



# Renewable Energy and Climate Solutions for 2050

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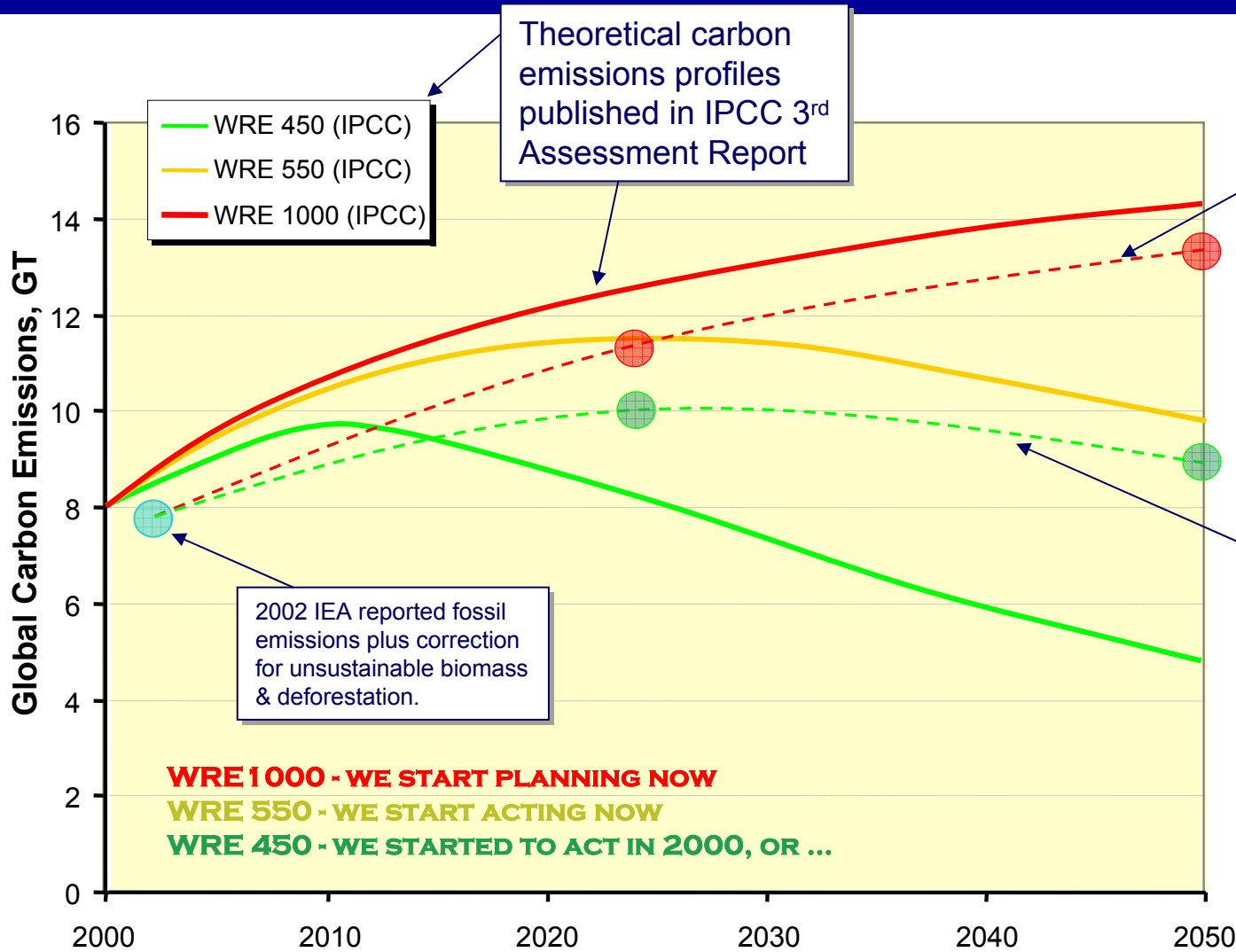
Materials online at: <http://rael.berkeley.edu>

*Climate 2050: Technology and Policy Solutions*  
*Montreal, Canada, October 25, 2007*

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Renewable and Appropriate Energy Laboratory - [rael.berkeley.edu](http://rael.berkeley.edu)

# High and low carbon pathways



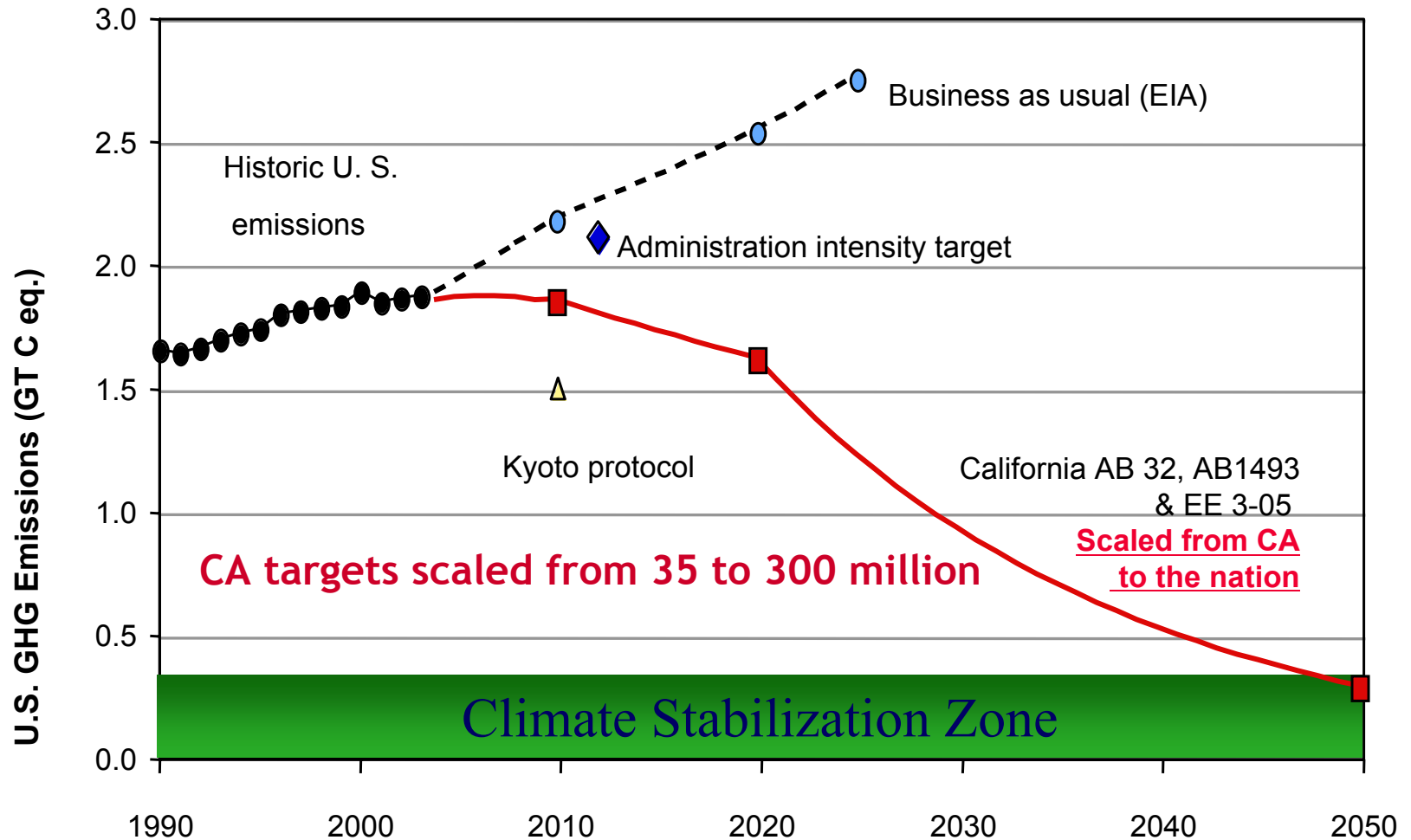
## >900 ppm Trajectory Energy by 2050:

- Coal over 2x, no Carbon Capture & Storage (CCS), some coal to liquids.
- Oil up 50%
- Gas over 2x
- Biofuels make up 10% of vehicle fuel mix.
- Electricity 1/3 of final energy.
- Modest increase in nuclear.
- Renewables provide 1/3 of electricity generation.
- Vehicle efficiency up 50%.

## <550 ppm Trajectory Energy by 2050:

- Coal up 50%, but half of power stations use CCS.
- Oil down 10-15%.
- Gas nearly 2-3x (note: adds volatility)
- Biofuels make up 20% of vehicle fuel mix.
- Green Hydrogen in use
- Strong shift to electricity as final energy (~50% final energy).
- Large increase in nuclear.
- Renewables provide half of electricity generation.
- Vehicle efficiency up 100%
- Sustainable biomass practices

