# A COMPARISON OF THE FOSSIL FUEL AND NUCLEAR ELECTRICITY INDUSTRIES

BW

March 18th, 2025

# BACKGROUND

- Rising electricity demand with population
- Energy grid falling behind
- Rising energy costs
- Need to reduce carbon emissions
- Need to find reliable clean energy source to keep up with electricity demand
- Lack of public trust in nuclear energy

# QUESTIONS

1. What are the historical trends between each type of energy source and how does their energy production, fuel consumption, and waste production compare?
2. Is nuclear energy a cleaner, more effective source of energy when comparing the amount of fuel consumed and waste produced to the energy output?
3. Would increasing the amount of nuclear energy produced help reduce greenhouse gas emissions from fossil fuels and how would the amount of nuclear waste compare?

# DATA

- Four sources of electricity generation
  - Coal
  - Petroleum
  - Natural Gas
  - Nuclear
- Annual net electricity generation
  - Percentage of total electricity generation
- Annual fuel consumption
- Annual waste production
- Data Sources
  - U.S. Energy Information Agency Monthly Energy Review[1]
  - Pacific Northwest National Laboratory[2]
- Not a lifecycle analysis

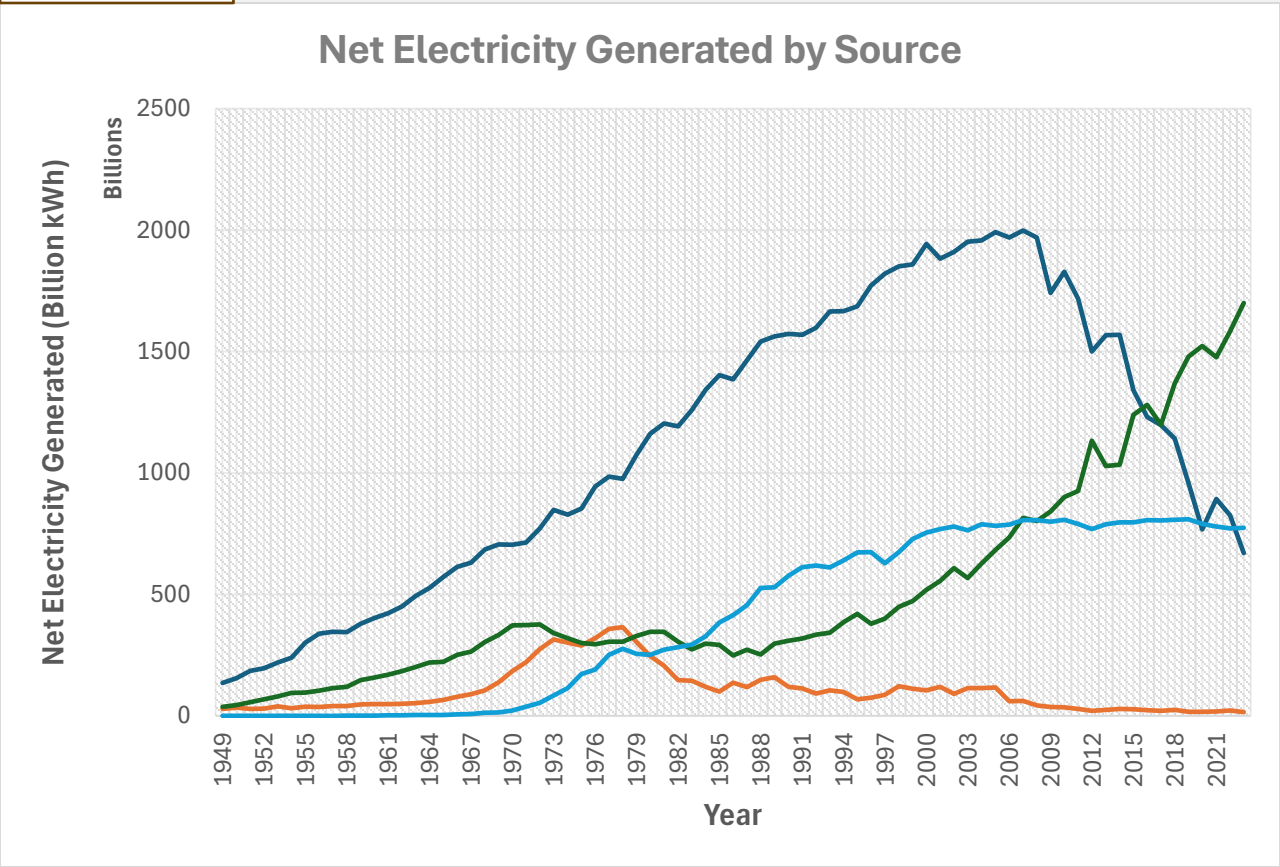
# HISTORICAL ELECTRICITY INDUSTRY

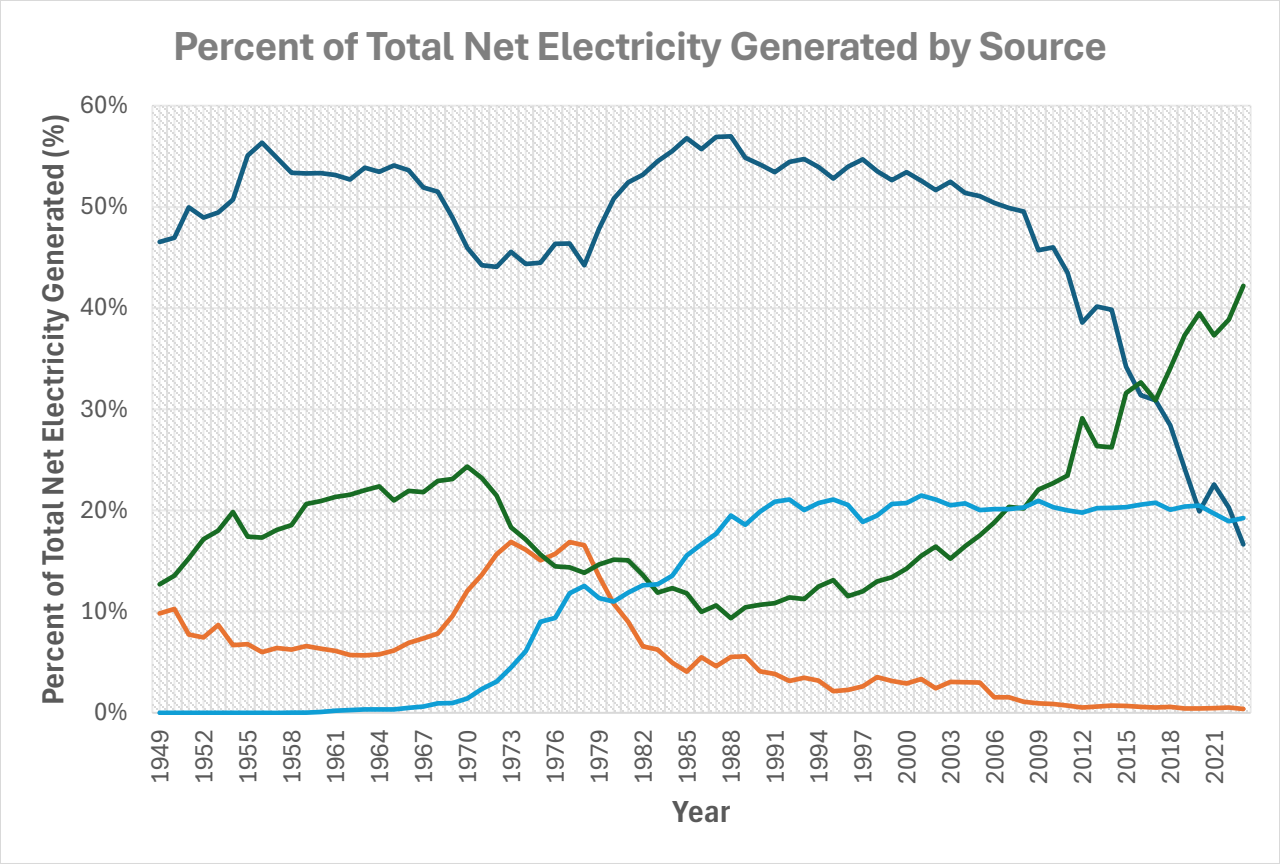
Net electricity generation, fuel consumption, and waste production

# NET ELECTRICITY GENERATION

- Decreasing trend in electricity generated from coal since 2008 and petroleum since 1978
- Increasing trend in electricity generated from natural gas since 1986
- Plateauing trend in electricity generated from nuclear since 2000
- More energy produced from nuclear than coal in 2023

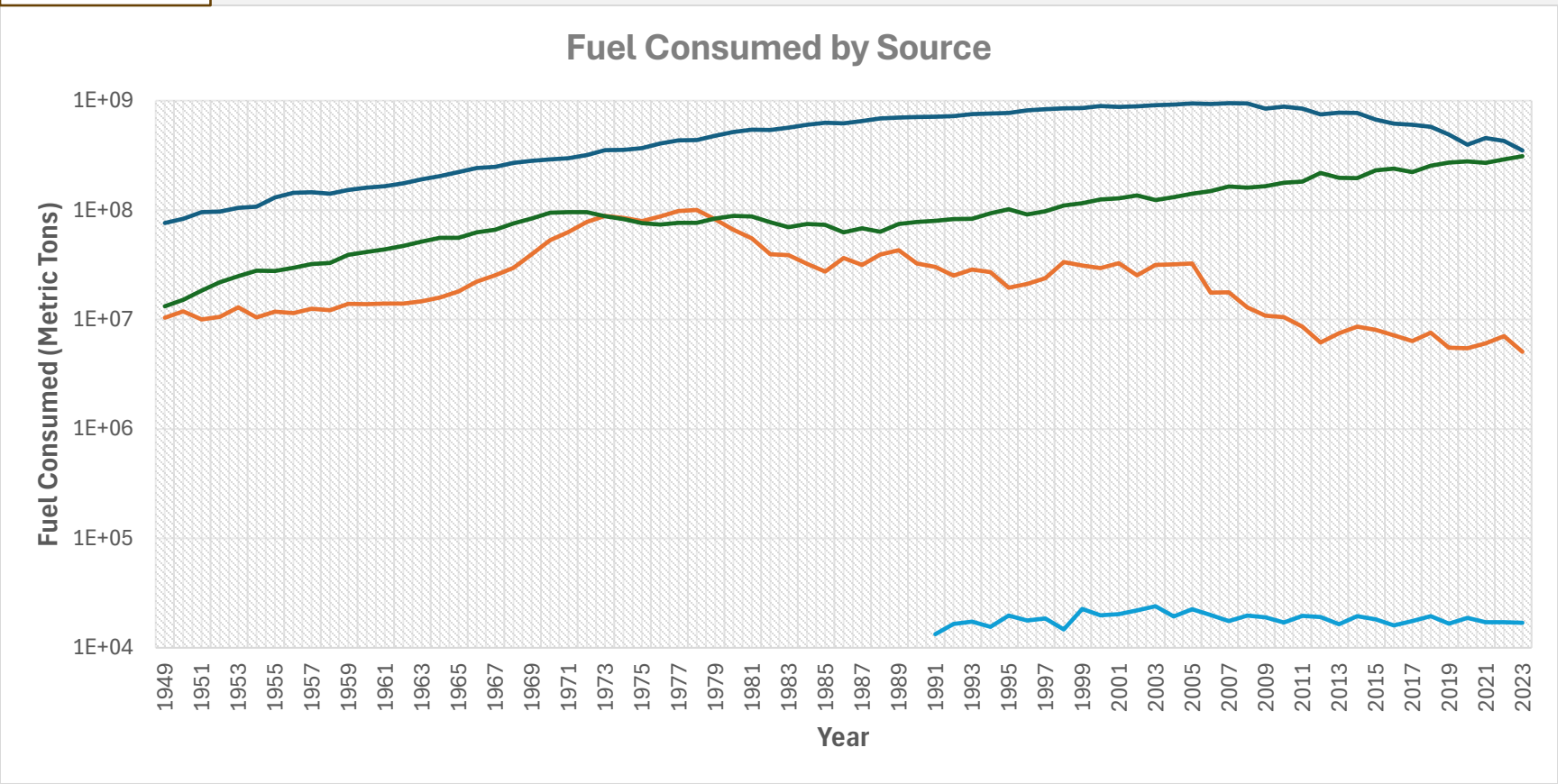
**LEGEND**
- Coal
- Petroleum
- Natural Gas
- Nuclear



