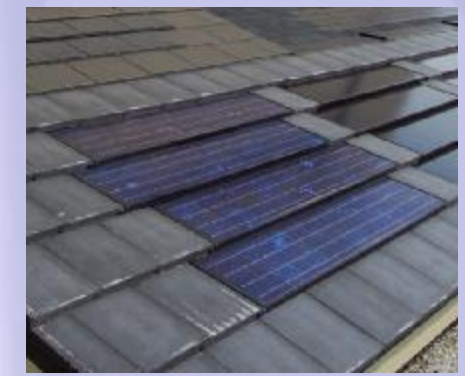
Federal R&D Agenda for Net-Zero Energy, High-Performance Green Buildings



Fourth Annual Public Policy Forum
International Facilities Managers Association
Federal Facilities Council

September 24, 2009

Dr. S. Shyam Sunder, Director
Building and Fire Research Laboratory
National Institute of Standards and Technology
U.S. Department of Commerce

National Science and Technology Council
Subcommittee for Buildings Technology R&D

Buildings Technology R&D Subcommittee

Co-Chairs

Shyam Sunder, Co-Chair (Director BFRL/NIST/DOC)
Jerry Dion, Co-Chair (Building Technologies/EE&RE/DOE)

Function

Assess Federal support for and policies relevant to building technology; identify R&D priorities and opportunities; develop long-range, interagency R&D plans; coordinate with other NSTC subcommittees (Infrastructure, Disaster Reduction,…); coordinate R&D implementation plans

Purpose

Provide R&D guidance aimed at supporting advances in buildings technology and related infrastructure, with a particular focus on enabling the energy efficient, automated operation of buildings and building systems

Purpose

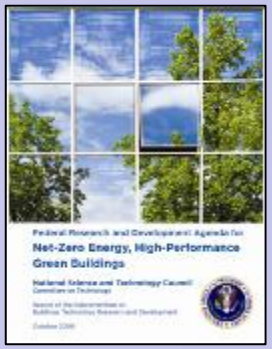
Provide R&D guidance to enable sustainable renewal of the nation's physical infrastructure, improve construction productivity, enhance disaster resilience of buildings, and benefit human health and productivity

Federal Membership

U.S. Department of Agriculture
U.S. Department of Commerce
U.S. Department of Defense
U.S. Department of Energy
U.S. Department of Health and Human Services
U.S. Department of Homeland Security
U.S. Department of Housing and Urban Development
U.S. Department of the Interior
U.S. Department of Labor
U.S. Department of State
U.S. Department of Veterans Affairs
U.S. Environmental Protection Agency
U.S. General Services Administration
National Aeronautics and Space Administration
National Science Foundation
Executive Office of the President
Office of the Architect of the Capital
Smithsonian Institution
U.S. Postal Service

Relevant Subcommittee Activities

- Stakeholder workshop on "*Net-Zero Energy, High-Performance Green Buildings"* including private/public sector participants
  - Ø May 15-16, 2008 Workshop held at the DOE Forrestal Auditorium
  - Ø Over 80 public- and private-sector participants
- Released: *"Federal R&D Agenda for Net-Zero Energy, High-Performance Green Buildings"*
  - Ø White House Public Release October 23, 2008
  - Ø http://bfrl.nist.gov/buildingtechnology/
- Developed for the Federal R&D Agenda:
  - Ø Implementation Plan (FOUO) February 27, 2009
  - Ø GHG Addendum (FOUO) May 14, 2009
- Developed a Proposal for a Presidential Initiative
  - Ø Eight Policies covering regulatory changes, tax and financial incentives, training and workforce development
  - Ø Briefed Susan Crawford, Special Assistant to the President for Science, Technology, and Innovation



Energy Statistics

U.S. energy consumption

- about 20% of global energy consumption
- 20 mbpd oil, 60 bcf natural gas, 3 million tons per day coal

U.S. energy-related CO2 emissions

- 5900 MMT in 2005 (45% oil, 35% coal, 20% NG), 21% of global
- 6900 MMT in 2030, 16% of global

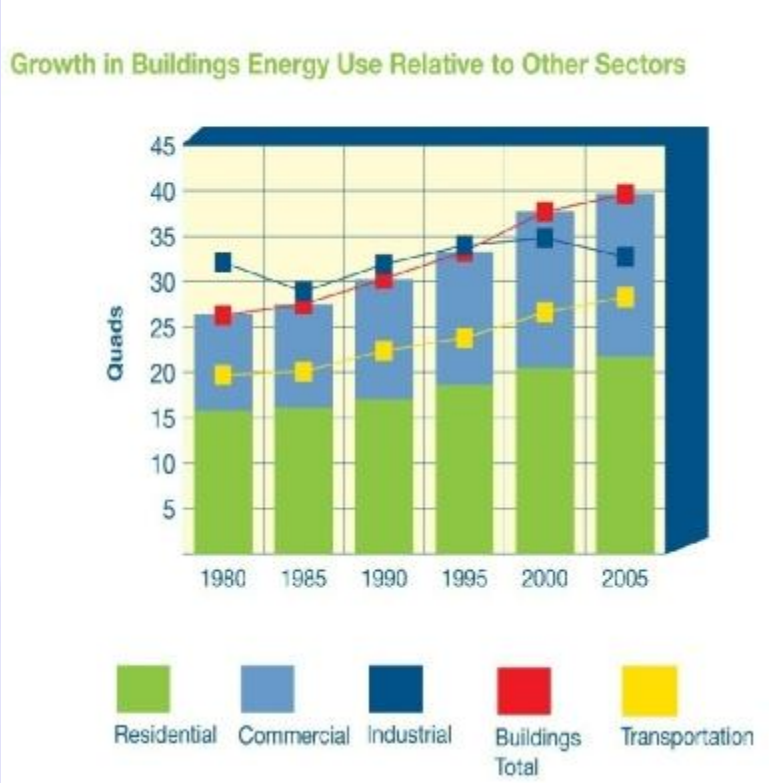
Global energy-related CO2 emissions

- 28,000 MMT in 2005 (40% oil, 40% coal, 20% NG)
- 43,000 MMT in 2030
- 60% of the 25-year increase will be in China, India, and other developing nations in Asia; only 7% of the increase in the U.S.

The buildings sector accounts for about 40% of U.S. primary energy use and about 40% of energy-related CO_2 emissions

