



superior performance.  
powerful technology.

## High-Performance 2G HTS Wire for an Efficient and Reliable Electricity Supply

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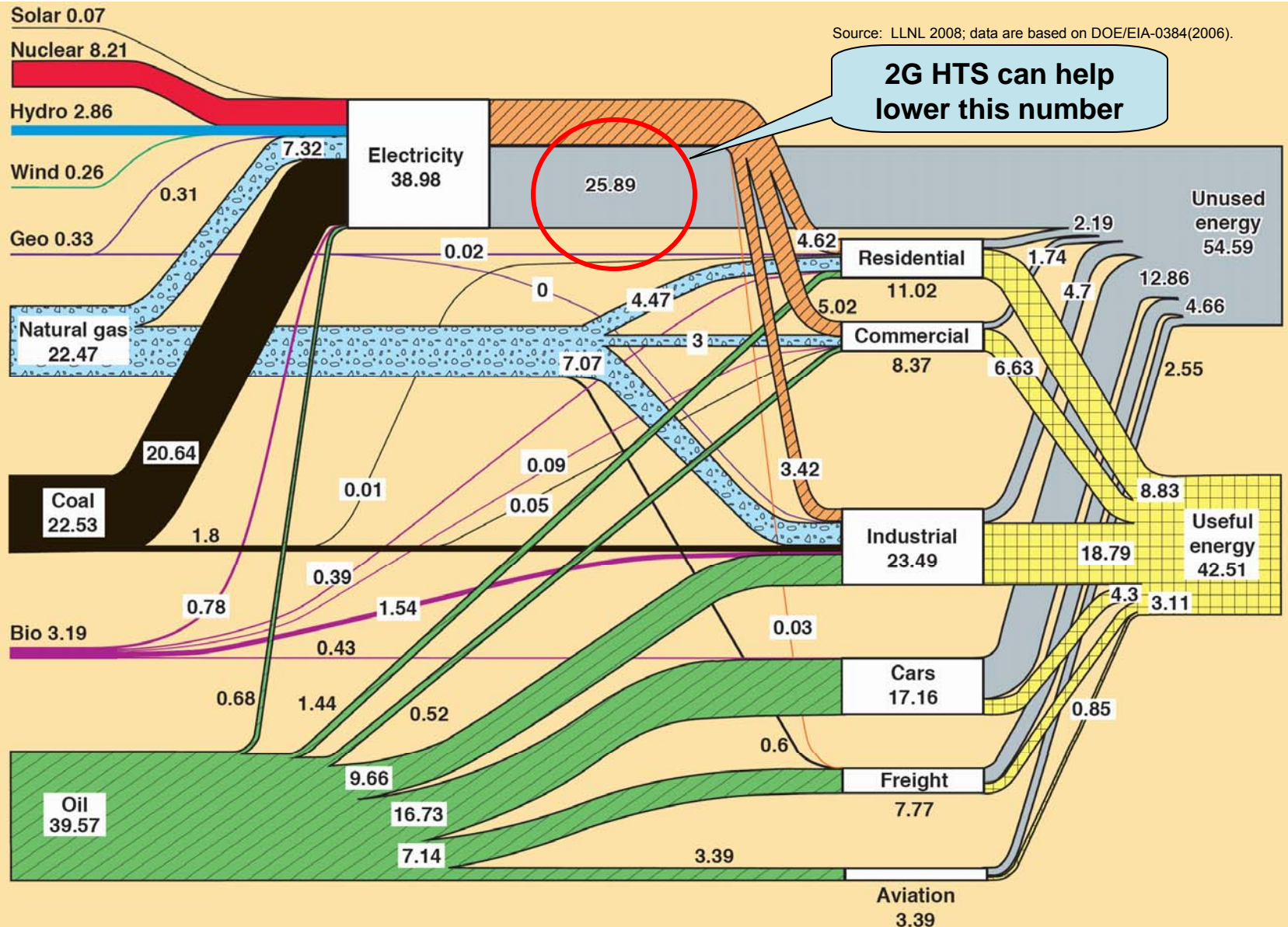
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# Outline

- Superconductivity for Electric Power Applications
- 2G HTS wire
- Energy applications of Superconductivity

# The Challenge: U.S. Energy Flow, 2006 DOE Study (Quads) and >60% of primary energy for electricity generation/use is lost

