The Clean Power Plan and Beyond

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Update for Stanford University

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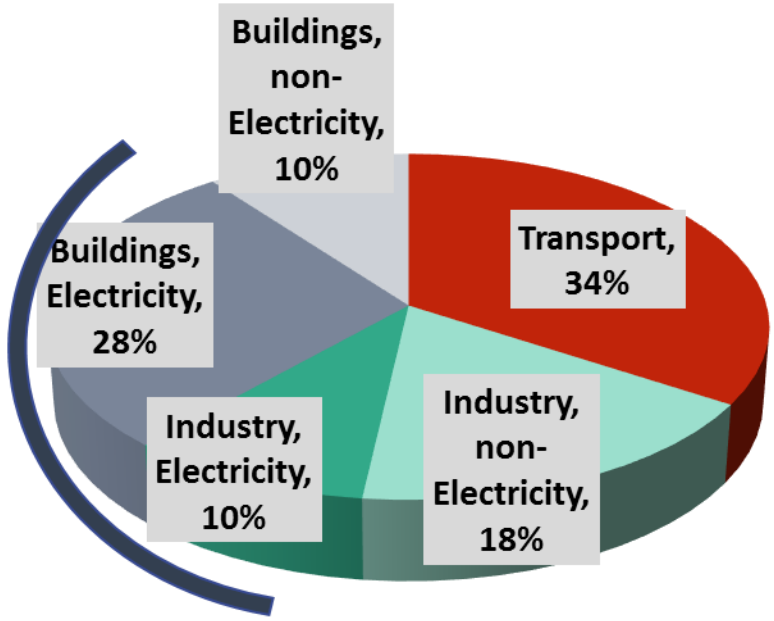
Background

The U.S. Clean Power Plan

- Under Sections 111(b) and (d) of the Clean Air Act, the U.S. made its first commitment at the federal level to reducing CO_2 from the electric power sector.
- EPA issued proposed rules for the Clean Power Plan in June 2014; final rules were issued in August 2015.
- The electricity sector is the source of 38% of CO_2 emissions
- The rule is designed to cut this sector's CO_2 emissions in 2030 to 32% below 2005 levels

U.S. CO_2 Emissions from the Energy Sector (2013)



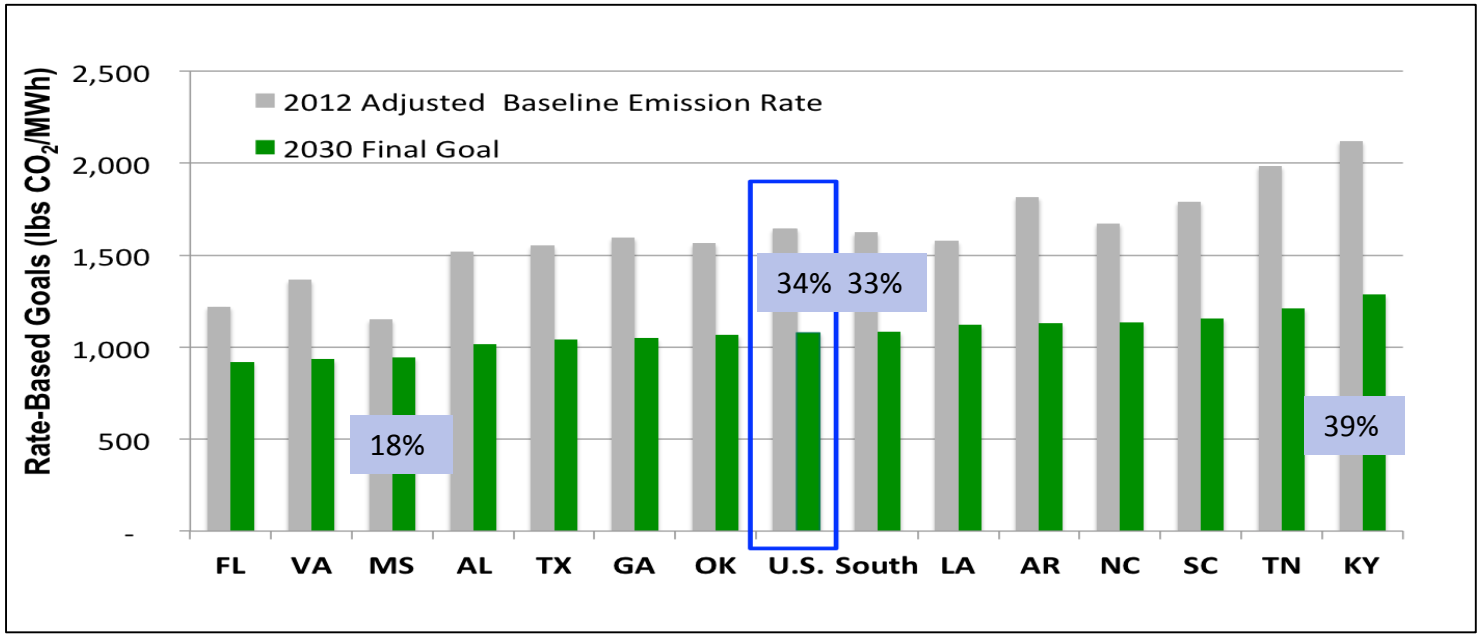
Source: EIA. 2015. *Annual Energy Outlook 2015*, Table 18.

How the State Goals were Created

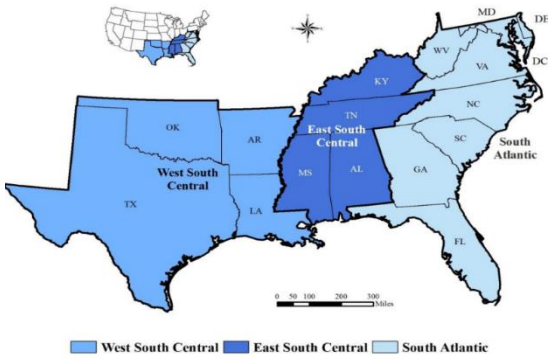
- **EPA developed state *goals* based on three building blocks:**
- BB1 – Coal Efficiency Improvement
- BB2 – Increased Natural Gas
- BB3 – Renewable Energy

- Goals are strictly based on the composition of the fleet in each state.
- To achieve these CPP targets, states are not restricted to these Building Blocks; they can also use nuclear power, energy efficiency,…

We Focus on the U.S. and the South



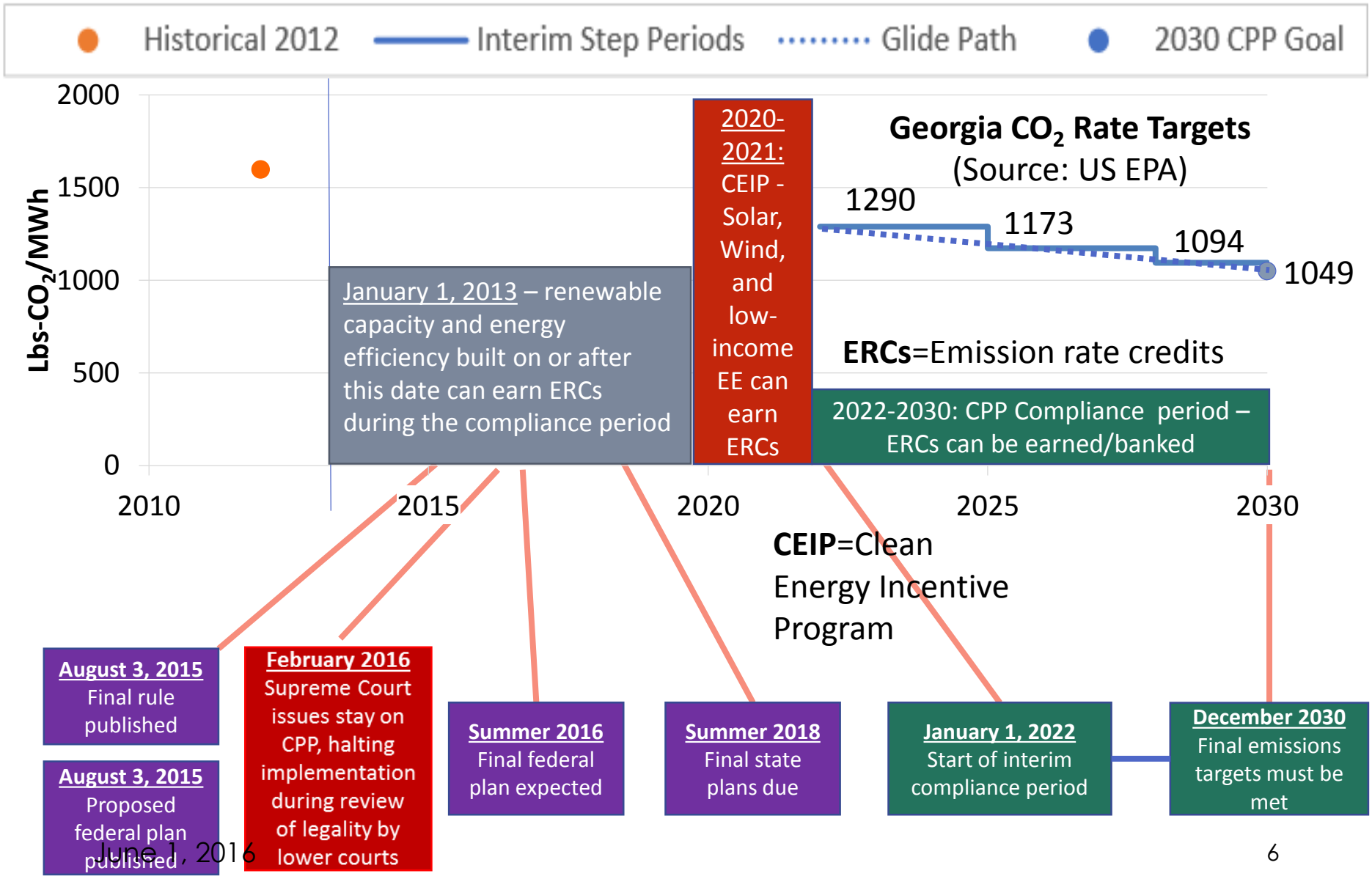
Overall, the rate-based goals of the U.S. and South are similar.



