High-Capacity Superconducting dc Cables

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Basic Research Needs for Superconductivity
DOE Basic Energy Sciences Workshop on Superconductivity
Sheraton National Hotel, 900 W. Orme Street, Arlington, VA 22204
8-11 May 2006

http://www.w2agz.com/bes06.htm

Superconducting Lines for the Transmission of Large Amounts of Electrical Power over Great Distances

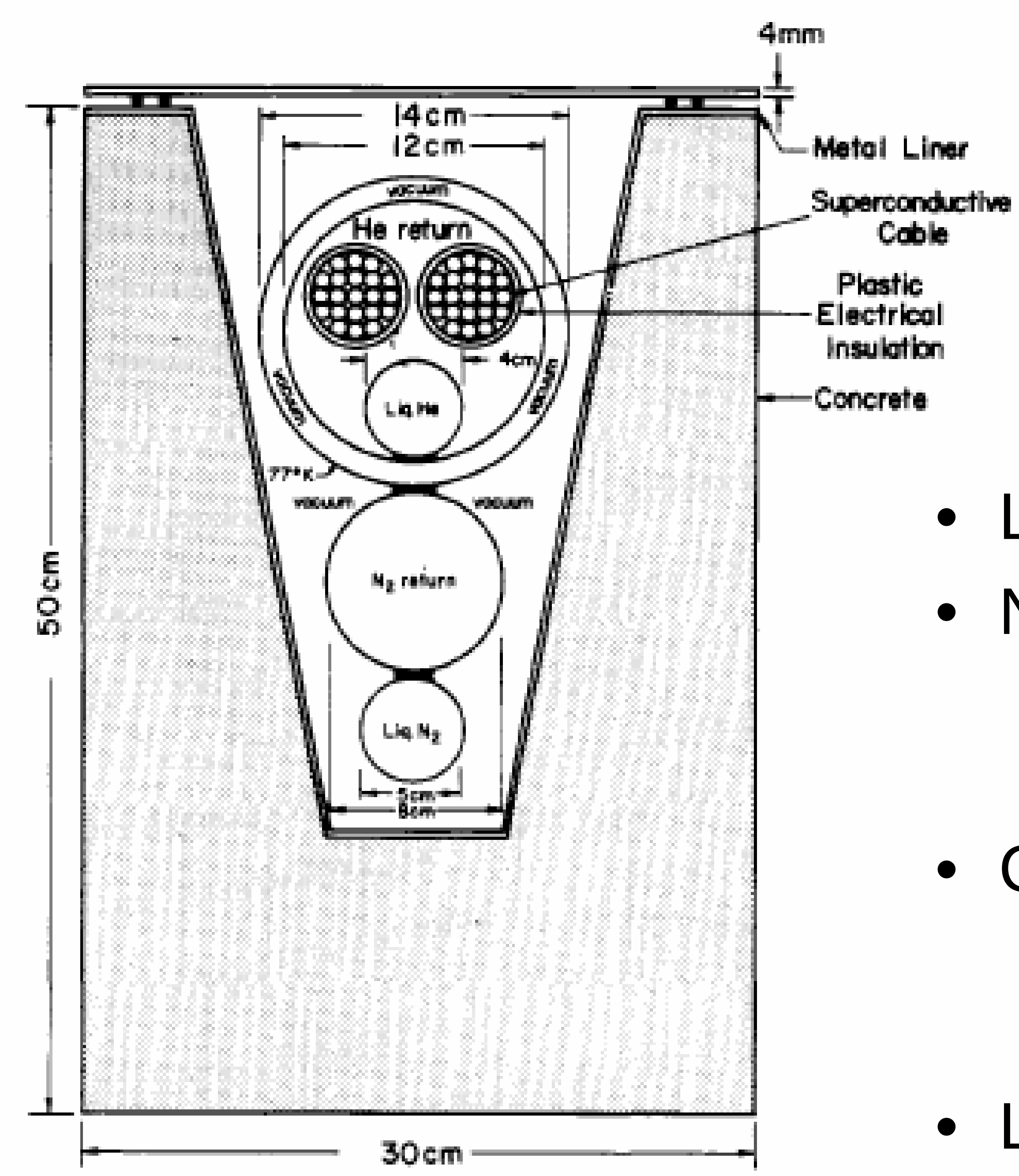
R. L. GARWIN AND J. MATISOO

Submitted 24 June 1966

PROCEEDINGS OF THE IEEE, VOL. 55, NO. 4, APRIL 1967

Rationale: Huge growth in generation and consumption in the 1950s; cost of transportation of coal; necessity to locate coal and nuke plants far from load centers.

Furthermore, the utilities have recently become aware of the advantages of power pooling. By tying together formerly independent power systems they can save in reserve capacity (particularly if the systems are in different regions of the country), because peak loads, for example, occur at different times of day, or in different seasons. To take advantage of these possible economies, facilities must exist for the transmission of very large blocks of electrical energy over long distances at reasonable cost.



