

# **From Firm Solar Power Forecasts to Firm Solar Power Generation**

An effective path to ultra-high renewable penetration

A New York Case Study

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*John Dise, Clean Power Research*

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*Agata Swierc, Clean Power Research*

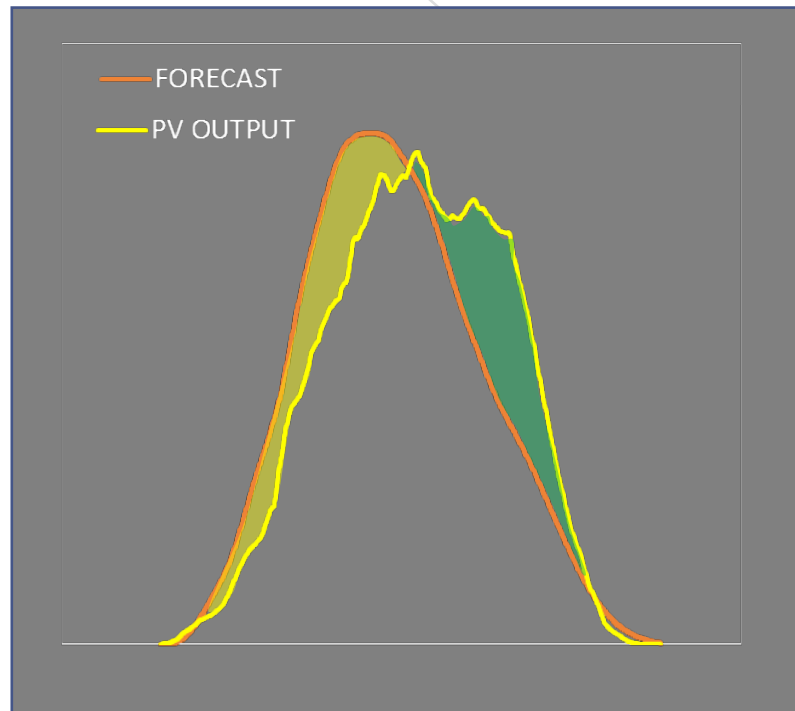
*Jorge Ferreira, Clean Power Research*

*Andrew Foster, Clean Power Research*

*Thomas Hoff, Clean Power Research*

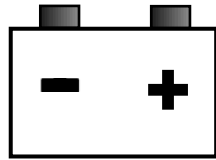
*Cristina Cornaro, University of Rome*

# FIRM SOLAR FORECASTS

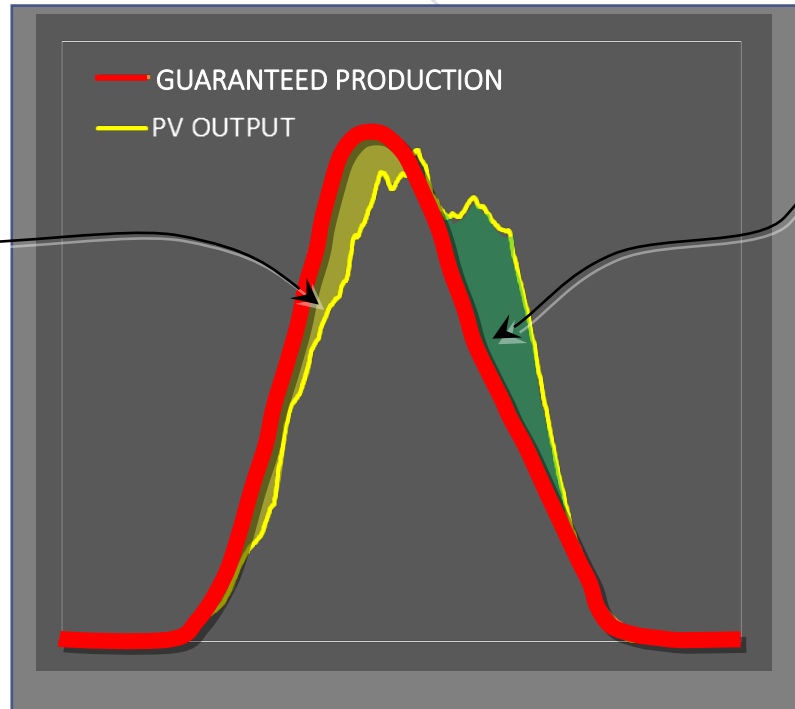


*Even the best forecasts are not perfect*

# FIRM SOLAR FORECASTS



+ SOLAR OVERSUPPLY & CURTAILMENT



*Even the best forecasts are not perfect*

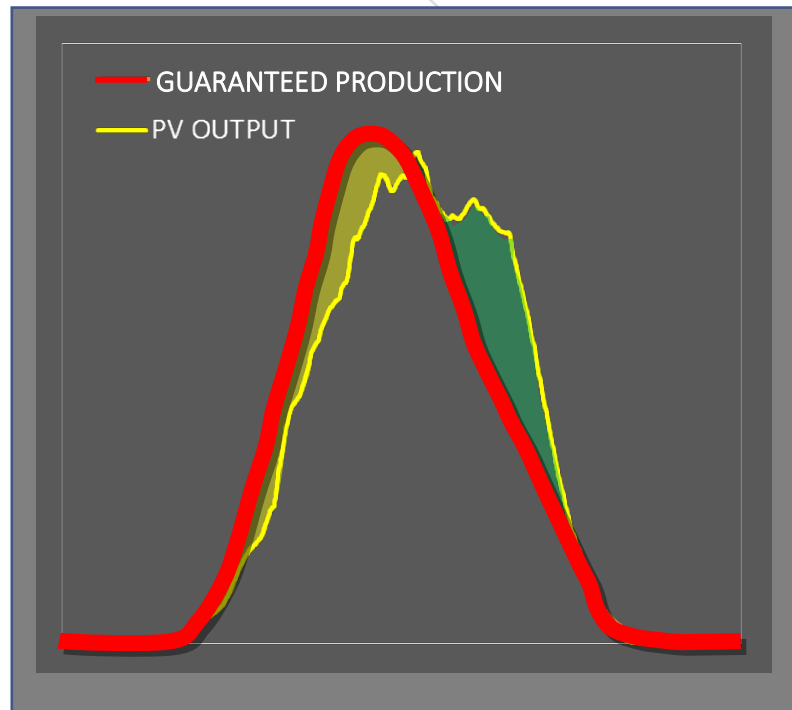
*But predicted output could be guaranteed*

*With backup storage and PV curtailment*

*Thus delivering firm forecasts to grid operators*

# FIRM SOLAR FORECASTS

## *Presentation Plan*



*An effective model validation metric*

*A low-cost deployable strategy for zero-uncertainty grid operations*

*An effective entry to firm PV power generation*

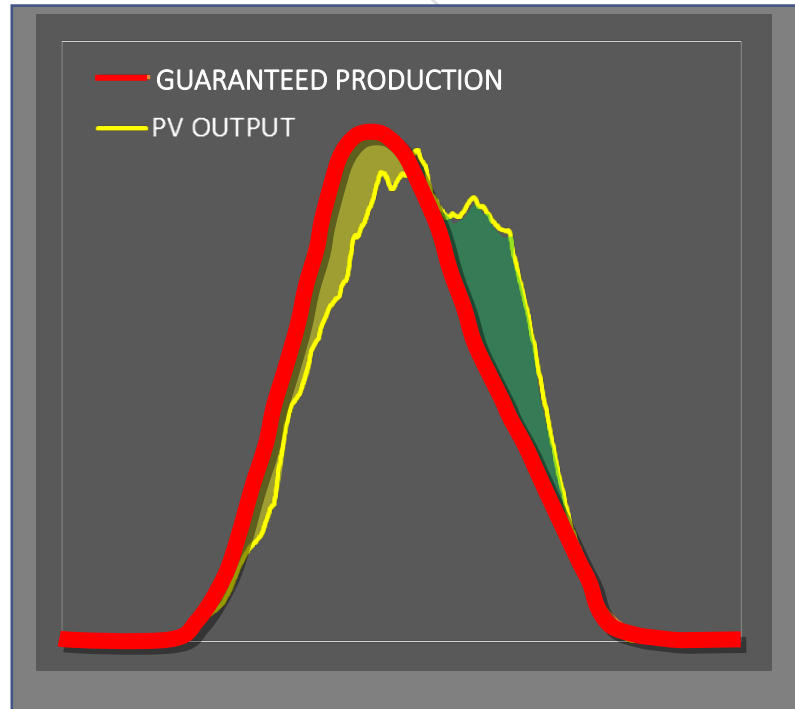
*NYISO Case study*

# Validation Metric

Standard metrics:

