An Assessment of the Efficacy and Cost of Alternative Carbon Mitigation Polices for the State of Indiana under the Framework of IN-MARKAL

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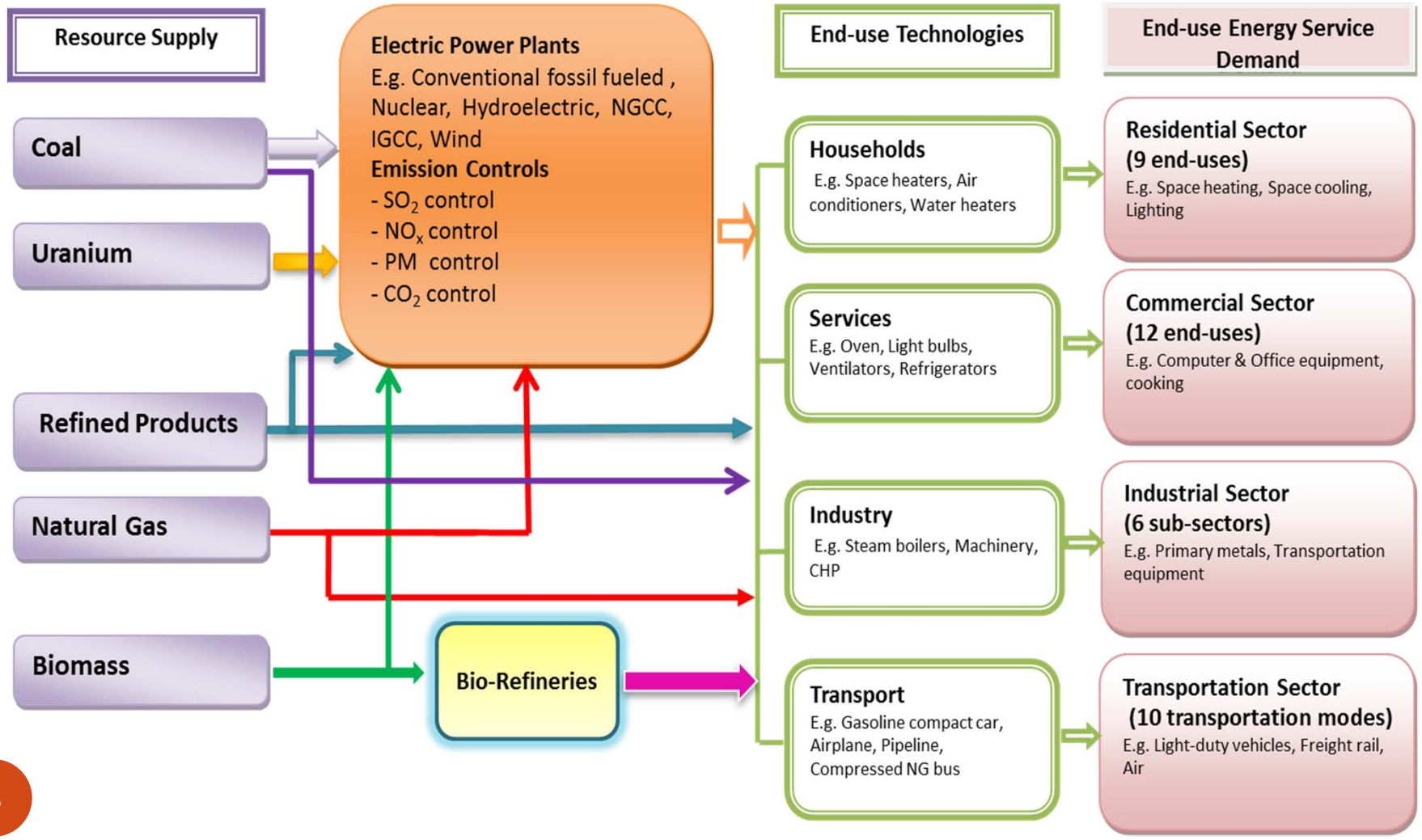
Overview Summary of Paper

- Research Motivation
- Research Objective
- Major Conclusions
  - RPS
    - Very cost effective
    - A less reliable generation mix
  - Carbon Tax
    - The least cost effective tool among tools examined
  - Emission Rate Cap
    - Deep carbon reductions with moderate cost
    - A diverse generation portfolio
    - Sharp increase in marginal coast of electricity during the policy phase-in

Methodology

- IN-MARKAL Model Structure



Scenario Formation

- RPS programs modeled in this study

Table 4-1 RPS scenarios name and description

Case Name	Name Description
RPSLSWO	RPS less stringent case (7% by 2019 and 10% by 2025); RECs produced out-of-state not eligible
RPSMSWO	RPS more stringent case (16% by 2019 and 25% by 2025); RECs produced out-of-state not eligible
RPSMSW15	RPS more stringent case (16% by 2019 and 25% by 2025); RECs produced out-of-state eligible; RECs cost $15/MWh
RPSMSW40	RPS more stringent case (16% by 2019 and 25% by 2025); RECs produced out-of-state eligible; RECs cost $40/MWh
RPSMSW45	RPS more stringent case (16% by 2019 and 25% by 2025); RECs produced out-of-state eligible; RECs cost $45/MWh
RPSMSW50	RPS more stringent case (16% by 2019 and 25% by 2025); RECs produced out-of-state eligible; RECs cost $50/MWh

