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A Carbon Dioxide Standard for Existing Power Plants: Impacts of the NRDC Proposal

Prepared for the American Coalition for Clean Coal Electricity

Released:
March 2014

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Context and Purpose

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- EPA intends to regulate CO_2 emissions from existing power plants under CAA Section 111(d)
- NRDC's 2012 proposal for a Section 111(d) standard has received much attention
  - NRDC's proposal provides for emission rate averaging among generators (which allows a form of emissions trading and thus cost savings) and use of offsite credits, in return for a more stringent target emission rate than likely would be achieved under source-specific emission standards
  - NRDC's cost analysis is limited in scope and the study does not include some policy-relevant impacts
- NERA analyzes the NRDC proposal
  - Uses updated information and improved assumptions
  - Considers a wide range of costs and policy-relevant impacts
- NERA's study evaluates impacts on the macro economy and energy markets that NRDC did not account for in its analysis

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Executive Summary

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- NERA used a state-of-the-art energy/economy model (N_{ew}ERA) to assess the impacts of the NRDC proposal
  - Updated information on costs for energy efficiency
  - More consistent economic logic on adoption of energy efficiency in the baseline and policy case
- Analyzed impacts of the NRDC CO_2 target rate in two cases: (1) maximum compliance flexibility (even more than NRDC); and (2) limited compliance flexibility

	Flexibility	Trading	Energy Efficiency/ New Renewables	Notes
1	Maximum	National	Credits	Closest to NRDC proposal, but with national rather than regional trading
2	Limited	Intra-State	No Credits	

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Key Findings of NERA's Analysis

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- Consumers would face more substantial costs from the policy than NRDC's analysis suggests
- Consumer costs would include costs to non-electric consumers of natural gas that were omitted from NRDC's analysis
- Overall policy costs are substantial and would increase significantly if the proposed emission limit is adopted but the degree of compliance flexibility in the NRDC proposal does not materialize
- The inter-state trading envisioned in the NRDC proposal would create "debtors" and "creditors" among states (which may lower the chance of achieving the proposed compliance flexibility)

Energy Consumers Would Bear Large Costs under the NRDC Proposal

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Present Values of Estimated Consumer Costs (2018-2033)(*)

	Maximum Flexibility	Limited Flexibility
Costs of Electricity Services (***)	$109 billion	$97 billion
Costs of Natural Gas (not for electricity)	$8 billion	$54 billion
Total Consumer Costs for Energy	**$116 billion**	**$151 billion**

Estimated Decline in Job Equivalents (2018-2033)(**)

	Maximum Flexibility	Limited Flexibility
Annual average loss	<1000	178,000
Cumulative loss (job-years)	5,000	2,850,000

On an annualized basis, total consumer costs for energy would be between $13 and $17 billion per year for 2018 through 2033

(*) Stated in 2012$, discounted to 2013, incremental to the baseline. Totals may not equal sum of rows due to rounding.
(**) Average over 2018-2033 relative to baseline. Job equivalents equal total labor income change divided by average income per job. Independent rounding of annual and cumulative job losses. These totals are change in net jobs, which includes increases in some sectors (e.g., energy efficiency) and decreases in others (e.g., coal).
(***) This is the only cost calculated by NRDC, as they did not calculate any other cost impacts on the rest of the economy. This cost includes the total cost of energy efficiency, including the portion spent directly by consumers.

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Energy Markets Would be Affected in Major Ways by the NRDC Proposal

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Annual Average, 2018-2033

	Total Coal Retirements Through 2033 (GW)	Coal-Fired Generation (TWh)	Natural Gas-Fired Generation (TWh)	Henry Hub Natural Gas Price (2012$/ MMBtu)	Delivered Electricity Price (2012¢/kWh)	Ele CO_2 Emissions (MMMT)
Maximum Flexibility						
Baseline	41	1,742	1,093	$4.08	11.8	2,081
NRDC CO_2 Standard	76	1,451	1,183	$4.17	12.9	1,836
Change	35	(291)	90	$0.09	1.0	(245)
% Change	+86.5%	-16.7%	+8.2%	+2.2%	+8.6%	-11.8%
Limited Flexibility						
Baseline	41	1,742	1,093	$4.08	11.8	2,081
NRDC CO_2 Standard	124	995	1,764	$4.74	12.2	1,597
Change	83	(747)	671	$0.65	0.4	(484)
% Change	+205.4%	-42.9%	+61.4%	+16.0%	+3.4%	-23.3%

Note: Independent rounding of scenario values and changes.

The impacts to consumers are derived from an analysis of how the CO_2 standard would affect energy markets

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Electricity Prices Would Increase Substantially in Most States under the NRDC Proposal

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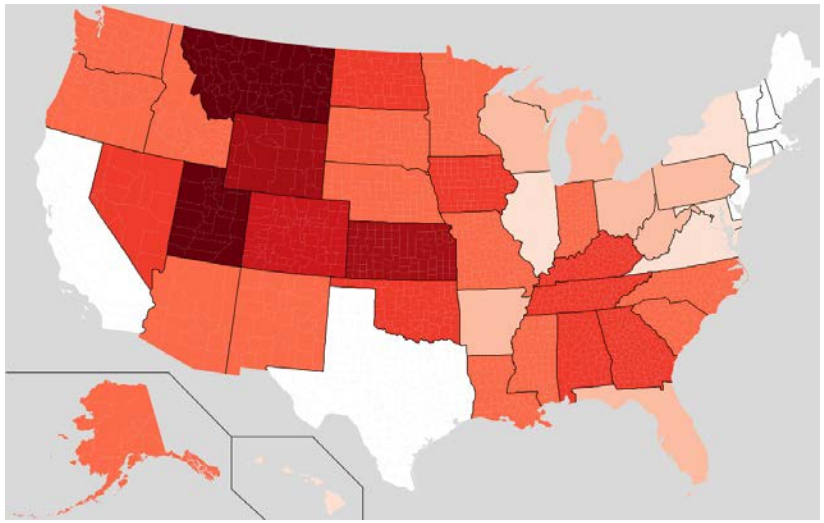
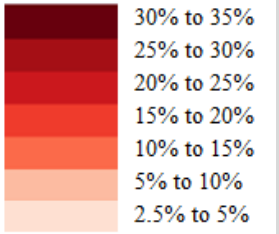
- In the Limited Flexibility case, electricity prices reflect the costs of fuel switching as well as net costs from intra-state trading and capital spending
- In the Maximum Flexibility case, electricity prices reflect the costs of fuel switching, plus:
  - Cost impacts from energy efficiency and new renewable credit transactions and capital spending
  - Net purchases/credits from inter-state trading ($24 billion is transferred from states that need to buy credits to states that can sell credits over 2018-2033, in present value)

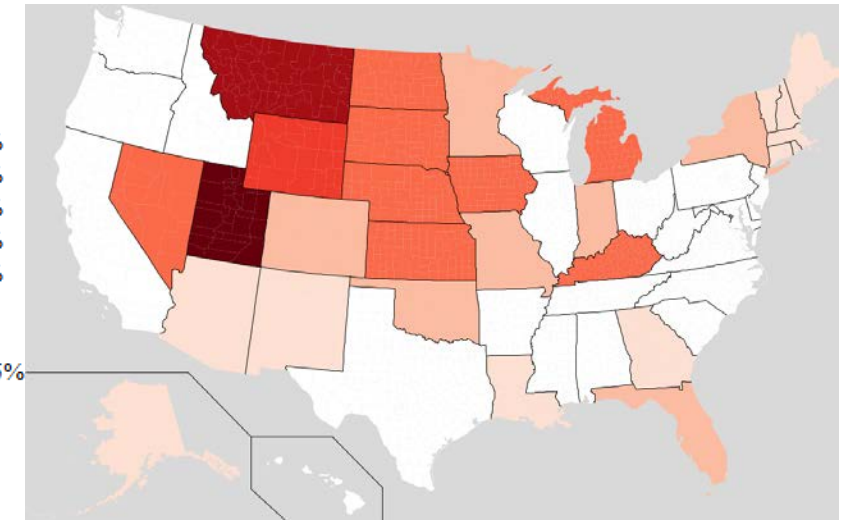
Change in 2018-2033 Average Delivered Electricity Price (Relative to Baseline)

Maximum Flexibility





Limited Flexibility



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NRDC Proposal

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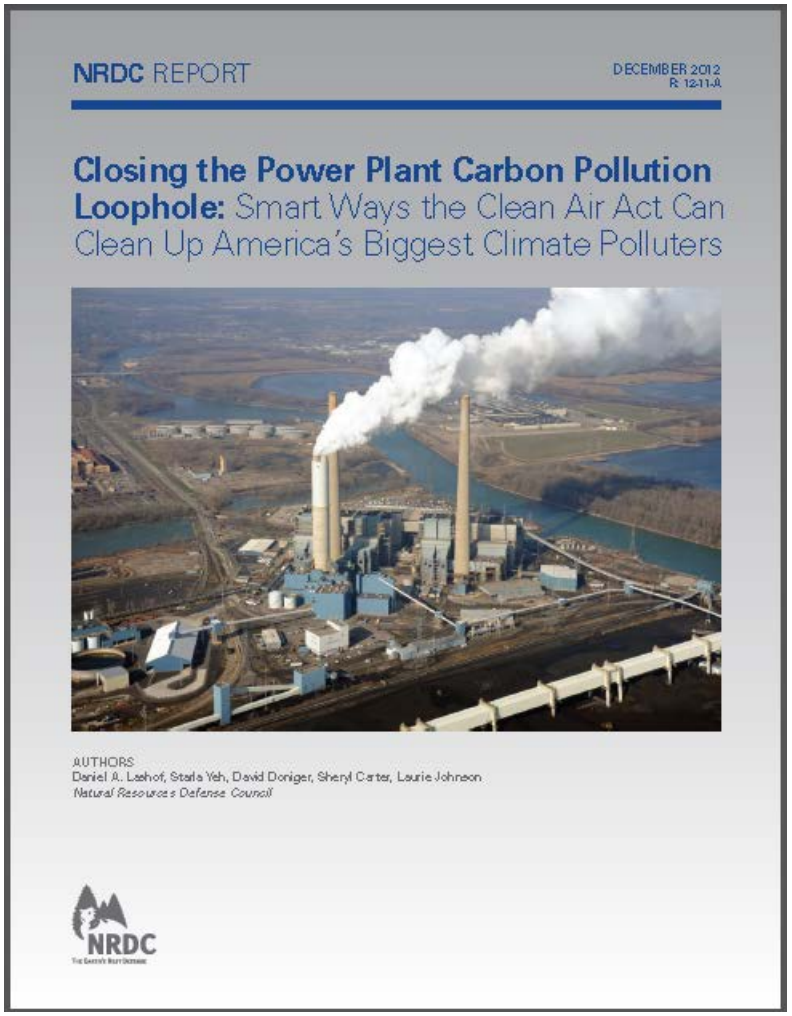
NRDC Proposal



Study available at: http://www.nrdc.org/air/pollution-standards/files/pollution-standards-report.pdf

- Regional CO_2 target emissions rates with averaging allowed within regions
- Fuel-specific CO_2 target rates (lbs/MWh):

	2016	2020	2025
Coal	1,800	1,500	1,200
Natural Gas/ Oil	1,035	1,000	1,000

- State composite target rate based on 2008-2010 share of coal vs. natural gas/oil generation
- Credits for energy efficiency (demand)
- Credits for generation from post-2013 new renewables
- Heat rate improvement retrofits for coal units

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NRDC Proposal Includes Four Sources of Flexibility/Cost Savings

