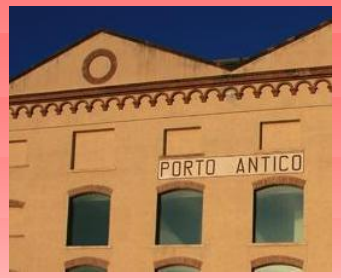


11th European Conference on Applied Superconductivity

September 15-19 2013 - Genova, Italy

Eucas 2013




# Dual use of future natural gas pipeline rights-of-way for the transport of electricity via HTSC cables

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*Financial support provided by the IBM Pension Fund*

*Poster 2P-LS2-10 PDF*

***Preavviso!***

Make sure the QR Code app in your Android iToy contains a browser with pdf reader plugin!

# Abstract

It appears likely that “clean” fossil fuels, exemplified by natural gas, given their current global abundance and accessibility, will continue to be exploited for at least the next two decades. We discuss a scenario whereby future natural gas/petroleum pipeline deployment provides an opportunity for creating a common right-of-way to transport both chemical and electrical energy, the latter via high capacity HTSC dc cables. Given the emergence of highly-Carnot efficient combined-cycle-gas-turbine (CCGT) generation technology, a significant portion of the natural gas delivered, perhaps as much as 40% or more, will be combusted at the end point to produce electricity. It would be useful to contemplate generating this electricity “in bulk” at the gas field “well head,” taking into account the savings wrought by transmitting a lower volume fraction of gas with reduced frictional and pumping losses, and also economies of scale by concentrating $CO_2$ capture and reprocessing at a single site, rather than at a multitude of gas delivery points. In this poster, we examine possible candidate scenarios in North America and Europe and the advantages such dual use rights-of-way might provide for increased, yet with minimal environmental impact, delivery of chemical and electrical energy. For an initial study of this concept, see:



P.M. Grant, “Cryo-Delivery Systems for the Co-Transmission of Chemical and Electrical Power,” AIP Conf. Proc. 823, 291 (2006); doi: 10.1063/1.2202428

# Preamble




- Discovery
  - Cu-Perovskites: 20-135 K (1986-1993)
  - $MgB_2$: 40 K (2001-2002)
  - Fe-Pnictides: 4-55 K (2006-Present)
- Power Application R&D
  - Basic wire development; OPIT, IBAD, RABiTS: USA, Japan, Germany, Italy, S. Korea, Russia (1987-2008)
  - ac & dc Cables; Many: USA, Japan, Europe, S. Korea, China, Russia (1992-Present)

- Power Control & Energy Storage (FCLs, SMES); Many: USA, Japan, Europe, S. Korea, China, Russia (1992-Present)
- Utility Demonstrations of Above Technologies
  - Investor-owned (Only in USA: EPRI membership)
  - "Public" (USA: LIPA, National Grid; Japan: TEPCO, Chubu)

- Government-sponsored R&D
  - DOE (USA, 1987-2008)
  - MITI, METI, ISTEC (Japan, 1987-Present(?))
  - KEPRI (S. Korea, 1990-Present(?))
- Commercial Development (1987-Present)
  - USA (AMSC, STI,...)
  - Japan (Furakawa, Fukushima, Sumitomo...
  - Europe (Columbus,...)

- # HTSC Commercial Applications in Power
  - At the time of its discovery, HTSC was heralded to soon embody a multibillion dollar market in Power Applications.
  - Yet today, despite billions of dollars of investment in R&D and demonstrations by governments worldwide, not one "investor owned utility" and only perhaps two or three "public utilities," have permanently deployed HTSC apps on the Grid.
  - Why not? (see "Upbraiding the Utilities")

Some reasons (private communications from several large US IOU's):

- Economic returns do not justify the investment, even if the cost of the wire were zero!
- Installation is a hassle, and current technology works pretty well and is improving (viz., "Smart Grid")
- Any new technology "skill set" would require lengthy negotiations with labor unions at the "lineman" level.
- So what's/where's the "compelling need" to deploy HTSC on the Grid?

Cold Facts

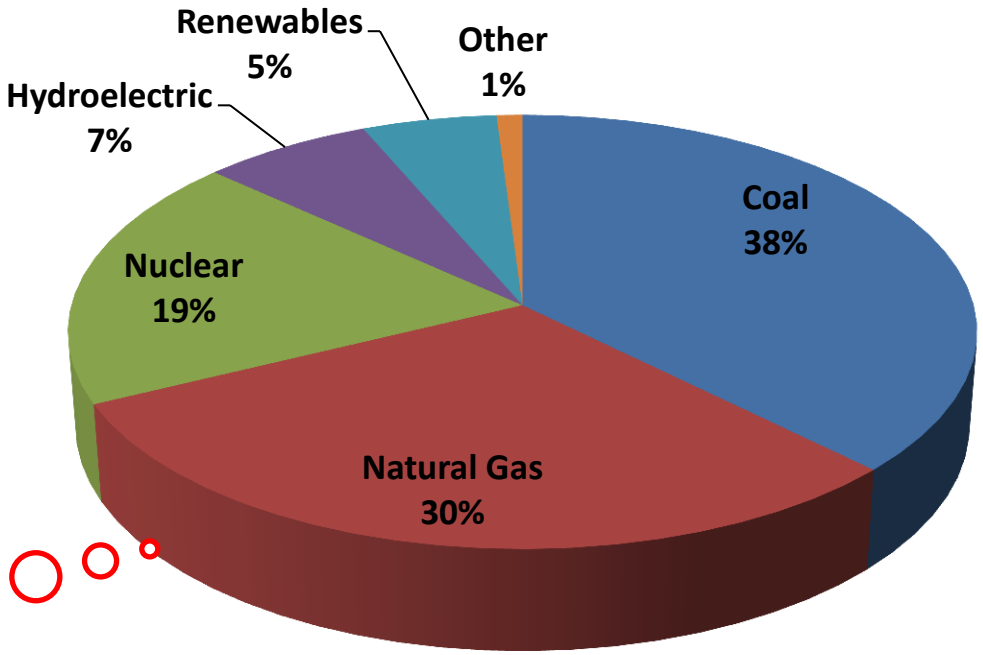
Upbraiding the Utilities
2011 P. M. Grant's
Editorial in Cold Facts

# Global Energy Needs:
# - Challenges & Approaches/Solutions -

- Challenges
  - An expanding global population aspiring to the energy-consumption standard of living existing in Europe and North America and targeted by the emerging societies of middle and western Asia, the Indian subcontinent, Africa and South America.
  - Possible adverse climate impact arising from the combustion products of increased amounts of fossil fuels consumed in pursuit of their objective.
  - Limited ability to address such needs via renewable alternatives and associated physical constraints and socio-eco-invasive impact imposed by widespread deployment of solar, wind, and bio-sourced alternative sources.
- Approaches/Solutions
  - Vast reserves of natural gas have been uncovered worldwide, and attendant cost-effective retrieval technologies have been developed.
  - ***Let's start using them!***

