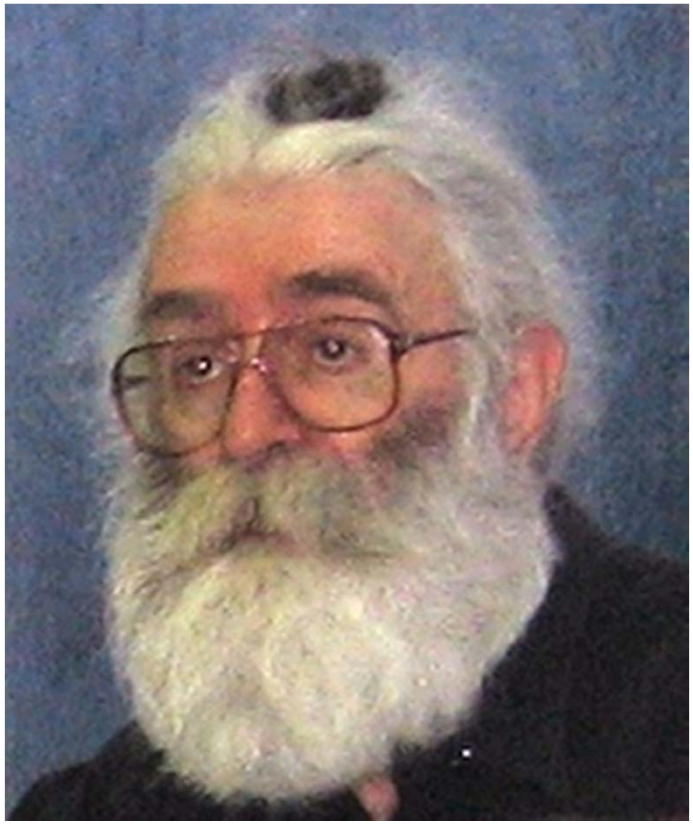
ICEC22-ICMC2008

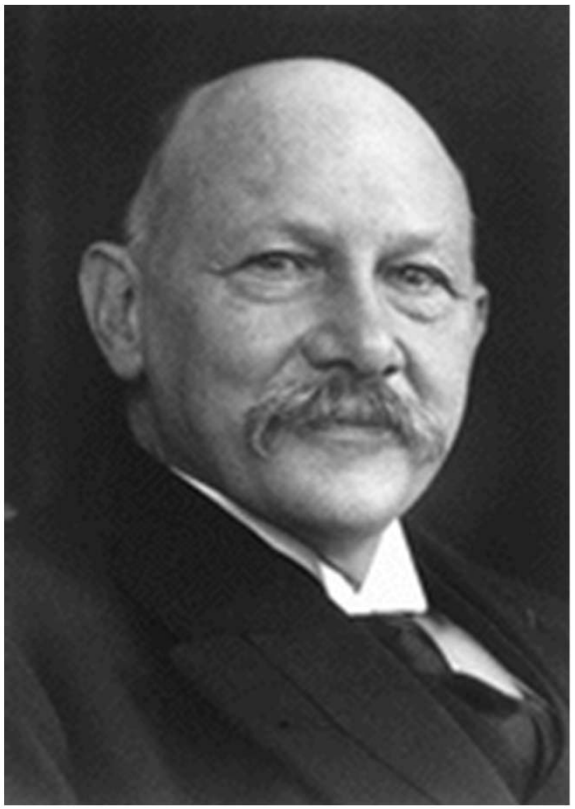
100 YEARS OF LIQUID HELIUM

July 21-25 2008

I AM NOT **Radovan Karadzic**!



July, 1908



Kammerlingh-Onnes

It's only been 100 years!

