INTERNATIONAL SEMATECH ISMI MANUFACTURING INITIATIVE ESH Technology Center

Accelerating Sustainable Manufacturing

The Feasibility of Alternative and Renewable Energy in the Semiconductor Industry

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Outline

- Technologies
- Survey of ISMI member companies
- Economic comparisons of power generating technologies
- Incentives
- Member company site economic analysis
- Other renewable energy options (green power, RECs)
- Conclusions/What's next?

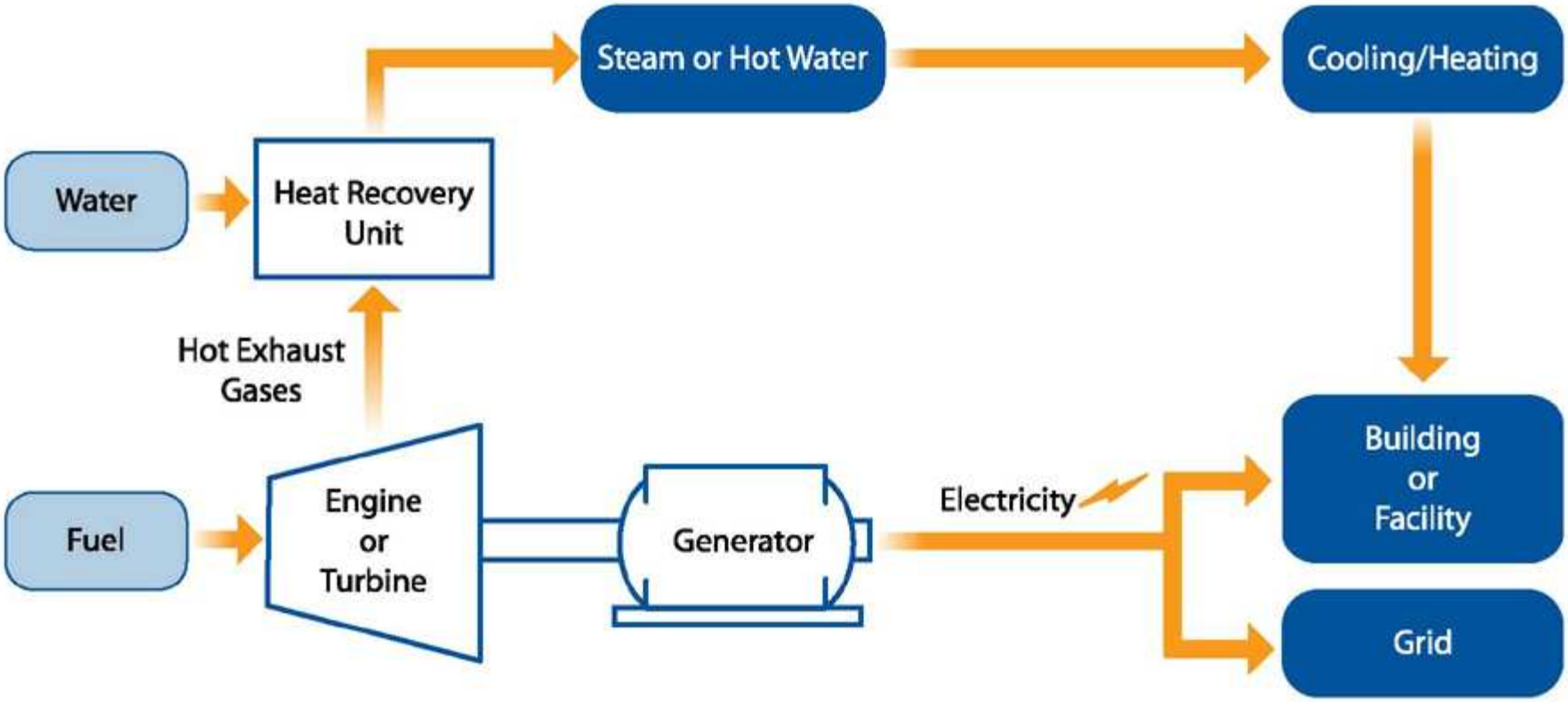
Alternative Technologies

- More fuel-efficient, less polluting than conventional technologies
- Can operate on natural gas, biomass, liquid fuels, coal, and hydrogen
- Investigated combined heat and power (CHP) and fuel cell technologies

Combined Heat and Power

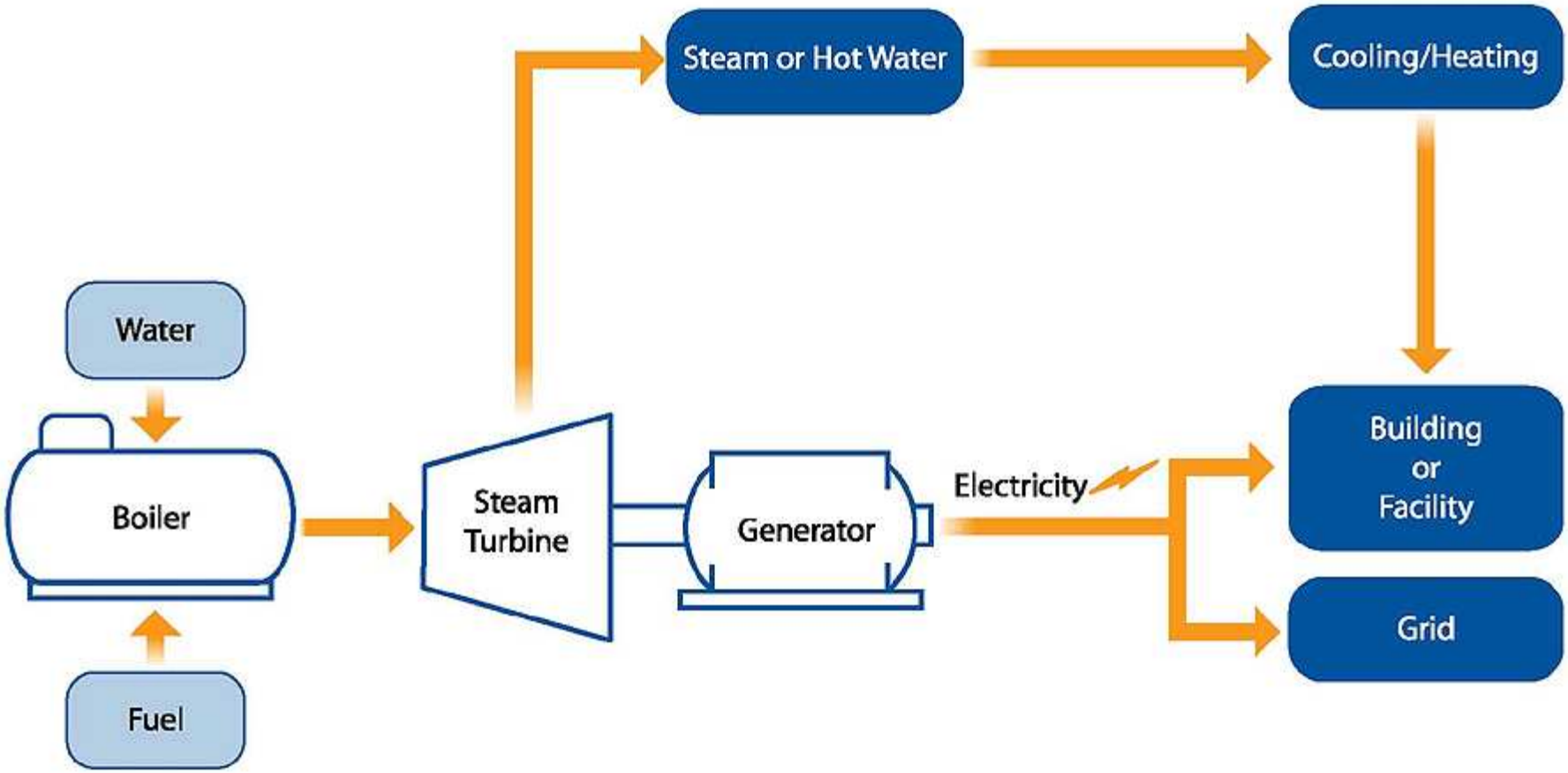
- Cogeneration - electricity and heat from power plant
- Trigeneration - electricity, heat, and chilled water from power plant
- Generation cost tied directly to energy prices
- Both are proven technologies used by several member companies
- System sizes of 1 to 50 MW

CHP - Gas Turbine or Engine With Heat Recovery Unit



Source: EPA Combined Heat and Power Partnership Program

CHP - Steam Boiler With Steam Turbine



Source: EPA Combined Heat and Power Partnership Program

Absorption Chiller

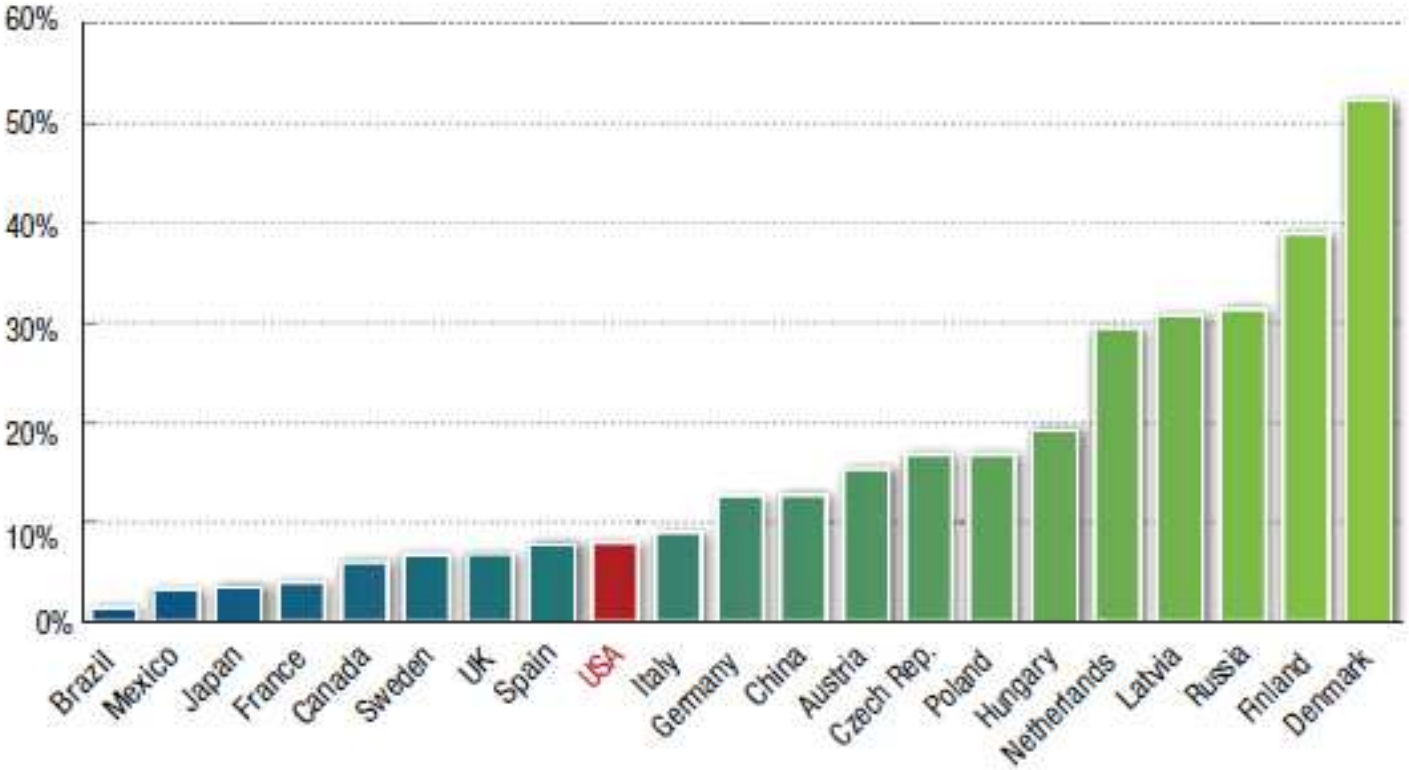
- Uses waste heat to generate chilled water

Source: Johnson Controls, Inc. - Used with permission.

Historical CHP Capacity and Growth Needed to Achieve 20% of Generation

Source: Combined Heat and Power – Effective Energy Solutions for a Sustainable Future, © U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy Industrial Technologies Program, 2008.

CHP Share of Total National Power Production



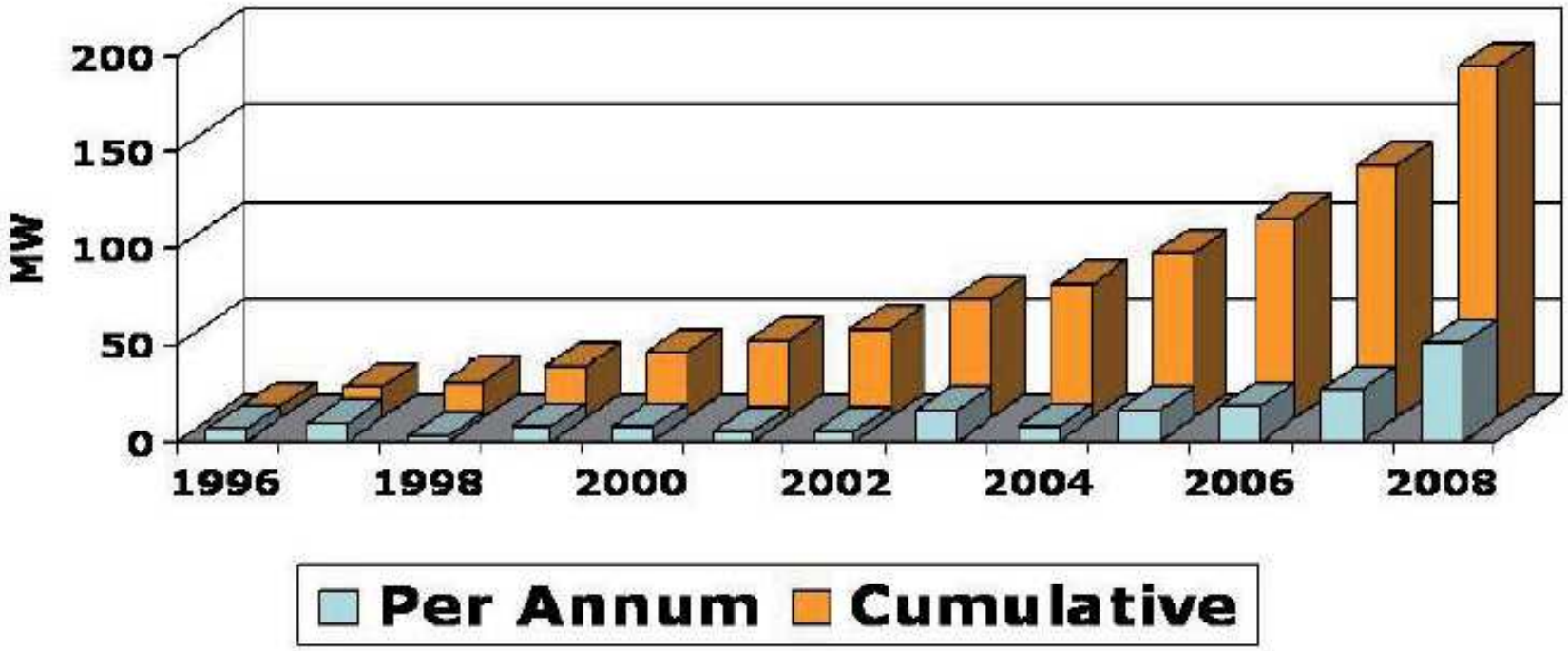
Source: Combined Heat and Power: Evaluating the benefits of greater global investment © Organisation for Economic Co-operation and Development/International Energy Agency, 2008.

Fuel Cells

- Electricity and heat from hydrogen or methane from fossil or renewable sources, e.g., anaerobic digesters or landfills
- Very efficient, low emissions
- Proven, but expensive technology
- Cost varies with energy prices
- Readily installed at member company sites
- System sizes of 10 kW to 5+ MW

Photo Courtesy of U.S. Department of Energy/National Renewable Energy Laboratory; Credit: City of Tulare, 2008.

World Annual and Cumulative Fuel Cell MWe Installed



Source: Large Stationary Survey, 2008 © Fuel Cell Today, 2008.

Renewable Technologies

- Non-polluting
- No fuel cost
- Success depends on location
- Investigated
  - Solar photovoltaic (PV)
  - Concentrating solar power (CSP)
  - Solar thermal (hot water)
  - Wind
  - Biomass
  - Geothermal
  - Hydrokinetic

Solar Photovoltaic

- Multiple types types
  - Silicon substrate (Si)
  - Thin film (TF)
  - Concentrating solar cells – relatively new
- Si and TF are proven technologies, enjoying rapid efficiency improvements and generous incentives
- Readily installed at member company sites
- System sizes 1 kW to 100+ MW

Photo Courtesy of 1house at a time, 2008.

Photo Courtesy of U.S. DOE/NREL; Credit: Beck Energy, 2005

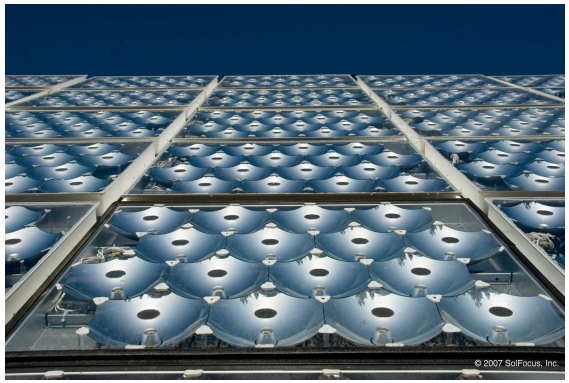
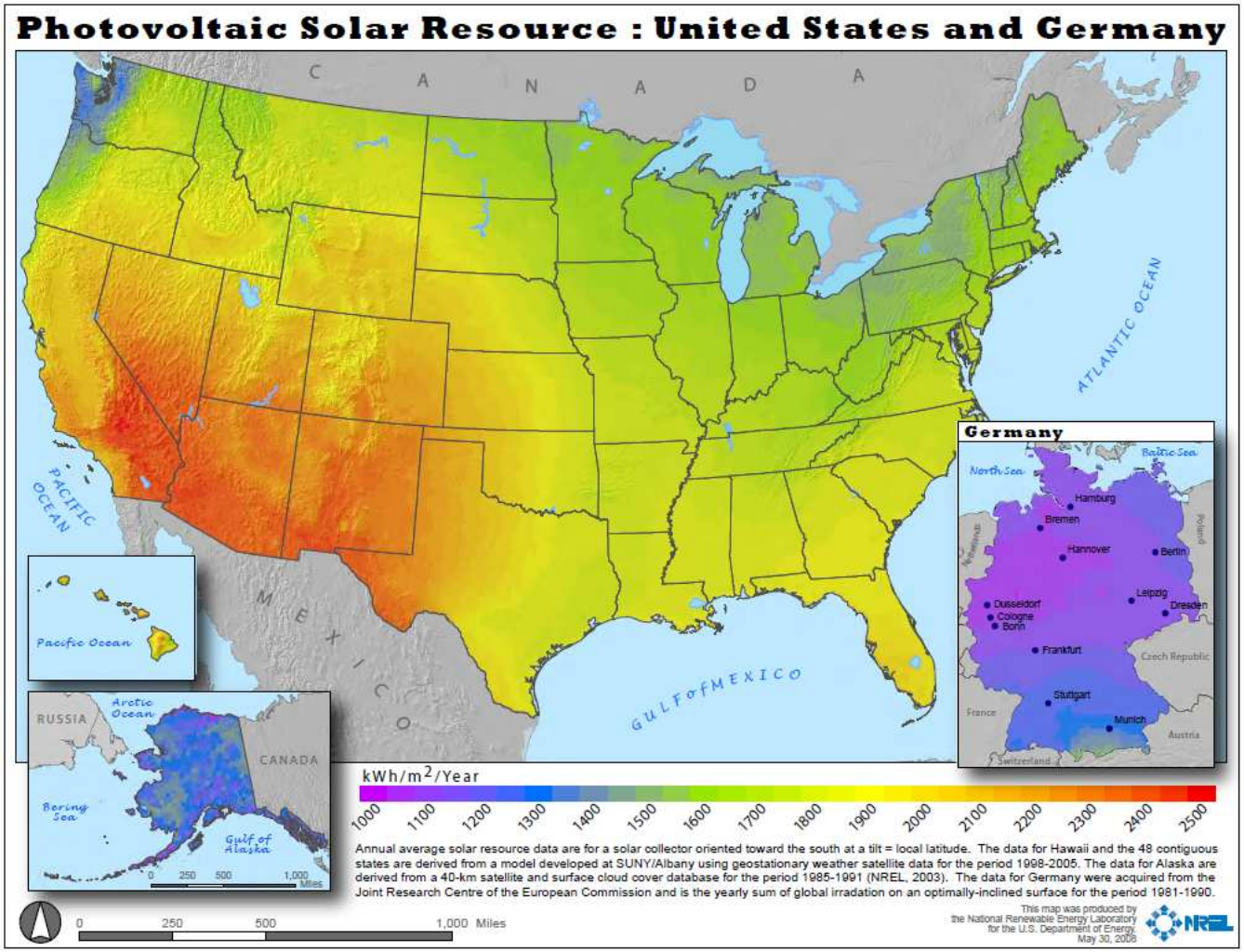


