SunShot U.S. Department of Energy

EPRI ELECTRIC POWER RESEARCH INSTITUTE

SHINES Kickoff Meeting 2016

Beneficial Integration of Solar PV, Energy Storage, Load Management, and Solar Forecasting

DE-EE0007163 – Electric Power Research Institute (EPRI)

Dr. Aminul Huque, Principal Technical Leader
865.218.8051, mhuque@epri.com

Co-Authors

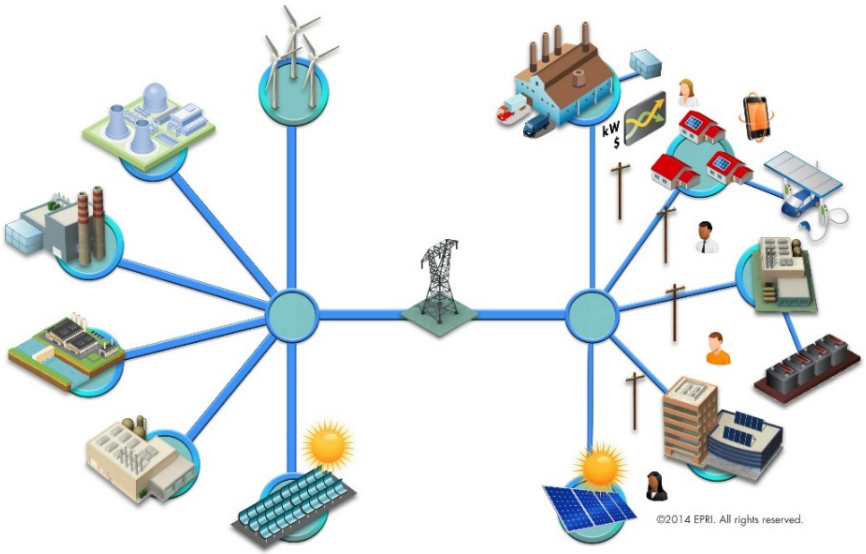
- Sam Duncan, Southern Company
- Dr. Arindam Maitra, EPRI
- Dr. Kenneth Loparo, CWRU
- Dr. Marija Prica, CWRU
- Skip Dise, CPR

Presentation Outline

- Project Objectives
- Key Innovation
- Approaches
- Project Partners & Roles
- Relevance to Solar Challenges

Vision

An electric infrastructure that provides safe, reliable, environmentally responsible, and affordable electricity to everyone and can manage multiple distributed energy resources to levels supported by customer choice.



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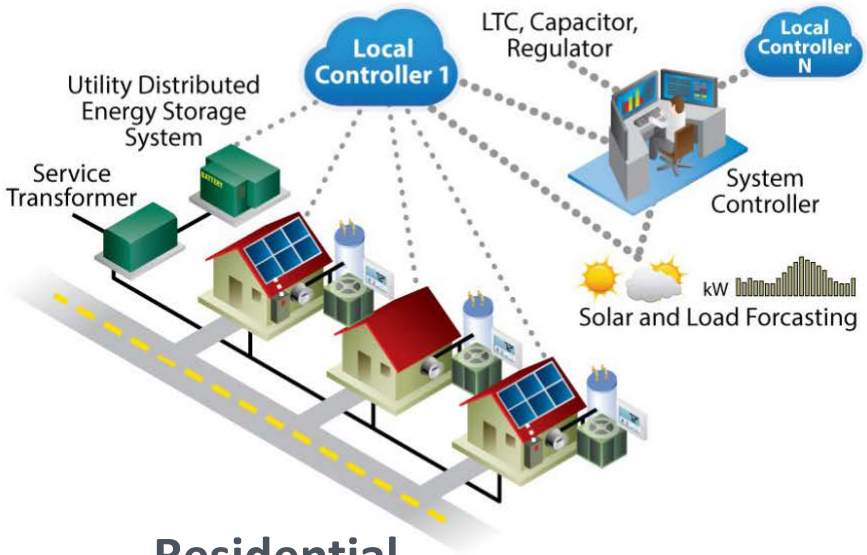
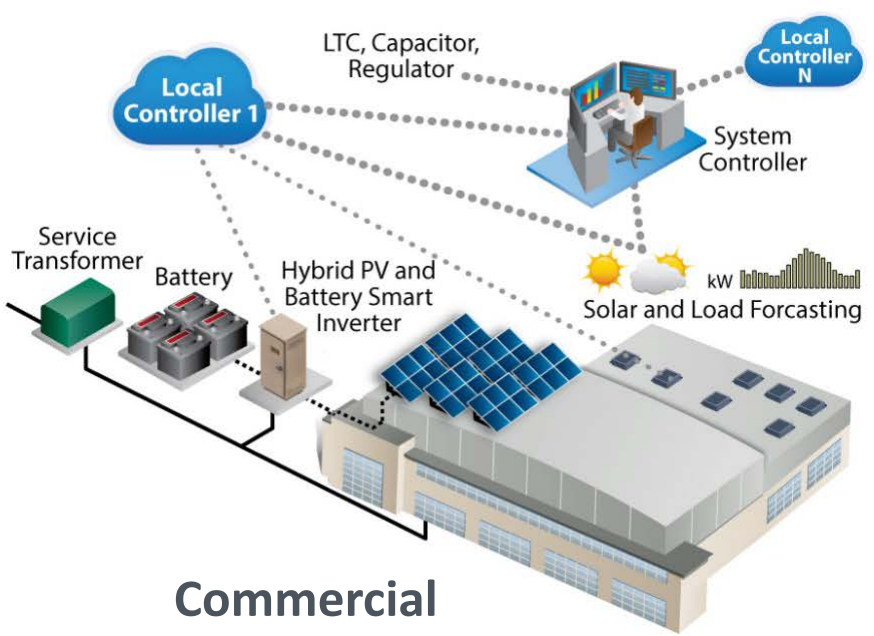
DOE's SHINES investment supports transformation of electric power system design and operation to seamlessly integrate solar and storage.

Objective

Beneficial Integration of solar photovoltaic generation, energy storage, load management, and advanced forecasting technique,
with
electric power delivery network
through
optimal control strategies at a minimized cost.