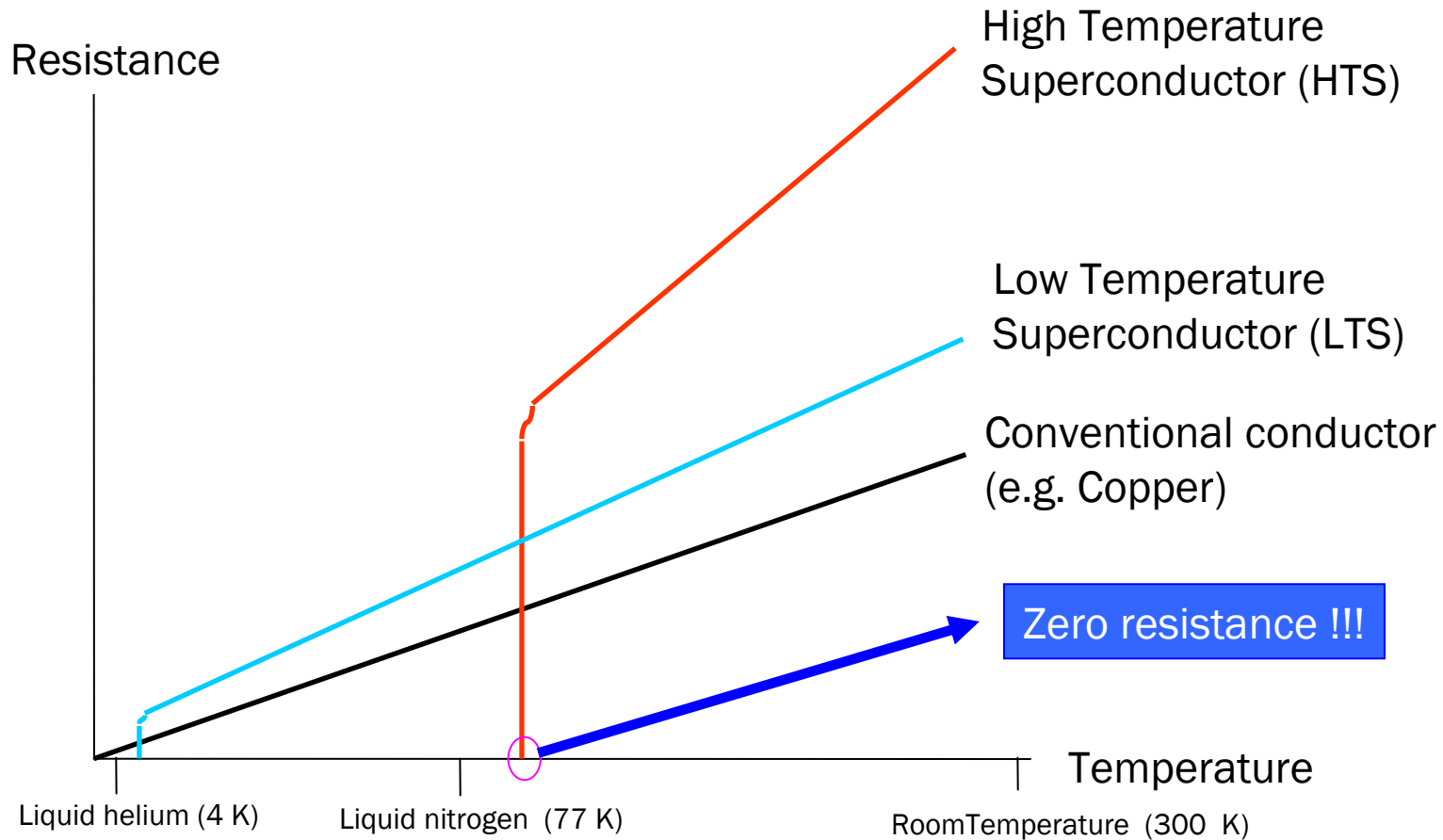
Source: LLNL 2008; data are based on DOE/EIA-0384(2006).



