Renewable Energy Sources

Monday, August 7, 4:00 - 5:30, Session A

2006 Energy

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NREL

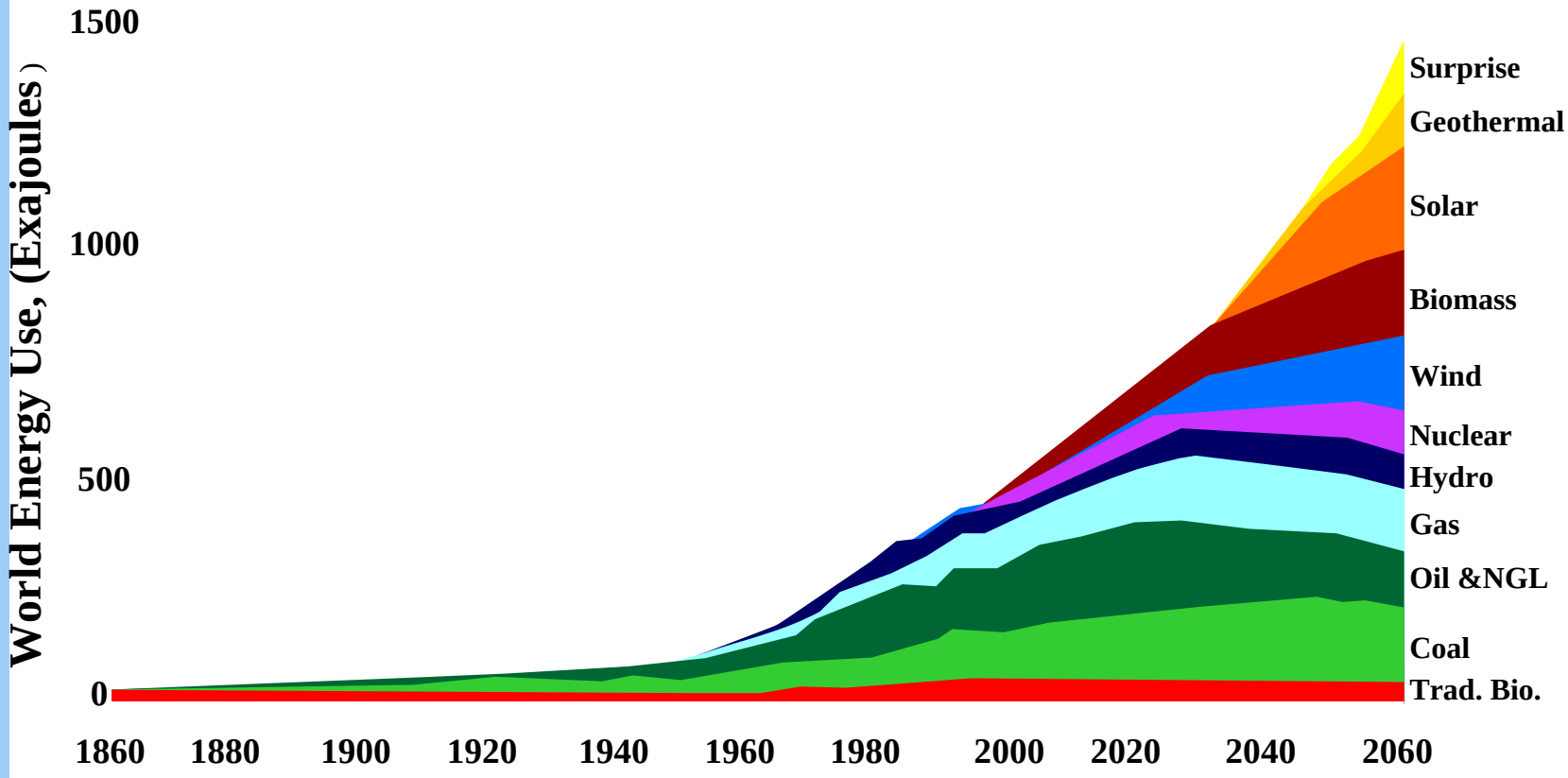
Content

Body Shop: Building Strategies

- Passive Solar Building Design
- Photovoltaics
- Concentrating Solar Power
- Solar Hot Water
- Solar Ventilation Preheat
- Ocean Thermal Energy Conversion
- Wind
- Renewables on Public Lands
- Renewable Market Drivers

The Future of Energy

Body Shop: Building Strategies



Source: *Shell, The Evolution of the World's Energy Systems*, 1995

Passive Solar Building Design

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Direct Gain

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NREL Thermal Test Facility

Sunspace

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NREL Solar Energy Research Facility

Trombe Wall

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NREL Solar Energy Research Facility

Case Study: NPS Zion Visitor Center

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Zion Visitor Center Energy Use

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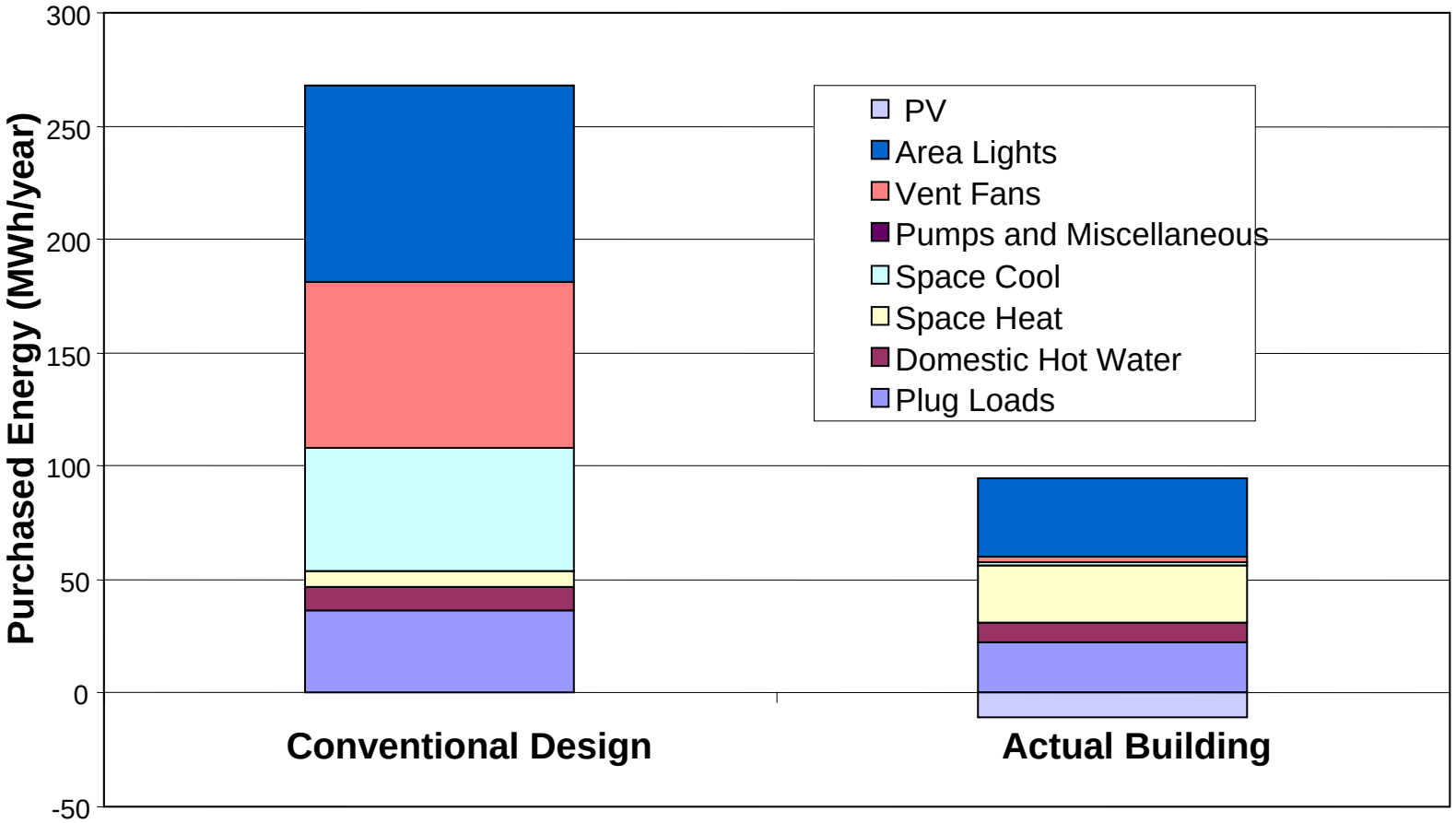

Photovoltaics

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Cost Effective PV Applications

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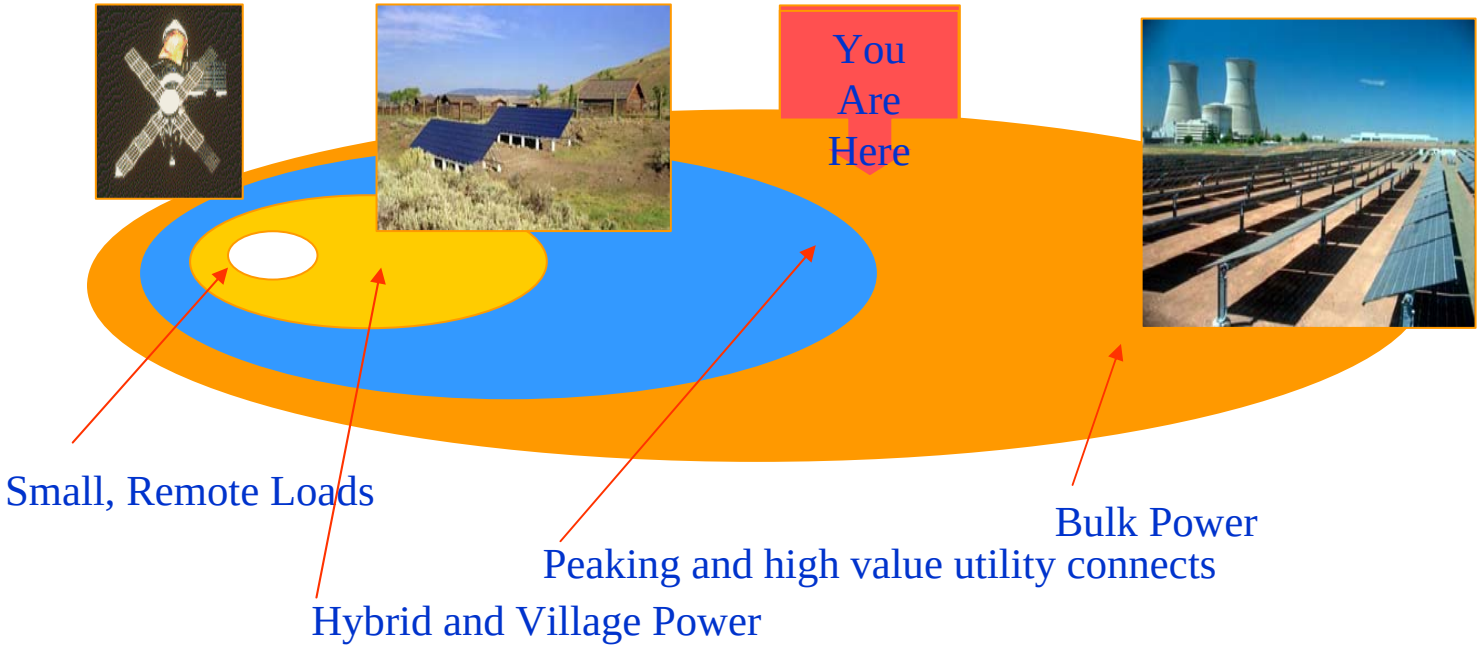
As the cost of PV comes down, and the cost of alternatives go up, PV applications grow from high-value niche applications to widespread use.



