SunShot
U.S. Department of Energy

SHINES Kickoff Meeting 2016

# SUNDIAL

## An Integrated SHINES System Enabling High Penetration Feeder-Level PV

Fraunhofer USA
ENERNOC
nationalgrid

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# A Vision for Integrating Hundreds of GW of Solar

## SHINES Solicitation Goals:

"develop and demonstrate integrated, scalable, and cost-effective technologies for solar that combine PV generation and energy storage and work seamlessly to meet both consumer needs and the needs of the electricity grid."

## SunDial Objectives:

- An extensible framework for readily and cost-effectively integrating loads, storage, and PV
- Test and pilot business models and market mechanisms to enable high penetration of PV

## Market Transformation: *A transparent, low-friction market for storage / solar integration on the feeder level*

- Flexible with respect to markets: multiple use cases, vendors, and business models
- Flexible with respect to asset location, ownership, and type

# Outline

- Project Team
- Technical Approach
- Project Execution
- Summary: A Vision for the Future of Solar

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## *Fraunhofer CSE Mission:* Dedicated to building tomorrow's energy future today

- Non-profit, applied R&D laboratory
- Located in Boston (MA), Southwest Test Center in Albuquerque (NM)
- Project Types
  - Product/Technology Development
  - Field Testing & Evaluation
  - Technology Assessment
- Focus Areas
  - Grid integration of renewables
  - Energy management & behavior
  - PV module and system technologies
  - Building enclosures

*Source*: Fraunhofer.