Specs

- LHe cooled
- Nb_3Sn (T_C = 18 K)
  - J_C = 200 kA/cm^2
  - H* = 10 T
- Capacity = 100 GW
  - +/- 100 kV dc
  - 500 kA
- Length = 1000 km

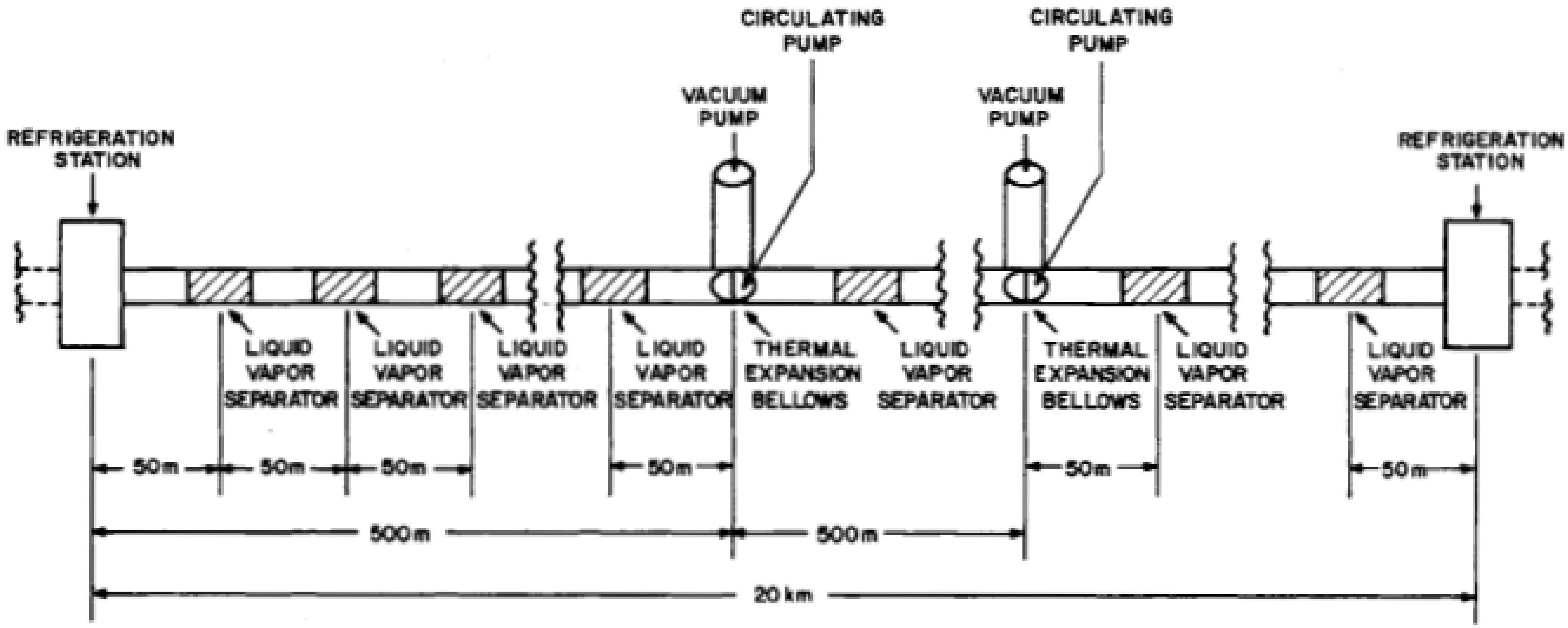
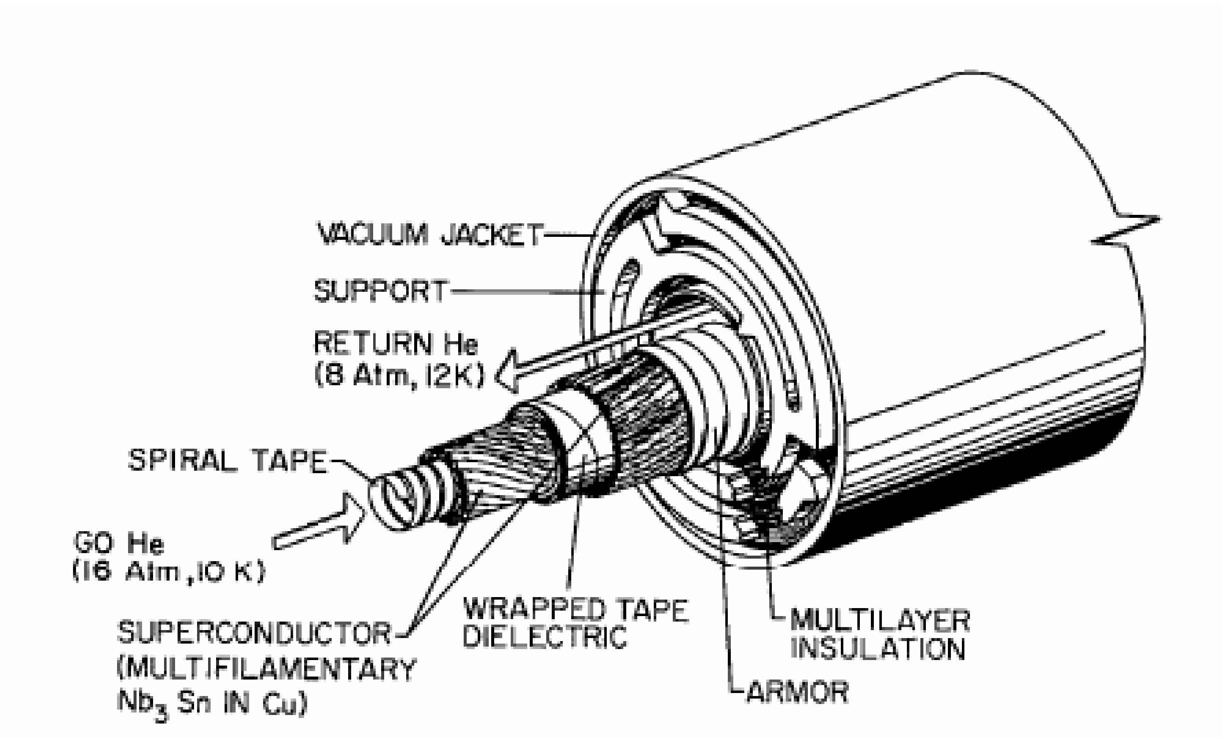