World PV Production

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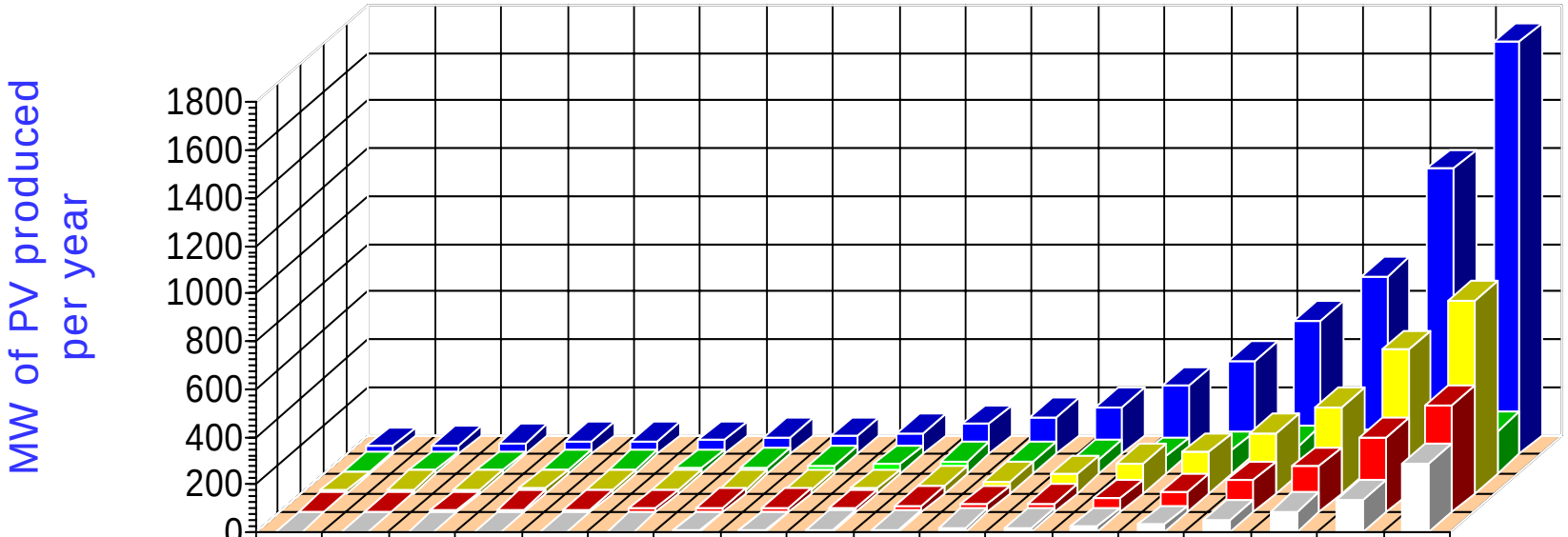

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Rest of World	3	4	4.7	5	4.6	4.4	5.6	6.35	9.75	9.4	18.7	20.5	23.42	32.6	55	83.8	140	290
Europe	6.7	7.9	10.2	13.4	16.4	16.55	21.7	20.1	18.8	30.4	33.5	40	60.66	86.38	135	193.3	314.4	450
Japan	12.8	14.2	16.8	19.9	18.8	16.7	16.5	16.4	21.2	35	49	80	128.6	171.2	251	363.9	602	810
United States	11.1	14.1	14.8	17.1	18.1	22.44	25.64	34.75	38.85	51	53.7	60.8	74.97	100.3	120.6	103	139	180
Total	33.6	40.2	46.5	55.4	57.9	60.09	69.44	77.6	88.6	125.8	154.9	201.3	287.7	390.5	561.8	744.1	1195	1727

Sources: *2004 World PV Cell/Module Production* from Paul Maycock, PV News, March and April issues, 2005; Energy Information Administration; NREL National Center for Photovoltaics

Simple DC PV System with Battery

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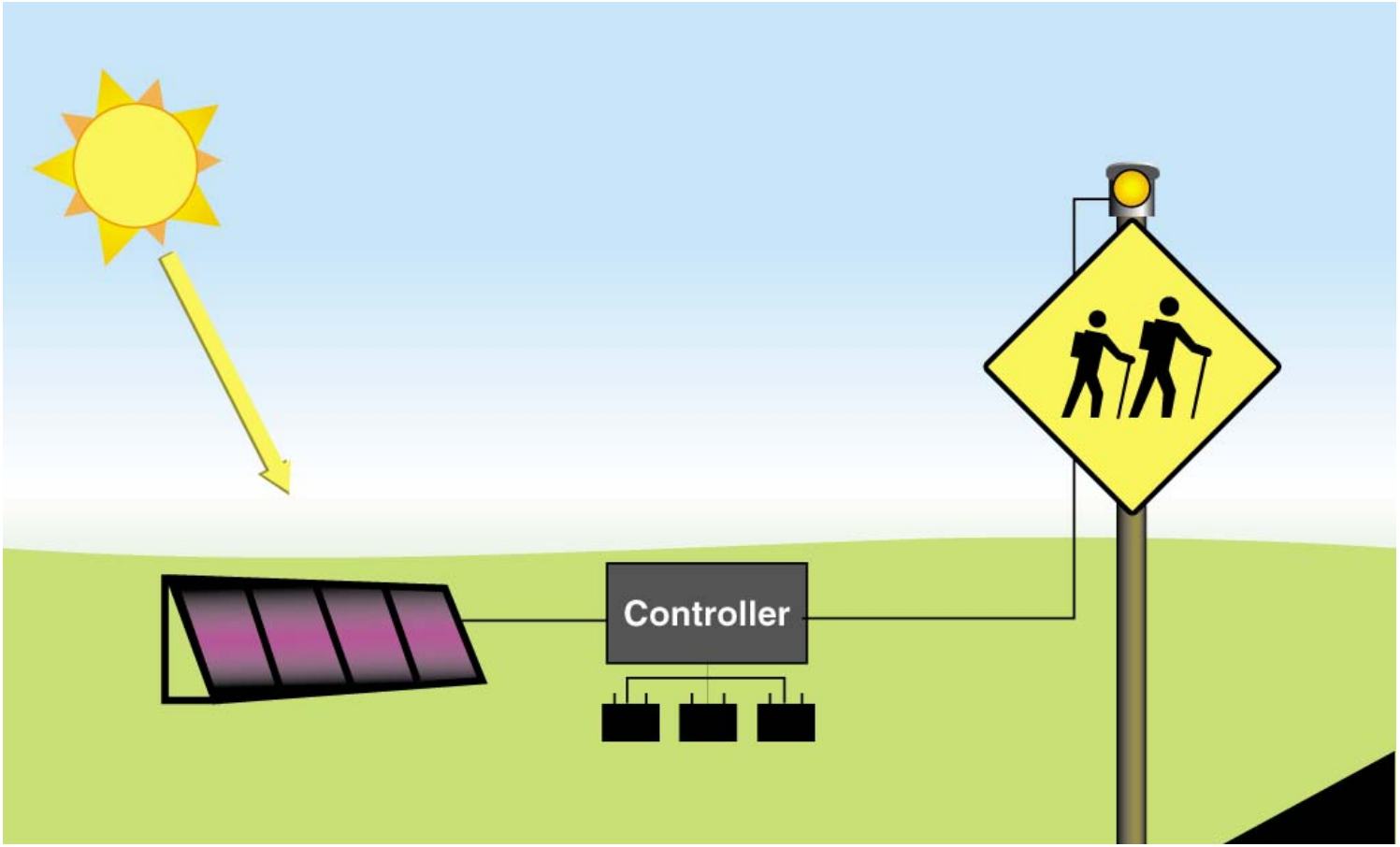

Case Study PJKK Federal Building, HI

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- 2 solar panels per lamp with peak output of 96 watts
- 39 Watt fluorescent lamps, 2500 lumens
- 90 amp-hour battery powers 12 hours per night
- ~$2500 per light

Grid-Connected PV System

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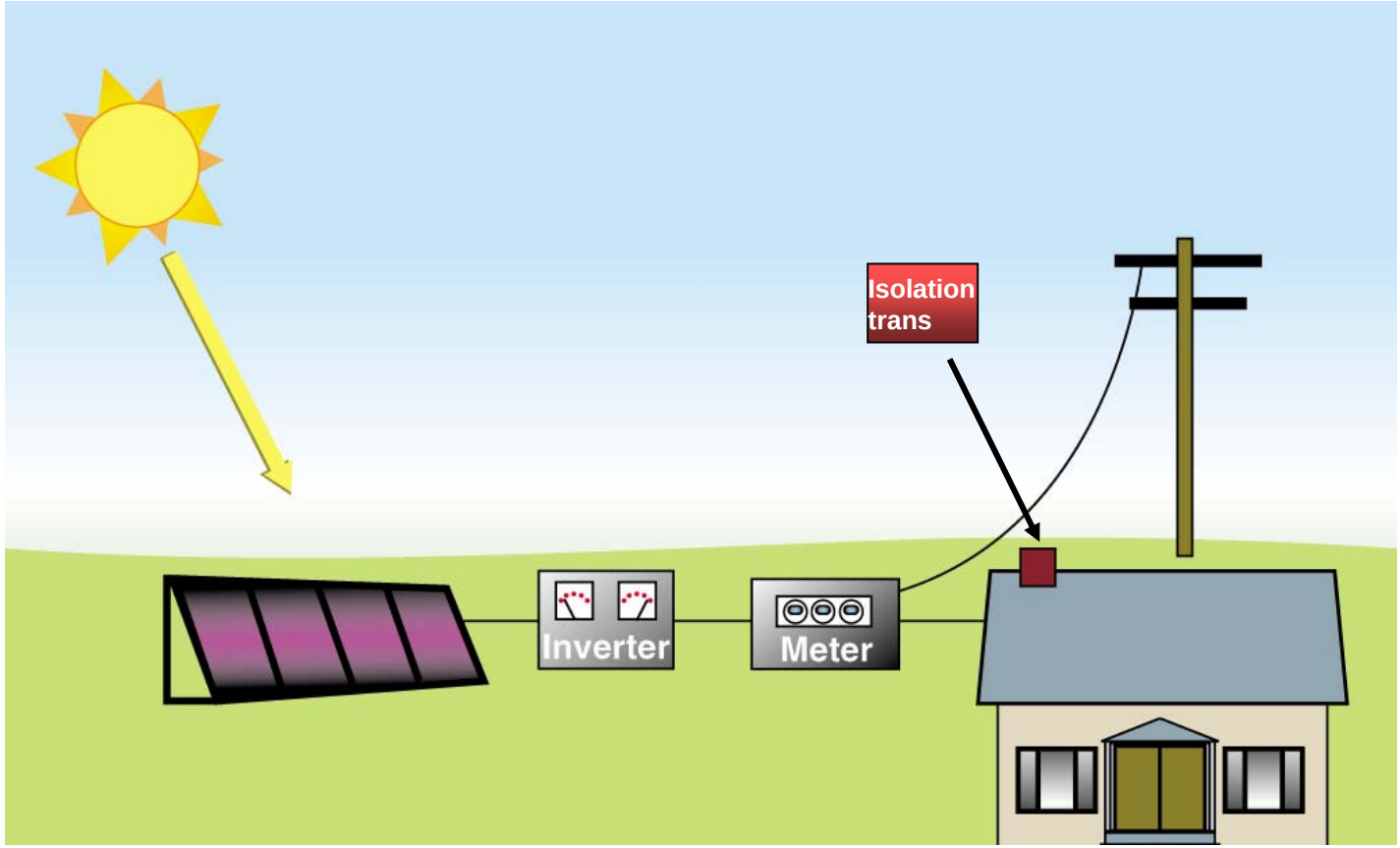

Utility-Connected PV Example: San Francisco, California

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- Building-Integrated Photovoltaics
- 1.25 kW PV Array
- Spacing between cells admits daylight into entry atrium below

Roofing Shingles

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Installing 17W integrated roofing shingle manufactured by United Solar

PV Integrated Membrane Roof

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100 kW photovoltaic rooftop array

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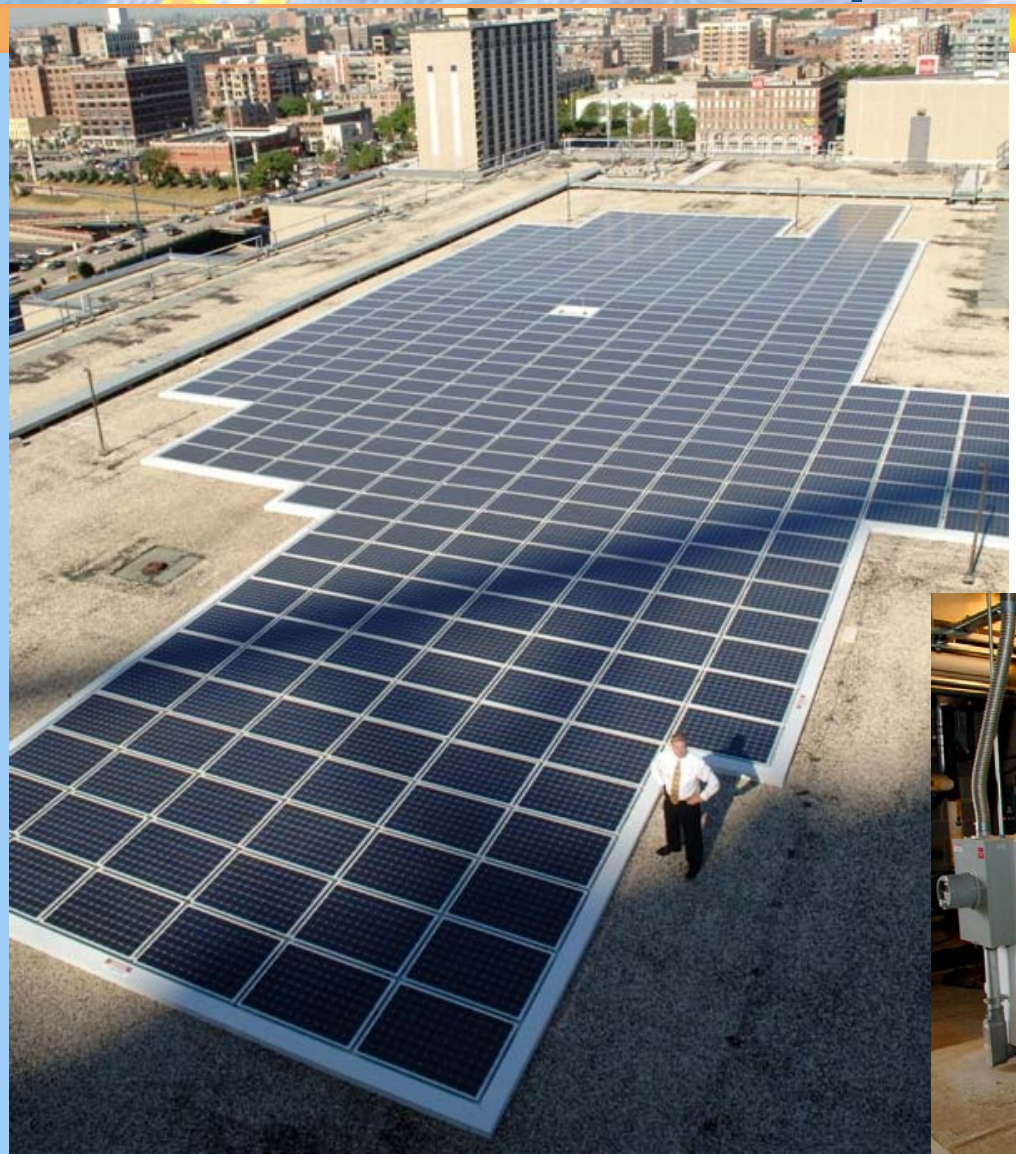