## Superconductivity offers efficient and reliable high power density devices and electricity transport for upgrading the existing power grid

- In-grid demonstration projects proving efficacy of superconductor-based solutions
  - *Transmission* - Superconducting power cables for congested areas, long-distance power from remote energy sources to demand centers
  - *Transformation* – High power density superconducting transformers including fault current limiting transformers
  - *Protection* – Fault current limiters reduce prospective fault currents to levels that can be handled by downstream equipment
  - *Generation* - Superconducting generators for land-based, off-shore, maritime and airborne applications
  - *Consumption* – Efficient use of electricity - Superconducting motors for industrial applications
  - *Storage* – Superconducting Magnetic Energy Storage (SMES) for load leveling energy storage and power quality

# Why high temperature superconductors? Unique materials with efficient, high power density operation



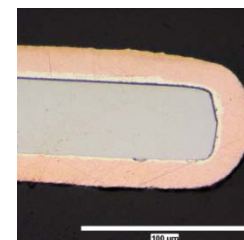
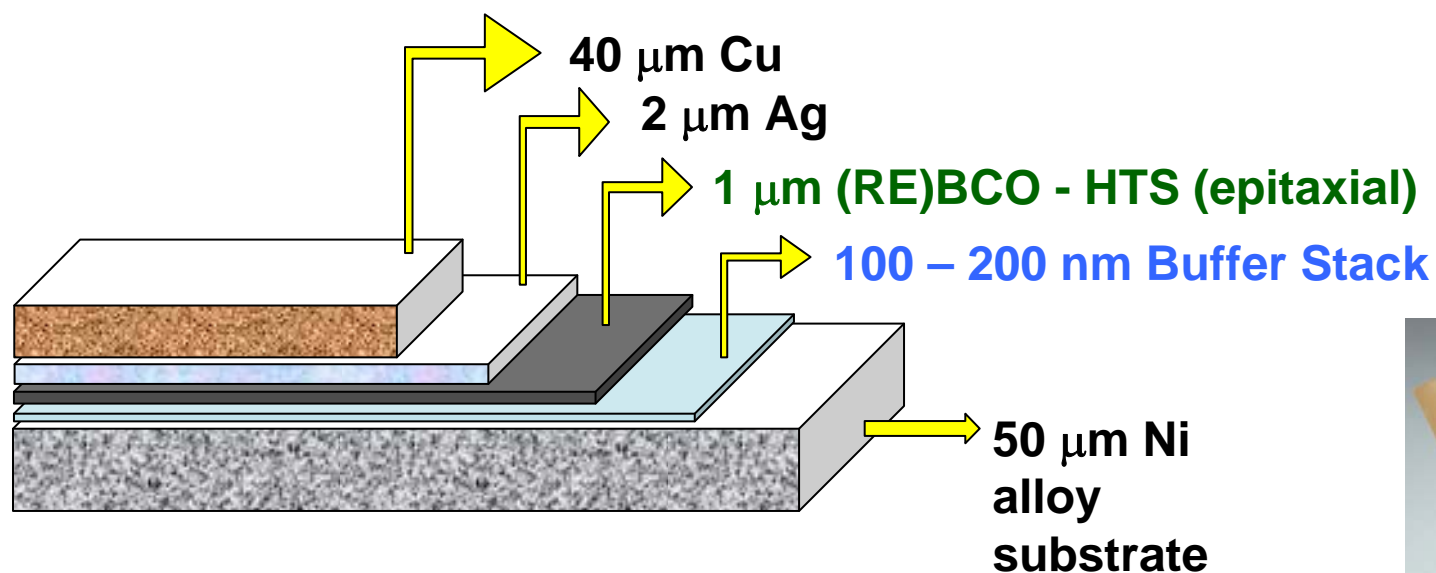
Current carrying capability of copper ~ 100 A/cm<sup>2</sup>