Fig. 2. A 20-km module of the 1000-km, 100-GW line.

- Refrigeration Spacing 20 km
- G-L Separator Distance 50 m
- Booster Pump Intervals 500 m
- Vacuum Pump Spacing 500 m
- Cost: $800 M ($8/kW) (1967)

$4.7 B Today!

LASL SPTL (1972-79)



Specifications

- 5 GW **(+/- 50 kV, 50 kA)**
- PECO Study **(100 km, 10 GW)**

Garwin-Matisoo Bottom Line

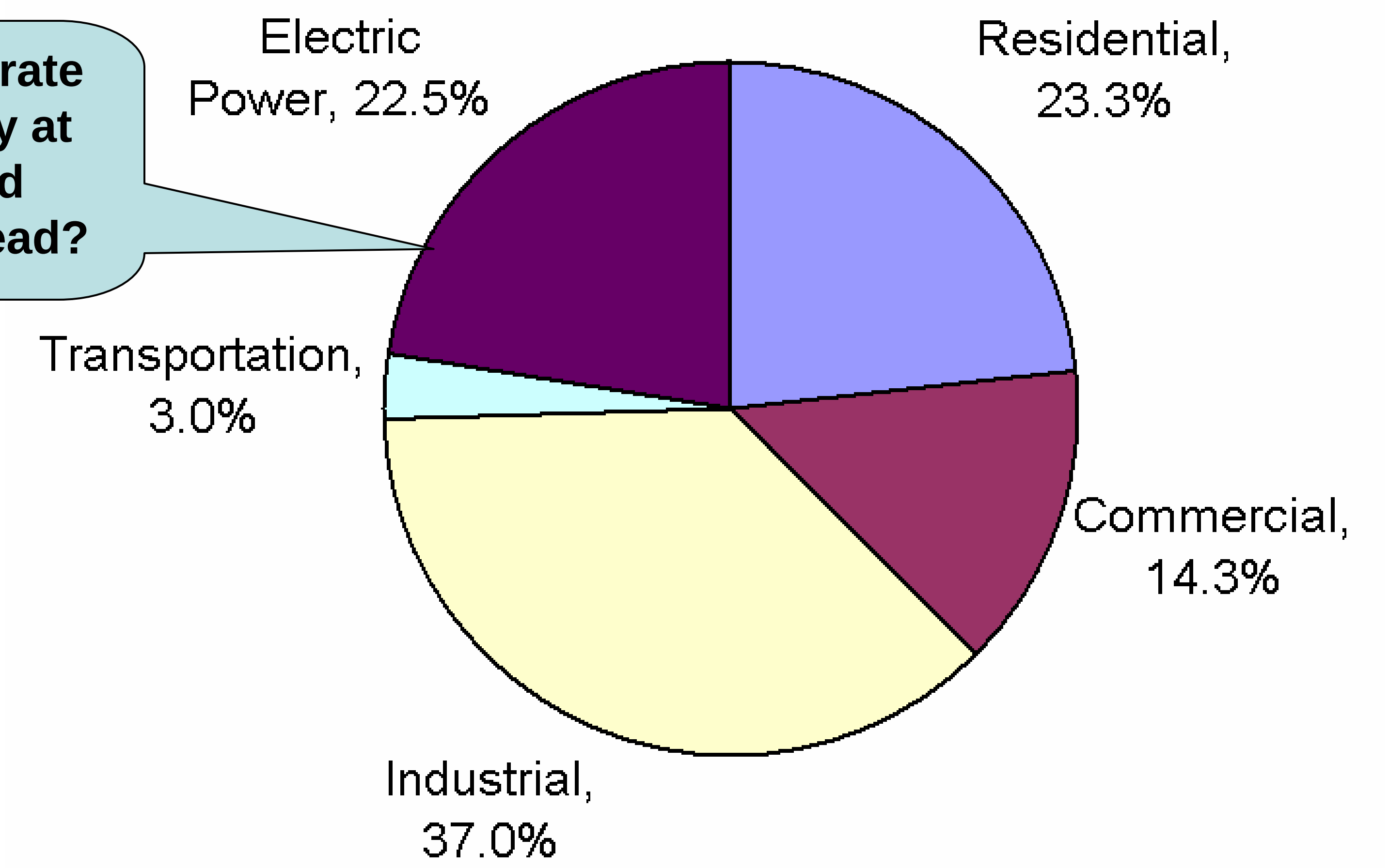
This is not an engineering study but rather a preliminary exploration of feasibility. Provided satisfactory superconducting cable of the nature described can be developed, the use of superconducting lines for power transmission appears feasible.

