Overview of BNL's Solar Energy Research Plans

March 8, 2011

BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

Office of Science
U.S. DEPARTMENT OF ENERGY

Outline

- Overview of the LISF Solar PV Project at BNL
- Challenges for Deployment of Utility-Scale Solar PV Systems
- Planned BNL Research Agenda using the LISF
- Conceptual Research Agenda for the NSERC

Long Island Solar Farm is constructing a large solar plant on the BNL campus …

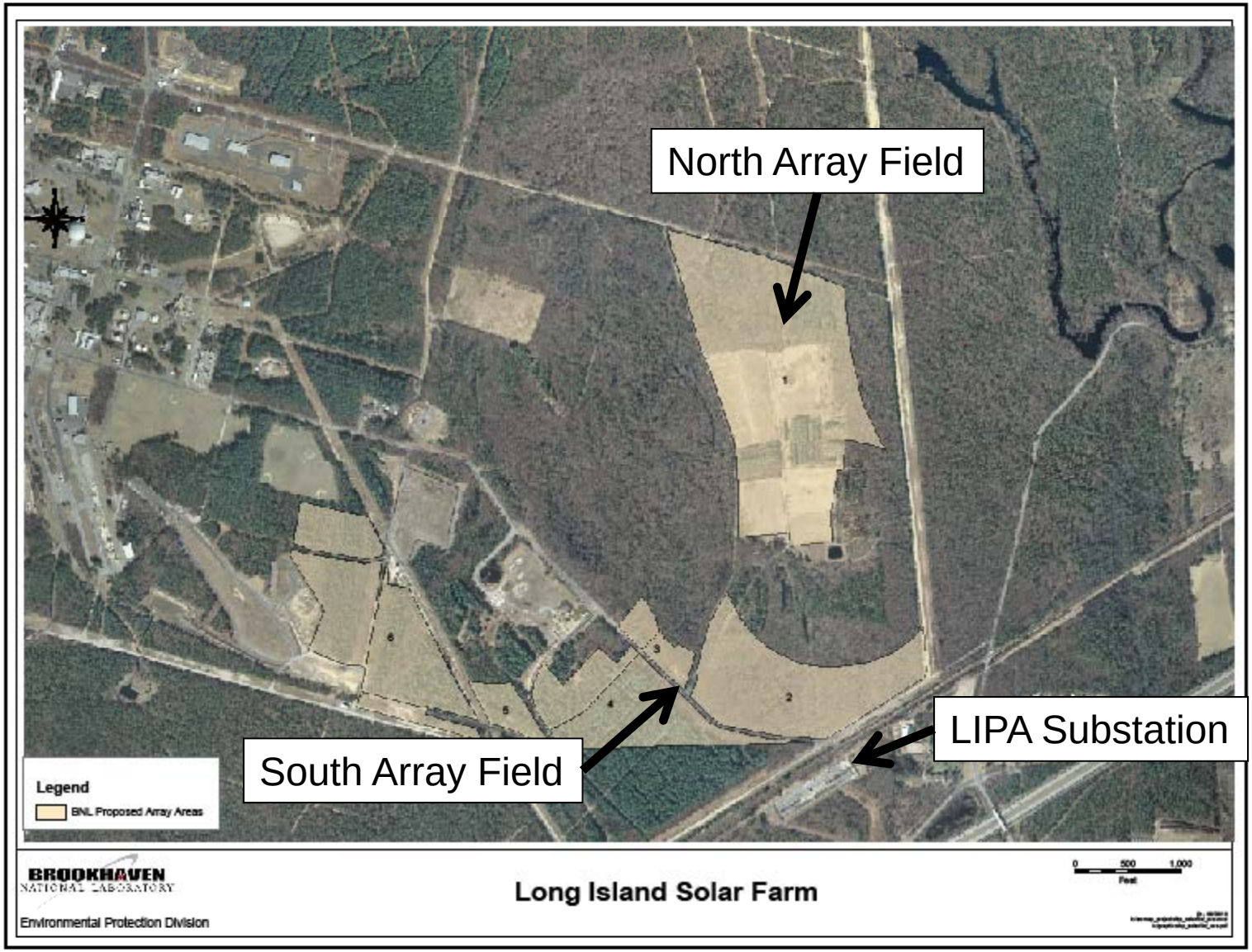
- 32 MWac grid-connected solar photovoltaic plant
- Located on 195 acres on BNL campus
- A unique research opportunity
- BNL is developing a research agenda to leverage this opportunity
- Collaborations with other interested organizations are being pursued (e.g. NREL)

