AGENDA: 3A

CALIFORNIA'S ENERGY FUTURE

SFBAQ

May 14, 2014

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CALIFORNIA CONTEXT

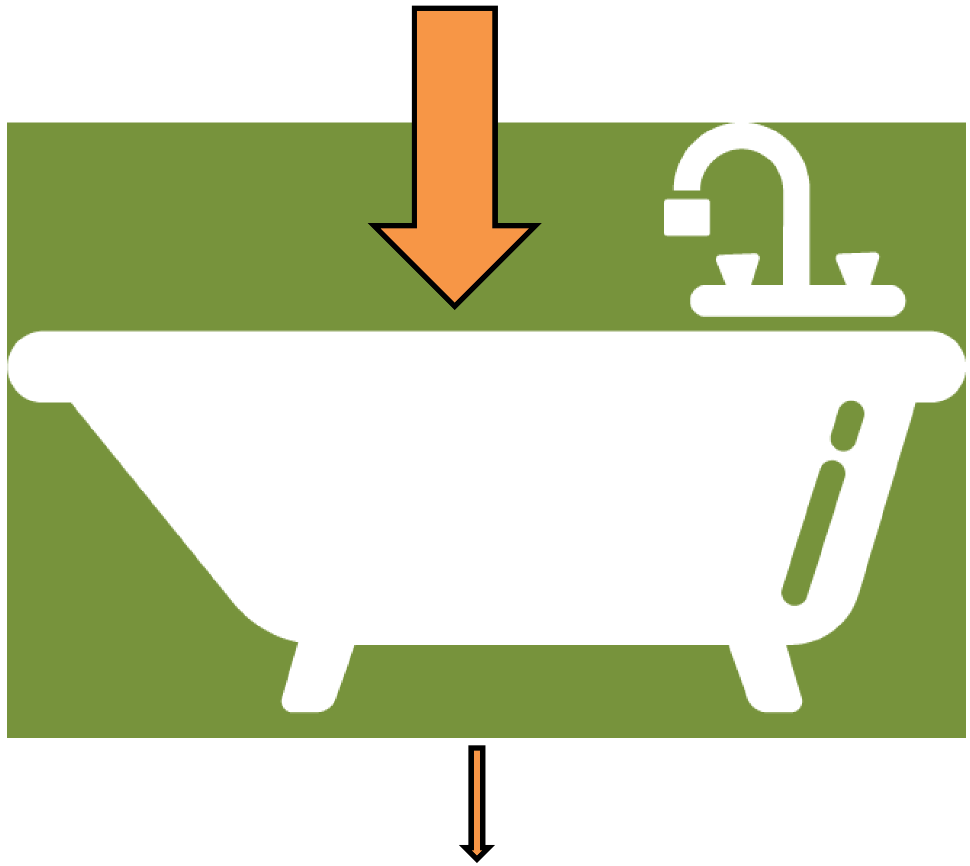
AB 32 requires reducing GHG emissions to 1990 levels by 2020, a reduction of about 25%.

Governor's executive order S-3-05 (2005) requires an 80% reduction below 1990 levels by 2050.

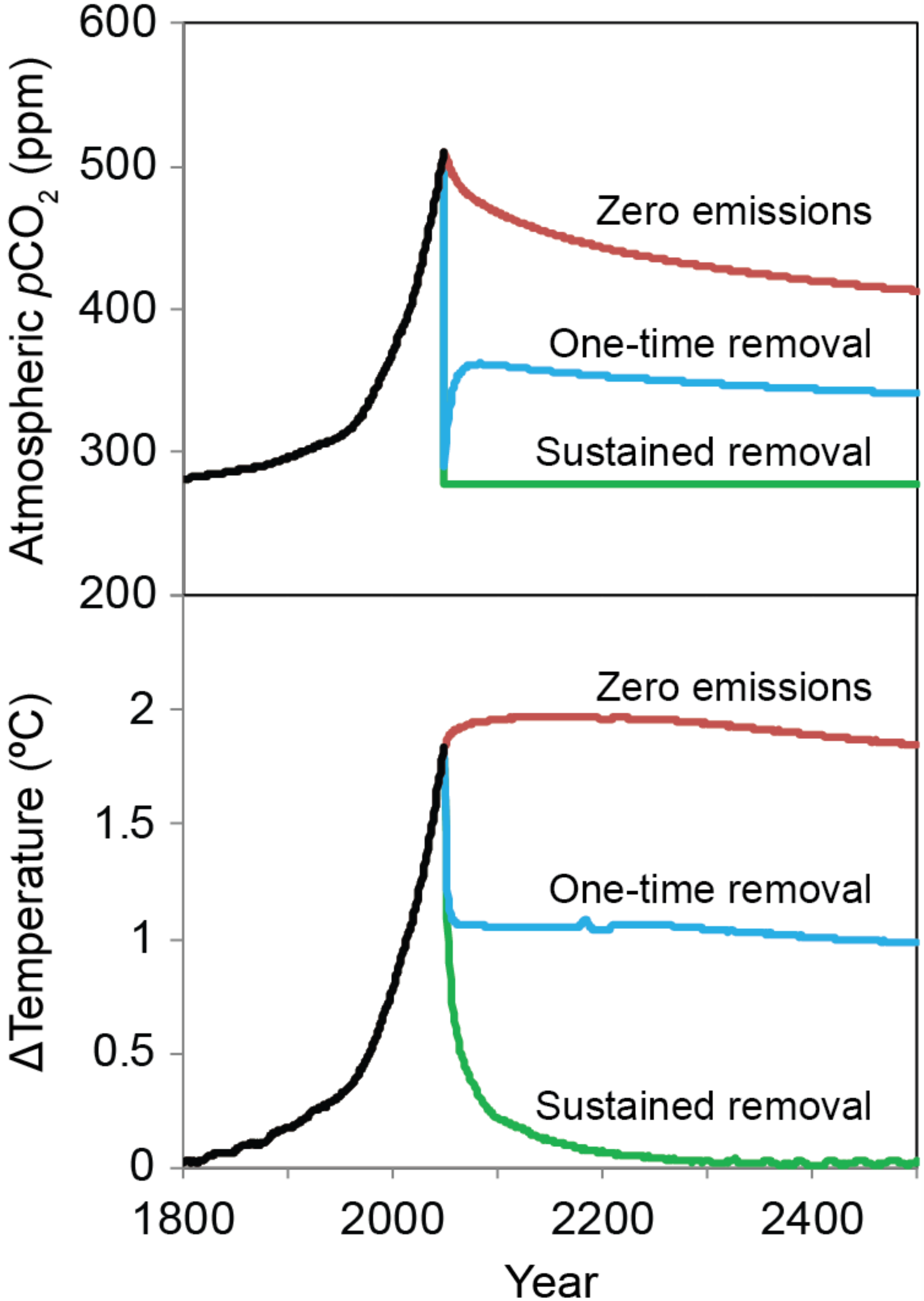
We must go from 480 mmT CO_2e today to 80 mmT CO_2e in 40 years.

Why near zero important?

40 Billion Tons/year



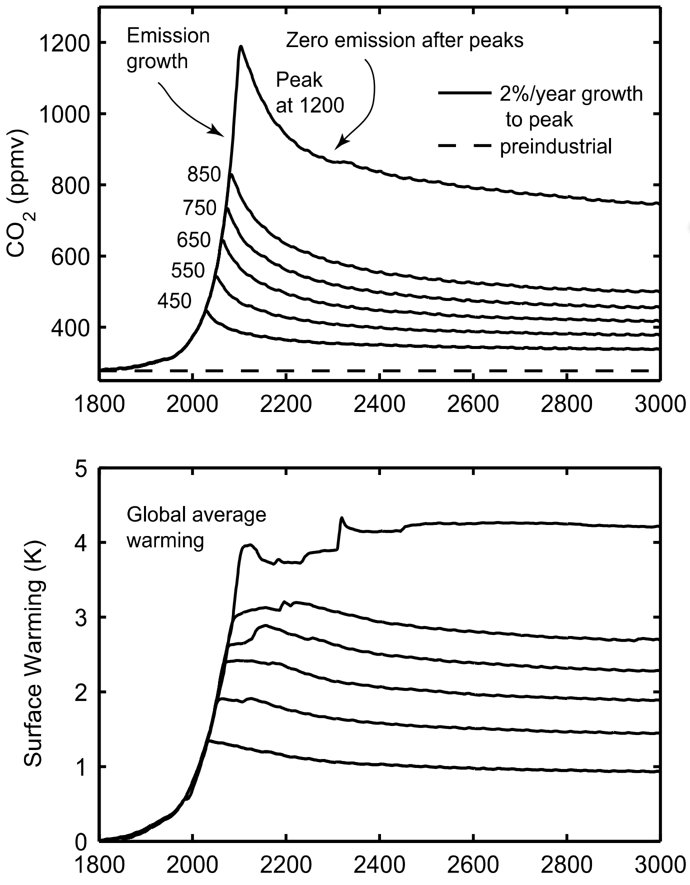
Several million tons per year



If we stop CO_2 emissions instantaneously what we have already emitted stays in the atmosphere for 100s of years.

If we removed all excess CO_2 from the atmosphere instantaneously, the oceans would transfer about ½ of it back

So even if we stopped today . . ..



Solomon (PNAS, 2008)

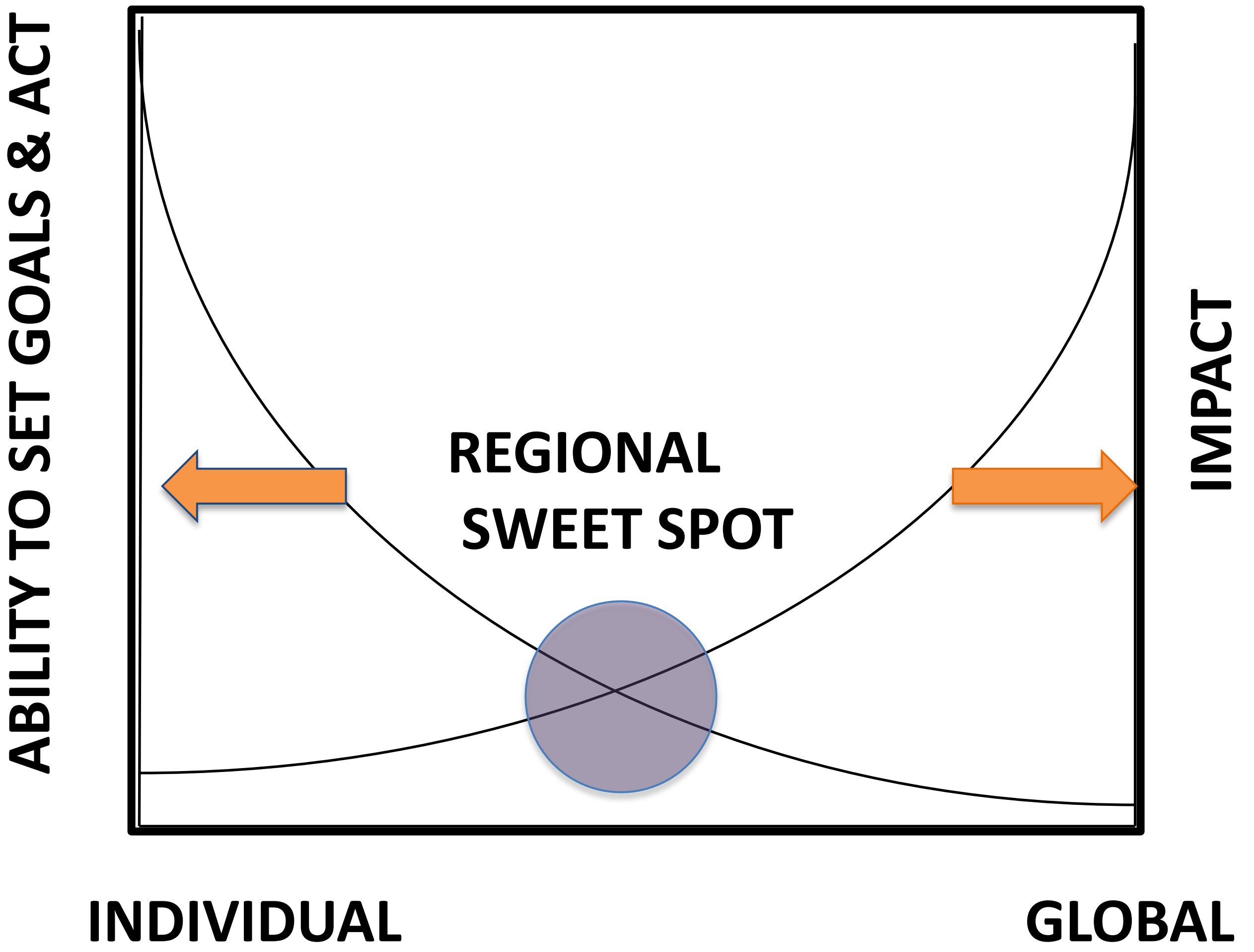
C02

AND

Temperature

Would remain locked in for centuries

WHY REGIONAL?



HAVE A GOAL

An emission goal leads to different solutions

ZERO EMISSIONS → STOP BURNING FOSSIL FUEL

NO COAL

NO OIL

NO GAS

unless CARBON CAPTURE AND STORAGE (CCS) is deployed

HOW DO WE MAKE DECISIONS ABOUT ENERGY?

ENVIRONMENT

ECONOMICS

SECURITY

A GOOD GOAL:

GO TO ZERO GHG EMISSIONS AS FAST AS POSSIBLE WHILE ENSURING RELIABILITY AND MINIMIZING COST IMPACTS

- ***"Fast as possible" is 2050 for planning***
- ***"zero" is 80% below 1990***
- ***Rule out the extremely expensive alternatives***
- ***Reliability much as today***

Three rules

- Get the accounting right
- Use feasible technology
- Don't leak

- Otherwise the regional plans will not add up to a solution

COUNT EVERYTHING, COUNT ONCE

Unless emissions are sequestered

1. **How much can we control demand through efficiency measures?** → **Decrease need for electricity and fuel.**

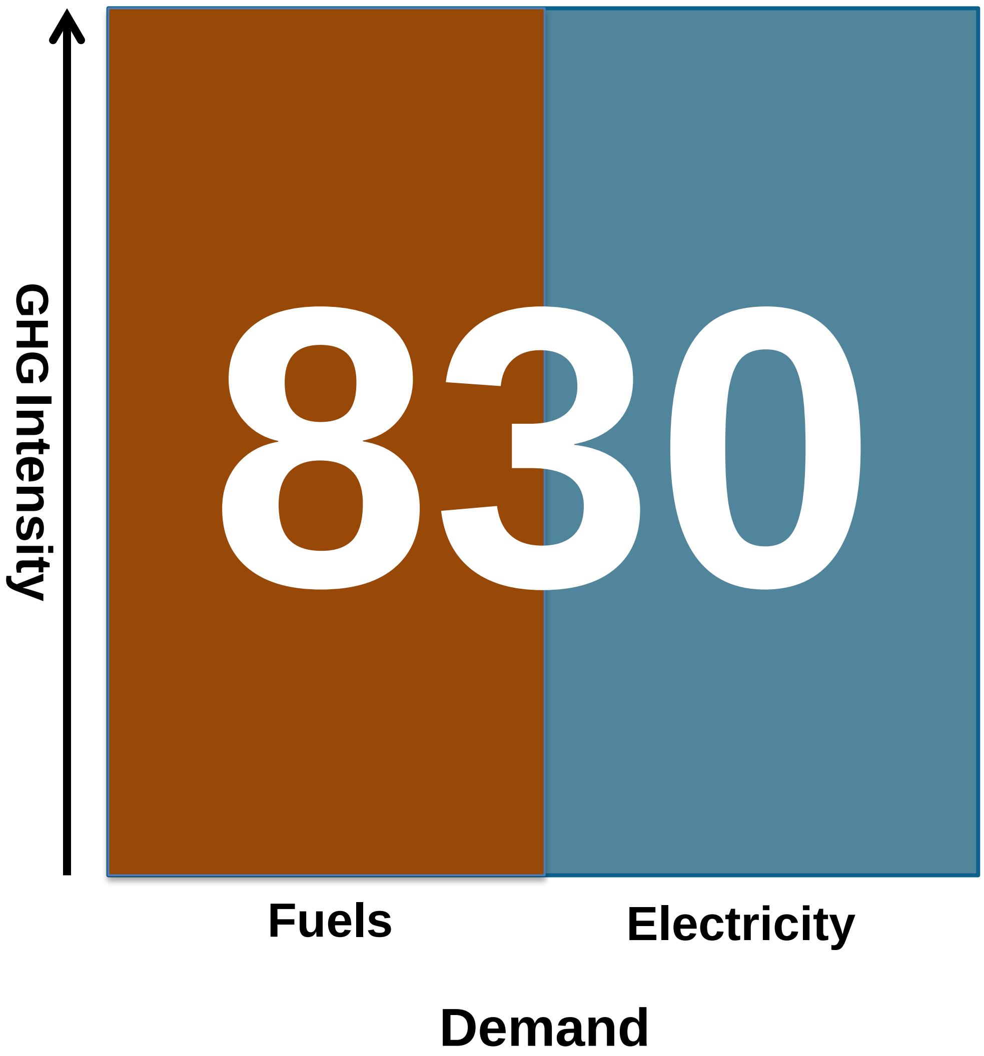
2. **How much do we electrify or convert to hydrogen fuel?** → **Increase demand for electricity, decrease demand for fuel.**

3. **How do we de-carbonize enough electricity demand?** → **Nuclear, CCS, Renewables**

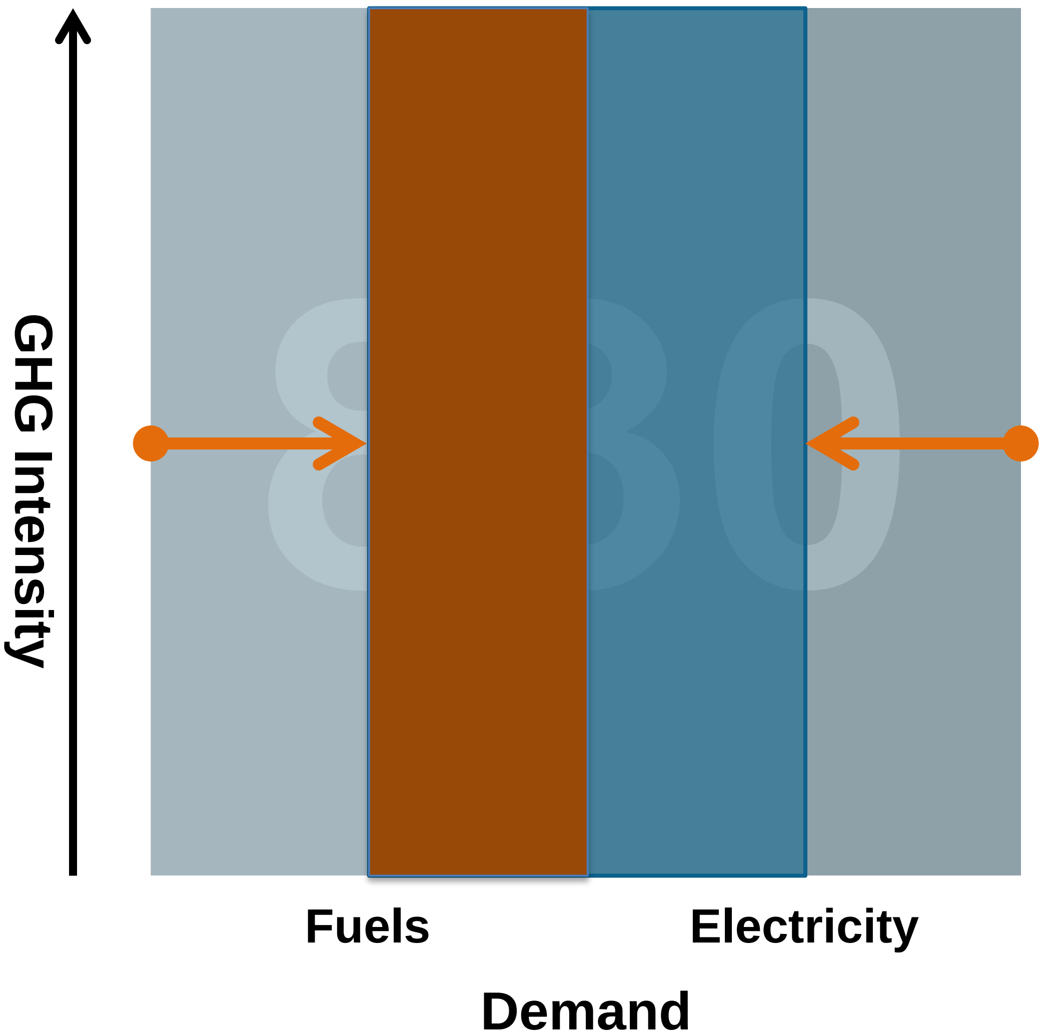
   How do we balance load? → **Biofuel or gas with CCS, Energy storage, or demand management.**

4. **How do we de-carbonize enough fuel (hydrocarbons or hydrogen) to meet remaining demand?** → **Biofuel, fuel from electricity?**

