



The 11th International Conference on
Materials & Mechanisms of Superconductivity
CICG Geneva, Switzerland – August 23 - August 28, 2015

“Whither Superconductivity for Electric Power?”

Paul Michael Grant

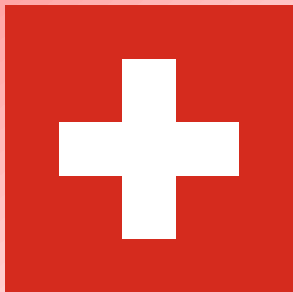
EPRI Science Fellow (Retired)

IBM Research Staff Member/Manager Emeritus

(etc, etc...& so forth and so on)

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Aging IBM Pensioner

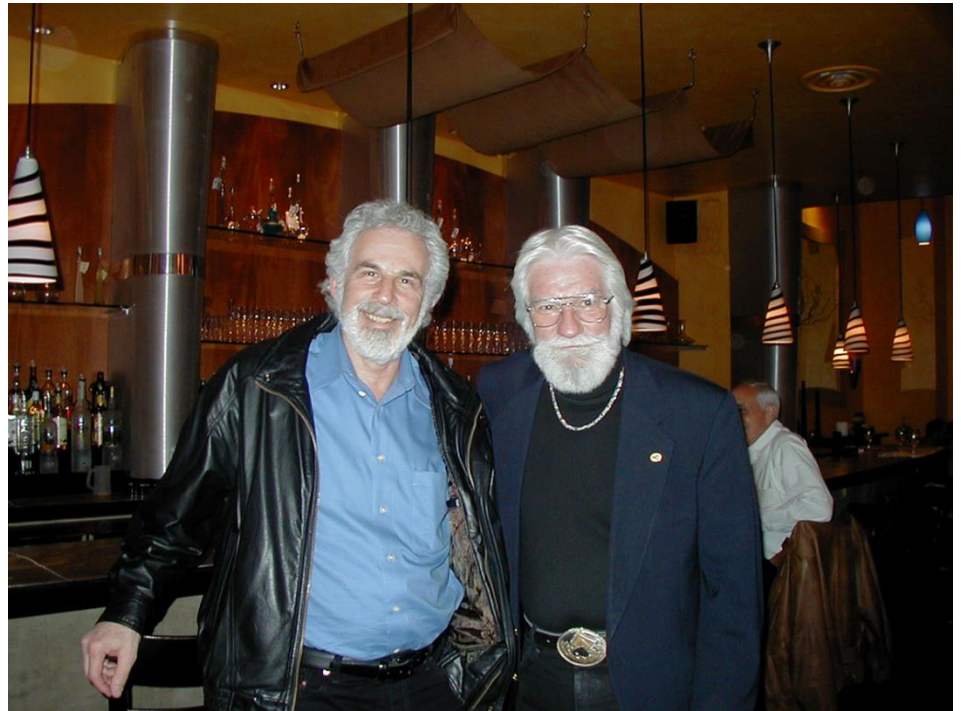


15:55-16:20 Th-S48 Room 3 Thursday 27 August 2015

Memories... (I think...)



M2S Interlaken '88 – Tc 125 K TI-2223



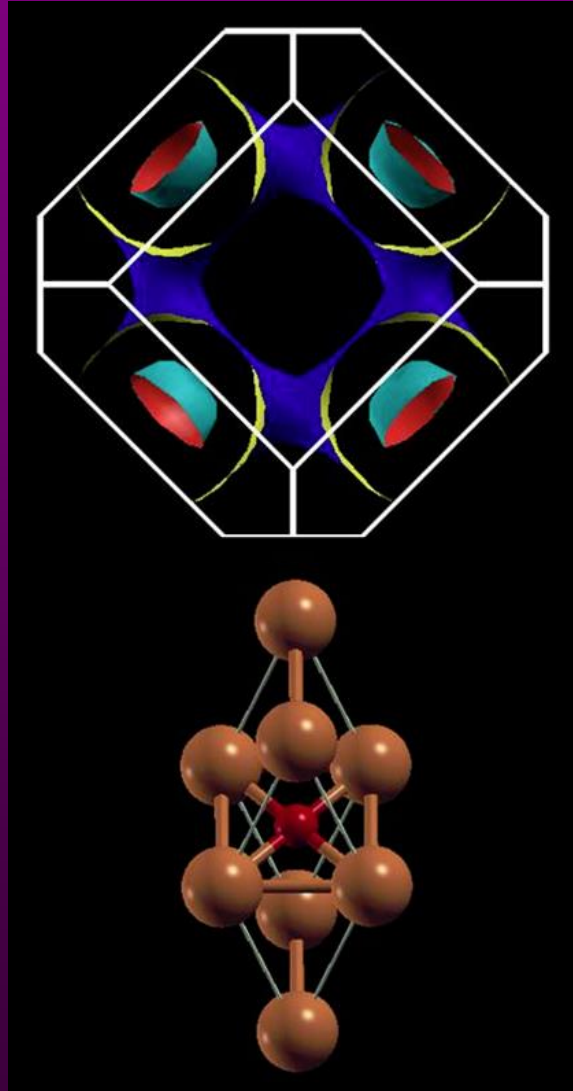
“Missing in Action”

