1. The climate crisis reinvented **(3.28.2016)**
Klein, chapters 1 & 2 | Optional: Dove & Kammen, chapter 1

2. Our mistrust of the future makes it hard to give up the past **(4.4.16)**
Klein, chapters 3 | Optional: Dove & Kammen, chapter 5

3. We don't tenure Mother Teresa **(4.11.2016)**
Klein, chapter 9 | Optional: Dove & Kammen, chapter 2

4. What are the barriers to action? **(4.18.2016)**
Klein, chapter 6 - 8 |

5. A new economics of the planet **(4.25.2016)**
Klein, chapter 4 | Optional: Dove & Kammen, chapter 3; Klein 12

6. Pasteur's Quadrant **(5.2.2016)**
Klein, chapter 7, 11 | Optional: Dove & Kammen, chapter 4

Resources:

Website: http://rael.berkeley.edu

Twitter: @dan_kammen

<u>Homework #1</u>: Due in class for L#3
List one item raised by Klein
in Chapters 1 – 3 where you:

a) want more information

b) have a strong factual agreement or disagreement

c) have a strong visceral agreement or disagreement

(b) is optional

Some Klein Questions:

"Nature speaks and mankind does not listen" (V. Hugo)

Chapter 1: The Right is Right

What explains the refusal to accept the science and current entitlement and economic success

Climate science has not always been politically driven. What changed?

"Coddling climate denies does not work" Jon Foley. Why?

Chapter 2: Hot Money

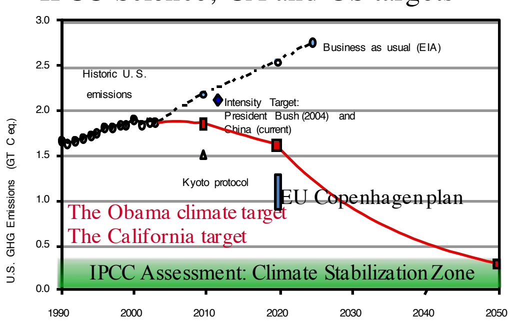
Economic growth = emissions? Can it really be that simple?

Chapter 3: Public and Paid For

The German energy transition, "Energiewende": shrewd or costly?

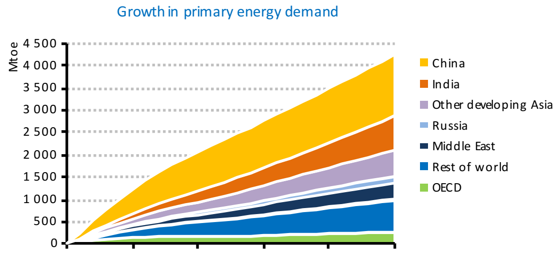
What institutions work to enable a social transformation? Which do not?

The Cascade of Commitment: IPCC Science, CA and US targets



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

Emerging economies continue to drive global energy demand

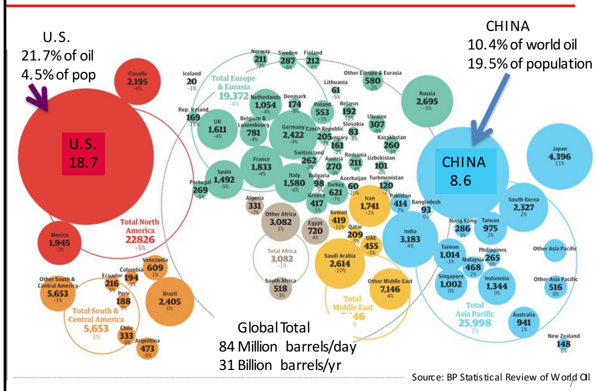


Global energy demand increases by one-third from 2010 to 2035, with China & India accounting for 50% of the growth

WORLD OIL CONSUMPTION, 2009 (Millions of barrels per day)

U.S.
21.7% of oil
4.5% of pop

CHINA
10.4% of world oil
19.5% of population

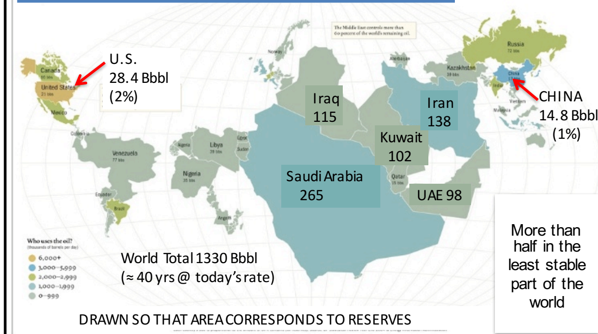


Global Total
84 Million barrels/day
31 Billion barrels/yr

Source: BP Statistical Review of World Oil

WHO HAS THE "CHEAP" (TO PRODUCE) EASY (TO EXTRACT) READILY ACCESSIBLE OIL..

