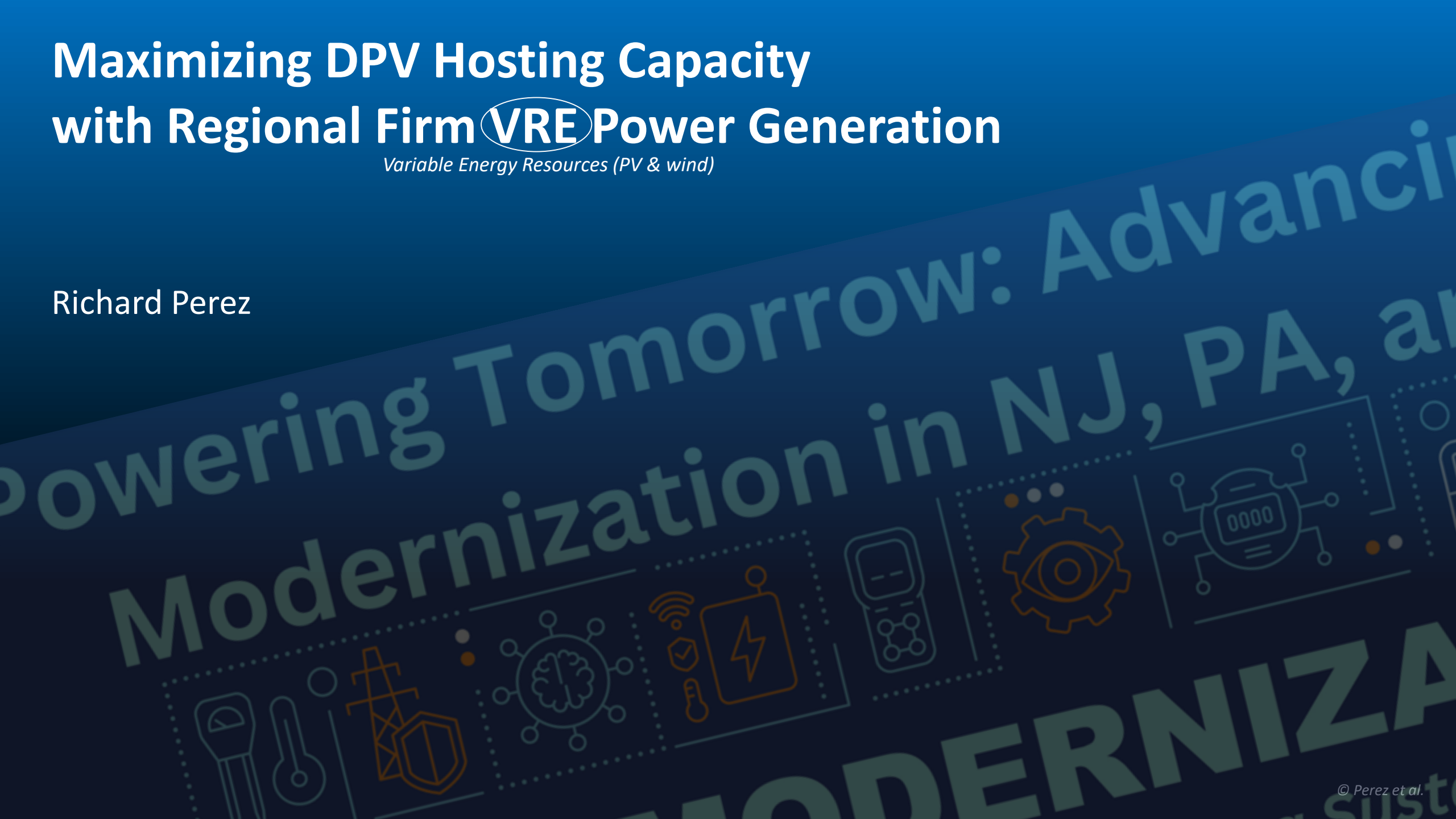
Maximizing DPV Hosting Capacity with Regional Firm VRE Power Generation

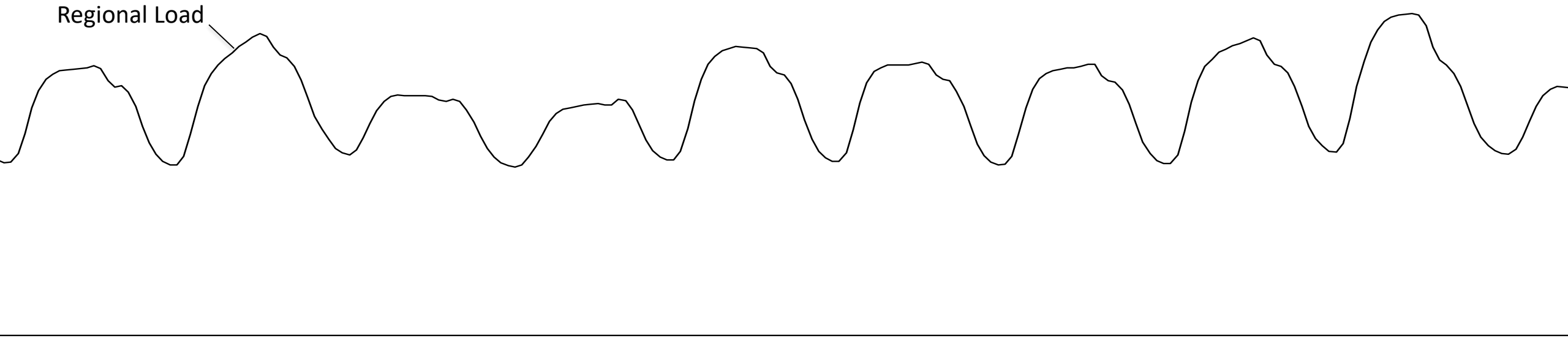
Variable Energy Resources (PV & wind)

Richard Perez

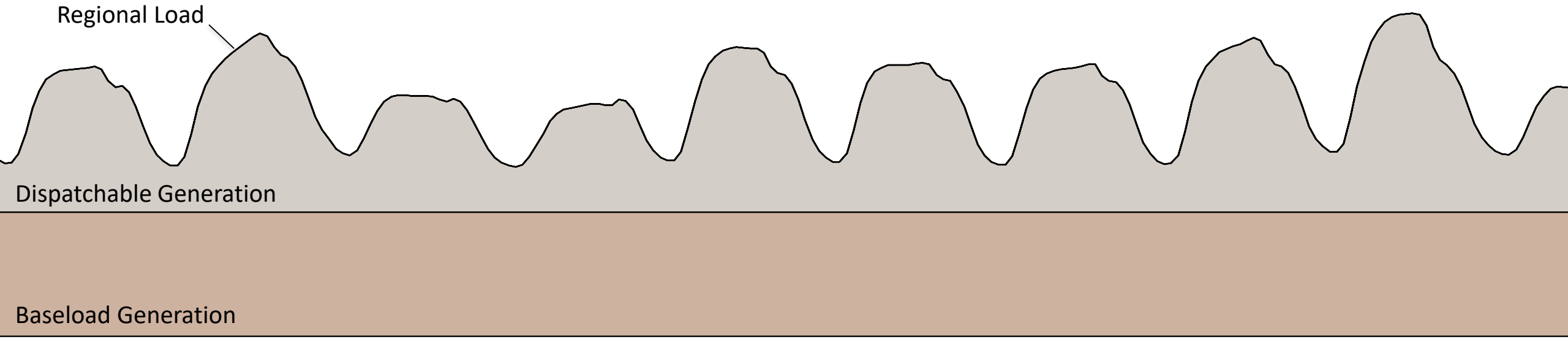


Intermittent vs. Firm VRE Power Generation

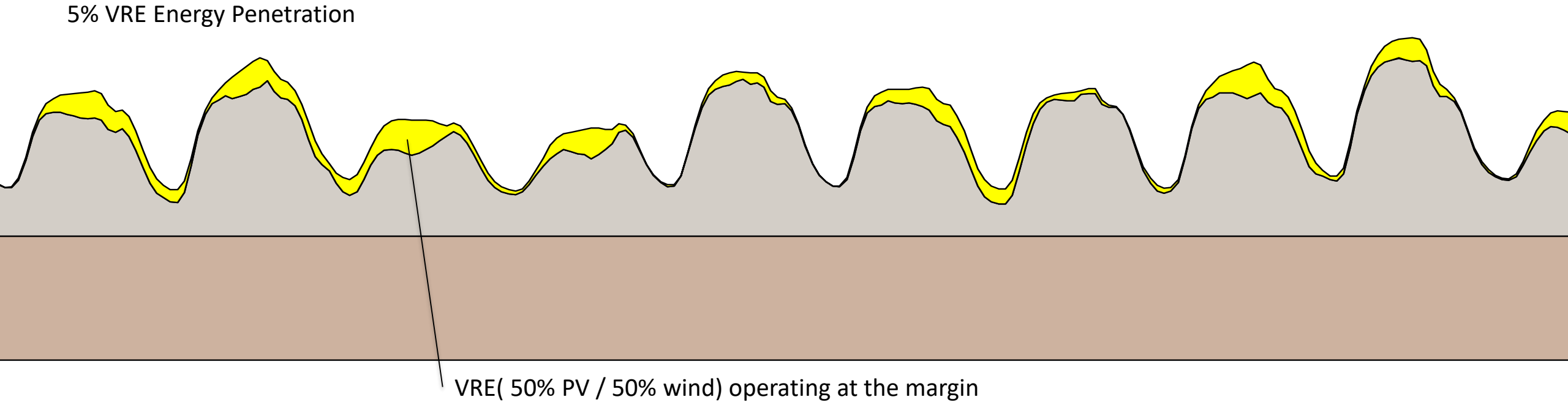
Intermittent VRE Power Generation



Intermittent VRE Power Generation

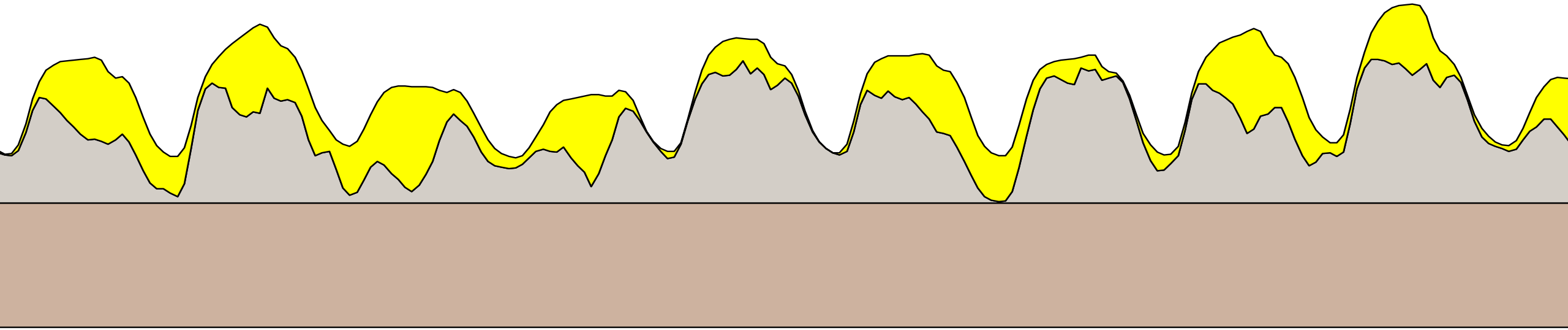


Intermittent VRE Power Generation at the Margin



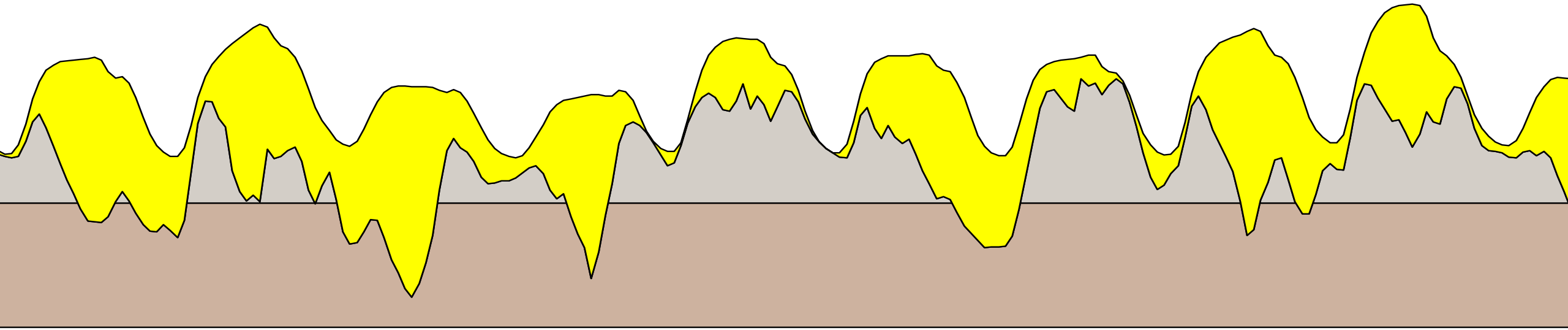
Intermittent VRE Power Generation at the Margin