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1. Emission rate averaging for regions
   - Outputs focus on five regions (ISO-NE, NYISO, MISO, PJM, and Southeast)
2. Electricity energy efficiency (demand side) credits
   - Assumptions based on study by Synapse Energy Economics
3. New renewable credits
   - Incremental renewable generation
4. Banking of emission reduction credits

NERA evaluates three sources of flexibility—national versus intra-state averaging as well as credits for both added electricity efficiency and new renewables

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NRDC Forecasts Total Energy Efficiency Credits Far Beyond Historical Results

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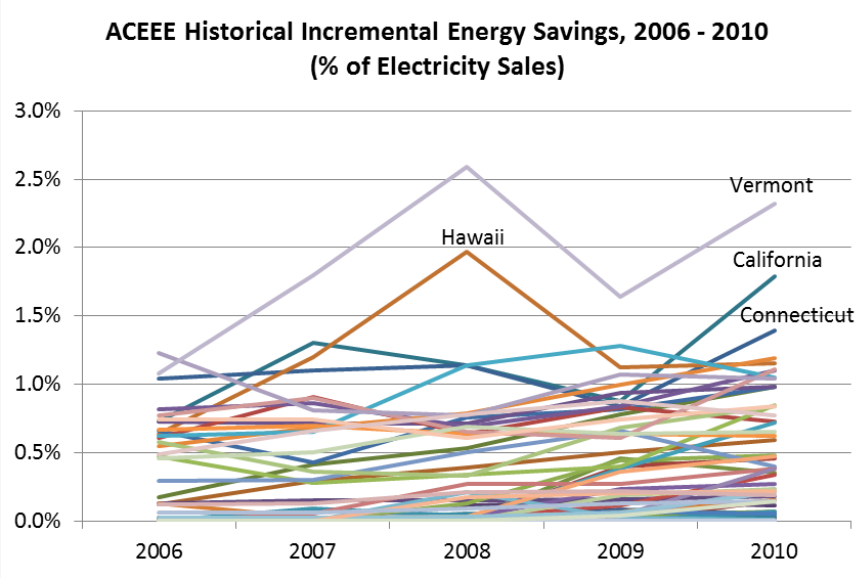
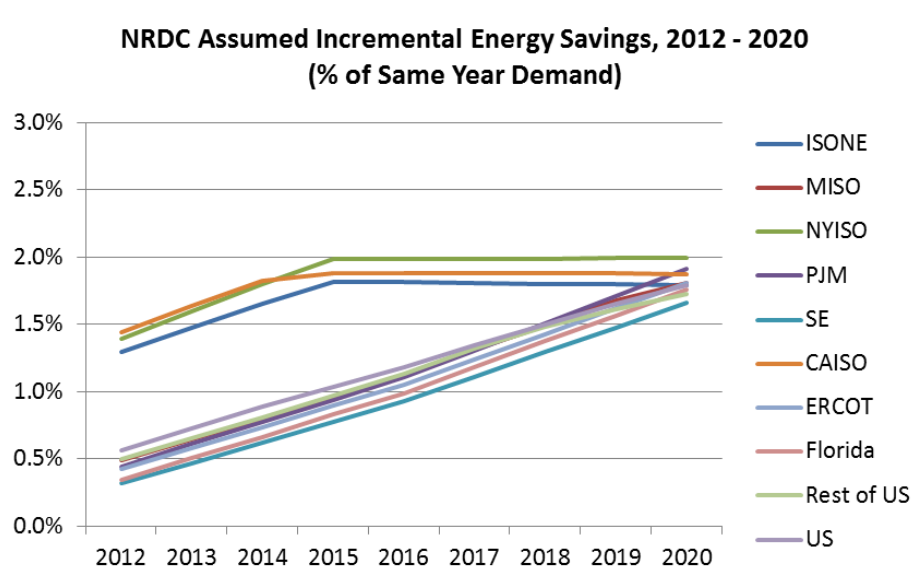
- NRDC assumes that every U.S. region would "ramp up" from its current level of energy efficiency to 2% *incremental* annual energy savings in 2020
- However, Vermont is the only state to achieve incremental savings of 2% from energy efficiency programs between 2006 and 2010; most states achieved less than 1%



Source: ACEEE, 2008 – 2012 State Energy Efficiency Scorecards



Source: NRDC (2012), Table III.3, Table II.4; NERA calculations

NERA allows for NRDC-potential additional electricity savings by region but does not presume they would occur

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NRDC's Energy Efficiency Credits Include Some "Baseline" Savings

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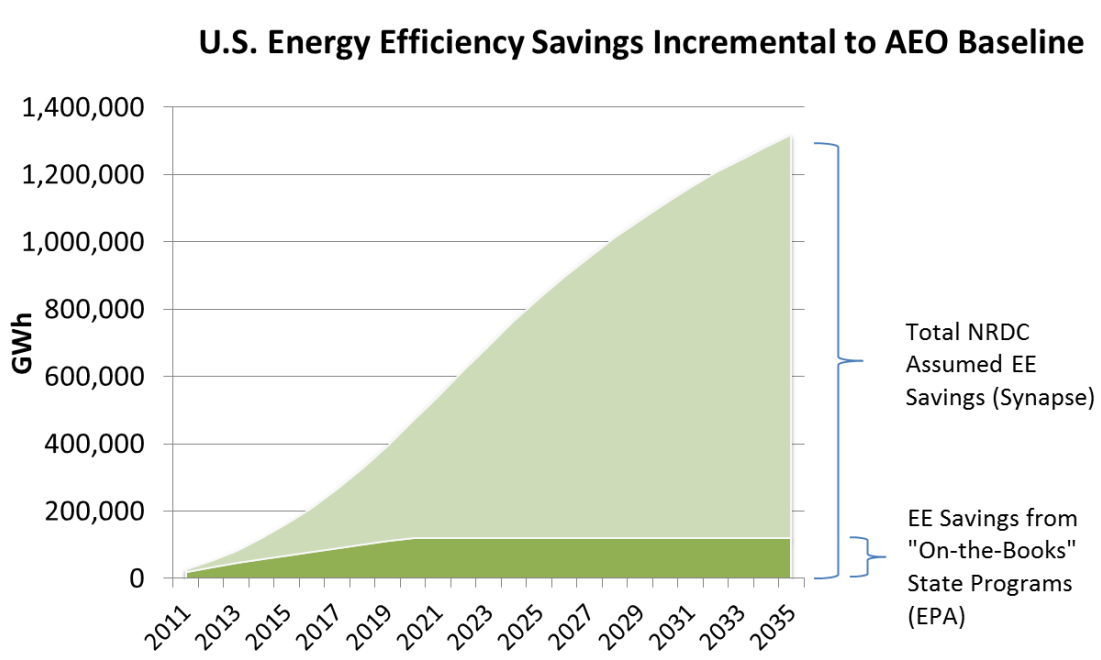
- NRDC allows future energy efficiency savings already required by "on-the-books" state programs and mandates to contribute to emissions credits in its policy scenario



Source: NRDC (2012) Table II.4; EPA (2011) Projected Energy Impacts of Existing State EE/RE Policies

NERA reduces potential credits available in NRDC's assumptions by subtracting out "on-the-books" programs/mandates (as estimated by EPA)

NRDC Includes Added Demand Response Programs Without Any Rationale for Why They Would Occur

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- NRDC assumes demand response programs (which are designed to reduce peak electricity demand) would increase in the policy case
- NRDC does not explain why its proposed policy would lead to more demand response programs—such programs do not necessarily lead to CO_2 emission reductions (and thus eligibility for credits)
- It is not possible to determine from the information NRDC has provided about its analysis method whether the inclusion of additional peak demand reduction in its policy case has resulted in overstatement or understatement of its estimate of the policy's costs

NERA does not include increases in demand response programs as there is no clear rationale for their increasing as a result of the NRDC policy

NRDC Assumes Energy Efficiency Credits are Cheaper than Electricity Prices

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- All of NRDC's energy efficiency credits are assumed by NRDC to cost less than the delivered price of electricity (in all regions)
  - NRDC assumes energy efficiency credits start at 4.9¢/kWh in 2012 and rise only to 7.3¢/kWh by 2041 (in 2012¢)
  - In contrast, average delivered residential electricity prices in July 2013 ranged from 8.9¢/kWh (Washington state) to 36.6¢/kWh (Hawaii)
- NRDC does not explain why at least some (if not all) of these energy efficiency gains would not be adopted without the credit program (and thus be part of the baseline)

NERA modified NRDC's electricity efficiency cost assumptions based on a recent academic study of the literature; also, NERA allowed cost-effective electricity efficiency to be chosen in the baseline case

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NERA Methodology

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Overview of NERA Methodology

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- Developed updated energy efficiency costs based upon a recent academic study that reviewed the cost literature
- Developed corrected/modified baseline energy efficiency—accounted for "on-the-books" savings and allowed cost-effective energy efficiency to be used even without the CO_2 target rate limit
- Evaluated the NRDC CO_2 target rate limit based upon two cases:
  1. "Maximum Flexibility" with national emission rate averaging and credits for energy efficiency and new renewables
  2. "Limited Flexibility" with intra-state emission rate averaging and no credits allowed for energy efficiency and new renewables
- Used up-to-date N_{ew}ERA model (AEO 2013) to estimate the impacts of the NRDC CO_2 target rate limit

We analyze effects of the NRDC CO_2 rate limit for two cases allowing different amounts of compliance flexibility

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NERA Assumptions on the Costs of Energy Efficiency in Electricity

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- A recent academic study reviewed the cost literature and provided conclusions regarding the likely costs of demand-side energy efficiency programs in electricity
- NERA used these costs to estimate electricity efficiency in the baseline and in the NRDC CO_2 target rate cases:

Model Year	NERA Price of EE (2012 ¢/kWh)
2018	11.2
2023	12.6
2028	12.6
2033	14.3
2038	14.3
2043	16.7

Source: Based on values in Allcott and Greenstone (2012), p. 16 and assumptions regarding increases over time in NRDC (2012), p. 37 and Synapse (2011), p. 51.

NERA uses a recent academic study that reviewed the literature to determine the cost of electricity efficiency

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NERA Assumptions Regarding the Baseline and the NRDC CO_2 Target Rates

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- Baseline includes CAIR and MATS, state RPS, and other environmental regulations as well as any energy efficiency that is "on-the-books" or found by the model to be cost-effective in the face of future electricity prices
- NERA evaluated the impact of NRDC's CO_2 target rate under two cases, Maximum Flexibility and Limited Flexibility:

	Flexibility	Trading	Energy Efficiency/ New Renewables	Notes
1	Maximum	National	Credits	Closest to NRDC proposal, but with national rather than regional trading
2	Limited	Intra-State	No Credits	

NERA Modeling of NRDC CO_2 Target Rates with National Trading and Credits

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- CO_2 emission target rate in lbs/MWh (based on 2010-2012 U.S. fossil shares: coal 61% and natural gas 39%):

	2018	2023	2028
Coal	1,800	1,500	1,200
Natural Gas	1,035	1,000	1,000
Target Rate	1,499	1,303	1,121

- Constraint imposed in model using above emission rate targets:

$$\frac{CO_2 \text{ Emissions from Fossil Units}}{\text{Applicable Generation}} \leq \text{Target Emission Rate}$$

where "Applicable Generation" = Generation from Fossil Units + Energy Efficiency[*/]
+ Generation from New Renewables[*/]

- Including credits for energy efficiency and new renewables (Maximum Flexibility case) makes it less expensive to meet a given CO_2 target rate

[*/] Energy efficiency and new renewables are included in "Applicable Generation" only in the Maximum Flexibility case; the Limited Flexibility case does not allow credits for those actions to count towards meeting the target rate.