WORLD CONVENTIONAL OIL *RESERVES* MAP (Billion barrels of oil)



World Total 1330 Bbbl
(≈ 40 yrs @ today's rate)

More than half in the least stable part of the world

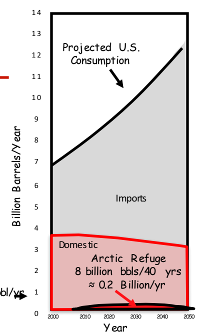
DRAWN SO THAT AREA CORRESPONDS TO RESERVES

2009 BP statistics

...NOT THE U.S. OR CHINA

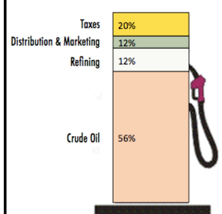
The View from 1950–1970 – then 4 decades to change
DRILL OUR WAY OUT OF THIS?

"..U.S. 22% of world oil consumption
2 percent of world oil reserves

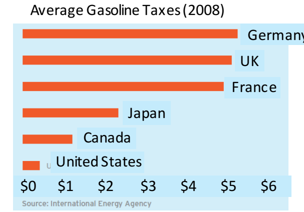


Oil for buildings: 0.6 Bbbl/yr

PRICE AS A MOTIVATOR FOR FUEL EFFICIENCY....



Average Gasoline Taxes (2008)



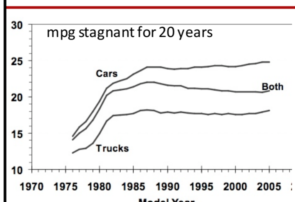
..With one little gasoline tax, we can make ourselves more economically and strategically secure, help sell more Chevy Volts and free ourselves to openly push for democratic values in the Middle East without worrying anymore that it will harm our oil interests.

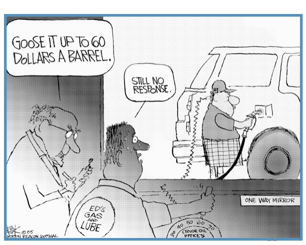
Yes, it will mean higher gas prices, but prices are going up anyway, folks. Let's capture some it for ourselves. (Tom Friedman, NYT, Feb 23, 2011)

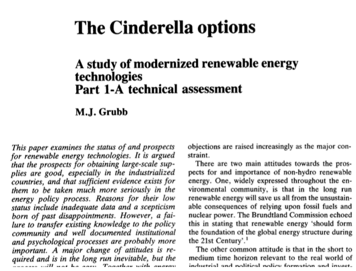
U.S. consumes ≈ 150 billion gallons/yr.... at 10¢/gal raise $15 B /yr

1975 CAFE STANDARDS FINALLY INCREASED TO 35 MPG BY 2020

Energy Independence and Security Act 2007







The Cinderella options

A study of modernized renewable energy technologies
Part 1-A technical assessment

M.J. Grubb

This paper examines the status of and prospects for renewable energy technologies. It is argued that the prospects for obtaining large-scale supplies are good, especially in the industrialized countries, and that sufficient evidence exists for them to be taken much more seriously in the energy policy process. Reasons for their low status include inadequate data and a scepticism born of past disappointments. However, a failure to transfer existing knowledge to the policy community and well documented institutional and psychological processes are probably more important. A major change of attitudes is required and is in the long run inevitable, but the

objections are raised increasingly as the major constraint.

There are two main attitudes towards the prospects for and importance of non-hydro renewable energy. One, widely expressed throughout the environmental community, is that in the long run renewable energy will save us all from the unsustainable consequences of relying upon fossil fuels and nuclear power. The Brundtland Commission echoed this in stating that renewable energy 'should form the foundation of the global energy structure during the 21st Century'.[1]

The other common attitude is that in the short to medium time horizon relevant to the real world of

Renewable energy is an enigma.
Everyone is in favor of it, but few take it seriously.
- Michael Grubb (1990)

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Keywords: Renewable energy; Energy policy process; Supply

Renewable energy is an enigma. Everyone is in favour of it, but few take it seriously. Most agree that renewable energy research deserves more money, but the funding remains small compared with much more speculative technologies such as nuclear fusion. Renewable energy is praised for its environmental advantages, whilst environmental objections are raised increasingly as the major constraint.

