

# Superconducting Magnetic Energy Storage (SMES) Systems for GRIDS

Qiang Li - *Advanced Energy Materials Group*

Drew W. Hazelton – *SuperPower Inc.*

Venkat Selvamanickam – *SuperPower and Univ. Houston*

*Presented by Traute Lehner - SuperPower Inc.*

**ABB**

**SuperPower** Inc.

UNIVERSITY of **HOUSTON**

**BROOKHAVEN**  
NATIONAL LABORATORY

*a passion for discovery*



U.S. DEPARTMENT OF  
**ENERGY**

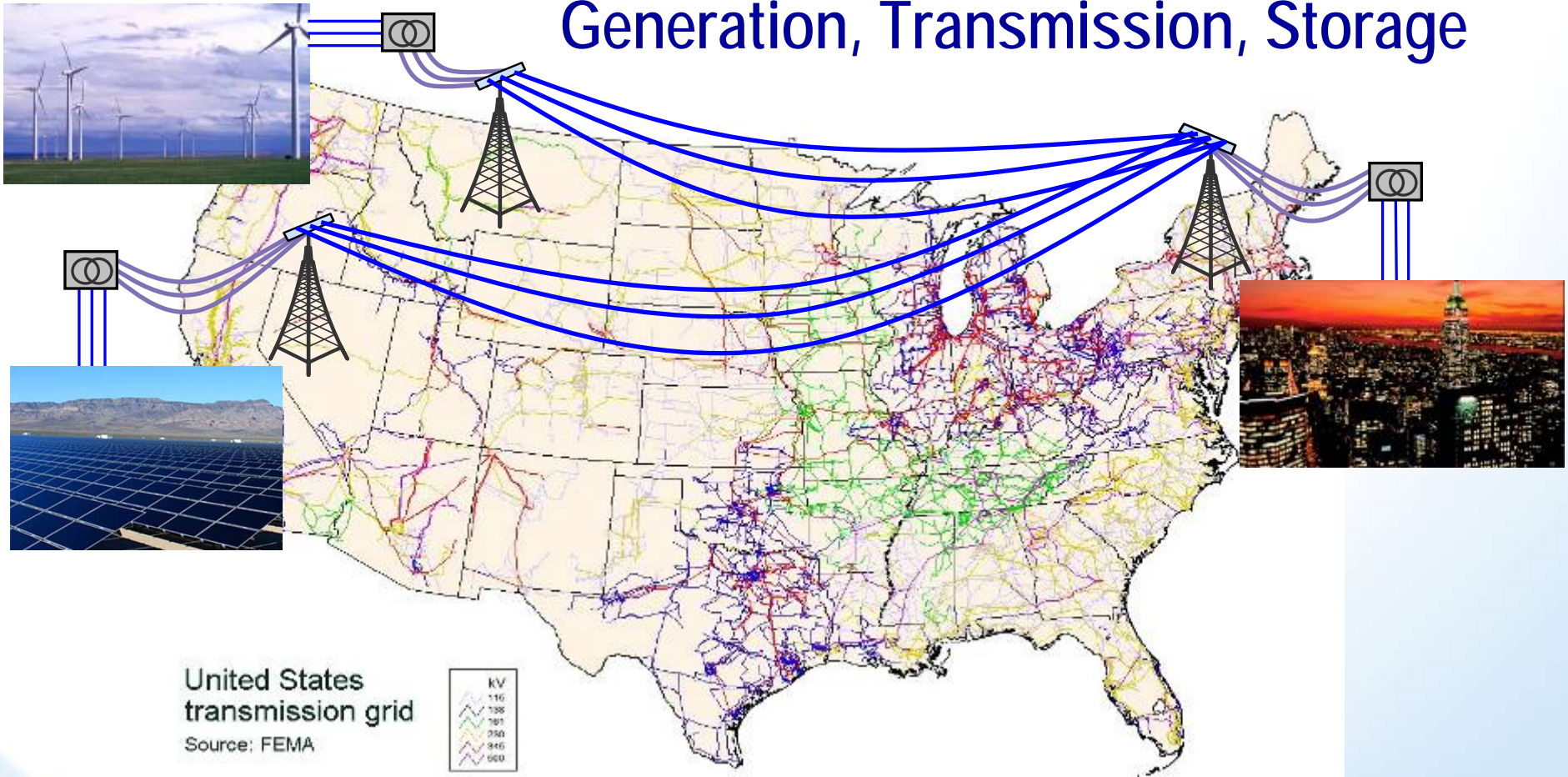
Office of  
Science

# Outline

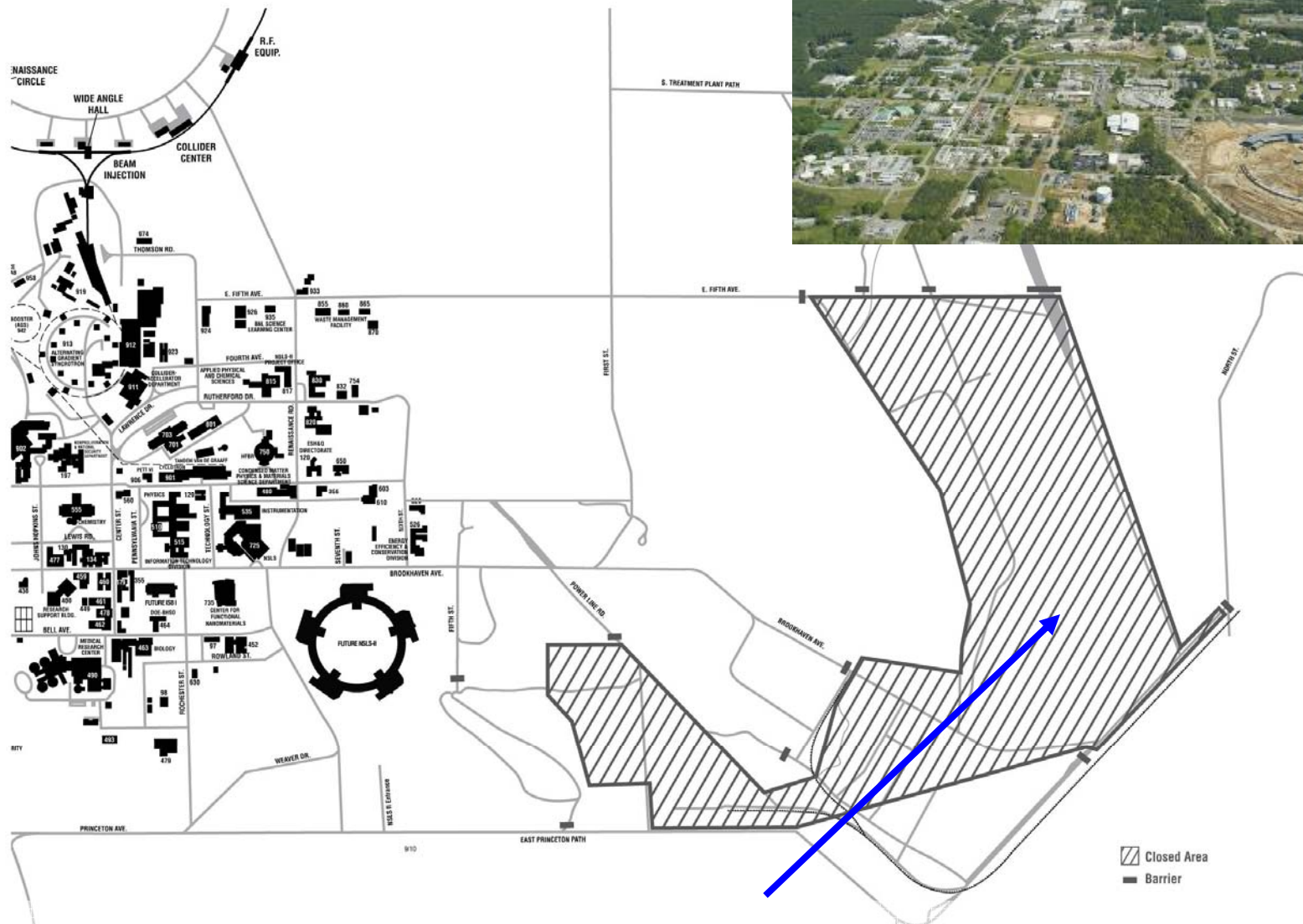
- ❖ Renewable energy challenges
- ❖ DOE ARPA-E SMES project
- ❖ R&D at Brookhaven Lab and SuperPower

