



# **The Promise of Solar: Variables to Consider When Evaluating the Use of Solar**

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National Renewable Energy Laboratory**



# Humanity's Top Ten Problems

Robert Smally, Nobel Laureate

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- Energy
- Water
- Food
- Environment
- Poverty
- Terrorism/War
- Disease
- Education
- Democracy
- Population (6.3 billion – 2003; 9-10 billion – 2050)



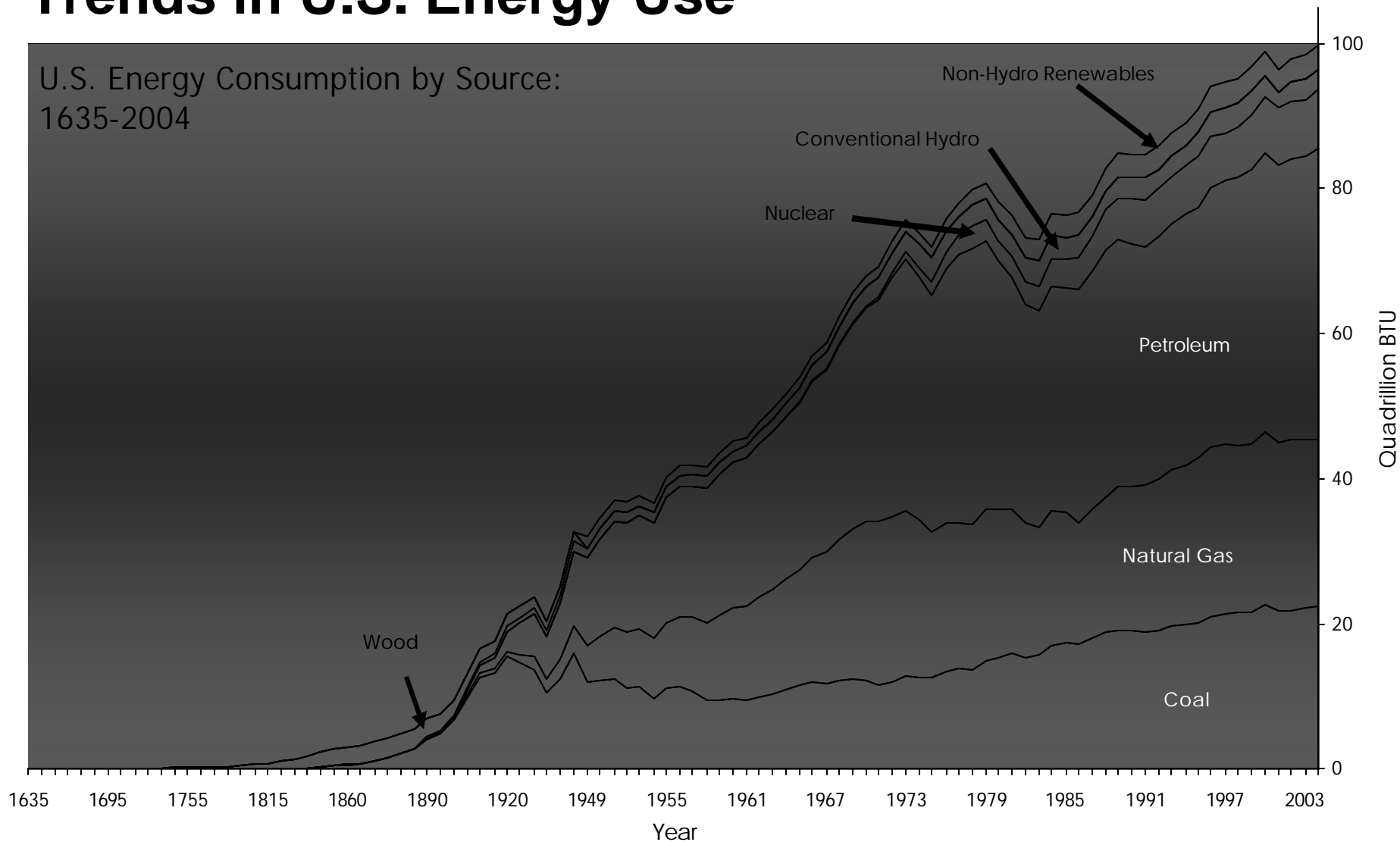
Humanity's problems are interconnected...