- Carbon tax scenarios modeled in this study

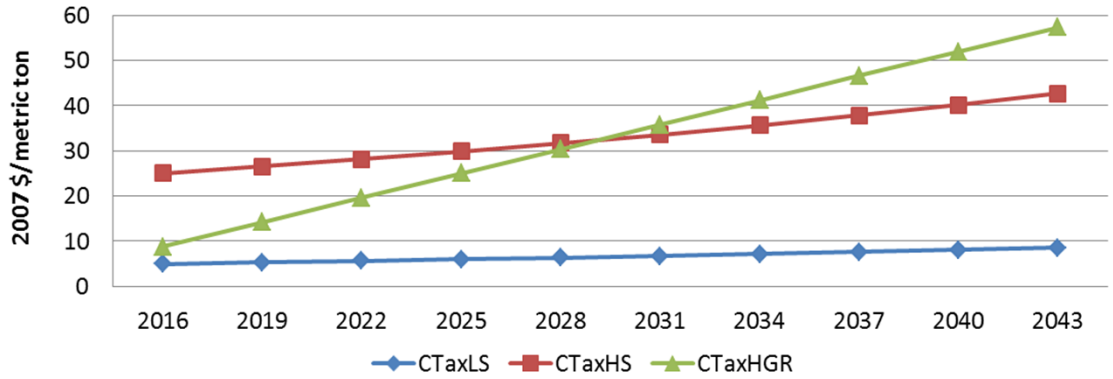


Figure 4-3 Carbon tax trajectories modelled in IN-MARKAL

- Carbon cap scenarios modeled in this study

Table 4-4 State goal for Indiana proposed by the EPA (pounds of CO_2 per MWh electricity generation)

	Option 1		Option 2	
State	Interim goal (2020-2029)	Final goal (2030 forward)	Interim goal (2020-2024)	Final goal (2025 forward)
Indiana	1,607	1,531	1,715	1,683

