Resilient Energy Systems

Cameron Bernhardt, Amy Syvrud, Byron To, Alyssa Zamora

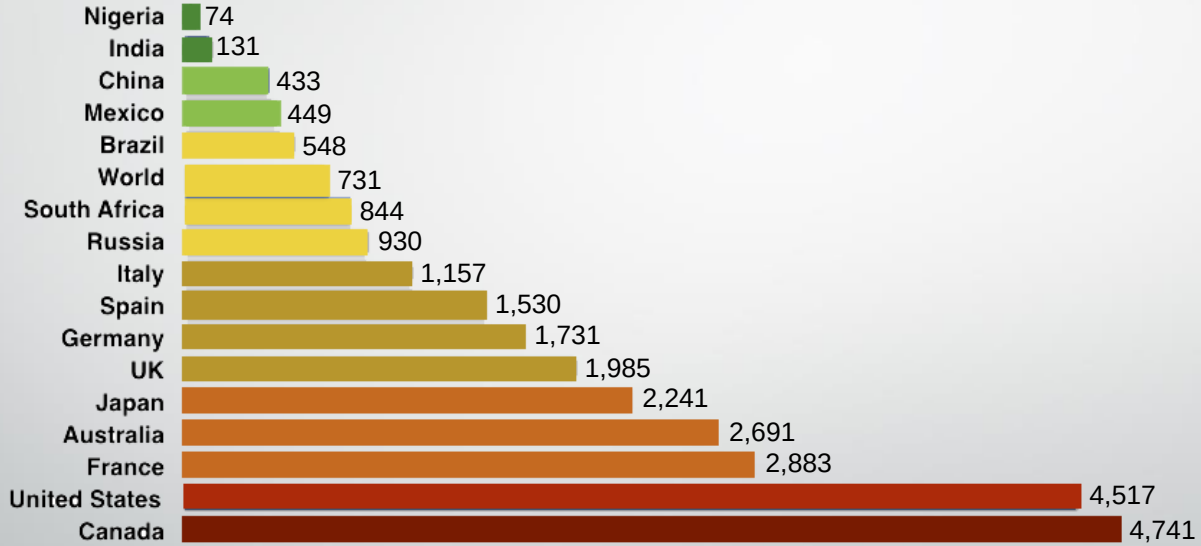
Outline

- Energy Systems Today
- Science & Economics
- Current Risks
- Resilient Solutions

50 MW Kumeyaay Wind Project on Campo Reservation

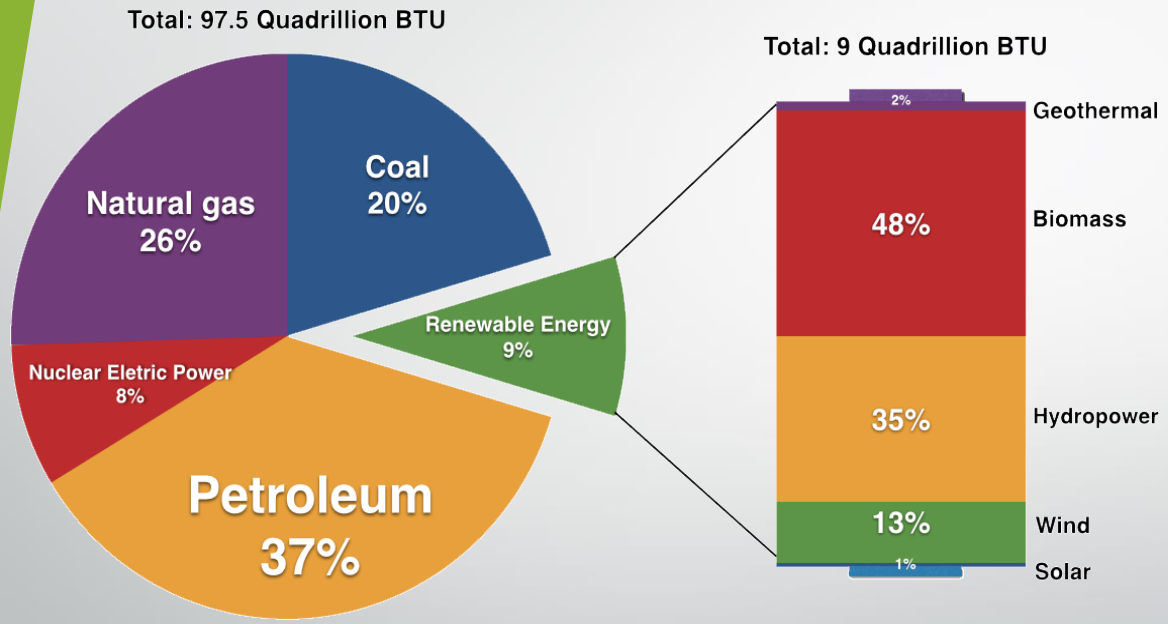
Residential Electricity Use

per capita (kWh/year)



