Global and Regional Solutions Directorate Strategy and Status

Brookhaven National Laboratory

Gerry Stokes, ALD

September 13, 2012

Who is Gerry Stokes?

- **Most Recently:**
  - **Associate Laboratory Director – Global and Regional Solutions – since 2009**
  - **President of the New York Energy Policy Institute (current)**
  - **President and CEO of Battelle-Japan – 2007-2009**

- **Past: 29 Years at Pacific NW National Lab (PNNL)**
  - **Founding Director Joint Global Change Research Institute (PNNL/UMd)**
  - **ALD (PNNL) – Environmental and Health Sciences Directorate; Emerging Technologies**
  - **Chief Scientist – Atmospheric Radiation Measurement Program**
  - **Director – PNNL Global Studies Program**
  - **Other (PNNL): Center Director - Applied Physics; Dept. Manager – Computational Sciences; Section Mgr. – Space Sciences**
  - **Program Manager End-use Load Conservation Assessment Program**

- **Other:**
  - **B.A. Physics – UC Santa Cruz; MS, PhD Astrophysics – University of Chicago**
  - **Fellow AAAS**
  - **On several National Academy panels on science education**

- **I came to BNL to make a difference …**

Why was GARS created?

There was a Significant Perceived Opportunity c.2009

- Unprecedented R&D opportunities in the applied sciences
  - Development of renewable and alternative energy sources is a major thrust of the current administration; this challenge should continue as it is a vital, long-term national security issue.
    - A strong emphasis on delivery of S&T to practice;
  - Non-proliferation and Homeland Security are enduring missions for DOE Labs -- BNL seeks to support an active risk reduction strategy with a bias to deployment

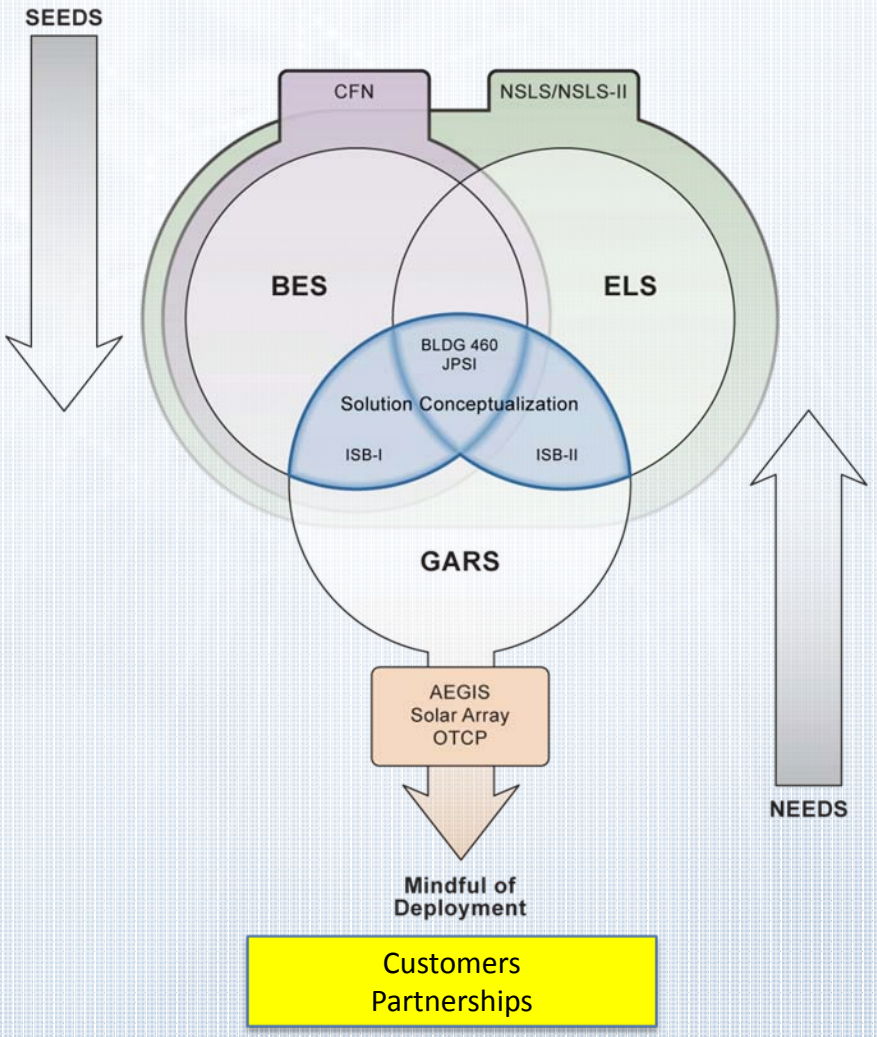
- Economic and market impact through tech transfer/active commercialization, as well as industrial research partnerships, are important to DOE, the State, and the Nation
  - Emphasis on DOE labs being today's "Bell Labs" – centers of innovation regionally, nationally.
  - Contractual obligation to seek deployment of lab developed technology.

The Opportunity Matched BNL **Strategic Intent**

- Need to **grow** (non-SC) revenue over 5-10 years (2x or more)
- BNL energy research has a focus on growing research in renewable energy applications involving **nanoscience/materials science** advances
    - energy storage, solar, nuclear, energy transmission
- Homeland and national security applications can leverage innovations in materials science/nanoscience, instrumentation & **leverage** unique capabilities and facilities at BNL (CFN, NSLS/NSLS-II, NYBlue)
- Strong applied/**translational research** focused in these areas with strong ties to **deployment** & commercial sector entities is the overarching goal

The discovery to deployment pipeline has its roots in basic research and its tools.

- But the focus has been on the three <u>deployment</u> elements of the pipeline:
  - A “solutions conceptualization” space where the basic and applied programs build ideas that can be taken to the “market”.
  - A strong applied (use inspired) R&D program that is a trusted and valued partner both for the customer and the rest of the laboratory.
  - Capabilities that are attractive to the applied market and a set of business practices and models that facilitate the generation of value for the customer and the laboratory.



The GARS Strategy for fulfilling this role is relatively simple

The Strategic Intent of GARS is clear

- Revitalize and grow the applied research program at Brookhaven around achieving impact through deployment.
- And this is achieved through three avenues …
  - An energy strategy with solid and effective reach back into the basic research strengths of the lab and outreach to the applied customers, engaging non-SC customers in DOE, State and Local Governments and the Private Sector.
  - A non-proliferation and national security strategy that is focused on the critical and emerging needs of international and regional authorities.
  - An aggressive technology deployment and commercialization strategy that serves the entire laboratory.

What would success look like?