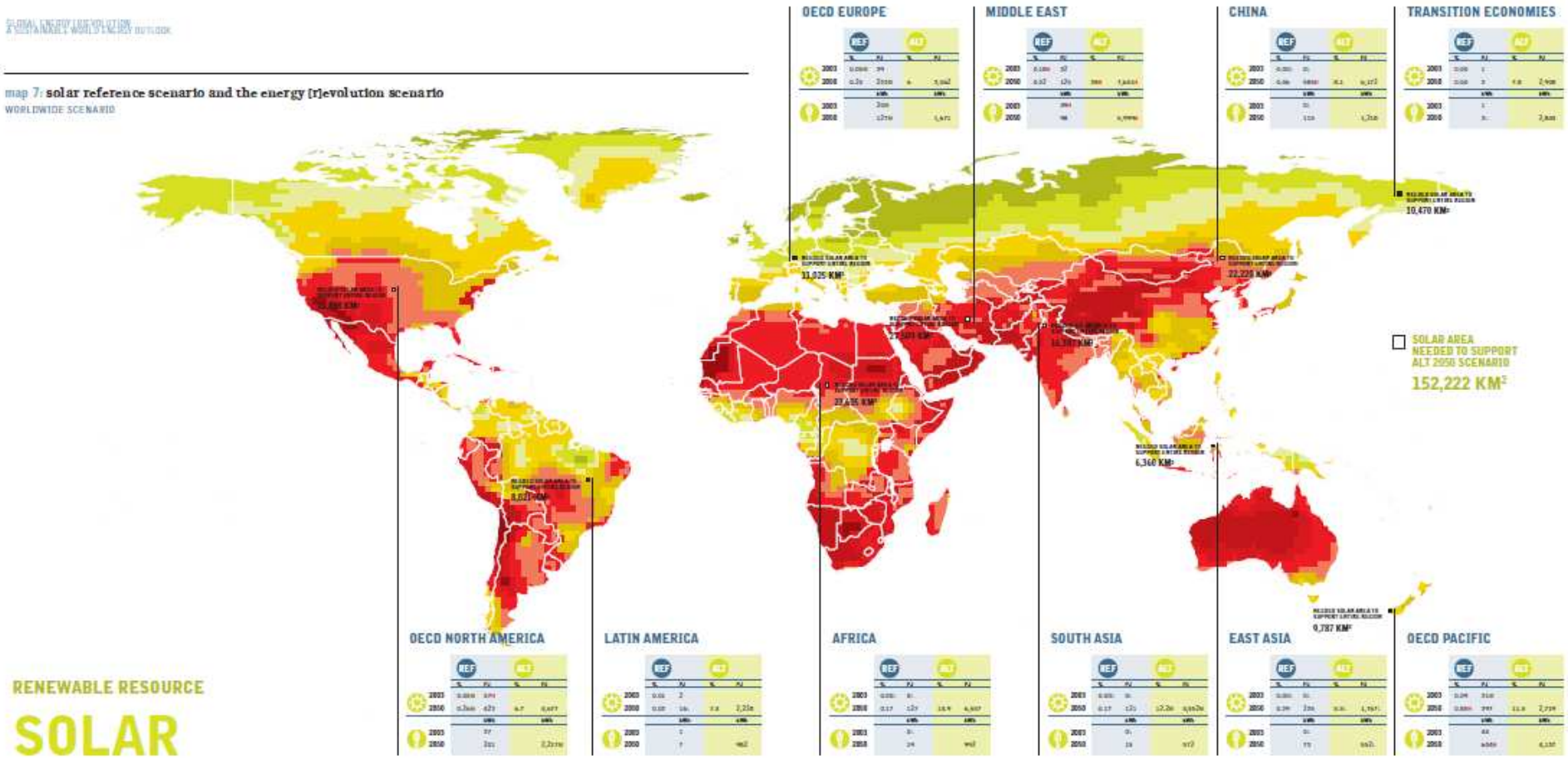
Photo Courtesy of SolFocus Inc., 2009

Solar Resources in the U.S. and Germany



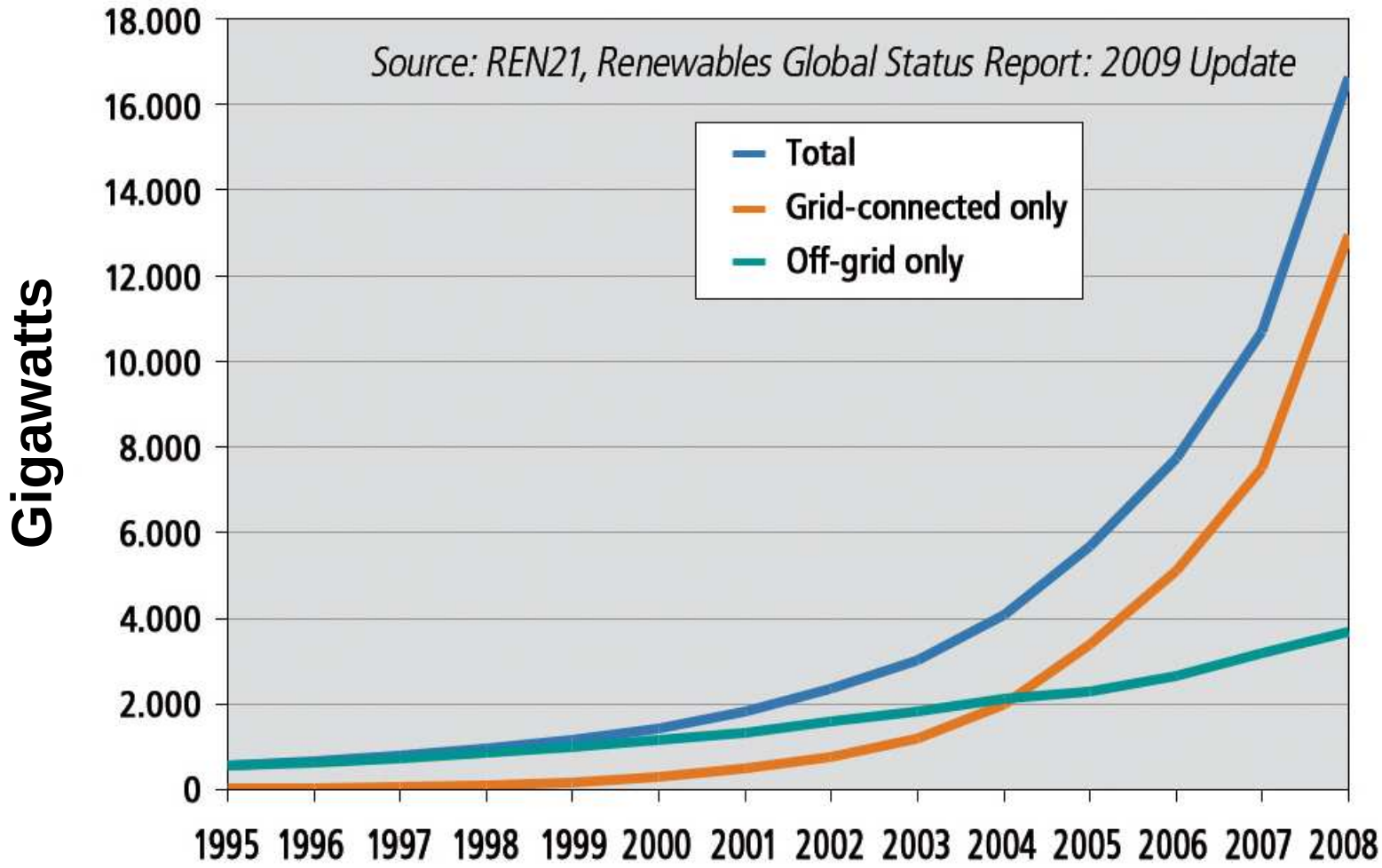
Source: Photovoltaic Solar Resource: United States and Germany © U.S. DOE/NREL, 2008.

Solar Resources in the World



Source: Taken from energy [r]evolution, A Sustainable Global Energy Outlook, report -global energy scenario by European Renewable Energy Council and Greenpeace. www.energyblueprint.info/, 2008.

Solar PV, Existing World Capacity, 1995-2008



Concentrating Solar Power

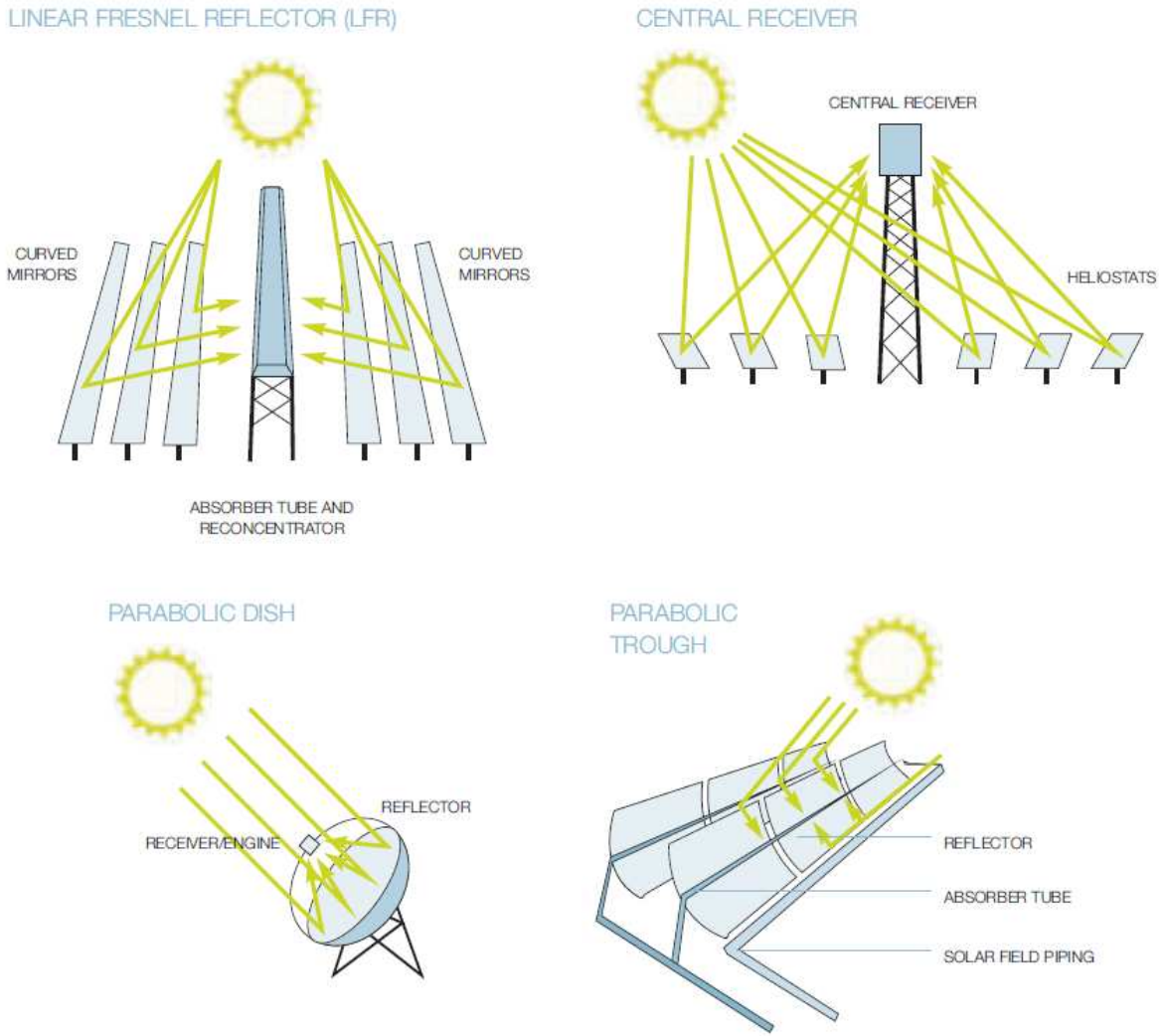
- Four types (clockwise from top)
  - Linear Fresnel Reflector (not pictured)
  - Central Receiver
  - Parabolic Dish
  - Parabolic Trough
- In early stages of commercialization
- System sizes 100 kW to 100 GW

Photo Courtesy of U.S. DOE/NREL; Credit: Sandia National Laboratories, 1989

Photo Courtesy of U.S. DOE/NREL; Credit: Gretz, Warren, 1991

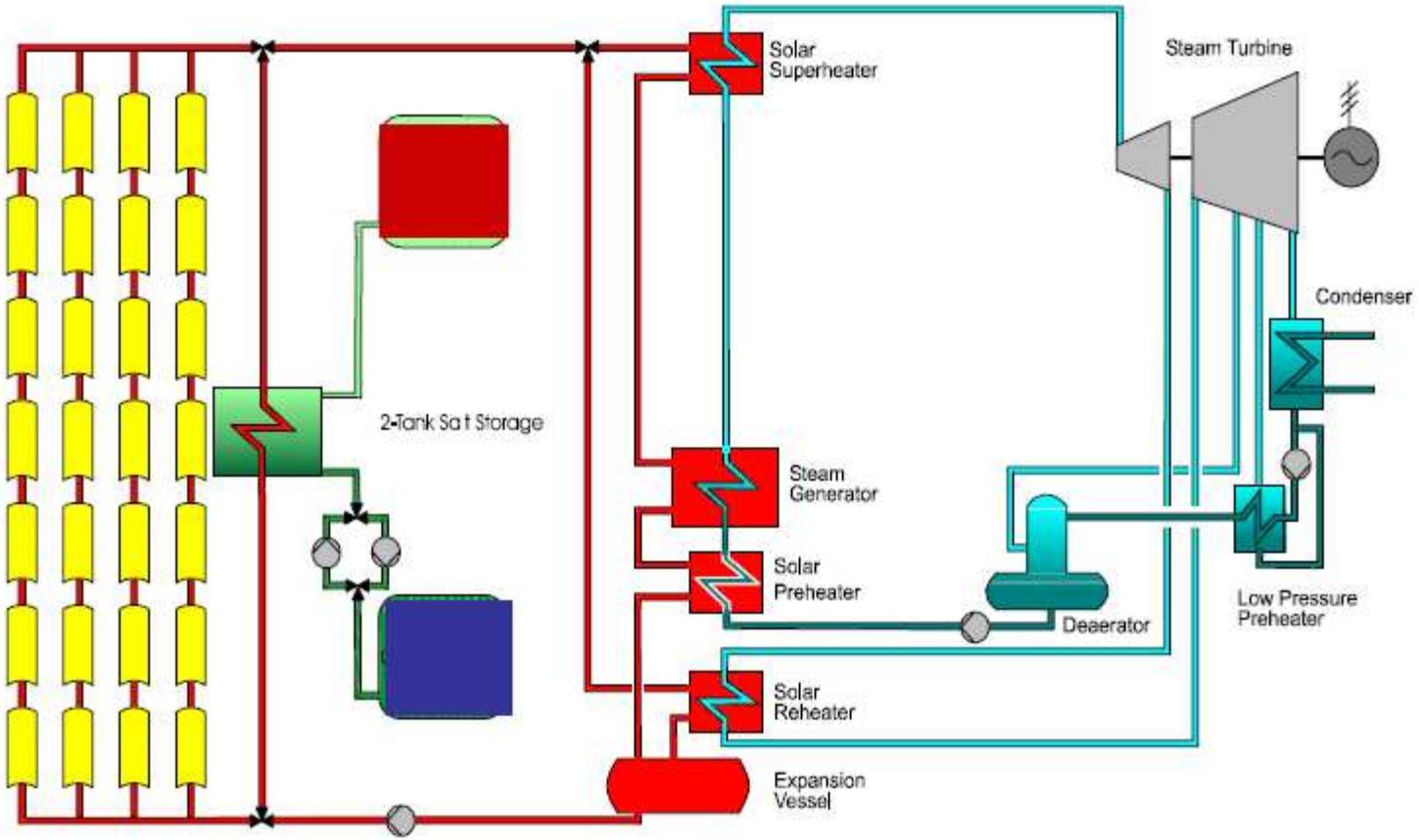
Photo Courtesy of U.S. DOE/NREL; Credit: Sandia National Laboratories, 2000

Types of CSP Systems



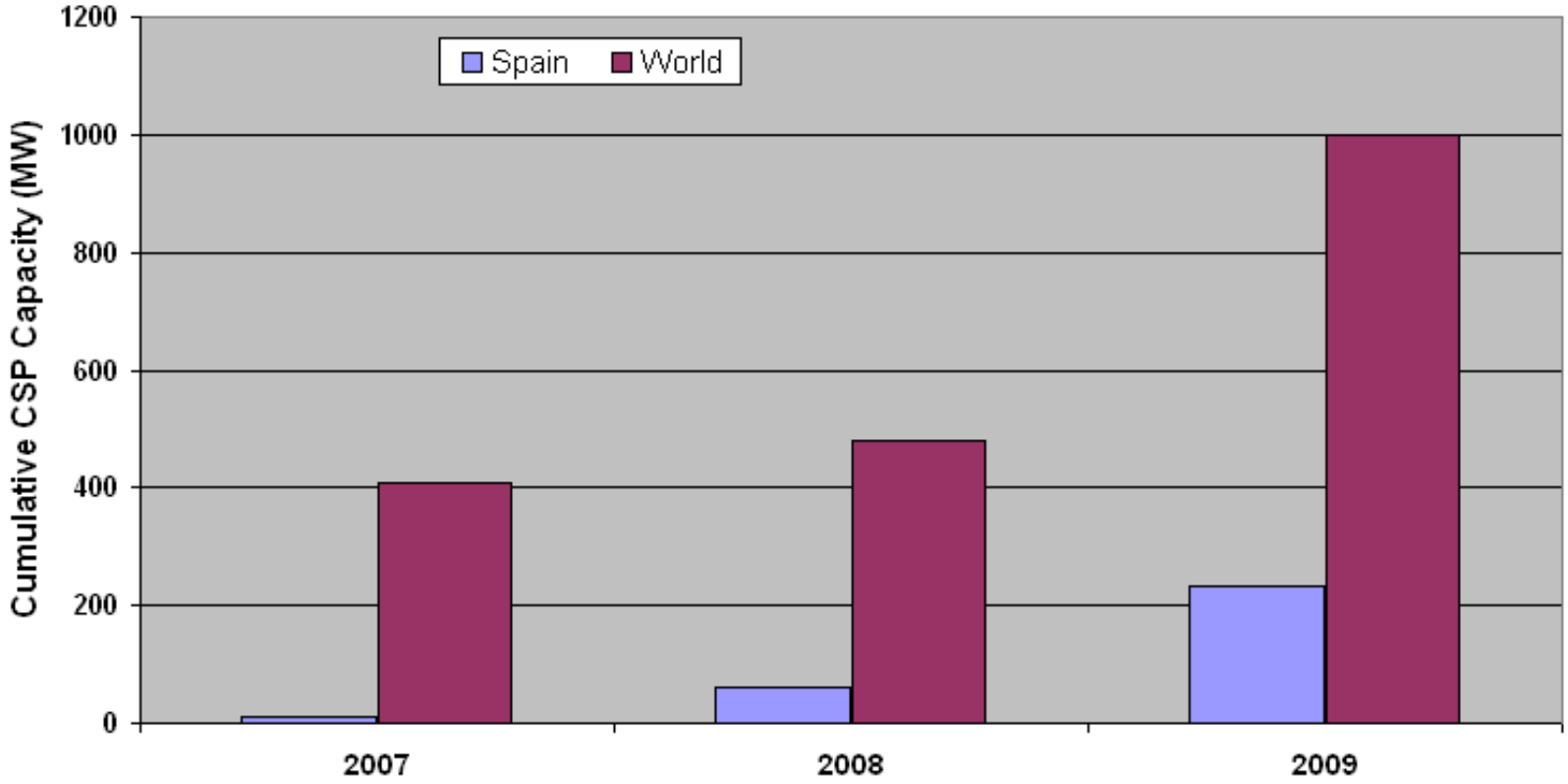
Source: Concentrating Solar Power Global Outlook 09: Why Renewable Energy is Hot, Greenpeace International, SolarPACES, and ESTELA, 2009.