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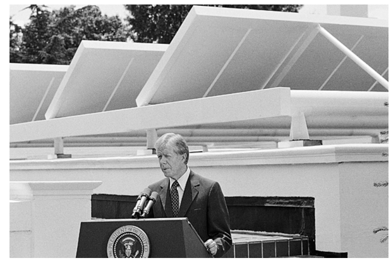
The other common attitude is that in the short to medium time horizon relevant to the real world of industrial and political policy formation and investment, non-hydro renewable sources are essentially irrelevant: that for the foreseeable future their contribution will remain marginal. This attitude is reflected in the levels of research, development and demonstration (RD&D) funding, with expenditure on the best supported of renewable technologies being a small fraction of direct government expenditure on fossil and nuclear sources (see Figure 1) and an even smaller component of total public support (see Figure 2).[2] It is apparent in the institutional balance, with the major international institutions devoted to nuclear power having no counterparts for renewable energy.[3] It is evident in the absence of renewable energy from general energy policy development – to take but two examples, the EC documents discussing the projected internal energy market,[4] and the original draft proposals for electricity privatization in the UK.[5] Above all, it is demonstrated by mainstream energy forecasts, which in almost every OECD country project non-hydro re-

A political, not just a technological lightning rod



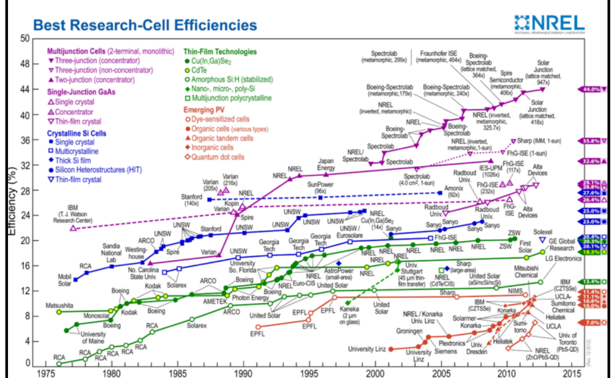
They were quietly removed by the Reagan administration during a roof resurfacing in 1986

In 1986 the Reagan administration quietly dismantled the White House solar panel installation while resurfacing the roof.

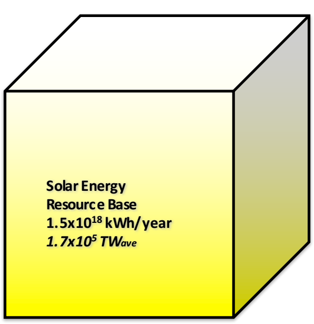
"Hey! That system is working. Why don't you keep it?" recalls mechanical engineer Fred Morse, now of Abengoa Solar, who helped install the original solar panels as director of the solar energy program during the Carter years and then watched as they were dismantled during his tenure in the same job under Reagan.

He then said, "Hey! This whole [renewable] R&D program is working, why don't you keep it."

We will return to this key issue at the end of the course



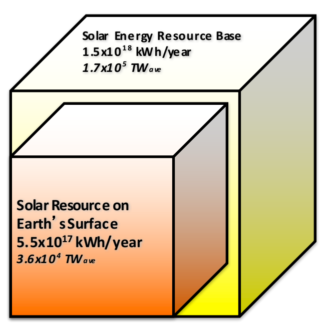
The Terrestrial Solar Resource



Wind Energy
Resource Base
$6x10^{14}$ kWh/year
72 TWave

Human Energy Use
(2050 estimate)
$4x10^{14}$ kWh/year
50 TWave

Solar Resource is VAST!



