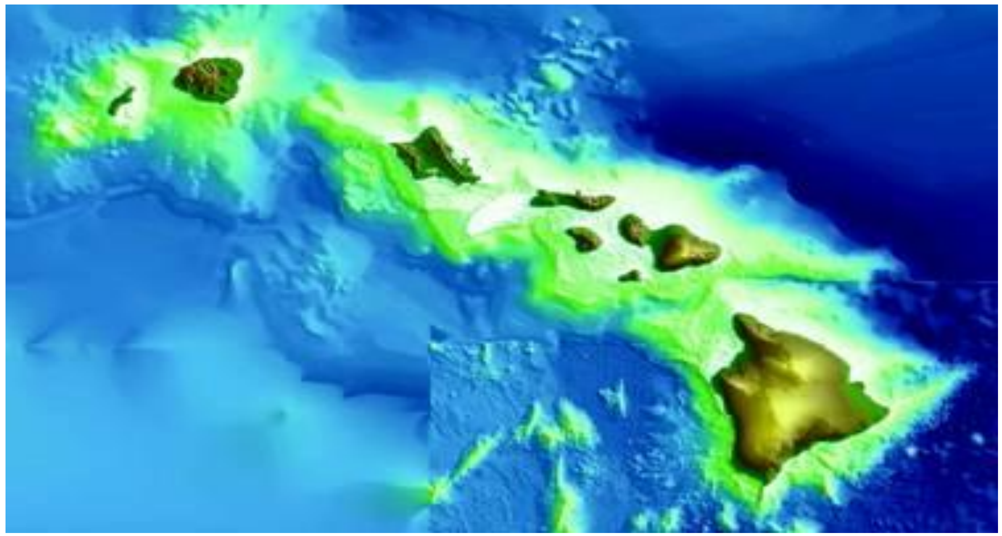
Comments on Energy Policy and Technologies – US and Hawaii



Terry Surles, surles@hawaii.edu

University of Hawaii

APEC Expert Group on Renewable and New Technologies

April 7, 2014

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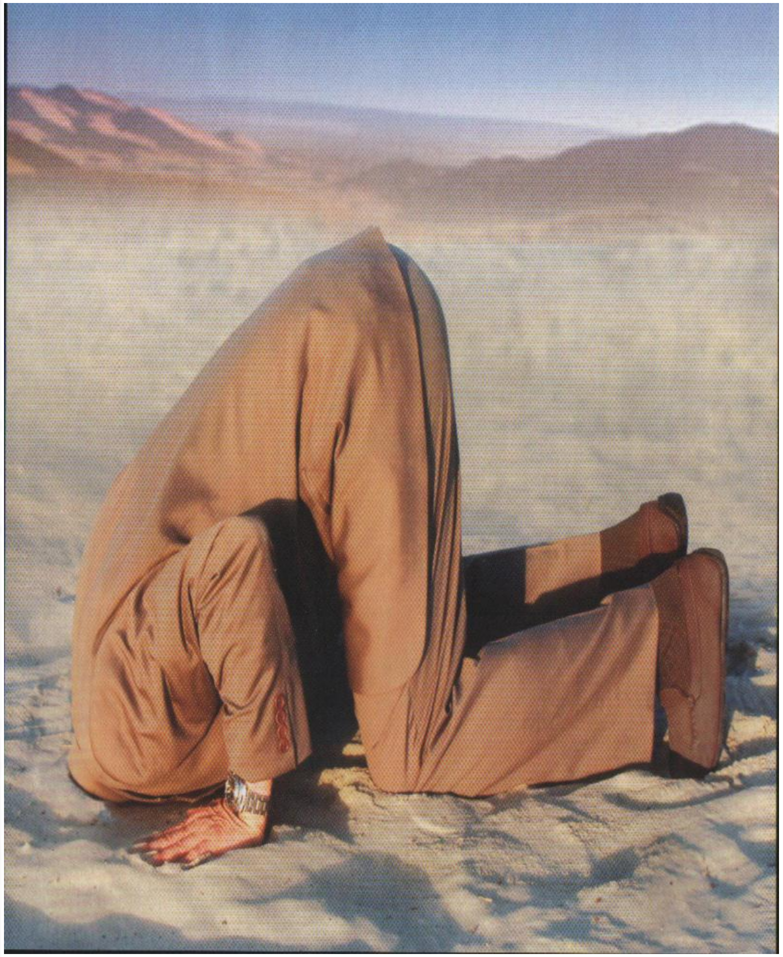
Climate Change:
Water/Energy Sustainability



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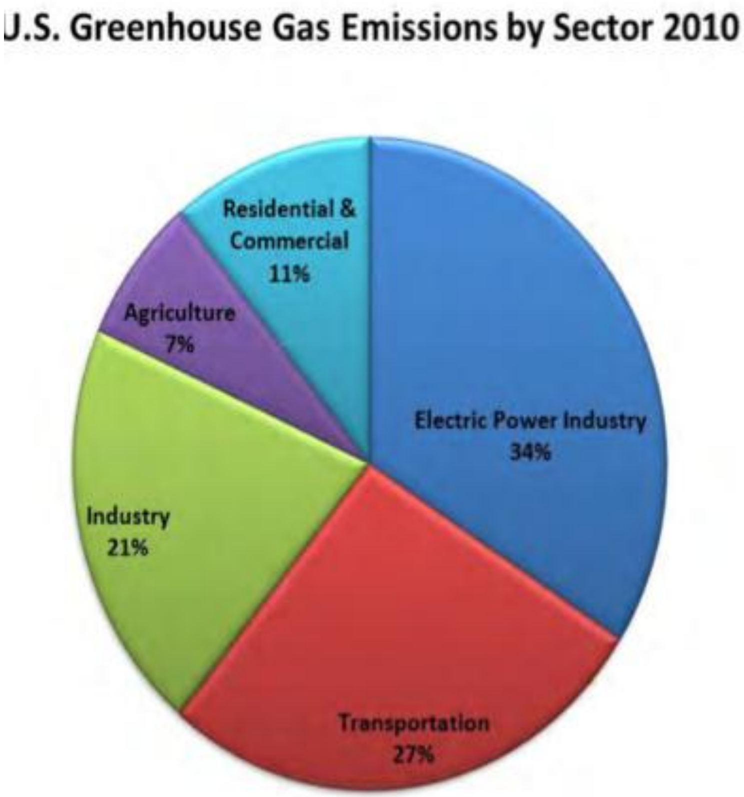
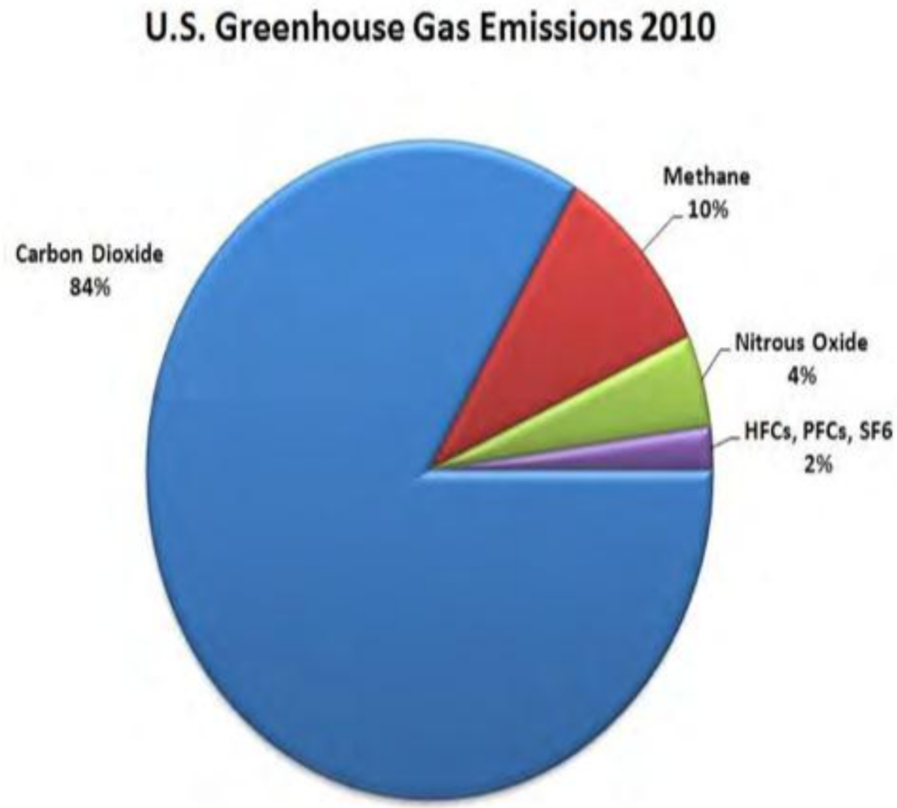
US GHG Emissions Inventory



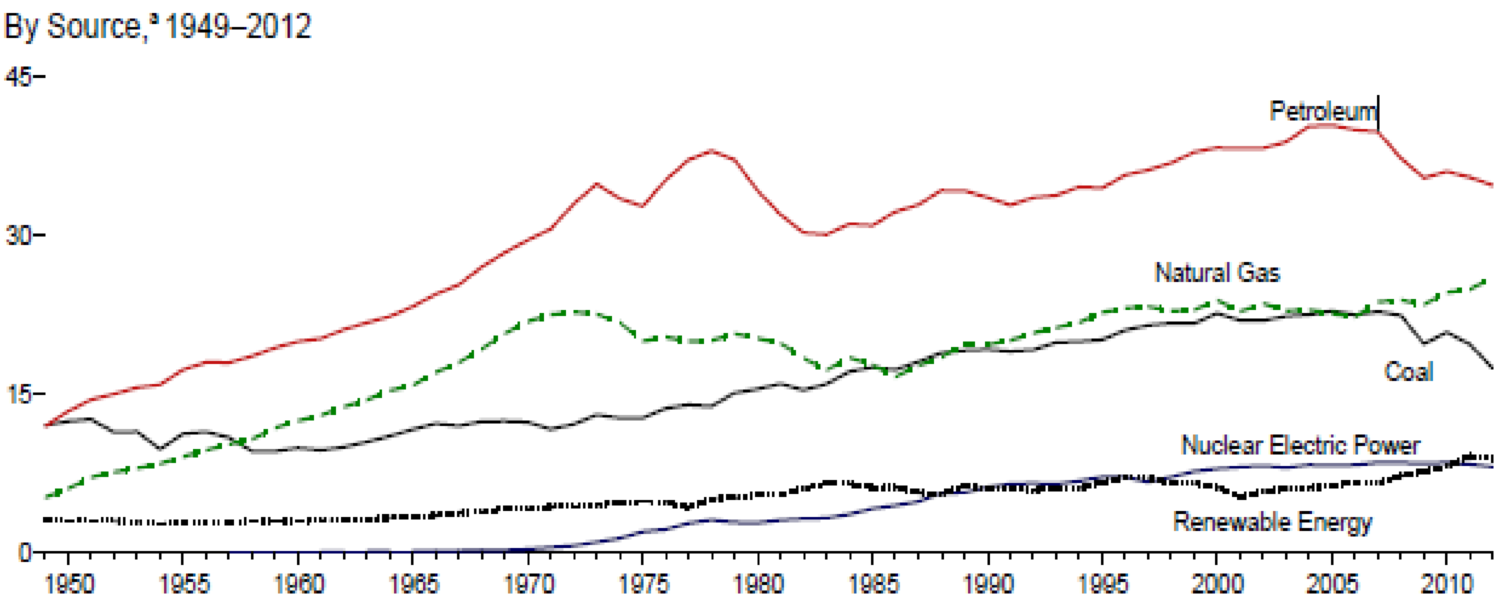


Source: EPA, 2012, Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2010

US Primary Energy Consumption: Fracking Wins, Reduction in Oil Use/Imports, Reduction in Coal for Electricity, Renewables Overtake Nuclear

(http://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf)

Figure 1.3 Primary Energy Consumption
(Quadrillion Btu)



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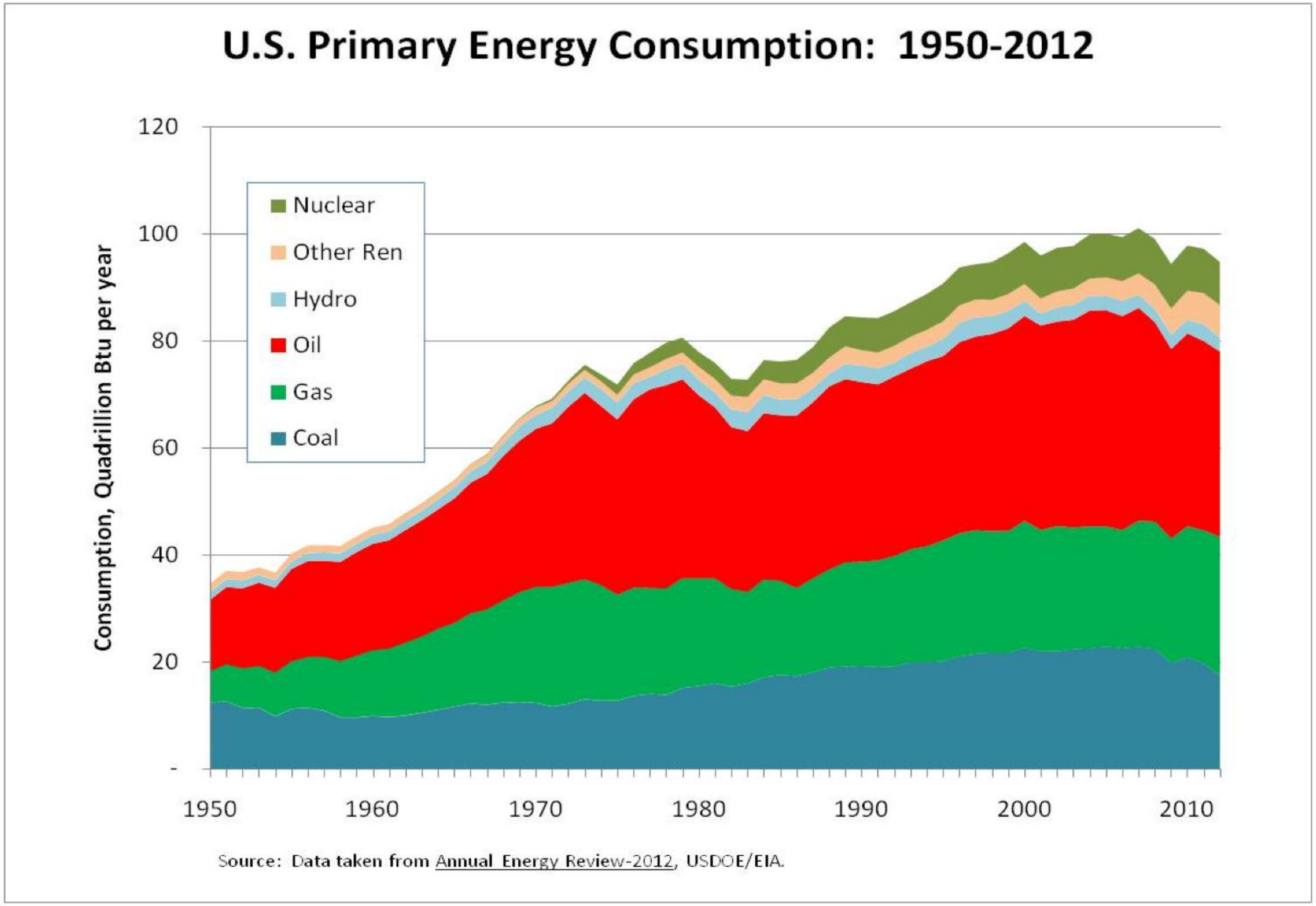
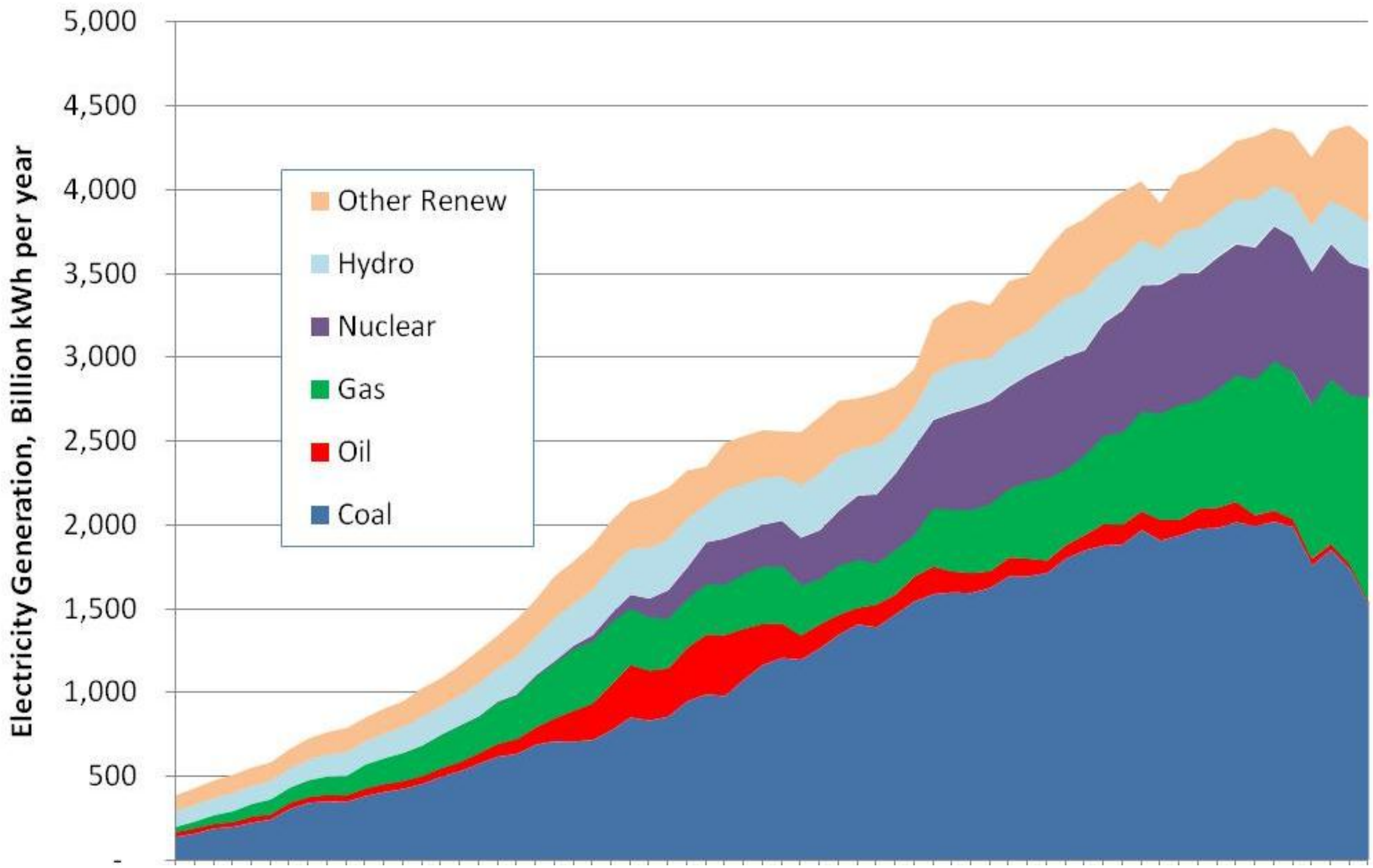
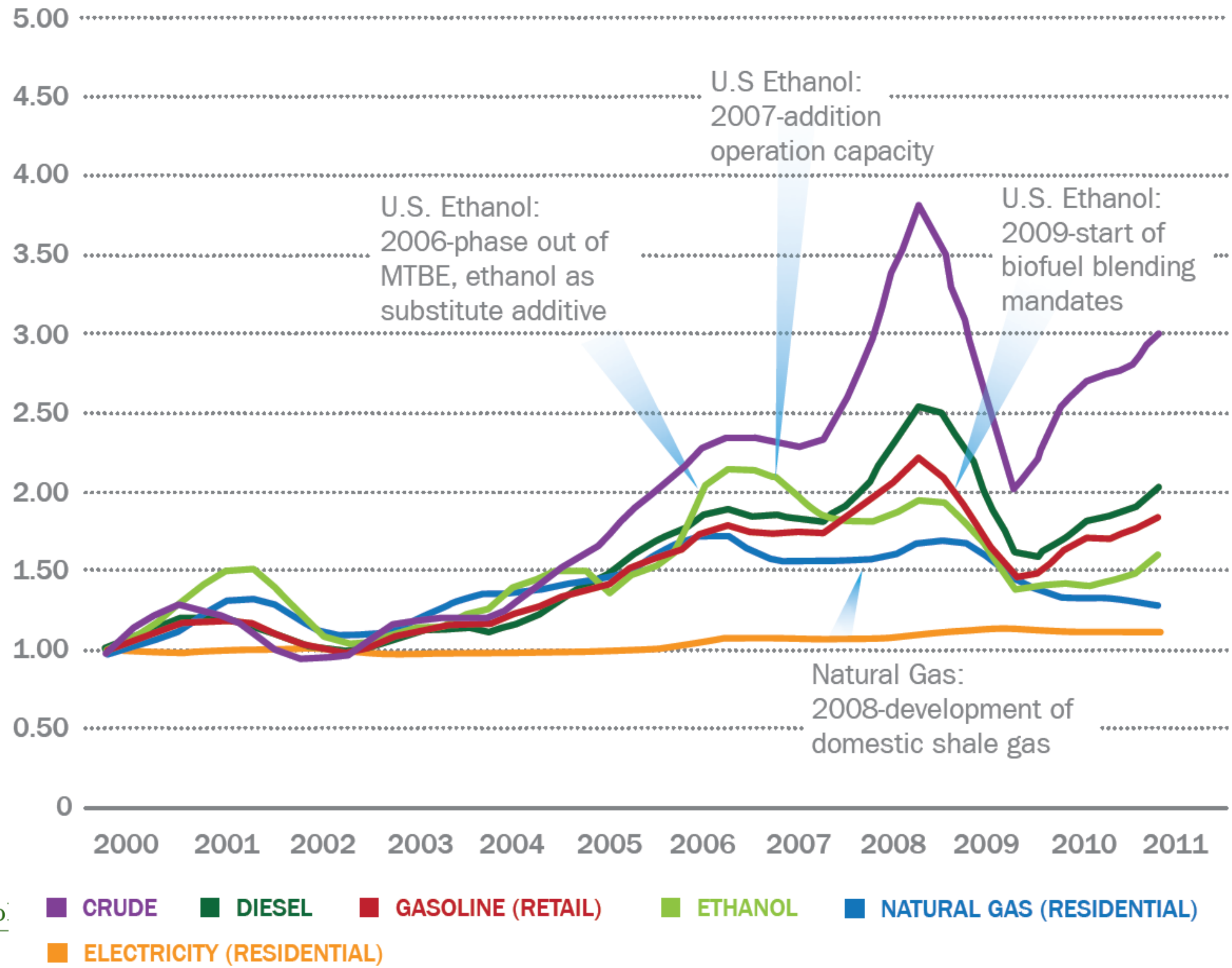
US Energy Consumption Has Not Increased in Ten Years



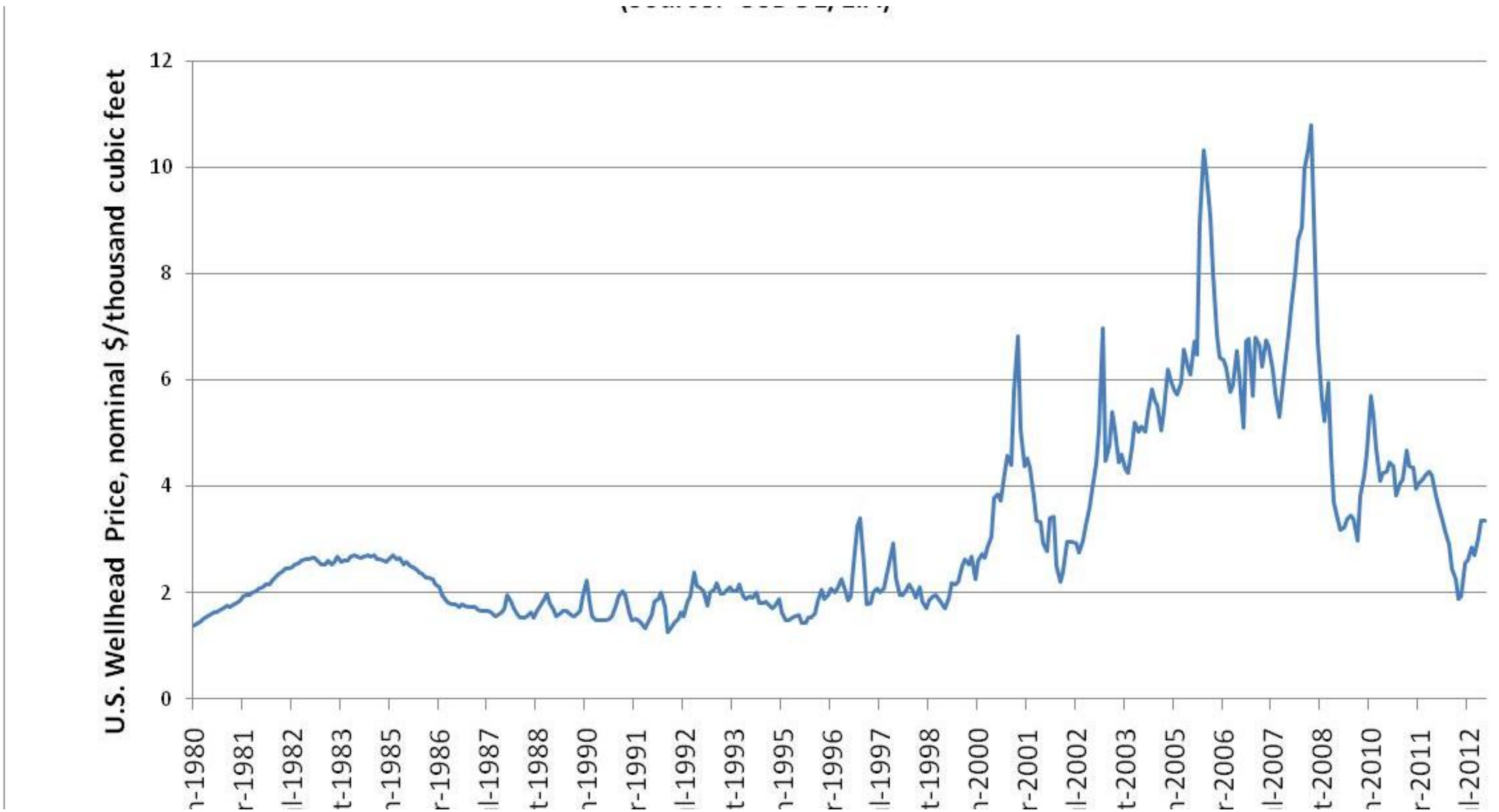
Current Issues: Natural Gas Has Seen Considerable Growth in the Electricity Sector