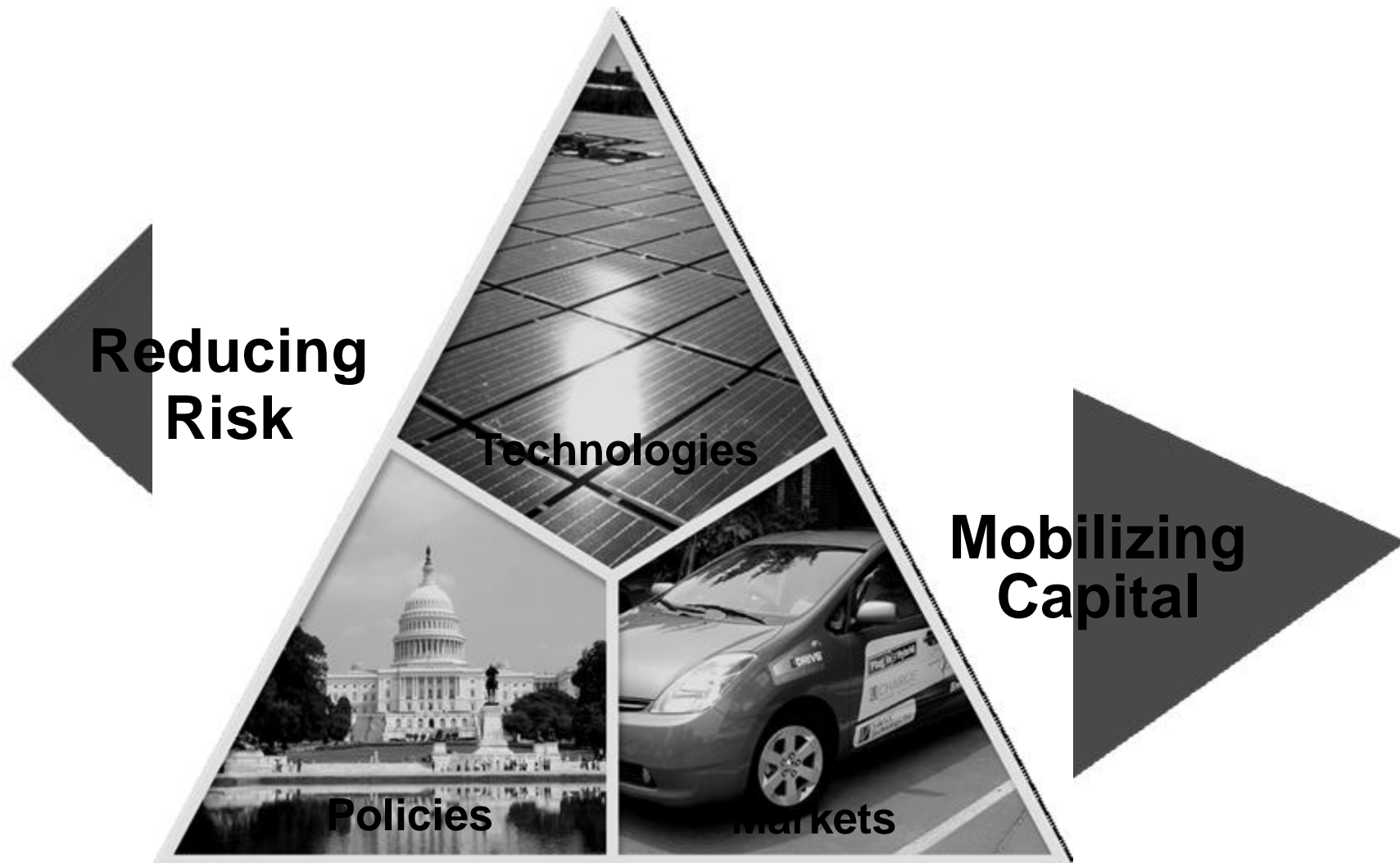


# Trends in U.S. Energy Use

U.S. Energy Consumption by Source:  
1635-2004

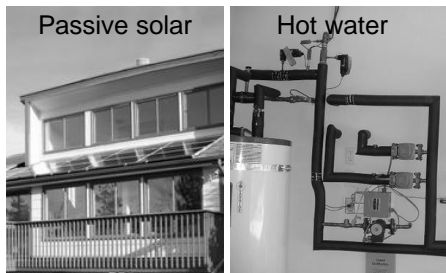


# Getting to “Significance” Involves....



# Applications of Solar

## Solar Thermal



## Photovoltaics (PV)



## Concentrating Solar Power (CSP)



Distributed  
Generation,  
on-site or near  
point of use



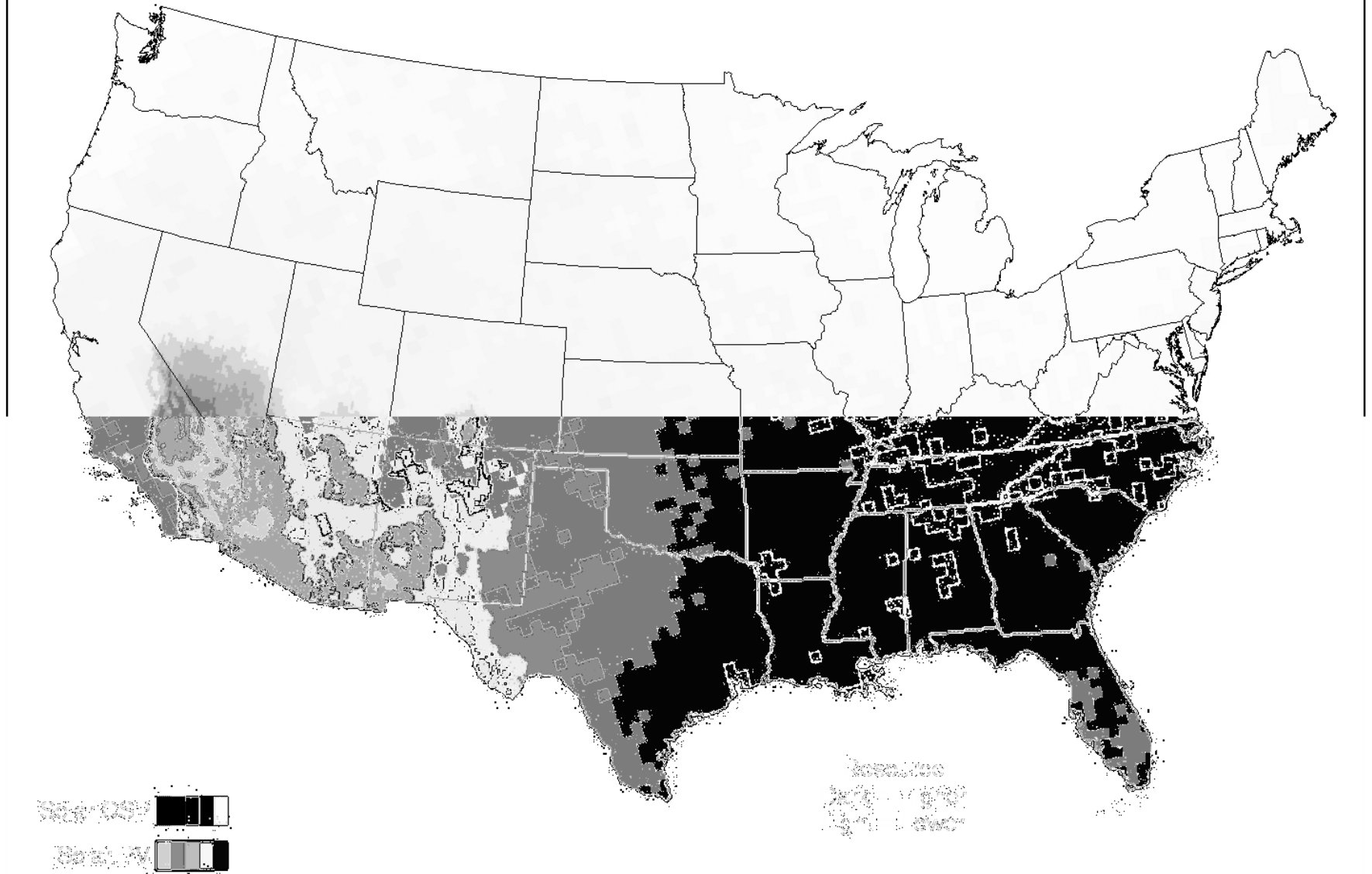
Centralized  
Generation,  
large users  
or utilities



- Transportation
- Residential & Commercial Buildings
- Industrial



# U.S. Renewable Resources



# Photovoltaics and Concentrating Solar Power

## Status in U.S.

### PV

- 526 MW
- Cost 18-23¢/kV

### CSP

- 355 MW
- Cost 12¢/kWh

## Potential:

### PV

- 11-18¢/kWh by 2010
- 5-10 ¢/kWh by 2015

### CSP

- 8.5 ¢/kWh by 2010
- 6 ¢/kWh by 2015

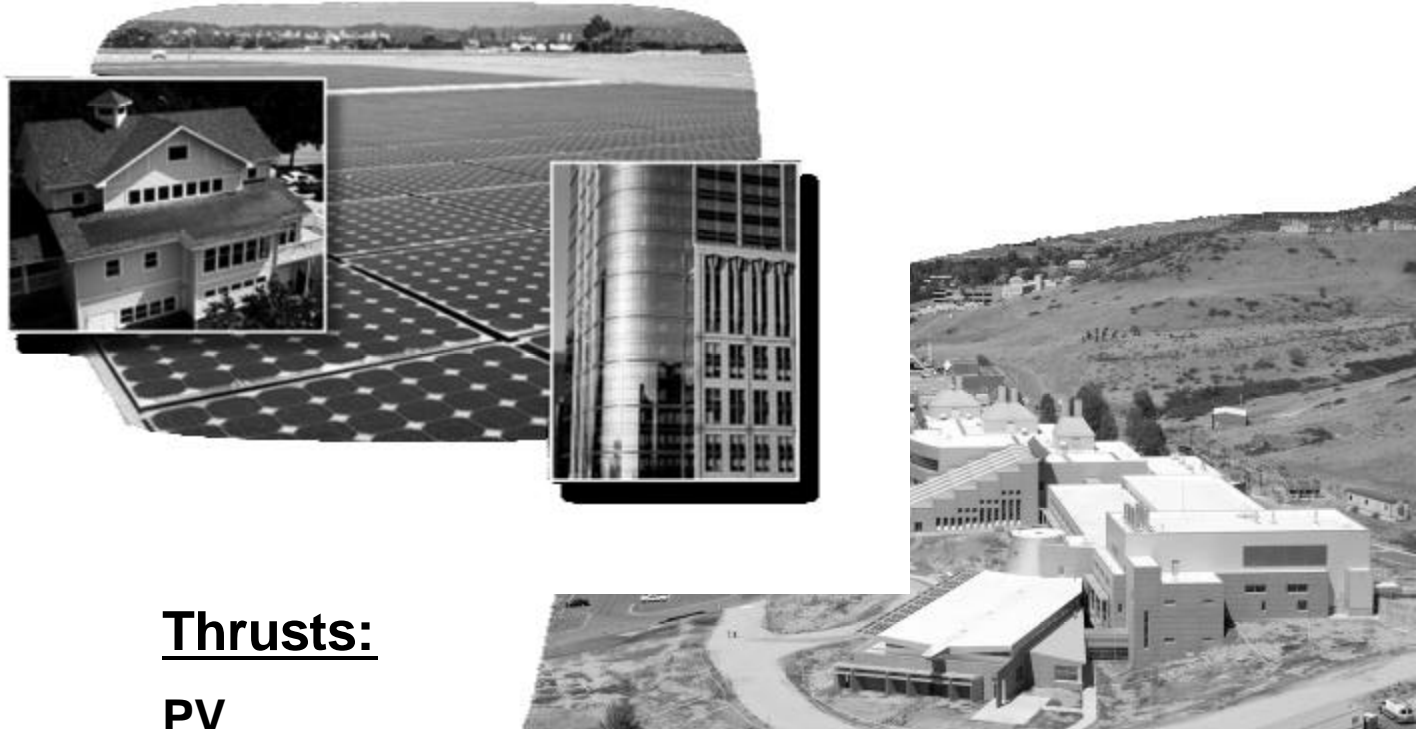
## Thrusts:

### PV

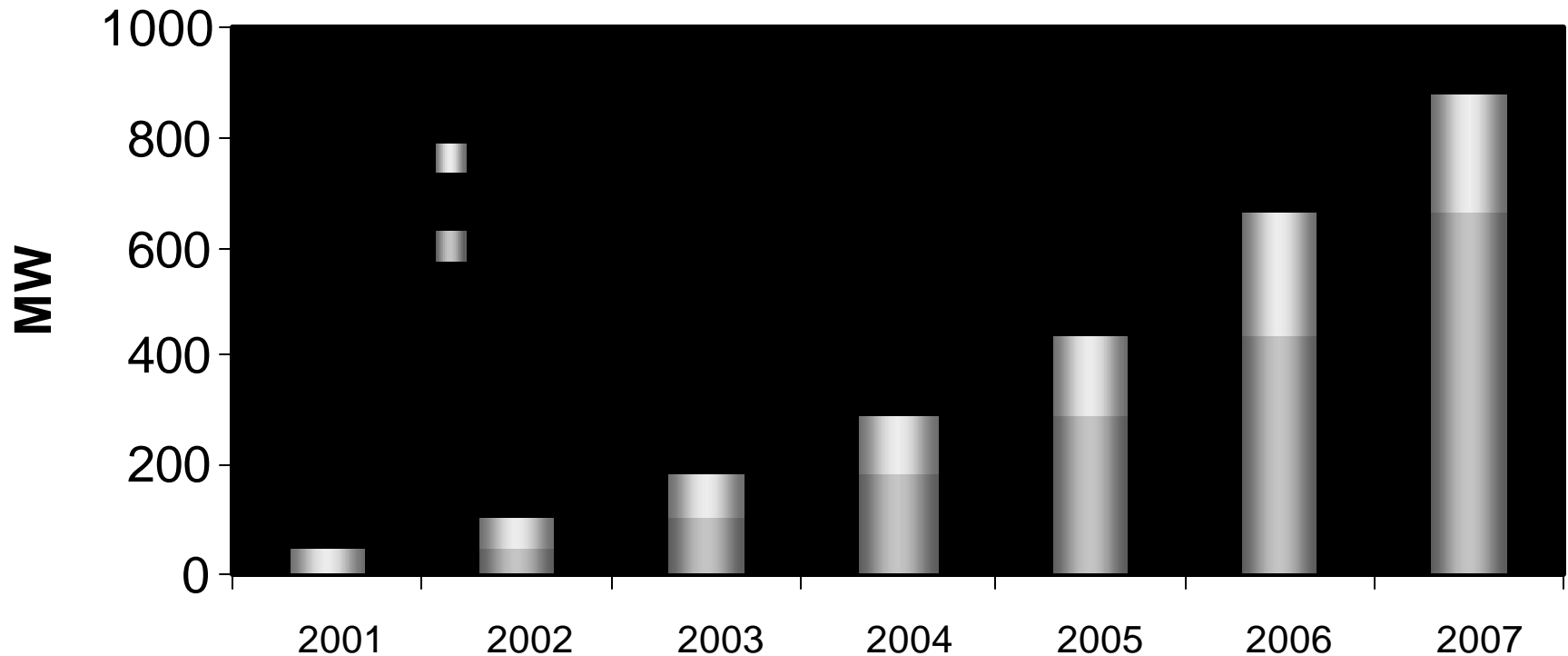
- Partnering with industry
- Higher efficiency devices
- New nanomaterials applications
- Advanced manufacturing techniques

### CSP

- Next generation solar collectors
- High performance storage

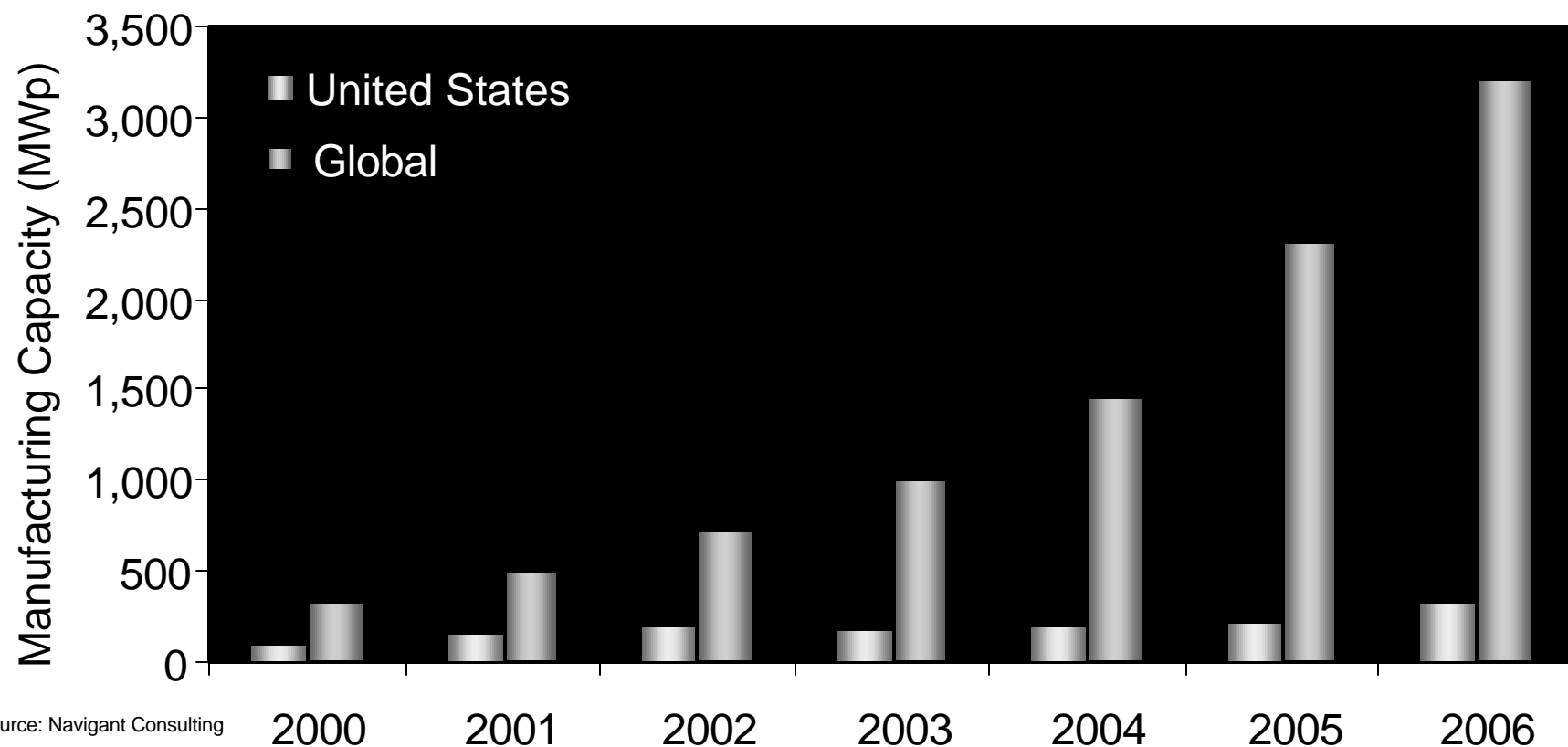


# U.S. Solar Photovoltaic Capacity Growth



	2001	2002	2003	2004	2005	2006	2007*
Annual growth (%)	n/a	134%	72%	57%	48%	52%	34%
Total capacity (MW)	46	108	186	291	432	658	883