Current carrying capability of 2G HTS tape ~ 25,000 A/cm<sup>2</sup>

Current carrying capability of superconductor layer ~ 5,000,000 A/cm<sup>2</sup>

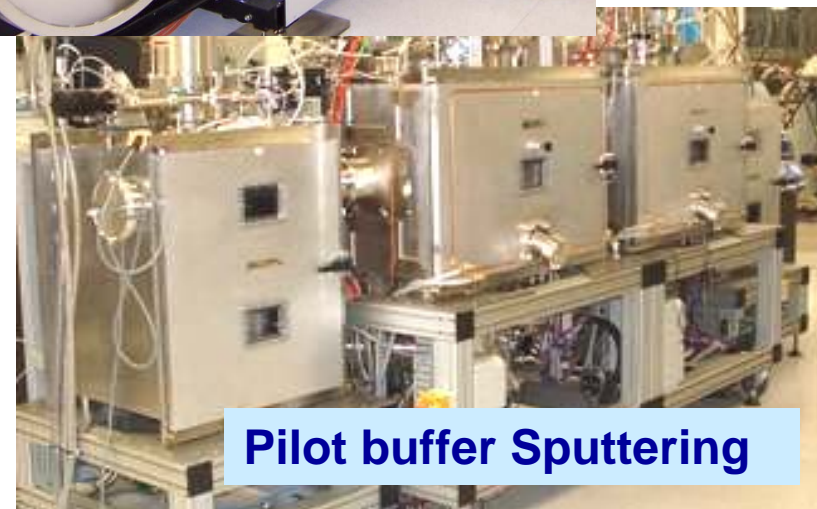
## Second generation (2G) high temperature superconductors (HTS) offer superior properties

- 2G HTS currently produced in long lengths by several manufacturers
- Capacity growth and price reduction is prime focus of 2G HTS community
- SuperPower® 2G HTS: produced by thin film vacuum deposition on flexible nickel alloy substrate in a continuous reel-to-reel process.



