

# Global Climate Change

## *What Role can Superconductivity Play?*

*Reflections Drawn from the 2007 Energy Modeling Forum*

*23 July - 3 August 2007, Snowmass, CO*

**Paul M. Grant**

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Principal, W2AGZ Technologies

2007 DOE Superconductivity Program Peer Review

Crystal City, VA

7 - 9 August 2007

<http://www.w2agz.com>

<http://www.w2agz.com/pes07.htm>



Oglethorpe IEEE-  
PES/AEI Course



Plain Talk about the Electric Power System for the Non-Power Engineering Professional

23 - 25 January 2007

Oglethorpe Power Corporation, Tucker, GA

Sponsored by the IEEE Power Engineering Society and the American Education Institute ([link](#) to course home page)

Advanced Transmission Technologies ([pdf](#), [ppt](#))

Paul M. Grant

[W2AGZ Technologies](#)

(Introduction by T. R. Schneider) ([pdf](#), [ppt](#))

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[Course Background Material](#)

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# Energy Modeling Forum

## *Potential Transformations Through Science*

Snowmass, CO


23 July - 3 August 2007

- Organizers
  - Bob Vallario (DOE BES)
  - John Weyant (EMF Director, Stanford)
- Major Participants
  - Bill Nordhaus (Yale)
  - Naki Nakicenovic (IIASA, Vienna)
  - Chris Green (McGill)
  - Nate Lewis\* (CalTech)
  - Tom Wilbanks (ORNL)
  - Bob Rosner\* (ANL)
  - Paco de la Chesnaye (EPA)
  - Rich Richels (EPRI)
  - Jim Sweeney (Stanford)
  - Brian Flannery (Exxon – Mobile)
  - Paul Grant\* (Stanford, W2AGZ Technologies)


\**Physicist*



# 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.

Published in  
**SCIENTIFIC  
AMERICAN**  
July, 2006

# Chauncey Starr 1912 - 2007



*Obituary, Nature, 14 June 2007*

# GCC: Jargon & Glossary

- IPCC: *Intergovernmental Panel on Climate Change*
  - Organized into disciplinary Working Groups (WGs) which periodically review extant peer-reviewed scientific and economic literature (both anecdotal and models).
  - Issues an “unanimous” interdisciplinary report intended to provide guidance to policy makers, particularly regarding mitigation issues and directions.
- CCIAV: *Climate Change Impacts, Adaptation and Vulnerability*
  - An ad hoc community of scholars which addresses a broader portfolio of issues not taken up (so far) by the IPCC which relate to “fallout” from global warming.
  - One of the approaches undertaken by the CCIAV community is Integrated Assessment Modeling (IAM), which addresses various GCC scenarios attempting to assess the interplay between mitigation, impact and adaptation.

# An Inconvenient Truth







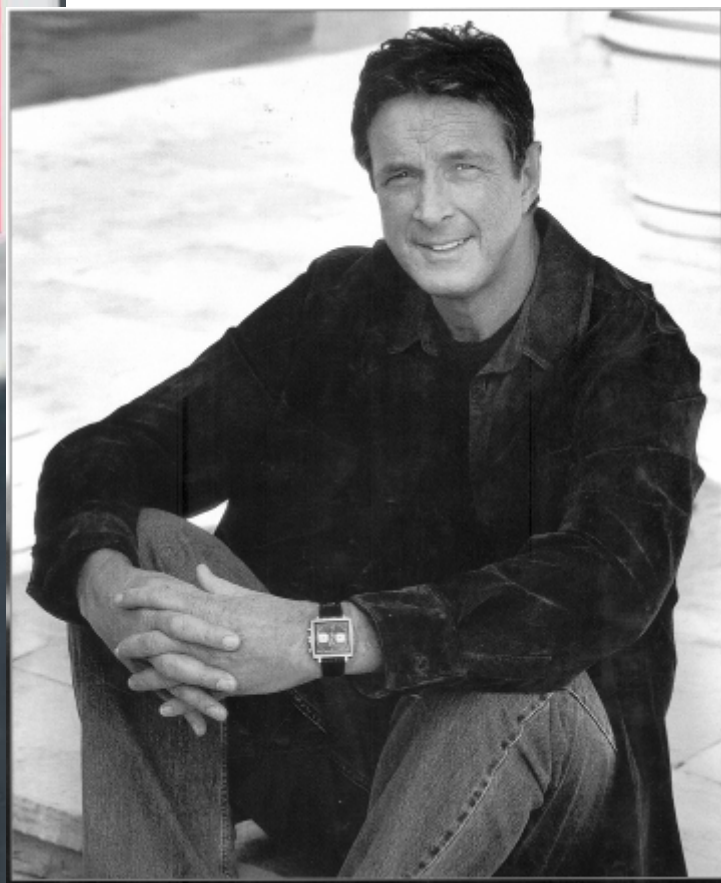
# The Day After Tomorrow





**MICHAEL  
CRICHTON**

**STATE OF FEAR**



# “Expert Opinion”

- Nate Lewis
  - Mitigation is more or less hopeless without massive skewing of the “laws of economics” through government intervention
- Bill Nordhaus
  - By 2100, the global economy will be rich enough to afford adapting to 500-600 ppm CO<sub>2</sub>
- Fred Singer
  - No problem (GCC is good for you...)
- William Ruddiman
  - Invention of agriculture 8000 years ago and subsequent methane emissions saved the planet from undergoing a “scheduled cyclic ice age.”
- Jesse Ausubel
  - To propose significant deployment of renewables is a “heresy.”
- Sean Hannity
  - It’s all due to Al Gore, Sean Penn and Leonardo DiCaprio flying around in private jets.