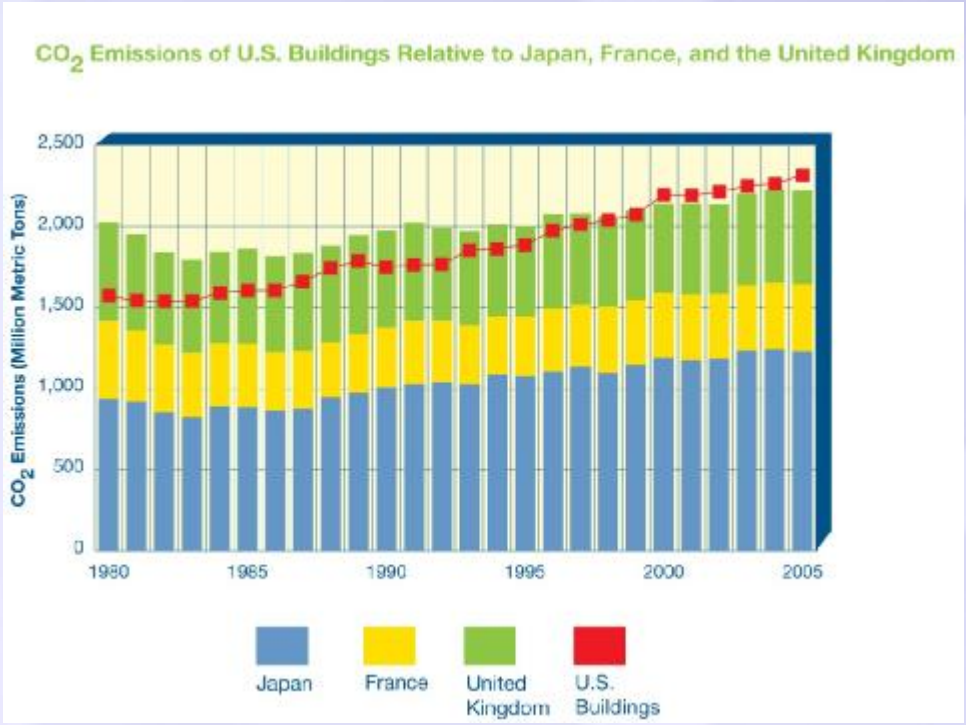
Fastest-Growing Energy Sector

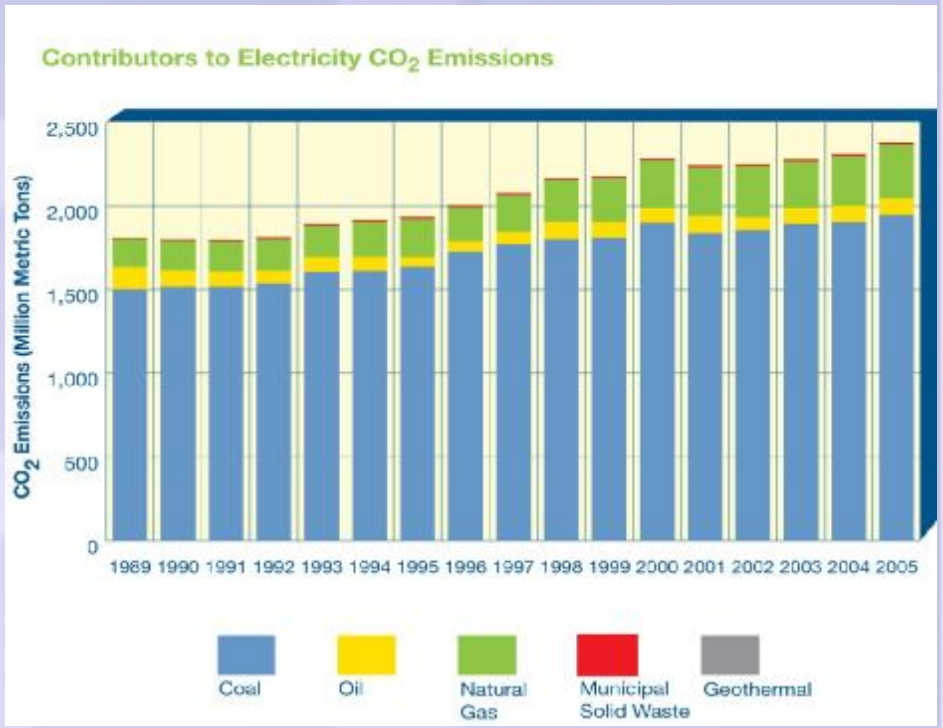
Energy consumption by commercial buildings sector rose 70% between 1980 and 2005



Buildings Environmental Footprint is Large

U.S. Buildings contribute 9% of world's carbon dioxide emissions (double the emissions of India)





U.S. Goals & Mandates

Obama-Biden comprehensive *New Energy for America* plan and *Livability of Cities* Urban Policy

- Reduce our Greenhouse Gas Emissions 80 Percent by 2050
- Build More Livable and Sustainable Communities
- Use Innovative Measures to Dramatically Improve Efficiency of Buildings
- Weatherize One Million Homes Annually
- Make the U.S. a Leader on Climate Change

New mandates in the Energy Independence and Security Act of 2007

- Vehicle efficiency: 40% increase in fuel economy standards by 2020
- Renewable fuels: 36 billion gals/year biofuels (21 billion advanced) by 2022
- Lighting: 30% increase in efficiency
- Appliances: significantly increased efficiency standards in 9 categories
- Federal buildings: 30% reduction in energy use by 2015

State and Local mandates

- Building Codes
- Renewable Power Standards

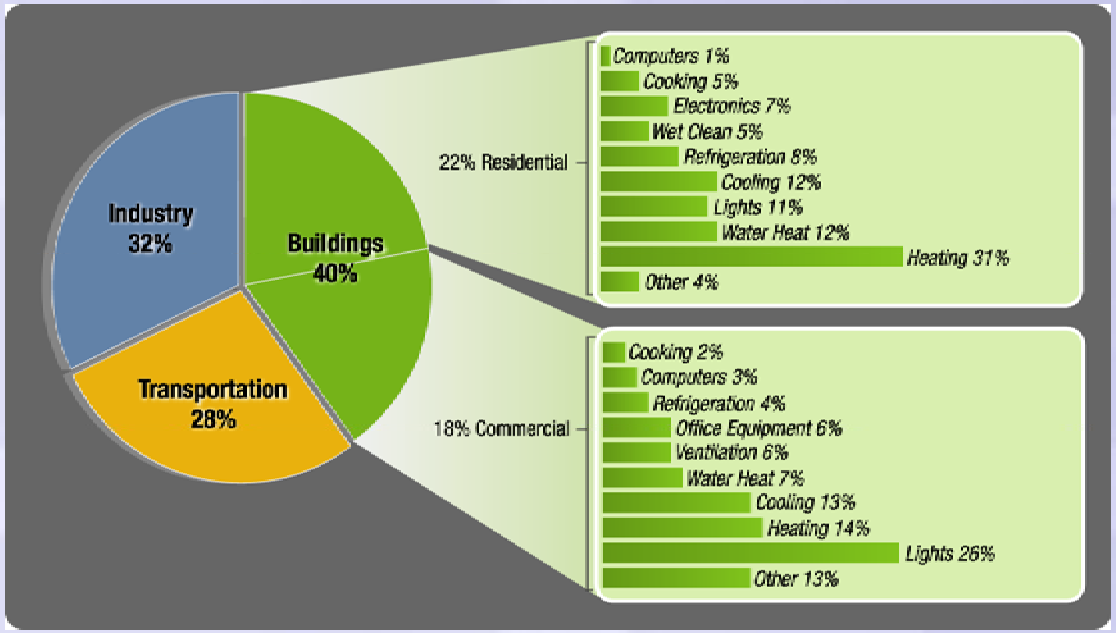
American Recovery and Reinvestment Act

- Unprecedented investments to improve the energy efficiency of Federal buildings, schools, hospitals, and low-income homes using existing cost-effective building technologies.
  - $12.0B DOE Low Income Weatherization Assistance Program, State Energy Program, Efficiency Block Grants and Buildings Efficiency R&D
  - $4.27B GSA High-Performance Green Buildings Program
  - $7.22B EPA (Brownfields, Water Revolving Funds and Capitalization Grants, Leaking Storage Tanks, Diesel Emissions, Superfund sites)
  - VA hospitals and other programs
- The application of existing, cost-effective building technologies in a typical design can yield efficiency improvements of 30 to 40 percent but fail to attain efficiency levels (70 percent) required to make buildings energy self-sufficient (i.e., net-zero energy)

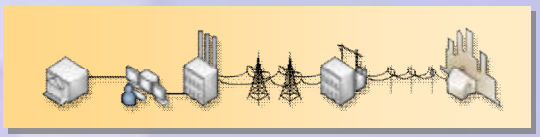
Why Buildings' Energy Use is Important

The combined residential and commercial buildings sector is the largest energy consumer in the U.S.