# A New Worldwide *Opportunity* for HTSC?

## *Natural Gas & Electricity!*



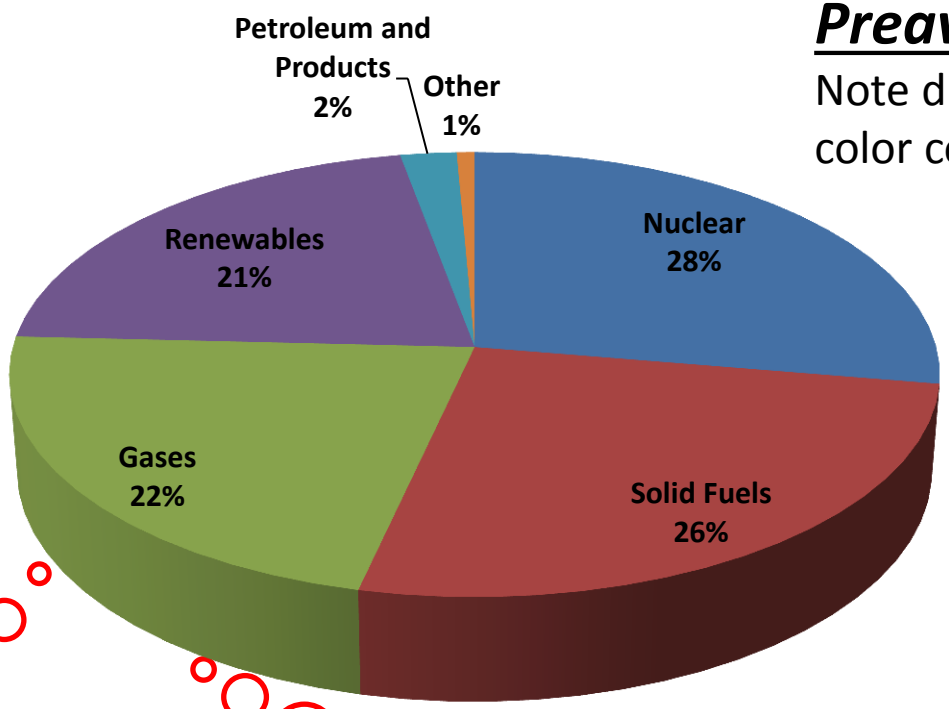

**USA**

**Wow!**

**2012 USA Electricity Generation by Primary Fuel Source**

Questions:

- "Gases" = NG?
- Where is Hydro?
- "Solid" = Coal?




***Preavviso!***

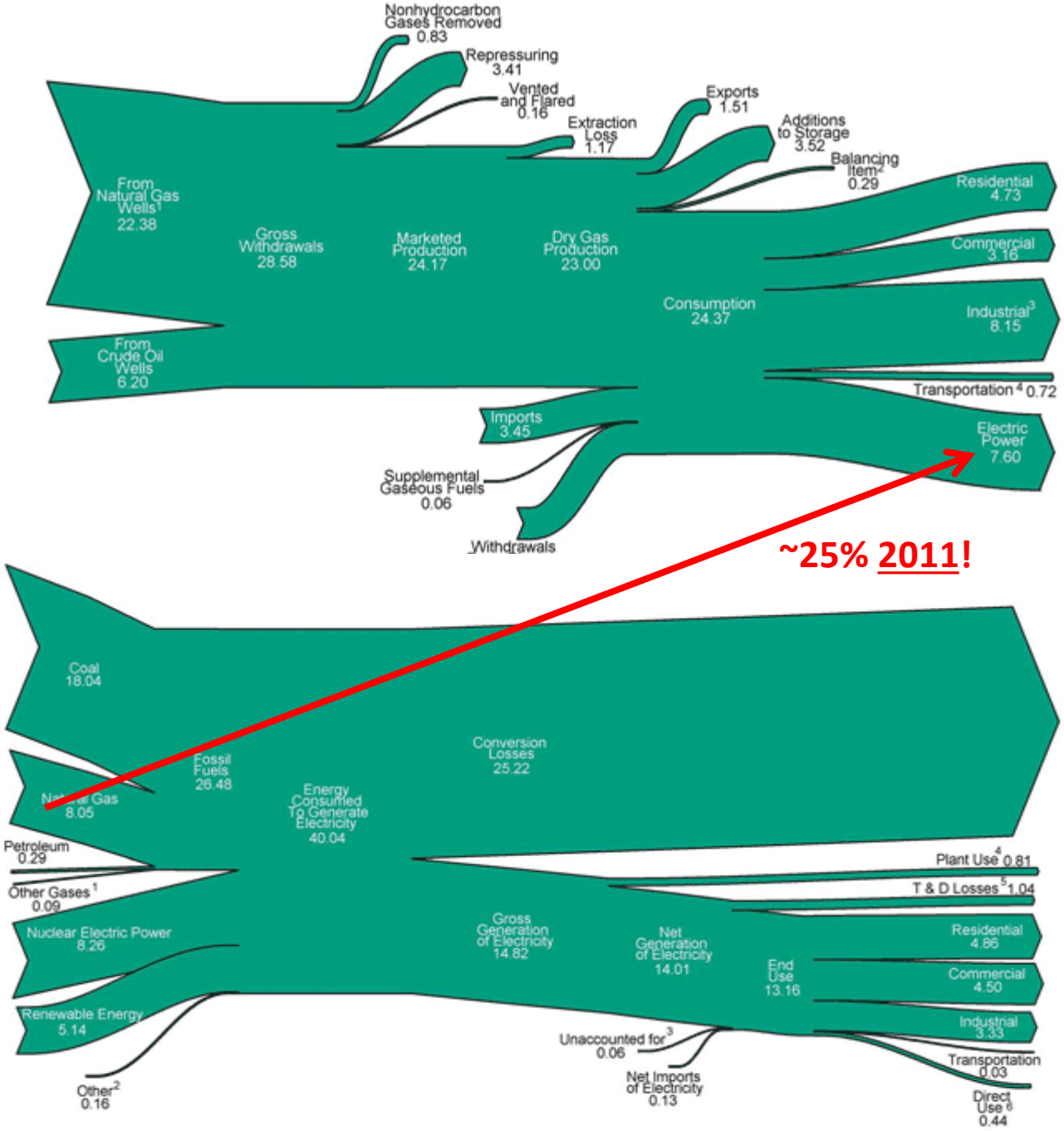
Note different "pie slice" color code from USA