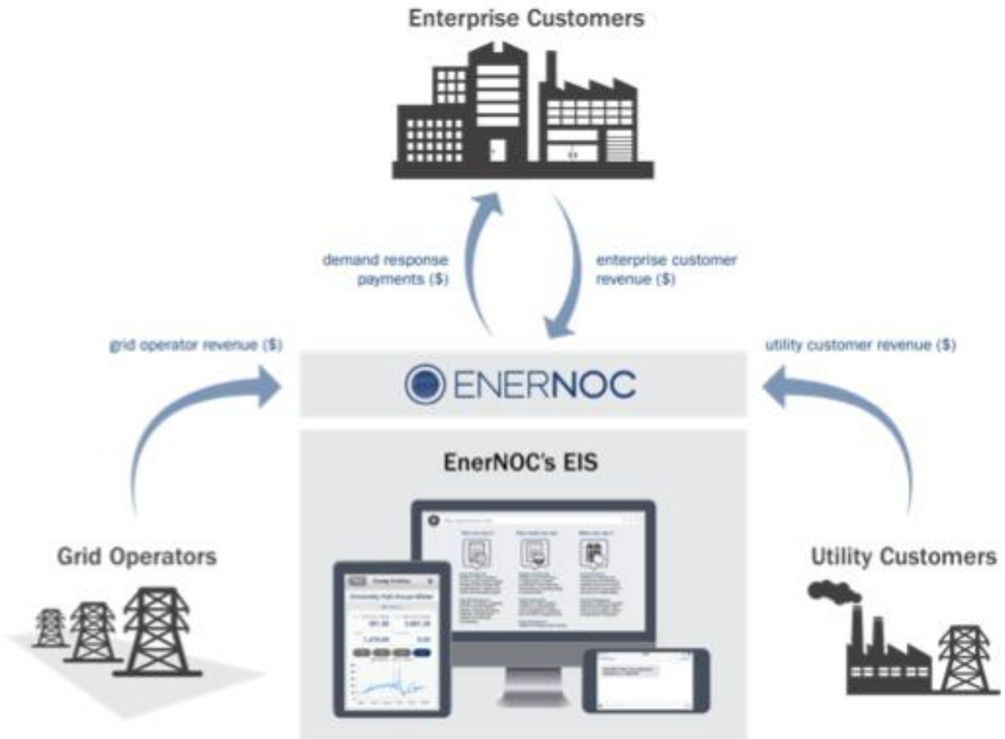
ENERNOC nationalgrid Fraunhofer USA

# EnerNOC's Energy Intelligence Software (EIS)

Helping Enterprise and Utility customers manage energy intelligently

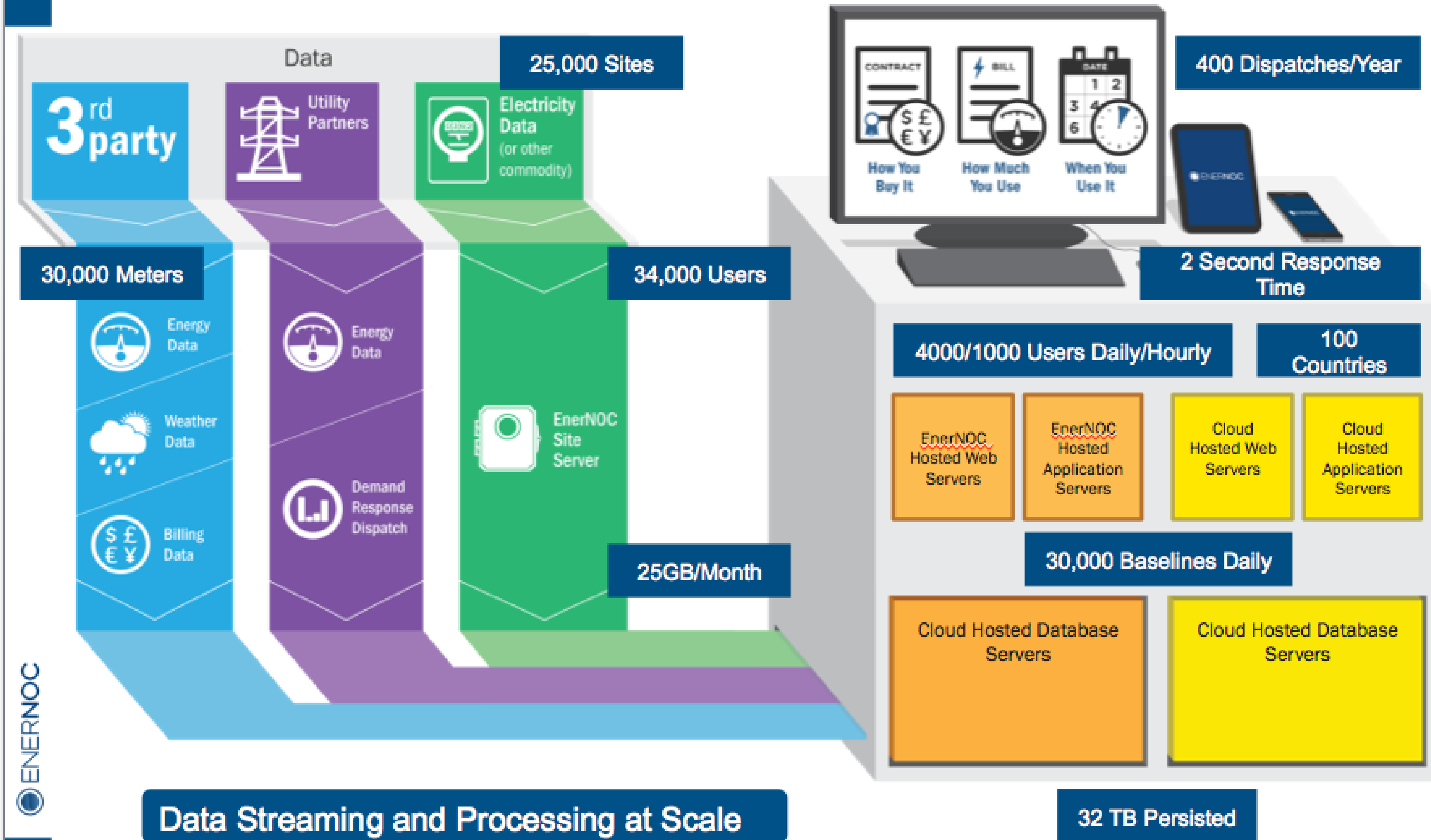
**Enterprises** leverage our software manage major cost drivers of their energy spend.

**Utilities** work with EnerNOC to manage end-user demand and procure additional capacity through virtual power plants




*Source*: EnerNOC.

# EnerNOC Platform

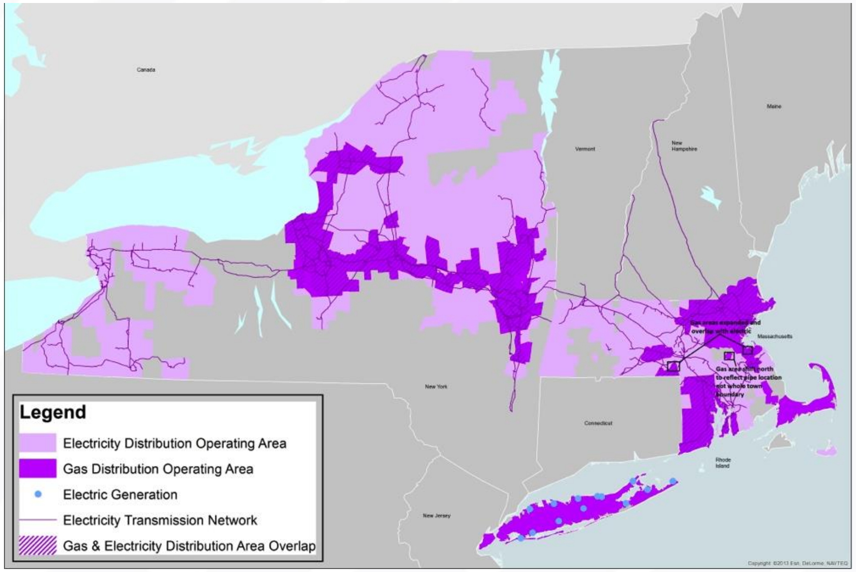



*Source*: EnerNOC.

nationalgrid

- One of the largest investor-owned electrical and gas utilities in the Northeast
- 3.4 million customers
- Multiple projects to explore the "Utility of the Future" including demand management, smart grid, microgrids, and renewables
- Innovation in renewable energy generation and energy efficiency programs.
  - Phase 1 Solar: 4.8MW of Utility-Owned Solar
  - Phase 2 Solar: up to 20MW of Utility-owned solar

## Electricity Distribution, Transmission & Generation - US




*Source*: National Grid.

# Phase II Solar

Purchase up to 20 MW's of turn-key solar sites, implemented with advanced inverters

National Grid's goal is to use these sites to further solar development in the Commonwealth through advanced technologies

- Lower interconnection costs
- Increase penetration of PV per Feeder
- Lessons Learned

Learn more about impacts of solar on areas by pre-selecting towns with:

- High PV penetration feeders
- Lightly loaded feeders
- Heavy loaded feeders

*Source*: National Grid.

