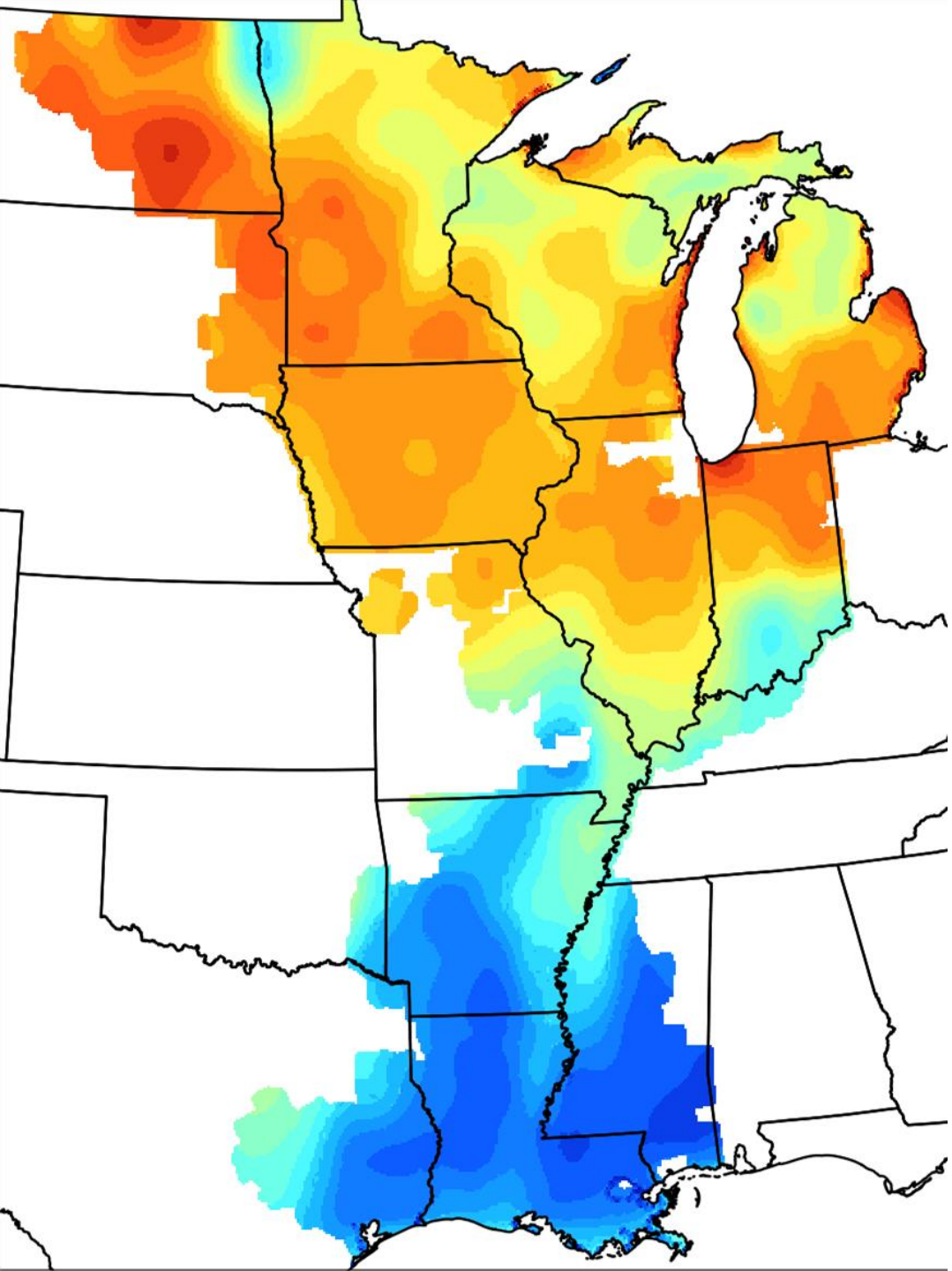
# Firm Power across the MISO region

Tue Sep 27th, 2022

Marc Perez, Ph.D.

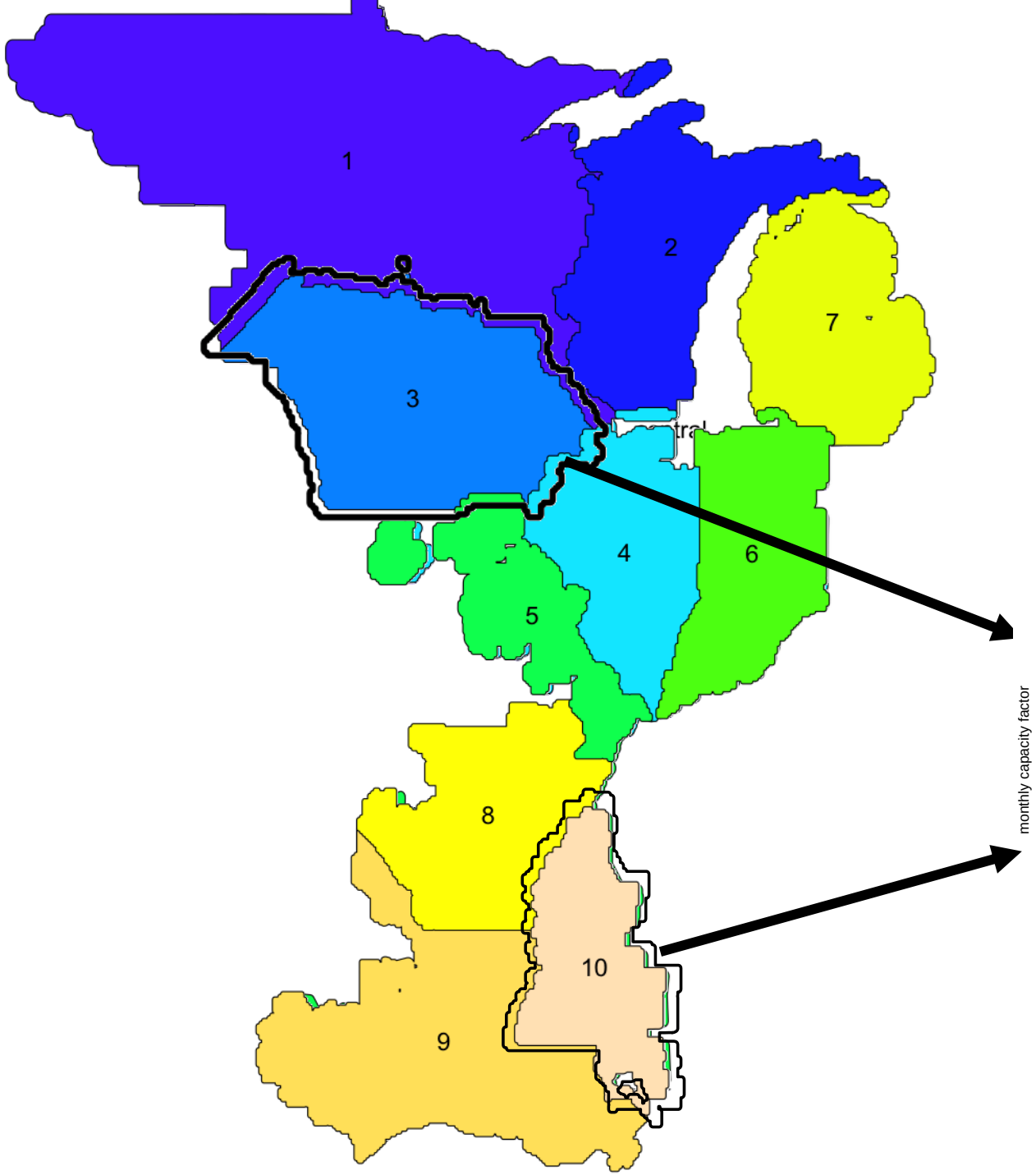
Clean Power Research®



# Firm Power in MISO

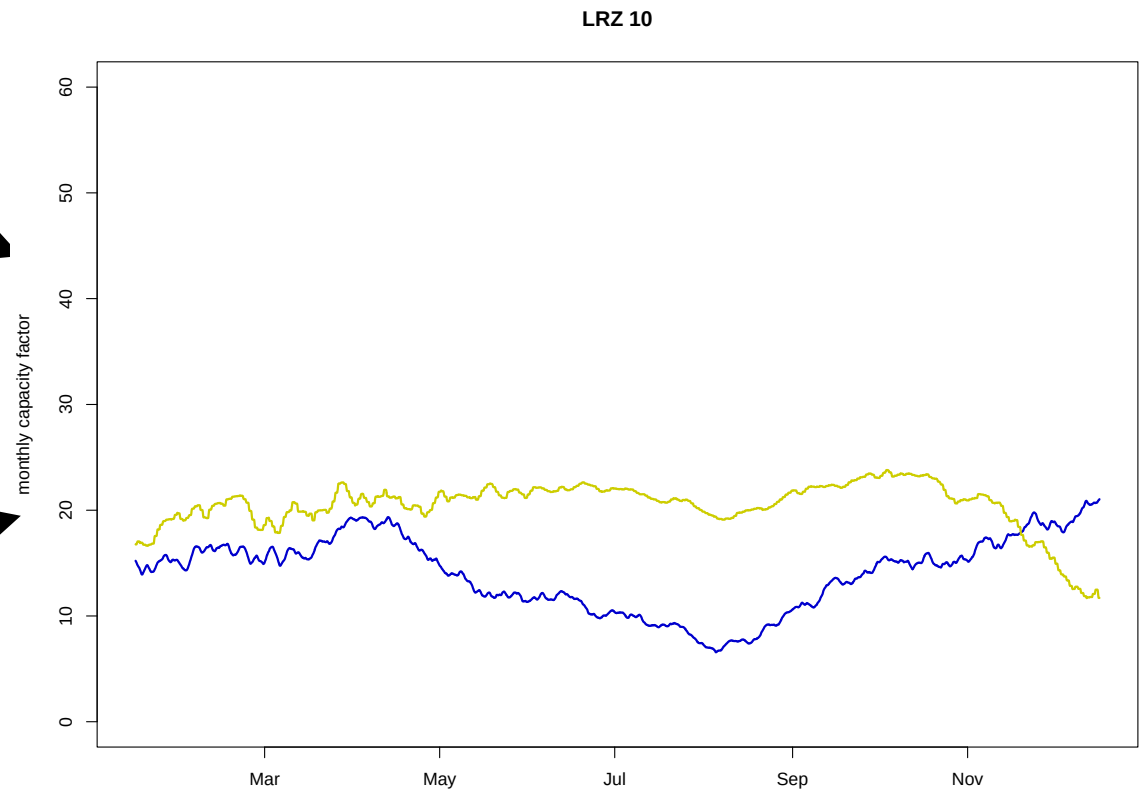
*What differences from Switzerland?*

- Different temporal profiles of variable renewables
- Different resources available
- Slightly different cost assumptions
- More opportunity for geographic dispersion




# Some Characteristics regarding MISO

- **Load:** 120 GW peak, 670 TWh/yr
- **Renewables:** 21 GW wind | 330 MW PV
- **Geography:**
  - 3 Macro Regions
  - 10 Load Resource Zones
- **Resource:** Vastly different resource characteristics




*Let's examine the influence these characteristics have on optimized capacity expansion and the costs that result*

# 4 cost scenarios linked to date and technological progress

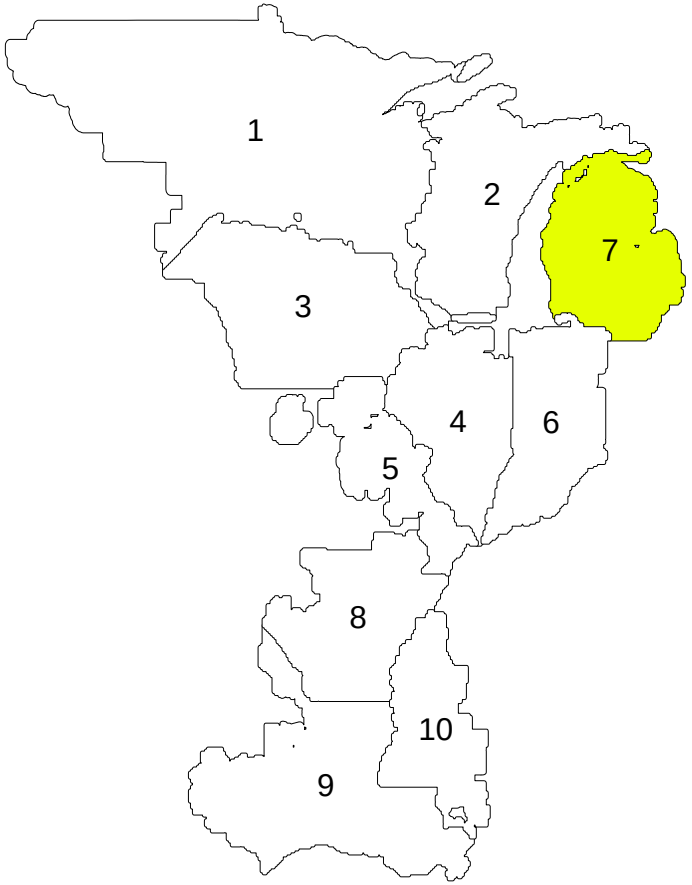
Each developed from latest NREL ATB[1]:

- 2050, high and low technological development
- 2025, high and low technological development


- These 4 scenarios are run for 14 distinct geographic zones (10 LRZs, 3 Regions and MISO) pictured on previous page. Each region with it's own distinct: Load shape and Resource Characteristics.