**Europe**

**About 3/4 that of US**

**BTW, it's around 23% Worldwide**

**2011 EU Electricity Generation by Primary Fuel Source**




## US Natural Gas Generation/End Use – 2011

**Units = $10^{12}$ ft$^3$**

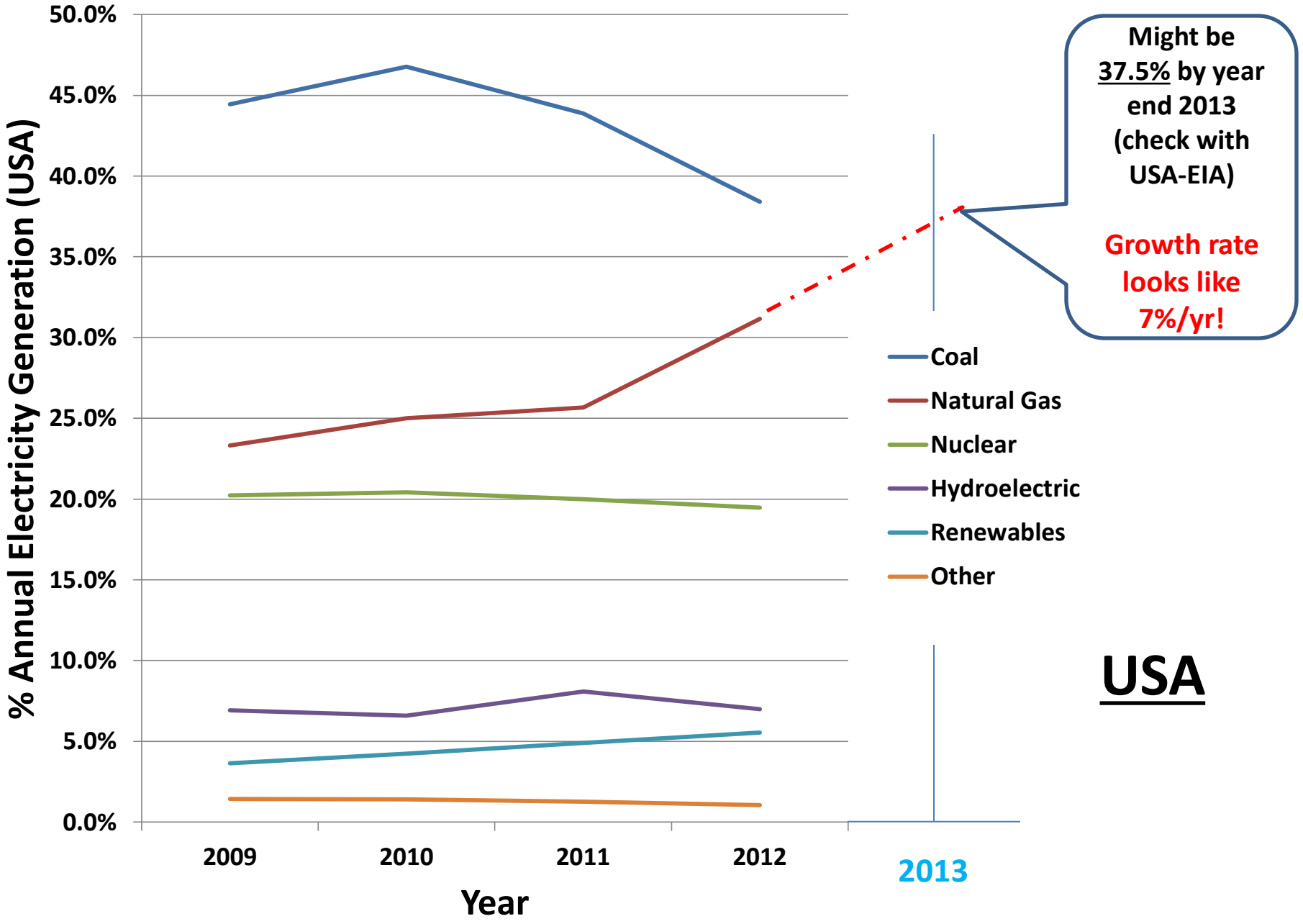
**= 1.35 x $10^4$ Twh**

***What/where are the equivalent data for the EU? (Couldn't find any...???)***

## US Electricity Generation/End Use – 2011

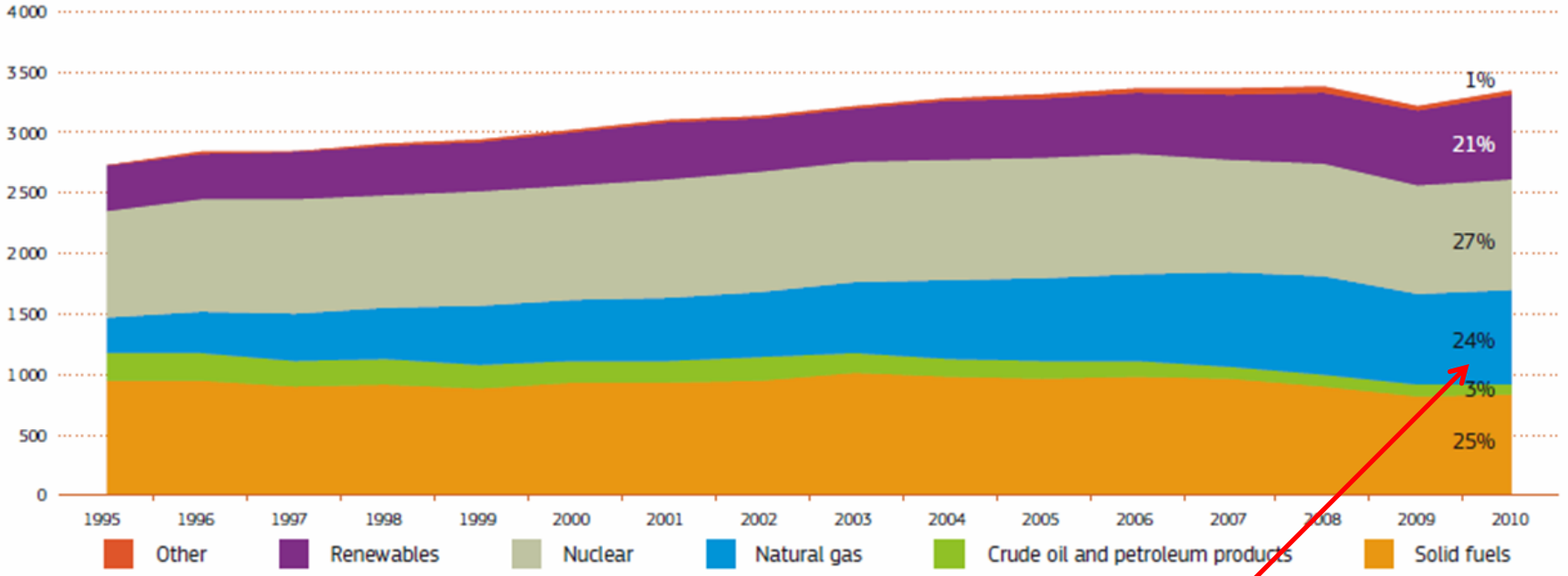
**Units = $10^{15}$ BTU**

**= 2.933 x $10^3$ Twh**


% Annual Electricity Generation (USA)
50.0%
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
2009
2010
2011
2012
2013
Year
Coal
Natural Gas
Nuclear
Hydroelectric
Renewables
Other
Might be 37.5% by year end 2013 (check with USA-EIA)
Growth rate looks like 7%/yr!
USA

# Europe

FIGURE 9 - EU-27 GROSS ELECTRICITY GENERATION (in TWh) (1995-2010)

