# MTEP18 Futures

*Summary of definitions, uncertainty variables, resource forecasts, siting process and siting results*

# MTEP18 Futures Key Takeaways

| MTEP18 Future | Limited Fleet Change | Continued Fleet Change | Accelerated Fleet Change | Distributed & Emerging Technologies |
|---|---|---|---|---|
| **Demand and Energy** | Low (10/90)<br>High LRZ9 Industrial | Base (50/50) | High (90/10)<br>Low LRZ9 Industrial | Base + EV<br>*Energy: 1.1%*<br>*Demand: 0.6%* |
| **Fuel Prices** | Gas: Base -30%<br>Coal: Base -3% | Base | Gas: Base +30%<br>Coal: Base | Base |
| **Demand Side Additions**<br>***By Year 2032*** | EE: - GW<br>DR: 2 GW | EE: - GW<br>DR: 3 GW | EE: 5 GW<br>DR: 4 GW | EE: 2 GW<br>DR: 3 GW<br>Storage: 2 GW |
| **Renewable Additions**<br>***By Year 2032***<br>***(% Wind and Solar Energy)*** | 10% | 15% | 30% | 20% |
| **Generation Retirements[1]**<br>***By Year 2032*** | Coal: 9 GW<br>Gas/Oil: 17 GW | Coal: 17 GW<br>Gas/Oil: 17 GW | Coal: 17 GW+<br>Gas/Oil: 17 GW | Coal: 17 GW<br>Gas/Oil: 17 GW<br>Nuclear: 2 GW |
| **$CO_2$ Reduction Constraint**<br>***From Current Levels by 2032*** | None | None | 20% | None |
| **Siting Methodology[2]** | MTEP Standard | MTEP Standard | MTEP Standard | "Localized" |

EV: Electric Vehicles    EE: Energy Efficiency    DR: Demand Response

1. In Accelerated Fleet Change Scenario 16 GW of coal retired. In addition, 8 GW of coal dispatched seasonally and must-run removed on all units.
2. "Localized" renewable siting assumes that at least 50% of incremental wind and solar energy will be sourced within each Local Resource Zone. Two thirds of solar sited as distributed.

# Contents

# Background on MTEP18 Futures

# MTEP18 Futures Development Timeline

### January PAC
- Timeline and expectations

### February PAC
- Review MTEP17 Futures
- MISO proposed updates to MTEP17 Futures

### April Workshop
- Review feedback & responses
- Updated Futures proposal
- Review uncertainty variables

### April PAC
- Review workshop takeaways
- Overview draft Futures

### May PAC
- Review April feedback
- Updated Futures proposal

### June PAC
- Finalize Futures definitions
- Future weighting

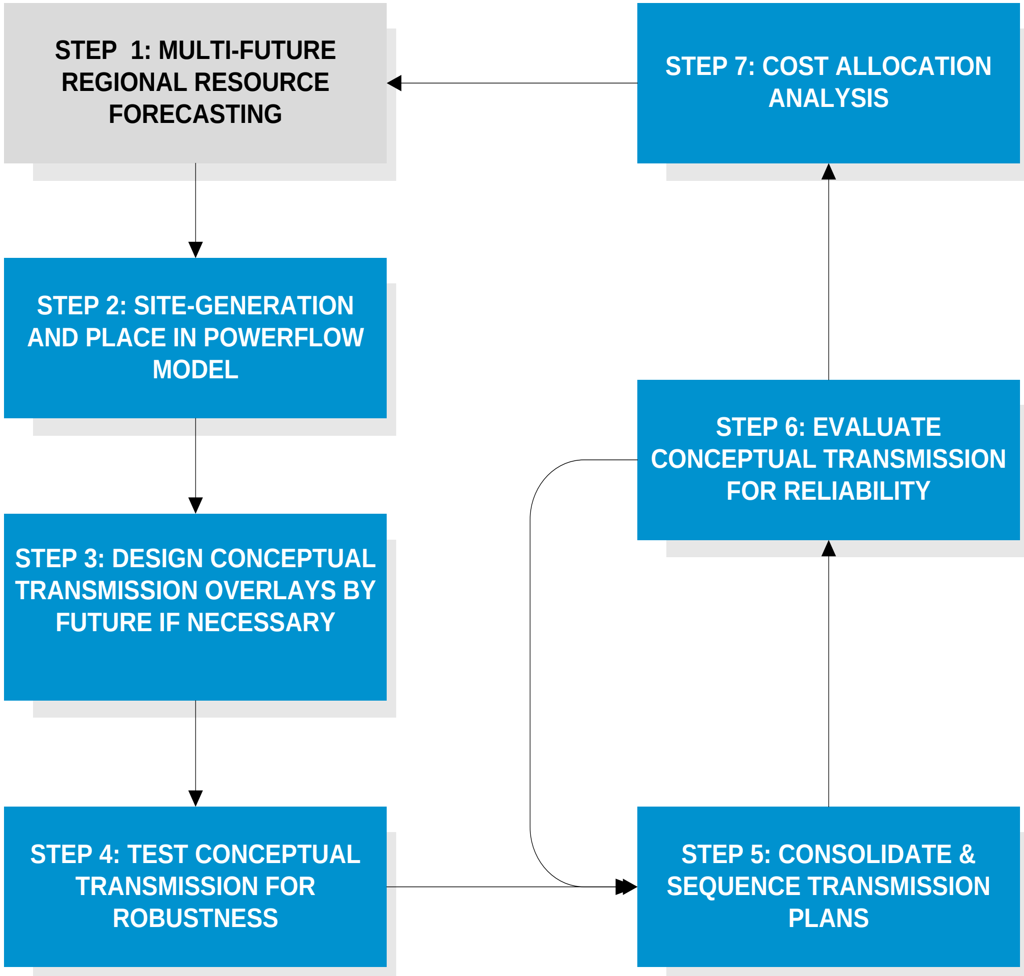
### July PAC
- Review siting methodology

### August PAC
- Finalize Future weights

### September PAC
- Draft Futures results and siting review

### October PAC
- MTEP18 Futures development, results and siting process slides posted

# Value-Based Planning



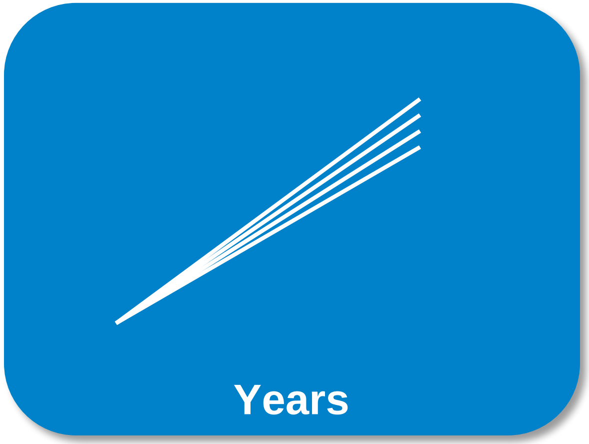

Objective of value-based planning is to develop the most robust plan under a variety of scenarios – not the least-cost plan under a single scenario

- The “best” transmission plan may be different in each policy-based future scenario
- The transmission plan that is the best-fit (most robust) against all these scenarios should offer the most future value in supporting the future resource mix

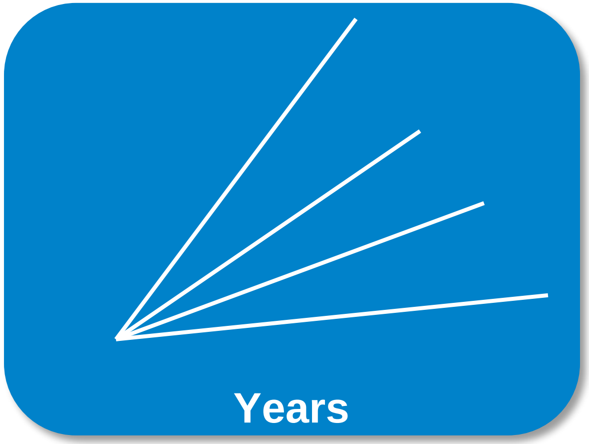
# Long-Term Planning Requires Broad Futures

- Scenario analysis is needed to obtain multiple long term views of theoretical supply and demand resource availability given different policy and economic drivers
- Adequate bookends ensure that MISO continues to plan the system reliably and efficiently

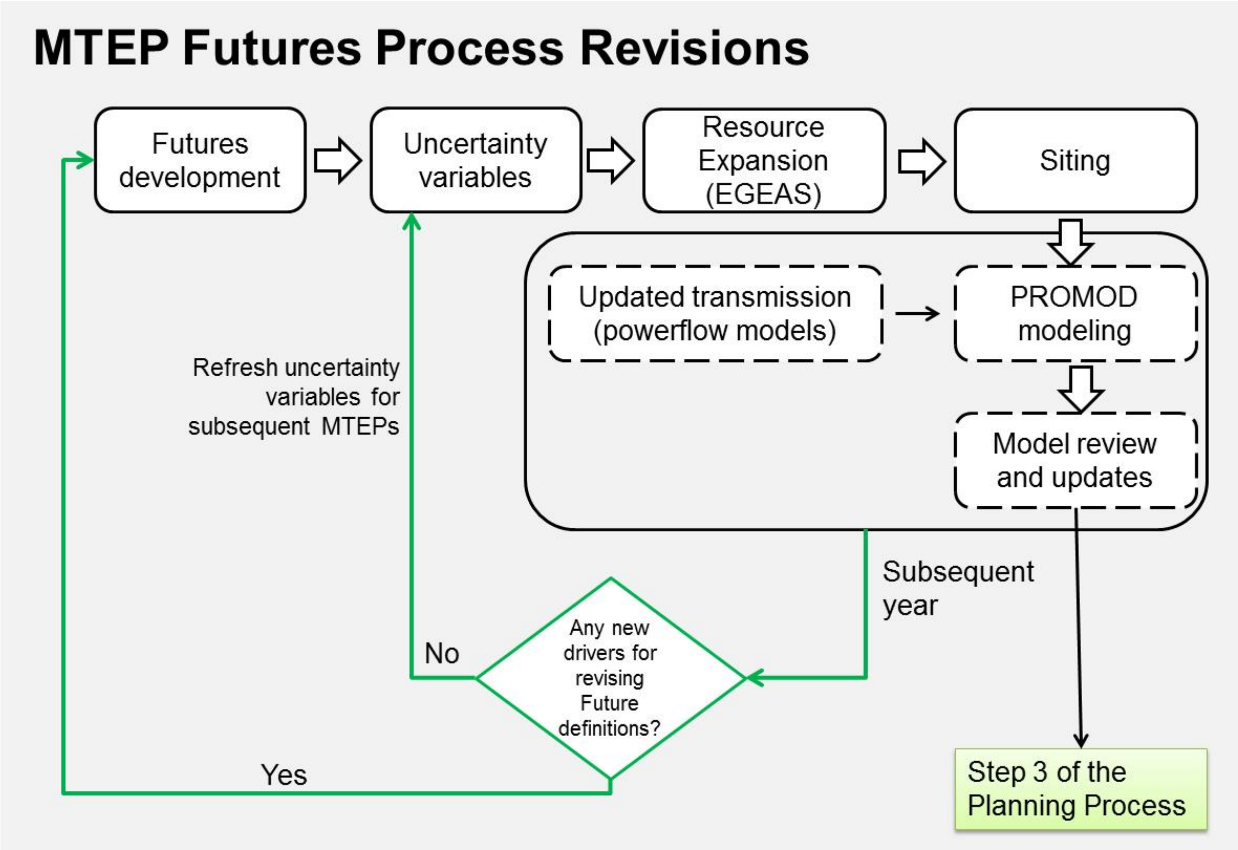
Narrow and less useful




Broad and more useful



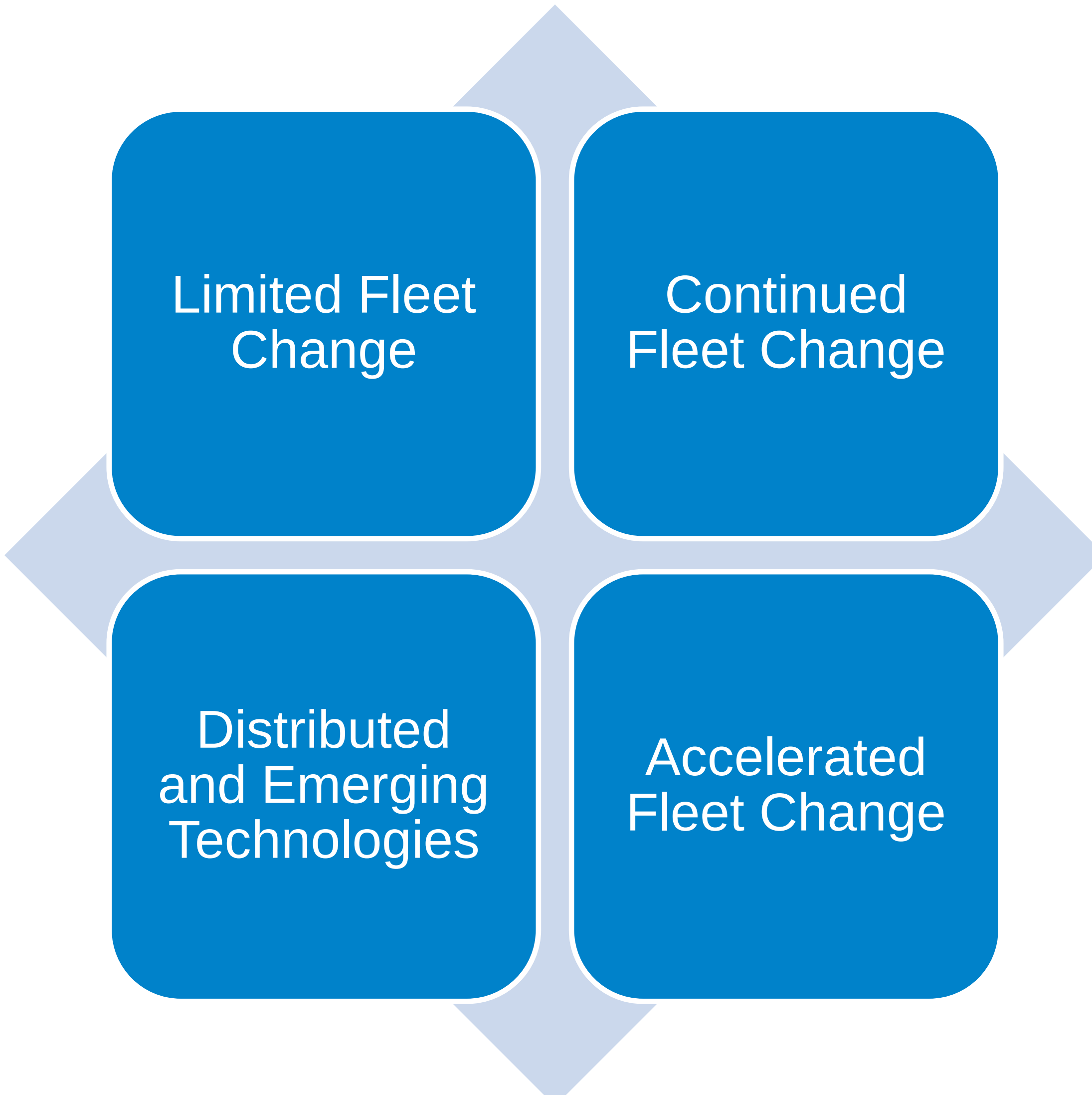
# MTEP18 Futures were largely developed using the MTEP17 Futures as starting points though definitions, narratives, and uncertainty variables were fully refreshed




Barring a significant change in policy or economic drivers, MTEP Futures will be used for multiple MTEP cycles. Determination of “significance” will occur at the Planning Advisory Committee, typically early in each calendar year.

# MTEP18 Futures Definitions and Assumptions

# MTEP18 Futures



# Limited Fleet Change

*Existing generation fleet remains relatively static without significant drivers of change. Some coal fleet reductions are expected as units reach the end of useful life. Renewable additions are driven solely by current Renewable Portfolio Standards under low demand & energy growth rates.*

- *Footprint wide, demand & energy growth rates are low; however, as a result of low natural gas prices, industrial production along the Gulf Coast increases.*
- *Natural gas prices are low due to increased well productivity and supply chain efficiencies along with low demand & energy.*
- *Low demand & energy and natural gas prices reduce the demand for and economic viability of new generation technologies.*
- *Thermal generation retirements are driven by unit useful life limits. Nuclear units are assumed to have license renewals granted and remain online.*
- *Lower levels of demand-side management programs are assumed due to low demand & energy.*

# Continued Fleet Change

*The fleet evolution trends of the past decade continue. Coal retirements reflect historical retirement levels based on average age of retirement. Renewable additions continue to exceed current Renewable Portfolio Standard Requirements as a result of economics, public appeal, and the potential for future policy changes. Natural gas reliance increases as a result of new capacity needed to replace retired coal capacity.*

- *Demand and energy growth rates are modeled at a level equivalent to a 50/50 forecast.*
- *Natural gas prices are consistent with industry long-term reference forecasts.*
- *Renewable additions continue along current trends. Wind & solar serve 15% of MISO energy by 2032.*
- *Maturity cost curves for renewable resources reflect some advancement in technology and supply chain efficiencies.*
- *Oil and gas generators retired at the useful life limit age. Coal units will be retired reflecting age and historical retirements beyond age limits. Nuclear units are assumed to have license renewals granted and remain online.*
- *Demand-side management programs modeled to reflect growth and technical potential of current programs.*

# Accelerated Fleet Change

*A robust economy with increased demand & energy drives higher natural gas prices. Carbon regulations targeting a 20% reduction from current levels are enacted in response to increased demand & energy, driving coal to both retirement and decreased production. Increased renewable additions are driven beyond renewable portfolio standards by need for new generation, technological advancement, and carbon regulation. Natural gas reliance increases as a result of new capacity needs driven by the need to replace retired capacity and provide flexibility to support the integration of intermittent renewable resources.*

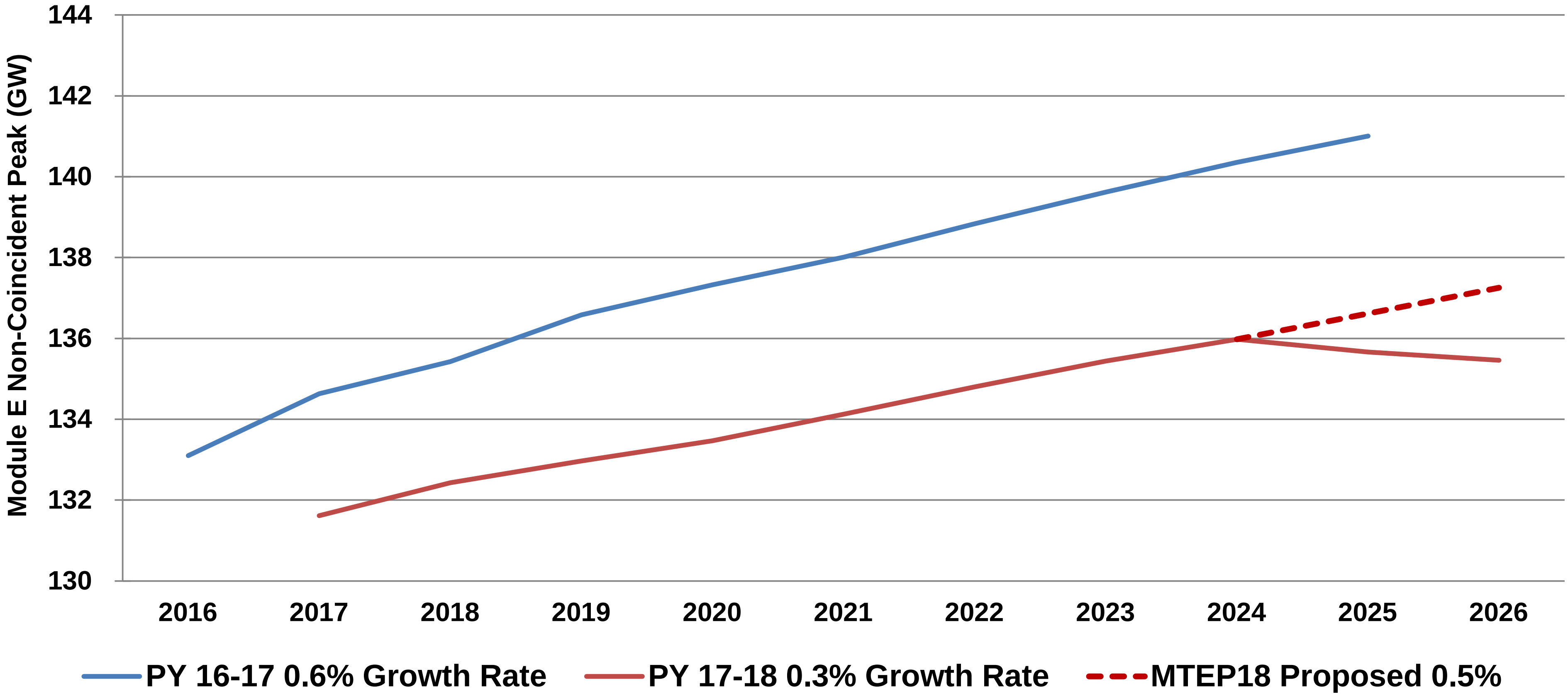
- *Demand & energy grows at a high rate due to a robust economy; however, as a result of high natural gas prices, industrial production along the Gulf Coast decreases.*
- *Natural gas prices are high due to increased demand.*
- *Retirements, economics, and  potential regulations drive renewable additions. Maturity cost curves for renewable technologies applied reflecting advancement in technologies.*
- *Oil and gas generators will be retired in the year the age limit is reached. Coal units will be retired  reflecting age and economics. Nuclear units are assumed to have license renewals granted and remain online.*
- *A 20% carbon reduction for current levels is modeled to reflect future national or state-level carbon regulation.*
- *High demand & energy levels  and carbon regulation drive greater potential for demand-side management programs.*

# Distributed and Emerging Technology

*Fleet evolution trends continue, primarily driven by local policies and emerging technology adoption. State level policies reflect desires for local reliability and optionality. Mid-level coal retirements reflect economics and age limits. Increased renewable additions are driven by favorable economics resulting from technological advancements and state-level renewable portfolio standards and goals with targeted increases in distributed solar. Natural gas reliance increases as a result of new capacity needs driven by load growth largely driven by electric vehicles, the need to replace retired capacity and provide flexibility to support the integration of intermittent renewable resources.*

- *Demand and energy forecast begins level equivalent to a 50/50 forecast and has high growth rate to reflect adoption of electric vehicle technology on a broader scale. Energy grows faster than demand reflecting smart-charging.*
- *Natural gas prices are consistent with industry long-term reference forecasts.*
- *Generation siting shows a strong preference for localized energy and capacity self-sufficiency within state jurisdictions.*
- *Maturity cost curves for renewable technologies applied reflecting advancement in technologies and supply-chain efficiencies. Renewable additions reach about 20% of MISO energy by 2032, increase from 15% in Continued Fleet Change Future comes primarily from solar.*
- *Increased deployment of energy storage devices driven by economies of scale resulting from commercial mass production of lithium ion batteries and other viable technologies.*
- *Oil and gas generators will be retired in the year the age limit is reached. Coal units will be retired reflecting age and economics. Nuclear units are assumed to have license renewals granted and remain online.*
- *Demand-side management programs grow in scale and scope due to technological advancement and economies of scale.*

# Load Serving Entities' peak demand forecast has decreased from last year's forecast




MISO proposes using first 8-year growth rate (.5%) versus a 10-year rate (.3%) to account for apparent anomalous forecast data

# Regional variations modeled within MTEP demand and energy forecasts*

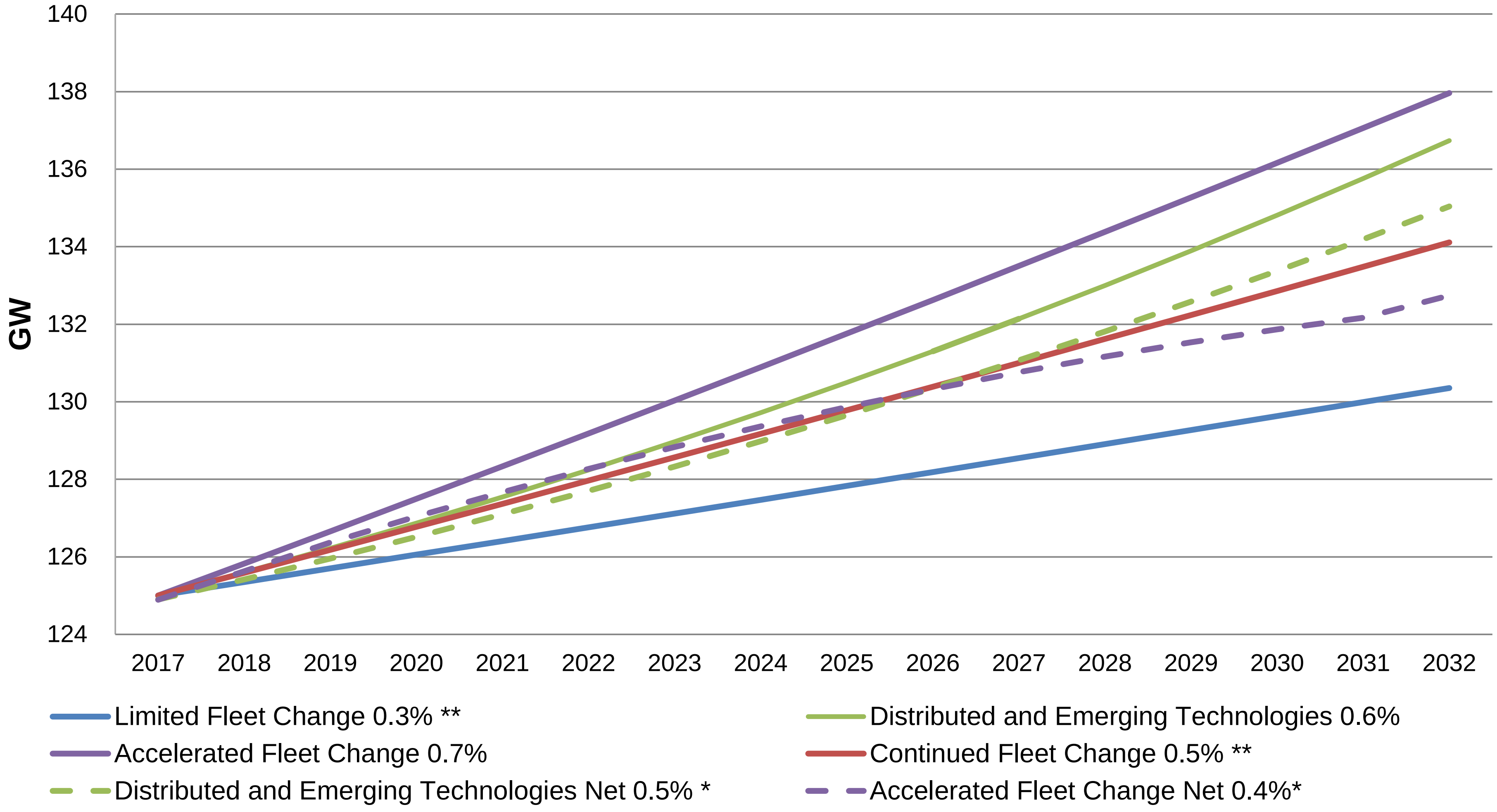
**MISO 0.5%**

| LRZ 1 | LRZ 2 | LRZ 3 | LRZ 4 | LRZ 5 | LRZ 6 | LRZ 7 | LRZ 8 | LRZ 9 | LRZ 10 |
|---|---|---|---|---|---|---|---|---|---|
| 0.5% | 0.2% | 0.4% | 0.1% | 0.1% | 0.2% | 0.0% | 0.4% | 0.4% | 0.5% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| LBA 1 0.4% | LBA 02 0.3% | LBA 03 0.5% | LBA 04 0.2% | LBA 05 0.2% | LBA 06 1.4% | LBA 07 -0.2% | LBA 08 0.0% |
| LBA 09 0.5% | LBA 10 0.2% | LBA 11 0.0% | LBA 12 0.6% | LBA 13 0.1% | LBA 14 0.3% | LBA 15 0.4% | LBA 16 0.4% |
| LBA 17 1.7% | LBA 18 0.1% | LBA 19 0.4% | LBA 20 0.3% | LBA 21 0.6% | LBA 22 0.0% | LBA 23 0.2% | LBA 24 1.0% |
| LBA 25 0.4% | LBA 26 1.1% | LBA 27 0.1% | LBA 28 1.5% | LBA 29 0.1% | LBA 30 0.3% | LBA 31 0.4% | LBA 32 0.2% |
| | | LBA 33 0.7% | LBA 34 0.2% | LBA 35 0.0% | LBA 36 0.1% | | |

***All growth rates represent a 10-year compound annual growth rate, beginning in 2017, adjusted for the apparent anomalous forecast data described previously.***

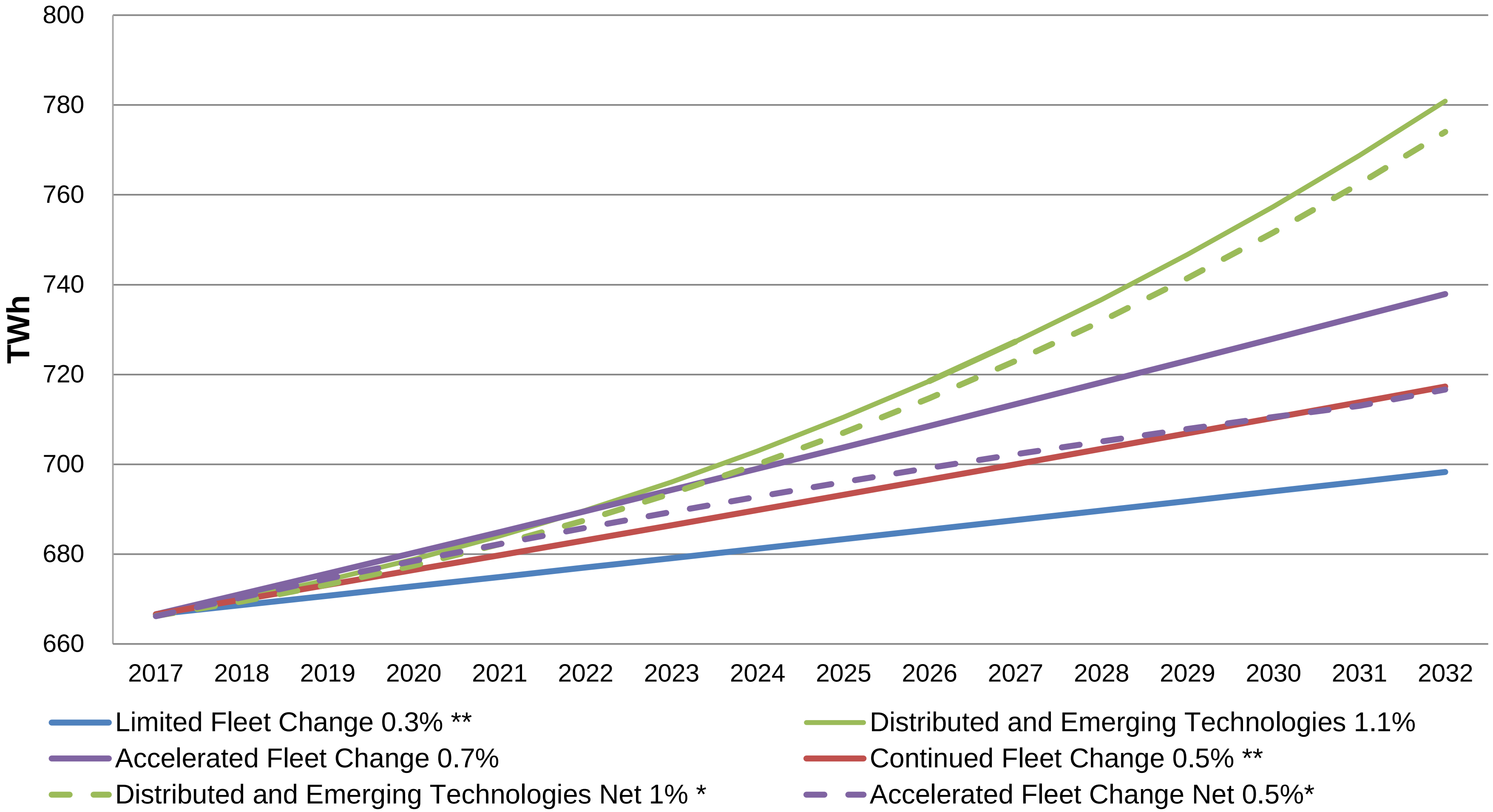
# MTEP18 Gross and Net Peak Demand Forecasts*




* *Net Forecasts* are the *Gross Forecasts* less economically selected energy efficiency programs

** No energy efficiency programs selected in low and mid scenarios due to program size

# MTEP18 Gross and Net Energy Forecasts



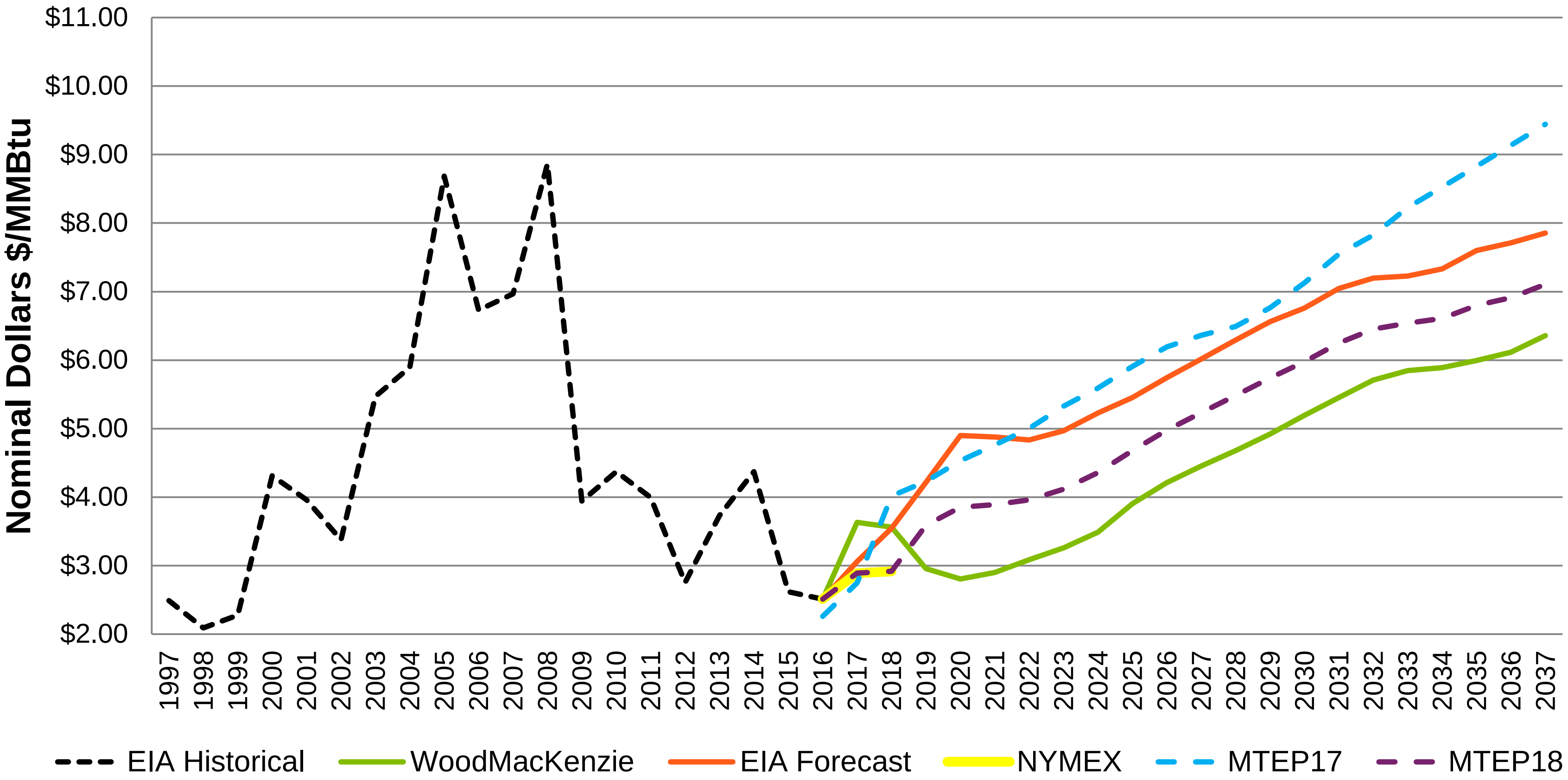

- Continued Fleet Change forecast is aggregated 50/50 forecast from Load Serving Entities (Module E)
- Accelerated and Limited Fleet Change forecasts are indicative of a 90/10 and 10/90 (respectively)
- Accelerated and Limited Fleet Change forecasts reflect LRZ 9 Industrial load being modeled low and high (respectively)

* *Net Forecasts* are the *Gross Forecasts* less economically selected energy efficiency programs

** No energy efficiency programs selected in low and mid scenarios due to program size

# MTEP18 Natural Gas Price Forecast

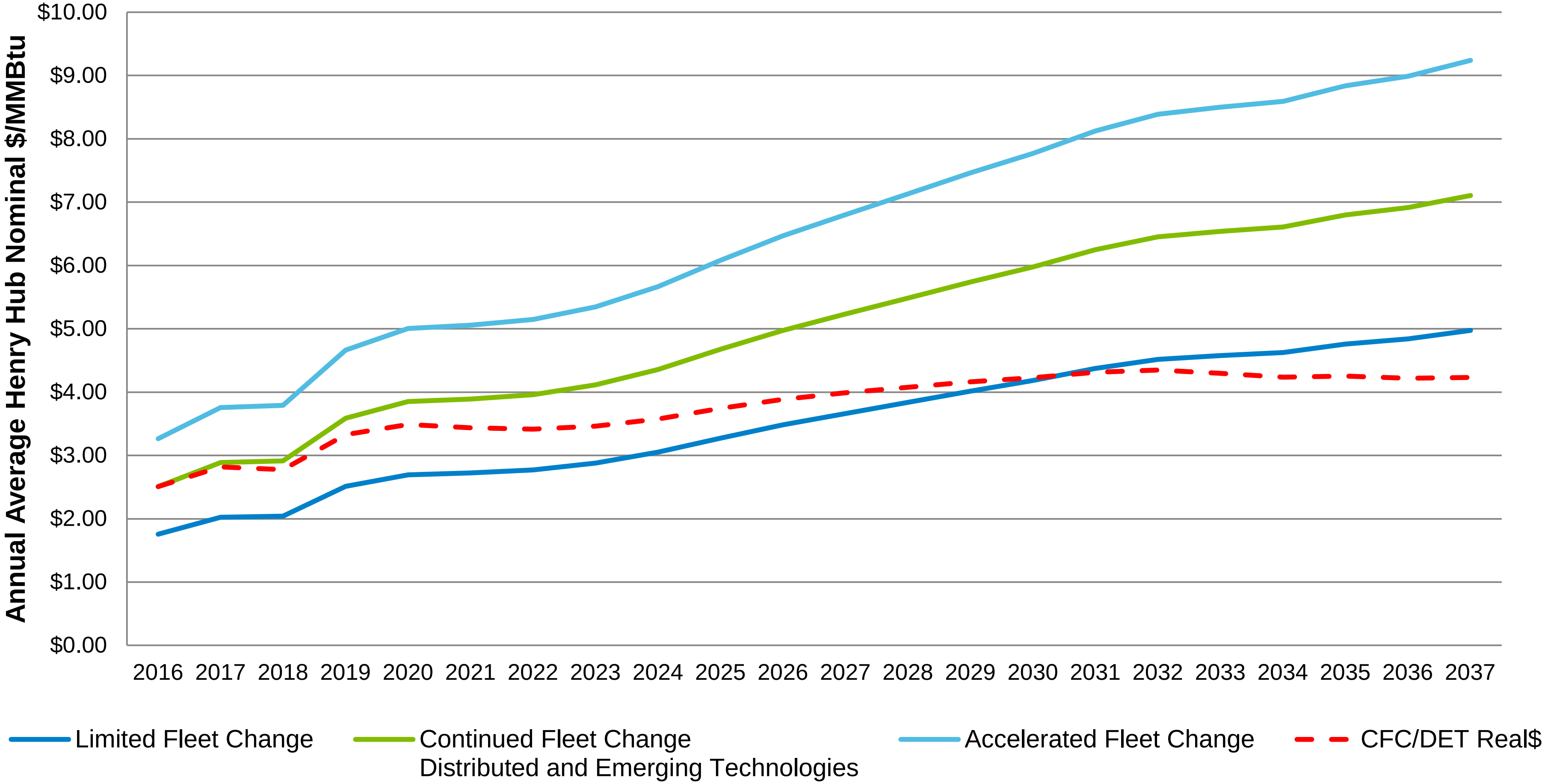
(Annual Average Values Henry Hub in Nominal $)




MISO used the NYMEX for the first two years and an average of the EIA and Wood Mackenzie forecasts for the out years as the MTEP18 base natural gas forecast.

