# Renewable energy
## and the smart grid

**Presentation 3rd Asian IAEE**

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Kyoto, Japan

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# Pleasure to be in Kyoto

- Always a pleasure to visit Japan
- Thanks to IEE Japan, especially Professor Kenichi Matsui for including me on the program

# My main message

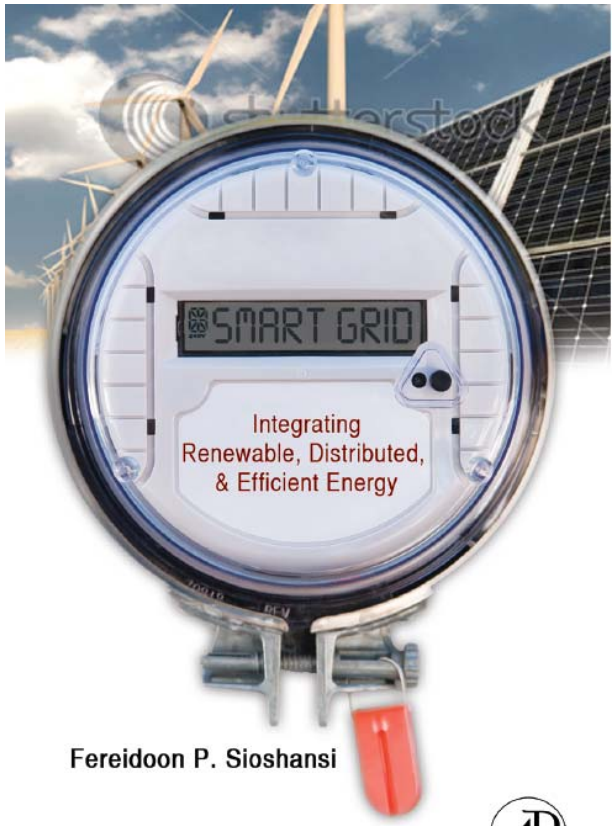
- Why future growth of renewable energy resources – broadly accepted as a major paradigm shift in the electricity sector – cannot be achieved without a more accommodating, more robust, and more capable grid
- The term “smart grid” gets in the way

# Proposed outline

- First: What paradigm shift?
- Second: What new demands on old grid?
- Third: What implementation challenges remain?

# Smart Grid

Nov 2011

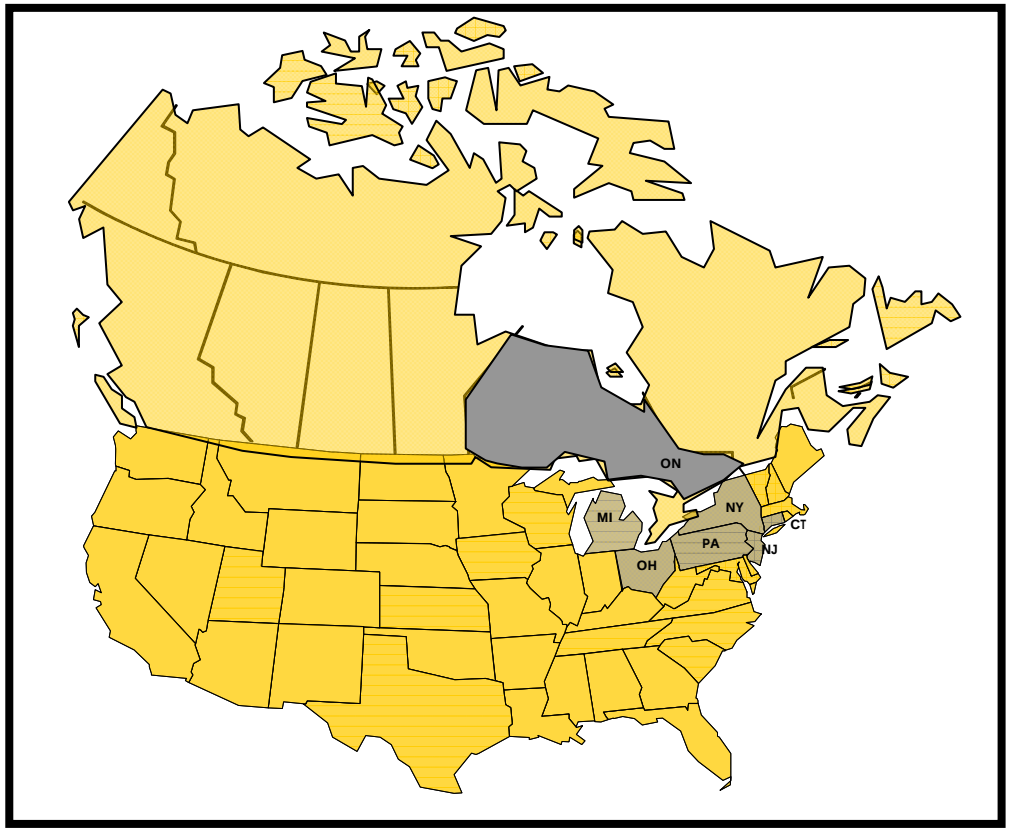


# First
# What paradigm change?

- 1. More reliable grid
- 2. Better balancing of supply & demand in real time
- 3. Integrating intermittent renewable energy
- 4. Accommodating distributed generation
- 5 Two-way conduit connecting loads to resources
- 6. Support “prices-to-devices” revolution

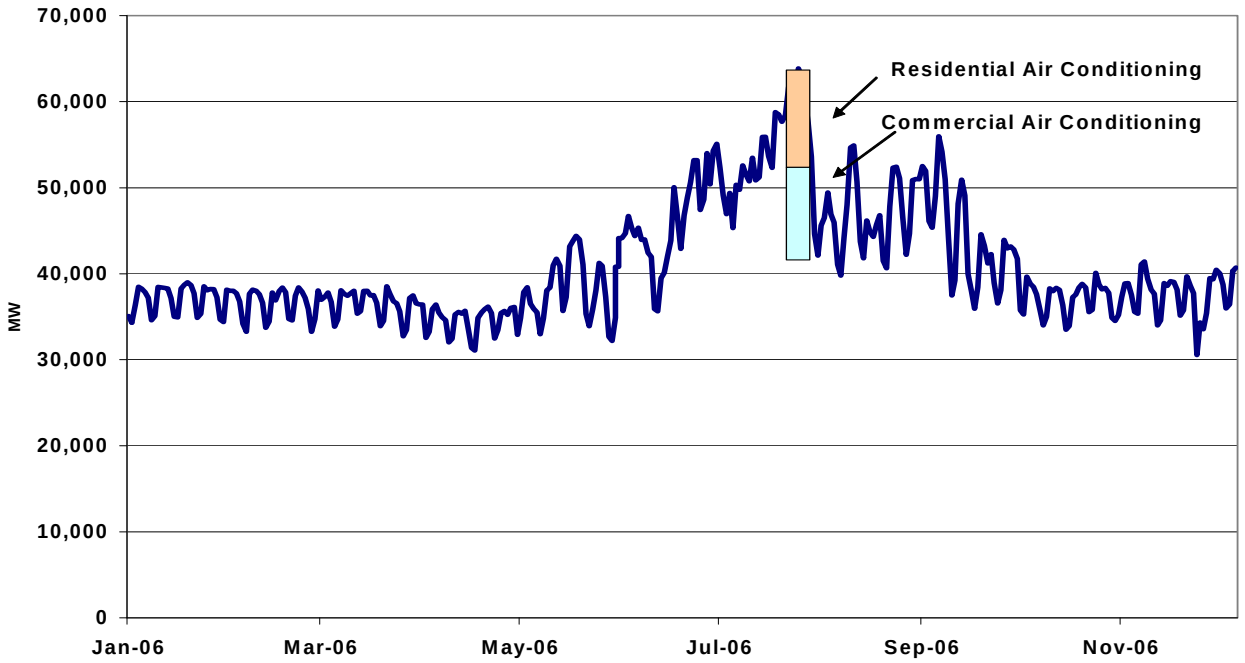
# Aug 03 Northeast Blackout

Need a more reliable grid



# Better balancing of load/generation

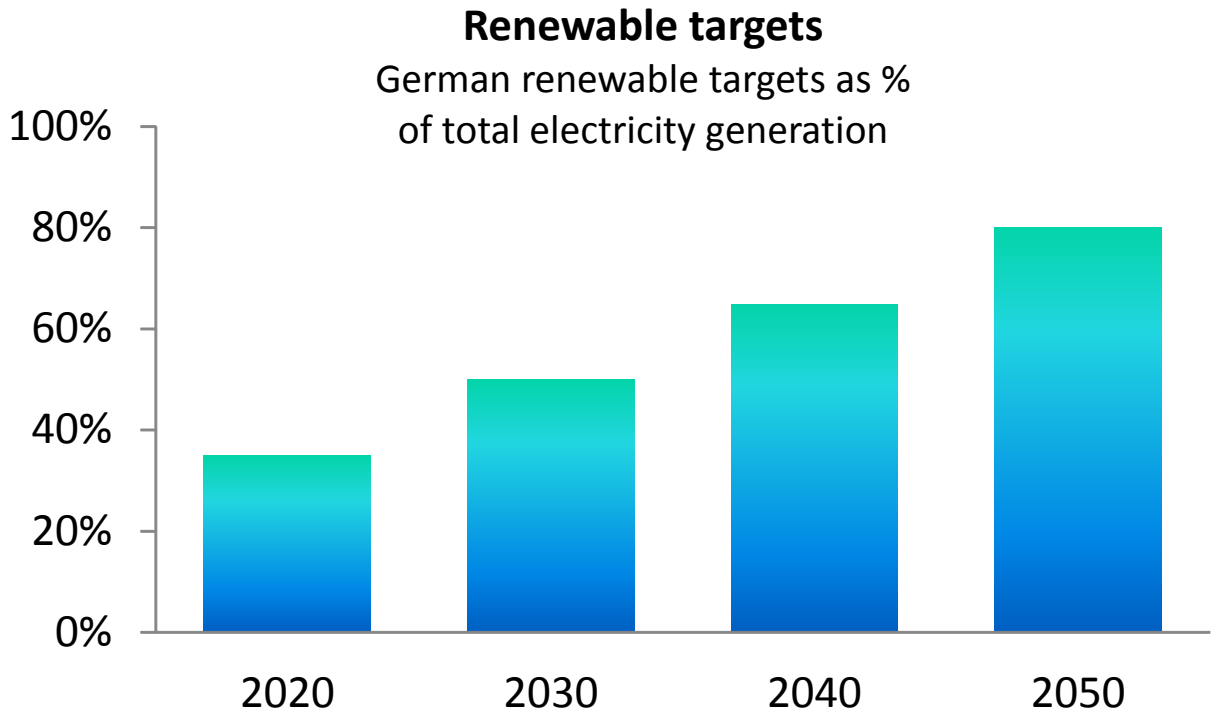
## CA's summer peaks are aggravated by flat pricing