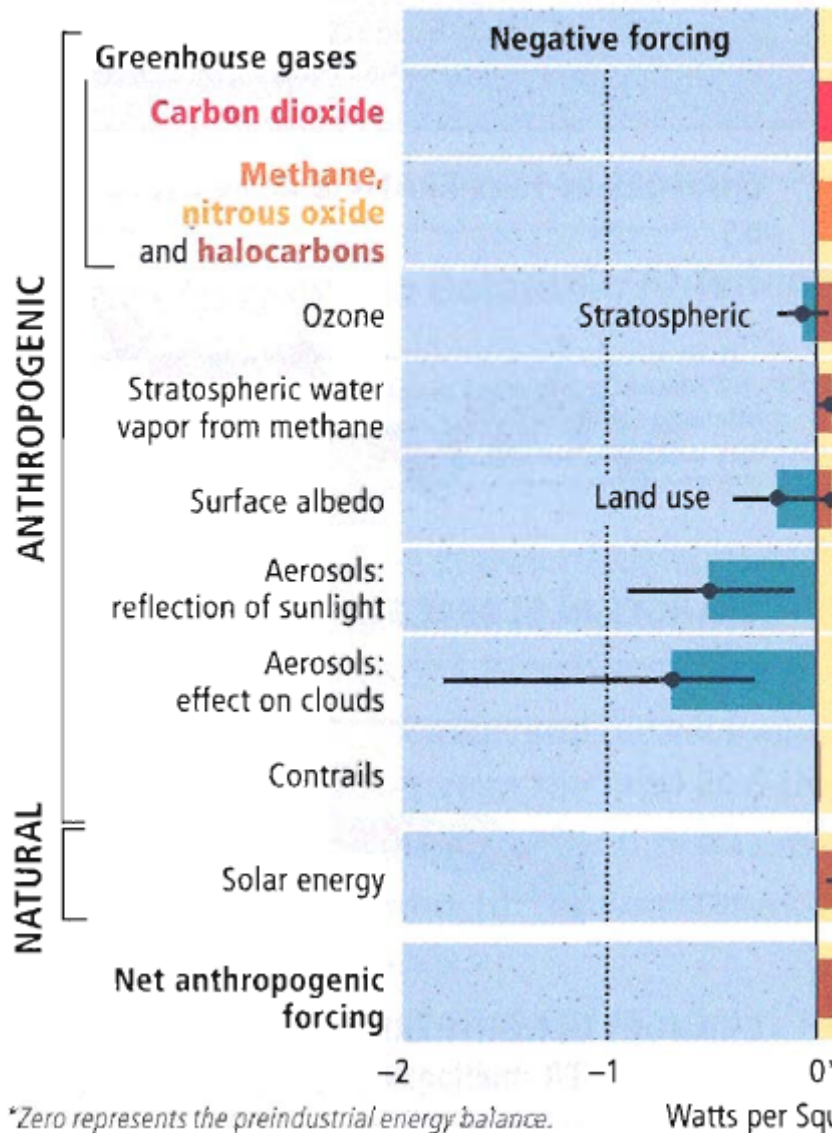
# “Greenhouse Gases”



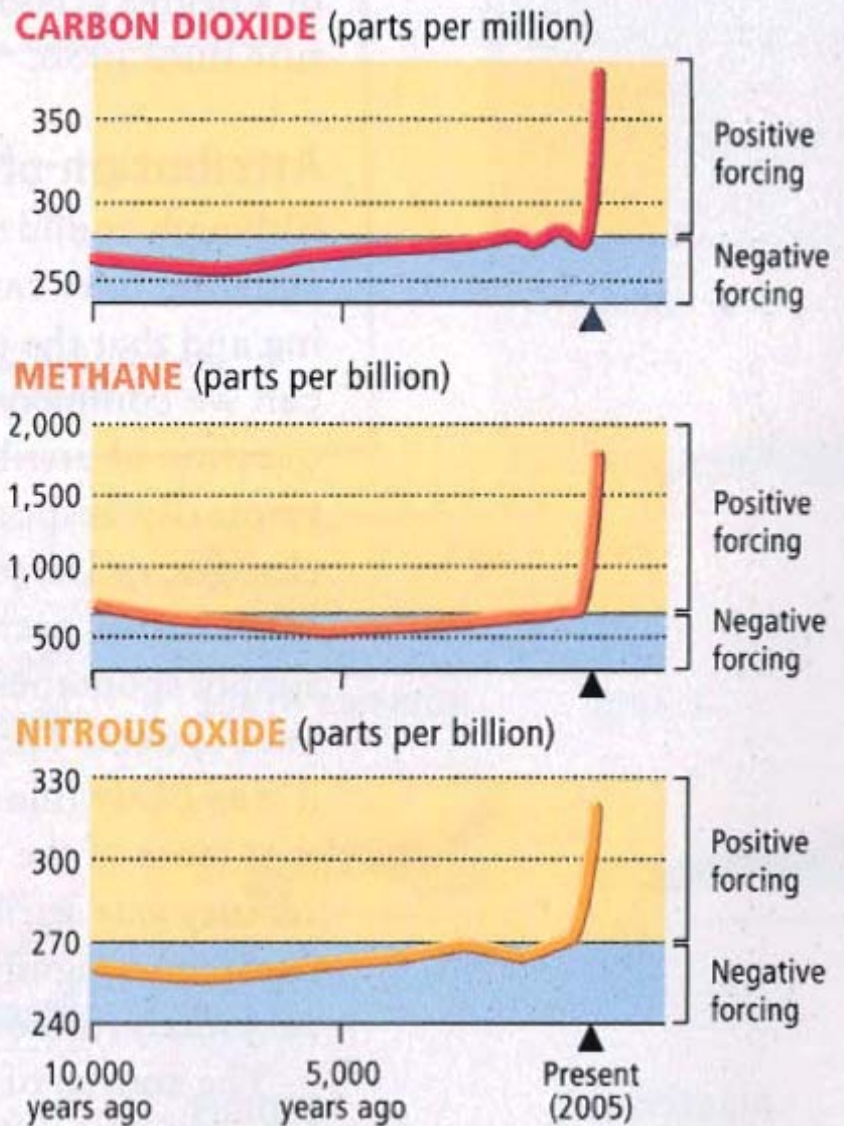


# SciAm – August, 2007 Issue

## Radiative Forcing: The Overview



## Greenhouse Gases: The Major Forcings



# Bob Laughlin's "Theory of Everything" (that's important!)

Theory of Everything

$$\mathcal{H} = - \sum_j \frac{\hbar^2}{2m} \nabla_j^2 - \sum_a \frac{\hbar^2}{2M_a} \nabla_a^2 - \sum_{j,k} \frac{Z_a Z_b e^2}{|r_j - r_k|} + \sum_{j,k} \frac{e^2}{|r_j - r_k|} + \sum_{\alpha\beta} \frac{Z_\alpha Z_\beta e^2}{|R_\alpha - R_\beta|}$$