CSP – Parabolic Trough Process Flow Diagram



Source: Concentrating Solar Power Commercial Application Study: Reducing Water Consumption of Concentrating Solar Power Electricity Generation, U.S. Department of Energy, 2008.

CSP Capacity – Spain and World, 2007-2009



Source: Data taken from Concentrating Solar Power Global Outlook 09: Why Renewable Energy is Hot, Greenpeace International, SolarPACES, and ESTELA, 2009.

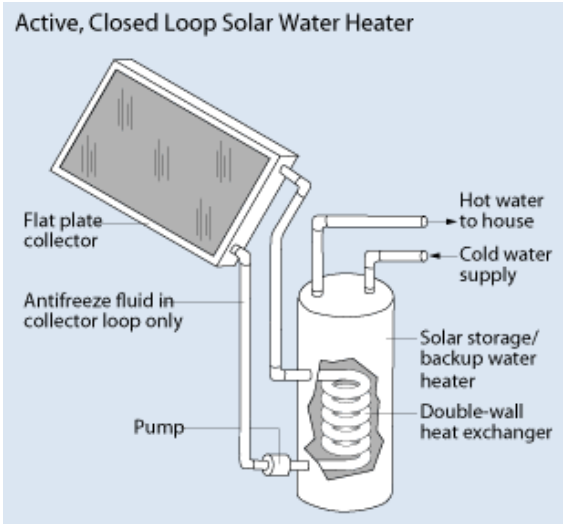
100 GW? Really?

- DESERTEC - EUMENA Concept
  - Network of renewable energy installations designed to provide power to Europe, The Middle East, and North Africa
  - Water desalination and transport
  - http://www.desertec.org/fileadmin/do____wnloads/DESERTEC-WhiteBook_en_small.pdf

Solar Thermal

- Hot water or process heat
  - Open loop
  - Closed loop
- Well developed, efficient, and cost-effective
- Readily installed at member company sites
- System sizes 2 kW to 2+ MW

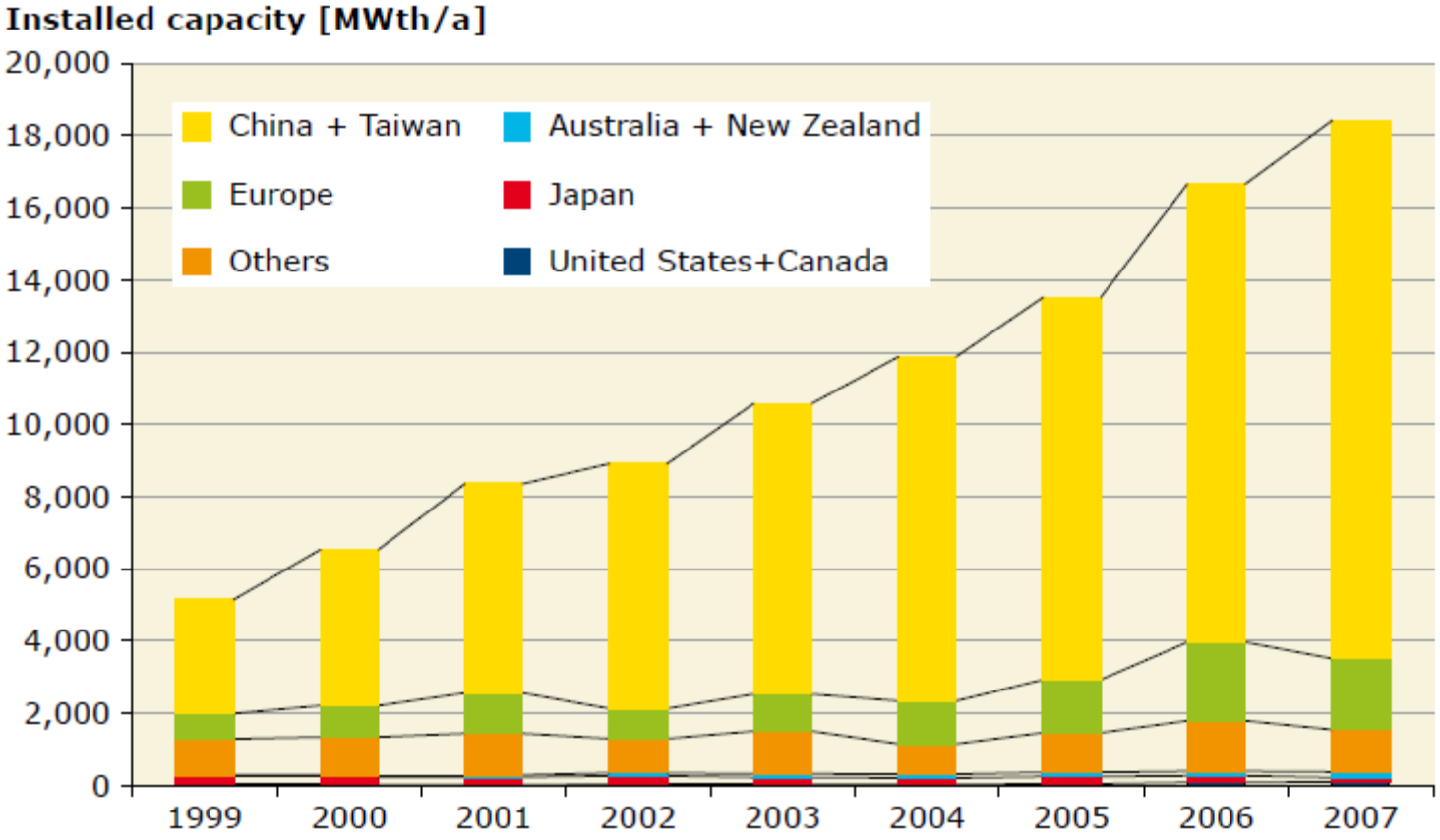
Photo Courtesy of U.S. DOE/NREL; Credit: Spink, Todd, 2001



Source: National Renewable Energy Laboratory

Evacuated Tube Hot Water Collector Installed by The Solar Guys, Australia

Annual Installed Capacity of Flat-plate and Evacuated Tube Collectors from 1999 to 2007



Europe: EU-27, Albania, Macedonia, Norway, Overseas Departments of France, Switzerland;
Others: Barbados, Brazil, India, Israel, Jordan, Mexico, Namibia, South Africa, Thailand, Tunisia and Turkey

Source: IEA Solar Heating and Cooling Programme, Solar Heat Worldwide, 2009 edition, www.iea-shc.org.

Wind

- From large (7 MW) to small (3 kW) turbines
- Proven and cost-effective technology
- Small turbines may be suitable for member company sites
- System sizes 3 kW to 500+ MW

100 kW Turbine

Photo Courtesy of Northern Power Systems, 2009

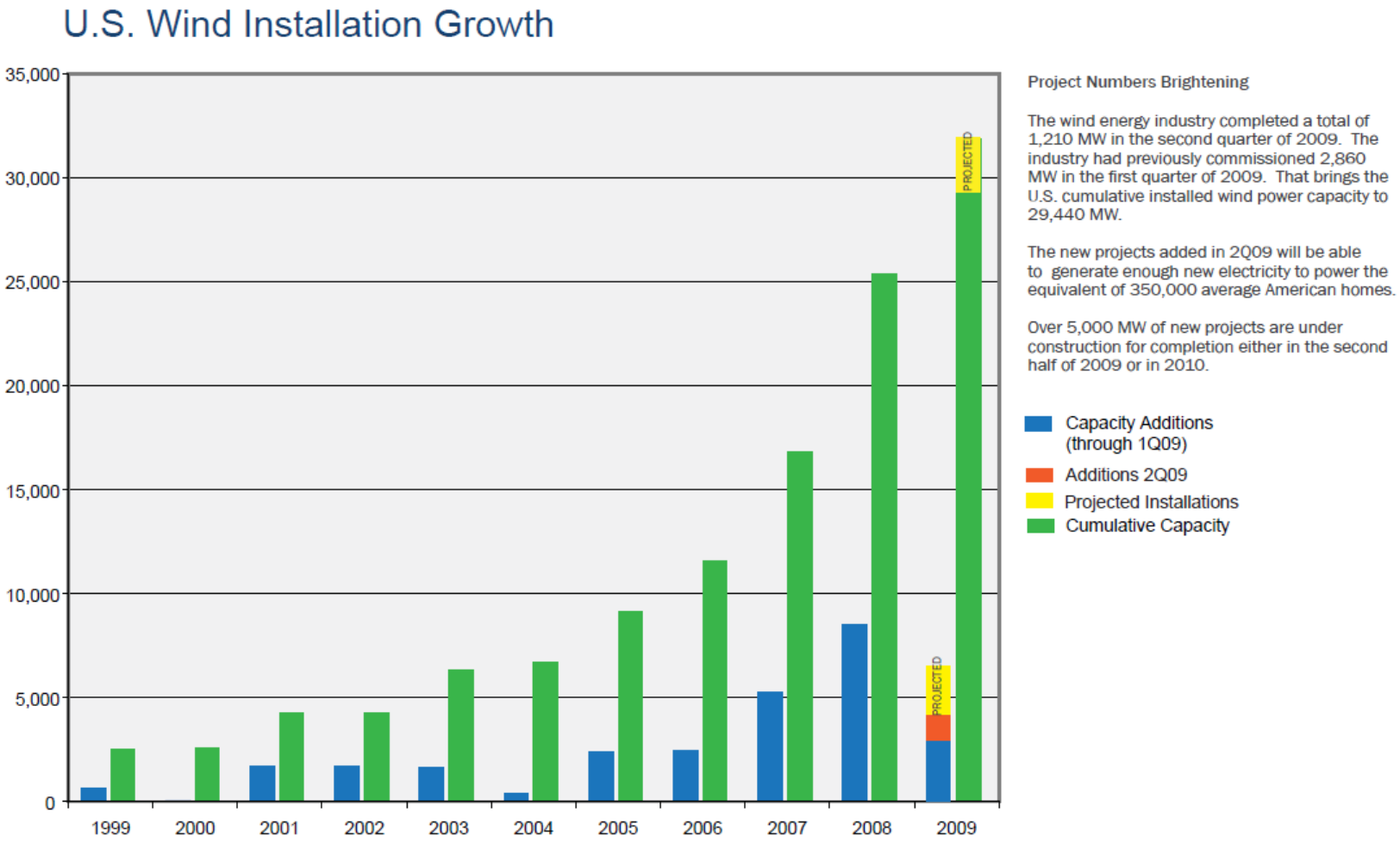
Offshore Wind Farm

Photo Courtesy of The Virginian-Pilot; Credit: Harper, Scott, 2009

1.5 MW Turbines

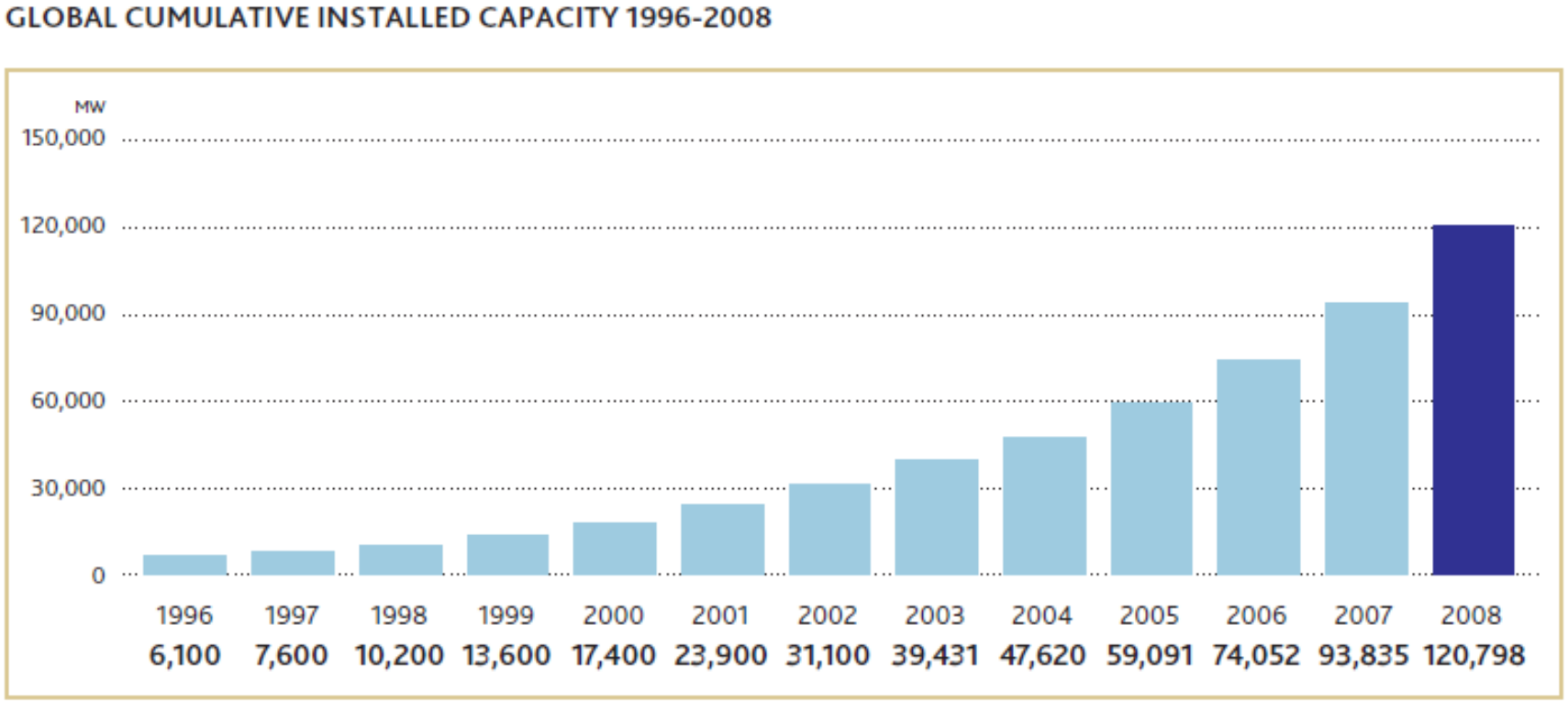
Photo Courtesy of U.S. DOE/NREL; Credit: Spink, Todd, 2008

U.S. Wind Capacity, 1999-2009



Source: AWEA 2nd Quarter 2009 Market Report, American Wind Energy Association, 2009.

Global Wind Capacity, 1996-2008



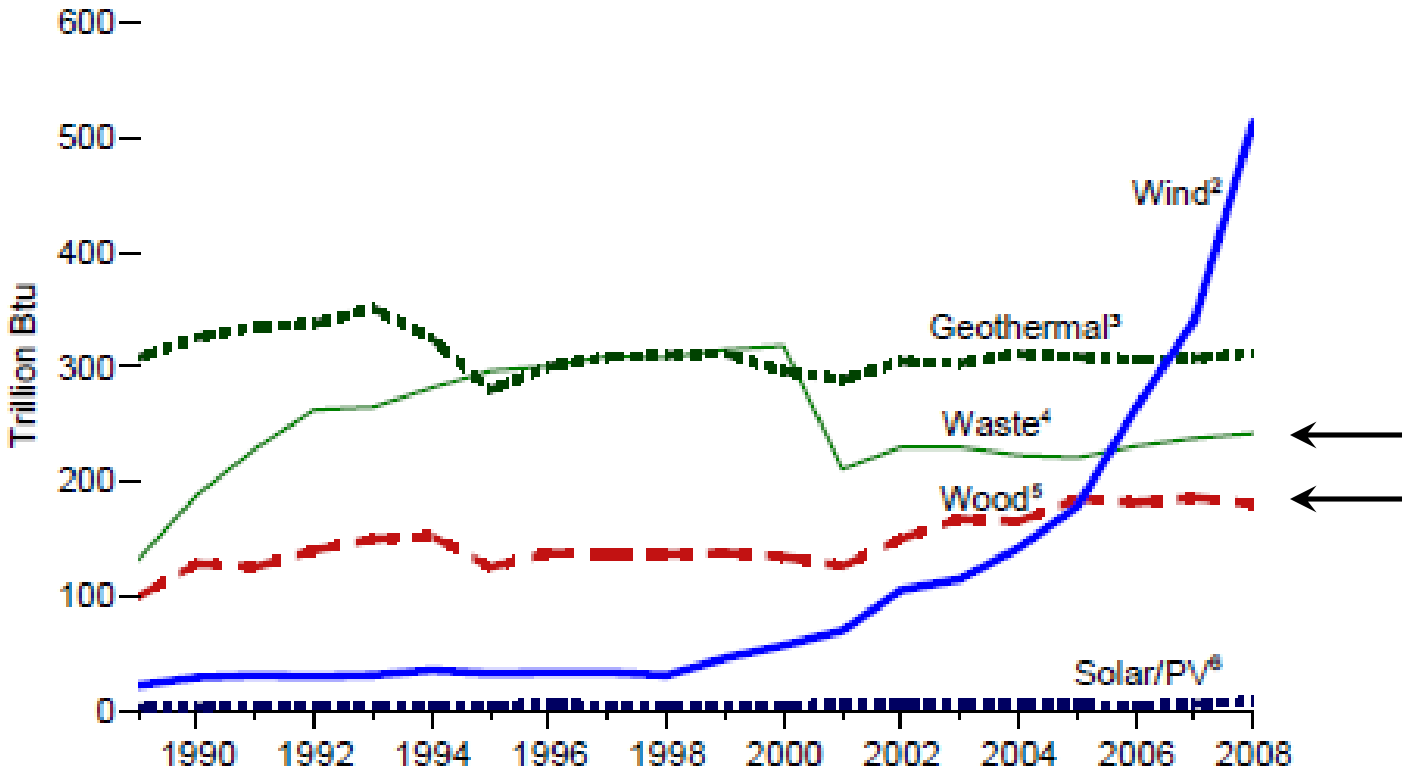
Source: Global Wind 2008 Report, Global Wind Energy Council, 2009.