“Fall Out” from M2S Interlaken 1988





The Holy Grail of HTSC

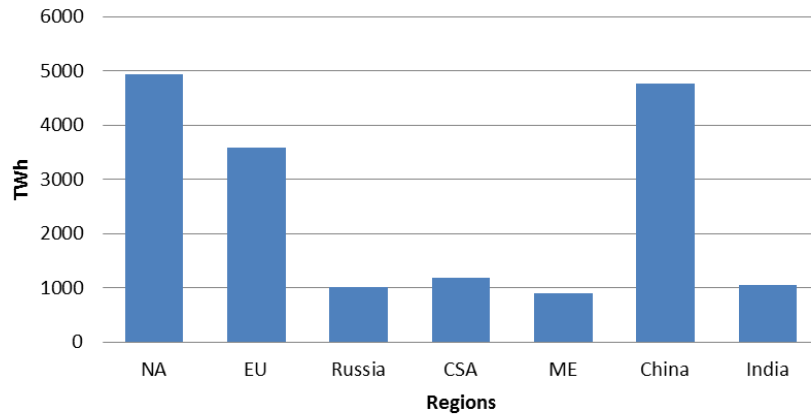


"The Short Story"

- Following the 1911 discovery, Kamerlingh Onnes attempted the construction of an electromagnet...unsuccessfully.
- Throughout the second half of the 20th Century and up to the present, many successful demonstrations of superconducting cables, transformers, current limiters, storage units, rotating machinery, etc., have been carried out. Yet, to date, no significant markets ($> 10^8$ USD/yr) have emerged for deployment worldwide in the Electricity Enterprise.
 - For a 1997 review, see *"Superconductivity and Electric Power: Promises, Promises...Past, Present and Future,"* P. M. Grant, IEEE Trans. Appl. Supercon. 7, 112 (1997). Available [on request](#) from www.w2agz.com.
 - Today, the principal "power" applications of superconductivity remain cabling and deflection magnets for hadron colliders and solenoids for medical MRI.
- What might constitute a "Longer Story?"
 - Advancing a current "technology addiction."
 - Satisfying a compelling social need.
 - Identifying a new opportunity.

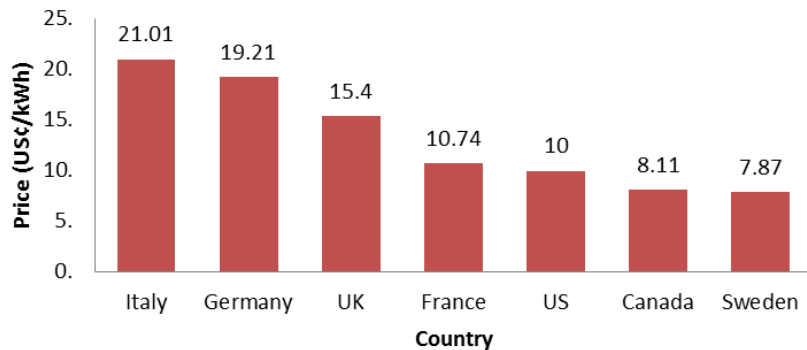
Electricity is Plentiful ...and Cheap!

Annual Regional Electricity Generation (TWh)



Region	Twh	% World
NA	4943.711	23%
EU	3581.738	17%
Russia	1012.476	5%
CSA	1177	5%
ME	906.9815	4%
China	4768.317	22%
India	1052.499	5%

**Electricity Prices (US¢/kWh)
By Country (2014)**



Country	US¢/kWh
Italy	21.01
Germany	19.21
UK	15.4
France	10.74
US	10
Canada	8.11
Sweden	7.87

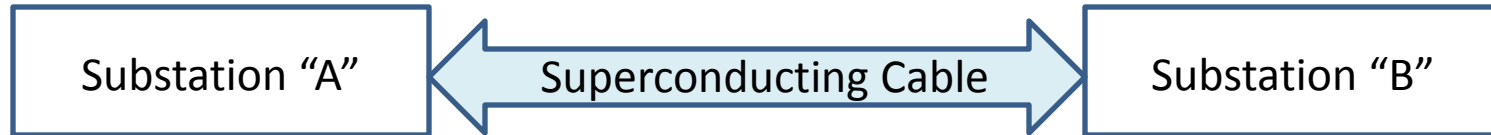
"New Opportunities"

- The IFCL-HTS "Project Hydra" or "AmpaCity;" the AMSC/DHS, Nexans/RWE concepts.
- Dual Use of emerging energy/power transport corridors.