Census Divisions in the South

NERC Regions in the South

Hypothetical Clean Power Plan Timeline



Questions and Methodology

Research Questions

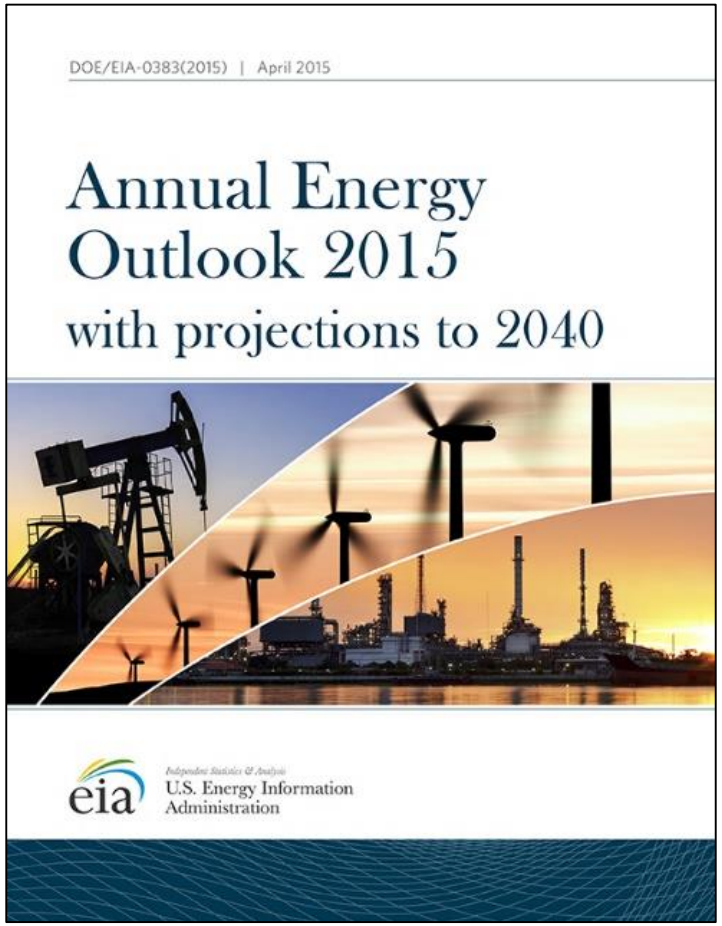
- What is the least-cost pathway for complying with the Clean Power Plan…and for going beyond the CPP?
- Are these pathways different in the South?
- What happens:
  - ✓ If only "existing" units are regulated?
  - ✓ If EE and solar policies are strengthened?
  - ✓ If the CPP is extended to 2040?
  - ✓ If other incentives for CO_2 emission reductions are added?
  - ✓ If the South complies with "rate goals" and the rest of the U.S. adopts "mass goals"?

Methodology

- Create region-level goals from EPA state goals
- Examine mass goals and a hybrid scenario
- Add accelerated EE deployment, lower solar costs, tax extenders and other policies
- Run these various scenarios in GT-NEMS
- Compare the compliance scenarios with the EIA Reference case
  - ✓ Fuel mix, end-use efficiency, and CO_2 emissions
  - ✓ Electricity rates and bills
  - ✓ Economic activity
  - ✓ Local air pollutants: SO_2, NOx, and mercury
- Map the results back to states (in progress)

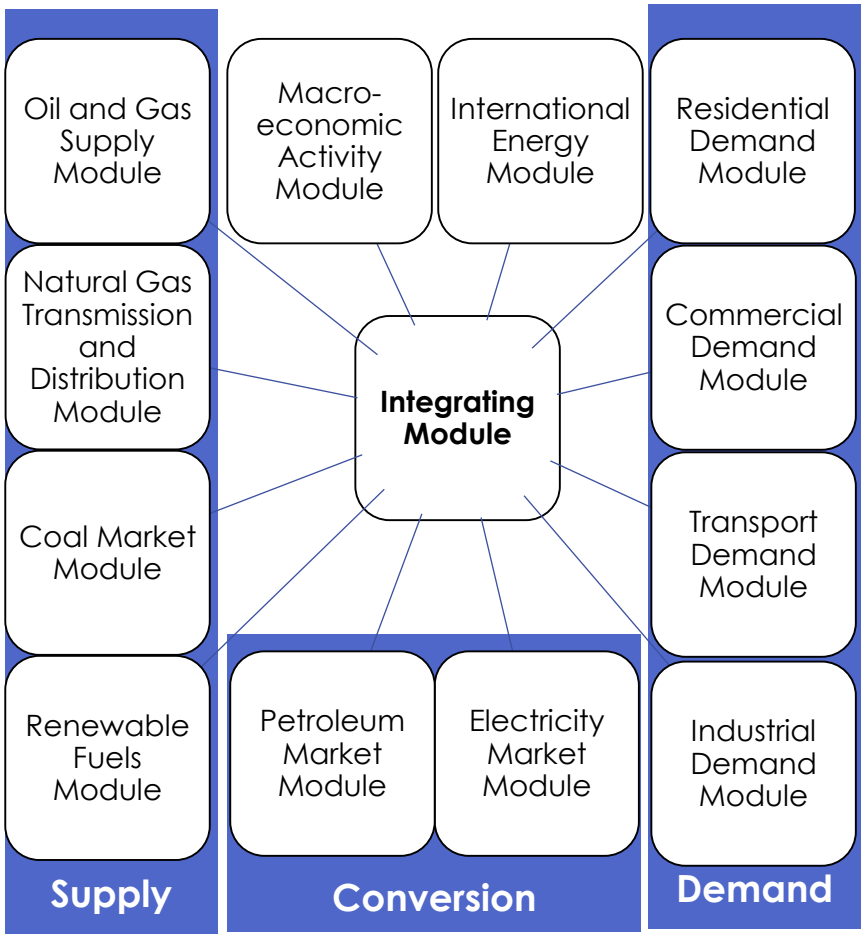
National Energy Modeling System (NEMS)

- Arguably the most influential model of the U.S. energy sector
- Balances the supply and demand for each fuel and consuming sector using general equilibrium principles
- Characterizes end-use and distributed generation in detail
- Reflects Clean Air Interstate Rule (CAIR), Mercury and Air Toxic Standards (MATS), Regional Greenhouse Gas Initiative (RGGI), California's AB32, State renewable portfolio standards,…
- Annual projections to 2040



We Use GT-NEMS to Model Compliance Scenarios

- Accounts for the economic competition between fuel types, the cost and benefits of technologies, and behavioral aspects of consumer choice.
- Twelve modules represent supply, demand, energy conversion, and macroeconomic/international energy market factors.
- A thirteenth "integrating" module ensures that a general market equilibrium is achieved among the other modules.