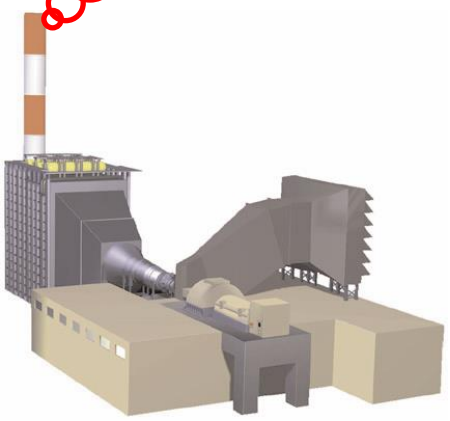


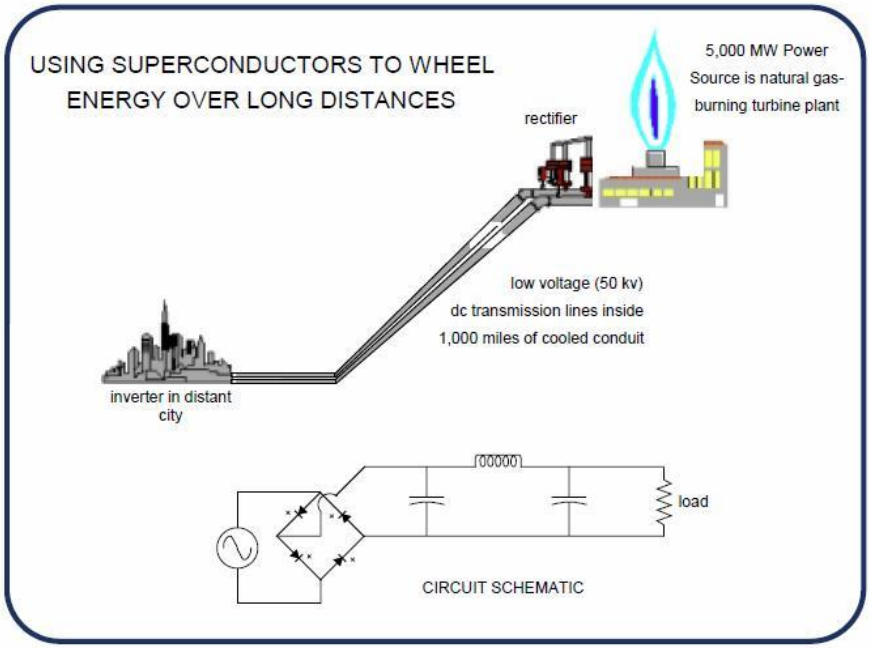

Growth rate of electricity generation by Natural Gas looks "flat" at present. Will discovery of additional reserves and deployment of fracking, especially in Poland and the Ukraine, lead to a future "upward slope?"

# Advantages of HTSC vis-a-vis Pipelines

- 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 of NG transported by pipeline.

**...and...consider “recycling” $CO_2$ emissions into alcohols!**






EPRI ePipe

EPRI WO8065-12

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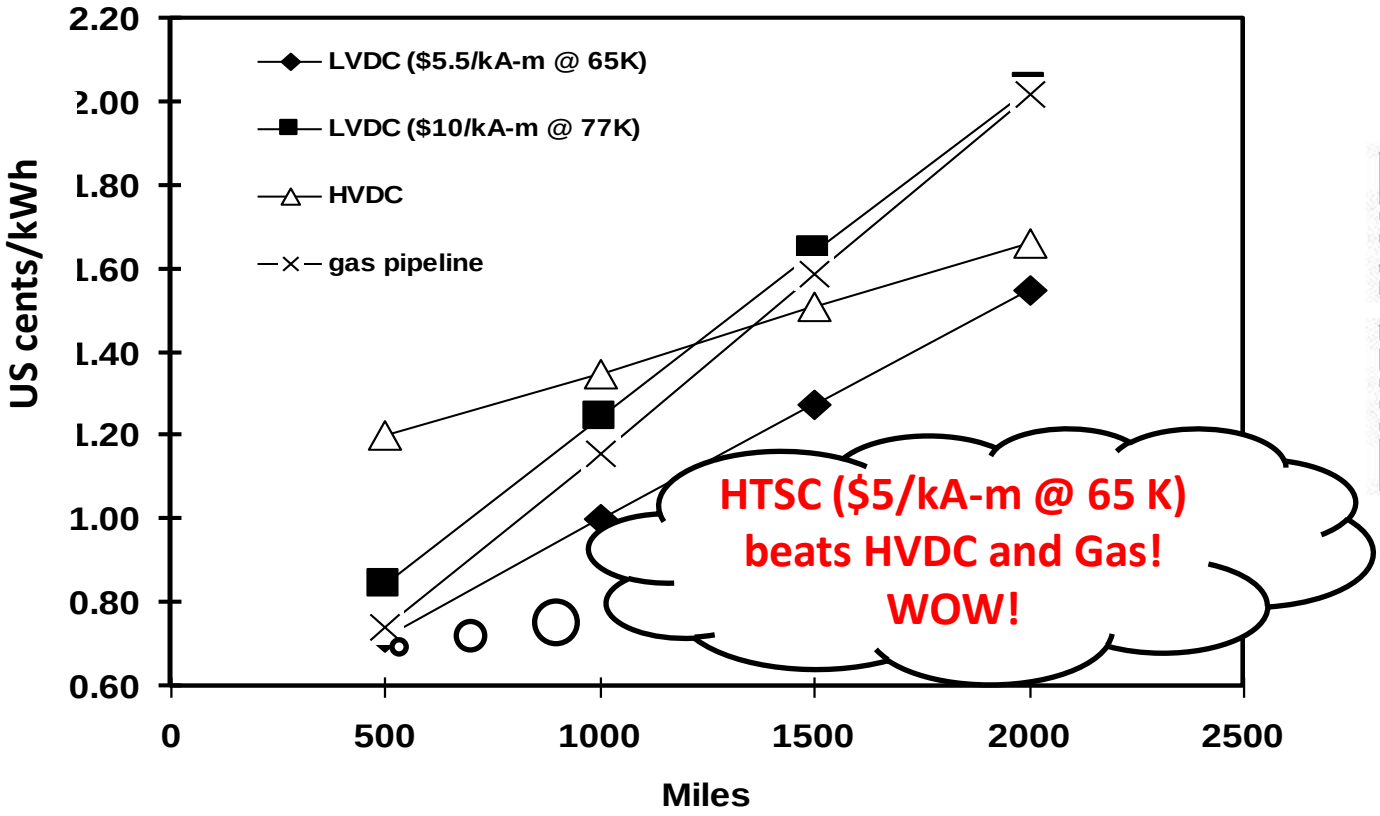
# Power Delivery cost comparison between Gas/HVDC/LVDC-HTSC Technology Options

## Marginal Cost of Power Delivery




EPRI ePipe

EPRI WO8065-12
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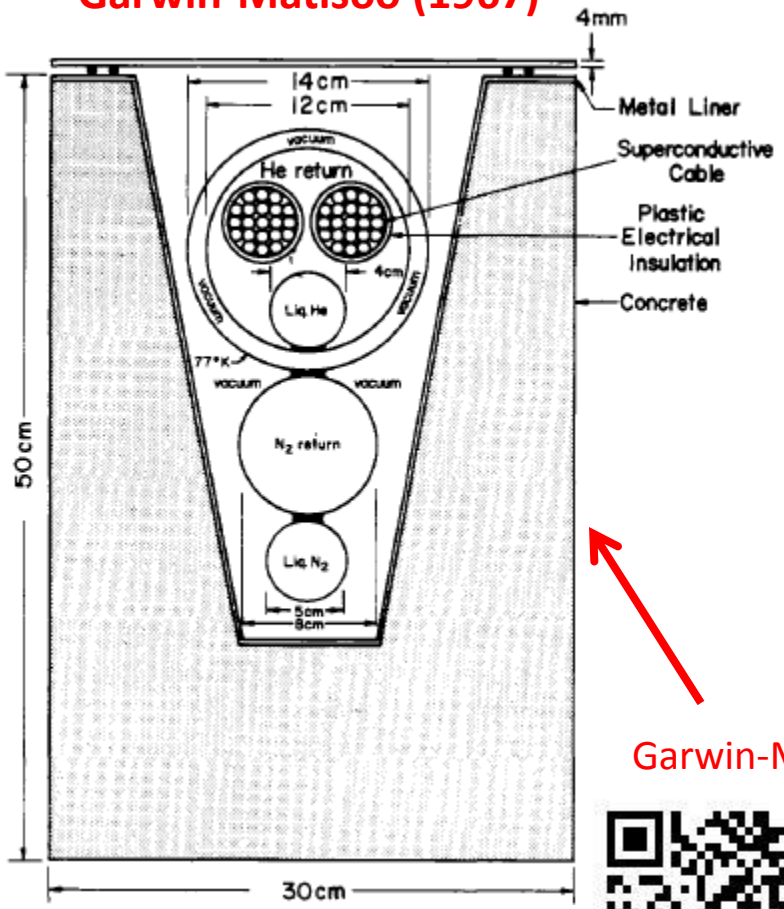
**Nota Bene! (That's Latin for Preavviso) This figure contains 1997 "English/US" units for distance and currency and needs to be updated... Sega!**