# Renewable Energy Challenges:

## Generation, Transmission, Storage

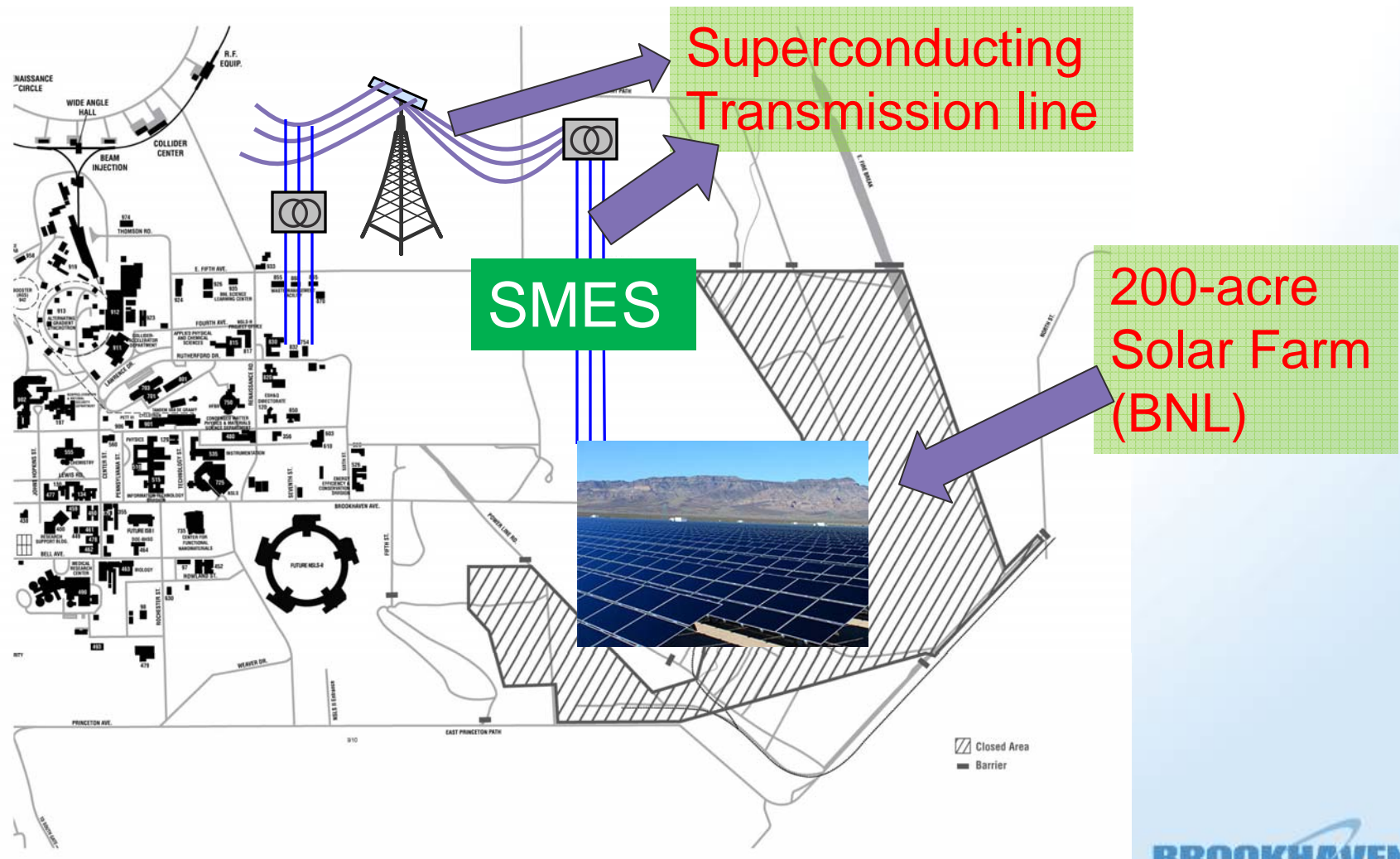


Electricity produced from renewable energy sources:  
California: 33% of its electricity by 2020  
New York: 30% by 2015