15% VRE Energy Penetration



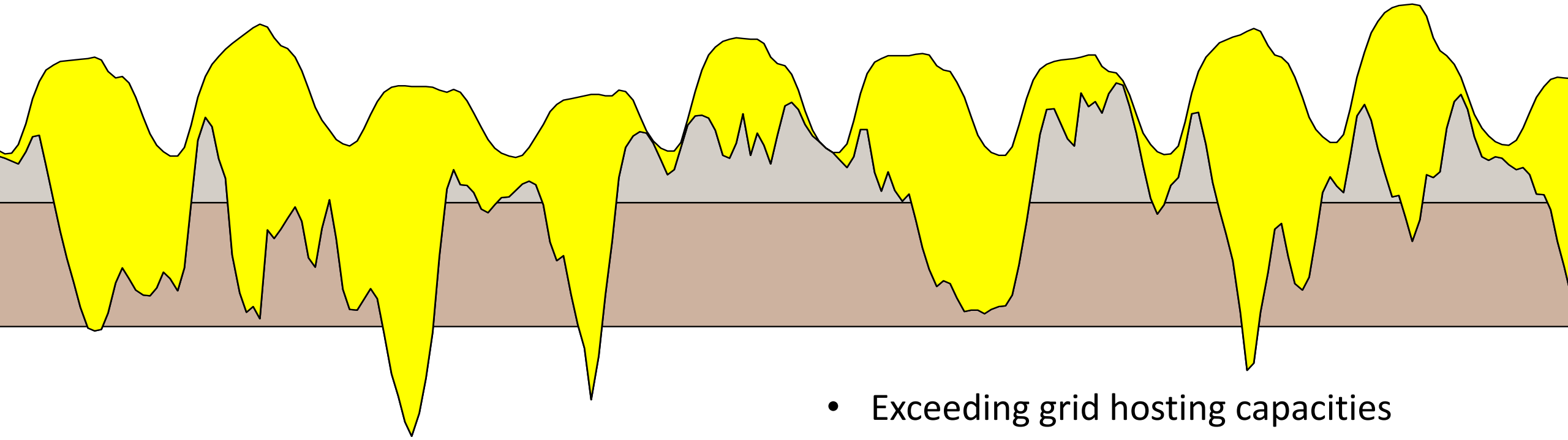
Intermittent VRE Power Generation at the Margin

30% VRE Energy Penetration

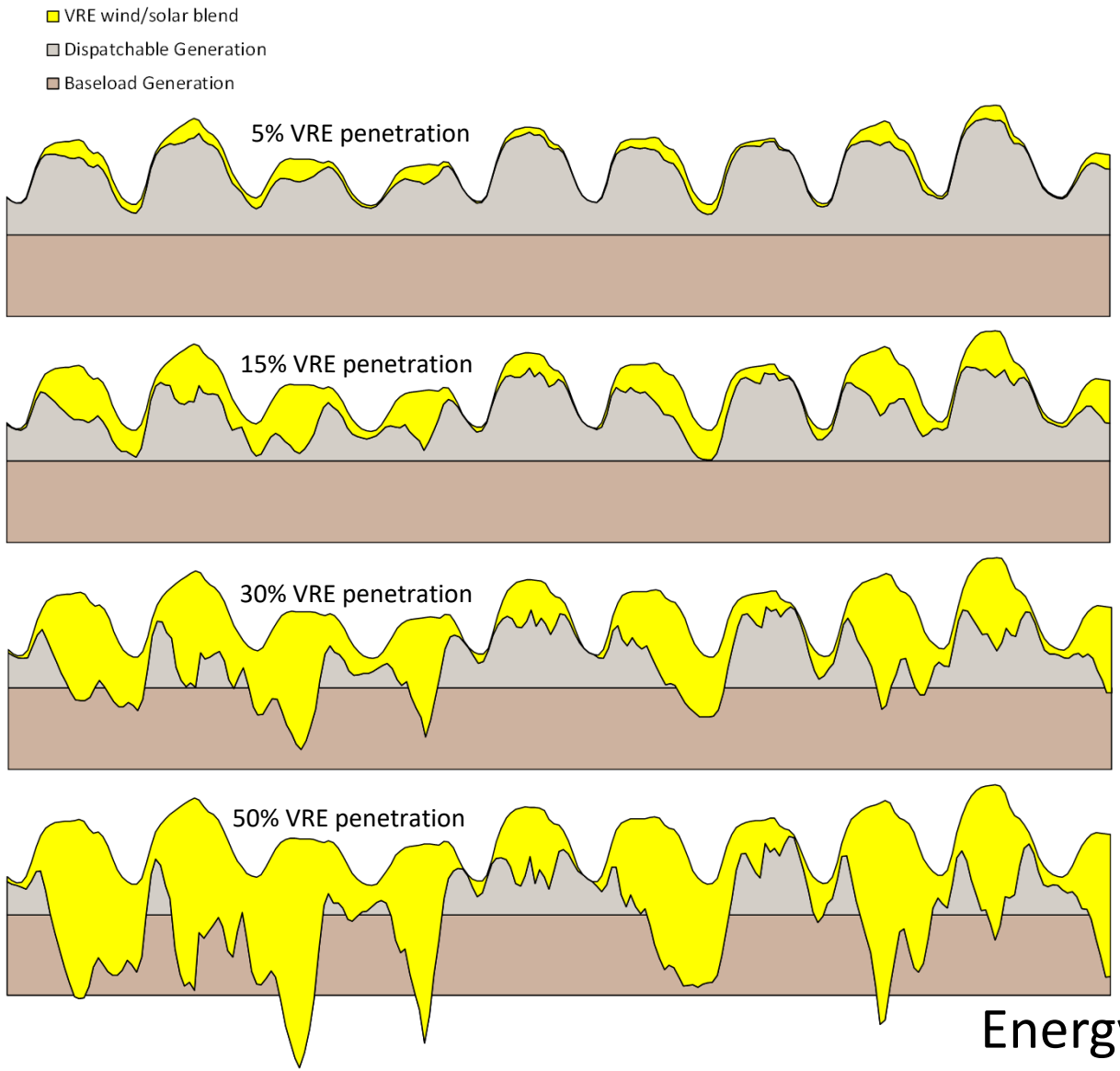


Intermittent VRE Power Generation at the Margin

50% VRE Energy Penetration

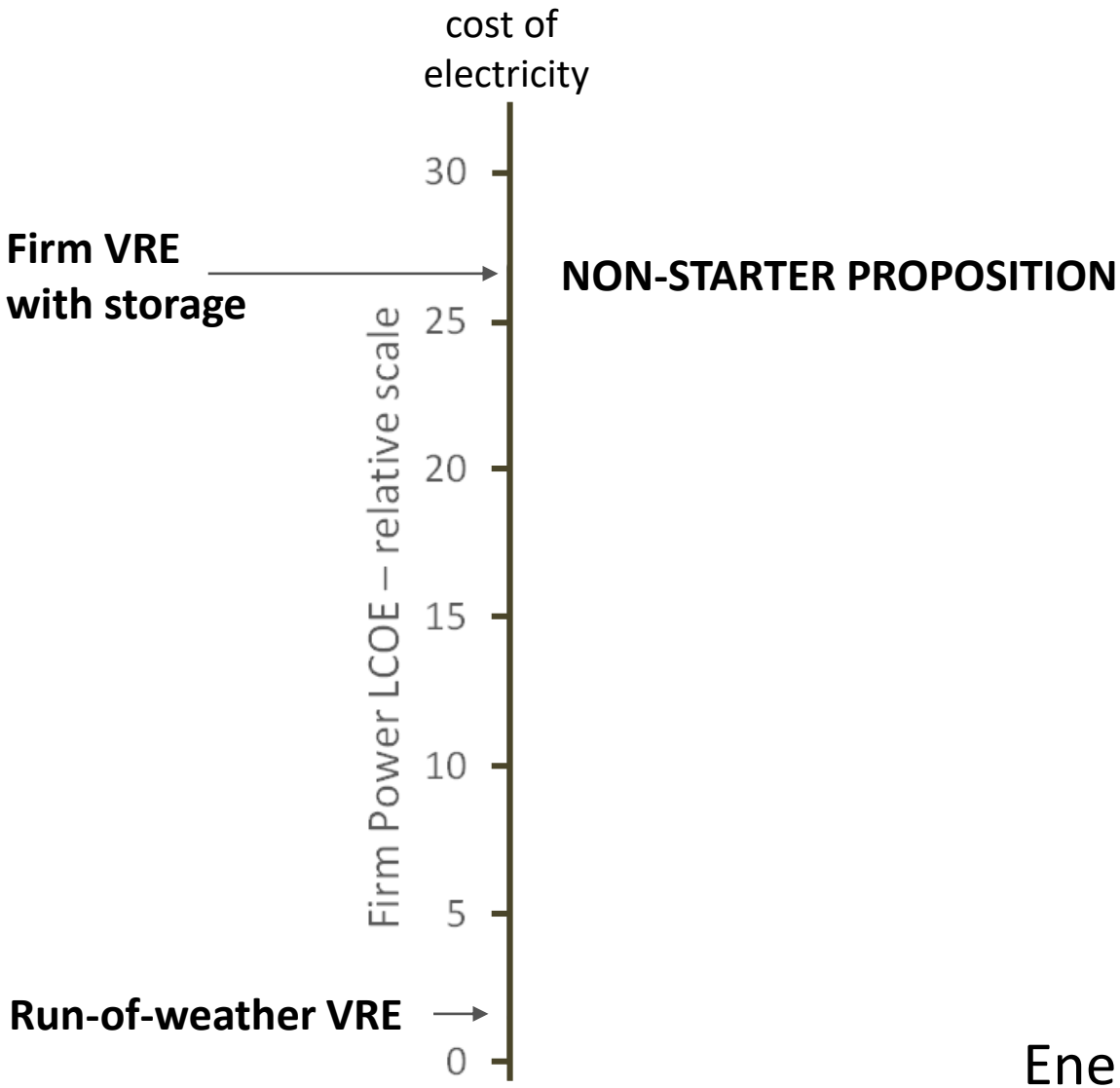


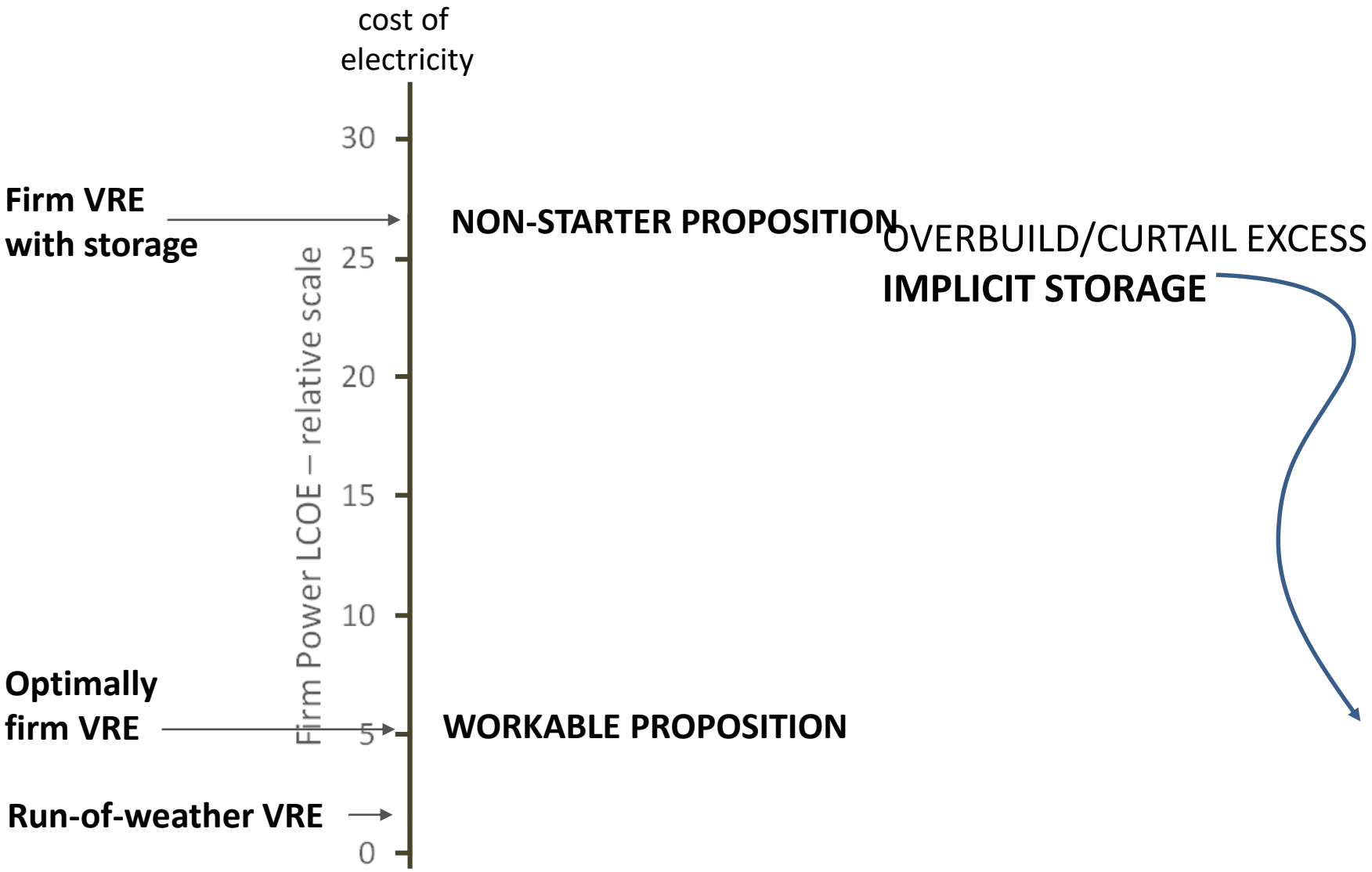
- Exceeding grid hosting capacities
- Negative market prices
- Reactive VRE curtailments
- Deployment moratoriums