Residential

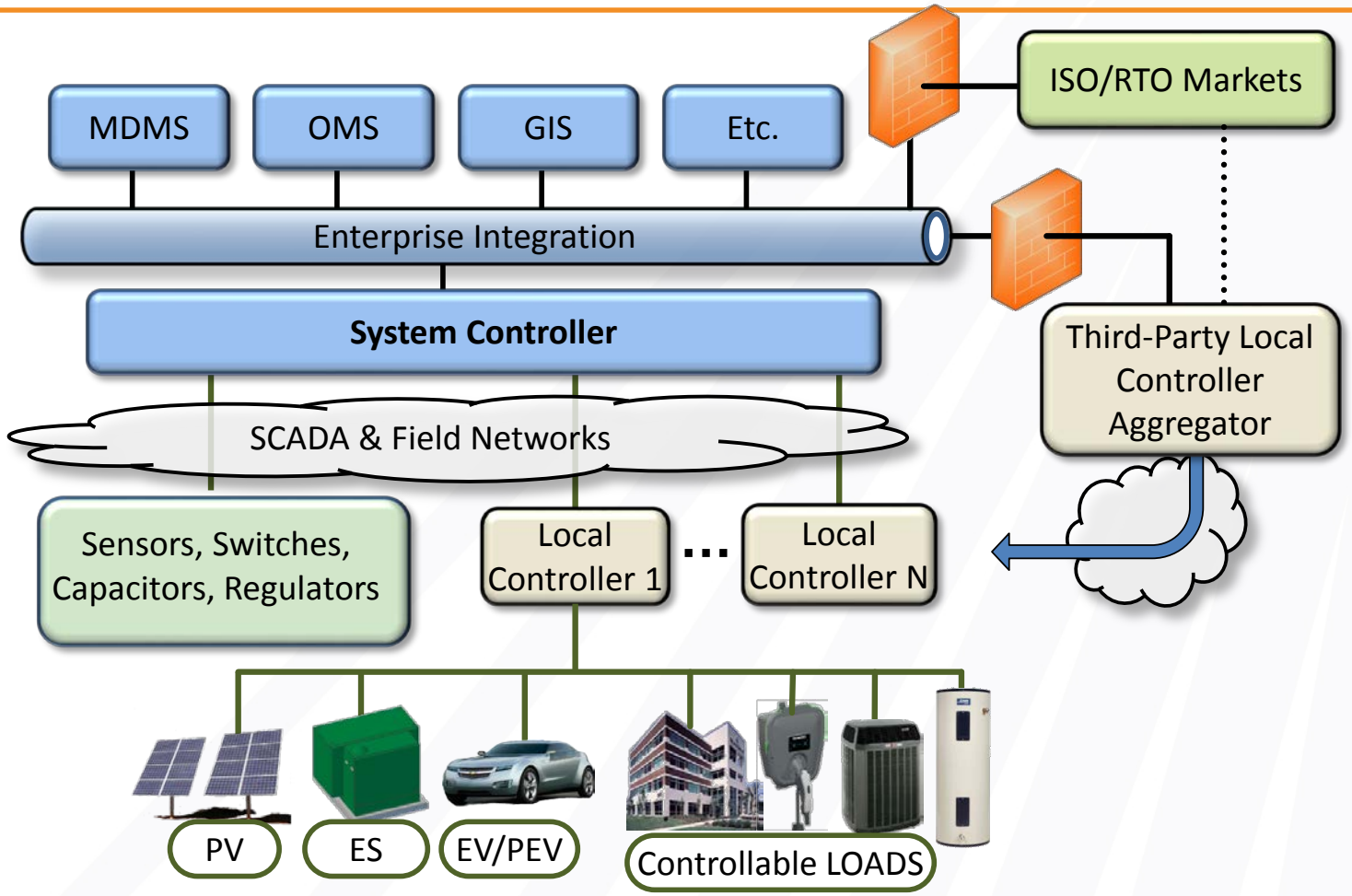


Commercial

Key Innovation

- In order to realize and demonstrate the sustainable and holistic integration of energy storage and solar, the **key innovation** of our proposal is the **two-level control architecture with optimization algorithms at each level –**
  - ***System controller*** maintaining wide area reliability of the electric system through coordinated control of multiple local controllers and other distribution equipment
  - ***Local Controller*** making solar PV more controllable through efficient utilization of energy storage, load management, smart inverters, and solar/load forecasting and also responding to system controller needs.

