MEETING UNITED STATES NATIONAL ENERGY DEMANDS

A Brief Review of the Magnitude of the Challenge

By

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PERSONAL THOUGHTS OF THE AUTHOR

- This Work Presents Personal Thoughts Of The Author
- Data Presented Is Based On Published Objective Evidence
- Opinions Presented Are The Subjective Thoughts Of The Author
- Attempted To Provide Comparative Examples To Provocatively Demonstrate The Magnitude Of The Challenge
- No Solutions Proposed – If I Could Do That, I Would Be Making Hotel Reservations In Stockholm!

NATIONAL ENERGY DEMAND

- Total Annual Energy Consumed Nationally
- Includes All Significant Energy Feed Stocks

Until late 1950,

the United States Was

Energy Self-Sufficient

- Can This Be Again Achieved?

SYSTEM APPROACH NEEDED

- The “Big Picture” Not Really Considered
- Single Sectors Targeted
  - Transportation
  - Residential – Heating
  - Power Grid
- A True “System-Level” Approach Needed to Competently Meet Sustainable Long-Term National Energy Demands

BASIC US ENERGY DEMAND

- Fuel Demands
  - Transportation
  - Residential
  - Commercial
  - Industrial
- Non-Fuel Demands
  - Product Feedstock – Plastics, Paint, Pharmaceuticals
  - Solvents, Industrial Chemicals
- Energy Production Losses

DATA SOURCES

- National Renewable Energy Laboratory
- Annual Energy Review 2005
- Energy Information Administration
- Federal Energy Regulatory Commission
- Lawrence Livermore National Laboratories
- US Army Corps Of Engineers

➢ Historical Information Somewhat Inconsistent

ENERGY DEMAND DEFINED

- Power
  - You are more likely to see national energy demand expressed in units of power rather than energy – Watts, Kilowatts, etc.
- Energy
  - Energy is power consumed integrated over some period – Watt-Seconds = Joules
  - Annual national energy demand is the national power consumption integrated over a year

UNITS OF ENERGY DEMAND

- The Correct Energy Units to Apply Are The Joule or BTU
- An Instantaneous Energy Demand Is The Power Demand At That Instant
  - Joules/Second = Watts
  - Defines The Power Capacity Required
- National Energy Demand Is Most Appropriately Expressed In Units Of Energy Consumed Over Some Period

METRIC OF ENERGY DEMAND

- QUAD – Quadrillion BTU (10^{15} BTU)
- EXAJOULE – 10^{18} Joules
- 1 Quad = 1.055 Exajoule
- In 2005, The National Energy Demand Was 111EJ or 105 Quads