ACTIONS TO REDUCE EMISSIONS

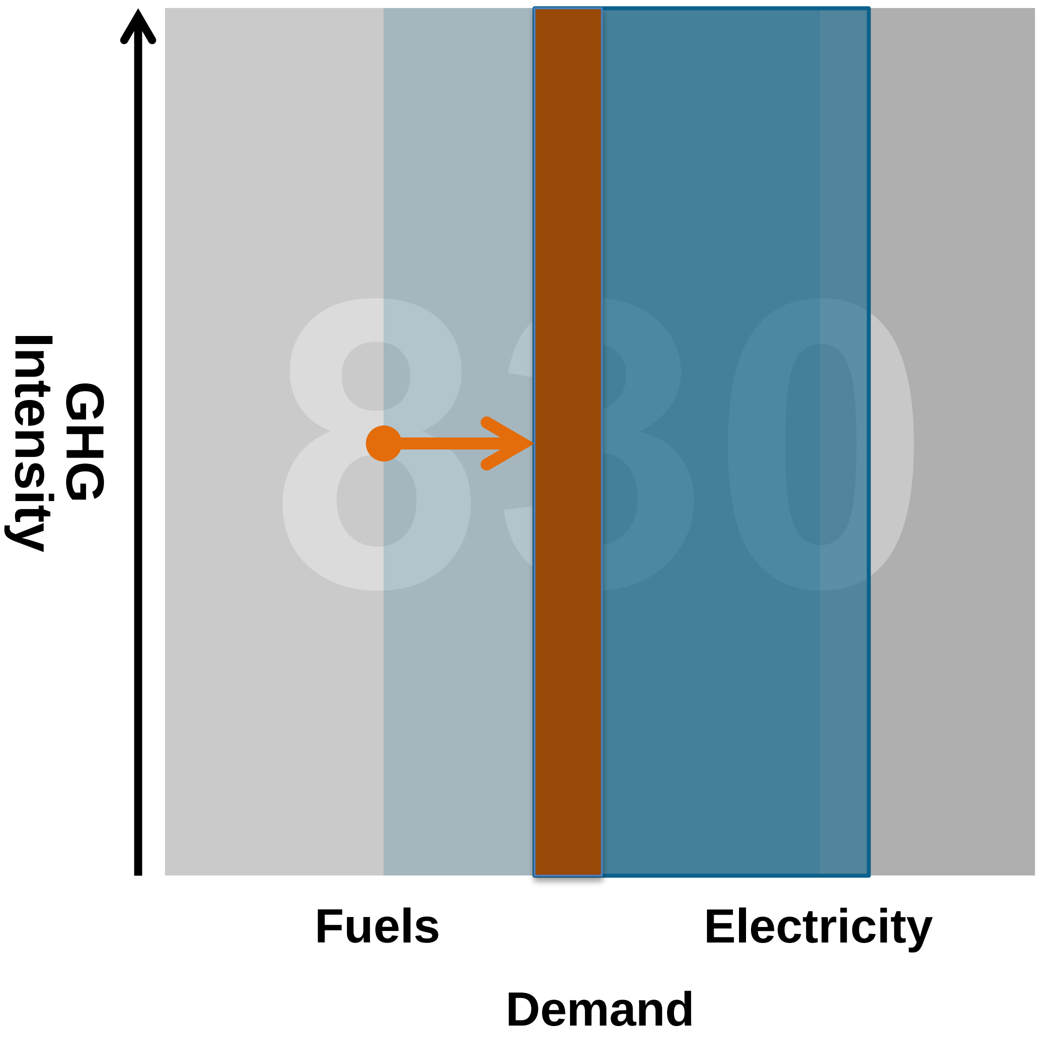


ACTIONS TO REDUCE EMISSIONS



1. Efficiency

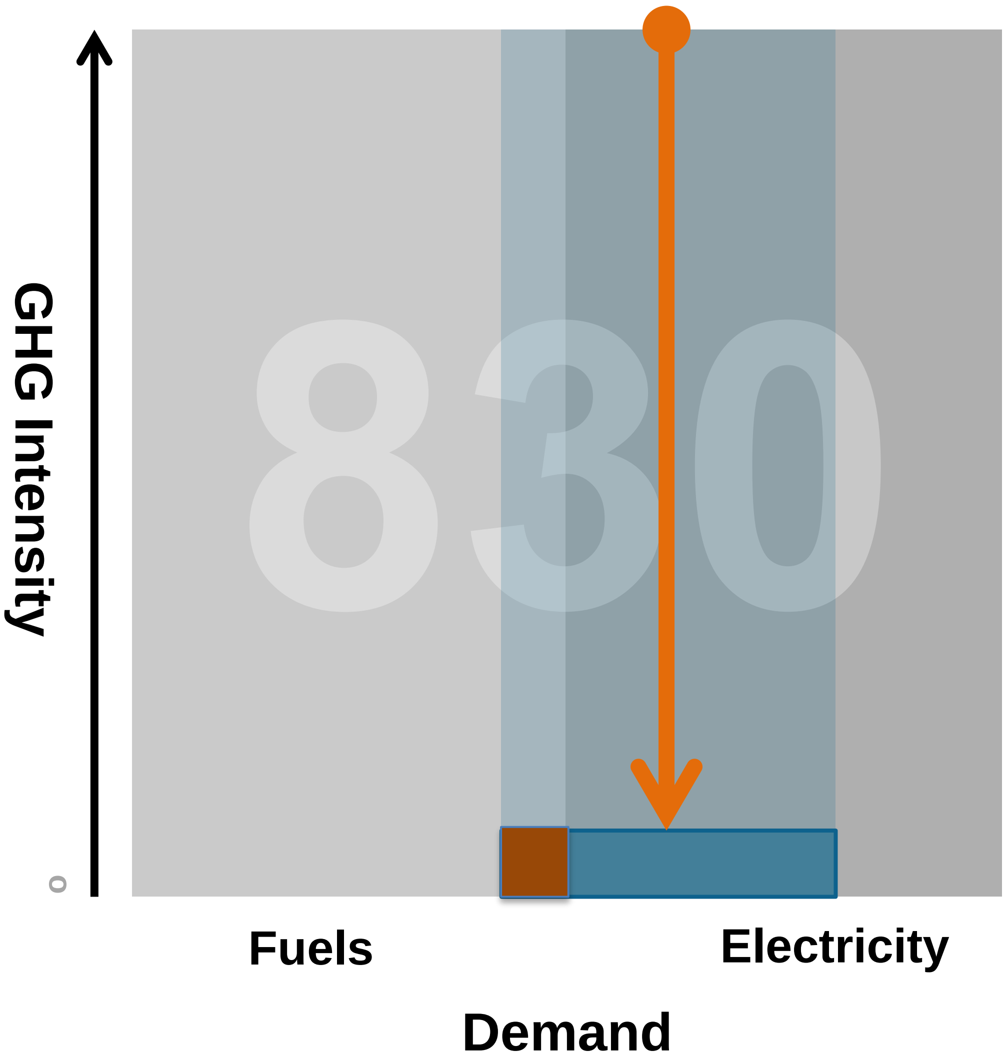
ACTIONS TO REDUCE EMISSIONS



1. Efficiency

2. **Electrification**

ACTIONS TO REDUCE EMISSIONS



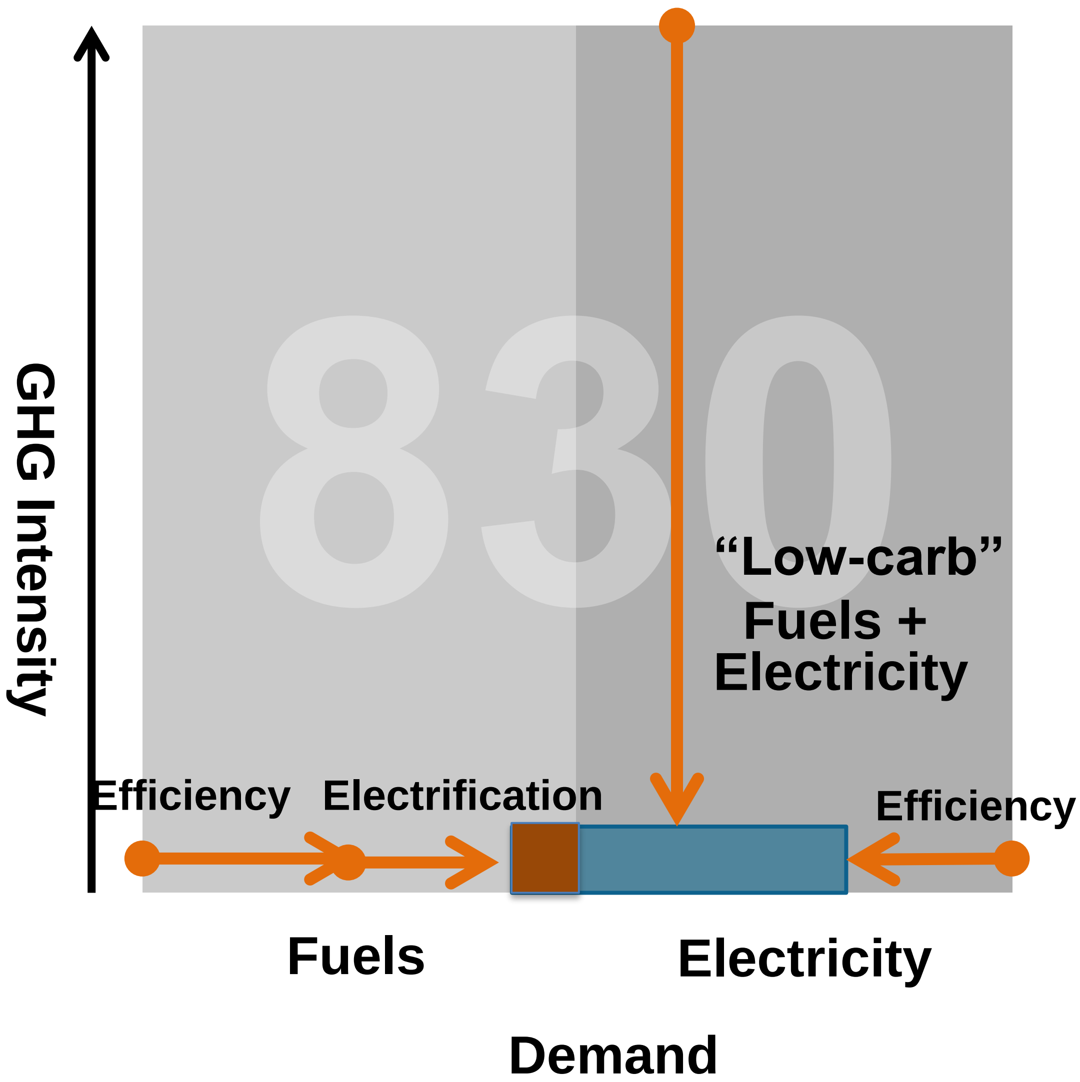
1. Efficiency

2. Electrification

3 “Low-Carb” Electricity

4. “Low-Carb” Fuels

ACTIONS TO REDUCE EMISSIONS



1. Efficiency

2. Electrification

3 "Low-Carb"
Electricity

4. "Low-Carb" Fuels

FEASIBILITY MEANS USING BIN 1 AND 2

BIN 1	Deployed at scale now
BIN 2	Has been demonstrated, not available at scale
BIN 3	In development
BIN 4	Research concept

DON'T LEAK

- **Can't use more than California's share of resources**

- **Can't cause other locations to increase their emissions as CA reduces theirs**
- (In reality this is really hard if neighbors are not doing the same thing)

RESULTS

THE SHORT ANSWER: YES

- We can get about 60% of cuts with implementation of technology we largely know about applied but this is without regard to cost, using non-commercial technology and unprecedented rates of deployment.

- We can get the rest of the cuts to 80% below 1990, but this will require new technology innovation and development.

BUT IT’S REALLY HARD

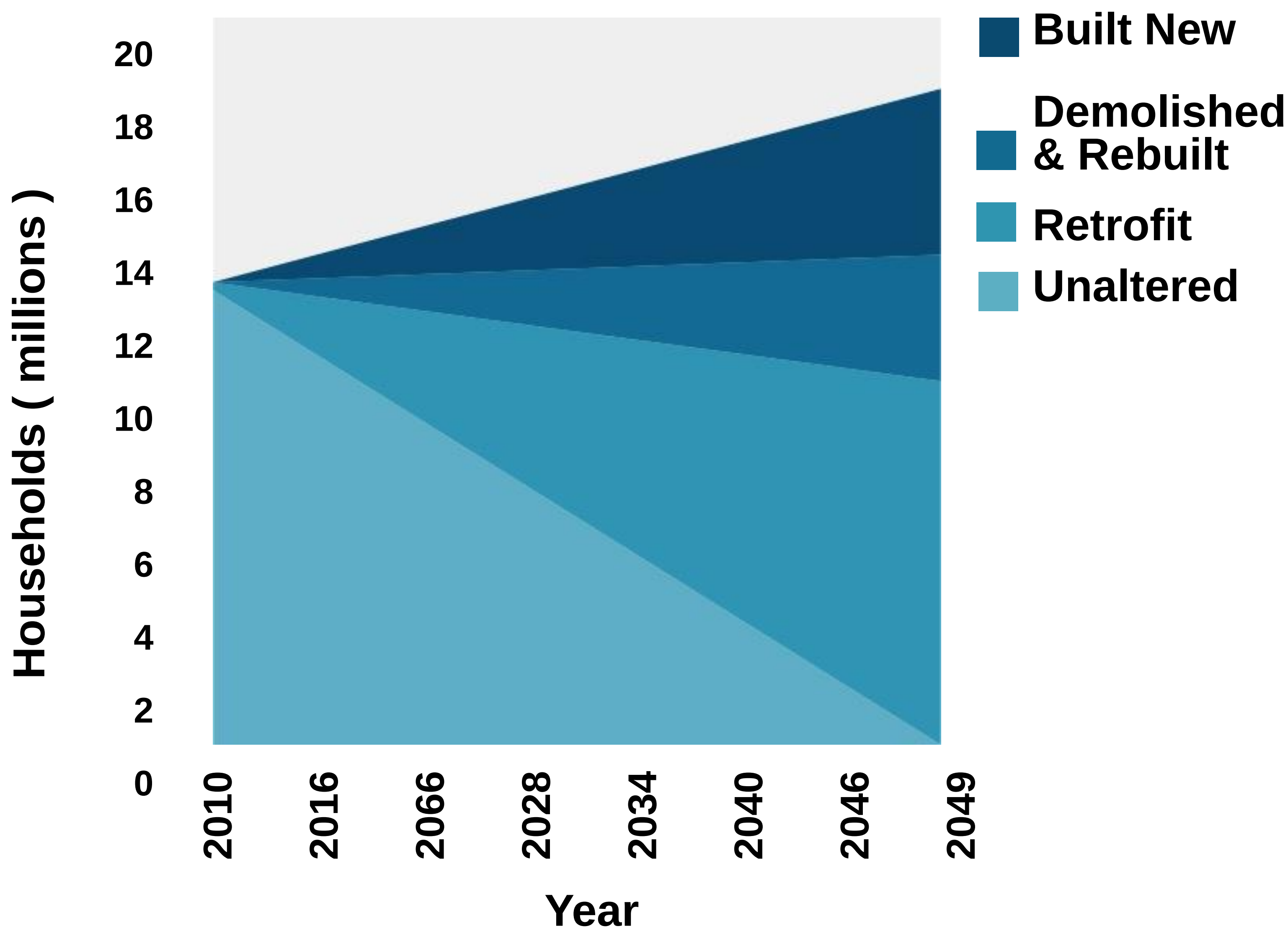
INCREASE ENERGY EFFICIENCY AND ELECTRIFY

Industry

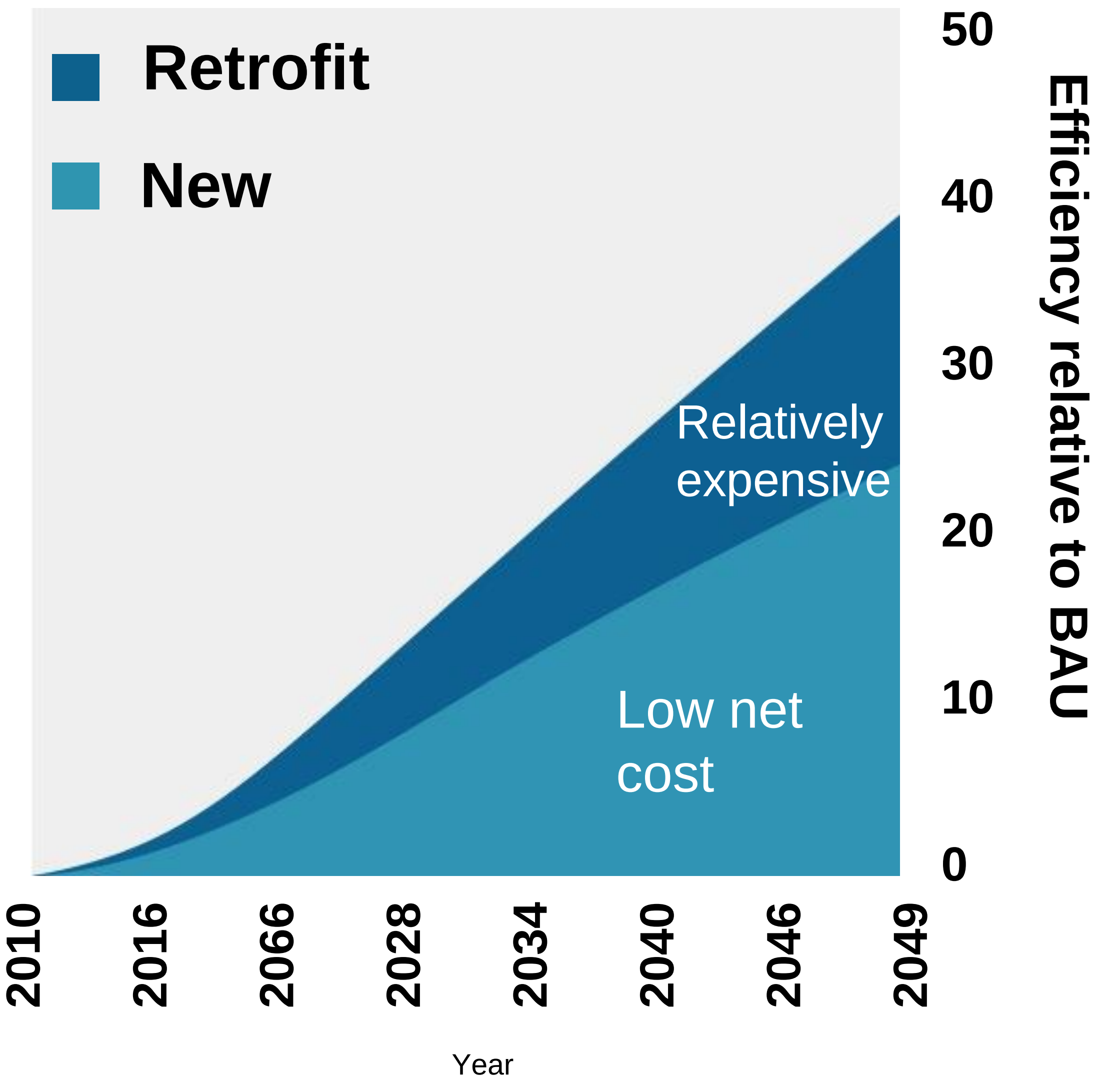
Buildings

Transportation

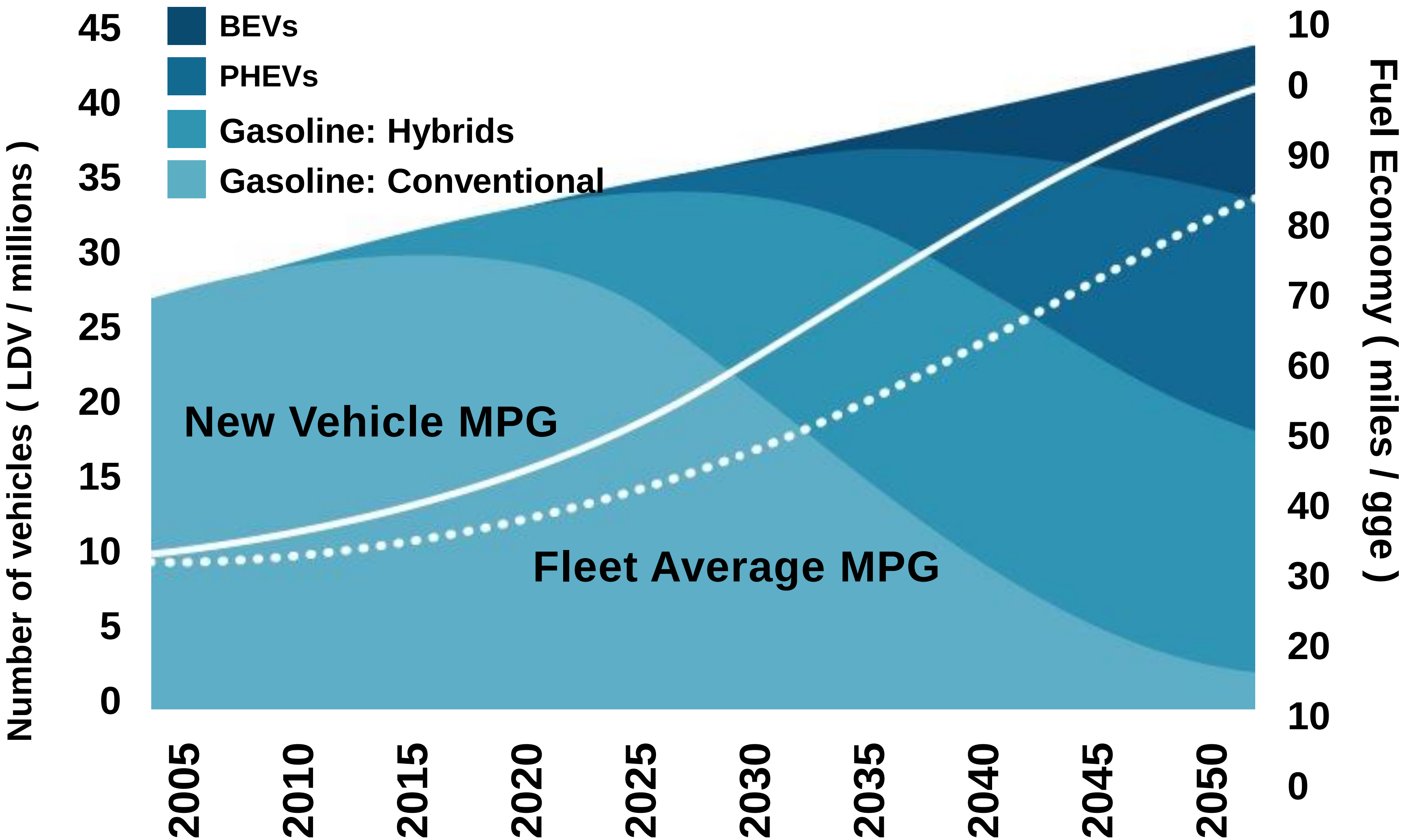
EFFICIENCY CHALLENGE: CHANGE EVERY SQUARE FT. OF BUILDINGS



COST OF EFFICIENCY



ELECTRIFICATION CHALLENGE: LIGHT-DUTY VEHICLE SCENARIO



MASSIVE EFFICIENCY AND ELECTRIFICATION

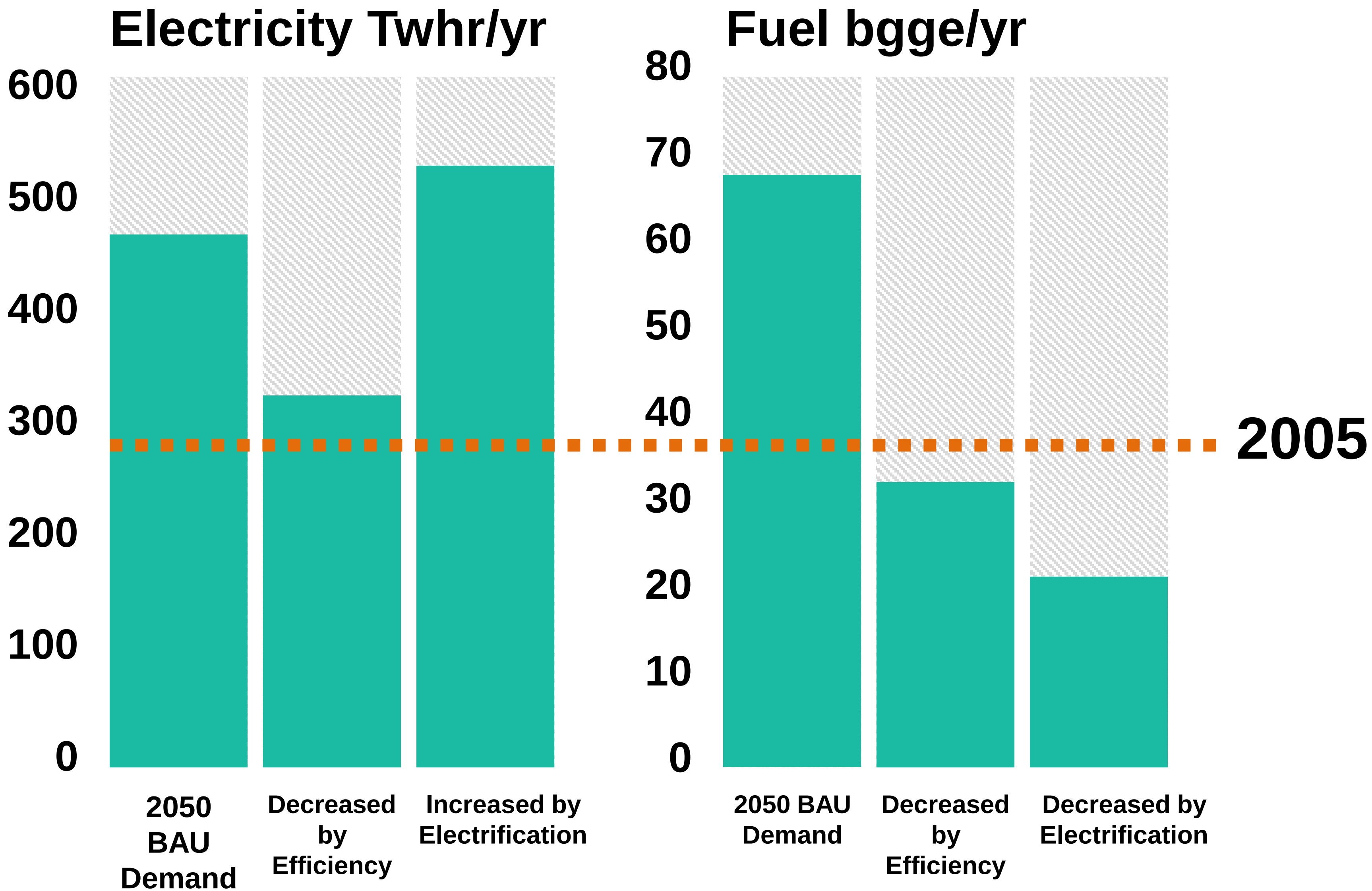
	EFFICIENCY	ELECTRIFICATION
BUILDINGS	40%	70%
INDUSTRY	0 – 15%	12%
CARS	60%	44%
TRUCKS	30%	18%
AIRPLANES	50%	0%
BUS / RAIL	0%	100%
MARINE	40%	0%

FIRST BIG QUESTION:

WHAT GIVES THE BIGGEST "BANG FOR THE BUCK" IN EFFICIENCY AND ELECTRIFICATION ACTIONS?

