



# Arkansas Governor's Commission on Global Warming

Energy Supply (ES)  
Technical Work Group  
Meeting #14, September 16, 2008

Office of the Governor  
Center for Climate Strategies

# Agenda

- Introductions
- Review and Approval of Prior Call Summary
- Dates and Times for Future GCGW and TWG meetings
- Review of Results of GCGW Meeting #9 (Sept . 9, 2008)
- Review Goals for GCGW Meeting #10 (Sept. 25, 2008)
- Continued Review and Revision of Priority Policy Option Designs and Inputs for Quantification **(Please note: focus of TWG discussion to be on ES-3A, ES-3B, ES-7)**
- Review of Next Steps for TWG
- Confirm Agenda, Date and Time for Next Meetings
- Public Comments and Announcements

# Future GCGW and CC TWG Meetings

- GCGW Meetings (9:00 am – 4:30 pm Central)
  - #10: Thursday, Sept. 25, 2008
- ES TWG Meetings
  - #14: Tuesday, Sept. 16, 2008 (9:00 – 11:00 am Central)
  - #15: Monday, Sept. 22, 2008 (2:00 – 4:00 pm Central)
- Final Recommendations to Governor
  - Friday, October 31, 2008

# Results of Sept. 9 GCGW Meeting

- GCGW provided unanimous approval for:
  - ES Forecast – Scenario #2 including Plum Point and Turk (Hempstead Co.) coal plants in reference case projection
  - ES-1 (Green Power Purchases and Marketing (Transfer to RCI-7))
  - ES-2 (Technology Research & Development)
  - ES-6 (Combined Heat and Power) (with text modifications)
  - ES-9 (Nuclear Power)
  - ES-11 (Efficiency Improvements and Repowering of Existing Plants)

# Goals for GCGW Meeting #9 (Sept.9, 2008)

- Goals: Obtain GCGW comments on and approval of TWG recommendations on pending priority policy options

# Development of Quantification for Remaining Pending Priority Policy Options

ES-3a: Renewable Portfolio Standard (RPS)

ES-3b: Renewable Energy Feed-In Tariff (REFIT)

ES-4: Grid-Based Renewable Energy Incentives and/or  
Barrier Removal

ES-5: Approaches Benefiting From Regional Application

ES-7: Geological Underground Sequestration for New Plants

ES-8: Transmission System Upgrades

ES-10: Carbon Tax

# Review of Quantification

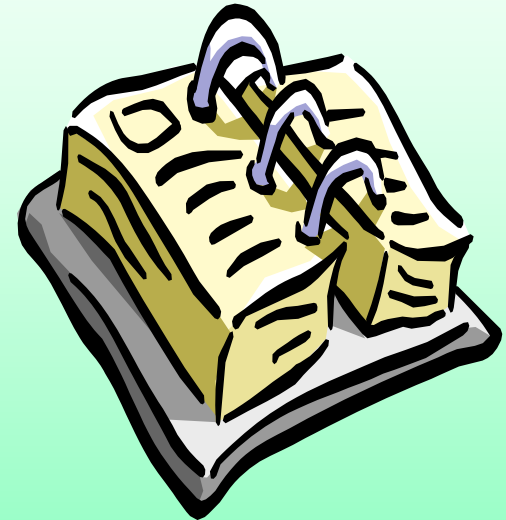
*See Reference Materials  
(Slides 10 through 116)*

# Next Steps for ES TWG

- Continue review of policy option quantification
- Continue development of remaining elements of template for pending priority policy options
- Respond to comments from GCGW meeting

# Next ES TWG Meeting

- **Agenda:**
  - Continue to develop quantification inputs and review results for priority policy options
- **Dates/Times for Next TWG Calls**
  - Monday, Sept. 23 (2:00 – 4 pm)



# Public Input, Announcements

# Reference Materials

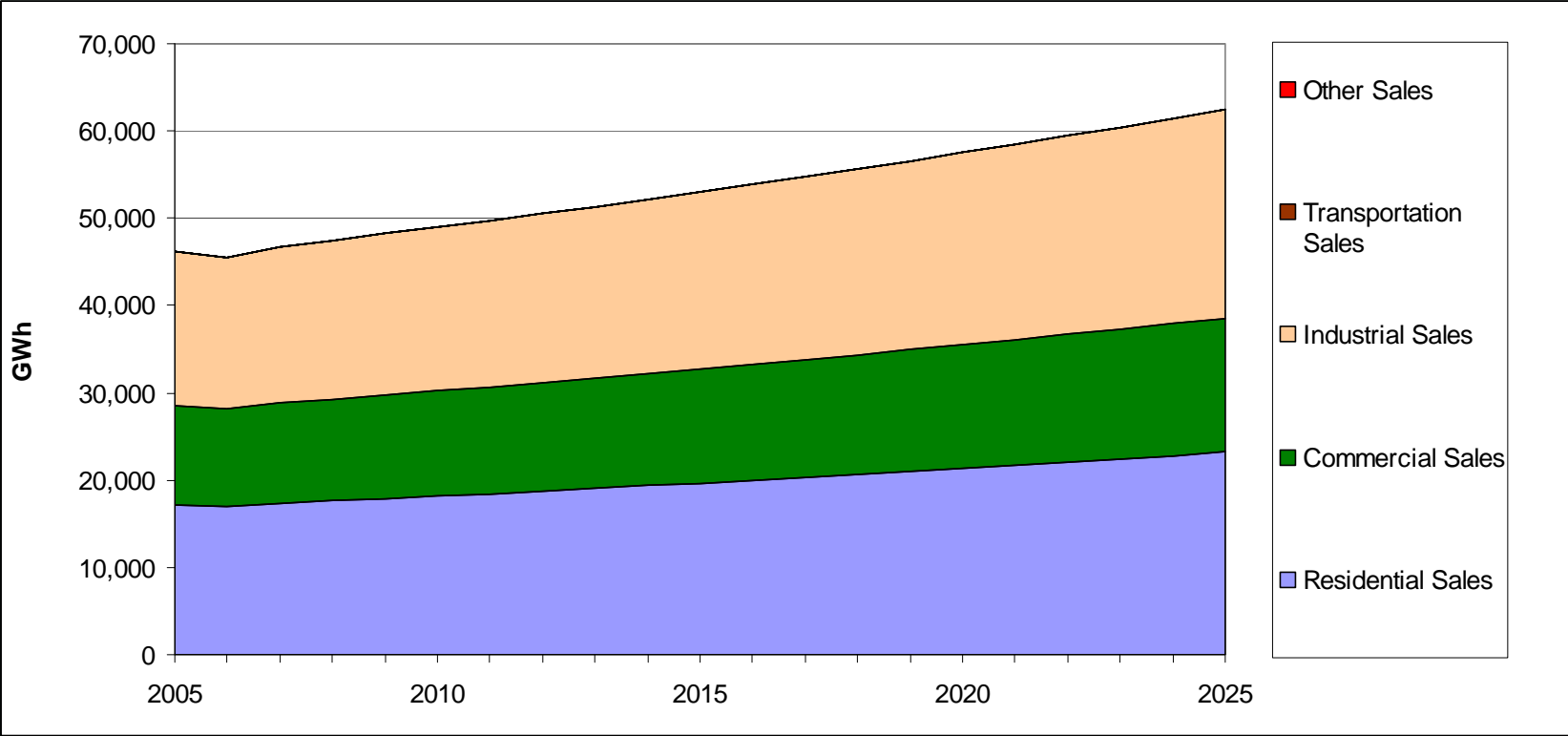
## Preliminary Results for the Arkansas Energy Supply GHG Forecast and Analysis of Stand- Alone Mitigation Options

# Outline

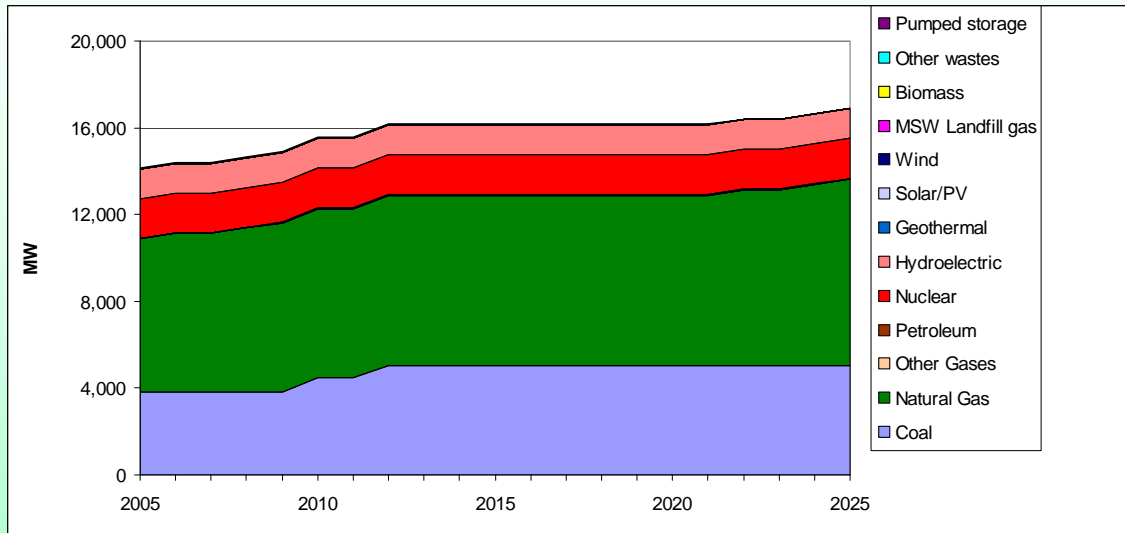
- Analytical framework for GHG forecast and analysis of energy supply options (*all issues resolved as per 22 August meeting*)
  - Electricity sales forecast
  - Electricity capacity expansion
  - Gross electricity generation forecast
  - Primary energy use forecast
  - Electricity imports/exports forecast
  - GHG emissions forecast
- Key inputs and results for selected mitigation options
  - ES-1 (*over to the RCI TWG*)
  - ES-2 (*not quantified*)
  - ES-3A (RPS) (*under discussion*)
  - ES-3B (Feed-in Tariffs) (*under discussion*)
  - ES-4 (Incentives) (*under preparation*)
  - ES-5 (*cap & trade - not quantified*)
  - ES-6 (CHP) (*under discussion*)
  - ES-7 (Geologic storage of CO<sub>2</sub>) (*under discussion*)
  - ES-9 (Nuclear) (*under discussion*)
  - ES-10 (*carbon tax - not quantified*)
  - ES-11 (Repowering) (*under preparation*)

# Summary of Results

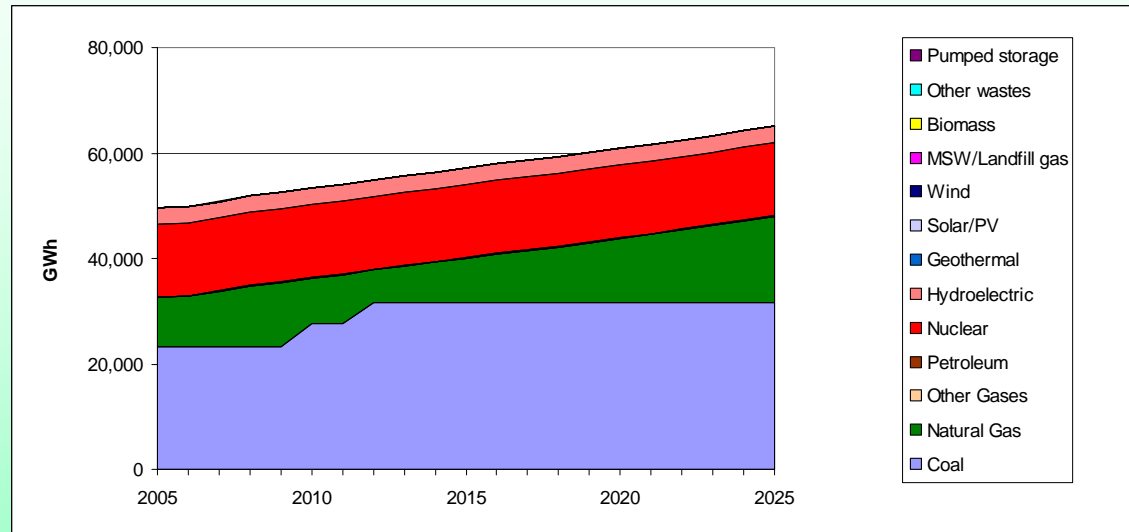
# Electricity sales forecast....



