

Innovation for a Sustainable Energy Future: Renewable Energy's Role



World Renewable Energy Congress

**Dr. Dan E. Arvizu
Laboratory Director**

July 21, 2008

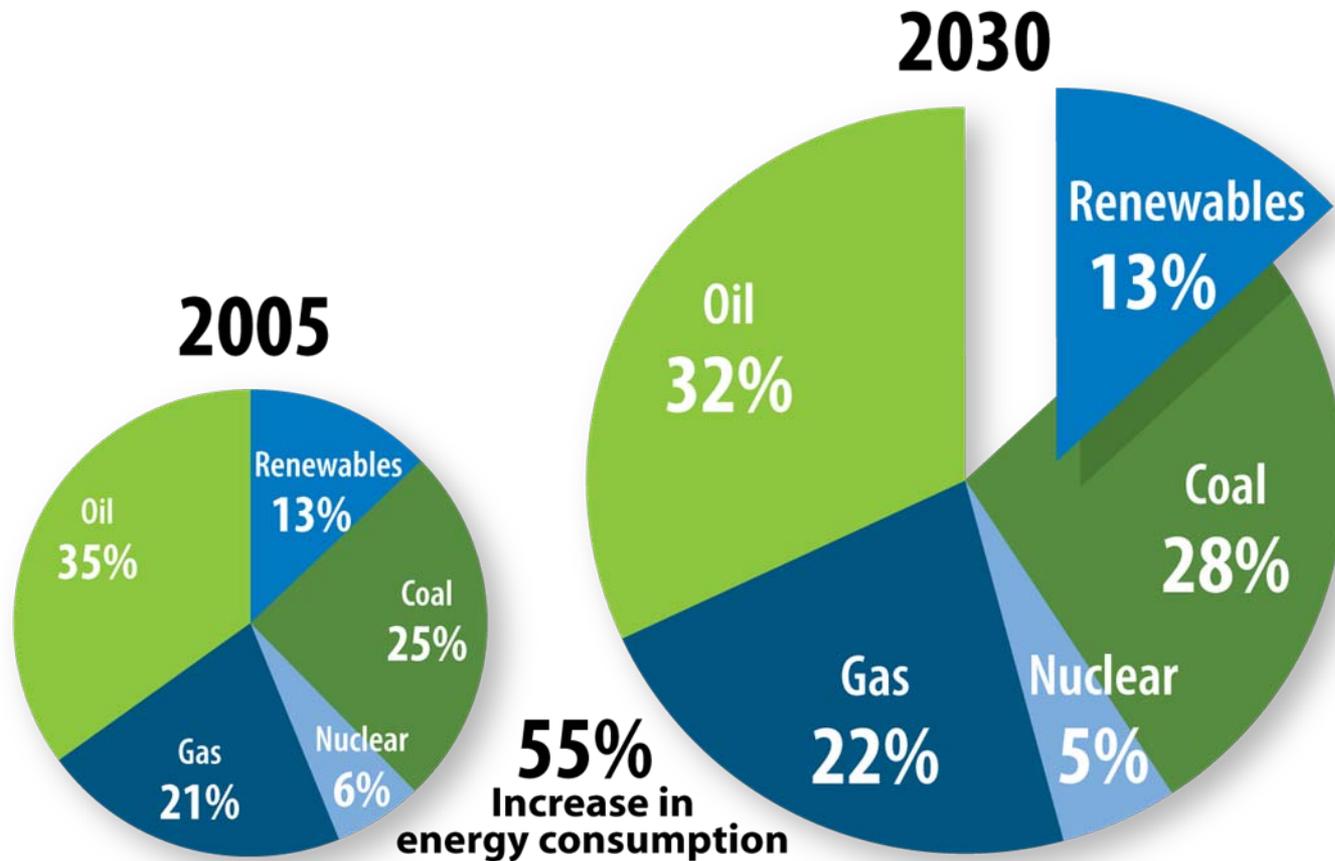
Mounting Evidence



Mounting Evidence



World Energy Supply and the Role of Renewable Energy



Source: IEA/OECD, World Energy Outlook 2007

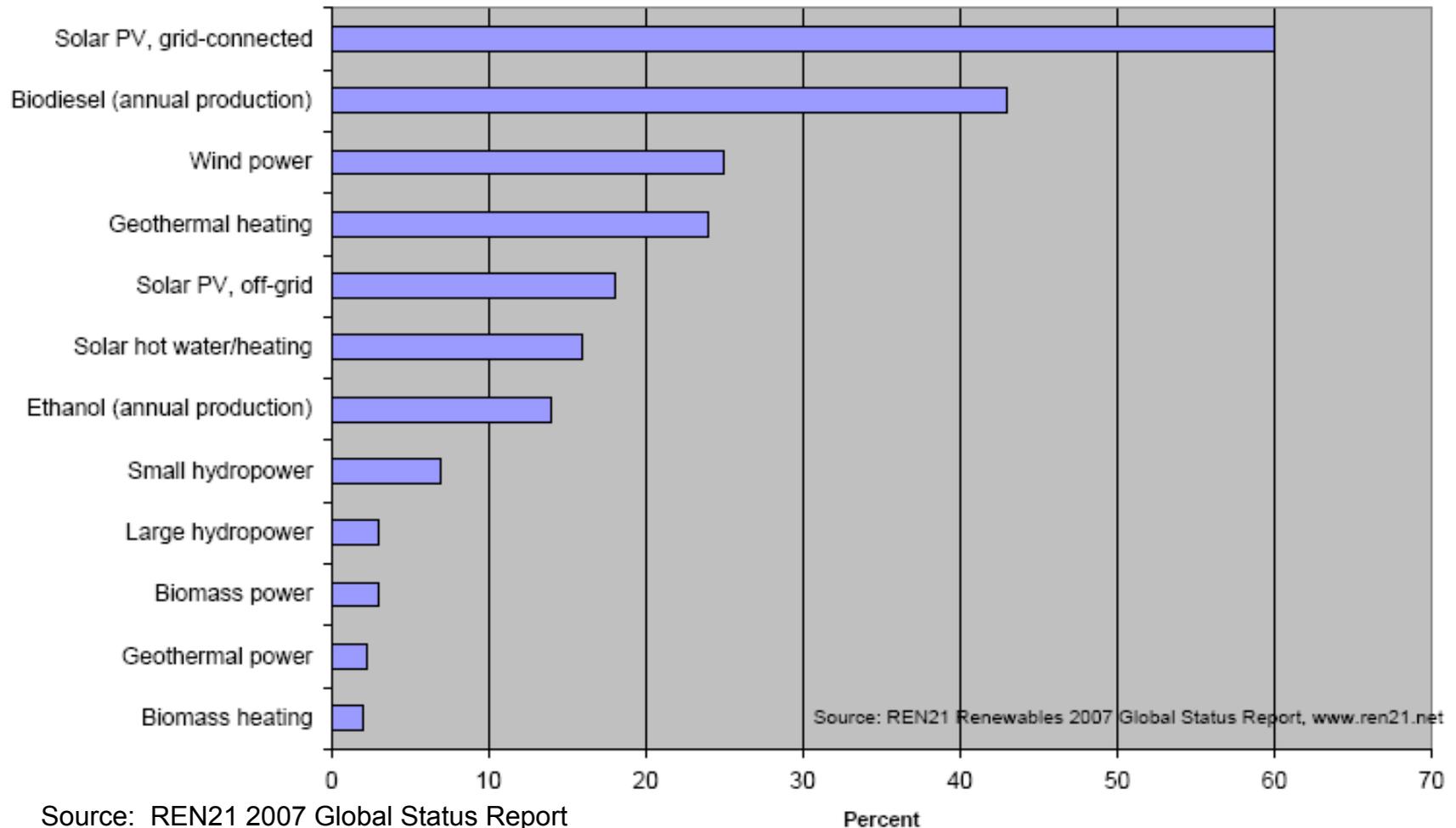
Table: Reference Scenario: World, p. 592