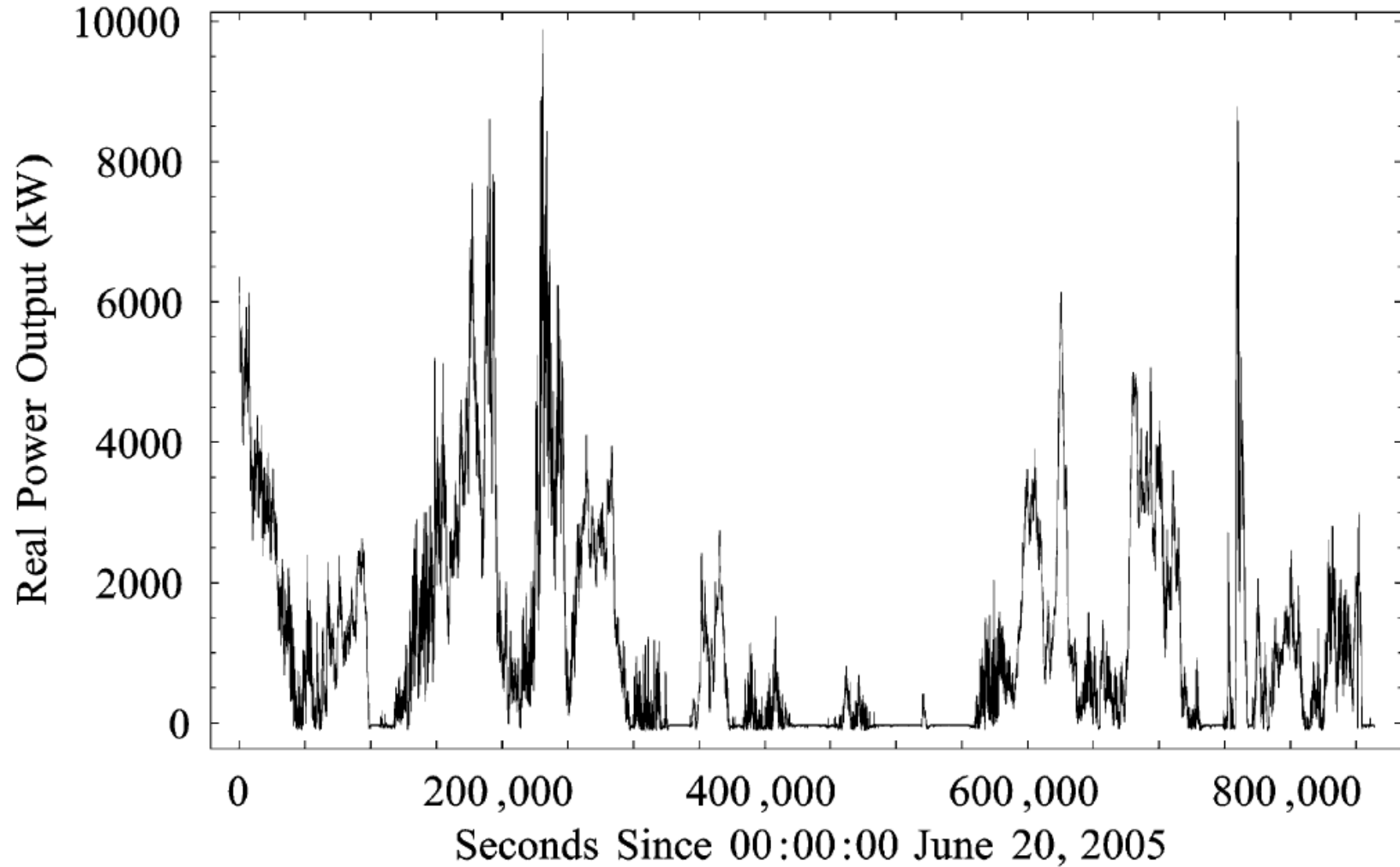


# 200-acre Solar Farm at Brookhaven Lab

# Superconductor-based energy storage/conditioning and transmission R&D – A Brookhaven proposal

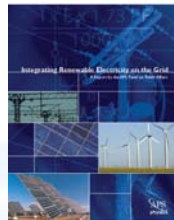
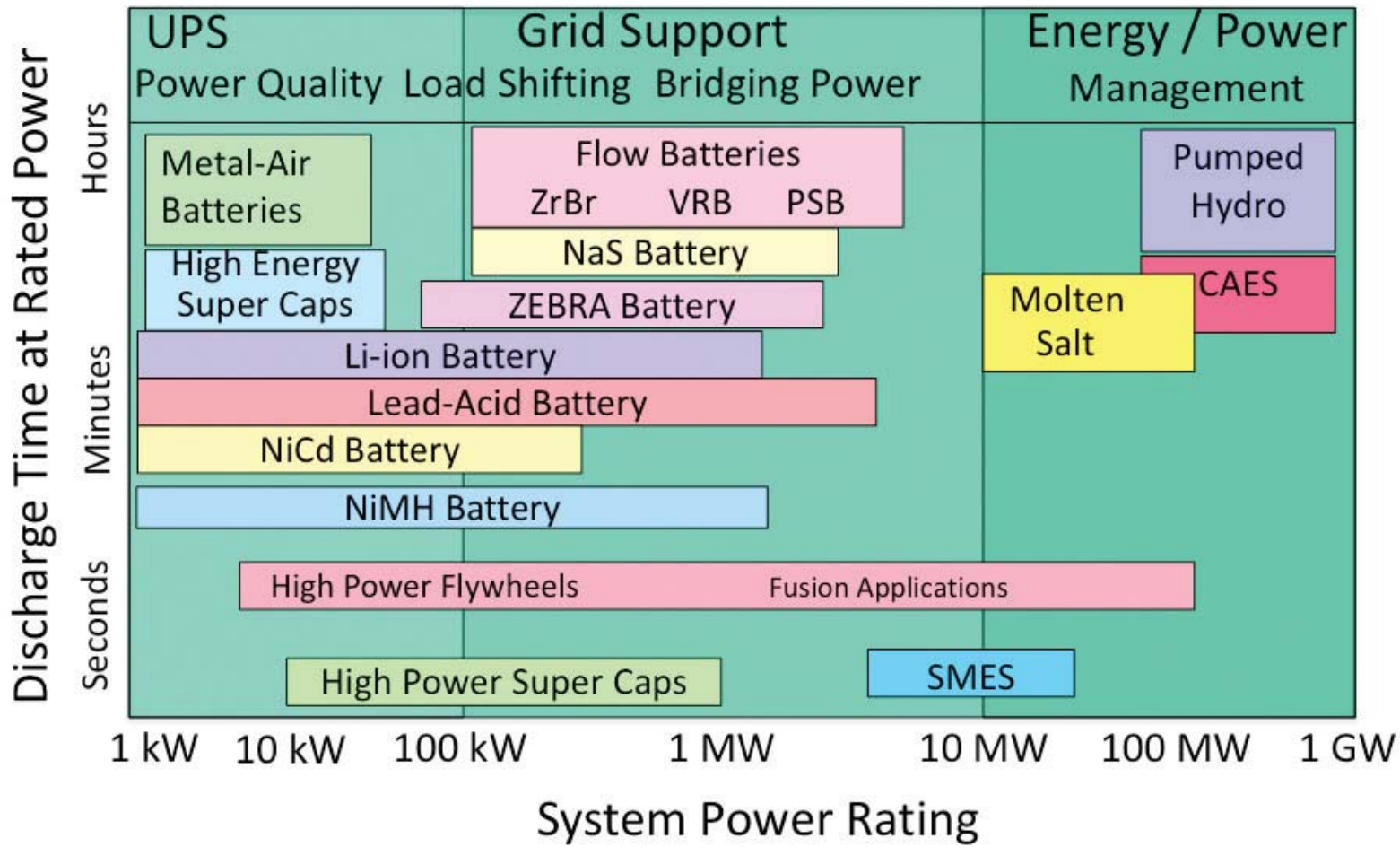