FOSSIL FUELS

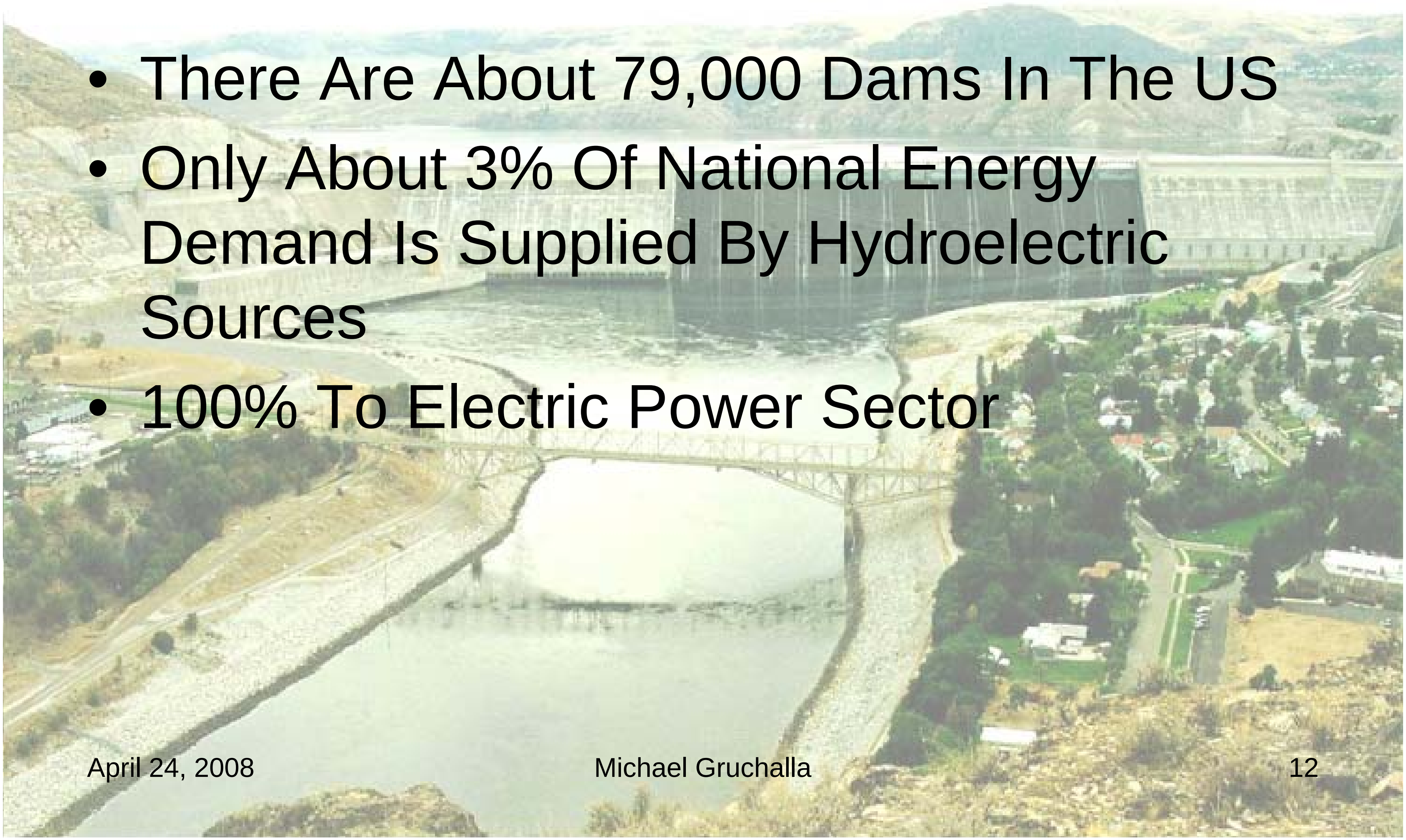
- Petroleum
  - 40% Of Annual National Energy Supply
  - 62% Imported And ~5% *Exported*
  - 65% Consumed In Transportation Sector
- Natural Gas
  - 24% Of Annual National Energy Supply
  - 16% Imported
  - 70% To Residential, Commercial And Industrial Sectors

FOSSIL FUELS

- Coal
  - 23% Of Annual National Energy Supply
  - 2% Imported – Almost Totally Domestic Supply
  - 87% To The Electric Power Sector
  - One Unit Train
    - ~100 Each 100-Ton Hopper Cars
    - Will Supply A 1,000MW Generating Unit For About One Day
      - ~0.4 Tons/hr Per MW Generated

HYDROELECTRIC

- There Are About 79,000 Dams In The US
- Only About 3% Of National Energy Demand Is Supplied By Hydroelectric Sources
- 100% To Electric Power Sector



NUCLEAR

- July 17, 1955 – First Commercial Nuclear Electric Power Delivered – Arco, Idaho
- December 2, 1957 – First Full-Scale Nuclear Power Plant Begins Service – Shippingport, Pennsylvania
- No New Orders For A Nuclear Power Plant Have Been Placed Since Mid 1970
- May 1996 – Last Nuclear Power Plant Goes On-Line
- June 23, 2006 – NRC Issues First License For A Major Nuclear Facility In 30 Years
  - A Commercial Uranium Enrichment Facility Located At Eunice, New Mexico
  - To Supply Feed Stock For Nuclear Power Industry

NUCLEAR

- A Total Of 104 Operational Nuclear Power Plants In The US
  - 69 Pressurized Water – 65,100MW
  - 35 Boiling Water – 32,300MW
- About 8% Of Nation Energy Demand Provided by Nuclear Plants
- 100% To Electric Power Sector
- ~1,000 New Nuclear Plants Would Be Required To Supply 80% Of The National Energy Demand
- ~100 New Plants Would Be Required To Supply Only An Additional 8% Of The National Energy Demand

