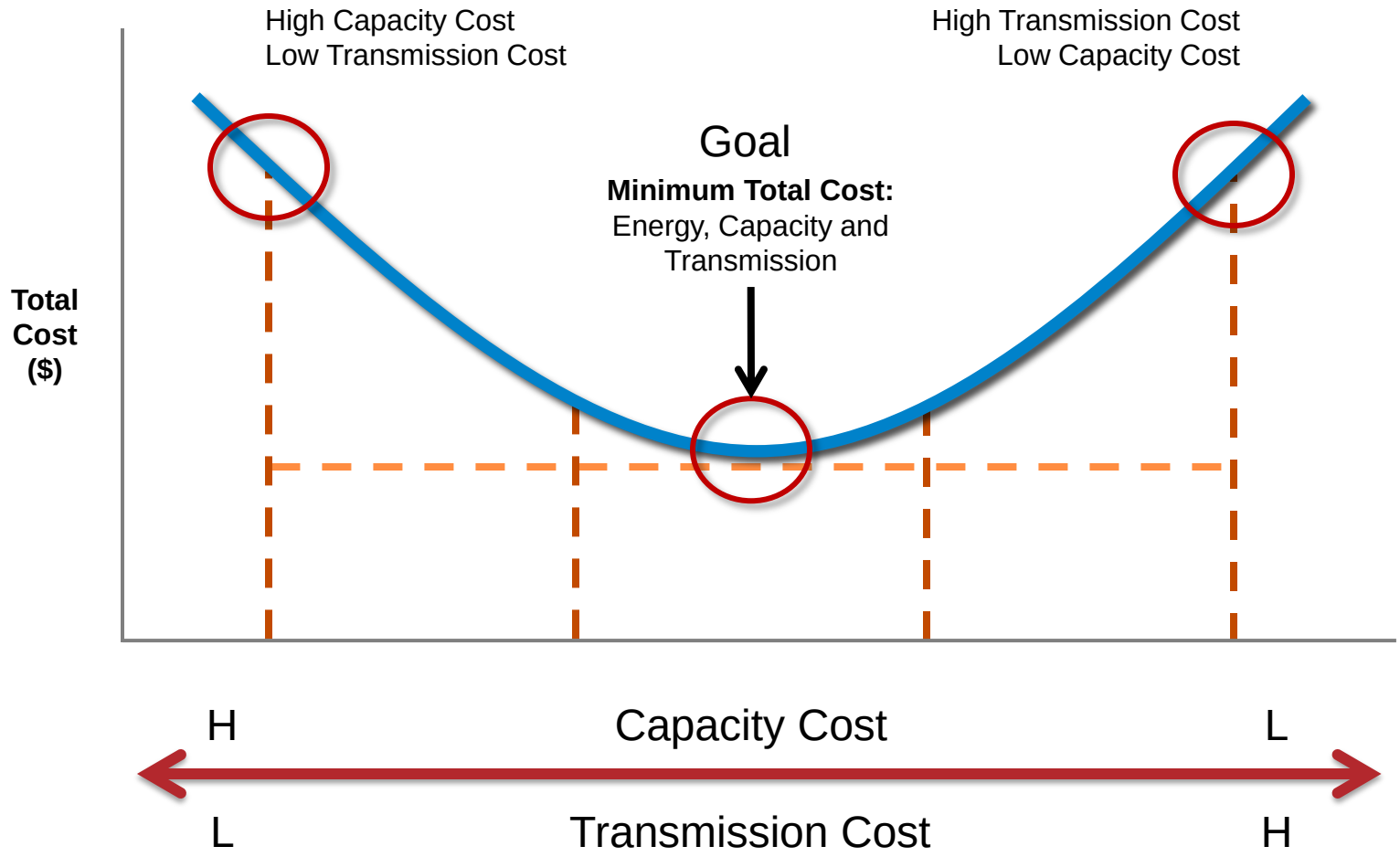
Development of Sensitivities and Scenarios in MISO's Transmission Planning Process

Contemporary Issues Technical Conference

September 1, 2015

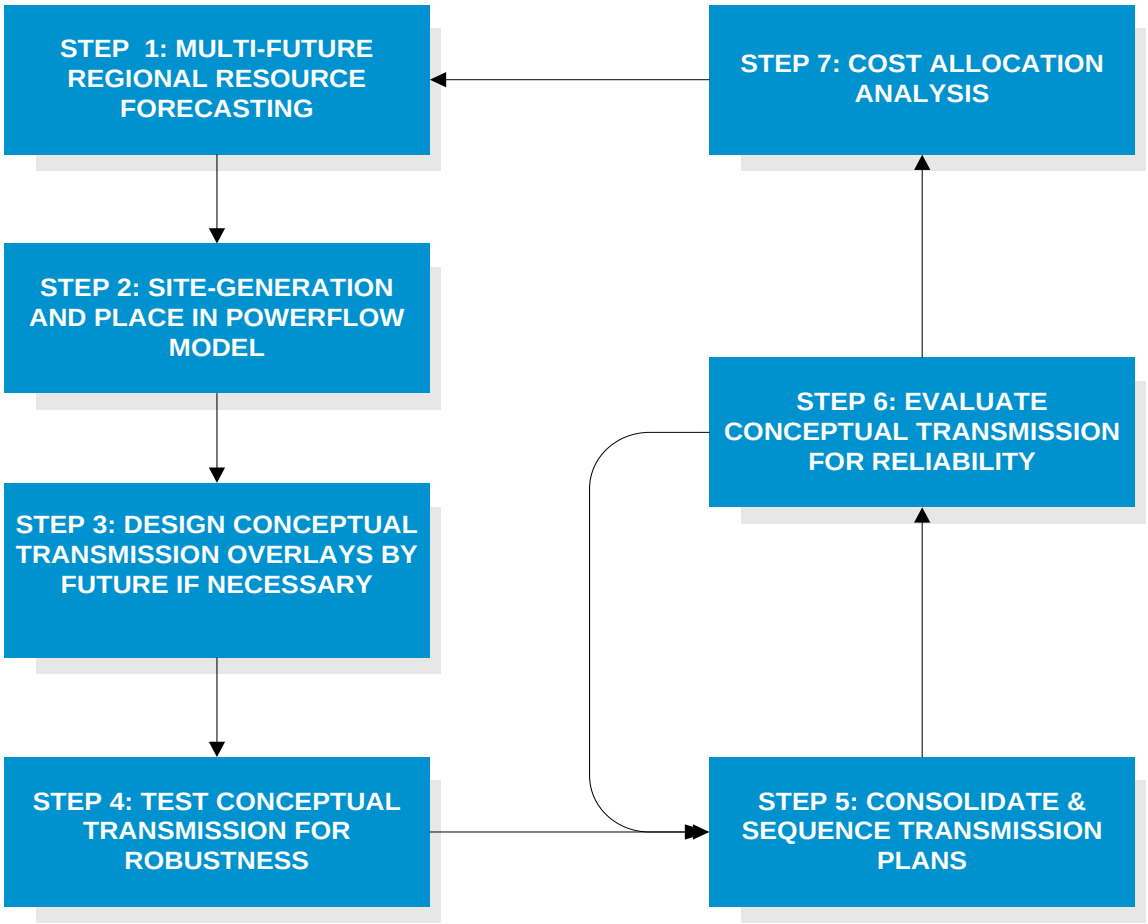
Focus is on minimizing the total cost of energy delivered to consumers



Why do we develop scenarios and sensitivities?

- One of the primary functions of MISO is Transmission Planning
- Annually, MISO develops Midcontinent Transmission Expansion Plan (MTEP) proposing a robust transmission plan that meets reliability and policy requirements
- High voltage transmission build takes about 8 to 10 years from planning to operation and this requires us to develop a view of the future to study and identify transmission that not only serves that future but a wide variety of futures (risk mitigation)
- Given different policy and economic drivers, resource forecasting is a necessary first step needed to obtain multiple long term views of theoretical supply and demand resource availability

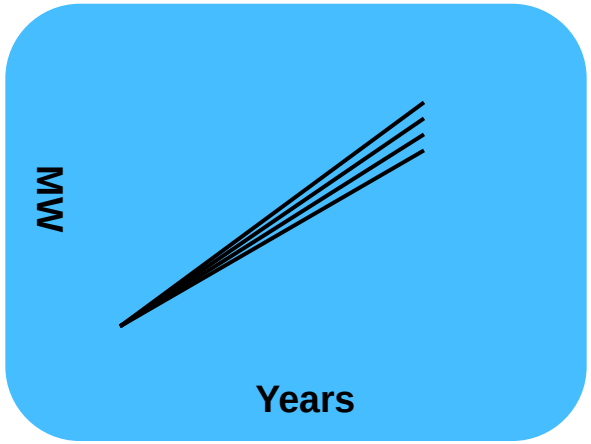
MISO's Value-Based Planning develops the most robust plan under a variety of scenarios – not the least-cost plan under a single scenario



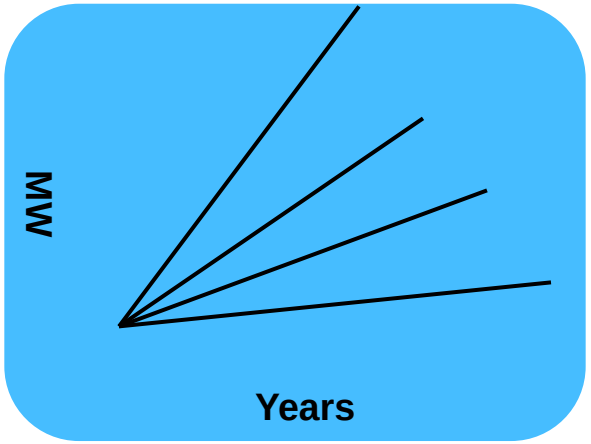
Futures development and Regional Resource Forecasting (RRF)

- Regional resource forecasting is needed to obtain multiple long term views of theoretical supply and demand resource availability given different policy and economic drivers
- Future scenarios and underlying assumptions are developed collaboratively with stakeholders through the Planning Advisory Committee
- The goal is a range of Futures linked to likely real-life scenarios that provides an envelope of outcomes that are significantly broad, rather than a single expected forecast

