Sensitivity of Solar Fossil Hybrid Electricity Technology Penetration to Price and Efficiency Projections

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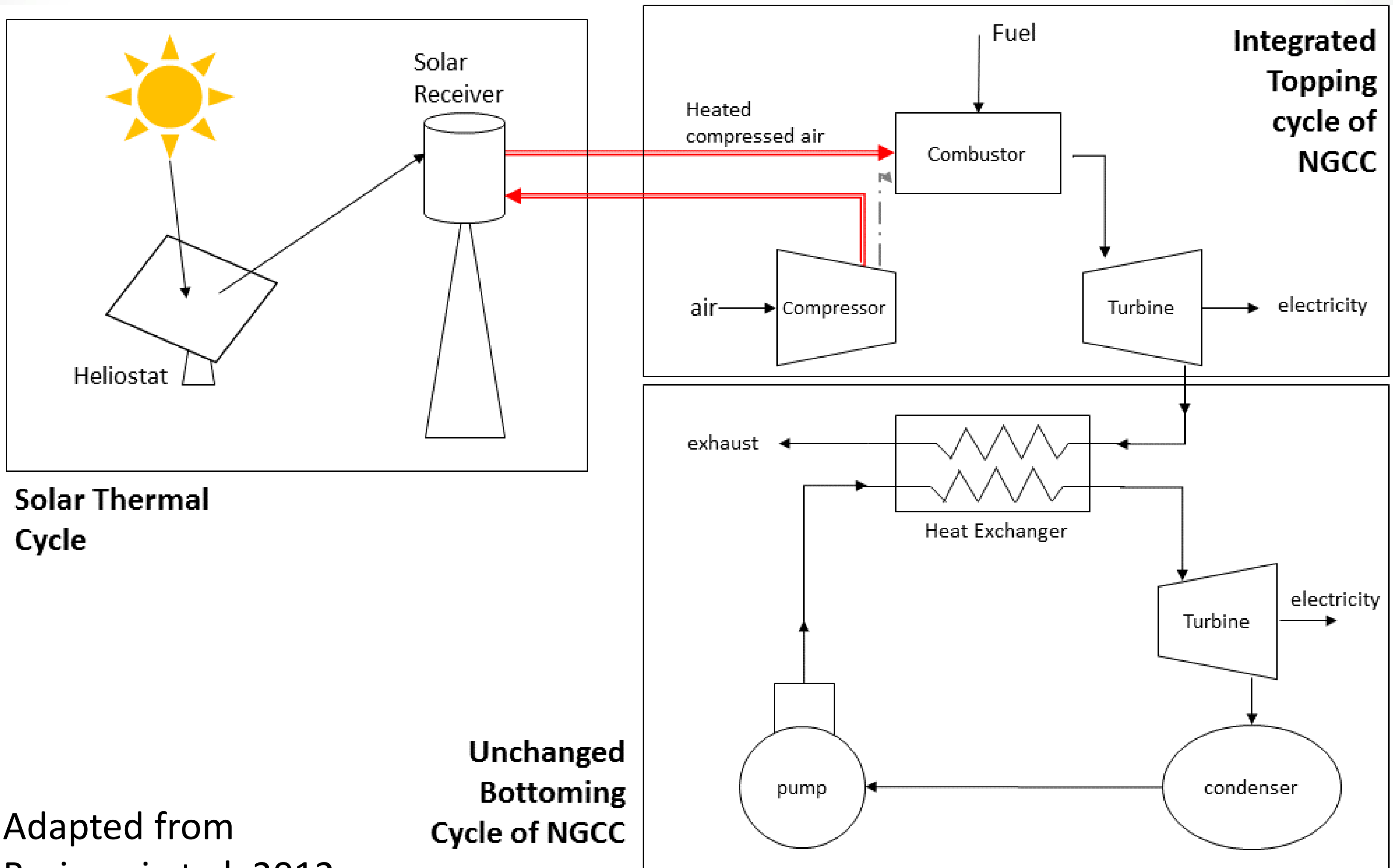
Motivation

- **New electricity generation capacity needed. Decision-makers consider:**
  - Fuel cost
  - Capital cost
  - Emissions
  - Intermittency
- **Previous studies analyze technological possibility of Hybrid solar gas combined-cycle***
  - Cost savings compared to independent fossil and renewable facilities
- **Now evaluate market potential**