Results – Base Scenario

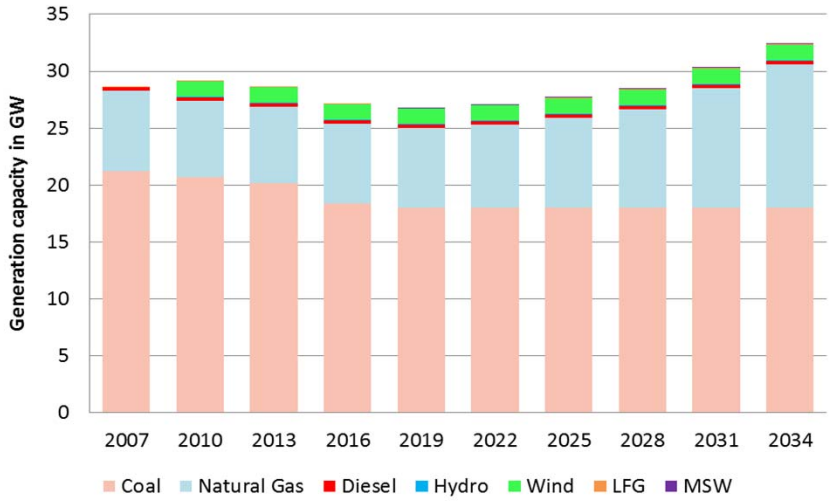


Figure 5-1 Indiana power system capacity portfolio for the BASE case

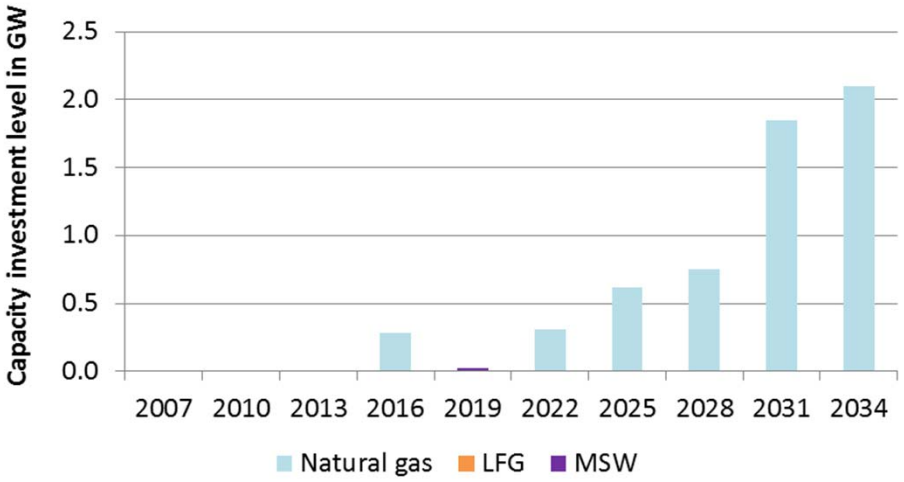


Figure 5-2 Indiana power system capacity investment for the BASE case

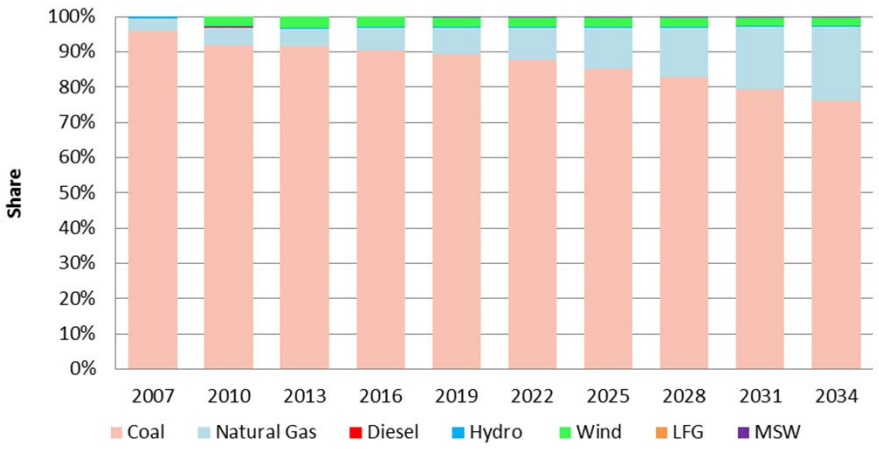


Figure 5-3 Indiana power system generation portfolio in percentage of total generation for the BASE case

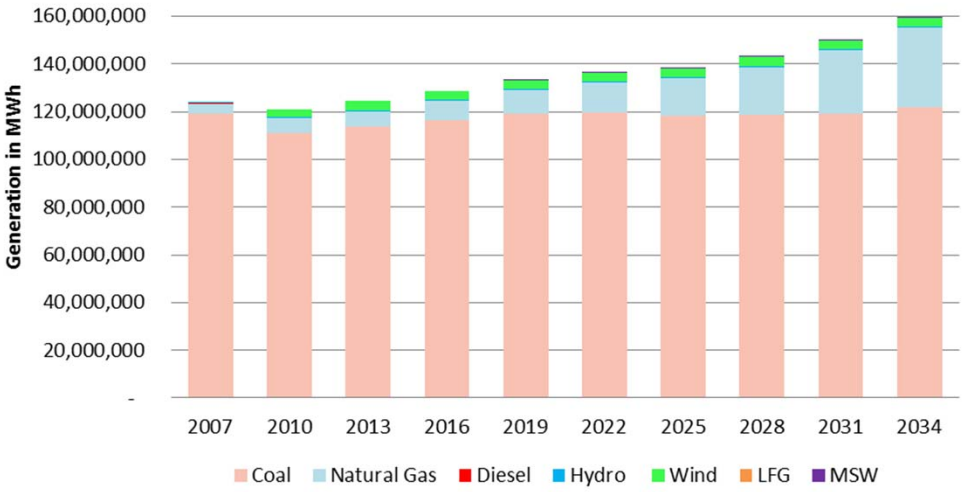


Figure 5-4 Indiana power system generation portfolio in MWh for the BASE case

Results – RPS Scenarios

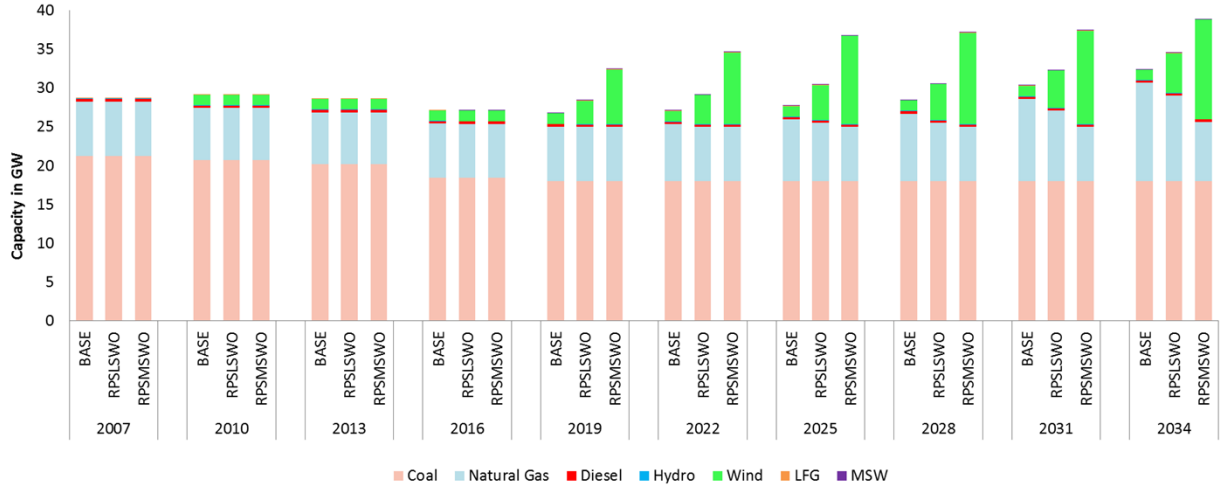


Figure 5-7 Indiana electricity capacity portfolio in GW in the BASE and RPS scenarios