SuperSuburb

A Future Cryo-powered Residential Community

Paul M. Grant

Principal, W2AGZ Technologies
Visiting Scholar, Stanford (2005 – 2008)
EPRI Science Fellow (retired)
IBM Research Staff Member, Emeritus
www.w2agz.com
http://www.w2agz.com

ICEC 22 – ICMC 2008
22 – 25 July 2008
Seoul, Korea

Novel Cryogenic Systems
TH-C2-C05
Thursday, 24 June 15:15

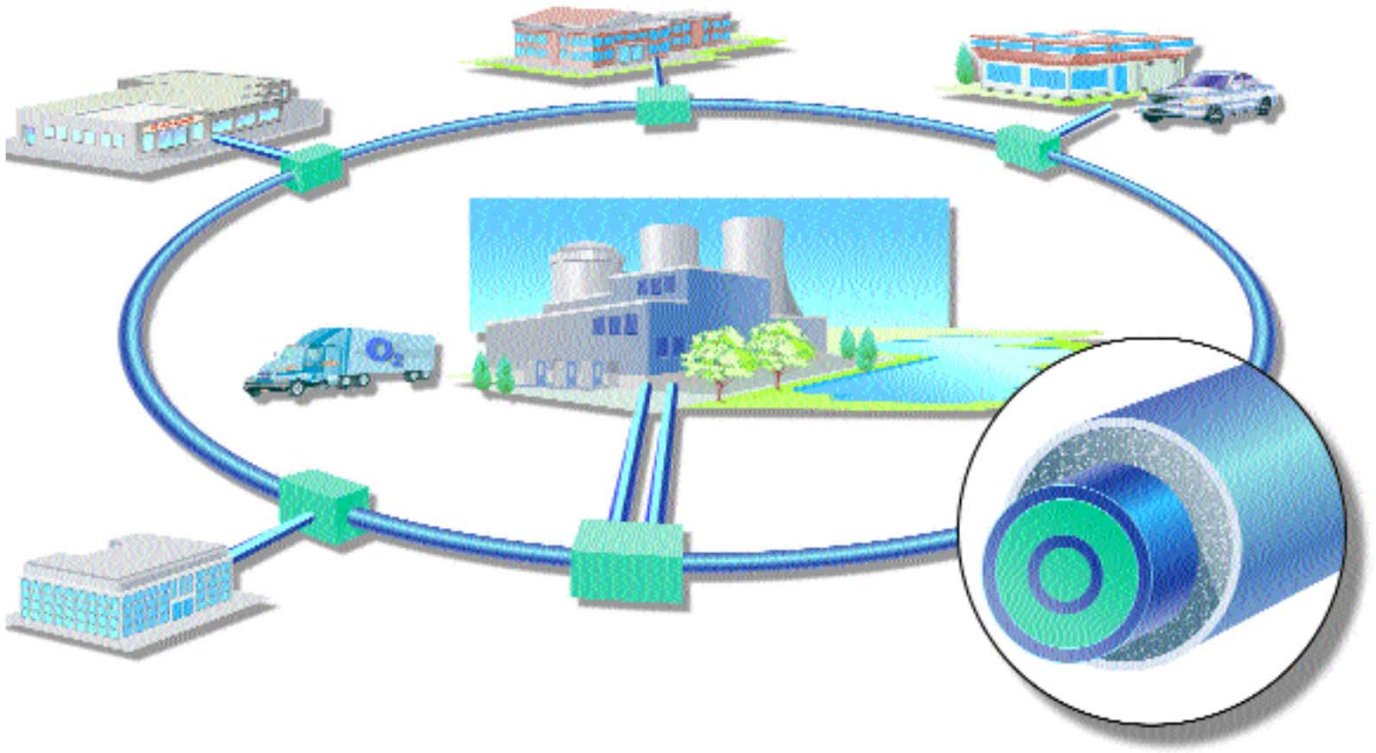
Boundary Conditions

- Carbonless
  - No CO_2
- Non-Eco-Invasive
  - Minimal land/ecology impact
- Off-the-table
  - Large scale renewables (wind, solar, bio)
  - Sequestration

Technology Menu

- Generation
  - HTGCR Nuclear (80%)
    - electrons
    - protons
  - PV Solar Roofs (20%)
- Transmission
  - Hydricity SuperCable
- Storage
  - Hydrogen + Hydricity Fuel Cell
- End Use Energy
  - Electricity
  - Hydrogen

