2007 IEPR
Scenario Analyses Project

Michael R. Jaske, PhD
California Energy Commission

June 18, 2007

Scenarios Project Team

- Energy Commission Staff:
  - Mike Jaske
  - Lana Wong
  - Ross Miller
  - Angela Tanghetti
  - Mark Hesters
  - Don Kondoleon
- Global Energy Decisions:
  - Richard Lauckhart
  - Bryan Swann
  - Mayank Garg
  - Ann Donnelly
  - Mike Donnelly
  - Gurinder Goel
- Navigant Consulting, Inc.:
  - Ron Nichols
  - Dave Larsen
  - Craig McDonald
- Aspen Environmental Group:
  - Carl Linvill

Background from Executive Summary (Agenda item 3a)

- This scenario project is designed to:
  - develop a greater understanding of the actions believed to be needed to achieve major reductions in green house gases (GHG) for the electricity sector,
  - Understand at least some of the consequences of these actions, and
  - Permit some degree of tradeoff comparisons.

Overview, cont'd

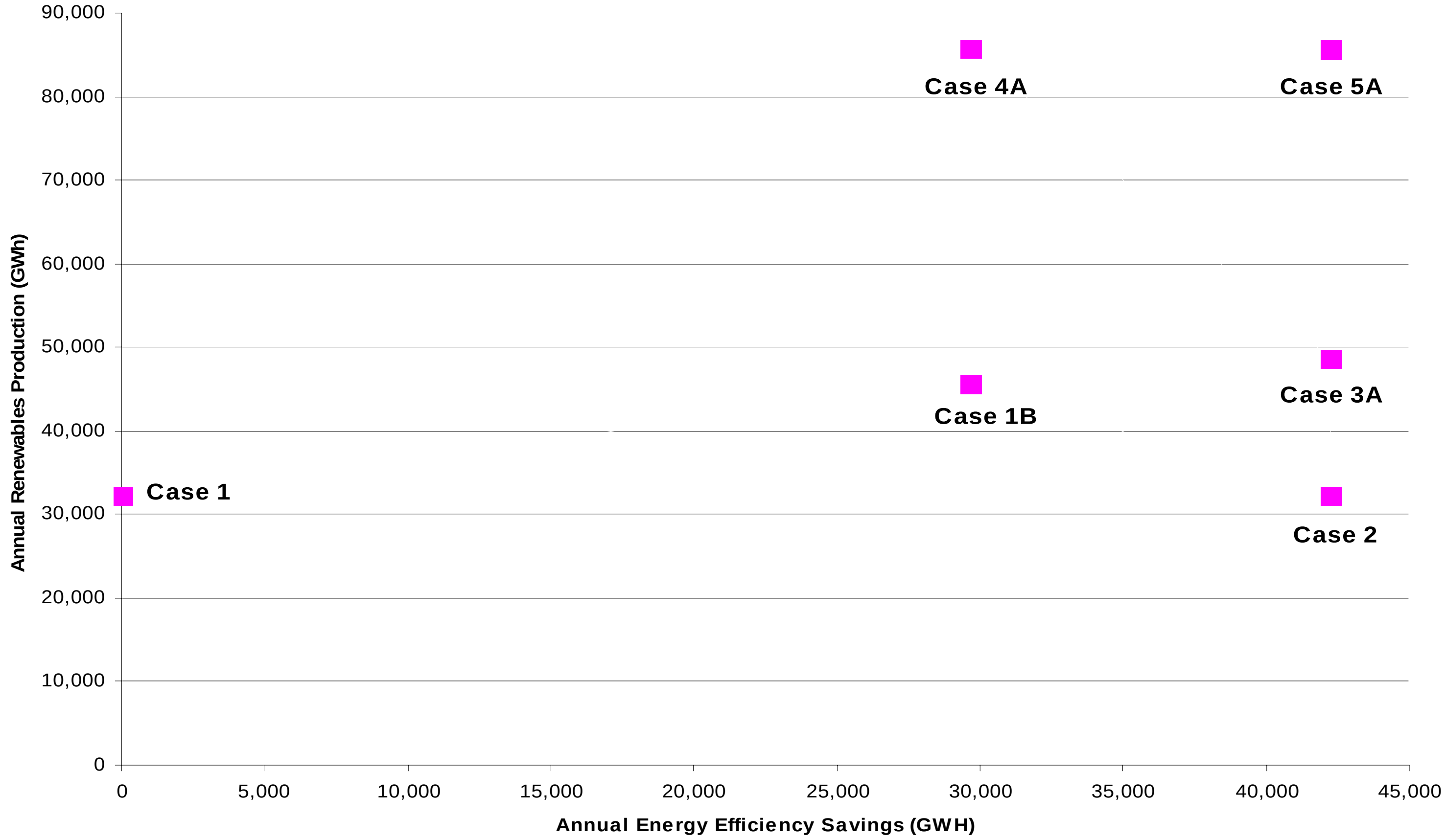
- Posted project documentation
  - Main report of 10 chapters (~250 pages)
  - Appendices volume (~150 pages)
  - Excel spreadsheets for detailed results
- Forthcoming documentation
  - Implications of aging power plant retirements
  - Impacts on natural gas prices of reduced UEG demand

Thematic Scenarios Assessed

- Case 1 — Current conditions extended into the future.
- Case 1B — Compliance with current requirements.
- Case 2 — High sustained natural gas and coal prices.
- Case 3A — High energy efficiency in California only.
- Case 3B — High energy efficiency throughout the West.
- Case 4A — High renewables in California only.
- Case 4B — High renewables throughout the West.
- Case 5A — High energy efficiency and renewables in California only.
- Case 5B — High energy efficiency and renewables throughout the West.

California Energy Commission

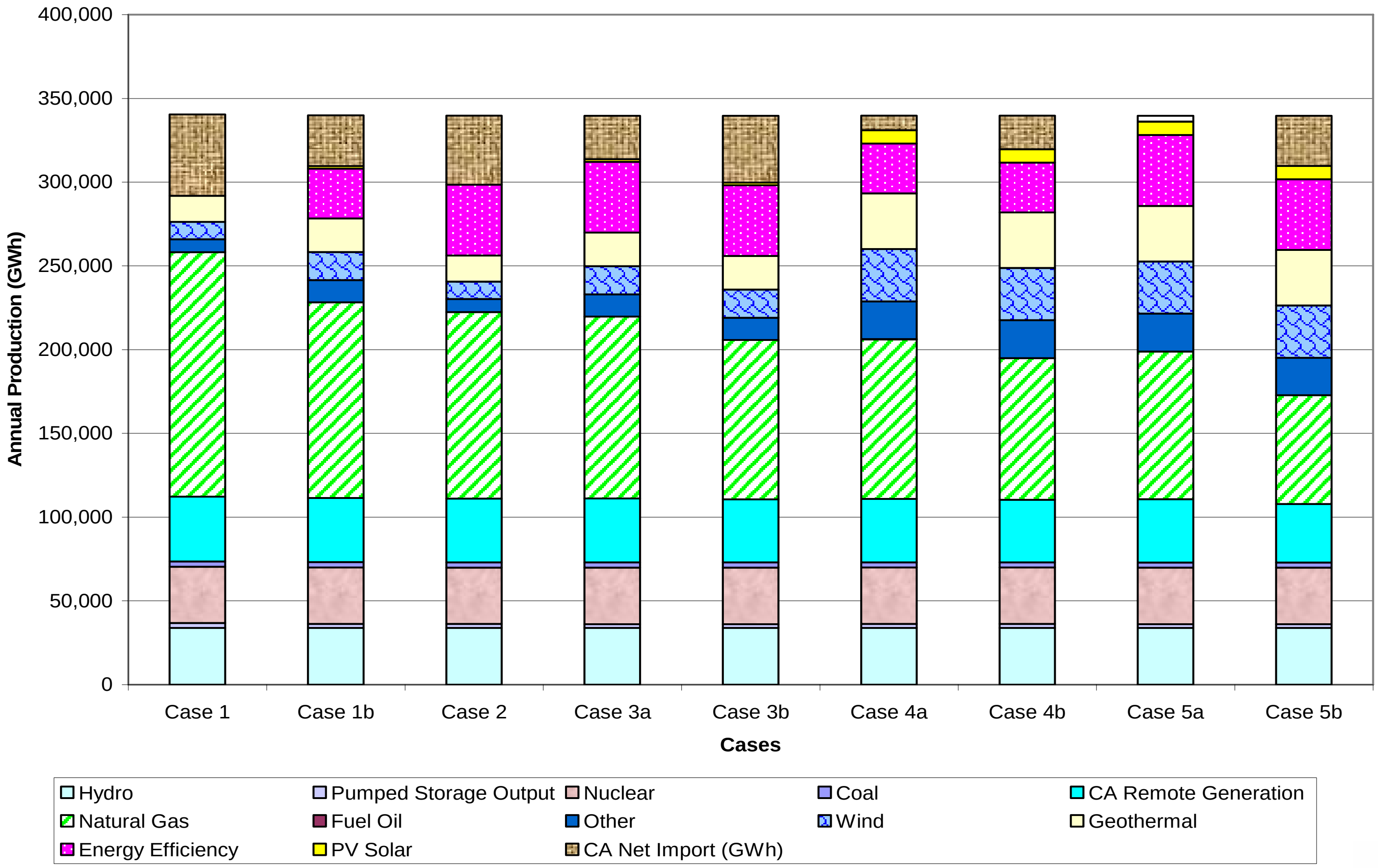
Figure ES-1: Preferred Resource Composition of California Thematic Scenarios in 2020



Source: Energy Commission Scenario Project

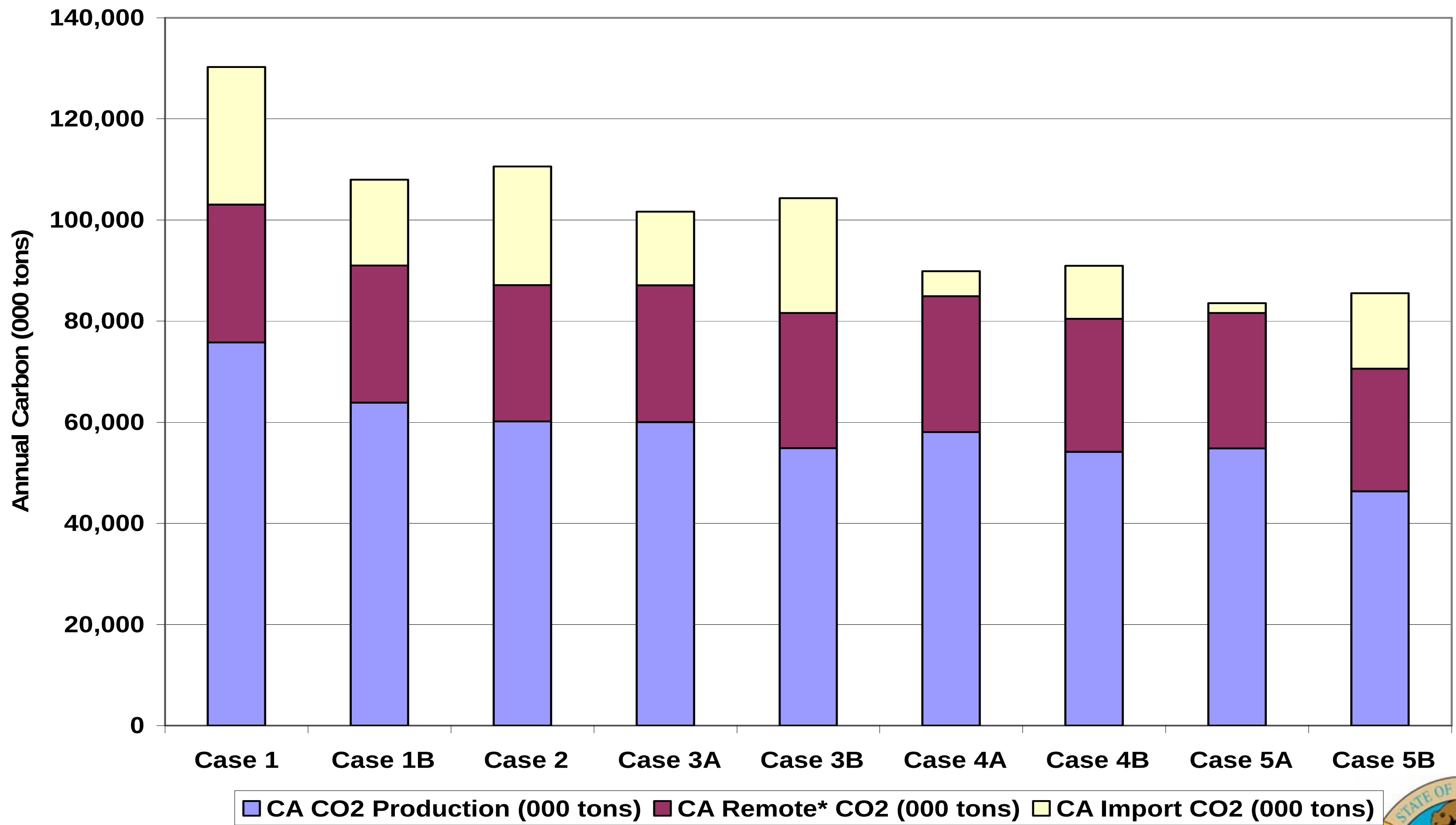
Figure ES-2: Comparing California Resource Mix in Year 2020

Figure ES-2: Comparing California Resource Mix in Year 2020



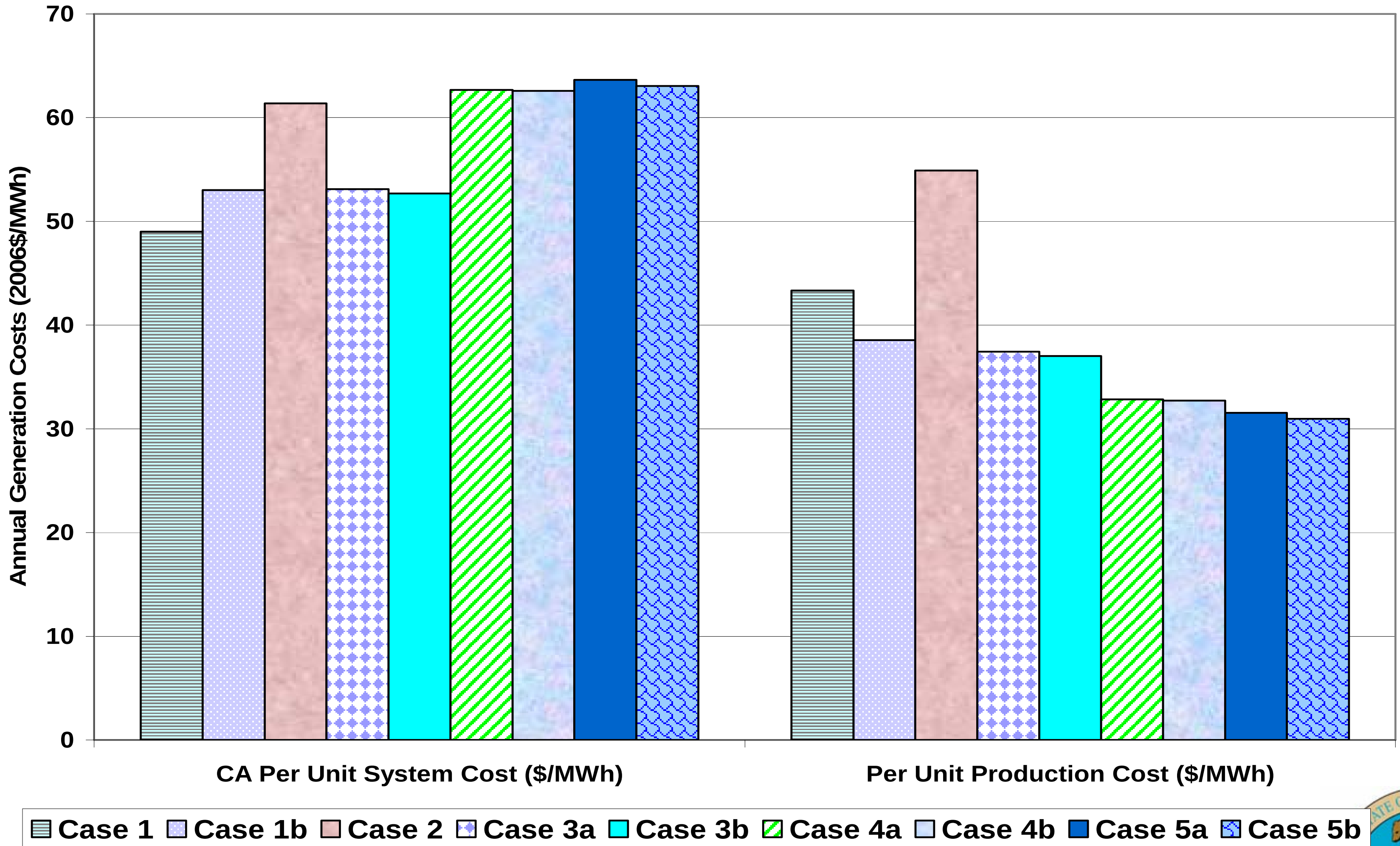
Source: Energy Commission Scenario Project

Figure ES-3: Comparing California Carbon Responsibility in Year 2020



Source: Energy Commission Scenario Project

Figure ES-5: California Generation Cost Comparison Across Cases on a Per Unit Cost Basis



Source: Energy Commission Scenario Project

Methodology and Basecase Assumptions (Agenda Section 3b)

- Background
  - Since 2005 IEPR, major shift in policy toward GHG emission reductions
  - Energy agencies have already emphasized EE and renewables
  - What are consequences of even larger focus on EE and renewables on GHG?
  - Improve assessment of "system impacts" aspects of high EE and renewables

Background, cont'd

- Scenario Project proposal
  - Developed internally in October 2006
  - Staff issued report proposing a scenario project in mid-January
  - January 29, 2007 Workshop
  - Feedback from participants
  - Limited adjustments to project design, but no changes to schedule

Methodology

- Use Global Energy Decisions product called Market Analytics
  - Utilize large portions of Global's assumptions
  - Selectively replace certain elements
- Conduct power flow assessments or use other techniques to determine when/where transmission should be added
- Create integrating database for PROSYM results and additional calculations
- Devise techniques to evaluate various sensitivity cases likely to be important to GHG emissions, costs, or reliability

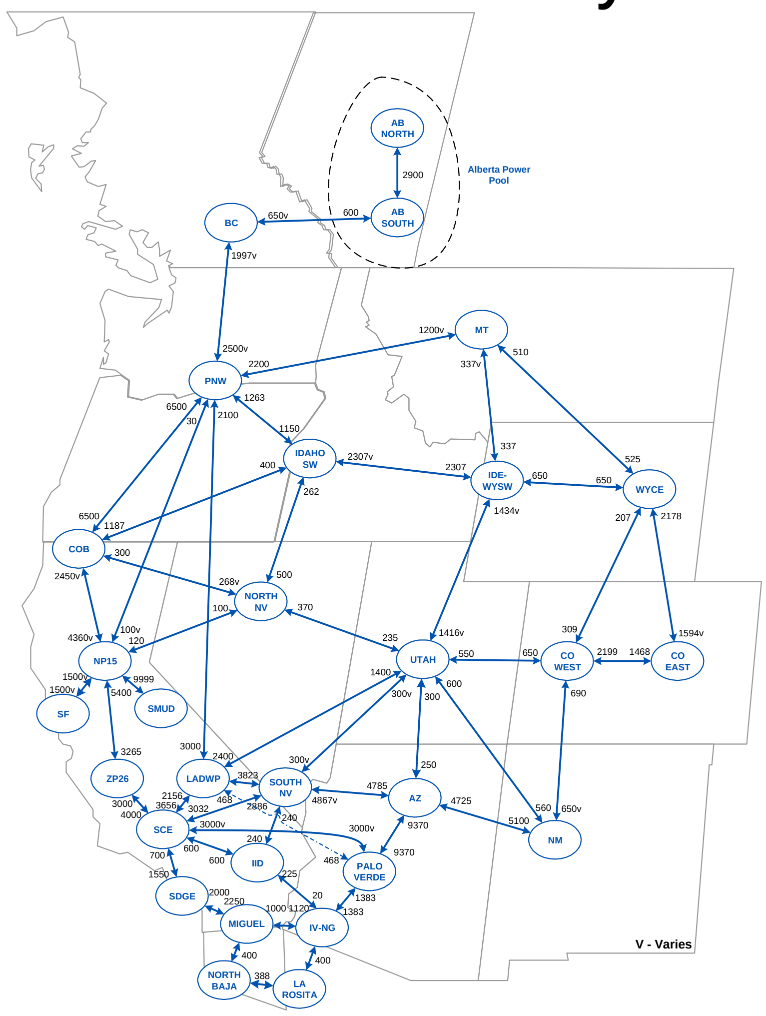
Production Cost Modeling

- Global Energy's Market Analytics product using PROSYM engine
- Zonal topology (29 in total, 10 for CA)
- Operates deterministically with a large number of uncertain variables set to "basecase" values
- "typical" week format for each month
- Least cost unit commitment and dispatch, while satisfying various constraints

Elements Substituted

- Topology for modeling California portion of Western Interconnection
- Load forecasts for California
- Basecase natural gas fuel price projections

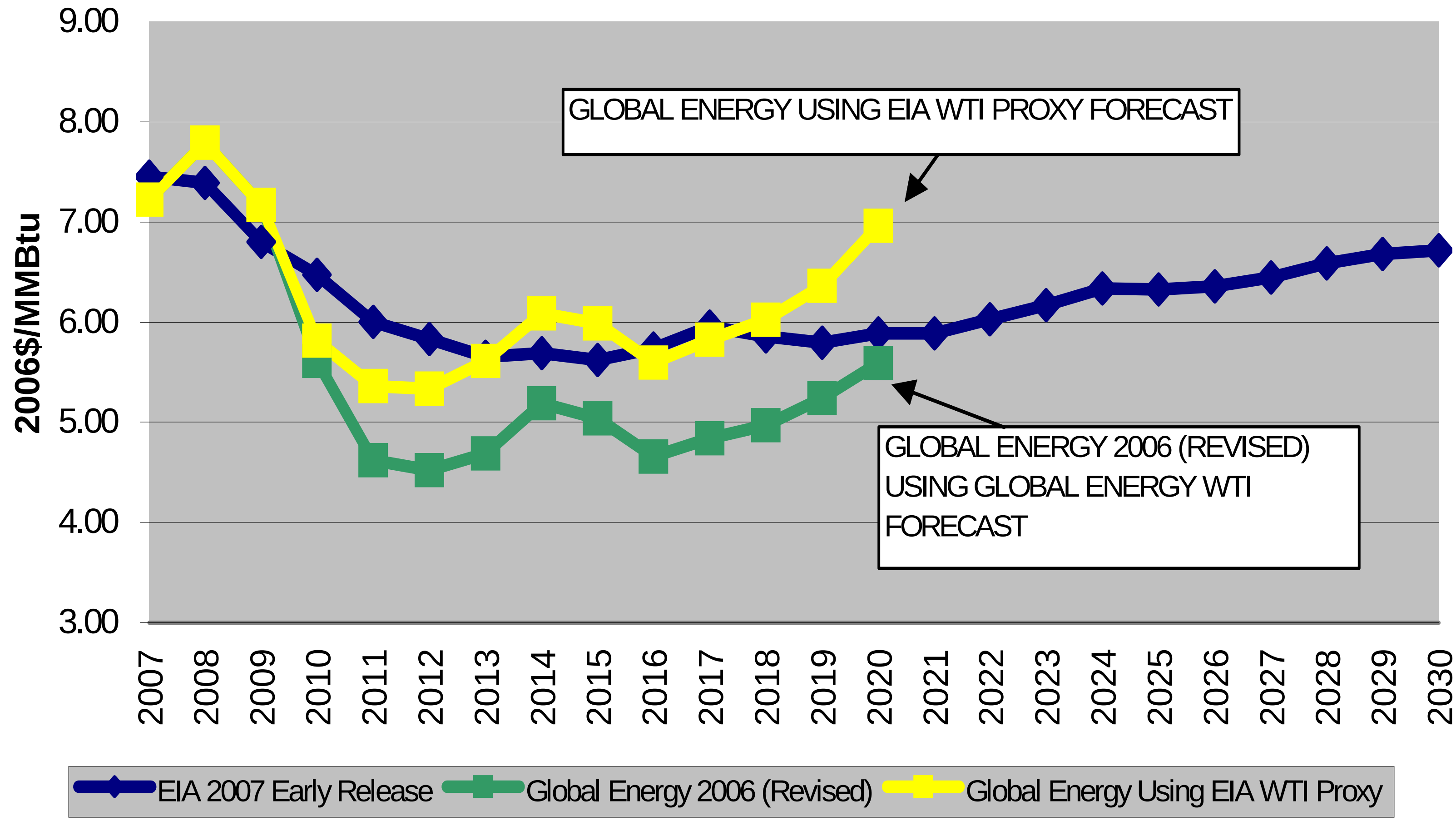
Figure 5-1: Topology of the Western Interconnection Used in the Analysis



California Load Forecasts

- CEC adopted 2007 load forecasts in June 2006, replacing those adopted in the *2005 IEPR*
- During summer 2006, the same adjustments used to create 2007 were applied to all future years
- These “consistent” load forecasts were used in this project

Basecase Natural Gas Price Forecasts (Figure H-1 from Appendix H-2)



Transmission Assessments

- Indepth power flow assessments not conducted in most cases
- Lines identified by PROSYM line utilization diagnostic outputs, or literal generation pockets unable to export power
- Cost estimates very preliminary, and not based on an actual project

Integrating Database

- PROSYM results dropped into a Microsoft Access database
- Results reported in the form of “scorecards” that allow cases to be compared to one another
- Some variables computed using Excel spreadsheets after scorecards queified for results
- Appendices C and D are examples of these scorecards

Total Cases Evaluated

- Fuel Prices for 2009-2020
  - 8 scenarios with 3 variants, plus 1 = 25
- Shocks for 2020
  - 9 scenarios with 3 variants = 27
- Stochastic for 2020
  - 2 scenarios = 2 (100 runs for each case)
- Total cases evaluated = 54

Construction of Scenarios/Cases (Agenda Section 3c)

- Story for each case
  - Use of preferred resource types
  - Geographic scope
- Overview of how assumptions were developed
- Sources of information

Development of Case 1

Theme: continuation of current conditions

Source: largely Global Energy Fall 2006 Reference Case

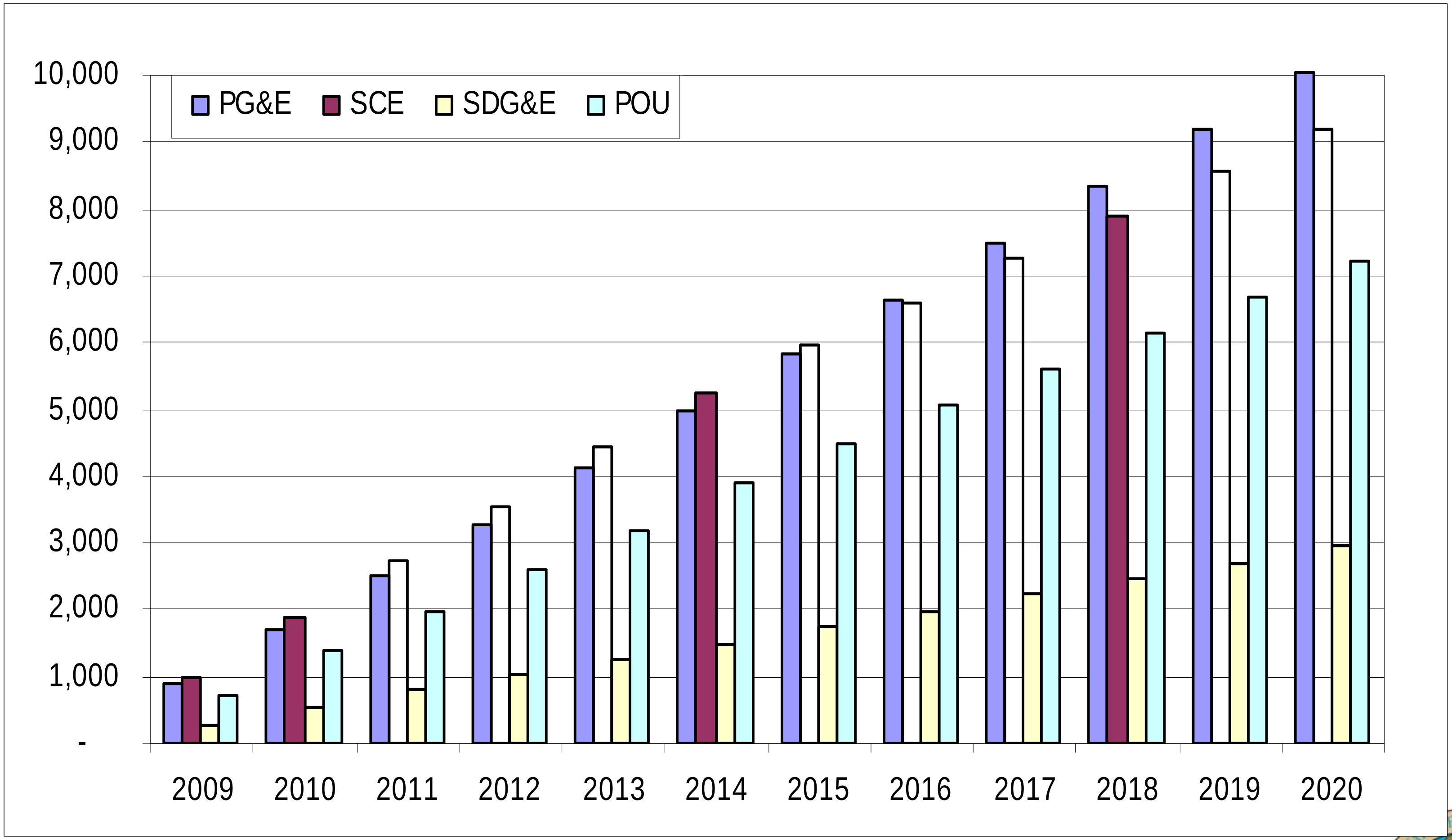
Changes:

- Revised topology
- CEC Staff directed fuel prices
- CEC 2006 load forecast for California transareas

Development of Case 1B

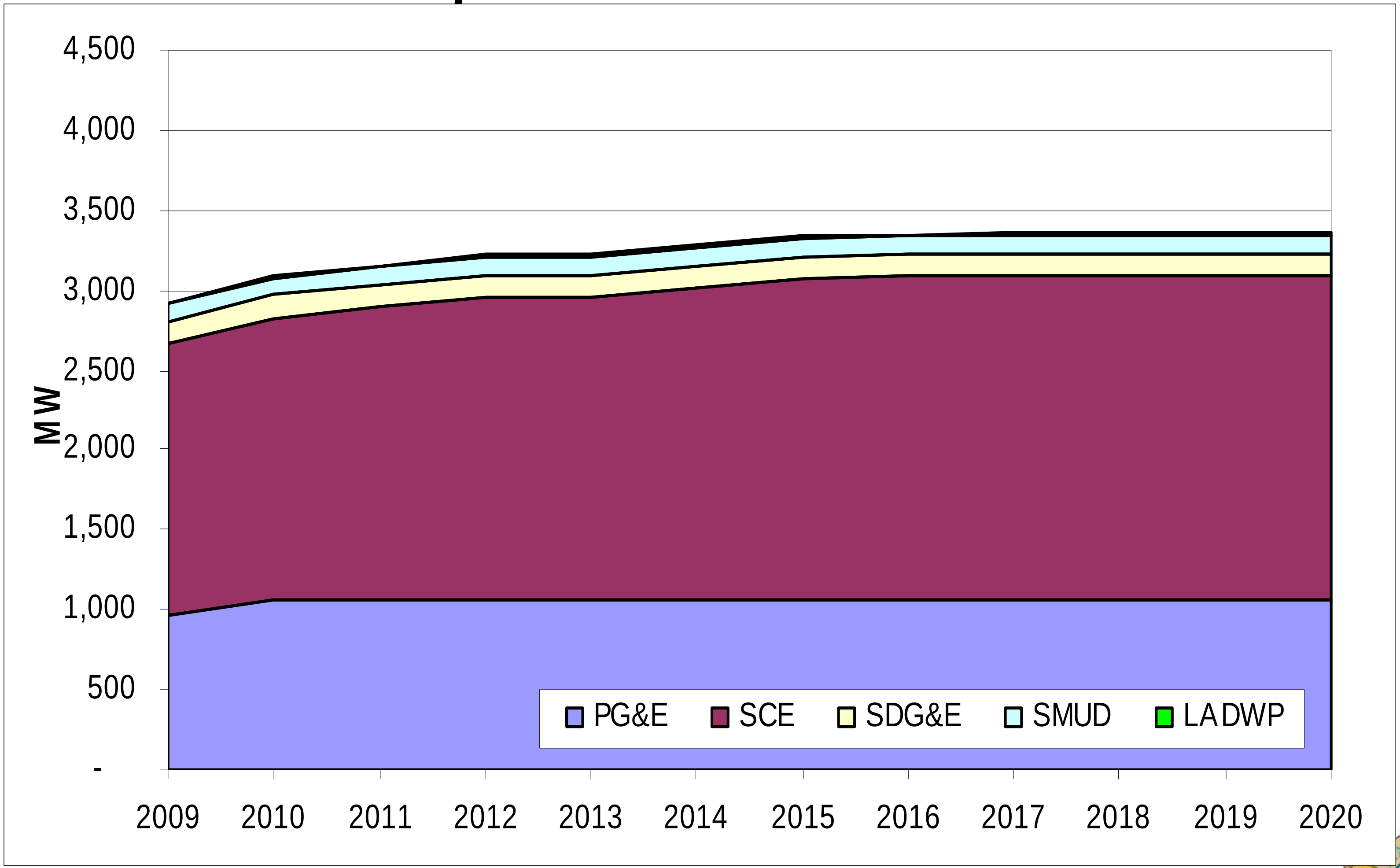
- Theme: current requirements
- Scope:
  - Energy efficiency and demand response with funding authorization
  - Rooftop solar photovoltaic
  - Renewable portfolio standards
  - West-wide
- Sources of Information:
  - Itron study of EE potential
  - CEC staff built-out of renewable resources