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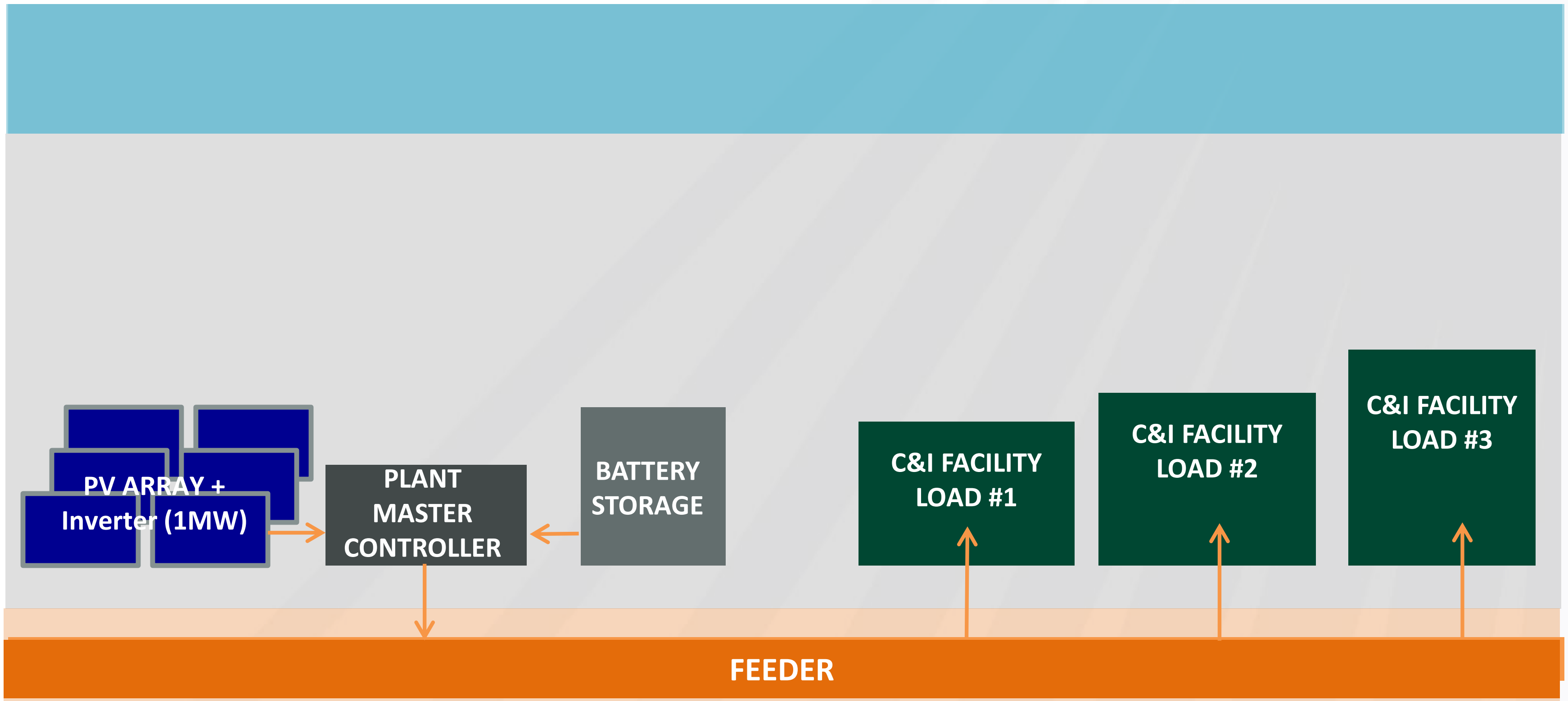
# The Concept

**Physically decouple storage, PV, and load management**

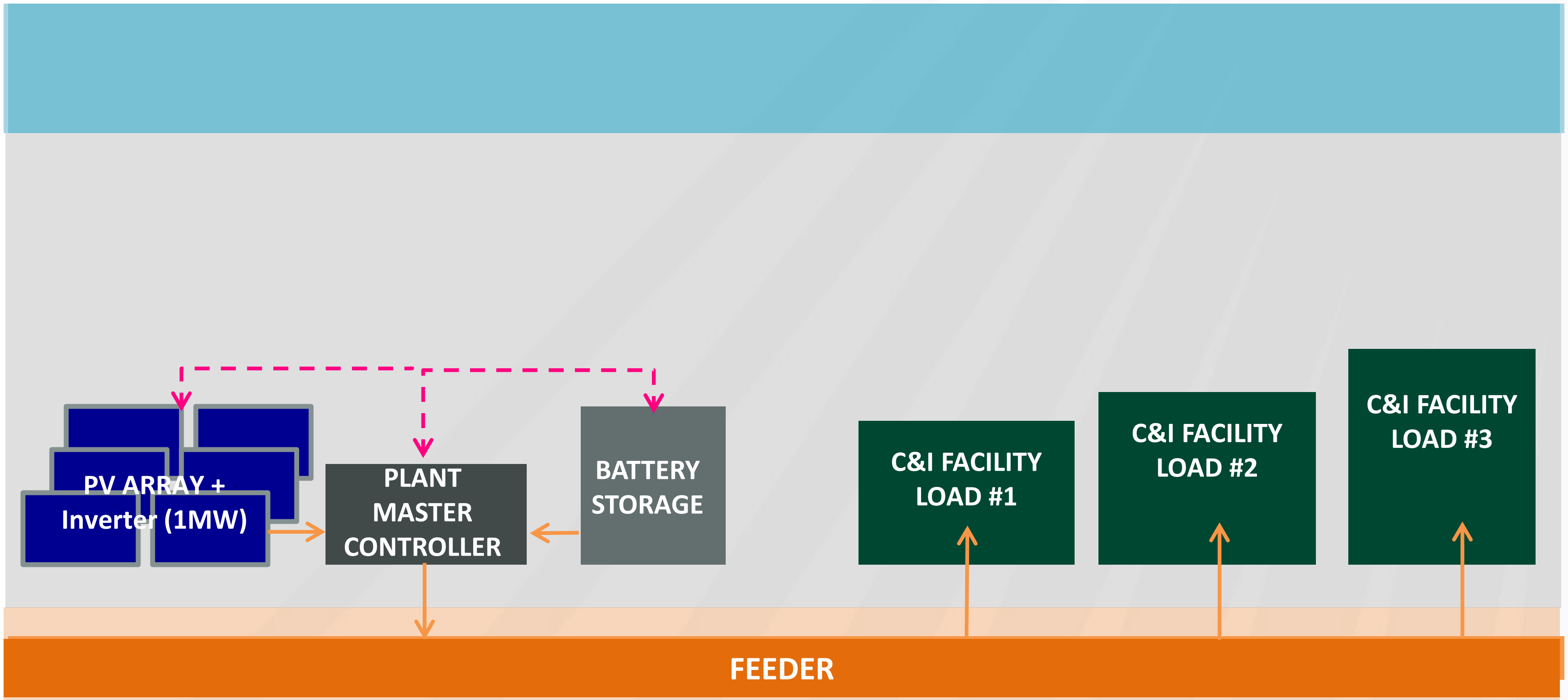
- **Global Scheduler:** Feeder-scale global optimization engine
  - Optimization over varying timescales and use cases
  - Leveraging PV, storage, AND aggregated load management resources
- **FLAME:** Facility load aggregation and management engine
  - Based on an existing, proven demand response aggregation business model
- **Plant Master Controller:** Local, fast, site-level control of PV and storage
  - Utilizing standard utility-scale PV/Storage control and integration capability
- Newly developed **interoperability interfaces**

