NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Renewable Energy: How Technology Innovation is Changing our Energy Future

DU Law & Policy Summit

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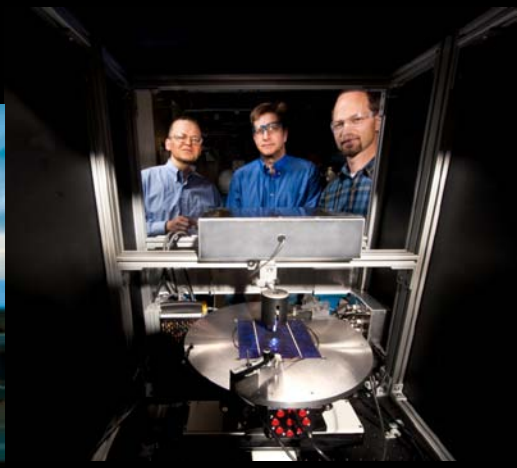
Laboratory Director

NREL's Mission is Unique

NREL develops renewable energy and energy efficiency technologies and practices, advances related science and engineering, and transfers knowledge and innovations to address the nation's energy and environmental goals.



National Goals and NREL's Role

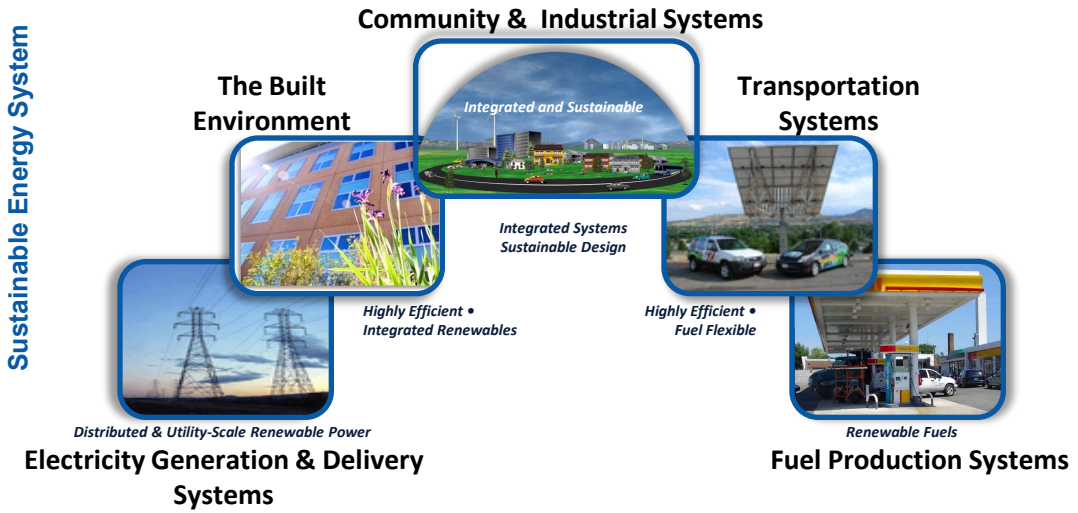
By 2035, 80% of America's electricity will come from clean energy sources

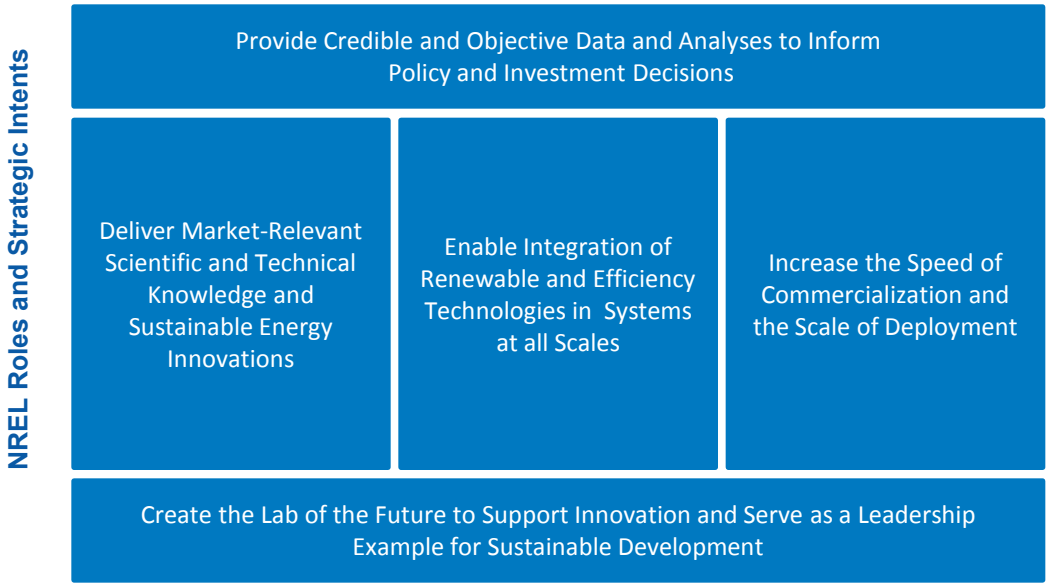
Support deployment of 1 million electric vehicles (EVs) on the road by 2015

Double renewable energy generation by 2012

Reduce our daily petroleum consumption in 2020 by 3.5 million barrels (18%)

Reduce energy-related greenhouse gas emissions by 17% by 2020 and 83% by 2050, from a 2005 baseline





The Role for Clean Energy—A Decade of Real Progress

Wind power capacity increased by more than **a factor of 10 to more than 200 GW.**

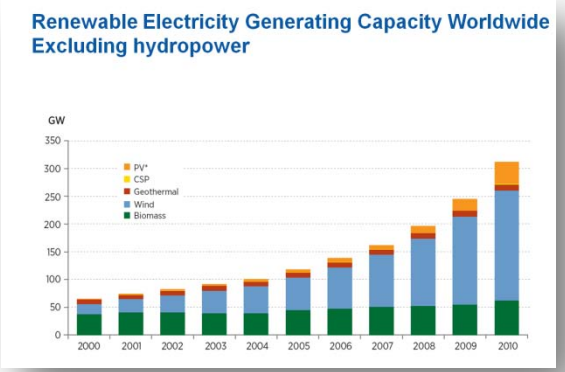
Solar PV global installed capacity **grew by factor of almost 30** to about 35 GW in 2010.

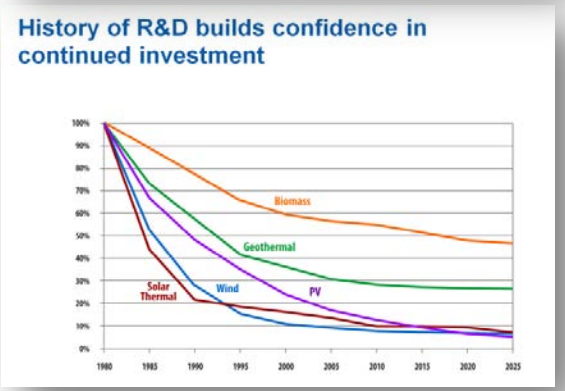
Biofuels emerged as a **major global industry** (~28 billion gallons/year)

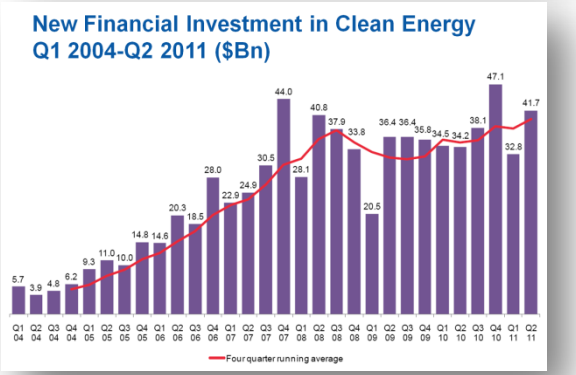
LEED-certified commercial buildings grew to more than 10,000