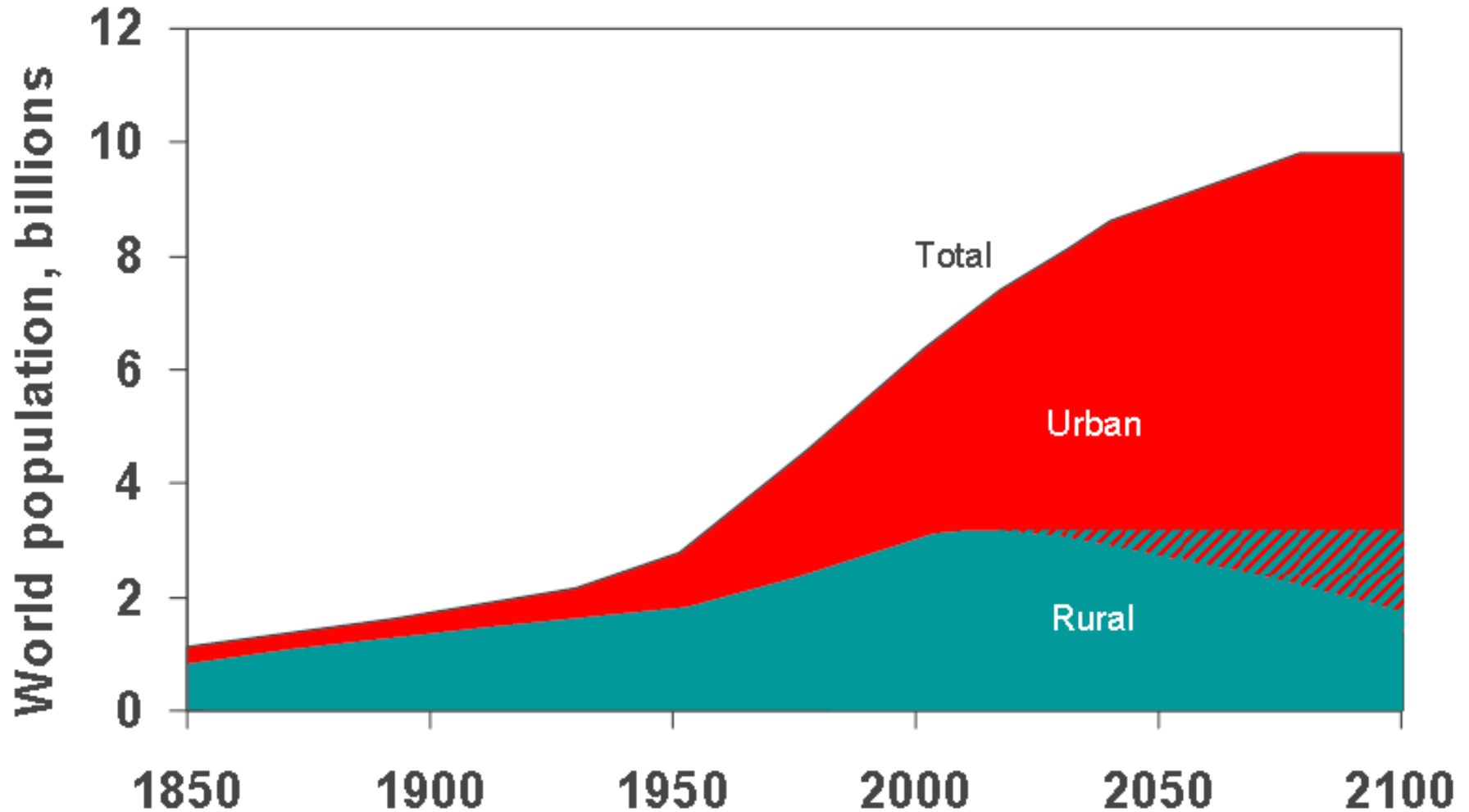
- 3 -> 10<sup>2</sup>
  - Chemistry
- 10<sup>2</sup> <-> 10<sup>3</sup>
  - Thermodynamics
- 10<sup>3</sup> <-> 10<sup>10</sup>
  - Cooperative Phenomena
- 10<sup>10</sup> <-> 10<sup>20</sup>
  - Emergent Behavior (Us)

- |                    |                 |                 |
|--------------------|-----------------|-----------------|
| • Hydrogen atom    | • Proteins      | • Flowers       |
| • Methane molecule | • DNA           | • Trees         |
| • water            | • Viruses       | • Cars          |
| • Air              | • Bacteria      | • Cheese        |
| • Rocks            | • Yeast         | • Sauce Bernais |
| • Concrete         | • Slime mold    | • Computers     |
| • Steel            | • Butterflies   | • Television    |
| • Glass            | • Sharks        | • Cars          |
| • Plastic          | • Rats          | • Jets          |
| • Buildings        | • Lawyers       | • Lawnmowers    |
| • Cities           | • Ebola virus   | • Sewage        |
| • Continents       | • Legislatures  | • Spotted Oats  |
|                    | • Civilizations | ...             |