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NERA's Cases Bracket NRDC's in Terms of Flexibility and Use Updated Assumptions on Energy Efficiency

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		NRDC Main Case	NERA Maximum Flexibility Case	NERA Limited Flexibility Case
Flexibility	Emission Rate Averaging	Regional	National	State
	Credits Allowed	Energy Efficiency/New Renewables	Energy Efficiency/New Renewables	None
Assumptions	Energy Efficiency Price	Synapse assumptions, always economical	Based on Allcott & Greenstone (2012)	Based on Allcott & Greenstone (2012)
	Baseline Energy Efficiency	AEO 2011 assumptions	AEO 2013 assumptions + "on-the-books" + any cost-effective energy efficiency	AEO 2013 assumptions + "on-the-books" + any cost-effective energy efficiency
	Energy Efficiency Use	Synapse (2011) assumptions	Adopted when cost-effective up to NRDC total (less "on-the-books" energy efficiency)	Adopted when cost-effective up to NRDC total (less "on-the-books" energy efficiency)
	Demand Response	Near-term Synapse (2011) assumptions	No demand response	No demand response

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Energy Market Assumptions in NRDC and NERA Cases

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	NRDC	NERA
Electricity Demand	AEO 2011 Reference Case	AEO 2013 Reference Case
Peak Electricity Demand	AEO 2011 Reference Case	EPA 2011 MATS analysis and AEO 2013 Reference Case
Reserve Margins	NERC 2012 Summer Short Term Reliability Assessment	EPA 2011 MATS analysis
Natural Gas Prices	Based on supply curves developed in 2011, regional differentials, and NRDC demand levels	Based on elasticity of demand, regional differentials, and NERA economy-wide demand levels
Coal Prices	Model output based on NRDC demand levels	Model output based on NERA demand levels

NERA used AEO's most recent energy market forecasts

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NERA Modeling Results

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National Financial Impacts on Generators and Consumers

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Impacts to Generators

Present Value of Changes in Revenues (2018-2033, 2012$)

	Maximum Flexibility	Limited Flexibility
Coal	-$93 million	-$239 million
Gas and Oil	-$2 million	$269 million
Other Technologies	-$9 million	$30 million
Total for All Generators	**-$103 million**	**$60 million**

Present Value of Changes in Net Revenues (2018-2033, 2012$)

	Maximum Flexibility	Limited Flexibility
Coal	-$25 million	-$58 million
Gas and Oil	-$10 million	$5 million
Other Technologies	-$5 million	$29 million
Total for All Generators	**-$40 million**	**-$24 million**

As with many regulatory policies:
(1) There could be winners and losers within the regulated sector while
(2) Consumers as a whole absorb net costs

Costs to Consumers

Present Value (2018-2033, 2012$)

	Maximum Flexibility	Limited Flexibility
Costs of Electricity Services(*)	$109 billion	$97 billion
Costs of Natural Gas (not for electricity)	$8 billion	$54 billion
Total Consumer Costs for Energy	**$116 billion**	**$151 billion**

(*) This is the only cost calculated by NRDC, as they did not calculate any other cost impacts on the rest of the economy. This cost includes the total cost of energy efficiency, including the portion spent directly by consumers.

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National Labor Impacts by Year, in Job-Equivalents

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Thousands of Job-Equivalents

	2018	2023	2028	2033	2018-2033 Average	2018-2033 Cumulative
Maximum Flexibility						
BAU	146,498	153,403	161,198	168,201	154,606	2,473,697
NRDC CO_2 Standard	146,368	153,329	161,341	168,505	154,606	2,473,693
Change	(131)	(75)	144	304	(0)*	(5)
Limited Flexibility						
BAU	146,498	153,403	161,198	168,201	154,606	2,473,697
NRDC CO_2 Standard	146,435	153,190	160,931	168,069	154,428	2,470,846
Change	(64)	(214)	(266)	(133)	(178)	(2,852)

Note: Job equivalents equal total labor income divided by average income per job. Cumulative job-equivalents represents job-years.

*Fewer than 1,000

- Results indicate lower average labor impacts if the CO_2 target rate is implemented with provision for energy efficiency credits, as in the Maximum Flexibility case
- Labor impacts may be much larger if the CO_2 target rate is implemented without provision for energy efficiency credits, as in the Limited Flexibility case

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Labor Impacts by Region, in Job-Equivalents

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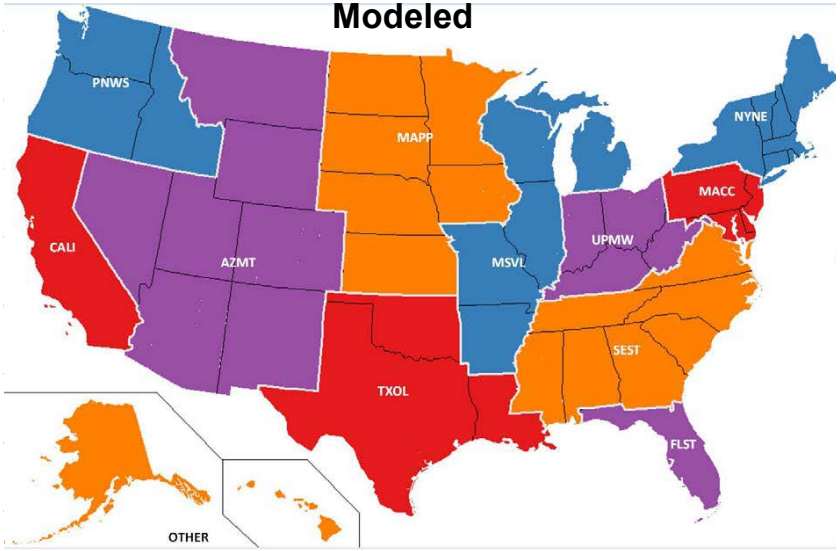
2018-2033 Labor Impacts
(Job-Equivalents, Relative to Baseline)

Maximum Flexibility

N_{ew}ERA Region	Annual Average Job-Equivalents	Cumulative Job-Years
CALI	1,000	23,000
NYNE	6,000	90,000
MACC	(3,000)	(48,000)
UPMW	(8,000)	(136,000)
SEST	(4,000)	(64,000)
FLST	6,000	89,000
MSVL	(15,000)	(248,000)
MAPP	(9,000)	(148,000)
TXOL	22,000	351,000
AZMT	(<1,000)	(4,000)
PNWS	6,000	88,000
US	**(<1,000)**	**(5,000)**

Definitions of Regions Modeled



Limited Flexibility

N_{ew}ERA Region	Annual Average Job-Equivalents	Cumulative Job-years
CALI	(5,000)	(81,000)
NYNE	(9,000)	(142,000)
MACC	(14,000)	(217,000)
UPMW	(43,000)	(692,000)
SEST	(23,000)	(372,000)
FLST	(3,000)	(52,000)
MSVL	(57,000)	(907,000)
MAPP	(16,000)	(260,000)
TXOL	4,000	66,000
AZMT	(9,000)	(136,000)
PNWS	(4,000)	(59,000)
US	**(178,000)**	**(2,852,000)**

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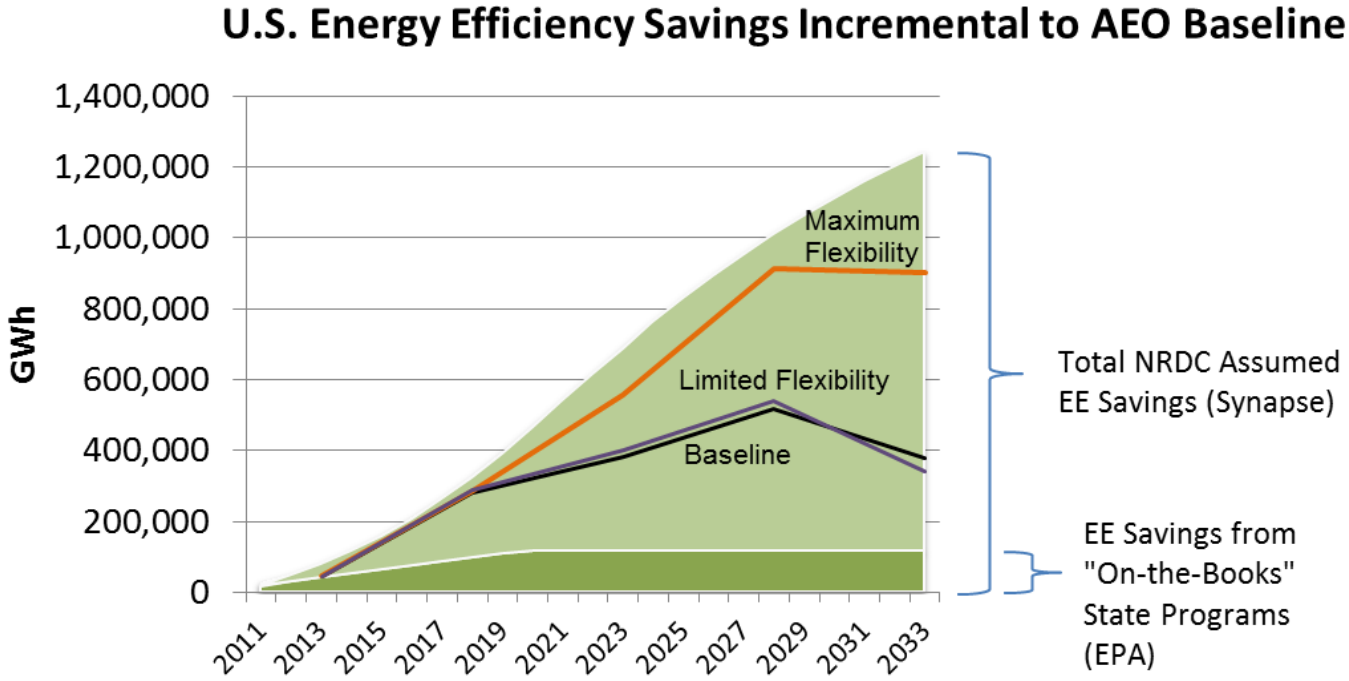
National Energy Efficiency Adopted



Source: NRDC (2012) Table II.4; EPA (2011) Projected Energy Impacts of Existing State EE/RE Policies

- In N_{ew}ERA, incremental energy efficiency is purchased to replace generation whenever it is cost-effective (including in the Baseline, which NRDC does not allow)
- There is a large increase in energy efficiency relative to the Baseline in the Maximum Flexibility case, which additionally allows credits for energy efficiency

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National Electricity Market Impacts

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Annual Averages, 2018-2033

	Total Coal Retirements Through 2033 (GW)	Coal-Fired Generation (TWh)	Natural Gas-Fired Generation (TWh)	Henry Hub Natural Gas Price (2012$/ MMBtu)	Delivered Electricity Price (2012¢/kWh)	Ele CO_2 Emissions (MMMT)
Maximum Flexibility						
Baseline	41	1,742	1,093	$4.08	11.8	2,081
NRDC CO_2 Standard	76	1,451	1,183	$4.17	12.9	1,836
Change	35	(291)	90	$0.09	1.0	(245)
% Change	+86.5%	-16.7%	+8.2%	+2.2%	+8.6%	-11.8%
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Change	83	(747)	671	$0.65	0.4	(484)
% Change	+205.4%	-42.9%	+61.4%	+16.0%	+3.4%	-23.3%

Note: Independent rounding of scenario values and changes.

