Study Guide for Test 3

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Contents

Major concepts in studying for Test #3:

1. Computer models of climate:
   a. Different purposes for models:
      - For pure science (model the climate system in detail)
        - If these are the emissions, this is what climate will do
      - For guiding policy (Integrated assessment models: integrate climate system with economy and energy use)
        - Under these policies, and these scenarios of population and technological innovation, this is what emissions will be produced by economic activity, this is how climate would change, and this is how it would affect the economy.

   b. Understand the difference between *transient climate response* and *equilibrium climate response*.
      - Transient climate response is the temperature at the time you reach a certain amount of greenhouse gases in the atmosphere
      - Equilibrium response is the final temperature, after you hold greenhouse gases constant at some level for a long time.
      - The equilibrium response is greater (hotter) than the transient response because the planet continues to warm up for hundreds of years after the amount of greenhouse gases stops changing. This is because it takes time for the ocean to fully warm up, just like it takes time for a pot of water to boil after you put it on the stove.

   c. Kaya identity
      - You won't have to do calculations with the Kaya identity, but I want you to understand the variables in it and how they relate to emissions:

        $$F = P \times g \times e \times f,$$

        where
        - F is greenhouse gas emissions (e.g., millions of tons of CO_2 per year),
        - P is the population (billions of people),
        - g is the per-capita gross domestic product (e.g., thousands of dollars per person per year), g represents the amount of economic activity per person. It's a rough measure of how much value (in dollars) the economy generates per person, and therefore the amount of stuff the average person can consume (food, shelter, energy, health care, other services)

- e is the energy-intensity of the economy (e.g., quads of energy per trillion dollars GDP), Reducing e means making the economy more energy efficient because the economy generates more value for the same amount of energy.
- and f is the emissions-intensity of the energy supply (e.g., millions of tons of CO_2 per quad of energy)
  Reducing f means reducing the fossil-fuel intensity of the economy (moving from fossil fuels to nuclear or renewable energy) or switching from carbon-rich fossil fuels, such as coal, to less carbon-rich ones, such as natural gas.

- Understand why policies to reduce greenhouse gases quickly tend to focus on reducing e and f, rather than reducing P and g.

d. Understand what it means for CO_2 to be a *stock pollutant*.

- What does this imply for what has to happen to *emissions* to stabilize CO_2 concentration in the atmosphere?
  - Emissions must drop until they're equal to the amount of CO_2 removed by nature (e.g., photosynthesis, weathering, and dissolving into the oceans).

2. Understanding future climate change

a. Understand the kinds of uncertainty in predicting future climates:

- Uncertainty about climate sensitivity (if these are the emissions, what will climate do?)
- Uncertainty about emissions.

b. Understand about tipping points:

- What are they?
- What are some examples?
- Why are we so unsure about tipping points?
- If we are so uncertain about tipping points, why do scientists and policymakers worry so much about them?
- Understand what made the "hole" in the stratospheric ozone layer a tipping point?

c. Why is studying past climate history important to understanding the future of climate change?

- Lessons from the pleistocene ice ages:
  - The pleistocene ice ages prove that CO_2 is a powerful cause of natural climate change
  - The Younger Dryas:
    * What is it?
    * What does it tell us about tipping points and abrupt climate change?

d. What do we know about how future climate change is likely to affect the economies of different countries?

- Which types of countries are likely to be hurt the most?
- Which types of countries are likely to be hurt the least (or even benefit)?
- How can countries try to reduce the economic damages they will suffer from climate change?

3. Principles of Policy Analysis

a. Compare *The Climate Fix* with *The Climate Casino*
b. How is climate policy like buying insurance (*Climate Casino*)?
c. Roger Pielke's Three Myths:

- What are the three myths?
  1. We lack political will
  2. We must trade off the economy for the environment
     - Understand Pielke's "Iron Law"
  3. We have all the technology we need.
- Understand the arguments Pielke makes about why these are myths
- Understand the rebuttals from people like Nordhaus, who think Pielke overstates the case (refer to slides from class too)

- Big question: Most of the public in the US believes climate change is an importand danger, that it's really happening, and that it's caused by human activity. Most people want the government to act to prevent dangerous climate change.f
  Why, then, has the US government done so little about climate change in the past 30 years?
  Pielke points to the "Iron Law": people think it's a problem, but are unwilling to spend much money.
  Nordhaus and others point to political polarization, which prevents government from taking action.
- About whether we have the technology we need, Pielke gets into an analysis of the Kaya Equation variables and says that e and f were not dropping as fast as they need to.
  How was his analysis biased by the time when he wrote the book (around 2008)? How have things changed since then?

d. What are Pielke's criteria for good climate policy?
   1. Policies should flow with public opinion
   2. The public will not tolerate significant short-term costs, even for big long-term benefits
   3. Policy must center on clean-energy innovation

e. What is "energy poverty" and why is it important for climate policy?
   - Roughly how many people around the world don't have access to any electricity?
   - Why does this matter?

