Generating Shared Socioeconomic Pathways for North Carolina

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Please answer these questions in a word document and submit to moodle. Your goal is to create an SSP for the state of North Carolina, choosing from either SSP2, SSP4, or SSP5 (only do one). Some data has been provided in the slides/in class, feel free to augment as necessary.

1. *For your chosen SSP, identify the underlying assumptions (how is mitigation vs adaptation likely to play out, economic growth, equitable growth, sustainable development etc...), drivers of emissions, and identifying characteristics of your SSP. What are the projected changes in emissions and warming for your SSP?*

   The Shared Socioeconomic Pathway 2 (SSP2), also known as the 'Middle of the Road' scenario, is chosen among the available SSP scenarios for its balanced approach to economic development and environmental sustainability. It envisions moderate economic growth and social development levels, along with climate change efforts evenly distributed across regions and social groups. This scenario assumes that current socioeconomic trends will continue without significant transformative changes. The primary assumptions of SSP2 are as follows.

   1) **Underlying Assumptions**: SSP2 assumes a balance between economic growth and environmental sustainability, with moderate economic growth rates and limited reductions in economic disparities between regions. Mitigation and adaptation policies are implemented incrementally rather than aggressively. One reason for optimism is the gradual increase in the share of renewable energy, a key feature of SSP2. While fossil fuel dependency remains substantial, this shift towards renewables leads to limited reductions in CO_2 emissions, offering a glimmer of hope in the fight against climate change. Social inequalities persist, resulting in varying capacities to respond to and adapt to climate change across different regions and social groups.
   2) **Drivers of Emissions and Key Characteristics**: The primary drivers of greenhouse gas (GHG) emissions under SSP2 are ongoing reliance on fossil fuels, land-use change such as deforestation and agricultural expansion, and continued industrialization and urbanization. Despite improvements in energy efficiency and technological advancements, total energy and resource demand continue to rise. This dynamic

results in high CO_2 emissions from energy production and industrial processes. Agriculture, forestry, and other land use (AFOLU) sectors also contribute to land conversion and deforestation emissions. Urbanization drives further energy consumption and emissions, particularly in rapidly developing economies.

3) **Projected Emission Trends and Climate Change Impacts**: In SSP2, there is encouraging news about global GHG emissions. They are expected to stabilize or even slightly decline through the mid-21st century, a positive sign of progress in climate change mitigation. By 2100, global average temperatures are projected to increase by approximately 2.5 to 3°C above pre-industrial levels. This scenario makes it unlikely to meet the Paris Agreement's goals of limiting warming to 1.5°C or well below 2°C. Such levels of warming are associated with increased climate risks, such as heightened frequency and intensity of extreme weather events, sea level rise, and widespread impacts on ecosystems and human systems. Regions with existing socioeconomic vulnerabilities are likely to face disproportionately severe impacts, exacerbating inequalities and limiting the effectiveness of adaptation measures.

2. *Using data from the slides as well as any exogenous information you want to include, describe the current demographic, environmental, and economic situation in North Carolina. What are the key industrial and employment sectors presently? What have population and economic growth trends looked like in the past?*

North Carolina has seen significant demographic and economic expansion in the past decade.[1] The state's population has surged to approximately 10.8 million in 2023, marking a robust 10% increase from the previous decade.[2] This growth, fueled by migration to urban centers like Raleigh, Charlotte, and Durham, has transformed these areas into vital employment and education hubs.[3] The state's population, with a balanced gender ratio of 51% female and 49% male and a median age of 39.3 years, underscores a strong working-age demographic.

