Using Overbuilding + Curtailment to Achieve 100% Clean Electricity

December 15, 2020

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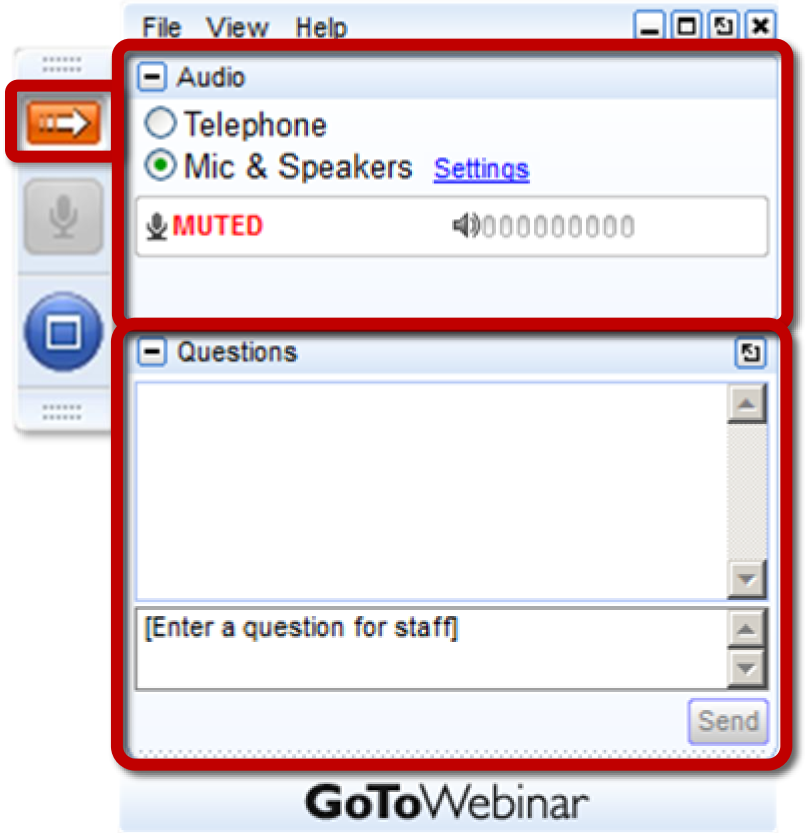

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Webinar Speakers

Marc Perez
Senior Researcher,
Clean Power Research

Brian Ross
Senior Program
Director, Great Plains
Institute

Warren Leon
Executive Director,
Clean Energy States
Alliance (moderator)

Clean Energy States Alliance

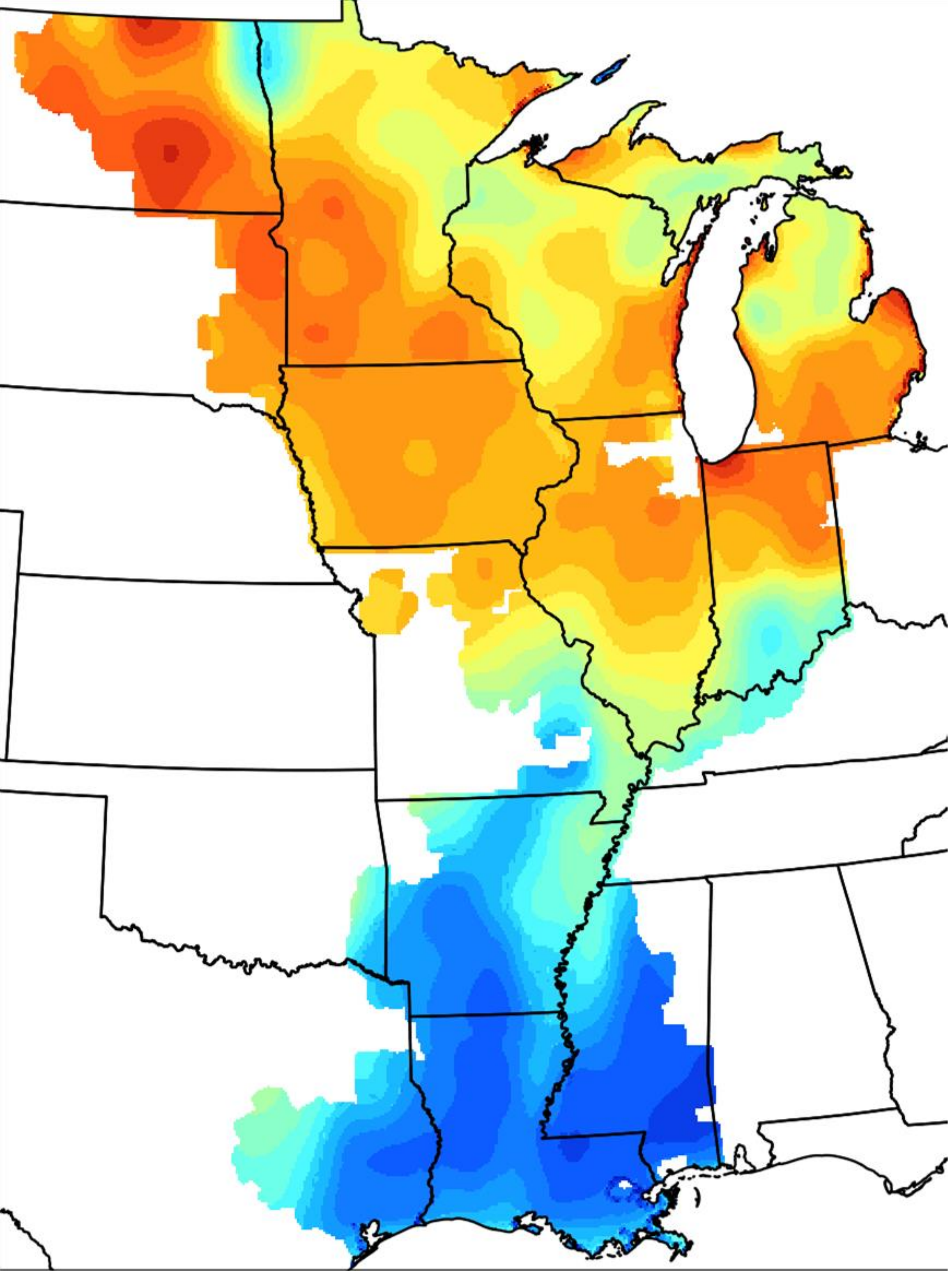
Using Overbuilding + Curtailment to Achieve 100% Clean Electricity

Case Studies across the midcontinent, isolated islands and New York State

Tuesday 15th December, 2020

Marc Perez, Ph.D.

Clean Power Research®



Why investigate 100% renewables?

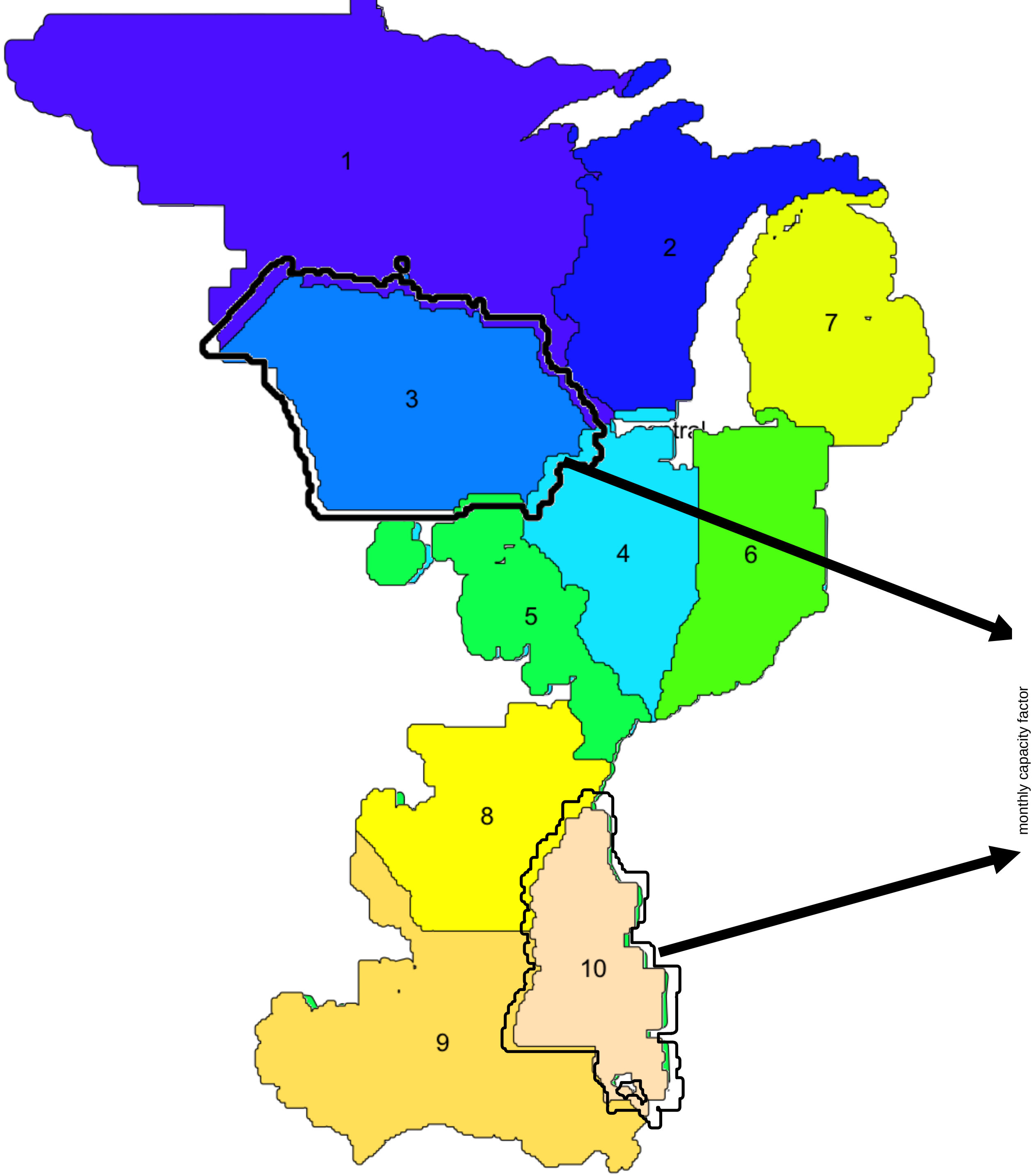
- Environmental Prerogative
- Socio-Economic Prerogative
- Resource availability : *1200 x more continental solar, 7x more wind resource than global primary energy demand.*

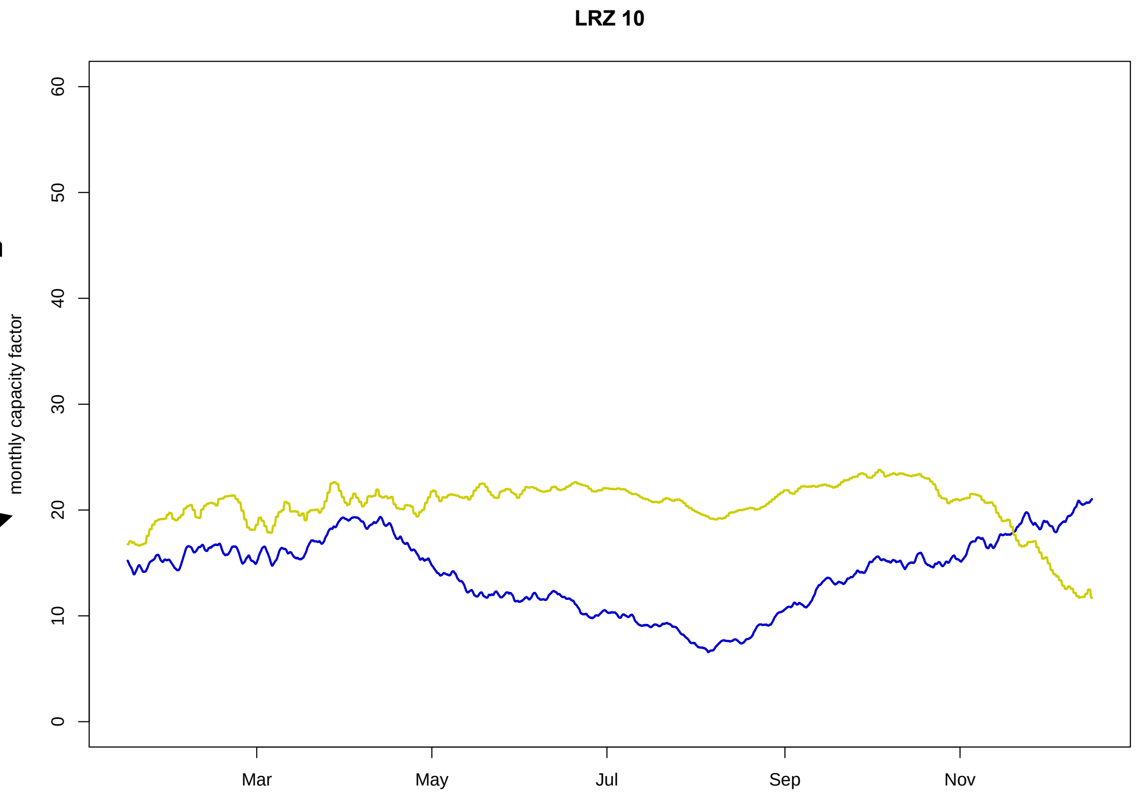
How do we investigate 100% renewables?

- Non-dispatchability of energy supply creates novel energy and power-balance dynamics that must be addressed.
- **CPT Model→** Using an optimized portfolio of solutions (storage, geographic dispersion, dispatchable backup, renewable hybridization), how far down can we drive costs when firmly serving load (24/7/365) with high levels of renewables?
- Solar and Wind resource have different spatial and temporal characteristics across large spatial regions: how does this affect cost? *Enter MISO as a case-study.*
- What <u>value</u> does a large interconnected region deliver in terms of reduced energy cost relative to smaller sub-regions?
- How do the expected prices of system components change the picture?

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

How do we optimize capacity expansion and dispatch?

Enter the **Clean Power Transformation (CPT)** model (used across MN Solar Pathways, Réunion, Italy, New York, Los Angeles)

- Optimizes capacities and dispatch of the following technologies:
  - Generation: Wind, solar, can include dispatchable gen like gas
  - Balancing: electricity storage and *implicit storage* (overbuilding + curtailment)

- Optimization is <u>LCOE cost-based</u> and four scenarios that include component costs and characteristics have been developed from the latest NREL ATB[1]:
  - 2050, high and low technological development
  - 2025, high and low technological development

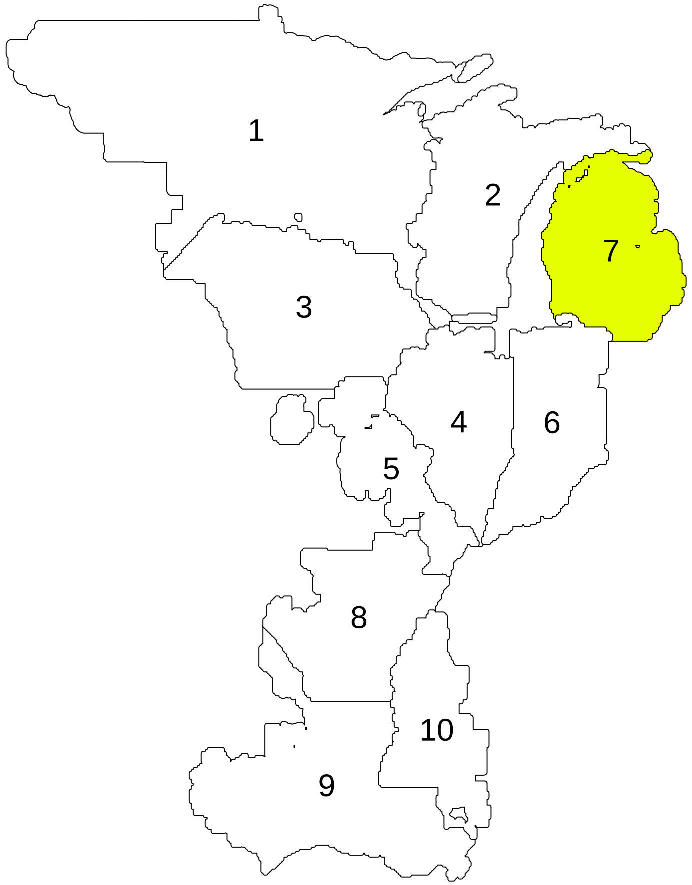
		Utility PV		Wind		Storage				Gas			
		CapEx $/kW	Opex $/kW-yr	CapEx $/kW	Opex $/kW-yr	CapEx $/kWh -pack	CapEx $/kW -BoS	Opex % total CapEx / yr	RT eff	CapEx $/kW	Opex fixed $/kW-yr	Opex variable $/MWh	Fuel cost $/MWh
2025	High	$ 733	$ 9	$ 1,311	$ 38	$ 99	$ 323	2.5%	85%	$ 872	$ 11	$ 5	$ 26
	Low	$ 1,042	$ 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

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

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

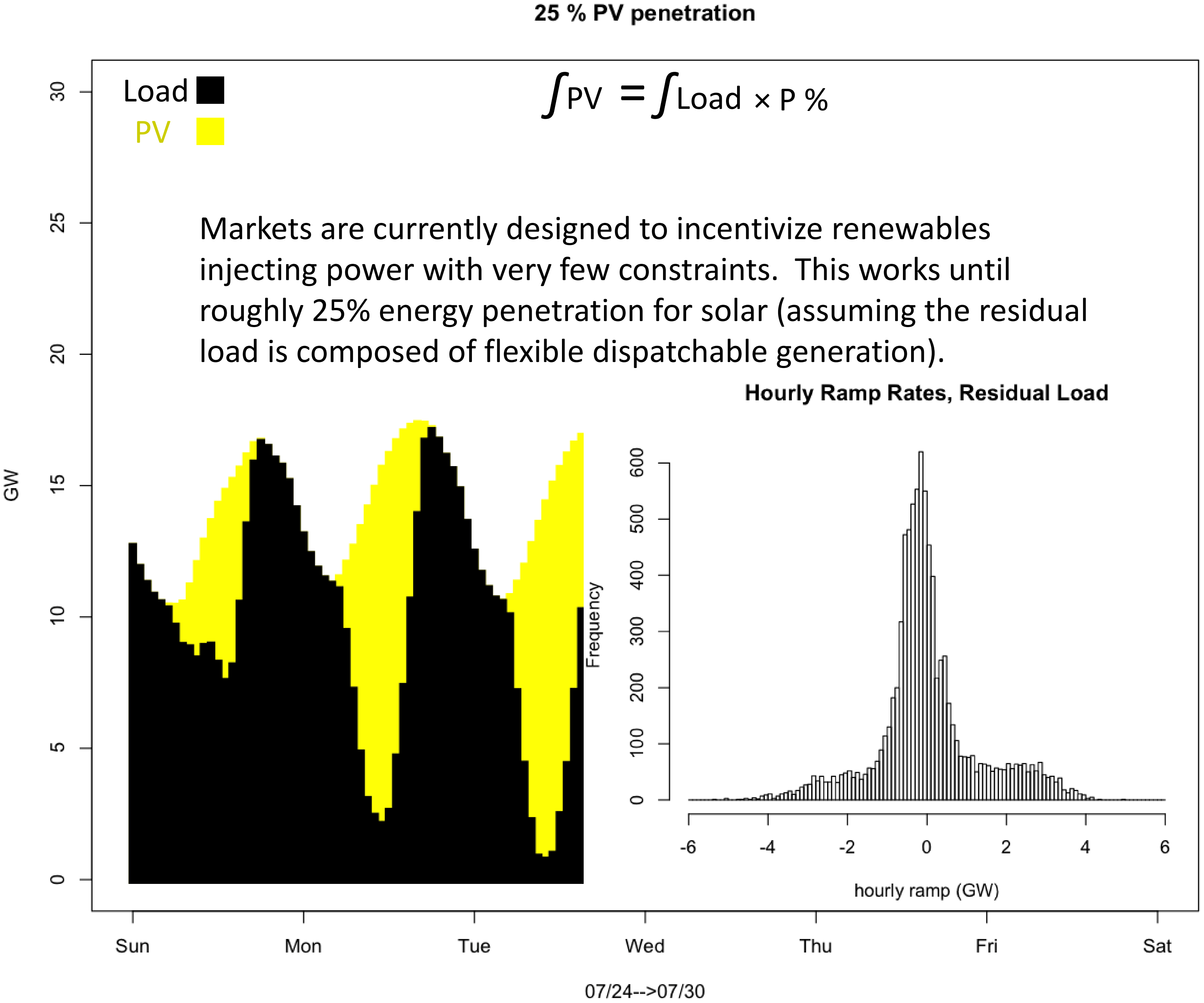
23,243 year-long hourly-interval dispatch simulations have been performed in seeking the optimal across these 56 distinct scenarios. *Let’s dive in.*

Let’s start the story when renewables are small enough in capacity to never exceed load in any given hour.

