

# **Comparative Life Cycle Air Emissions of Coal, Domestic Natural Gas, LNG, and SNG for Electricity Generation**

By:

Paulina Jaramillo

Advisors:

W. Michael Griffin

H. Scott Matthews

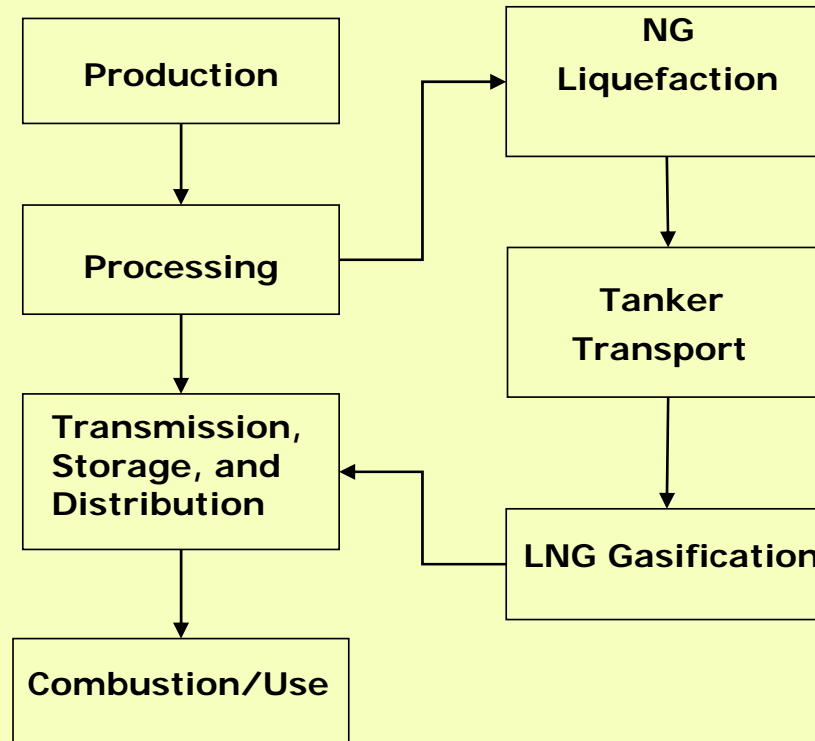
Civil and Environmental Engineering Department  
Carnegie Mellon University

*Green Design*

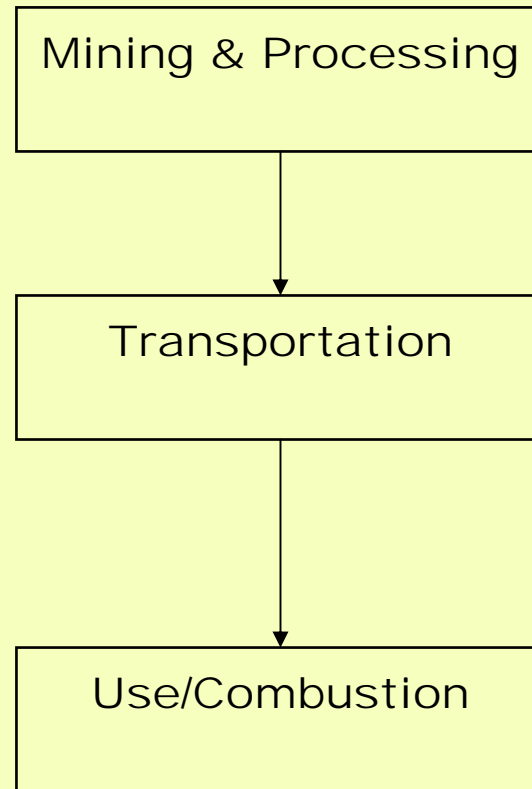
# INTRODUCTION

- Demand for natural gas for electricity generation will increase in the future.
- Natural gas is considered to be a “cleaner” fuel than coal, producing less greenhouse gases and criteria air pollutants.
- To increase natural gas supply, will necessitate LNG imports or SNG production.
- This work extends current life cycle GHG emissions to include the impacts of LNG imports and SNG production.
- It also includes a comparison of life cycle  $\text{NO}_x$ , and  $\text{SO}_x$  emissions.