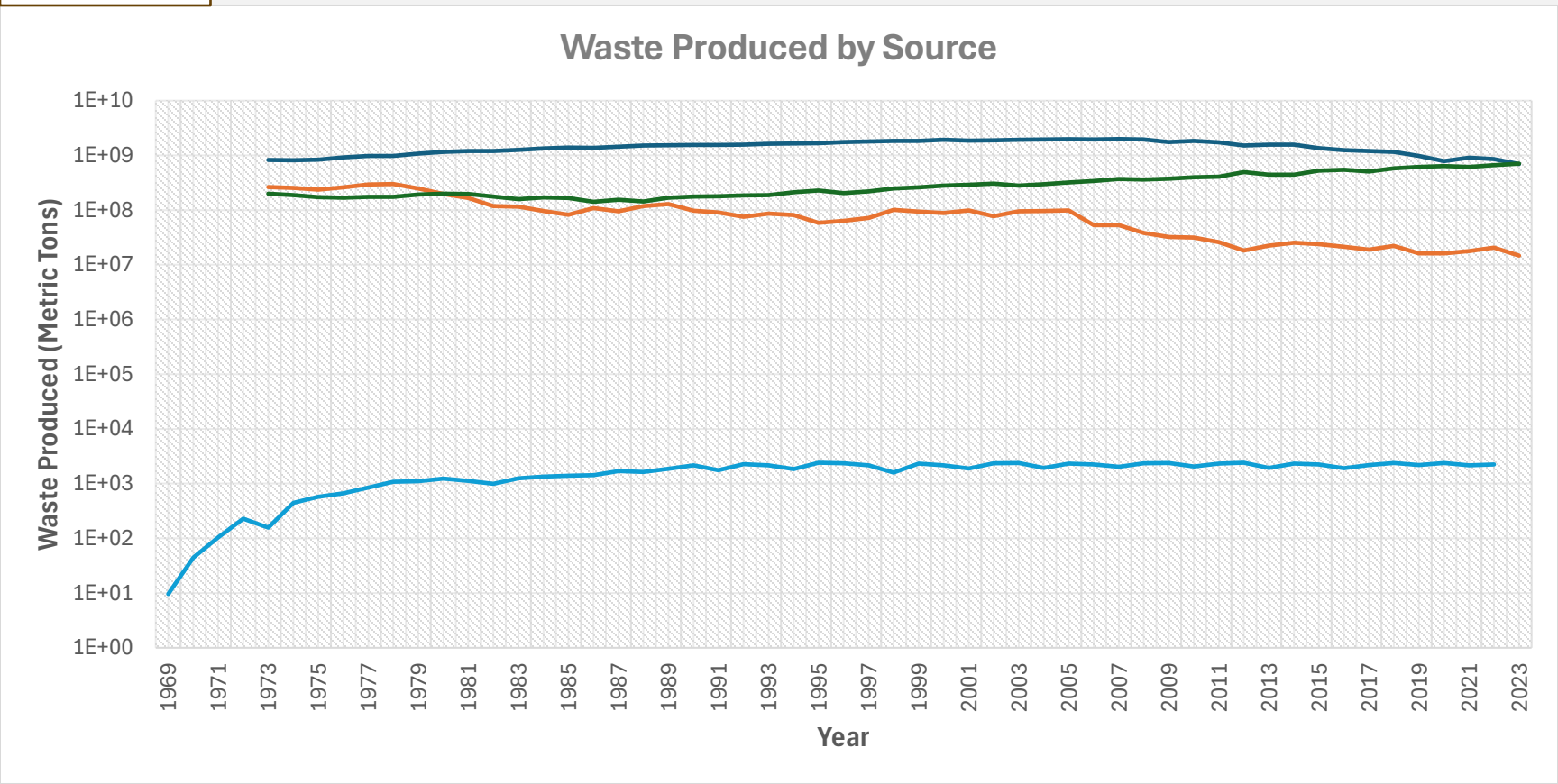
# FUEL CONSUMPTION

- Orders of magnitude more fuel consumed from fossil fuel sources than nuclear by mass
- Coal historically consumed the most fuel by mass
- Fuel consumption for fossil fuels follows net electricity generation



# WASTE PRODUCTION

- Waste from fossil fuels traced by CO2 emissions
- Waste from nuclear traced by mass of initial heavy metal of discharged assemblies
  - Non-fissionable waste removed from reactors
- Several orders of magnitude more CO2 emissions than nuclear waste



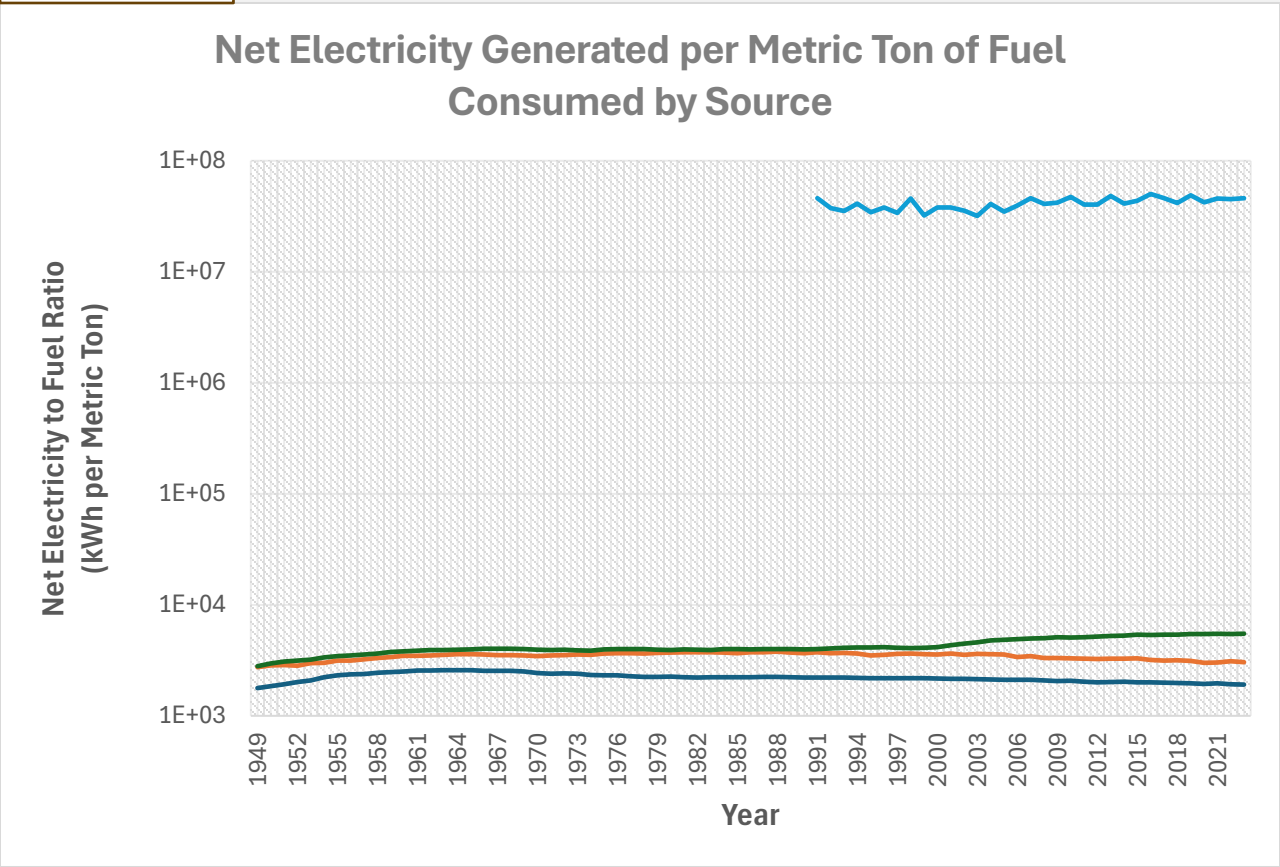
# ELECTRICITY, WASTE, AND FUEL

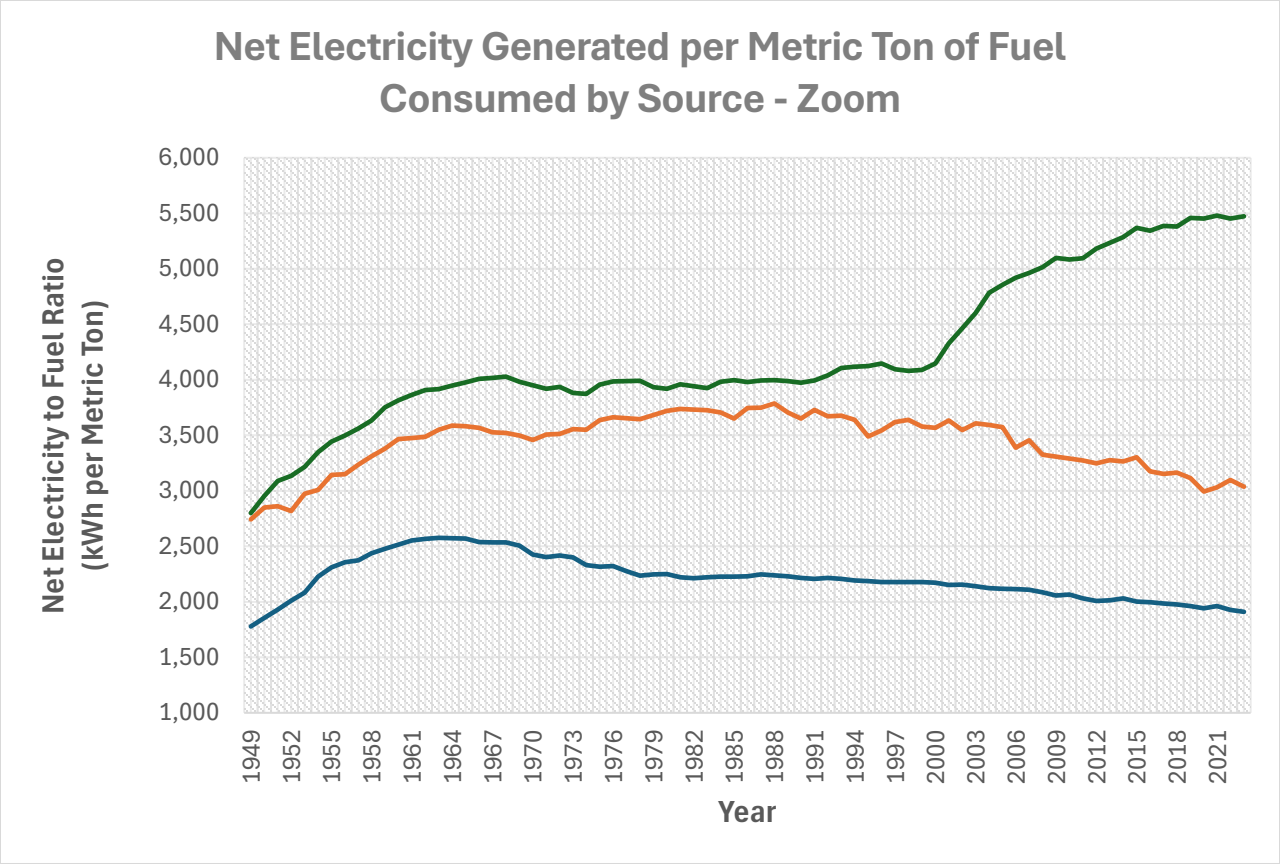
Relationships and dependencies

# NET ELECTRICITY & FUEL

- Nuclear generates the most electricity per metric ton of fuel
- Natural gas increase in electricity from fuel by mass since 2000
- Petroleum and coal following small decrease in efficiency
- Nuclear produced 8283 times the energy per metric ton of fuel than natural gas in 2022