Source: David Hungerford, CEC

# 80% by 2050!

German target post Fukushima




Source: German Govt. proposals

# Distributed generation

California Gov. envisions 12 GW of DG by 2025

**Residential Retrofit**

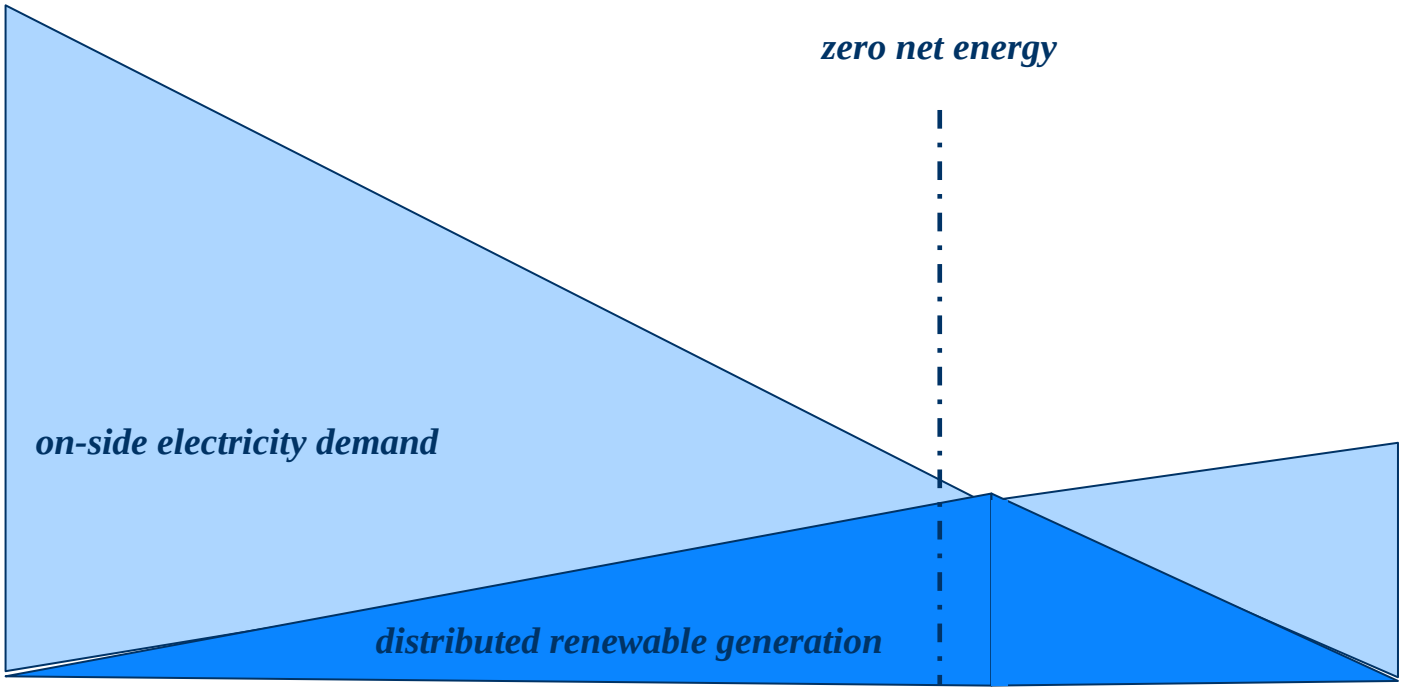
**New Production Homes**

**Commercial & Public**

**Power Plants**

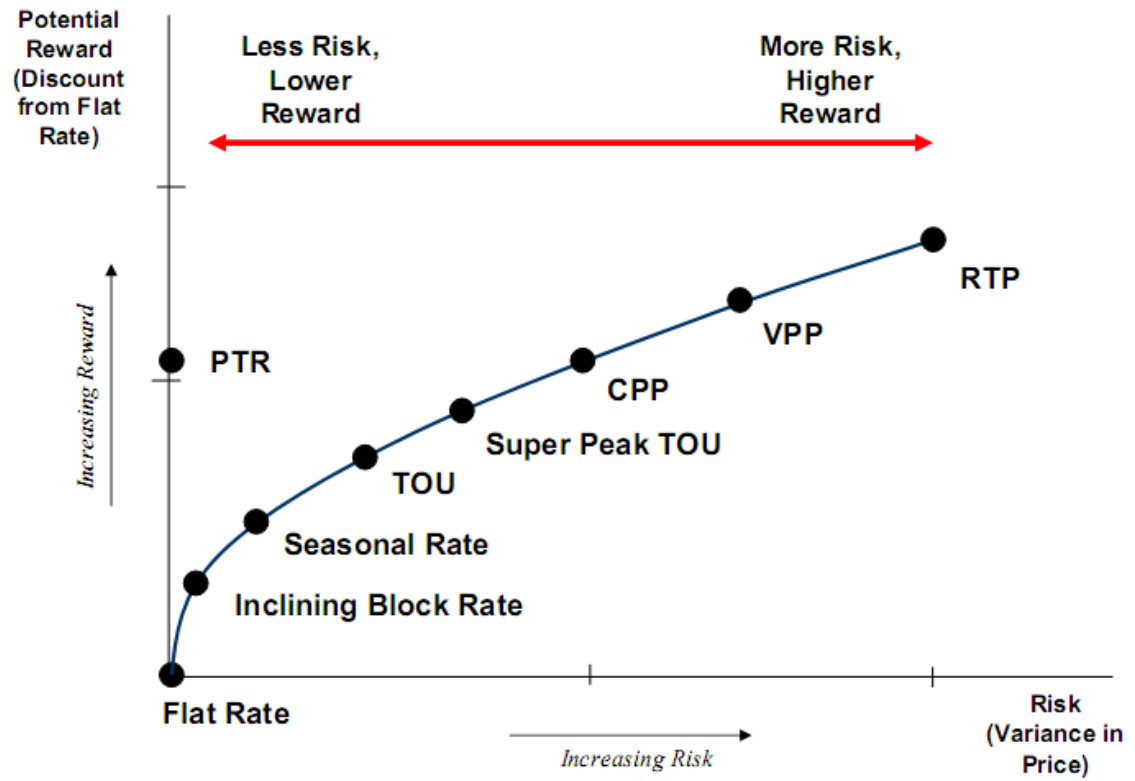
# Zero Net Energy

Grid as two-way conduit connecting loads to resources



# Prices-to-devices

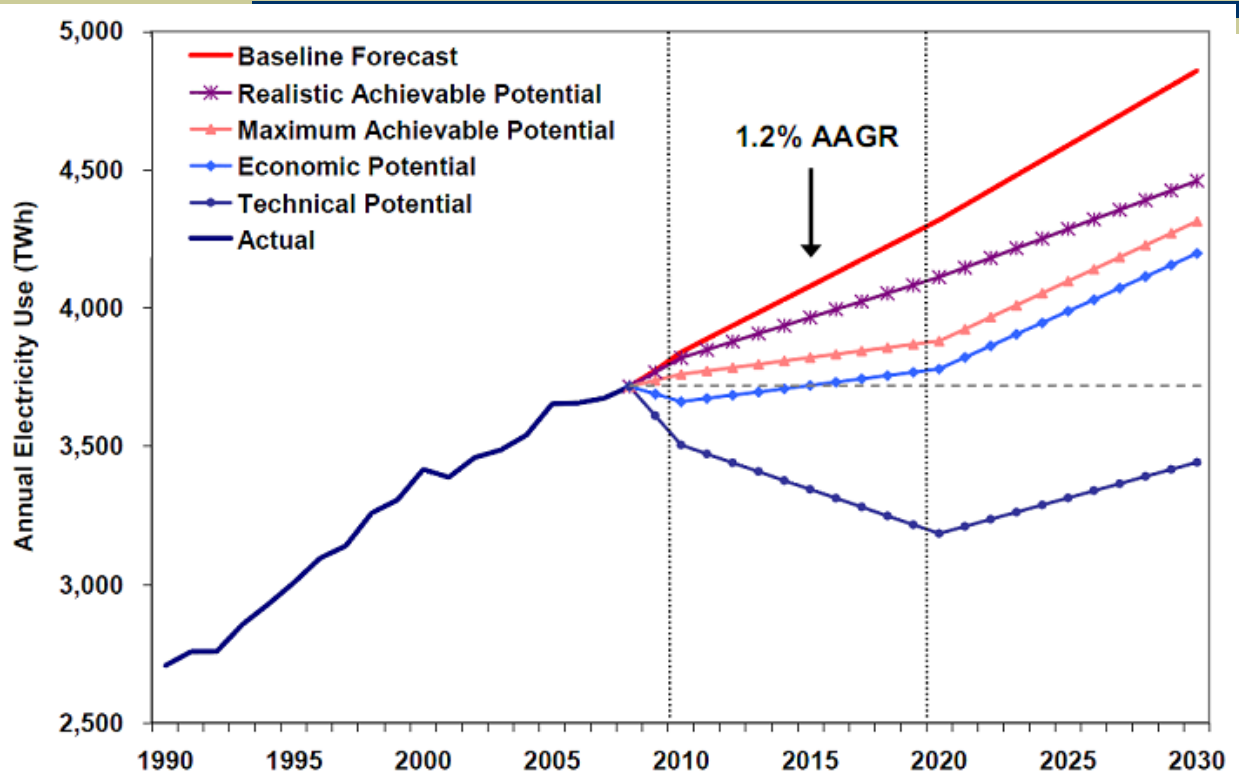
## Delivering smart prices to smart devices