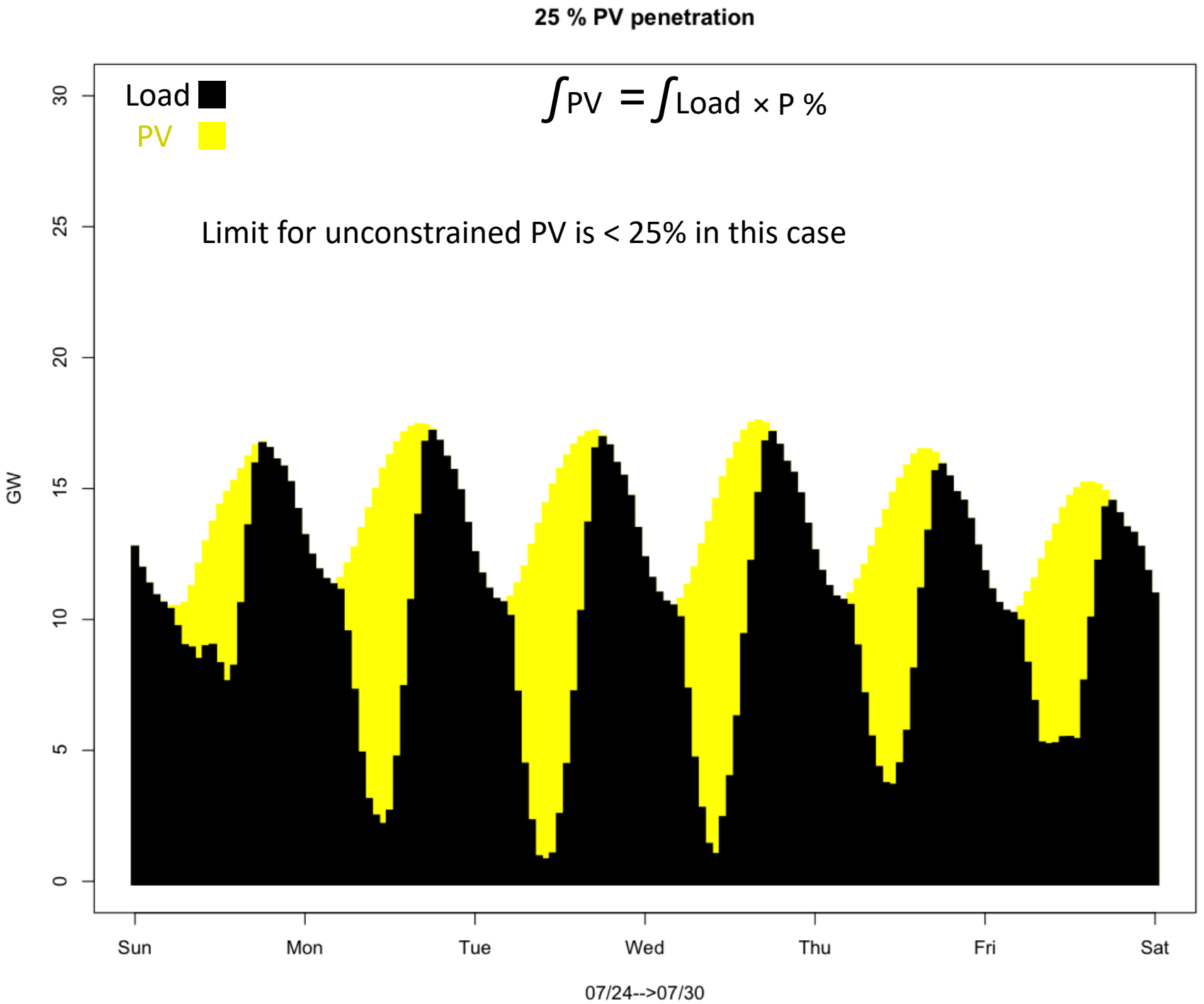
| | | Utility PV | | Wind | | Storage | | | | Gas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CapEx $/kW | Opex $/kW-yr | CapEx $/kW | Opex $/kW-yr | CapEx $/kWh -pack | CapEx $/kW -BoS | Opex % total CapEx / yr | RT eff | CapEx $/kW | Opex fixed $/kW-yr | Opex variable $/MWh | Fuel cost $/MWh |
| 2025 | High | $ 733 | $ 9 | $ 1,311 | $ 38 | $ 99 | $ 323 | 2.5% | 85% | $ 872 | $ 11 | $ 5 | $ 26 |
| | Low | $ 1,042 | $ 13 | $ 1,500 | $ 42 | $ 155 | $ 552 | 2.5% | 85% | $ 872 | $ 11 | $ 5 | $ 39 |
| 2050 | High | $ 356 | $ 4 | $ 813 | $ 24 | $ 41 | $ 133 | 2.5% | 85% | $ 800 | $ 11 | $ 5 | $ 29 |
| | Low | $ 899 | $ 11 | $ 1,294 | $ 38 | $ 112 | $ 471 | 2.5% | 85% | $ 800 | $ 11 | $ 5 | $ 65 |

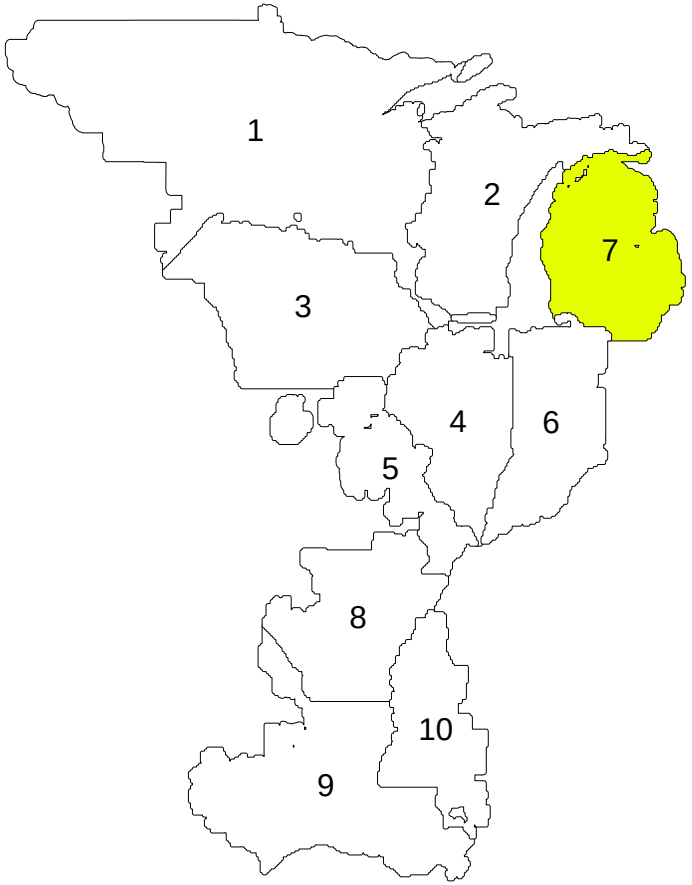
[1]NREL (National Renewable Energy Laboratory). 2019. 2019 Annual Technology Baseline. Golden, CO: National Renewable Energy Laboratory.




# Consider LRZ 7

2025, low technological development, PV *alone*, no overbuild



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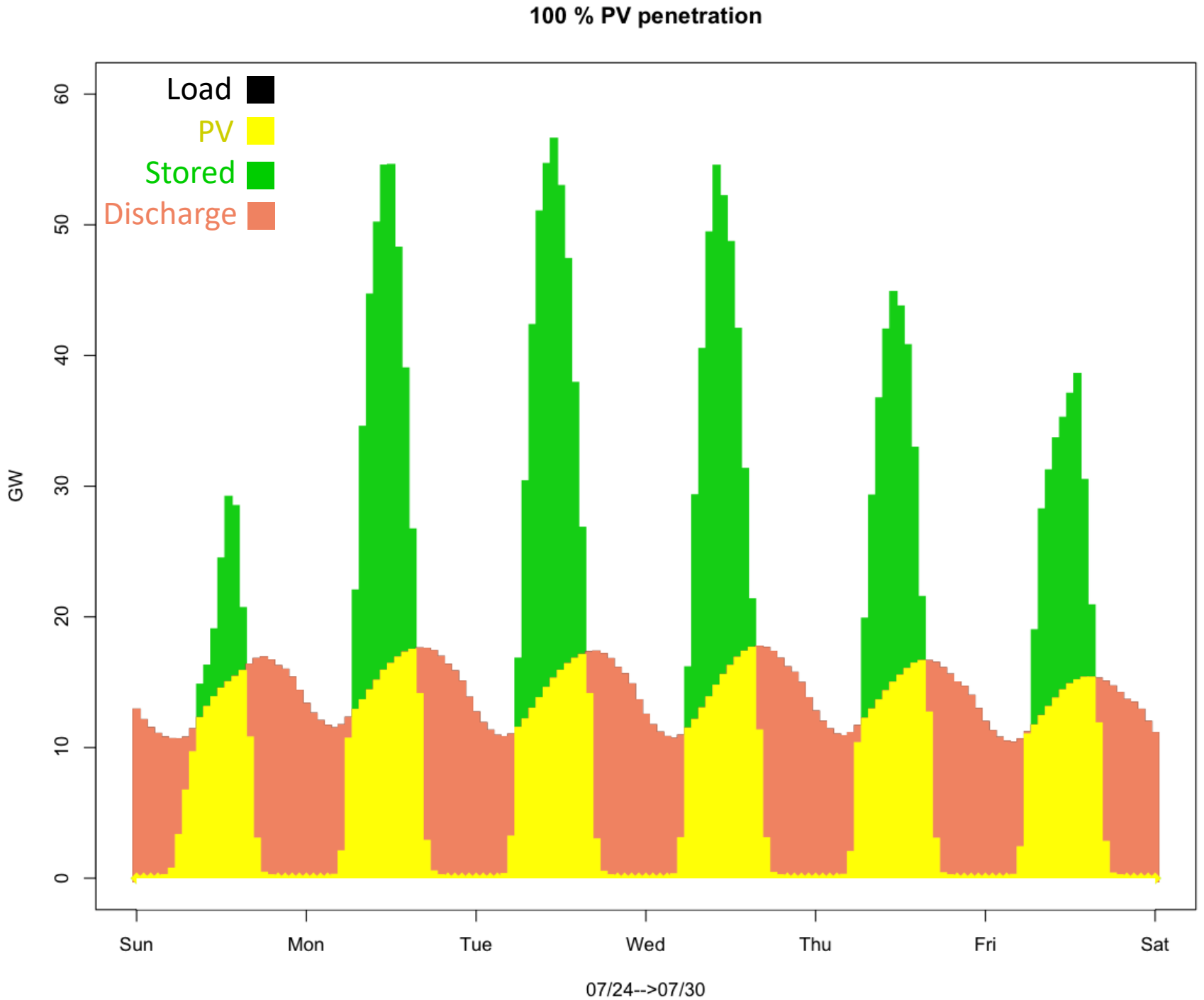

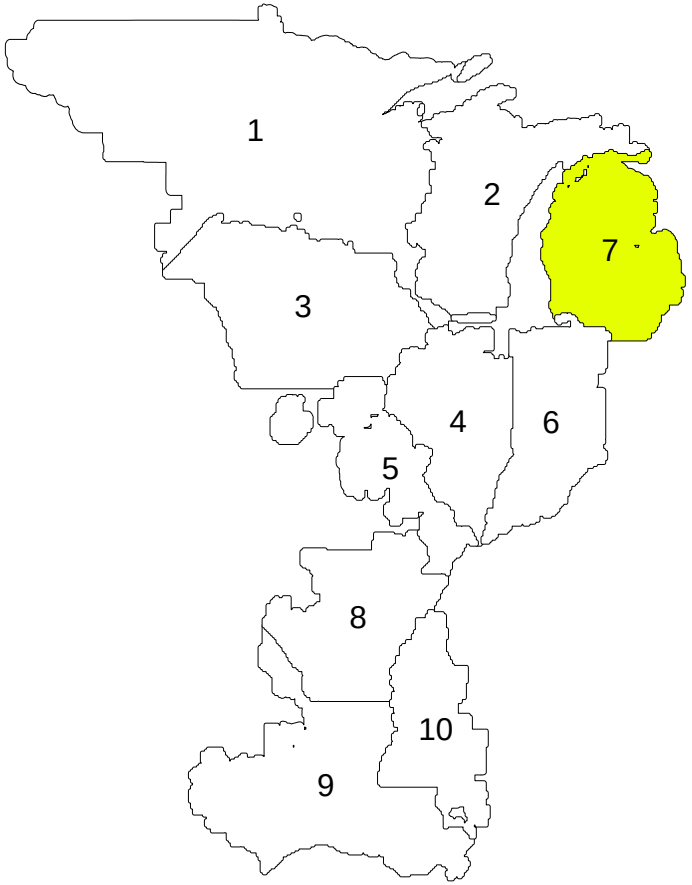


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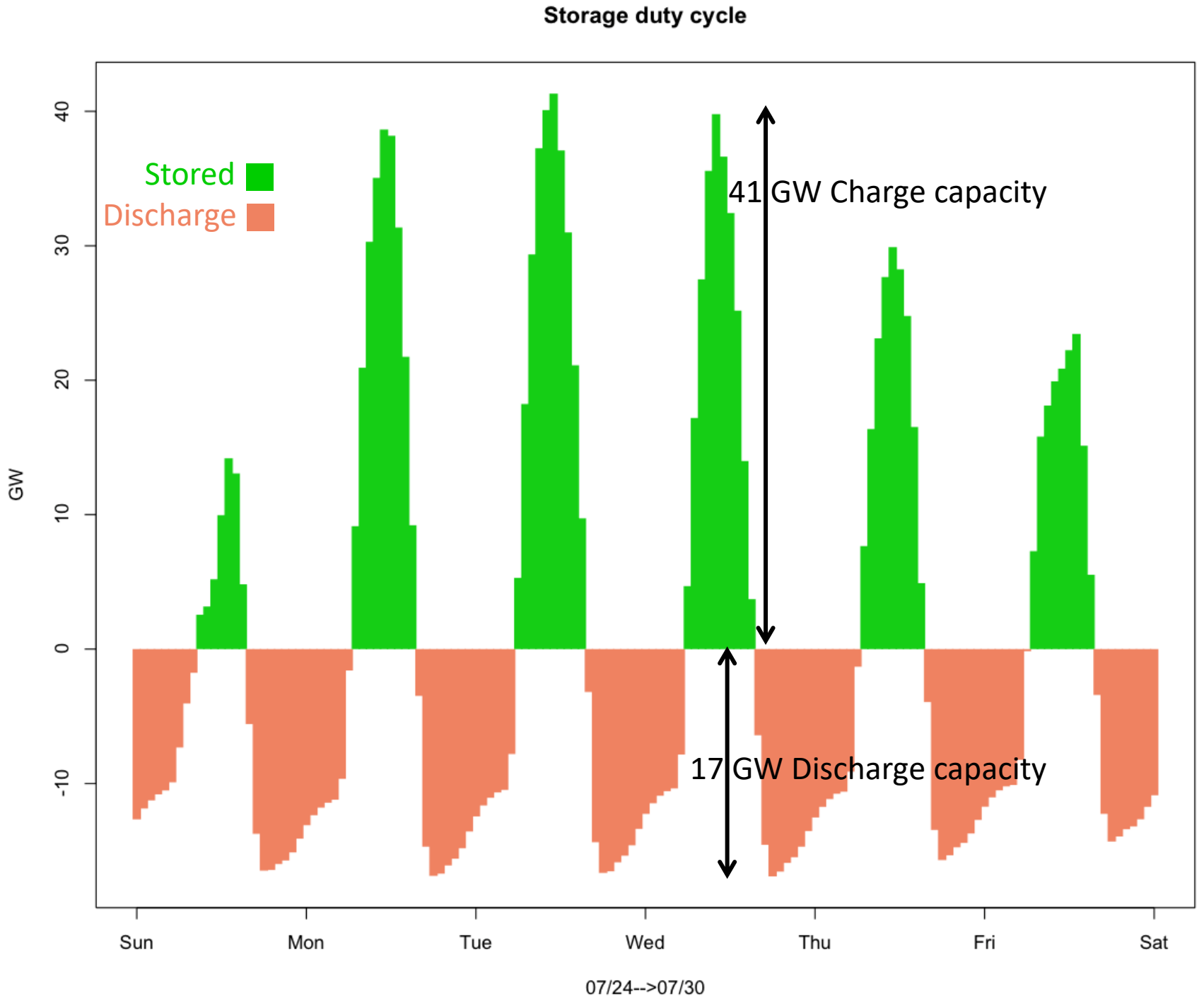