Watch for this: Efficiency matters more where the supply technology can not be easily decarbonized

THE DEMAND ADJUSTMENT



DOUBLE ELECTRICITY AND DE-CARBONIZE IT

WE HAVE ELECTRICITY CHOICES

NUCLEAR ELECTRICITY

NO TECHNICAL BARRIERS, NOT LEGAL

COAL OR PLENTIFUL GAS WITH CARBON

CAPTURE AND, STILL HAS EMISSIONS

CA HAS PLENTY OF RENEWABLE ENERGY

RENEWABLE ENERGY IS MOSTLY SMALL SCALE AND INTERMITTENT

NUCLEAR ELECTRICITY
NO TECHNICAL BARRIERS

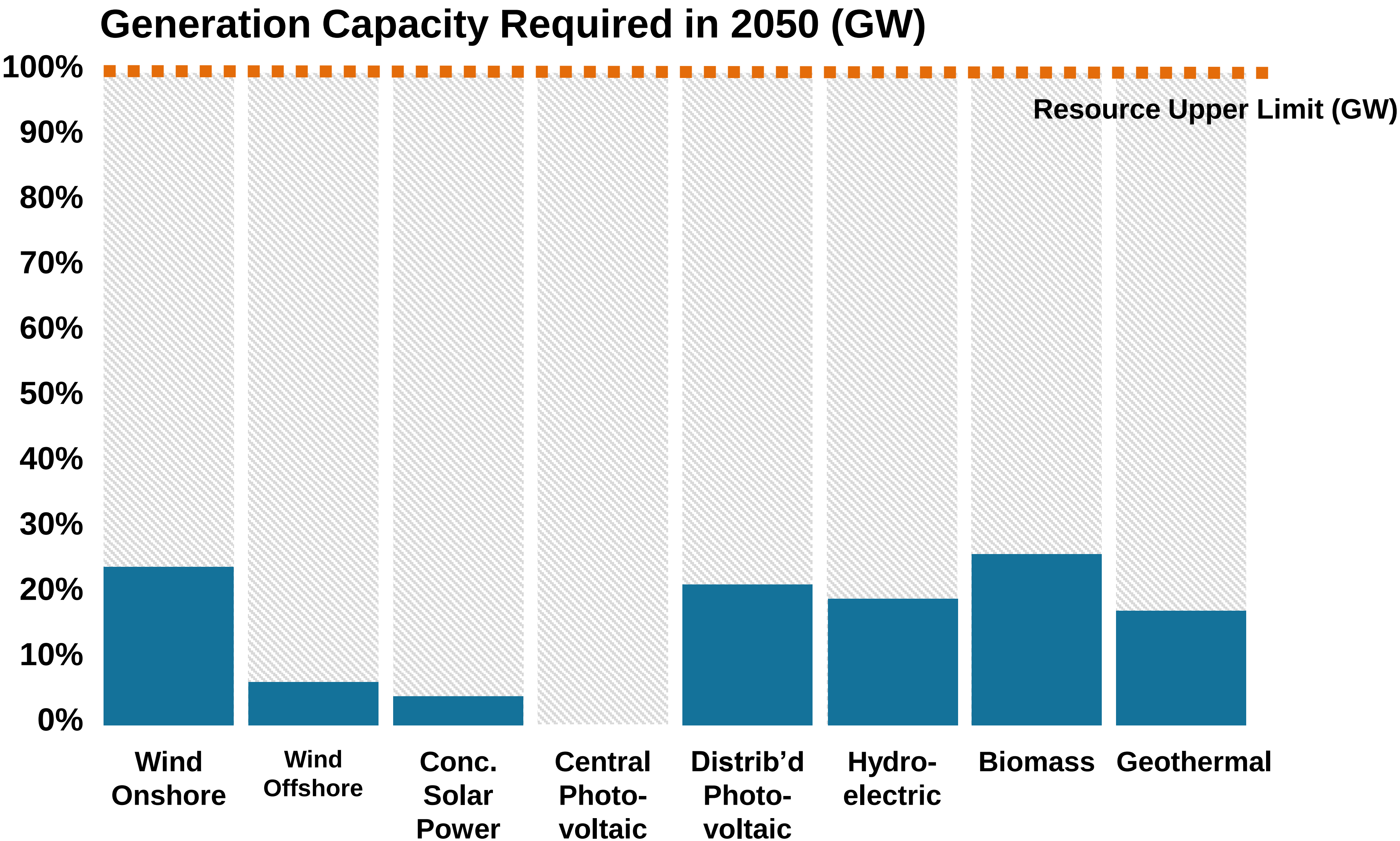
- **Mature technology**
- **Adequate land, fuel, safety**
- **Cooling water: use air cooling**
- **Cost: best estimate: 6–8¢/kWh**
  similar to fossil / CCS, renewables
- **62% nuclear required build rate 2020–2050: 1.4 GW/yr**

- **Challenges of Nuclear: Institutional**
  - Waste disposal: CA law
  - Public acceptance
- **Fukushima: “It could have been avoided”– no one died**
- **Factually, nuclear is second safest form of electricity**

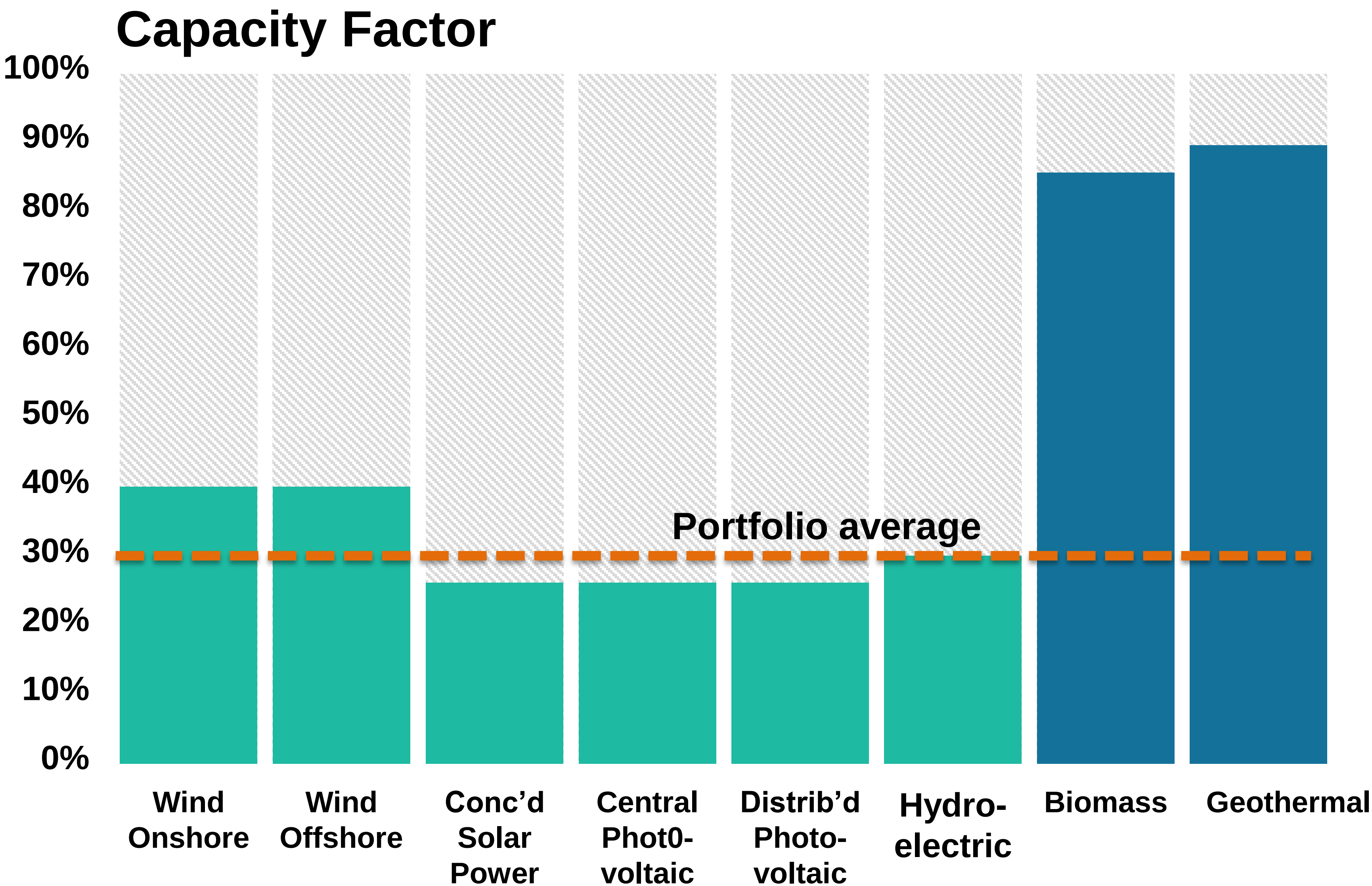
COAL OR GAS WITH CARBON CAPTURE AND STORAGE → STILL HAS EMISSIONS

- Coal or gas with CCS can provide 100% of projected 2050 energy (48 GW).
- Residual Emissions: at 90% capture rate
    - 28 mmt CO_2e, for coal about 1/3rd the total budget
    - 13 mmt CO_2e for gas about 1/6th the total budget
- Using gas without saline reservoirs, about 60 years capacity exists in-state.
- Massive new infrastructure required.

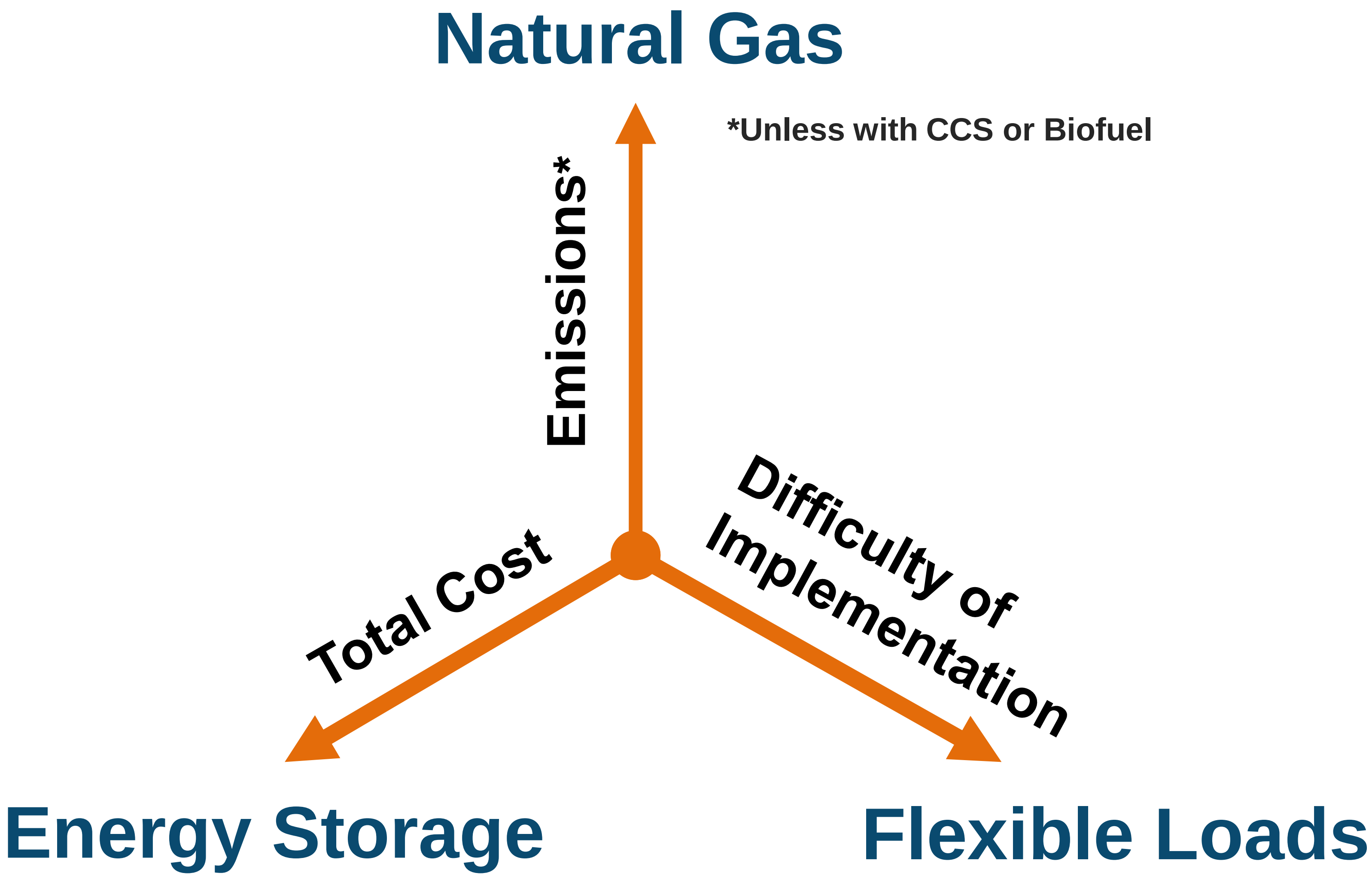
CA HAS PLENTY OF RENEWABLE ENERGY



RENEWABLE ENERGY IS LARGELY INTERMITTENT

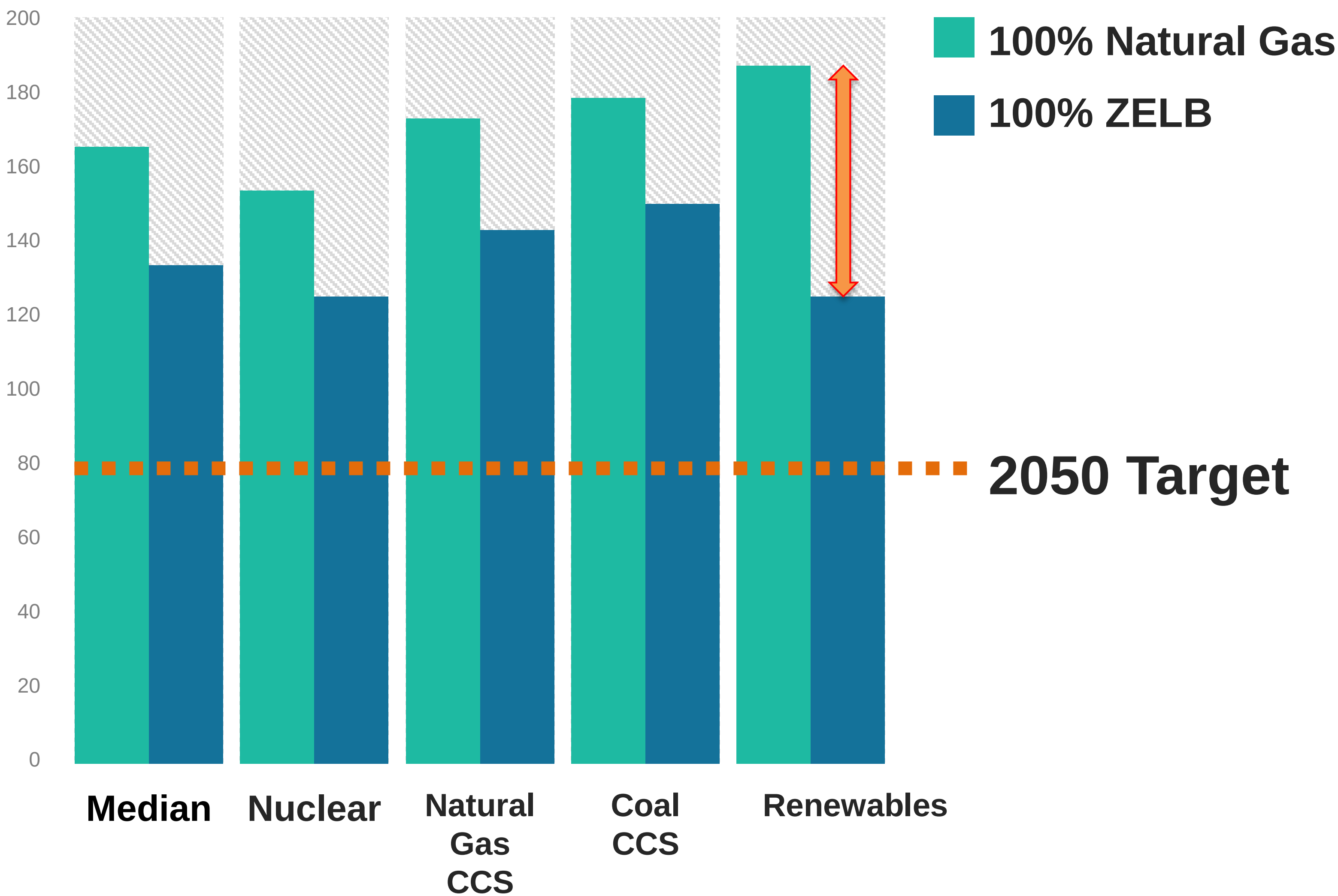


LOAD BALANCING CAN ADD EMISSIONS



ZERO EMISSION LOAD BALANCING (ZELB)

GHG Emissions ($MtCO_2e$ / yr) Impact of ZELB



NUCLEAR AND CCS TECHNOLOGY MATURITY

	Nuclear Technology	Coal or Natural Gas CO2 Capture	CO2 storage
BIN 1	Generation III+ reactors	High-efficiency coal gasification, high-efficiency natural gas combined cycle, ultra-supercritical pulverized coal combustion, solid-oxide fuel cell (SOFC), solvent separation	Injection into oil/gas reservoirs
BIN 2	Small modular reactors (LWR)	Post-combustion CO2 capture technologies with 90% capture efficiency, integrated gasification systems with CCS, amine solvent separation	Saline aquifer injection
BIN 3	Generation IV (including small modular Na-cooled reactors)	New capture methods with >90% effectiveness, lower cost CO2 capture technologies of all kinds, metal-organic framework separations, membrane separation	Coal bed injection
BIN 4			Shale Injection

RENEWABLE TECHNOLOGY MATURITY

	Wind	Concentrated Solar Power (CSP)	Solar Photovoltaic (PV)	Geothermal	Hydro and Ocean	Biomass
Bin 1	Onshore, shallow offshore turbines	Parabolic trough, central receiver	Silicon PV, Thin-film PV, Concentrating PV	Conventional geothermal	Conventional hydro	Coal/biomass co-firing, direct fired biomass
Bin 2		Dish Stirling				Biomass gasification
Bin 3	Floating (deepwater) offshore turbines		”Third generation” PV		Wave, tidal and river turbines	
Bin 4	High-altitude wind			Enhanced geothermal systems (EGS)		

Load balancing technology bins

	Natural Gas	Storage*	Demand Side Management
Bin1	Combustion turbine	Pumped hydro	Commercial-scale critical peak demand response
Bin 2		"First generation" compressed air energy storage (CAES), battery technologies (Na/S, advanced Pb/Acid, Ni/Cd, Li ion as found in electric vehicles)	Commercial time-of-use demand-side management
Bin 3	Variable fossil generation with CCS	Battery technologies (some advanced Pb/Acid, Vanadium redox, Vanadium flow, Zn/Br redox, Zn/Br flow, Fe/Cr redox, some Li ion), flywheel, "second generation" CAES	Residential time-of-use demand-side management

SECOND BIG QUESTION:

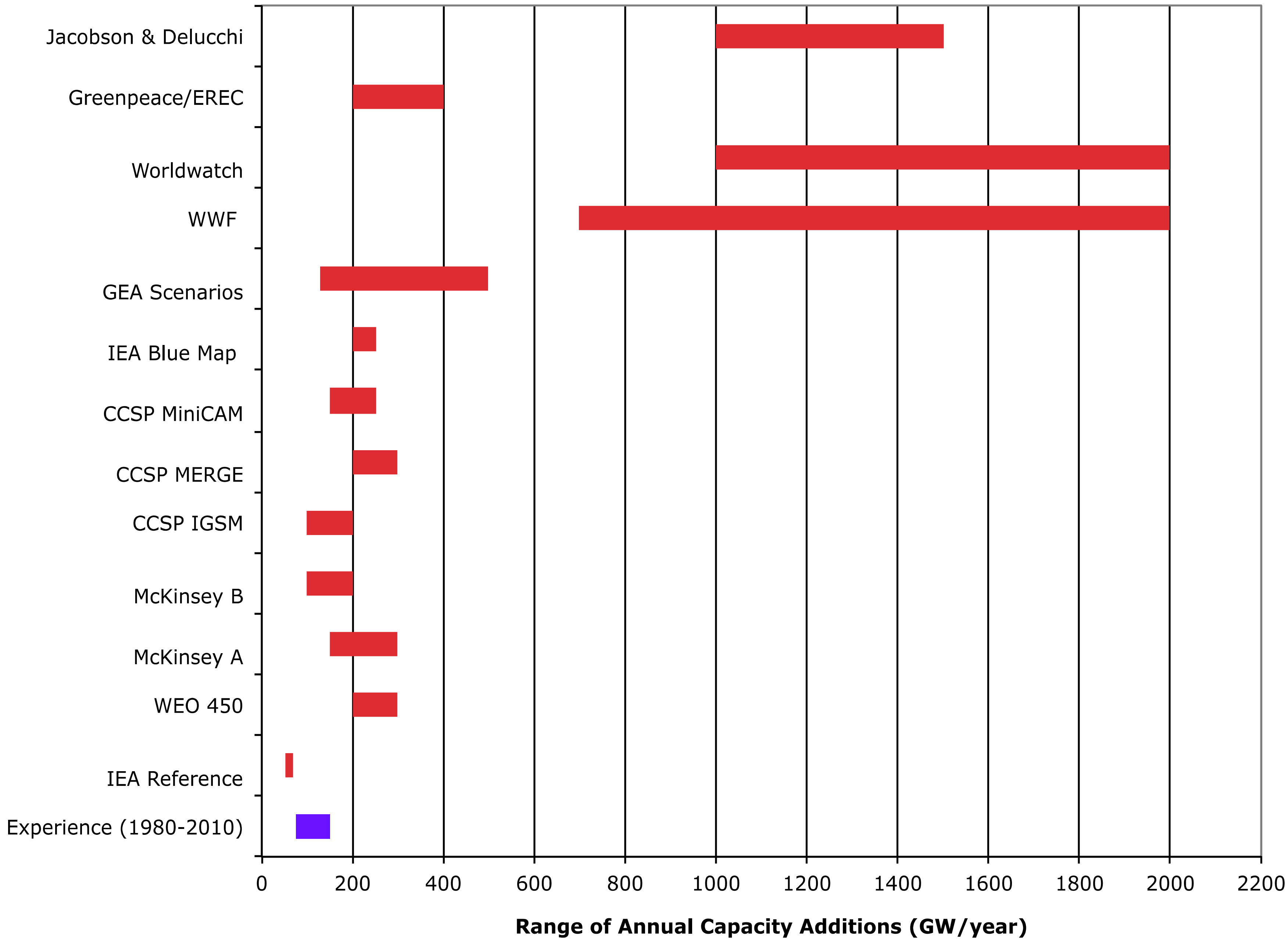
TO DOUBLE ELECTRICITY *AND* DE-CARBONIZE IT:

HOW DO WE CHOOSE?

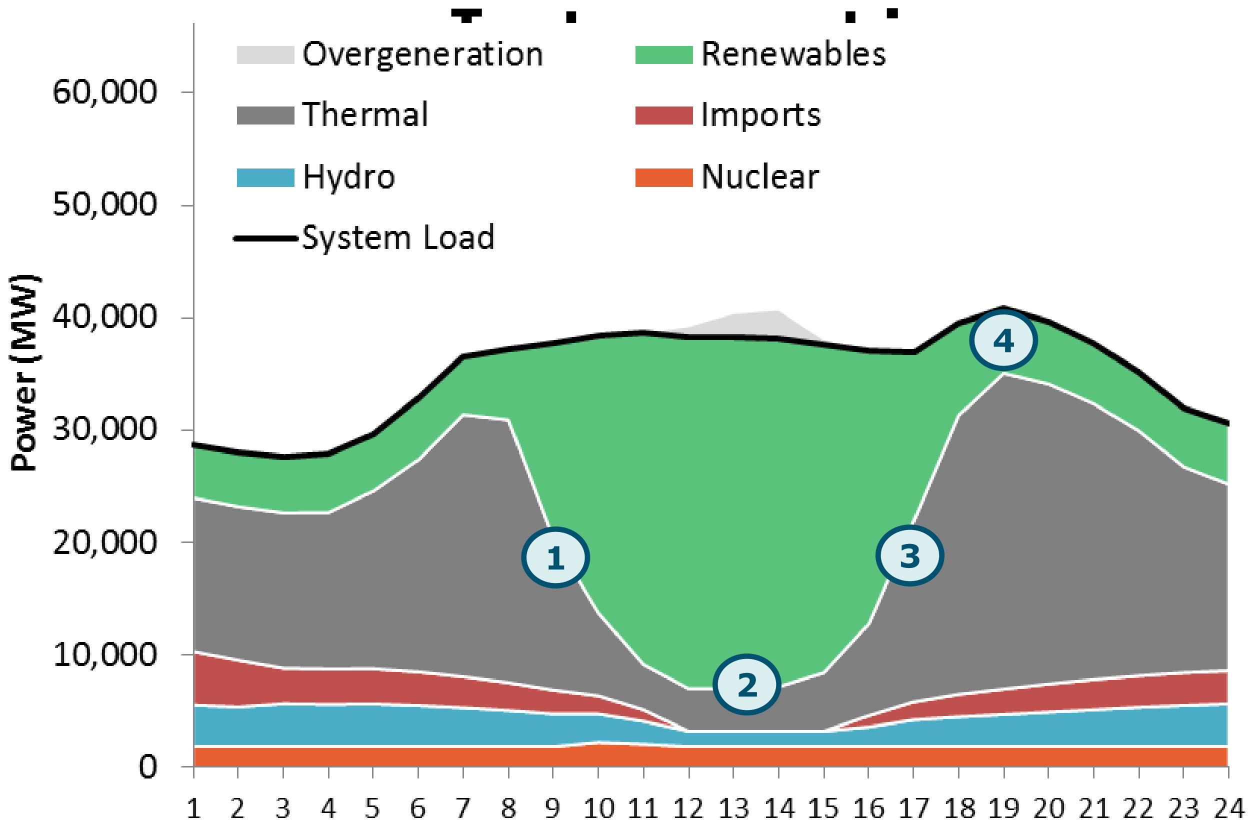
System integration issues may be more important than capacity: *eg* reliability, transmission, business models

When Comparing Electricity Choices:

- What are the system requirements? What else do you need beyond capacity to make the system work reliably?
- How fast can you construct a system that eliminates emissions? By 2050?
- How much will it cost?
- What are the other externalities? Eg water and land use?
- What are the policy and business frameworks required to make it work?