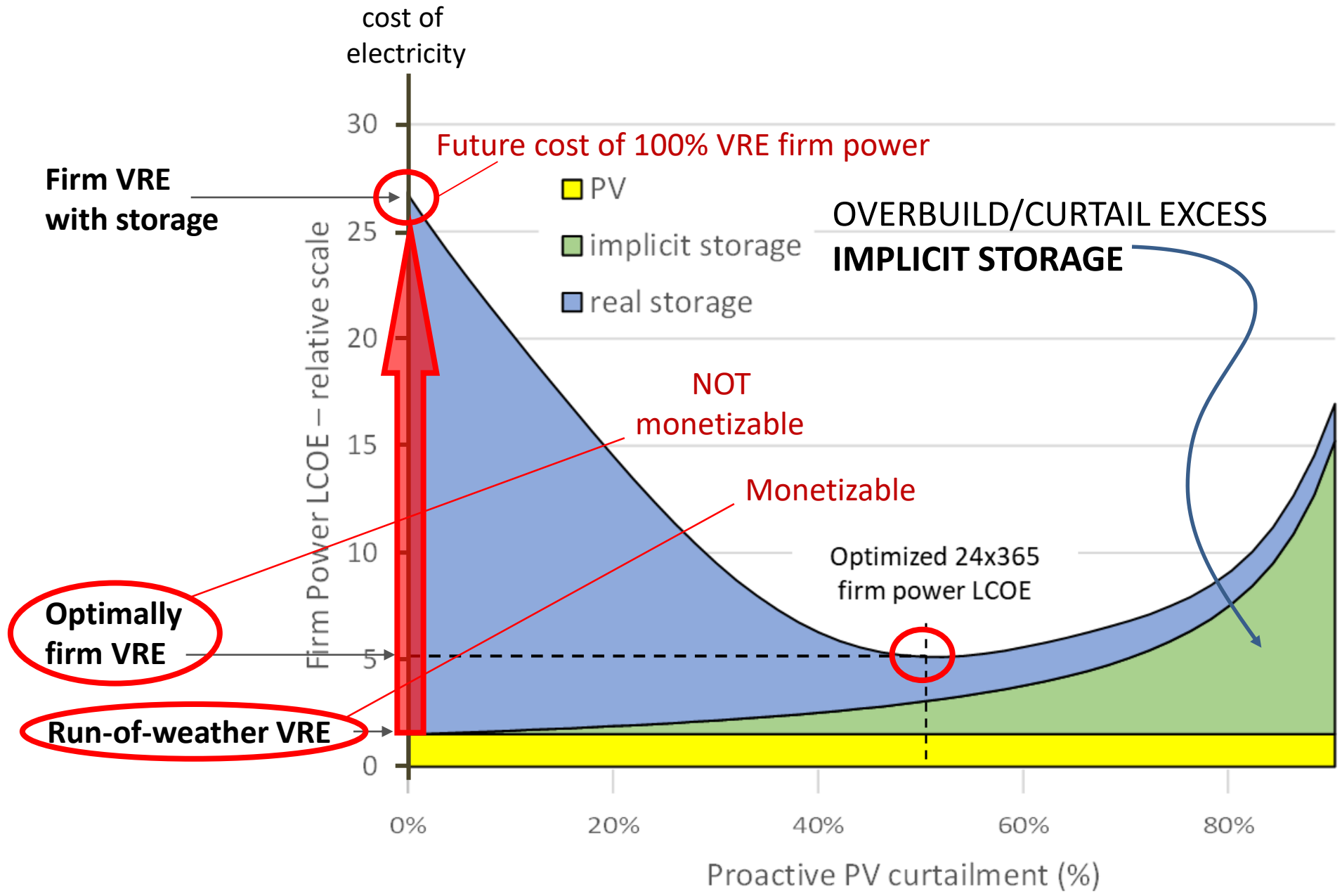


Energy Storage

UNCONSTRAINED VRE → ? → FIRM VRE


cost of
electricity
30
25
20
15
10
5
0
Firm Power LCOE – relative scale
Firm VRE
with storage
NON-STARTER PROPOSITION
Run-of-weather VRE
Energy Storage


cost of electricity
30
25
20
15
10
5
0
Firm Power LCOE – relative scale
Firm VRE with storage
NON-STARTER PROPOSITION
OVERBUILD/CURTAIL EXCESS
IMPLICIT STORAGE
Optimally firm VRE
WORKABLE PROPOSITION
Run-of-weather VRE



IEA PVPS

24/365 100%RE Solutions

MISO - North USA 2040
55%PV 45%Wind 5%e-fuel
4.5 cents per kWh

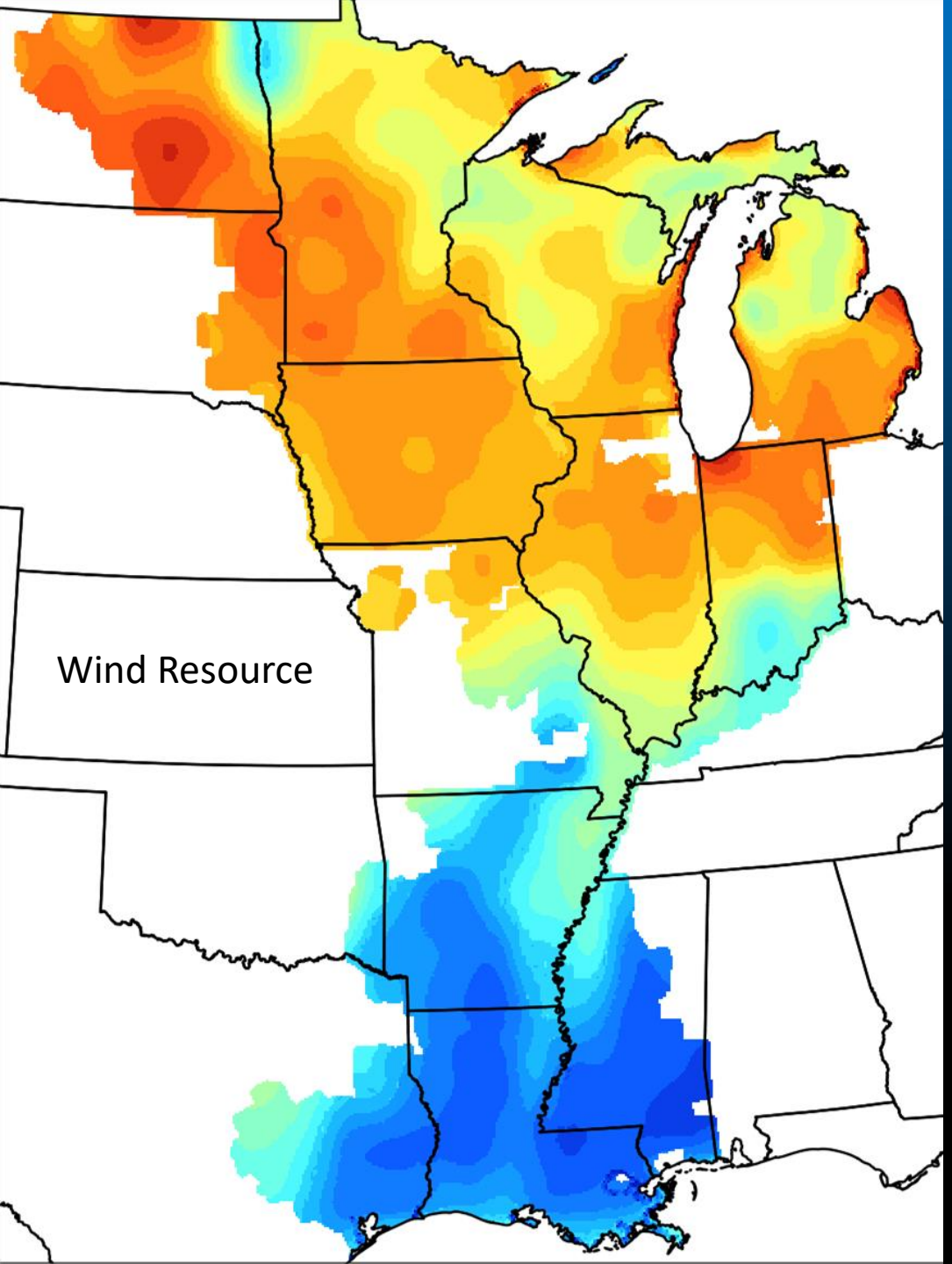
Switzerland 2040
45%PV 45%Hydro 10%e-fuel
7 cents per kWh

Northern China 2040
100% PV
6 cents per kWh

Subtropical Islands 2035
100% PV
5 cents per kWh

Italy 2040
60%PV 25%Wind 15% Hydro
4.5 cents per kWh

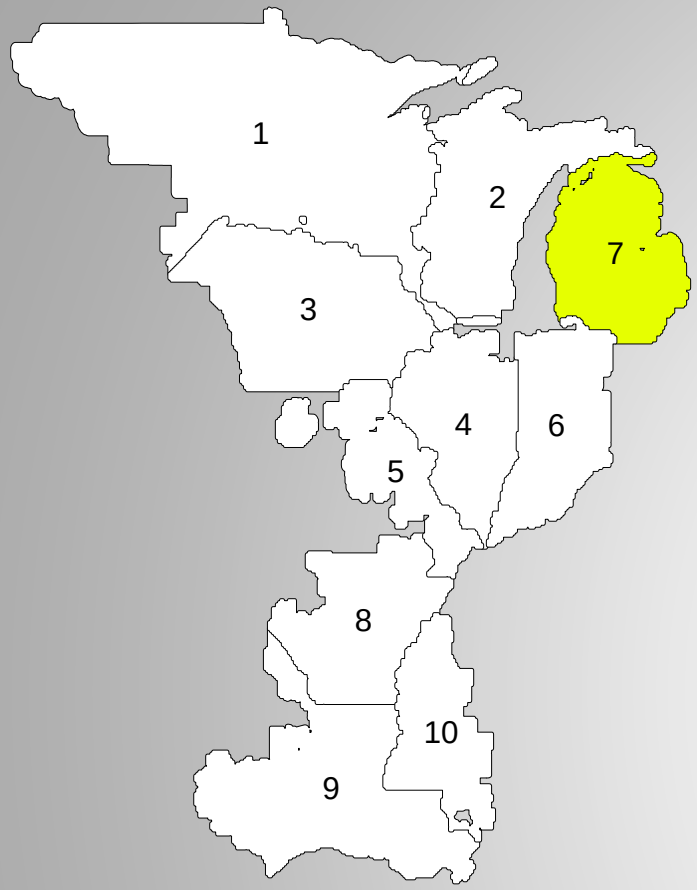
East Australia 2050
100% PV/Wind blend
3.8 cents per kWh



MN SOLAR PATHWAYS US Dept. of Energy

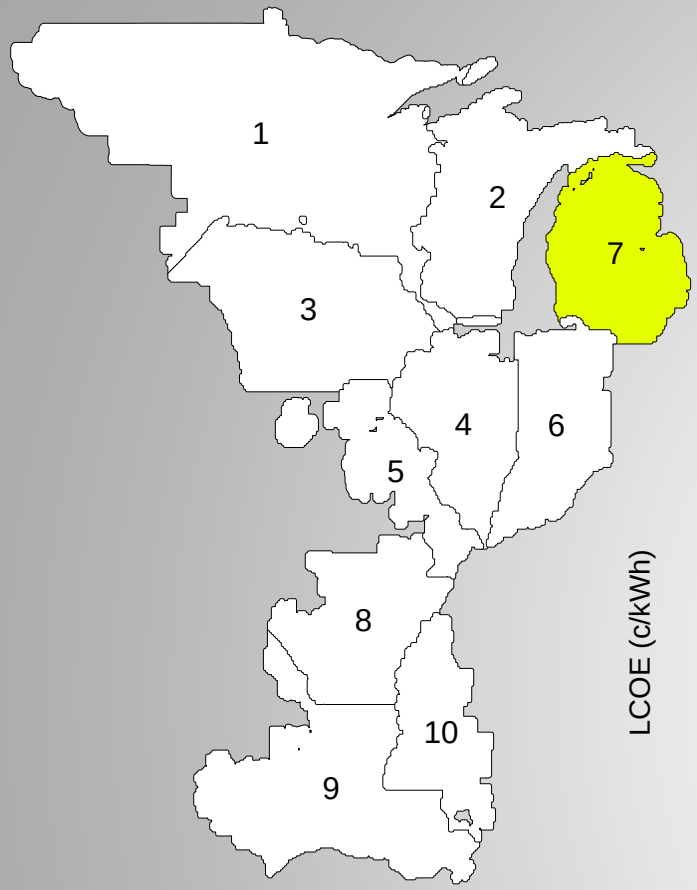
- [nearly] 100% Renewables
- Solar PV + wind
- Impact of (PV/wind/storage) technology costs
  - 2025 low tech development
    PV: $1050/kW Wind: $1,500/kW Storage: $175/kWh
  - 2050 high tech development
    PV: $360/kW Wind: $800/kW Storage: $40/kWh
- Flexibility: Keep 5% dispatchable gen