Harold Washington Social Security Center here in Chicago

Meter Transformer & Inverter

Case Study: Naval Air Station North Island

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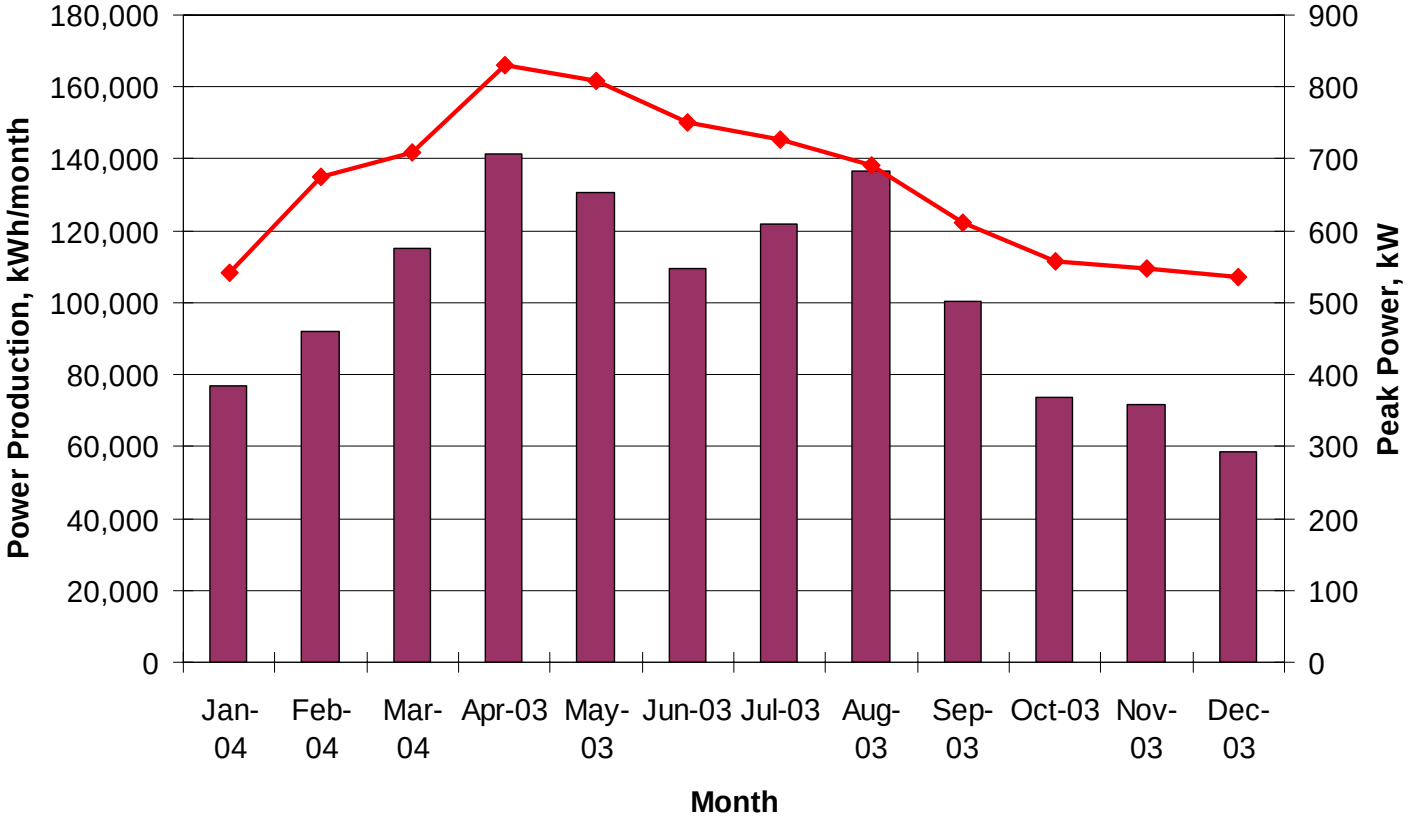
924 kW-rated, $7.7M cost ($8.28/W), $228k/year savings

NASNI PV System Performance

Body Shop: Building Strategies



829 kW AC maximum delivery

1,228,658 kWh/year delivery

PV Generation Station, 5 MW, Tracking and Fixed Arrays, APS (test site)

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Hybrid PV/Generator System

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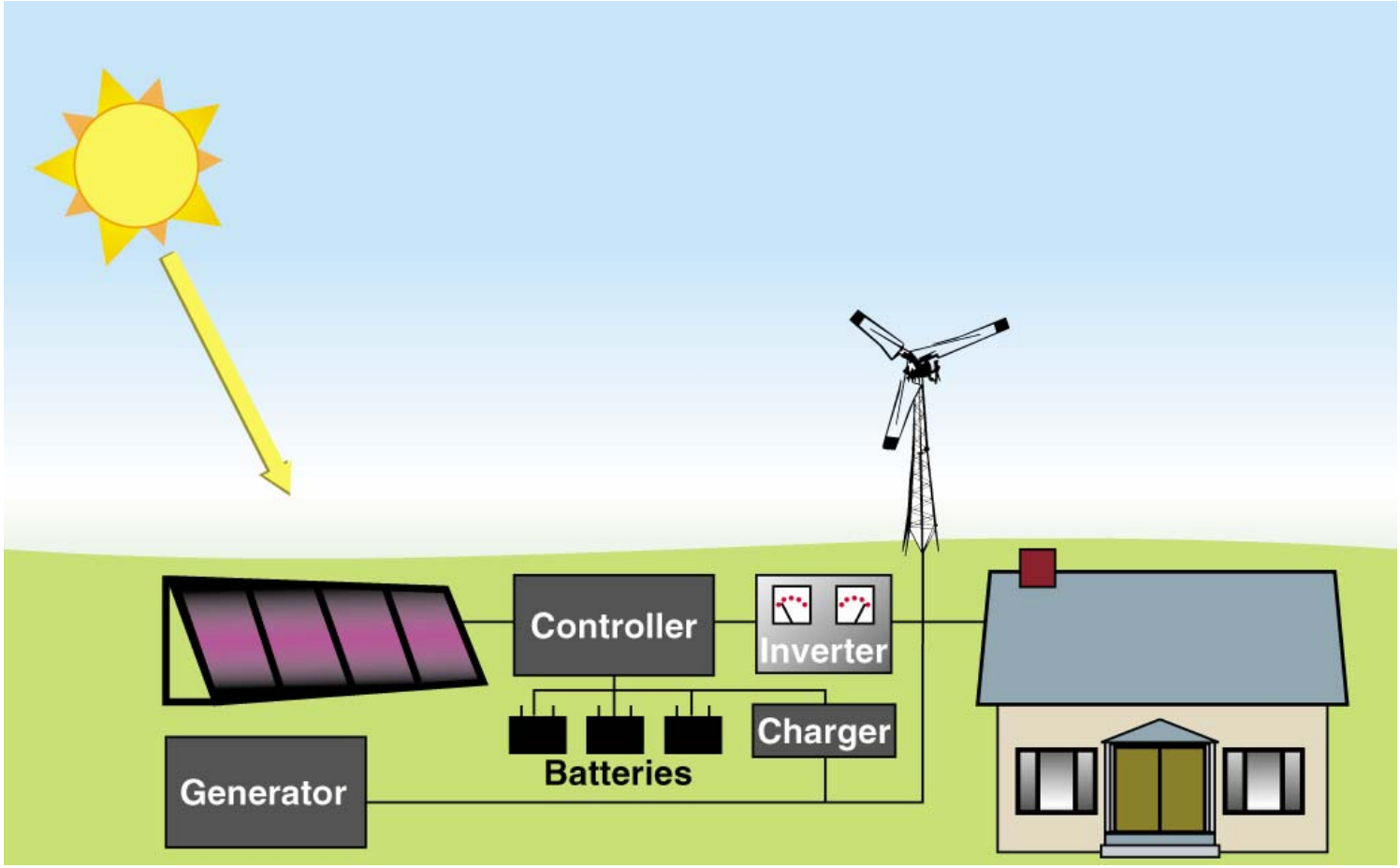

Case Study: Joshua Tree National Park

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- 20.5 kW PV Array
- 613 kWh battery bank
- 35 kW propane generator
- $273,000 cost financed by Southern California Edison under 15 year tariff