MBE, RMSE, MAE  
%MBE, %RMSE, %MAE  
Forecast Skill

Perfect forecast metric: cost of storage + overbuild

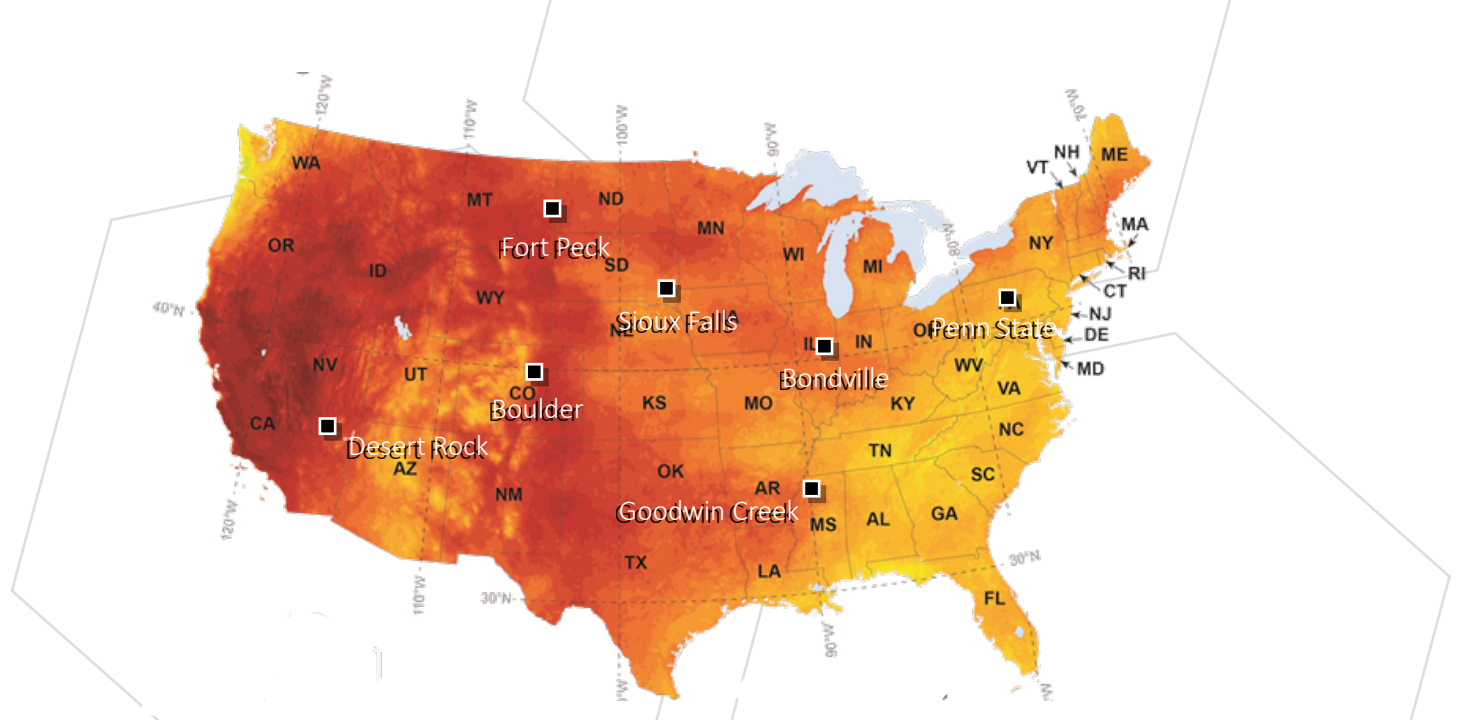


@ current technology cost:  
\$1000/kW PV    \$200/kWh Storage  
@ future technology cost:  
\$400/kW PV    \$50/kWh Storage

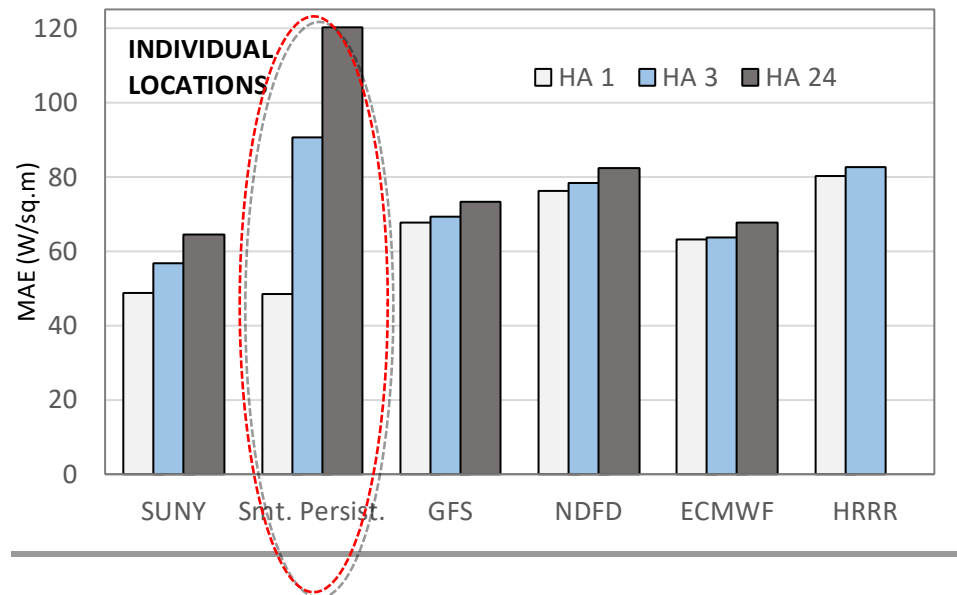
# Validation Metric

Considered forecast models:

- SUNY (SolarAnywhere)
- GFS
- ECMWF
- NDFD
- HRRR
- Smart Persistence

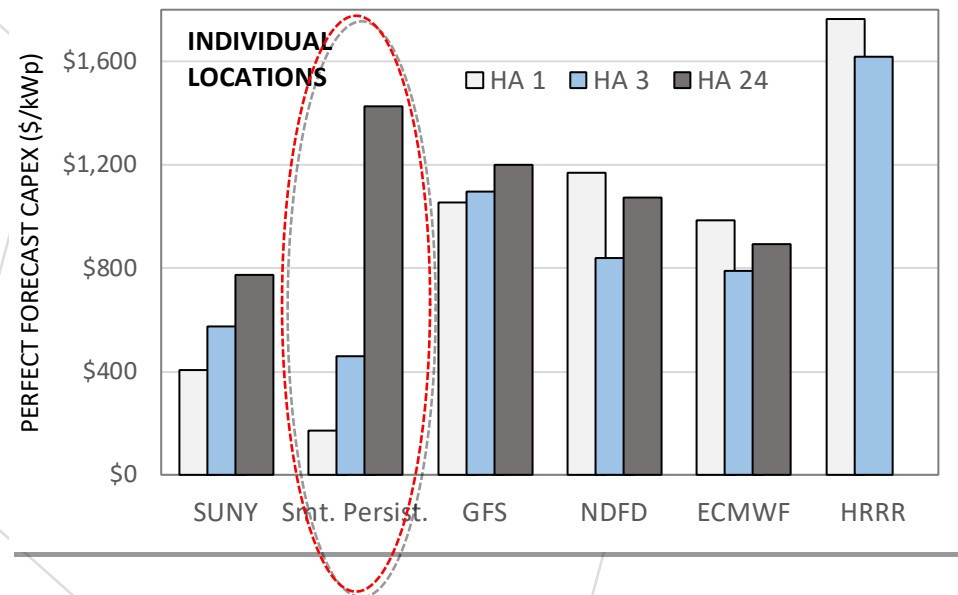


## MAE

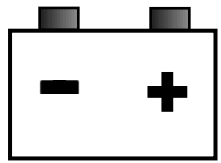


## Firm Forecast Metric

\$1000/kW PV / \$200/KWh Storage

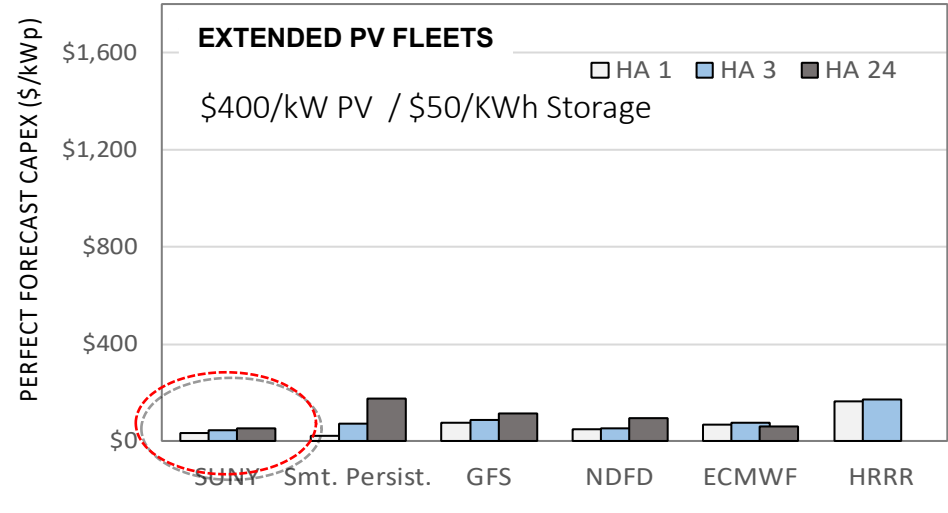


# Valid Cost Strategy for Zero-Uncertainty PV Fleet Operations

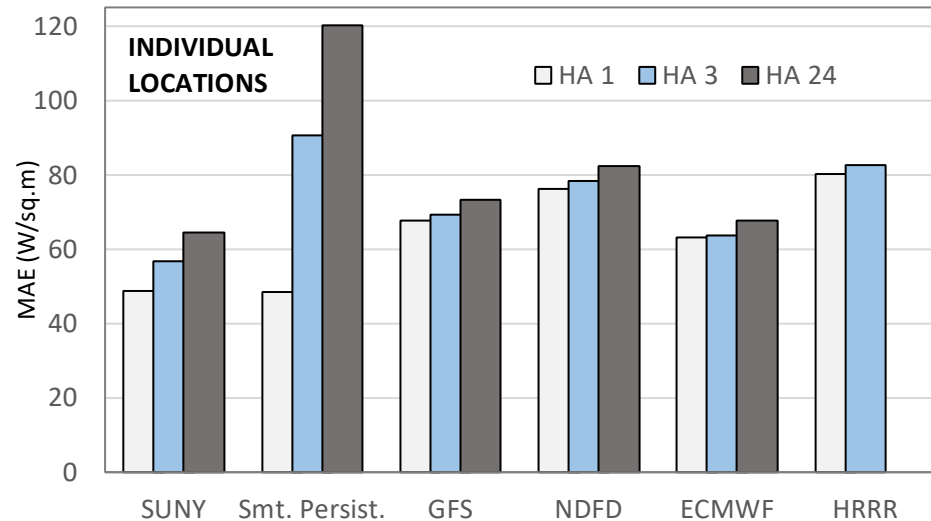


+ OVERSUPPLY/CURTAILMENT

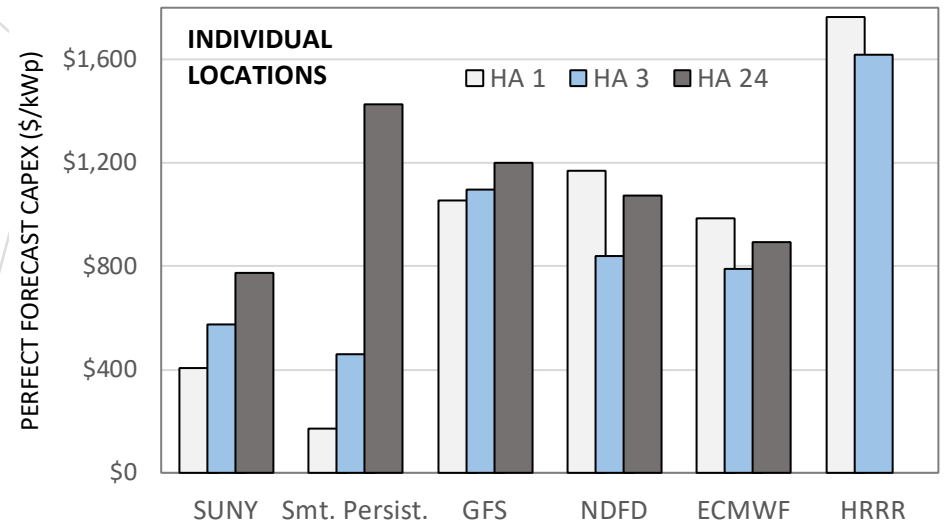
⇒ *FIRM FORECASTS*



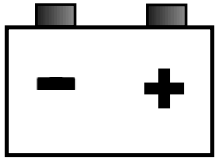
## MAE



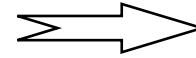
## Firm Forecast Metric



# An Effective Entry Step to Least-Cost Firm PV Power Generation



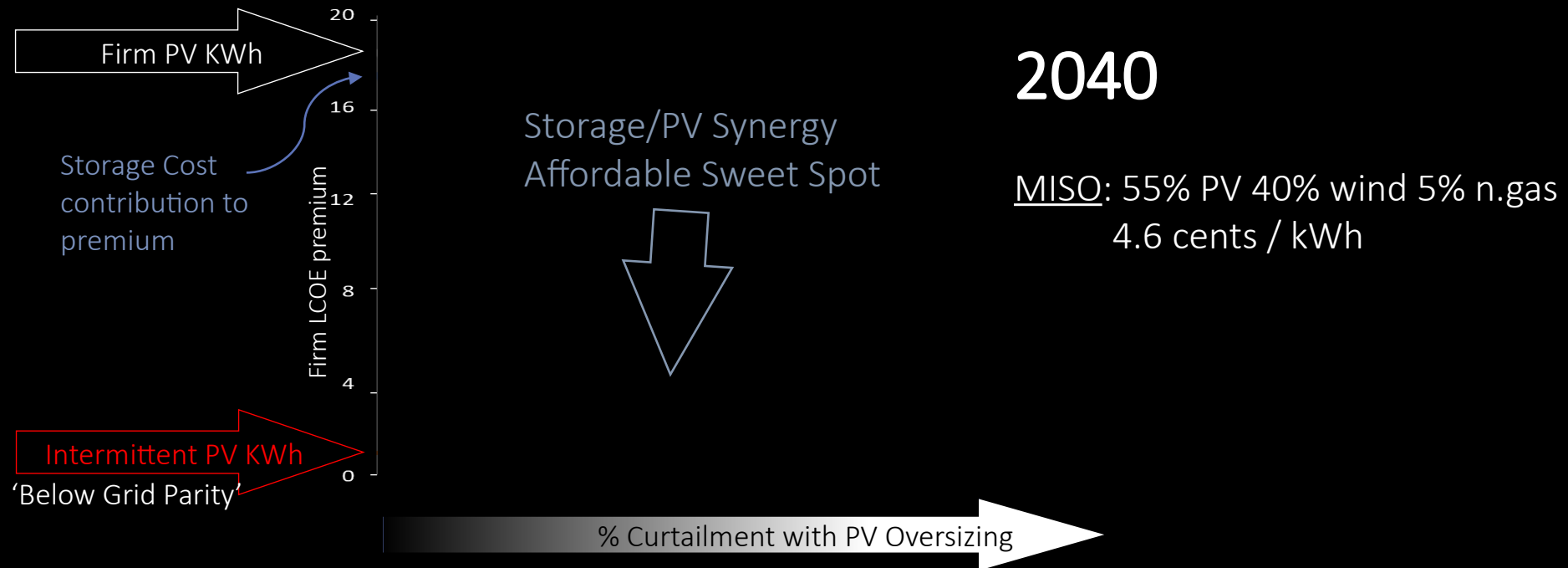
+ SOLAR OVERSUPPLY & CURTAILMENT



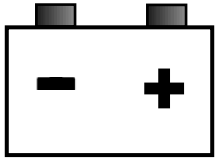