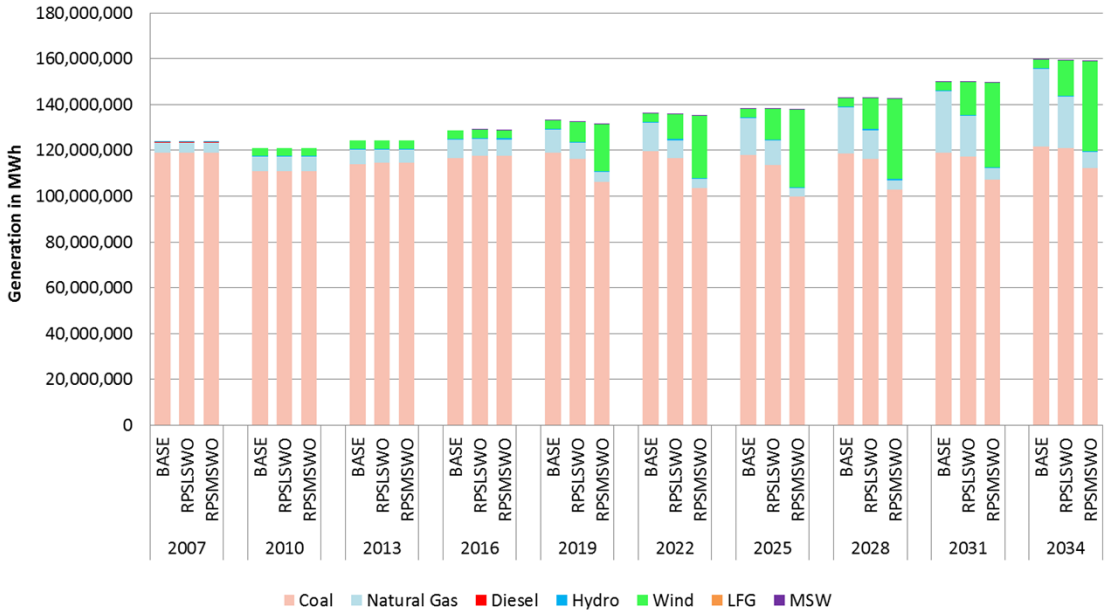


Figure 5-9 Indiana electricity generation portfolio in MWh in the BASE and RPS scenarios

Results – RPS Scenarios

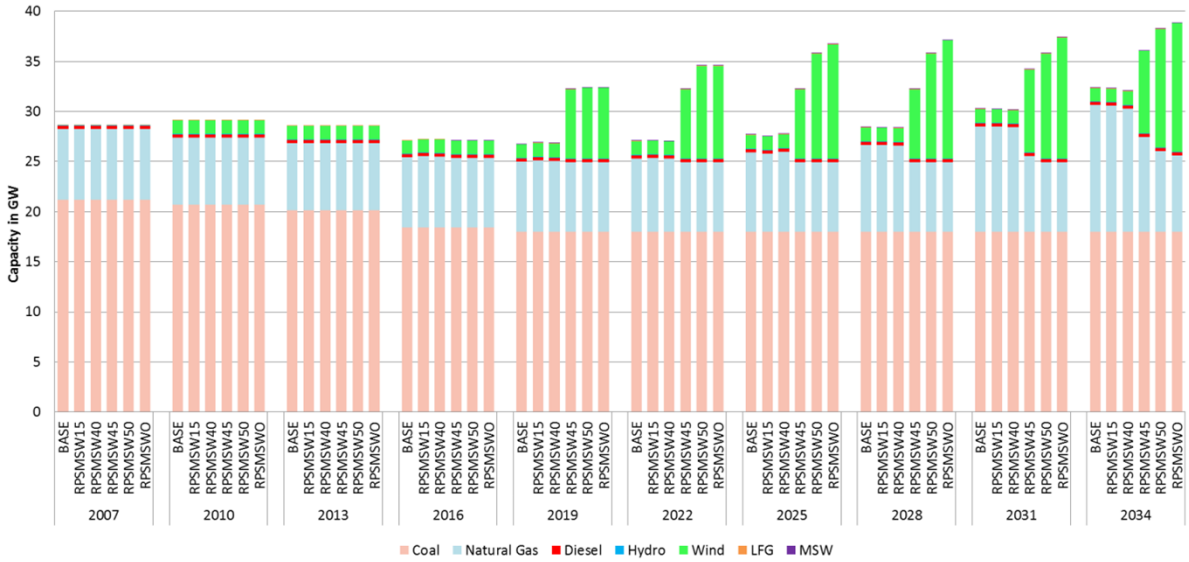


Figure 5-10 Indiana electricity capacity portfolio in GW in the BASE case and more stringent RPS cases with and without out-of -state derived RECs as a compliance option