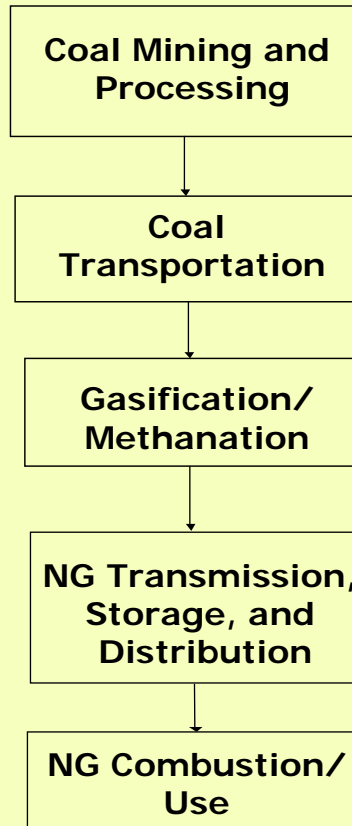
# NG/LNG LIFE CYCLE



# COAL LIFE CYCLE



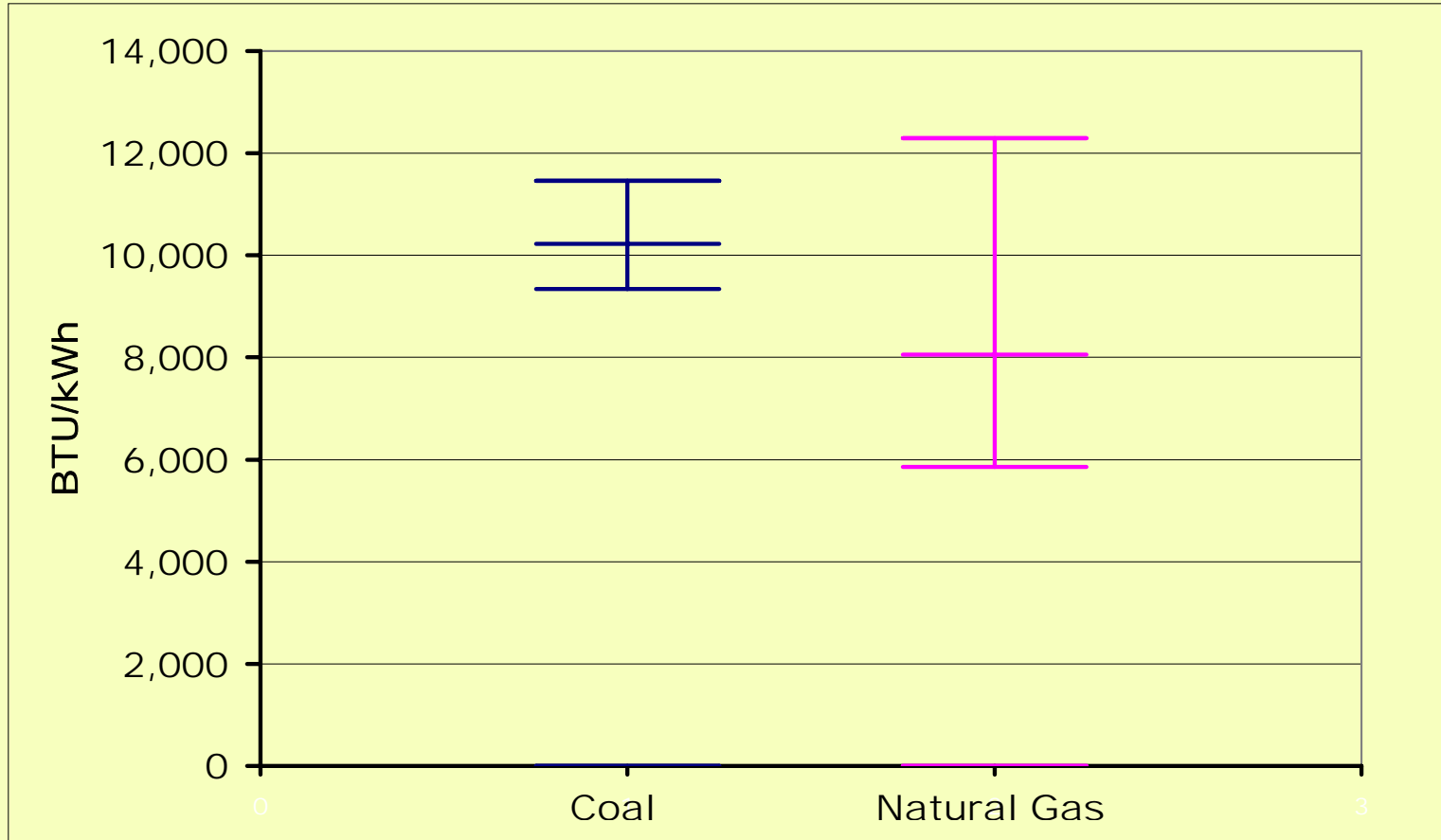
# SNG LIFE CYCLE



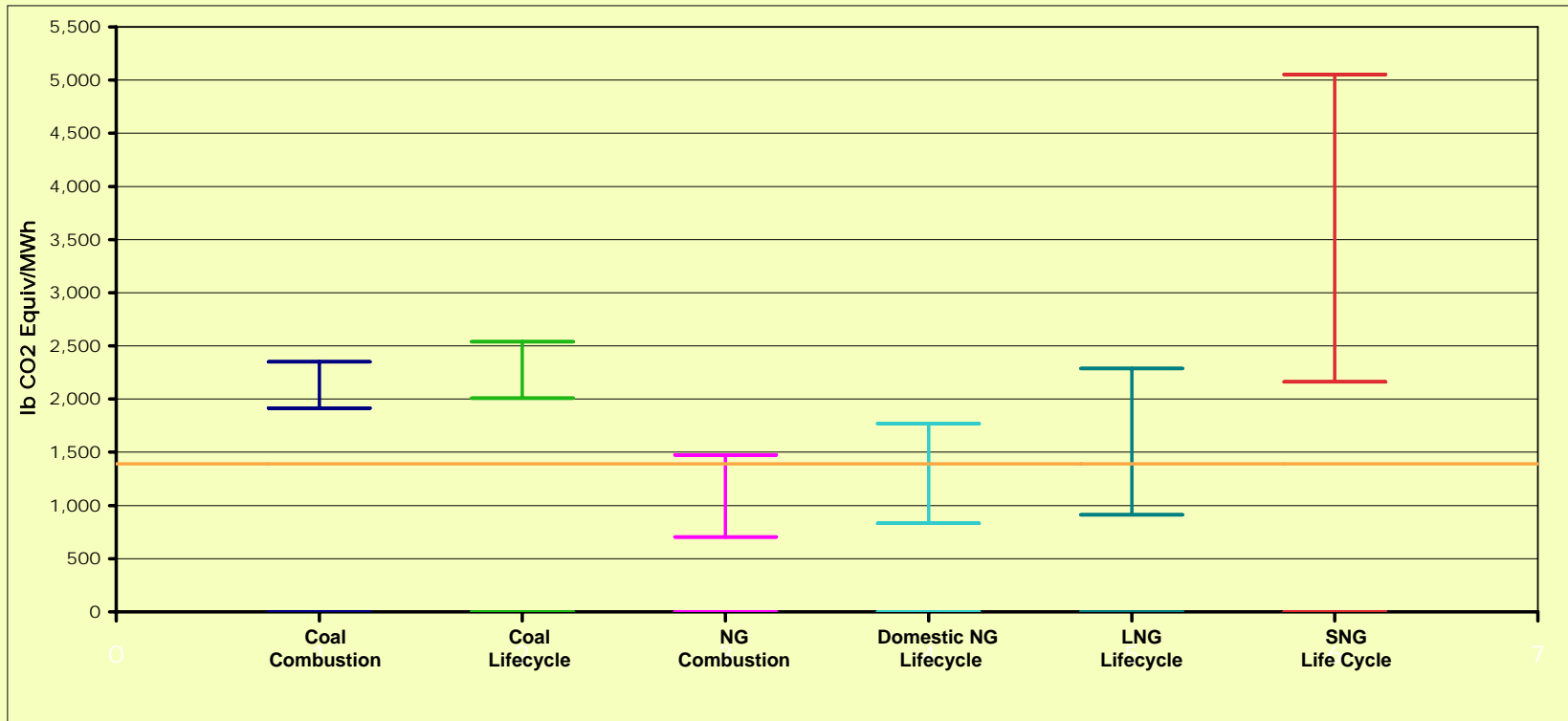
# DATA SOURCES

- EPA GHG Emissions and Sources Document.
- EPA Inventory of Methane Emissions from Natural Gas Systems.
- DOE Data.
- Economic Census Data.
- AP 42 Emission Factors.
- EIO-LCA.
- Peer Reviewed Papers.