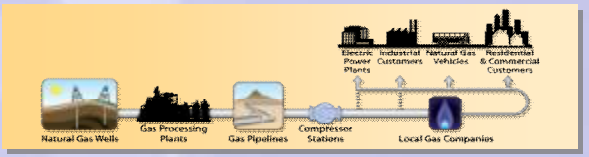
40% of U.S. Primary Energy Consumption



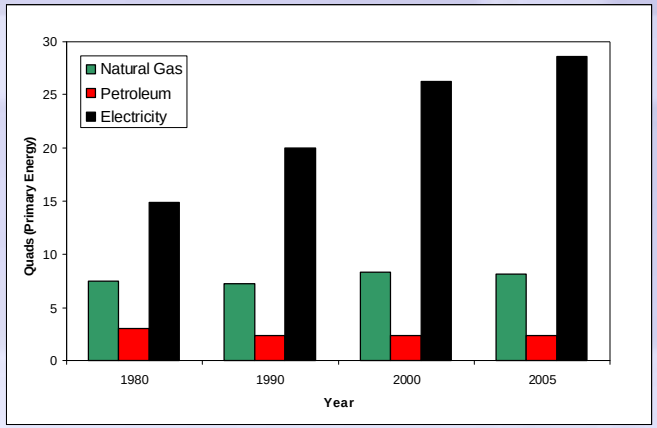
72% of U.S. Electricity



55% of U.S. Natural Gas

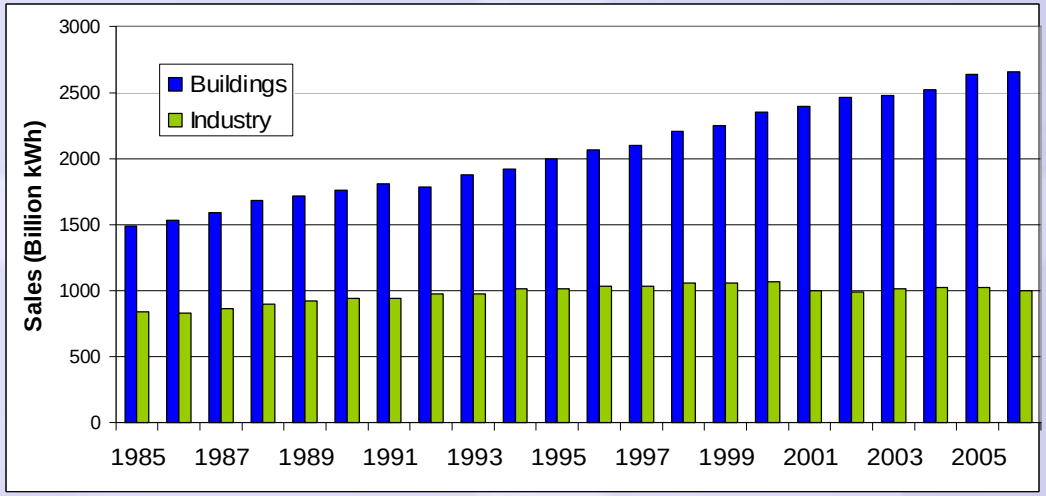


Electricity Growing Source of Building Energy



Source: 2007 BED, Tables 1.1.1

Electricity increased from 56% of overall primary energy use in buildings in 1980 to 72% in 2005



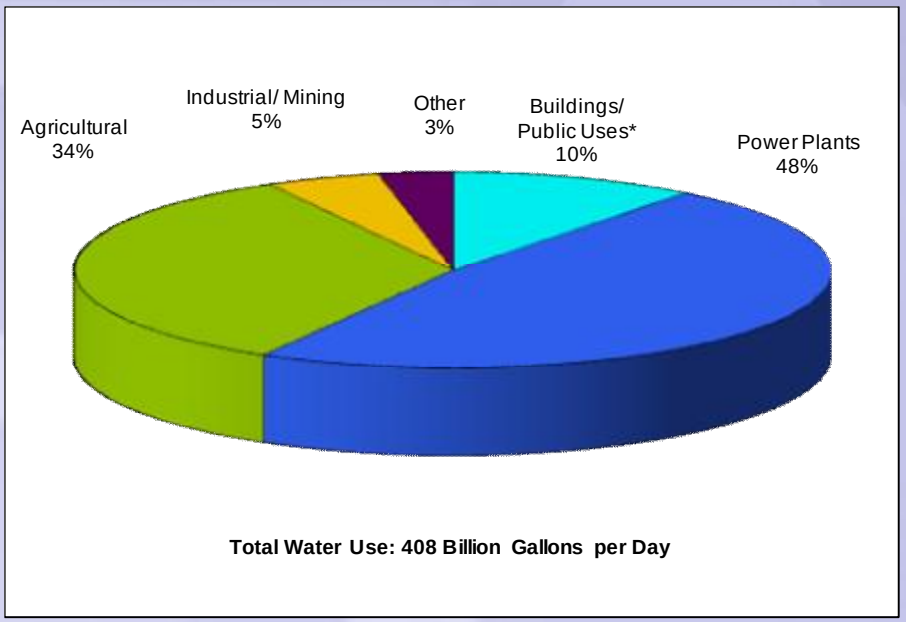
Buildings electricity demand is driving need for electricity infrastructure

Source: EIA Annual Energy Review, Table 8.9, June 2007

Buildings Water Use is Significant

Including electric generation, buildings account for 45 percent of U.S. water use:

- Not including electricity, per capita use is 100 gallons per day for domestic use
- Approximately 140 billion gallons of water per day or 470 gallons per capita per day is used to provide electricity to buildings

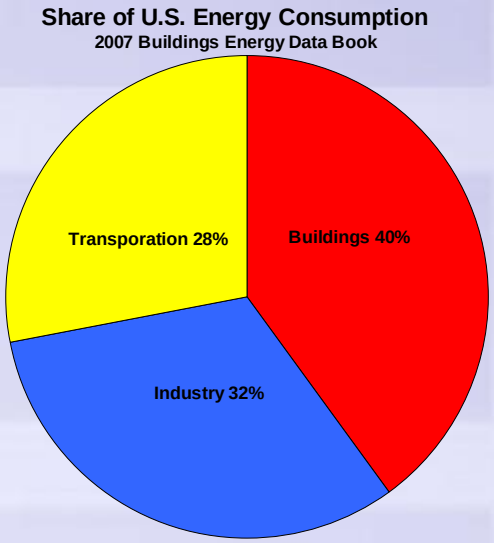


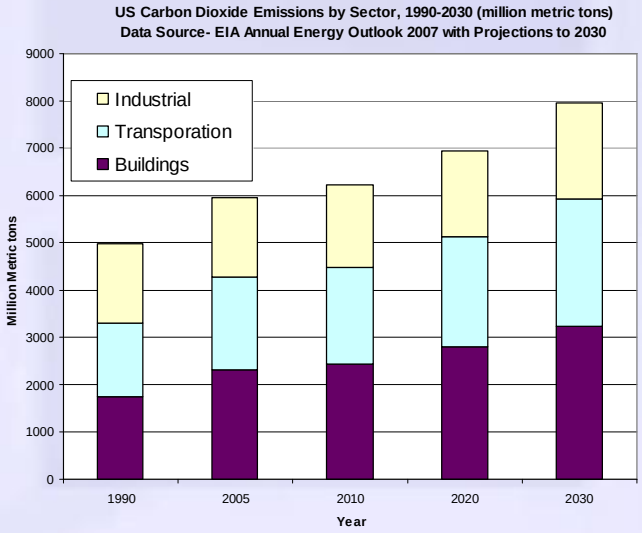
*Does not include self-supplied water of approximately 4 billion gallons/day.