US PV Shipments by End Use

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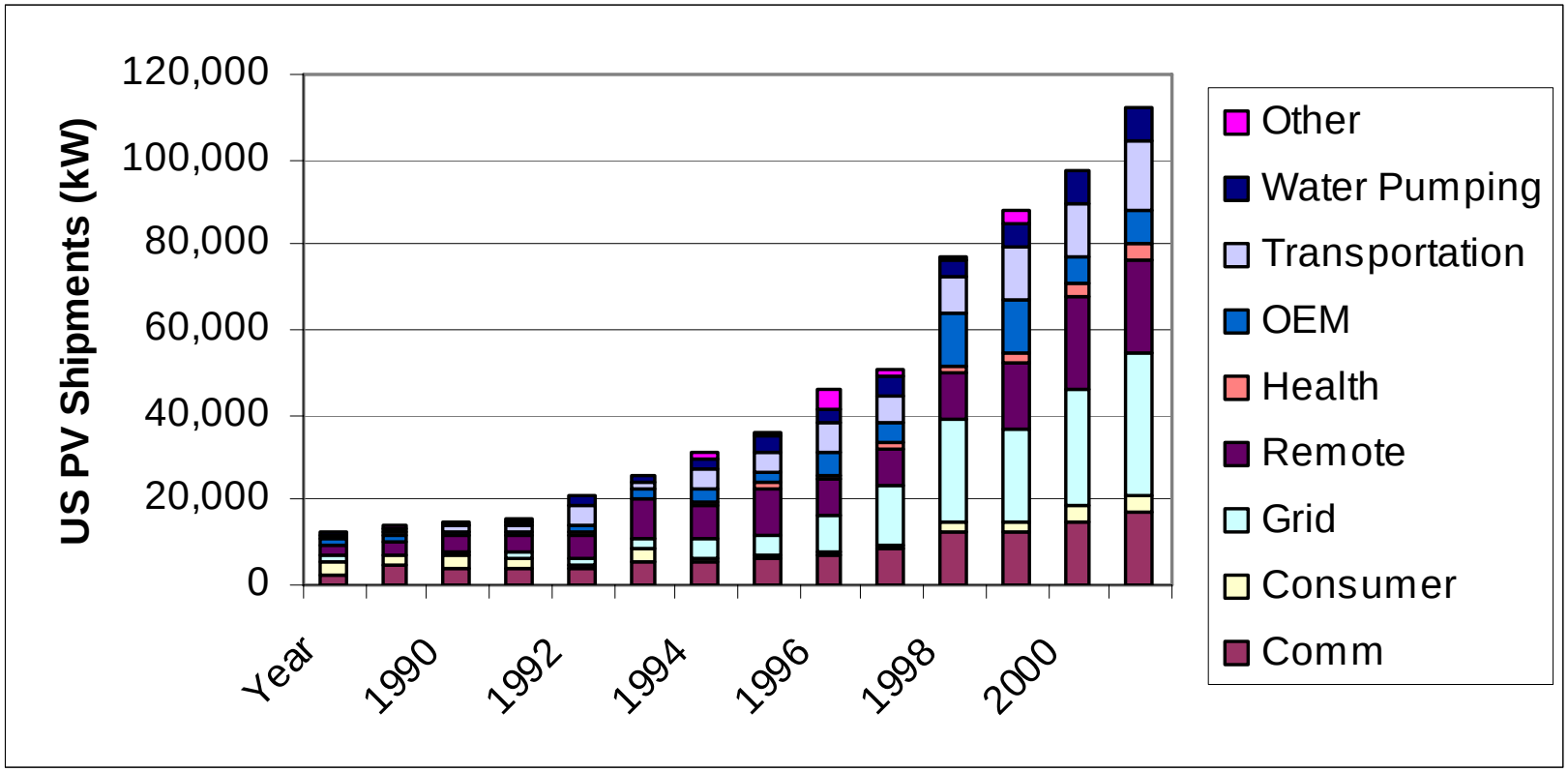
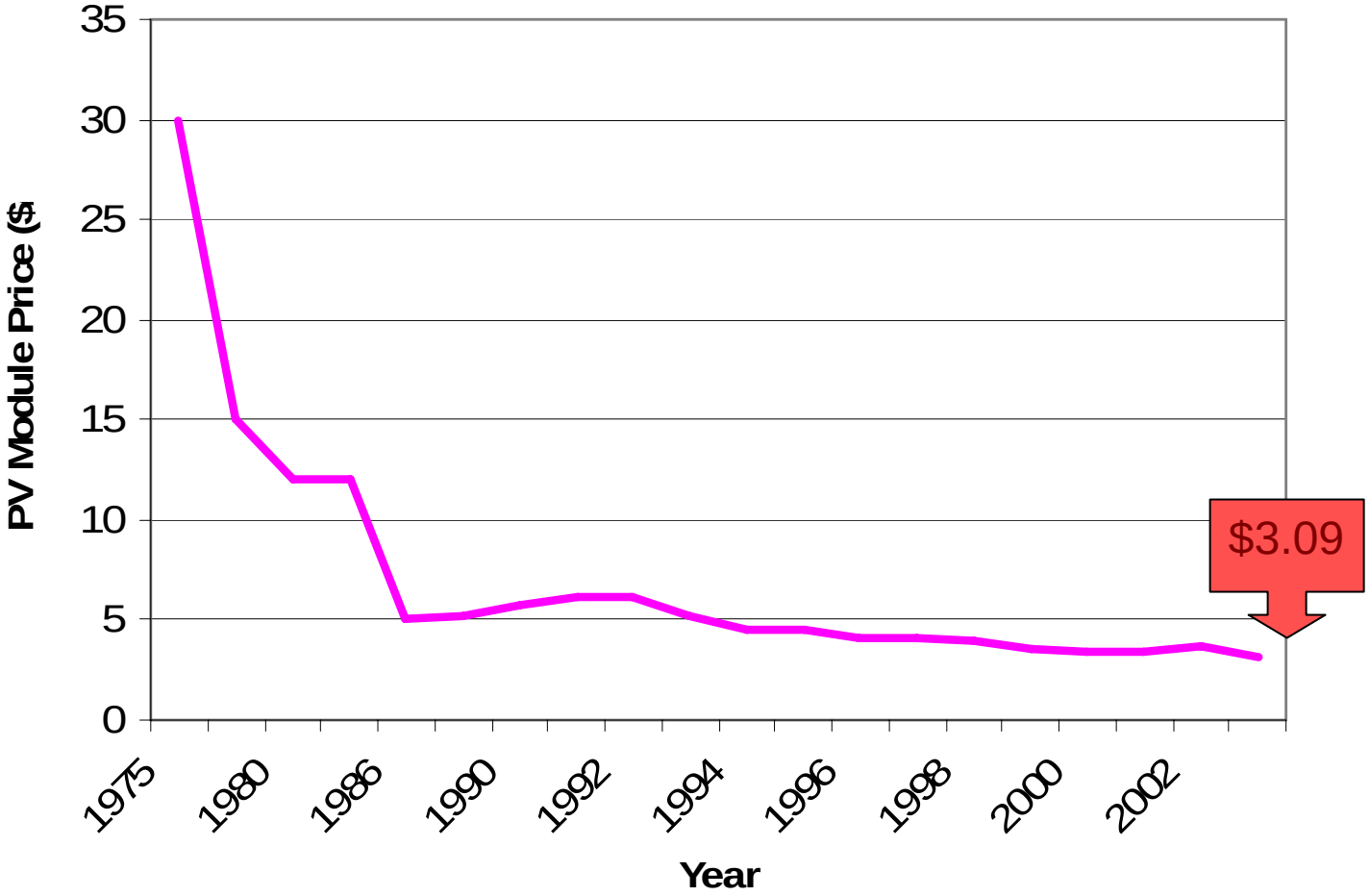


Price of PV Modules

Body Shop: Building Strategies



Source: EIA 2005 data

Cost of Photovoltaic Systems

Body Shop: Building Strategies

- Small Grid Connected: $8,800/kw

	Material Cost ($/kW)	Labor Cost ($/kW)	Equipment Rental Costs ($/kW)	Total ($)
PV Modules	$5,730	$248	$107	$6,085
Roof Preparation	$100	$100	0	$200
Rack Structure	$150	$150	0	$300
Array Electrical	$300	$248	0	$548
Utility Connection	$10	$20	0	$30
Inverter	$590	$80	0	$670
Other Elect	$500	$200	0	$700
AC Disconnect	$33	$12	0	$44
DC Disconnect	$43	$12	0	$55
Isolation Transformer	$110	$55	0	$165
Total	$7,566	$1,124	$107	$8,796

- Small Off Grid with Batteries, etc

  <u>$17, 000/kW</u>

Source: RS Means “Green Building Project Planning and Cost Estimating”

Concentrating Solar Power

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Line-Focusing Parabolic Trough Systems

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CSP Schematic

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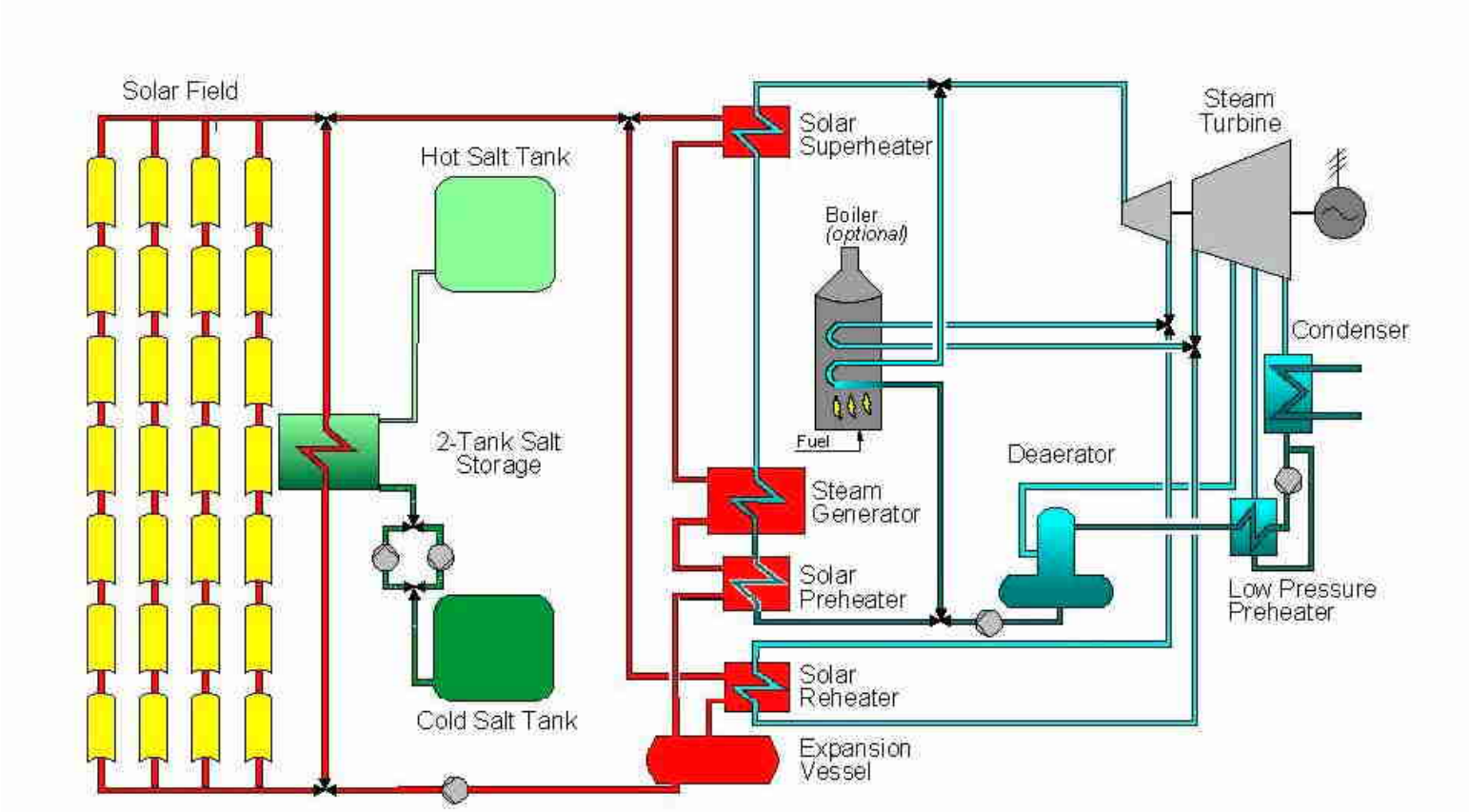

Solar Energy Generating Station (1 of 9)
100 MW, Mojave Desert, CA

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Dish Stirling - 6 25kW under test at SNL Albuquerque, NM

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Photo: R. Montoya, Courtesy of Stirling Energy Systems. Inc.

Solar Hot Water

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Types of Solar Water Heating Collectors

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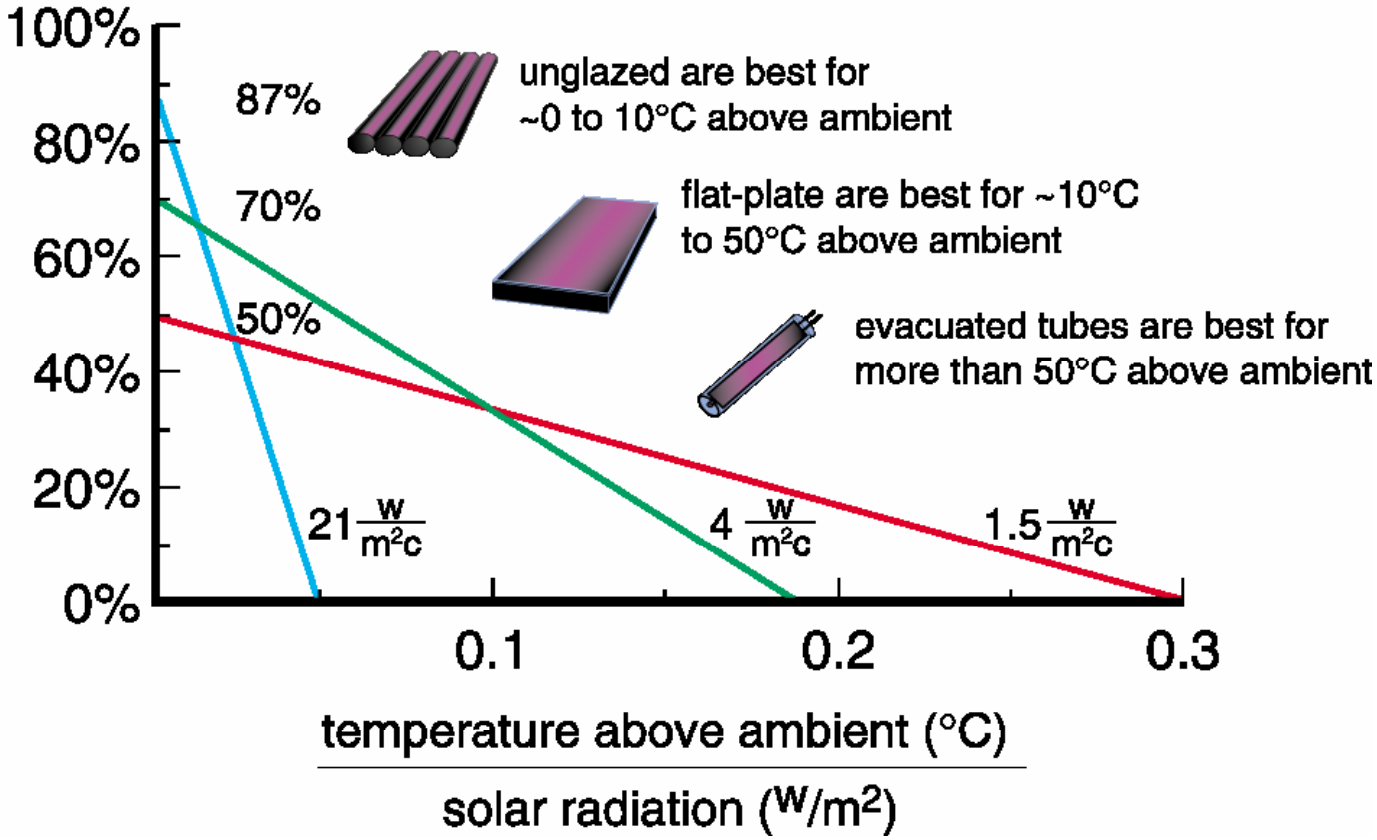
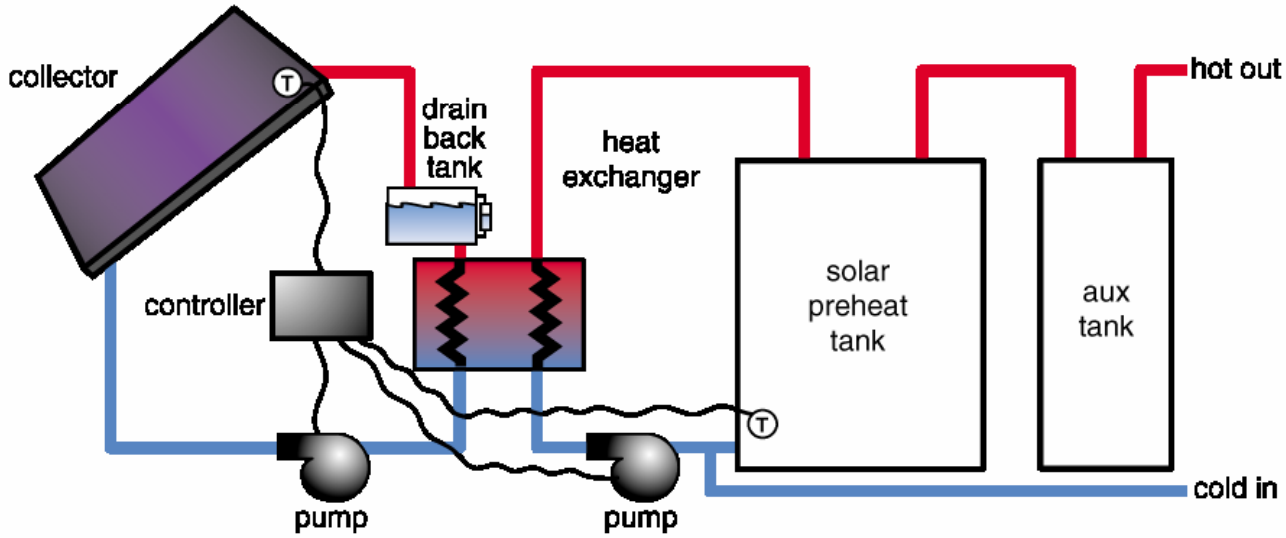
Efficiency = % of solar captured by collector