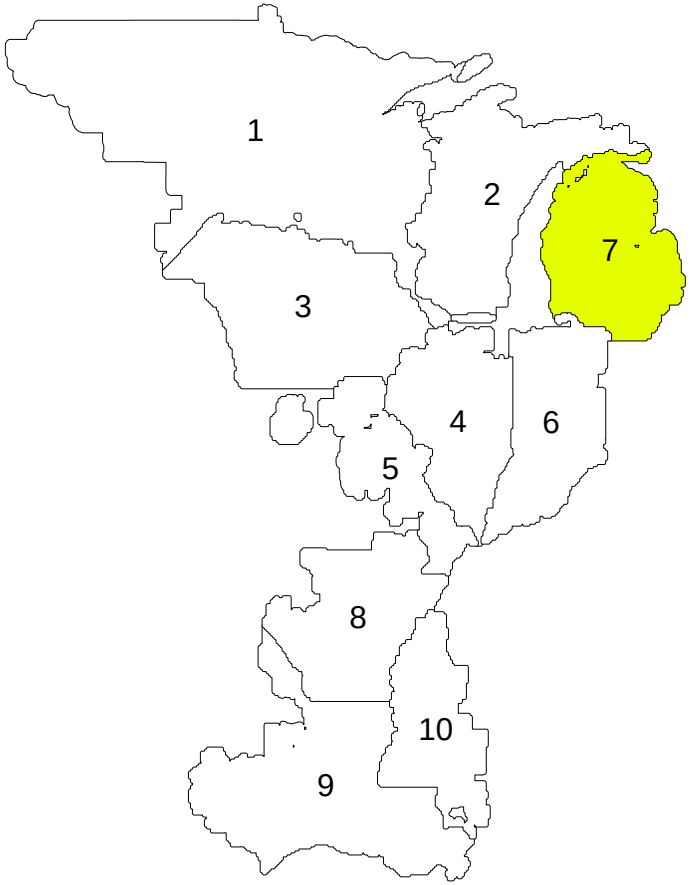


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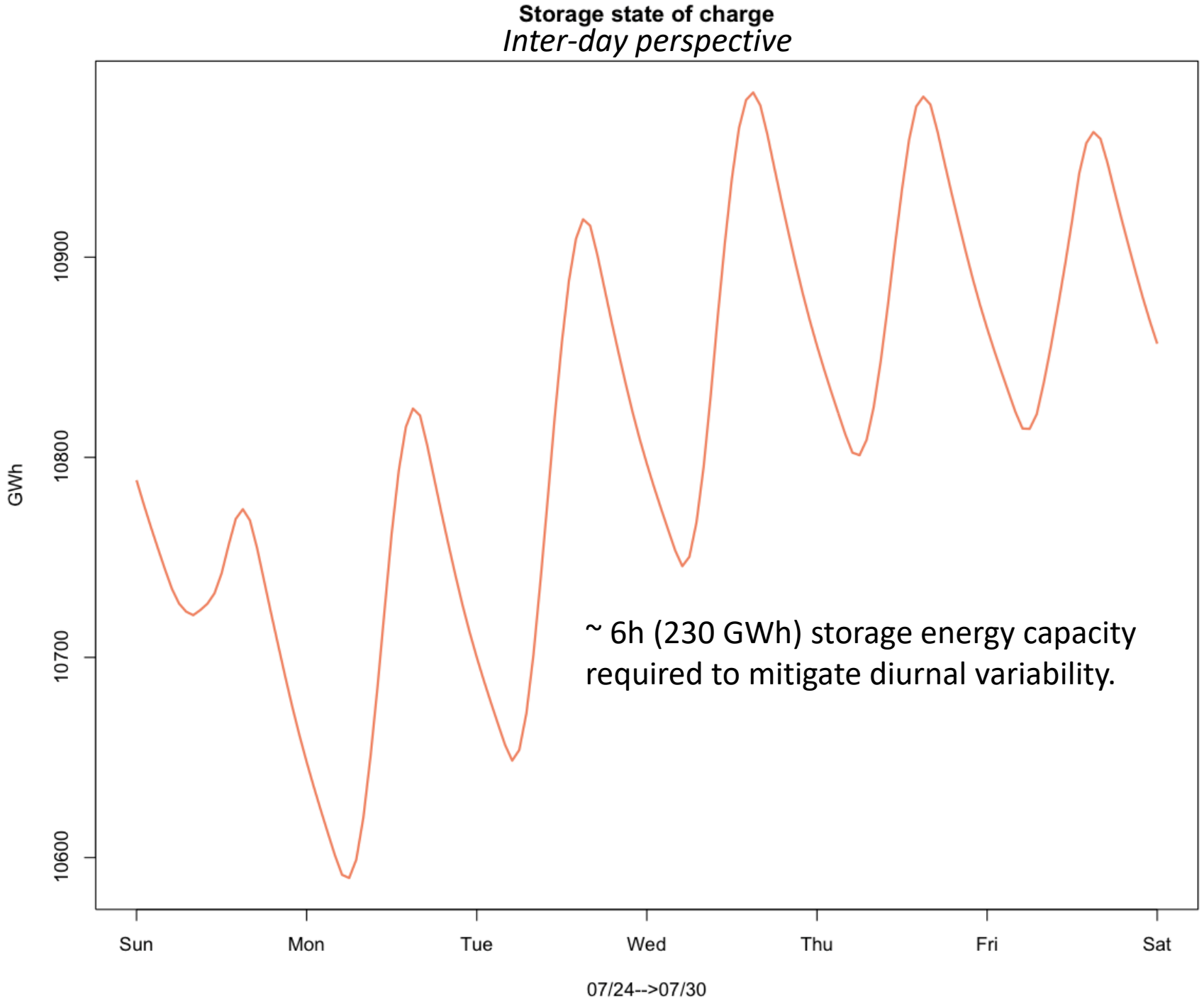

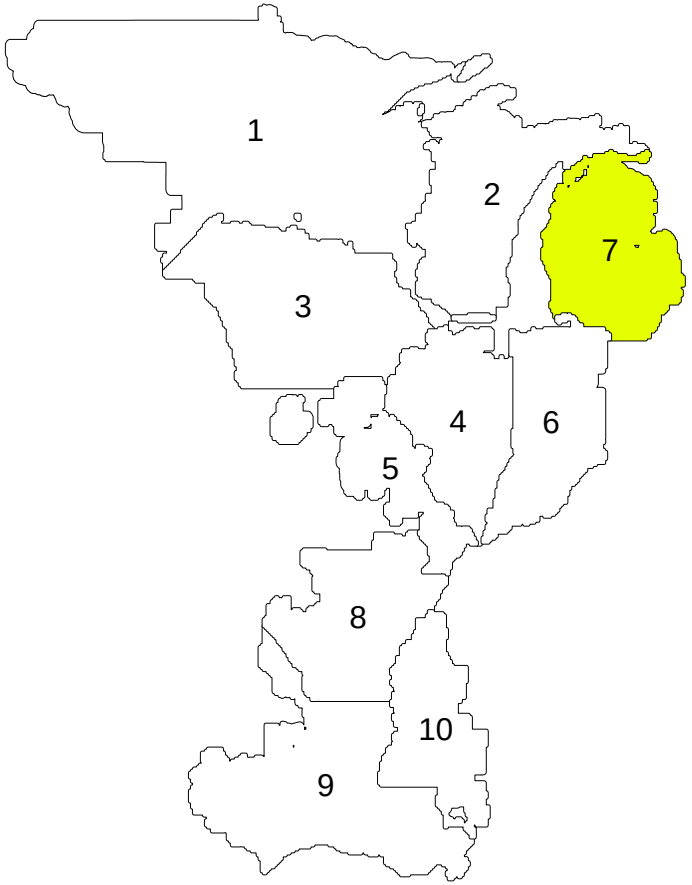


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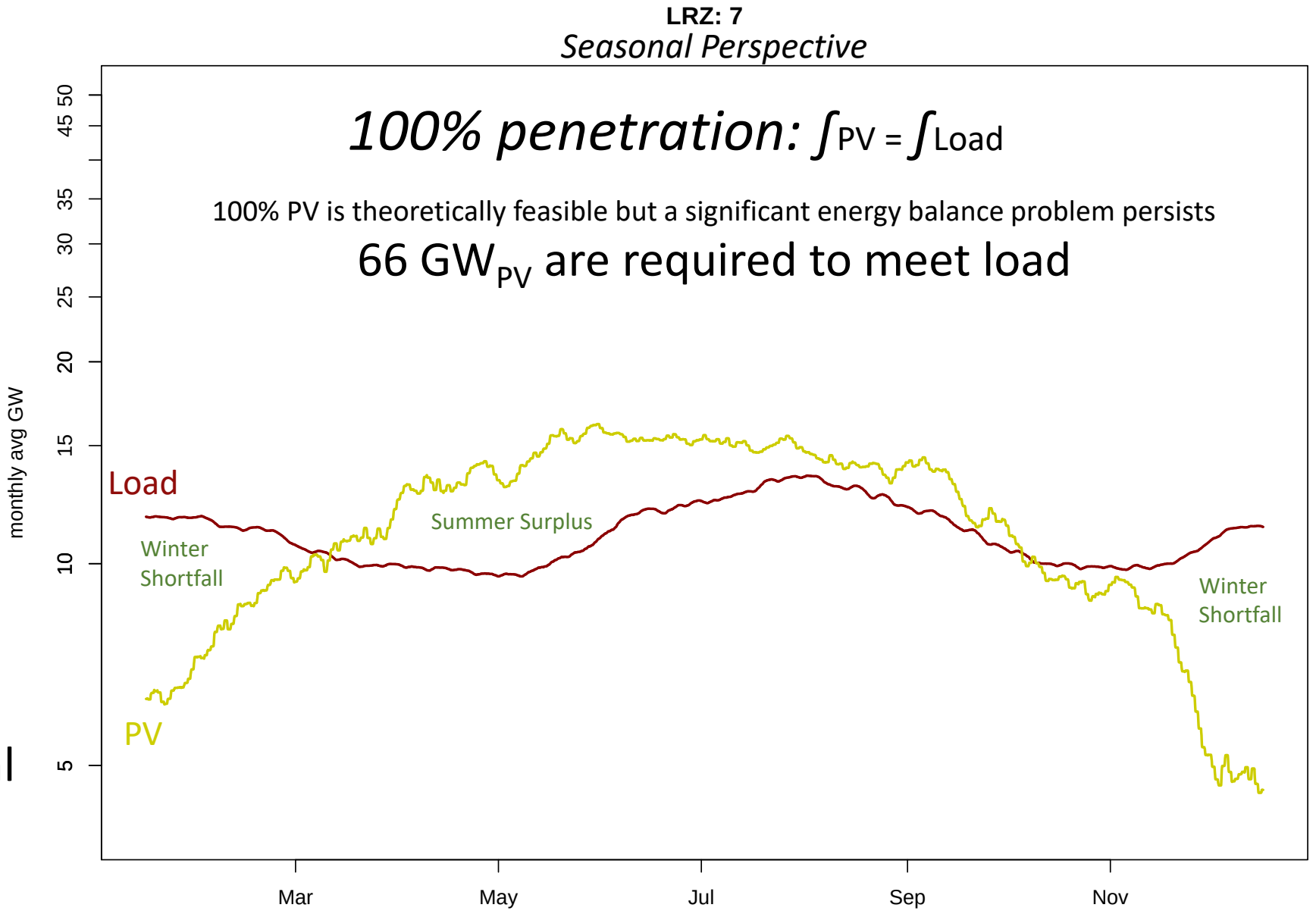

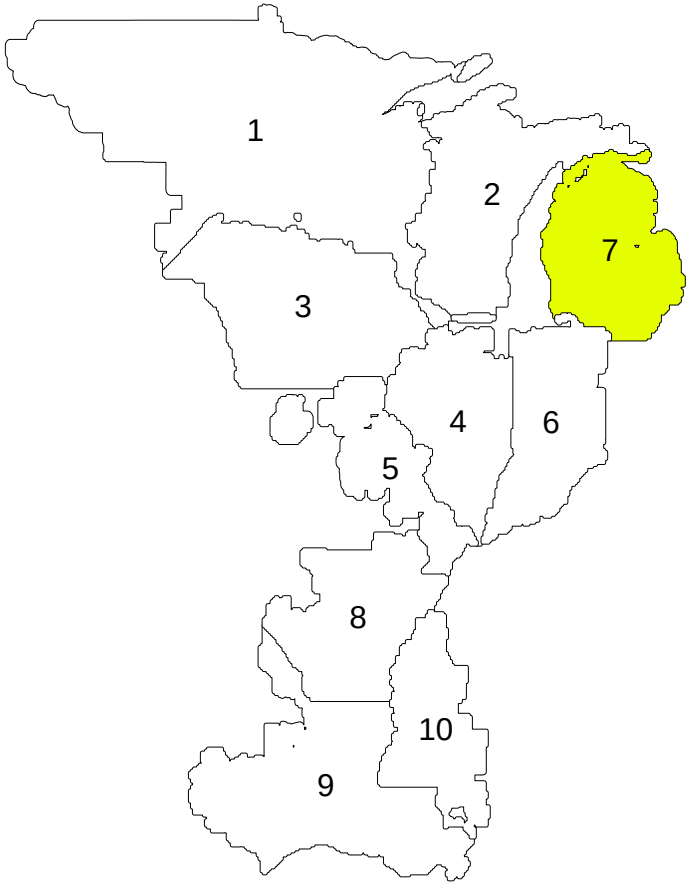


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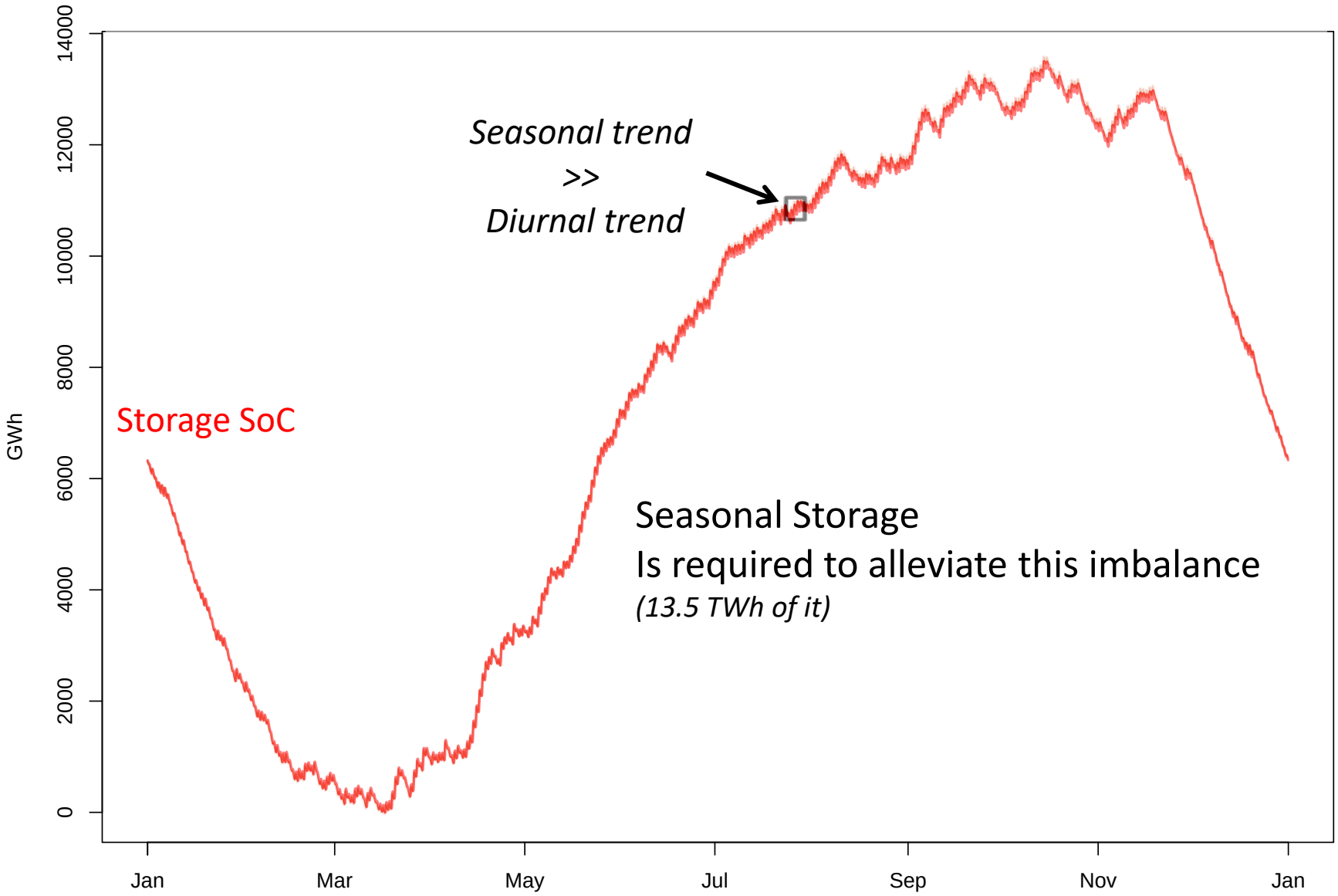