Costs have been significantly reduced and are **approaching grid parity**

Clean energy grew from $1B/year to a **$211B/year market**







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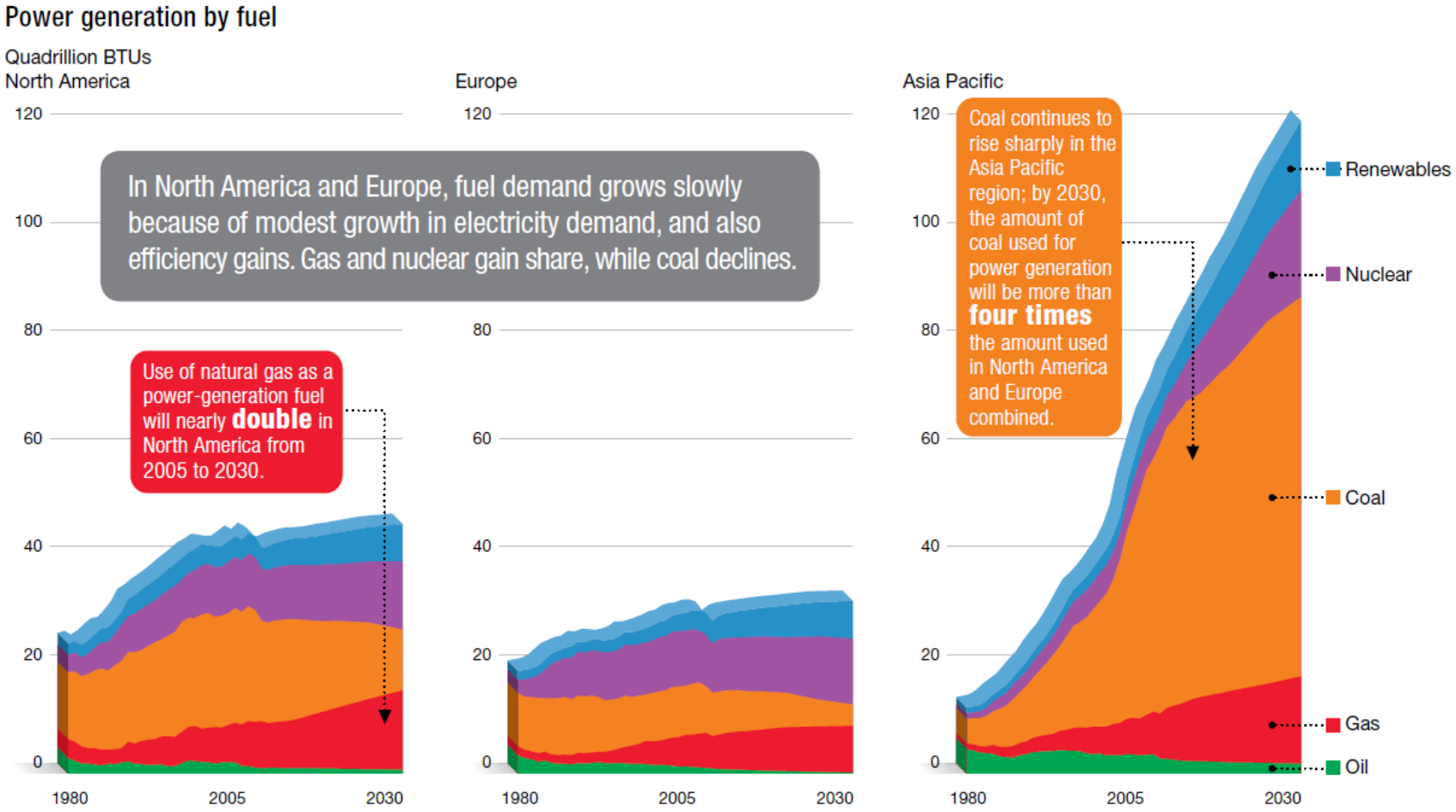
IEA 2011 *Clean Energy Progress Report*

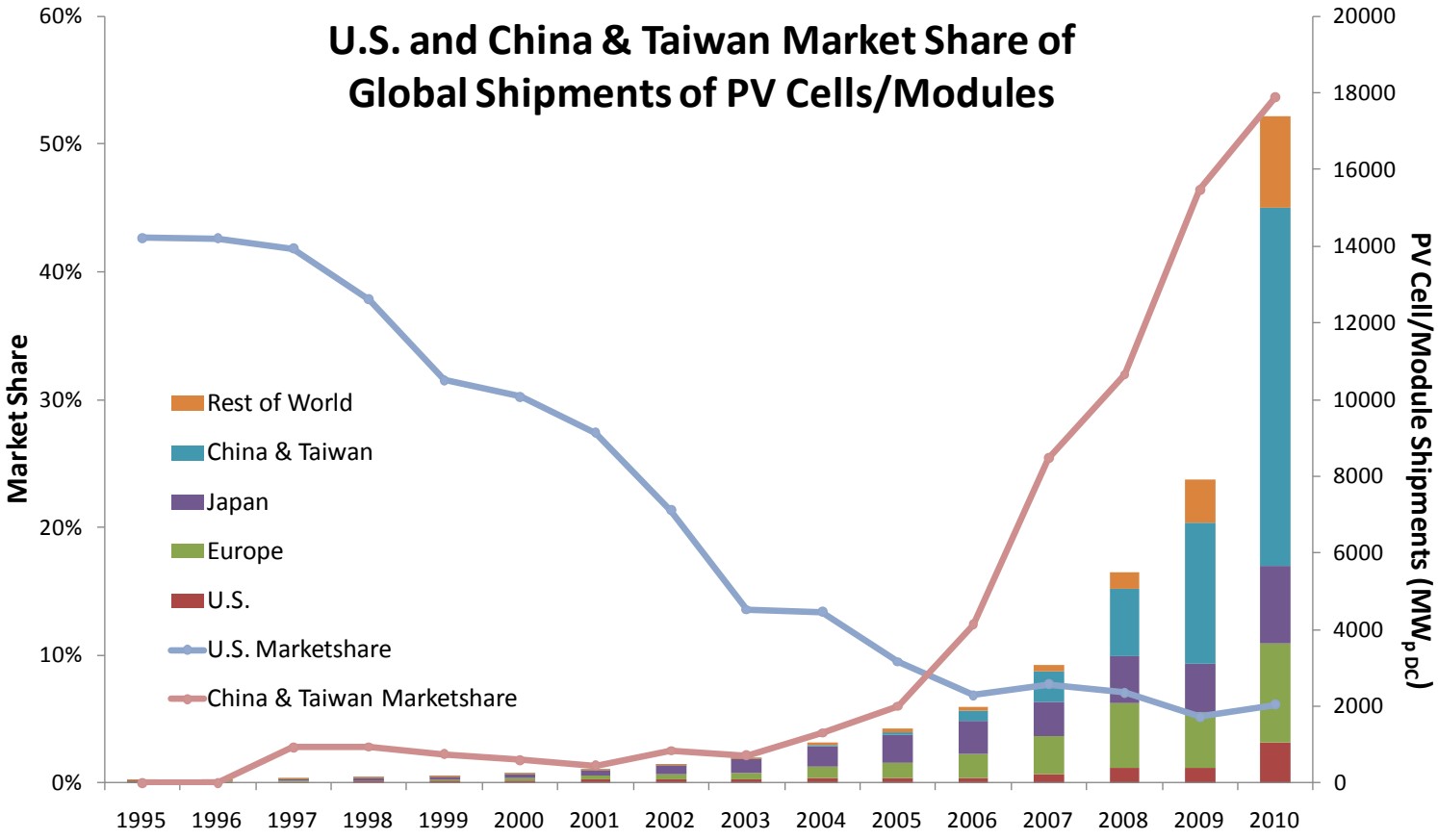
"While 19.5% of global electricity in 1990 was produced from renewable sources, this share fell to 18.5% in 2008."