24/365 Power

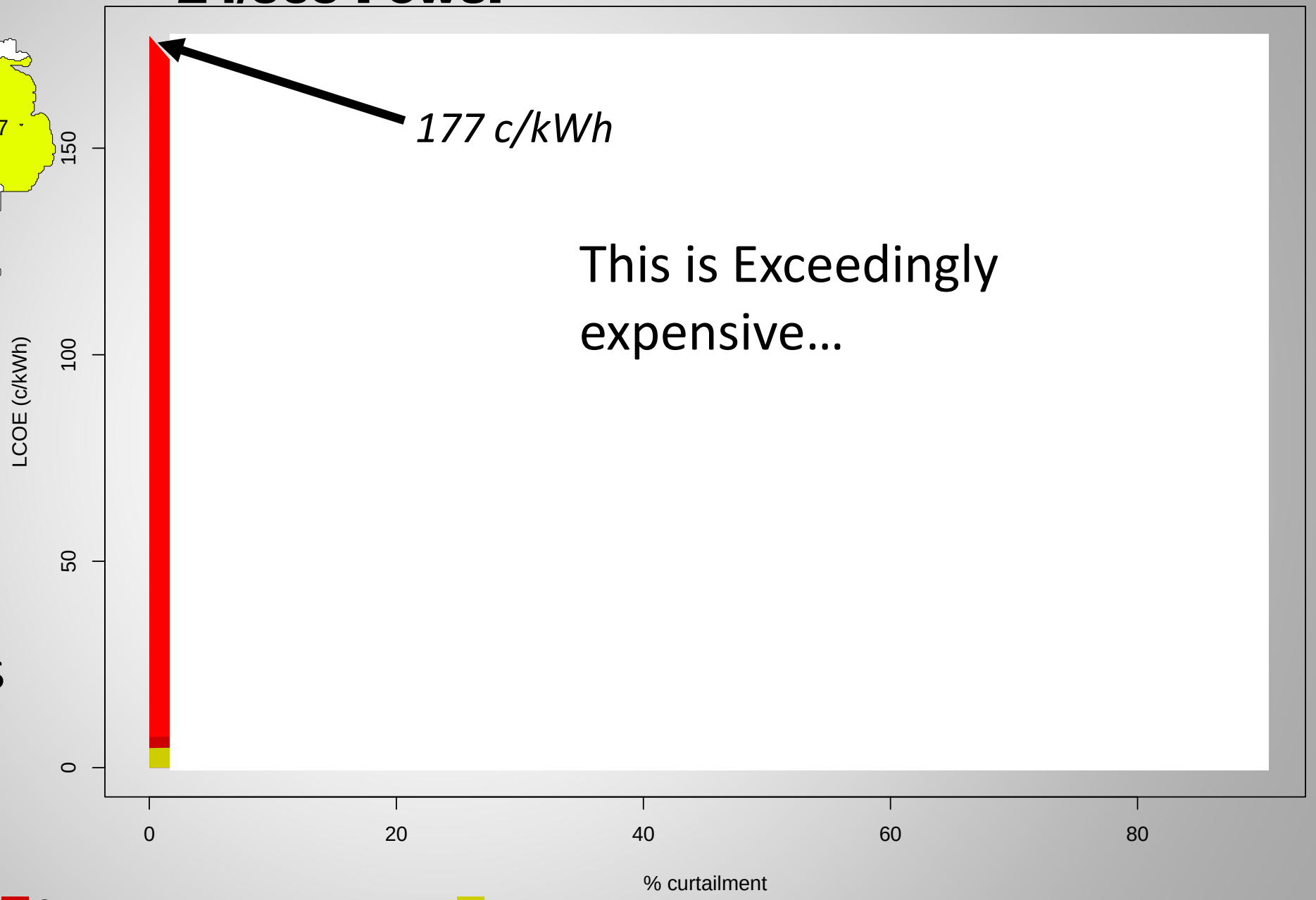


Consider LRZ 7

- 2025 low tech $$
- Just PV
- No overbuild



24/365 Power



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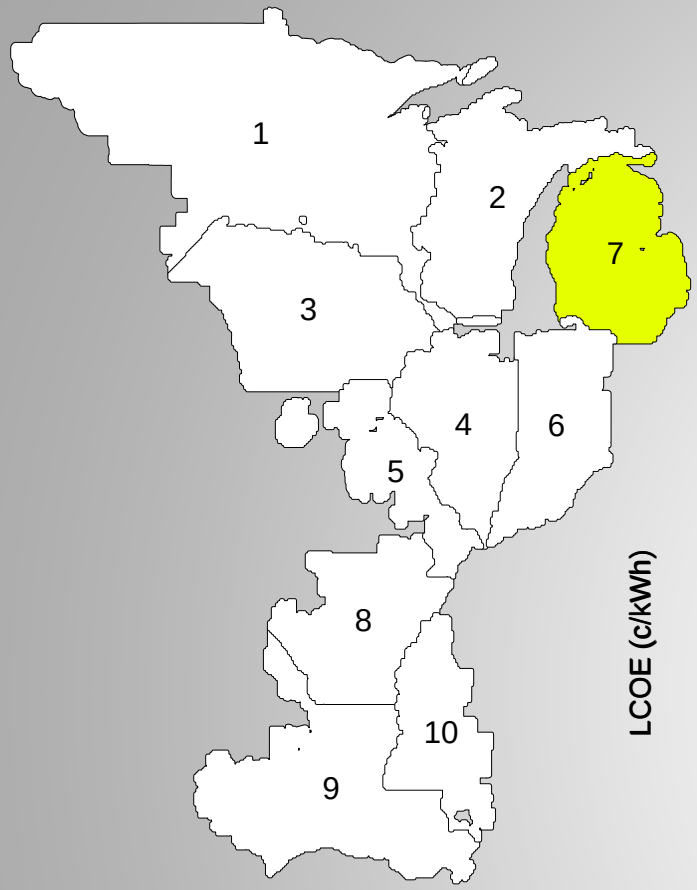


24/365 Power

Implicit Storage is very economical

26.9 c/kWh

LCOE (c/kWh)

0
50
100
150

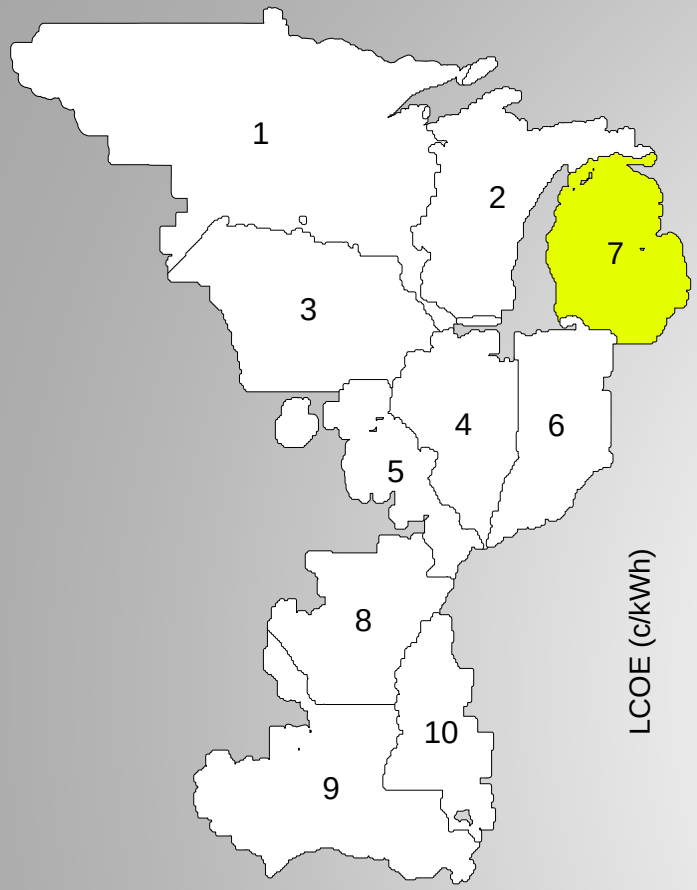
0
20
40
60
80

% curtailment

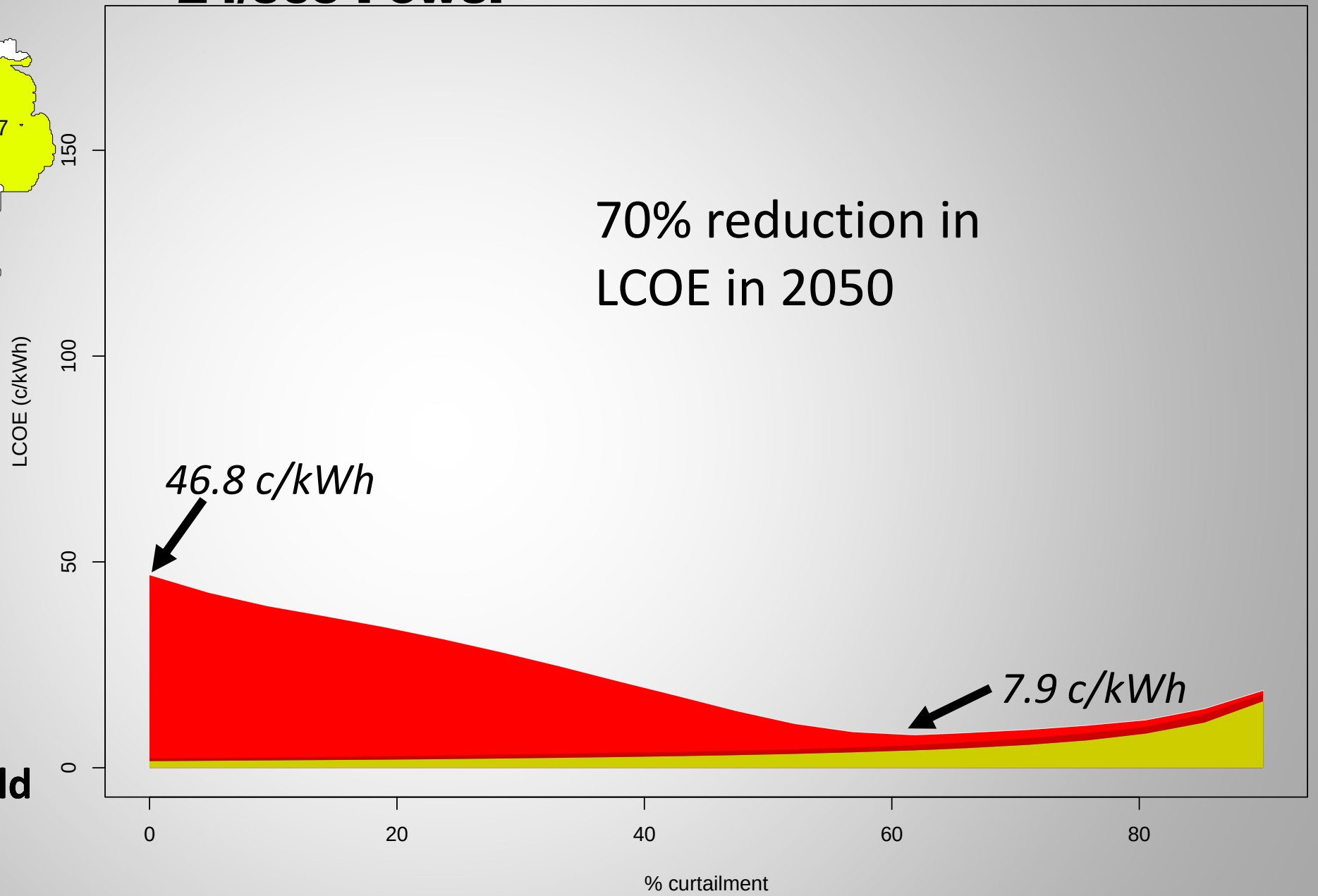
Storage energy component
Storage power component
PV
Implicit Storage