# CURRENT POWER PLANT TECHNOLOGY

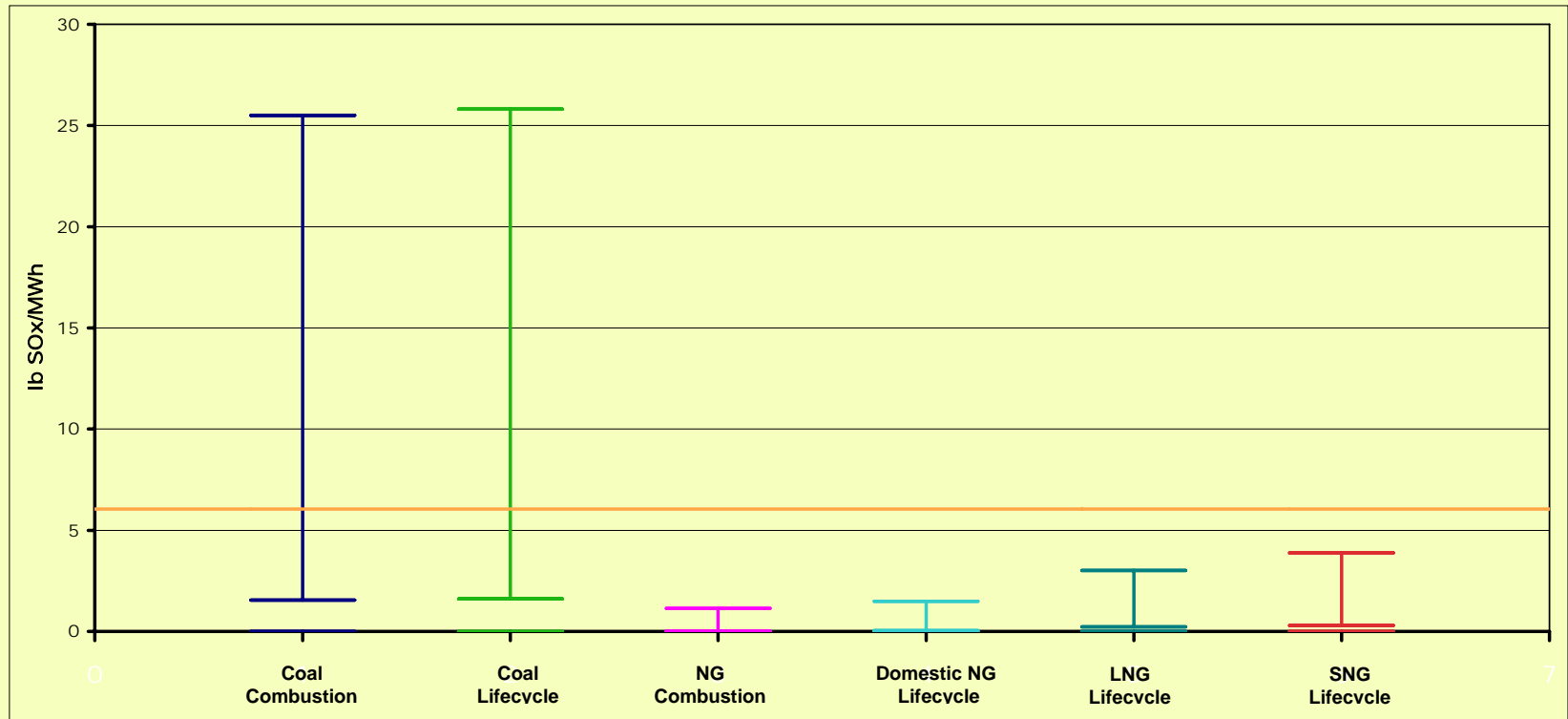


# GHG EMISSIONS WITH CURRENT POWER PLANT TECHNOLOGY



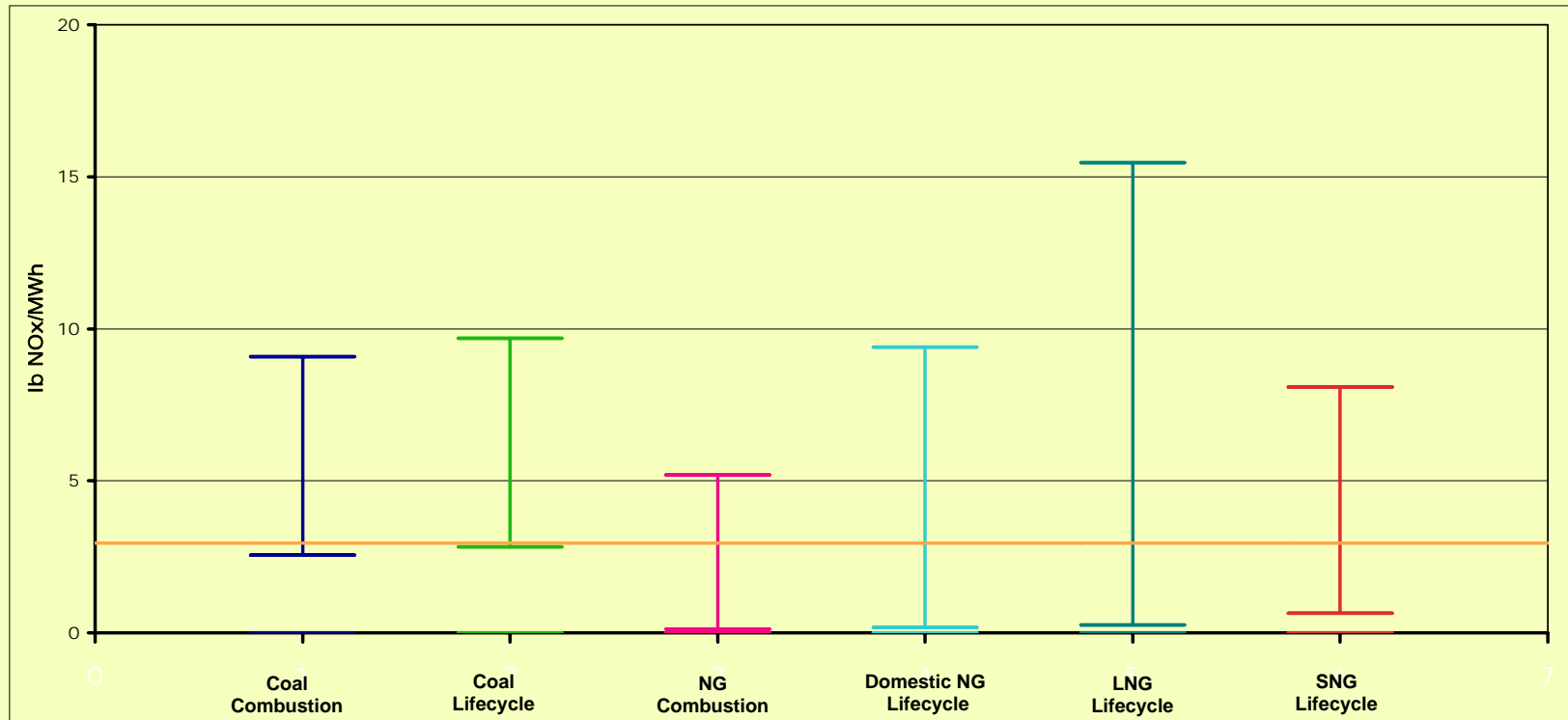
Orange line represents current average emissions from electricity generation