Many expect electricity demand to grow faster than renewable energy generation



The Outlook for Energy: A View to 2030 31

Global U.S. Position Ceded to China & Taiwan

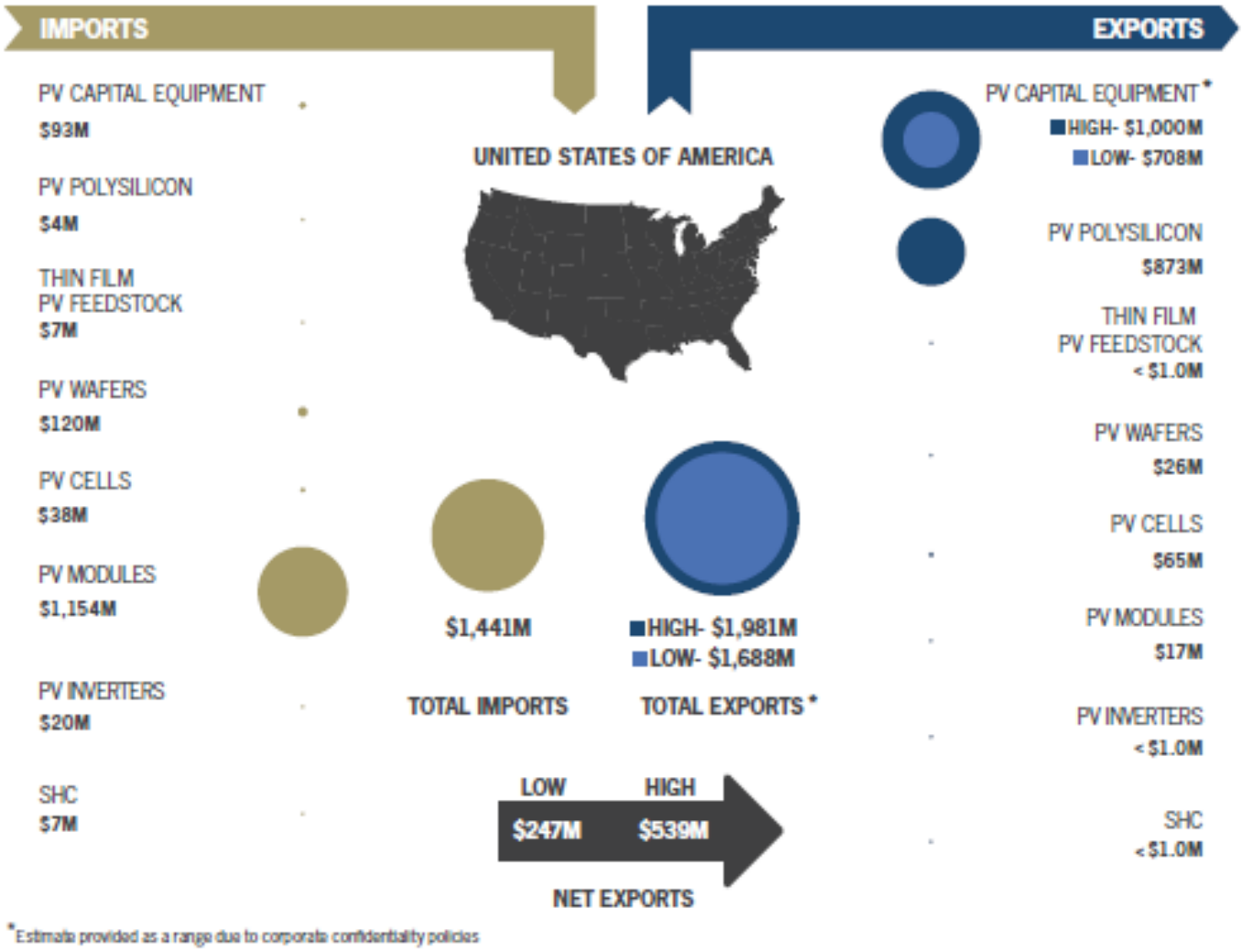


Between 2000 and 2010 global shipments grew 53% (CAGR) and:

- U.S. market share has slipped from 30% to 7% (30% CAGR)
- While China/Taiwan has grown from <2% to 54% (115% CAGR)

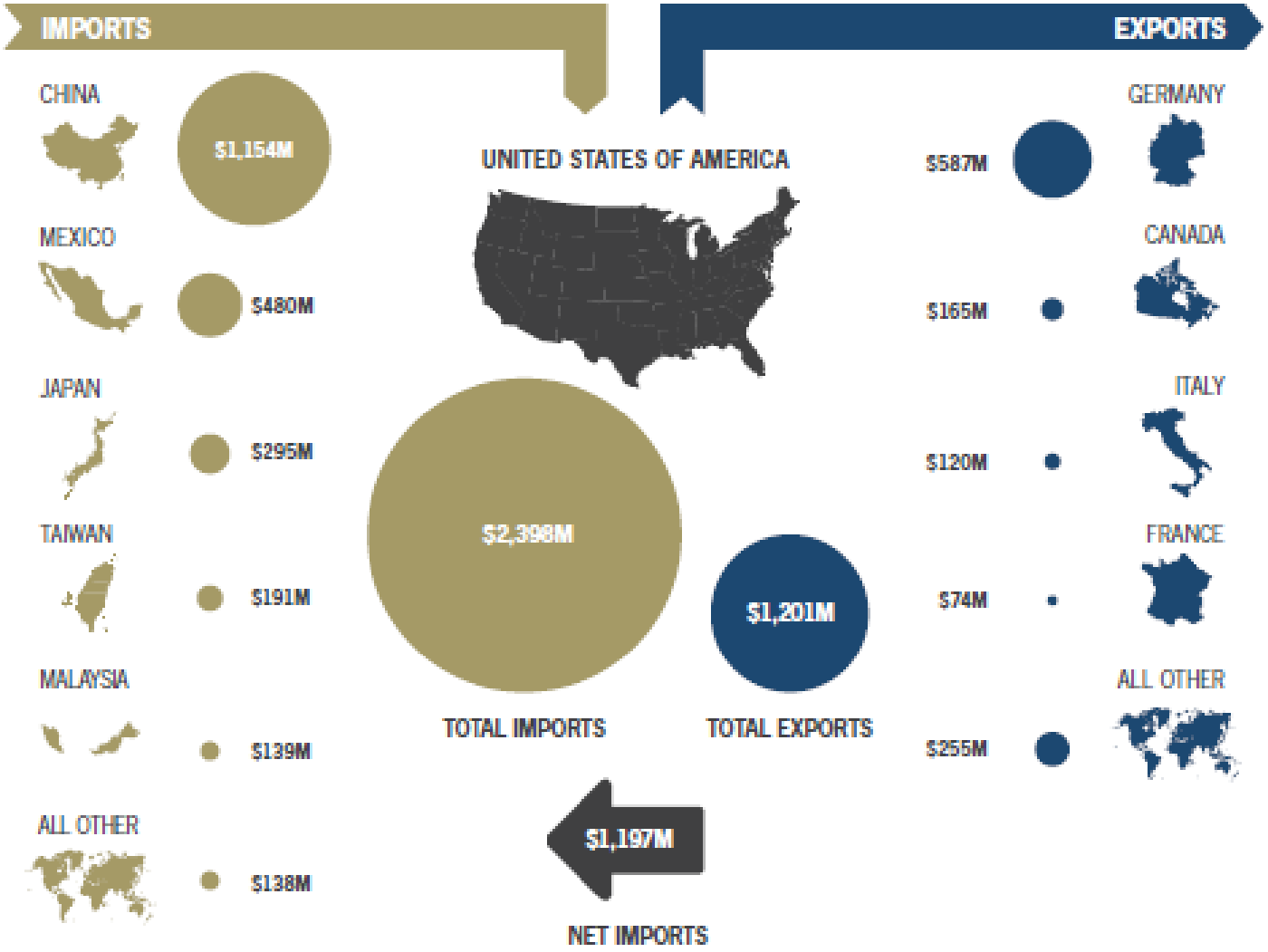
Sources: [NREL slide using data from: Mints, P.; Donnelly, J. (2011). "Photovoltaic Manufacturer Shipments, Capacity and Competitive Analysis 2010/2011." Report NPS-Supply 6, Navigant Solar Services Program. Palo Alto, CA.

US-China Solar Energy-Related Trade Flows



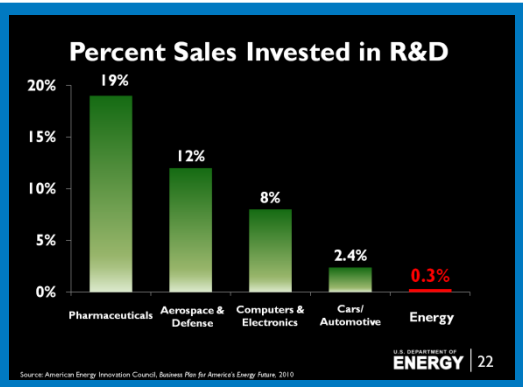
GTM Research and International Trade Commission. (2011). "U.S. International Trade Assessment 2011: Trade Flows and Domestic Content for Solar energy-related Goods in the United States."