Consider LRZ 7

- **2050 lowest $$**
- Just PV
- **Optimal overbuild**

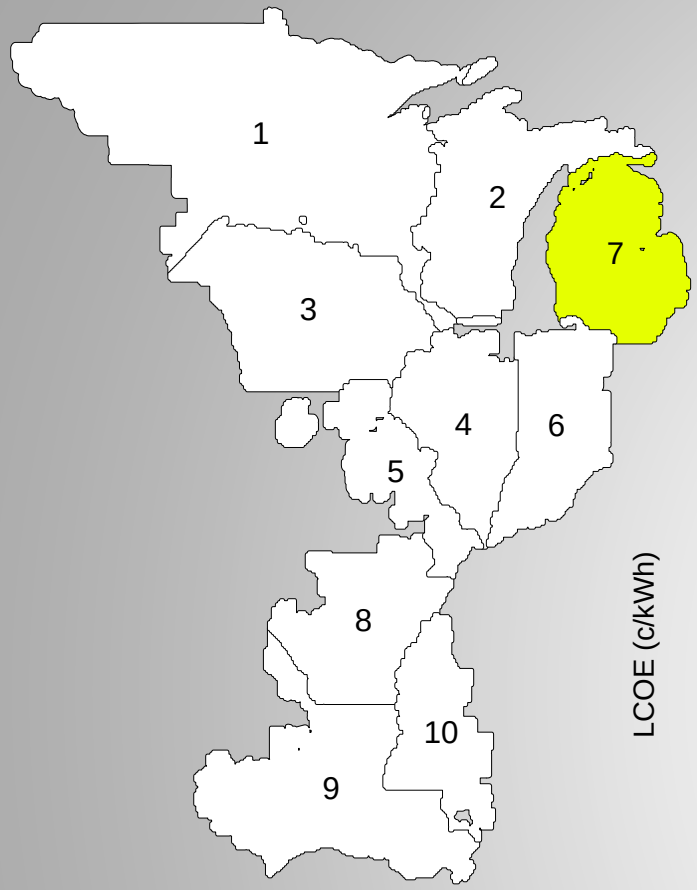


24/365 Power

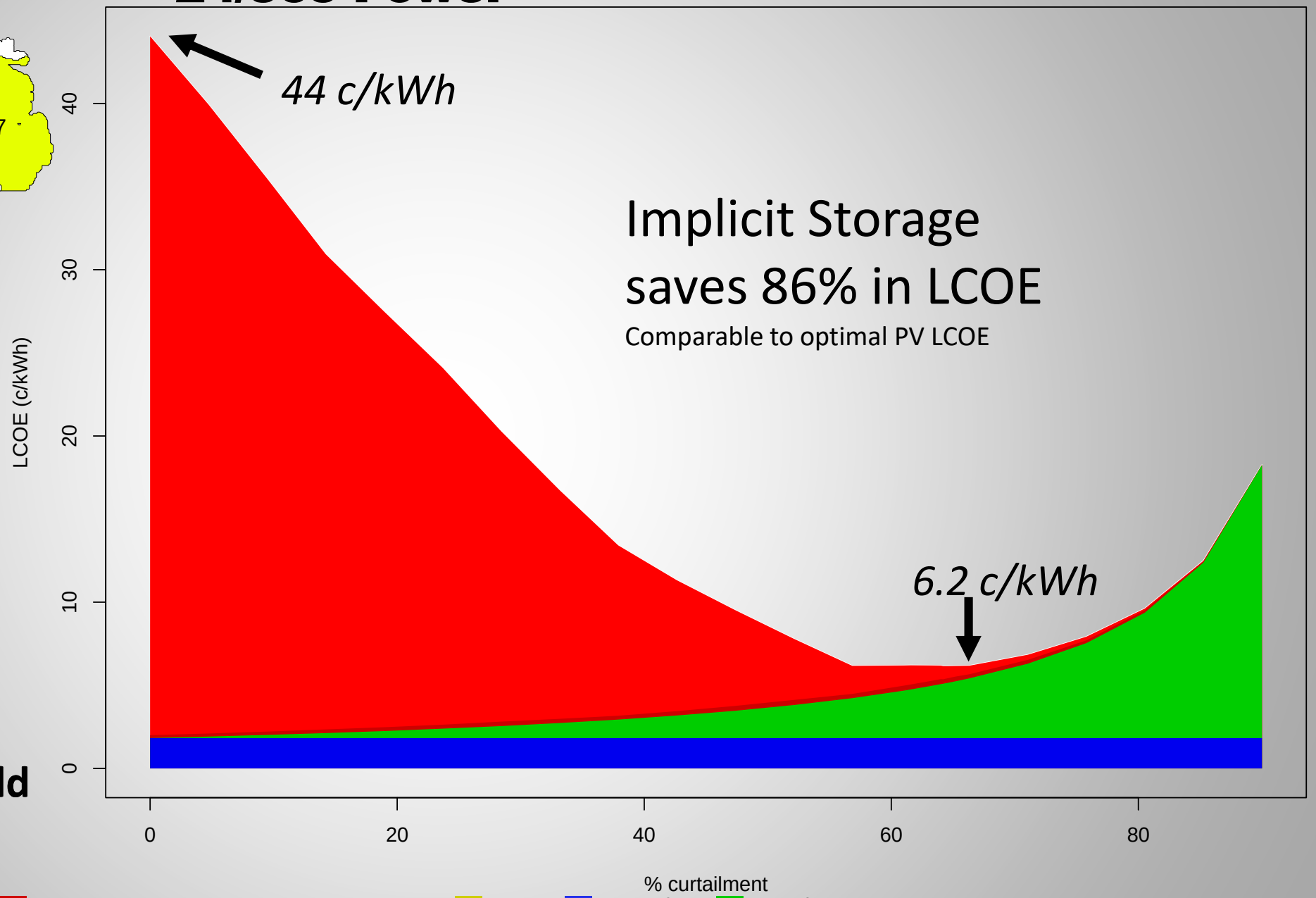


Consider LRZ 7

- **2050 Hi tech $$**
- **JUST WIND**
- **Optimal overbuild**

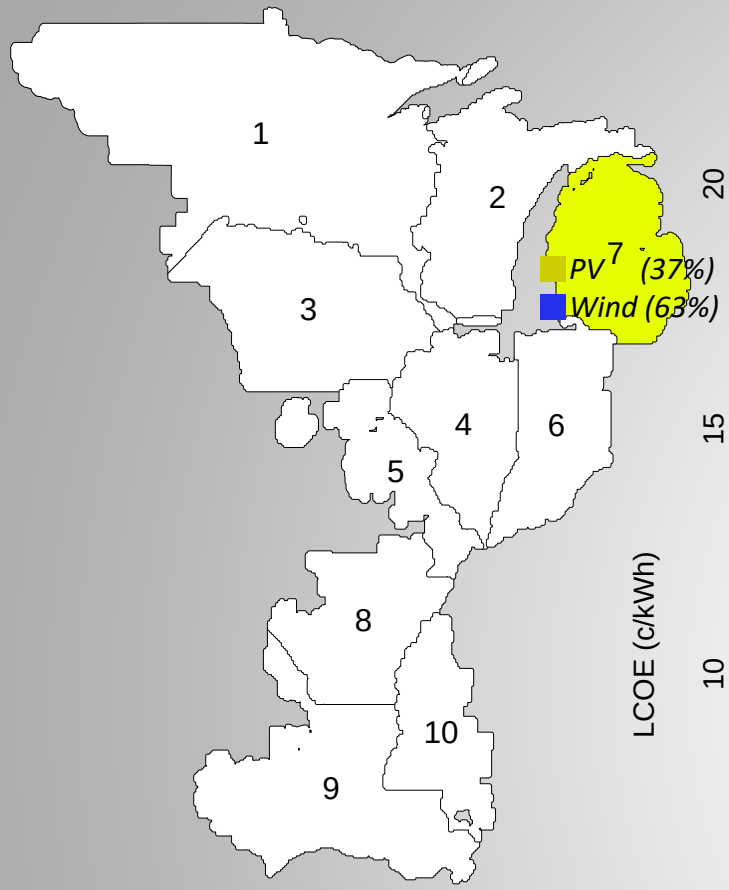


24/365 Power



Consider LRZ 7

- **2050 Hi tech $$**
- **Just WIND/PV**
- **Optimal overbuild**



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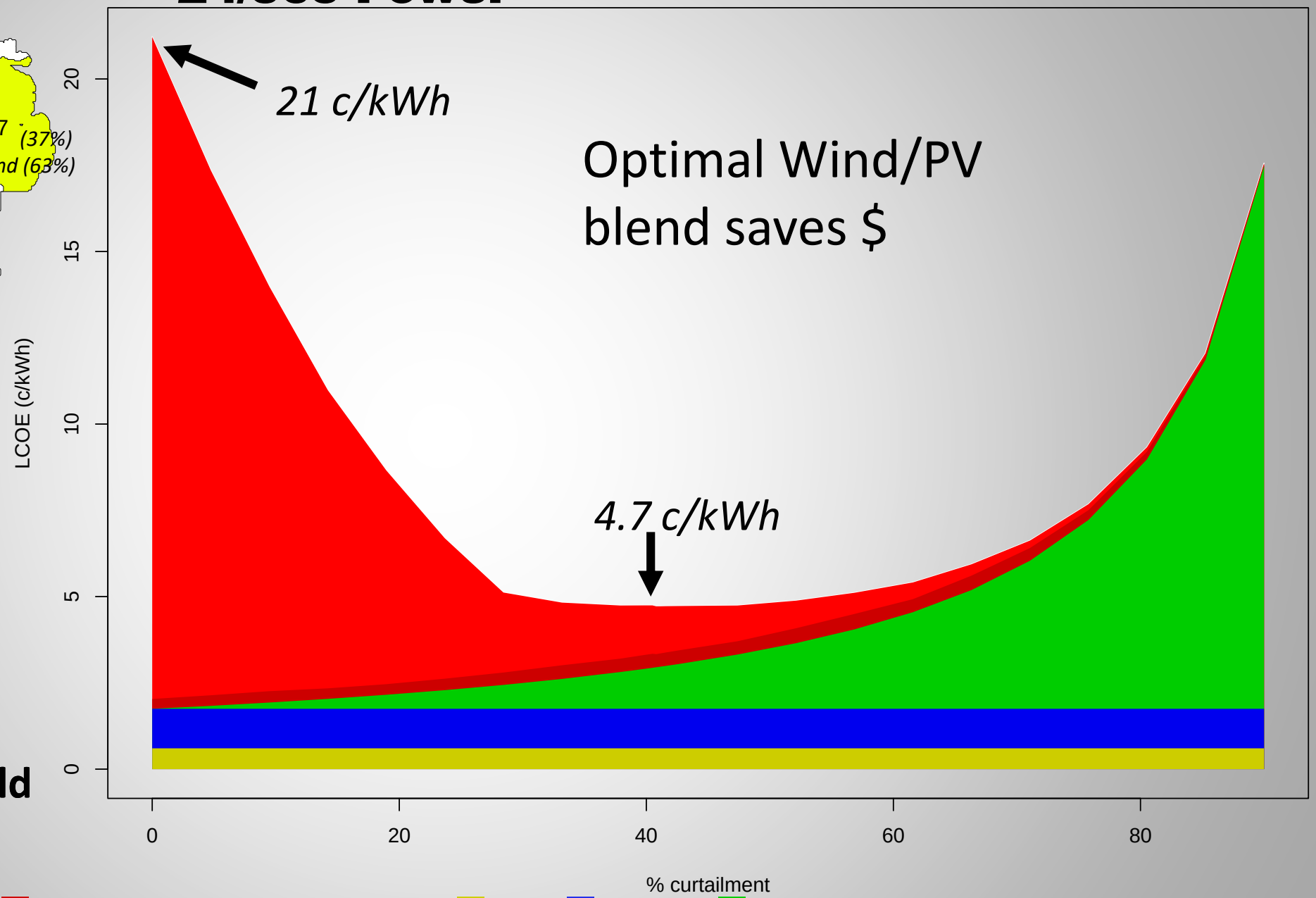
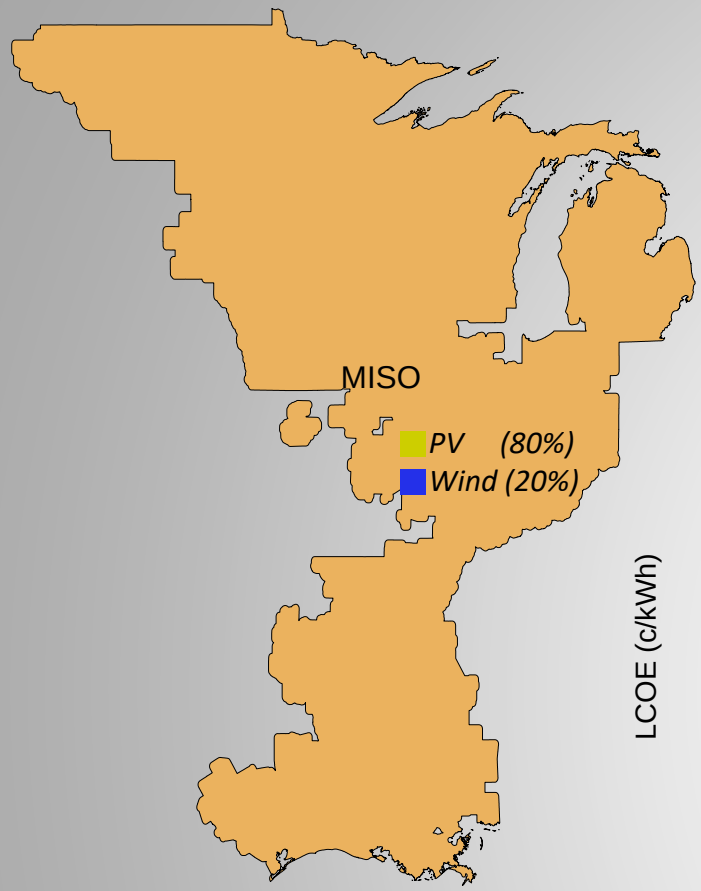


Consider MISO

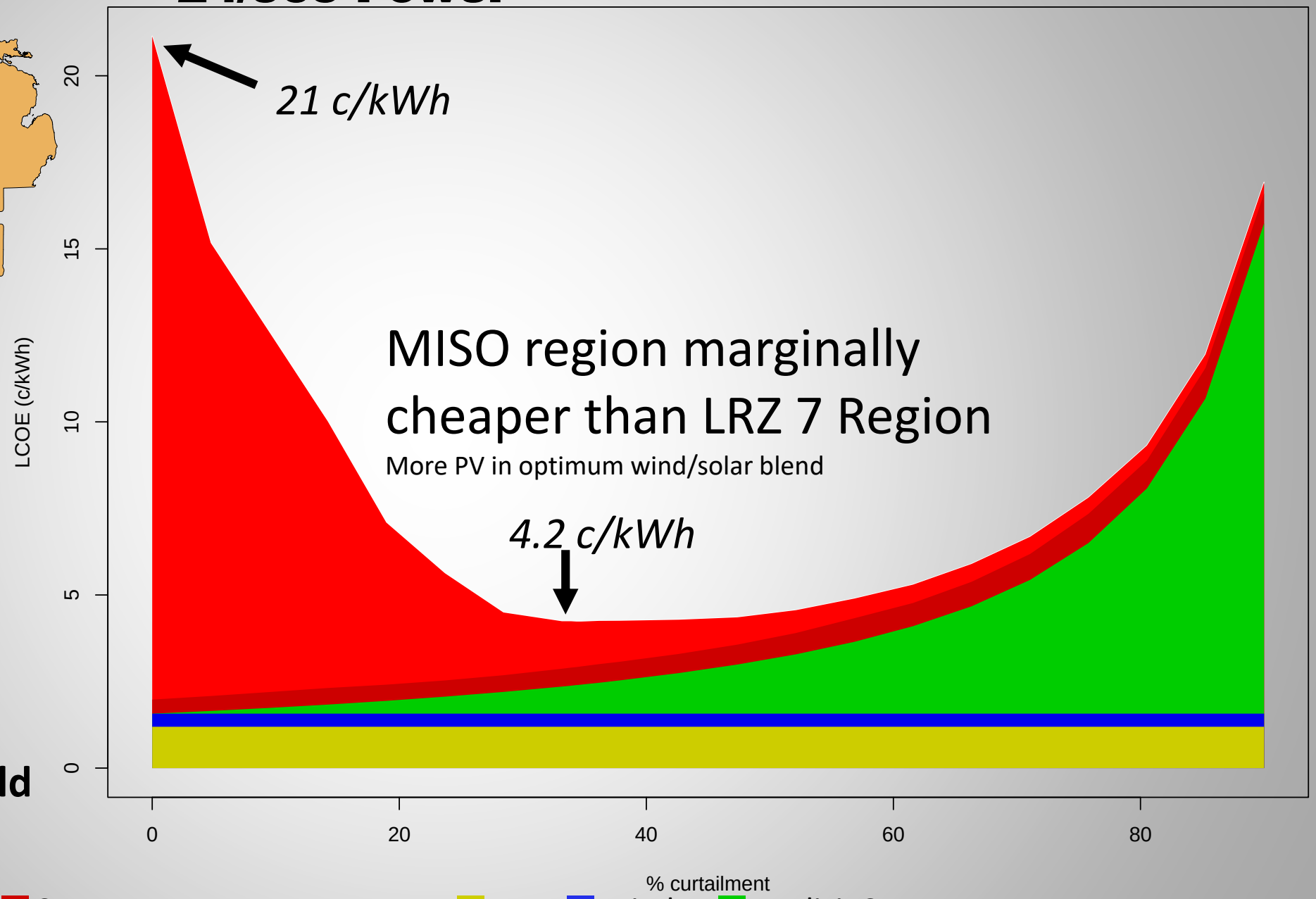
- 2050 Hi tech $$
- Opt. WIND/PV
- Optimal overbuild