Source: Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., and Maupin, M.A., 2004, Estimated use of water in the United States in 2000: Reston, Va., U.S. Geological Survey Circular 1268; http://www.epa.gov/WaterSense/water/save/use.htm

A recent U.S. study shows 36 states will have local, regional or statewide water shortages by 2013

R&D Rationale





Buildings represent largest user of energy (40%) and electricity (72%) and contributor of CO_2 emissions (39%)

- **U.S. spends $515B/year in energy costs for operation and use of constructed facilities**

An additional 5-8% of U.S. CO_2 emissions are attributable to cement production

- **1 ton of cement produces about 1 ton of CO_2**
- **130 million tons/year used in U.S.; about 2.3 billion tons/year globally**

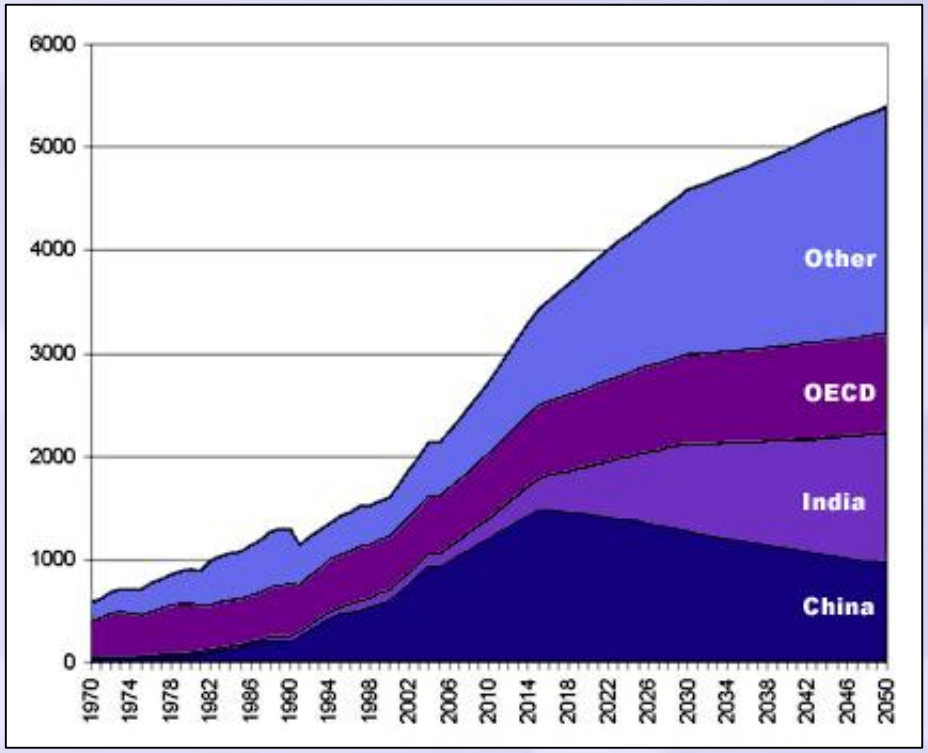
R&D Rationale (Contd. 2)

- **<u>R&D Vision:</u> Enable design of new buildings and retrofit of existing buildings that over the life cycle:**
  - **produce as much energy as they consume (i.e., net-zero energy) while significantly reducing greenhouse gas emissions**
  - **double service life of building materials, products, and systems while minimizing life cycle impacts**
  - **halve use of domestic water (e.g., to 50 gal/day/person or less) while maximizing water recycling and rainwater harvesting and minimizing stormwater runoff**
  - **achieve breakthrough improvements in indoor occupant health, productivity, and comfort**

- **R&D vision can be achieved only**
  - **through use-inspired basic research that enables innovative building technologies, practices, and standards**
  - **by overcoming technical barriers to technology adoption and implementation**

R&D Rationale (Contd. 3)

Global Cement Demand by Region and Country (1970-2050)



Source: USGS and IEA

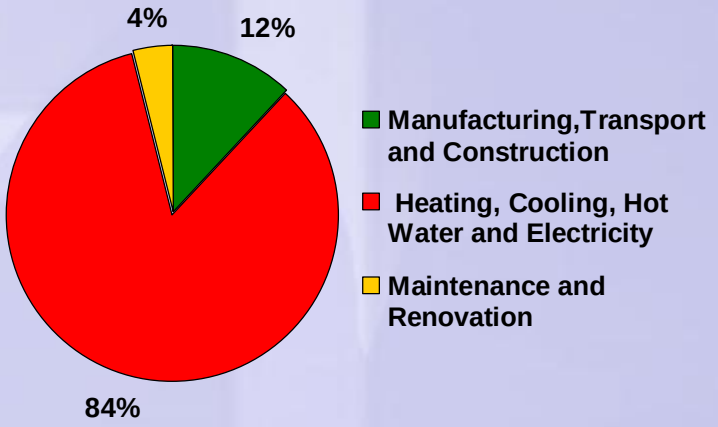
Greatest potential in retrofitting and renovating existing buildings

- Ø Replacement rate of existing building stock roughly 1% per year

New buildings also extremely important

- Ø 34 million new homes projected 2005-2030
- Ø 48% increase in commercial building floor space projected (from 73 to 108 billion sq. ft.)

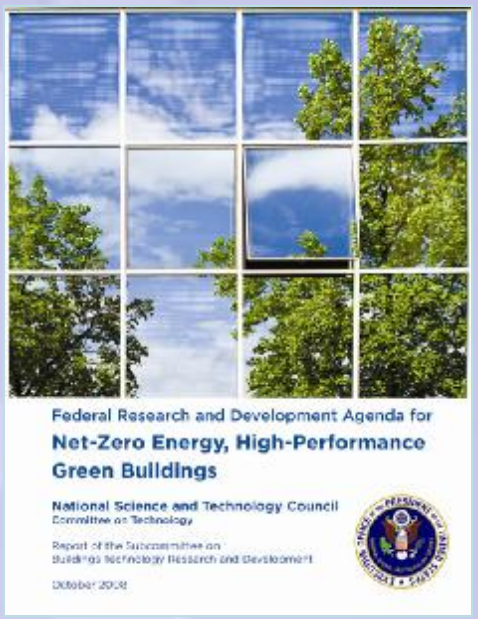
Building Life Cycle Energy Use



Scope and Direction of Federal R&D Agenda

- Integrated, Performance-Based Design and Operation
- Net-Zero Energy Building Technologies and Strategies
- Water Use and Rainwater Retention
- Material Utilization, Waste, and Life Cycle Environmental Impacts
- Occupant Health and Performance
- Overcoming Barriers to Implementation

The scope of this report is limited to R&D on new technologies, protocols, and practices at the building site, unless they apply as well to groups of buildings or communities.

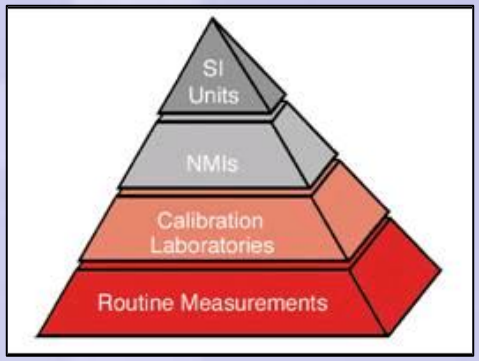


Integrated, Performance-Based Design and Operation

Goal 1: Develop the enabling measurement science to achieve net-zero energy, high-performance green building technologies

Focus Area a. Develop rigorous metrics that enable high-performance building goals to be predicted, assessed, monitored, and verified and new energy-efficient technologies, products, and practices to be developed

Focus Area b. Enable widespread adoption of high-performance goals by developing practical tools and processes to address the complex interactions of building components and systems throughout the building life cycle



Net-Zero Energy Building Technologies and Strategies

Goal 2: Develop net-zero energy building technologies and strategies

Focus Area a. Develop building envelope materials, components, systems, and construction techniques to minimize building energy loads

Focus Area b. Develop ultra energy-efficient components and subsystems that minimize energy and satisfy building needs