From 2005 to 2020, North Carolina reduced its net greenhouse gas (GHG) emissions by 38%, from 152 million to 94 million metric tons of CO_2 equivalent ($MtCO_2e$).[4] This reduction

[1] U.S. Census Bureau. (n.d.). North Carolina population change between census decades. Retrieved October 4, 2024, from https://www.census.gov/library/stories/state-by-state/north-carolina-population-change-between-census-decade.html

[2] U.S. Census Bureau. (n.d.). 2020s state population estimates: Detailed datasets. Retrieved October 4, 2024, from https://www.census.gov/data/datasets/time-series/demo/popest/2020s-state-detail.html

[3] U.S. Census Bureau. (n.d.). *Population estimates tables*. Retrieved October 4, 2024, from https://www.census.gov/programs-surveys/popest/data/tables.html

[4] North Carolina Department of Environmental Quality. (2024, January 31). *DEQ releases 2024 update to state greenhouse gas inventory showing continued declines in NC climate*. Retrieved October 4, 2024, from

was primarily achieved through the electricity sector, which decreased emissions by almost 50% due to the transition from coal to natural gas and renewable energy sources.[4] The state aims to further reduce net emissions by 64% by 2050.[4] North Carolina also ranks second in the U.S. for installed solar capacity, with over 7,500 MW as of 2023, providing clean energy to approximately 930,000 homes.[4]

North Carolina's economic landscape is characterized by a diverse industrial base that spans technology, finance, manufacturing, and clean energy sectors. This diversity has been a critical factor in the state's economic growth, with the Gross State Product (GSP) currently standing at approximately $600 billion as of 2023.[5] The GSP has expanded by approximately 23% over the past decade, reflecting the state's resilience and adaptability in the face of economic challenges. Steady employment and industrial output increases across various sectors have been key to this growth. Notably, recent investments in clean energy have contributed significantly, creating nearly 30,000 jobs and adding over $10 billion to the state's GSP during construction. Federal incentives, such as the Inflation Reduction Act, have played a crucial role in driving investment in renewable energy and infrastructure, further enhancing North Carolina's economic growth.

3. *Using data from UNC's Demographics Center, the US Census, or other sources, find or create projections of how the population and economy will grow relative to baseline in your chosen SSP. Justify your projections based on your SSP's narrative.*

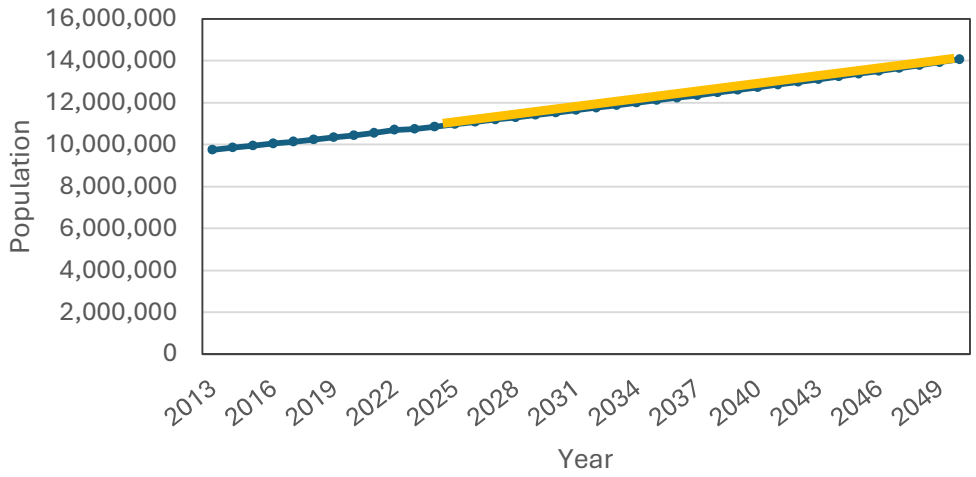

Figure 1 Projected Population Growth of North Carolina from 2013 to 2050

https://www.deq.nc.gov/news/press-releases/2024/01/31/deq-releases-2024-update-state-greenhouse-gas-inventory-showing-continued-declines-nc-climate

[5] U.S. Bureau of Economic Analysis. (2023). *State gross domestic product (GDP) and personal income: First quarter of 2023* (BEA Publication No. STGDPPI1Q23).