24/365 Power

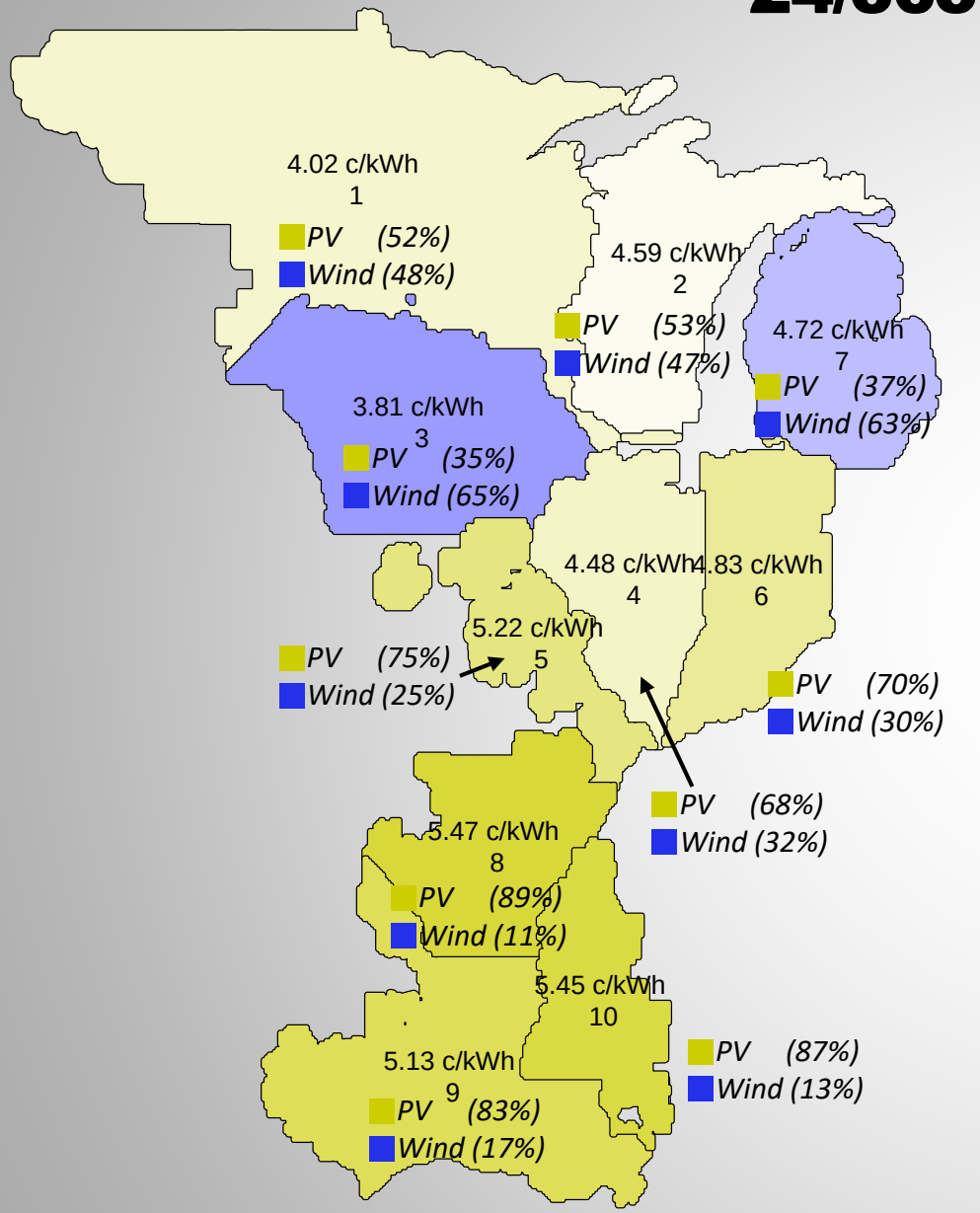


Consider MISO

- 2050 Hi tech $$
- Opt. WIND/PV
- Optimal overbuild



24/365 Power



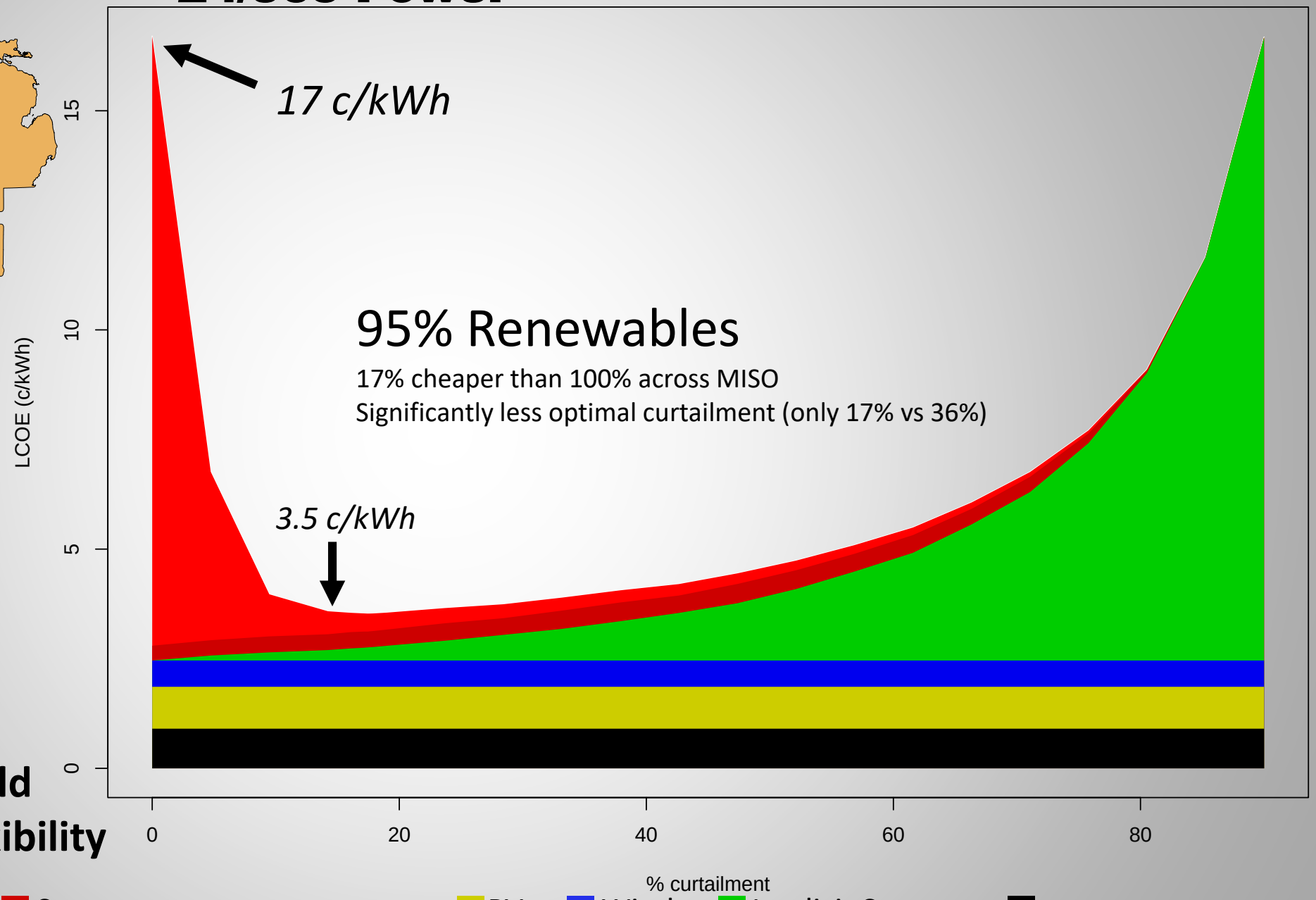
If each LRZ islanded themselves and optimized their resource blends, the electricity price would be:

4.65 c/kWh

Slightly more expensive than the MISO as a whole

Regional resiliency possible without large-scale interconnection

24/365 Power



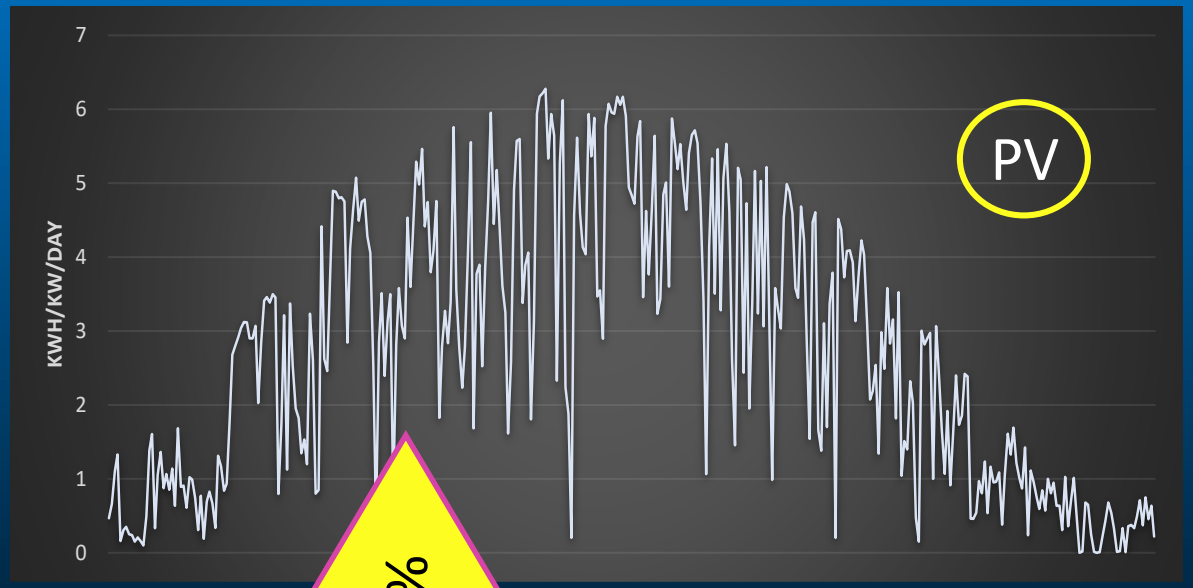
Consider MISO

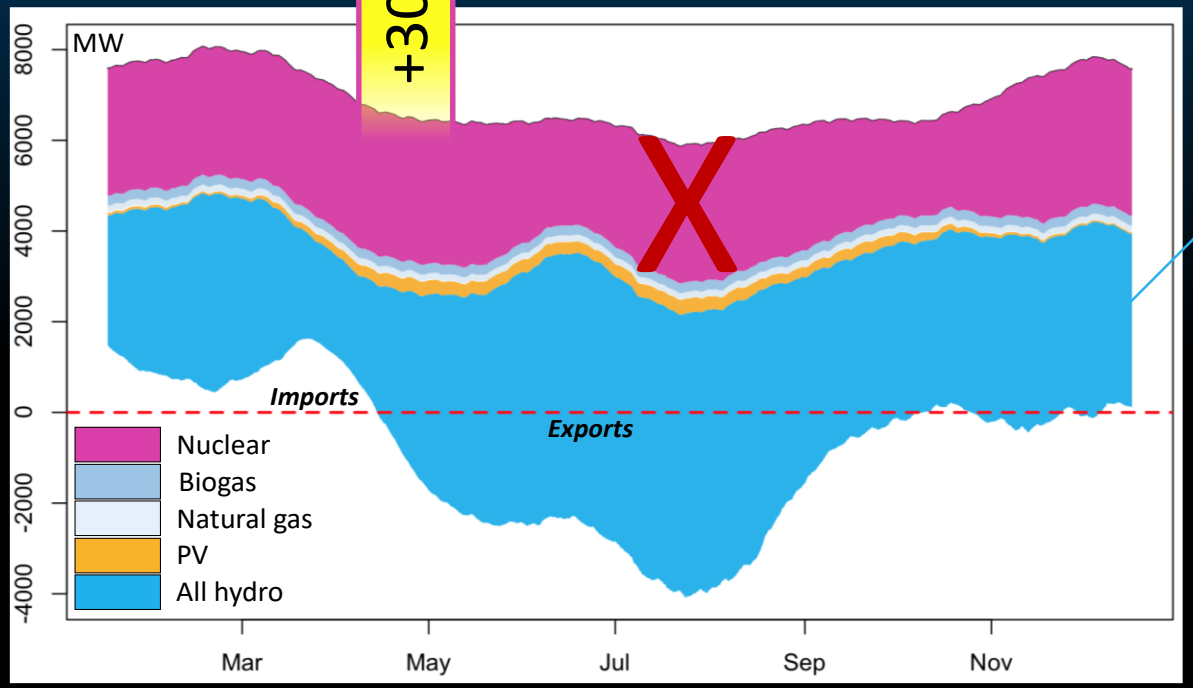
- 2050 Hi tech $$
- Opt. WIND/PV
- Optimal overbuild
- 5% Nat. Gas Flexibility

Firm PV Power in Switzerland (FIPPS)
Swiss Federal Office of Energy

- [nearly] 100% Renewables
- Solar PV + hydro
- Impact of (PV/storage) technology costs
- Flexibility from dispatchable gen