LISF Overview…

- Project Developer/Owner/Operator
  - Long Island Solar Farm, LLC
- Purchaser of Power
  - Long Island Power Authority (LIPA)
- Project Host
  - U.S. Department of Energy at BNL
  - Easement granted for use of land
- Estimated Project Life
  - 30-40 years
- Construction Schedule
  - Fall 2010 – Early 2012

LISF Technical Specifications…

- Capacity
  - 32 MW (ac) delivered to LIPA
- PV Module Specifications
  - BP Solar Models BP3225T and BP3230T
  - Number: ~164,000
  - Technology: Crystalline Silicon solar photovoltaic modules
- PV Module Installation:
  - Ground mounted
  - Module Tilt: 27°Fixed; Array Azimuth: 180°
- Inverter Power Blocks:
  - Manufacturer: SMA Sunny Central 630HE
  - Net Nameplate Rating: 1.25MW

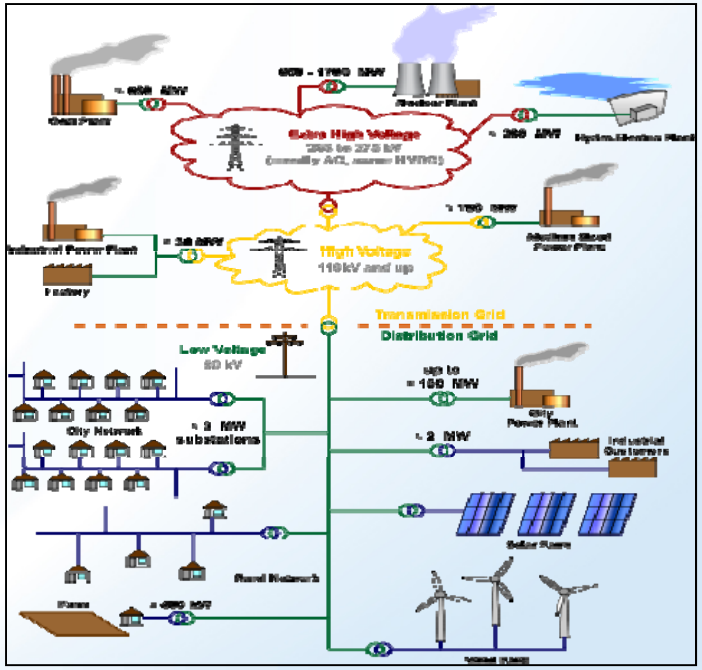

North Array Field
South Array Field
LIPA Substation
Legend
BNL Proposed Array Areas
BROOKHAVEN
NATIONAL LABORATORY
Environmental Protection Division
Long Island Solar Farm
0
500
1,000
Feet

BNL is developing a solar energy research agenda based on the LISF plant…

- Discussions with various organizations
  - NREL
  - BP Solar, EPRI
  - NYPA, NYSERDA
- Review of various studies and documents
  - EERE Workshop Report on High Penetration of PV into the Distribution Grid, February 2009
  - EERE Renewable Systems interconnection Study, February 2008
  - EERE Solar Energy Technology Program Multi-year Plan
- BNL research will focus on deployment and grid integration of large-scale, distributed PV systems
  - Particularly for Northeastern U.S.

