energetic, economic, and lifecycle) of various proposed energy extraction schemes
- be able to analyze in practice, and through teamwork, important contemporary problems of energetics (e.g., energy consumption per capita, carbon and water intensity of energy sources, alternatives of demand and supply), and express the process and results in written and presentation formats

W[1]	L[1]	Course Topics and Contents	Readings & Assignments
Part 1 – Energy and Sustainability in Context			
1	**1**	**MON 1/09** *Introduction – ARG* Introduction: Subject Overview and Administration Sustainable Energy textbook	Readings: • Text – Ch. 1
1	**2**	**THU 4/09** *Energy and Sustainability – ARG* Overview of units and dimensions for global energy flows Energy conversions The Energy Lifecycle Sustainable development definitions Time and space scales Population and consumption growth Tradeoffs and choices Uncertainty The Energy-Prosperity-Environmental Dilemma • *Reading link: http://books.google.com/books?id=pwsAAAAAMBAJ&lpg=PA5&pg=PA16#v=onepage&q&f=false	Readings: • Kates- Sustainable Development • Ehlrich & Holdren 1972*
Part II – General Analytical Tools			
2	**3**	**MON 8/09** *Technical Performance – Dr. Mohamed Ibrahim Hassan Ali* Energy Transfer and Conversion Methods • Physical properties (density, heat capacity, latent heat, ...)	Readings: • Text – Ch. 3

[1] W = Week; L = Lecture

		• Chemical reactions and kinetics – fossil and biomass fuel time-scales • Transport phenomena and rates • Energy storage modes • Electrochemical conversions • Thermodynamics and efficiency analysis • Exergy concept	
2	**4**	**THU 11/09** *Technical Performance – Dr. Mohamed Ibrahim Hassan Ali* Thermodynamics and Efficiency Analysis Methods • First and second laws • Availability • Power cycles and heat pumps • Topping and bottoming cycles • Examples of thermodynamic analysis for different energy systems	Readings: • Text – Ch. 3
3	**5**	**MON 15/09** *Term project: Writing Skills Seminar Part 1 – Kevin Garvey*	Assignments: • Term paper discussion Assignments: • HW#1 released
3	**6**	**THU 18/09** *Toolbox 1 & 2 – Dr. Itsung Tsai* Basics of energy evaluation Estimates of scale and economics Estimation practice and unit conversions Estimation of Electric Vehicle power, battery & energy requirement. Economic Feasibility Assessment Methods Engineering, capital, and investment costs • Fuel costs • Life cycle costs • Environmental Externalities (emissions, wastes, etc.) • Uncertainties Overview of Energy Supply Portfolio	Readings: • SEWHA – Ch. 2, 3 & III.A • Text: Ch. 5
4	**7**	**MON 22/09** *Toolbox 1 & 2 Continued – Dr. Itsung Tsai*	
Part III – Energy Sustainability			
4	**8**	**THU 25/09** *Environmental Effects of Energy, Energy Resources and Economics – ARG* Energy Resource Assessment	Readings: • Text – Ch. 2 & 4 • Hardin – Tragedy of the

		Energy Supply, Demand, and Storage Planning Methods Global Change Issues and Responses/Climate Change Discussion of Sustainability Issues	Commons • SEWHA – Ch. 1
5	**9**	**MON 29/09** *Energy and Sustainability Systems and Metrics – ARG* Scoping of analytical models and model boundaries Simulation, economic, life-cycle models System dynamics Discussion of public misconceptions on energy problems	Readings: • Text – Ch. 6 Assignments: • HW#1 due • HW#2 released
5	**10**	**THU 2/10** *Sustainability Case Studies – Linden Coppell, Head of Sustainability, Etihad Airways* • Etihad Airways Sustainability Strategy	
6	**11**	**MON 6/10** *No class - Mount Arafat Day & Eid Al Adha*	
6	**12**	**THU 9/10** *Energy, Water, and Land Use – ARG* Major Systems, Interactions, and Trends Land Use Issues Food – Water – Energy Nexus	Readings: • Text – Ch. 7
Part IV – Supply Side Energy Technologies			
7	**11**	**MON 13/10** *Biomass Energy – ARG* • Resource types and requirements • Technical and environmental issues • Land use (ecological stress, competition with food, water use, topsoil erosion, occupational hazards) • Utilization options • Economic projections, lifecycle analysis of biomass conversion • Biodiversity issues from monoculture Biomass conversion to liquid fuels • Hydrothermal/biological/thermochemical methods Integrated Seawater Energy and Agriculture System (ISEAS)	Readings: • Text – Ch. 10 Assignments: • HW#2 due • HW#3 released
7	**12**	**TUE 14/10** *Fossil Fuels and Fossil Energy – Visit to Schlumberger's Training Center*	Readings:

		Fossil fuel resource base Harvesting energy from fossil fuels Environmental impacts	• Text – Ch. 8
7	**13**	**THU 16/10** *Hydropower – Dr. Taha Ouarda* Technical issues (hydraulic head, turbines, etc.) Reliability and growth potential Water management (inundation, leaching, fish impacts, irrigation, waste management, etc.) Life cycle aspects and economics Energy and Water • Hydropower – dams and river impacts, water retention • Biomass production • Geothermal	Readings: • Text – Ch. 12
8	**14**	**MON 20/10** *Geothermal Energy – Dr. Rita Souza* Characterization Size and Distribution Operation Attributes	Readings: • Text – Ch. 11
8	**15**	**THU 23/10** *Part 1: Solar Resource and Solar Technologies – Dr. Nicolas Calvet* This lecture aims to provide a global vision of solar energy resource and solar technologies. The different solar radiations as well as the instruments to measure them are presented. The potential of solar energy is evaluated firstly in the world and secondly in the particular case of the United Arab Emirates. The selection process of ideal locations where to install solar plants is also clarified. Then, the different solar technologies such as photovoltaic, solar thermal (for hot domestic water or air heating systems), concentrated photovoltaic (CPV) or concentrated solar power (CSP) are explained in detail with their advantages and drawbacks. At the end of this lecture the student should be able to answer to the question: how to produce heat and electricity using the sun as source of energy.	Readings: • Text – Ch. 13 • SEWHA – Ch. 6
9	**16**	**MON 27/10** *Part 2: Thermal Energy Storage for Concentrated Solar Power – Dr. Nicolas Calvet* This lecture aims to present the advantage of using thermal energy storage (TES) in concentrated solar power (CSP) plants. The added value of the dispatchability of CSP plants with storage is developed.	Assignments: • HW#3 due

		The different storage systems already used in commercial CSP plants (two-tank molten salt system, saturated steam storage) as well as systems developed at demonstration level (high-temperature concrete storage, honeycomb ceramic) or research level (sand storage, combined sensible/latent heat storage for direct steam generation (DSG)) are explained. Some ongoing or planned research projects in the TES group at Masdar Institute are briefly presented. At the end of this lecture the student should be able to answer to the question: why and how to store thermal energy in CSP plants.	
9	**17**	**THU 30/10** *Nuclear Power – Dr. Youssef Shatilla* Nuclear energy basics Reactor designs and output Proliferation Nuclear waste disposal Nuclear Energy Economics The recent experience – Finish reactor The potential future technologies (pebble bed reactors, mobile reactors) Fission material availability and costs Waste transportation and storage Nuclear Fusion – the next 50 years	Readings: • Text – Ch. 9 • The future of nuclear Assignments: • HW#4 released
10	**18**	**MON 3/11** *Wind Energy – Dr. Taha Ouarda* Resource grade and distributions • Performance issues (intermittency and storage needs) • Environmental, technical, and land use issues • Economic projections	Readings: • Text – Ch. 15
Part V – Energy Use, Demand Side Management & Case Studies			
10	**19**	**THU 6/11** *Energy Efficiency in Buildings – Dr. Peter Armstrong* HVAC systems Building design and orientation Design approach Renewable energy options Lighting Building and equipment efficiency standards	Readings: • Text – Ch. 20
11	**20**	**MON 10/11** *Mid-term exam (in class)*	
11	**21**	**THU 13/11** *Term project: Writing Skills Seminar Part 2 – Kevin Garvey*	