US Natural Gas Costs Have Become Decoupled From Petroleum Costs in the US

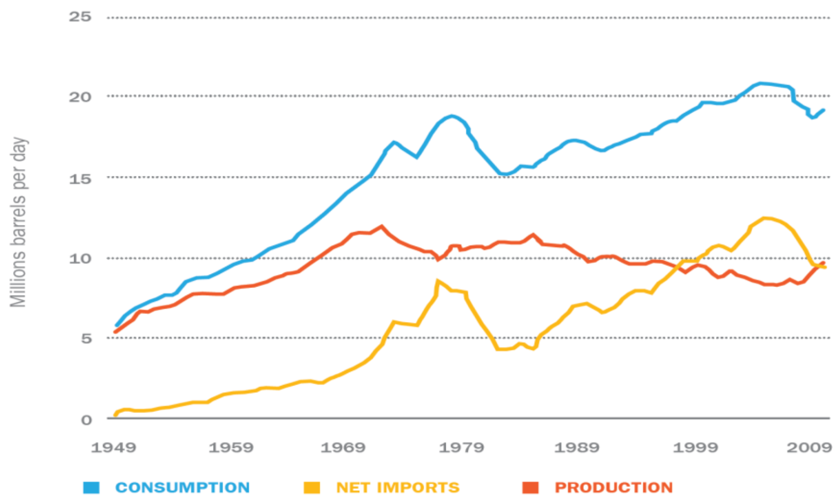


With the Advent of Fracking, Natural Gas Prices Have Plummeted

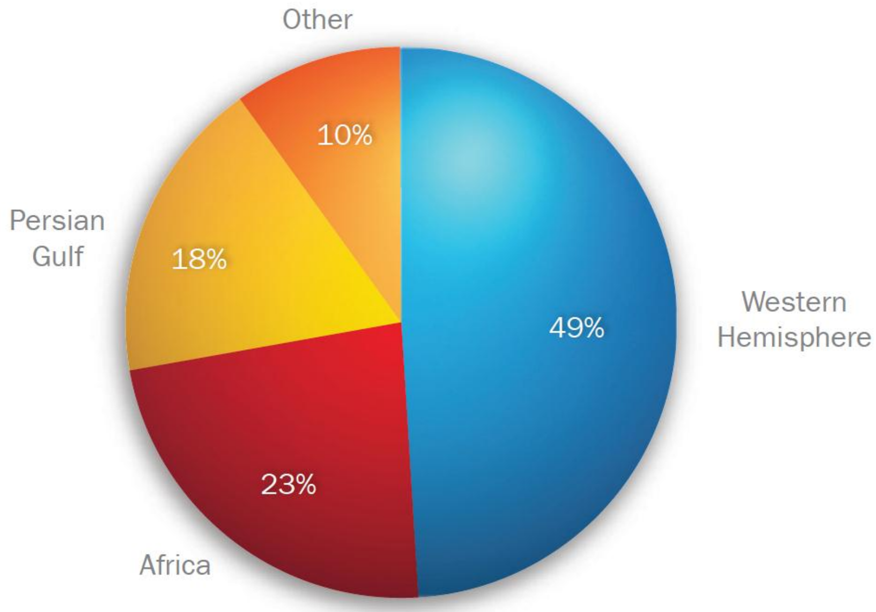


Sources of Liquid Fuels – Imports Now (2013) below 50% of Use

Trends in US Consumption, Production, and Import of Liquid Fuels - 2011



Sources of US Petroleum, 2010



- Due to Bakken and recession, less than 50% of liquid fuels in US are imported - lowest since 1995
- Import of liquid fuels responsible for 70% of national trade deficit (~$1 billion per day)
- Only 20% of oil from Persian gulf but has large impact on costs

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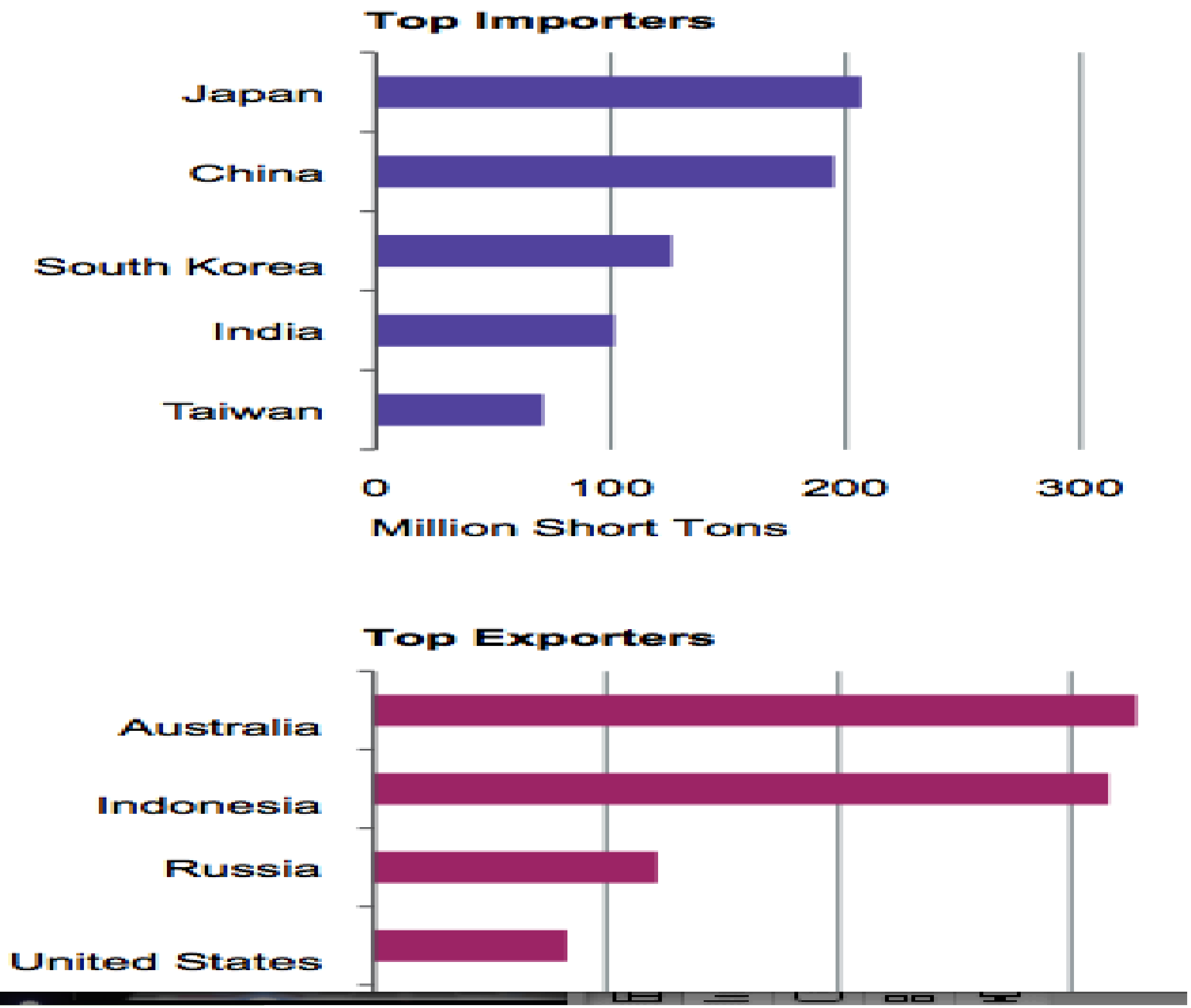
From 2011 DOE QTR

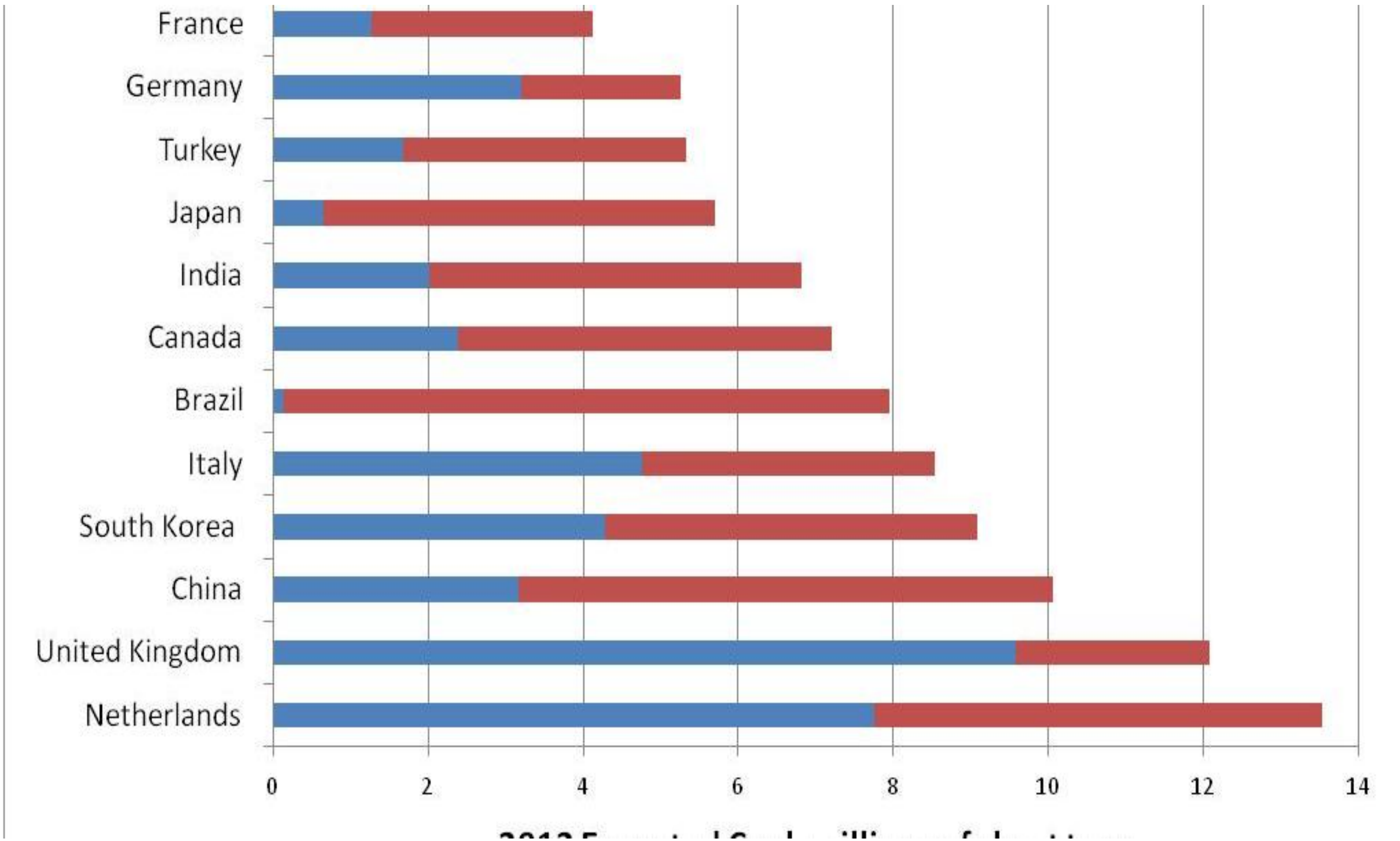
Current Issues: New Regulations May Lead to Closure of 30GW of Coal-fired Capacity

	Affected Units	Regulatory	Quantity, MW
Air Toxics Hg, Ni, V particulates	Principally coal and oil units	MACT	410,000+ coal, oil
CSAPR/ NAAQS	All fossil units	CAA	Complex-Need unit data, operating conditions, etc.
CCP	Coal Only	RCRA	330,000 (utility) Thousands? Industrial
Water OTC/316B	Most thermal plants, including nuclear	CWA	247,000
Regional Haze	All units, but largest burden falls on coal fleet	CAA	15% of coal?
GHG	1st source with a GHG "BACT" is an NGCC	CAA	800,000+

With Decrease of Coal Use in US, the Country Has Become a More Significant Exporter of Coal



Breakout of US Coal Exports
(blue = steam, red = metallurgical)



Where Things Are Happening: States (PUCs) More Aggressive (and Flexible) in Developing Policy Instruments

- Energy Efficiency and Demand Side Management Standards and Goals
  - Standards developed for building codes and appliances
  - PUCs now denying most coal-fired applications based on future carbon prices
- Renewable Portfolio Standards (RPS) now in 34 of 50 states, plus DC
  - Feed-in tariffs (with an eye towards grid stability)
  - Net metering laws and regulations
- Power Purchase Agreements - national law
  - Under PURPA (now repealed) - based on avoided cost
  - New PPAs must (and generally do) take into account ancillary services - grid stability, reliability, Var support from fossil-fired systems
  - State-based PUCs tend to limit interstate transmission as they also look for "green" job creation within their states
- T&D investments, access and interconnection - "Dueling laws"
  - BUT, various public (ISOs, state EPA) and private intervenors can drag out interconnection time and increase costs for any IPP

Recent Example: AB 2514 – Landmark Energy Storage Law in California

- Considered establishing Energy Storage Procurement Targets for 2020
  - IF cost-effective
  - IF commercially available
- Directed California Public Utility Commission to convene a proceeding to evaluate energy storage procurement targets:
  - Required CPUC to consider information from CAISO and integration of storage with other programs, including demand side management
  - Utility-owned, customer-owned, and third party-owned are eligible

CPUC decision on October 17, 2013 requires utilities to purchase 1.3 GW of storage. However will it prove to be too prescriptive?

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Carbon Management Options

Reduce Carbon Intensity

- Renewables
- Nuclear
- Fuel Switching

Improve Efficiency

- Demand Side
- Supply Side

Carbon Storage

- Capture & Store
- Enhance Natural Sinks

All options needed to meet:

- **Affordable energy demand**
- **Environmental objectives**
- **Security objectives**

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Energy Efficiency – The Most Cost Effective Approach

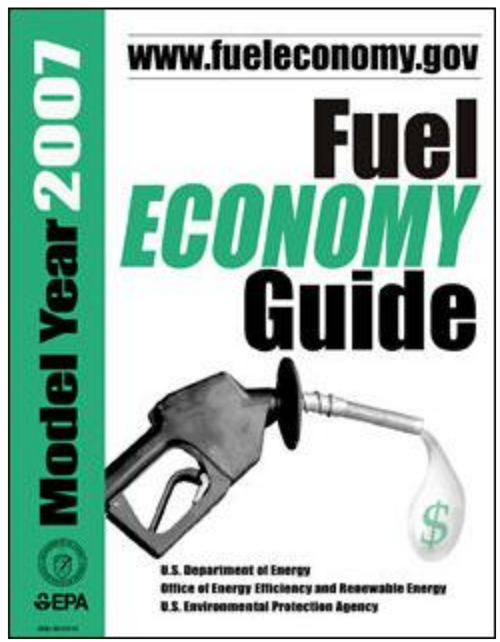
LIGHT OUTPUT EQUIVALENCY

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:

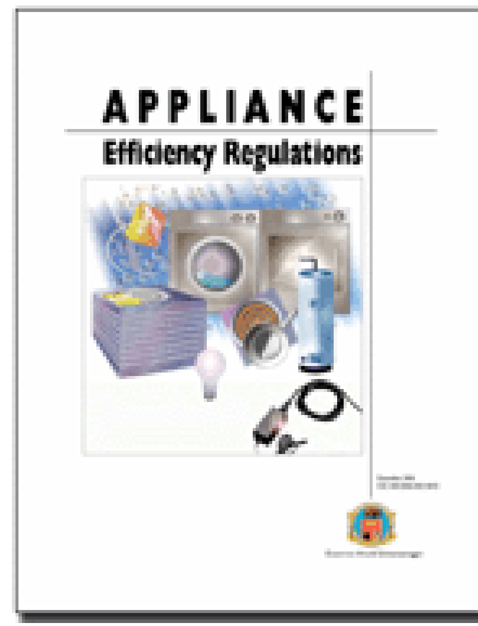
INCANDESCENT LIGHT BULBS	MINIMUM LIGHT OUTPUT	COMMON ENERGY STAR QUALIFIED LIGHT BULBS
WATTS	LUMENS	WATTS
40	450	9-13
60	800	13-15
75	1,100	18-25
100	1,600	23-30
150	2,600	30-52

LEARN MORE AT energystar.gov

Lighting

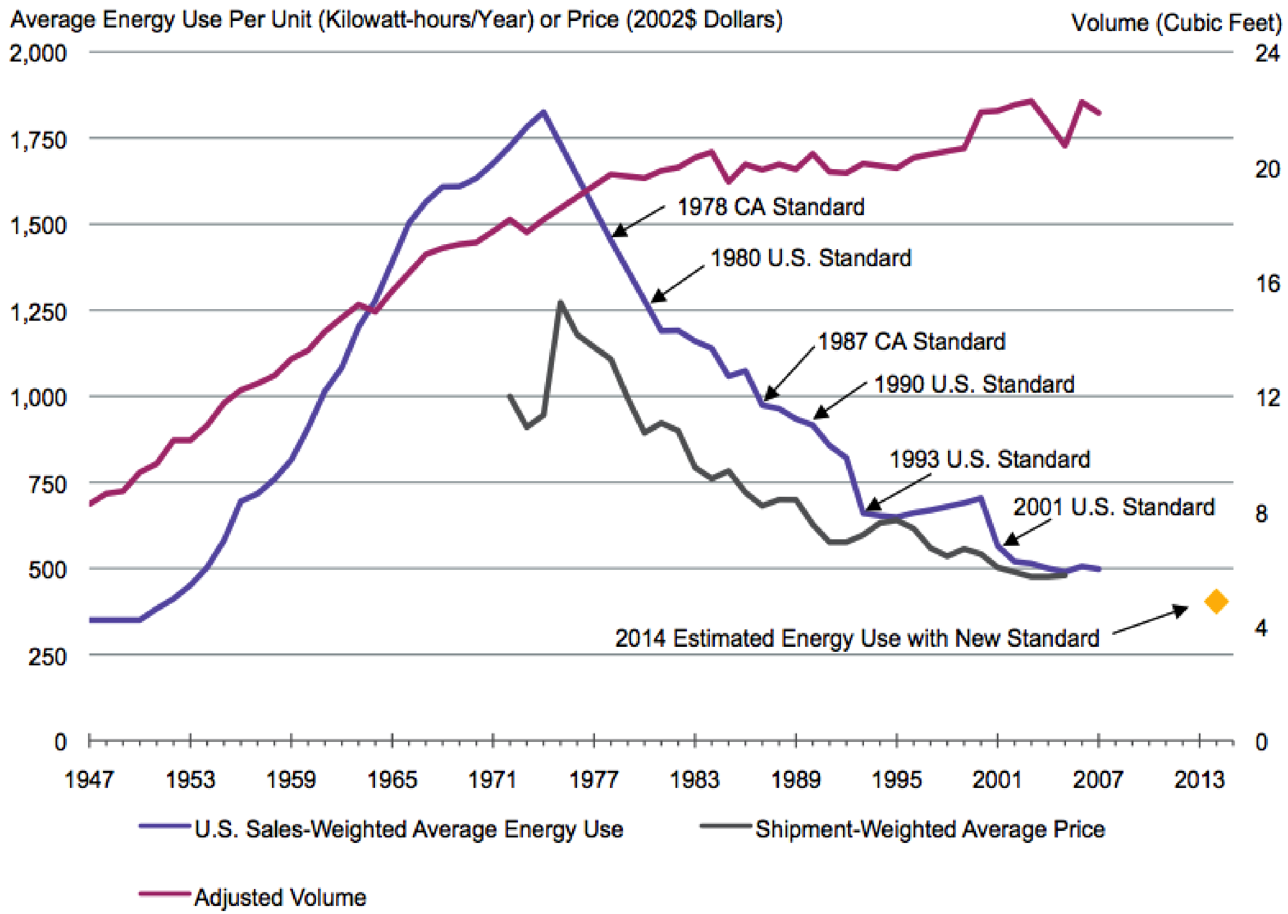


Transportation



Appliances

Refrigeration Efficiency as an Example



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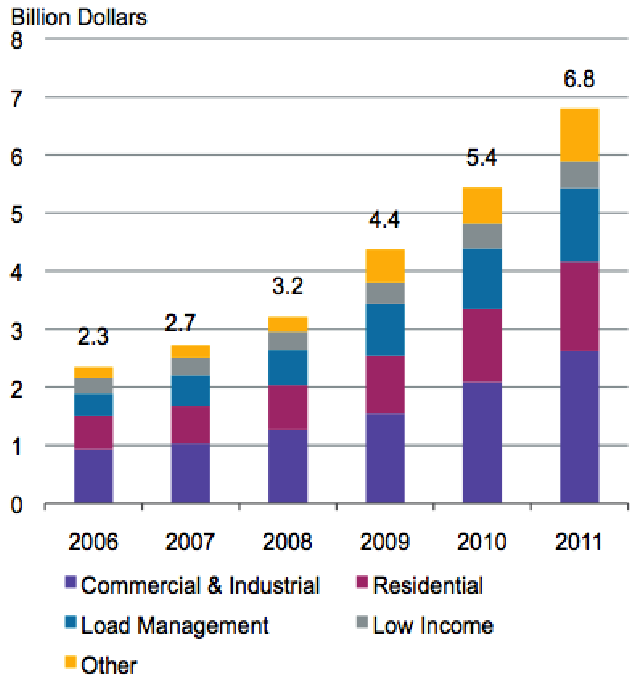
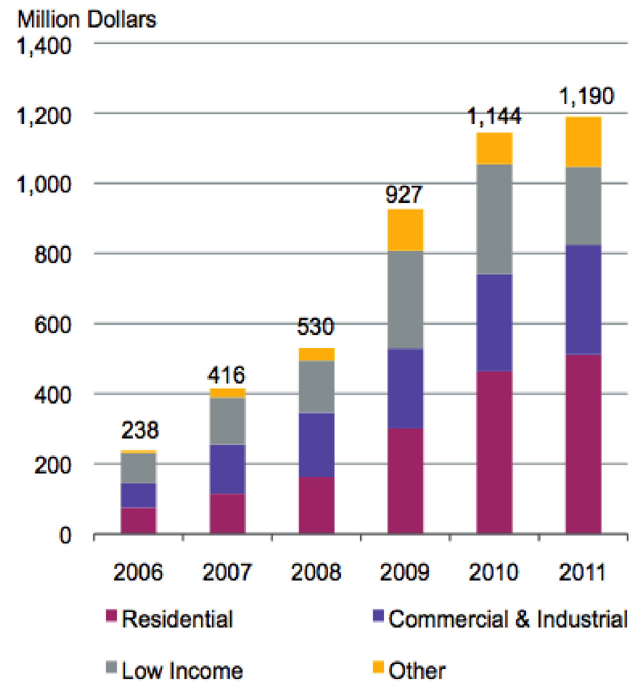
State Public Utility Commissions Approve Energy Efficiency Budgets

Figure 3-5: Energy Efficiency Program Budgets for U.S. Electric Utilities, 2006-2011



Note: Actual expenditures could vary from the budget numbers.
Source: Patrick Wallace and Hilary Jane Forster, Consortium for Energy Efficiency, *State of the Efficiency Program Industry: Budgets, Expenditures, and Impacts 2011*, March 14, 2012, http://library.cee1.org/sites/default/files/library/8000/2011_CEE_Annual_

Figure 3-6: Energy Efficiency Program Budgets for Gas Utilities, 2006-2011



Note: Actual expenditures could vary from the budget numbers.
Source: Patrick Wallace and Hilary Jane Forster, Consortium for Energy Efficiency, *State of the Efficiency Program Industry: Budgets, Expenditures, and Impacts 2011*, March 14, 2012, http://library.cee1.org/sites/default/files/library/8000/2011_CEE_Annual_