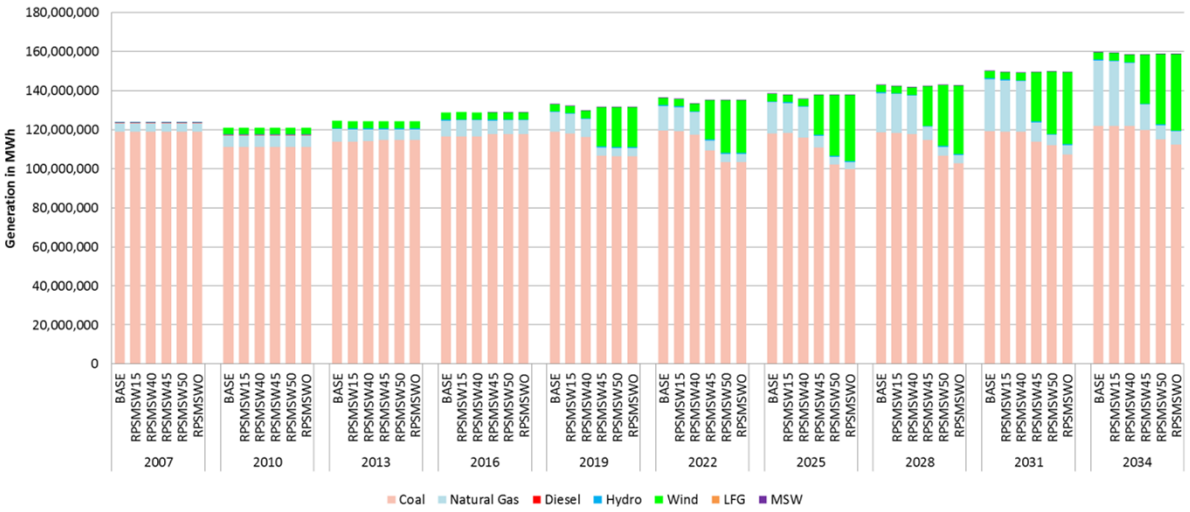


Figure 5-11 Indiana electricity generation portfolio in MWh in the BASE case and more stringent RPS cases with and without out-of -state derived RECs as a compliance option

Results – Carbon Tax Scenarios

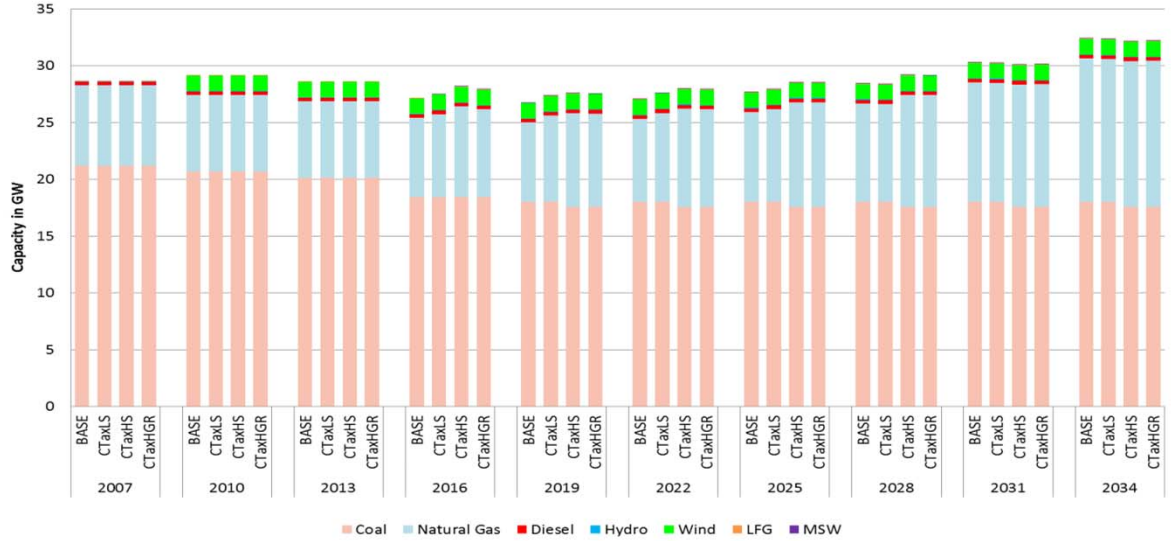


Figure 5-18 Indiana electricity capacity portfolio in GW in the BASE and carbon tax scenarios