PV Module Trade Flows

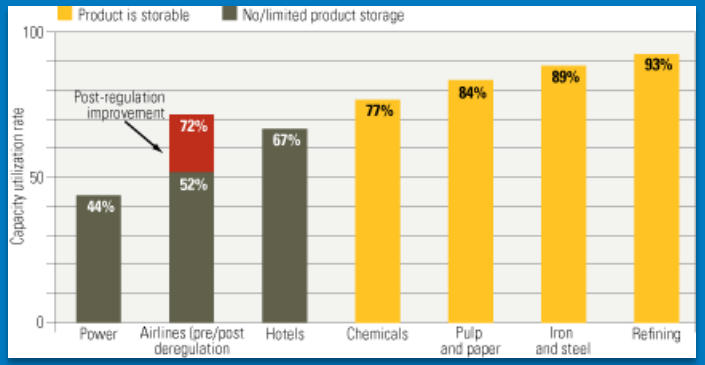


GTM Research and International Trade Commission. (2011). "U.S. International Trade Assessment 2011: Trade Flows and Domestic Content for Solar energy-related Goods in the United States."

Energy Sector Challenges



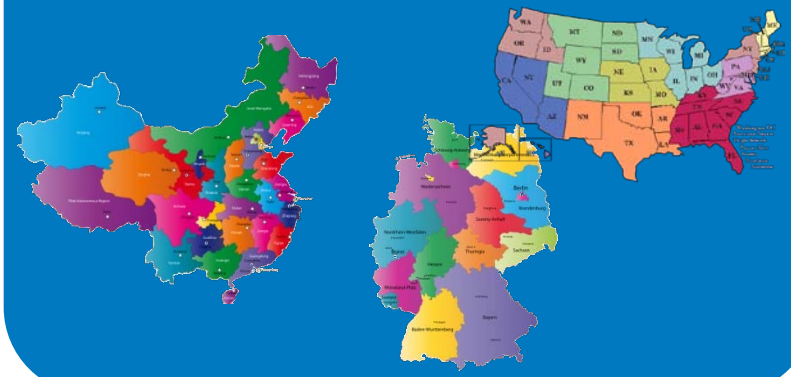
R&D Investment Drives Innovation



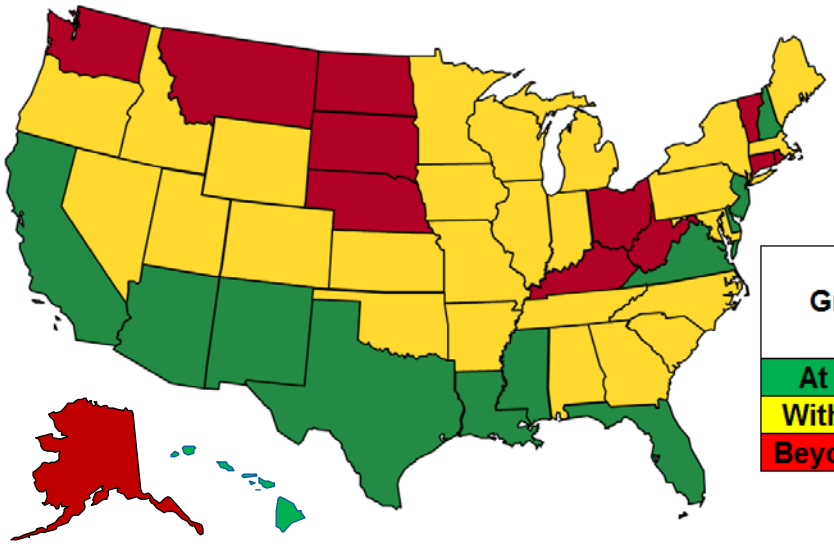
Asset Utilization

Capital Intensive with Long Life Cycles

National Strategies Driving Energy Market



Grid Parity with $1 / Watt



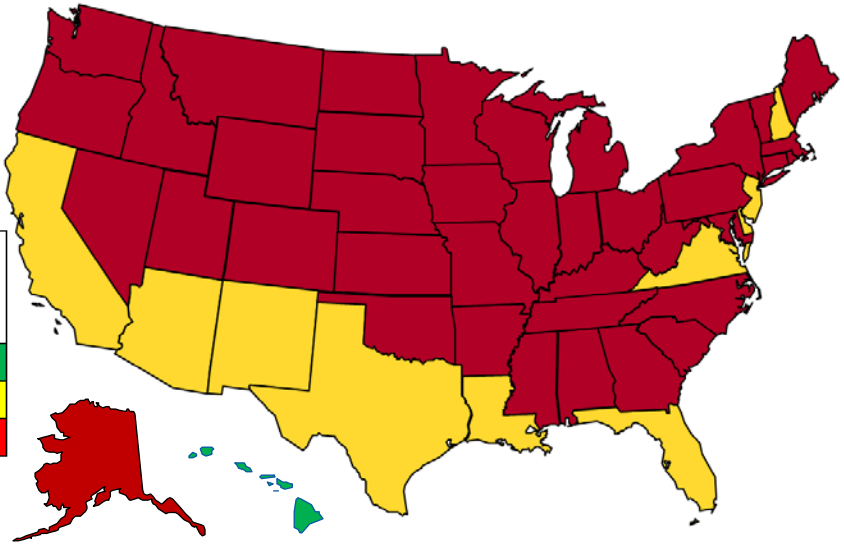
$1 / Watt Scenario

Grid Parity 2017

At or below parity

Within 25% of parity

Beyond 25% of parity

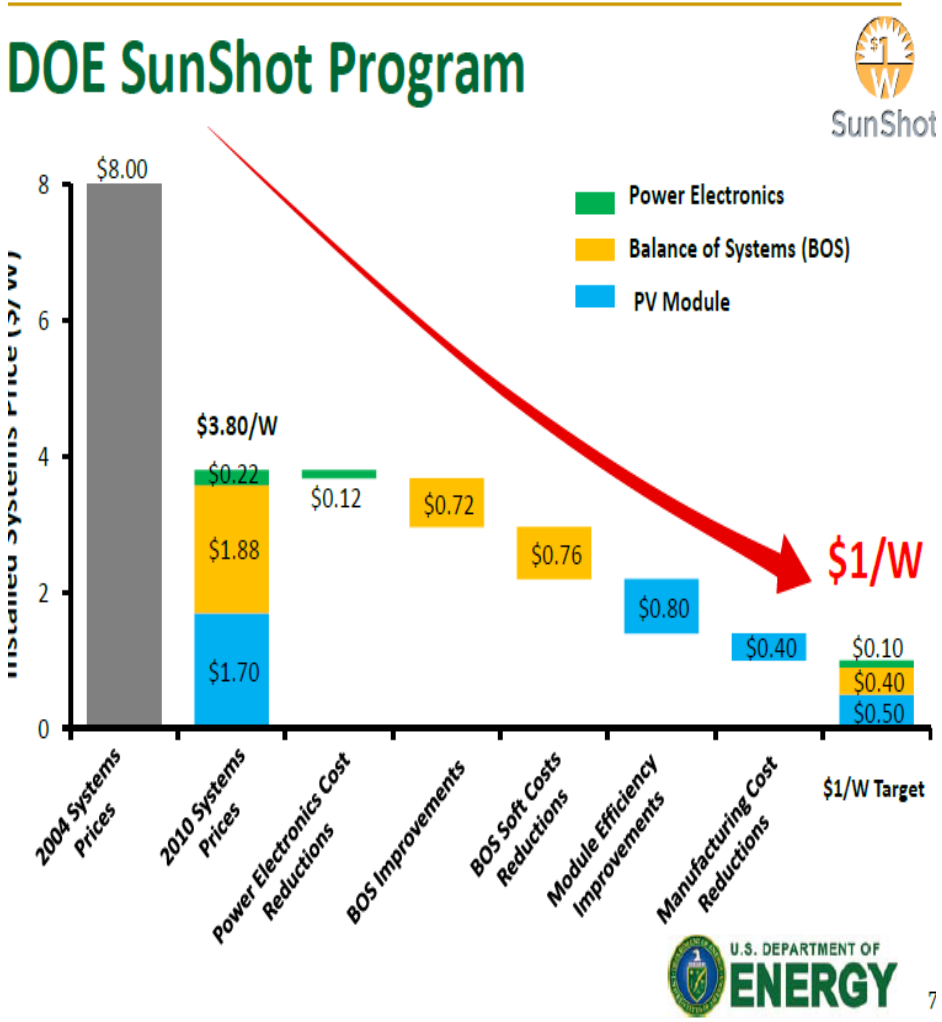


Current Projection

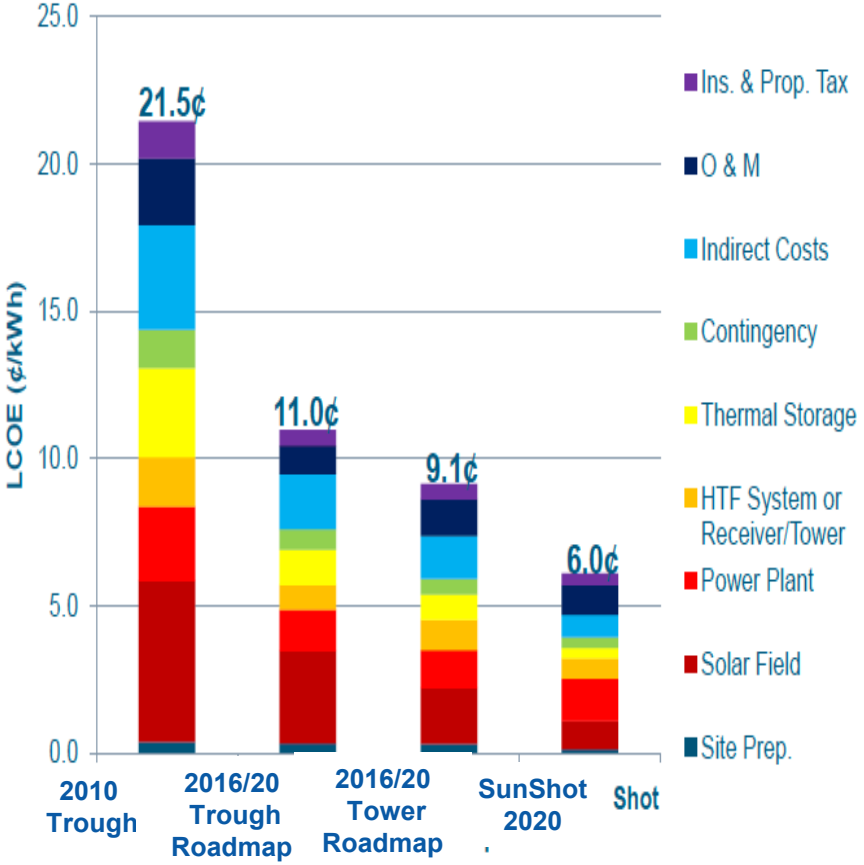
- Assumes no Federal, State, Local, and Utility incentives
- Assumed an installed system size of 20 MW, and an 86% conversion factor between DC and AC module capacity.