**FIRM/CONSTANT PV 24/7/365**



# An Effective Entry Step to Least-Cost Firm PV Power Generation

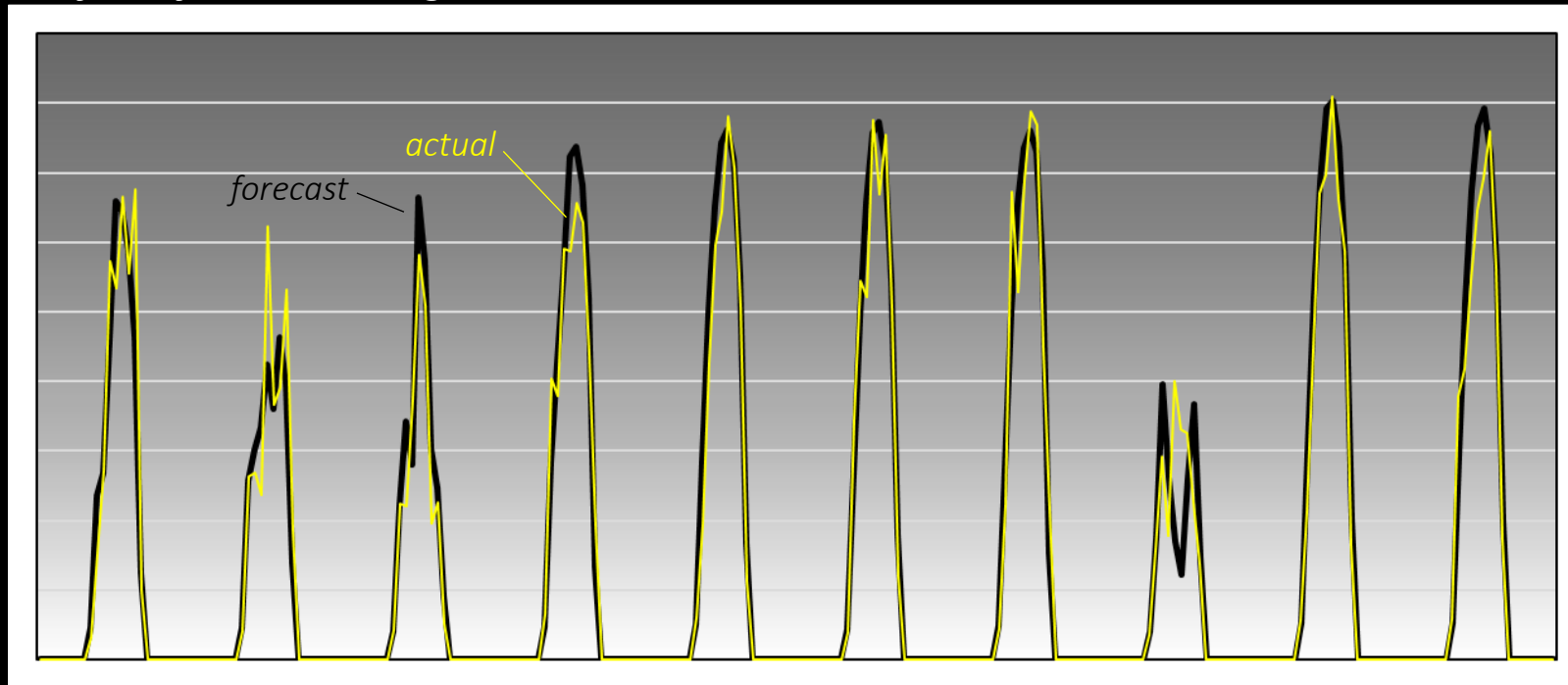


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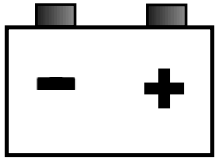


+ SOLAR OVERSUPPLY & CURTAILMENT (implicit storage)

*Perfect forecast logistics*

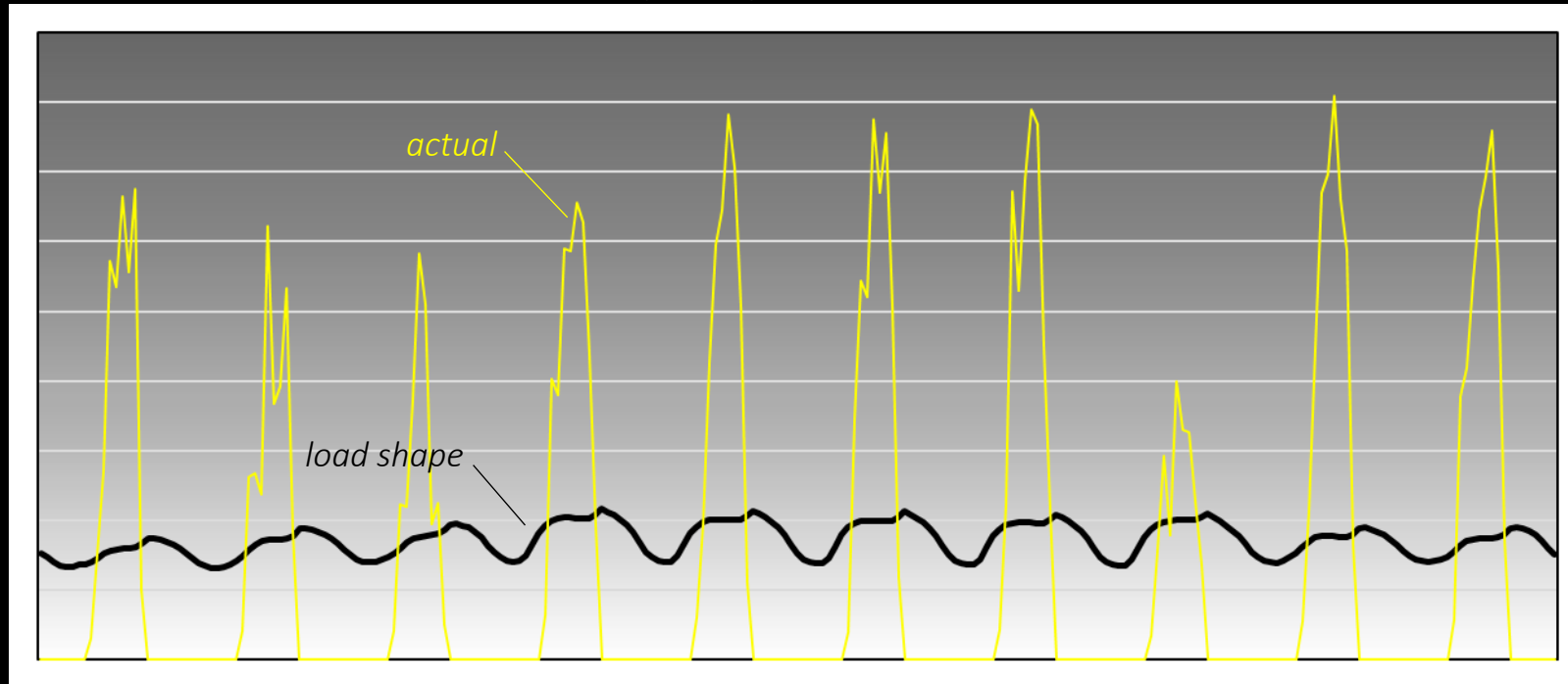


# An Effective Entry Step to Least-Cost Firm PV Power Generation



+ SOLAR OVERSUPPLY & CURTAILMENT (implicit storage)

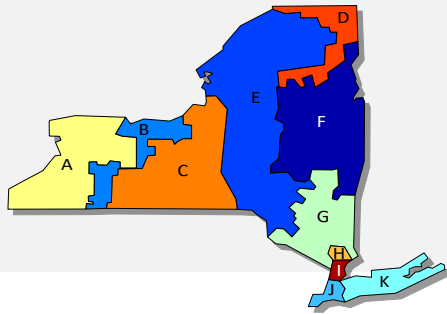
*Firm Power (i.e., 100%-ready) logistics*



# An Effective Entry Step to Least-Cost Firm PV Power Generation

## NYISO CASE STUDY NYISO Zones

32 GW

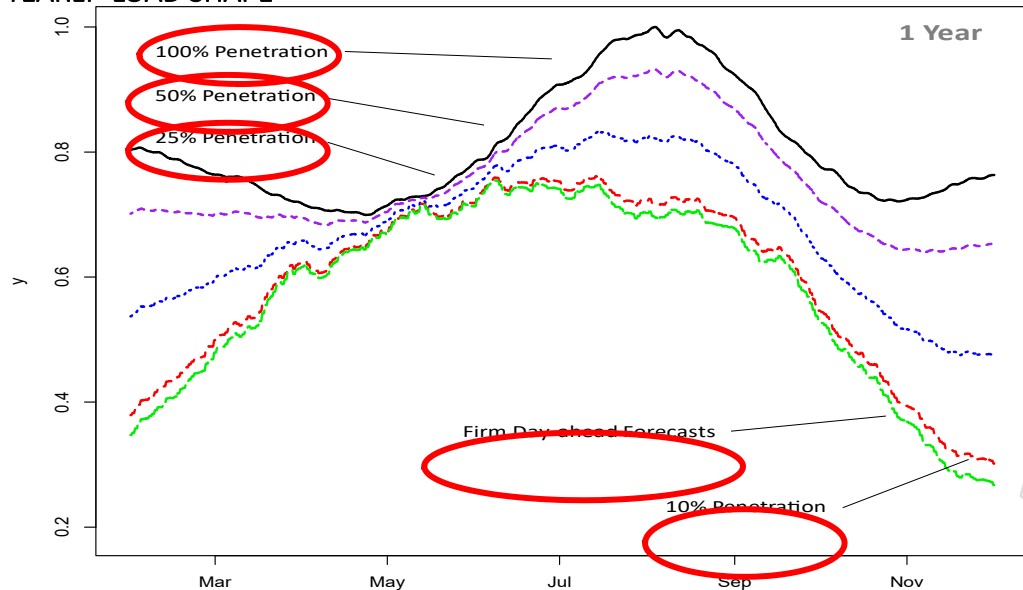


- 11 Regions
- Single PV Plants
- Homogeneously dispersed fleets
- Entire NYISO
- Flexibility 0%, 2.5% & 5%