- Strong, innovative applied R&D programs, coupled to BNL core competencies in nanoscience/material science that are internationally recognized, attractive to partners, and respected for quality
- National and regional impact through accelerated deployment of technology meeting the highest needs, strong regional partner with industry and universities
- Tangible commercial value for the nation, the region and the laboratory through identification, protection, enhancement and deployment of intellectual property
- Increased revenues through growth in non-SC funding
- Scientific discovery and technological accomplishment on equal footing at BNL

This evening I will focus on energy

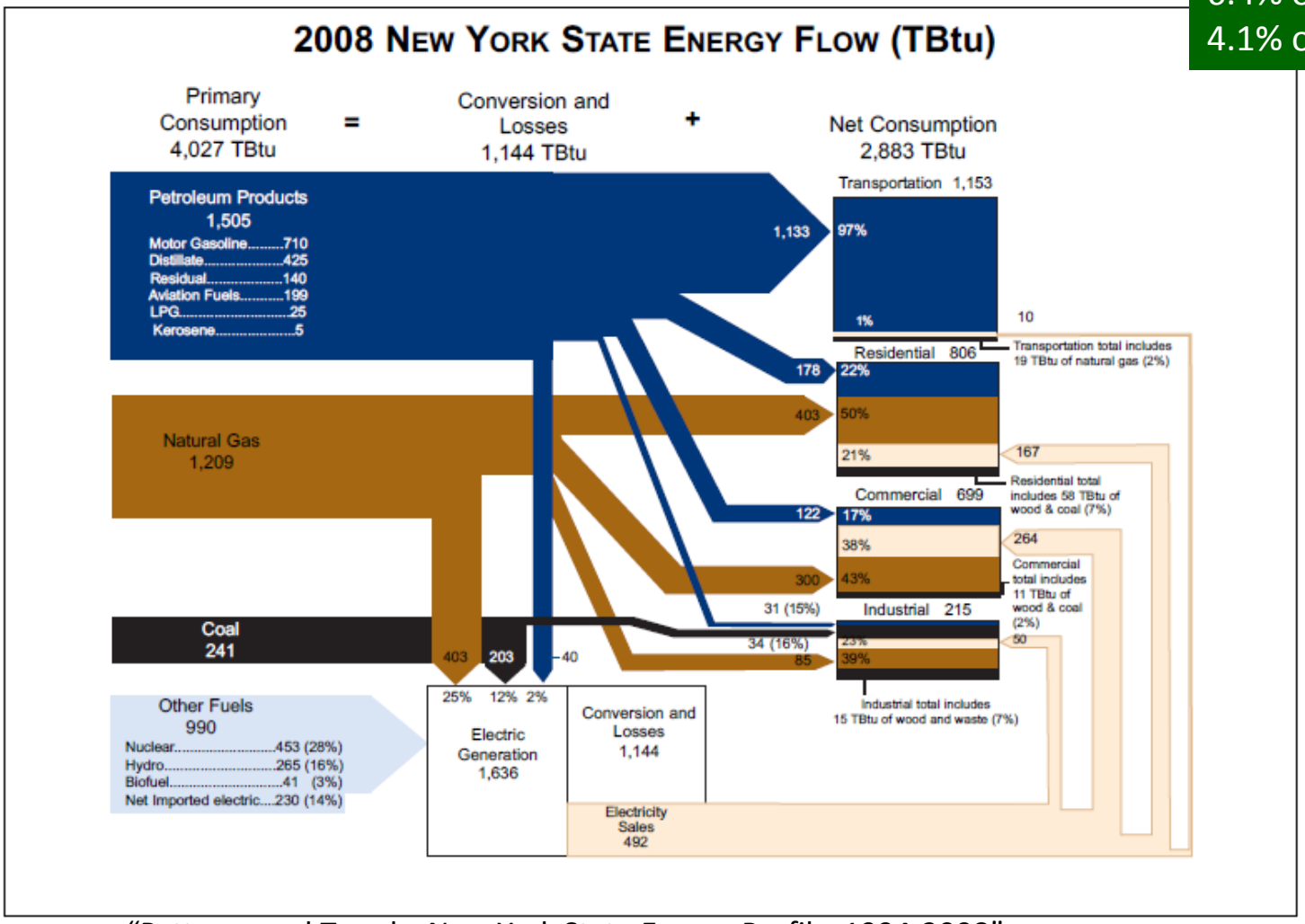
A major laboratory initiative that has evolved to its current state over the past four years

The BNL strategy has become a market back approach – starting with the State of New York

- BNL is not now a large part of the DOE applied research portfolio.
- It is the only multi-program National Laboratory in the Northeast (population ~60M).
- New York and the Northeast have some of the most pressing grid problems in the country –
  - Congestion
  - Aging infrastructure
- Our goal is to focus on solutions for the State of New York to both focus our portfolio and strategy.

New York and NY's problems don't look like the rest of the country…

6.4% of US population
4.1% of primary energy



New York Energy Flows (NYSERDA)

"Patterns and Trends: New York State Energy Profiles1994-2008", New York State Energy Research and Development Authority.
http://www.nyserda.org/publications/default.asp

The New York State 80 by 50 Plan: an early driver for BNL strategy

- Recognizing the benefits of action and the risks of inaction, in August 2009 the Governor of New York signed Executive Order 24, which tasks the State to reduce GHG emissions from all sources within the state to a level 80% below the 1990 level by 2050.

- It established a Climate Action Council that is to develop a Climate Action Plan to achieve that goal, taking into account economic and other considerations, draft released September 30, 2010.

Our selection of energy goals and focus areas are aligned with the 80% Carbon Reduction by 2050

All scenarios to meet this goal suggest:

- Increased electrification, particularly in light vehicle transportation
- Displacement of fossil fuels with sustainable fuels

NYS Challenges

ELECTRIC SYSTEMS

- Must increase our efficiency (NY delivered electric efficiciency = 30%)
- Increased use of renewable generation (wind/solar)
  - Intermittency issues
  - Transmission
  - Reliability
- Ability to deliver/manage electricity
  - Grid congestion

SUSTAINABLE FUELS

- Displace fossil fuels with sustainable fuel sources

Brookhaven Basic Research

ELECTRIC SYSTEMS

- High efficiency organic photovoltaics
- Superconducting transmission
- Materials for batteries