Key Issues

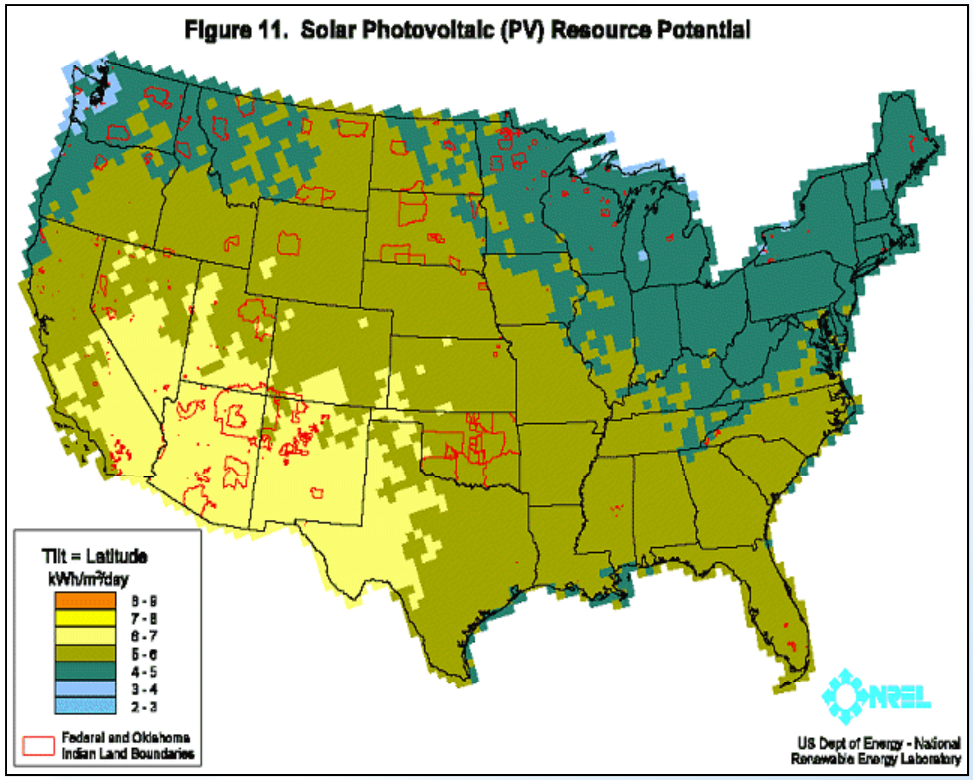
- **Variability and Non-Dispatchability**
  - Solar energy varies
  - Solar generation cannot be dispatched when needed
- **Grid Integration**
  - Grid is not designed for two-way power flow
  - Distributed generation can adversely impact grid control
- **Environmental Impacts**
  - Utility-scale solar PV plants can have impacts on local environment and ecology



Source: http://www.soldata.dk/pyr-80spc.htm

The LISF will also help characterize solar PV system performance in the Northeast..

- Solar generation tends to concentrate in the south and southwest
  - Highest solar insolation
- Performance data sets for utility-scale solar PV plants in the Northeast are not readily available
  - LISF data will help system designers



Research using LISF Data
Key Issue 1: Solar Variability and Non-dispatchability

- Develop database with time-resolved solar resource and meteorological data for BNL (Northeast U.S.) and solar plant electrical performance
- Examine statistical relationship between solar radiation input and solar plant output
- Study the impacts of weather variations and cloud transients on large-scale PV system performance
- Characterize the variability of PV generation as a function of cloud and meteorological conditions
- Develop models for real-time forecasting ("now-casting") AND DAY AHEAD FORECASTING of available solar irradiation and impact on power production

Research using LISF Data
Key Issue 2: Grid Integration

- Establish the performance characteristics of large-scale solar PV plants located in the Northeast and factors affecting capacity credit
- Evaluate the impacts of large-scale solar PV plants on electrical distribution system power quality
- Study the impacts of large-scale high penetration solar PV arrays on the reliability and stability of the grid and local distribution systems
- Characterize the response of various system elements (e.g., inverter recovery) following rapid changes in solar insolation due to cloud transients and how it impacts array output OVERLAP WITH WORK BY OTHERS – COORDINATE TO AVOID DUPLICATION
- Develop models to predict the response of the solar plant and individual components (e.g., inverters) to fault conditions
- Evaluate the impact of surface soiling on solar plant performance
- Study the impact of aging degradation on solar plant performance
- Develop an integrated performance model to forecast generation and study grid impacts due to high-penetration variable solar power and how control schemes can be used to mitigate these impacts