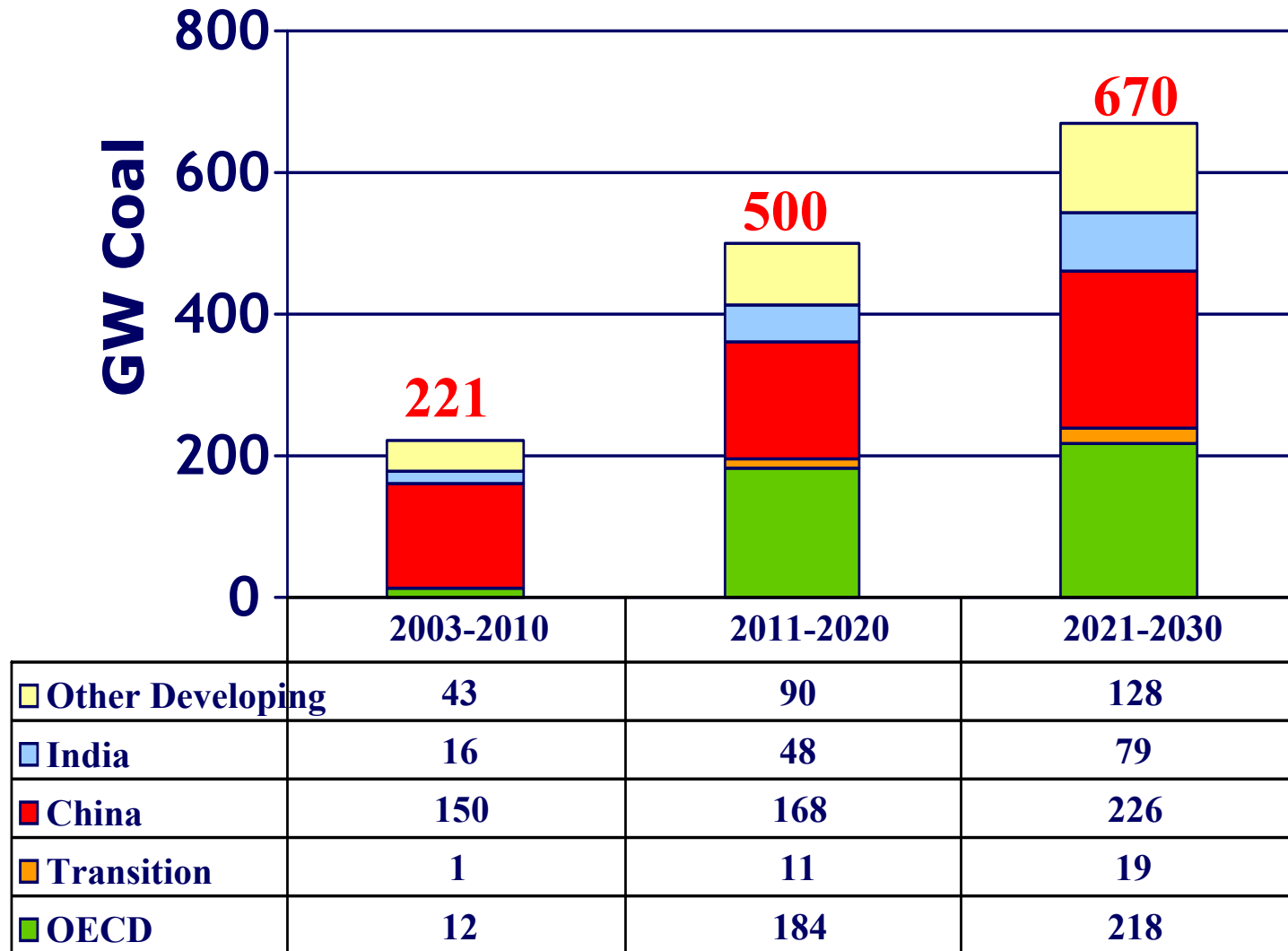
# The California commitment - scaled to the nation



Kammen, "September 27, 2006 – A day to remember", *San Francisco Chronicle*, September 27,



# New Coal by the Decades



>\$1 trillion in capital

Source: IEA, WEO 2004



**COAL IS NOT THE ONLY ISSUE:  
UNCONVENTIONAL HYDROCARBONS ARE PLENTIFUL:**

**TAR SANDS**

**SHALE OIL**

**DEEP WATER, POLAR, AND OTHER PETROLEUM RESERVES**

**Athabasca basin tar sand mine:  
10% bitumen by weight in the soil.  
~ \$30/barrel of energy required to refine**



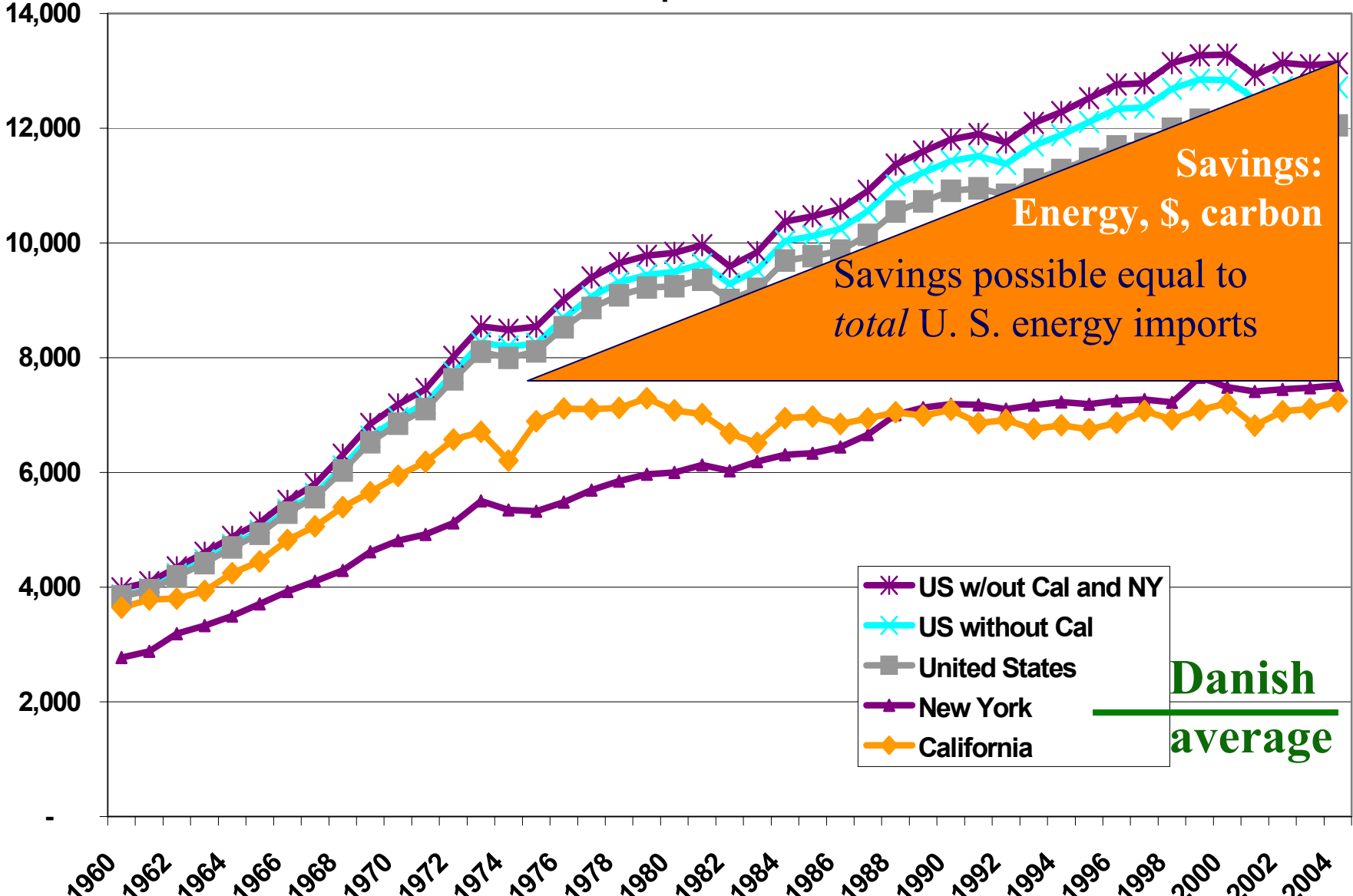
$\text{CH}_4 \rightarrow \text{H}_2\text{S}$  separation, then  $\text{H}_2$  & elemental sulfur separation



PLT. 38 SULFUR BLOCK & TANK AREA  
RESTRICTED ACCESS  
PERMITS CALL SECONDARY U/G 15474  
EMERGENCY CALL 911  
FLAME RESISTANT COVERALLS REQUIRED  
NO SMOKING, NO BEARDS