## Sum of Ten Turbines Ten Days at 1 Second Resolution

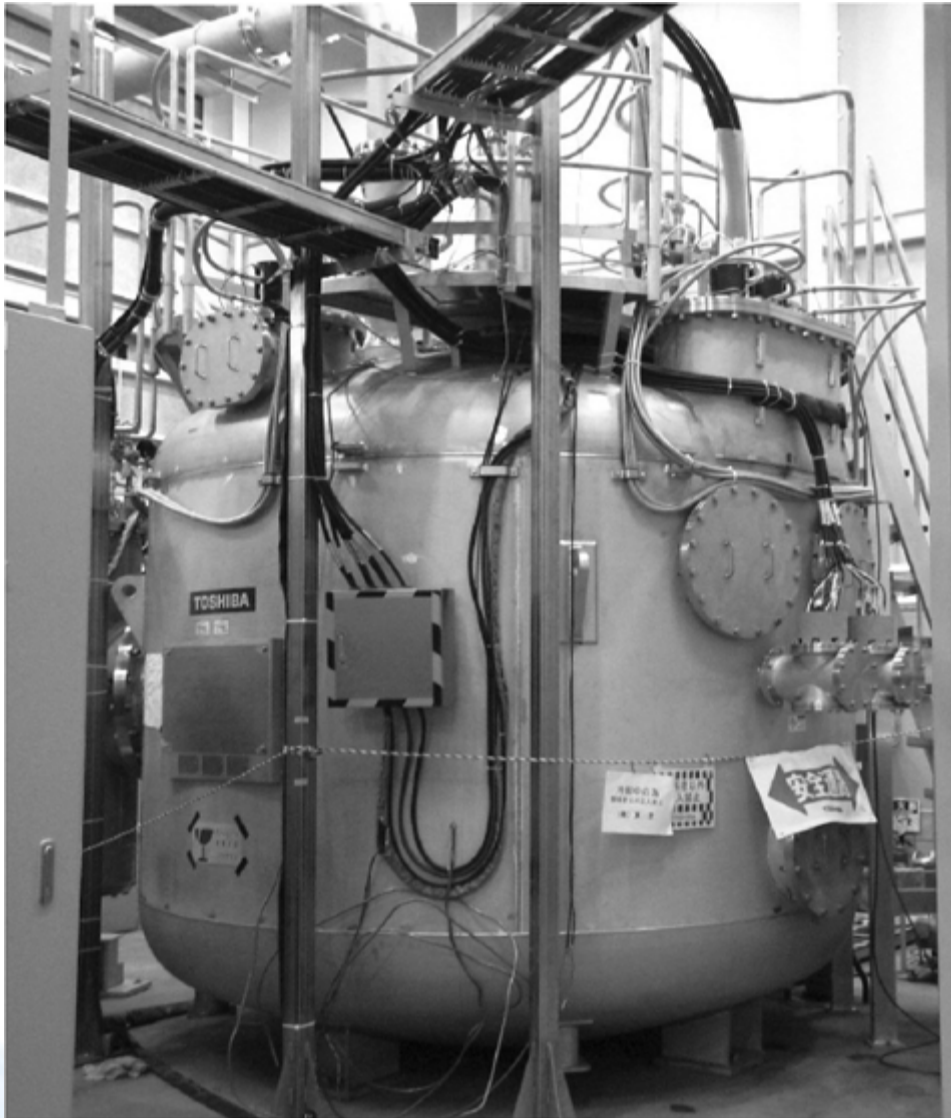


J. Apt, *Journal of Power Sources* **169**, 369–374 (2007).

# Energy Storage Options



Integrating Renewable Electricity on the Grid APS Report  
 – Chaired by G. Crabtree/J. Misewich

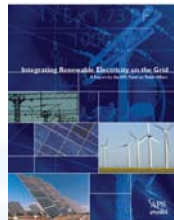
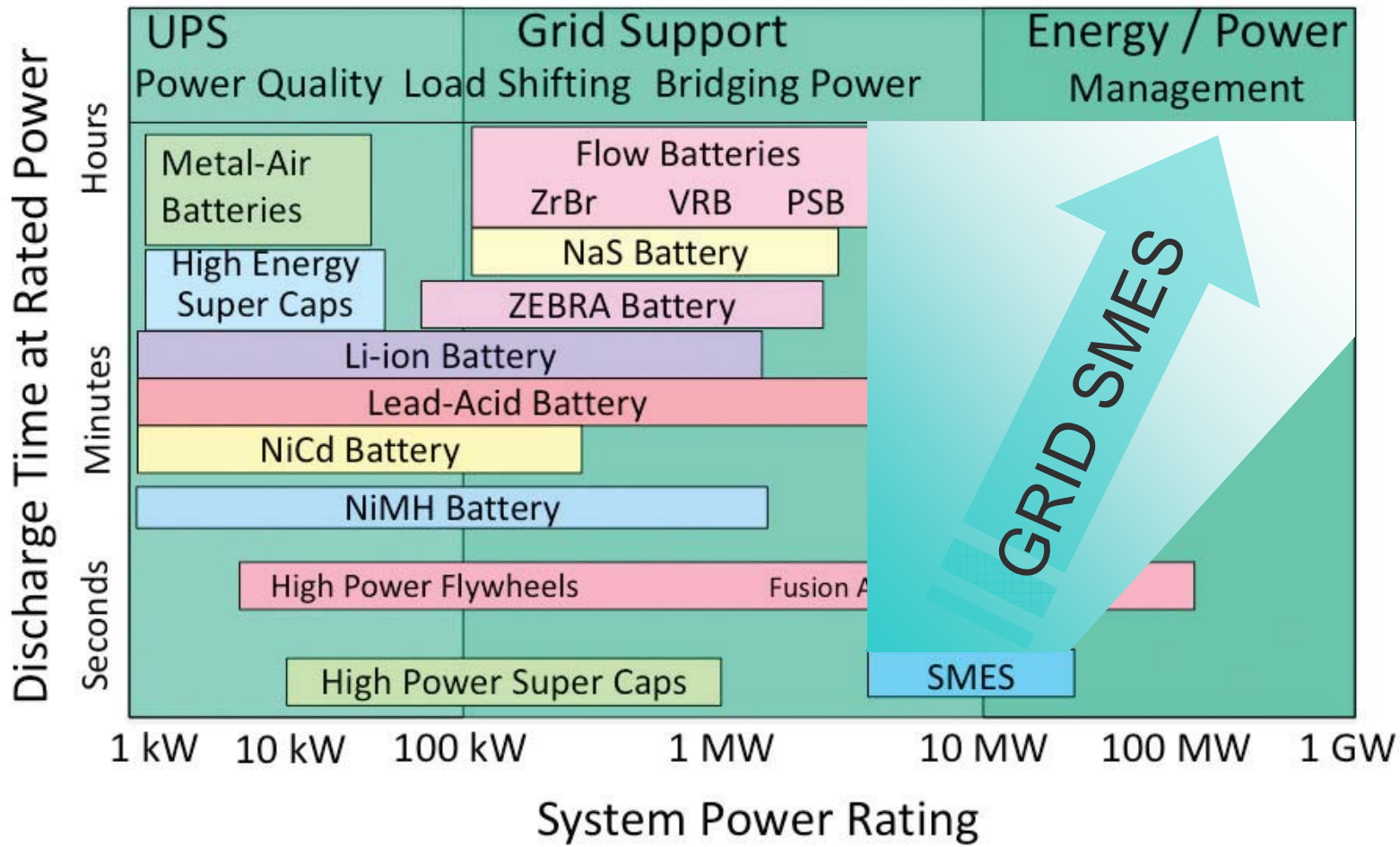