Source: Enerdata via World Energy Council, 2010

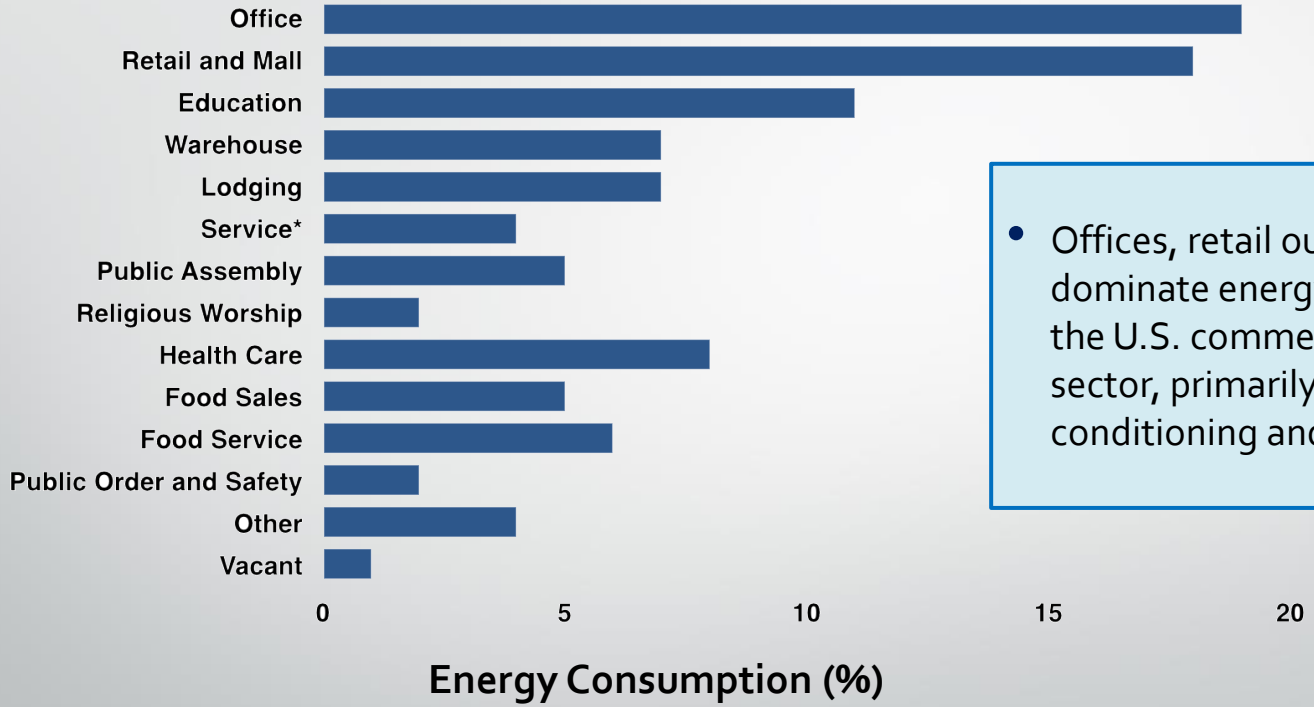
National Energy Consumption



Source: U.S. Energy Information Administration

- For renewables, the U.S. consumes mostly **hydropower** and **biomass**.
- Power from **solar, wind, and geothermal make up only 20%** of the country's renewable energy.
- **Only 1% of renewable energy comes from solar,** despite strong accessibility to sunlight across the nation.

U.S. Commercial Energy Consumption

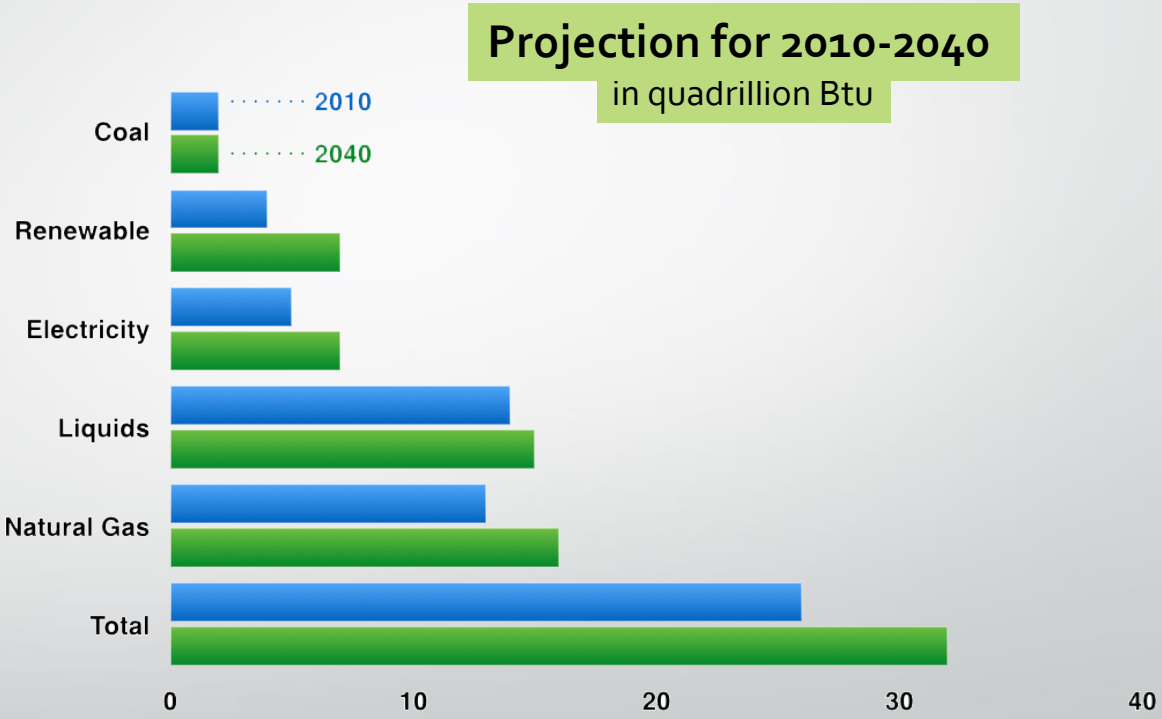


- Offices, retail outlets, and malls dominate energy consumption in the U.S. commercial building sector, primarily due to air conditioning and lighting demands.

Source: U.S. Department of Energy

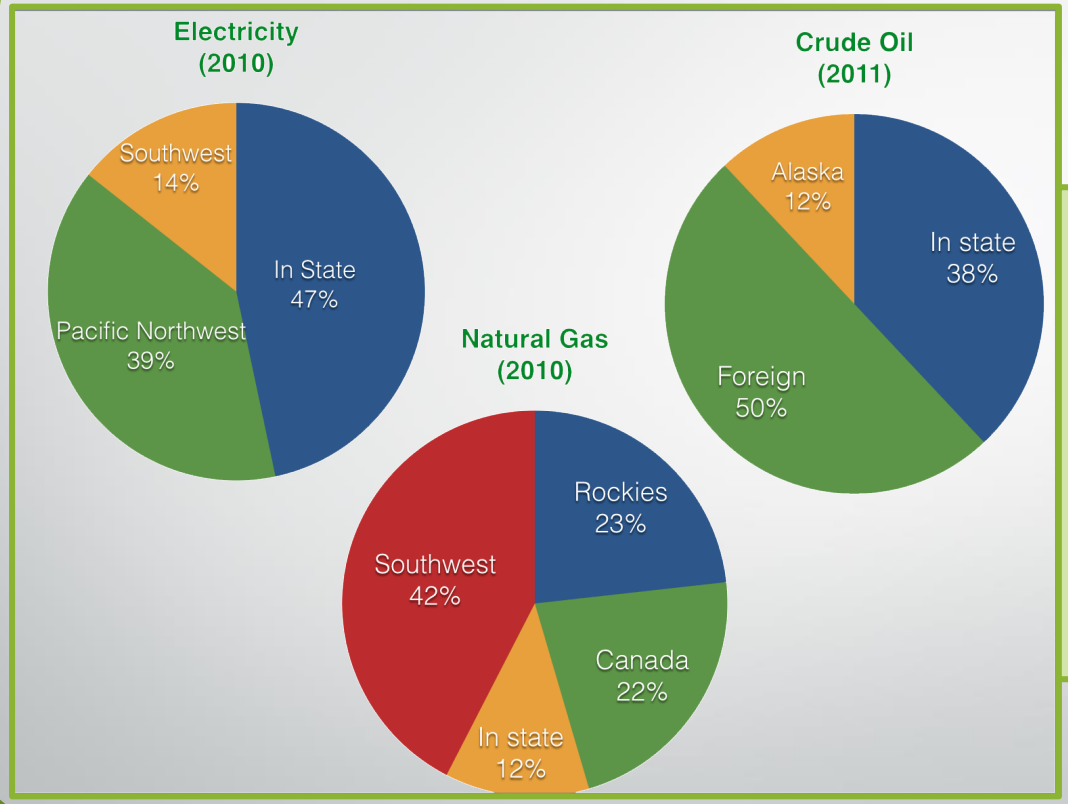
U.S. Industrial Energy Use

- The average annual growth in U.S. industrial energy consumption from 2010 to 2040 is **projected to be 0.6%.**
- The ***rate of growth for*** industrial consumption of ***renewables in the U.S. is greater than any other energy source.***