SuperCity

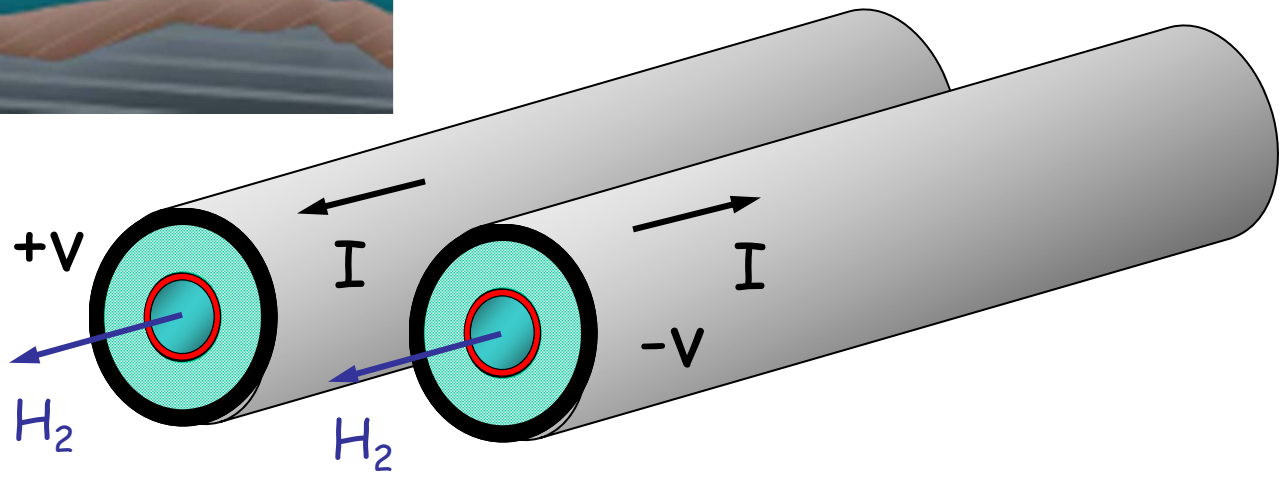


P. M. Grant, The Industrial Physicist, October/November 2001, p. 22
P. M. Grant, The Industrial Physicist, February/March 2002, p. 22

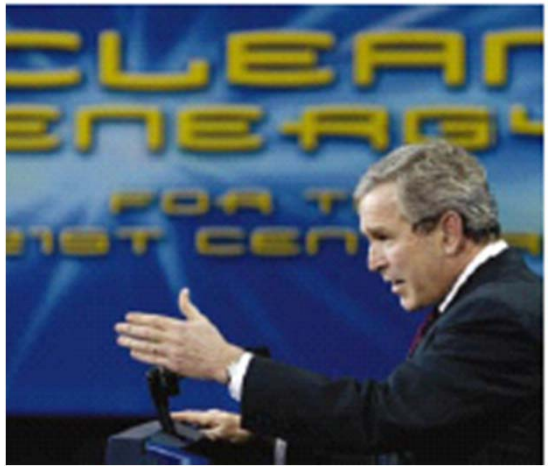
SuperGrid

Combining Superconducting Wires Cooled with Cryogenic Hydrogen
To Create a Dual-Energy Delivery Continental-Scale System