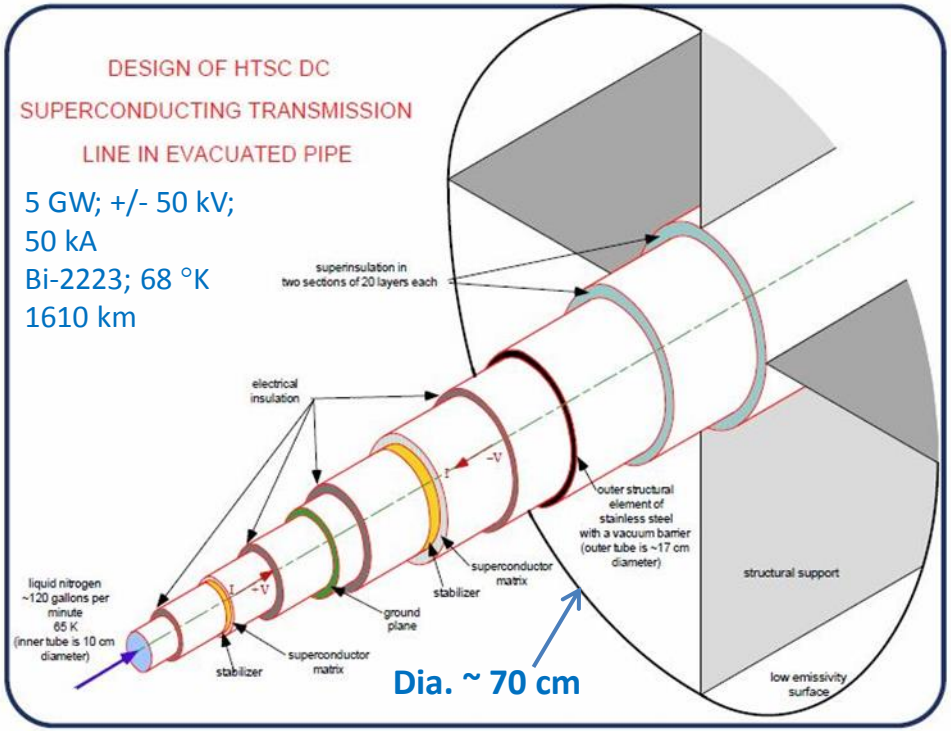
# Superconducting Cable Anthology

## Garwin-Matisoo (1967)




100 GW; +/- 100 kV; 500 kA
$Nb_3Sn$; 4 °K
1000 km

## EPRI ePipe (1997)




Garwin-Matisoo

EPRI ePipe

Garwin-Matisoo IEEE
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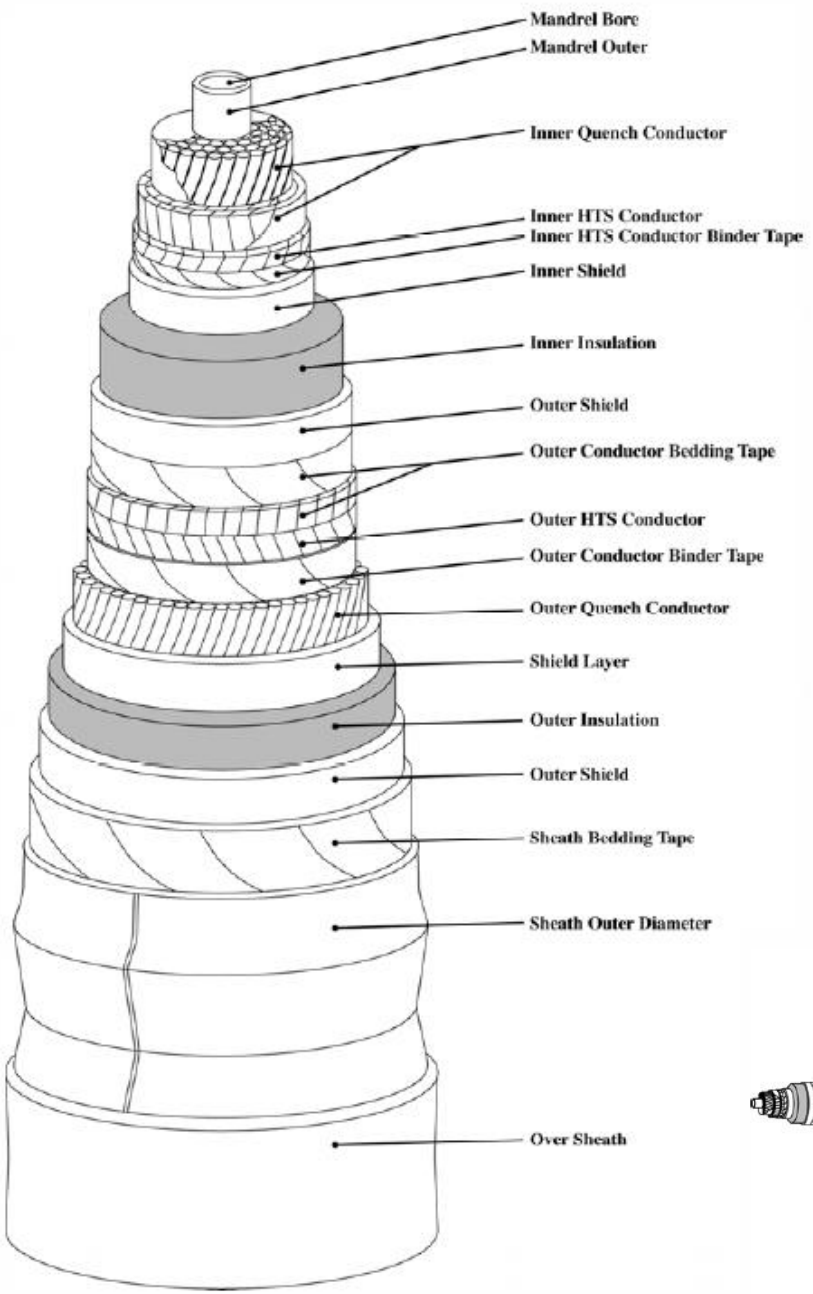
EPRI WO8065-12
W2AGZ Technologies