Sources: EIA Annual Energy Outlook 2016; Wood Mackenzie North America Power & Renewables Long-Term Outlook 2016, NYMEX, retrieved from SNL

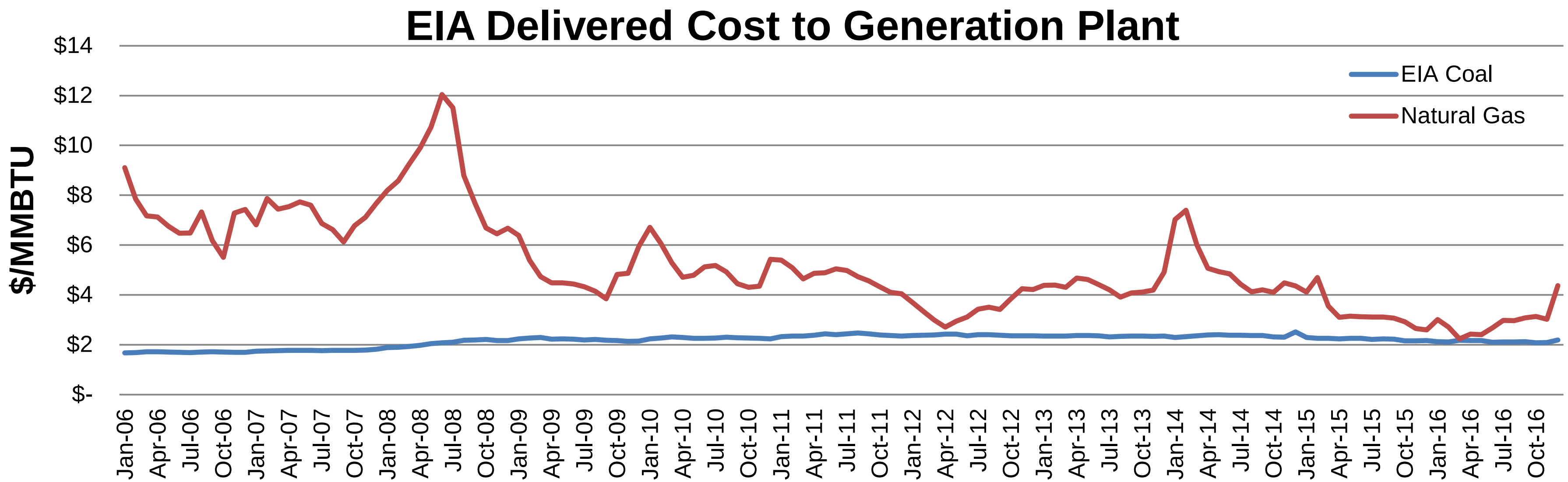
# Natural Gas Price Bands




MISO proposes to use +/- 30% as the high and low MTEP18 natural gas price forecasts, which represents a 95% confidence interval.

# Coal prices and gas prices not strongly correlated historically

- Delivered coal prices stable compared to natural gas
  - Limited low gas & coal price correlation will be captured
  - Per EIA, about 10-1: 30% drop in natural gas prices = 3% drop in coal prices
  - No correlation for gas/coal price increases

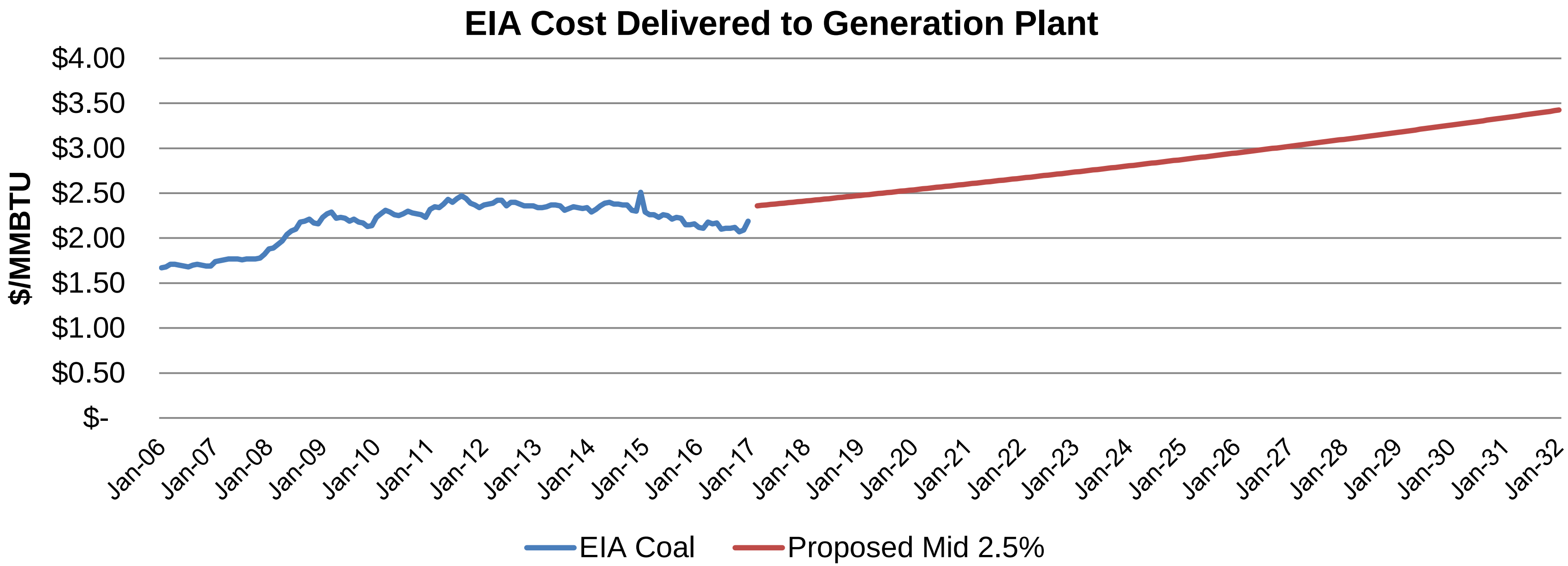



The -30% low gas starting price could only justify a -3% low coal starting price in the LFC Future.

http://www.eia.gov/outlooks/steo/query/
https://www.eia.gov/analysis/studies/fuelelasticities/pdf/eia-fuelelasticities.pdf

# Proposed MTEP18 Coal Price Forecast

- Historically, delivered coal prices increased by 2.3%-2.4%
  - All Futures assume 2.5% inflation rate




MISO proposed 2.5% inflation for coal price forecast.

# MTEP18 Demand Response, Energy Efficiency, & Distributed Generation Incremental Technical Potential

| MTEP18 Programs | | Limited Fleet Change | | Continued Fleet Change / Distributed and Emerging Technology | | Accelerated Fleet Change | |
|---|---|---|---|---|---|---|---|
| | | Capacity (GW) | Energy (GWh) | Capacity (GW) | Energy (GWh) | Capacity (GW) | Energy (GWh) |
| 15 Year Technical Potential** | Demand Response (DR) | 8.0 | 632 | 9.0 | 712 | 12.1 | 1,078 |
| | Energy Efficiency (EE) | 9.6 | 36,980 | 10.8 | 41,319 | 25.6 | 100,341 |
| | Distributed Generation (DG) | 2.3 | 3,791 | 2.8 | 4,199 | 6.4 | 13,264 |

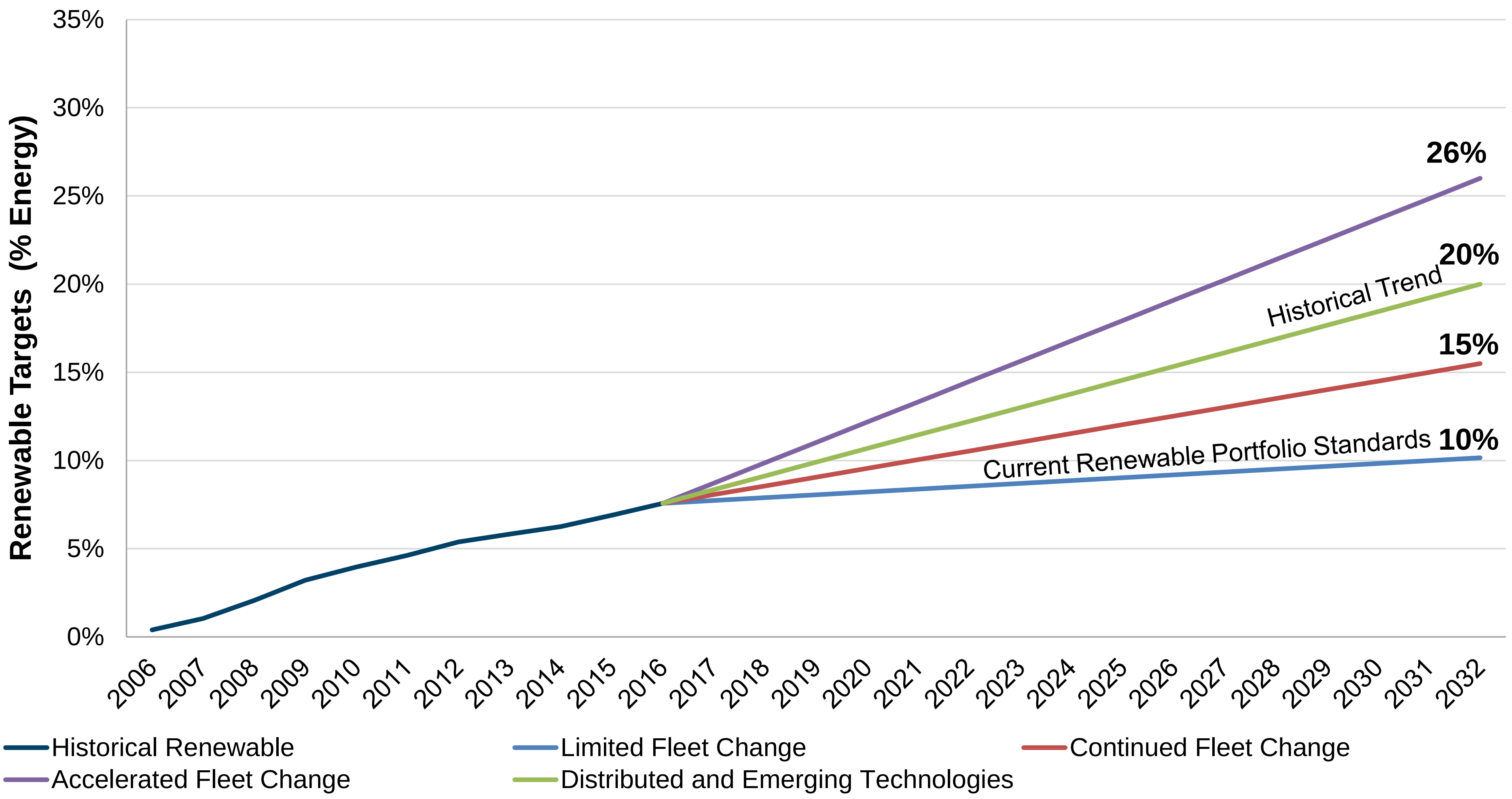
**Technical Potential** represents the maximum feasible potential under each scenario. Existing DR and EE mandates/goals deducted from technical potential. Only economically viable programs will be implemented in the MTEP18 models (each program will be offered against supply-side alternatives)

State mandates and goals met in all MTEP18 Futures, additional DR/EE/DG up to listed potential were allowed to be economically selected.

**AEG Report: https://www.misoenergy.org/Events/Pages/DREEDG20160208.aspx*

*** Existing DR programs modeled as base assumptions and excluded from table*

# Renewable Energy Targets by Future

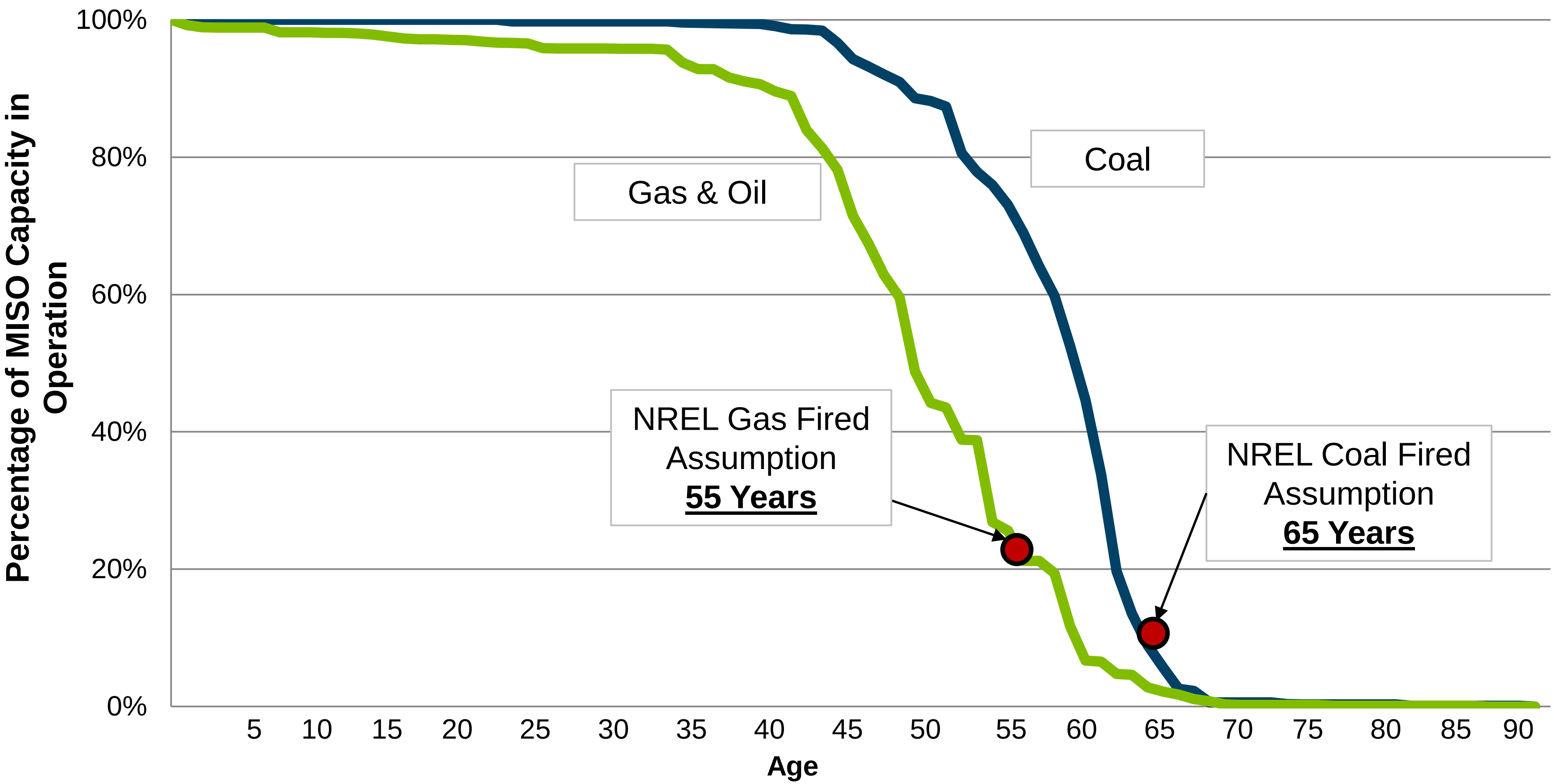


# MTEP18 Retirement Methodology

- Thermal unit age-related retirements occur in the year the useful life is reached unless planned retirement is sooner.
  - Oil & gas units retire at 55 years of age in all futures
  - Coal retires at 65 years of age in the Limited Fleet Change Future
  - In the Continued Fleet Change, Accelerated Fleet Change and Distributed and Emerging Technologies Futures, coal retires at 60 years of age reflecting historical trends, while preserving at least 1/3rd of any utilities coal fleet.
  - The Accelerated Fleet Change Future had units cycle seasonally to better meet $CO_2$ reduction targets without steeper retirement levels.
- Nuclear units assumed to have license renewals granted and remain online.
- Nuclear units retire with license expiration in the Distributed and Emerging Technology Future.
- Attachment Y and public and/or officially declared retirements (e.g. IRP) are included

# Useful Life Related Retirements

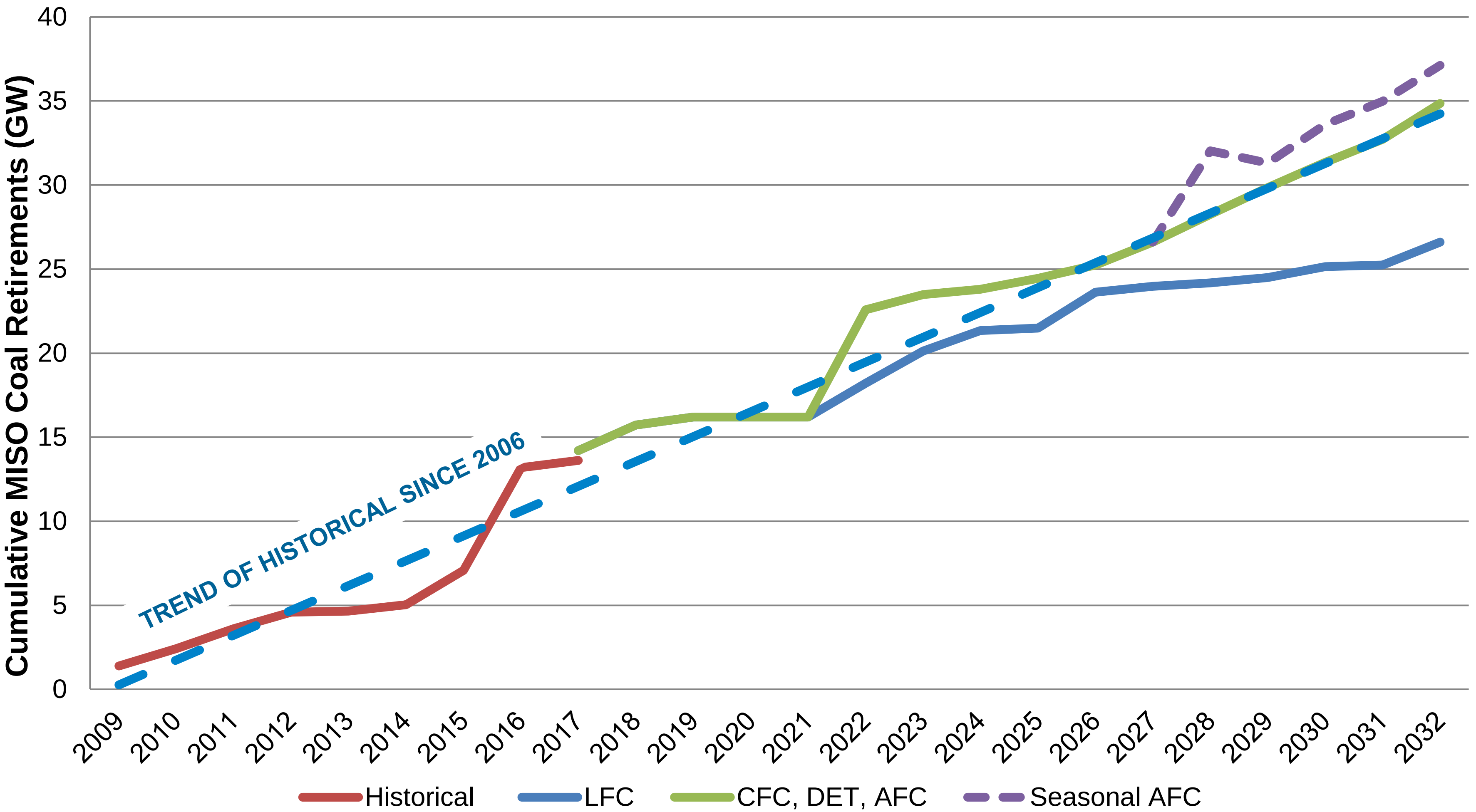
## Historical Analysis of MISO Generation Fleet




MISO to retire all non-coal fossil units at 55 years and coal units at 65 years based on historical analysis with support from NREL analysis.

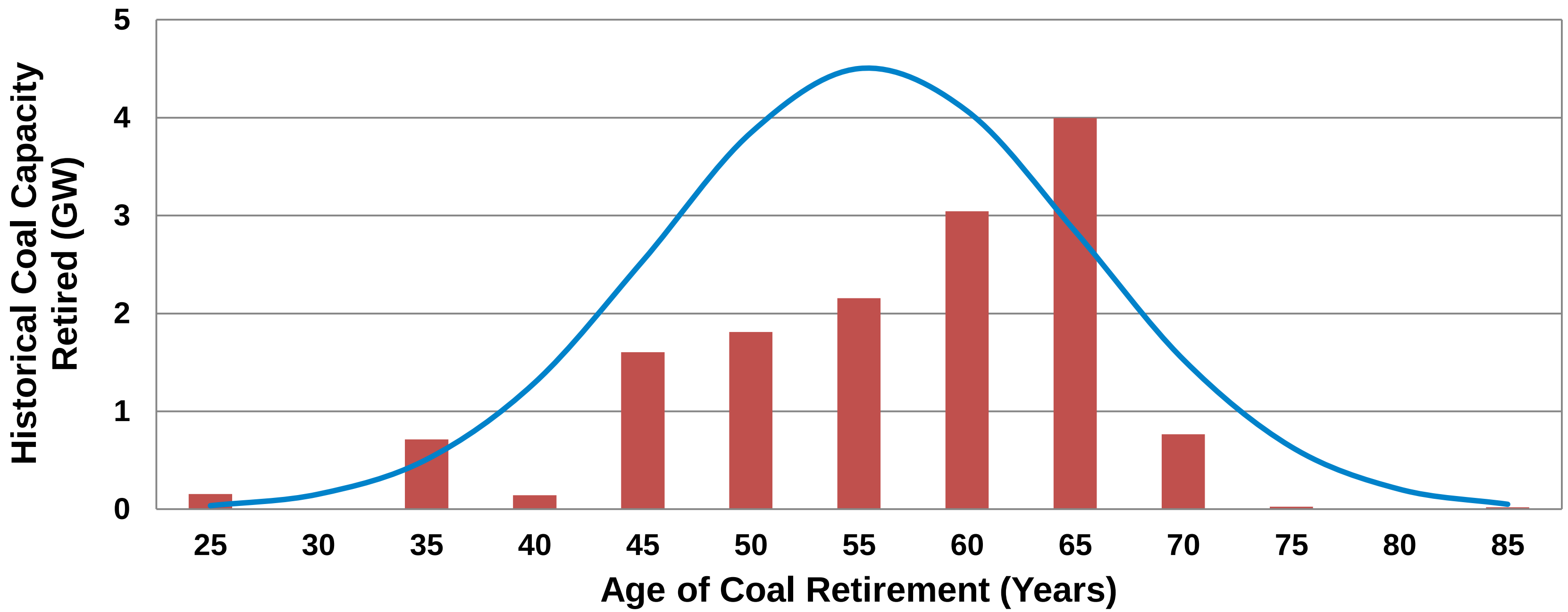
*NREL age-related assumptions:* http://www.nrel.gov/analysis/reeds/pdfs/reeds_documentation.pdf (*Page 24)*

# Coal units in the MISO footprint have been retiring due to multiple drivers- MTEP18 Futures project retirements in line with historical trends



# Historical Coal Retirements

- 91% of MISO's retired coal capacity did not achieve its assumed 65 year useful life; 48% retired prior to age 60.
- Retiring current fleet at 60 years of age, while preserving 1/3 of any utility's coal fleet, retires about <u>25%</u> of MISO's existing coal fleet.
- Common trend is members are moving to a "balanced" fleet




As a mid-coal retirement level, MISO will retire all units at 60 years of age, but preserving 1/3 of any utility's coal fleet.

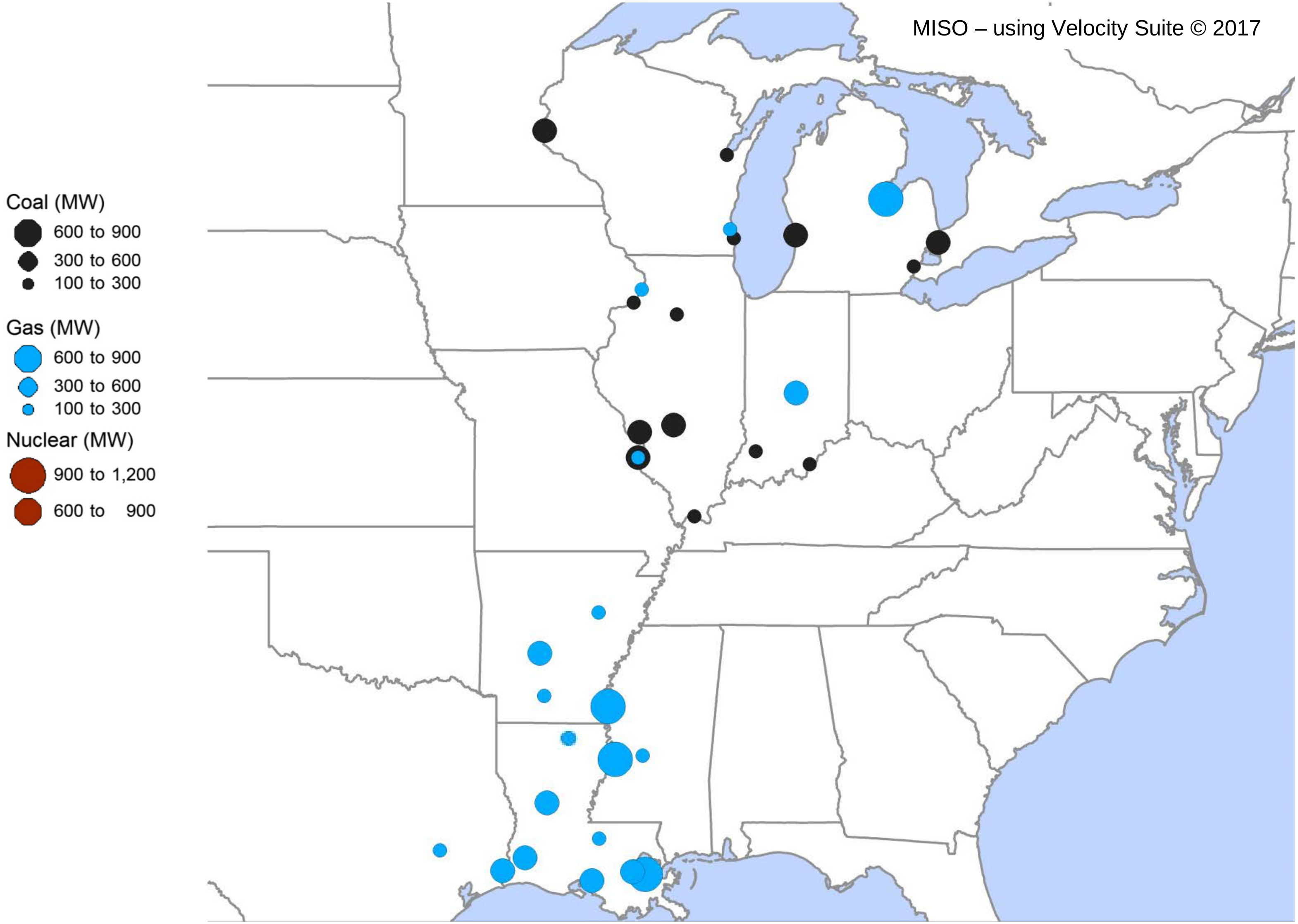
# MTEP18 Retirement Criteria

| | Retirements by 2032 (GW) | Retirements by 2032 (% of Fleet) | Criteria | Rationale |
|---|---|---|---|---|
| Coal - Low | 9.7 GW | 15% | 65 years | Useful life statistics |
| Coal - Mid | 16.5 GW | 25% | 60 years; preserve 1/3 of a utility's fleet | Expected age of retirement (Historical trends) |
| Coal - High | 16 GW & decrease output | 25% | 60 years; preserve 1/3 of a utility's fleet; Remove "must run" | Economic analysis plus expected age of retirement (Historical trends) |
| Oil/Gas | 16.1 GW | 22% | 55 years | Useful life statistics |

- Coal retirement levels driven by multiple factors: lower NG cost, increased renewables, regulatory uncertainty, wear and tear due to increased cycling
- No **assumed** retirements before first model year (2022)
- High-level in AFC future will limit coal output due to carbon reduction and to reflect an increase in cycling trends
- At higher load with higher renewable & DSM penetration, 16GW coal retirements with coal at lower capacity factors shown to be more economic than 24 GW of coal retirements

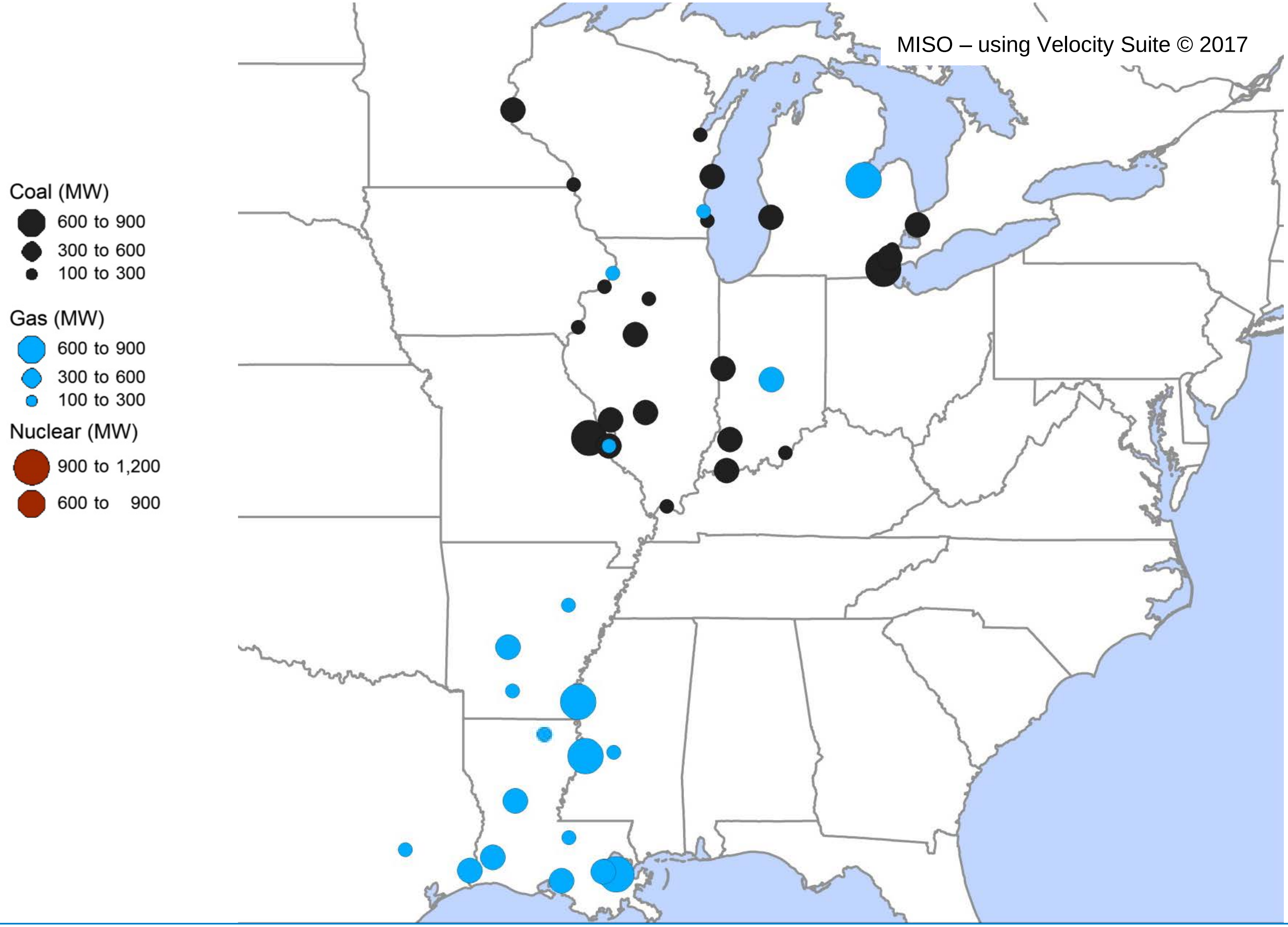
# MISO Assumed Retirements

## Limited Fleet Change



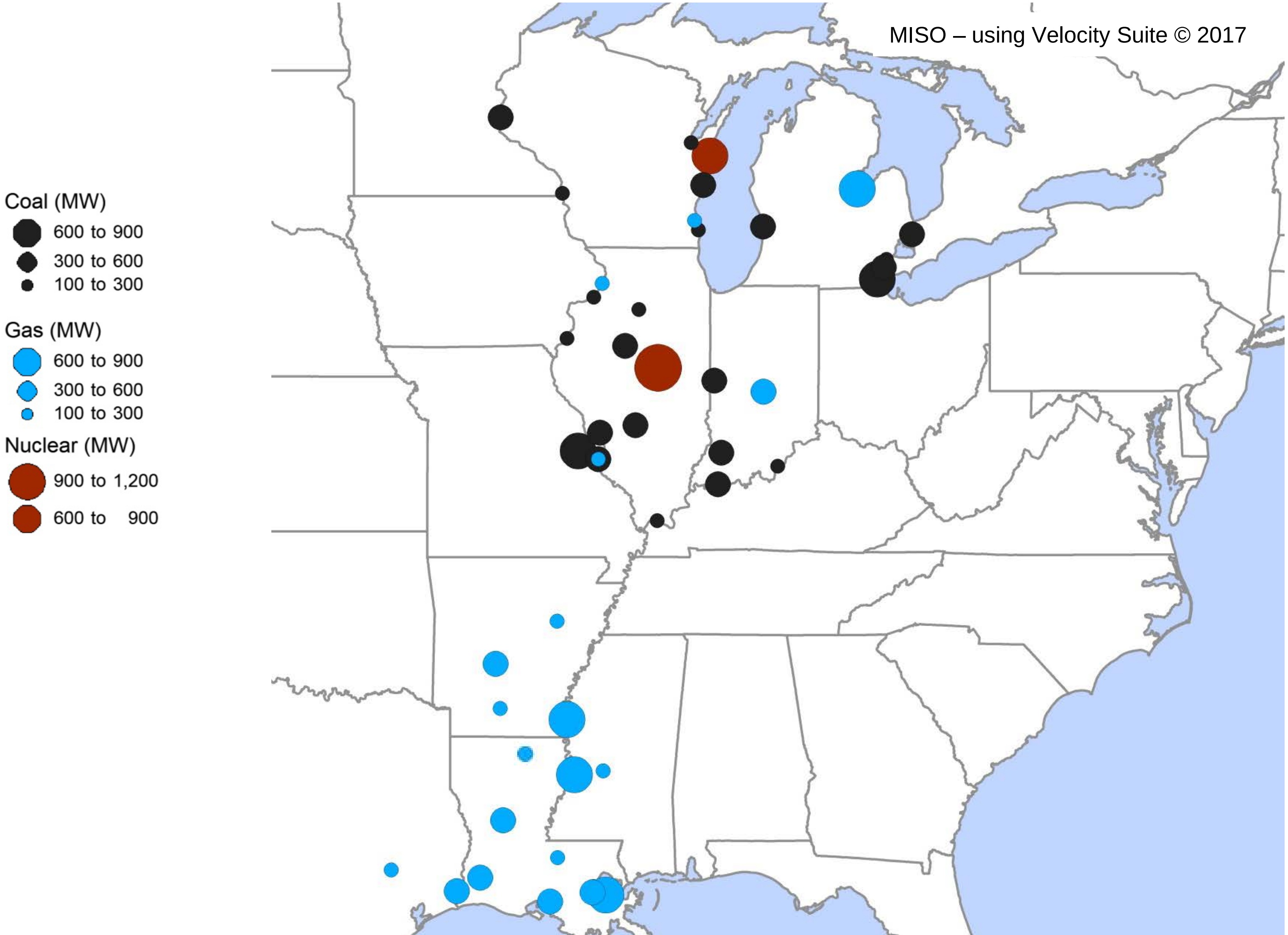
# MISO Assumed Retirements

## Continued & Accelerated Fleet Change



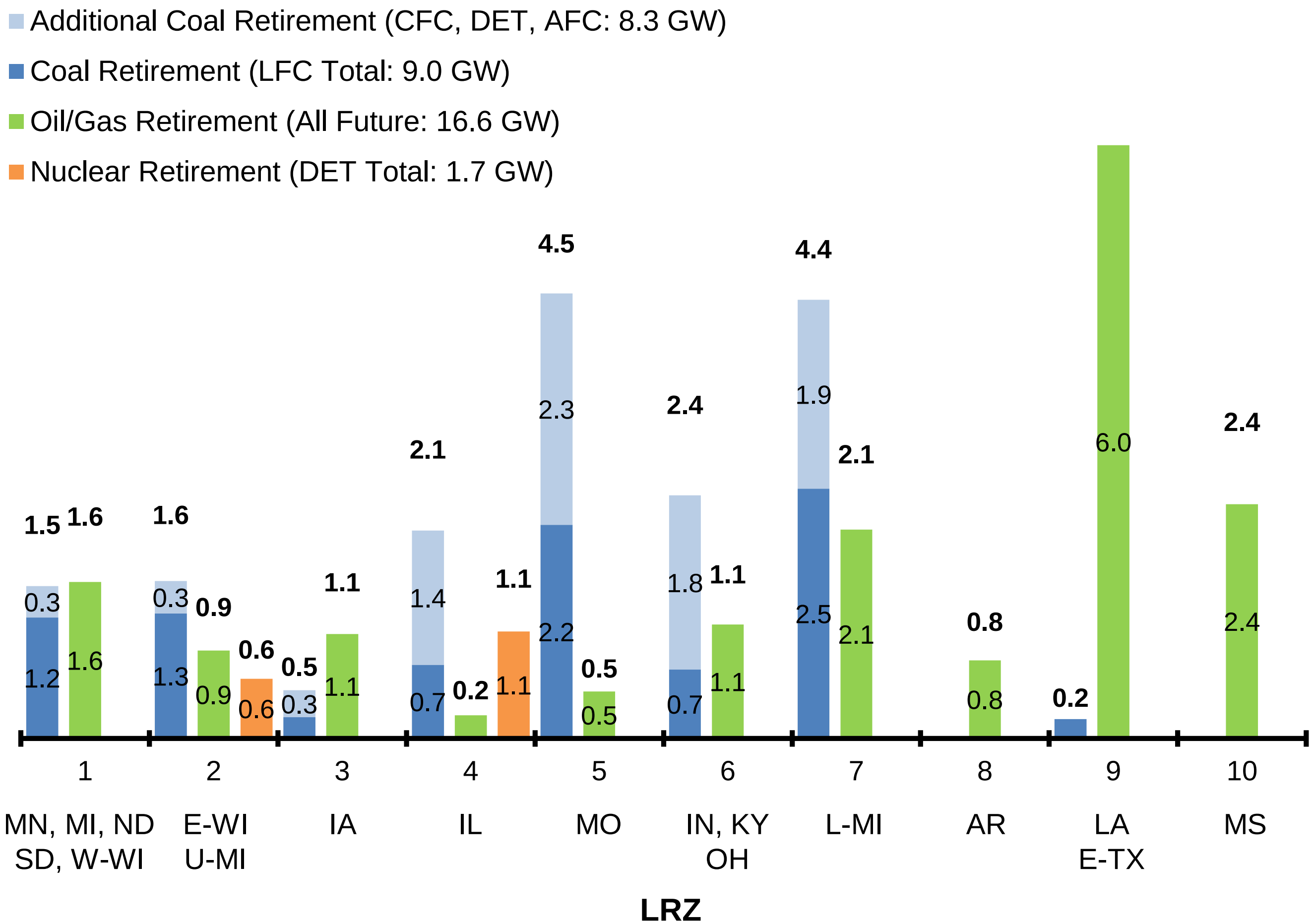
# MISO Assumed Retirements

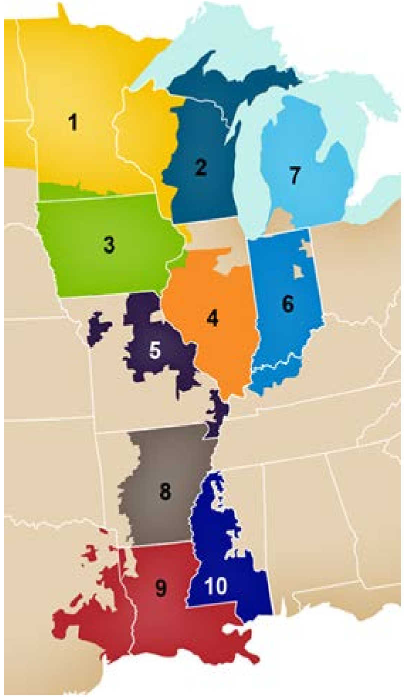
## Distributed and Emerging Technologies