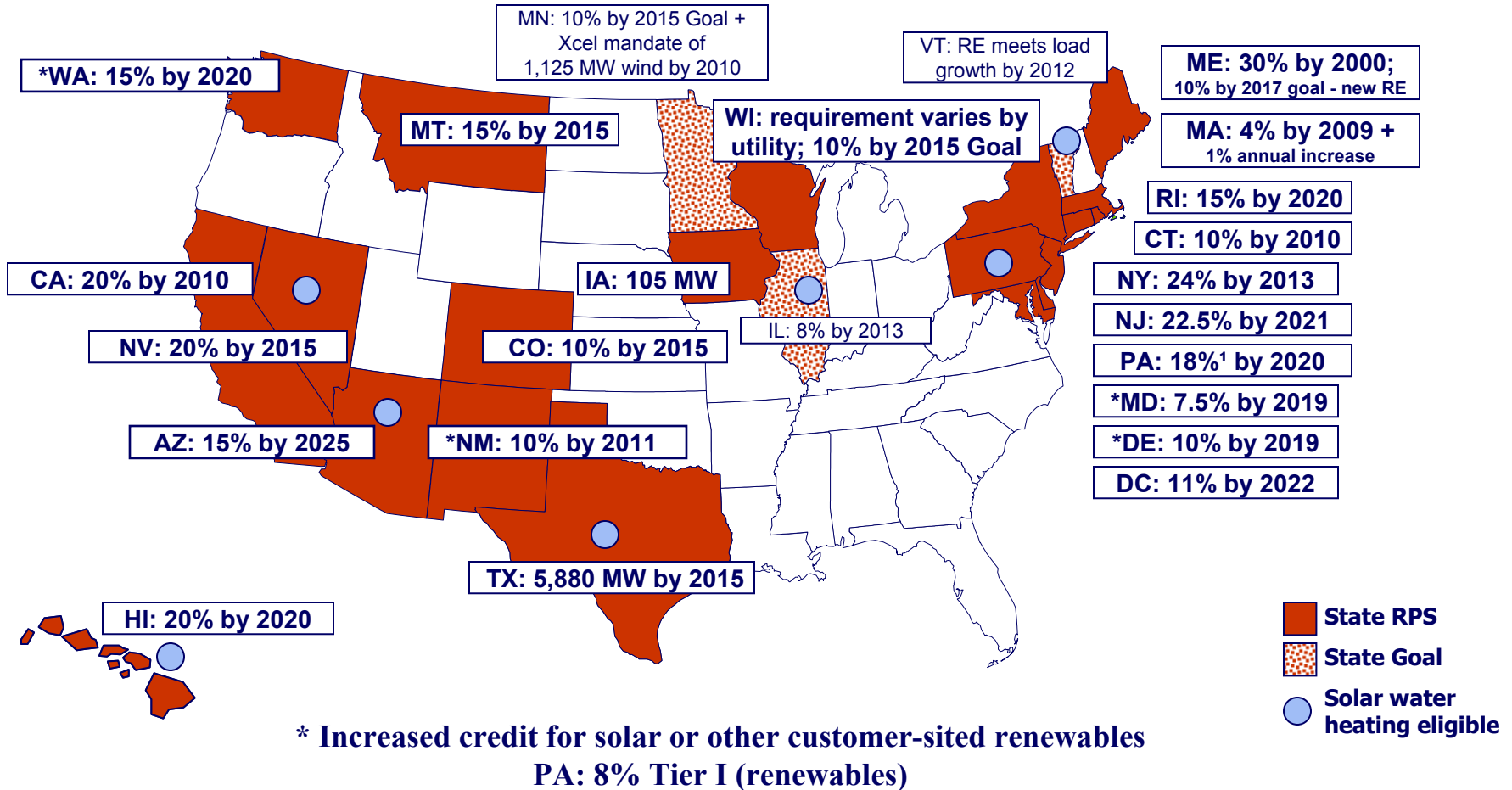


# Per Capita Electricity Consumption kWh/person

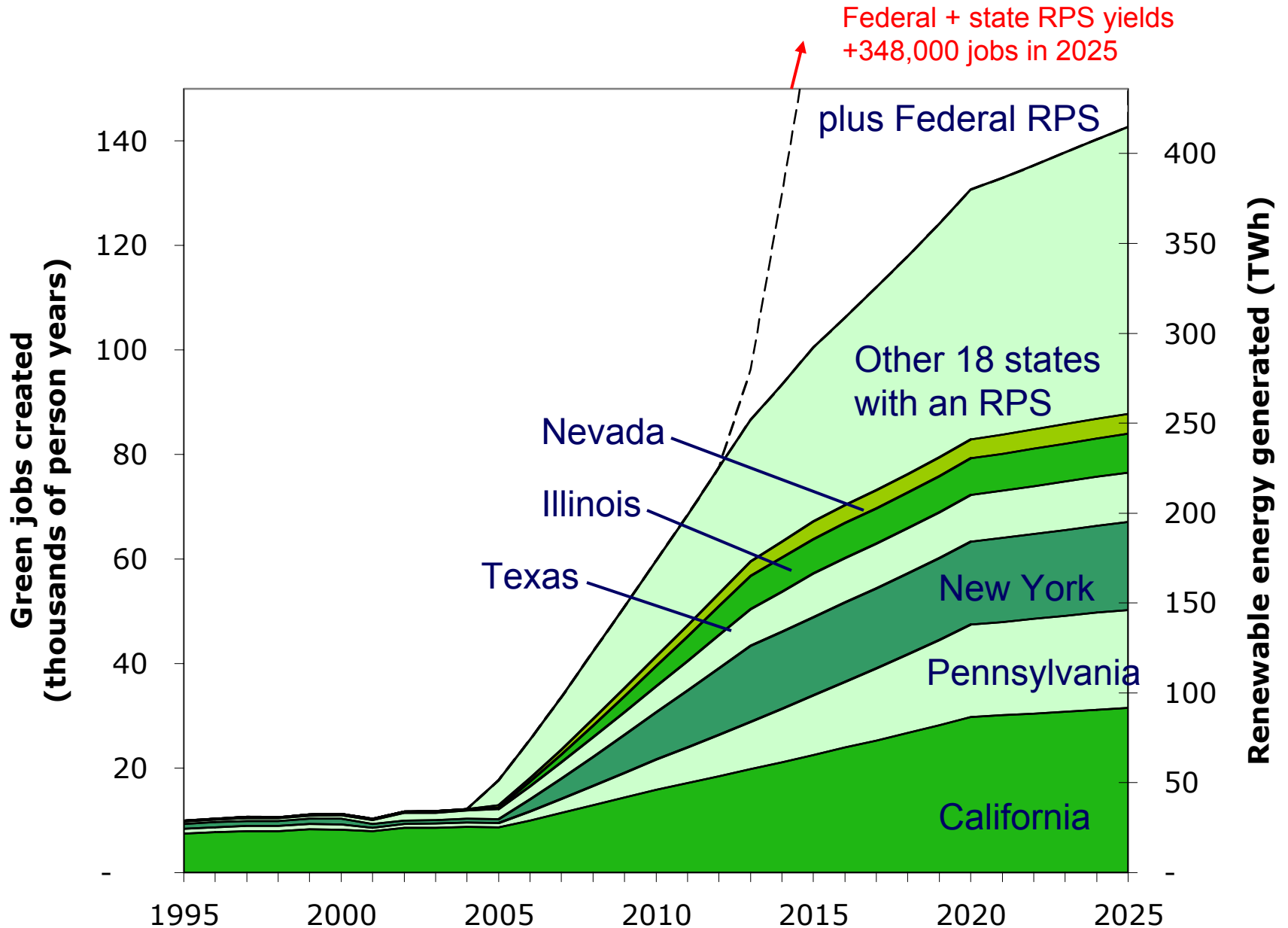


# Renewable Energy Portfolio Standards (RPS)

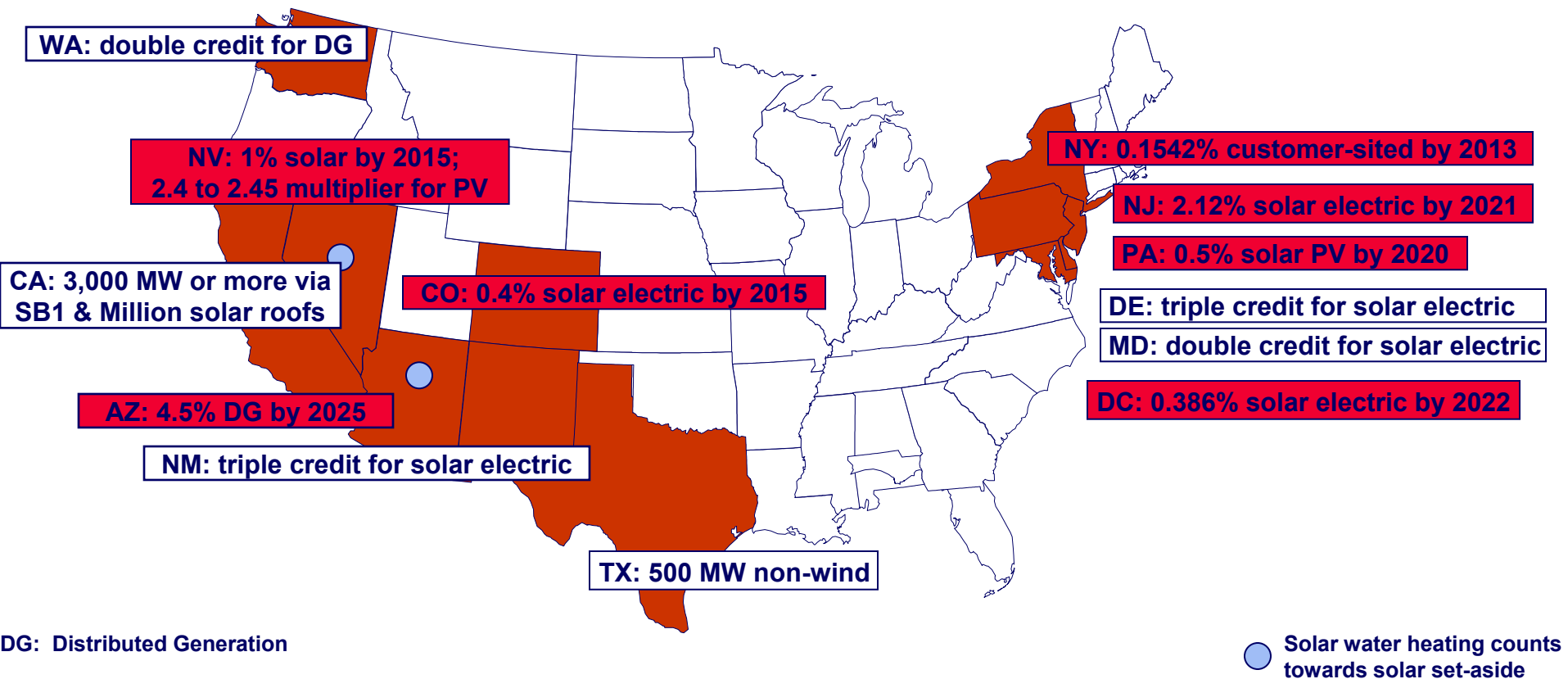
## 26 states + Washington, DC, and counting



# Green Collar Job Creation



# ***Solar & Distributed Generation Provisions in RPS Policies***



# Solar Energy for Many Applications

Moscone Center, SF: 675,000 W



Residential Solar: 1000 - 4000 Watts/home  
**CA Solar Initiative/Million Solar Roofs:**  
**3,000 - 10,000 MW of solar to be built**



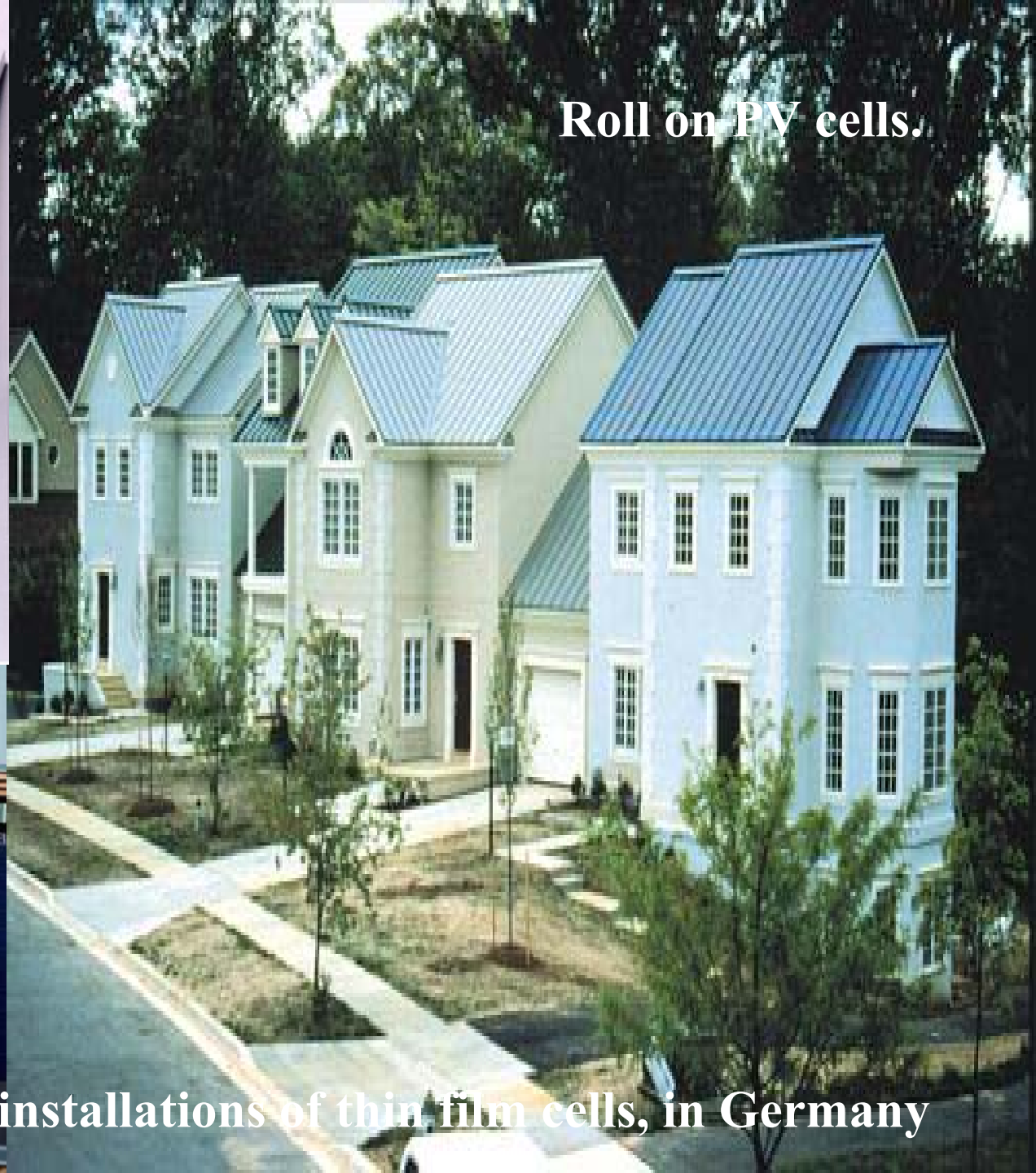
Kenyan PV market: Average system: 18W  
**Largest penetration rate of any nation**