The cryostat for the 10 MVA/20 MJ SMES prototype, tested at an actual power system including hydro power generators in order to compensate the fluctuating power load from a metal rolling factory

T. Katagiri *et al.*, *IEEE Trans. Appl. Supercond.*, 19, 1993–1998, (2009).

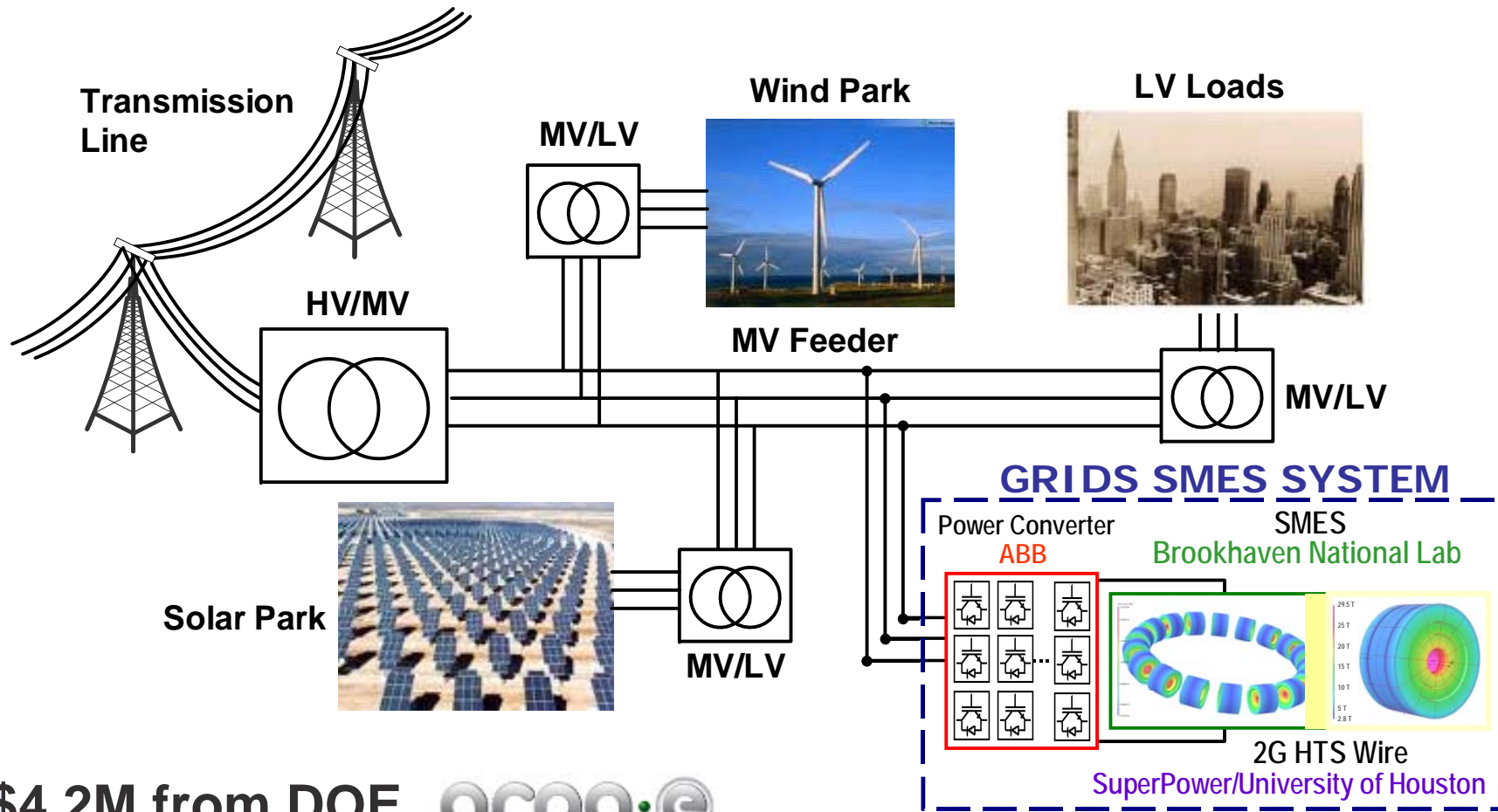
Nomura, et al, *IEEE Trans. Appl. Supercond.*, vol 20 (2010)

# Energy Storage Options



Integrating Renewable Electricity on the Grid  
 APS Report – Chaired by Crabtree/Misewich

# Superconducting Magnet Energy Storage (SMES) System with Direct Power Electronics Interface for GRIDS (\$5.3M)\*



**\*\$4.2M from DOE** 

Team (co-PI):

ABB Inc. (Ramanan)

Brookhaven Lab (Li)

Oct. 2010

SuperPower (Hazelton)

U of Houston (Selva)

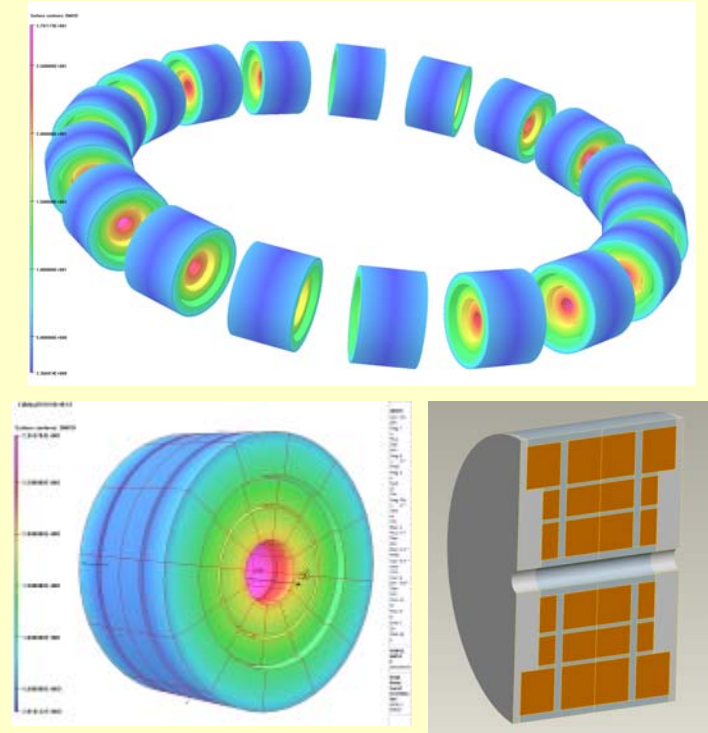
Brookhaven Science Associates



## Brookhaven GRID SMES (25-32 T)

- Fast dynamic response
- Nearly infinite cycling
- Magnetic energy  $\sim B^2$
- Size  $\sim R^2$ , ( $\sim R^3$  batteries)
- Solid state operation
- Environmentally friendly