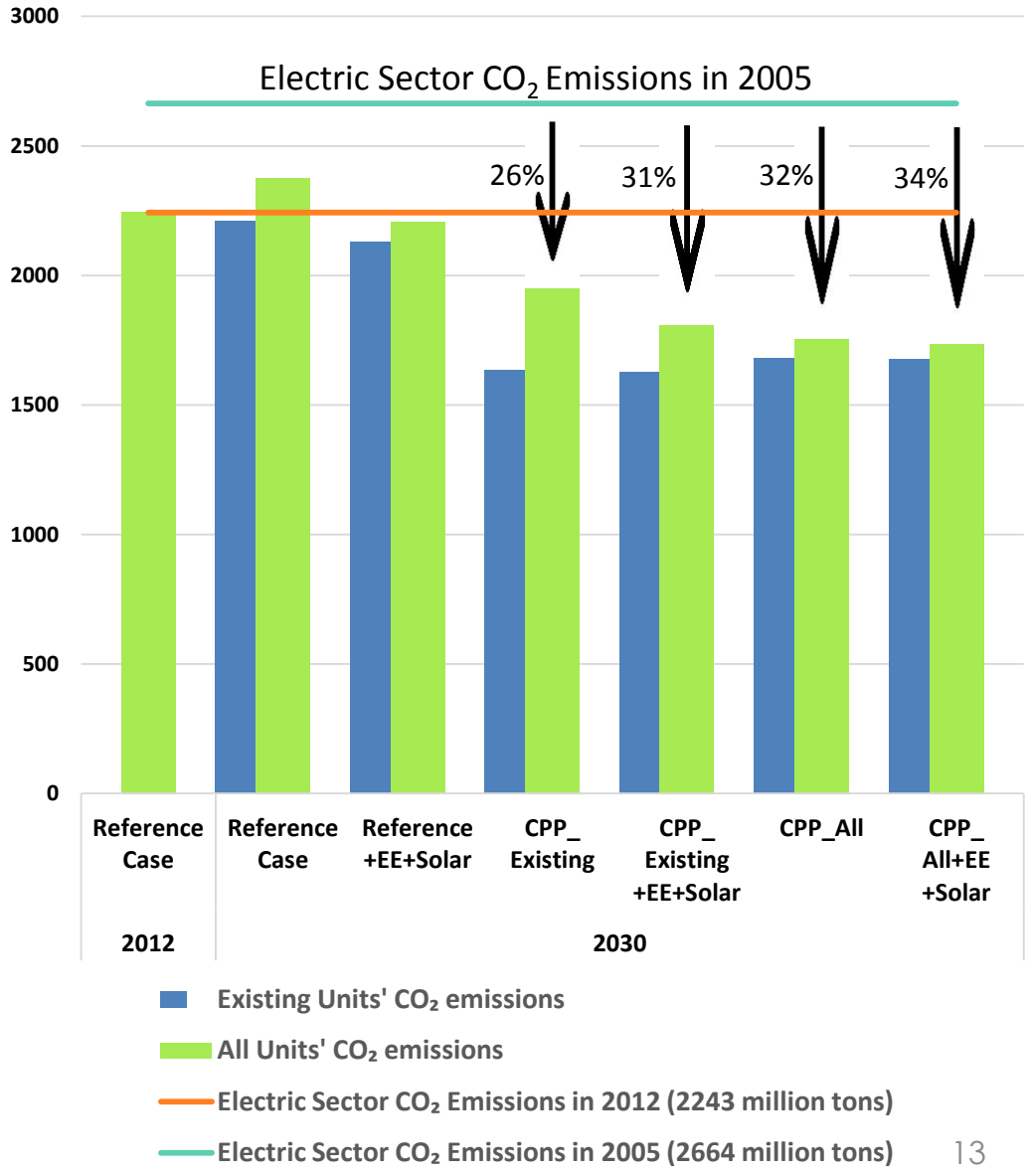


Results

Scenarios Can Meet the 32% Goal

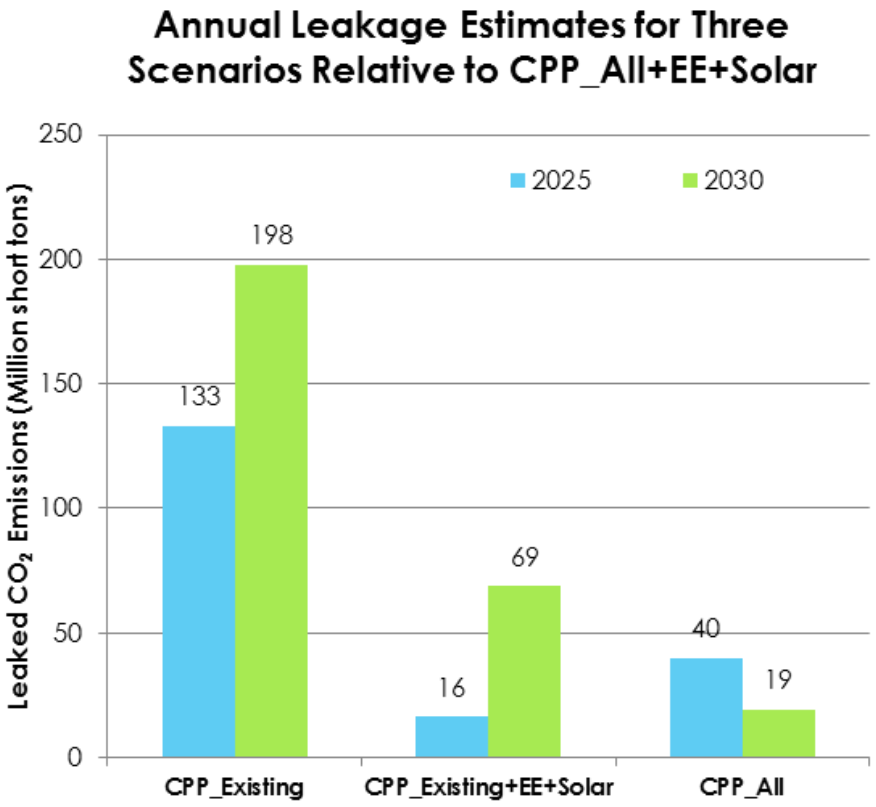
Electric sector CO_2 emission are reduced in 2030 from 2012 levels:

- 26% when only existing EGUs are regulated and the EE+Solar features are excluded
- 32% when both existing and new EGUs are regulated
- 34% when EE+Solar policies added



"Leakage" Can Compromise Mass-Based Compliance Scenarios

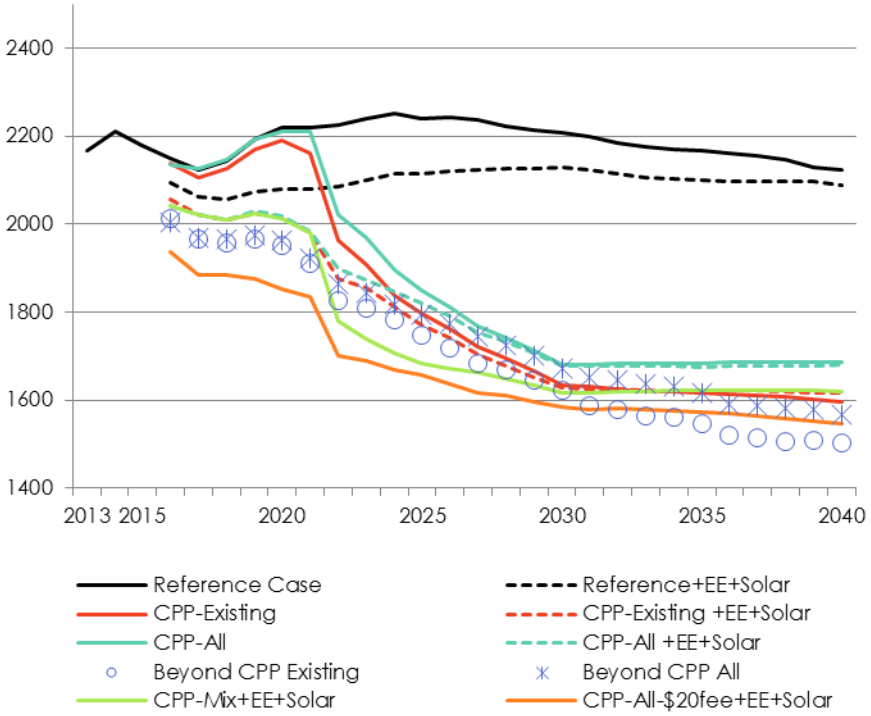
- Use of mass-based goals on existing affected units causes leakage – the shift in emissions within a state from covered to uncovered fossil generators.
- Existing NGCCs face a cost under a mass system that new NGCCs do not.
- The environmental integrity of the CPP can therefore by compromised.