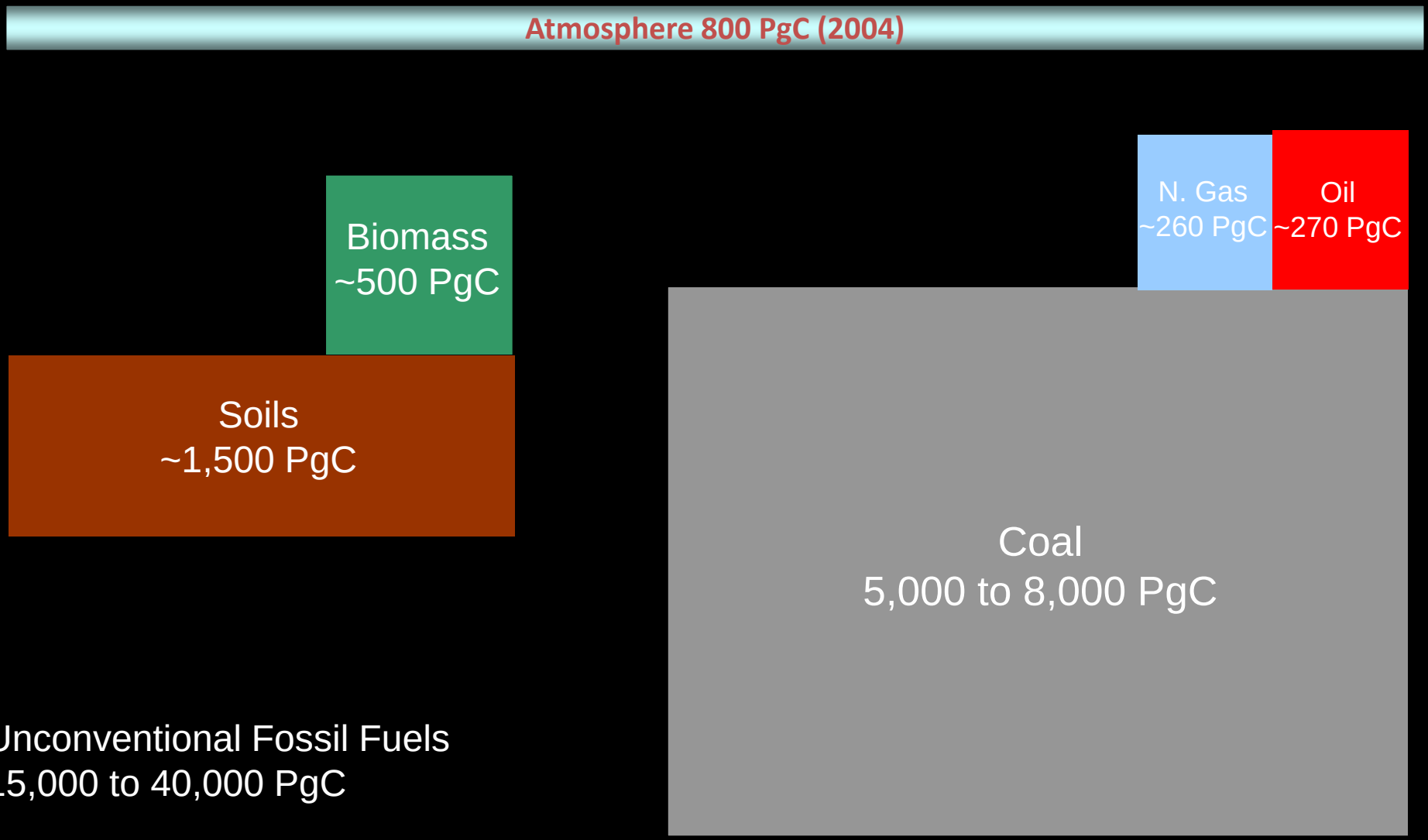
SUSTAINABLE FUELS

- Engineered biosystems
- Catalysis for fuel cells
- Fuels from carbon dioxide

Looking ahead (two and a half years ago)…

- There are clearly big decisions necessary to achieve goal – many probably need to made sooner rather than later – infrastructure, fuel sources.
  - The role of nuclear and CCS
  - The reliability and capacity of the grid
  - The role for biomass
- The baseline energy scenario is for a very robust economy with a growing industrial base – not the contraction seen since 1990 - and the move to electrification, is consistent with a 21st Century economy (info, bio and nano).
- All renewable energy is from within the state resources, adding a significant sector to the state economy.
  - How the state cooperates with its neighbors will be important (generation, grid) is important.
  - Achievement of renewable goals is a critical success factor for the strategy.

Carbon Reservoirs



Now NY State faces a different challenge

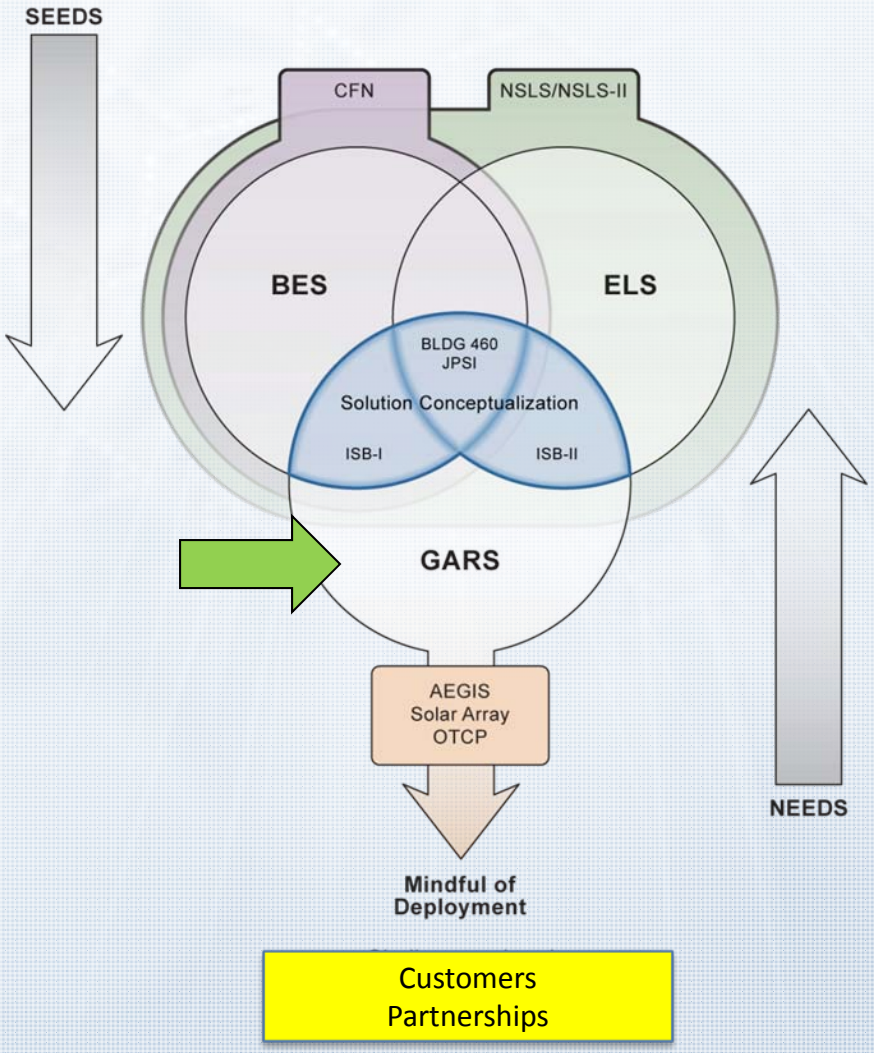
- The shale gas in the state and elsewhere now suggests a “dash to gas”
- With a move to gas there would be an expansion of the gas infrastructure – power, residential and commercial buildings, even vehicles
- This infrastructure could cast a shadow into the future strand the asset or not meet the “80 by 50” goal.