P. M. Grant, C. Starr, T. Overbye, "A Power Grid for the Hydrogen Economy," Scientific American, July 2003, p. 76.



The Hydrogen Economy



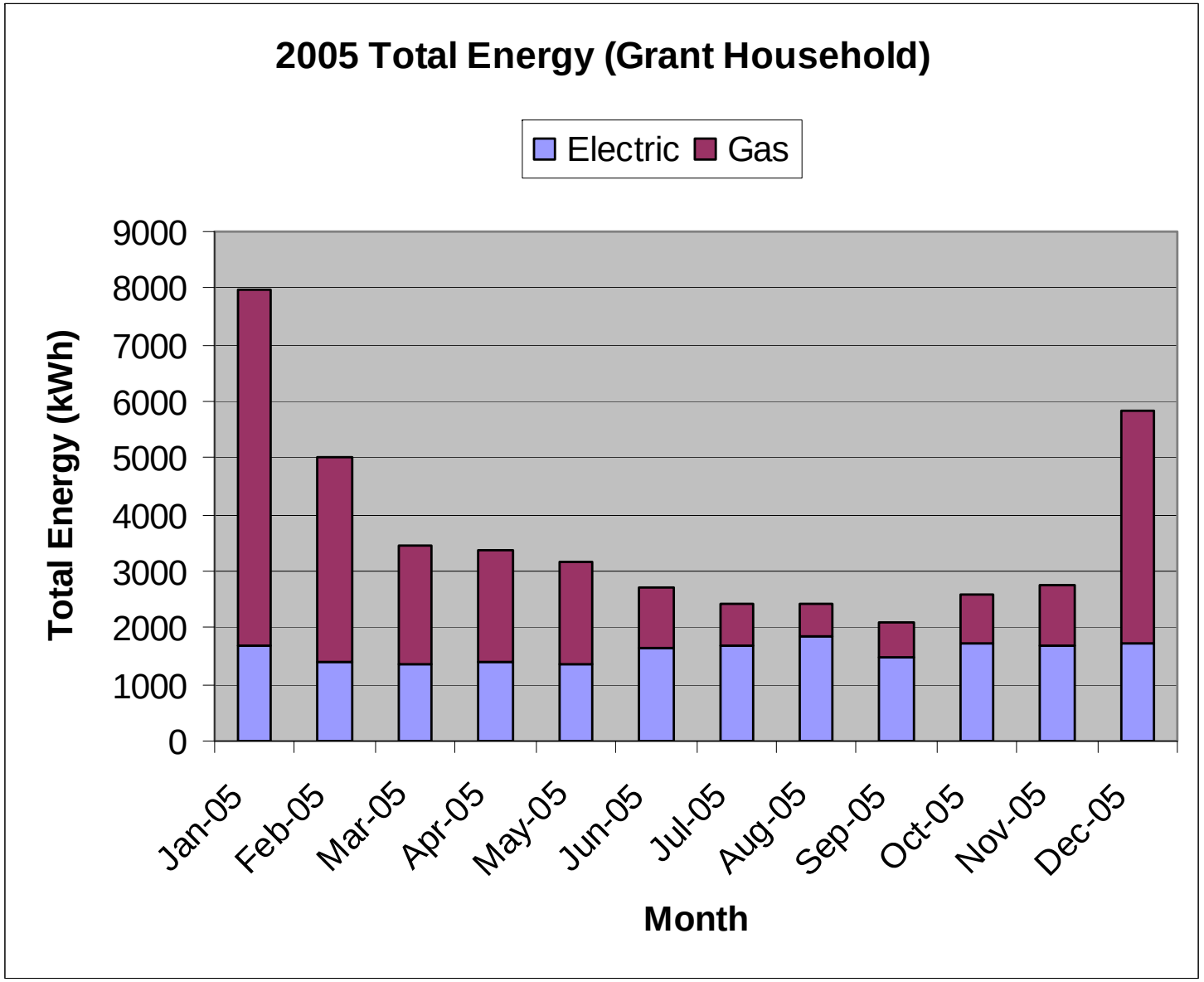
- You have to make it, just like electricity
- Electricity can make H_2, and H_2 can make electricity ($2H_2O \Leftrightarrow 2H_2 + O_2$)
- You have to make a lot of it
- You can make it cold, - 419 F (21 K)

P. M. Grant, “Hydrogen Lifts Off…with a Heavy Load,” Nature 424, 129 (2003)

SuperSuburb Parameters

- Electricity for residential appliances, lighting, space conditioning and cooking
- Hydrogen for storage of electricity and personal transportation
- Off the Agenda:
  - Commercial business; shopping centers
  - Electric rail/rapid transport
  - Street lighting

California Living!



