Perspectives on Energy Efficiency and Renewable Energy Futures

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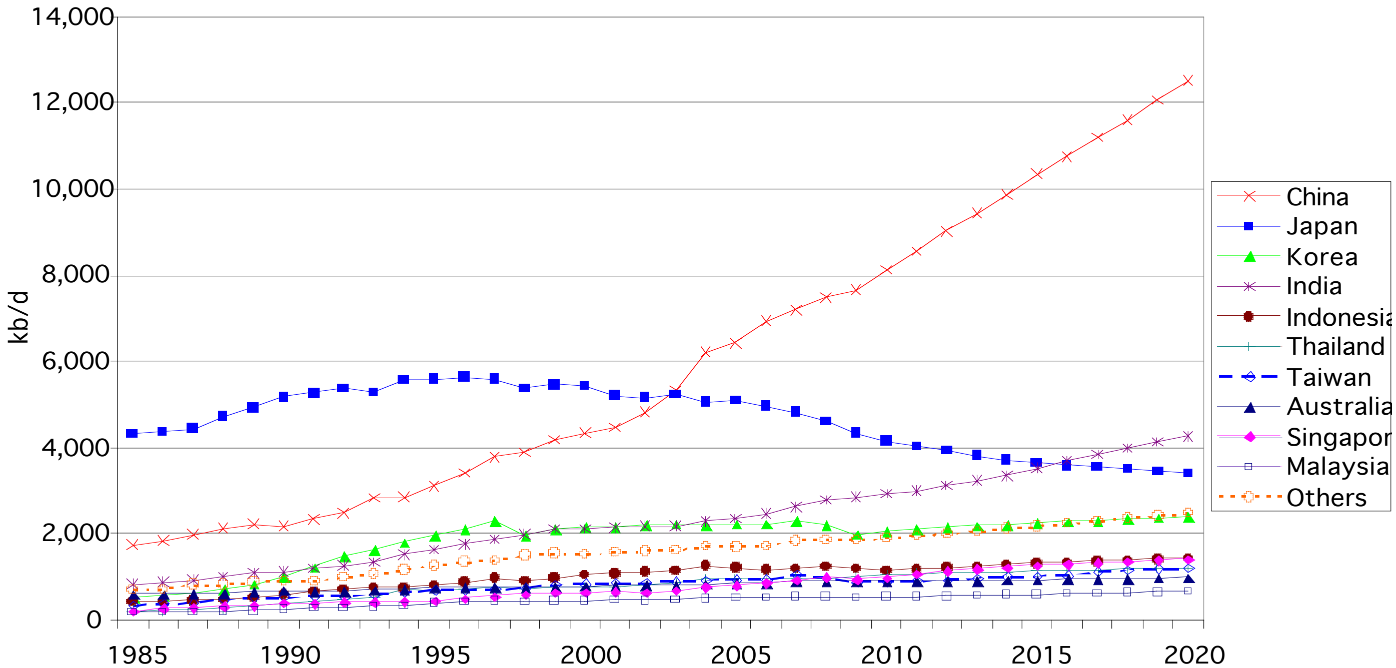
Energy Security Concerns:
Oil Market Tightness to Return

➢ Over the long term, China and India will lead not only regional, but also global oil demand growth.

Asian Petroleum Product Demand by Country



Source: FGE (2009).

A Paleoclimatic Perspective

Paleoclimate data support the point that the warmth of the last half century is unusual in at least the previous 1300 years. The last time the polar regions were significantly warmer than present for an extended period (125,000 years ago), reductions in polar ice volume led to 4 to 6 meters of sea level rise.

IPCC (2007) conservatively supports a one meter sea-level rise. Significant melting of the Greenland icecap will lead to greater sea level rise

Extreme Weather

NATURE|Vol 436|4 August 2005

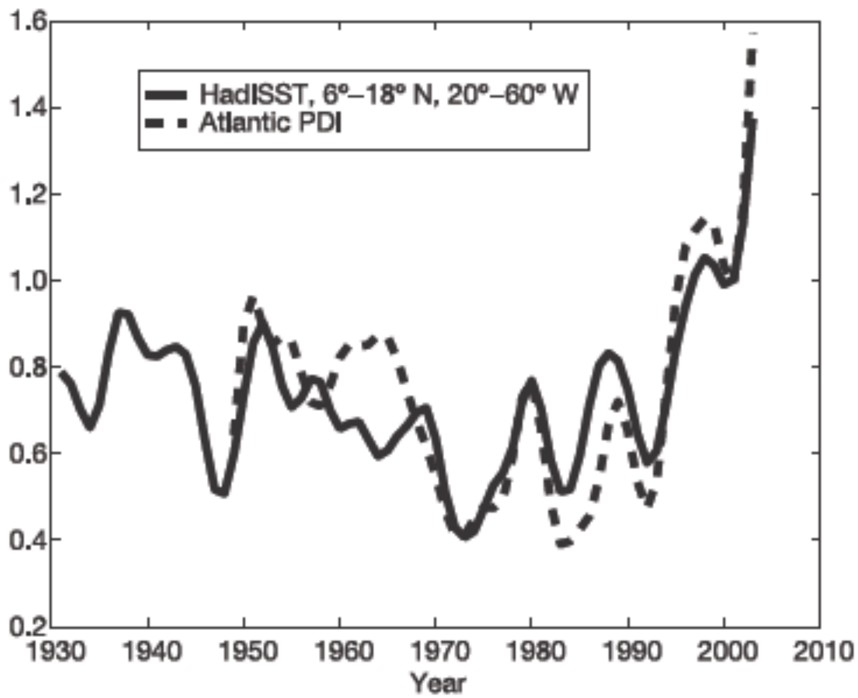


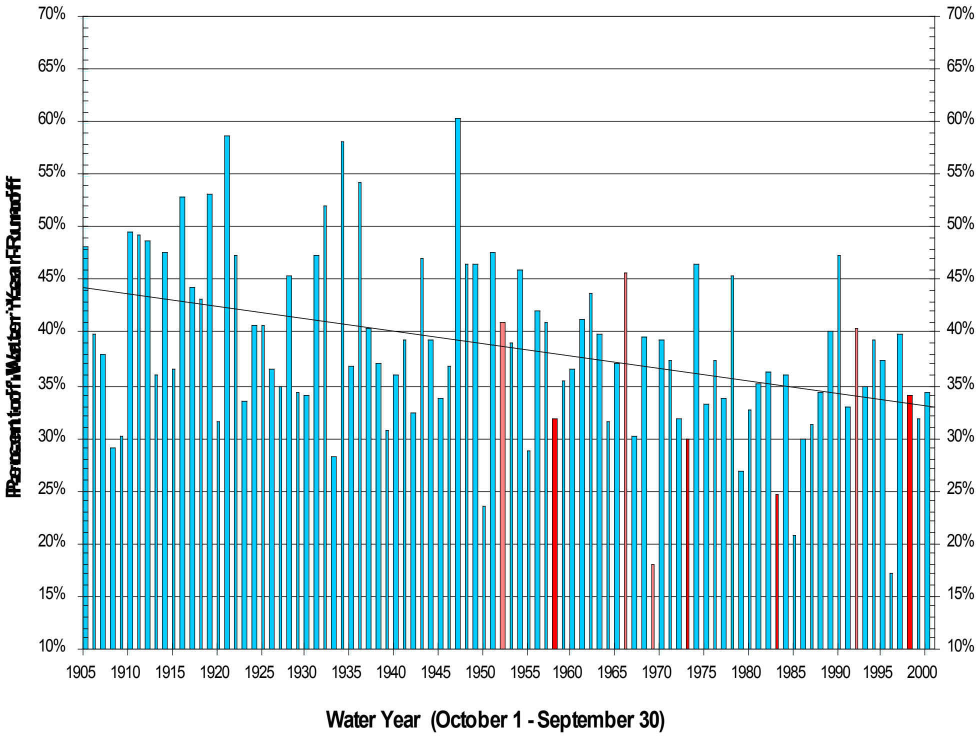
Figure 1 | A measure of the total power dissipated annually by tropical cyclones in the North Atlantic (the power dissipation index, PDI) compared to September sea surface temperature (SST). The PDI has been multiplied by 2.1×10^{-12} and the SST, obtained from the Hadley Centre Sea Ice and SST data set (HadISST)[22], is averaged over a box bounded in latitude by 6° N and 18° N, and in longitude by 20° W and 60° W. Both quantities have been smoothed twice using equation (3), and a constant offset has been added to the temperature data for ease of comparison. Note that total Atlantic hurricane power dissipation has more than doubled in the past 30 yr.