Global Indicators

Selected Indicators	2005	↗ 2006	↗ 2007 (estimated)
Investment in new renewable capacity (annual)	\$40	↗ 55	↗ 71 billion
Renewables power capacity (existing, excl. large hydro)	182	↗ 207	↗ 240 GW
Renewables power capacity (existing, incl. large hydro)	930	↗ 970	↗ 1,010 GW
Wind power capacity (existing)	59	↗ 74	↗ 95 GW
Grid-connected solar PV capacity (existing)	3.5	↗ 5.1	↗ 7.8 GW
Solar PV production (annual)	1.8	↗ 2.5	↗ 3.8 GW
Solar hot water capacity (existing)	88	↗ 105	↗ 128 GWth
Ethanol production (annual)	33	↗ 39	↗ 46 billion liters
Biodiesel production (annual)	3.9	↗ 6	↗ 8 billion liters
Countries with policy targets	52	↗	66
States/provinces/countries with feed-in policies	41	↗	46
States/provinces/countries with RPS policies	38	↗	44
States/provinces/countries with biofuels mandates	38	↗	53

Source: REN21 2007 Global Status Report

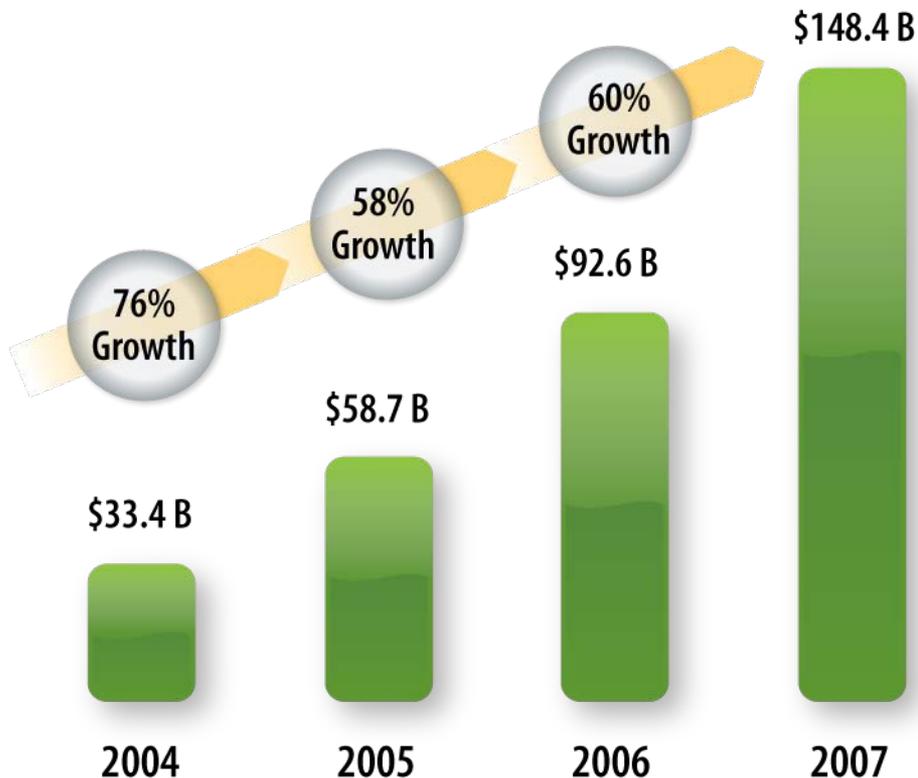
Average Annual Growth Rates of Renewable Energy Capacity, 2002-2006



Source: REN21 2007 Global Status Report

Percent

Global New Investment in Clean Energy



1% of global fixed asset investment

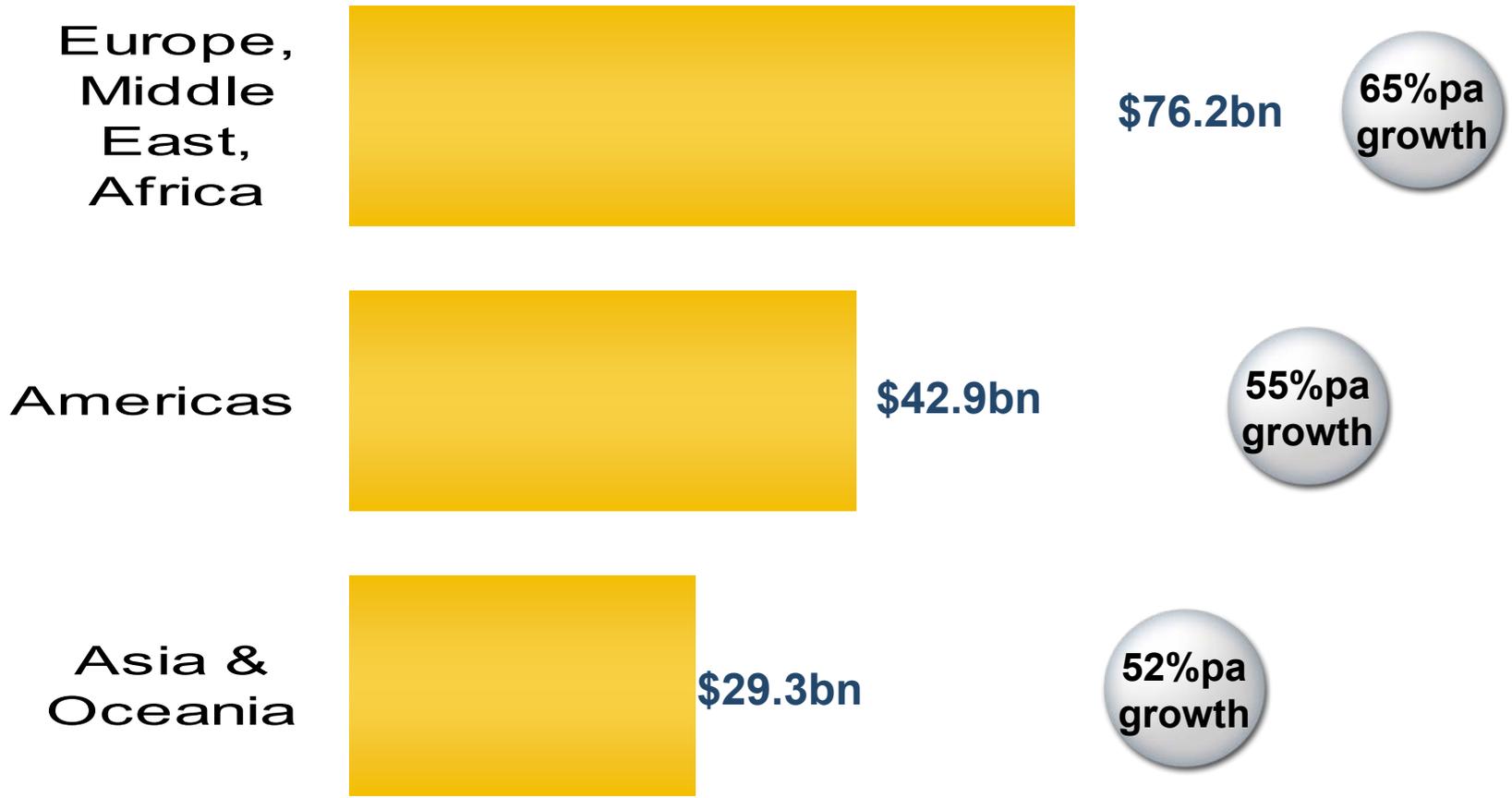
10.5% of global energy industry infrastructure investment

2.5 times the size of commercial aircraft investment sector

Adjusted for reinvestment. Geared re-investment assumes a 1 year lag between VC/PE/Public Markets funds raised and re-investment in projects.