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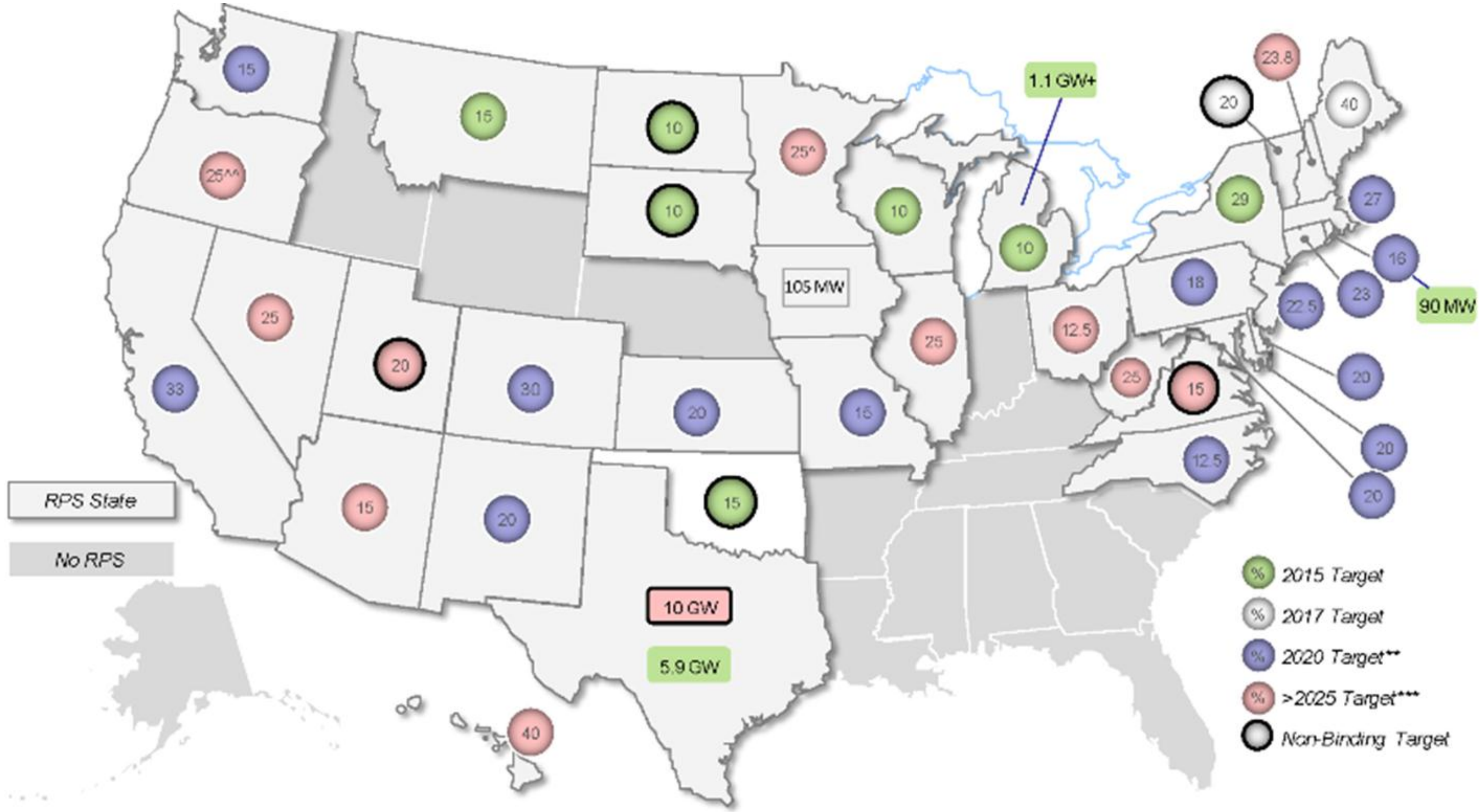
State RPS Map

RPS – Renewable Portfolio Standard



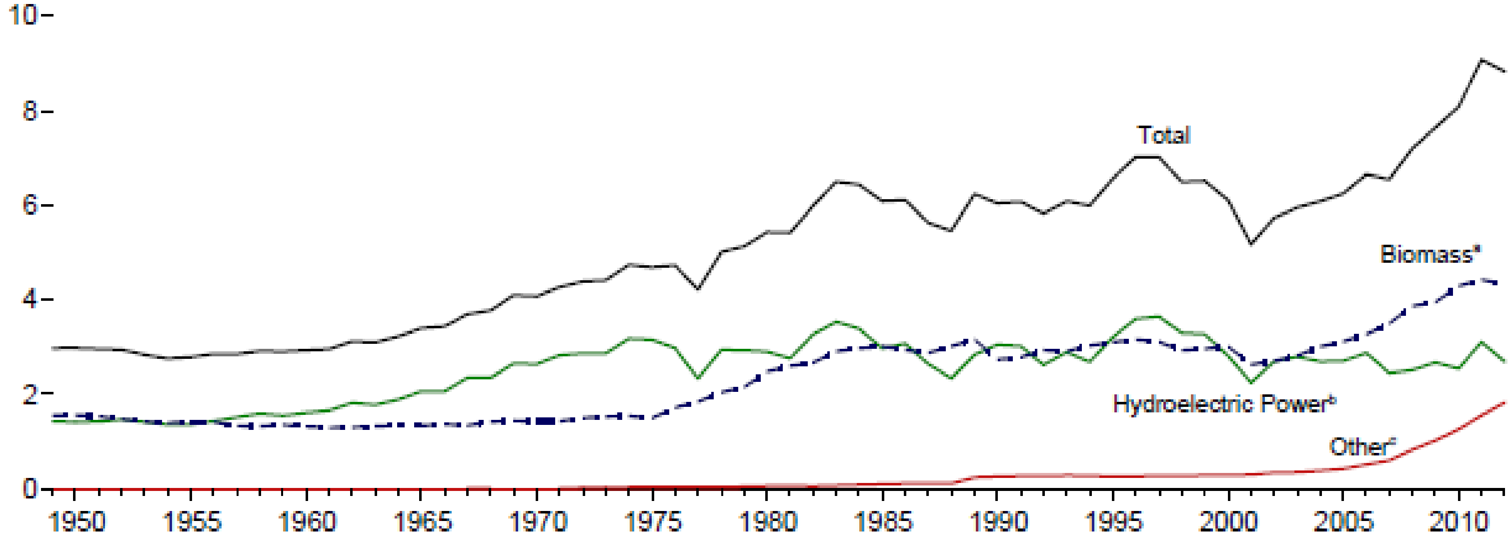
Note: *Includes states with installed capacity >1 MW. **Includes targets for 2019 (RI), 2021(MO, NC), and 2022 (MD). ***Includes Hawaii, with target date of 2030. ^Separate target for Xcel Energy at 30% by 2020. ^^By 2025: 25% (large utilities), 10% (small); 5% (smallest)

Source: IHS Emerging Energy Research

Renewable Energy Consumption - note hydro decrease in 2012 due to extensive national drought

Figure 10.1 Renewable Energy Consumption
(Quadrillion Btu)

Total and Major Sources, 1949–2012



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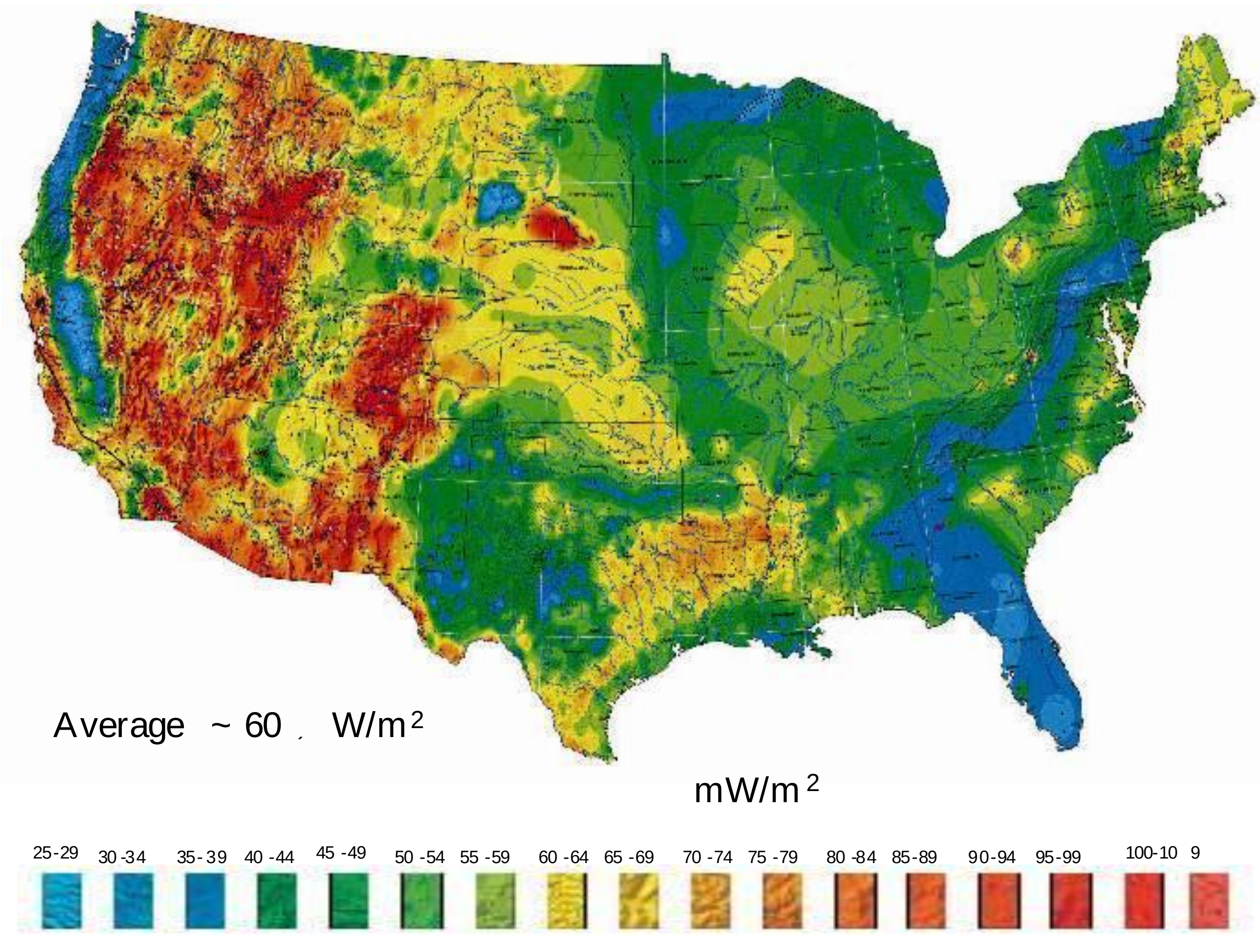
More than 100 GW of Estimated Undeveloped Geothermal in US: Issues Are Lack of Transmission, Remote from Load Centers, Interstate Commerce



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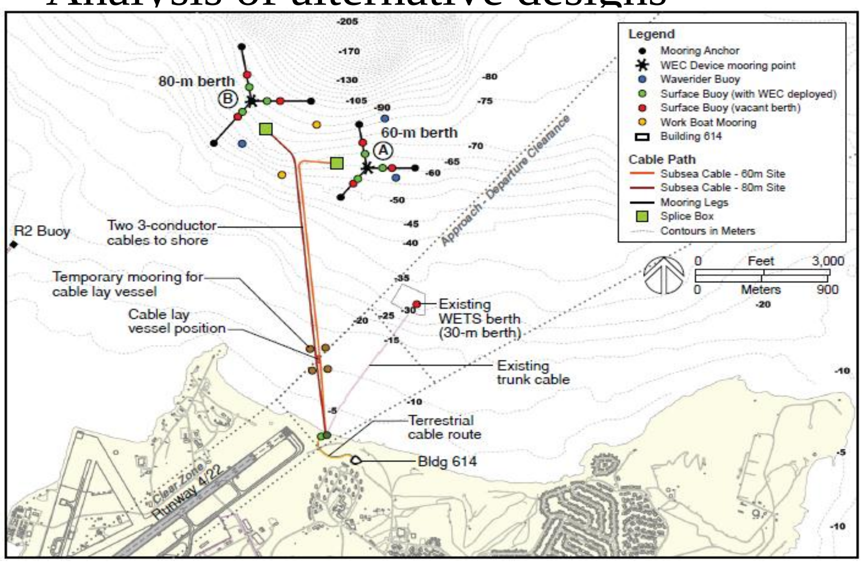
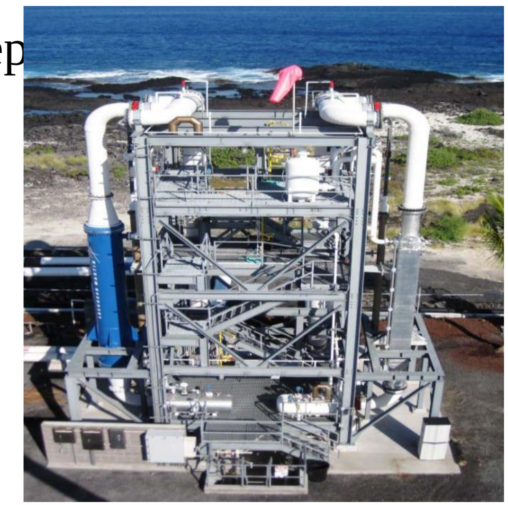
Ocean Resources Are Not Ready for Prime Time

- **Hawaii National Marine Renewable Energy Center - US DOE funding to:**
  - Facilitate commercial development of wave energy conversion devices
  - Reduce technology risk for ocean thermal energy conversion (OTEC)
  - Oregon State University is the other Center
- **Sea Water Air Conditioning (cost reduction)**
  - Plume modeling to characterize impacts of discharge dep
  - Environmental monitoring to verify performance
  - Analysis of alternative designs



Kaneohe Bay - WETS



Makai OTEC Test Facility

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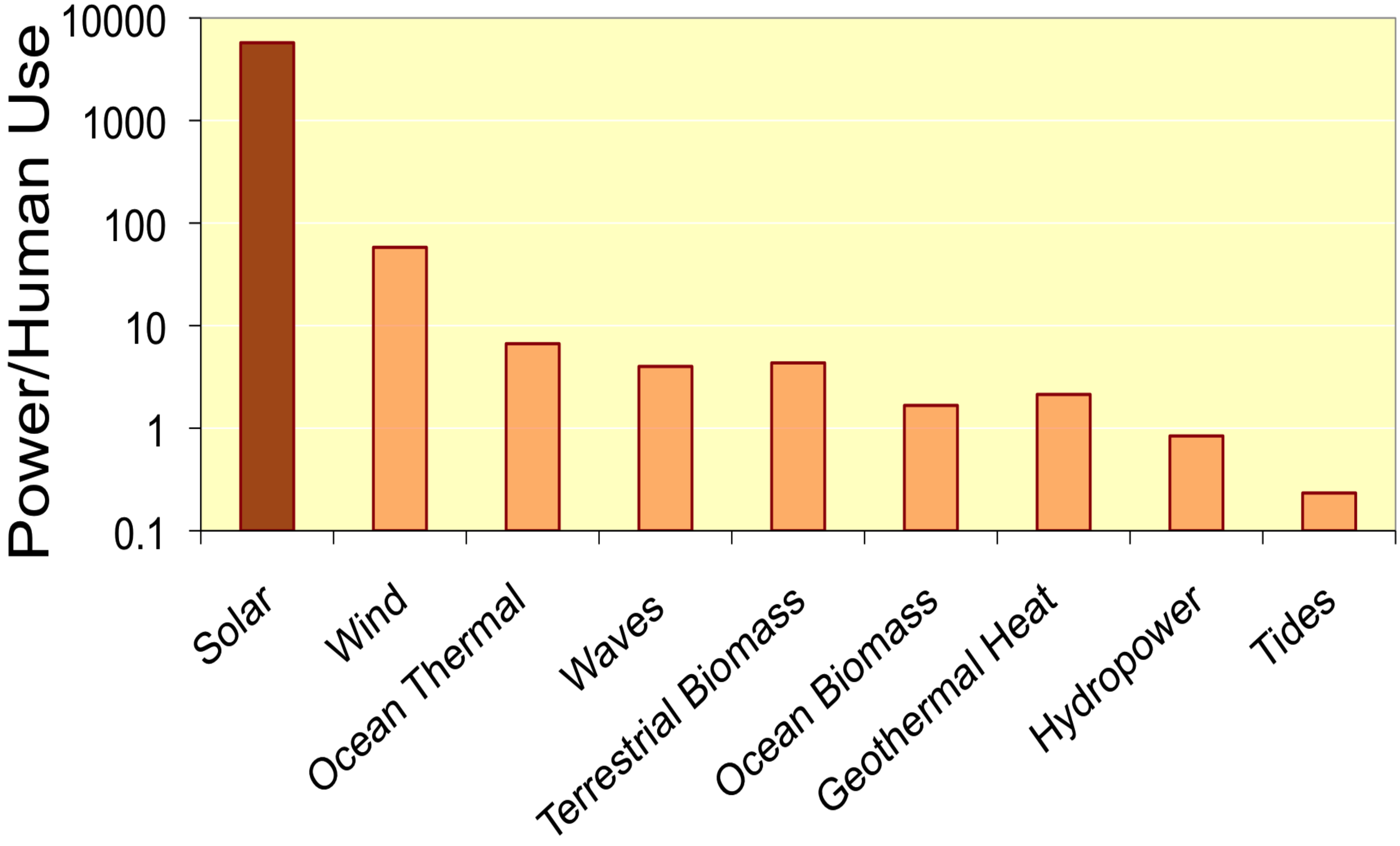
On to Variable Renewable Resources,
Solar Energy is Largest Renewable Energy Resource



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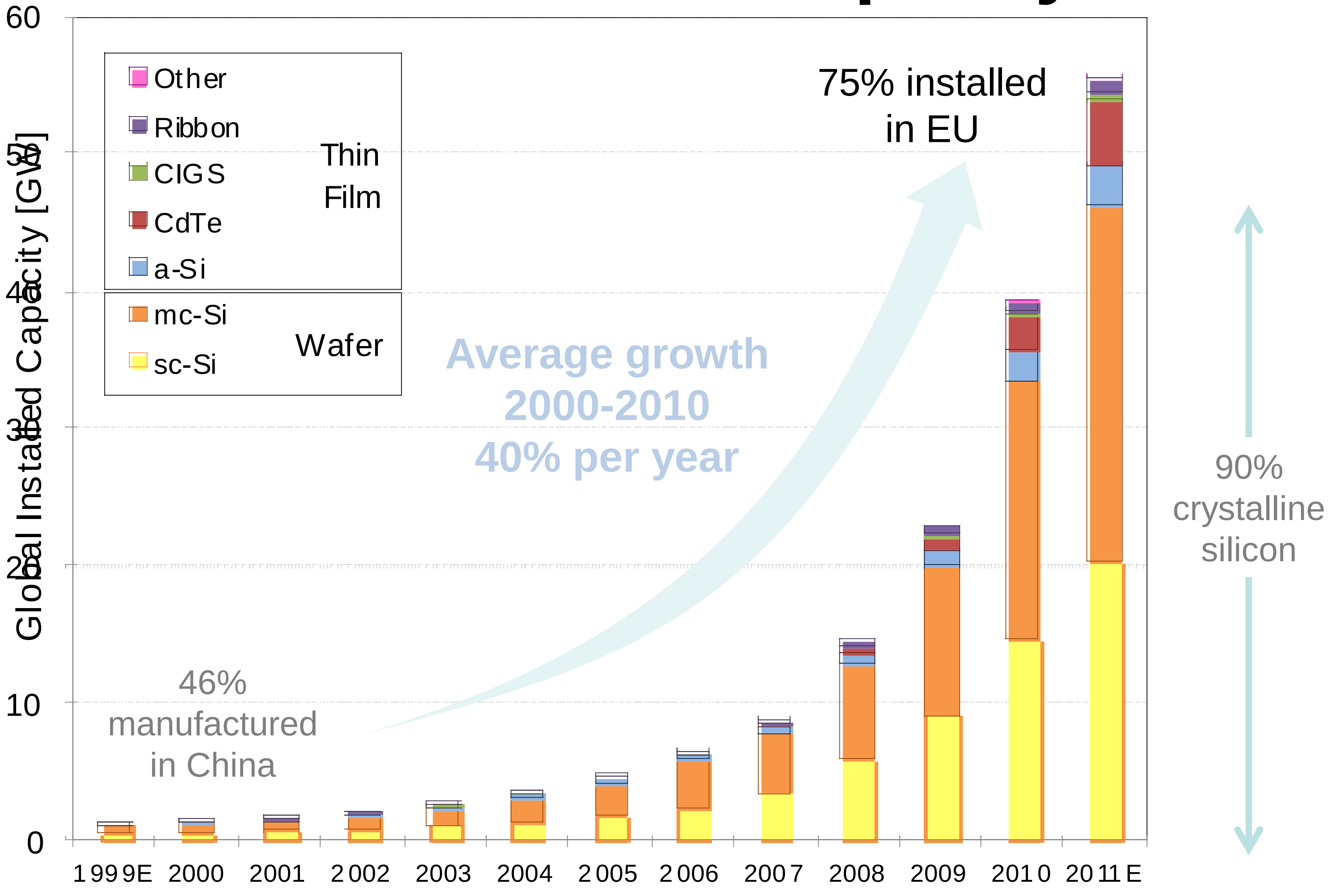
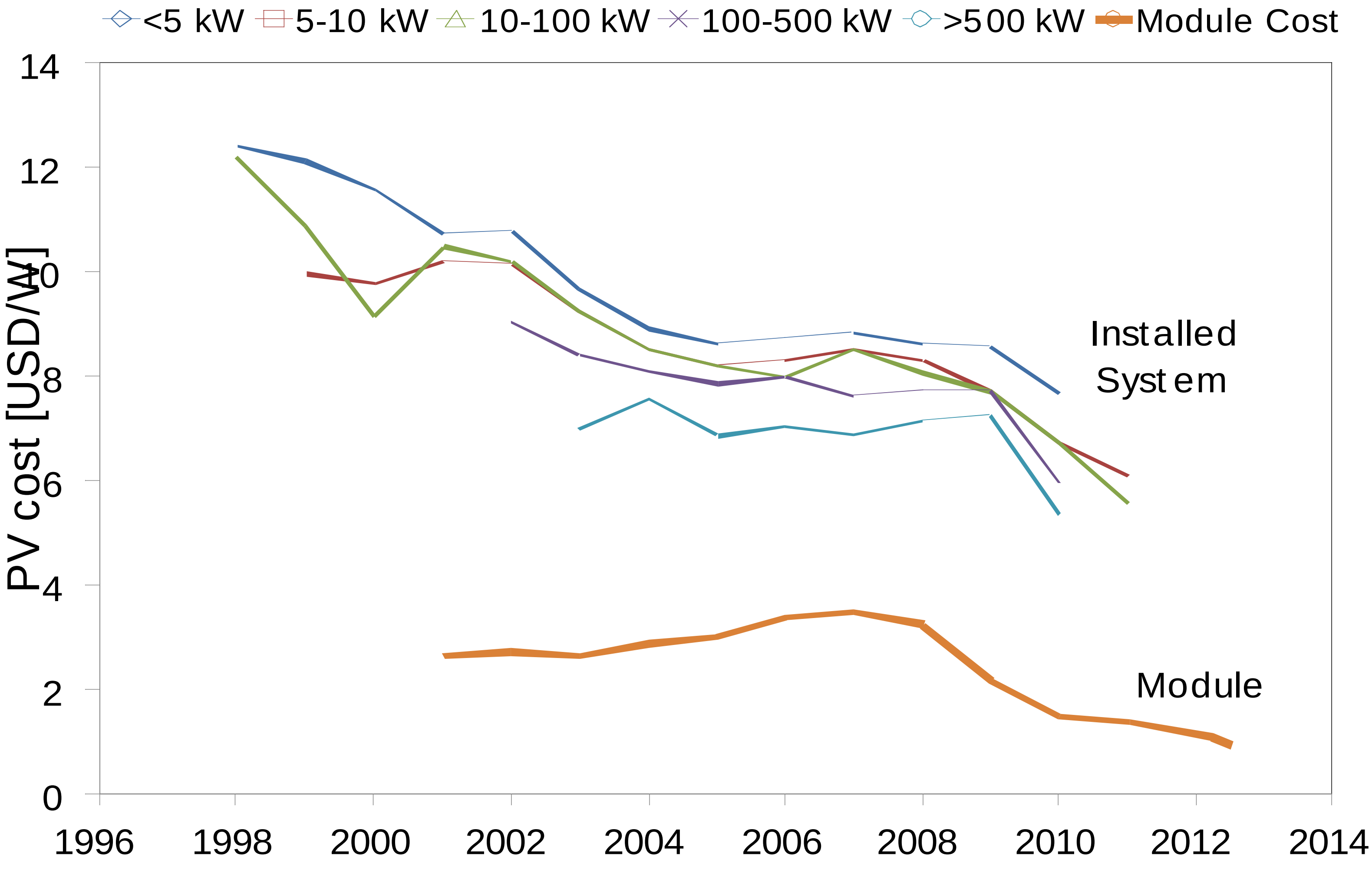
PV Industry is Growing Rapidly, BUT Now with an Overcapacity



DOE (2008), EPIA (2011), EIA (2012), UN (2012)

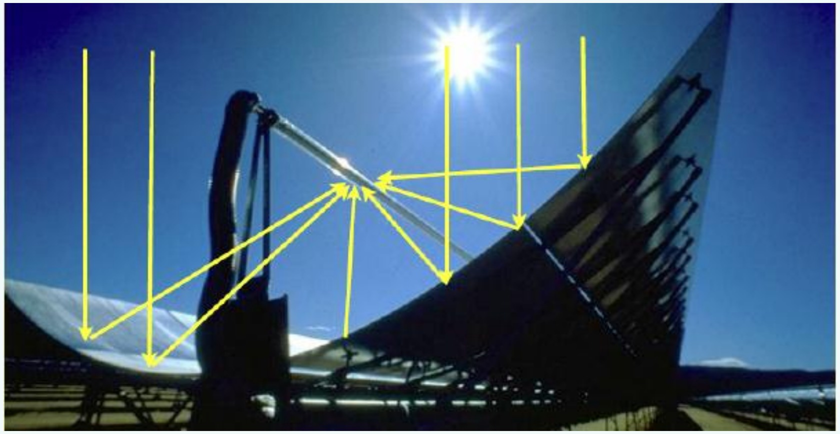
Module and Installed System Cost Have Declined Rapidly - Role of Third Parties