Continued CO_2 emission will lead to warmer sea-surface temperatures

Warmer sea-surface temperatures have been associated with increase hurricane intensity

Jeff Schmaltz, MODIS Rapid Response Team NASA GSFC

Principal Reservoir: Sierra Snow Pack Is Shrinking AND Runoff Will Start Too Early in the Year



Sacramento River Runoff (1906-2001)
April to July as a Percent of Total Runoff

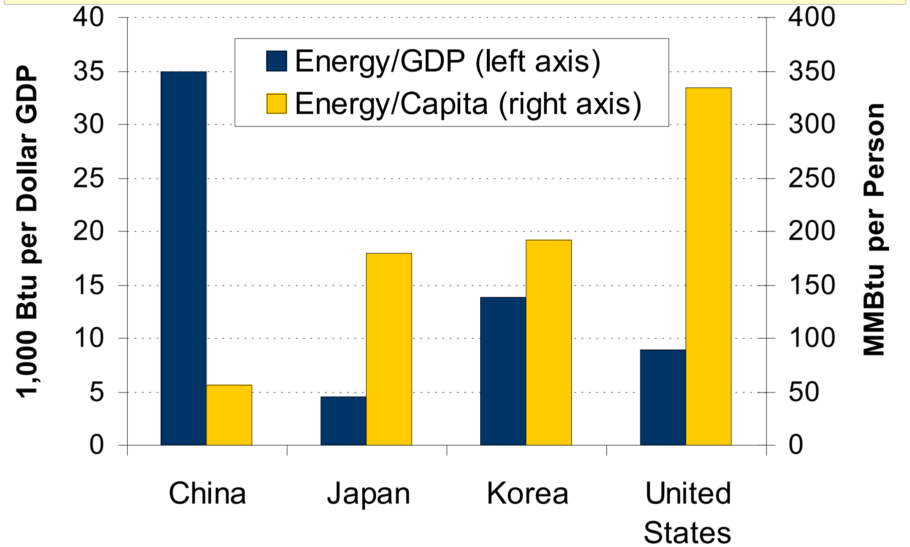
Source: California Protection Agency, Environmental Protection Indicators for California, 2001

Warmer Winters Have:

- Reduced snow pack
- Earlier snow melt
- Decreased Spring runoff by 10%
- Major effects on water supply, Cal Fed and Delta

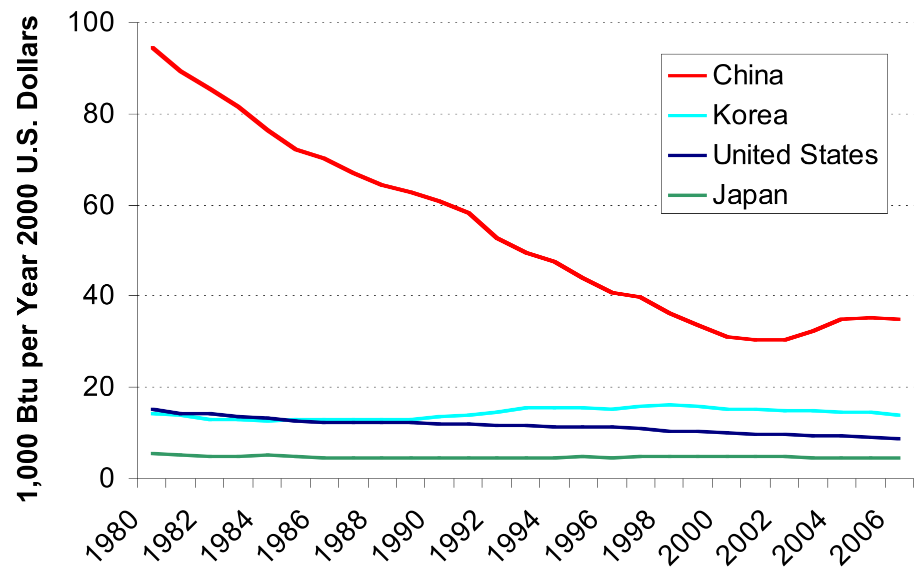
Energy Policies Must Be Understood Within Each Countries' Energy Consumption Context

Current Energy Intensity and Per-Capita Energy Consumption



Source: U.S. Energy Information Administration; data for 2006; dollar GDP based on market exchange rates

Energy Intensity Over Time



Source: U.S. Energy Information Administration; dollar GDP based on market exchange rates

- Differences driven by relative levels of: energy efficiency, industrial composition, urbanization, affluence, cultural preferences, etc.

Countries Developing Policies to Enhance Alternative Technologies and Reduce Energy Use

- Japan
  - Cool Earth 50: Reduce GHG 50% by 2050
  - Okinawa/Hawaii Initiative
  - Promoting Innovation and Entrepreneurship: Opportunities for U.S.-Japan Cooperation, Palo Alto, CA in February
- China - National Climate Change Program
  - Reduce carbon intensity by 45% by 2020
- Korea - Low Carbon, Green Growth
  - Reduce GHG by 30% below expected levels by 2020
- Asian Development Bank - Asia Solar Energy Initiative
  - Current efforts in India and South Asia - proposal to International Smart Grid Action Network

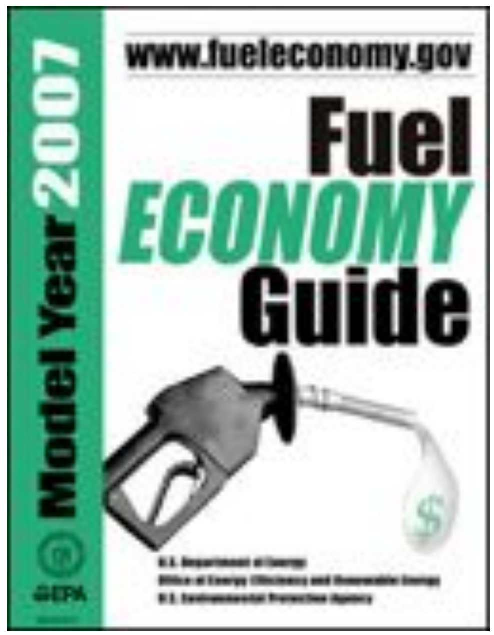
Energy Efficiency – The Most Cost Effective Approach

LIGHT OUTPUT EQUIVALENCY

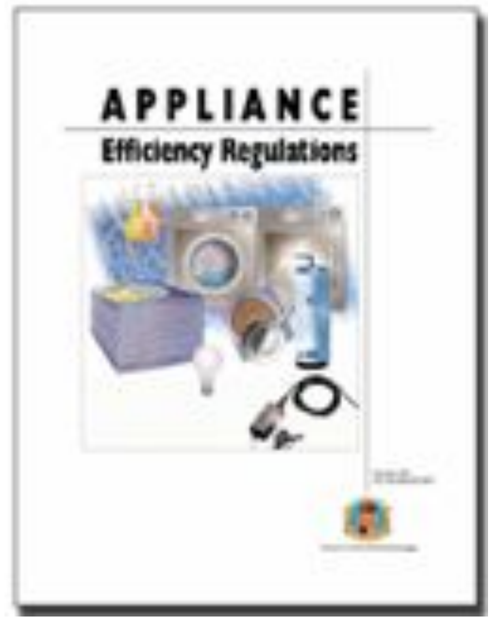
To determine which ENERGY STAR qualified light bulbs will provide the same amount of light as your current incandescent light bulbs, consult the following chart:

40	450	9-13
60	800	13-15
75	1,100	18-25
100	1,600	23-30
150	2,600	30-52

Lighting

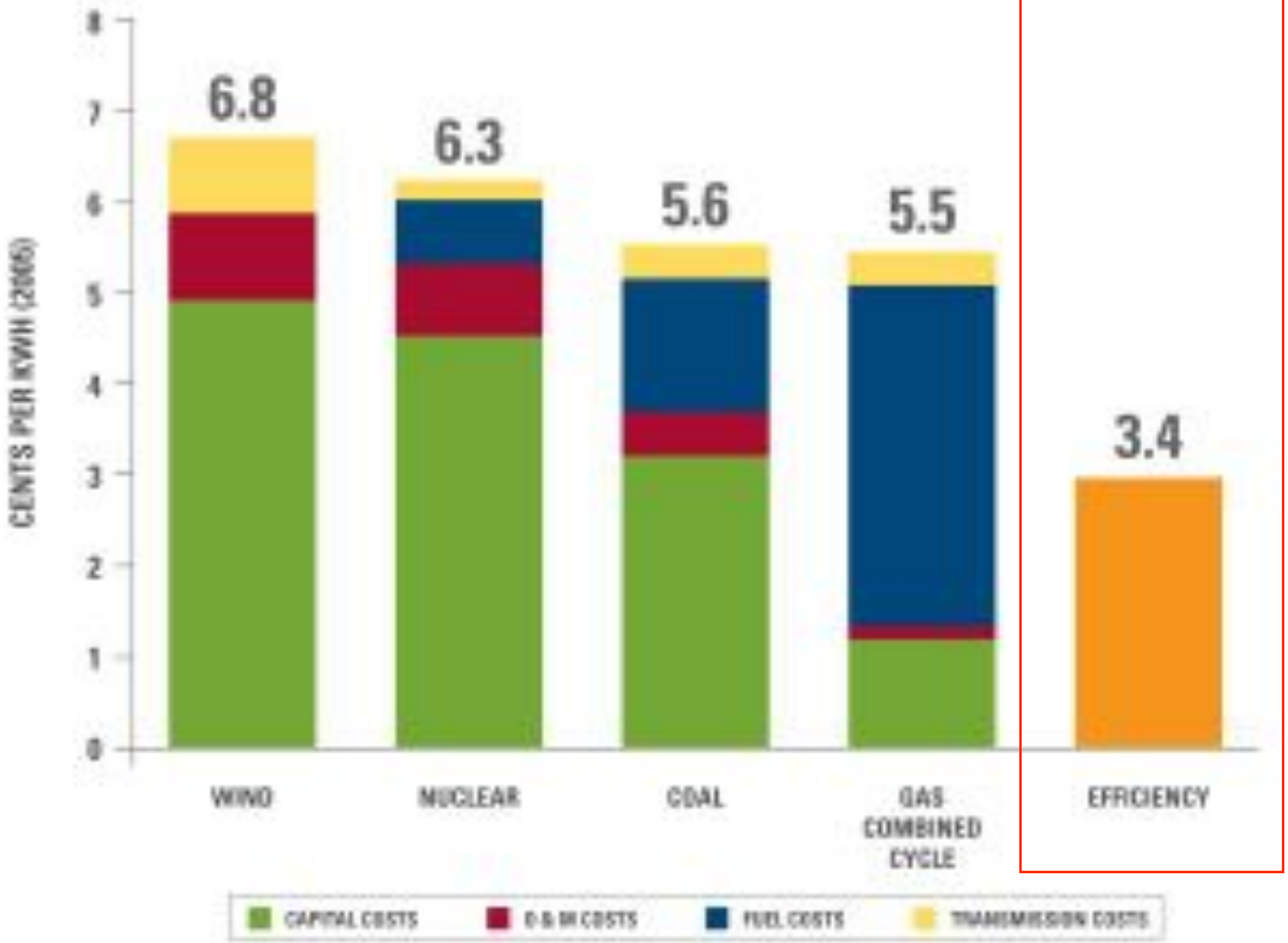


Transportation

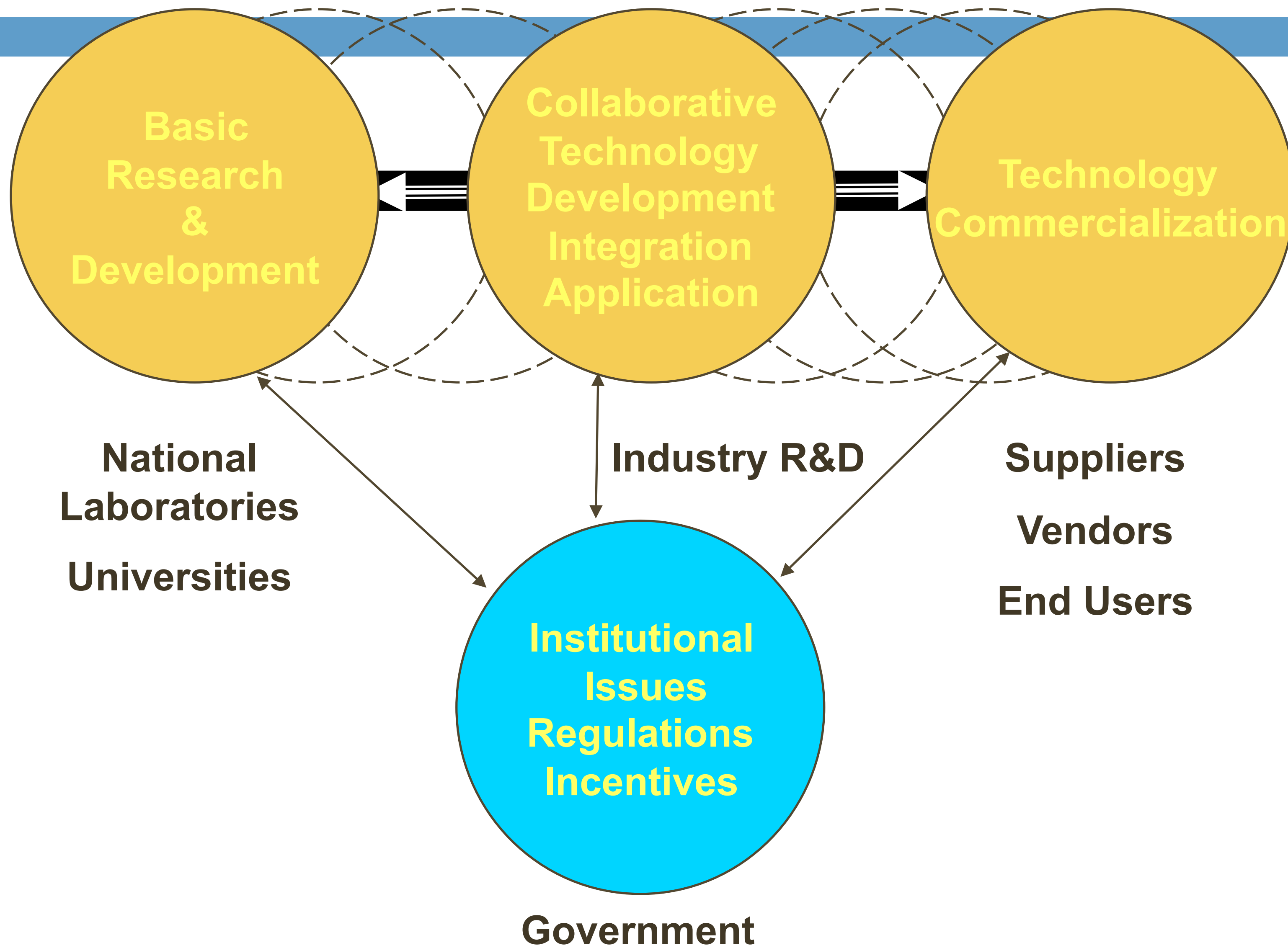


Appliances

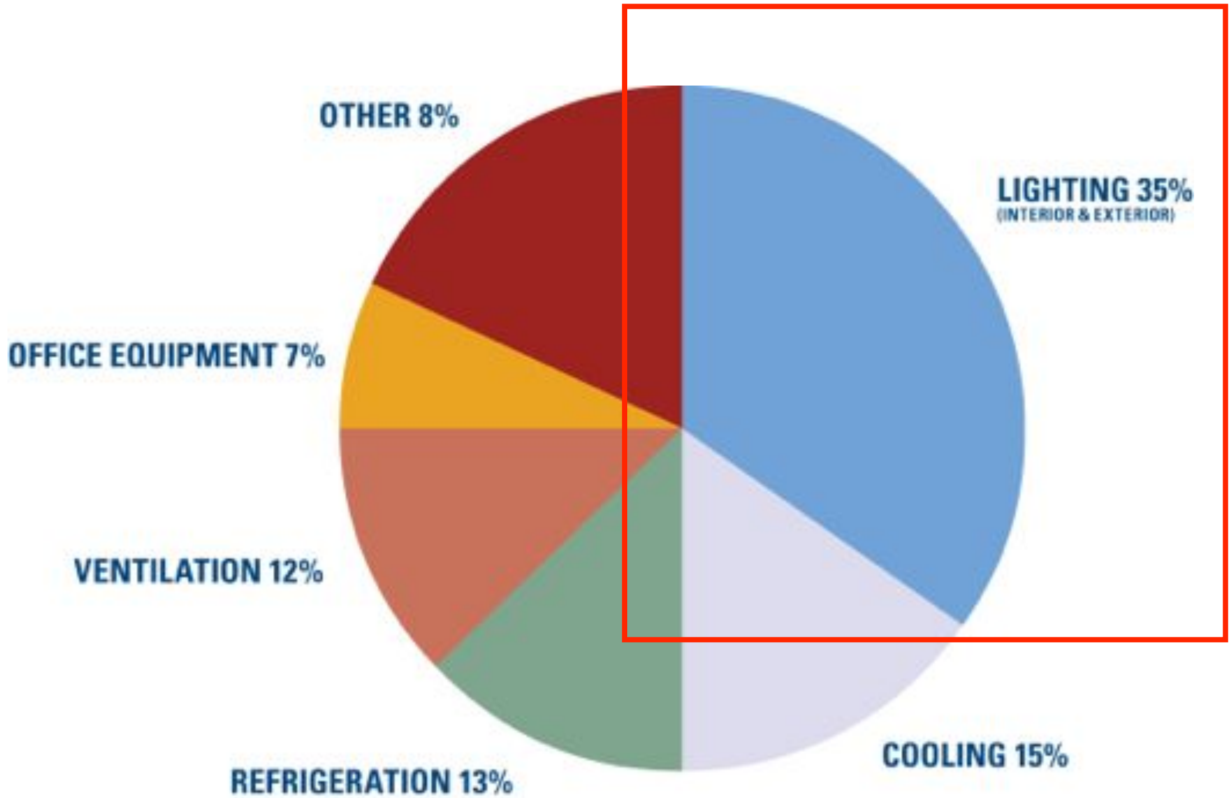
Cost of New Generation vs. Efficiency: Standards Drive Technology