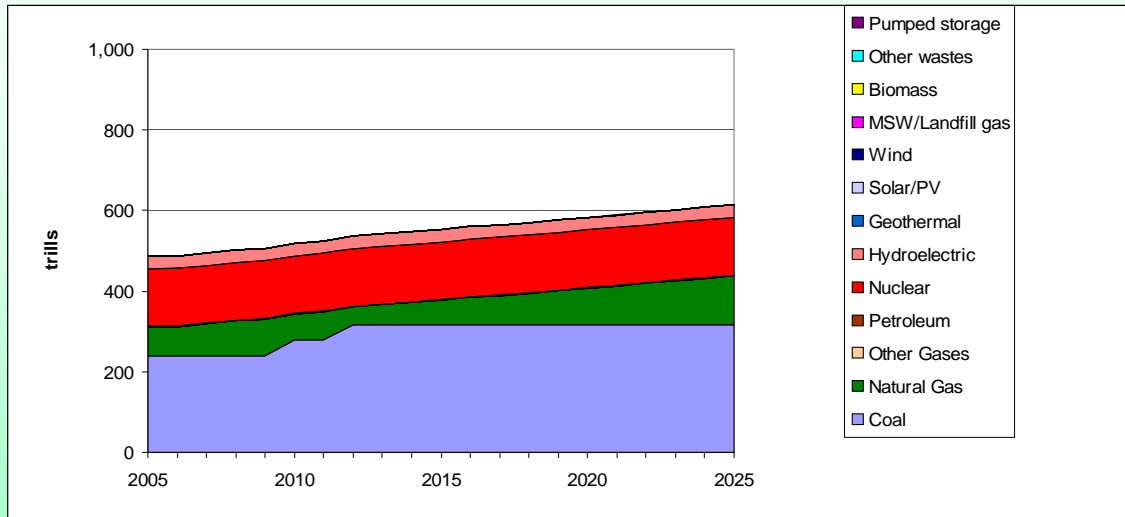
# Capacity expansion (total MW)....



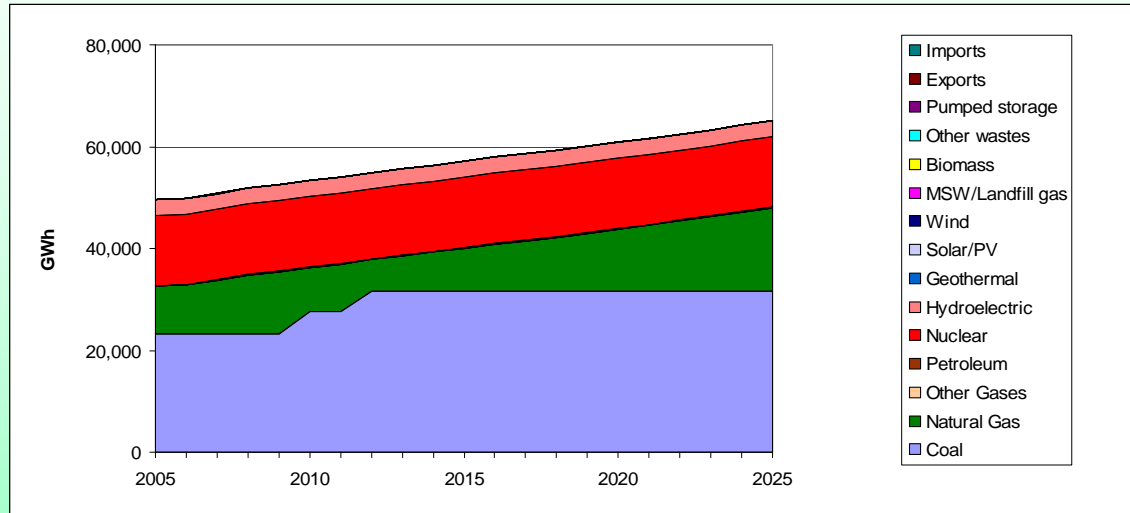
# Gross in-state generation (GWh)...



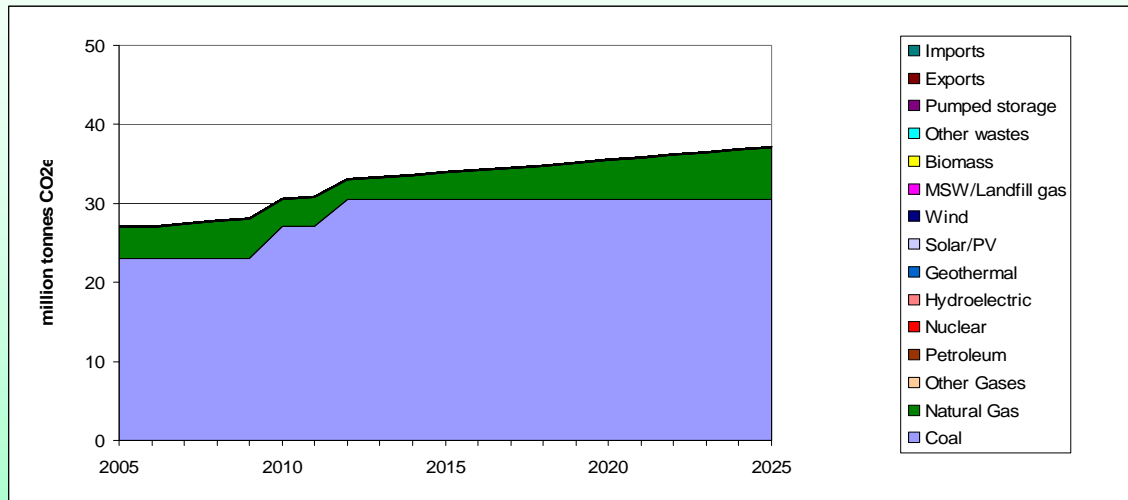
# Primary energy use (trillion Btu) ...



# Import/export generation ...



# GHG emissions (million tonnes CO<sub>2</sub>e)...



## Results for ES-3A (RPS):

Policy No.	Policy Option	GHG Reductions (MMtCO <sub>2</sub> e)			Net Present Value		Level of Support
		2015	2025	Total	2009–2025	Effectiveness	
				2009-2025	(Million \$)	(\$/tCO <sub>2</sub> e)	
Scenario #2	Plum point build in 2010; build Hempstead in 2012	0.3	3.6	21.9	\$718	\$32.79	Pending

## Results for ES-3B (Feed-in tariffs)

Option	Description	GHG Reductions			Net Present Value (Million \$)	Cost-Effectiveness (\$/tCO <sub>2</sub> e)	Level of Support
		2015	2025	Total 2009-2025			
ES-3B	REFIT	0.2	2.0	12.3	511.1	41.7	Pending

## Results for ES-6 (CHP):

Scenario	Description	GHG Reductions (MMtCO <sub>2</sub> e)			Net Present Value		Level of Support
		2015	2025	Total 2009-2025	2009-2025 (Million \$)	Effectiveness (\$/tCO <sub>2</sub> e)	
ES-6	CHP	0.6	2.9	20.0	\$886	\$44.30	Pending

## Results for ES-7 (Geologic sequestration):

Policy No.	Policy Option	GHG Reductions (MMtCO <sub>2</sub> e)			Net Present Value	Cost- Effectiveness (\$/tCO <sub>2</sub> e)	Level of Support
		2015	2025	Total 2009-2025	2009-2025 (Million \$)		
Scenario #1	no build of new Hempstead plant BAU (THIS IS THE BAU)						
Scenario #2	build Hempstead in 2012 with no mitigation or technology upgrade	-1.1	-1.8	-21.7	-\$649	\$29.9	Pending
Scenario #3	build Hempstead in 2012 with transition to CCS with CO <sub>2</sub> piped to MS for enhanced oil recovery	-1.1	0.7	-7.1	\$580	-\$81.3	Pending
Scenario #4	build Hempstead in 2012 with transition to CCS with CO <sub>2</sub> stored in AR	-1.1	0.7	-7.1	\$580	-\$81.3	Pending
Scenario #5	build Hempstead in 2012 as IGCC	-1.1	-1.8	-21.9	-\$316	\$14.4	Pending
Scenario #6a	build Hempstead in 2012, but with mitigation (NGCC-repowering)	0.7	0.6	9.5	-\$338	-\$35.6	Pending
Scenario #6b	build Hempstead in 2012, but with mitigation(Offsets)	0.7	0.6	9.5	\$395	\$8.3	Pending
Scenario #7a	no build of Hempstead, replaced with expanded energy efficiency, renewable energy, and natural gas (energy efficiency & wind)	1.9	1.3	21.9	\$1,178	\$53.7	Pending
Scenario #7b	no build of Hempstead, replaced with expanded energy efficiency, renewable energy, and natural gas (energy efficiency, wind, & NGCC)	2.1	1.5	24.9	\$547	\$21.9	Pending
Scenario #8	build Hempstead in 2020 with transition to CCS with CO <sub>2</sub> stored in AR	0.0	0.7	5.2	\$1,016	\$196.2	Pending

## Results for ES-9 (Nuclear)...

Scenario	Description	GHG Reductions (MMtCO <sub>2</sub> e)			Net Present Value	Effectiveness (\$/tCO <sub>2</sub> e)	Level of Support
		2015	2025	Total 2009-2025	2009-2025 (Million \$)		
ES-9	Nuclear	0.0	9.8	58.9	\$1,574	\$26.7	Pending

## Results for ES-11 (Repowering)...

Option	Description	GHG Reductions (MMtCO <sub>2</sub> e)			Net Present Value		Level of Support
		2015	2025	Total	2009–2025 (Million \$)	Effectiveness (\$/tCO <sub>2</sub> e)	
				2009–2025			
ES-11	Repower existing coal station with NGCC	2.3	2.3	31.8	\$1,568	\$49.33	Pending

# Analytical Framework

# Overall framework for developing the GHG mitigation analysis:

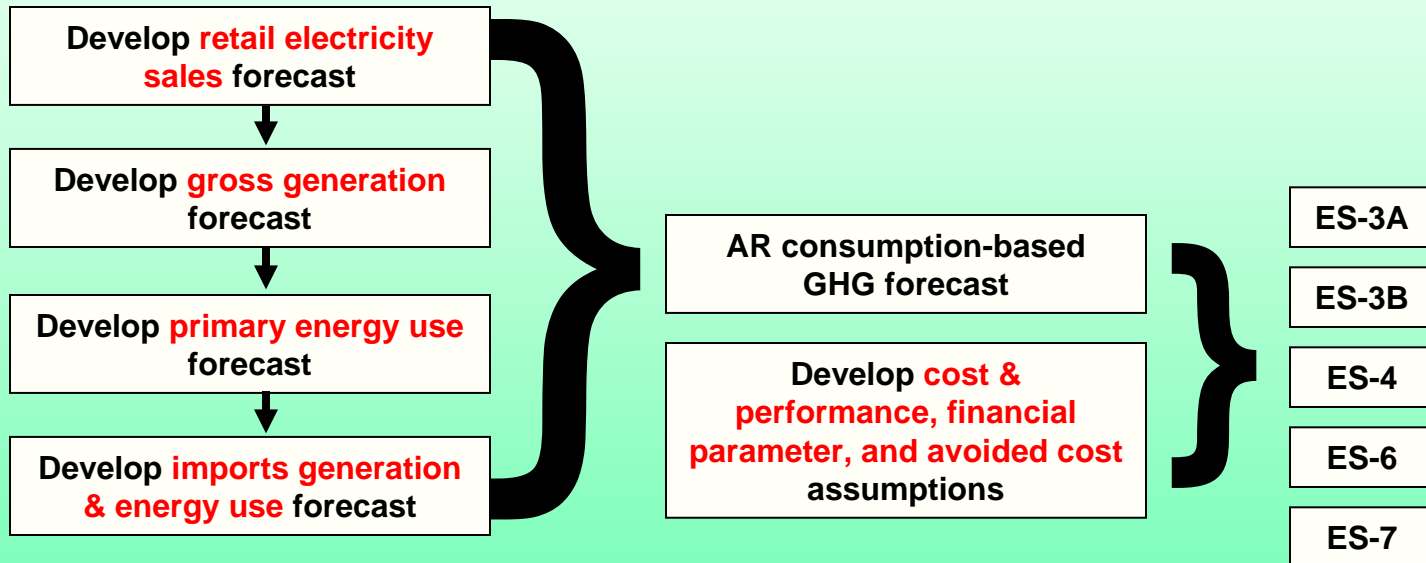
- Assume a planning horizon of 2005–2025;
- Consider two Reference Scenarios as follows:
  - **Reference Scenario #2:** Include **all** planned capacity additions INCLUDING the Hempstead plant;
- Assume a electricity sales growth rate over the 2005–2025 period as the previously discussed GHG forecast 1.37%/year (*decision from 25 July TWG meeting*)
- Assume a policy for electric self-sufficiency over the forecast period (i.e., no imports from SPP/SERC) and natural gas combined cycle capacity built as needed (*decision from 25 July TWG meeting*)
- Assume no net exports in any year (*decision from 8 August TWG meeting*)
- Consider a range of sources regarding cost and performance assumptions for new electric generating capacity