Source: A. Faruqui, Brattle Group, Aug 2010

# 664 TWh EE potential

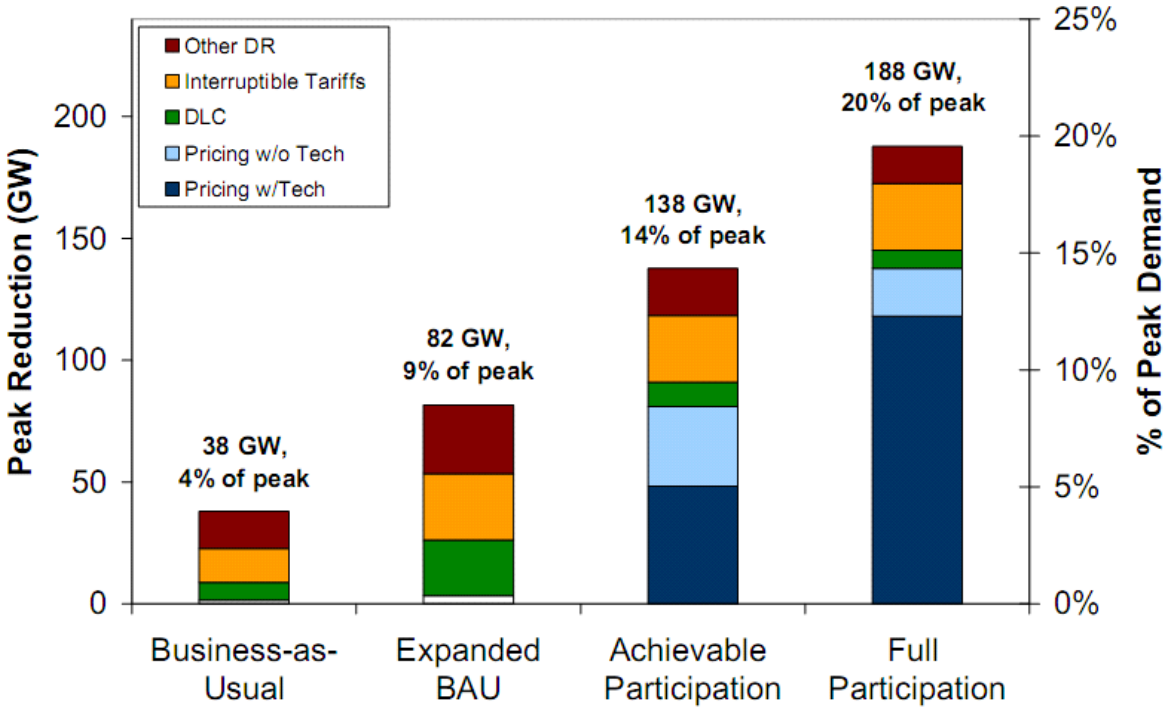
## EPRI claims 14% energy reduction possible by 2030




Source: A. Faruqui, Brattle Group, Aug 2010

# Demand Response

As much as 20% of US peak load may be managed by DR




Source: National assessment of DR potential, FERC, June 2009

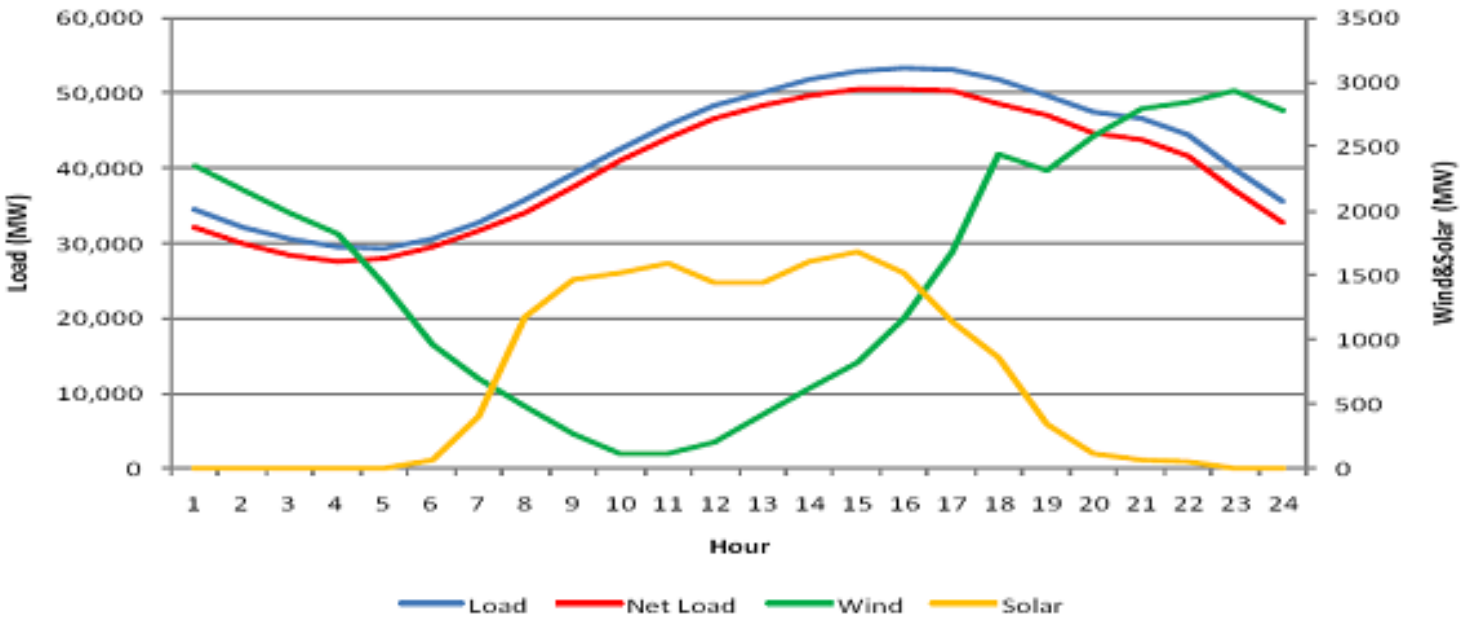
# Second

New demands on old grid

- Existing grid not capable of handling new requirements
  - Reliability
  - Real-timer balancing
  - Renewable integration
  - Distributed generation
  - Connecting loads & resources as a “conduit”
  - Prices-to-devices

# Balancing in real time

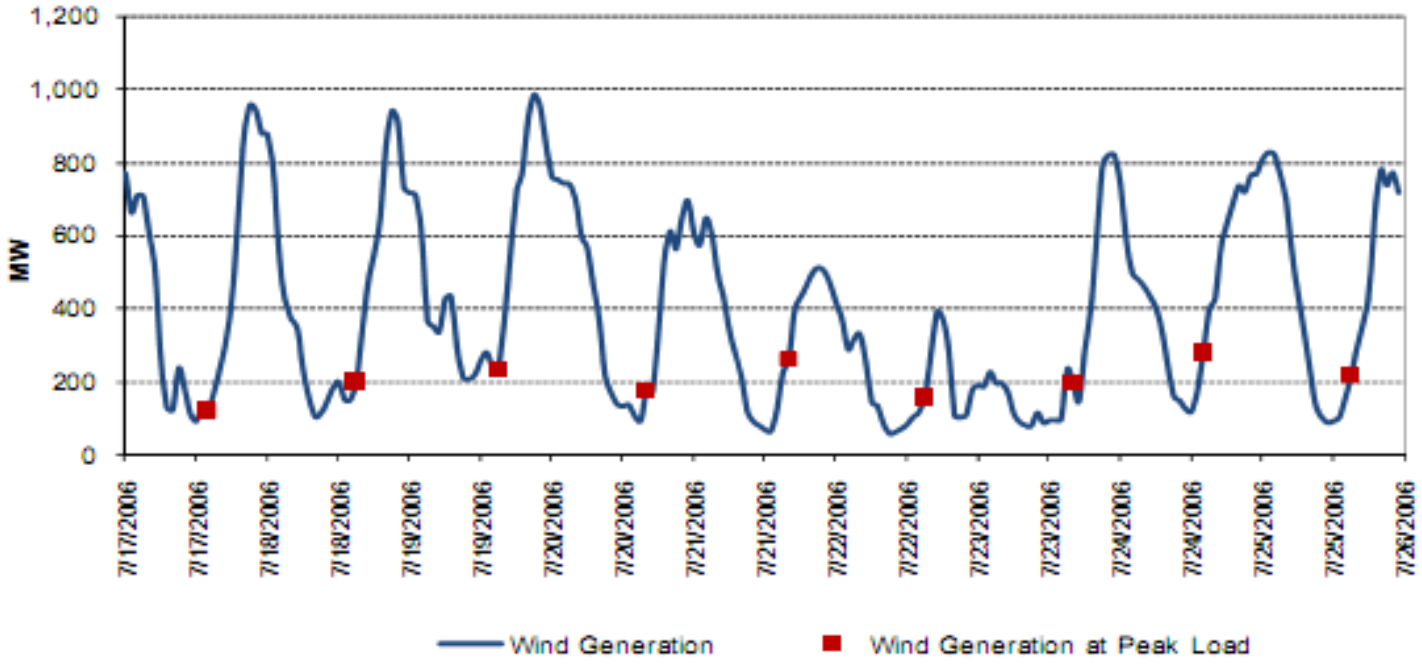
## Based on simulated CA data for 25 July 2012, MW




Source:

# Wind not available when needed

## CA wind capacity during all-time summer peak load in 2006




Source:

# Think of it as massive battery

*Or DG on wheels*

# Third
# Implementation challenges remain

- Enormous up-front costs, elusive distant gains
  - How do we finance, how do we distribute pains/gains?
- Investment, regulatory & policy misalignments
  - Utilities, are by and large, heavily regulated & slow to act
- Technology – a lot more is expected
  - Rapidly evolving on multiple fronts
- Integration
  - Getting various components to “synergize” is major challenge
- Implementation & execution
  - What is easy on paper is often difficult in practice
- Managing public expectations
  - Many more painful lessons to be learned along the way

# Questions?

- Thank you

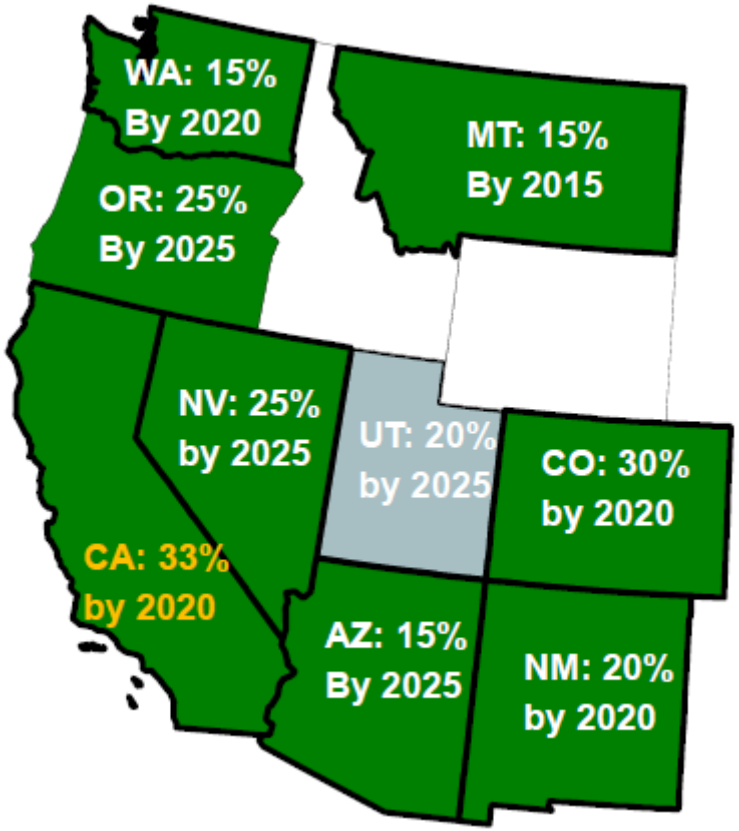
# Few take away points

- Current grid may not be *smart* but ain't *dumb*
  - Considered a significant "engineering achievement"
- Rapid progress on multiple fronts
  - Ample funding, R&D and entrepreneurial zest
- Expect more setbacks/surprises
  - Regulators reluctant to mandate dynamic pricing
  - Small but vocal opposition to smart meters, data privacy, etc
- No panacea, but a critical step in right direction
  - Driven by desire for cleaner/greener/more efficient future