Research using LISF Data
Key Issue 3: Environmental Impacts

- Continue current programs on recycling of solar panels
- Perform life-cycle assessments of large-scale solar PV plants and energy policy options
- Verify our understanding of impacts of large-scale solar array to the local environment, including microclimate, meteorology, and hydrology, and the associated impacts to the habitats for local plants and animals
- Collect data useful for evaluating the impacts of large-scale solar plants to regional and global climate, including greenhouse gas emissions
- Observe and document impacts to local plant and animal life near the large array

A suite of advanced research instruments will be installed in the LISF plant…

- BNL is working with BP Solar to incorporate instrumentation into the array
- Data will be obtained at high sample rates for research purposes
  - Solar Resource Data: sample rates up to 1 per second
  - Meteorological Data: sample rates up to 1 per second
  - Power Quality Data: sample rates up to 512 per cycle
- All data will be time synchronized
- Plans to participate in the NREL PV Variability Database

Solar Irradiance and Meteorological Data will be collected…

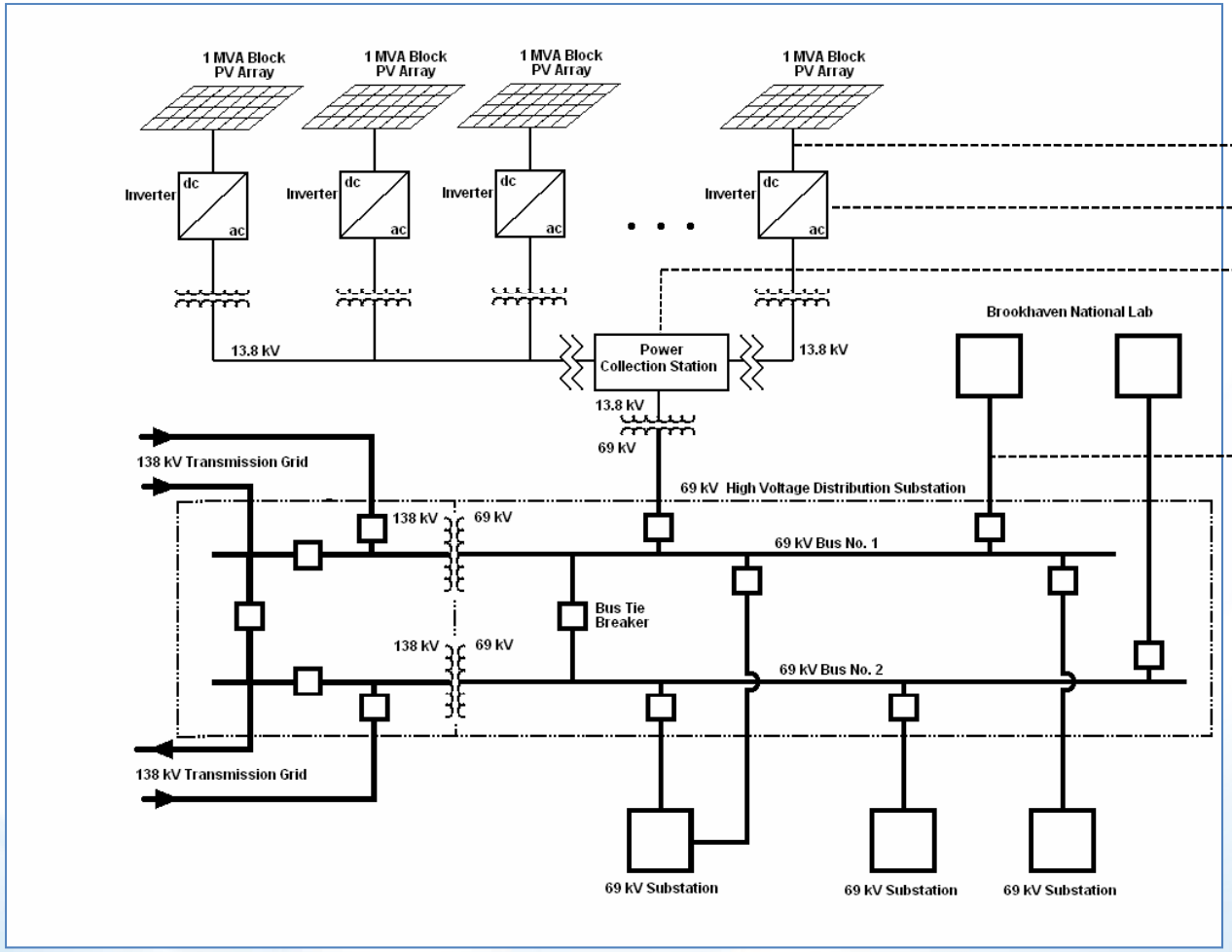
- Field-based pyranometers: up to 32 pairs to measure direct and diffuse irradiance at each inverter node covering the entire array