*Barigozzi et al. 2012, Spelling & Laumert 2015

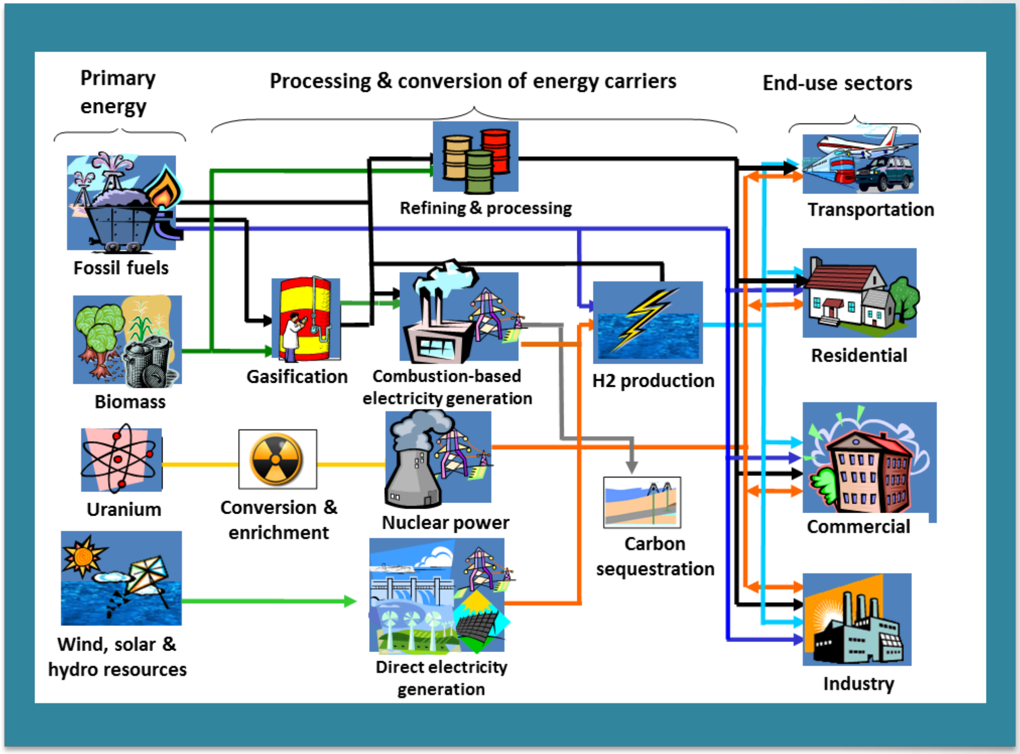
ISCC
Integrated Solar Combined Cycle



Adapted from Barigozzi et al. 2012

EPAUS9r MARKAL

- **Bottom-up and technology-rich**
  - Captures the full system from energy resource supply/extraction technologies to end-use technologies in all sectors
  - Energy technologies (existing and future techs) are characterized by cost, efficiency, fuel inputs, emissions
  - Technologies are connected by energy flows
  - Covers 9 US Census divisions
- **Optimization**
  - The model picks the "best" way (lowest system-wide cost) to meet energy demands choosing from the full "menu" of energy resources and technologies
  - The model makes these choices from 2005 to 2055, giving us a snapshot of possible future energy mixes



- **Emissions and impacts**
  - All technologies and fuels have air and GHG emissions characterized
  - Standards and regulations are included in the baseline, and additional policies can be modeled

Methods

- Used the EPA US 9-region MARKAL model (EPAUS9r)
- Added representation* of ISCC technology to regions 7, 8, and 9
- Tested various cost and fuel savings attributes for hybrid technology
- Altered how the technology fits into Renewable Portfolio Standards (RPS)

*Barigozzi et al. 2012, Spelling & Laumert 2015

Nested Sensitivity

Possible Fuel Savings	15%	20%	25%	30%
Possible Cost Increases	$700	$800	$900	$1,000
RPS fulfillment	Full	Partial	None	

Cost increases: $/kW compared to NGCC investment

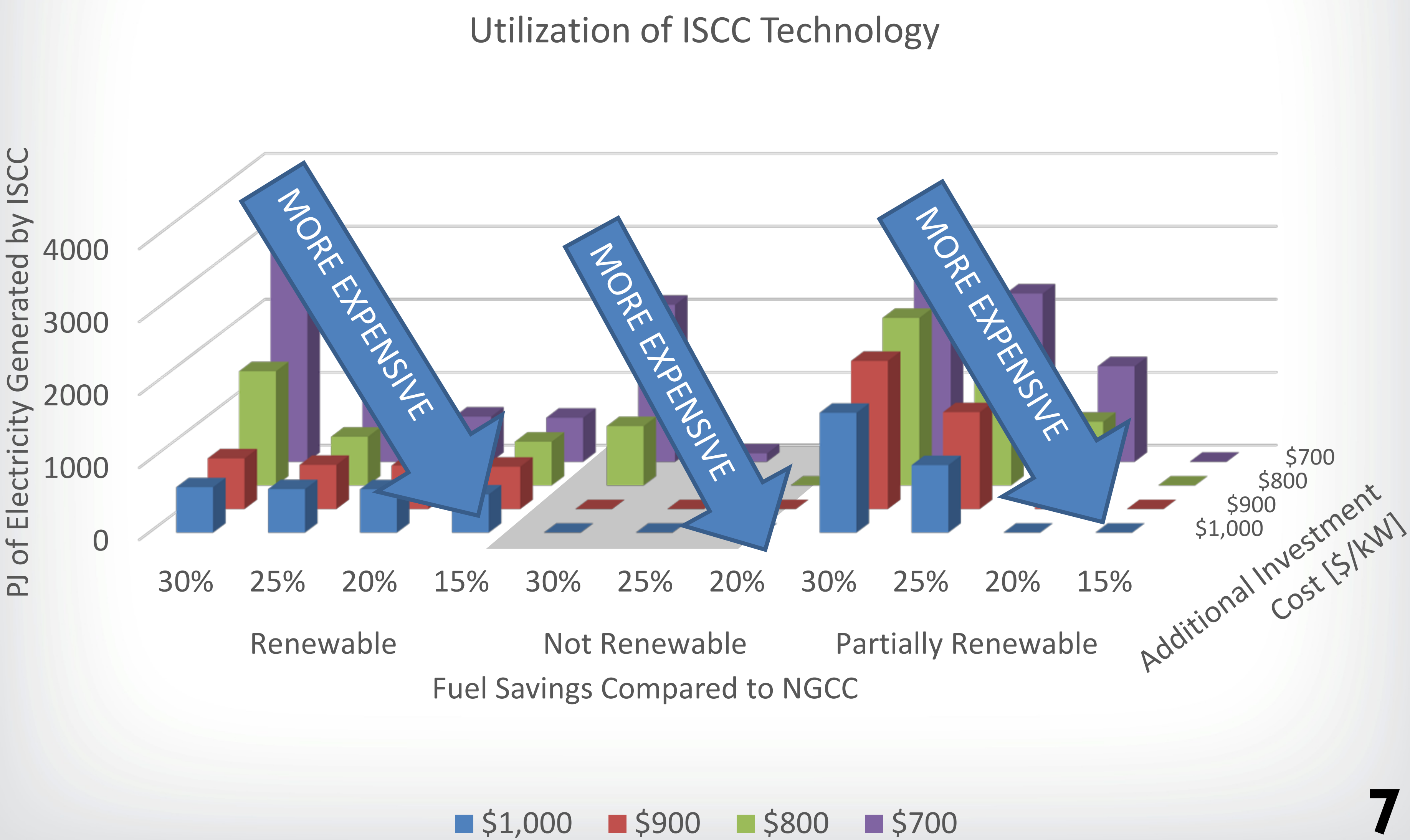
	100% of electricity counts toward RPS Renewable															
Fuel Savings/ Solar Fraction	30%				25%				20%				15%			
Increased Cost	$700	$800	$900	$1,000	$700	$800	$900	$1,000	$700	$800	$900	$1,000	$700	$800	$900	$1,000