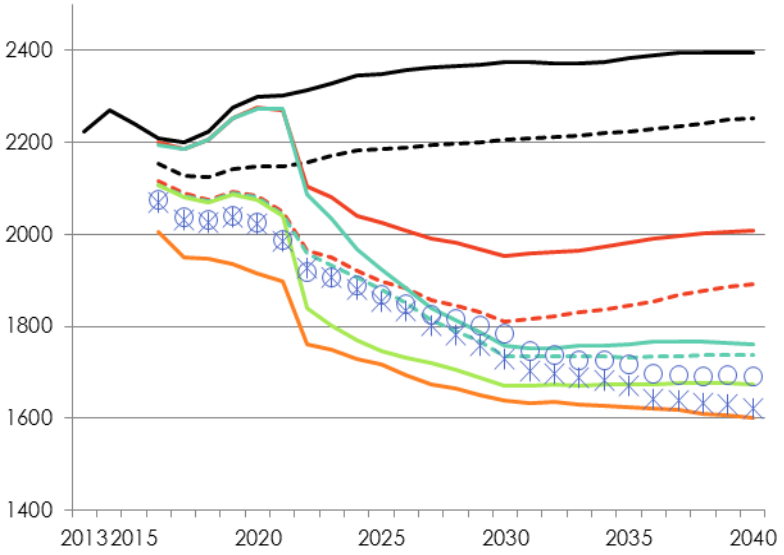
- **Enhanced energy efficiency helps plug the leakage.**

Timelines of CO_2 Emissions from "Affected" Units

U.S. CO_2 Emissions – Existing Units (Million Short Tons)



U.S. CO_2 Emissions – All Units (Million Short Tons)



- Emissions from existing units decline steeply in 2022 when the CPP mass-based goals are imposed as a standalone policy.
- They decline earlier under other scenarios.

- Emissions from all units see an upward tick after 2030.
- With "foresight" of future policies, reductions continue thru 2040.

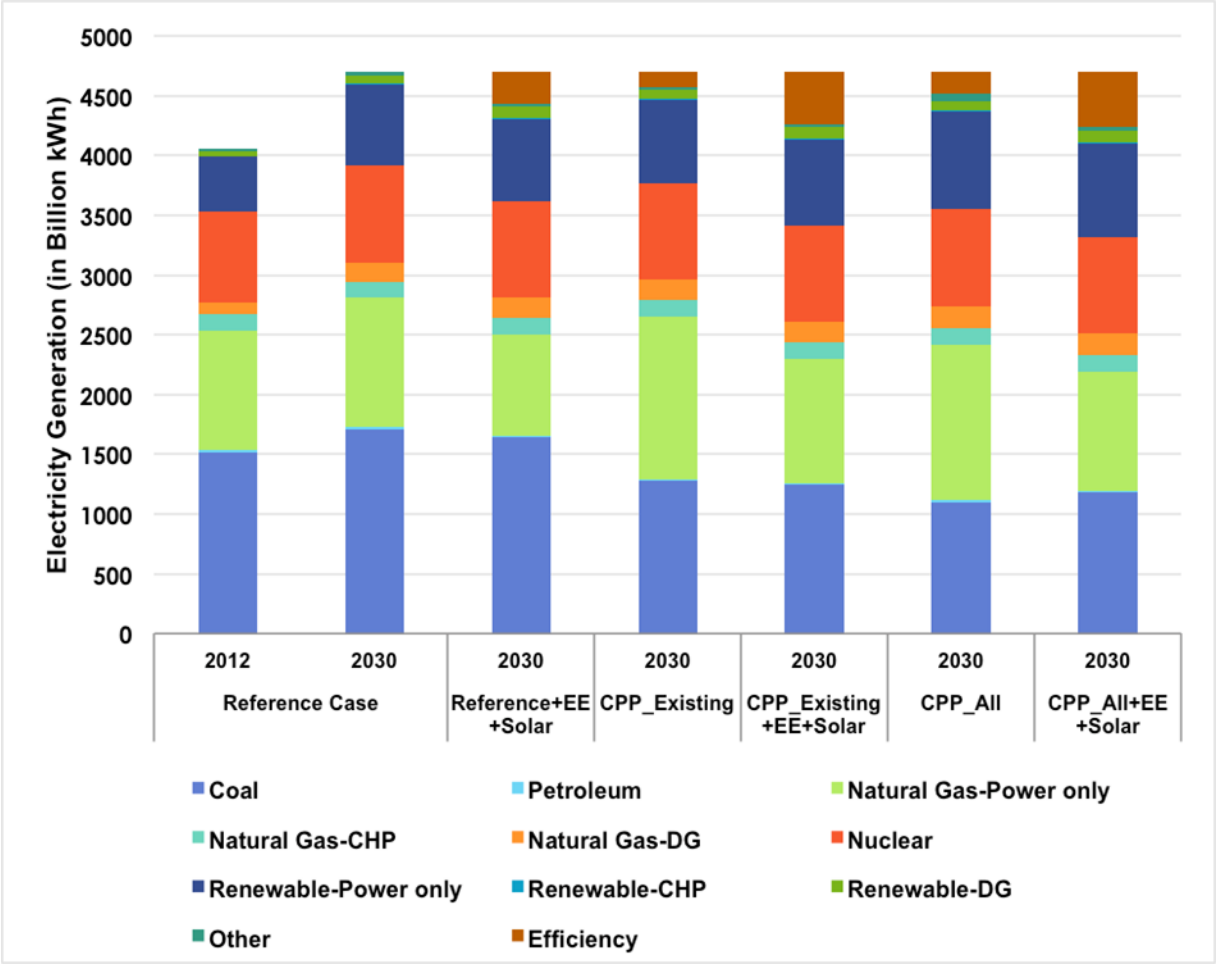
The Fuel Mix Transformation

CPP compliance reduces coal generation.