R&D and Public Policy to Commercialization Process

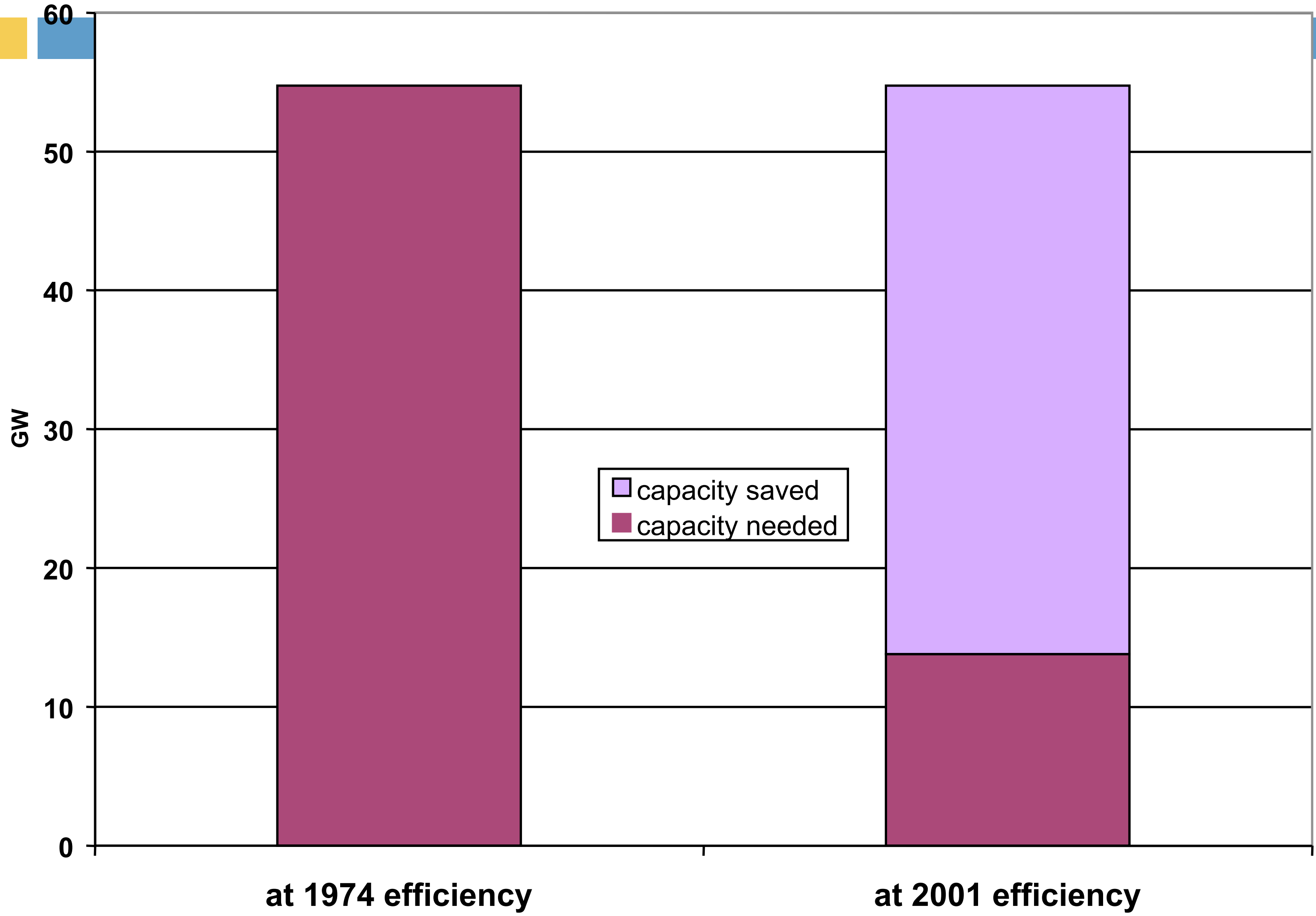


Commercial Building Electricity Consumption by End Use

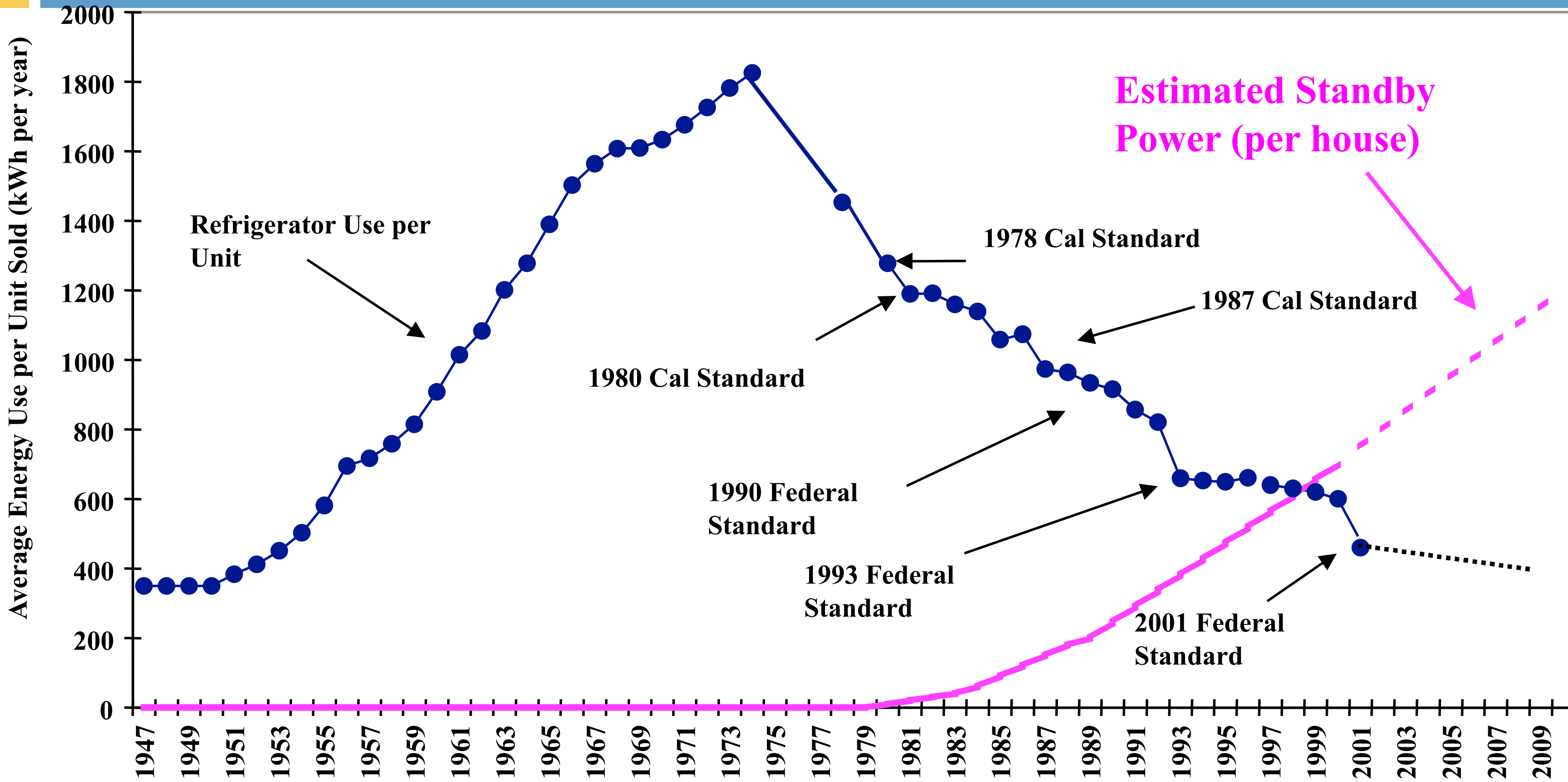


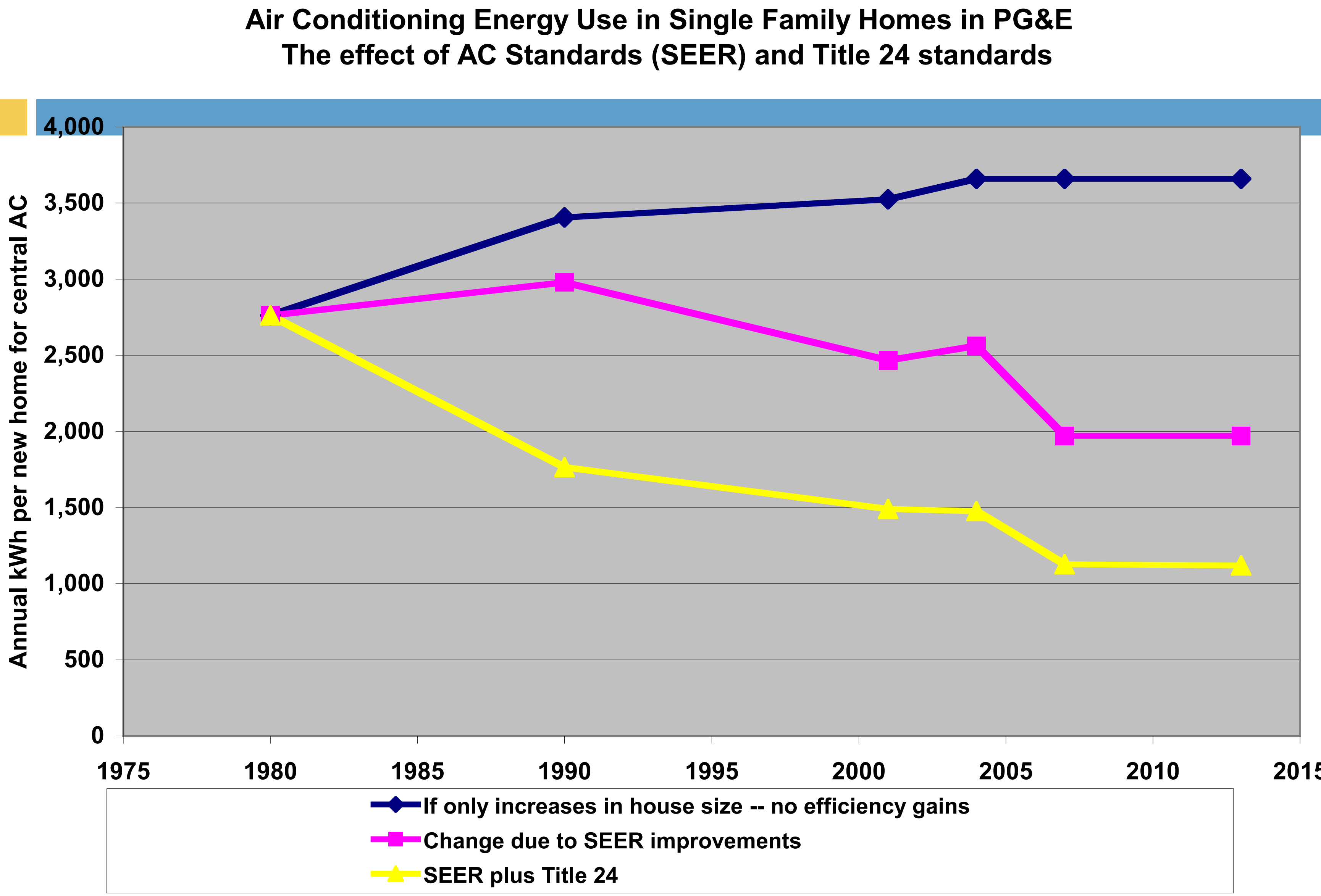
Future of Architectural Lighting Will Be Shaped by New Knowledge, Technologies and Energy Policies

Electricity Generating Capacity for 150 Million Refrigerators + Freezers in the US



United States Refrigerator Use (Actual) and Estimated Household Standby Use v. Time




Air Conditioning Energy Use in Single Family Homes in PG&E
The effect of AC Standards (SEER) and Title 24 standards
Annual kWh per new home for central AC
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
If only increases in house size -- no efficiency gains
Change due to SEER improvements
SEER plus Title 24