	Does not count for RPS Not renewable		
Fuel Savings/ Solar Fraction	30%		25%
Increased Cost	$700	$800	$700

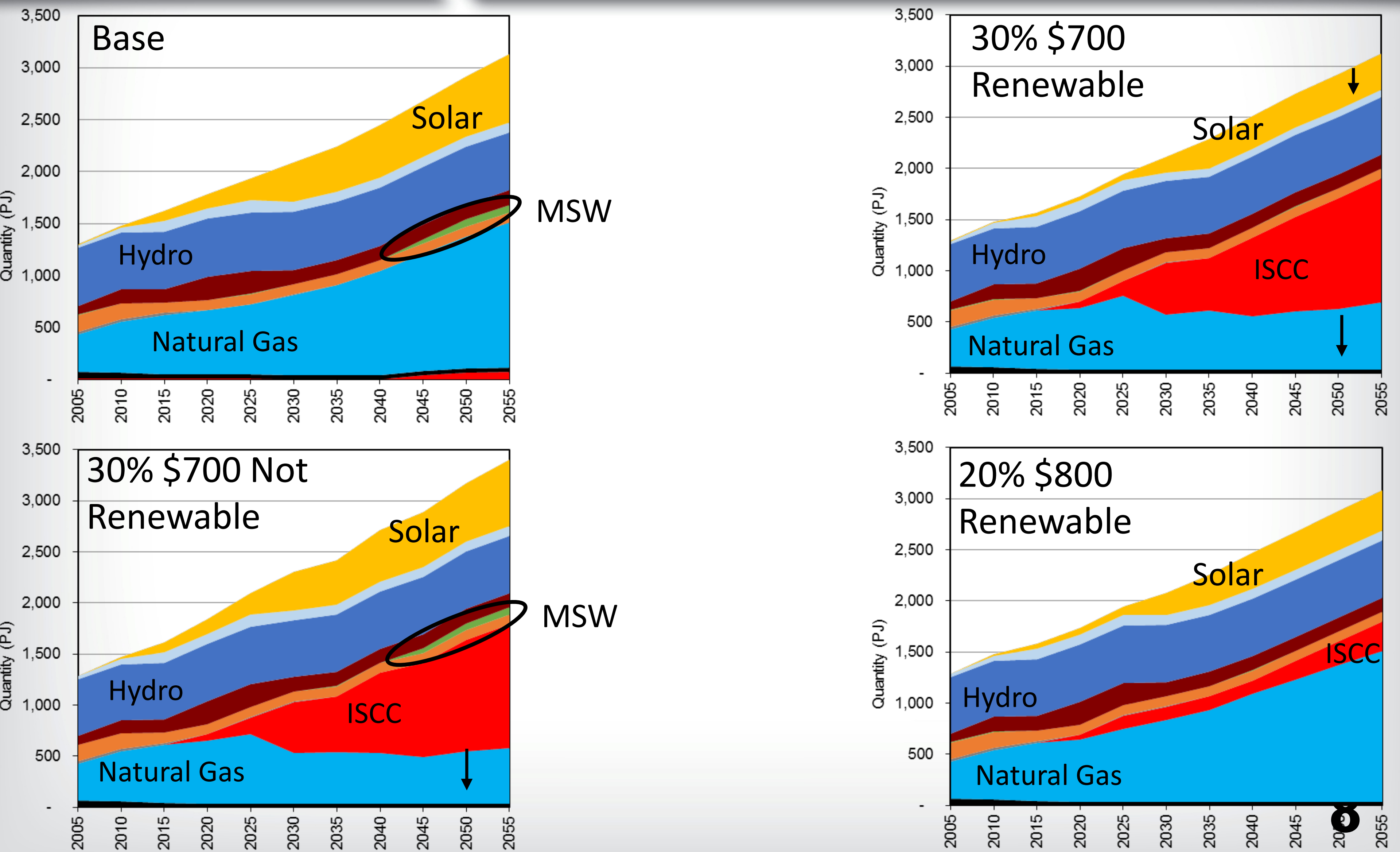
Without RPS incentive, ISCC not used when too expensive, inefficient