# Back up slides

- Most likely NOT used

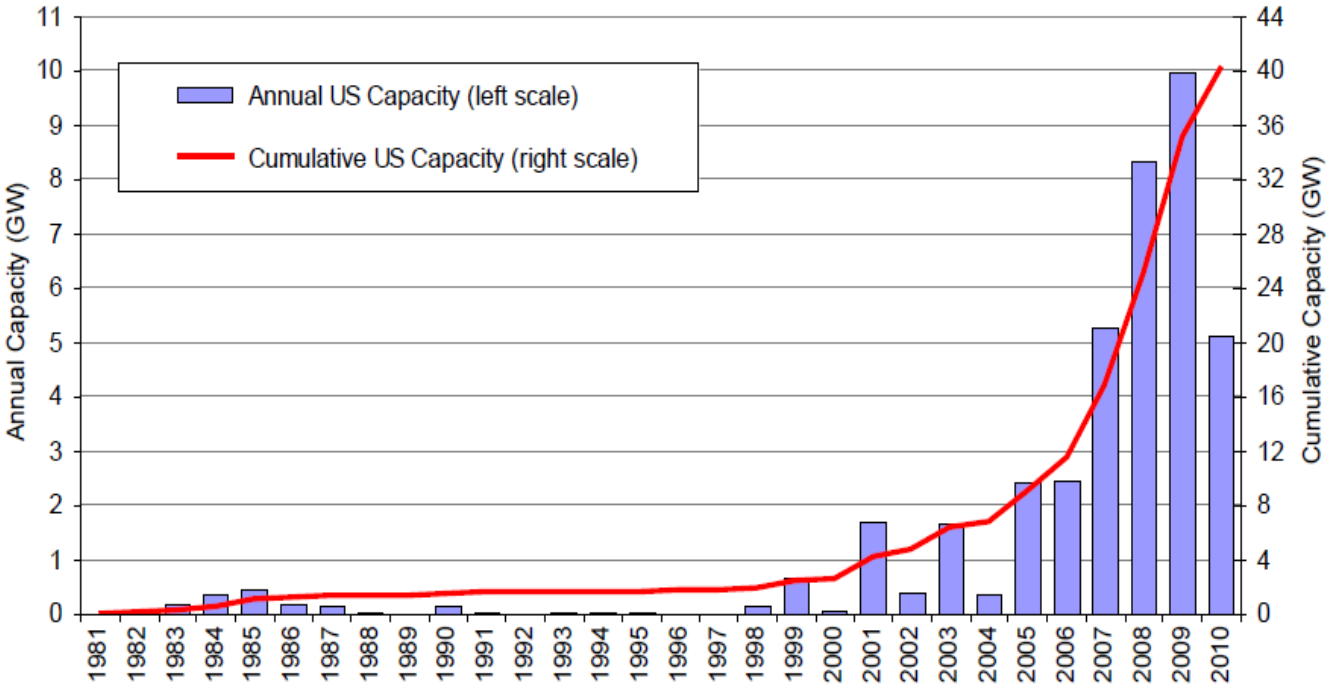
# RPS mandates in WECC




Source: Black & Veatch

# US wind

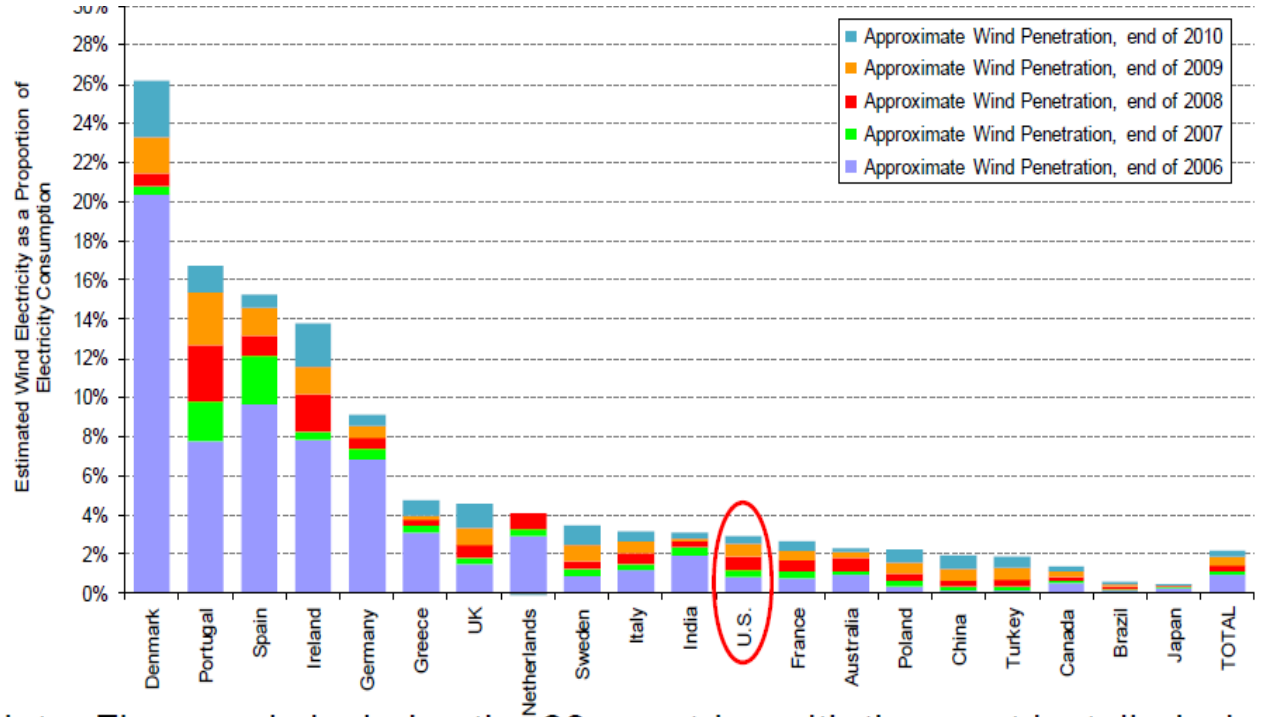
US wind capacity, annual & cumulative, GW




Source: 2010 Wind Technologies Market Report, Ryan Wiser and Mark Bolinger, Lawrence Berkeley National Laboratory, June 2011

# Rising double digits

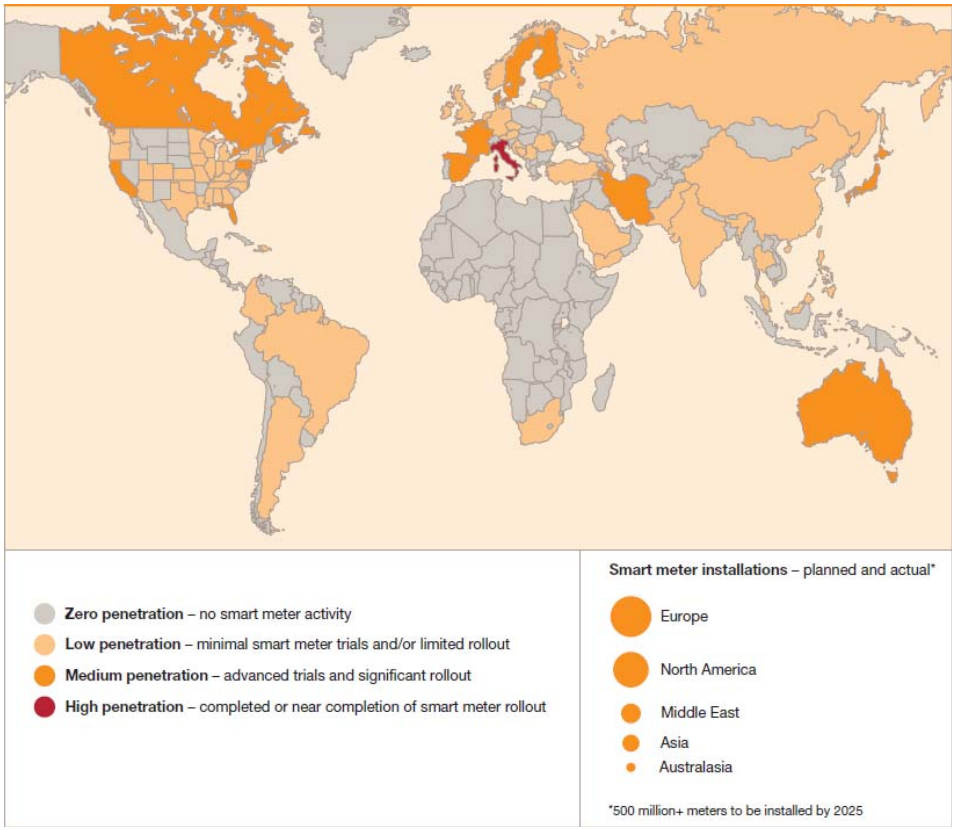
Wind generations as % of total electricity consumption




Source: 2010 Wind Technologies Market Report, Ryan Wiser and Mark Bolinger, LBL, June 2011