- Baseline irradiance: precise measurement of solar irradiance at base station to quantify uncertainties in field data

  - *Solar tracking measurements*
  - *Rotating shadowband radiometer*

  - Meteorological measurements:
    - *Temperature (air and panel)*
    - *Relative Humidity*
    - *Barometric Pressure*
    - *Wind speed and direction*
    - *Rain gauge*
  - Total Sky Imagers

Power Quality data will be collected for research purposes…



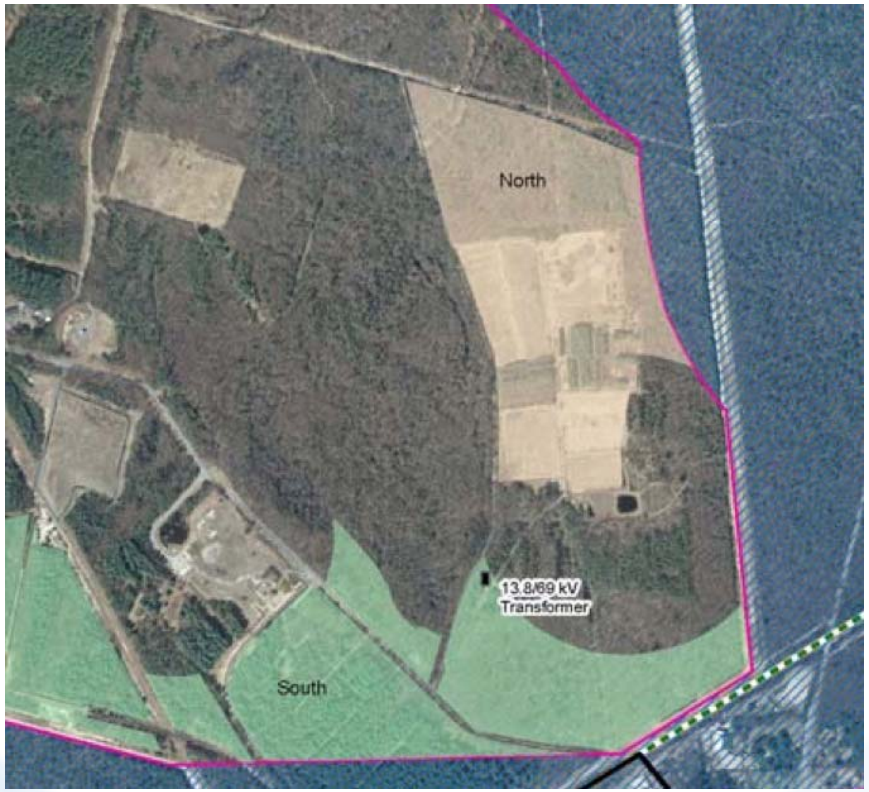
Data Acquisition System
- Power Quality

<u>Power Quality Data</u>

- String level
- Inverters
- Array Substation
- LIPA Feeders to BNL

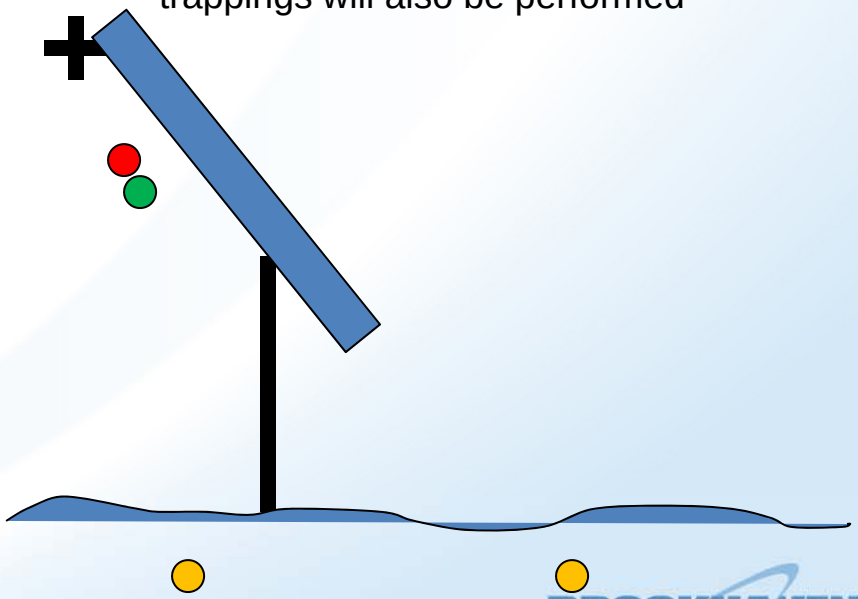
Environmental monitoring instruments for research purposes…

North array only



- Relative Humidity (at 10 locations in north array)
- Soil Temperature (2 at 10 locations in north array)
- Air Temperature below panel (at 10 locations in north array)

* Data from the BNL Met instruments, along with mobile instruments and animal trappings will also be performed



The complete solar energy research agenda will require LISF plant data plus other capabilities…

Challenge	Issue	LISF Data	Other Capabilities
Variability and Non-Dispatchability	Reliable Data Sets	X	
	Impacts of Weather	X	X
	Managing Non-Dispatchability		X
	Forecasting Models	X	X
Grid Integration	Impact of Penetration Levels	X	X
	Advanced Grid Communication/Control		X
	Load Flow and Fault Currents	X	
	Deployment of New Technologies		X
Environmental and Ecological	Impacts to Local Vegetation/Animals	X	
	Impacts to Regional/Global Climate	X	
	Life-Cycle Assessments	X	
	Recycling Options	X	X
System Performance In Northeast	Compare Different Technologies		X
	Performance Degradation		X
	O&M Processes	X	X

BNL is exploring the development of a Northeast Solar Energy Research Center (NSERC)

- Supplement research using the LISF array
  - Dedicated research array for field testing
  - Laboratory space for standardized testing
- NSERC Research would enable research in various other areas of interest to the solar industry
  - Testing under actual Northeast conditions