- > 10<sup>20</sup>
  - CLIMATE !
- **SIZE MATTERS !**

# World Population: 1850 - 2100



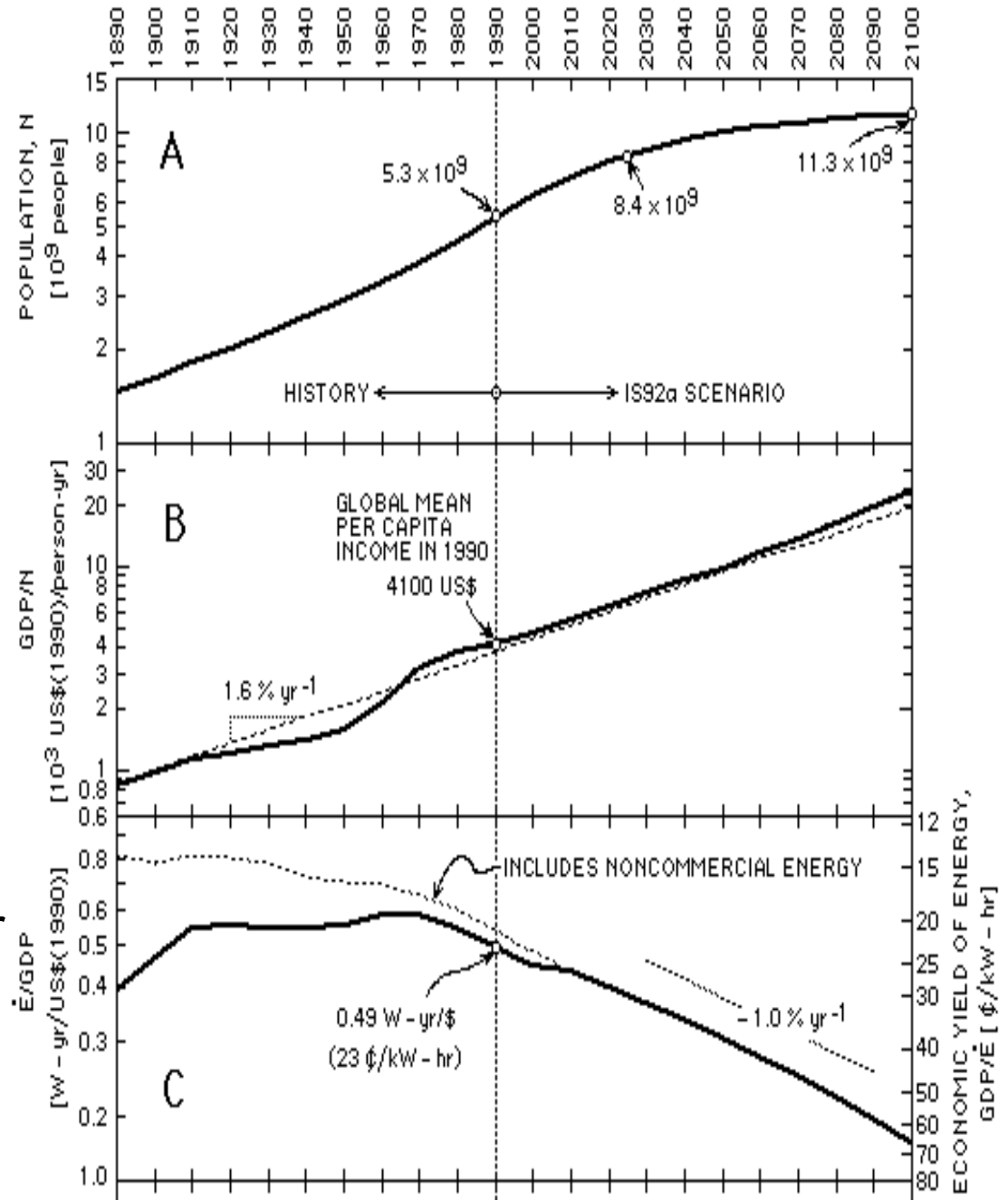
From Global Energy  
Perspective – 2007

Nate Lewis, Cal Tech

Population Growth to  
10 - 11 Billion  
People in 2050

Per Capita GDP Growth  
at 1.6% yr<sup>-1</sup>

Energy consumption per  
Unit of GDP declines  
at 1.0% yr<sup>-1</sup>

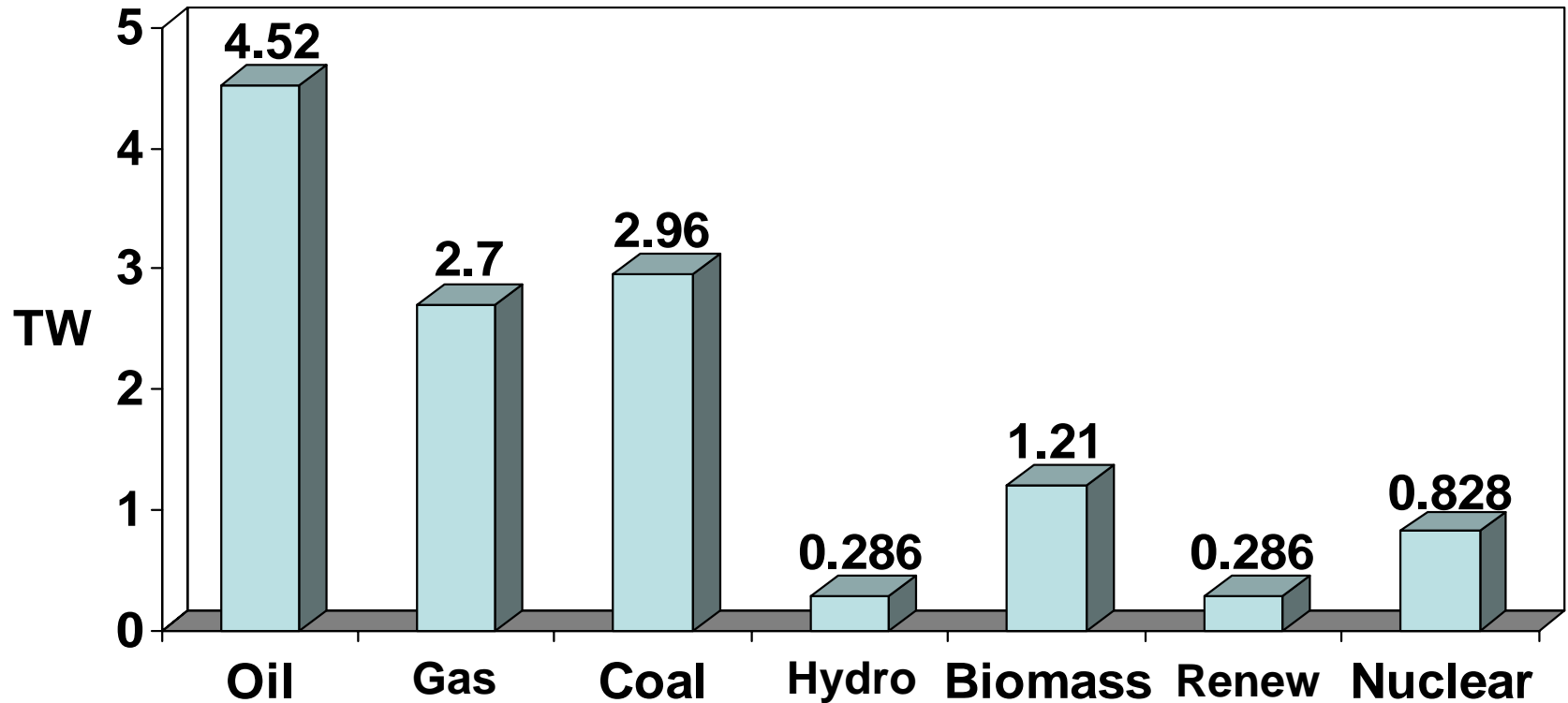




# Enfranchisement of Women



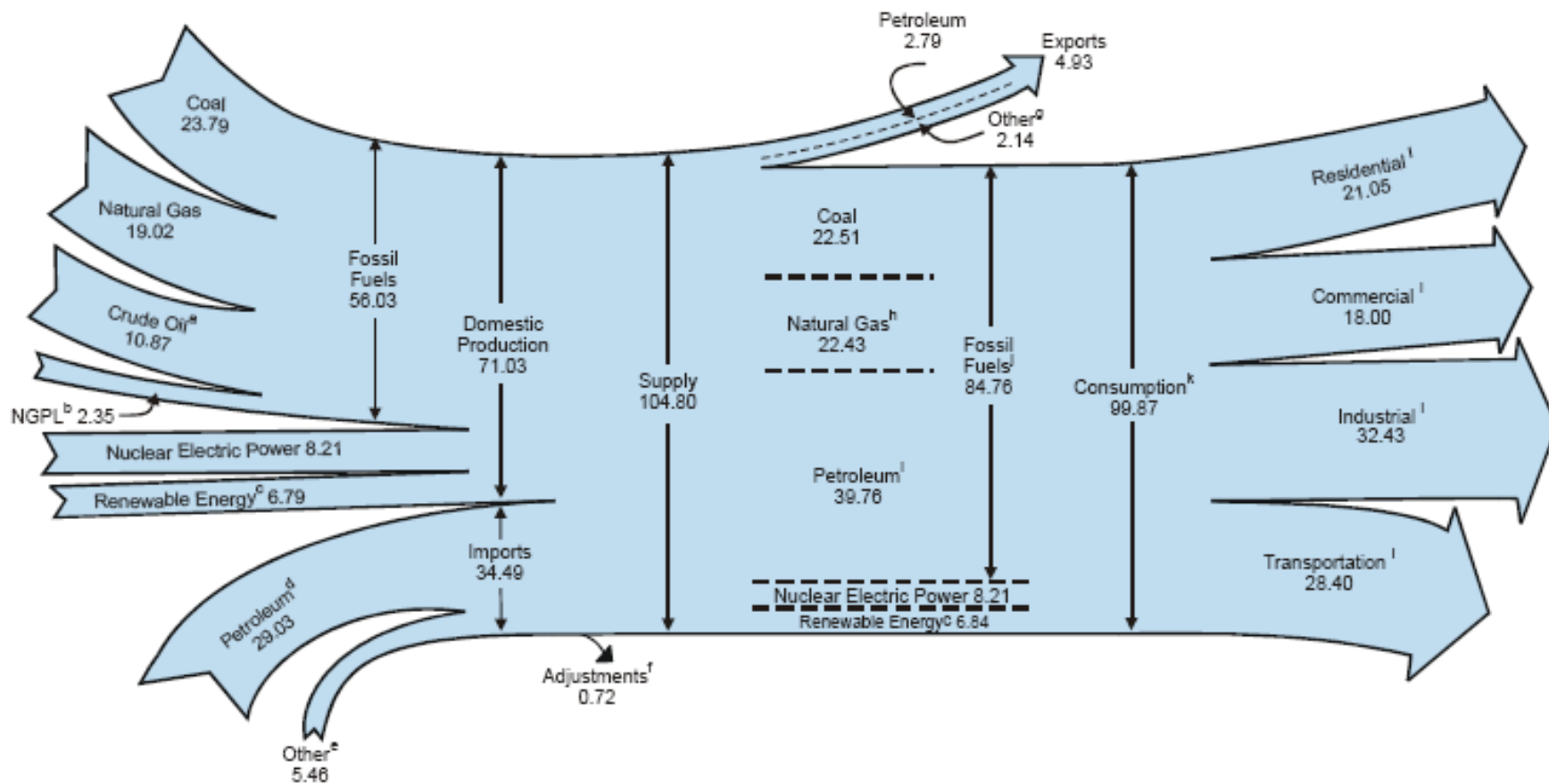