4. Energy Efficiency and Clean Energy

   a. What is the difference between *primnary* and *secondary* energy consumption.
      - When you use your computer or charge your phone, are you using *primary* or *secondary* energy?

   b. How have the energy efficiency and the greenhouse gas emissions intensity of the world economy been changing over the last 40 years or so?
      - Except for a brief period around 2000–2007,
        - Energy efficiency has been getting better (e, the energy intensity of the economy has been dropping) very steadily.
        - Emissions intensity has been getting better (f, the emissions intensity of the energy supply) has been dropping very steadily.
      - This is good news, but we need for both e and f to drop much faster over the next several decades if we're going to hit our goals to limit global warming.

   c. Renewable Energy
      i. How have solar and wind energy been changing over the last several decades?
         - Wind and solar are the fastest-growing sources of new electricity generation in the US and in the world
         - China leads the world in installing solar and wind energy. It also leads the world in selling wind and solar technology to other countries.
         - Wind and solar have become much cheaper in the last decade and are now the cheapest ways to generate electricity.

      ii. WHat are the obstacles to running our economy on renewable energy instead of fossil fuels?
         - Only about 10% of the world's electricity comes from wind and solar energy and other modern renewables.
         - Wind and solar are intermittent: They only work when the sun is shining and the wind is blowing.
           - We need storage for when the sun is down or the sky is cloudy, and the wind is not blowing.
             * Batteries have become much cheaper in the last decade, but the cost needs to come down a lot before we can use them to store all the energy we'd need.

d. Nuclear power:

   i. Understand what nuclear power is.
   ii. Nuclear power uses much less fuel than fossil fuels (3 kg uranium instead of 10,000 tons of coal)
   iii. People are afraid of nuclear power because radioactive waste is scary and accidents (like Chermobyl in the Soviet Union) can be dramatic and deadly.
   However, coal kills many more people. Air pollution from coal power plants kills around 50,000 people people every month in the US alone. This is more than all the nuclear power accidents in history, all around the world.
   However, air pollution deaths occur one at a time and don't get reported much in the press, so people are not as aware of them.
   iv. The biggest challenge to expanding nuclear power is the cost. While solar and wind power have become much cheaper over the last decade, nuclear power has become more expensive because power plants are taking longer to build and are costing many times more than the original budgets estimated.
   New nuclear technologies promise to be much cheaper and faster to build, but they have not been proven to work.

5. What can we do if we don't reduce emissions quickly?

   a. **Adaptation:** We can convert unmanaged systems to managed ones so climate change won't affect them as much
   However, some systems are unmanageable, and the worse climate change gets, the harder and more expensive it becomes to convert unmanaged systems to managed ones.

   b. **Geoengineering:** Deliberately altering the climate to counteract or cancel-out the effects of increased greenhouse gas concentrations.

      i. Understand Daniel Sarewitz's criteria for a *technological fix*, which Pielke explains in *The Climate Fix*:
         1. Must work on a direct cause and effect relationship
         2. We must be able to assess the effects.
         3. It must build upon an established technological base
            - Steady progress by incremental improvements rather than hoping for big breakthroughs
      ii. **Albedo engineering** (**Solar Radiation Management**): Spray liquid droplets of sulfate chemicals into the strateosphere to mimic the colling that happens after big volcanic eruptions.
         - Pros:
           - Cheap, easy to do with current technology.
         - Cons:
           - We can't completely cancel out changes in temperature and precipitation simultaneously.
           - Effects will be different in different places around the world
           - It won't address some other effects of climate change, such as ocean acidification.
           - Once we start it, if we stop abruptly it might be worse than if we never did it (**termination shock**)
           - There could be bad consequences that we don't know about.
         - Mixed:
           - While we can't **exactly cancel out** both temperature change and precipitation at the same time, we *can* significantly **reduce** changes in both temperature and precipitation.
         - Policy challenges:
           - Getting governments around the world to agree on where to "set the thermostat" (what temperature to aim for)
           - Who is responsible for unintended consequences

    - Who is responsible for maintaining it, decade after decade?
        * The US is not even maintaining our existing infrastructure: bridges, roads, electrical distribution, water treatment, etc.

2. **Carbon dioxide removal**:
    - Natural methods (plant trees, improve agriculture and soil management, promote coastal carbon capture)
    - Artificial methods: Bioenergy with carbon capture and storage (BECCS) and direct air capture

3. Policy considerations:
    - What does Pielke think?
        - How do albedo engineering and direct air capture meet the criteria for a technological fix?
    - What does Nordhaus think?
        - Salvage therapy: fire truck vs. fire insurance
        - Concerns about moral hazard and the illusion of safety
    - What role should geoengineering have in climate policy according to Nordhaus and Pielke?