  - Technology development test bed
- BNL is holding this workshop to obtain stakeholder input for the development of NSERC
  - Identify key research issues
  - Discuss research and testing interests for NSERC
  - Determine capabilities to include

Preliminary Research Agenda for the NSERC

- Smart Grid Integration Studies
  - Research on strategies that improve communication and control
  - Techniques for integrating large numbers of systems into utility grids
- Energy Storage Research
  - Value propositions for integrated grid-level storage COORDINATE WITH OTHERS TO AVOID DUPLICATION/ MAKE UNIQUE TO NORTHEAST
  - Evaluation of storage and control alternatives
  - Reduce intermittency, resource extension
  - Frequency regulation capability
- Field Testing for Deployment of New Technologies
  - Evaluation and testing of new design concepts, such as inverters with capability for voltage regulation and VAR control
  - Comparison of performance for components and systems using different technologies
- Reliability and Degradation Studies
  - Long-term reliability and degradation studies under Northeast conditions
  - Standardized test conditions to evaluate component degradation
  - Post mortem testing and failure analyses
- System response to cloud transients
  - Deliberate shading for standardized tests
- Supplemental research on environmental impacts
  - Impacts to water due to leaching from different solar technologies

NSERC would include a dedicated research array for field testing of solar system technologies…

- Solar PV Array Size
  - 500kw to 1.0 MW
  - Connected to BNL electrical distribution system
  - Crystalline Silicone PV modules
  - Open racks for comparison tests of other PV technologies
- Configuration
  - Multiple, small (100kw) arrays
  - Fixed tilt and Trackers
  - Re-configurable to simulate different operating scenarios
- BOP Equipment
  - Capability for running macro and micro inverters
  - Capability to include storage
- Research instrumentation
  - Similar to LISF (meteorological, solar resource, power quality)
  - High Sample Rates – 1 sec data