	Only Solar Fraction Counts toward RPS Partially Renewable										
Fuel Savings/ Solar Fraction	30%				25%				20%		
Increased Cost	$700	$800	$900	$1,000	$700	$800	$900	$1,000	$700	$800	$900

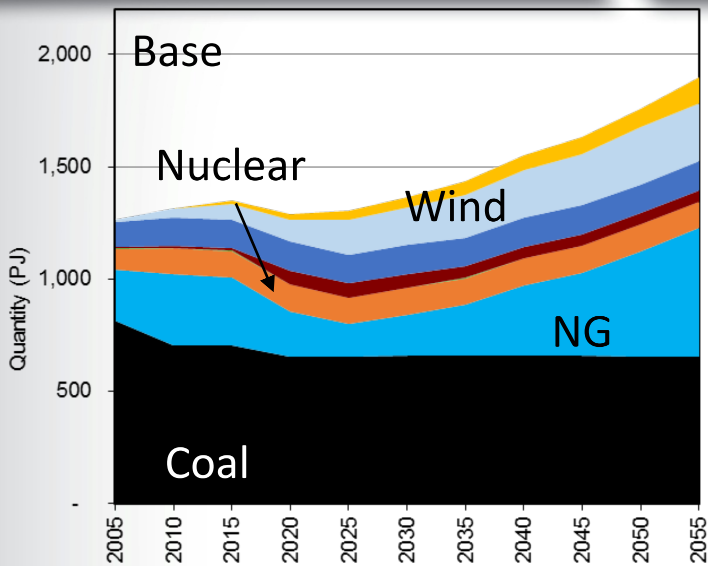