Solar Water Heating Systems

Body Shop: Building Strategies



- Freeze protection
- Overheat Protection
- Good hard water tolerance
- Maintenance requirements

US Solar Thermal Shipments

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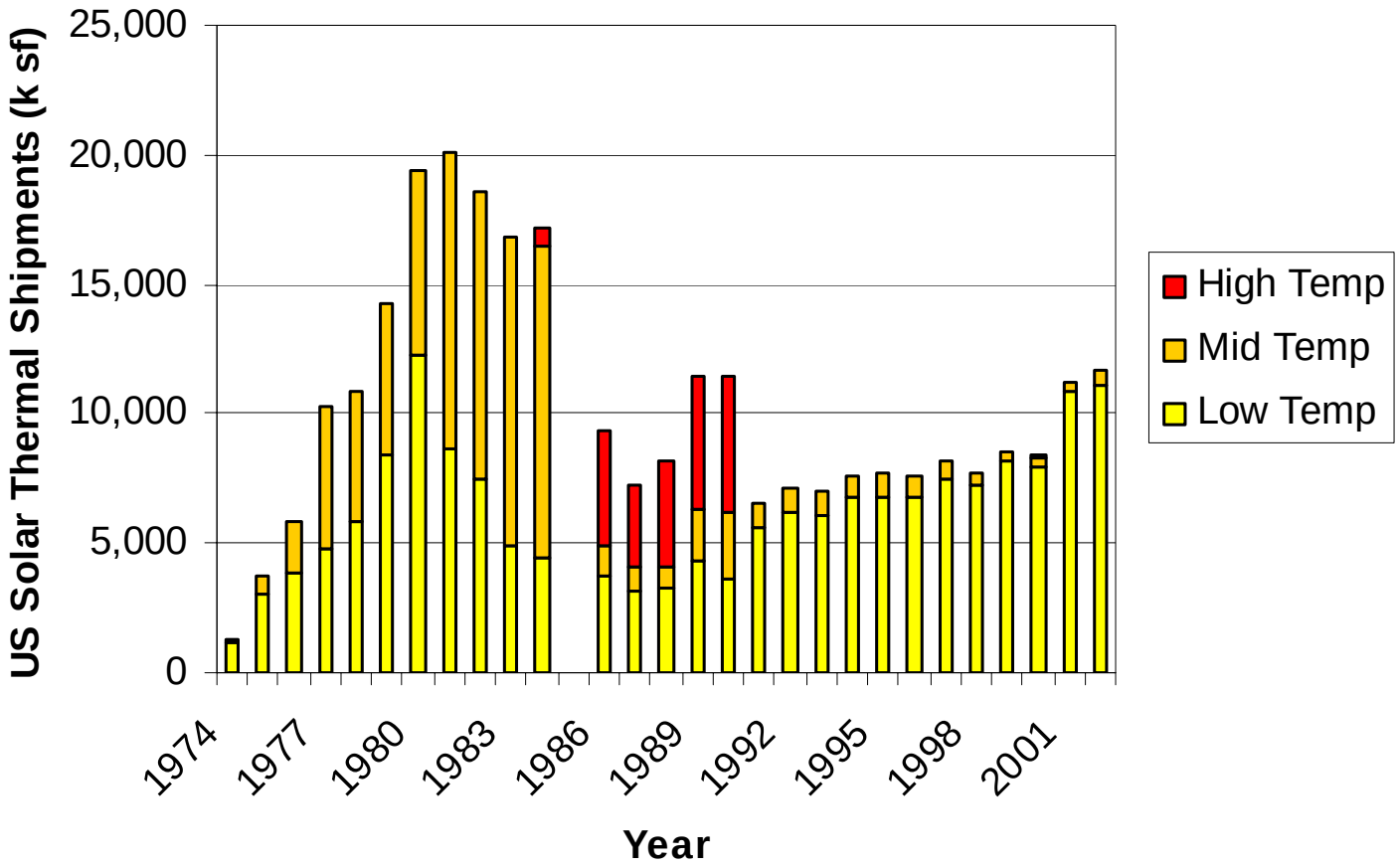

Source: EIA 2003 Data

Case Study: Swimming Pool Fort Huachuca, AZ

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- 2,000 square feet of unglazed collectors
- 3,500 square feet indoor pool
- Installed cost of $35,000
- Meets 49% of pool heating load
- Saves 835 million Btu/ year of natural gas
- Annual savings of $5,400
- Installed by the Army in June, 1980.

Solar Hot Water at SSA Philadelphia

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Case Study:USCG Housing, Honolulu HI

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- 62 units installed 1998
- 80 sf per system
- Cost $4,000 per system
- $800 per system HECO rebate
- Savings of 9,700 kWh/year and $822/year per system
- Simple Payback 4 years (with rebate)

Case Study:USCG Solar Water Heater Performance

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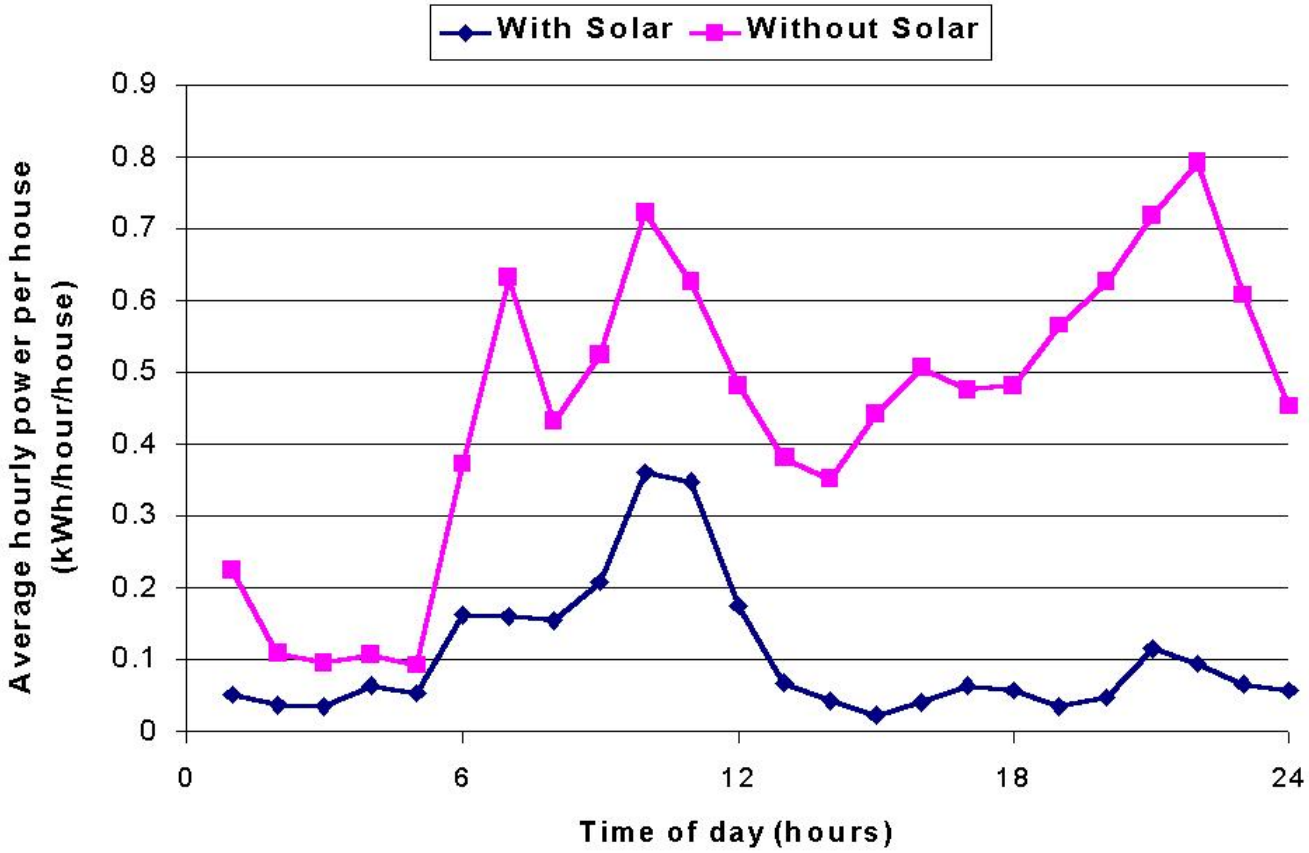

Case Study: Phoenix Fed.Correctional Inst.

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Case Study: FCI Phoenix Solar Water Heating

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- 17,040 ft2 parabolic trough solar field
- 23,000 gallon storage tank
- Installed cost of $650,000
- Saves $65,548/year average.
- Energy Savings Performance Contract (ESPC)
  - Prison pays Industrial Solar Tech. 90% of Arizona Public Service rate (10% savings)
- Term 20 years.