NSERC would include laboratories to support solar energy research projects…

- Solar Energy Research
  - Standardized testing of solar system components
  - Solar Resource Simulators
  - Load simulators
  - Environmental chambers
  - Failure Analyses
- National PV Environmental Research Center
  - Environmental, health and safety aspects of photovoltaic systems
  - Life-cycle analyses
- Meteorological Services program
  - On site Met services

Building 526 can be Renovated for NSERC

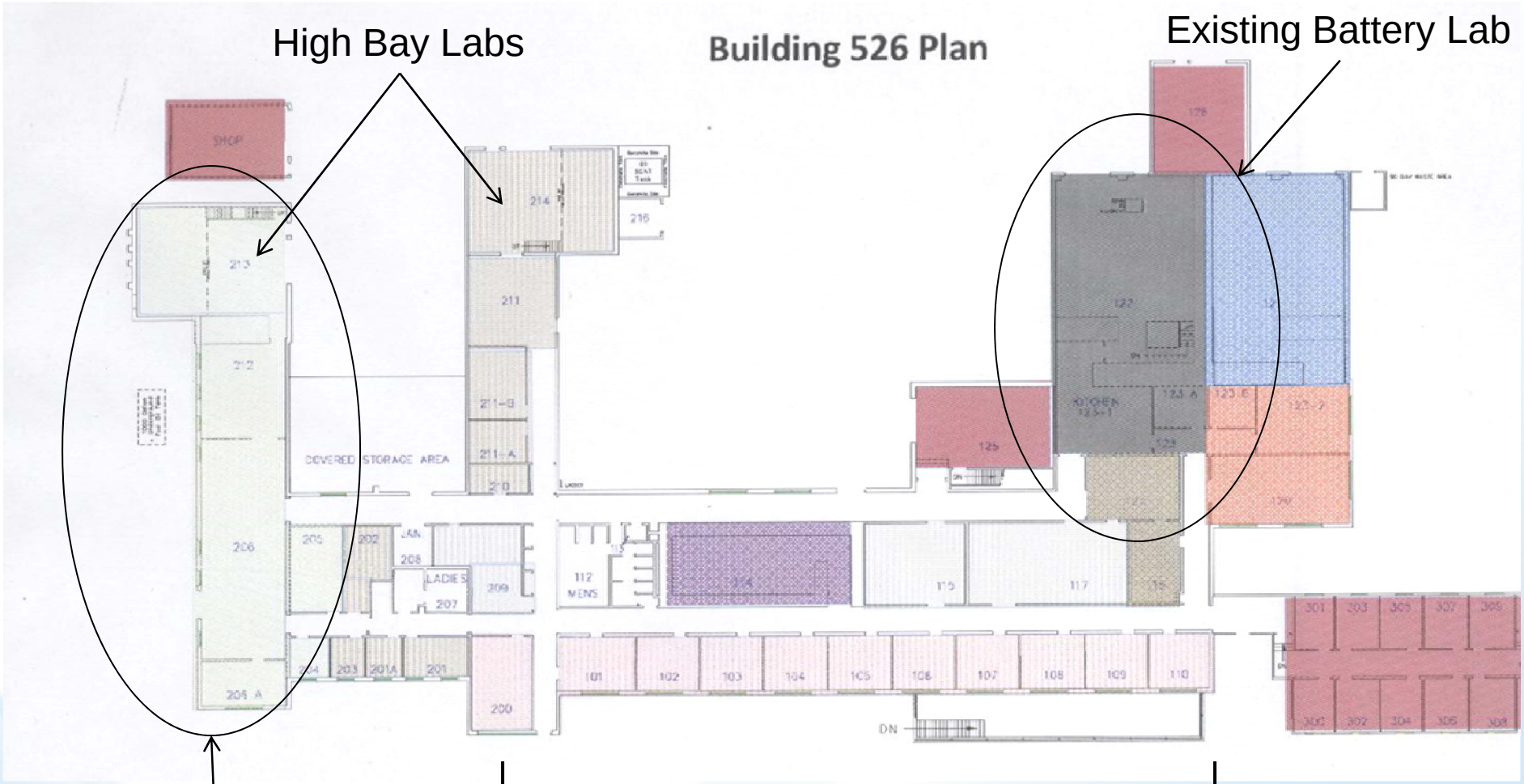
One Story Poured Concrete Structure with Partial Basement