SOLAR

- Insolation ~ $1kW/m^2 = 100mW/cm^2$
- Realized Collection ~$10\ mW/cm^2$
- Average Annual Integrated Insolation Over The Entire Centennial US Is ~$5.5kW\text{-}hr/m^2$/Day
- Insignificant Contributions to Present National Energy Demand

WIND

- Wind Turbines >4MW Units Commercially Available
- Reliability Issues
- Inability To Store Off-Peak Energy
- Insignificant Contributions to Present National Energy Demand

GEOTHERMAL

- Geothermal Research Has Not Produced Optimistic Results To Date
- Environmental Impact – Could Extracting Geothermal Energy Actually Result In Cooling Of The Earth’s Core?
- Insignificant Contributions to Present National Energy Demand

BIOMASS

- There Are Effectively No Operational Biomass Energy-Supply Systems Of Significance
- Considerable Research
  - Biodiesel – BioWillie
  - Residue Harvesting
  - Almost Any Plant-Derived Biological Waste Can Be Used As A Feedstock
- Insignificant Contributions to Present National Energy Demand

BIOLOGICAL

- Power-Plant Feed-Stocks
  - Wood
  - Methane
- Fuels
  - Ethanol
  - Methane
- Sources
  - Corn/Maize
  - Milo (Grain Sorghum)
  - Sugar Cane/Sugar Beet – Brazil Has Just Declared It Is Energy Self-Sufficient Through A Nationally-Mandated Ethanol Initiative To Manufacture Ethanol From Sugar Cane

ALTERNATIVE-ENERGY CONTRIBUTIONS

- Wood, Energy-Producing Waste, Alcohols, Geothermal, Solar and Wind
- All Alternative Sources Combined Contribute About 4% Of Total National Energy Demand
- Although A Small Contribution, It Is Greater Than The Hydroelectric Contribution And About One-Half The Nuclear Contribution

ENERGY PRODUCTION LOSES

- Almost All National Energy Production and Energy Conversion Is By Means Of Heat Engines
  - Steam turbines
  - Automobiles
- Carnot Cycle – Best Possible Heat Engine Efficiency
  - ~70% For T_{max} = 1000°K and T_{min} = 300°K
  - ~40% Actual Achieved – Steam Turbine
  - Automobile ~8% Efficient