# EPRI Superconducting dc Cable (2009)

10 GW; +/- 50 kV; 50 kA
YBCO; 68 °K
Constructed in 1 km segments

HTSC dc Cable

EPRI 1020458
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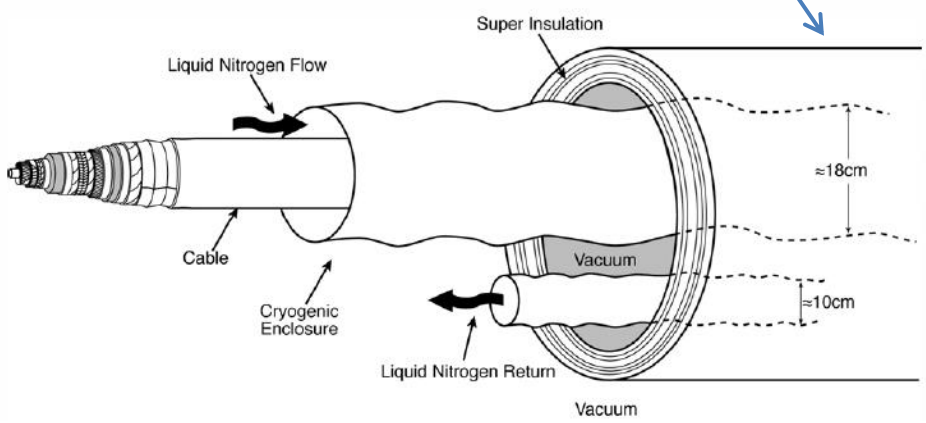
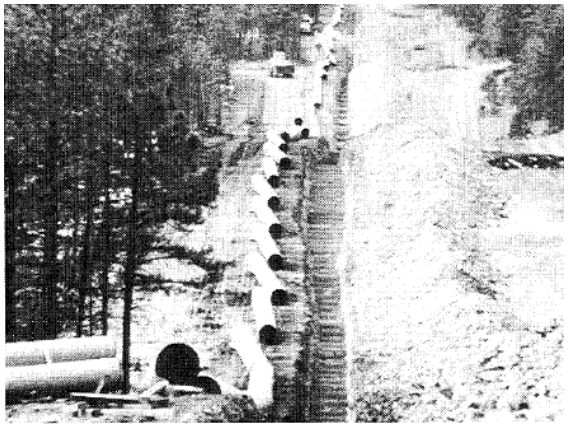
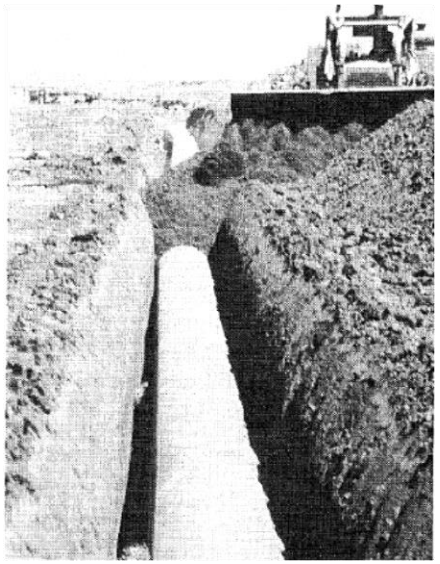
**Dia. ~ 70 cm**



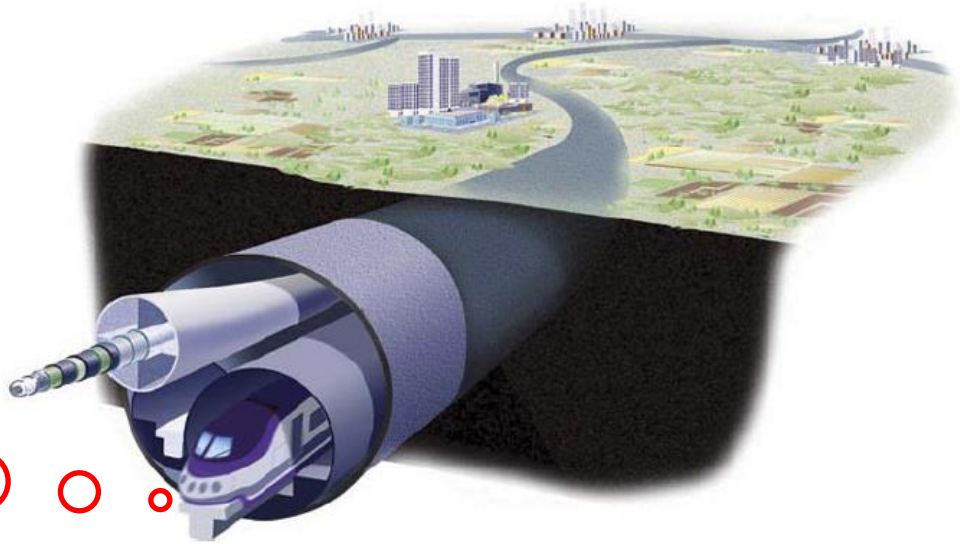
# So: Is there enough room underground for both wires and pipes?











Maybe even for a Train?

A Canadian's View of the World!

# USA/Canada




The United States is Down Here!