Utilization

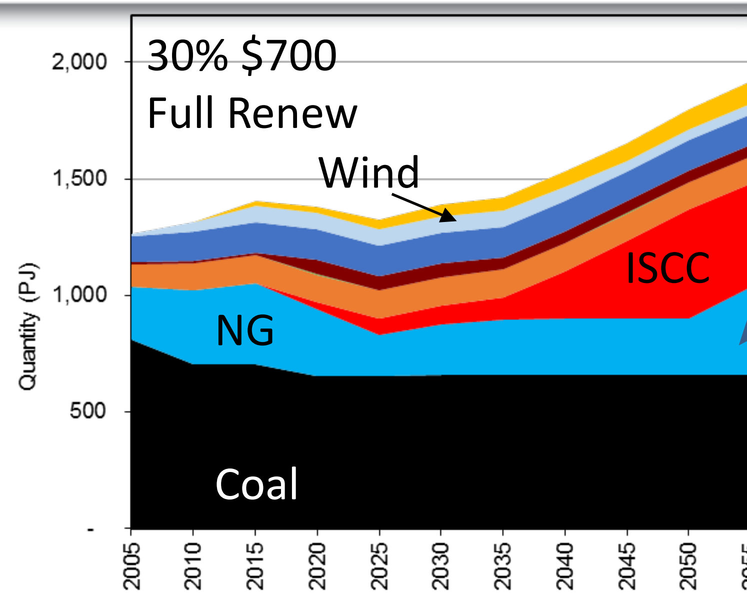


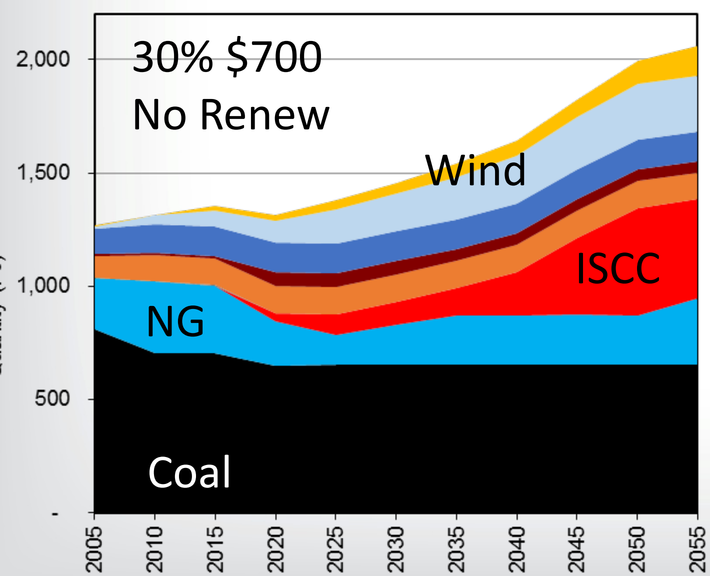
Region 9 Electricity Mix



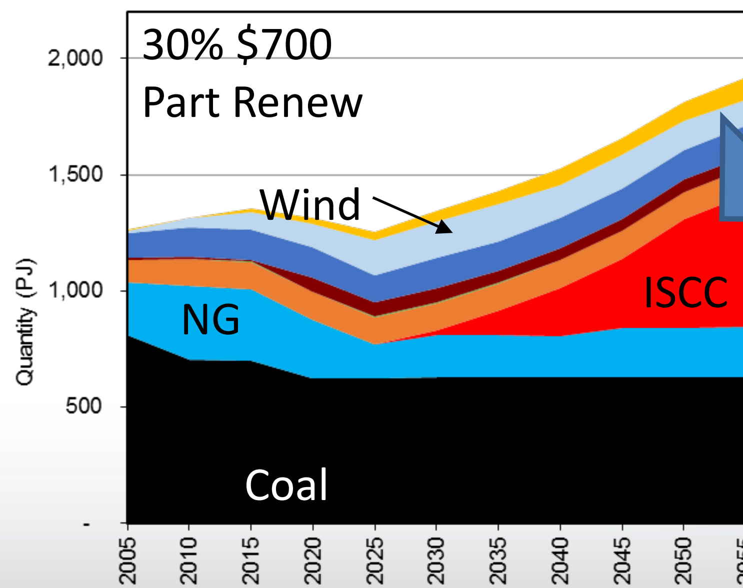
Region 8 Electricity Mix





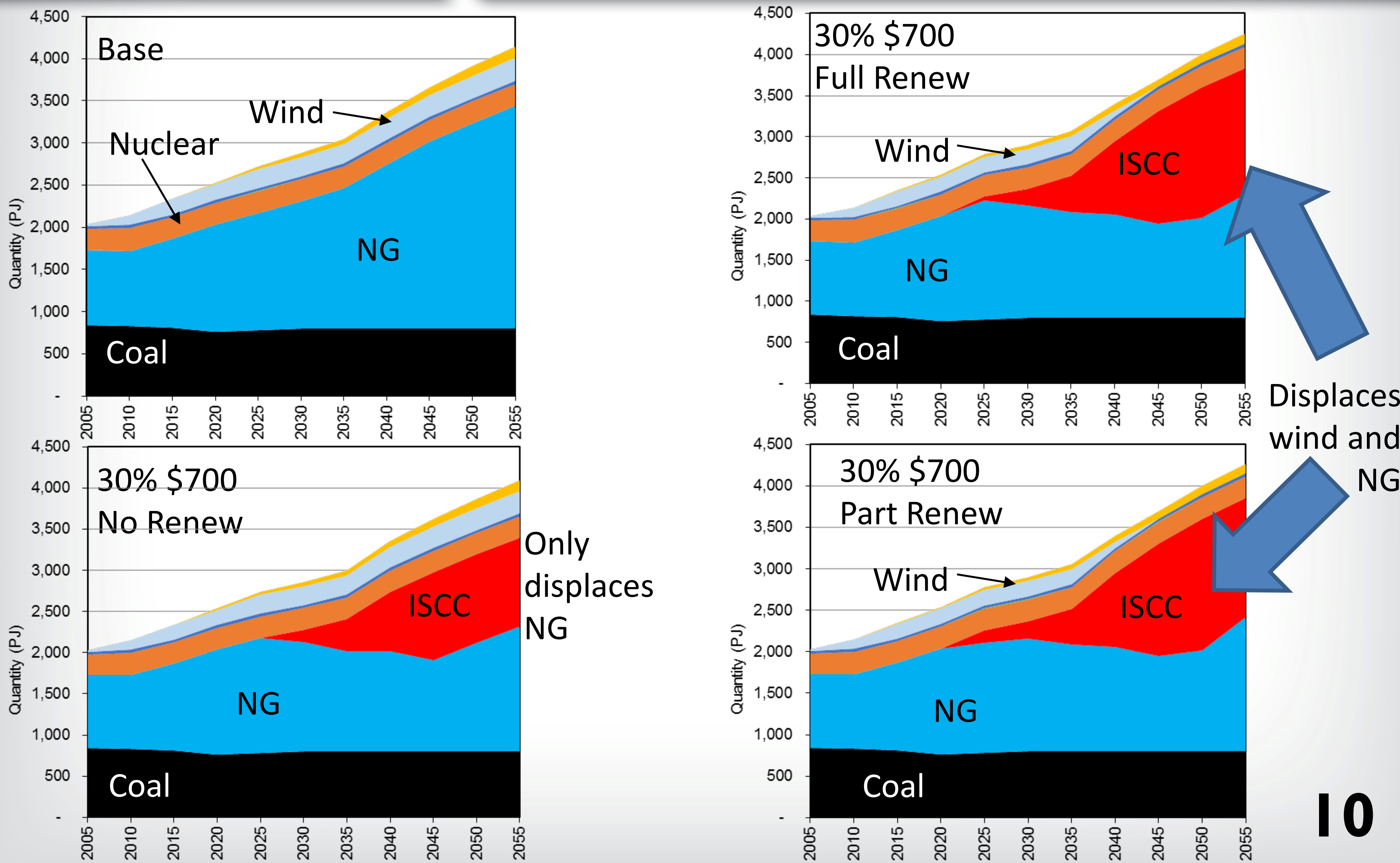