# Mean Global Energy Consumption 1998



Global Total: 12.8 TW

US: 3.3 TW (99 Quads)  
**(1 TW Electricity)**

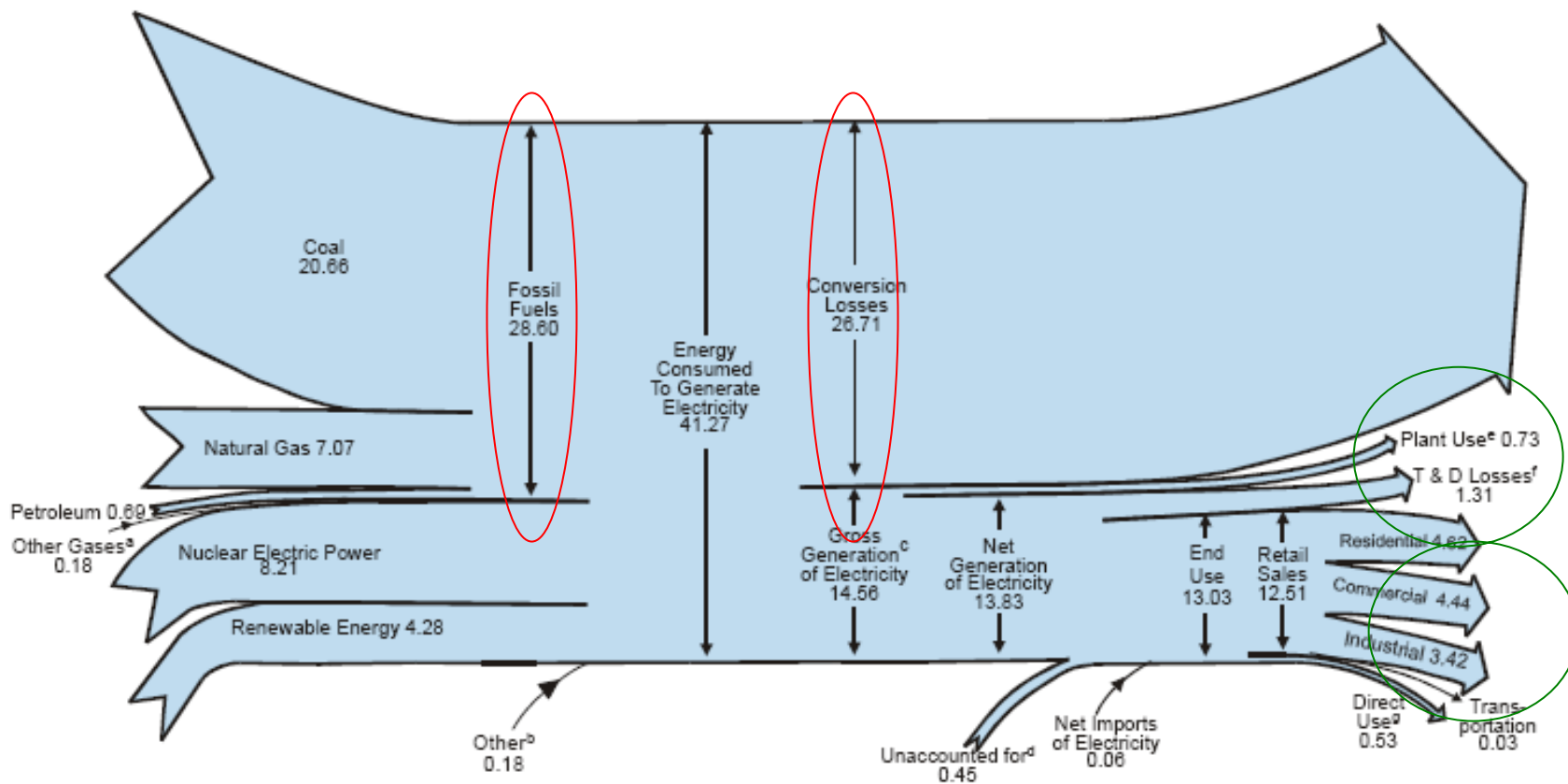
**Diagram 1. Energy Flow, 2006**  
(Quadrillion Btu)



# The Trioka Challenge of GCC

- Mitigation
  - If GCC is principally CO<sub>2</sub> emissions-driven:
    - How do we stop or stabilize them?
    - Can we stop or stabilize them?
    - *Does superconductivity have a role?*
- Impact
  - In any event, heat already stored in the oceans will continue to warm the planet?
  - What impact will this have on the human condition?
    - Massive redistribution of land and water resources?
- Adaptation
  - Since continuing warming is inevitable, what technologies need to be developed to ameliorate its impact?
    - *Does superconductivity have a role?*

**Diagram 5. Electricity Flow, 2006**  
(Quadrillion Btu)



# Mitigation

- SuperGrid
  - Nuclear
  - Hydrogen
  - Superconductivity (efficiency!)
- DOE PR 1997
  - Transmission savings
  - Rotating machinery
  - Transformers