GLOBAL COOLING: make 100 m^2 of gray roofing white and offset 10 t of CO_2

16

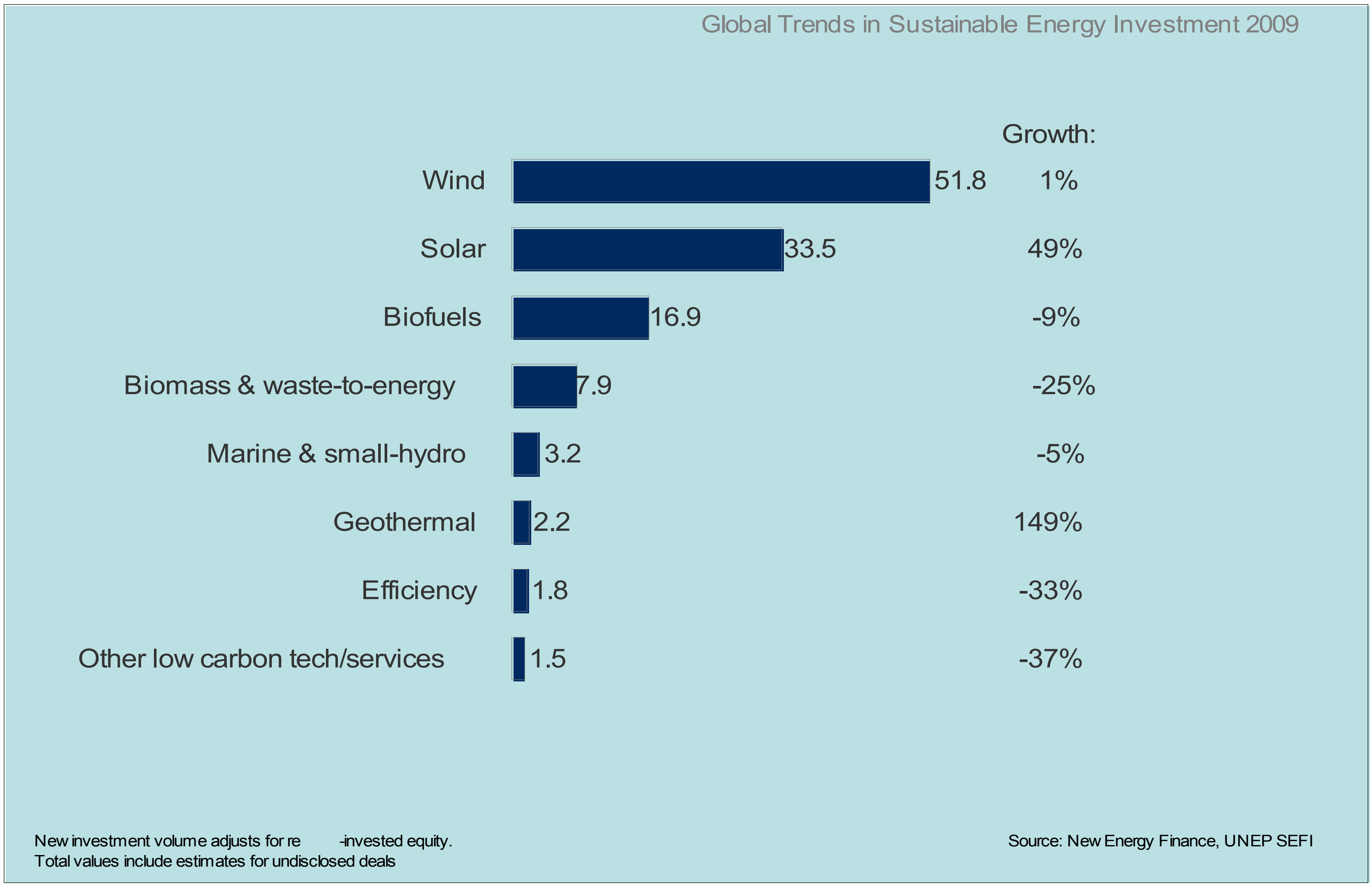
Top Countries with Installed Renewable Electricity by Technology (2008)

Source: REN21, IGA, EIA

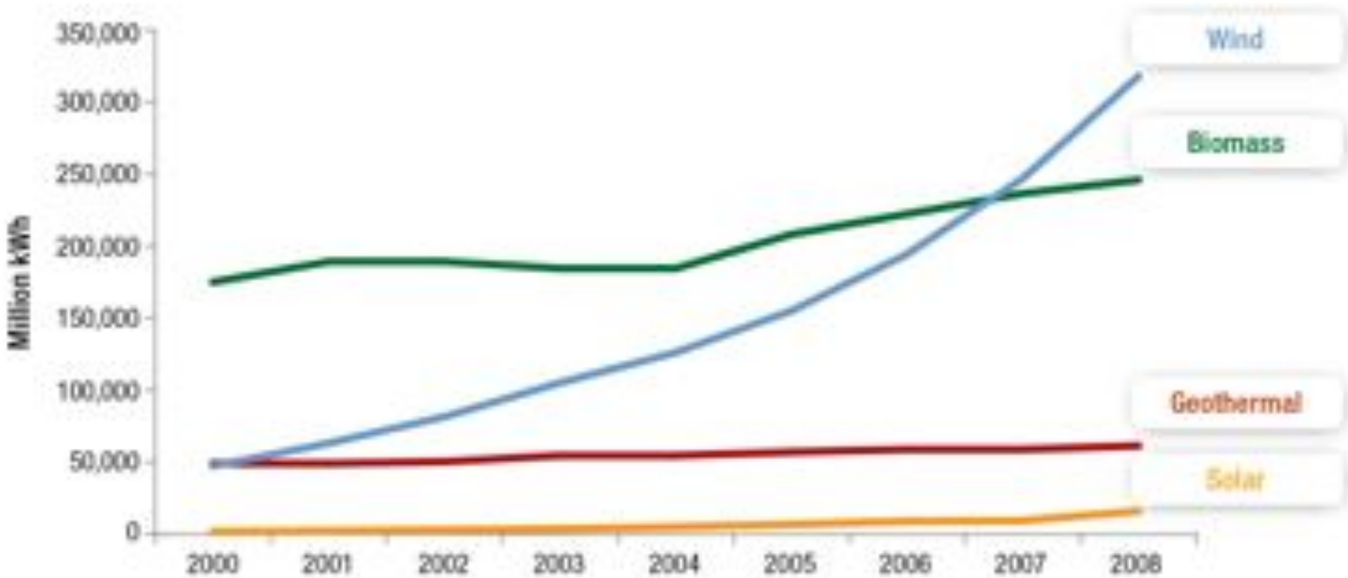
EERE 2008 Renewable Energy Data Book

Global Renewable Energy Development | July 2009 p.35

Financial New Investment by Technology (2008) and growth (2007) - $ billions



Renewable Electricity Generation Worldwide by Technology



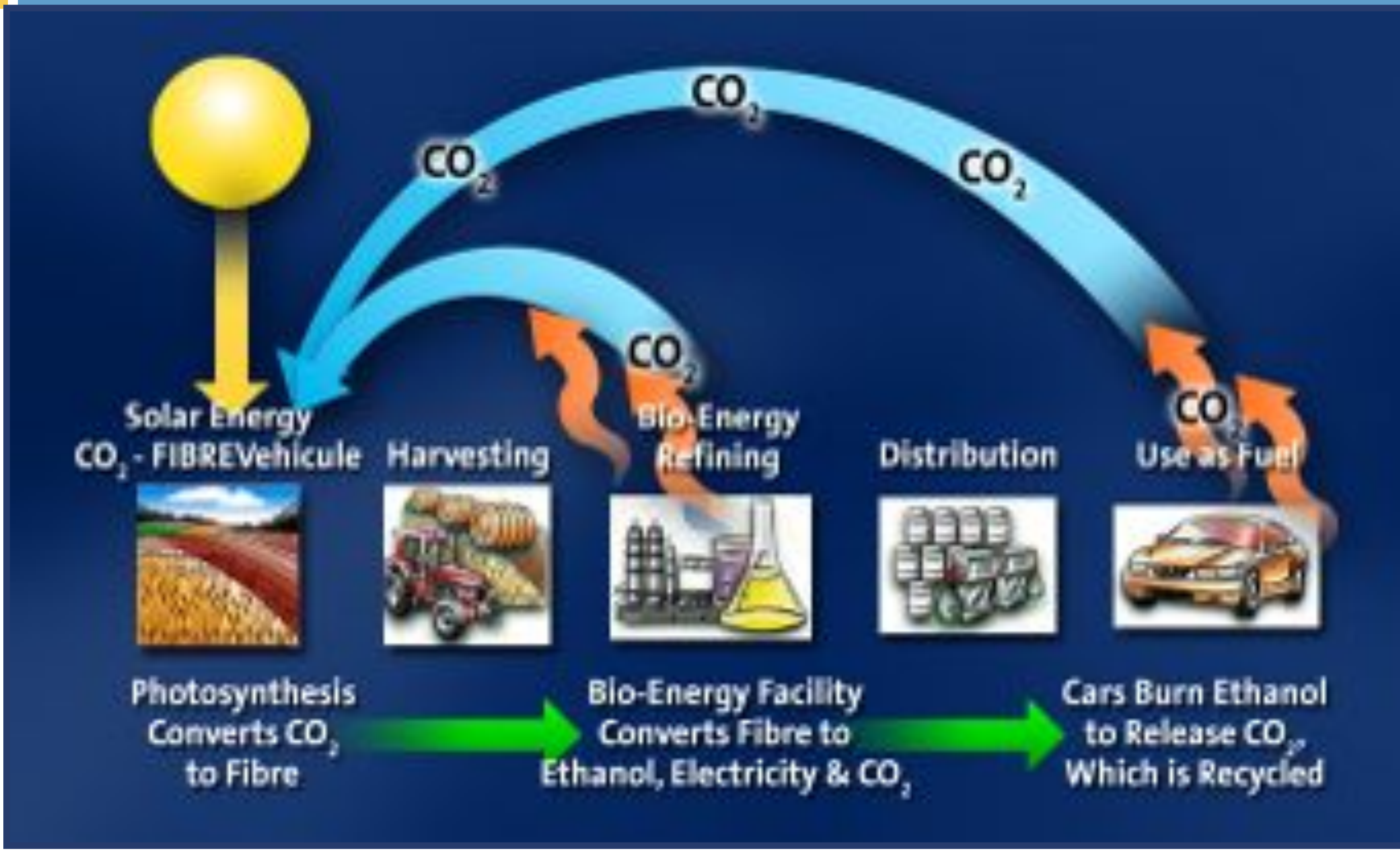
Sources: IEA, REN21, NREL, UNDP, Martinot, WWEA, BP

Note: World capacity data used, with generation derived using capacity factors of 14% for solar power, 30% for wind, 70% for geothermal, 54% for biomass.