Whether it is necessary or desirable is another matter entirely!

2004 Natural Gas End Use

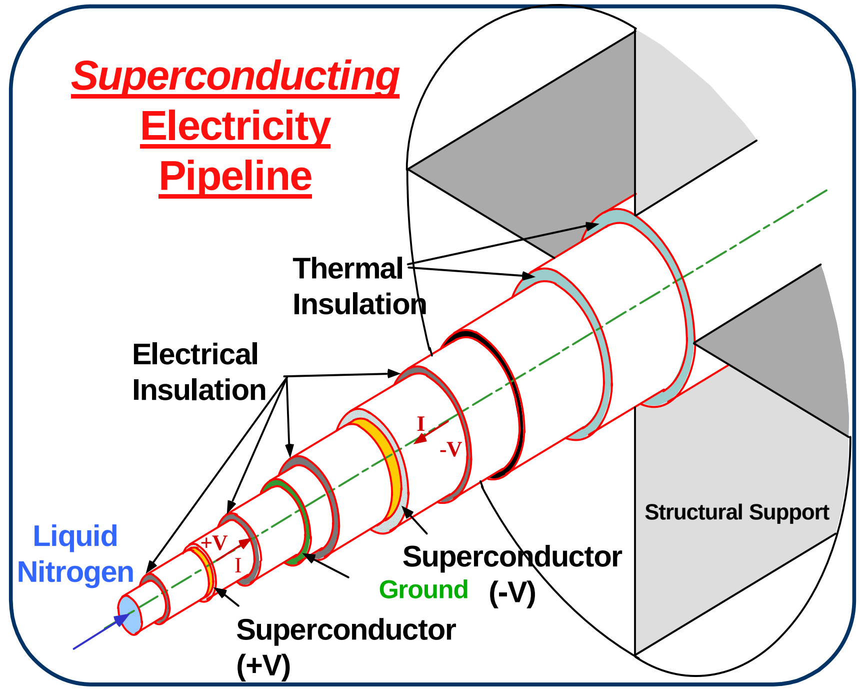
Schoenung, Hassenzahl and Grant, 1997
(5 GW on HTSC @ LN_2, 1000 km)

Why not generate this electricity at the gas field wellhead instead?