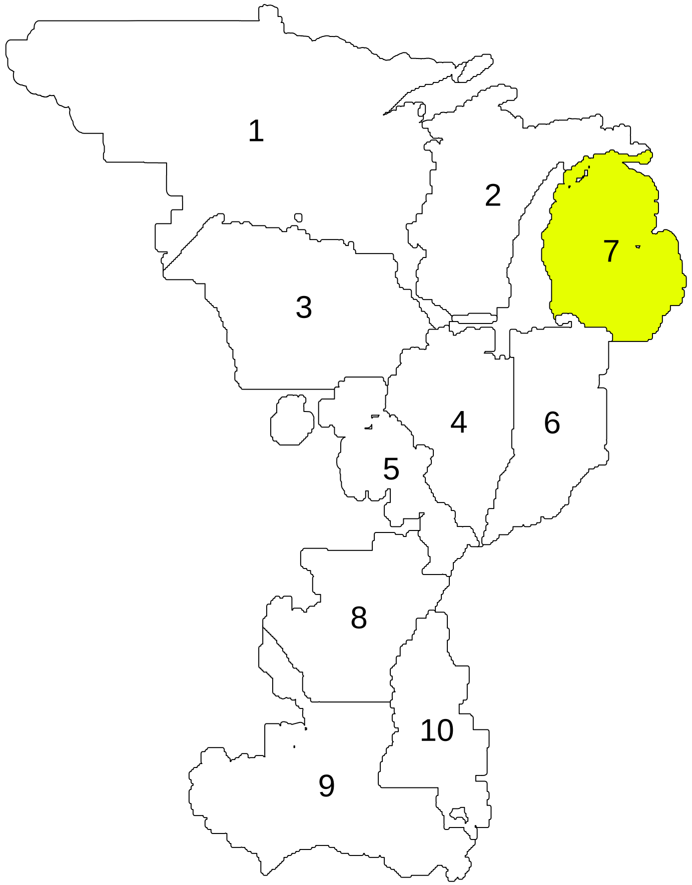


Consider LRZ 7

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



Markets are currently designed to incentivize renewables injecting power with very few constraints. This works until roughly 25% energy penetration for solar (assuming the residual load is composed of flexible dispatchable generation).



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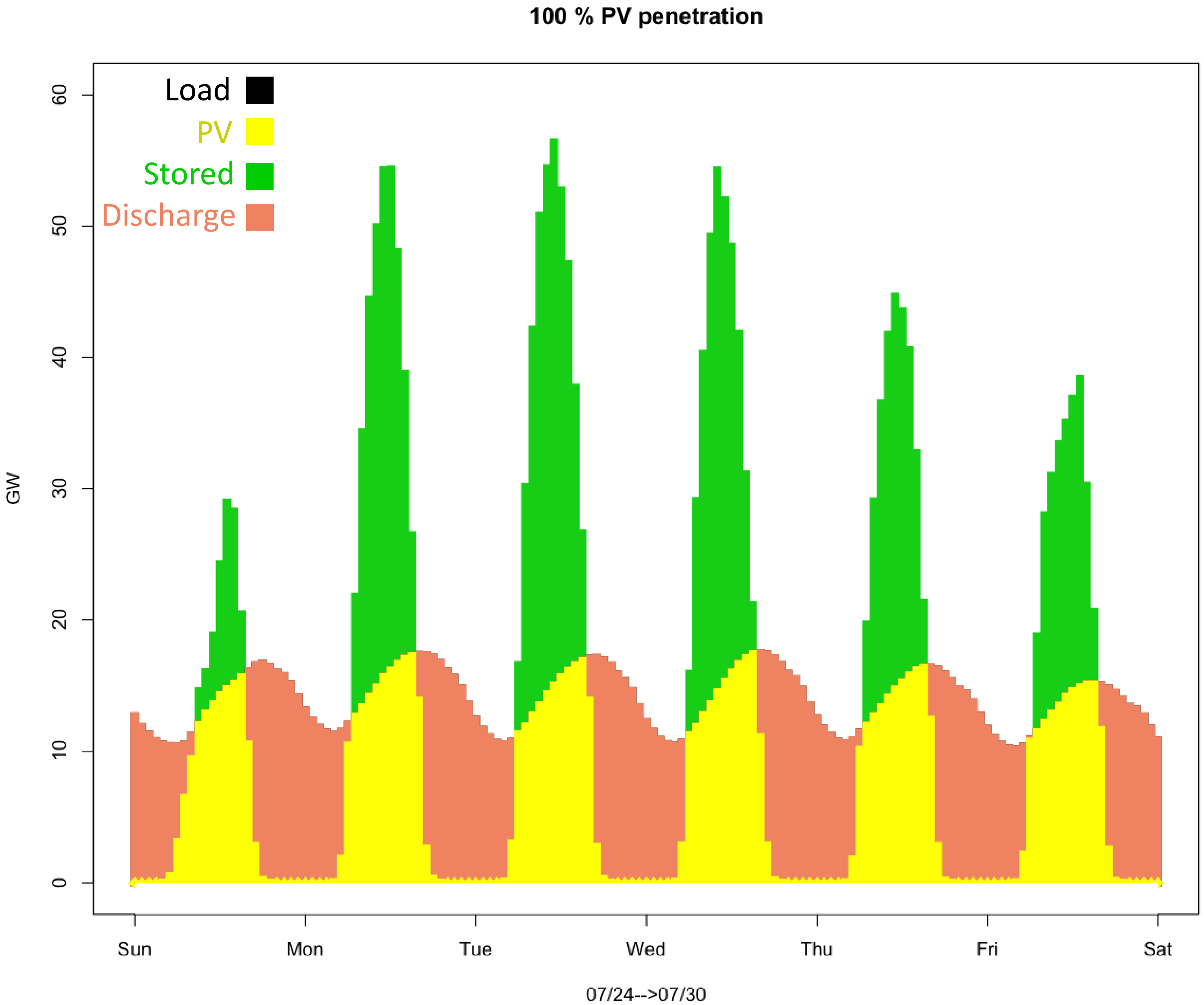

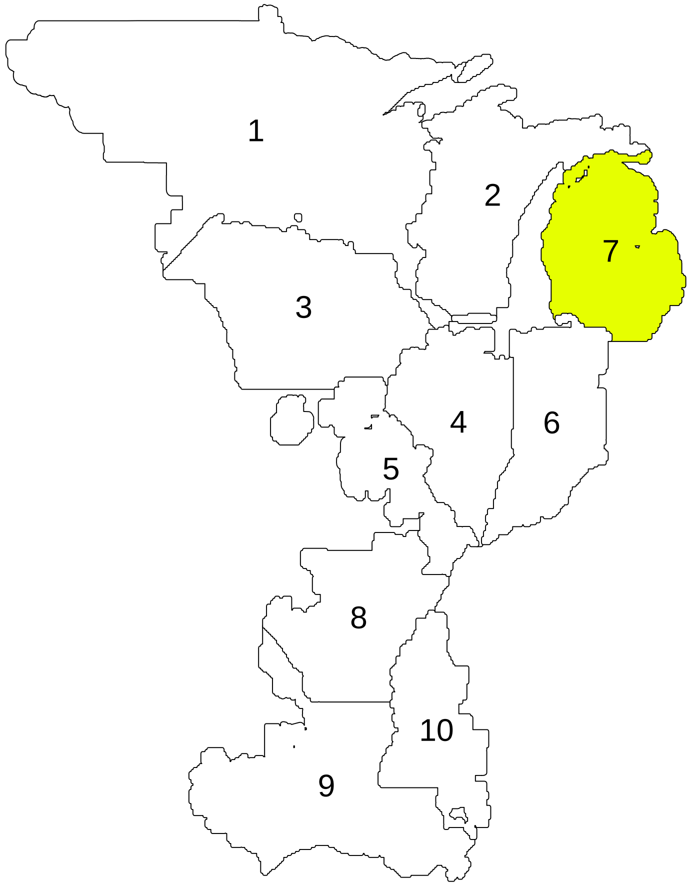

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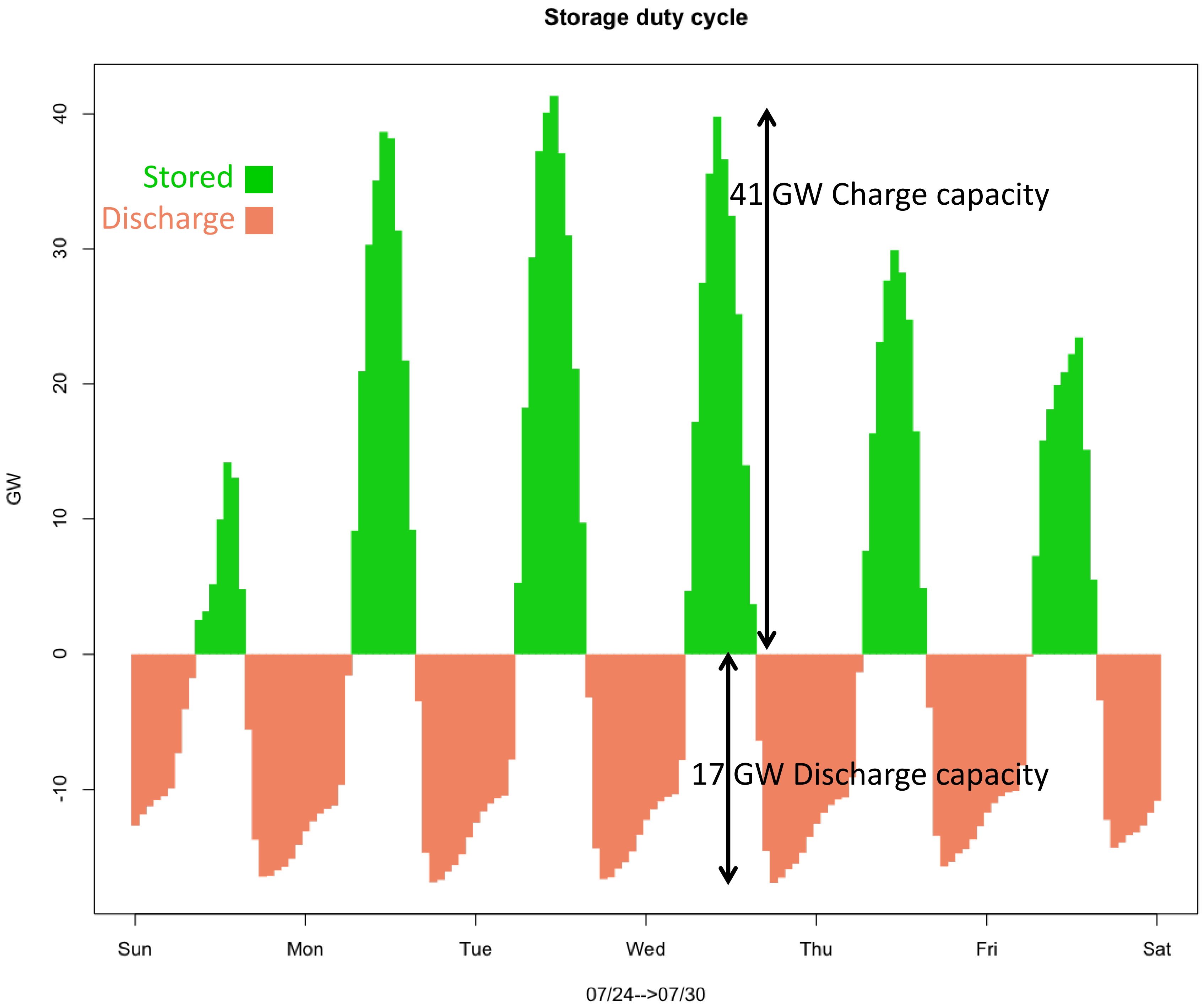

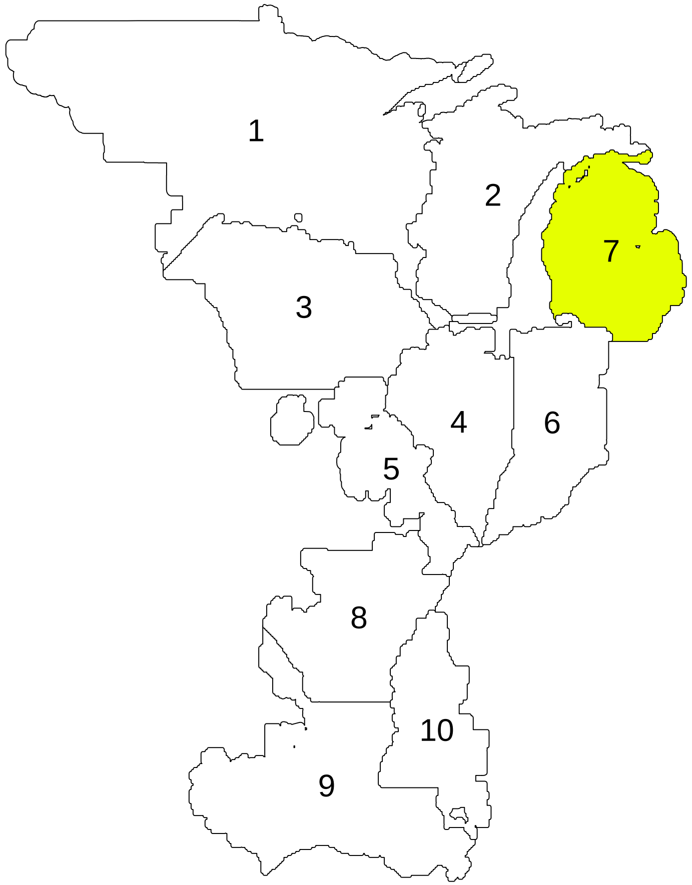

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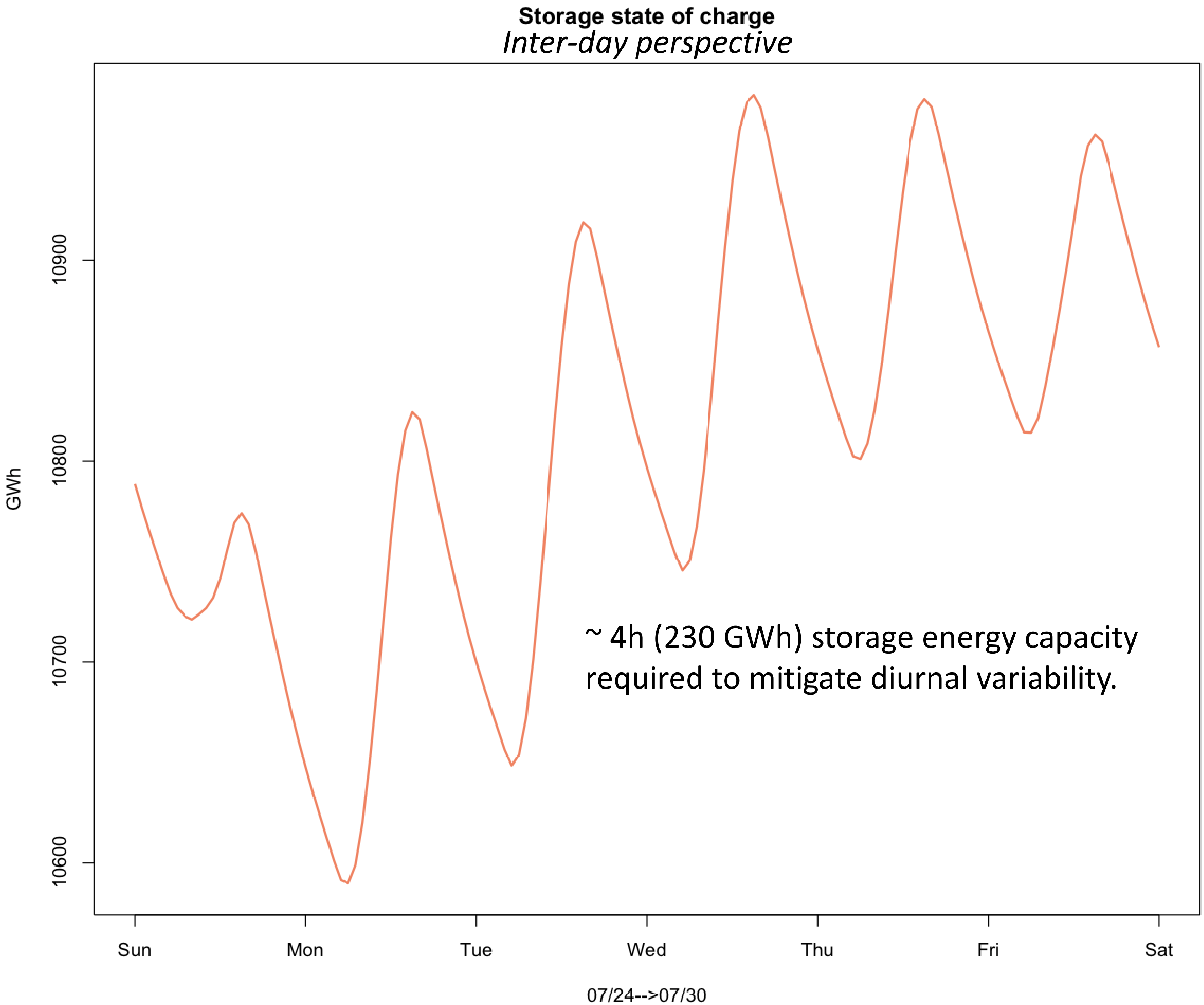