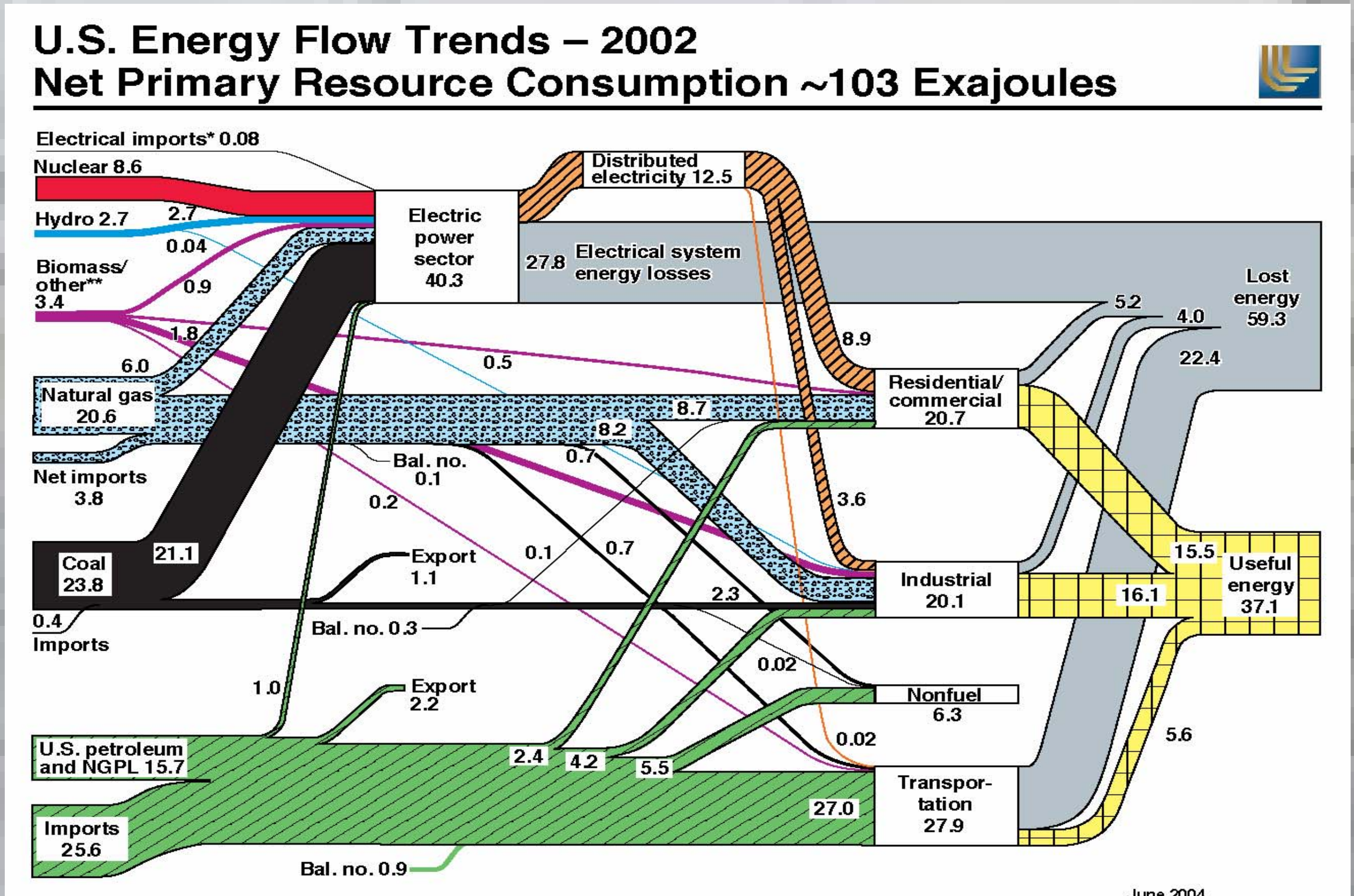
ENERGY PRODUCTION LOSES

- At Least 62% Of The Total Energy Input Into The National Energy Supply System Is Wasted As Lost Heat
- In The Case Of An Automobile, Of Every $1 In Fuel Purchased, ~$0.08 Is Used To Propel The Vehicle, And $0.92 Is Discarded As Heat

FUEL COMPARISONS

- 1kg Coal $\Rightarrow$ ~3kW-hr Generated
- 1kg Oil $\Rightarrow$ ~4kW-hr Generated
- 1kg Uranium $\Rightarrow$ ~7,000kW-hr Generated
- All These Use A Carnot Generating Cycle
  - ~2/3 Of Energy Available In The Fuel Is Lost As Heat

US ENERGY FLOW



Source: Production and end-use data from Energy Information Administration, *Annual Energy Review 2002.*
*Net fossil-fuel electrical imports.
**Biomass/other includes wood, waste, alcohol, geothermal, solar, and wind.

June 2004
Lawrence Livermore National Laboratory
http://eed.llnl.gov/flow

THREATS TO NATIONAL ENERGY SUPPLY

- Natural Disasters
  - Hurricanes – Katrina
  - Earthquakes – California
  - Mt. St. Helens
- Human Error
  - Three-Mile Island
- Equipment Failure
  - Blackout Of 1965 – Classic Cascade Failure
    - Single Relay Failure In Sir Adam Beck Station No. 2
    - 80,000 Square Miles Affected
    - 30 Million Souls Affected

THREATS TO NATIONAL ENERGY SUPPLY

- Vandalism
- Political Instability
- Terrorism
- Profit Incentives
  - Foreign – House Of Saud – OPEC
  - Domestic – Export Of US Resources
- Emerging Nations
  - China
  - European Union
- **GLOBALIZATION**