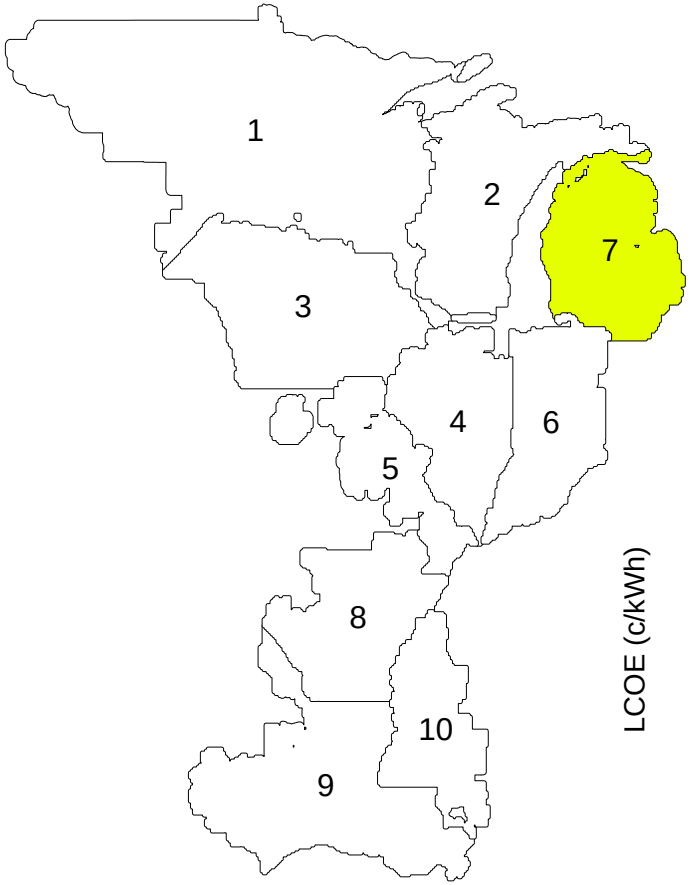


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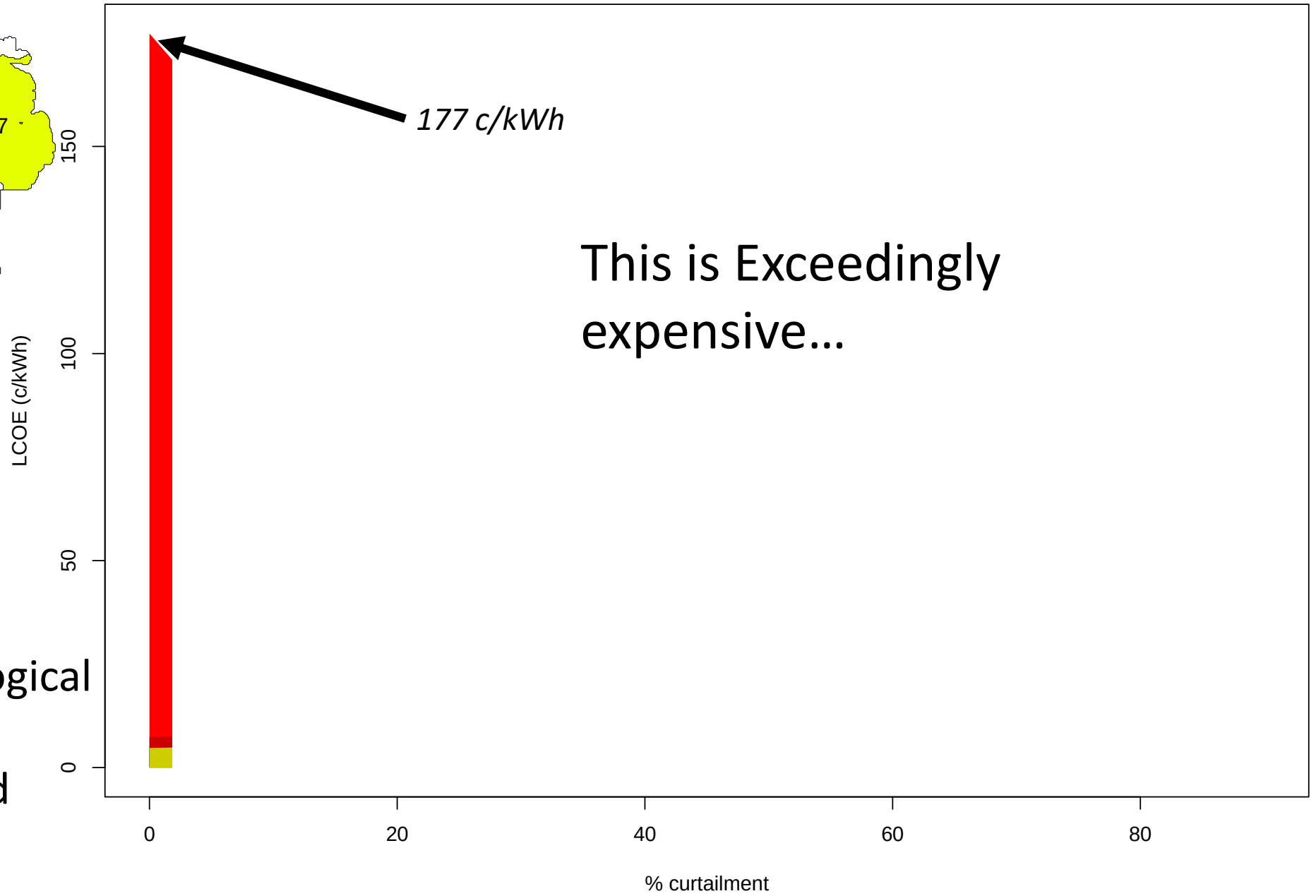
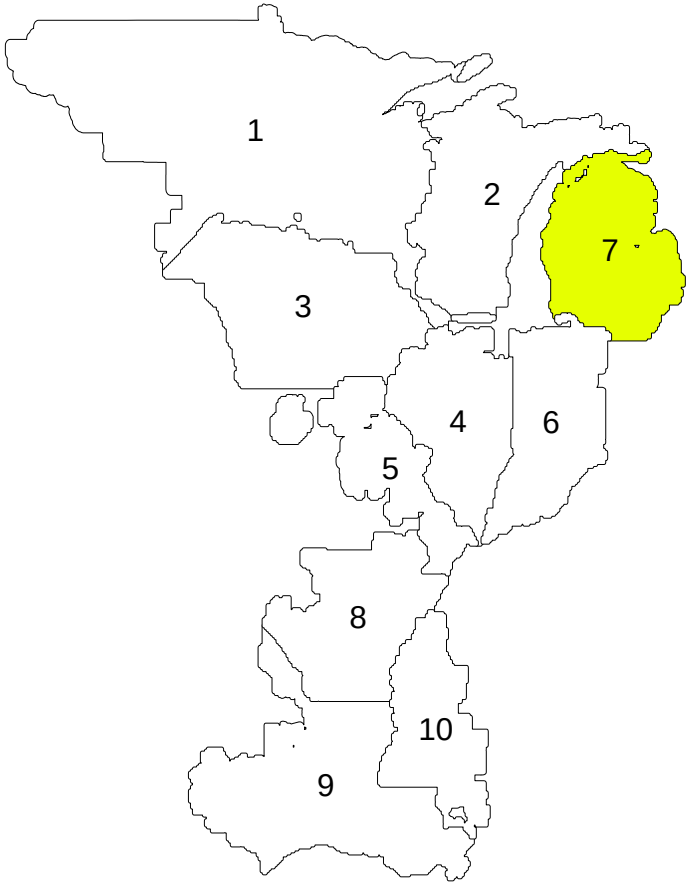
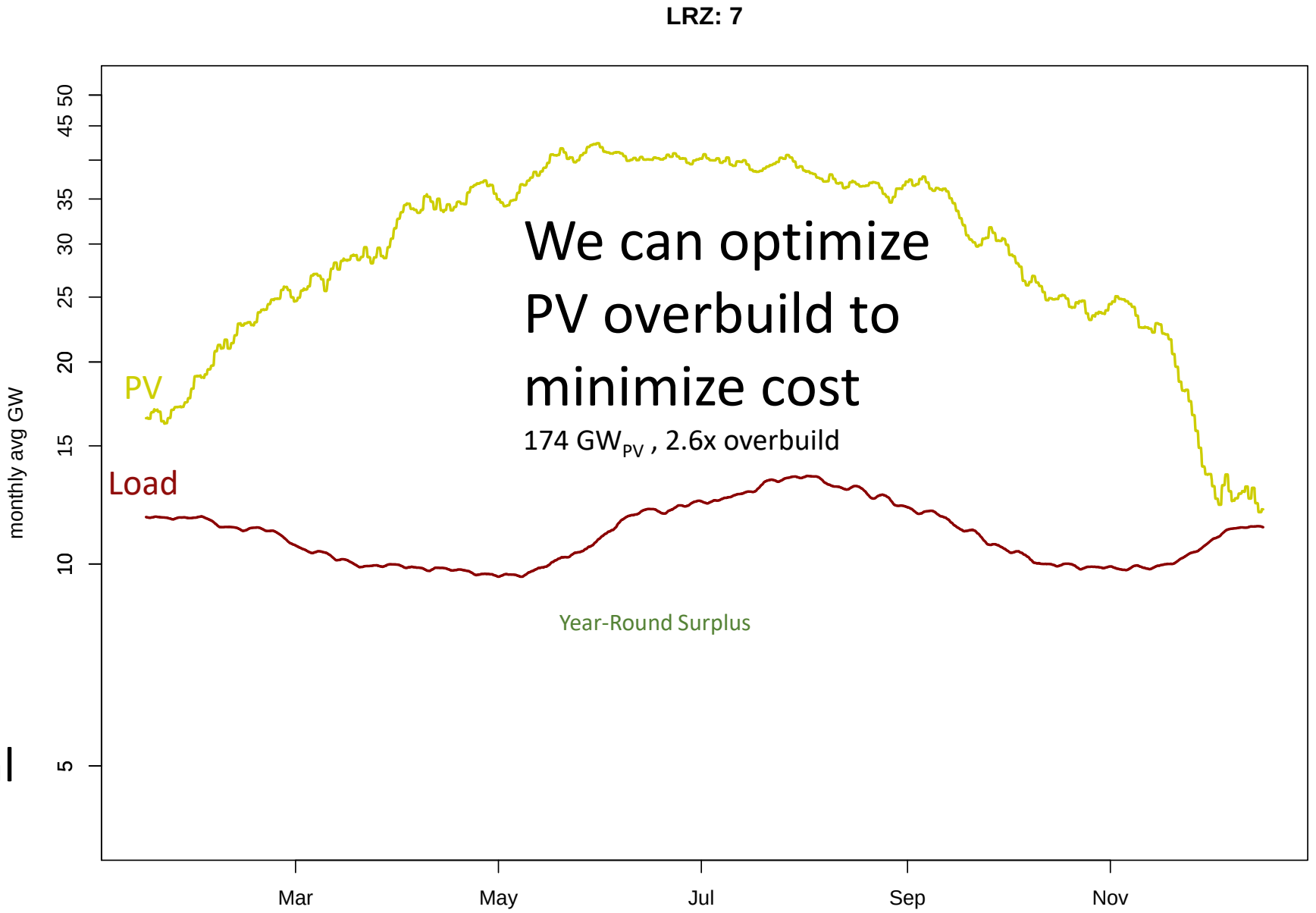
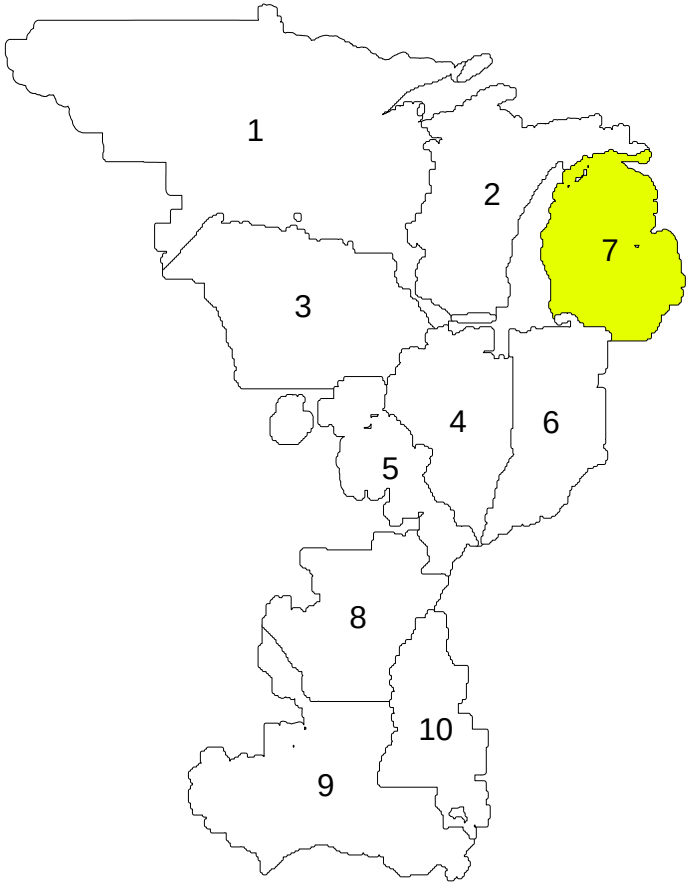





# Consider LRZ 7

2025, low technological development, PV *alone*, optimal overbuild



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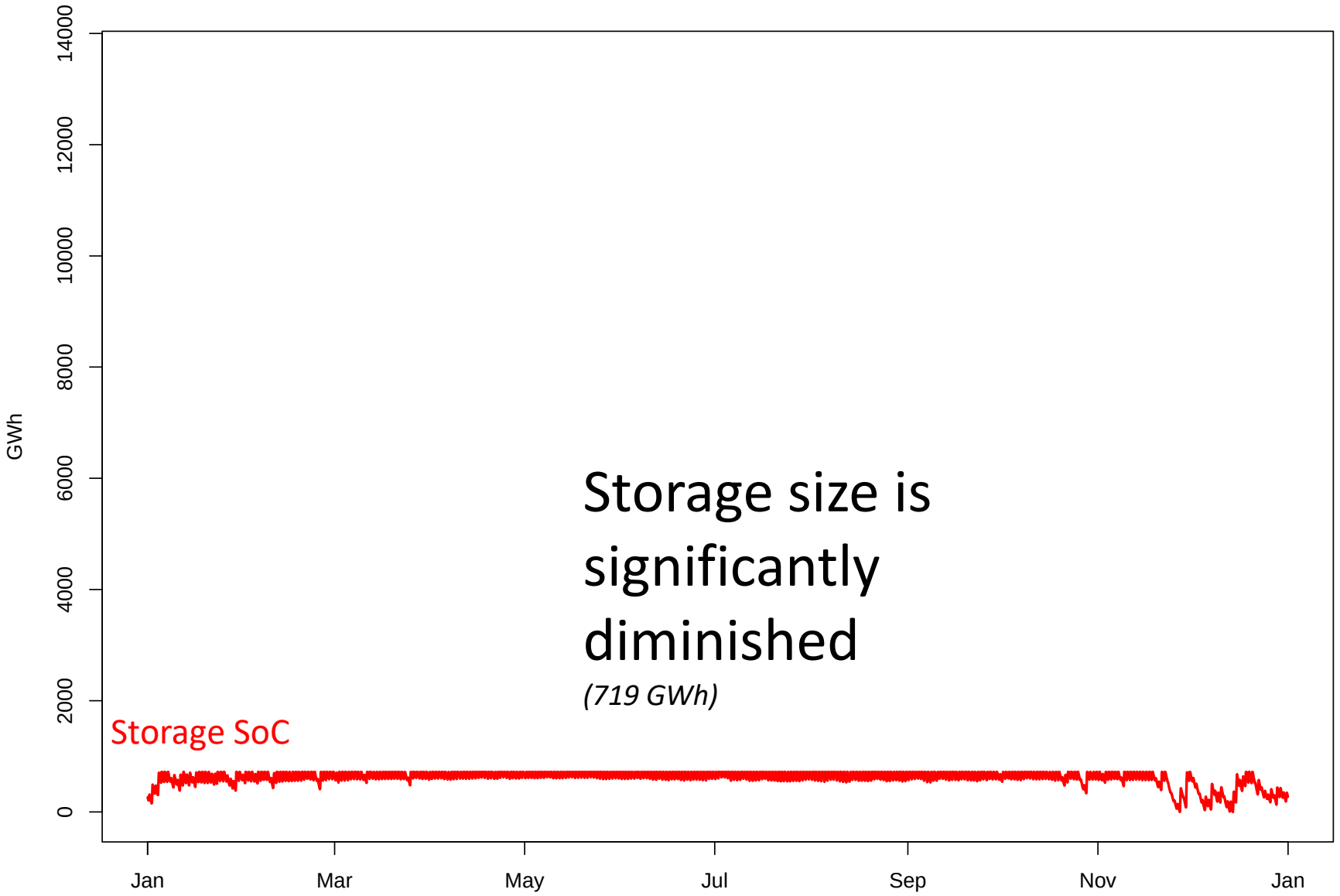