e-Pipe

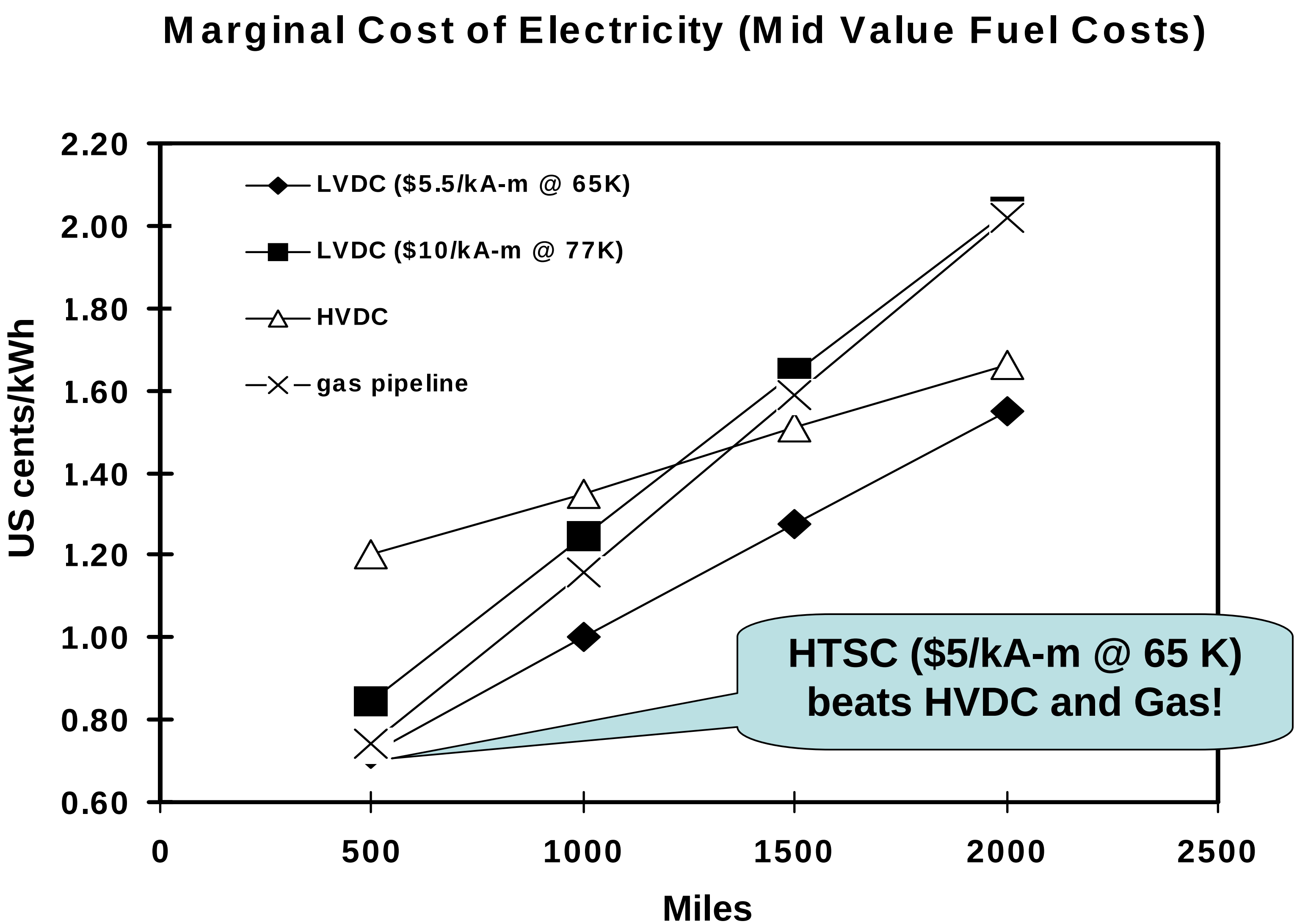

CYPRUS
Nicosia
Mediterranean Sea
Latakia
SYRIA
Hims
Beirut
LEBANON
Damascus
Golan Heights
Haifa
ISRAEL
Jerusalem
Gaza Strip
Amman
West Bank
JORDAN
Al Aqabah
Alexandria
Cairo
EGYPT
Luxor
Aswān
Tropic of Cancer
Administrative Boundary
Halā'ib
Yanbu al Bahr
Medina
Tabūk
Ha'il
SAUDI
ARABIA
Riyadh
Mosul
Karkūk
Tigris
Euphrates
Baghdad
IRAQ
Al Hillah
Al Kūt
An Nāṣirīyah
Al Baṣrah
KUWAIT
Kuwait
Hafar al Bāṭin
Dhahran
Manama
BAHRAIN
QATAR
Persian Gulf
Tehrān
Qom
Bākhtarān
Arak
Dezful
Ahvāz
Ābādān
Bandar-e Būshehr


Superconducting
Electricity
Pipeline
Thermal
Insulation
Electrical
Insulation
Liquid
Nitrogen
+V
I
-V
Superconductor
Ground
(-V)
Superconductor
(+V)
Structural Support

e-Pipe Specs (EPRI, 1997)