## The basic approach we've used in this memo....

- Explicitly document input data and results regarding the GHG forecast, including the following:
  - Sales forecast;
  - Planned capacity/retirement schedule
  - Generation forecast;
  - Primary energy use forecast.
  - GHG emissions forecast
- Explicitly document input data and results regarding the GHG mitigation analysis, including the following:
  - Cost & performance assumptions for new capacity
  - Financial parameter assumptions
  - Avoided electric expansion costs
  - GHG reductions and costs associated with each of the quantifiable energy supply mitigation options on a standalone basis
- Continue to solicit feedback from the ES TWG regarding any input data or assumptions that needs to be corrected/revisited

# We've followed the steps in the flow diagram below for the stand-alone analysis of GHG mitigation options....

- For utilities..... non-utility generators.... commercial CHP...and... industrial CHP....
- For each Reference Scenario....



## Spreadsheets where GHG emissions & mitigation option analysis are calculated available upon request....

- For the GHG forecast, the following spreadsheets have been developed:
  - Reference Scenario #2: “ES-7 (#2) - 3 August 2008.xls”
- For the assumptions used to analyze mitigation options, the following spreadsheet has been developed:
  - “Cost & performance assumptions.xls”
- For analysis of mitigation options, the following spreadsheet **folders** have been developed:
  - ES-3A
  - ES-3B (sensitivities for effectiveness of tariff)
  - ES-4
  - ES-6
  - ES-7 (sensitivities 1, 2, 3, 4, 5, 6, 7a, 7b, 8)
  - ES-9 (sensitivities low, mid, high costs)

## **Default assumptions have been assumed for the following....**

- Electricity sales forecast
- Transmission and distribution losses (%)
- Utility/NUG capacity expansion profile
- New capacity cost & performance characteristics
- Natural gas and other fossil fuel price projections
- Retirement schedule of 2005 capacity
- Incremental NGCC capacity to meet electricity self-sufficiency criterion
- GHG emission factors
- Financial parameters

## **Default assumptions can be readily changed to explore alternative scenarios....**

- Key objective is to have the TWG reach consensus on values for the complete set of default assumptions.
- Until then, the default assumptions included in the spreadsheet calculations are considered provisional

# Sales Forecast

# Default approach

- Obtain historical electricity sales by sector for AR for the Base Year, 2005
- Assume growth rate through 2025 in AR is the same as for the surrounding SPP/SERC region, using AEO2007 outputs
- Revise sales forecast as appropriate based on input from the ES TWG

## Focusing on electricity sales for AR in 2005....

- Total retail electricity sales in AR for the 2005 Base Year were 46,165 GWh (Source: US Electric Utility Sales data available from [http://www.eia.doe.gov/cneaf/electricity/page/sales\\_revenue.xls](http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls))
- Here's the breakdown of electricity sales by sector:

	2005
<b>Total</b>	
Residential Sales	17,134
Commercial Sales	11,366
Industrial Sales	17,665
Transportation Sales	0
Other Sales	0
All Sector Sales	46,165

## For the period 2006-2025....

- Average annual retail sales growth rate in the forecast period is assumed to be as follows (source: AEO2007)

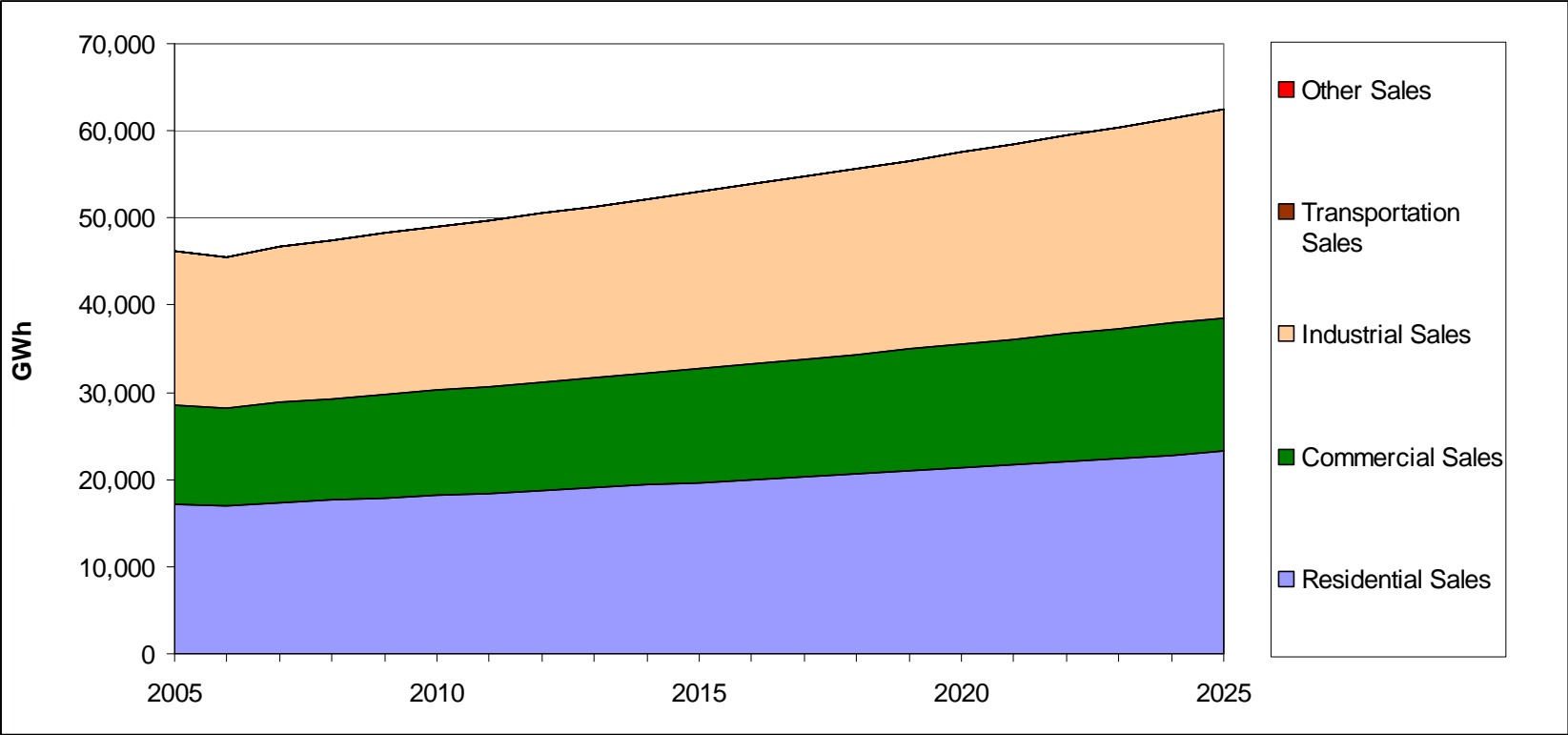
	2005	2025	Growth (%/yr)
<b>Total</b>			
Residential Sales	17,134	23,120	1.51%
Commercial Sales	11,366	17,604	2.21%
Industrial Sales	17,665	19,888	0.59%
Transportation Sales	0	0	NA
Other Sales	0	0	NA
All Sector Sales	46,165	60,612	1.37%

## For the period 2006-2025....

- Average annual retail sales growth rate in the forecast period is assumed to be the same as that of the SPP region (source: AEO2007)

	2005	2025	Growth (%/yr)
<b>Total</b>			
Residential Sales	17,134	23,120	1.51%
Commercial Sales	11,366	17,604	2.21%
Industrial Sales	17,665	19,888	0.59%
Transportation Sales	0	0	NA
Other Sales	0	0	NA
All Sector Sales	46,165	60,612	1.37%

# Results....



# Capacity Expansion

# Default approach

- Obtain in-state electric generating capacity for the Base Year, 2005
- Obtain state planned annual capacity retirement/derating schedule
- Obtain state planned annual capacity addition schedule, with and without Hempstead plant
- Revise capacity expansion plan as appropriate based on input from the ES TWG

# Electric generating capacity in 2005 ....

- Plant type-specific AR nameplate capacity data (MW) was obtained from the ES TWG subsequent to the 25 July meeting

	Utilities/NUGs			Commercial & Industrial CHP			Sector Total		
	Actual	Self-sufficiency criterion	Total	Retail	On-site	Total	Retail	On-site	Total
Coal	3,793	0	3,793	0	0	0	3,793	0	3,793
Natural Gas	6,468	614	7,082	41	187	228	7,123	187	7,310
Other Gases	0	0	0	0	0	0	0	0	0
Petroleum	23	0	23	0	0	0	23	0	23
Nuclear	1,834	0	1,834	0	0	0	1,834	0	1,834
Hydroelectric	1,387	0	1,387	0	1	1	1,387	1	1,388
Geothermal	0	0	0	0	0	0	0	0	0
Solar/PV	0	0	0	0	0	0	0	0	0
Wind	0	0	0	0	0	0	0	0	0
MSW Landfill gas	0	0	0	0	0	0	0	0	0
Biomass	0	0	0	54	244	298	54	244	298
Other wastes	0	0	0	0	0	0	0	0	0
Pumped storage	28	0	28	0	0	0	28	0	28
<b>Total</b>	<b>13,533</b>	<b>614</b>	<b>14,147</b>	<b>95</b>	<b>432</b>	<b>527</b>	<b>14,242</b>	<b>432</b>	<b>14,674</b>

## Focusing on planned capacity retirements/deratings during the period 2006–2025 ....

- The default assumption is the following schedule of planned capacity retirements (confirmed during the 25 July 2008 meeting)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Gases	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Petroleum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydroelectric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MSW Landfill gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other wastes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumped storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

# Planned capacity additions during the period 2006–2025

••••

- The coal plant capacities were assumed to be 665 MW for Plum Point and 600 MW for Hempstead based on state docket materials
- The natural gas capacities are combined cycle units built to satisfy the criteria that AR be self-sufficient in electricity production