Source: New Energy Finance, IMF WEO Database, IEA WEO 2007, Boeing 2006 Annual Report

New Investment 2007 and Average Growth 2005 to 2007 – By Region



Note: Excludes re-investment adjustment

Source: New Energy Finance

Technology Development Programs



Efficient Energy Use

- Vehicle Technologies
- Building Technologies
- Industrial Technologies



Renewable Resources

- Wind and water
- Solar
- Biomass
- Geothermal



Energy Delivery and Storage

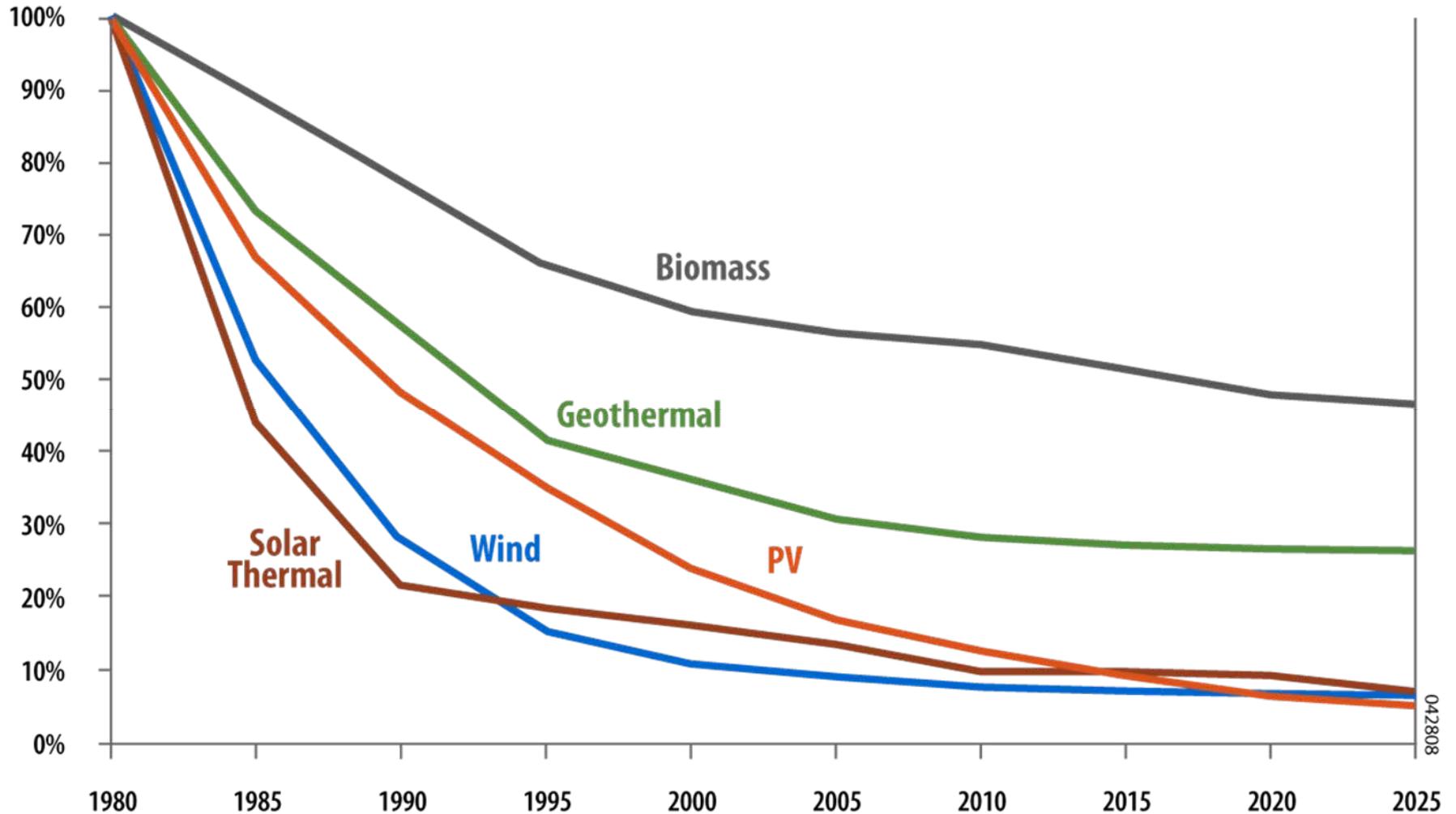
- Electricity Transmission and Distribution
- Alternative Fuels
- Hydrogen Delivery and Storage