NRDC's CO_2 target rate would lead to large impacts on the electricity market under Maximum Flexibility and substantially greater impacts under Limited Flexibility

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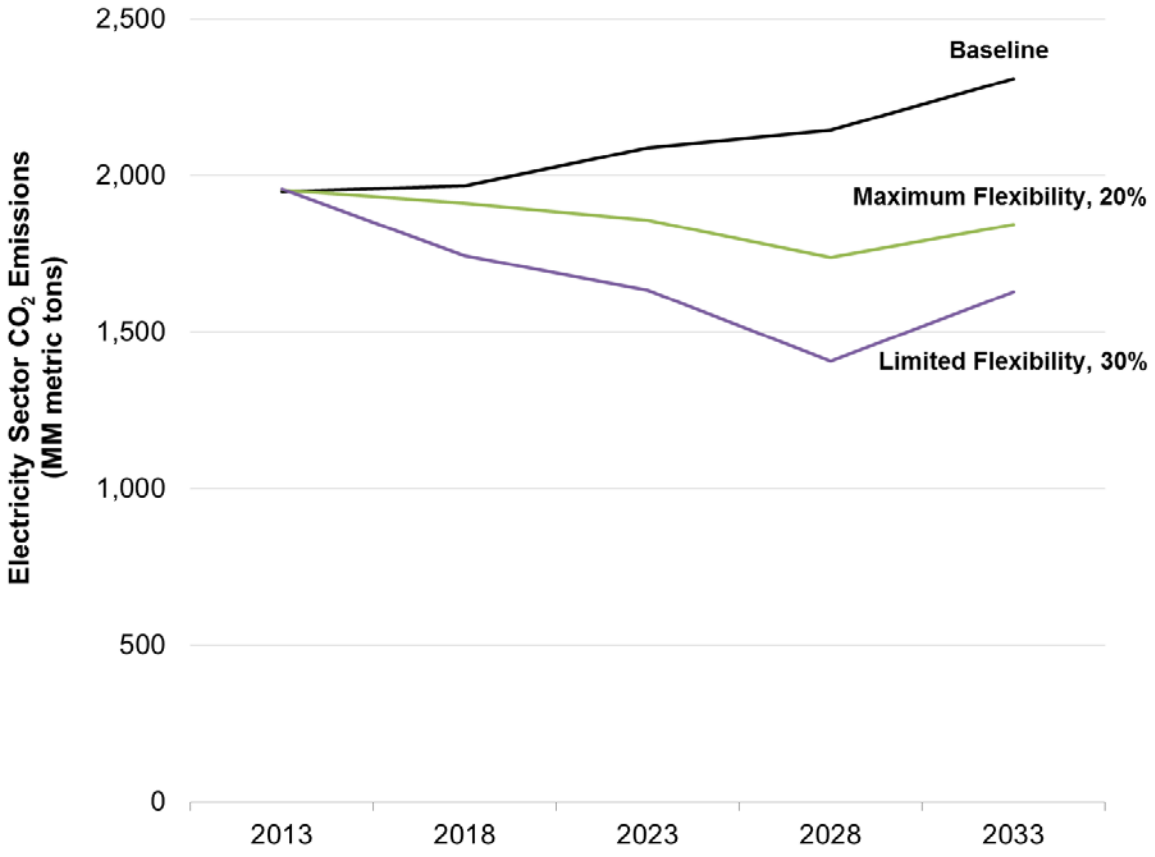
National Electricity Sector CO_2 Emissions



- The 2033 percentage reductions in U.S. electricity sector CO_2 emissions would be 20% in the Maximum Flexibility case and 30% in the Limited Flexibility case (relative to the Baseline)
- After the standard is fully phased in (2028), CO_2 emissions would begin to rise as electricity demand increases over time

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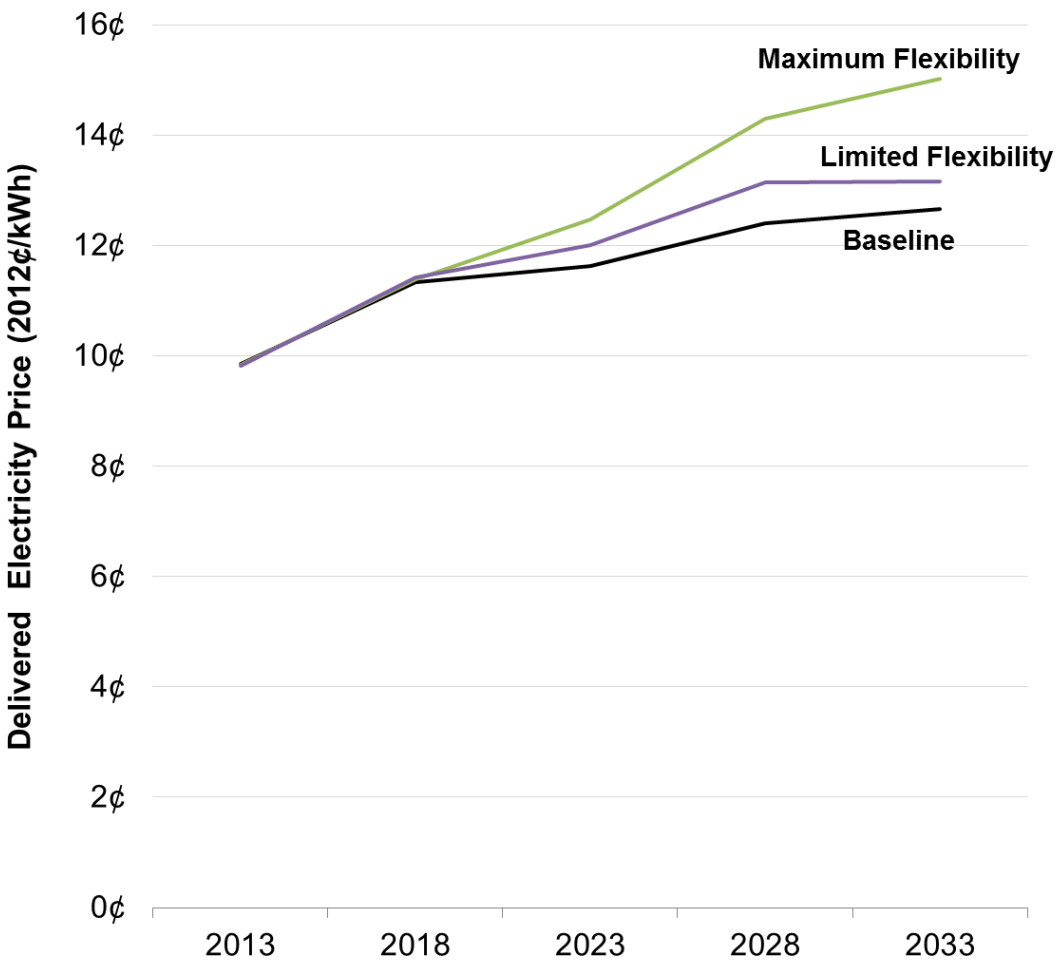
National Average Delivered Electricity Prices (All Sectors)



- Energy efficiency does not reduce transmission and distribution costs, so retail rates/kWh rise as efficiency increases, because T&D costs are spread over fewer kWh
- Costs for energy efficiency paid by distribution utilities are passed to consumers through retail rates, also resulting in higher rate impacts in the Maximum Flexibility case.
- National average delivered electricity prices in 2033 would be 2.4 ¢/kWh higher than Baseline in the Maximum Flexibility case
- Results will vary state to state

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National Delivered Prices and Total Electricity Bills by Ratepayer Class

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- Utility energy efficiency costs would be passed to residential and commercial consumers through higher retail electricity prices, and rates per kWh for transmission & distribution would also increase as kWhs decrease
  - Thus, NRDC's CO_2 target rate would lead to larger residential and commercial electricity price increases in the Maximum Flexibility case, which assumes energy efficiency credits, than in the Limited Flexibility case
- Industrial rates are more affected by changes in gas prices, and thus industrial rate increases are higher in the Limited Flexibility case, which has a larger effect on gas demand and hence on gas prices than the Maximum Flexibility case

	Delivered Electricity Price 2018 - 2033 Avg (2012¢/kWh)				Total Annual Electricity Bills 2018 - 2033 Avg (billion 2012$)				Annual Generation 2018 - 2033 Avg (TWh)
	Res	Com	Ind	*All Sectors*	Res	Com	Ind	*All Sectors*	
Maximum Flexibility									
Baseline	14.4	12.5	7.8	*11.8*	$203.0	$168.3	$86.0	*$457.3*	4,188
NRDC CO_2 Standard	16.0	13.9	8.0	*12.9*	$209.1	$173.0	$88.4	*$470.5*	3,988
Change	1.6	1.5	0.2	*1.0*	$6.1	$4.7	$2.4	*$13.2*	(200)
% Change	+11.4%	+11.7%	+2.3%	*+8.6%*	+3.0%	+2.8%	+2.8%	*+2.9%*	-4.8%
Limited Flexibility									
Baseline	14.4	12.5	7.8	*11.8*	$203.0	$168.3	$86.0	*$457.3*	4,188
NRDC CO_2 Standard	14.8	12.9	8.2	*12.2*	$206.1	$171.6	$89.2	*$466.9*	4,115
Change	0.4	0.4	0.4	*0.4*	$3.1	$3.3	$3.3	*$9.6*	(73)
% Change	+3.0%	+3.4%	+4.6%	*+3.4%*	+1.5%	+1.9%	+3.8%	*+2.1%*	-1.7%

Note: Res = residential consumers, Com = commercial consumers, Ind = industrial consumers.

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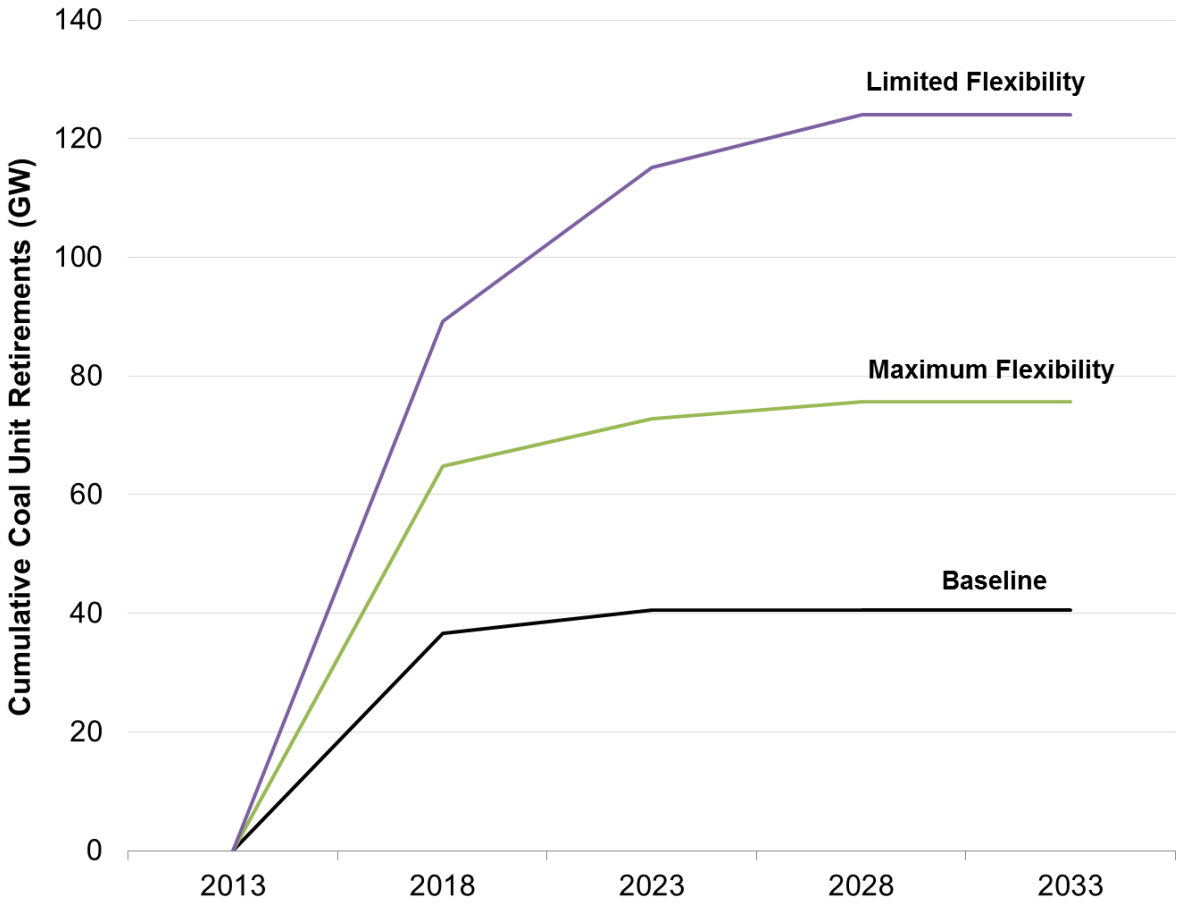
National Coal Unit Retirements



