# Superconductivity as an Energy Carrier

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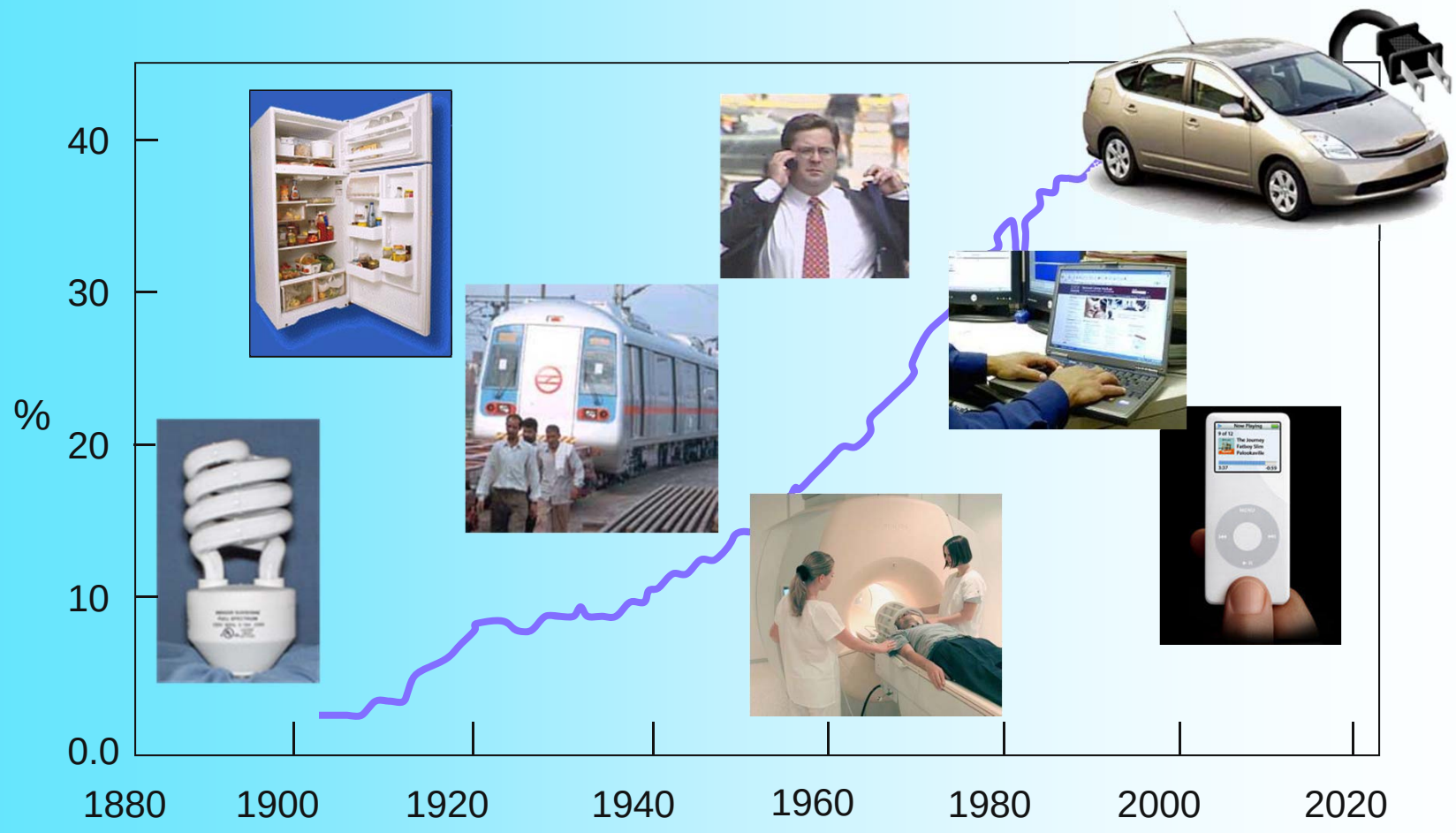
Argonne National Laboratory

University of Illinois at Chicago

*Boosting Urban Electricity*
*Public Panel Discussion*
*Chicago, IL. August 1, 2011*