Narrow and less useful



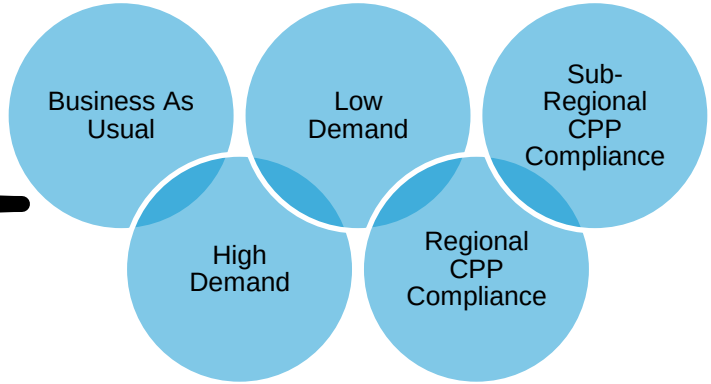
Broad and more useful



Multiple factors considered when developing Futures

Demand Response and Energy Efficiency Resources	Nuclear Renaissance	Generation Retirements
Fuel Prices	Fuel Supply Abundance	Distributed Generation
Smart Grid and Electric Vehicles	Demand and Energy growth	Emissions Limits
Fuel Supply Limitations	Federal renewable energy mandates (wind, solar, etc.)	Emission Costs (Carbon Tax)

Key Factors



MTEP16 Futures

Snapshot of futures studied over the years

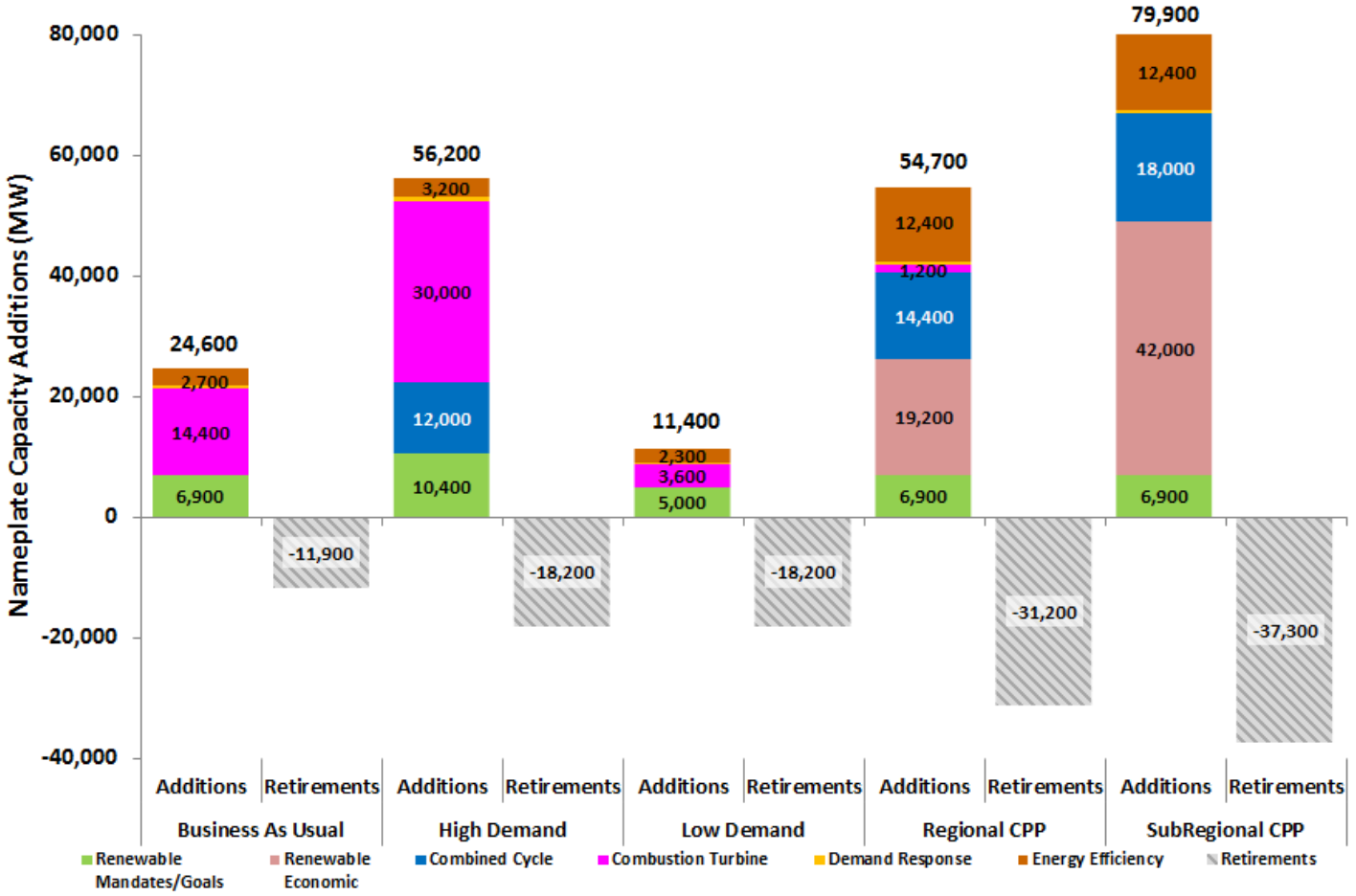
Drivers	Study	Futures	Uncertainties																																													
			Capital Costs																	Demand and Energy				Fuel Cost (Starting Price)				Fuel Escalations				Emission Costs				Siting				Other Variables							
			Coal	Combined Cycle	Combustion Turbine	Nuclear	Wind Onshore	IGCC	IGCC w/ CCS	CC w/ CCS	Pumped Storage Hydro	Compressed Air Energy Storage	Photovoltaic	Biomass	Conventional Hydro	Demand Response	Energy Efficiency	Wind Offshore	Distributive Generation - Peak	Demand Response Level	Energy Efficiency Level	Demand Growth Rate	Energy Growth Rate	Gas	Oil	Coal	Uranium	Gas	Oil	Coal	Uranium	SO_2	NO_x	CO_2	Hg	Limited Transmission	Delayed Lead Time on Coal/IGCC	Nuclear Siting Limitations	CC&CT Siting Limitations	Inflation	Coal Retirements	Wind Penetration Mandate	National Mandates	% of Carbon Reduction	Wind Credit	Wind Capacity Credit	Discount Rate
Business As Usual	MTEP-08	Reference	M	M	M	M	M	M	M	M	-	-	-	-	-	M	M	-	-	-	-	-	-	M	M	M	M	-	-	-	-	M	M	M	M	M	M	M	M	M	-	M	-	-	-	-	M
	MTEP-09	Reference	L	L	ML	L	L	L	ML	ML	-	-	-	-	-	-	-	-	-	-	-	MH	MH	MH	M	M	ML	H	H	ML	ML	M	M	L	H	-	-	-	-	MH	M	M	L	-	M	M	M
	MTEP-10	Business as Usual MLD+E	MH	MH	MH	MH	MH	MH	-	-	MH	-	M	M	M	-	-	M	M	-	-	ML	ML	L	M	M	H	L	L	L	L	M	M	L	M	-	-	-	-	L	M	M	L	L	-	L	MH
	MTEP-11	Business as Usual	M	M	M	M	M	M	-	-	M	M	M	M	M	-	-	M	M	M	M	M	M	M	M	M	M	L	L	L	L	M	M	L	M	-	-	-	-	L	M	L	L	L	-	-	-
	MTEP-12	Business as Usual	M	M	M	M	L	M	-	-	M	M	M	M	M	-	-	M	M	M	M	M	M	M	M	M	M	L	L	L	L	M	M	L	-	-	-	-	-	L	M	M	L	-	-	-	-
	MTEP-13	Business as Usual	M	M	M	M	M	M	M	M	M	M	M	M	M	-	-	M	-	M	M	M	M	M	M	M	M	-	M	M	M	L	L	L	-	-	-	-	-	M	L	M	-	-	-	-	-
Environmental	MTEP-08	DOE 20% Wind Mandate	M	M	M	M	M	M	M	M	-	-	-	-	-	M	M	-	-	-	-	M	M	M	M	M	M	-	-	-	-	M	M	M	M	M	M	M	M	M	-	MH	-	-	-	-	M
	MTEP-08	DOE 30% Wind Mandate	M	M	M	M	M	M	M	M	-	-	-	-	-	M	M	-	-	-	-	M	M	M	M	M	M	-	-	-	-	M	M	M	M	M	M	M	M	M	-	H	-	-	-	-	M
	MTEP-08	Environmental	M	H	H	M	M	M	H	H	-	-	-	-	-	H	H	-	-	-	-	L	L	H	H	L	M	-	-	-	-	M	M	H	H	M	M	L	M	H	-	M	-	-	-	-	M
	MTEP-08	Regulatory Limitation	M	H	H	M	M	M	M	M	-	-	-	-	-	H	H	-	-	-	-	M	M	H	H	M	M	-	-	-	-	M	M	M	M	H	MH	M	H	M	-	M	-	-	-	-	M
	EWITS	Scenario 1,2,3 20% Fed Wind	L	L	ML	L	L	L	ML	ML	-	-	-	-	-	-	-	-	-	-	-	MH	MH	MH	M	M	ML	H	H	ML	ML	M	M	L	H	-	-	-	-	MH	M	L	M	-	M	H	M
	MTEP-10	Federal RPS Future	MH	MH	MH	MH	MH	MH	MH	MH	MH	-	M	M	M	-	-	M	M	-	-	ML	ML	L	M	M	H	M	M	M	M	M	M	L	M	-	-	-	-	M	M	M	M	L	-	L	MH
	MTEP-10	Combined Policy	MH	H	H	H	H	H	H	H	H	-	MH	MH	MH	-	-	MH	MH	-	-	ML	VH	M	M	L	VH	M	M	M	M	M	M	MH	M	-	-	-	-	M	H	M	M	H	-	L	MH
	MTEP-11	Federal RPS	M	M	M	M	M	M	M	M	M	M	M	M	M	-	-	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	L	M	-	-	-	-	M	M	M	M	L	-	-	-
	MTEP-11	Combined Policy	M	H	H	H	H	H	H	H	H	H	H	H	H	-	-	H	H	M	M	M	M	H	M	L	H	M	M	M	M	M	M	M	M	-	-	-	-	M	H	L	M	H	-	-	-
	MTEP-12	Combined Policy	H	H	H	H	L	H	H	H	H	H	H	H	H	-	-	M	H	M	M	M	H	H	M	L	H	M	M	M	M	M	M	M	-	-	-	-	-	M	H	M	M	-	-	-	-
	MTEP-13	Environmental	M	M	M	M	M	M	M	M	M	M	M	M	M	-	-	M	-	M	M	M	M	H	L	L	H	-	M	M	M	L	L	M	-	-	-	-	-	M	H	H	-	-	-	-	-
High Growth	MTEP-10	BAU with H growth for D+E	MH	MH	MH	MH	MH	MH	MH	MH	MH	-	M	M	M	-	-	M	M	-	-	H	VH	L	M	M	H	M	M	M	M	M	M	L	M	-	-	-	-	M	M	M	L	L	-	L	MH
	MTEP-10	BAU H Demand & MH Energy	MH	MH	MH	MH	MH	MH	-	-	MH	-	M	M	M	-	-	M	M	-	-	H	MH	L	M	M	H	MH	MH	MH	MH	M	M	L	M	-	-	-	-	H	M	M	L	L	-	L	MH
	MTEP-11	BAU with High D & E	M	M	M	M	M	M	M	M	M	M	M	M	M	-	-	M	M	M	M	H	H	M	M	M	M	M	M	M	M	M	M	L	M	-	-	-	-	M	M	L	L	L	-	-	-
	MTEP-12	Historical Growth	M	M	M	M	L	M	M	M	M	M	M	M	M	-	-	M	M	M	M	H	H	M	M	M	M	M	M	M	M	M	M	L	-	-	-	-	-	M	M	M	L	-	-	-	-
	MTEP-13	Robust Economy	M	M	M	M	M	M	M	M	M	M	M	M	M	-	-	M	-	M	M	H	H	H	M	M	M	-	H	H	H	L	L	L	-	-	-	-	-	H	L	M	-	-	-	-	-
High Retirements	MTEP-10	Carbon Cap & trade	MH	H	H	H	MH	H	H	H	H	-	MH	MH	MH	-	-	MH	MH	-	-	L	L	M	M	L	VH	M	M	M	M	M	M	MH	M	-	-	-	-	M	H	M	L	H	-	L	MH
	MTEP-10	Carbon Cap with Nuclear	MH	H	H	H	MH	H	-	-	H	-	MH	MH	MH	-	-	MH	MH	-	-	L	L	M	M	L	VH	L	L	L	L	M	M	MH	M	-	-	-	-	L	H	M	L	H	-	L	MH
	MTEP-11	Carbon Constraint	M	H	H	H	M	H	-	-	H	H	H	H	H	-	-	H	H	M	M	L	L	H	M	L	H	L	L	L	L	M	M	M	M	-	-	-	-	L	H	L	L	H	-	-	-
	MTEP-13	Generation Shift	M	M	M	M	M	M	M	M	M	M	M	M	M	-	-	M	-	M	M	L	L	M	L	L	M	-	L	L	L	L	L	L	-	-	-	-	-	L	M	M	-	-	-	-	-
Low Growth	MTEP-12	Limited Growth	H	M	M	M	L	M	-	-	M	M	M	M	M	-	-	M	M	M	M	L	L	M	M	L	H	L	L	L	L	M	M	L	-	-	-	-	-	L	M	M	L	-	-	-	-
	MTEP-13	Limited Growth	M	M	M	M	M	M	M	M	M	M	M	M	M	-	-	M	-	M	M	L	L	L	M	L	M	-	L	L	L	L	L	L	-	-	-	-	-	L	L	M	-	-	-	-	-
Other	MTEP-08	Gas Only Future	M	M	M	M	M	M	M	M	-	-	-	-	-	M	M	-	-	-	-	M	M	M	M	M	M	-	-	-	-	M	M	M	M	M	H	H	M	M	-	M	-	-	-	-	M
	MTEP-09	Gas Only Future	L	L	ML	L	L	L	ML	ML	-	-	-	-	-	-	-	-	-	-	-	MH	MH	MH	M	M	ML	H	H	ML	ML	M	M	L	H	-	-	-	-	MH	M	M	L	-	M	M	M