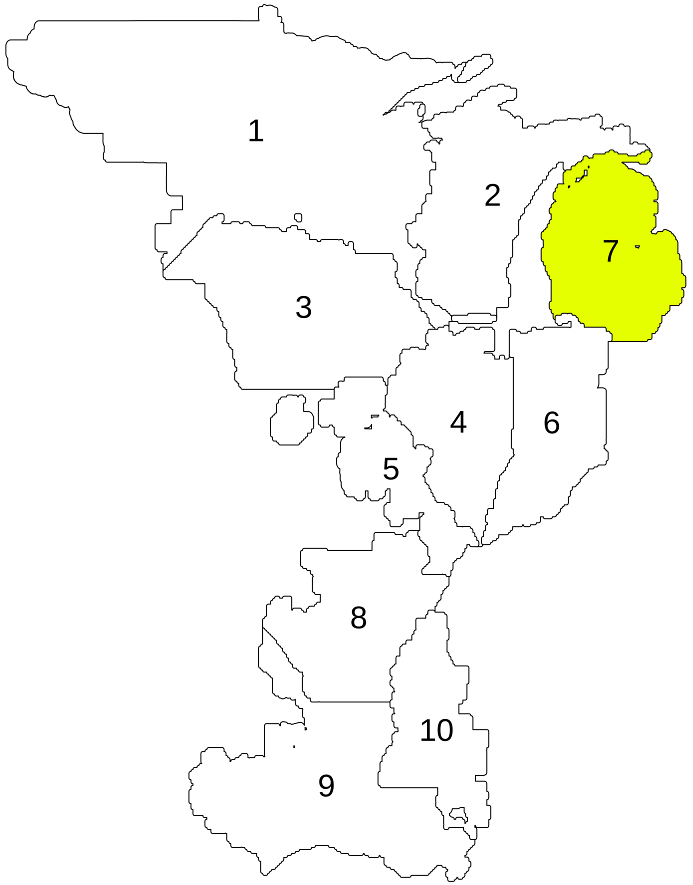

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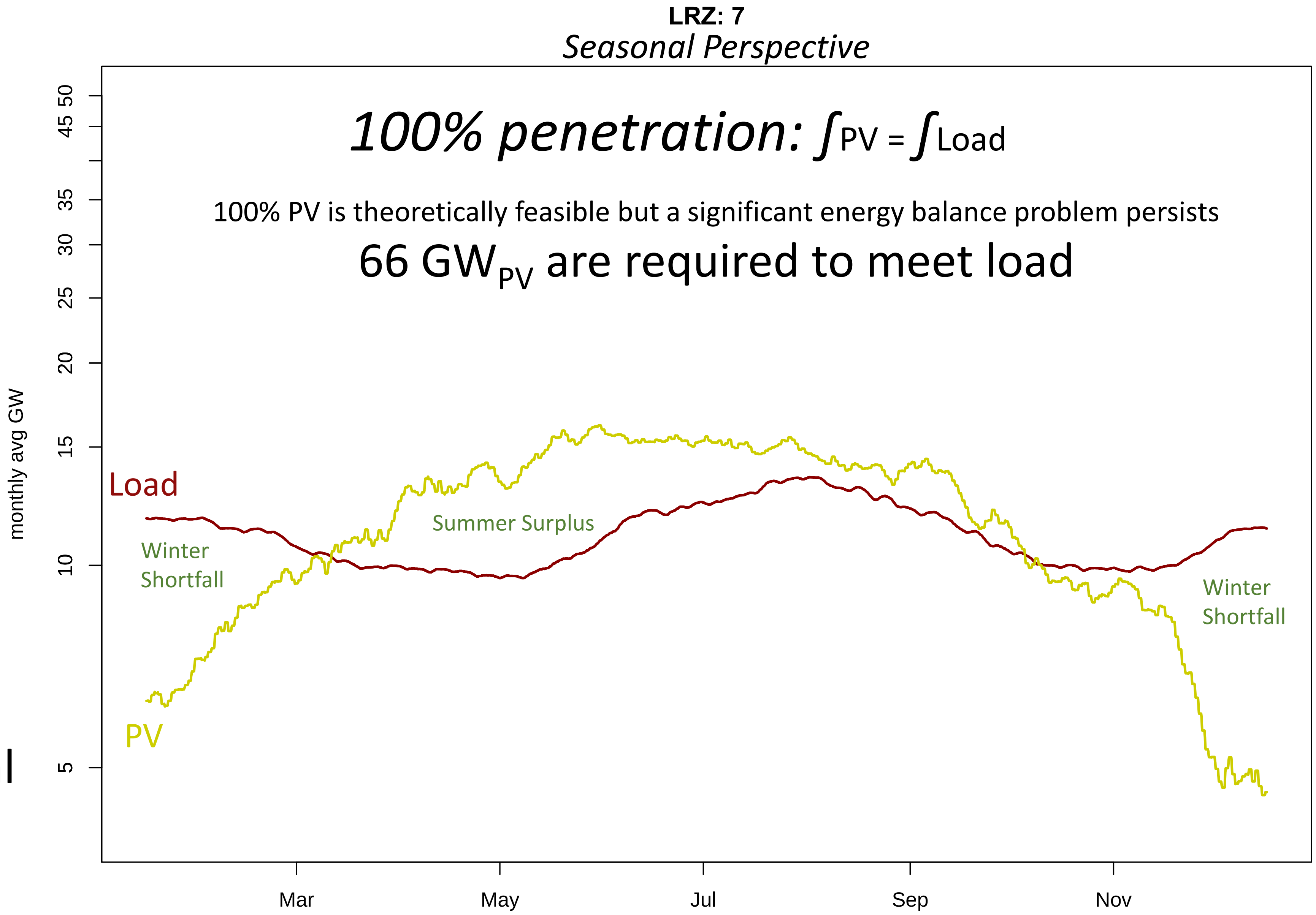

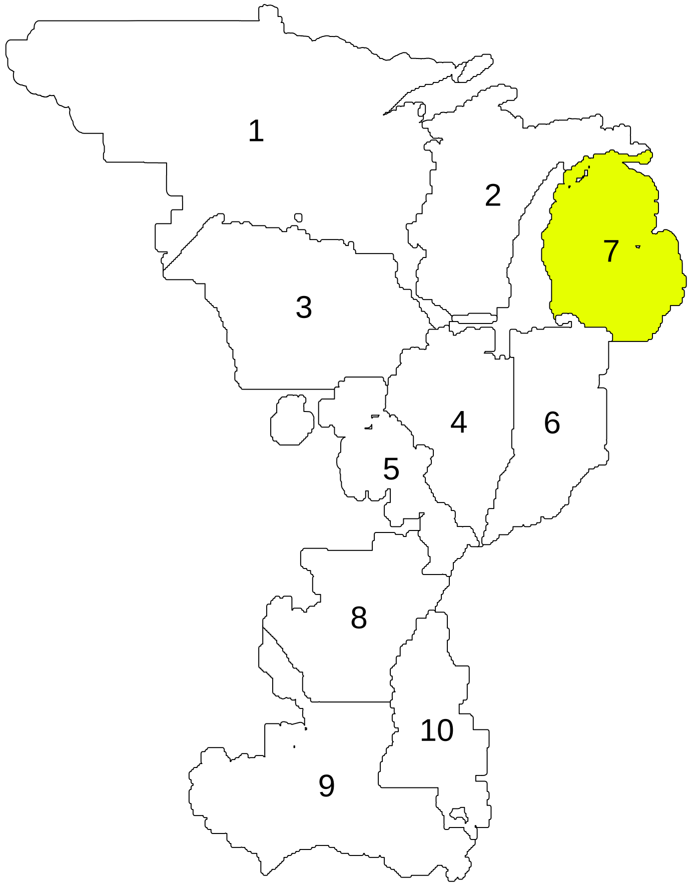

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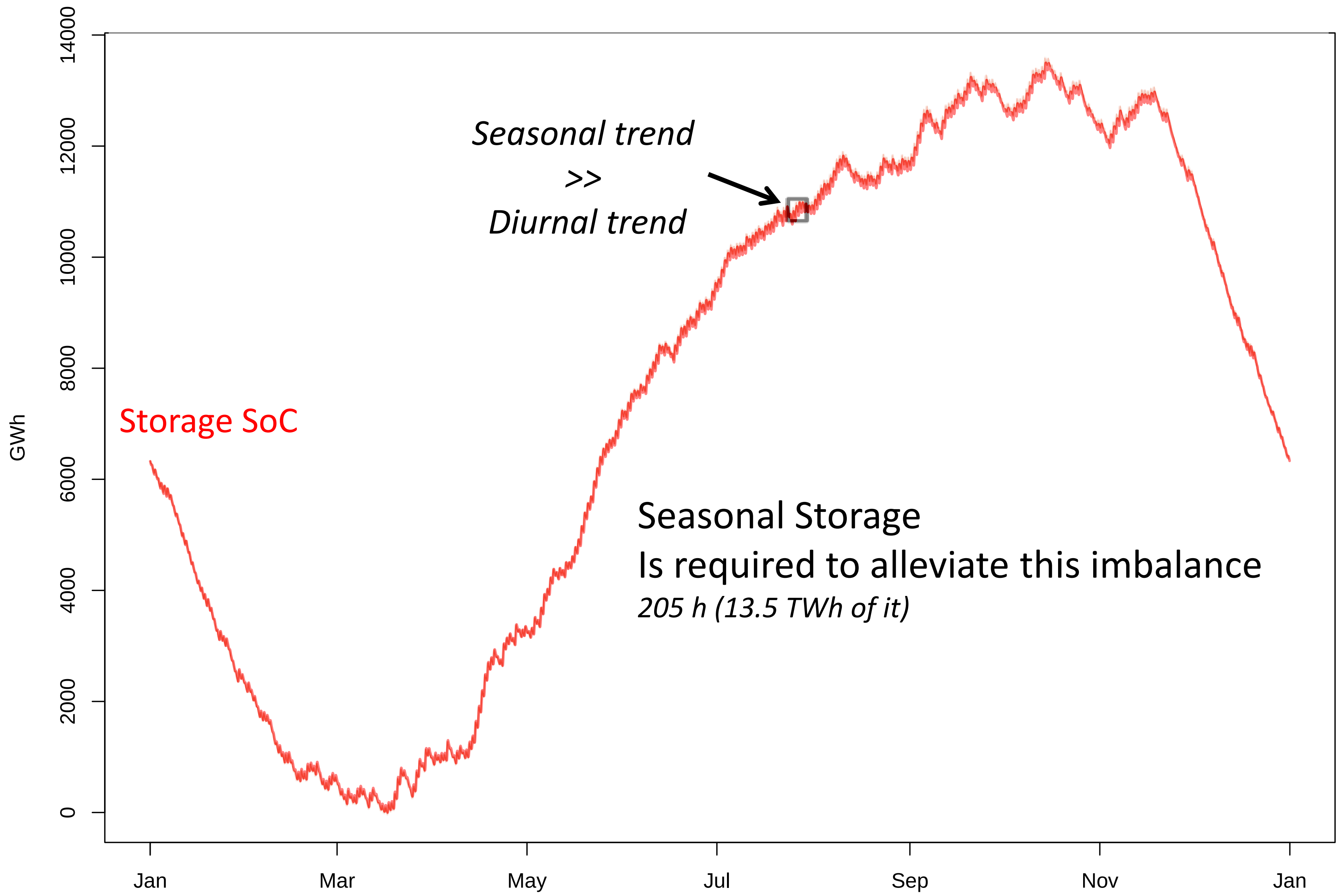

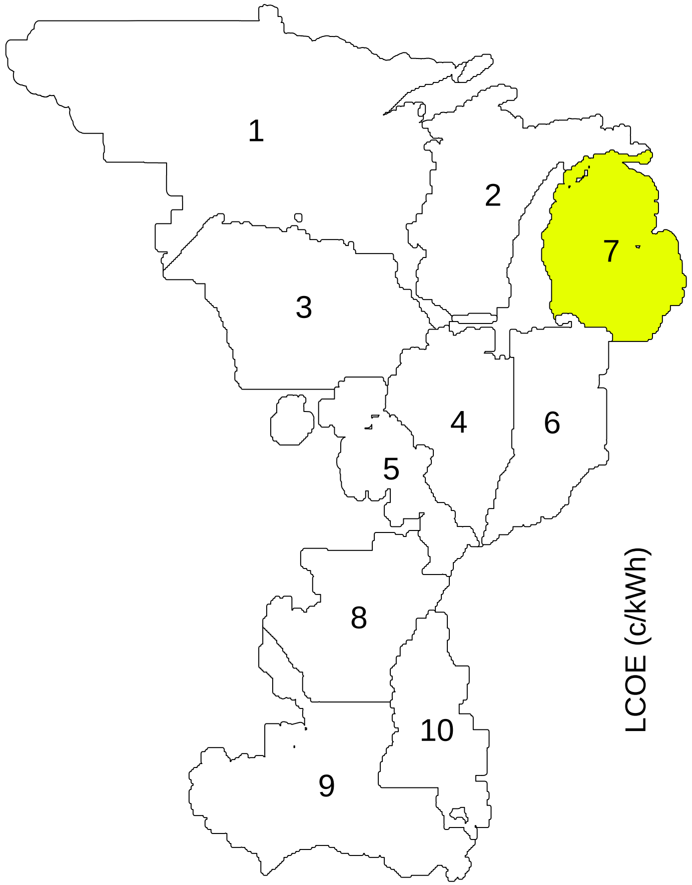

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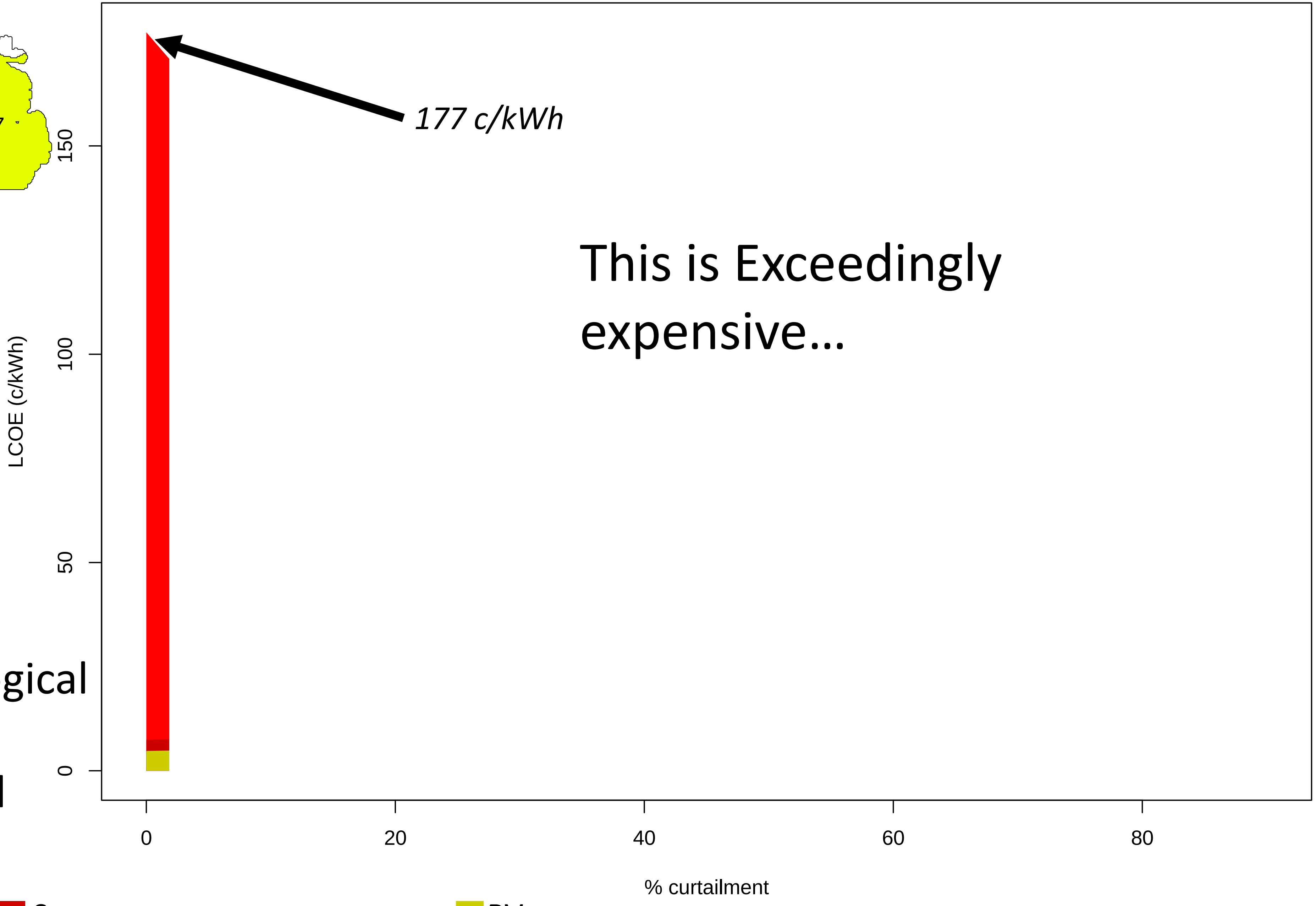
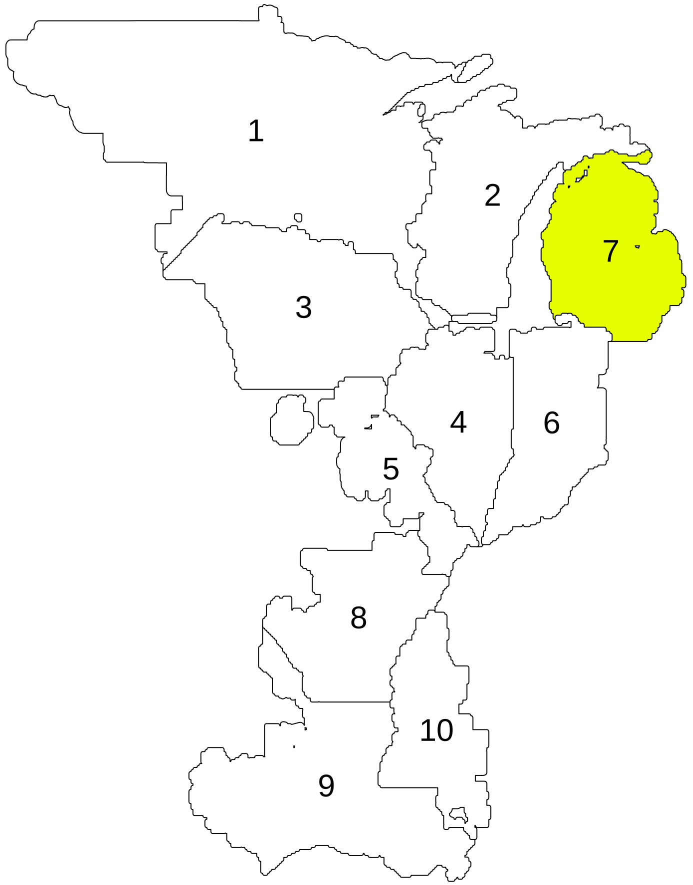


