I. <u>STUDENT VERSION</u>

Title: Nuclear Energy – Costs and Benefits

Project Summary: In this project, you and your group will implement basic cost-benefit analysis techniques in a fictionalized energy market. You will practice using mathematical tools to make informed strategic decisions from the perspective of an energy company. This project involves using Net Present Value (NPV) to assess the value of a long-term project (building a new nuclear reactor) and calculating expected outcomes when the future is uncertain.

Instructions to students:

- **Background Information:** Nuclear power is the second largest source of clean energy and accounts for roughly 20% of all energy in the United States and 10% of global energy. Nuclear energy is generated with a small land footprint, is one of the most reliable and consistent energy sources, and generates electricity without daily greenhouse gas emissions. Despite all this, the continued use of nuclear energy remains controversial for multiple reasons, and it has been multiple decades since a nuclear reactor began operation in the United States. The up-front costs of building a nuclear reactor are substantial, with a single plant requiring as much as a decade of construction and billions of dollars of investment. Once operational, the radioactive waste generated by the reactor is dangerous and must be stored indefinitely. Moreover, each nuclear reactor comes with the possibility of rare but catastrophic nuclear meltdowns like the Fukishima meltdown in 2011 that displaced over 200,000 people from their homes. For more information on how nuclear energy works, click here. To get a clear view for some of the pros and cons for nuclear energy, click here.

  In this project, you will act as the final decision maker at a profit-maximizing power company. You will use realistic, fictional information to assess the costs and benefits of building a new 1.21 gigawatt (Great Scott!) nuclear reactor. You will "decide" whether to build a nuclear power plant or the outside option, a series of hydroelectric plants (you have an abundance of rivers!). If you choose to build the nuclear plant, construction begins. If not, the firm will build the hydro plants.

- **Groups:** You will work on this in small groups of 2-4, depending on class size.

- **Data/Information:** The nuclear power plant under consideration is capable of producing 1.21 gigawatts of power. "Overnight costs" are the direct cost of building the plant, with no consideration of interest payments or other financial complications. If you could build the whole thing overnight, this is how much it would cost. The overnight cost for this reactor is projected to be 5425 $/kW in 2020 dollars. Note that there are 1000 kW in a MW, and 1000 MW in a GW, so 1,000,000 kW = 1000 MW = 1 GW. Construction of the facility takes 10 years, and for simplicity we will assume that the overnight costs are spread evenly across the 10 years. The plant is expected to operate for a 60-year window at an average of 98% capacity (so 98% of the 1.21 GW). The Levelized Cost of Energy (LCOE) measures the lifetime average cost for the energy. First a total cost number is calculated, including overnight costs, maintenance, fuel, and all other direct costs of producing energy over the lifetime of the plant. Then divide the total costs by the total output of the plant. This gives a lifetime dollars per megawatt hour ($/MWh) for the energy. The estimated LCOE at this plant is $69.39/MWh in 2020 dollars. Knowing energy prices far into the future is tricky business, but we are just going to assume that energy can be sold at $0.11/kWh (in 2020 dollars) throughout the life of the plant. Initially, the prevailing real interest rate that you will use to discount future cash flows is 3 percent. There is an outside project, a hydroelectric power plant, where the NPV is estimated to be 987 million dollars. Your company can build one or the other, but not both. The numbers here are based on industry trends but are hypothetical. This is not real data.

(Only use the following information for questions 4 and 5). Through some incredibly convenient means that exist only in classroom exercises, you know that there is a 20% chance that changing weather patterns and other trends reduce the hydro NPV to $400 million, and a 1% chance that the hydro NPV is only $100 million. On the other hand, your nuclear plant should operate consistently, but there is a 0.05% chance of small nuclear waste leaks reducing the nuclear NPV to $50 million, and a 0.000007% chance of a catastrophic nuclear meltdown that changes the nuclear NPV to –$2.5 billion.

- **Procedure/plan of action to complete the project:**
  Pre-project Assignment for students:
  Think about these questions. We will discuss them in class before dividing into groups.

  - Why do you think we use LCOE to measure the cost of energy, rather than total costs, or daily costs, or some other measure?
  - The startup costs for a nuclear plant are very high. How will interest rates (proxy for discount rate), affect your NPV calculations and comparisons?
  - We only listed some costs and benefits. What other considerations would you realistically need to have in order to make your decision?

After the preliminary discussion of these questions, you will be assigned to groups, and group members will work together to decide whether we should build the nuclear plant. Read the following questions, discuss them and work through them in your groups. Answers will be submitted in a word document or PDF file, 1-2 pages long, by the due date announced in class. Excel spreadsheets are also to be submitted with all relevant calculations clearly labeled. Each question will be graded on either computational correctness (C), reasoning (R), or both, as indicated at the beginning of the question. See “Deliverables and Evaluation” below for details on grading. After submitting the group answer document and spreadsheet, each of you will submit your own student survey about how the group work was divided and carried out.

1) (C) If we do not do time discounting, how much profit will the firm make from the nuclear power plant? Explain how you got to this number.
2) (C, R) If we do discount the future, and the annual discount rate is 4%, what is the NPV of building the nuclear power plant? Repeat for discount rates of 5% and 6%. At which

discount rates should we build this nuclear power plant? At which discount rates should we switch to the hydroelectric system? Explain.

3) (R) Name two reasons why the price of electricity might change from one year to the next. (Hint: we already counted for inflation by using 2020 dollars, so don't say inflation). Describe how incorporating forecasted energy prices that vary from year to year would affect your analysis. How might it change your results? Explain.
4) (C, R) Now consider the probabilistic information in the second paragraph of the data section. If you are a risk-neutral decision maker, which project should you choose, based on expected value? Explain.
5) (R) Explain how the precautionary principle might be relevant here. How might it change your decision from 3, and do you think it should? Explain.

Duration: This is a one-week project that will be completed mostly in class.

Deliverables and evaluation: You are expected to be prepared for the pre-project discussion questions.

At the end of the project, each team will submit (1) written results and explanations, and (2) an Excel spread sheet showing all calculations. Furthermore, each of you will submit (3) individual surveys. Items (1) and (2) will be graded simultaneously, question by question. As mentioned previously, each question has a C, an R, or both. There are 3 C's and 4 R's for which you will be graded.

- For the C components, groups will receive either full credit, half credit, or no credit. Full credit is given under two conditions: the spreadsheet shows accurate or very nearly accurate computations, <u>and</u> the process of solving is explained in enough detail that I can replicate your work. You will receive half credit if the calculations and the written process show near understanding of the material. If understanding is not demonstrated in either the computational correctness or the explanation, then no credit.
- For the R components, your group is being asked to make decisions or judgements. Students will receive full, half, or no credit for their answers. For full credit, the judgments must be compatible with your calculations (i.e., no endorsing unprofitable projects, etc.), and your explanations should be reasonable and direct. For half credit, you may either have a correct judgement with a weak explanation, or a false judgment with a mostly correct explanation. If you fall short of both of these, you receive no credit.

The student surveys are to give some accountability for the participation of your teammates. You will be graded on whether you complete the survey or not, as well as whether you met the expectations of the assignment or not, according to your peers' evaluation of your work. The survey will be available until the final due date. You will answer the following questions about each student in your group:

- Did the student come prepared to discuss the material?
- Did the student participate in the discussion, either to ask or to answer questions?
- Did the student do the part that the group agreed they would do?
- What did this student contribute to the final submission?

Lastly, you are expected to be prepared for post-project discussions.