End-to-End Integration of DER with Power System Network

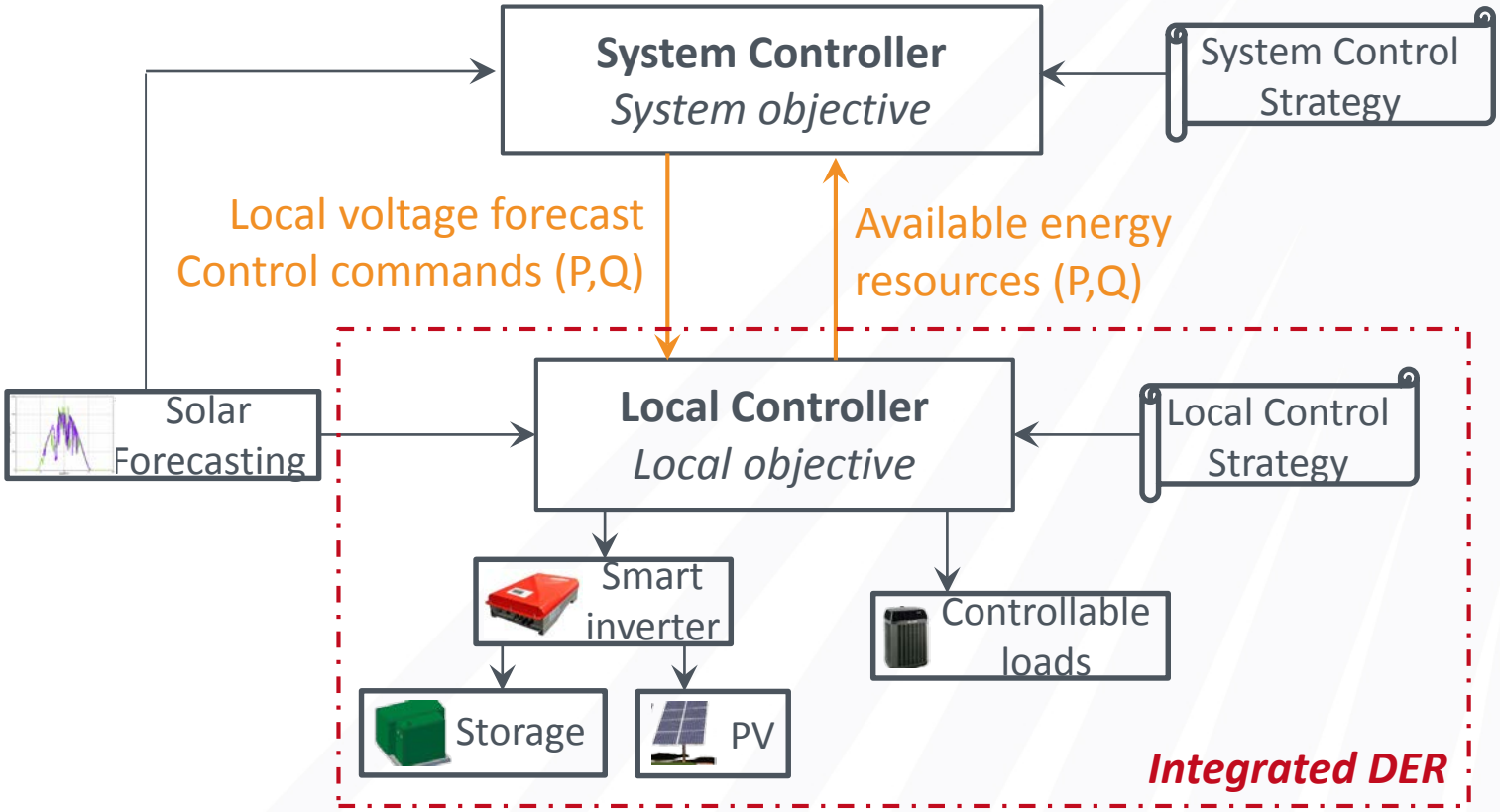


End-to-end integration will optimize existing resources and local DER while maintaining operational integrity of electric grid.

Proposed Innovations

- **End-to-end integrated system** through two-level **optimized control architecture**
- **Controllable Distributed Energy Resources** combining energy storage, and management with solar PV
- **Improved predictability of solar PV generation** through high resolution solar forecasting
- **Reduced lifetime cost of solar plus storage system cost** through reliable integrated smart inverters
- **Optimum operation of resources and settings of controllers** through distribution feeder modeling and impact studies
- **Interoperable and scalable solution** with open standards and communication protocols

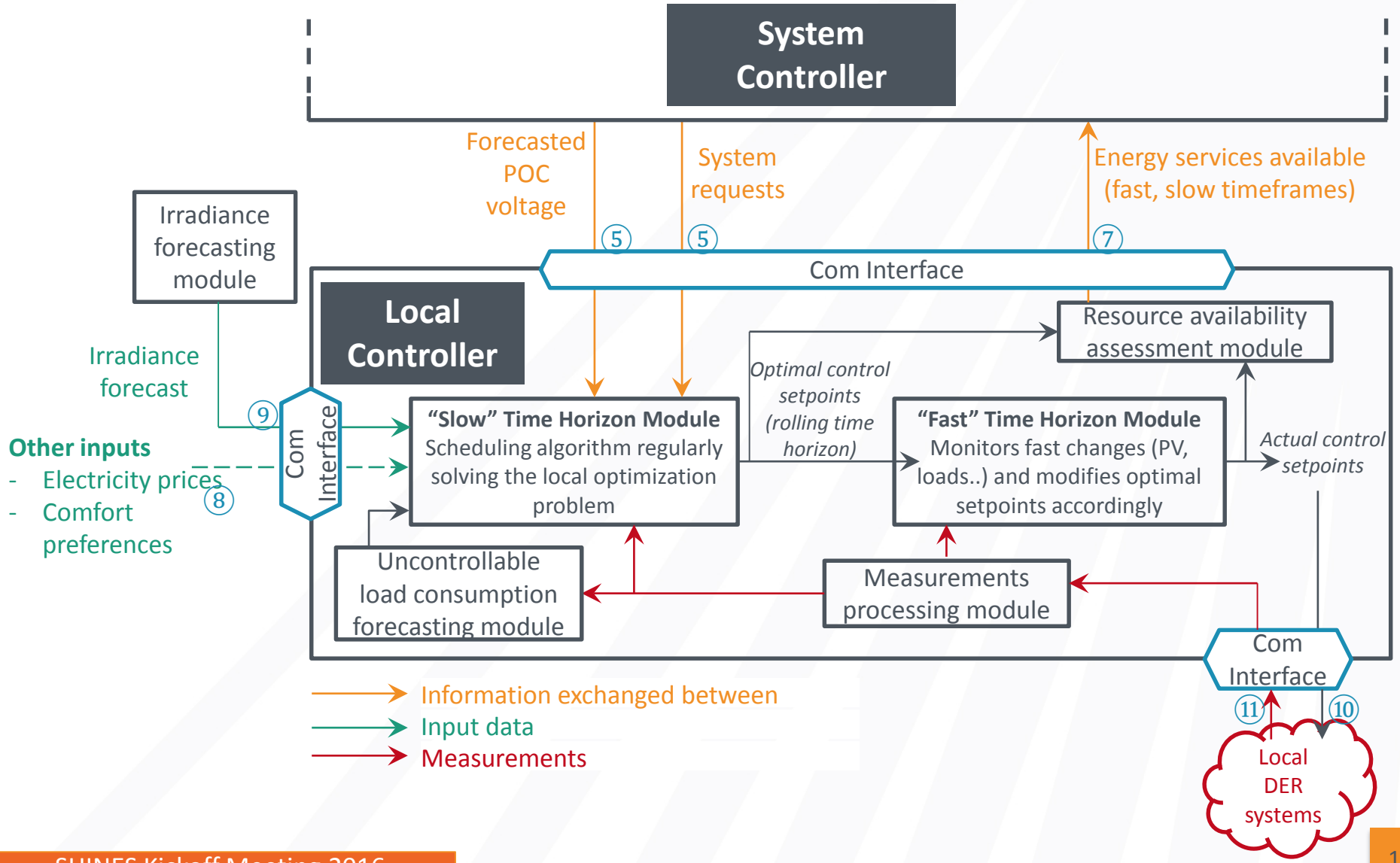
Approach – Two-Level Control Strategy



Execution Approach

Solution Design	Systems Design & Implementation	Site Demonstrations	Performance Assessment & Impact Analysis
- Control architecture - Functional requirements - Performance metrics	- Local & system controllers - Smart inverter design & development - Improved solar forecasting module	- Site preparations - PV & ESS Commission - Data collection	- Solution technical performance - Impact on PV hosting capacity - Cost & benefit analysis