Focus Area c. Develop supply-side technologies that, when coupled with energy efficiency, can achieve net-zero energy buildings and communities





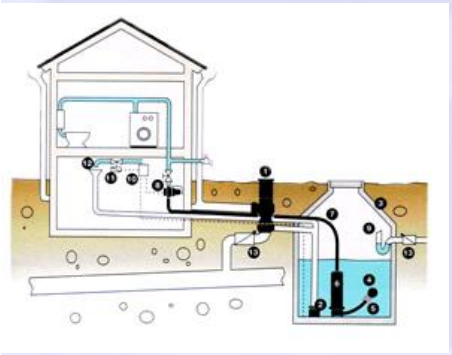
Water Use and Rainwater Retention

Goal 3: Develop the scientific and technical bases for significant reductions in water use and improved rainwater retention

Focus Area a. Reduce water use through more efficient water-saving appliances, fixtures, and water systems

Focus Area b. Develop analyses and technologies to overcome environmental, health, and technical barriers to widespread water recycling and increased rainwater harvesting

Focus Area c. Develop low-impact development practices to significantly reduce stormwater runoff



Safe Home Products

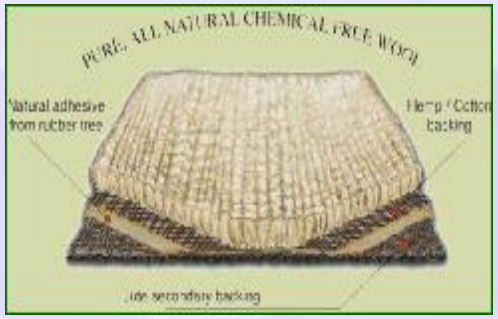
Material Utilization, Waste, and Life Cycle Environmental Impacts

Goal 4: Develop processes, protocols, and products for building materials that minimize resource utilization, waste, and life cycle environmental impacts

Focus Area a. Develop processes that minimize waste generation from building construction, renovation, and demolition

Focus Area b. Expand life cycle inventory data and perform life cycle assessments to identify the full environmental and public health impacts of product and material choices

Focus Area c. Develop new materials and products with minimal environmental and public health impacts over their life cycles



Pure Home Center

Occupant Health and Performance

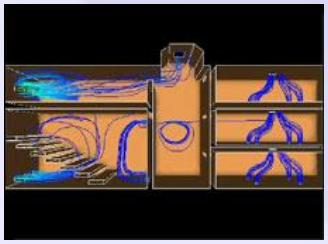
Goal 5: Develop the knowledge and associated energy efficiency technologies and practices needed to promote occupant health, comfort, and productivity

Focus Area a. Develop technologies to improve indoor environmental quality and reduce building energy consumption

Focus Area b. Develop the knowledge necessary to support scientifically sound and building-specific standards and codes that address the health and comfort of building occupants

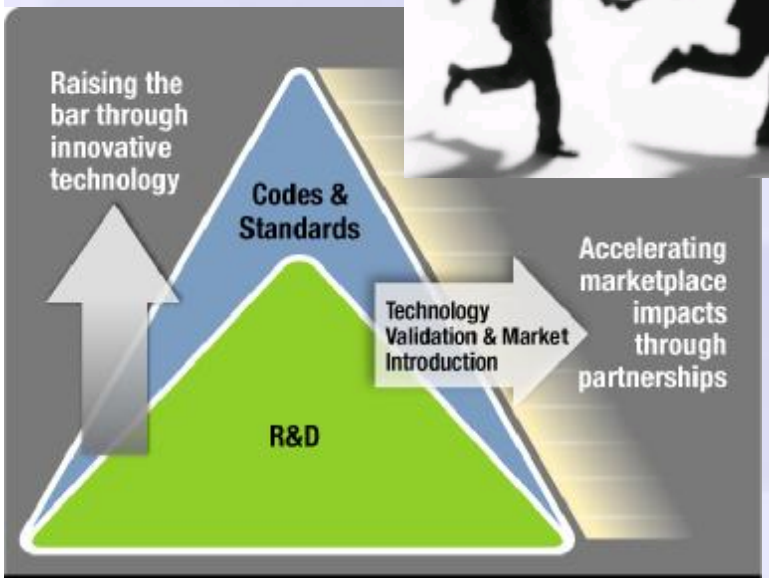
West Side Yards
Goldman Sachs Image

WBDG



Overcoming Barriers to Implementation

Goal 6: Enable technology transfer for net-zero energy high-performance green buildings



Focus Area a. Develop high-performance building design tools and guidance for urban planners, architects, engineers, contractors, and owner/operators

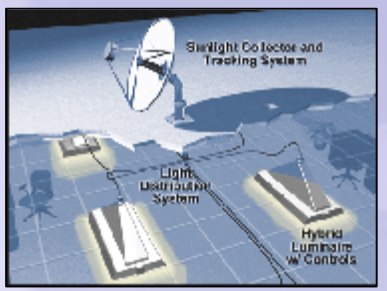
Focus Area b. Develop tools and guides that enable the use of modern, adaptive performance-based building codes

Focus Area c. Research and develop effective incentives for adopting and using innovative technologies and practices

Future High-Performance Technologies

Lighting Systems

- Ø Solid State Lighting
- Ø Intelligent natural daylighting distribution systems

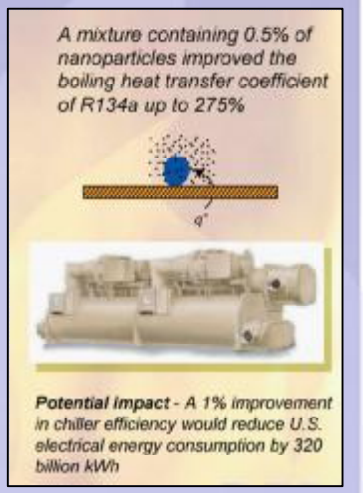


Hybrid Solar Lighting

Building Envelope Systems

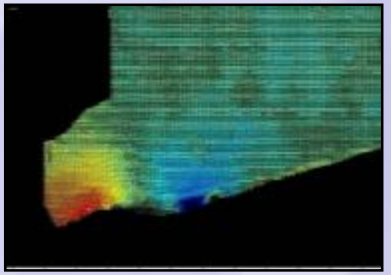
- Ø Dynamic response (shades and electrochromic windows)
- Ø Highly insulating façade systems
- Ø Natural lighting technologies/designs (Green)

Solar Tracking Facility to Characterize Performance of Photovoltaic Cell Technologies



Intelligent Systems and Controls

- Ø Diagnostic and real-time monitoring tools
- Ø Sensors for improved building monitoring
- Ø Grid/consumer supply/demand integration