- NRDC's CO_2 target rate would lead to substantial incremental coal retirements
- Coal retirements would be much greater without national averaging or offsite credits
- The *additional* coal retirements (above Baseline) would increase from 35 GW under the Maximum Flexibility case to 83 GW in the Limited Flexibility case
- Most retirements would occur by 2023 in all cases

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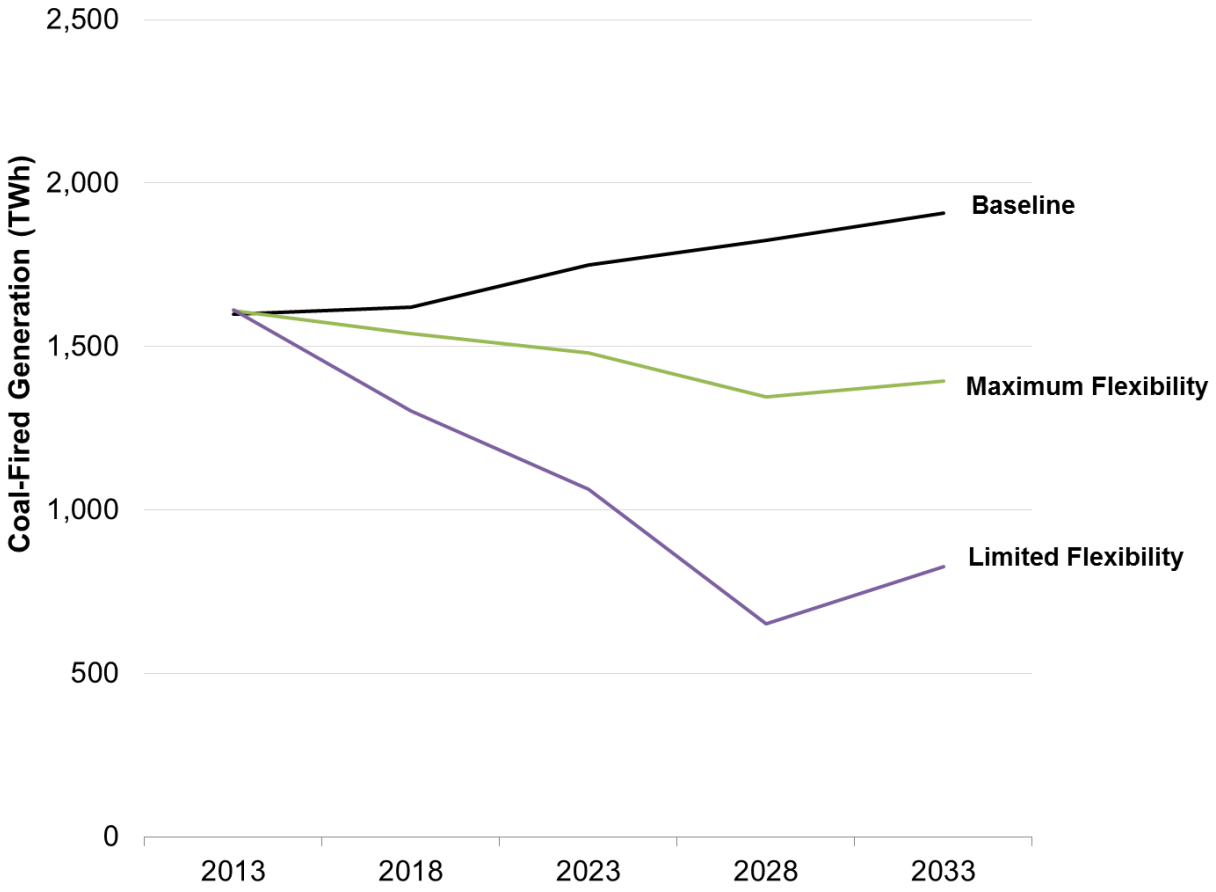
National Coal-Fired Generation



- NRDC's CO_2 target rate would lead to large reductions in coal-fired generation
- Reductions in coal-fired generation would be much greater without national averaging or offsite credits
- Coal-fired generation in 2028 would decrease by about 26% in the Maximum Flexibility case and 64% in the Limited Flexibility case

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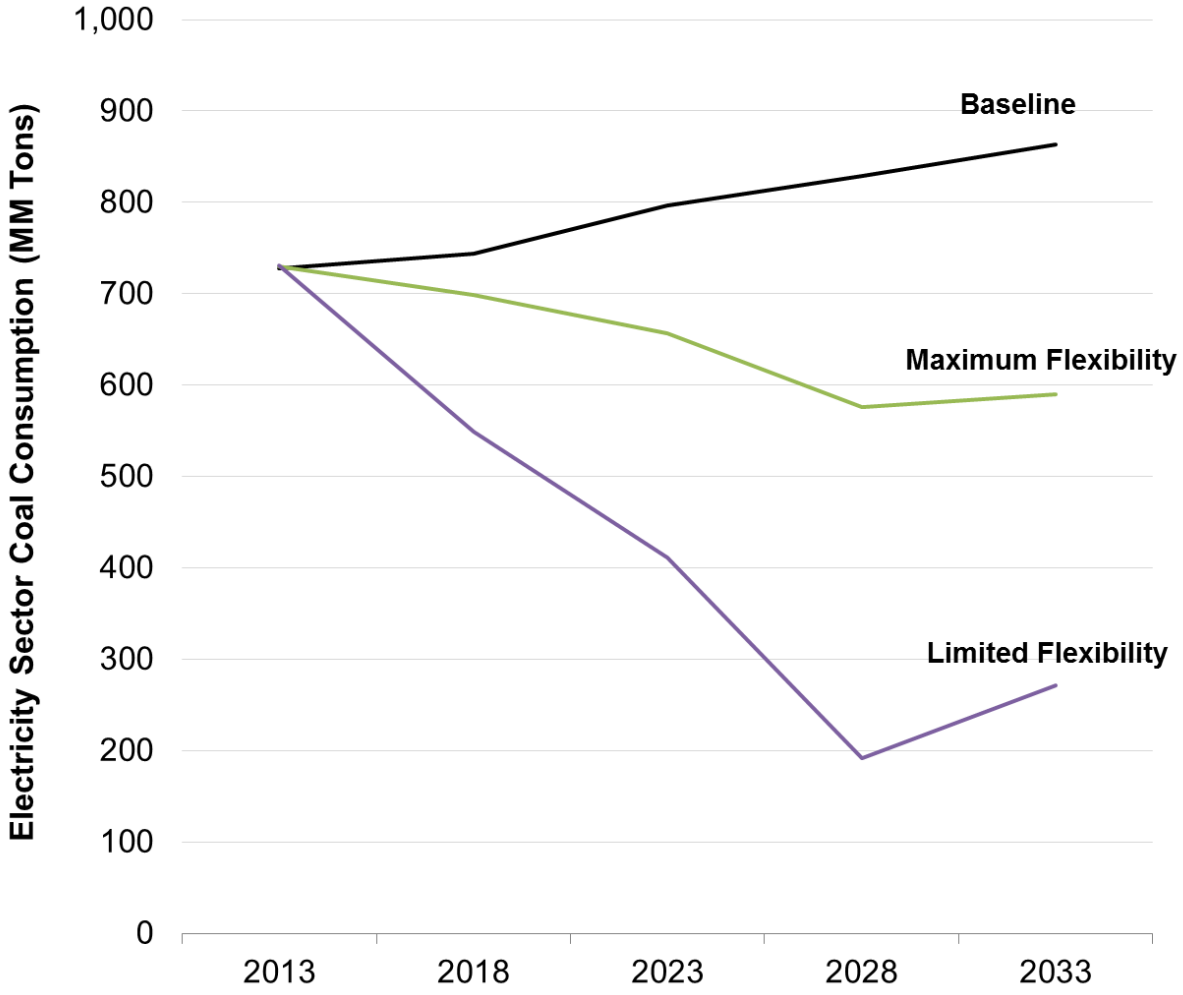
National Coal Consumption



- The decrease in coal-fired generation from NRDC's target rate would lead to large reductions in coal use
- Reductions in coal use would similarly be much greater without national averaging or offsite credits
- Coal use in 2028 would decrease by about 30% in the Maximum Flexibility case and 77% in the Limited Flexibility case

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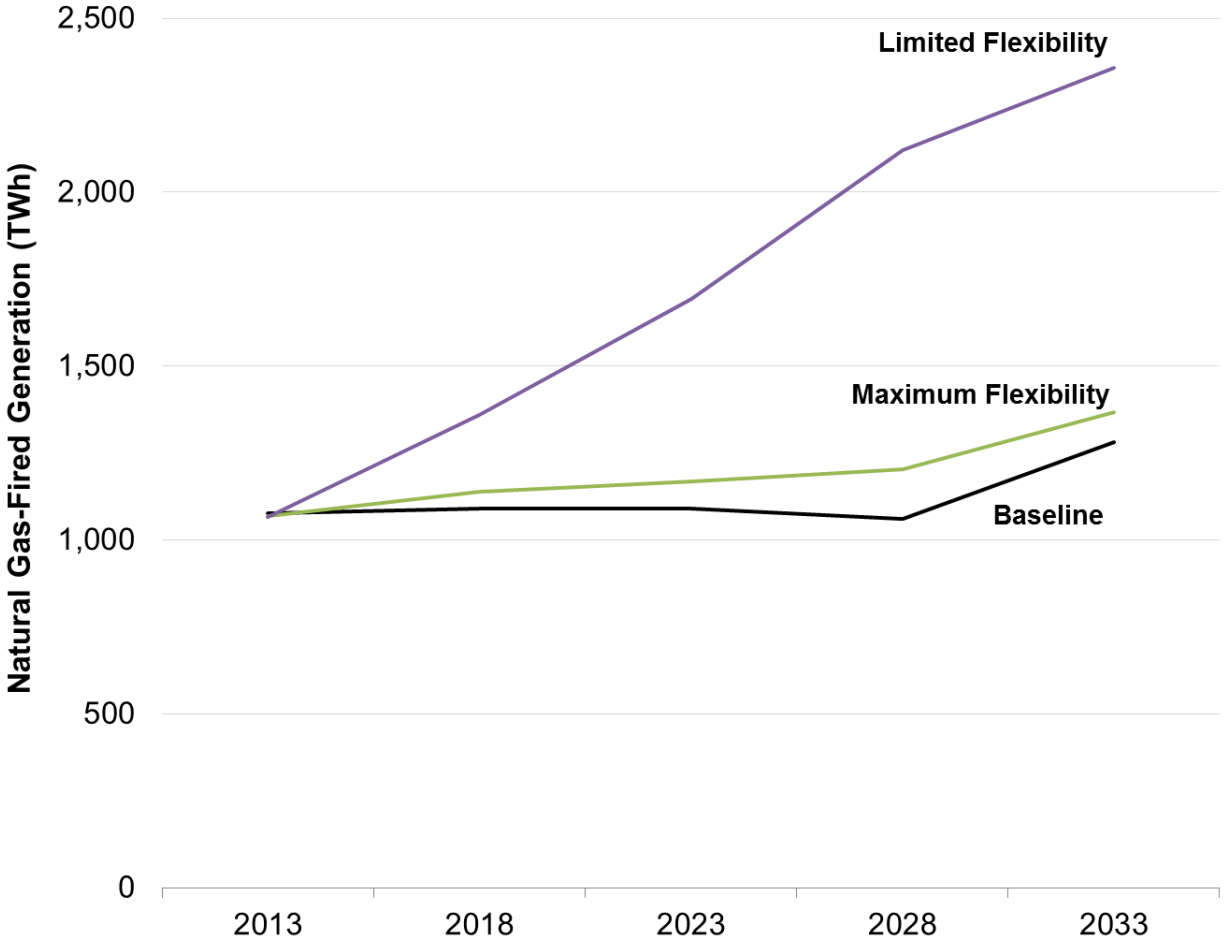
National Natural Gas-Fired Generation