# Assumed coal and natural gas/oil retirements by 2032

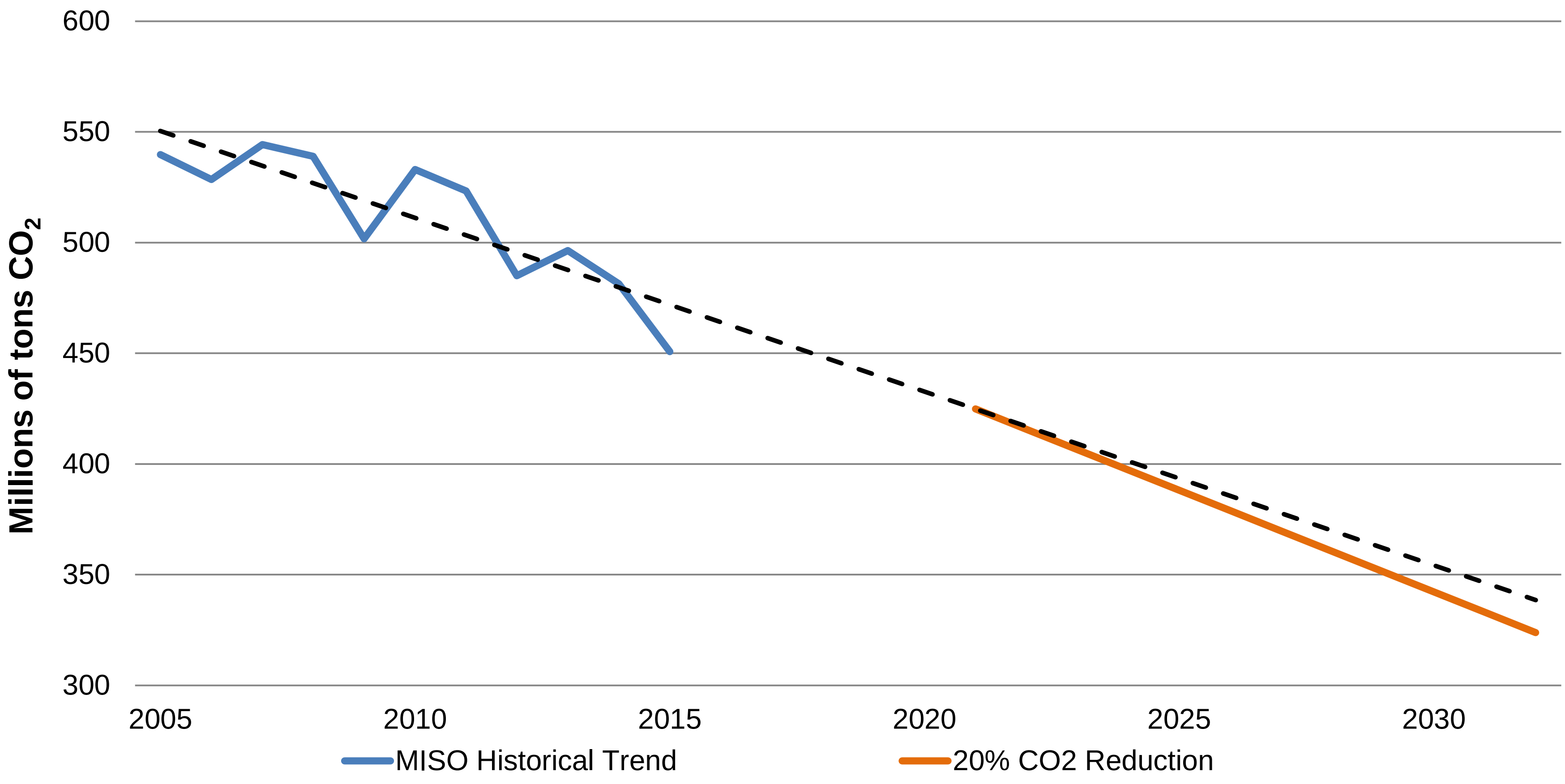
## Age limits based on statistical analysis*
## Nuclear license expiration used for DET



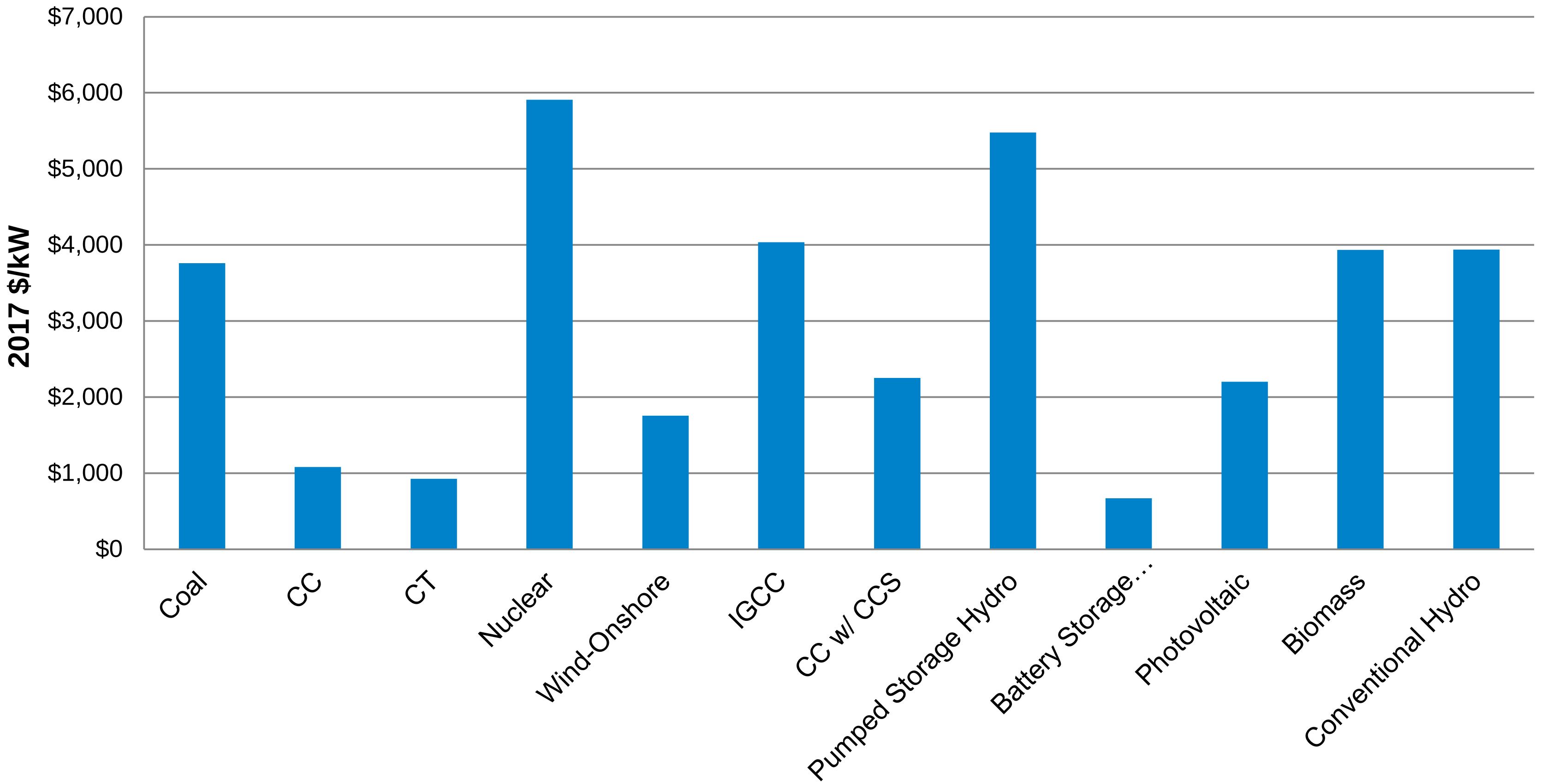

*Based on statistical analysis of MISO fleet with support from industry analysis (NREL)

# $CO_2$ Constraint applied only in Accelerated Fleet Change Future




A $CO_2$ constraint applied to the Accelerated Fleet Change Future targeting 20% additional emissions reductions by 2030, & continuing on into the future.

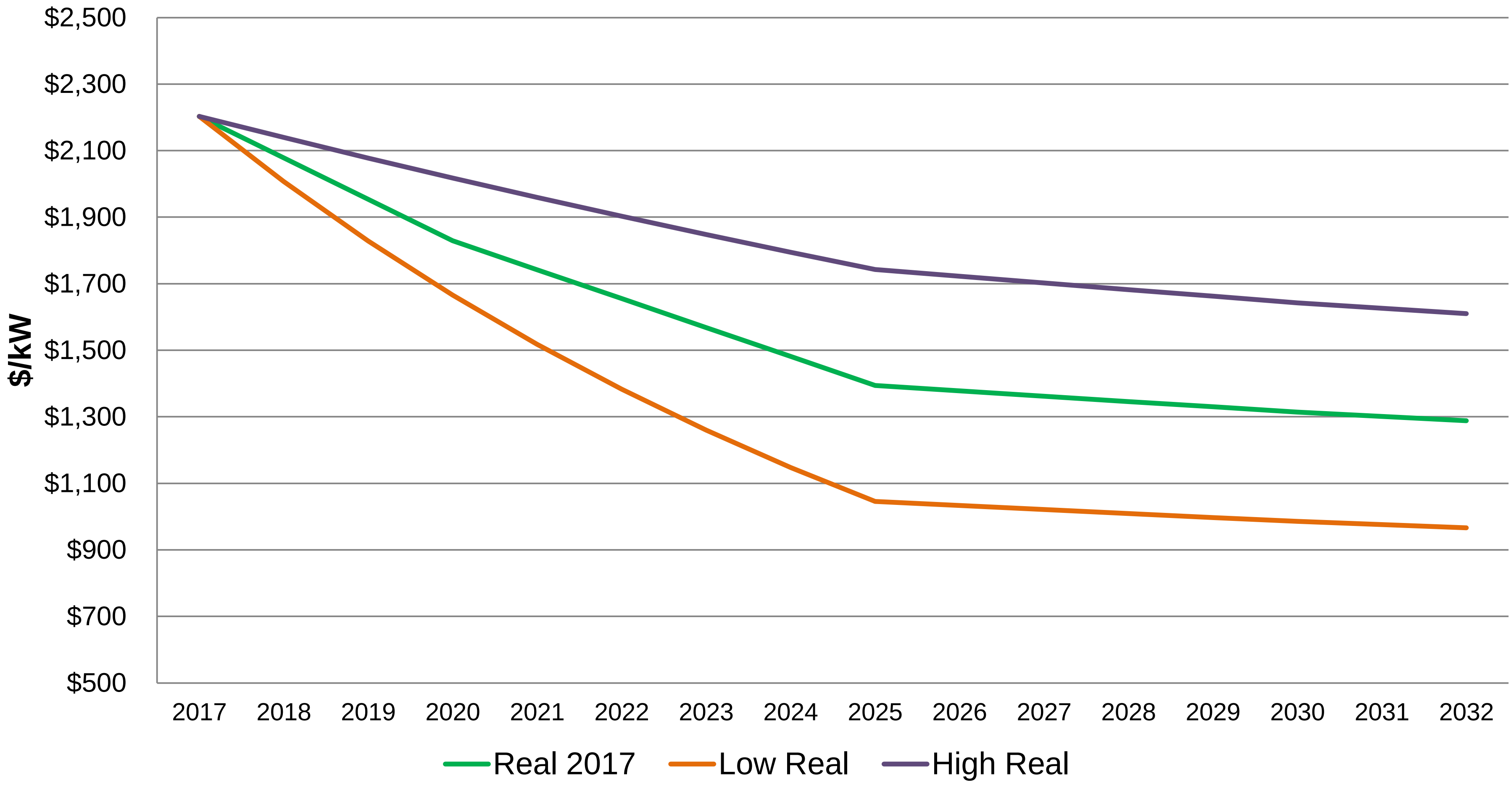
# MTEP18 Unit Capital Costs




- Costs referenced from the NREL ATB Report
- Solar values reflect a 20% adder for DC to AC conversion

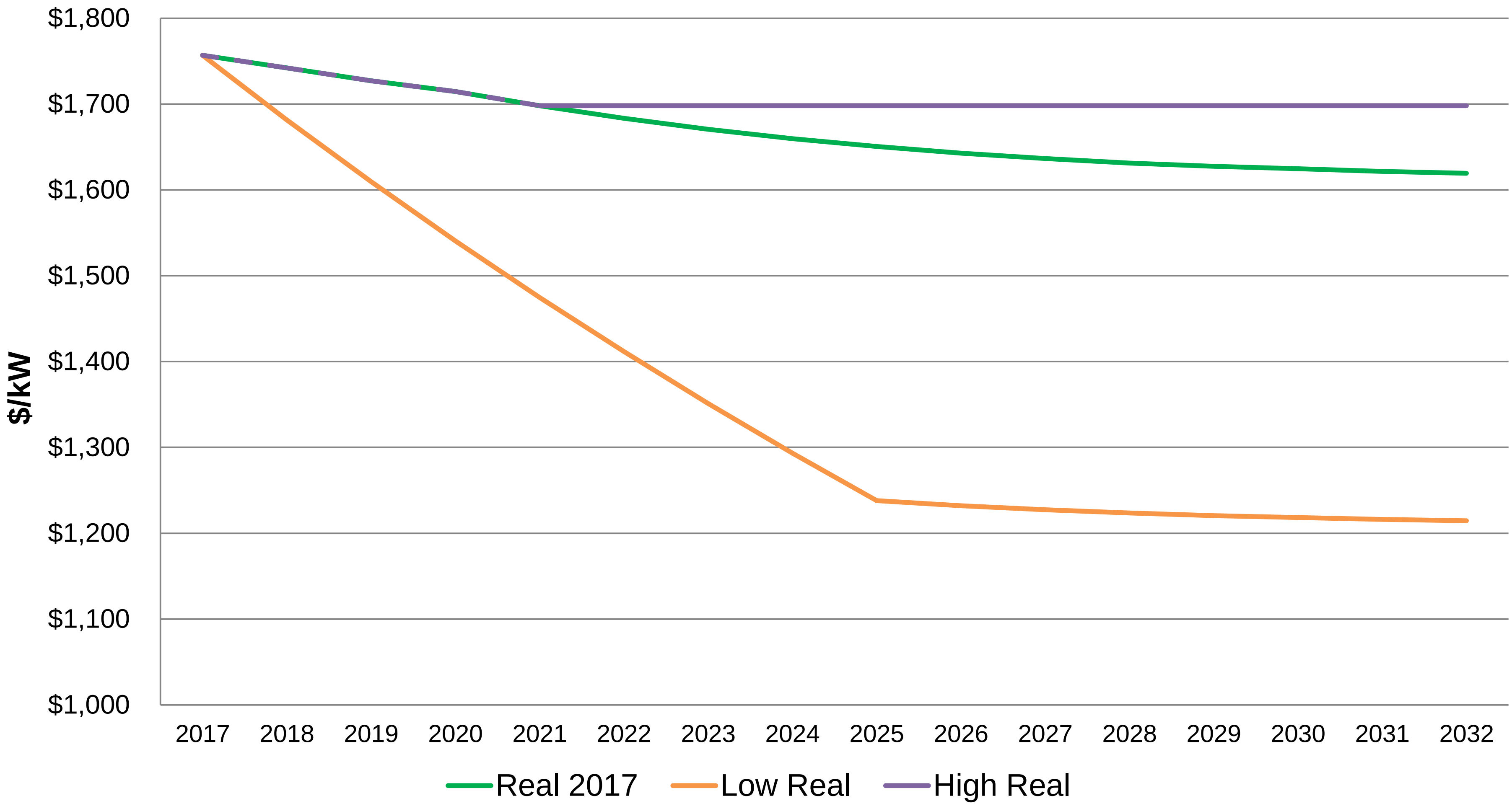
*Source: http://www.nrel.gov/analysis/data_tech_baseline.html*

# MTEP18 Solar Capital Costs



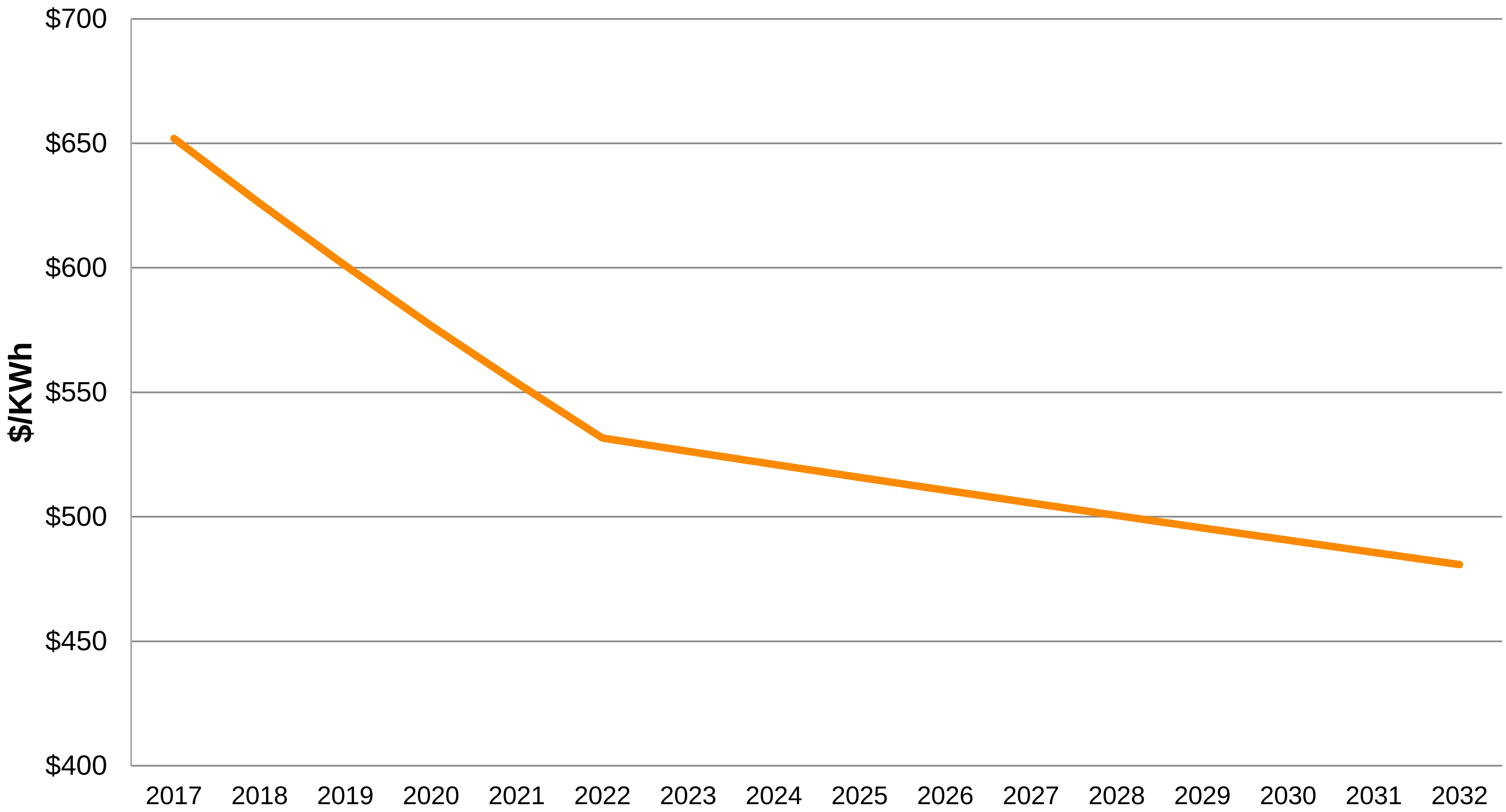

- Mid ("Real 2017") maturity curve sourced from sourced NREL ATB 2016: *http://www.nrel.gov/analysis/data_tech_baseline.html*
- High and low maturity curves are +/- 25% in 2025 of mid maturity curve

# MTEP18 Wind Capital Costs



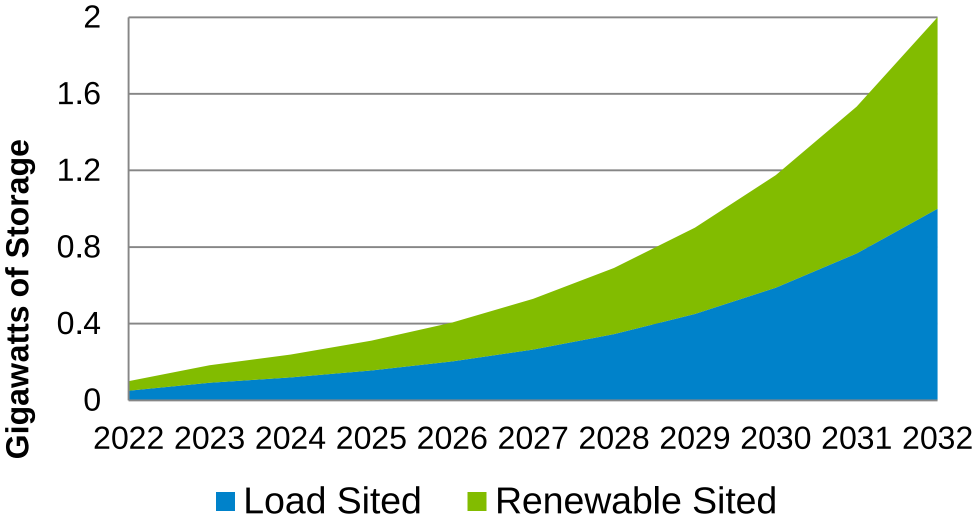

- Mid (“Real 2017”) maturity curve sourced from sourced NREL ATB 2016: *http://www.nrel.gov/analysis/data_tech_baseline.html*
- Low maturity curve is - 25% in 2025 of mid maturity curve
- High maturity curve follows NREL learning curve for the first 5 years then remains flat for the remaining years.

# MTEP18 Storage (Li Ion) Capital Cost




- Maturity curve based on LAZARD's Levelized Cost of Storage Report Version 2.0: *https://www.lazard.com/media/438042/lazard-levelized-cost-of-storage-v20.pdf*
- Technology assumes an average of Energy and Power – which results in 4% cost reduction for the first 5 years, followed by a 1% cost reduction thereon

# MISO proposed to add 2 GW of storage by 2032 in the Distributed & Emerging Technology Future - storage offered as an option in all Futures




- DET Future assumes that battery storage grows at similar penetration rate as renewables
- Capital costs assumed to decline by 4% annually for first 5 years and 1% thereon
- ~20 MW online with 80 MW queued

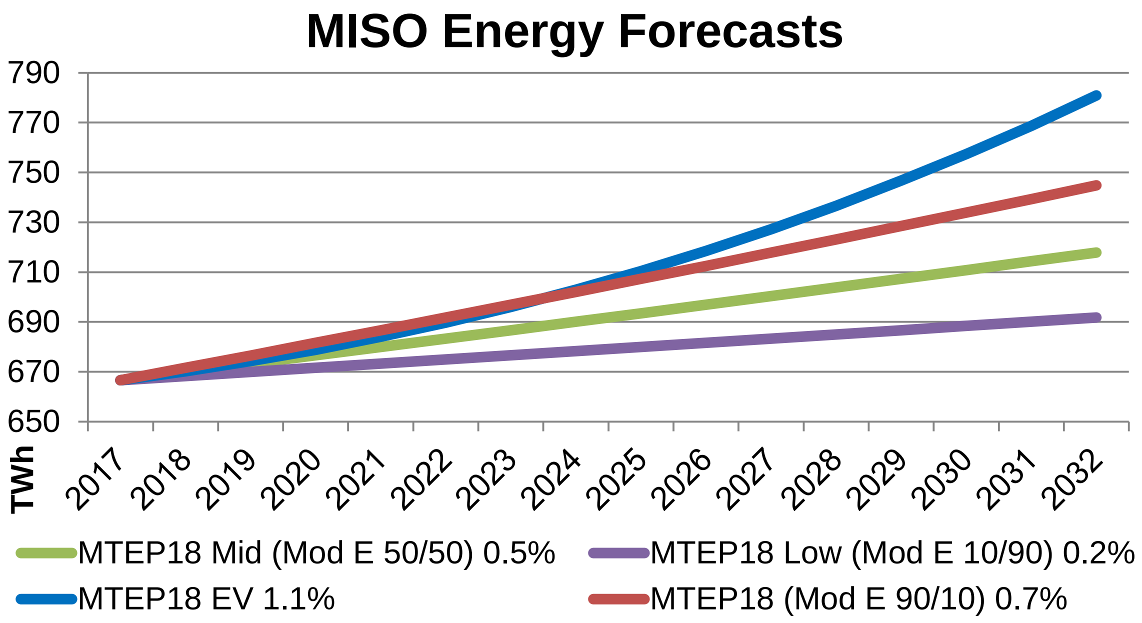
## Storage sited 50% Top Load Buses + 50% Top Renewable Buses

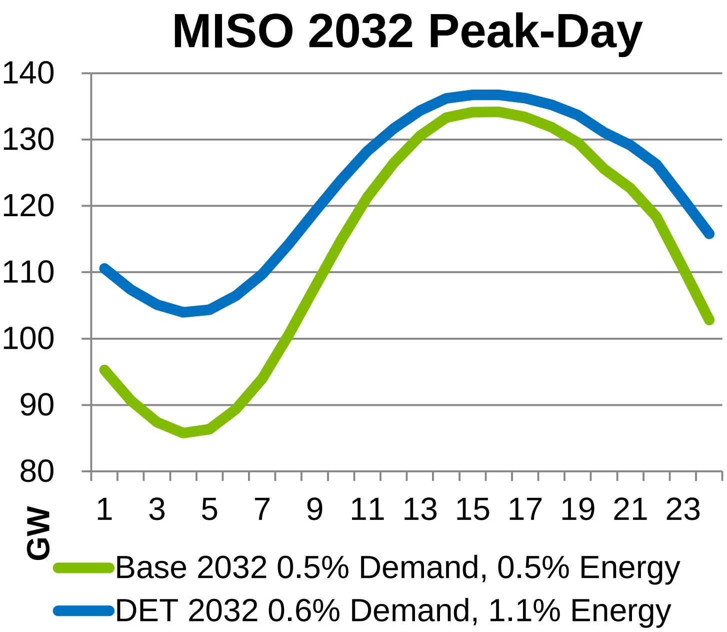
| | |
|---|---|
| Top Load Buses | • Goal: Capture energy arbitrage, peaker deferment, & renewable integration benefits*<br>• Distributed sited solar at top load buses ("Local Hybrid Projects")<br>• Split by LRZ using load ratio share – no site exceeding 100 MW by 2032 |
| Top Renewable Buses | • Goal: Capture renewable integration benefits ("Grid Scale Hybrid")*<br>• Split by LRZ using ratio of renewable capacity – no site exceeding 100 MW by 2032 |

**Benefit list not all encompassing – showing rationale for siting using what can be captured with current models*

# Electric Vehicle Load Impacts in Distributed & Emerging Technology Future

- Future assumes 25% of new car sales in 2032 are electric vehicles
- Increases energy by approximately 60 TWh in 2032
- Assume 80% off-peak, 20% on-peak charging



# MTEP18 Futures Matrix

| Future | Uncertainties | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maturity Cost Curve | | Demand and Energy | | | | | Fuel Cost (Starting Price) | | | Fuel Escalations | | | Emission Costs | | | Other Variables | | |
| | Wind Onshore | Photovoltaic | Demand Response Level | Energy Efficiency Level | Demand Growth Rate | Energy Growth Rate | Natural Gas Forecast | Oil | Coal | Uranium | Oil | Coal | Uranium | $SO_2$ | $NO_x$ | $CO_2$ | Inflation | Retirements | Renewable Portfolio Standards |
| Limited Fleet Change | H | H | L | L | L | L | L | M | L | M | M | M | M | - | M | - | M | L | L |
| Continued Fleet Change | M | M | M | M | M | M | M | M | M | M | M | M | M | - | M | - | M | M | M |
| Distributed and Emerging | M | L | M | M | $M^{+}$ | $H^{+}$ | M | M | M | M | M | M | M | - | M | - | M | M | $M^{+}$ |
| Accelerated Fleet Change | L | L | H | H | H | H | H | M | M | M | M | M | M | - | M | H | M | H | H |

# MTEP18 Uncertainty Variables

| Uncertainty | Unit | Low (L) | Mid (M) | High (H) |
|---|---|---|---|---|
| New Generation Capital Costs[1] | | | | |
| Coal | ($/KW) | 3,760 | | |
| CC | ($/KW) | 1,082 | | |
| CT | ($/KW) | 925 | | |
| Nuclear | ($/KW) | 5,908 | | |
| Wind-Onshore[1] | ($/KW) | 1,757 | | |
| IGCC | ($/KW) | 4,035 | | |
| IGCC w/ CCS | ($/KW) | 7,046 | | |
| CC w/ CCS | ($/KW) | 2,250 | | |
| Pumped Storage Hydro | ($/KW) | 5,477 | | |
| Battery Storage (Lithium Ion)[1,9] | ($/KW) | 668 | | |
| Compressed Air Energy Storage | ($/KW) | 1,295 | | |
| Photovoltaic$_{AC}$[1] | ($/KW) | 2,203 | | |
| Biomass | ($/KW) | 3,934 | | |
| Conventional Hydro | ($/KW) | 3,937 | | |
| Demand and Energy | | | | |
| Baseline 20-Year Demand Growth Rate[2] | % | 0.2% | 0.5% (.6% in DET) | 0.7% |
| Baseline 20-Year Energy Growth Rate[3] | % | 0.2% | 0.5% | 0.7% (1.1% in DET) |
| Demand Response & Energy Efficiency Levels - EE trimmed by estimated Mandates & Goals | % | AEG Low Growth | AEG Existing Programs Plus | AEG CPP 111(d) Case |
| Natural Gas | | | | |
| Natural Gas[4] | ($/MMBtu) | Forecast-30% | Combined NYMEX, EIA, and Wood Mackenzie | Forecast +30% |

# MTEP18 Uncertainty Variables, cont'

[1] *All costs are overnight construction costs in 2017 dollars; sourced from NREL Annual Technology Baseline 2016. MTEP18 cost varies using maturity curve over time versus having high and low starting points at the front of the study period.*

[2] *Mid values for years 1 - 10 of demand growth are derived from Module-E; Years 11-20 are extrapolated; H & L values are derived using LFU metric. Add .5% EV growth for DET Future*

[3] *Energy values are calculated using Module E, the corresponding demand forecast and historical load factors. Add .5% EV growth for DET Future*

[4] *NYMEX, EIA, and Wood Mackenzie*

[5] *Powerbase default for oil is $9.87/MMBtu*

[6] *Powerbase range for coal is $1 to $4, with an average value of $1.84/MMBtu*

[7] *Tonnage limit applies all units evenly. Reduction is from 2016 emission levels.*

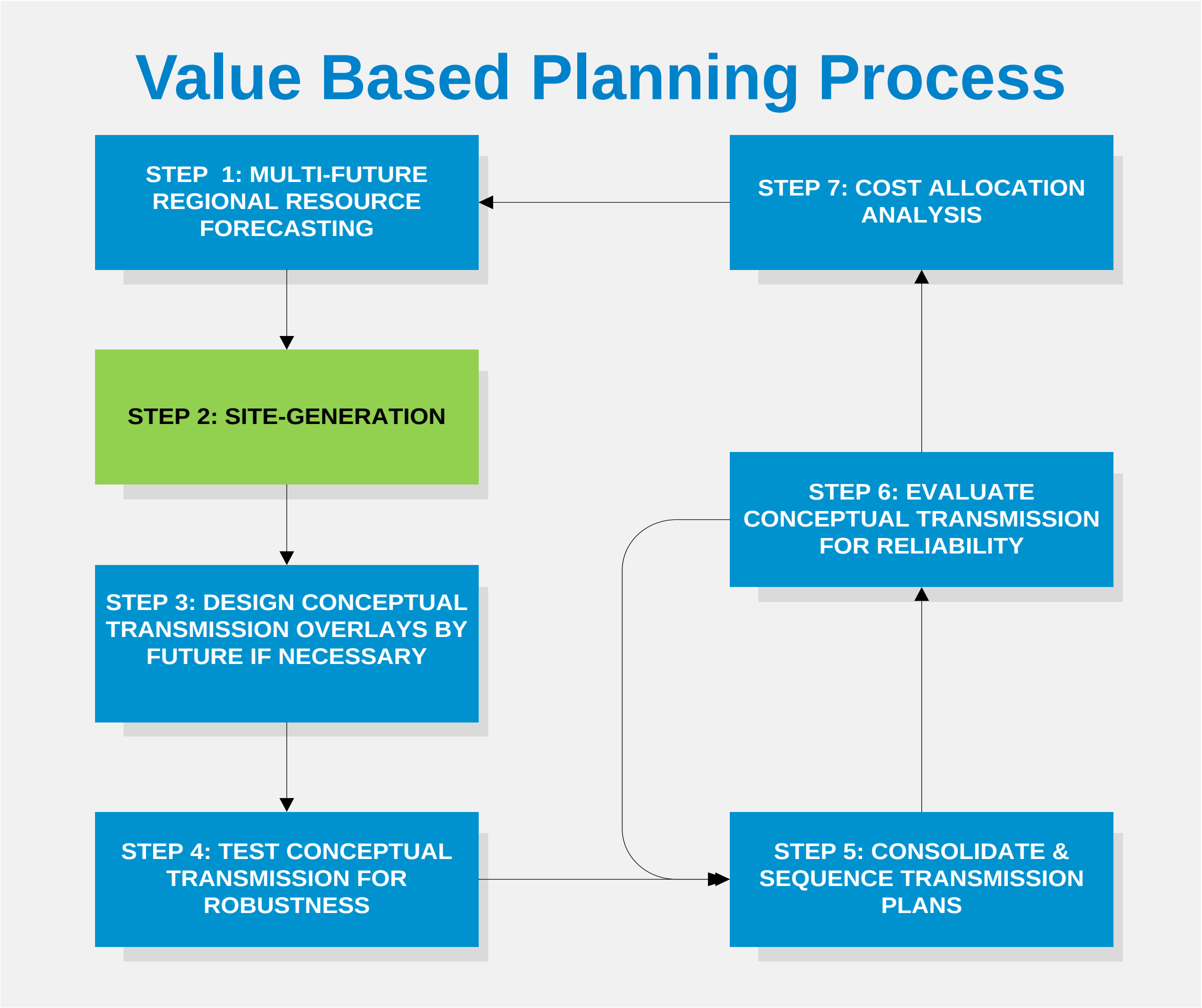
[8] *Lazard used for Li Ion battery costs and maturity curve*

https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/Workshops%20and%20Special%20Meetings/2015/DR%20EE%20DG%20Workshops/20150915/20150915%20DR%20EE%20DG%20Potential%20Study.pdf

| Uncertainty | Unit | Low (L) | Mid (M) | High (H) |
|---|---|---|---|---|
| **Fuel Prices (Starting Values)** | | | | |
| Oil | ($/MMBtu) | | Powerbase default[5] | |
| Coal | ($/MMBtu) | Powerbase default -3% | Powerbase default[6] | |
| Uranium | ($/MMBtu) | | Powerbase default | |
| **Fuel Prices (Escalation Rates)** | | | | |
| Oil | % | | 2.5% | |
| Coal | % | | 2.5% | |
| Uranium | % | | 2.5% | |
| **Emissions Costs/Constraints** | | | | |
| $NO_x$ | ($/ton) | | Annual $155 Seasonal $300 | |
| $CO_2$ | (Tons)[7] | | | 20% by 2030 |
| **Other Variables** | | | | |
| Inflation | % | | 2.5 | |
| Retirements | MW | Age-related oil/gas (55 years) & coal (65 years) | Age-related oil/gas (55 years) & coal (60 years), 35% of nuclear in DET | Age-related oil/gas (55 years) & coal (60 years, reduced operation) |
| Renewable Portfolio Standards | % | State Mandates and goals | 15% energy from wind and solar (20% in DET, emphasis on solar | 26% energy from wind and solar |
| Cost Maturity Curves | % | More aggressive than NREL ATB, achieving -25% by 2025 | Based on NREL ATB | Less aggressive than NREL ATB |