LBNL (Nov 2012) Tracking the Sun V

Concentrating Thermal Systems in California/Nevada Deserts (Sterling now not being used, and other cancellations due to CPUC actions)

Concentrate to line



Parabolic trough

Fresnel lens

Concentrate to a point

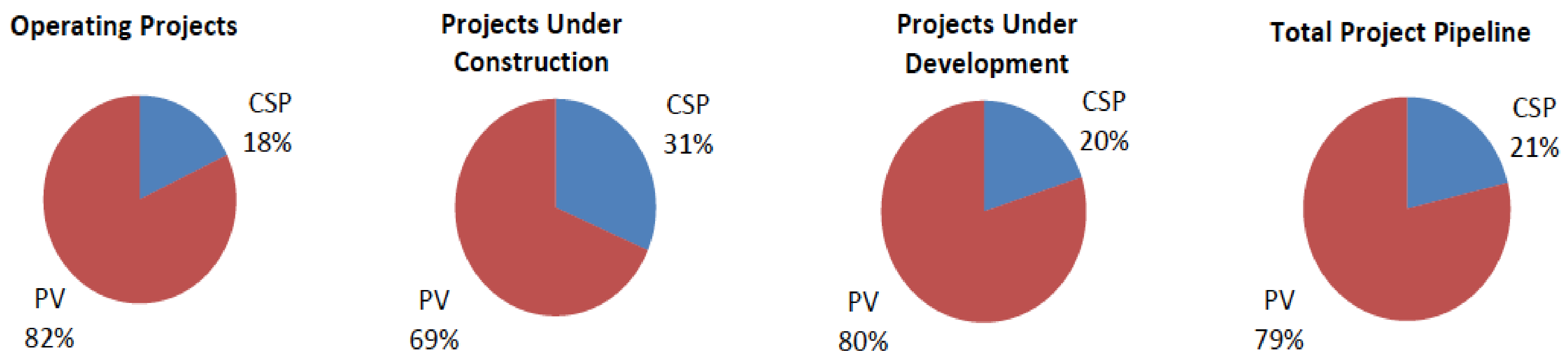
Sterling engine with dish

Power tower

Utility Scale Solar Pipeline in the United States

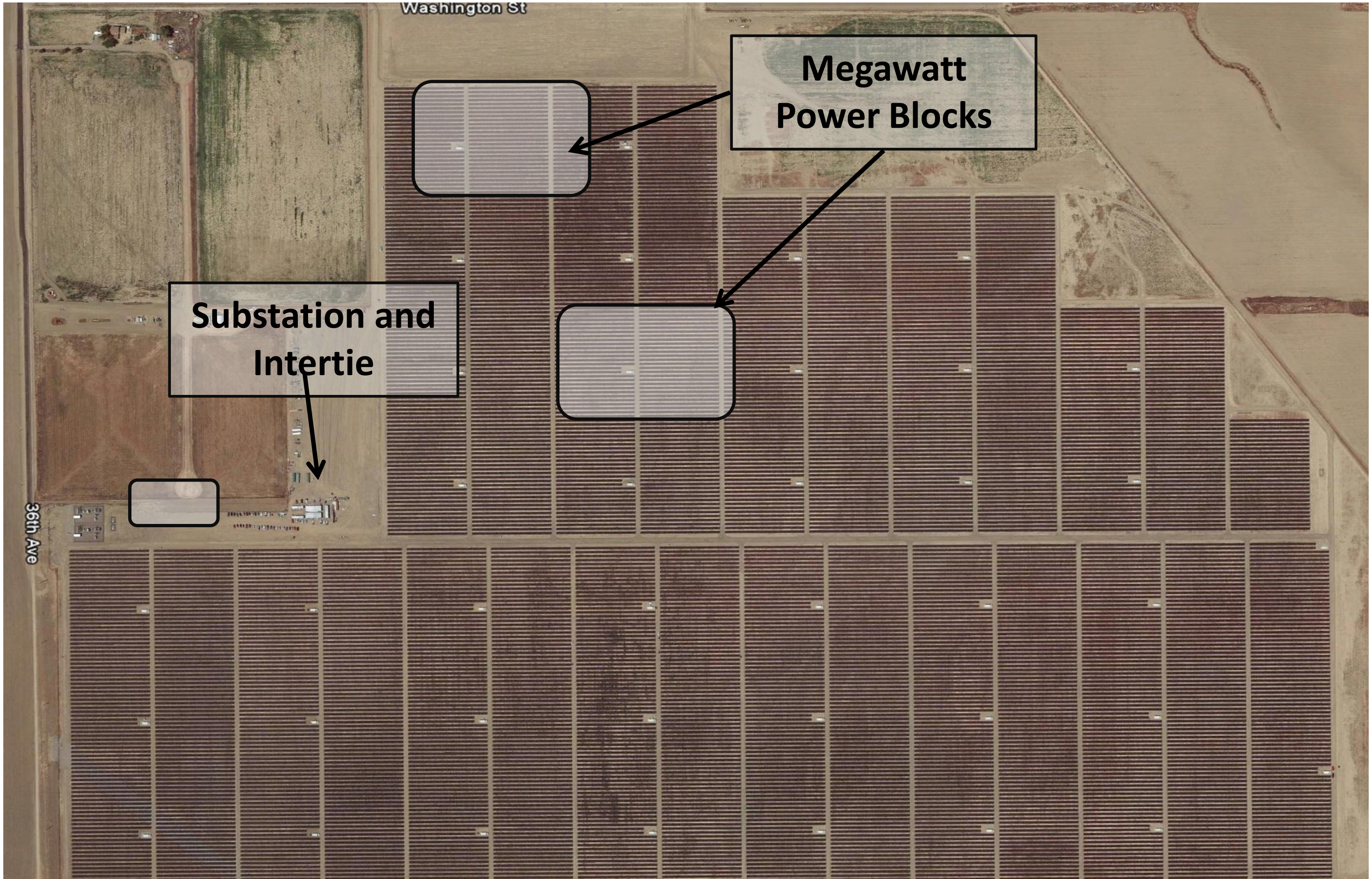
Utility-Scale Solar Projects in the United States
Operating, Under Construction, or Under Development
Updated February 11, 2013

Utility-Scale Project Capacity by Technology and Completion Status (MW)				
Technology	Operating	Under Construction	Under Development	Total
CSP	523	1,317	5,244	7,084
PV	2,387	2,870	20,981	26,239
Total	**2,910**	**4,187**	**26,225**	**33,323**

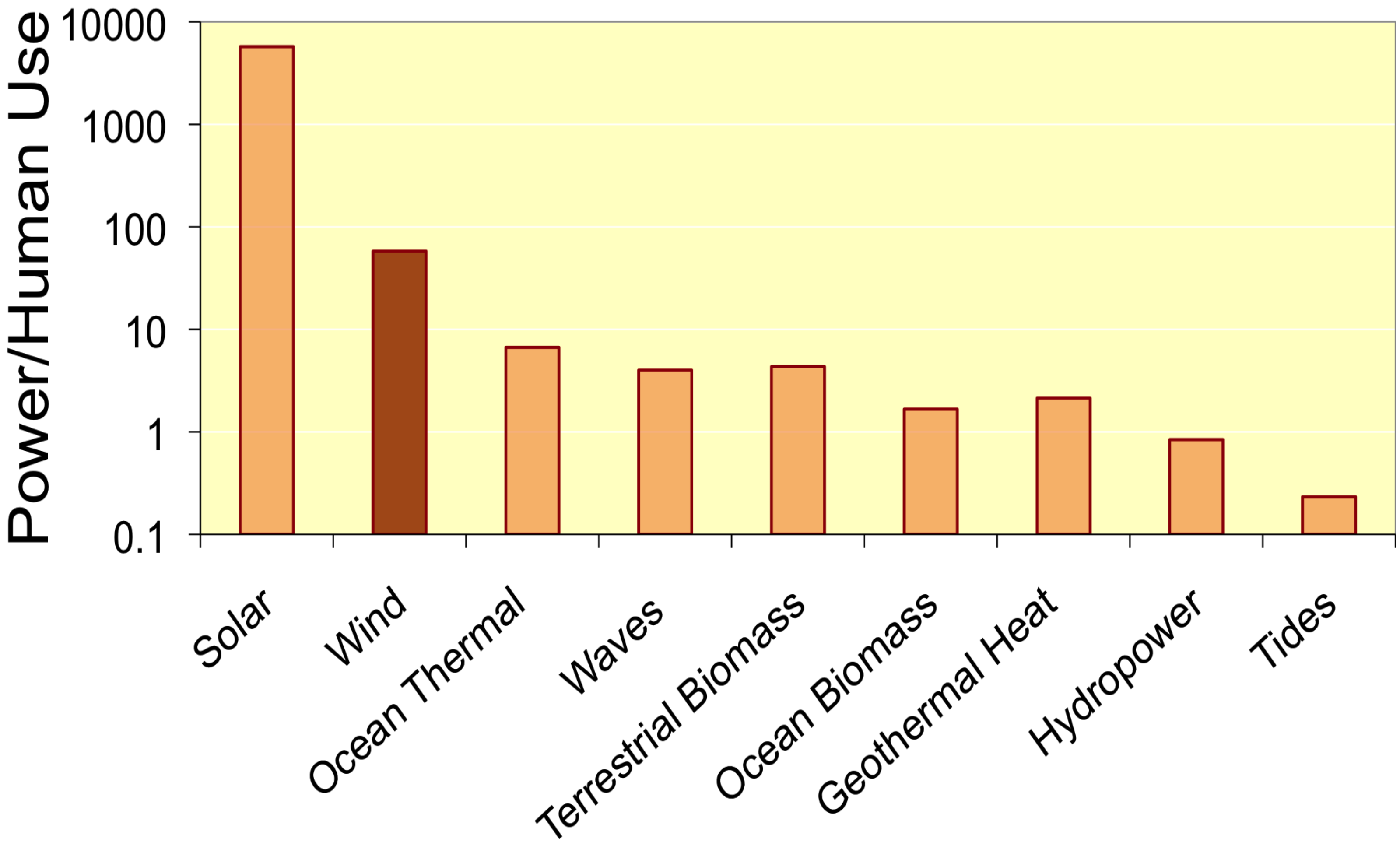


Installed Capacity:
California (1,049 MW) >> Nevada (332 MW) ~ Arizona (586 MW)

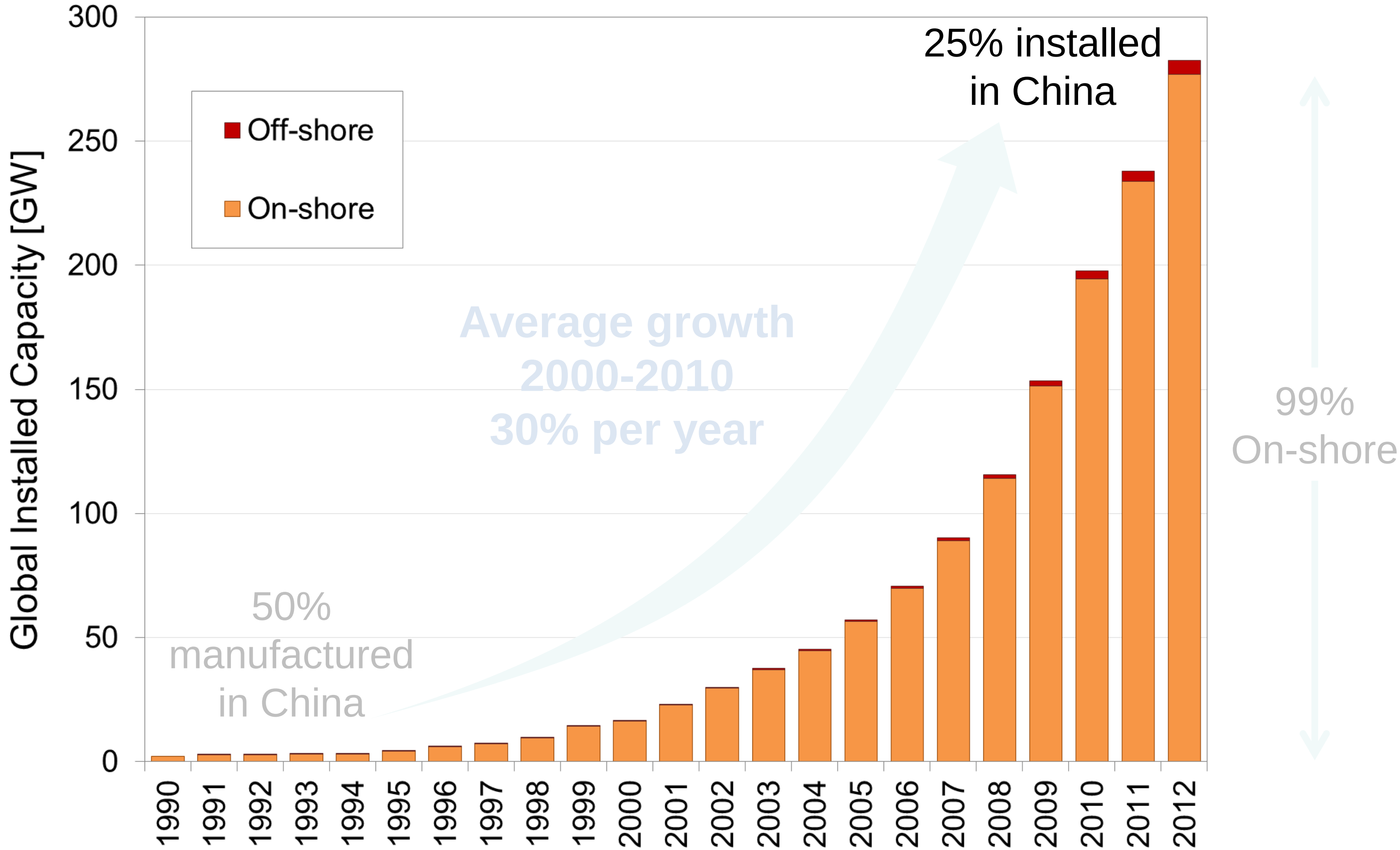
Utility Scale System: One MW = six acres



Wind Energy is Second Largest Renewable Energy Resource



Wind Industry Is Also Growing Rapidly



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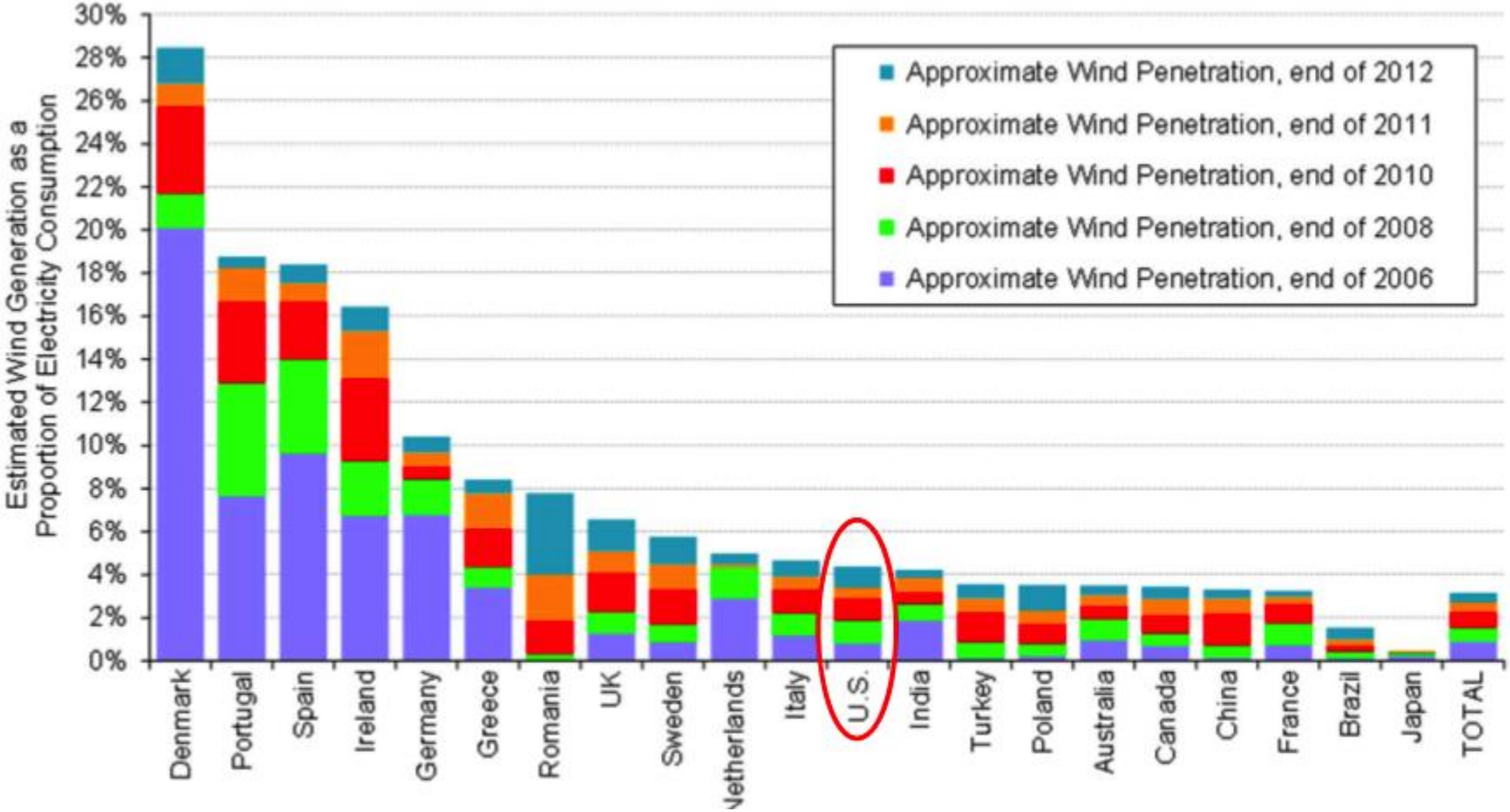
In 2012, US Installed More Wind than China some of following slides from Wiser and Bollinger, LBNL

Annual Capacity (2012, MW)		Cumulative Capacity (end of 2012, MW)	
U.S.	**13,131**	China	75,372
China	12,960	**U.S.**	**60,005**
Germany	2,415	Germany	31,467
India	2,336	Spain	22,462
U.K.	1,958	India	18,602
Italy	1,272	U.K.	9,113
Spain	1,112	Italy	7,998
Brazil	1,077	France	7,593
Canada	936	Canada	6,214
Romania	923	Portugal	4,363
Rest of World	6,838	*Rest of World*	42,368
TOTAL	**44,958**	**TOTAL**	**285,558**

However, US Significantly Lags Other Countries in Wind Penetration Percentage



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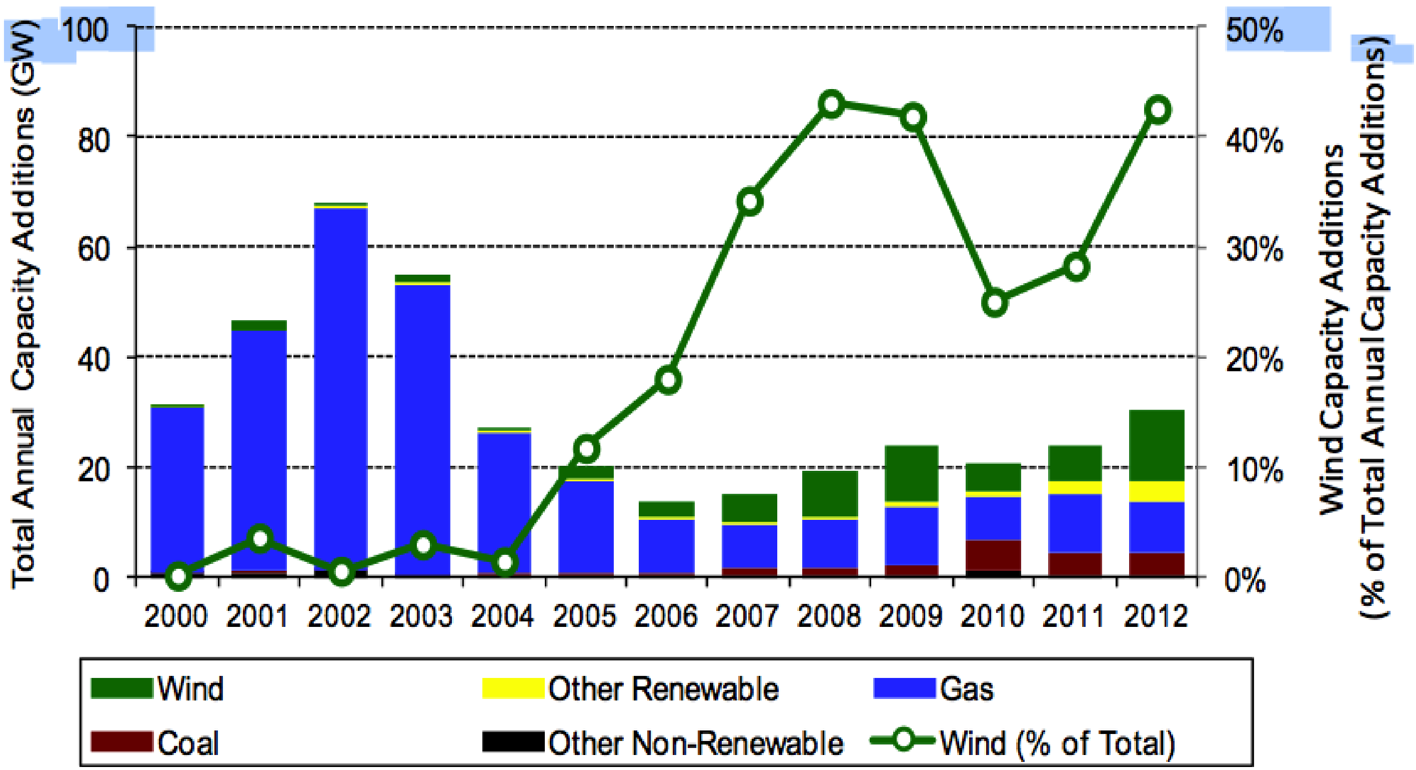
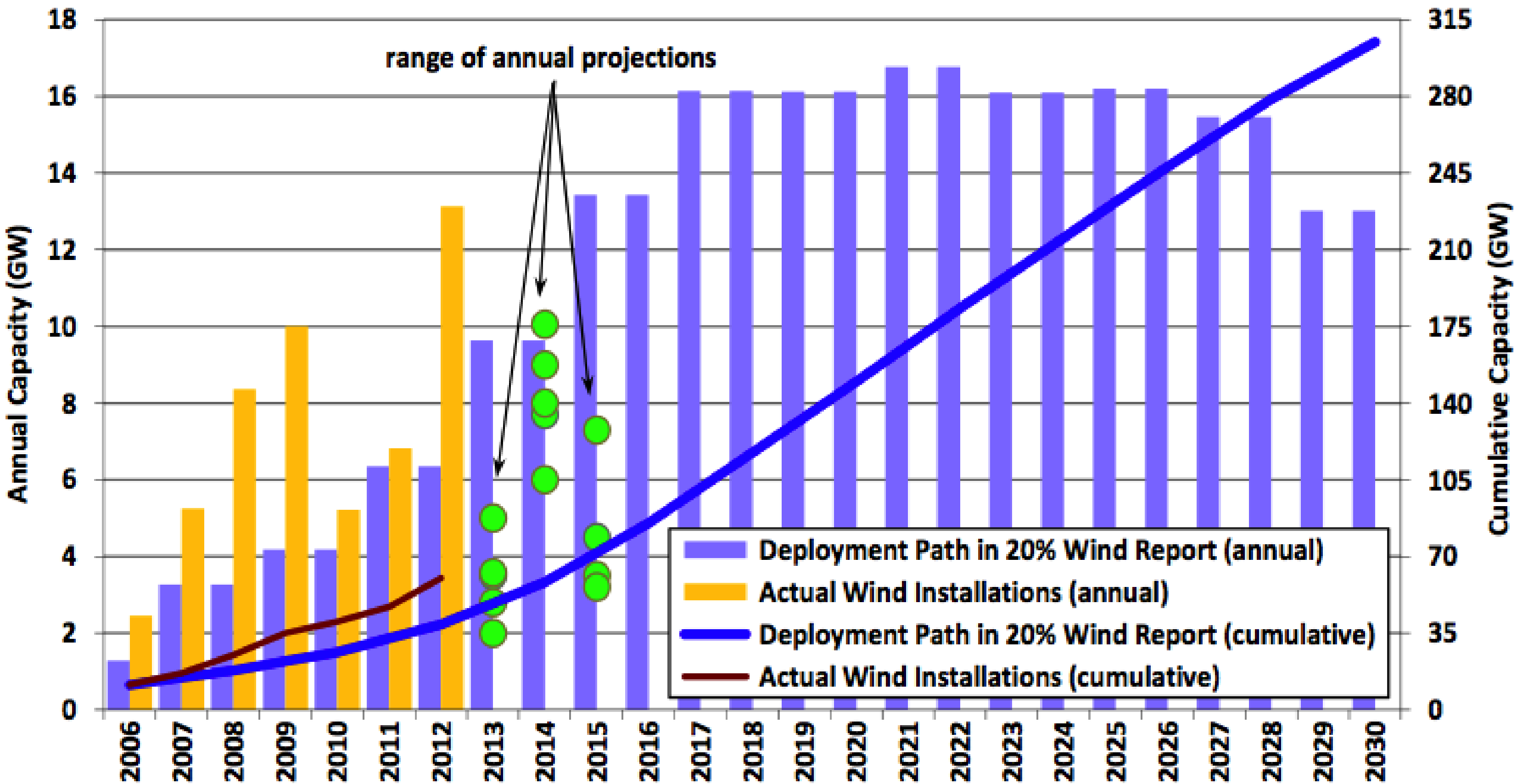
Percentage of Wind Installed Increased, But More Natural Gas Likely