**LEGEND**
- Coal
- Petroleum
- Natural Gas
- Nuclear

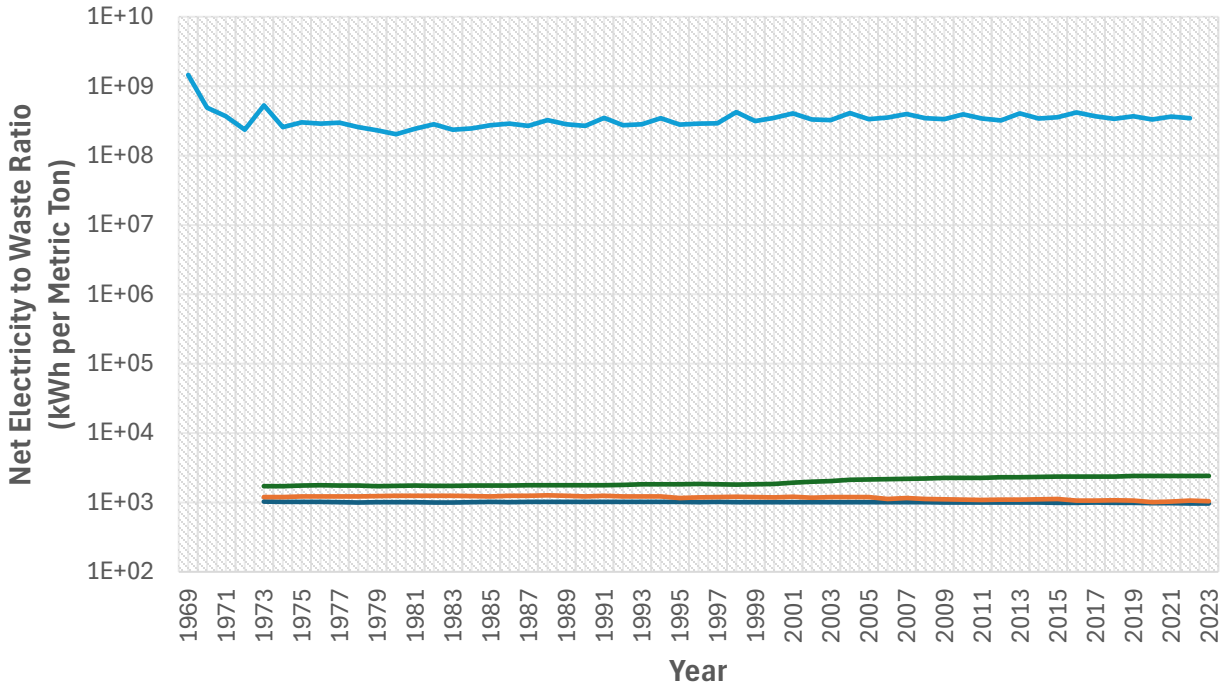


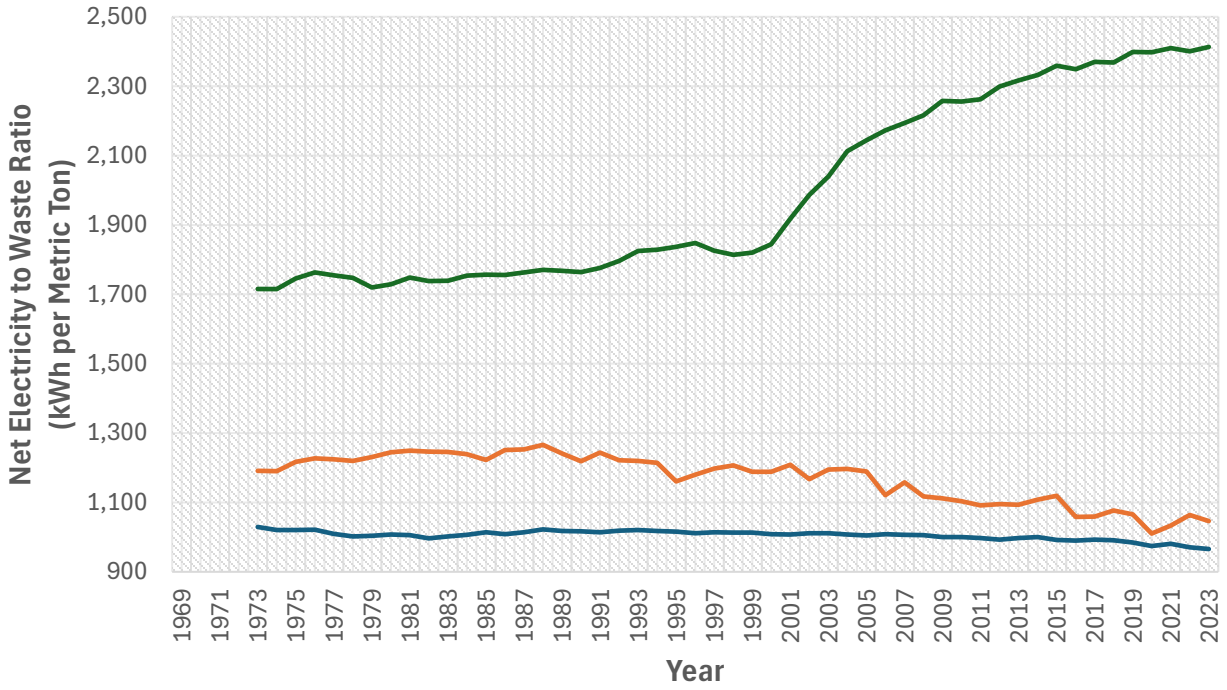



# NET ELECTRICITY & WASTE

- Nuclear generates the most electricity per metric ton of waste
- Fossil fuels follow similar trends in CO2 production compared to fuel consumption
- Nuclear produced 144,404 times more energy per metric ton of waste than natural gas in 2022

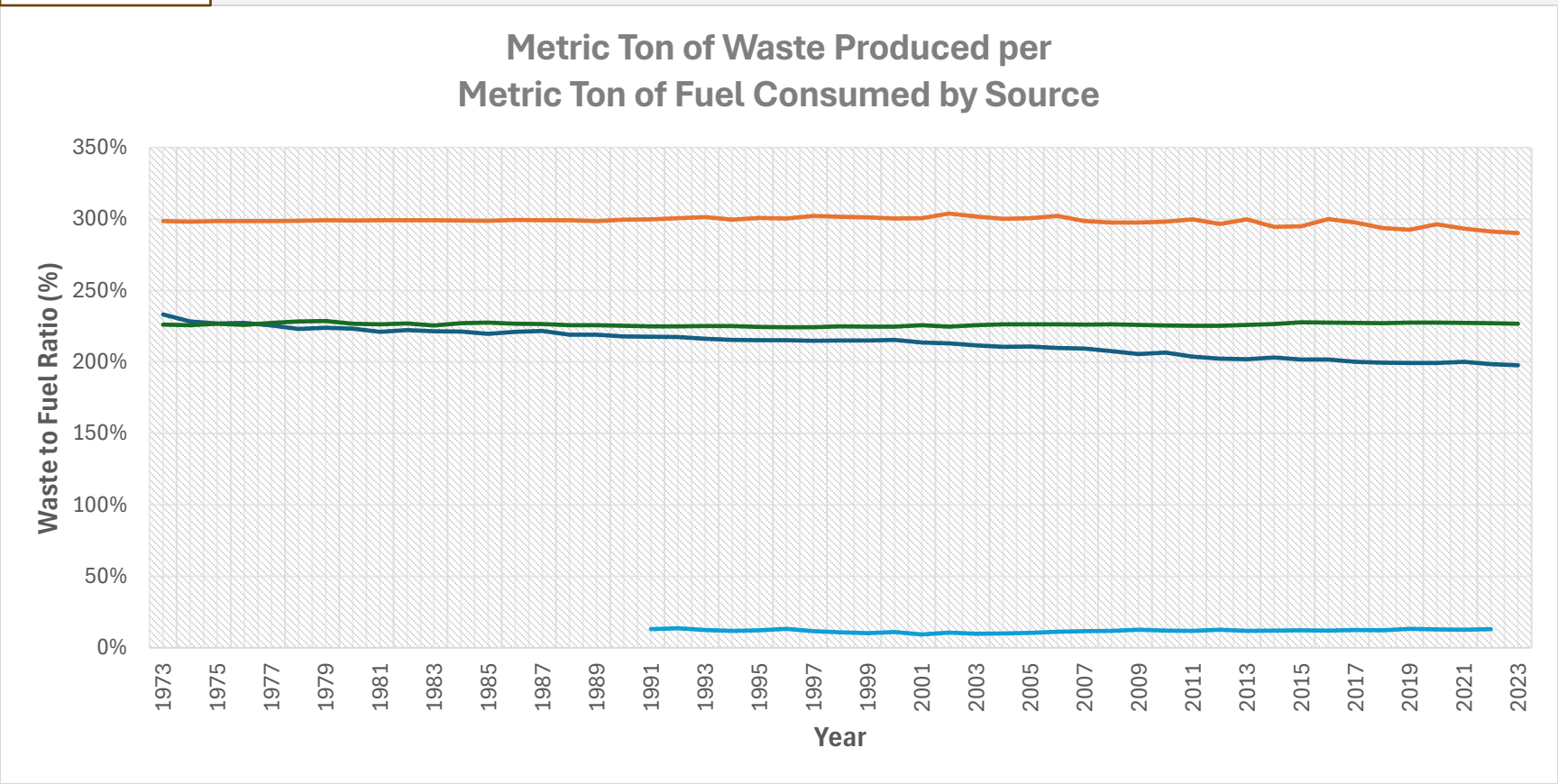
**LEGEND**
- Coal
- Petroleum
- Natural Gas
- Nuclear



# WASTE & FUEL

- Nuclear is only source that produces less waste than fuel consumed by mass
  - 15 times smaller ratio than coal in 2022
- Petroleum creates four times as much waste to fuel by mass
- Coal is only source that shows strong decrease in ratio
  - ~36% over the past 40 years



# SIMULATED NUCLEAR INCREASE

Historically increasing net electricity generation from nuclear by 10% and 25%

# DESCRIPTION OF METHOD

- Increased the amount of electricity produced by nuclear by a set percent each year
- Equally split the extra electricity into three parts and subtracted it from coal, petroleum, and natural gas electricity generation
- For cases when electricity from petroleum was reduced to zero, all surplus was subtracted from coal
- Fraction of total net electricity generation from coal, petroleum, natural gas, and nuclear was kept the same as in the original data
- Fuel and waste estimated were found by multiplying the estimated electricity generated by the electricity to fuel/waste ratios

# 10% NUCLEAR POWER INCREASE (1)

- Increasing the historical amount of net electricity produced from nuclear by 10% each year
- Small reduction in fossil fuel electricity generation
- Largely the same as original data