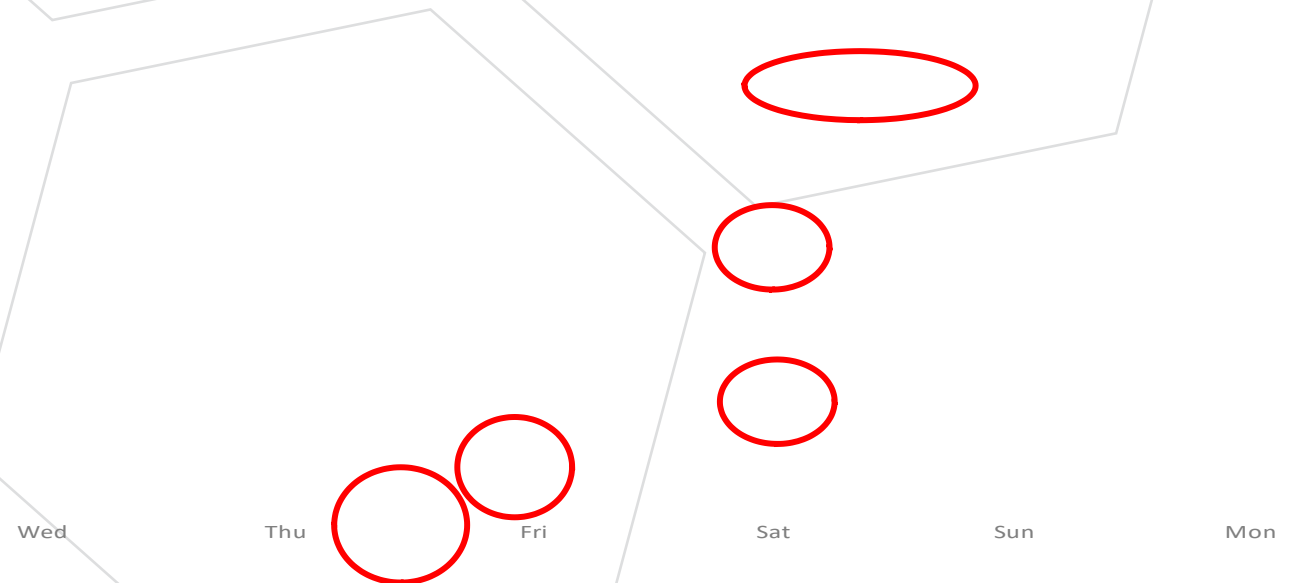
### Grid Energy Penetration

- Near 0% (current)
- 10%
- 25%
- 50%
- 100%

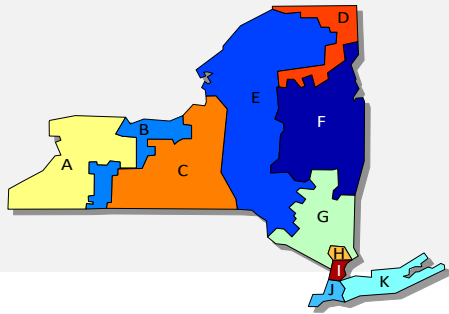
### YEARLY LOAD SHAPE



### DAILY LOAD SHAPE



# NYISO CASE STUDY NYISO Zones

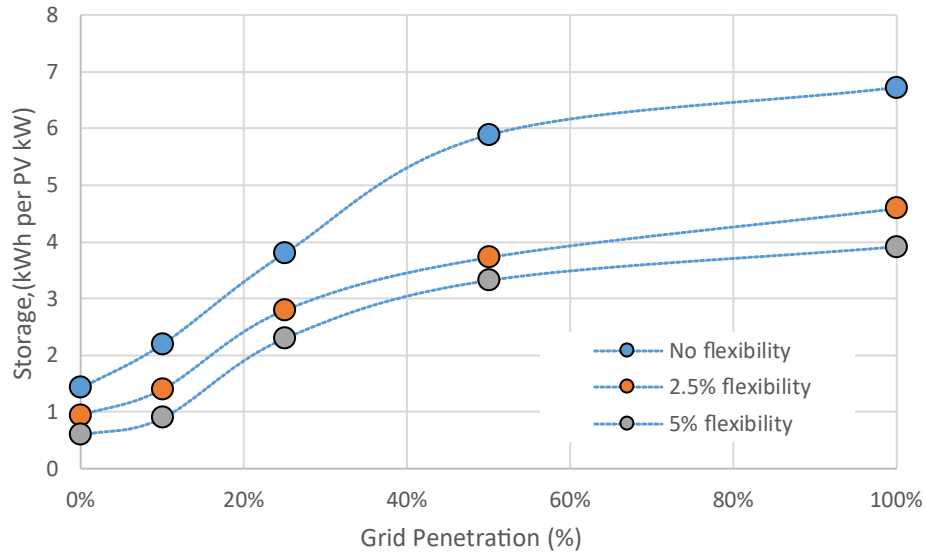


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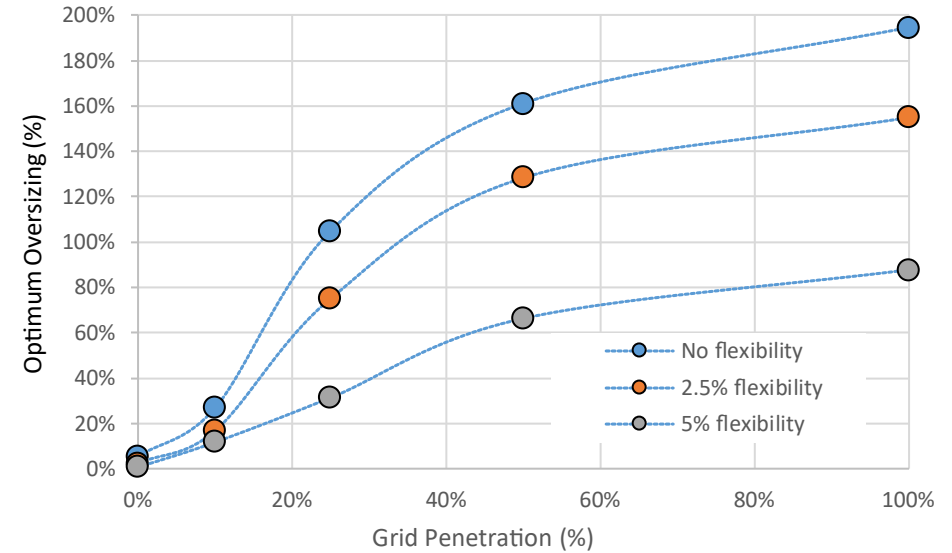
## Grid Energy Penetration

- Near 0% (current) → Firm Forecasts
- 10%
- 25%
- 50%
- 100% → Firm Power Gen Required

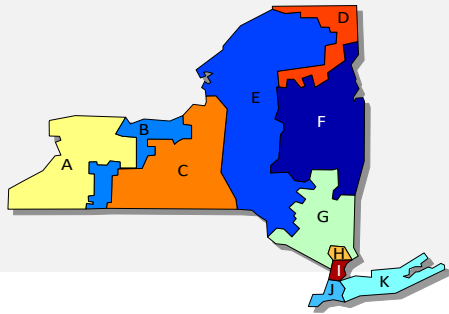
## STORAGE



## IMPLICIT STORAGE



# NYISO CASE STUDY NYISO Zones

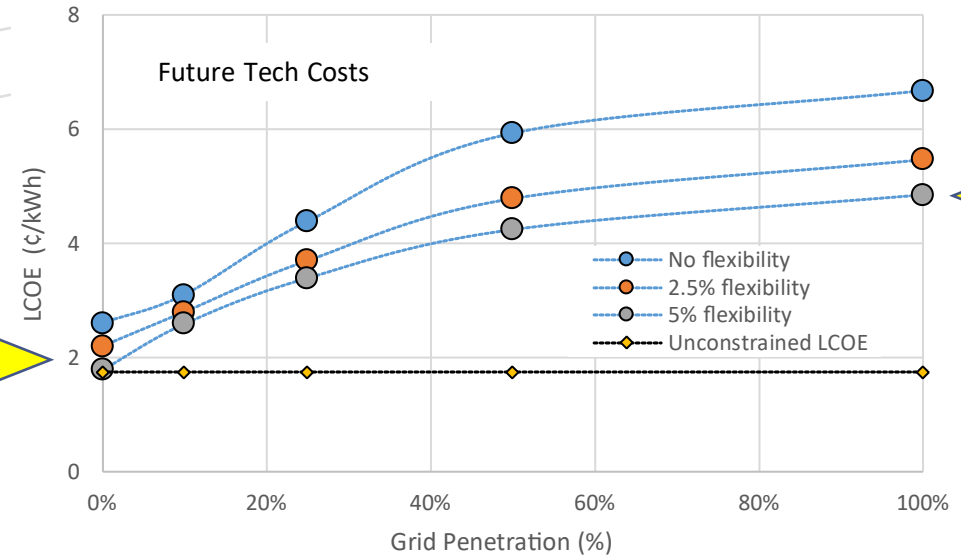
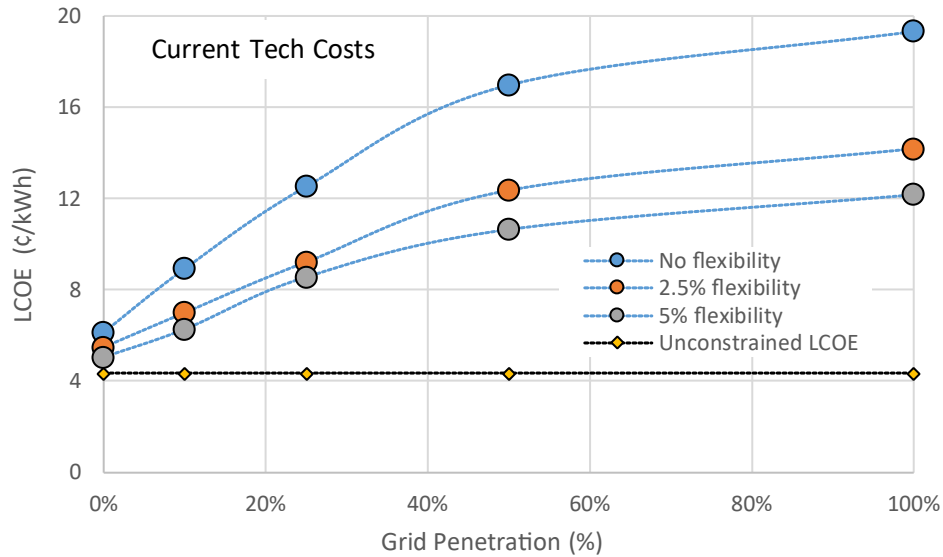