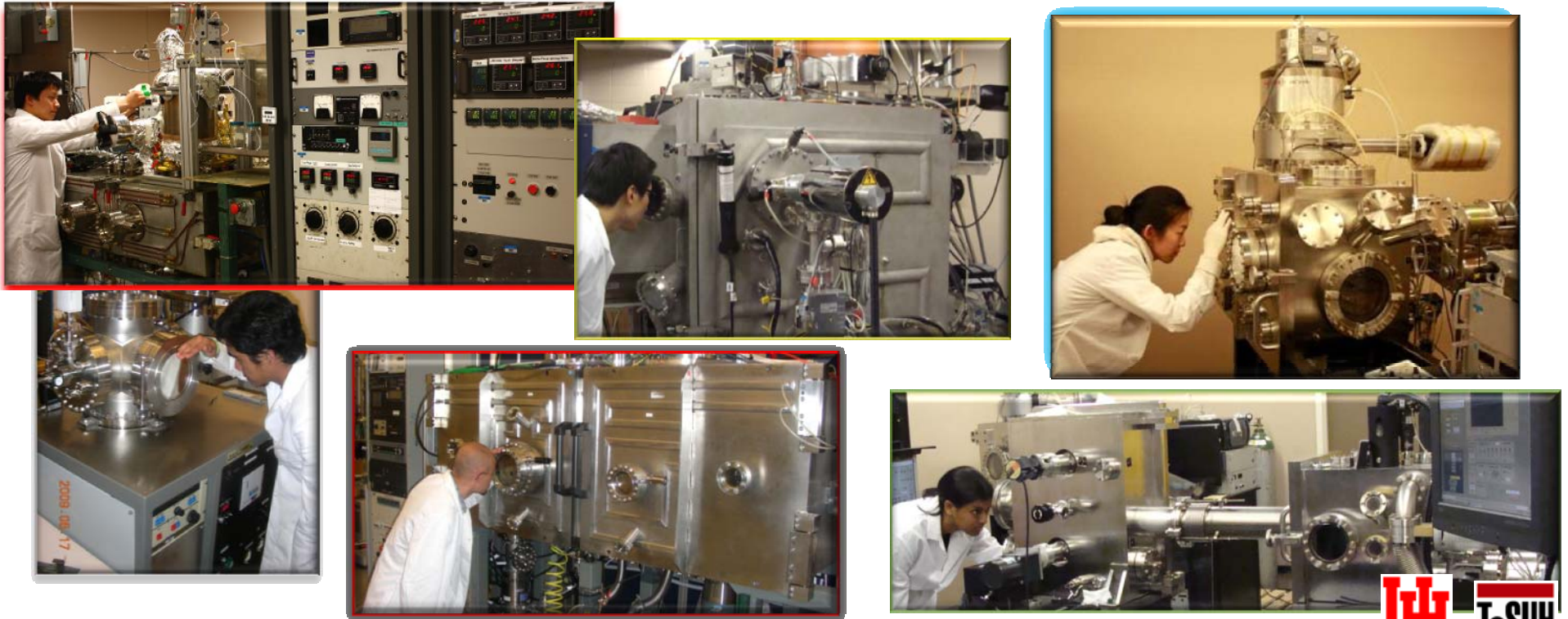
SuperPower 2G HTS Architecture

# 2G HTS wire being produced in pilot manufacturing facility at SuperPower since 2006



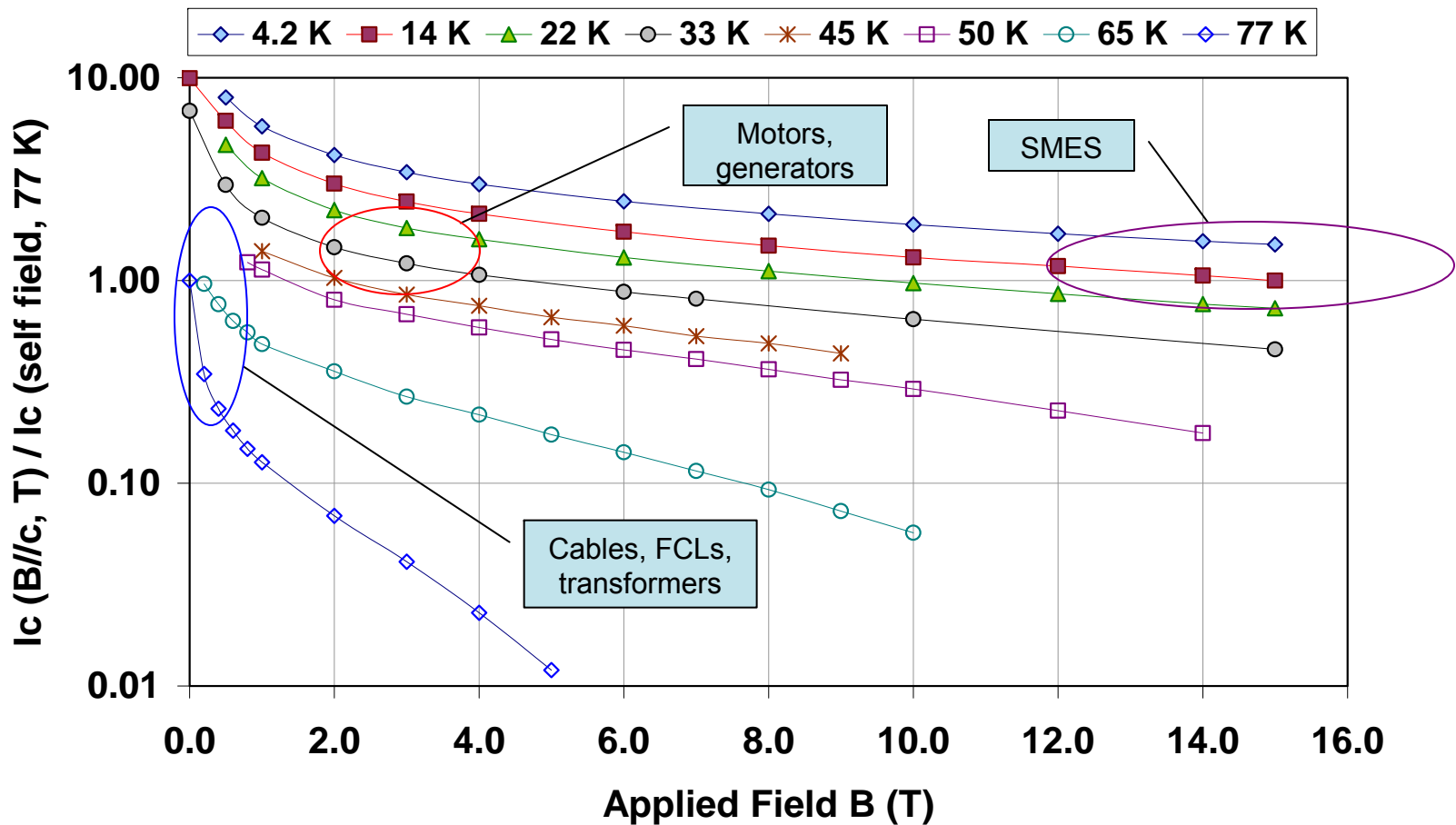
# SuperPower and UH collaborate to commercialize HTS in energy applications