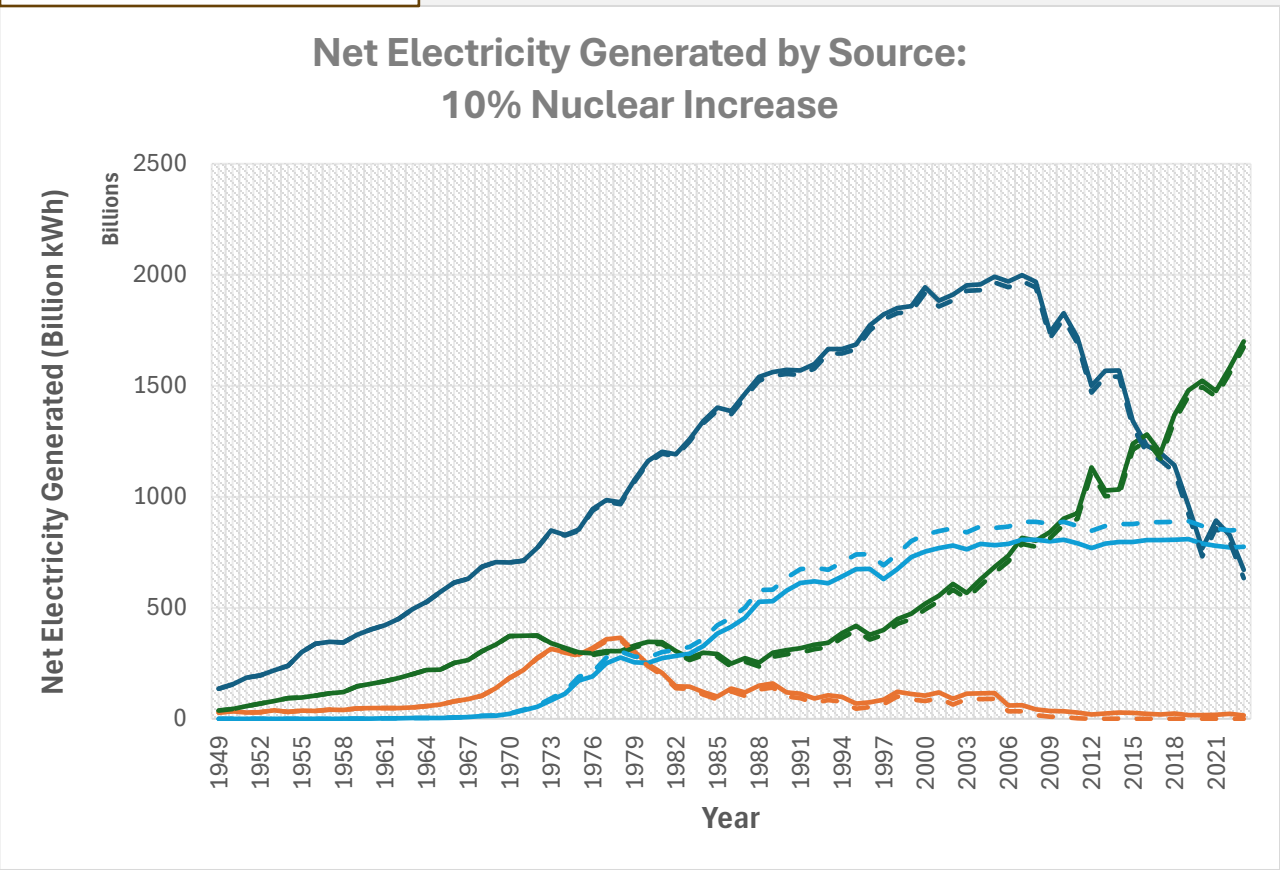
**LEGEND**

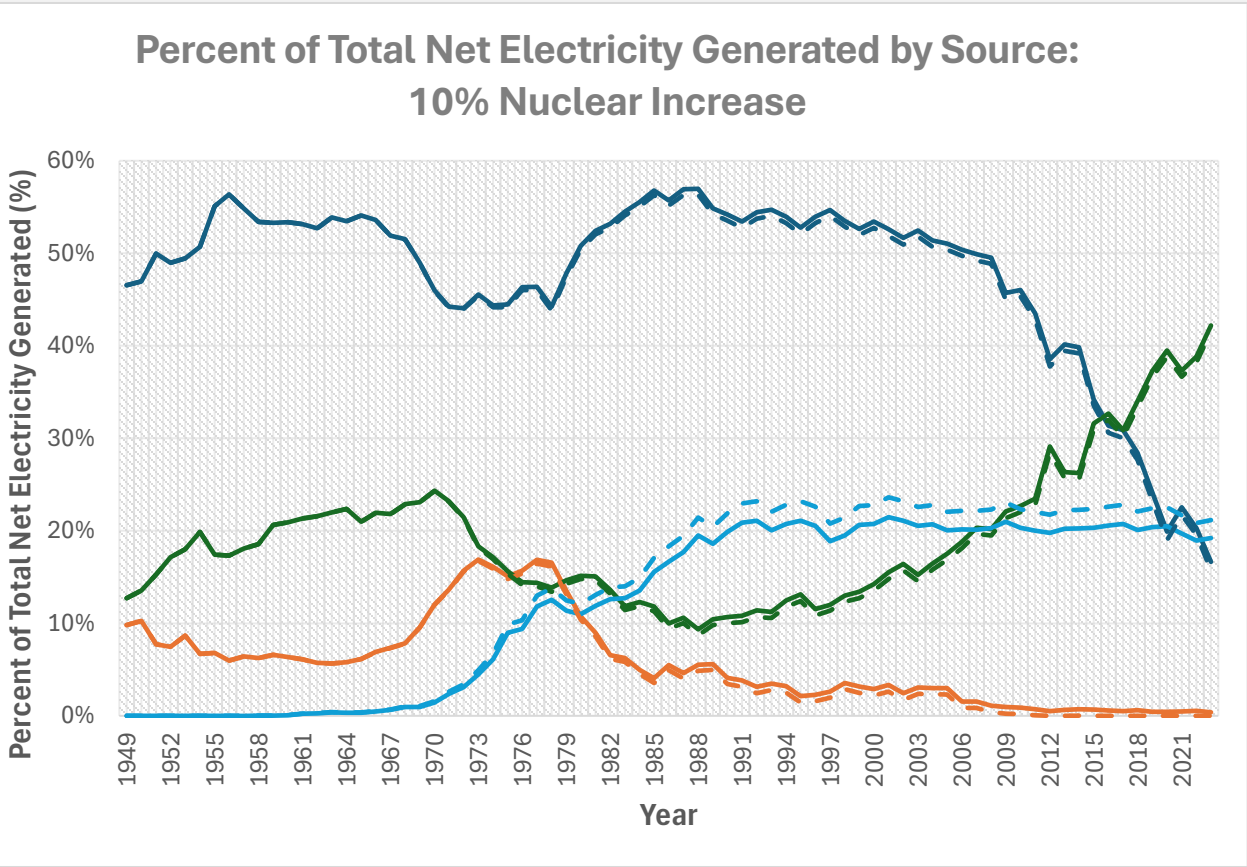
Coal — Original

Petroleum - - - Simulated

Natural Gas

Nuclear

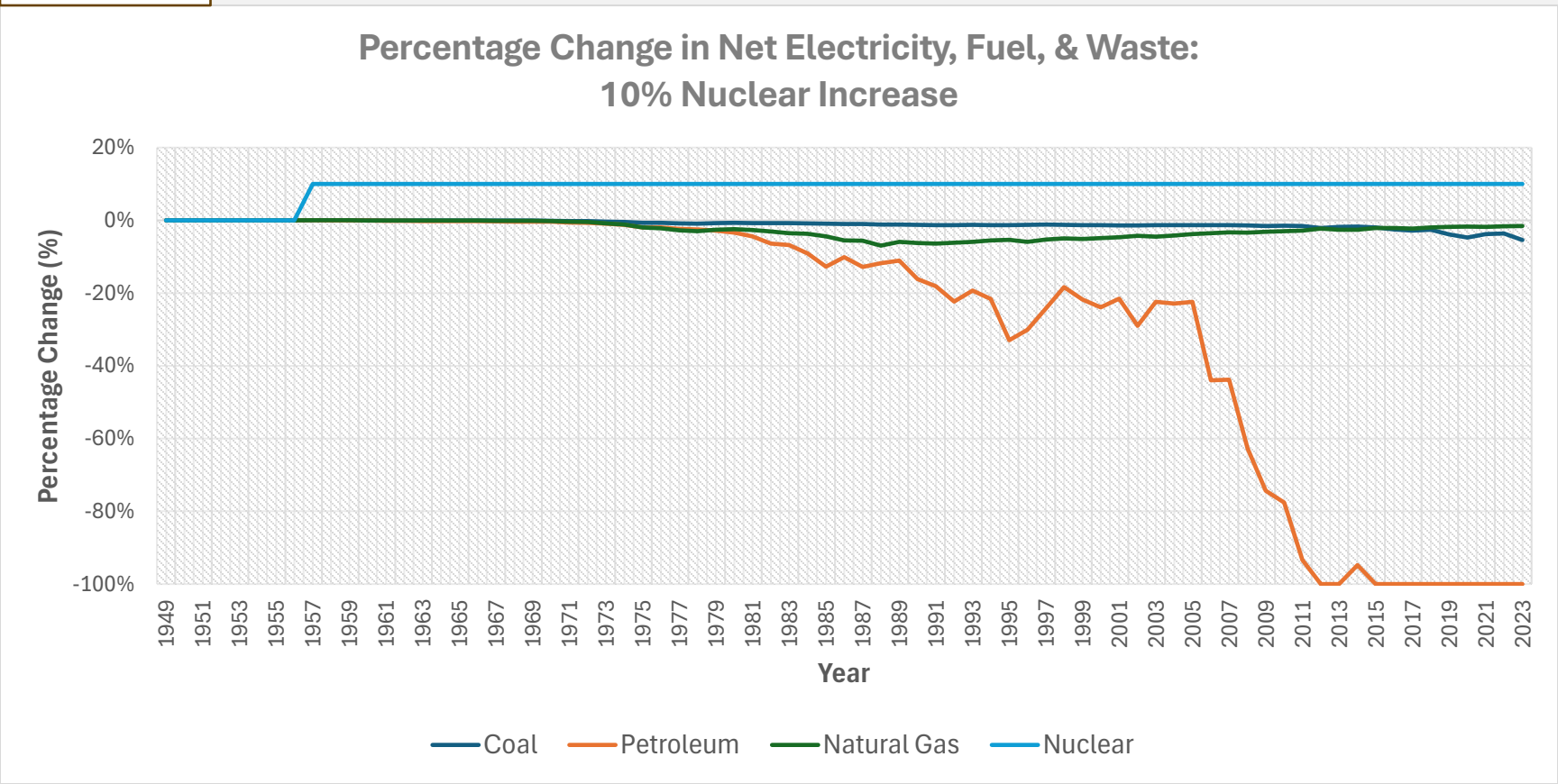


# 10% NUCLEAR POWER INCREASE (2)

- Difference in net electricity, fuel, and waste were equivalent
- Maximum reduction in coal by 5.41%
- Maximum reduction in natural gas by 6.95%
- Petroleum fully reduced from 2012 onward aside from 2014 spike

**LEGEND**
- Coal
- Petroleum
- Natural Gas
- Nuclear

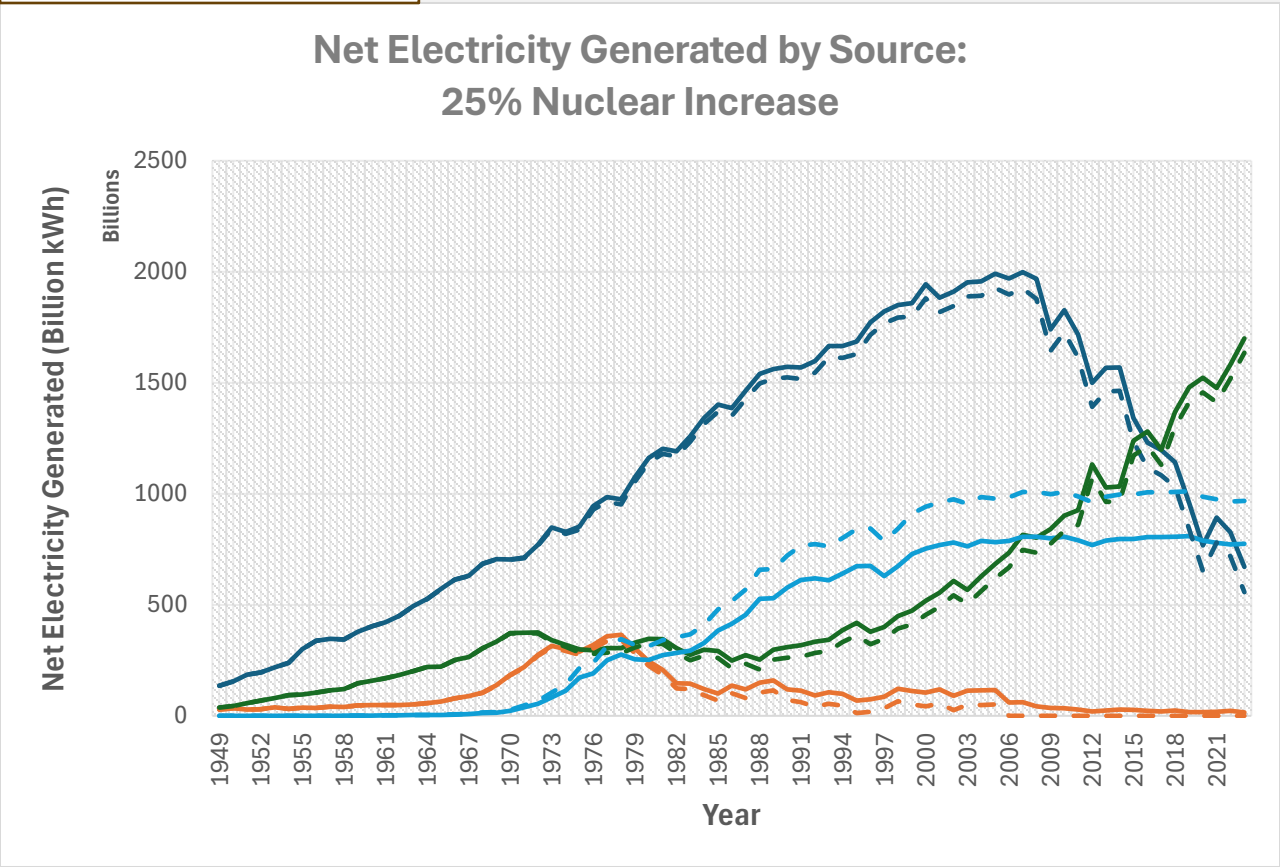


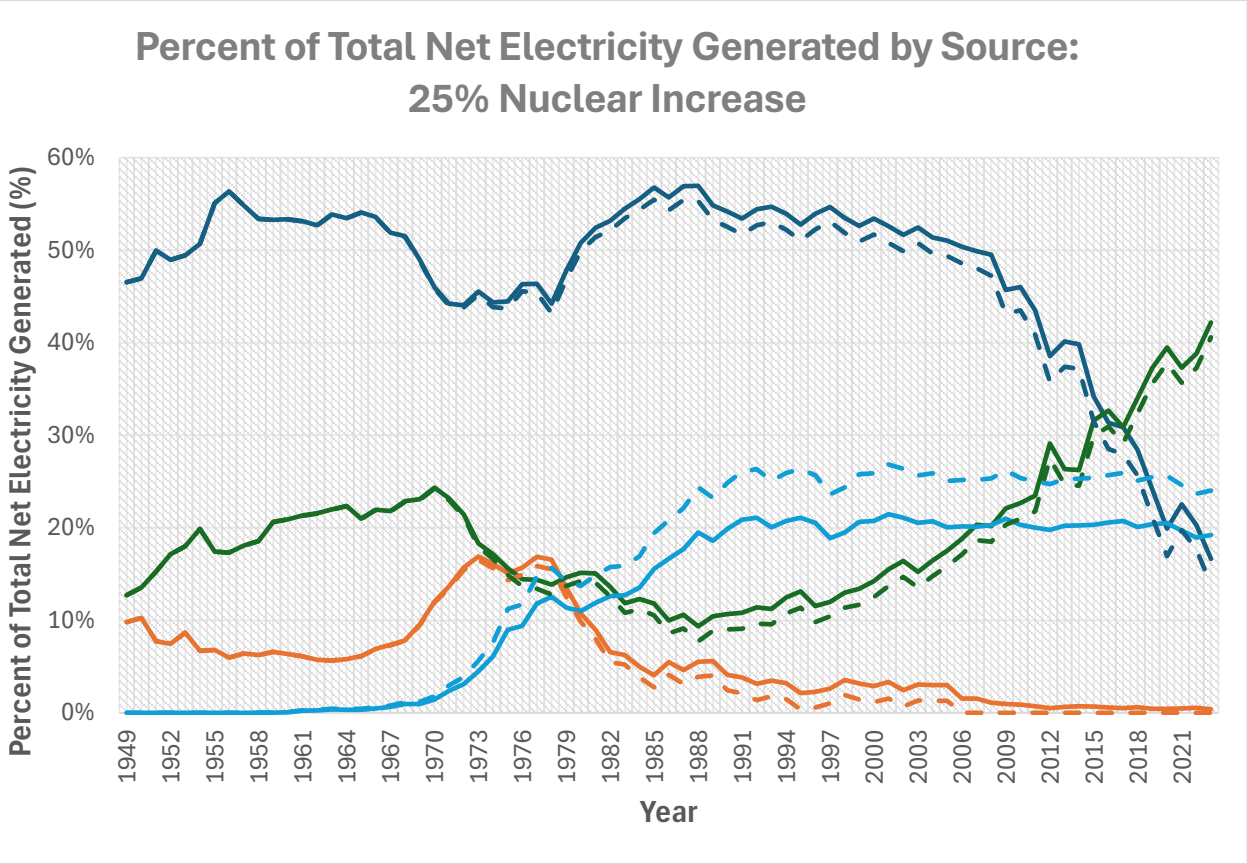
# 25% NUCLEAR POWER INCREASE (1)

- Increasing the historical amount of net electricity produced from nuclear by 25% each year
- Noticeable difference in all sources after 1980