# Smart Grid

## It is contagious



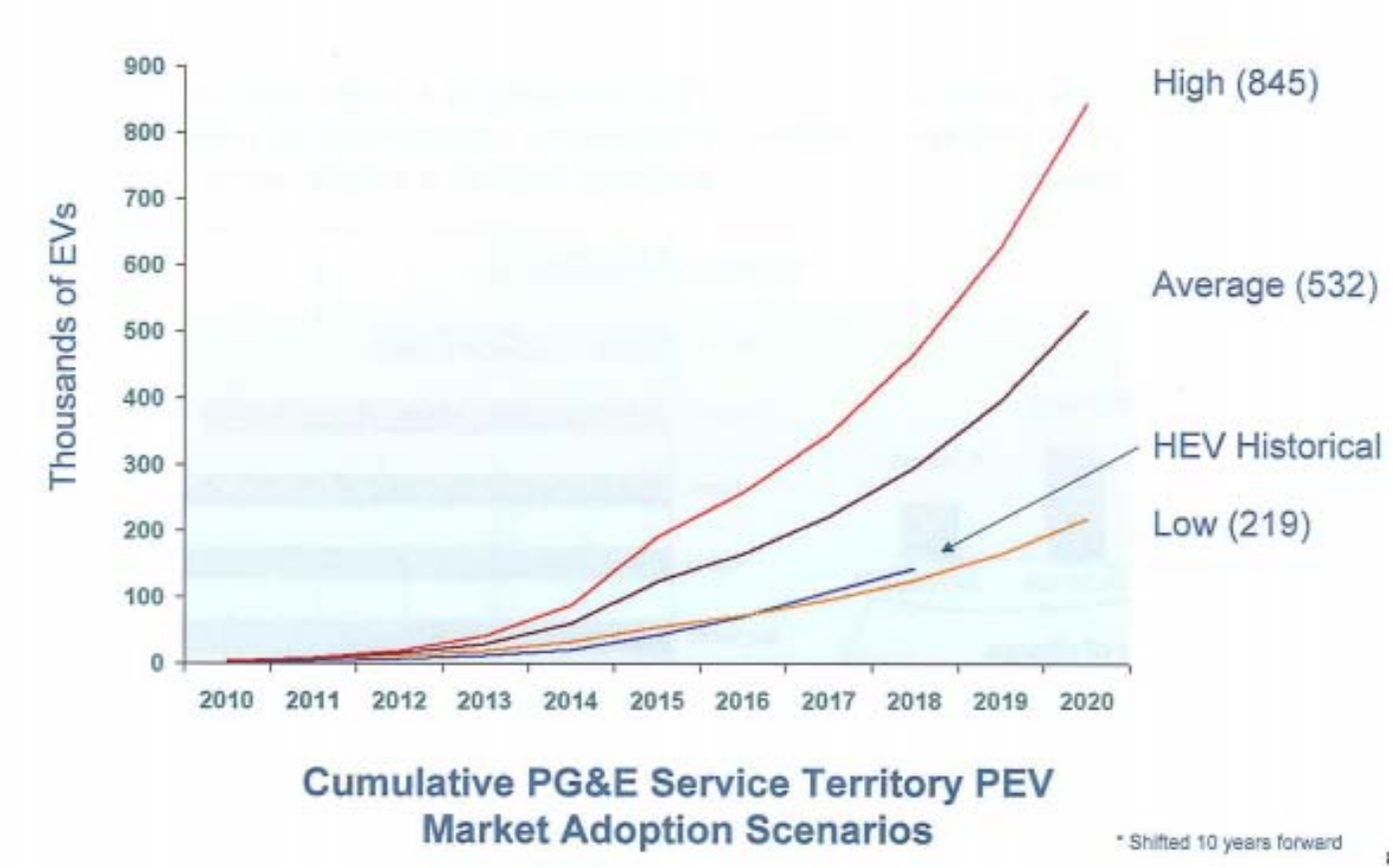

Source: Smart from the start, PwC, 2010

# Renewables are for real

SunPower claims it can install 1 MW per day

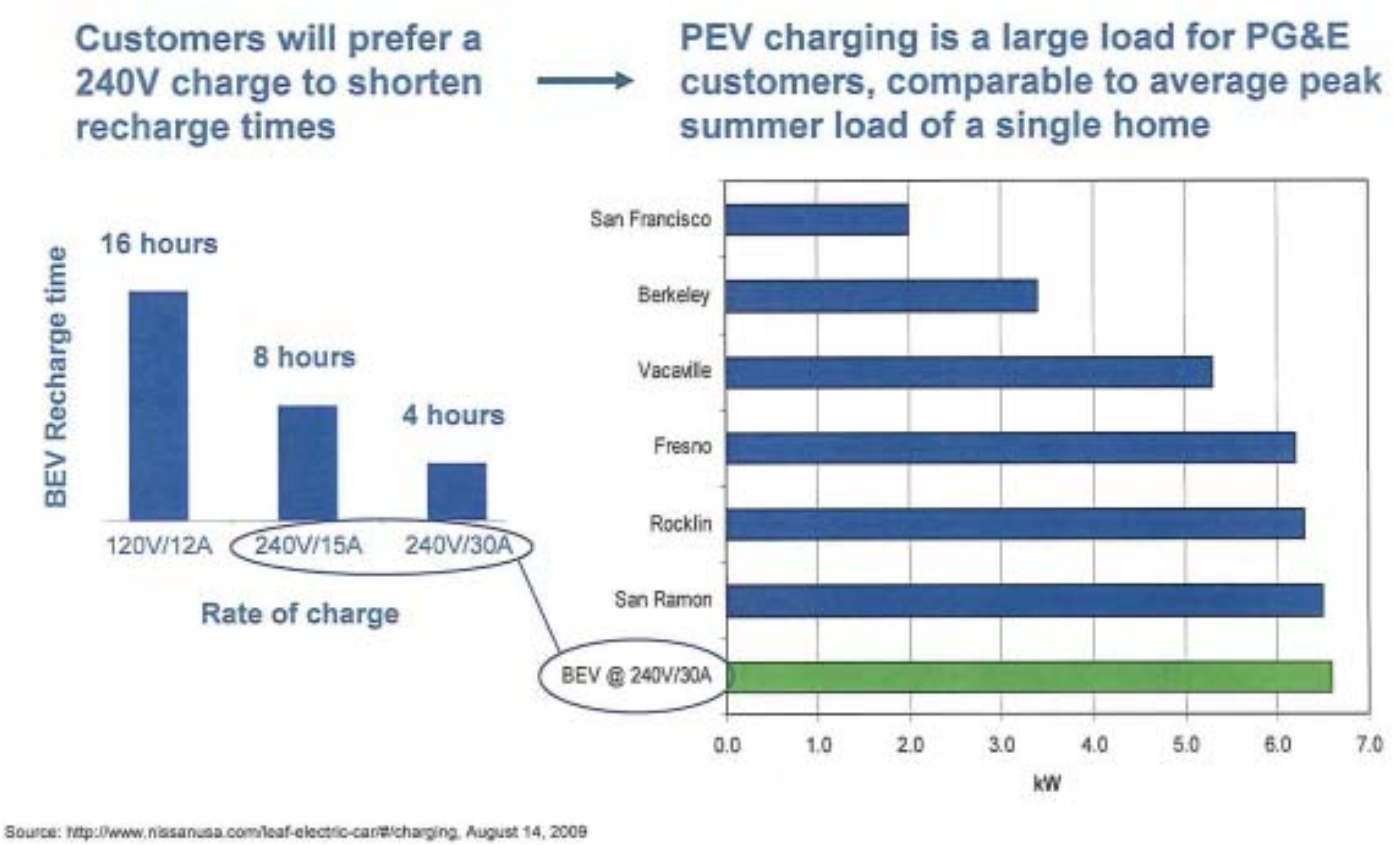
# EV Penetration

Alternative projections of # EVs on PG&E system



# EVs massive load on network

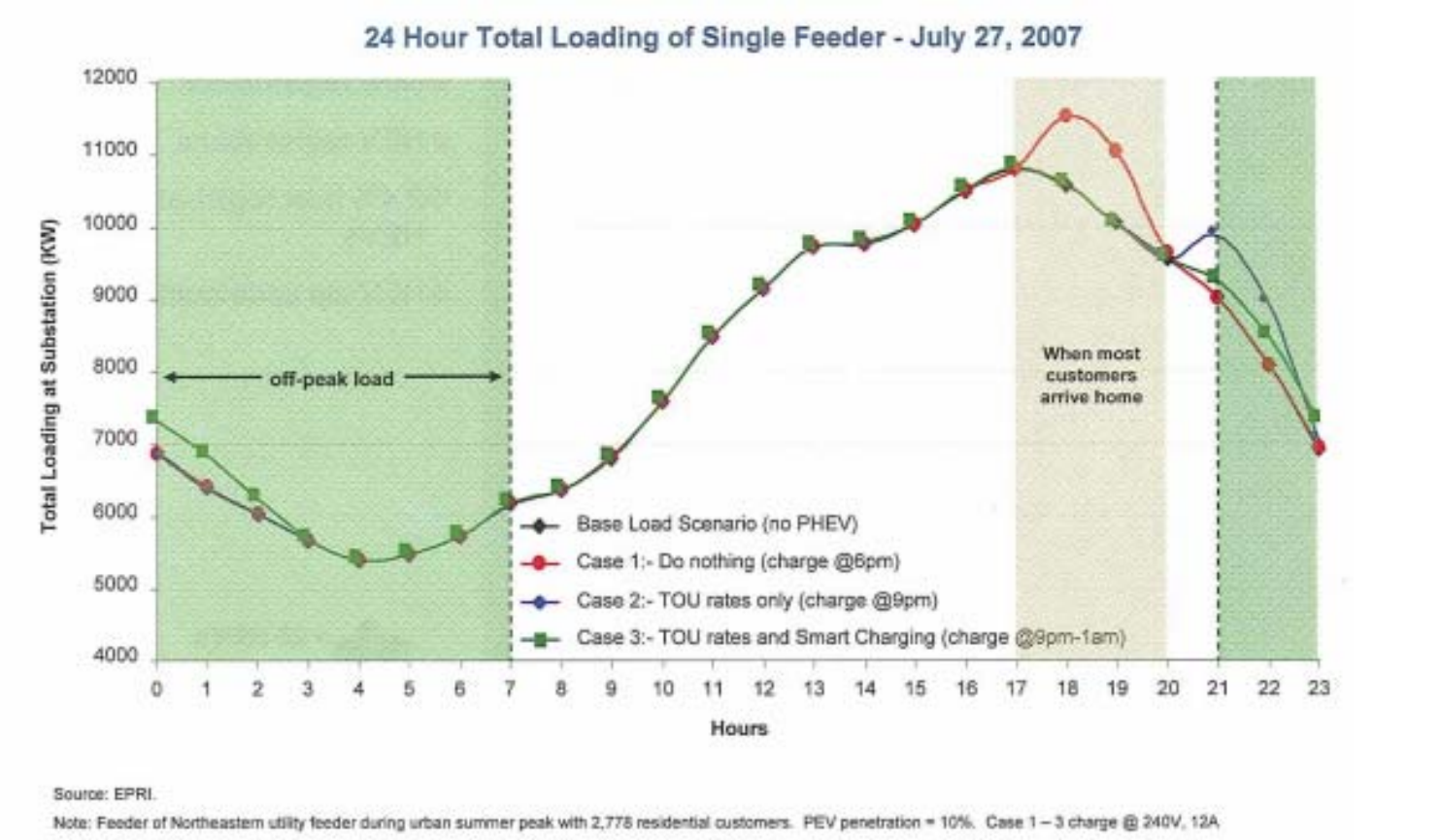
A fast charging EV more than an entire house load