Biomass

- Burn as fuel to generate electricity and heat
- Often combined with alternative and conventional power generating systems
- Proven and cost-effective technologies
- More suitable for utilities
- System sizes 10 to 100+ MW

Photo Courtesy of U.S. DOE/NREL;
Credit: Gretz, Warren, 1997

Biomass and Other Renewables – Global Capacity

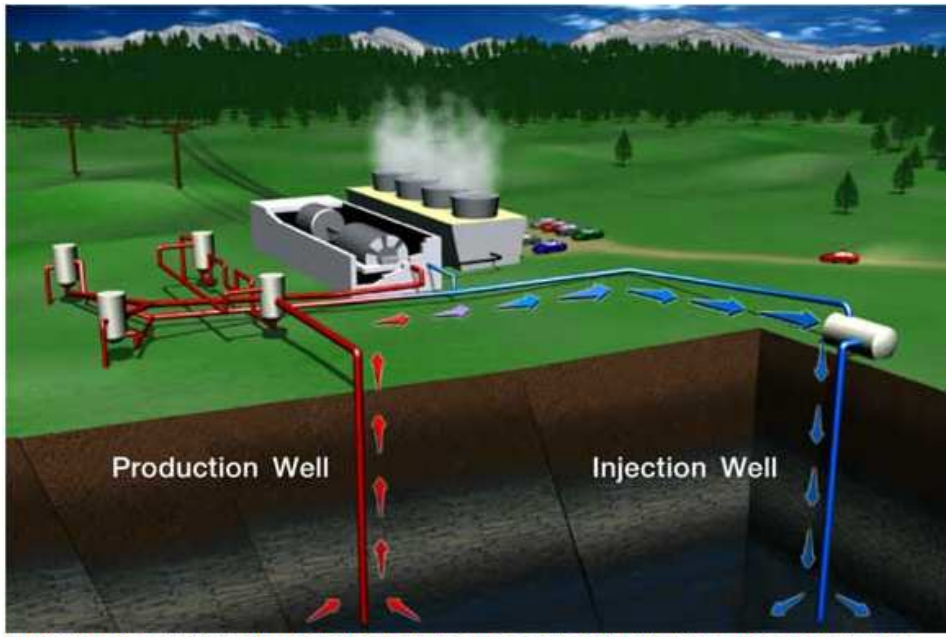


Source: Annual Energy Review 2008, Energy Information Administration, 2009.

Geothermal

- Power from hot underground formations
- Proven and cost-effective technology
- Member company sites not located on such formations
- System sizes 1 MW to 50+ MW

Source: Geothermal Education Office, Tiburon, California, 2000.

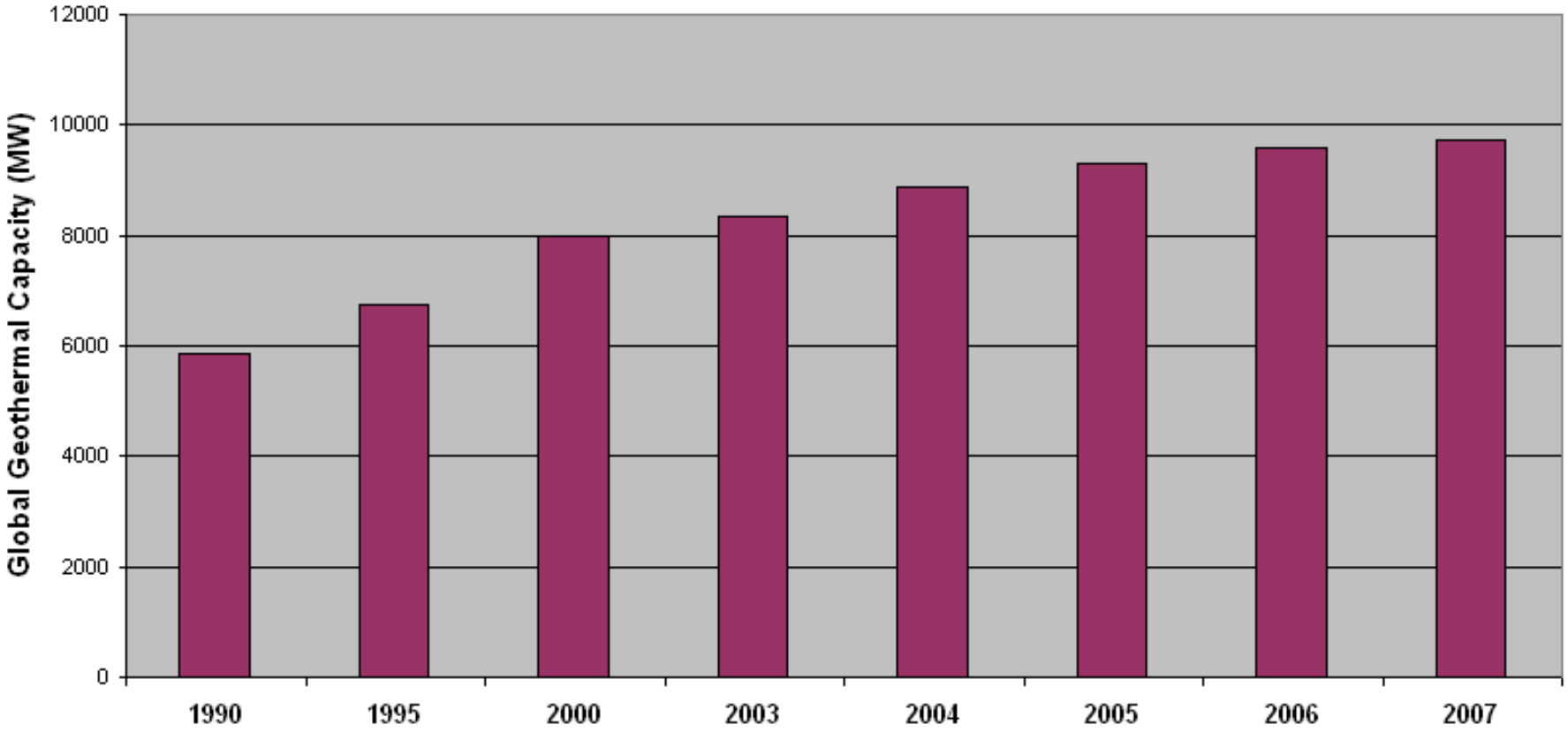


Natural steam from the production wells power the turbine generator. The steam is condensed by evaporation in the cooling tower and pumped down an injection well to sustain production.

World Geothermal Investment

Source: 13.1. Global Geothermal: A Snapshot and Look Forward, Proceedings from World Bank's GeoFund – IGA International Geothermal Workshop, with permission from New Energy Finance, 2009.

Global Geothermal Capacity



Source: Data Taken From Renewable Energy-geothermal: Cumulative installed geothermal power capacity, British Petroleum and International Geothermal Association, 2008.

Hydrokinetic

- Types
  - Elevated storage – hydroelectric dams
  - Wave power
  - Tidal power
- Wave and tidal power still under development
- Not suitable for member company sites
- System sizes 100 kW to 20+ GW

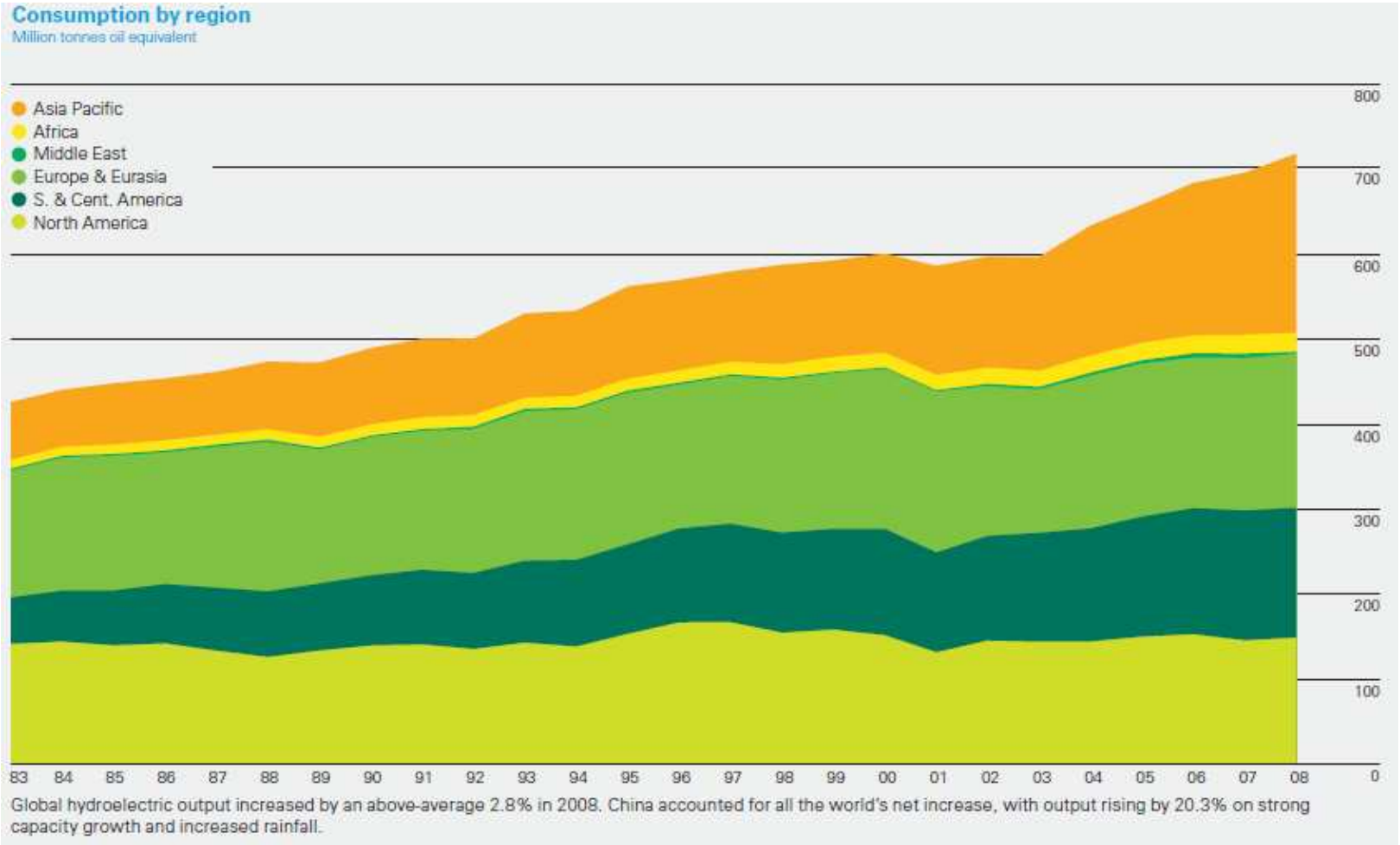
Photo Courtesy of Wikipedia Commons Public Domain; Credit: unknown, 2008

Pelamis Wave Energy Converter

Verdant Power Turbines

Photo Courtesy of Verdant Power Inc., 2009

Global Hydroelectric Output, 1983-2008



Source: BP Statistical Review of World Energy 2009, BP p.l.c., 2009.

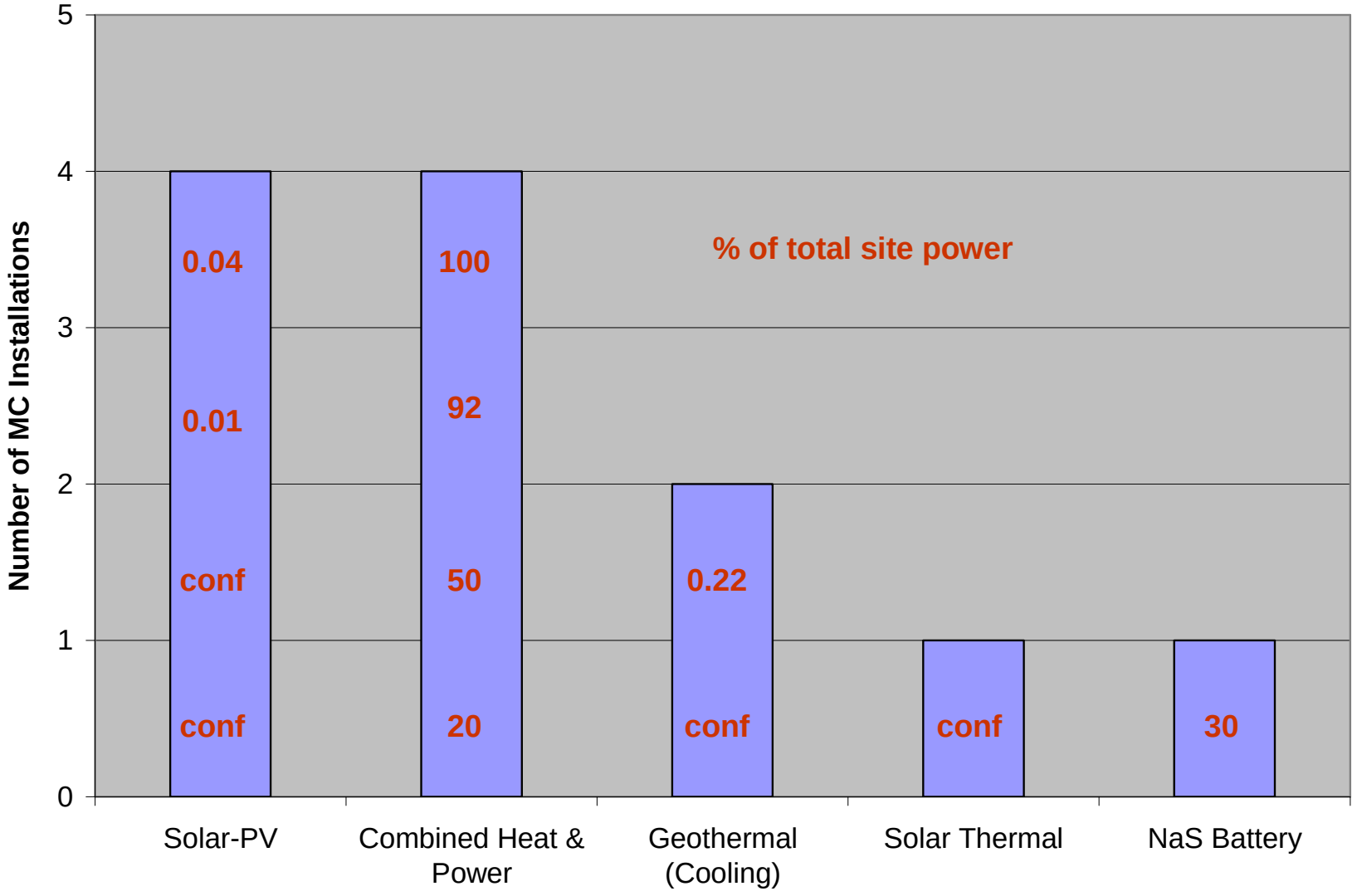
Applicability to Member Company Sites

- Technology robust and readily installed at member company sites
  - Solar PV – Silicon & Thin Film (10 to 1000 kW)
  - Solar Thermal – (80 to 1000 kW)
  - Small Wind (10 to 100 kW)
  - Fuel Cells (10 kW to 10 MW)
  - Combined Heat & Power (Cogen/Trigen) (1 to 20 MW)
- Not applicable to most member company sites
  - CSP – Early stages of commercialization
  - Onshore Wind – Difficult to permit, limited sites
  - Offshore Wind – Limited access
  - Geothermal – Limited access
  - Hydroelectric – Limited access
  - Biomass & Conventional Technologies (Coal, IGCC, CT, CCGT, nuclear) – Fuel handling and permitting difficulties

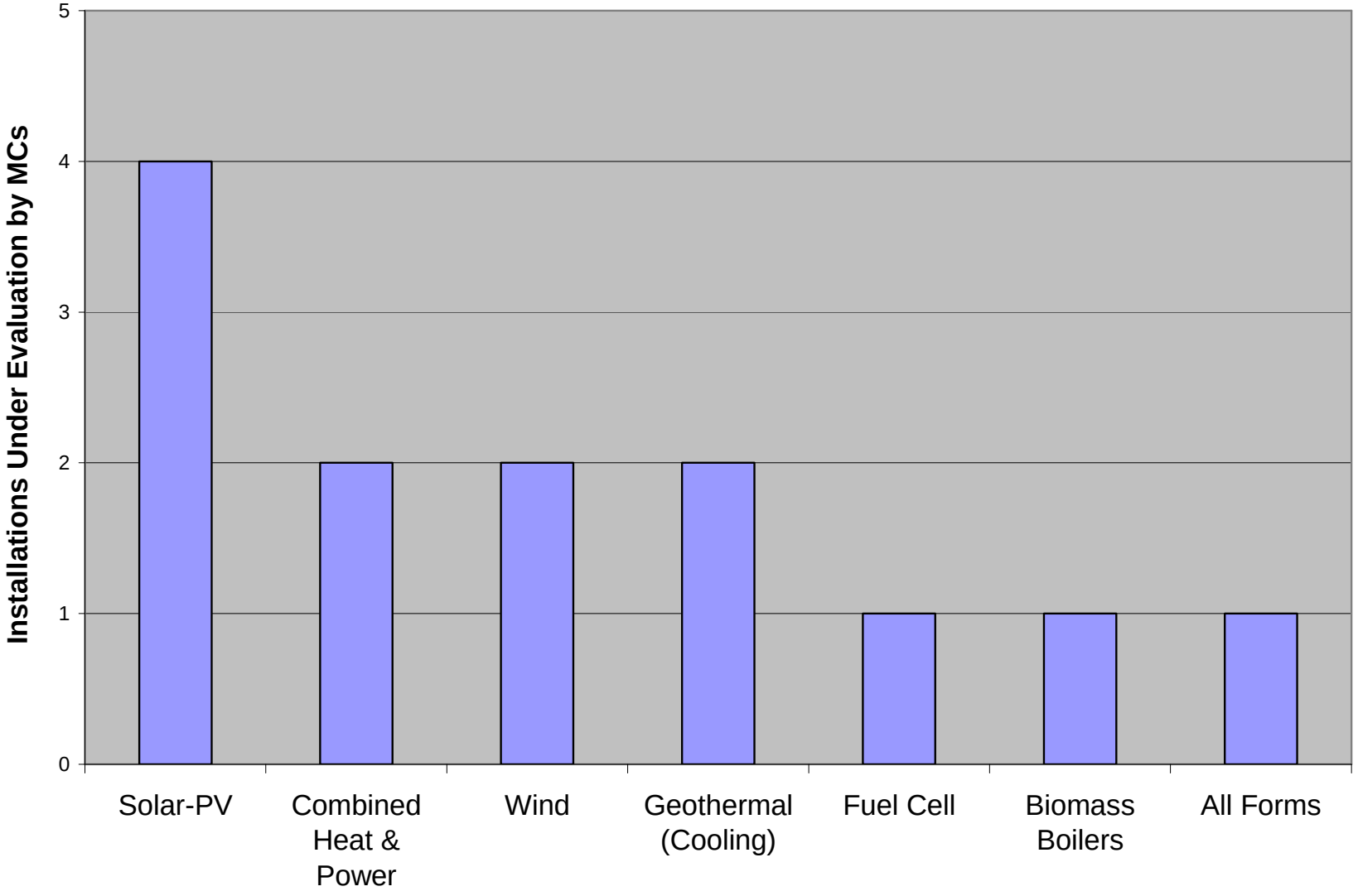
Survey of ISMI Member Companies

- Responses
  - 12 of 16 member companies responded
  - 19 responses received
  - 28 sites reported
- AE/RE Installations
  - 5 member companies have no installations
  - 7 member companies have a total of 12 installations
    - Installed - Solar Photovoltaic (PV), Solar Thermal, Geothermal, Cogeneration, Trigeneration, NaS Batteries
    - Not Installed - Wind, Biomass, Hydrokinetic and Fuel Cells
- 10 of 19 Respondents (7 of 12 member companies) Prefer Solar PV