Only displaces NG

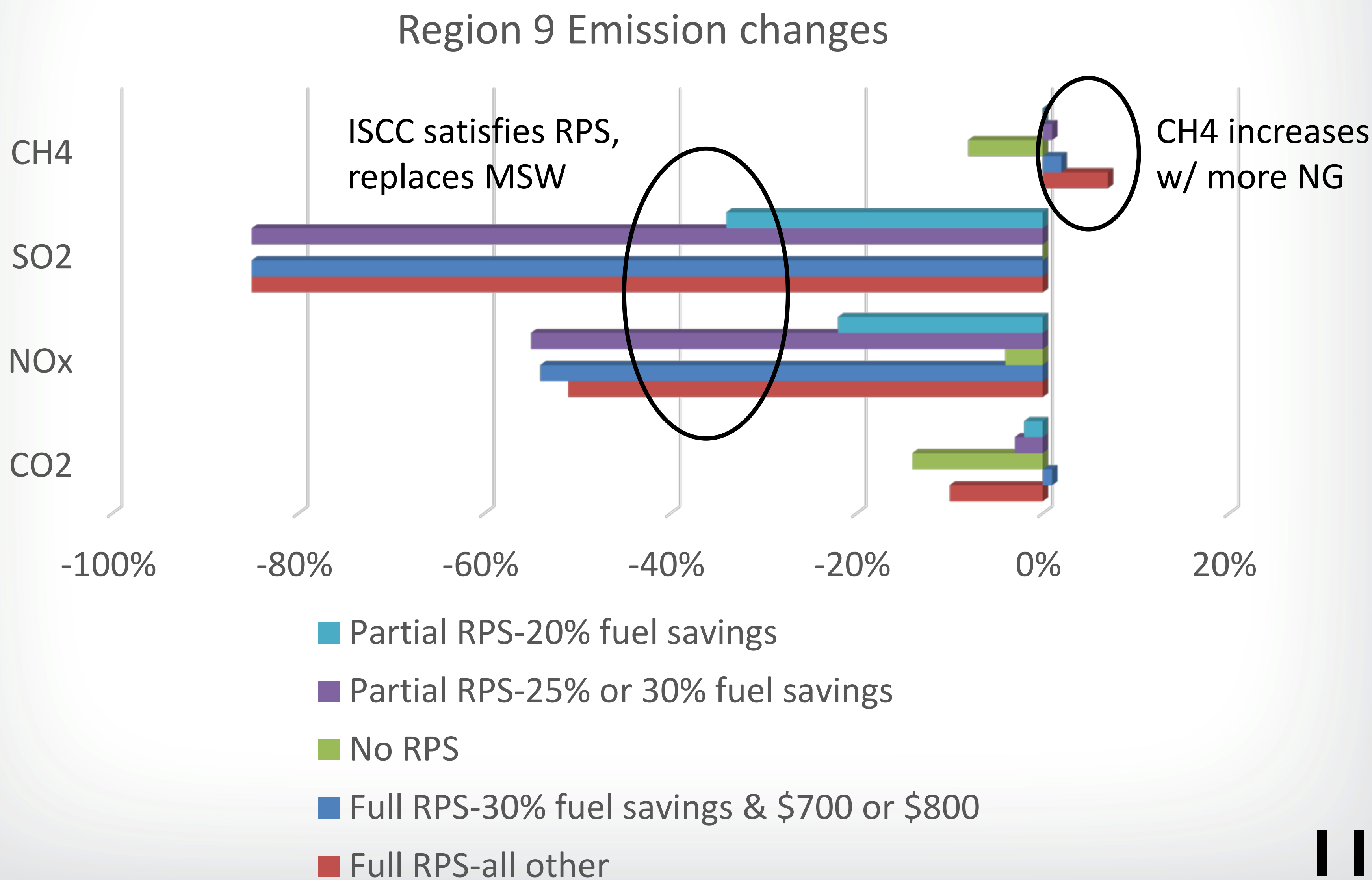


Displaces wind and NG

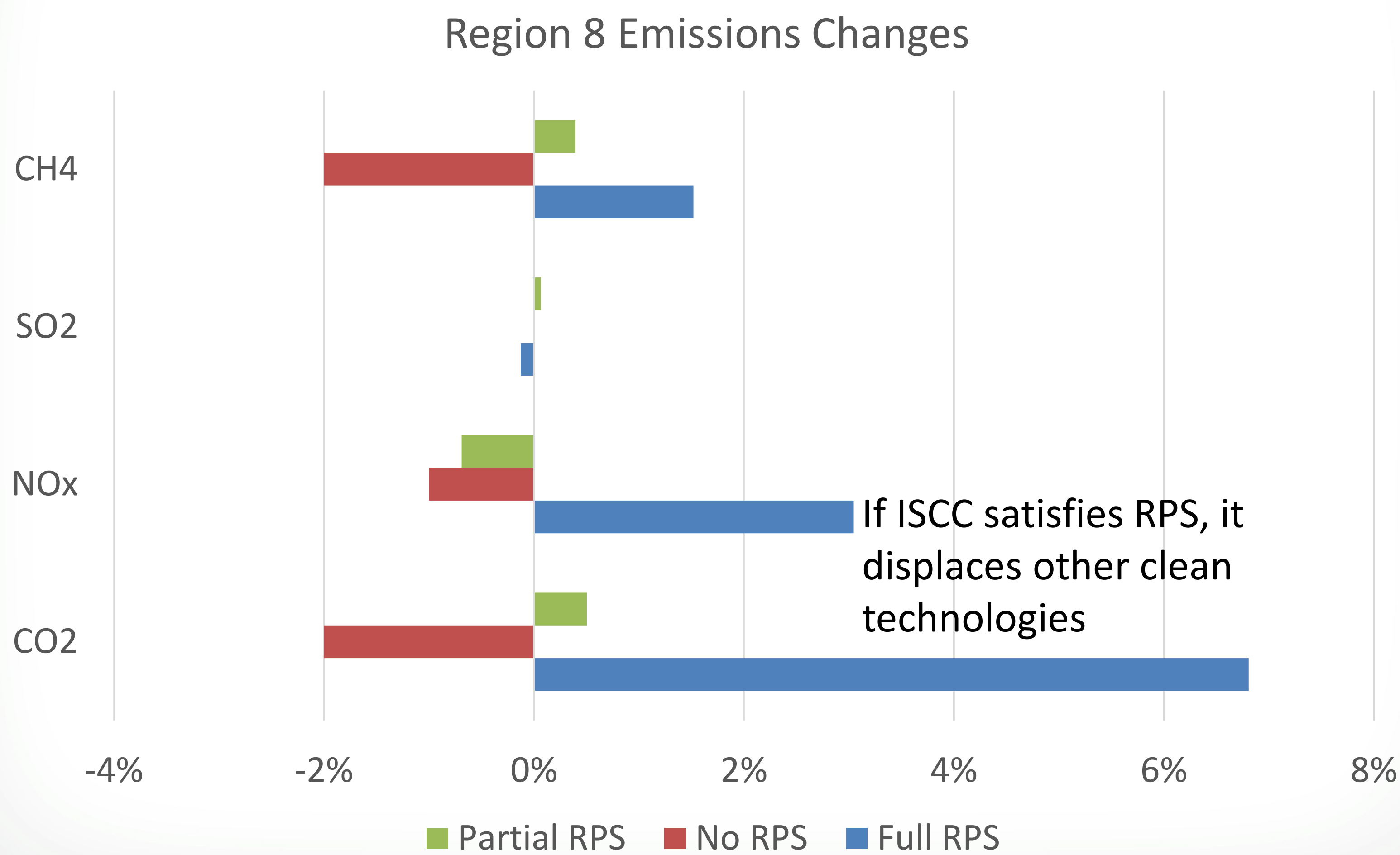
Region 7 Electricity Mix



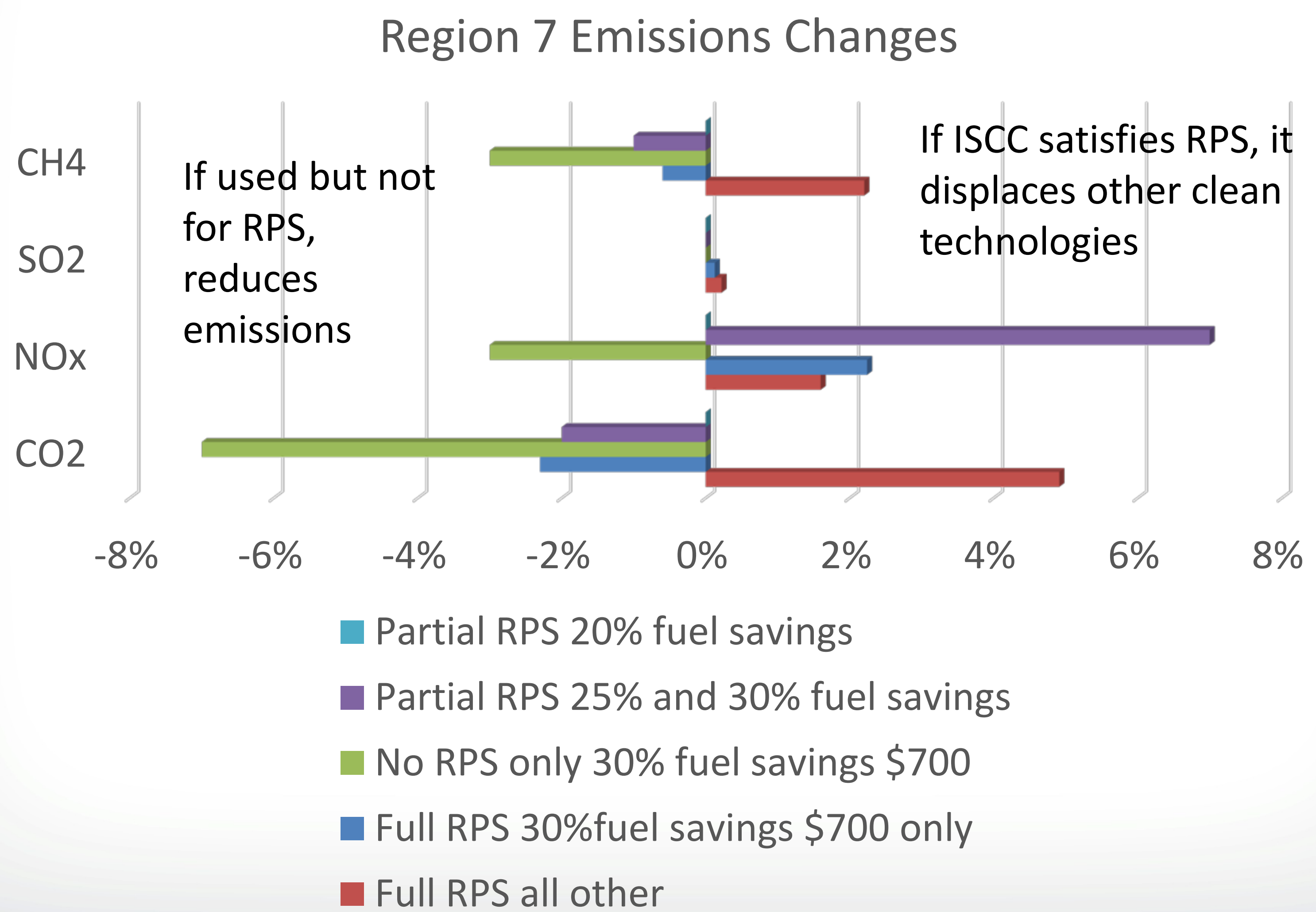
Emissions


Region 9 Emission changes
CH4
SO2
NOx
CO2
ISCC satisfies RPS, replaces MSW
CH4 increases w/ more NG
-100%
-80%
-60%
-40%
-20%
0%
20%
Partial RPS-20% fuel savings
Partial RPS-25% or 30% fuel savings
No RPS
Full RPS-30% fuel savings & $700 or $800
Full RPS-all other