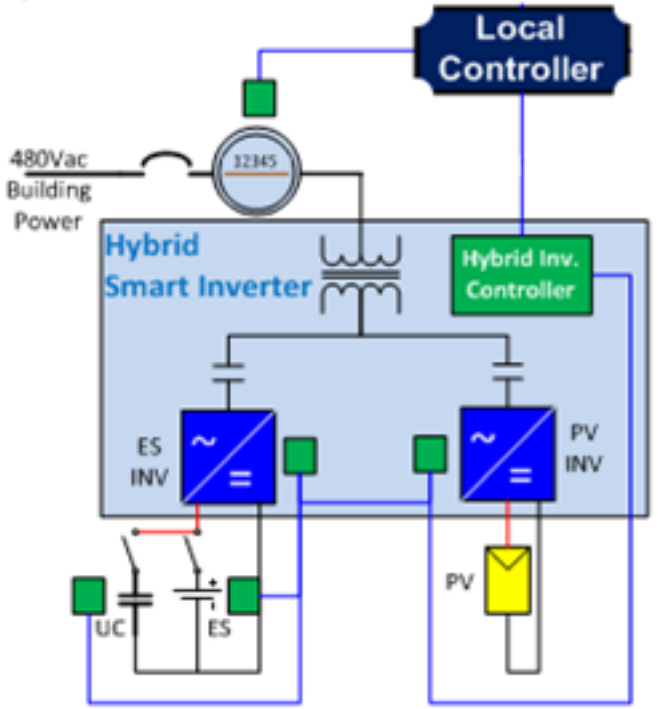
Approach – Local Controller Functional Blocks



Approach – Smart Inverters

Convert PV Inverter into AC-Coupled Hybrid Smart Inverter for PV & ES Integration

- Use of commercial PV inverter technology – proven reliability and cost reduction due to volume production

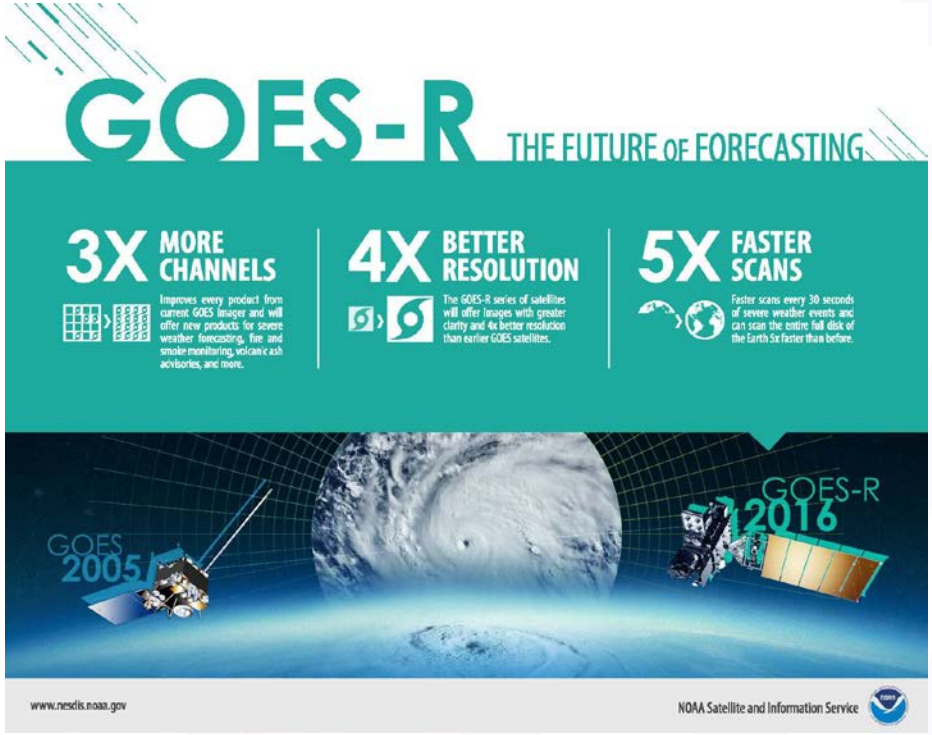


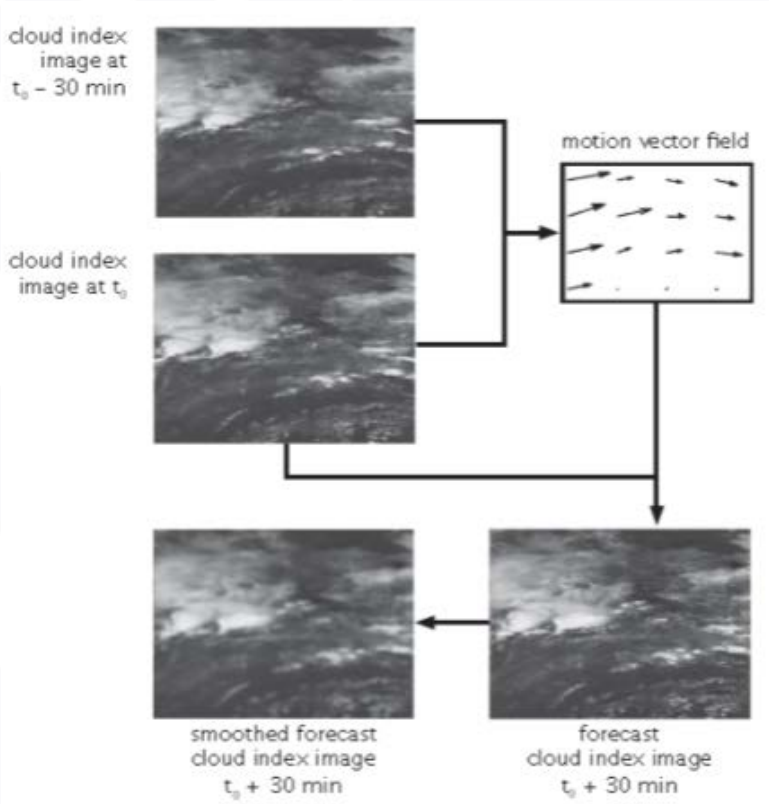
SiC-based DESS with Integrated Battery

- 4-quadrant high power density smart inverter
- Integration of utility distributed energy storage system with customer assets

Approach – Advanced Solar Forecasting

- One-min temporal, 1-km spatial resolution, 30-min ahead, and
- Thirty-min temporal, 1-km spatial resolution, 7-day ahead solar forecasting