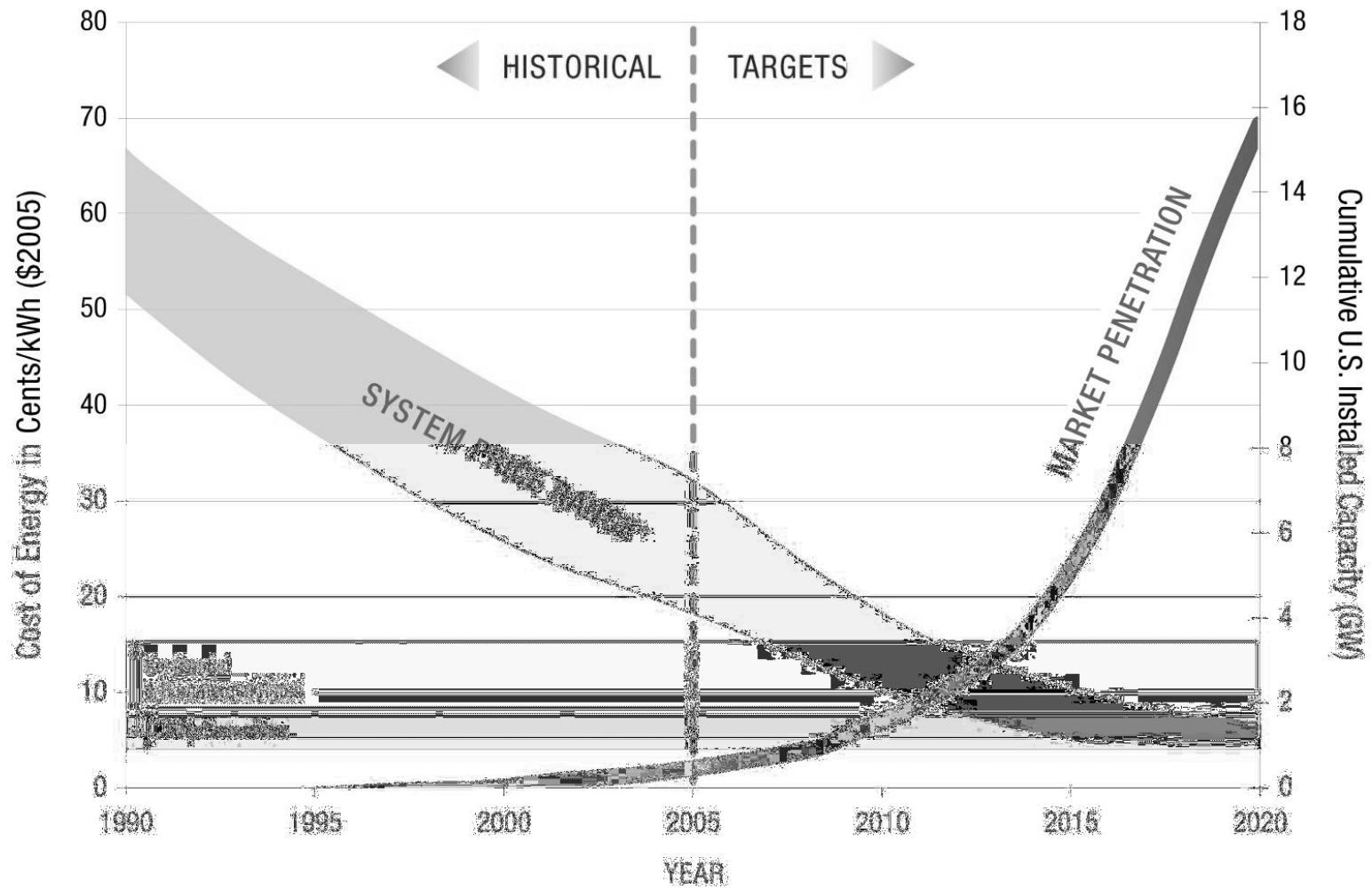
# Solar Manufacturing Capacity



	2000	2001	2002	2003	2004	2005	2006
<b>Total Global Manufacturing Capacity (MWp)</b>	225	328	504	728	1,002	1,460	2,303
<b>Annual Global Growth</b>	28%	54%	45%	38%	46%	58%	39%
<b>Total U.S. Manufacturing Capacity (MWp)</b>	90	143	179	170	186	212	314
<b>Annual U.S. Growth</b>	14%	58%	26%	-5%	9%	14%	48%

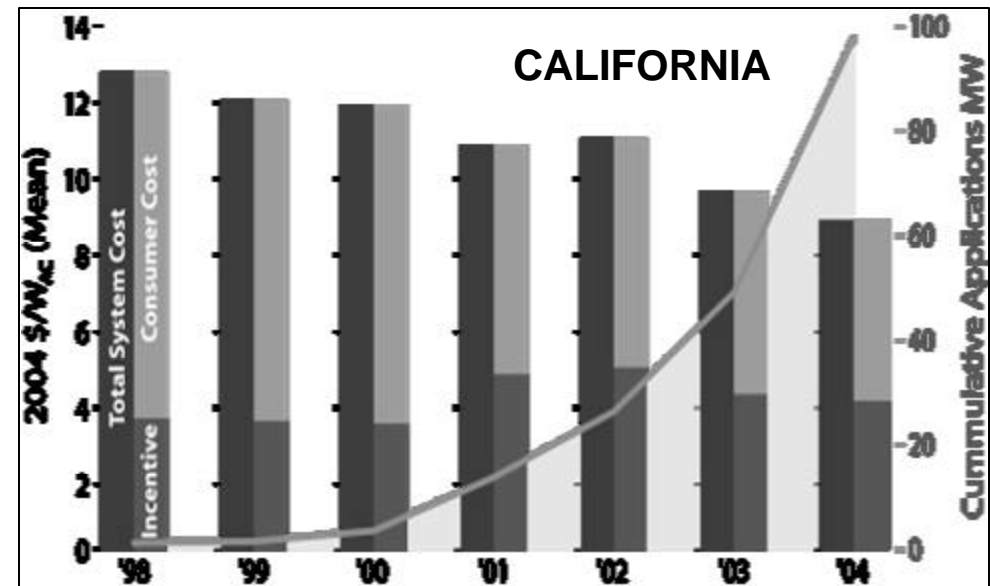
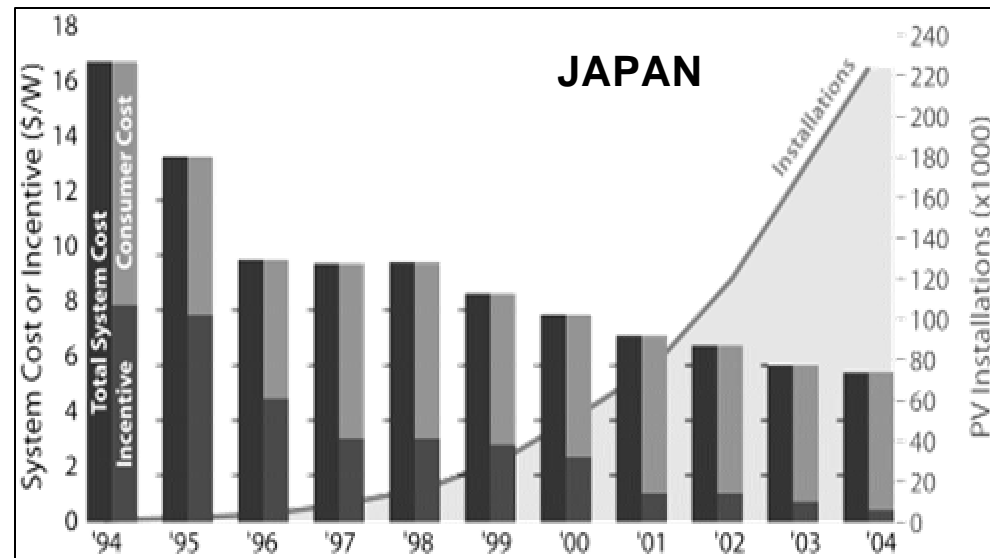
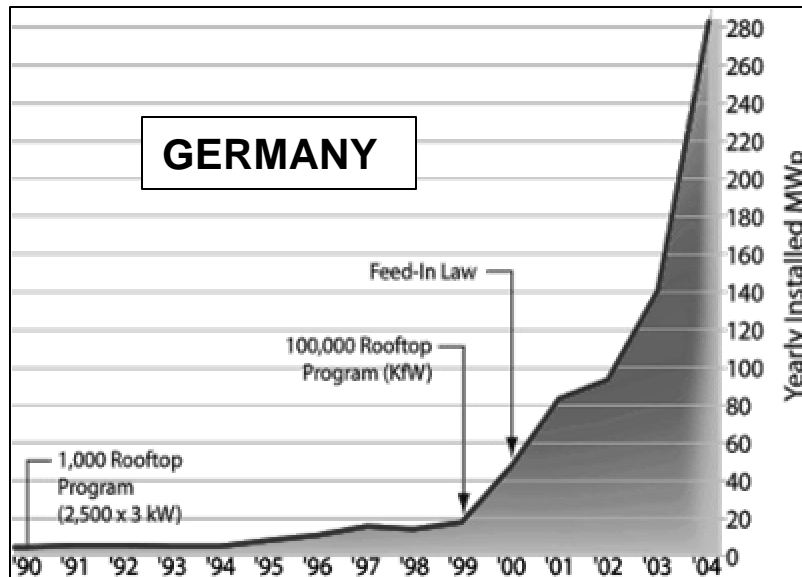