Solar constant: 1368 W/m^2

Surface, 30 – 50% less

Solar constant: 1 kW/m^2

x 0 – 8 hours/day, or

An average of

4 kWh/m^2/day

Wind Energy
Resource Base
$6x10^{14}$ kWh/year
72 TWave

Human Energy Use
(mid- to late-century)
$4x10^{14}$ kWh/year
50 TWave

The World's Largest Solar Thermal Power Plant (Parabolic Trough)

Solar Energy Generating System (SEGS)
310 MW
San Bernadino County, CA

19

The World's Largest Solar Thermal Power Plant (T

Ivanpah Solar Thermal Project
370MW
San Bernardino County, CA

20

Electrical System for Home Conversion and Storage of Solar Energy

Abstract. Energy storage has long been a problem in connection with home utilization of solar energy. A solution which utilizes solar semiconductor cells for conversion to d-c power is proposed. The d-c power is used to drive an alternator which is connected directly across the residential power lines. Thus a-c power is delivered to the power lines when a surplus of power is available in the home and is used in other parts of the power distribution system. At latitude 42°N there is 3 times more yearly energy recoverable than is used by an average residence on the basis of a 10-by-10-m collection area. At the present state of technical development the cost of such a large-area semiconductor solar cell would be prohibitive.

The approximate 1 kw/m^2 of solar power available at sea level on a clear bright day with the sun at its zenith has attracted considerable attention in terms of methods of utility, and many techniques have been proposed for making use of this energy (*1*). Commercial utilization in metropolitan and urban areas does not appear to be economically attractive because of the cost of the land. Home utilization could be carried out by using roof areas. The major problem here is one of storing energy during periods of peak solar power for use during the night and when the sun is not shining. Systems have been suggested and tried in which energy is stored in specific heat and heat of fusion of water and other suitable chemicals. With these systems a large storage volume is required, together with recirculation of the fluid.

A new energy storage system which has attractive prospects is shown in Fig. 1. In this system, semiconductor cells (*2*) are used to convert the solar power into direct-current electricity. This electrical power is used to drive a d-c motor, which in turn is mechanically coupled to an alternator. The output of the alternator is connected directly across the power lines and is thus always operating at approximately synchronous speed. A rectifier located between the semiconductor cells and the d-c motor prevents any power from flowing back into the solar cells. An auxiliary semiconductor cell is used to monitor the solar power and control the field excitation of the d-c motor at the correct value. With this method of excitation the d-c motor and associated system always represents the optimum load to the main semiconductor cells so as to abstract maximum power therefrom at all levels of solar activity. During periods of significant solar irradiation, the alternator is driven slightly above synchronous speed and feeds power into the power lines to be used locally or, if the local demand is not sufficient, to be delivered to the power lines for distribution. During the time that energy is fed into the power lines, the conventional kilowatt-hour meter is reversed in operation and kilowatt-hours are subtracted. Thus, basically, ... nected power companies represent potential energy storage points. Under some circumstances a central energy-storage facility such as a reversible hydroelectric system might be required.

Calculations have been made to determine the annual consumption and recovery of energy for a typical resident. Fritz and MacDonald (*4*) have tabulated isolines of average daily solar radiation received on a horizontal surface at the ground for the different months of the year. This tabulated information can be used to compute a yearly energy flux of 1347 kw hr/m^2 for Detroit, Mich. If Daniels' suggested (*5*) roof area of 100 m^2 is used and if a semiconductor cell conversion efficiency of 10 percent and a rotary converter conversion efficiency of 75 percent are assumed, the yearly energy available electrically as 60-cy/sec power is 10,100 kw hr. The average yearly consumption of electrical power per residence for 1958, obtained by extrapolating published data (*6*), is 3400 kw hr. Thus, it appears that even at the latitude of Detroit (42°N) the total yearly solar energy available is nearly three times the average yearly energy requirement. More southern latitudes of the United States would be roughly 50 percent more favorable but, on the other hand, a more typical residential yearly energy consumption would also be roughly 50 percent greater and is currently increasing at 7 percent per year.

If the generated electricity is valued at the current residential rate of 2 ct/kw hr, the solar energy would represent a potential total yearly return of $200. For the system described the peak power capability of the rotary equipment would have to be 11 kw. The costs of the rotary equipment, assuming that an inexpensive induction motor design is used for the alternator, would probably be less than $1000. At the present state of technical development the cost of a large-area semiconductor converter would be prohibited. For instance, the fabrication of a 100 m^2 panel from currently available solar cells would cost in the neighborhood of $250,000. It is worth remembering, however, that this cost is predominately one of fabrication and will be greatly reduced when new techniques—for instance, evaporative methods of fabrication—are developed.