The population growth projection shown in the graph aligns closely with the SSP2 narrative, which envisions moderate development without significant economic or social disruptions. Under SSP2, North Carolina's annual population growth rate remains remarkably stable, reflecting historical trends between 2013 and 2023. This steady increase, reaching around 14 million by 2050, is driven by moderate migration to urban areas and balanced regional development. The projection also assumes that birth rates, death rates, and migration patterns will follow historical norms without significant shifts in demographic policies or extreme population booms or declines. This stability is a core feature of SSP2, where changes are incremental rather than transformative, supporting a gradual rise in population over time.[6]

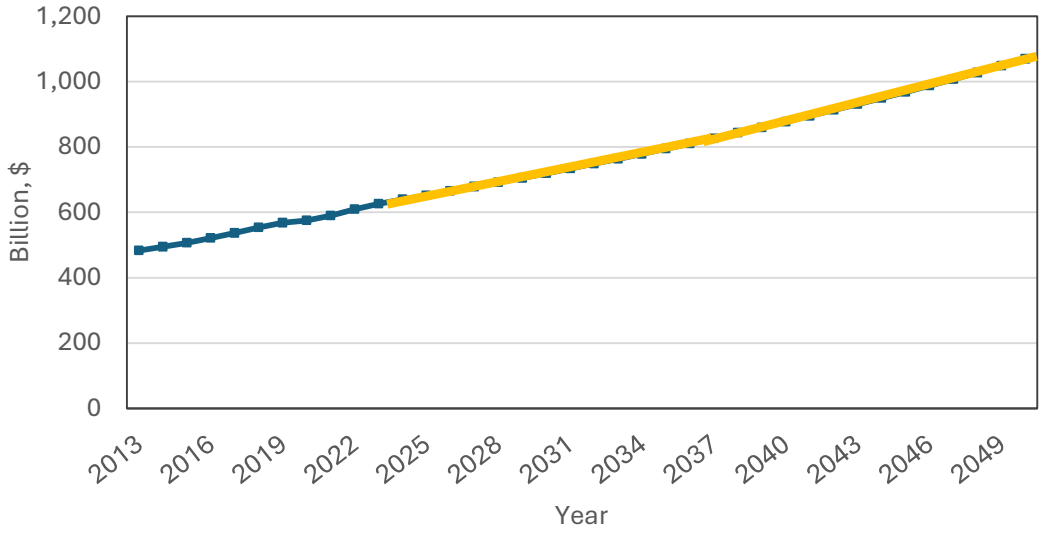

Figure 2 Projected Gross State Product (GSP) Growth of North Carolina from 2013 to 2050

The economic growth projection shown in the graph is consistent with the SSP2 scenario, which envisions moderate "middle-of-the-road" development. North Carolina's Gross State Product (GSP) is projected to grow steadily and significantly from around $482 billion in 2013 to over $1 trillion by 2050. This trajectory follows an average annual growth rate of 2-2.5%, reflecting SSP2's expectation of incremental technological advancements, balanced regional development, and stable economic policies. The gradual increase is driven by diverse industries such as technology, finance, and clean energy, with no rapid disruptions or policy-induced accelerations. This aligns with SSP2's emphasis on maintaining economic stability while achieving gradual improvements.[7]

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[6] U.S. Census Bureau. (n.d.). *North Carolina profile*. Retrieved October 4, 2024, from https://data.census.gov/profile/North_Carolina?g=040XX00US37

[7] U.S. Bureau of Economic Analysis. (n.d.). *GDP by state*. Retrieved October 4, 2024, from https://www.bea.gov/data/gdp/gdp-state

4. *Using whatever data sources you can find, create data sources for deforestation and vehicle electrification in your SSP in North Carolina.*