# PV Cost and Market Penetration Targets

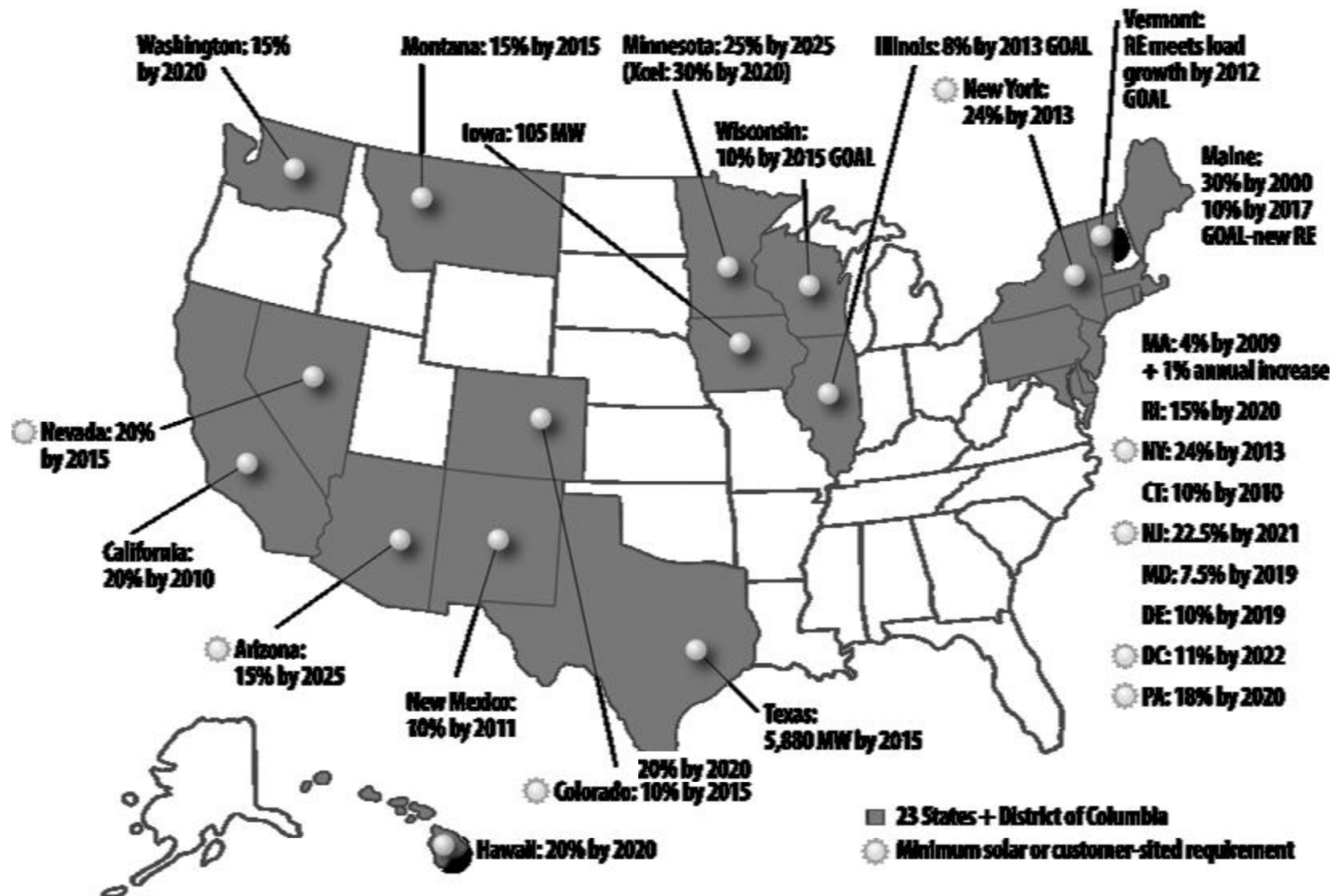


# Solar PV Example

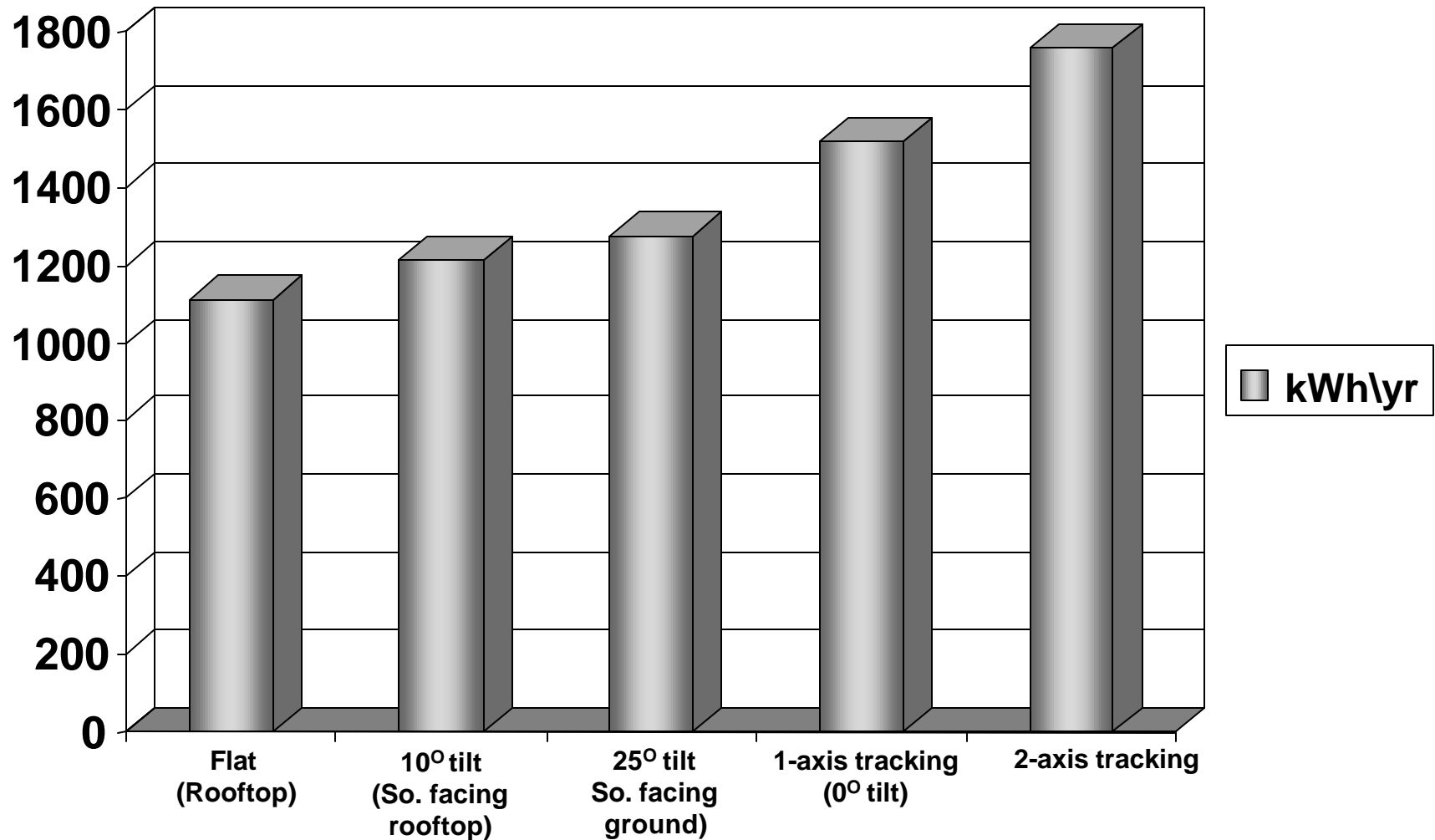
**Market Growth  
is Enabled by  
Progressive  
Public Policy**