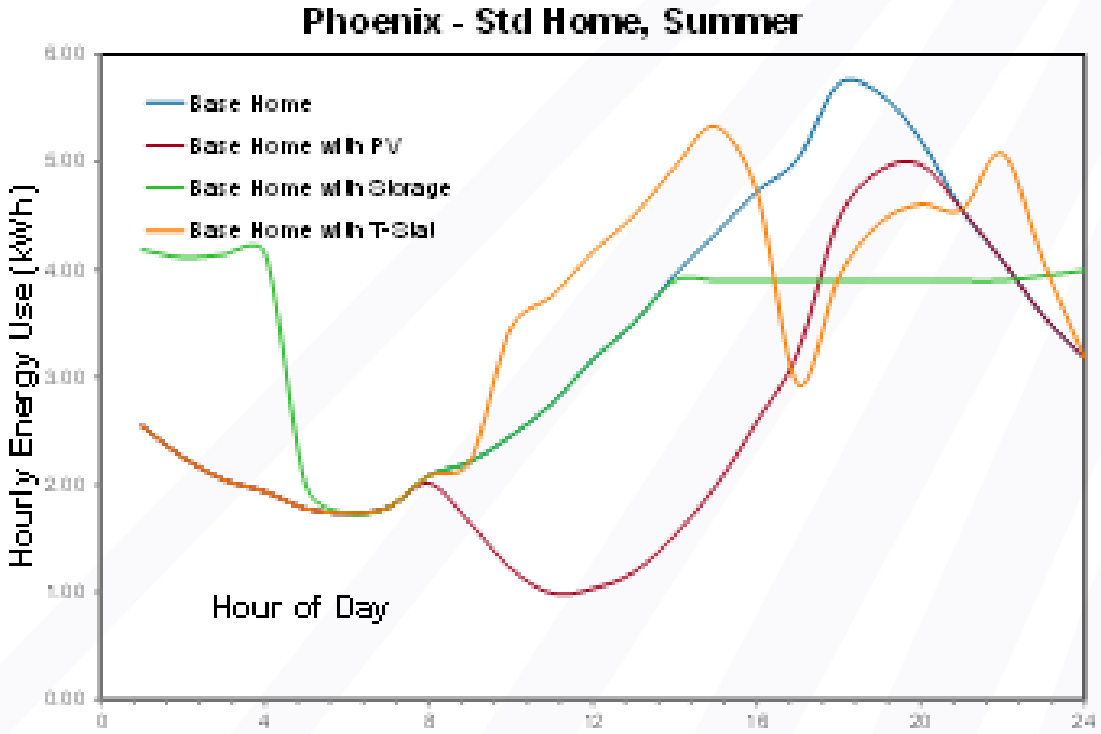




- Images from ***newest satellite platform GOES-R*** will be utilized to generate higher resolution solar forecast data.

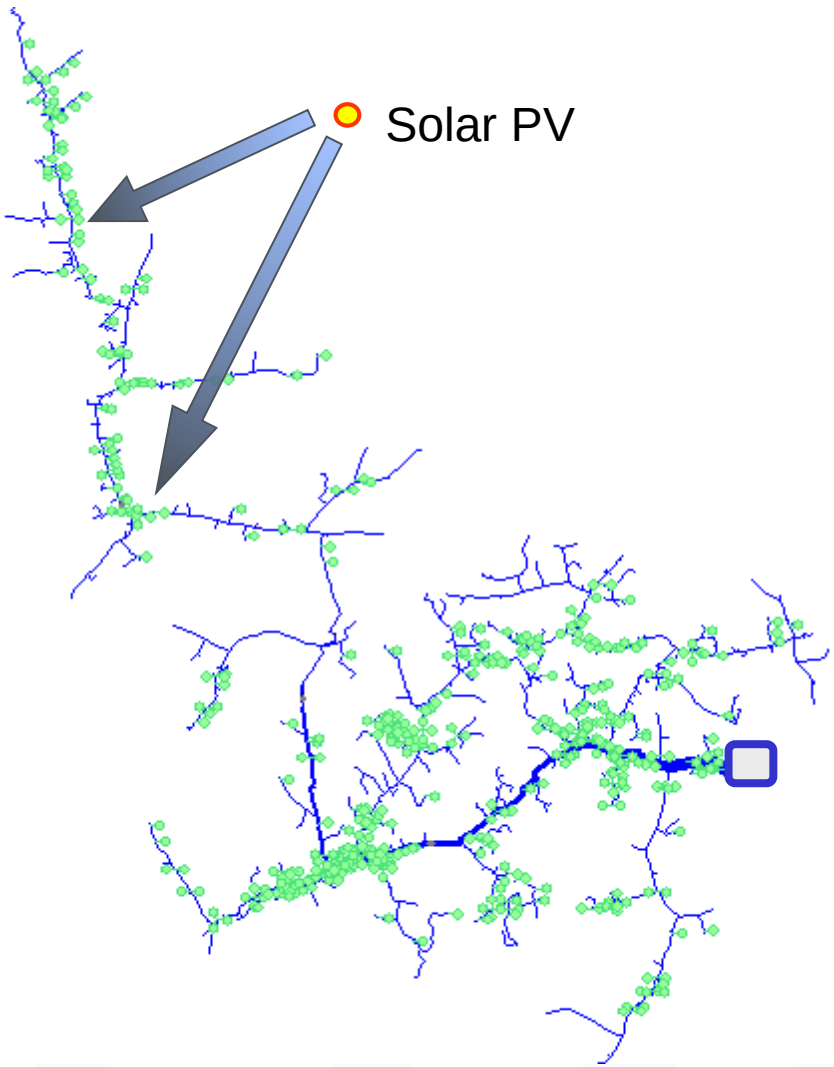
Approach – Load Management

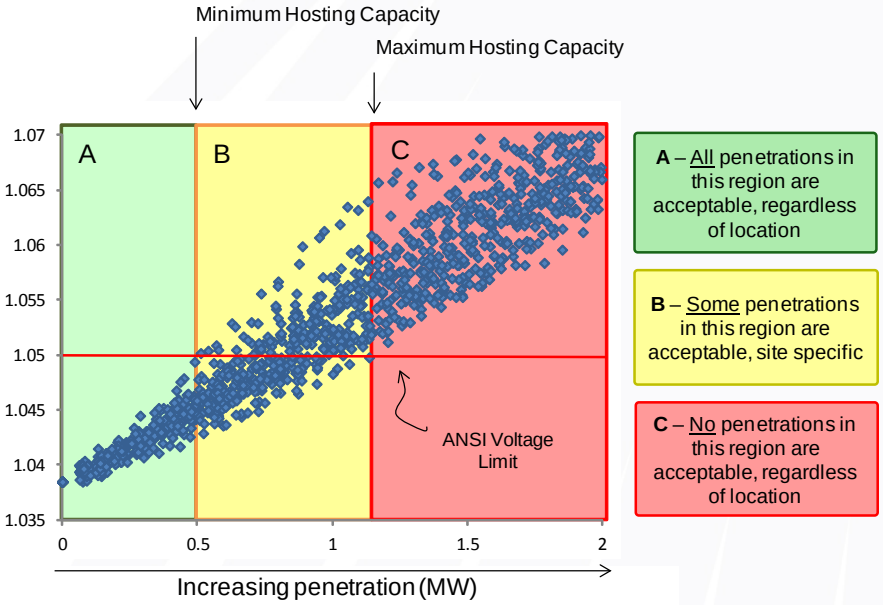
- Different load management control schemes including pre-heating and/or pre-cooling of air and water, adjustment of temperature set points, and execution of demand response will be utilized to control the load shape.