- SuperPower has established its HTS technology development operation at Houston
- HTS research equipment in place at University of Houston
- Prime focus is continued technology development and price:performance improvements
- SuperPower also establishing Specialty Products facility at UH Research Park

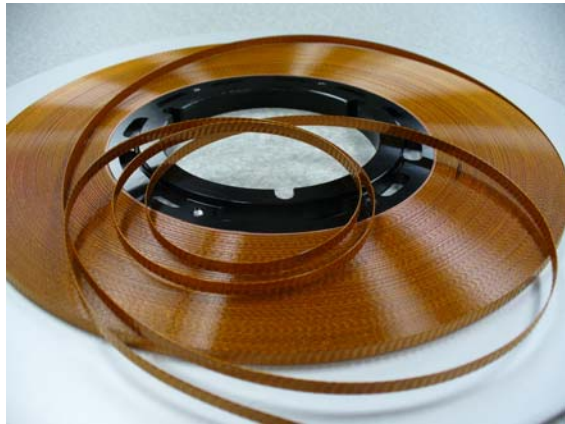


# 2G HTS offers excellent performance for all electrical device operating ranges

Normalized  $I_c$  vs. Applied Field  $I/c$



SuperPower 2G HTS can be provided with insulation or modified to reduce ac coupling losses without impacting conductor properties



Wrapped polyimide insulation



ROEBEL Cable Demonstrated by Karlsruhe Institute of Technology (KIT) with SuperPower<sup>®</sup> 2G HTS Wire

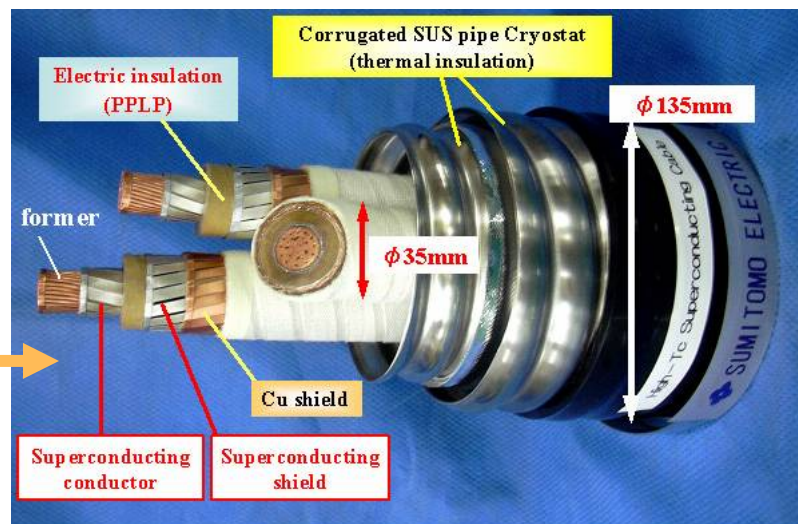


# HTS offers significant benefits in energy applications

- Cleaner
- More efficient
- Safer
- Smaller footprint
- Lighter
- Security benefits



**HTS Cable**



**HTS Transformer**



**HTS Fault Current Limiter**



**HTS Motor**

# U.S. HTS Cable Installations

*National Grid, Albany, NY  
34.5 kV, 800 A, 48 MVA, 350 m  
Cable by Sumitomo Electric  
Cryogenics by Linde*



*Bixby station, American  
Electric Power,  
Columbus  
13.2 kV, 3000 A, 69  
MVA, 200 m  
Cable by Southwire &  
NKT cables  
Cryogenics by Praxair*