SWITZERLAND





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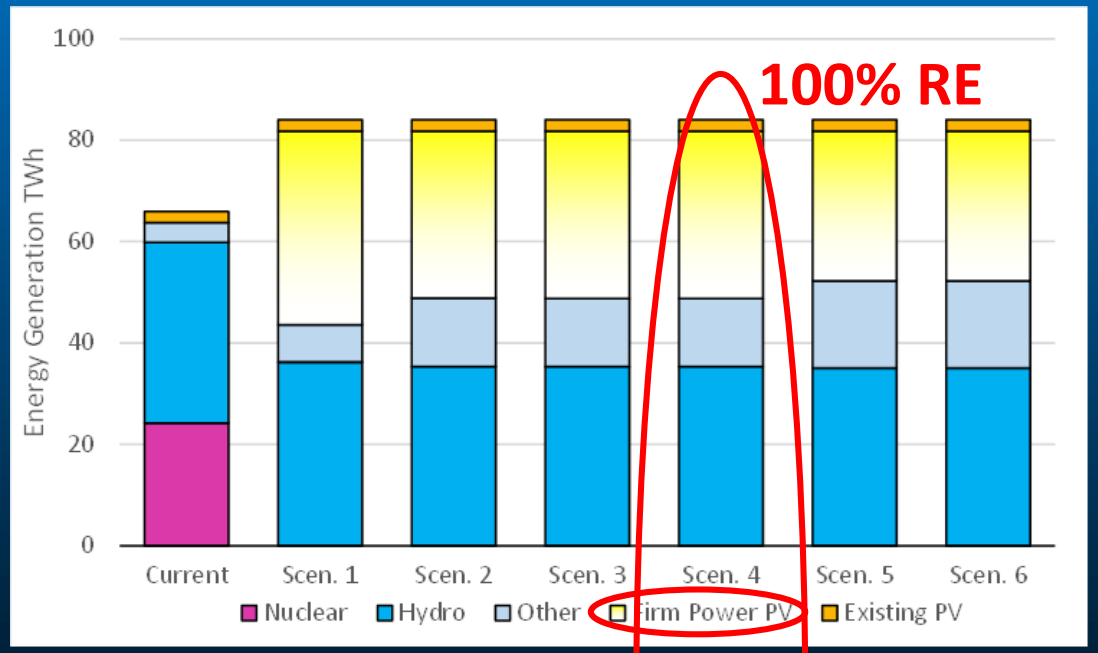
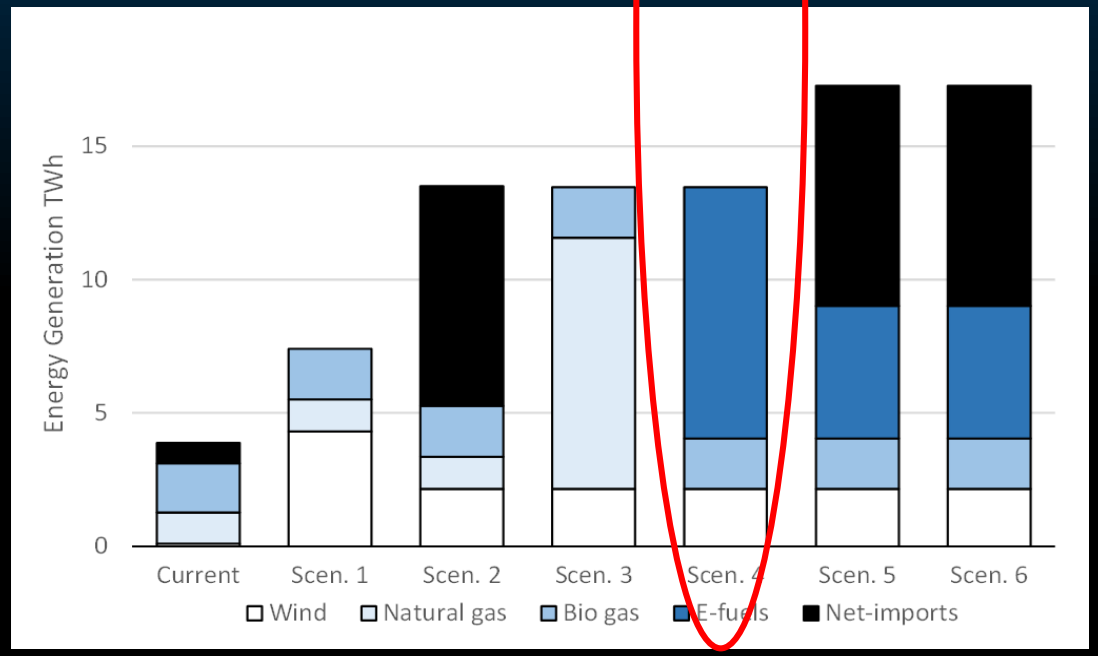
18 TWh Run of river hydro
50 GWh Two-way Pumped Hydro
10 TWh One-way Long-term Buffer Storage

OBJECTIVE 2050

30% LOAD GROWTH
100% NUCLEAR PHASE OUT
VERY LIMITED WIND POWER DEVELOPMENT
LIMITED HYDRO GROWTH POTENTIAL





Firm PV Power in Switzerland (FIPPS)
Swiss Federal Office of Energy

6 SCENARIOS

e-fuel @ 20cts/kWh bio gas @ 11 cts, wind @ 12 cts

2 PV/STORAGE COST ASSUMPTIONS

- Small scale systems
  - PV @ CHF 860/kW, storage @ CHF 330/kWh
- Utility-scale systems
  - PV @ CHF 310/kW, storage @ CHF 45/kWh

2 INTERCONNECTION CONFIGURATIONS

- Interconnected Grid with net-0 import/exports
- Autonomous Grid

OBJECTIVE 2050

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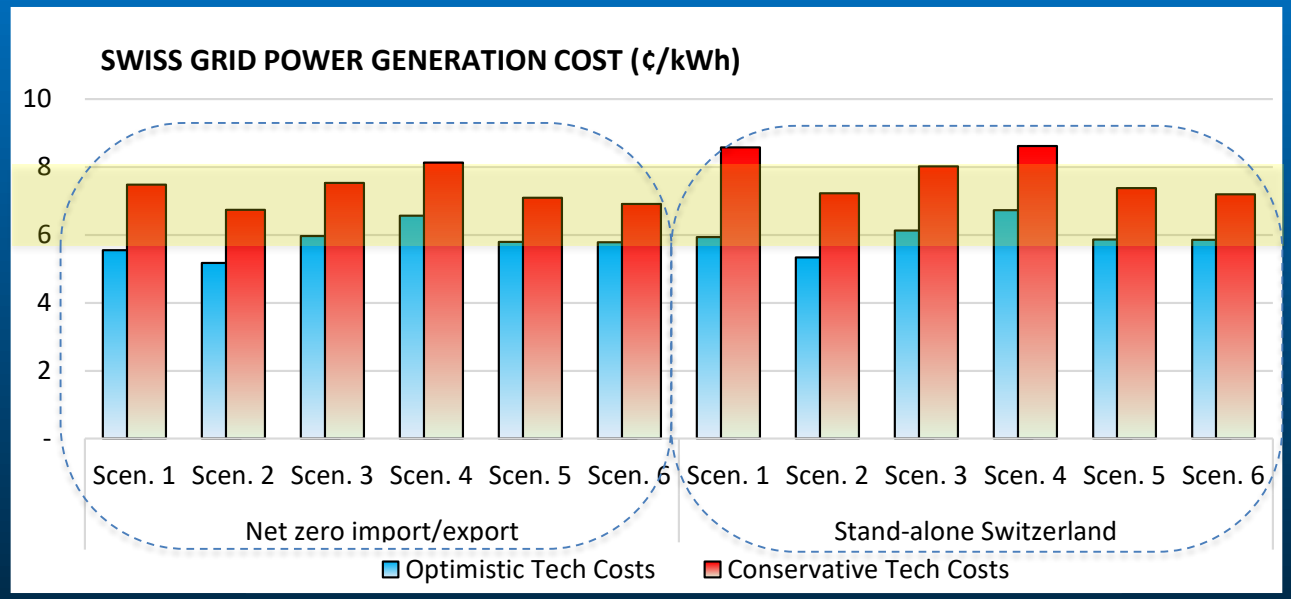
100% NUCLEAR PHASE OUT

VERY LIMITED WIND POWER DEVELOPMENT

LIMITED HYDRO GROWTH POTENTIAL



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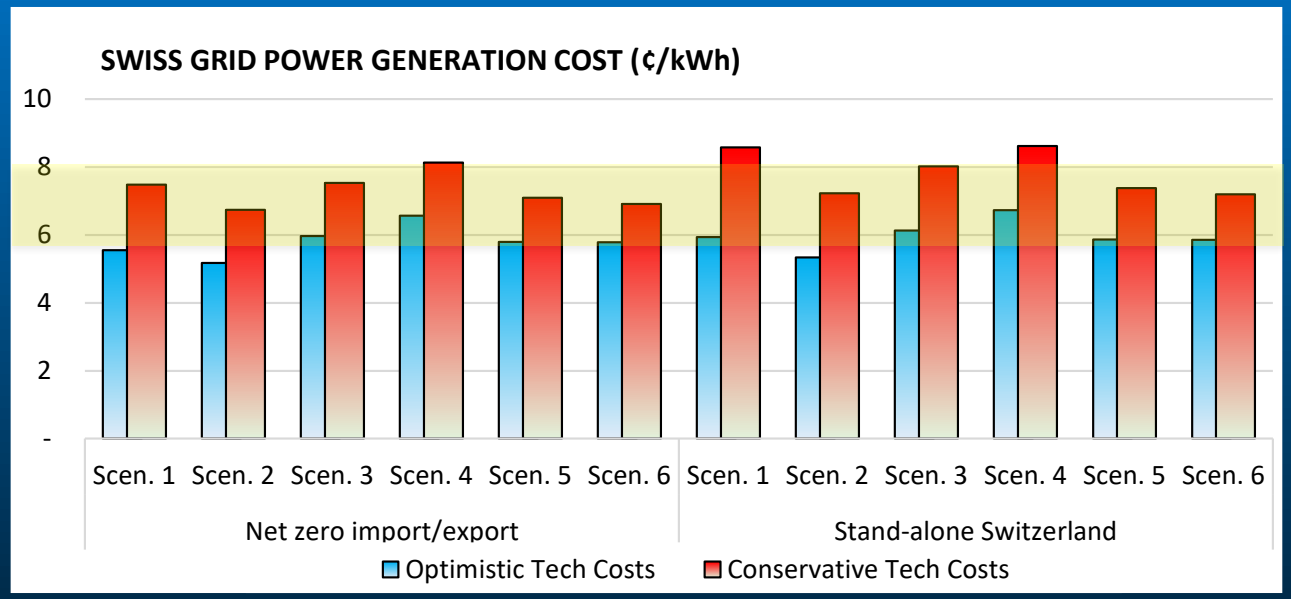
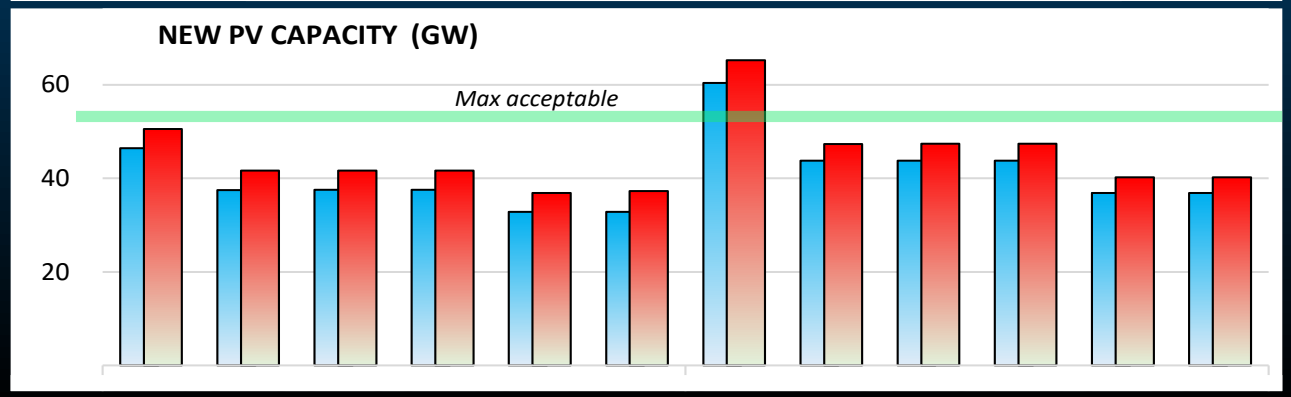
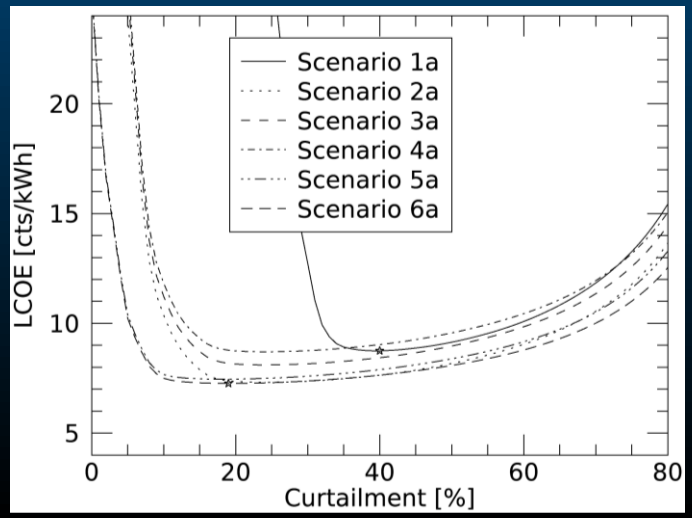
LIMITED HYDRO GROWTH POTENTIAL