# MTEP18 Siting Methodology

# Generation siting process is used to predict where future generation units would likely be located



# General MTEP Siting Methodology

- Different siting process for different types of units – thermal, renewable, demand-side resources
- Siting process designed to reasonably predict proximal location of future units
  - Siting done at 230kV or higher voltage level
- Siting process is unique for each future
- Stakeholder review is essential to inform if a site is not a feasible location

# MTEP17/18 Siting Methodology Refinements Address Main Stakeholder Concerns Identified

| | |
|---|---|
| Thermal Generation | • Consider nonattainment areas<br>• Update unit sizing<br>• Update greenfield siting criteria |
| Renewable Generation | • Identify additional wind zones<br>• Identify solar zones |
| Alternative Technologies | • Differentiate between commercial/industrial and residential programs in demand response siting<br>• Develop distributed generation siting methodology<br>• Formalize storage siting |
| Other | • Incorporate zonal resource adequacy requirements<br>• Increase consistency in siting of external resources |

# Generation Unit Sizes for Siting

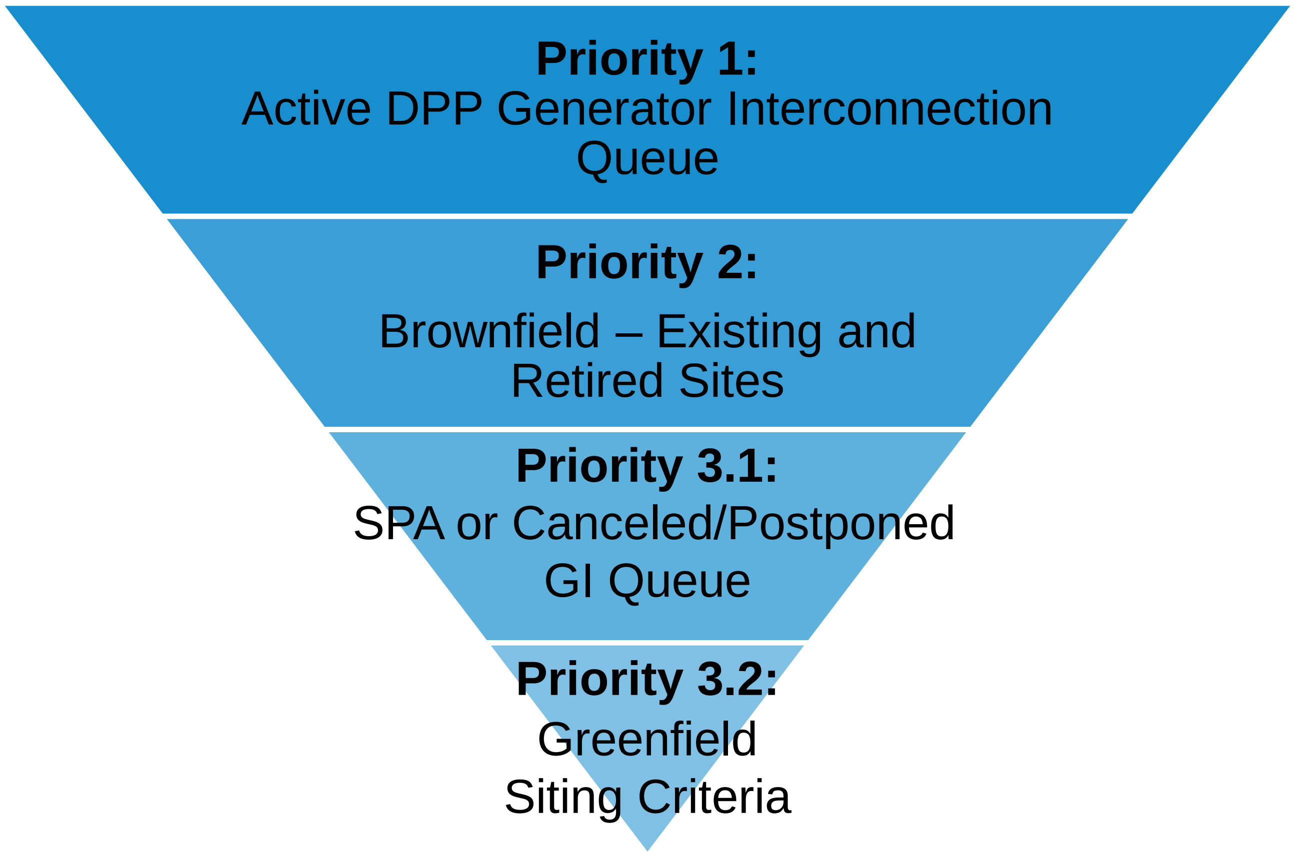
| Unit Type | Size* |
|---|---|
| CC | 600 MW |
| CT | 300 MW |
| Solar | Matched to Site |
| Nuclear | 1,200 MW |
| Wind | Matched to Site |

**Sizes based on typical size in GI Queue as well as stakeholder feedback*

- When possible, forecast units will match size of existing site or queued capacity
  - **For simplicity, MISO will round up to nearest 100 MW**
- Restrict total site capacity to 1,200 MW, unless justified

# Thermal Generation Siting Methodology
(Coal, Gas, Oil, & Nuclear)

# Thermal Siting Methodology




- Diversity in siting across futures encourages robust solution development
- Stakeholder review essential to inform if a site is not a feasible location

# Brownfield Siting Guidelines

- Targeting newer sites that may be able to expand:
  - **CC**
    - Use 200MW+ sites built since 2000
  - **CT**
    - Use 100MW+ sites built since 1990
    - Prefer sites near urban areas
  - **Coal**
    - Only consider Existing/Planned sites 200 MW+
    - Only consider sites outside the 25 miles buffer of a major urban area
  - **Nuclear**
    - Expand an existing site twice – 1,200 MW intervals

# Greenfield Siting Guidelines

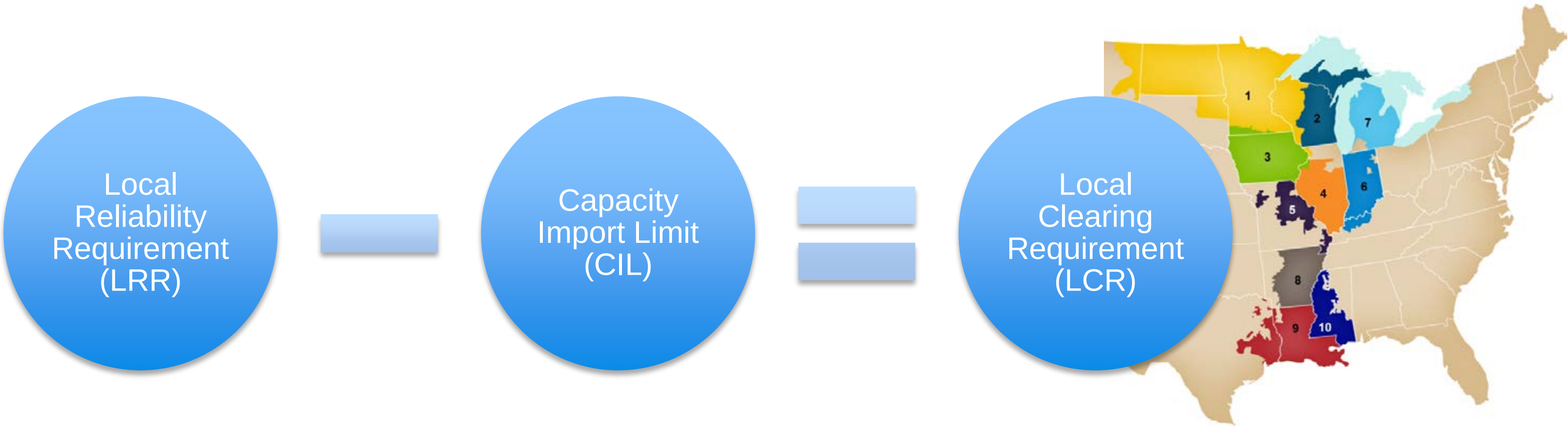
| Fuel Type / Criteria | Railroad/Navigable Waterway | Class I Lands | Urban Area | Major River/ Lake | Gas Pipeline | Coal Mine/ Dock |
|---|---|---|---|---|---|---|
| Coal | Within 1 mile (Prefer multiple) | Outside 20 miles | Outside 25 miles | Within half a mile | Prefer Access | Within 20 miles |
| Biomass | Within 1 mile (Prefer multiple) | Outside 20 miles | Outside 25 miles | Within half a mile | Prefer Access | - |
| CC | - | Outside 20 miles | (Prefer near load) | Within 2 miles | Within 10 miles | - |
| CT | - | Outside 20 miles | | - | Within 5 miles | - |

# National Ambient Air Quality Standards, Transmission Considerations, and Load Pockets

- New thermal generation will not be sited in latest identified NAAQS nonattainment areas (except lead)
  - Large coal retirement could be replaced by natural gas
- Where all things are equal, transmission and/or deliverability will be considered
  - Consider the number of lines/ratings of a substation
  - Export congested areas and load pockets would be a lower priority
- Load pocket siting will follow same priority-based system for consistent methodology
  - Nonattainment areas will limit siting
  - Queue and brownfield will be considered

# Zonal Resource Adequacy Requirements

- Siting in 5, 10, and 15[1] year cases will meet both Local Clearing Requirements and North/South transfer limits in each Future
- Local Reliability Requirements (LRR) and Capacity Import Limits referenced from the latest LOLE Report[2]
- North/South transfer limit of 1,000 MW used in MTEP siting process




1. 15 year case will assume same Local Clearing Requirements as the 10 year case
2. 2017 Loss of Load Expectation Report, see https://www.misoenergy.org/Library/Repository/Study/LOLE/2017%20LOLE%20Study%20Report.pdf

# Renewable Generation Siting Methodology
(Wind and Solar)

# MTEP Wind Zones

| Tier 1 | Tier 2 | Tier 3 | Tier 4 | Tier 5 |
|---|---|---|---|---|
| **Existing RGOS Zones** | **50%* VCE Clusters / Queue (A)** | **50% VCE Clusters / Queue (W)** | **50% VCE Clusters / Non-Queue** | **80% VCE Incremental Zones** |
| Remaining capacity in existing RGOS zones, up to MVP-enabled amount** | 50% VCE Zones coincident with active Queue positions | 50% VCE Zones coincident withdrawn Queue positions | 50% VCE Zones, Other (Incremental to Tiers 1-3) | 80% VCE Zones (Incremental to 50% and Tiers 1-4) |

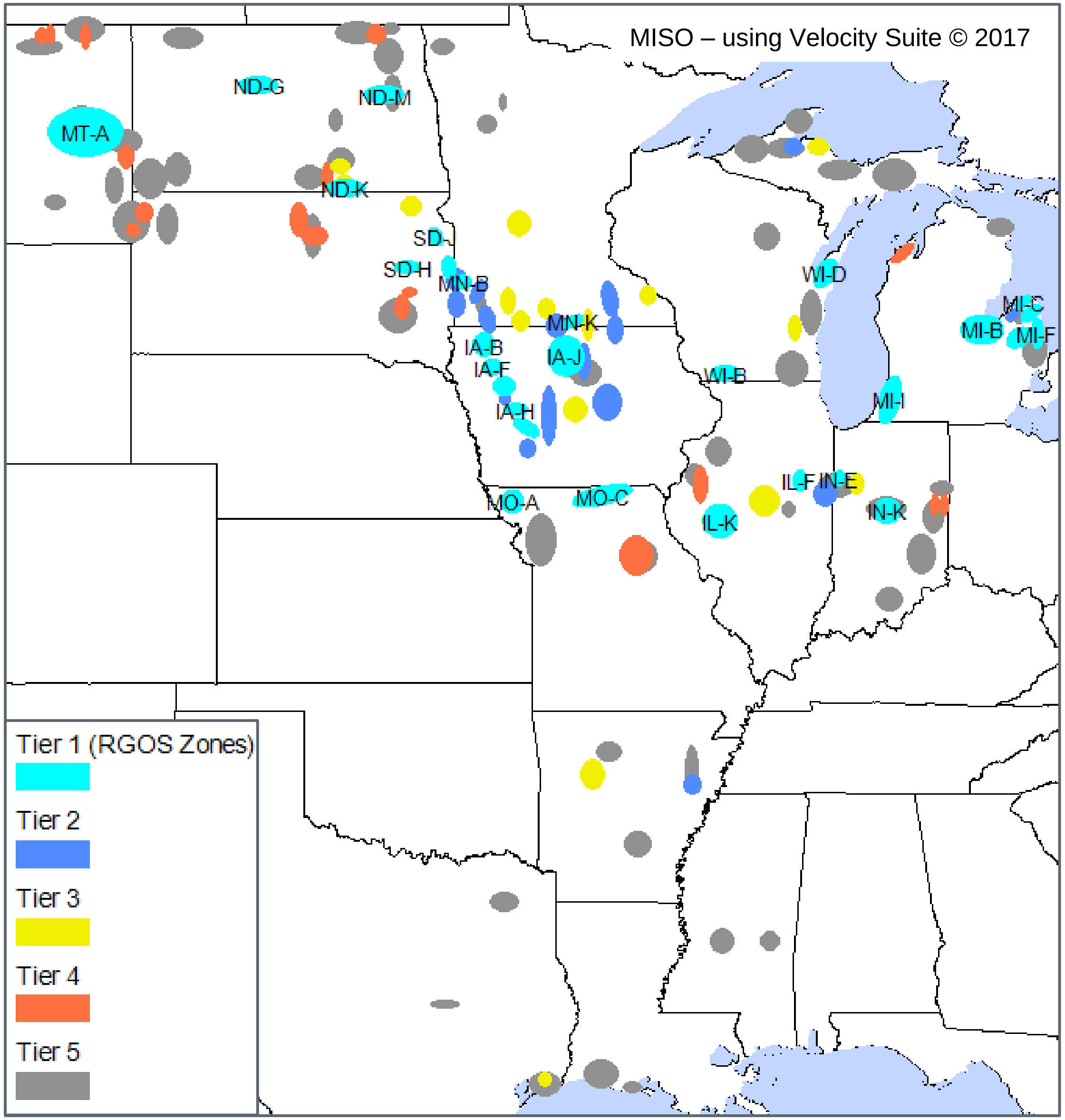
*Existing Zones* — Tier 1; *Planned/likely areas for wind expansion* — Tiers 2–3; *Potential areas for future wind expansion* — Tiers 4–5

- *VCE results (location/MW) are used as an indication of potential wind growth zones*
- *Existing wind locations are allowed to expand if in close proximity to future (queue) locations*
- *Tiers 4 and 5, based solely on VCE study results, will be revisited as siting needs evolve.*
- *MISO will continue to monitor developing trends; should there be a shift in concentrations of wind developments MISO will adjust zones/tiers accordingly*

* "50% VCE" refers to results from the 50% $CO_2$ reduction case

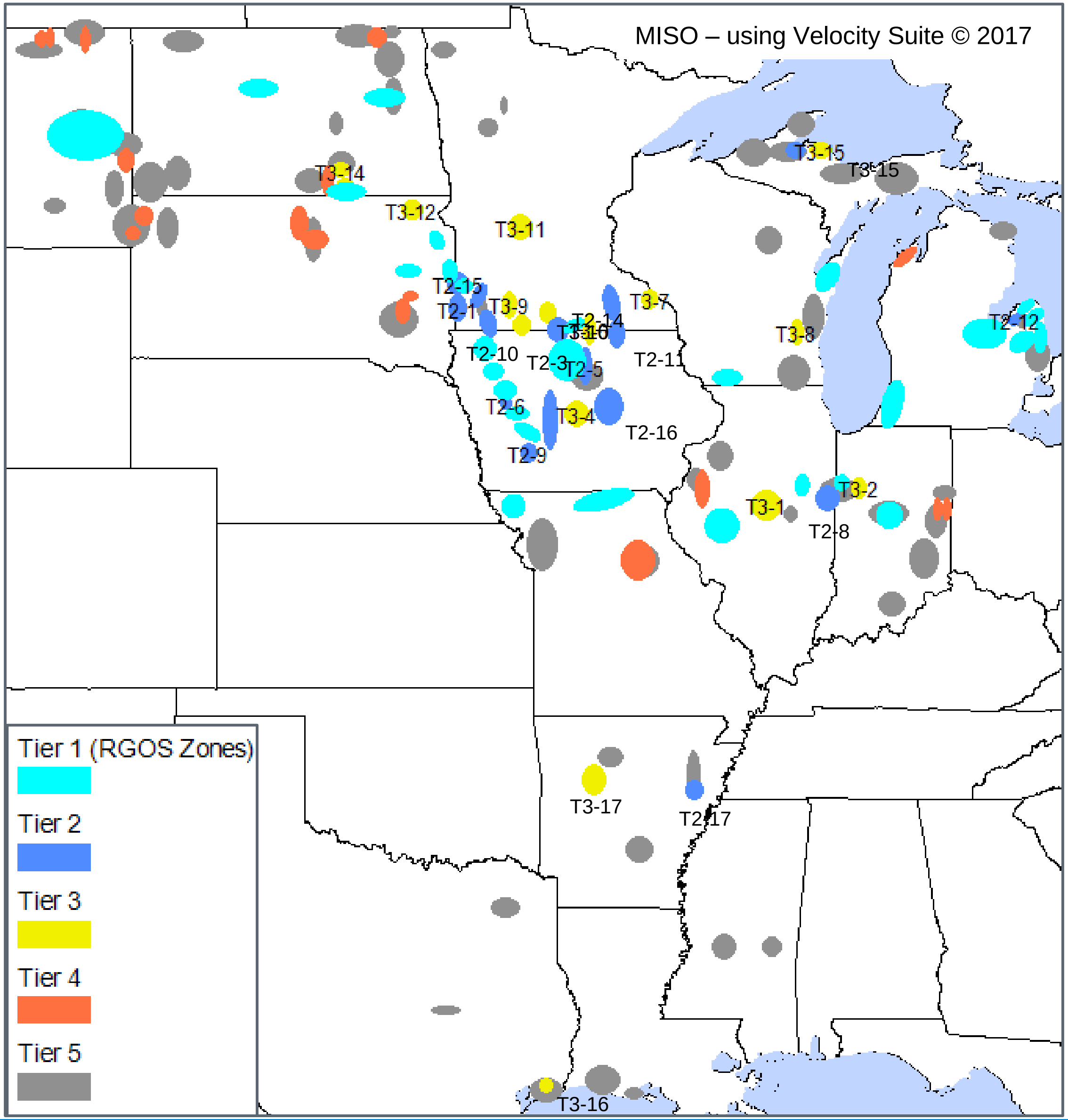
** Multi-Value Project (MVP)-Enabled capacity, see https://www.misoenergy.org/Planning/TransmissionExpansionPlanning/Pages/MVPAnalysis.aspx

# MTEP Tier 1 Wind Zones (RGOS Zones)



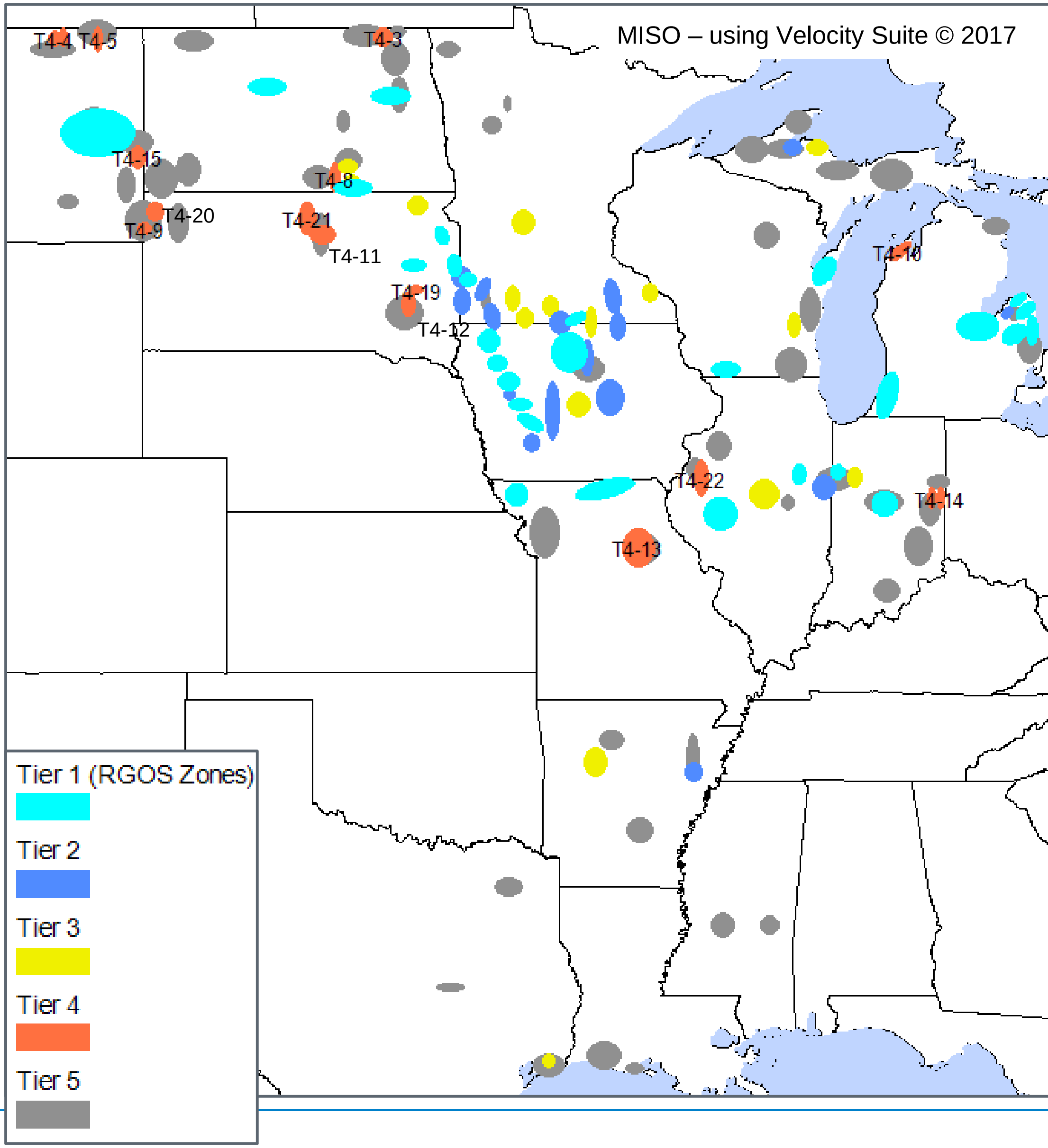

| Wind Zone | Size (MW) |
|---|---|
| IA-B | -- |
| IA-F | 586 |
| IA-G | -- |
| IA-H | 433 |
| IA-I | 398 |
| IA-J | 909 |
| IL-F | 37 |
| IL-K | 757 |
| IN-E | 156 |
| IN-K | 311 |
| MI-B | 437 |
| MI-C | 822 |
| MI-D | 379 |
| MI-E | 1,160 |
| MI-F | 1,215 |
| MI-I | 837 |
| MN-B | -- |
| MN-K | -- |
| MO-A | 653 |
| MO-C | 1,047 |
| MT-A | 134 |
| ND-G | 852 |
| ND-K | -- |
| ND-M | 503 |
| SD-H | 318 |
| SD-J | 341 |
| SD-L | 275 |
| WI-B | 601 |
| WI-D | 594 |

# MTEP Tier 2 and 3 wind zones



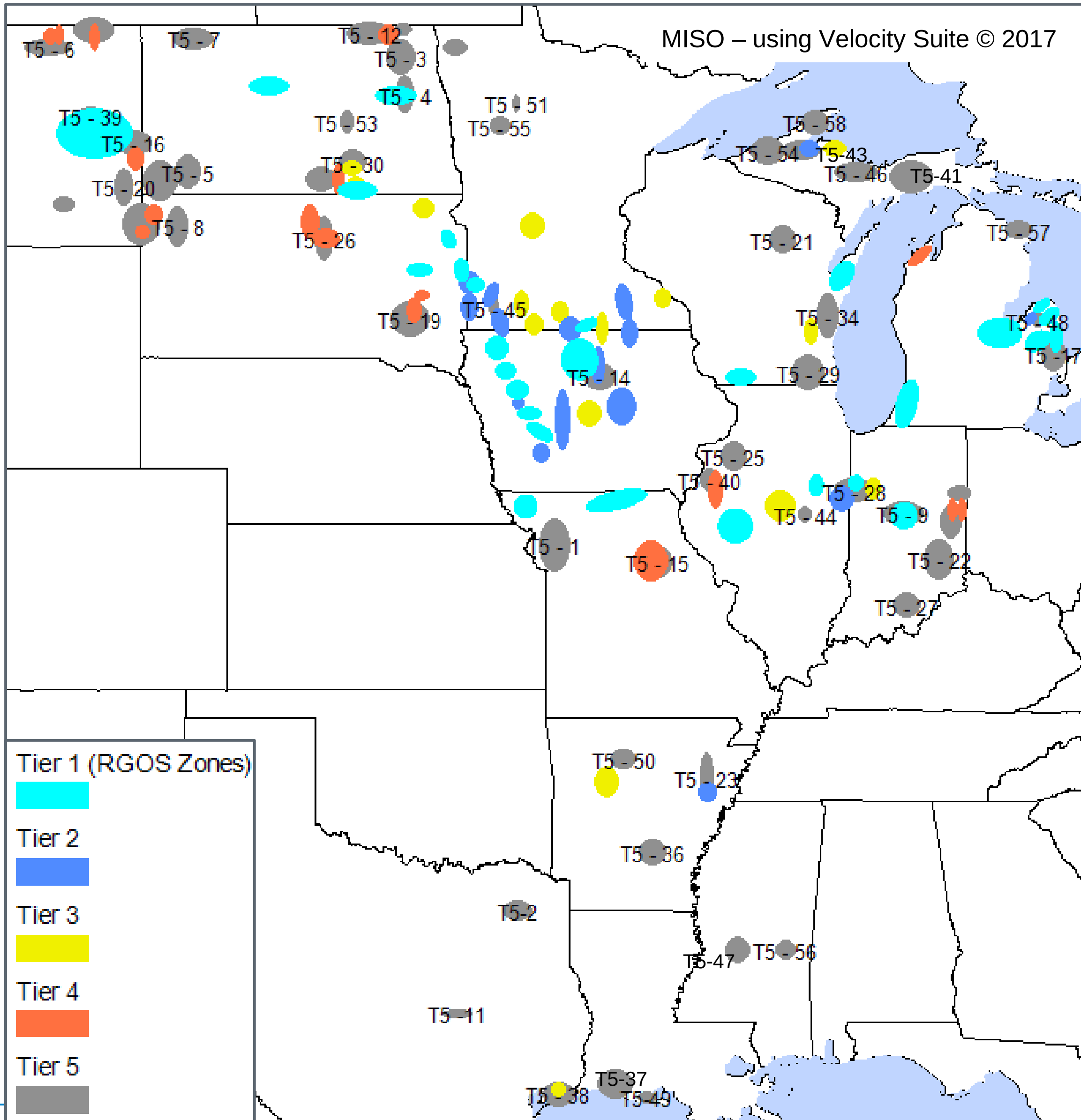

| Wind Zone | Size (MW) |
|---|---|
| T2-1 | 1,240 |
| T2-2 | 2,074 |
| T2-3 | 1,291 |
| T2-5 | 1,240 |
| T2-6 | 267 |
| T2-8 | 1,399 |
| T2-9 | 858 |
| T2-10 | 813 |
| T2-11 | 1,895 |
| T2-12 | 720 |
| T2-13 | 231 |
| T2-14 | 1,154 |
| T2-16 | 2,447 |
| T2-17 | 100 |
| T2-18 | 200 |
| **T2 Subtotal** | **15,729** |
| T3-1 | 1,551 |
| T3-2 | 820 |
| T3-4 | 2,495 |
| T3-5 | 592 |
| T3-6 | 1,363 |
| T3-7 | 1,636 |
| T3-8 | 840 |
| T3-9 | 1,001 |
| T3-10 | 801 |
| T3-11 | 1,858 |
| T3-12 | 2,100 |
| T3-13 | 1,080 |
| T3-14 | 1,260 |
| T3-15 | 1,000 |
| T3-16 | 100 |
| T3-17 | 500 |
| **T3 Subtotal** | **18,997** |

# MTEP Tier 4 wind zones




| Wind Zone | Size (MW) |
|---|---|
| T4-2 | 2,320 |
| T4-3 | 2,280 |
| T4-4 | 2,100 |
| T4-5 | 2,100 |
| T4-6 | 2,100 |
| T4-8 | 1,260 |
| T4-9 | 2,100 |
| T4-10 | 2,100 |
| T4-11 | 1,680 |
| T4-12 | 2,100 |
| T4-13 | 2,100 |
| T4-14 | 2,098 |
| T4-15 | 390 |
| T4-16 | 1,680 |
| T4-17 | 1,680 |
| T4-19 | 1,680 |
| T4-20 | 1,661 |
| T4-21 | 1,582 |
| T4-22 | 1,108 |
| **T4 Subtotal** | **34,119** |

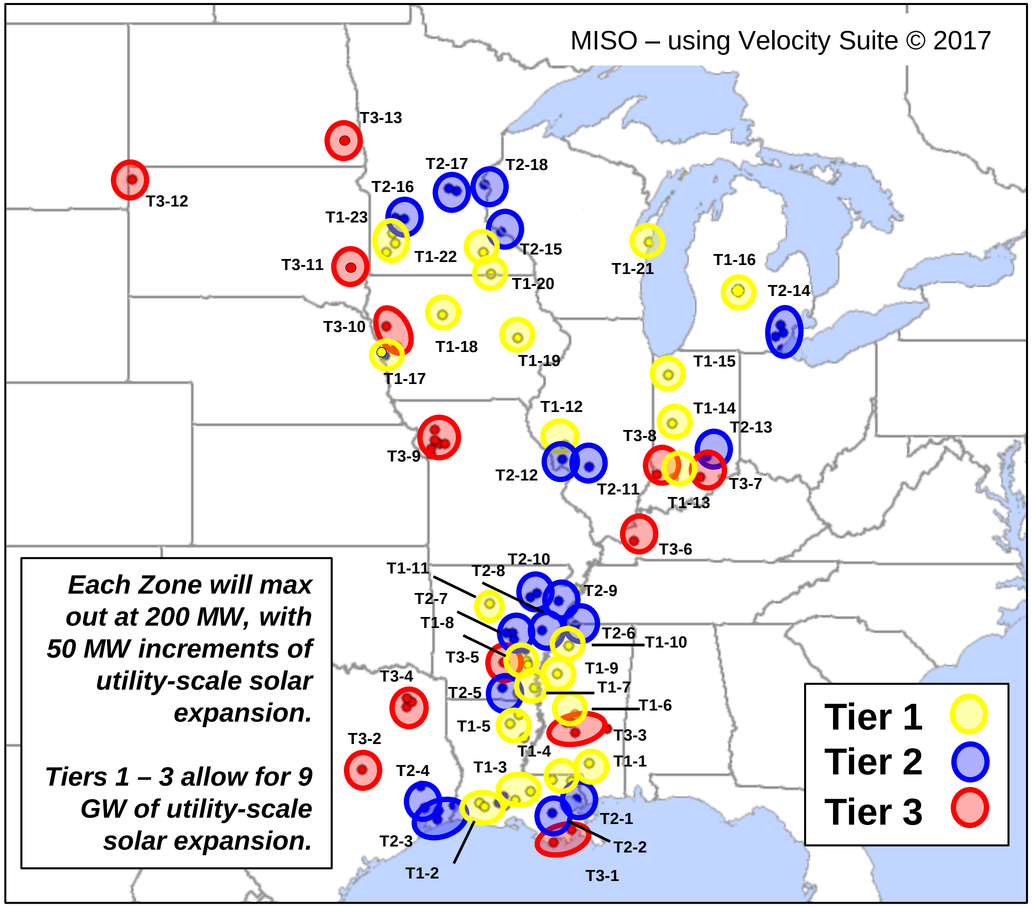
# MTEP Tier 5 wind zones




| Wind Zone | Size (MW) |
|---|---|
| T5-1 | 400 |
| T5-2 | 400 |
| T5-3 | 400 |
| T5-4 | 400 |
| T5-5 | 400 |
| T5-6 | 400 |
| T5-7 | 400 |
| T5-8 | 400 |
| T5-9 | 400 |
| T5-10 | 400 |
| T5-11 | 400 |
| T5-12 | 400 |
| T5-13 | 400 |
| T5-14 | 400 |
| T5-15 | 400 |
| T5-16 | 400 |
| T5-17 | 400 |
| T5-18 | 400 |
| T5-19 | 400 |
| T5-20 | 400 |
| T5-21 | 400 |
| T5-22 | 400 |
| T5-23 | 300 |
| T5-24 | 400 |
| T5-25 | 400 |
| T5-26 | 400 |
| T5-27 | 400 |
| T5-28 | 400 |
| T5-29 | 400 |

| Wind Zone | Size (MW) |
|---|---|
| T5-30 | 400 |
| T5-31 | 400 |
| T5-32 | 400 |
| T5-33 | 400 |
| T5-34 | 400 |
| T5-35 | 400 |
| T5-36 | 400 |
| T5-37 | 400 |
| T5-38 | 300 |
| T5-39 | 400 |
| T5-40 | 400 |
| T5-41 | 400 |
| T5-43 | 200 |
| T5-44 | 400 |
| T5-45 | 400 |
| T5-46 | 400 |
| T5-47 | 400 |
| T5-48 | 400 |
| T5-49 | 400 |
| T5-50 | 400 |
| T5-51 | 400 |
| T5-52 | 400 |
| T5-53 | 400 |
| T5-54 | 400 |
| T5-55 | 400 |
| T5-56 | 400 |
| T5-57 | 400 |
| T5-58 | 400 |

# Utility Solar Siting



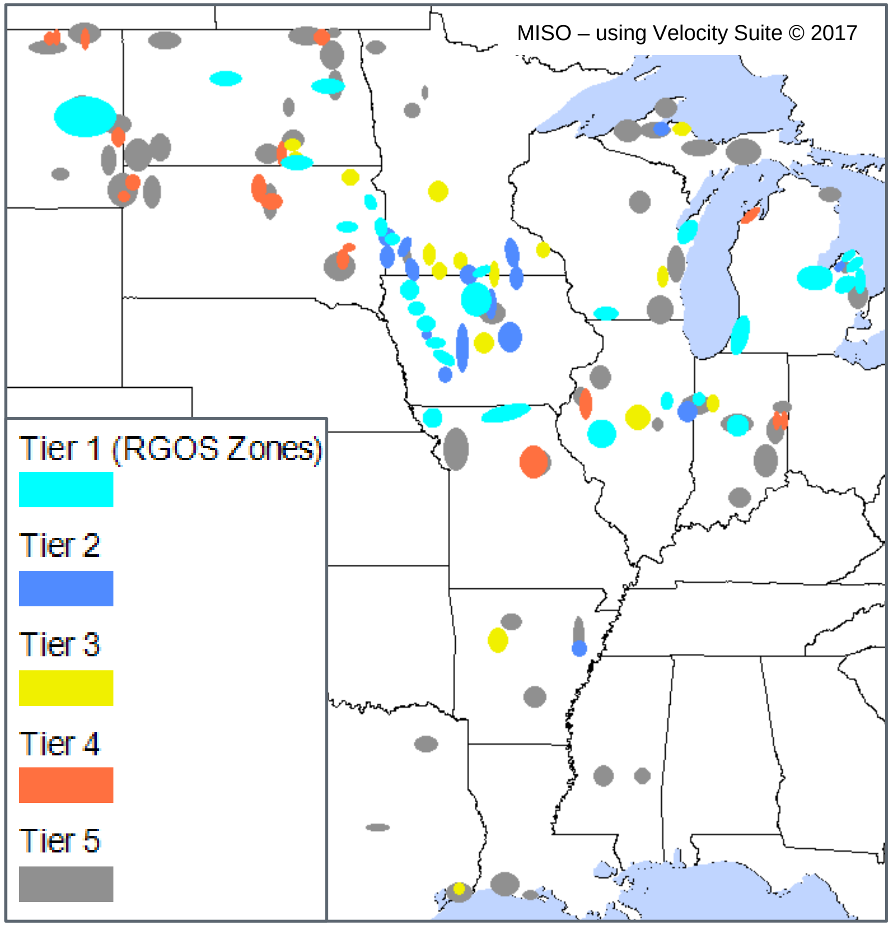

| Tier 1 (5 GW) | Tier 2 (4 GW) | Tier 3 (3 GW) |
|---|---|---|
| Active Queue Project Sites (GIA, DPP-SIS) | SPA and Withdrawn Queue Project Sites | VCE Sites |

- Solar capacity forecast from EGEAS will be split 2/3 utility & 1/3 distributed* or 1/3 utility & 2/3 distributed in "localized" siting methodology
- The distributed portion will be sited top 20 load buses per LBA, distributed on a load ratio share

** Solar Energy Industries Association -Year 2015 in Review expects non-utility segments to make up 40%, and utility segment 60% by 2021 - http://www.seia.org*

# MISO will continue to update renewable zones as needed based on new developments

- New developments include:
  - Queue activity
  - Emerging trends
  - Additional analysis
- Wind sited in all LRZs in DET Future
- Tiers 4 and 5 zones being reviewed in MTEP19 siting workshop




* Tier 5 zones are based on the VCE 80% carbon reduction case.