Case Study: FCI Phoenix Solar Performance

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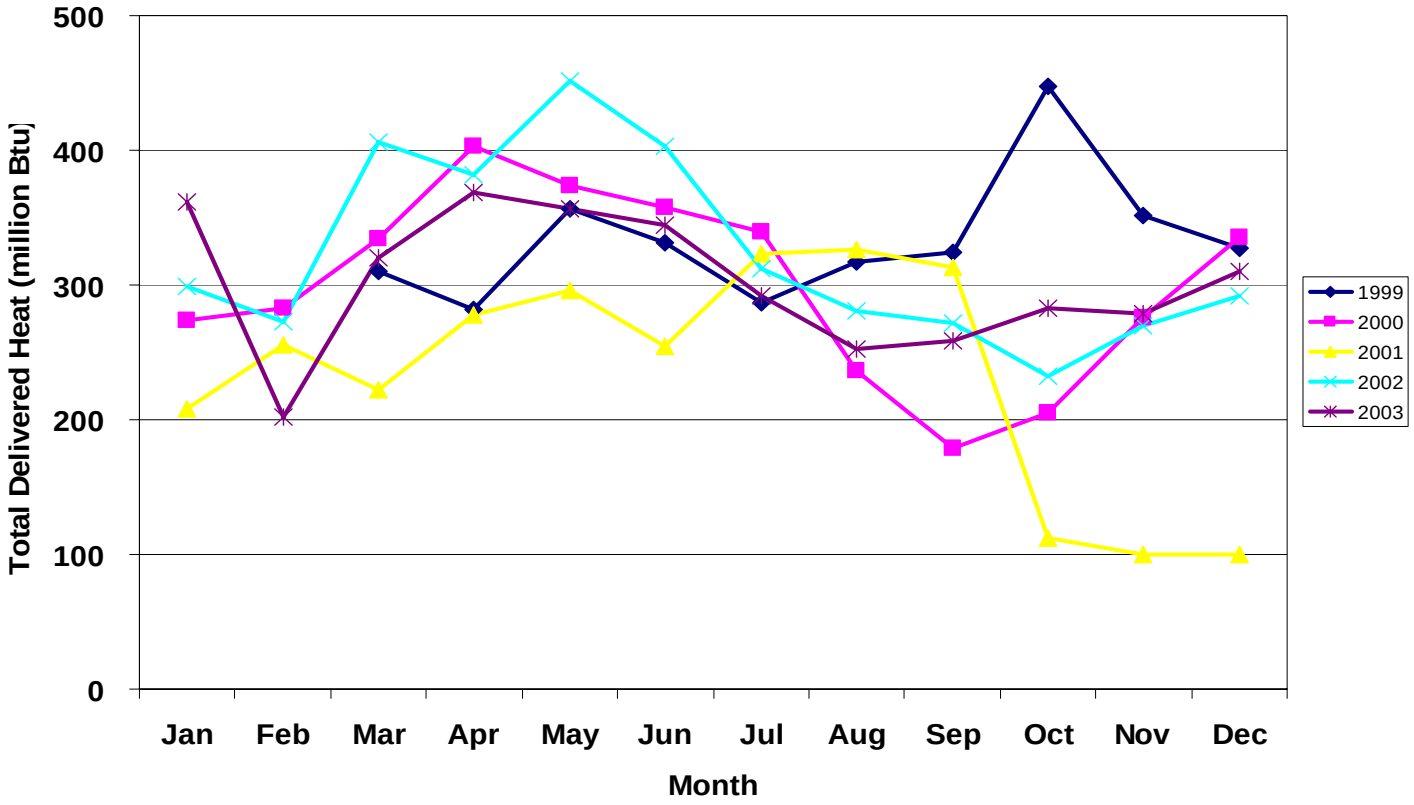

3,441 Million Btu/year average delivery

(1,008,499 kWh/year)

Solar Water Heating Costs

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- Single, small system $155/ft^2$
- Large central system $40/ft^2$
- Swimming Pool system $18/ft^2$

Source: RS Means "Green Building Project Planning and Cost Estimating, FCI Phoenix project

Solar Ventilation Preheat Transpired Solar Collectors

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Transpired Collector Principle

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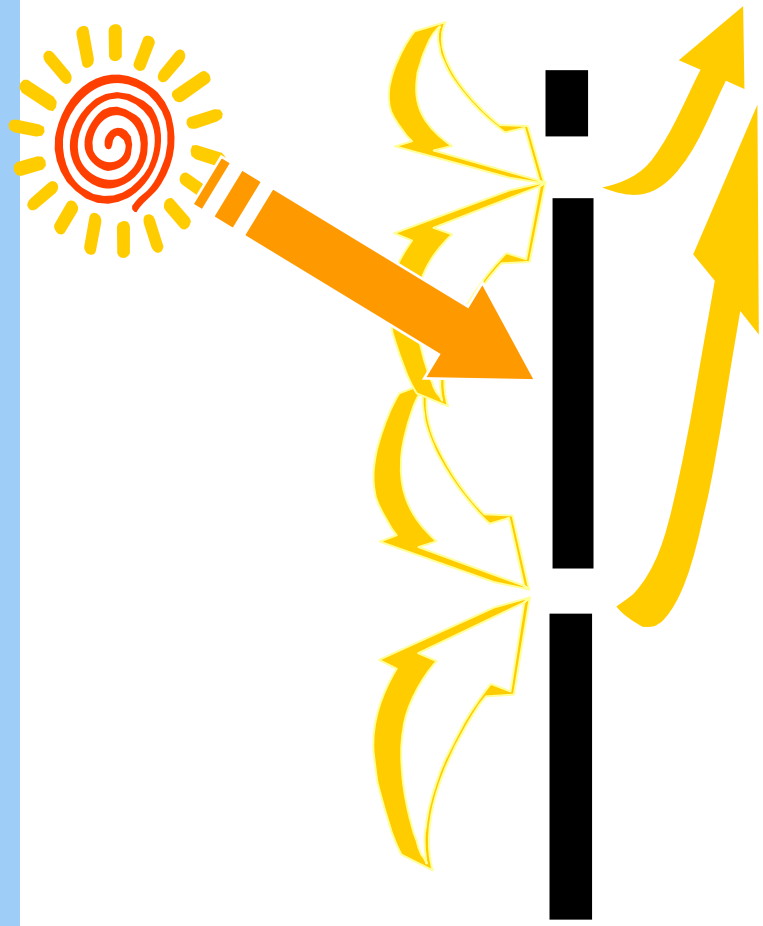

- Sun warms the surface
- Heat conducts from surface to thermal "boundary layer" of air 1 to 3 mm thick
- Boundary layer of air is drawn into hole before heat can escape by convection

Solar Ventilation Air Preheating System

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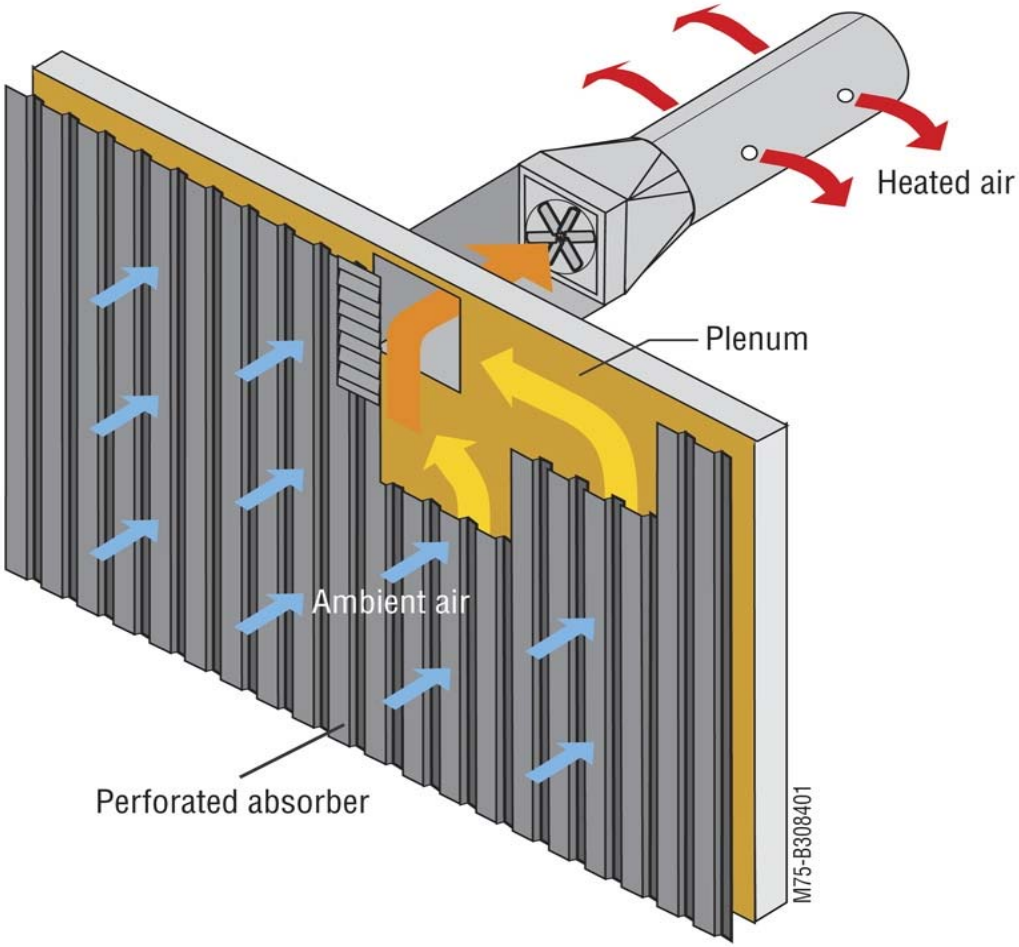

Typical Applications

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- Preheating ventilation air for:
  - Industrial and maintenance buildings.
  - School and institutional buildings.
  - Apartment buildings.
  - Commercial and penthouse fans.
  - Aircraft hangers.
- Crop drying
- Process air heating

Case Study: NREL Chemical Storage

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- 300 ft^2
- 3,000 CFM
- $6000 cost
- 63% measured efficiency
- Saves 14,310 kWh/year
- Saves $726/year of electric heat (no flames allowed in building)
- Payback = 8.3 years

Other Federal Installations

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Environmental Protection Agency, Golden CO

Other Federal Installations

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Bureau of Reclamation, Leadville CO

Other Federal Installations

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US Army, Fort Carson, CO

Solar Ventilation Preheat System Costs

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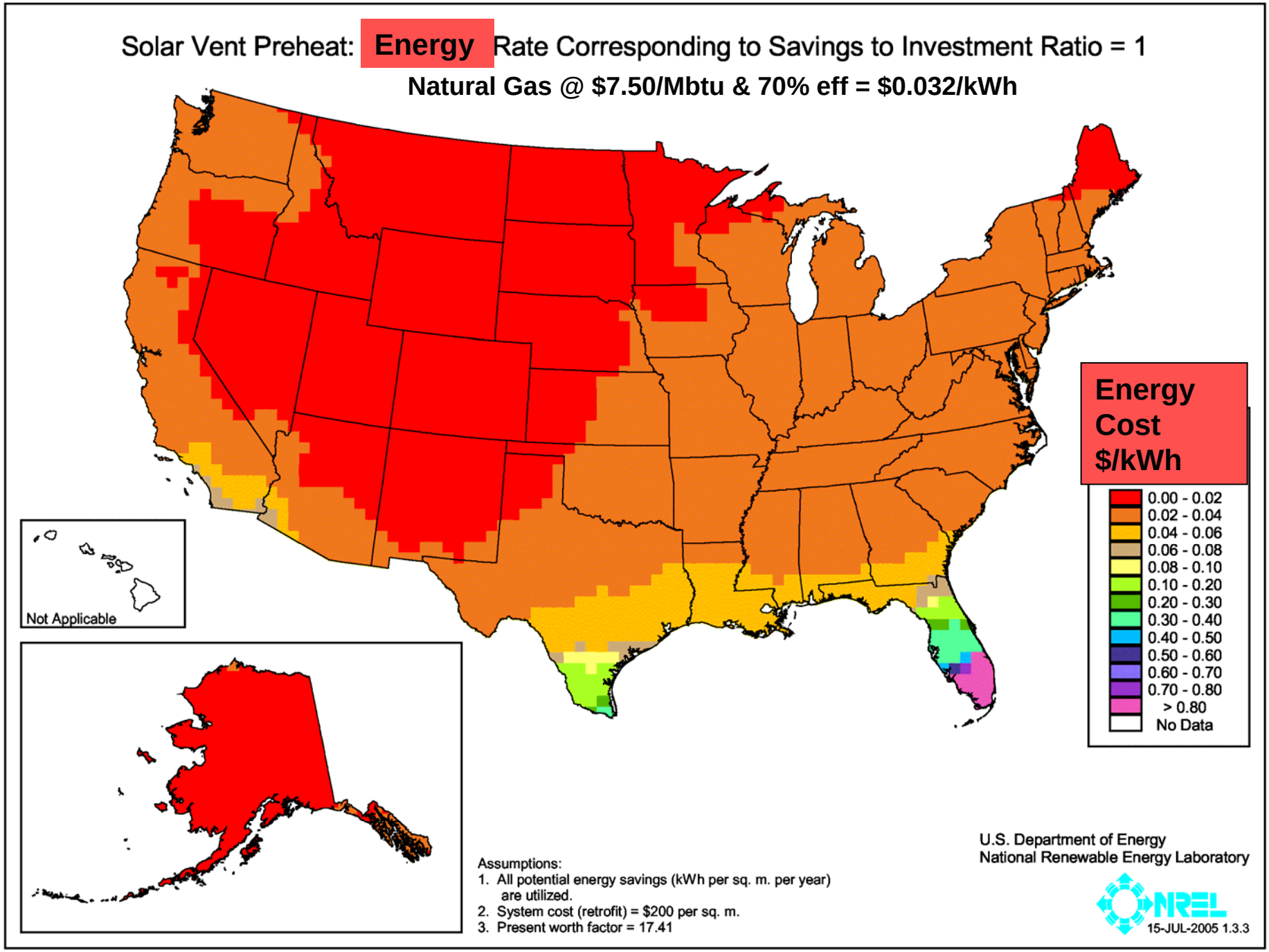
- Installation Costs in Retrofit Applications
  - Absorber
    $9.50/ft^2
  - Supports, Flashing, Etc.
    $2.50/ft^2
  - Installation
    $4.00/ft^2
  - Other Costs
    $4.00/ft^2
  - Total
    $20.00/ft^2