GLOBALIZATION

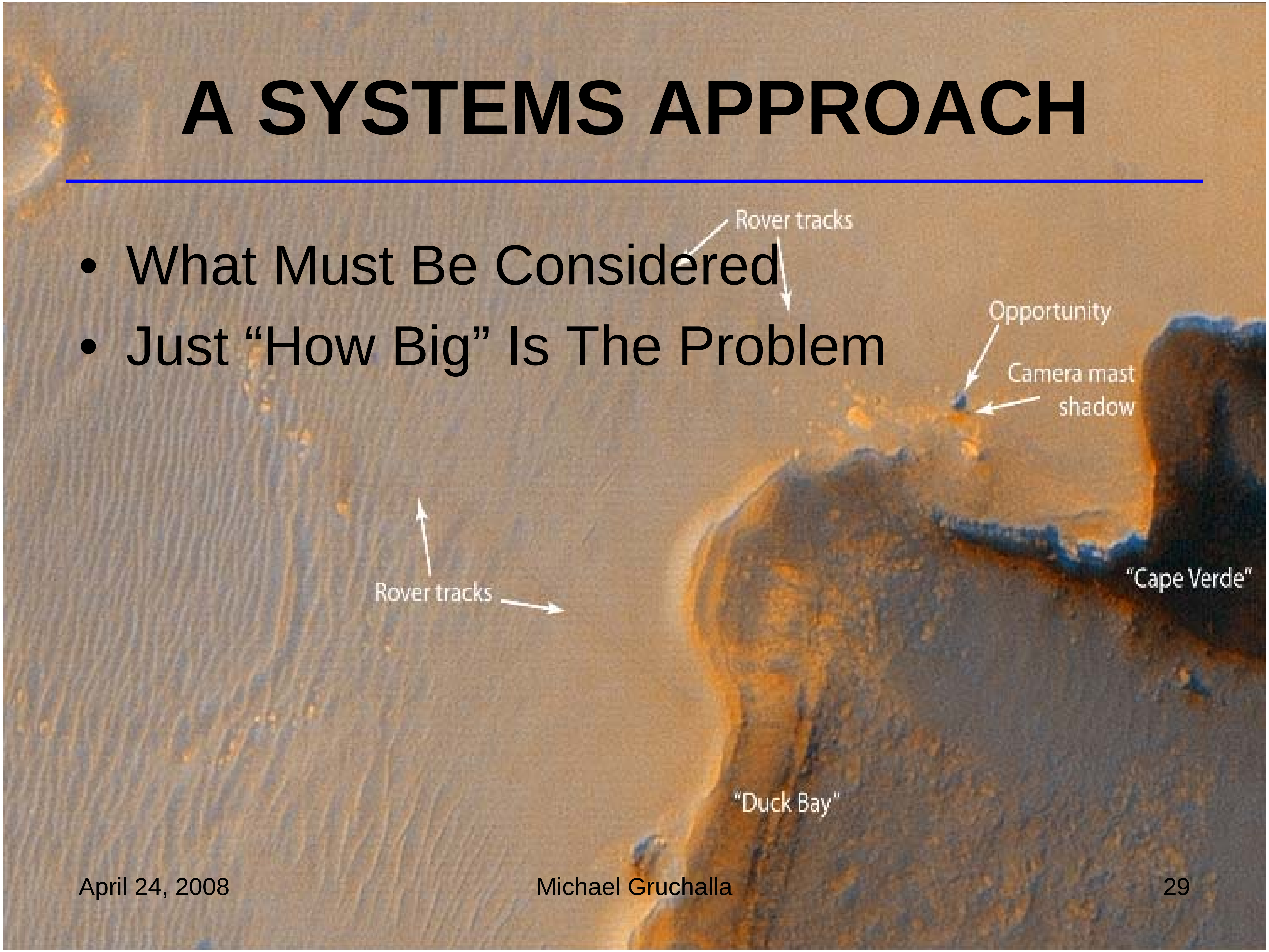
- If New And Substantial Domestic Oil and Gas Reserves Are Discovered, Why Would A Commercial Energy Company Market Those Products Domestically If Those Products Could Be Marketed At A Higher Price Globally?
  – Valle Vidal, New Mexico
  – Otero Mesa, New Mexico
  – Padre Island, Texas
  – ANWR, Alaska

NATIONALIZATION

- Bring All US Energy Production Under Federal Government Ownership
- Would Represent A Very Provocative And Substantial Expansion Of Central-Government Control In The US
- If The Energy Companies Are Nationalized, Can The Government Supply Energy As Efficiently As Private Companies?
- Would There Be Any Means Of Accountability?
  - Internal Revenue Service
  - Judicial System
- An Irreversible Decision

A SYSTEMS APPROACH

- What Must Be Considered
- Just “How Big” Is The Problem



SOME SYSTEM-LEVEL ISSUES

- Reliable/Renewable Domestic Feed Stocks
- Feed-Stock Delivery
- Fuel Manufacturing
- Fuel Delivery
- Fuel Thermodynamic Conversion Efficiency
- Energy-Production Waste Stream
- Atmospheric Carbon Loading And Carbon Balance