- Utilized weighted average wholesale electricity prices from the 2008 EIA-861 Data. The data were escalated to 2017 prices based on an annual electricity escalation rate of 1%.
- Current projection for utility scale PV is assumed to be $2/Watt by 2017.

Solar Electricity: R&D Thrusts

Photovoltaics

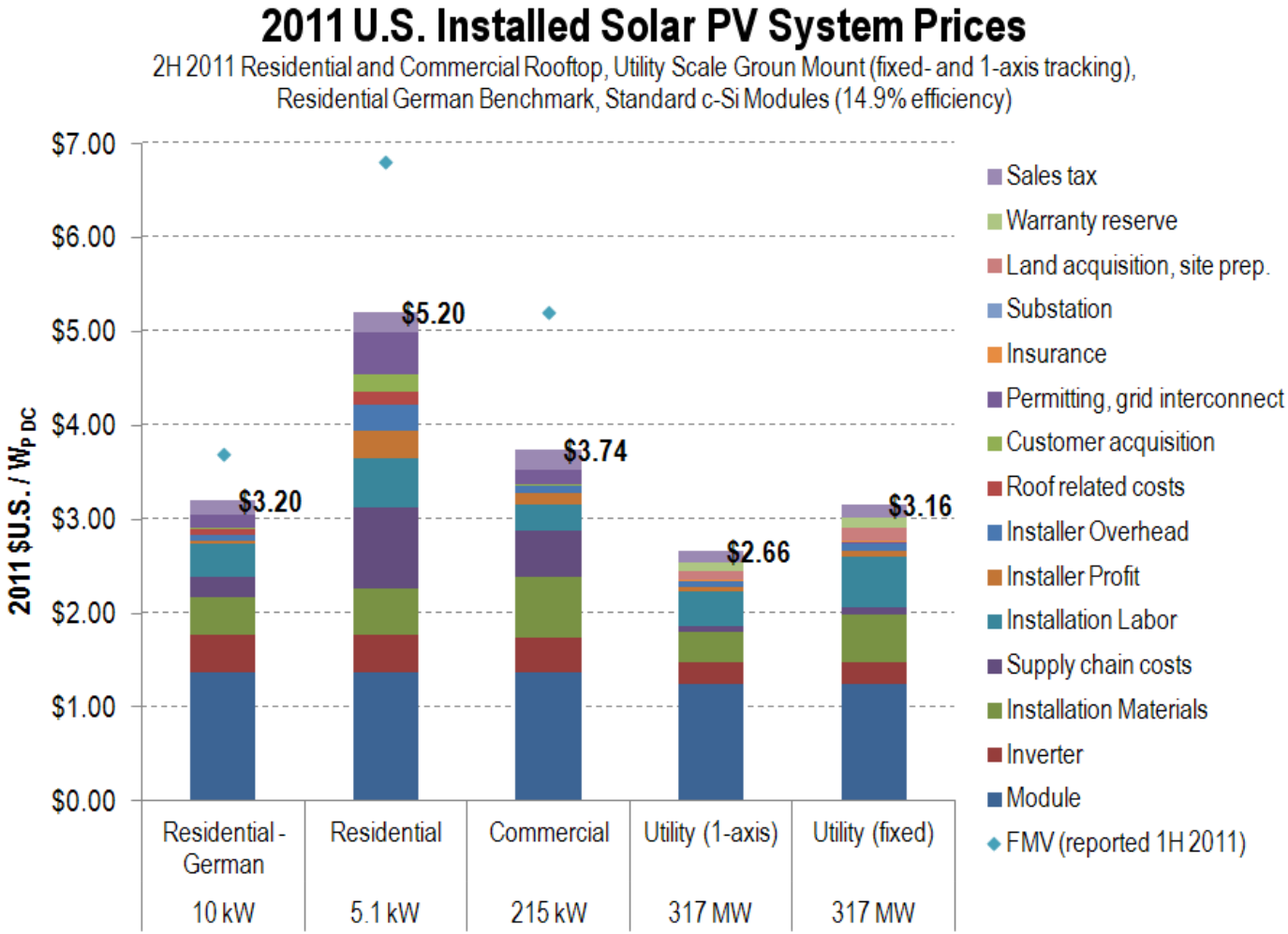


CSP



2011 Installed system prices

Excludes financing costs (cash purchase), without subsidy. Typical cost results based on national average labor rates.



- Calculated 2011 Residential Fair Market Value (FMV): $9.60/$W_{P\ DC}$

  5 kWP DC, California (per kWh rates: $0.16 retail, $0.27 PPA), 30% ITC grant, $0.95/kWh SCE rebate, 6.3% cost of capital (IRR)

Source NREL internal cost models.
(FMV reported 2011, partial year): Barbose et al (2011). "Tracking the Sun IV/" Lawrence Berkeley National Laboratory.