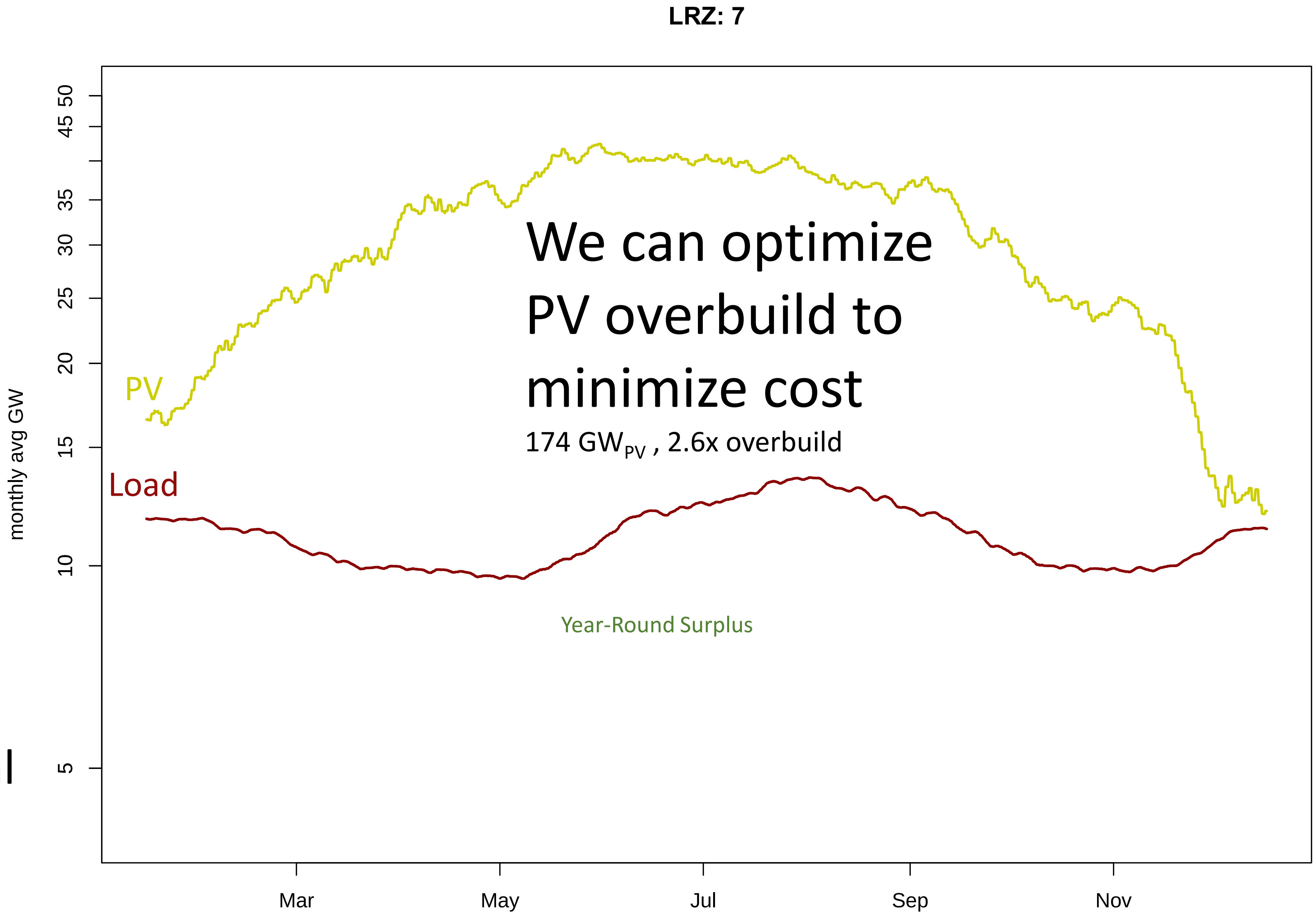
This is Exceedingly expensive…

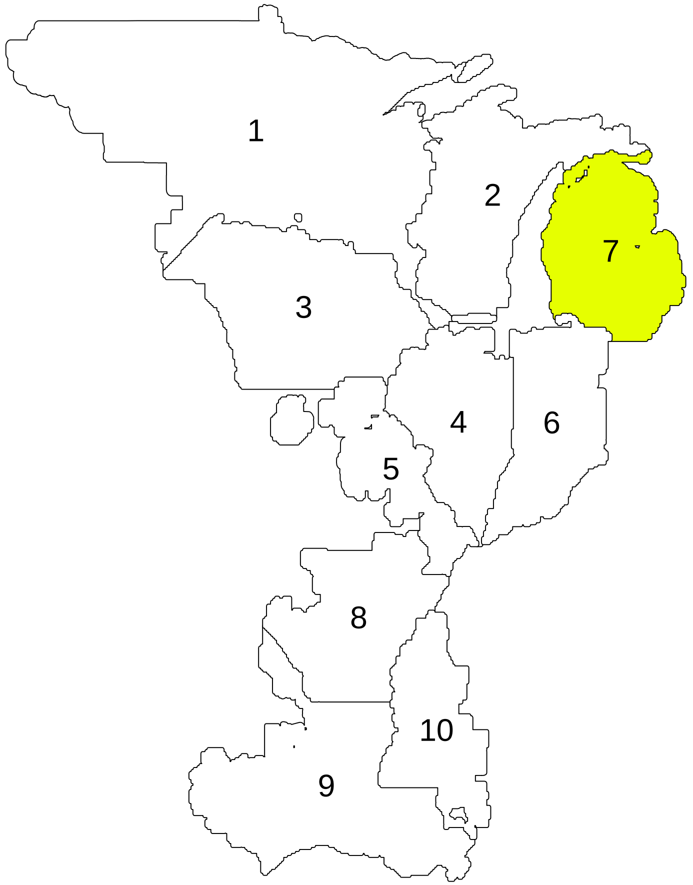
Storage energy component Storage power component PV



Consider LRZ 7

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





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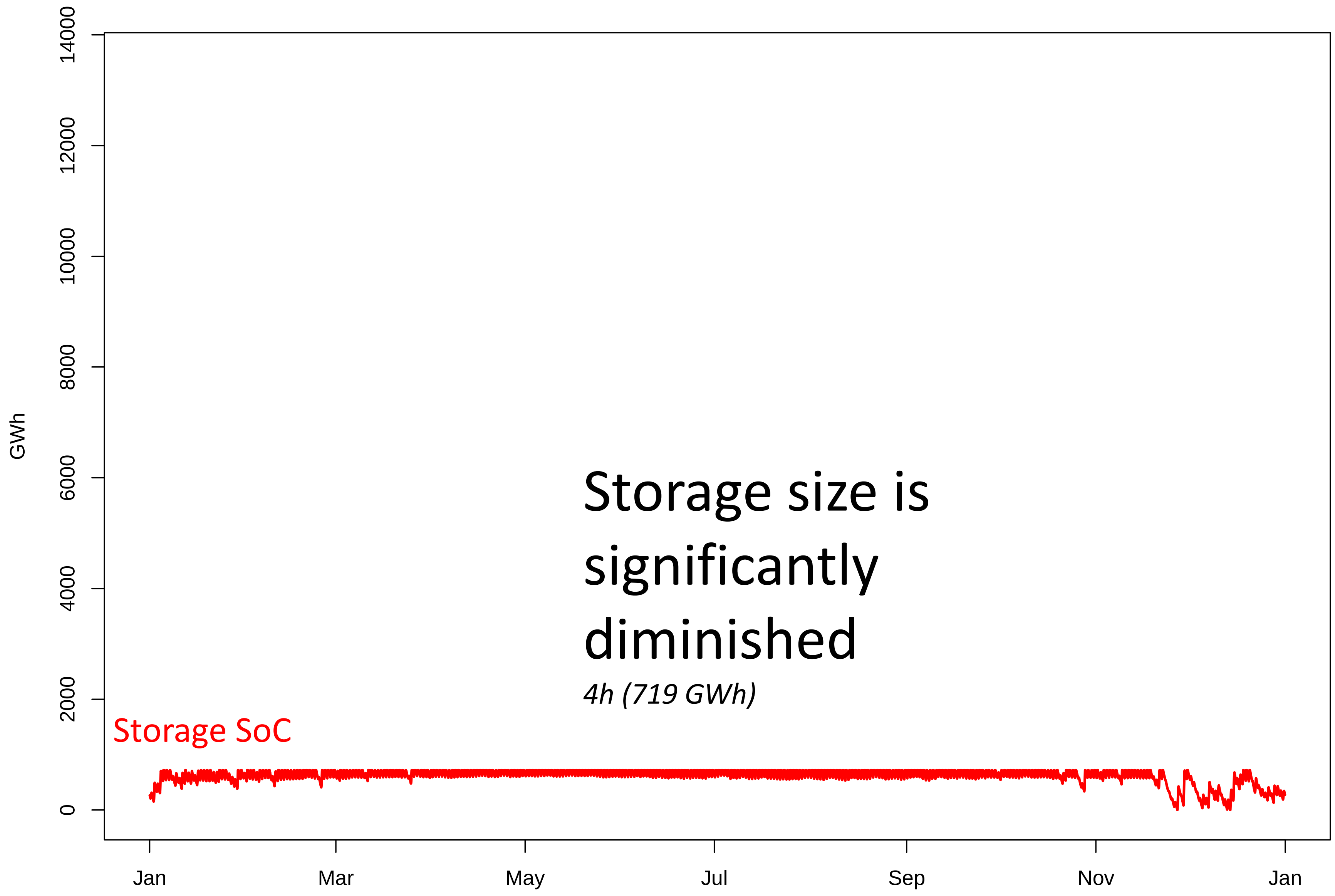
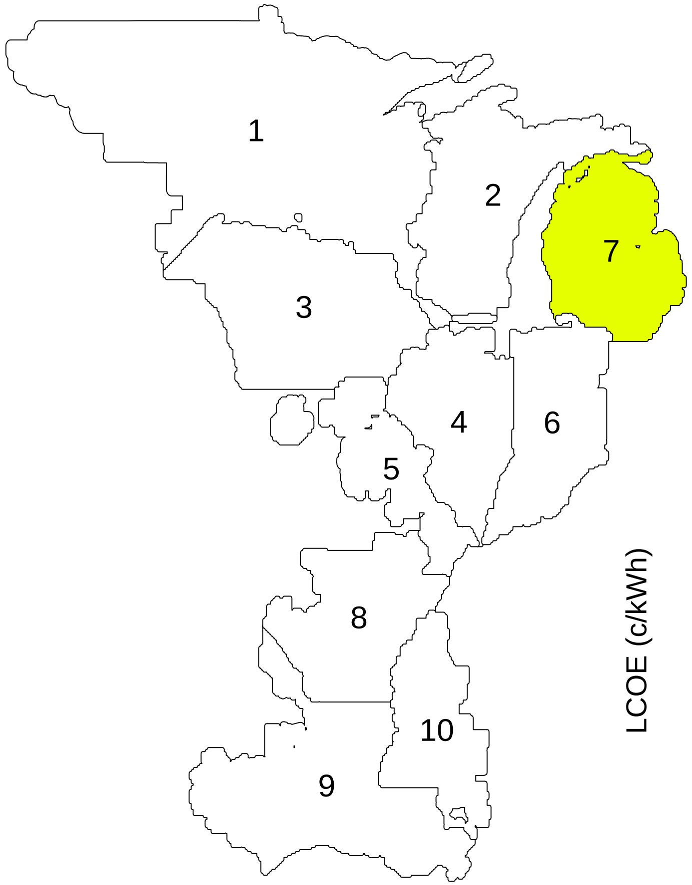
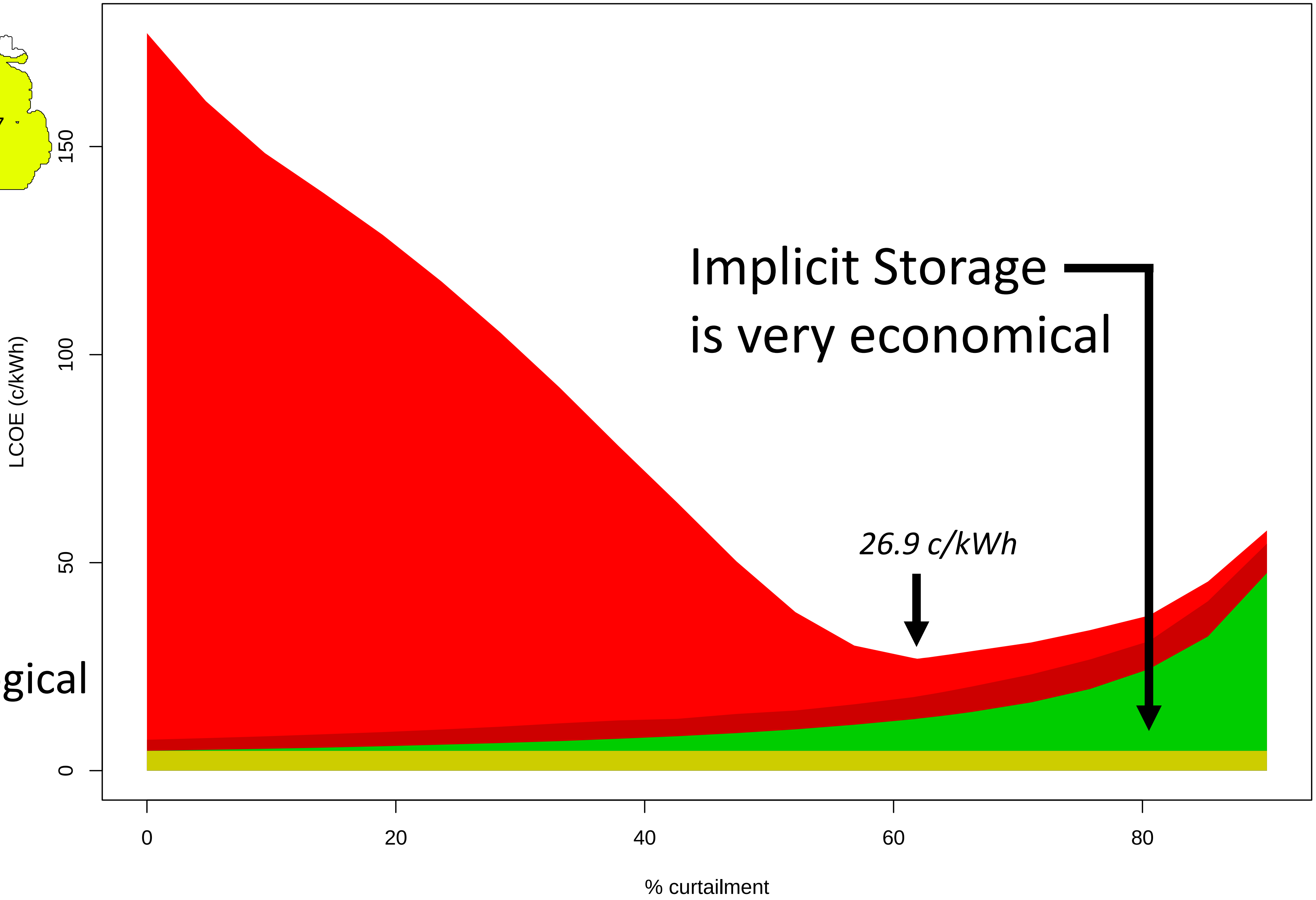
2025, low technological development, PV *alone*, optimal overbuild