HOW BIG IS THE PROBLEM

- Consider That The National Energy Demand Is To Be Provided Totally By Solar Systems
- Only The Net Energy Consumed Must Be Supplied – Not A Heat Engine – No Carnot Loss
  - ~40EJ Required Annually
  - Assume Perfect Insolation – ~5.5kW-hr/m^2/day = 7.2GJ/m^2/yr
  - Collection Efficiency ~15% – ~1GJ/m^2 Captured
- ~1GJ Energy Ideally Collected Each Year For Each Square Meter Of Collector Area

HOW BIG IS THE PROBLEM

- National Annual Energy Demand ~40EJ And Annual Solar Collection Is ~1GJ/m^2
  - Required Collector Area = ~40Gm^2
  - Total Surface Area Of The Continental US Is ~9.1Tm^2 $\cong$ 3.5 Million Square Miles
  - Very Optimistically ~0.4% Of Total US Surface Area Needed
  - More Conservative Figure Is ~4% $\cong$ 140kMi^2 To Account For More Realistic Collection Efficiency, Weather And Maintenance

HOW BIG IS THE PROBLEM

- $140 kMi^2$ Of Solar Collector Area Required
  - Nominally Twice The Area Of Utah
  - Nominally The Area Of California Or Montana
  - Nominally The Area Of New Jersey, Maine, Massachusetts, Maryland, Connecticut, Virginia, West Virginia, New Hampshire, Vermont, Delaware And Rhode Island Combined
  - Nominally One-Half The Area Of Texas
- Very High Installed Cost
  - ~$10 Per Installed Photovoltaic Watt
  - 110EJ/Yr $\Rightarrow$ ~$3.5x10^{12}$W = \$$3.5x10^{13}$ = $35T Solar
  - ~3X GNP

HOW BIG IS THE PROBLEM

- Consider That The National Energy Demand Is To Be Provided Totally By Wind
- Only The Net Energy Consumed Must Be Supplied – No Carnot Loss ~40EJ Required Annually
- Typical Large Wind Turbine 4MW
  - Assume ¼ Capacity On Average Delivered 24/7/365
  - Assume Energy Produced During Off-Peak Periods Can Be Stored And Effectively Utilized On Peak
- A Single Wind Turbine Will Supply 8.8GW-hr Annually $\cong$ 32TJ/yr

HOW BIG IS THE PROBLEM

- A Total Of ~40EJ Required Annually
  - ~32TJ/Turbine Available
  - ~1.25 Million 4MW Turbines Required
  - Continental US Surface Area ~$3.5x10^6 mi^2$
  - One Turbine Required On About Each Three Square Miles Of The Entire Country
  - Turbines Required On A 2mi x 2mi Grid Over The Entire Continental US
  - More Wind Turbines Than Cell Towers
- Very High Installed Cost
  - ~$2 Per Installed Wind-Turbine Watt
  - 110EJ/Yr $\Rightarrow$ ~$3.5x10^{12}$W = \$$7x10^{12}$ = $7T Wind
  - ~1/2 GNP

HOW BIG IS THE PROBLEM

- Consider That The National Energy Demand Is To Be Provided Totally By Geothermal
- Total Energy Released By Mt. St. Helens In 1980 Was ~2EJ
  - 450MT
  - 27,000 Hiroshima Devices – One Per Second For Nine Hours
  - Would Supply The National Energy Demand For About 7 Days
- One Mt. St. Helens Geothermal Event Would Be Required Each Week To Supply The US Energy Demand If We Could Convert The Thermal Energy To Useful Work With 100% Efficiency – About One Per Day At 14% Conversion Efficiency

SOME ALTERNATIVE-ENERGY PROPOSALS

- Solar – Infeasible
- Wind – Infeasible
- Traditional Nuclear – Politically Incorrect
- Hydrogen-Based Economy
- Ethanol-Based Economy
- Alternative Nuclear – Little Interest