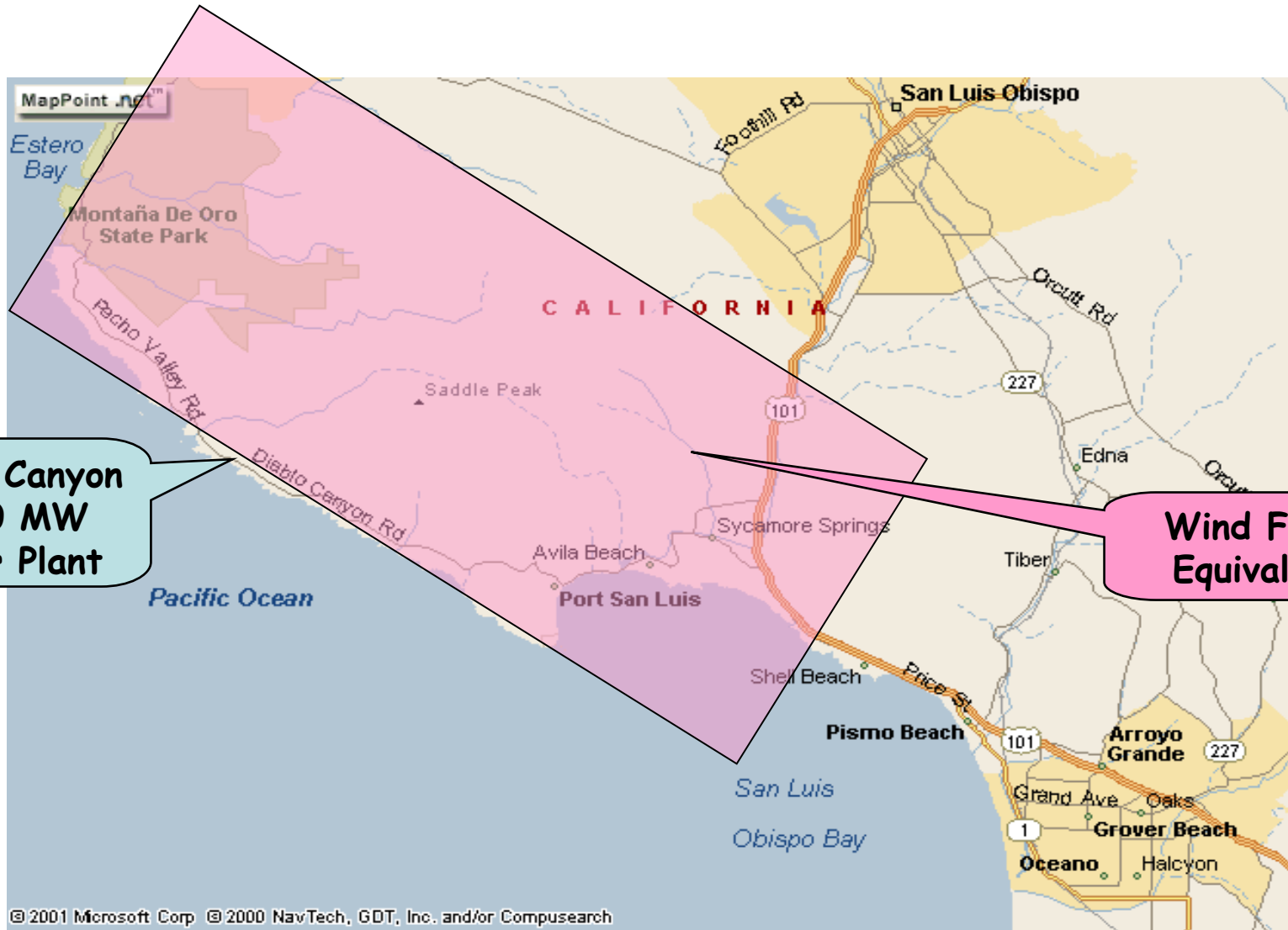


# Diablo Canyon





# California Coast Power



**Diablo Canyon  
2200 MW  
Power Plant**

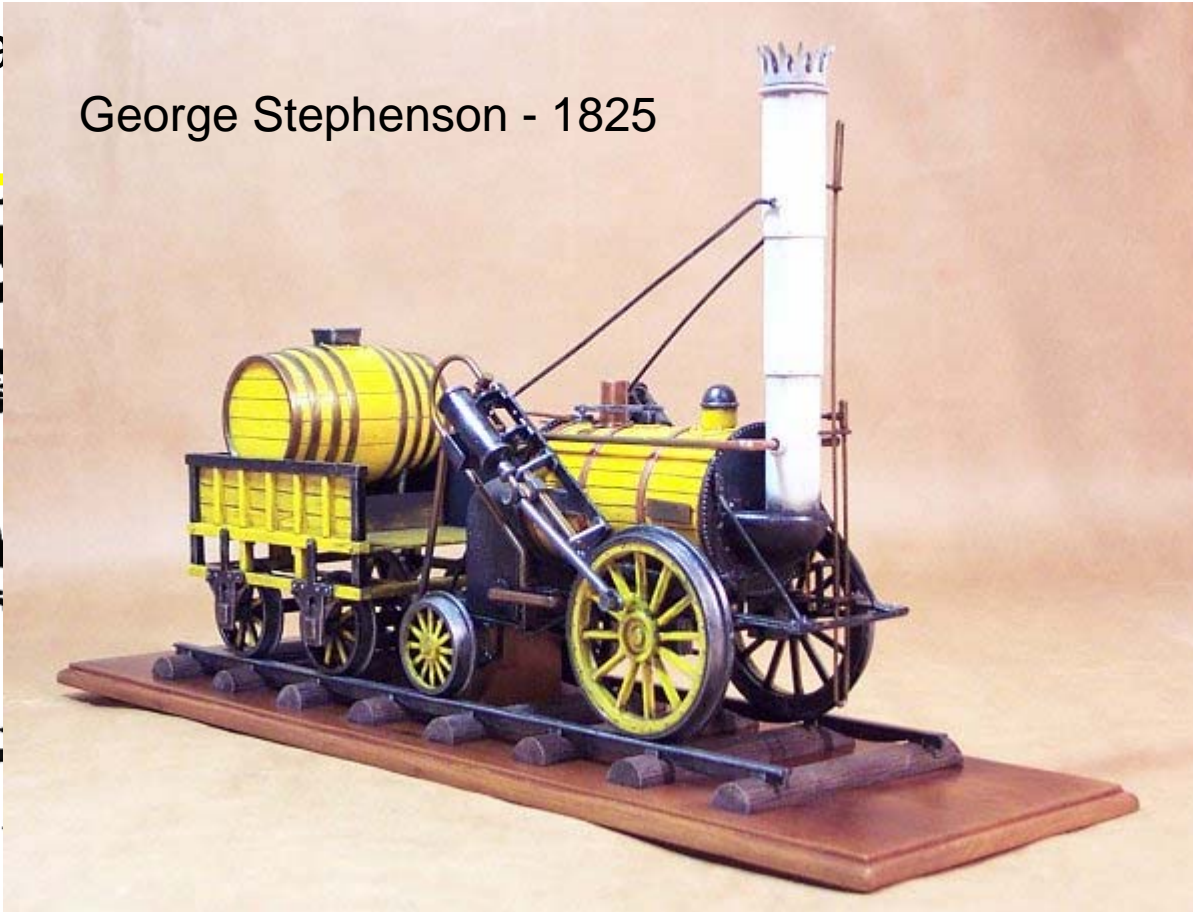
**Wind Farm  
Equivalent**

# Vision of a Sailing Railway

Monorail

in 1828

George Stephenson - 1825



Source: Marshall, 1938

# U.S. Electricity Production/Loss Summary

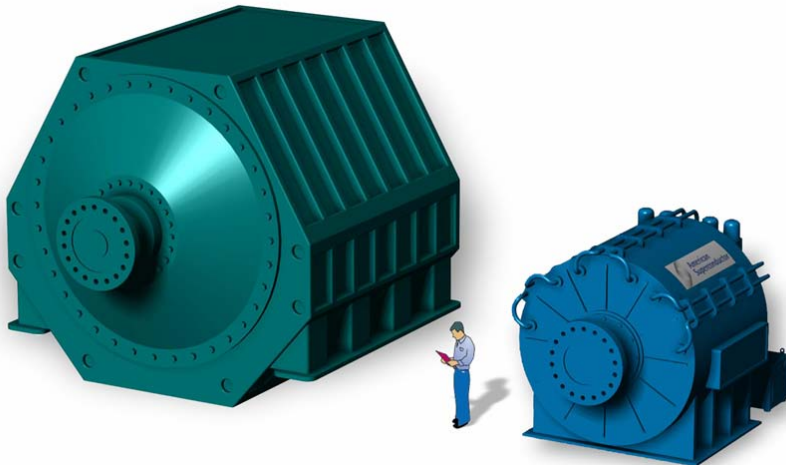
	<b>TkWh</b>	<b>% in T&amp;D Loss and In-Plant Use</b>	<b>Revenue @ \$0.10/kWh (B\$)</b>	<b>No. of 500 MW Power Plant Equivalents</b>	<b>Capital Cost @ \$800/kW (B\$)</b>
<b>Total</b>	<b>3.24</b>		<b>324</b>	<b>740</b>	<b>296</b>
<b>T&amp;D Losses</b>	<b>0.28</b>	<b>8%</b>	<b>28</b>	<b>63</b>	<b>25</b>
<b>In-Plant Used</b>	<b>0.15</b>	<b>5%</b>	<b>15</b>	<b>35</b>	<b>14</b>

# Superconductivity and T&D Efficiency

	<b>1994</b>	<b>2014 @ 2%/yr</b>	<b>2014 Plants Saved 0.2% Penetration 4× Efficiency</b>
<b>Total</b>	<b>740</b>	<b>360</b>	
<b>T&amp;D Losses</b>	<b>63</b>	<b>31</b>	<b>11</b>
<b>In-House Use</b>	<b>35</b>	<b>17</b>	<b>6</b>

# Superconductivity and End Use Efficiency

- US Dispatchable Generation Capacity ~ 1 TW
- ~ 20% Goes To Large Motors > 1000 hp
- Superconductivity increases efficiency roughly 4% from 92 – 96