IFCL-HTS

“I” = “inherently”

What is it?



A Transient Model of High-Temperature Superconducting Cables in Electric Power Supply

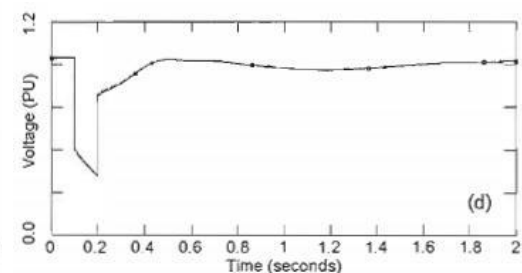
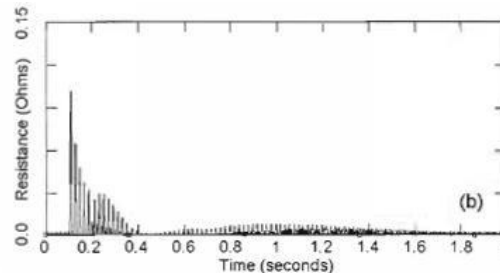
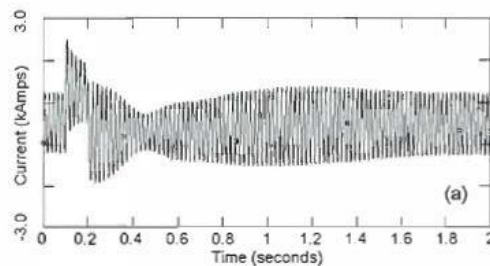
Kim Hoj Jensen and Vladislav Akhmatov

(Tech. U. Denmark, 2005?)

$$\rho_{HTS} = \rho_C \left(\frac{I(t)}{I_C} \right)^{n-1} \left(\frac{T_C - T_0}{T_C - T(t)} \right)^n \quad \rho_{HTS} = \alpha T(t) + \beta \quad \rho_T = \left(\frac{1}{1+r} \rho_{HTS}^{-1} + \frac{r}{1+r} \rho_M^{-1} \right)^{-1} \quad R(t) = \frac{l}{aN} \rho_T(t)$$

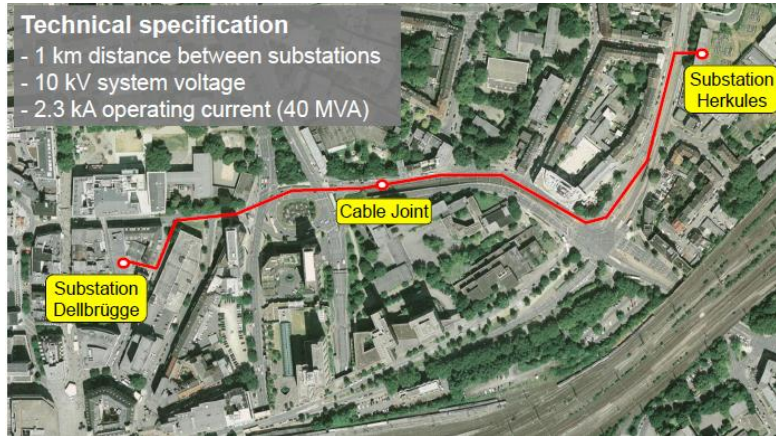
$$L \frac{dI(t)}{dt} = -R(t)I(t) - \Delta U(t)$$