2005 GHE Energy Consumption Statistics

Energy (kWh)	*Electricity*	*CH_4*	*Total*
Annual Total	18894	24882	43776
Monthly Average	1575	2073	3648
Standard Deviation	174	1747	1748
Skewness	-0.15	1.51	1.69
Kurtosis	-1.57	1.88	2.42

Monthly GHE Consumption

Power (kW)	*Electricity*	*Natural Gas*	*Total*
Monthly Mean	2.16	2.84	4.99
Standard Deviation	0.24	2.39	2.39
Mean + STD	2.39	5.23	7.39
Mean - STD	1.92	0.45	2.60

Baseline Electric Power and Energy Storage Requirements per GHE in SuperSuburb

Baseline Power (kW)	Energy Stored (kWh)	Hydrogen Mass Equivalent (kg)	Volume as Liquid (21 K, 14.7 psia) (cube edge in meters)	Volume as Gas (300 K, 2000 psia) (cube edge in meters)
5.99	6129	187	1.38	2.63

GHE Transportation Energy Consumed

Miles/Year	DOE H_2 Mileage (kWh/mile)	H_2 Daily Mass Consumption (kg)	SuperCable H_2 Delivery Power (kW)
30,000	0.76	1.91	2.61

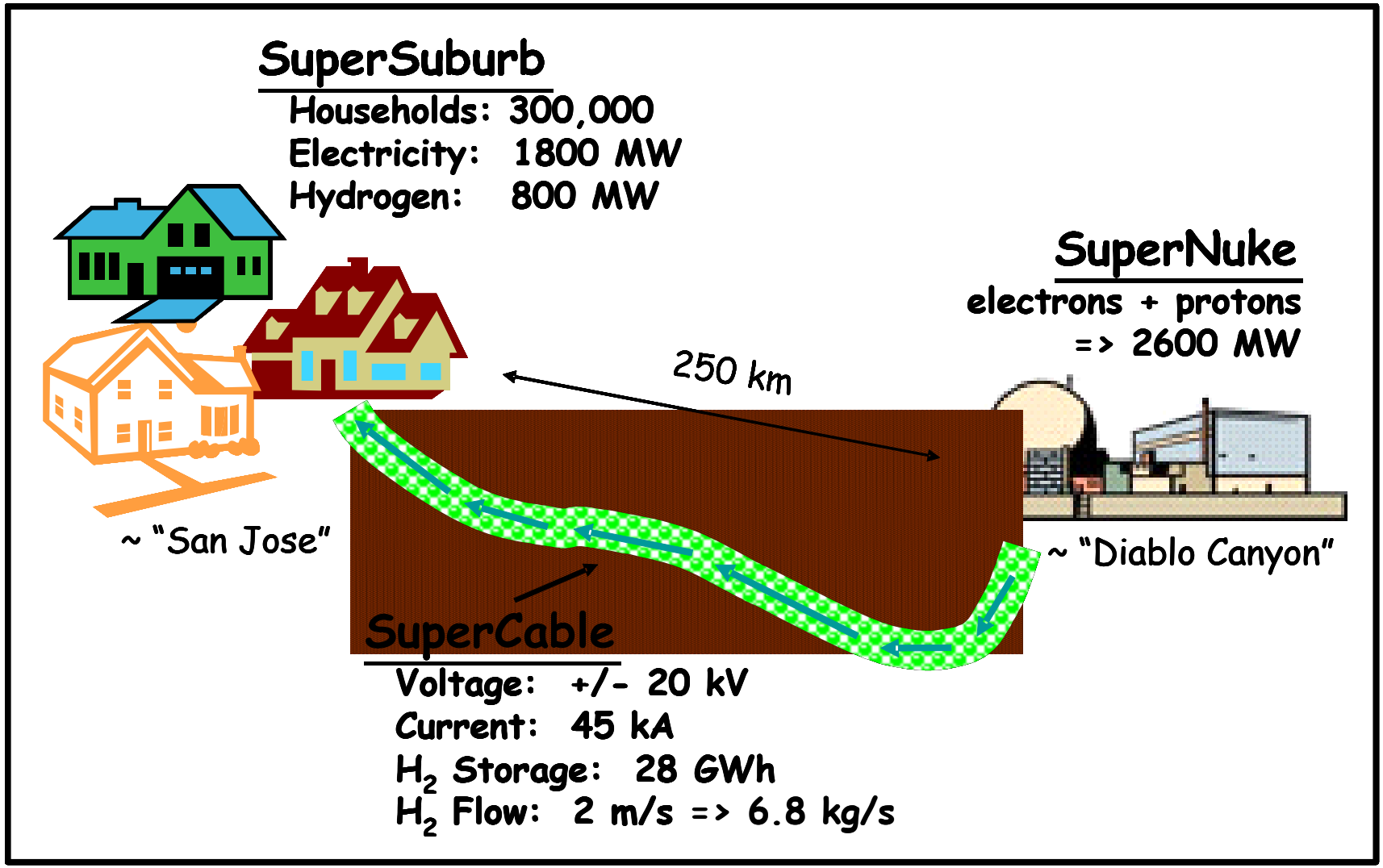
Number of GHEs per H_2 Station and Individual Station Capacity