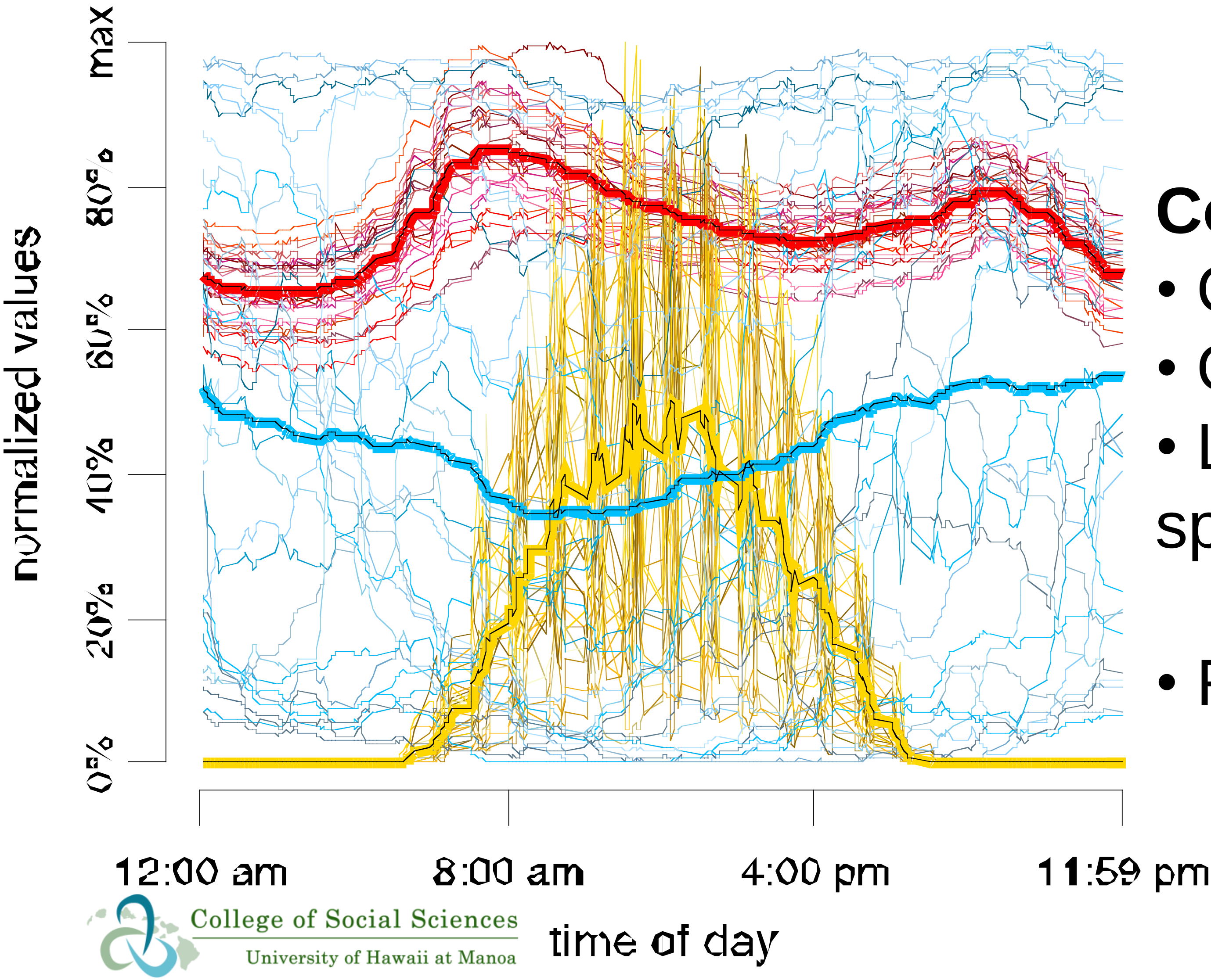


- Wind was, for the first time, the largest resource added in terms of gross capacity, despite persistently low natural gas prices

Wind Systems Were on Track to Meet Projections, BUT Loss of PTC in 2013 Led to Only 300MW Installed



Wind and Solar Resources are Variable



Consequences

- Curtailment
- Grid instability
- Large spinning reserves
- Rapid ramping

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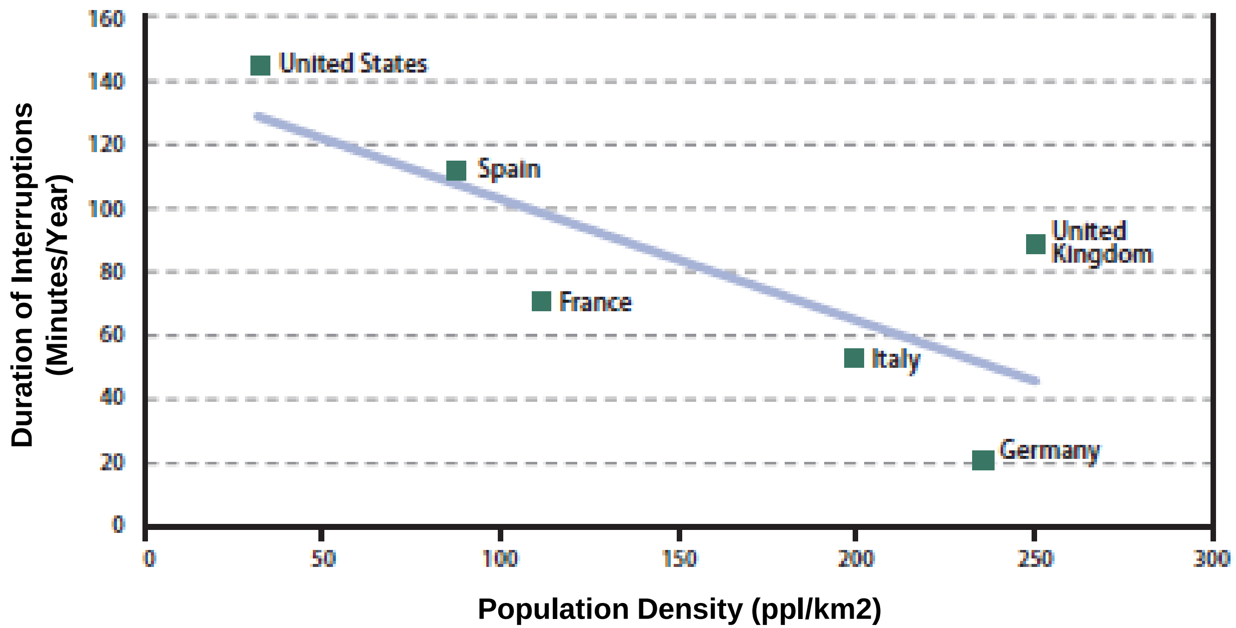
timeseries data obtained from Bonneville Power Administration

plot concept motivated by Hawkins, 2005

Interruptions Due to Variability of Renewable Generation: Cost of Interruptions Is $79B with 66% from Momentary (Less than 5 Minute) Events

Average Duration of Interruptions for Selected Countries, 2006



Source: United States Reliability Data: J.H. Eto and K.H. Lacommare, *Tracking the Reliability of the U.S. Electric Power System: An Assessment of Publicly Available Information Reported to State Public Utility Commissions* (Berkleley, CA: Lawrence Berkeley *4th Benchmarking Report on Quality of Electricity Supply 2008*

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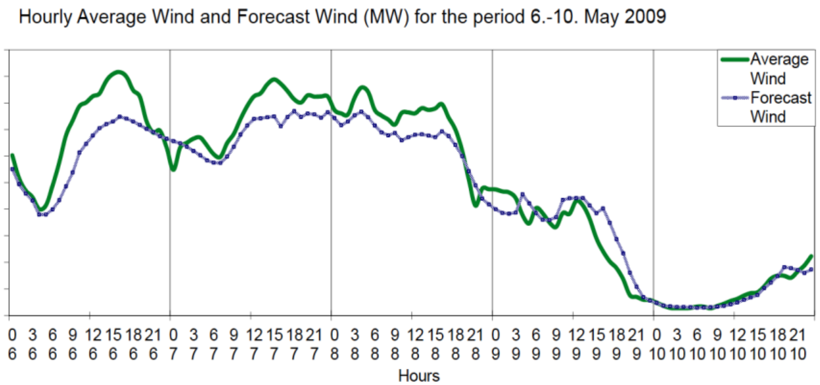
New Technologies Must Be Utilized to Increase Flexibility in Power Supply and Delivery



Improved Forecasting

Wider Area Aggregation (Transmission)

Flexible Dispatchable Generation (Natural Gas and (gasp!) Diesel Plants)

Energy Storage

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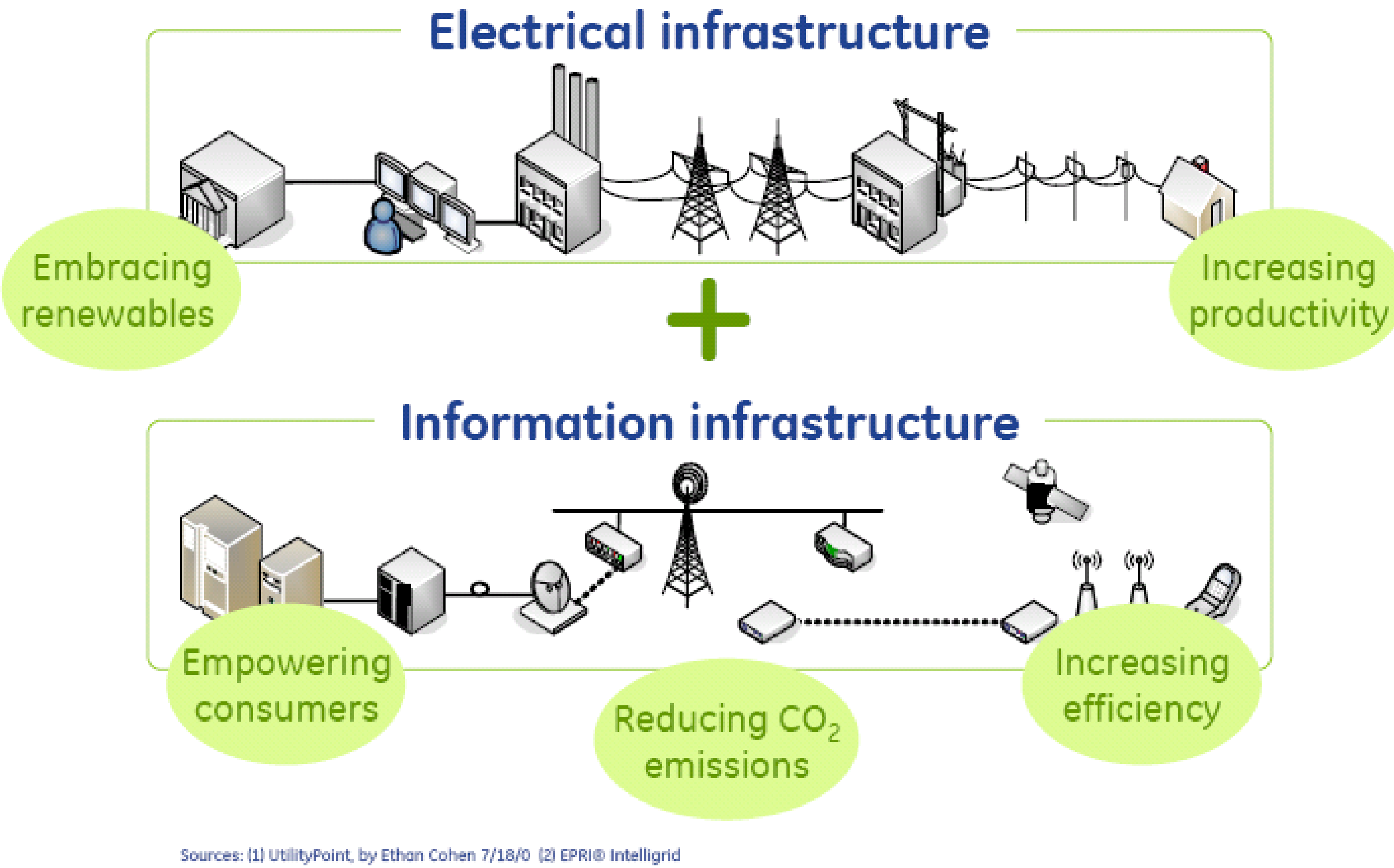
Smart Grid Solutions:
Can We Integrate Two Infrastructures?



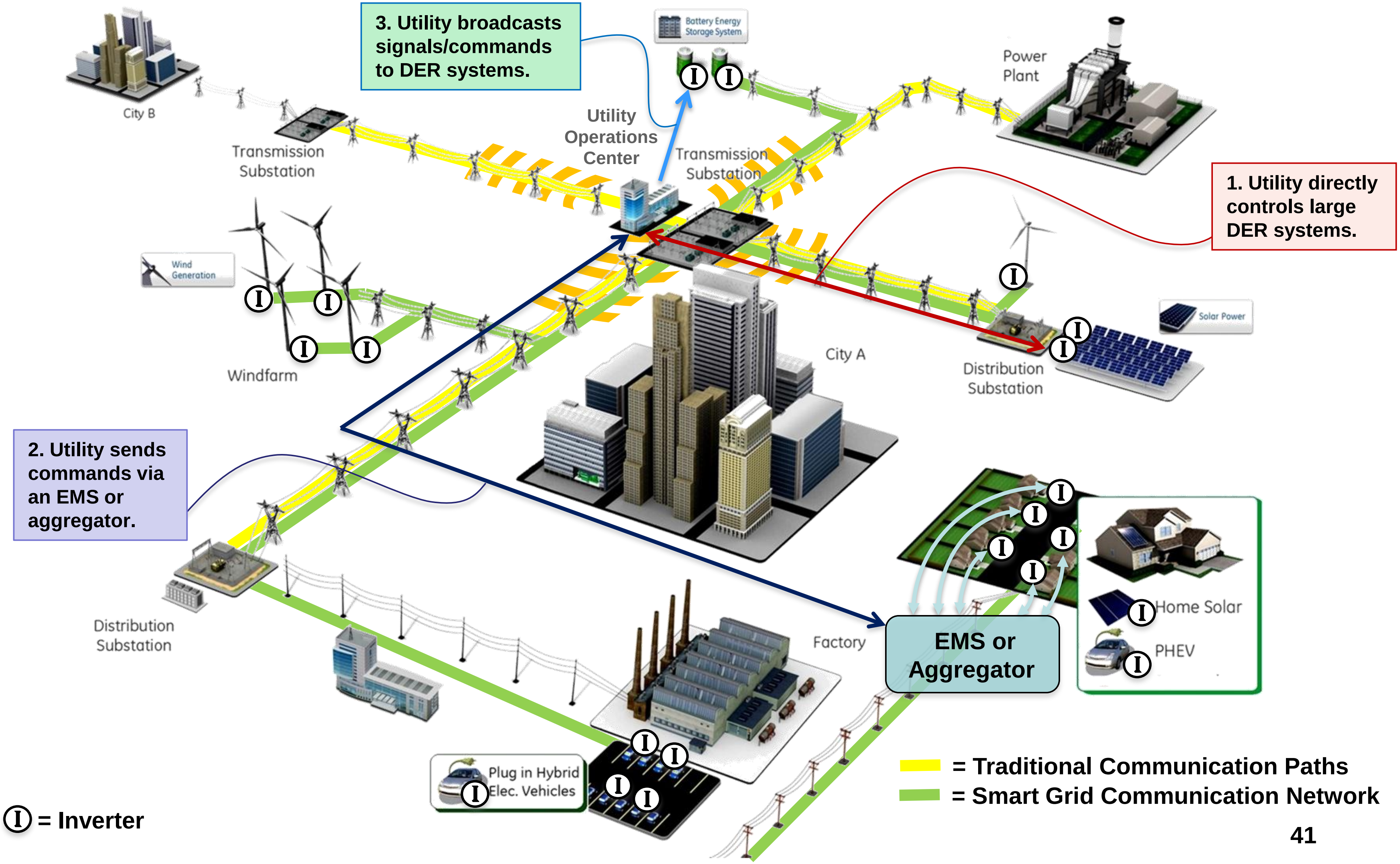
Better Management of Distributed Resources and Loads

39

What Goes into the Smart Grid? - Emergence of New Technologies and Improved System Integration

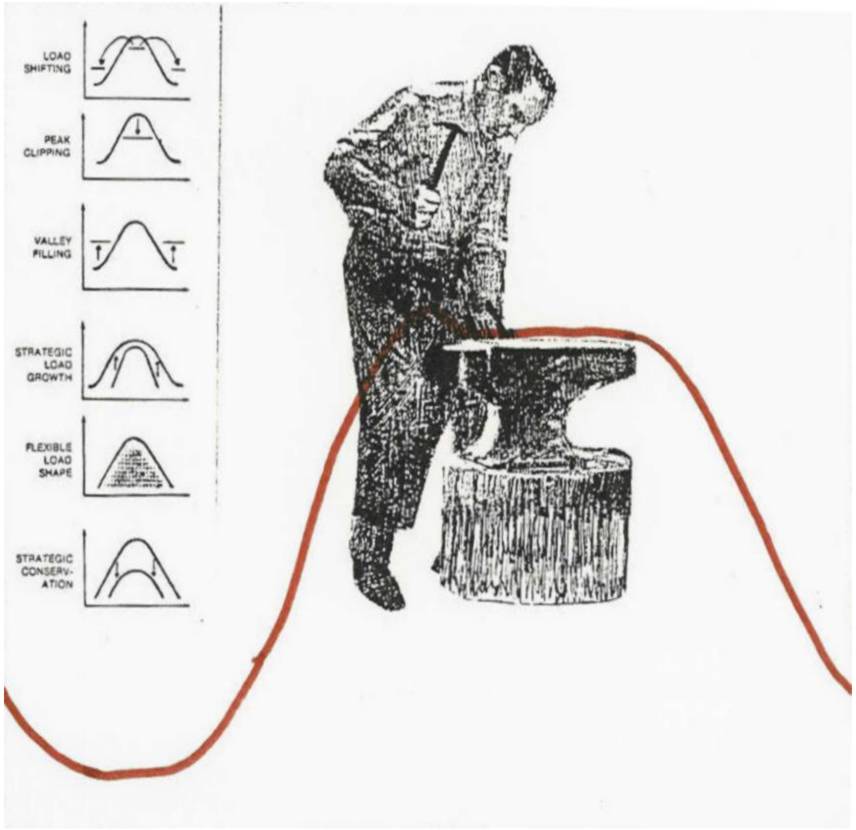
- Higher capacity cables, transformers
- Extensive and integrated communications and information systems - AMI
- Automated distribution systems
- More extensive sensing, forecasting, and monitoring
- Ability to control power flows – power electronics
- Local generation sources that can provide watts and Vars
- Intermittent, non-dispatchable sources of power
- Energy storage
- "Smart" end uses and customer interfaces
- Hierarchical controls that can assess and dispatch all grid and customer assets

Smart Electricity Grid Communications



Modern Grid Roadmap for Collaboration - Smart Grid as a Platform

- The Modern Grid is an umbrella, a platform, not a technology
- It is not an exhaustive enumeration of precisely-defined but stove-piped requirements (an anathema to Smart Grid objectives).
- How the consumer manages electricity use will define future technological evolution - some systems (such as small storage) may be on customer side of the meter
- Standards and architectures are necessary but not sufficient for reliable interoperability
- Contextual architecture and flexibility are requirements if we are to be prepared
- Many applications have yet to be developed - the emergence of "transactive energy"



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Energy Storage Is a Broad Asset Class

Chemical Storage

(Batteries)

Mechanical Storage

(Flywheel)

Bulk Mechanical Storage

(Compressed Air)

Thermal Storage

(Ice)

(Molten Salt)

Bulk Gravitational Storage

(Pumped Hydro)

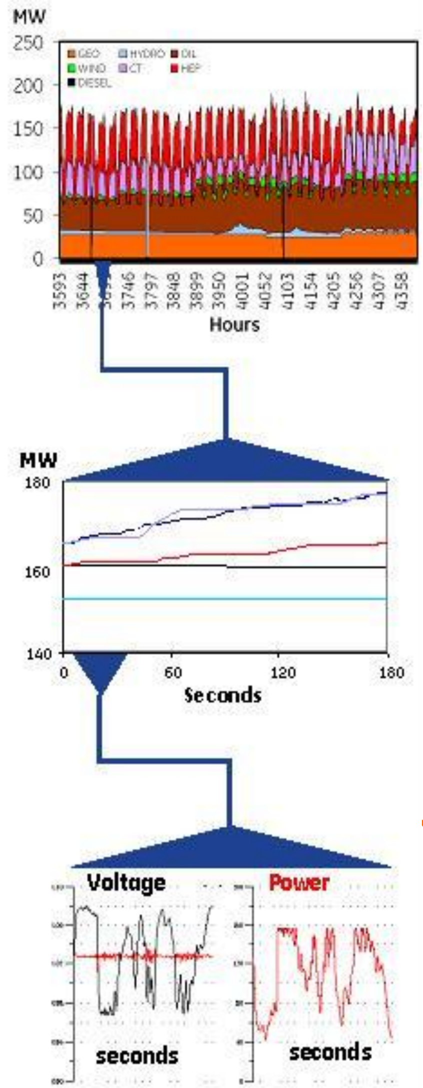
(Gravel)

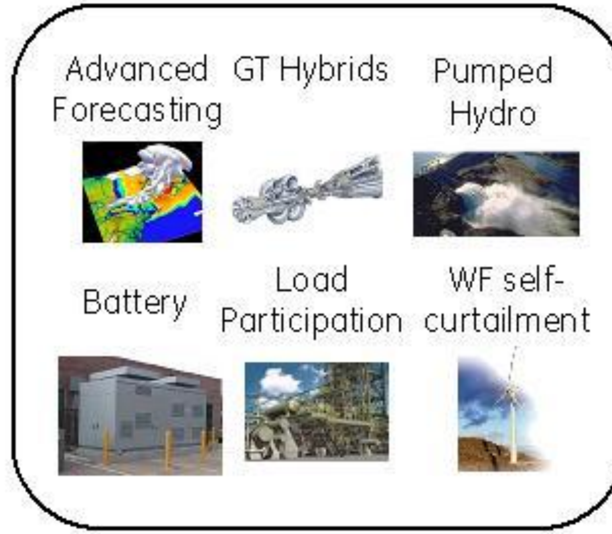
Energy Storage: Mitigation for Higher Penetration of Intermittent Renewable Resources, But What Problem Are We Trying to Solve?