Foundational Science and Advanced Analytics

Efficiency – Low Hanging Fruit

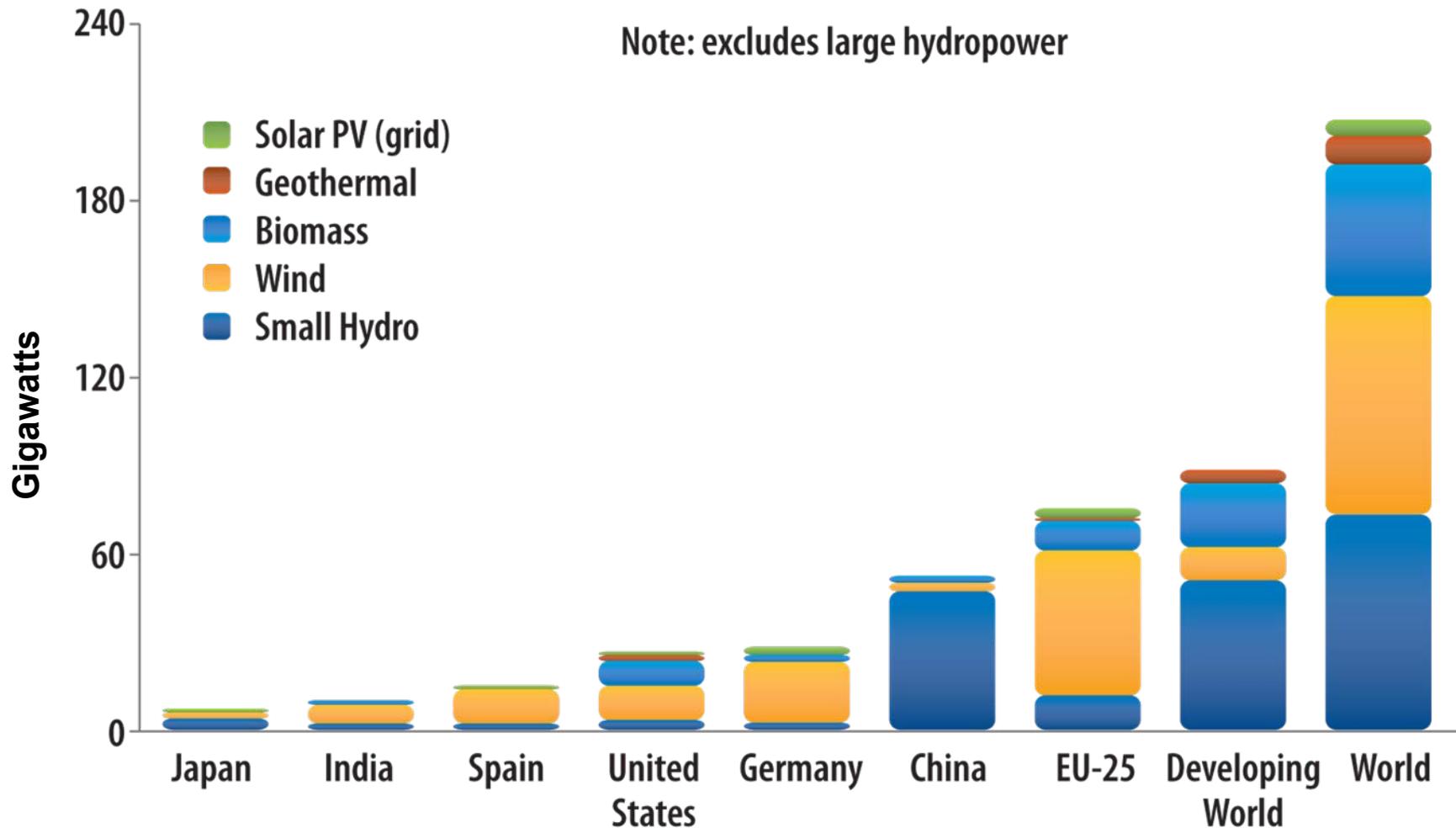


Past Investments Have Dramatically Reduced Costs of Renewable Supply Options



Global Renewable Electricity Capacity

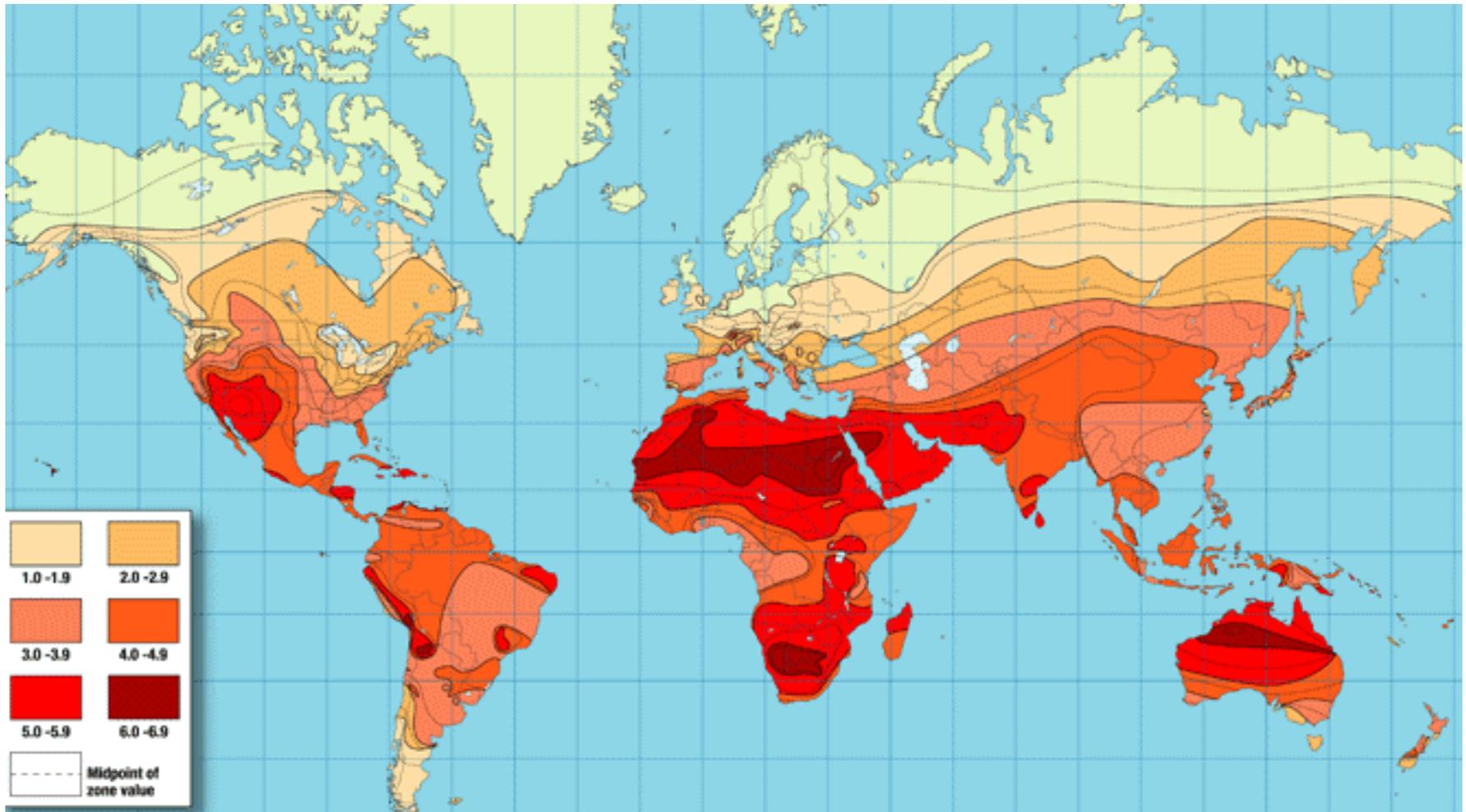
Developing World, EU, and Top Six Countries, 2006