# Alternative Technologies Siting Methodology

(Demand Response, Energy Efficiency, Distributed Generation, Storage)

# Distributed and emerging technologies siting methodology further refined for MTEP18

| | MTEP18 Siting Methodology | |
|---|---|---|
| **MTEP 2018 Future** | **Limited Fleet Change<br>Continued Fleet Change<br>Accelerated Fleet Change** | **Distributed & Emerging Technology** |
| **Distributed[1] Resources** | 1/3 of Solar Capacity Expansion: Distributed<br>(Top 20 Load Buses per LBA) | 2/3 of Solar Capacity Expansion: Distributed<br>(Top 20 Load Buses per LBA) |
| **Demand Side[1] Programs** | Residential: Top 10 Non-Industrial Load Buses per LBA<br>Commercial & Industrial: Top 10 Industrial Load Buses per LBA | |
| **Battery Storage[2]** | 1/2: Top Load & Distributed PV Buses<br>1/2: Top Utility Scale Renewable Buses | |

MISO requested stakeholder feedback on distributed siting buses at June PAC to incorporate in MTEP18

1. Bus level siting (magnitude and location) to be reviewed through MTEP18 process; sites commented as infeasible will be excluded
2. A minimum of 2 GW of battery storage by 2032 included in the Distributed & Emerging Technology Future; storage offered as a resource option in all proposed MTEP18 Futures

# External Resources Siting Methodology

# Siting of External Resources

- Goal is consistent siting assumptions between RTOs
- Each model development, MISO will request latest siting information from neighboring regions
- Exhausting neighbors list priority-based approach used for all supply-side unit types
  - Priority 1: Queue Generators + EV New Entrants
  - Priority 2: Brownfield sites + retired sites
  - Priority 3: Greenfield Sites

# MTEP18 Futures Weights

# MTEP18 Future Weights

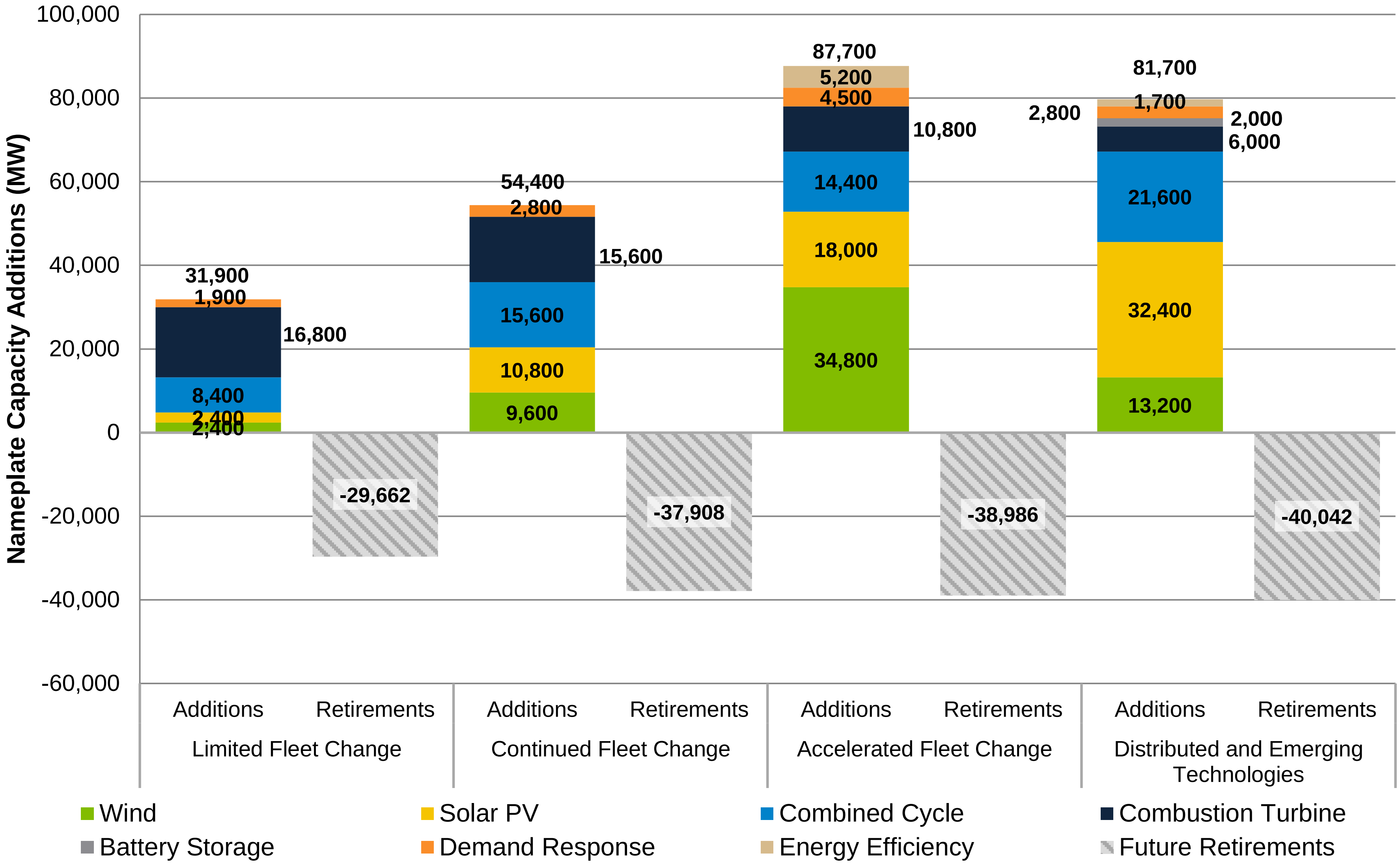
| MTEP18 Future | Sector Average | Final MTEP18 |
|---|---|---|
| Limited Fleet Change | 22% | **25%** |
| Continued Fleet Change | 32% | **30%** |
| Accelerated Fleet Change | 20% | **20%** |
| Distributed and Emerging Technologies | 26% | **25%** |

- Weights used to identify the relative impact each Future has on the benefit-to-cost ratio of transmission solutions in the MTEP18 cycle
- Sectors provided weights for each Future indicative of their views about the probability that a particular future will occur
- MISO rounded sector average weights to 5% increments to alleviate implications of over-precision for final MTEP18 weights

# MTEP18 Resource Expansion and Siting Results

# MTEP18 Nameplate Capacity Additions

(2017 through 2032)

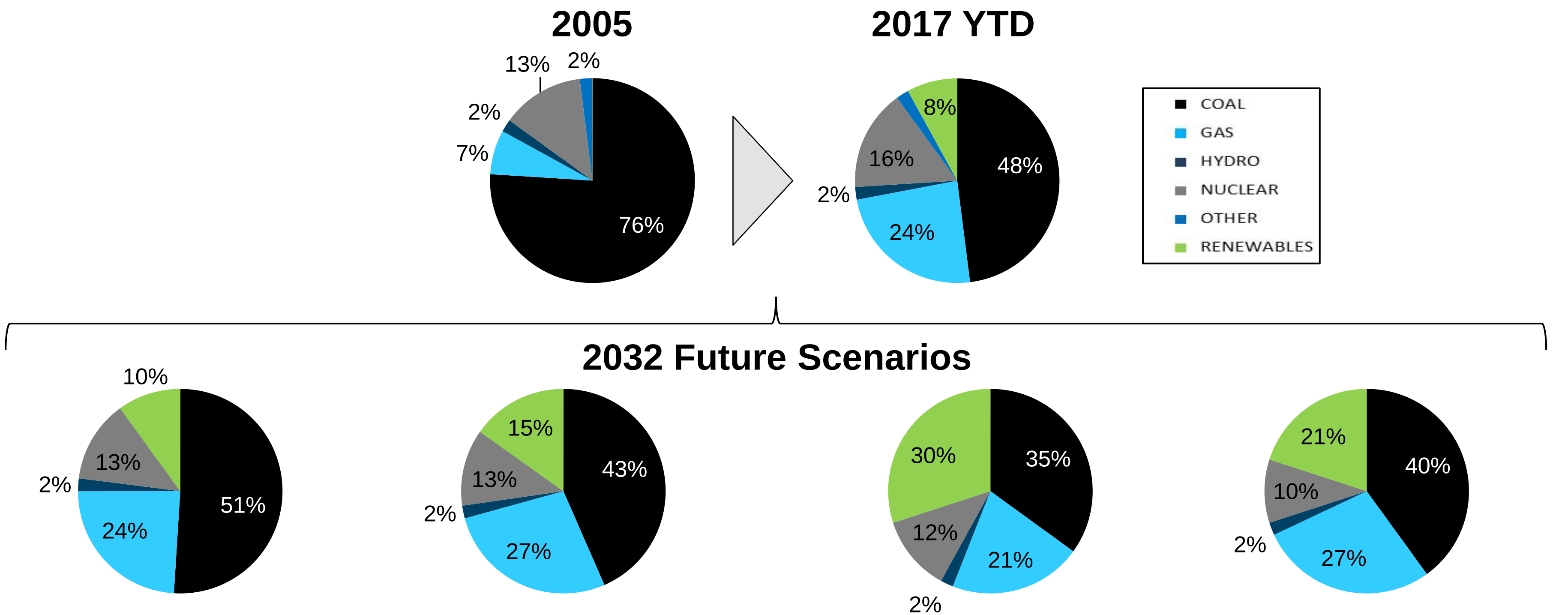





MISO

# MTEP18 Energy Projections by Future

(2017 through 2032)*




**Limited Fleet Change**
Stalled generation fleet changes. Limited renewables additions driven solely by existing RPS under limited demand growth.

**Continued Fleet Change**
Continuation of the renewable addition and coal retirement trends of the past decade.

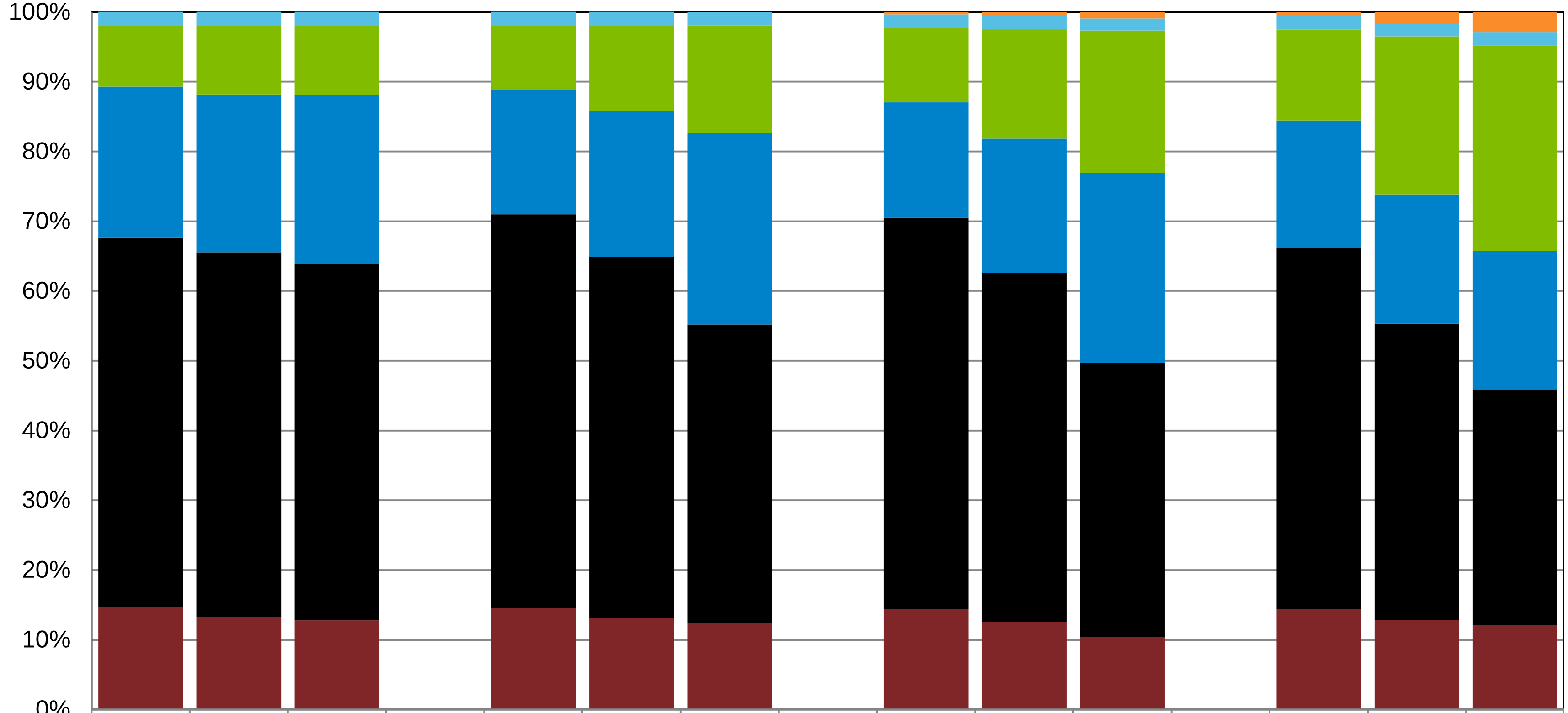
**Accelerated Fleet Change**
Renewables and demand side technologies added at a rate above historical trends. Fleet changes result in a 20% $CO_2$ emission reduction[1].

**Distributed & Emerging Tech**
New renewable additions largely distributed and storage resources co-located with largest sites.

*1. Emission reductions from current levels by year 2031*

**Energy mix does not consider transmission constraints – outputs from the EGEAS model*

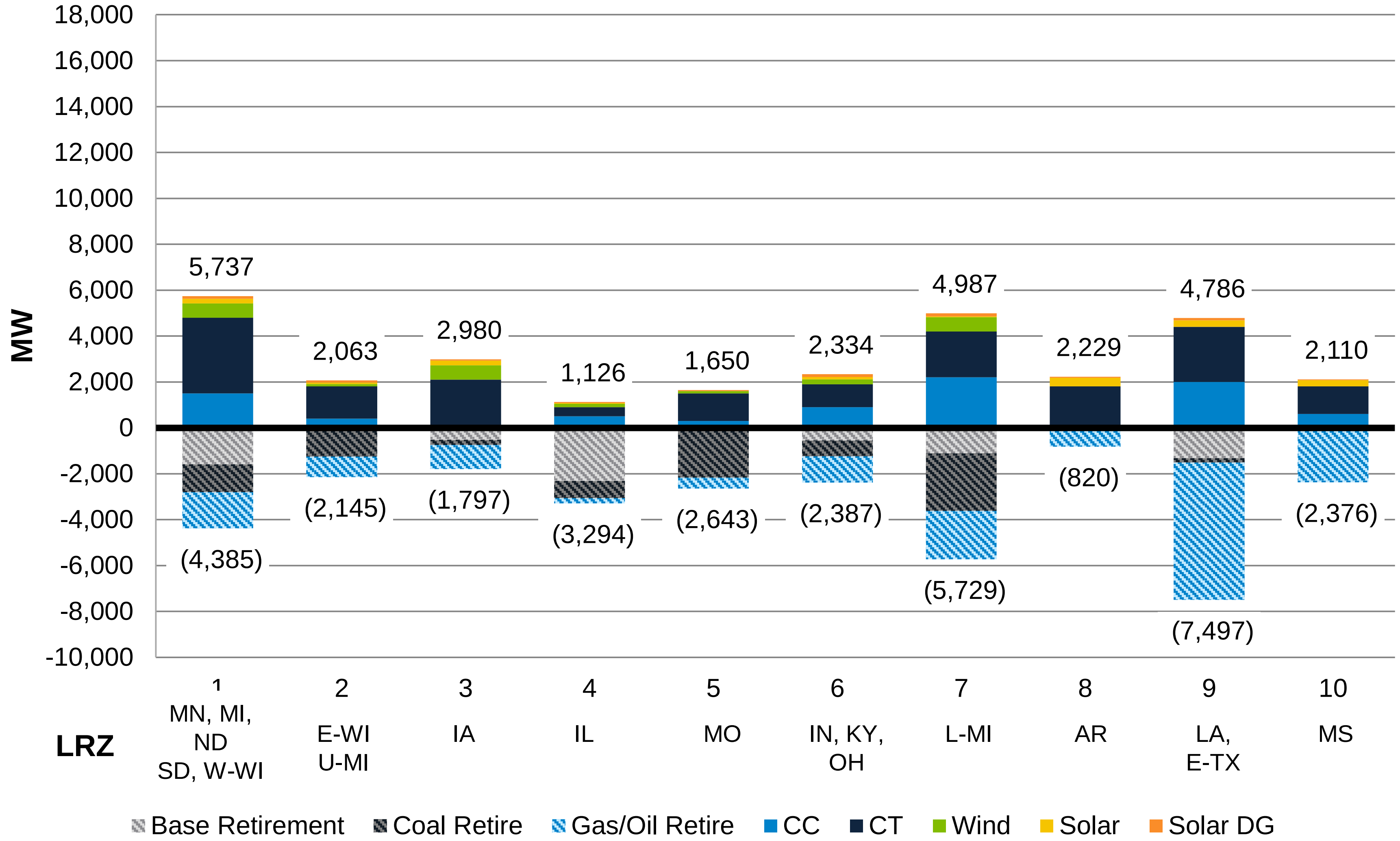
# MTEP18 Energy Comparisons by Future:
(2022, 2027 & 2032)




| | LFC 2022 | LFC 2027 | LFC 2032 | CFC 2022 | CFC 2027 | CFC 2032 | DET 2022 | DET 2027 | DET 2032 | AFC 2022 | AFC 2027 | AFC 2032 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DSM | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 1% | 1% | 2% | 3% |
| Hydro | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% |
| Renewable | 9% | 10% | 10% | 9% | 12% | 15% | 11% | 16% | 20% | 13% | 23% | 29% |
| Gas | 22% | 23% | 24% | 18% | 21% | 27% | 17% | 19% | 27% | 18% | 19% | 20% |
| Coal | 53% | 52% | 51% | 56% | 52% | 43% | 56% | 50% | 39% | 52% | 42% | 34% |
| Nuclear | 15% | 13% | 13% | 15% | 13% | 12% | 14% | 13% | 10% | 14% | 13% | 12% |

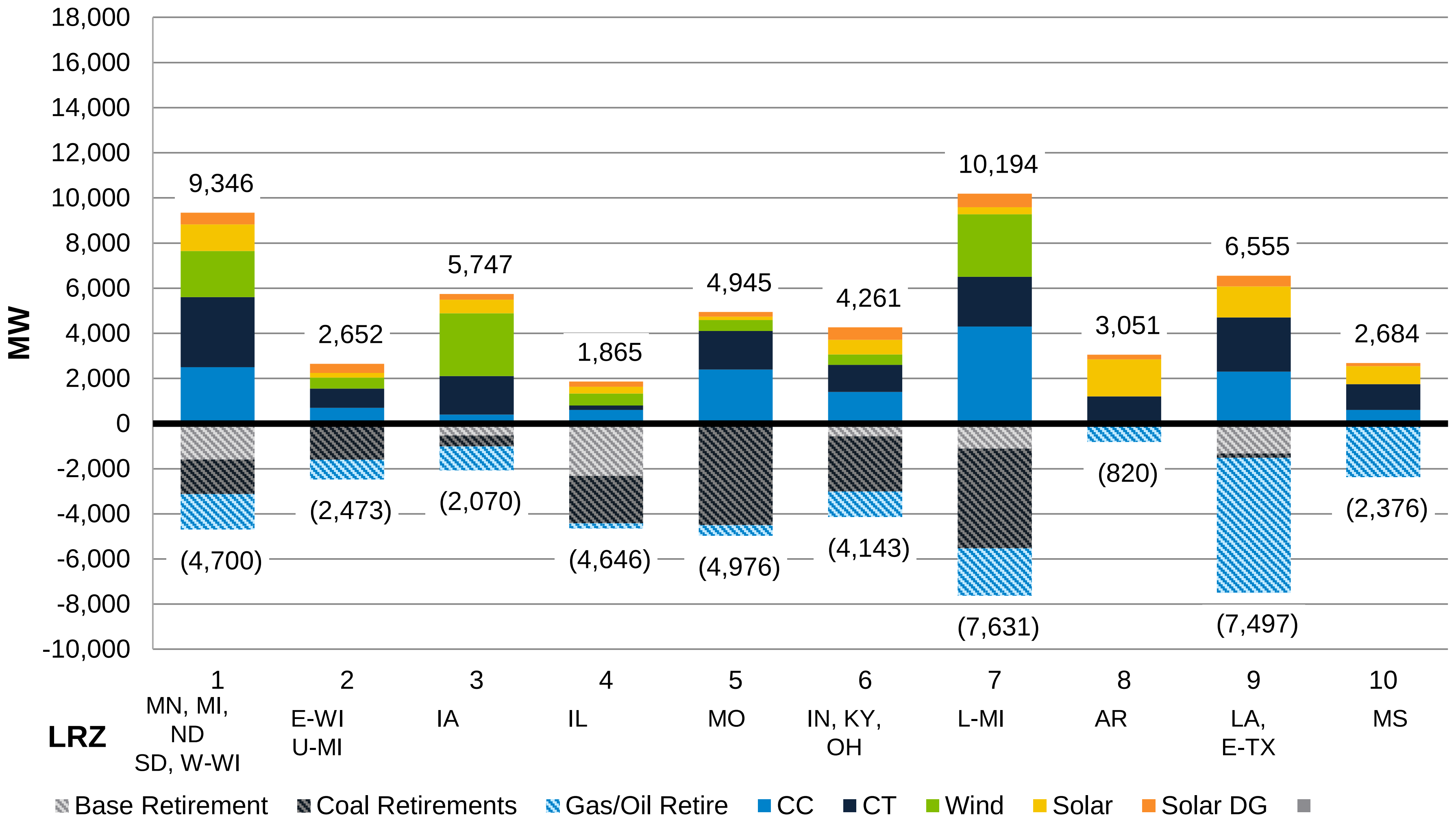
# Capacity Additions & Retirements by LRZ – 2032

## Limited Fleet Change



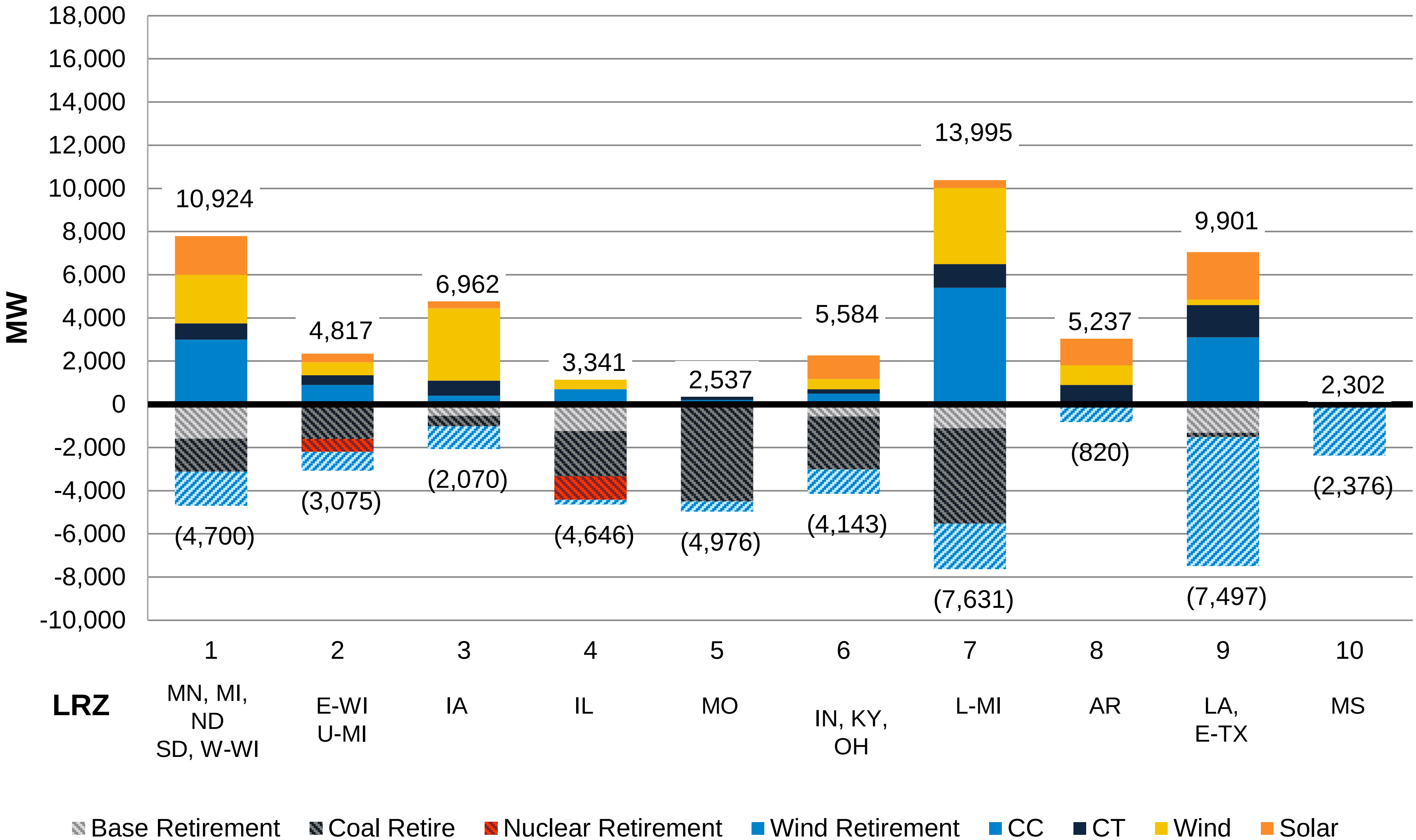
# Capacity Additions & Retirements by LRZ – 2032

## Continued Fleet Change



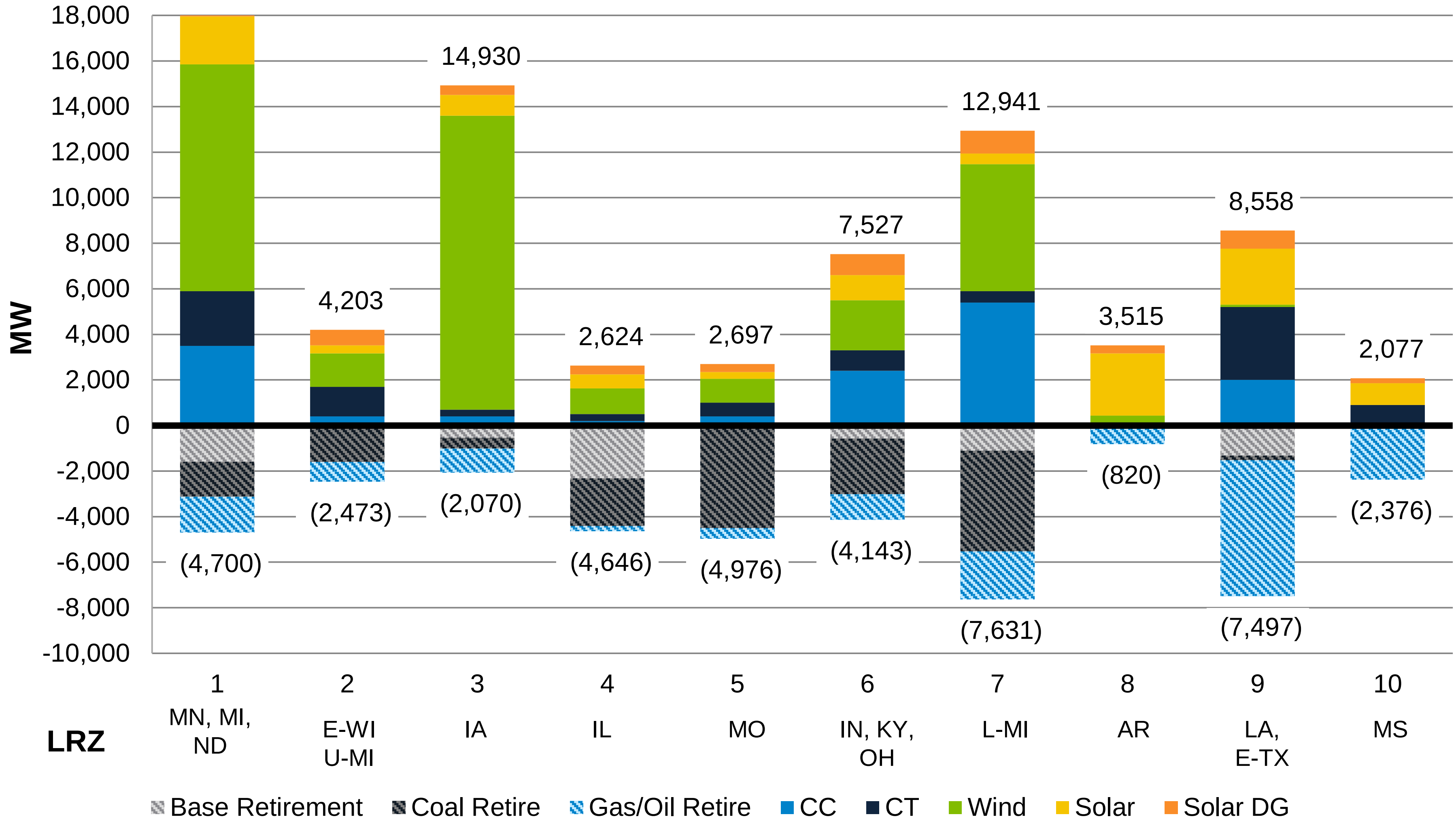
# Capacity Additions & Retirements by LRZ – 2032

## Distributed and Emerging Technologies



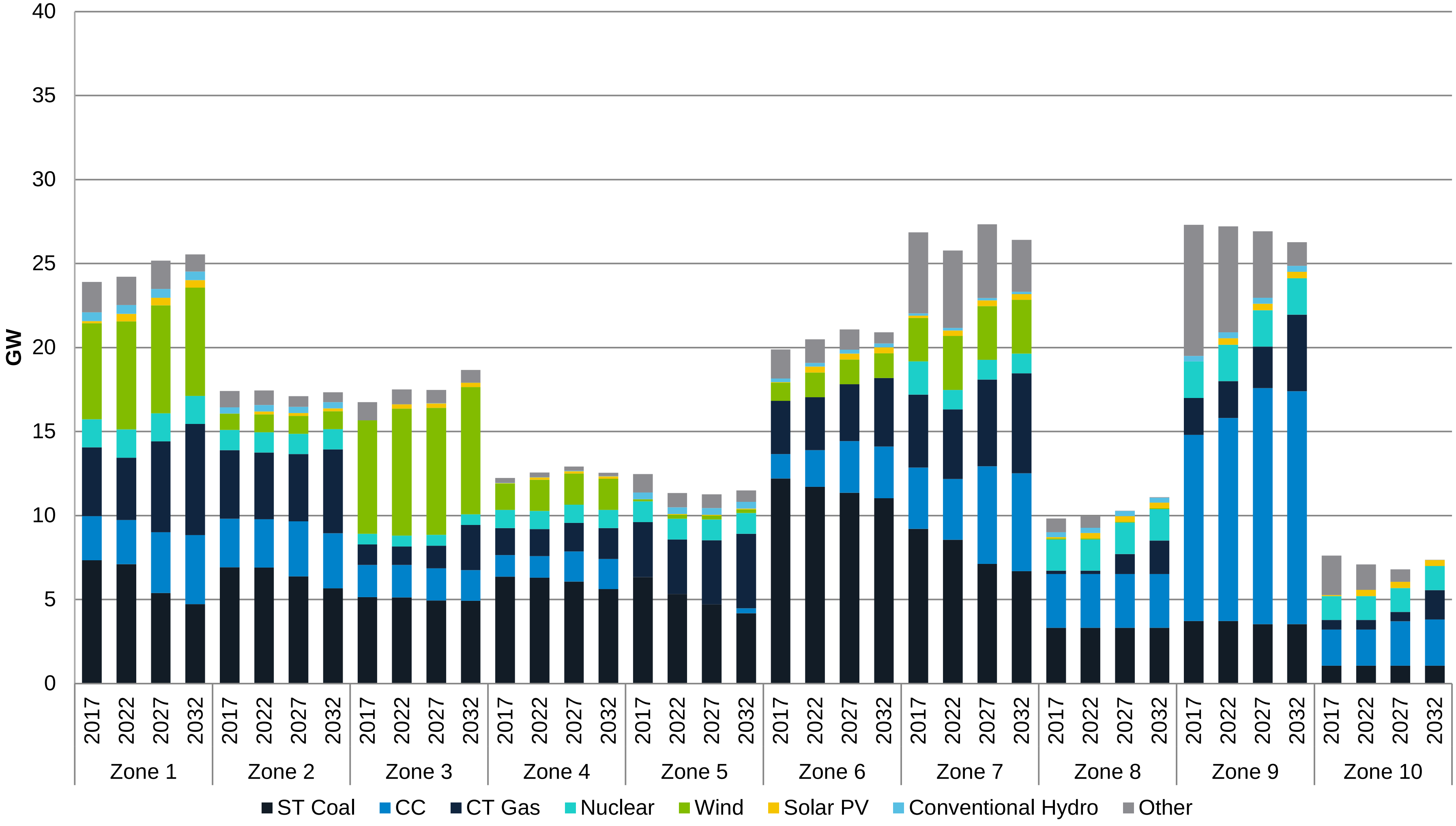
# Capacity Additions & Retirements by LRZ – 2032