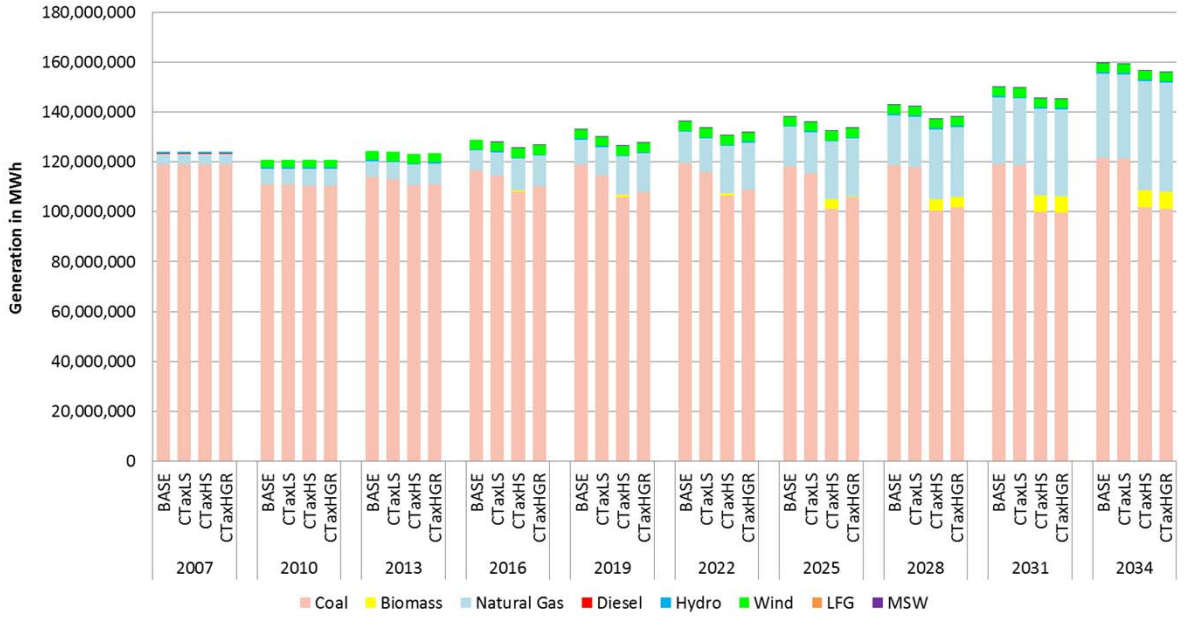


Figure 5-20 Indiana electricity generation portfolio in MWh in the BASE and carbon tax scenarios

Results - Rate-Based Carbon Cap Scenarios

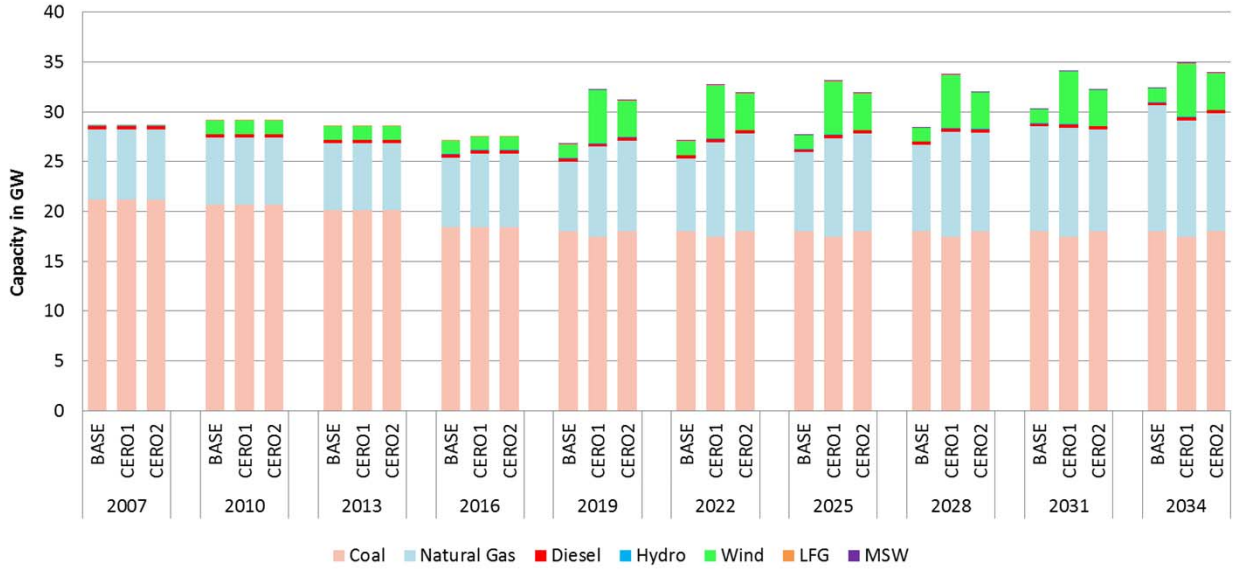


Figure 5-23 Indiana electricity capacity portfolio in GW in the BASE and carbon cap scenarios