# State Policy Framework Renewable Electricity Standards



# PV System Performance: Output from a 1 KW (DC) system







# Pros and cons of central versus distributed approach to community-based renewable generation

## *Distributed or Rooftop PV Systems*

Pro	Con
<ul style="list-style-type: none"><li>• Consumers in homes with PV tend to conserve more</li><li>• No line losses</li><li>• For new construction, the cost of the home's PV can be included in the homes construction cost and therefore in the mortgage</li></ul>	<ul style="list-style-type: none"><li>• Individual maintenance</li><li>• Home layouts need to consider orientation for PV</li></ul>

## *Central Systems Serving Community*

Pro	Con
<ul style="list-style-type: none"><li>• Lower cost than distributed PV</li><li>• Can be 1-axis tracking PV which produces 30% more energy than fixed PV</li><li>• Could be wind, biomass, etc. based</li><li>• Central O&amp;M and performance monitoring</li><li>• Can double as an amenity (such as shading a parking structure)</li><li>• Maintained by technology experts</li></ul>	<ul style="list-style-type: none"><li>• Transmission and distribution losses</li><li>• May require land (unless installed on top of parking or other structure)</li><li>• Metering to credit individual homes can be more difficult</li><li>• A community based power system with a micro-grid is a non-traditional approach to power delivery.</li></ul>

# Large-scale Applications of PV





# Distributed Applications of PV



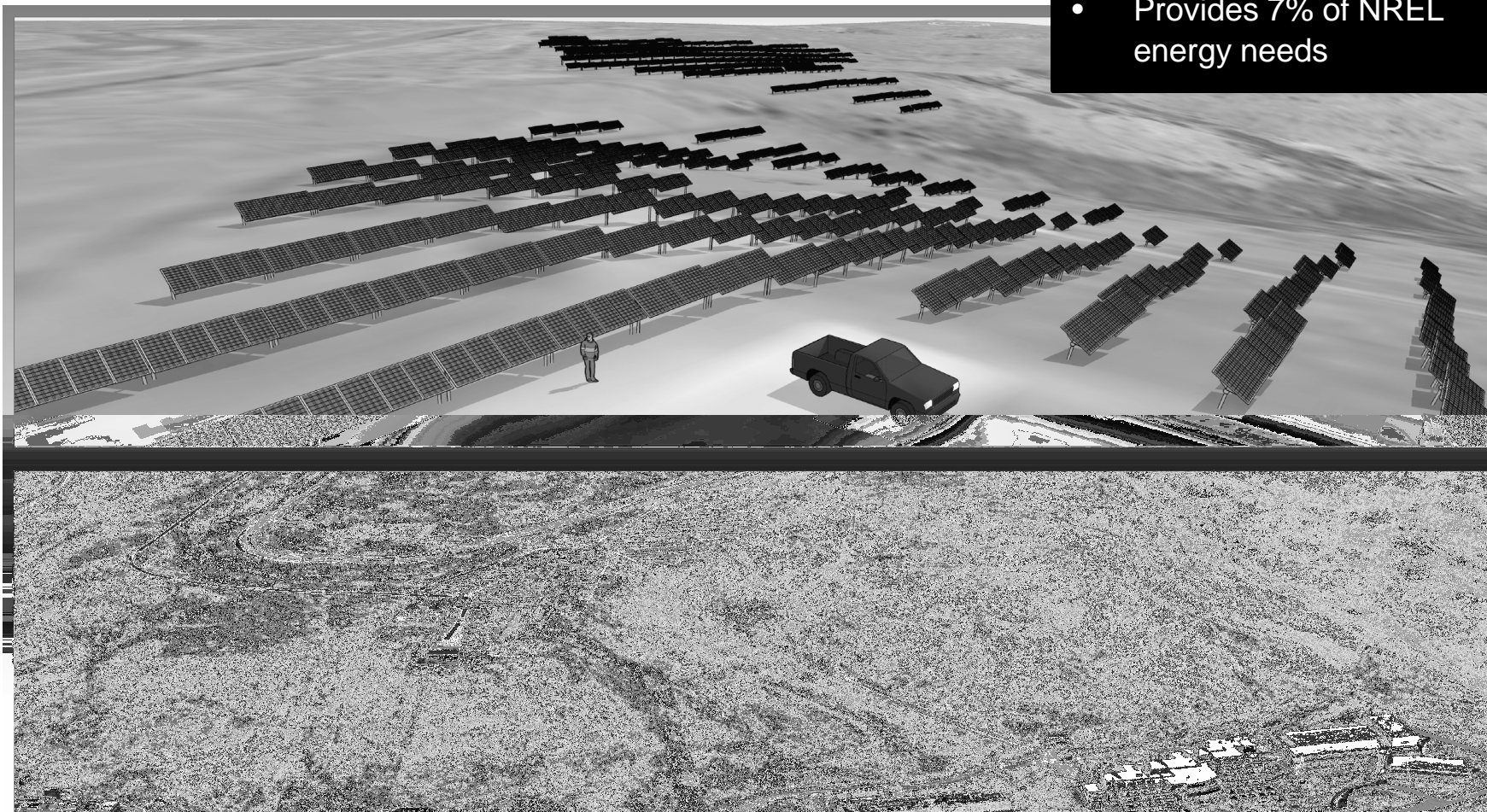
# Examples of integrated solar roofing products





# NREL's Mesa Top PV Project

- 750 kWdc (1,200,000 kWh) single-axis tracking PV system
- Located on South Table Mountain on 5-6 acres
- Grid connected (NREL "side of the meter")
- Provides 7% of NREL energy needs



## **Xcel Solar\*Rewards Program**

- CO statute requires solar resource acquisitions from 2006 – 2020 (20% renewables by 2020)
- Acquisitions made through RFP process
- SO-REC\* Purchase Contract (100kW-2MW tier)
  - Rebate: \$2/watt up to \$200K
  - SO-RECs: bidders compete based on SO-REC price offering over 20 year term
- Current RFP response due April 2008
  - Two RFPs completed (oversubscribed)

\*Solar Energy and Customer-Sited Renewable Energy Credits (\$/MWH)