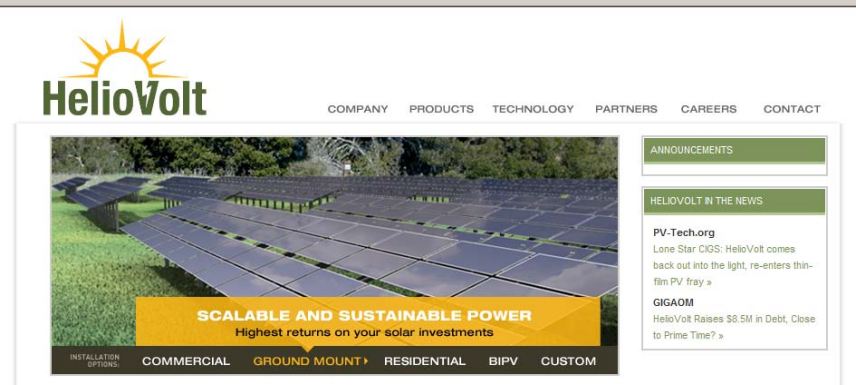
Market Relevant Process Innovation

"Black Silicon" Nanocatalytic Wet-Chemical Etch

2010 R&D 100

Flash Quantum Efficiency System

2011 R&D 100



Revolutionary CIGS thin-film manufacturing process using inkjet printing

HelioVolt

R&D 100 2008

Silicon Ink NREL Incubator Project

2011 R&D 100

innovation Impact: Partnering is Key


The Vision

Smart Grid/Grid Integration

Current U.S. Status

The Grid

- 30,000 transmission paths; >180K miles of transmission lines
- 14,000 transmission substations
- Distribution grid connects substations to over 100 million loads

Utility Sector

- 3,170 traditional electric utilities (239 investor-owned, 2,009 publicly owned, 912 consumer-owned rural cooperatives, and 10 Federal electric utilities)

NREL Research Thrusts

DG Interconnection Standards

- IEEE Standards Development
- Standards Testing and Validation

Smart-Grid Data Hub

RE Grid Integration

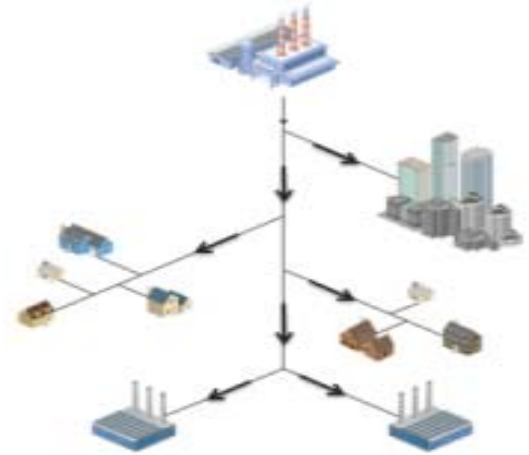
- Power Electronics for Interconnection monitoring and control
- Grid-to-vehicle interface

Artist Rendering of the Energy System Integration Facility

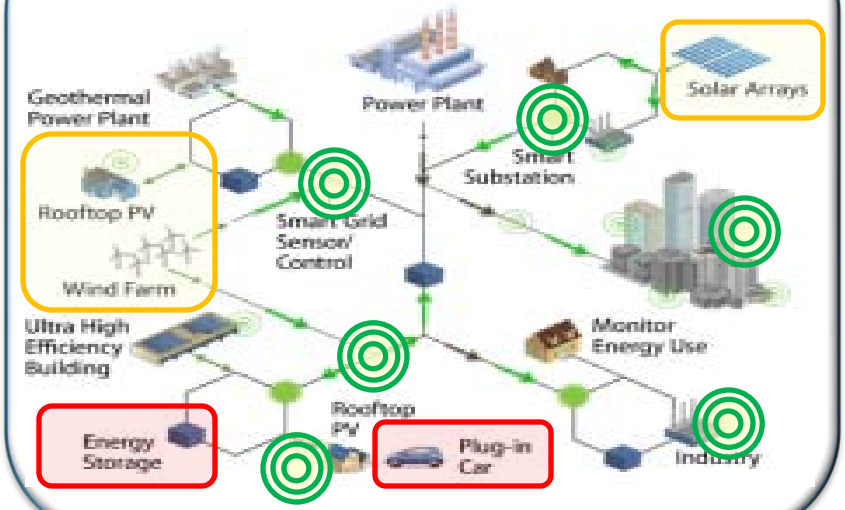
Updated 9/10

Why Energy Systems Integration?

Current Energy Systems



Future Energy Systems



New Challenges – Need to tackle difficult problems

- Increasing penetration of variable RE in grid
- New communications and control models
- Electrification of transportation
- New energy technologies and services integrating energy storage
- Increasing system flexibility
- Understanding interactions between electricity/thermal/fuels

NREL PV Grid Integration Activities

NREL is working with Utilities, System Integrators, Universities and other National Laboratories to help integrate higher levels of PV into the electric power grid

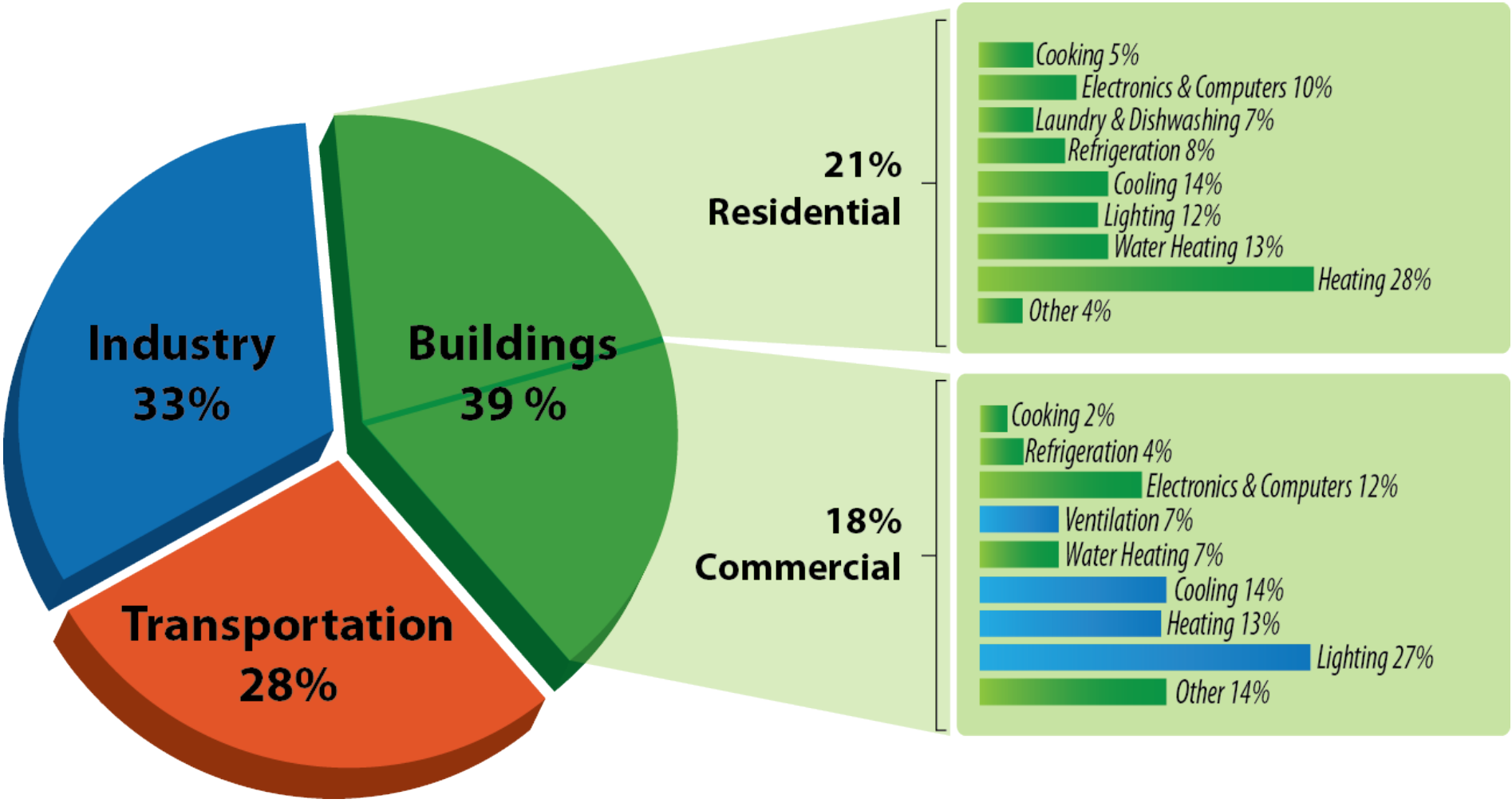
- **Distribution Integration**
  - Monitoring real-world high penetration cases
  - Developing and validating models and simulations
  - Updating integration approaches and standards
- **Transmission Integration**
  - Collecting and validating field data
  - Conducting operational analysis and optimization
  - Developing models for new technologies
  - Integrating into transmission expansion planning