**LEGEND**

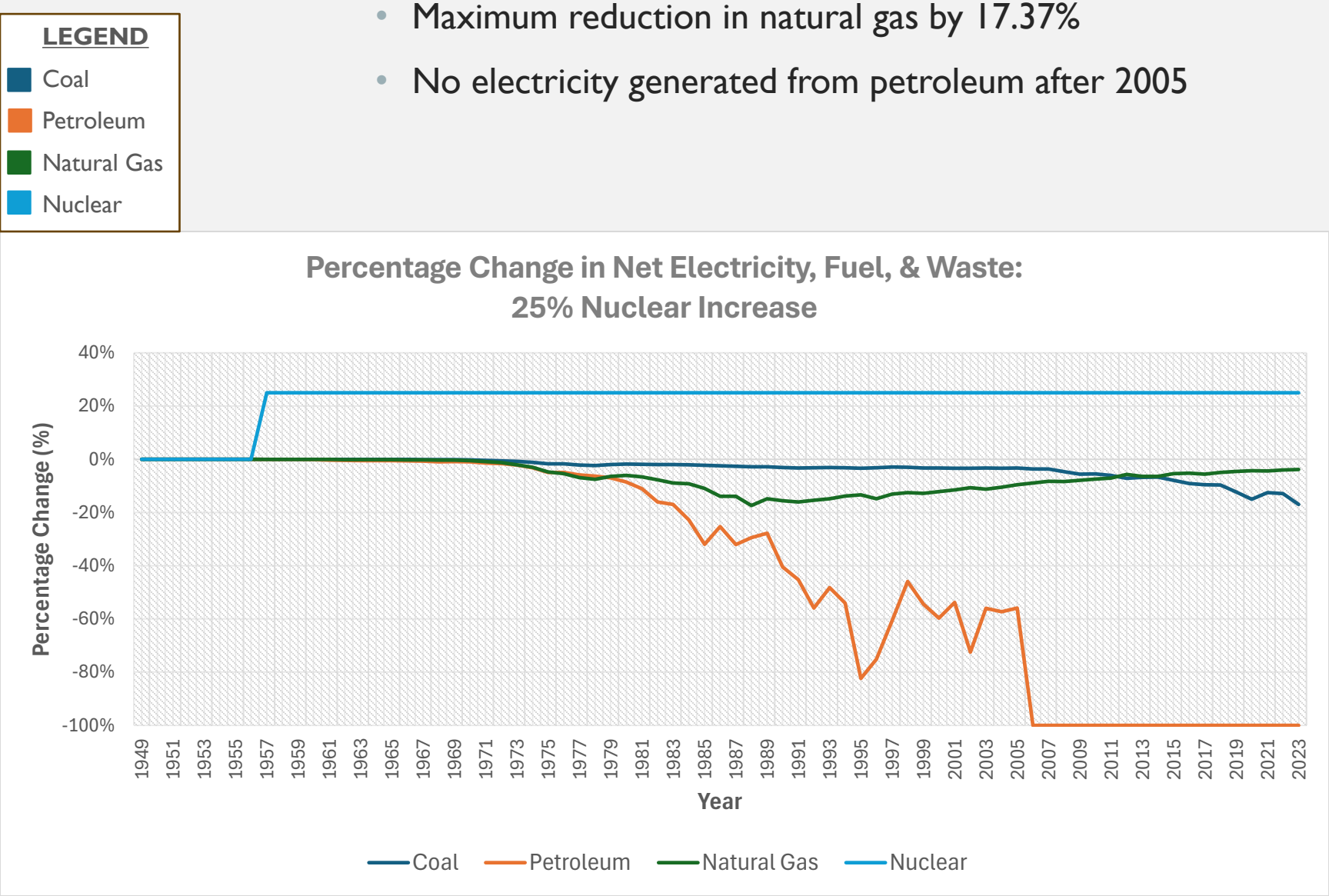
Coal — Original
Petroleum - - Simulated
Natural Gas
Nuclear



# 25% NUCLEAR POWER INCREASE (2)

- Maximum reduction in coal by 16.96%
- Maximum reduction in natural gas by 17.37%
- No electricity generated from petroleum after 2005



# RESULTS

Final conclusions and recommendations for the future

# CONCLUSION OF FINDINGS

Q1

- Fossil fuels have had volatile history of electricity generation
- Nuclear electricity generation has plateaued
- Much more fossil fuel consumption and CO2 production than nuclear counterparts

Q2

- Nuclear generates more electricity per metric ton of fuel consumed and waste produced than any other source examined
- Natural gas is the cleanest fossil fuel out of those examined

Q3

- The amount of CO2 reduced depends on the amount of additional electricity generated by nuclear
- Focusing a reduction on a dirtier fossil fuel like coal or petroleum will help reduce more CO2 emissions per kilowatt-hour of electricity

# RECOMMENDATIONS

- Nuclear energy should be prioritized to help reduce CO2 emissions from dirty fossil fuels like coal and petroleum
- Even a 10% increase in nuclear energy could remove petroleum from being used to generate electricity
  - This would mean adding ~9 nuclear reactors based on the current U.S. count of 94[3]
- There is currently no source that yields a better fuel/waste to energy output ratio than nuclear
- Focusing on nuclear energy will lead to further advancements to make it safer and cheaper
- Below are further readings about nuclear energy published by the World Nuclear Association
  - Radioactive Waste – Myths and Realities
  - Nuclear Power in the USA

# REFERENCES


1. U.S. Energy Information Administration. (2025). *Monthly Energy Review February 2025*. https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf
2. U.S. Department of Energy. (2022). *Nuclear Fuel Data Survey*. https://gc859.pnnl.gov/summary/table2
3. World Nuclear Association. (2024, August 27). *Nuclear Power in the USA*. https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power#notes-amp-references

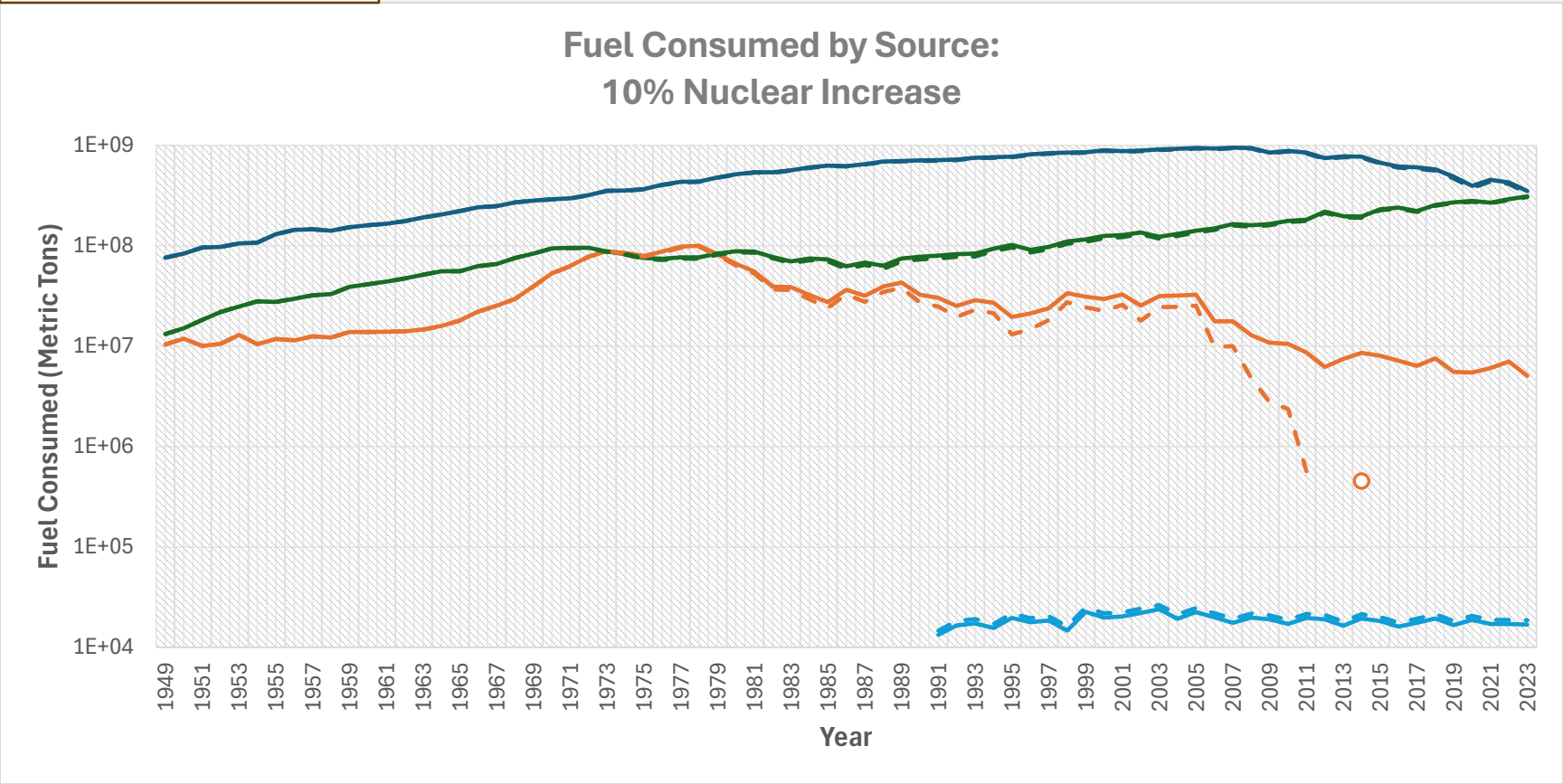
# APPENDIX FIGURES

Nuclear increase of 50% and 100% + additional 10% and 25% plots

# 10% NUCLEAR POWER INCREASE (3)

**LEGEND**

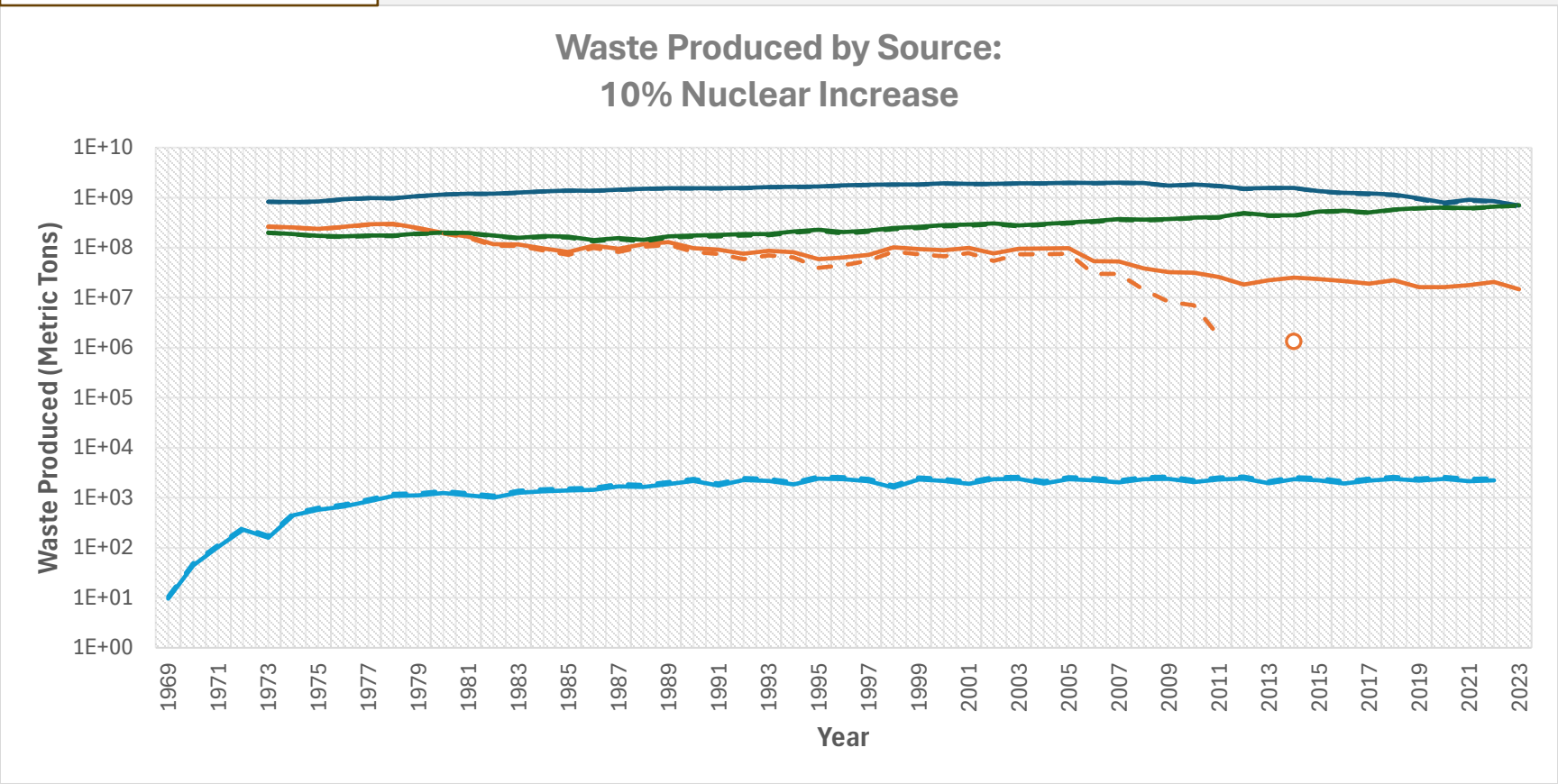
- Coal
- Petroleum
- Natural Gas
- Nuclear
- Original
- Simulated