	<u>California</u>	<u>Japan</u>
2005 Annual PV Installations	50 MW	290 MW
Average Cost for Residential System	\$8.8/Wac	\$7.4/Wac
Average Cost Reduction from 99-04	5.2%/year	8.9%/year

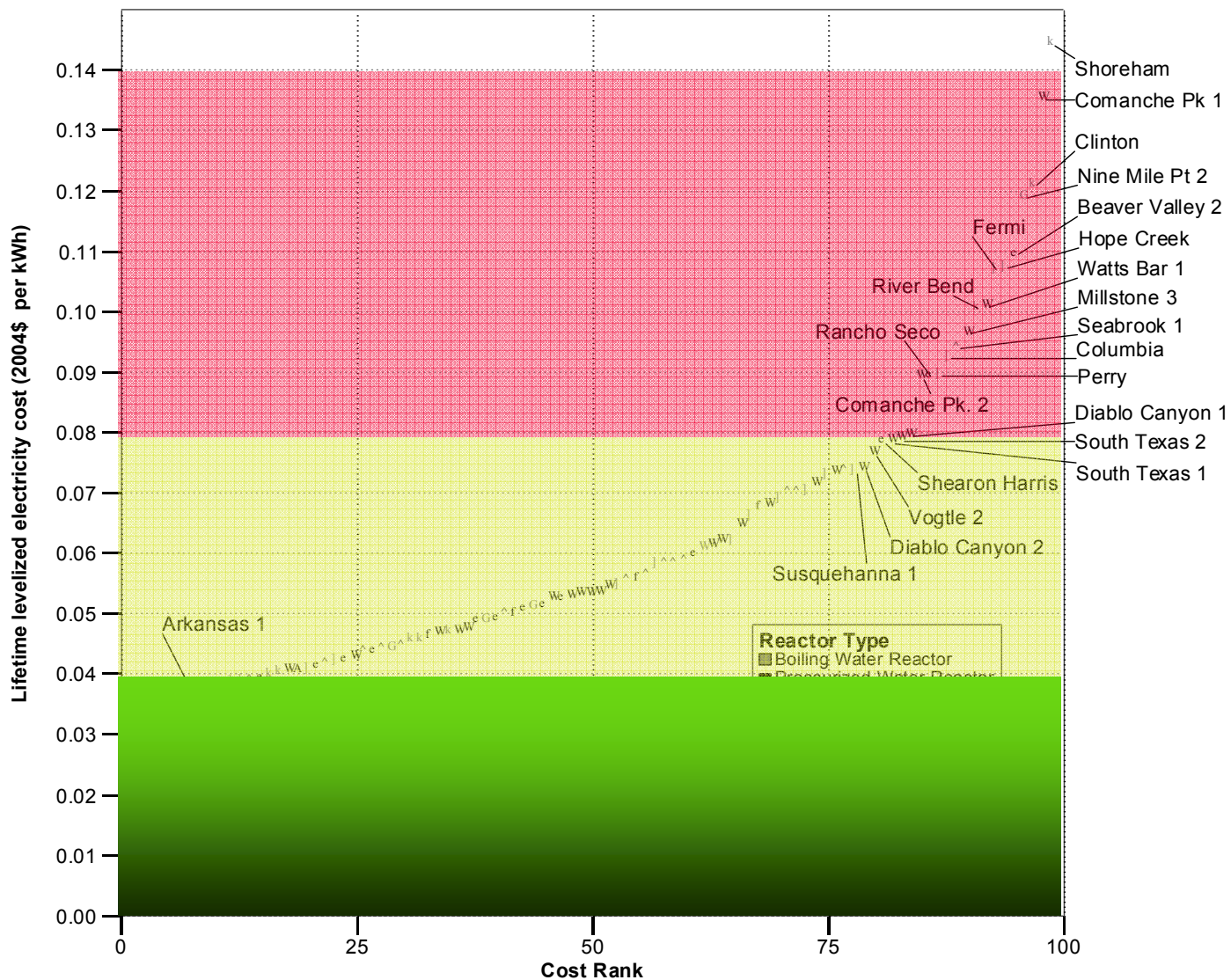


**Roll on PV cells.**



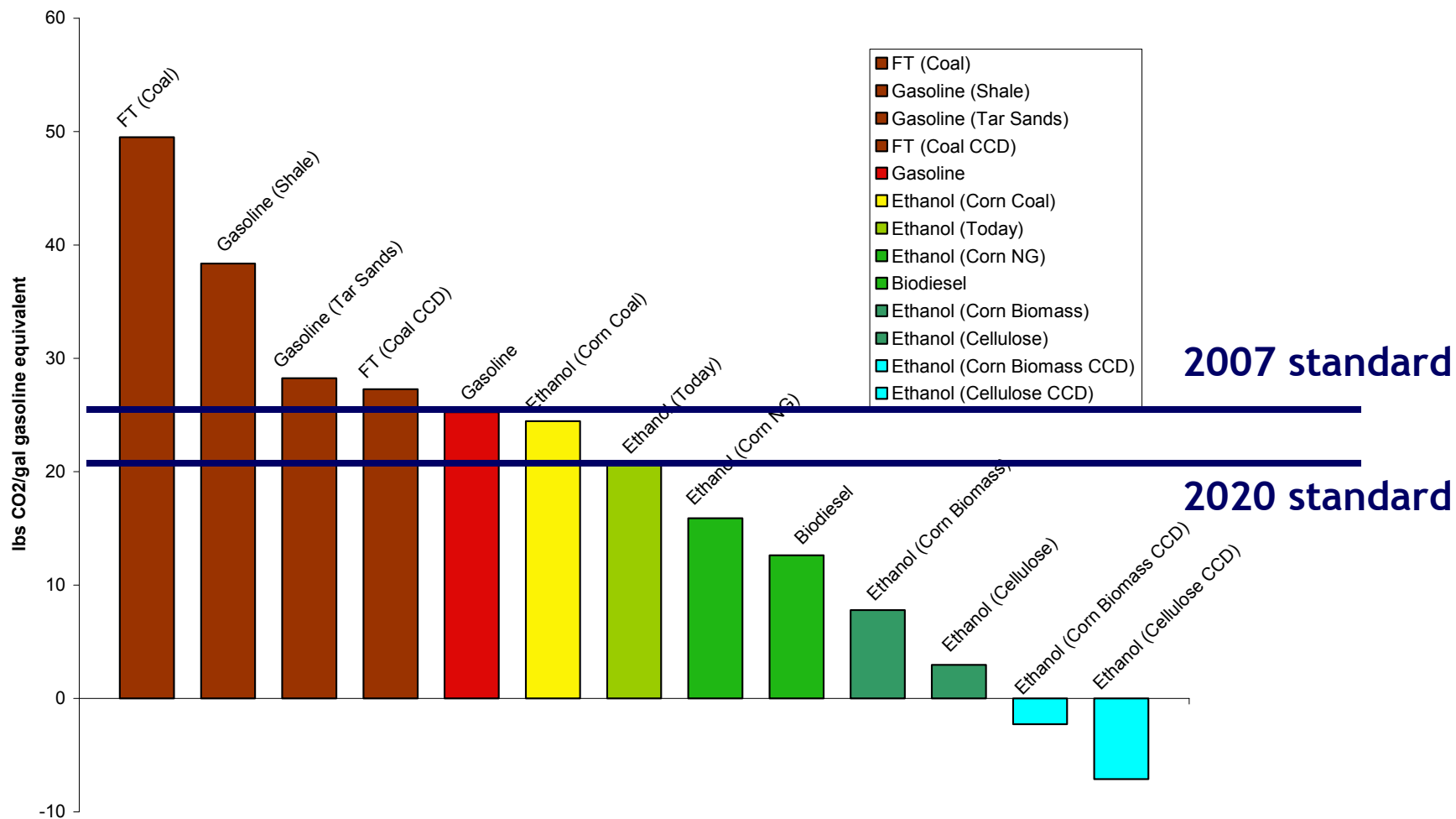
**Solar photovoltaic installations of thin film cells, in Germany**