"Hours"
Spinning reserve & day-ahead scheduling

"Minutes"
Load-following

"Seconds"
Faster than AGC

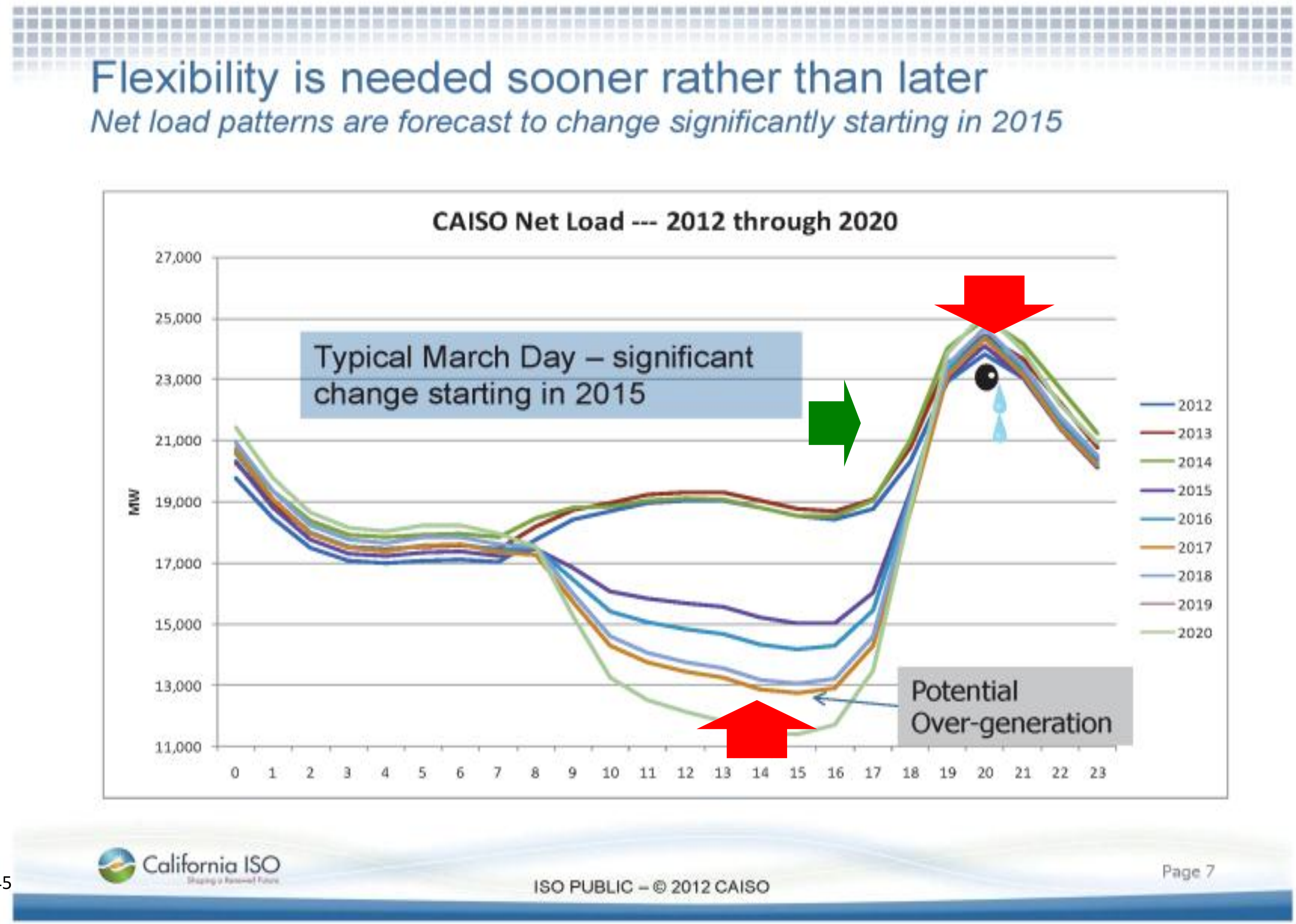




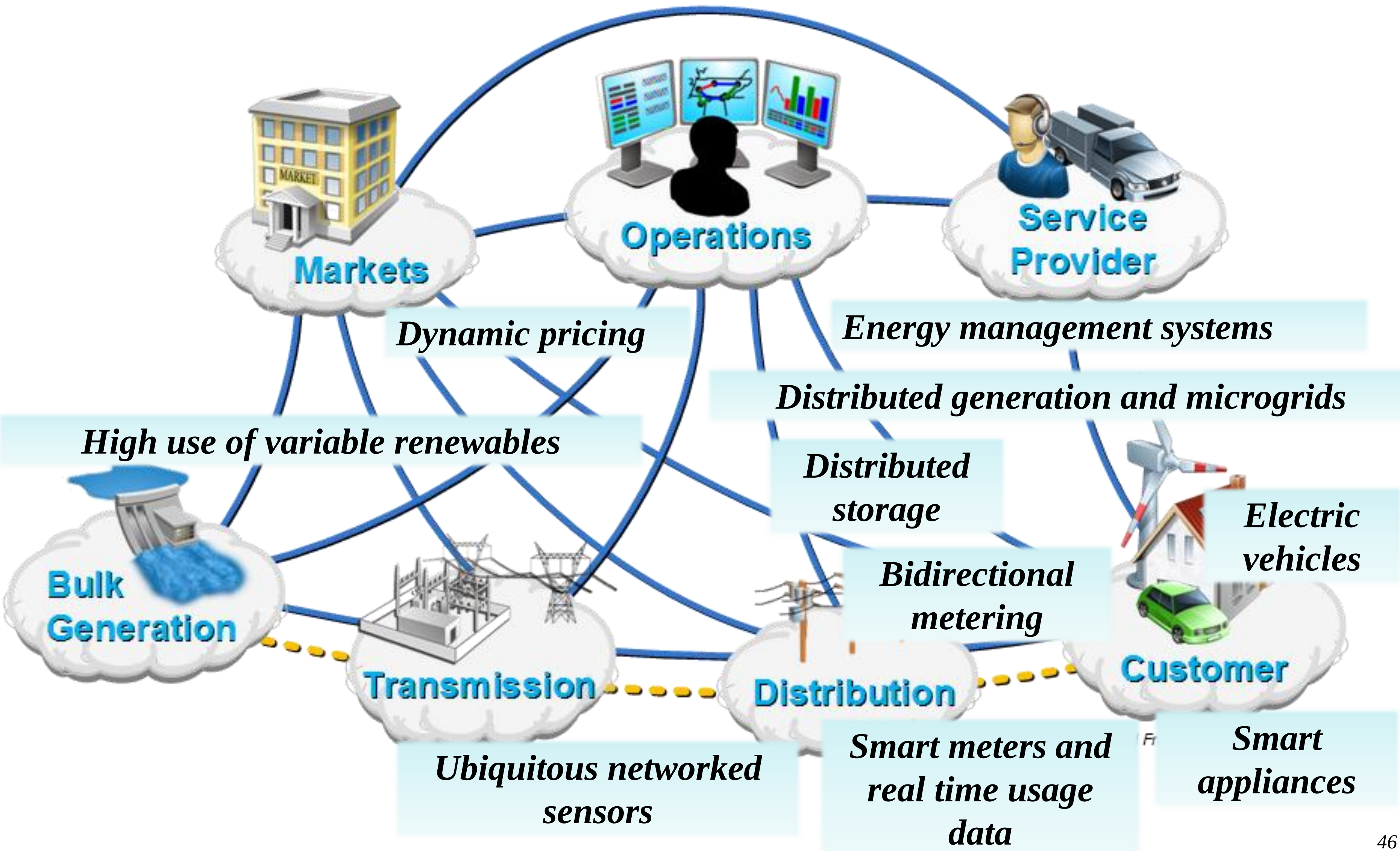
Possible Program

- Quantify performance of mitigation technologies, including energy storage, in each timescale
- Develop battery storage & controls for ramp rate relief
- Explore partnerships to demonstrate performance of battery storage and controls solutions

California Example: Energy Storage Flattens "Duck's" Head

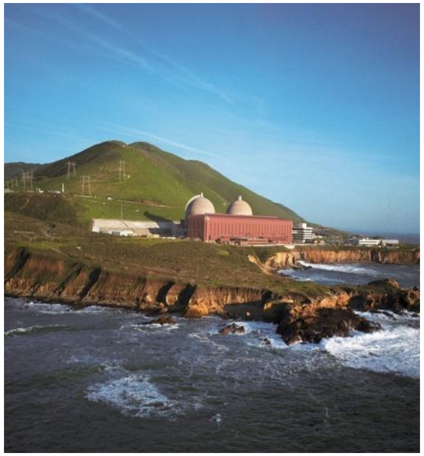


Summary: Smart Grid Systems Will Integrate Numerous Technologies



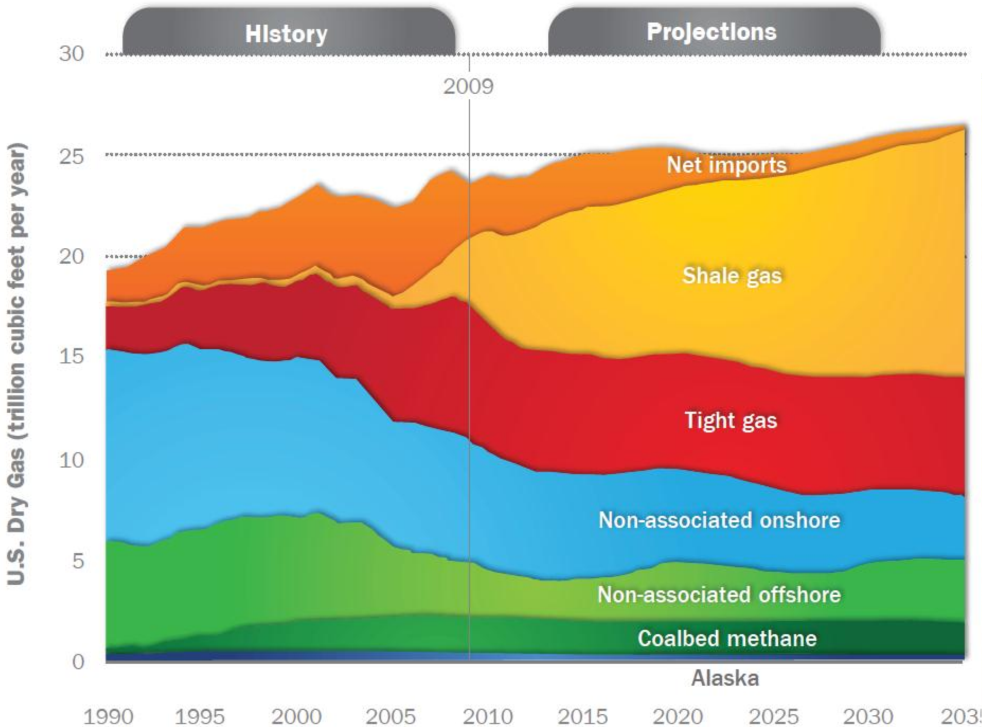
Nuclear Energy in the U.S.

- **Excellent record of safety and production**
- **All plants expected to operate for at least 60 years and possibly to 80 years**
  - However, San Onofre (SONGS) will not operate
- **20 license applications for 31 new reactors**
- **Construction depends on financing**
  - Loan guarantees
    - Award $8B for first two Southern Company Plants
    - These are the only two being built
    - Increase authority to $50B
  - Need regulated markets
- **Focus on near-term deployment of advanced ALWRs, extending the life of existing reactors and on R&D for advanced reactor and fuel cycle technologies**

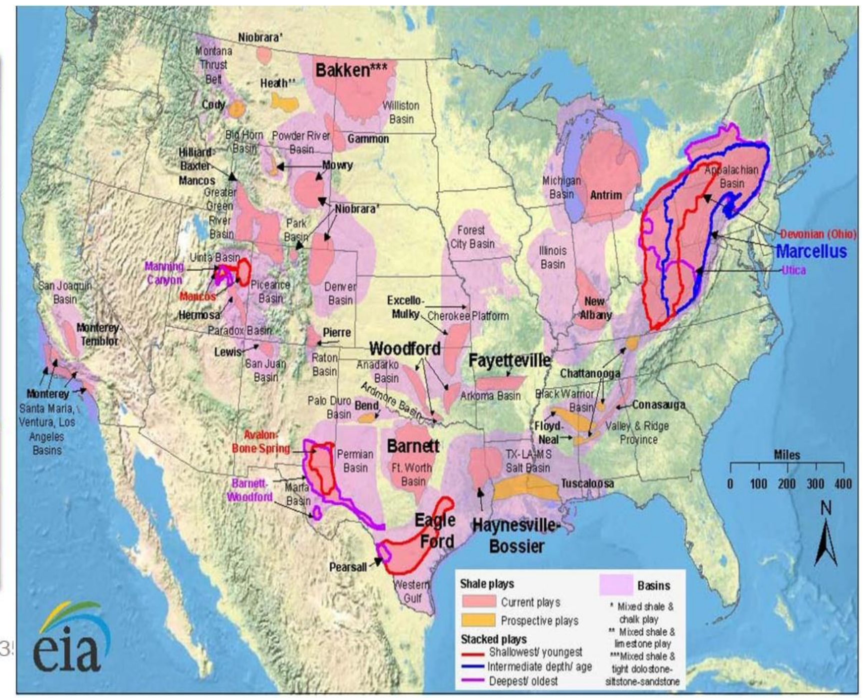


- ***104 reactors supply 20% of electricity, operating in 31 states***
- ***70% of emissions-free electricity is nuclear, displacing the equivalent of annual CO_2 from U.S. cars***
- ***1/10 of light bulbs in U.S. are powered from HEU down-blended from Russian warheads***
- ***Nuclear energy is safe because of redundant systems, automatic shutdown systems and multiple layers of separation***

Back to Fossil Fuels - Natural Gas: Some Locations Have Yet to be Developed (Monterey Shale)



Historical and Projected Domestic Production of Natural Gas



Map of United States shale deposits

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Barnett Shale (Texas) as an Example of the Dramatic Increase in Natural Gas Production

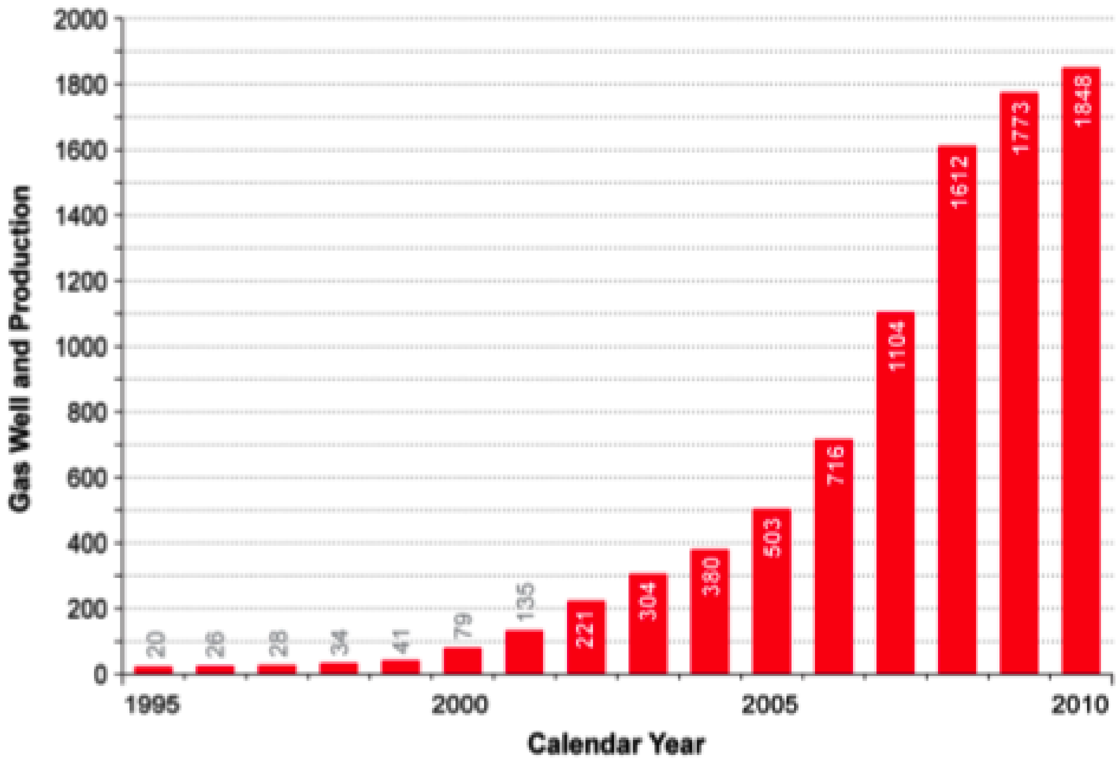


Figure 72. Gas production in the Barnett Shale (bcf), 1995-2010 (TRRC, 2012e)

Future of Coal: Carbon Capture and Storage (CCS): Geological Security Increases Over Time

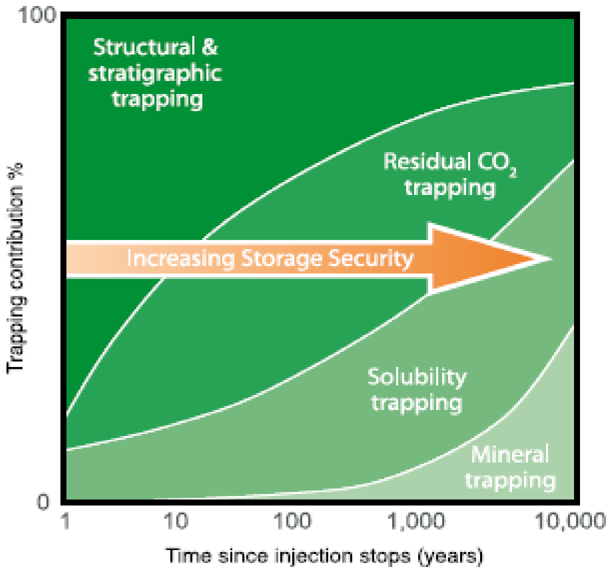


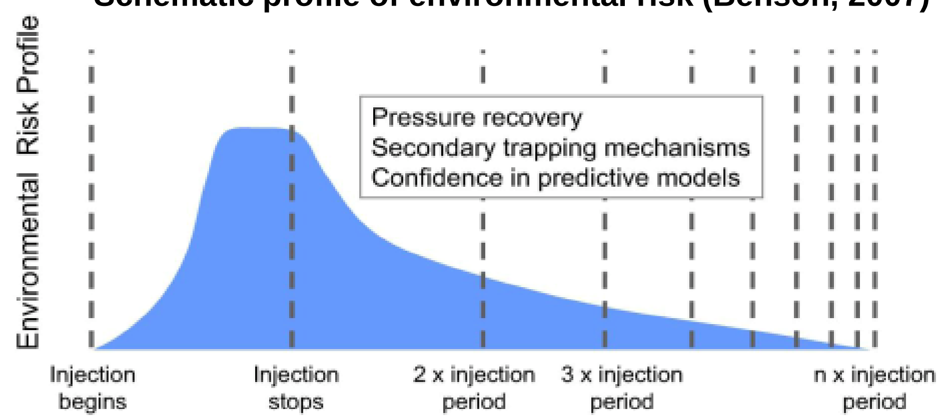
Figure 5.9 Storage security depends on a combination of physical and geochemical trapping. Over time, the physical process of residual CO_2 trapping and geochemical processes of solubility trapping and mineral trapping increase.

Schematic evolution of expected trapping mechanisms over time (IPCC, 2005)

"It is considered likely that 99% or more of the injected CO_2 will be retained for 1000 years" (IPCC, 2005)

- **Trapping mechanisms reduce CO_2 mobility over time**
- **Risk profiles are expected to decline over time**
- **Site characterization, site operations, and monitoring strategies work to promote storage security (e.g., DOE Best-Practices documents)**

Schematic profile of environmental risk (Benson, 2007)



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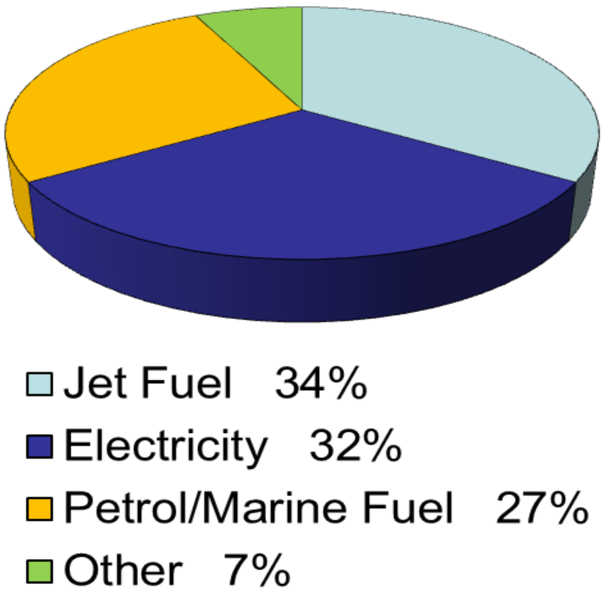
Unresolved "Dangling" Issues Will Make CCS a Longer-Term Resource: No Carbon Price Signal in the US

- **Liability**
  - **Oil and gas companies have different perspectives from utilities who are unfamiliar with subsurface activities**
  - **Need to examine true cost of dealing with logistics of storage**
- **Public acceptance**
  - **Some groups supportive (NRDC, Environmental Defense), others anti-CCS (Environmental Justice, etc.)**
  - **Public education is critical**
- **Financial/regulatory issues for owners/investors**
  - **Who will own and manage pore space**
  - **Long term monitoring costs**
  - **Nature of final regulations**
  - **Costs of initial drilling**

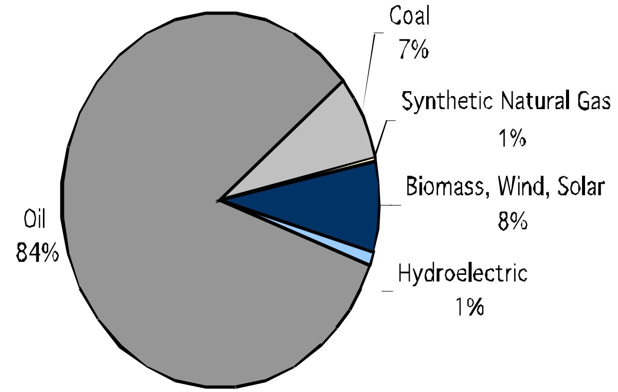
Hawaii Still Primarily a Fossil-Fired State

- **Primary energy: 90% fossil fuel, all imported;**
- **Electricity: 91% fossil, 84% from petroleum**
- **10% ethanol in gasoline, all imported**
- **Highest electricity rates in the United States $0.35 - $0.45 per kWh**
- **Energy expenditures account for 13% of Hawaii's Gross State Product**
- **Abundant renewable resources but only 12% of electricity produced from renewables**



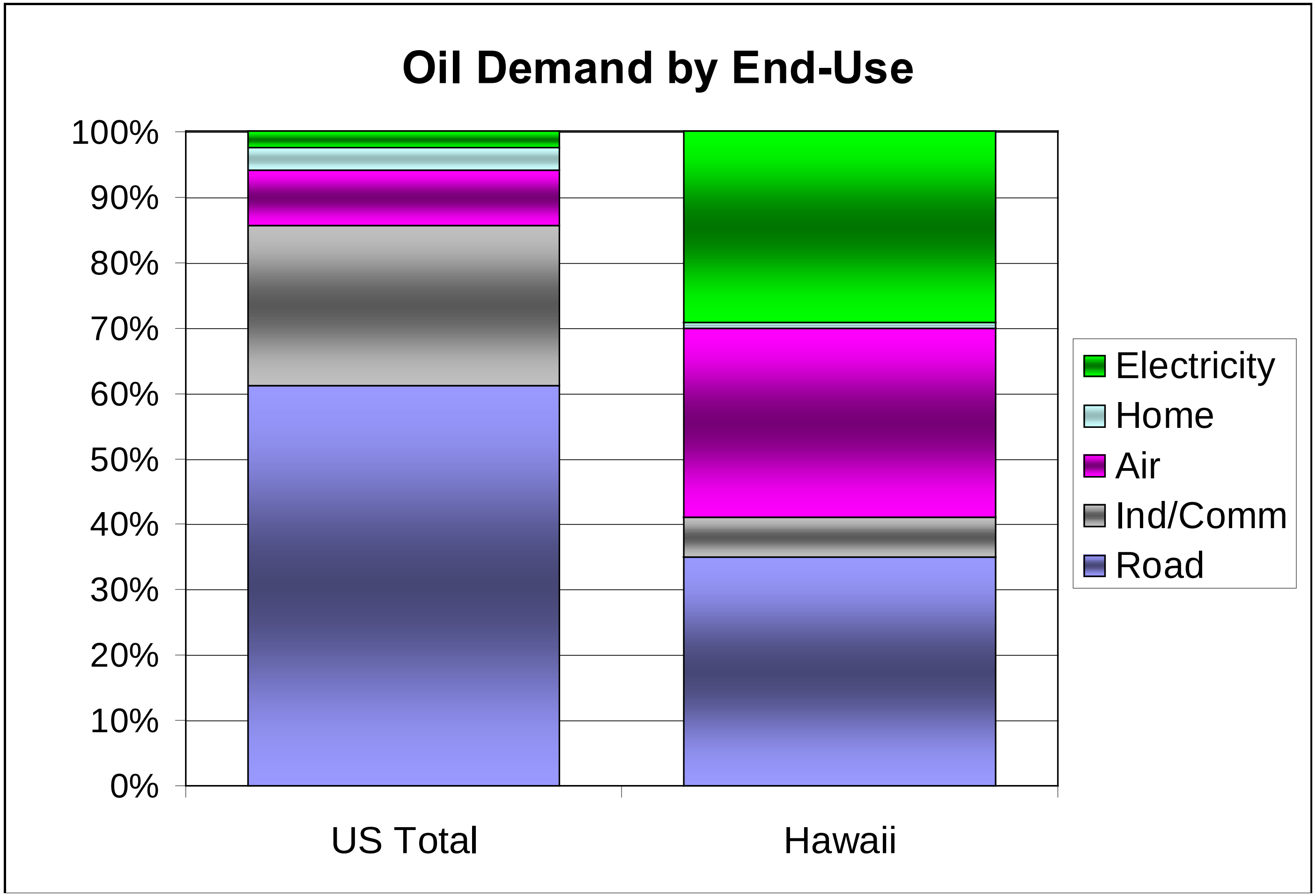
Issues

- ➢ **Energy insecurity**
- ➢ **Economic drain**
- ➢ **Price volatility**
- ➢ **Environmental harm**