***Enables a transparent, broadly scalable mechanism to achieve and simplify feeder-scale integration of PV, loads, and battery storage***

# Architecture – Major Components



# Architecture – Major Components



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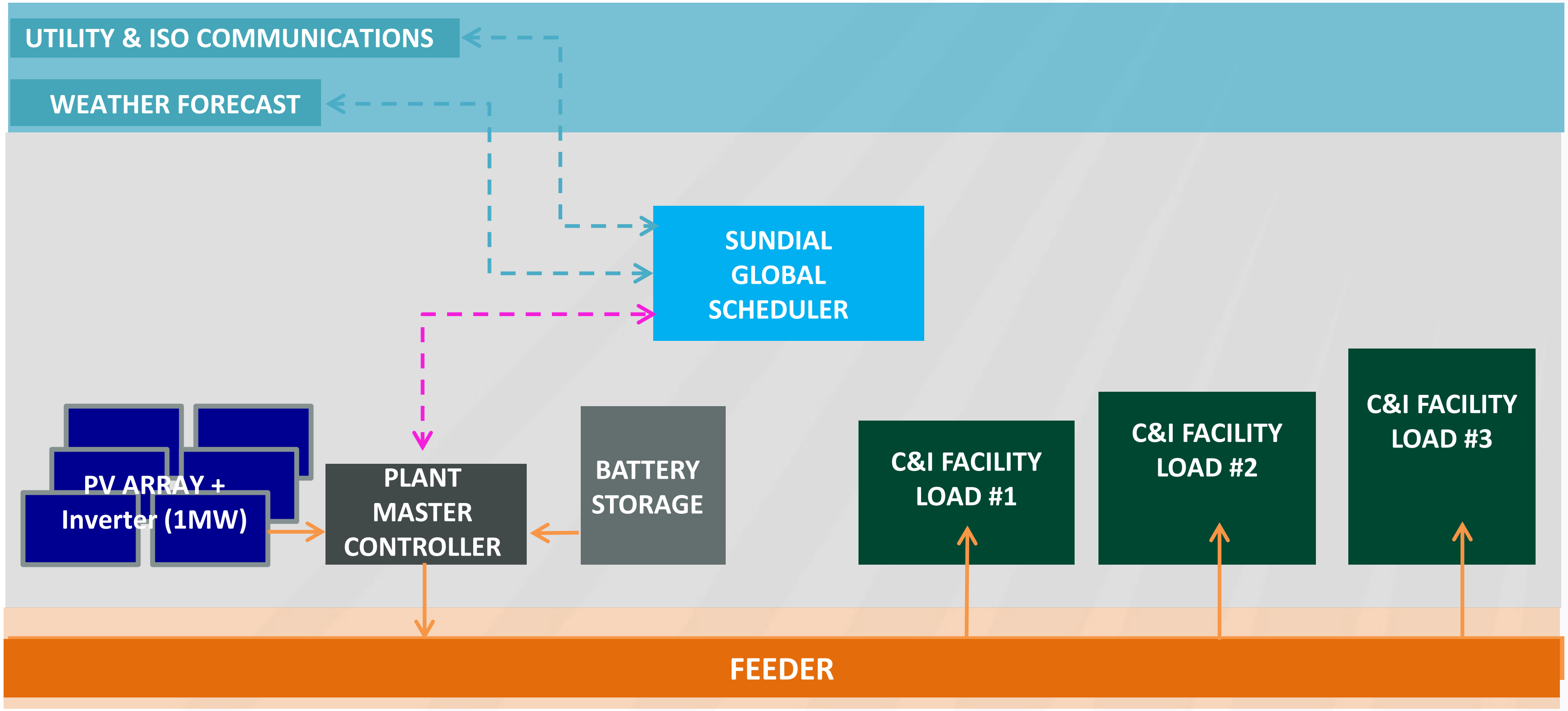
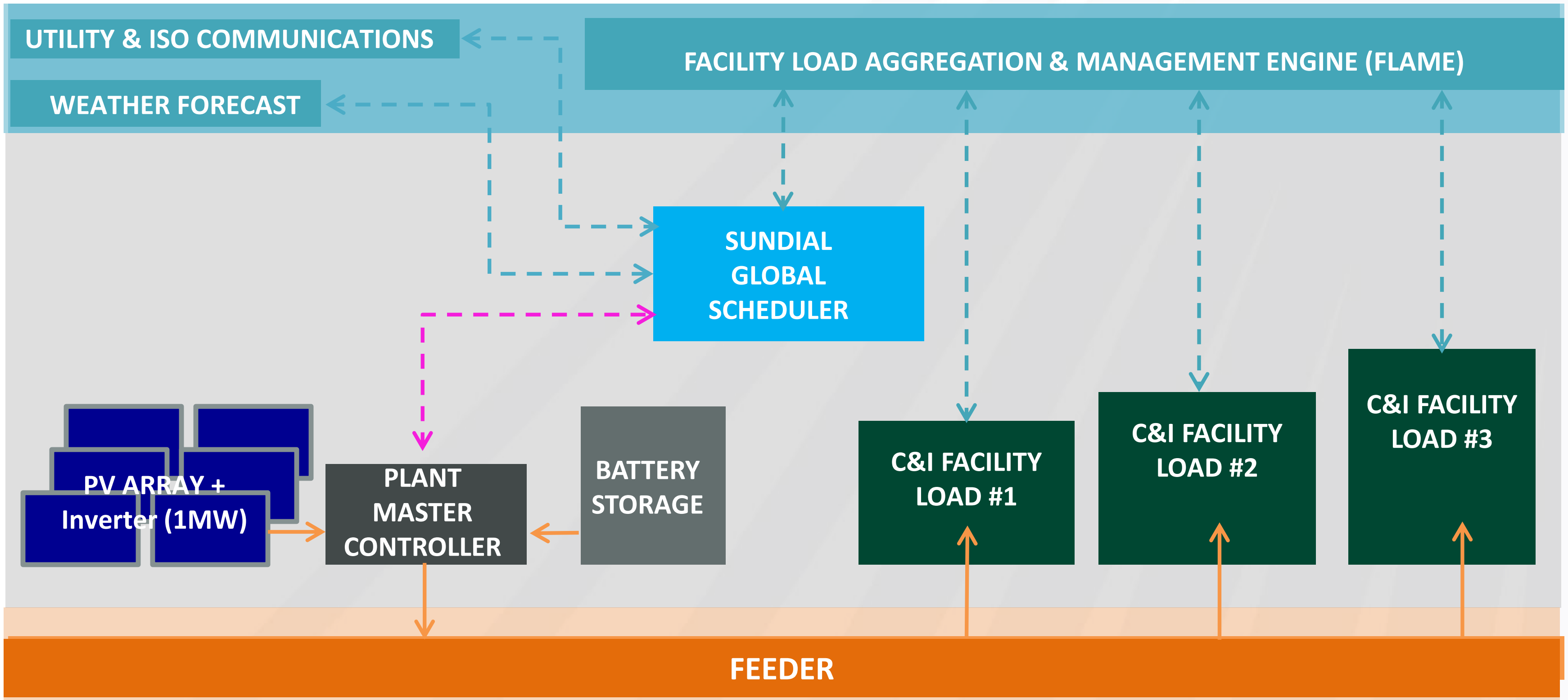