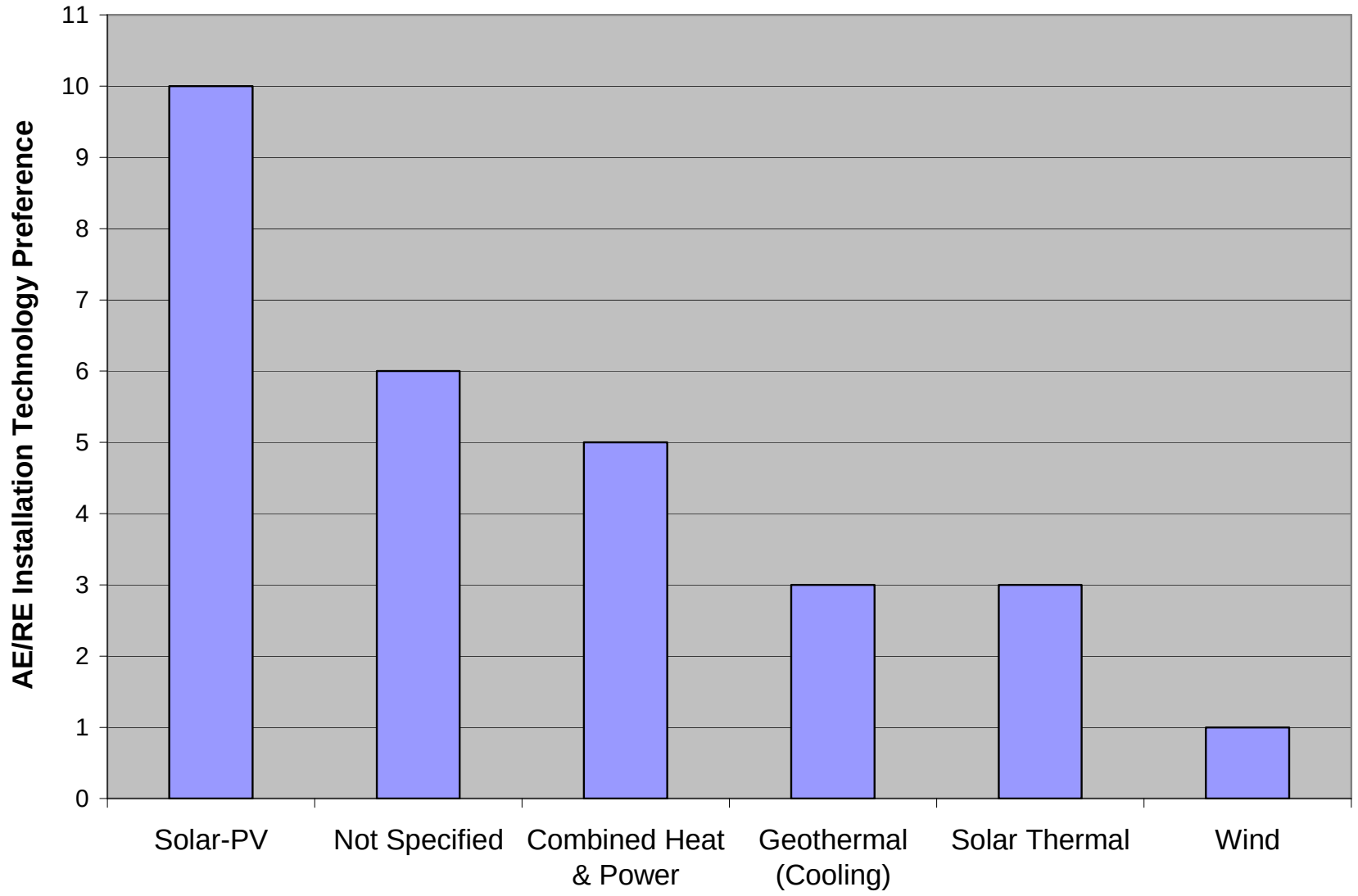
Existing Alternative Energy/Renewable Energy Installations at Member Company Sites



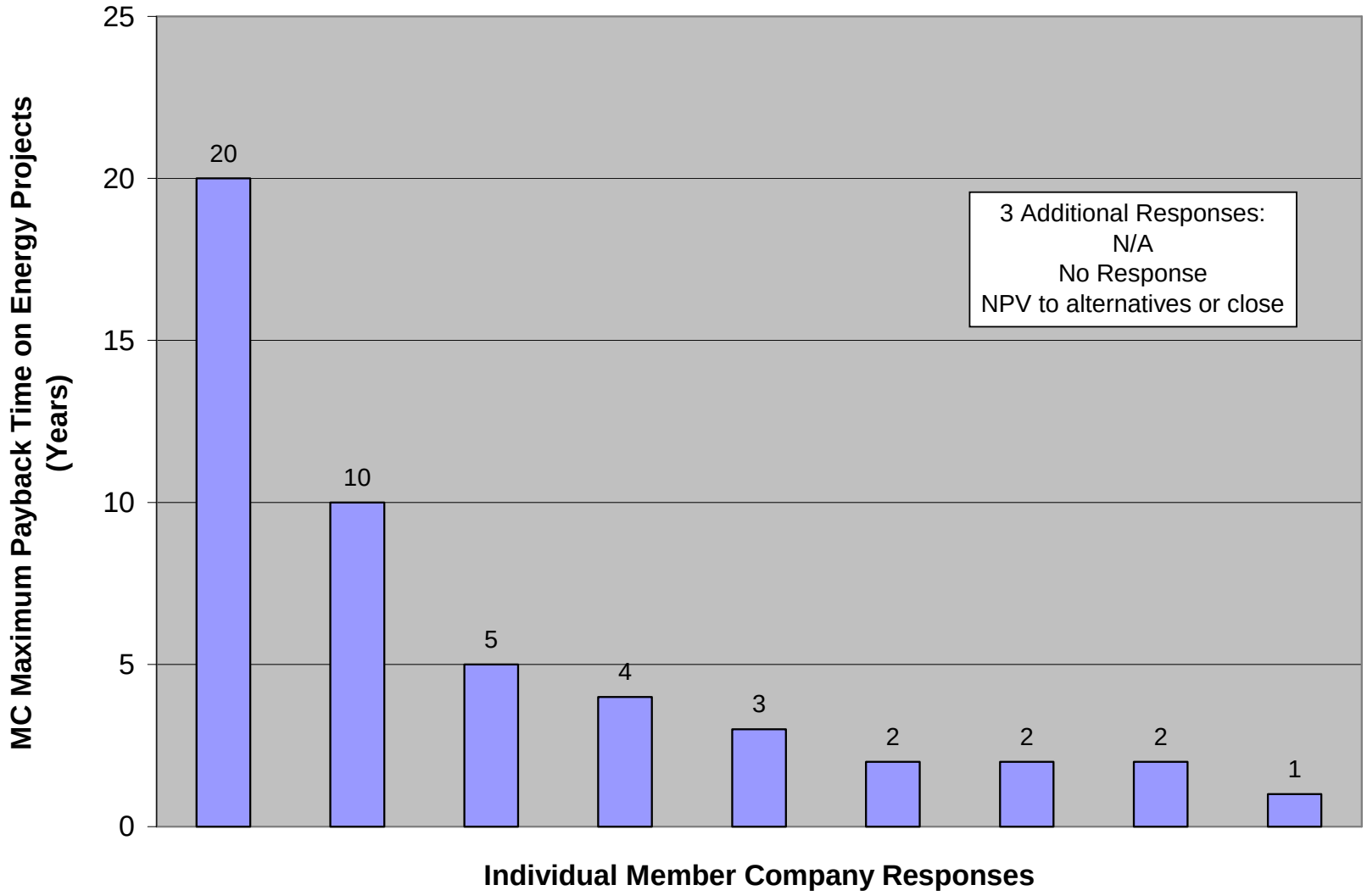
Alternative Energy/Renewable Energy Installations Under Evaluation



Alternative Energy/Renewable Energy Installation Technology Preference



Member Company Maximum Payback Time on Energy Projects

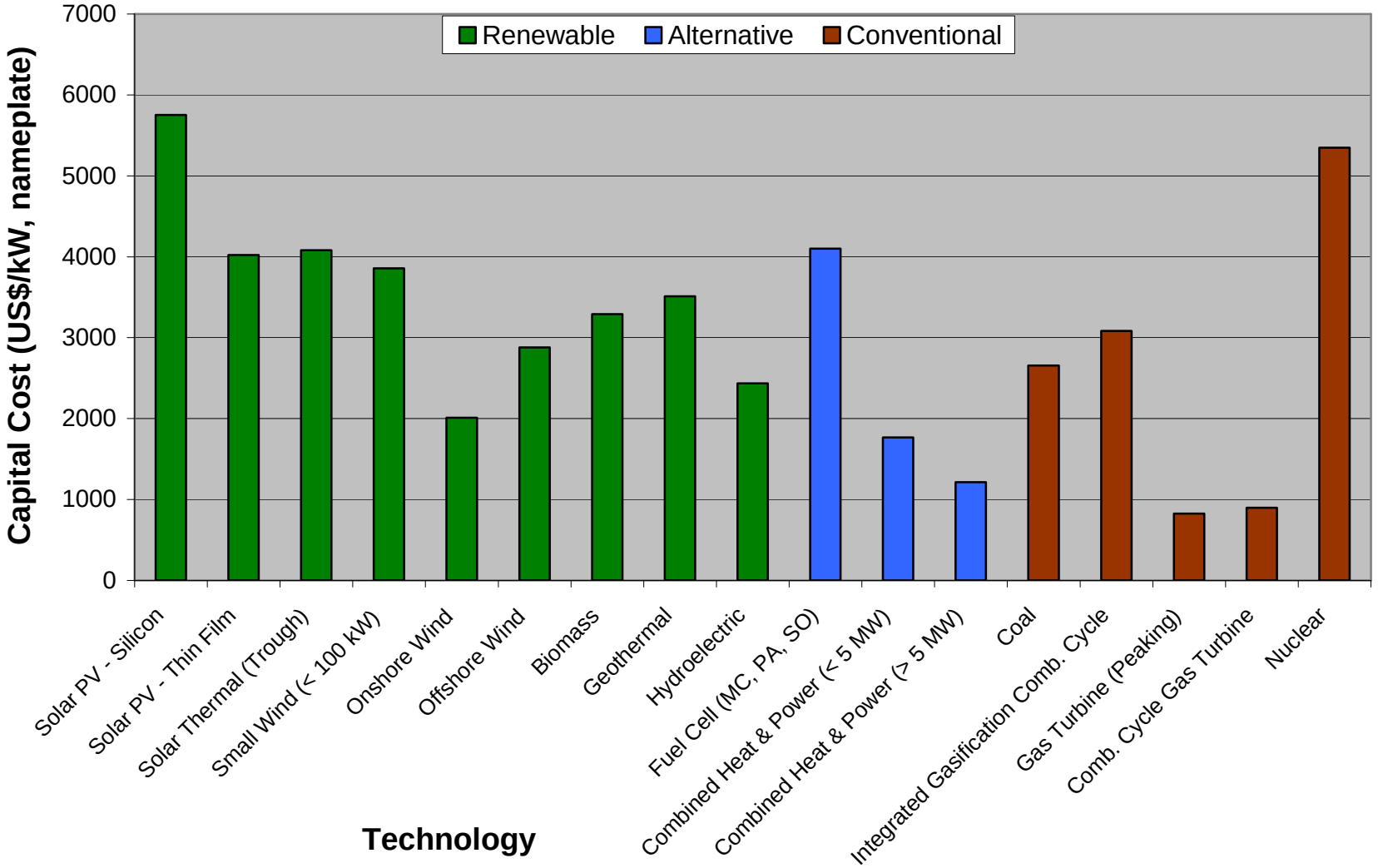


Economic Comparisons of Power Generating Technologies

- Installed Capital Costs
  - Reported in $/kW of nameplate capacity
  - Does not take into account capacity factor or fuel costs
  - Shows initial investment cost, but poor indicator of overall cost of producing electricity
- Levelized Cost of Electricity
  - Ratio of total costs to power generated over the plant lifetime
  - Reported in $/MWhr
  - Includes capital, installation, fixed and variable operating and maintenance, insurance, and financing costs
  - Accounts for capacity factor
  - Reported with and without incentives
  - Cost of carbon emissions not included
  - Best measure of cost of electricity, especially for new generation

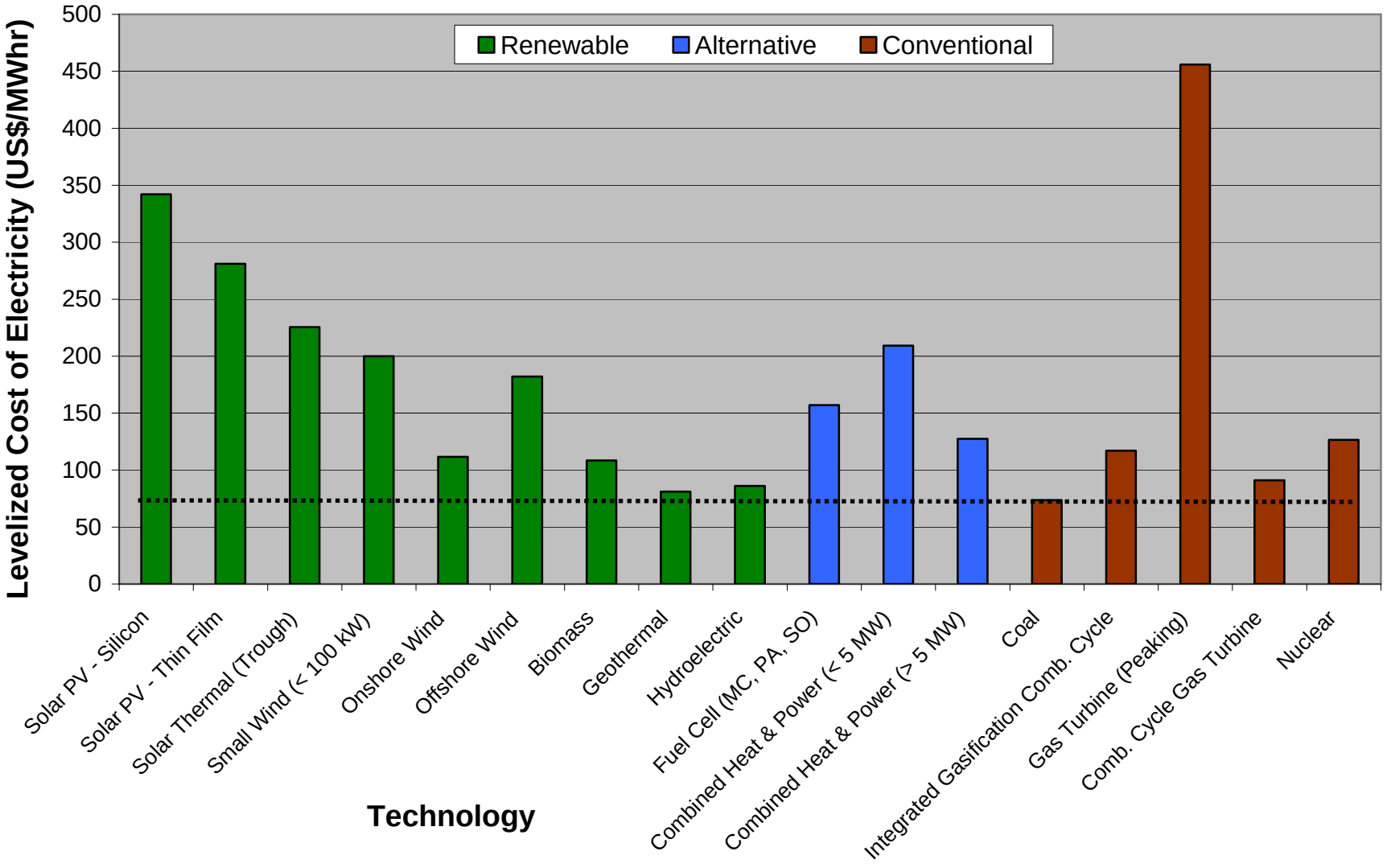
Installed Capital Costs for Renewable, Alternative, and Conventional Sources of Electricity, United States

(Sources: CPUC, PACE Global Energy Services, NREL, Lazard, National Fuel Cell Research Center, DOE, ExxonMobil, USEPA, AWEA, CanWEA)



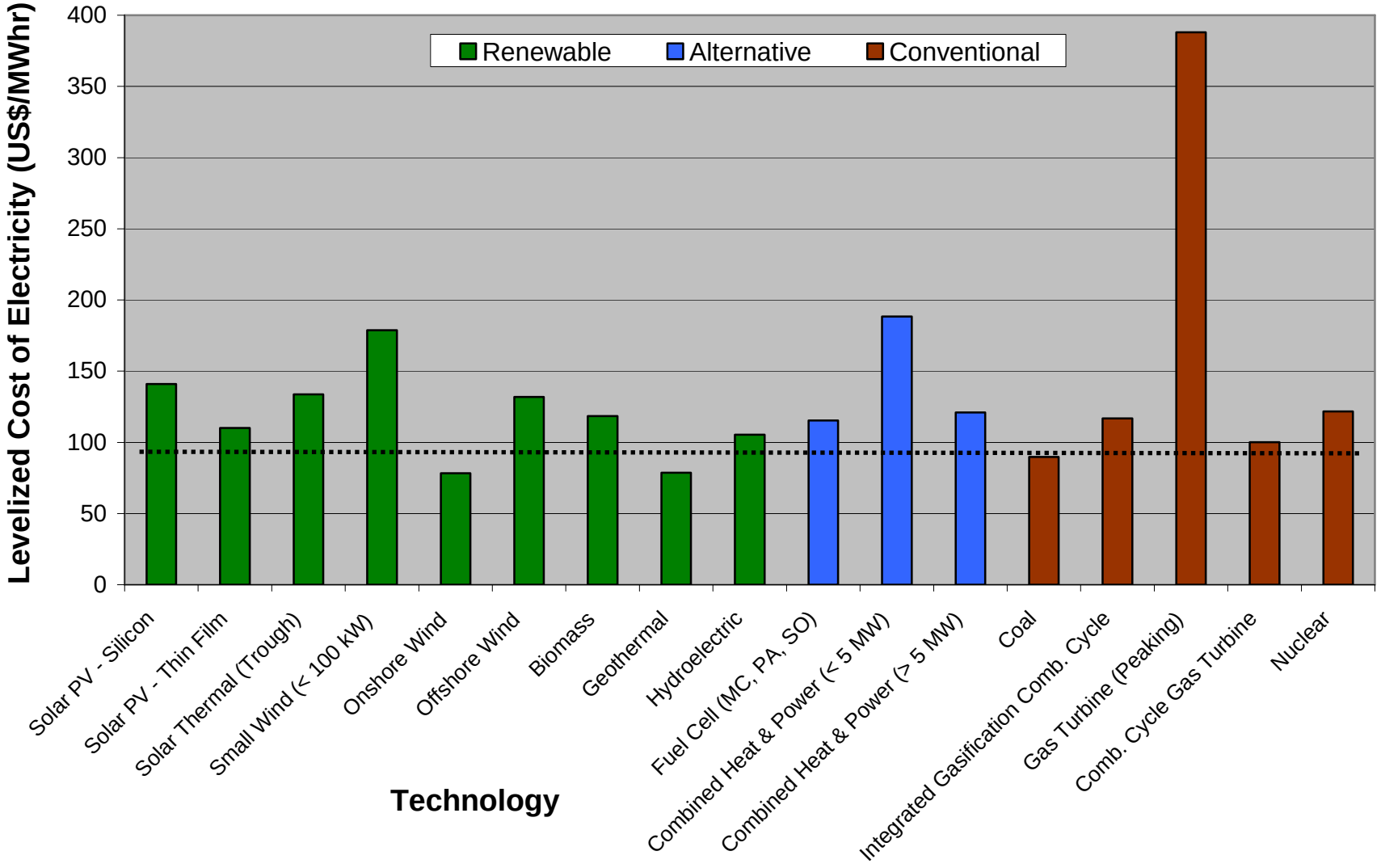
Levelized Cost of Electricity for Renewable, Alternative, and Conventional Sources – No Incentives

(Sources: World Economic Forum, REN21, CPUC, Lazard, CEC, Photon Consulting)



Levelized Cost of Electricity for Renewable, Alternative, and Conventional Sources – With Incentives

(Sources: CPUC, Lazard, NREL, CEC)



Incentives

- Incentives are financial tools used by governments, utilities, and other entities to subsidize and encourage the adoption of alternative and renewable technologies.
- Many types
  - Feed In Tariff (FIT) – payment per kWhr generated to a renewable energy producer. The cost is usually distributed over all electricity users.
  - Investment Tax Credit (ITC) – reduction in tax, usually a percentage of installed capital cost. Now available in the U.S. as a grant.
  - Depreciation Deduction (D) – allowing depreciation of installed capital to be deducted from taxes. U.S. uses Modified Accelerated Cost Recovery System (MACRS) plus bonus depreciation (60, 16, 10, 6, 6, 2% over years one through six).
  - Production Incentive (PI) – payment per kWhr generated, which is in addition to the value of the electricity on the open market. Usually offered by states, local utilities, or other entities.
  - Rebate (R) – payment per kW installed. In U.S. is offered by state governments and local utilities.