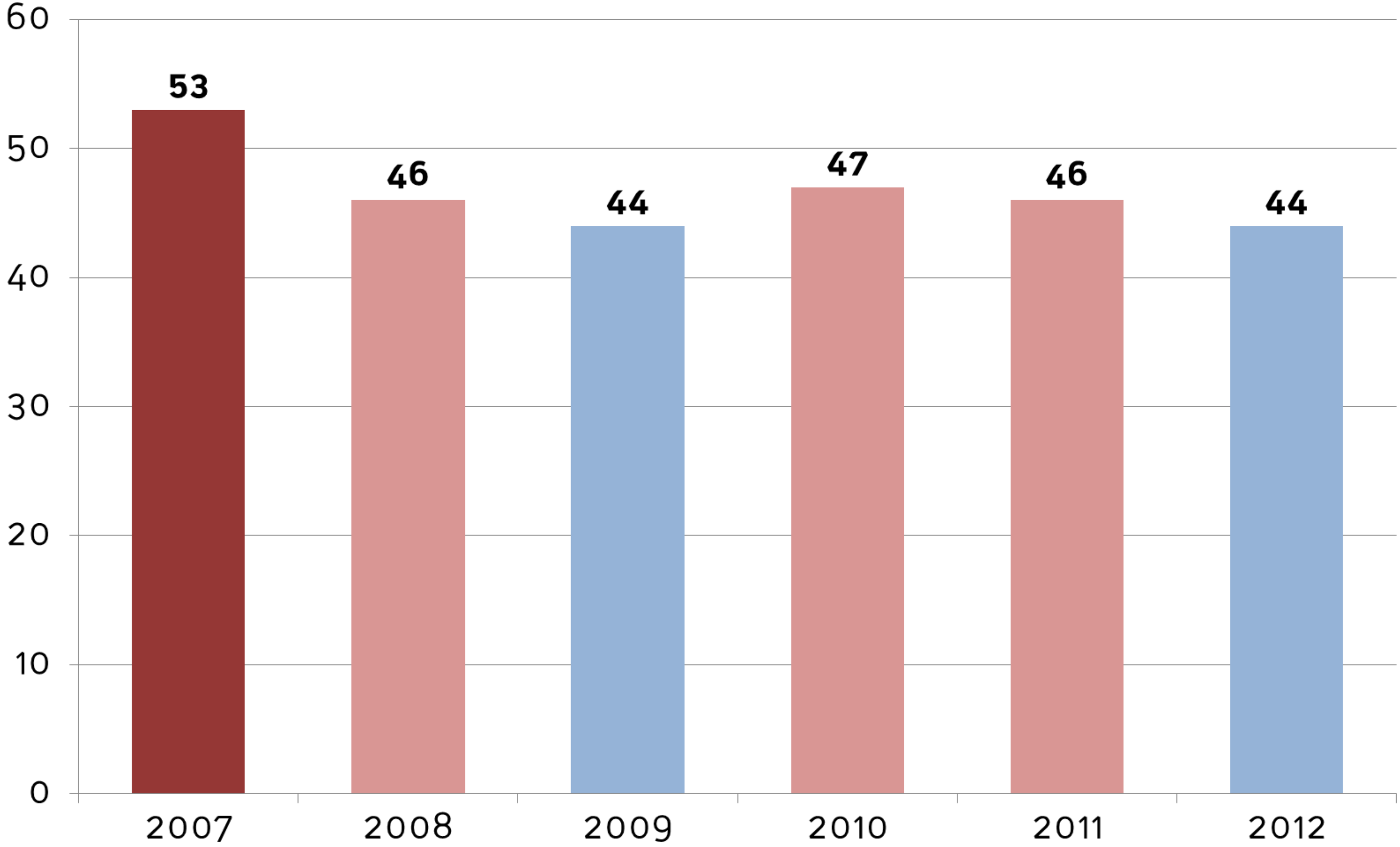


A Paradigm Shift is Needed

Comparison of US and Hawaii Oil Demand

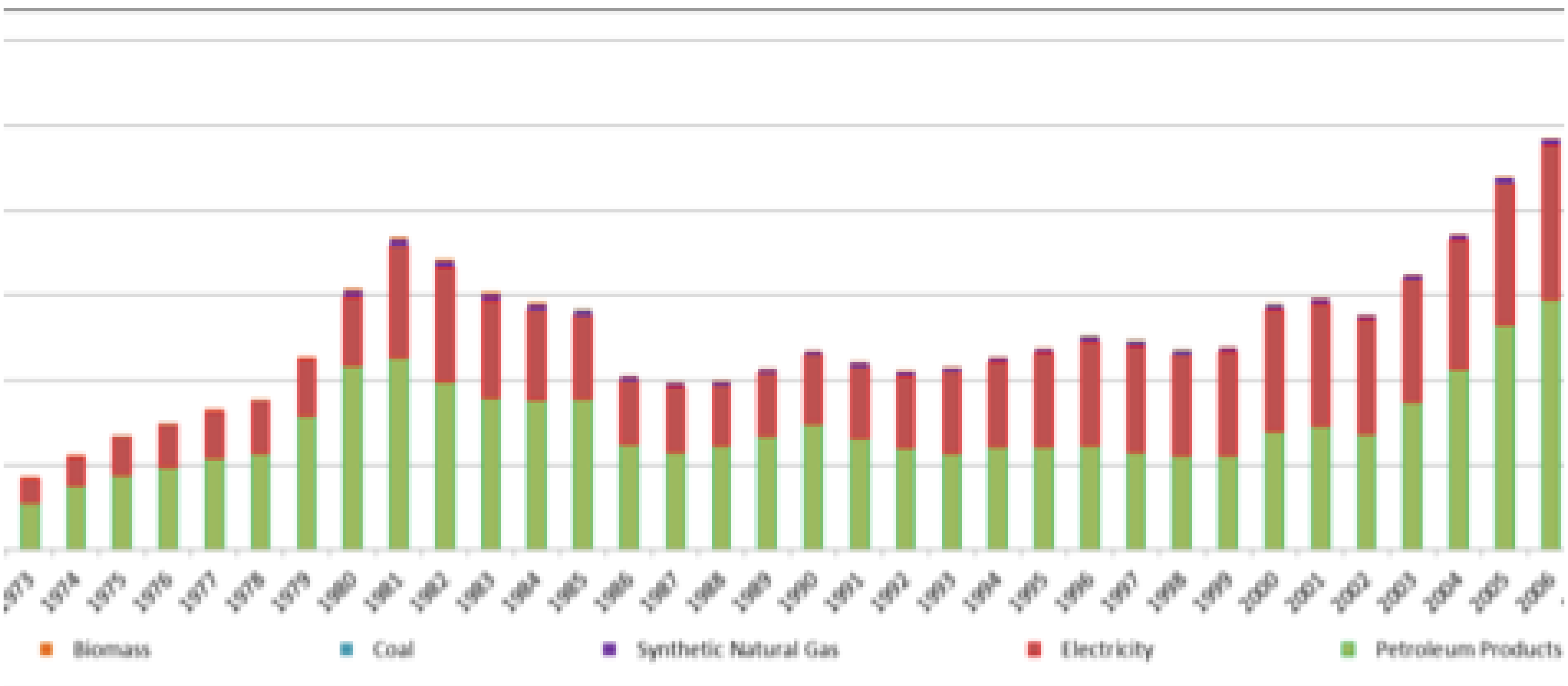


Millions of barrels of oil imported annually to Hawaii – good trend, but SLOW



Fuel Costs Have Risen to About 6% of Hawaii's GSP

Figure 14: Fuel Cost as Percent of Hawaii GSP



Increase in Utility Low Sulfur Fuel Oil (LSFO) Costs (Post-Fukushima) Severely Impacts Hawaii Electricity Users

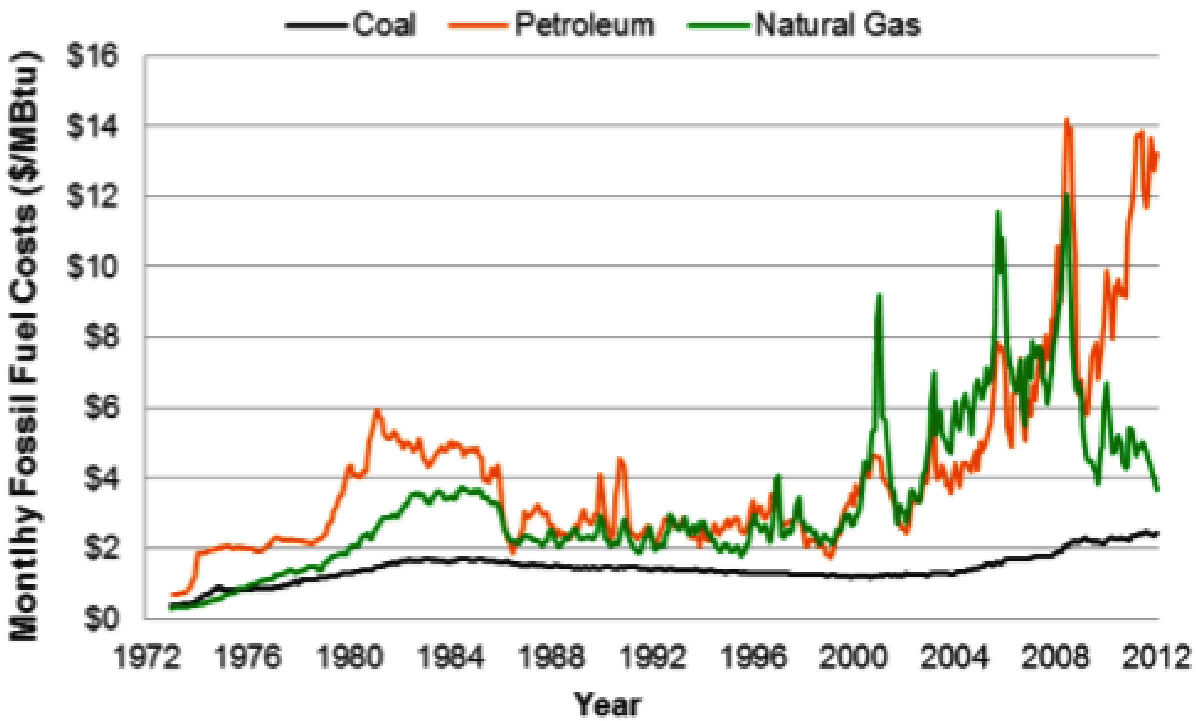


Figure 3. Volatility in fossil fuel costs for power generators

Source: EIA, "Monthly Energy Review," April 27, 2012.

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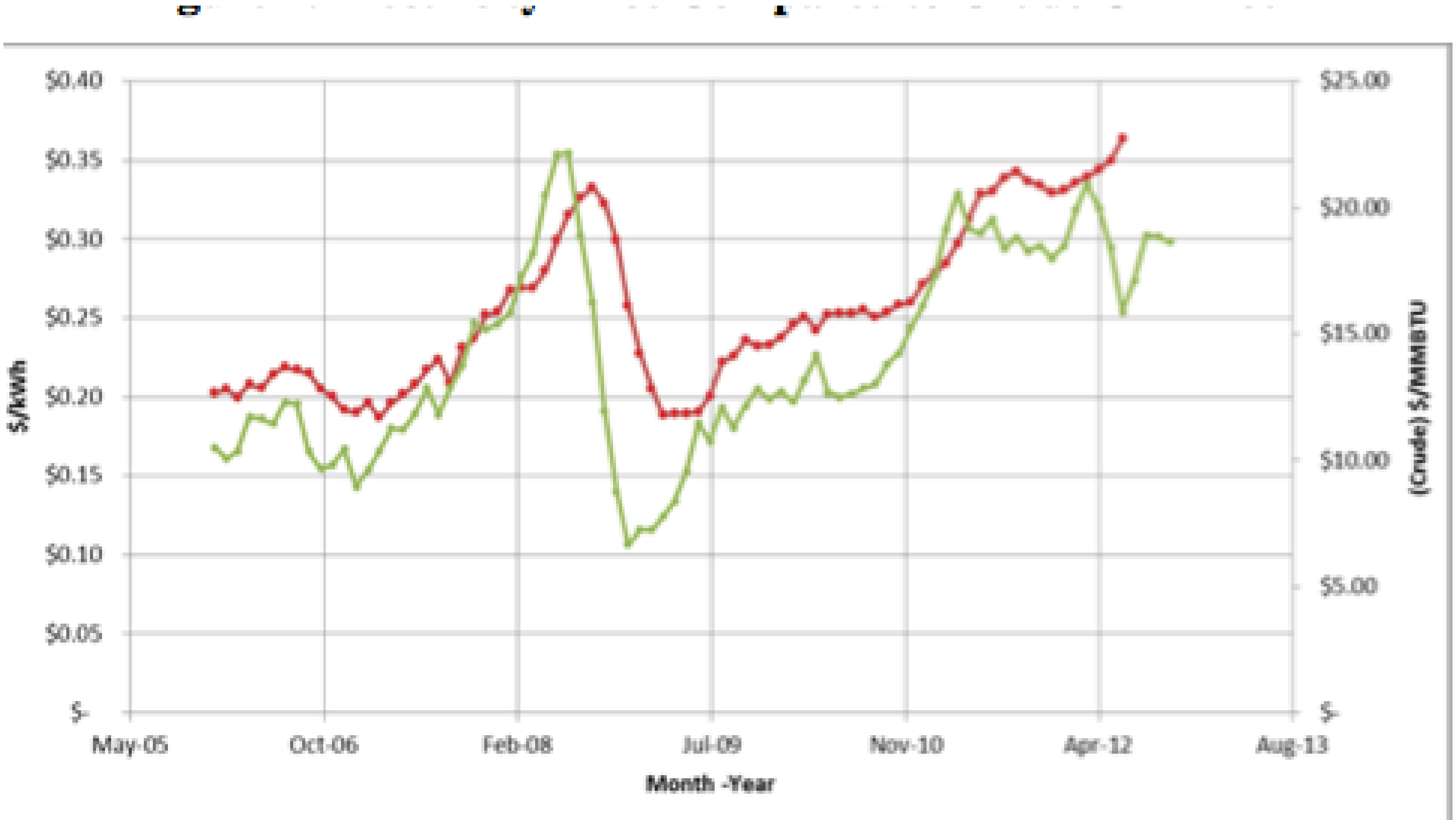
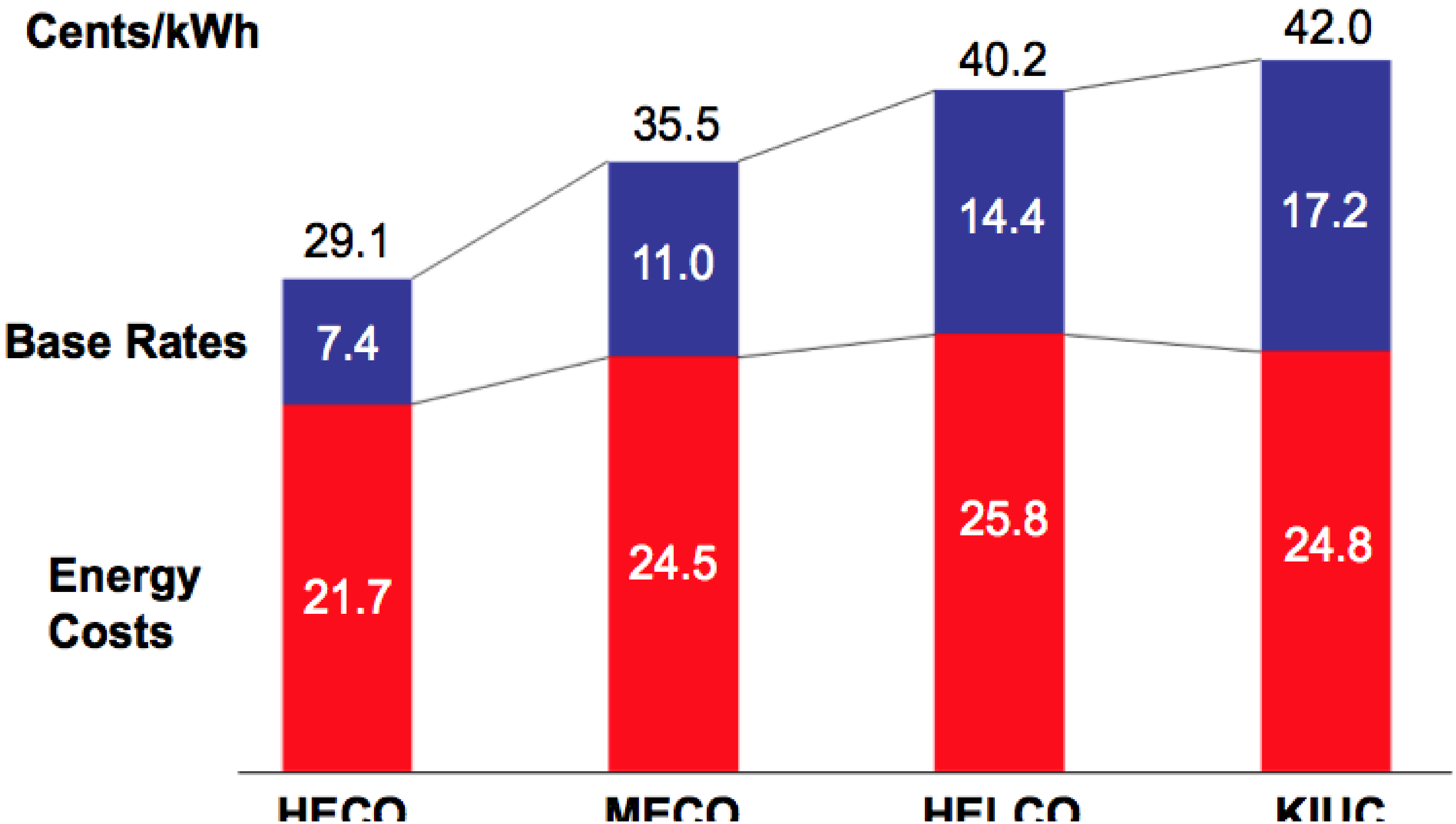
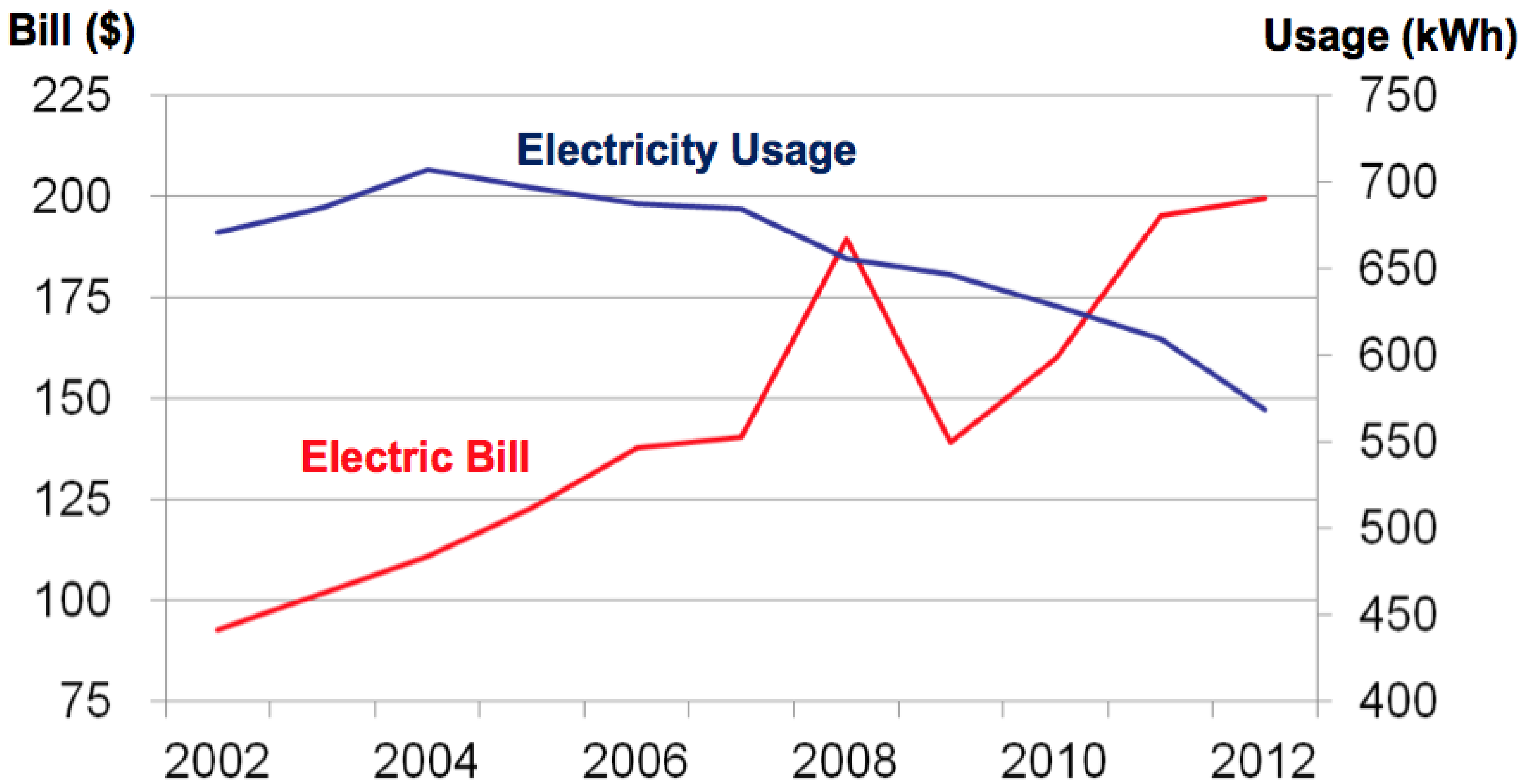
Electricity Prices in Hawaii Are Correlated to LSFO Prices



Electricity Rates for Hawaii's Consumers Versus About 10 cents/kWh for US

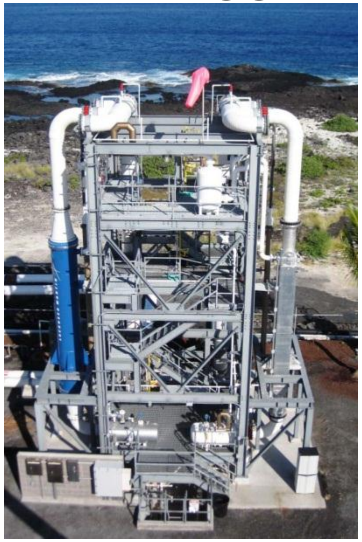


Costs Go Up, But Conservation Also Increases



These Issues Require Hawaii to Move Forward with Renewable and Energy Efficient Solutions

- **Hawaii Clean Energy Initiative: *70% clean energy by 2030***
  - **30% Renewable Energy, 40% Energy Efficiency**
- **Tools:**
  - **Renewable and Energy Efficiency Portfolio Standards, Net Metering, Feed-in tariff, Reliability standards, Fuels standards, Building Code**
  - **Aggressive state tax policy**



Courtesy Makai Ocean Engineering

<u>Uncertainties</u>

Undersea cable between islands

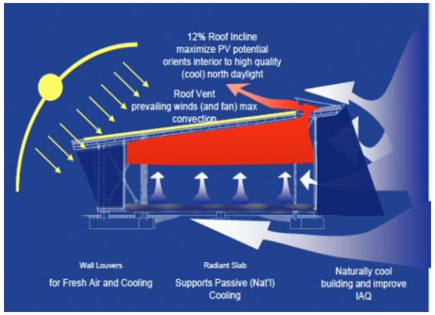
Alternative fuels (biofuels, LNG)

Disruptive technologies (e.g. OTEC)

Energy efficiency and demand response

Energy Storage

Smart grids



Courtesy OPT

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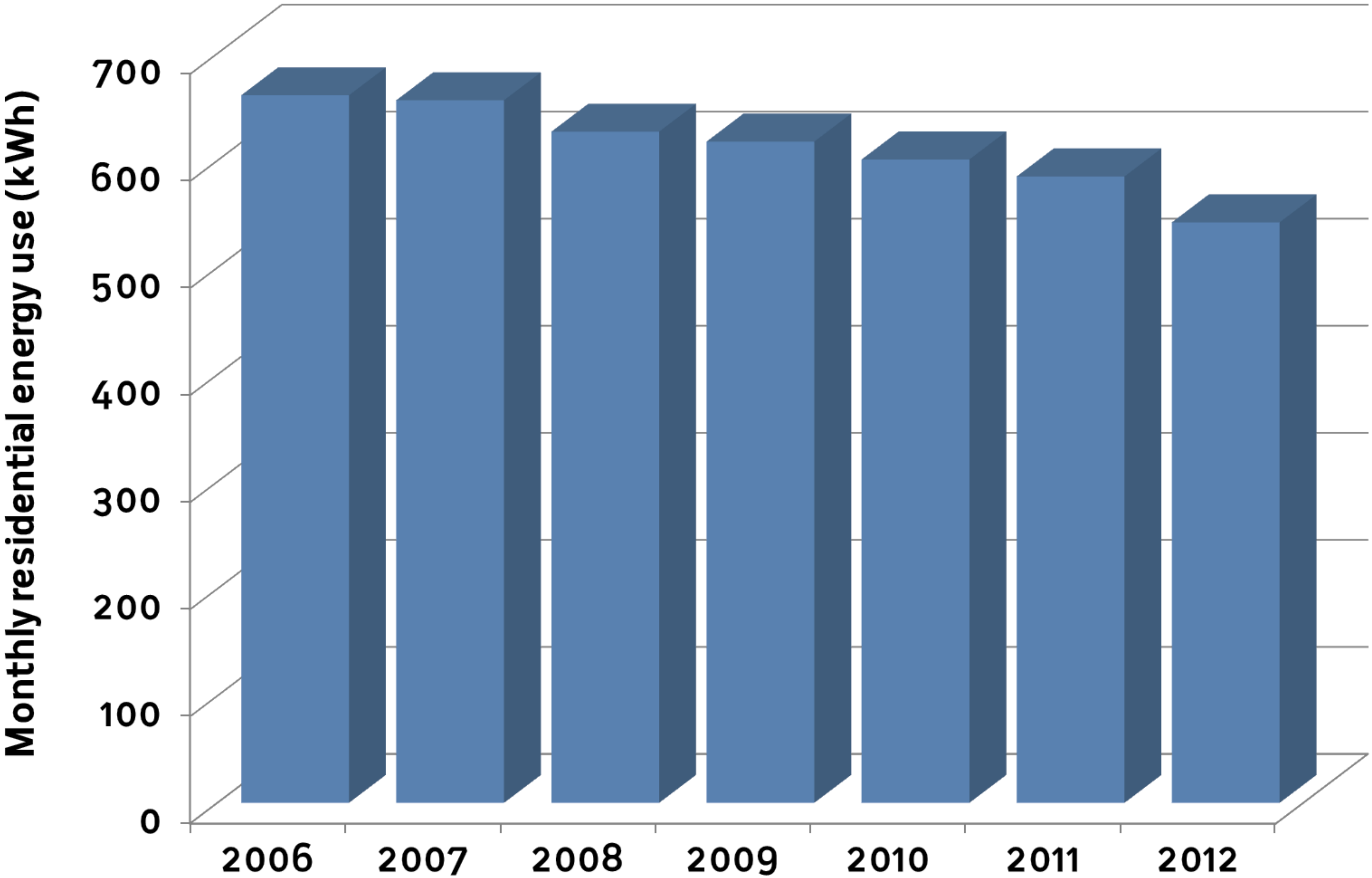
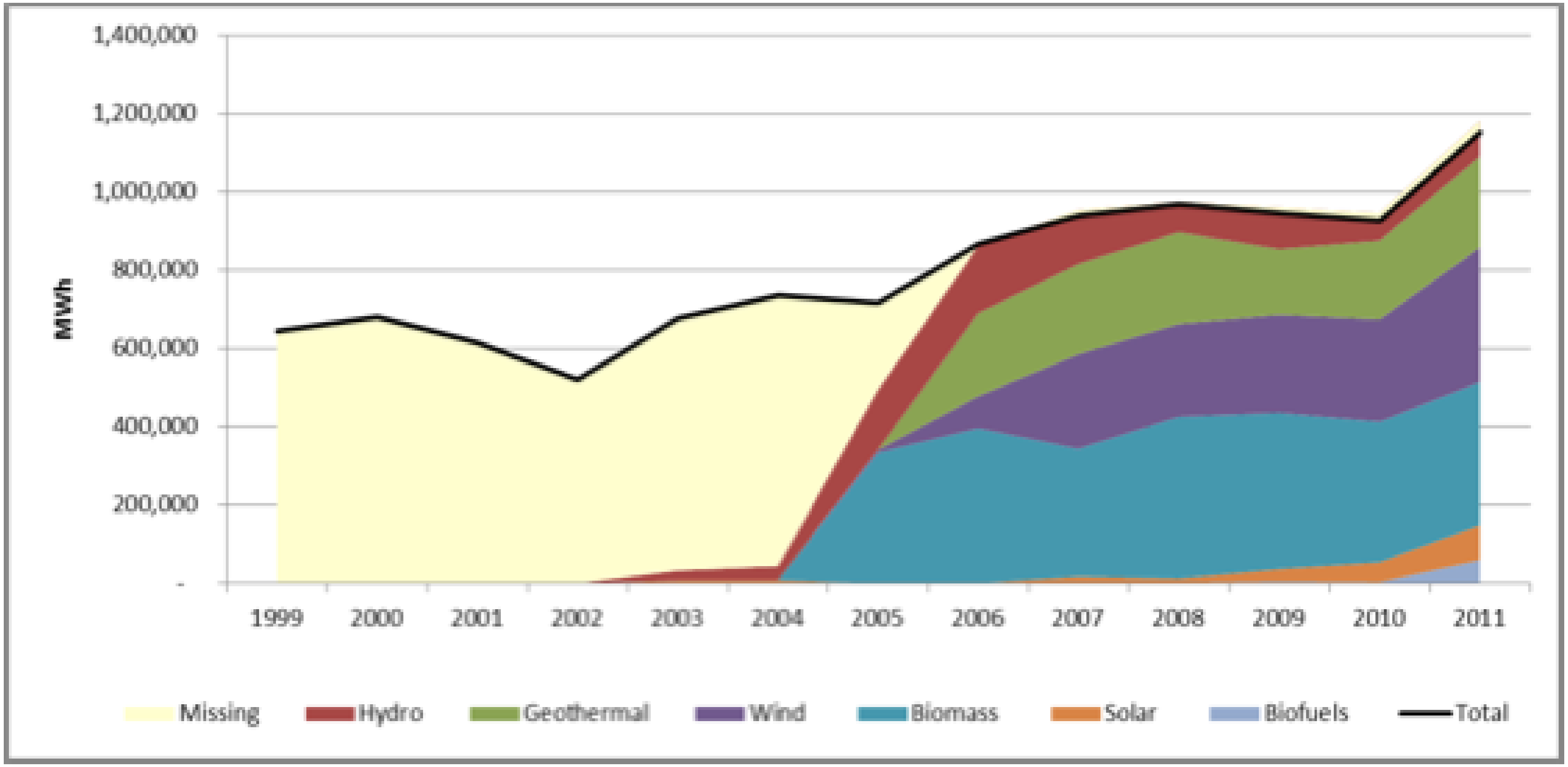
Residential Electricity Use per Customer with Energy Efficiency Portfolio Standard