# Architecture – Major Components



# SunDial Global Scheduler

## Works for Different Use Cases

- PV intermittency mitigation
- Load Shaping
- Peak Load Reduction
- And more…

## Determines System State (Current & Predicted Future)

- Solar resource
- Battery
- Loads and Load Sink/Shed Potentials
- Grid Constraints, Pricing

## Performs Optimization

- Minimize cost based on objective function defined by the current use case
- Shrinking horizon scheduling approach
- Updated according to new information at subsequent scheduling steps.

## Generates Control Signals

- PMC, FLAME, Battery

**Implemented as an extension of, e.g., PNNL's VOLTTRON distributed control and sensing platform**

# Global Scheduler Platform

Implementation-Specific
Example implementations
to be demonstrated

- **Optimization Layer**
- **Applications Layer**

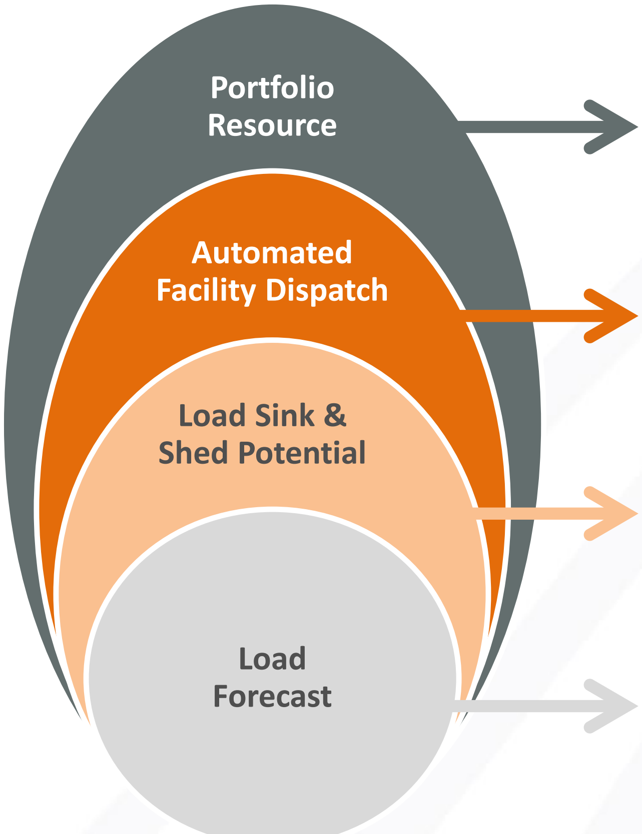
Open Source
Interoperability Framework
Leverage existing standards,
identify Gaps

- **Device / Data Model Layer**
- **Communications Layer**

Extend existing platform, e.g., VOLTTRON, to incorporate…

- Supply-side interoperability interfaces
- Expanded applications layer and global optimization tools
- Extension of existing interoperability standards

# Facility Load Aggregation & Management Engine (FLAME)




Statistical representation of expected portfolio loads and shed/sink potentials and their costs, over time