Available Incentives – by Country

Country	Fuel Cells	CHP	Solar PV	CSP	Solar Thermal	Wind	Biomass	Geothermal	Hydro
Austria			FIT			FIT		FIT	
China			FIT			FIT			
Germany			FIT	FIT		FIT	FIT	FIT	FIT
Ireland		FIT	FIT		ITC	FIT	ITC/FIT	ITC	FIT
Israel			FIT	FIT		FIT			
Italy			FIT	FIT		FIT	FIT	FIT	FIT
Japan	ITC	ITC	ITC	ITC	ITC	ITC	ITC	ITC	ITC
Korea	ITC/FIT		FIT	FIT					
Malaysia			DD	DD	DD		DD		DD
Singapore									
Scotland			FIT			FIT	FIT	FIT	FIT
Taiwan			FIT						
U.S.	ITC/DD	ITC/DD	ITC/DD	ITC/DD	ITC/DD	ITC/DD	ITC/DD	ITC/DD	ITC/DD

FIT = Feed in Tariff
ITC = Investment Tax Credit or Grant
DD = Depreciation Deduction

Available Incentives – by U.S. State

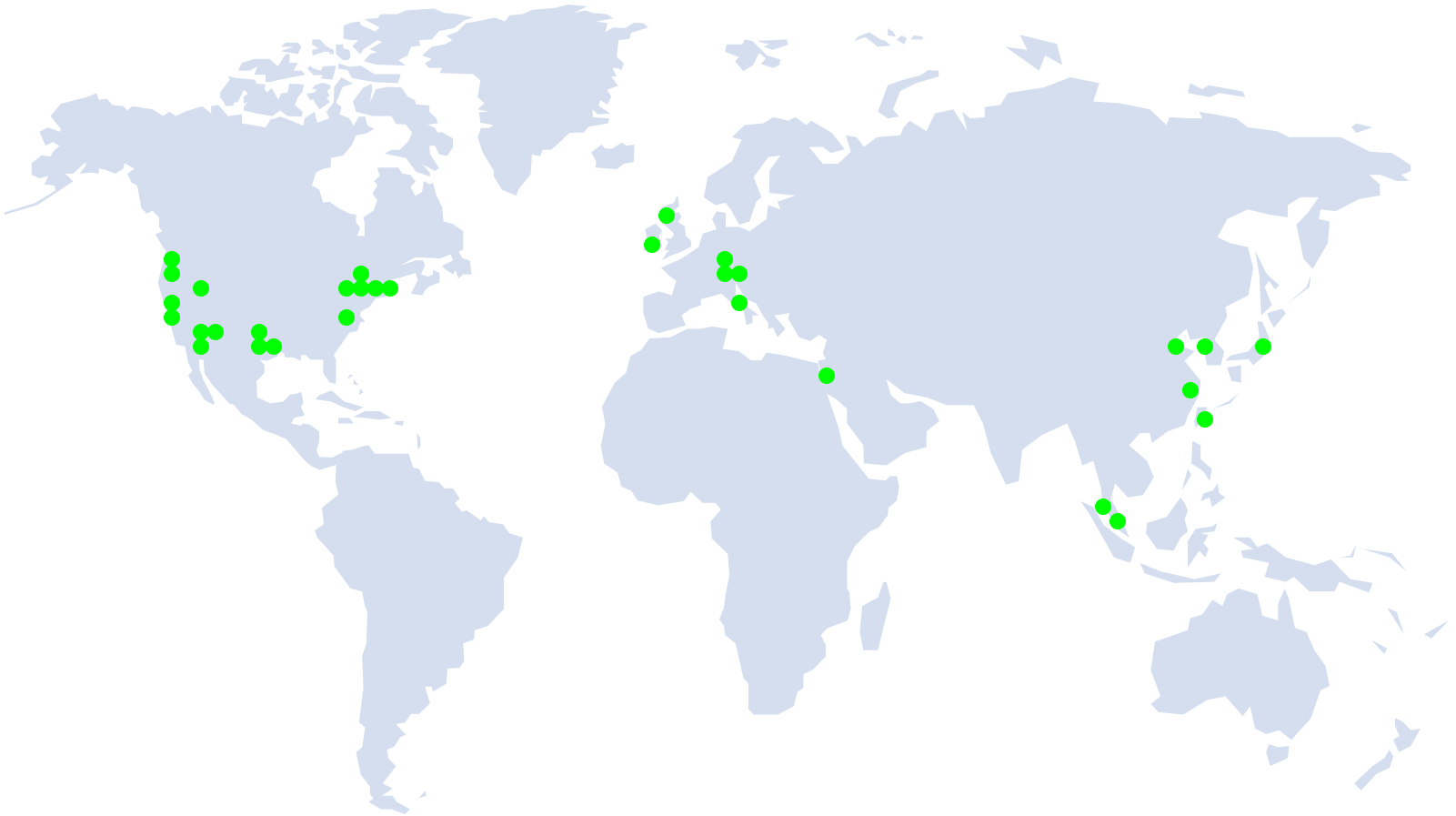
State	Fuel Cells	CHP	Solar PV	CSP	Solar Thermal	Wind	Biomass	Geothermal	Hydro
Arizona			ITC/R	ITC	ITC/PI	ITC			
California	R		FIT/R	FIT	R	FIT/R	FIT	FIT	
Idaho			PI			PI			
Maine	PI	PI	R/PI	PI	R	R/PI	PI	PI	PI
Mass.			R/PI		ITC	R/PI			
New Mex.			ITC/PI	ITC		ITC	ITC	ITC	
New York	R		R						
Oregon			FIT/PI/R		PI	R/PI			
Texas			R						
Utah			PI/R	FIT	ITC/PI	FIT	FIT	FIT	FIT
Vermont			ITC/R/FIT/PI		ITC/R	FIT	FIT		FIT
Virginia									
Wash.			PI			PI			

FIT = Feed in Tariff
ITC = Investment Tax Credit or Grant
PI = Production Incentive
R = State or Local Rebate

Member Company Site Economic Analysis

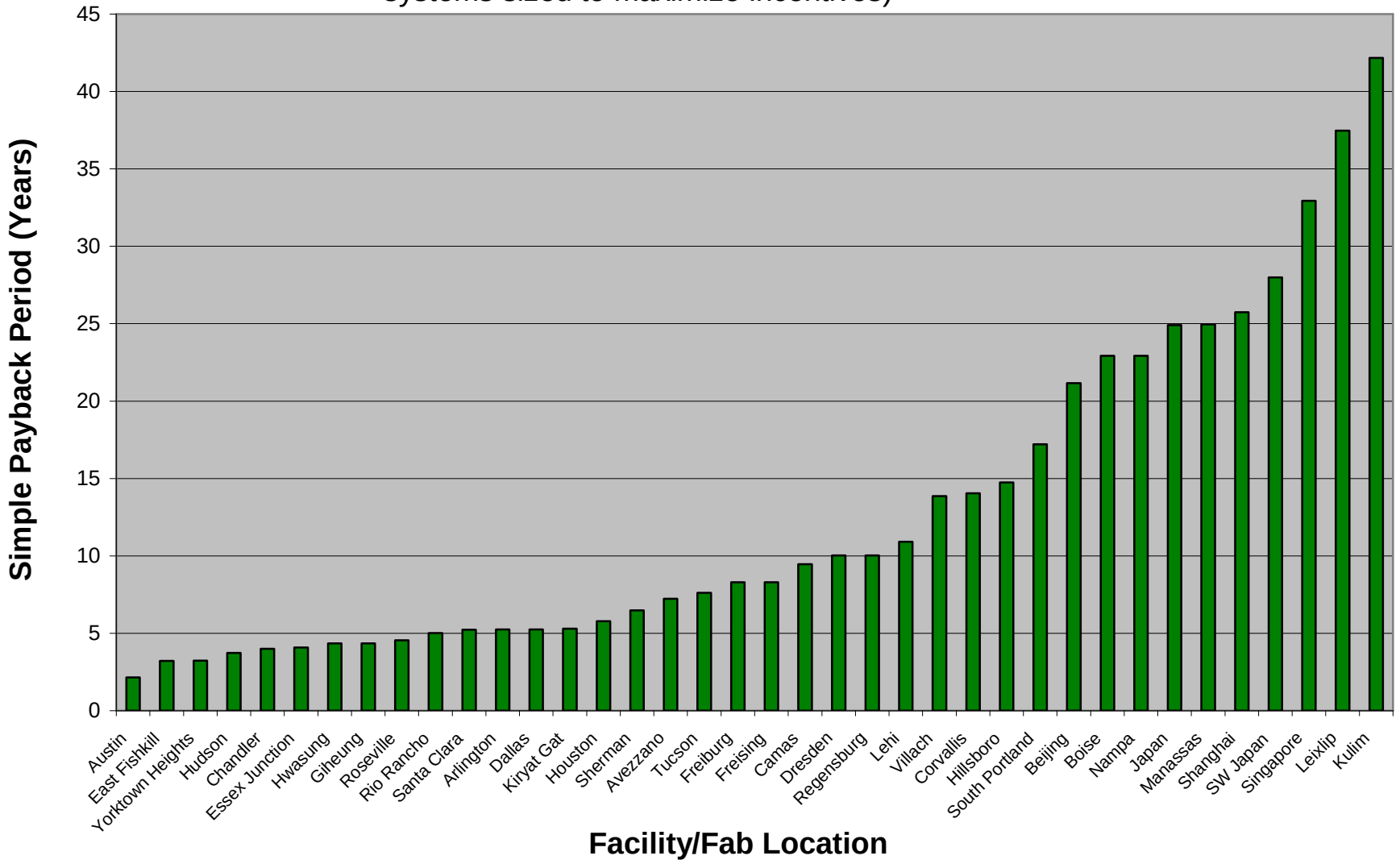
- Analyzed solar PV – Si, solar thermal, small wind, fuel cell, and combined heat & power
- Simple payback period
  - Based on U.S. capital, installation, and O&M costs
  - Incentives included for each location
  - Industrial electricity rates for each location
  - Natural gas cost = 8.00 US$/million BTU
- Sites with a payback > 50 years are not shown
- Conversion efficiency, manufacturing costs, incentives, regulations, and fuel and electricity costs are rapidly changing, so these analyses must be updated frequently.

ISMI Member Company Locations



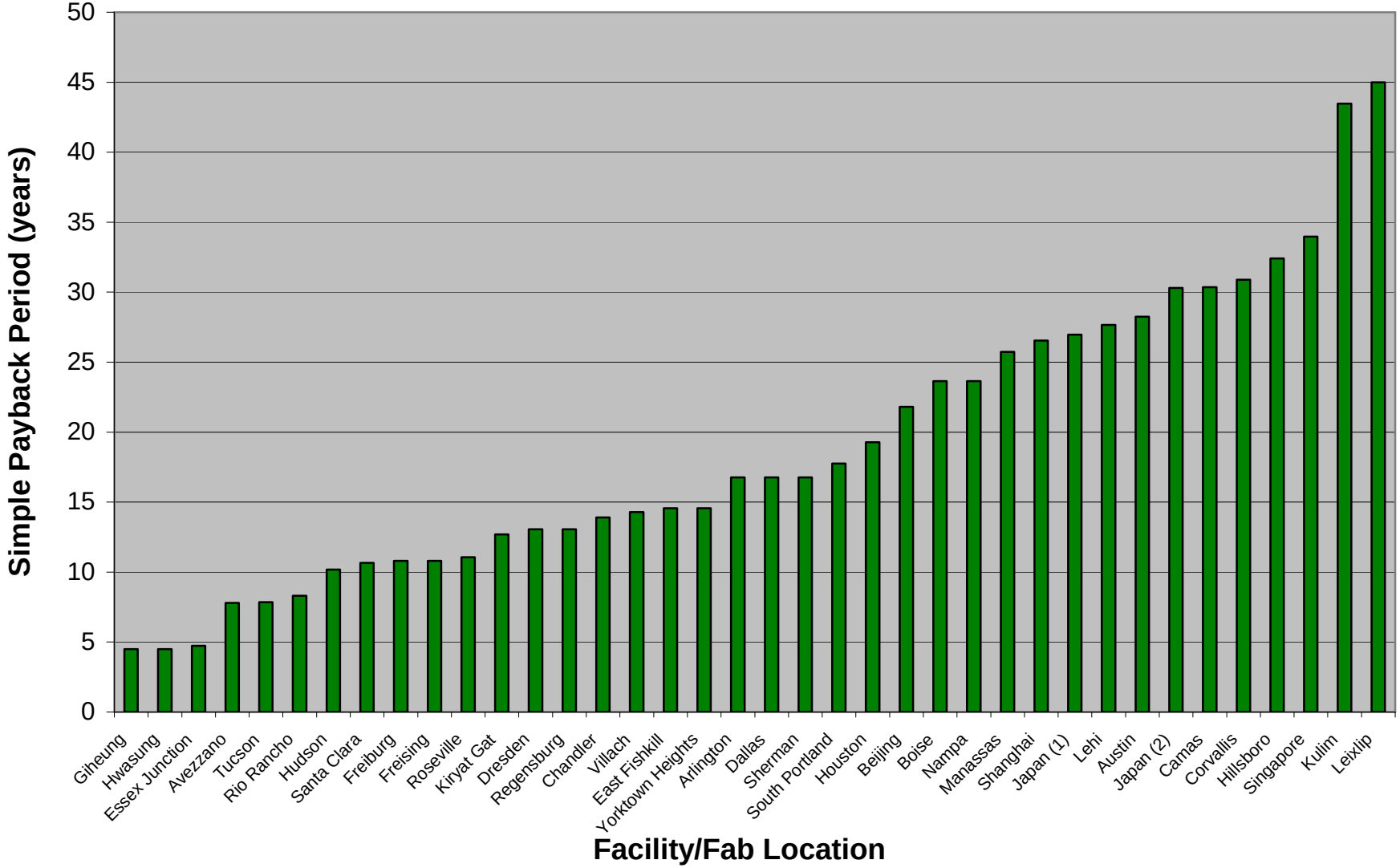
Economic Analysis of 19.5 to 50 kW (DC) Solar PV-Si Roof-Mounted System

(based on U.S. installed cost 103K to 265K USD, systems sized to maximize incentives)



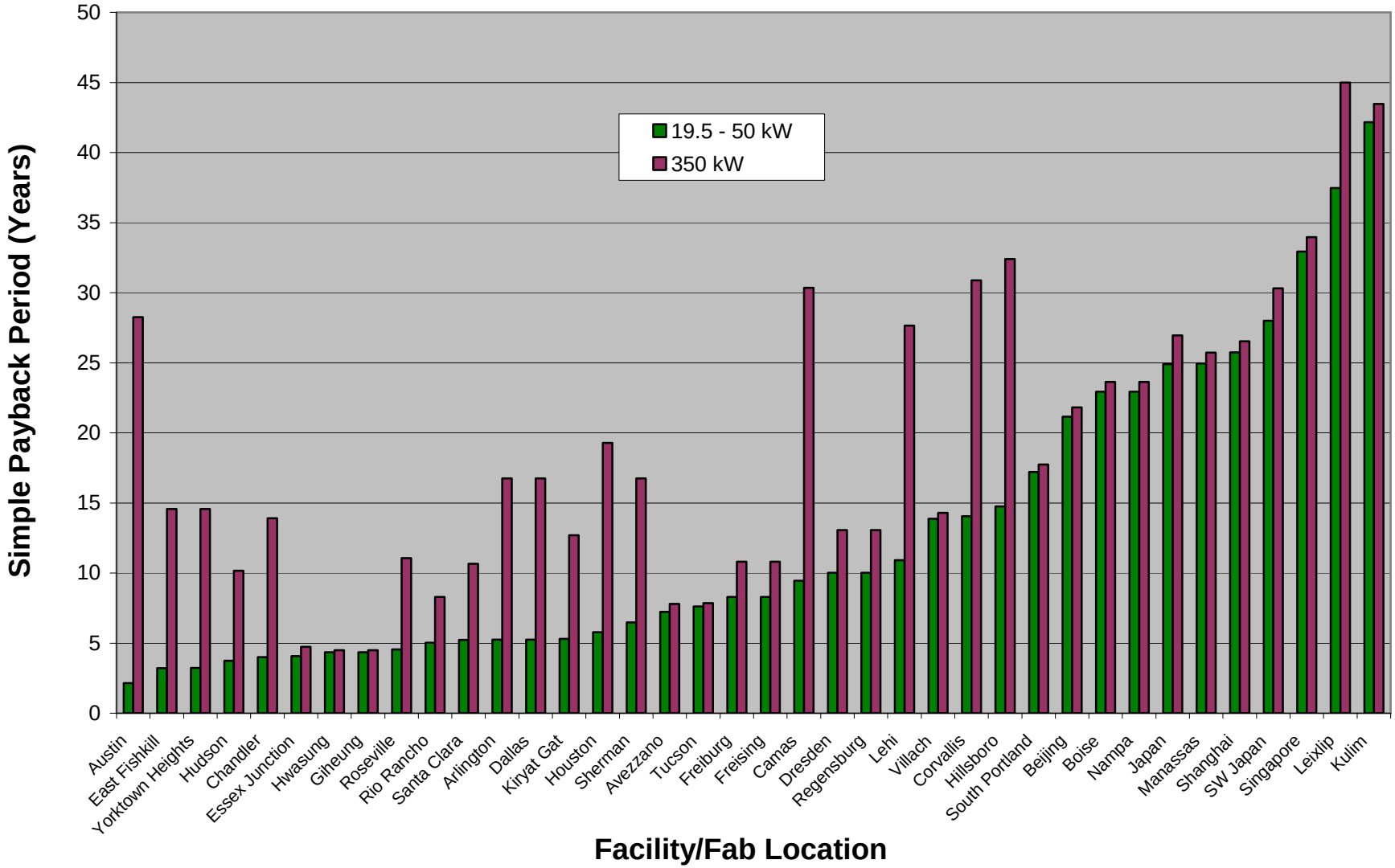
Economic Analysis of 350 kW (DC) Solar PV-Si Roof-Mounted System

(based on U.S. installed cost 1.941 million USD)



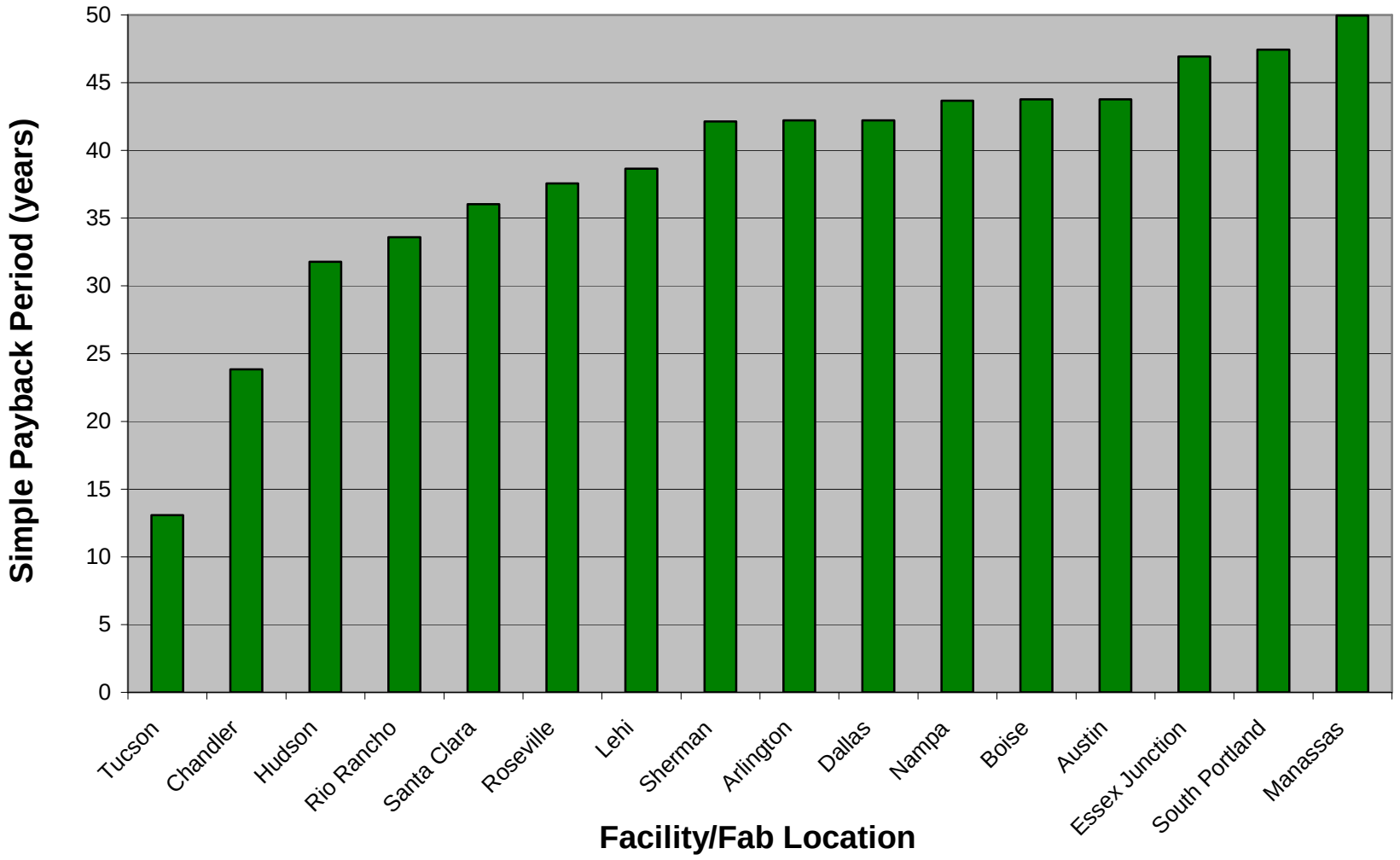
Comparison of 19.5-50 kW to 350 kW Systems