Figure 2-4: Projected Cumulative Impacts of California Energy Efficiency Programs in Case 1B



Source: Navigant Consulting

Figure 2-5: Projected Cumulative California Demand Response for Case 1B



Source: Navigant Consulting

Rooftop Solar PV Penetration
(Revised version of Table 2-2)

Transarea	2010	2015	2020
Arizona	0	0	39
California	108	414	514
Nevada	95	211	243
Total	203	625	796

Figure 2-6: Renewable Portfolio Standards by State as of April 2007

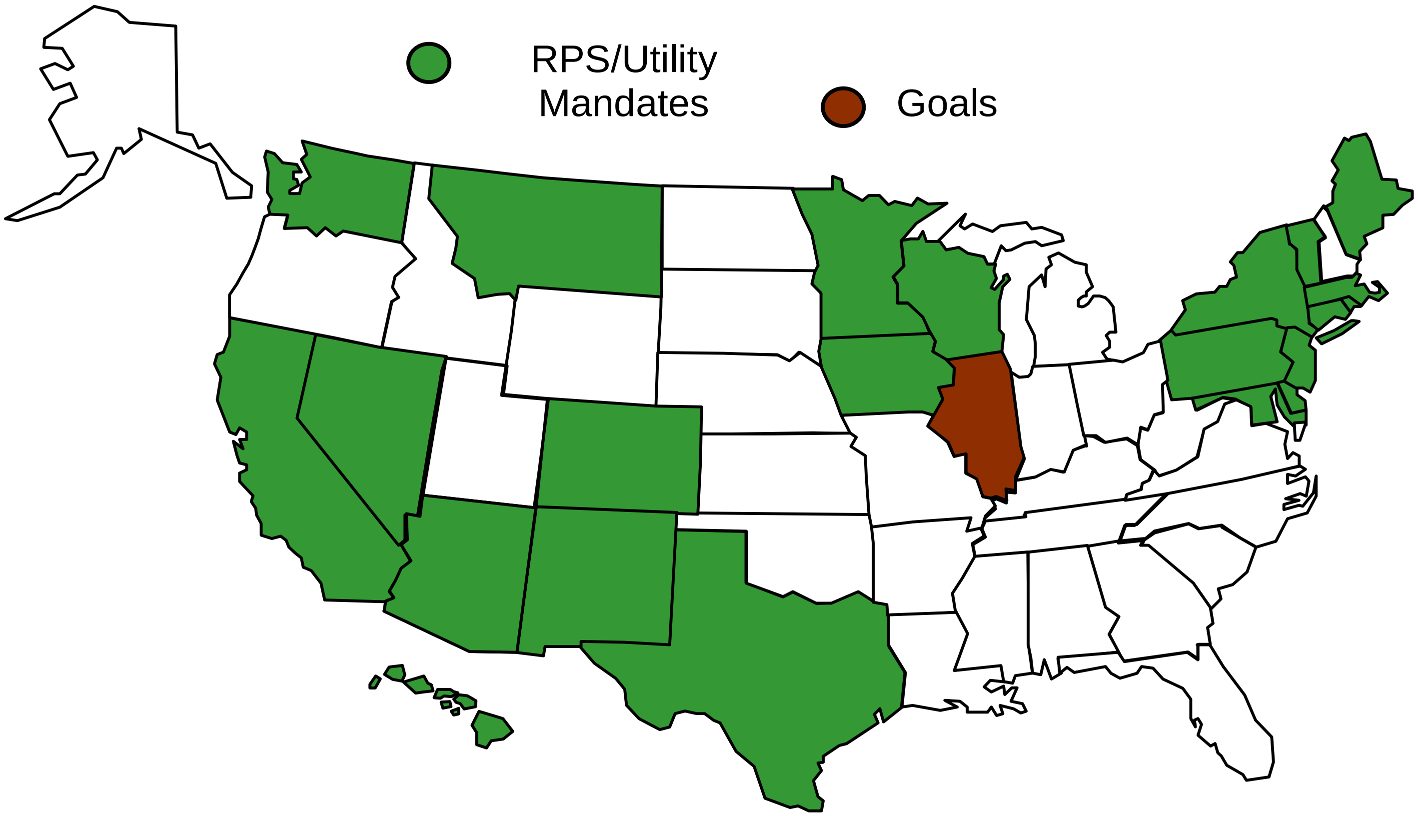
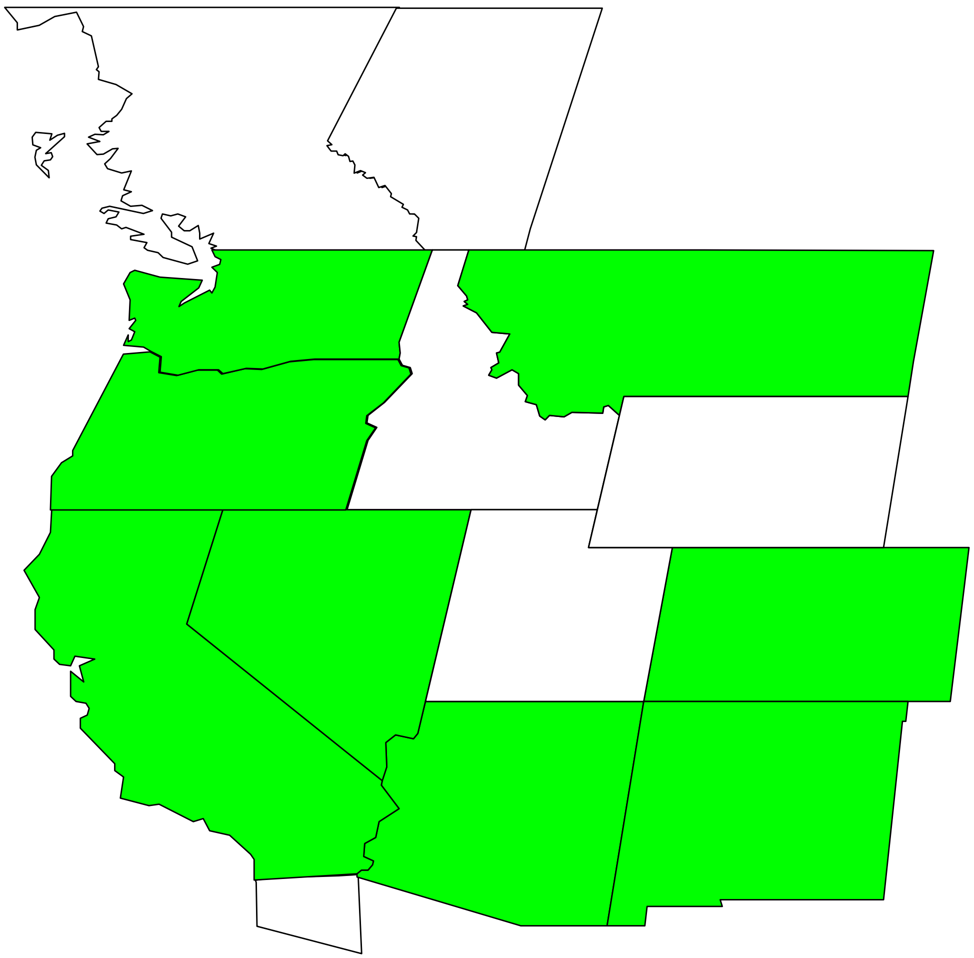


Figure 2-7: Installed Renewable Capacity by State and Province Year 2017 (MW)



Development of Case 3A

- Theme: High Energy Efficiency
- Scope:
  - Economic potential for IOU loads
  - POU savings assumed to achieve the same percentage increase from Case 1B savings as was the case for IOU potential
  - California Only
- Sources of Information:
  - 2006 Itron Study

Figure 2-9: Projected Cumulative Energy Efficiency Impacts for Case 3A

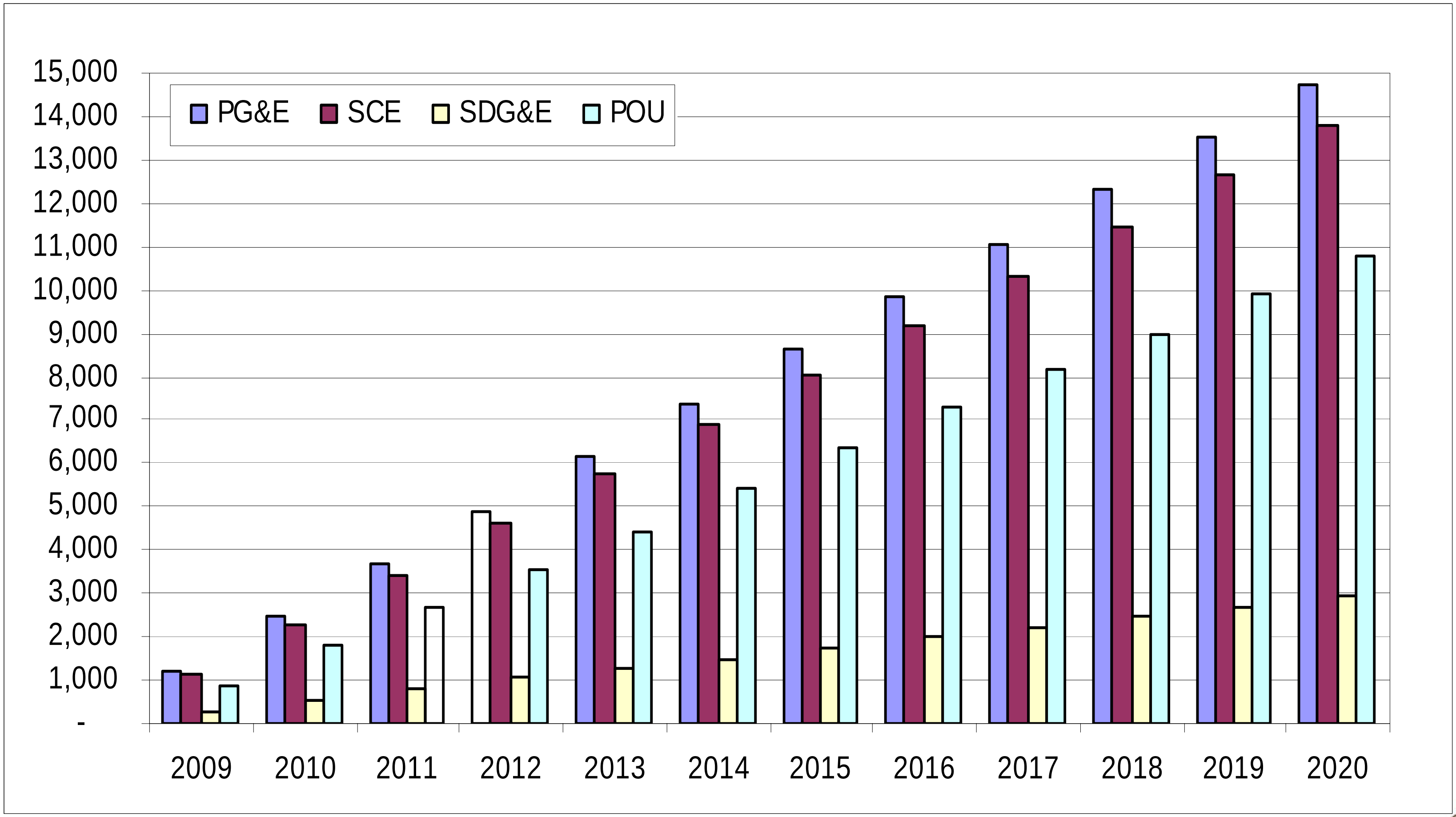


Figure 2-10: Projected Cumulative Impacts on Net Energy for Load

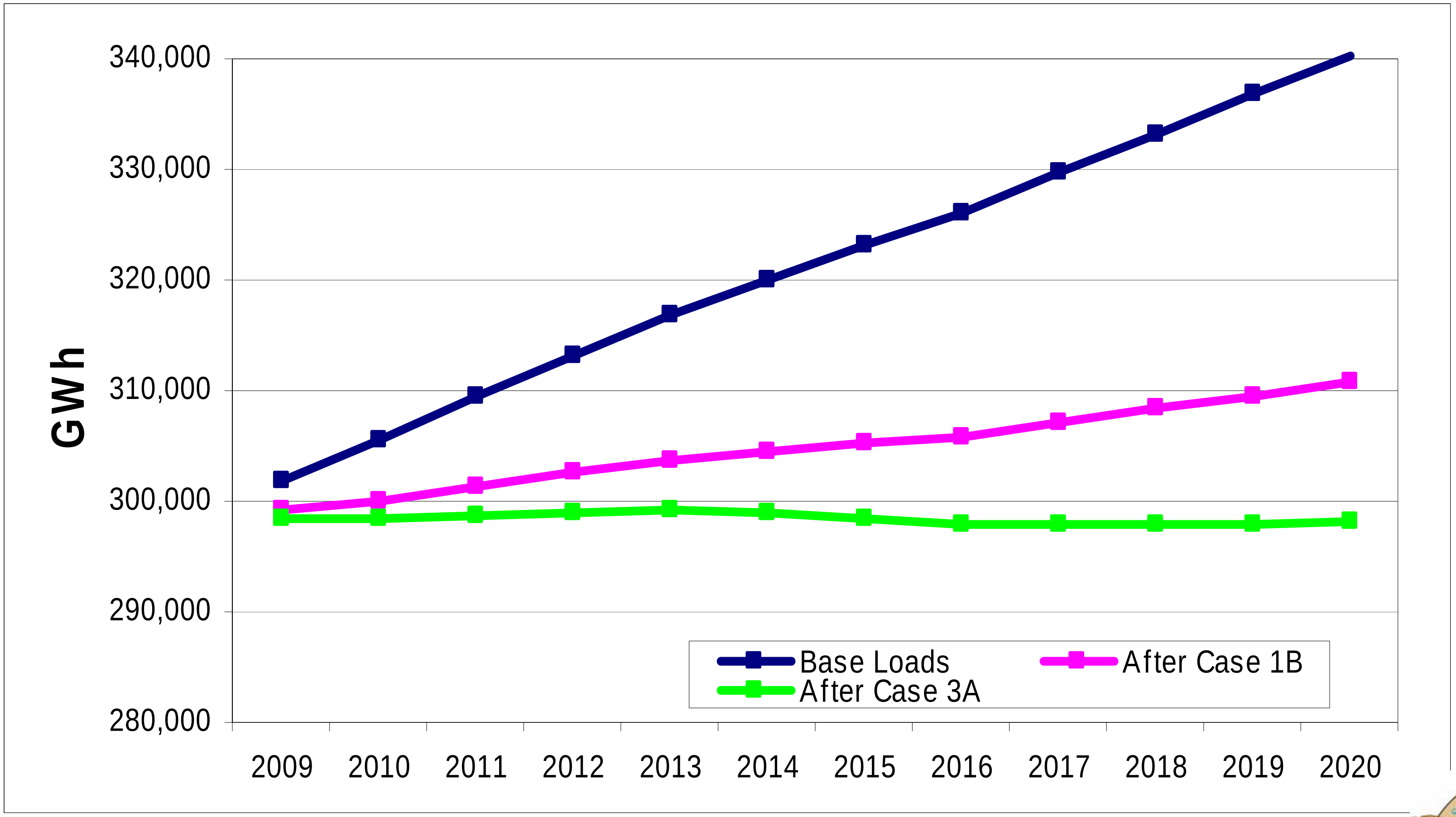
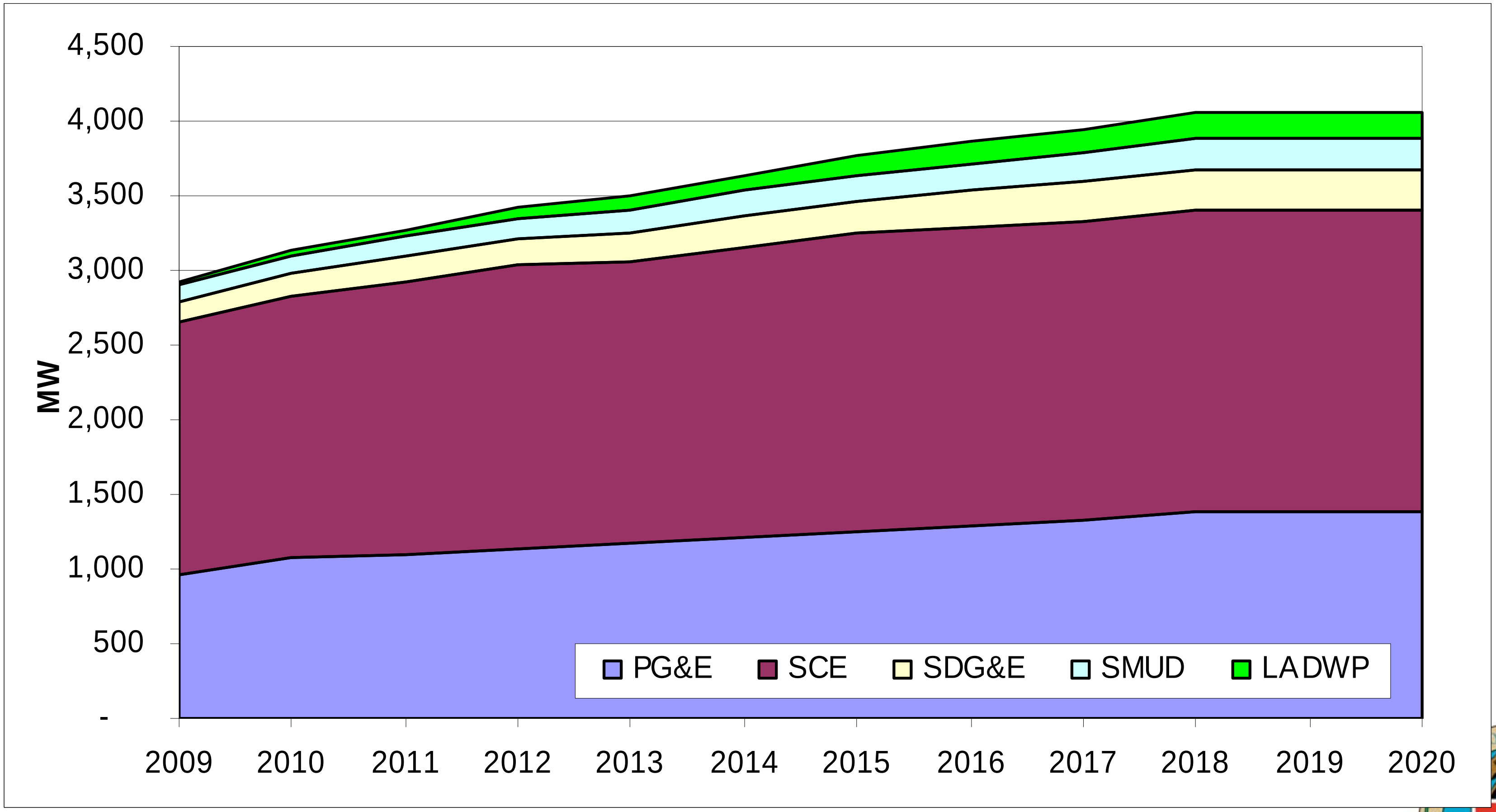


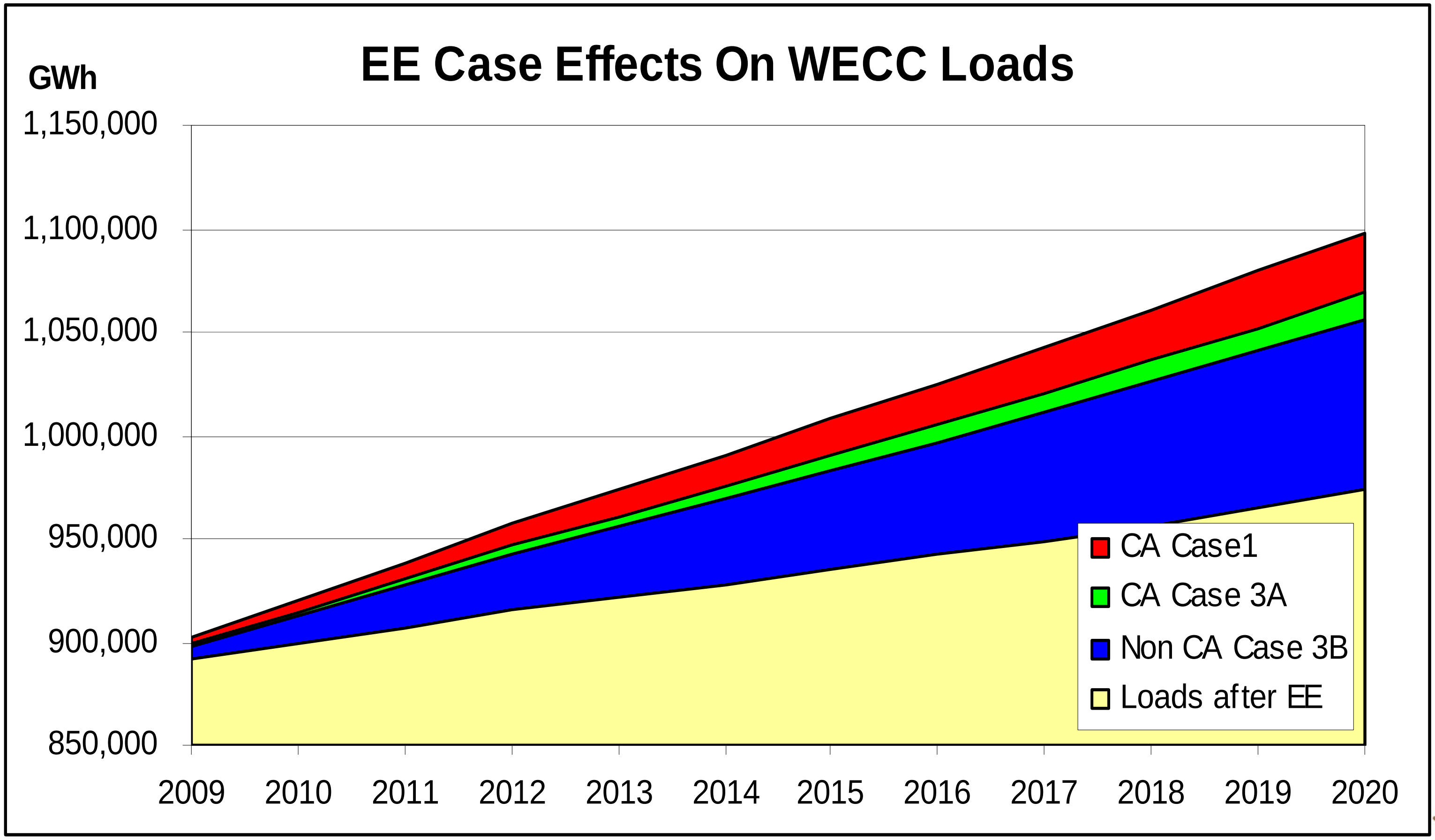
Figure 2-11: Projected Cumulative California Demand Response Capacity for Case 3A



Development of Case 3B

- Theme: High Energy Efficiency
- Scope:
  - EE in California same as Case 3A
  - EE in Rest-of-WECC pushed up toward the level of economic potential
  - West-wide
- Sources of Information:
  - Rest-of-WECC from CDEAC reports
  - LBL report for WGA on utility IRPs

Figure 2-12: Impacts of High Energy Efficiency in Total WECC Net Loads for Case 3B



Development of Case 4A

- Theme: High Renewables
- Scope:
  - Wind, CSP, geothermal, biomass, and rooftop PV
  - An increment of 13,000 MW of nameplate capacity beyond Case 1B is installed by 2020
  - Not an RPS compliance analysis
  - Some additional transmission capacity developed
  - California Only
- Sources of Information:
  - PIER-funded IAP study for renewable capacity using the 33% by 2020 scenario
  - Numerous other studies for production profiles and costs

Case 4A Resource Additions in California by Technology (Nameplate Capacity in MW)

Resource Type	2015	2020
CSP	-232	1,179
PV Rooftop	3,034	3,884
Wind	1,259	5,812
Geothermal	528	1,669
Biomass	183	674
Total	4,772	13,218

Development of Case 4B

- Theme: High Renewables
- Scope:
  - Additional 16,000 MW of capacity beyond Case 1B gradually added and installed by 2020
  - West-wide
  - Substantial increase in transmission capacity
- Sources of Information:
  - California is the same as Case 4A
  - Rest-of-WECC from CDEAC Task Force Reports

Case 4B Resource Additions in Rest-of-WECC by Technology (Nameplate Capacity in MW)

Resource Type	2015	2020
CSP	548	1,184
PV Rooftop	88	423
Wind	5,183	12,792
Geothermal	566	1,448
Biomass	93	385
Total	6,478	15,932

Development of Case 5A

- Theme: High EE and Renewables
- Scope:
  - Same EE as in Case 3A
  - Same rooftop solar PV as in Case 4A
  - Same supply-side renewables as in Case 4A
  - California Only
- Sources of Information: No new info

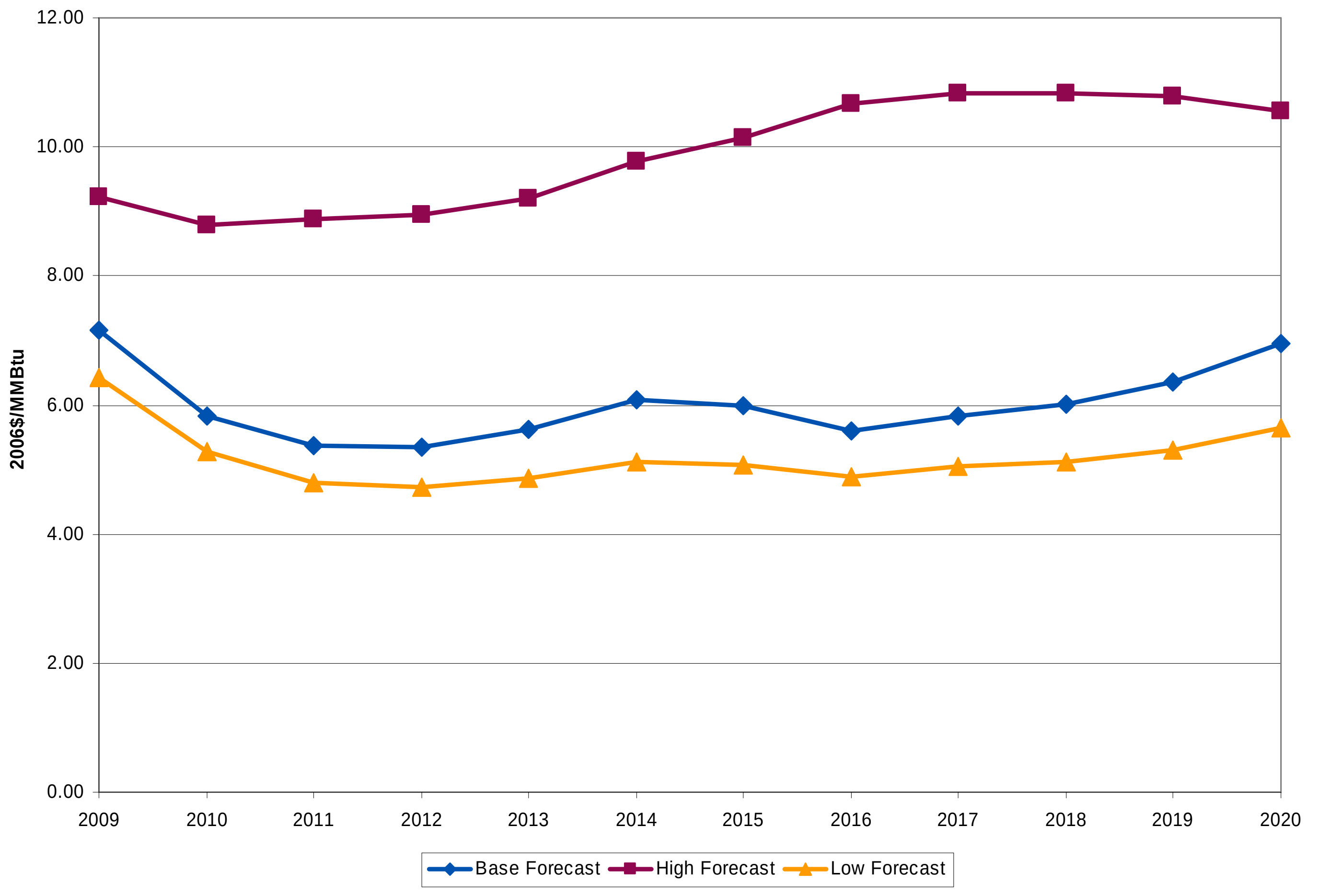
Development of Case 5B

- Theme: High EE and Renewables
- Scope:
  - Same EE as in Case 3B
  - Same rooftop solar PV as in Case 4B
  - Same supply-side renewables as in Case 3B
  - West-wide
  - Slight increase in transmission capacity
- Sources of Information: No new info

Development of Case 2

- Theme: Sustained High Fuel Prices
- Scope:
  - Utility management decision-making
  - Focus on costs
  - West-wide
- Sources of Information:
  - Cost of Generation Study

Basecase, Sustained Scarcity, and Low Consumption Natural Gas Price Projections ($2006)



Basecase, Sustained Scarcity, and Low Consumption Coal Price Projections ($2006)

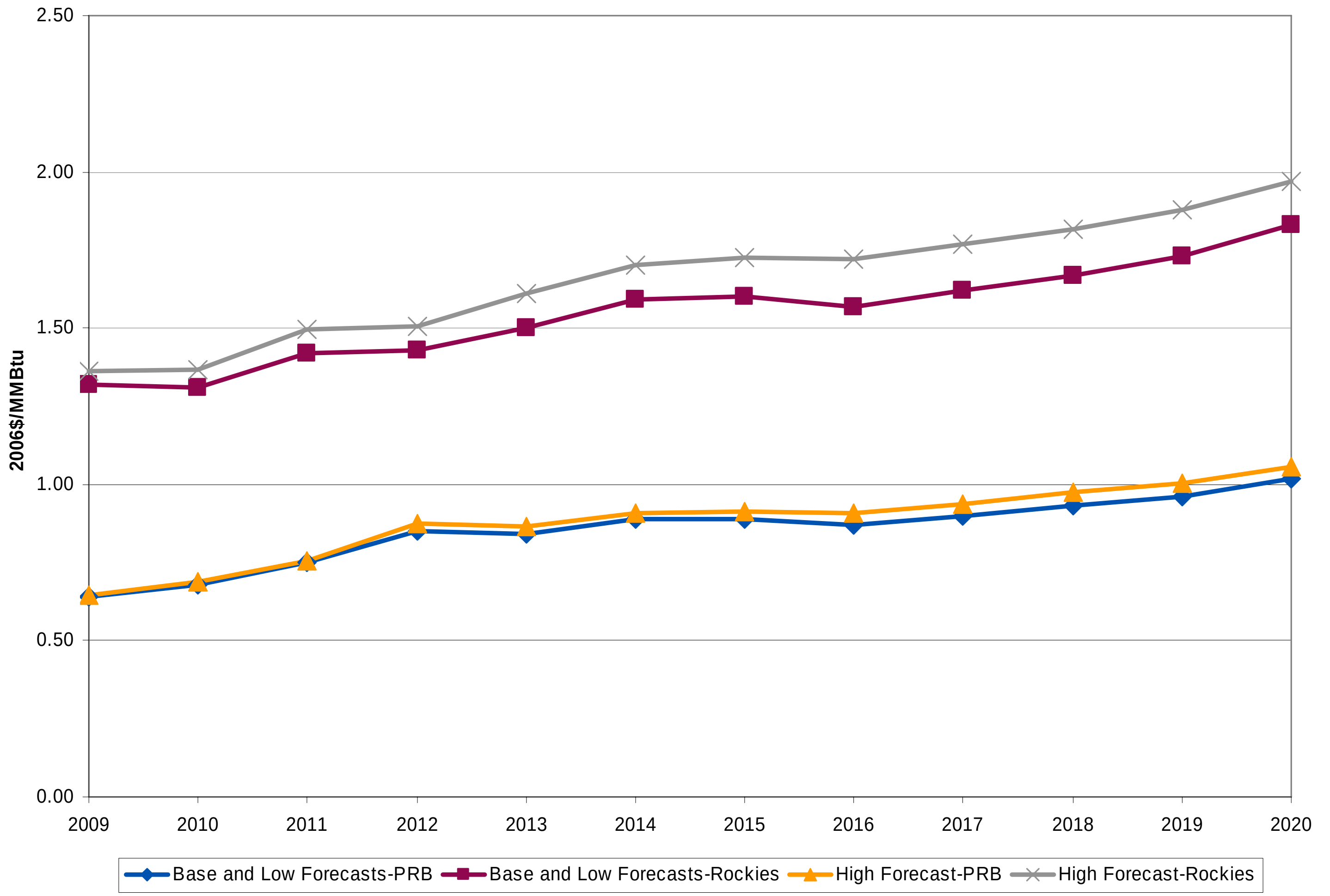


Table 2-4: Alternative Resource Costs Under a Sustained Scarcity Pricing of Natural Gas