Curtailment script within customer acceptance parameters

Building model calibrated with prior load control events

Predicted loads based on historic building data and exogenous weather factors

# Facility Load Aggregation & Management Engine (FLAME)

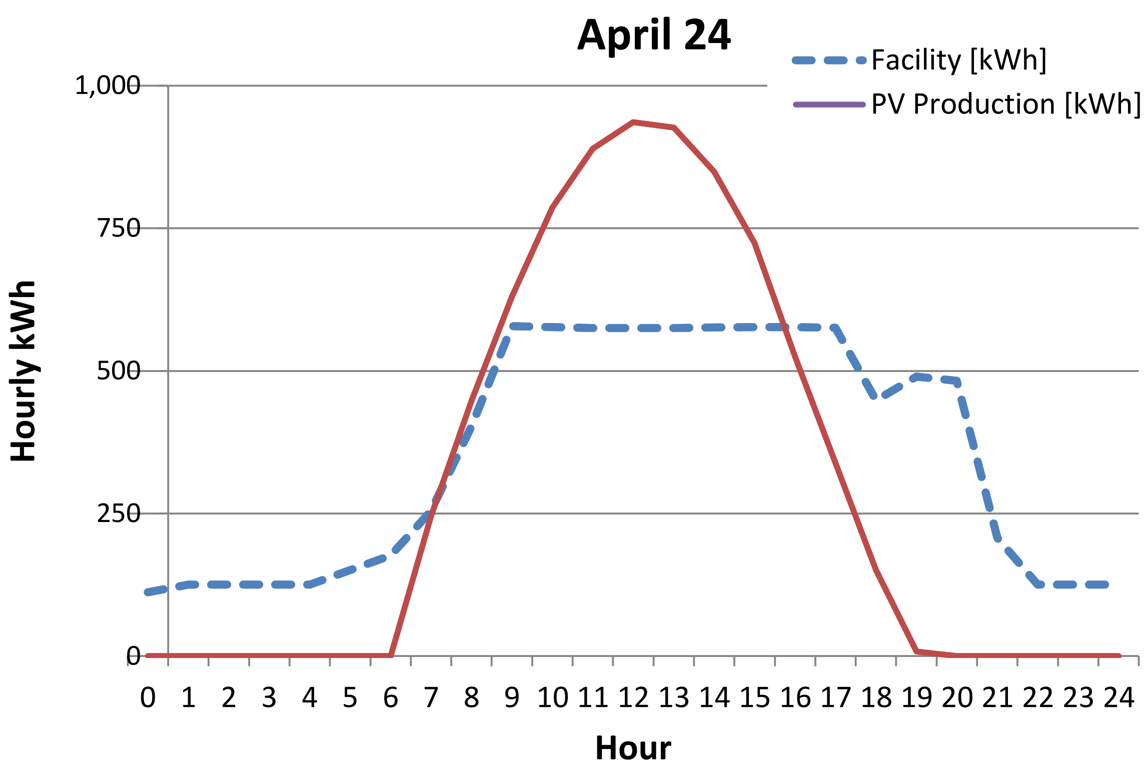
- Cloud-based aggregation and control
- Local EnerNOC Site Servers to implement load management, transfer data to and from Global Scheduler
- Readily extensible – can integrate additional facilities as needed/desirable
- Manages complexity locally so Global Scheduler doesn't have to
  - Limits data flows to Global Scheduler

# Different Use Cases

***Illustrative Examples***

| Use Case | Goal | Battery Storage | FLAME |
|---|---|---|---|
| PV Intermittency | Limit max. rate of change to <10%/min | Seconds to minutes | ~5-15 minutes (fans, pumps, lighting) |
| Feeder-scale Load Shaping | Limit net power flow and morning/evening ramps | 15 min to 4+ hours | 15 min to 4 hours (pre-cooling, HVAC) |
| Peak Load Shaving / Demand charge reduction | Match generation and loads | 15 min to 4+ hours | 15 min to 4 hours (pre-cooling, HVAC) |
| Volt-Var | Optimize voltage | Real/Reactive power | n/a |

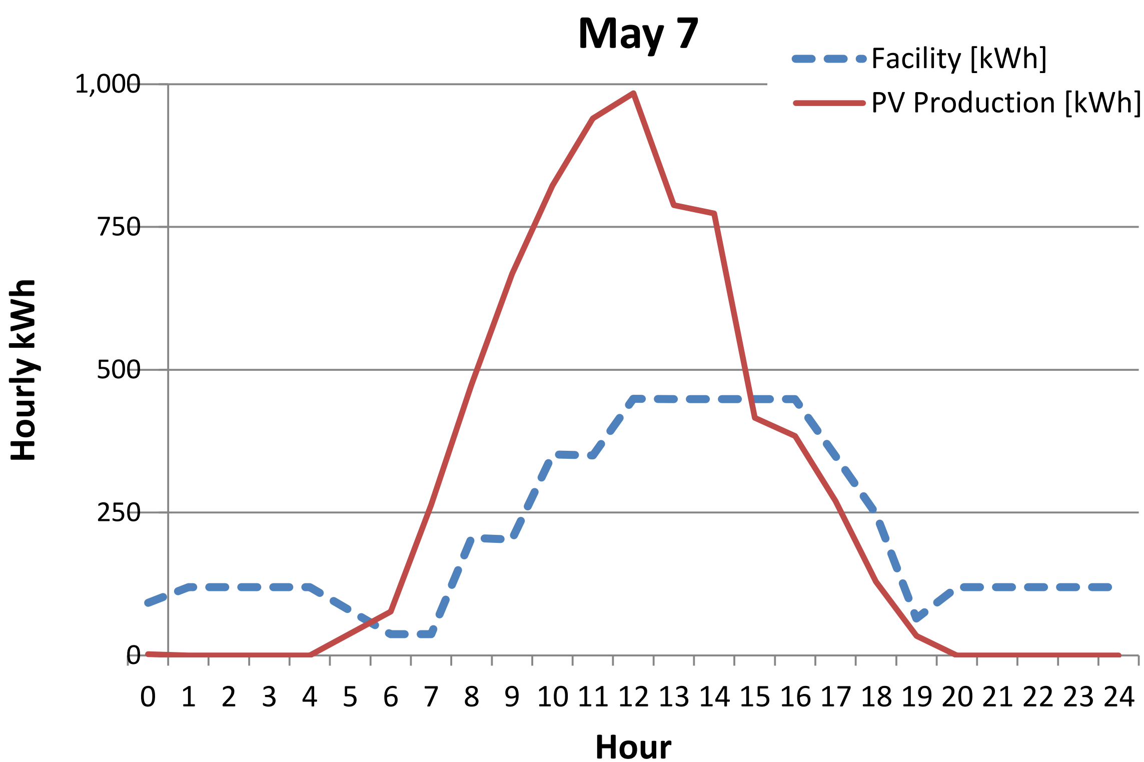
# Challenge: Sunny Spring Days




- "Typical" April 24th
- Big Box Retail
- PV = 1,000 kW
- Building Peak = 1,000 kW
- $T_{high}$ = 73°F

*Sources*: DOE/OpenEI, Fraunhofer calculations.