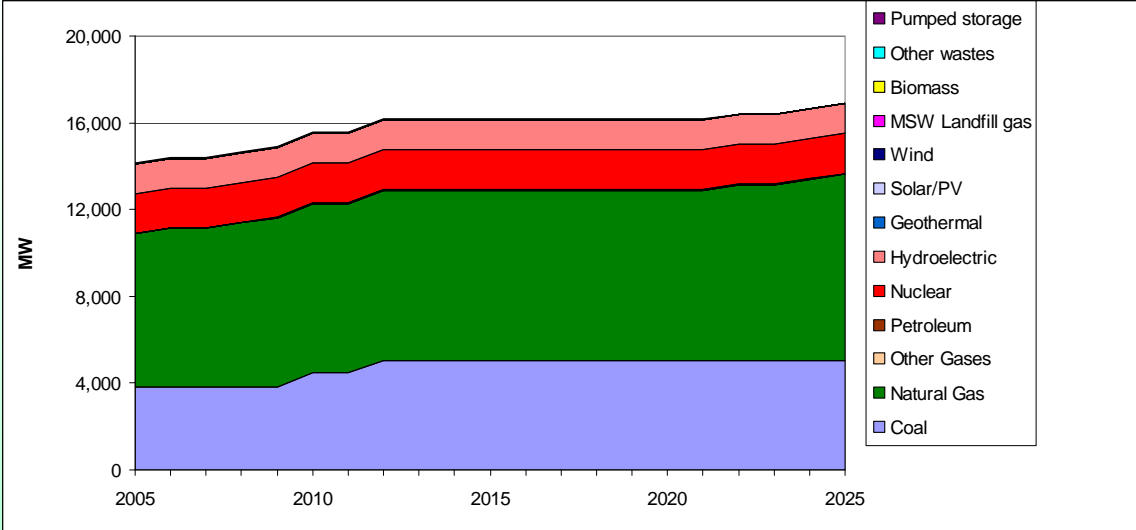
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Coal	0	0	0	0	0	665	0	600	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Gases	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Petroleum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydroelectric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MSW Landfill gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other wastes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumped storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	665	0	600	0	0	0	0	0	0	0	0	0	0	0	0	0

## Reference Scenario #2: Net annual planned capacity additions (MW) during the period 2005–2025 ....

- The new coal capacity is the Plum Point plant in 2010 and the Hempstead plant in 2012
- The natural gas annual capacity additions are combined cycle units built to satisfy the criteria that AR be self-sufficient in electricity production

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Coal	0	0	0	0	0	665	0	600	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Gas	614	250	0	250	250	0	0	0	0	0	0	0	0	0	0	0	0	250	0	250	250
Other Gases	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Petroleum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydroelectric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MSW Landfill gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other wastes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumped storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

# Results....



# Gross Generation Forecast

## Default approach

- Obtain historical net electricity generation by generator type for AR for the Base Year, 2005
- Assume on-site power plant electricity use in AR is the same as for the surrounding SPP/SERC region (using AEO2007 outputs) to calculate gross generation in the Base Year, 2005
- For existing units except natural gas-fired stations operational during the planning period, assume annual gross generation for 2006–2025 equals 2005 levels
- For existing NG-fired stations, assume they are backed down as needed to satisfy the criterion that there be no net exports in any year
- Revise gross generation forecast as appropriate based on input from the ES TWG

## **Focusing on on-site electricity use at utility/NUG power stations ....**

- Electric power production at utilities/NUGs is typically reported net of power used on site. In order to reflect the total level of GHG emissions, an estimate of on-site power use is needed.
- AEO2007 provides estimates of on-site power use by region (national average was 0.9% in 2005);
- **Default assumption: on-site power use at electric utilities/NUGs in AR follow the same pattern as in the SPP/SERC regions (0.8% in 2005).**

# Applying on-site electricity use to AR utilities and non-utility generators net generation in 2005....

- Total gross generation was 46,176 GWh for utilities/NUGs
- Total gross generation was 2,012 GWh for CHP facilities
  - Used the SPP/SERC average of about 80% to estimate on-site use for CHP facilities

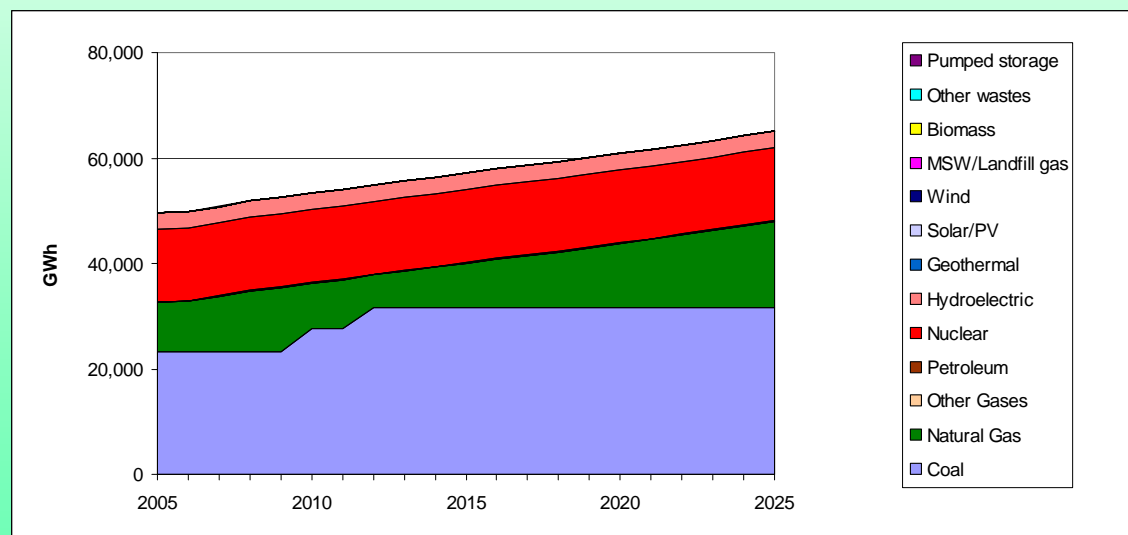
	Utilities/NUGs			Commercial & Industrial CHP			Sector Total		
	Actual	Self-sufficiency criterion	Total	Retail	On-site	Total	Retail	On-site	Total
Coal	23,227	0	23,227	0	0	0	23,227	0	23,227
Natural Gas	5,851	3,495	9,346	37	169	206	9,383	169	9,552
Other Gases	0	0	0	3	13	15	3	13	15
Petroleum	164	0	164	8	36	44	172	36	208
Nuclear	13,802	0	13,802	0	0	0	13,802	0	13,802
Hydroelectric	3,111	0	3,111	-1	-3	-3	3,111	-3	3,108
Geothermal	0	0	0	0	0	0	0	0	0
Solar/PV	0	0	0	0	0	0	0	0	0
Wind	0	0	0	0	0	0	0	0	0
MSW Landfill gas	0	0	0	0	0	0	0	0	0
Biomass	0	0	0	316	1,433	1,749	316	1,433	1,749
Other wastes	0	0	0	0	0	0	0	0	0
Pumped storage	20	0	20	0	0	0	20	0	20
<b>Total</b>	<b>46,176</b>	<b>3,495</b>	<b>49,671</b>	<b>363</b>	<b>1,648</b>	<b>2,012</b>	<b>50,034</b>	<b>1,648</b>	<b>51,683</b>

## Capacity factor assumptions for planned capacity additions....

- New power stations:
  - Plum Point: 75%
  - Hempstead: 75%
  - NGCC plants to satisfy self-sufficiency criterion: 65%
- Existing power stations:
  - All stations except NG-fired stations: same capacity factor as in 2005 for all years
  - NG-fired stations: capacity factor set to avoid net exports

# Results for Reference Scenario #2 (utilities/NUGs) (GWh) ....

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
<b>Utilities and non-utilities</b>																						
Coal	23,227	23,227	23,227	23,227	23,227	27,596	27,596	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538
Natural Gas	9,346	9,570	10,463	11,587	12,243	8,650	9,365	6,286	7,033	7,774	8,554	9,382	9,987	10,633	11,425	12,271	13,002	13,862	14,699	15,626	16,518	
Other Gases	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Petroleum	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164
Nuclear	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802
Hydroelectric	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MSW Landfill gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other wastes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumped storage	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (production-based)	49,671	49,895	50,788	51,912	52,568	53,343	54,058	54,922	55,669	56,410	57,190	58,018	58,623	59,269	60,060	60,907	61,638	62,498	63,335	64,262	65,154	
Total (consumption-based)	49,671	49,895	50,788	51,912	52,568	53,343	54,058	54,922	55,669	56,410	57,190	58,018	58,623	59,269	60,060	60,907	61,638	62,498	63,335	64,262	65,154	



# Primary Energy Forecast

## Default approach

- Obtain historical primary energy use by power plant fuel type for AR for the Base Year, 2005
- Calculate average heat rates by fuel type for the Base Year, 2005
- For existing units operational during the planning period, assume average heat rates for 2006–2025 equals 2005 levels
- Revise primary energy use forecast as appropriate based on input from the ES TWG

# Primary energy use in 2005 for electric utilities, NUGs, and CHP facilities....

- Total primary energy use was 485.1 trillion Btu for utilities/NUGs
- Total gross generation was 16.3 trillion Btu for CHP facilities
  - Used the SPP/SERC average of about 80% to estimate on-site use for CHP facilities

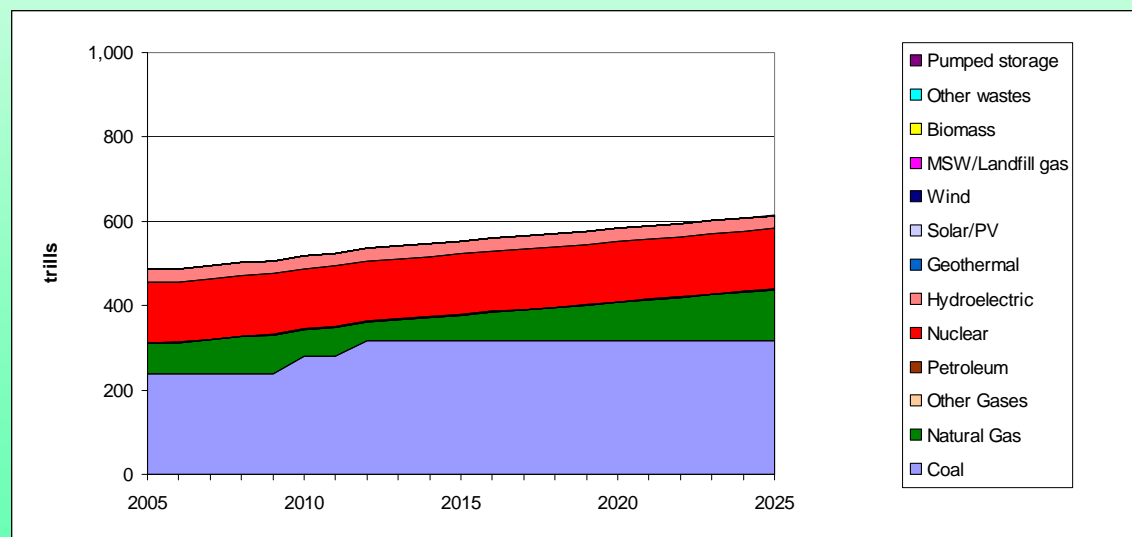
	Utilities/NUGs			Commercial & Industrial CHP			Sector Total		
	Actual	Self-sufficiency criterion	Total	Retail	On-site	Total	Retail	On-site	Total
Coal	238.9	0.0	238.9	0.0	0.0	0.0	238.9	0.0	238.9
Natural Gas	46.9	23.5	70.4	0.4	1.7	2.0	70.8	1.7	72.5
Other Gases	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Petroleum	1.8	0.0	1.8	0.1	0.2	0.3	1.8	0.2	2.1
Nuclear	142.9	0.0	142.9	0.0	0.0	0.0	142.9	0.0	142.9
Hydroelectric	30.9	0.0	30.9	0.0	0.0	0.0	30.9	0.0	30.9
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar/PV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MSW Landfill gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	0.0	0.0	0.0	2.5	11.4	13.9	2.5	11.4	13.9
Other wastes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pumped storage	0.2	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.2
<b>Total</b>	<b>461.6</b>	<b>23.5</b>	<b>485.1</b>	<b>2.9</b>	<b>13.3</b>	<b>16.3</b>	<b>488.0</b>	<b>13.3</b>	<b>501.3</b>