Despite the shadow of gas - The BNL Strategy is tied to a low carbon future

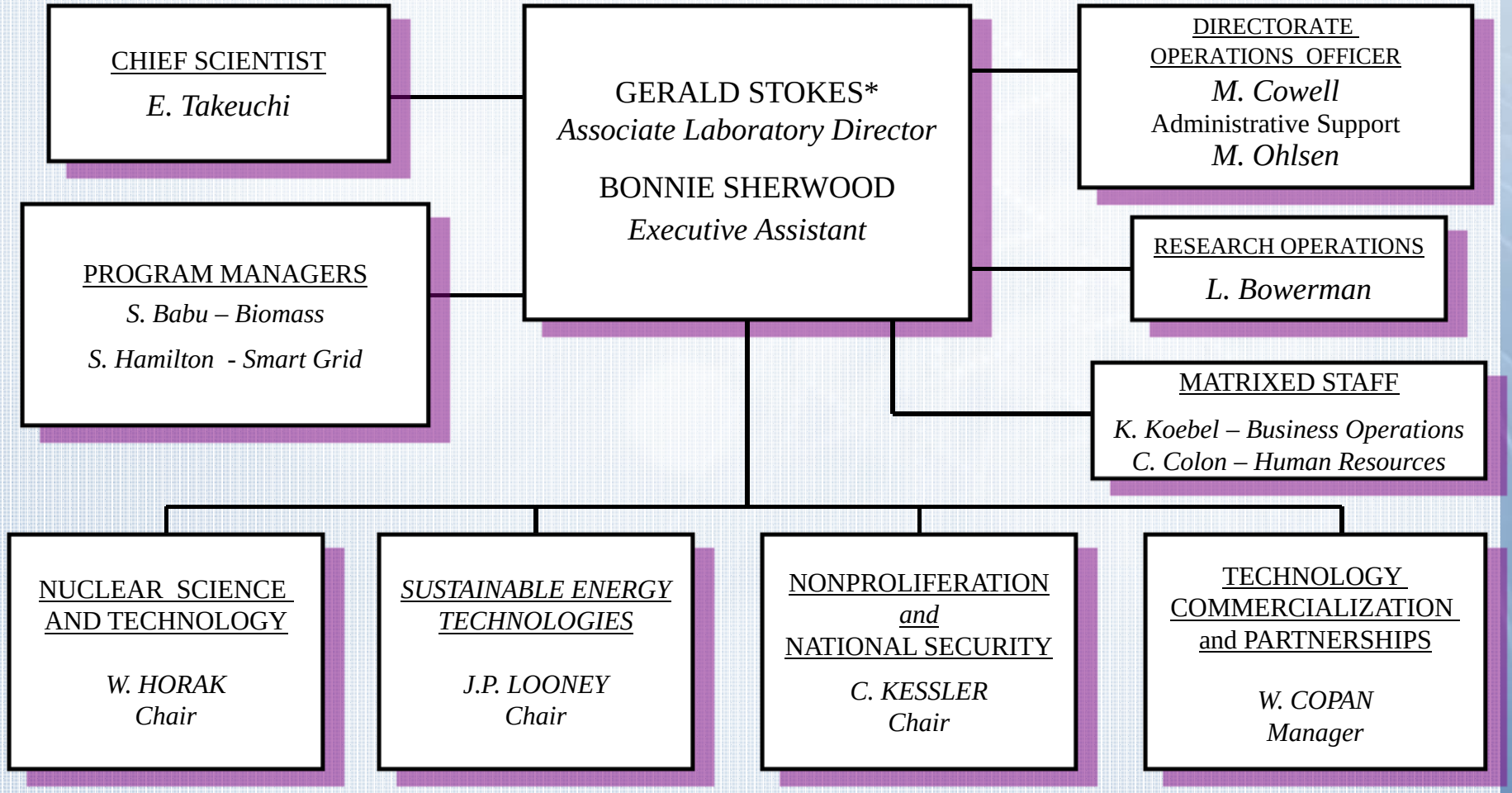
- Science technology for electric infrastructure
  - De-carbonized generation
  - Renewables integration
  - Grid scale storage
  - A robust & effective distribution system
- Sustainable chemical conversions
  - Improved catalysts for synthesis of fuels by sustainable pathways
  - Electro-catalysis chemical-electrical conversion in fuel cells
  - Solar-to-fuel conversion through oxidation-reduction reactions
- The outcomes implicit in each of the 7 thrust areas are also of national and global interest

GARS was reorganized in late 2010 to increase its ability to deliver

- Past state: expertise based organization with a boutique style marketing approach.
- Organizing for growth and to build out innovation side of the organization.
- Changes
  - Create Sustainable Energy Technology Department.
  - Re-creating Nuclear Energy Department.
  - Moving to capability based technical groups
  - Establishing an explicit marketing function



The GARS Directorate.



Brookhaven Energy R&D: A Collaborative Approach

Basic Research, Applied Research, and Industry Working Together

BNL Resources

BNL Research

NYS SmartGrid Consortium

NY BES+ New York Battery and Energy Storage Technology Consortium

NYEPI New York Energy Policy Institute

nyserda Energy. Innovation. Solutions.

NY State Consortia/Resources

ENERGY CHALLENGES: New York and Beyond

- Electric Systems
- Sustainable Fuels

DOE ALIGNMENT/LEVERAGE

- DOE Priority Research Directions
- 4 Energy Frontier Research Centers

Collaborators/Joint Appointments

Stony Brook University · GM · Columbia University · Rensselaer · GE · Binghamton University · CUNY · RIT · IBM · SYRACUSE · College of Nanoscale Science & Engineering

In addressing these energy thrusts we have three approaches

- Build from basic science results outward to the applied components of DOE and the private sector.
- Select applied programs that impact multiple thrusts and that provide useful feedback to the basic research programs.
- Where possible use facilities to attract both partners and the applied and private sector customer set who can provide the market needs informing the use-inspired portfolio.

Nuclear Science and Technology Department

a traditional BNL strength

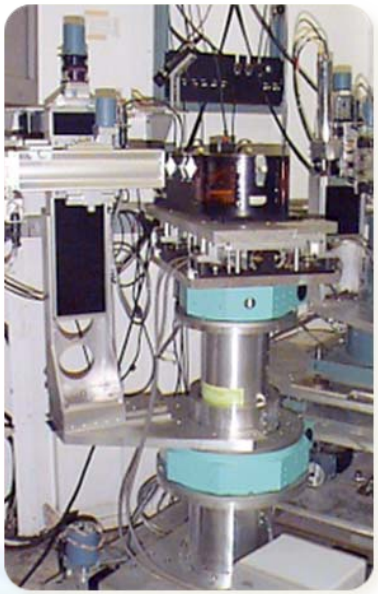
NNDC – one of the longest running programs in the history of DOE

NRC – What is safety analysis going to look like in the post-Fukushima world

MRE/MEE – material are at the heart of almost all new technologies

Nuclear Data is the link between basic science and applications

- **Nuclear Science Community**
  - experiments



Nuclear Data Community

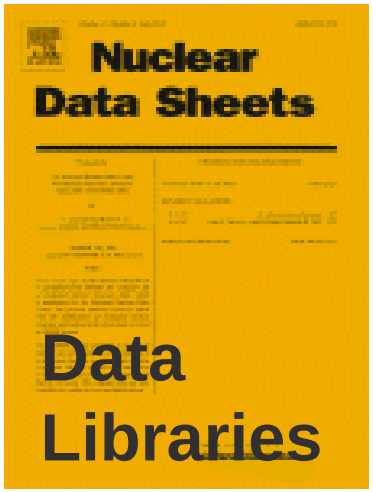
- compilation
- evaluation (exp. + theory)
- dissemination
- archival

Application Community

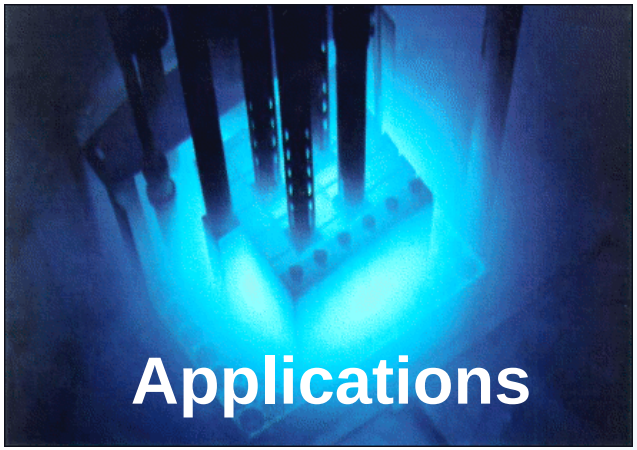
Needs data:

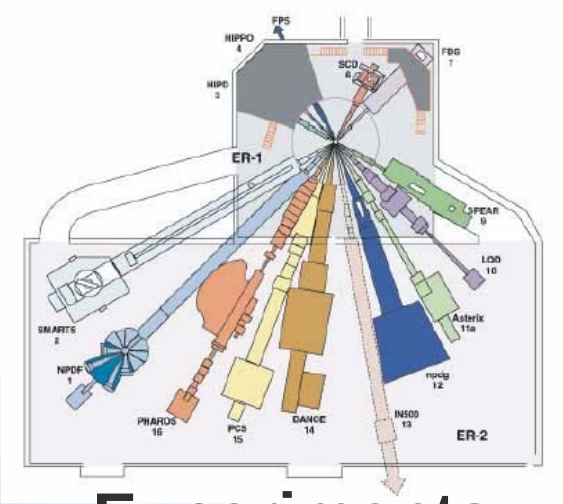
- complete
- organized
- traceable
- readable

One of the longest running programs at BNL

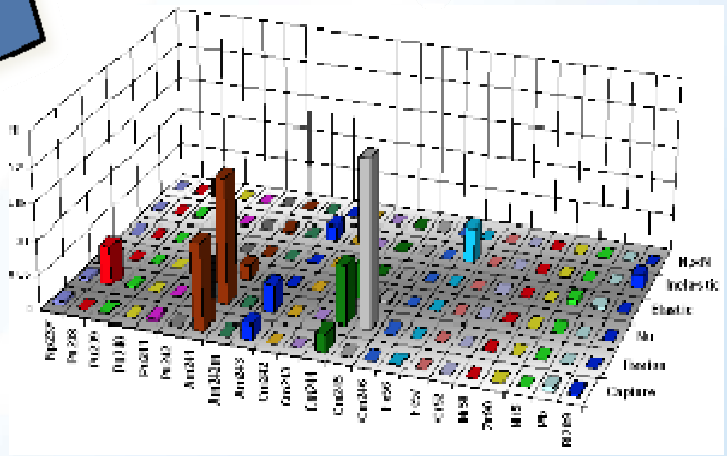


Data Libraries





Experiments



Sensitivities

Real time and in-situ studies of Materials in a Radiation Environment (MRE) and extreme environments (MEE) are essential for future energy applications.

MRE Concept and Mission

Concept: Separate facility located outside of the NSLS II ring with two end stations:

- Active materials
- Ion Beam Accelerators for in situ study of radiation damage

Mission:

- Provide a large community of users in nuclear energy and security applications significantly greater access to synchrotron characterization tools than currently exists in the US.
- Perform in situ investigations of radiation effects using ion beams (capability unique in the world)

Applications:

- New materials for fission and fusion reactors such as nuclear fuels and structural materials for high radiation environments and nuclear waste forms
- Provide data for use with computer simulations, assessing material performance during off-nominal conditions, and licensing
- Nuclear forensics, security and nonproliferation applications
- Doping induced defects on semiconductor performance

Impact: DOE-NE, NRC, NNSA and commercial nuclear industry

Real time and in-situ studies of Materials in a Radiation Environment (MRE)

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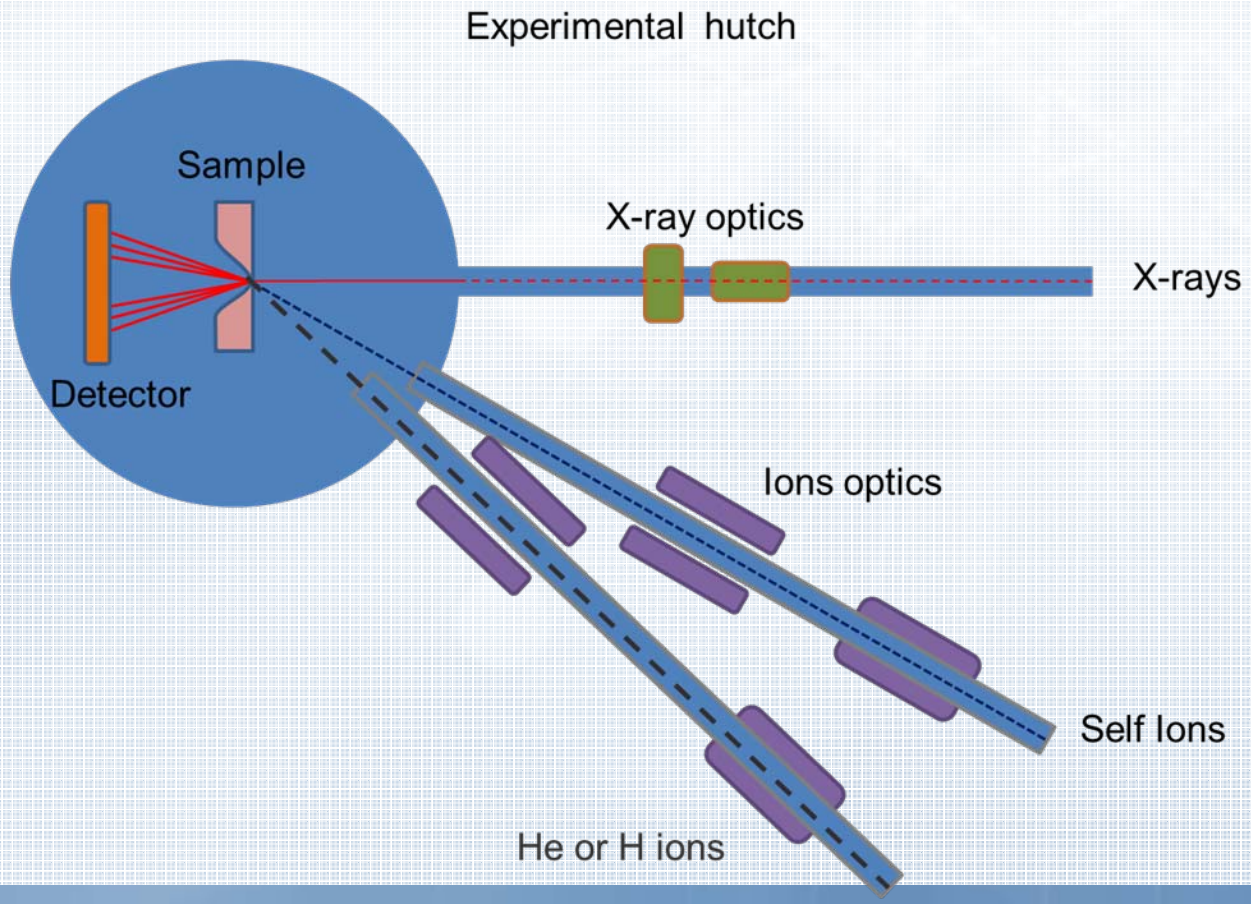


Sustainable Energy Technology Department

our engine of growth

BNL Site – evolving to a major test bed for new technology and approaches

AEGIS – our laboratory for the study and improvement of the grid

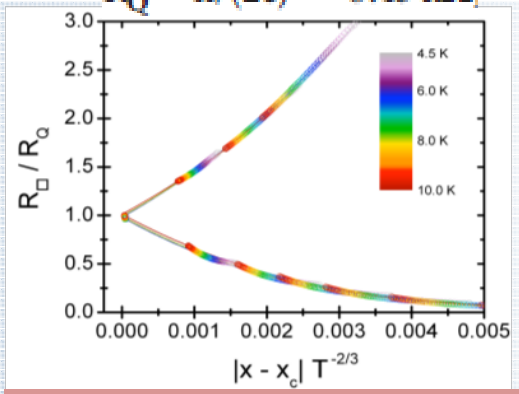
New York State – our partner and proving ground for deployment