$$C_P \frac{dT(t)}{dt} = P(t) - h(\Delta T)A\Delta T(t)$$



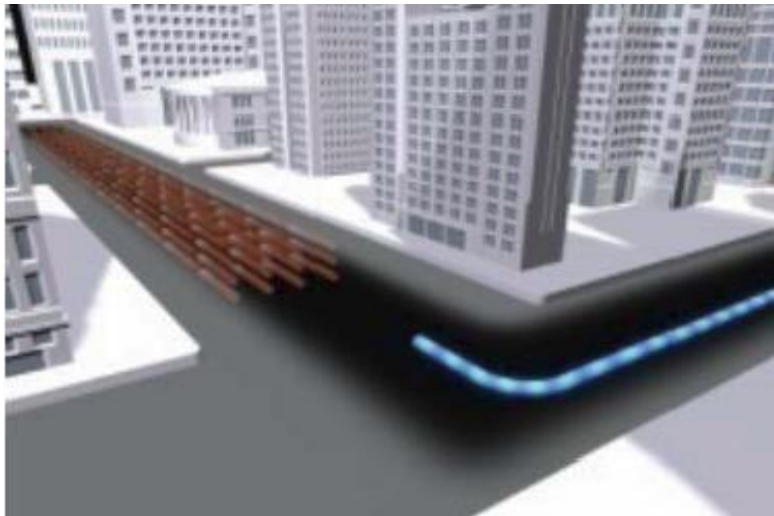
IFCL-HTS “Implementations”

AmpaCity – Essen (RWE, Nexans, KIT,...)



- Pilot operation in progress
- Funding: 13.5 M Euros
 - Nexans 36%
 - RWE 33%
 - BMWi 25%
 - KIT 6%
- Next...Muelheim (2020) ?

Project Hydra – (AMSC, ConEd, DHS,...)



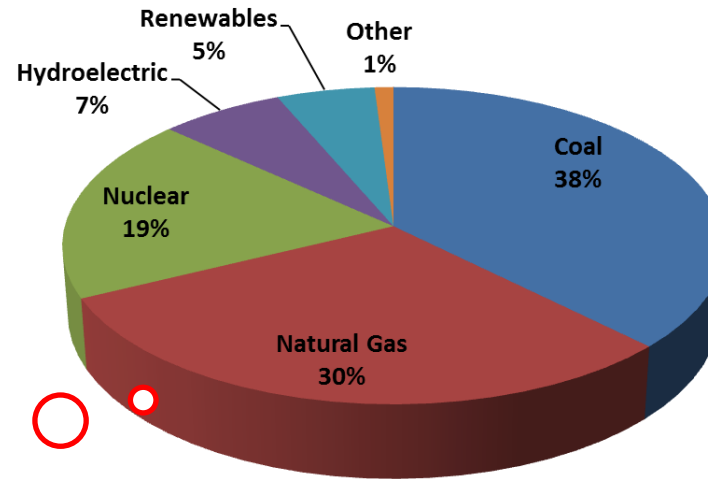
- First proposed in 2007 by DHS
- Funded by DHS at 30 M USD
- Contracted with AMSC & ConEd for installation in mid-Manhattan
- Put on hold in 2011
- Project moved to two adjacent substations in Yonkers
- Cable conductor now sits on site
- Future “uncertain”

DHS “Resilient Electric Grid” (2015)

- Objective: Protection of the US Grid against:
 - Natural Disasters
 - *e.g. “SuperStorm Sandy”*
 - “Unnatural” Disasters
 - *1960-70 attacks on California & Oregon substations by the SLA and environmental extremists*
 - *Most recent 2013 attack on PGE Metcalf transmission substation in San Jose*
- “Due Diligence” Study Underway
 - Objective: Assess the risk and readiness of the US (and some international) HTSC wire, cable, and cryogenic companies to undertake large scale production necessary to implement the REG
 - *e.g., would Gen I wire be sufficient, or is Gen II really needed, or both?*
 - DHS and EPRI have formed a 7 person team of “experts” to report their recommendations by 4Q15.
 - *Full Disclosure: I’m a member! Con Quidado!*

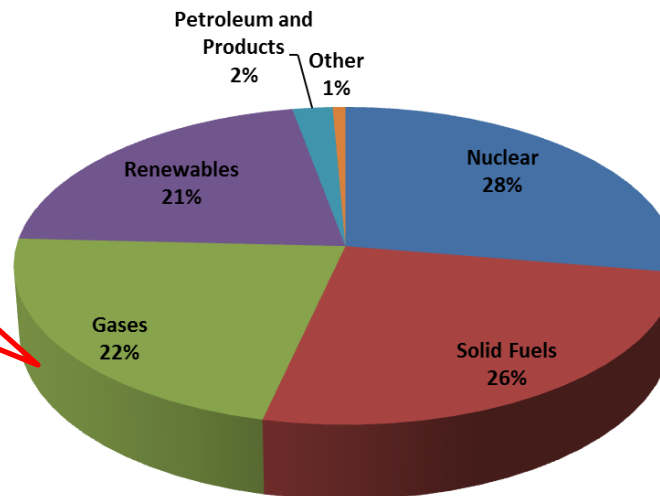
“Dual Use” of Energy Transport Corridors