Jacobson & Delucchi
Greenpeace/EREC
Worldwatch
WWF
GEA Scenarios
IEA Blue Map
CCSP MiniCAM
CCSP MERGE
CCSP IGSM
McKinsey B
McKinsey A
WEO 450
IEA Reference
Experience (1980-2010)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
Range of Annual Capacity Additions (GW/year)

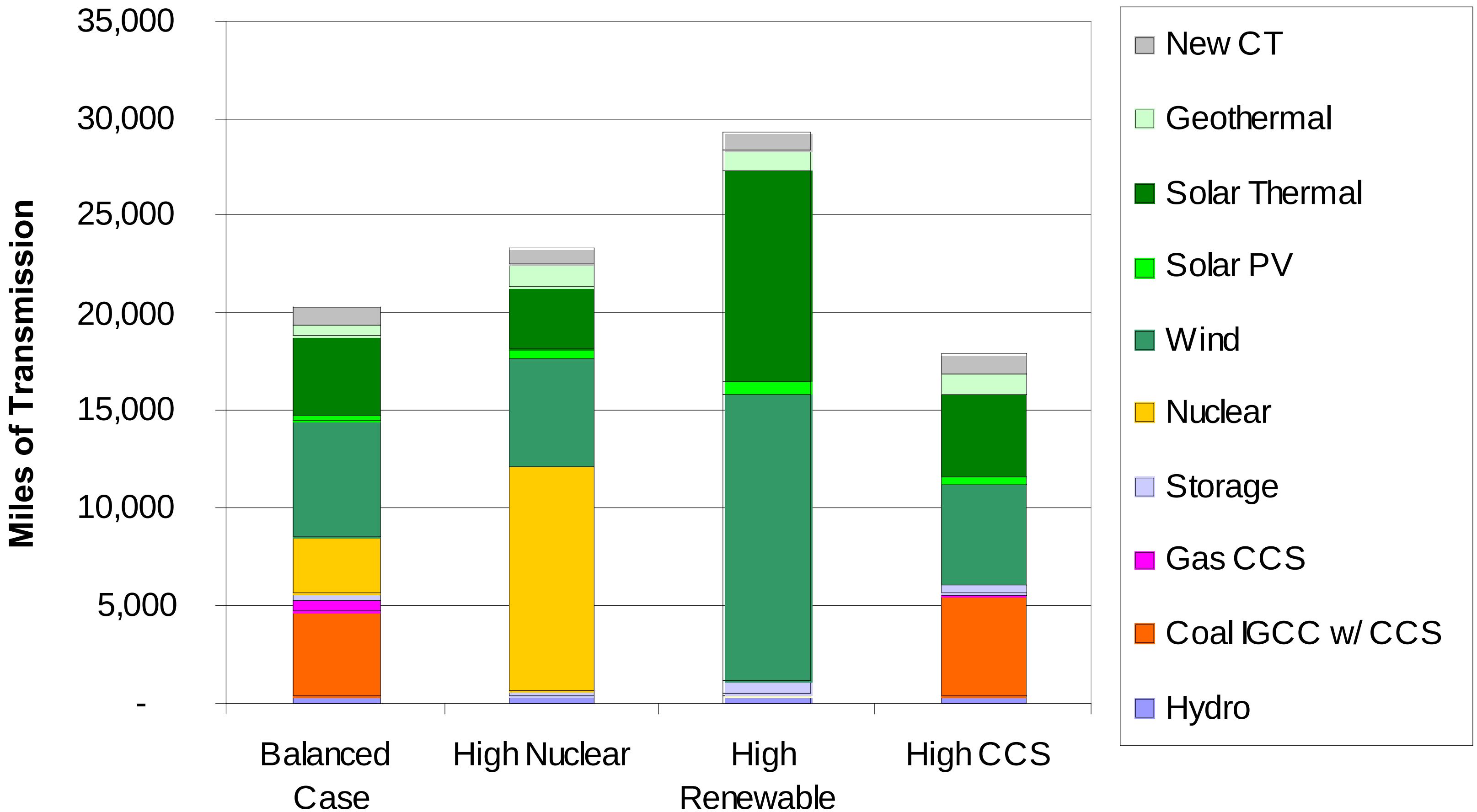
Flexible Capacity Planning Problem for Renewables



1. Downward ramping capability
2. Minimum generation flexibility
3. Upward ramping capability
4. Peaking capability
5. Sub-hourly ramping capability

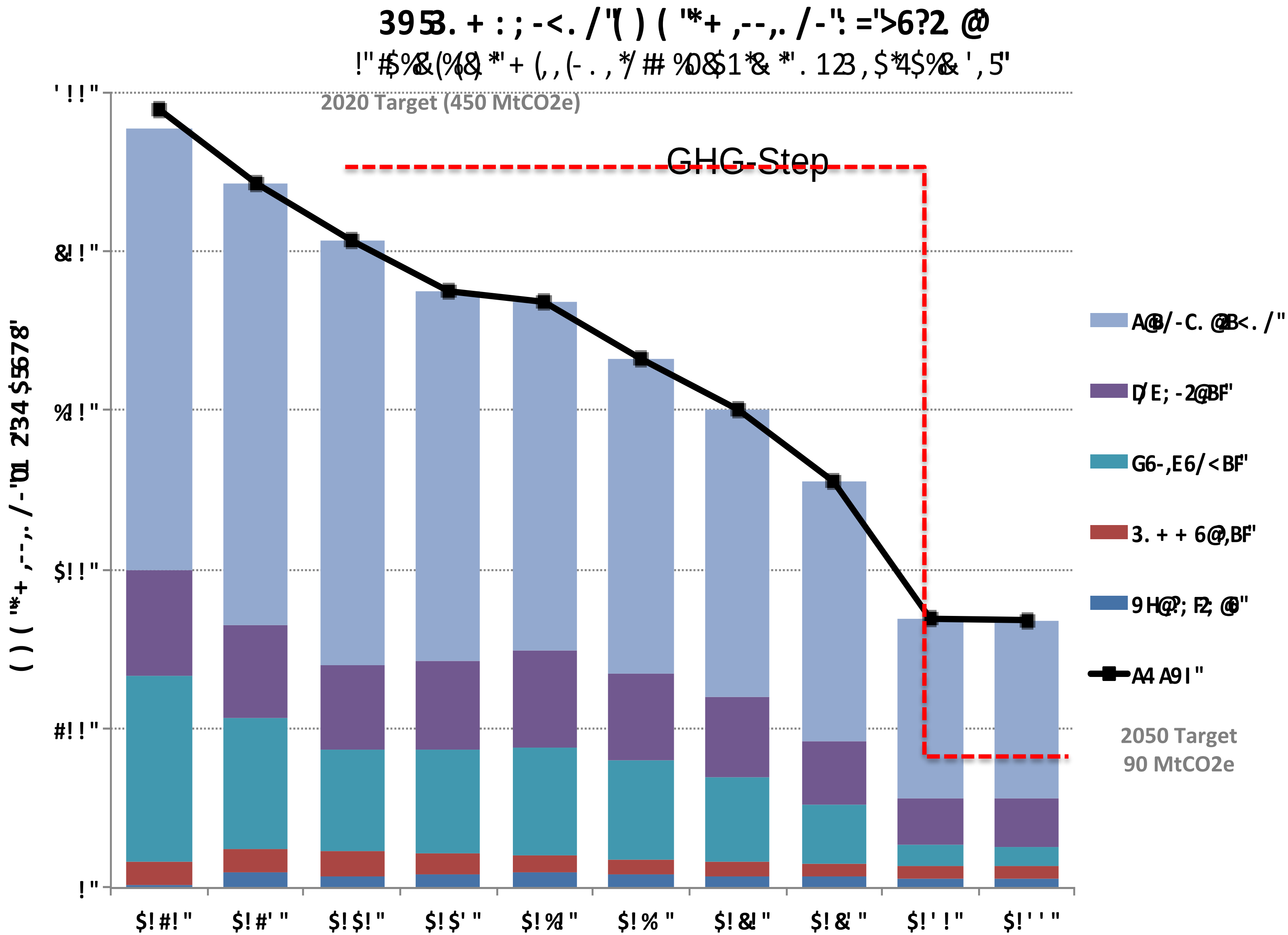
Problem: How to plan system with significant levels of variable generation so that peak and flexible capacity requirements are met at least cost, subject to emissions constraints?

2050 New Transmission Requirements



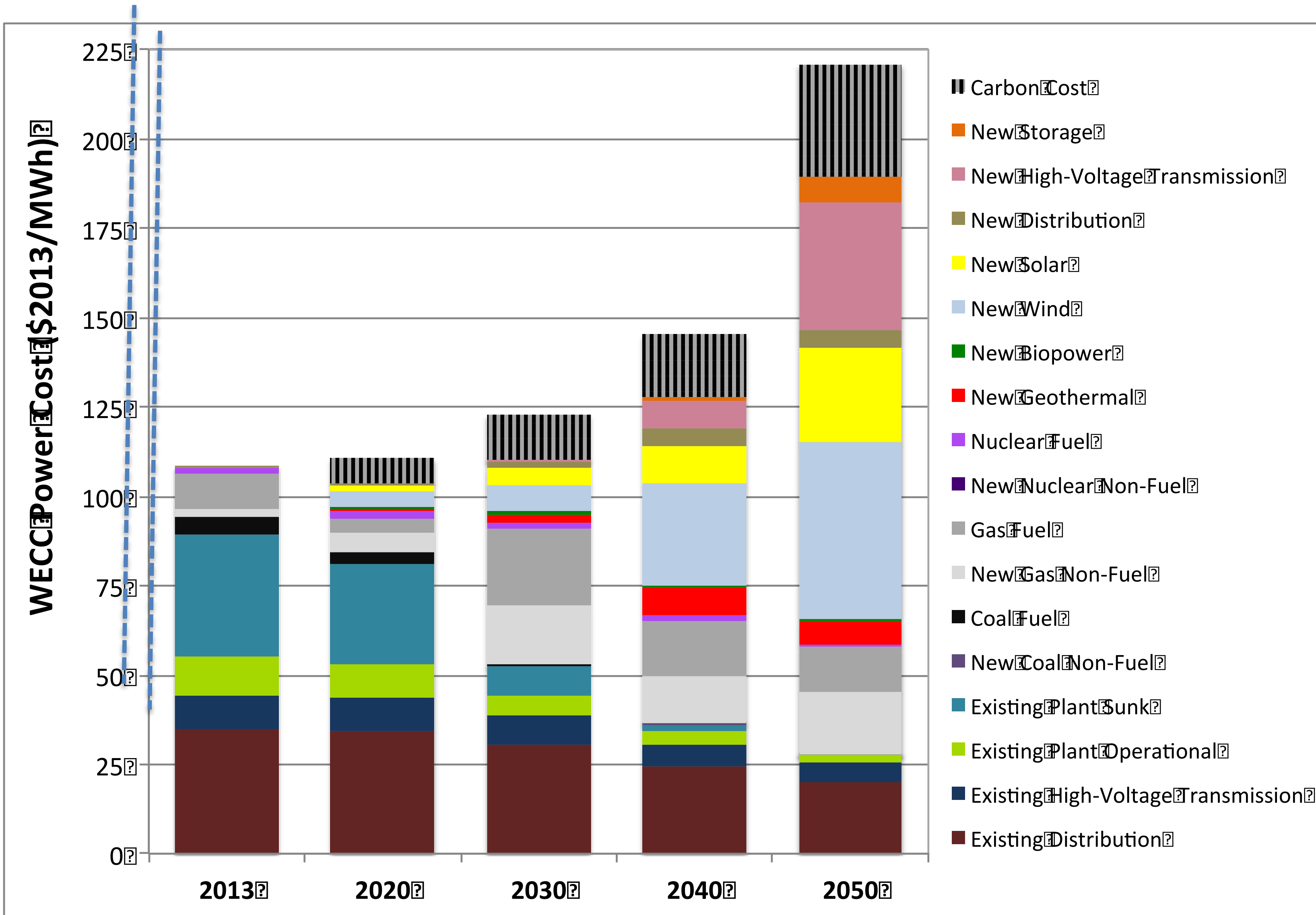
Williams et al, 2012, SOM

50


2020 Target (450 MtCO2e)
GHG-Step
2050 Target
90 MtCO2e

Power system cost increasingly dominated by flexibility rather than energy

- Allocation of carbon revenues important



The median electricity case

About equal parts of nuclear/renewable/CCS

Assume ½ load balancing is without emissions
½ is with natural gas

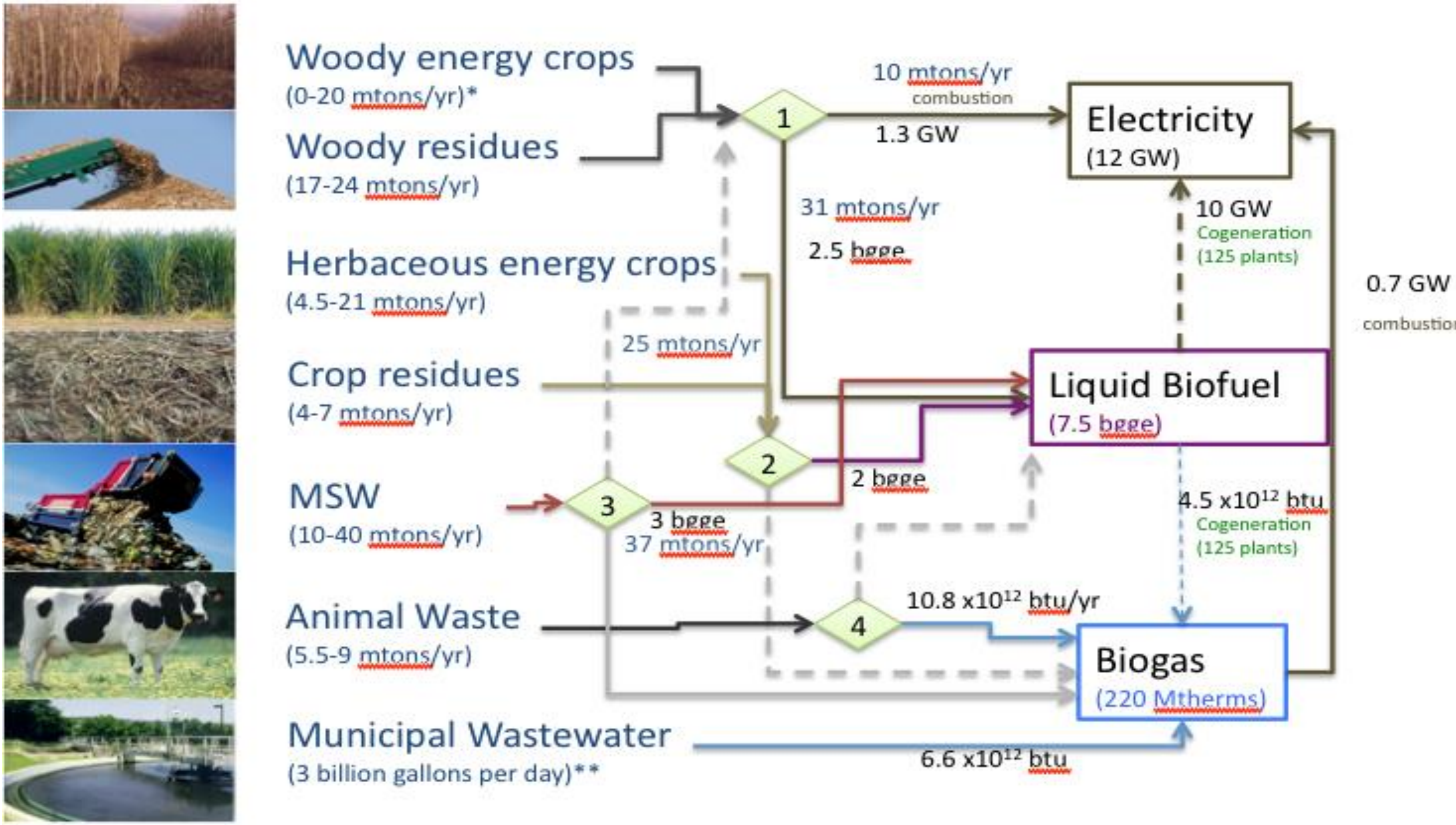
Almost all emissions from electricity are from load balancing

AFTER ALL THESE MEASURES, WE STILL NEED 27 BILLION GGE/YR FUEL

- Biofuels are the choice in the pipeline
- How much biomass?
  - Count all wastes, all crops on marginal lands →
  - Assume we import as much as we make here
- How green?
  - Assume we crack the technology to make this fuel without GHGs

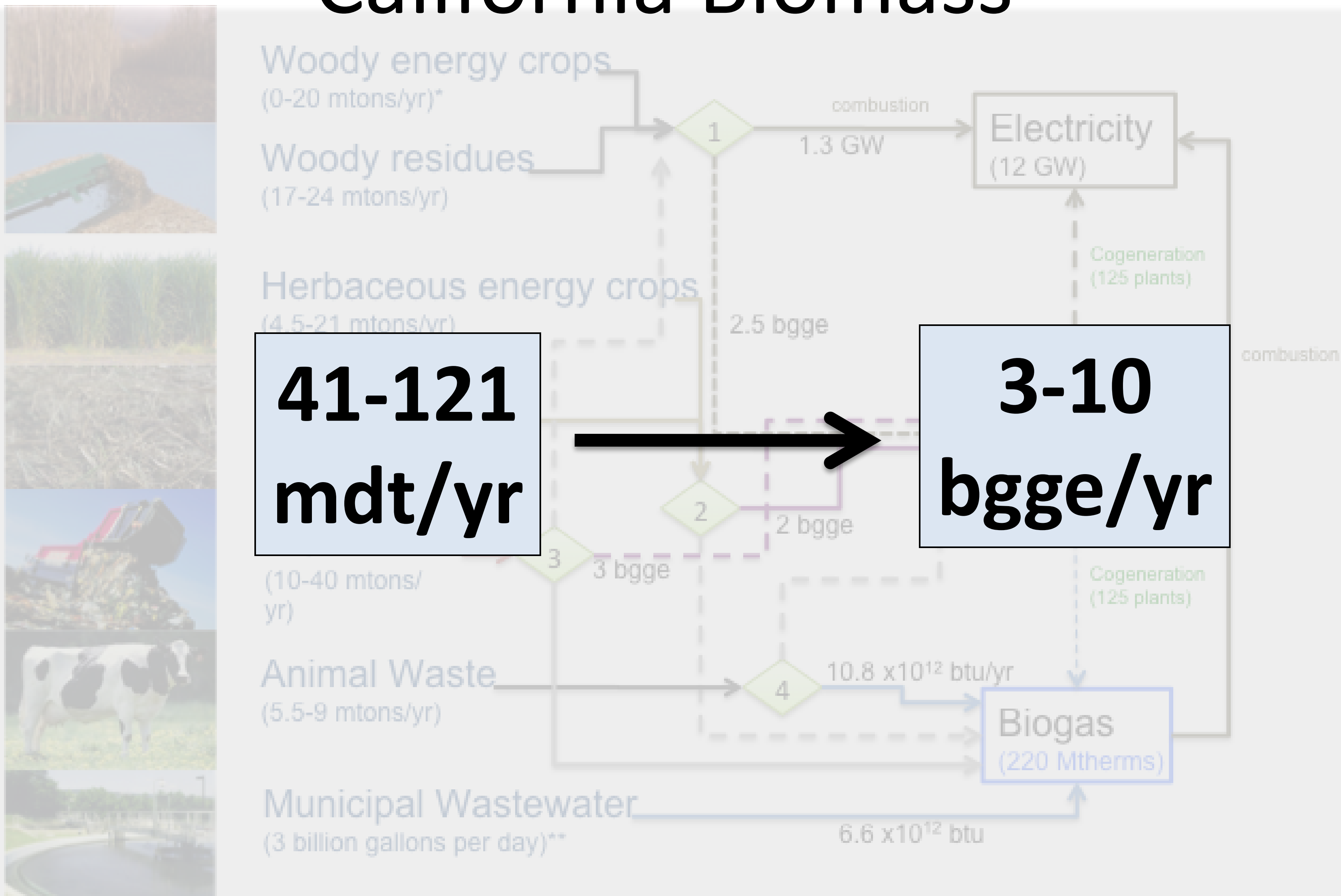
- Estimate
  13 billion gge/yr
  might be available
  ↓
- **WE MAY NOT HAVE A SOLUTION TO THE FUEL PROBLEM**

California Biomass



*technical recoverable yield (50-80% of gross biomass production depending on type)
**not currently used for energy production

California Biomass



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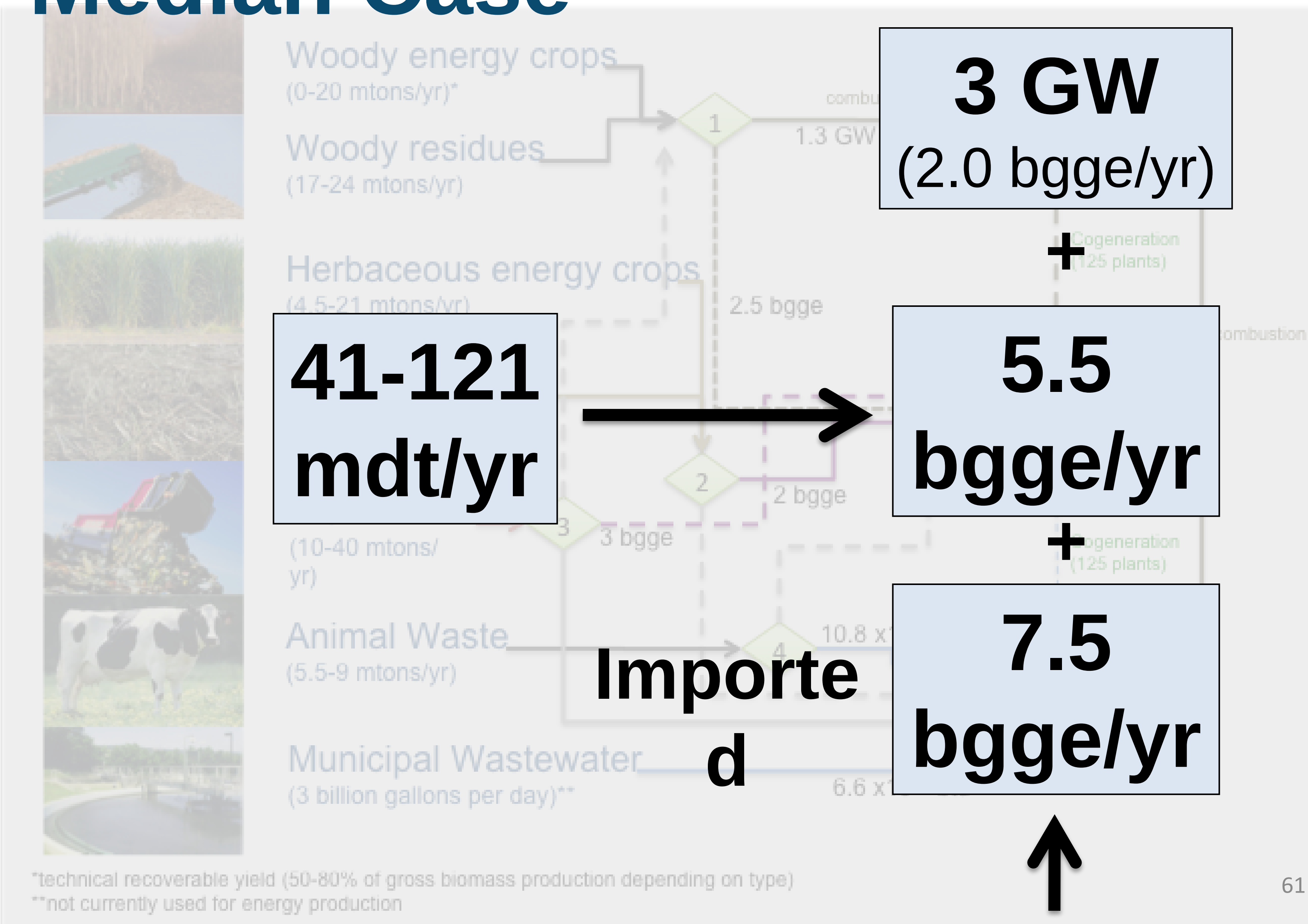
Median Case