Electric Infrastructure: Advanced Materials for Renewables Integration

DOE – BES
Unraveling the nature of HTS

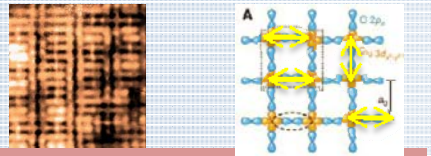
Critical point at the pair quantum resistance

$R_Q = h/(2e)^2 = 6.45\ \mathrm{k\Omega}$

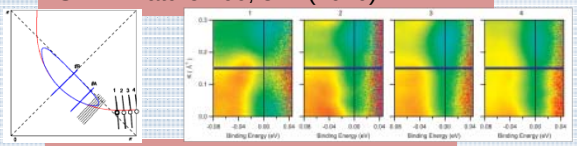


Nature ***472****, 458 (2011)*

Evidence for Localized Pairing in the Normal State



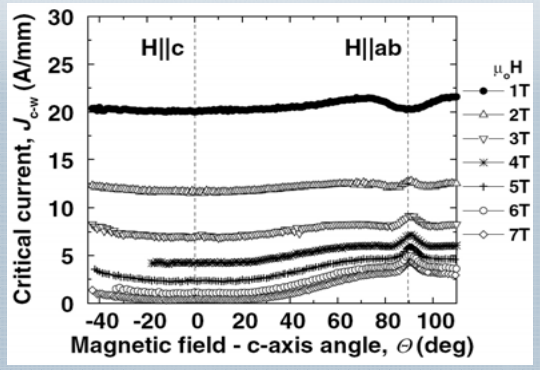
STM - Nature 466, 374 (2010)



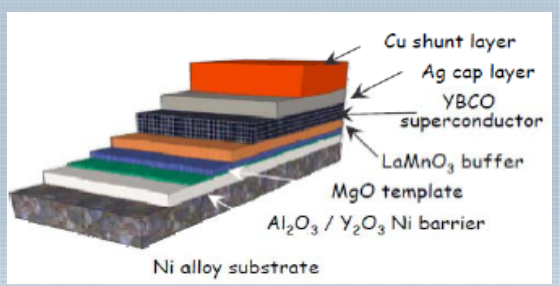
ARPES - Nature 456, 77 (2008)

DOE (BES & EERE)
Improved Critical Properties

2G YBCO Coated Conductors



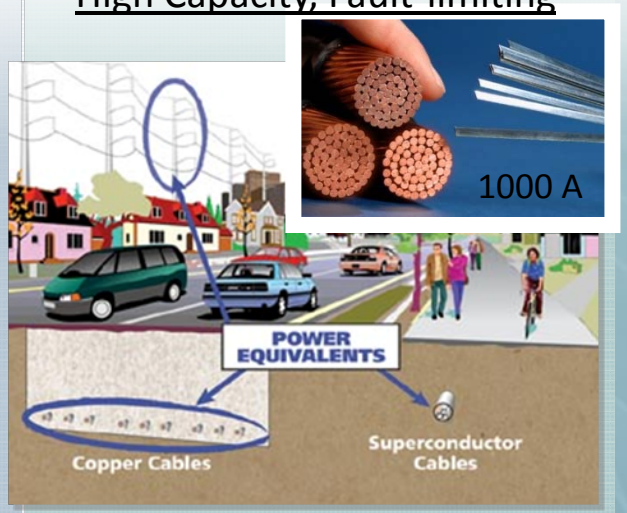
Engineering strong/isotropic pins to achieve record high $J_c(H)$ and T_c in $YBa_2Cu_3O_7$ for HTS cables



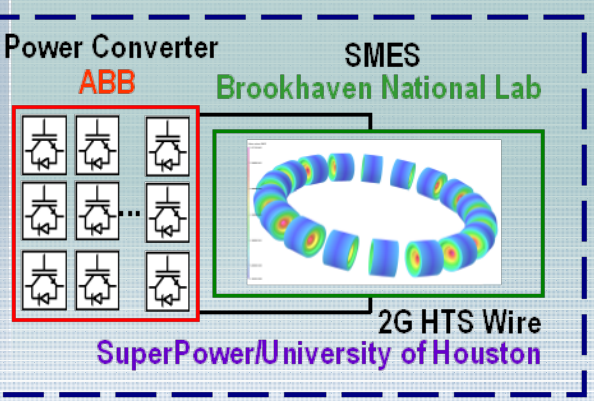
Sub-atmospheric growth process enables reel-to-reel production of long length HTS tapes (BNL Patent)

BNL-Industry CRADA / ARPA-E
HTS Cables, SMES

High Capacity, Fault-limiting

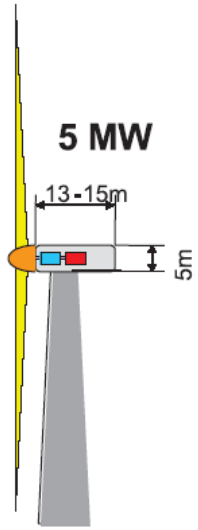
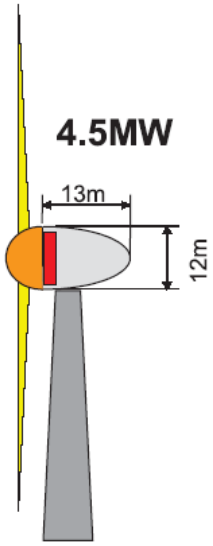
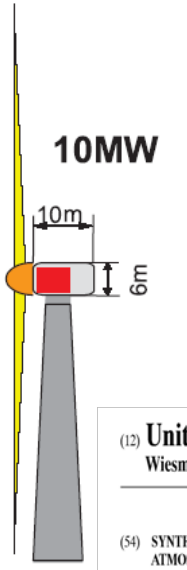


GRIDS SMES SYSTEM

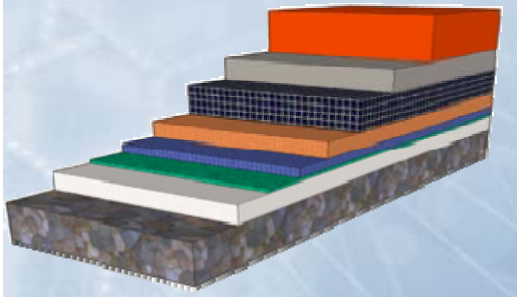


Core Capability: Cond. Matter Science & Mater. Sci. / Applied Mater. Sci.

Size Comparison of Large Wind Turbines

	Main Stream Geared	Conventional Direct Drive	Optimized HTS Direct Drive (AMSC)
			
	5 MW	4.5MW	10MW
	13-15m	13m	10m
	5m	12m	6m
Mass of Nacelle + Hub + Blades	m_{Top} ~310 to 430t	m_{Top} ~500t	
Extrapolated for 10 MW	m_{Top} ~750t – 850t	m_{Top} ~800t-900t	m_{Top}<500t

Generator
Gearbox
Hub
Blade
Nacelle
Tower

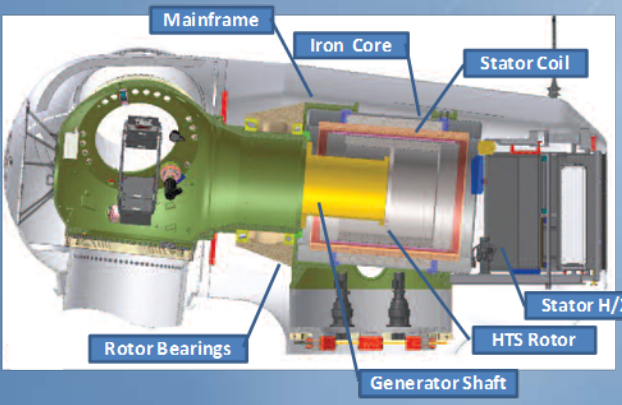


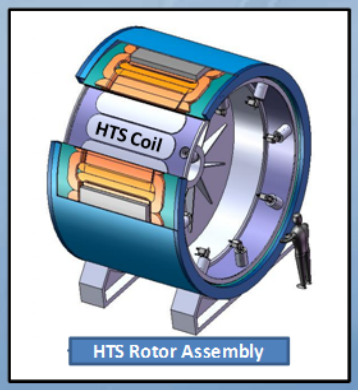
(12) **United States Patent**
Wiesmann et al.