US Households (2005)	Number of Stations (1998)	Households per Station	Turnover Rate (days)	H_2 Mass (kg)	Liquid "cube" (meter)	Gas "cube" (meters)
75,000,000	187,000	401	3	2298	3.2	6.1

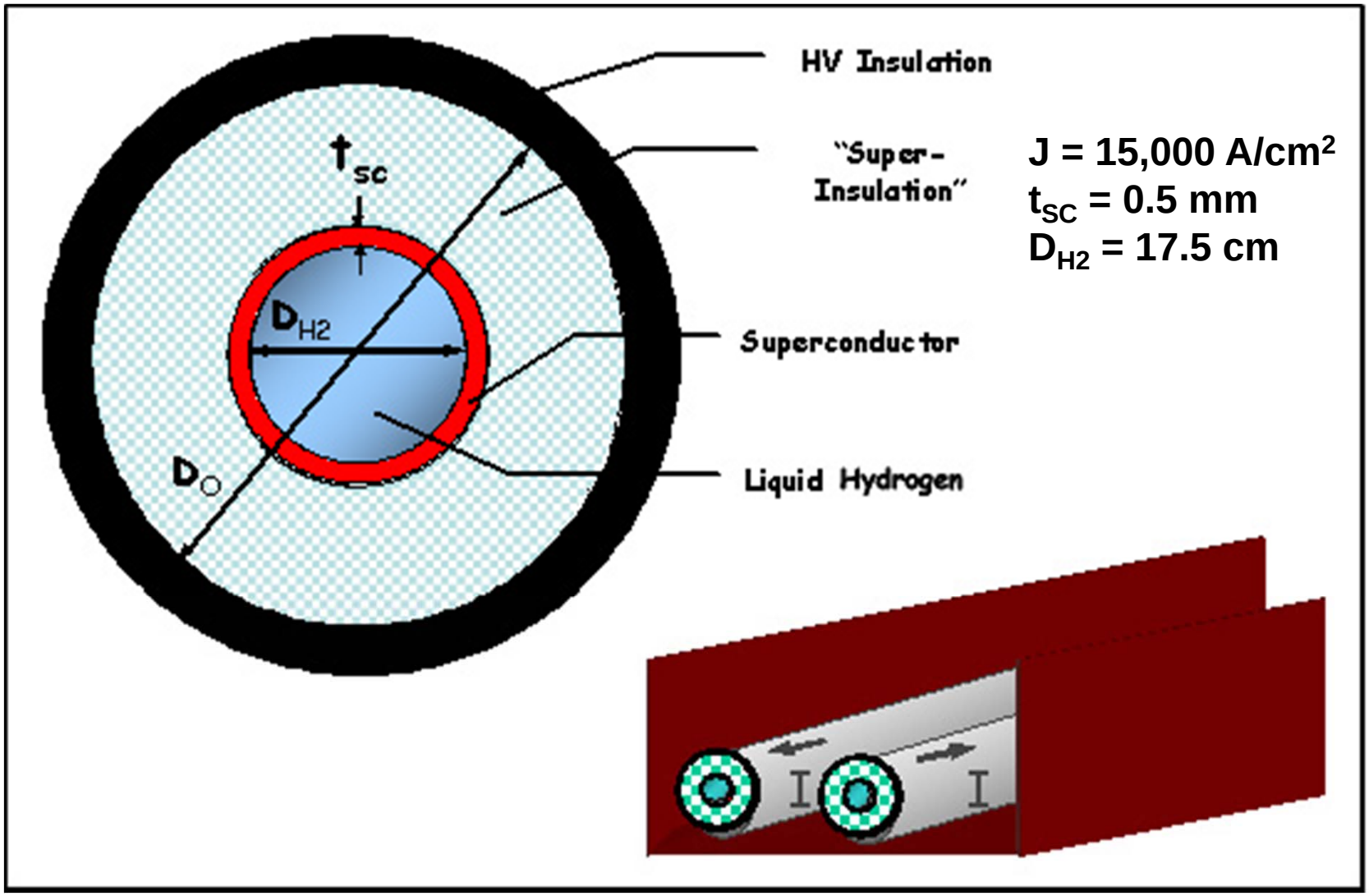
Baseline Electric and Hydrogen Power Needs of a “San Jose” SuperSuburb of GHEs