Electricity Generation by Primary Fuel Source (2011-12)



USA

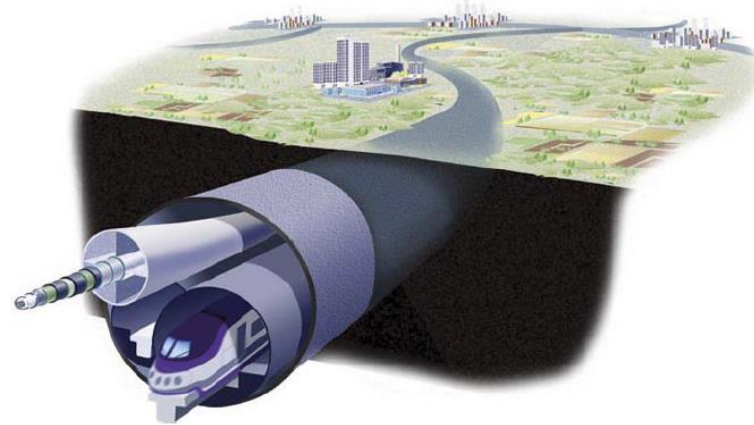
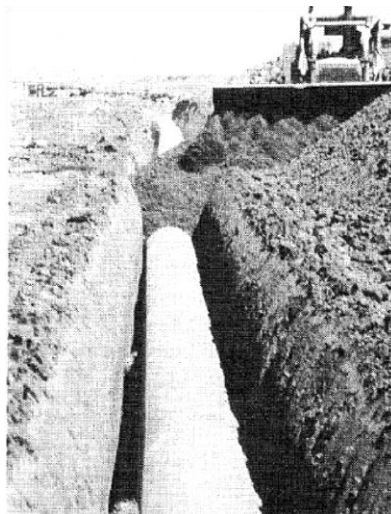
Wow!



Europe

The “Dual Use” Concept Embodied

- Almost all NG used for electricity generation is “combusted” at a “local” delivery point using modern, efficient, combined cycle gas turbine (CCGT) technology.
- Why not “combust” that gas portion so-used at the “well-head” instead and deliver the “electrons” over a low-loss HTSC dc cable? As well as reducing volume...and...frictional loss due to NG transported by pipeline.
- ...and...consider “recycling” well-head generated CO₂ emissions into alcohols...and “pipe” those down the same ROW!



The ROW Dual Use concept has been documented in several peer reviewed journals as well as member magazines of the APS, IOP, IEEE, and Nature...contact the author/speaker for a linkable anthology.

Opportunities to Exploit the Keystone XL Pipeline ROW for the Dual Transport of Chemical and Electrical Energy

North American shale plays
(as of May 2011)