## Accelerated Fleet Change



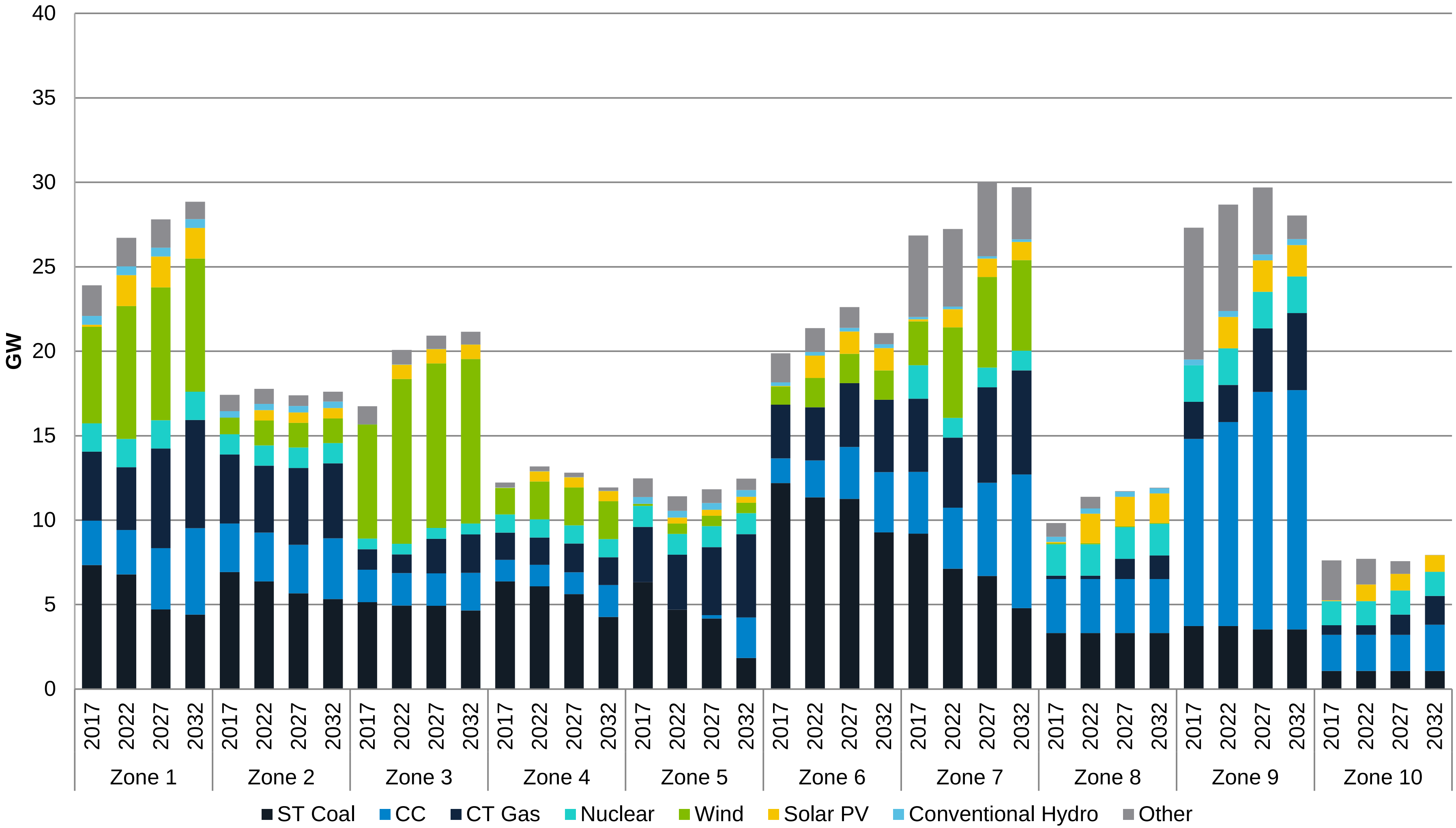
# Zonal Nameplate Capacity by Fuel

## Limited Fleet Change



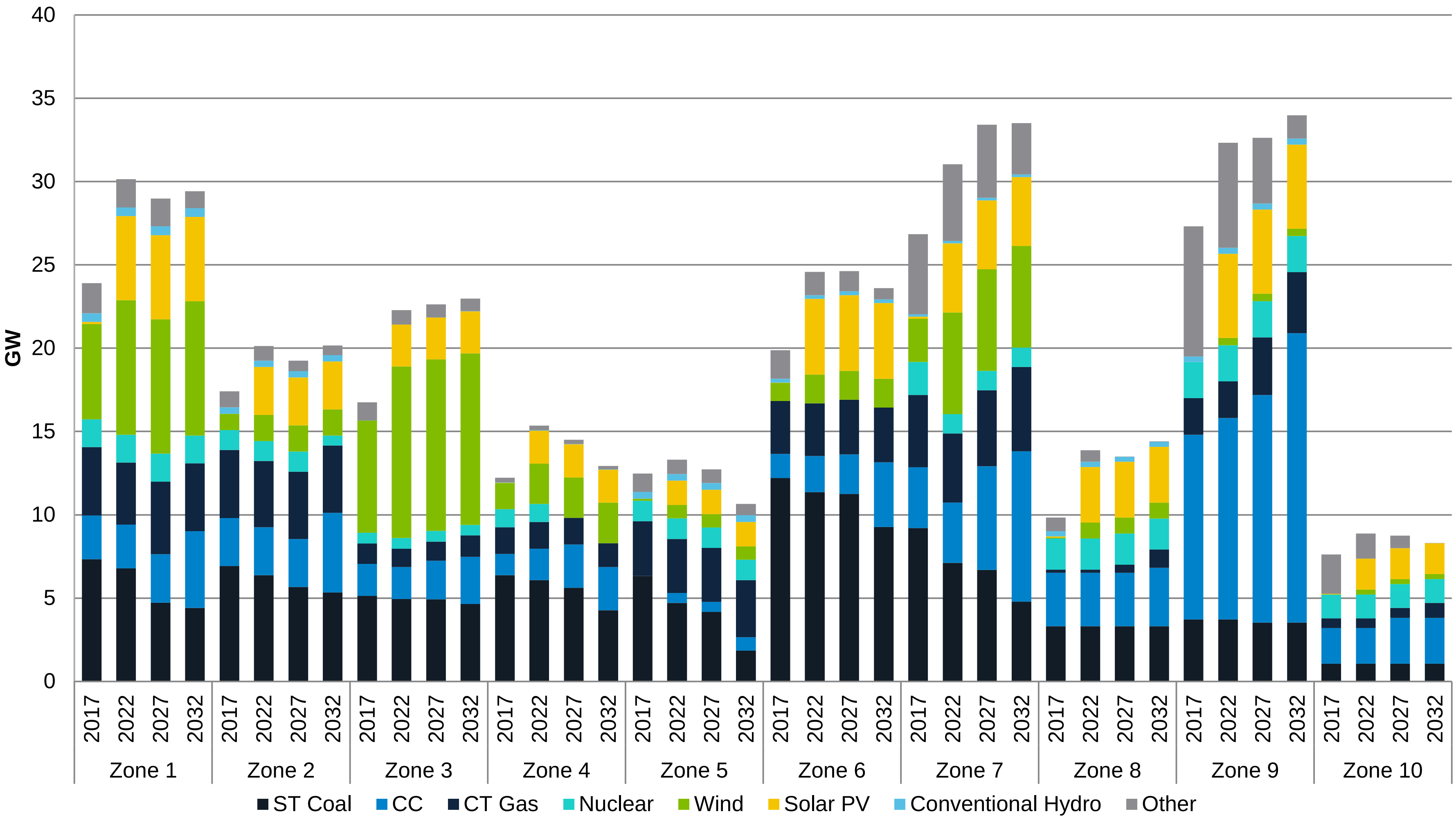
# Zonal Nameplate Capacity by Fuel

## Continued Fleet Change



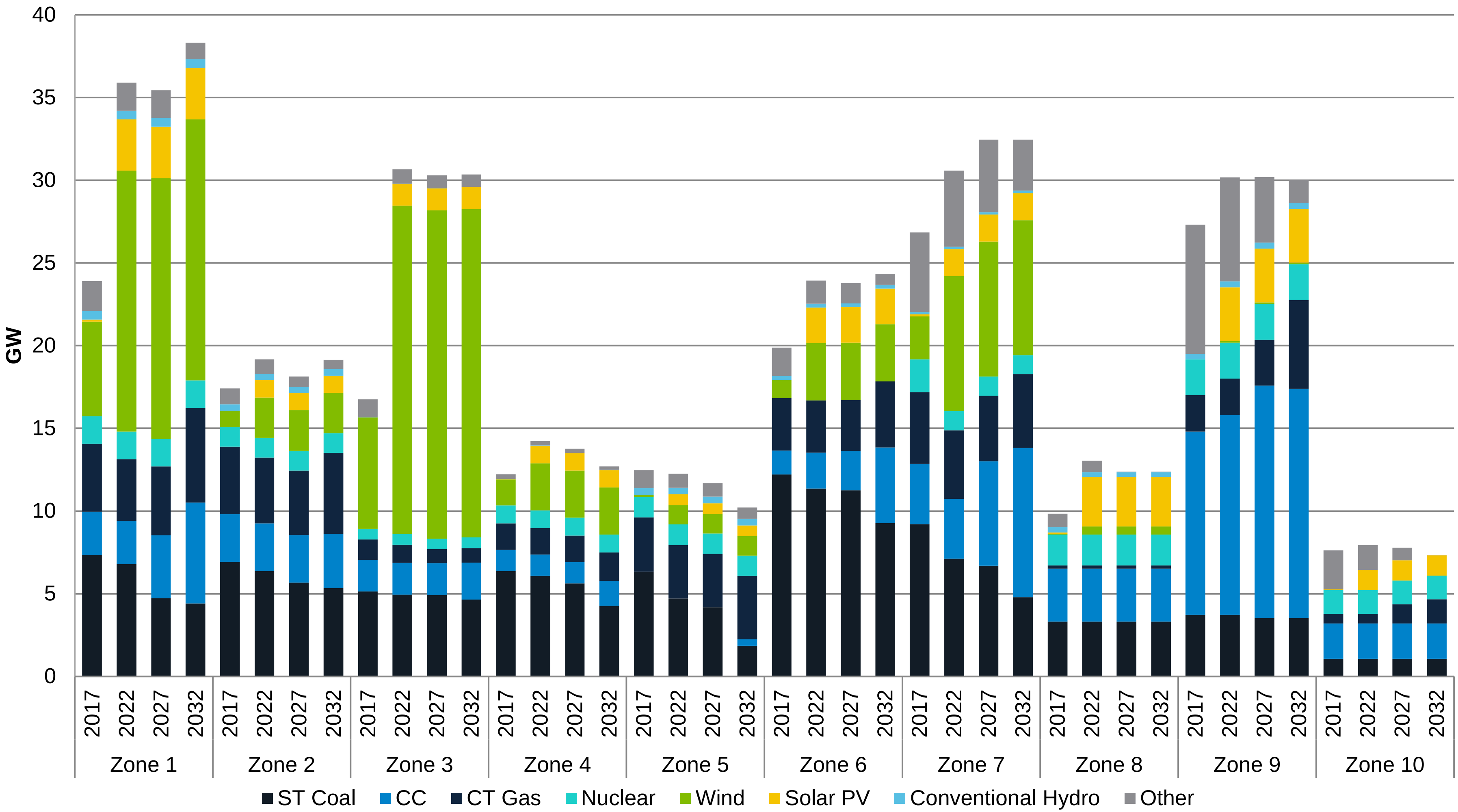
# Zonal Nameplate Capacity by Fuel

## Distributed & Emerging Technologies



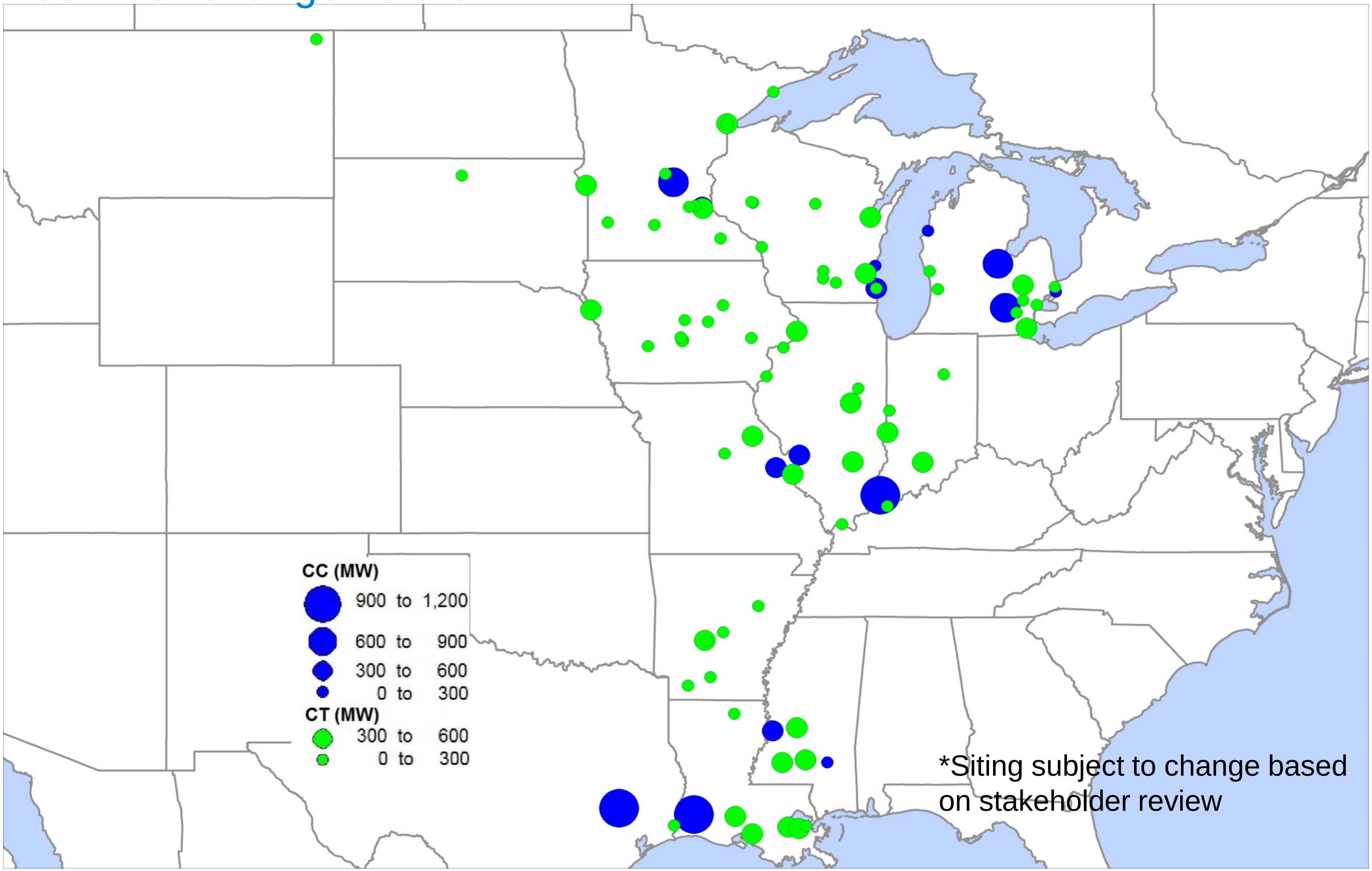
# Zonal Nameplate Capacity by Fuel

## Accelerated Fleet Change



# MISO Thermal Regional Resource Forecast Units*

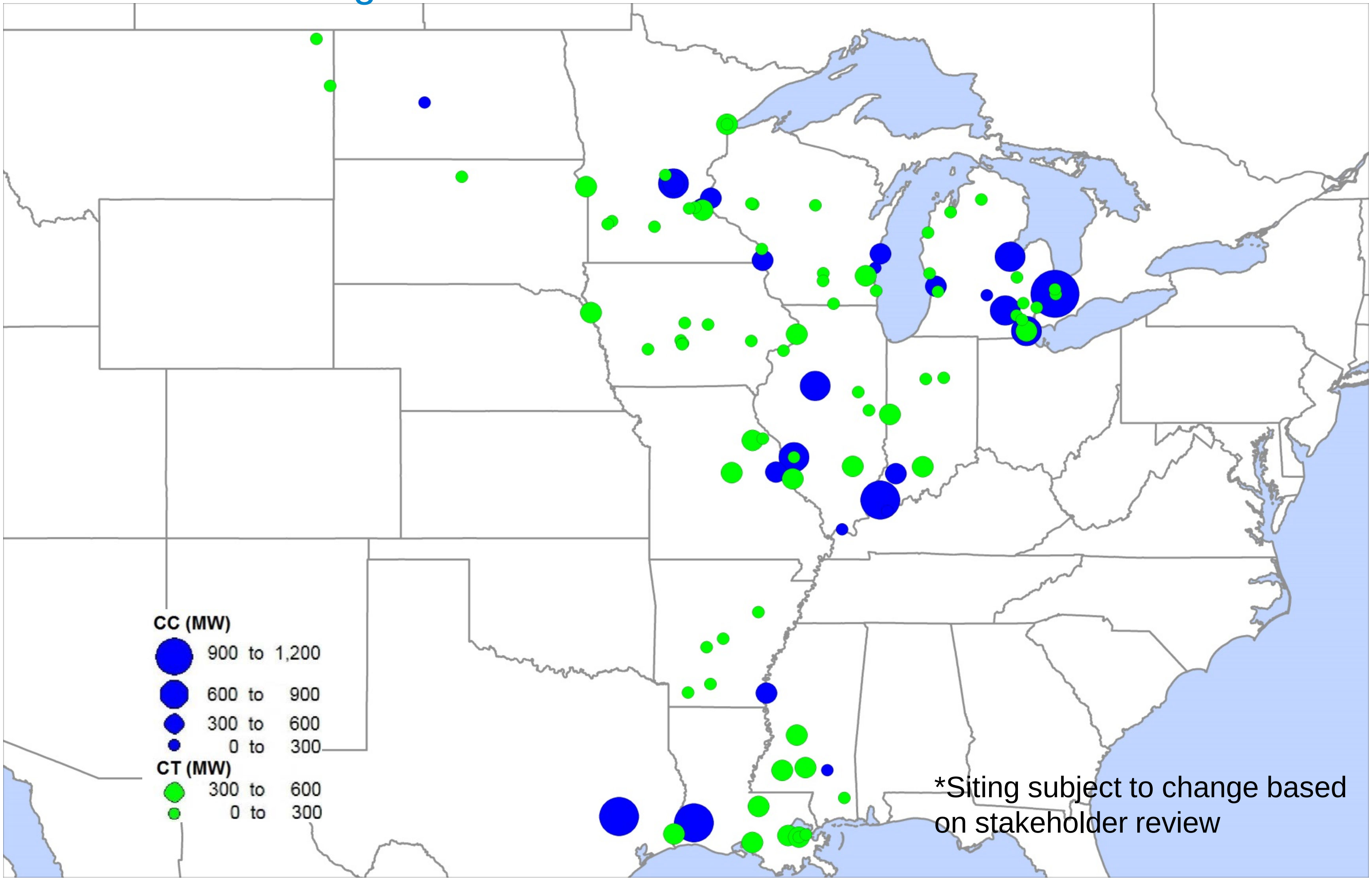
## Limited Fleet Change Future




*Siting subject to change based on stakeholder review

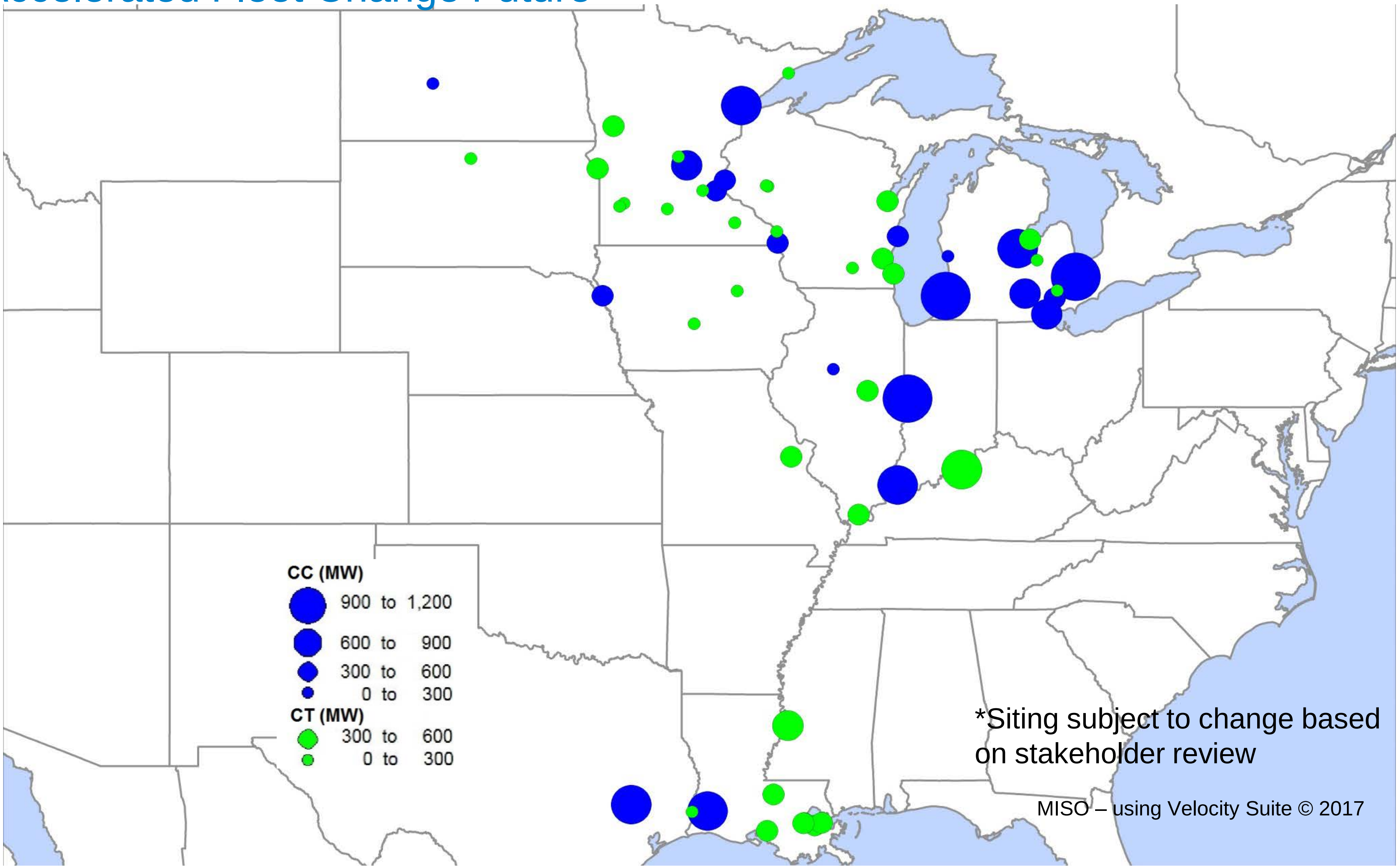
# MISO Thermal Regional Resource Forecast Units*

## Continued Fleet Change Future



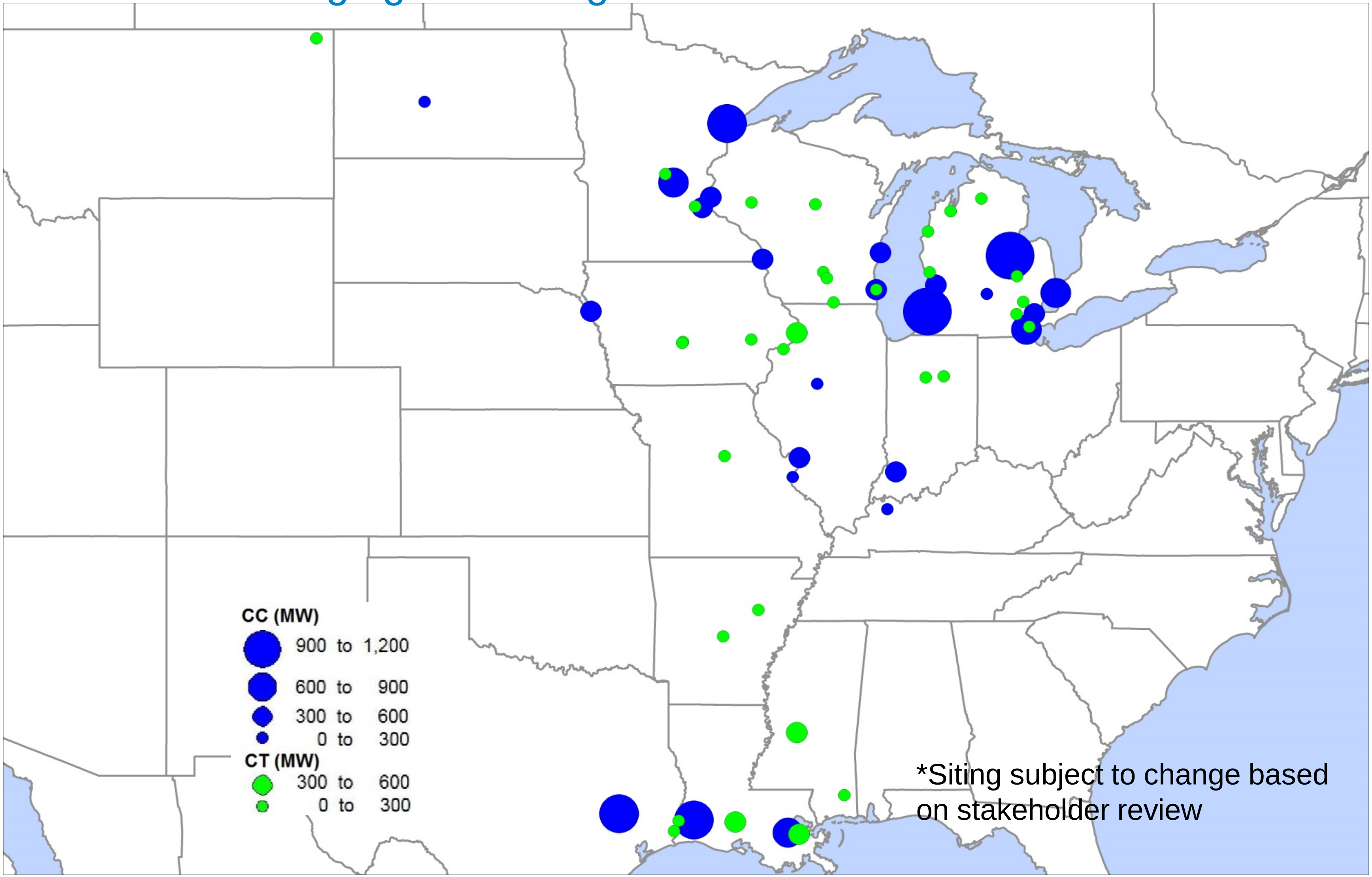
# MISO Thermal Regional Resource Forecast Units*

## Accelerated Fleet Change Future



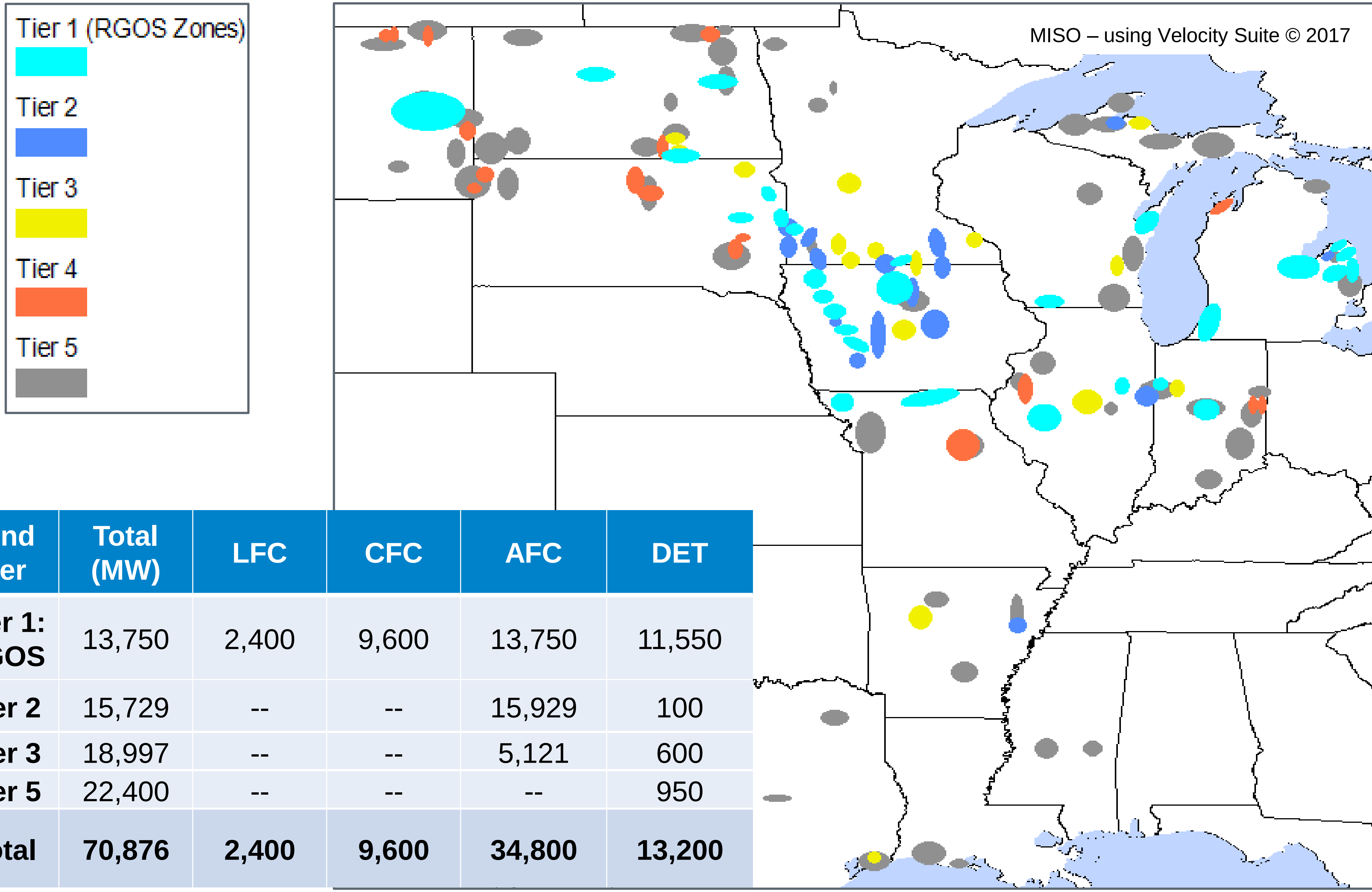
# MISO Thermal Regional Resource Forecast Units*

## Distributed and Emerging Technologies



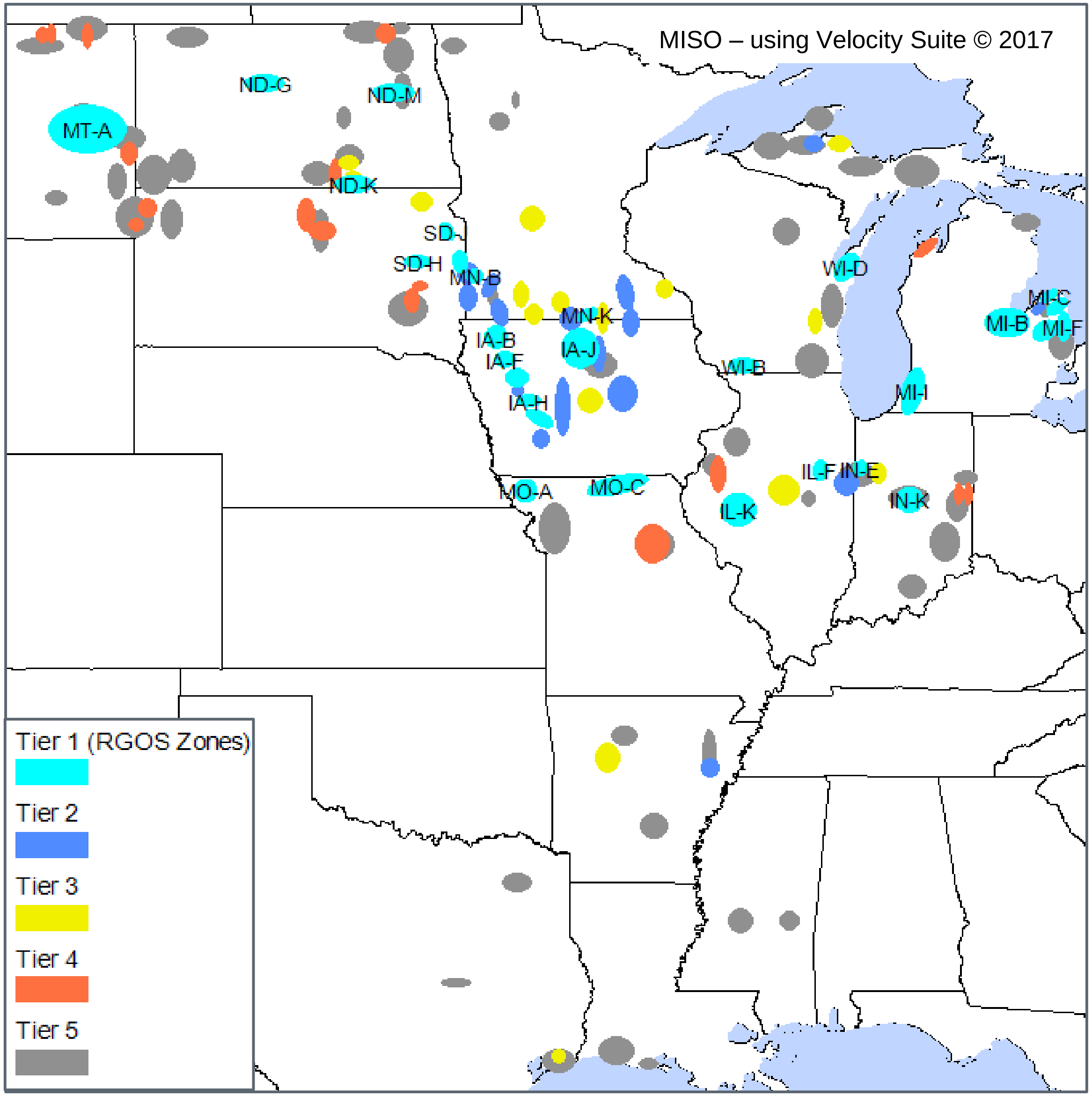

*Siting subject to change based on stakeholder review

# DRAFT MTEP18 MISO Wind Siting




| Wind Tier | Total (MW) | LFC | CFC | AFC | DET |
|---|---|---|---|---|---|
| **Tier 1: RGOS** | 13,750 | 2,400 | 9,600 | 13,750 | 11,550 |
| **Tier 2** | 15,729 | -- | -- | 15,929 | 100 |
| **Tier 3** | 18,997 | -- | -- | 5,121 | 600 |
| **Tier 5** | 22,400 | -- | -- | -- | 950 |
| **Total** | **70,876** | **2,400** | **9,600** | **34,800** | **13,200** |

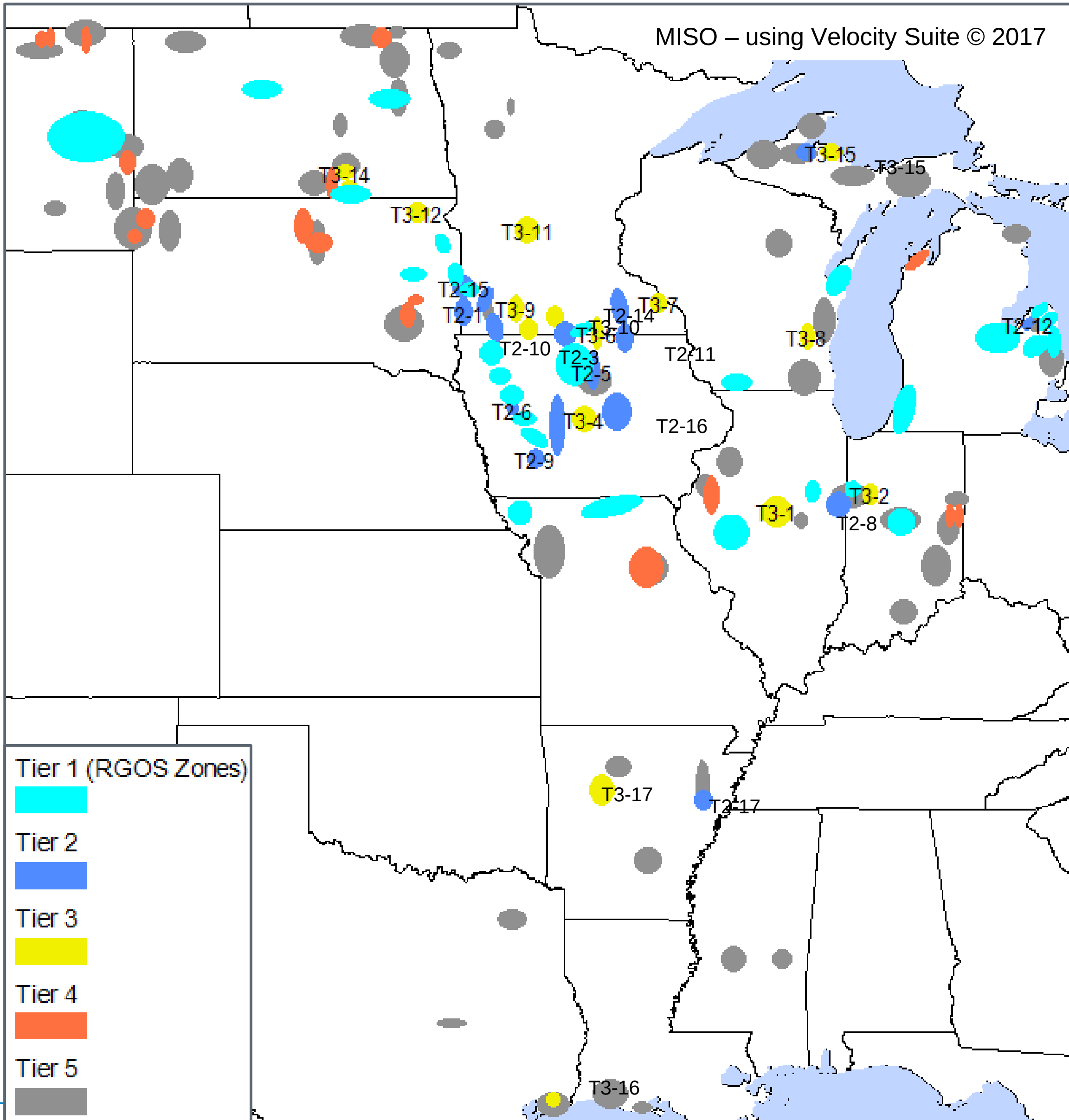
# MTEP Tier 1 RGOS Wind Zones




| Wind Zone* | Size (MW) | LFC | CFC | AFC | DET |
|---|---|---|---|---|---|
| IA-F | 586 | 103 | 491 | 586 | 586 |
| IA-H | 433 | 103 | 433 | 433 | 433 |
| IA-I | 398 | 103 | 398 | 398 | 398 |
| IA-J | 909 | 103 | 491 | 909 | 674 |
| IL-F | 37 | 37 | 37 | 37 | 37 |
| IL-K | 757 | 103 | 491 | 757 | 674 |
| IN-E | 156 | 103 | 156 | 156 | 156 |
| IN-K | 311 | 103 | 311 | 311 | 311 |
| MI-B | 437 | 103 | 437 | 437 | 437 |
| MI-C | 822 | 103 | 492 | 822 | 675 |
| MI-D | 379 | 103 | 379 | 379 | 379 |
| MI-E | 1,160 | 103 | 491 | 1160 | 674 |
| MI-F | 1,215 | 103 | 491 | 1215 | 674 |
| MI-I | 837 | 103 | 491 | 837 | 674 |
| MO-A | 653 | 103 | 491 | 653 | 653 |
| MO-C | 1,047 | 103 | 491 | 1047 | 674 |
| MT-A | 134 | 103 | 134 | 134 | 134 |
| ND-G | 852 | 103 | 491 | 852 | 675 |
| ND-M | 503 | 102 | 490 | 503 | 503 |
| SD-H | 318 | 102 | 318 | 318 | 318 |
| SD-J | 341 | 102 | 341 | 341 | 341 |
| SD-L | 275 | 102 | 275 | 270 | 275 |
| WI-B | 601 | 102 | 490 | 601 | 601 |
| WI-D | 594 | 102 | 490 | 594 | 594 |
| **Total** | **13,750** | **2,400** | **9,600** | **13,750** | **11,550** |

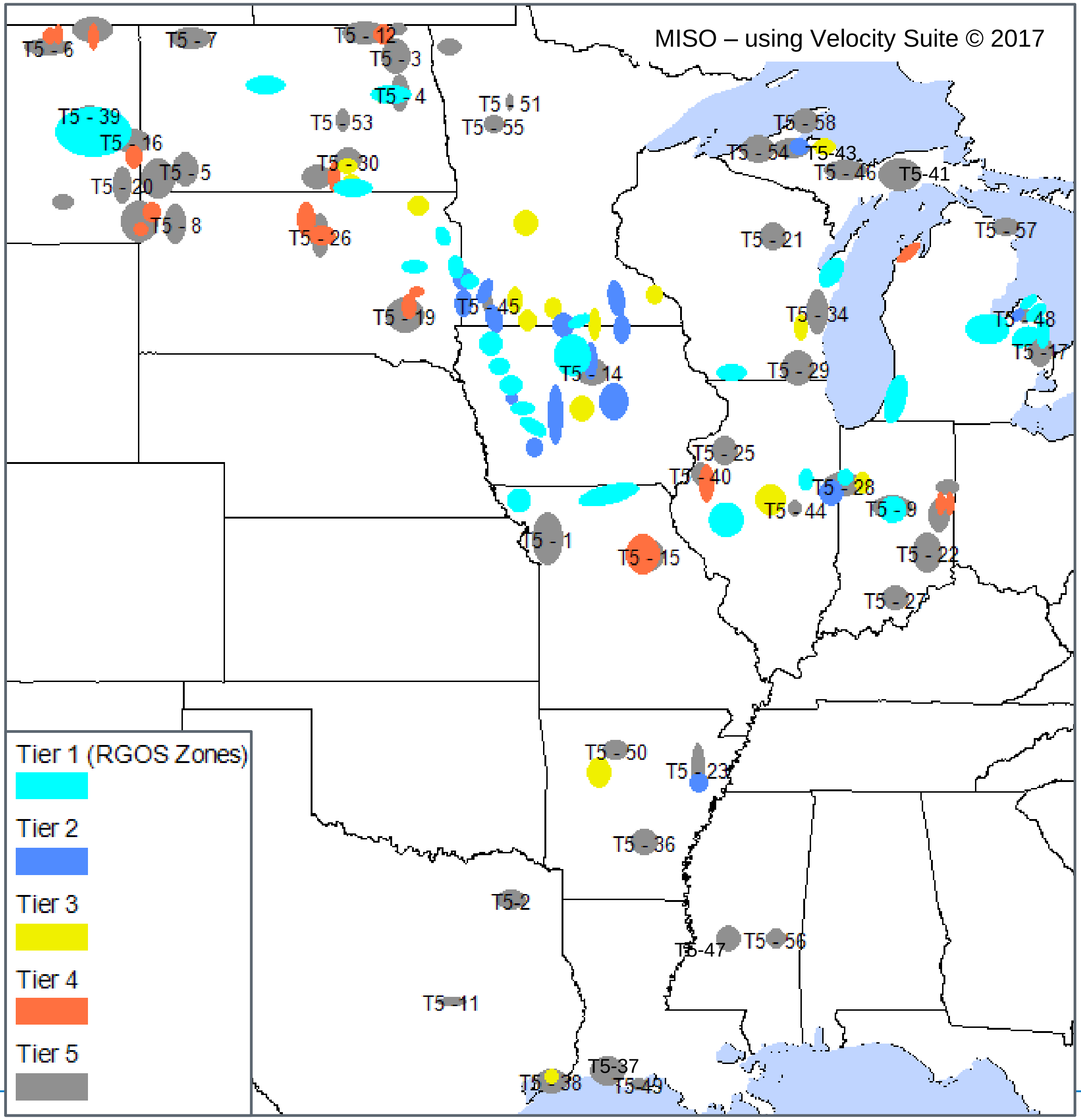
*** IA-B, IA-G, MN-B, MN-K and ND-K are full so no wind sited there**