MTEP16 Futures Matrix

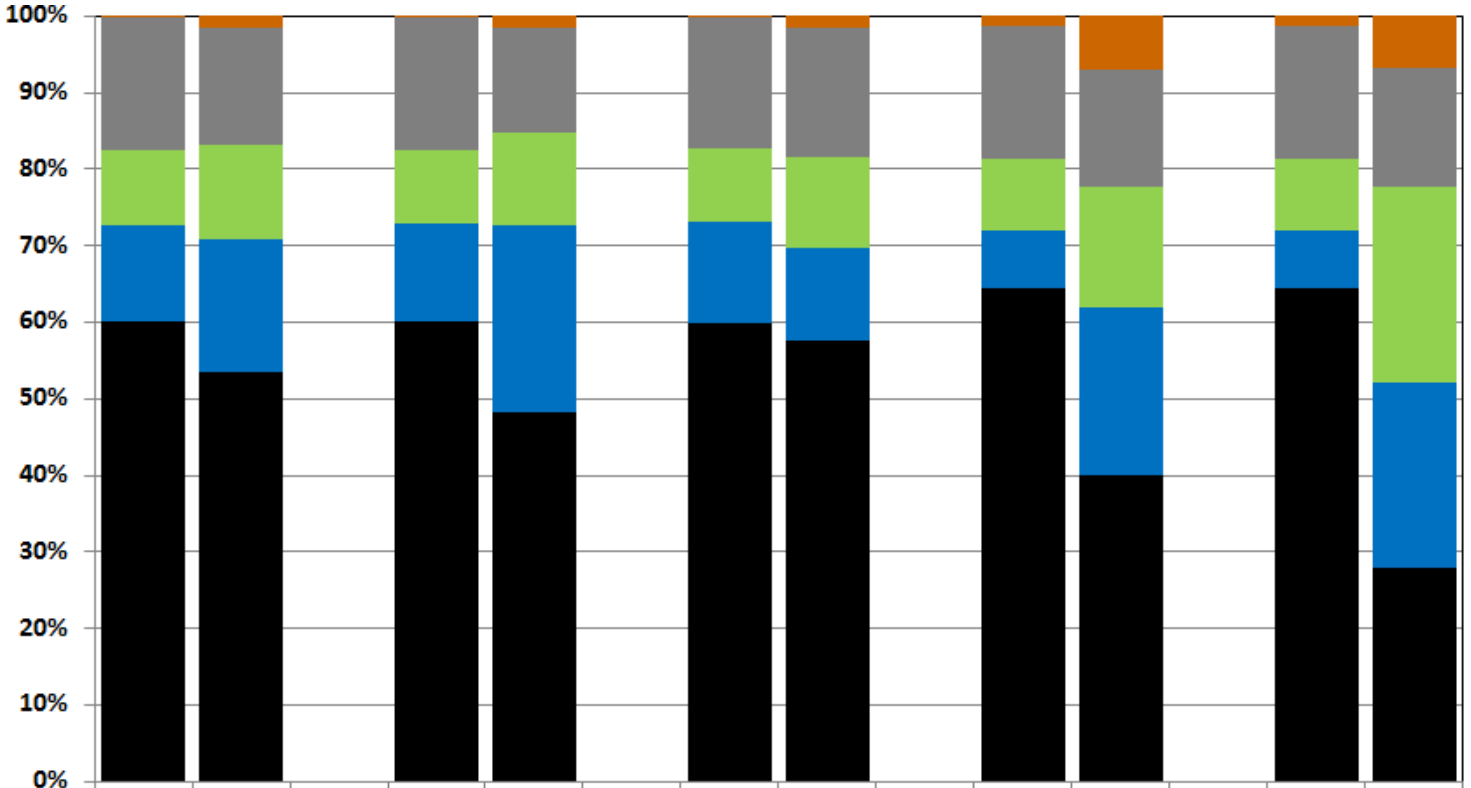
Future	Baseline Demand / Energy Growth (20-year)	Retirement Level* (GW)	Inflation	Peak Natural Gas Price (2015 $/MMBtu)	Incremental Renewables (GW) N/C: North/Central S: South	CO_2 Cost (2015 $/ton)
Business as Usual	0.75% / 0.82%	No Additional	2.5%	$4.11	N/C: 4.2 Wind/ 1.4 Solar S: 0 Wind/ 0 Solar	N/A
High Demand	1.55% / 1.61%	Age-related	4.0%	$4.11	N/C: 7.2 Wind/ 1.6 Solar S: 0 Wind/ 0 Solar	N/A
Low Demand	0.11% / 0.19%	Age-related	2.0%	$3.29	N/C: 2.4 Wind/ 1.3 Solar S: 0 Wind/ 0 Solar	N/A
Regional CPP Compliance	0.75% / 0.82%	14 GW coal + age-related	2.5%	$4.93	N/C: 4.2 Wind/ 1.4 Solar S: 0 Wind/ 0 Solar + cost maturity curves	$25 / ton
Sub-Regional CPP Compliance	0.75% / 0.82%	20 GW coal + age-related	4.0%	$4.93	N/C: 4.2 Wind/ 1.4 Solar S: 0 Wind/ 0 Solar + cost maturity curves	$40 / ton

*12 GW of MATS related coal-retirements are assumed in all Futures
Age-related retirement assumption applies to non-coal, non-nuclear generation only

MTEP-16 Capacity Forecast (2015 through 2030)



MISO Energy Production by Fuel Type

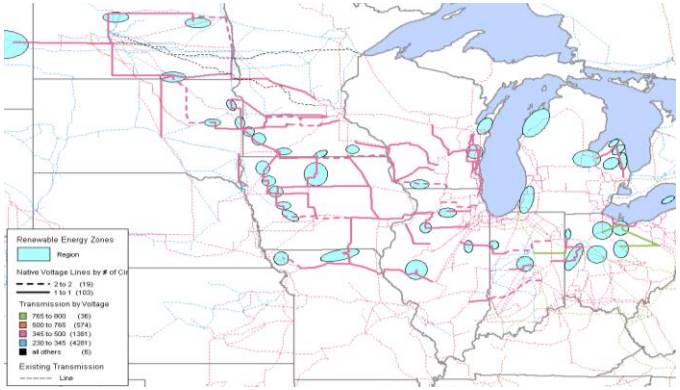


	BAU 2015	BAU 2030		HD 2015	HD 2030		LD 2015	LD 2030		CPP 2015	CPP 2030		SCPP 2015	SCPP 2030
DSM	0%	2%		0%	2%		0%	1%		1%	7%		1%	7%
Other	17%	15%		17%	14%		17%	17%		17%	15%		17%	15%
Renewable	10%	12%		10%	12%		10%	12%		10%	16%		10%	26%
Gas	13%	17%		13%	25%		13%	12%		7%	22%		7%	24%
Coal	60%	53%		60%	48%		60%	58%		64%	40%		64%	28%