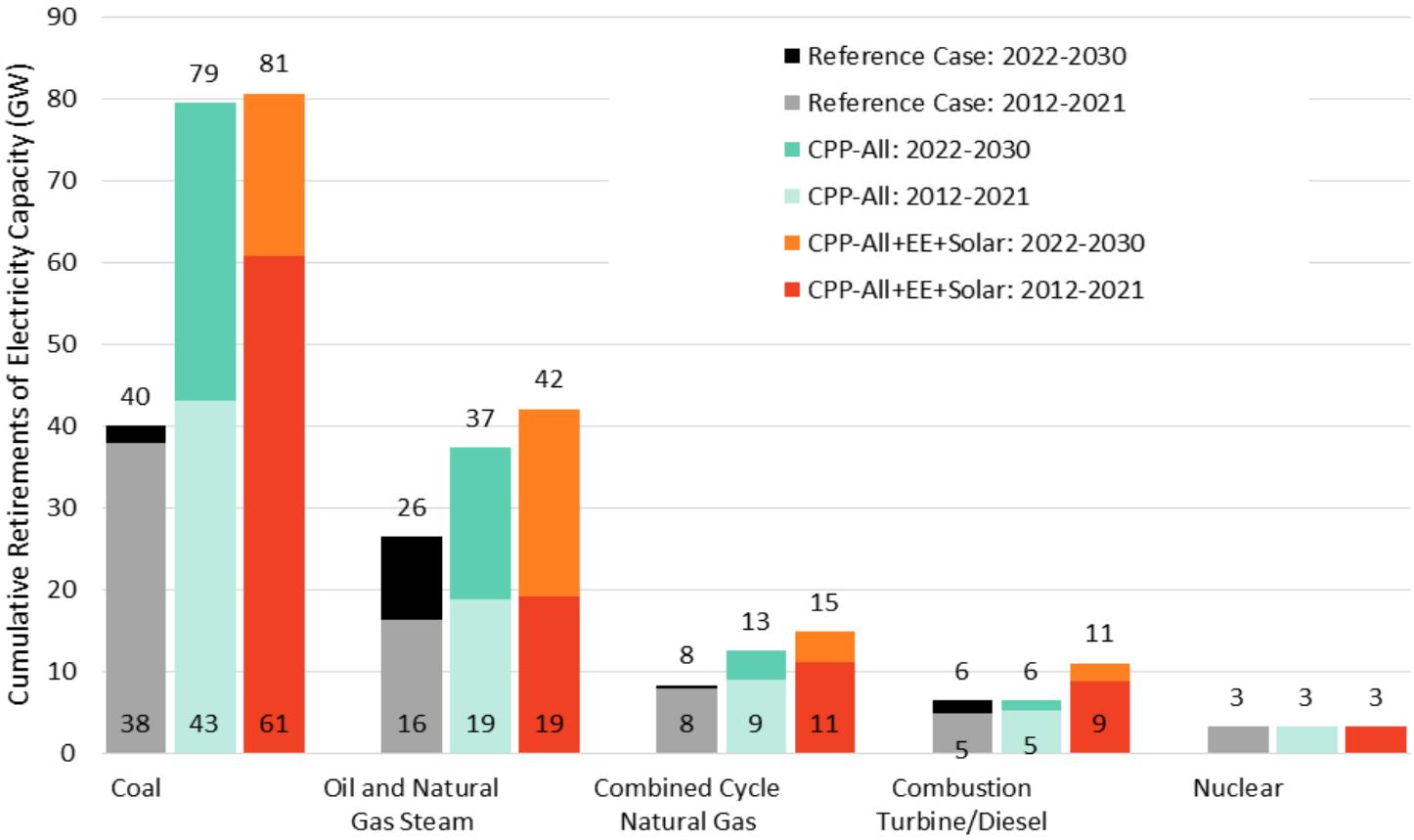
Coal is mostly replaced by NGCC units, especially when only **existing** EGUs are regulated.

Renewables and EE gain market share when mass-goals for **all** EGUs are implemented.

This is especially the case when the EE+Solar features are added.

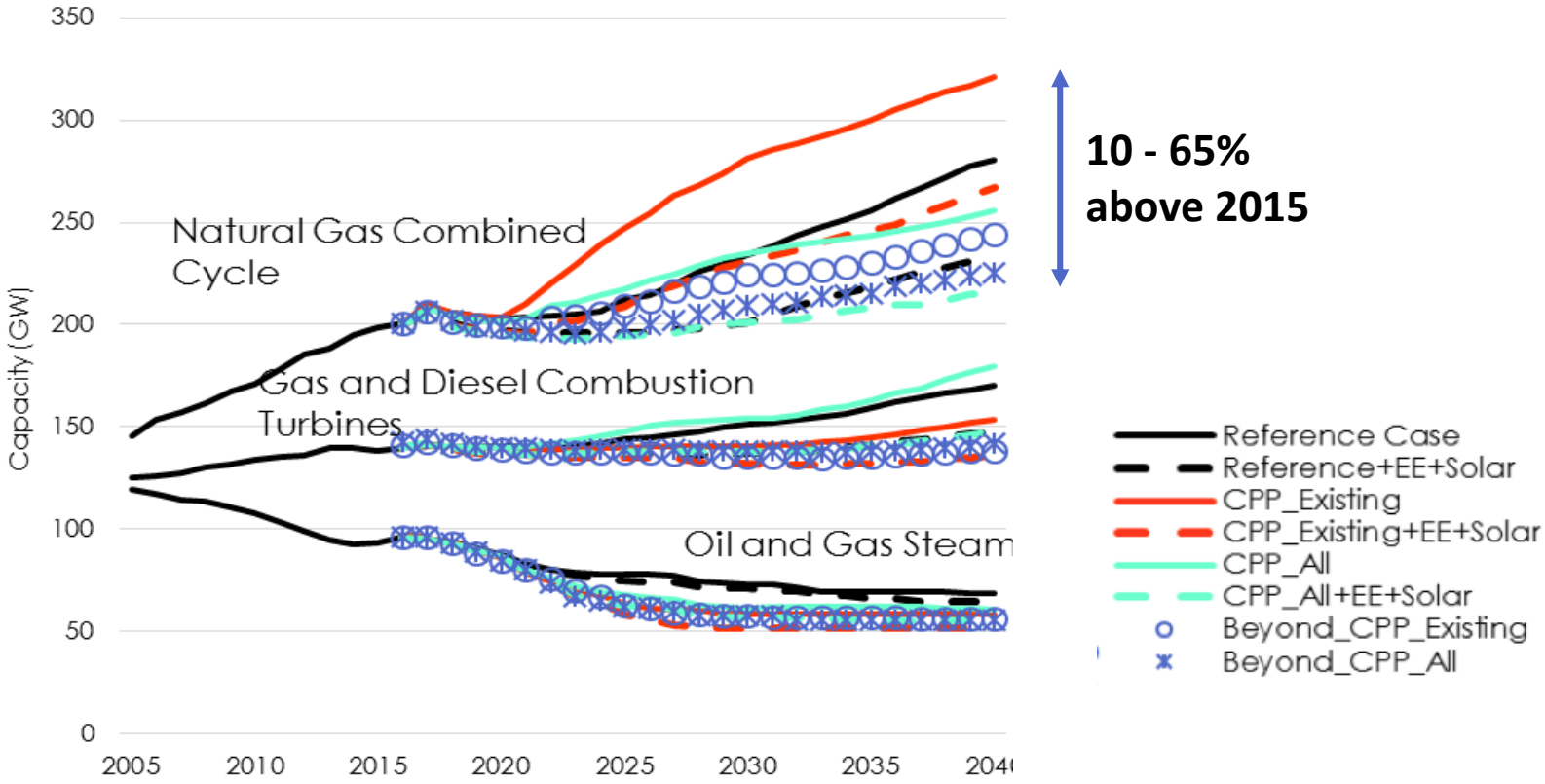


Accelerated Fossil Plant Retirements



- The CPP scenarios could double the pace of fossil-plant retirements.
- By 2030, the CPP-All+EE+Solar strategy retires 152 GWs – 15% of the electric power sector capacity in 2012.
- About 50% of the total retired capacity is coal.

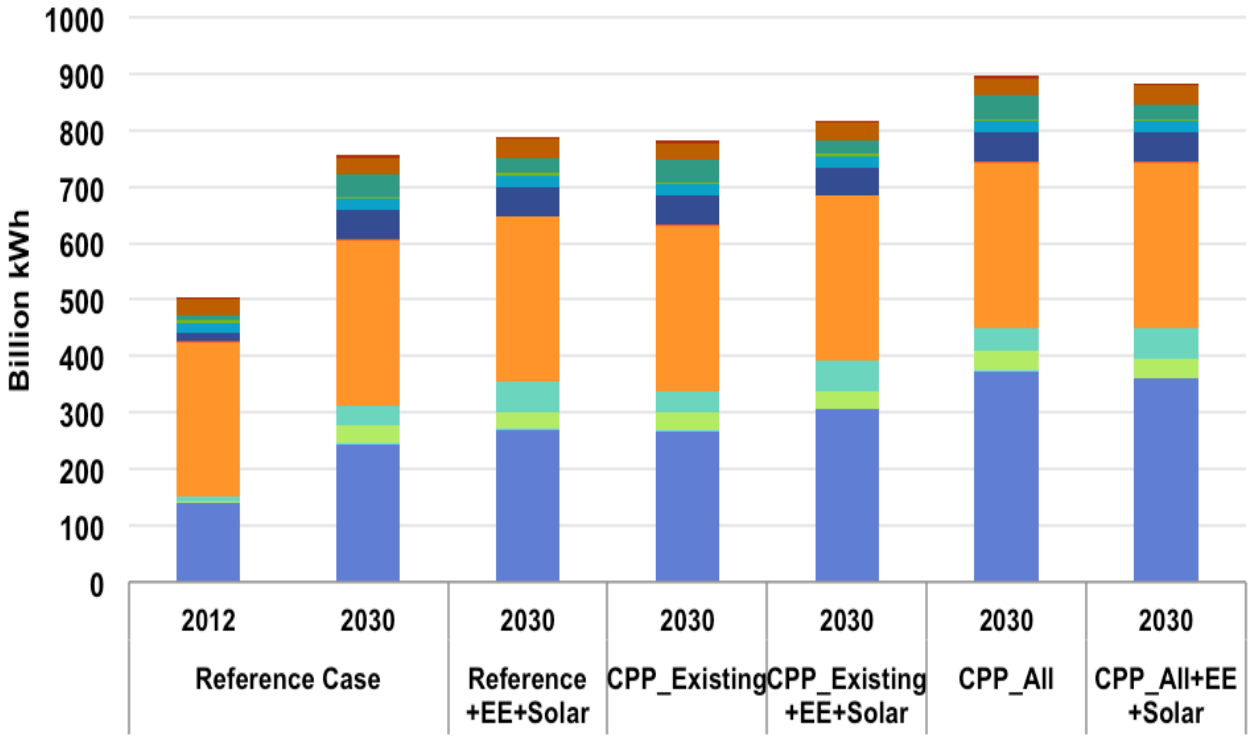
NGCC Expands 10% – 65% in 2040, Depending on EE+Solar and Foresight



- All compliance strategies favor NGCC technologies, since these are efficient and carbon-lean natural gas options.
- Oil and gas "steam" retires across all scenarios.