# SO<sub>x</sub> EMISSIONS WITH CURRENT POWER PLANT TECHNOLOGY



Orange line represents current average emissions from electricity generation

# NO<sub>x</sub> EMISSIONS WITH CURRENT POWER PLANT TECHNOLOGY



Orange line represents current average emissions from electricity generation

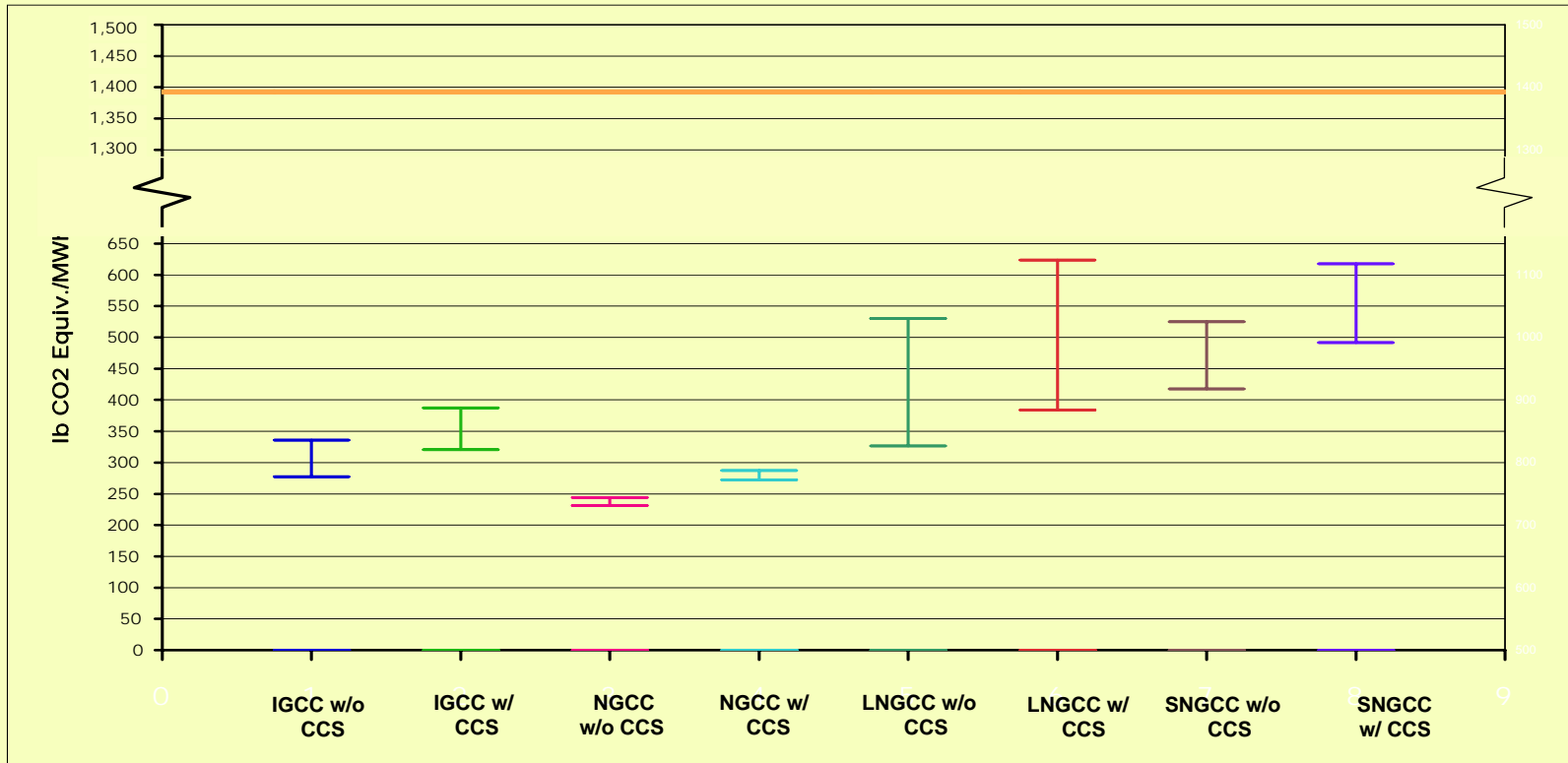
# CARBON CAPTURE AND SEQUESTRATION (CCS)