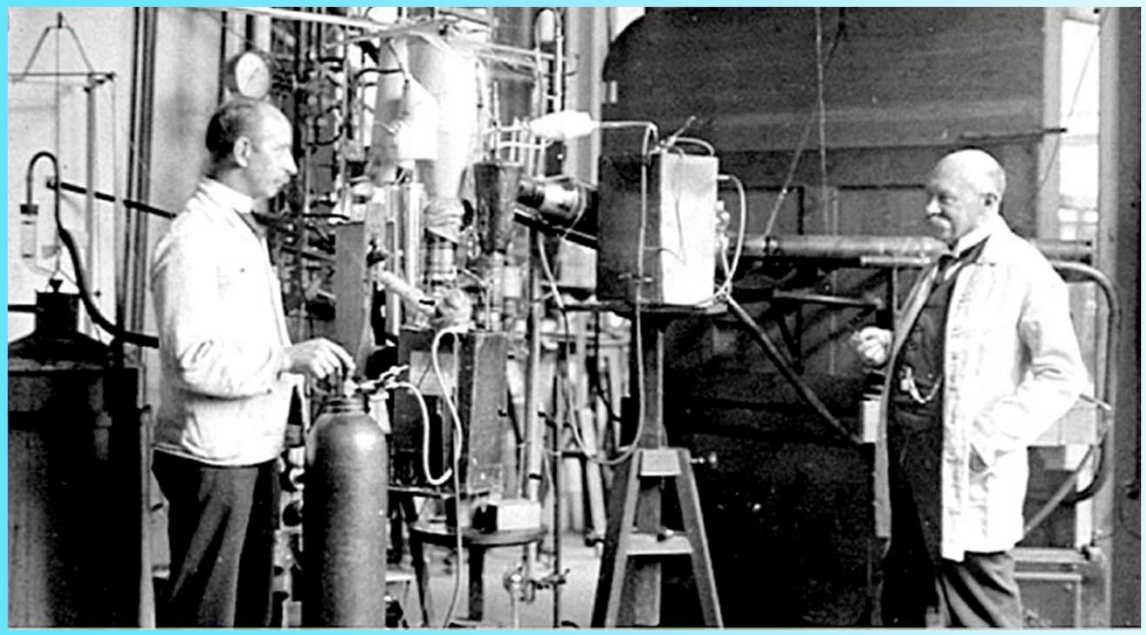
# *The Great Enabler*

40% of US primary energy devoted to electricity production

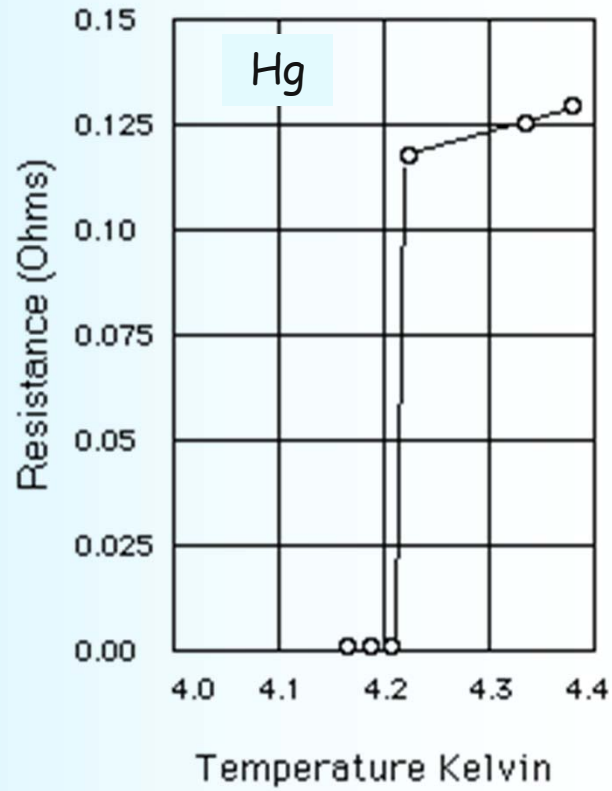



source: EPRI

# 100 Years of Superconductivity

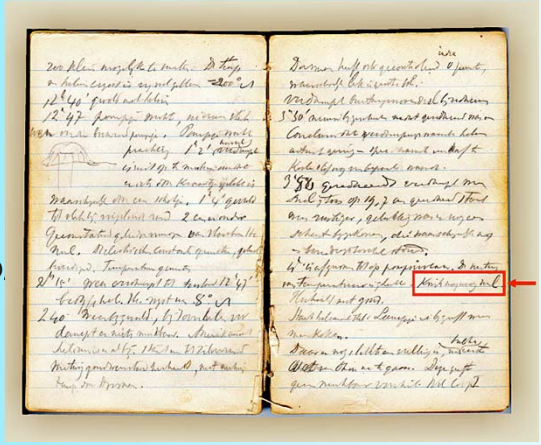


Kamerlingh Onnes
Leiden, The Netherlands
April 8, 1911