Particle Image Velocimetry Image of Air Flow Distribution through Heat Exchanger

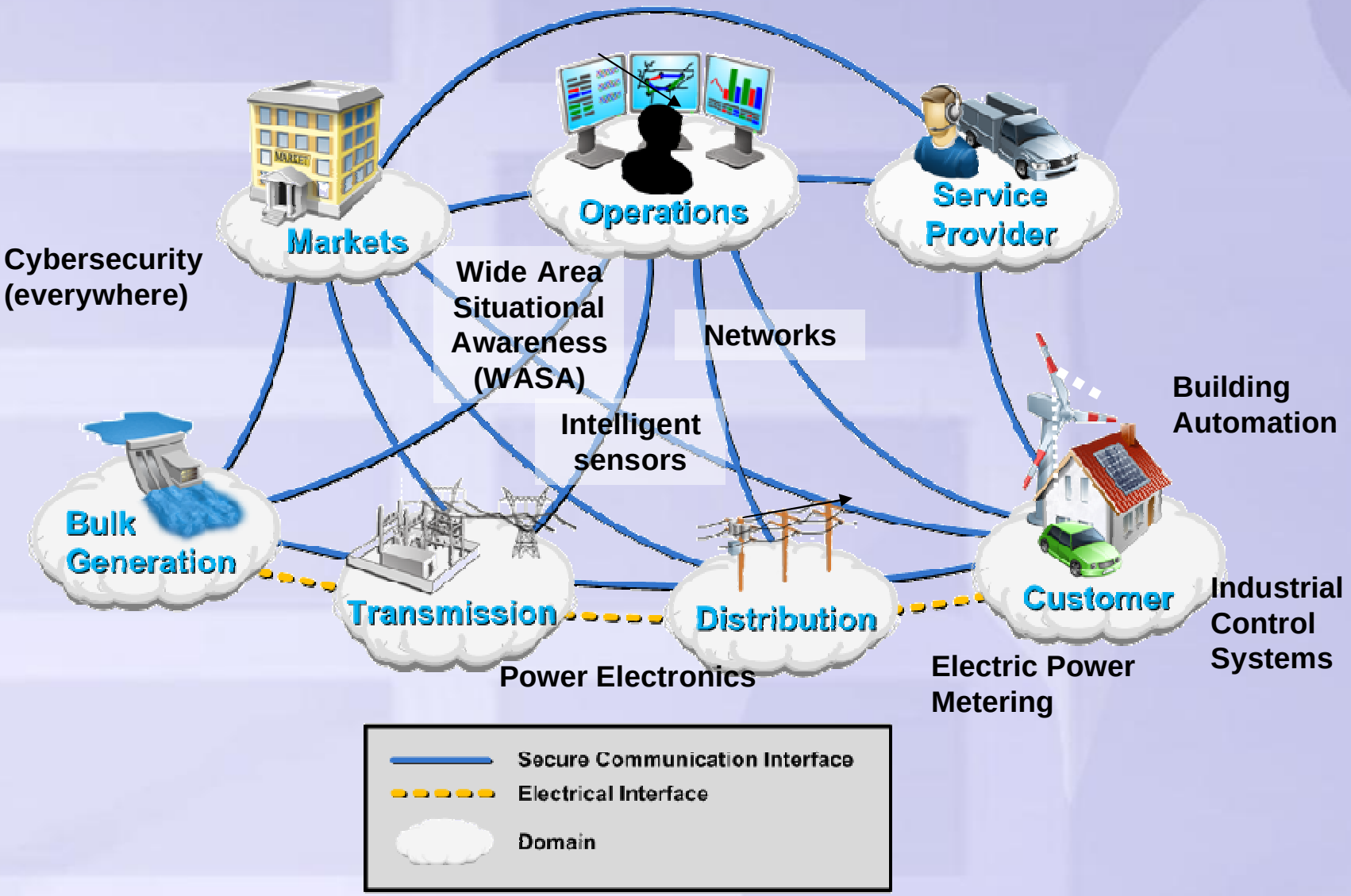
NIST's 0.5 meter Guarded Hot Plate Capable of Providing Measurements of Thermal Insulation from 90 to 900 K

Heating, Cooling, and Refrigeration

Boric Acid Nano Lubricant

- Ø Nano-fluids and lubricants
- Ø Thermally-activated heat pumps
- Ø Distributed refrigeration/water-source heat pump
- Ø Thermoelectric cooling
- Ø Frostless heat pump
- Ø Improved residential HVAC air distribution systems

Smart Grid Conceptual Model



Energy Efficient, Smart Buildings Critical to Smart Grid Success

2009 Path Forward

Advance the *Federal R&D Agenda Report*

- Disseminate the Federal R&D Agenda report to stakeholder groups
- Socialize within the USG the Federal R&D Agenda *Implementation Plan*
  - Three levels of R&D implementation
  - Approximate pricing levels
- Brief Federal policy leaders on the Federal R&D Agenda Report and Implementation Plan

Next Steps for the Federal R&D Agenda:

- Examine policy alternatives for accelerating technology adoption including regulatory, buildings codes and standards, incentives, education and awareness opportunities
- Develop detailed roadmaps for each of the R&D goals in partnership with key stakeholder organizations
- Engage the key stakeholders — universities, National Laboratories, standard and code development organizations, professional societies, and private sector companies —to implement the R&D agenda
- Publicize the Federal performance requirements for purchases and procurements
- Evaluate successes and lessons learned
- Refine the research agenda

Recent U.S. Congress Interests in Building Policy

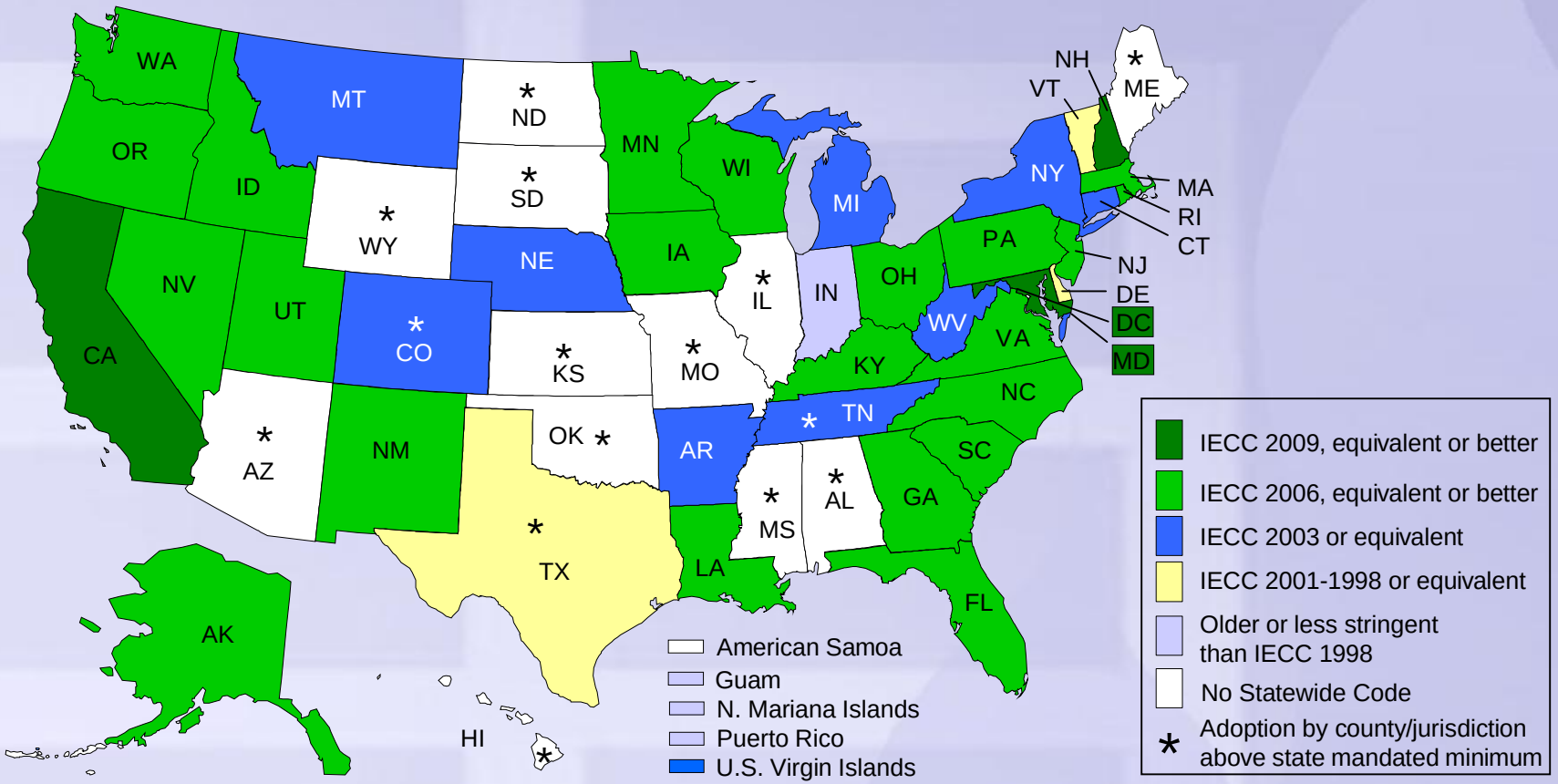
- *Energy Efficiency in Buildings – Critical Barriers and Congressional Policy (June 2009)* by the Congressional Research Service (CRS)
  - Ø Based on *Carbon Lock-In: Barriers To Deploying Climate Change Mitigation Technologies (Nov 2007) mandated by EPAct 2005.*
    - Ø Key Barriers: industry structure, incomplete/imperfect information, high (first) costs, technical risks, market risks, and unfavorable utility fiscal policies.
    - Ø Secondary Barriers: external benefits and costs, lack of specialized knowledge, policy uncertainty, infrastructure limitations
  - Ø Includes Energy Price Stability as an additional issue