## The Mackenzie Valley Pipeline

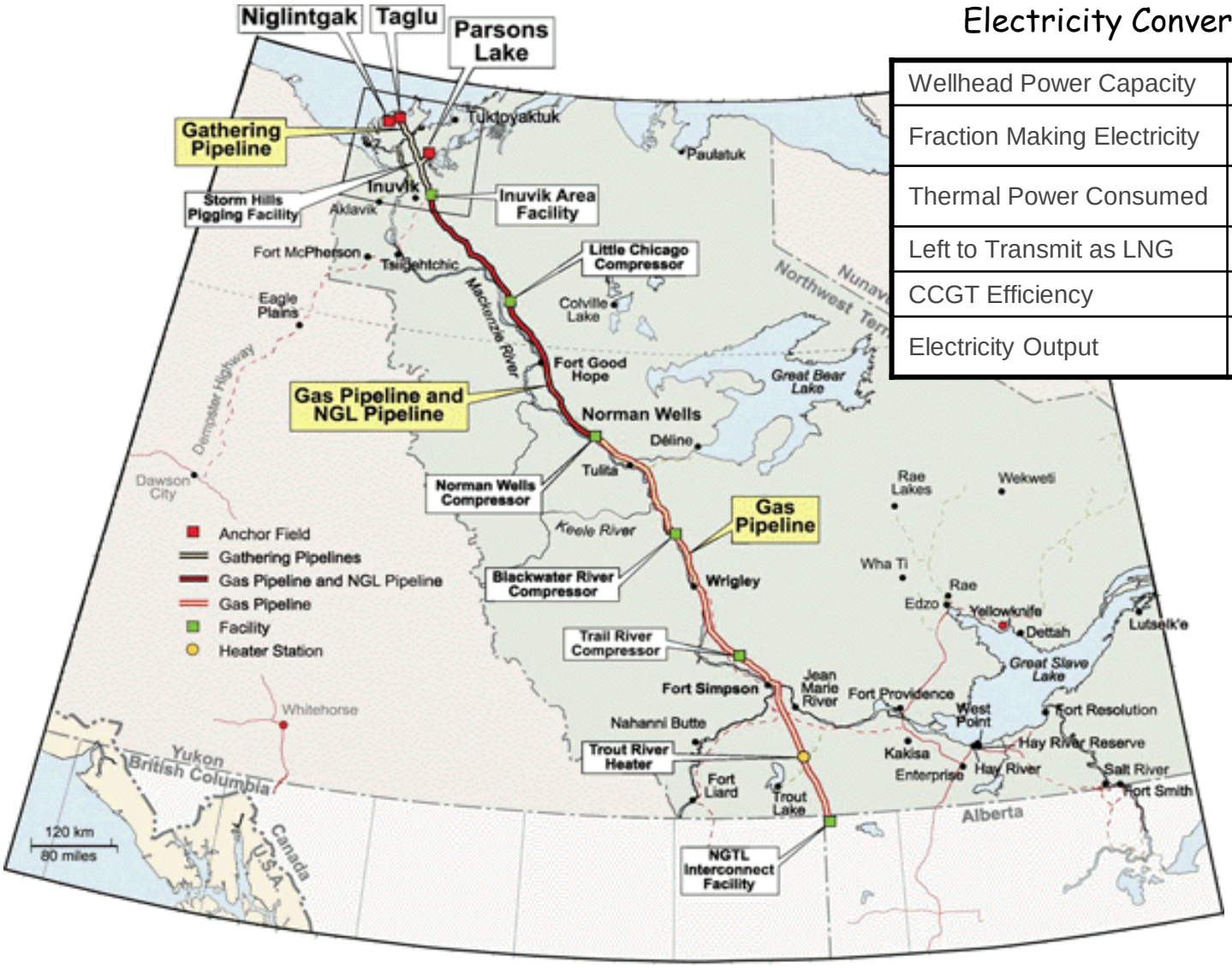
**1220 km**

**18 GW-thermal**

**2000 - ?**



# “The Really Big Picture”




## 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) |

Cryo-Delivery

Co-Transmission (2006)

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







Smart Grid

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

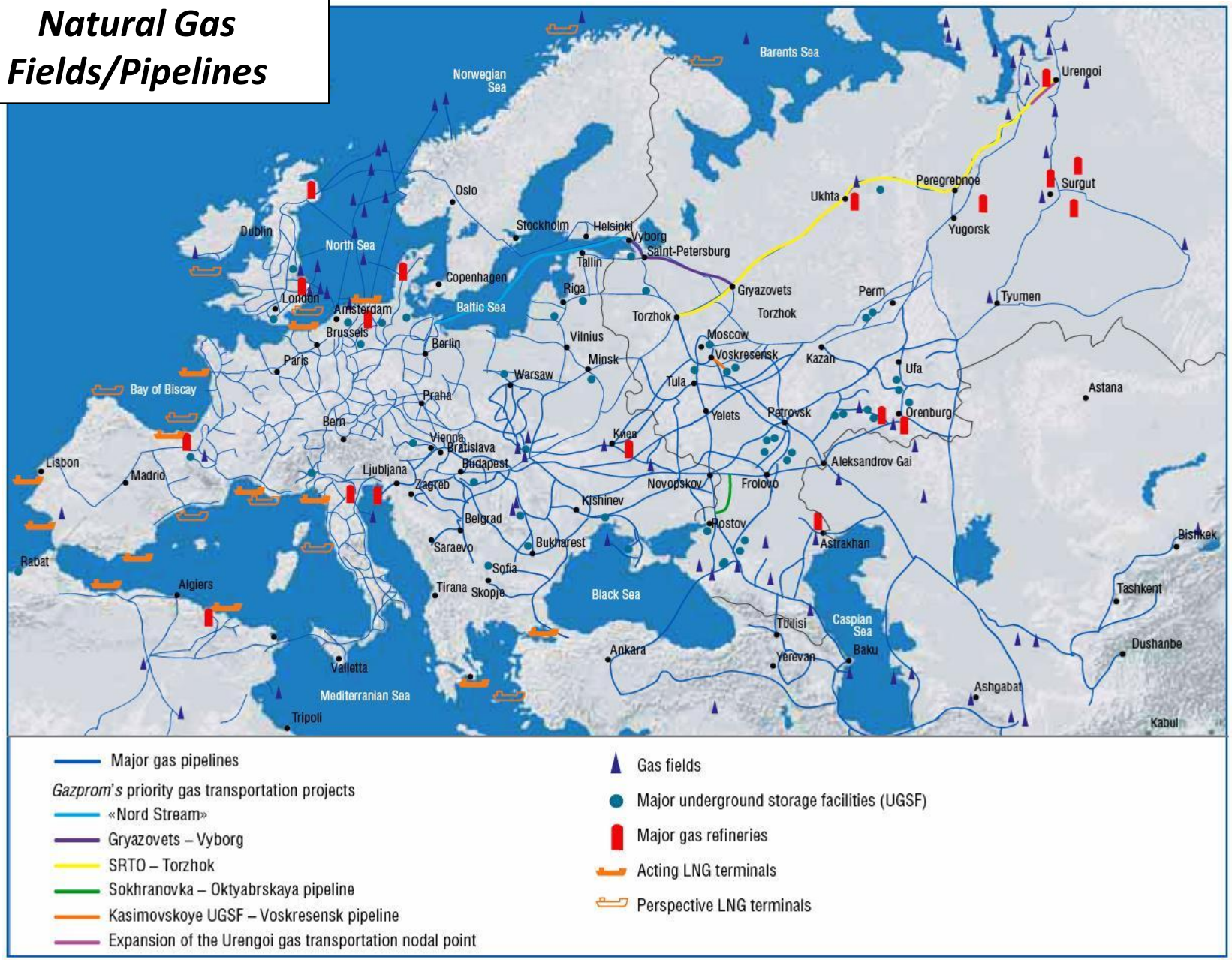
# Europe

***"A Modest Proposal"***

***Design/Deploy a Methane/Electricity ePipe Infrastructure to Socio-economically and Enviro-responsibly service the Emerging Energy Needs of the European Union***

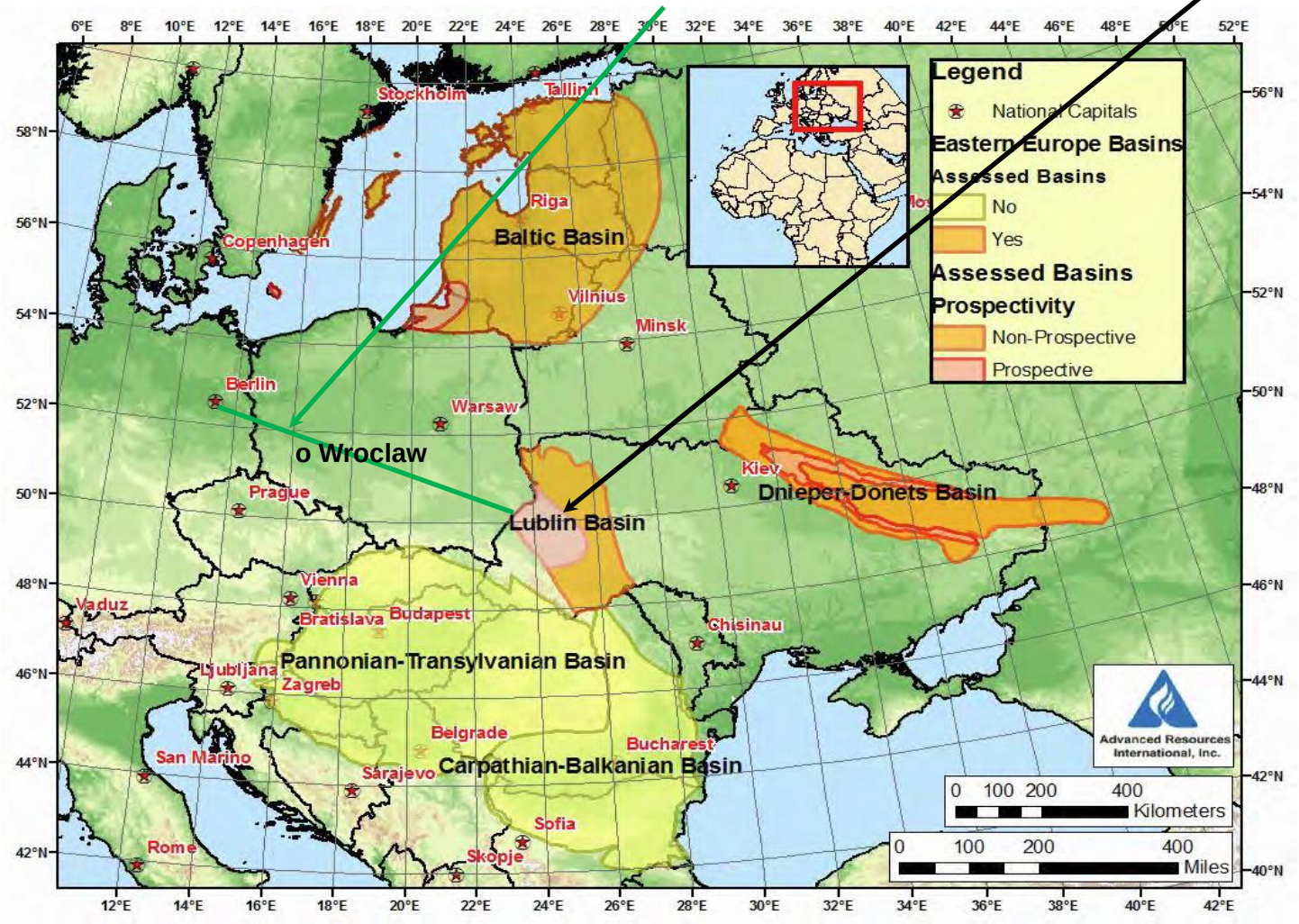
# Where are the Opportunities?