(Solar PV-Si, Roof-Mounted)



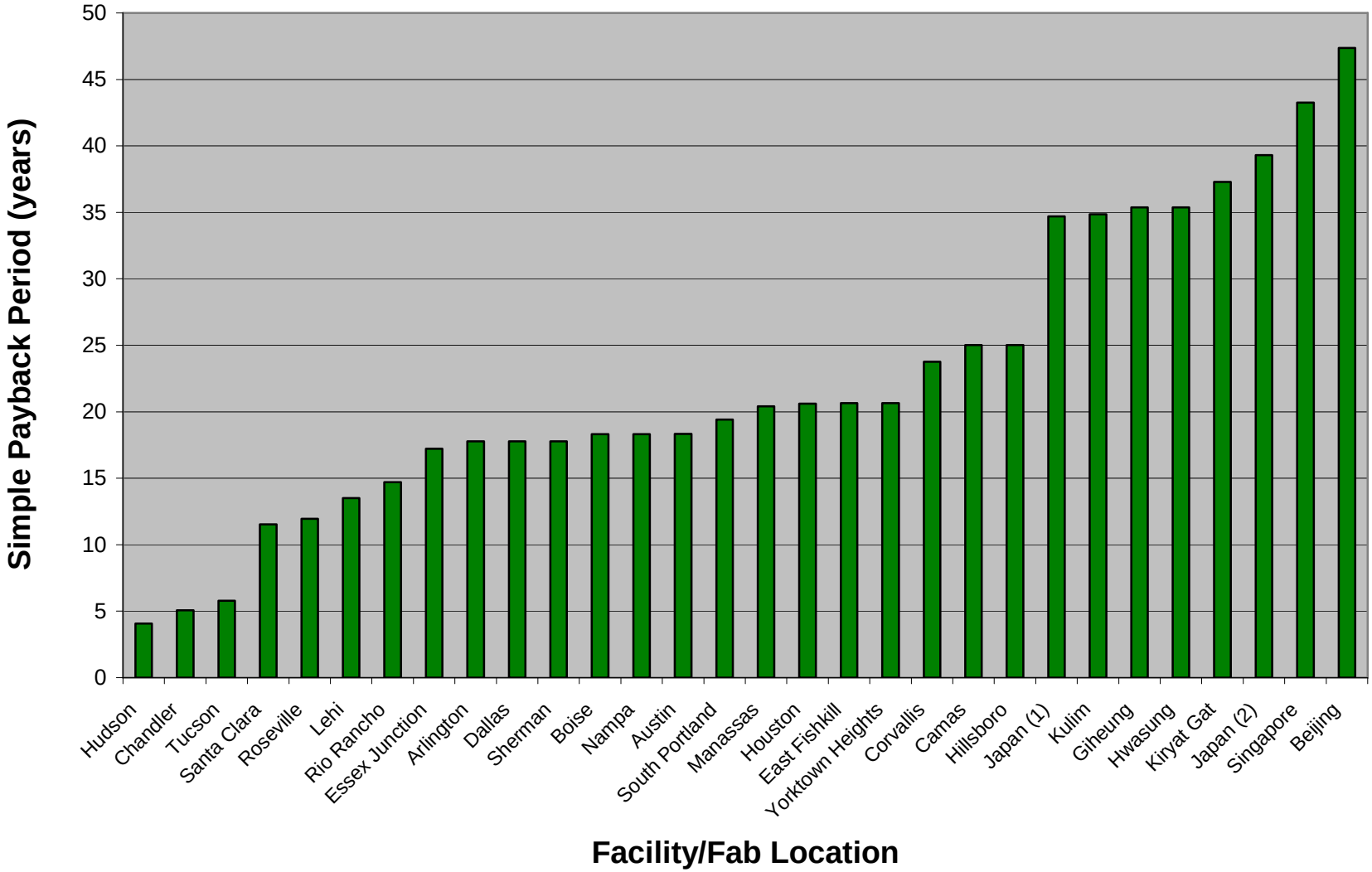
Economic Analysis of 837 kW Solar Thermal System Fab Industrial Hot Water Loop

(180 deg F supply, 150 deg F return, based on U.S. installed cost 1.08 million USD)



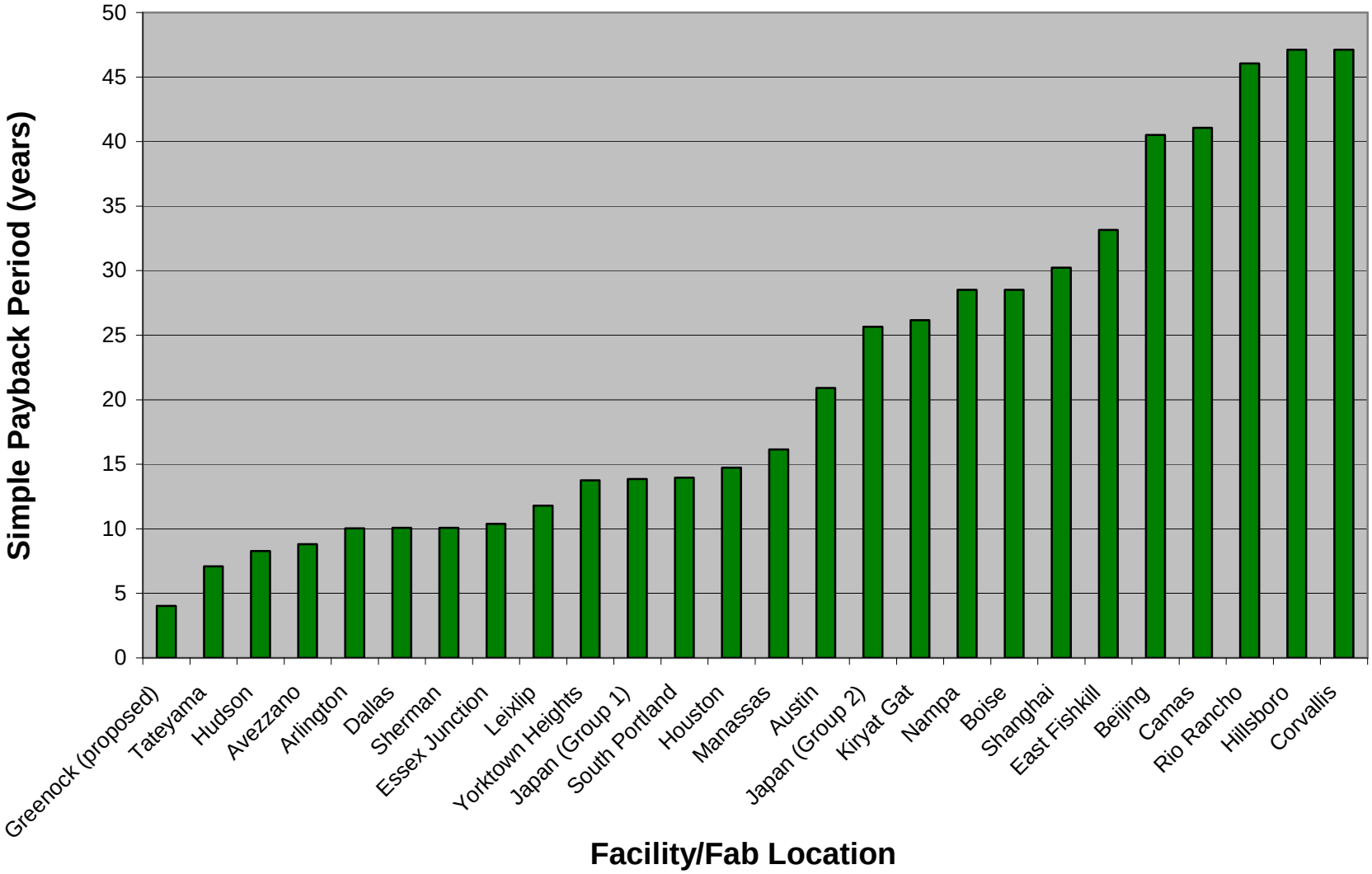
Economic Analysis of 80 kW Solar Thermal System Facility Domestic Usage

(120 deg F supply, based on U.S. installed cost 160K USD)



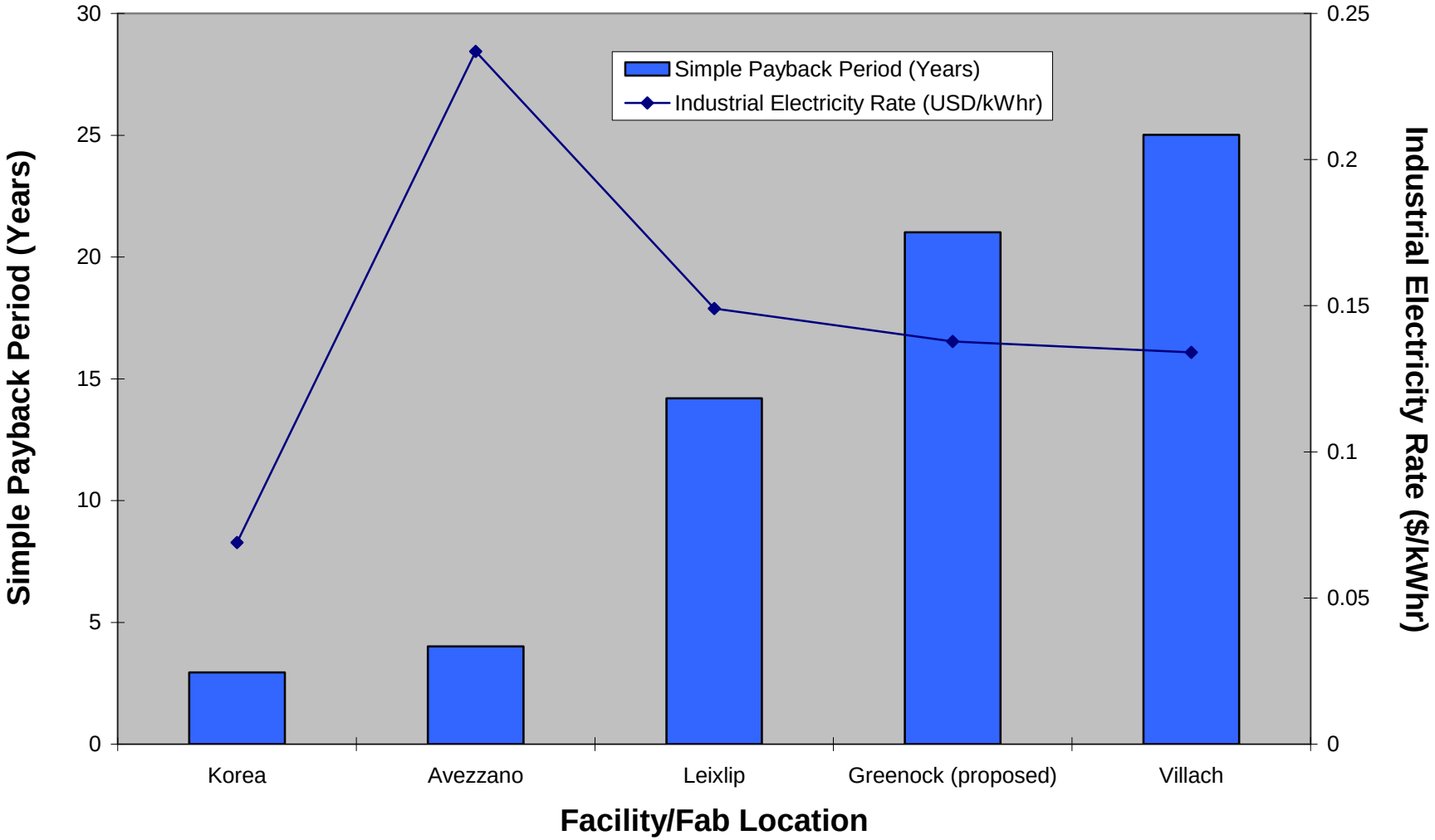
Economic Analysis of 100 kW (DC) Wind Turbine System

(based on U.S. installed cost 386K USD)



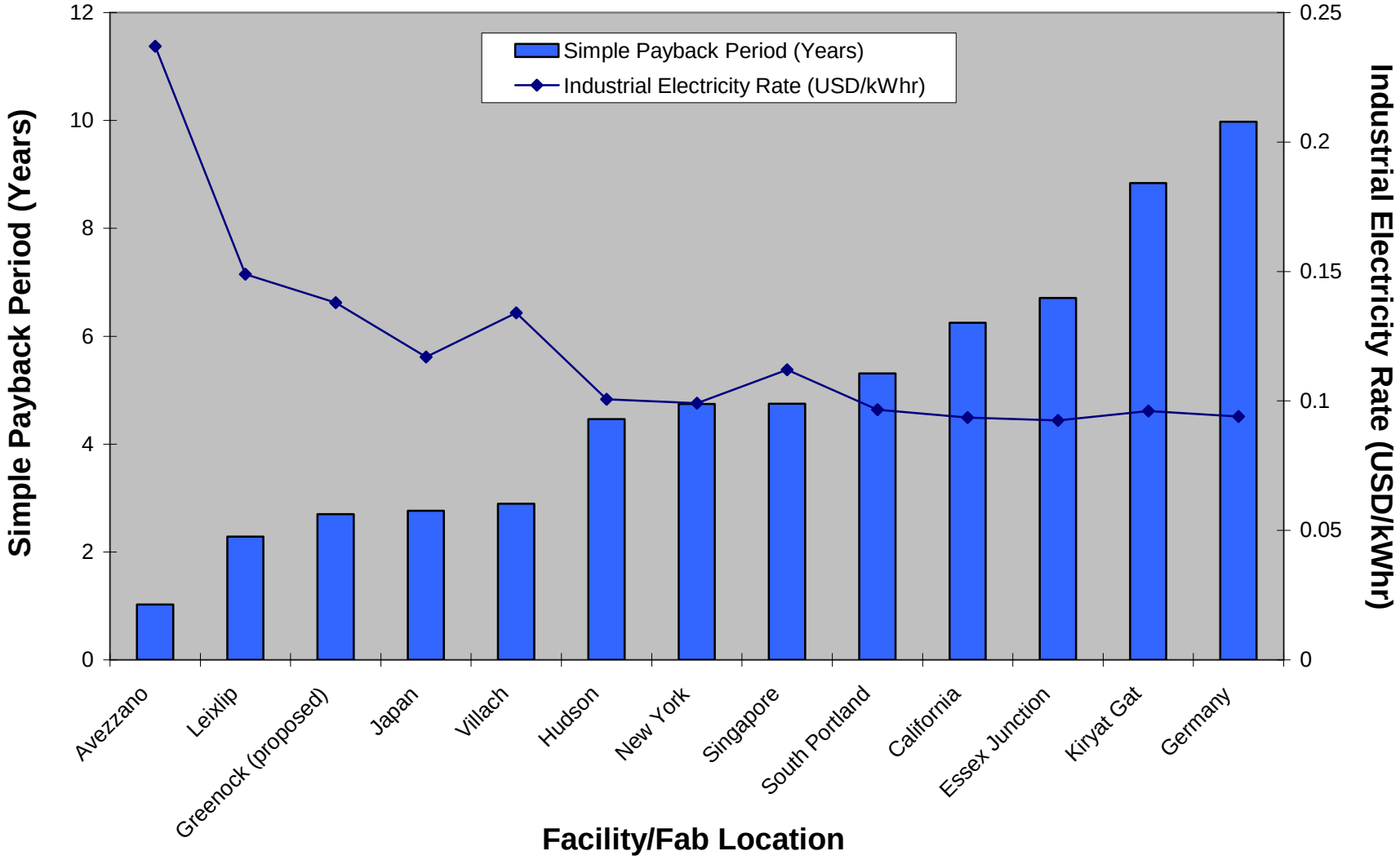
Economic Analysis of 1 MW Fuel Cell System

(based on U.S. installed cost 4.1 million USD)



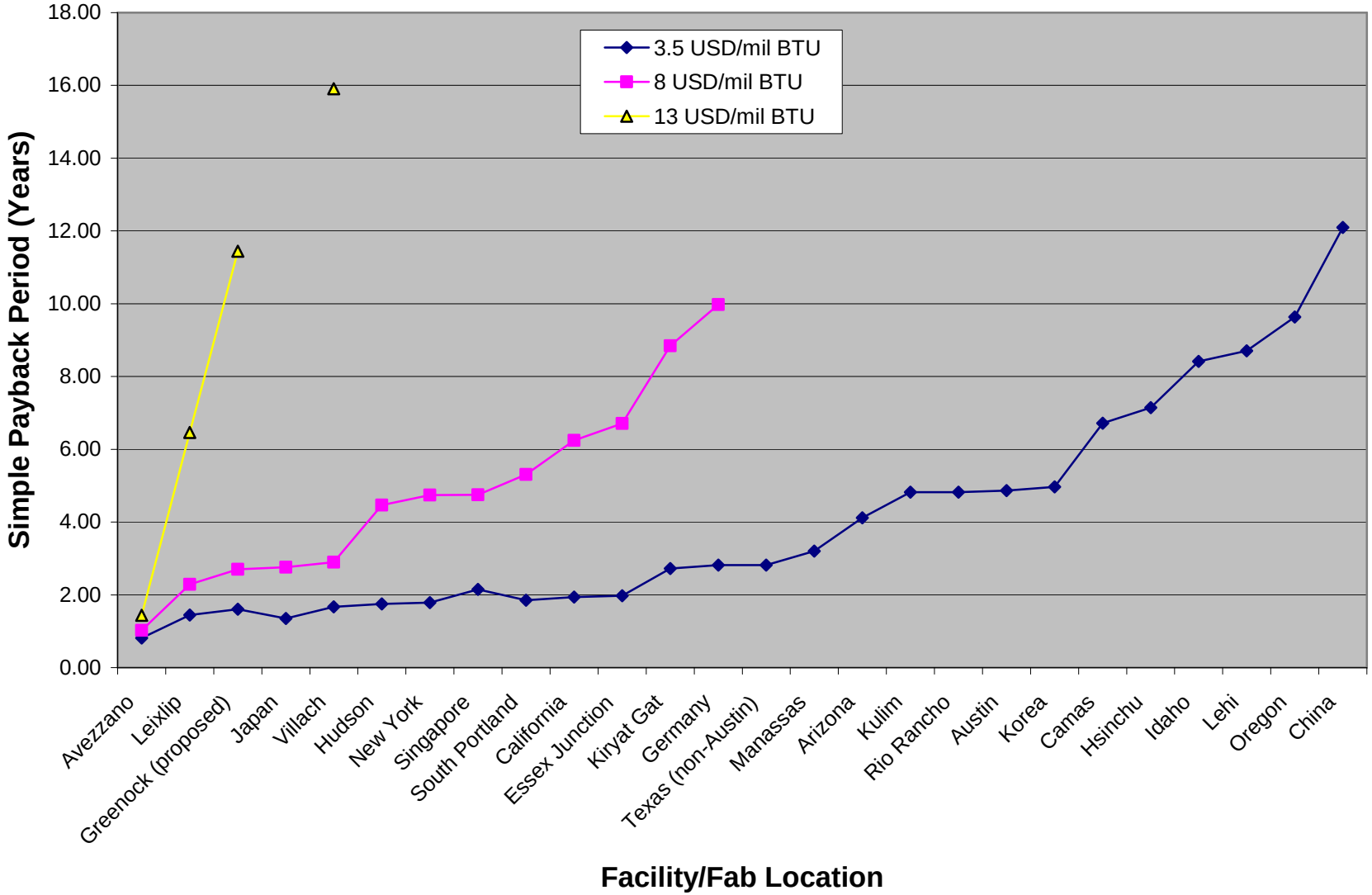
Economic Analysis of 10 MW Combined Heat and Power System