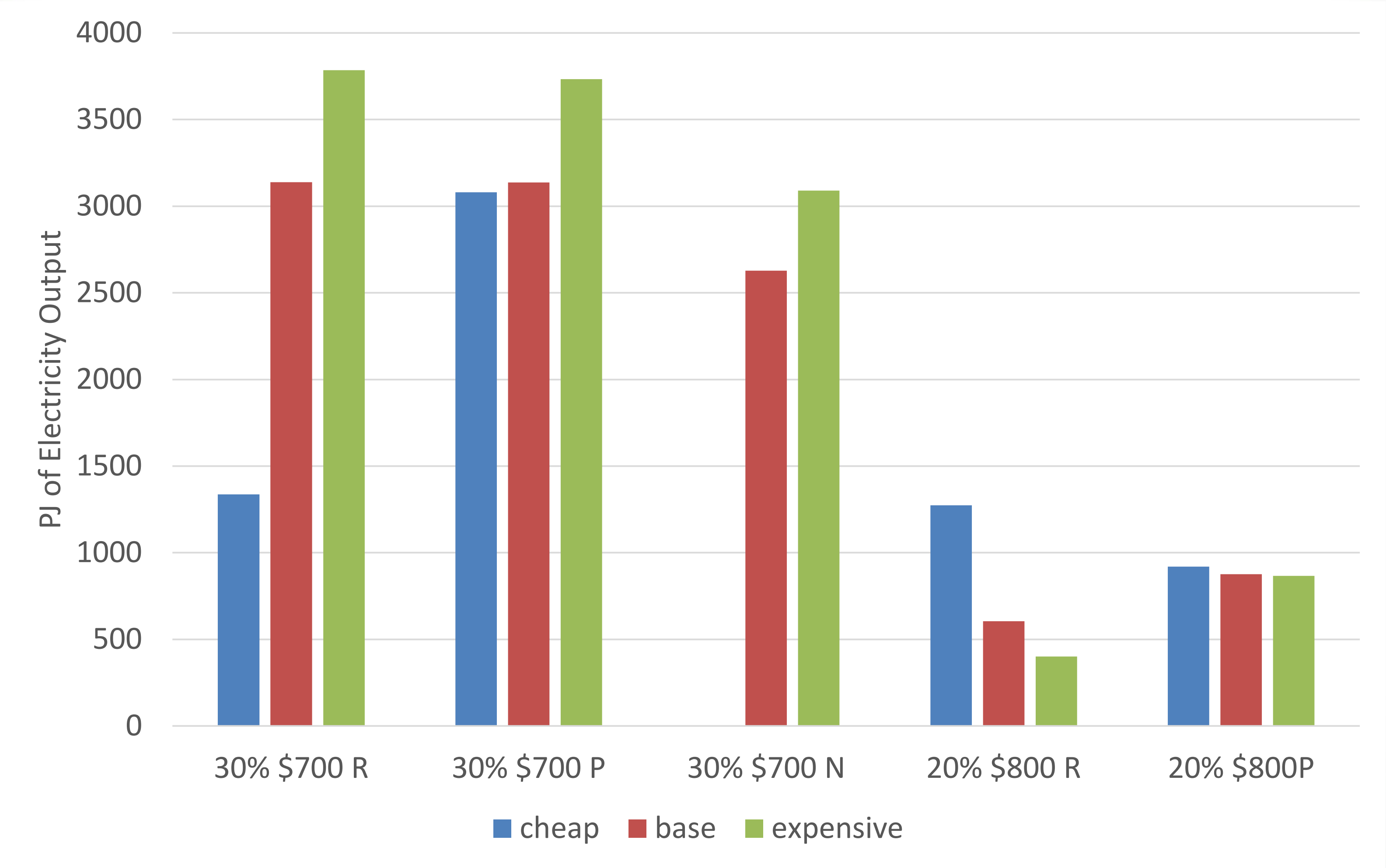
Emissions


Region 8 Emissions Changes
CH4
SO2
NOx
CO2
If ISCC satisfies RPS, it displaces other clean technologies
-4%
-2%
0%
2%
4%
6%
8%
Partial RPS
No RPS
Full RPS

Emissions


Region 7 Emissions Changes
CH4
SO2
NOx
CO2
If used but not for RPS, reduces emissions
If ISCC satisfies RPS, it displaces other clean technologies
-8%
-6%
-4%
-2%
0%
2%
4%
6%
8%
Partial RPS 20% fuel savings
Partial RPS 25% and 30% fuel savings
No RPS only 30% fuel savings $700
Full RPS 30%fuel savings $700 only
Full RPS all other

Sensitivity to NG Price



Discussion

- **ISCC can be economically viable**
- **Siting of ISCC facilities will be important**
  - Tested parameters assume good solar resource
  - Large land area required
- **RPS definitions are important to technology deployment and emissions**
- **Emissions reductions are not proportional to ISCC adoption**

References

- Barigozzi, G., G. Bonetti, G. Franchini, A. Perdichizzi, and S. Ravelli. 2012. 'Solar Hybrid Combined Cycle Performance Prediction Influence of Gas Turbine Model and Spool Arrangements', *Journal of Engineering for Gas Turbines and Power-Transactions of the Asme*, 134: 11.
- Lenox, C., R. Dodder, C. Gage, D. Loughlin, O. Kaplan, and W. Yelverton. 2013. "EPA US Nine-region MARKAL Database: Database Documentation." In. Cincinnati, OH: US EPA.
- Spelling, J., and B. Laumert. 2015. 'Thermo-economic Evaluation of Solar Thermal and Photovoltaic Hybridization Options for Combined-Cycle Power Plants', *Journal of Engineering for Gas Turbines and Power-Transactions of the Asme*, 137: 11.