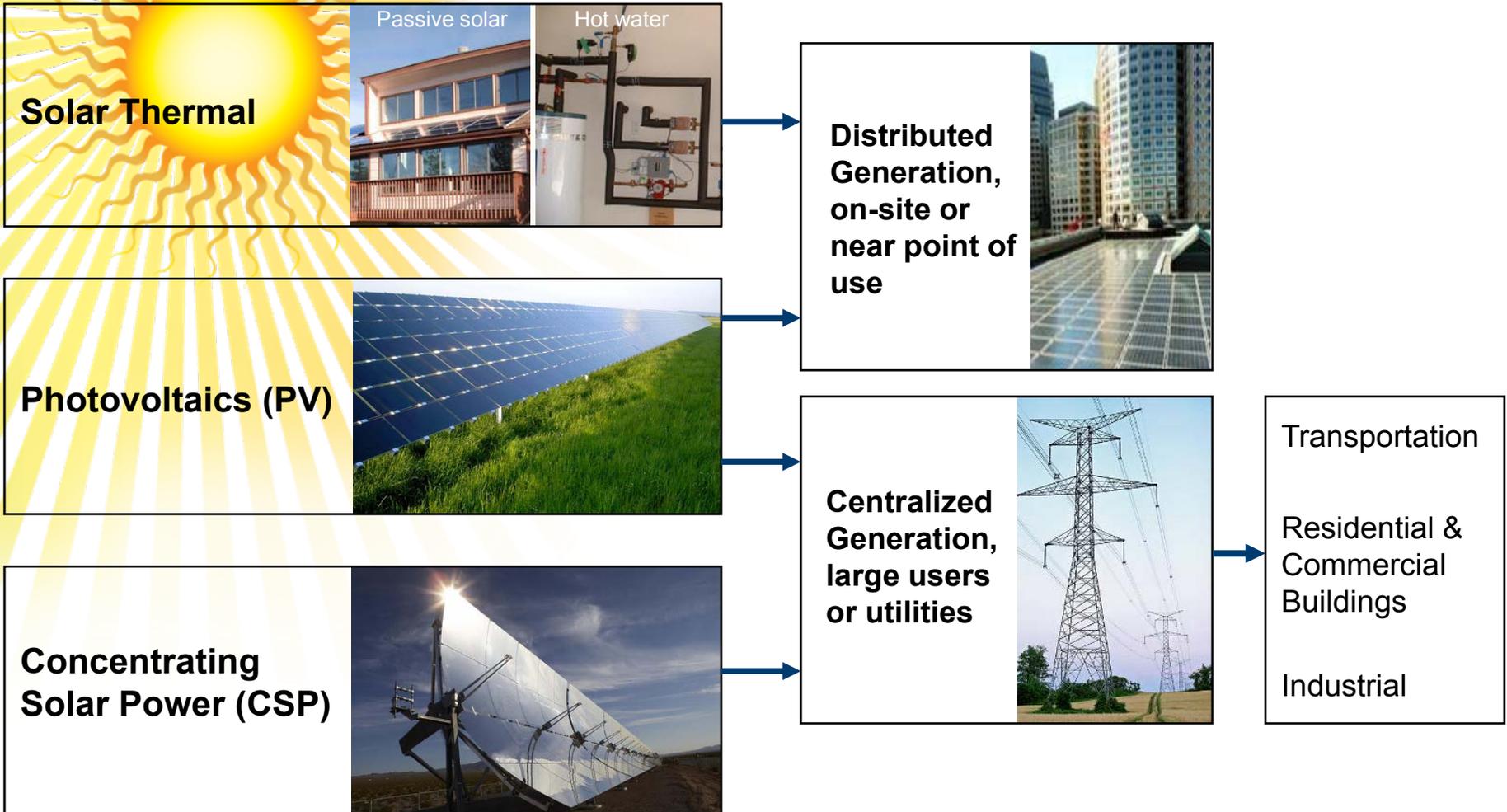
Solar Energy

Robust Global Solar Resource



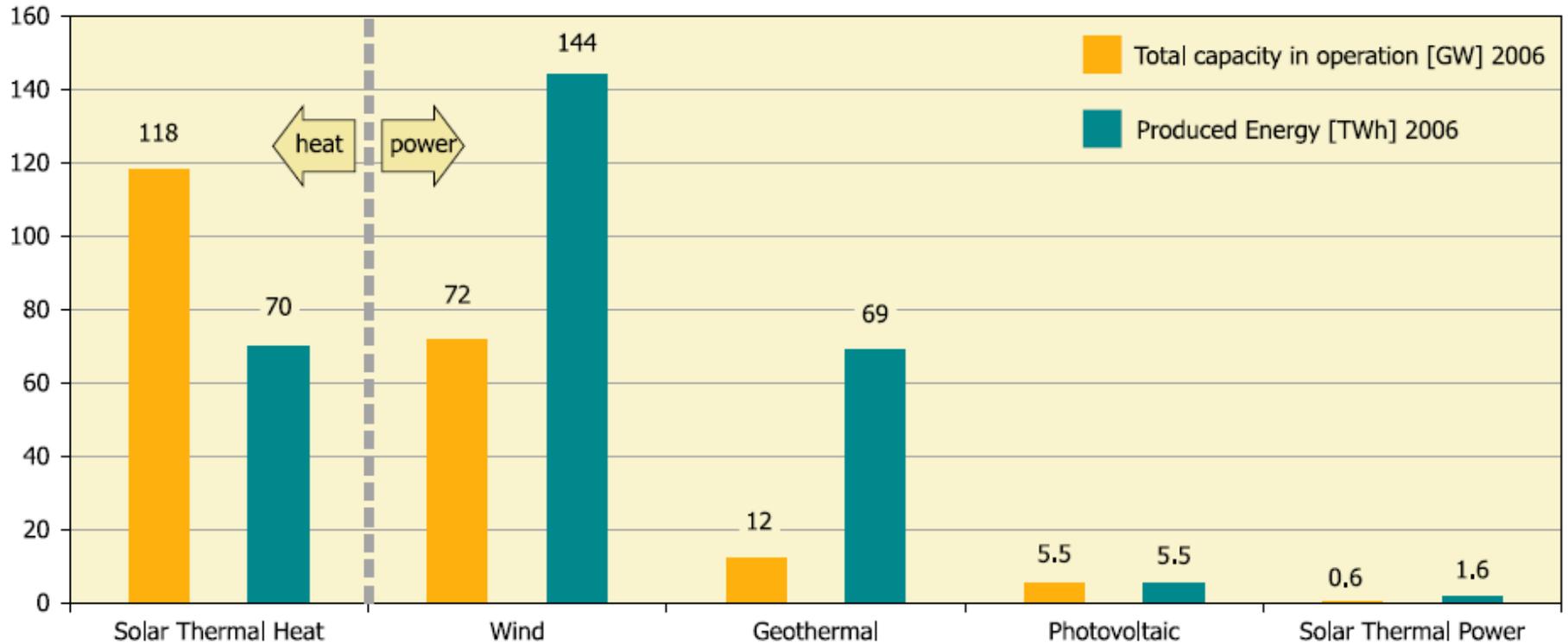
Source: <http://howto.altenergystore.com/Reference-Materials/Solar-Insolation-Map-World/a43/>

Applications of Solar Heat and Electricity



Heat & Power Worldwide

Total capacity in operation [GW_{el}], [GW_{th}] and produced energy [TWh_{el}], [TWh_{th}] 2006