# The Cost of Nuclear Power from the U. S. Civilian Reactor Fleet



Hultman, Koomey & Kammen (2007) *ES&T*

# An Alternative Fuel is Not Necessarily a Low-Carbon Fuel, but it can be (California Executive Order S-7-01)

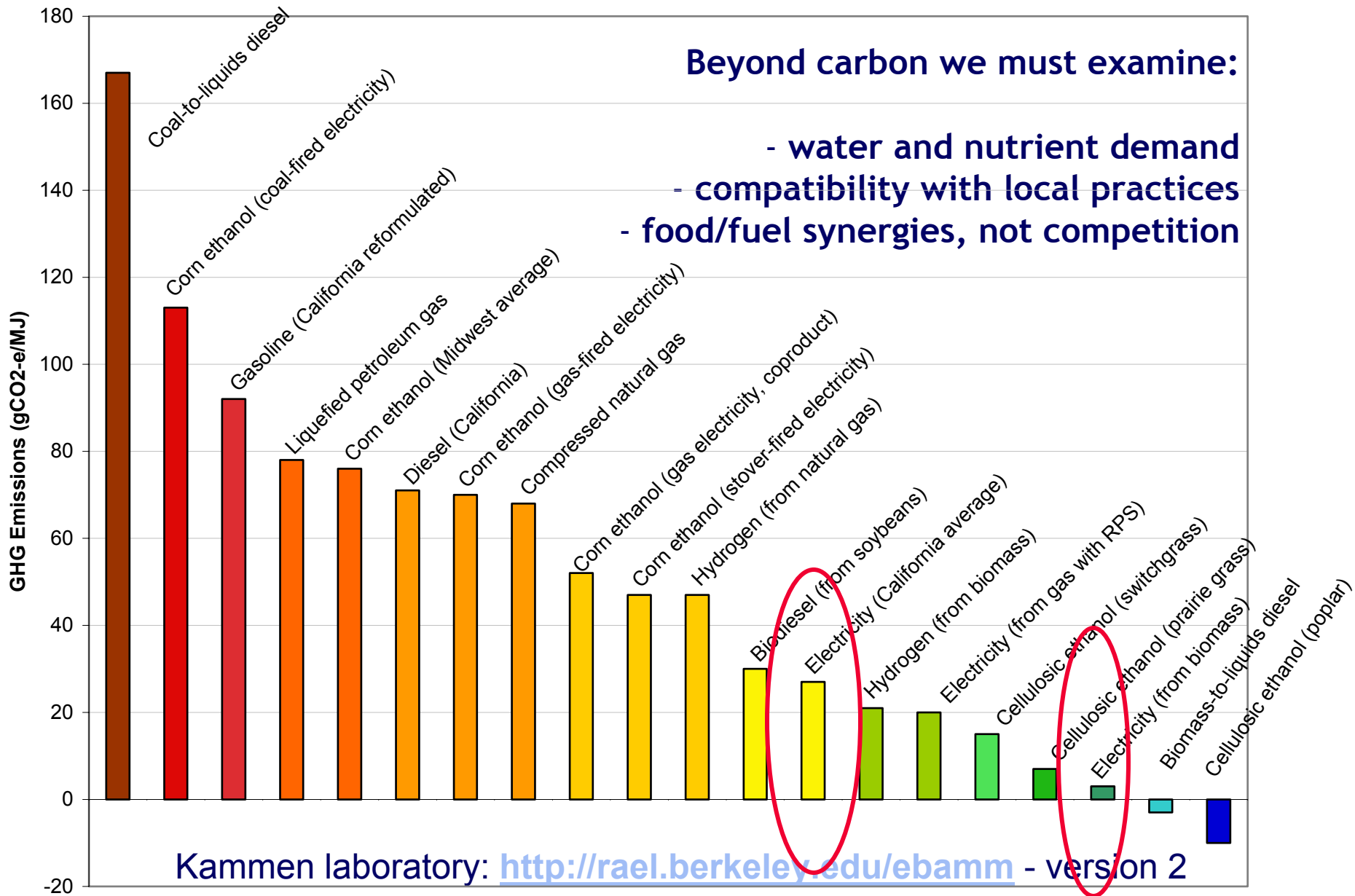




# Plug In Partners / e.g. CalCars.org



# From a Low Carbon Fuel Standard to a Sustainable Fuel Standard



# A promising crop: *Miscanthus X Giganticus*



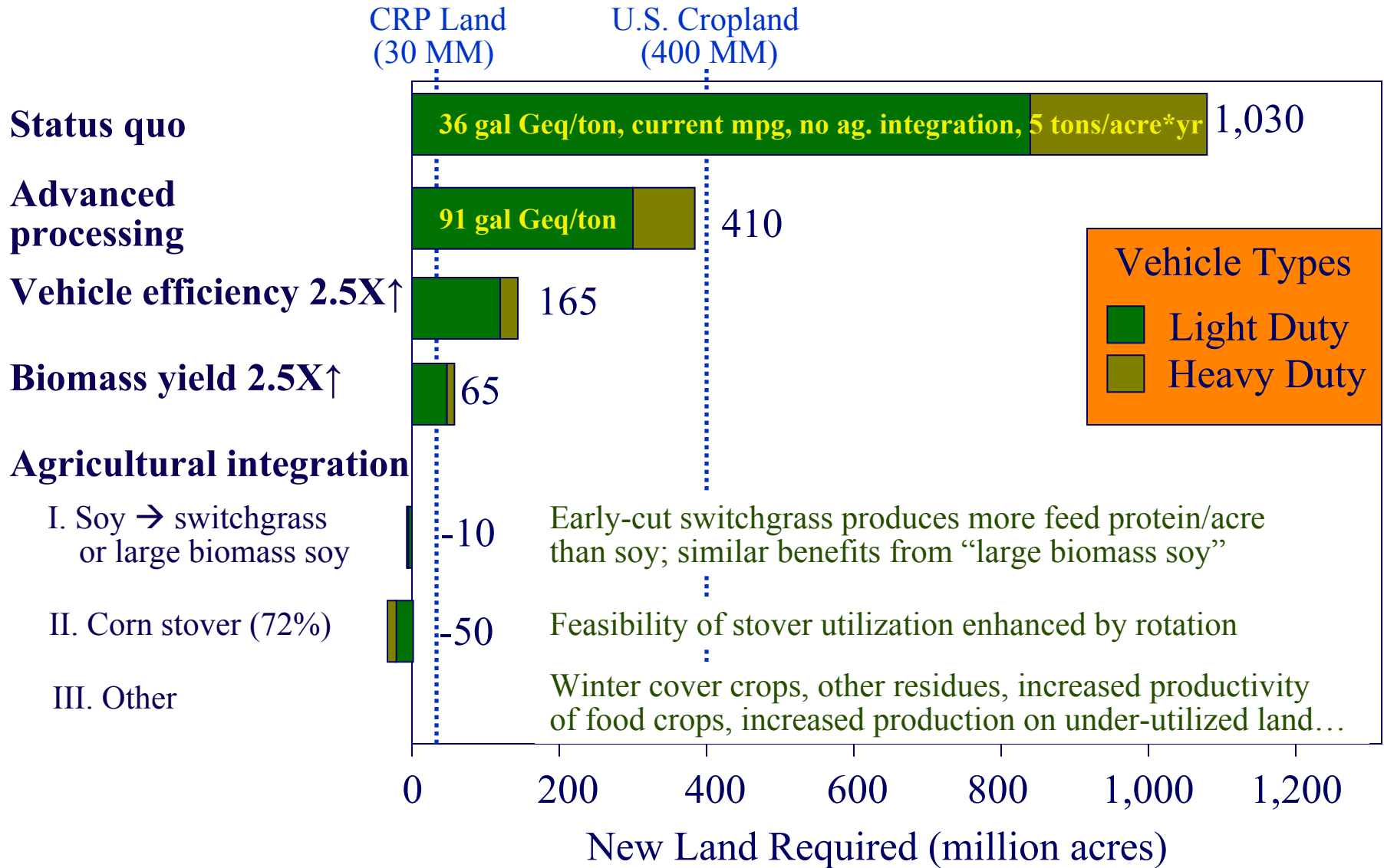
Top left: summer Miscanthus growth (sterile)

Top right: Miscanthus stands (UK)

Right: winter harvest of the C4 plant, Miscanthus after growing season and nutrients and water returned to the soil

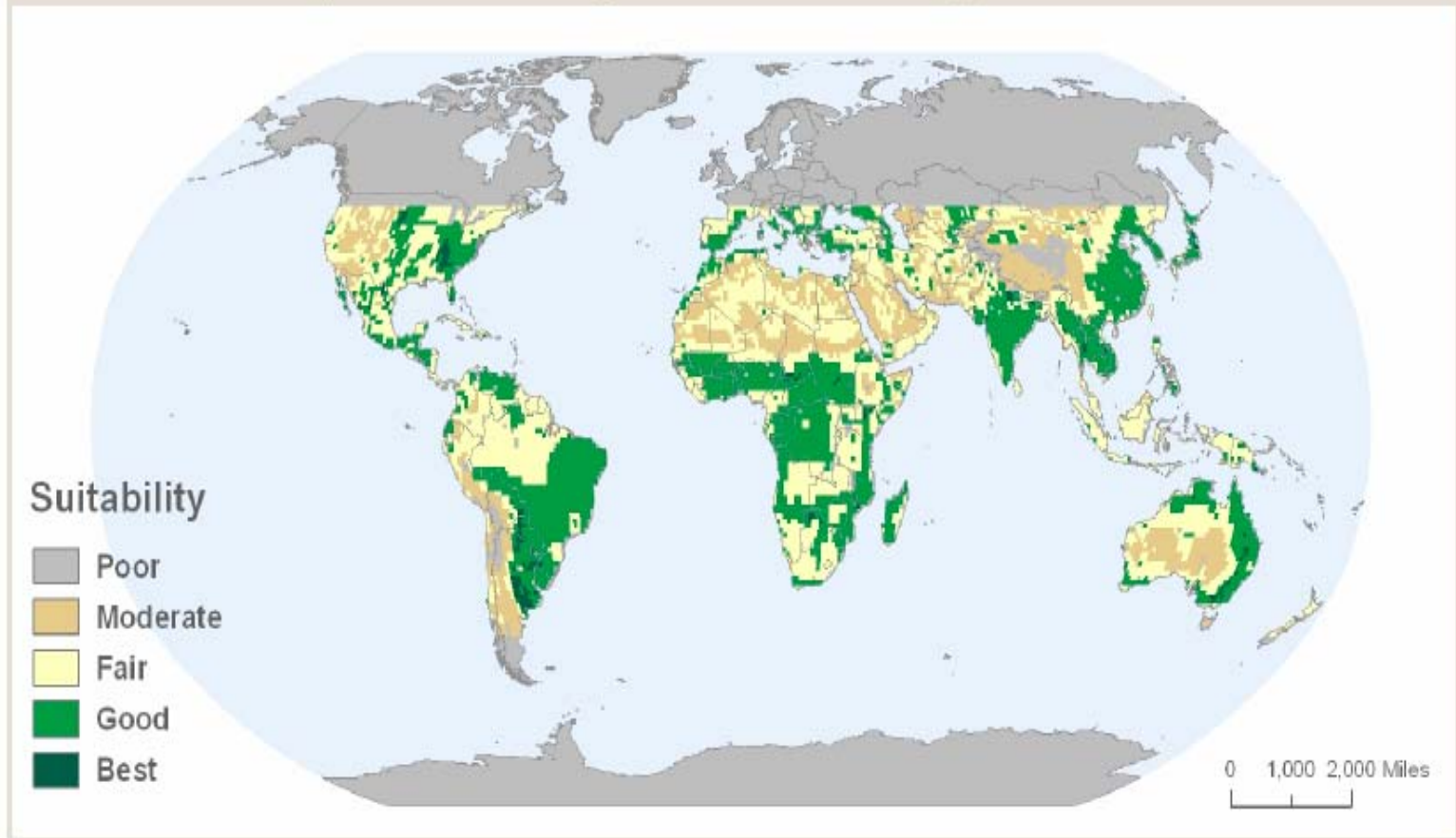


# Land Required to Satisfy Current U.S. Mobility Demand



***U.S. mobility demand, the largest per capita in the world, could be met from land now used for agriculture while maintaining food production (L. Lynd)***

## Optimal Sorghum Growing Areas



**Figure 1.** Optimal sorghum growing areas are based on solar radiation, minimum, maximum, and monthly temperature, annual precipitation, and soil texture. Produced by the UC-Berkeley Geospatial Imaging and Informatics Facility (GIIF) as an early demonstration of the data methods available for this study.