## Heat rate assumptions for planned capacity additions in AR....

- New power stations:
  - Plum point: 9,425 Btu/kWh (source: <http://sec.edgar-online.com/2007/02/08/0001193125-07-023538/Section19.asp>)
  - Hempstead: 9,000 btu/kWh (source: direct testimony of James A. Kobyra in docket 06-1254-U)
  - NGCC units (7,200 btu/kWh; 250 MW unit size; 65% annual capacity factor) (*decision at 8 August TWG meeting*)
- Existing power stations:
  - All stations: same heat rate factor as in 2005

# Results for AR for Reference Scenario #2 (trillion Btu) ....

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
<b>Utilities and non-utilities</b>																						
Coal	238.9	238.9	238.9	238.9	238.9	280.1	280.1	315.6	315.6	315.6	315.6	315.6	315.6	315.6	315.6	315.6	315.6	315.6	315.6	315.6	315.6	315.6
Natural Gas	18.7	19.2	21.0	23.3	24.6	17.4	18.8	12.6	14.2	15.7	17.2	18.9	20.1	21.5	23.1	24.8	26.3	28.0	29.7	31.6	33.4	33.4
Other Gases	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Petroleum	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Nuclear	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9	142.9
Hydroelectric	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar/PV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MSW Landfill gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other wastes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pumped Storage	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Exports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total (production-based)	433.4	433.9	435.7	437.9	439.3	473.2	474.7	504.0	505.5	507.0	508.6	510.2	511.5	512.8	514.4	516.1	517.6	519.4	521.1	522.9	524.8	524.8
Total (consumption-based)	433.4	433.9	435.7	437.9	439.3	473.2	474.7	504.0	505.5	507.0	508.6	510.2	511.5	512.8	514.4	516.1	517.6	519.4	521.1	522.9	524.8	524.8



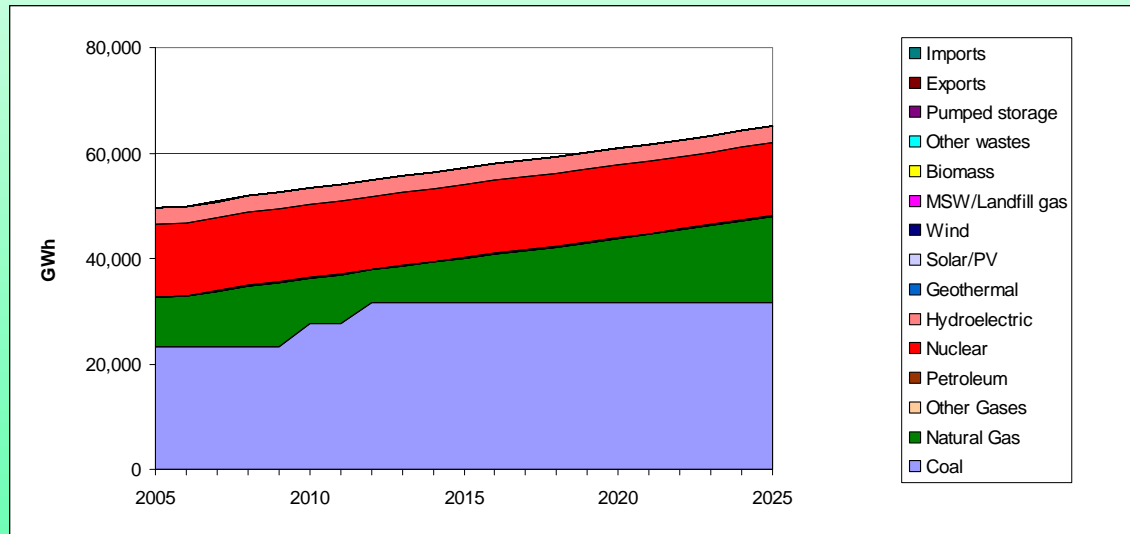
# Electricity Imports/Exports Forecast

## Default approach ....

- All AR demand for electricity met by in-state sources
- All additional power needed to satisfy in-state demand that exceeds power provided by planned additions is from NGCC (250 MW minimum capacity)
- New NGCC units are operated to their maximum assumed capacity factor (65%) in each year of operation, regardless of the AR supply/demand balance
- The “lumpiness” associated with NGCC capacity additions implies a commitment to annual exports until demand catches up

# Results for Reference Scenario #2....

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Utilities/NUGs	23,227	23,227	23,227	23,227	23,227	27,596	27,596	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538	31,538
Coal	9,346	9,570	10,463	11,587	12,243	8,650	9,365	6,286	7,033	7,774	8,554	9,382	9,987	10,633	11,425	12,271	13,002	13,862	14,699	15,626	16,518
Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Gases	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164
Petroleum	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802	13,802
Nuclear	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111	3,111
Hydroelectric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MSW/Landfill gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other wastes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumped storage	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (production-based)	49,671	49,895	50,788	51,912	52,568	53,343	54,058	54,922	55,669	56,410	57,190	58,018	58,623	59,269	60,060	60,907	61,638	62,498	63,335	64,262	65,154
Total (consumption-based)	49,671	49,895	50,788	51,912	52,568	53,343	54,058	54,922	55,669	56,410	57,190	58,018	58,623	59,269	60,060	60,907	61,638	62,498	63,335	64,262	65,154

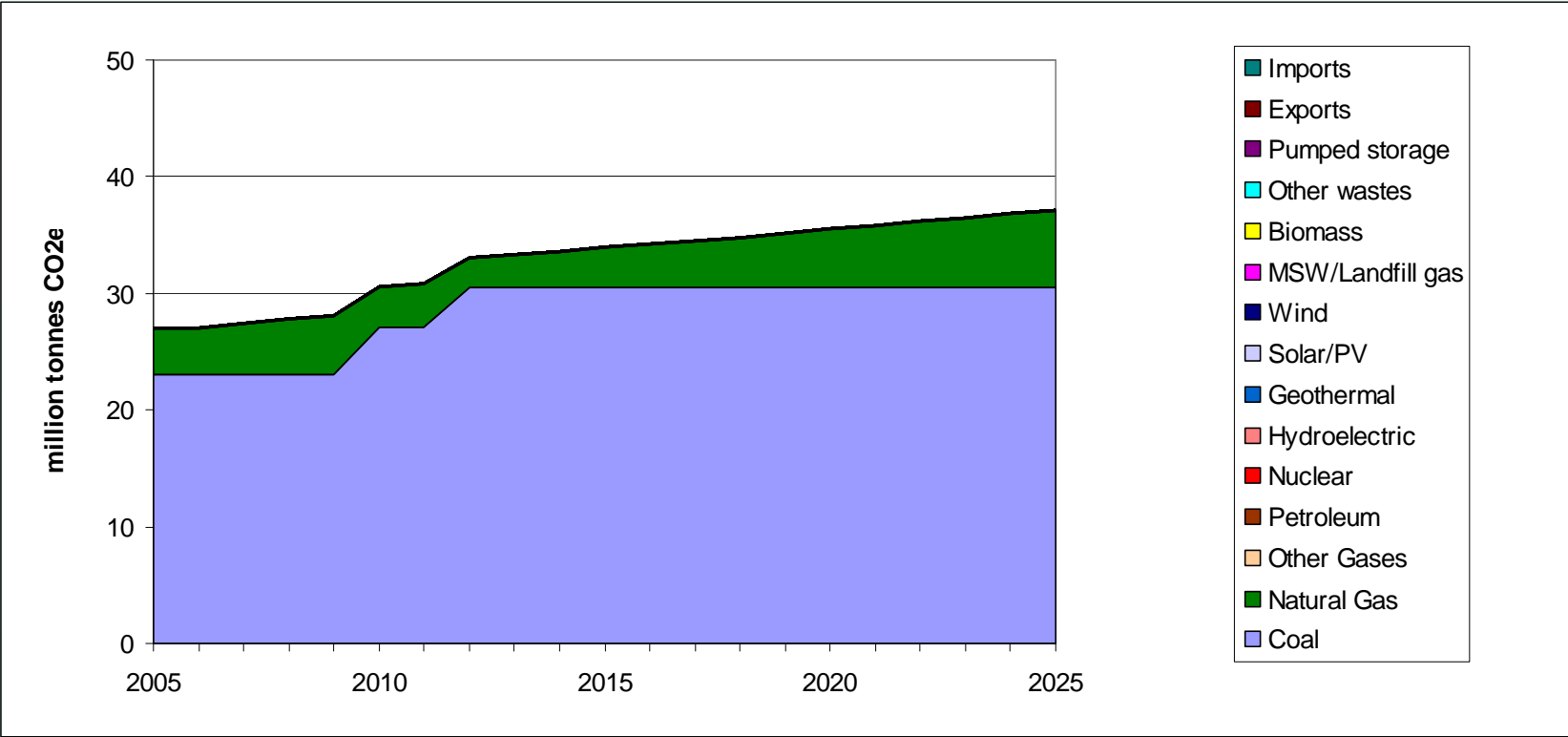


# **GHG Emission Forecast**

## Default approach ....

- In-state power production: Multiply annual levels of primary energy use at AR power stations by GHG emission factors for CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, CO<sub>2</sub>e (units of tonnes per MMBtu) for the period 2005–2025
- Power imports: Not applicable
- Power exports: Multiply annual levels of primary energy use associated with power imports to AR by the appropriate emission factor, assuming the average mix in AR

# Results for Reference Scenario #2....



# **ES-1: Green Power Purchases**

**The analysis of ES-1 is being  
undertaken by the RCI TWG...**

**ES-2**

**Technology Research &  
Development Fuels**

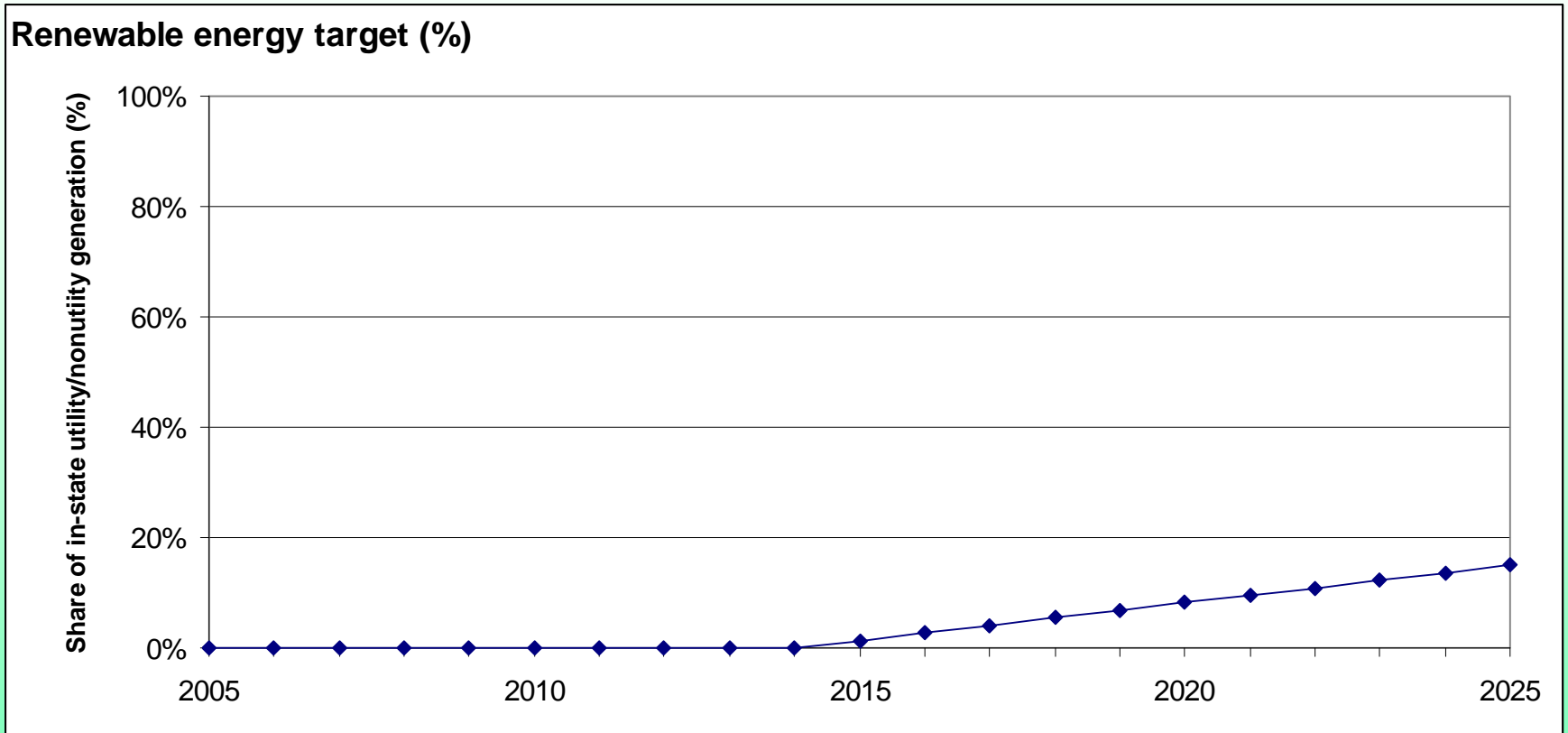
**ES-2 has been deemed  
unquantifiable by the ES TWG...**