Source: U.S. Energy Information Administration

California's Energy Sources



Source: California Energy Almanac

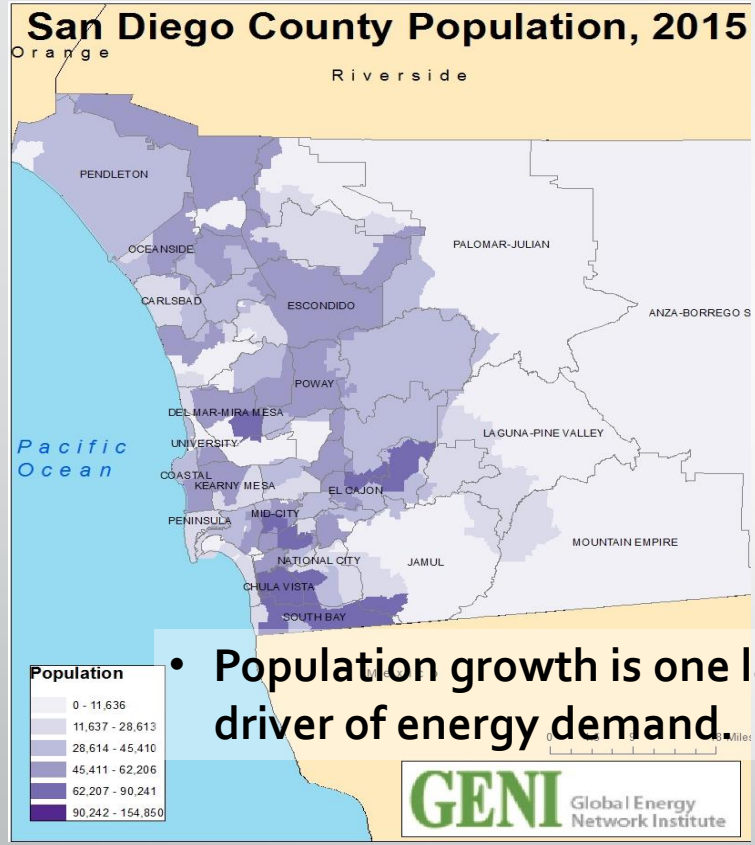
- Most of California's electricity comes locally from the state, while natural gas is imported from the Southwest and crude oil from foreign countries.

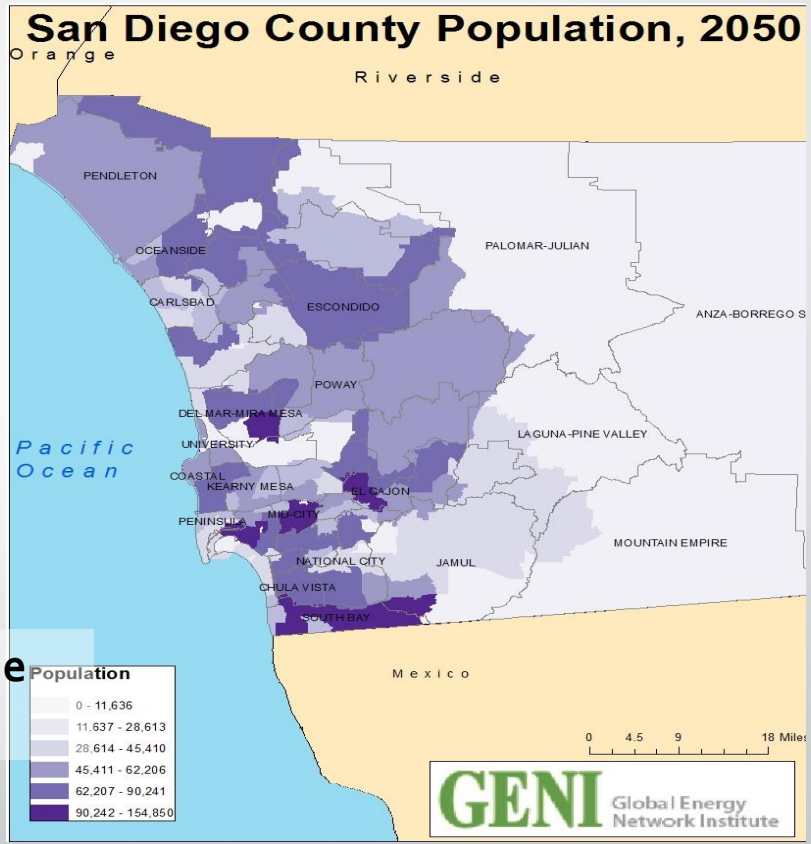
Background of San Diego

- San Diego is California's second largest city and the eighth largest in the nation.
- Between 1990 and 2004, San Diego's population increased by 16% to about 1.3 million people.
- During this same timeframe, residential energy use increased roughly 45%, commercial use increased nearly 108%, while industrial use increased only 2%.