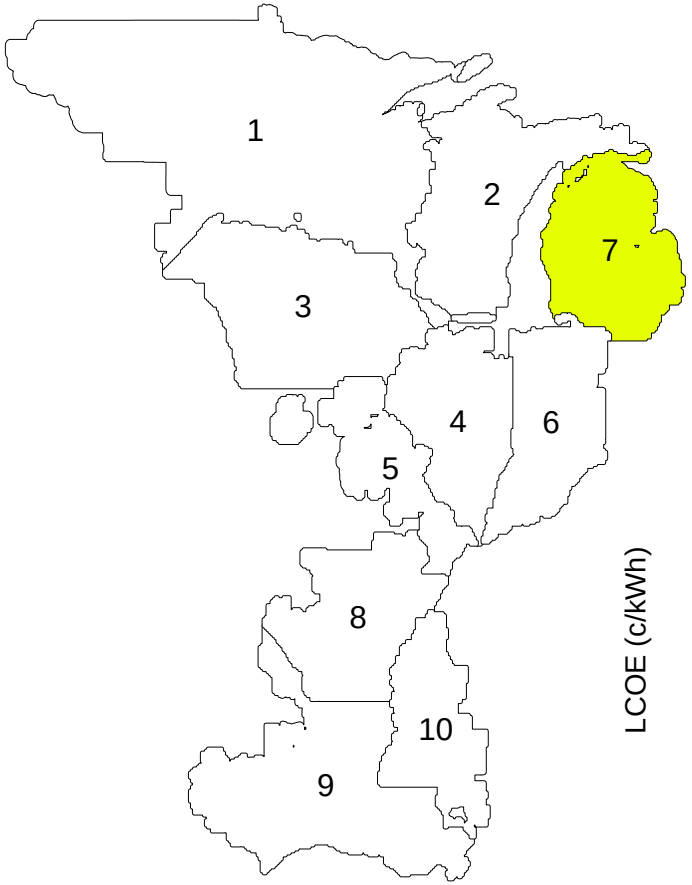


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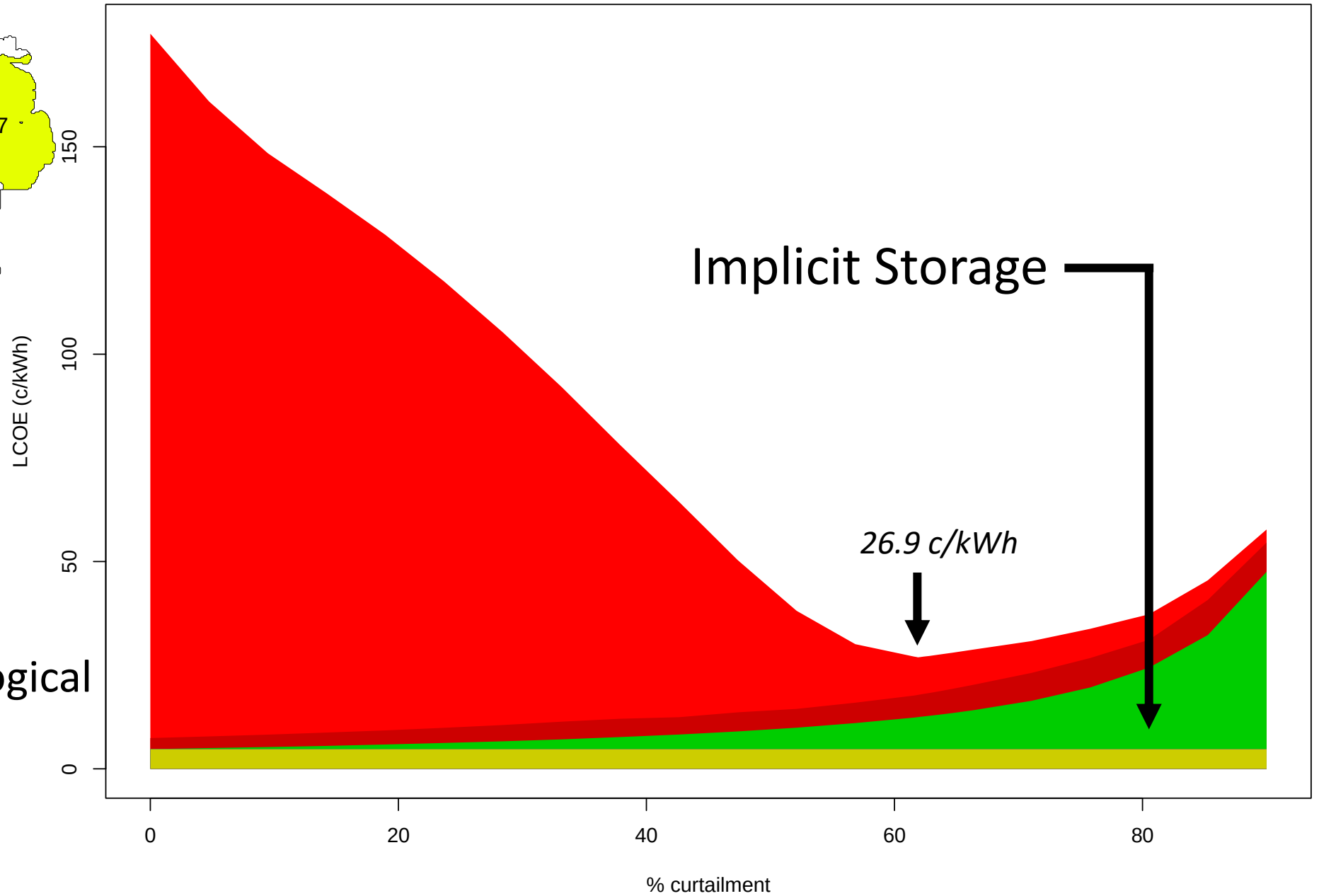
2025, low technological development, PV *alone*, optimal overbuild



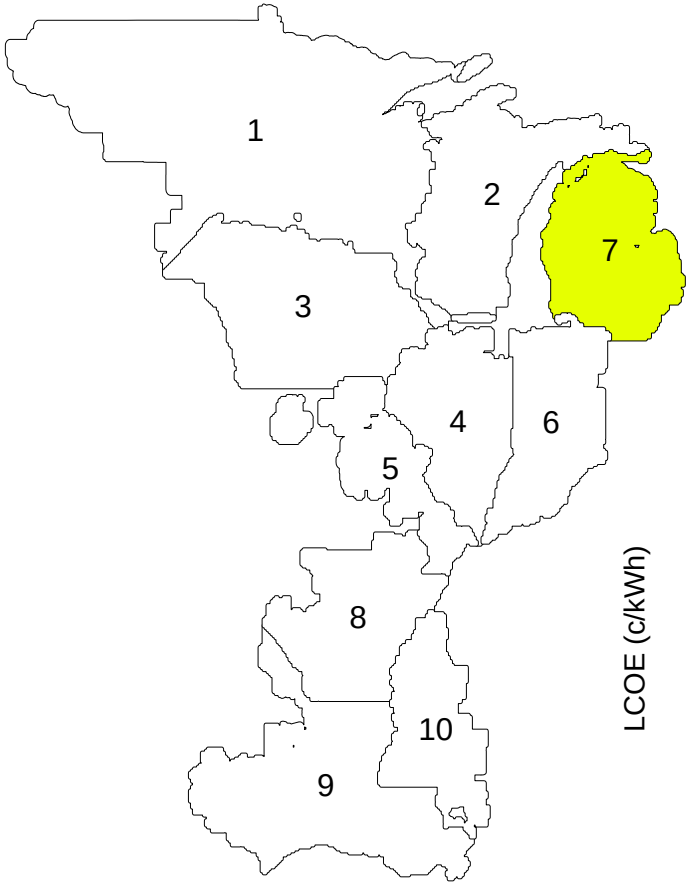
2050 , High

~~2025 , Low~~ Technological Development, MISO LRZ 7, 100% PV + storage

**26.9 c/kWh**

*174 $GW_{PV}$ 719 GWh Storage*

Let’s look at the impact of price




# Consider LRZ 7

2050, high technological development, PV *alone*, <u>optimal</u> overbuild

## 70% reduction in LCOE in 2050

*Optimally-built in 2025 is still cheaper than no overbuild in 2050*

*46.8 c/kWh*

*26.9 c/kWh*

*2025, low tech dev.*

*7.9 c/kWh*

LCOE (c/kWh)