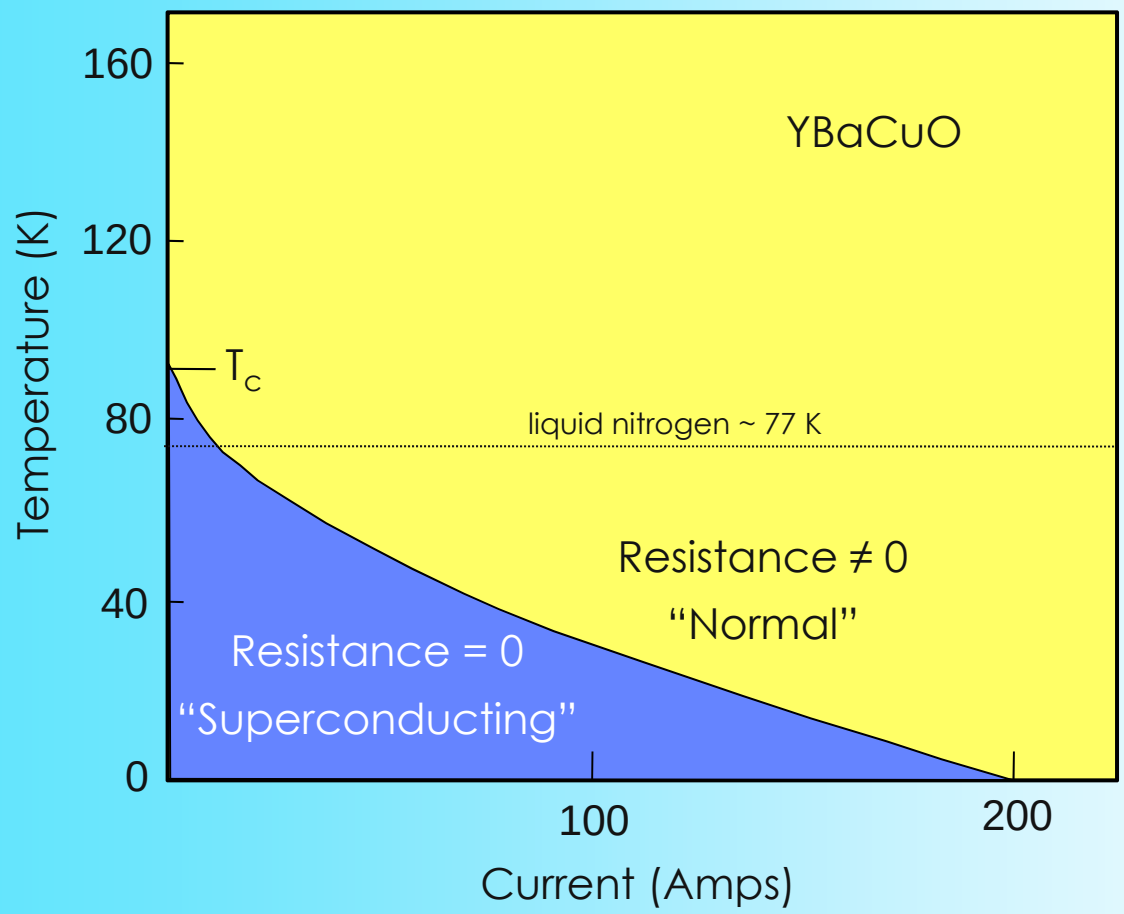



The Discovery of Superconductivity
Dirk van Delft and Peter Kes,
Physics Today 63(8), 38 (2010)

http://ptonline.aip.org/dbt/dbt.jsp?KEY=PHTO
D&Volume=63&Issue=9&usertype=indiv



# What is Superconductivity?




Key points

Maximum current at zero resistance (= critical current)