Source: City of San Diego

San Diego Population Density



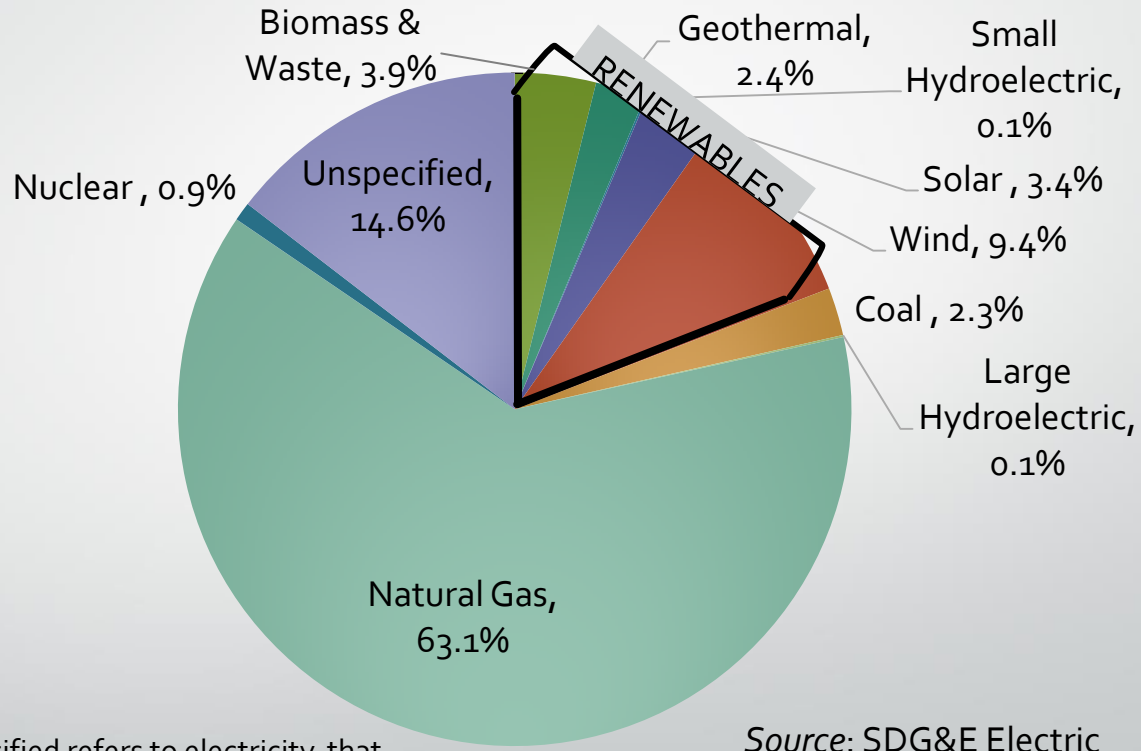


- **Population growth is one large driver of energy demand.**

Source: SANDAG; *Map By*: Vincent Tong

SDG&E 2012 Energy Mix

- Most of San Diego's energy comes from natural gas, while **only 19.2% of San Diego's energy comes from renewable sources.**



*Unspecified refers to electricity that cannot be traced to a specific source.

Source: SDG&E Electric Generation Fact Sheet

San Diego Transmission Lines Map

Source: Times of San Diego

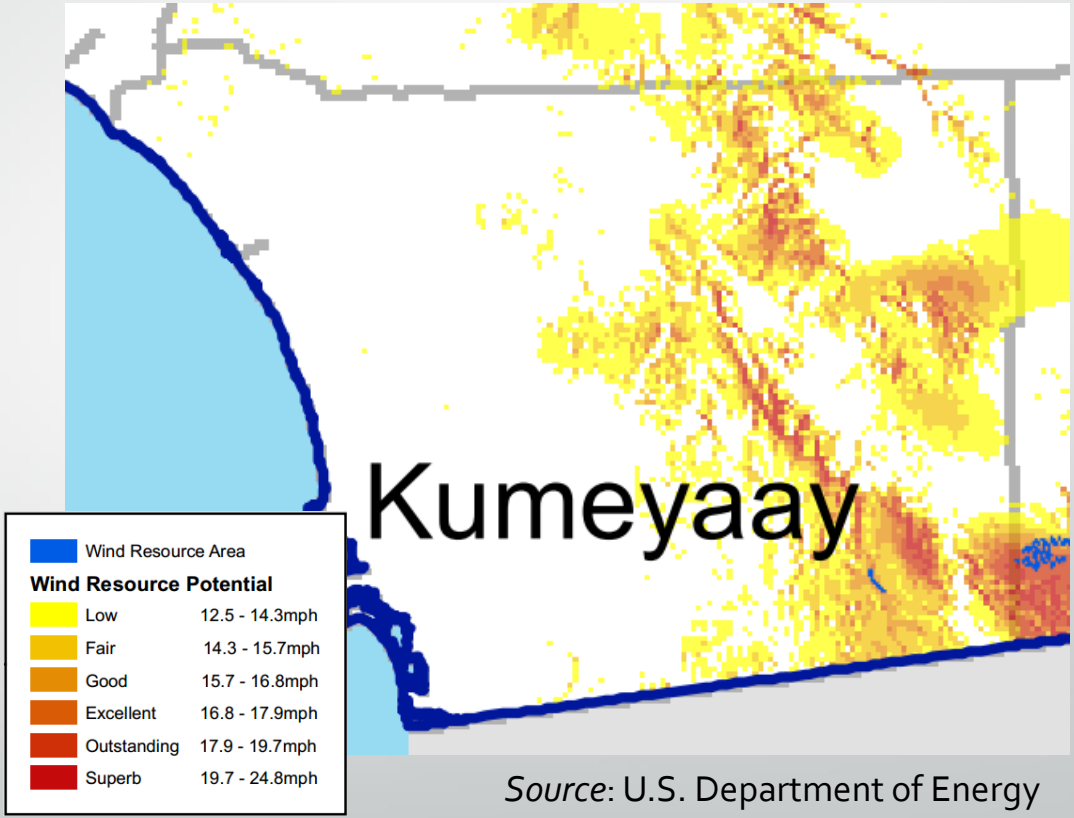
- Half of San Diego's power comes locally, while half is imported into the county.
- The peak energy demand in San Diego is 4500 MW; while the base load demand is 2000 MW.
- Small peak plants and large base load plants satisfy these demands.

Source: GENI

San Diego Wind Resource Potential

- The Kumeyaay Wind Farm supplies power to over 30,000 homes.
- San Diego County's wind power potential is about 6,900 MW, of which 1,530 MW can be used to power about 380,000 homes.

Source: California Energy Commission, 2005 Report



Source: U.S. Department of Energy

San Diego Geothermal Sources

- Some of the closest geothermal sources in San Diego are located in the **Imperial Valley Basin.**
- The hot water from these reservoirs can be **pumped directly to heat homes and offices.**

Source: California Energy Commission

San Diego Biomass Energy Potential

Source Category	Capacity and Energy Potential
Urban Wood Wastes	40-100 MW, or 300-800 GWh, per year
Agricultural Wastes	Negligible, more economically valuable use as fertilizers
Forestry Wood Wastes*	3-8 MW, or 20-57 GWh
Landfill Gas	72 MW, or 505 GWh

* The sustainability of forestry wood wastes is highly uncertain and difficult to predict in the long run.