- In the future, advanced coal and NG technologies could be used with 90% CCS

	Efficiency (HHV)	Efficiency (HHV)
	IGCC	NGCC
<b>No CCS</b>	38%	50%
<b>With CCS</b>	32%	43%
<b>Energy Penalty</b>	16%	17%

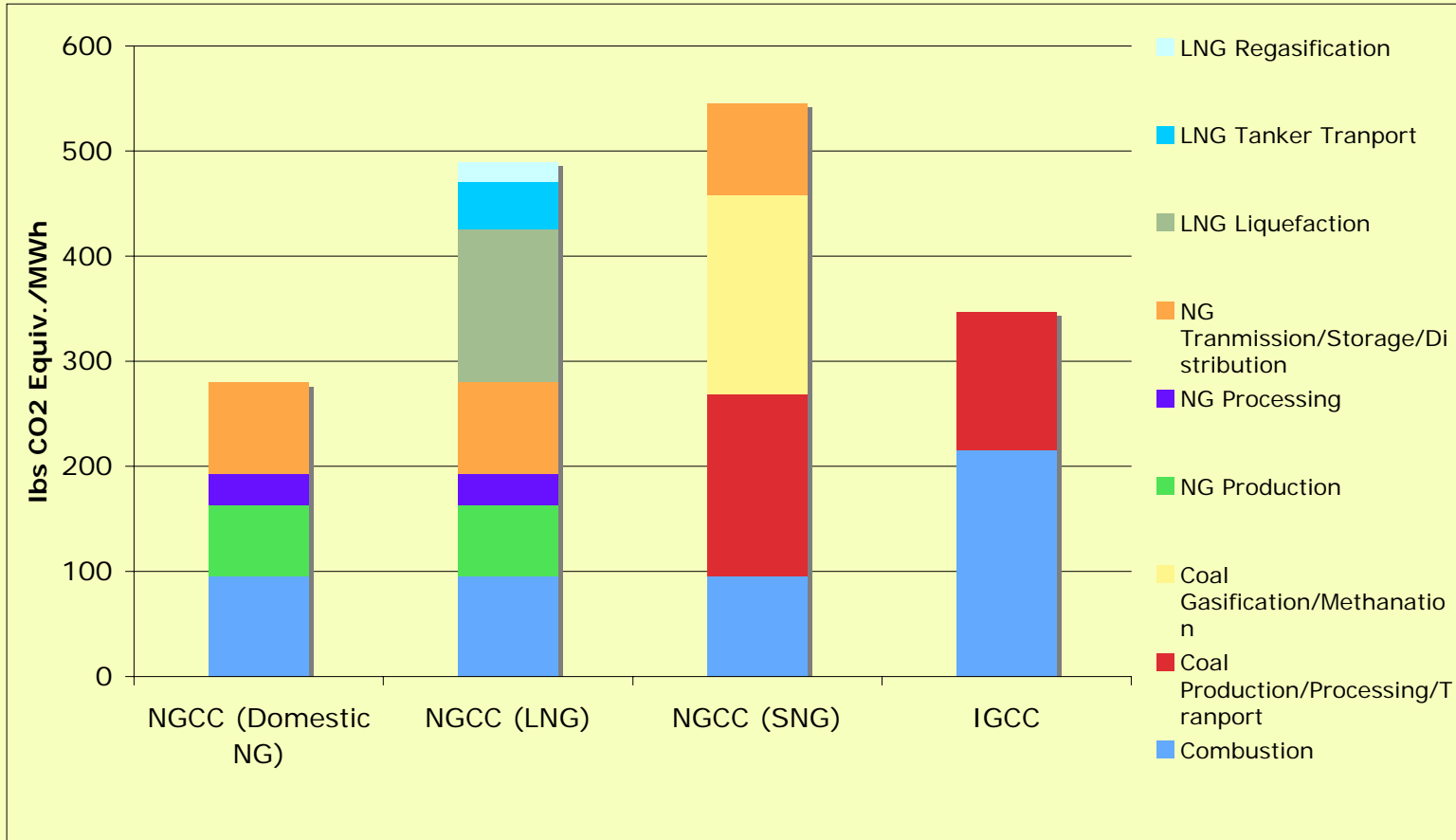
Source: Rubin et-al

# GHG EMISSIONS WITH ADVANCED POWER PLANT TECHNOLOGY

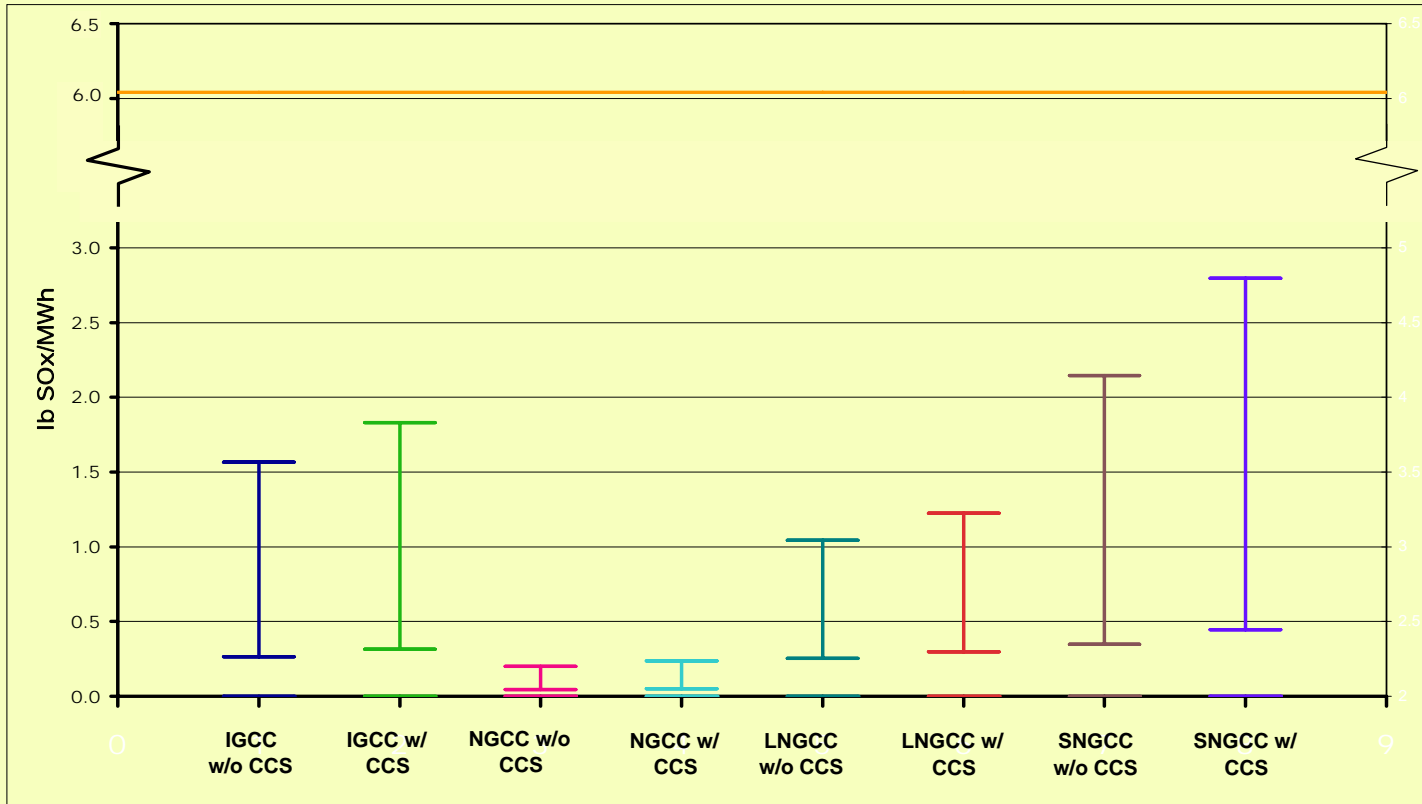


Orange line represents current average emissions from electricity generation

# GHG EMISSIONS WITH ADVANCED POWER PLANT TECHNOLOGY

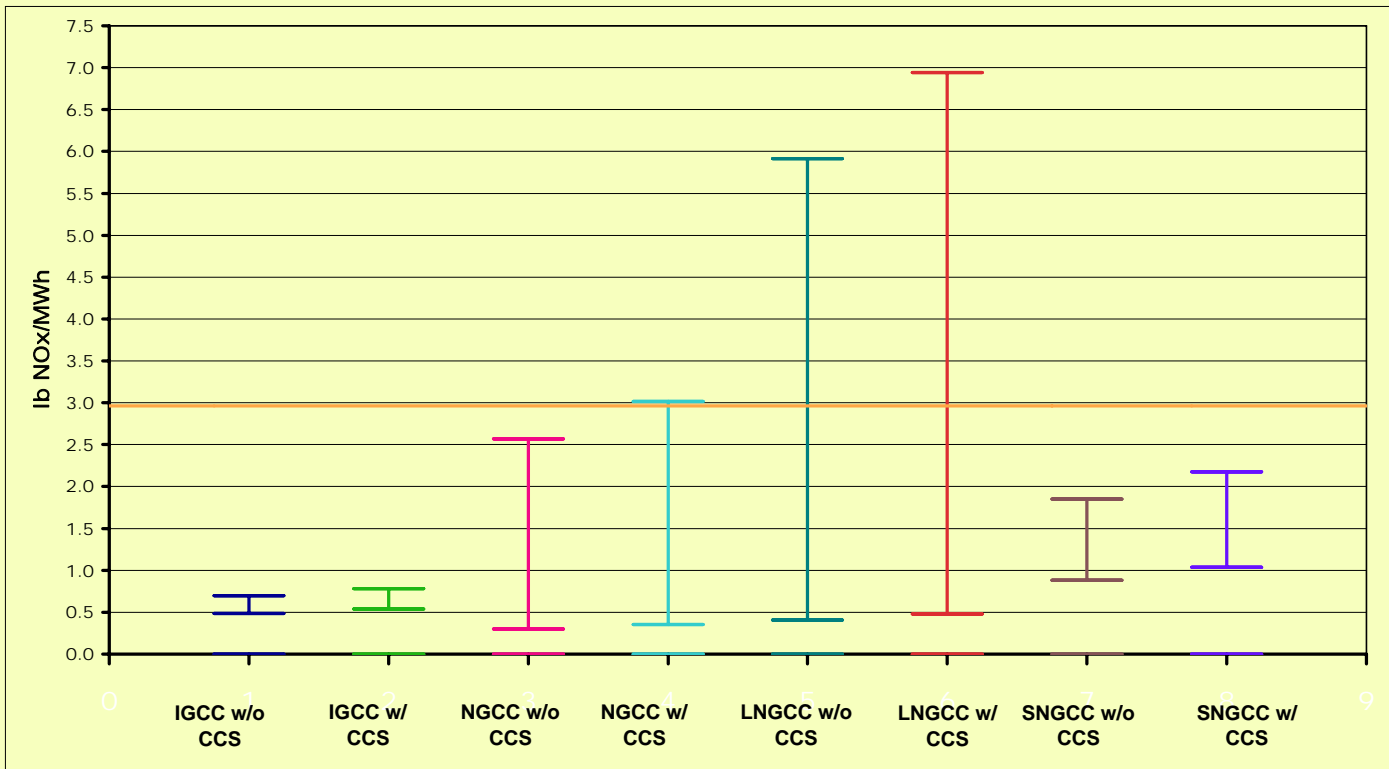


# SO<sub>x</sub> EMISSIONS WITH ADVANCED POWER PLANT TECHNOLOGY



Orange line represents current average emissions from electricity generation

# NO<sub>x</sub> EMISSIONS WITH ADVANCED POWER PLANT TECHNOLOGY



Orange line represents current average emissions from electricity generation