		$6/mmbtu	$10/mmbtu
Technology	Fixed Costs	Full Cost	Full Cost
	($/MWh)	($/MWh)	($/MWh)
Pulverized Coal	41.40	53.2	55.2
Sequestered Coal	61.46	79.8	81.8
Combined Cycle	17.72	62.1	90.1
Gas Turbine	197.97	262.3	302.3
Wind in Calif	69.24	74.7	74.7
Wind in RofW	69.23	74.7	74.7
Solar Parabolic	145.00	146.4	146.4
Biomass	49.51	60.6	60.6
Geothermal Binary	44.93	66.7	66.7

Case 2 Resource Mix

- Fewer Changes than anticipated in original project design
- Specific modifications:
  - Case 3A energy efficiency for California
  - Increased energy efficiency for Rest-of-WECC
  - Modest switch from natural gas to coal in Alberta, and from gas to geothermal in North Baja, in out years of assessment

Technology Potential and Cost (Agenda item 3d)

- In the ideal world:
  - Use zonal "supply curves" to devise scenarios and estimate costs
  - No such compilation of resource potential, ranked by cost, exists.
- This study:
  - Abstracted from previous studies
  - Acquired "pre-release" results of some PIER-funded research projects

Major Sources

- Energy efficiency
  - Itron study of 2004 released in 2006
  - CDEAC studies from 2005-2006
- Rooftop Solar PV
  - PIER-funded Navigant Study
  - NREL "PV Watts" data for production profile
- Supply-side Renewables
  - PIER-funded IAP project
  - CDEAC studies from 2005-2006
  - Calif. QF and NREL wind production data

Figure 4-1: Instant Cost of Renewable Technologies (per kW, $2006)

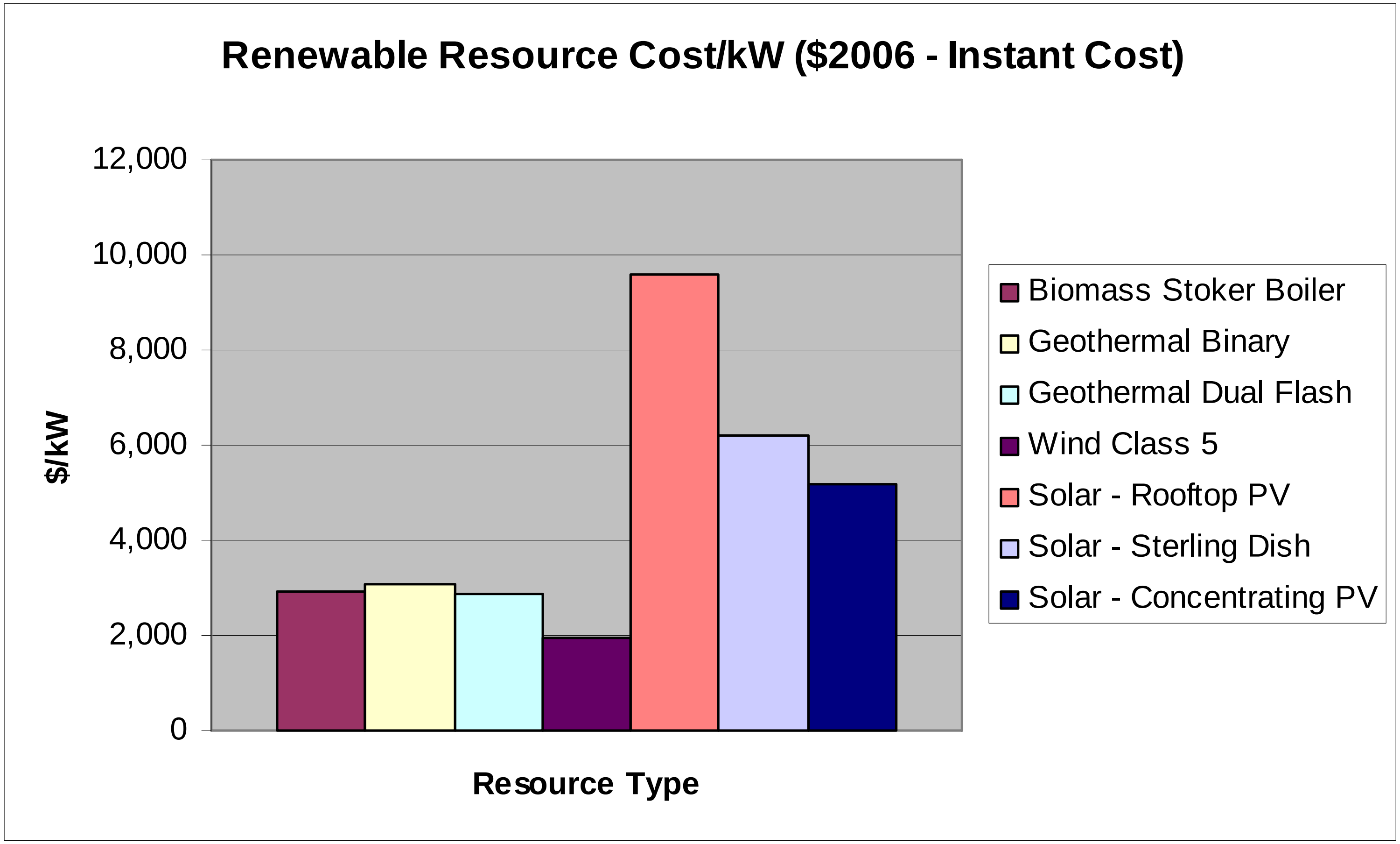


Figure 4-2: Cumulative California IOU Energy Efficiency (2009–2020) by Customer Segment and IOU

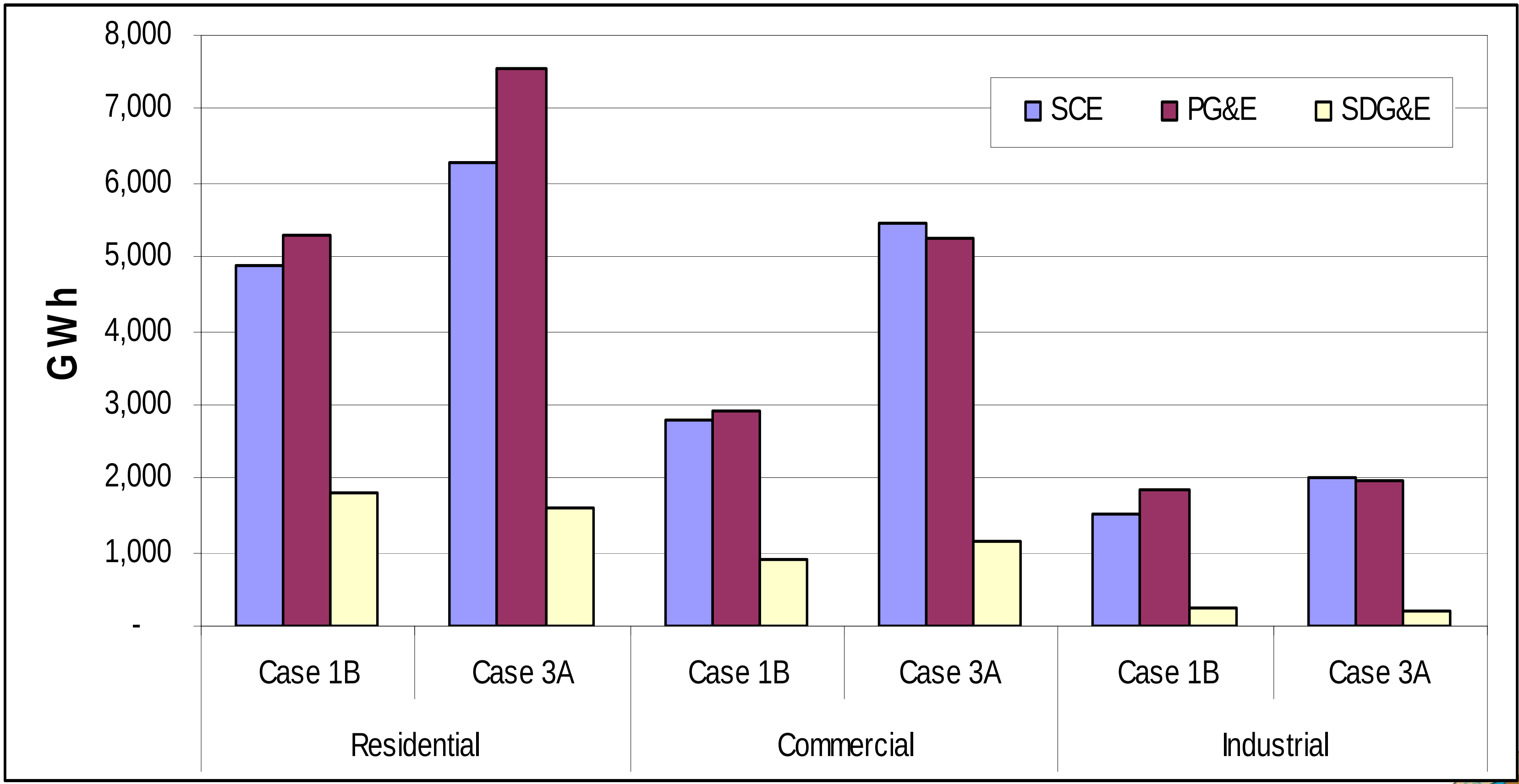


Figure 4-3: Comparison of the Incremental Energy Efficiency Potential by Customer Segment

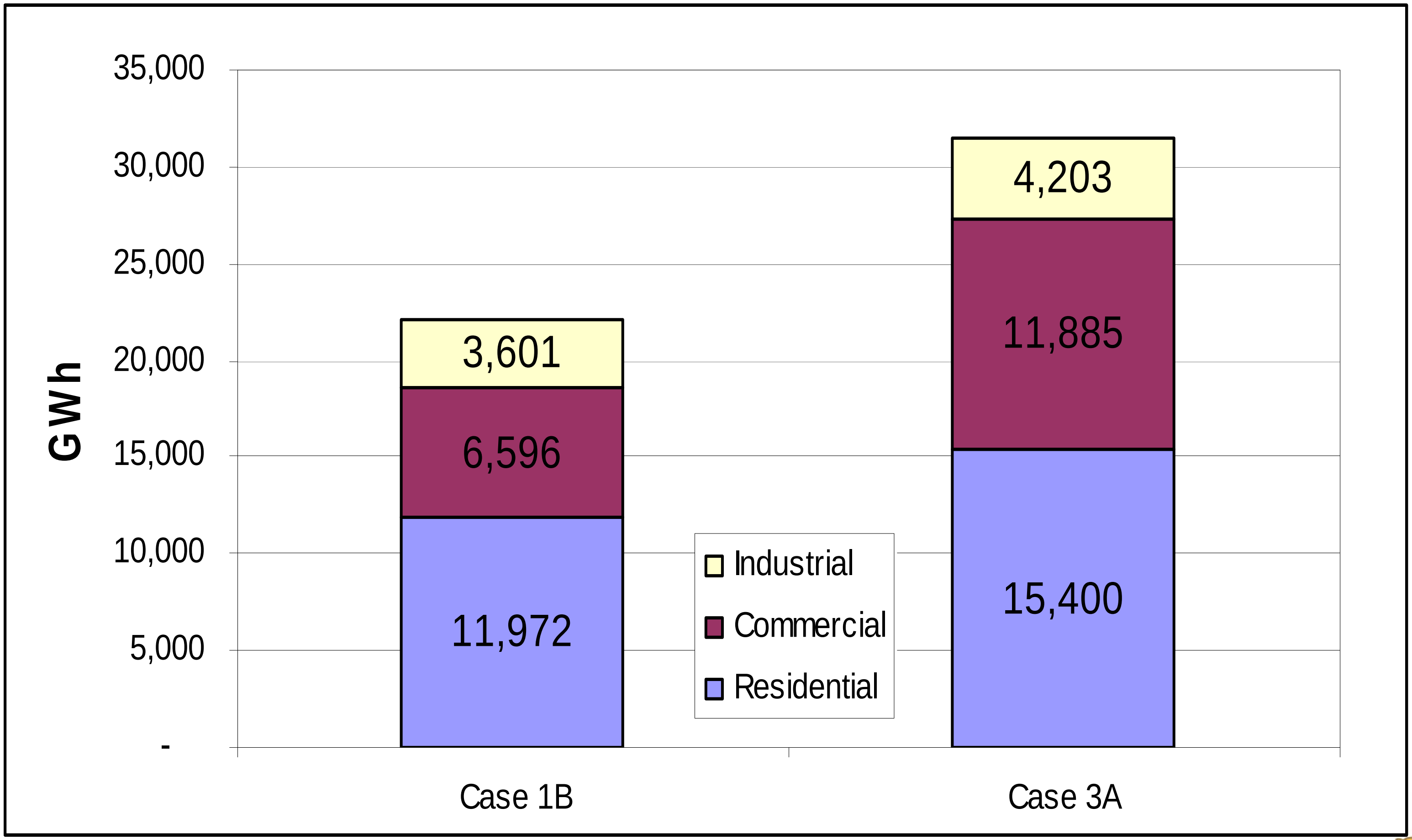


Figure 4-4: Expected Cost of Energy Efficiency Savings

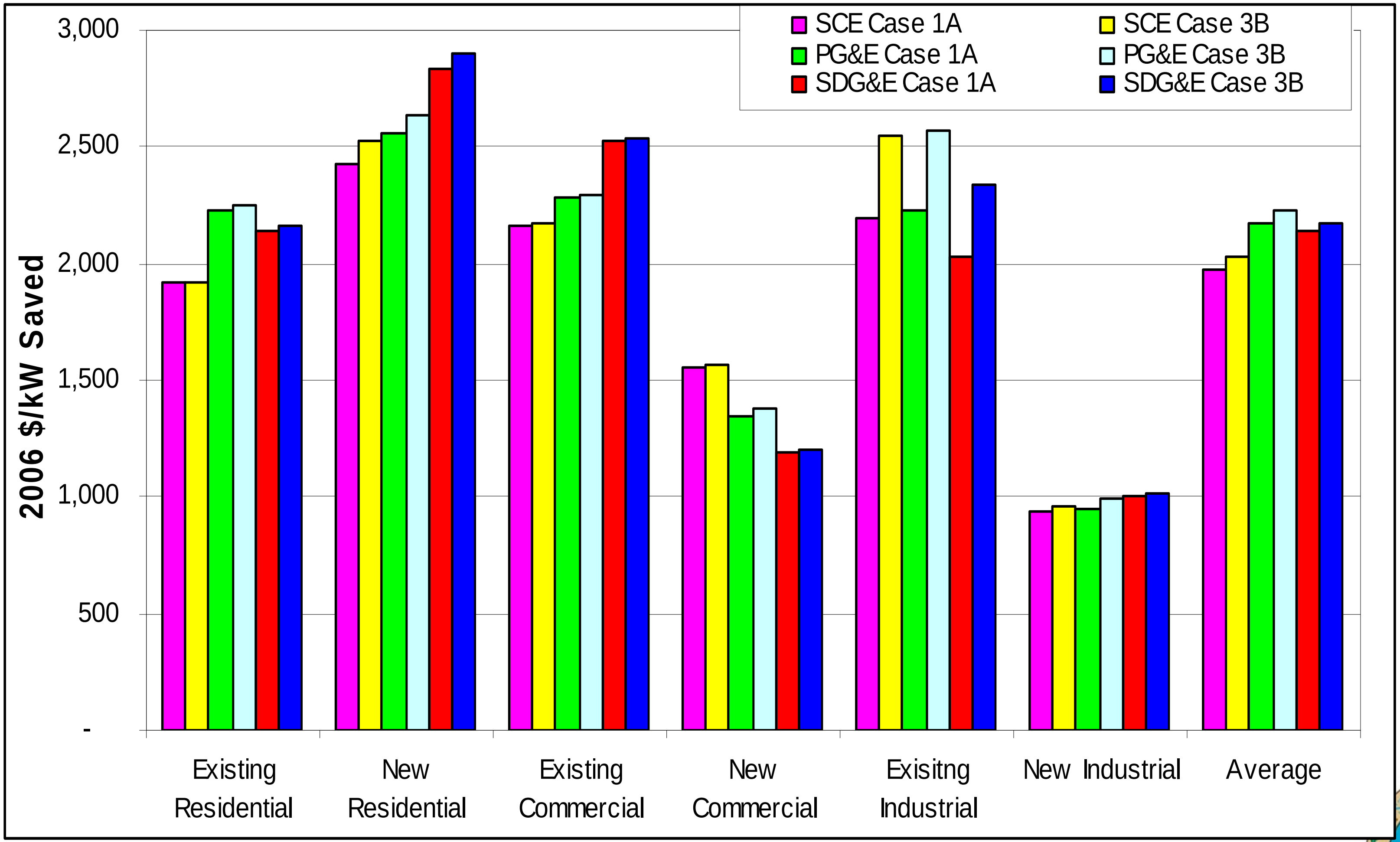


Figure 4-5: Energy Efficiency Impact on Loads for Typical April Week

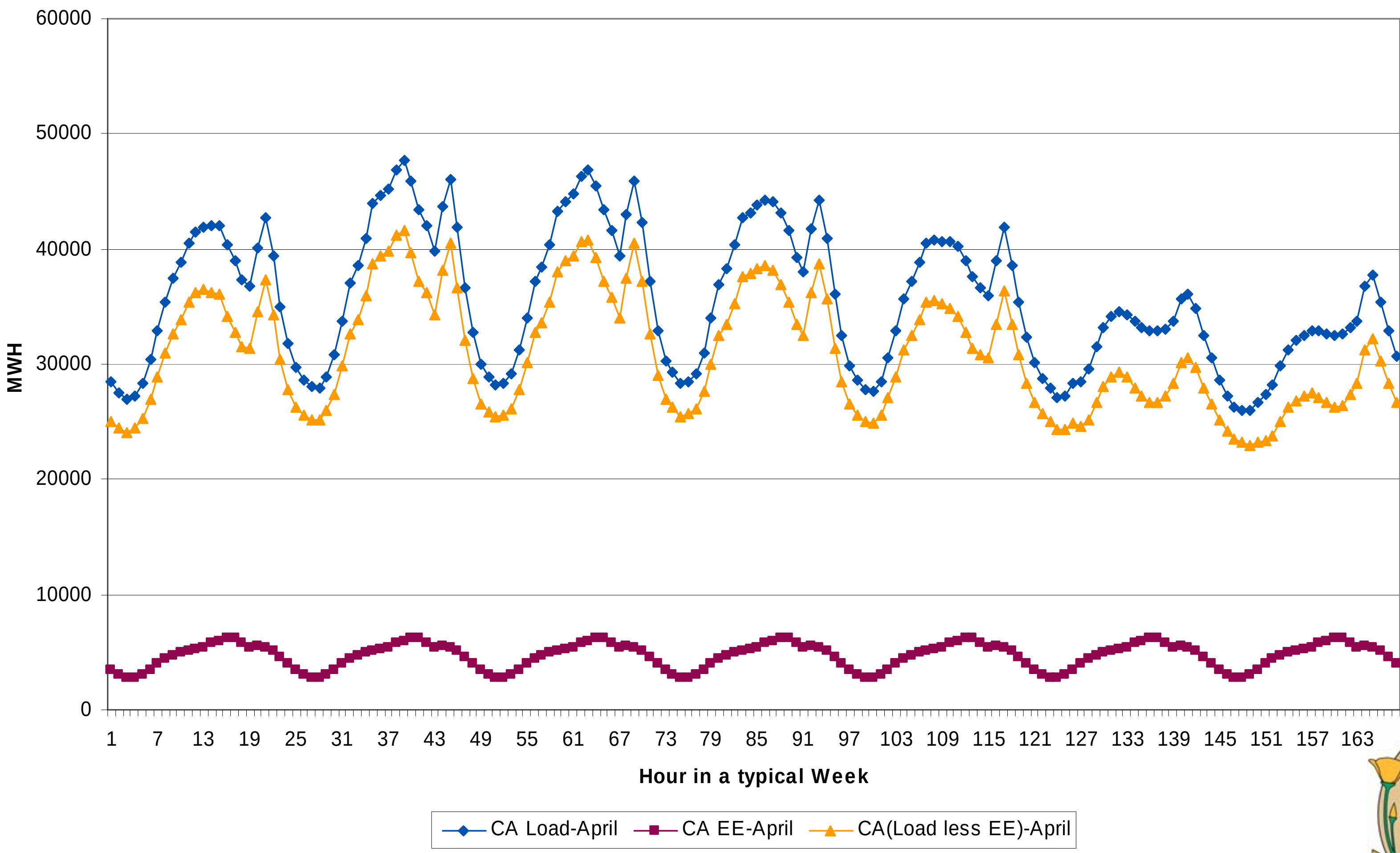


Figure 4-6: Energy Efficiency Impact on Loads for Typical July Week

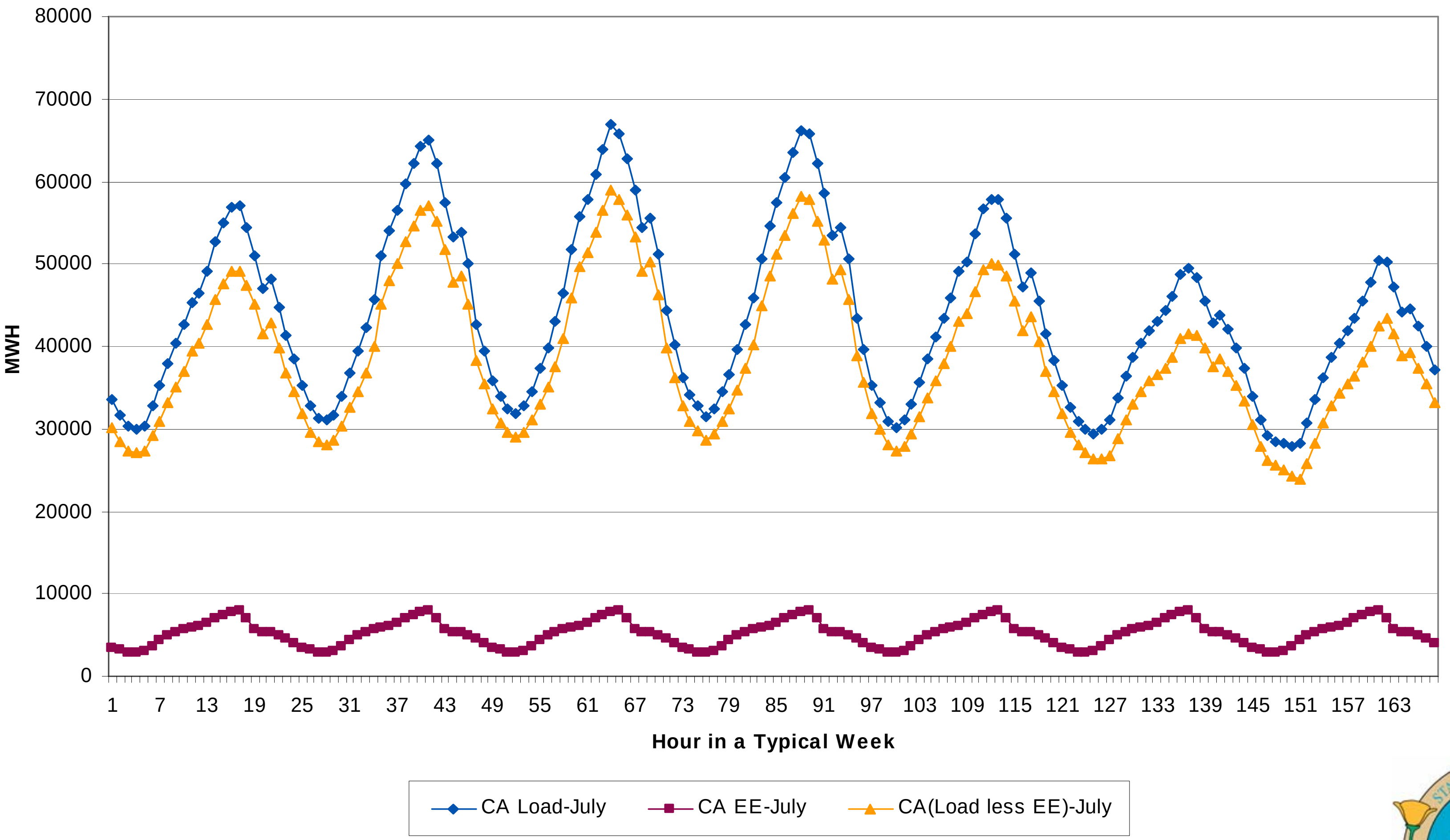
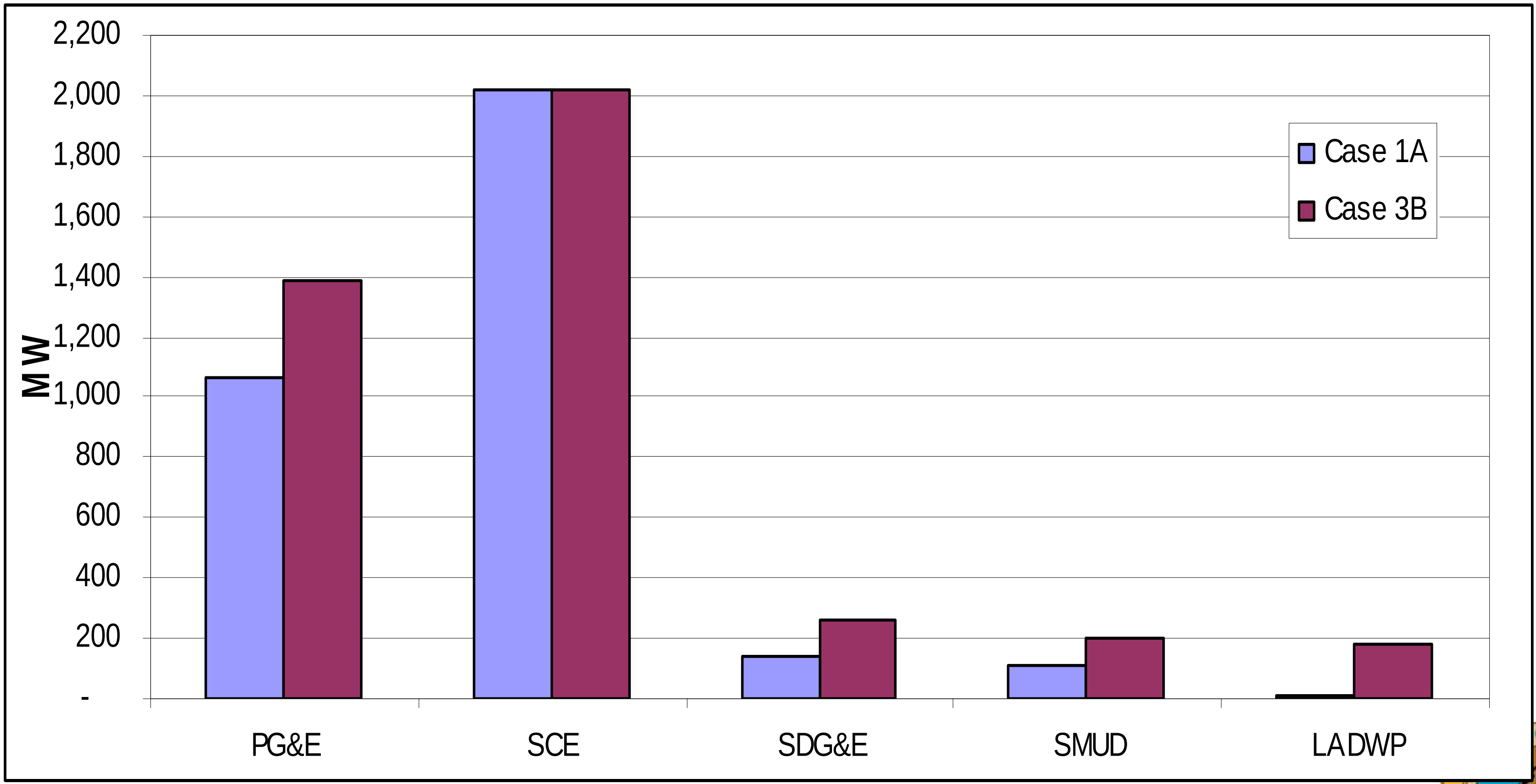


Figure 4-7: Dispatchable Demand Response Capacity by Utility and Case



Rooftop Solar PV

- Policy makers in several states have made a major commitment to rooftop solar PV
- PIER program funded a rooftop solar PV study by Navigant that developed a penetration projection model for California
- Arizona has also funded Navigant to prepare an assessment for that state

Appendix Table G-3
MW of PV Penetration for PV Scenario 1

Scenario 1: Business-As-Usual System Pricing, CA CSI and Federal Incentives

	Total Installations		
Cumulative Market Segment	**2006**	**2010**	**2016**
Residential	4	43	357
Total Installations due to New Construction	0	2	39
Commercial	58	141	487
Total Installations due to New Construction	*0*	*4*	*20*
Total	**62**	**184**	**844**

	Total Installations		
Annual Market Segment	**2006**	**2010**	**2016**
Residential Retrofits	4	16	108
Residential New Construction	0	1	14
Commercial Retrofits	58	29	147
Commercial New Construction	0	1	5

Appendix Table G-4
MW of PV Penetration for PV Scenario 2

Scenario 2: Aggressive System Pricing, New Business Models, CA CSI and Federal Incentives

	Total Installations		
Cumulative Market Segment	**2006**	**2010**	**2016**
Residential	4	135	2,258
Total Installations due to New Construction	*0*	*5*	*178*
Commercial	58	267	2,126
Total Installations due to New Construction	*0*	*5*	*42*
Total	**62**	**402**	**4,384**

	Total Installations		
Annual Market Segment	**2006**	**2010**	**2016**
Residential Retrofits	4	63	1,154
Residential New Construction	0	4	81
Commercial Retrofits	58	132	771
Commercial New Construction	0	2	11

Deterministic Results for Thematic Scenarios (Agenda item 3e)

- Chapter 6 provides aggregated results using several viewpoints
  - Electricity production by resource type
  - GHG emissions
    - Aggregate emissions
    - California carbon responsibility
  - Fuel use in power generation
  - System and production costs
  - Criteria pollutant emissions