(10) Patent No.: US 6,794,339 B2
(45) Date of Patent: Sep. 21, 2004

(54) SYNTHESIS OF $YBa_2Cu_3O_7$ USING SUB-ATMOSPHERIC PROCESSING

Solovyoy, et al., "The Effects of HF Partial Pressure and Pressure Gradients of YBCO Growth in the BaF_2 Process",





amsc

arpa·e

Superconducting Wires for Direct-Drive Wind Generators

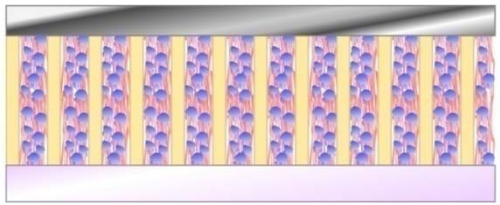
($1.4 M, ARPA-E and AMSC, Phase I)

Brookhaven Electric Grid R&D

Generation

Organic photovoltaics

- Inexpensive for large scale deployment
- Issue of efficiency



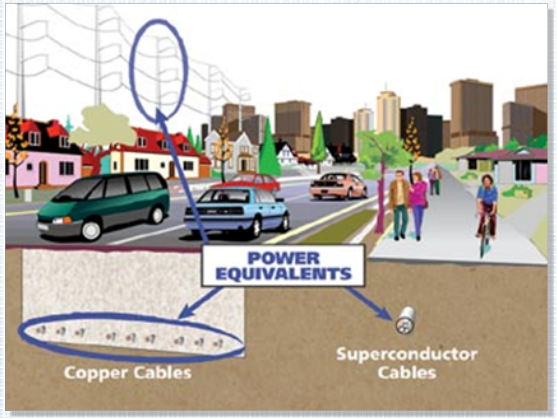
- **BNL Contribution**
- Nano-structured PV with double the efficiency per active unit area

Columbia University EFRC

Transmission

Superconducting Lines

- Power density driver



- **BNL Contribution**
- Reel-to-reel growth of superconducting materials

SuperPower Inc.

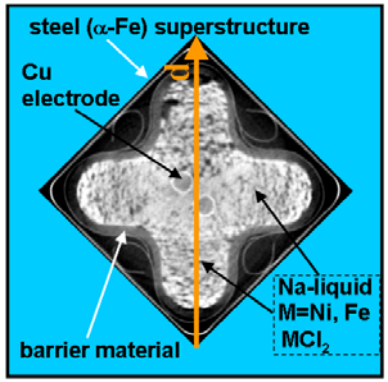
American Superconductor®

EFRC Center for Emergent Superconductivity

Storage

Batteries

- X-ray probes, materials



GE

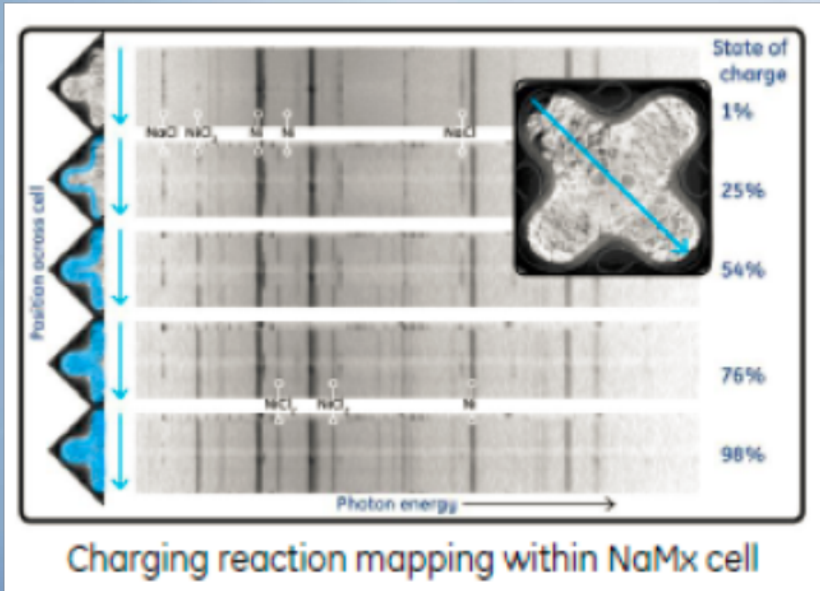
- **BNL Contribution**
- X-ray tools probing real batteries in operation
- **SMES**
- Grid scale storage

arpa·e

EFRC Northeast Center For Chemical Energy Storage

STONY BROOK STATE UNIVERSITY OF NEW YORK

Example: General Electric, Schenectady NY



Charging reaction mapping within NaMx cell

"Our collaborations with the National Synchrotron Light Source have helped to improve our fundamental knowledge and in turn have allowed us to realize significant gains in battery performance. These advancements are foundational to our new business and our ability to bring leadership technology to market."

GE

Glen Merfeld
Energy Storage Leader,GE Global Research

$170M investment: 450 jobs

Lessons Learned:

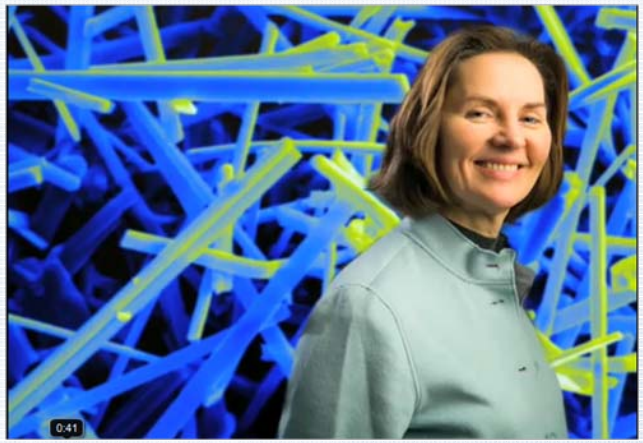
Important to identify "needs" of industry

Overlap with materials science capabilities and expertise

Photon Science for Energy Storage Workshops (3)

Energy Storage: a pending proposal

CELESTE
Center for Extended Lifetime Energy Storage TEchnologies



- Distinguished leader: Dr. Esther Takeuchi
  - National Academy of Engineering
  - National Medal of Technology
  - President of Electrochemical Society
  - Over 140 patents in energy storage
- Tied to Stony Brook: AERTC
  - 49,000 s.f., new state-of-the-art lab space
- Leverages NSLS, NSLS-II, CFN
  - Facilities provide key support for hub science
- Strong New York State support
  - $12.5M direct matching from NY State
  - Leveraging NY investments for battery and grid
  - NYSERDA, NYBEST, NYSTAR Network of CATs