# MTEP Tier 2 and 3 wind zones



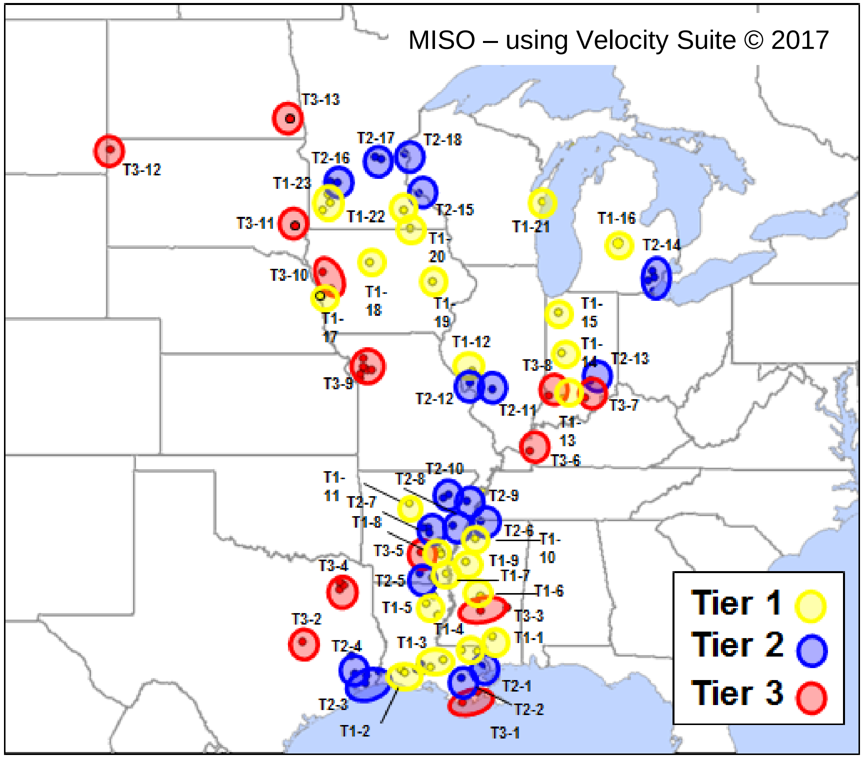

| Wind Zone | Size (MW) | AFC | DET |
|---|---|---|---|
| T2-1 | 1,240 | 1,240 | -- |
| T2-2 | 2,074 | 2,074 | -- |
| T2-3 | 1,291 | 1,291 | -- |
| T2-5 | 1,240 | 1,240 | -- |
| T2-6 | 267 | 267 | -- |
| T2-8 | 1,399 | 1,399 | -- |
| T2-9 | 858 | 858 | -- |
| T2-10 | 813 | 813 | -- |
| T2-11 | 1,895 | 1,895 | -- |
| T2-12 | 720 | 720 | -- |
| T2-13 | 231 | 231 | -- |
| T2-14 | 1,154 | 1,154 | -- |
| T2-16 | 2,447 | 2,447 | -- |
| T2-17 | 100 | 100 | 100 |
| T2-18 | 200 | 200 | -- |
| **T2 Subtotal** | **15,729** | **15,729** | **100** |
| T3-1 | 1,551 | 335 | -- |
| T3-2 | 820 | 335 | -- |
| T3-4 | 2,495 | 335 | -- |
| T3-5 | 592 | 335 | -- |
| T3-6 | 1,363 | 335 | -- |
| T3-7 | 1,636 | 335 | -- |
| T3-8 | 840 | 335 | -- |
| T3-9 | 1,001 | 335 | -- |
| T3-10 | 801 | 335 | -- |
| T3-11 | 1,858 | 335 | -- |
| T3-12 | 2,100 | 335 | -- |
| T3-13 | 1,080 | 334 | -- |
| T3-14 | 1,260 | 334 | -- |
| T3-15 | 1,000 | 334 | -- |
| T3-16 | 100 | 100 | 100 |
| T3-17 | 500 | 334 | 500 |
| **T3 Subtotal** | **18,997** | **5,121** | **600** |

# MTEP Tier 5 wind zones




| Wind Zone | Size (MW) | DET |
|---|---|---|
| T5-2 | 400 | 200 |
| T5-11 | 400 | 150 |
| T5-23 | 300 | 150 |
| T5-36 | 400 | 150 |
| T5-47 | 400 | 150 |
| T5-56 | 400 | 150 |

# DRAFT MTEP18 MISO Solar Siting




| Solar Tier (MW) | Total Available Capacity | Limited Fleet Change | Continued Fleet Change | Accelerated Fleet Change | Distributed and Emerging Technology |
|---|---|---|---|---|---|
| **Tier 1** | 4,600 | 1,600 | 4,600 | 4,600 | 4,600 |
| **Tier 2** | 3,600* | -- | 2,600 | 5,400 | 3,600 |
| **Tier 3** | 3,250 | -- | -- | 2,000 | 2,600 |
| **Distributed** | N/A | 800 | 3,600 | 6,000 | 21,600 |
| **Total** | **11,450*** | **2,400** | **10,800** | **18,000** | **32,400** |

*Tier capacity expanded for AFC*

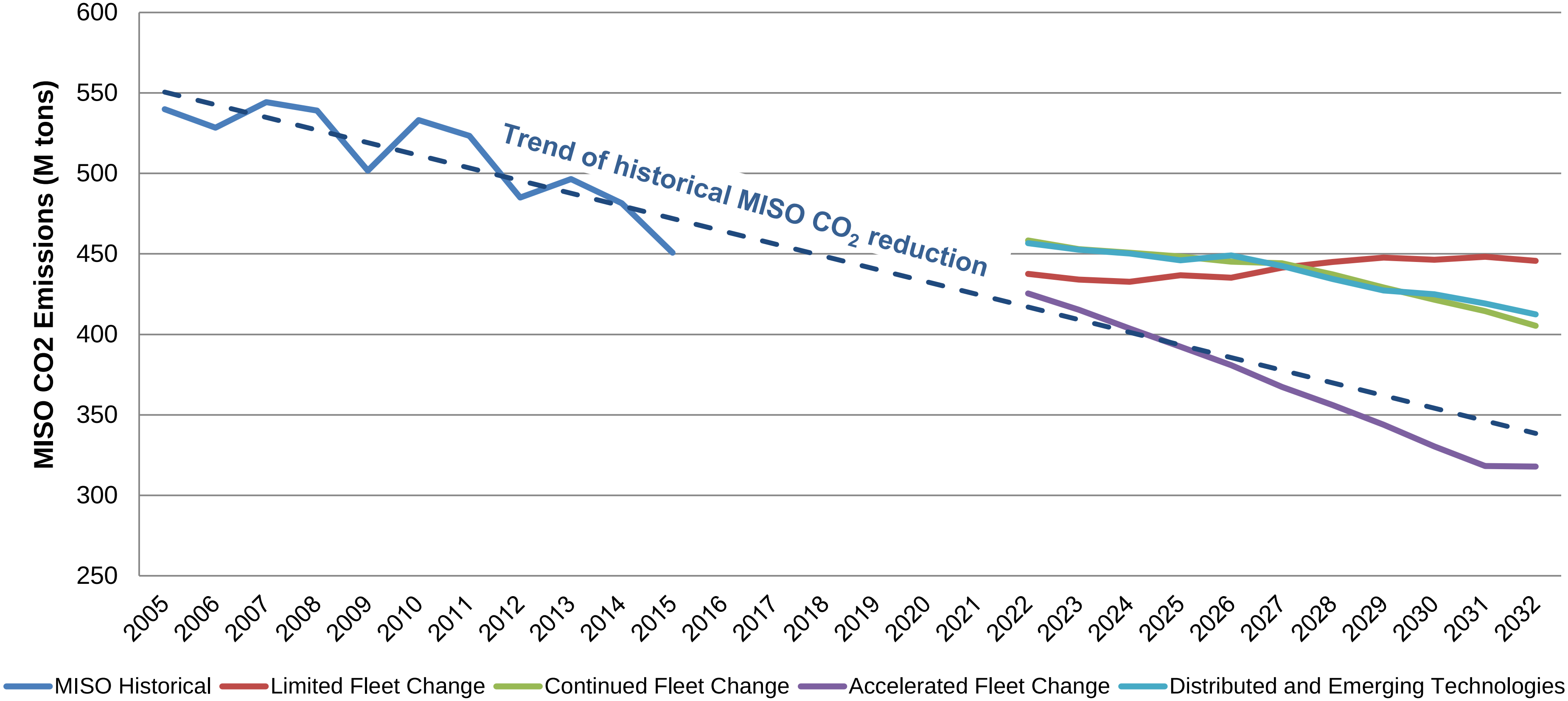
# MISO Solar Siting by Tier

| Tier 1 - Solar Zones | Limited Fleet Change | Continued Fleet Change | Accelerated Fleet Change | Distributed and Emerging Technology |
|---|---|---|---|---|
| Tier 1 - 01 | 70 | 200 | 200 | 200 |
| Tier 1 - 02 | 70 | 200 | 200 | 200 |
| Tier 1 - 03 | 70 | 200 | 200 | 200 |
| Tier 1 - 04 | 70 | 200 | 200 | 200 |
| Tier 1 - 05 | 70 | 200 | 200 | 200 |
| Tier 1 - 06 | 70 | 200 | 200 | 200 |
| Tier 1 - 07 | 70 | 200 | 200 | 200 |
| Tier 1 - 08 | 70 | 200 | 200 | 200 |
| Tier 1 - 09 | 70 | 200 | 200 | 200 |
| Tier 1 - 10 | 70 | 200 | 200 | 200 |
| Tier 1 - 11 | 70 | 200 | 200 | 200 |
| Tier 1 - 12 | 70 | 200 | 200 | 200 |
| Tier 1 - 13 | 70 | 200 | 200 | 200 |
| Tier 1 - 14 | 69 | 200 | 200 | 200 |
| Tier 1 - 15 | 69 | 200 | 200 | 200 |
| Tier 1 - 16 | 69 | 200 | 200 | 200 |
| Tier 1 - 17 | 69 | 200 | 200 | 200 |
| Tier 1 - 18 | 69 | 200 | 200 | 200 |
| Tier 1 - 19 | 69 | 200 | 200 | 200 |
| Tier 1 - 20 | 69 | 200 | 200 | 200 |
| Tier 1 - 21 | 69 | 200 | 200 | 200 |
| Tier 1 - 22 | 69 | 200 | 200 | 200 |
| Tier 1 - 23 | 69 | 200 | 200 | 200 |

| Tier 2 - Solar Zone | Continued Fleet Change | Accelerated Fleet Change | Distributed and Emerging Technology |
|---|---|---|---|
| Tier 2 - 01 | 145 | 300 | 200 |
| Tier 2 - 02 | 145 | 300 | 200 |
| Tier 2 - 03 | 145 | 300 | 200 |
| Tier 2 - 04 | 145 | 300 | 200 |
| Tier 2 - 05 | 145 | 300 | 200 |
| Tier 2 - 06 | 145 | 300 | 200 |
| Tier 2 - 07 | 145 | 300 | 200 |
| Tier 2 - 08 | 145 | 300 | 200 |
| Tier 2 - 09 | 144 | 300 | 200 |
| Tier 2 - 10 | 144 | 300 | 200 |
| Tier 2 - 11 | 144 | 300 | 200 |
| Tier 2 - 12 | 144 | 300 | 200 |
| Tier 2 - 13 | 144 | 300 | 200 |
| Tier 2 - 14 | 144 | 300 | 200 |
| Tier 2 - 15 | 144 | 300 | 200 |
| Tier 2 - 16 | 144 | 300 | 200 |
| Tier 2 - 17 | 144 | 300 | 200 |
| Tier 2 - 18 | 144 | 300 | 200 |

| Tier 3 - Solar Zone | Accelerated Fleet Change | Distributed and Emerging Technology |
|---|---|---|
| Tier 3 - 01 | 154 | 200 |
| Tier 3 - 02 | 154 | 200 |
| Tier 3 - 03 | 154 | 200 |
| Tier 3 - 04 | 154 | 200 |
| Tier 3 - 05 | 154 | 200 |
| Tier 3 - 06 | 153 | 200 |
| Tier 3 - 07 | 154 | 200 |
| Tier 3 - 08 | 154 | 200 |
| Tier 3 - 09 | 154 | 200 |
| Tier 3 - 10 | 154 | 200 |
| Tier 3 - 11 | 153 | 200 |
| Tier 3 - 12 | 154 | 200 |
| Tier 3 - 13 | 154 | 200 |

# $CO_2$ Emissions - constraint applied only in Accelerated Fleet Change Future

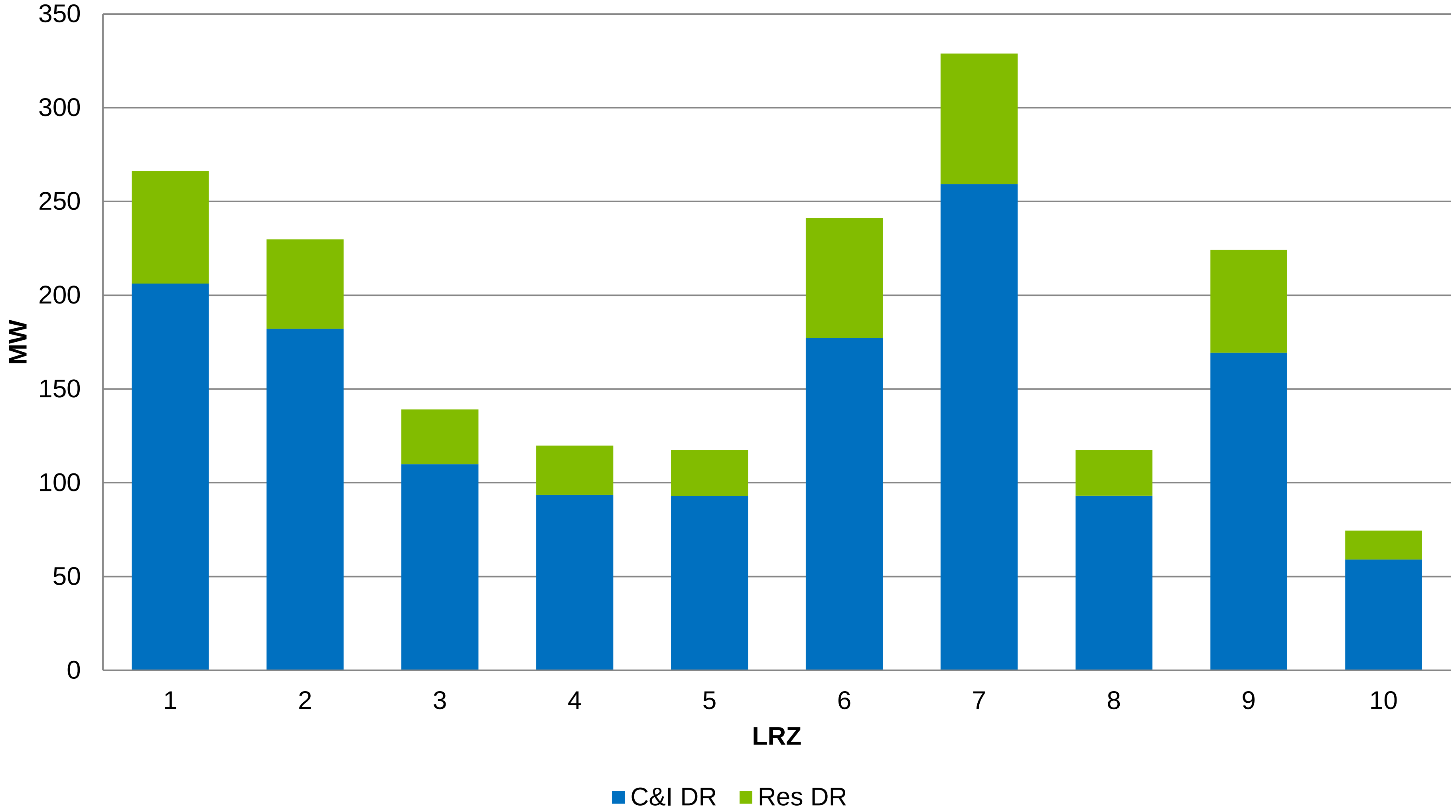



A $CO_2$ constraint applied to the Accelerated Fleet Change Future targeting 20% additional emissions reductions by 2030, & continuing on into the future.

# Demand Side Programs Selected

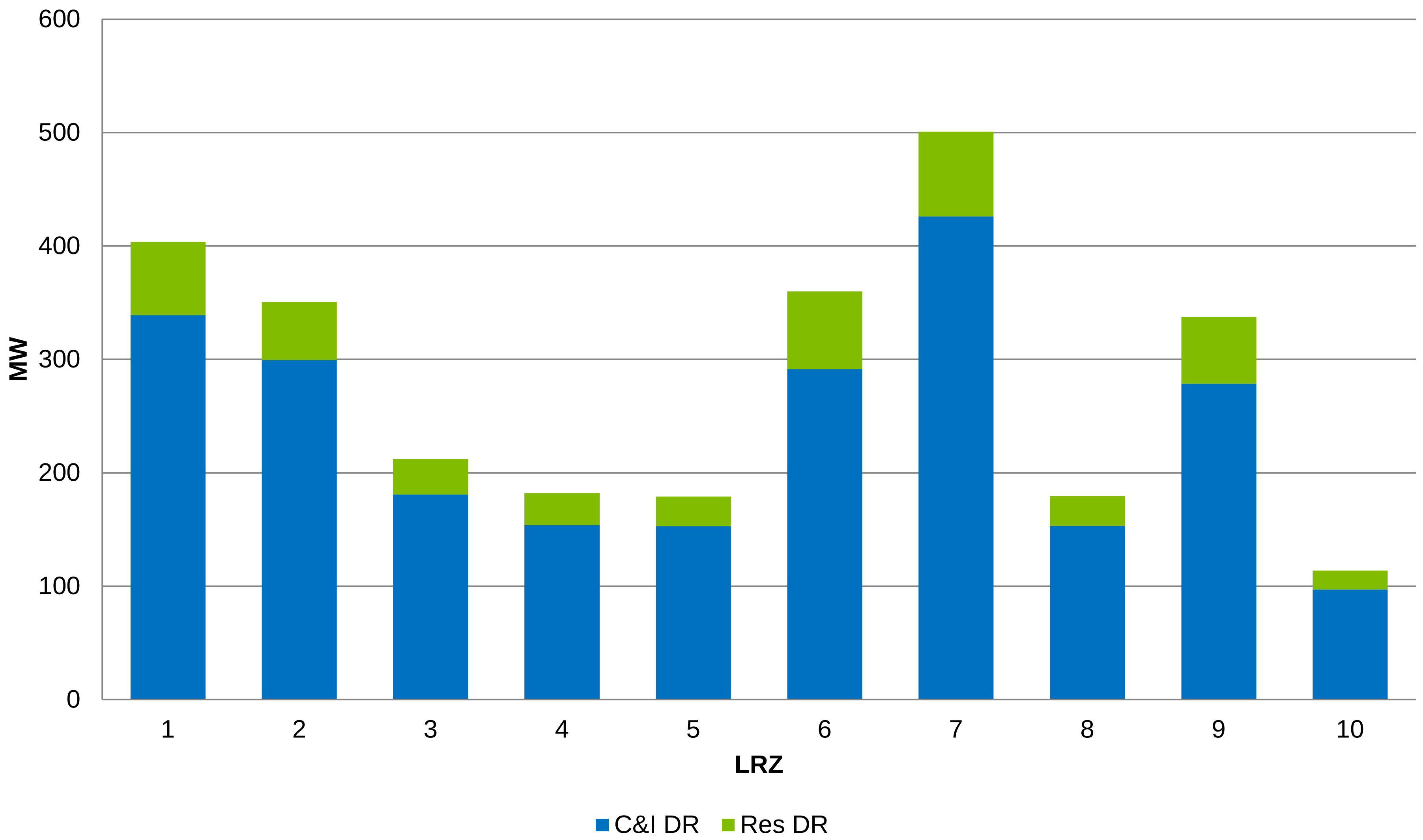
| MTEP18 Programs | | Limited Fleet Change | | Continued Fleet Change | | Accelerated Fleet Change | | Distributed and Emerging Technologies | |
|---|---|---|---|---|---|---|---|---|---|
| 15 Year Potential** | C&I vs Residential | Capacity (GW) | Energy (GWh) | Capacity (GW) | Energy (GWh) | Capacity (GW) | Energy (GWh) | Capacity (GW) | Energy (GWh) |
| Demand Response | C/I | - | - | 0.7 | 55.9 | 1.0 | 74 | 0.7 | 55.9 |
| Direct Load Control | C/I | 1.2 | 100 | 1.4 | 113 | 2.2 | 165 | 1.4 | 113 |
| | R | 0.4 | 35 | 0.4 | 37 | 1.3 | 120 | 0.4 | 37 |
| Price-Responsive Demand | C/I | 0.2 | 49 | 0.2 | 56 | 0.8 | 178 | 0.2 | 56 |
| | R | 0.0 | 5 | 0.0 | 5 | 0.5 | 95 | 0.0 | 5 |
| High-cost Energy Efficiency | C/I | 2.7 | 10,989 | 3.1 | 13,842 | 9.0 | 38,379 | 3.1 | 13,842 |
| | R | 3.5 | 12,401 | 3.8 | 13,997 | 6.2 | 23,521 | 3.8 | 13,997 |
| Low-cost Energy Efficiency | C/I | 1.6 | 6,276 | 1.7 | 6,851 | 4.9 | 19,766 | 1.7 | 6,851 |
| | R | - | - | - | - | 0.3 | 1,508 | - | - |
| Distributed Generation | C/I | 1.1 | 857 | 0.7 | 1,077 | 3.3 | 8,210 | 0.7 | 1,077 |
| | R | 1.0 | 2,680 | 1.1 | 3,121 | 2.6 | 5,054 | 1.1 | 3,121 |

# Demand Response Additions by LRZ – 2032
## Limited Fleet Change



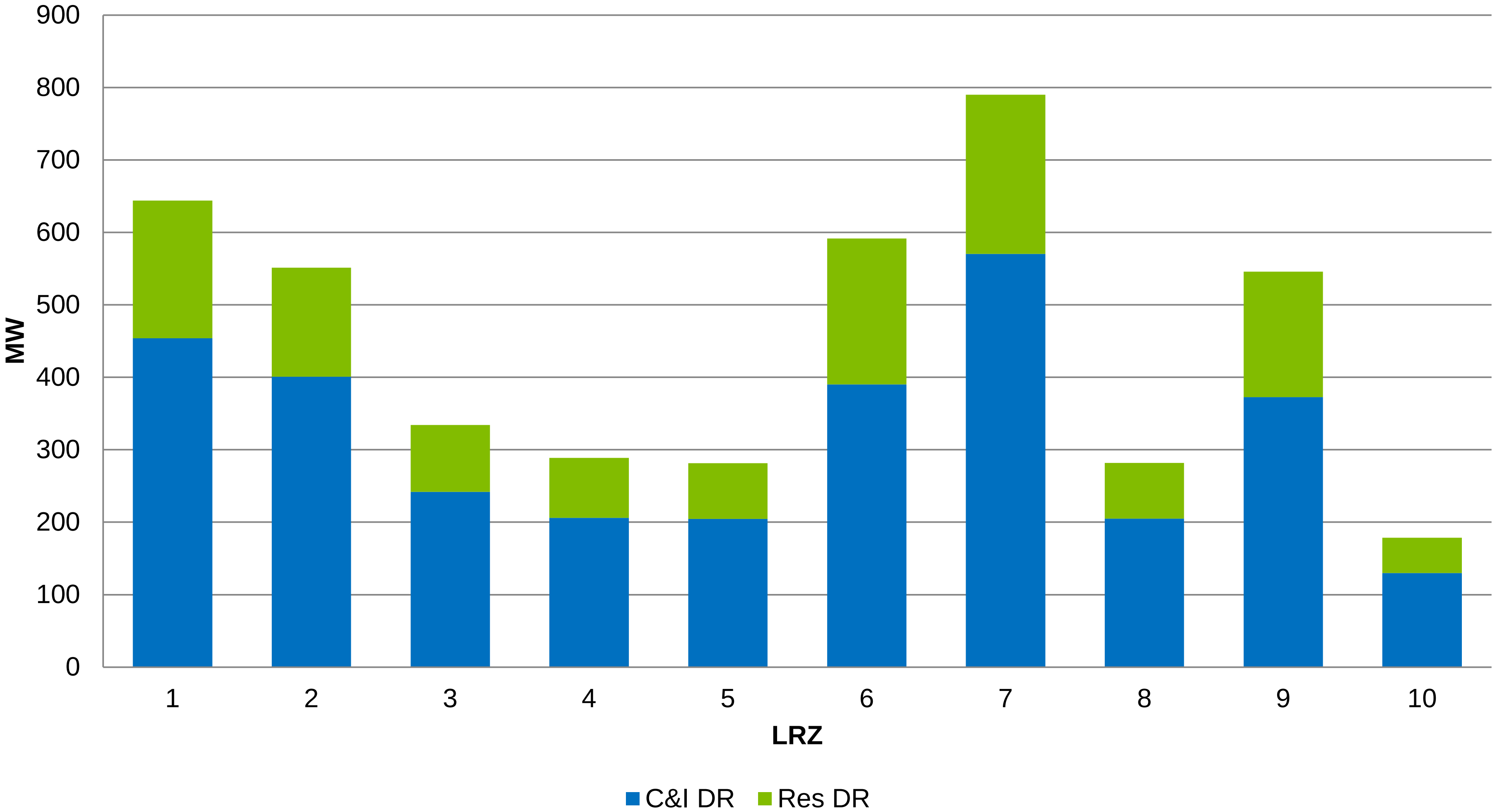
# Demand Response Siting by LRZ – 2032

## Continued Fleet Change/Distributed and Emerging Technologies



# Demand Response Additions by LRZ – 2032

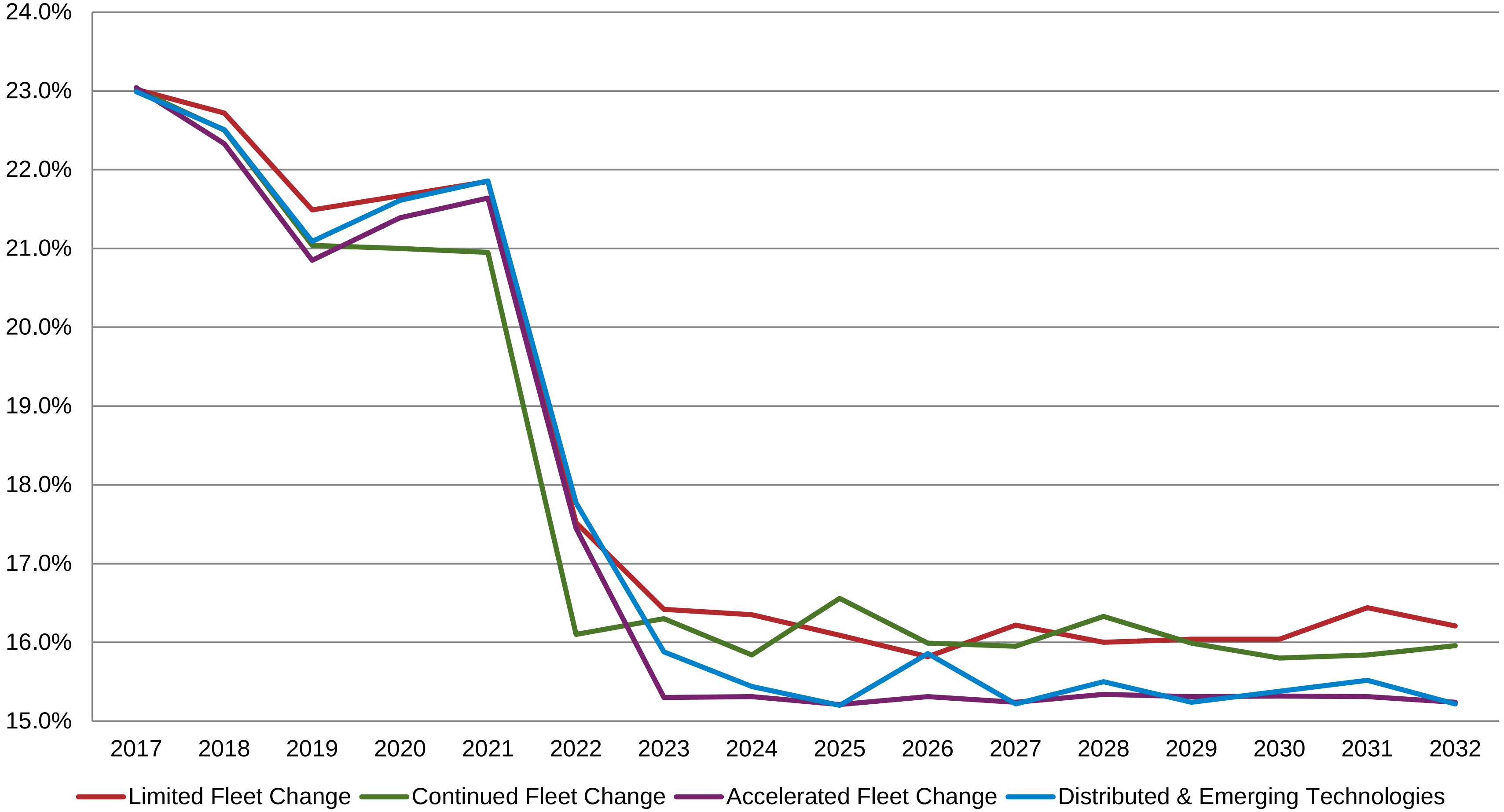
## Accelerated Fleet Change



# MTEP18 siting results meet Zonal Resource Adequacy Requirements

| Percentage over zonal Local Clearing Requirement in 2032 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **LRZ 1** | **LRZ 2** | **LRZ 3** | **LRZ 4** | **LRZ 5** | **LRZ 6** | **LRZ 7** | **LRZ 8** | **LRZ 9** | **LRZ 10** |
| **LFC** | 100% | 131% | 133% | 179% | 194% | 152% | 100% | 150% | 111% | 171% |
| **CFC** | 102% | 125% | 136% | 155% | 192% | 140% | 108% | 143% | 110% | 181% |
| **DET** | 101% | 122% | 127% | 157% | 140% | 135% | 106% | 150% | 118% | 163% |
| **AFC** | 105% | 127% | 120% | 139% | 130% | 135% | 101% | 130% | 104% | 140% |

# MISO Forecasted Planning Reserve Margin Requirement by MTEP Future



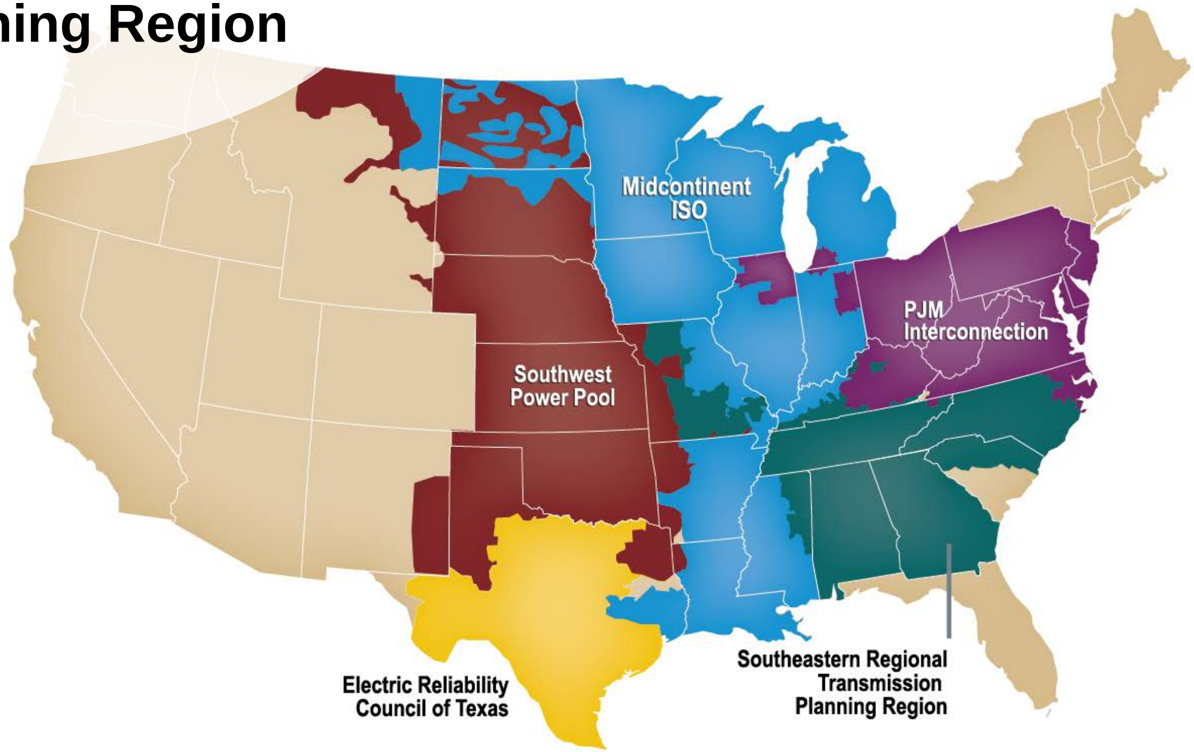
# MTEP18 External Region Resource Forecasts

# MTEP Modeling of External Regions

- MISO's regional economic models include most of the Eastern Interconnection
- Consistent assumptions are applied to all regions to prevent biases driven solely from differing assumptions
- Regional differences modeled when available and appropriate (e.g. 50/50 demand and energy forecasts, natural gas transportation adders, site-specific wind and solar profiles)
- In MTEP18 Futures, carbon reduction assumptions consistent with MISO's were applied to all regions in the Accelerated Fleet Change Future
  - Assumed historical trend coal retirements for external regions modeled at the same age threshold as MISO coal fleet
  - Age-base retirements use consistent age-limits from MISO fleet analysis
- MISO regularly coordinates with neighboring regions to update base data and information

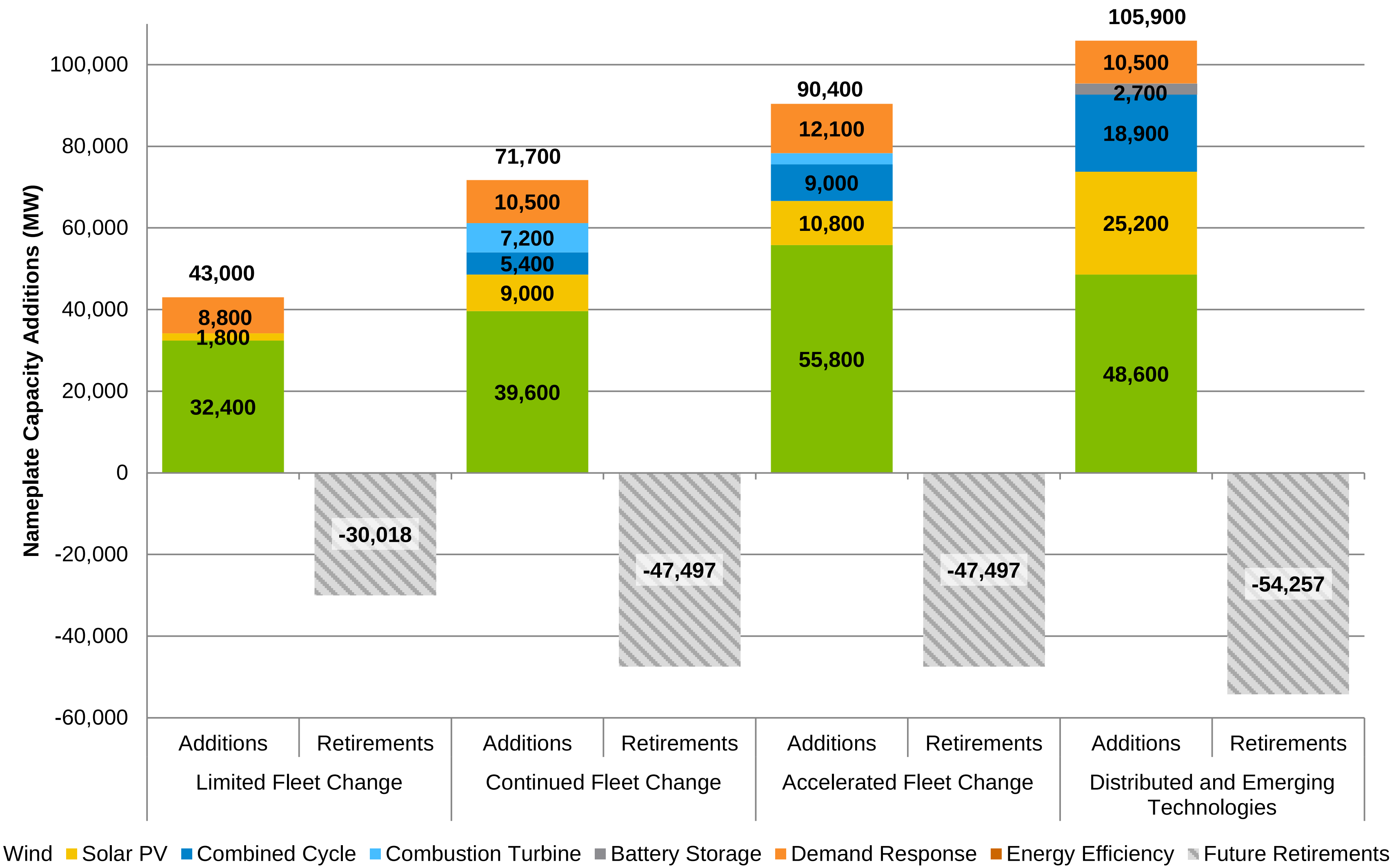
# MTEP Resource Forecast Regional Definitions

- **MISO**
- **PJM**
- **SPP (Includes Integrated System)**
- **NYISO**
- **Southeastern Regional Transmission Planning Region**
  - **SERC**
    - SOCO
    - Duke
    - AEC
    - CPL
    - SC
    - SCEG
  - **TVA Region**
    - TVA
    - AECI
    - LG&E