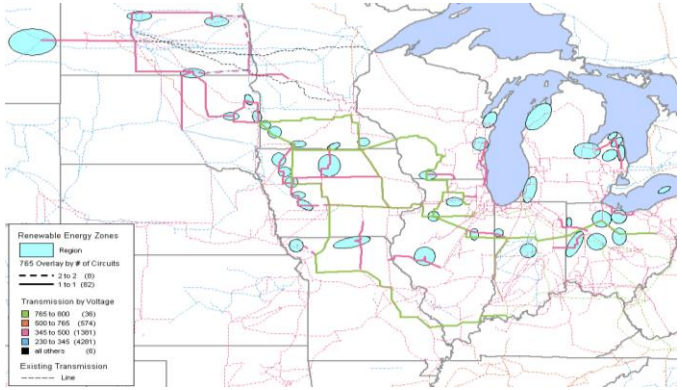
Siting of Regional Resource Forecast (RRF) units

- The generation forecast developed in Step 1 of the process is sited in a powerflow model for production cost modeling purposes only
- A set of siting rules are used to site the forecasted capacity, by future, for every region
  - Priority 1: Generators with a “future” status
  - Priority 2: Brownfield sites (coal, CT, CC, nuclear methodology)
  - Priority 3: Retired/mothballed sites which have not been re-used
  - Priority 4: Greenfield sites
    - Queue & “New Entrants” in canceled or postponed status
  - Priority 5: Greenfield sites
    - Greenfield siting methodology

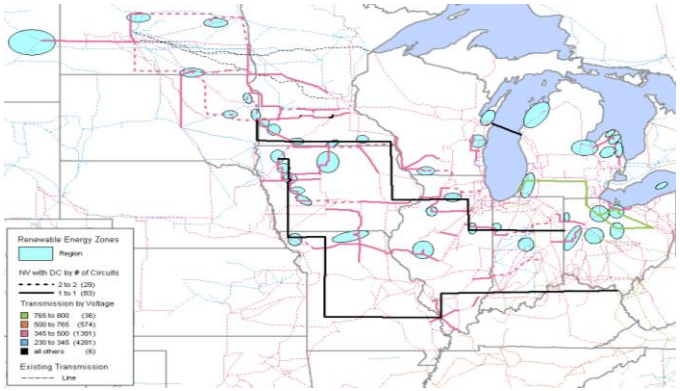
Design conceptual transmission by Future, if necessary



Native Voltage Transmission Overlay Strategy

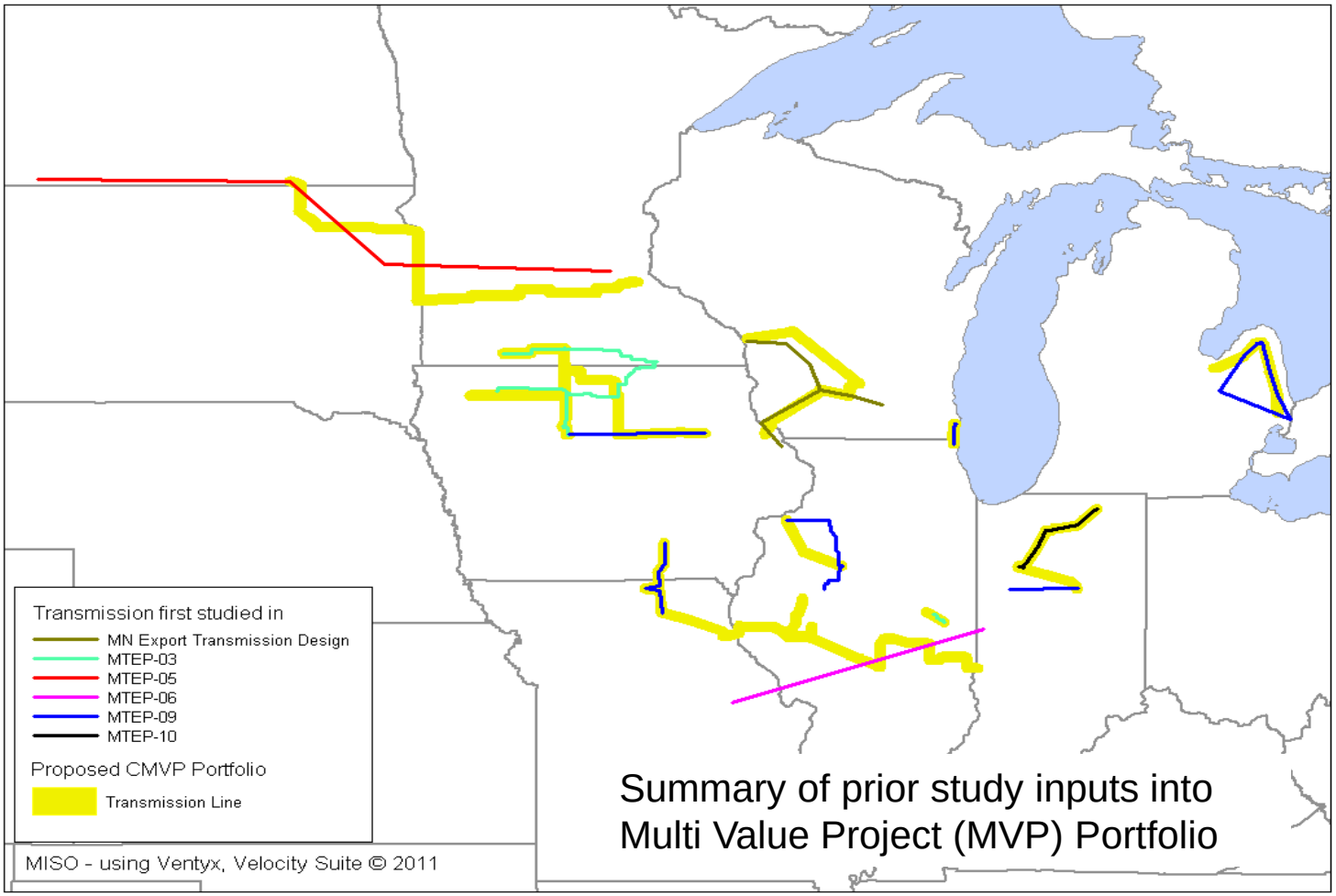


765 kV Transmission Overlay Strategy

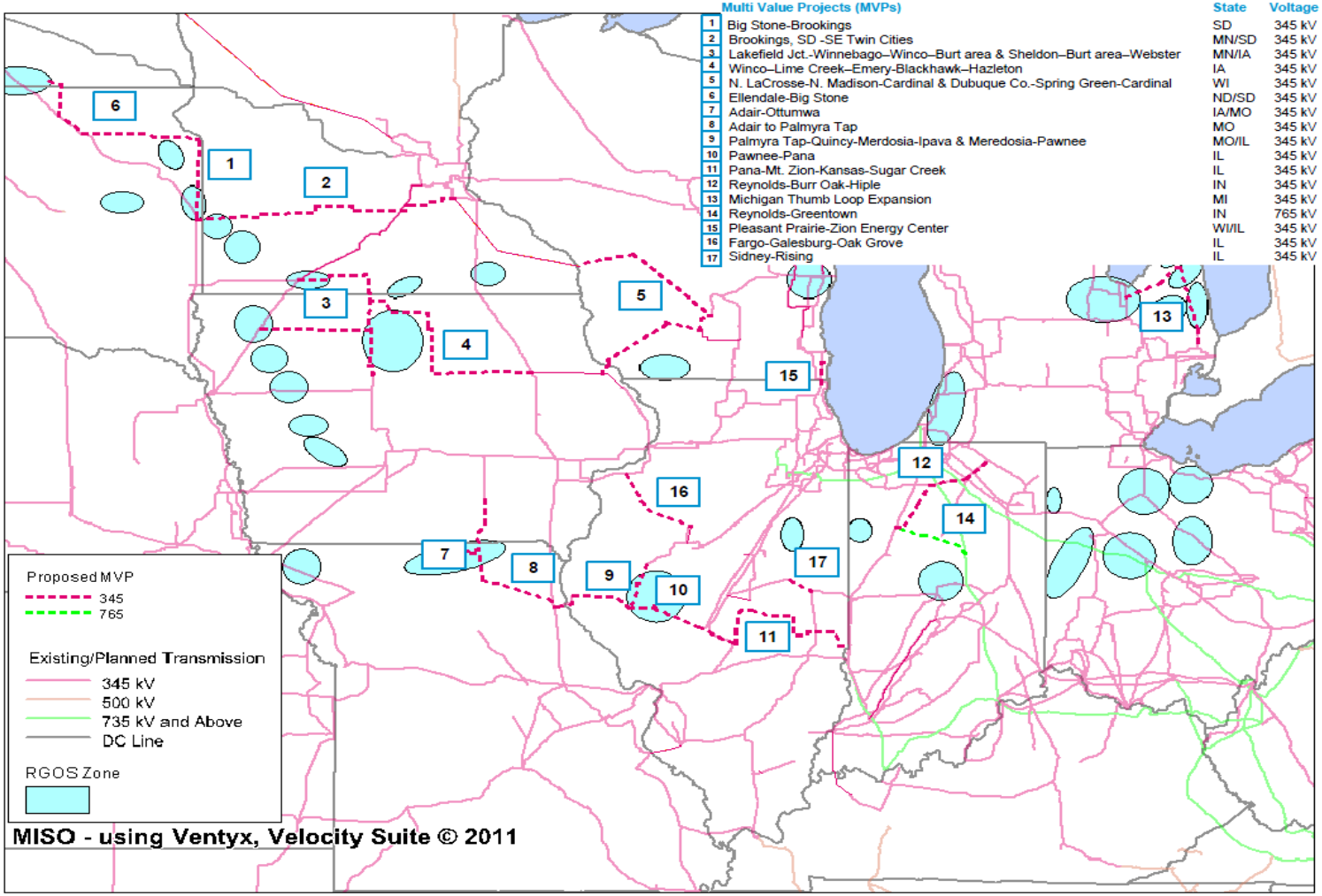


Native Voltage with DC Transmission Overlay Strategy

Test conceptual transmission for robustness



Consolidate and sequence transmission plans



Multi Value Project (MVP) Portfolio

Evaluate conceptual transmission for reliability

Reliability assessment using a suite of tests to determine system performance:

- Steady-state analysis
- Voltage stability
- Short-circuit stability
- Dynamic/transient stability assessments

For any identified reliability issues, both MISO and TOs develop plans to ensure system reliability with the addition of proposed transmission

Cost allocation analysis

Allocation Category	Driver(s)	Allocation to Beneficiaries
Participant Funded ("Other")	Transmission Owner identified project that does not qualify for other cost allocation mechanisms. Can be driven by reliability, economics, public policy or some combination of the three.	Paid by requestor (local zone)
Transmission Delivery Service Project	Transmission Service Request	Generally paid for by Transmission Customer; Transmission Owner can elect to roll-in into local zone rates
Generation Interconnection Project	Interconnection Request	Primarily paid for by requestor; 345 kV and above 10% postage stamp to load
Baseline Reliability Project	NERC Reliability Criteria	100% allocated to local Pricing Zone
Market Efficiency Project	Reduce market congestion when benefits are 1.25 times in excess of cost	Distributed to Local Resource Zones commensurate with expected benefit; 345 kV and above 20% postage stamp to load
Multi Value Project	Address energy policy laws and/or provide widespread benefits across footprint	100% postage stamp to load and exports other than PJM

Appendix

Business As Usual

"The baseline, or Business as Usual, future captures all current policies and trends in place at the time of futures development and assumes they continue, unchanged, throughout the duration of the study period. Demand and energy growth rates are modeled at a level equivalent to the 50/50 forecasts submitted into the Module E Capacity Tracking (MECT) tool. All current state-level Renewable Portfolio Standard (RPS) and Energy Efficiency Resource Standard (EERS) mandates are modeled. All applicable and enforceable EPA regulations governing electric power generation, transmission and distribution (NAICS 2211) are modeled. To capture the expected effects of environmental regulations on the coal fleet, a total of 12.6 GW of coal unit retirements are modeled, including units which have either already retired or publicly announced they will retire."

High Demand

"The High Demand future is designed to capture the effects of increased economic growth resulting in higher energy costs and medium – high gas prices. The magnitude of demand and energy growth is determined by using the upper bound of the Load Forecast Uncertainty metric and also includes forecasted load increases in the South region. All current state-level Renewable Portfolio Standard (RPS) and Energy Efficiency Resource Standard (EERS) mandates are modeled. All existing EPA regulations governing electric power generation, transmission and distribution (NAICS 2211) are incorporated. To capture the expected effects of environmental regulations on the coal fleet, 12.6 GW of coal unit retirements are modeled, including units which have either already retired or publicly announced they will retire. Additional, age-related retirements are captured using 60 years of age as a cutoff for non-coal, non-nuclear thermal units and 100 years for conventional hydroelectric."

Low Demand

"The Low Demand future is designed to capture the effects of reduced economic growth resulting in lower energy costs and medium – low gas prices. The magnitude of demand and energy growth is determined by using the lower bound of the Load Forecast Uncertainty metric. All current state-level Renewable Portfolio Standard (RPS) and Energy Efficiency Resource Standard (EERS) mandates are modeled. All applicable EPA regulations governing electric power generation, transmission and distribution (NAICS 2211) are modeled. To capture the expected effects of environmental regulations on the coal fleet, 12.6 GW of coal unit retirements are modeled, including units which have either already retired or publicly announced they will retire. Additional, age-related retirements are captured using 60 years of age as a cutoff for non-coal, non-nuclear thermal units and 100 years for conventional hydroelectric."

Regional Clean Power Plan Compliance

"The Regional Clean Power Plan future focuses on several key items from a footprint wide level which in combination result in significant carbon reductions over the course of the study period. Assumptions are consistent with MISO CPP Phase I & II analyses, and include the following:

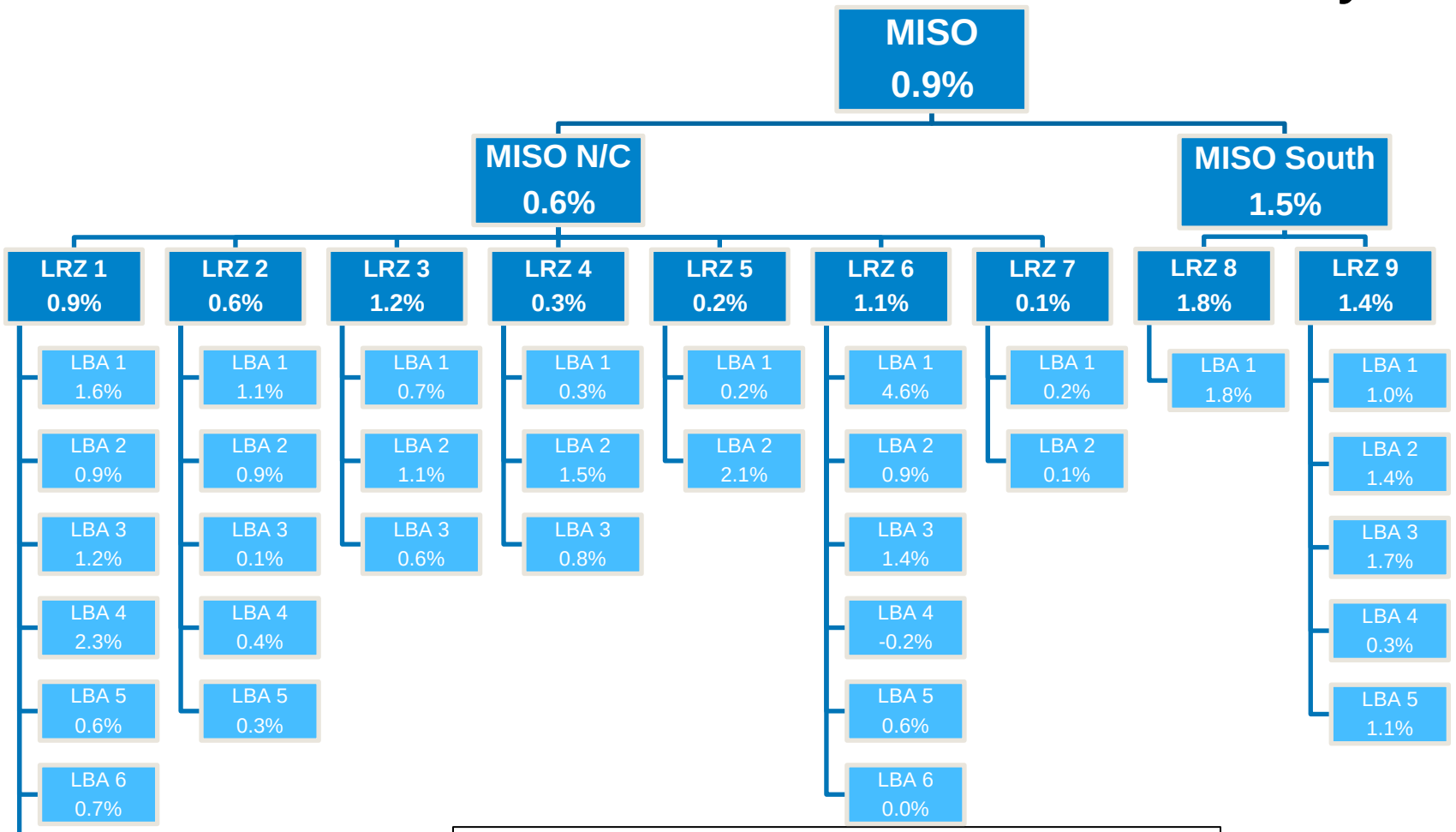
- *To capture the expected effects of existing environmental regulations on the coal fleet, 12.6 GW of coal unit retirements are modeled, including existing or announced retirements.*
- *14 GW of additional coal unit retirements, coupled with a $25/ton carbon cost, state mandates for renewables, and half of the EE annual growth used by the EPA, result in a significant reduction in carbon emissions by 2030.*
- *Additional, age-related retirements are captured using 60 years of age as a cutoff for non-coal, non-nuclear thermal units and 100 years for conventional hydroelectric.*
- *Solar and wind include an economic maturity curve to reflect declining costs over time.*
- *Demand and energy growth rates are modeled at levels as reported in Module E.*

Sub-Regional Clean Power Plan Compliance

"The Sub-Regional Clean Power Plan future focuses on several key items from a zonal or state level which combine to result in significant carbon reductions over the course of the study period. Assumptions are consistent with MISO CPP Phase I & II analyses, and include the following:

- *To capture the expected effects of existing environmental regulations on the coal fleet, 12.6 GW of coal unit retirements are modeled, existing or announced retirements.*
- *20 GW of additional coal unit retirements, coupled with a $40/ton carbon cost, state mandates for renewables, and half of the EE annual growth used by the EPA, result in a significant reduction in carbon emissions by 2030.*
  - *These increased retirements and carbon cost levels from the Regional CPP Future are consistent with regional/sub-regional CPP assessments performed by MISO and other organizations since the CPP's introduction*
- *Additional, age-related retirements are captured using 60 years of age as a cutoff for non-coal, non-nuclear thermal units and 100 years for conventional hydroelectric.*
- *Solar and wind include an economic maturity curve to reflect declining costs over time.*
- *Demand and energy growth rates are modeled at levels as reported in Module E.*