- American Recovery and Reinvestment Act of 2009 (P.L. 111-5)

CRS Key Conclusions

- Congressional policies since 1975 have
  - focused persistently on the critical barriers of industry structure, imperfect information, and high first costs.
  - addressed technical risk to a limited degree through technology demonstrations
- Using *Lock-in* report as a guide, appears that significant policy gaps remain with respect to utility rate policies, market risks, and energy price stability
- Policy makers may benefit from a complete and integrated understanding of the full set of barriers to building efficiency and the range of carbon outcomes they imply

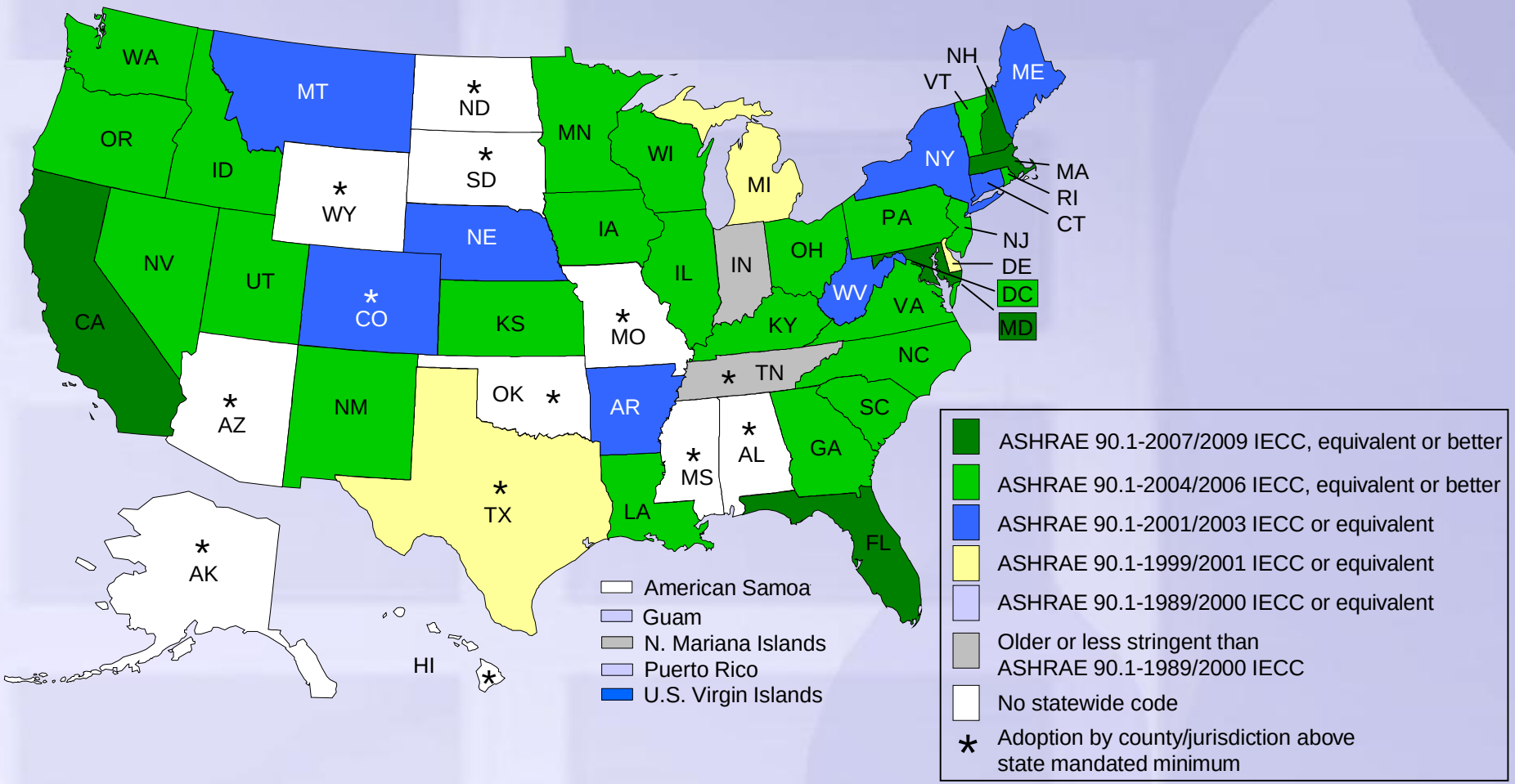
Status of Residential Energy Codes



Source: BECP's Status of State Codes
http://www.energycodes.gov/implement/state_codes/index.stm

as of 10/1/09

Status of Commercial Energy Codes



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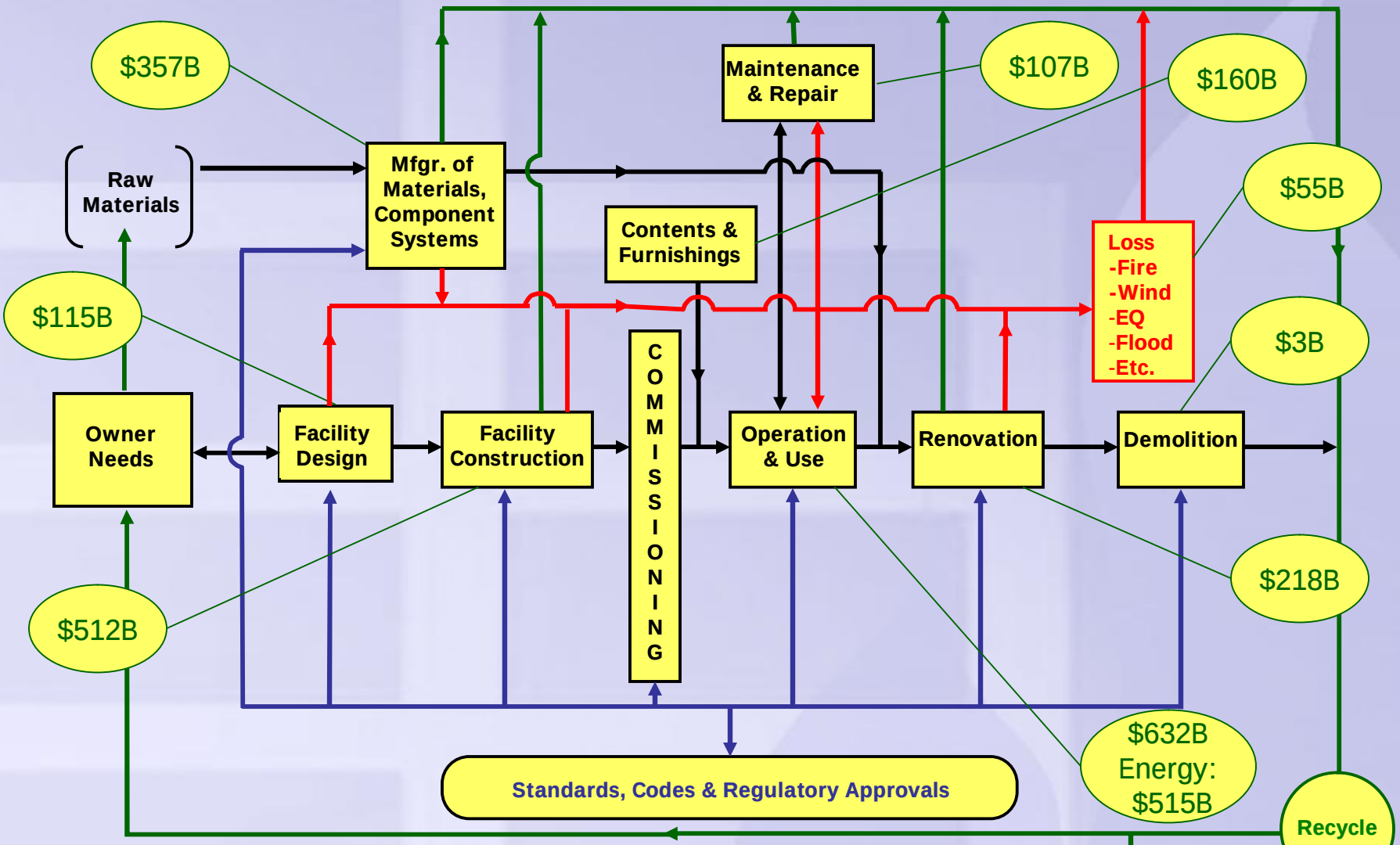
Impacts of Construction Industry Supply Chain in 2007