Source: San Diego Regional Renewable Energy Group

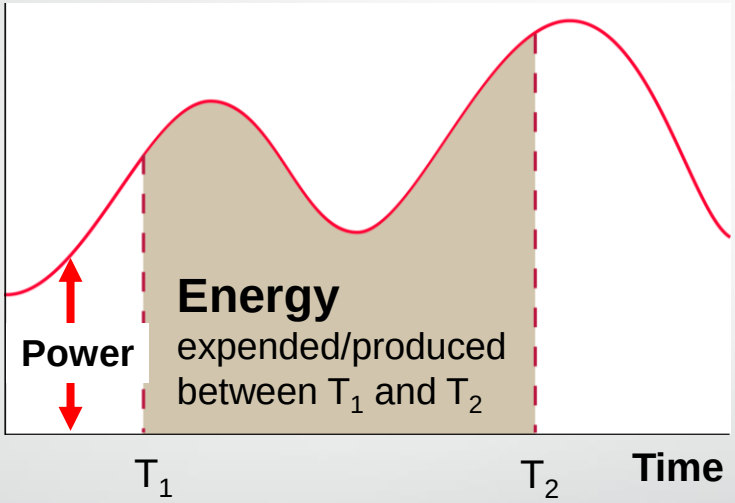
- Most of San Diego's biomass energy comes from **urban wood wastes.**
- Urban wood waste is used to fuel bioenergy plants, which can then be used to **produce electricity for homes and offices.**

Science & Economics

A glance at energy production and electrical grid operation

Power and Energy

Power
(instantaneous rate of energy flow per unit time)



Source:
John Jurewitz,
Pomona College

- **Watts** measure instantaneous ***rates*** **of power**
- **Watt-hours** measure ***volumes*** **of energy**

Electricity Generation

- Nearly all processes that generate electricity involve these four steps:

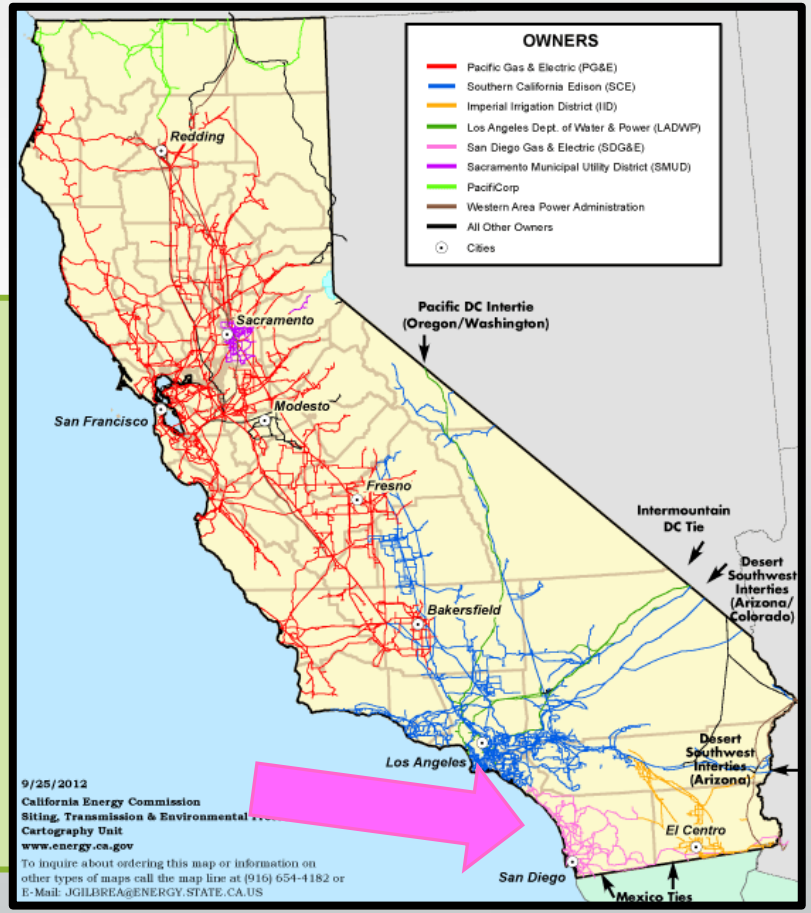
1. An energy source is burned to heat water, turning it into steam…
2. The steam spins a turbine at high pressure…
3. The spinning turbine turns large magnets within copper wire coils…
4. The moving magnets displace electrons, creating an electrical current.

Source: Origin Energy

California's Electric Transmission Lines

- SDG&E is the **3rd largest electrical utility in the state of California.**
- San Diego's population is growing rapidly and will force **SDG&E to expand in the near future.**

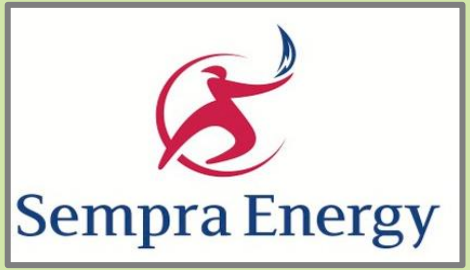
Source: U.S. Census Bureau



Source: California Energy Commission, 2012

San Diego Gas & Electric

- Provides natural gas and electricity to San Diego County and south Orange County
  - 3.4 million consumers; 4100 employees
- Utility parented by Sempra Energy
  - 31 million customers worldwide
  - Controls SDG&E's management and operations