Woody energy crops
(0-20 mtons/yr)*
Woody residues
(17-24 mtons/yr)
Herbaceous energy crops
(4.5-21 mtons/yr)
(10-40 mtons/
yr)
Animal Waste
(5.5-9 mtons/yr)
Municipal Wastewater
(3 billion gallons per day)**
1.3 GW
2.5 bgge
2 bgge
3 bgge
Cogeneration
(125 plants)
3 GW
(2.0 bgge/yr)
+
41-121
mdt/yr
5.5
bgge/yr
+
7.5
bgge/yr
Imported
*technical recoverable yield (50-80% of gross biomass production depending on type)
**not currently used for energy production

We might expect biomass to provide about ½ the fuel demand (27 bgge/yr) where CCS is not possible

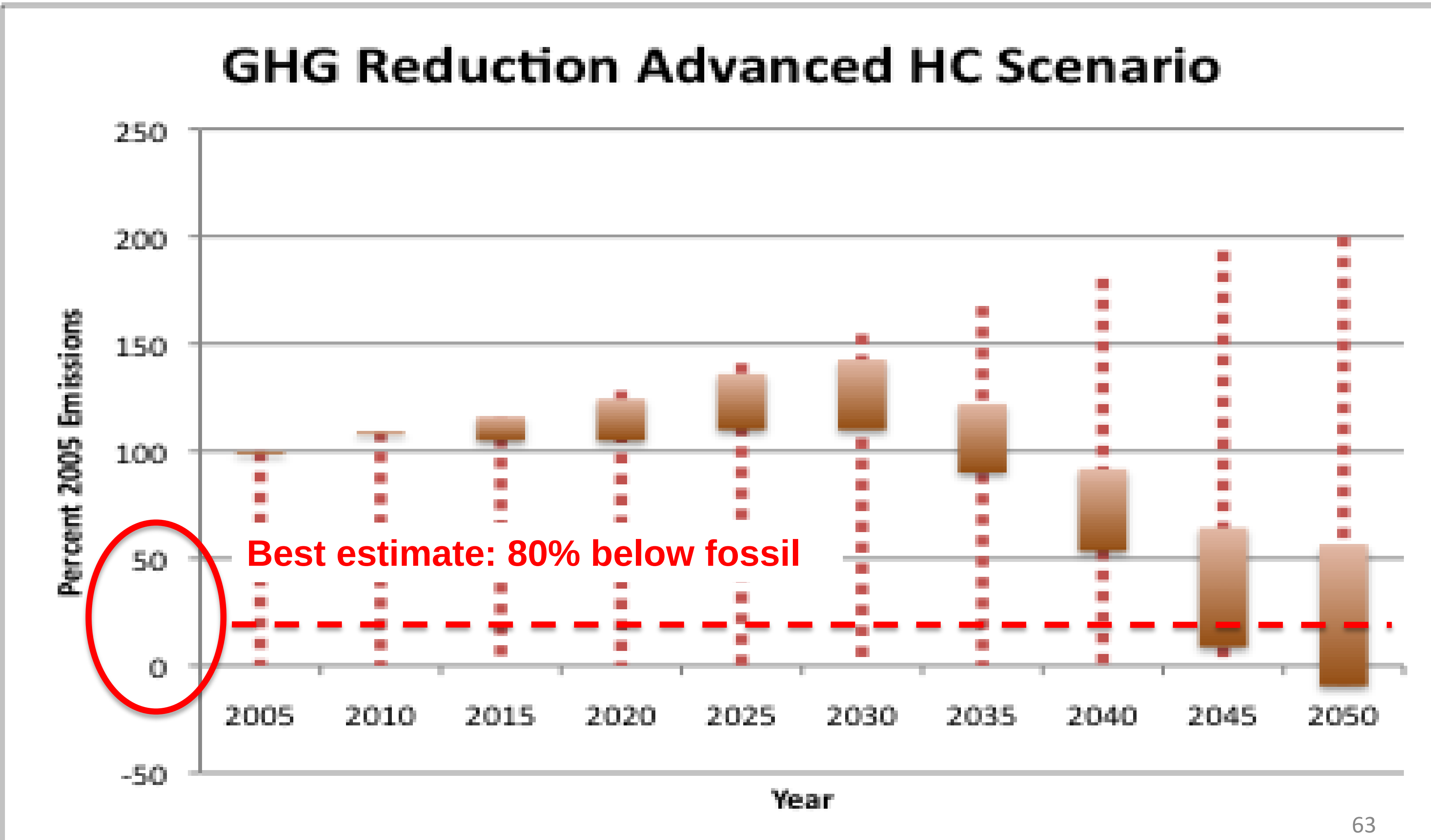
including 2 bgge/yr for about half the required load balancing)

13 bgge/yr

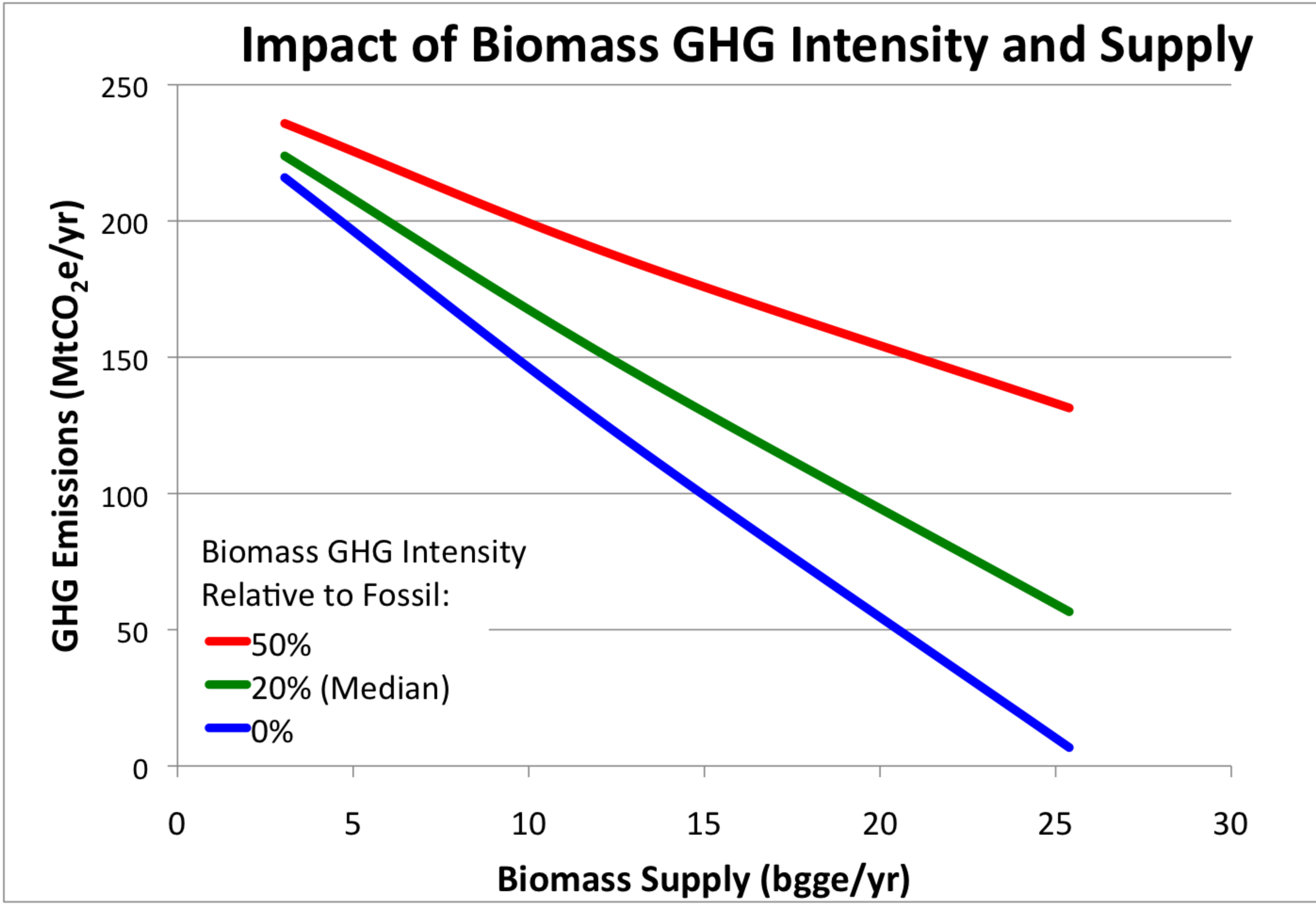
+

7.5 bgge/yr

Advanced drop-in biofuels could have a low GHG footprint by 2050



Biomass GHG Intensity and Supply



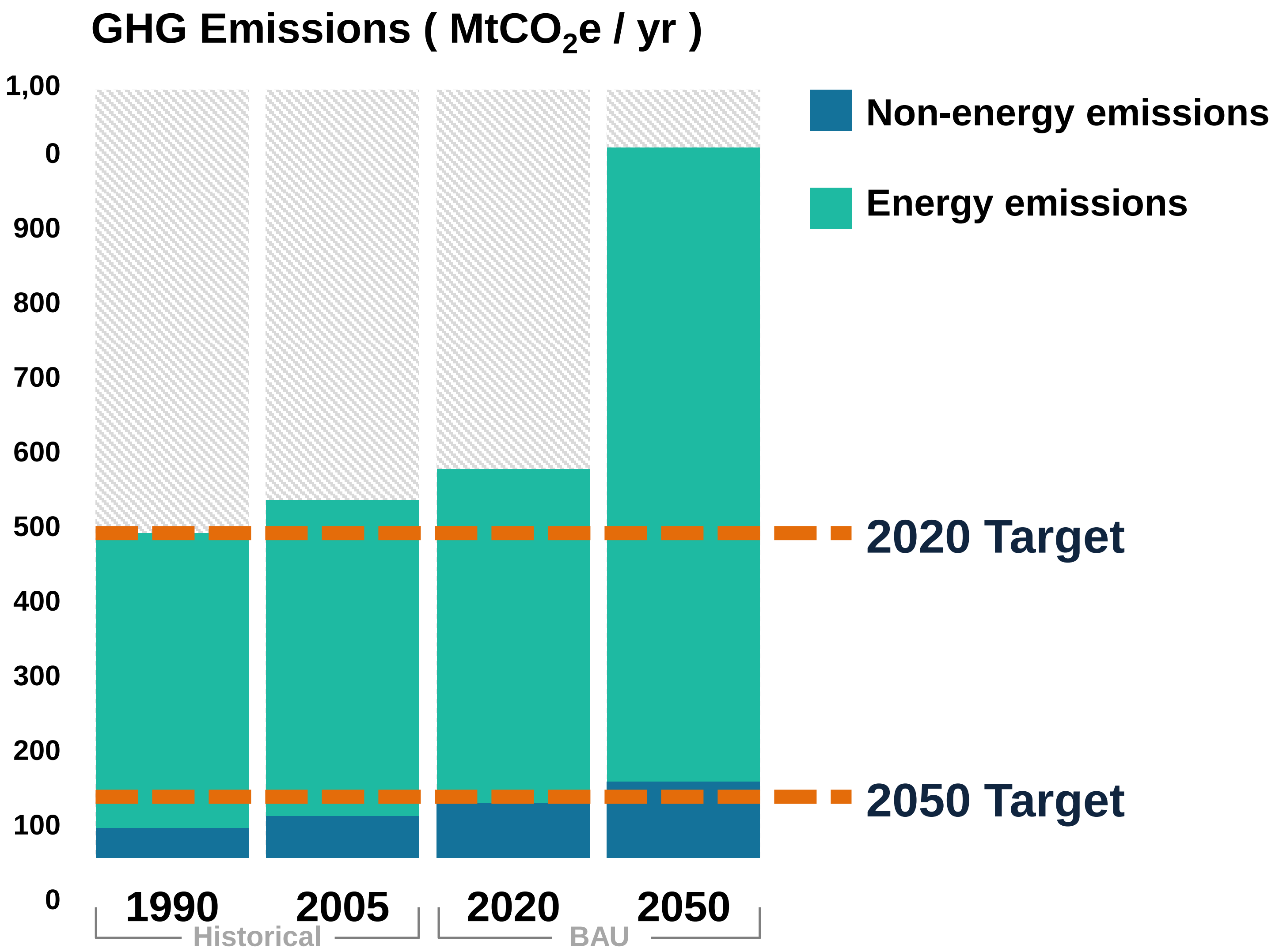
THIRD BIG QUESTION:

HOW CAN WE FILL THE FUEL GAP?

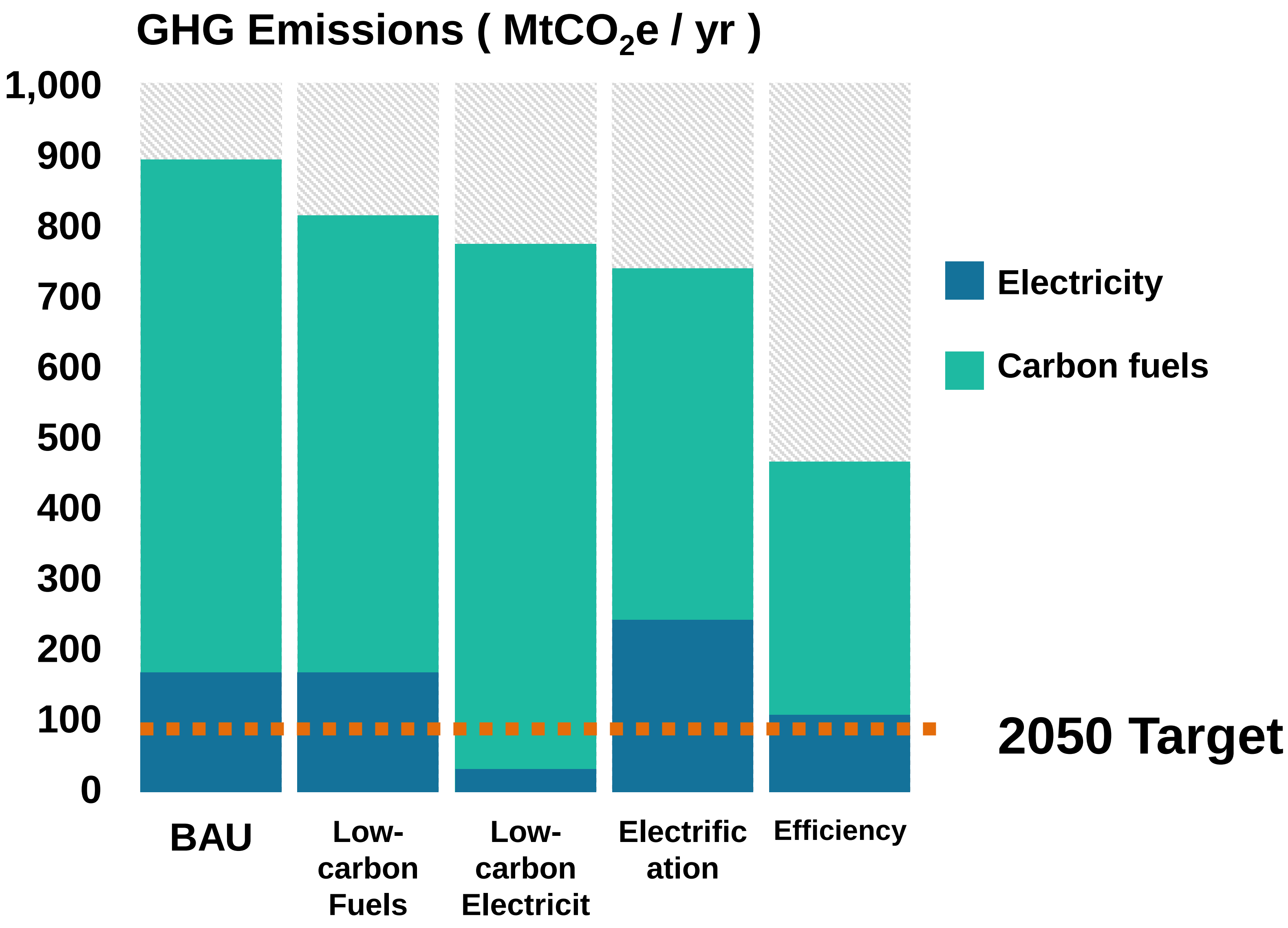
What can we count on from biofuel without adverse impacts? What has to happen to get this much?

How do we get the rest of the decarbonized fuel we need?