Stony Brook University

SGRID^3 :

A regional partnership

(SBU, New York State, utilities)

SGRID^3 Goals

- Lower the cost of electric power by 5-10%
- Improve the quality and reliability of electric power
- Ensure the security of the Smart Grid

SGRID^3 fills an unmet need:

- Creates a development, demonstration, and deployment infrastructure for smart grid
- Create and maintain New York jobs
  - grid technology
  - information and communication technology
  - new spin-off grid technology service companies

Early Demo

- Use BNL as a "lab"
- Deploy new smart sensors
- Dispatch capacitor banks
- Reduce waste

Initial funding $5M

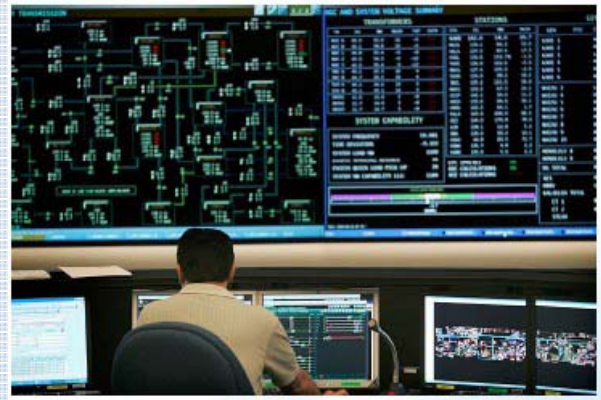
TPC -$90M

Make Long Island the "Silicon Valley of Smart Grid"...

Smarter Electric Grid Research, Innovation, Development. Demonstration, Deployment Center (SGRID^3) at BNL/SBU

With a model-forward approach, SGRID^3 will provide the facility and focus on the Northeast electric grid with modeling and simulation using actual power systems in real time operation

- Integrated System Models
- Historical and real time data and measurements
- Geographically-based information
- Component Models
- Simulations of natural and unnatural events
- Developing and testing advanced micro-grid management strategies



Initial funding from Empire State Development Corporation

SGRID^3 via its Advanced Electrical Grid Innovation and Support (AEGIS) Center will facilitate the development of new capabilities to allow utilities to monitor and model their grids in real time – a capability that currently does not exist.

- **Develop knowledge that will guide future utility investments in the electrical transmission and distribution systems in the Northeast.**
- **Provide computing capability for grid studies with simulation focused on natural and unnatural events**

LISF: Research for utility-scale solar

TOOLS

Outfit 200 acre solar farm with suite of instruments for research

- Solar data
- Meteorological data
- Performance data

ISSUES

Variability and Non-Dispatchability

- Solar energy varies
- Solar generation non-dispatchable

Grid Integration

- Grid not designed for two-way power flow
  Distributed generation impacts stability

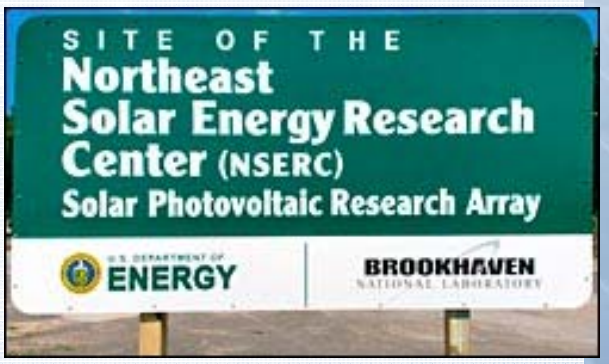
Environmental Impacts

- Local ecology

Northeast Solar Energy Research Center (NSERC) at Brookhaven National Laboratory

Grid-connected 1MW solar energy research array with reconfigurable architecture for field testing innovative new smart grid technologies

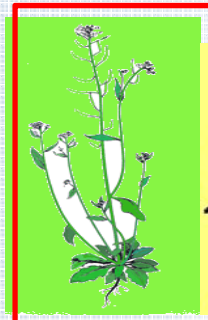
- Renewable Energy Integration
- Advanced Smart Grid Sensors
- Distribution Simulation and Automation
- Distributed Generation and Storage
- Advance Power Electronics
- Interoperability, Communications & Security
- Solar Technology & Grid-Related Standards & Codes

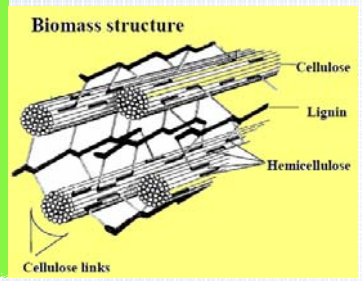


NSERC will provide unique capabilities for renewable energy and smart grid research:

- **1MW grid-connected solar research array**
- **Field testing under actual northeastern US conditions**
- **No UL listing or interconnect permits needed**
- **Instrumented smart micro-grid test bed**
- **Access to data from eastern interconnection**

Thermochemical Conversion of Biomass to Renewable Fuels – reaching back into basic research

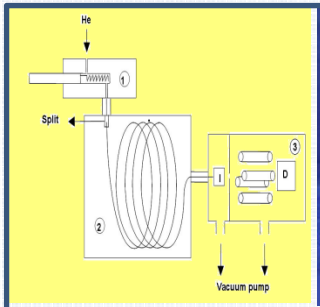




Arabidopsis

Biomass Structure

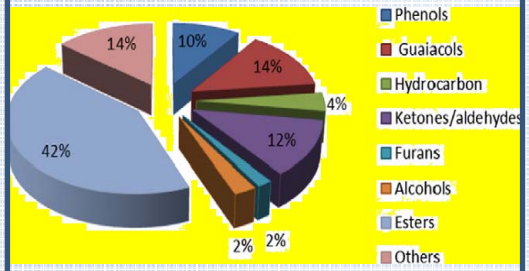
ELS: BIOLOGY



High-pressure pyroprobe

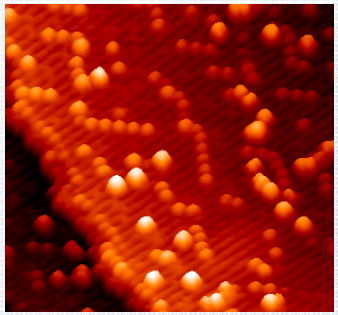
GC-MS

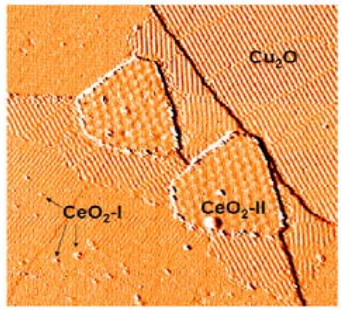
GARS: SET



Characterization of thermochemical conversion products for conditioning and conversion

GARS: SET





150nm x 150nm

BNL's proprietary low-cost and low-temperature nano-catalysts with tailored crystalline structure for product conditioning and synthesis

BES: CFN-CHEMISTRY

Renewable chemicals, Fuels, and power

TEA, LCA, & Bus. Plan

GARS: SET

Having “something to offer” to the applied energy customer

- Real world experience is critical as we try to understand needs.
- Important example questions:
  - How will the smart grid impact distribution? **AEGIS**
  - What are the real challenges of renewable integration? **BNL micro-grid, LISF and a solar test array**
  - Is there a pathway to sustainable fuels? **TCC of biomass**
  - How do new materials evolve under the influence of extreme environments? **MRE beamline for NSLSII**