Consider LRZ 7

2025, low technological development, PV *alone*, <u>optimal</u> overbuild



Storage energy component Storage power component PV Implicit Storage

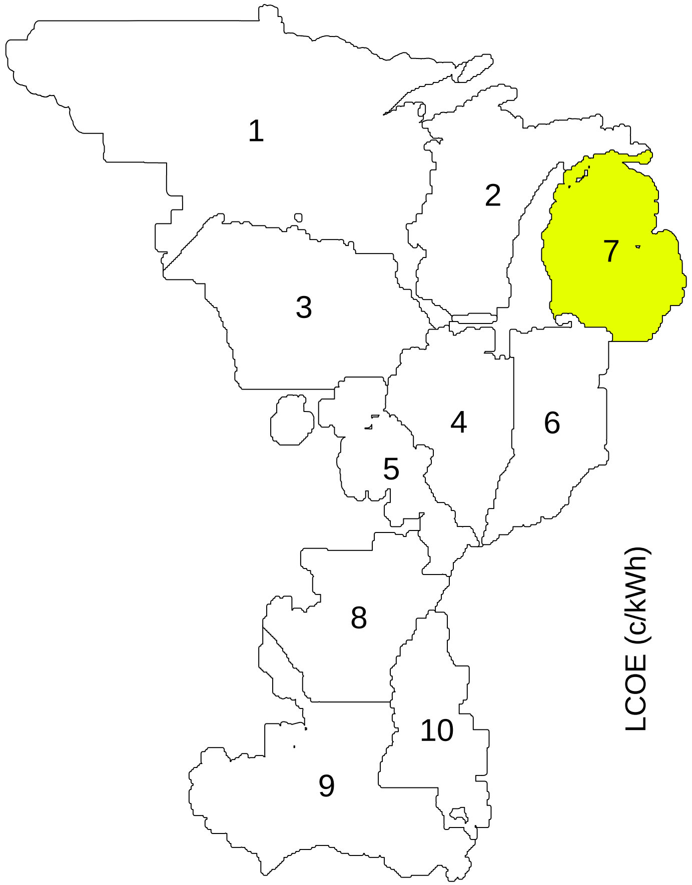
2050 , High

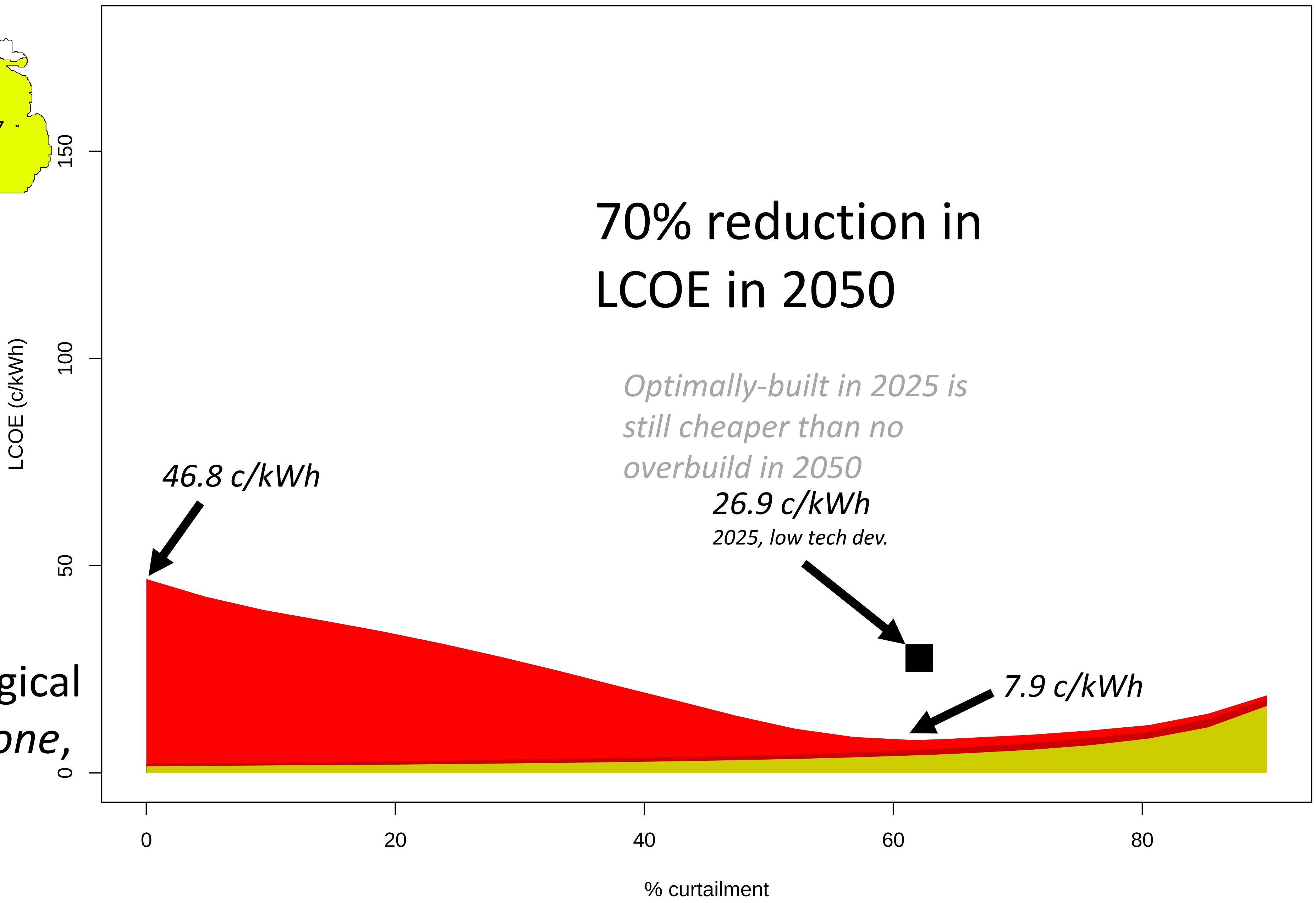
~~2025 , Low~~ Technological Development, MISO LRZ 7, 100% PV + storage

$\boxed{\text{26.9 c/kWh}}$

174 GW_{PV} | 4h (719 GWh) Storage

Let’s look at the impact of price





Consider LRZ 7

2050, high technological development, PV *alone*, optimal overbuild

Storage energy component Storage power component PV

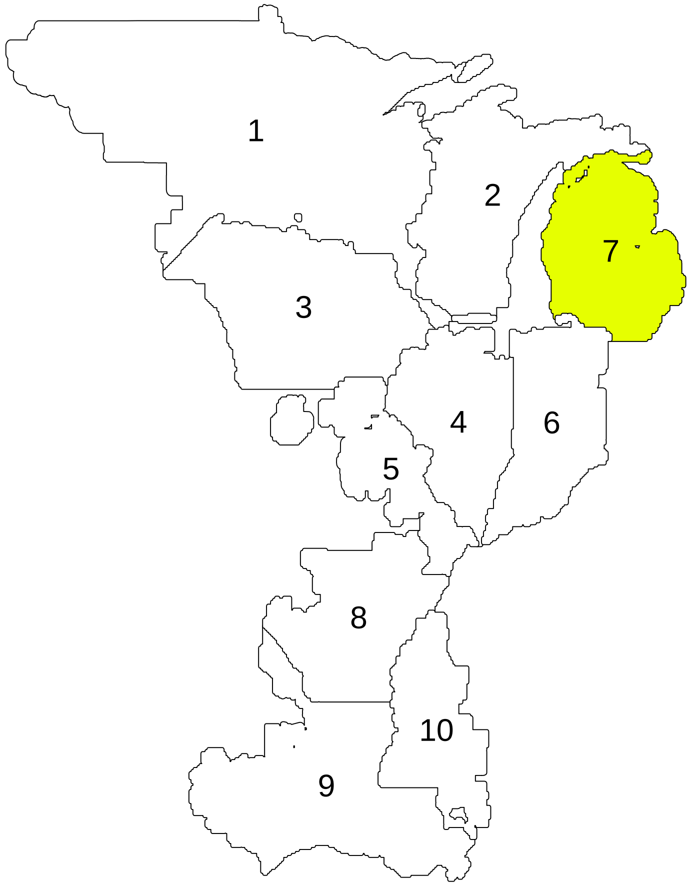
Wind

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

$\boxed{\text{7.9 c/kWh}}$

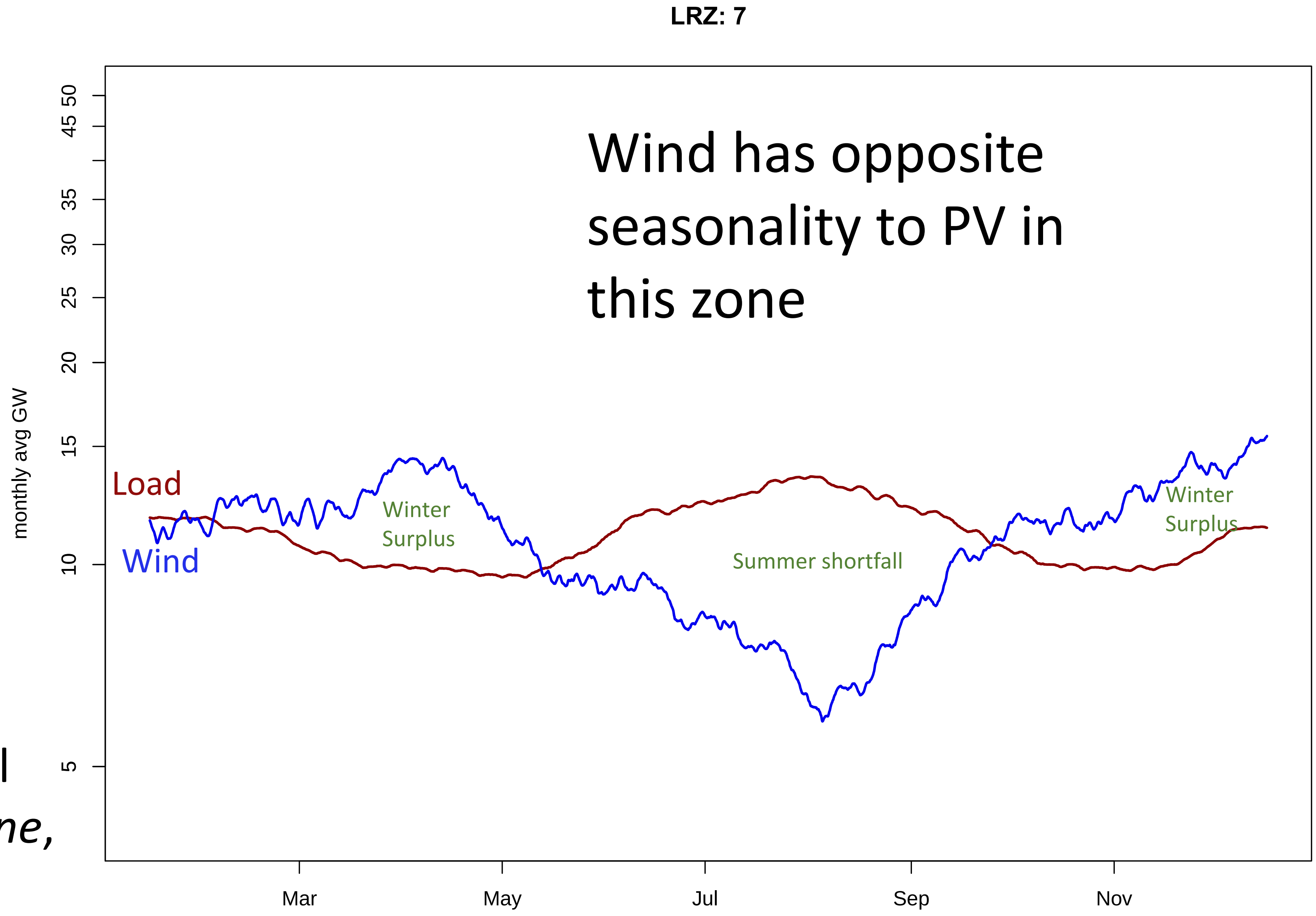
174 GW$_{PV}$ | 4h (719 GWh) Storage

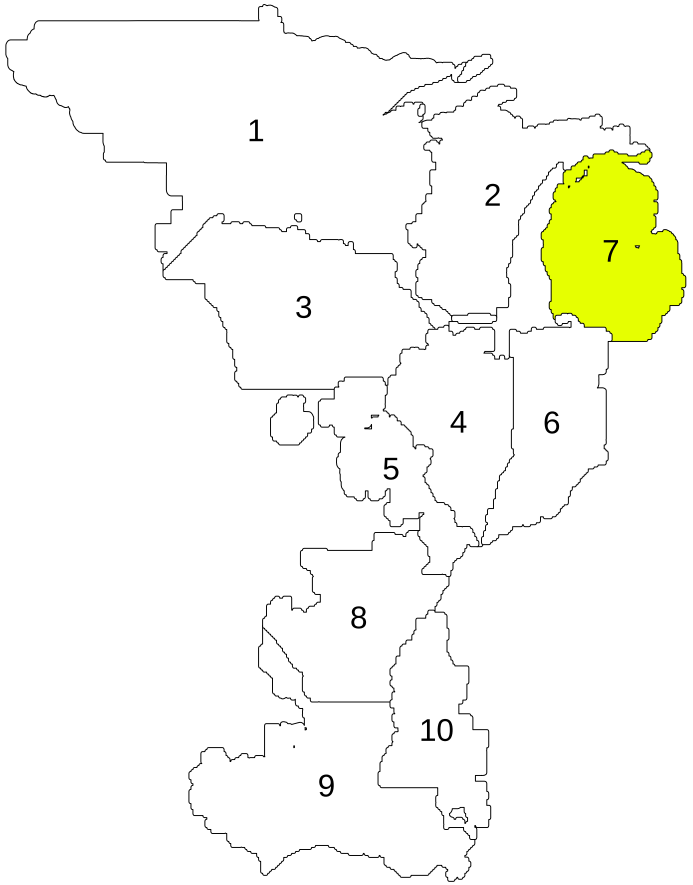
What about wind? Does the same hold true?



Consider LRZ 7

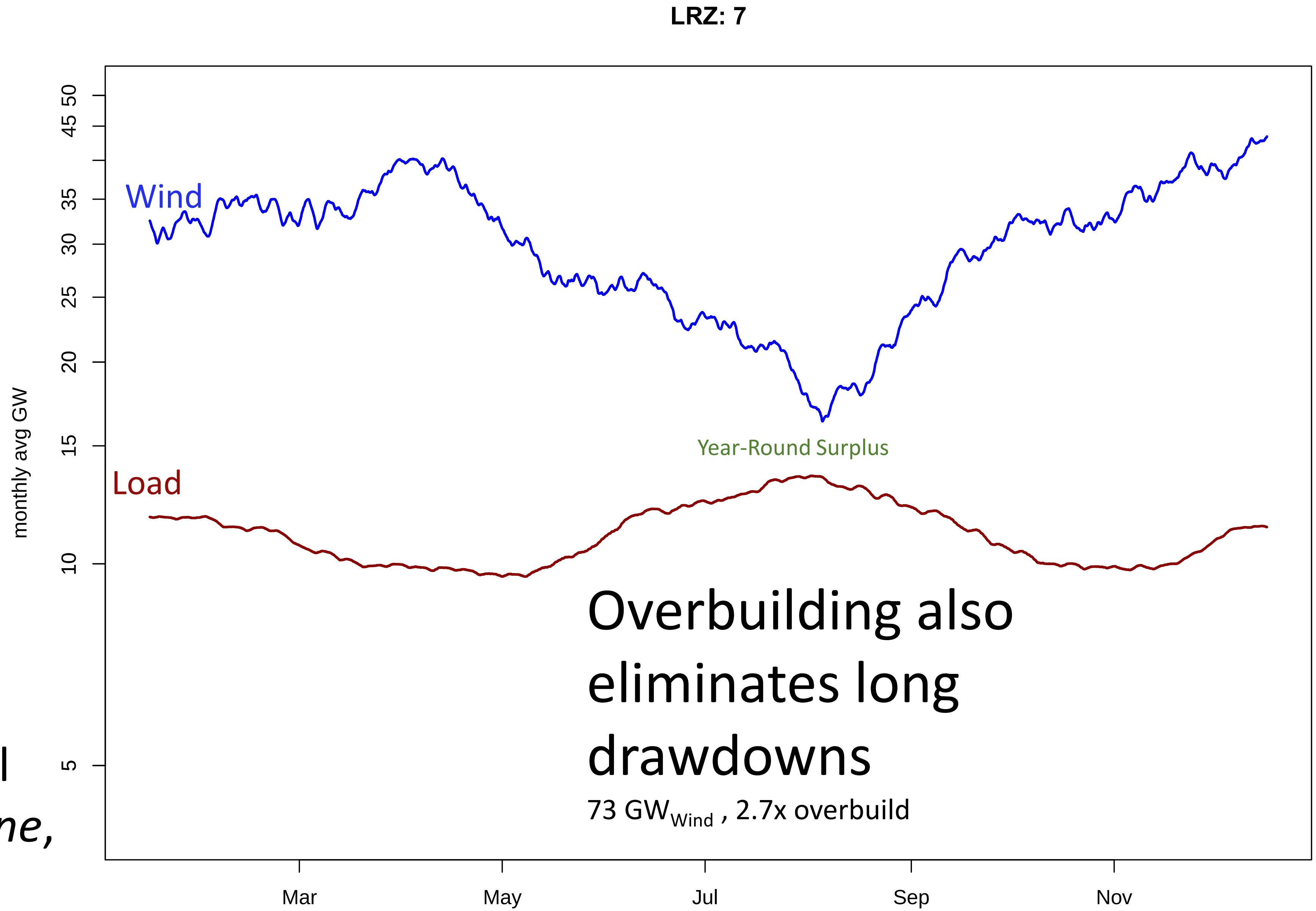
2050, high technological development, Wind *alone*, <u>no</u> overbuild