Source: http://www.nissanusa.com/leaf-electric-car/#/charging, August 14, 2009

# Will EVs fry the grid?

EV charging must be strictly curtailed during peak periods

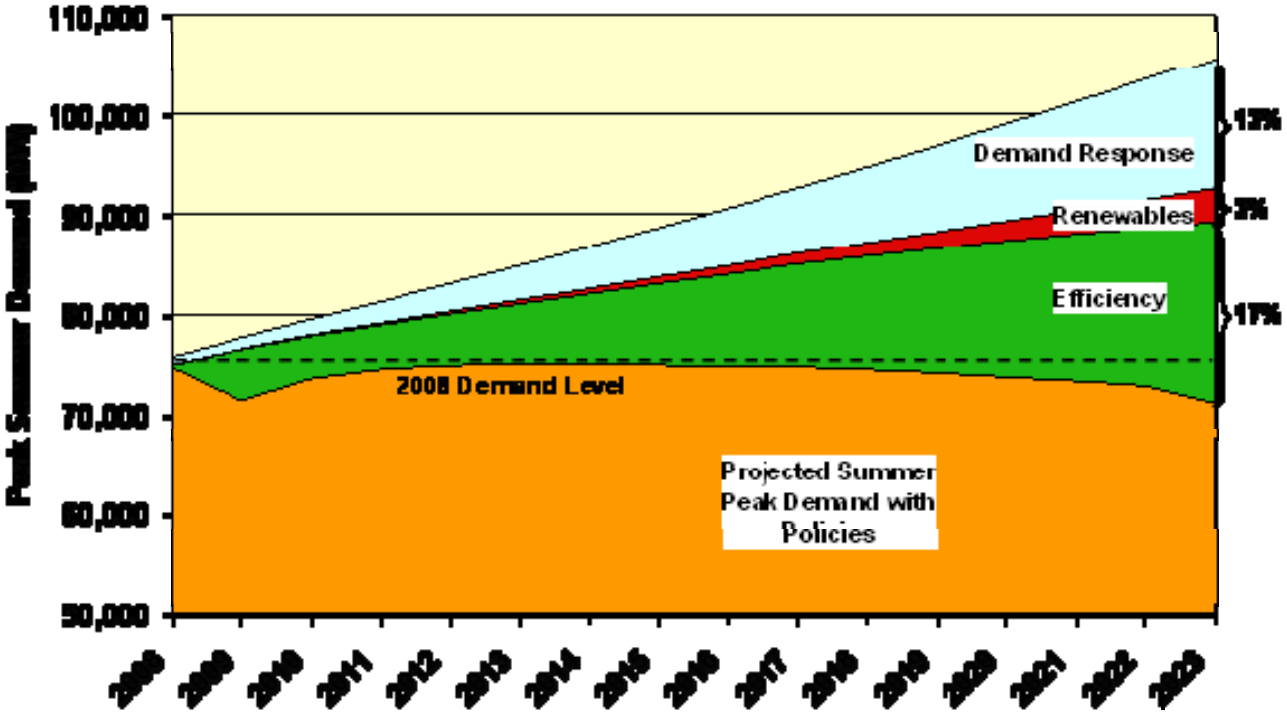



Source: EPRI.

Note: Feeder of Northeastern utility feeder during urban summer peak with 2,778 residential customers. PEV penetration = 10%. Case 1 – 3 charge @ 240V, 12A

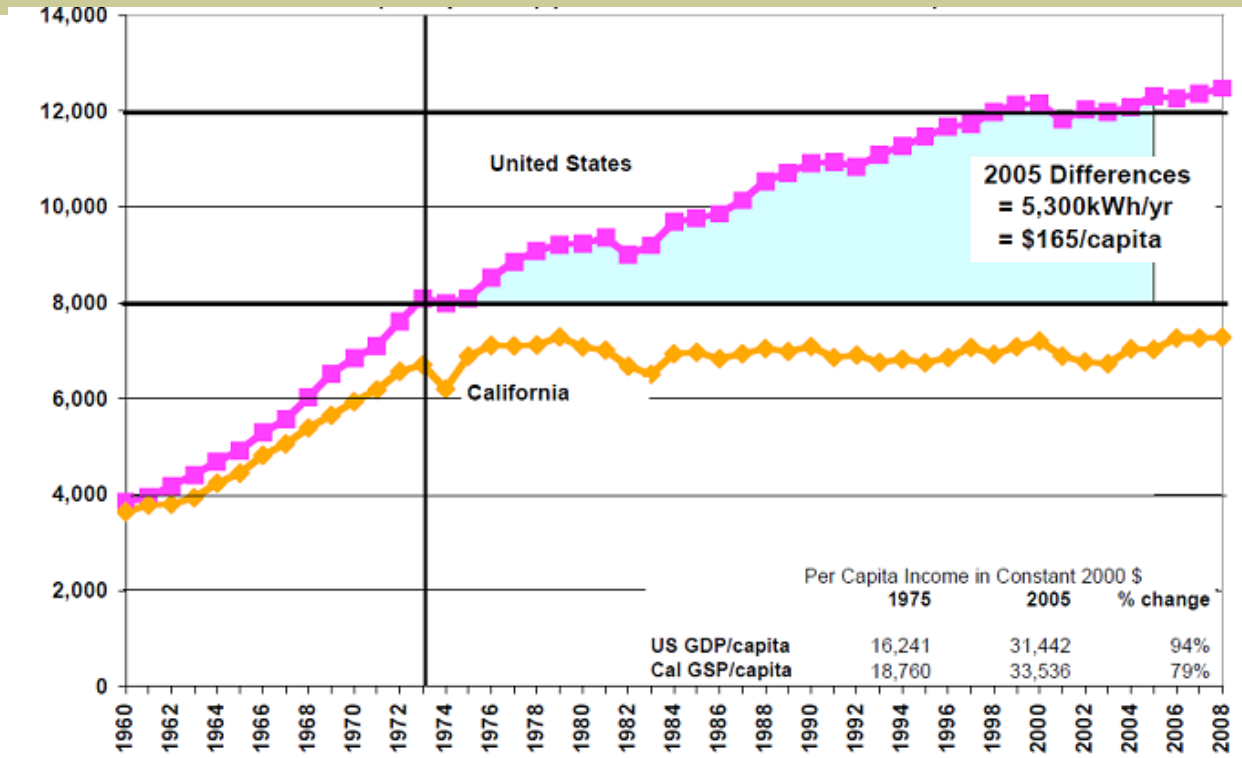
# No more power plants?

Texas ACEEE study, Mar 2007



# California keeps it flat

## Per capita electricity consumption




Source: A. Faruqui, Brattle Group, Aug 2010

# Costs *and* perhaps benefits?

EPRI study Apr 2011

*Summary of Estimated Cost and Benefits of the Smart Grid*

| | 20-Year Total ($billion) |
|---|---|
| Net Investment Required | 338 – 476 |
| Net Benefit | 1,294 – 2,028 |
| Benefit-to-Cost Ratio | 2.8 – 6.0 |

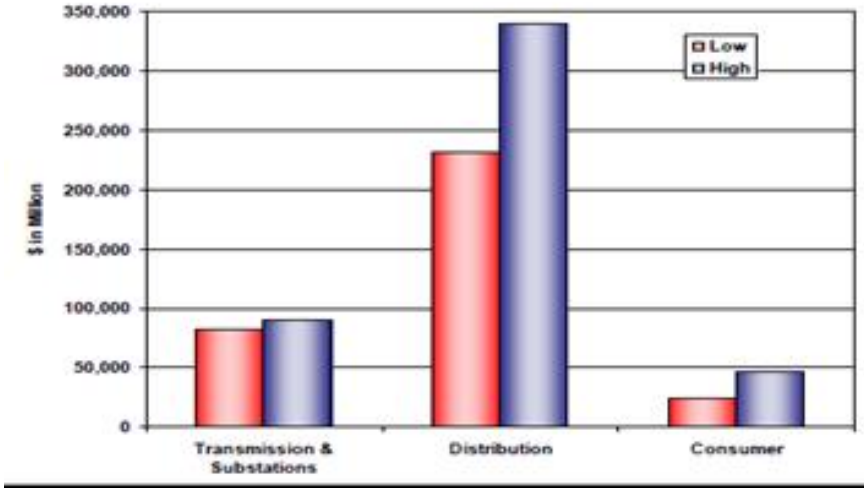
Source: Estimating the Costs and Benefits of the Smart Grid, EPRI, April 2011

# The costs

## EPRI study Apr 2011

*Total Smart Grid Costs*

| Costs to Enable a Fully Functioning Smart Grid ($M) | | |
|---|---|---|
| | **Low** | **High** |
| Transmission and substations | 82,046 | 90,413 |
| Distribution | 231,960 | 339,409 |
| Consumer | 23,672 | 46,368 |
| **Total** | **337,678** | **476,190** |



