NPRE 412 | Spring 2025
HW 1 | Due 2025.01.28

- Show your work.
- This work must be submitted online as a `.pdf` through Canvas.
- Work completed with LaTeX or Jupyter earns 1 extra point. Submit source file (e.g. `.tex` or `.ipynb`) along with the `.pdf` file.
- If this work is completed with the aid of a numerical program (such as Python, Wolfram Alpha, or MATLAB) all scripts and data must be submitted in addition to the `.pdf`.
- If you work with anyone else, document what you worked on together.

---

1. (a) (1 point) What are you hoping to learn in this class?

   Solution: I am hoping to learn about the policy, economics, and less math-related issues with nuclear. I want to develop a stronger foundation for learning about nuclear policy for my future in nuclear engineering.

   (b) (1 point) By what day and time every week must online quizzes be completed?

   Solution: For full credit, the quizzes need to be submitted before class begins at 9:30am on Tuesdays.

   (c) (1 point) When is homework due every week?

   Solution: For full credit, the homeworks need to be submitted before class begins at 9:30am on Tuesdays.

2. (a) (1 point) In your opinion, what is the most compelling reason to support nuclear power?

   Solution: Nuclear is a clean, reliable, versatile power source. I believe nuclear is one of, if not the only, feasible energy source that can be deployed everywhere. Solar is great (I have a few gripes about voltaic panels), unless you live in the UK. Geothermal is great, unless you do not live near a fault line or volcano. Hydroelectric is great, unless you live in a prairie. Advanced nuclear is realistically the only way to globally decarbonize.

   (b) (1 point) In your opinion, what is the most compelling reason to oppose nuclear power?

   Solution: The radioactive waste and cost are the biggest issues. We can dramatically reduce the radioactive waste issue with breeder reactors. However reprocessing and breeding raise non-proliferation concerns. The US tried to set an example, but few serious nuclear nations followed our lead and have their own reprocessing programs. The cost is something I know less about, which is why I am here!

3. Domestic electricity consumption data can be found at eia.gov.
   (a) (5 points) Using the energy consumption data you can find on this website, predict the average annual growth rate of domestic (United States) electricity demand for the period between 2025 and 2050. Your answer should be reported as a percent (%).

   Solution: I predicted the annual domestic energy growth rate between 2025 and 2050 will be **0.843%**.

   (b) (10 points) Cite your sources, explain your logic, and defend your prediction.

   Solution: Energy Data from the EIA dating back to 1960.
   This prediction takes the historic average annual growth rate from 1960 to 2022 and linearly extrapolates until 2050. By using energy date over the past 62 years, the prediction is subject to fewer localized perturbations caused by transient instabilities, such as: the Russian invasion of Ukraine and future or sitting presidents.

   This prediction does not account for the current public perception regarding the future of energy. However, using current trends for future predictions will result in biases toward the present. Arguing current trends are more apt predictors than historical trends may be more accurate. This prediction uses data for energy and not electricity, which have historically been tightly correlated.

   However, since roughly 2000, the annual domestic energy production has remained relatively constant. From roughly 1970 to 1985, there was a similar plateau in energy production that was later followed by a decade-long spike in energy production. As the current energy production plateaus in a similar manner as from 1970 to 1985, basing energy projections off the past two decades would be foolhardy. When predicting the trends over decades, using data dating back as far as possible is the wisest.

4. International electricity consumption data can be found at iea.org.
   (a) (5 points) Using the data you can find on this website and any other additional sources, predict the average annual growth rate of worldwide electricity demand for the period between 2025 and 2040. Your answer should be reported as a percent (%).

   Solution: I predicted the annual global energy growth rate between 2025 and 2040 will be **0.357%**.

   (b) (10 points) Cite your sources, explain your logic, and defend your prediction.

   Solution: Energy Data form the IEA dating back to 2010.

   To predict this growth in energy, I took the average of the annual change in global energy production between 2010 and 2024. This average growth rate is used as the projected percent increase between 2025 and 2040. Taking and applying the average of historic trends to the future will be more accurate over decades compared to years. As the projection period is 15 years, the average growth rate is an apt predictor.

This data includes OECD and select non-OECD countries, which discounts a great portion of Africa, the Middle East, Eastern Europe, and South America. Although most of these countries hold the greatest potential for increasing energy production, these countries may take decades or more to become substantial contributors to global energy capacity. Therefore, discounting these counties will not affect the projection significantly.