Critical current is only ~20% of theoretical value
→ "glass ceiling"

Critical current depends on density and nature of defects

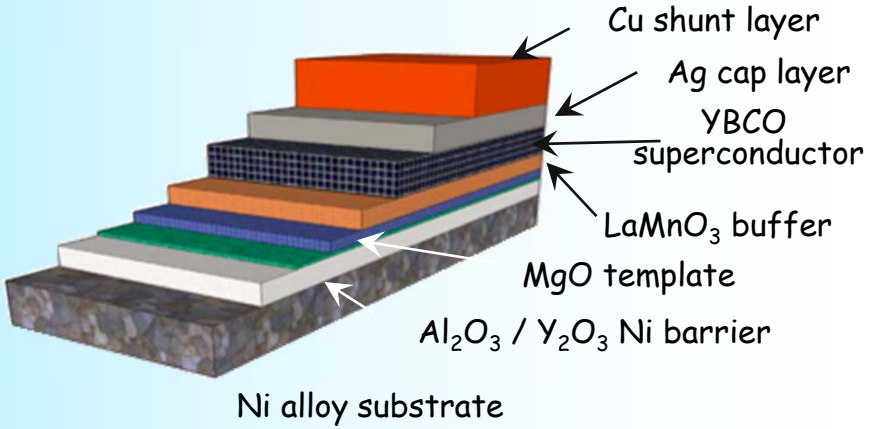
Superconductor must be kept cold

e.g., immersed in liquid nitrogen ~ 77 K

(room temperature ~ 300 K)