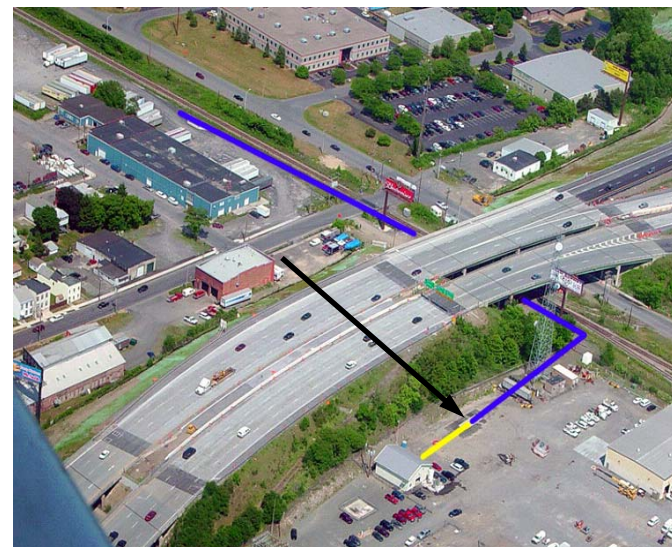
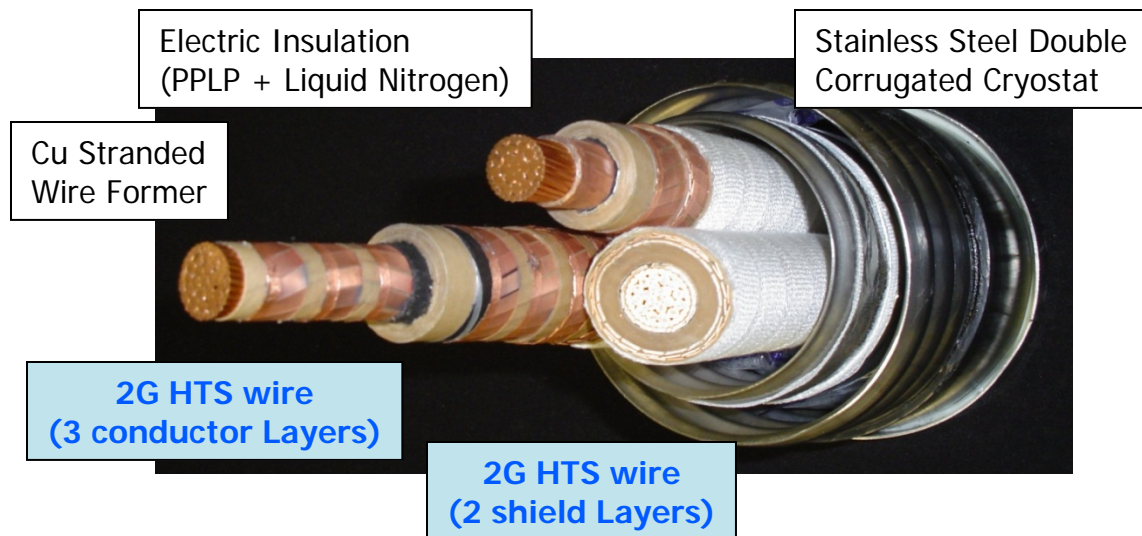


*Long Island, NY  
New York, NY (DHS)  
Hydra Project  
Columbus, OH*

*Long Island Power Authority  
138 kV, 574 MW, 600 m  
Cable by Nexans  
Cryogenics by Air Liquide*



# Demonstration of the world's first device made with 2G HTS conductor in a live power grid



**Installation at Albany Cable site (Aug. 5, 2007)**



350 m cable made with 30 m segment of 2G HTS wire was energized in the grid in January 2008 & supplied power to 25,000 households in Albany, NY

## Power transmission cable manufactured by Sumitomo Electric Industries with SuperPower 2G HTS wire

### Benefits

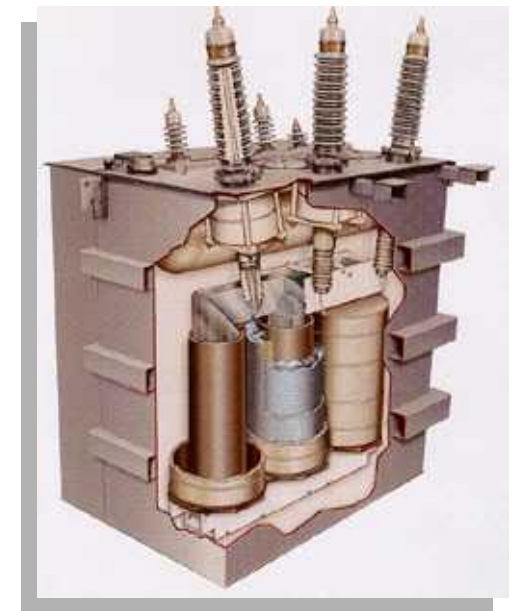
- 5 (AC) to 10 (DC) times more capacity than comparable conventional cables
- Can be used in existing underground conduits → saves trenching costs
- Liquid nitrogen coolant is also dielectric medium (no oil)
- Greatly reduced right-of-way (25 ft for 5 GW, 200 kV compared to 400 feet for 5 GW, 765 kV for conventional overhead lines)
- Operating at high currents, can obviate the need for step-up / step down transformers
- Can be used on conventional equipment with minor modifications