Natural Gas

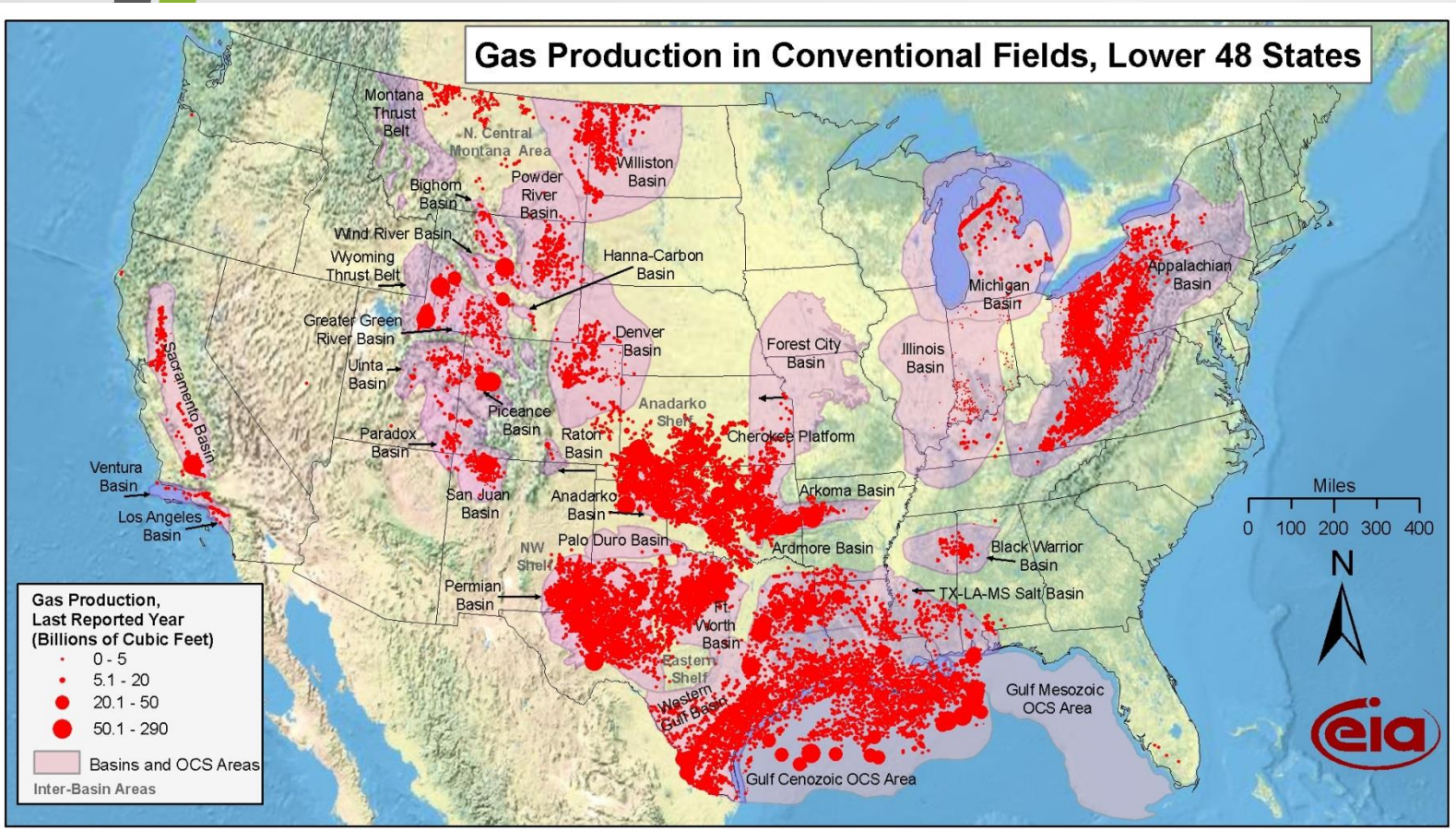
An Insufficient Alternative

The "Best" Fossil Fuel

- ***63.1%*** of SDG&E's 2012 Power Mix
- More sustainable than oil and coal, but ***not the answer to energy dilemma***
  - 29% less CO_2 than oil; 44% less than coal
  - *"…not a bridge to a renewable energy future - **it's a gangplank** to more warming and away from clean energy investments."*
    – Anthony Ingraffea, Cornell University

Natural Gas Problems

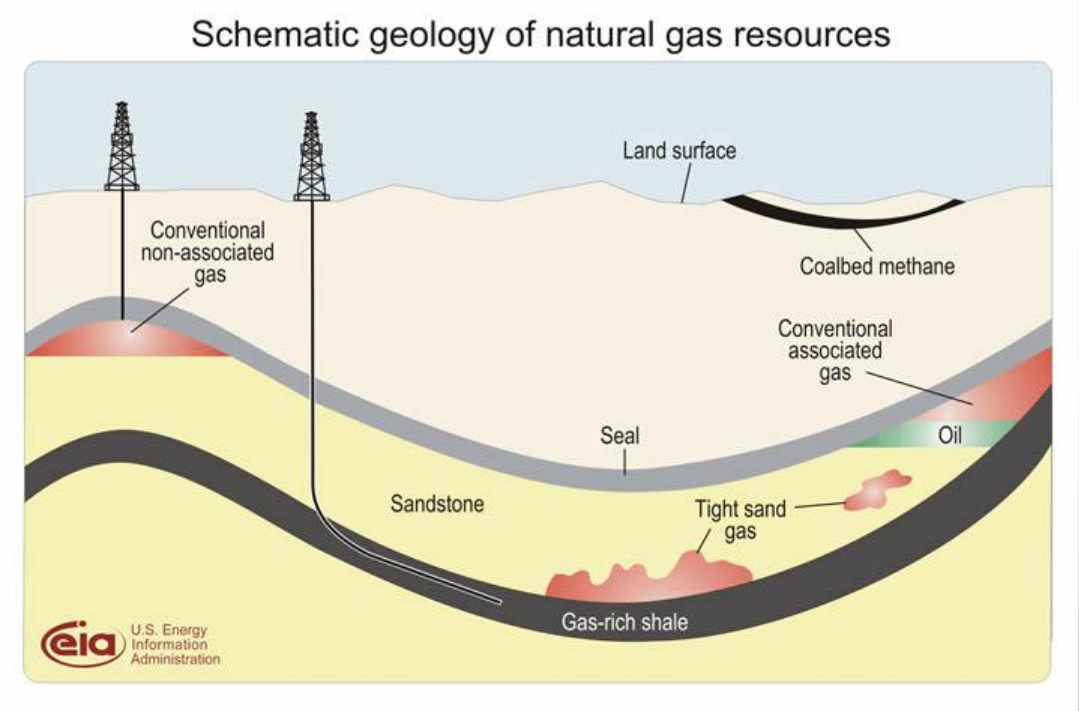
- Although CO_2 emissions are roughly four times greater than CH_4 emissions, ***CH_4 climate impacts are 20x greater over 100-year period.***
  – E.P.A., I.P.C.C.
- ***Unless CH_4 leaks can be kept under 2%, gas is inferior to coal*** with regard to climate. *– N.C.A.R., 2011*
- **Harmful extraction, volatile prices**



*California is the #2 natural gas consumer in the U.S., but **88%** of the gas it consumes is **produced out-of-state.***
- E.I.A., SDG&E

Source: U.S. Energy Information Administration, 2009

Natural Gas Extraction



Source: U.S. Energy Information Administration

- Extracted by **drilling vertically into Earth**
  - **Hydraulic fracturing ("fracking"),** horizontal drilling, acidizing
  - Controversial and debated environmental impacts
- Conventional natural gas sources are **expanding**
  - **Developing technology** makes unconventional extraction more economically viable