# Superconducting Cable Installed in the Grid

Long Island
2008
574 MW 138 kV




High current density

→ up to five times the power of conventional copper cables

# *Adding Renewable Electricity Generation*

Coal
48% of electricity
34% of CO2 emissions
Hg, $SO_x$, $NO_x$

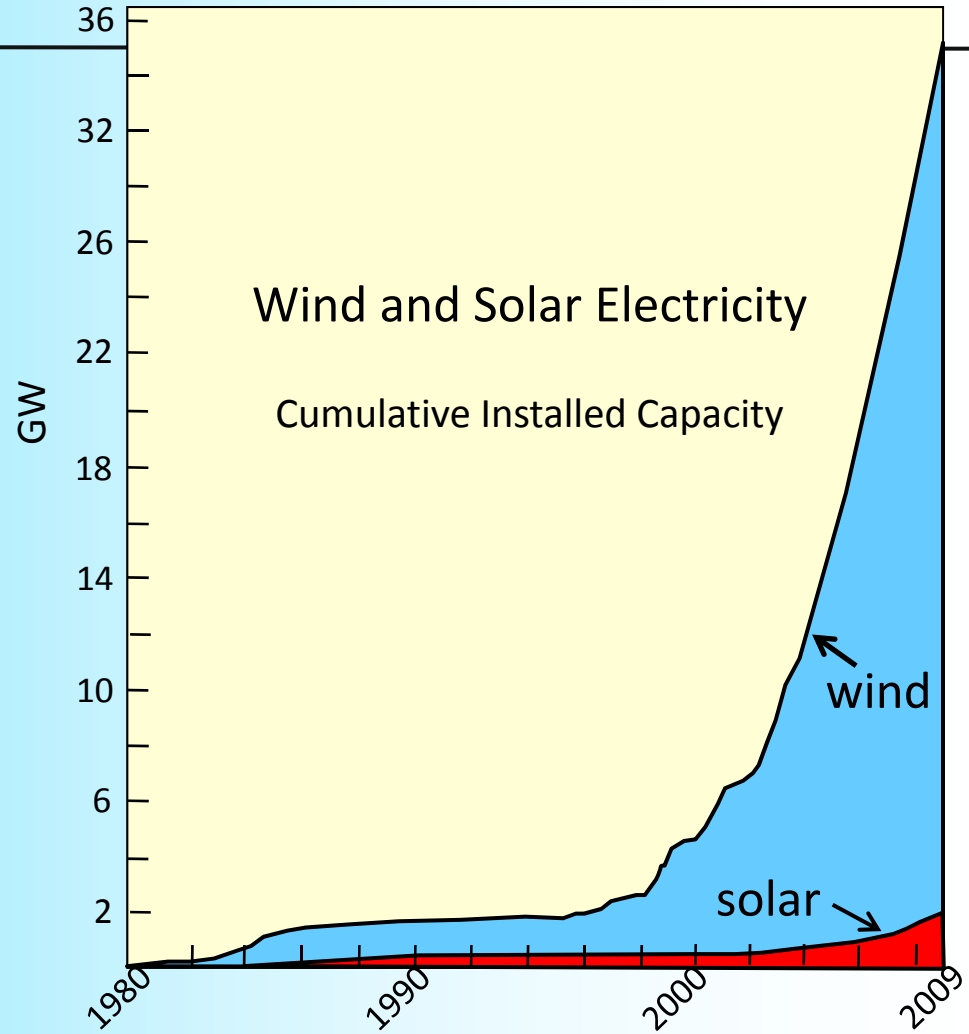
# Installed Wind and Solar Capacity

| Wind Farm | Installed capacity( MW) | State |
|---|---|---|
| Altamont Pass | 576 | California |