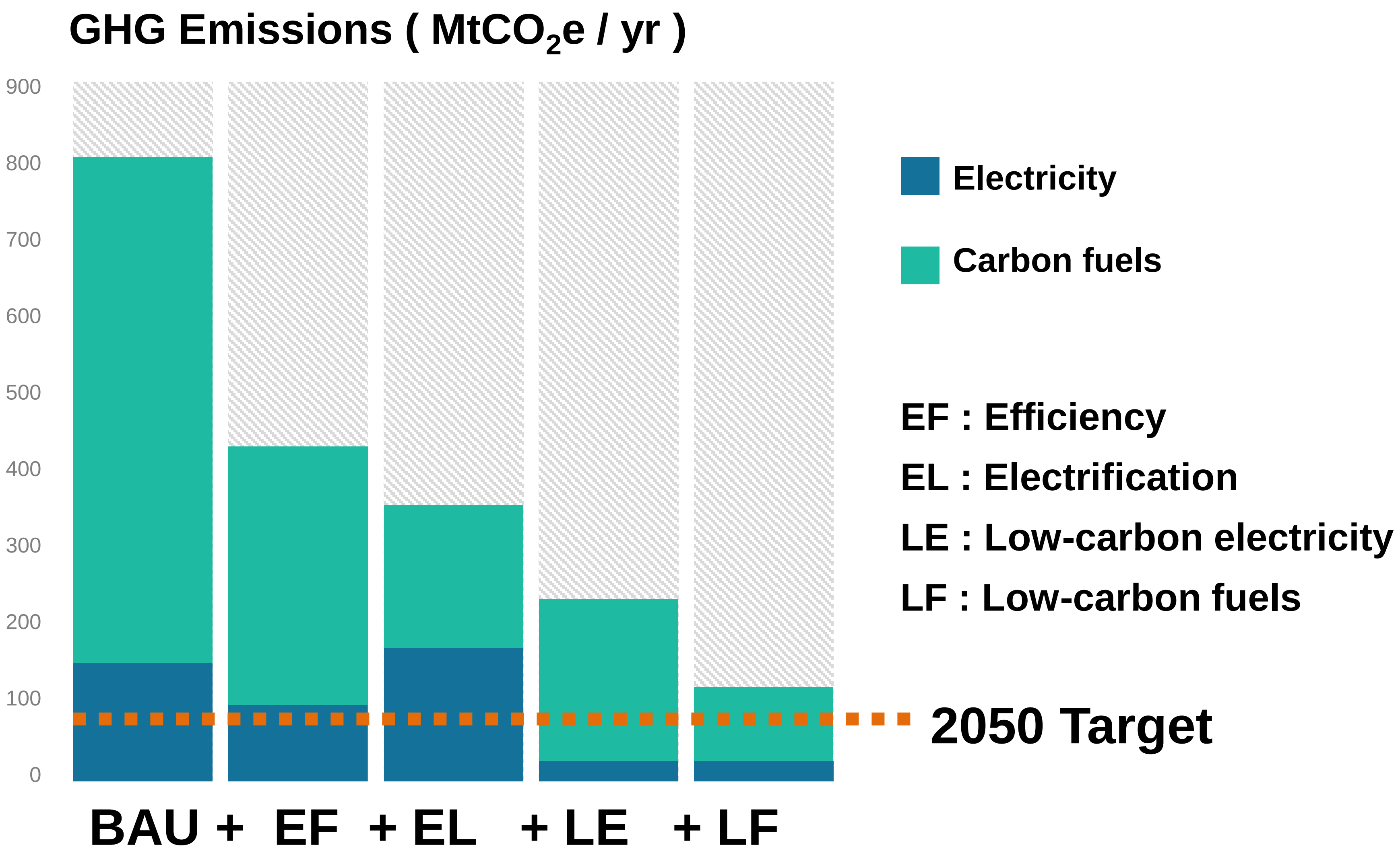
HISTORICAL AND BAU EMISSIONS



GHG REDUCTIONS WITH A SINGLE STRATEGY

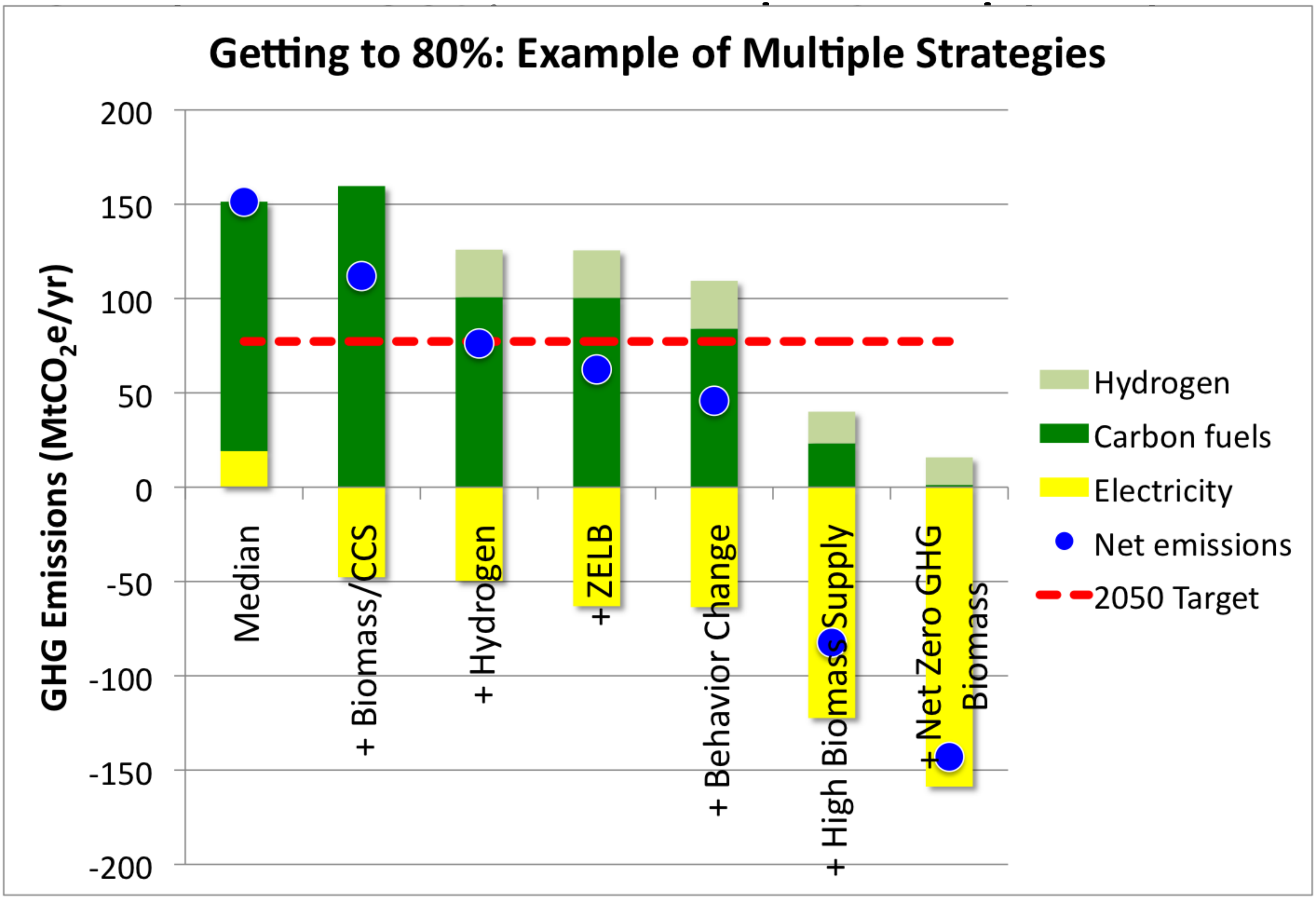


GETTING TO 60% (BELOW 1990): ALL 4 ACTIONS

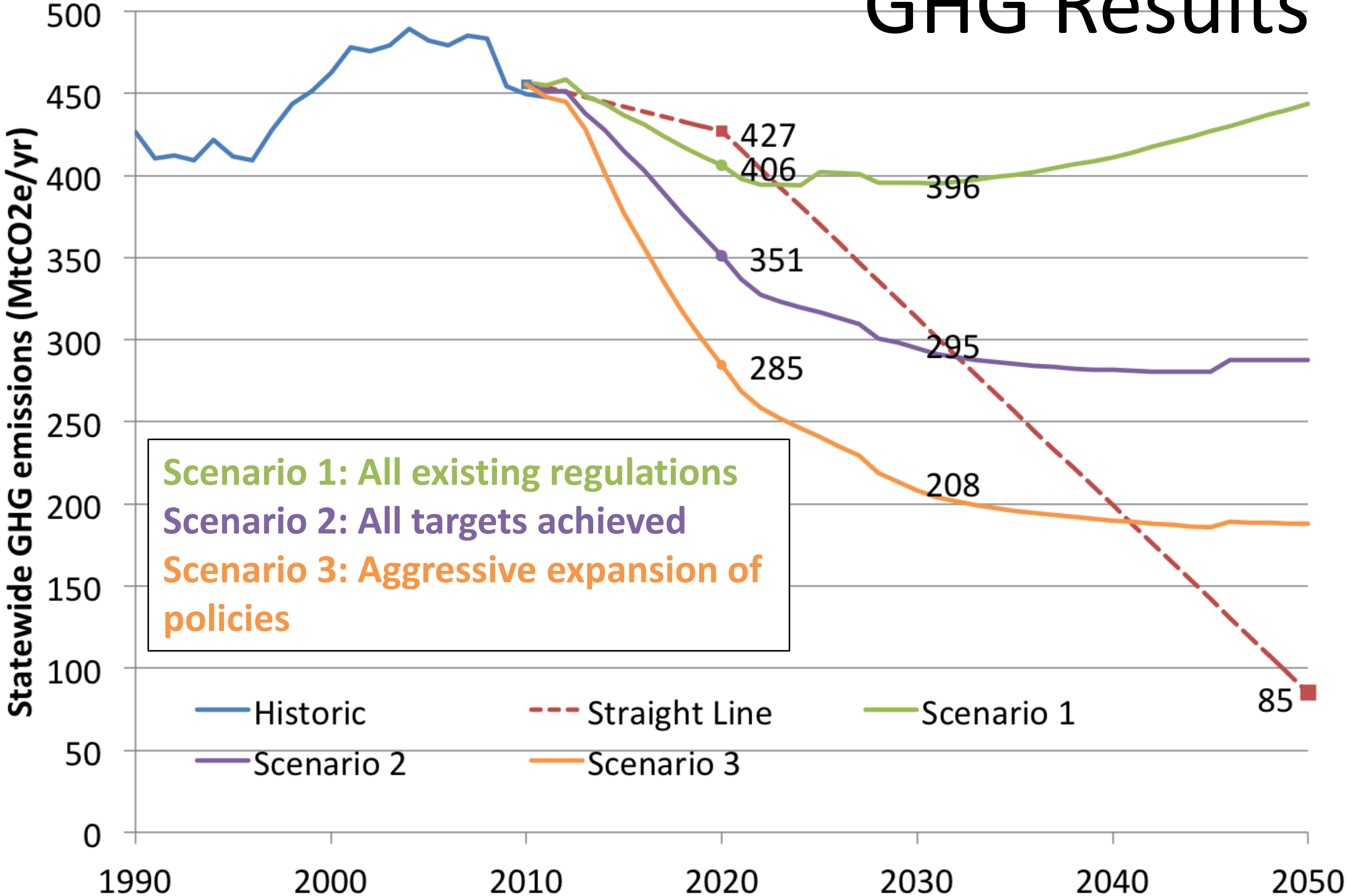


Strategies for Getting to 80%

		GHG Impact
1.	100% effective CCS	Small
2.	Eliminate fossil/CCS (use nuclear instead)	
3.	100% ZELB for load balancing	Moderate
4.	Net-zero GHG biomass	
5.	Behavior Change (10% reduction in demand)	
6.	Biomass/CCS (20% of electricity, offsets fuels)	
7.	Hydrogen (30% replacement of HC fuels)	
8.	Biomass/Coal/CCS (make fuels + electricity)	Large
9.	Double biomass supply	
10.	Fuel from sunlight (need net-zero carbon source)	Transformative
11.	Fusion electricity	
12.	Others?	


Getting to 80%: Example of Multiple Strategies
GHG Emissions (MtCO2e/yr)
200
150
100
50
0
-50
-100
-150
-200
Median
+ Biomass/CCS
+ Hydrogen
+ ZELB
+ Behavior Change
+ High Biomass Supply
+ Net Zero GHG Biomass
Hydrogen
Carbon fuels
Electricity
Net emissions
2050 Target

GHG Results



Statewide GHG emissions (MtCO2e/yr)
500
450
400
350
300
250
200
150
100
50
0
1990
2000
2010
2020
2030
2040
2050
427
406
396
351
295
285
208
85
Scenario 1: All existing regulations
Scenario 2: All targets achieved
Scenario 3: Aggressive expansion of policies
Historic
Straight Line
Scenario 1
Scenario 2
Scenario 3

Take-aways

- 60% emission cuts will take unprecedented rates of change over in all sectors to deploy what we already know how to do.

- 80% means we need serious innovation

SOME KEY PRINCIPLES FOR REGIONAL ENERGY PLANNING

HAVE A GOAL

PLANNING TO REDUCE IS NOT THE SAME
AS HAVING A STRATEGY TO GET TO A GOAL

ACCOUNTING MATTERS

COUNT EVERYTHING
COUNT ONCE

MIND YOUR BOUNDARIES

DON'T LEAK
DON'T TAKE MORE THAN YOUR SHARE

GET THE QUESTIONS RIGHT

NEED THE BIG PICTURE

References

- CCST California's energy future reports can be found at www.ccst.us

- Carbon Clean up: Acting to solve our climate problem will take big investment and a strategic approach, Technology Review March 2012, http://www.technologyreview.com/view/511401/carbon-cleanup/
-
- J. Long and J. Greenblatt, Innovation will be required for radical reductions in greenhouse gas emissions, but what innovation?, Spring, 2012, Issues in Science and Technology, NAP. http://www.issues.org/28.3/long.html
-
- Piecemeal cuts won't add up to radical reductions, To meet ambitious emissions targets will require systems thinking and massive breakthroughs in technology and fuels, October 26, 2011: Nature 478, 429 (2011), http://www.nature.com/news/2011/111026/full/478429a.html
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- California's Energy Future, the view to 2050, Summary Report, May 2011, California Council on Science and Technology, http://www.ccst.us/publications/2011/2011energy.pdf

- A Blind Man's Guide to Energy Policy, Fall 2008, Issues in Science and Technology,
- http://www.issues.org/24.2/long.html

REDUCING GHG EMMISSIONS THROUGH ENERGY AND INNOVATION

EMILIO CAMACHO, ESQ.
ADVISOR
COMMISSIONER DAVID HOCHSCHILD
CALIFORNIA ENERGY COMMISSION

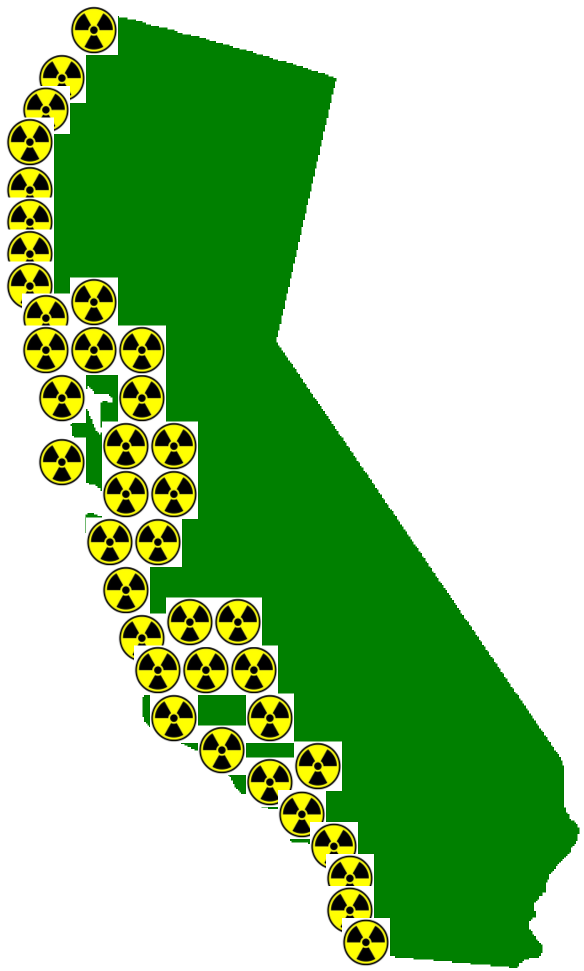
The California Energy Commission

1972: Rand Corporation report: CA energy demand growing 8% per year, predicts 40 new nuclear power plants may be needed

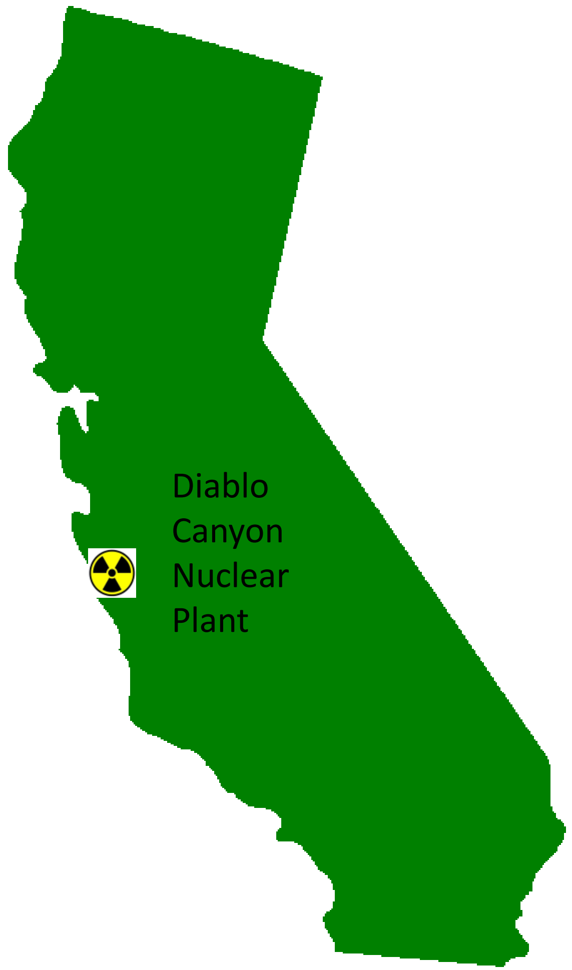
1974: Jerry Brown elected Governor. California Energy Commission created to help CA lead on energy efficiency and renewables

1975: CA initiates first efficiency standards for buildings and appliances

If California Had 40 Nuclear Plants…



California Today



The California Energy Commission

- The state's primary energy policy and planning agency with six basic responsibilities:
    - Forecasting future energy needs;
    - Promoting energy efficiency and conservation by setting the state's appliance and building efficiency standards;
    - Supporting public interest energy research that advances energy science and technology through research, development and demonstration programs;
    - Developing renewable energy resources and alternative renewable energy technologies for buildings, industry and transportation;
    - Licensing thermal power plants 50 megawatts or larger;
    - Planning for and directing state response to energy emergencies.

The California Energy Commission

- 5 Commissioners Appointed by the Governor.
- The Commissioners represent:
  - Engineering / physical science;
  - Economics;
  - Law;
  - Member of the public; and
  - Environmental protection.

We care about our home

Global perspective: we are all part of the problem

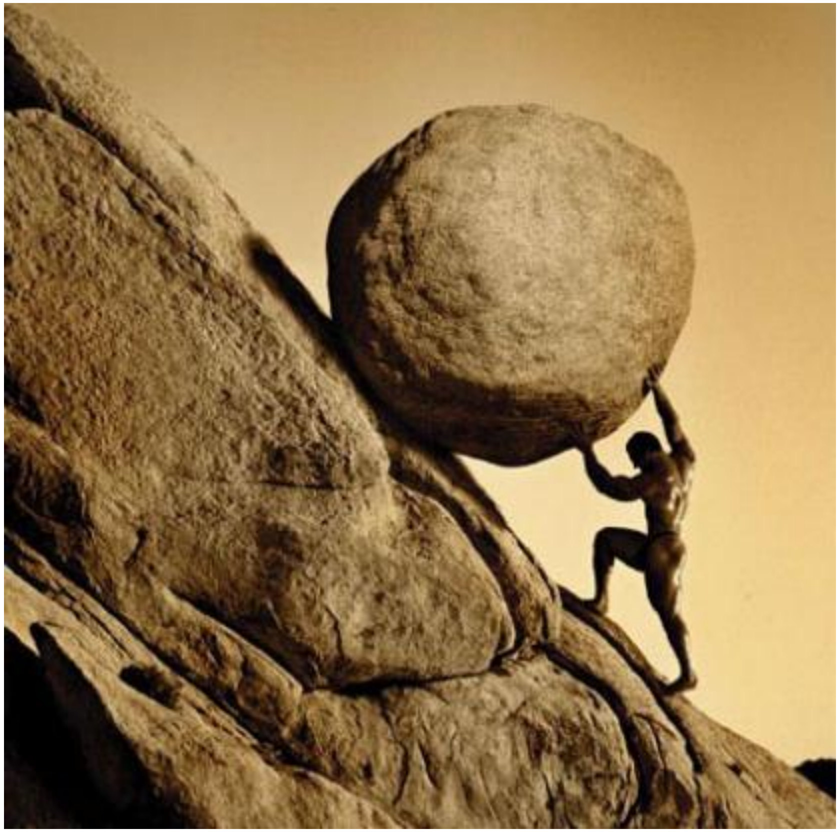
Global perspective: we are all part of the solution

The Challenge is Big…

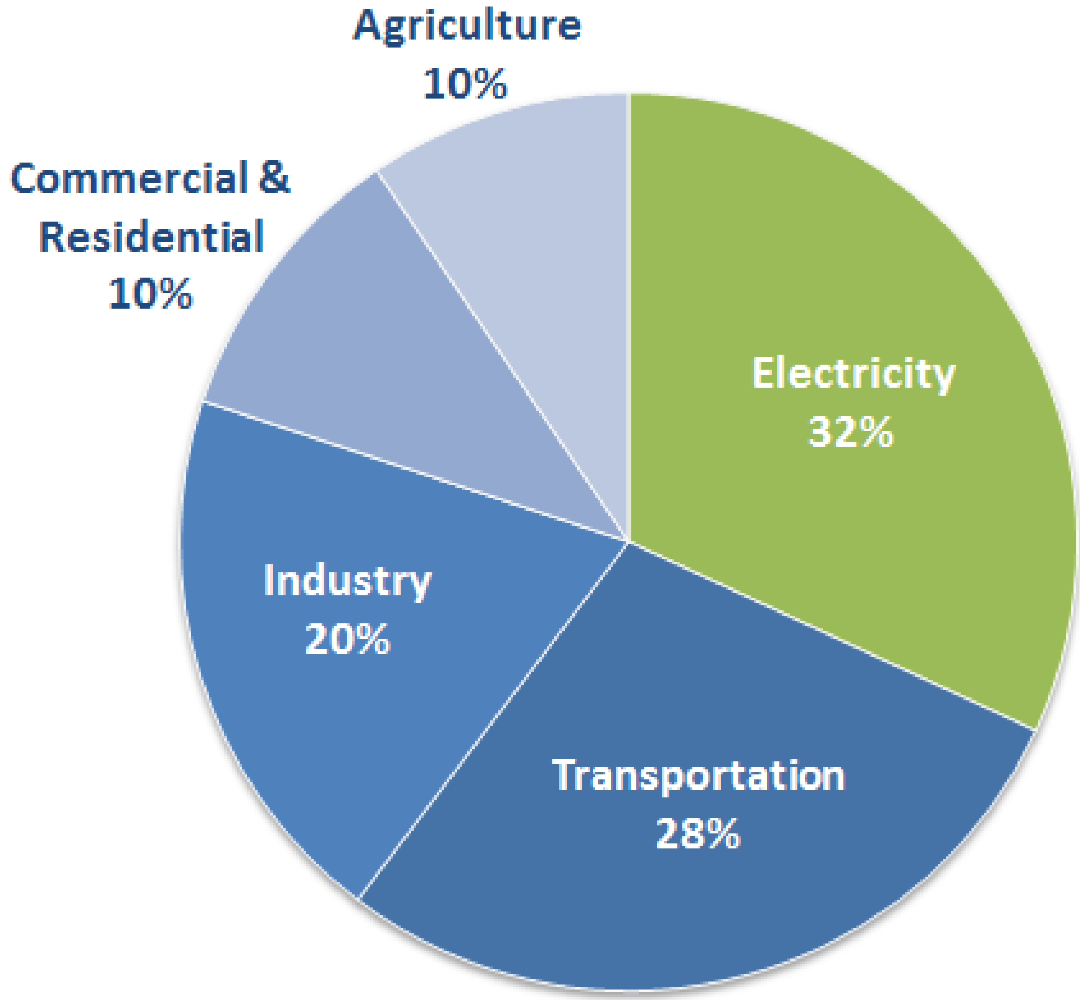
The Goal:
Reduction of GHGs to 1990 levels by 2020

&

Reduction of GHGs to 80% below 1990 levels by 2050

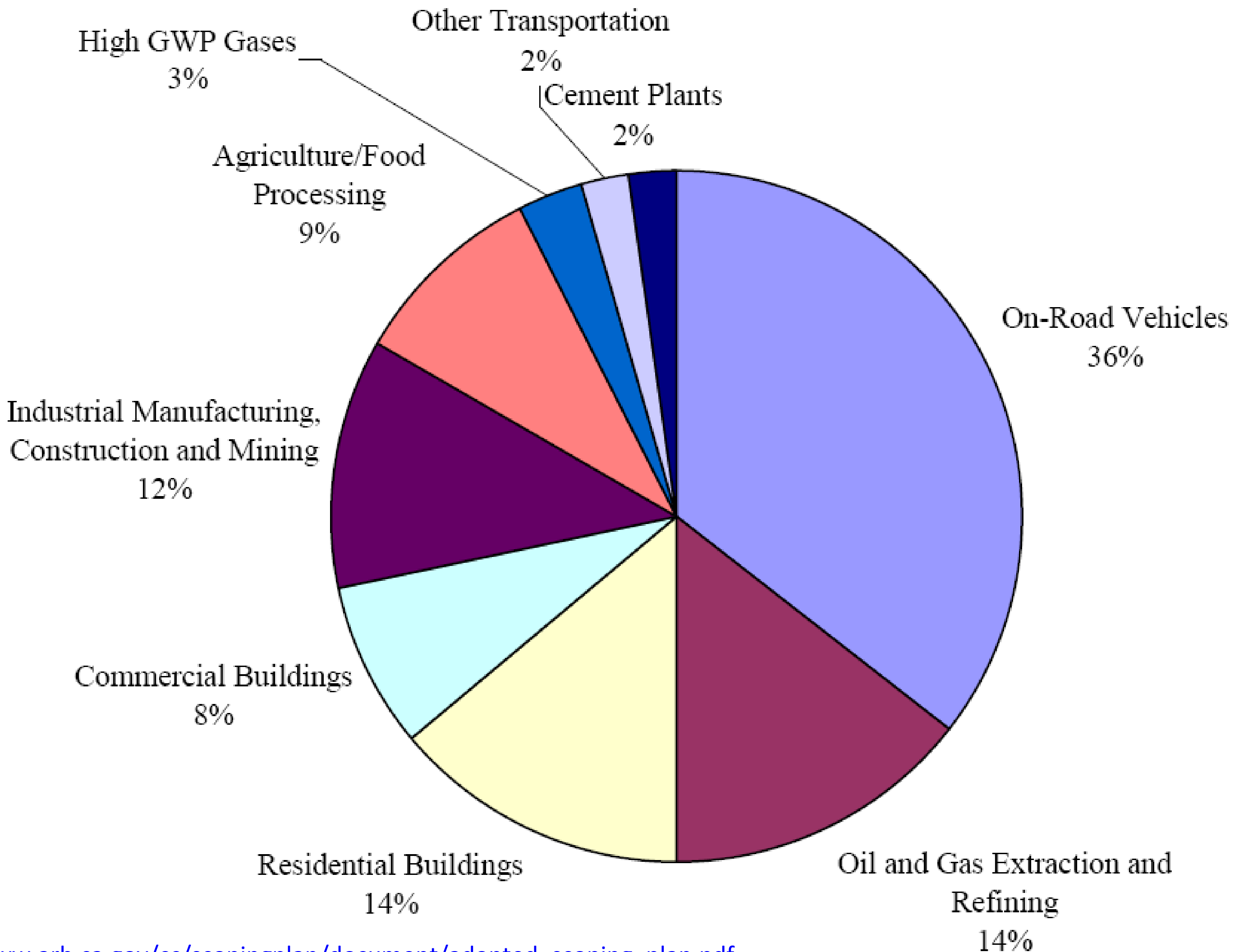


Total U.S. Greenhouse Gas Emissions by Economic Sector in 2012



Source: US EPA

California's Greenhouse Gas Emissions



http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf

The Nine County Jurisdiction of the Air District

Almanac Emission Projection Data (published in 2013)

2012 Estimated Annual Average Emissions

SAN FRANCISCO BAY AREA AIR BASIN

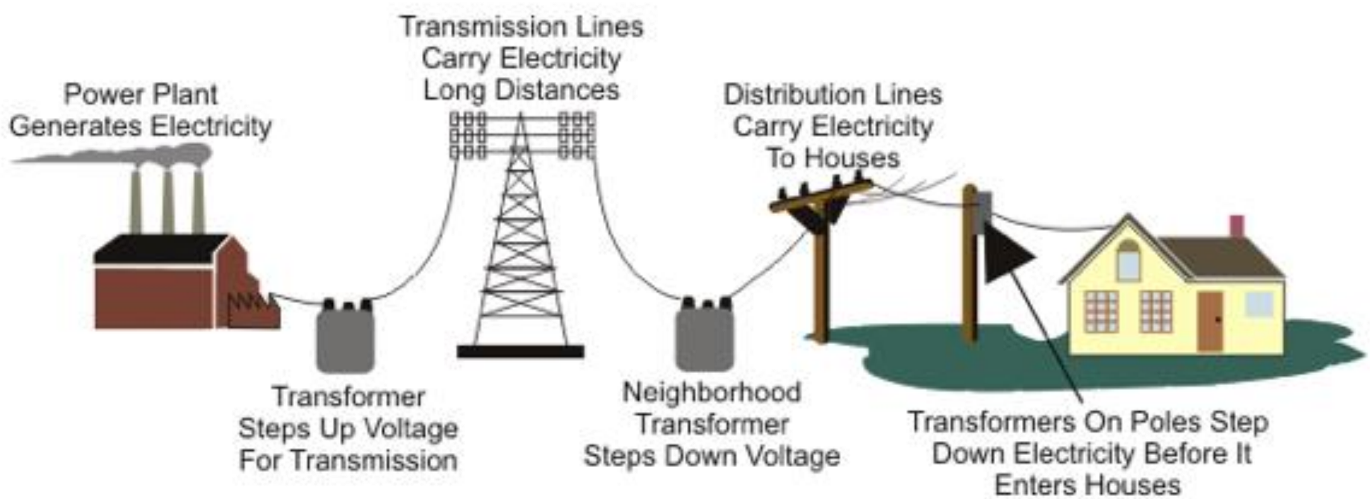
All emissions are represented in Tons per Day and reflect the most current data provided to ARB.

See detailed information.

Start a new query.