# 10% NUCLEAR POWER INCREASE (4)

**LEGEND**

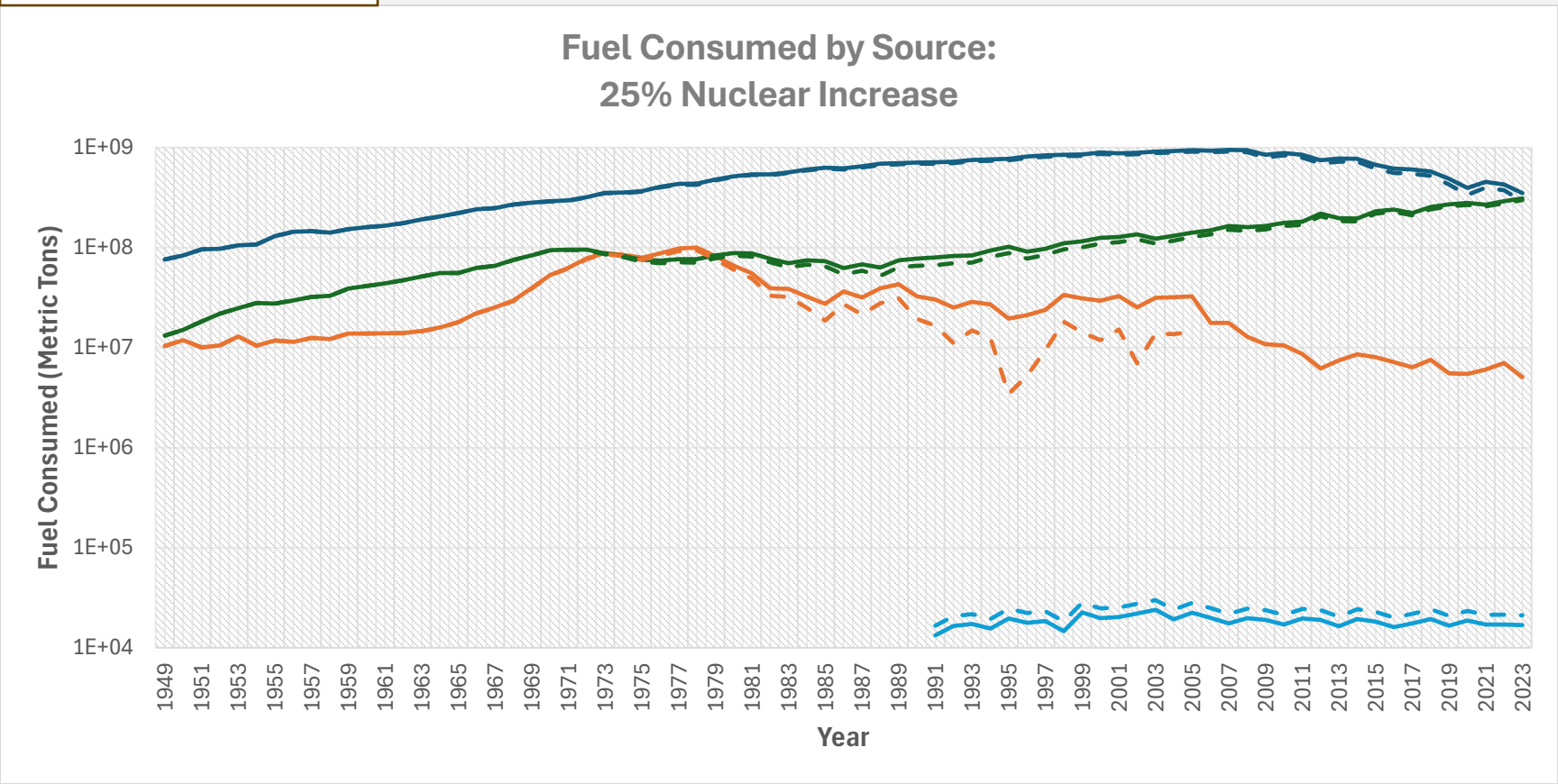
- Coal
- Petroleum
- Natural Gas
- Nuclear
- Original
- Simulated



# 25% NUCLEAR POWER INCREASE (3)

**LEGEND**

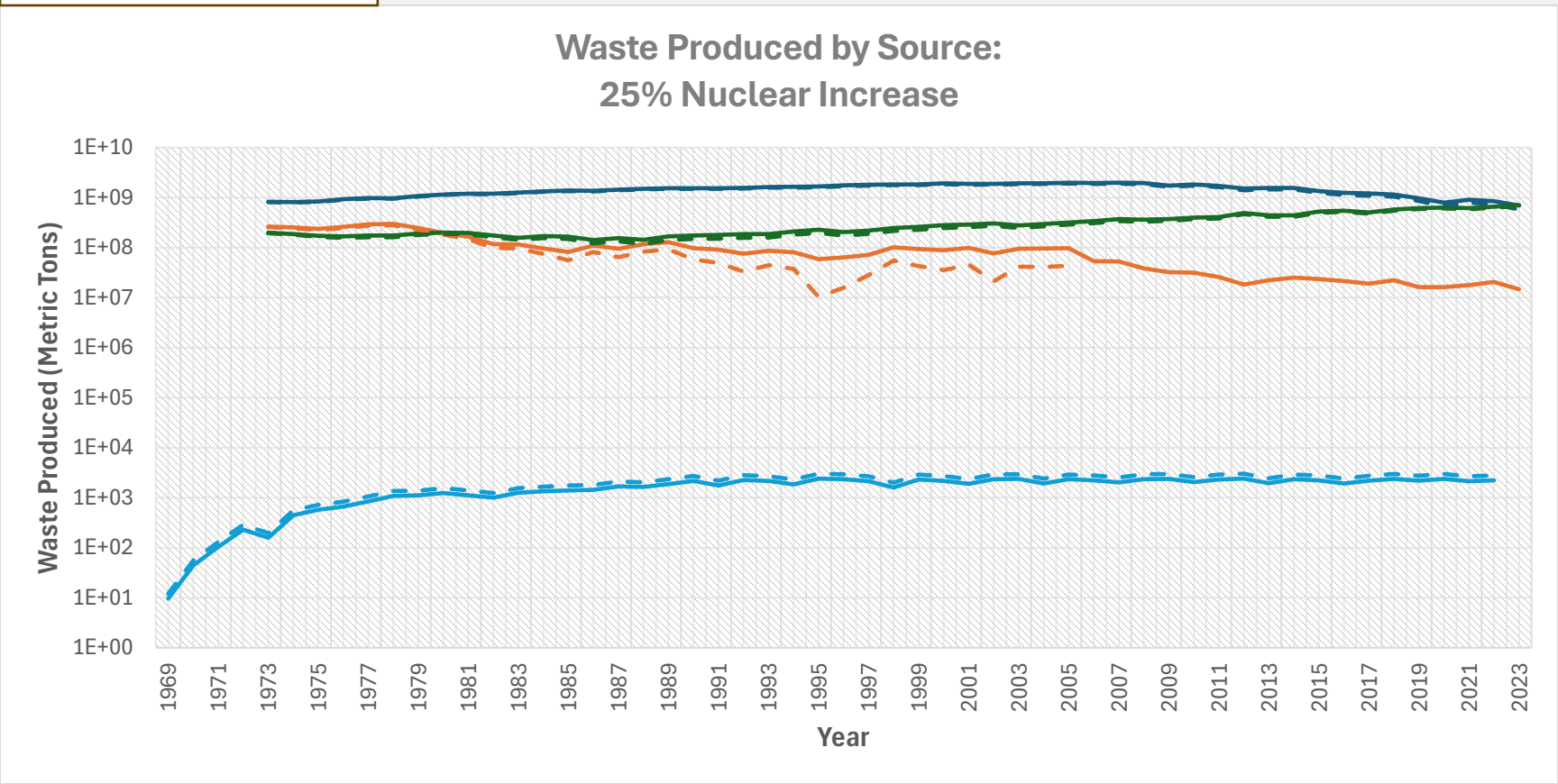
- Coal
- Petroleum
- Natural Gas
- Nuclear
- — Original
- - - Simulated



# 25% NUCLEAR POWER INCREASE (4)

**LEGEND**

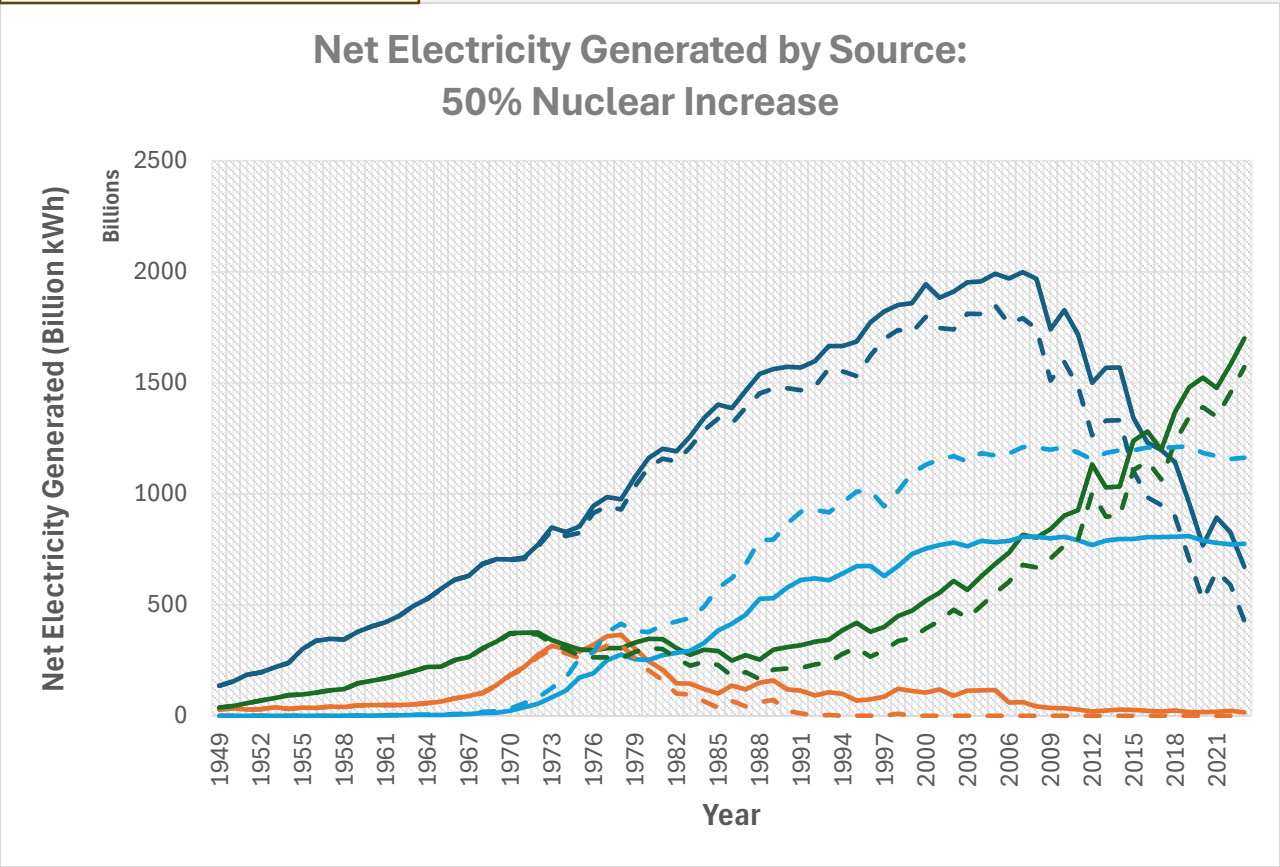
- Coal
- Petroleum
- Natural Gas
- Nuclear
- — Original
- - - Simulated