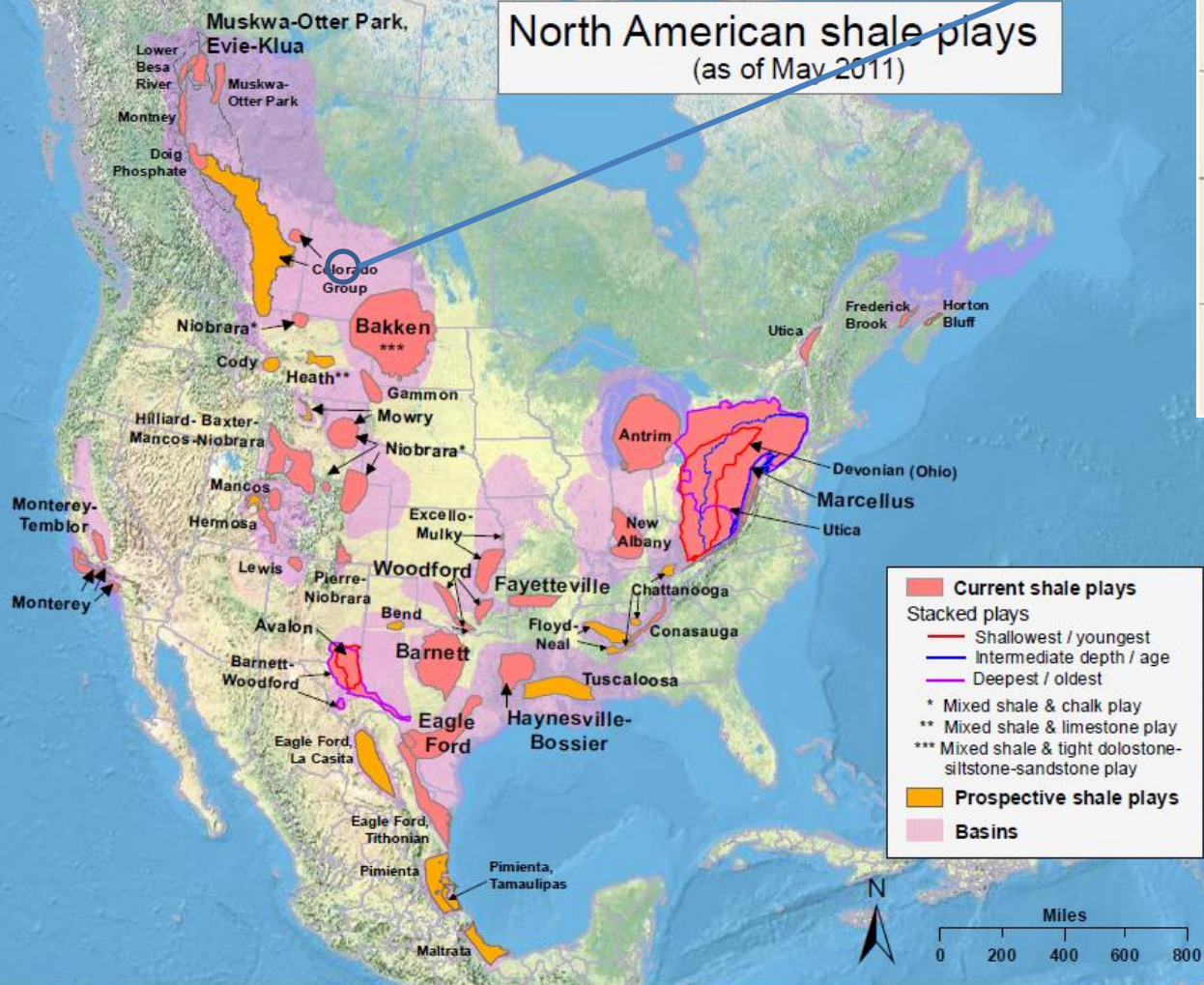


Smart Grid



Fraternal Twins

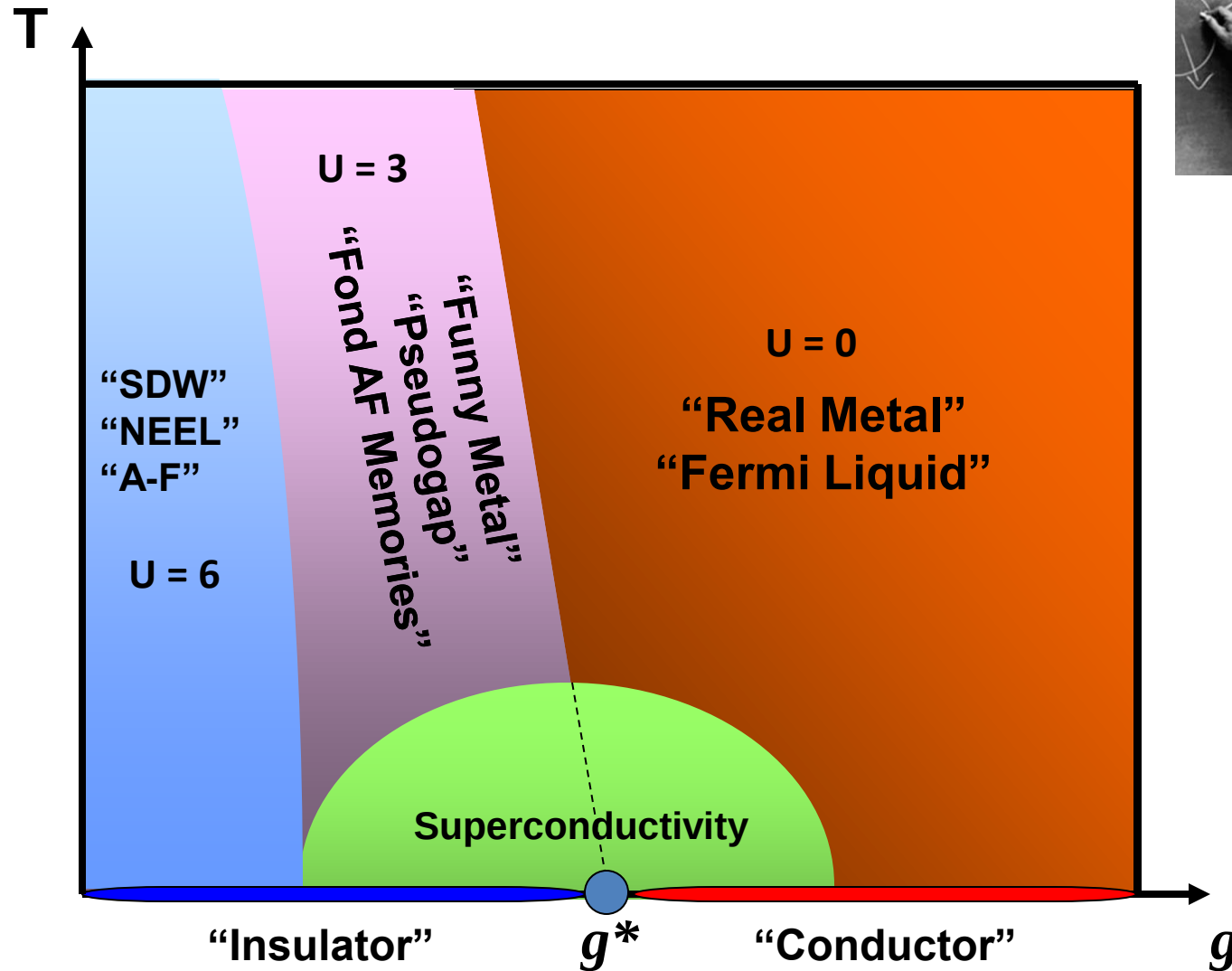
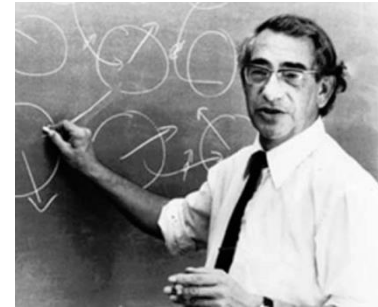
2013 P. M. Grant's
Editorial in Smart
Grid News