12	**22**	**MON 17/11** *Alternative energy in the Middle East – Michel Abi Saab, Masdar Future Energy* Masdar City Case Study: the SIEMENS building	
12	**23**	**THU 20/11** *Energy Use in Transportation and Industry – ARG* Elements of the Transportation System Transportation Energy Use Trends and Sustainability Challenges Energy use in industry Waste management industry Eco-Effectiveness Life-cycle analysis and design for sustainability	Readings: • Text – Ch. 18 and 19 • Cradle to Cradle
13	**24**	**MON 24/11** *Smart Grids – Dr. Talal Rahwan* The smart grid represents a vision of a future electricity grid, radically different to those currently deployed, where the bidirectional flow of both electricity and information allows demand to be actively managed in real time, such that electricity can be generated at scale from intermittent renewable sources. • *Reading link: http://cacm.acm.org/magazines/2012/4/147362-putting-the-smarts-into-the-smart-grid/fulltext	Readings: Text – Ch. 16 & 17
13	**25**	**THU 27/11** *Smart Grids (continued) – Dr. Talal Rahwan*	
14	**26**	**THU 4/12** *Autonomous Agents and Multi-Agent Systems Research – Dr. Talal Rahwan* The autonomous behavior expected of the smart grid, its distributed nature, and the existence of multiple stakeholders each with their own incentives and interests, challenges existing engineering approaches. Artificial intelligence, and particularly, the fields of autonomous agents and multi-agent systems are essential for delivering the smart grid. • *Reading link: http://eprints.soton.ac.uk/337560/	
15	**27**	**MON 8/12** *Energy and Desalination – Dr. Hassan Arafat*	

		Energy requirements of different desalination options Co-generation plants operations and flexibility of dispatch Reverse osmosis as an option for the Gulf Solar desalination	
15	**28**	**THU 11/12** *Synergistic Complex Systems – All* The Complex Systems View Case Studies	Readings: • Text – Ch. 21 Assignments: • HW#4 due
16		**MON 15/12** *Project oral presentations*	Assignments: • **Final projects due**
16		**TUE 16/12** *Project oral presentations*	
16		**THU 18/12** *Project oral presentations*	

Out-of-class assignments and due dates for submission	4 assignments (1 approximately every 2 weeks). You may drop the lowest grade for the homeworks, but only if you have completed all 4 assignments. 1 in class midterm exam. 1 final project in teams of 2-4, including oral presentation.
Methods and dates of student evaluation, including relative weight of various assessment methods in determining course grade	Class participation 10% Homework 30% Mid-term exam 20% Term project 40% [30% for written paper and 10% for oral presentation]
Teaching and learning methodologies	Lectures. In-class discussion. Recitations for assignments. Problem solving. Teamwork.
Main course text	Sustainable Energy – Choosing Among Options. J.W. Tester, E.M. Drake, M.J. Driscoll, M.W. Golay, and W.A. Peters. MIT Press, Cambridge MA, Second Edition 2012
Recommended readings	Relevant and important academic papers are occasionally distributed to the students on the individual course topics or assignments. In addition, we recommend the following resources: ***Encyclopedia of Energy Technology and the Environment.*** Bisio and Boots, 1995. ***Energy at the Crossroads.*** Vaclav Smil, MIT Press 2003. ***Renewable Energy Resources,*** Twidell and Weir, 2nd Ed., Taylor and Francis, London, 2006.

	Sustainable Energy Without the Hot Air [SEWHA], David McKay, UIT, 2008 http://www.withouthotair.com/download.html ***The Future of Nuclear Power: An Interdisciplinary MIT Study***, Deutch and Moniz, Chairs (2005). See: http://web.mit.edu/nuclearpower/ ***The Future of Geothermal Energy***, Tester et al. (2006). See http://www1.eere.energy.gov/geothermal/future_geothermal.html ***The Future of Coal: MIT Coal Study,*** Deutch et al. (2007). See: http://web.mit.edu/coal/The_Future_of_Coal.pdf ***The Intergovernmental Panel on Climate Change (IPCC): Climate Change 2007: – Summary for Policymakers,*** See: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf
Instructional materials and resources	A teaching assistance website is established at: https://source.masdar.ac.ae/