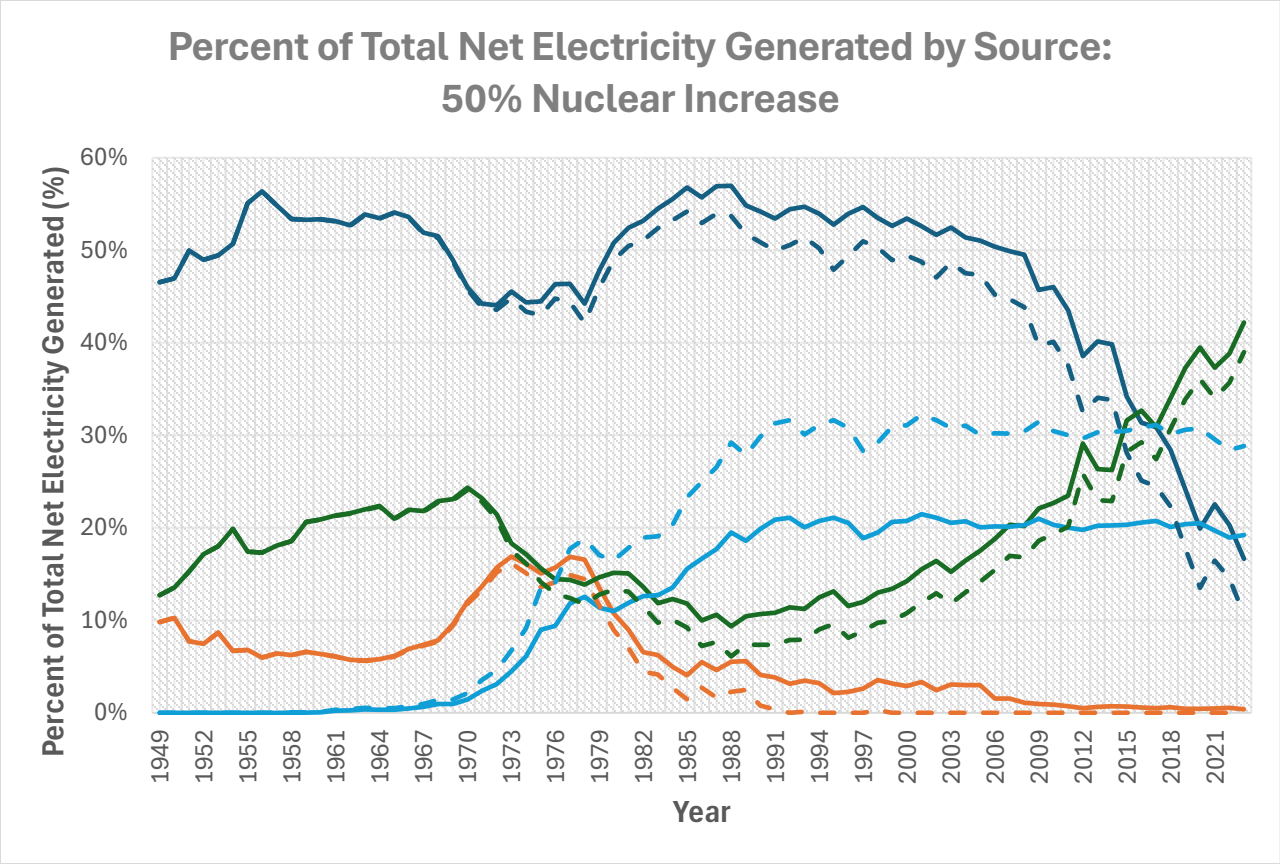


# 50% NUCLEAR POWER INCREASE (1)

**LEGEND**

- Coal
- Petroleum
- Natural Gas
- Nuclear
- — Original
- - - Simulated

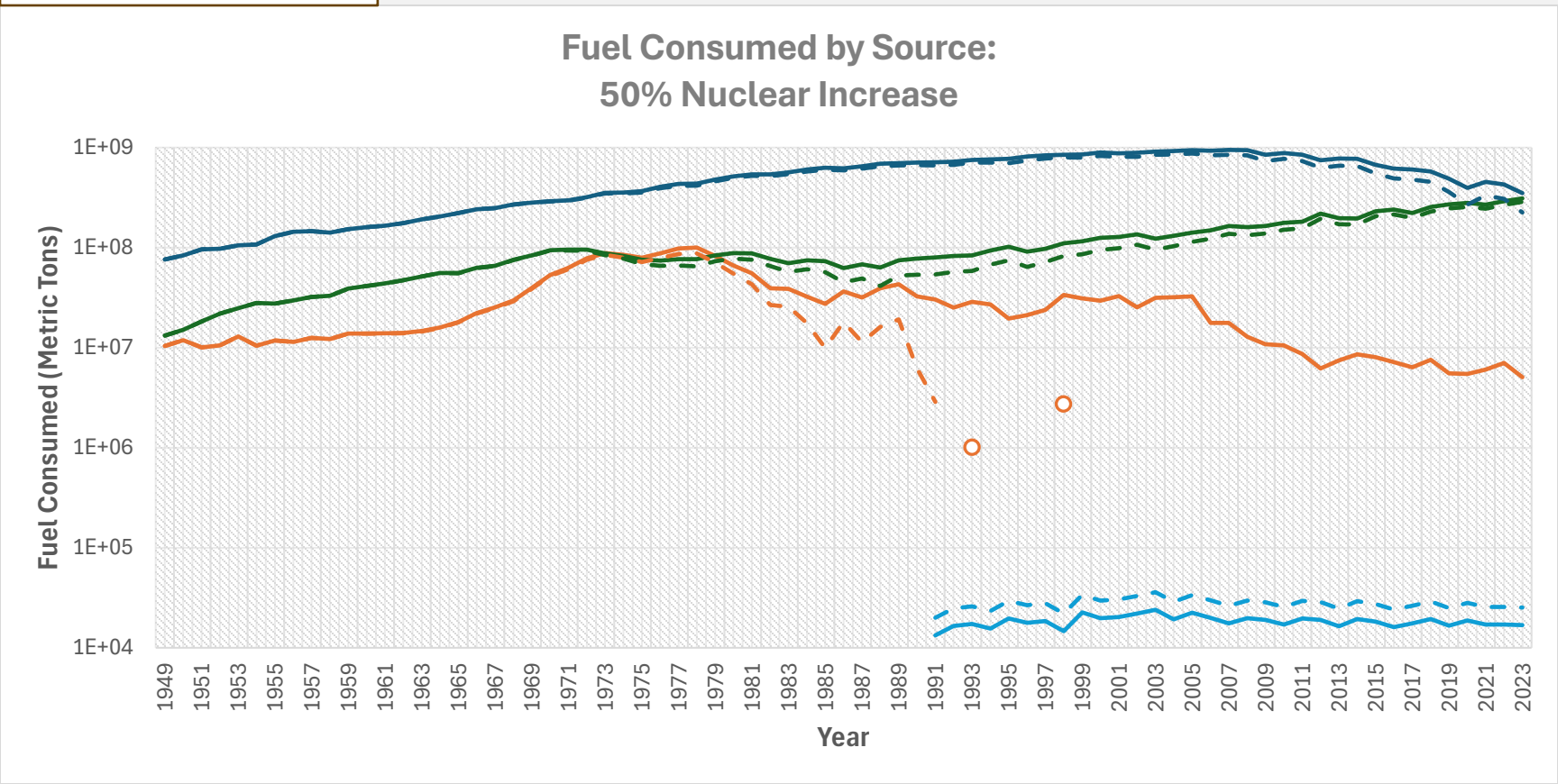


# 50% NUCLEAR POWER INCREASE (2)

**LEGEND**

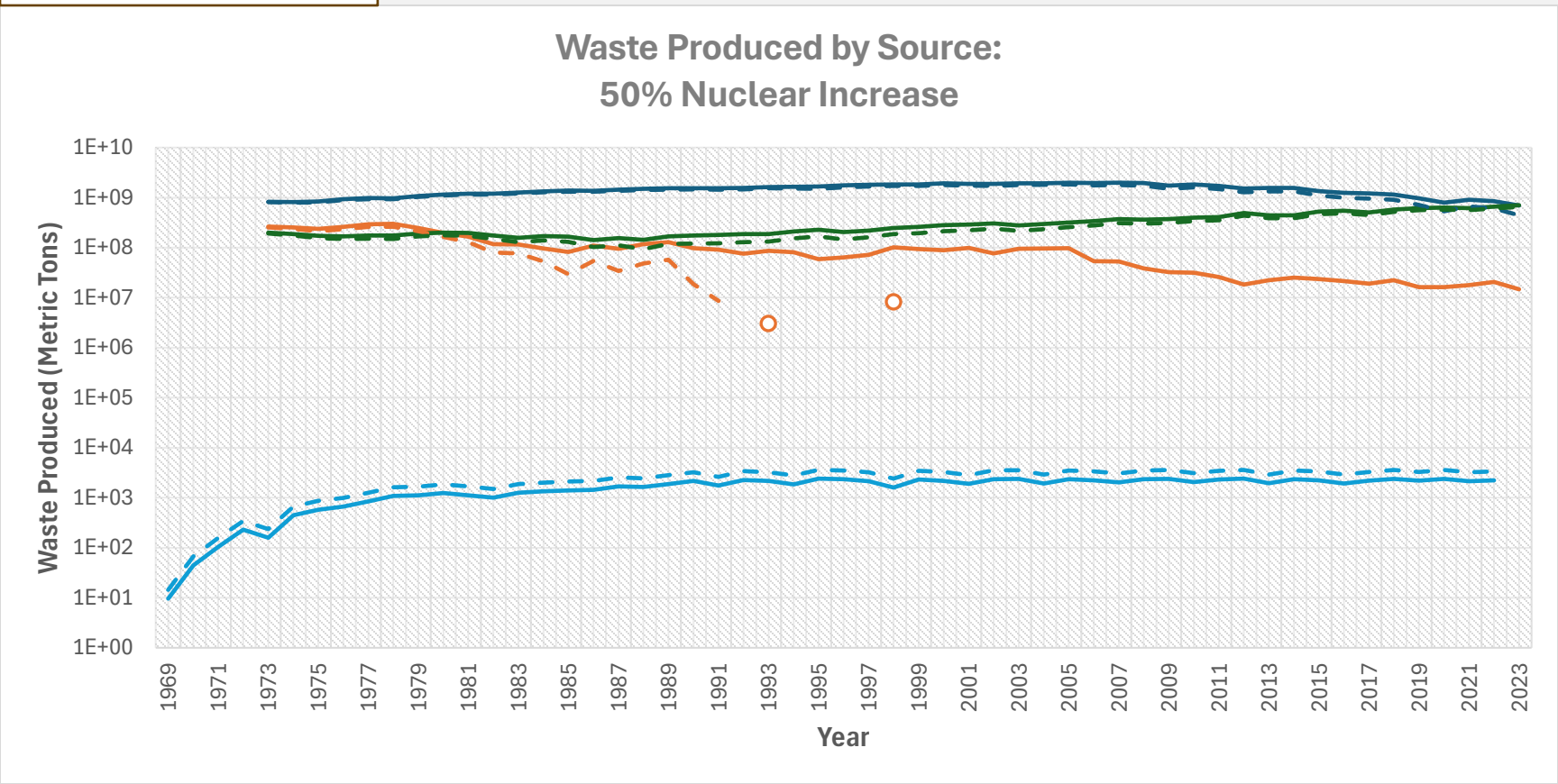
- Coal
- Petroleum
- Natural Gas
- Nuclear
- Original
- Simulated



# 50% NUCLEAR POWER INCREASE (3)

**LEGEND**

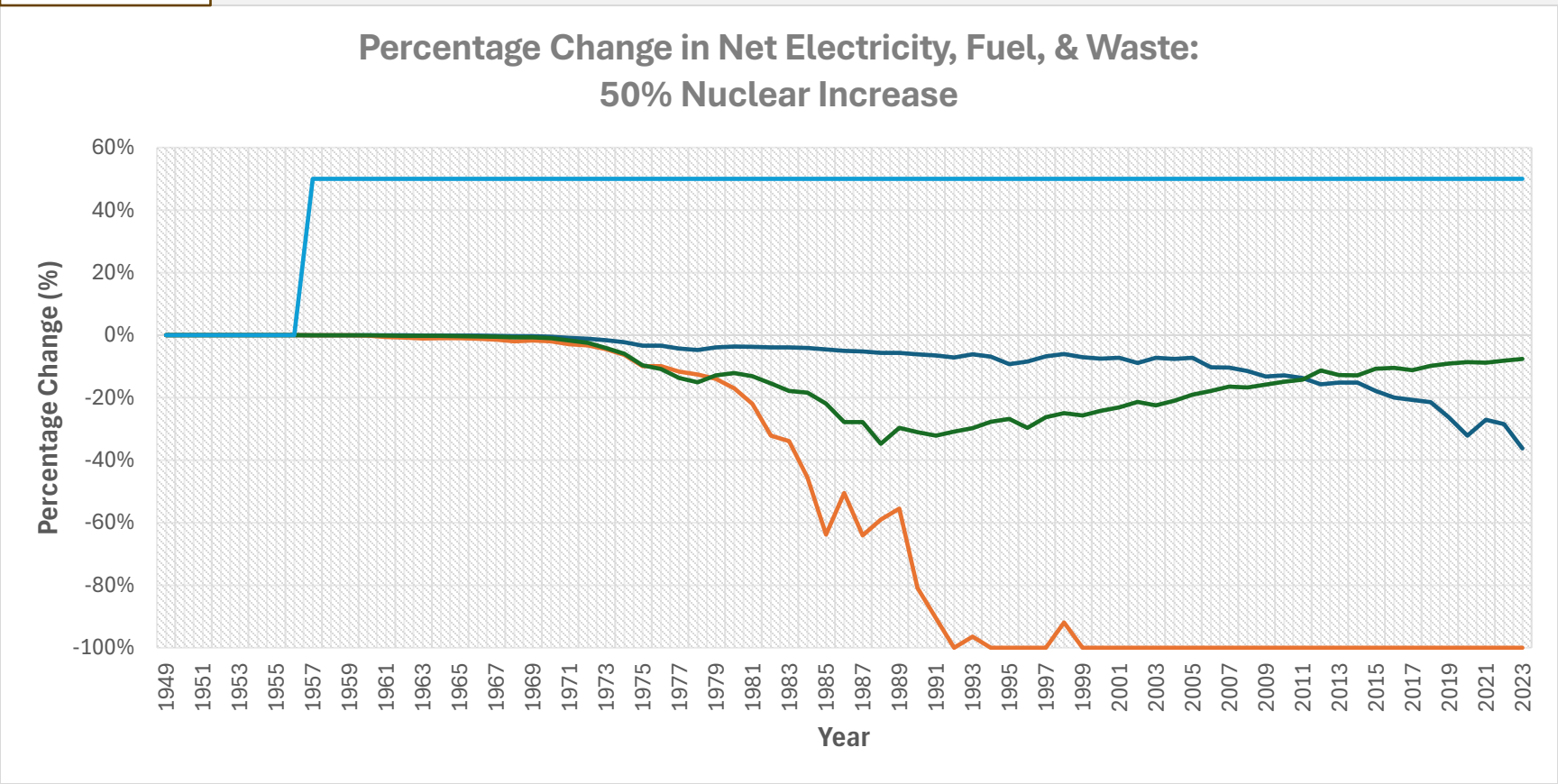
- Coal
- Petroleum
- Natural Gas
- Nuclear
- — Original
- - - Simulated