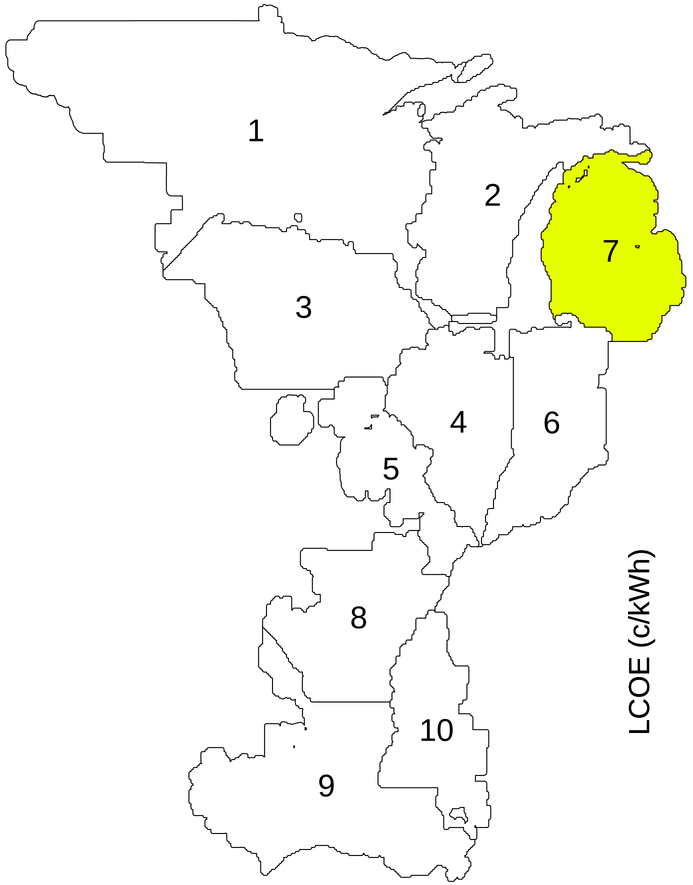




Consider LRZ 7

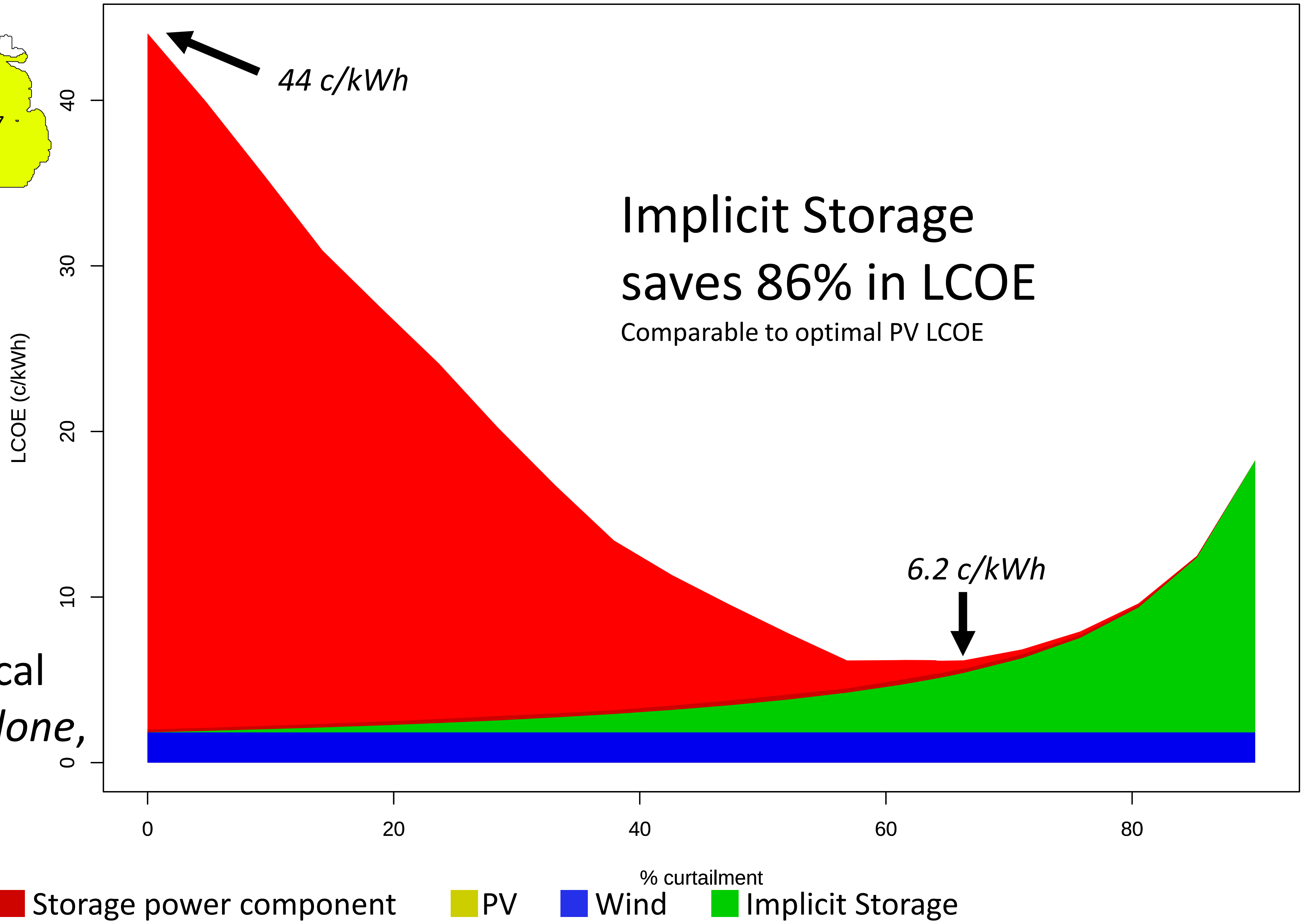
2050, high technological development, Wind *alone*, <u>optimal</u> overbuild





Consider LRZ 7

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



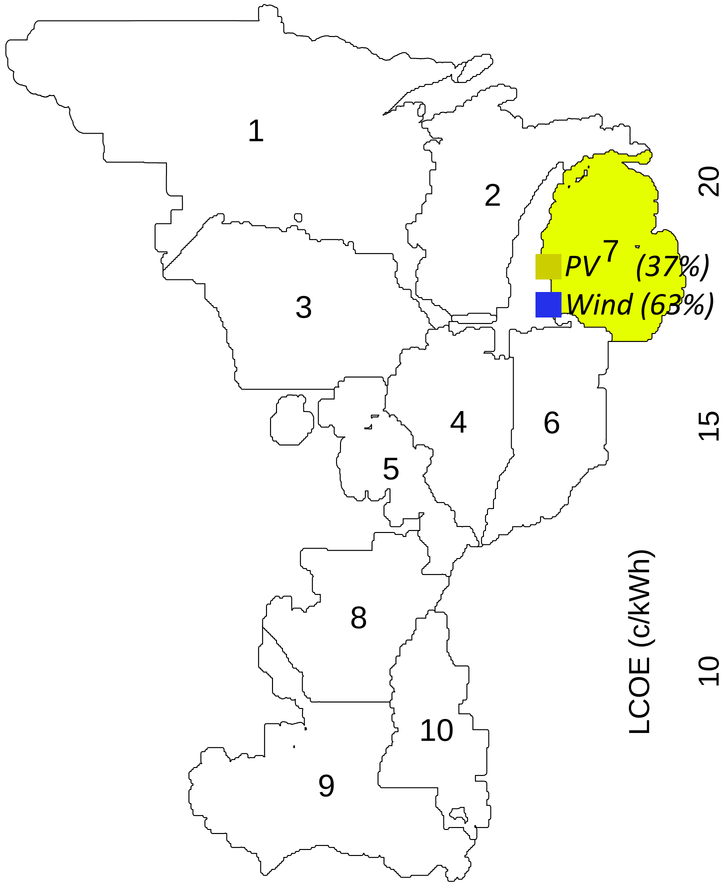
Wind + PV

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

$\boxed{\text{6.2 c/kWh}}$

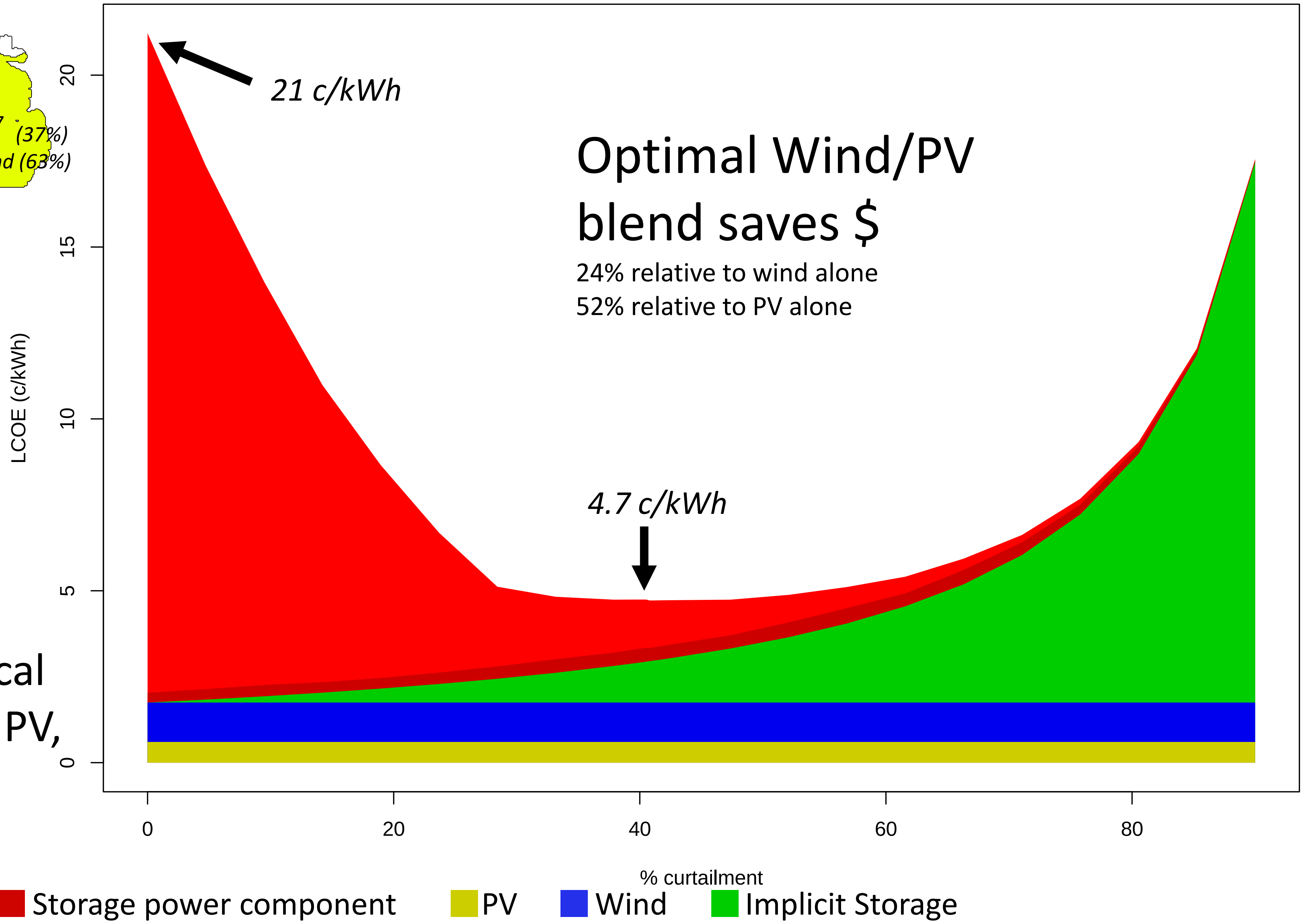
73 GW_{Wind} | 3h (239 GWh) Storage

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



Consider LRZ 7

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



Optimal Wind/PV blend saves $

24% relative to wind alone

52% relative to PV alone

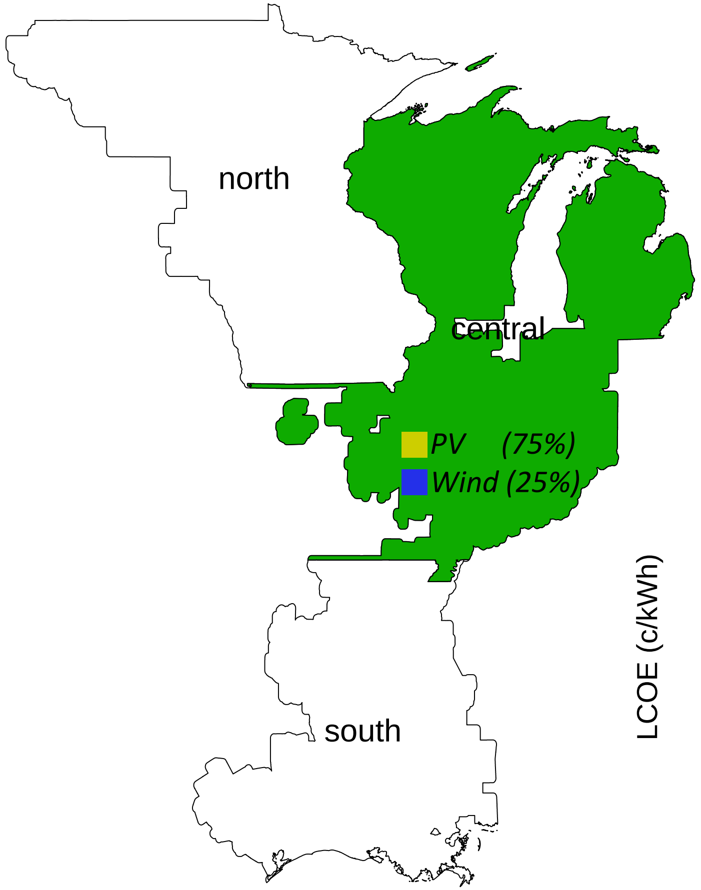
MISO Central Region

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

$\boxed{\text{4.7 c/kWh}}$

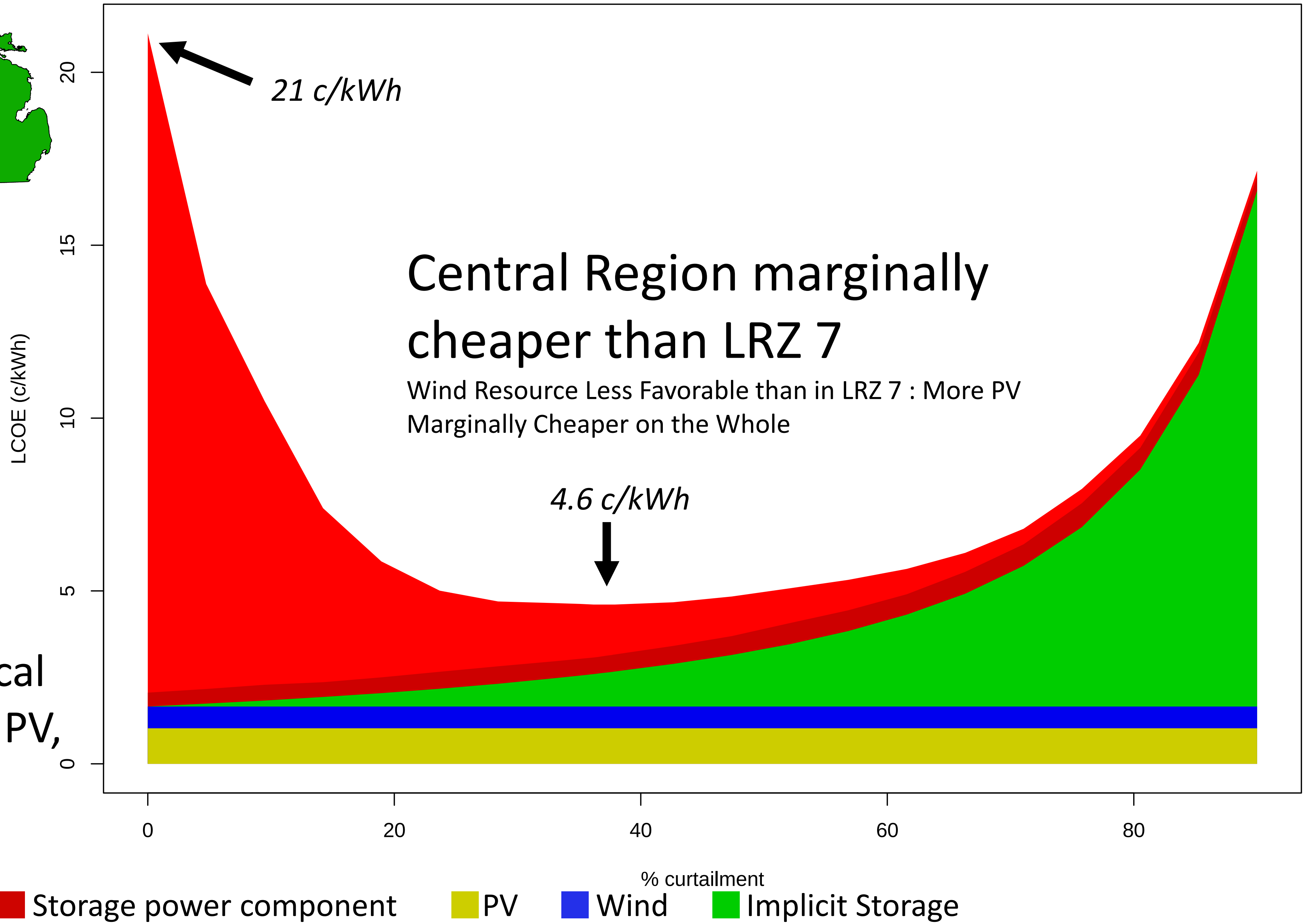
28 GW$_{Wind}$, 42 GW$_{PV}$ | 6h (419 GWh$_{Storage}$)

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



Consider *Central*

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



Central Region marginally cheaper than LRZ 7

Wind Resource Less Favorable than in LRZ 7 : More PV
Marginally Cheaper on the Whole