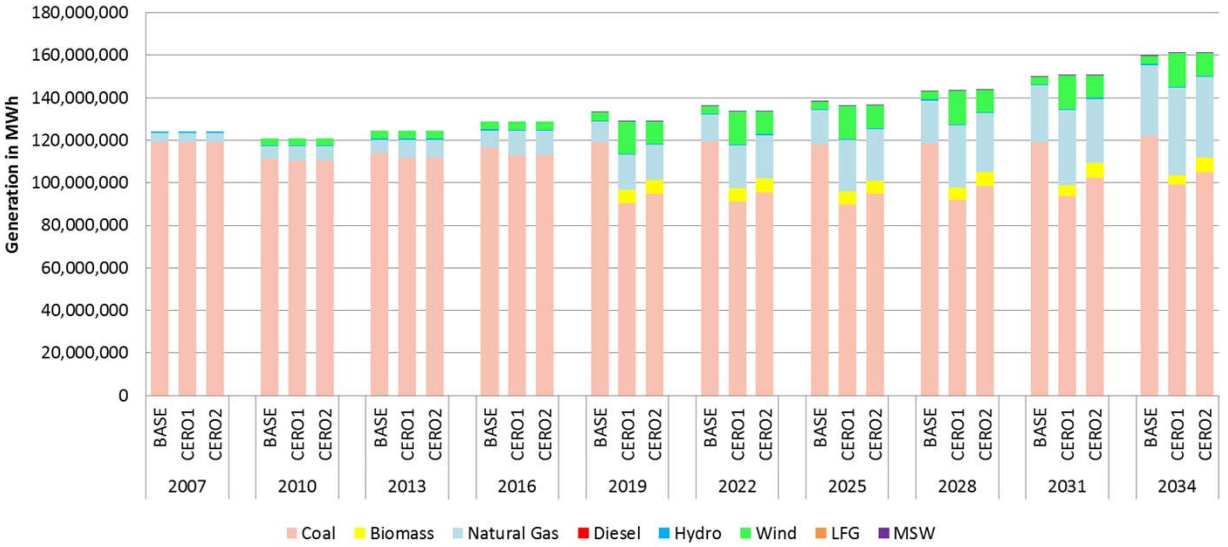


Figure 5-26 Indiana electricity generation portfolio in MWh in the BASE case and carbon cap scenarios

Results - Comparison across Policies

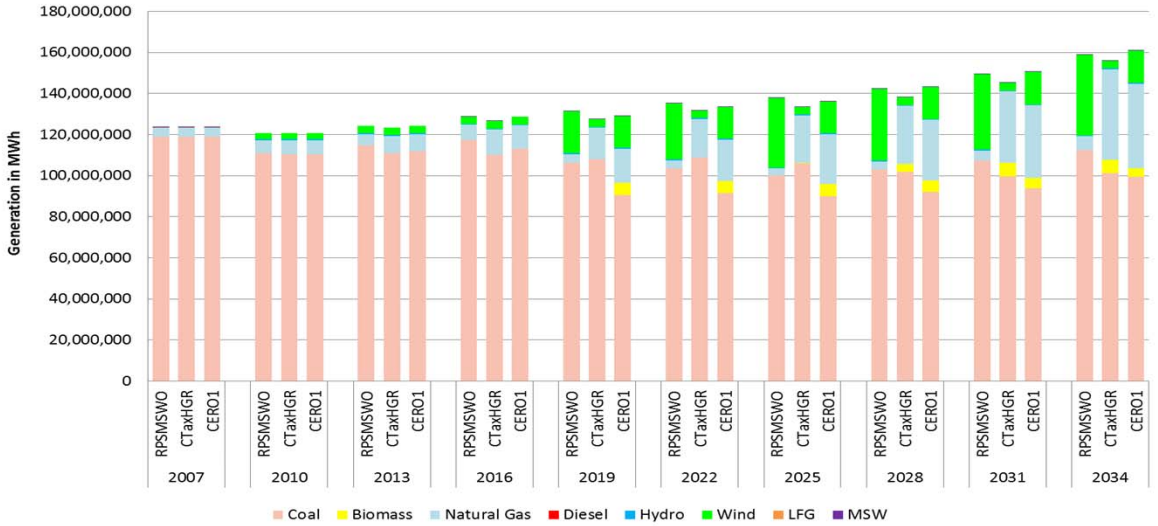


Figure 5-29 Electricity generation portfolio in the RPSMSWO, CTaxHGR and CERO1 cases