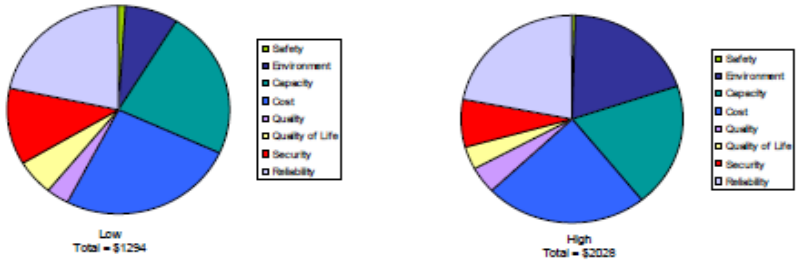

Source: Estimating the Costs and Benefits of the Smart Grid, EPRI, April 2011

# And the benefits

## EPRI study Apr 2011

*Estimated Benefits of the Smart Grid*

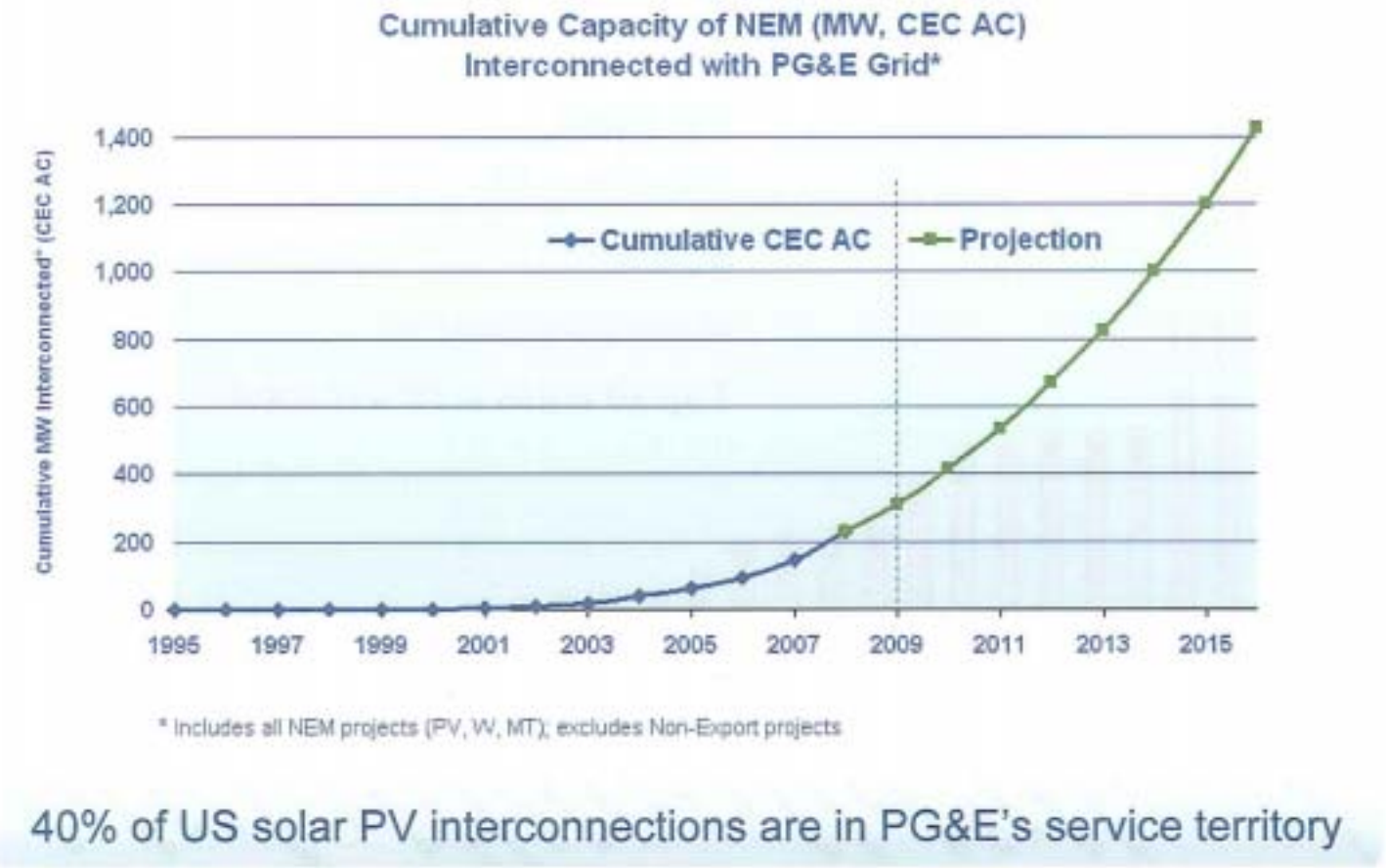
| Attribute | Net Present Worth (2010) $B | |
|---|---|---|
| | Low | High |
| Productivity | 1 | 1 |
| Safety | 13 | 13 |
| Environment | 102 | 390 |
| Capacity | 299 | 393 |
| Cost | 330 | 475 |
| Quality | 42 | 86 |
| Quality of Life | 74 | 74 |
| Security | 152 | 152 |
| Reliability | 281 | 444 |
| **Total** | **1294** | **2028** |




Source: Estimating the Costs and Benefits of the Smart Grid, EPRI, April 2011

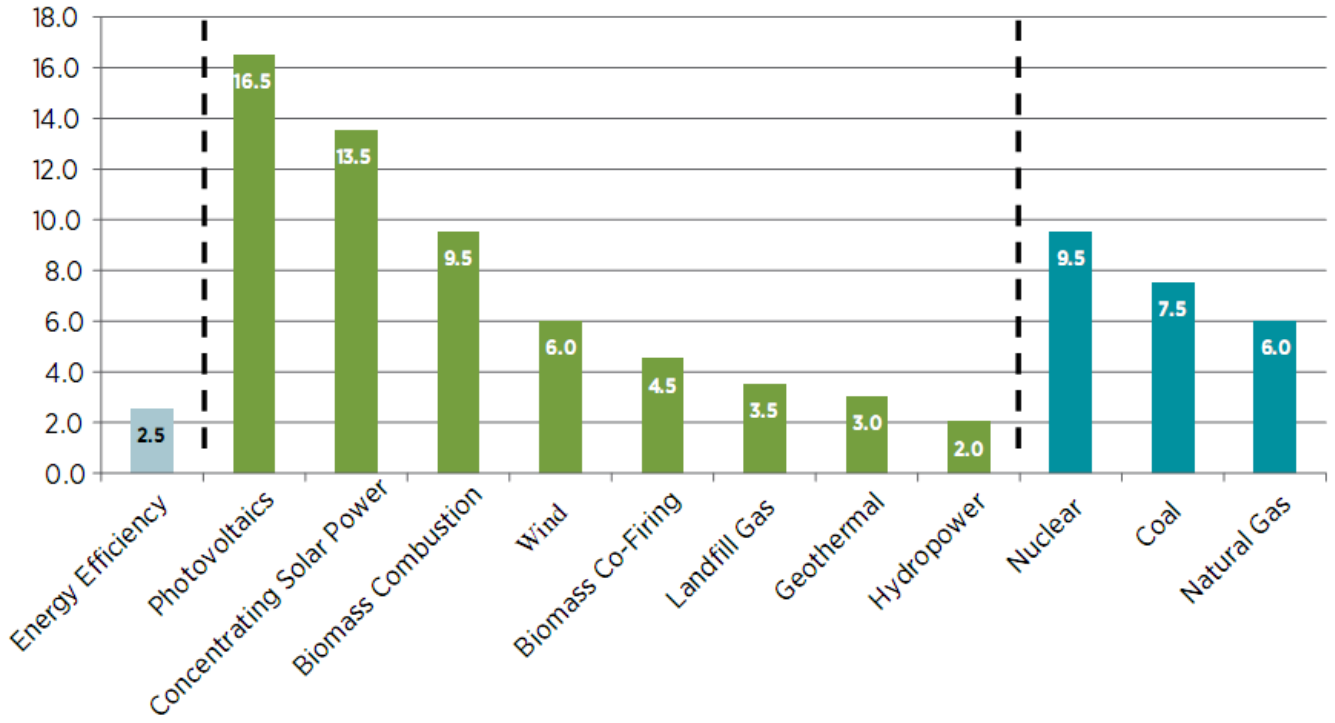
# Exponential PV growth

Customer installed PVs on PG&E system 1,400 MW by 2015




40% of US solar PV interconnections are in PG&E's service territory

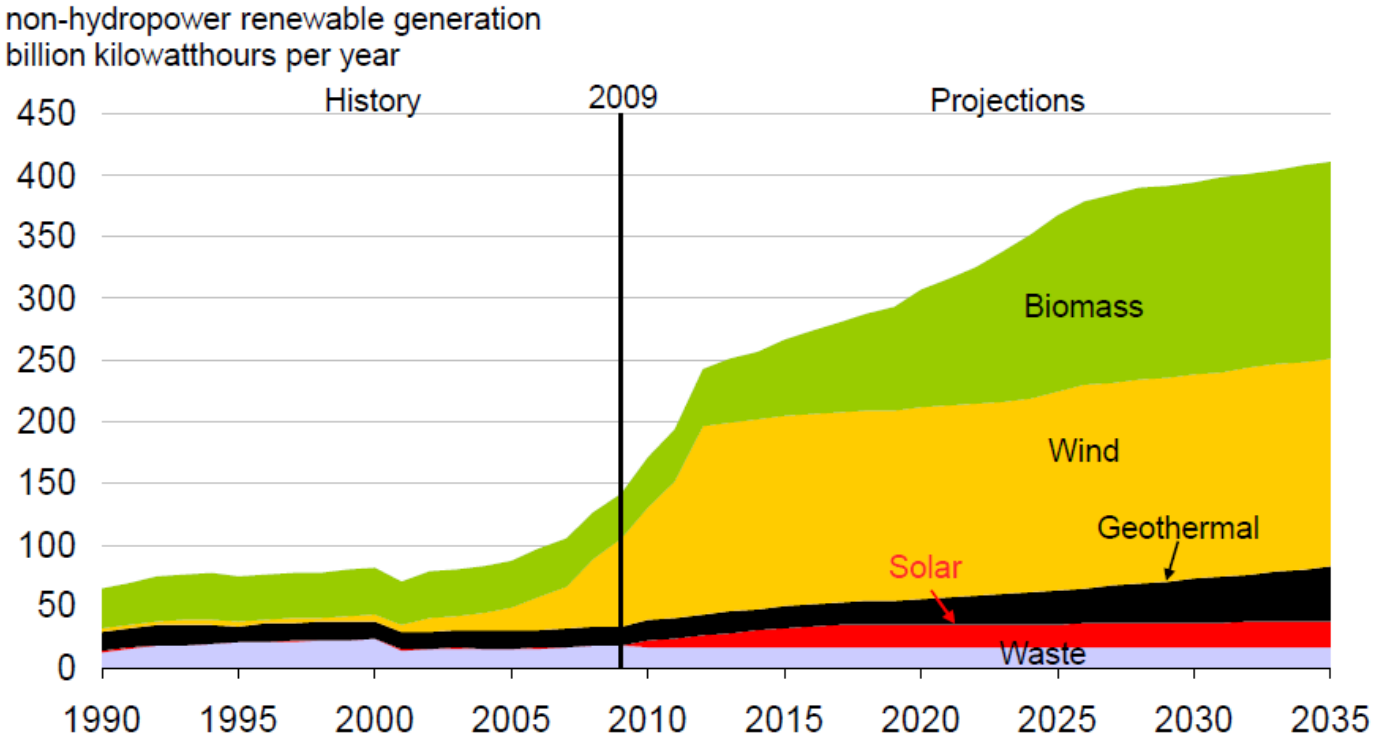
# 5. The cheapest kWh is the one you don't use




* Includes current federal & state level incentives, natural gas price is assumed at $4.50/MMBTU
Source: US Renewable Energy Quarterly Report, ACORE, Oct 2010