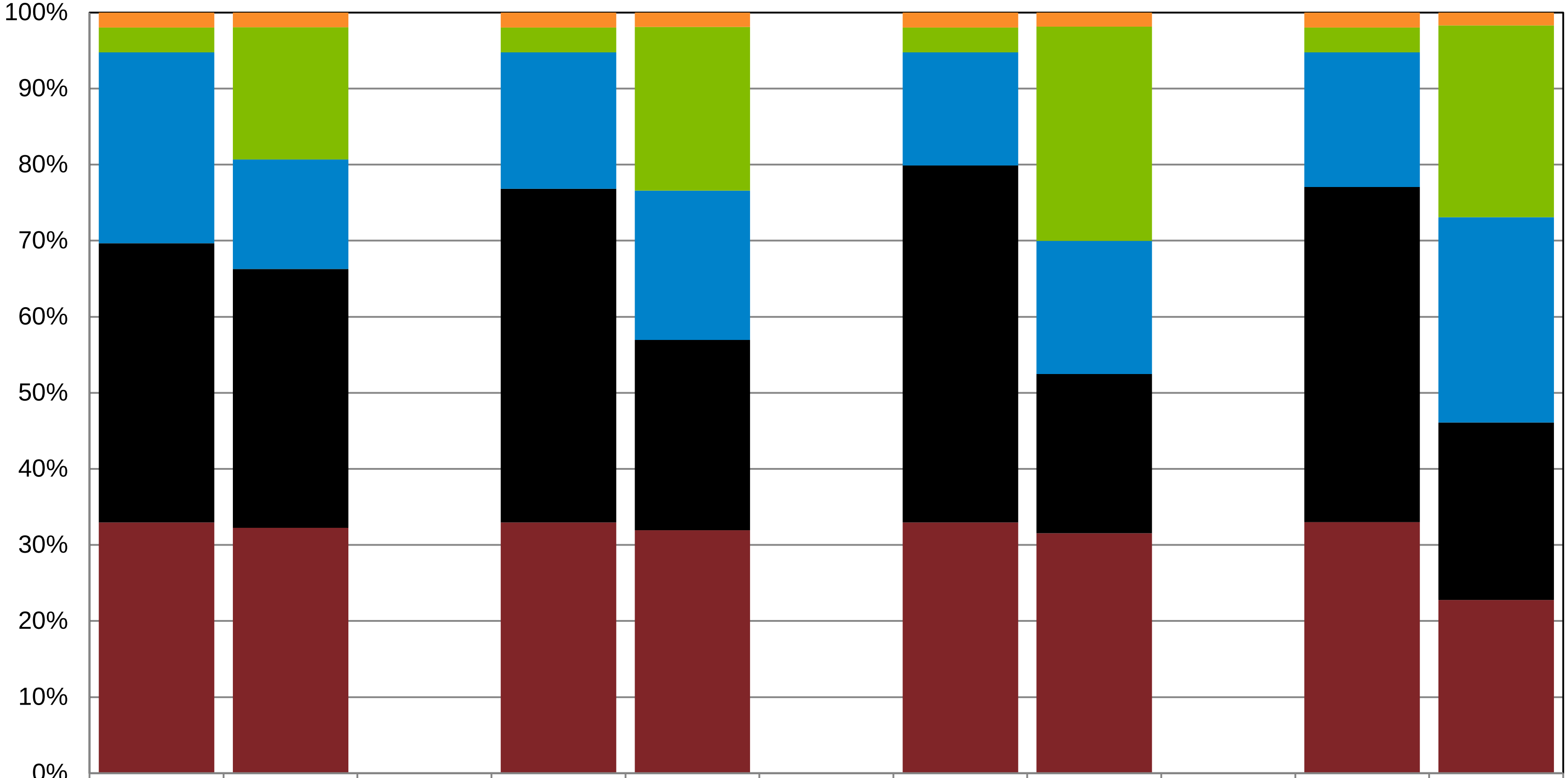
# MTEP18 PJM Nameplate Capacity Forecast

(Year 2017 – 2032)



# MTEP18 PJM Energy Comparisons by Future

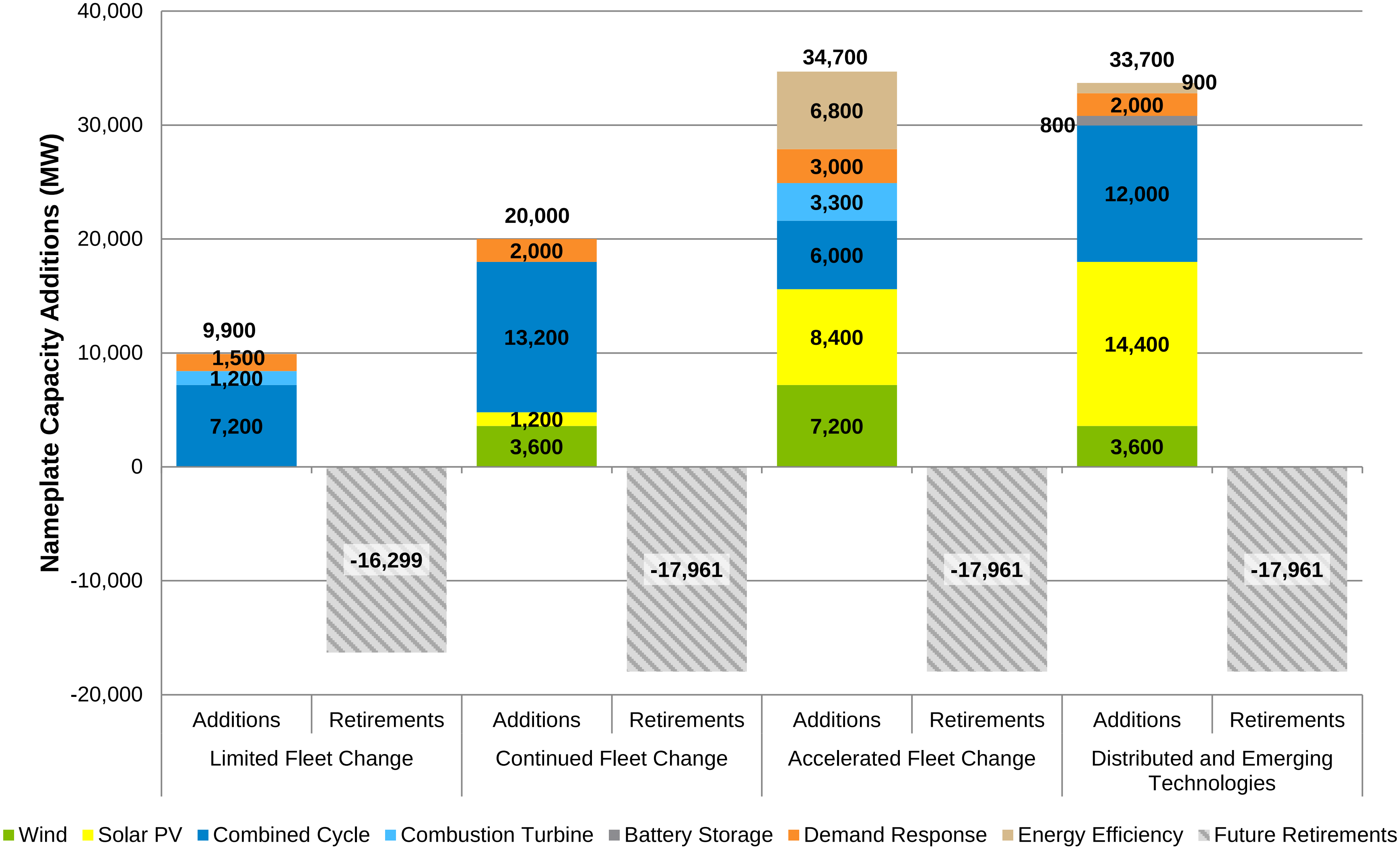
(Year 2017 vs 2032)




| | LFC 2017 | LFC 2032 | | CFC 2017 | CFC 2032 | | AFC 2017 | AFC 2032 | | DET 2017 | DET 2032 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydro | 2% | 2% | | 2% | 2% | | 2% | 2% | | 2% | 2% |
| Renewable | 3% | 17% | | 3% | 21% | | 3% | 28% | | 3% | 25% |
| Gas | 25% | 14% | | 18% | 20% | | 15% | 17% | | 18% | 27% |
| Coal | 37% | 34% | | 44% | 25% | | 47% | 21% | | 44% | 23% |
| Nuclear | 33% | 32% | | 33% | 32% | | 33% | 31% | | 33% | 23% |

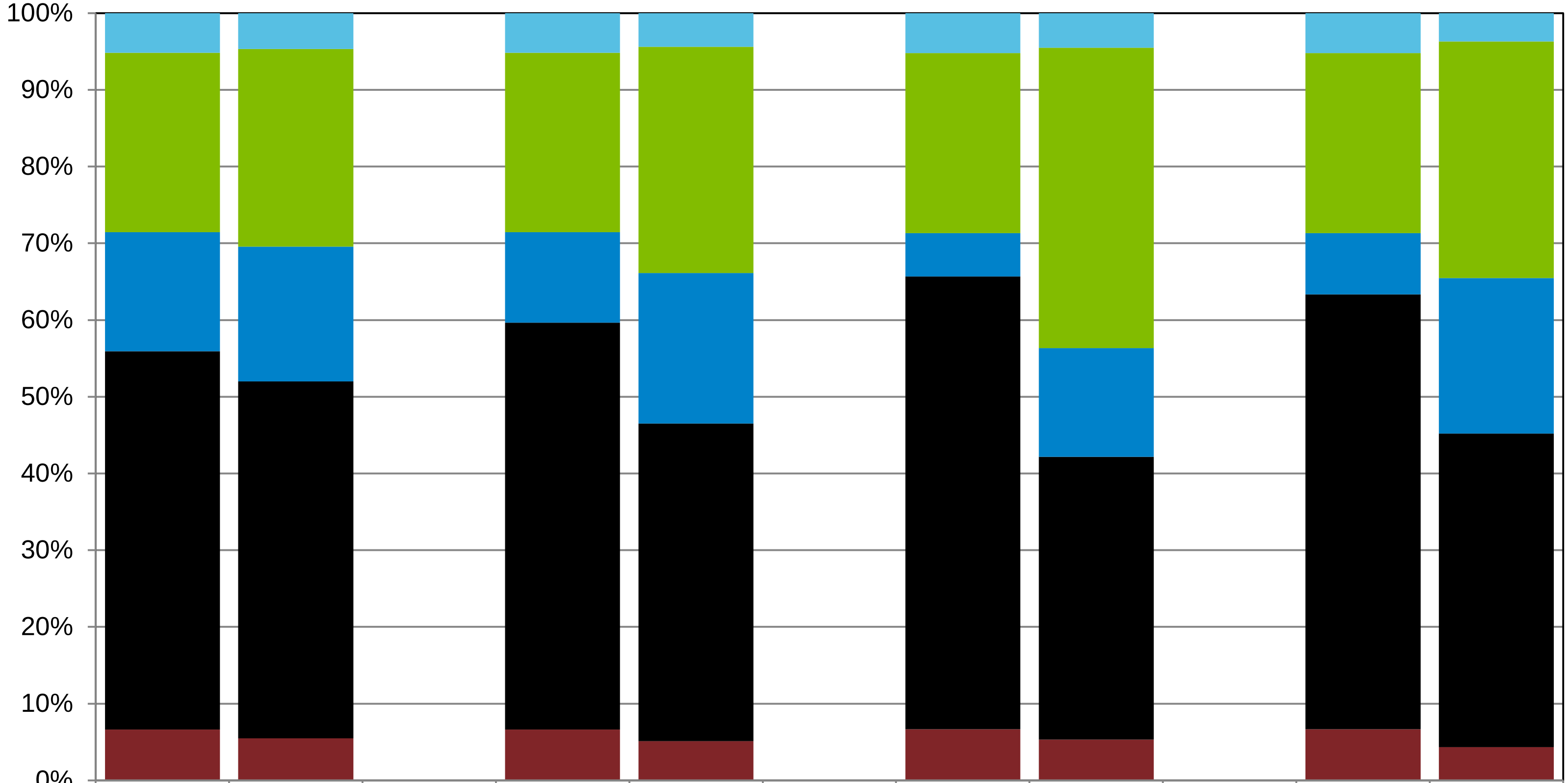
# MTEP18 SPP Nameplate Capacity Forecast

(Year 2017 – 2032)



# MTEP18 SPP Energy Comparisons by Future

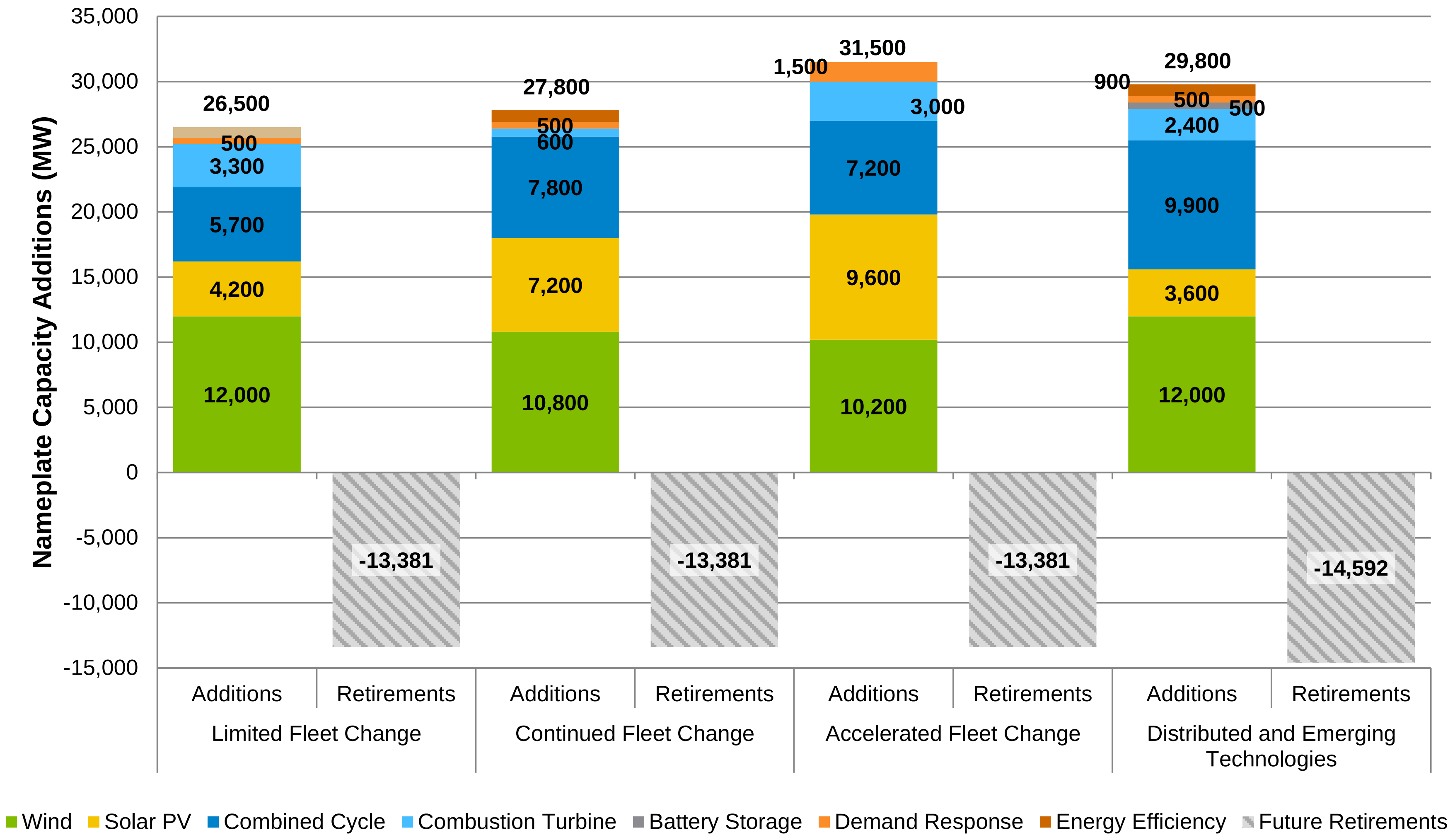
## (Year 2016 vs 2031)




| | LFC 2017 | LFC 2032 | | CFC 2017 | CFC 2032 | | AFC 2017 | AFC 2032 | | DET 2017 | DET 2032 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydro | 5% | 5% | | 5% | 4% | | 5% | 4% | | 5% | 4% |
| Renewable | 23% | 26% | | 23% | 29% | | 23% | 36% | | 23% | 31% |
| Gas | 16% | 18% | | 12% | 20% | | 6% | 13% | | 8% | 20% |
| Coal | 49% | 47% | | 53% | 41% | | 59% | 34% | | 57% | 40% |
| Nuclear | 7% | 5% | | 7% | 5% | | 7% | 5% | | 7% | 4% |

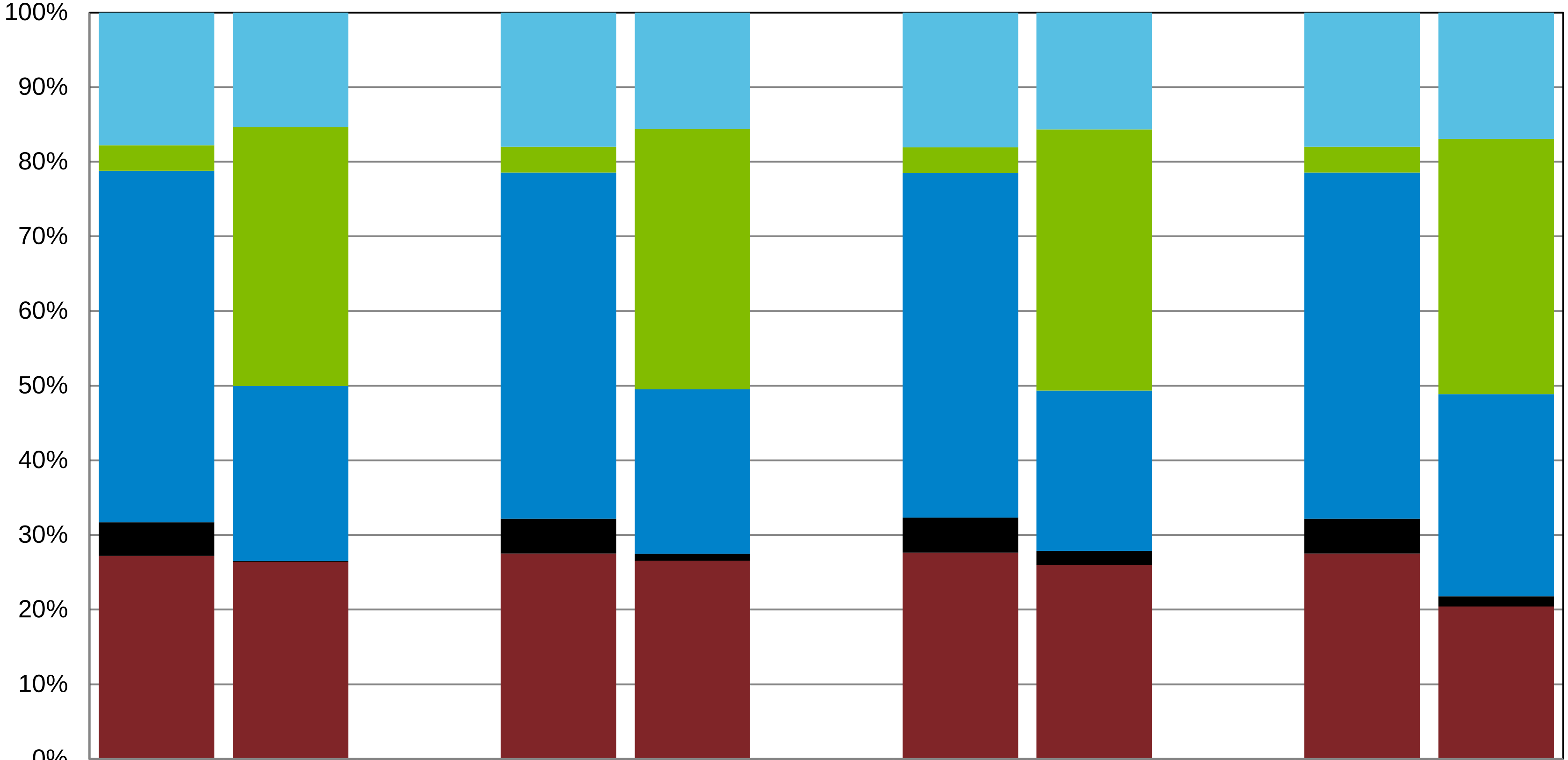
# MTEP18 NYISO Nameplate Capacity Forecast

(Year 2017 – 2032)



# MTEP18 NYISO Energy Comparisons by Future

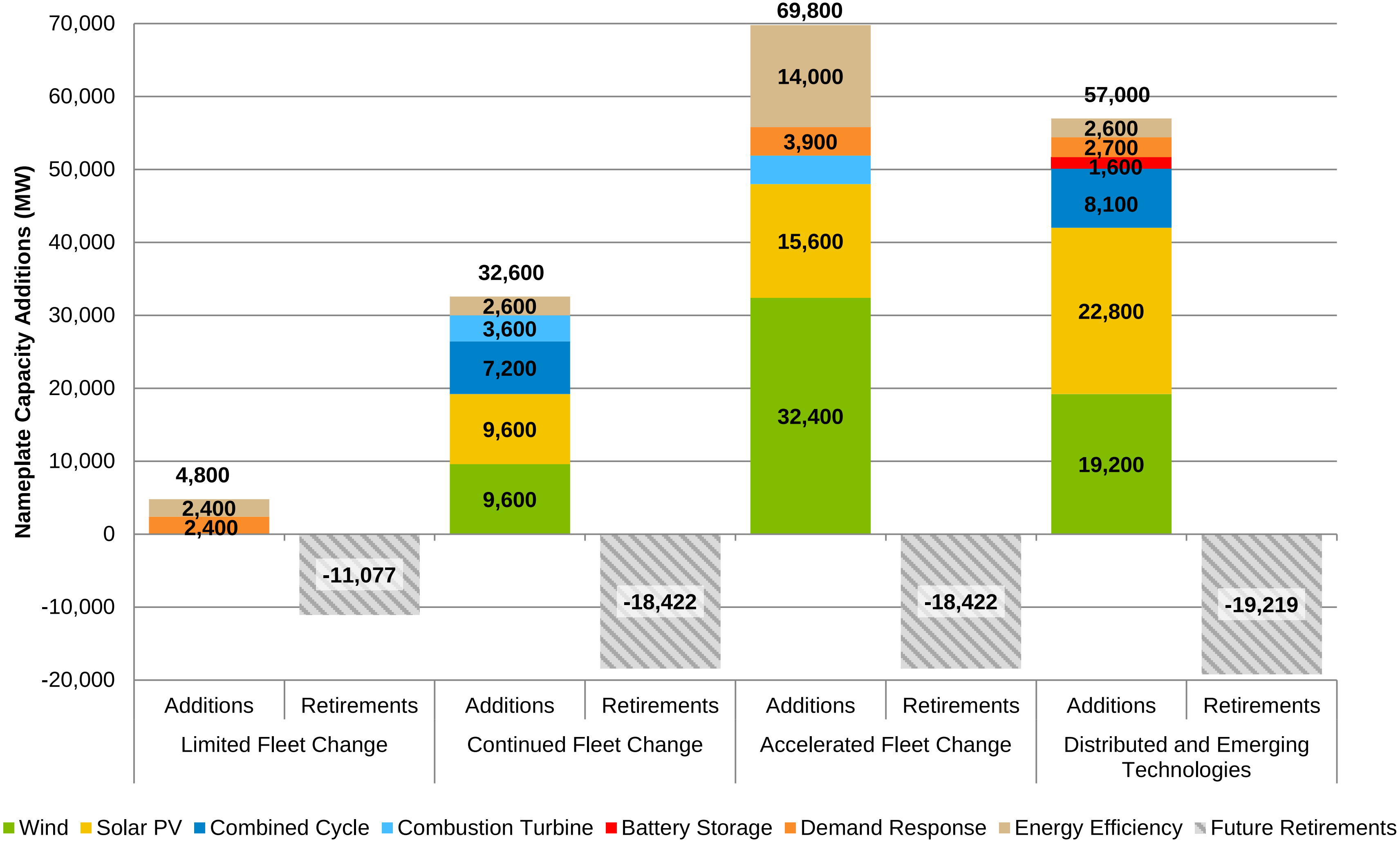
(Year 2017 vs 2032)




| | LFC 2017 | LFC 2032 | | CFC 2017 | CFC 2032 | | AFC 2017 | AFC 2032 | | DET 2017 | DET 2032 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydro | 18% | 15% | | 18% | 15% | | 18% | 16% | | 18% | 17% |
| Renewable | 3% | 34% | | 3% | 34% | | 3% | 35% | | 3% | 33% |
| Gas | 46% | 23% | | 45% | 21% | | 45% | 21% | | 45% | 26% |
| Coal | 4% | 0% | | 5% | 1% | | 5% | 2% | | 5% | 1% |
| Nuclear | 27% | 26% | | 27% | 26% | | 27% | 26% | | 27% | 20% |

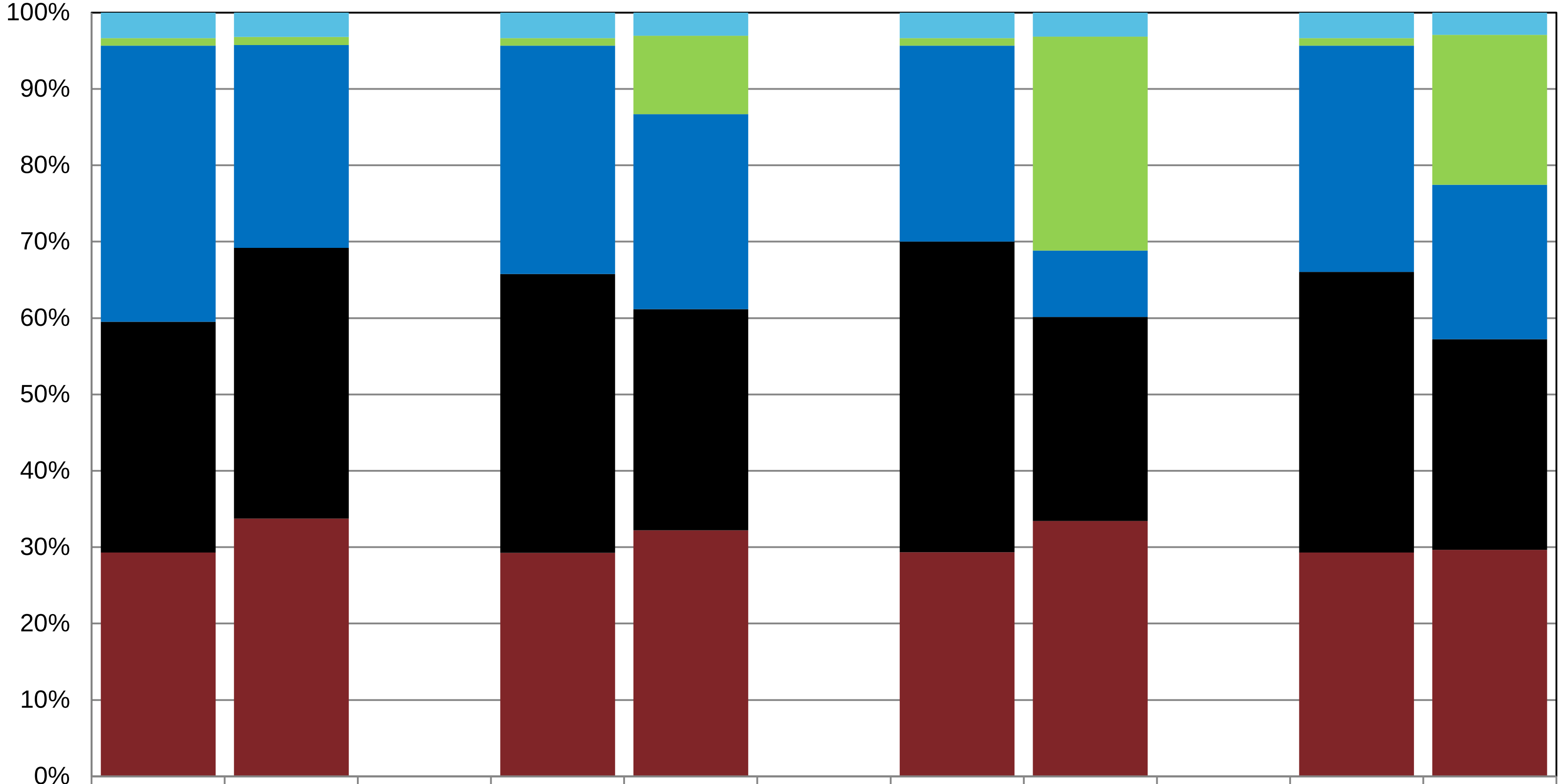
# MTEP18 SERC Nameplate Capacity Forecast

(Year 2017 – 2032)



# MTEP18 SERC Energy Comparisons by Future

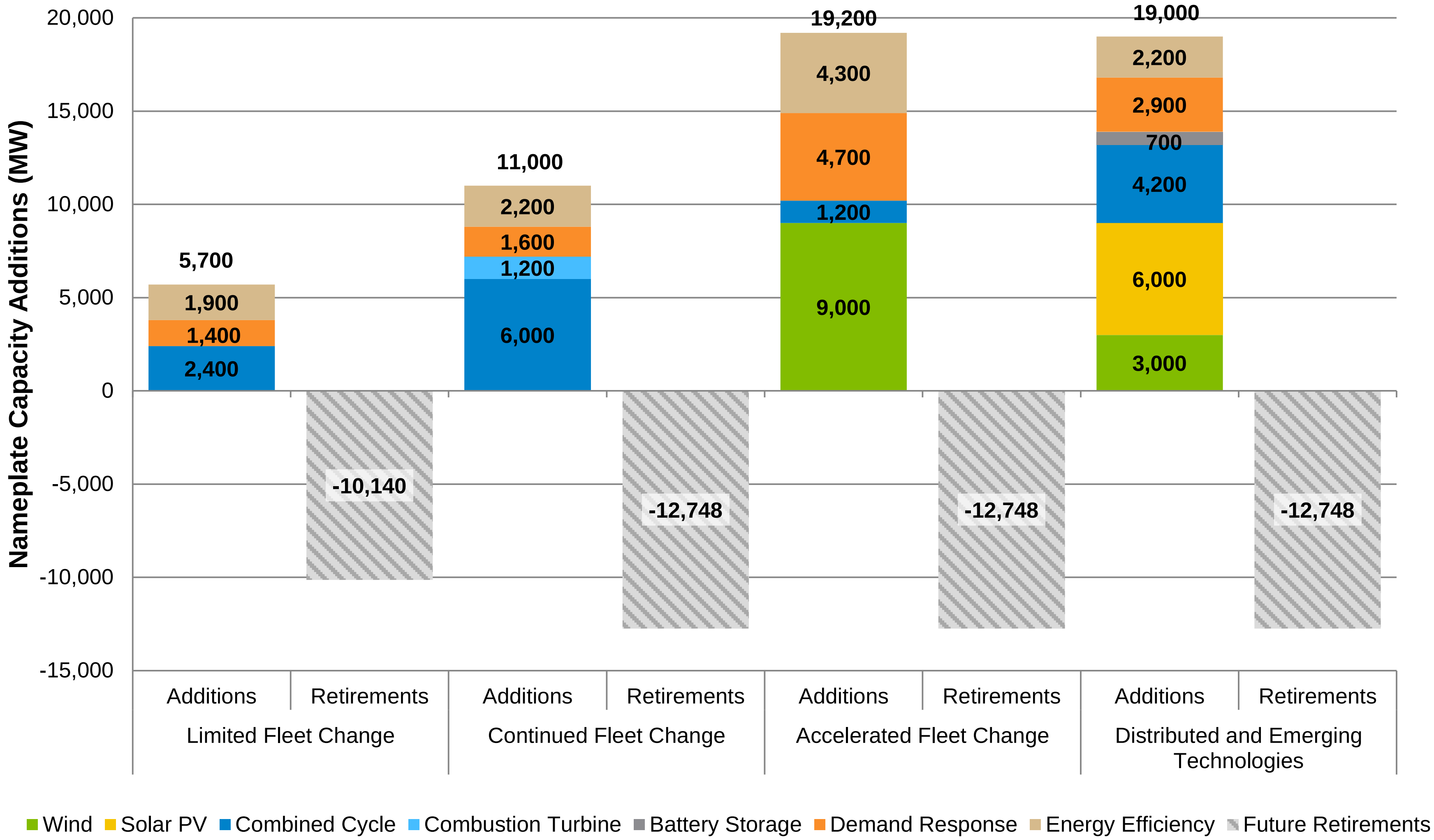
(Year 2017 vs 2032)




| | LFC 2017 | LFC 2032 | | CFC 2017 | CFC 2032 | | AFC 2017 | AFC 2032 | | DET 2017 | DET 2032 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydro | 3% | 3% | | 3% | 3% | | 3% | 3% | | 3% | 3% |
| Renewable | 1% | 1% | | 1% | 10% | | 1% | 25% | | 1% | 19% |
| Gas | 36% | 26% | | 30% | 25% | | 26% | 8% | | 30% | 20% |
| Coal | 30% | 35% | | 36% | 28% | | 41% | 24% | | 37% | 27% |
| Nuclear | 29% | 33% | | 29% | 32% | | 29% | 30% | | 29% | 29% |

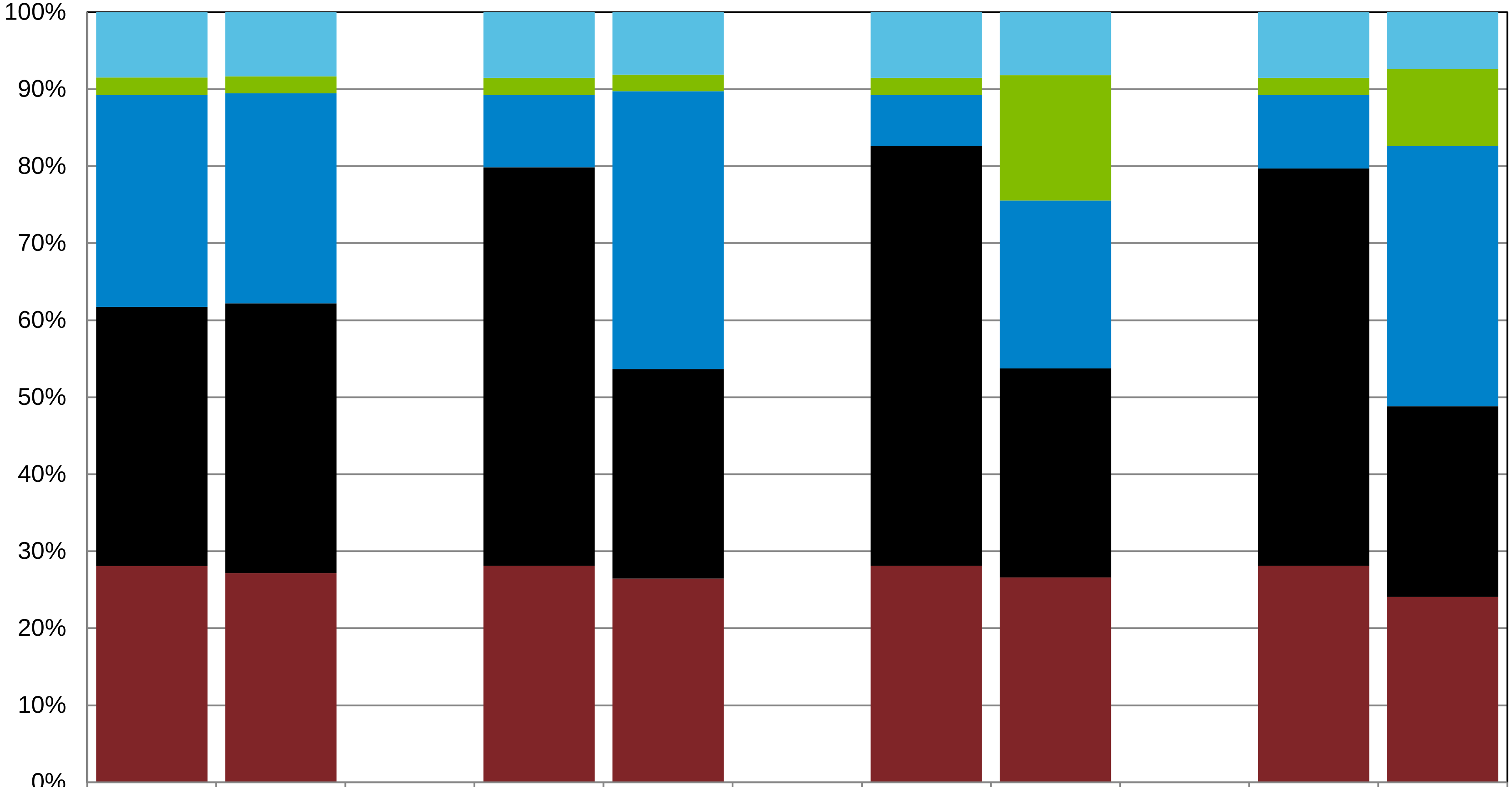
# MTEP18 TVA Region Nameplate Capacity Forecast

(Year 2017 – 2032)



# MTEP18 TVA Region Energy Comparisons by Future

(Year 2017 vs 2032)




| | LFC 2017 | LFC 2032 | | CFC 2017 | CFC 2032 | | AFC 2017 | AFC 2032 | | DET 2017 | DET 2032 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydro | 8% | 8% | | 8% | 8% | | 8% | 8% | | 8% | 7% |
| Renewable | 2% | 2% | | 2% | 2% | | 2% | 15% | | 2% | 10% |
| Gas | 27% | 26% | | 9% | 35% | | 7% | 20% | | 10% | 33% |
| Coal | 34% | 34% | | 52% | 26% | | 54% | 25% | | 51% | 24% |
| Nuclear | 28% | 26% | | 28% | 25% | | 28% | 25% | | 28% | 23% |

# References

# Additional information on the MTEP18 Futures can be found in the following meeting materials:

- January 18 Planning Advisory Committee – MTEP18 Futures Update
  - *https://www.misoenergy.org/Events/Pages/PAC20170118.aspx*
- February 15 Planning Advisory Committee – MTEP18 Futures Update
  - https://www.misoenergy.org/Events/Pages/PAC20170215.aspx
- April 4 MTEP18 Futures Development Workshop
  - https://www.misoenergy.org/Events/Pages/FuturesDevelopmentMTEP1820170404.aspx
- April 19 Planning Advisory Committee – MTEP18 Futures Update
  - https://www.misoenergy.org/Events/Pages/PAC20170419.aspx
- May 17 Planning Advisory Committee – MTEP18 Futures Presentation
  - *https://www.misoenergy.org/Events/Pages/PAC20170517.aspx*
- June 14 Planning Advisory Committee – MTEP18 Futures & Weighting Process
  - *https://www.misoenergy.org/Events/Pages/PAC20170614.aspx*
- July 19 Planning Advisory Committee – MTEP18 Futures Siting Process
  - *https://www.misoenergy.org/Events/Pages/PAC20170719.aspx*
- August 11 –Economic Planning Users Group – MTEP18 Futures Overview
  - *https://www.misoenergy.org/Events/Pages/EPUG20170811.aspx*
- August 16 – Planning Advisory Committee– MTEP18 Futures Weighting
  - *https://www.misoenergy.org/Events/Pages/PAC20170816.aspx*
- September 27– Planning Advisory Committee– MTEP18 Futures Results Review & Weights
  - *https://www.misoenergy.org/Events/Pages/PAC20170927.aspx*