HYDROGEN-BASED ECONOMY

- A “Clean” Fuel – Low Emissions, Sort Of
- No Convenient Hydrogen Source
  - Hydrogen Must Be “Manufactured”
  - Using Other Energy Sources – Electricity
- Not A Compatible Fuel For Existing Systems
- National Energy Demand Unchanged
  - Current Energy Inputs Simply Redirected To Manufacture Hydrogen
  - Added Inefficiencies – Higher Energy Losses
  - Net Emissions Unchanged, Perhaps Increased
- No Storage Or Distribution Infrastructure

ETHANOL-BASED ECONOMY

- A “Clean” Fuel – 1:1 Carbon Balance
- Existing Storage and Distribution Infrastructure Suitable
- Compatible Fuel For Many Existing Systems
- Considerable Controversy As To Feasibility
  - Cost To Produce Exceeds Price
  - Food Crops Diverted To Energy Production

FUEL CELLS

- Not A Heat Engine
  - No Carnot Loses
  - Very High Conversion Efficiency Possible
  - Considerable Debate As To The “Plant-To-Wheel” Efficiency
- Hydrogen Fuel Problematic
  - No Hydrogen Source
  - Difficult To Store
  - No Distribution Infrastructure
- Methanol Fuel
  - Derived From Hydrocarbon Sources

FUEL CELLS

- Direct Ethanol Fuel Cell
  - – Ethanol Can Be “Grown”
  - – Easily Stored
  - – Existing Distribution Suitable
  - – Direct Ethanol Fuel Cells Not Yet A Reality

ALTERNATIVE NUCLEAR

- Colliding-Beam Fusion Reactor – CBFR
  - A True Fusion Reaction – $B^{11} + p^{+} \Rightarrow He^{4} + e^{-}$
  - A LINAC – Not A TOKAMAK
  - LINAC Beam Dynamics Well Understood
  - "Low Energy" – ~1MEV Electrons – Reduced Activation Of Materials – Reduced Radioactive Waste (maybe)
  - Only Waste Product Is Helium
  - Output Is A Charged-Particle Beam
    - A Current – Possibly Collected In A MHD (DEC) Structure
    - No Carnot Losses
- Little Interest In Any Alternative Nuclear Approaches
  - Particularly Anything With "Fusion" In The Name
  - NMR Rumored Changed to MRI To Be Politically Correct

ALTERNATIVE NUCLEAR

- Dense Plasma Focus – DPF, “Focus Fusion”
  - A True Fusion Reaction – $B^{11} + p^{+} \Rightarrow He^{4} + e^{-}$
  - A “Simple” Pulsed-Power Machine – Not A TOKAMAK
  - DPF Beam Dynamics Well Understood
  - “Low Energy” – ~1MEV Electrons – Reduced Activation Of Materials – Reduced Radioactive Waste (again maybe)
  - Only Waste Product Is Helium
  - Output Is A Charged-Particle Beam
    - A Current – Possibly Collected In A MHD (DEC) Structure
    - No Carnot Losses

Image courtesy of focusfusion.org, used with permission

ALTERNATIVE NUCLEAR

- Little Interest In Any Alternative Nuclear Approaches
  - Particularly Anything With “Fusion” In The Name
  - NMR Changed to MRI To Be Politically Correct
- However, The Department of Energy Is Apparently Considering New Funding of Fusion Research For Energy Production