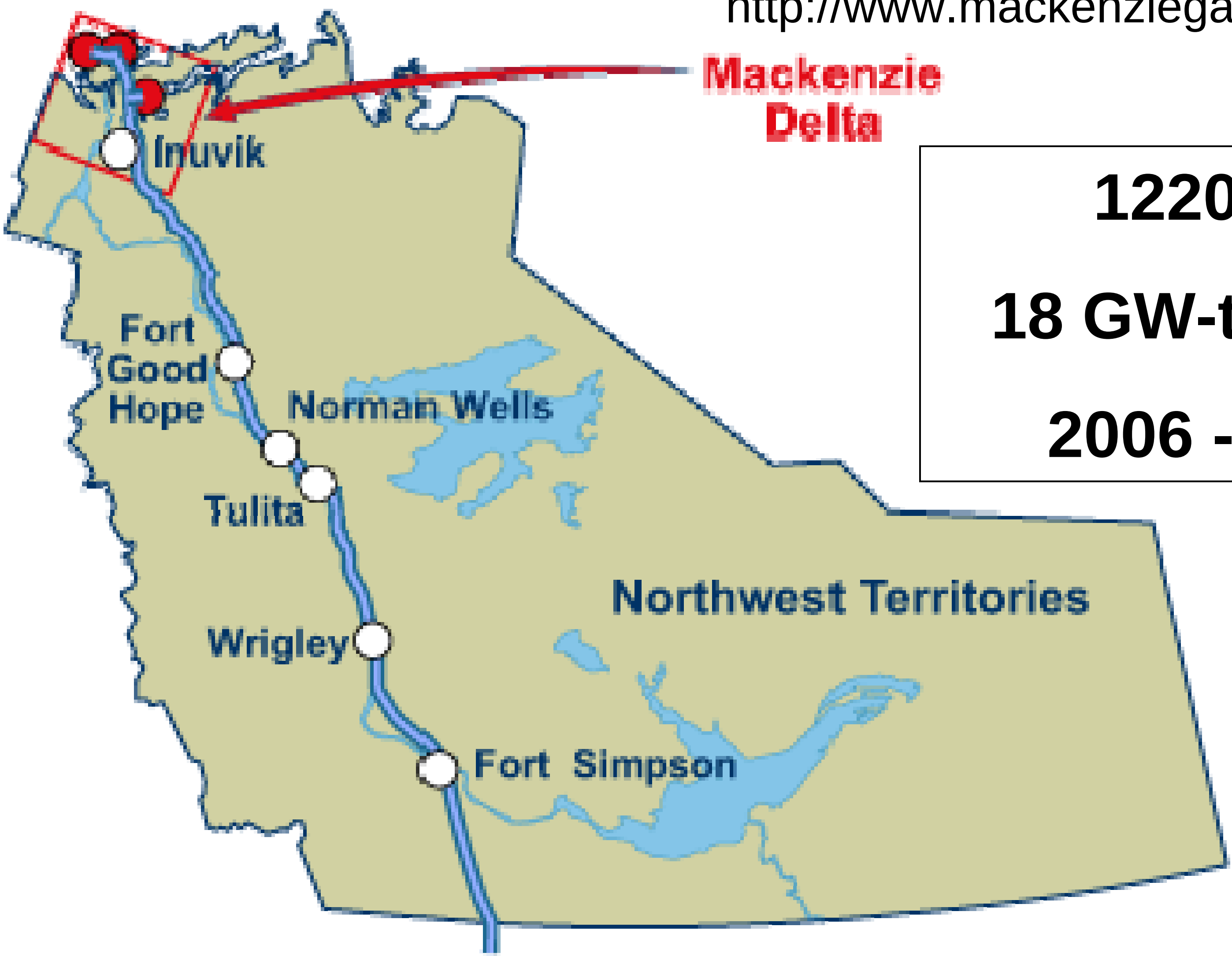
Capacity	5 GW (+/- 50 kV,50 kA)
Length	1610 km
Temperature Specs: - 1 K/10 km @ 65 K - 1 W/m heat input	- 21.6 kliters LN_2/hr - 100 kW coolers - 120 gal/min
Vacuum: - 10^{-5} – 10^{-4} torr	- 10 stations - 10 km spaced - 200 kW each