Hydraulic Fracturing

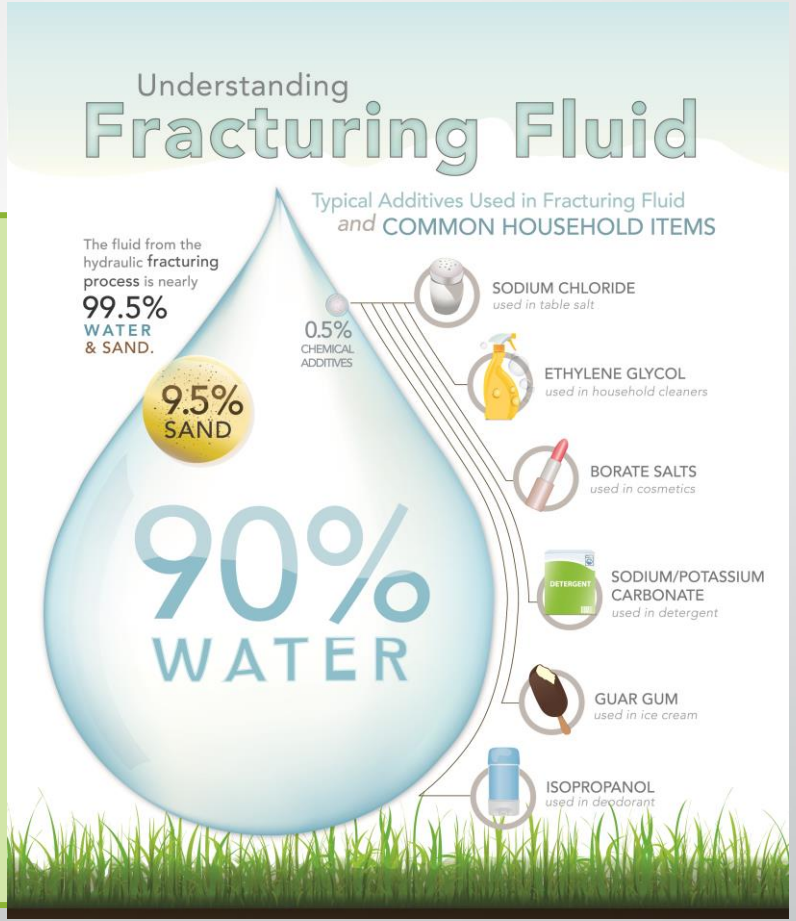
- ***Hydraulic Fracturing – Shale Natural Gas Extraction***
  - A video by SMT Learning briefly describing the hydraulic fracturing and horizontal drilling extraction processes.
  - http://www.youtube.com/watch?v=lB3FOJjpy7s
- ***Negative Consequences of Hydraulic Fracturing***

Groundwater Contamination	**Higher Water Prices**
Surface Water Contamination	Release of Radioactive Materials
Induced Seismic Activity	Expensive Wastewater Treatment

Natural Gas

Fracturing Fluid

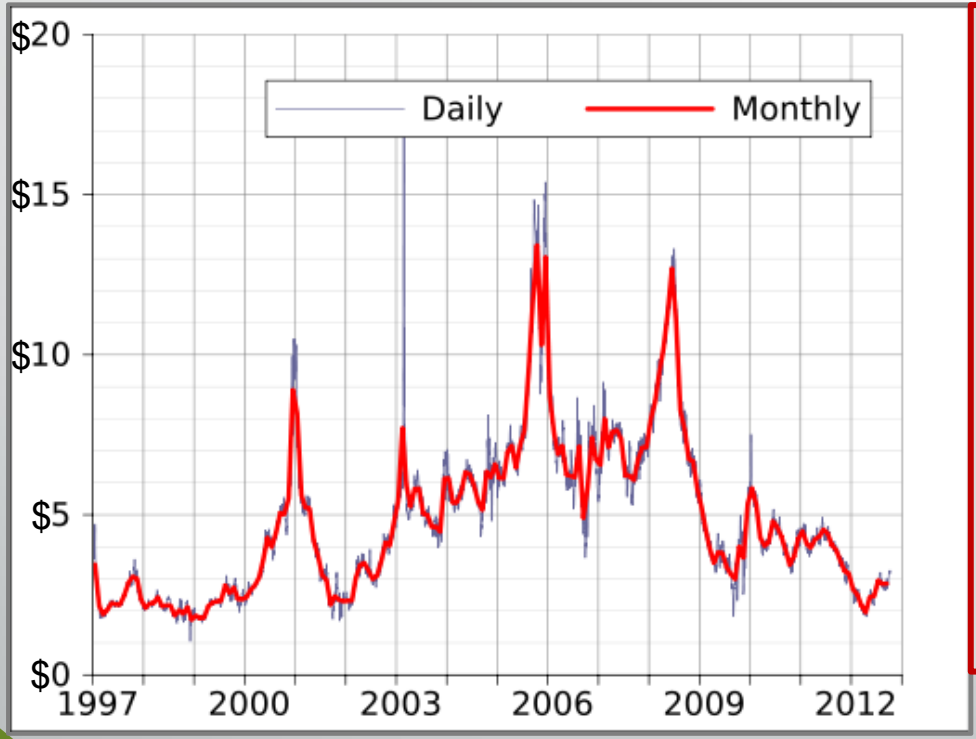
- While these chemicals are harmless in common household items, they are not as welcomed in our groundwater supplies.
  - The EPA has *proven* that **groundwater supplies have been contaminated by fracking fluid**, as well as escaped methane.
- Hydraulic fracturing's **heavy reliance on water** for production **makes natural gas a vulnerable energy source** for the San Diego region.



Source: EnergyFromShale

Natural Gas Prices

($/MMBtu)



- Factors affecting prices:
  - Variation in shortages, production, imports, delivery constraints, operating accidents
  - **Seasonal fluctuations in temperature** raise demand
- Prices closely **linked to oil, renewables, and other energy sources**

Source: Henry Hub, E.I.A.

Predominant Generation Technologies

Economics

	Capital Costs	Operating Costs	Start-Up Times	Dispatchability
Large Hydro	High	Very Low	Instantaneous	High
Nuclear	Very High	Very Low	Very Slow	"Sluggish"
Coal	High	Low	Slow	"Sluggish"
Conventional Gas-Fired	Medium	Medium	Medium	High, but Ramping and Turndown Limits
Simple-Cycle Gas Turbines (Peaking)	Low	High	Fast	High
Combined-Cycle Gas Turbines	Medium	Medium-Low	Medium	High, but Ramping and Turndown Limits