Area: 11,030 ft^2

Offices: 12

Labs: 14

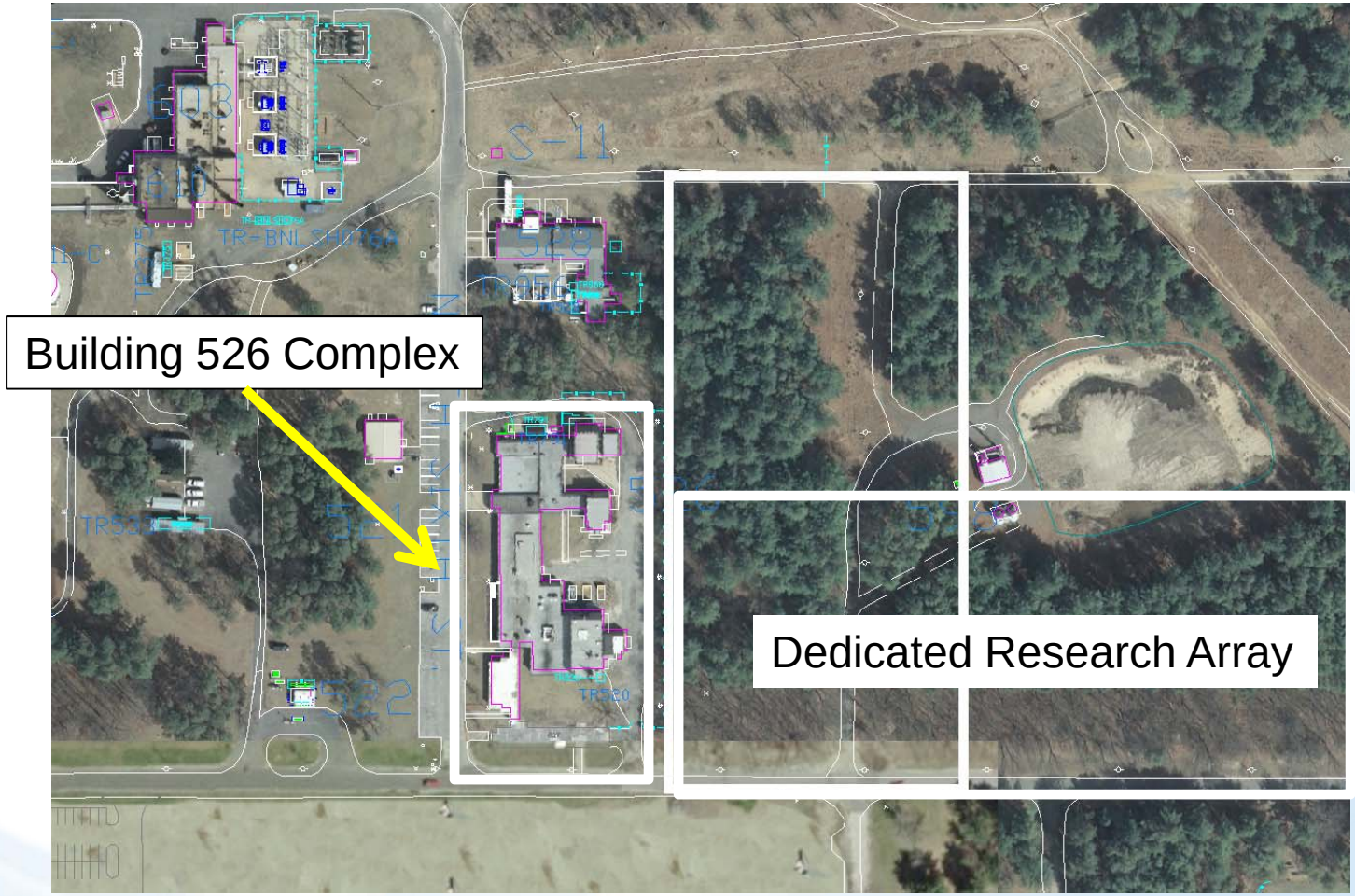
To Dedicated Solar PV Research Array
(Adjacent to East side of Building 526)



Solar Energy Labs

Offices

Possible NSERC Location at BNL



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