MTEP15 BAU Demand Growth Rate Granularity

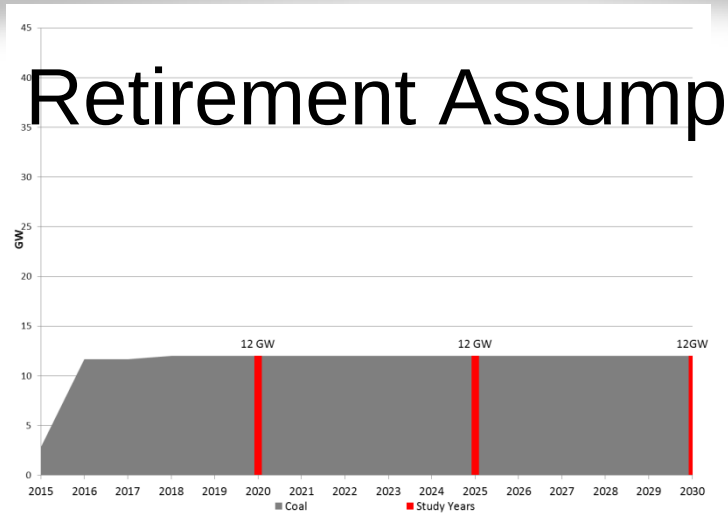


All growth rates represent a 10-year compound annual growth rate, beginning in 2015

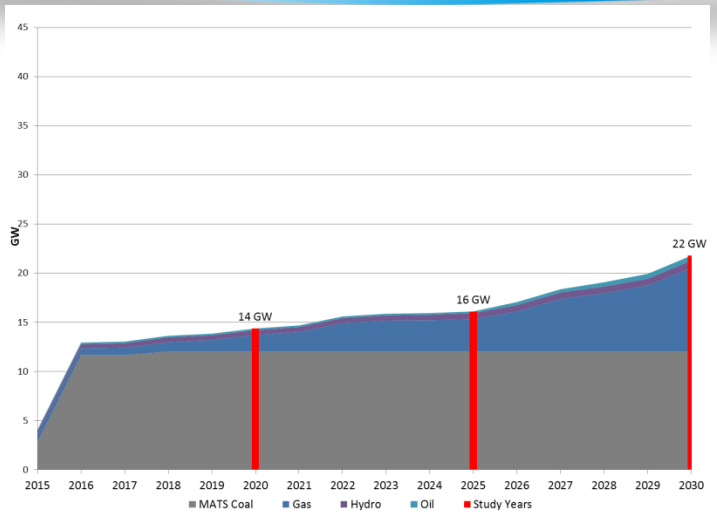
Retirements

- Baseline 12 GW of coal retirements assumed to occur on 12/31/15 unless publicly announced date available
- Additional 14 GW and 20 GW of coal retirements occur in the Regional and Sub-Regional CPP Futures in the 2020 – 2025 timeframe
- Age-related retirements occur in the year in which the threshold is reached in all futures except the BAU
  - Coal retirements are captured through MATS and CPP impacts; age-related retirement assumptions only applied to non-coal, non-nuclear thermal units.