# Power Purchase Agreement “Wiring Diagram”

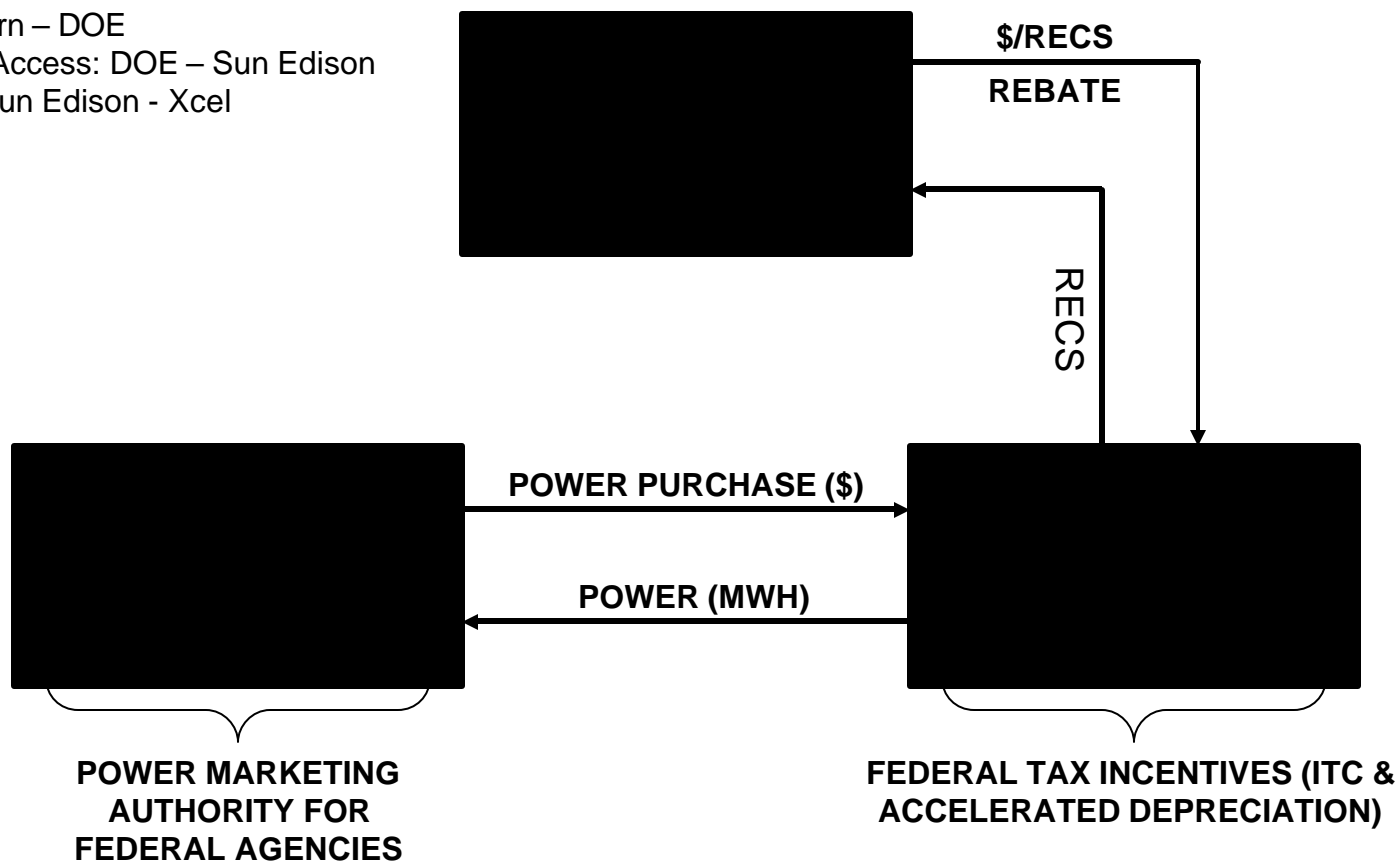
## Agreements for NREL

PPA: Western/DOE - Sun Edison

IAA: Western – DOE

Easement/Access: DOE – Sun Edison

SO-REC: Sun Edison - Xcel



# **What's In It for the Parties?**

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## **Xcel**

- Secures RECs to meet State statute/Public Utilities Commission requirement (Amendment 37) renewable energy use requirements
- Cost recovery
- Corporate benefits of using renewable energy

## **Third Party Developers (profitable business)**

- Federal tax incentives
- Xcel Rebate and REC revenues
- Sale of electricity

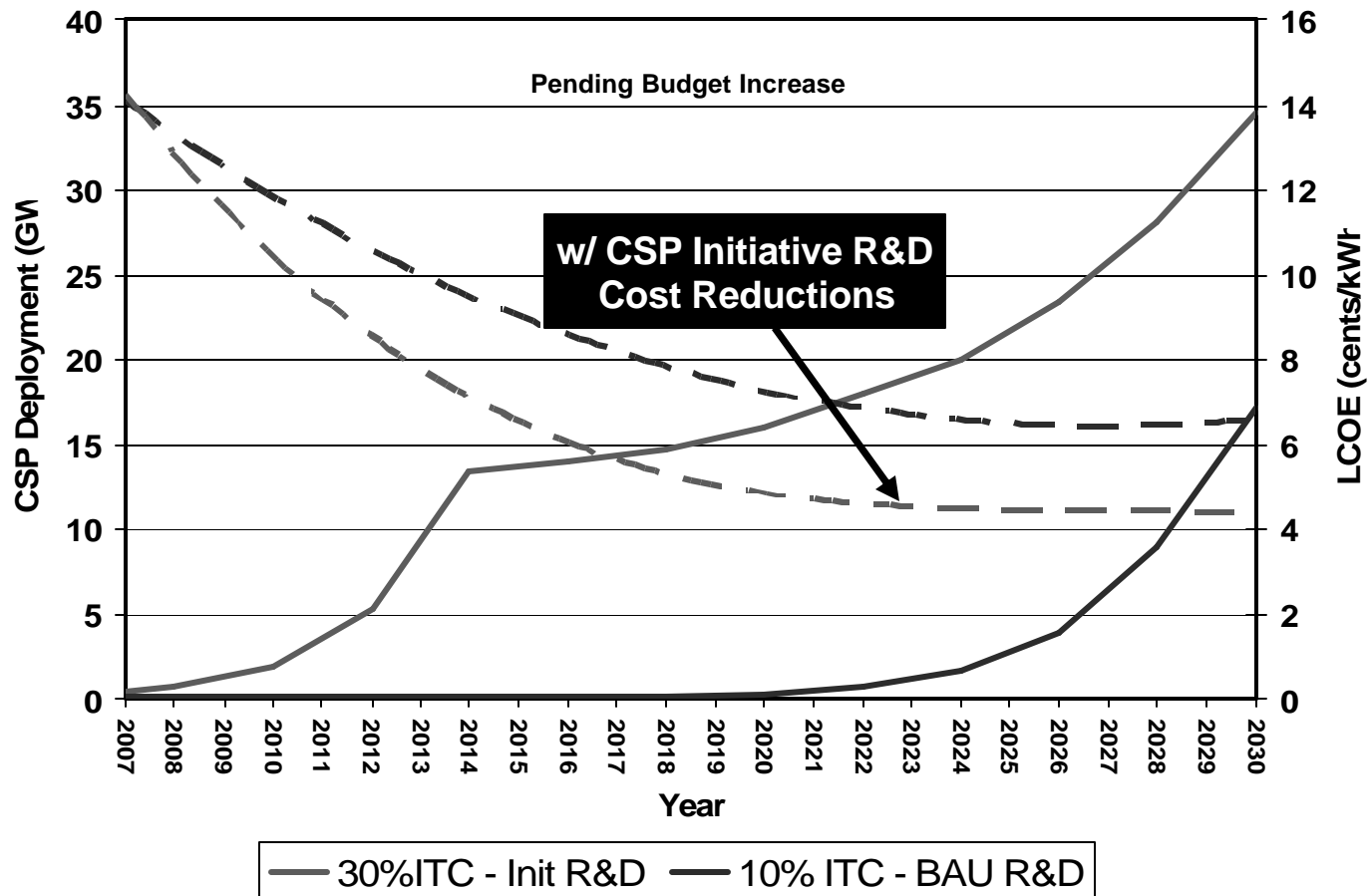
## **User**

- Purchase of power at  $\leq$  utility electric price (or greater)
- Lease/easement considerations?
- End of term ownership/early “buyout”
- Supports use of renewable energy without capital investment





# CSP Cost and Market Penetration Targets



**Targeting CSP plants at GW-scale with  
baseload-equivalent price/dispatchability.**





# The Vision



Vehicles and Fuels



Energy Smart  
Buildings



Renewables

**A Renewable Energy Community**

# It starts with sustainable land use planning.....



*Planned community where homes have solar access*



## Guiding principles

- All development & building should occur in the context that all resources are limited
- Communities and buildings can be resource providers not just resource users
- Land is a stewardship role for future generations
- It is less expensive short and long term to build in harmony with the environment
- Communities are planned for people and technologies are to be supportive not dominant
- Environmental education is an essential "first step" in the rediscovery of our intuitive sense of integrating with the environment

\* Images courtesy of Wonderland Hills (<http://www.whdc.com>)

\*\* Text courtesy of Dewees Island principles (<http://www.deweesisland.com/>)

# Buildings – Efficiency coupled with passive and active solar



*“The NAHB Research Center predicts that zero energy homes could be moving into the mainstream of the nations housing markets as early as 2012 and hold the potential for reducing the energy consumption of all single family homes by 19% by 2050 even as more than a million new homes are added annually”.*

## Vehicles Can Be Part of the Home Package

Toyota Dream House PAPI



*Plug-in vehicle in a Japanese Home*



*Net Zero Energy Canadian Home*



**E-vehicles are also part of the green program at Terramor Village.  
(Photo courtesy of EDAW.)**

Terramor Village homes will include a 110-volt electric outlet for charging Neighborhood Electrical Vehicles (NEVs).