Figure 6-1: Composition of Generation to Meet California Load in 2010

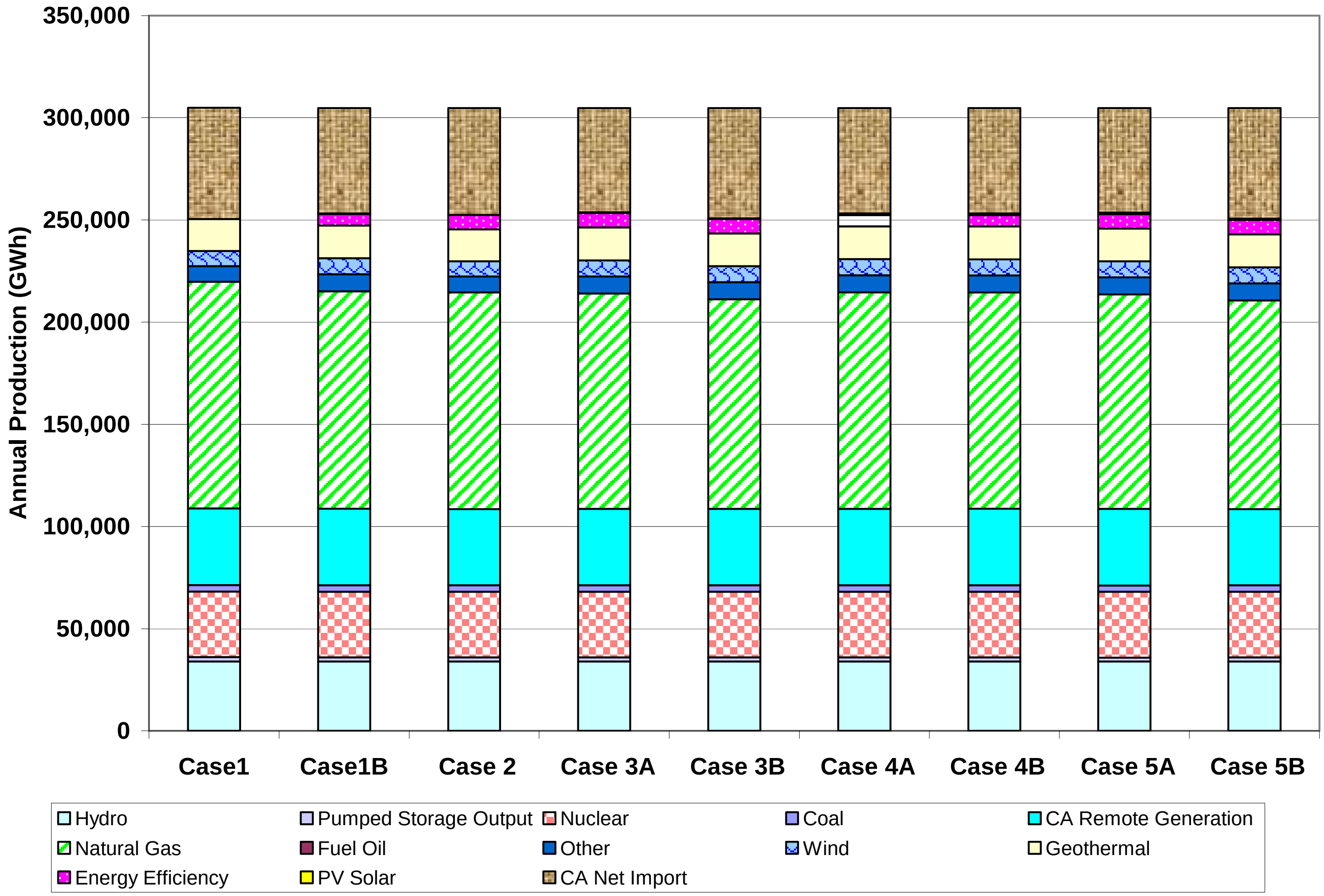


Figure 6-2: Composition of the Rest-of-WECC Generation in 2010

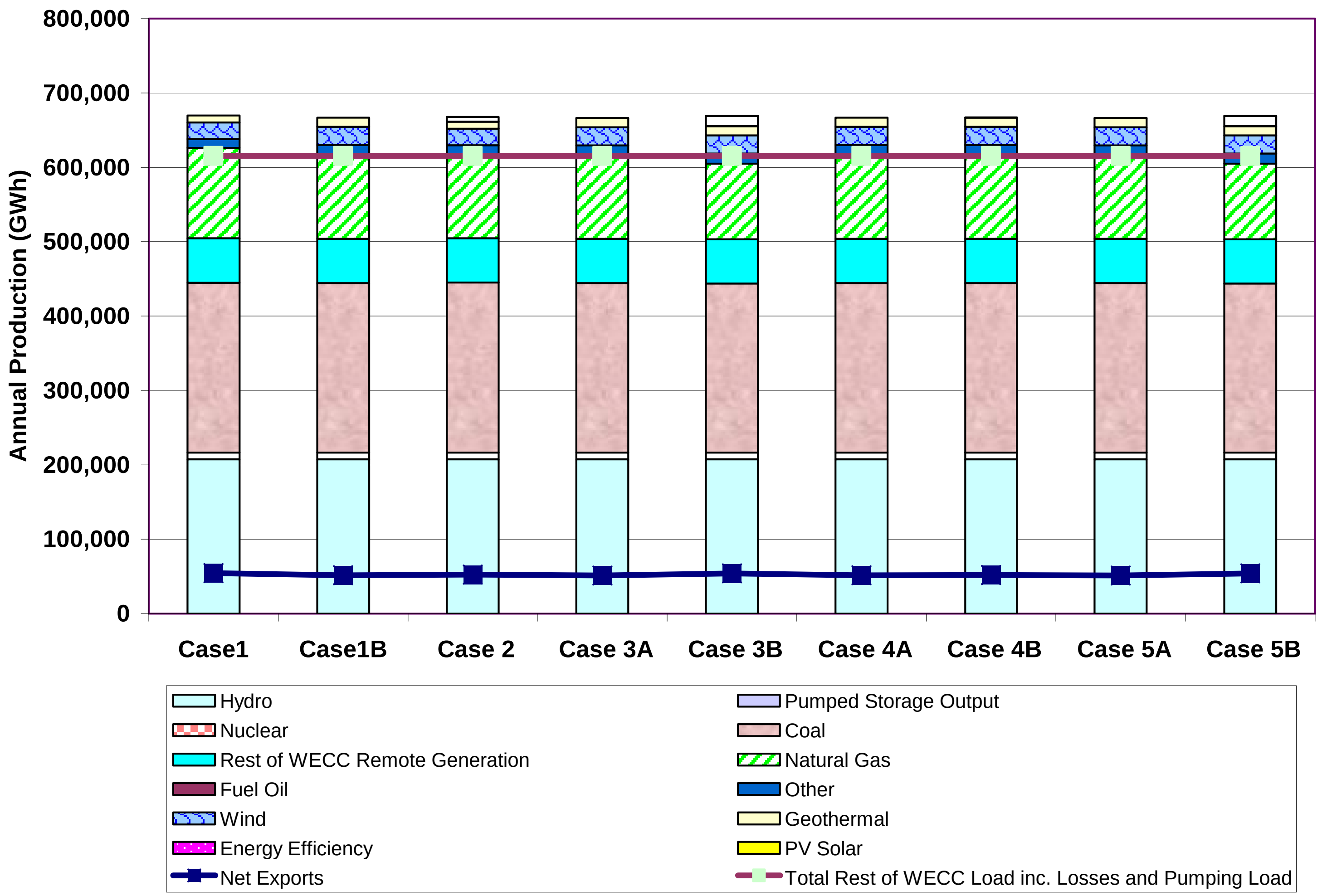


Figure 6-3: Composition of Generation to Meet California Load in 2020

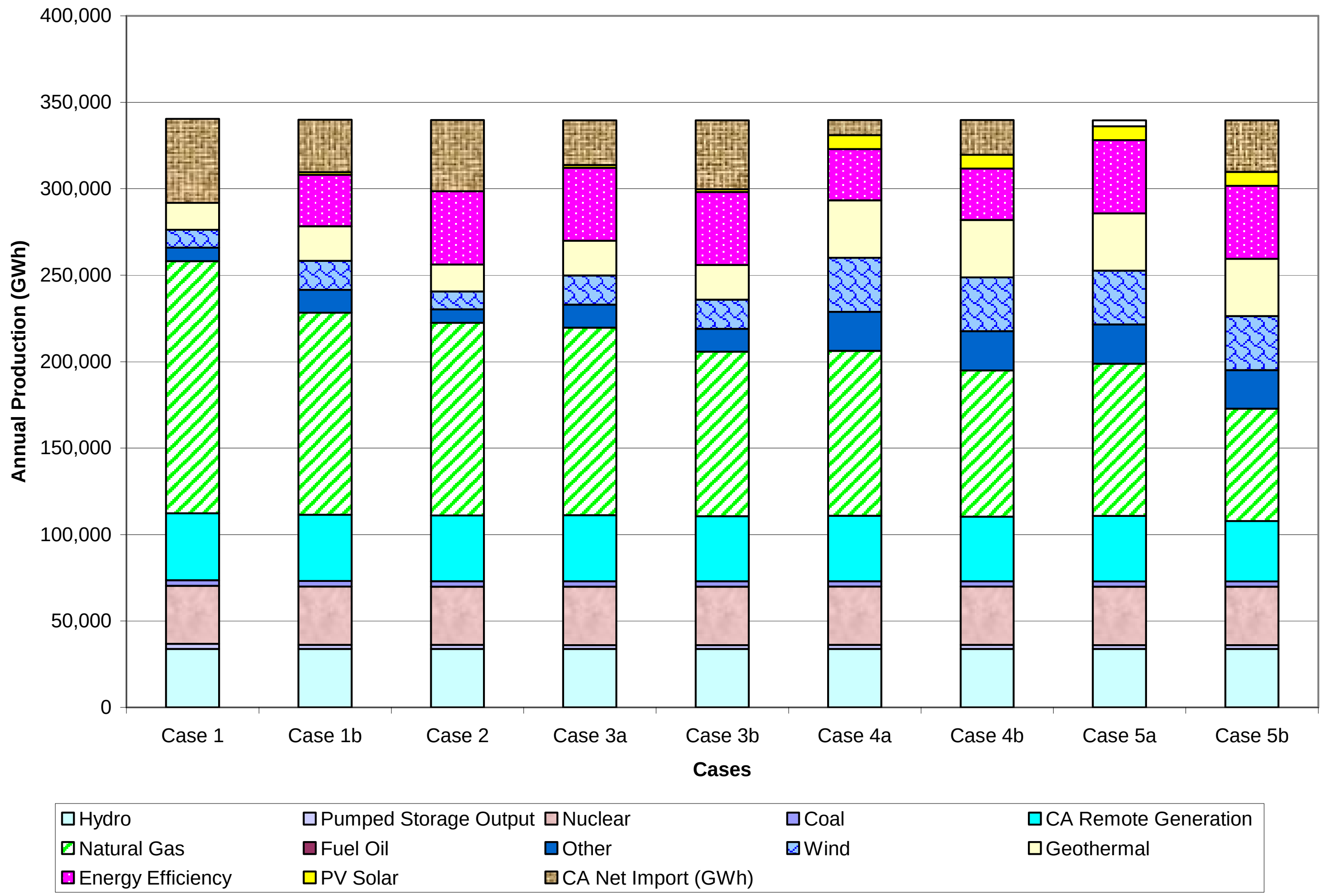


Figure 6-4: Composition of Generation to Meet Rest-of-WECC Load in 2020

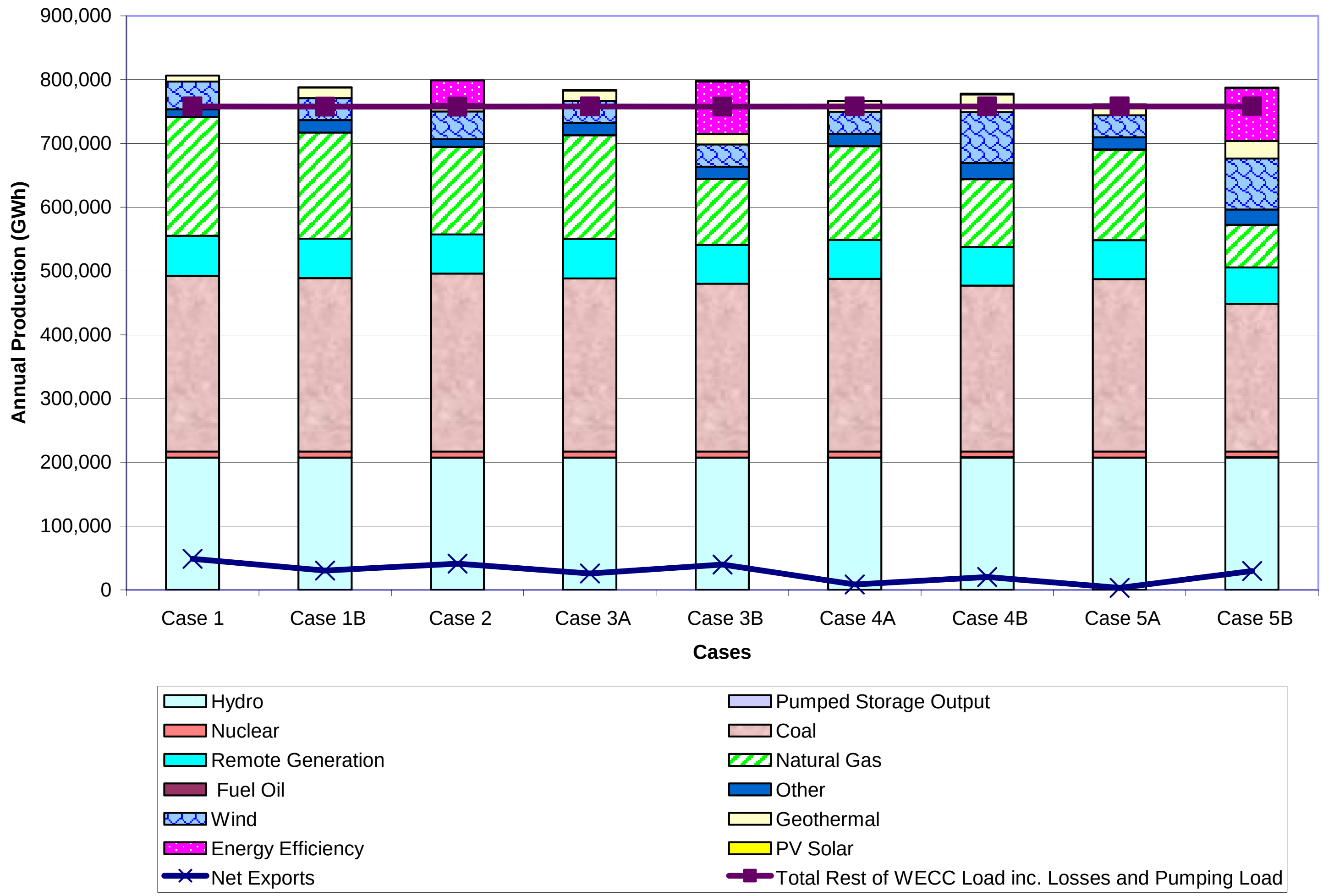


Figure 6-5: California Instate Carbon Production Through Time by Case

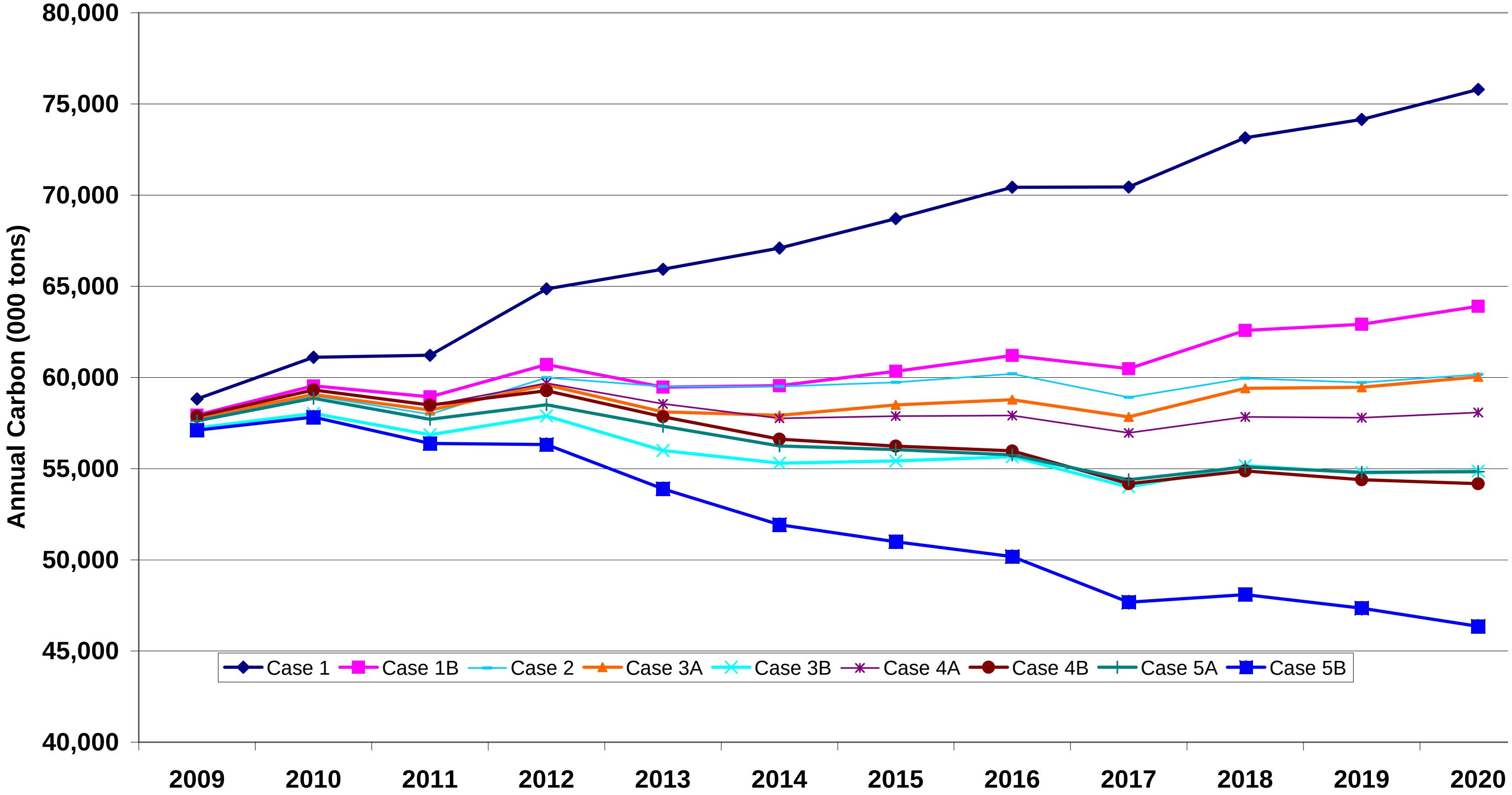


Figure 6-6: California Carbon Responsibility (Includes Instate Generation, Remote Generation and Net Imports Through Time by Case)

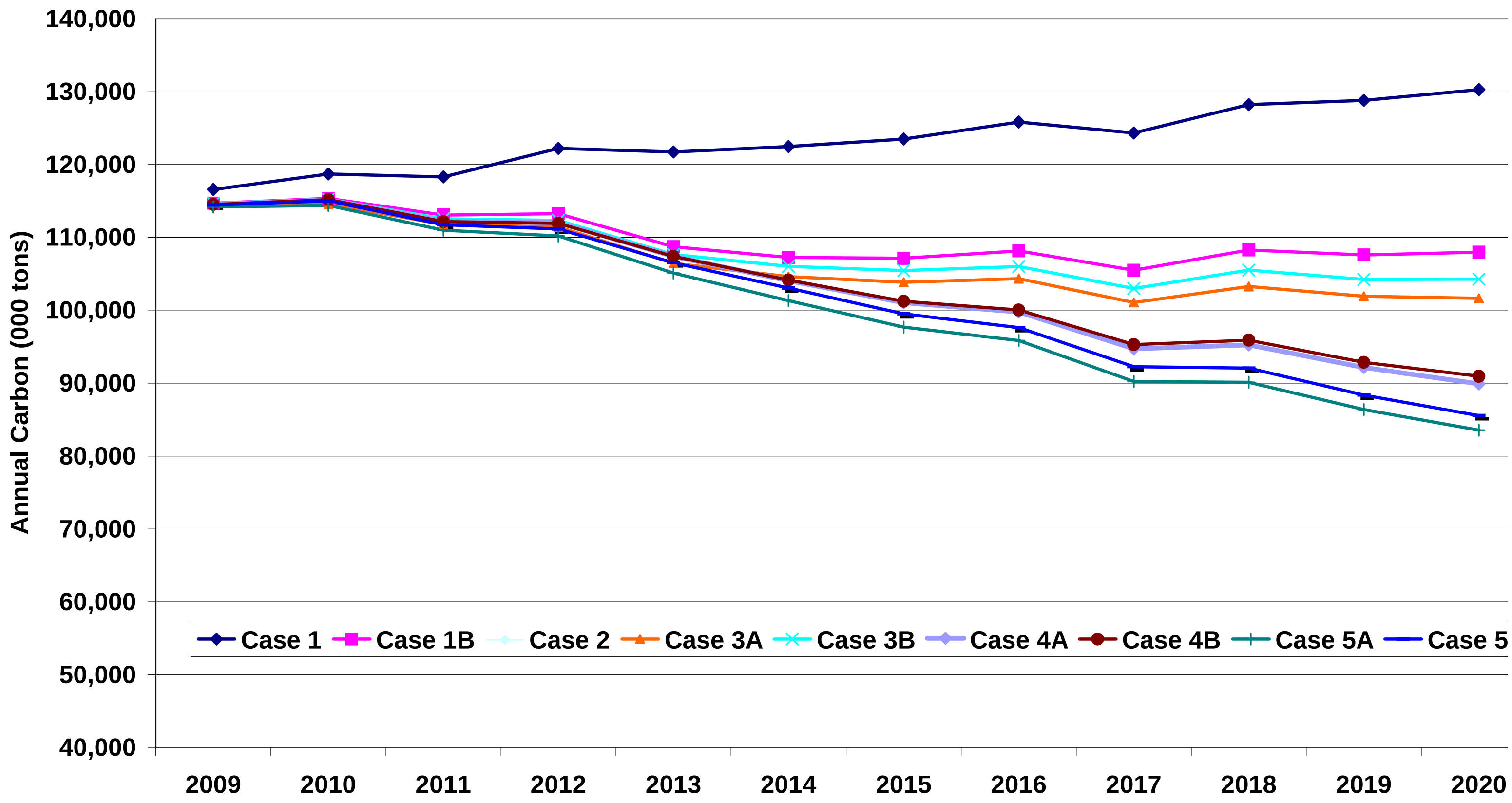


Figure 6-7: Rest-of-WECC Carbon Production Through Time by Case

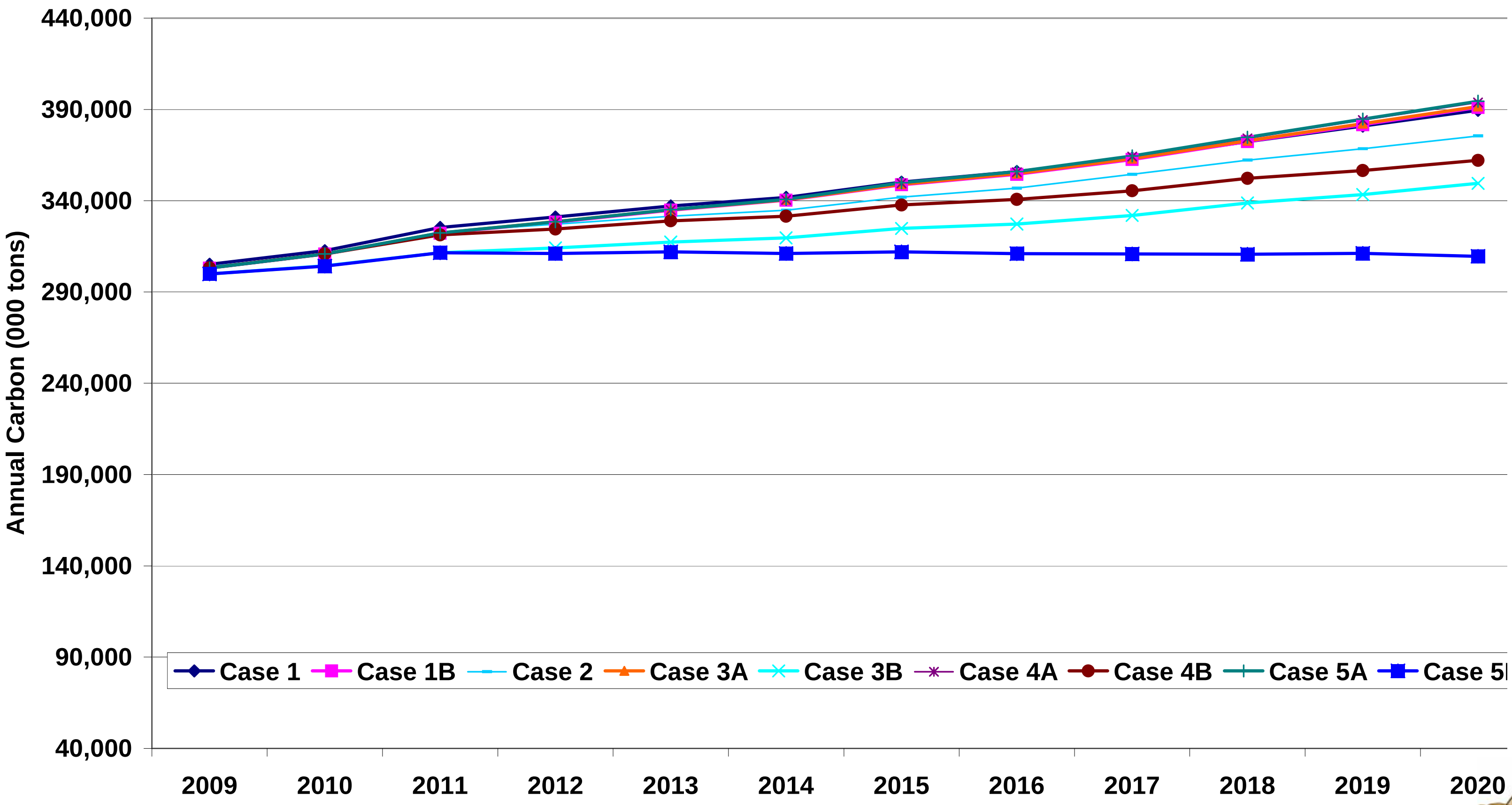


Figure 6-8: California Carbon Responsibility for Case 1 (Current Conditions)

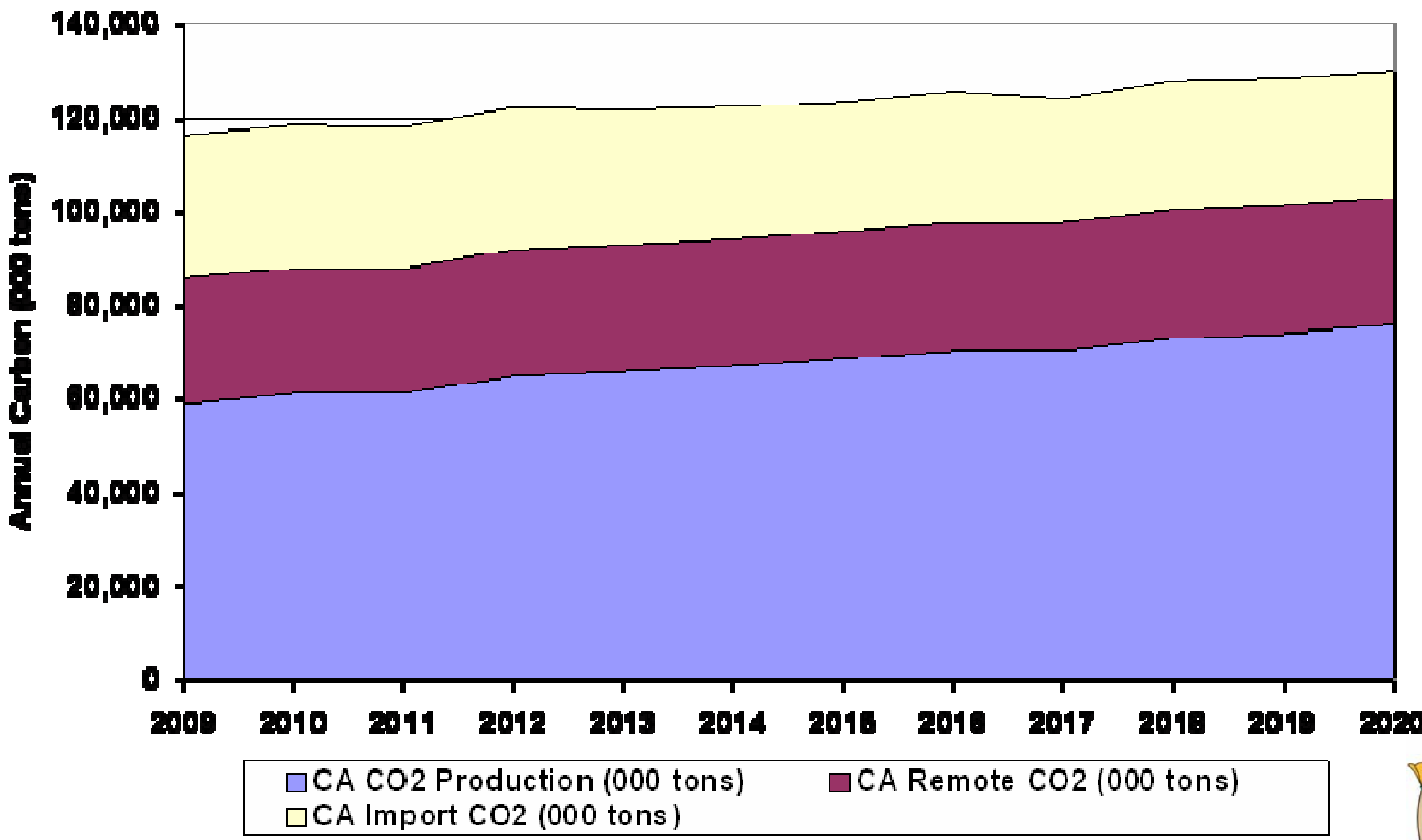


Figure 6-9: California Carbon Responsibility for Case 1B (Current Requirements)

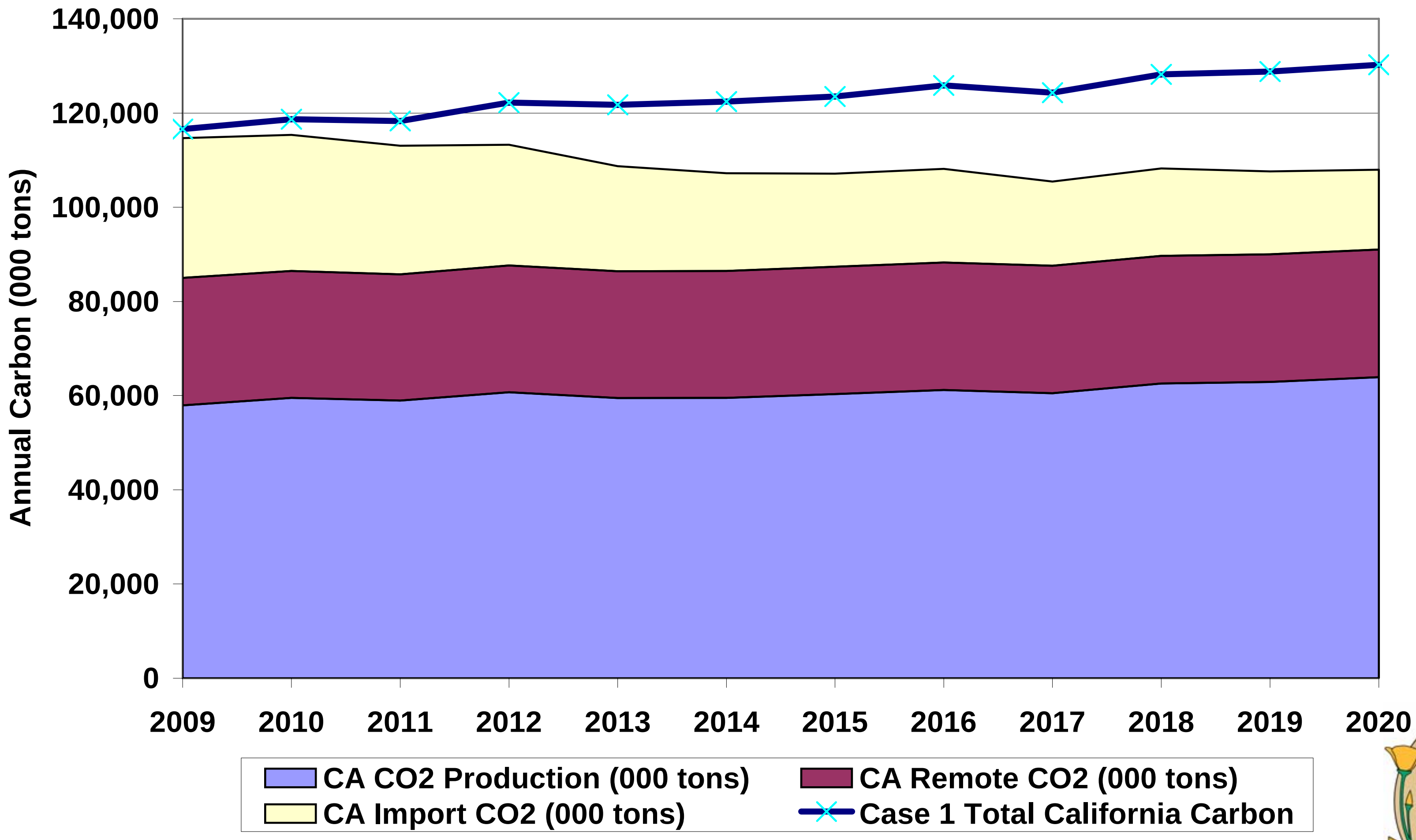


Figure 6-11: California Carbon Responsibility for Case 3A (High Energy Efficiency Instate)