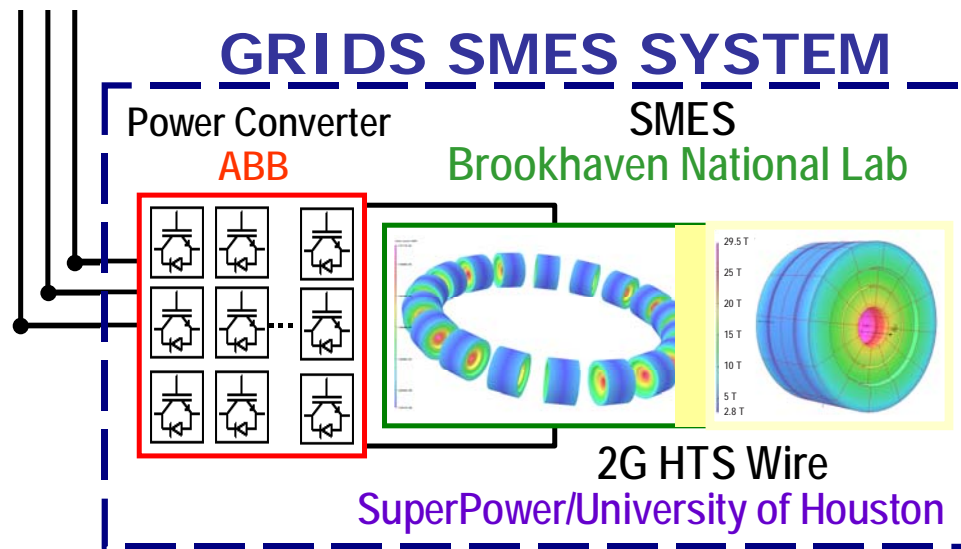
### Ultra-High Field Magnet



The performance of each sub-system will have to be propelled far beyond the present state-of-the-art

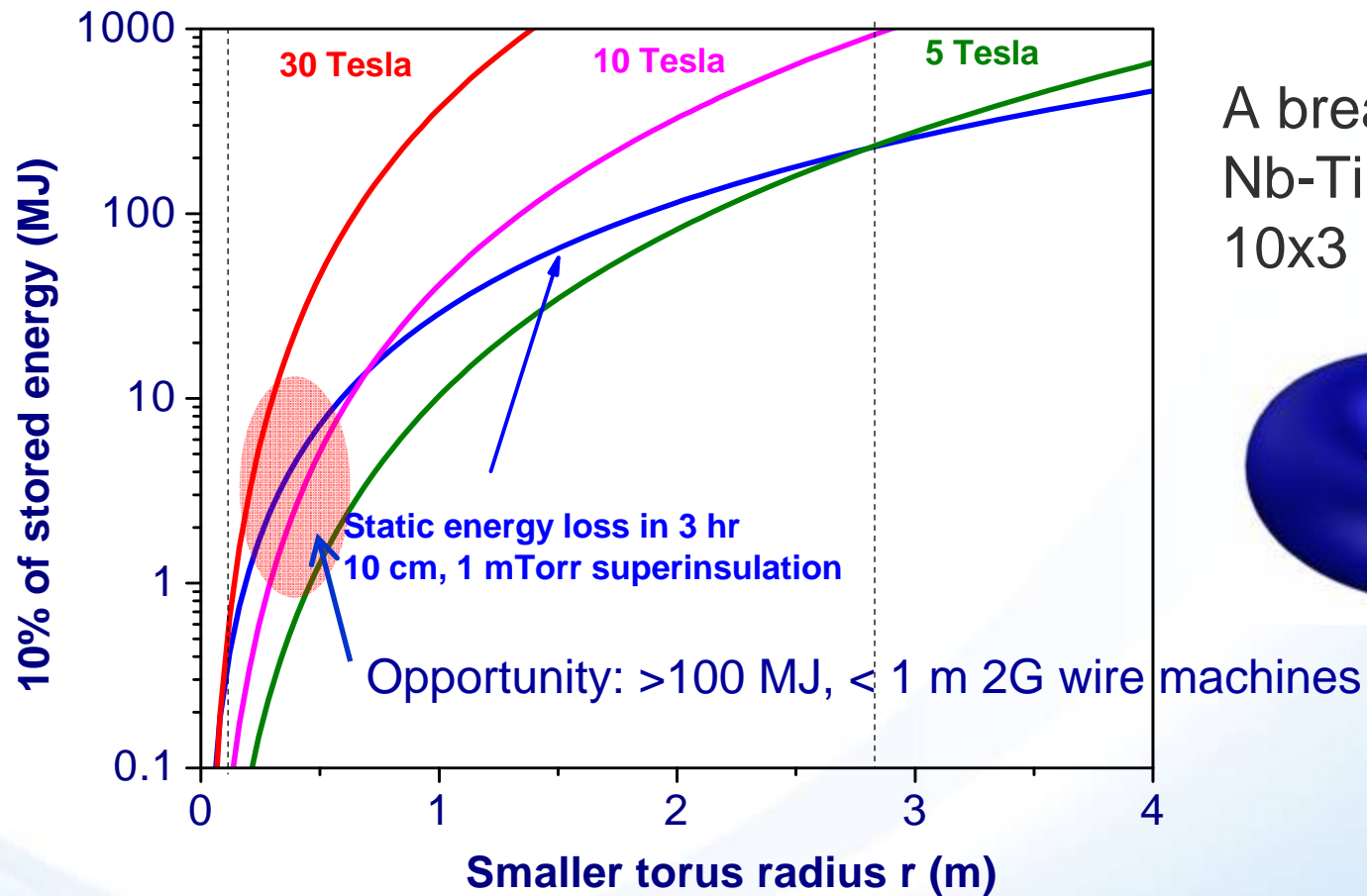
# Technology Advances (Revised, ARPA-E)

- Ultra-high field (25T) prototype magnet (20 kW, 3.2 MJ)
- 2G HTS wire with  $I_c > 600$  A
- Modular, scalable converter concept for direct connection to medium voltage grid with high round trip efficiency (> 85%)

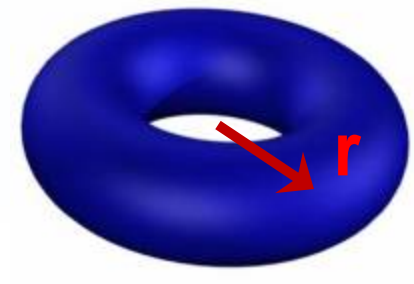


# Static losses in toroidal SMES at 5 K

- Why do we need ultra-high fields?