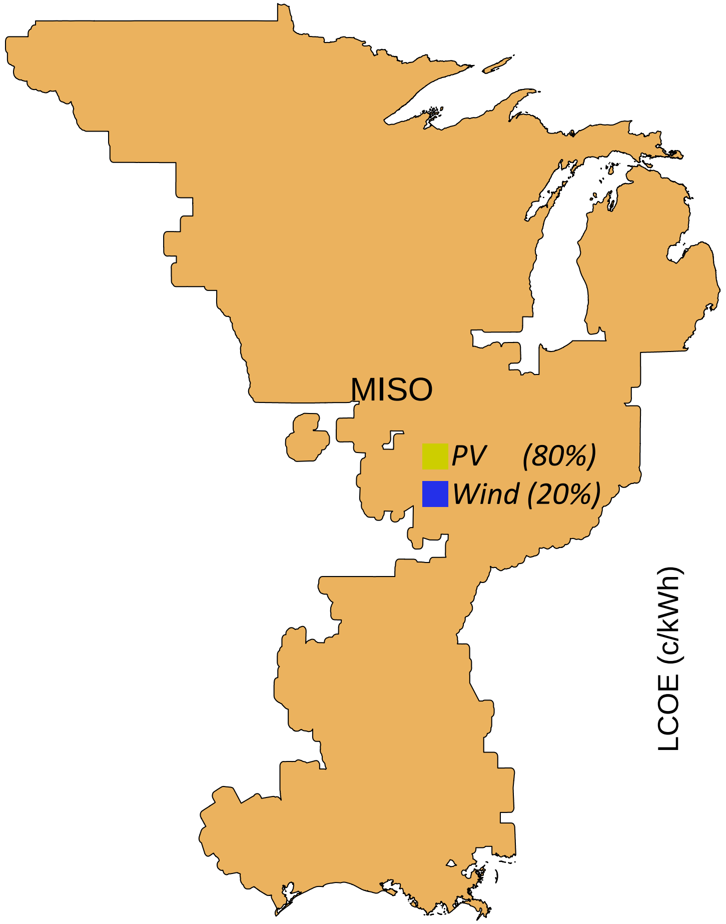
All of MISO

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

$\boxed{\text{4.6 c/kWh}}$

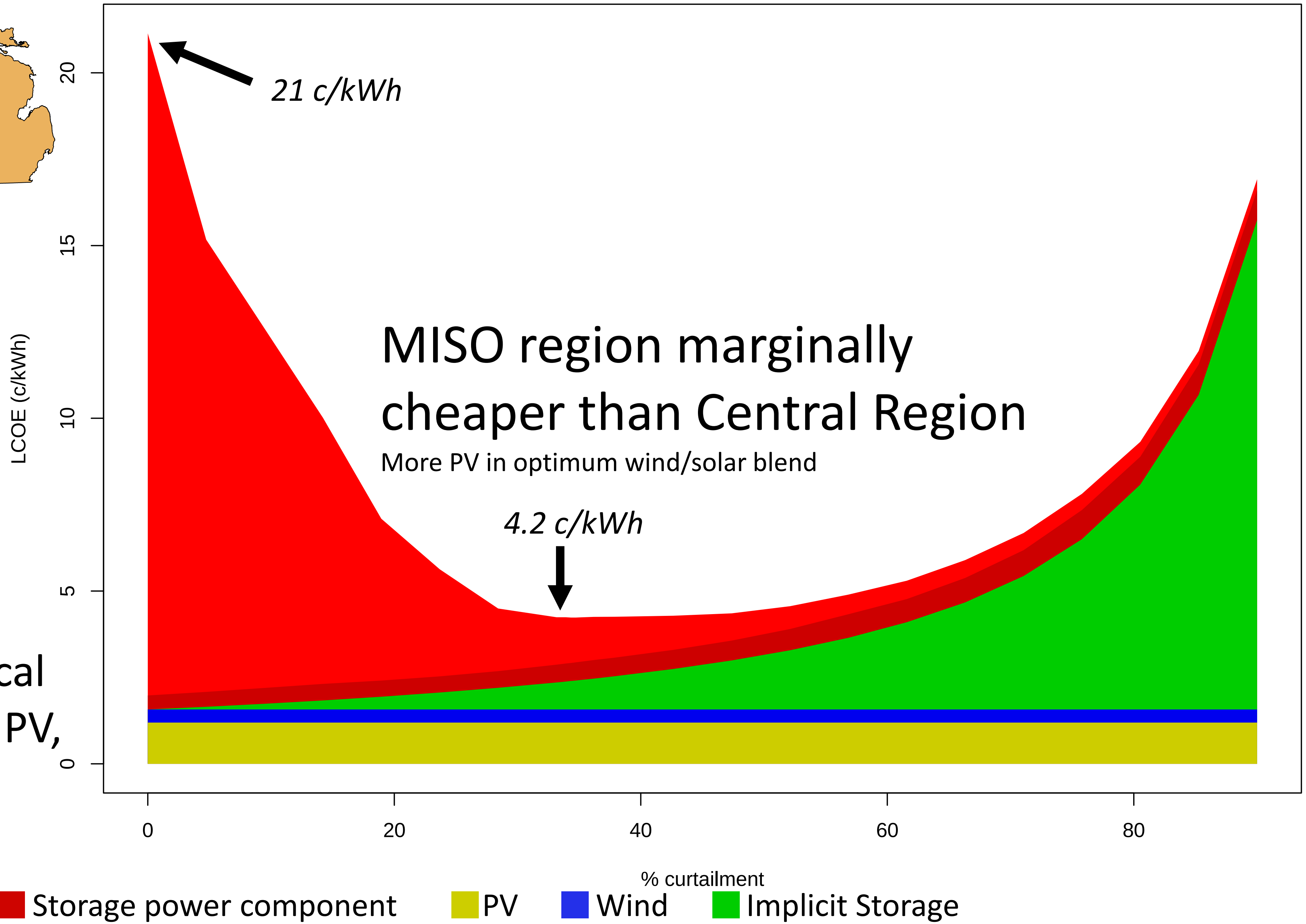
52 GW$_{Wind}$, 243 GW$_{PV}$ | 5h (1.6 TWh$_{Storage}$)

What about all of MISO?



Consider *MISO*

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



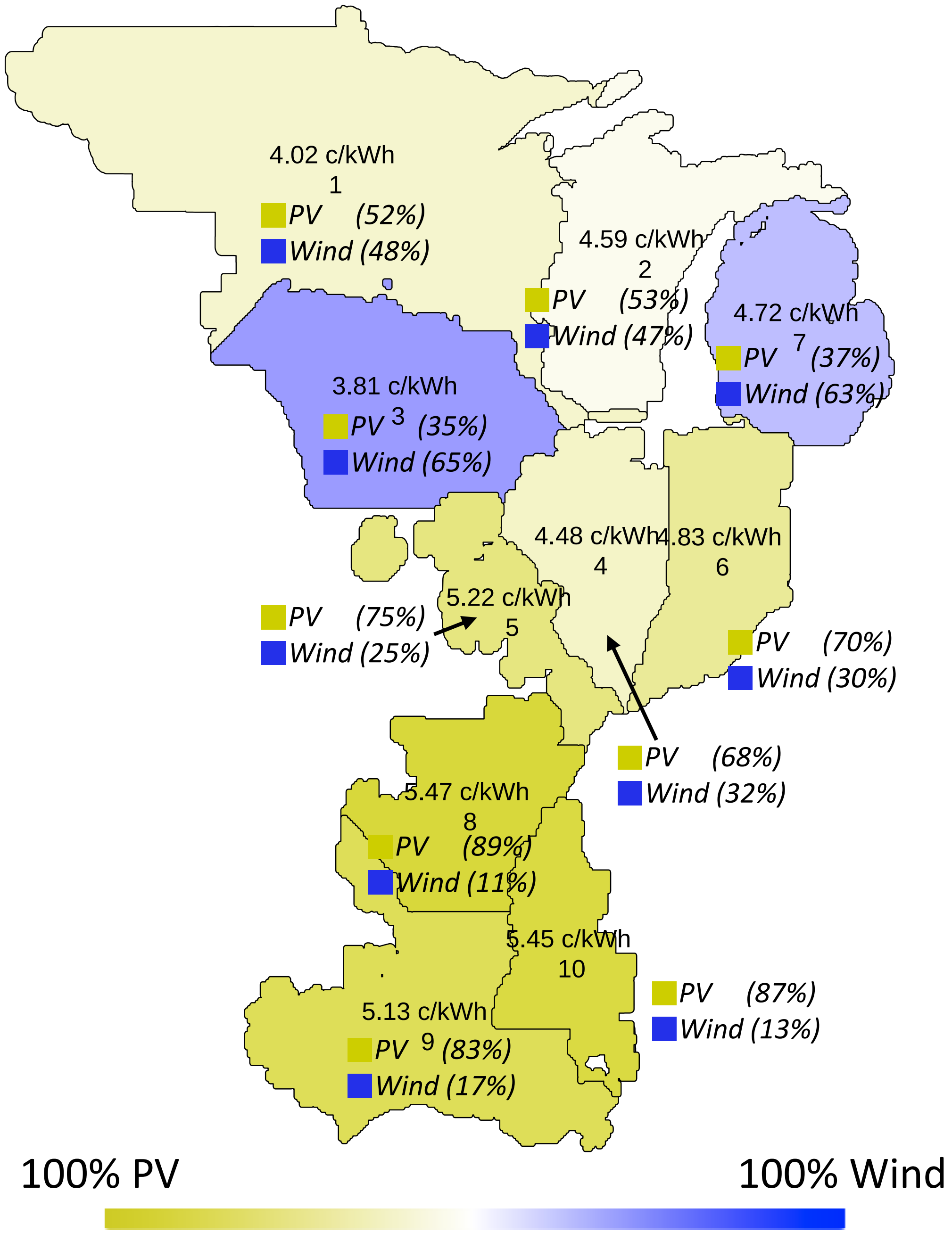
2050, high Technological Development, All of MISO, 100% Wind + PV + storage

$\boxed{4.2\ \text{c/kWh}}$

57 GW_{Wind} , 511 GW_{PV} | 5h (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?



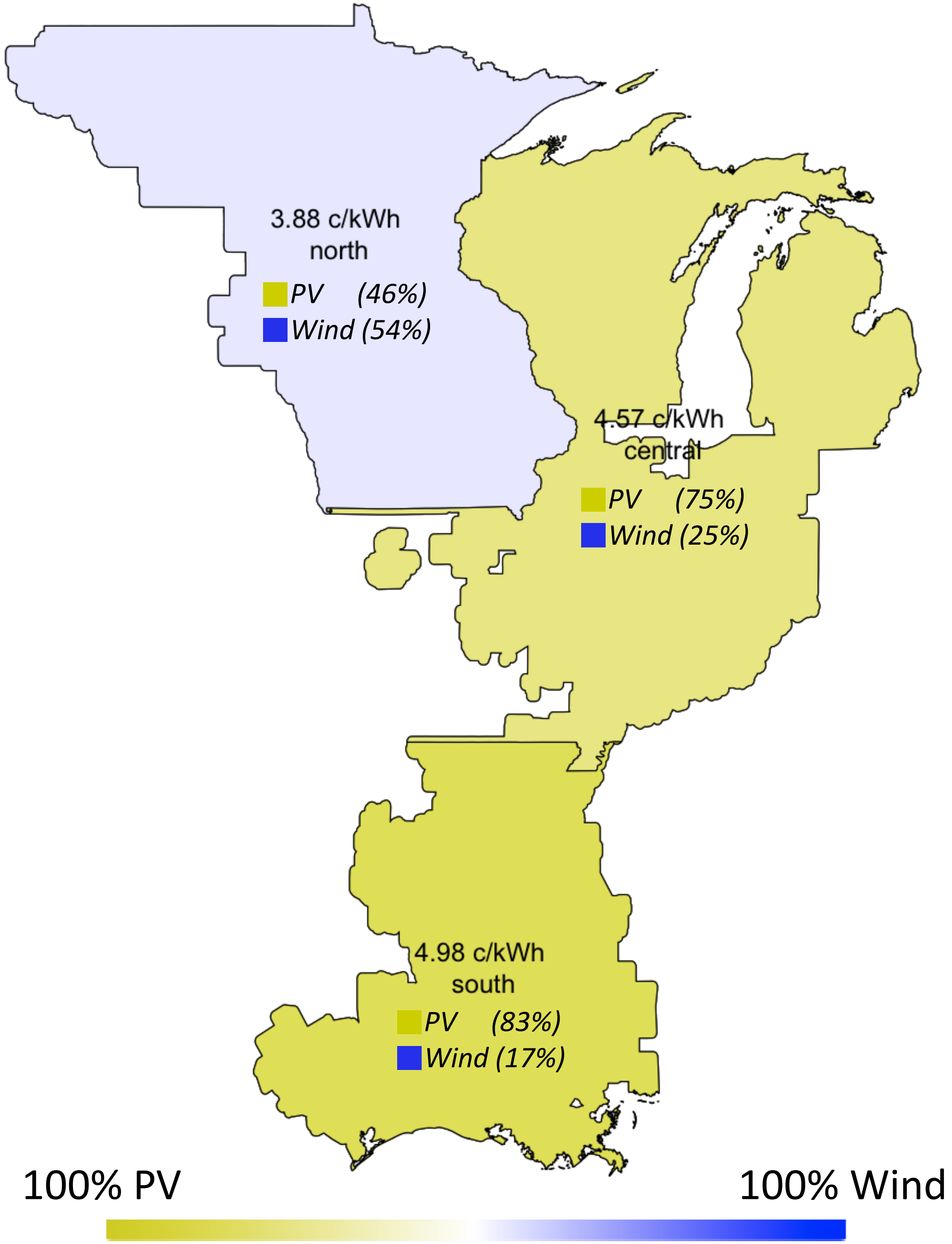
If each LRZ islanded themselves and optimized their resource blends, the electricity price would be:

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

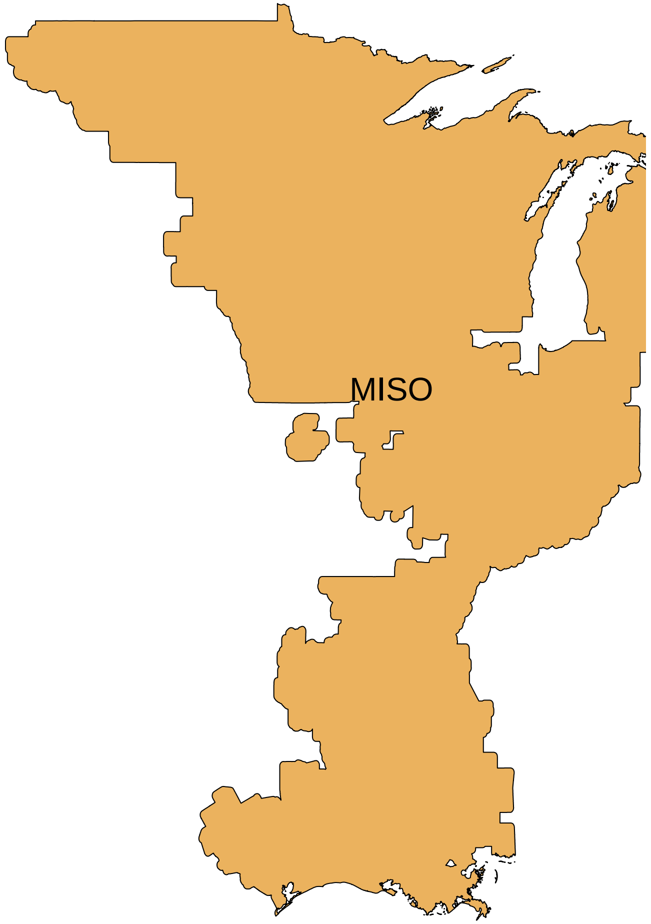
weighted average cost

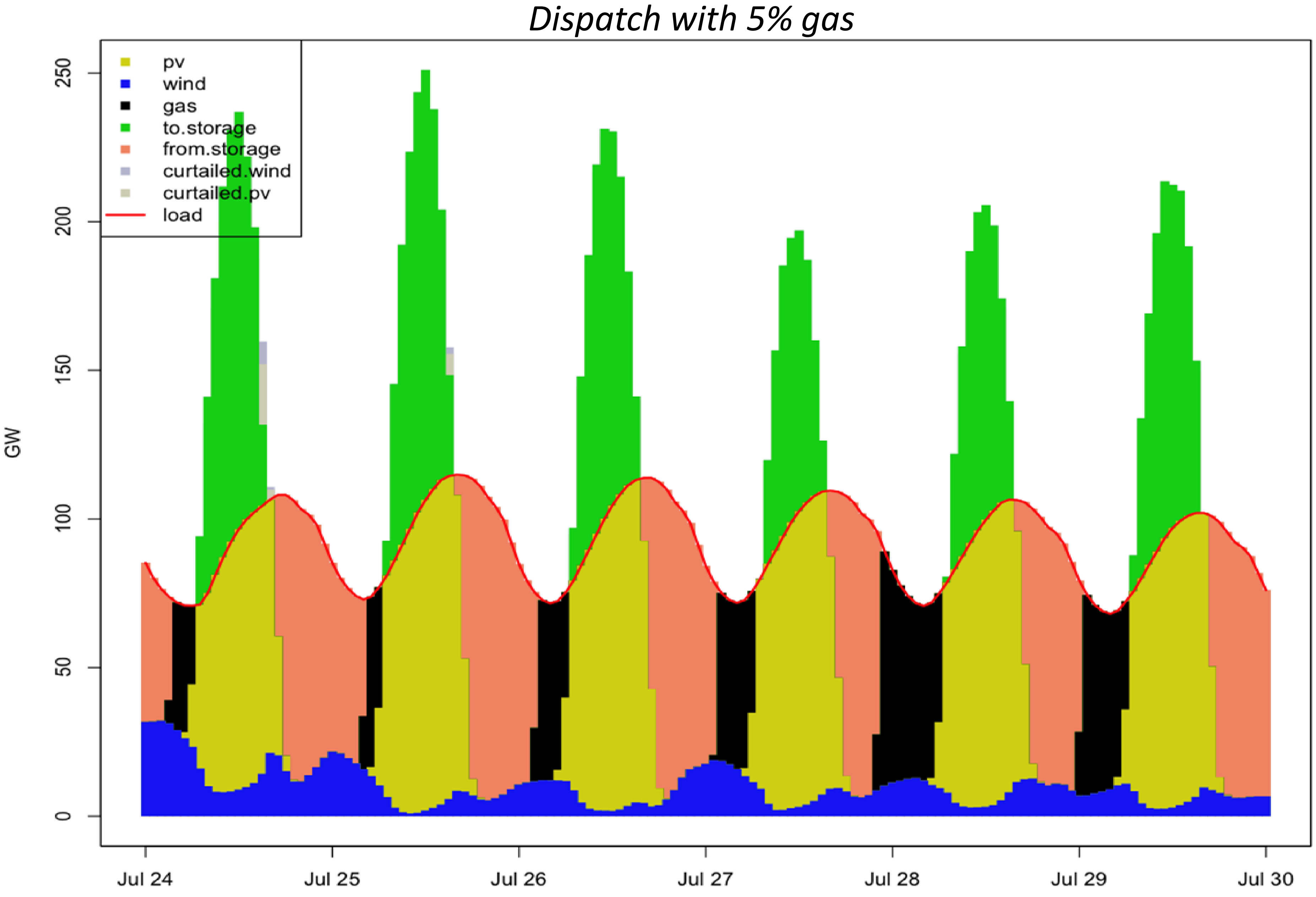
This equates to $30 Bn/yr

<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 +
<u>optimal</u> overbuild + ga