0 50 100 150

0 20 40 60 80

% curtailment

Storage energy component  Storage power component  PV

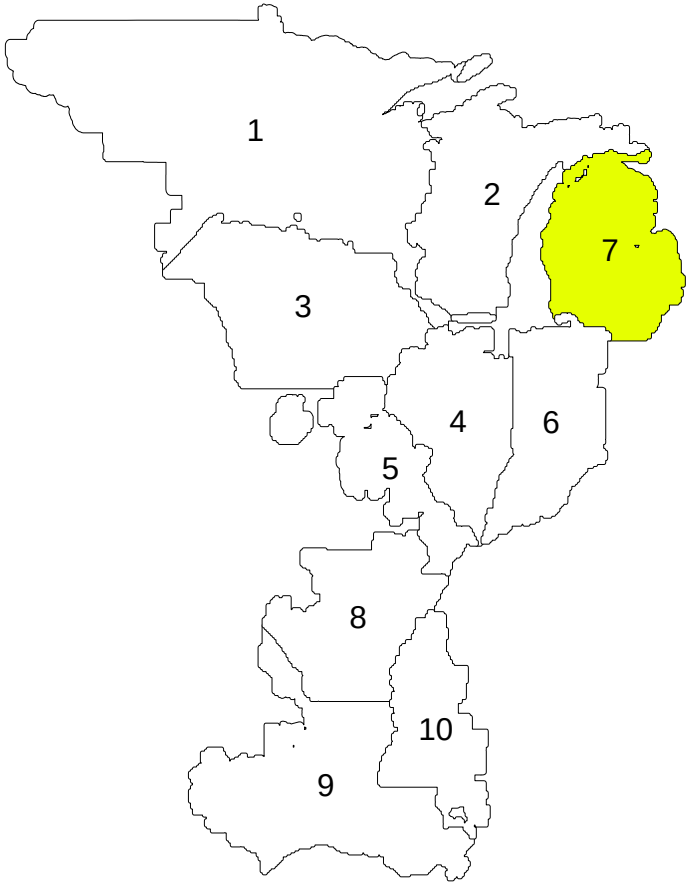
Wind

2050, high Technological Development, MISO LRZ 7, 100% ~~PV~~ + storage

**7.9 c/kWh**

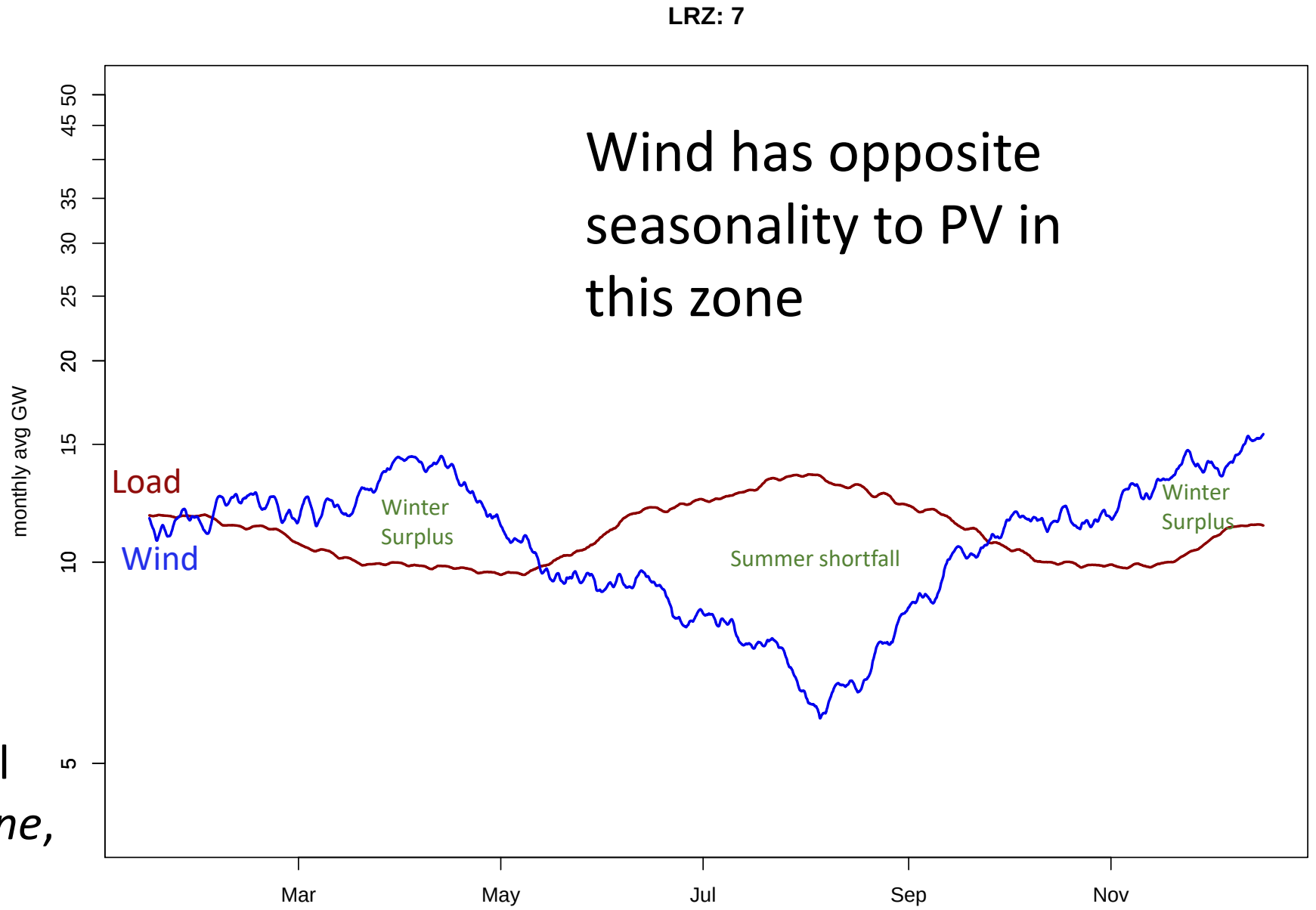
*174 $GW_{PV}$ 719 GWh Storage*

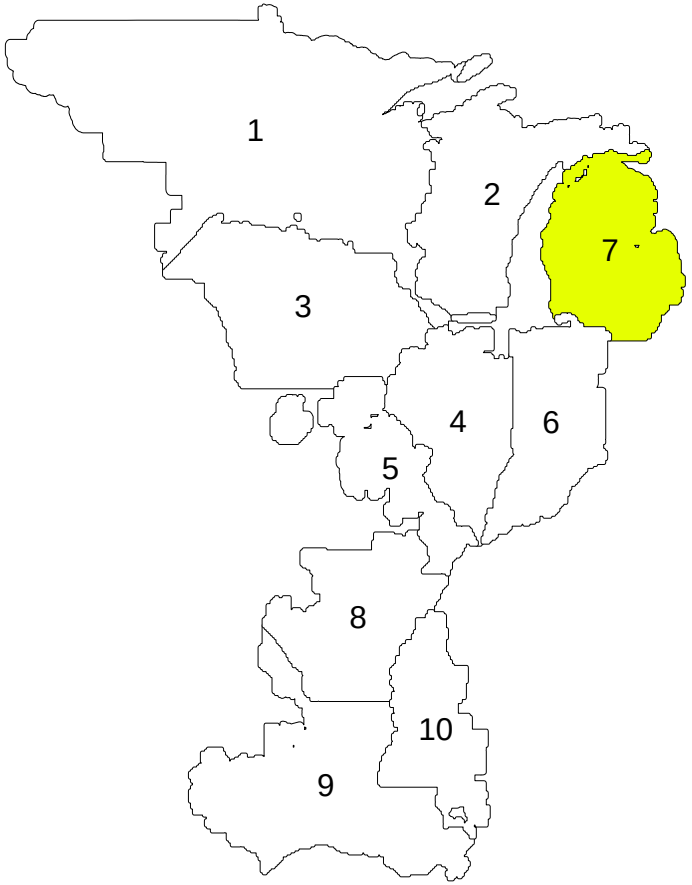
What about wind? Does the same hold true?




# Consider LRZ 7

2050, high technological development, Wind *alone*, <u>no</u> overbuild



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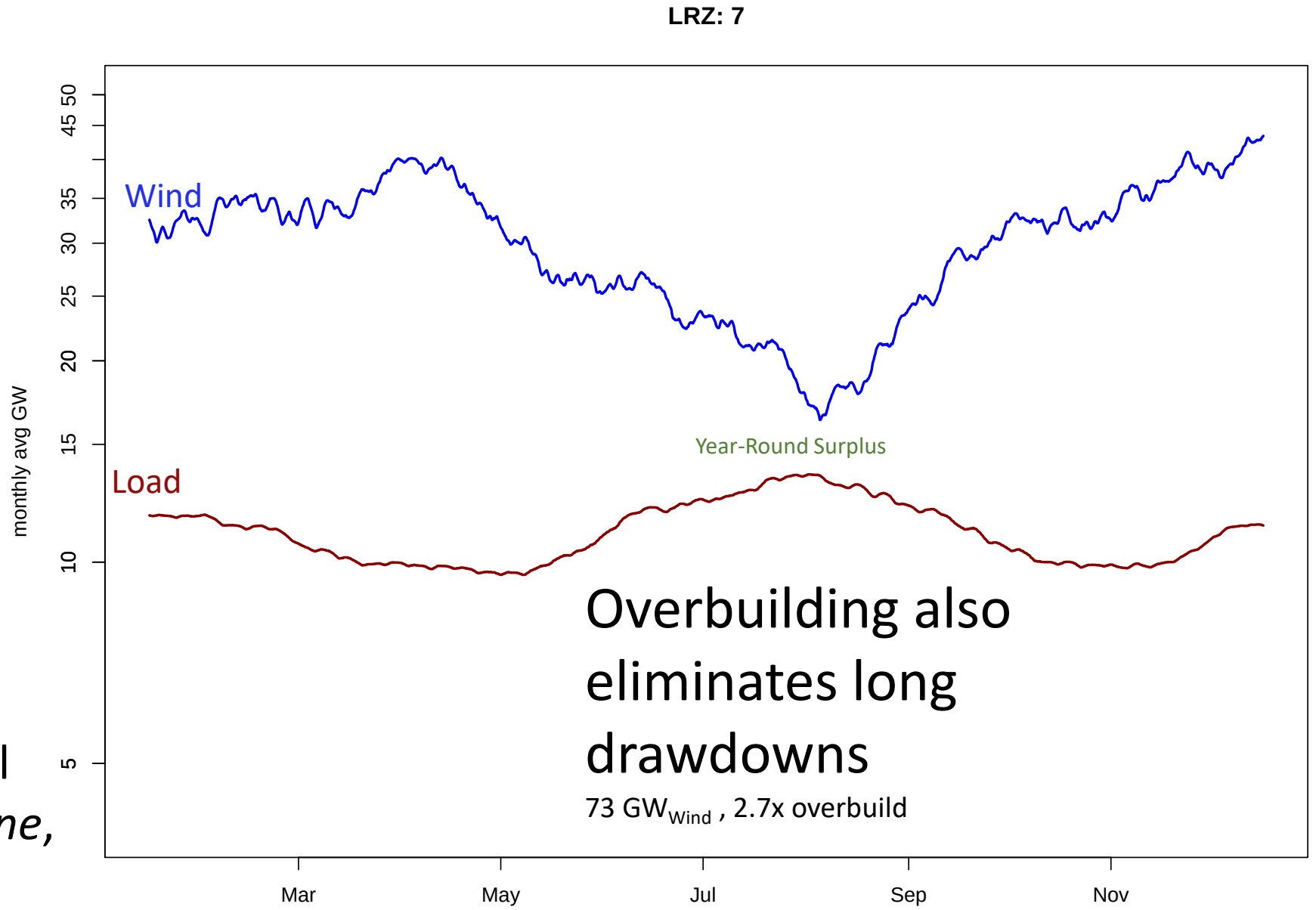
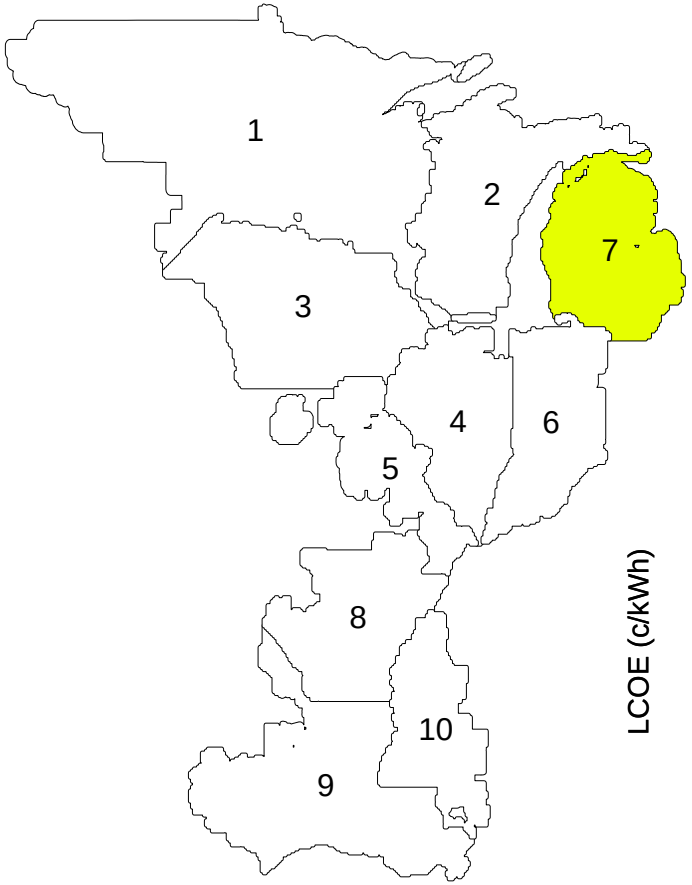
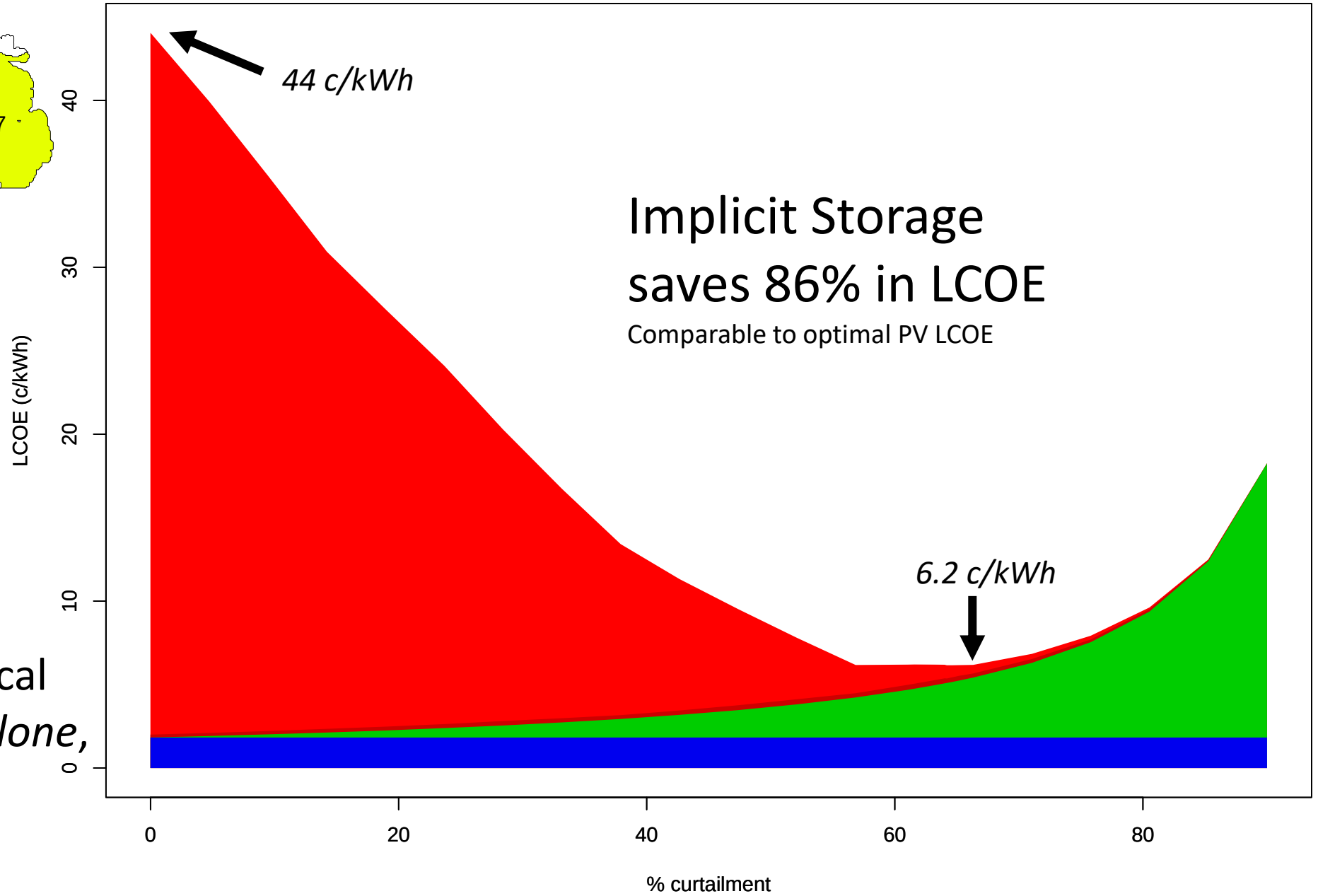
2050, high technological development, Wind *alone*, <u>optimal</u> overbuild