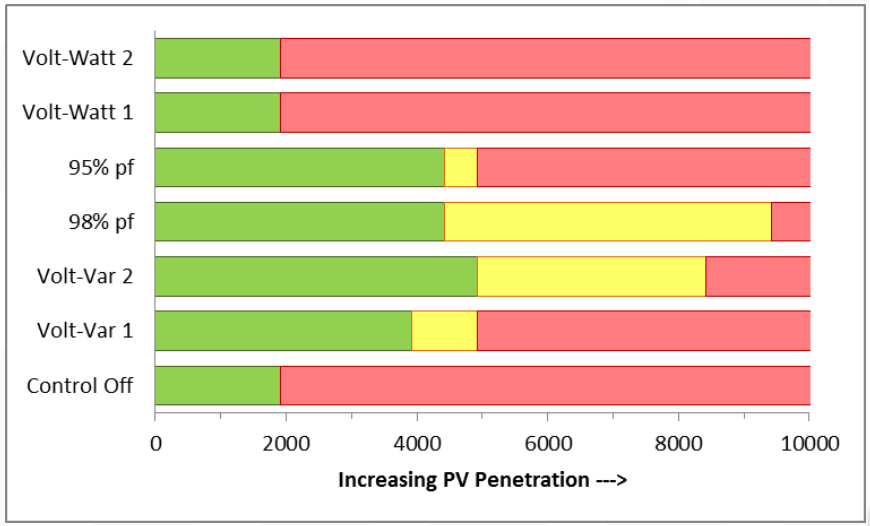


Assumed 3.6 kW PV, 4.4 kW/7.7 kWh storage with algorithmic control of load shapes for storage and T-stat technologies.

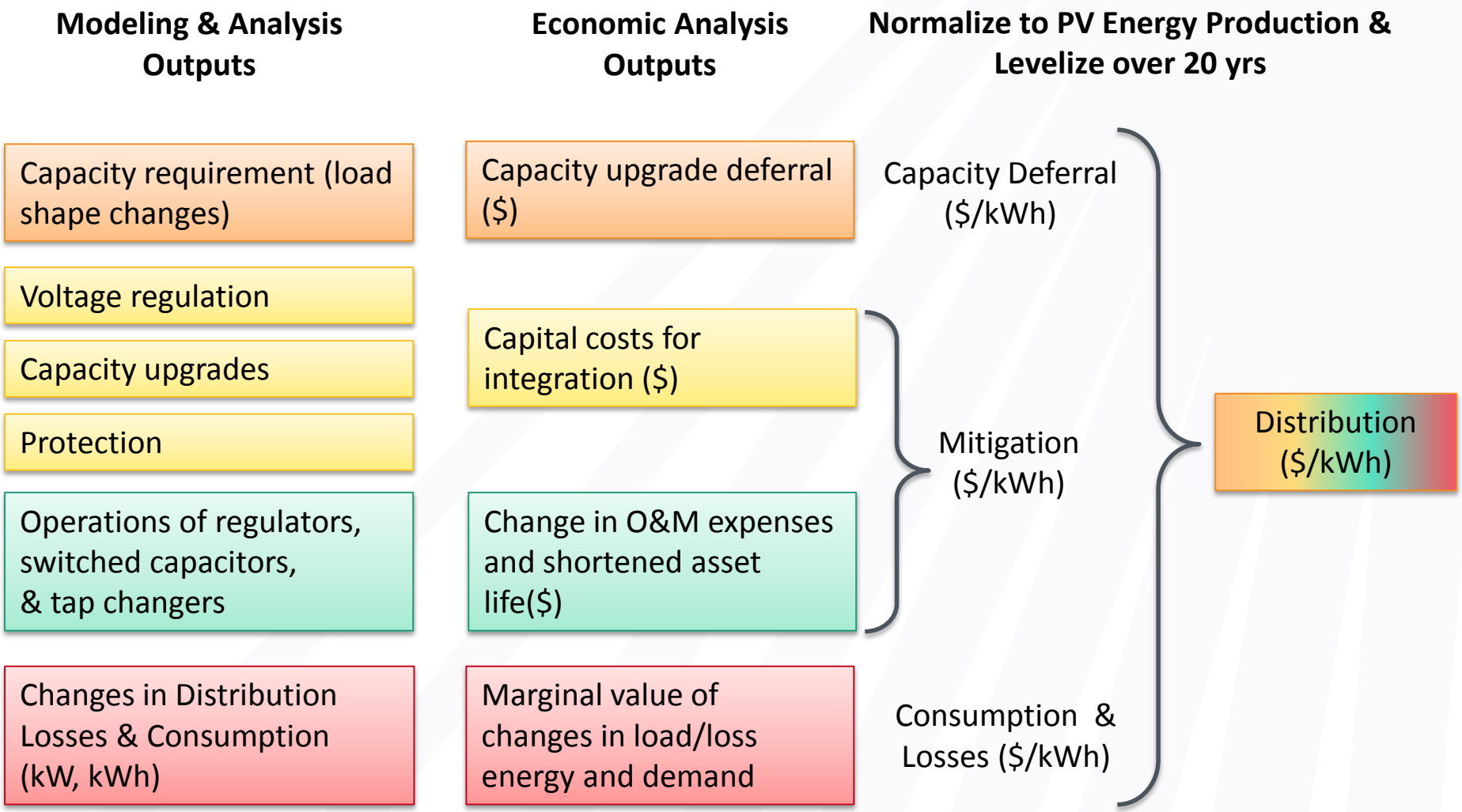
Approach – Distribution System Modeling







Approach – Cost/Benefit Analysis



EPRI SHINES Project Team

Utility Partners	Industry Partners	University Partners
• FirstEnergy	• Eaton	• Case Western Reserve University
• ConED	• GE (Alstom Grid)	• City University of NY, Queens College
• NYPA	• Clean Power Research	
• Southern Co	• PowerHub	
• Gulf Power	• LG Chem	
• LADWP†	• Smart Inverter vendors	
• AECC†		
• AEP†		
• Duke†		

† *Supplemental Project Participants*

Roles

Team	Project Responsibilities
Electric Power Research Institute	Project management, controllers functional requirements, circuit modeling, economic assessment, performance validation, and tech transfer
Utilities	Customer engagement, performance metrics and benchmarking, and technical review
Case Western Reserve University	Control algorithm development, circuit impact studies, commercial demonstration site hosting
Queens College/ CUNY	Commercial demonstration site hosting
Eaton	Local controller and 4-quadrant hybrid smart inverter
GE (Alstom)	System controller
PowerHub	SiC-based DESSS with integrated Li-Ion battery
Clean Power Research	Improved solar forecasting from GOES-R satellite images and PowerClerk interface with distribution simulation tools
LG Chem	Supplying Li-Ion batteries for CWRU demonstration site