# CONCLUSIONS

- Overall life cycle carbon emissions of LNG and current coal are closer than generally reported. SNG has much higher life cycle carbon emissions than coal or LNG
- In a future containing IGCC and NGCC plants with CCS, carbon emissions from both coal and a NG/LNG/SNG mix could be very similar.
- The use of advanced technologies with coal or a NG/LNG/SNG mix could greatly reduce  $\text{SO}_x$  and  $\text{NO}_x$  emissions.

# POLICY IMPLICATIONS

- Assuming the overall life cycle carbon emissions of LNG and current coal are closer than generally reported...
- And .... in a future containing IGCC and NGCC plants with CCS, emissions from both fuels could be very similar, further diminishing the differences between natural gas and coal emissions...
- We ask... should we invest in a dedicated infrastructure for LNG that could limit future energy policy decisions or make them more costly?

# POLICY IMPLICATIONS

- Increased LNG imports:
  - would increase our reliance on foreign fuels.
  - increased demand for natural gas by the electricity industry has and will continue to increase prices for residential consumers and chemical industry.
    - » We estimate that residential, commercial, and industrial consumers have paid a \$120 billion premium for natural gas since 2000.
    - » Natural gas consumers have already paid 130% of the costs to build these power plants.
  - will probably fail to bring NG prices down to 1990's level.

**QUESTIONS?**