GHE Households	Base Electric Power (MW)	Electricity to be Stored as H_2 (tonnes)	Base H_2 Power (MW)	H_2 Stations
300,000	1798	56,104	782	748

The Cryogenic Neighborhood



The CryoNet



J = 15,000 A/cm^2
t_{SC} = 0.5 mm
D_{H2} = 17.5 cm

SuperCable Physical Parameters

Operating Current Density, J (A/cm^2)	t_{SC} (cm)	Hydrogen Flow Rate (m/s)	D_{H2} (cm)	Maximum Magnetic Field (T)
15, 000	0.05	2	17.5	0.10

SuperSuburb SuperCable Monopole Minutia and Costs)

HTSC Tape Parameters							
Width (mm)	Thickness (mm)	Length (m)	Total No. Tapes	Tape Req'd (km)	Approx. No. Splices	Tape C/P ($/kA×m)	HTSC Cost (M$)
4	0.25	800	~300	~80,000	~100,000	50	591

SuperSuburb SuperCable Thermal Loss Budget (W/m)

Radiation	Flow Friction	Addenda Loss	1.0 % Ripple	Total
0.70	0.49	0.20	0.09	1.48

SuperSuburb SuperCable Refrigeration Requirements

Temperature Rise (K/km)	Total Rise for 250 km SuperCable (K)	Permissible Rise Prior to Re-Cool (K)	Total Number of Cooling Stations Required
0.045	11	1	11

Station Spacing (km)	Cooling Power per Station (kW)	Cost of Heat Uplift ($/kW)	Per Station Cost (K$)	Total Station Cost (M$)
22.25	32.9	5	164	1.85

Bottom Line

SuperSuburb SuperCable Economic Factors.

Cost of Electricity ($/kWh)	Line Losses in Conventional Transmission (%)	Annual Value of Losses on 1800 MW Transmission Line (M$)	Additional Capital Costs for HTSC and Refrigeration (M$)	FRB Discount Rate (%)	Period for ROI (Years)
0.05	5 %	39.4	1185	5.5 %	18

Why Build SuperSuburbs?

- Reduce carbon emissions
  - Climate impact?
  - Declining carbonaceous reserves
- Reduce ecological footprint/impact
  - Maintain open space
  - Maintain wilderness
  - No wind, solar farms, biomass, seqestration

Where to Build Them?

- Nuclear Friendly
- Growing Middle Class
- Growing Light Industry
- Visionary Culture
- Space
- Risk-taker
- Stable Economy