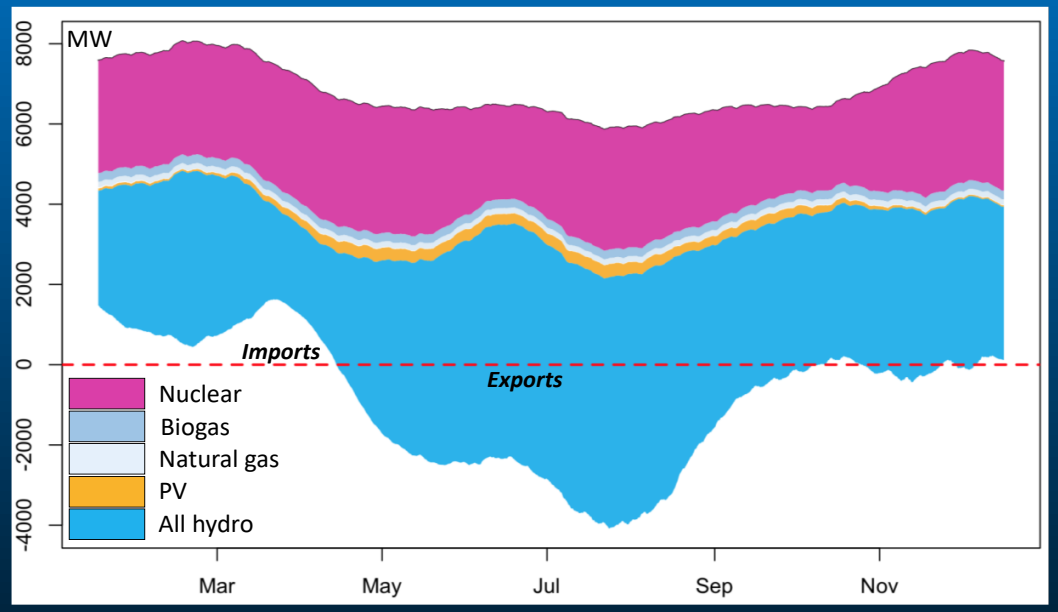




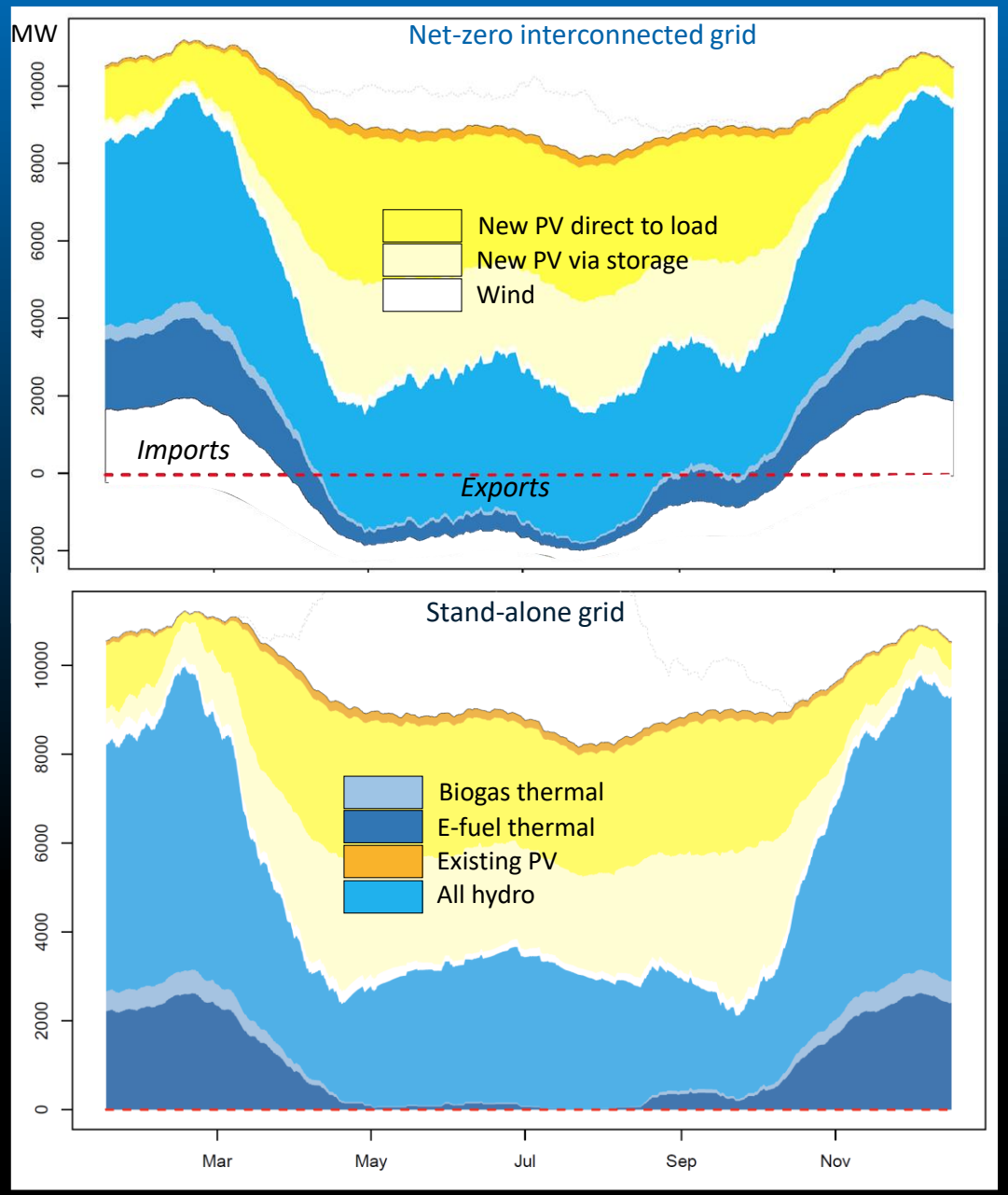
Firm PV Power in Switzerland (FIPPS)
Swiss Federal Office of Energy

2022 SWISS TSO WHOLESALE AVERAGE DAY AHEAD/SPOT PRICE:
23 Cts / kWh





2022 → 2050



REGIONAL FIRM VRE POWER TAKEWAYS

- Situations with vastly different environments indicate that 100% RE power grids are economically viable.
- Implicit storage (aka CURTAILMENT) is central to achieving this objective.
- Long term storage and large-scale interconnection may not be indispensable.
- EXPENSIVE e-fuel thermal generation (5-10%) is an effective catalyst.

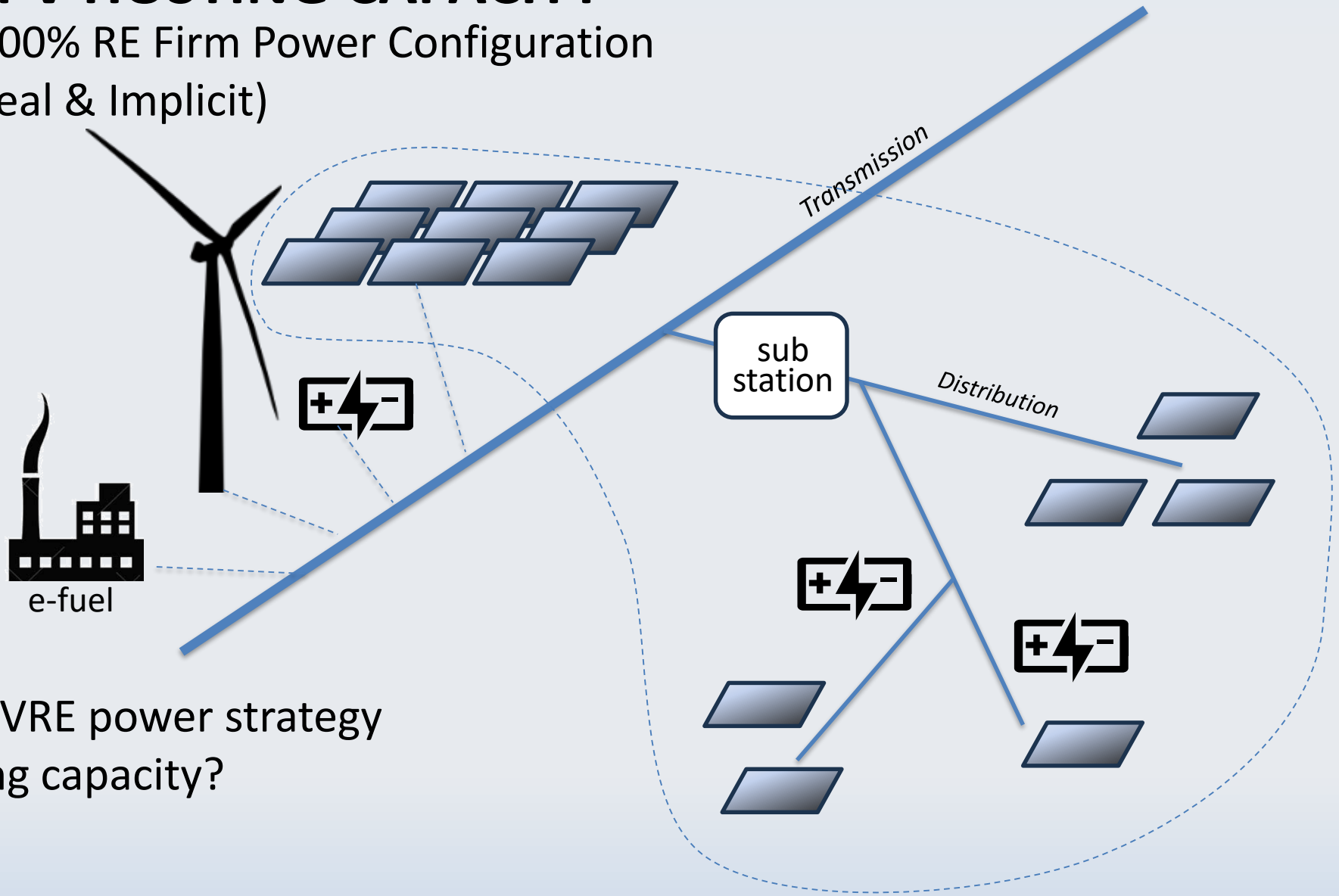
- New market rules enabling least-cost firm power 100% VRE grids must be crafted and implemented

"The economic model must fit the physics of the resource and not vice versa"

Jan Remund, Operating Agent IEA PVPS Task 16

DISTRIBUTION PV HOSTING CAPACITY

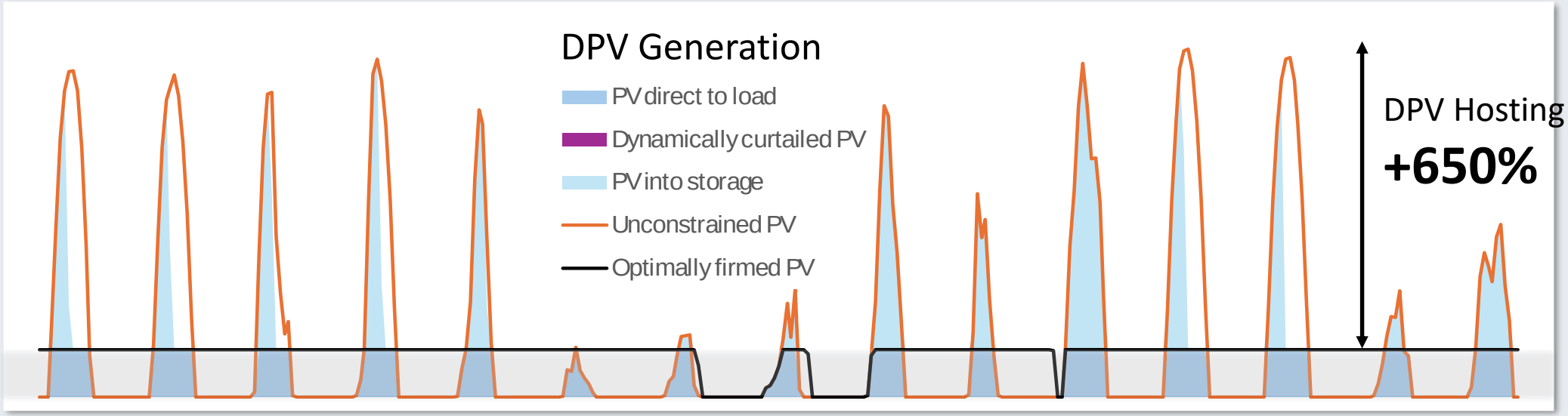
Optimum Regional 100% RE Firm Power Configuration
PV, Wind, Storage (Real & Implicit)
E-fuel Thermal



- Can a regional firm VRE power strategy increase DPV hosting capacity?
- By how much?

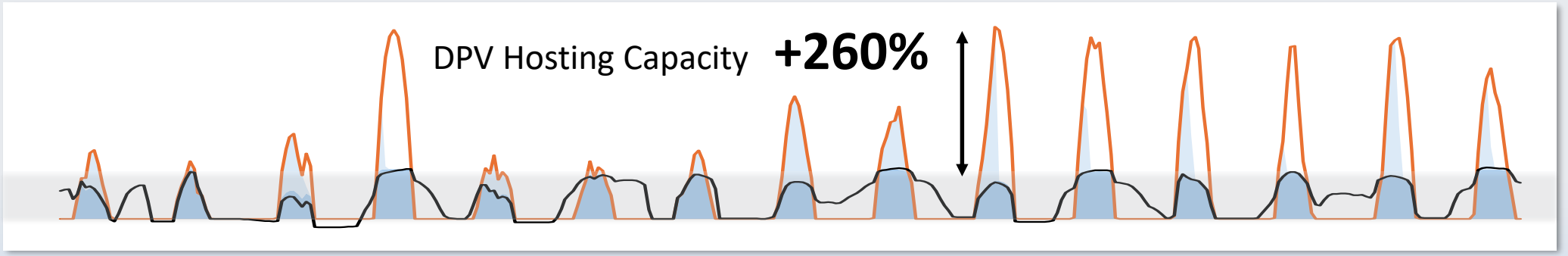
LOUISIANA (MISO 9) – Regional baseload generation

95% PV & 5% new e-fuel thermal – 2040 LCOE: 5.9 cts/kWh



IOWA (MISO 3)

47.5% PV, 47.5% Wind & 5% new e-fuel thermal – 2040 LCOE: 4.1 cts/kWh



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- **DPV HOSTING CAPACITY INCREASES MULTIFOLD**

DISCLAIMER

UNCONSTRAINED PV AT THE MARGIN

Net Metered 10 KW PV
Passive Solar
Electric transportation
Outage-resilient nanogrid
NET ZERO
Minimal GHG Footprint
Minimal Energy Bills

Thank you