L. J. GIACOLETTO
Scientific Laboratory, Ford Motor Company, Dearborn, Michigan

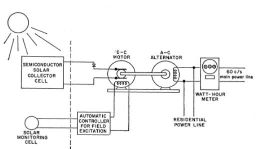


Fig. 1. Solar energy utilization system.

Instructions for preparing reports. Begin the report with an abstract of from 45 to 55 words. The abstract should *not* repeat phrases employed in the title. It should work with the title to give the reader a summary of the results presented in the report proper.

Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* **125**, 16 (1957)].

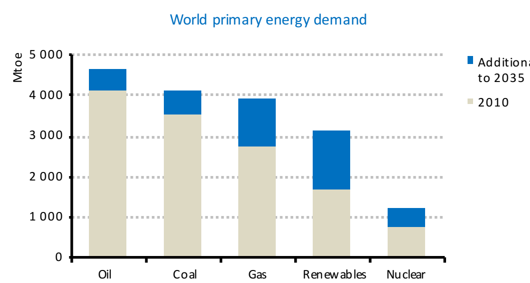
References

1. F. Daniels and J. A. Duffie, *Solar Energy Research* (Univ. of Wisconsin Press, Madison, 1955); *Proc. World Symposium App. Solar Energy, Phoenix, Ariz.*, 1955 (Stanford Research Inst., Menlo Park, Calif., 1956); *Trans. Conf. on Use of Solar Energy, The Scientific Basis* (Univ. of Arizona Press, Tucson, 1958).
2. M. B. Prince, *J. Appl. Phys.* **26**, 534 (1955); J. J. Loferski, *ibid.* **27**, 777 (1956).
3. P. C. Putman, *Power from the Wind* (Van Nostrand, New York, 1958).
4. S. Fritz and T. H. MacDonald, *Heating and Ventilating* **46**, 61 (1949).
→ F. Daniels, *Sci. Monthly* **82**, 247 (1956).
6. T. R. Gates, Ed., "Residential consumption of electric power 1925-57," *Economic Almanac 1958, Natl. Ind. Conf. Board* (Crowell, New York, 1958).

6 August 1959

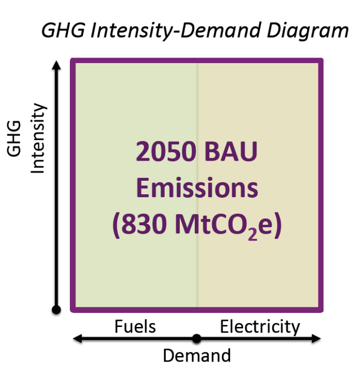
9 OCTOBER 1959 915

Natural gas & renewables become increasingly important

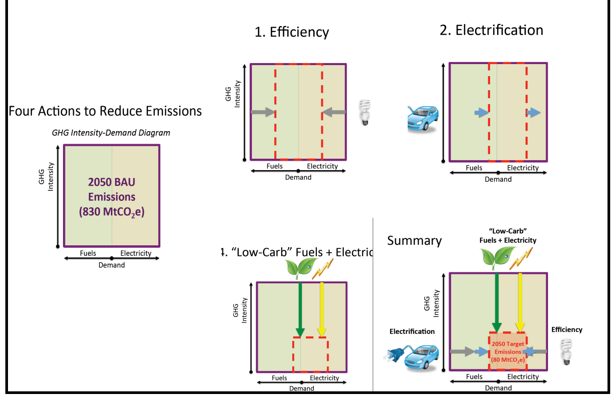


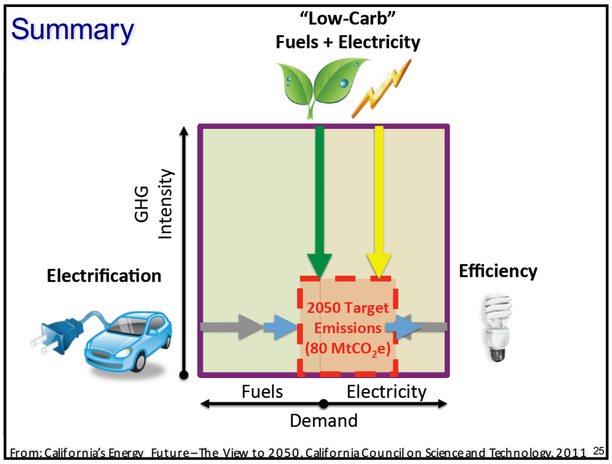
Renewables & natural gas collectively meet almost two-thirds of incremental energy demand in 2010-2035