This approximation would be more accurate if more data were included, however, this IEA database dated back to 2010. Although, the accuracy could be improved with more data, this is less of a concern for global energy production compared to national energy production. Global trends are recorded over many counties while national trends are recorded over a single country.

5. (a) (5 points) Do some research using the resources available to you. What was the installed, coal-fired electricity capacity in the United States in **2023** (in GW)?

Solution: All parts of this question use the EIA monthly energy data.

Via the total electric net summer capacity, the total coal-fired electricity capacity in December 2023 was **178.4 GW**.

(b) (5 points) What is the total installed electricity capacity in the United States in **2023** (in GW)?

Solution: Via the total electric net summer capacity, the total electricity capacity in December 2023 was **1,187.6 GW**.

(c) (5 points) How do the capacity factors of coal-fired plants and nuclear powered plants compare?

Solution: Via the capacity factors and usage factor at electric generators, the average capacity factors of **coal-fired plants and nuclear powered plants in 2023 were 42.4% and 93%, respectively**. Nuclear powered plants had a capacity factor over double that of coal-fired plants.

6. (a) (10 points) Using the Electricity Data Browser at eia.gov, what share of electricity *net generation* was from US coal-fired plants in 2023? Please report this to a tenth of a percent resolution.

> **Solution:** Via the Electricity Data Browser, coal-fired plants accounted for **16.1%** of total generation capacity in 2023.

(b) (10 points) Similarly report the nuclear power share of net electricity generation in 2023.

> **Solution:** Via the Electricity Data Browser, nuclear powered plants accounted for **18.5%** of total generation capacity in 2023.

(c) (10 points) If the United States decided tomorrow to replace all coal-fired electricity generation with nuclear power, how many new nuclear reactors would need to be built to do that? Making any assumptions you need to concerning the average capacity of new nuclear reactors, but be realistic and state your assumptions.

Solution: Assuming coal-fired and nuclear plants are treated as base-load electricity generation, nuclear needs to replace the capacity of coal scaled by the capacity factor of coal. The amount of energy nuclear would need to make up is

$$0.424(178.4\ GW) = 75.6\ GW \tag{1}$$

Assume nuclear energy has a capacity factor of 93%, the total capacity would be the capacity we need to replace divided by the capacity of nuclear.

$$\frac{75.6\ GW}{0.93\ Capacity\ Factor} = 81.34\ GW \tag{2}$$

Assume each nuclear reactor has a 1 GW capacity, the number of reactors is the required capacity divided by the capacity per reactor.

$$\frac{81.34\ GW}{1GW/Reactor} = 81.34\ GW \tag{3}$$

However, you cannot build 1/3 of a reactor, so the final number of reactors required to replace coal-based power plants is **82 nuclear reactors** with 1 GW capacity each.

(d) (10 points) Assume it takes 10 years to build a nuclear reactor in the United States and the reactor vessel must be installed in year 9. Let us imagine that, unfortunately, builds are constrained by the limited global heavy forging capacity. Assume that only 5 new reactor vessels can be delivered to our shores (from Japan, South Korea, and the UK, primarily) per year. In what year will we have completed the replacement of current coal with nuclear?

Solution: I will assume the government of the United States has the foresight to start purchasing reactor vessels starting today. If we purchased 5 reactor vessels a year, the years it would take to obtain 82 vessels is given as:

$$\frac{82\ vessels}{5\ vessels/year} = 16.4\ years \tag{4}$$

However, the vessel can only be installed in the 9th year, so we need an additional year bringing the total to 17.4 years. If this plan started this second, the reactors would be completed in **2042 between May and June**.

(e) (10 points) Assuming the domestic electricity demand growth rate you estimated before, what quantity of electricity generation will be needed in the United States that year (in TWh)?

Solution: Assuming the 2023 energy usage was 4,183 TWh annually and the energy usage will grow annually with a constant rate of 0.843 %, the future energy usage is given as:

$$4183.271\ TWh\left(1 + 0.00843\frac{1}{year} \cdot 19.4\ years\right) = \mathbf{4867.41\ TWh}. \tag{5}$$

This is an increase in energy consumption of 684.14 TWh by 2042.