| Capricorn Ridge | 662 | Texas |
| Fowler Ridge | 750 | Indiana |
| Horse Hollow | 736 | Texas |
| Roscoe Wind Farm | 781 | Texas |
| San Gorgonio Pass | 619 | California |
| Sweetwater | 585 | Texas |
| Tehachapi Pass | 690 | California |

Largest Solar Thermal Electric Plant
SEGS Mojave Desert (CA) 354 MW

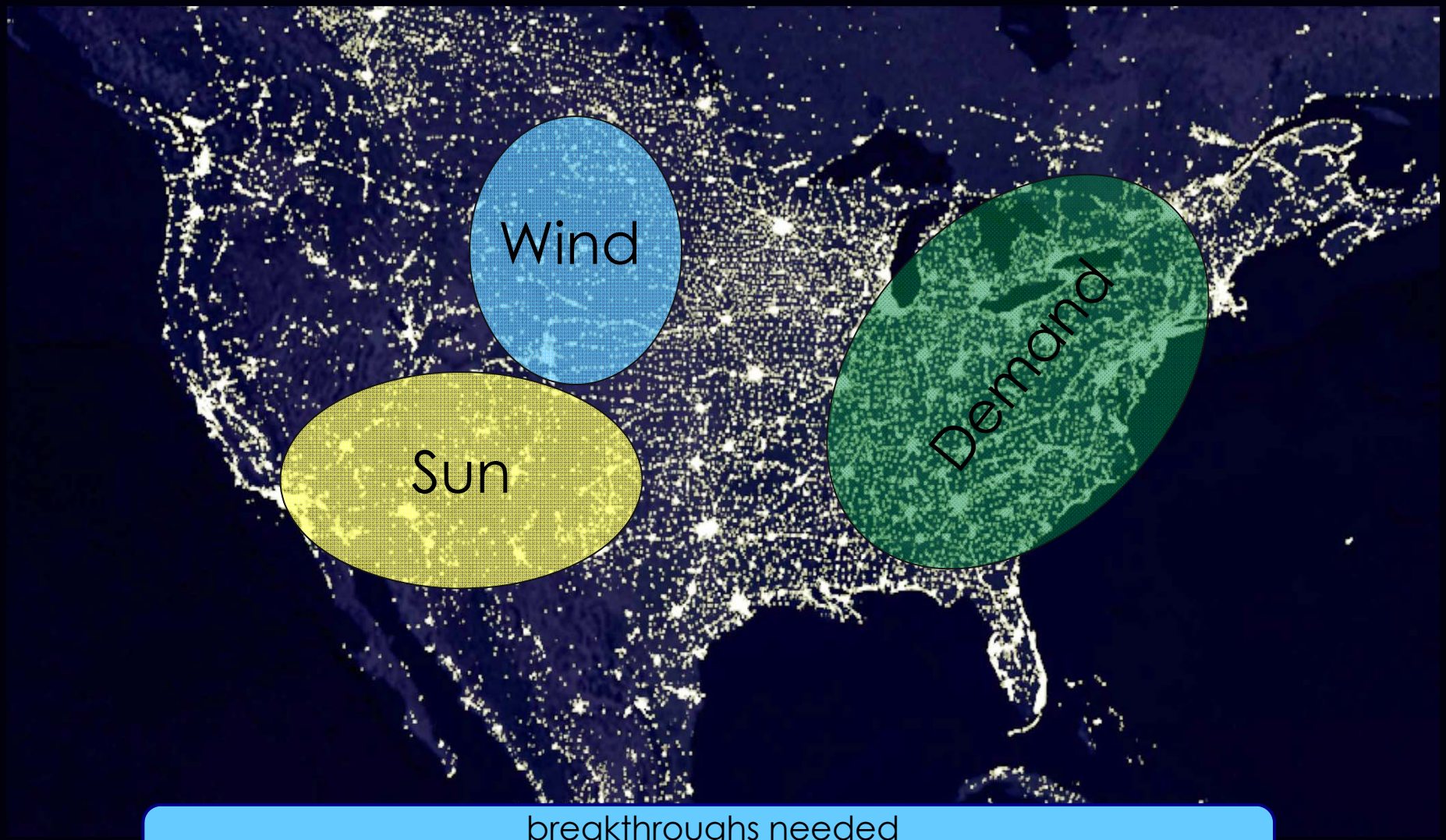
Ivanpah Mojave Desert (CA) 400 MW
(under construction)
Todd Woody, NYT 10-28-10