- **Deforestation**[8]**:** North Carolina has experienced a gradual decline in forest cover over the past decade, with an average annual reduction of around 0.3% due to urbanization, agricultural expansion, and infrastructure development. According to data from the USDA Forest Service, forested areas in the state have decreased by approximately 3% between 2013 and 2023. Under the SSP2 scenario, this rate of decline is expected to continue steadily, resulting in an estimated 5-7% reduction in forest cover by 2050. The SSP2 scenario, which assumes moderate development and environmental management policies, suggests that deforestation will follow historical patterns. However, to counter this trend, aggressive conservation efforts and rapid land use changes are needed.[8]
- **Vehicle Electrification**[9]**:** North Carolina has made significant strides in vehicle electrification over the past decade, largely driven by state and federal incentives. In 2018, there were approximately 10,000 registered zero-emission vehicles (ZEVs) in the state. By 2023, this number had increased to around 30,000, reflecting a compounded annual growth rate (CAGR) of 25%. Under the SSP2 scenario, this moderate growth trajectory is expected to continue, fueled by incentives such as the Inflation Reduction Act and investments in charging infrastructure. By 2050, the number of registered ZEVs in North Carolina will reach approximately 500,000, assuming a more balanced pace of technological adoption and infrastructure development. This projection is consistent with SSP2's narrative of gradual but steady progress in clean energy adoption and vehicle electrification initiatives across the state.

5. *Using data from Duke Energy, find or create projections of future energy mix (e.g. the amount of coal, renewables, oil, nuclear etc.) in your SSP. Justify how your projections match your SSP.*

Based on Duke Energy's proposed Carolina Carbon Plan, North Carolina's energy mix is projected to shift significantly by 2050. This transformation, aligned with the SSP2 scenario's moderate development pathway, promises a future of balanced growth in renewable energy, maintaining reliability and affordability for consumers. The benefits of this plan are vast, offering a more sustainable and cleaner energy future for North Carolina.[9]

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[8] U.S. Forest Service. (n.d.). *National Forests in North Carolina*. Retrieved October 4, 2024, from https://www.fs.usda.gov/nfsnc

[9] Duke Energy. (2022, May 16). *Duke Energy files proposed Carolinas Carbon Plan to deliver a cleaner energy future for customers*. Retrieved October 4, 2024, from https://investors.duke-energy.com/news/news-details/2022/Duke-Energy-files-proposed-Carolinas-Carbon-Plan-to-deliver-a-cleaner-energy-future-for-customers-05-16-2022/default.aspx

1) **Coal Reduction**[9]: Duke Energy has already retired two-thirds of its coal plants in North Carolina and South Carolina, a strategic move that ensures stability in the energy grid. By 2035, the remaining coal facilities will be retired, resulting in coal contributing less than 5% of the state's energy mix by 2050. This change reflects a steady transition from high-emission sources under SSP2 without abrupt changes that could disrupt grid stability.
2) **Increased Renewable Energy**[9]: Renewable energy, primarily from solar and wind, will see significant growth, a development that promises an exciting future for clean energy in the region. Duke Energy plans to add 7,600 MW and 11,900 MW of new solar capacity by 2035. In addition, wind resources will be developed both onshore and offshore, further diversifying the renewable energy portfolio. By 2050, renewables are expected to account for 60-70% of the total energy mix.
3) **Natural Gas as a Transitional Source**[9]: Natural gas will continue to serve as a transitional fuel to support the growing share of intermittent renewable energy. The energy mix will include 2,000 MW of hydrogen-capable natural gas units to replace coal and provide backup for renewable energy sources. This strategy aligns with SSP2's moderate pathway, maintaining a stable energy supply while gradually decreasing reliance on fossil fuels. The use of hydrogen in these units will help reduce carbon emissions, making it a key component of our transition plan.
4) **Nuclear and Emerging Technologies**[9]: Nuclear energy will remain a key contributor to the energy mix, providing stable baseload power. Duke Energy also plans to explore small modular nuclear reactors to maintain grid reliability. Additionally, the utility will invest in 3,700 MW to 5,900 MW of energy storage capacity. We are also committed to early development of zero-emission technologies like hydrogen, which we believe will play a significant role in our future energy mix.