e-Pipe/Gas/HVDC Cost Comparison



The Mackenzie Valley Pipeline

http://www.mackenziegasproject.com



1220 km

18 GW-thermal

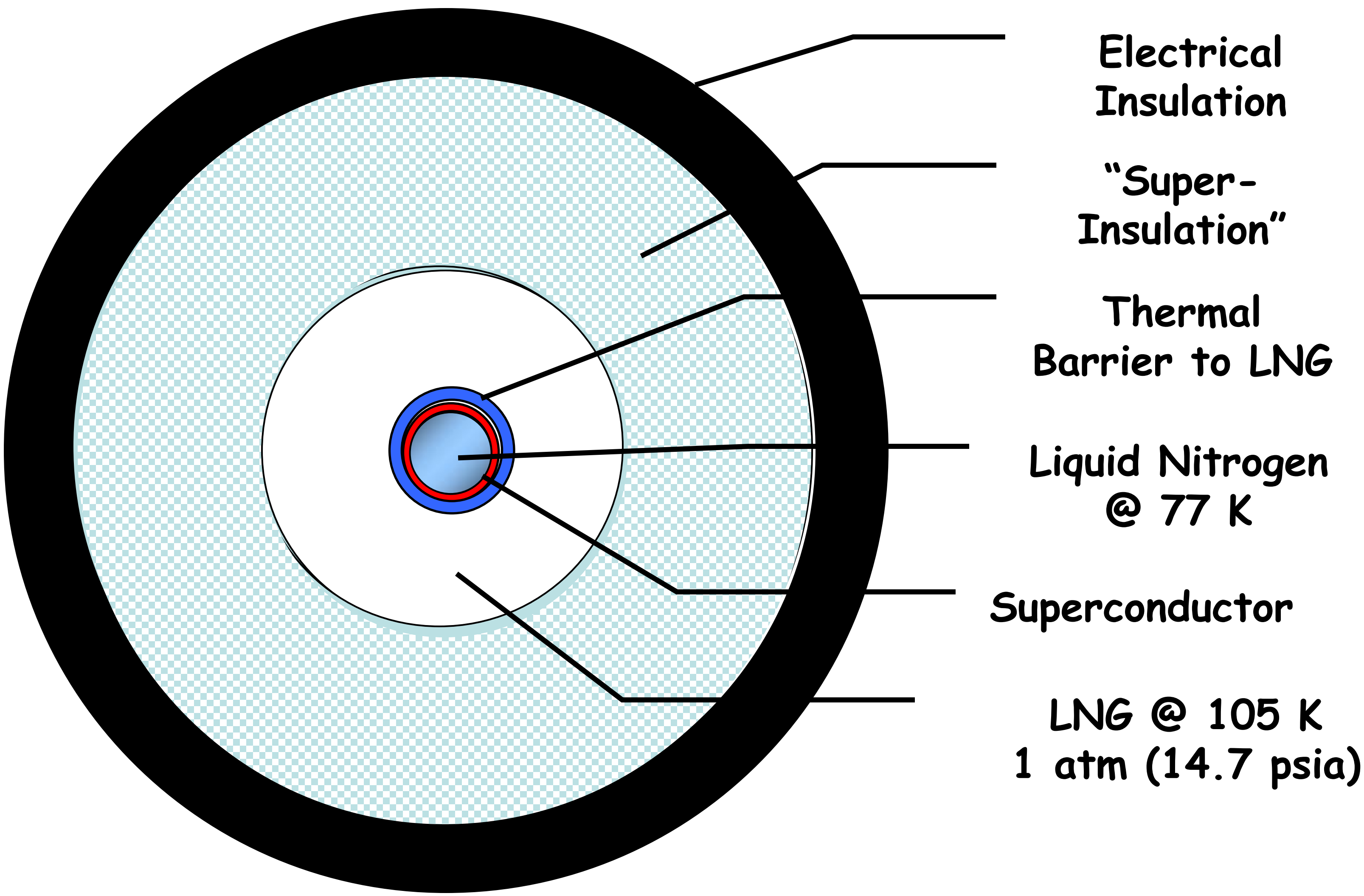
2006 - 2009

MVP Specs

Pipeline Length	1220 km (760 mi)
Diameter	30 in (76 cm)
Gas Pressure	177 atm (2600 psia)
Pressurization Stations	~250 km apart
Flow Velocity	5.3 m/s (12 mph)
Mass Flow	345 kg/s
Volume Flow	1.6 Bcf/d (525 m^3/s)
Power Flow	18 GW (HHV Thermal)
Construction Schedule	2006 - 2010
Employment	25,000
Partners	Esso, APG, C-P, Shell, Exxon
Cost	$ 7.5 B (all private)