# Forest Resources Under Stress

(Bailis, Ezzati and Kammen, *Science*, 2005)

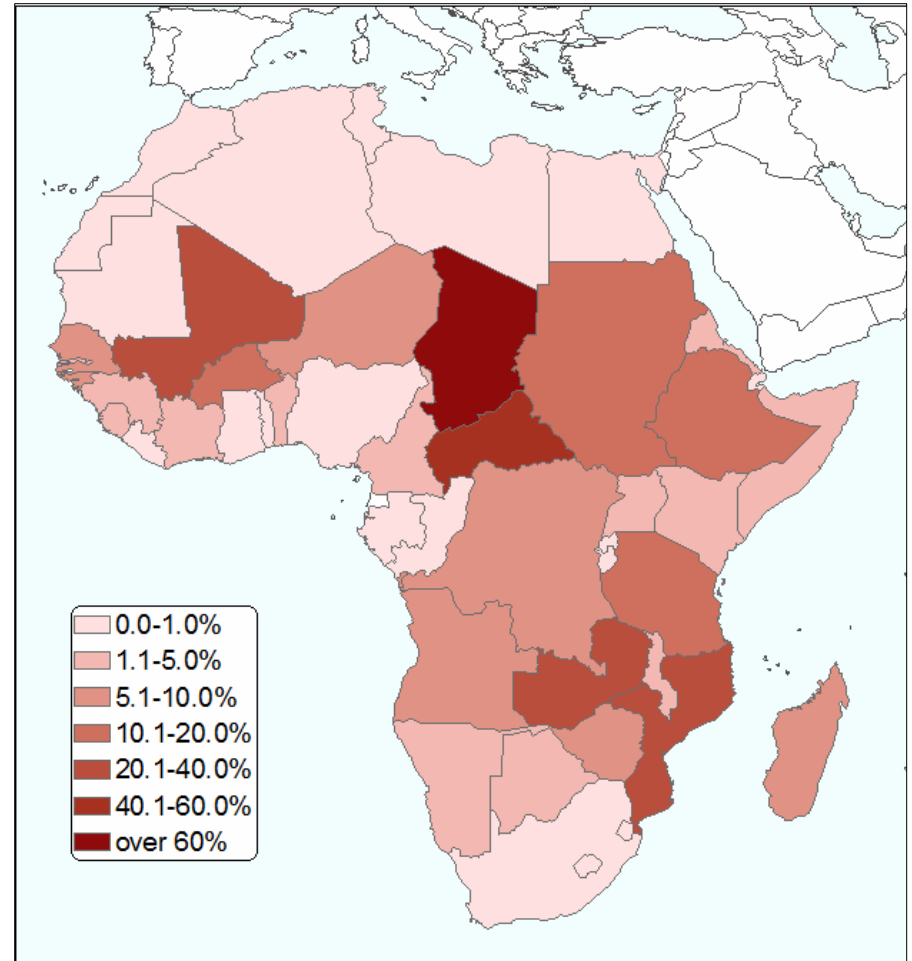


GEORGE HOLLAND

COOKSTOVE SMOKE is ubiquitous in Kenya, where wood, charcoal and other biomass fuels are used for cooking and heating. Particulates in smoke are a major contributor to respiratory disease, the leading cause of illness in developing nations.

# Ethanol can Displace Gasoline Consumption in Africa

- Using only post-harvest crop losses as inputs (up to 50 percent of yields), biofuels can play a significant role
- Implications for poverty alleviation, job creation, urban health, and foreign currency savings
- Metrics for ecological and cultural sustainability must be part of the planning process



Source: FAO/IIASA 2002, EIA 2007, ICRISAT 2007



按照当前的增长速度，**25年内中国的建筑面积将翻一番。**  
**At current growth rates, the built area of China will double within 25 years**







中国采取大规模的高效住房建筑方式来满足这一增长速度  
——每年建筑**1100**万套‘超级大院’住房

**China is efficient at building housing on a mass scale to meet this rate of growth  
– 11 million new ‘SuperBlock’ housing units are built each year**





人们认识到可持续发展的需要.....

The need for sustainable development is recognized...

**“我们将大力发展循环经济，降低能源和资源消耗，构建一个资源保护和环境友好型社会，确保在经济发展、人口、资源和环境中实现稳步平衡。”**

**中国国家主席胡锦涛2006年11月17日在亚太经济合作组织(APEC)工商领导人峰会上的讲话**

***"We will endeavor to develop a circular economy, lower energy and resources consumption and build a resource-conserving and environment-friendly society and ensure sound balance between economic development, population, resources and environment."***

**Chinese President Hu Jintao, CEO summit of the Asia-Pacific Economic Cooperation (APEC), Nov. 17 2006**

# 青岛生态小区：位置

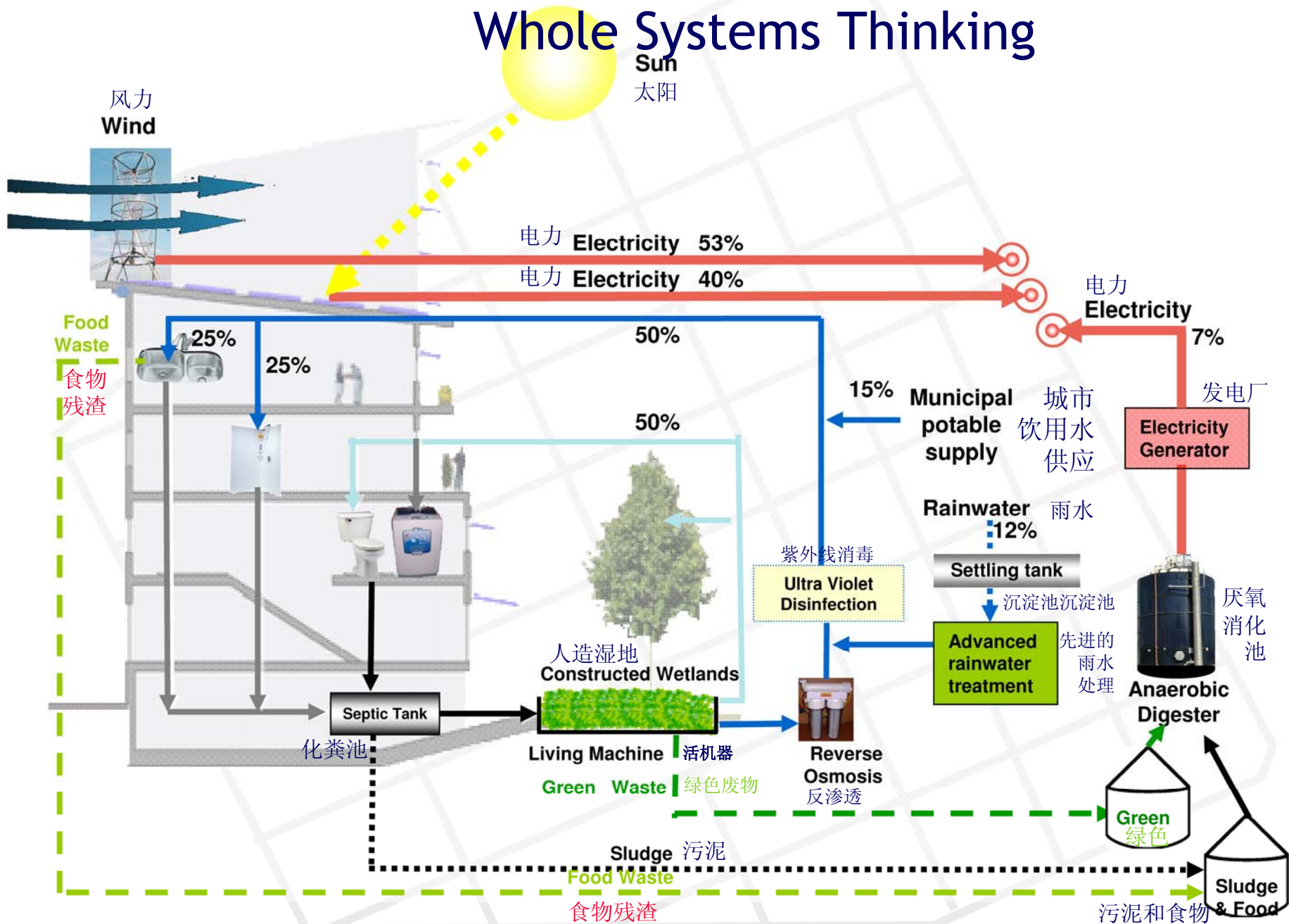
## Qingdao Eco-Site: Location

(Qingdao City/UC Berkeley/ARUP collaboration)