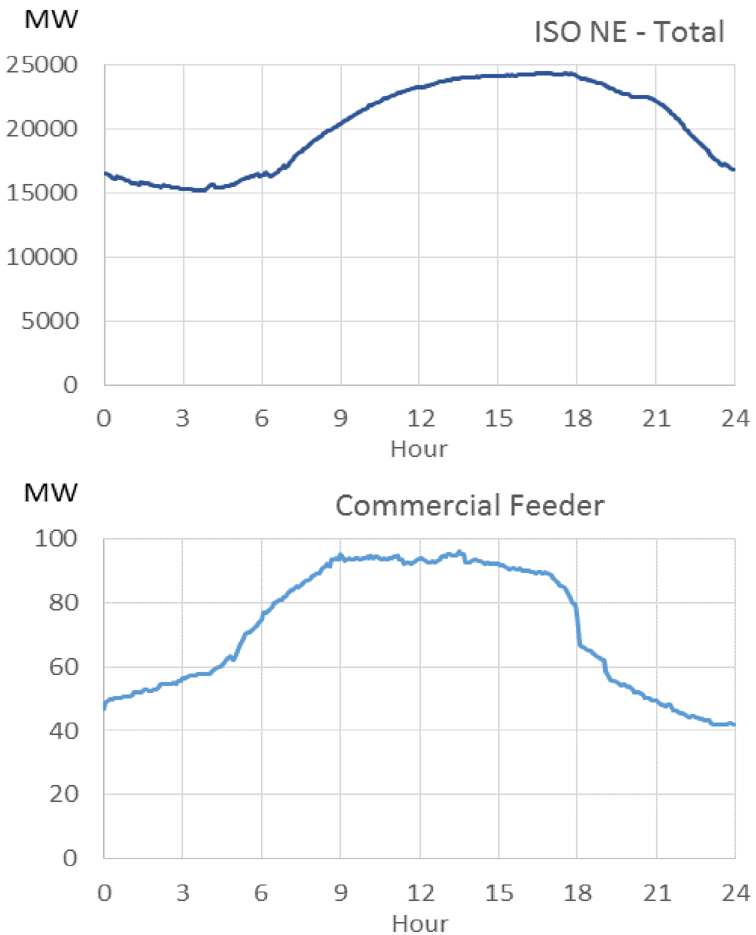
# Challenge: Cooler Sunny Spring Days




- “Typical” May 7th
- Big Box Retail
- PV = 1,000 kW
- Building Peak = 1,000 kW
- $T_{high}$ = 56°F

*Sources*: DOE/OpenEI, Fraunhofer calculations.

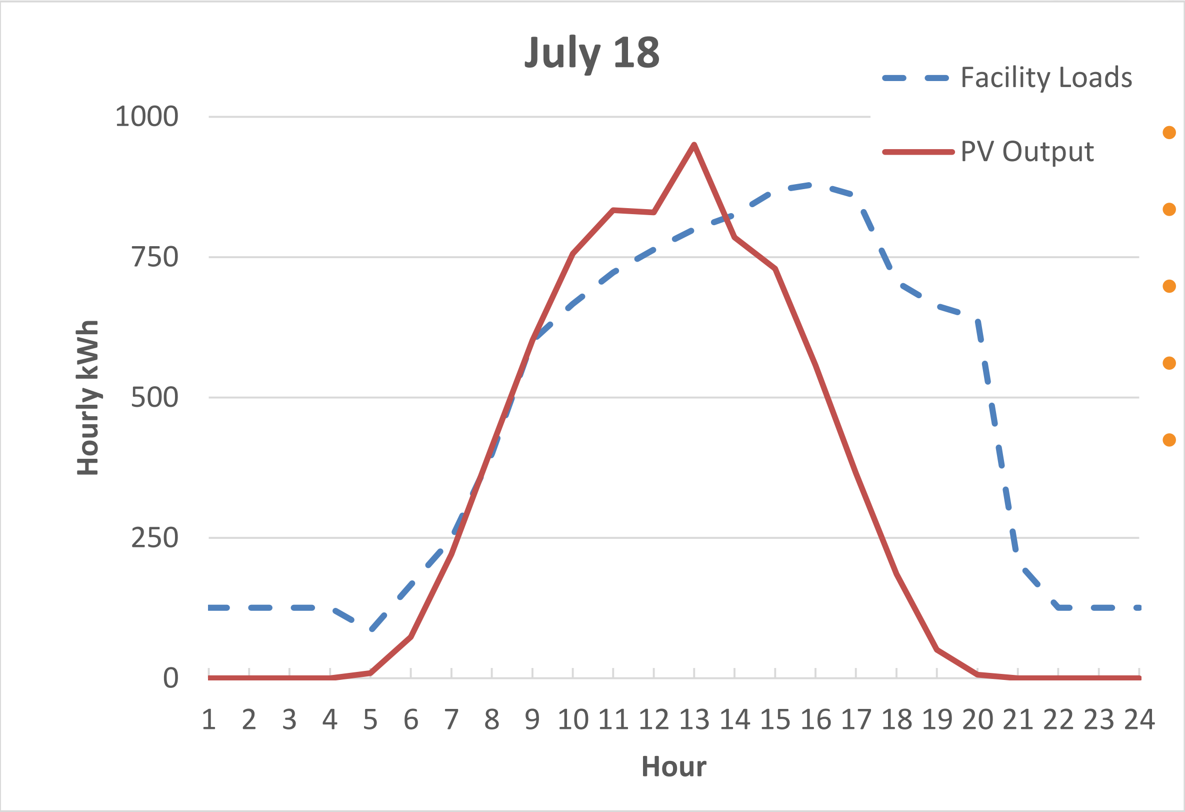
# ISO New England – Summer Peak: An unforgiving context




- System peak continues to increase
- Electricity consumption flat-decreasing due to EE

*Sources*: National Grid.