EERE 2008 Renewable Energy Data Book

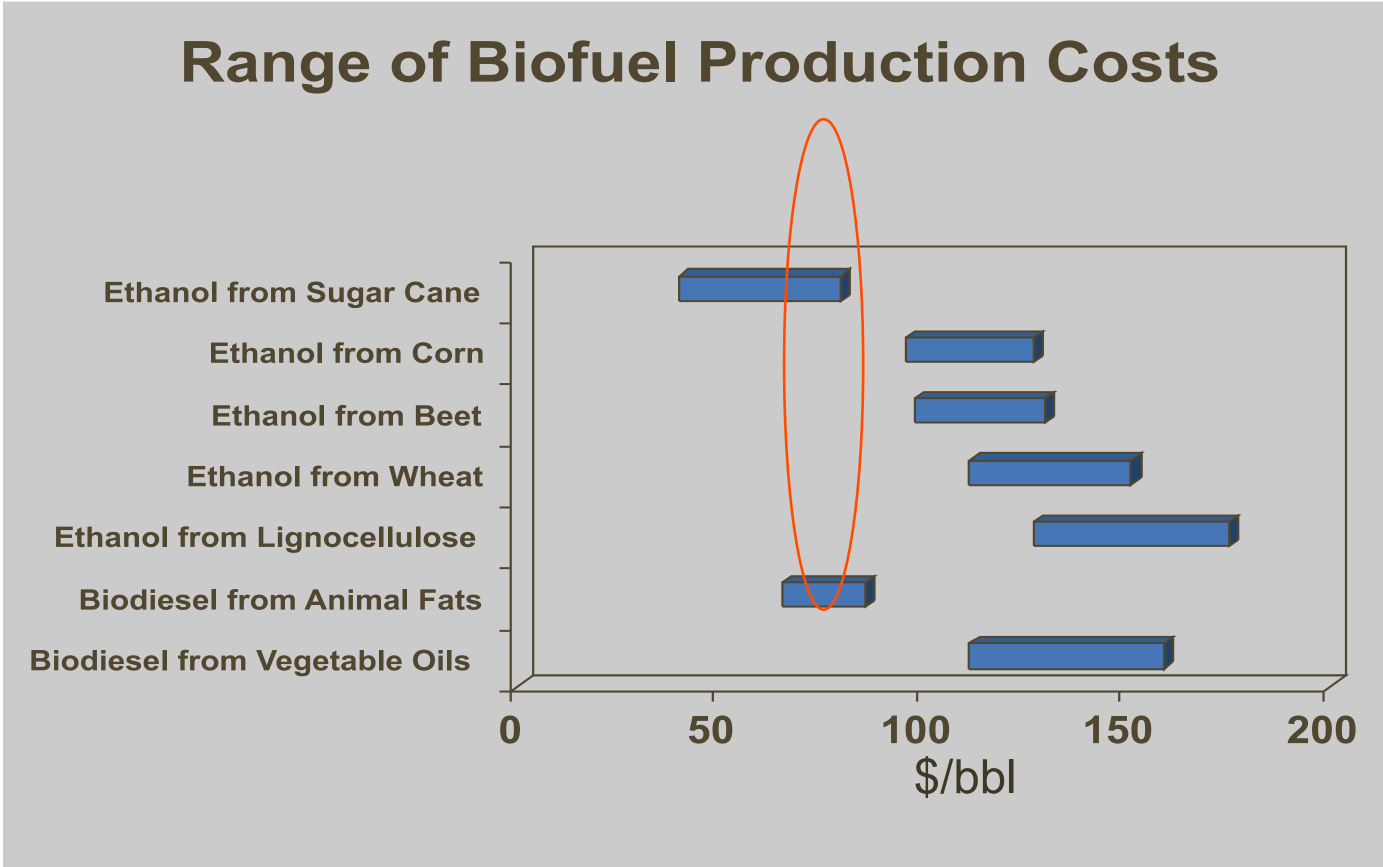
Global Renewable Energy Development | July 2009 p.32

Well-to-Wheels Life Cycle Analysis for Carbon



Brazil—the Saudi Arabia of biofuels—is currently the only country that truly has a large, viable industry…

Although the US ethanol market is also sizable.



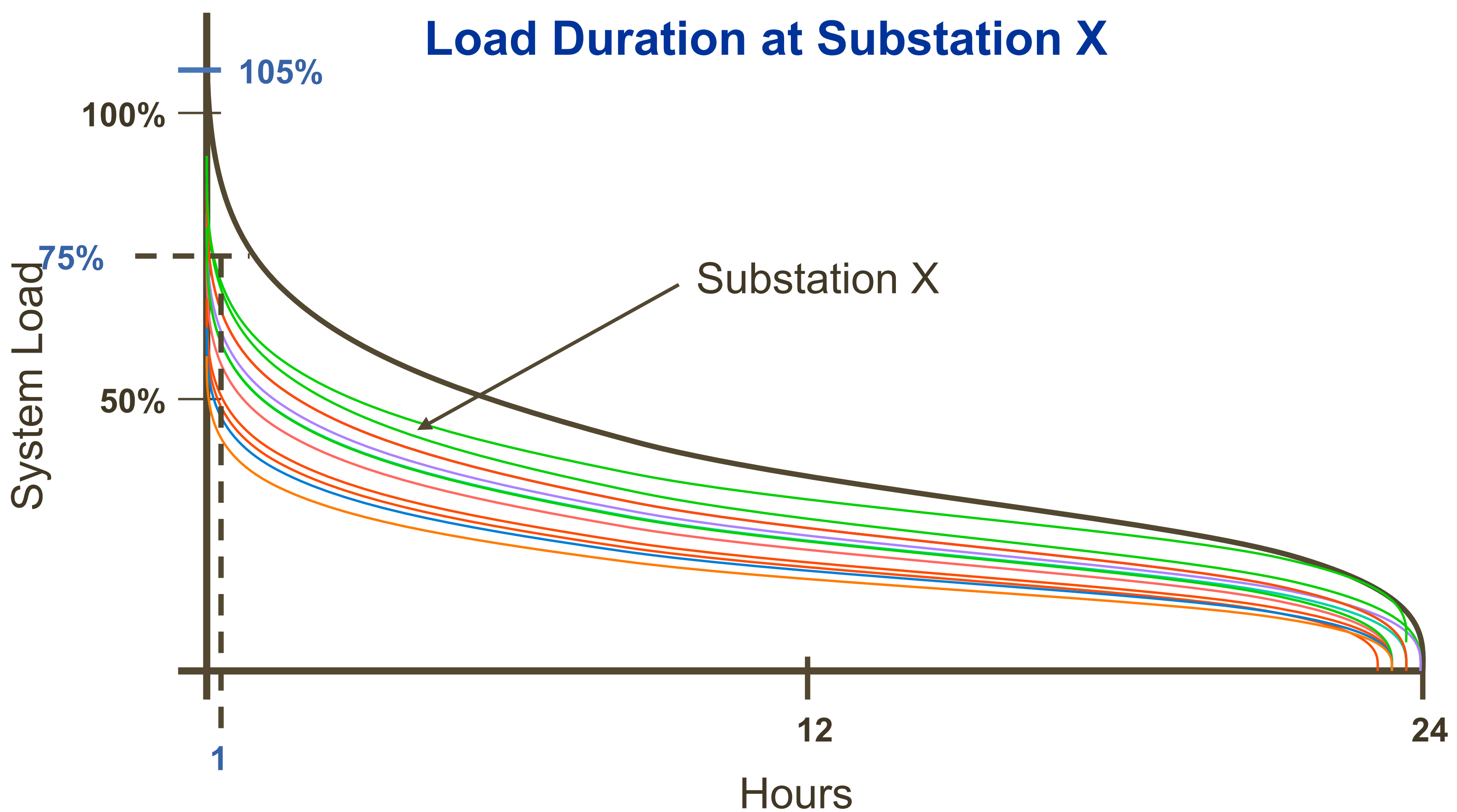
Significant development of bio-fuels will have an impact on water, food, and land resources

Why Electricity Storage: Without Storage, Generation Must Instantaneously Equal Consumption