Solar Vent Preheat: Energy Rate Corresponding to Savings to Investment Ratio = 1
Natural Gas @ $7.50/Mbtu & 70% eff = $0.032/kWh
Energy Cost $/kWh
0.00 - 0.02
0.02 - 0.04
0.04 - 0.06
0.06 - 0.08
0.08 - 0.10
0.10 - 0.20
0.20 - 0.30
0.30 - 0.40
0.40 - 0.50
0.50 - 0.60
0.60 - 0.70
0.70 - 0.80
> 0.80
No Data
Not Applicable
Assumptions:
1. All potential energy savings (kWh per sq. m. per year) are utilized.
2. System cost (retrofit) = $200 per sq. m.
3. Present worth factor = 17.41
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
15-JUL-2005 1.3.3

Ocean Thermal Energy Conversion (OTEC)

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OTEC Schematic

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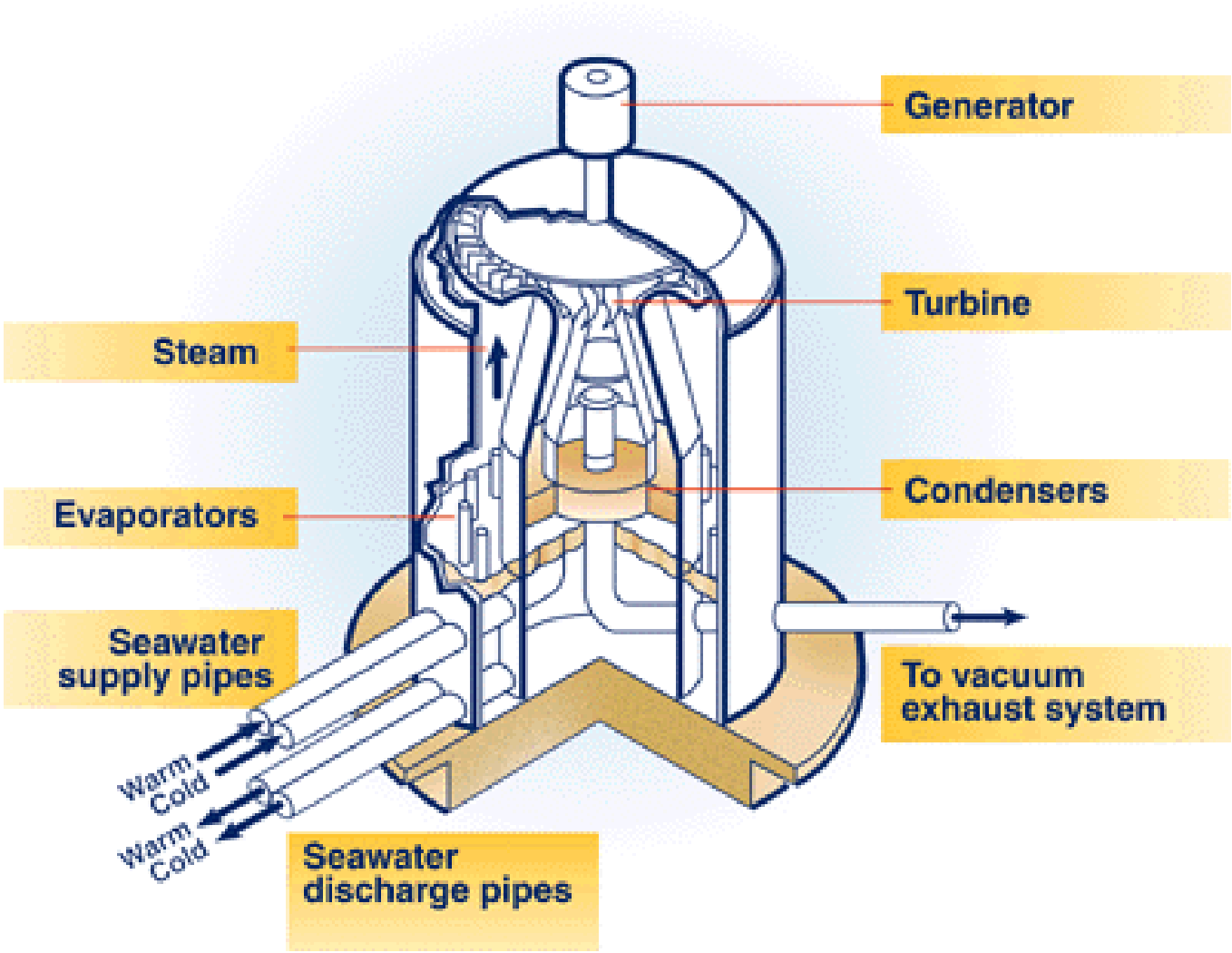

DoD OTEC Projects

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- 7 MW OTEC Project at US Navy Diego Garcia
  - Production of Potable Water & Seawater Cooling
- 12 MW OTEC Project at US Army Kwajalein Atoll, Marshall Islands
  - Production of Potable Water & Seawater Cooling
- Both provide base load power and displace diesel generators

Wind

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Wind: Fastest-Growing Energy Source

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- Wind is the fastest growing energy source worldwide, increasing 37% in past year.
- 67% in U.S. in 2001
- Wind electricity prices competitive with most fuels
- Wind energy is growing faster than the personal computer market and as fast as the cell phone market.

Top five wind energy markets

Body Shop: Building Strategies

2003 Year End

(installed capacity, in MW)

Germany	**14,609**
United States	**6,374**
Spain	**6,202**
Denmark	**3,110**
India	**2,110**

Source: 1850-1949, Energy Perspectives: A Presentation of Major Energy and Energy-Related Data, U.S. Department of the Interior, 1975; 1950-1996, Annual Energy Review 1996, Table 1.3. Note: Between 1950 and 1990, there was no reporting of non-utility use of renewables

Wind Energy Cost

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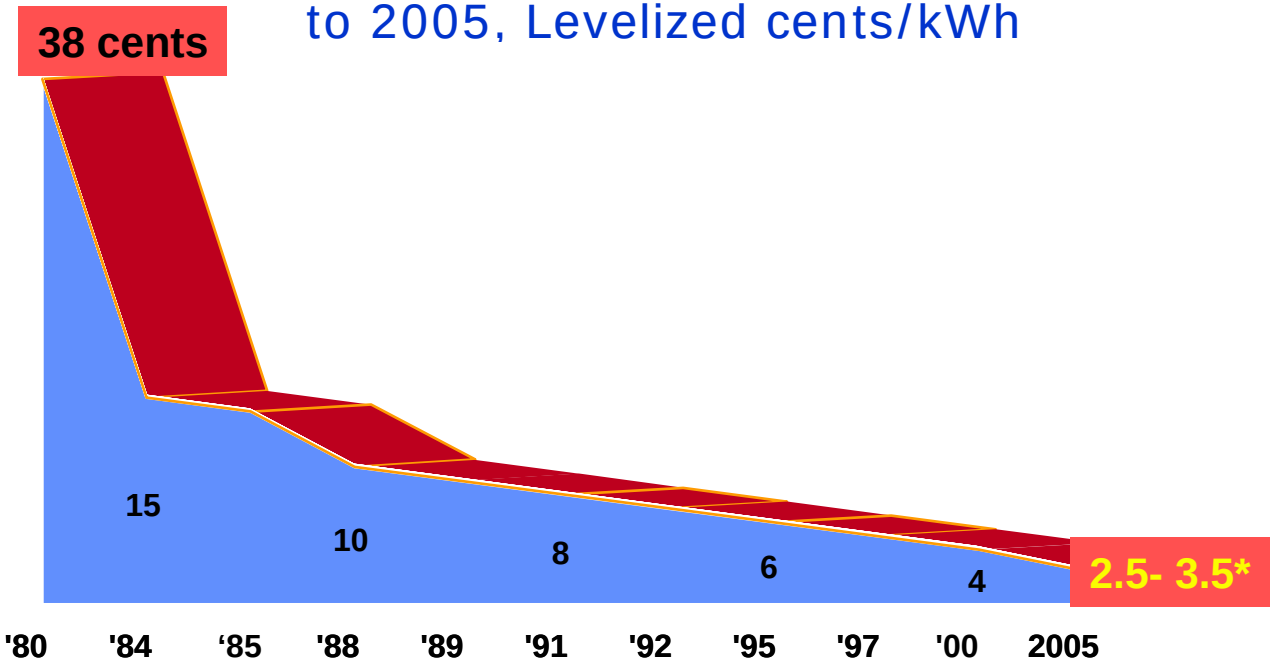
NREL's National Wind Technology Center – R&D Results

Cost of Wind-Generated Electricity 1980 to 2005, Levelized cents/kWh



Assumptions: Levelized cost at "excellent" wind sites, large project size, not including PTC (post 1994), costs in nominal cents/kWh.

Acquiring Wind Least-Cost: Wind Speed Matters

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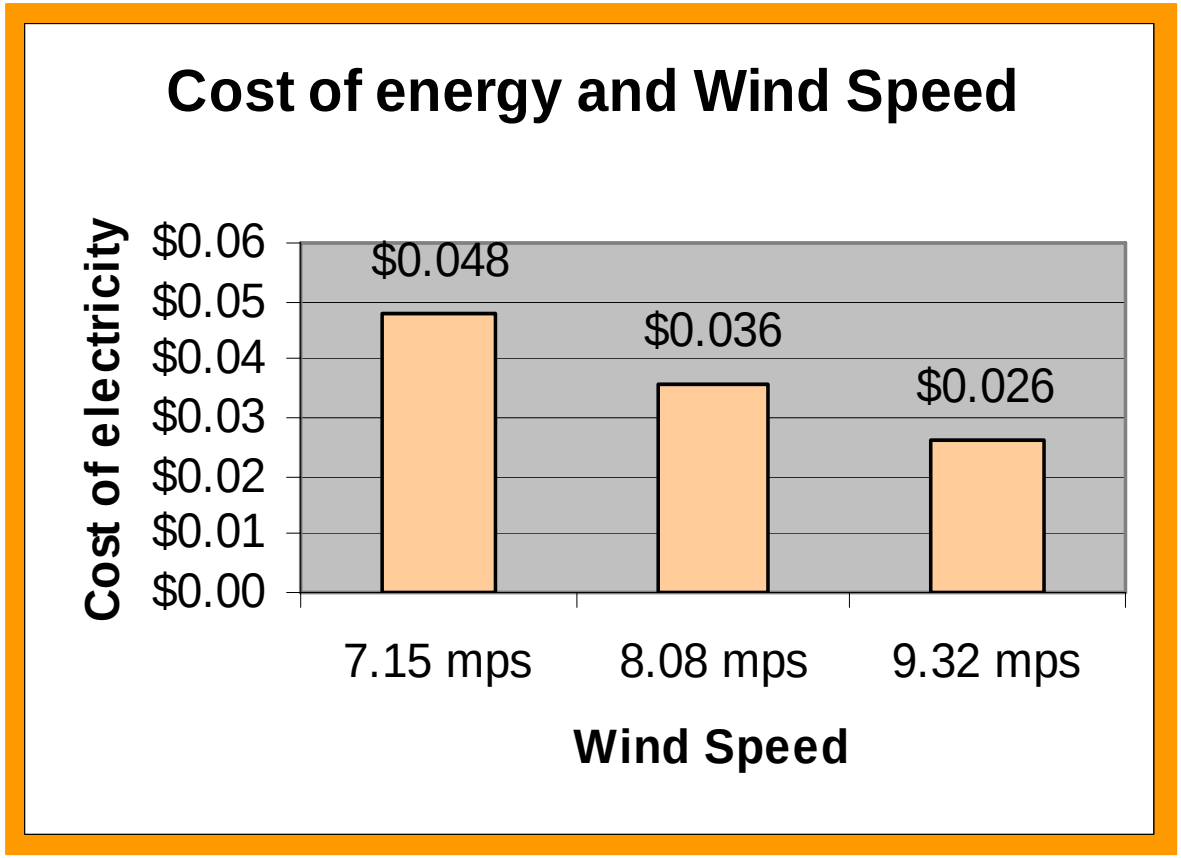

Palm Springs, CA (750MW)

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Renewables on Public Lands
NREL Resource Assessments

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- BLM Western US Public Lands
  - Solar (PV & CSP), Wind **(Sample)**, Biomass
- USFS US Public Lands
  - Solar (PV & CSP) & Wind
- EPA Brownfields (contaminated sites)
  - Solar (PV & CSP) Wind, & Biomass
- DOE Federal Lands
  - Solar (PV & CSP) Wind, & Biomass