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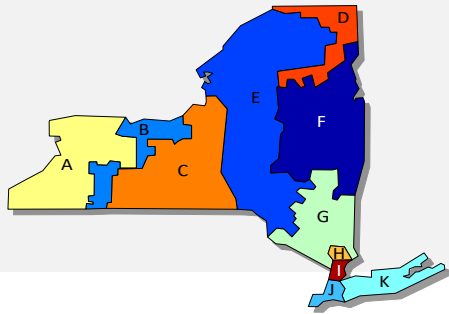
## Grid Energy Penetration

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### LCOE



# NYISO CASE STUDY NYISO Zones

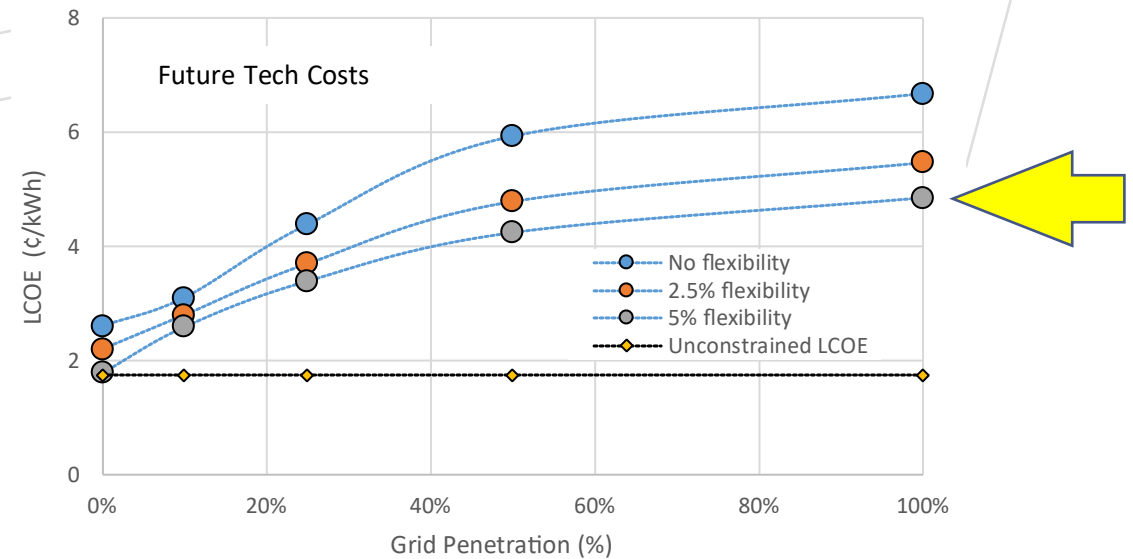
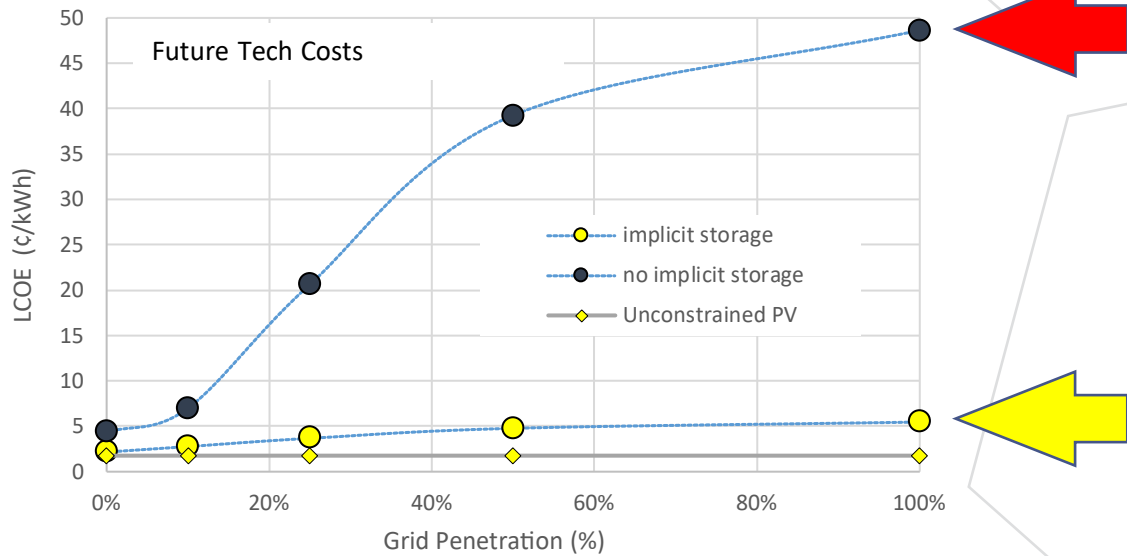


- 11 Regions
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## Grid Energy Penetration

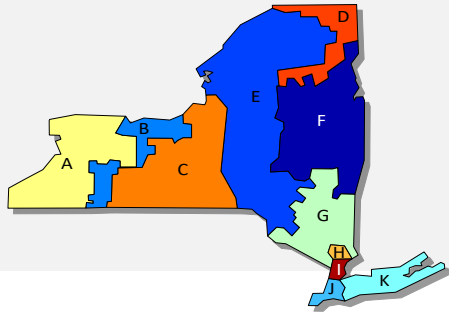
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- 100% → Firm Power Gen Required