Now for 60 Seconds of Science

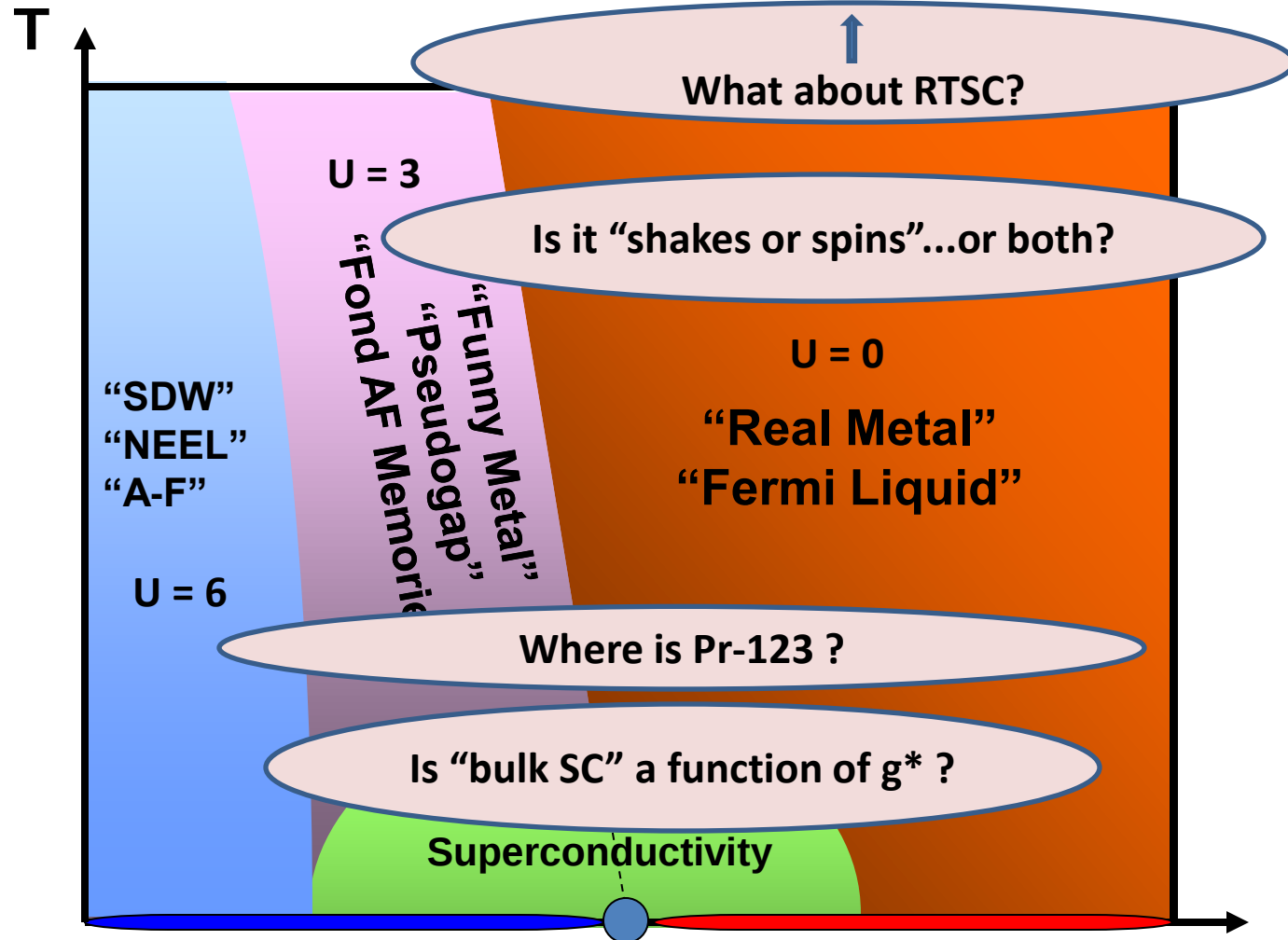
Five Cosmic Questions needing Cosmic Focus
on
Materials and Mechanisms of
Superconductivity