# Consider LRZ 7

2050, high technological development, Wind *alone*, <u>optimal</u> overbuild



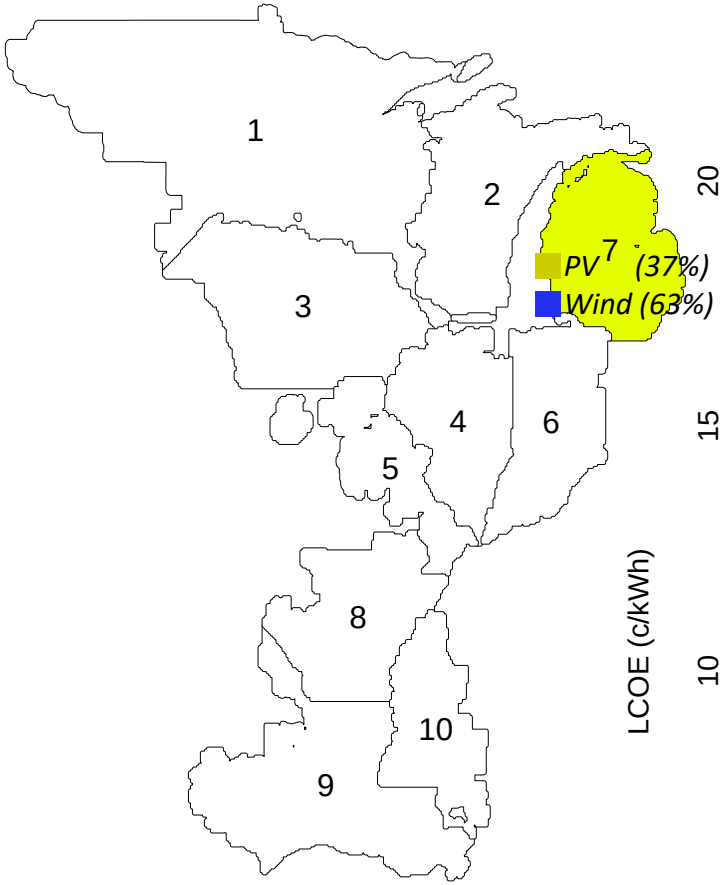
Wind + PV

2050, high Technological Development, MISO LRZ 7, 100% ~~Wind~~ + storage

**6.2 c/kWh**

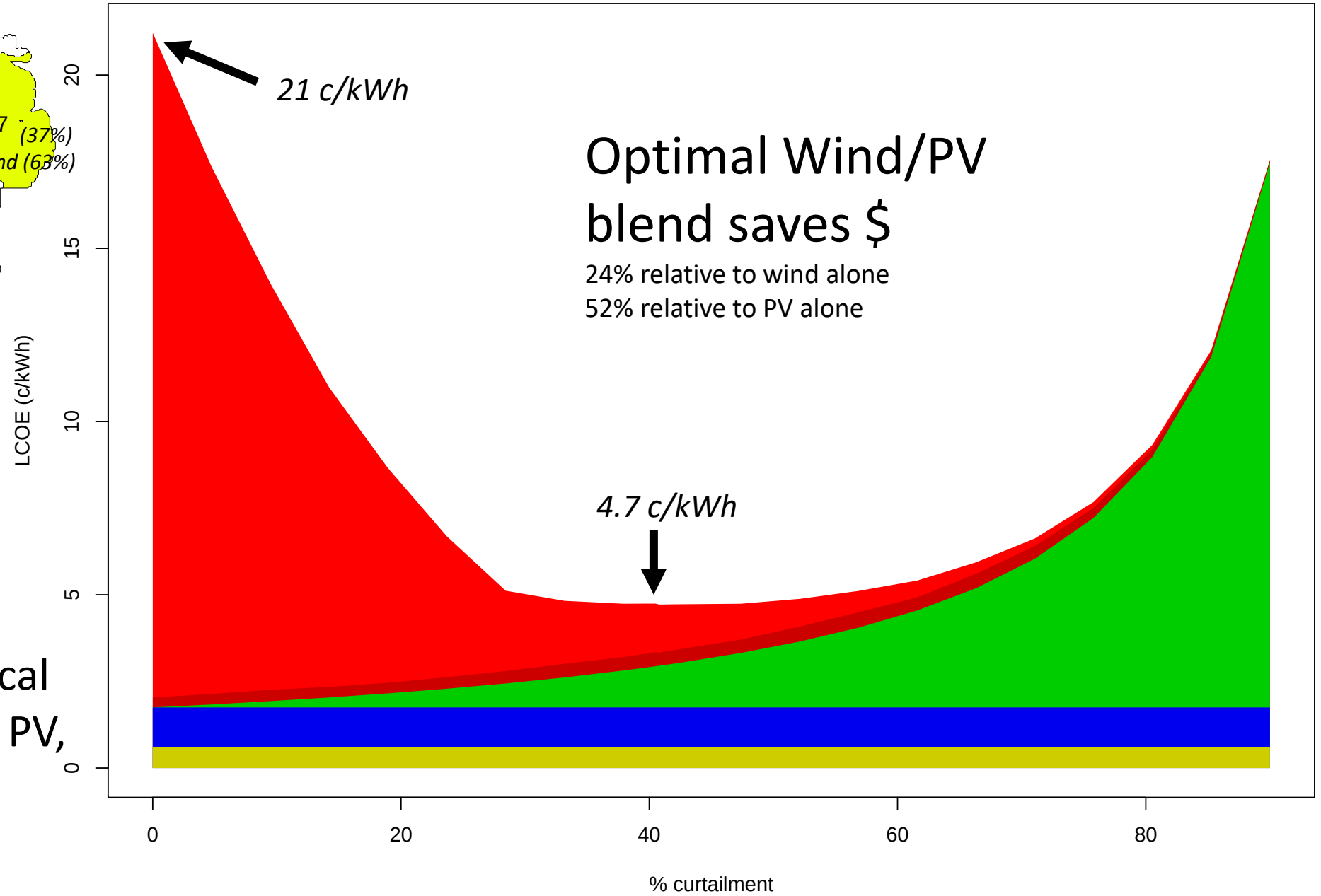
*73 $GW_{Wind}$ 239 GWh Storage*

What about a blend? Can we reduce costs further by hybridizing the resources?




# Consider LRZ 7

2050, high technological development, Wind + PV, optimal overbuild



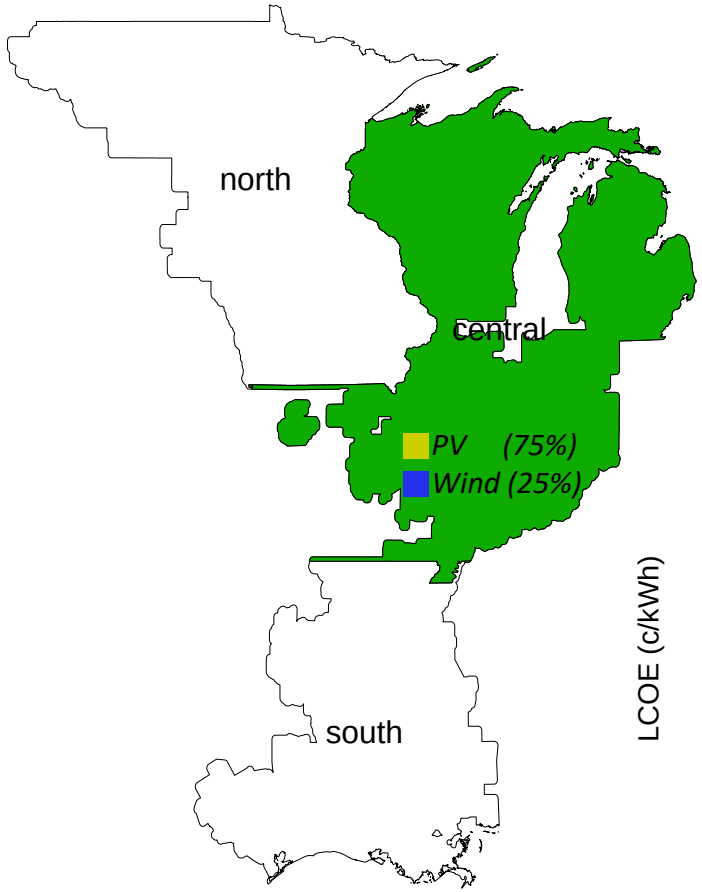
MISO Central Region

2050, high Technological Development, ~~MISO LRZ 7~~, 100% Wind + PV + storage

**4.7 c/kWh**

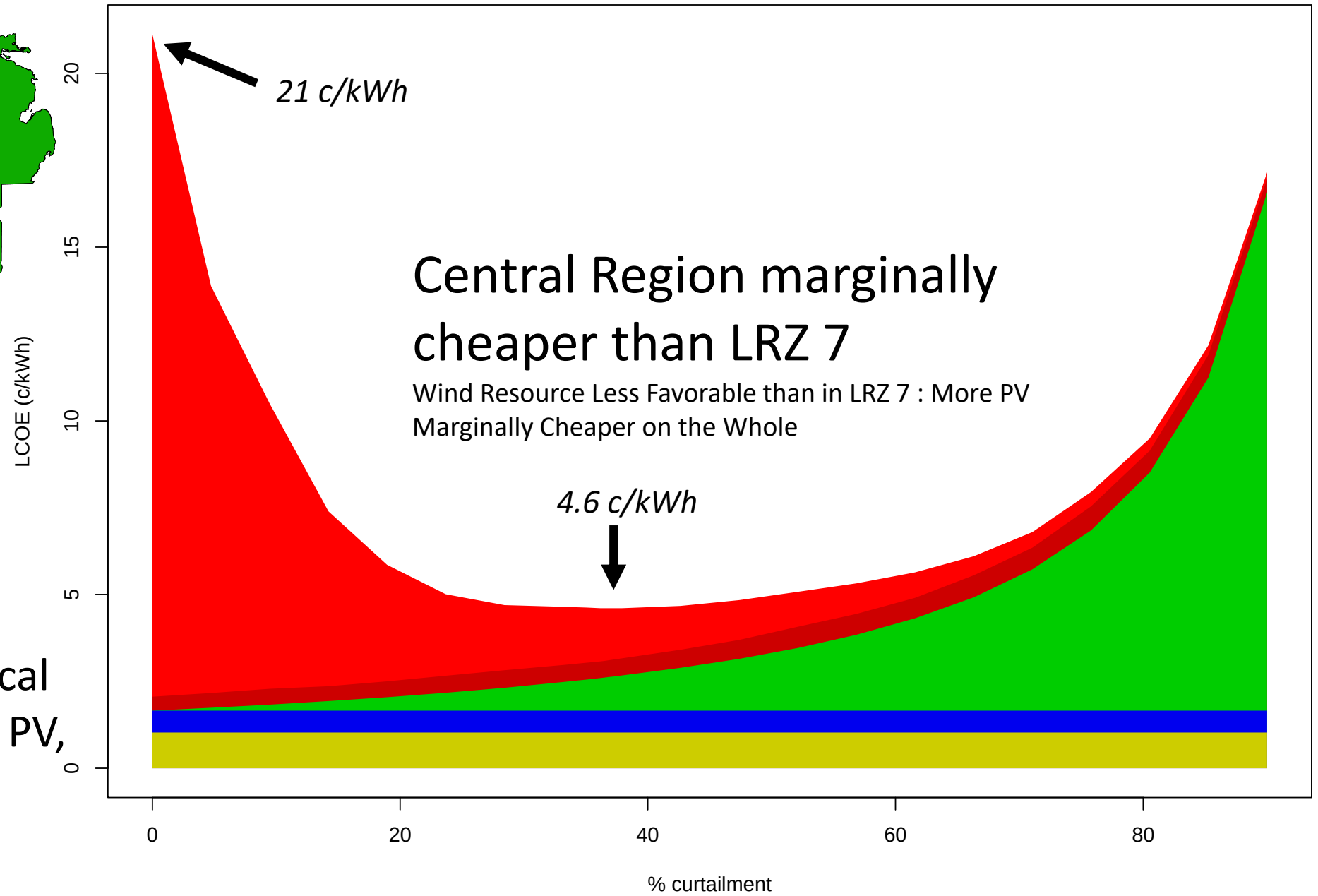
*28 $GW_{Wind}$, 42 $GW_{PV}$, 419 $GWh_{Storage}$*

What about a larger region, how do the dynamics change here?




# Consider *Central*

2050, high technological development, Wind + PV, optimal overbuild



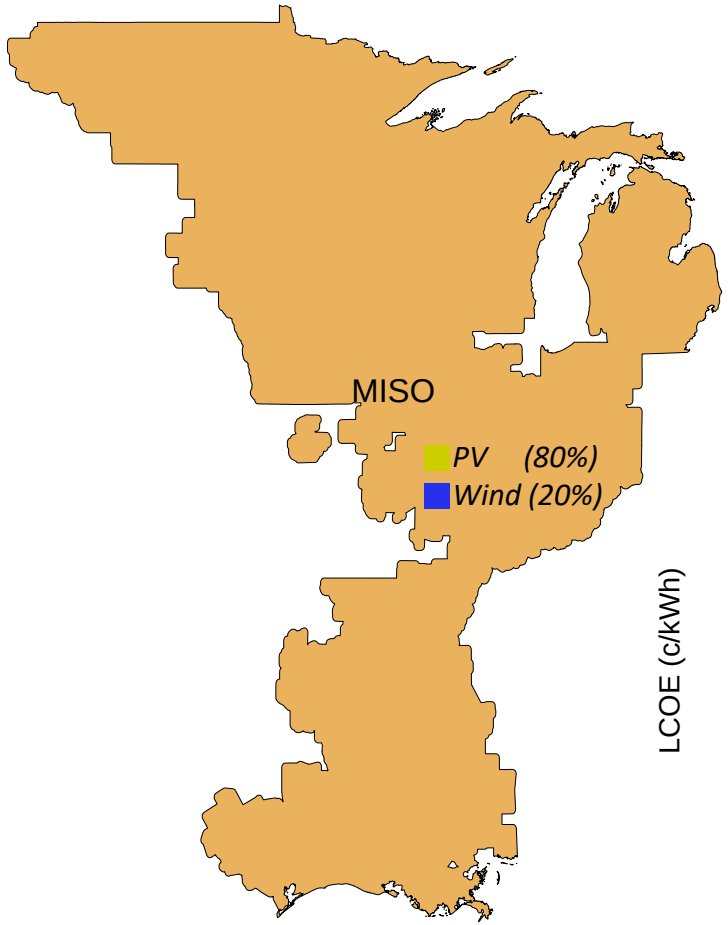
All of MISO

2050, high Technological Development, MISO ~~Central Region, 100%~~ Wind + PV + storage

**4.6 c/kWh**

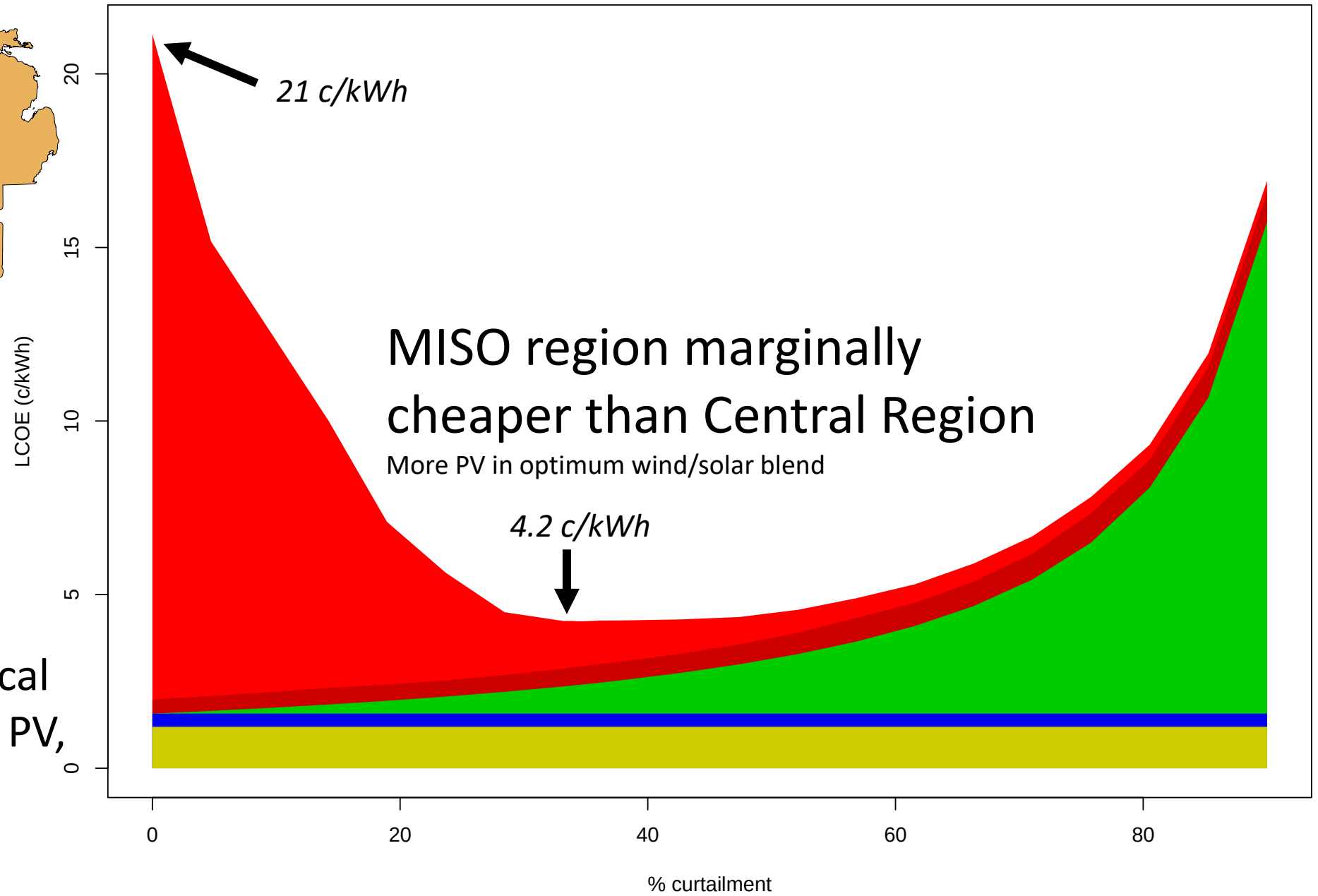
*52 $GW_{Wind}$, 243 $GW_{PV}$, 1.6 $TWh_{Storage}$*

What about all of MISO?