% curtailment

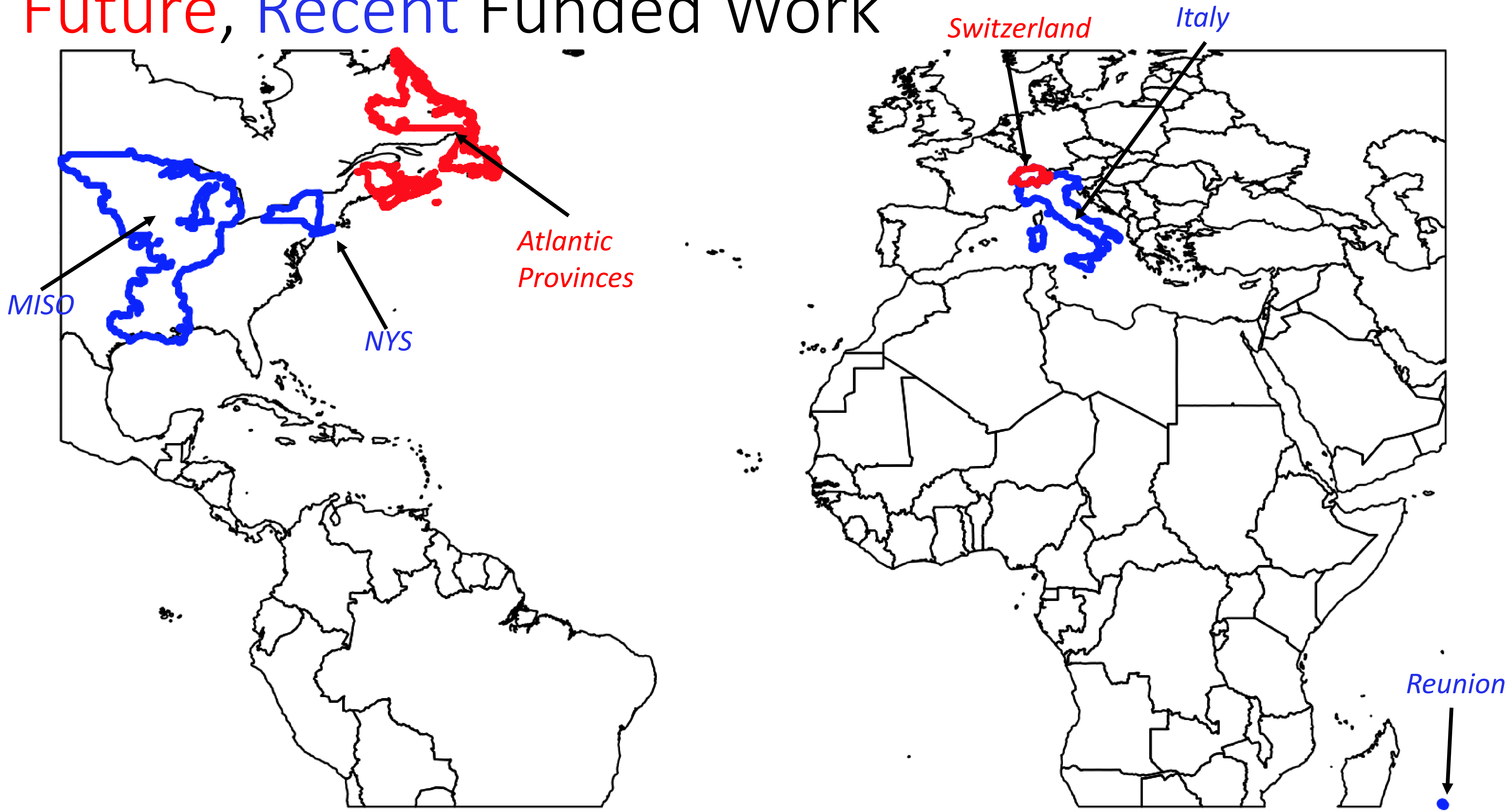
Storage energy component   Storage power component   PV   Wind   Implicit Storage   gas

Key takeaways

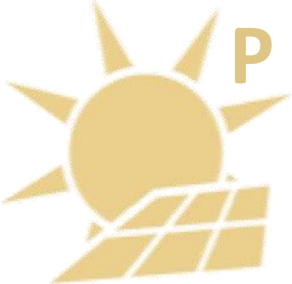
- **The Value of Implicit Storage** Implicit Storage (Overbuilding + Curtailment) is highly cost-effective in every case
- **The Value of Hybridizing Wind+PV** Wind + PV hybrid resourcing is significantly cheaper than either alone due to seasonal resource anticorrelations, even in areas that have a dominant resource. (i.e. MISO North still wound up with 46% PV at the optimal point)
- **The Impacts of 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** In 2050, high technological development scenarios drive PV CapEx so low that even in areas where wind appears dominant, PV is largely favored.
    - This is despite a very strong wind resource in the northern part of MISO territory
    - Exceptions include MISO-North and LRZ 3 and 7 where the very strong wind resource tilts the balance
- **95% Renewables is significantly cheaper** Allowing 5% gas or some other dispatchable gas to perform some of the work otherwise done by storage (both implicit and real). It may also be more acceptable as it correspondingly reduces the amount of optimal curtailment.
- **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*

Future, Recent Funded Work



100% MISO Load



30% Wind 65% Solar 5% Gas

3.5 c/kWh

Clean Energy States Alliance

Using Overbuilding + Curtailment to Achieve 100% Clean Electricity

Case Studies across the midcontinent, isolated islands and New York State

Tuesday 15th December, 2020

Marc Perez, Ph.D.

Clean Power Research®

MN SOLAR PATHWAYS

illuminating pathways to 10% solar

Implementation

Great Plains Institute

10% by 2030,
High Renewables Future by 2050





Opportunities, Constraints to Solar Deployment

1. Utilities
2. Solar industry
3. Residential customers
4. Business customers
5. Advocacy organizations
6. Governments (not State)
7. State agencies
8. Economic development entities

Opportunities and Constraints to Solar Deployment

Local and State Siting

- Barriers to use of marginal lands (such as brownfields)
- Agricultural protection
- Interaction with ecological services
- Interaction with rural character
- Local/distributed/rooftop deployment in cities

Market Integration

- Transmission planning and interconnection barriers
- Project financing: PPAs/Remuneration in an "implicit storage" future

Additional Concerns

- Equity impacts of deployment choices
- Decommissioning/ Recycling uncertainties

Siting Opportunities, Constraints

Deployment barrier: Siting utility scale and community scale solar has faced increasing opposition, and land use conflicts are increasing siting costs and threatening deployment goals.

- **Prime farmland exclusion rule**
- **Agricultural practices and economic development**
- **Natural resource conflicts or concerns**
- **Rural character and property value conflicts**
- **Limited access to brownfield redevelopment opportunities**

Energy Market Opportunities, Constraints

Deployment barrier: ISO market rules, transmission planning, project finance and risk standards don't necessarily contemplate an "implicit storage" future

- **High curtailment rates**
- **Dispatch rules**
- **Changes in transmission planning**
- **Structure of purchase power agreements**
- **Financial risks in a high curtailment future**

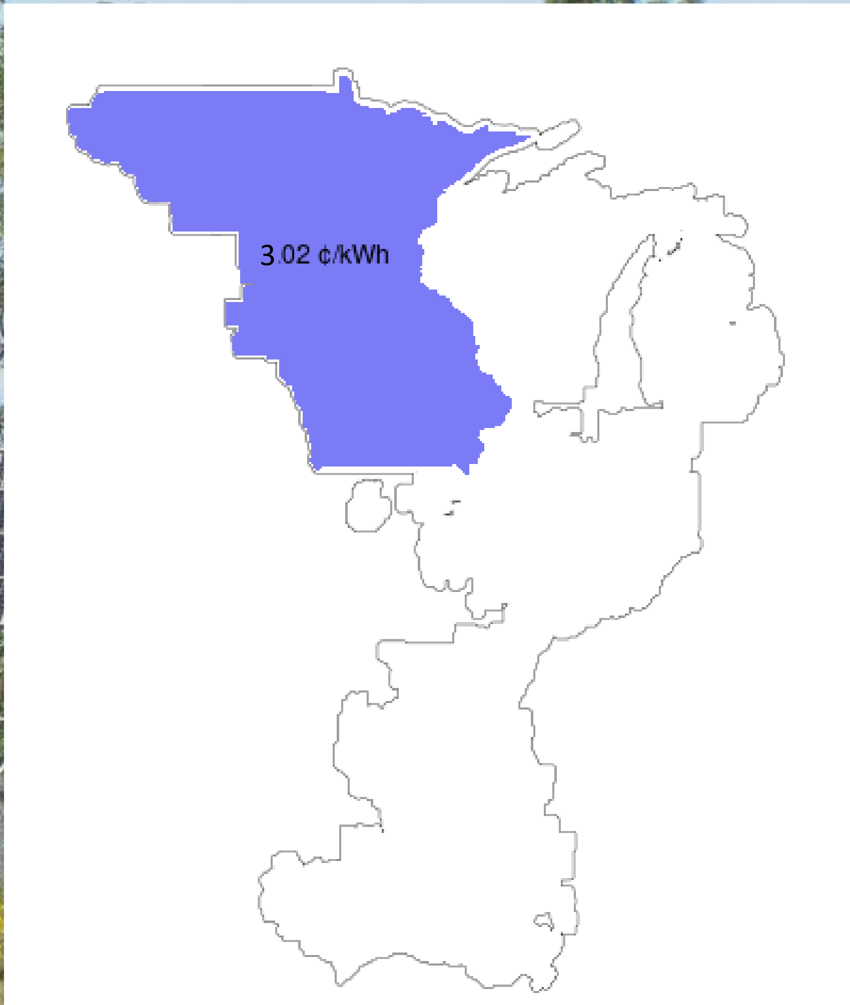
Additional Considerations of Deployment Choices

Deployment barrier: Uncertain downstream impacts of deployment choices raised high visibility concerns.

- **Equity impacts of different deployment choices: are we fixing problems, or exacerbating them?**
  - **Who pays? Who benefits?**
  - **Transition costs and assess to**
- **Concerns about long term risks or perceived risks** (mainly at the local level)
  - **decommissioning,**
  - **electronic waste disposal**

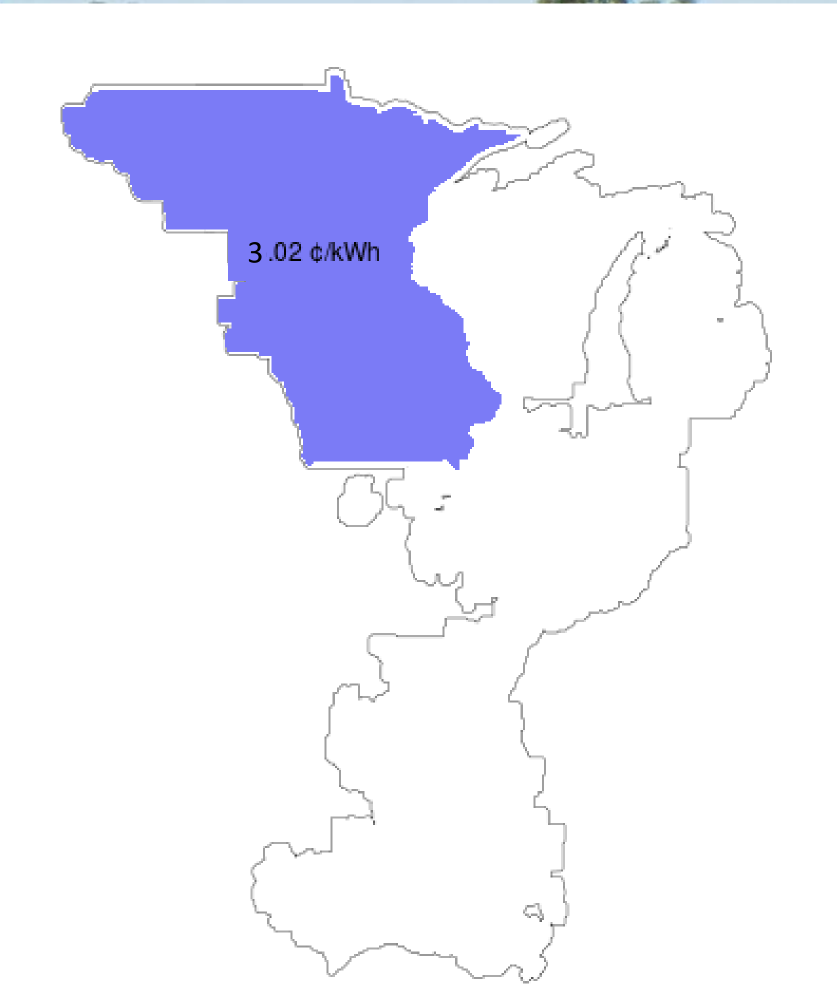
Implementing Implicit Storage

- MISO North region (MN, IA, N.D.)
- Optimizing wind/solar mix
- 95% Renewables
- 2050 year of interest



Siting Implicit Storage

- 128% of load
- Optimal curtailment – 22%
- 24.1 GW deployed wind capacity
- 51 GW deployed solar capacity
- 49 GW of new utility/ community scale solar
- **343,000 – 490,000 acres of solar development**



Siting Partnerships

Different venues for different authorities

- State siting authority (currently 50 MW threshold)
  - ✓ Prime farmland exclusion rule as a siting barrier
  - ✓ Natural resource and water quality protections,
  - ✓ consideration of local standards and community input
- Local siting authority (under 50 MW threshold)
  - ✓ Agriculture as economic base
  - ✓ Community character and visual impacts
  - ✓ Development opportunity costs
  - ✓ Natural resource protection

Siting Partnership

Brightfields as siting alternative

- ✓ Approximately 8,000 acres of closed landfills and associated buffer areas in 120 sites under Pollution Control Agency oversight or ownership
- ✓ Other states have seen significant solar development on closed landfills and other brownfields
- ✓ Financial and administrative barriers have limited solar development of these sites in Minnesota

Brightfields

Closed landfills as development opportunity

- ✓ Created legislative initiatives for site-specific analysis of 120 closed landfills managed by MPCA, prioritization of sites for development
- ✓ Creating Minnesota best practices for brightfield development
- ✓ Changing cleanup and assessment of brownfields to accommodate solar development

Siting Partnerships

Solar+Natural Resources (Ecological Services)

- ✓ Partnership discussion - 12-15 natural resource advocates, agencies, stakeholders
- ✓ Five uses cases considered, each use case having different co-benefit potential
- ✓ All presented significant deployment opportunities, on scale with the deployment needs

Use Cases for Natural Resource Integration

1. Drinking water protection in nitrate contamination areas
2. Surface water protection in impacted watersheds to serve as infiltration areas or buffers
3. Carbon sequestration and soil restoration
4. Habitat buffers and restoration of function around core habitat areas
5. Growth management to limit sprawl and protect rural character

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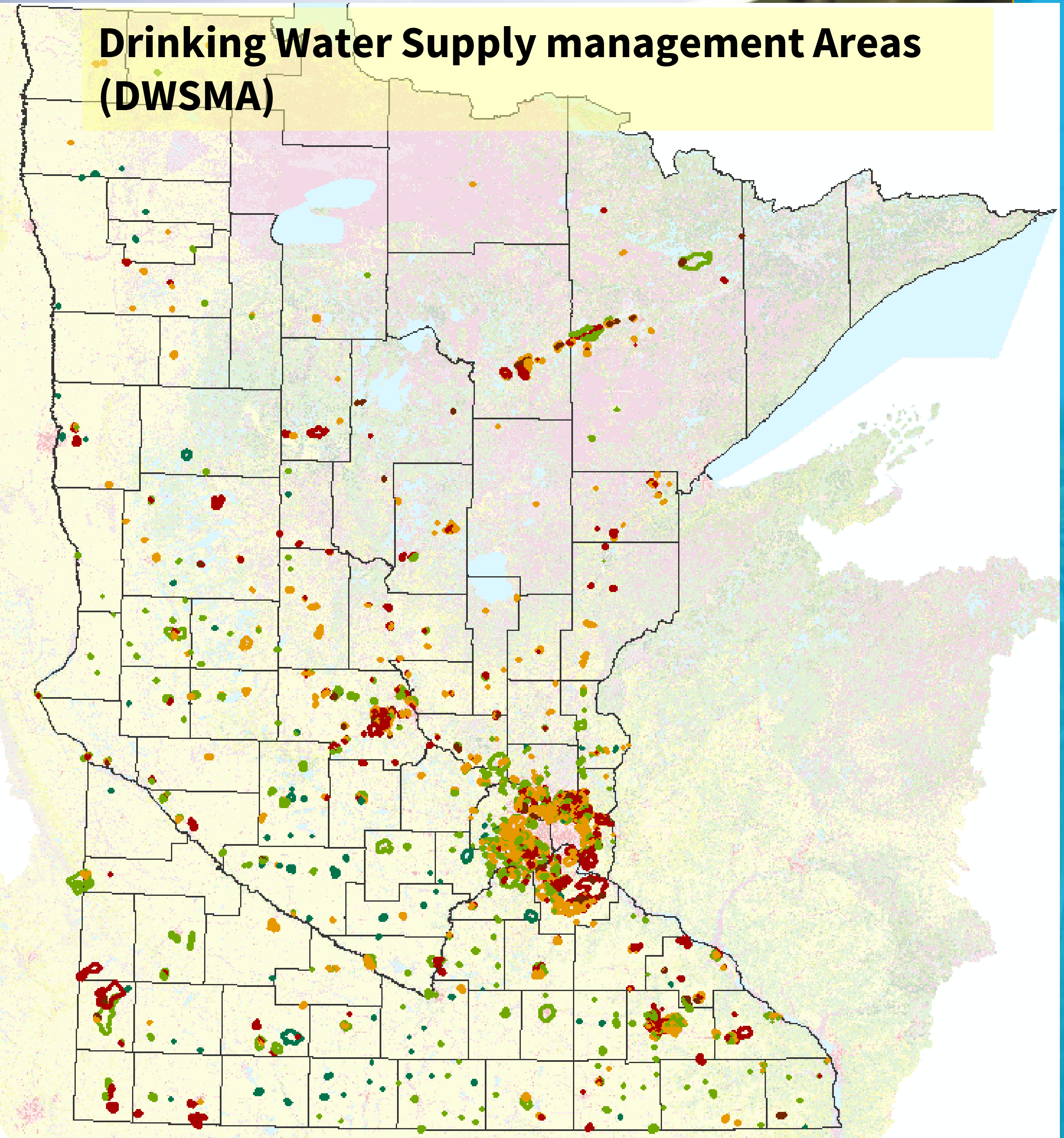
Photo credit: Brian Ross



Locate solar in source water protection zones.

- Size of opportunity: 118,000 acres

Pathway to Implementation

- Map vulnerable and highly vulnerable Drinking Water Supply Management Areas with interconnection opportunities.
- Facilitate discussion between source water organizations, local communities, funders, solar developers, local utilities.

Possible Near Term Next Steps

- Create site design and management standards for source water protection
- Identify low risk, low barrier opportunities
- Pilot a project.

Photo credit: Katharine Chute

Documenting Water Quality Best Practices

PV Stormwater Management Research and Testing (PV-SMaRT)

National study to identify stormwater management best practices for achieving water quality benefits.

Three-year study funded by DOE

- Scientific measurement of storm water infiltration and runoff under a variety of ground covers, soil types, hydrologic regimes, and solar designs.
- Evaluation of water quality regulation in five states across the country (including MN)
- Create solar design and siting best practices that can be compliance pathways for water quality regulation
- Turn water quality into a solar development asset rather than a perceived liability.

THANK YOU

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Thank you for attending our webinar

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Upcoming Webinars

Closing the Energy and Transportation Affordability Gap for Connecticut's Low- and Moderate-Income Households
Thursday, December 17, 1-2pm ET

Solar+Storage Fire Safety Training: Single and Multifamily Residential
Tuesday, January 12, 1-2pm ET

Applying New Data from NREL's State and Local Planning for Energy (SLOPE) Platform
Wednesday, January 27, 1-2pm ET

Read more and register at: www.cesa.org/webinars

Clean Energy States Alliance