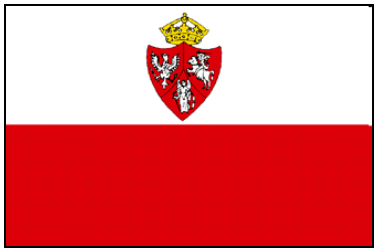
***Current European Natural Gas Fields/Pipelines***



# Scenario I

**The Wola Obszańska (Lublin) gas field in Poland/Ukraine was discovered in 1989. It began production in 1992 and produces natural gas. The total proven reserves of the Wola Obszańska gas field are around 37 billion cubic feet ($1\times10^9 m^3$). "Dual-Pipe" to Berlin?**





# Scenario II

...along the way, there's...

# Krio Odolanow

A hundred kilometres to the north-east of Wroclaw lies KRIO Odolanów, a branch of the Polish Oil and Gas Company, which operates the only installation in Europe for **helium recovery** from natural gas. The technology utilized in KRIO Odolanów is based on cryogenic processes and its two main products are liquid helium and liquefied natural gas.



Low-methane gas purification

Low temperature distillation of natural gas

Helium purification, liquefaction and storage




So, why not extend the "Dual-Pipe" to Brussels? It is the European Union...

# ”Polish-Ukraine-Pipe-Dream” vs. North American MVP Numbers (Natural Gas Delivery Statistics...Sources/Comparisons)*

| Sources | Reserves $10^9$ cu·ft | Reserves Twh | wrt US | wrt MVP |
|---|---|---|---|---|
| US Total | 28,600 | $3.86 \cdot 10^5$ | - | - |
| MVP | 7060 | $9.34 \cdot 10^4$ | 25% | - |
| Lublin** | 37 | $5.00 \cdot 10^2$ | 0.13% | 0.52% |

## Lublin – Berlin Pipeline Corridor “electrons/$CH_4$ Energy Delivery ePipe Split”

| Total Delivered Power (GW) | $CH_4$ Portion (GW) | “electrons” Portion (GW)*** | CCGT efficiency – 50% (GW) | Years Until Exhaustion** |
|---|---|---|---|---|
| 2.5 | 1.0 | 1.0 | 0.5 | 22.3 |

**Scan the QR Codes in Bibliography for the references below...*and then let’s discuss!***

*US-DOE-EIA: http://www.eia.gov/analysis/studies/worldshalegas/ Table I (note only proven reserves data are used, not possible recoverable shale deposits).

**https://en.wikipedia.org/wiki/Wola_Obsza%C5%84ska_gas_field (if nearby Ukrainian are available provable reserves were to be included, perhaps 5 times this number could be realized).

***See EPRI Report WO8065-12, March, 1997 (pdf), EPRI Report 1020458 (pdf), for possible HTSC cable designs.

# Path Forward in the European Union



- **Present and Encourage Consideration/Study of the R-O-W Dual Use Concept by the Following EU Institutions:**
  - European Institute of Innovation & Technology (EIT)
  - European Research Council (ERC)
  - European Executive Agency (REA)
  - Institute for Advanced Sustainability Studies (IASS)

- **Engage/Inform the R&D and Planning Staffs of Major European Gas & Electric Utilities and Their Equipment Suppliers:**
  - Gazprom; RWE; EDF Group (UK & France); E.ON; PGE (Poland)
  - Siemens; BASF; ABB; Nexans; Prysmian Group
  - European Pipeline Group (Ductile Pipes, Valves & Fittings)

- **Engage Major European Technical Universities, Institutes and Companies Focusing on HTSC Power Application Development:**
  - KIT; MPI-Stuttgart; Université Paris-Sud
  - CERN; CNR-INFM
  - Nexans; Columbus Superconductors

- **Initiate, Investigate and Undertake Novel Technologies Relevant to the R-O-W Dual Use Concept:**
  - "Real Time" Recovery of $H_2O$, $CO_2$ from the "Tailpipe Emissions" of Wellhead CCGT Generators for Recycling into Methanol/Ethanol.
  - Conduct Demonstration Projects Exploring the Efficacy of Co-transportation of Chemical and Electrical Power via a L-$H_2$ (or L-$CH_4$) Cooled HTSC "SuperGrid." (Such as the $H_2$ + $MgB_2$ Cable Experiment Reported in Talk 1A-LS-05).
  - Finally, in Anticipation of the Exhaustion in 3-4 Decades of Recoverable Natural Gas Resources Throughout Europe, Explore the Efficacy of Re-using the Now-installed R-O-W Dual Use Delivery Infrastructure by Installing on the Sites of the Depleted Wellheads...

*...the Exploitation of Multi-century Reserves of Recyclable, Reprocessable, Proliferation-safe Thorium-based Nuclear Fission Generation of Electricity Accompanied by Hydrogen Production...aka*

## *"The Energy Amplifier!"*

Energy Amplifier



Stanford (2011)
W2AGZ Technologies

**Grazie Mille!**

# Bibliography

## Author

Paul M. Grant
W2AGZ Technologies

## YouTube

What's Next For Superconductivity?
Physics World interviews Paul Grant

## Smart Grid

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

## Cold Facts

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## Poster PDF

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## EPRI ePipe

EPRI WO8065-12
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## Pipe-to-Power

EPRI TR-104787
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HTSC dc Cable



EPRI 1020458
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Garwin-Matisoo



Garwin-Matisoo IEEE
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HTSC Power Apps



Wroclaw (2010)
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Cryo-Delivery



Co-Transmission (2006)
W2AGZ Technologies

Shale Gas Reserves



EIA Shale Data (2013)

Lublin Gas Fields



Wola Wikipedia

Energy Amplifier



Stanford (2011)
W2AGZ Technologies