Current Value of Built Assets	$36.4 T
Construction Contribution to GDP	$648 B
Construction Contribution as % of GDP	4.9 %
Value of Construction Put in Place	$1 162 B
Volume of Construction Work	$1 309 B
Construction Employment (Establishment Surveys)	7.9 M
Construction Employment (Household Surveys)	11.7 M

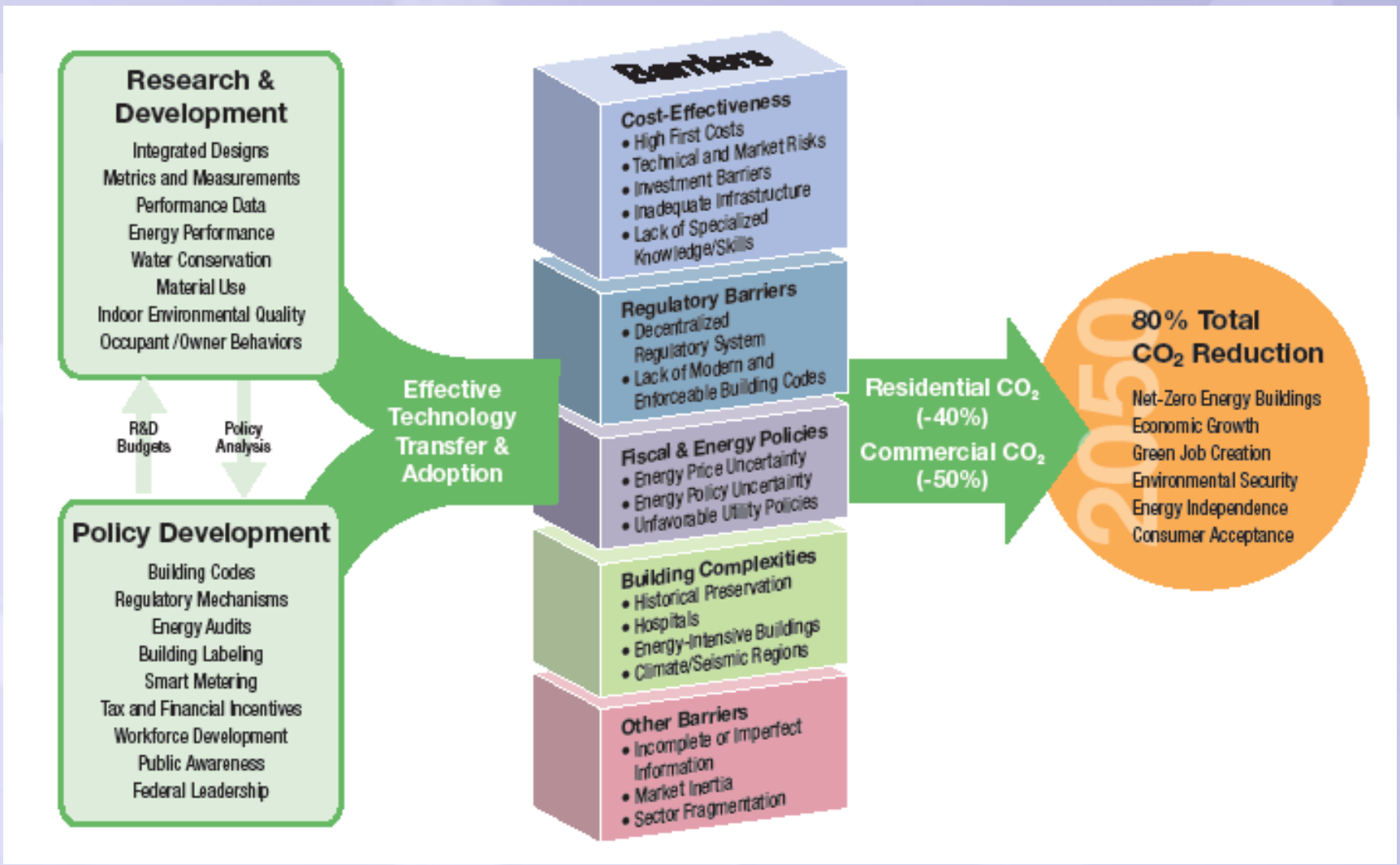
Key *Drivers* for Change in Construction

- Energy independence, environmental security, and sustainability
- Renewal of Nation's aging physical infrastructure
- Demand for better quality, faster, and less costly construction
- Competition due to globalization and offshoring
- Homeland security and disaster resilience

Key *Barriers* to Change in Construction

- Declining productivity and industry fragmentation
- Minimum first-cost mindset precludes lower-cost investment options based on life-cycle performance
- Prescriptive standards and codes stifle innovation and competitiveness
- Low profit margins and R&D investment

Conceptual Framework



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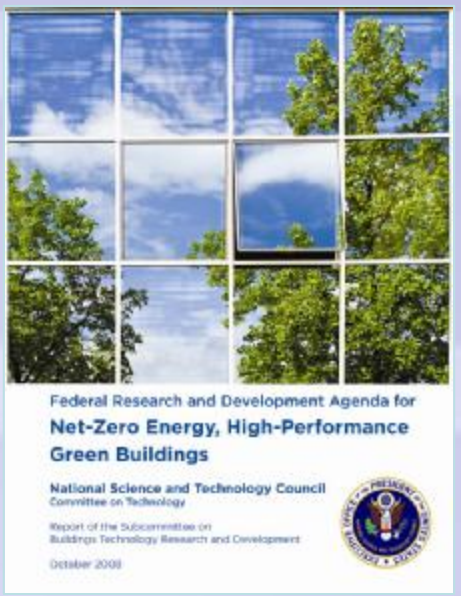

Report can be downloaded at

http://bfrl.nist.gov/buildingtechnology/

http://ostp.gov/galleries/NSTC%20Reports/FederalRDAgendaforNetZeroEnergyHighPerformanceGreenBuildings.pdf

http://bfrl.nist.gov/buildingtechnology/documents/FederalRDAgendaforNetZeroEnergyHighPerformanceGreenBuildings.pdf