A break-even 5 T Nb-Ti machine is 10x3 m torus



# Brookhaven Team for GRIDS SMES and other programs:

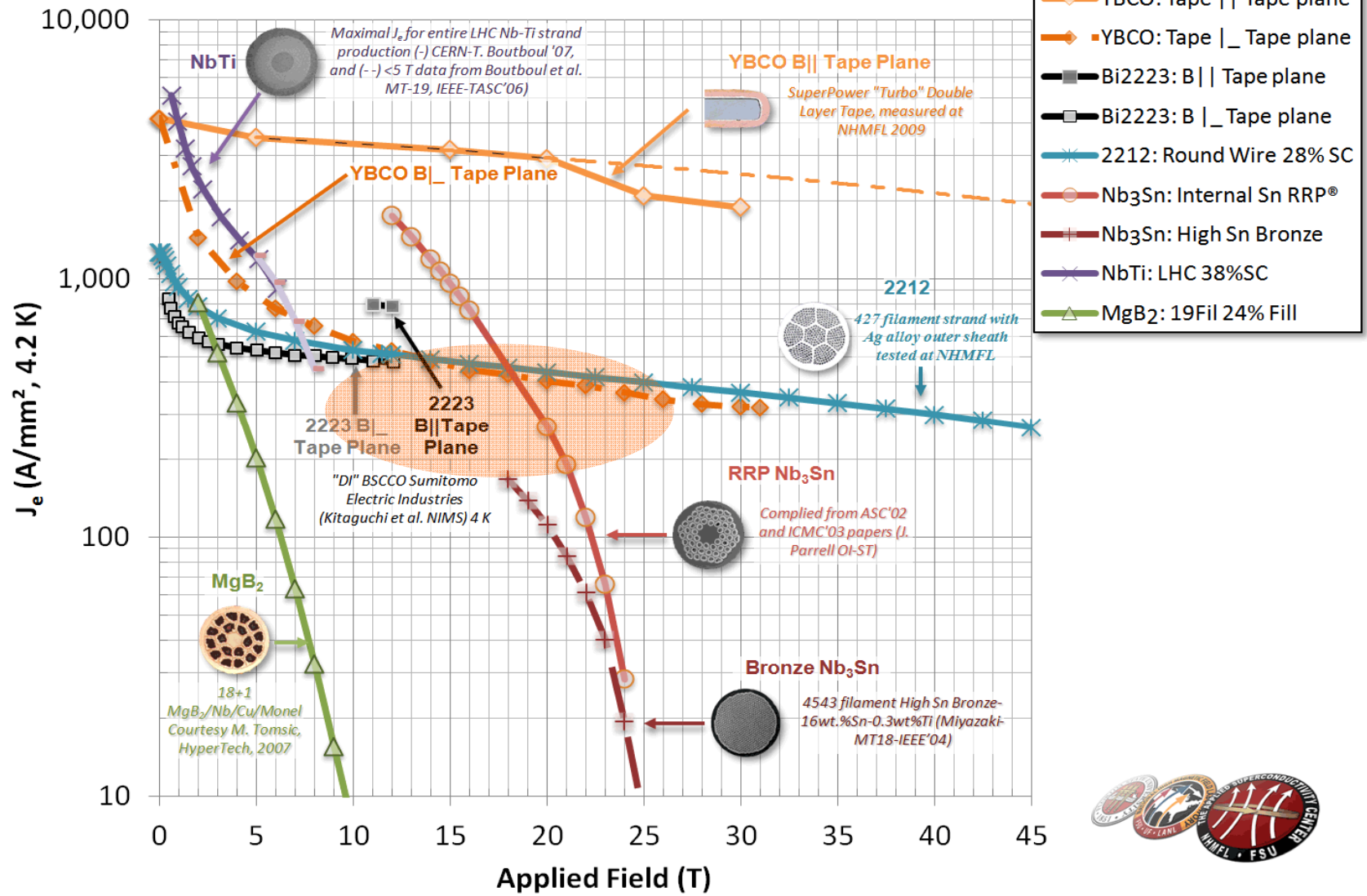
Advanced Energy Materials Group: Q. Li (P.I.), V. Solovyov, and I. Dimitrov

Magnet Division: R. Gupta and P. Wanderer

- ❖ Magnet design and construction
- ❖ Quench protection
- ❖ HTS wire enhancement
- ❖ Low resistive/persistent current joints
- ❖ SMES-side superconductor switch
- ❖ New superconducting materials



### Current Density Across Entire Cross-Section



Superconducting wire selection:  
2G wire - high  $I_c$  and high strength

## SuperPower tasks - Schenectady

- Manufacture and supply of high quality 2G HTS conductor
  - Nom. 7 km in total
  - >1 km delivered to date (on schedule)
  - SCS12050-AP wire type
    - 12 mm wide,
    - 100 microns copper stabilizer (50/side)
    - AP (advanced pinning) formulation
    - $I_c$  (@77K, sf): 300 A (2011), 325 (2012)
- Support BNL coil design and test activity