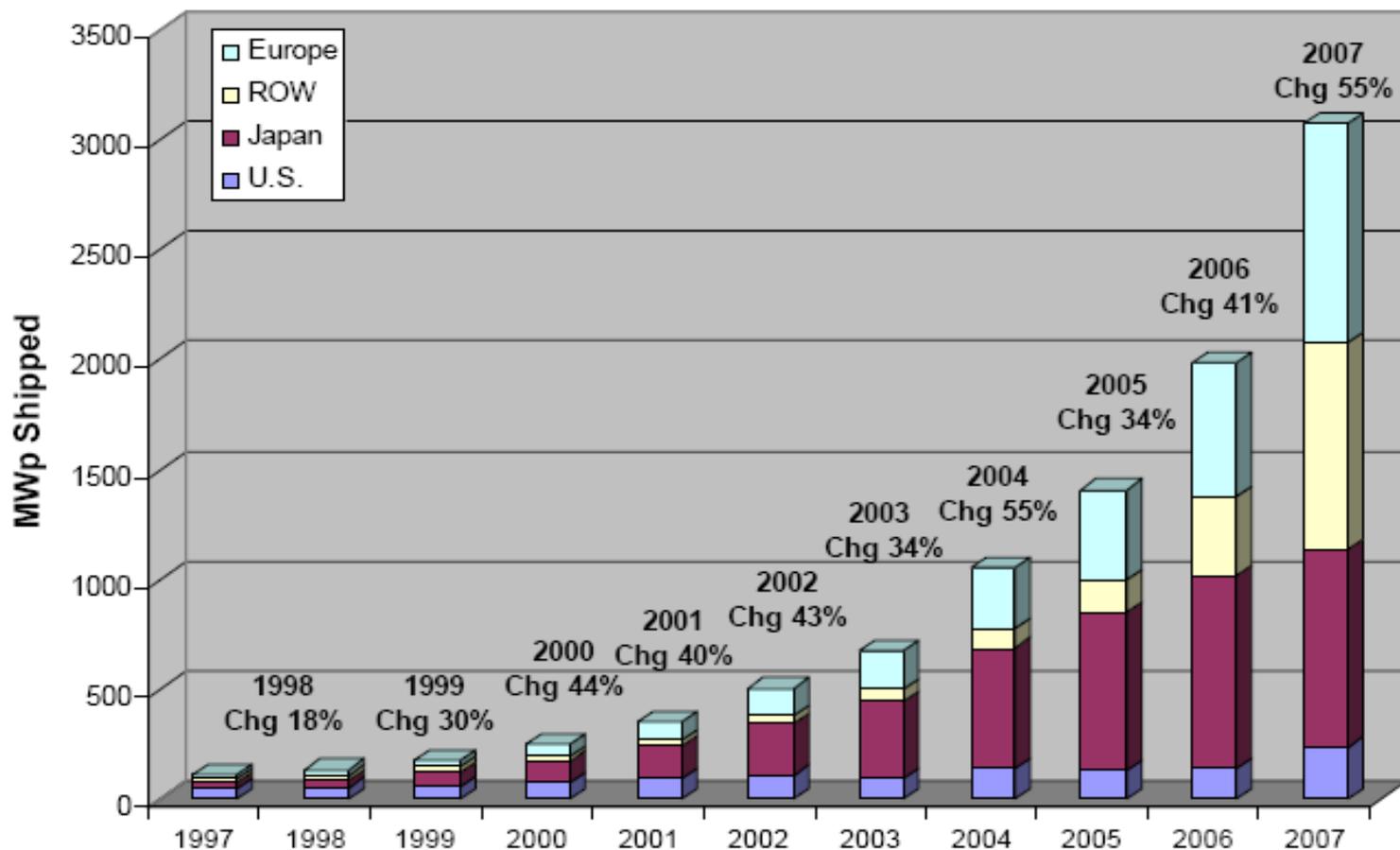


Total capacity in operation [GW_{el}], [GW_{th}] 2006 and annually energy generated [TWh_{el}], [TWh_{th}].

Sources: Fawer, M.: Sarasin Sustainability Report 2006 and IEA SHC, 2007.

World Wide PV Shipments

REGIONAL PV SHIPMENT GROWTH IN MWp
ANNUAL GROWTH BY REGION AND WORLD
1997-2007



PV Research Thrusts

- Higher performance cells/modules
- New nanomaterials applications
- Advanced manufacturing techniques

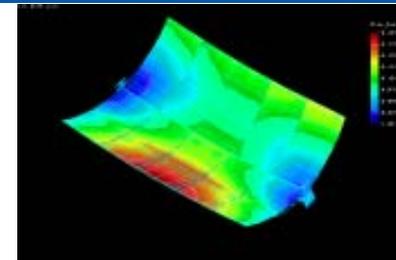


8.22-megawatt Alamosa, Colo., PV solar plant

Concentrating Solar Power Research

Parabolic Trough R&D

Optimize receiver and concentrator designs, develop next-generation collector design, and create advanced evaluation capabilities.



Thermal Storage R&D

Develop advanced heat transfer fluids for more efficient operation at high temperatures, and test innovative designs for low-cost storage options.



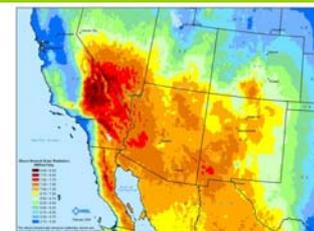
Advanced CSP Concepts

Next generation CSP systems and components



Technology Acceptance

Resource assessment, CSP penetration analysis, grid integration, land use



Focus on Key Barriers

Technology Cost and Performance

Technology Acceptance



Wind Energy

Source: Megavind Report *Denmark's future as leading centre of competence* within the field of wind power

Robust Global Wind Resource



Source: <http://howto.altenergystore.com/Reference-Materials/Solar-Insolation-Map-World/a43/>

Pacific Northwest National Laboratory

National Renewable Energy Laboratory

Innovation for Our Energy Future

International Market Drivers

- Europe and U.S.
 - High mandated purchase rates (85-90% of retail, 10-12 cents/kWh)
 - Strong government and public commitment to the environment, including climate change
 - Population density & existing developments driving off shore deployment in Europe
 - Production Tax Credit and state RPS programs driving U.S. market
- Developing World
 - Huge capacity needs
 - Lack of existing infrastructure (grid)
 - Pressure for sustainable development (IDB's, climate change)
 - Tied aid



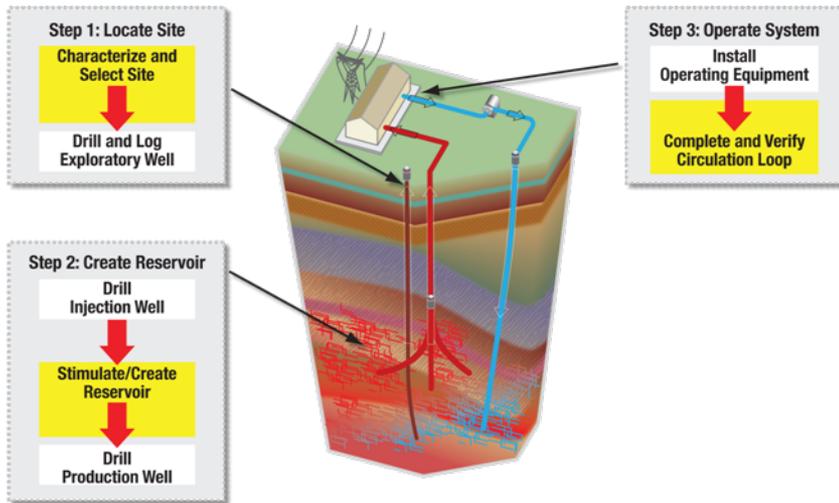
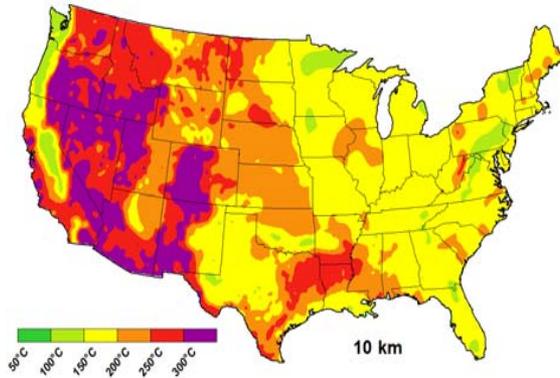
The European Research Agenda

Topic	Showstopper	Barrier	Bottleneck
Wind resource estimate and mapping	Availability of wind data in the public domain	Resource mapping of high wind sites that are yet unexplored	Cost-effective measurement units
Wind turbine technology	Robust, low maintenance offshore turbines with increased reliability	Design tools for turbines in extreme conditions – laboratories for accelerated testing of large components	Component level design tools and multiparameter control strategies
Wind farms	Storage systems at wind farm level	Wind flow in/around wind farms – control of wind farm – risk assessment methodology	-----
Grid integration	Initiatives for a Trans European grid with connection point for wind power plants	Control strategies and requirements for grid compatibility and to support and maintain a stable grid	Components and technologies for grid connection
Public support and the environment	Effects of large scale wind power on ecology; communication to public and policy makers	Monitoring of effects near wind farms Equipment to monitor e.g. bird collisions and sea mammals behavior	Exchange and communication of R&D results
Standards and certification	-----	Developments of new standards on energy yield calculation, grid connection, risk assessment, design criteria, O&M standardization	Accelerated finalization of ongoing standards

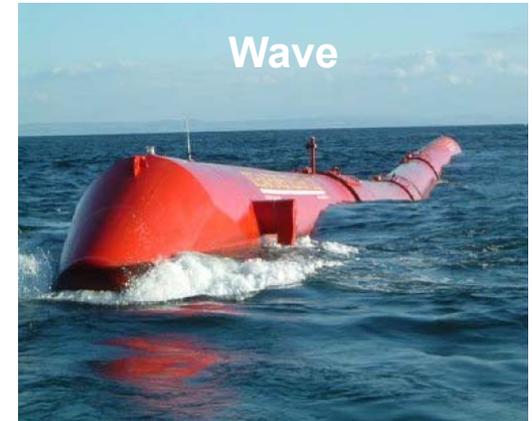
Source: Professor Arthouros Zervos, National Technical University of Athens, President European Wind Energy Association