### LCOE, No Implicit storage

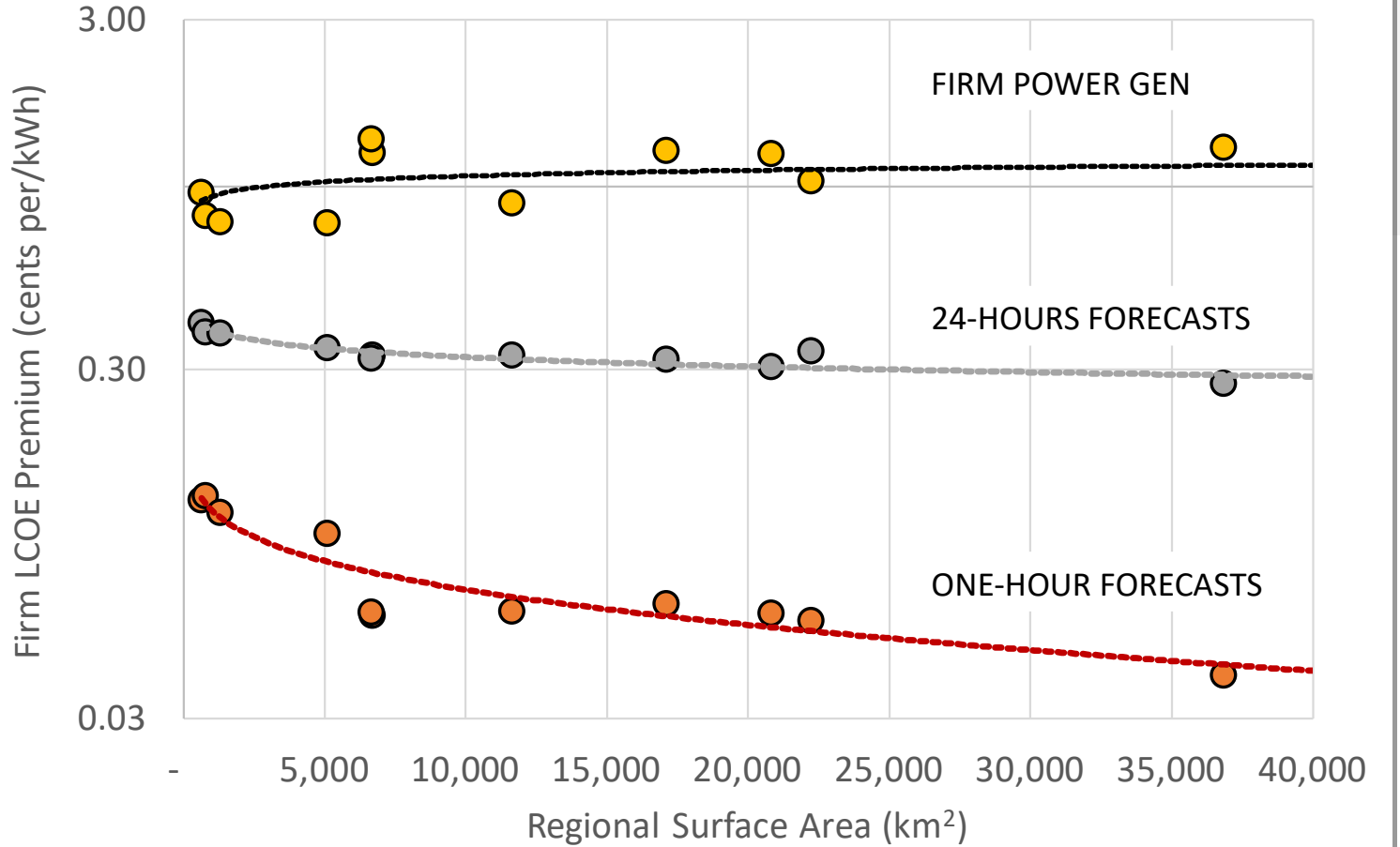


# Influence of regional interconnection

## NYISO CASE STUDY NYISO Zones



## LCOE PREMIUM

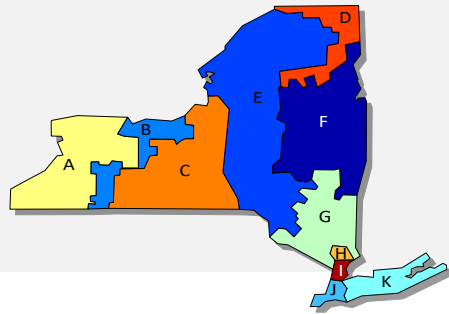




*Influence of regional interconnection*

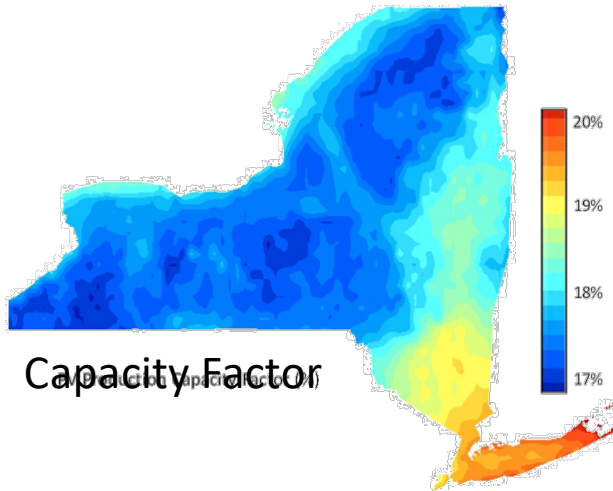
*Influence of the solar resource*

## NYISO CASE STUDY

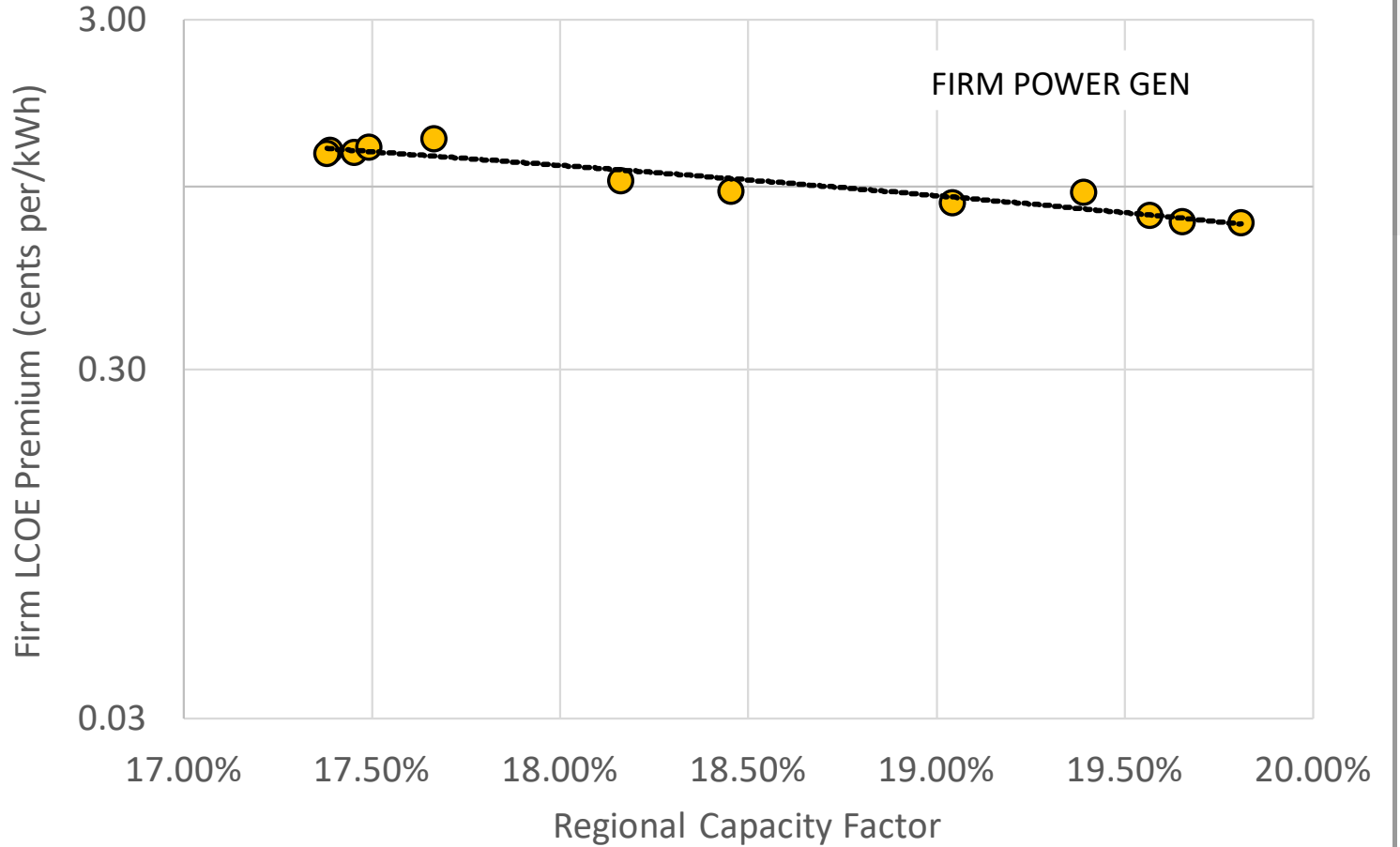


20%

17%



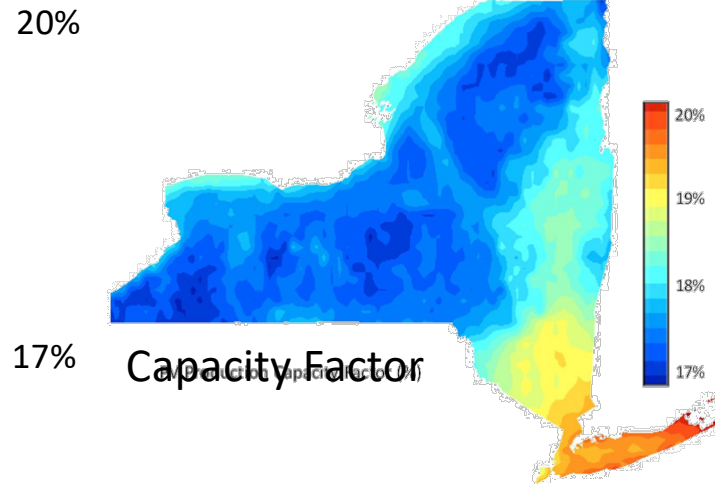
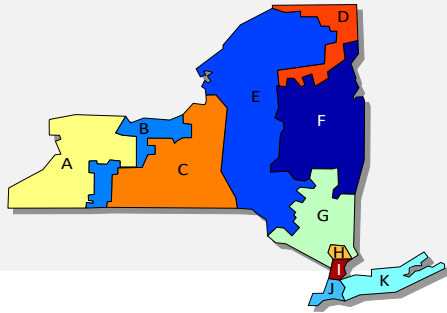
## LCOE PREMIUM