Largest PV Electric Plants
DeSoto (FL) 25 MW
Sarni (Canada) 80MW
Finsterwald (Germany) 80 MW




wind exceeds solar in installed capacity
solar poised for rapid growth

## *Making the Grid Ready for Renewables*




breakthroughs needed
long distance reliable, efficient delivery of electricity

# *Long Distance DC Superconducting Transmission*

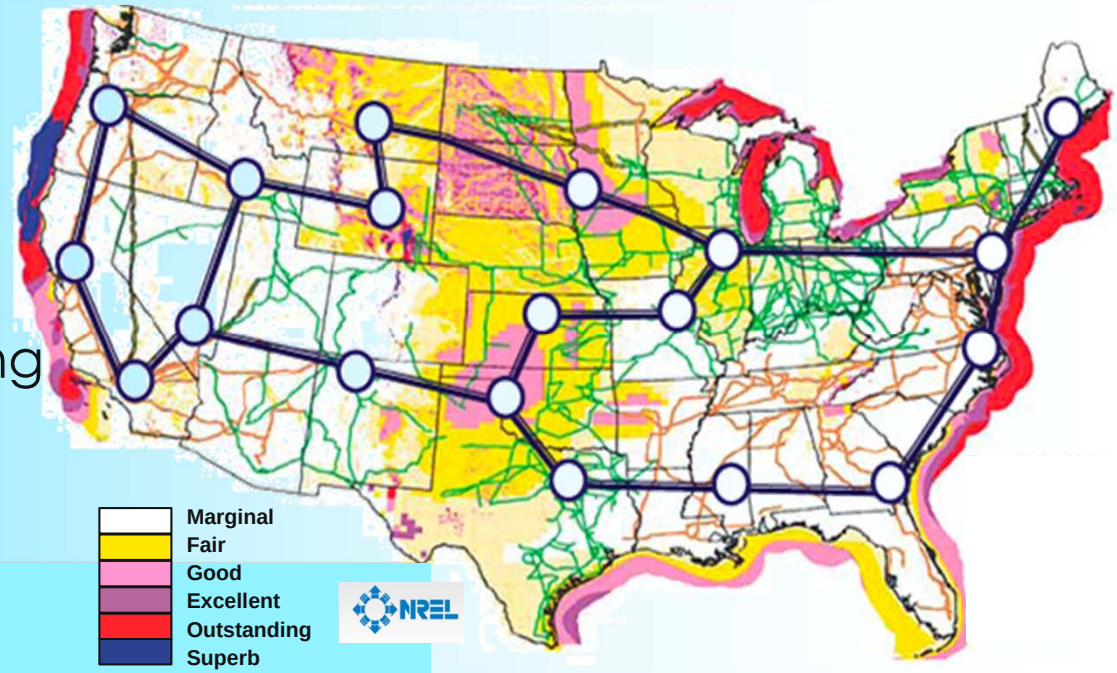
lower voltage: 200 kV vs 765 kV

multi-terminal topology

reduced right of way:
25 ft vs 600 ft

no AC losses: reduced cooling

An Interstate Highway System
for Electricity




*Superconductor Electricity Pipeline*
*AC/DC Converter Stations*

*American Superconductor*

Superconductor Electricity Pipelines

a White Paper
May 2009

http://www.amsc.com/products/applications/utilities/superconductorpipeline.html

# Offshore Wind - 50% More Power/Area

Source: http://webberenergyblog.wordpress.com/2010/02/13/offshore-wind-energy-cape-wind-vs-visual-impacts/

*Technical Challenges*

Construction

Anchoring

Salt water corrosion

Maintenance

*Societal Challenge*

Aesthetics

*Superconducting Wind Turbines*

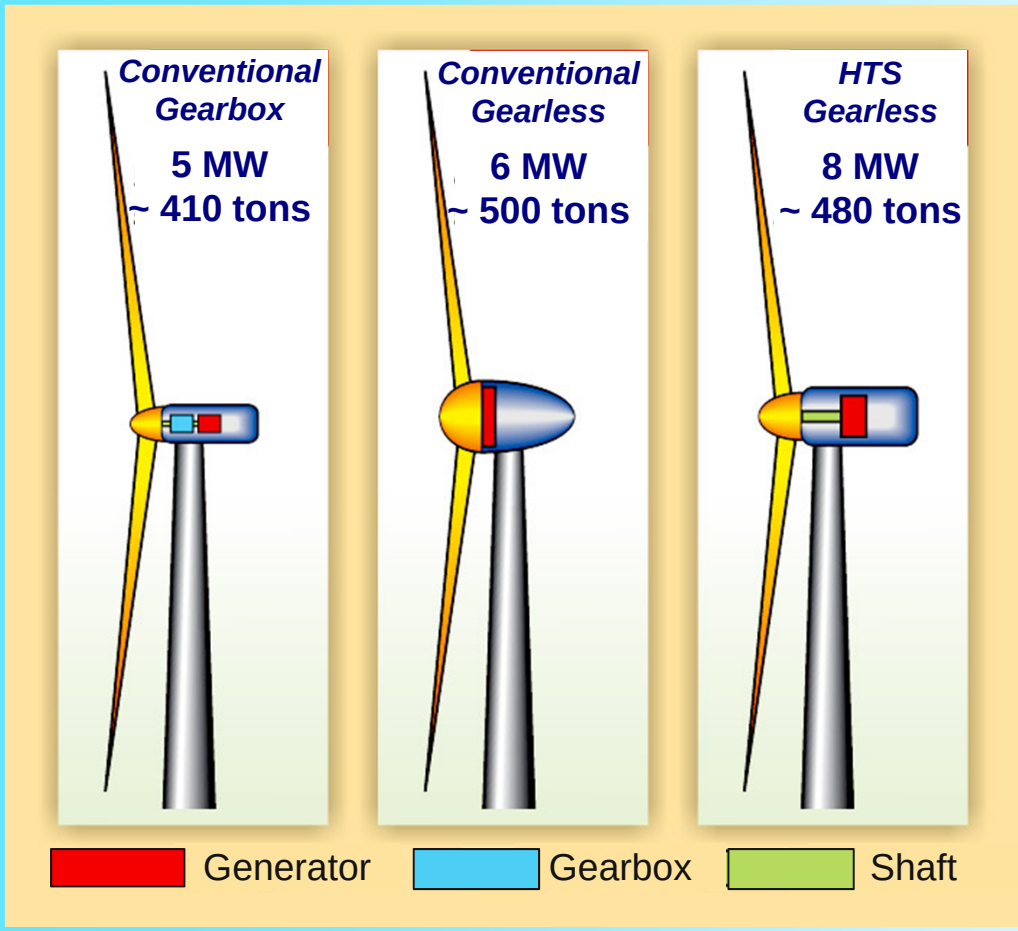
Direct drive – eliminates high maintenance gear box

Twice the capacity/weight – fewer towers, less maintenance

Close to shore/population centers

– reduced long distance transmission

# Superconducting Wind Generation




Matthews, Physics Today **62**(4), 25 (April 2009)