- Savings ~ 8 GW or emissions from 16 fossil plants



- Can be simply implemented through building code revision

# Impact

- Sell your Florida beachfront
- Put a levee around the White House
- Boon for Mexico and Africa
- Global redistribution of water and temperature
  - ...but we won't know the details until it happens!





**SCENARIO 1**  
Low emissions

2020–2029



2090–2099

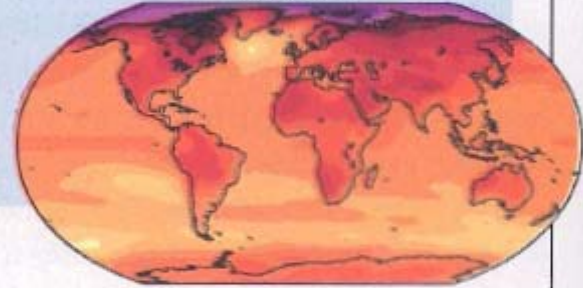


**SCENARIO 2**  
Moderate emissions

2020–2029



2090–2099

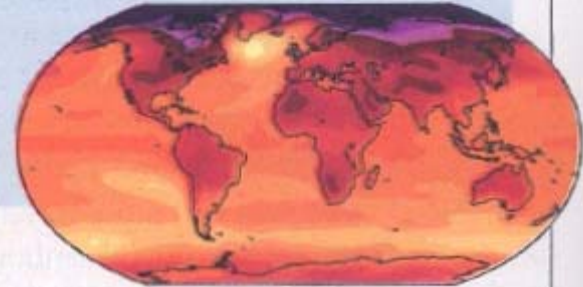


**SCENARIO 3**  
High emissions

2020–2029



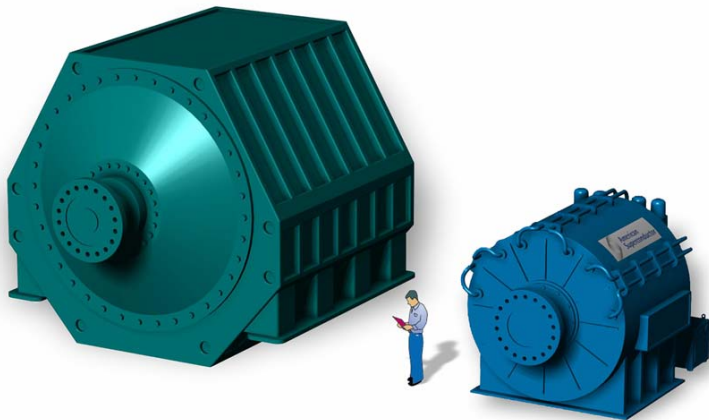
2090–2099





# Adaptation and Superconductivity

- Highly efficient “motors” for “moving” water
  - Models predict large distances between water reserves and agricultural and urban end use.
  - Likely to have “Venice-like” or “new New Orleans” mega-urban centers requiring continuous removal of seepage.



- “Red October” superconducting magnetohydrodynamic pumps.

# Road to Room Temperature Superconductivity

Loen, Norway, July 2007

- Weinstock, Barnes, Gurevitch, Grant
- Possible, but don't hold your breath
- RTSC would enable the hydrogen economy and hybrid vehicles

“You can’t always get what you want...”



“...you get what you need!”