Utility Partners

- Southern California Edison (SCE)
- Sacramento Municipal Utility District (SMUD)
- Xcel Energy (Colorado)
- CPS Energy (San Antonio)
- Arizona Public Service (APS)
- Kauai Island Electric Cooperative (KIUC)
- Maui Electric Company (MECO)
- FPL/NextEra
- Sempra Energy

NREL Research Support Facility: A glimpse into the future

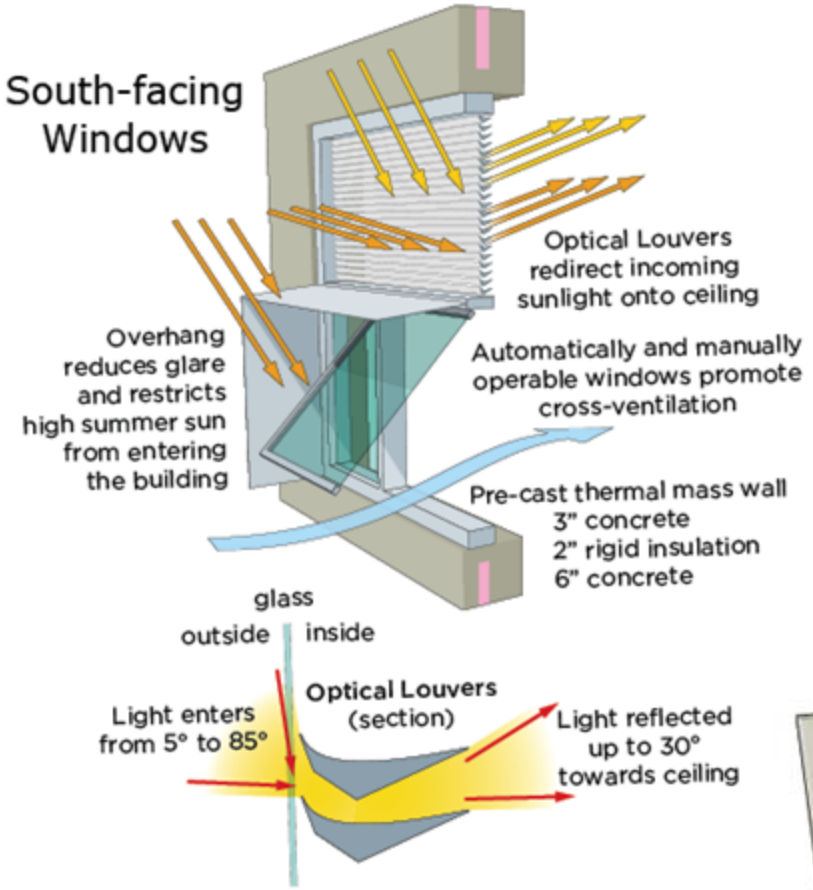
Energy Consumption in the U.S.