High Resolution Wind Maps Support Resource Assessment

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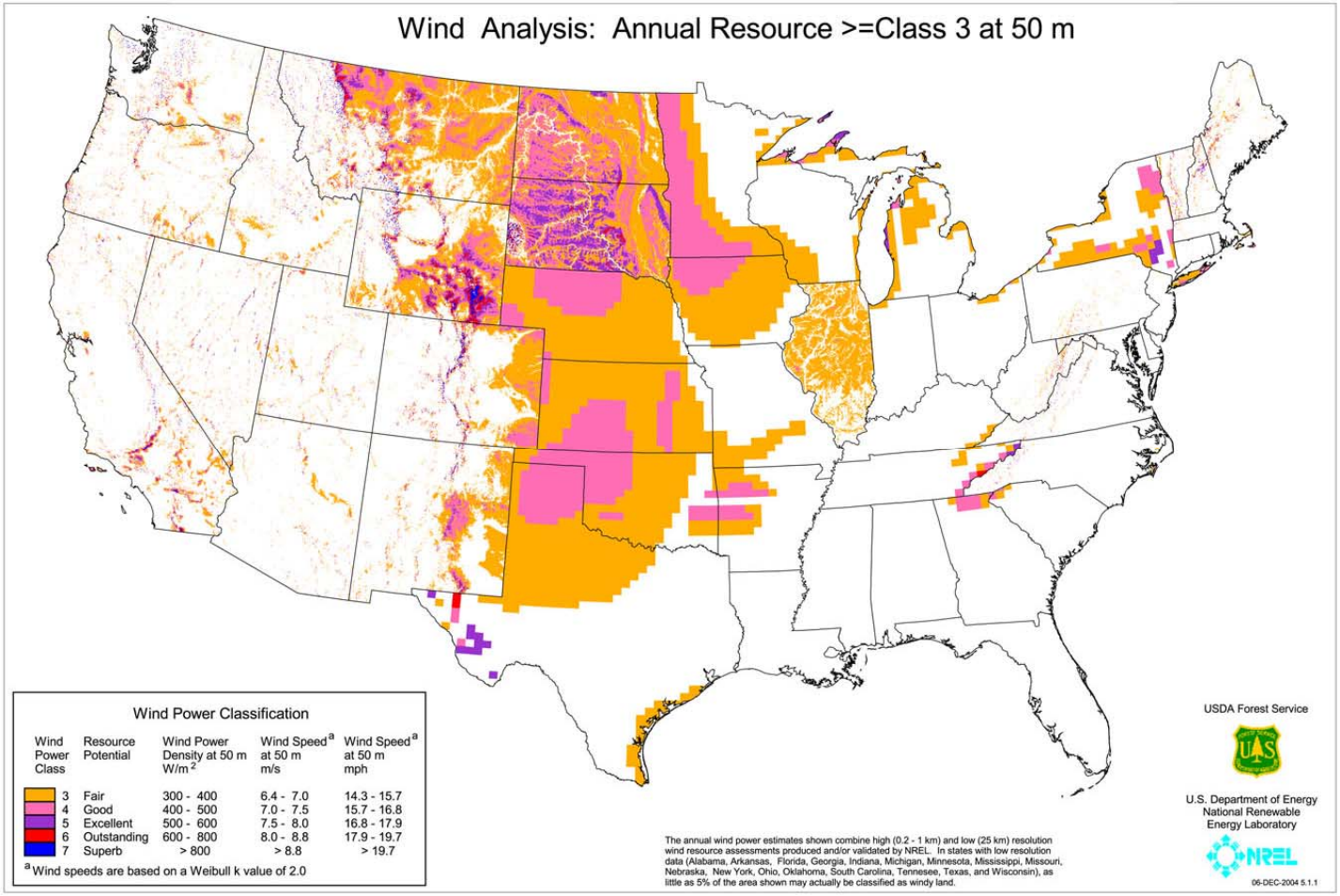

BLM – Assessment of High Potential Wind Resources

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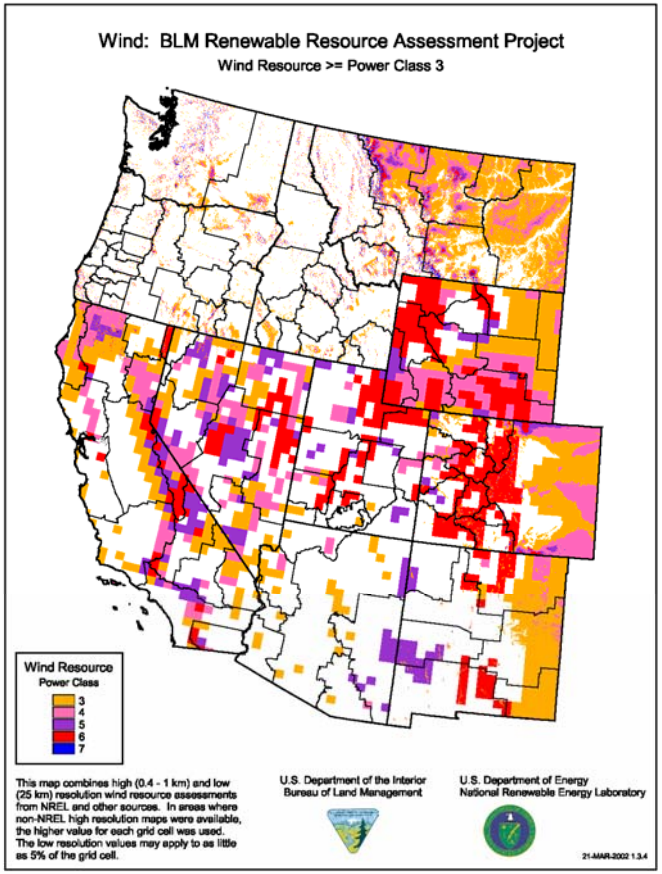
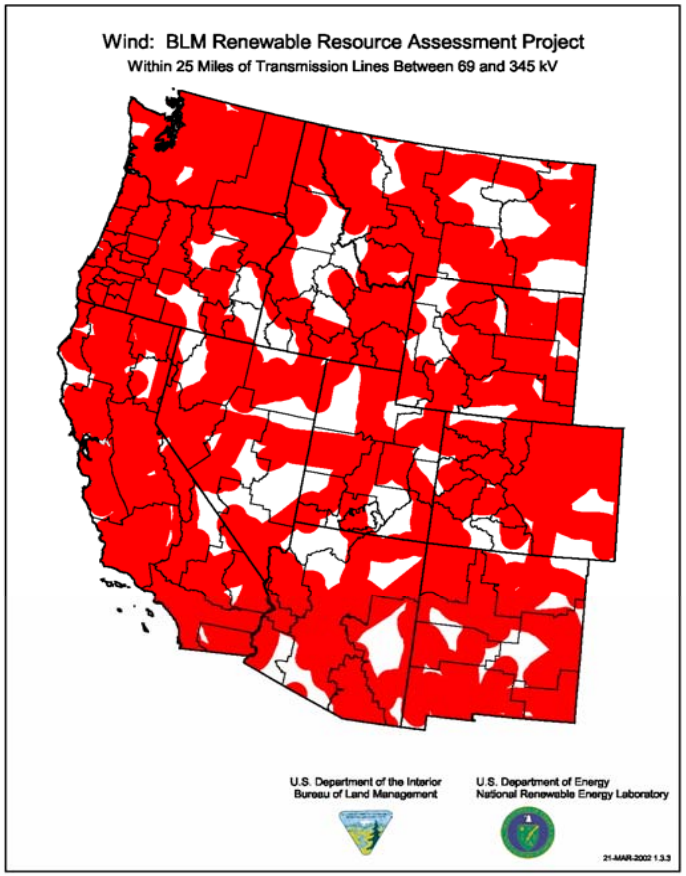


Map supplied by the National Renewable Energy Laboratory



Map supplied by the National Renewable Energy Laboratory

BLM – Assessment of High Potential Wind Resources

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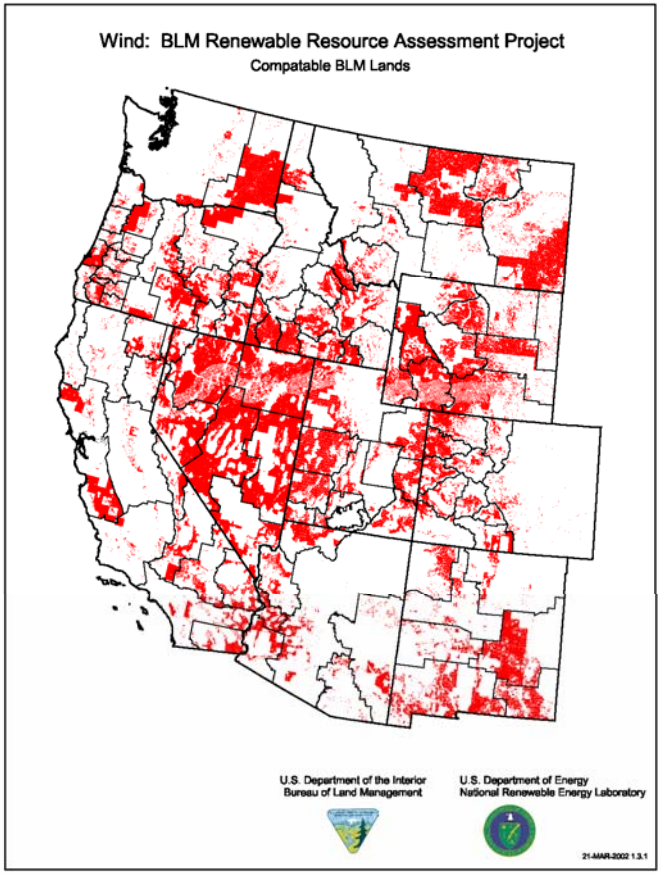
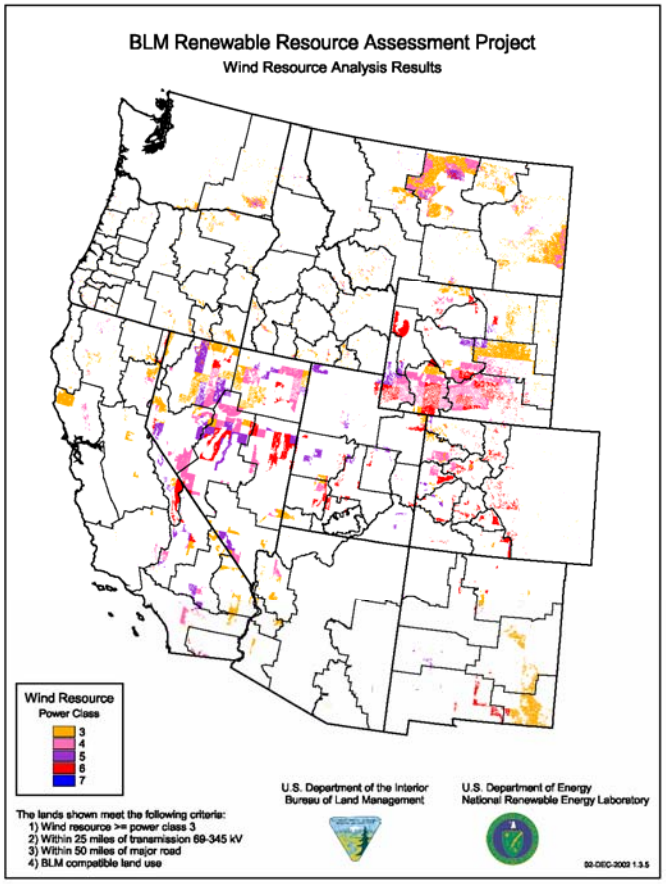


Map supplied by the National Renewable Energy Laboratory



Map supplied by the National Renewable Energy Laboratory

BLM – Resource Assesment for Public Lands Success

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- RE Assessment led to high Wind Industry interest in development on BLM lands
- Industry favorable BLM Wind Development Policy for land leasing
- BLM Wind Programmatic Environmental Impact Study
  - **Enhances federal land development NEPA compliance**
- Wind Power Potential Analysis for Land Use Plan Amendments
- 70 Wind Leases since 2003 (5 in previous 10 years)
- Development in 2 years may result in 2000 MW
- In response to WGA 30GW goal by 2015 – BLM Solar Development Policy for land leasing

RE Market Drivers

Body Shop: Building Strategies

- EPACT 05
  - Aggressive Federal Goals for Electricity from Renewable Sources
  - Solar Tax Credit 10%>30%
  - Restore PTCs for Wind & Biomass
    - Procurement Session 4B
- Expansion of State RPSs
- State RE financial incentives

For More Information …

Body Shop: Building Strategies

US DOE Federal Energy Management Program
www.eere.energy.gov/femp

National Renewable Energy Laboratory
www.nrel.gov

Database of State Incentives for Renewable Energy
www.dsireusa.org

Thank You!

Body Shop: Building Strategies

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