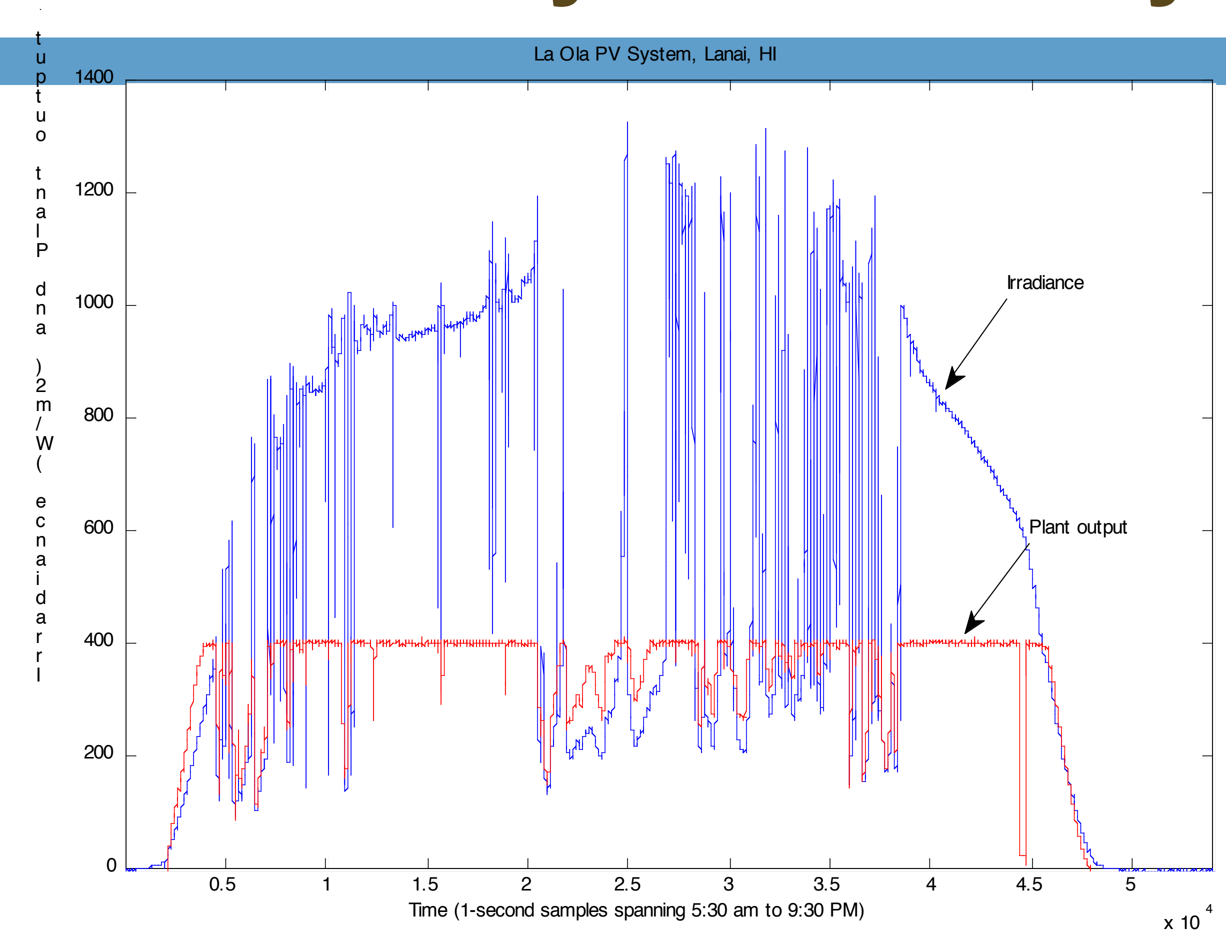
Electricity storage has benefits that will:

- Maintain quality power and reliability
- Provide customer services -- cost control, flexibility and convenience
- Improve T&D stability
- Provide “emissionless” regulation
- Enhance asset utilization and defer upgrades
- Increase the value and dispatchability of intermittent renewable generation

How Energy Storage Works – Upgrade Deferral Based on Load Management



PV Variability in Actual System



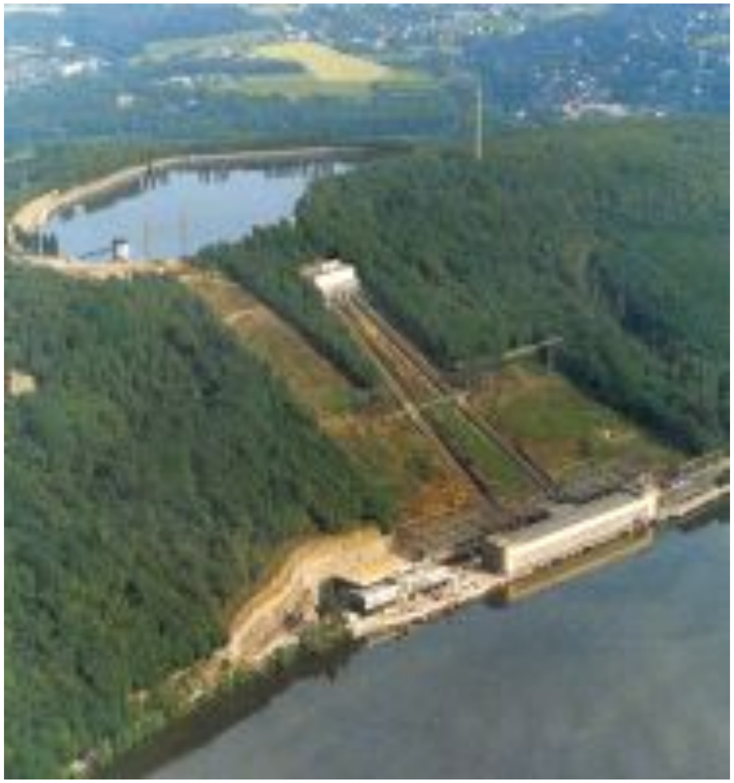
- Irradiance and PV system ac output A typical partly cloudy day in July
- PV system rating: 1,300 kW ac, presently limited to 400 kW ac (intentionally)

Energy Storage Technologies Will Be Needed to Address Renewable Intermittency Issues

Energy

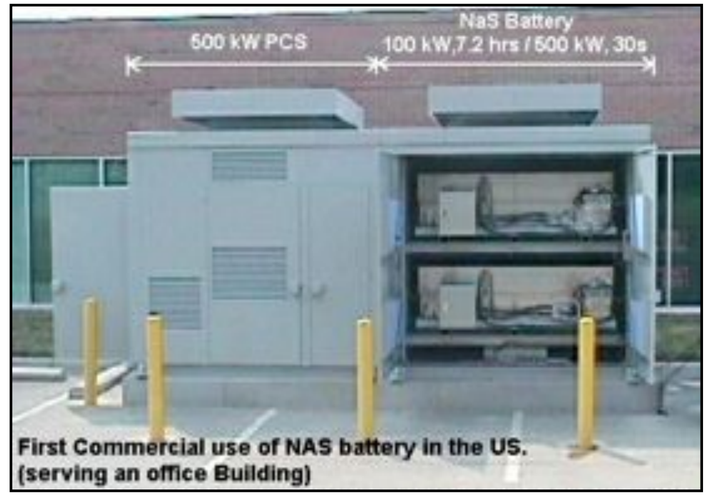
- Pumped Hydro
- Compressed Air Energy Storage (CAES)
- Batteries
  - NAS
  - Flow Batteries
  - Lead Acid
  - Lithium Ion
  - NiMH
  - NiCad
- Flywheels
- Electrochemical Capacitors

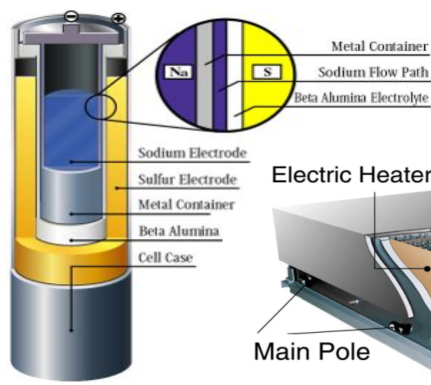
Power

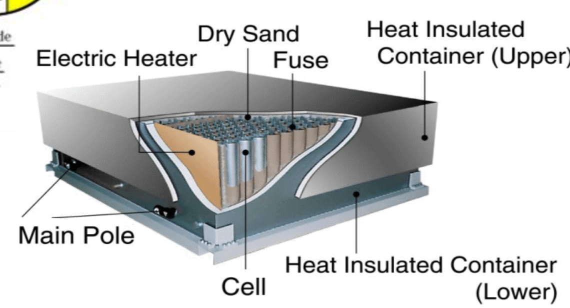


Herdecke pumped storage plant
Germany

Sodium Sulfur (NAS) - Japan







Flow Batteries - China

- Vanadium Redox
- Zinc Bromine

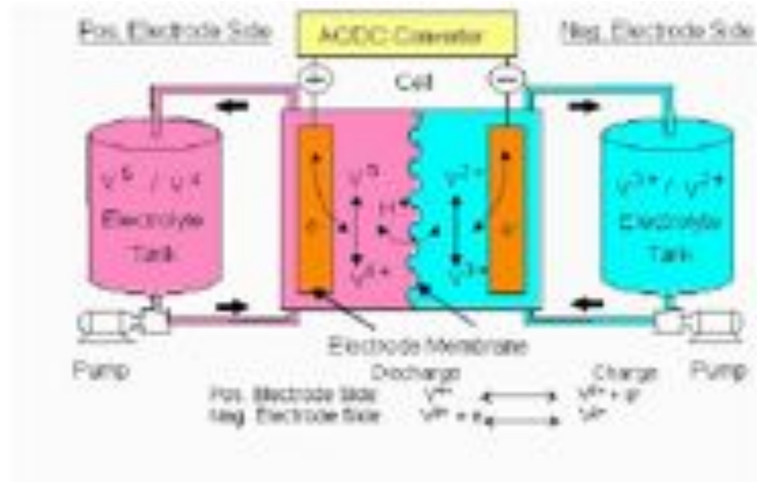
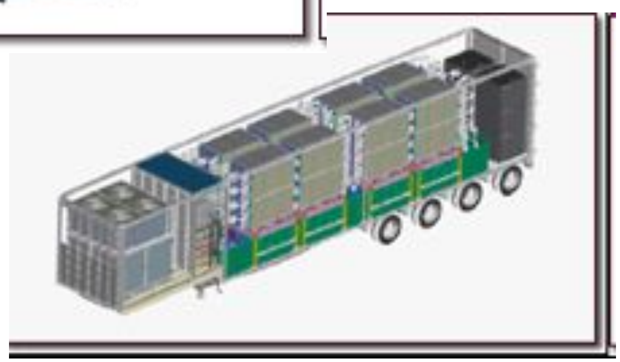


Photo Courtesy of Sumitomo Electric Industries, Ltd. (SEI) – Copyright 2001



"Smart Grid" - Linking IT to Electricity: Communications, Control, and Information Systems

- Take advantage of technologies developed for exogenous applications
- Resolves issues arising from greater penetration of distributed energy resources and technologies on grid
- Critical component for more effective and efficient load management, demand response, demand-side management
- Major concern is the effective linking of electrical and mechanical engineering skills with information technology profession – need for training!