The Colossal Quantum Conundrum (According to John Hubbard)

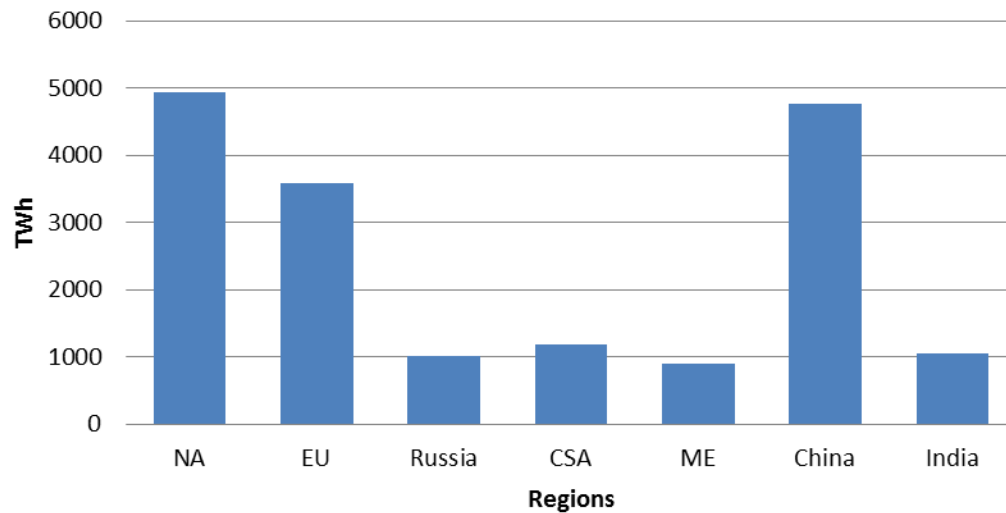


The Colossal Quantum Conundrum

-- HTSC/RTSC...Five Cosmic Questions --

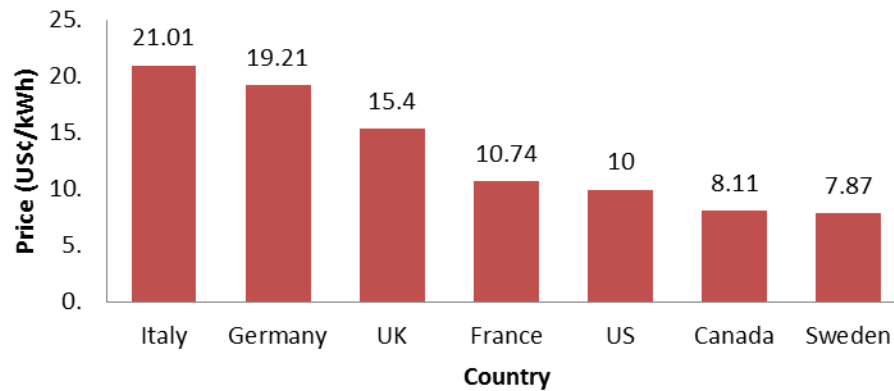


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