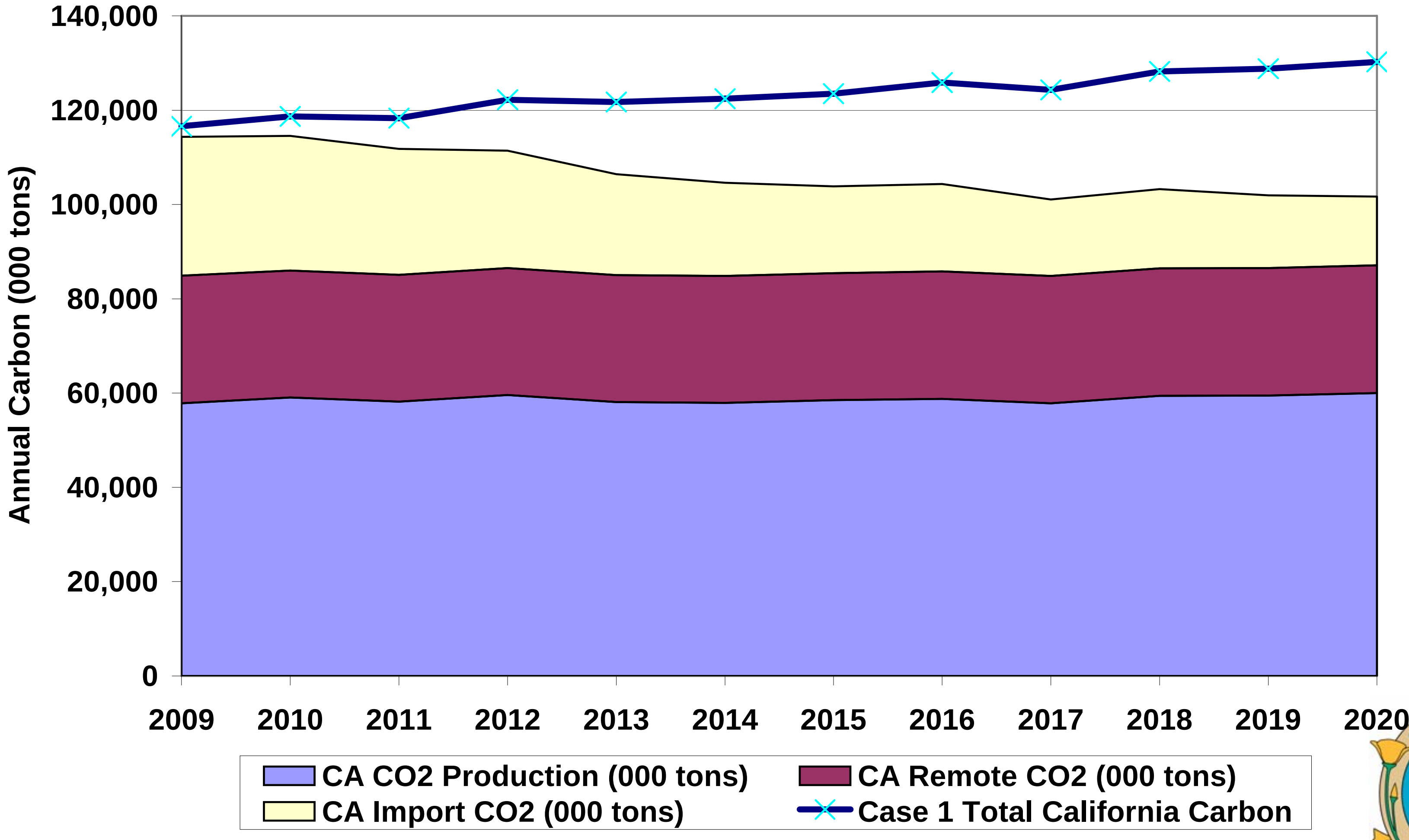


Figure 6-13: California Carbon Responsibility for Case 4A (High Renewables Instate)

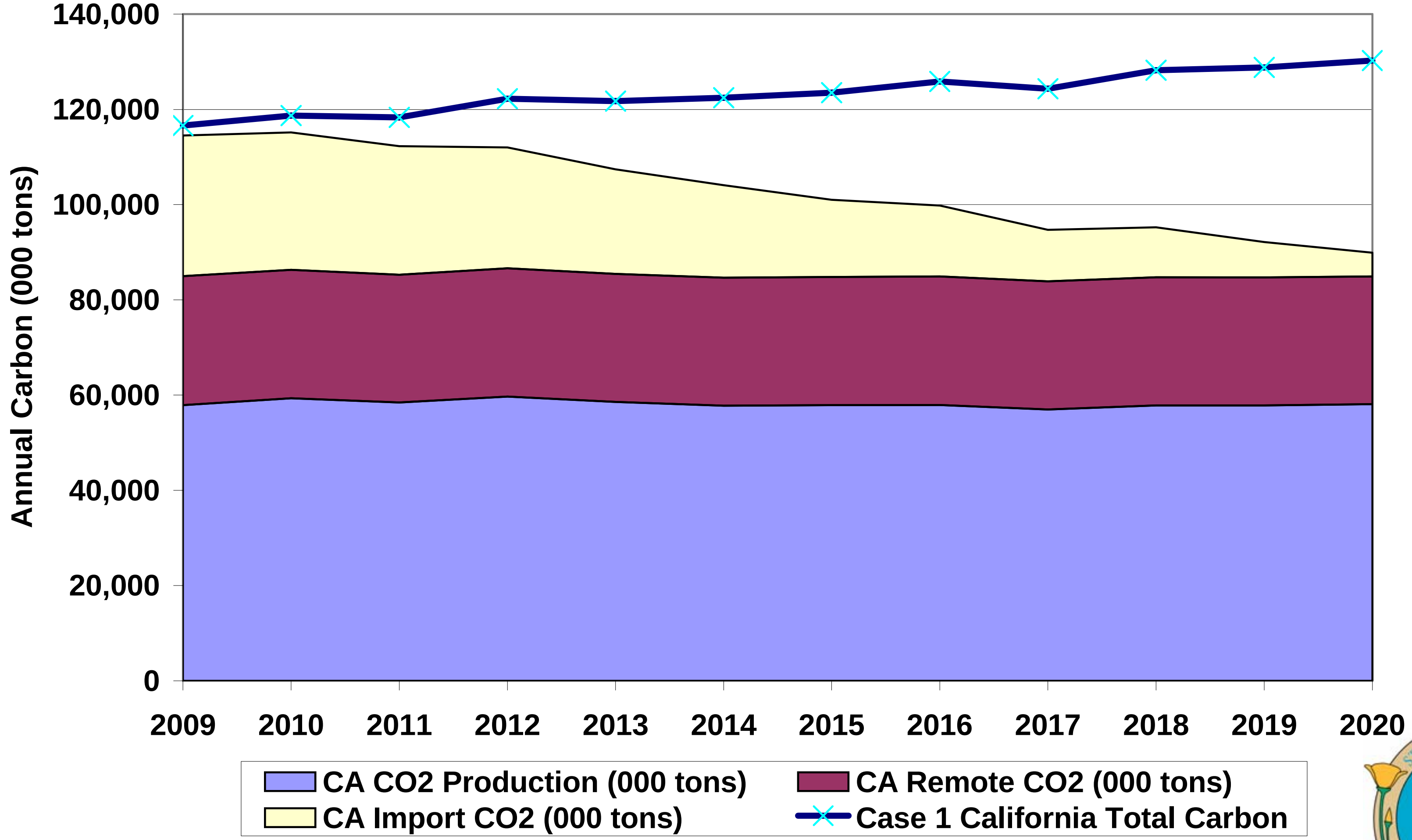


Figure 6-15: California Carbon Responsibility for Case 5A (High Energy Efficiency and Renewables Instate)

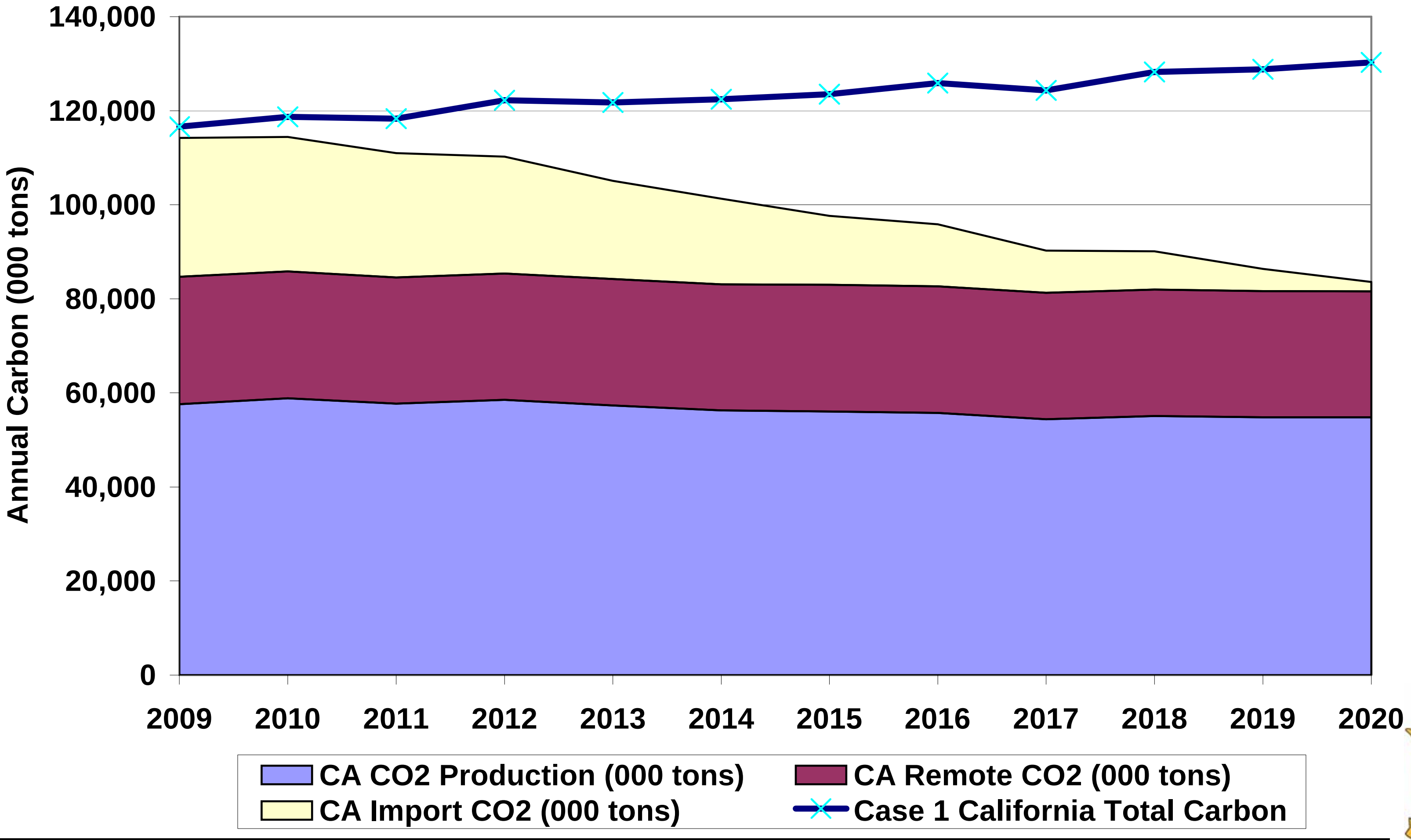
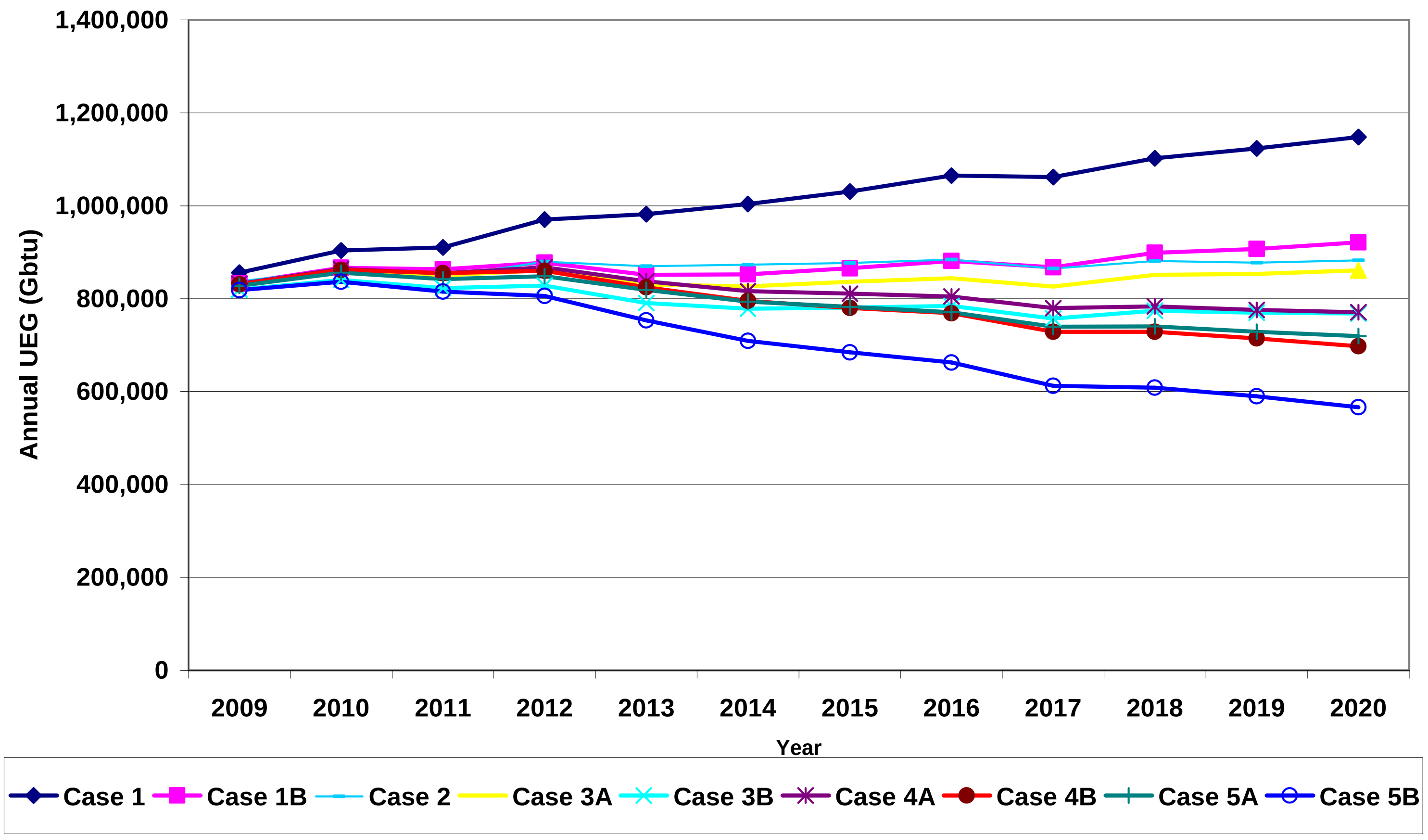


Figure 6-18: Total California Gas Consumption (GBTu)



California Energy Commission

Figure 6-17: Total WECC Natural Gas Consumption (GBTu)

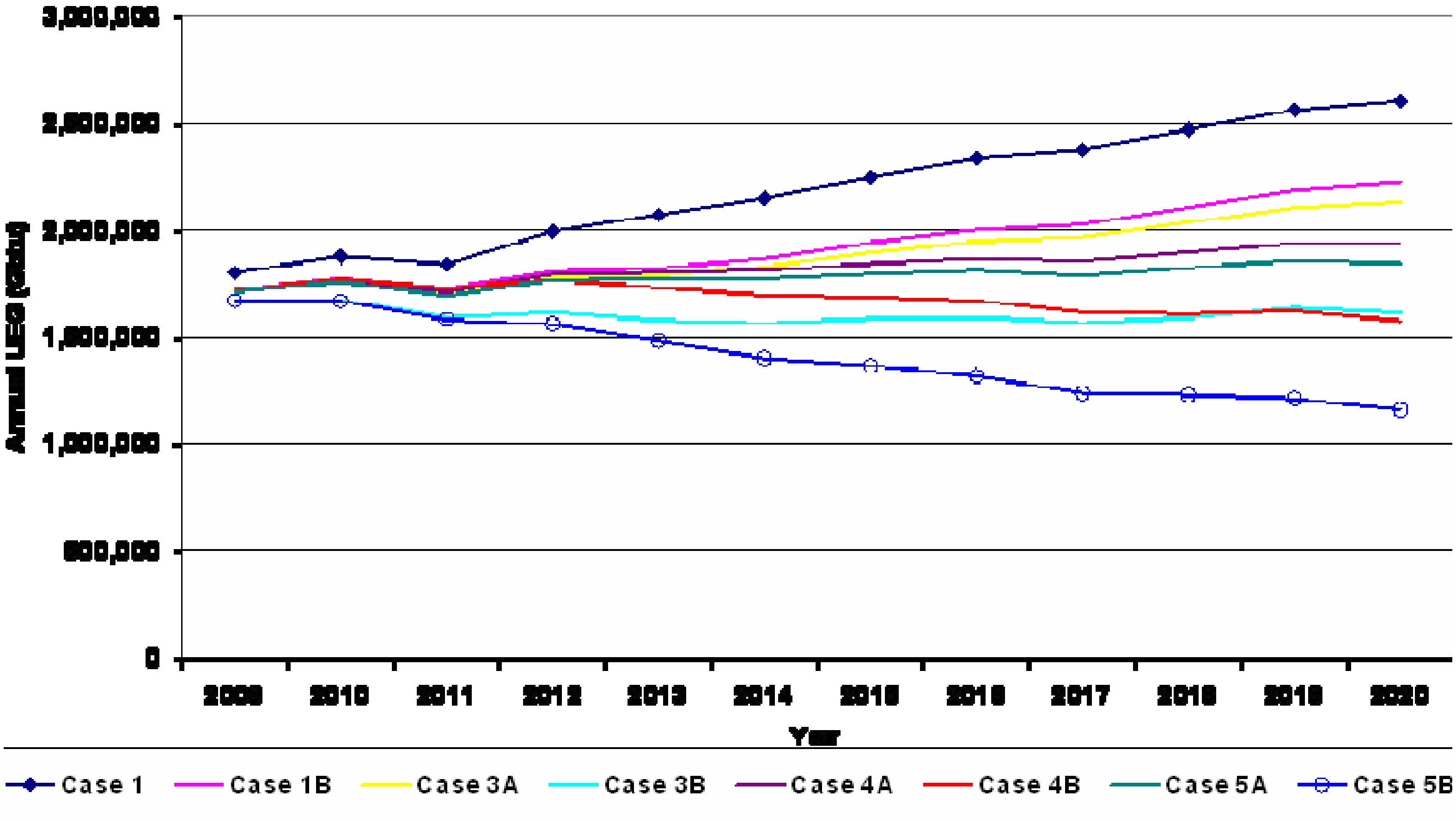


Figure 6-19: Comparison of UEG Gas Consumption Across Cases for 2020

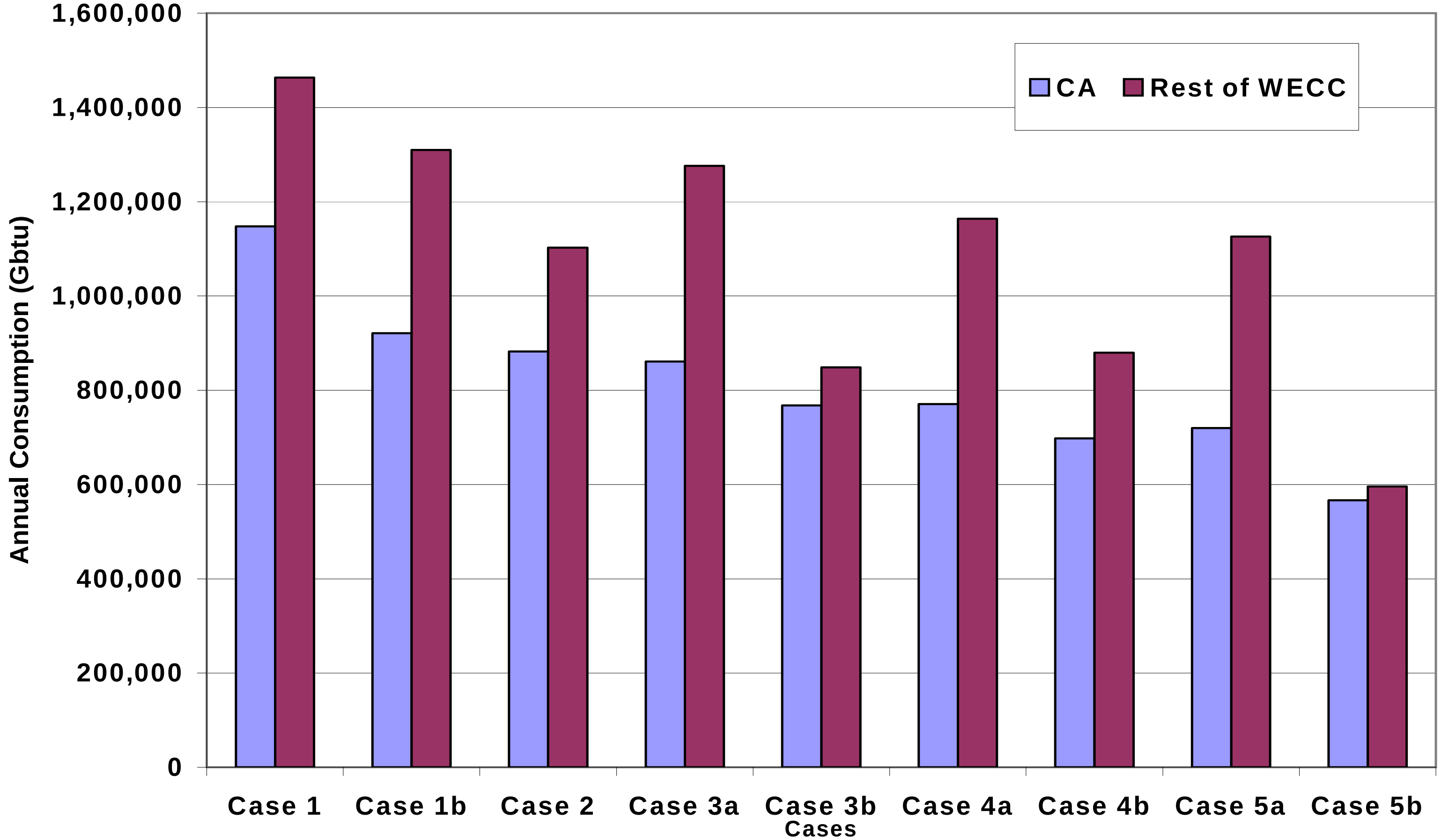


Figure 6-20: Total WECC Coal Consumption (GBTu)

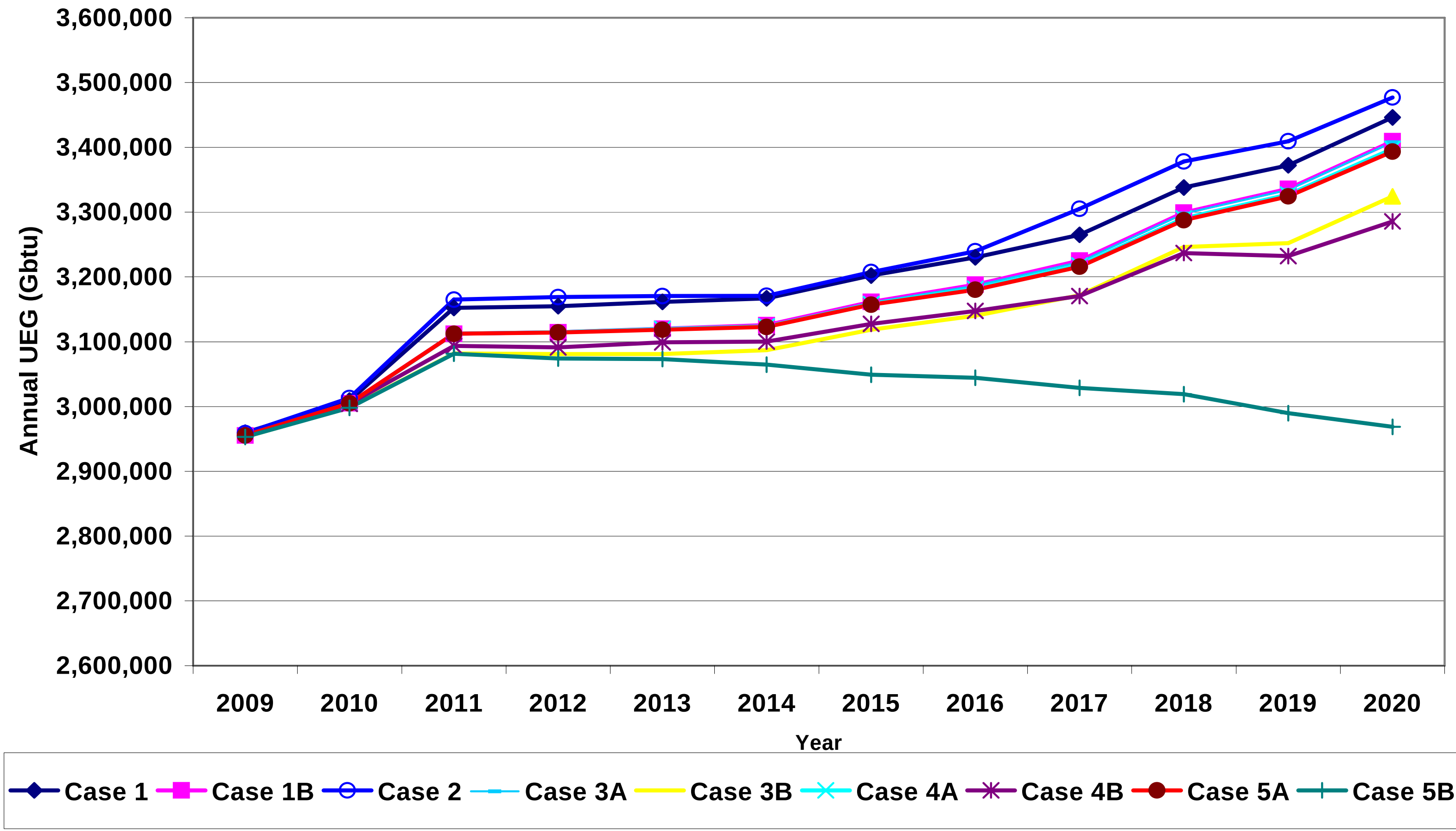


Figure 6-21: Comparison of UEG Coal Consumption Across Cases for 2020

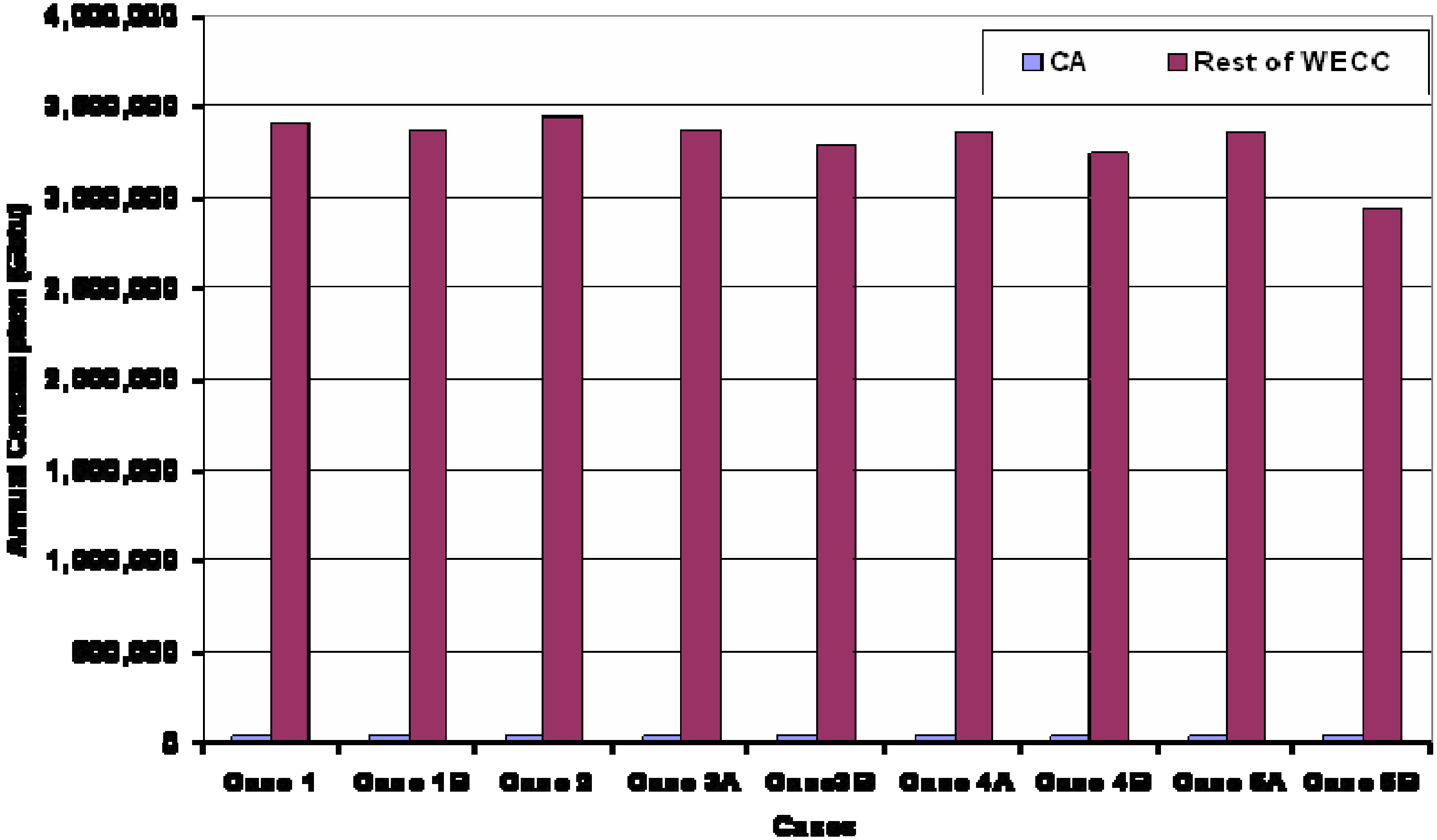


Table 6-18: Levelized System Costs by Case (levelized 2009-2020, $2006)

	Case 1	Case 1B	Case 2	Case 3A	Case 3B	Case 4A	Case 4B	Case 5A	Case 5B
Total WECC System Cost	32.94	34.67	41.95	34.63	36.70	35.94	36.63	35.93	38.95
CA System Cost	40.90	46.38	57.38	46.67	46.43	51.14	51.06	51.70	51.29
Rest of WECC System Cost	29.12	29.31	34.84	29.20	32.09	29.15	30.16	29.02	33.21

Figure 6-22: Levelized System Costs

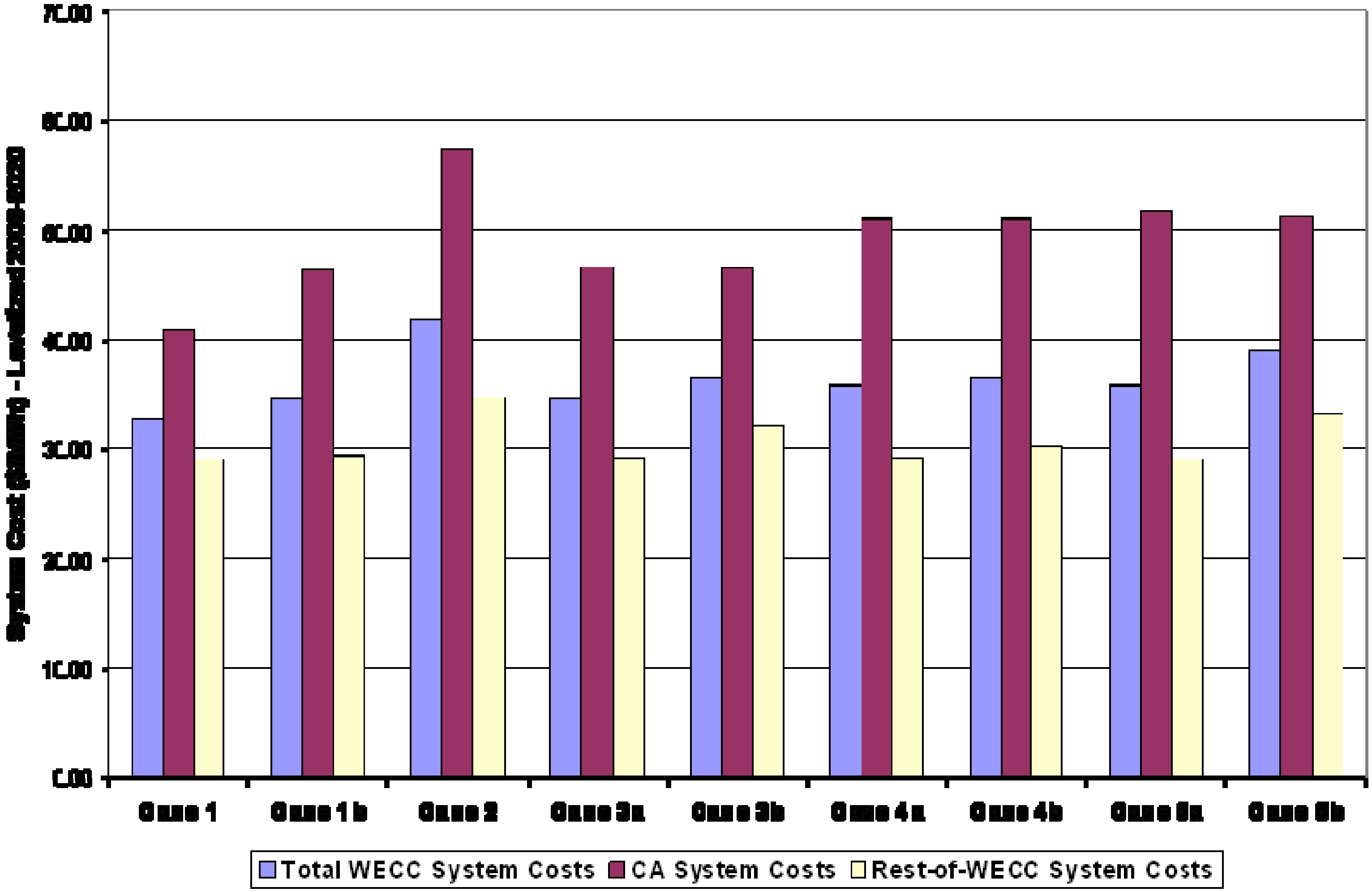


Figure 6-23: Unit Cost Comparison Through Time Case 1 versus Case 5A ($2006/MWh)

