EVSS 650: Energy Production and Resource Management

Take-Home FINAL EXAM
Due: 1 May 2013 (7 PM)

You are permitted to use your class notes, your textbook, and any other useful materials you have discovered throughout the semester (including useful web sites). You are NOT permitted to discuss the exam in any way, direct or indirect, with ANYONE alive or dead (except me) until you have received your final grade, and you are NOT permitted to use materials prepared by any other student (past or current) except for the notes and handouts from their presentation.

Show all your work and state all your assumptions for all the problems. Evaluate any numbers you take from "the literature" enough to demonstrate that they are appropriate. Include diagrams when helpful, and include citations when necessary. Hopefully you will use your exam as a reference in the years to come, so make it a maserpiece!

25 points each

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1. **(a)** Summarize in a few paragraphs the *scientific case* that (1) atmospheric *concentrations* of greenhouse gasses have been increasing rapidly since the era of fossil-fuel burning began, and (2) the average *temperature* of the Earth is rising.
(b) What *natural* factors (i.e. not man-made) could lead to an increase in atmospheric greenhouse gas concentration? On approximately what timescale?
(c) Summarize (in your own words) the argument that *anthropogenic* forces (i.e. human activity) are *primarily* responsible for the increasing trend in atmospheric concentration of greenhouse gasses.

2. You've been tasked by President Obama to come up with a 10-point Energy Plan. Even if you feel otherwise, assume that he is intelligent, courageous, politically savvy, and that he agrees with you on all the issues. Let's further assume that you actually hope to get something done in the next 5 years (in other words, be optimistic and visionary but realistic). In 2 pages or less, put together a 10-point plan to form the basis of our national energy policy.

3. **(a)** From *first principles**, **calculate** the area of a solar PV array needed to generate enough electricity at noon on a sunny day in Arizona to satisfy the peak electrical power demand for the entire United States (if you can't find a better number, build an array to produce 900 GW). Express your answer in *square miles* and as a *percentage* of the area of Arizona. [Do not just look up a number and trust it, though it's not a bad idea to look up some estimates to compare your result with.]
   (b) Describe 3 or 4 practical considerations that would require the array to have a larger area than you calculated above. Estimate how much larger it would be.
   (c) What part of the US would you recommend we cover with PV cells?
   **[Hints: The "solar constant" is a measure of the energy flux carried by electromagnetic radiation from the Sun and arriving at Earth. Its value is 1356 Watts per square meter (outside the atmosphere). Provide and explain realistic assumptions regarding how much of this this is transmitted through our atmosphere and how much can be converted into electricity using a large PhotoVoltaic array (they are not 100% efficient, and they never will be)].*

4. **(a)** Derive a realistic estimate for the maximum number of wind turbines we can pack on a square mile. Explain your reasoning in and provide references if necessary.
   (b) Counting the land between the turbines, what percentage of the combined area of N. Dakota, S. Dakota, and Nebraska would be required to produce enough electricity to satisfy the peak US demand? Describe all the steps in your calculation.
   (c) Describe a strategy for optimally utilizing the "dead space" between the wind mills in a way that does not interfere with their operation. The ideal strategy probably should take advantage of the windmills' presence.
   [Hints: As in problem 4, you can assume 900 GW or use a more realistic estimate. You can use real data for wind turbines (but try to find a fairly modern wind power plant), or you can make any assumptions you need, so long as they are well defined].

EXTRA CREDIT [5 pts]. Write an essay of approximately 1 typed page in length and targeted at an entering MES graduate student. Describe the most important lessons that they could, should, or will learn in this course and why they are important in the context of the MES curriculum.