# Consider *MISO*

2050, high technological development, Wind + PV, <u>optimal</u> overbuild



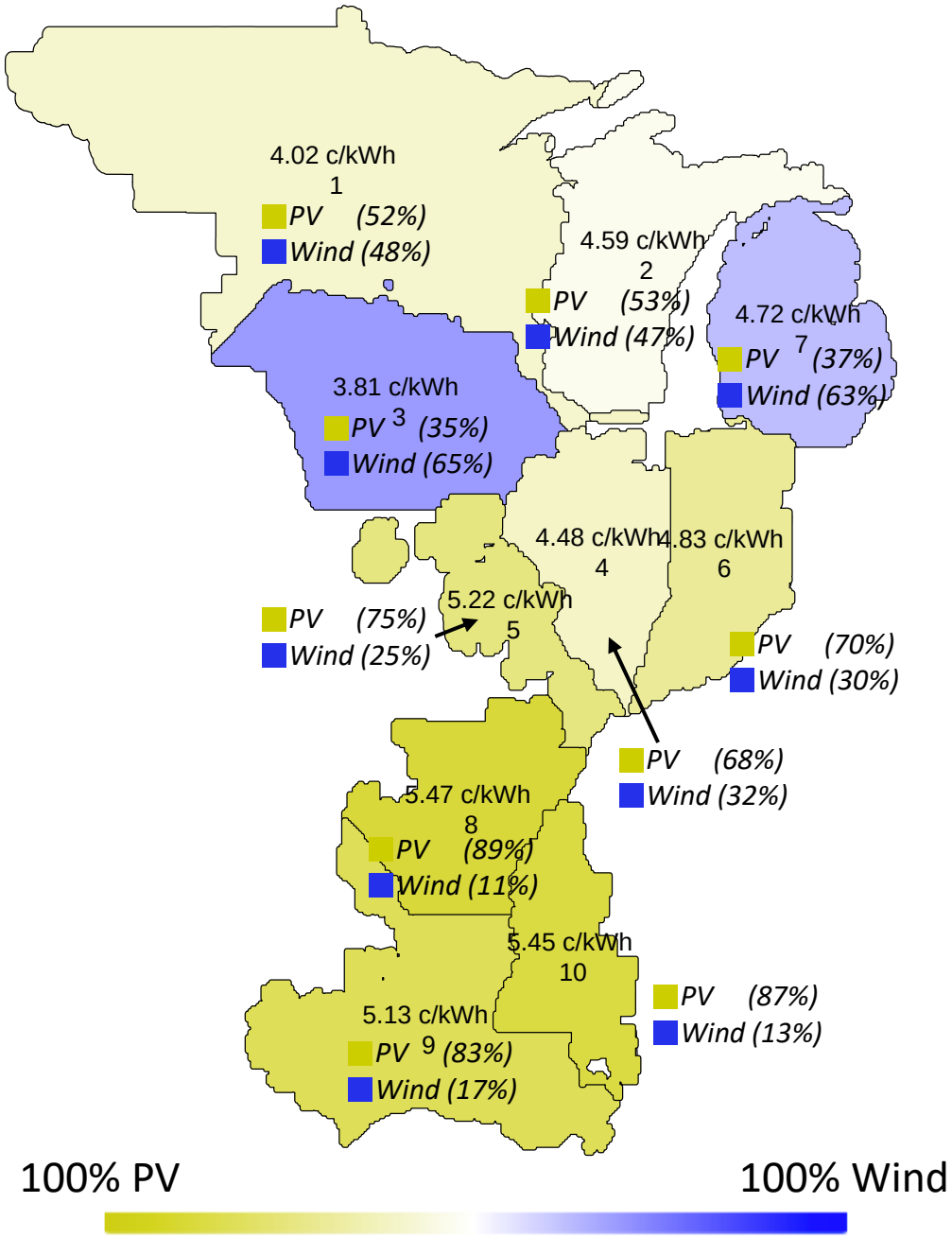
2050, high Technological Development, All of MISO, 100% Wind + PV + storage

**4.2 c/kWh**

*57 $GW_{Wind}$, 511 $GW_{PV}$, 2.7 $TWh_{Storage}$*

With 667 TWh of annual usage, this equates to $28 Bn of annual expenditures

What if each LRZ optimized for themselves?



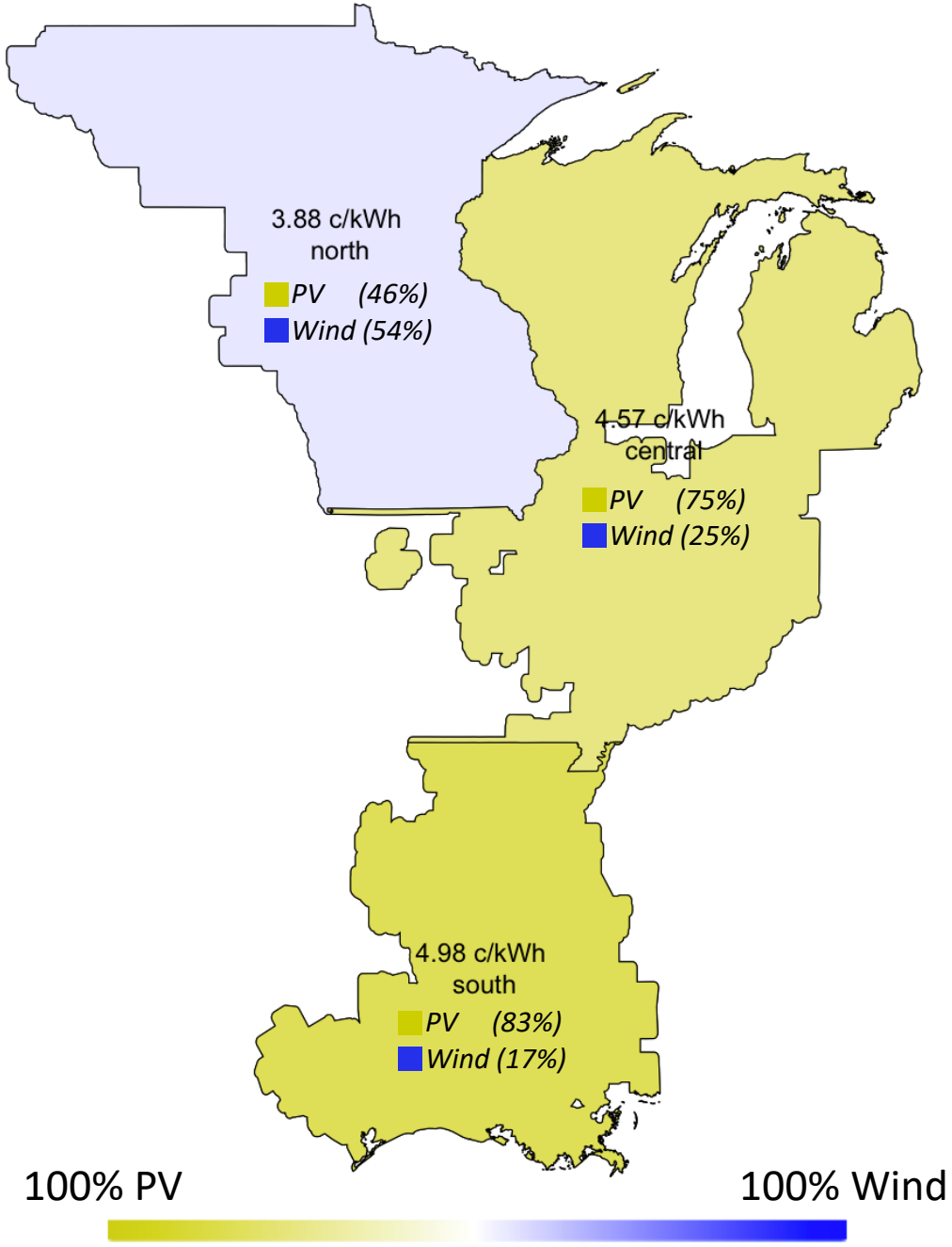

*If each LRZ islanded themselves and optimized their resource blends, the electricity price would be:*

**4.65 c/kWh**

*weighted average cost*

This equates to $31 Bn/yr

<u>The MISO-region interconnection will save ratepayers $3 Bn/yr</u>




*The picture is similar if each MISO Region Islanded themselves*

**4.53 c/kWh**

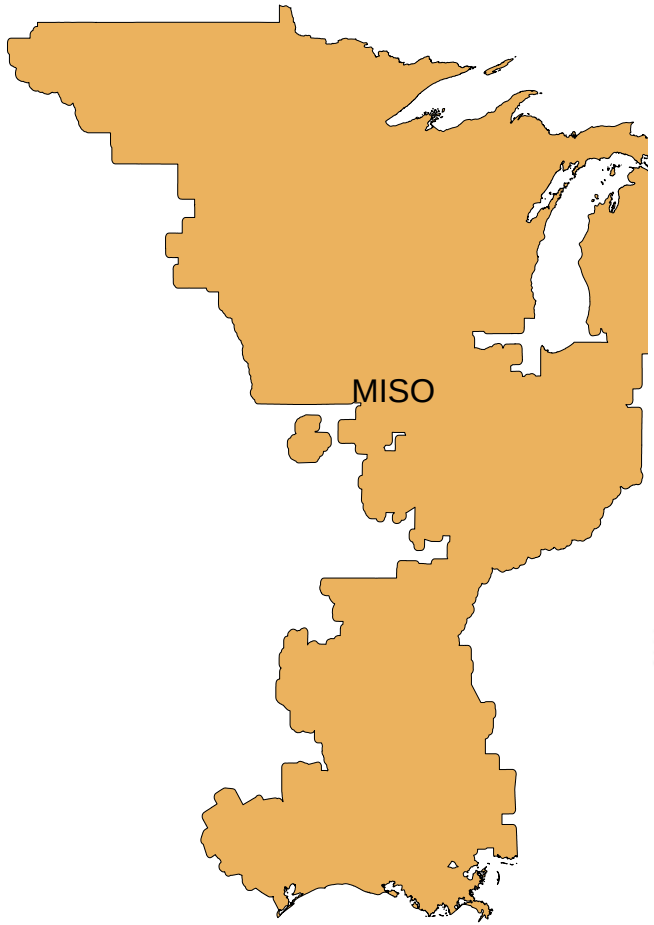
*weighted average cost*

This equates to $30 Bn/yr

<u>The MISO-region interconnection will save ratepayers $2 Bn/yr</u>

The larger the interconnection region, the lower the cost

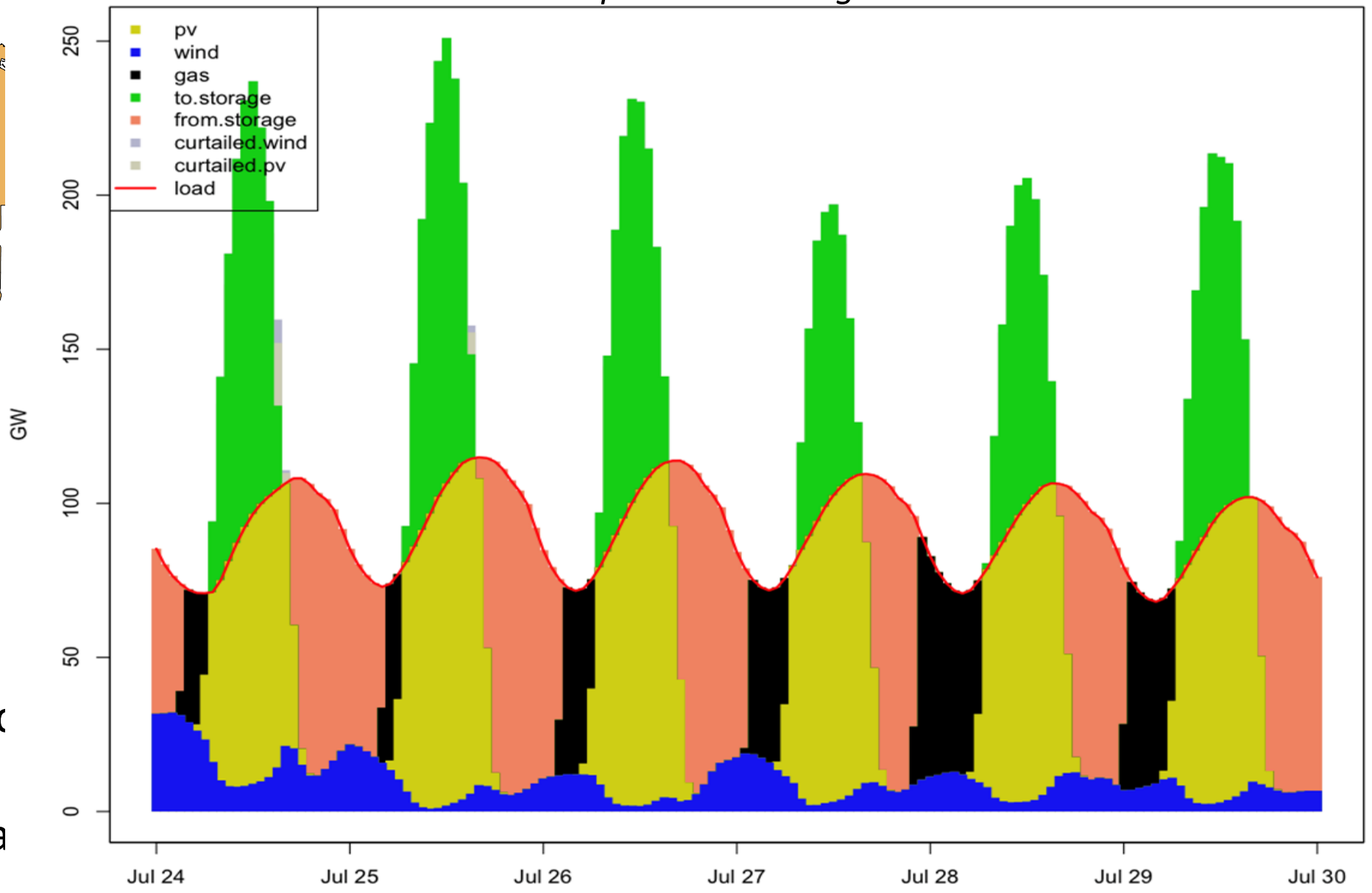
*Finally, what about adding 5% new-build gas as we did for MN?*




# Consider *MISO*

2050, high technologic
development, Wind +
optimal overbuild + ga

*Dispatch with 5% gas*




% curtailment

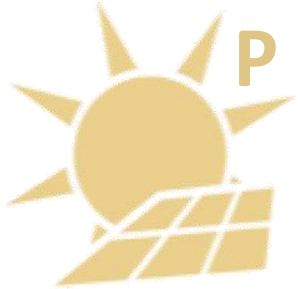
Storage energy component | Storage power component | PV | Wind | Implicit Storage | gas

# Key Takeaways for MISO study

- **The Value of Implicit Storage** Implicit Storage has similar value to each other region studied
- **The Value of Hybridizing Wind+PV** Wind + PV hybrid resourcing is significantly cheaper than either alone due to seasonal resource anticorrelations.
- **Sensitivity to Cost** Nominal technology costs change the LCOEs and relative costs change the technological mix:
  - Raise wind cost relative to PV cost, decrease optimal wind percentage
  - Raise storage cost relative to renewables, increase implicit storage use
  - Confidence and consensus surrounding cost will help solidify the planning process
- **PV is Favored in 2050 across MISO despite wind resource** Largely linked to >> predicted relative drop in price
- **95% *Variable* Renewables is significantly cheaper** Allowing 5% gas or some other dispatchable gen to perform some of the work otherwise done by storage (both implicit and real).
- **The Value of MISO** The larger the region we interconnect across, the lower the aggregate cost. On the whole this will save ratepayers billions annually.*

**Renewables were uniformly distributed and co-located with storage in this study: biasing the siting to higher-resource areas (wind in the N, PV in the S) will decrease the cost significantly but entails significant T&D expenditure*

# 100% MISO Load


30% Wind 65% Solar 5% Gas

*3.5 c/kWh*

# *Thanks!*

# Firm Power across the MISO region

Tue Sep 27th, 2022

Marc Perez, Ph.D.

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