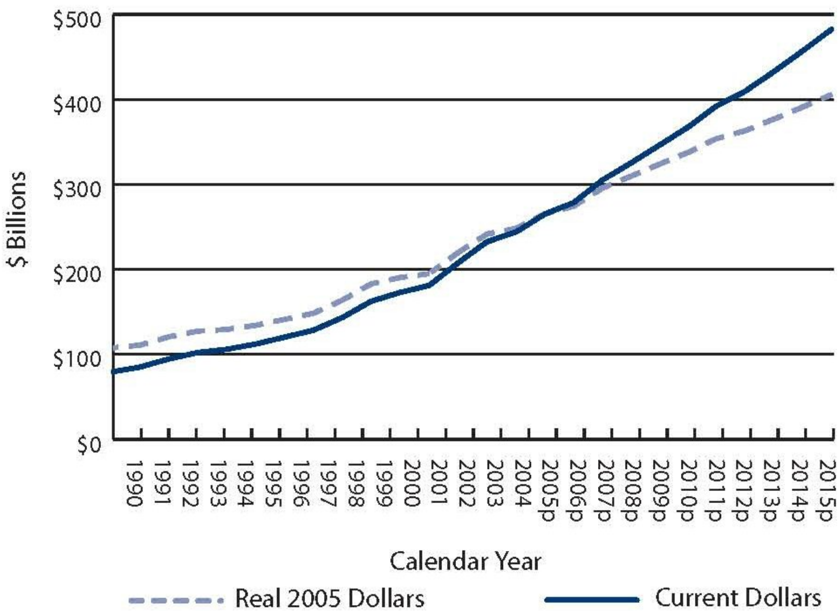
FY2006 NATIONAL BUDGETS

- NREL - $280M
  - ~10% Decrease
- DOE – $23.5B
  - Renewal-Energy Budget Decrease ~35%
- NSF – $5.58B
  - ~1.8% Increase
- NIH – $28.8B
  - ~0.7% Increase
- Cost Of Compliance With IRS – $274.2B
  - ~3.5% Increase
  - ≅ 22% Of Federal Revenue
  - ~22% Surcharge

COST OF IRS COMPLINACE

Measuring the Cost of Compliance

Figure 1
Total Federal Income Tax Compliance Costs
1990–2015



Source: Internal Revenue Service, Tax Foundation calculations.

Table 1
Total Federal Income Tax Compliance Costs
Calendar Years 1990–2015

	Current Dollars	Real 2005 Dollars	Percent of Federal Revenue
1990	$79.7	$107.6	14.1%
1991	$85.1	$111.0	15.5%
1992	$94.7	$120.7	16.4%
1993	$102.2	$127.4	16.3%
1994	$106.0	$129.3	15.6%
1995	$112.2	$134.2	15.1%
1996	$120.3	$141.2	14.4%
1997	$128.5	$148.4	13.9%
1998	$143.4	$163.8	14.3%
1999	$162.6	$183.1	15.0%
2000	$172.9	$190.5	14.5%
2001	$181.1	$194.9	16.0%
2002	$207.7	$219.8	21.7%
2003	$232.5	$241.6	24.8%
2004	$243.9	$248.3	24.4%
2005p	$265.1	$265.1	22.2%
2006p	$278.6	$274.4	21.9%
2007p	$305.3	$295.8	22.8%
2008p	$325.7	$310.0	23.0%
2009p	$346.9	$324.3	22.9%
2010p	$368.4	$338.3	22.8%
2011p	$391.9	$353.7	21.5%
2012p	$409.5	$363.1	20.7%
2013p	$432.7	$376.9	20.7%
2014p	$457.2	$391.1	20.7%
2015p	$482.7	$405.8	20.7%

CONCLUSIONS

- Annual US Energy Demand Of ~111EJ Unlikely To Drop
- Globalization And Emerging Nations Will Place Increasing Demands On Limited Global Energy Resources
- Historical Global Energy Reserves Reaching End Of Production Life
- Questionable That Significant New Reserves Of Fossil Fuels Will Be Found

CONCLUSIONS

- Not Clear That Domestic Production Would Be Marketed Domestically
- Nuclear Still Politically Incorrect
- Traditional Experiments In Alternative-Energy Systems Have Been Less Than Encouraging
- No Viable Alternative-Energy Approaches On The Horizon

CONCLUSIONS

- There Is No Clear Indication That There Are Any Effective, Organized Efforts For Assuring An Adequate Future US Energy Supply, Much Less Taking Any Useful Action To Develop Means To Meet The Future US Energy Demands
- This Is A Challenge That Must Be Met In Ones Of Years, Not Tens Of Decades

CONCLUSIONS

- When Motor Fuel Reaches $10/Gal, And Electrical Power $1/kW-hr, Perhaps The US Leadership Will Take An Objective Interest
- By Then It Will Be Too Late

CONCLUSIONS

- Global Technological Leadership Of A Nation Is Fueled By The Availability Of A Sustainable Energy Supply
- Brazil, Rather Than China, May Emerge As The Next Global Technological Leader
- What Will Become Of US Global Technological Leadership As US Market Share Of Limited Global Energy Resources Diminishes?
- Will We Find A Solution In “The Undiscovered Country?”

THE UNDISCOVERED COUNTRY

So, good luck and safe journey as we all go forward to explore the

“Undiscovered Country”

The Future

"Second star to the right,

and straight on 'till morning'"

Thank You For The Opportunity To Share These Thoughts On National Energy Issues With You