- NRDC's CO_2 target rate would lead to increases in natural gas-fired generation
- Natural gas increases would be much greater in the case without national averaging or offsite credits
- The increase in 2033 gas-fired generation would be 85 TWh (7%) under the Maximum Flexibility case and 1,075 TWh (84%) in the Limited Flexibility case

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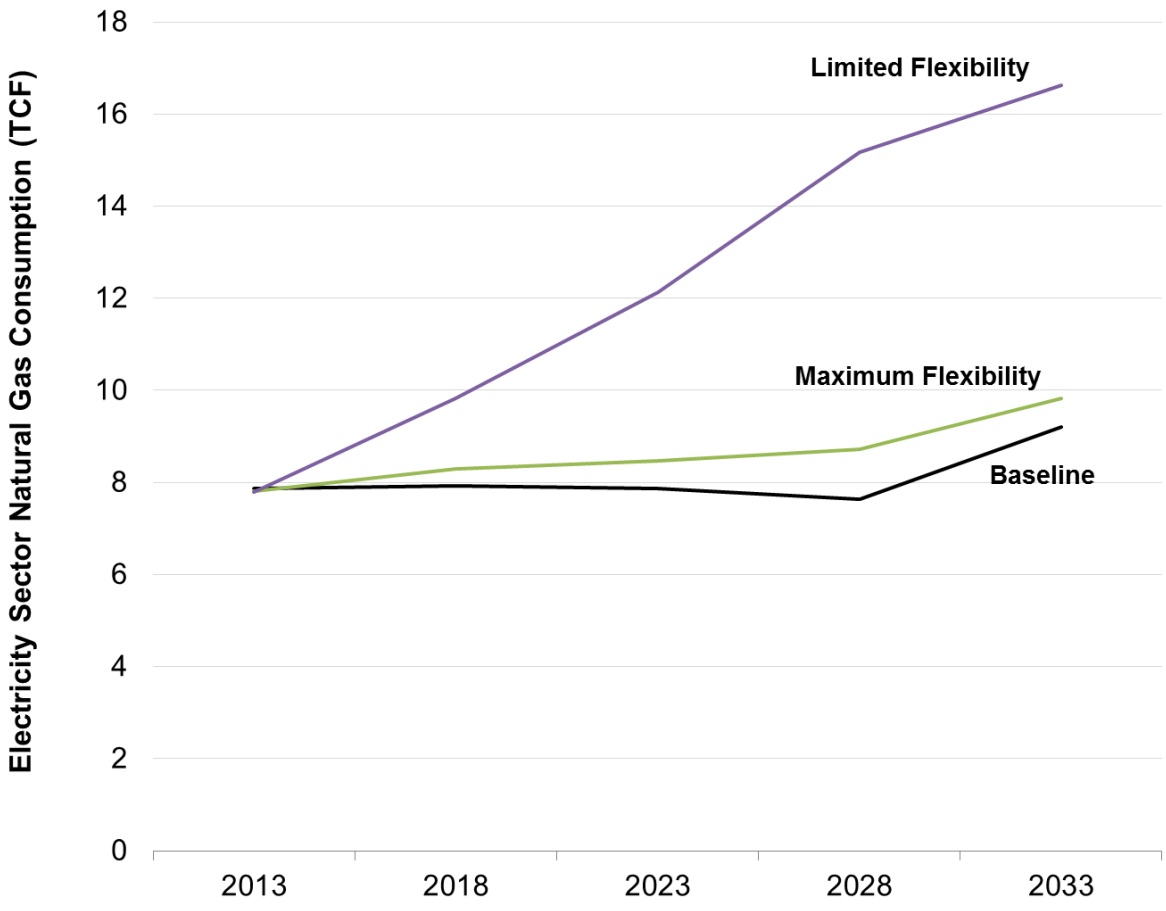
National Natural Gas Consumption For Electric Power Generation



- The increase in natural gas-fired generation under NRDC's CO_2 target rate would lead to increases in natural gas consumption for electricity
- Natural gas increases would be much greater in the case without national averaging or offsite credits
- The increase in 2033 electricity sector natural gas use would be about 0.6 Tcf (7%) under the Maximum Flexibility case and about 7.4 Tcf (81%) in the Limited Flexibility case

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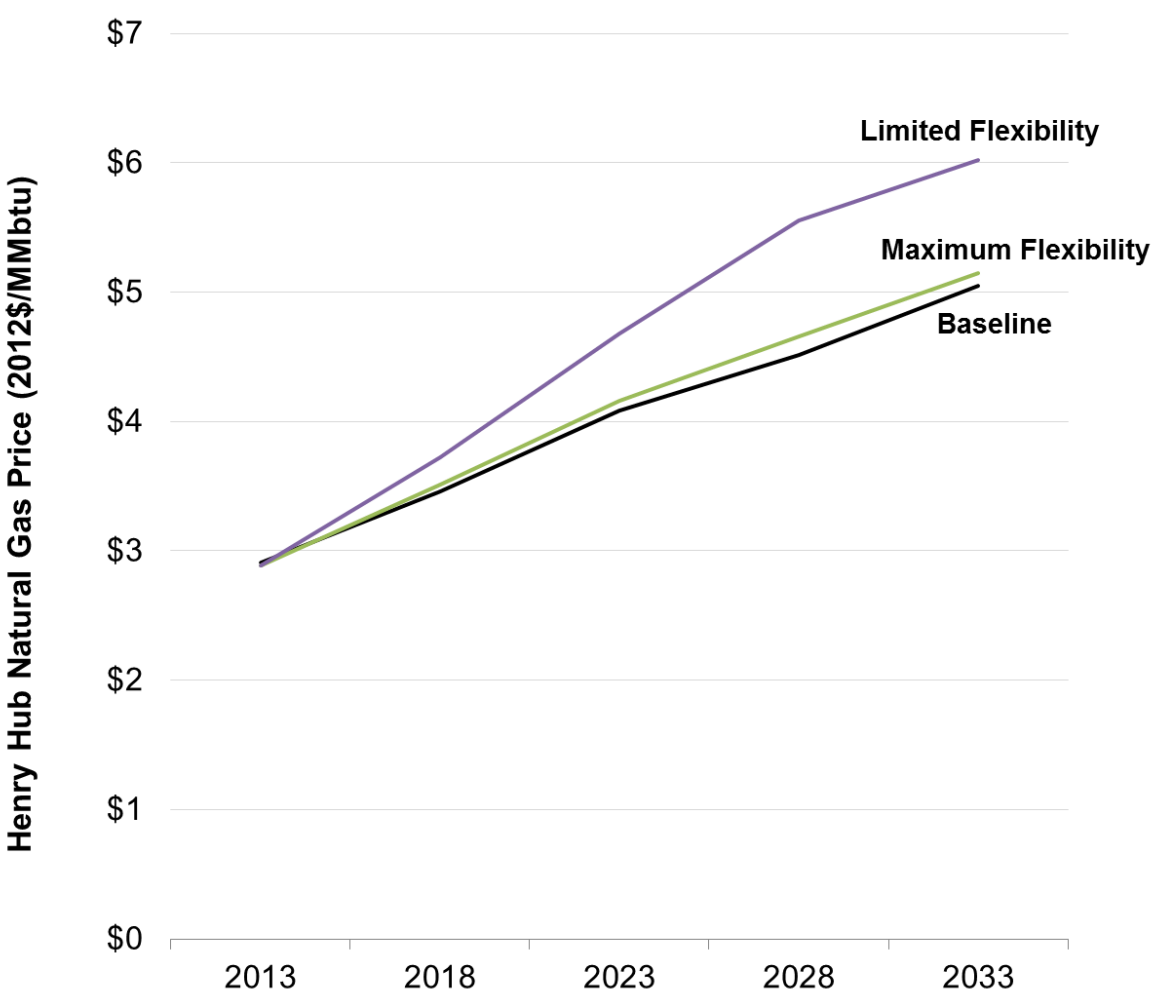
Henry Hub Natural Gas Price



- The N_{ew}ERA model calculated natural gas price responses to fuel-shifting under NRDC's CO_2 target rate
- NRDC's CO_2 target rate would lead to natural gas prices increase in the Limited Flexibility case as generation shifts to natural gas (a rise of about $0.97 or 19% in 2033)
- Natural gas prices would not change significantly in the Maximum Flexibility case, since offsite credits and credit trading reduce the need for fuel switching

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Comparisons to Results Provided by NRDC (Changes from Baseline)

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Comparison of NRDC and NERA Results (Relative to Respective Baseline)

	Year(s)	Unit	NRDC Main Case	NERA Maximum Flexibility Case	NERA Limited Flexibility Case
COSTS					
PV of Electricity Service Costs	2018-2033	Billion 2012$	40	109	97
PV of Non-Electricity Natural Gas Costs	2018-2033	Billion 2012$	Not Reported	8	54
PV of Consumer Costs	2018-2033	Billion 2012$	N/A	116	151
MARKET IMPACTS					
Coal Retirements	Through 2020	GW	59	32	75
Energy Efficiency Use	2020	TWh	482	174	19
Coal-Fired Generation	2020	TWh	(484)	(270)	(685)
Natural Gas-Fired Generation	2020	TWh	18	78	601
New Renewables Generation	2020	TWh	1	(2)	(1)
ELECTRICITY SECTOR CO_2 EMISSIONS					
Coal	2020	MM metric tons	Not Reported	(263)	(683)
Natural Gas / Oil	2020	MM metric tons	Not Reported	33	229
Total U.S.	2020	MM metric tons	(511)	(230)	(454)

Notes:

N_{ew}ERA model year 2023 was used for comparisons with NRDC year 2020. (In N_{ew}ERA every 5th year is modeled and the limits in 2023 are most similar to those in 2020 in the NRDC analysis.)

Present values in year 2013 were calculated using a discount rate of 5%; NRDC 2030 compliance costs were applied to years 2031-2033.

NRDC new renewables generation was calculated as the change in wind, biomass, and "other renewables" generation from 2012 to 2020.

NRDC CO_2 emissions reductions were converted from short tons to metric tons.

NRDC only provided non-cost results for the year 2020, thus limiting our ability to compare Market Impacts and Electricity Sector CO_2 Emissions for any other time period.