6. *Using En-Roads (MIT's climate scenario modeling tool), adjust all the sliders based on your projections at 2050. What is the amount of warming projected to occur? Include the plot of green house gas net emissions relative to baseline.*

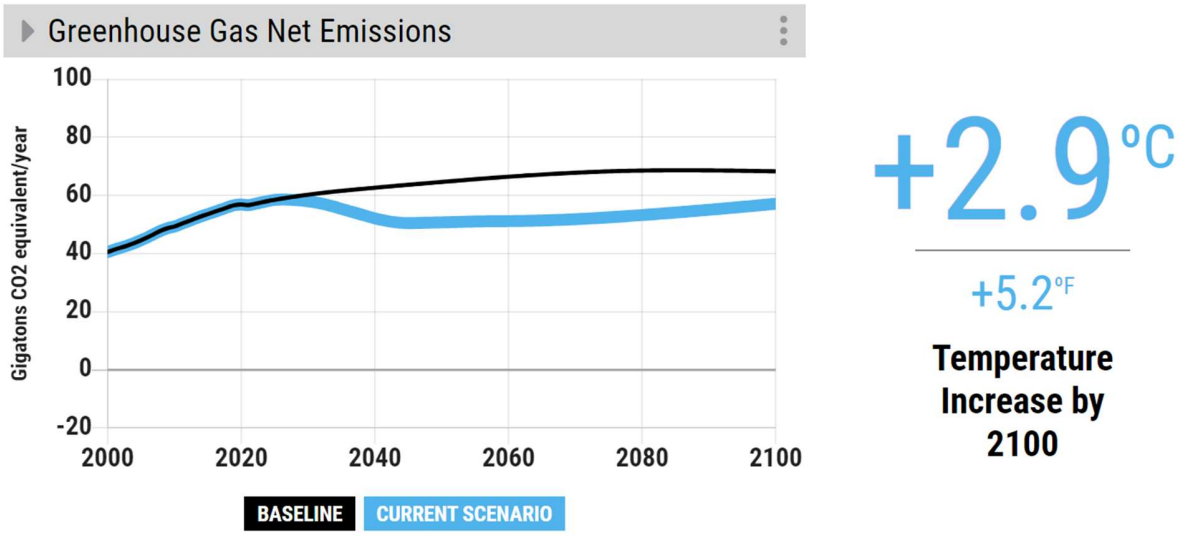

Figure 3 Projected Greenhouse Gas Net Emissions and Temperature Increase for North Carolina by 2100

The graph vividly illustrates the net greenhouse gas (GHG) emissions trajectory under the current scenario compared to the baseline. It's a trajectory that demands our immediate attention. Under the adjusted scenario, net emissions will decline around 2030 and reach lower levels than the baseline, especially by mid-century. However, the emissions trend slightly rises toward 2100 due to residual emissions from hard-to-decarbonize sectors, a concerning development that underscores the urgency of our work.

Despite the reduction in GHG emissions compared to the baseline, the current scenario projects a global temperature increase of +2.9°C (5.2°F) by 2100. This indicates that, while mitigation efforts have had a positive impact, they are still insufficient to limit global warming to below 2°C. It's a call to action, highlighting the need for more robust emissions reduction strategies and policy interventions. The responsibility is ours to act now.

7. *How does your SSP's emissions compare to the UN's SSP?*

The projected greenhouse gas (GHG) emissions under North Carolina's SSP2 scenario show a gradual decline starting around 2030, indicating a positive trend. However, the current policies and technology adoption rates result in a projected temperature increase of +2.9°C by 2100, which is higher than the global target of limiting warming to below 2 °C. This suggests

that North Carolina's current strategies, while insufficient, have the potential for improvement and deeper emission reductions.

North Carolina's emissions are slightly higher than the UN's global SSP2 scenario, anticipating a temperature increase of around 2.6-2.8°C. This discrepancy is due to a slower transition to renewable energy and continued reliance on fossil fuels like coal and natural gas. The UN's SSP2, which assumes greater international cooperation, underscores the importance of a global effort in reducing emissions and achieving a sustainable future.

The results presented are based only on the factors collected and reflected in the model, such as energy consumption, industrial activities, and transportation. Since it was impossible to account for every potential element influencing emissions, the current scenario might not fully align with the UN's pathway. The observed differences could be attributed to the limited scope of data used, suggesting that further comprehensive analysis is needed to more accurately compare North Carolina's SSP2 scenario with the global SSP2 scenario.

References

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5. U.S. Bureau of Economic Analysis. (2023). State gross domestic product (GDP) and personal income: First quarter of 2023 (BEA Publication No. STGDPPI1Q23).
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