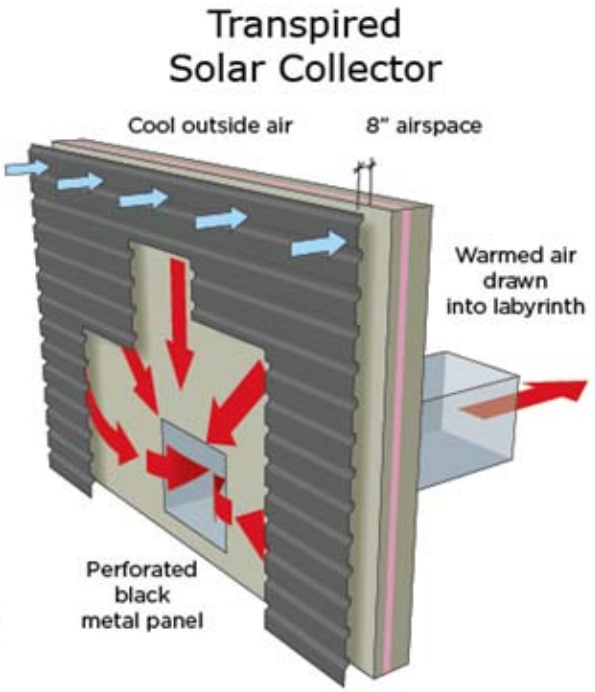


Source: Buildings Energy Data Book, 2006

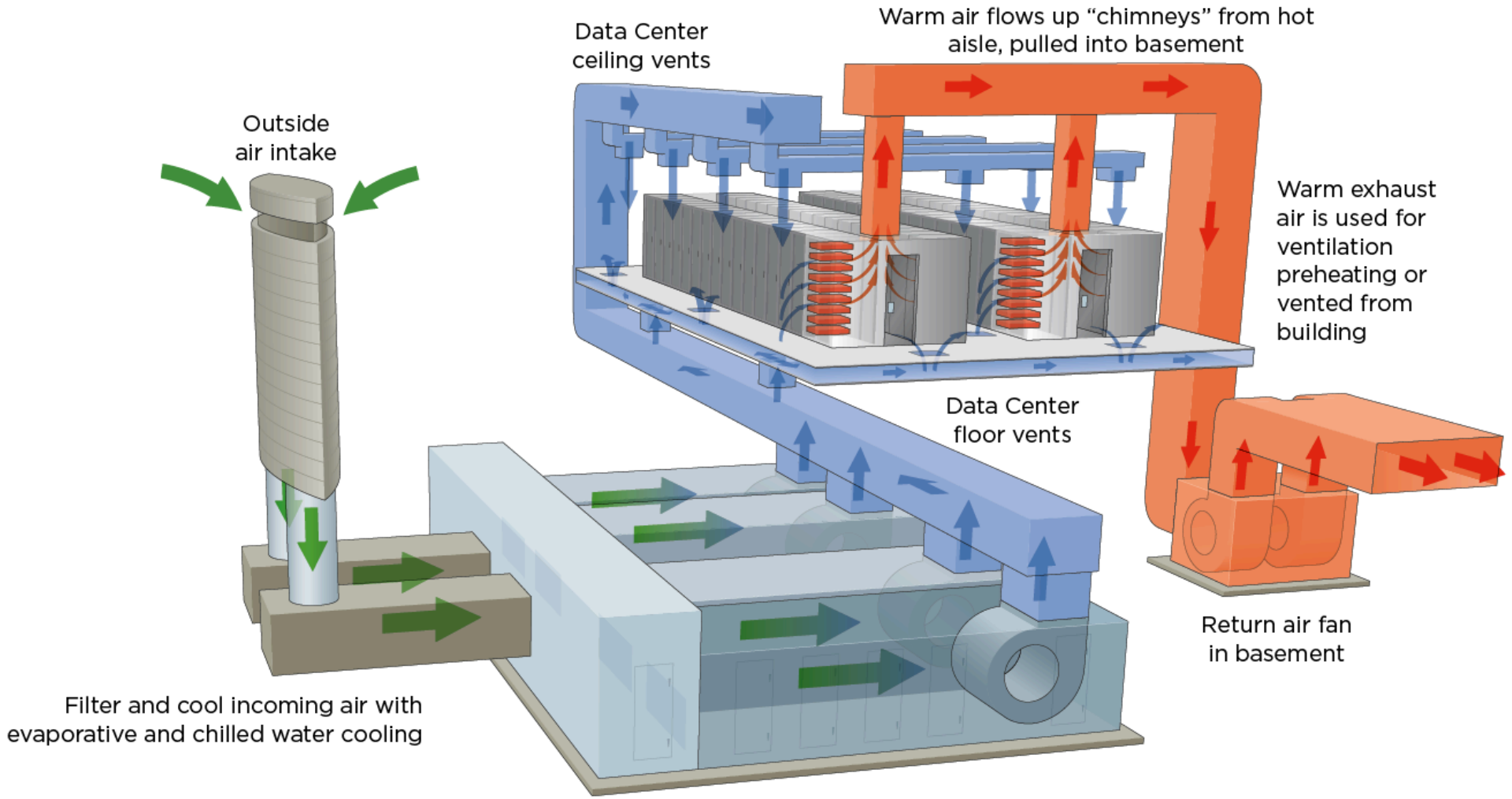
The Path to Net Zero

Energy Efficiency Features

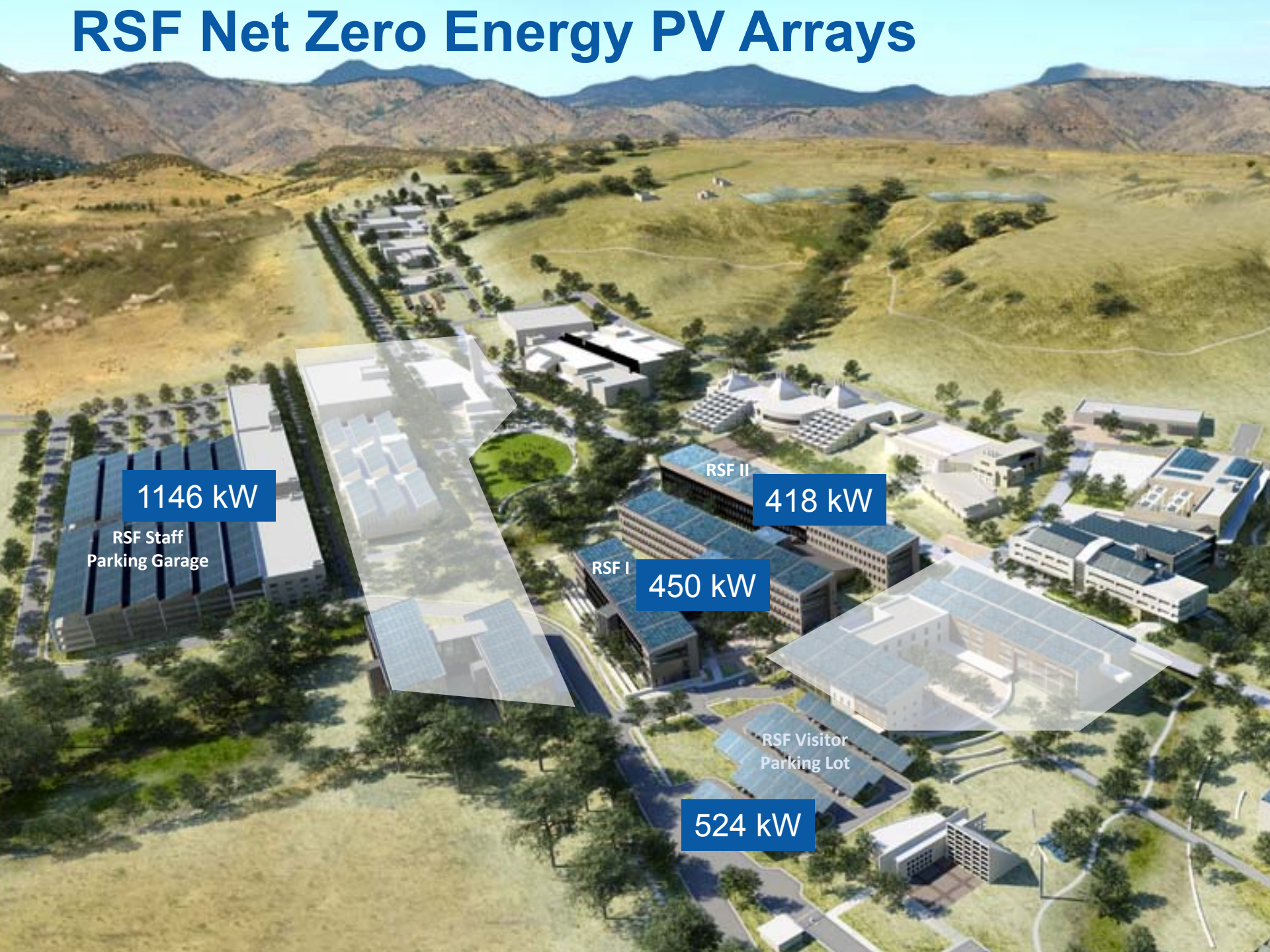




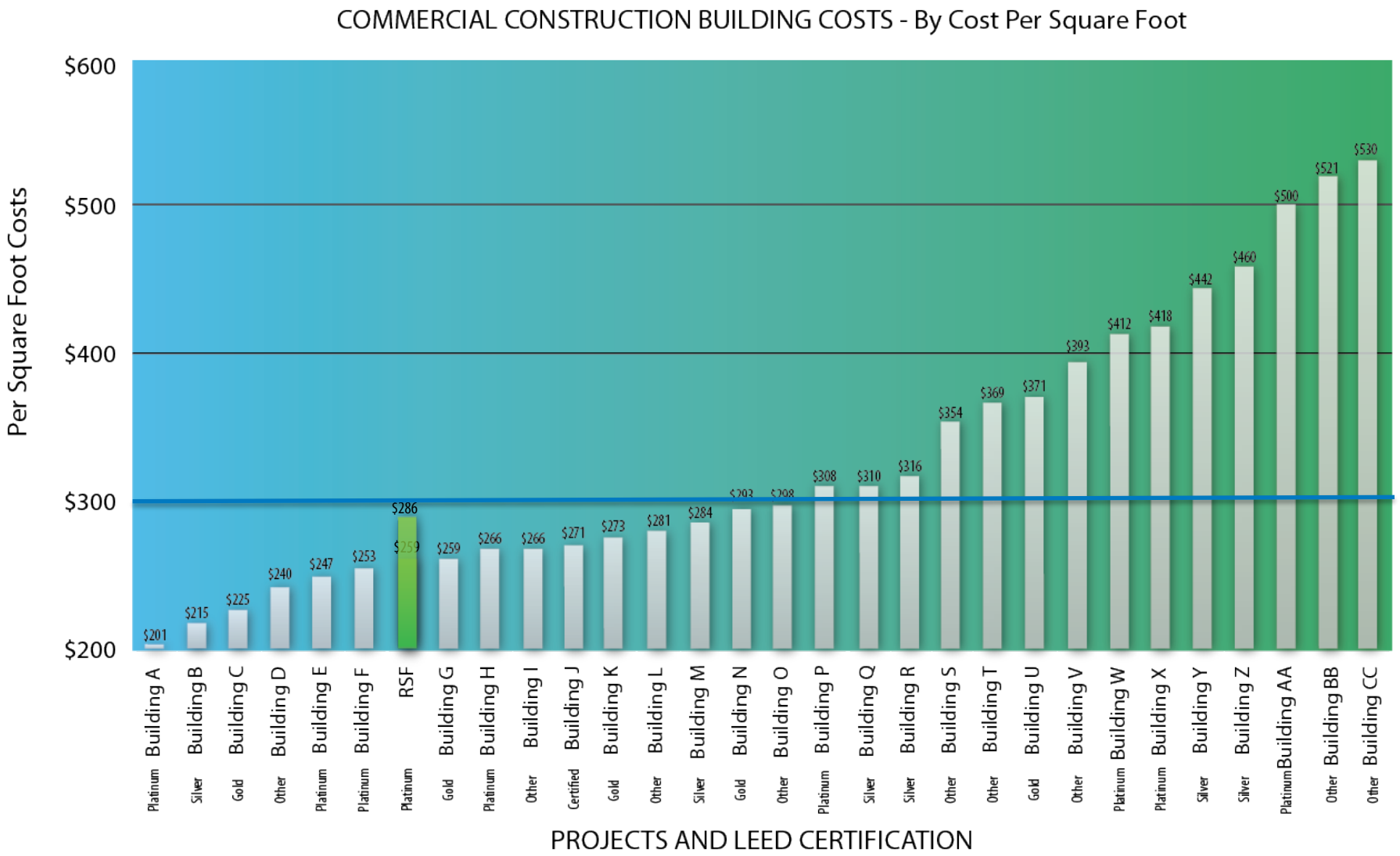
Green Data Center



RSF Net Zero Energy PV Arrays



Construction Costs



A glimpse into the future

If all commercial buildings operated in this fashion, the percent renewable energy contribution to the energy mix would be a game changer.

To achieve this vision, we must…

- Innovate
- Integrate
- Collaborate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