Sources:

NRDC (2012) Table 8.1, p. 25; Table 9.1, p. 29; Figure 13.3, p. 46; Figure 13.2, p. 43

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Comparisons to Results Provided by NRDC (Changes from Current Levels)

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- Impact estimates presented up to this point have compared outcomes of the policy scenario to projected baseline outcomes in the same future year
  - "Cumulative effects" include baseline changes over time as well as changes due to the policy
  - Cumulative impact estimates are also useful because they can indicate when a policy may contribute to substantial disruptions of the energy system and economy
- Relative to levels in the first year of the modeled projections ("current conditions"), both NRDC and NERA project large changes in coal capacity and energy efficiency by 2020 as a result of complying with the target CO_2 rate proposed by NRDC

Comparison of NRDC and NERA Results (Relative to Current Conditions)

	Year(s)	Unit	NRDC Main Case	NERA Maximum Flexibility Case	NERA Limited Flexibility Case
Coal Retirements	Through 2020	GW	80	73	115
Energy Efficiency Use	2020	TWh	482	437	282
New Renewables Generation	2020	TWh	146	58	59

Notes:
N_{ew}ERA model year 2023 was used for comparisons with NRDC year 2020. (In N_{ew}ERA every 5th year is modeled and the limits in 2023 are most similar to those in 2020 in the NRDC analysis.)
NRDC New Renewables Generation was calculated as the change in wind, biomass, and "other renewables" generation from 2012 to 2020.
Current conditions imply 2013 for NERA's analysis and 2012 for NRDC's analysis.
NERA's coal retirement numbers do not include any retirements prior to mid-2013, while NRDC's numbers would include such retirements.

Sources:
NRDC (2012) Figure 13.2, p. 43; text, p. 45

Comparisons to Results Provided by NRDC/Synapse (Job Impacts)

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- In a report prepared for NRDC, Synapse (2013) estimated the job impacts of changes in electricity and energy efficiency spending under NRDC's target CO_2 rate
- Synapse's (2013) methodology for estimating job impacts is inferior to NERA's methodology in several important ways
  - Synapse used IMPLAN, an input-output multiplier method that does not fully account for spending interactions in the economy (NERA used N_{ew}ERA, a general equilibrium model of the economy that does account for these interactions)
  - Synapse did not account for negative impacts on jobs of higher *delivered* electricity prices and natural gas prices (NERA's job impacts do account for market impacts of delivered energy price changes)
  - Synapse projects increases in jobs from spending on energy efficiency (NERA's analysis accounts for all potential effects of energy efficiency on the economy, not just the positive effects of the expenditures)

Comparison of NRDC and NERA Job Impacts (Job-Equivalents Relative to Baseline)

Model Year	NRDC Main Case	NERA Maximum Flexibility Case	NERA Limited Flexibility Case
2016	75,800	(131,000)	(64,000)
2020	210,400	(75,000)	(214,000)

Notes:

N_{ew}ERA model years 2018 and 2023 were used for comparisons with NRDC years 2016 and 2020, respectively. (In N_{ew}ERA every 5th year is modeled and the limits in 2018 and 2023 are most similar to those in 2016 and 2020 in the NRDC analysis.)

Job equivalents equal total labor income change divided by average income per job. The table shows changes in net jobs, which includes increases in some sectors (e.g., energy efficiency) and decreases in others (e.g., coal).

Sources: Synapse (2013) Table 1, p. 4

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About NewERA

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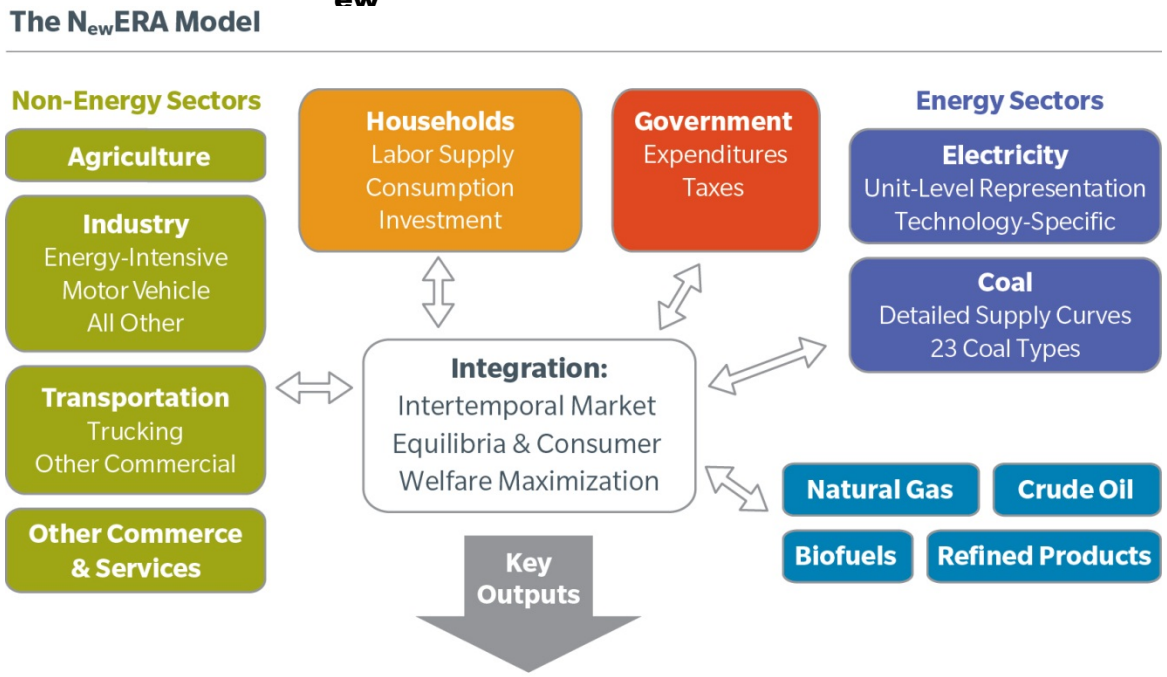
N_{ew}ERA Model

N_{ew}ERA Model Structure



Macroeconomic (National/Regional)	**Primary Energy** (National/Regional)	**Electricity** (National/Regional/Generating Unit)
Welfare	Demand	Prices
GDP, consumption, investment	Prices	Builds, retrofits, retirements
Output by sector	Production	Load and Dispatch

Key N_{ew}ERA energy outputs:

Electricity Sector
- Capacity
- Generation
- Retirements
- Wholesale and Delivered Electricity Prices
- Emissions

Other Energy Sectors
- Production
- Consumption
- Energy Prices

Economic Outputs
- GDP
- Consumption
- Employment

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N_{ew}ERA Electricity Sector Model: Overview

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- Bottom-up dispatch and capacity planning model
  - Unit-level information on generating units in 34 U.S. regions
  - Detailed coal supply curves by coal type
  - Regional electricity demand and capacity requirements
- Least-cost projection of market activity
  - Satisfies demand and all other constraints over model time horizon
  - Projects unit-level generation and investment decisions and regional fuel and electricity prices
- Data sources
  - Model calibrated to U.S. Energy Information Administration *Annual Energy Outlook 2013*
  - Other electricity sector data from EIA, EPA, NERC, NREL, NETL, Ventyx Velocity Suite, and HellerWorx

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NewERA Electricity Sector Model: Unit-Level Detail

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- Represents electricity capacity and generation at the unit level
  - 16 generating technologies, including renewables
  - Unit physical attributes: capacity, utilization, heat rate, outages, retrofits, emission rate
  - Unit costs: capital, fixed O&M, variable O&M, transmission and distribution, refurbishment
- Projects unit generation and investment decisions to minimize sector costs over projection period
  - Available actions include retirements, new builds, retrofits, coal type choice (for coal units), and fuel switching
  - Units will retire if they cannot remain profitable
  - Units can also be forced to take certain actions at specified times, or given a choice to act or retire

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N_{ew}ERA Electricity Sector Model: Fuel Supply

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- Model represents supply of five fuels: coal, natural gas, oil, biomass, and uranium
- Detailed supply curves for 23 coal types
  - At each "step" on supply curve, provides price, annual production limit, and total coal reserves available at that price
  - Transportation matrix determines coals that can be delivered to each unit and the cost of delivery
  - Coal units assigned an initial coal type, but can incur a capital costs to switch to other coal types when reasonable

N_{ew}ERA Electricity Sector Model: Electricity Demand

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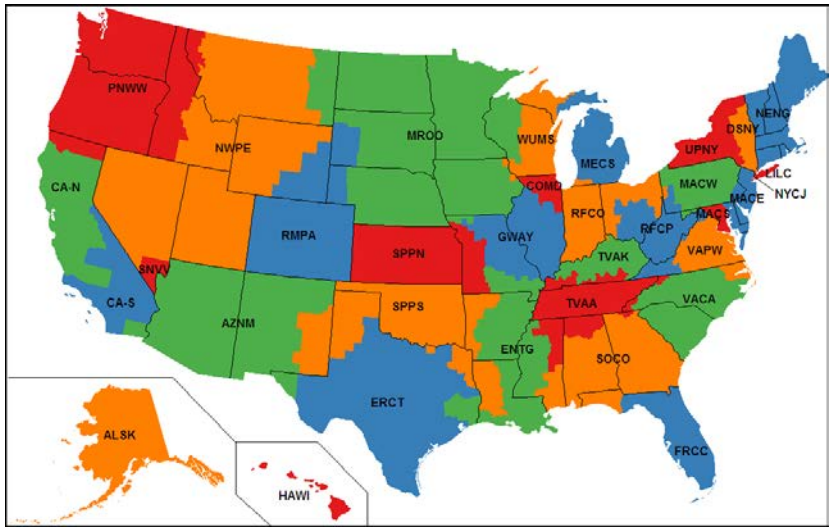
- Demand by region for 34 U.S. regions
- 25 electricity demand "load blocks"
  - Ten in summer and five each in winter, spring, and fall
  - Reflects peak vs. off-peak demand in each season
- Regional "reserve margins" based on peak demand
  - Regions required to have capacity in excess of peak demand for system reliability



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N_{ew}ERA Electricity Sector Model: Model Solution

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- Model is required to meet many electricity market and regulatory constraints
  - Regional demand, reserve capacity requirements, fuel availability, forced retrofits, RPS or emissions regulations
  - Flexible to a variety of user-specified constraints, from unit-specific actions to market-wide regulations
- Finds the least-cost way to satisfy all constraints
  - Uses perfect foresight of market conditions
  - Chooses investments and operation of units to minimize present value of costs over the entire model period