Demonstration Sites

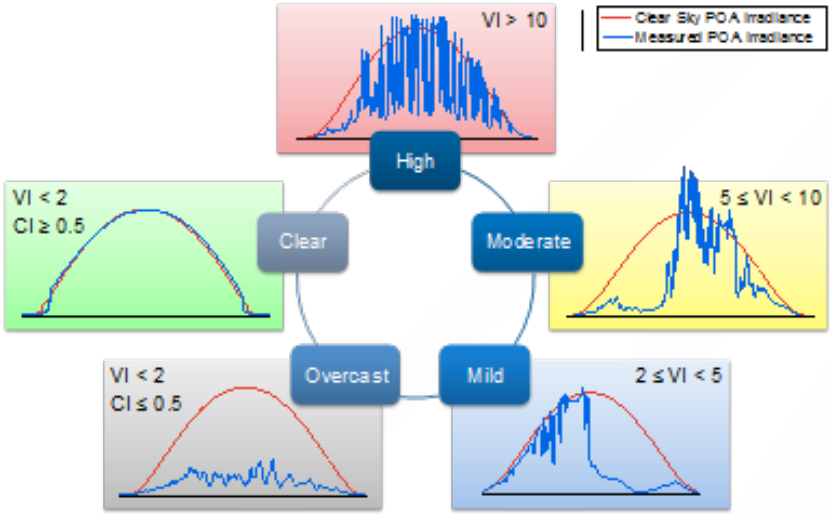
	Commercial Site#1	Commercial Site#2	Residential site#1
Owner	CWRU	Queens College/CUNY	Individual home owners
Utility	FirstEnergy/MCCo	NYPA/ConED	Southern Co/Gulf Power
PV	50kW	50 - 60kW	Two; each 4-6kW
Energy Storage	50kW/200kWh	100kW/200kWh	30kW/34kWh
Solar Forecasting	CPR	CPR	CPR
Smart Inverter	Eaton AC-coupled hybrid Inverter	TBD – DC coupled hybrid inverter will be considered	PV String Inverter – TBD PowerHub SiC-based 4-quadrant
Battery	LG Chem	TBD	DESS Integrated
Local Controller	Eaton	TBD – BEMS will be considered	TBD – HEMS will be considered
System Controller	GE (Alstom)	TBD	TBD
Data Monitoring and Analysis	CWRU, EPRI	Queens College, EPRI	Home Owners, EPRI