Mix of Renewable Generation

- Distributed and utility-scale solar grows rapidly in all scenarios, particularly when "all" affected units are covered.
- The additional load reductions from EE policies primarily offset the growth of natural gas generation.
- Wind generates more electricity than hydro by 2030 in CPP-All scenarios.



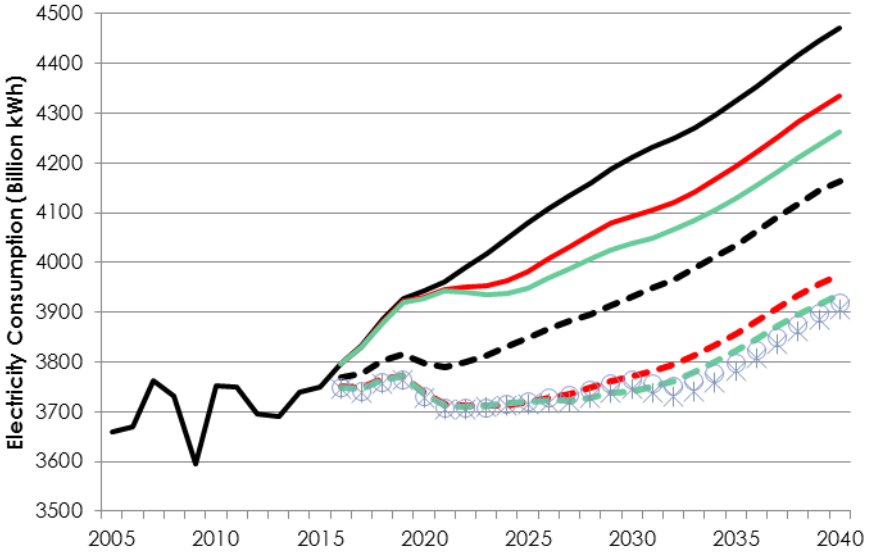
The Benefits of Reduced Pollution

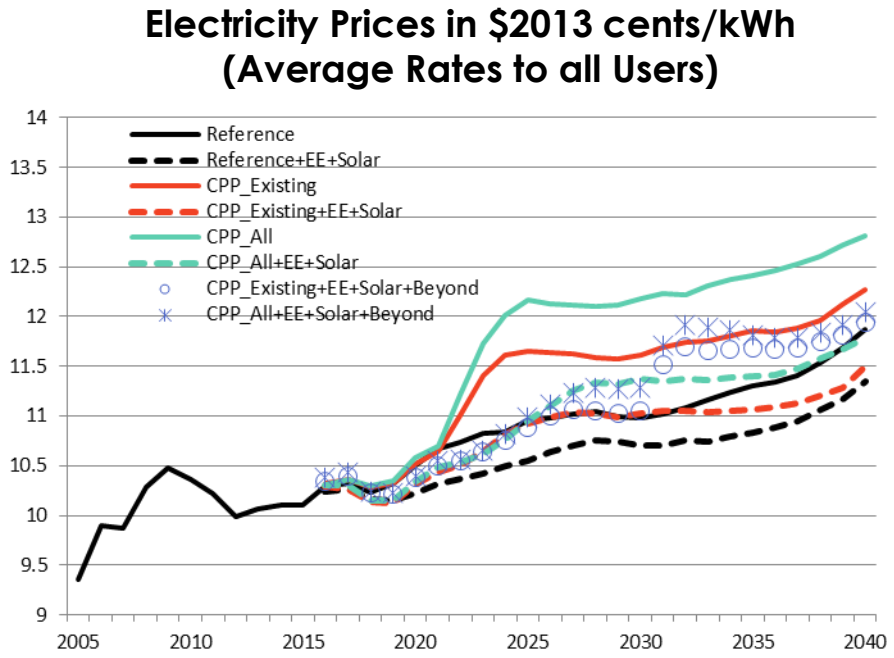
Monetized benefits in 2030 (in $2013 B)*	Carbon Dioxide	Sulfur Dioxide	Nitrogen Oxide	Total
CPP-Existing	22	18 - 42	5 - 16	45 - 80
CPP-Existing+EE +Solar	31	25 - 57	7 - 22	63 - 110
CPP-All	29	20 - 44	6 - 19	55 - 92
CPP-All +EE+Solar	33	23 - 52	6 - 20	62 - 105

*Benefits per ton (in $2013) = $51.7 for CO_2, $45,600-103,600 for SO_2 and $12,100-38,300 for NOx.

- The benefits of reducing CO_2, SO_2 and NOx in the year 2030 are estimated to be $45 - $110 billion (in $2013).
- The co-benefits from local pollution abatement exceed the benefits from carbon mitigation.