# **ES-3A: Renewable Energy Portfolio**

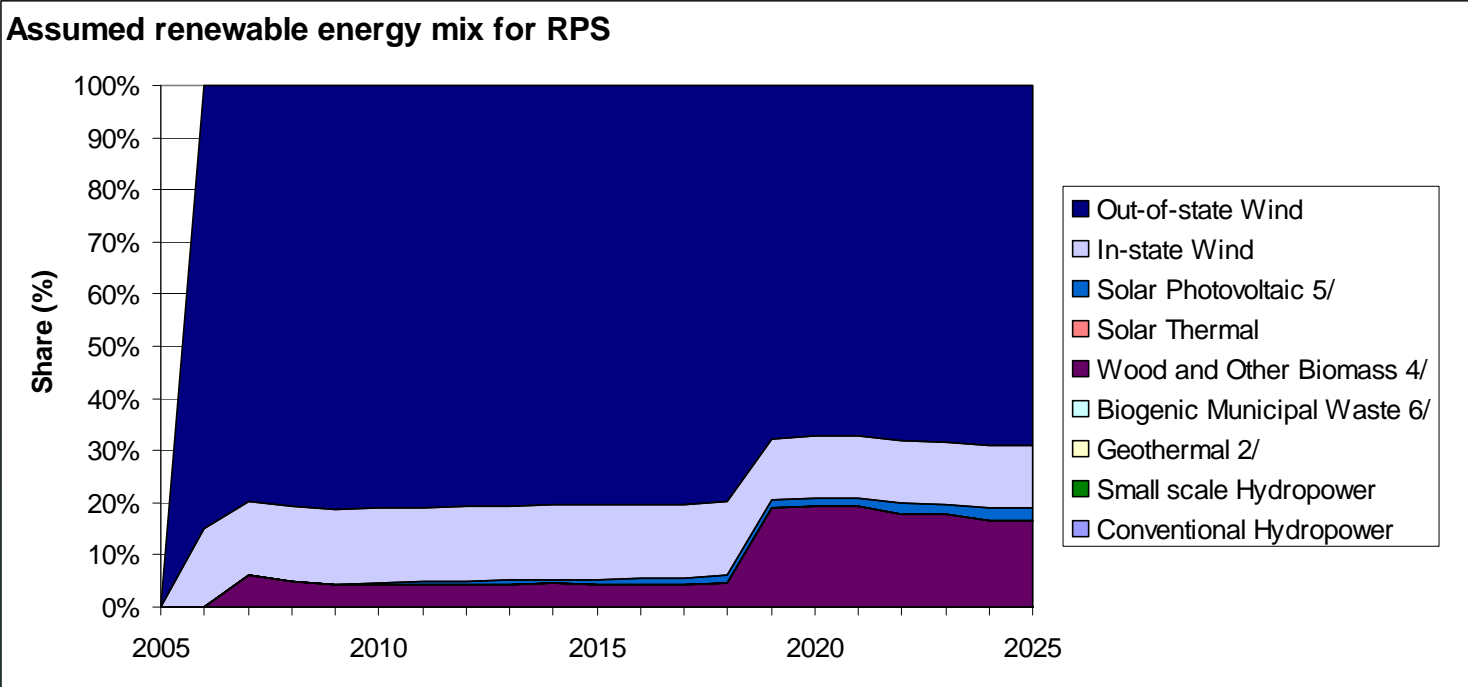
## Default analytical approach ...

- Assume AEO2008 outputs represent least cost expansion plan for each NERC region modeled.
- Assume renewable energy mix for the **SPP** region best approximates the AR renewable resource base
- Use combination of NETL and EIA cost and performance assumptions
- Assume 2% engineer, procure, construct adder (as per NETL)
- Assume 50% capital cost for the EIA estimate of wind to reflect recent studies
- Compare new renewable resources to avoided costs in AR: \$58.28/MWh (source: 2008 Entergy Arkansas Avoided Cost Filing as provided by AR RCI TWG)

# Renewable energy target...



# Renewable least-cost renewable energy mix (based on AEO2008 for SPP region)...



# Assumed cost and performance characteristics of new renewable capacity in AR...

	Cost component						Source	EPC Percenta
	Capital 2005 \$/kW	Trans 2005 \$/kW	Fixed O&M 2005 \$/kW-	Variable O&M 2005 mills/kW	Cap factor %	Heat rate btu/kWh		
Hydroelectric	1,530	0	13.13	3.30	47%	10,107	EIA	2%
Geothermal	1,530	0	13.13	3.30	47%	10,107	EIA	2%
MSW	1,627	0	107.50	0.01	75%	13,648	EIA	2%
Landfill gas	1,627	0	107.50	0.01	75%	13,648	EIA	2%
Biomass	1,871	0	50.18	2.96	75%	8,911	EIA	2%
Solar	4,406	80	10.99	0.00	35%	10,280	EIA	2%
In-state Wind	1,845	80	28.51	0.00	35%	10,280	EIA	2%
Out-of-state Wind	1,845	80	28.51	0.00	35%	10,280	EIA+	2%

## Estimated levelized costs for new renewable electric capacity (2005\$/MWh) in AR...

Capacity type	Capacity	Transmission	Fixed O&M	Variable O&M	Fuel	Total
Hydroelectric	59.9	0.0	3.1	3.3	0.0	66.3
Geothermal	40.4	0.0	3.1	3.3	0.0	46.8
MSW	27.1	0.0	16.2	0.0	0.0	43.2
Landfill gas	27.1	0.0	16.2	0.0	0.0	43.2
Biomass	31.1	0.0	7.5	2.9	22.0	63.6
Distributed solar PV	157.0	0.0	0.0	0.0	0.0	163.4
In-state Wind	65.7	2.9	9.2	0.0	0.0	77.8
Out-of-state Wind	65.7	2.9	9.2	0.0	0.0	77.8

# Capacity credit assumptions for renewable technologies...

## Capacity credit for intermittent renewables

Hydroelectric	50%
Geothermal	100%
Solar	15%
In-state Wind	15%
Out-of-state Wind	15%
MSW Landfill gas	100%
Biomass	100%

# Cost and performance assumptions regarding back-up capacity for reliability to account for intermittency...

Capacity type: Natural gas combustion turbine

Characteristics:

Overnight Capital	Trans	Fixed O&M	Variable O&M	Cap factor	Heat rate	
2005 \$/kW	2005 \$/kW	2005 \$/kW-yr	2005 mills/kWh	%	btu/kWh	
Natural Gas CT	428	0	3.4	11.4	50%	10,807

Levelized cost (2005\$/MWh):

Capacity type	Capacity	Transmission	Fixed O&M	Variable O&M	Fuel	Total
CT	13.4	0.0	0.3	3.5	20.0	37.2

# Results...

Policy No.	Policy Option	GHG Reductions (MMtCO <sub>2</sub> e)			Net Present Value		Level of Support
		2015	2025	Total 2009-2025	2009-2025 (Million \$)	Effectiveness (\$/tCO <sub>2</sub> e)	
ES-3A	RPS	0.3	3.6	21.9	\$719	\$32.83	Pending

# ES-3B: Feed-in Tariffs

## Default analytical approach ...

- Fully equivalent to the effectiveness of the German experience
- Relative to Feed-in tariff level set to have no more than a 5% rate impact by 2025
- Focus on wind and solar PV only (reasonably good data available)
- Assume societal cost of the option is the full cost of the technology if tariff level is less than busbar costs; at tariff level if more than busbar costs  
*(changed from cost of tariff itself at 22 August TWG meeting)*
- All other assumptions same as ES-3A

# Feed-in tariff effect in Germany

## a) Wind generation (units as noted)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Small scale wind capacity tariff (\$/kWh)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Large scale wind capacity tariff (\$/kWh)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Wind capacity (MW)	60	600	1,140	1,680	2,220	2,760	3,300	3,840	4,380	4,920	5,460	6,000
Small scale capacity (placeholder assumption)	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Large scale capacity (placeholder assumption)	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%

## a) Solar PV generation (units as noted)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Small scale solar PV tariff (\$/kWh)										0.65	0.65	0.65
Large scale solar PV tariff (\$/kWh)										0.61	0.61	0.61
Solar PV capacity capacity (MW)										600	1,350	2,100
Small scale capacity (placeholder assumption)										90%	90%	90%
Large scale capacity (placeholder assumption)										10%	10%	10%

# Results ...

Run	Option	Description	GHG Reductions			Net Present Value (Million \$)	Cost-Effectiveness (\$/tCO <sub>2</sub> e)	Level of Support
			2015	2025	Total 2009-2025			
11	ES-3B	REFIT	0.2	2.0	12.3	511.1	41.7	Pending

# **ES-4: Grid-Based Renewable Energy Incentives**

**Under preparation...**

# **ES-5: Regional Approaches**

**ES-5 has been deemed unquantifiable by the ES TWG**

# ES-6: CHP

## Default analytical approach ...

- Establish target for CHP penetration by 2025 based on draft EPA report.
- Calculate displaced fuel use and reduction from electricity associated with CHP units
- Compare new CHP to avoided electricity costs in AR: \$58.28/MWh (source: 2008 Entergy Arkansas Avoided Cost Filing as provided by AR RCI TWG)

# CHP resources and potential in AR (source: EPA)...

## Existing CHP in Arkansas

Application	Sites	MW
SIC 20: Food Processing	3	18.7
SIC 24: Wood Products	2	22.5
SIC 26: Paper	4	423.5
SIC 4952: WWTP	1	1.7
SIC 8060: Healthcare	1	8.5
SIC 8220: College/Univ	1	4.1
<b>Total</b>	<b>12</b>	<b>479.0</b>

## CHP Potential at Existing Industrial and Commercial/Institutional facilities 2003; within-the-fence thermal and electric

	100 kW to 1 MW		1 MW to 5 MW		5 MW to 20 MW		> 20 MW		Total	
	Sites	MW	Sites	MW	Sites	MW	Sites	MW	Sites	MW
Industrial	509	79	222	322	57	499	5	206	793	<b>1,105</b>
Commercial	2,001	220	109	117	13	73	0	0	2,123	<b>410</b>
<b>Total</b>	<b>2,510</b>	<b>298</b>	<b>331</b>	<b>439</b>	<b>70</b>	<b>572</b>	<b>5</b>	<b>206</b>	<b>2,916</b>	<b>1,515</b>

Note: Analysis assumes 100% of CHP potential is installed by 2025

# Combined heat and power (CHP) cost and performance characteristics...

Parameter

Average full-capacity-equivalent hours of operation

Fraction of new capacity

Average net heat rate by fuel (btu per kWh)

Useable cogenerated heat output (% energy input)

Fraction useable heat output replacing space/water/process heat

Average overnight installed capital costs by fuel type (2005\$/kW)

CHP transmission cost (2005\$/kW)

Economic life of system (years)

Fixed O&M costs (2005\$/kW)

Variable O&M costs (2005 \$/MWh)

2025				
NG	Biomass	Coal	electricity	oil
5,000	5,000	5,000		
83%	18%	0%		
10,000	13,000	12,000		
40%	40%	40%		
90%	90%	90%		
\$2,000	\$2,500	\$2,500		
\$0	\$0	\$0		
20	20	20		
0	0	0		
16.00	20.00	20.00		