What is the Smart Grid?

What is it now...and for the near future?

- Mainly, meters – “Advanced Metering Infrastructure” (AIM)
- Currently, very few truly new and innovative functions
  - “Smart Meters” - automated/remote meter reading
  - Time-differentiated rates – “giving customers a choice” (TOU, real time pricing, peak activated rates)
  - Display energy use and cost information to the consumer
  - Improved reliability - identifying and locating an outage when a meter doesn’t respond
  - Better voltage control – remote capacitor and tap changer controls
  - Integration of “smart” appliances
- **“Idiot savant” grid – being able to do individual, isolated functions better with new technology. The functions are still not being designed to talk to each other**
- **Most of the Smart Grid applications have not been written, or even specified, or even conceived!!!**
- **Problem with incorporation into “legacy” systems**

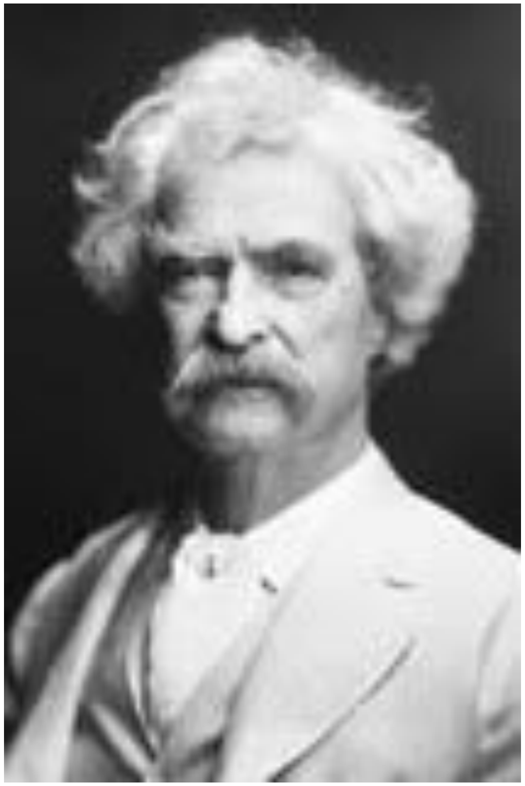
By Nick Anderson, The (Louisville) Courier-Journal, The Washington Post Writers Group

Fossil-Fired Systems Still Needed in a Renewable Energy Future

- Changes in fossil-fired generation facilities operation and maintenance need to occur to make large-scale, but intermittent, wind a reality.
- Long term operation of multiple facilities at min power raise issues such as how to address ramp rates and how to manage AGC.
- Units might spend much more time at lower loads and equipment changes are needed to improve thermal efficiencies
- Major changes are required to upgrade and/or modify facilities in order to meet new system requirements.
- For the existing fleet, re-evaluation of larger units having distributed and disaggregated responses to address renewable resource variability as this may be most appropriate rather than having one unit address renewable resource variability.
- The utility will need new paradigms for operational procedures from supplying kilowatts to playing significant role of providing ancillary services, such as reactive power. Can ancillary services, such as Var support, be provided on a localized basis?

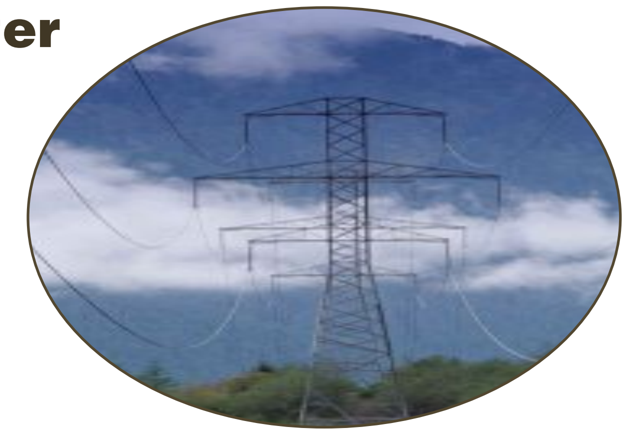
“Whiskey’s for drinking, water’s for fighting over.”

– *Mark Twain*



Energy and Water are Inextricably Linked

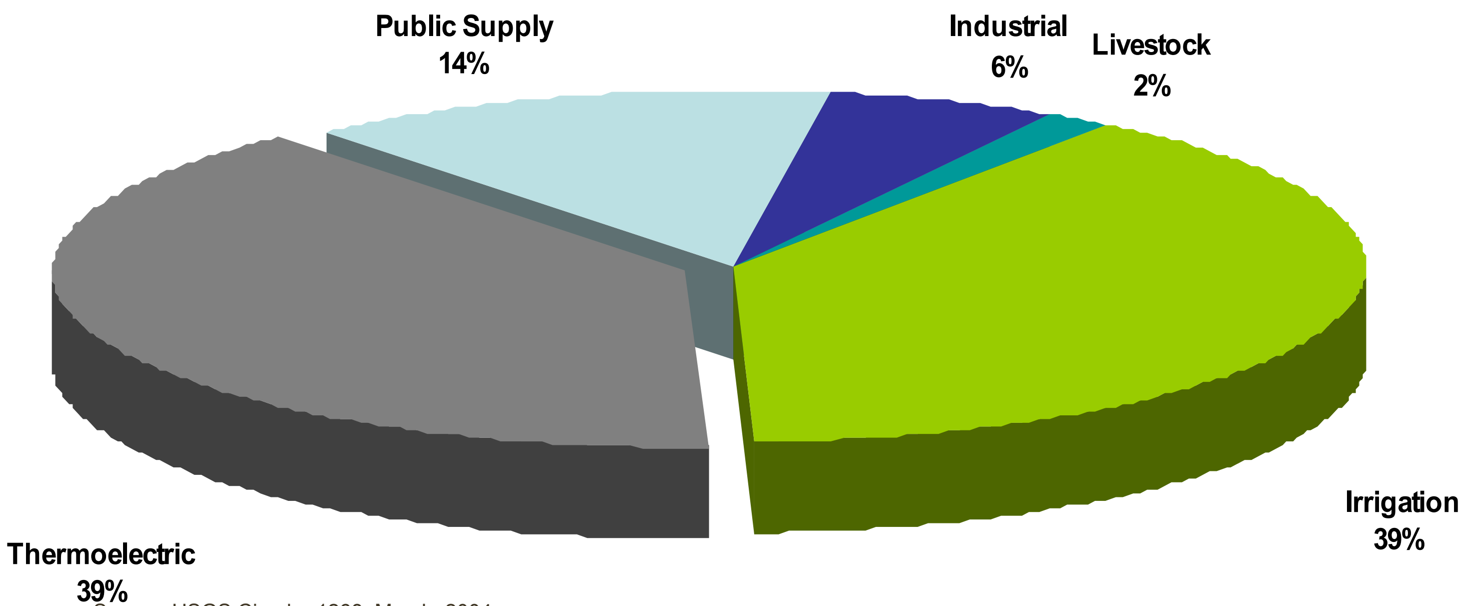
Energy production and generation require water



Water pumping, treatment, and distribution require energy

As Much Freshwater Is Used For Producing Electricity As For Irrigation

Estimated Freshwater Withdrawals by Sector, 2000



Source: USGS Circular 1268, March, 2004

Water/Energy Nexus: Need to Address Demand from Both Directions

- Reduce energy required for water development, transportation, treatment, consumer delivery, processing and recycling gray water, climate-appropriate landscaping, drip irrigation, etc.
- Develop technologies for decreasing water needs for energy development and generation: fossil fuels, nuclear, natural gas, biomass, and solar (CSP) technologies
- Reduce industrial, agricultural, and water process energy costs through improved load management and metering technologies.

Success of Tamarisks in Invasive Environment Leads to Lessons Learned Beneficial to Native Habitat

Invasive environment

Native environment

PICHTR: Pacific International Center for High Technology Research

- → PICHTR is a non-profit organization, founded in 1983 as a hub for Pacific Rim technology development
- → PICHTR and MOFA have long history, including 1.8MW demonstration on Big Island and Solar installations in Fiji
- → PICHTR runs multiple federally-funded projects, such as the USDOE Hawaii Renewable Energy Development Venture (HREDV)

Vunivau, Fiji PICHTR Trained Technicians Installed about 700 Solar Homes System

- SHS provides evening lights and a DC power outlet for appliance
- Also set up effective payment system, similar to cell phone payments
- Potential for additional 12,000 households
- Fiji Department of Energy is also funding
- Added value: improved student test scores

PICHTR Leads HREDV: Invest U.S. DOE Funds to Accelerate Technology Commercialization Through…

1. Competitively Awarded Funding

- Accelerate commercialization for local companies
- Support mainland companies investing in commercialization activities in Hawaii

2. Training & Capacity Building

- Enhance the competitiveness of local companies

3. Strategic Partnerships

- Facilitate partnerships among industry players
- Coordinate with multiple levels of government

Driving to a Sustainable Future: The "E"s are Linked

- Environment
- Energy
- Economics
  - Replicability
  - Scalability
  - Expandability
- Equity
- Education