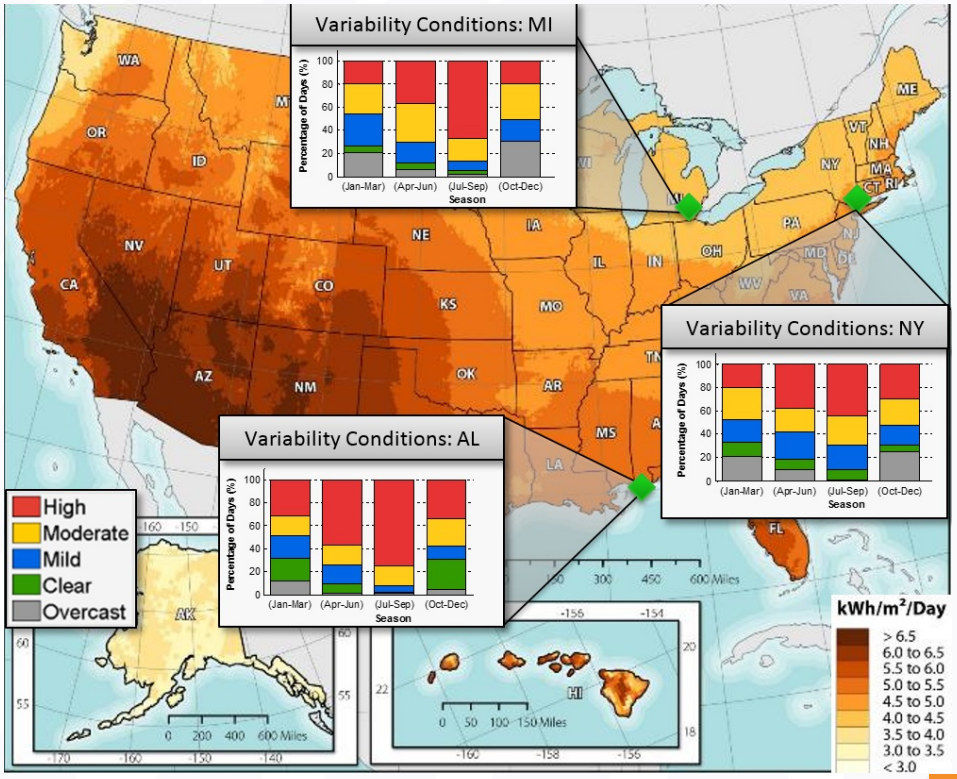
Demonstration Plan

Two PV market segments: residential and commercial, and

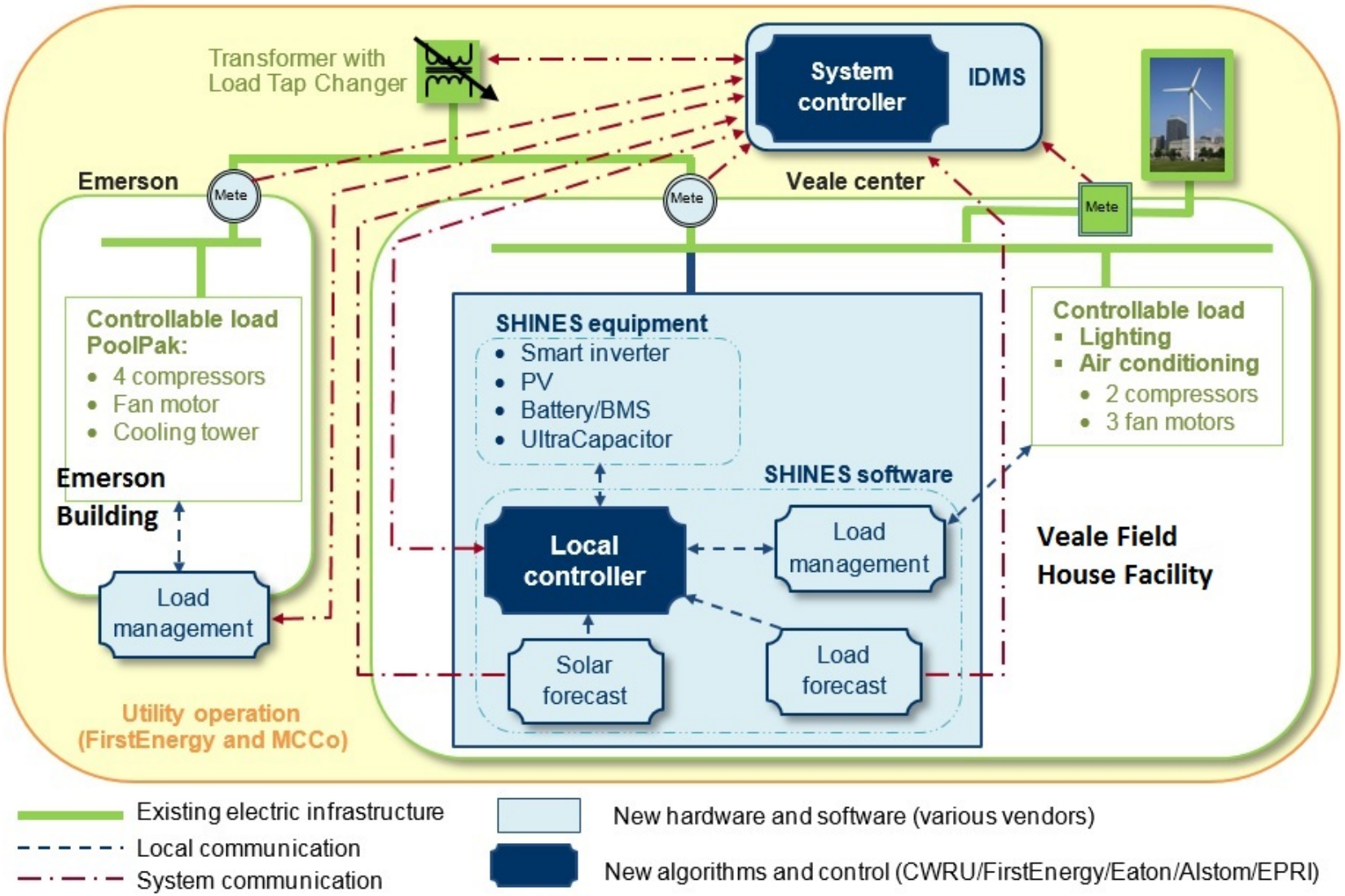
Three geographically diverse utility service territories.

- *Geographical location significantly impacts solar variability*
- *Distribution circuits and loads are also different*

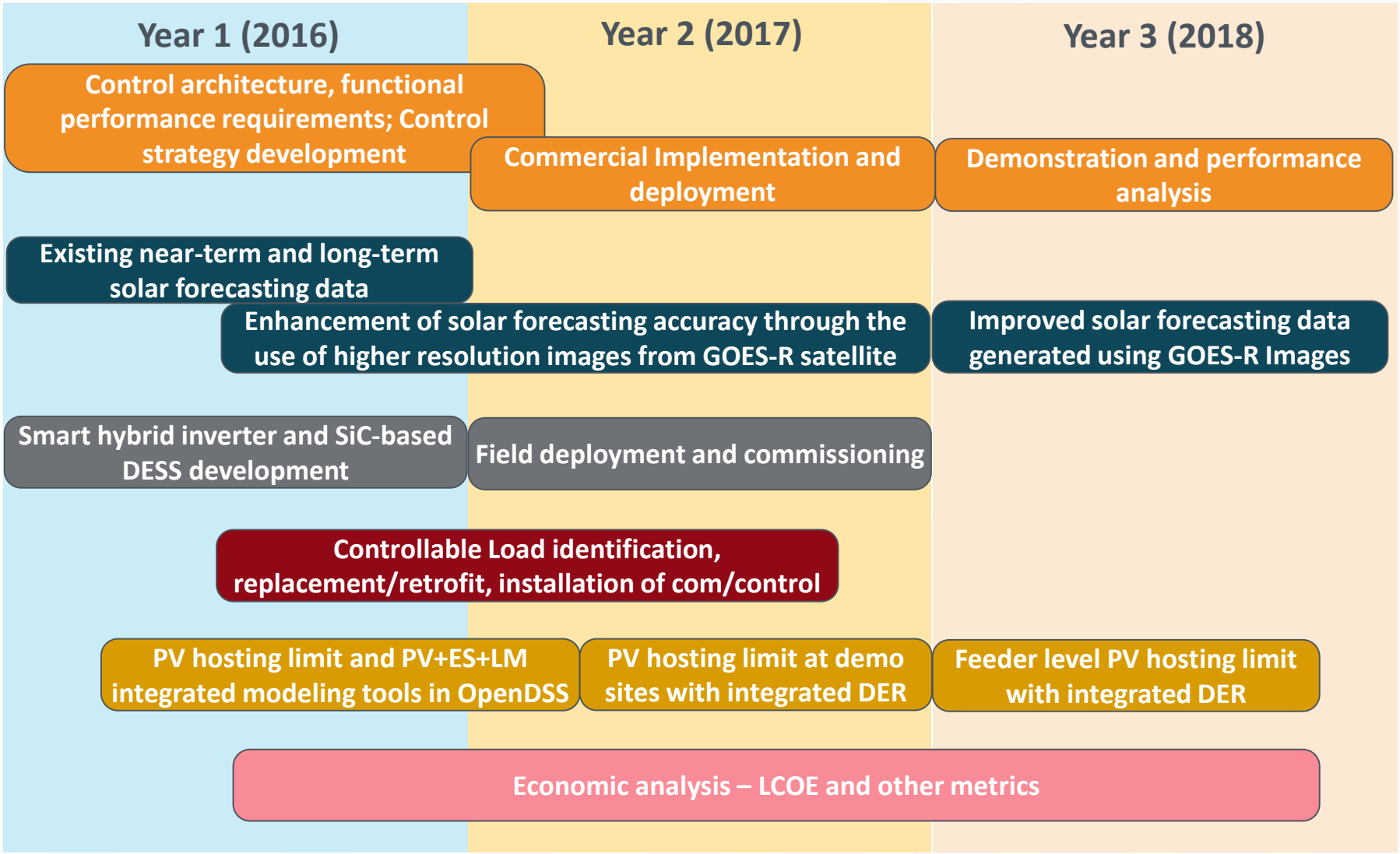




Development and Demonstration Site at Case Western Reserve University (CWRU)



Project Schedule



Relevance to Solar Challenge

- **Making the grid ready for seamless integration of solar plus storage to support customer choice**
  - *while optimizing the electric system: technically and economically*
- **Making solar plus storage more operationally integrated**
  - *in a cost competitive manner*
- **Improving the value proposition of solar plus storage and other distributed energy resources**
  - *extending benefits beyond customer premises*

Together…Shaping the Future of Electricity