Design for eventual conversion to high pressure cold or liquid H_2

LNG SuperCable



MVP Wellhead Electricity

Electricity Conversion Assumptions

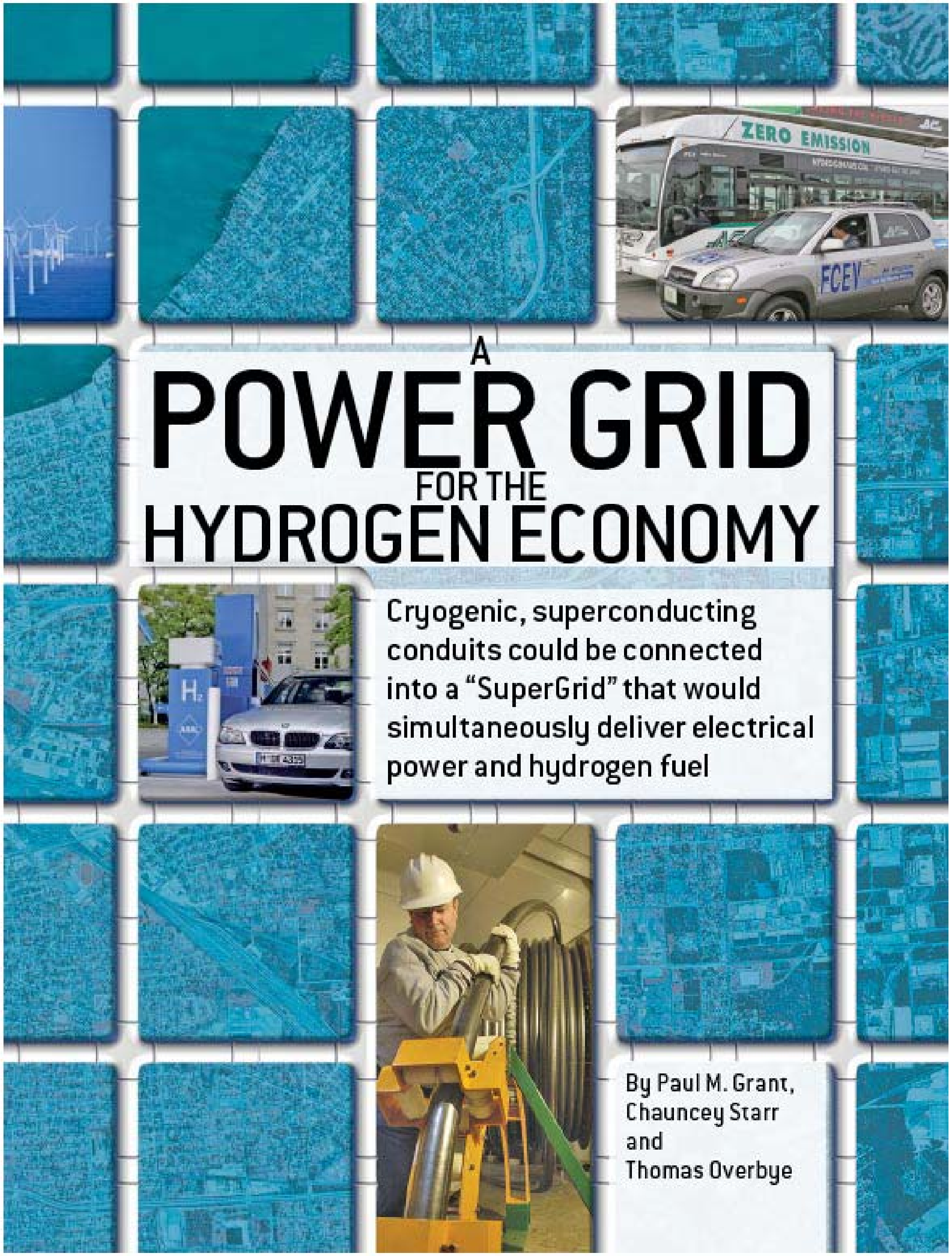
Wellhead Power Capacity	18 GW (HHV)
Fraction Making Electricity	33%
Thermal Power Consumed	6 GW (HHV)
Left to Transmit as LNG	12 GW (HHV)
CCGT Efficiency	60%
Electricity Output	3.6 GW (+/- 18 kV, 100 kA)

SuperCable Parameters for LNG Transport

CH_4 Mass Flow (12 GW (HHV))	230 kg/s @ 5.3 m/s
LNG Density (100 K)	440 kg/m^3
LNG Volume Flow	0.53 m^3/s @ 5.3 m/s
Effective Pipe Cross-section	0.1 m^2
Effective Pipe Diameter	0.35 m (14 in)

It's 2030

- *The Gas runs out!*
- Build HTCGR Nukes on the well sites in the Mackenzie Delta (some of the generator infrastructure already in place)
- Use existing LNG SuperCable infrastructure to transport protons and electrons


A POWER GRID FOR THE HYDROGEN ECONOMY

Cryogenic, superconducting conduits could be connected into a "SuperGrid" that would simultaneously deliver electrical power and hydrogen fuel

By Paul M. Grant, Chauncey Starr and Thomas Overbye

On the afternoon of August 14, 2003, electricity failed to arrive in New York City, plunging the 10 million inhabitants of the Big Apple—along with 40 million other people throughout the northeastern U.S. and Ontario—into a tense night of darkness.

Appearing in

SCIENTIFIC AMERICAN

July, 2006

“Gubser’s Charge”

- Visionary
  - ***Yes!***
- Futuristic
  - ***Yes!***
- Considers Total System or Functionality
  - ***Studies Underway and It’s Looking Good***
- Basic Research May Be in Materials other than Superconductors
  - ***No! (Well…maybe cryo-Ge bipolars)***
- Can’t Be Done or Not Practical
  - ***It Can Be Done!***
  - ***Practicality Depends Not on Technology, but Rather on Societal and Economic Motivation!***
- Depends on Material or Engineering Breakthrough
  - ***No! (But RTSC with R = 0 Would Be Nice!)***