Evaluating Potential New Directions

Enhanced Geothermal Systems



Ocean Kinetic Energy



Tidal



Pelamis—Ocean Power Delivery

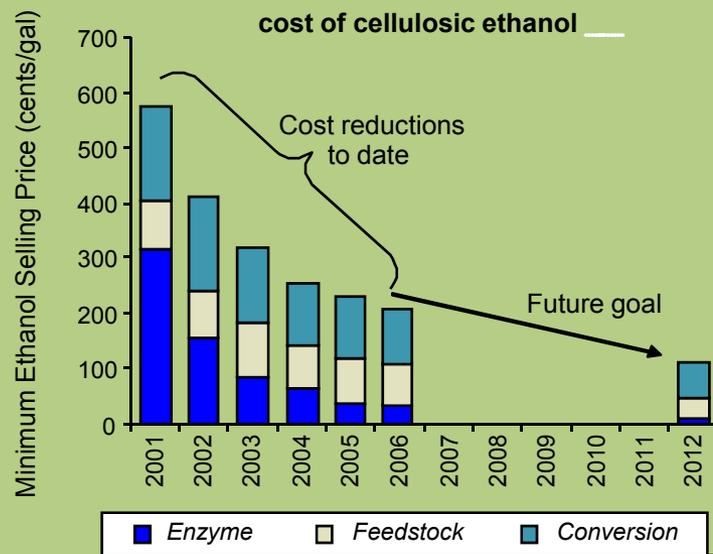
Verdant—Power RITE Turbine



Bioenergy

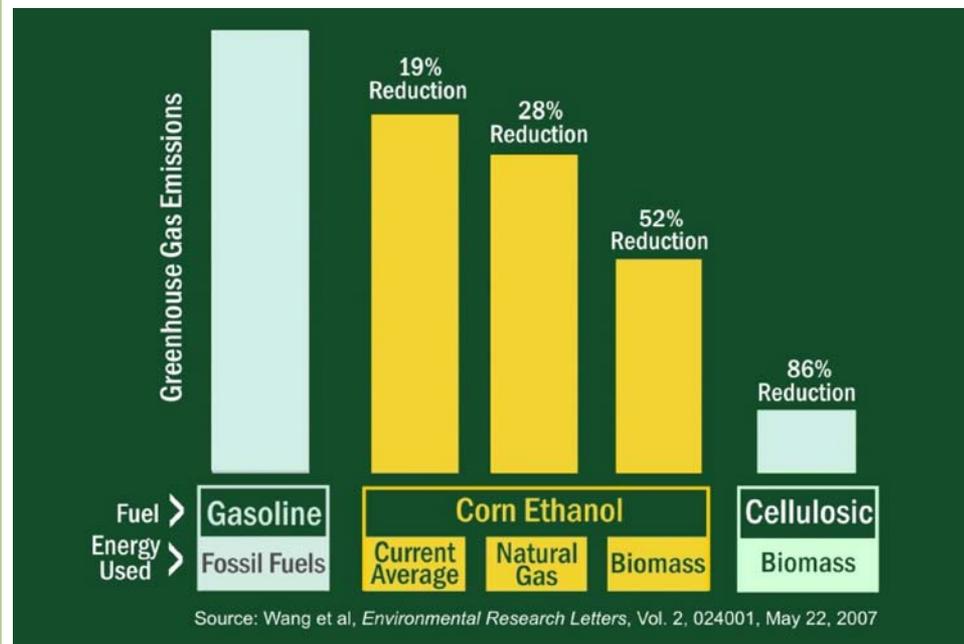
Biofuels Cost and Environmental Potential

Historical and Projected Cellulosic Ethanol Costs

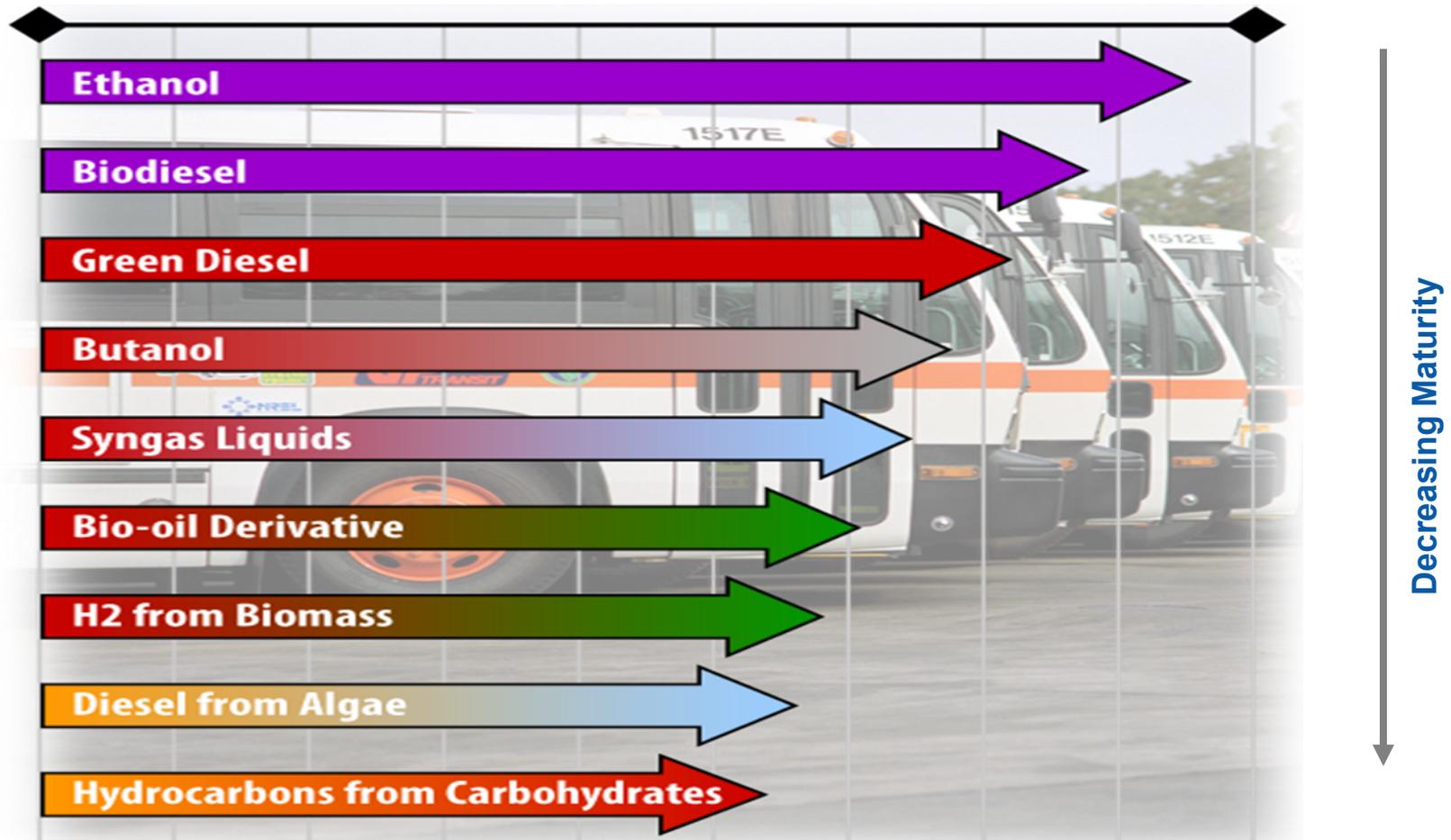


Source: Research Advances: NREL Leads the way: Cellulosic Ethanol. March, 2007. Figures are for biochemical conversion