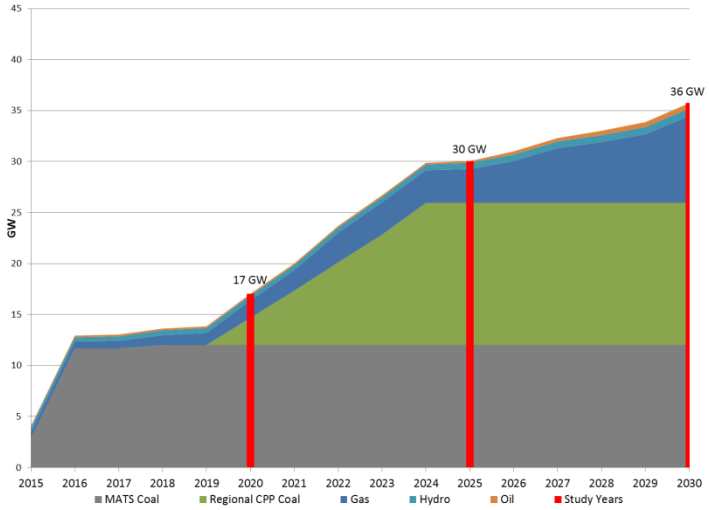
Retirement Assumptions



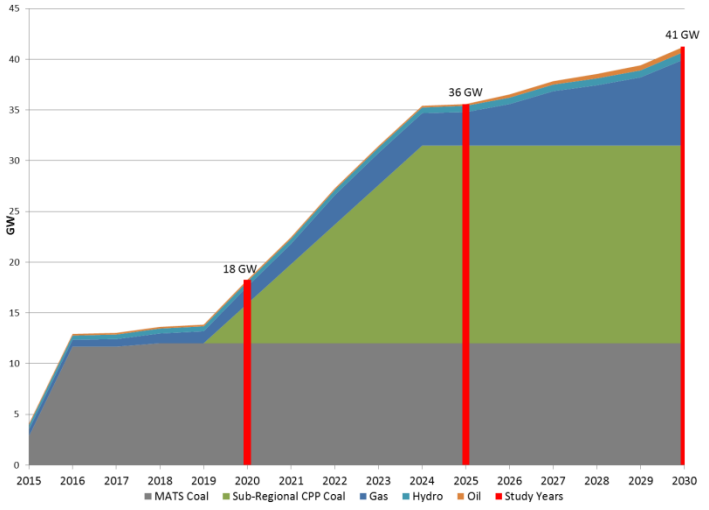
MISO BAU Retirements



MISO Age-Related High/Low Demand Retirements

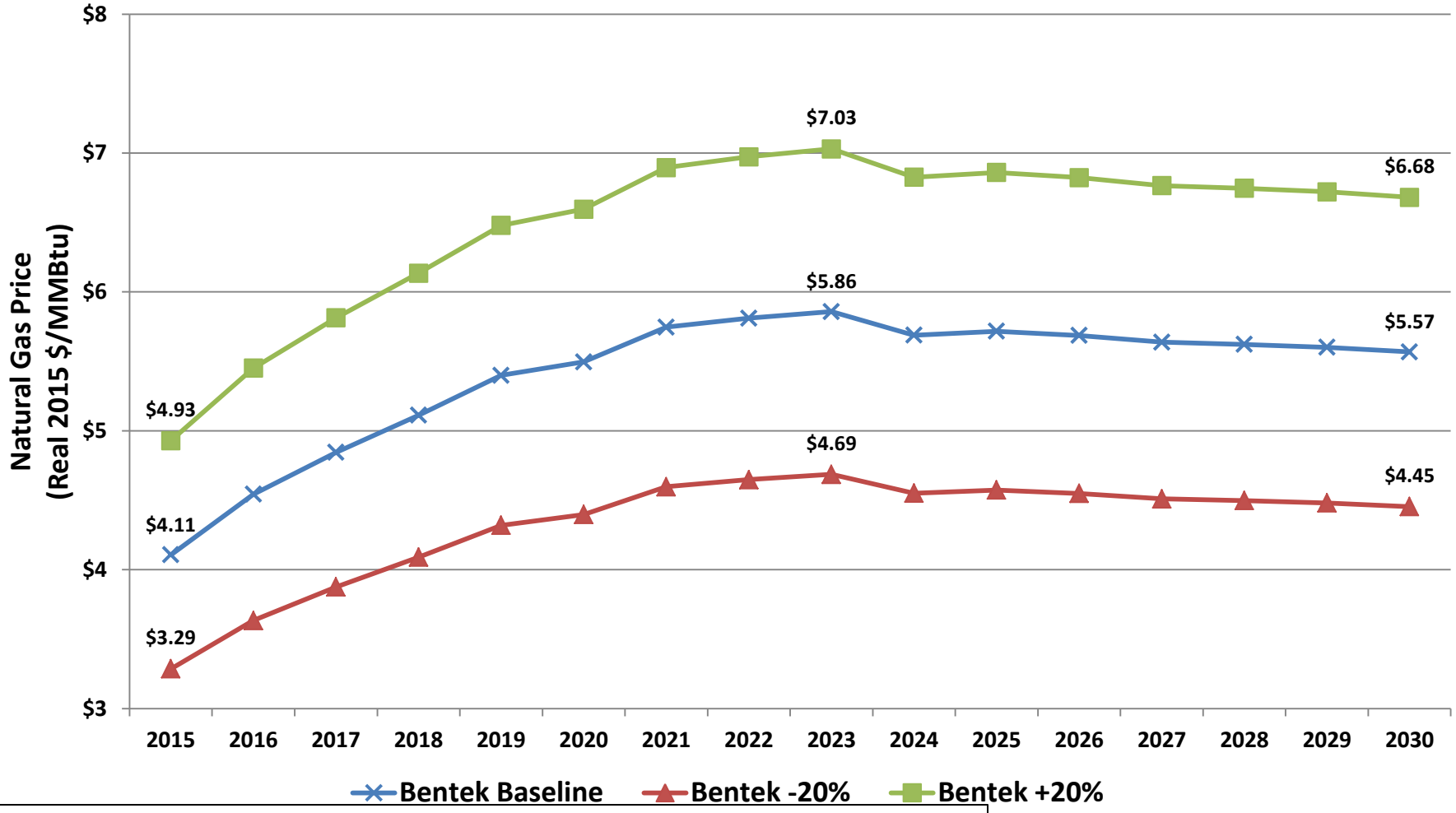


MISO Age-Related CPP Regional Retirements



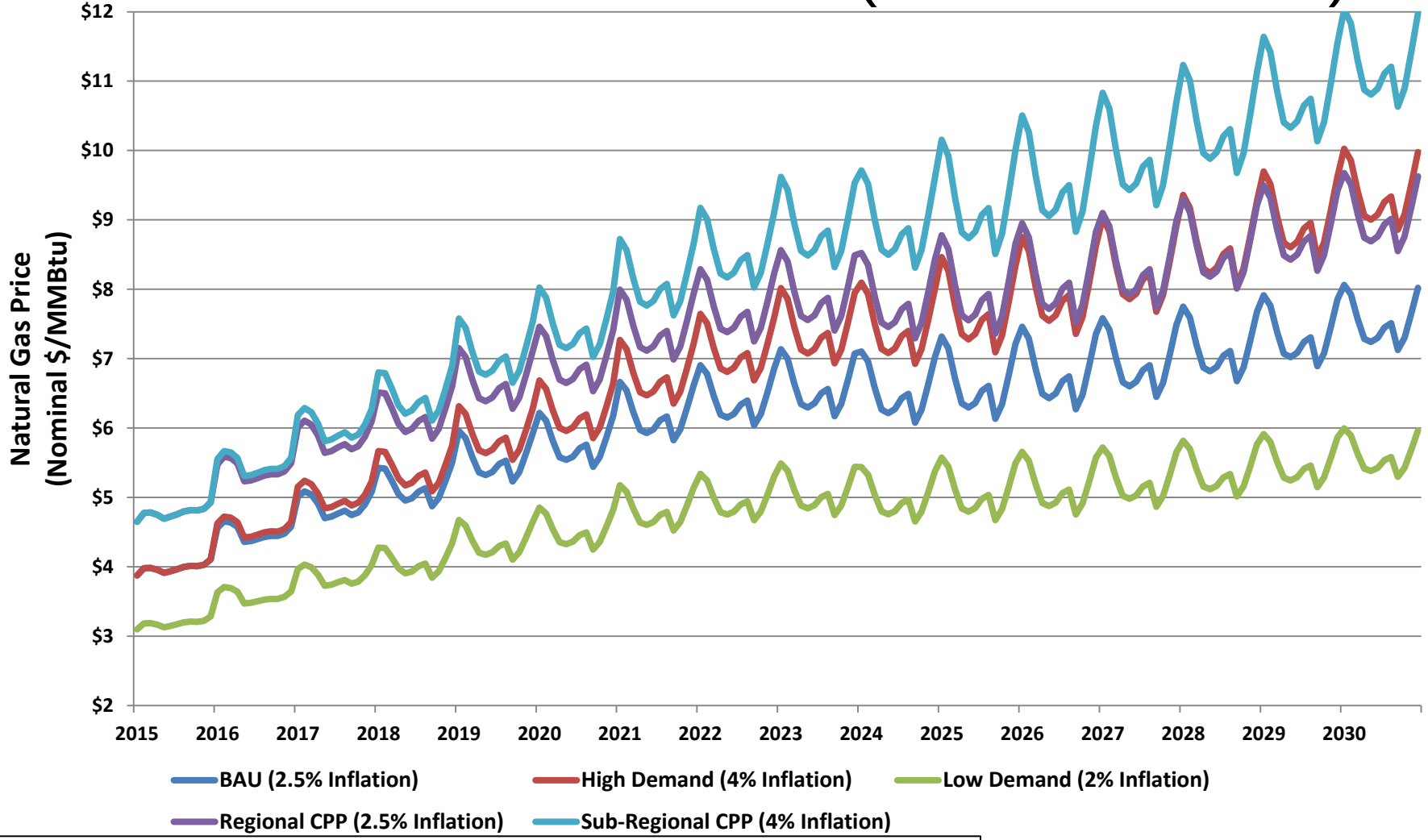
MISO Age-Related CPP Sub-Regional Retirements

Natural Gas Peak Forecasts (Real, 2015 $)



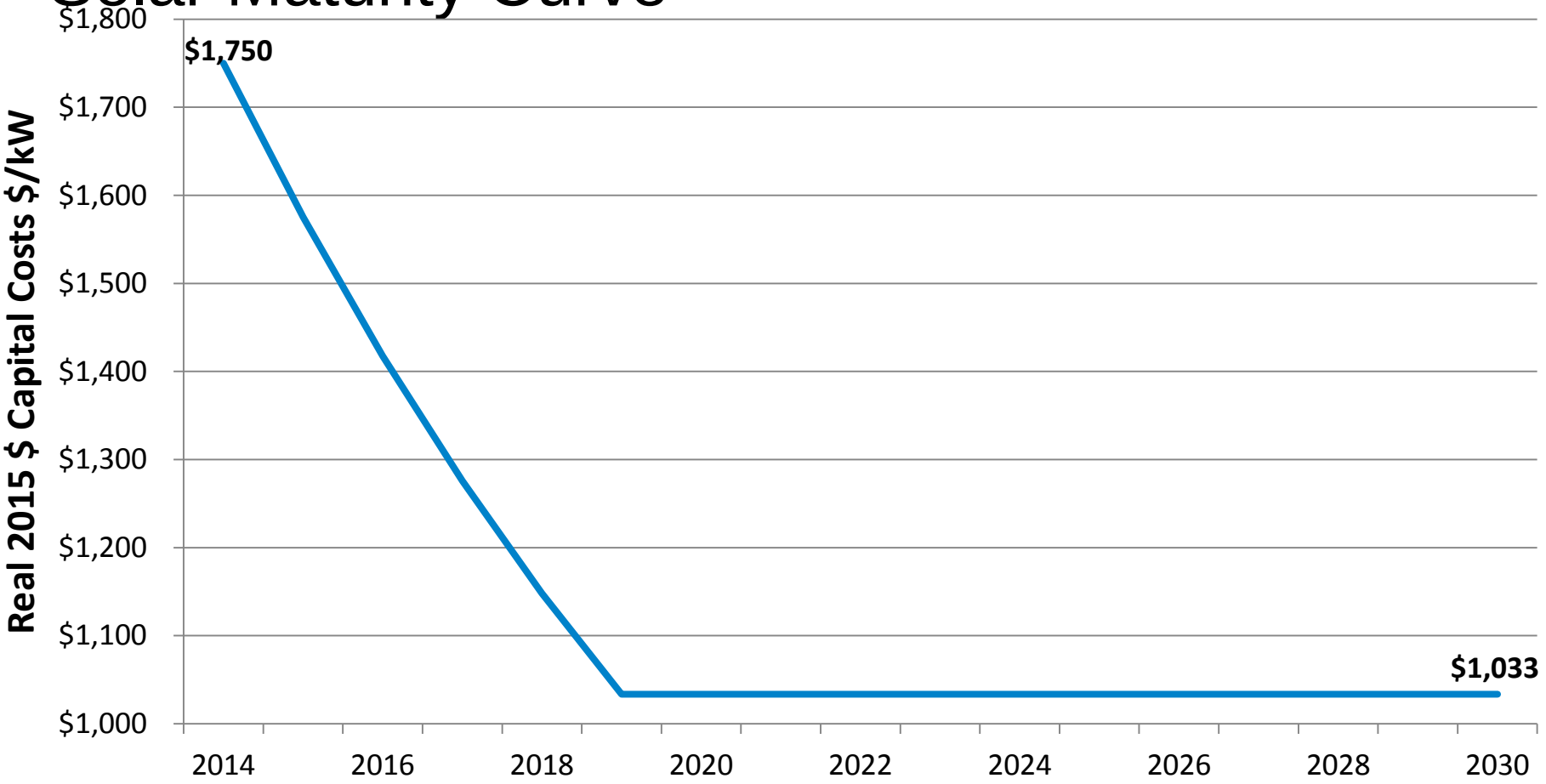
Baseline forecast developed as part of Phase III Electric-Natural Gas Infrastructure Analysis by Bentek

Natural Gas Peak Forecasts (Nominal 2015 $)



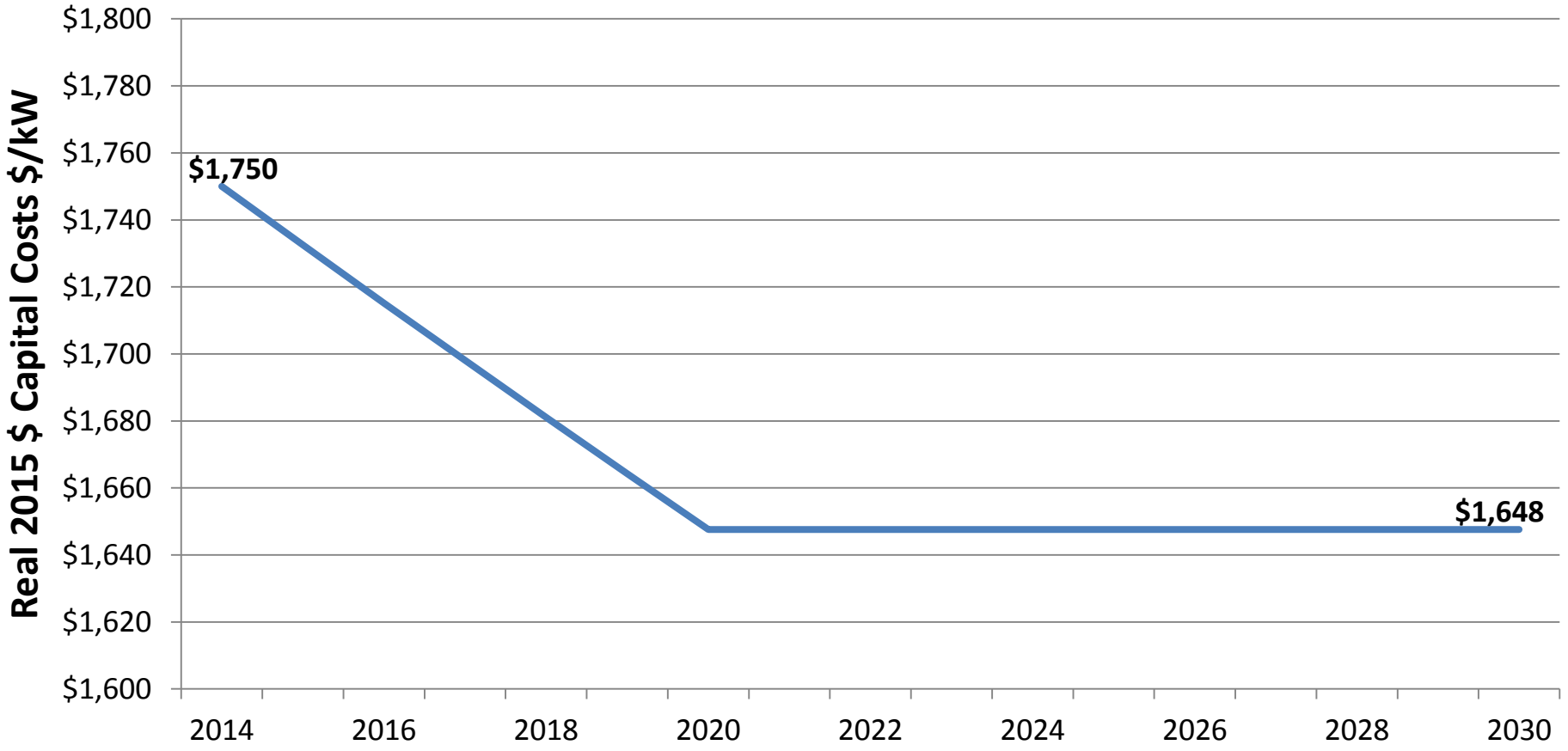
Baseline forecast developed as part of Phase III Electric-Natural Gas Infrastructure Analysis by Bentek