*Influence of regional interconnection*

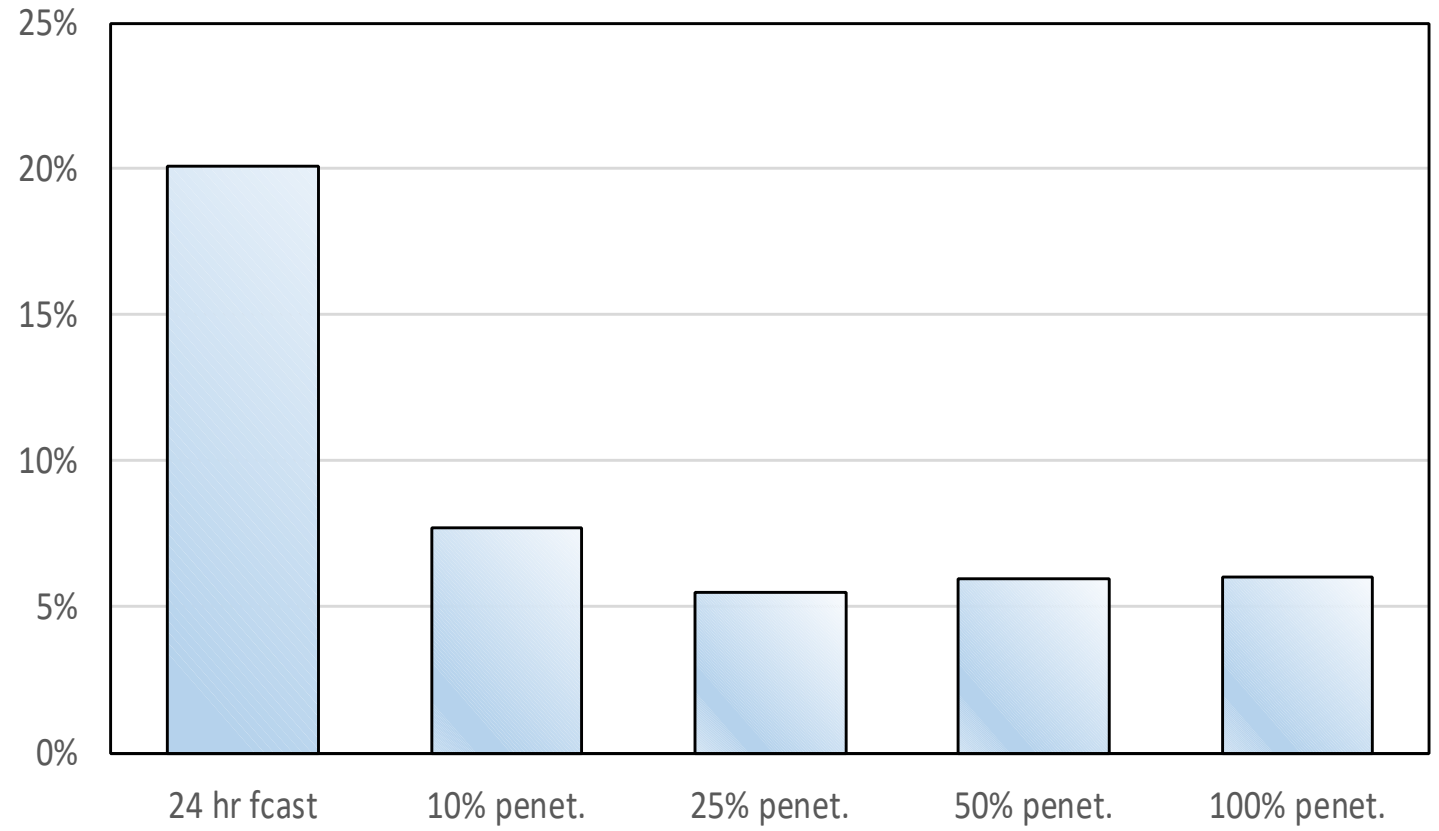
*Influence of the solar resource*

## NYISO CASE STUDY NYISO Zones



## LCOE PREMIUM

single plant vs. distributed fleet



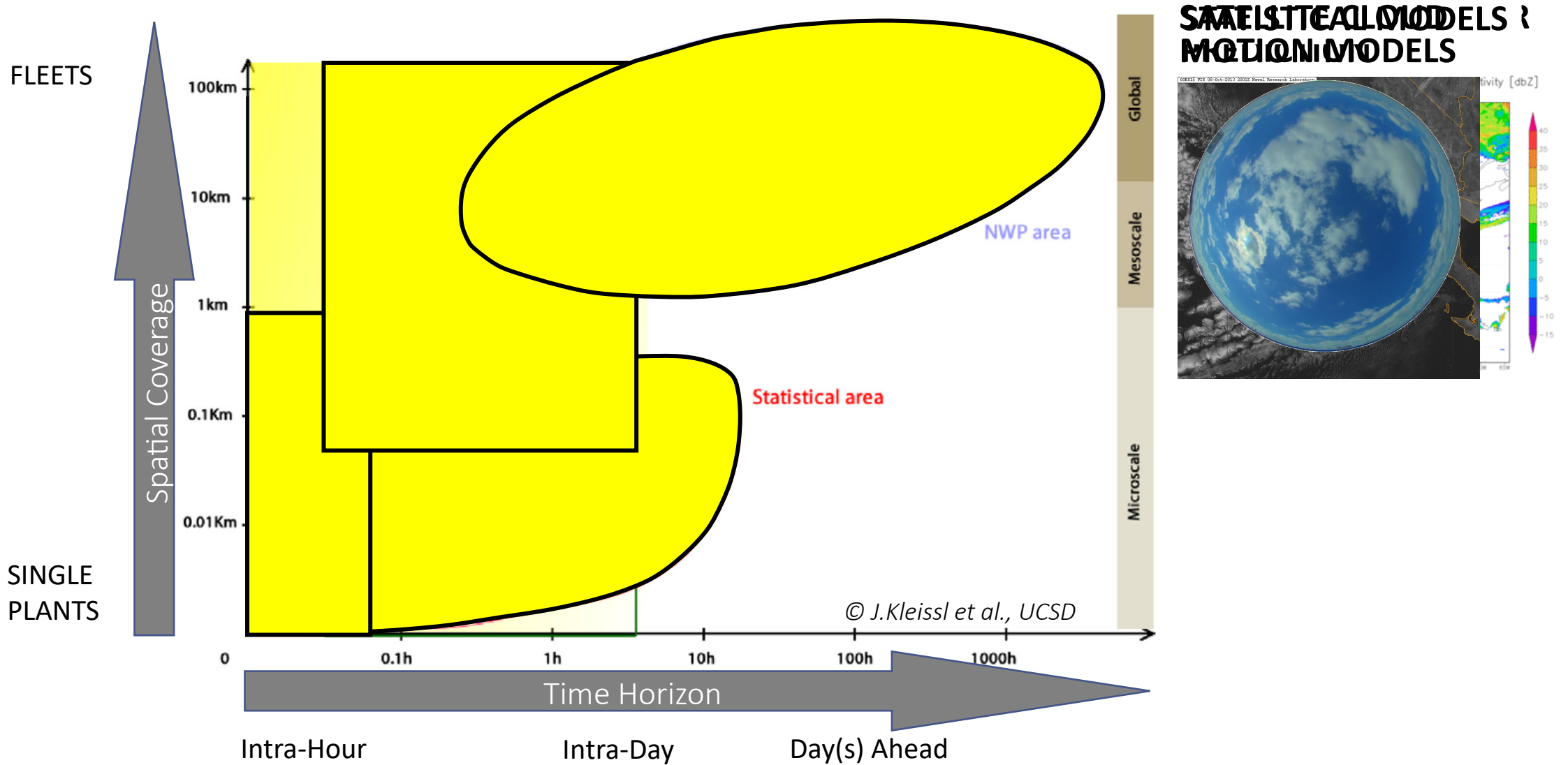
## **CONCLUSIONS**

- **Firm forecasts constitute an effective evaluation metric, more reflective of operational costs than standard metrics**
- **Firm forecast strategies can be economically justifiable today**
- **Firm forecasts strategies -- applying storage both real and implicit -- constitute a very effective entry step to achieve least cost ultra-high PV penetration when firm power generation will be a prerequisite**
- **The NYISO case study points that a [2040] target ultra-high penetration straight business LCOE of 4-5 cents per kWh would be achievable with the strategy**
- **Firm PV power generation could be contained within electrical regions at a modest cost premium (decreasing with penetration), thus alleviating the need for major trans-regional grid buildup and enhancing localized resiliency**

***THANK YOU***



# Solar Forecasts Types and Horizons



# Solar Forecasts Types and Horizons