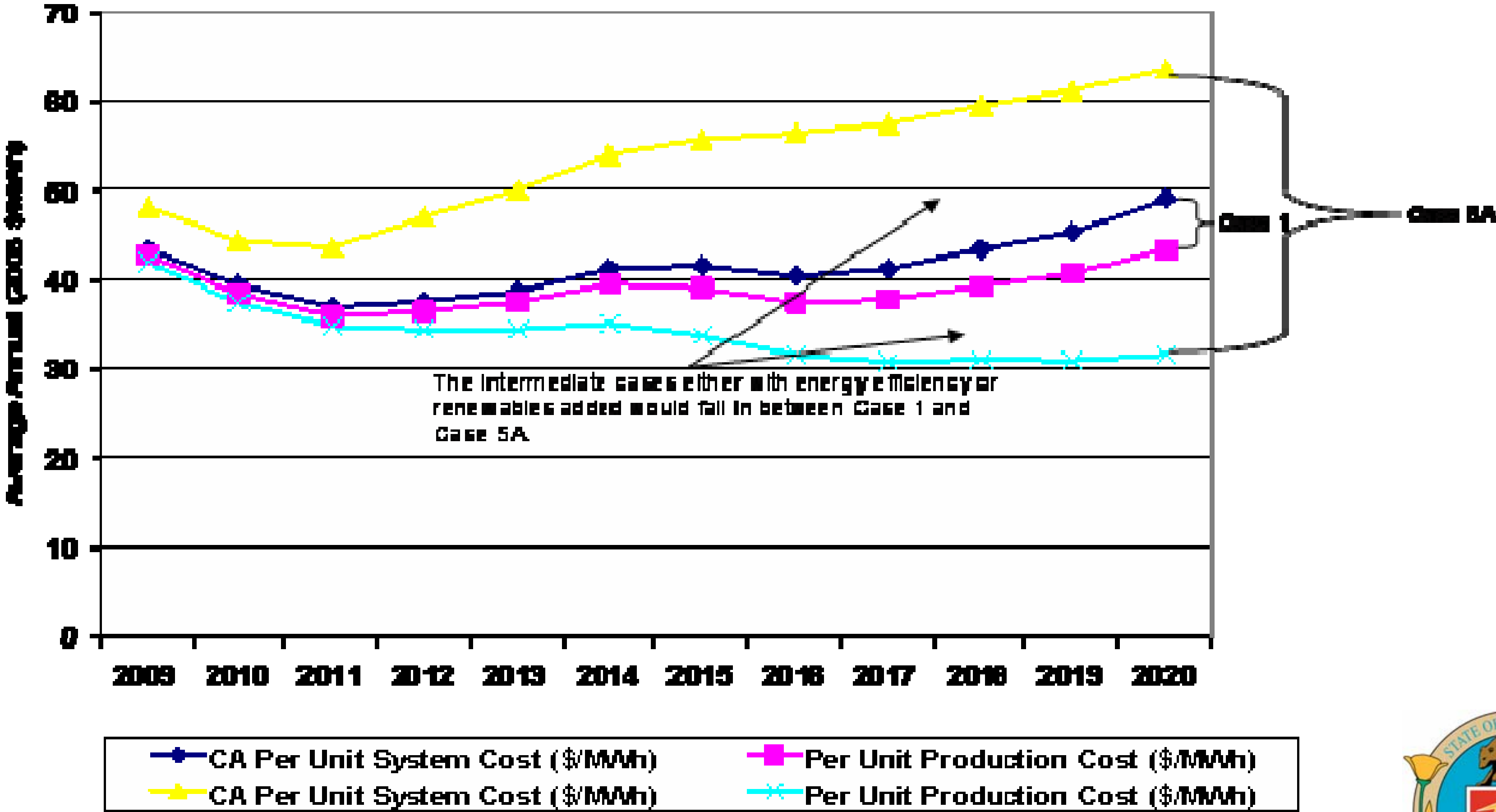


Figure 6-24: California Instate Criteria Pollutant Emissions for NOx and SO2 in 2020 (000 tons)

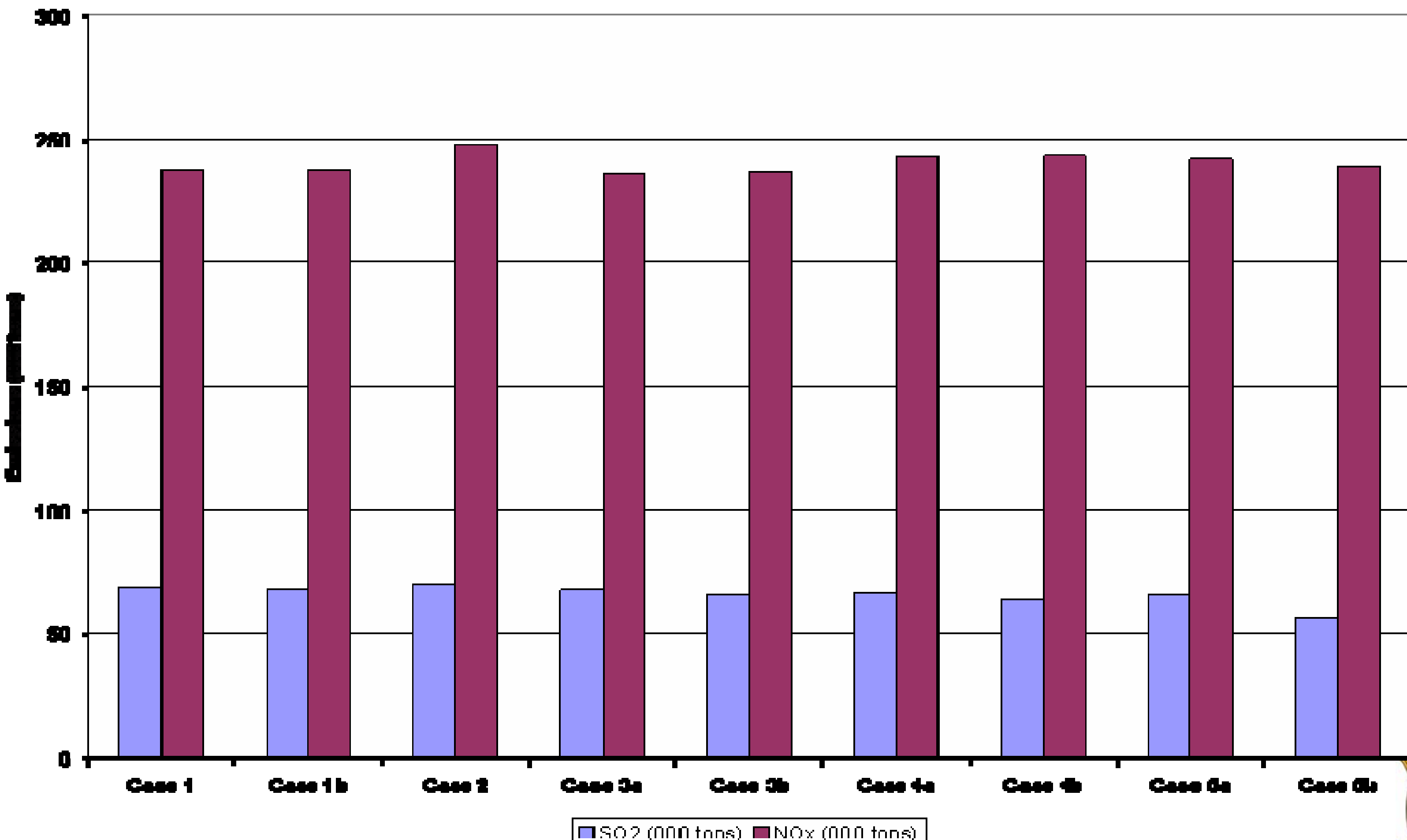
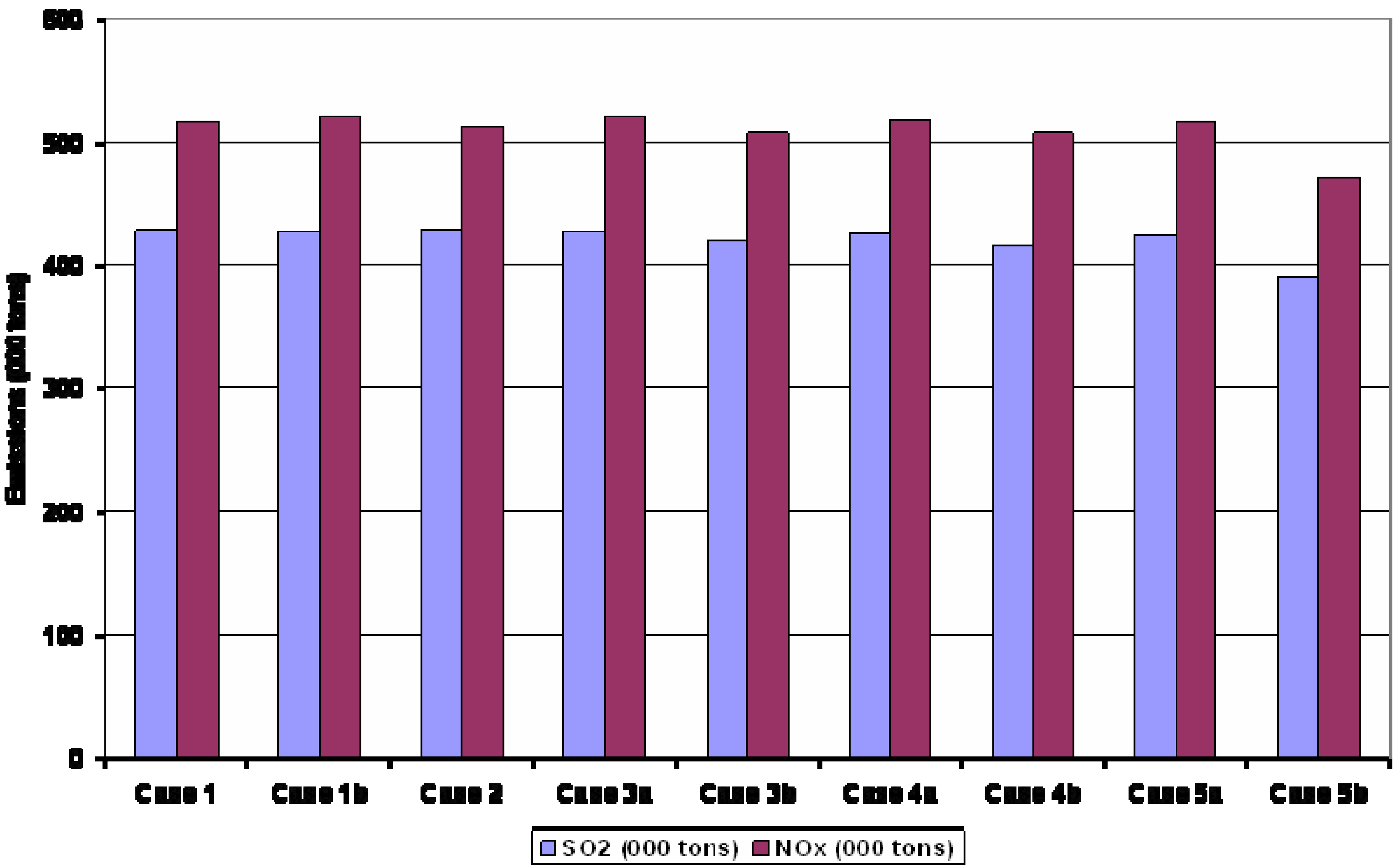


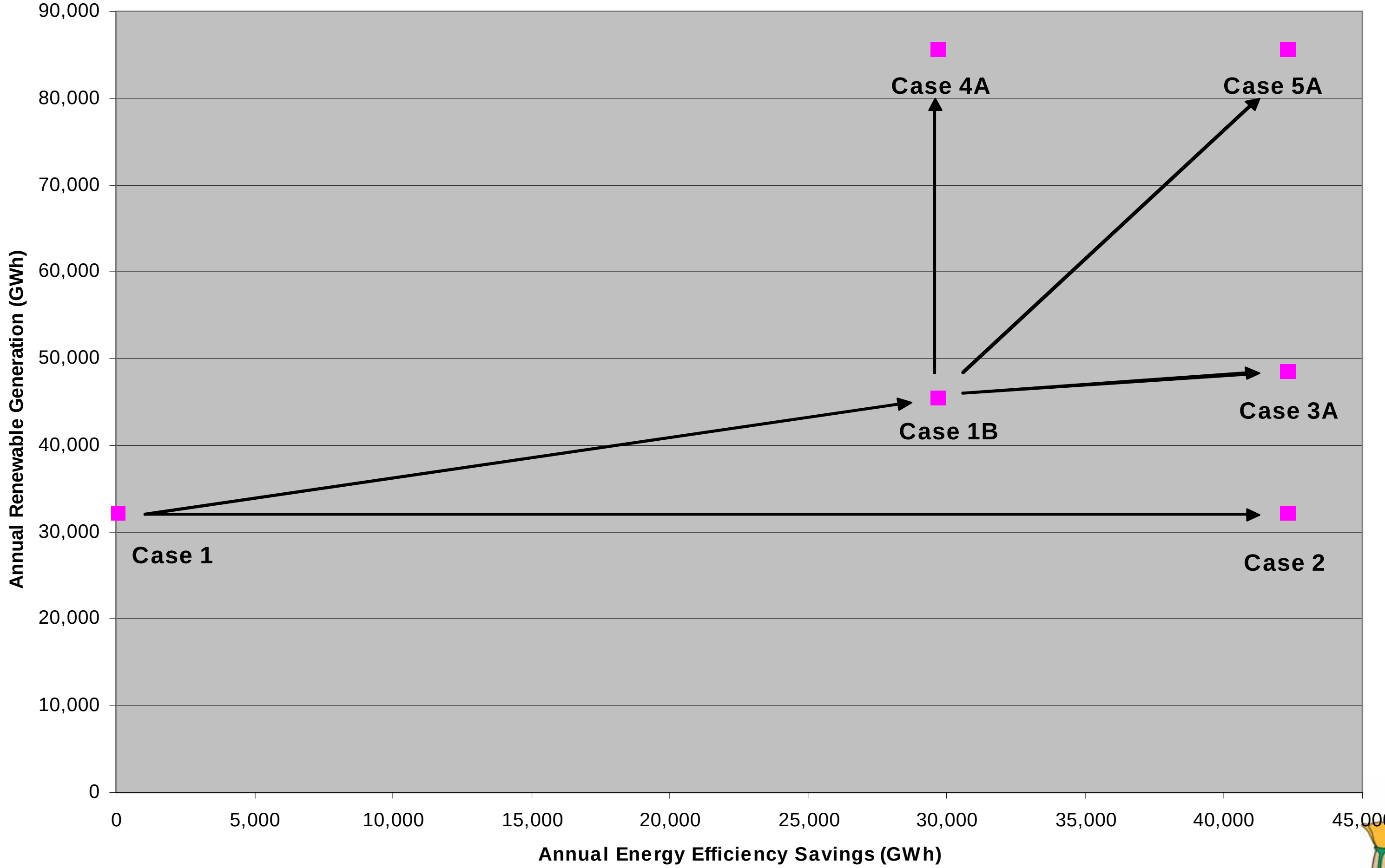
Figure 6-25: Rest-of-WECC Criteria Pollutant Emissions for NOx and SO2 in 2020 (000 tons)



Evaluation of Energy Efficiency and Renewables by Comparing Cases (Agenda item 3f)

- Chapter 7 compares various cases to each other
- The cases were designed to have common inputs except for limited changes, so differences in results can be attributed to differences in inputs

Relationships Between Cases



Identifying Impacts of Preferred Resource Strategies

Preferred Resource Strategy	Results Case	Reference
High levels of energy efficiency in California only	Cases 3A	Case 1B
High levels of supply-side renewables in California only	Case 4A	Case 1B
High levels of both energy efficiency and supply-side generating technologies in California only	Cases 5A	Case 1B
High levels of energy efficiency in Rest-of-WECC	Cases 3B	Case 3A
High levels of supply-side renewable generating technologies in Rest-of-WECC	Case 4B	Case 4A
High levels of both energy efficiency and supply-side renewable generating technologies in Rest-of-WECC	Case 5B	Case 5A

Impacts Assessed

- Chapter 7 includes six subsections identifying impacts of each strategy
- Each is quantified in terms of:
  - Generation changes
  - Cost changes
  - GHG emission changes

Table 7-1: Generating System Changes in Response to Increased California Energy Efficiency*

	California Generation (GWh)		Rest-of-WECC Generation (GWh)	
Resource Type	**Assumed Increases**	**Predicted Decreases**	**Assumed Increases**	**Predicted Decreases**
Year 2015				
EE	6596	0	0	0
Gas Fired	0	4037	0	2448
Coal	0	0	0	46
Pumped Storage	0	97	0	-6
Year 2020				
EE	12625	0	0	0
Gas Fired	0	8620	0	4138
Coal	0	0	0	119
Pumped Storage	0	167	0	-4

Table 7-1: Generating System Changes in Response to Increased California Energy Efficiency*

	California Generation (GWh)		Rest-of-WECC Generation (GWh)	
Resource Type	**Assumed Increases**	**Predicted Decreases**	**Assumed Increases**	**Predicted Decreases**
Year 2015				
EE	6596	0	0	0
Gas Fired	0	4037	0	2448
Coal	0	0	0	46
Pumped Storage	0	97	0	-6
Year 2020				
EE	12625	0	0	0
Gas Fired	0	8620	0	4138
Coal	0	0	0	119
Pumped Storage	0	167	0	-4

Table 7-1: Generating System Changes in Response to Increased California Energy Efficiency*

	California Generation (GWh)		Rest-of-WECC Generation (GWh)	
Resource Type	**Assumed Increases**	**Predicted Decreases**	**Assumed Increases**	**Predicted Decreases**
Year 2015				
EE	6596	0	0	0
Gas Fired	0	4037	0	2448
Coal	0	0	0	46
Pumped Storage	0	97	0	-6
Year 2020				
EE	12625	0	0	0
Gas Fired	0	8620	0	4138
Coal	0	0	0	119
Pumped St[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 7-1: Generating System Changes in Response to Increased California Energy Efficiency*

	California Generation (GWh)		Rest-of-WECC Generation (GWh)	
Resource Type	**Assumed Increases**	**Predicted Decreases**	**Assumed Increases**	**Predicted Decreases**
Year 2015				
EE	6596	0	0	0
Gas Fired	0	4037	0	2448
Coal	0	0	0	46
Pumped Storage	0	97	0	-6
Year 2020				
EE	12625	0	0	0
Gas Fired	0	8620	0	4138
Coal	0	0	0	119
Pumped Storage	0	167	0	-4

Table 7-2: Projected Costs of High Energy Efficiency Case in California Only

	Projected Costs for California (2006 $ Billion)		
Cost Component	Case 1B	Case 3A	Difference
2015			
System Costs	14.6	14.3	0.3
Production Costs	10.7	10.4	0.3
EE Program Expenses	1.1	1.3	0.2
Generation Capital	1.7	1.7	0
Transmission Upgrades	0.3	0.4 -	0.1
		-	
2020			
System Costs	16.4	15.7	0.7
Production Costs	11.9	11.1	0.8
EE Program Costs	1.1	1.3	0.2
Generation Capital	2.3	2.2	0.1
Transmission Upgrades	0.3	0.4 -	0.1

-

-

Table 7-3: Carbon Emission Impacts from High Energy Efficiency in California Only

	2020 Carbon (000 tons)		
Region/Category	Case 1B	Case 3A	Difference
CA			
CA CO2 Production	63,907	60,032	3,876
CA Remote* CO2	27,087	27,048	38
CA Import CO2	16,982	14,572 -	2,410
		-	
Rest of WECC		-	
Rest of WECC CO2 Production	354,757	355,389	632
Rest of WECC Remote* CO2	36,294	36,247	47
WECC		-	
CA (includes remote* and Imports)	107,976	101,652	6,324
Rest of WECC (includes remote*)	391,051	391,637	585
Total WECC	499,027	493,289 -	5,738

Table 7-4: Generating System Changes in Response to High California-Only Renewable Development* (Year 2020 portion of Table)

	California Generation (GWh)		R-of-W Generation (GWh)	
Resource Type	Assumed Increases	Predicted Decreases	Assumed Increases	Predicted Decreases
Year 2020				
Wind	14407	0	0	0
Geothermal	13156	0	0	0
Biomass	5317	0	0	0
Central Solar	4095	0	0	0
Rooftop PV	6407	0	0	0
Gas Fired	0	21489	0	19660
Coal	0	0	0	937
Pumped Storage	0	155	0	0

Table 7-4: Generating System Changes in Response to High California-Only Renewable Development* (Year 2020 portion of Table)

	California Generation (GWh)		R-of-W Generation (GWh)	
Resource Type	Assumed Increases	Predicted Decreases	Assumed Increases	Predicted Decreases
Year 2020				
Wind	14407	0	0	0
Geothermal	13156	0	0	0
Biomass	5317	0	0	0
Central Solar	4095	0	0	0
Rooftop PV	6407	0	0	0
Gas Fired	0	21489	0	19660
Coal	0	0	0	937
Pumped Storage	0	155	0	0

Table 7-4: Generating System Changes in Response to High California-Only Renewable Development* (Year 2020 portion of Table)

	California Generation (GWh)		R-of-W Generation (GWh)	
Resource Type	Assumed Increases	Predicted Decreases	Assumed Increases	Predicted Decreases
Year 2020				
Wind	14407	0	0	0
Geothermal	13156	0	0	0
Biomass	5317	0	0	0
Central Solar	4095	0	0	0
Rooftop PV	6407	0	0	0
Gas Fired	0	21489	0	19660
Coal	0	0	0	937
Pumped Storage	0	155	0	0

Table 7-4: Generating System Changes in Response to High California-Only Renewable Development* (Year 2020 portion of Table)

	California Generation (GWh)		R-of-W Generation (GWh)	
Resource Type	Assumed Increases	Predicted Decreases	Assumed Increases	Predicted Decreases
Year 2020				
Wind	14407	0	0	0
Geothermal	13156	0	0	0
Biomass	5317	0	0	0
Central Solar	4095	0	0	0
Rooftop PV	6407	0	0	0
Gas Fired	0	21489	0	19660
Coal	0	0	0	937
Pumped Storage	0	155	0	0

Table 7-5: Projected Costs of High Renewable Case in California Only

	Projected Costs for California (2006 $ Billion)		
Cost Component	Case 1B	Case 4A	Difference
2015			
System Costs	14.6	16.4	1.8
Production Costs	10.7	10.1	0.6
Rooftop PV Costs	0.5	2.5	2.0
Generation Capital	1.7	2.1	0.4
Transmission Upgrades	0.3	0.4	0.1
2020		-	
System Costs	16.4	18.9	2.5
Production Costs	11.9	9.9	2.0
Rooftop PV Costs	0.6	3.0	2.4
Generation Capital	2.3	4.4	2.1
Transmission Upgrades	0.3	0.4	0.1

-

Table 7-6: Carbon Emission Impacts from High Renewables in California Only

	2020 Carbon (000 tons)		
Region/Category	Case 1b	Case 4a	Difference
CA			
CA CO2 Production	63,907	58,078	5,829
CA Remote* CO2	27,087	26,843	244
CA Import CO2	16,982	4,970 -	12,012
		-	
Rest of WECC		-	
Rest of WECC CO2 Production	354,757	357,924	3,167
Rest of WECC Remote* CO2	36,294	35,932	362
WECC		-	
CA (includes remote* and Imports)	107,976	89,891	18,085
Rest of WECC (includes remote*)	391,051	393,856	2,805
Total WECC	499,027	483,747	15,280

-

Table 7-7: Generating System Changes in Response to High California-Only Combined Energy Efficiency and Renewable Development* (2020 only)

	California Generation (GWh)		R-of-W Generation (GWh)	
Resource Type	Assumed Increases	Predicted Decreases	Assumed Increases	Predicted Decreases
Year 2020				
Energy Efficiency	12,625	0	0	0
Wind	14,407	0	0	0
Geothermal	13,156	0	0	0
Biomass	5,317	0	0	0
Central Solar	4,095	0	0	0
Rooftop PV	6,407	0	0	0
Gas Fired	0	28,663	0	24,534
Coal	0	0	0	1,259
Pumped Storage	0	205	0	0

Table 7-7: Generating System Changes in Response to High California-Only Combined Energy Efficiency and Renewable Development* (2020 only)

	California Generation (GWh)		R-of-W Generation (GWh)	
Resource Type	Assumed Increases	Predicted Decreases	Assumed Increases	Predicted Decreases
Year 2020				
Energy Efficiency	12,625	0	0	0
Wind	14,407	0	0	0
Geothermal	13,156	0	0	0
Biomass	5,317	0	0	0
Central Solar	4,095	0	0	0
Rooftop PV	6,407	0	0	0
Gas Fired	0	28,663	0	24,534
Coal	0	0	0	1,259
Pumped Storage	0	205	0	0

Table 7-7: Generating System Changes in Response to High California-Only Combined Energy Efficiency and Renewable Development* (2020 only)

	California Generation (GWh)		R-of-W Generation (GWh)	
Resource Type	**Assumed Increases**	**Predicted Decreases**	**Assumed Increases**	**Predicted Decreases**
Year 2020				
Energy Efficiency	12,625	0	0	0
Wind	14,407	0	0	0
Geothermal	13,156	0	0	0
Biomass	5,317	0	0	0
Central Solar	4,095	0	0	0
Rooftop PV	6,407	0	0	0
Gas Fired	0	28,663	0	24,534
Coal	0	0	0	1,259
Pumped Storage	0	205	0	0

Table 7-8: Projected Costs of Combined High Efficiency and High Renewable Case in California Only

	Projected Costs for California (2006 $ Billion)		
Cost Component	Case 1B	Case 5A	Difference
2015			
System Costs	14.6	16.2	1.6
Production Costs	10.7	9.8	0.9
EE Program Costs	1.1	1.3	0.2
Rooftop PV Costs	0.5	2.5	2.0
Generation Capital	1.7	2.1	0.4
Transmission Upgrades	0.3	0.4	0.1
		-	
2020			
System Costs	16.4	18.4	2.0
Production Costs	11.9	9.1	2.8
EE Program Costs	1.1	1.3	0.2
Rooftop PV Costs	0.6	3.0	2.4
Generation Capital	2.3	4.4	2.1
Transmission Upgrades	0.3	0.4	0.1

-

Table 7-9: Carbon Emission Impacts from High Energy Efficiency and Renewables in California Only

	2020 Carbon (000 tons)		
Region/Category	Case 1B	Case 5A	Difference
CA			
CA CO2 Production	63,907	54,836	9,071
CA Remote* CO2	27,087	26,777	310
CA Import CO2	16,982	1,934	15,048
Rest of WECC			
Rest of WECC CO2 Production	354,757	358,607	3,850
Rest of WECC Remote* CO2	36,294	35,840	454
WECC			
CA (includes remote* and Imports)	107,976	83,547	24,429
Rest of WECC (includes remote*)	391,051	394,447	3,396
Total WECC	499,027	477,994	21,033

Table 7-10: Generating System Changes in Response to Increased Energy Efficiency in Rest-of-WECC and California (2020 portion of Table only)

	California Generation (GWh)		R-of-W Generation (GWh)	
Resource Type	**Assumed Increases**	**Predicted Decreases**	**Assumed Increases**	**Predicted Decreases**
Year 2020				
EE	0	0	82,408	0
Gas Fired	0	13,396	0	58,840
Coal	0	0	0	8,381
Pumped Storage	0	-11	0	54
Other	0	0	0	173
Imports to CA	0	-13,958	0	0
Exports from RofW	0	0	0	-13,958

Table 7-10: Generating System Changes in Response to Increased Energy Efficiency in Rest-of-WECC and California (2020 portion of Table only)

	California Generation (GWh)		R-of-W Generation (GWh)	
Resource Type	Assumed Increases	Predicted Decreases	Assumed Increases	Predicted Decreases
Year 2020				
EE	0	0	82,408	0
Gas Fired	0	13,396	0	58,840
Coal	0	0	0	8,381
Pumped Storage	0	-11	0	54
Other	0	0	0	173
Imports to CA	0	-13,958	0	0
Exports from RofW	0	0	0	-13,958

Table 7-10: Generating System Changes in Response to Increased Energy Efficiency in Rest-of-WECC and California (2020 portion of Table only)

	California Generation (GWh)		R-of-W Generation (GWh)	
Resource Type	Assumed Increases	Predicted Decreases	Assumed Increases	Predicted Decreases
Year 2020				
EE	0	0	82,408	0
Gas Fired	0	13,396	0	58,840
Coal	0	0	0	8,381
Pumped Storage	0	-11	0	54
Other	0	0	0	173
Imports to CA	0	-13,958	0	0
Exports from RofW	0	0	0	-13,958

Table 7-10: Generating System Changes in Response to Increased Energy Efficiency in Rest-of-WECC and California (2020 portion of Table only)

	California Generation (GWh)		R-of-W Generation (GWh)	
Resource Type	Assumed Increases	Predicted Decreases	Assumed Increases	Predicted Decreases
Year 2020				
EE	0	0	82,408	0
Gas Fired	0	13,396	0	58,840
Coal	0	0	0	8,381
Pumped Storage	0	-11	0	54
Other	0	0	0	173
Imports to CA	0	-13,958	0	0
Exports from RofW	0	0	0	-13,958

Table 7-11: Projected Costs of High Energy Efficiency Case in Rest-of-WECC and in California

	Projected Costs For Rest-of-WECC (2006 $ Billion)		
Cost Component	Case 3A	Case 3B	Difference
2015			
System Costs	21.3	21.4	0.1
Production Costs	16.3	14.7	1.6
EE Program Expenses	0	2.5	2.5
Generation Capital	3.7	2.9	0.8
Transmission Upgrades	1.1	1.1	0
2020			
System Costs	27.3	24.9	2.4
Production Costs	19.8	16.6	3.2
EE Program Costs	0	2.5	2.5
Generation Capital	6.1	4.4	1.7
Transmission Upgrades	1.2	1.2	0

Table 7-12: Carbon Emission Impacts from High Energy Efficiency in Rest-of-WECC and California

	2020 Carbon (000 tons)		
Region/Category	Case 3A	Case 3B	Difference
CA			
CA CO2 Production	60,032	54,868	5,164
CA Remote* CO2	27,048	26,755	293
CA Import CO2	14,572	22,671 -	8,099
		-	
Rest of WECC			
Rest of WECC CO2 Production	355,389	313,679	41,710
Rest of WECC Remote* CO2	36,247	35,782	465
		-	
WECC		-	
CA (includes remote* and Imports)	101,652	104,294	2,642
Rest of WECC (includes remote*)	391,637	349,461	42,175
Total WECC	493,289	453,755	39,533

-

-

Table 7-13: Generating System Changes in Response to High Renewable Development in Rest-of-WECC and California*

	California Generation (GWh)		Rest-of-WECC Generation (GWh)	
Resource Type	Assumed Increases	Predicted Decreases	Assumed Increases	Predicted Decreases
Year 2015				
Wind	0	0	18,655	0
Geothermal	0	0	4,465	0
Biomass	0	0	2,020	0
Central Solar	0	0	0	0
Rooftop PV	0	0	164	0
Gas Fired	0	4,491	0	17,336
Coal	0	0	0	3,047
Pumped Storage	0	33	0	13
Imports to CA	0	4,648	0	0
Exports from RofW	0	0	0	4,648
Year 2020				
Wind	0	0	45,061	0
Geothermal	0	0	11,415	0
Biomass	0	0	5,809	0
Central Solar	0	0	0	0
Rooftop PV	0	0	790	0
Gas Fired	0	10,619	0	40,283
Coal	0	0	0	10,590
Pumped Storage	0	5	0	94
Imports to CA	0	11,315	0	0
Exports from RofW	0	0	0	11,315

Table 7-14: Projected Costs of High Renewable Case in Rest-of-WECC and in California

	Projected Costs For Rest-of-WECC (2006 $ Billion)		
Cost Component	Case 4A	Case 4B	Difference
2015			
System Costs	21.2	22.1	0.9
Production Costs	16.1	15.4	0.7
Rooftop PV Costs	0.2	0.2	0
Generation Capital	3.6	4.8	1.2
Transmission Upgrades	1.3	1.7	0.4
		-	
2020			
System Costs	26.5	28.6	2.1
Production Costs	19.0	17.1	1.9
Rooftop PV Costs	0.2	0.5	0.3
Generation Capital	6.0	8.7	2.7
Transmission Upgrades	1.3	2.4	1.1

-

Table 7-15: Carbon Emission Impacts from High Renewables in Rest-of-WECC and California

	2020 Carbon (000 tons)		
Region/Category	Case 4A	Case 4B	Difference
CA			
CA CO2 Production	58,078	54,172	3,906
CA Remote* CO2	26,843	26,314	528
CA Import CO2	4,970	10,451 -	5,481
		-	
Rest of WECC			
Rest of WECC CO2 Production	357,924	326,713	31,212
Rest of WECC Remote* CO2	35,932	35,390	542
		-	
WECC		-	
CA (includes remote* and Imports)	89,891	90,938	1,047
Rest of WECC (includes remote*)	393,856	362,102	31,754
Total WECC	483,747	453,040	30,707

-

-

Table 7-16: Generating System Changes in Response to Combined High EE and High Renewable Development in Rest-of-WECC and CA

	California Generation (GWh)		Rest-of-WECC Generation (GWh)	
Resource Type	Assumed Increases	Predicted Decreases	Assumed Increases	Predicted Decreases
Year 2015				
Energy Efficiency	0	0	48,070	0
Wind	0	0	18,655	0
Geothermal	0	0	4,465	0
Biomass	0	0	725	0
Central Solar	0	0	1,344	0
Rooftop PV	0	0	165	0
Gas Fired	0	13,811	0	46,706
Coal	0	0	0	10,310
Pumped Storage	0	20	0	16
Fuel Oil	0	9	0	11
Imports to CA	0	14,671	0	0
Exports from RofW	0	0	0	14,671
Year 2020				
Energy Efficiency	0	0	82,448	0
Wind	0	0	45,061	0
Geothermal	0	0	11,415	0
Biomass	0	433	2.950	0
Central Solar	0	0	2,904	0
Rooftop PV	0	0	790	0
Gas Fired	0	23,132	0	75,545
Coal	0	37	0	38,752
Pumped Storage	0	7	0	5
Fuel Oil	0	32	0	52
Imports to CA	0	26,348	0	0
Exports from RofW	0	0	0	26,348

Table 7-17: Projected Costs of Combined EE and High Renewable Case in Rest-of-WECC and CA

	Projected Costs for Rest-of-WECC (2006 $ Billion)		
Cost Component	Case 5A	Case 5B	Difference
2015			
System Costs	21.1	22.2	1.1
Production Costs	16.0	13.8	2.2
EE Program Costs	0	2.5	2.5
Rooftop PV Costs	0.2	0.2	0
Generation Capital	3.6	3.9	0.3
Transmission Upgrades	1.3	1.8	0.5
2020			
System Costs	26.3	26.9	0.6
Production Costs	18.8	14.3	4.5
EE Program Costs	0	2.5	2.5
Rooftop PV Costs	0.2	0.5	0.3
Generation Capital	6.0	7.1	1.1
Transmission Upgrades	1.3	2.5	1.2

Table 7-18: Carbon Emission Impacts from High EE and Renewables in Rest-of-WECC and California

	2020 Carbon (000 tons)		
Region/Category	Case 5A	Case 5B	Difference
CA			
CA CO2 Production	54,836	46,356	8,480
CA Remote* CO2	26,777	24,257	2,520
CA Import CO2	1,934	14,932 -	12,998
		-	
Rest of WECC			
Rest of WECC CO2 Production	358,607	276,607	81,999
Rest of WECC Remote* CO2	35,840	32,996	2,844
		-	
WECC		-	
CA (includes remote* and Imports)	83,547	85,545	1,999
Rest of WECC (includes remote*)	394,447	309,604	84,843
Total WECC	477,994	395,149	82,845

-

-

Sensitivity Assessments (Agenda item 3g)

- Chapter 8 outlines three sets of sensitivity or supplemental assessments
  - Lower and higher fuel prices compared to basecase
  - “shocks” that occur for about one year and dissipate
  - Stochastic assessment looking at limited set of variables from a probabilistic perspective

Table 5-5: Summary of Cases Assessed

Thematic Scenario	Fuel Price Sensitivities	Physical Performance Sensitivities	Evaluation and/or Side Analyses
1A – Current Conditions	Reference case with high (P75) and low (P25) alternatives 2009-2020	2020 deviations: - Gas price spike - High hydro - Low hydro	Stochastic assessment performed on this case
1B – Current Requirements	Reference case with high (P75) and low (P25) alternatives 2009-2020	2020 deviations: - Gas price spike - High hydro - Low hydro	
2 – Sustained High Gas Prices	Assumed $10/mmbtu gas price used to develop resource plan		Can be used to ascertain how utility decision-makers might have shifted resource mix with knowledge of high fuel prices
3A – High EE in California only	Reference case with high (P75) and low (P25) alternatives 2009-2020	2020 deviations: - Gas price spike - High hydro - Low hydro	
3B – High EE in both California and Rest-of-WECC	Reference case with high (P75) and low (P25) alternatives 2009-2020	2020 deviations: - Gas price spike - High hydro - Low hydro	This case has been used by Global Gas to develop low UEG impacts on natural gas price methodology

Table 5-5: Summary of Cases Assessed (cont.)