Energy Efficiency Reduces Electricity Rates & Bills

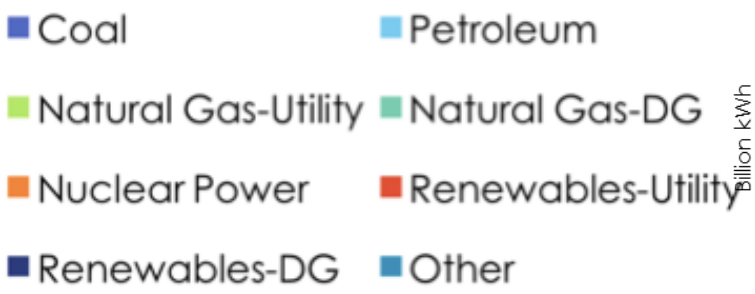


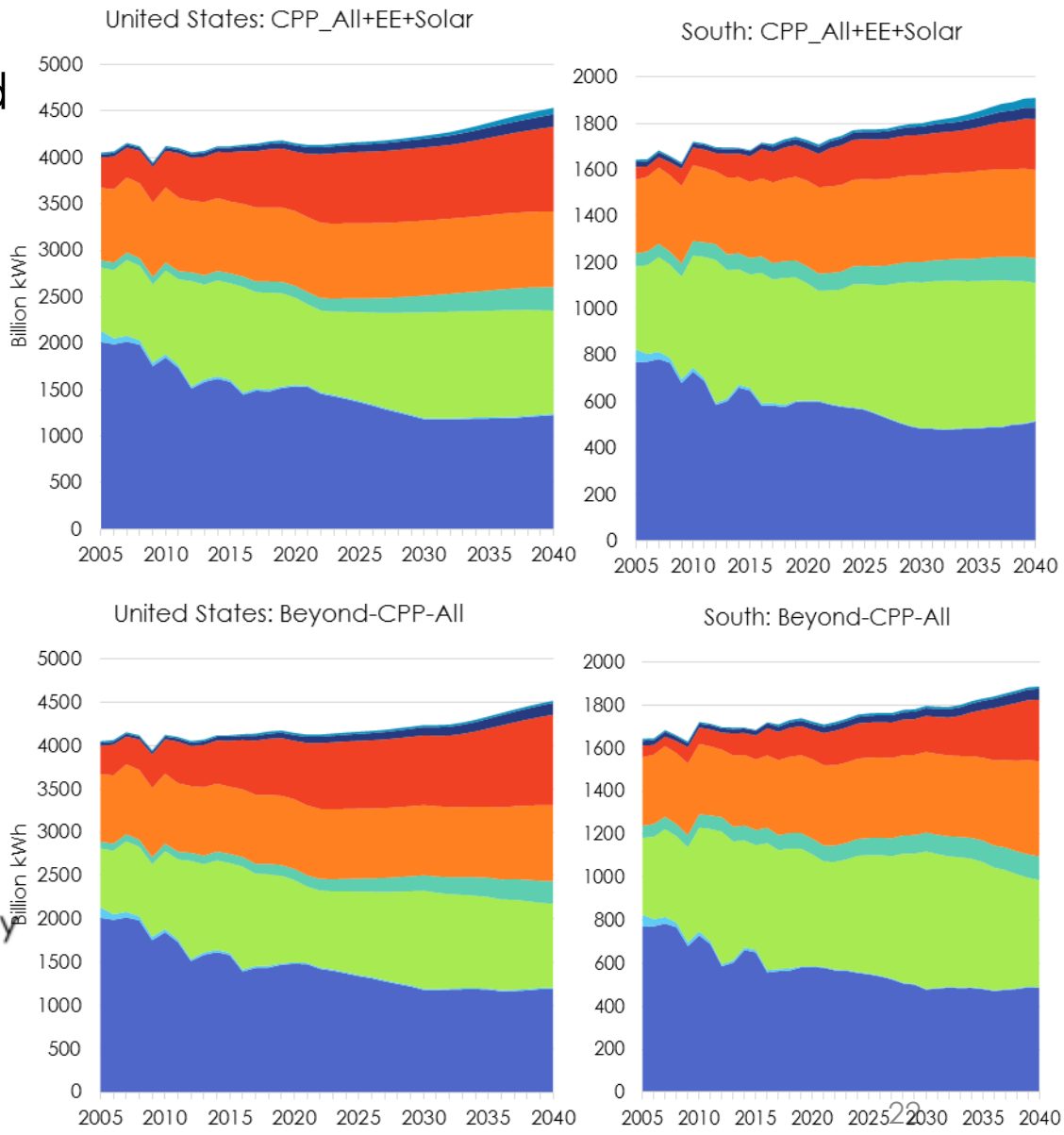


- Electricity consumption in 2030 is cut by 440-469 billion kWh relative to the Reference case – ~10%. Natural gas use in buildings is also cut.
- Electricity consumed in 2030 is still greater than in 2012.
- Without enhanced EE and solar, the CPP compliance scenarios reduce electricity consumption by only 120 billion kWh in 2030, or 3% less than in the Reference case.

The Virtue of Foresight

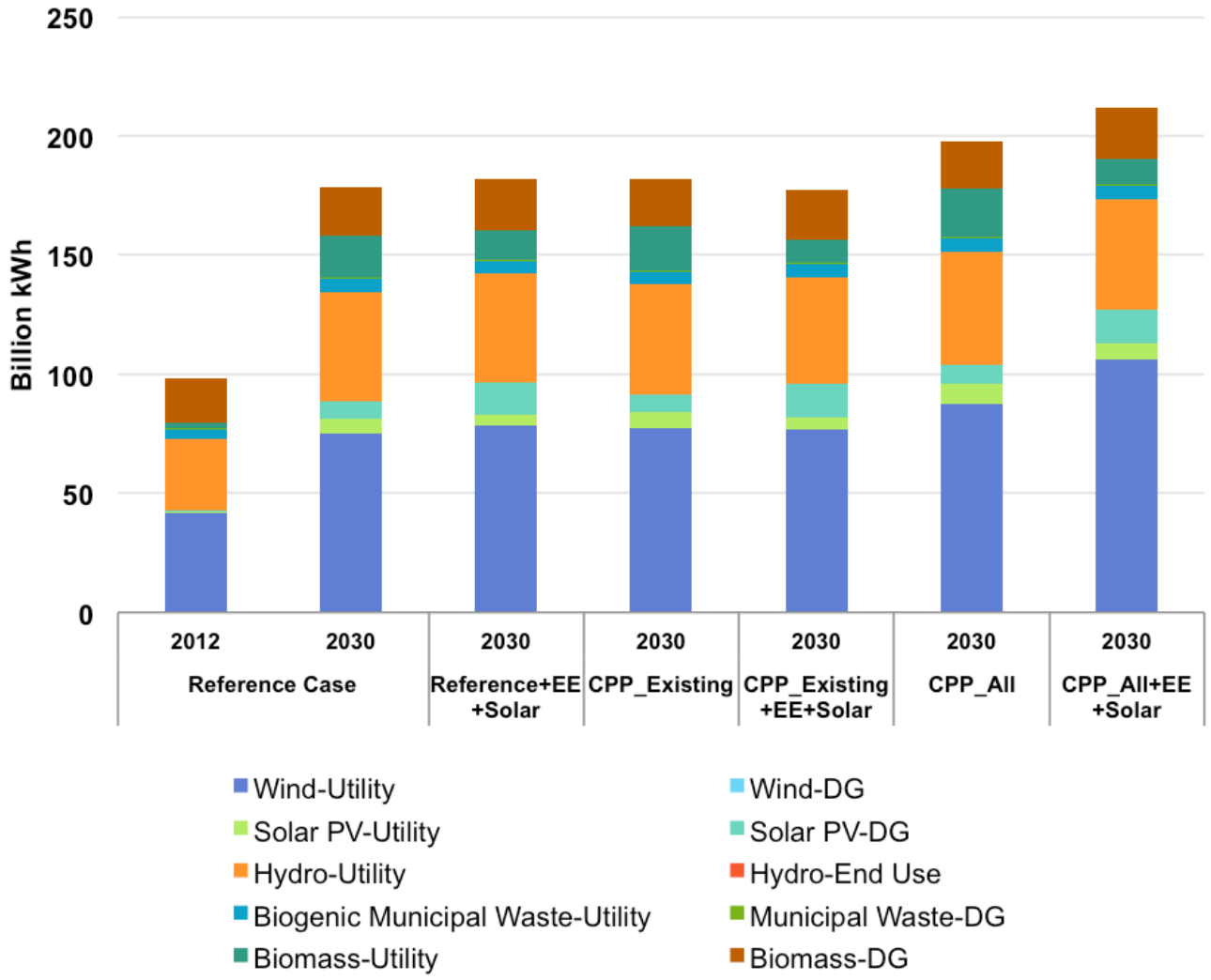
- Looking ahead could avoid natural gas lock-in and a legacy of missed opportunities heading into the mid-century.
- If CO_2 reduction requirements become increasingly stringent, least-cost decisions today could be quite different.





The South's Distinct Mix of Renewables

In the compliance scenarios, proportionately more natural gas, EE, and renewables are added and more coal is retired in the South than in the rest of the U.S.



Conclusions and Next Steps

Conclusions

- Regulating "all" EGUs (not just "existing" units) has multiple advantages:
  - Lowers CO_2 emissions by preventing leakage
  - Greater reduction of coal and smaller expansion of NGCC
  - More renewables and EE
- Looking ahead to more stringent standards:
  - Avoids natural gas lock-in and a legacy of missed opportunities heading into the mid-century
- EE has multiple benefits:
  - Reduces CO_2 emission by building less natural gas capacity to meet future demand growth
  - Makes the fuel transformation more affordable to consumers.

Next Steps

- Engage others in discussions of our modelling results
- Continue to compare findings across other studies of the CPP
- Publish results as a Georgia Tech working paper + book chapter + journal manuscript
- Translate to state "stats", particularly focused on energy costs to consumer.

For More Information

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Extras

Definition of Scenarios

Scenario	Description
Reference Case	Annual Energy Outlook 2015 Reference Case.
Reference+EE+Solar	The "EE+Solar" changes are introduced throughout the planning period representing progressive improvements in energy-efficiency and solar technologies and additional policies: extension of the Production Tax Credit for wind energy and extension of the Investment Tax Credit for solar energy with a higher incentive in 2020-21 to model the CEIP.
	Updated cost of installed utility-scale, residential, and commercial solar PV systems based on estimates from GTM/SEIA, Bloomberg New Energy Finance, Deutsche Bank, and national laboratories.
	Residential energy-efficiency improvements and capital cost reductions for residential appliances and equipment, lighting, and miscellaneous energy uses; improved building shells to model the CEIP.
	Commercial energy-efficiency improvements including higher-efficiency space heating and cooling equipment with stronger standards for rooftop units, as well as tighter building shell requirements.
	Industrial energy-efficiency includes a 30 percent investment tax credits for CHP through 2040, the EIA's High Technology assumptions for CHP systems and electric motors, and process efficiency improvements in five manufacturing subsectors.