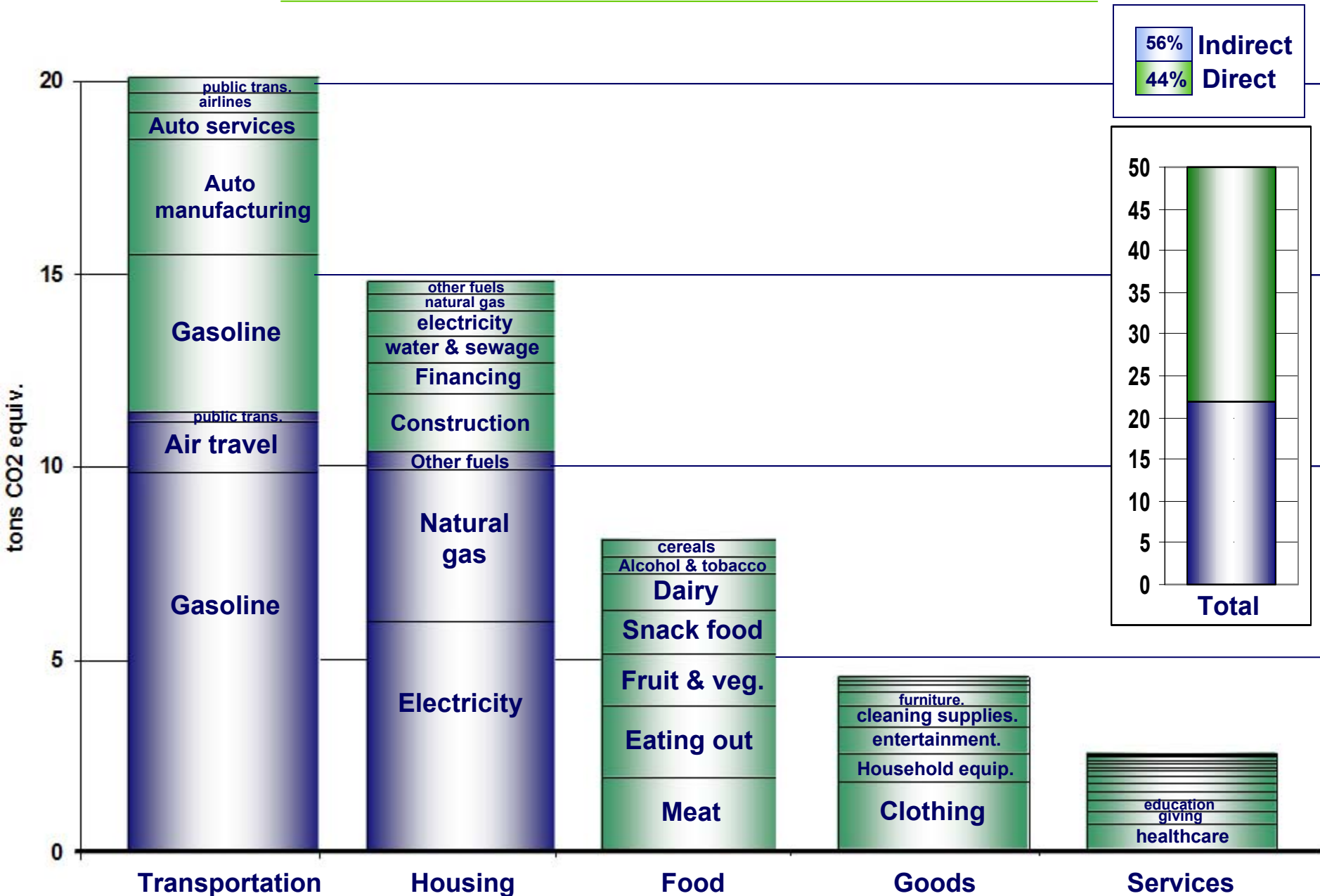


# 全面系统思考

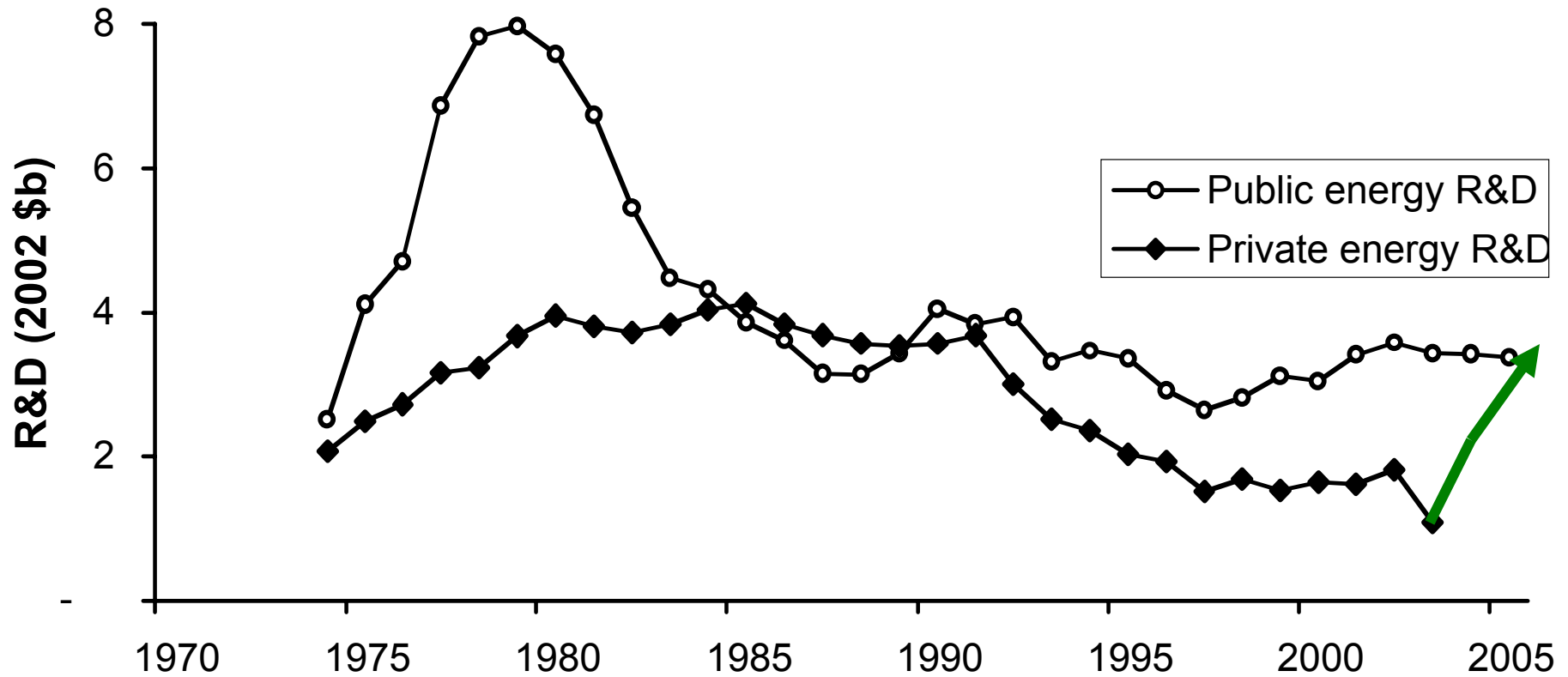
## Whole Systems Thinking



# Summary of GHG Emissions for Typical U.S. Household (LEAPS Results) 50 Metric tons of CO<sub>2</sub> equivalent gases



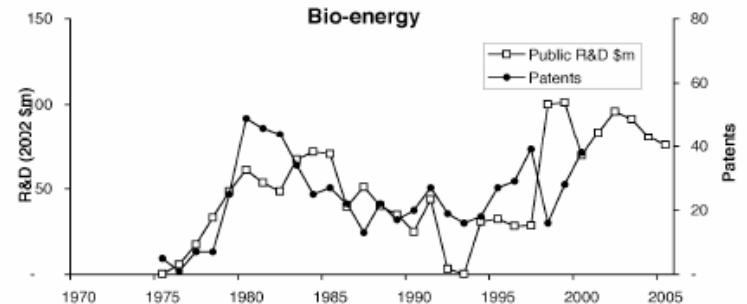
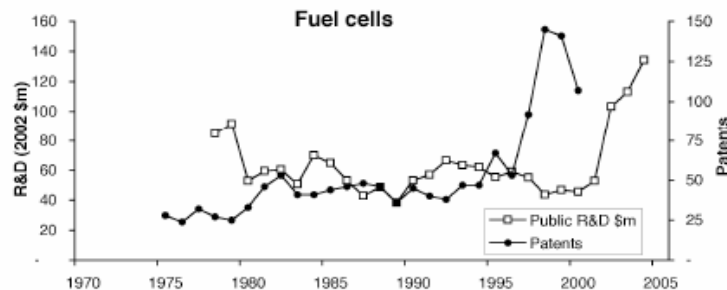
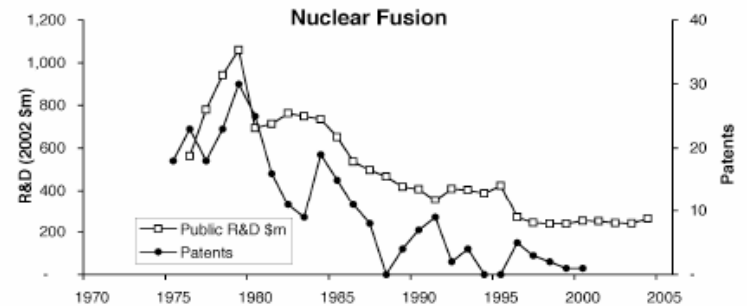
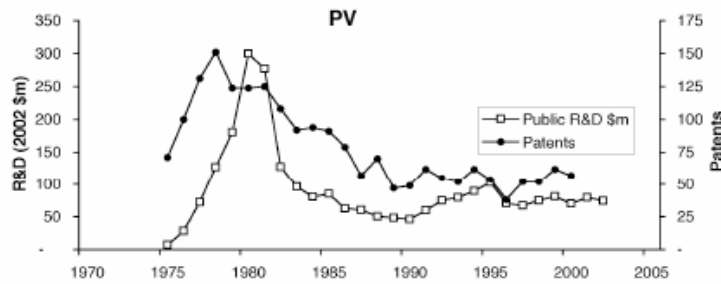
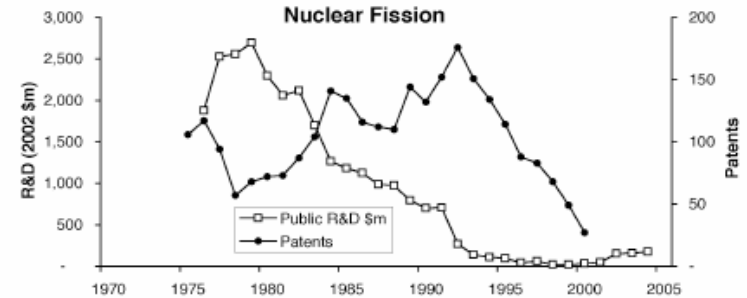
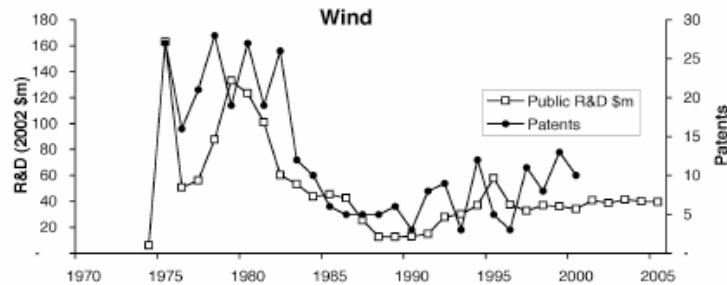
# United States' Public and Private Sector Energy Research and Development Spending



Kammen and Nemet (2005)

“Reversing the incredible shrinking energy R&D budget,” *Issues in Science & Technology*, Fall, 84 - 88.