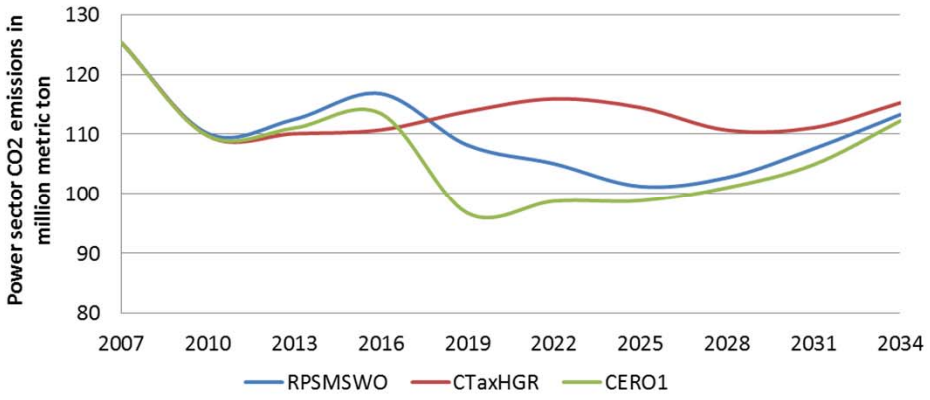


Figure 5-30 Power sector CO_2 emissions in the RPSMSWO, CTaxHGR and CERO1 cases

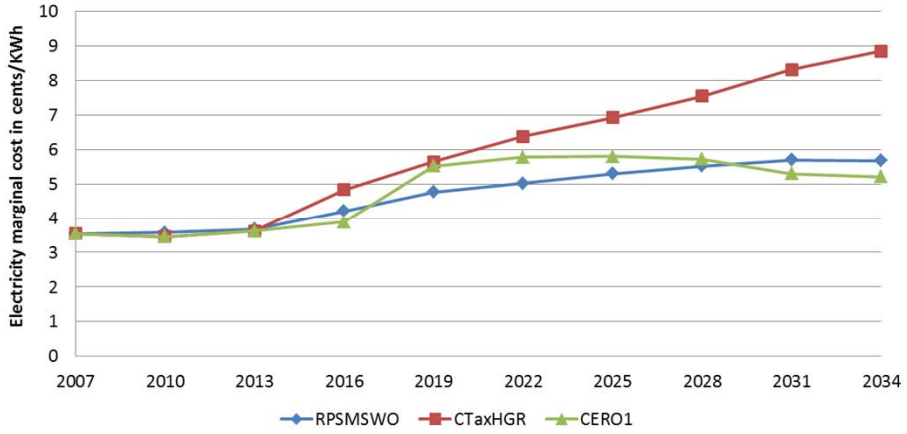


Figure 5-32 Marginal cost of electricity in the RPSMSWO, CTaxHGR and CERO1 cases

Results - Comparison across Policies

Table 5-10 Accumulated CO_2 emissions over the modeling horizon by scenario

Case	Electricity system cumulative CO2 emission in million metric ton	Electricity system cumulative CO2 emission reduction from the BASE in million metric ton	% change of electricity system cumulative CO2 emission from the BASE	Energy system cumulative CO2 emission in million metric ton	Energy system cumulative CO2 emission reduction from the BASE in million metric ton	% change of energy system cumulative CO2 emission from the BASE
BASE	3,665.38			5699.26		
RPSMSWO	3,308.18	357.20	-9.75%	5345.57	353.70	-6.21%
CTaxHGR	3,411.16	254.22	-6.94%	5468.66	230.60	-4.05%
CERO1	3,215.87	449.51	-12.26%	5251.65	447.61	-7.85%

Table 5-11 LMCOE by scenario

Scenario	LMCOE in cents/KWh	LMCOE % change from BASE
BASE	8.41	
RPSMSWO	9.14	8.66%
CTaxHGR	11.57	37.52%
CERO1	9.29	10.45%

Table 5-12 Comparison of cost effectiveness of carbon reduction across scenarios

Scenario	% change of LMCOE from BASE / % reduction of electricity sector CO2 emissions from BASE	Energy system CO2 emissions abatement cost in $/metric ton
RPSMSWO	0.89	35.00
CTaxHGR	5.41	103.66
CERO1	0.85	17.75

Results - Comparison across Policies

- RPSMSWO vs CCAPvsRPSMS

Table 5-13 Carbon tax trajectory identified in the CCAPvsRPSMS case in 2007$/metric ton

	2019	2022	2025	2028	2031	2034
CCAPvsRPSMS	29.60	44.60	104.30	63.30	59.10	38.90

Table 5-14 LMCOE in the BASE, RPSMSWO and CCAPvsRPSMS cases

Scenario	LMCOE in cents/KWh	LMCOE % change from BASE
BASE	8.41	
RPSMSWO	9.14	8.66%
CCAPVSRPSMS	14.44	71.64%

Table 5-15 Comparison of cost effectiveness of carbon reduction for the RPSMSWO and CCAPvsRPSMS cases

Scenario	% change of LMCOE from BASE / % reduction of electricity sector CO2 emissions from BASE	Energy system CO2 emissions abatement cost in $/metric ton
RPSMSWO	0.89	35.00
CCAPvsRPSMS	6.83	14.17

Conclusions

- Major contributions
  - IN-MARKAL
  - Major results:
    - The increment to the LMCOE: 8.66-37.52%
    - The reduction of cumulative power sector CO_2 emissions: 6.94-12.26%
    - RPS
    - Carbon tax
    - Emission-rate cap

- Limitations
  - Reliability concern of power generation system
  - Transmission network
  - Difficulty in policy enforcement and associated costs

Thank you!

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