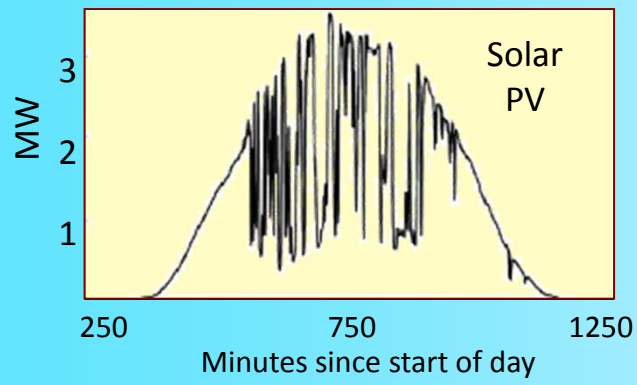
Wind turbine output limited by weight supported on the tower

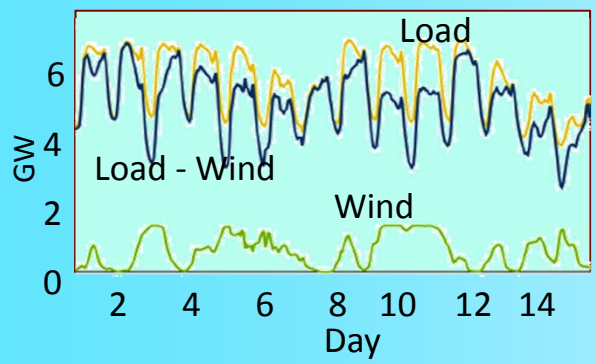
Superconducting generators: half the size and weight

→ twice the output per tower, half the number of towers

# Superconducting Magnetic Energy Storage

Renewable Variability



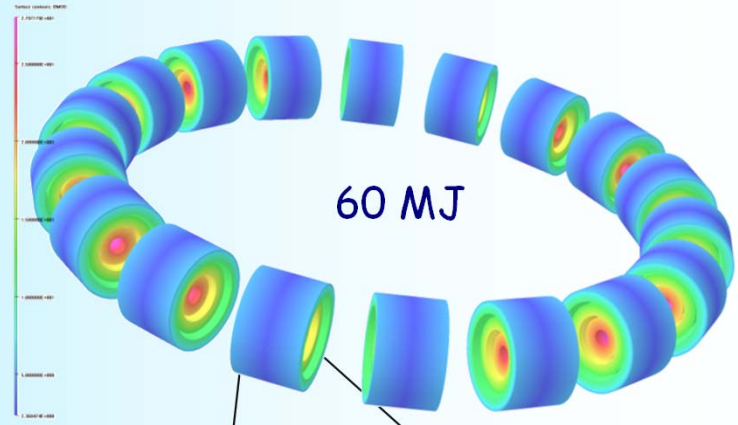



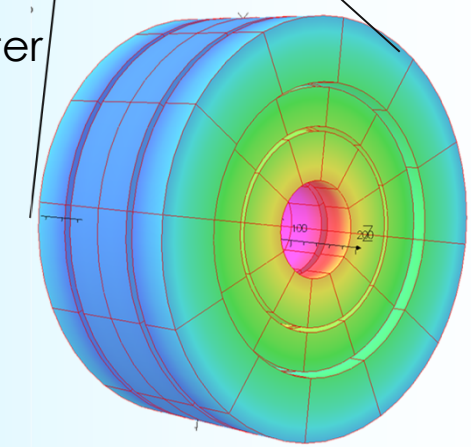

BNL-SuperPower
Modular SMES

ARPA-E funding

2.5 MJ modules at 25 T

60 MJ torus ~ meter diameter



2.5 MJ

PV and SMES are DC
no AC-DC conversion

SMES

Store energy in magnetic field ~ $H^2$

High field reduces size and cost

# *Perspective*

Electricity grid challenges

- Higher capacity for growth in urban areas

Renewable electricity challenges

- Long distance transmission from remote sources
- Storage to mitigate variability
- Higher capacity offshore wind turbines

Superconductivity meets the challenges

- High power DC transmission
- High efficiency, fast response storage
- High capacity/low weight wind turbines