Thematic Scenario	Fuel Price Sensitivities	Physical Performance Sensitivities	Evaluation and/or Side Analyses
4A- High Renewables in California only	Reference case with high (P75) and low (P25) alternatives 2009-2020	2020 deviations: - Gas price spike - High hydro - Low hydro	
4B – High Renewables in both California and Rest-of-WECC	Reference case with high (P75) and low (P25) alternatives 2009-2020	2020 deviations: - Gas price spike - High hydro - Low hydro	Stochastic assessment performed on this case
5A- High EE and Renew in California only	Reference case with high (P75) and low (P25) alternatives 2009-2020	2020 deviations: - Gas price spike - High hydro - Low hydro	
5B- High EE and Renew in both California and Rest-of-WECC	Reference case with high (P75) and low (P25) alternatives 2009-2020	2020 deviations: - Gas price spike - High hydro - Low hydro	This case will be the final one used by Global Gas for evaluating low UEG impacts on natural gas prices (using meth. for Case 3B)

Figure 8-1: Natural Gas Price Forecasts ($2006/MMBtu)

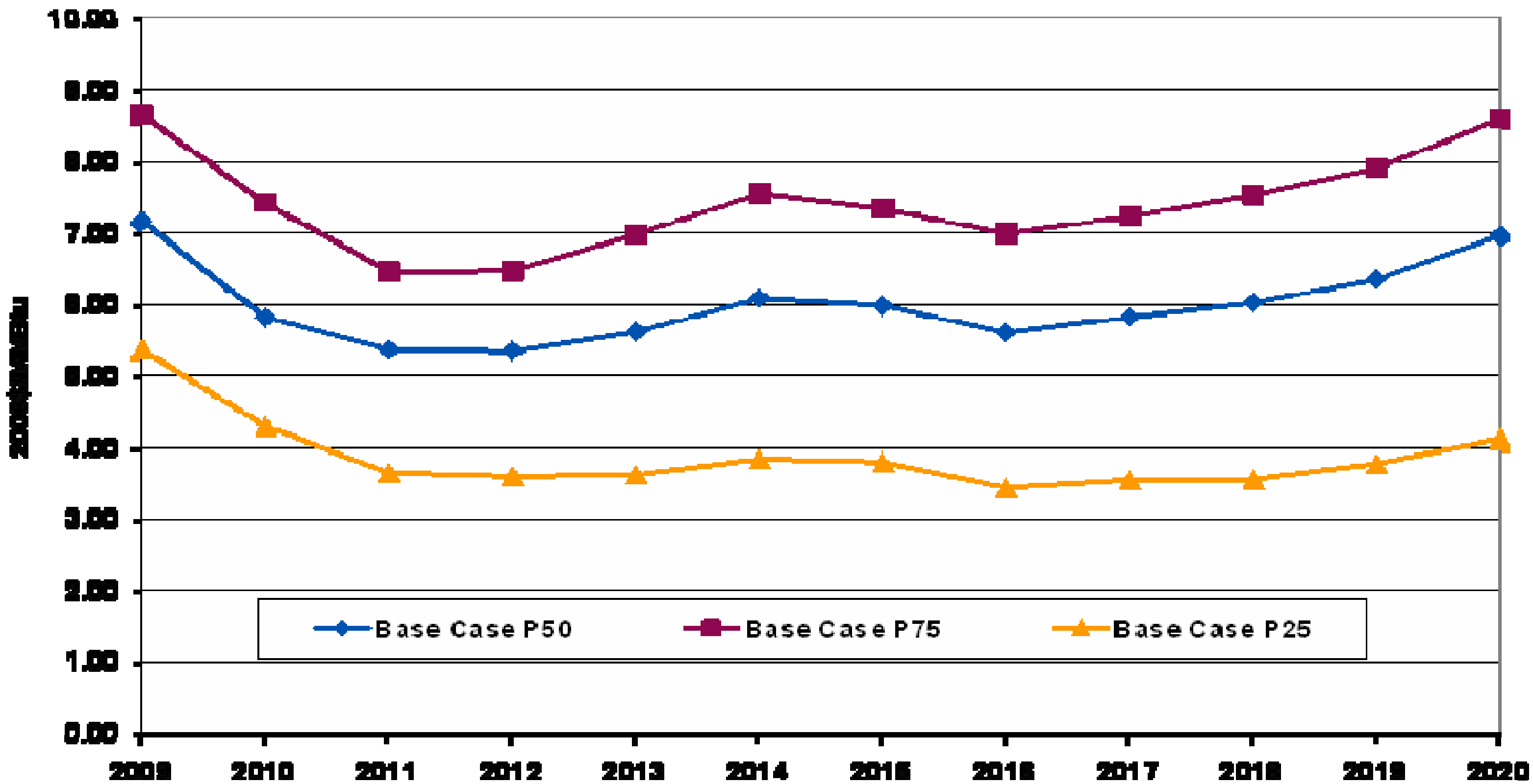
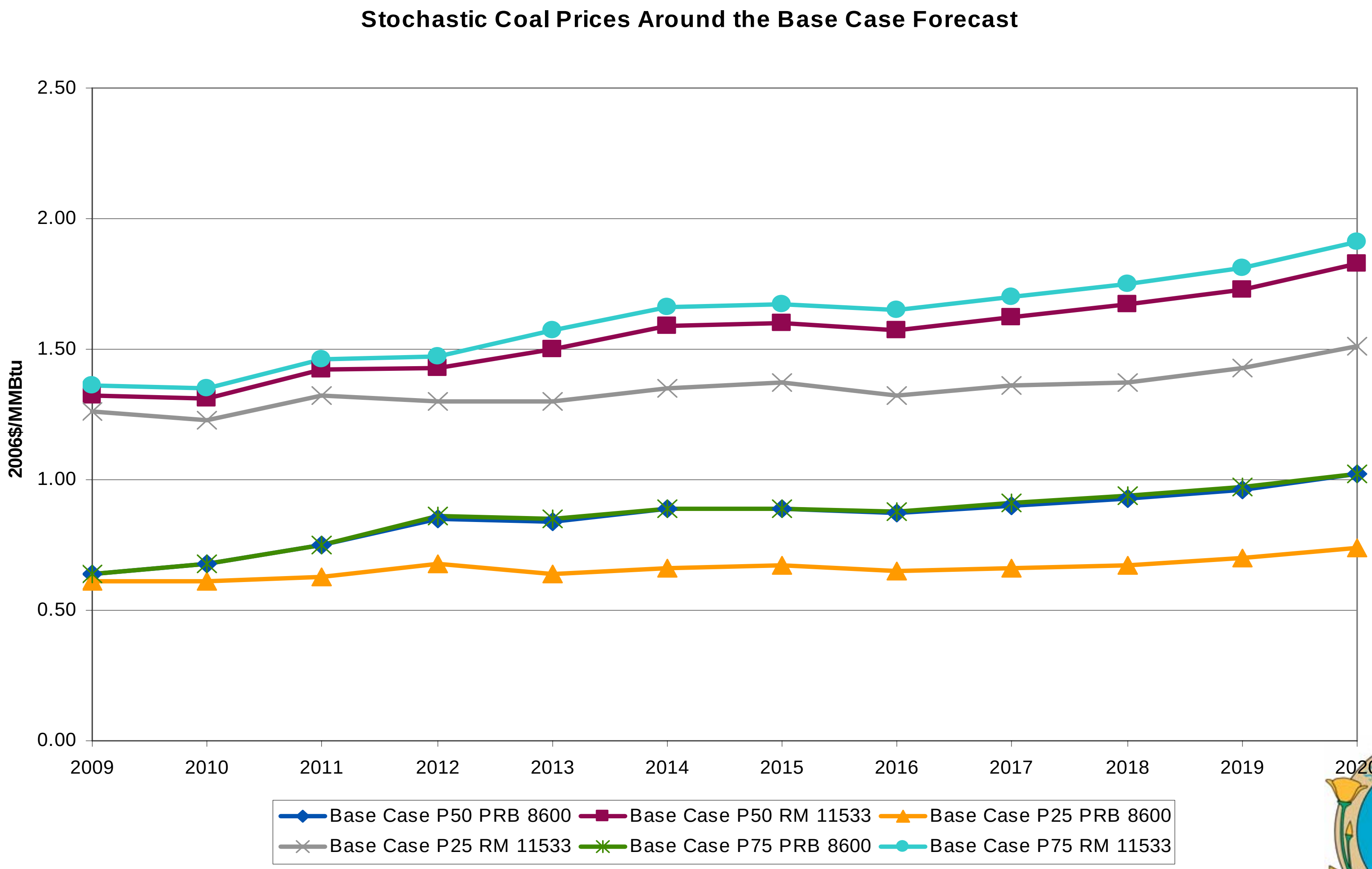


Figure 5-3: Stochastic Coal Prices ($2006)



Fuel Cost Sensitivity Evaluation

- Many variables change in some ways, some large and some small
- Large changes
  - Production costs
  - imports
- Small changes
  - Resource mix
  - Capital cost of resource additions

Figure 8-2: System and Production Unit Cost Trends for Case 1 – Current Conditions (High and Low Natural Gas Price Projections)

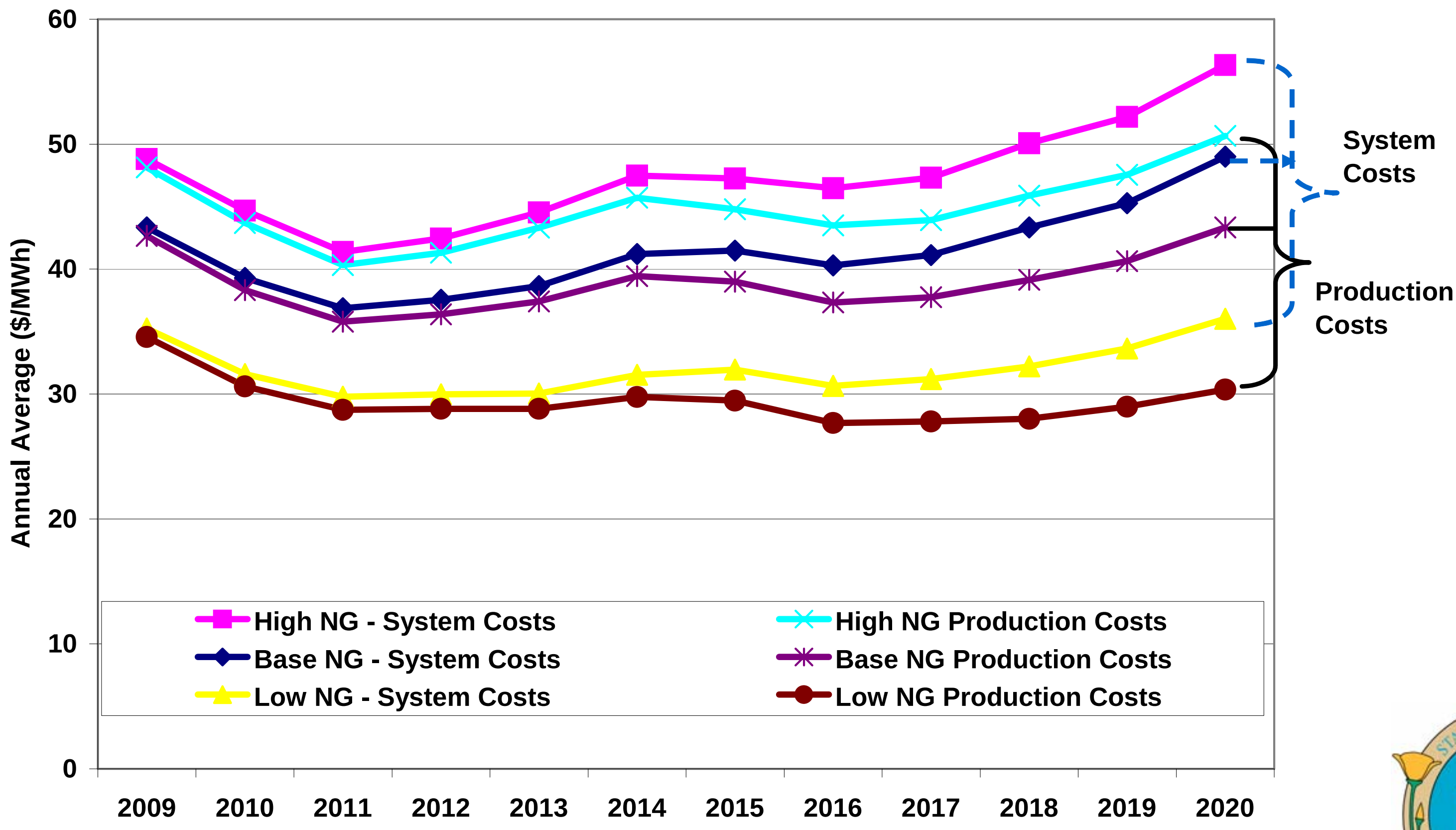


Figure 8-3: System and Production Unit Cost Trends for Case 1B – Current Requirements (High and Low Natural Gas Price Projections)

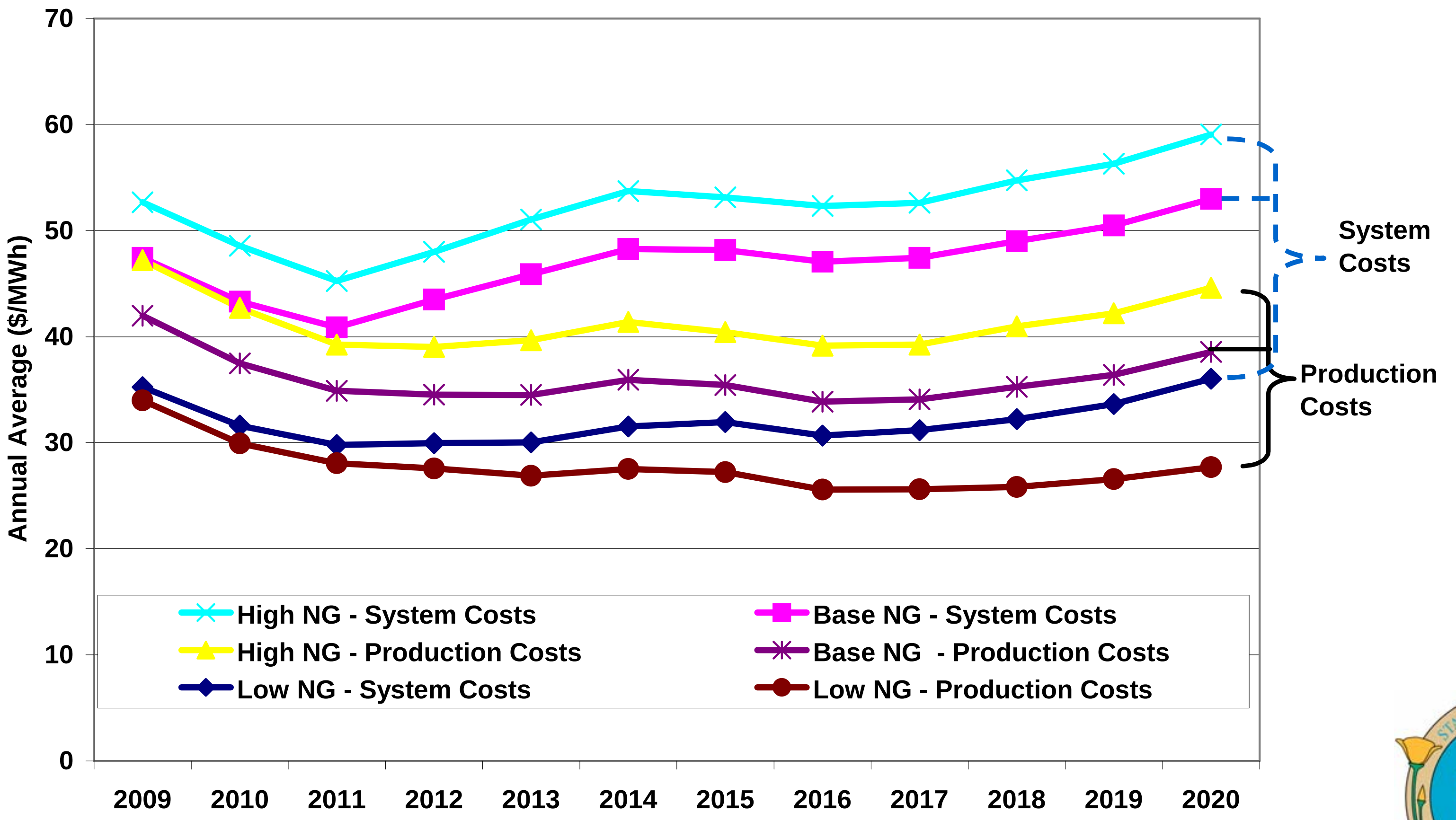


Figure 8-4: System and Production Unit Cost Trends for Case 3A – High Energy Efficiency in California Only (High and Low Natural Gas Price Projections)

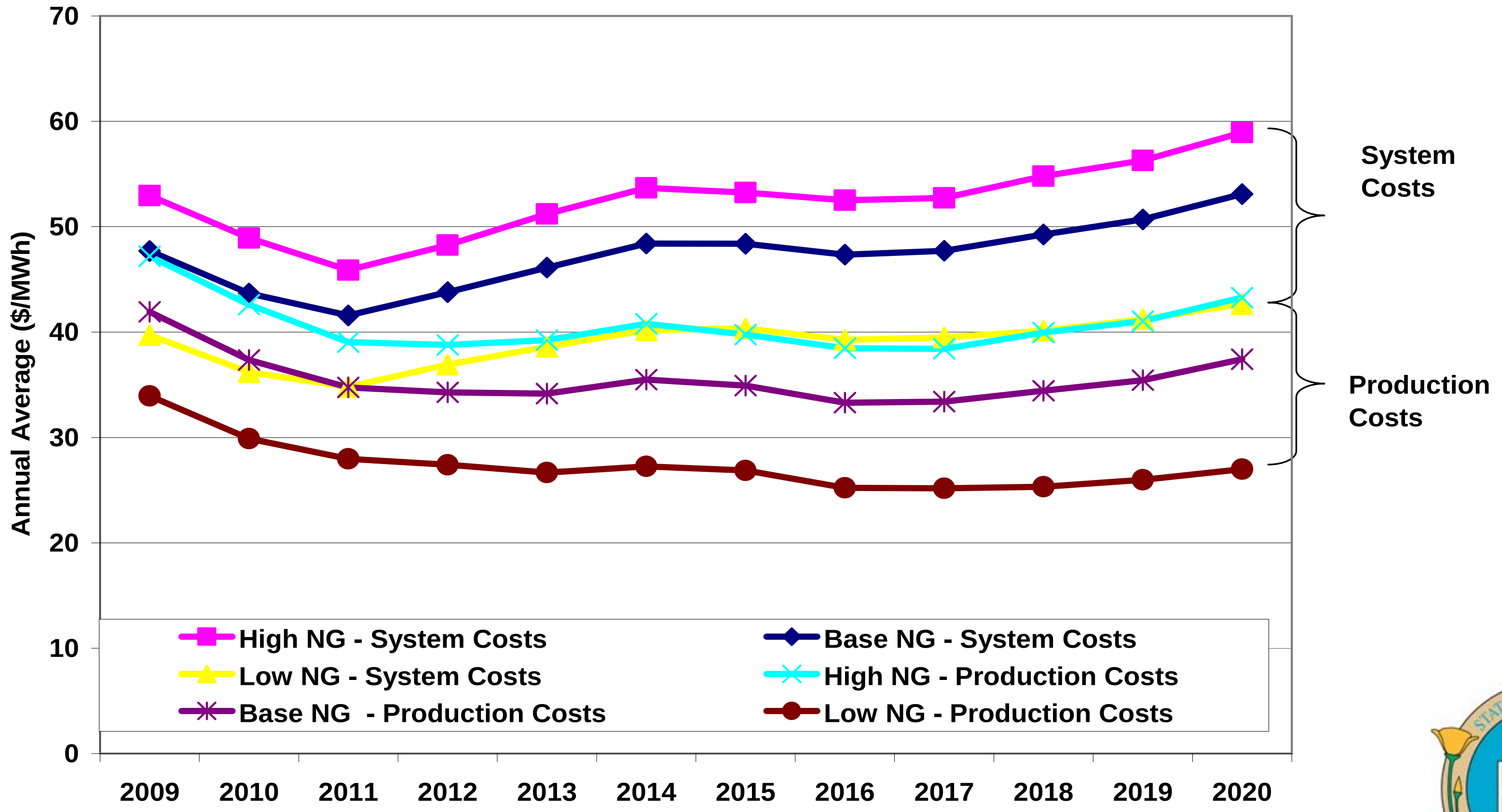


Figure 8-6: System and Production Unit Cost Trends for Case 4A – High Renewables in California Only (High and Low Natural Gas Price Projections)

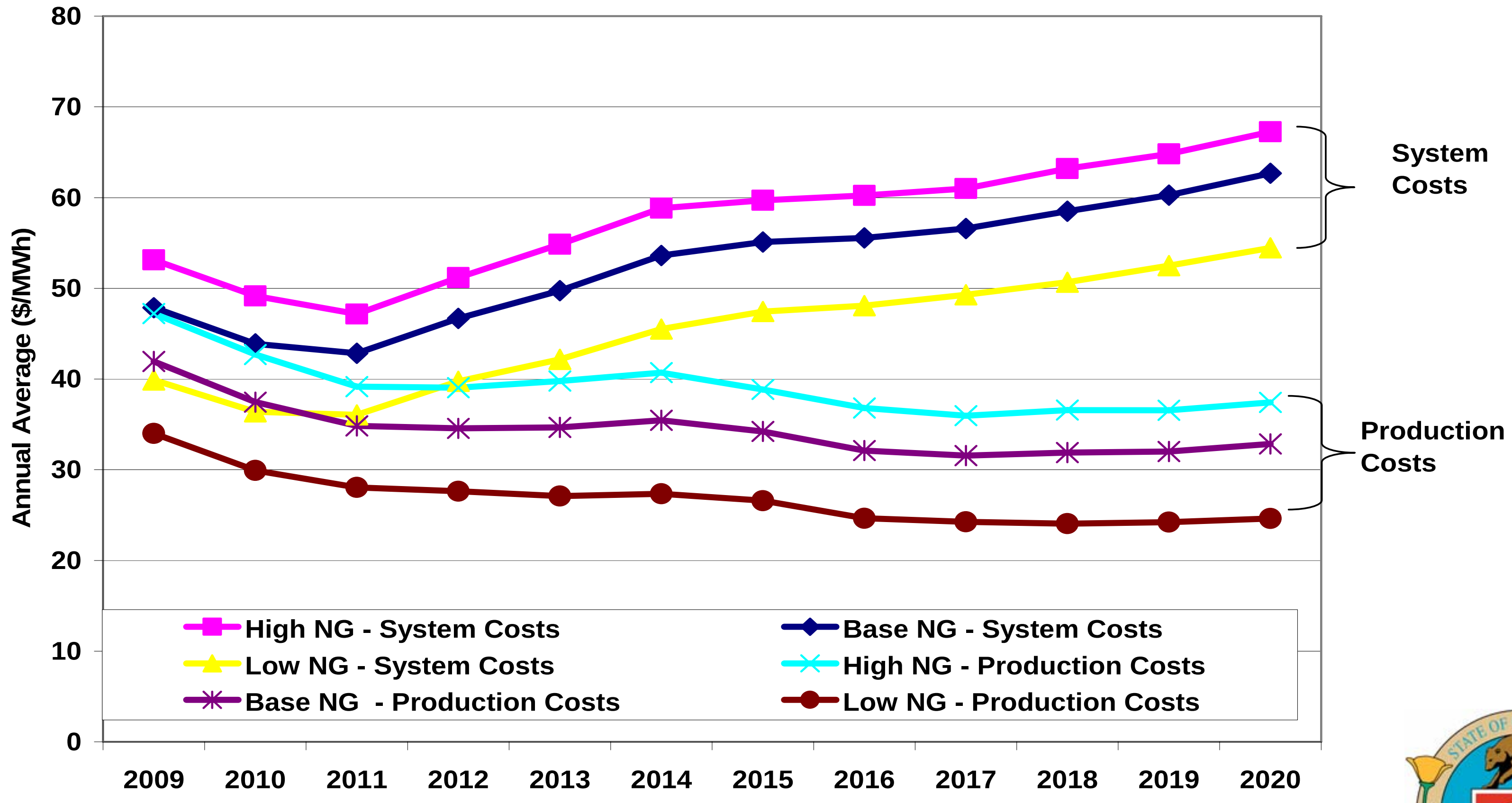
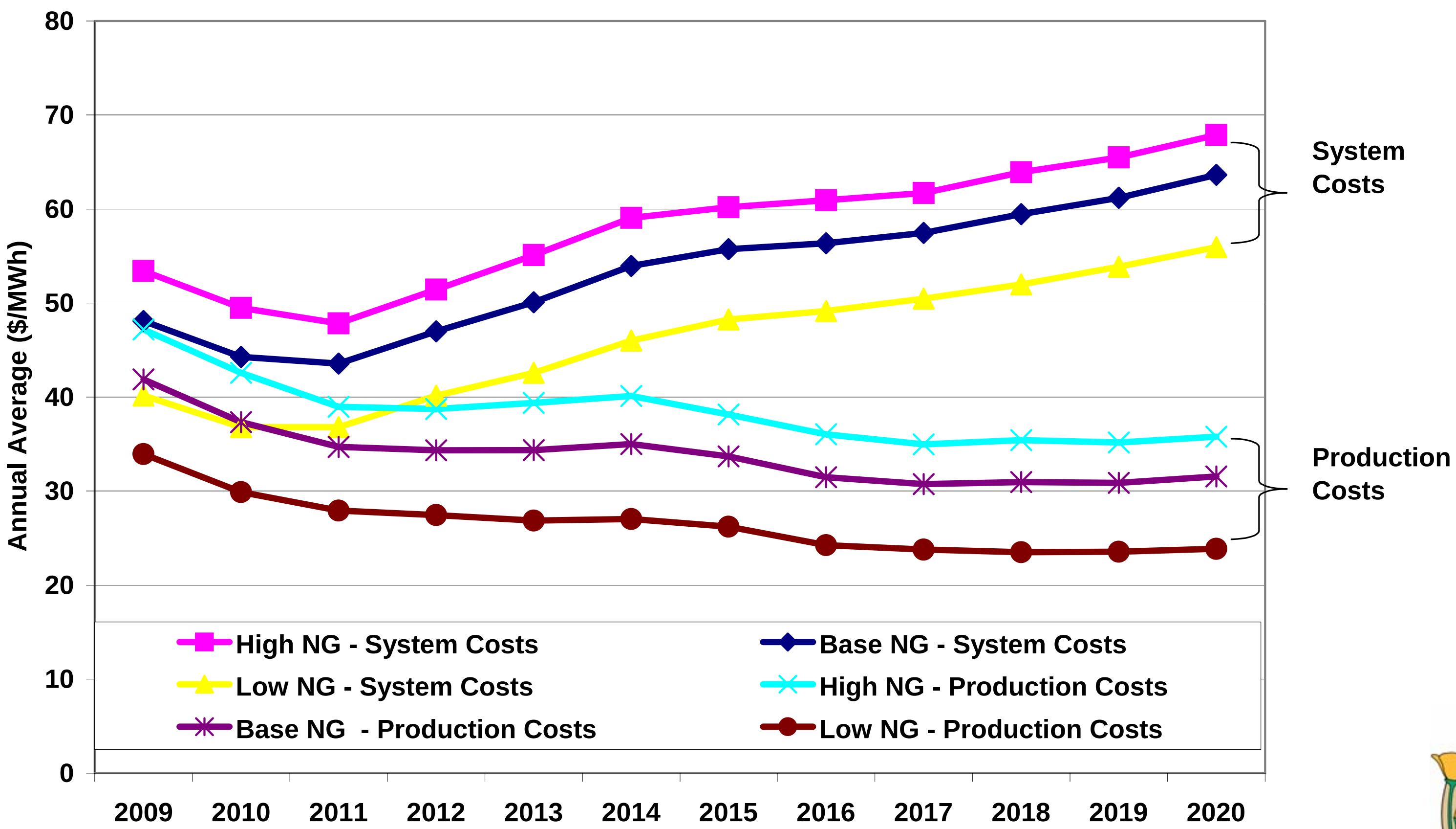


Figure 8-8: System and Production Unit Cost Trends for Case 5A – High EE and Renewables in CA Only (High and Low NG Price Projections)



Exogenous Shocks

- The basecase datasets were modified to conduct special sensitivities just for 2020:
  - Natural gas prices averaging $20/mmbtu reflecting a hurricane Katrina-type removal of major production capacity requiring one year to replace;
  - High hydro generation across all major hydro-electric generation regions; and
  - Low hydro generation across all major hydro-electric generation regions.