## HTS Transformers for the power grid – half the size and weight

### Benefits:

- Greater efficiency
- Smaller, lighter and quieter
- Can run indefinitely above rated power without affecting transformer life
- Do not require cooling oil like conventional transformers, thus eliminating the possibility of oil fires and related environmental hazards / costs
- 5/10 MVA, 24.9kV HV/4.16kV LV 3- $\phi$  prototype developed by Waukesha Electric, SuperPower, ORNL and Energy East

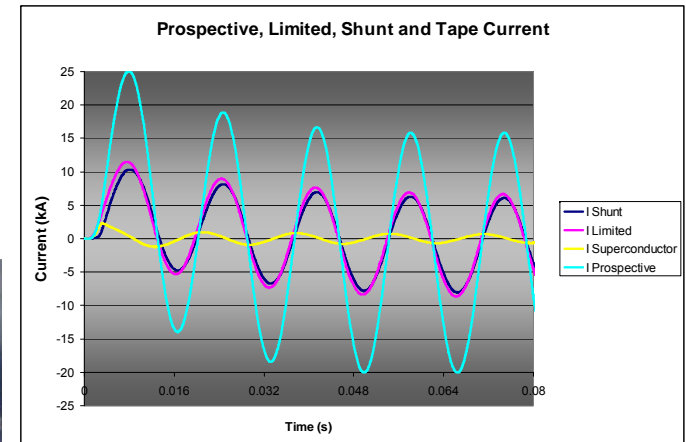
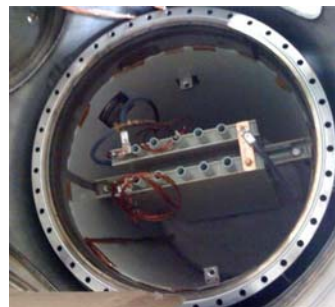


# Fault current limiting feature: a bonus with superconducting devices

- Fault-current limitation successfully demonstrated in several US projects
  - Zenergy in Southern California Edison grid demonstration
  - AMSC / Siemens
  - SuperPower
  - Other international projects – Nexans, Korea, Japan, China
- FCL rapidly detects and limit surges at high power levels
- FCL transformer being constructed in a \$21.2M Smart Grid program Waukesha Electric Systems, SuperPower, University of Houston, Oak Ridge National Laboratory
- To be installed Southern California Edison grid by 2014



Initial Zenergy FCL Installation on SCE Grid



FCL Function Demonstrated in SuperPower Test Module

## Superconducting generators offer benefits for wind energy production

- High power generators under development for wind turbines and off-shore power production.
  - More economical
  - Fewer generators to maintain for same power generation
  - Superconducting generators can mitigate voltage fluctuation → enhance power system stability, larger reactive power output capacity<sup>1</sup>
- Cooling of superconductors consumes 1% of produced power
- Superconductors can be used in auxiliary systems such as Superconducting Magnetic Energy Storage (SMES) for smoothing wind generator output<sup>2</sup>

Superconducting generators can be beneficial in high power wind turbines

- Reduce generator weight & volume by 50% or more (above 5 MW, conventional generators are too heavy)
- More efficient
- Direct drive without gearbox possible.
- No Rare Earth magnet limitations



<sup>1</sup> Sakamoto et al. 15th PSCC, Liege, 22-26 August 2005

<sup>2</sup> Takahashi et al.  
DOI 10.1109/ICEMS.2007.4412245

## Launch of superconducting devices in energy applications has fueled growth of 2G HTS demands

- After 20+ years since its discovery, HTS is now inserted in devices in electric power devices and in other industrial devices
- Rapid growth of HTS market projected as wire cost is reduced and price : performance continues to improve
- The 2G HTS community is rapidly scaling capacity to meet the increasing demands for conductor



## For more information contact

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