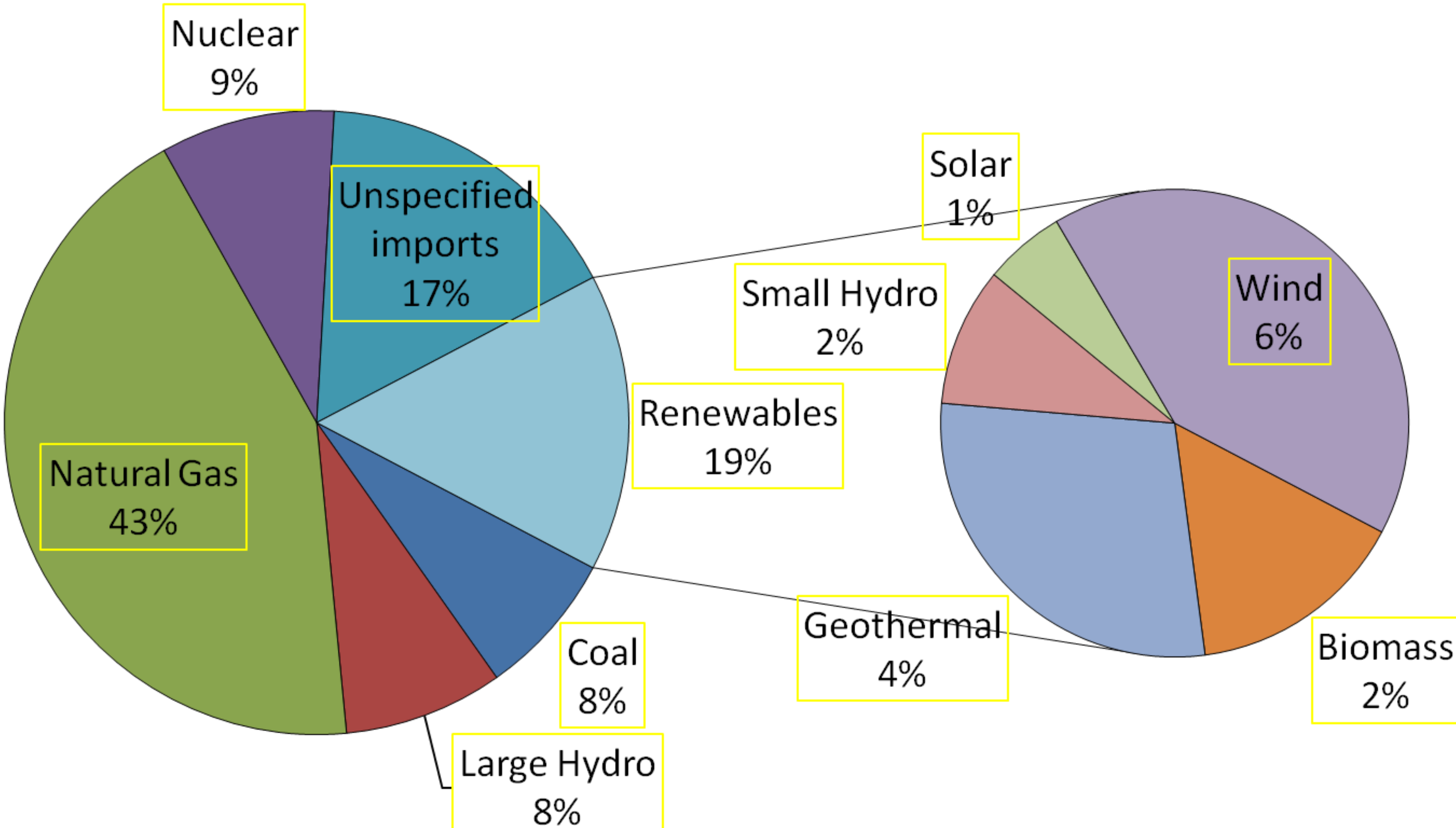
STATIONARY SOURCES	TOG	ROG	CO	NOX	SOX	PM	PM10	PM2.5
FUEL COMBUSTION	18.8	4.3	27.7	34.0	9.4	1.4	1.4	1.3
WASTE DISPOSAL	192.7	3.1	1.9	1.1	0.5	-	-	-
CLEANING AND SURFACE COATINGS	38.2	26.8	0.0	0.0	0.0	-	-	-
PETROLEUM PRODUCTION AND MARKETING	69.7	14.9	0.9	0.6	2.1	-	-	-
INDUSTRIAL PROCESSES	12.3	10.0	1.9	3.9	7.9	8.4	4.5	1.4
* TOTAL STATIONARY SOURCES	331.6	59.2	32.4	39.7	19.8	9.7	5.8	2.8
AREAWIDE SOURCES	TOG	ROG	CO	NOX	SOX	PM	PM10	PM2.5
SOLVENT EVAPORATION	68.4	57.9	-	-	-	-	-	-
MISCELLANEOUS PROCESSES	64.0	14.9	127.4	15.8	0.5	173.9	95.2	31.5
* TOTAL AREAWIDE SOURCES	132.3	72.8	127.4	15.8	0.5	173.9	95.2	31.5
MOBILE SOURCES	TOG	ROG	CO	NOX	SOX	PM	PM10	PM2.5
ON-ROAD MOTOR VEHICLES	90.6	83.4	720.9	166.0	0.9	13.4	13.2	6.9
OTHER MOBILE SOURCES	54.9	49.6	391.3	96.1	1.7	4.8	4.7	4.4
* TOTAL MOBILE SOURCES	145.5	133.0	1112.2	262.1	2.7	18.2	17.9	11.3
GRAND TOTAL FOR SAN FRANCISCO BAY AREA AIR BASIN	609.5	265.0	1272.0	317.6	23.0	201.9	118.9	45.6

Electricity



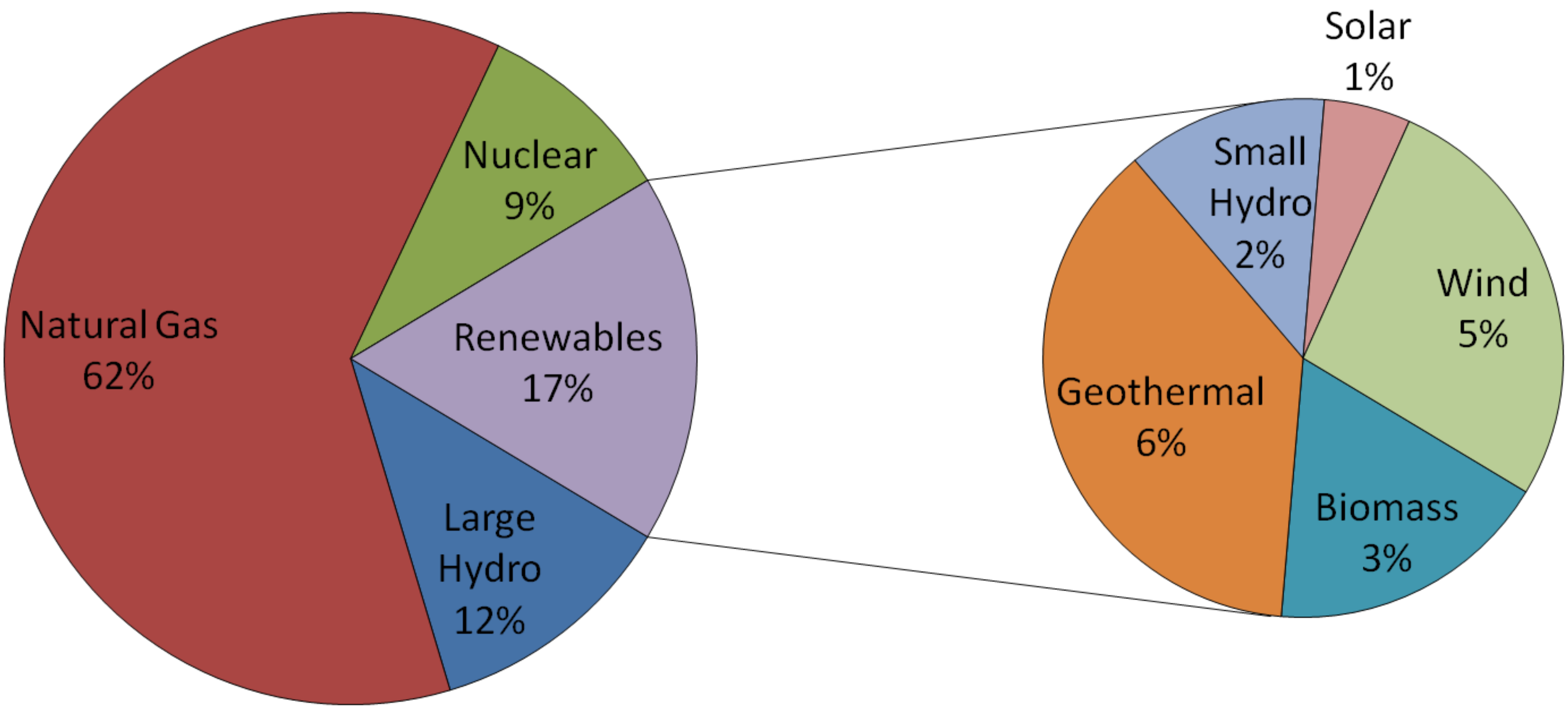
Different to Generate Electricity

California Total Electricity Sources in 2012, includes Electricity Imports (34% of total)



Sources: California Energy Commission, QFER and SB 1305 Reporting Requirements. In-state generation is reported generation from units 1 MW and larger.

California In-State Electricity Generation in 2012



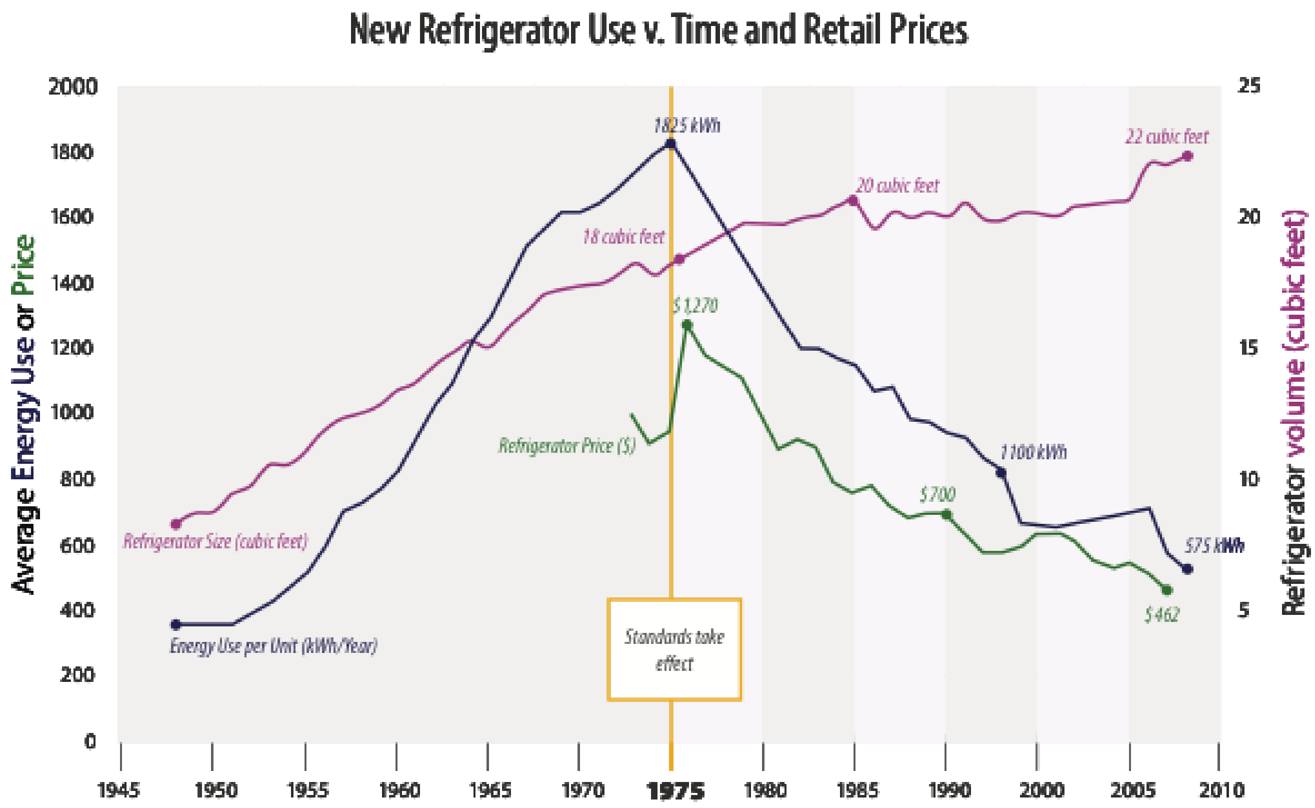
Sources: California Energy Commission, QFER and SB 1305 Reporting Requirements. In-state generation is reported generation from units 1 MW and larger.

Reducing GHG Emissions in the Energy Sector

- Demand Response
- Energy efficiency
- Electrification
- Renewable energy
- Energy storage
- R&D
- Biofules
- Integration of resources and new technologies
- Grid alternatives

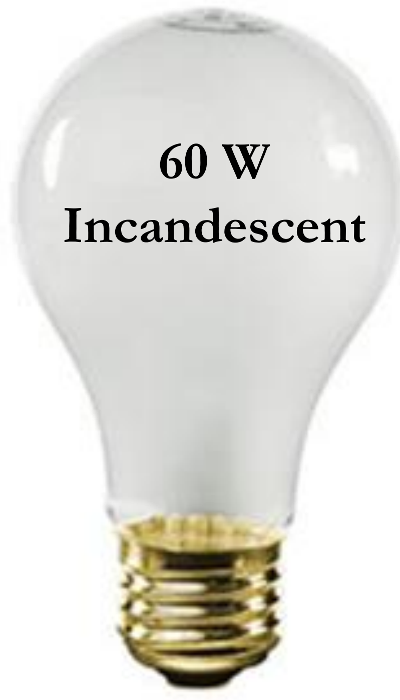
Demand Response

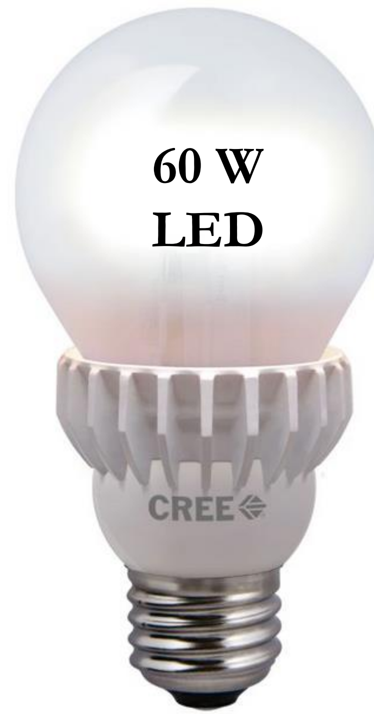
Energy Efficiency



Energy Efficiency

Tale of Two Lightbulbs…





Lumins:	800	800
Color Rendition:	100	97
Dimmable:	Yes	Yes
Annual Electricity Cost:	$10	$3
Lifespan:	1 Year	25 years

Efficiency: New Construction

CA Leads in New Solar Home Construction

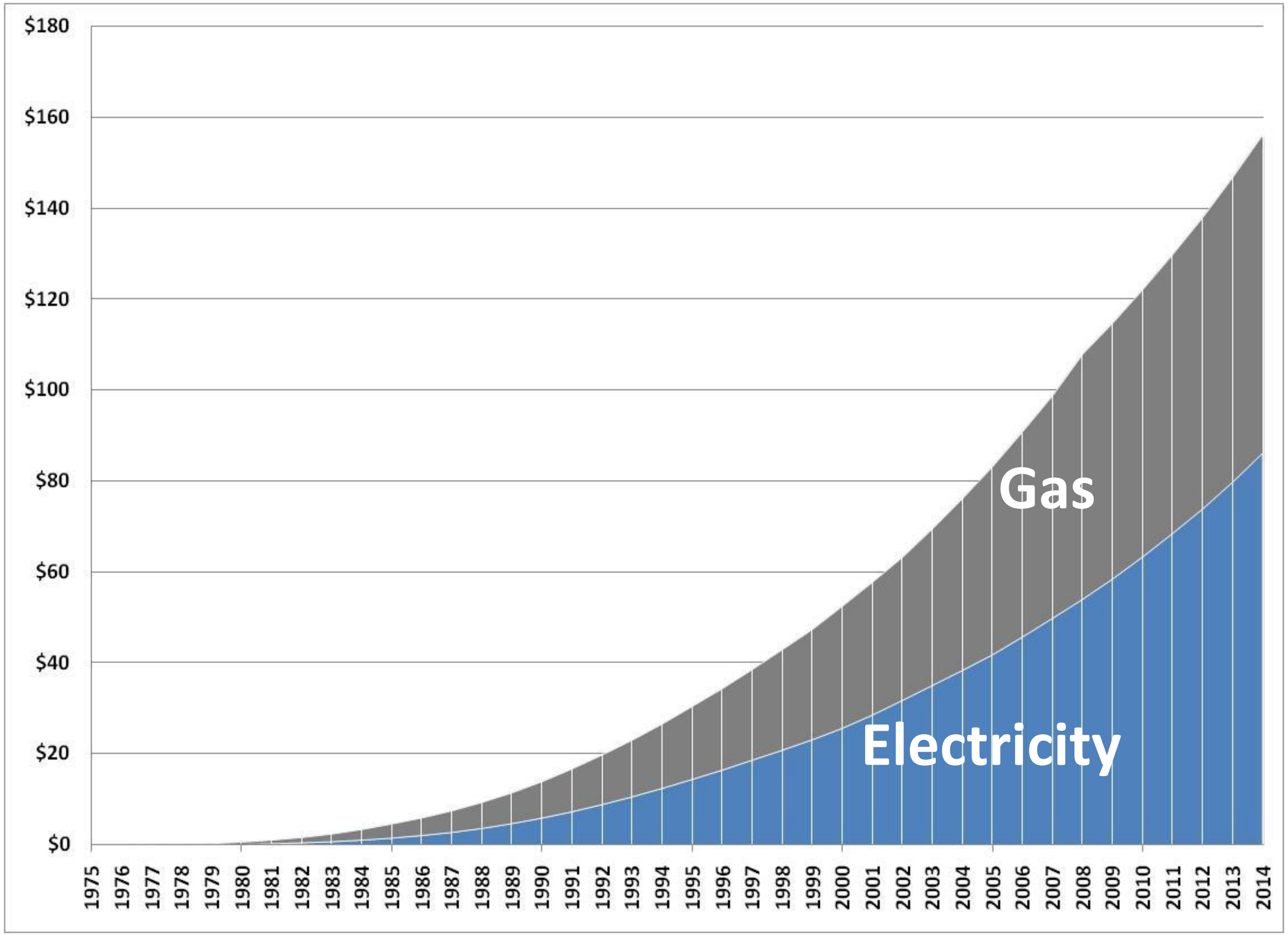
Rocklin Zero Energy Community

Over 8000 New Solar Homes Installed in CA. 12,000 more under way.

Efficiency: Existing Buildings

Over $140 Billion in Cumulative Energy Savings since 1975 From California Building & Appliance Standards

$Billions



- Source: California Energy Commission estimate based on gross savings to California customers using average residential and commercial rates for each utility.

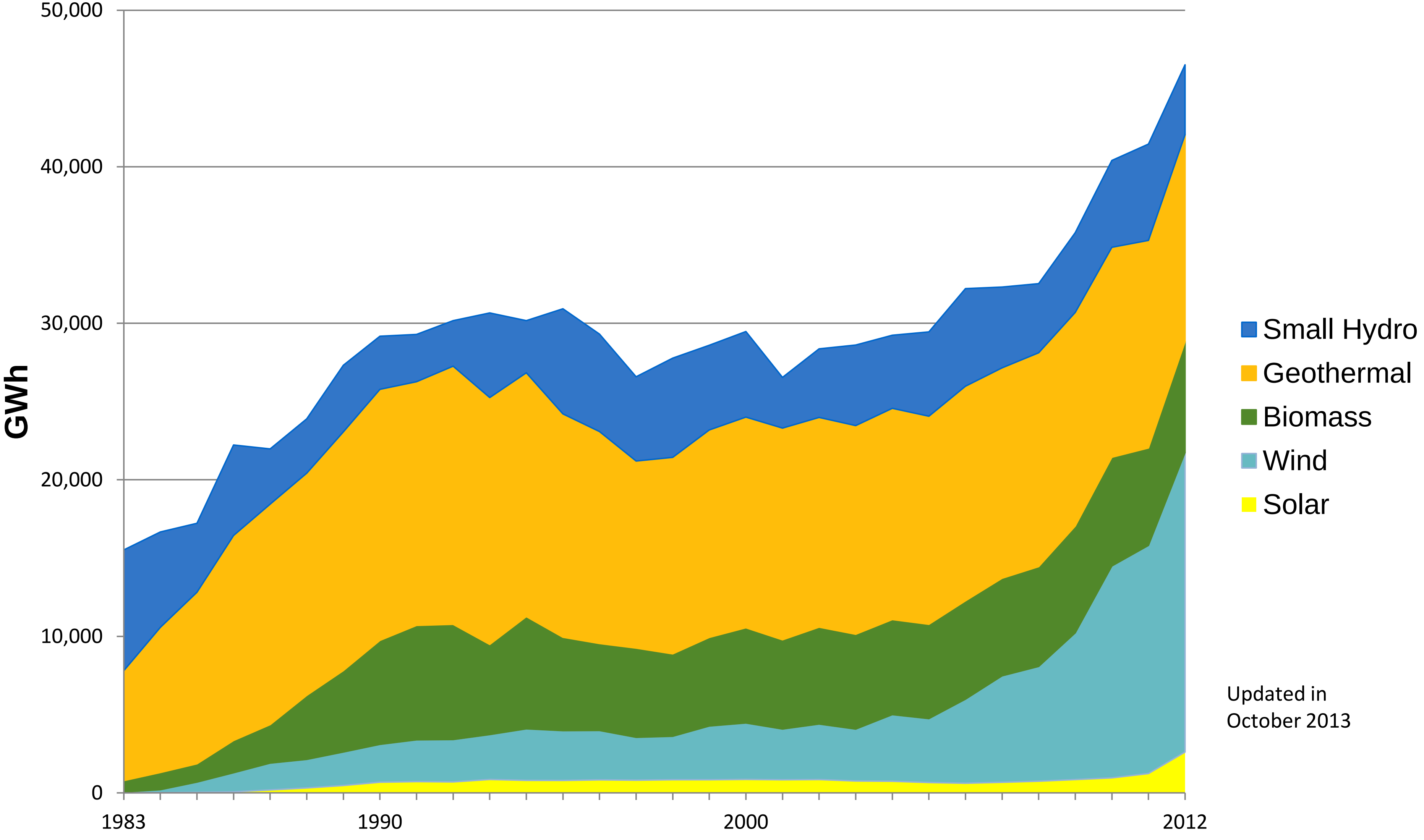
Electrification

Largest Manufacturing Operation in CA is now Electric Vehicles

Tesla Factory
Fremont, CA

Over 3000 workers now working at the Tesla Factory

California Renewable Energy
Generation by Resource Type (In-State and Out-of-State)



The World's Largest Solar Thermal Power Plant (Tower)

Ivanpah Solar Thermal Project
393MW
San Bernardino County, CA

World's Largest Thin Film Solar PV Project…

Desert Sunlight Solar Project
550 MW
Riverside County, CA

World’s Largest Wind Project

Alta Wind Energy Center
1550MW
Kern County

The World's Largest Silicon PV Project

Solar Star Project

579 MW

Kern County, CA

World's Largest Geothermal Power Plant

Geysers Geothermal Power Plant
955MW
Napa County, CA

High speed rail is coming to California and it will be 100% powered by renewables…