Federal research has achieved major reductions in the cost of cellulosic ethanol



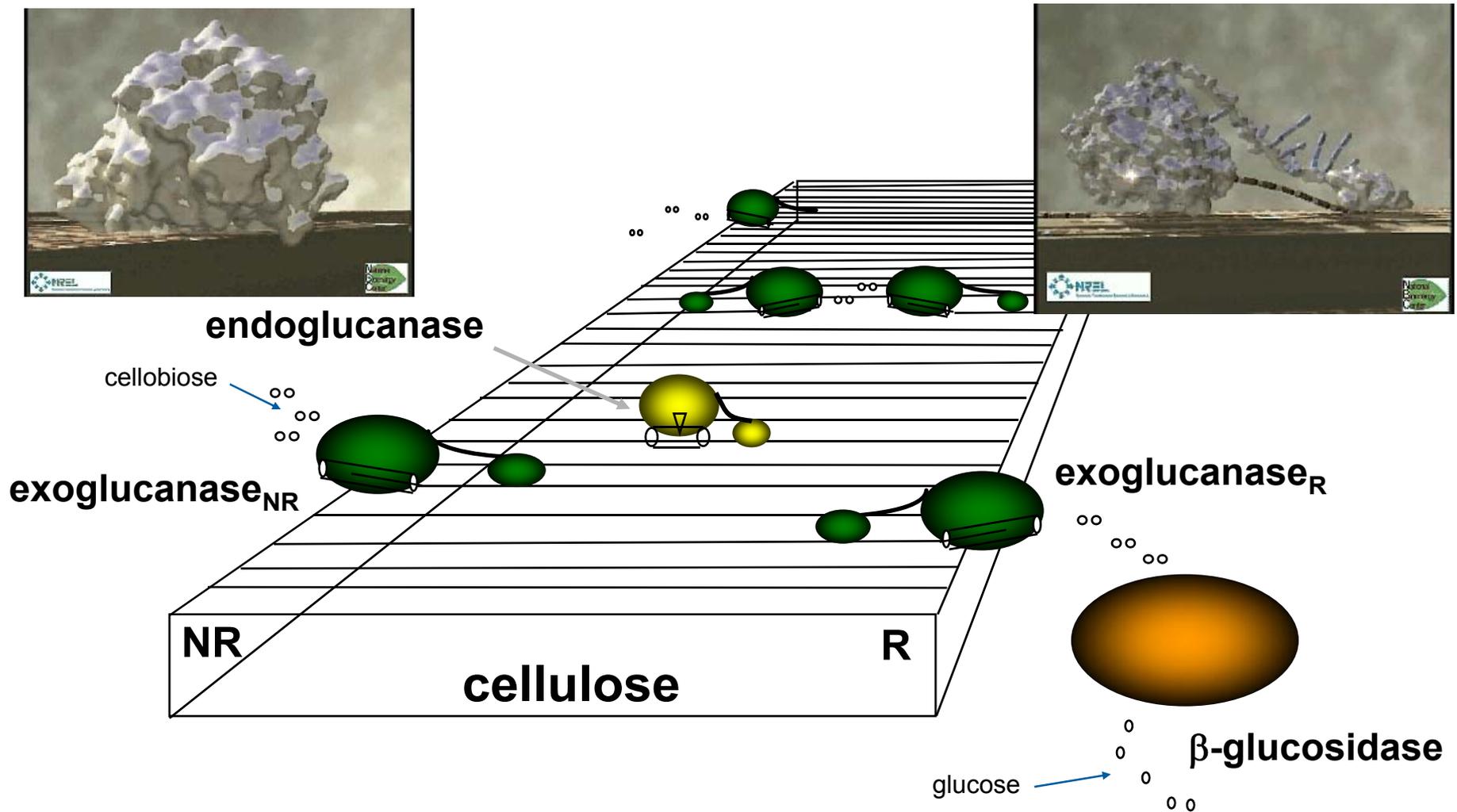
Range of Biofuels Pathways & Technology Maturity



Organizations Leading the R&D



Action of Fungal Cellulases



NREL International Renewable Fuels Collaborations

- 
- **China**
 - Biofuels Technoeconomic and Life Cycle Assessments
 - Discussing a Researcher Exchange program
 - **India**
 - Biofuels Roadmap development
 - **Brazil**
 - Biofuels Life Cycle Assessment
 - **Sweden**
 - Biomass Thermochemical Conversion
 - **International Energy Agency**
 - Participation in 4 biofuels implementing agreements
 - Hydrogen HyWays study

Resource, Technology, and Market Information

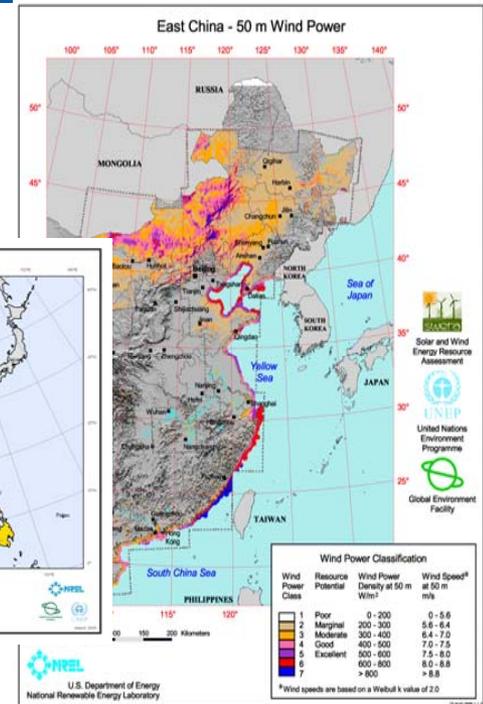
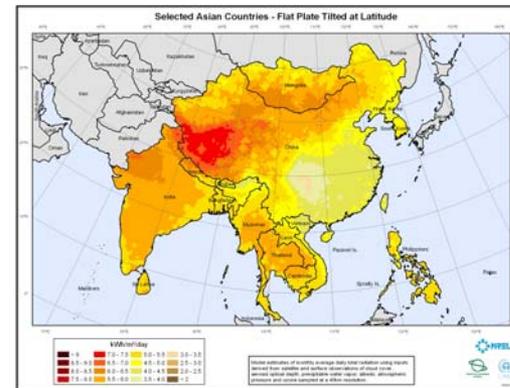
Objective: Provide highest-quality and timely data to inform RE project decisions and policy analysis.

Activity Examples:

Wind, solar and biomass resource mapping in the United States and key international markets

Targeted R&D collaboration through the IEA and bilateral programs

Biofuels, wind, solar, buildings, and other technology collaboration with European Union countries, Brazil, China, India, and others



Resource, Technology, and Market Information resource maps, supply potential, technology cost and performance data, R&D collaboration, as foundation for project conceptualization and policy planning

Future Strategic Drivers



Global Context

Attributes of a Future Energy System

- Carbon neutral
- Highly integrated/convergence to electrons
- Globalization of markets/distributed systems
- Strong Demand for Technology Solutions

Opportunities for Disruptive Technologies and Entrepreneurial companies

Our Partner Needs

- Speed
- Rapid capital growth
- Flexibility
- Innovation
- Sustainable competitive advantages



Promise of renewable energy is profound and can be realized if we...

- 
- Aggressively seek a global sustainable energy economy
 - Accelerate investment in technology innovation
 - Acknowledge and mitigate the carbon challenge with the necessary policies

It is a matter of international will and leadership



NREL

National Renewable Energy Laboratory

Innovation for Our Energy Future



Visit us online at www.nrel.gov

Operated for the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy by Midwest Research Institute • Battelle