Definition of Scenarios

Scenario	Description
CPP-Existing	CPP state-level goals for CO_2 mass emissions from existing EGUs (as described in the the EPA CPP Technical Support Document) are modeled directly by specifying constraints on emissions in the Electricity Market Module. Constraints at the state level are aggregated into the 22 NERC region constraints using weights based on a matrix of state-to-NERC-region generation in 2012.
CPP-Existing+EE+Solar	The changes to resource costs, technology performance, and future policies that were modeled in the "Reference+EE+Solar" scenario are added to the "CPP-Existing" compliance scenario.
CPP-All	CPP state-level goals for CO_2 mass emissions from existing and new EGUs are modeled directly by specifying constraints on emissions in the Electricity Market Module (EMM). Constraints at the state level are aggregated into 22 NERC region constraints using weights based on a matrix of state-to-NERC-region generation in 2012.
CPP-All +EE+Solar	The changes to resource costs, technology performance, and future policies that were modeled in the "Reference+EE+Solar" scenario are added to the "CPP-All" compliance scenario.
Beyond CPP Existing	Same as "CPP-Existing+EE+Solar," except a $20-ton price on carbon is applied to all electricity sector activities from 2031-2040.
Beyond CPP All	Same as "CPP-All+EE+Solar," except a $20-ton price on carbon is applied to all electricity sector activities from 2031-2040.
CPP-All+$20fee+EE+Solar	Same as "CPP-All+EE+Solar," except a $20-ton price on carbon is applied to all electricity sector activities in 2022.
CPP-Mix+EE+Solar	Same as "CPP-All+EE+Solar," except that seven regions representing the South comply with rate-based CPP goals instead of mass-based CPP goals.

One Week "Delay" in Economic Growth

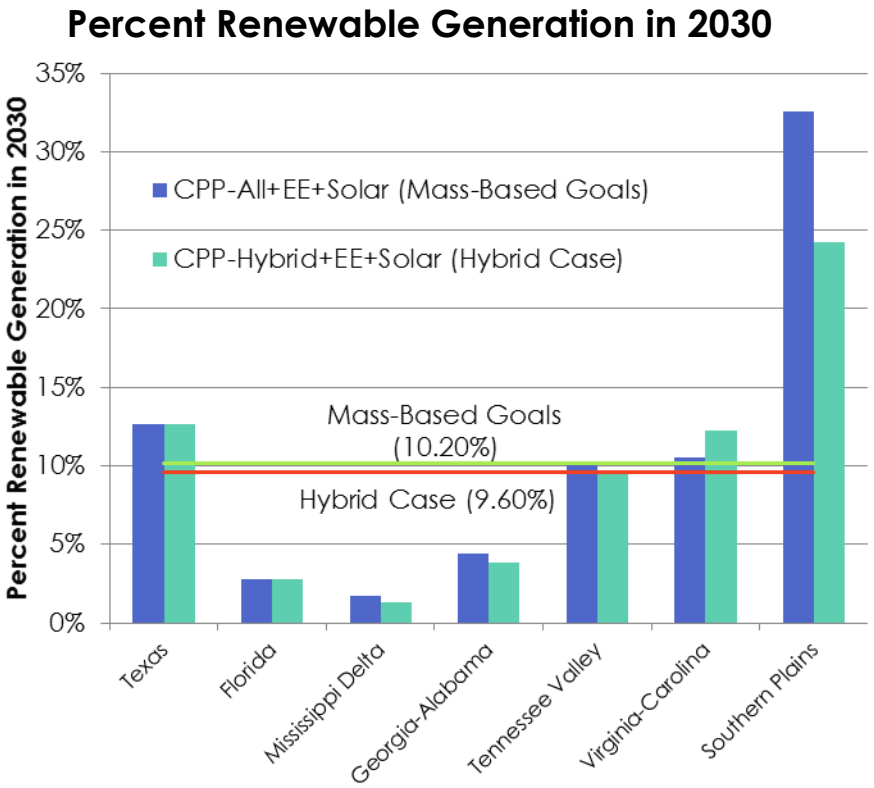
	Consumption	Investment	Government Spending	Exports	Imports	GDP
Reference Case in 2012	10,450	2,436	2,954	1,960	2,413	15,369
Reference Case in 2030	16,275	4,473	3,286	4,815	4,886	23,894
Reference Case +EE+Solar	16,227	4,443	3,284	4,809	4,845	23,850
CPP-Existing	16,241	4,477	3,283	4,806	4,908	23,833
CPP-All	16,200	4,441	3,282	4,801	4,860	23,799
CPP-Existing +EE+Solar	16,214	4,477	3,281	4,796	4,912	23,793
CPP-All+EE+Solar	16,180	4,436	3,281	4,795	4,857	23,770

National GDP is estimated to grow $60 - $120 billion less in the compliance scenarios, due principally to reduced consumption.

This is equivalent to less than a week's delay in GDP growth in 2030.

Renewables Grow more Slowly in the South with Rate-Based Goals

Region		
	South	Rest-of-Nation
Mass-based Goals Nationwide: CPP-All+EE+Solar		
2030	10.2%	27.7%
2040	12.2%	29.8%
Rate-based Goals in South/ Mass-based Goals in Rest-of-Nation		
2030	9.6%	28.6%
2040	10.2%	31.4%



- There are also potential lost opportunities from choosing a compliance pathway that differs from the rest of the nation.

Total Resource Costs (in billions $2013)

	Installed capacity	Transmission	Retrofits	Fixed O&M Costs	Capital Additions
Reference Case	121.5	6.0	20.4	367.7	68.8
Reference+EE+Solar	118.5	5.8	18.0	362.8	64.0
CPP_Existing	140.1	7.3	19.6	362.2	63.6
CPP_Existing+EE+Solar	134.6	6.8	16.5	356.3	60.6
CPP_All	144.6	7.2	19.6	363.3	63.7
CPP_All+EE+Solar	140.6	7.0	16.3	358.5	60.9
Beyond_CPP_Existing	150.4	7.8	14.1	357.1	59.5
Beyond_CPP_All	152.3	7.8	14.2	358.0	59.6

	Non-Fuel Variable O&M	Fuel Expenses	Purchased Power	Energy Efficiency Costs	Total	(% Change from Reference Case)
Reference Case	67.2	879.2	27.9	0.0	1558.9	--
Reference+EE+Solar	62.0	809.6	27.9	0.0	1468.5	-6.16%
CPP_Existing	65.8	889.9	28.9	21.0	1598.6	2.48%
CPP_Existing+EE+Solar	59.0	794.1	28.3	4.7	1460.9	-6.71%
CPP_All	64.3	889.3	31.9	21.4	1605.3	2.89%
CPP_All+EE+Solar	58.0	787.0	28.7	4.7	1461.7	-6.65%
Beyond_CPP_Existing	57.9	788.9	28.5	4.7	1469.0	-6.12%
Beyond_CPP_All	56.8	787.6	28.9	4.7	1469.8	-6.06%

Total resource costs would be approximately 6% higher in the two CPP compliance scenarios that only cap emissions, compared with the Reference case.

In contrast, they would be approximately 3% lower than the Reference case in the two compliance scenarios that also include "EE+Solar" features.

Rising Electricity Bills are Moderated by Energy Efficiency

($2013)	Households	Businesses	Industry	Total
Reference Case 2012	527.1	431.9	211.7	1172.7
Reference Case 2030	563.6	469.4	252.6	1289.5
Reference+EE+Solar	489.3	451.0	229.6	1173.7
CPP-Existing	576.2	480.4	264.6	1325.1
CPP-Existing+EE+Solar	494.3	427.5	234.1	1159.7
CPP-All	593.1	497.2	277.0	1371.6
CPP-All+EE+Solar	503.6	438.0	241.8	1187.4
Beyond-CPP-Existing	495.2	428.3	233.7	1161.1
Beyond-CPP-All	500.7	434.7	238.9	1178.3

- Per capita electricity bills are forecast to increase by 12% between 2012 and 2030.
- Higher increases would occur in the compliance scenarios if EE+Solar features are not included.
- Electricity bills could drop back to 2012 levels with compliance if EE+Solar policies were added.