Solar Maturity Curve



Note: Starting cost taken from Lazard 2014 LCOE Report: Page 11
http://www.lazard.com/PDF/Levelized%20Cost%20of%20Energy%20-%20Version%208.0.pdf
Estimated cost decline taken from EIA AEO 2014 Assumptions Report: Page 98
http://www.eia.gov/forecasts/aeo/assumptions/pdf/0554(2014).pdf

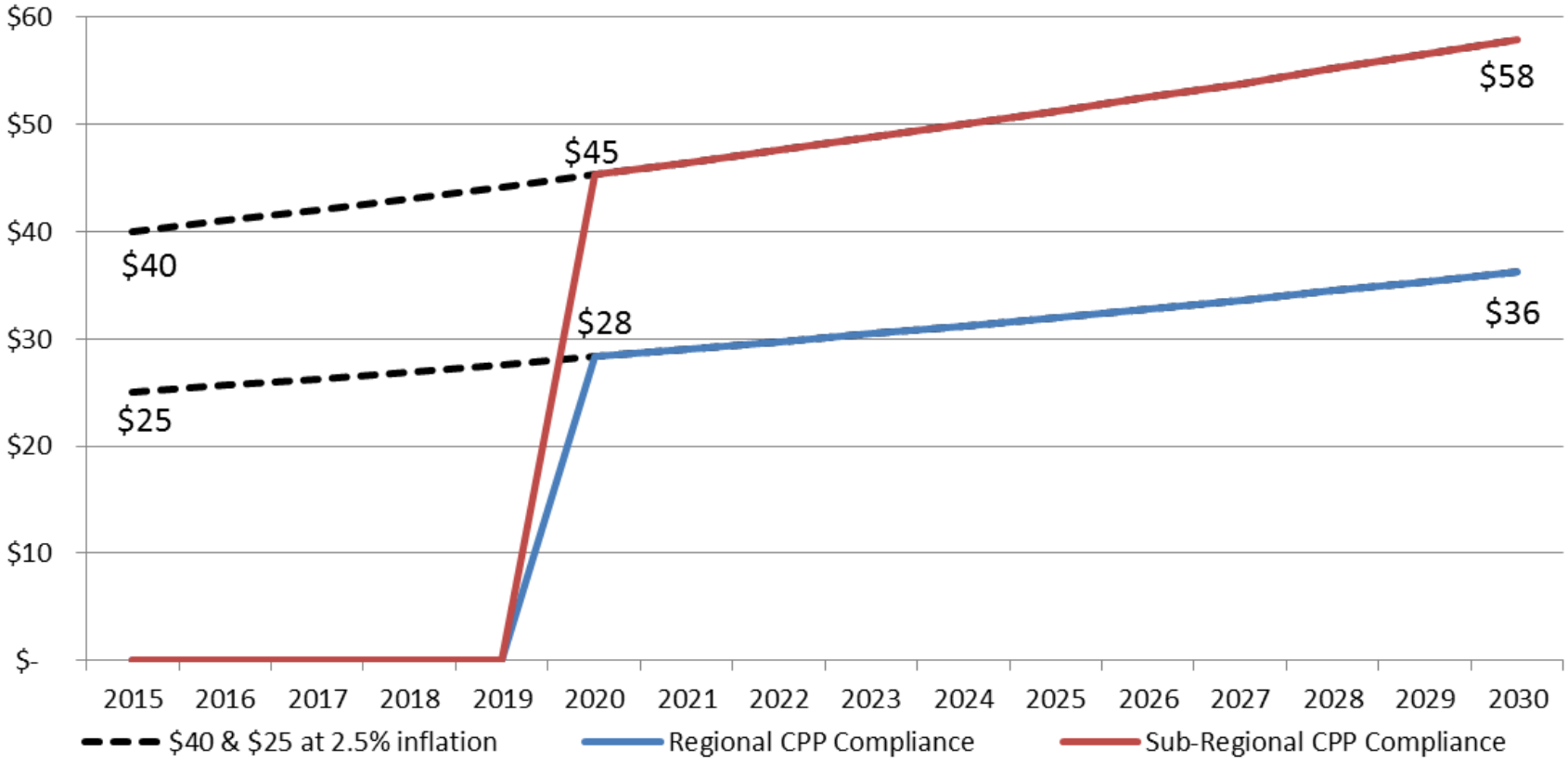
Wind Maturity Curve



Note: Starting cost taken from DOE LBNL 2013 Wind Technologies Market Report: Page 50
http://energy.gov/sites/prod/files/2014/08/f18/2013%20Wind%20Technologies%20Market%20Report_1.pdf
Estimated cost decline taken from EIA AEO 2014 Assumptions Report: Page 98
http://www.eia.gov/forecasts/aeo/assumptions/pdf/0554(2014).pdf

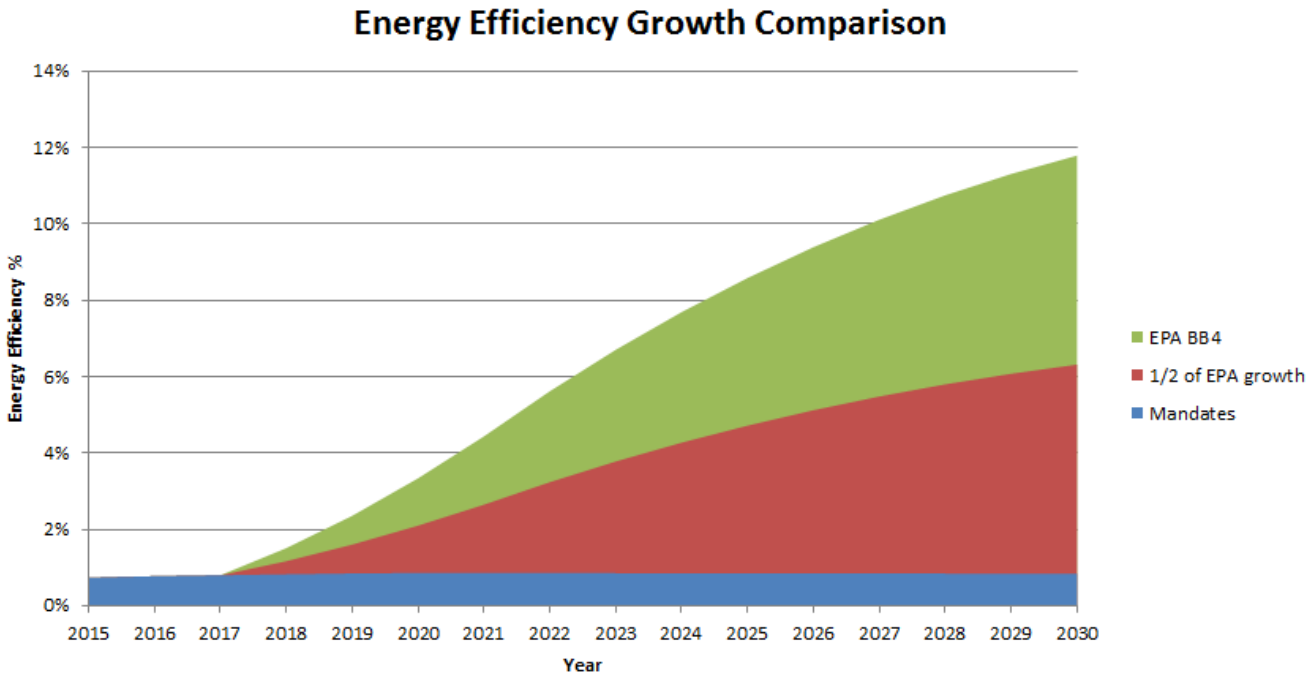
Carbon Cost

Regional and Sub-Regional CPP futures will use $25/ton and $40/ton prices, respectively beginning in 2020



Demand Side Management

- State mandates for DR / EE modeled in BAU / High Demand / Low Demand
- Half of the EE annual growth used by the EPA from the CPP analysis is modeled in the Regional and Sub-regional CPP Futures



Capital Costs for New Generation

- Utilize EIA capital cost data, released April 2013*
- Escalate costs using GDP Implicit Price Deflator** to convert to 2015 baseline values
- Mid value for wind to be modeled 10% lower than EIA estimates
- Mid value for solar to be modeled 25% lower than EIA estimates
- High and Low values will be set +/- 25% from Mid values for all generator types
- An economic maturity curve will be applied to solar and wind to reflect declining costs over time

** Full capital cost report: http://www.eia.gov/forecasts/capitalcost/*

*** As defined in the EIA Short Term Energy Outlook: http://www.eia.gov/forecasts/steo/report/us_eco.cfm*

Capital Costs for New Generation

New Generation Capital Costs				
Resource	**Unit**	**Low (L)**	**Mid (M)**	**High (H)**
Coal	($/KW)	2,279	3,039	3,799
CC	($/KW)	795	1,060	1,324
CT	($/KW)	525	700	875
Nuclear	($/KW)	4,296	5,728	7,160
Wind-Onshore	($/KW)	Maturity Curve	2,292	2,579
IGCC	($/KW)	2,940	3,919	4,899
IGCC w/ CCS	($/KW)	5,126	6,835	8,544
CC w/ CCS	($/KW)	1,627	2,170	2,712
Pumped Storage Hydro	($/KW)	4,108	5,477	6,846
Compressed Air Energy Storage	($/KW)	971	1,295	1,618
Photovoltaic	($/KW)	Maturity Curve	4,012	5,014
Biomass	($/KW)	3,196	4,261	5,326
Conventional Hydro	($/KW)	2,281	3,041	3,801
Wind-Offshore	($/KW)	4,840	6,453	8,066

** Full capital cost report: http://www.eia.gov/forecasts/capitalcost/*

*** As defined in the EIA Short Term Energy Outlook: http://www.eia.gov/forecasts/steo/report/us_eco.cfm*

Notes on Inflation

- Most-recent 20-year growth rate for the CPI is 2.4%; since 1960, the maximum 20-year growth is 6.3% and the minimum is 1.9%
- Based on this information, MISO recommends the following inflation rates for use in the MTEP futures (no change from MTEP15):

Level	Inflation Value
Low	2.0%
Mid	2.5%
High	4.0%