# More renewable generation

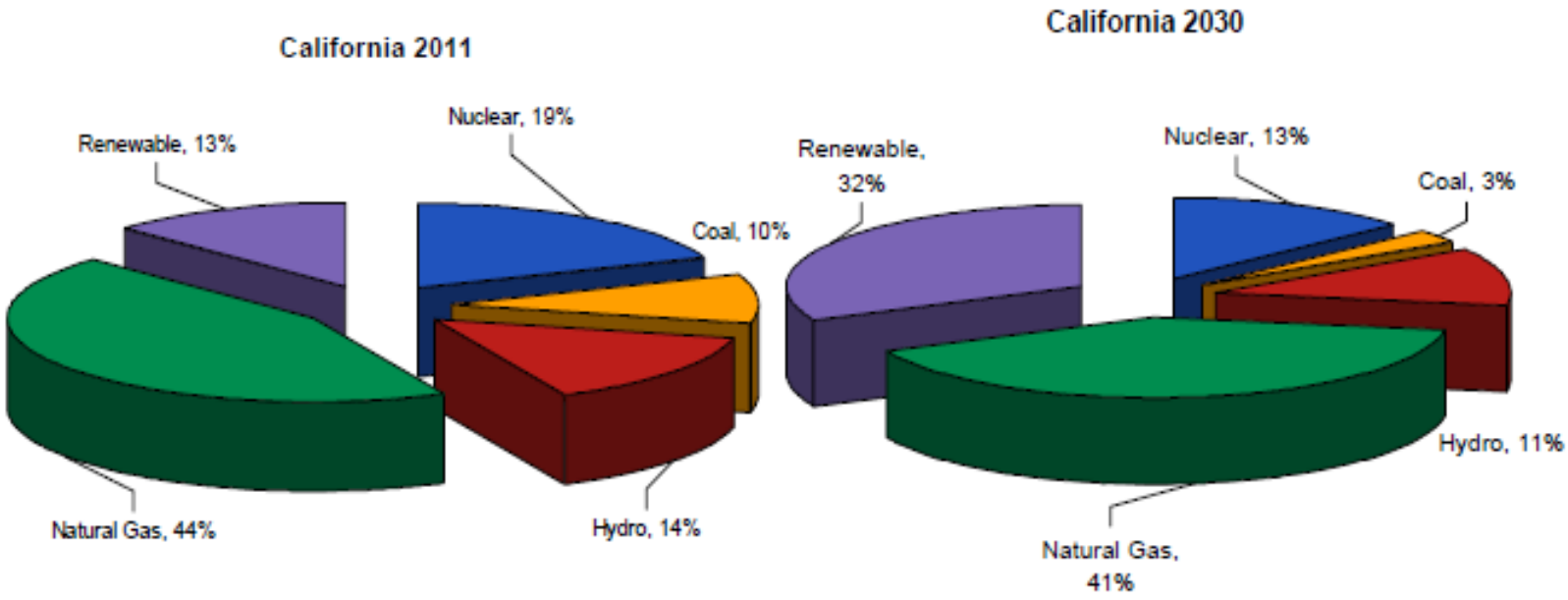
US non-hydro generation 1990-2035, in bkWh




Source: EIA's Annual Energy Outlook 2011, 16 Dec 2010

# California going low-carbon

## Don’t count on nuclear, CCS, cap-&-trade, or market signals




Source: Black & Veatch

# Numbers talk

**Annual and cumulative installed wind capacity, in MW**

| Annual Capacity (2010, MW) | |
|---|---|
| China | 18,928 |
| **U.S.** | **5,113** |
| India | 2,139 |
| Germany | 1,551 |
| U.K. | 1,522 |
| Spain | 1,516 |
| France | 1,186 |
| Italy | 948 |
| Canada | 690 |
| Sweden | 604 |
| *Rest of World* | 5,205 |
| **TOTAL** | **39,402** |

| Cumulative Capacity (end of 2010, MW) | |
|---|---|
| China | 44,781 |
| **U.S.** | **40,267** |
| Germany | 27,364 |
| Spain | 20,300 |
| India | 12,966 |
| France | 5,961 |
| U.K. | 5,862 |
| Italy | 5,793 |
| Canada | 4,011 |
| Portugal | 3,837 |
| *Rest of World* | 28,371 |
| **TOTAL** | **199,513** |

Source: 2010 Wind Technologies Market Report, Ryan Wiser and Mark Bolinger, Lawrence Berkeley National Laboratory, June 2011

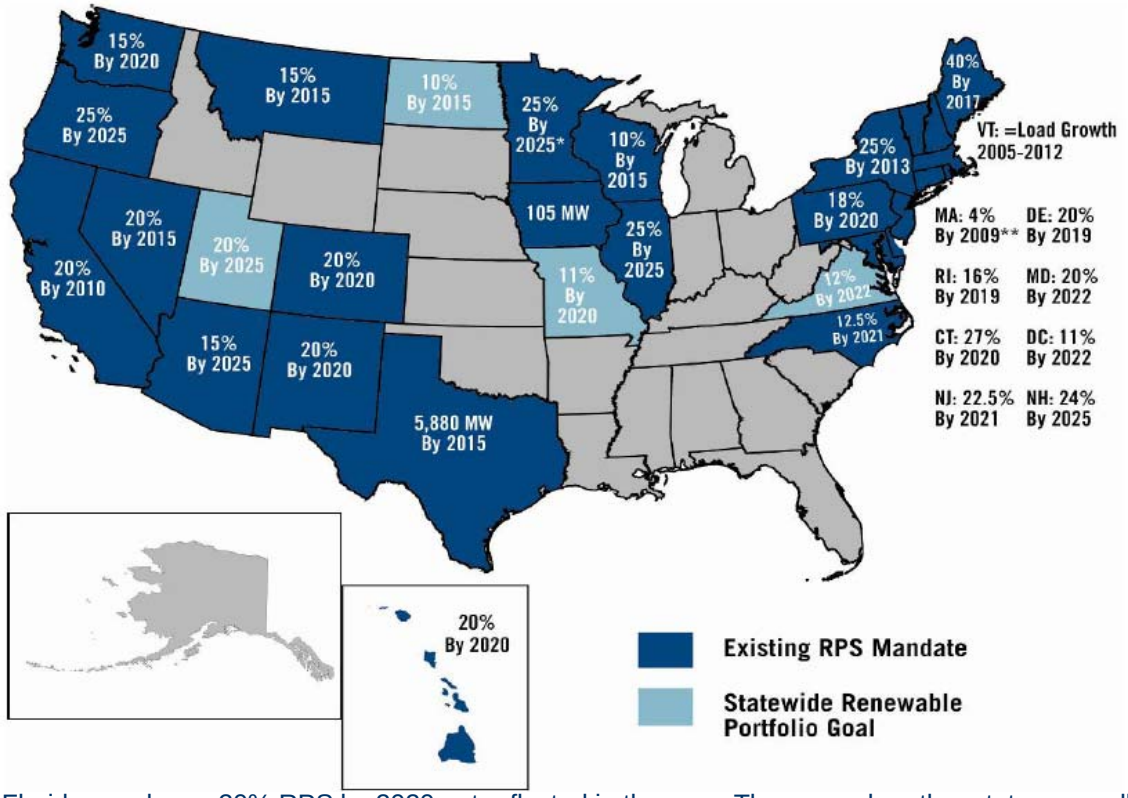
# Renewable Growth

Reproduce graph fm BP, page 40, LEFT chart from source below

http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/O/2012_2030_energy_outlook_booklet.pdf

# Renewable portfolio standards

## US states with mandatory targets

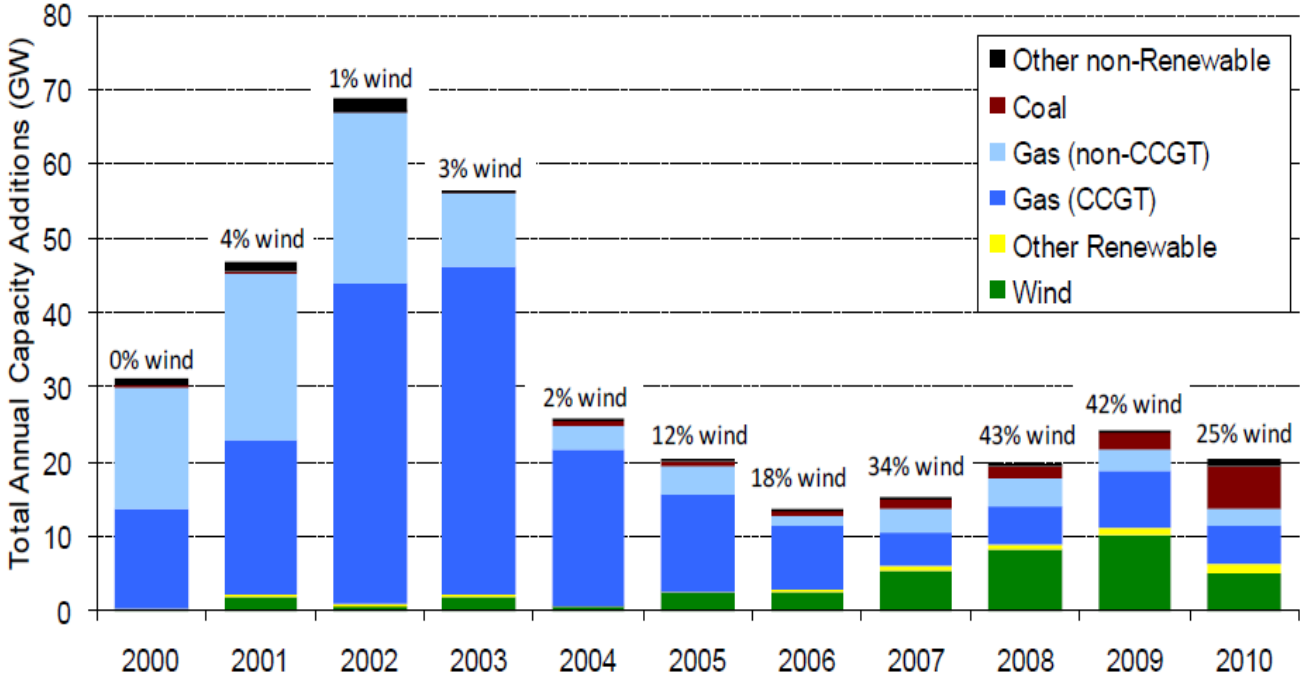



* Florida now has a 20% RPS by 2020 not reflected in the map. There may be other states as well that have adopted mandates since the map was published

Source: Edison Electric Institute, 8 Apr 08

# US wind contribution

Contribution of wind as % of new capacity additions, 2000-10




Source: 2010 Wind Technologies Market Report, Ryan Wiser and Mark Bolinger, Lawrence Berkeley National Laboratory, June 2011