# Patents and R&D Funding Correlated



Kammen and Nemet (2005)

“Reversing the incredible shrinking energy R&D budget,” *Issues in Science & Technology*, Fall, 84 - 88.

And Nemet, dissertation, 2007



California Public Utilities Commission  
505 Van Ness Ave., San Francisco, CA

**PRESS RELEASE**

**PROPOSAL: \$620 MILLION, 10 YEAR PROGRAM  
THE INSTITUTE WILL BE A HUB FOR GLOBAL PARTNERSHIPS**

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FOR IMMEDIATE RELEASE

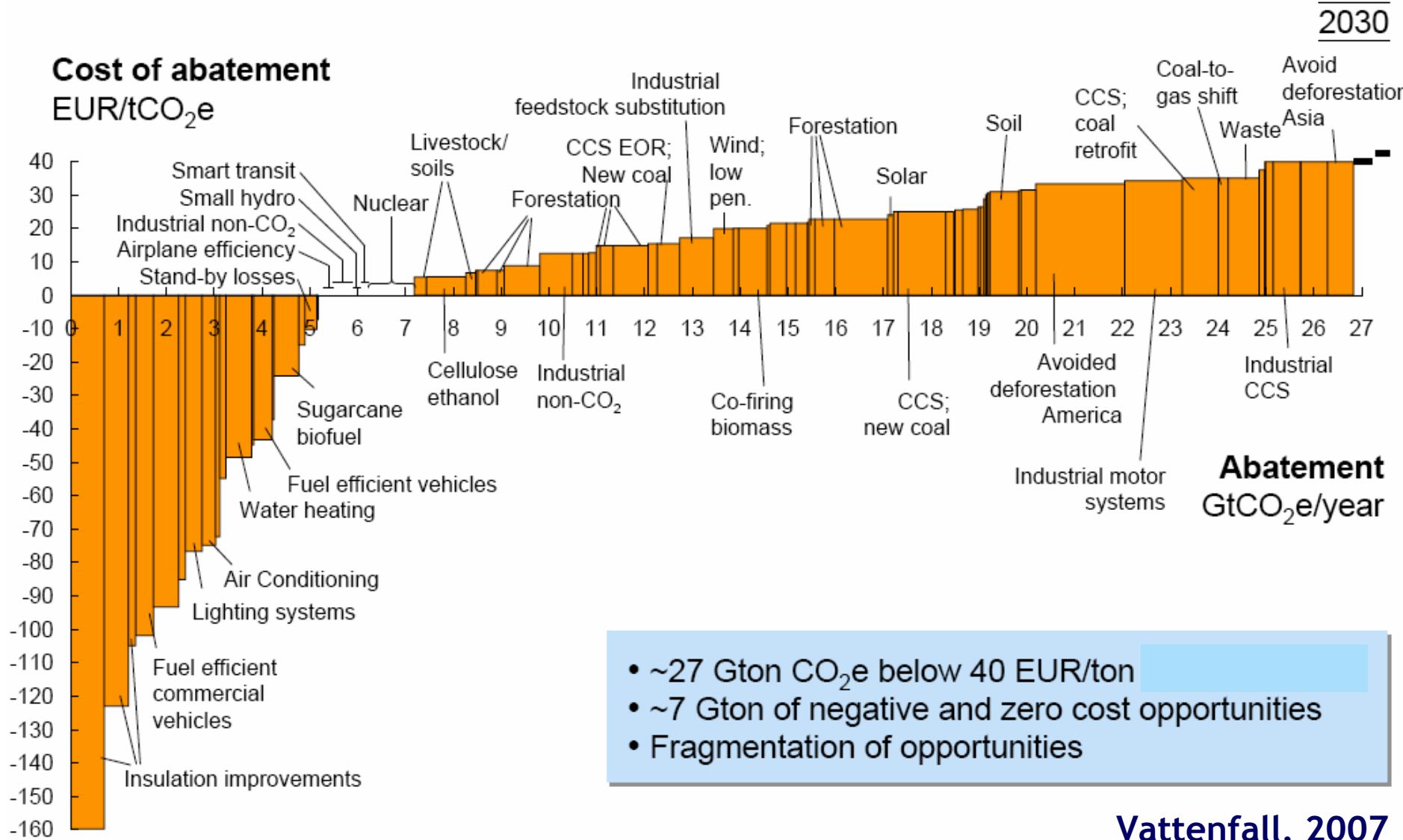
Media Contact: Terrie Prosper, 415.703.1366, [news@cpuc.ca.gov](mailto:news@cpuc.ca.gov)

**PUC CONSIDERS UC PROPOSAL  
CREATING CLIMATE SOLUTION INSTITUTE**

SAN FRANCISCO, September 20, 2007 - The California Public Utilities Commission (PUC), as part of its continuing effort to aggressively pursue ways for California to reduce greenhouse gas emissions, today said it will analyze and act upon a proposal by the University of California to create the California Institute for Climate Solutions.

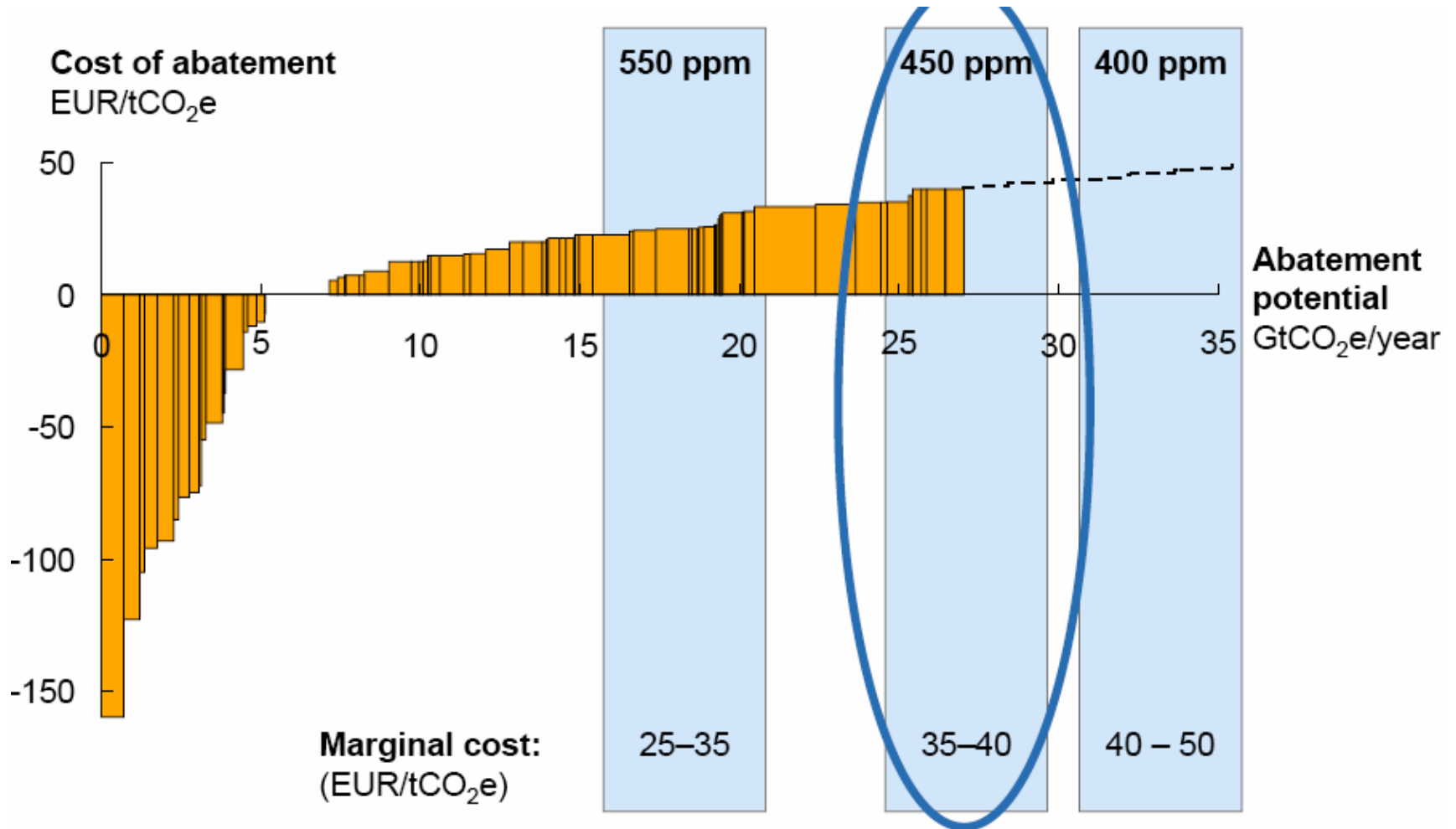


# Global CO<sub>2</sub> Abatement Opportunities



Vattenfall, 2007

# Global CO<sub>2</sub> Abatement Opportunities



Vattenfall, 2007

# Enabling a Clean Energy Future

- Clean energy sources today are evolving rapidly, but are a small component of our overall energy system
- Rapid growth of the clean energy sector will require a coordinated commitment to *technology push* and *demand pull*
  - Aggressive R&D will need to be coupled with strong support for clean energy market expansion
  - Business and consumer involvement is vital
- One new California/Germany/Iceland per year, at minimum, is needed, and we must be successful in making current regulations work
- Pricing carbon/greenhouse gas emissions is vital to moving from sector support strategies to long-term sustainability policies