# Results ...

Scenario	Description	GHG Reductions (MMtCO <sub>2</sub> e)			Net Present Value		Level of Support
		2015	2025	Total	2009–2025	Effectiveness	
				2009-2025	(Million \$)	(\$/tCO <sub>2</sub> e)	
ES-6	CHP	0.6	2.9	20.0	\$886	\$44.30	Pending

**ES-7: CO<sub>2</sub>  
Sequestration From  
New Fossil Plants**

## Default analytical approach ...

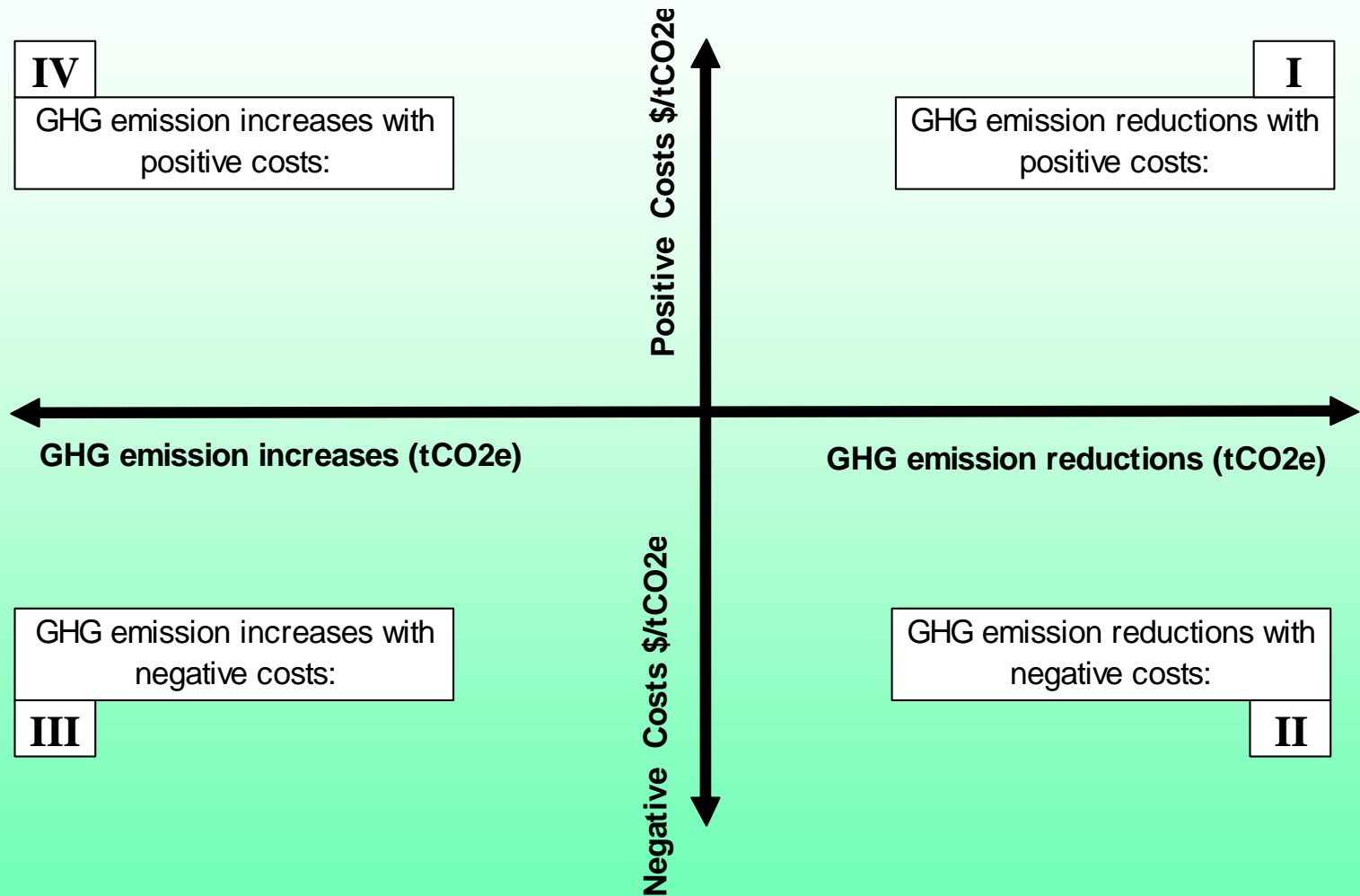
- Analysis undertaken relative to the following scenarios and sensitivities

Scenario #1	no build of new Hempstead plant BAU ( <b>THIS IS THE BAU</b> )
Scenario #2	build Hempstead in 2012 with no mitigation or technology upgrade
Scenario #3	build Hempstead in 2012 with transition to CCS with CO2 piped to MS for enhanced oil recovery
Scenario #4	build Hempstead in 2012 with transition to CCS with CO2 stored in AR
Scenario #5	build Hempstead in 2012 as IGCC
Scenario #6	build Hempstead in 2012, but with mitigation
	<i>Sensitivity 6(a) - NGCC-repowering</i>
	<i>Sensitivity 6(a) - Offsets</i>
Scenario #7	no build of Hempstead, replaced with expanded energy efficiency, renewable energy, and natural gas
	<i>Sensitivity 7(a) - displacement by energy efficiency and wind</i>
	<i>Sensitivity 7(a) - displacement by energy efficiency, wind, and NGCC</i>
Scenario #8	build Hempstead in 2020 with transition to CCS with CO2 stored in AR

## Summary of key assumptions ...

Key Assumptions		Capacity		Capacity	Heat rate (btu/kWh)			Carbon capture	Carbon capture
		(MW)	Type	factor (%)	No CCS	With CCS	Online year	(%)	online year
Scenario #1	Plum point	665	Pulv coal	75%	9,425	NA	2010	0%	NA
	Hempstead	NA	NA	NA	NA	NA	2026	NA	NA
Scenario #2	Plum point	665	Pulv coal	75%	9,425	NA	2010	0%	NA
	Hempstead	600	Pulv coal	75%	9,000	NA	2012	0%	NA
Scenario #3	Plum point	665	Pulv coal	75%	9,425	NA	2010	0%	NA
	Hempstead	600	Pulv coal	75%	9,000	15,366	2012	83%	2020
Scenario #4	Plum point	665	Pulv coal	75%	9,425	NA	2010	0%	NA
	Hempstead	600	Pulv coal	75%	9,000	15,366	2012	83%	2020
Scenario #5	Plum point	665	Pulv coal	75%	9,425	NA	2010	0%	NA
	Hempstead replacement	600	IGCC	75%	8,922	NA	2012	0%	NA
Scenario #6a	Plum point	665	Pulv coal	75%	9,425	NA	2010	0%	NA
	Hempstead replacement	600	NGCC	75%	6,719	NA	2012	0%	NA
Scenario #6b	Plum point	665	Pulv coal	75%	9,425	NA	2010	0%	NA
	Hempstead replacement	600	CO2 offsets	75%	NA	NA	2012	0%	NA
Scenario #7a	Plum point	665	Pulv coal	75%	9,425	NA	2010	NA	1
	Hempstead replacement	600	EE & wind	NA	NA	NA	2012	NA	1
Scenario #7b	Plum point	665	Pulv coal	75%	9,425	NA	2010	NA	1
	Hempstead replacement	600	EE, wind, NG	75%	NA	NA	2012	NA	1
Scenario #8	Plum point	665	Pulv coal	75%	9,425	NA	2010	0%	NA
	Hempstead	600	Pulv coal	75%	9,000	15,366	2020	83%	2020

# Summary of potential results . . .



## **Background for analysis of Scenario #2 ...**

- Plum Point plant comes on line as scheduled in 2010 (665 MW) with no CO<sub>2</sub> mitigation technology
- Hempstead plant also comes on line as scheduled in 2012 (600 MW) with no CO<sub>2</sub> mitigation technology
- Any in-state electric generation deficit NOT associated with meeting in-state electricity demand is assumed to be exported to the SPP/SERC region;

## **Background for analysis of Scenario #3 ...**

- Plum Point plant comes online as scheduled in 2010 (665 MW) with no CO<sub>2</sub> mitigation technology
- Hempstead plant also comes online as scheduled in 2012 (600 MW) with no CO<sub>2</sub> mitigation technology
- Hempstead plant (only) undergoes a retrofit in 2020 for carbon capture, transmission, storage (out-of-state), and monitoring;
- 50-mile connector pipeline is built between Hempstead plant and existing CO<sub>2</sub> pipeline in Mississippi
- Plum Point plant remains a pulverized coal unit with no CCS

## Background for analysis of Scenario #3 (cont'd) ...

- Assumed retrofit technology is chemical absorption with monoethanolamine (MEA); note: could also consider oxy-firing technology
- 50-mile connector pipeline in AR to an existing CO<sub>2</sub> pipeline located out-of-state (e.g., in MS)
- Connector pipeline is designed to be capable of a mass flow rate between 5 and 40 tCO<sub>2</sub>/yr
- Assumes carbon capture retrofitting cost and performance characteristics as below (source: Appendix 3.E of "The Future of Coal: Options for a Carbon-Constrained World," MIT, 2007:

	MEA	Oxy-firing
derating	41%	36%
Coal plant capacity factor (%)	75%	75%
Incremental Capital cost (2005\$/kW)	1,604	1,044
Incremental Capital cost (2005\$/kWh)	0.0000	0.0000
Incremental O&M cost (2005\$/kWh)	0.0121	0.0161
Heat rate before retrofit (btu/kWh)	9,749	9,749
Heat rate after retrofit (btu/kWh)	16,644	15,164
efficiency penalty (btu/kWh)	6,895	5,416
efficiency penalty (%)	71%	56%
Carbon capture (%)	83%	84%

## Background for analysis of Scenario #4 ...

- Plum Point plant comes on line as scheduled in 2010 (665 MW) with no CO<sub>2</sub> mitigation technology
- Hempstead plant also comes on line as scheduled in 2012 (600 MW) with no CO<sub>2</sub> mitigation technology
- Hempstead plant undergoes a retrofit in 2020 for carbon capture and storage
- 450-mile pipeline is built between Hempstead plant and ultimate CO<sub>2</sub> enhanced oil recovery (EOR) storage site in AR
- Plum Point plant remains a pulverized coal unit with no CCS

## Background for analysis of Scenario #4 (cont'd) ...

- CO<sub>2</sub> is assumed to be sequestered in EOR recovery sites in AR (note: good potential sites exist in AR as summarized in table below from recent study (NETL, 2008))

Table 3. Major Oil Reservoirs Screened as Favorable for CO<sub>2</sub>-EOR

Basin/Area	Major Oil Reservoirs Data Base	
	# of Total Reservoirs	# Favorable For CO <sub>2</sub> -EOR
1. Alaska	42	32
2. California	187	86
3. Gulf Coast (AL, FL, MS, LA)	298	155
4. Mid-Continent (OK, AR, KS, NE)	246	102
5. Illinois/Michigan	172	72
6. Permian (W TX, NM)	228	190
7. Rockies (CO, UT, WY)	187	92
8. Texas, East/Central	213	161
9. Williston (MT, ND, SD)	95	54
10. Louisiana Offshore	156	99
11. Appalachia (WV, OH, KY, PA)	188	68
Total	2,012	1,111

- Costs and performance characteristics same as for Scenario #3

## **Background for analysis of Scenario #5 ...**

- Plum Point plant comes on line as scheduled in 2010 (665 MW) with no CO<sub>2</sub> mitigation technology
- Hempstead plant also comes on line as scheduled in 2012 (600 MW) as an IGCC plant with CO<sub>2</sub> stored in AR

## Background for analysis of Scenario #5 (cont'd) ...

- The cost & performance characteristics of IGCC units are taken from a recent NETL study and are summarized below

### Assumed cost and performance characteristics of new capacity in AR

		Cost component				Source		EPC Percentage	
		Overnight Capital	Trans	Fixed O&M	Variable O&M				
		2005 \$/kW	2005 \$/kW	2005 \$/kW-yr	2005 mills/kWh	%	btu/kWh		
IGCC		1,803	0	34.40	6.33	80%	8,922	NETL	2%