Table 8-4: WECC Hydro Energy for Low and High Hydro Case

Year	Hydro Condition	GWh
Average	Normal	246,167
1997	Wet	300,319
2000-2001	Dry	213,547

Figure 8-10: Natural Gas Prices Averaging $20/MMBtu

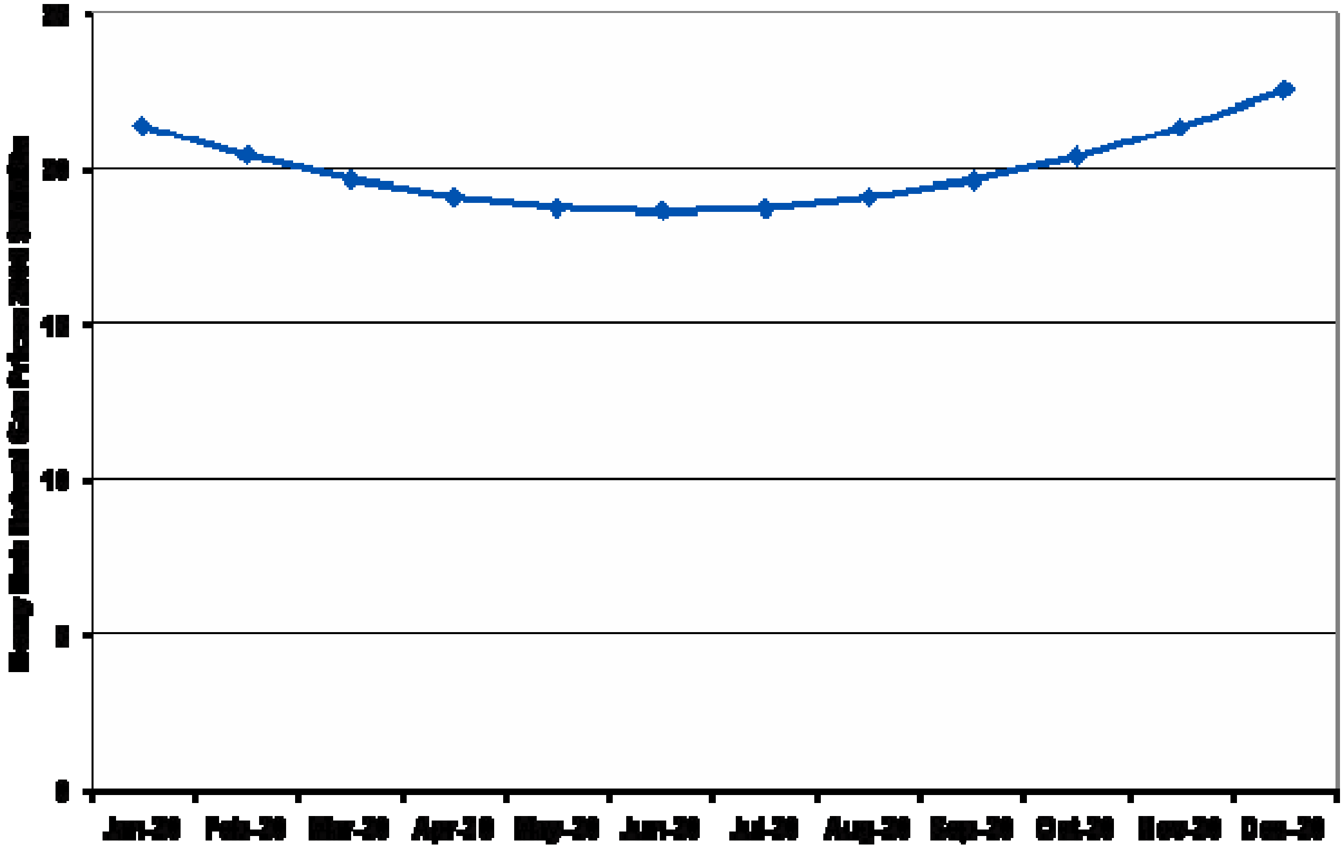


Figure 8-11: Annual California Generation by Resource Type in 2020 for Case 1 – Current Conditions Shock Sensitivity Results

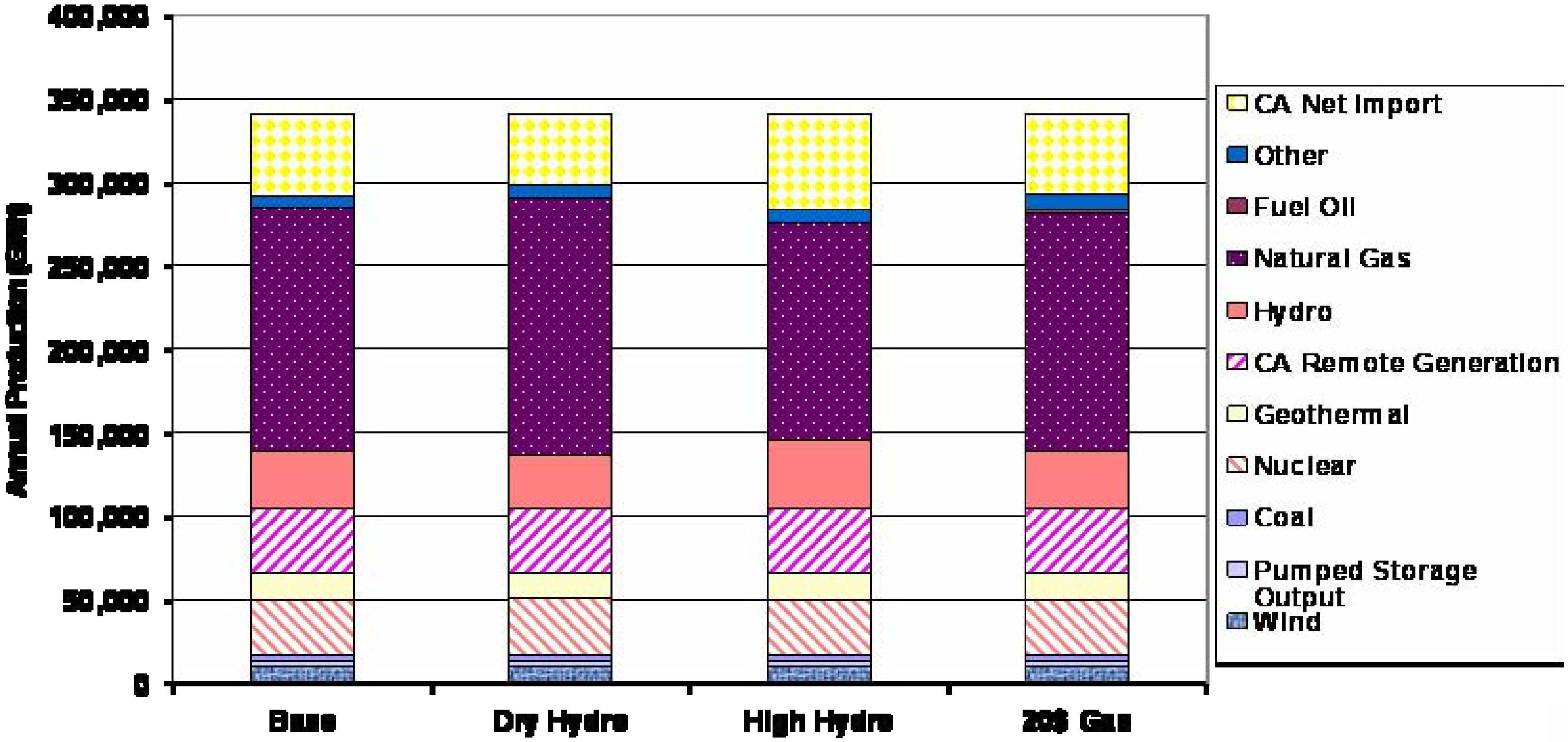


Figure 8-12: Annual California Generation by Resource Type in 2020 for Case 1B – Current Requirements Shock Sensitivity Results

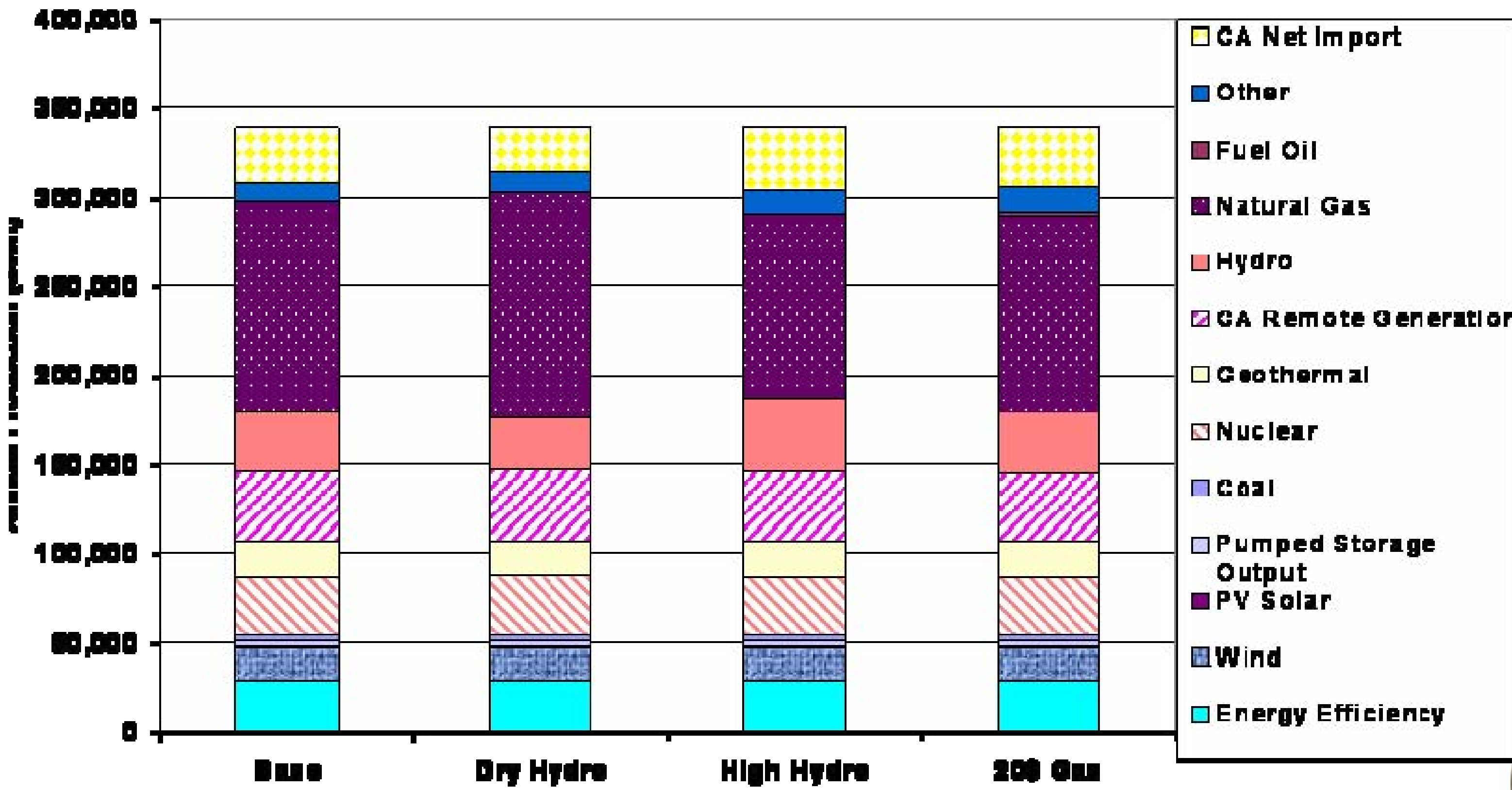


Figure 8-18: Annual California Generation by Resource Type in 2020 for Case 5A – High EE and Renewables in CA Only Shock Sensitivity

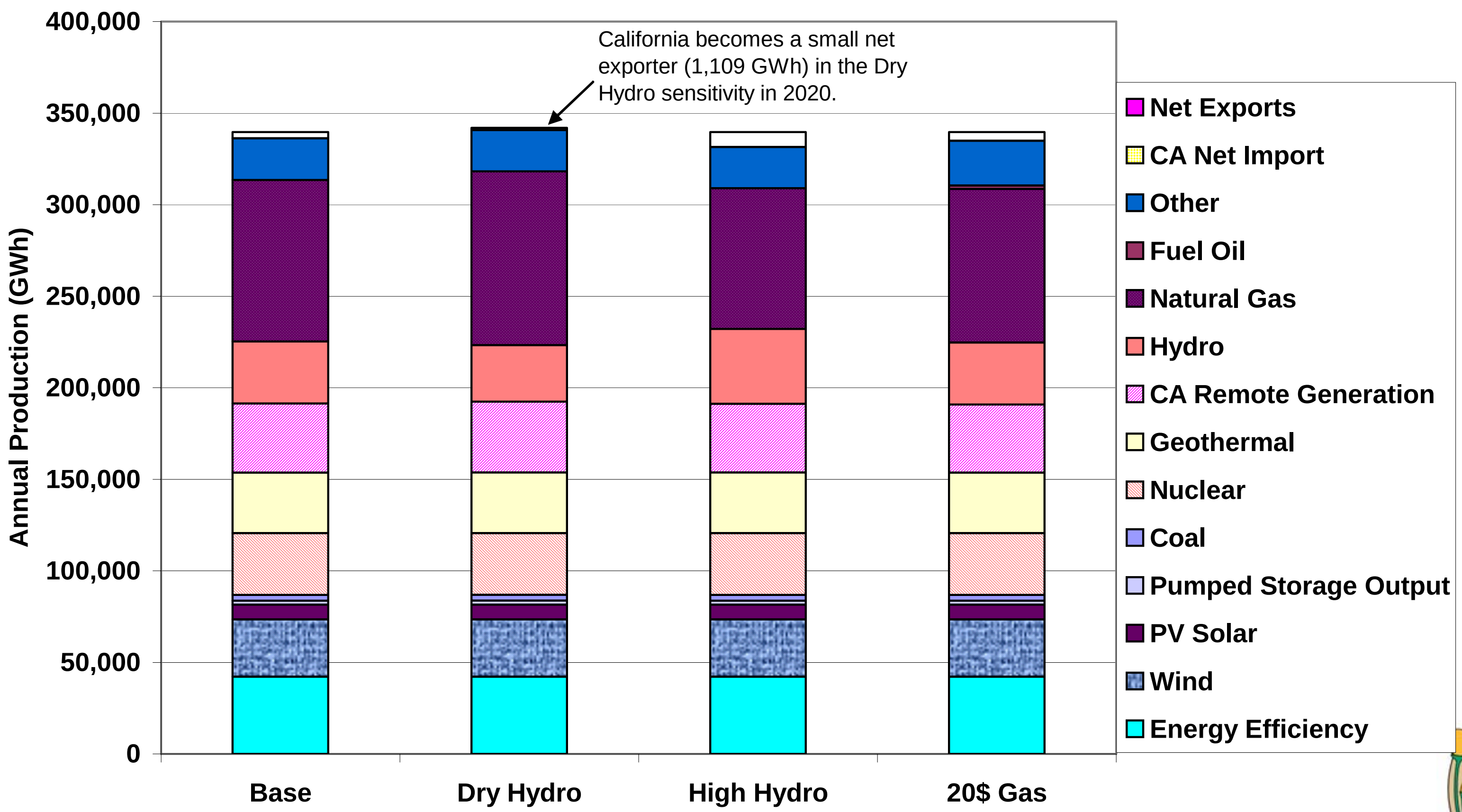


Figure 8-20: Comparison between Case 1B and Case 5A Shock Sensitivities for California System Costs in 2020 ($2006/MWh)

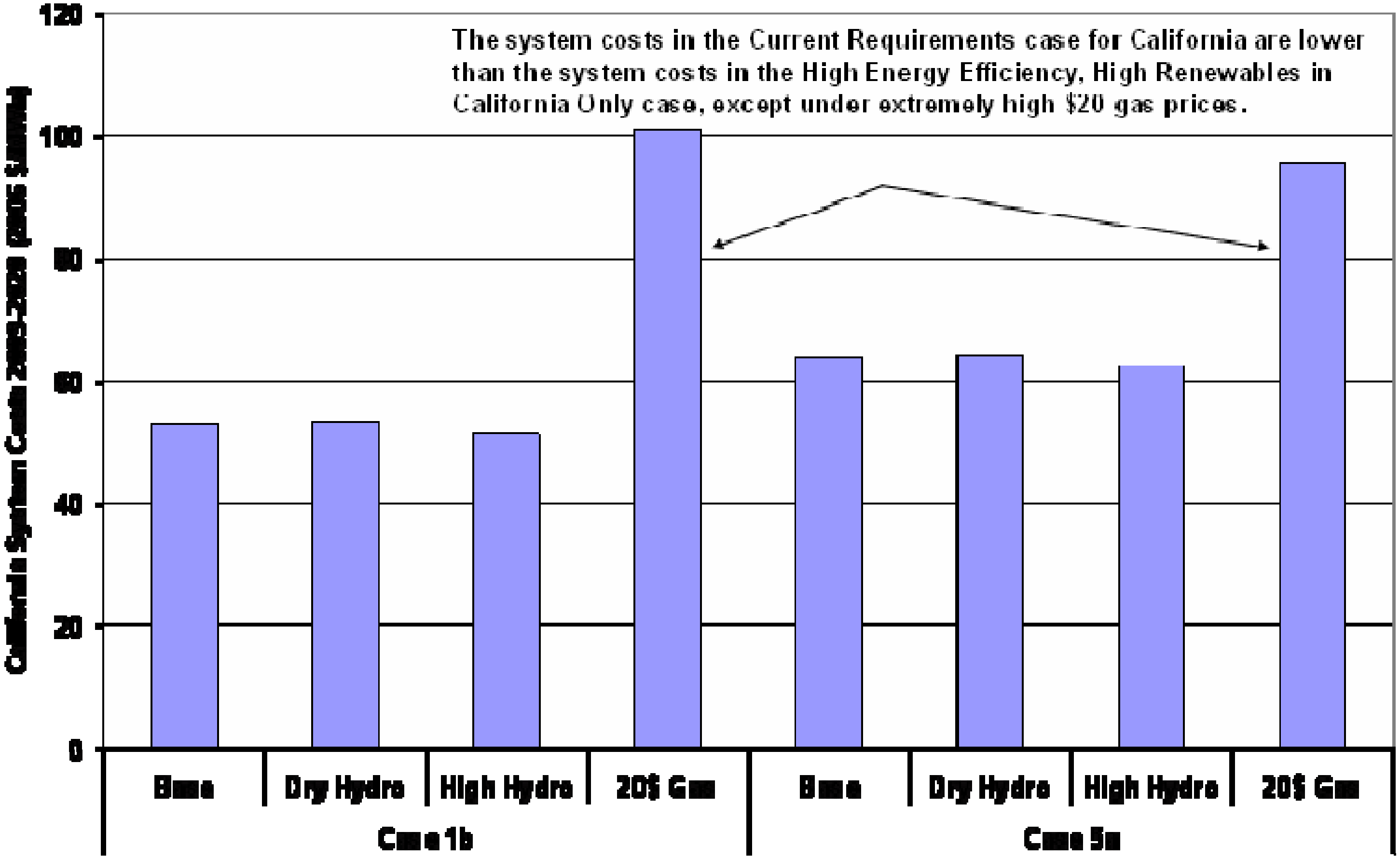
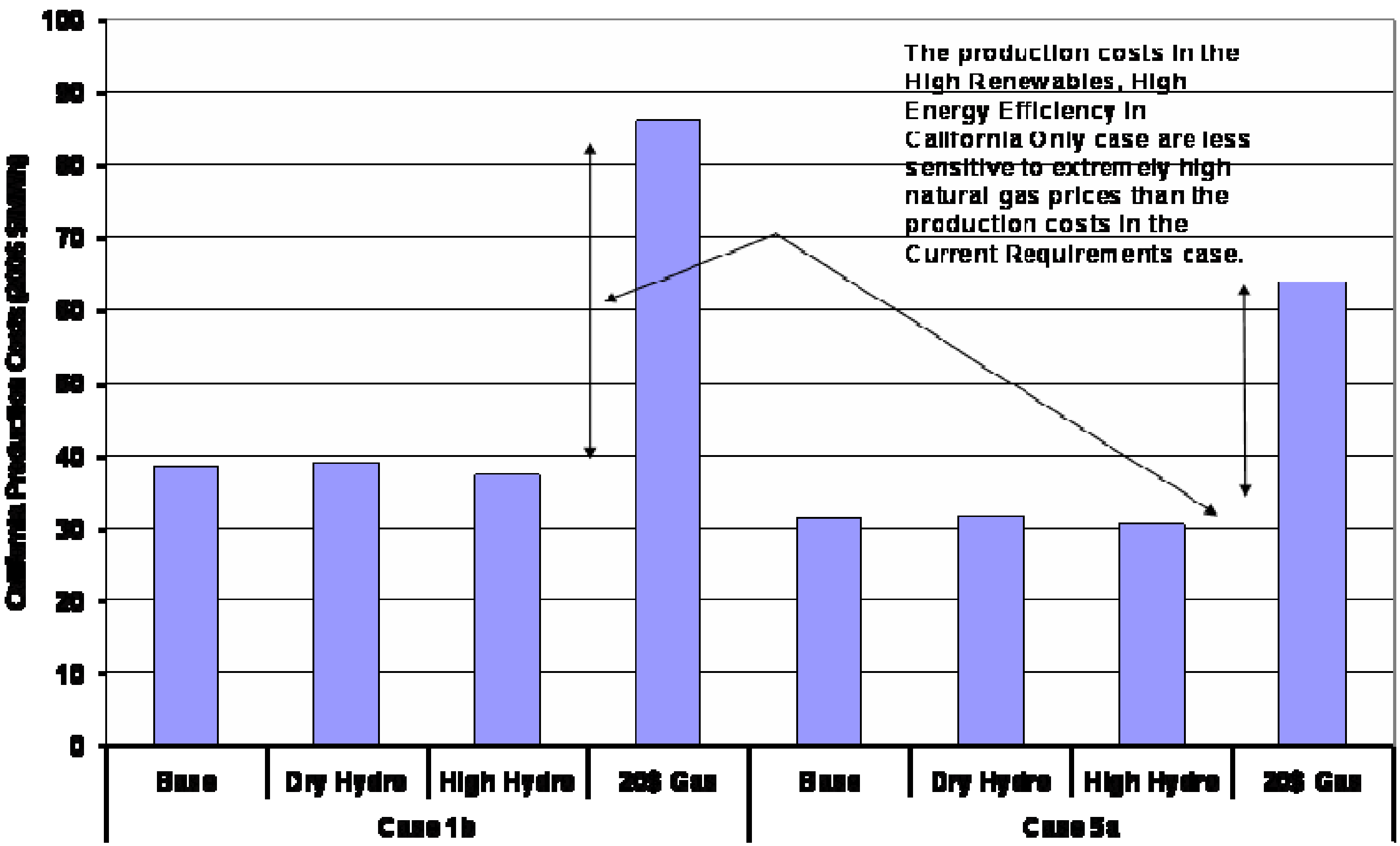


Figure 8-21: Comparison between Case 1B and Case 5A Shocks for California Production Costs in 2020

($2006/MWh)



Stochastic Analyses of 2020

- Variables being assessed:
  - Natural gas fuel prices
  - Daily loads profile
  - Unit outages
  - Weekly hydro generation
  - Daily wind and solar production profiles
- Monte Carlo analysis using 100 draws for each day

Stochastic Analyses

- Expected insights:
  - Reliability differences as large elements of resource mix shift from dispatchible to "as available" with substantial variations in output
  - Better understanding of both range and distribution of results than sensitivity or shock assessments
- Limited opportunity to assess cases since run time of model is so long. Thus Case 1 and 4B were selected.

Table 8-5: Stochastic Performance and Reliability

Resource Adjustments to Test Reliability of Case 1 for 2020

	Base Case (MW)	Reduced Gen	Difference (Base-Case1)
Load	191372	191372	0
Total	191372	191372	0
Hydro	63175	63175	0
Pumped Storage	4126	4126	0
Dependable Wind	5785	5785	0
Thermal	172245	152283	19962
Purchase	401	401	0
Total	245732	225769	19962
Margin	28.41	17.97%	

Table 8-6: Comparison of Expected Range of Cost Variability from Stochastic Assessment for Year 2020 ($2006)

	Deterministic	Stochastic		
Alternative Case	Basecase Values	10th Percentile	Expected Value	90th Percentile
Case 1	45,074,700	40,931,681	44,327,464	48,023,428
Case 4b	47,523,895	44,426,300	46,771,217	49,397,181

Figure 8-22: Stochastic Analysis for Case 1 — Distribution of Total System Costs ($2006)

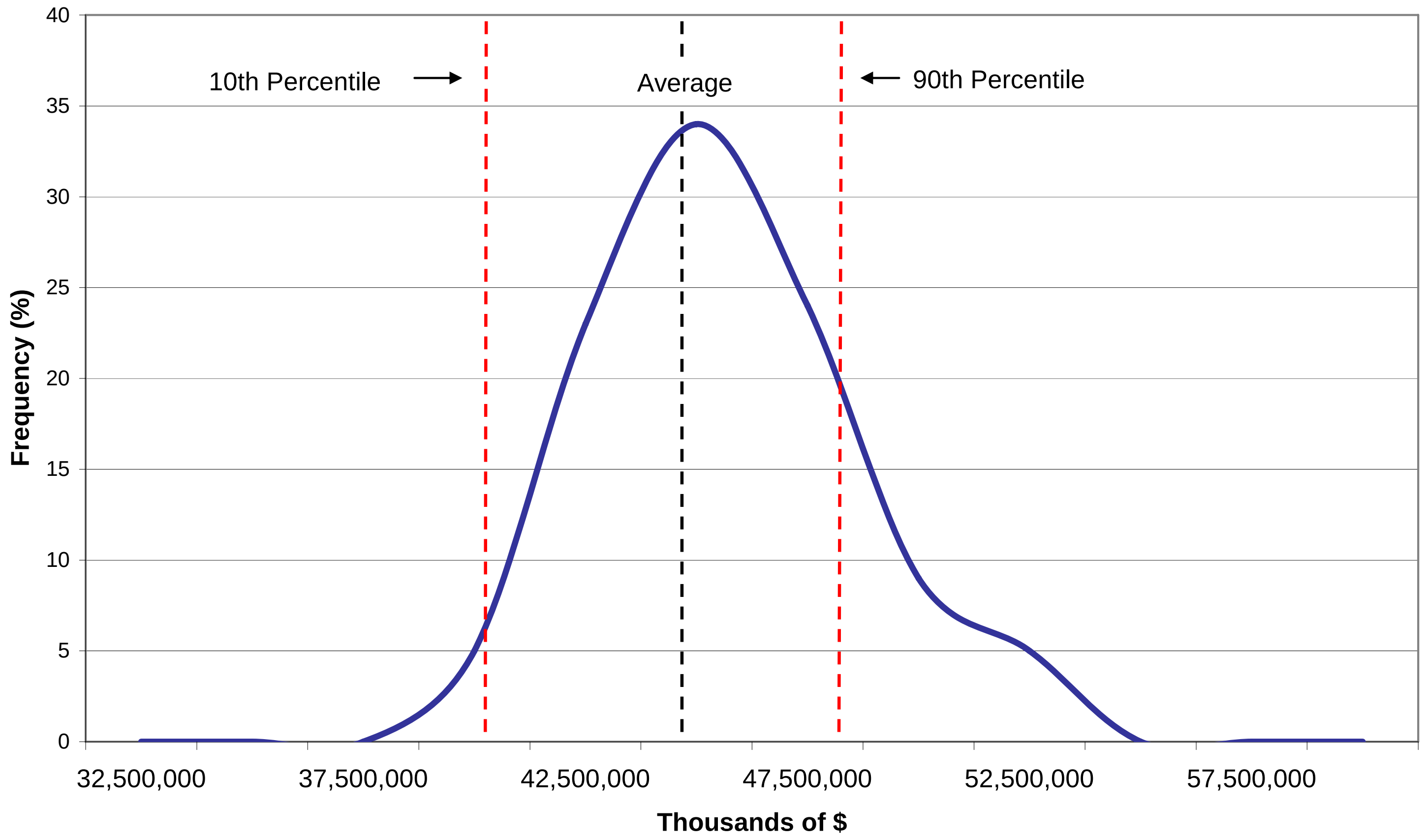
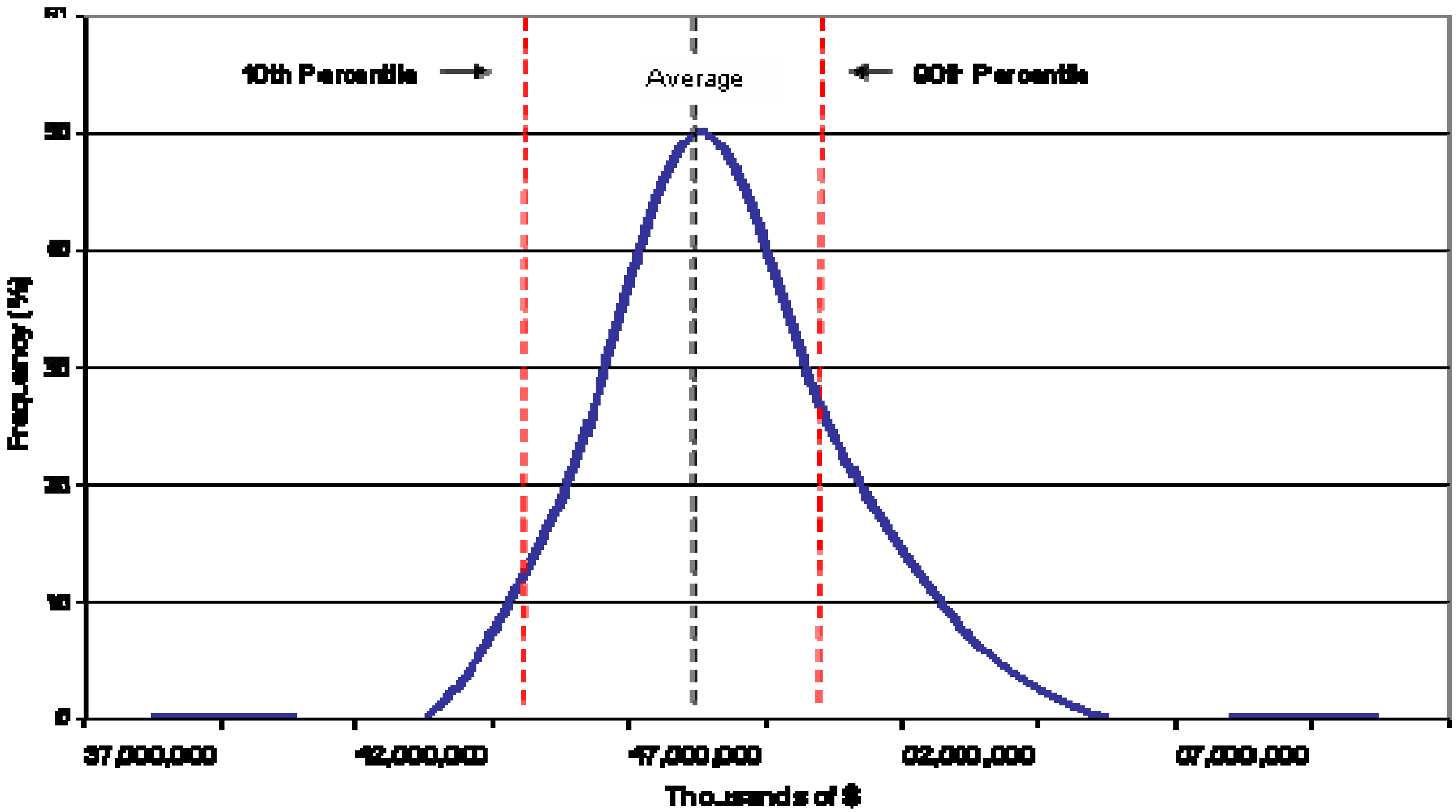


Figure 8-23: Stochastic Analysis for Case 4B — Distribution of Total System Costs ($2006)



Interpreting Stochastic Results

- Case 4B is less sensitive to fuel prices
- Case 4B is skewed to the right of Case 1, because increase in capital costs is higher than the decrease in production costs
- Case 4B misses some of the lower range of Case 1 because it cannot gain as much when fuel prices are low

Limitations of the Study

- Chapter 9 has an extended discussion
- Design and Execution
- Assumptions used in the modeling
  - Data
  - Modeling tools
  - Uncertainty Characterizations

Data Assumptions

- Efficiency and Demand Response Resource Assumptions
- Preferred Supply-Side Renewable Resource Assumptions
- Non-Preferred Supply Side Resource Assumptions
- Consequences of Data Assumptions Limitations

Modeling Assumptions

- Transarea Modeling Does Not Address Local Reliability Requirements
- The Resource Portfolios Do Not Completely Address the Consequences of Aging Power Plant Retirements
- Transmission Requirements and Costs Are Approximations
- The Attribution of Carbon Emissions to California Imports Is Not Definitive

Modeling Assumptions, cont'd

- Non-GHG Environmental Assessment Results Are Approximations
- Electricity Demand Feedback from Resource Plan Consequences
- Resource Plan Feedback from Natural Gas Price Consequences
- Resource Portfolios Are Not Optimized Relative to a Specified Objective
- Consequences of Modeling Assumption Limitations

Uncertainty Characterization Assumptions

- Electricity Demand Uncertainties
- Performance and Cost Uncertainties of Renewable Resources
- System Integration Costs and Performance
- Environmental and Economic Regulation Uncertainties
- Consequences of Uncertainty Characterization Limitations

Analytic Extensions

- Chapter 10 outlines a long set of possible extensions
- Three elements of the original scope are delayed, but work is in process:
  - Aging power plant retirements
  - Impacts of lower power generation fuel consumption on natural gas market clearing prices
  - Water consumption for power generation

Analytic Extensions

- The Commission should consider:
  - whether any of the extensions ought to be undertaken
  - The venue to which the results might be contributed
  - The timeframe of this effort
  - Staff effort alone or in conjunction with others