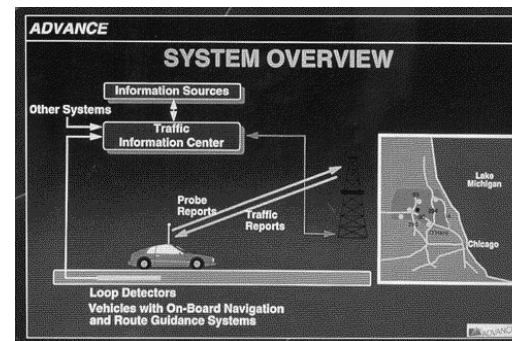
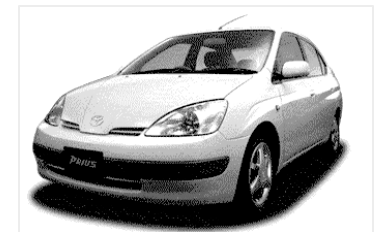


**Notice the latest generation of solar panels on one of the Terramor homes. (Photo courtesy of Shea Homes.)**

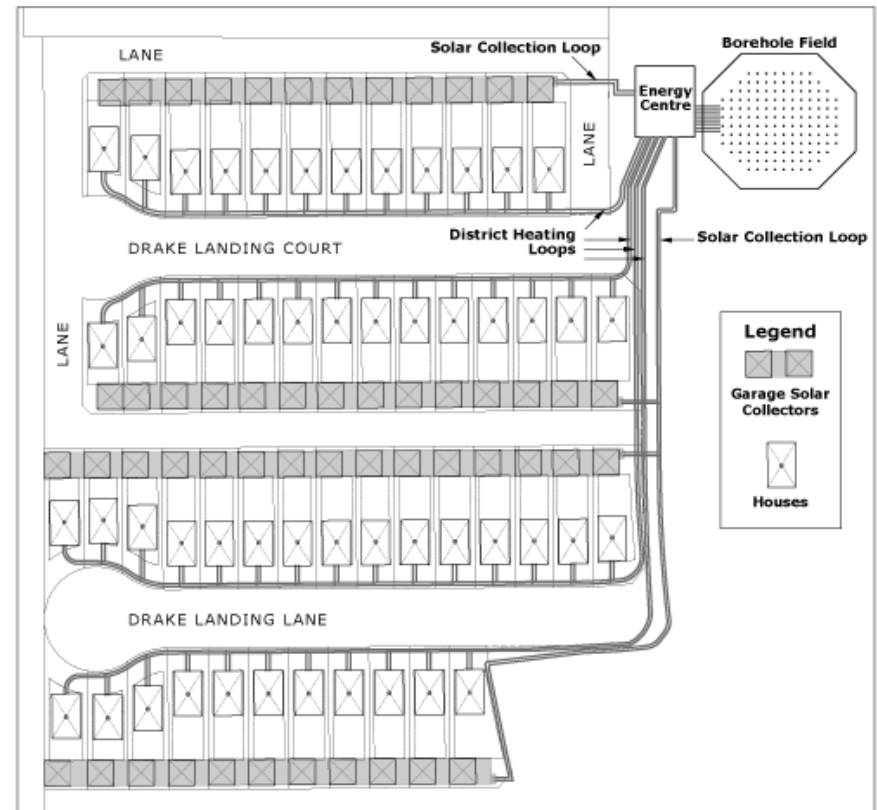
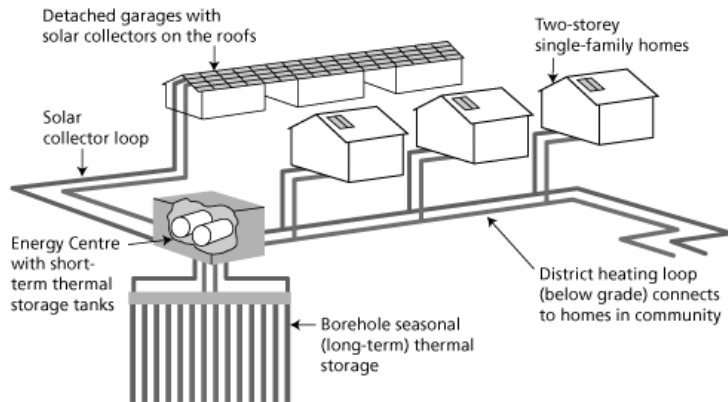


# What types of vehicles are in a Renewable Community?

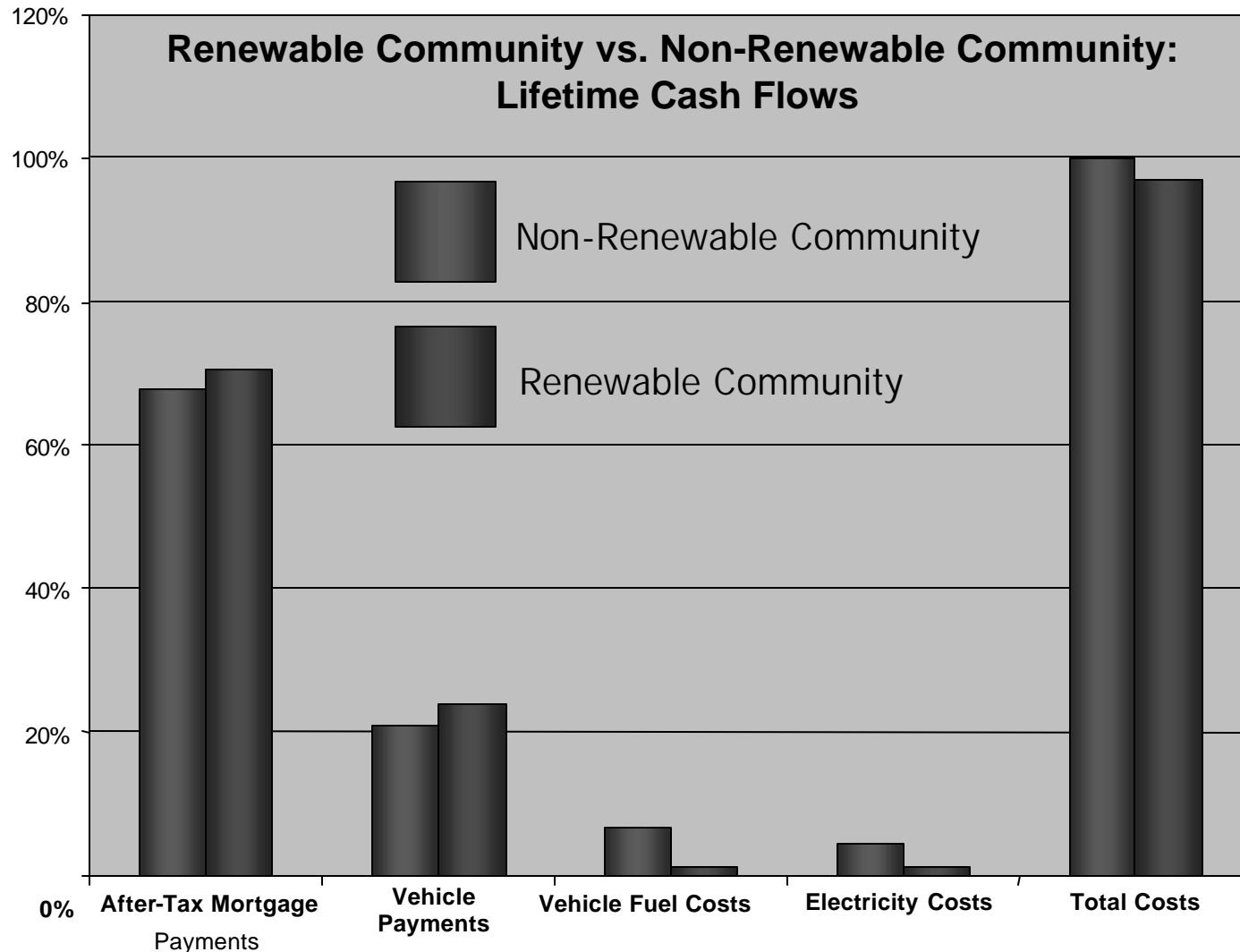
- Electric Vehicles + Bi-directional plug-in
- Hybrid Electric Vehicles + Plug-in
- Fuel Cell Vehicles + Plug-in
- CNG/LNG Vehicles + home refueling
- Clean Diesel / biodiesel
- Car share program
- Others...



# Community with microgrid, using GSHP and Solar



## From a Consumer's Point of View: A Renewable Community Can Cost Less Than a Non-renewable Community!



# The time is now to....

- develop an integrated approach to clean energy on a community level
- plan for a deeper transformation to a nearly carbon-neutral urban economy