# 50% NUCLEAR POWER INCREASE (4)

**LEGEND**

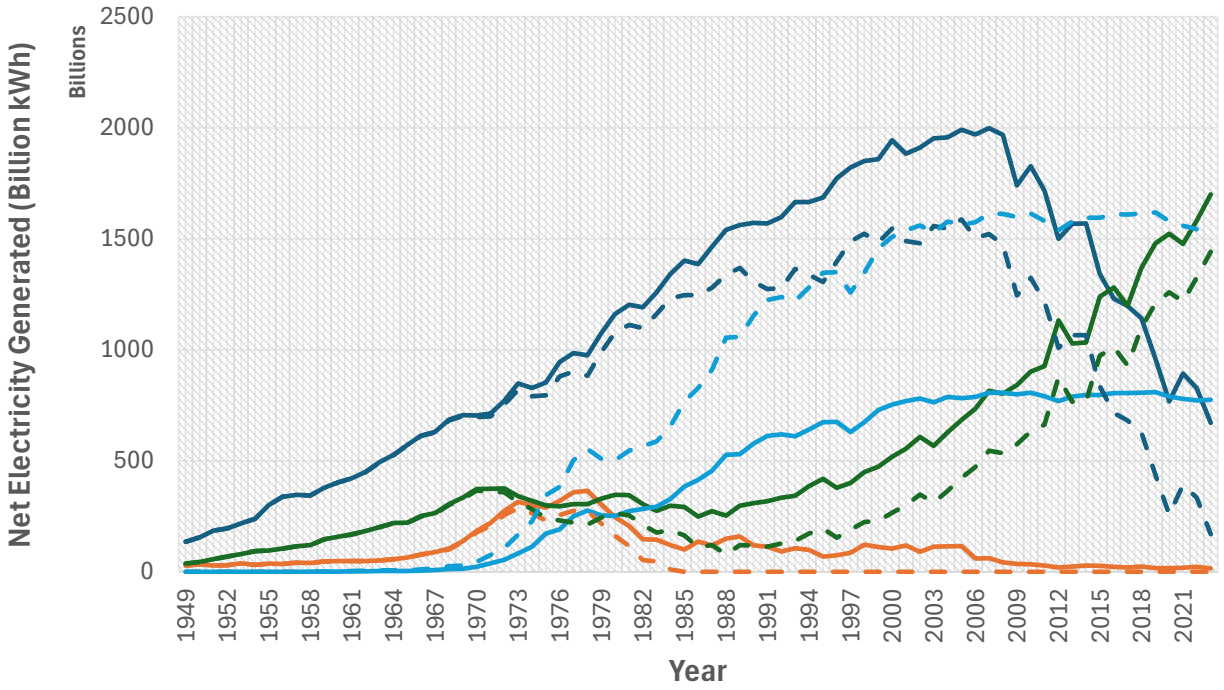
- Coal
- Petroleum
- Natural Gas
- Nuclear

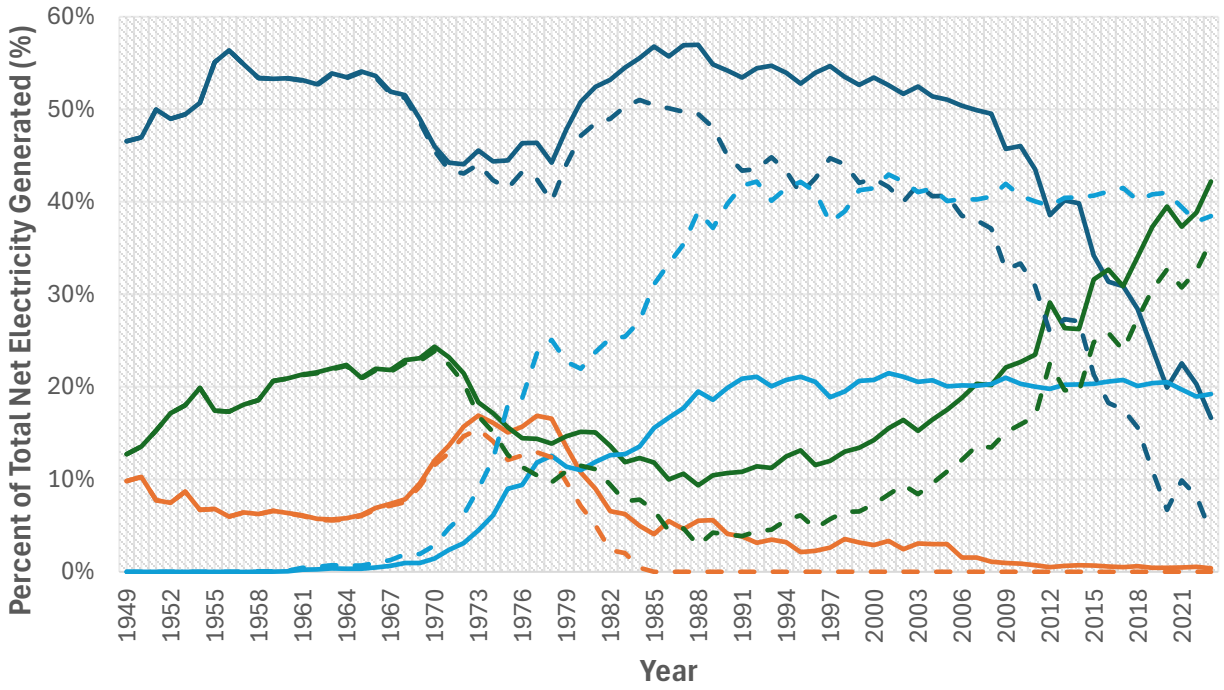


# 100% NUCLEAR POWER INCREASE (1)

**LEGEND**

- Coal
- Petroleum
- Natural Gas
- Nuclear
- — Original
- - - Simulated

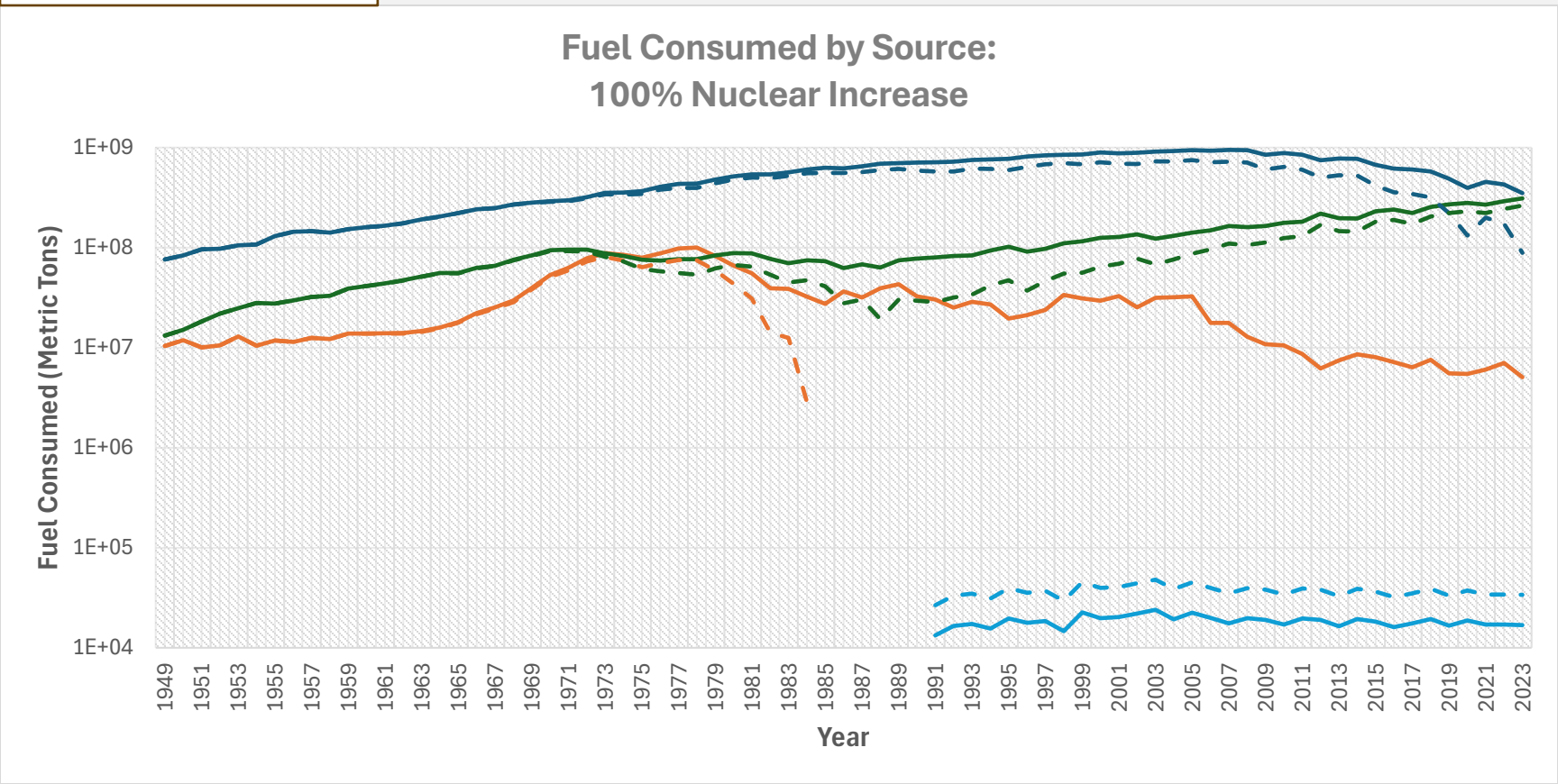


# 100% NUCLEAR POWER INCREASE (2)

**LEGEND**

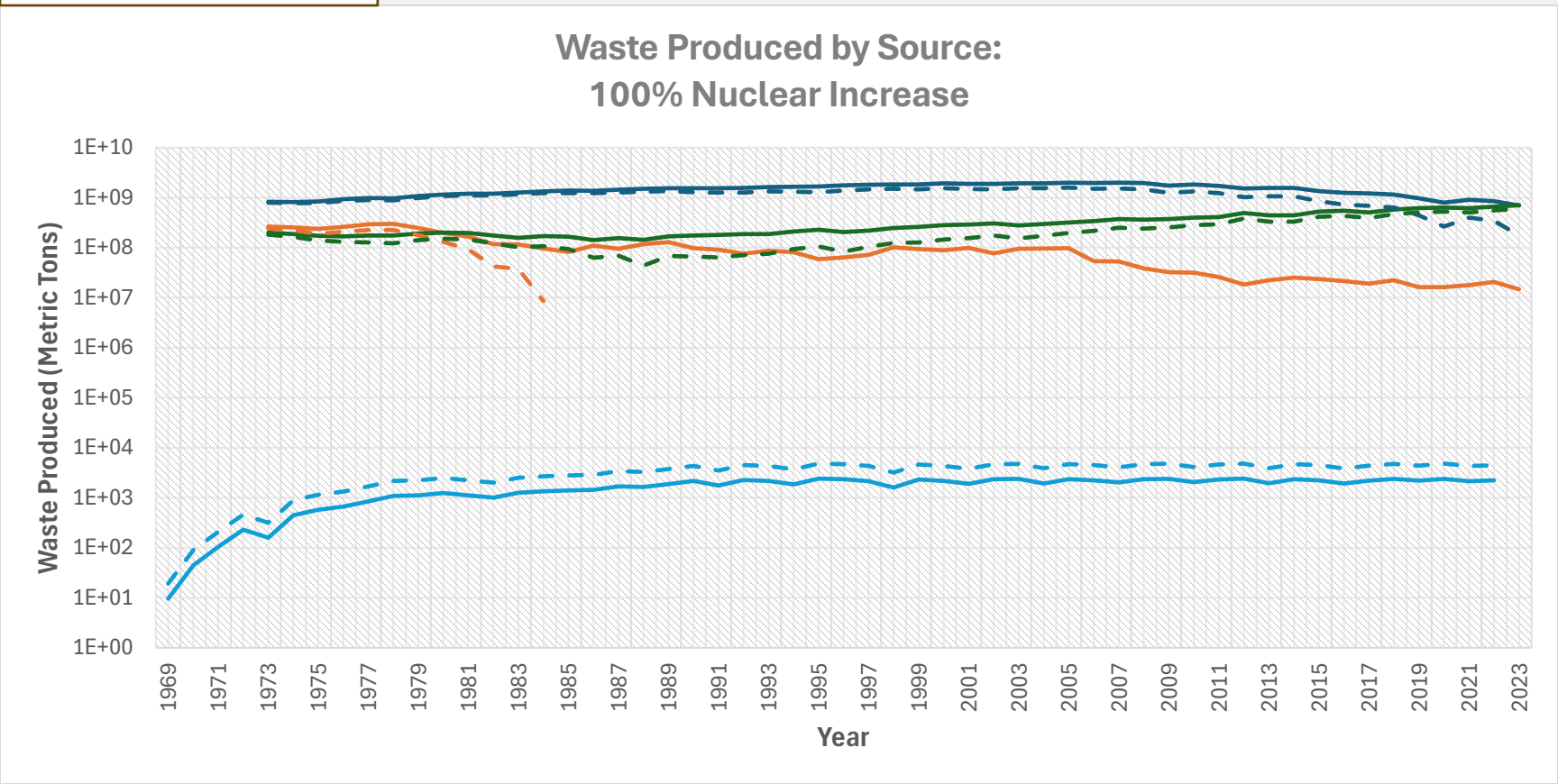
- Coal
- Petroleum
- Natural Gas
- Nuclear
- Original
- Simulated



# 100% NUCLEAR POWER INCREASE (3)

**LEGEND**

- Coal
- Petroleum
- Natural Gas
- Nuclear
- — Original
- - - Simulated



# 100% NUCLEAR POWER INCREASE (4)

**LEGEND**

- Coal
- Petroleum
- Natural Gas
- Nuclear