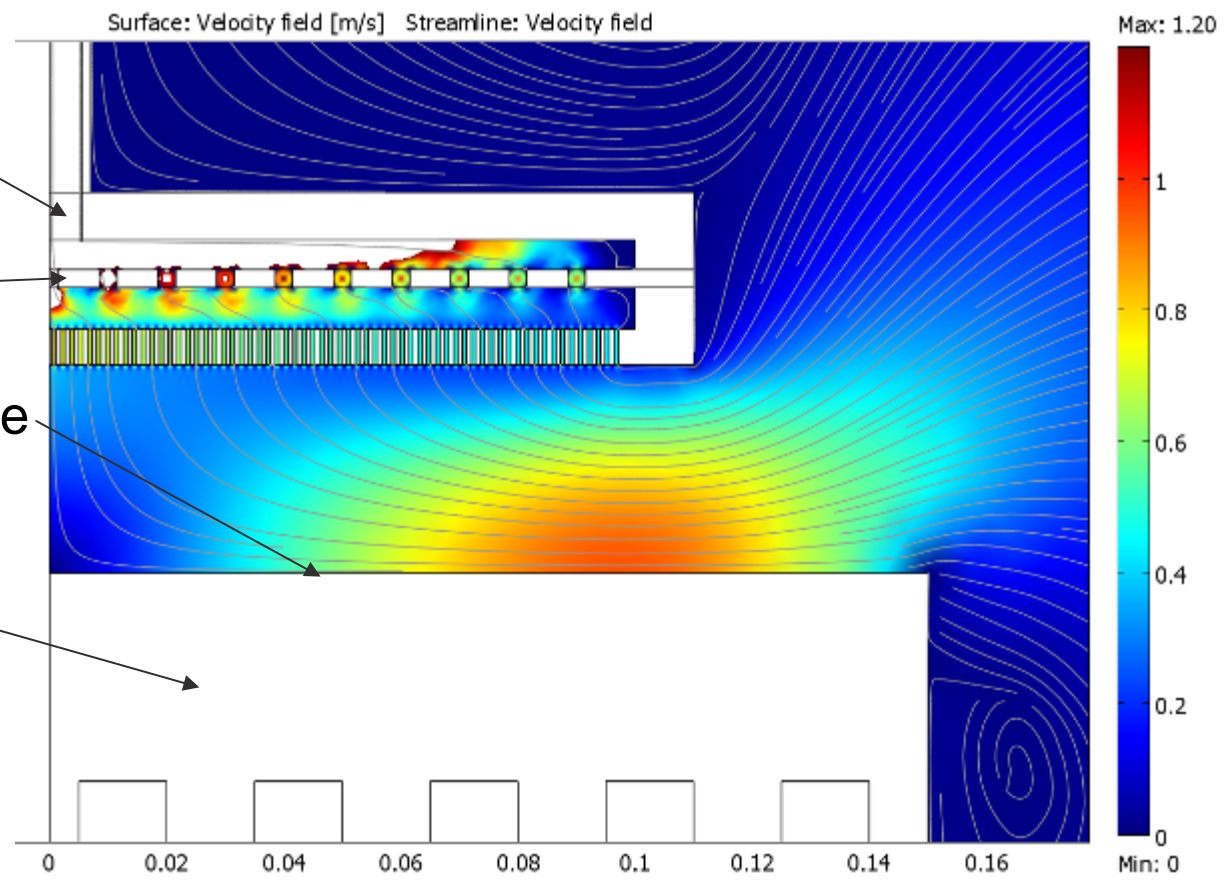
## SuperPower / U Houston tasks

- Primary focus - MOCVD process improvement to enhance both price + performance of 2G HTS conductor
  - Modeling of MOCVD reactor flow and reaction
  - Improved precursor conversion efficiency
  - Improved thermal monitoring and control
  - Improved pinning performance at low temperature / high field
- New Ic test equipment installed to measure in field performance as a function of temperature, field and field angle
  - 4.2 K to 77 K
  - 0 to 9 Tesla
  - 600 A capability
  - 0 to 360 degrees

# CFD model of current MOCVD showerhead

## Velocity field profile

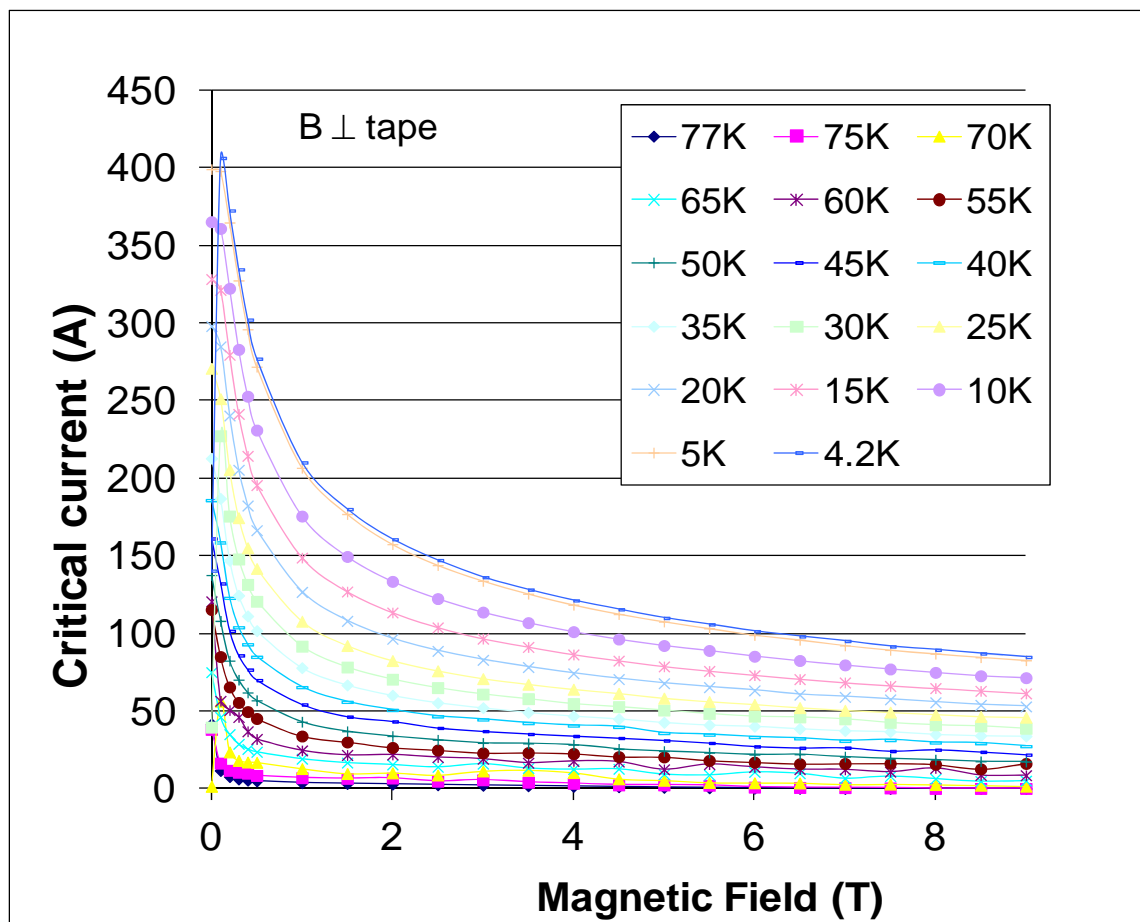
Precursor delivery  
Showerhead  
2G HTS tape surface  
Heater



# New Ic test measurement system



# Early data on SuperPower 2G HTS conductor (narrow bridge sample)



# Summary

- ARPA-E SMES for Grid-scale rampable intermittent dispatchable storage – for renewables
- Team: ABB, SuperPower, U. Houston, BNL
- \$5.3M (\$4.2M investment from ARPA-E)
- 2010-2013
- Deliverables
  - UHF magnet 25T and up
  - High performance 2G HTS wire: >600A
  - Modular, scalable converter concept