CALIFORNIA
High-Speed Rail Authority

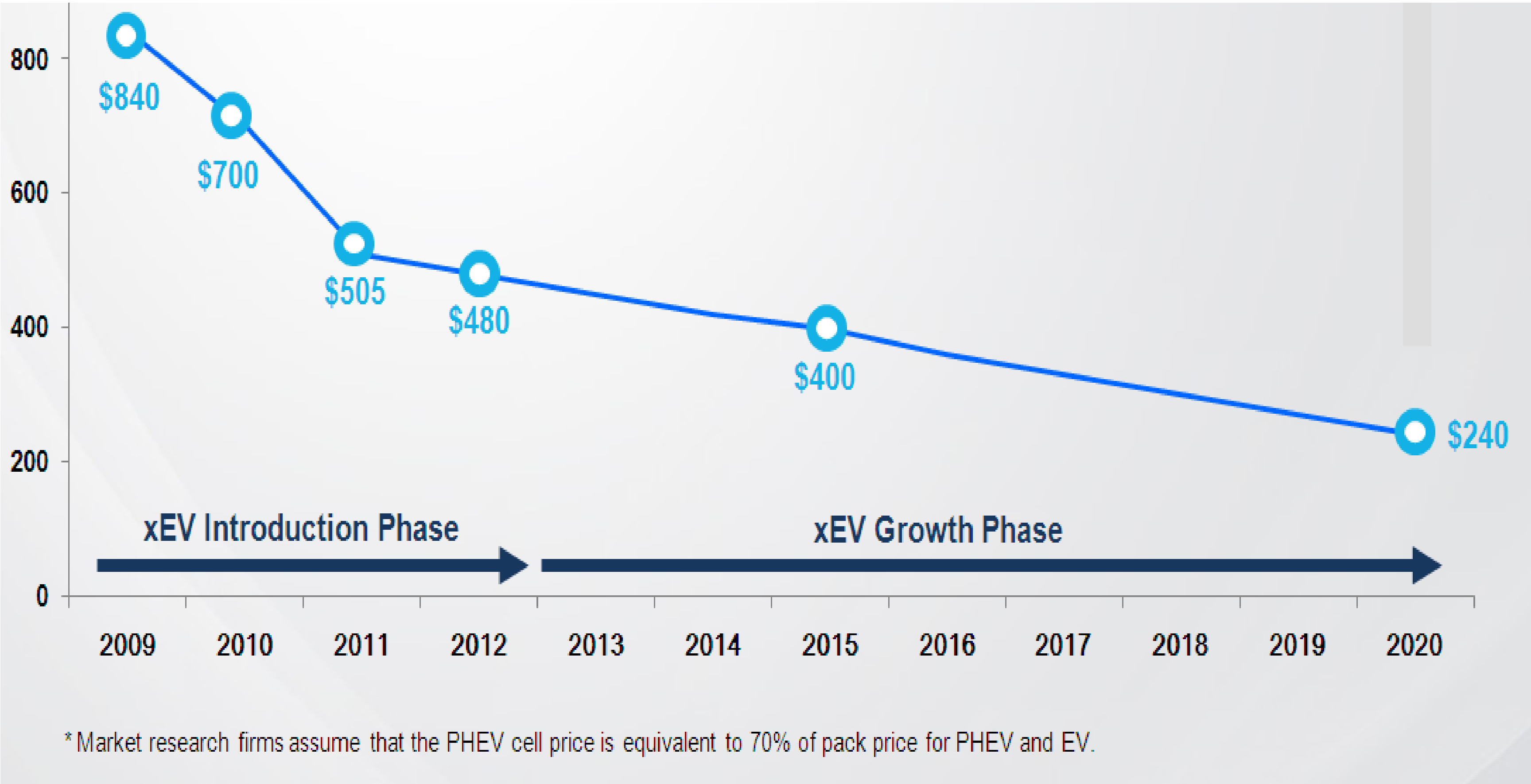
Renewable Energy Future

Others are exploring the possibility of meeting their electricity needs with 100 % renewable energy:

- Palo Alto
- Marin County
- San Francisco
- San Jose
- Santa Barbara
- Parts of Los Angeles
- Lancaster

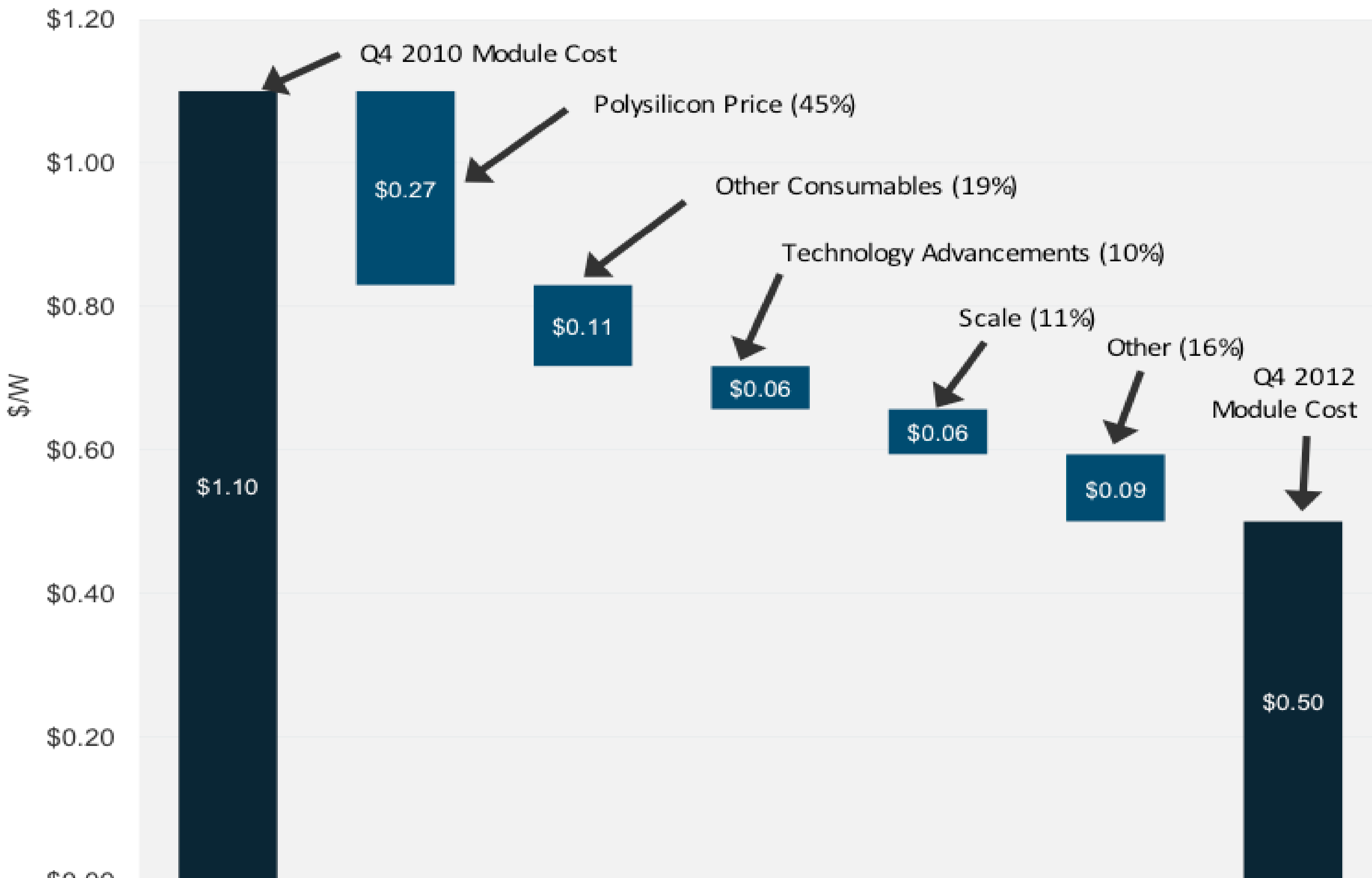
Energy Storage

Example: Lithium Ion Battery Cell Cost Forecast: 70% Reduction by 2020



Source: Roland Berger, Samsung

Research and Development Example: Source of PV Cost Declines

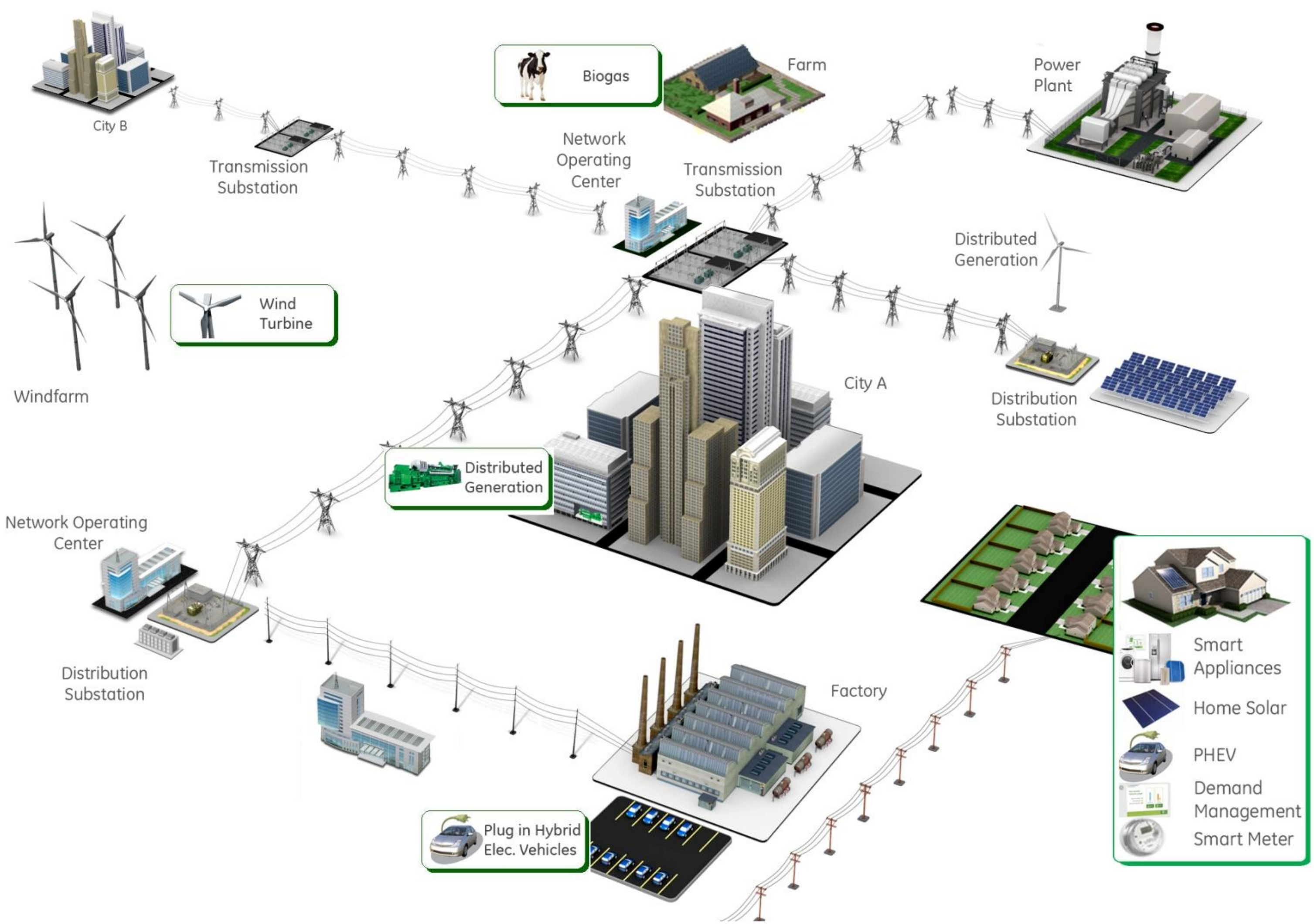


Source: GTM Research

Biofuels
A potential peaking plant solution?

- Landfill gas
- Agricultural waste
- Sustainable forestry

Integration



Grid Alternatives

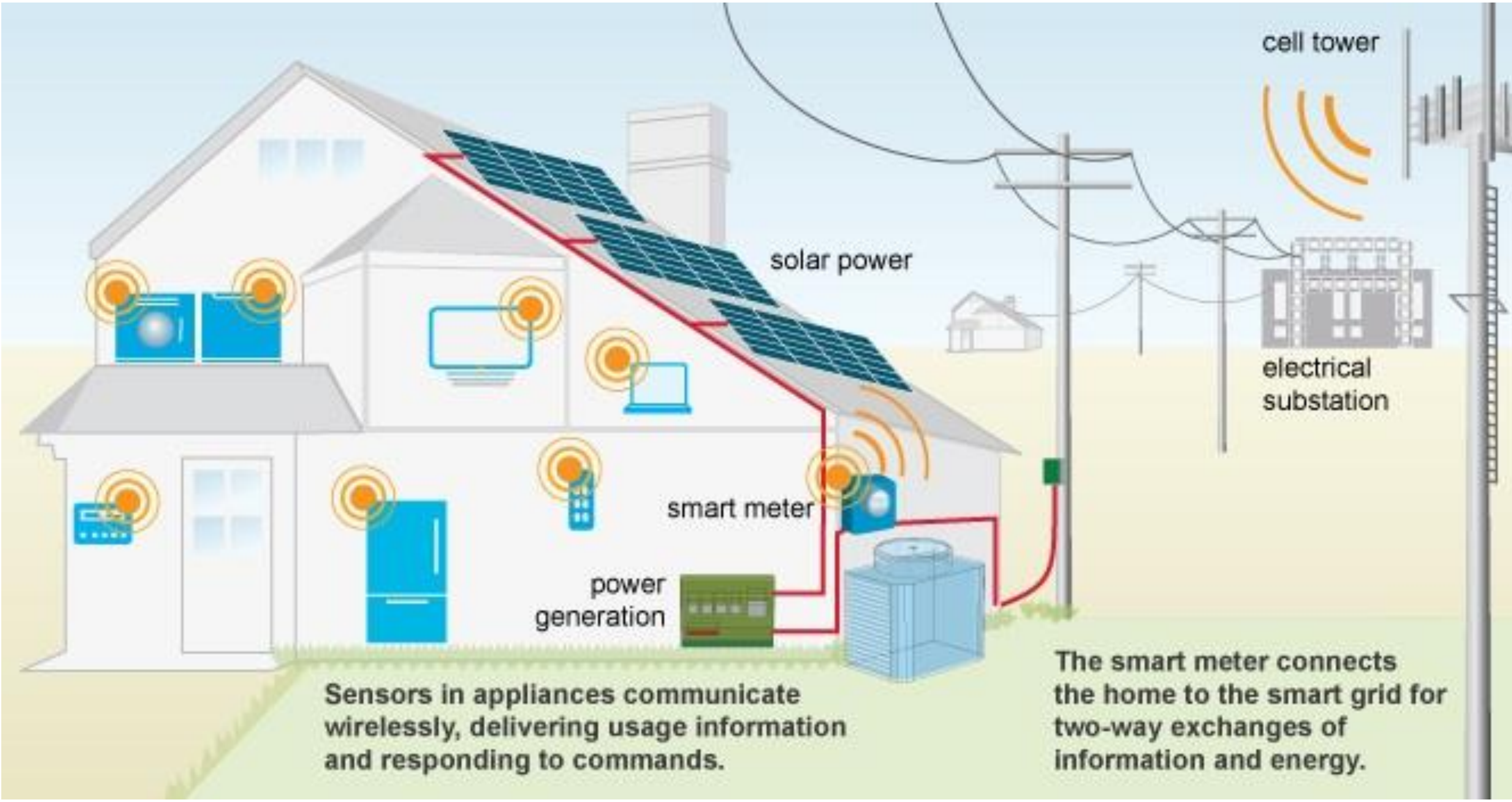
- Smart grid
- Micro grid

Smart Grid

A distribution system that allows information from a customer's meter to flow in two directions:

1. Inside the house to thermostats, appliances, and other devices.

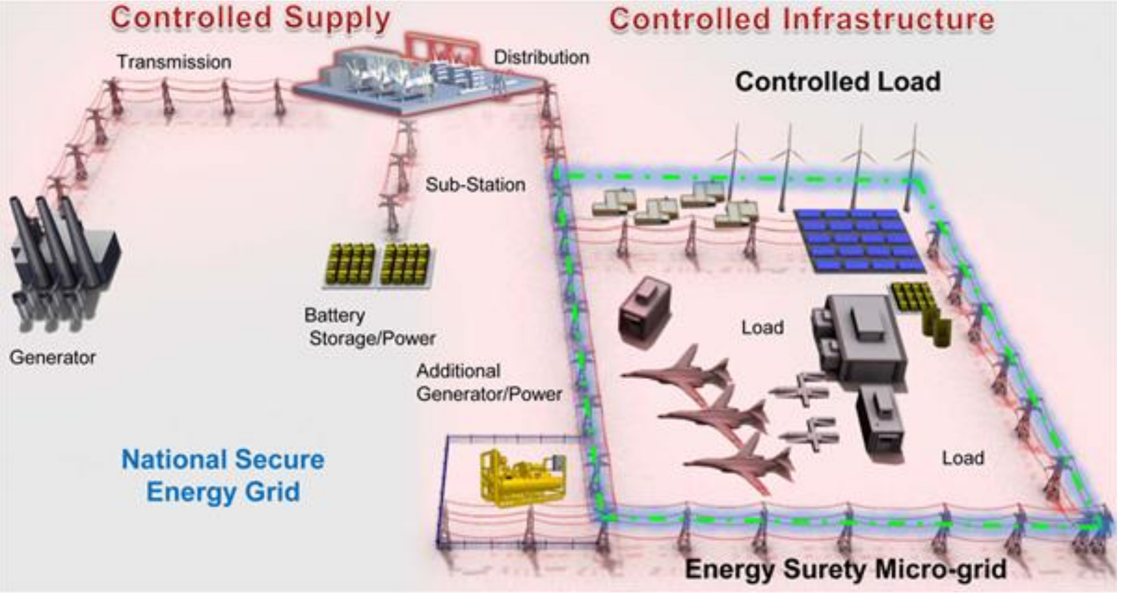
2. From the house back to the utility.


cell tower
solar power
electrical
substation
smart meter
power
generation
Sensors in appliances communicate
wirelessly, delivering usage information
and responding to commands.
The smart meter connects
the home to the smart grid for
two-way exchanges of
information and energy.

Microgrid

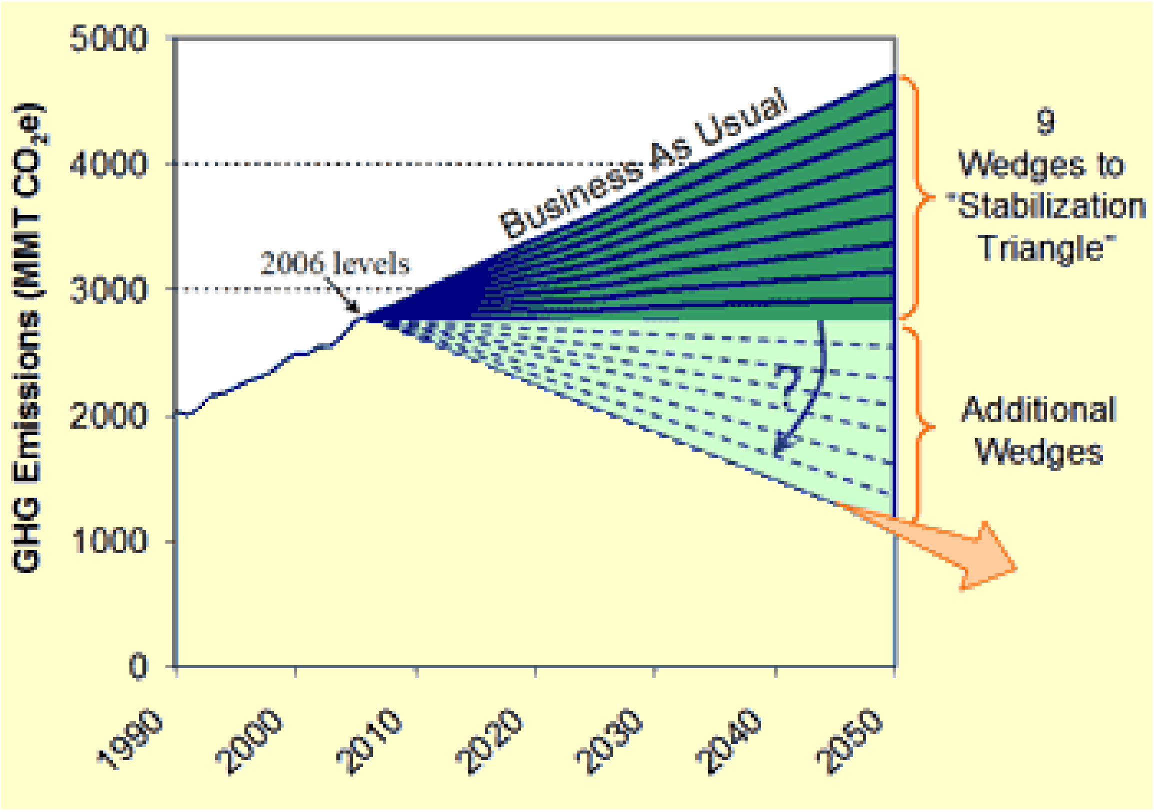
UCSD

Military



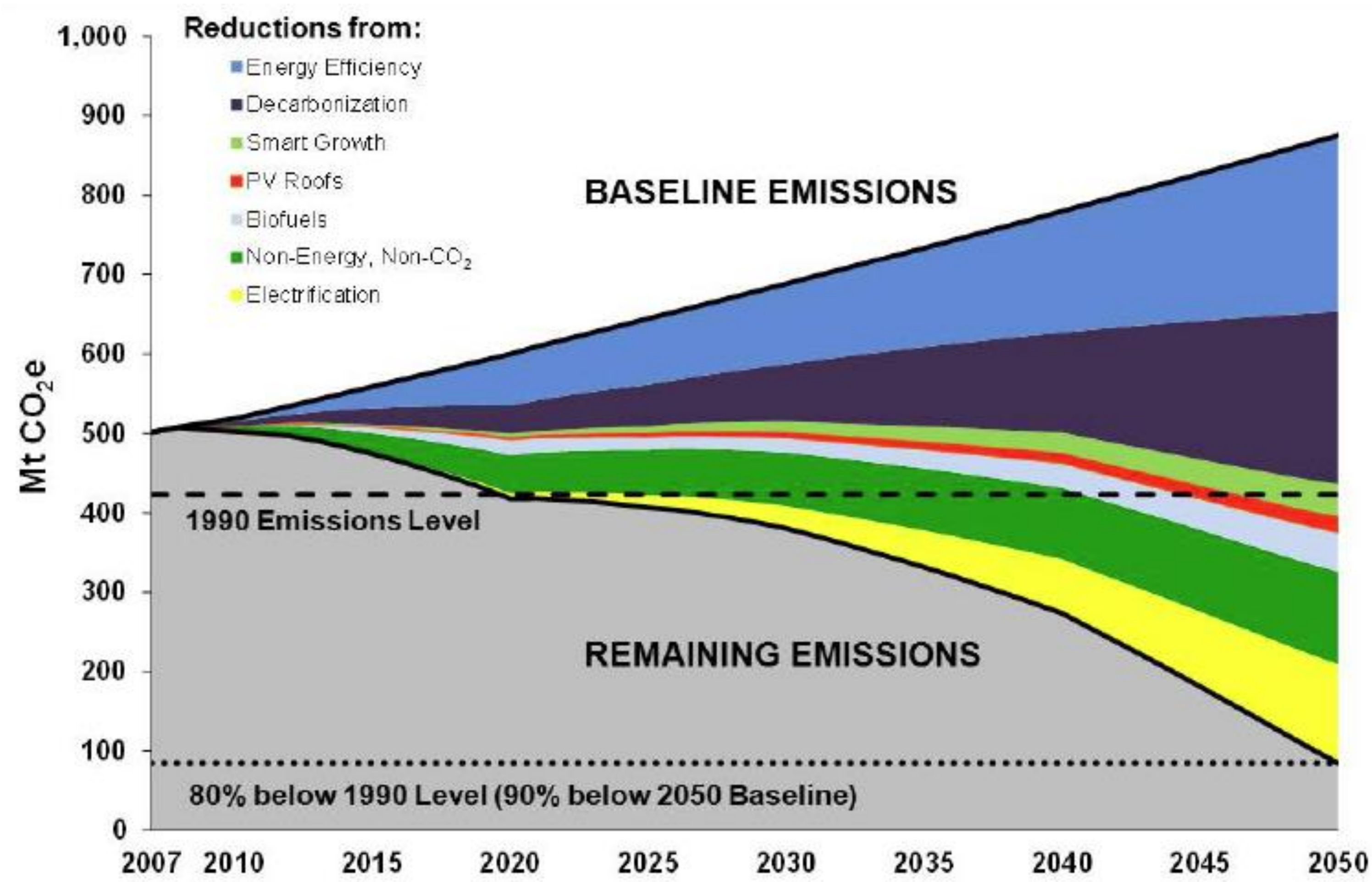
Steps to move towards meeting the 2050 goals

Stabilization triangle to reduce GHGs



Source: Pacala and Socolow

Sample Approach



Source: Lawrence Berkeley National Lab

Will alternative fuels play a major role in energy generation?

Major hurdles towards the 2050 goals

- Cost
- Integration of new technologies
- Coordination with key players
- Implementation/enforcement challenges

How should the Air District coordinate the activities of sister agencies?

- Creating a working group
- Exchanging ideas
- Supporting each other's efforts
- Coordination

Thank you for your time

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