(based on U.S. installed cost 12 million USD)



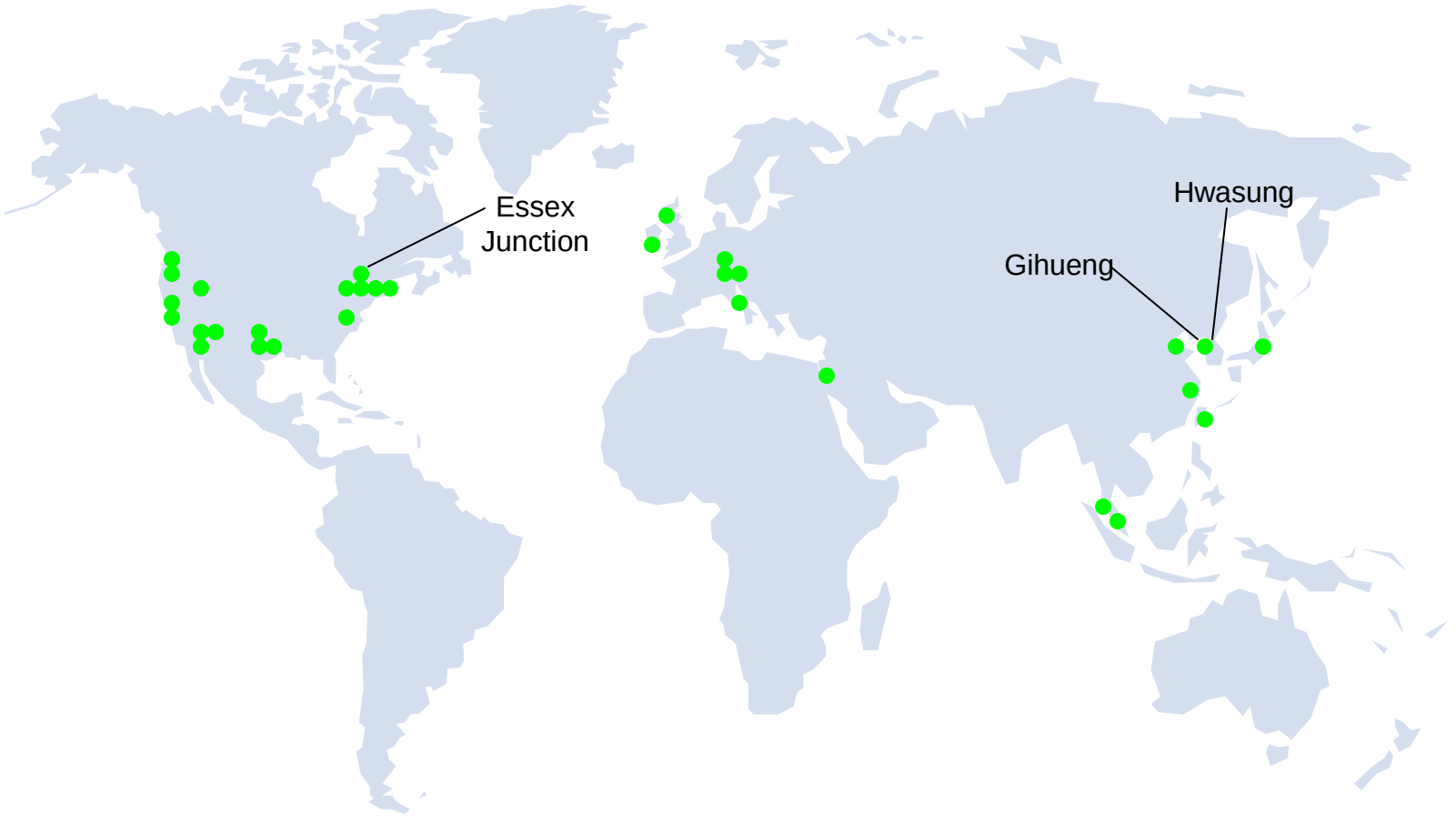
10 MW Combined Heat and Power System
Impact of Natural Gas Price

(based on U.S. installed cost 12 million USD)

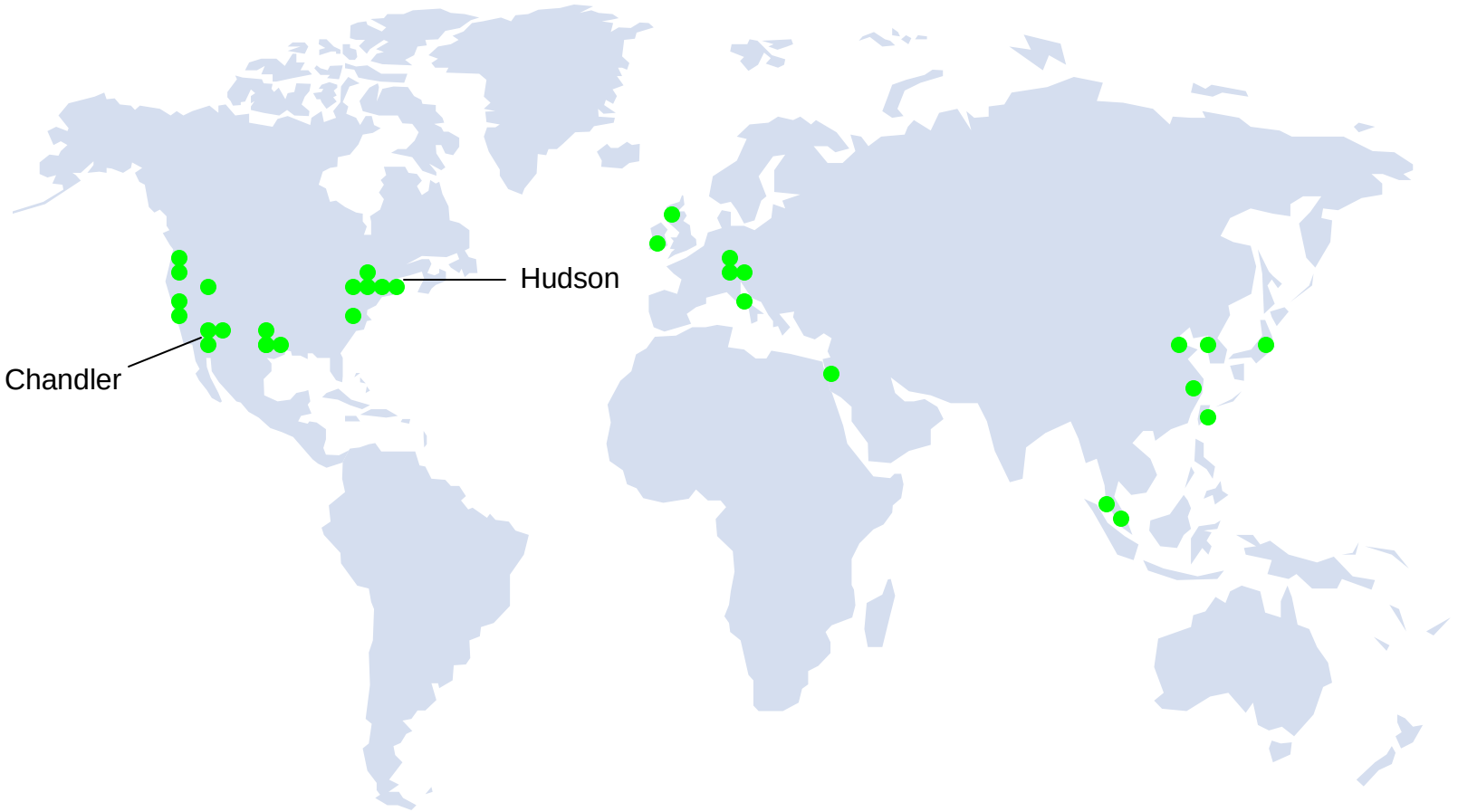


Member Company Locations with < 5-yr Payback
19.5-50 kW Solar - PV

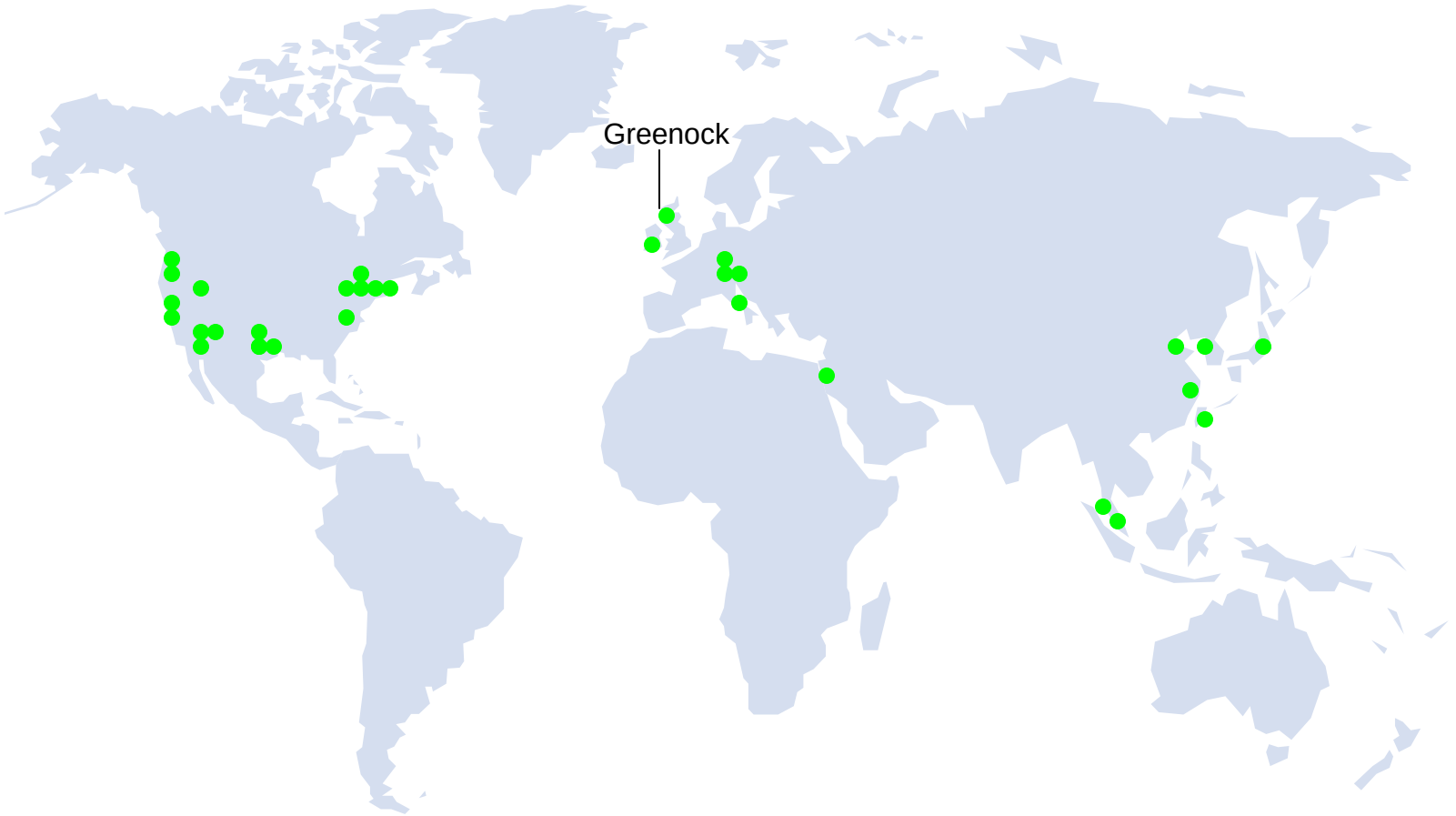
Member Company Locations with < 5-yr Payback
350 kW Solar - PV



Member Company Locations with < 5-yr Payback
80 kW Solar Thermal - Domestic



Member Company Locations with < 5-yr Payback
100 kW Wind Turbine

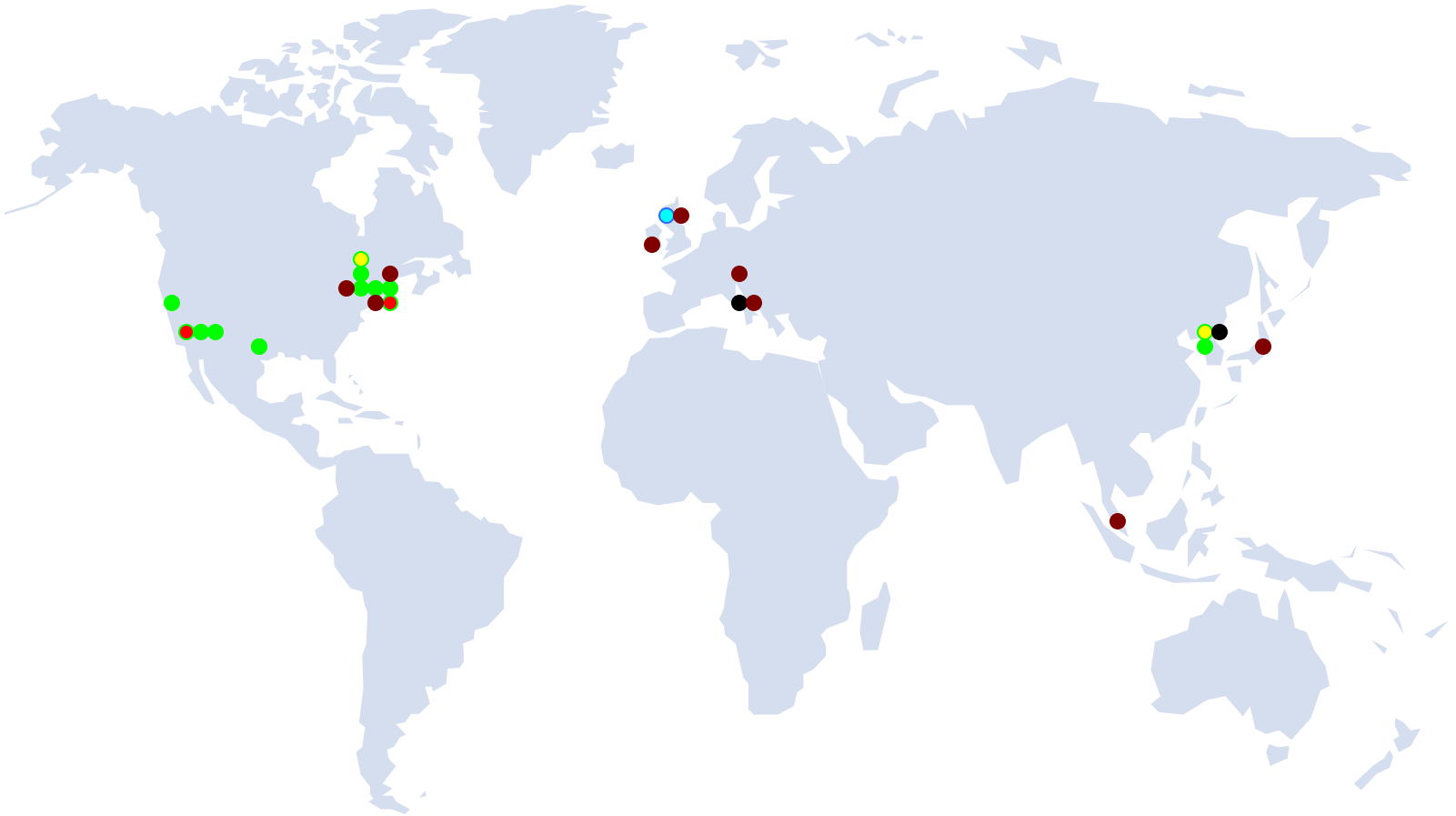


Member Company Locations with < 5-yr Payback
1 MW Fuel Cell

Member Company Locations with < 5-yr Payback
10 MW CHP

(Nat. Gas Cost = 8 USD/million BTU)

Summary of AE/RE Technologies at Member Company Sites (< 5-yr Payback)



Solar PV - small Solar (350 kW) Solar Thermal Wind (100 kW) Fuel Cell CHP

Other Renewable Energy Options (1)

City	Country	Green Power Available?
	Austria	Yes
	China	Trial Basis
	Germany	Yes
	Ireland	Yes but not certified
	Israel	No
	Italy	Yes
	Japan	Yes
	Korea	No
	Malaysia	No
	Scotland	Yes but not certified
	Singapore	Yes but not certified
	Taiwan	No
Arlington	US	Yes
Austin	US	Yes but not certified
Boise	US	Yes
Camas	US	Yes
Chandler	US	Yes
Corvallis	US	Yes
Dallas	US	Yes
East Fishkill	US	Yes
Essex Junction	US	Yes but not certified
Hillsboro	US	Yes
Houston	US	Yes
Hudson	US	Yes
Lehi	US	Yes
Manassas	US	Yes
Nampa	US	Yes
Rio Rancho	US	Yes
Roseville	US	Yes but not certified
Santa Clara	US	Yes
Sherman	US	Yes
South Portland	US	No
Tucson	US	Yes
Yorktown Heights	US	Yes

Green Power – renewable power available from local utilities

- A way to support the renewable energy industry and reduce environmental impact
- Available to most member company sites
- In some cases, can select technology (solar, wind, biomass, geothermal, hydrokinetic) to support preferred or lower impact technology
- Cost premium of 0.5 to 10 U.S. cents/kWhr
- Hedge against rising electricity costs
- Six of ten member companies with sites in the U.S. purchase green power

Other Renewable Energy Options (2)

- Renewable Energy Certificate (REC) – “represents the property rights to the environmental, social, and other nonpower qualities of renewable electricity generation. A REC, and its associated attributes and benefits, can be sold separately from the underlying physical electricity associated with a renewable-based generation source” EPA, 2009
  - 1 REC = 1 MWhr
  - Available to all member companies, only 1 of 14 purchases RECs
  - Can get them from any source and apply them to any facility
  - Prices can vary from $5 to $90 and depend on many factors
  - Another way to support the renewable energy industry and reduce environmental impact

Green Power vs. RECs vs. AE/RE Installations?

Conclusions

- Technologies readily installed at member company sites include solar PV, solar thermal, small wind, fuel cells, and CHP.
- Rapidly declining costs and generous incentives currently give some technologies at some sites **payback periods of 1 to 5 years**, which fit within most member company requirements.
- The most promising AE technology is CHP, which can generate 100% of facility power usage.
- The most promising RE technology is Solar-PV, but most power used at a facility will still come from the grid.

What's Next?

- Increased deployment of technologies will continue to bring down costs and increase conversion efficiencies.
- Carbon cap & trade regulations and tight fuel supplies will increase conventional electricity costs.
- Governments and utilities will scale back incentives for technologies that reach price parity in order to encourage manufacturers to continue cost reduction and efficiency improvement.
- For many technologies, price parity **without** incentives will be reached within 5 to 10 years.

Thank You !!