Source: NETL, 2007 "Cost and Performance Baseline for Fossil Energy Plants," DOE/NETL-2007/1281, August 2007 (available at [http://www.netl.doe.gov/energy-analyses/pubs/Bituminous%20Baseline\\_Final%20Report.pdf](http://www.netl.doe.gov/energy-analyses/pubs/Bituminous%20Baseline_Final%20Report.pdf))

## Background for analysis of Scenario #6 ...

- Plum Point plant comes online as scheduled in 2010 (665 MW) with no CO<sub>2</sub> mitigation technology
- Hempstead plant also comes online as scheduled in 2012 (600 MW) but with two sensitivities
  - A) Plant comes on line in 2012 as an NGCC instead of a pulverized coal unit
  - B) Plant comes on line in 2012, but CO<sub>2</sub> offsets are purchased

## Background for analysis of Scenario #6 (cont'd) ...

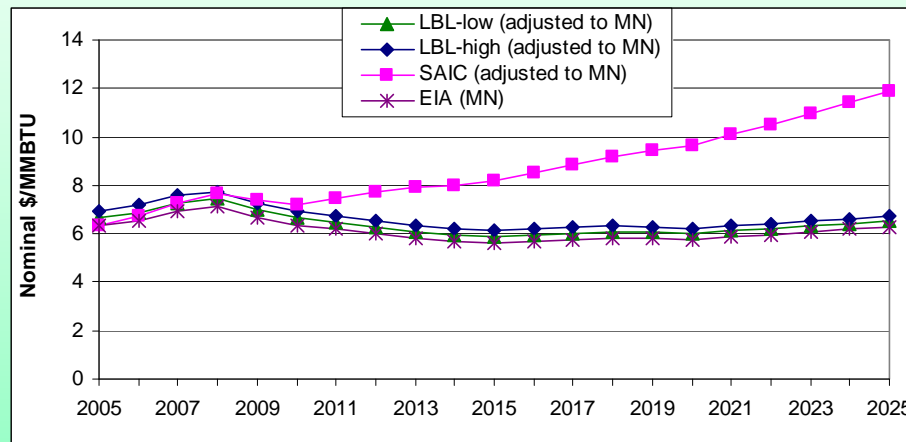
- For Scenario 6(a), the cost & performance characteristics of NGCC units are taken from a recent NETL study and are summarized below

### Assumed cost and performance characteristics of new capacity in AR

	Cost component						Source	EPC Percentage
	Overnight Capital	Trans	Fixed O&M	Variable O&M	Cap factor	Heat rate		
	2005 \$/kW	2005 \$/kW	2005 \$/kW- yr	2005 mills/kWh	%	btu/kWh		
Natural Gas CC	551	0	9.57	1.29	65%	6,719	NETL	2%

## Background for analysis of Scenario #6 (cont'd) ...

- The default NG fuel price forecast was adopted after a review of AEO2008 outputs for the West South Central region, a recent LBL study, and a recent SAIC study
- The SAIC forecast in the trajectory below has been used in the analysis thus far



Sources:

- 1) EIA, 2008, AEO2008; 2) LBL, 2006, memo Mark Bolinger and Ryan Wiser, Berkeley Lab (LBNL). December [http://eetd.lbl.gov/ea/emp/reports/53587\\_memo.pdf](http://eetd.lbl.gov/ea/emp/reports/53587_memo.pdf); 3) SAIC, 2007 "Greenhouse Gas Initiatives Analysis Using the National Energy Modeling System," A Study Performed for the Natural Gas Council, October

## Background for analysis of Scenario #7 ...

- Plum Point plant comes on line as scheduled in 2010 (665 MW) with no CO<sub>2</sub> mitigation technology
- Hempstead plant also comes on line as scheduled in 2012 (600 MW), but with two sensitivities:
  - A) Hempstead plant output is displaced, as practicable, by energy efficiency and wind generation
  - B) Hempstead plant output is displaced, as practicable, by energy efficiency, wind/natural gas generation

## Background for analysis of Scenario #7 (cont'd)...

- Two sensitivities:
  - Sensitivity #1: output from Hempstead plan replaced by mix of demand-side energy efficiency and wind power
  - Sensitivity #2: output from Hempstead plan replaced by mix of demand-side energy efficiency, wind power, and NGCC
- Three options for energy efficiency at a cost of \$30/MWh (source AR RCI TWG):
  - Option #1: Assumed a default upper bound for energy efficiency savings of 1.0%/yr
  - Option #2: Assumed a default upper bound for energy efficiency savings of 1.5%/yr, based on the recent Minnesota target
  - Option #3: Assumed a default upper bound for energy efficiency savings of 2.0%/yr, based on the Midwestern states target. *This is the default*
- Reliability considerations:
  - Electricity generation from wind backed up by NGCT (capital costs, variable O&M costs, and fixed O&M costs included)

# Basis for DSM assumptions ...

- Recently, several states have established legislative targets for demand-side energy efficiency. For example:
  - **Minnesota** established a trajectory of energy savings for electric utilities in through recent legislation (i.e., 216B.241 ENERGY CONSERVATION IMPROVEMENT) in which Subd. 1c. specified that “...each individual utility and association shall have an annual energy-savings goal equivalent to **1.5 percent** of gross annual retail energy sales unless modified by the commissioner under paragraph (d)....”
  - **12 Midwestern states:** The Midwest Governor’s Association on November 15, 2007, at its Midwest Energy Summit agreed upon a region-wide goal for energy efficiency savings to “...Meet at least **2 percent** of regional annual retail sales of natural gas and electricity through energy efficiency improvements by 2015, and continue to achieve an additional 2 percent in efficiency improvements every year thereafter.”
- Therefore, to explore the effect of increased investment in demand-side energy efficiency, the annual levels of efficiency improvement of 1%, 1.5%, and 2.0% were explored

## **Background for analysis of Scenario #8 ...**

- Plum Point plant comes on line as scheduled in 2010 (665 MW) with no CO<sub>2</sub> mitigation technology
- Hempstead plant also comes on line in 2020 (600 MW) as a pulverized coal unit but with CCS
- 450-mile pipeline is built between Hempstead plant and ultimate CO<sub>2</sub> enhanced oil recovery (EOR) storage site in AR

## Summary results ...

Policy No.	Policy Option	GHG Reductions (MMtCO <sub>2</sub> e)			Net Present Value	Cost- Effectiveness	Level of Support
		2015	2025	Total 2009-2025	2009-2025 (Million \$)	(\$/tCO <sub>2</sub> e)	
Scenario #1	no build of new Hempstead plant BAU (THIS IS THE BAU)						
Scenario #2	build Hempstead in 2012 with no mitigation or technology upgrade	-1.7	-1.9	-25.6	-\$615	\$24.1	Pending
Scenario #3	build Hempstead in 2012 with transition to CCS with CO <sub>2</sub> piped to MS for enhanced oil recovery	0.7	5.3	55.4	\$614	\$11.1	Pending
Scenario #4	build Hempstead in 2012 with transition to CCS with CO <sub>2</sub> stored in AR	0.7	5.3	55.4	\$614	\$11.1	Pending
Scenario #5	build Hempstead in 2012 as IGCC	0.6	2.9	39.6	-\$281	-\$7.1	Pending
Scenario #6a	build Hempstead in 2012, but with mitigation (NGCC-repowering)	0.2	0.2	4.2	\$0	\$0.0	Pending
Scenario #6b	build Hempstead in 2012, but with mitigation(Offsets)	0.2	0.2	4.2	\$395	\$8.3	Pending
Scenario #7a	no build of Hempstead, replaced with expanded energy efficiency, renewable energy, and natural gas (energy efficiency & wind)	4.4	6.6	92.7	\$2,099	\$22.7	Pending
Scenario #7b	no build of Hempstead, replaced with expanded energy efficiency, renewable energy, and natural gas (energy efficiency, wind, & NGCC)	4.7	7.2	106.0	\$1,191	\$11.2	Pending
Scenario #8	build Hempstead in 2020 with transition to CCS with CO <sub>2</sub> stored in AR	3.7	5.3	79.4	\$1,016	\$12.8	Pending

# ES-8: T&D System Upgrades

**Under preparation...**

# ES-9: Nuclear Power

# Background for analysis of nuclear power as a GHG reduction option ...

- New nuclear station comes online in 2020 (1,500 MW)
- Three cost and performance scenarios

	Min	Max	Central
EPC	50%	50%	50%
Base generation capital cost	3,066	3,999	3,533
Total capital cost (2005\$/kW)	4,599	5,999	5,299
Variable O&M (2005\$/MWh)	\$0.51	\$0.51	0.51
Fixed O&M (2005\$/kW-yr)	\$63.29	\$82.55	72.92
Nominal Heat Rate (BTU/kWh)	10,400	10,400	10,400
Capacity factor (%)	80%	90%	85%
Fuel (2005\$/mmbtu)	1.0	1.0	1.0

- Account for upstream fuel cycle emissions for resources displaced by nuclear station

# Upstream energy inputs for nuclear power ...

## Upstream CO2 emissions for nuclear electric power stations

Nuclear (GJ input per GJ of nuclear fuel delivered to the power station)	Mining & milling	Conversion & transformation	Enrichment	fuel fabrication	Fuel Chain
Natural gas	-	-	-	-	-
petroleum	-	-	-	-	-
Coal	-	-	-	-	-
gasoline	-	-	-	-	-
diesel	0.00077	0.00077	0.00326	0.00004	0.00483
heavy fuel oil	-	-	-	-	-
Biomass	-	-	-	-	-
electricity (end use)	0.00000	0.00000	0.00002	0.00000	0.00002
Total-fuels	0.00077	0.00077	0.00328	0.00004	0.00485

# Upstream energy inputs for coal power ...

## Upstream CO2 emissions for coal-fired electric power stations

<b>Coal</b> (GJ input per GJ of coal delivered to the power station)	Extraction	Beneficiation and processing	Transport	Generation	Fuel Chain
Natural gas	0.00007	-	-	-	0.00007
petroleum	0.00514	-	-	-	0.00514
Coal	0.00063	-	-	-	0.00063
gasoline	0.00021	-	-	-	0.00021
diesel	0.00395	-	0.00880	-	0.01275
heavy fuel oil	0.00049	-	-	-	0.00049
Biomass	-	-	-	-	-
electricity (end use)	0.00169	-	-	-	0.00169
Total-fuels	0.01219	-	0.00880	-	0.02099
Total-fuel & feedstock losses	1.01219	-	0.00880	-	1.02099

## Upstream energy inputs for NG power ...

Domestic NG (GJ input per GJ of coal delivered to the power station)	NG			Fuel Chain
	Extraction	Processing	Transport	
Natural gas	0.02253	0.02467	0.00367	0.05088
petroleum	-	-	-	-
Coal	-	-	-	-
gasoline	0.00022	-	-	0.00022
diesel	0.00245	0.00024	-	0.00269
heavy fuel oil	0.00022	-	-	0.00022
Biomass	-	-	-	-
electricity (end use)	0.00022	0.00072	-	0.00095
Total-fuels	0.02564	0.02564	0.00367	0.05496
Total-fuel & feedstock losses	1.02564	0.02564	0.00367	1.05496

## Summary results ...

Scenario	Description	GHG Reductions (MMtCO <sub>2</sub> e)			Net Present Value		Level of Support
		2015	2025	Total	2009–2025 (Million \$)	Effectiveness (\$/tCO <sub>2</sub> e)	
				2009–2025			
ES-9	Nuclear	0.0	9.8	58.9	\$1,574	\$26.7	Pending

# ES-10: Carbon Tax

**Requires more discussion...**

# ES-11: Repowering

# Results...

Option	Description	GHG Reductions (MMtCO <sub>2</sub> e)			Net Present Value		Level of Support
		2015	2025	Total 2009-2025	2009-2025 (Million \$)	Effectiveness (\$/tCO <sub>2</sub> e)	
ES-11	Repower existing coal station with NGCC	2.3	2.3	31.8	\$1,568	\$49.33	Pending