Actions to reduce emissions



From: California's Energy Future–The View to 2050, California Council on Science and Technology, 2011 23




Summary
"Low-Carb"
Fuels + Electricity
GHG
Intensity
Electrification
Efficiency
2050 Target
Emissions
(80 MtCO2e)
Fuels
Electricity
Demand
From: California's Energy Future–The View to 2050, California Council on Science and Technology, 2011
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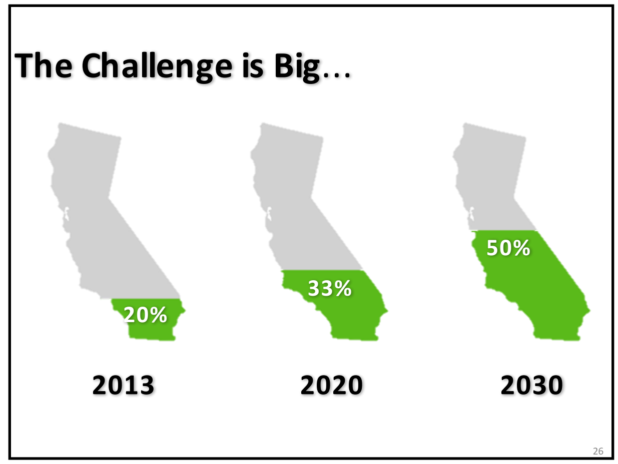
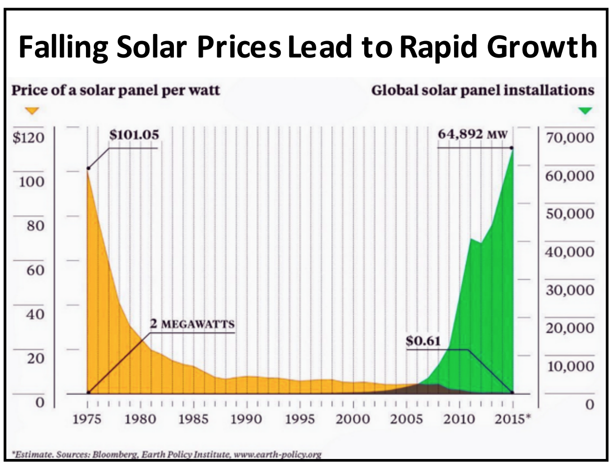
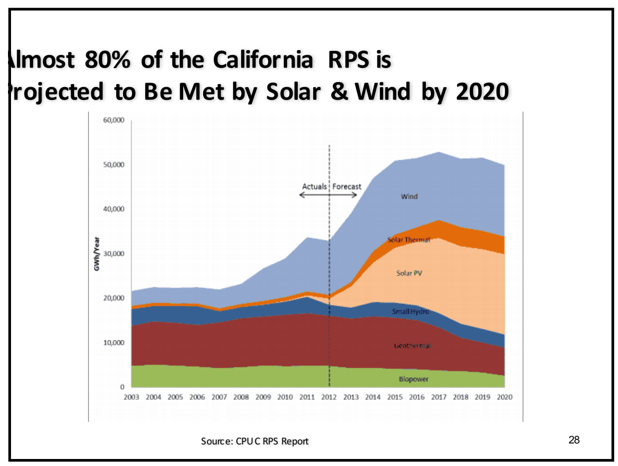

The Challenge is Big…
20%
33%
50%
2013
2020
2030
26


Falling Solar Prices Lead to Rapid Growth
Price of a solar panel per watt
Global solar panel installations
$120
100
80
60
40
20
0
$101.05
2 MEGAWATTS
$0.61
64,892 MW
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1975
1980
1985
1990
1995
2000
2005
2010
2015*
*Estimate. Sources: Bloomberg, Earth Policy Institute, www.earth-policy.org


lmost 80% of the California RPS is
rojected to Be Met by Solar & Wind by 2020
60,000
50,000
40,000
30,000
20,000
10,000
0
GWh/Year
Actuals
Forecast
Wind
Solar Thermal
Solar PV
Small Hydro
Geothermal
Biopower
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Source: CPUC RPS Report
28