# Challenge: Summer Peak Day




- “Typical” July 18th$^{th}$
- Big Box Retail
- PV = 1,000 kW
- Building Peak = 1,000 kW
- $T_{high}$ = 93°F

*Sources*: DOE/OpenEI, Fraunhofer calculations.

# A Market for Aggregated, Feeder-Scale Demand-Side PV Support

## Multiple *potential* business models accessible to multiple participants

- Potential T&D deferral
- Avoided system upgrades for storage- and load-aggregated PV
- Virtual Power Plant
    - Robust alternative to net metering
    - Multiple markets: day ahead, real time, demand response, capacity
    - Bid into markets as a single controllable aggregated resource
    - Future localized market for grid support

SunDial enables assets…

…from different owners…

…at different locations…

…to engage in cooperative business models

# Meeting SHINES FOA Technical Targets

- **LCOE:** $0.14/kWh with $1.55/W solar; $0.10/kWh with $1.00/W solar in MA
- **Efficiency:** 90% RT efficiency achievable
  - Displace ~25% of electrochemical storage throughput with load management
    - approaches or exceeds 100% RT efficiency
  - Co-located storage on the primary side of the MV transformer
- **Component lifetimes:**
  - Limit cycling on battery through load management
  - Account for replacement in lifetime LCOE calculations

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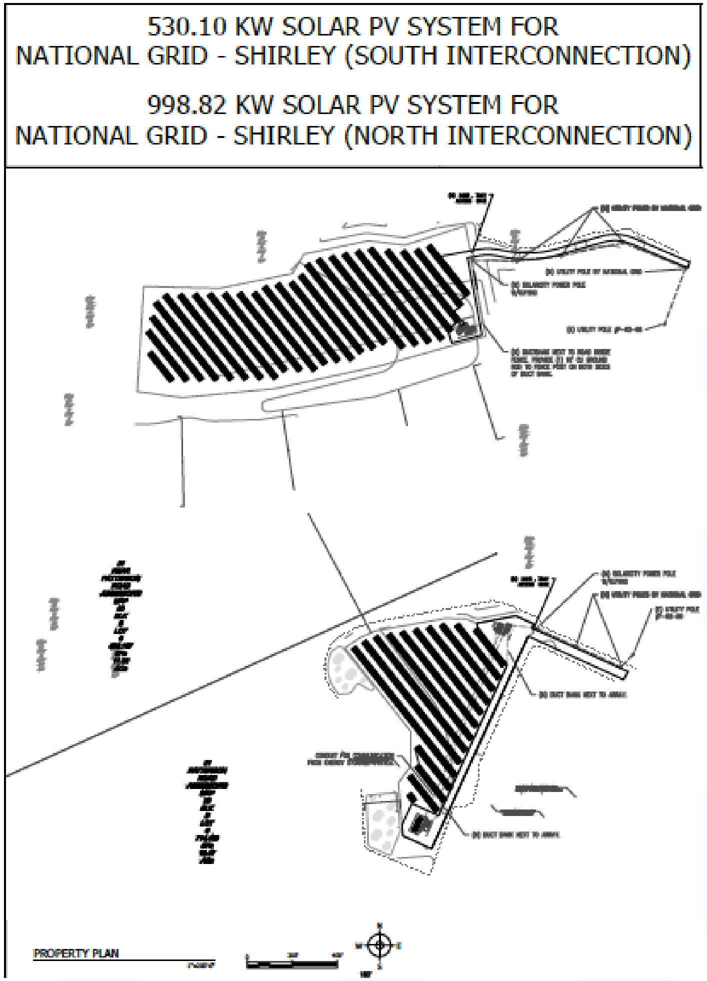
# Project Execution Plan

- **Year 1:** System Modeling and Algorithm Development, Customer Recruitment, PV Commissioning & Storage procurement
- **Year 2:** FLAME deployment, Storage deployment, Global scheduler deployment, field test plan; Demonstration starts near end of Year 2
- **Year 3:** Field testing, demonstration, and evaluation, synthesize lessons learned

# Demonstration at National Grid Phase 2 PV Site




- Shirley, MA
- Hosted on a 9MVA feeder, approx. 7MW PV installer or under construction
  - Two adjacent PV sites
- N&S Plant Master Controllers (PMCs)
  - Aggregated site-level devices
  - Implements Real & Reactive power control
- Global Scheduler interfaces to each

*Source*: National Grid.

# National Grid Phase 2 PV Site

*Source*: National Grid.

# Facility Recruitment


## Feeder Comprises:

- ~7MW of load
- 18 50kW+ customers
- 3 customer ~50% of load
- Mix of C&I
- Recruitment building on National Grid's energy efficiency program

*Sources*: Steward Health Care, Thermofab, Wikimedia Commons.

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# Project Outcomes

- Standardized interoperability interface for integration of aggregated loads with DG
- Develop new, low-friction market mechanism for localized PV support services
- Leverage aggregated resources to reduce interconnection complexity
- Commercial implementation of distribution-scale DSM aggregation engine for integration with solar
- Demonstrate technical and commercial feasibility of scalable approach for decoupled solar, storage, and load management