N_{ew}ERA Electricity Sector Model: Model Outputs

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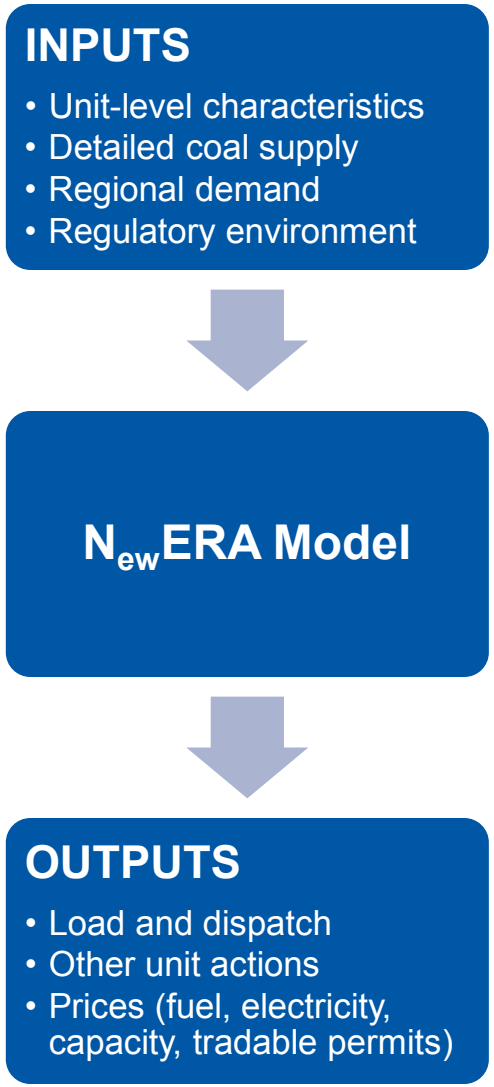
- Model period 2013 – 2043 with outputs for every 5th year (flexible to user specification)
  - Results focused on period from 2013 - 2033
- Unit-level and regional activity
  - Generation, investments in retrofits or capacity, retirements, operational costs, and revenues from generating and capacity services
- Regional prices
  - Minemouth and delivered coal, non-coal fuels, wholesale electricity, capacity, renewable energy credits, and emissions credit where applicable
  - Separate cost-of-service calculation reflects delivered prices in regulated jurisdictions



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Appendix: Annual Impacts

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Annual Electricity Market Impacts: Baseline

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- Table shows the annual model values that are displayed in graphs in the main presentation.
- Note that annual values are weighted by the appropriate number of years in calculating all 2018-2033 averages
  - Consistent with the N_{ew}ERA model, outputs for individual model years are applied to the following five years (e.g., 2018 values are used for years 2018-2022)
  - When averaging, 2018, 2023, and 2028 are weighted for five years each and 2033 is weighted for a single year

Baseline

	2018	2023	2028	2033	2018-2033 Avg	2018-2033 Cum Total
Cumulative Coal Retirements (GW)	37	41	41	41		
Coal-Fired Generation (TWh)	1,619	1,749	1,824	1,908	1,742	27,871
Electricity Sector Coal Use (TBtu)	14,291	15,365	15,910	16,473	15,269	244,304
Electricity Sector Coal Use (MM Tons)	744	797	829	863	795	12,714
Natural Gas-Fired Generation (TWh)	1,089	1,091	1,061	1,282	1,093	17,492
Electricity Sector Natural Gas Use (TCF)	7.92	7.86	7.63	9.20	7.89	126.23
Henry Hub Natural Gas Price (2012$/MMBtu)	3.46	4.09	4.51	5.05	$4.08	
Delivered Electricity Price (2012¢/kWh)	11.3	11.6	12.4	12.7	11.8	
Ele Coal CO2 Emissions (MMMT)	1,538	1,661	1,731	1,812	1,654	26,465
Ele Natural Gas / Oil CO2 Emissions (MMMT)	429	426	412	497	427	6,830
Ele CO2 Emissions (MMMT)	1,967	2,087	2,144	2,310	2,081	33,301

Annual Electricity Market Impacts: NRDC CO_2 Standards

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Maximum Flexibility: NRDC CO_2 Target Rate

	2018	2023	2028	2033	2018-2033 Avg	2018-2033 Cum Total
Cumulative Coal Retirements (GW)	65	73	76	76		
Coal-Fired Generation (TWh)	1,541	1,479	1,345	1,394	1,451	23,219
Electricity Sector Coal Use (TBtu)	13,482	12,607	11,036	11,230	12,303	196,854
Electricity Sector Coal Use (MM Tons)	698	656	576	590	640	10,244
Natural Gas-Fired Generation (TWh)	1,140	1,169	1,203	1,368	1,183	18,926
Electricity Sector Natural Gas Use (TCF)	8.29	8.48	8.71	9.82	8.58	137.23
Henry Hub Natural Gas Price (2012$/MMBtu)	3.51	4.16	4.66	5.15	$4.17	
Delivered Electricity Price (2012¢/kWh)	11.4	12.5	14.3	15.0	12.9	
Ele Coal CO2 Emissions (MMMT)	1,462	1,398	1,266	1,312	1,372	21,945
Ele Natural Gas / Oil CO2 Emissions (MMMT)	449	459	472	531	464	7,428
Ele CO2 Emissions (MMMT)	1,911	1,857	1,738	1,844	1,836	29,379

Limited Flexibility: NRDC CO_2 Target Rate

	2018	2023	2028	2033	2018-2033 Avg	2018-2033 Cum Total
Cumulative Coal Retirements (GW)	89	115	124	124		
Coal-Fired Generation (TWh)	1,302	1,065	653	827	995	15,922
Electricity Sector Coal Use (TBtu)	10,848	8,169	3,841	5,314	7,475	119,607
Electricity Sector Coal Use (MM Tons)	549	412	192	271	377	6,032
Natural Gas-Fired Generation (TWh)	1,360	1,693	2,121	2,358	1,764	28,226
Electricity Sector Natural Gas Use (TCF)	9.83	12.14	15.17	16.63	12.64	202.32
Henry Hub Natural Gas Price (2012$/MMBtu)	3.72	4.68	5.55	6.02	$4.74	
Residential Electricity Price (2012¢/kWh)	11.4	12.0	13.1	13.2	12.2	
Ele Coal CO2 Emissions (MMMT)	1,212	979	588	752	915	14,643
Ele Natural Gas / Oil CO2 Emissions (MMMT)	532	655	820	874	682	10,907
Ele CO2 Emissions (MMMT)	1,745	1,634	1,407	1,628	1,597	25,557

Tables show the annual model values that are displayed in graphs in the main presentation.

Totals may differ from sum of rows due to independent rounding.

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Annual Electricity Market Impacts: Changes Relative to Baseline

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Maximum Flexibility: Change Relative to Baseline

	2018	2023	2028	2033	2018-2033 Avg	2018-2033 Cum Total
Cumulative Coal Retirements (GW)	28	32	35	35		
Coal-Fired Generation (TWh)	-78	-270	-479	-514	-291	-4,652
Electricity Sector Coal Use (TBtu)	-809	-2,759	-4,874	-5,242	-2,966	-47,451
Electricity Sector Coal Use (MM Tons)	-46	-141	-252	-273	-154	-2,469
Natural Gas-Fired Generation (TWh)	50	78	141	85	90	1,434
Electricity Sector Natural Gas Use (TCF)	0.37	0.61	1.09	0.62	0.69	10.99
Henry Hub Natural Gas Price (2012$/MMBtu)	$0.05	$0.07	$0.15	$0.09	$0.09	
Delivered Electricity Price (2012¢/kWh)	0.0	0.8	1.9	2.4	1.0	
Ele Coal CO2 Emissions (MMMT)	-76	-263	-465	-500	-282	-4,520
Ele Natural Gas / Oil CO2 Emissions (MMMT)	20	33	59	34	37	598
Ele CO2 Emissions (MMMT)	-56	-230	-405	-466	-245	-3,923

Limited Flexibility: Change Relative to Baseline

	2018	2023	2028	2033	2018-2033 Avg	2018-2033 Cum Total
Cumulative Coal Retirements (GW)	53	75	83	83		
Coal-Fired Generation (TWh)	-317	-685	-1,172	-1,081	-747	-11,949
Electricity Sector Coal Use (TBtu)	-3,442	-7,196	-12,069	-11,159	-7,794	-124,698
Electricity Sector Coal Use (MM Tons)	-196	-385	-637	-592	-418	-6,682
Natural Gas-Fired Generation (TWh)	271	601	1,060	1,075	671	10,734
Electricity Sector Natural Gas Use (TCF)	1.91	4.27	7.55	7.43	4.76	76.08
Henry Hub Natural Gas Price (2012$/MMBtu)	$0.26	$0.59	$1.04	$0.97	$0.65	
Residential Electricity Price (2012¢/kWh)	0.1	0.4	0.7	0.5	0.4	
Ele Coal CO2 Emissions (MMMT)	-326	-683	-1,143	-1,060	-739	-11,822
Ele Natural Gas / Oil CO2 Emissions (MMMT)	104	229	407	376	255	4,076
Ele CO2 Emissions (MMMT)	-223	-454	-736	-682	-484	-7,744

Tables show the annual model values that are displayed in graphs in the main presentation.

Totals may differ from sum of rows due to independent rounding.

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Average Delivered Electricity Prices by Ratepayer Class

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U.S. Average Delivered Electricity Price (2012¢/kWh)

	2018	2023	2028	2033	Average 2018 -2033
Baseline					
Residential	13.7	14.2	15.2	15.2	14.4
Commercial	11.8	12.2	13.2	13.3	12.5
Industrial	7.7	7.6	7.9	8.7	7.8
All Sectors	11.3	11.6	12.4	12.7	11.8
Maximum Flexibility					
Residential	13.7	15.4	18.3	19.0	16.0
Commercial	11.9	13.4	16.0	16.7	13.9
Industrial	7.7	7.8	8.3	8.9	8.0
All Sectors	11.4	12.5	14.3	15.0	12.9
Limited Flexibility					
Residential	13.8	14.6	16.0	15.5	14.8
Commercial	11.9	12.6	14.0	13.7	12.9
Industrial	7.7	8.0	8.6	9.4	8.2
All Sectors	11.4	12.0	13.1	13.2	12.2
Maximum Flexibility Change (relative to Baseline)					
Residential	0.1	1.3	3.1	3.9	1.6
Commercial	0.1	1.2	2.7	3.5	1.5
Industrial	0.0	0.2	0.3	0.2	0.2
All Sectors	0.0	0.8	1.9	2.4	1.0
Limited Flexibility Change (relative to Baseline)					
Residential	0.1	0.4	0.8	0.4	0.4
Commercial	0.1	0.4	0.8	0.4	0.4
Industrial	0.0	0.3	0.7	0.7	0.4
All Sectors	0.1	0.4	0.7	0.5	0.4

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U.S. Total Electricity Bills by Ratepayer Class

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U.S. Total Electricity Bills (billion 2012$)

	2018	2023	2028	2033	Average 2018 -2033
Baseline					
Residential	$188.5	$200.6	$214.7	$229.2	$203.0
Commercial	$155.6	$166.0	$178.6	$191.5	$168.3
Industrial	$80.3	$84.2	$90.5	$100.7	$86.0
All Sectors	$424.3	$450.8	$483.7	$521.4	$457.3
Maximum Flexibility					
Residential	$187.6	$204.3	$228.3	$245.2	$209.1
Commercial	$155.0	$169.3	$188.3	$204.0	$173.0
Industrial	$80.0	$85.5	$96.2	$105.6	$88.4
All Sectors	$422.7	$459.1	$512.8	$554.8	$470.5
Limited Flexibility					
Residential	$187.8	$202.1	$222.1	$238.1	$206.1
Commercial	$155.4	$167.9	$185.7	$199.8	$171.6
Industrial	$79.7	$86.3	$97.7	$108.6	$89.2
All Sectors	$422.9	$456.3	$505.5	$546.5	$466.9
Maximum Flexibility Change (relative to Baseline)					
Residential	($0.8)	$3.6	$13.6	$16.0	$6.1
Commercial	($0.6)	$3.3	$9.7	$12.5	$4.7
Industrial	($0.3)	$1.3	$5.7	$4.9	$2.4
All Sectors	($1.7)	$8.3	$29.1	$33.4	$13.2
Limited Flexibility Change (relative to Baseline)					
Residential	($0.7)	$1.5	$7.4	$8.9	$3.1
Commercial	($0.2)	$1.9	$7.1	$8.3	$3.3
Industrial	($0.5)	$2.1	$7.2	$8.0	$3.3
All Sectors	($1.4)	$5.5	$21.8	$25.1	$9.6

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