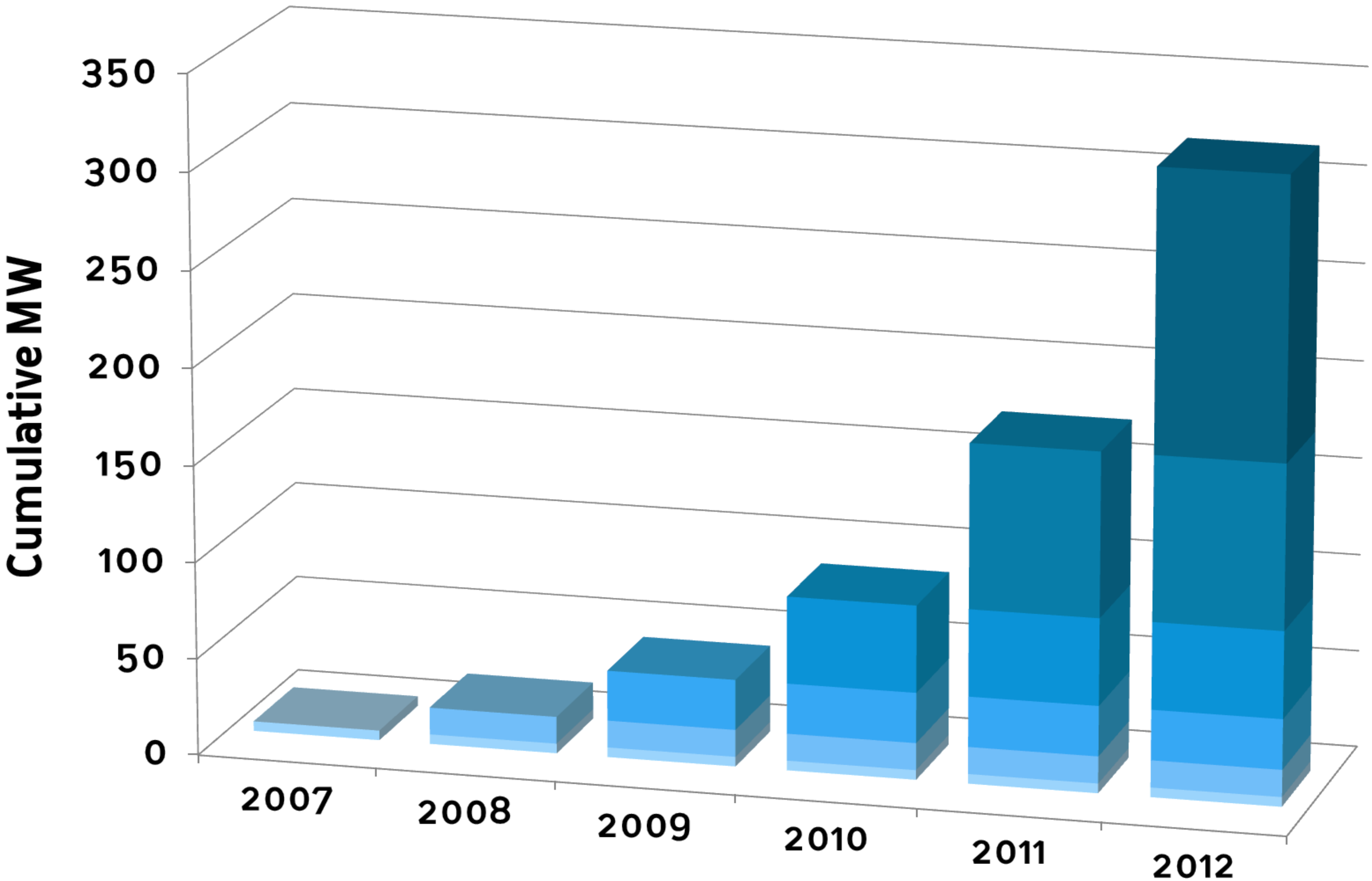


Hawaii's Renewable Energy Usage

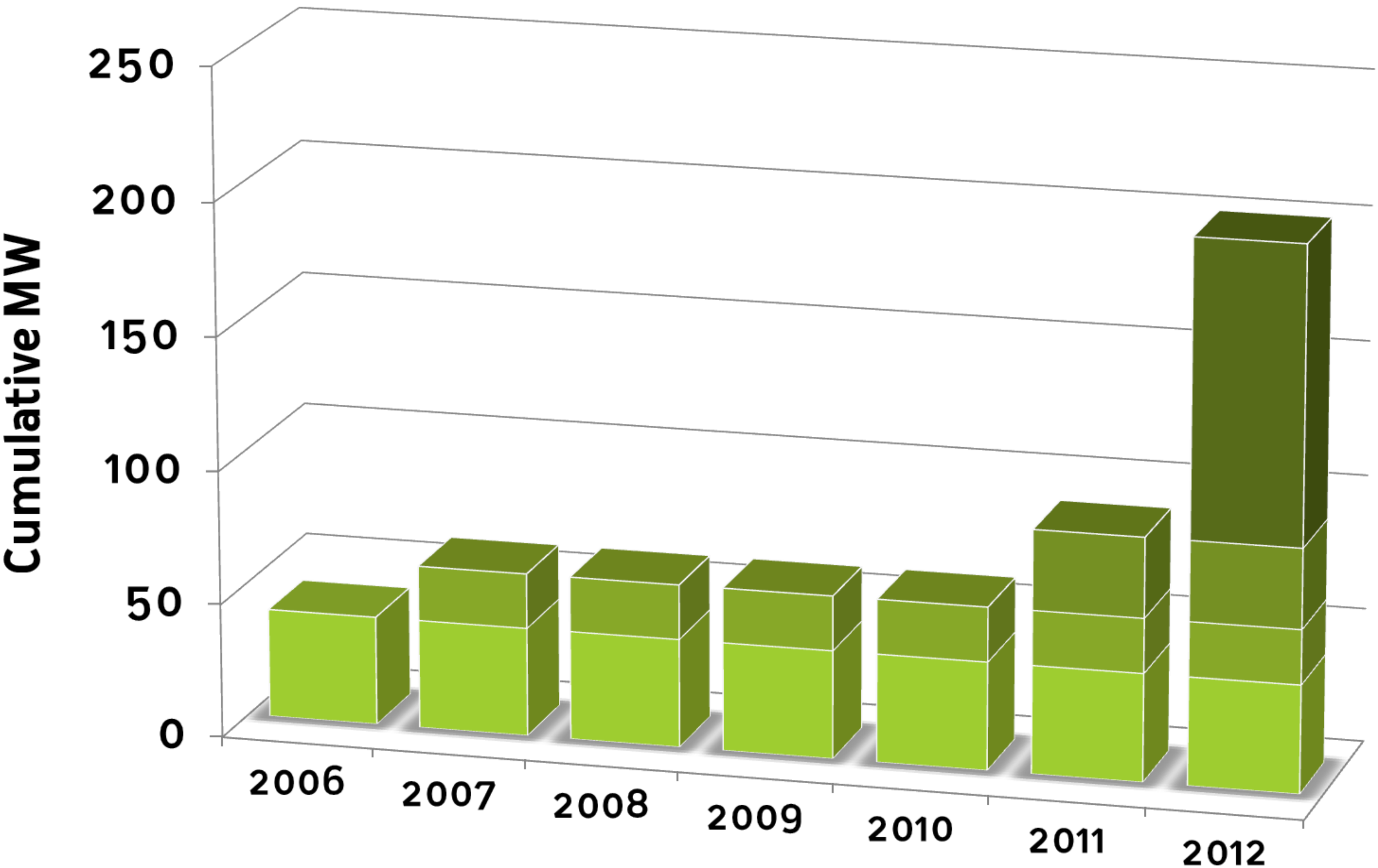
Figure 20: Renewable Generation by Fuel



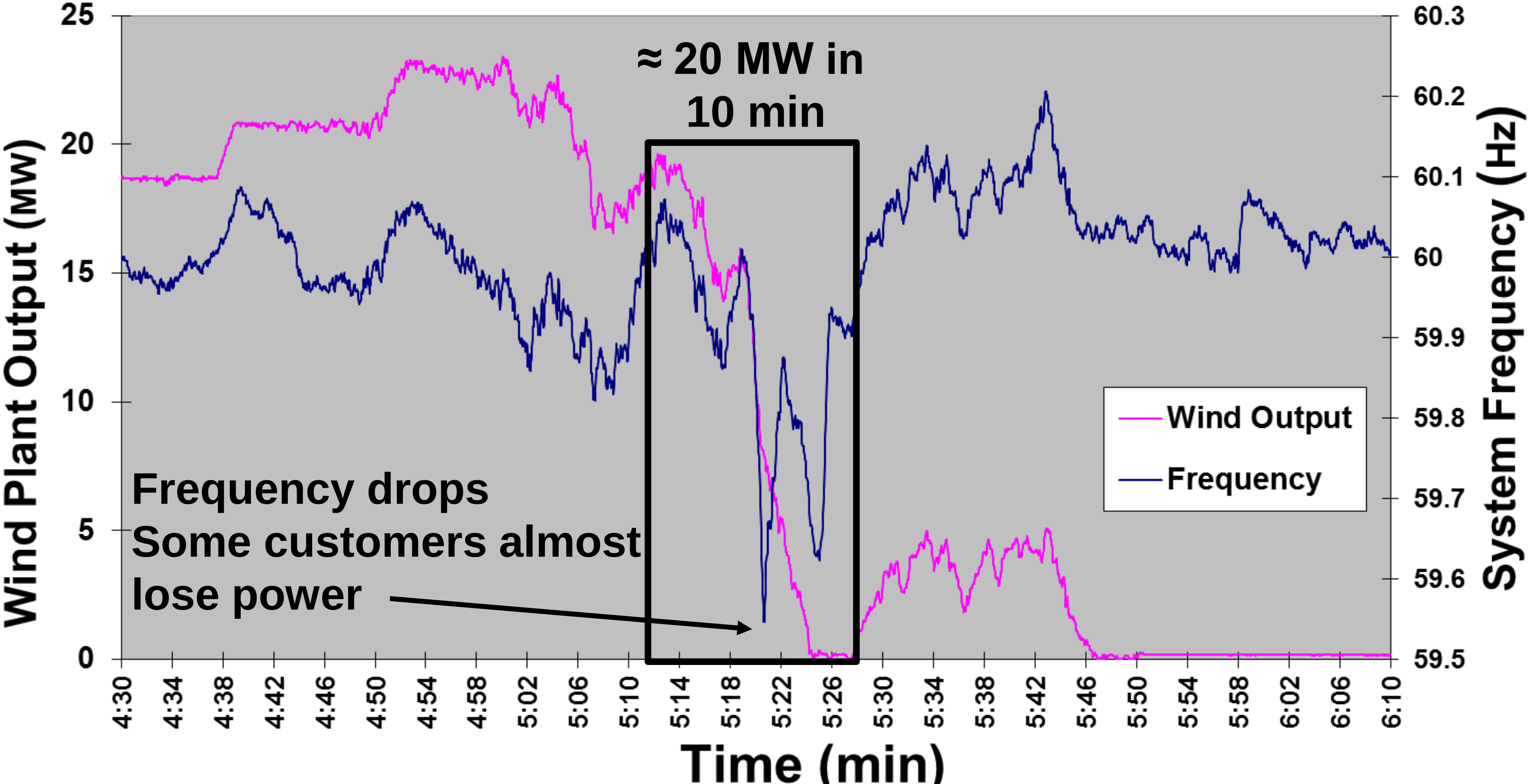
Installed Solar Capacity (MW) – Result of Tax Benefits and NEM Regulations



Installed Wind Capacity (MW)



Example of Key Integration Challenge
Managing Large Wind Ramp on Maui



Actual event from February 29, 2008

Source: Maui Electric Co.

Hawaii Testing and Evaluation of BESS for Grid Support

Grid-scale Energy Storage photos courtesy of Altairnano

Hawi 10 MW Wind farm at Upolu Point Hawaii Island

- 1MW, 250kW-hr Li-ion titanate at wind/utility interface
- Frequency regulation, wind smoothing, power quality

HECO feeder with high penetration (>1 MW Distributed PV)

- 1MW, 250 kW-hr Li-ion titanate at substation
- Voltage, VAR, Frequency regulation, power quality

Molokai Secure Renewable Microgrid

- 2MW, 375kW-hr Li-ion titanate, ~100kW community BESS,
- Operating reserves, frequency regulation, smoothing, peak shifting.

Maui Sub-Station BESS

Manages fluctuations due to very high percentages of PV penetration on distribution lines

Kauai Waste Water Treatment Facility

- ~1MW, 2MW-hr integrated into MW PV system
- PV smoothing, energy storage/load shifting

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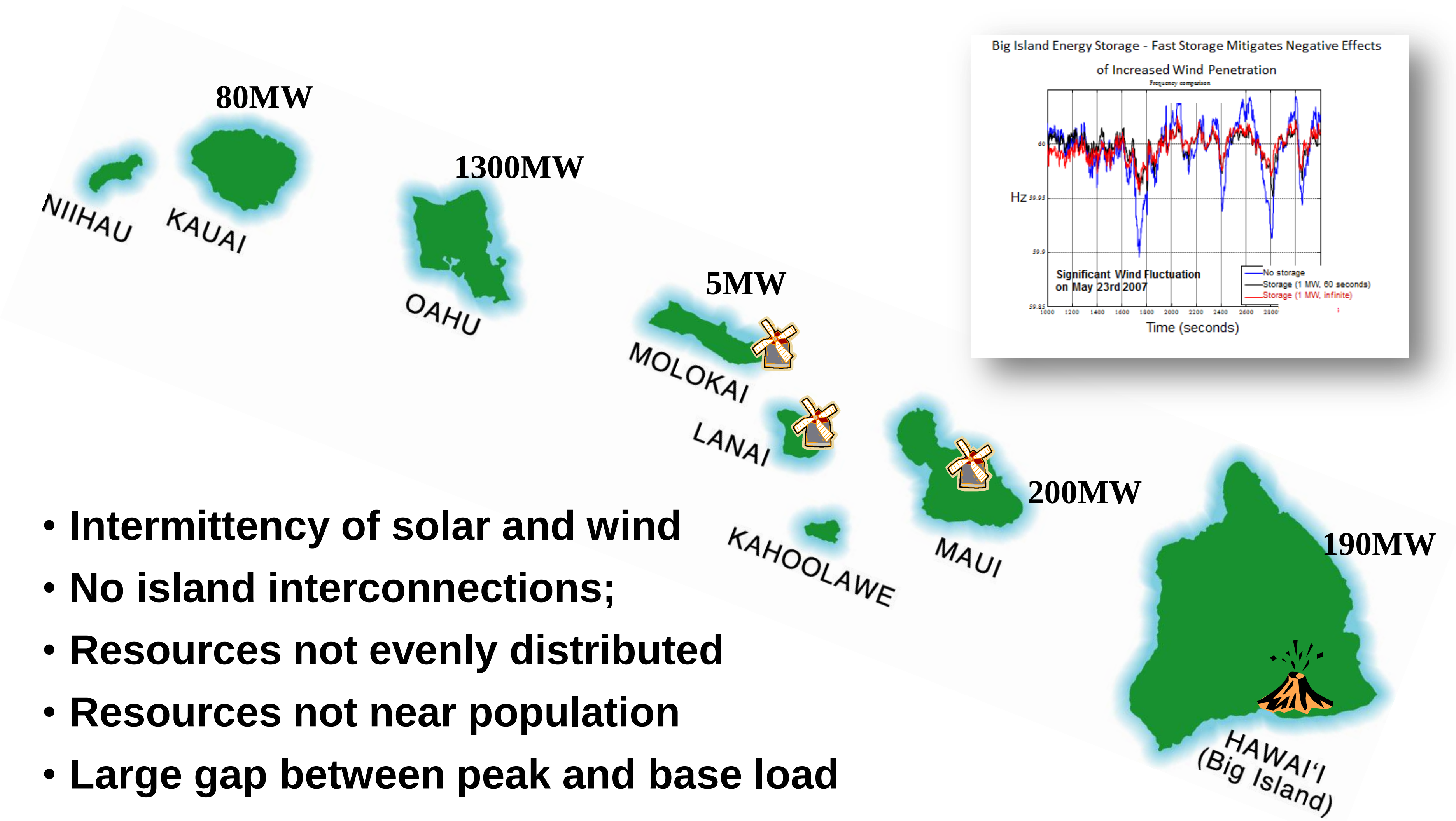
Integration of Renewable Energy Resources is Complicated



- Intermittency of solar and wind
- No island interconnections;
- Resources not evenly distributed
- Resources not near population
- Large gap between peak and base load

Opportunity to validate and deploy new technologies

Hawaii Energy Integration Studies

- **Oahu Wind Integration Transmission Studies**
  - With appropriate system modifications (no storage, no smart grids), Oahu can reliably accept 25% of its energy - from 500 MW Wind and 100 MW of PV
- **Hawaii Solar Integration Studies**
  - Analysis of wind plus high penetrations of photovoltaics for the islands of Oahu and Maui
- **Oahu- Maui Integration study (2nd Q 2013)**
  - Analysis of two way flow between counties to quantify benefits and impacts of undersea connection of Maui and Oahu
- **EV charging study (2nd Q 2013)**
  - Evaluate use of EV to utilize curtailed energy under high penetration scenarios

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Hawaii Renewable Integration and Transmission Study

- Supports the HCEI Energy Agreement in which Hawaiian utilities and cooperatives will integrate large amounts of renewable energy onto their electric grids
- First study to evaluate power system impacts from variable renewable energy sources on the electrical generators, grid, and transmission expansion analysis (e.g., cable)
- System planning work to date focuses on:
  - OWITS- Up to 400 MW wind from Lanai and/or Molokai via undersea cable; 100 MW of wind in Oahu; 100 MW of PV in Oahu
  - Expansion of solar work on Kauai, Lanai, and new PV study looks at Oahu/Maui
- Our Resource Planning work assesses the resources across the state

Hawaii Smart Grid Demonstration Projects

- **Maui Smart Grid Demonstration Project (2009)**
  - USDOE funded, HNEI led project to manage home energy usage using smart grid technology allowing peak load reduction and management of intermittent renewable energy.
- **Japan-US Island Grid Project (2011)**
  - NEDO funded, Hitachi led project to integrate advanced PV, energy storage, and EV into island wide smart grid environment to enable high penetration of central and distributed renewables
- **Smart Grid-Enabled PV Inverters (2012)**
  - Demonstration of advanced PV inverter functionality in smart grid environment (voltage, power quality) in both high penetration and sparse distribution lines.

Three projects have partners in common and propose to share hardware, results, and lessons learned

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Maui Smart Grid Demonstration Project (2009)

- Funded by US DOE with cost share from partners
- Implement advanced communications and control technologies to improve grid performance
- Demonstrate new “Smart Grid” technologies to:
  - Reduce peak demand by 15%
  - Better integrate wind and solar power
  - Address wind curtailment and variability
  - Improve grid reliability
  - Inform consumer demand decisions

Maui Electric Company, Ltd.

Hawaii Natural Energy Institute
University of Hawaii at Manoa

Hawaiian Electric Company

ALSTOM

SILVERSPRING NETWORKS

HNU-ENERGY
Harnessing the Power of Light

medb
maui economic development board, inc.

University of Hawai'i Mānoa

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Japan – United States Smart Grid Demonstration Project (2011)

HITACHI
Inspire the Next
HITACHI CONSORTIUM

medb
maui economic development board, inc.

COUNTY OF MAUI · STATE OF HAWAII

STATE OF HAWAII · 1959 · UA MAU KE EA O KA ʻĀINA I KA PONO

MIZUHO

NEDO
New Energy and Industrial Technology Development Organization

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Sandia National Laboratories

CyberDefense

Pacific Northwest
NATIONAL LABORATORY

Other supporting partners
Nissan Motor Co., Ltd.
Advanced Energy Company
U.S. Verizon Gr.
Okinawa Electric Power Co.

Hawaii Natural Energy Institute
University of Hawaii at Manoa

Hawaiian Electric Company

UNIVERSITY of HAWAIʻI
MĀNOA

Maui Electric Company

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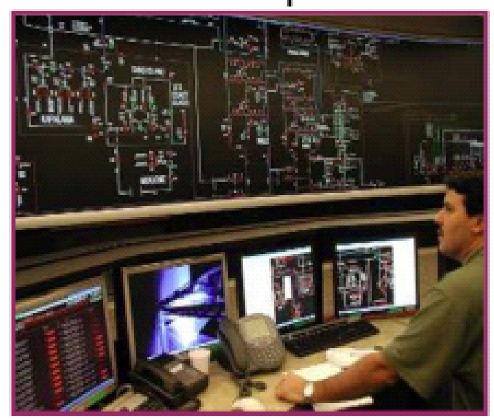
75

Japan – United States
Island Smart Grid Demonstration Project

- Objectives
  - Build the capability to integrate more renewable energy while managing costs
  - Leverage external resources to test new smart grid technologies and concepts in Hawaii
  - Enhance grid operability and reliability
  - Ensure cyber security



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Source: HECO

The Role of Test Beds in Smart Grid/Microgrid Development

- Test beds are an important element for demonstrating the multiple benefits enabled by smart grid technologies
- Benefits include enabling more “behind the meter” efficiency measures in buildings and industry and increased electricity generation from intermittent renewable power sources like wind and photovoltaics
- Country specific test beds can incorporate local grid operating conditions, environmental factors, and social considerations
- Broader efforts allow for better incorporation of variable renewable systems and of demand response technologies

▶ A common goal is to expand testing and evaluation capabilities by identifying gaps and coordinating joint research and evaluation efforts

Island Test Beds Provide Benefits to Islands and Technology Development

- **Isolation is an asset:** Lack of continental grid interconnections provides a unique testing environment
- **Builds human capacity:** Testing activities can be linked with local universities and schools
- **Environmental benefits:** Increased use of renewables and energy efficiency reduces local air and GHG emissions and reduces water consumption for power generation
- **Supports green tourism:** The energy and environmental impacts of smart grid directly support green tourism
- **Economic benefits:** An international test bed can increase international investment and decrease imported fuel costs

Basics for Sustainable, Secure Futures

- **Environment - carbon**
- **Energy - security, scalability expandibility, replicability**
- **Economics – value to consumers, ROI**
- **Equity - fairness**
- **Education – technical understanding, behavior**

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