Source: John Jurewitz, Pomona College

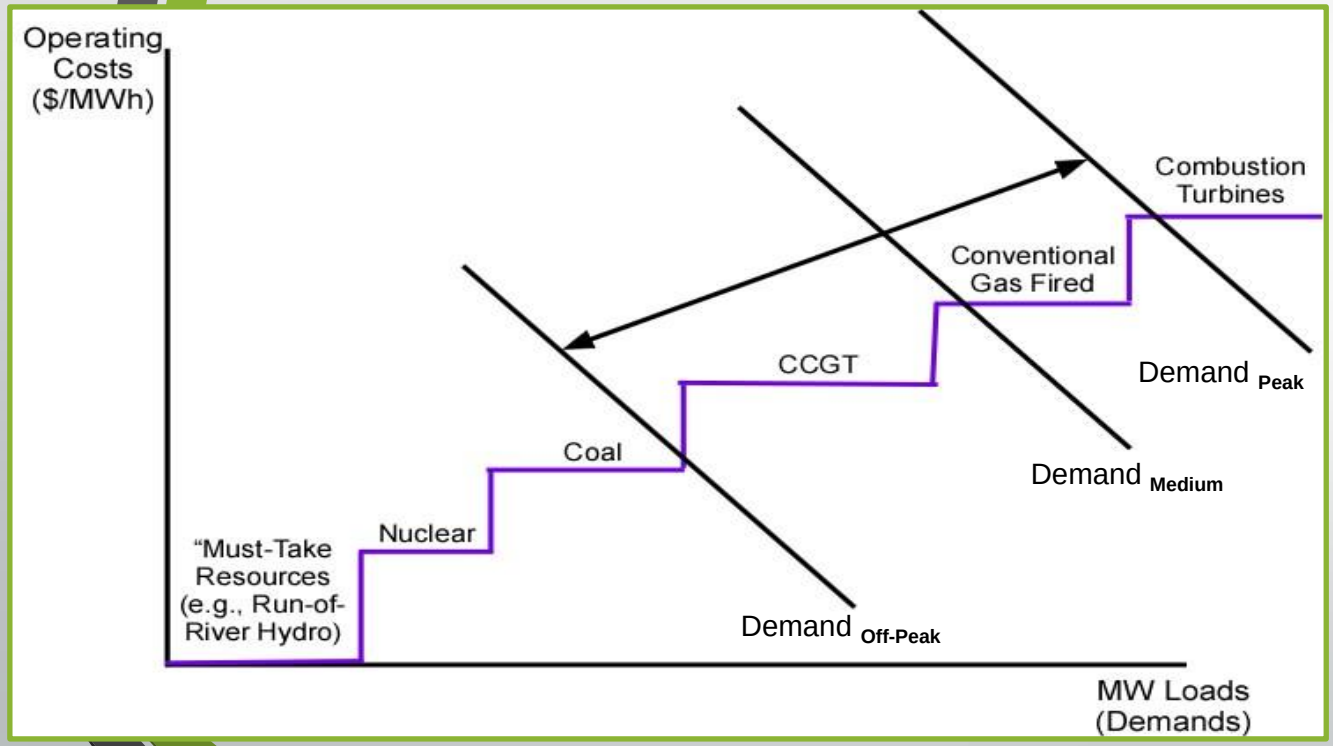
Renewable Generation Technologies

Economics

	Capital Costs	Operating Costs	Start-Up Times	Dispatchability
Small Hydro	High	Very Low	Instantaneous	Intermittent; Non-Dispatchable
Wind	Medium	Medium	Instantaneous (adequate wind)	Intermittent; Non-Dispatchable
Solar Photovoltaic	Very High	Very Low	Instantaneous (adequate sunlight)	Diurnally "Predictable"; Non-Dispatchable
Solar Thermal	High	Medium	Takes Time From Cold State	Dispatchable (when hot)
Geothermal	High	Medium	Hours	Dispatchable
Biomass	Medium	Medium	Hours	Dispatchable

Source: John Jurewitz, Pomona College

Simple Operating "Merit Order"



Source: John Jurewitz, Pomona College

- Base load plants have low operating costs and poor dispatchability.
- For cost-effectiveness, run generation with **relatively low operating costs.**
- **Complicated execution:**
  - Start-up times
  - Minimum turndowns
  - "Must-take" reliability

Barriers Of Entry For Renewables

- **Lack of price incentives** for expensive capital investments.
  - Our systems need to be **energy efficient** for them to be cost-efficient.
  - Many developing countries **lack the governmental, institutional, and structural support** required for costly renewable investments.
  - Engineers, city planners, and workers are **not trained or educated** to deal with renewable technologies.

UN Secretary-General Ban Ki-moon at the solar test facility in Denver, Colorado.

A Renewable Future

"***By 2020, we should be headed in a downward direction for oil output*** *in the world each year instead of an upward direction, as we are today."*
- Charles "Dean of Oil Analysts" Maxwell

Source: Energy Trends Insider

- The costs of renewable technologies are **decreasing over time.** The **prices of natural gas, coal, and oil will increase** as we pass "peak oil."
- Upfront capital investments can **finance further development** of renewables and allow for their **rapid integration** when they become more energy-efficient.

Risks of Our Energy Systems

A growing population, reliance on natural gas, and climate-driven change

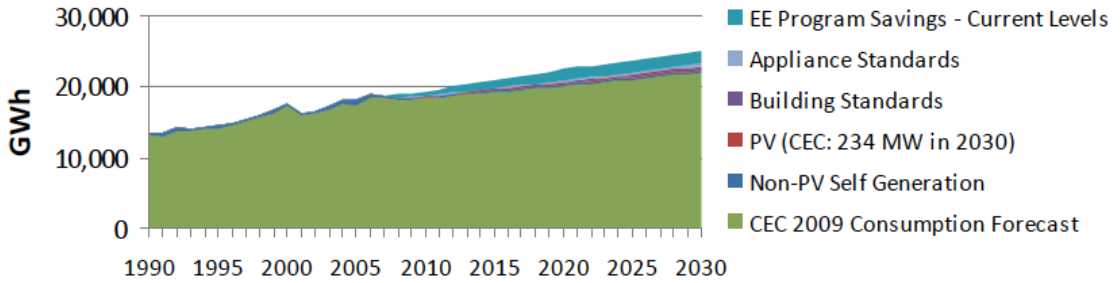
How will population growth impact our consumption levels?

Year	Gigawatt Hours	Population Size
2007	18,648	3.12 million
2020	20,555	3.33 million
2030	22,647	3.53 million

Source: San Diego County Fact Sheet

- Region's total electricity consumption from 2007 is expected to increase by 20% by 2030 because of our growing population.

San Diego County Business as Usual Electricity Forecast 2010-2030



Source: California Center for Sustainable Energy, 2009.

Source: SANDAG

How much is our energy consumption contributing to climate change?

Table 1: San Diego County GHG Emissions Overview	
Intergovernmental Panel on Climate Change Category	**Percentage of Total**
Energy	**91%**
Industrial (non-fuel)	5%
Waste	2%
Agriculture, Forestry, Land Use	2%
Source: Energy Policy Initiatives Center, University of San Diego, 2008.	

Source: SANDAG

- **91%** of our GHG emissions are **energy** related.
  - 46% are due to transportation.
  - 33% are due to electricity and natural gas end-uses only.

What are the risks of relying so heavily on natural gas?

- Natural gas prices have been volatile and will likely climb in the future.
- California imports almost **90%** of its natural gas via interstate pipelines. California, and especially San Diego, which lie at the end of the pipelines, are vulnerable to supply disruptions due to:
  - Political situations
  - Natural disasters
- Methane in natural gas has costly environmental repercussions if it escapes into the atmosphere.

Source: CA Gov. Energy Alamanac

Source: U.S. Energy Information Administration

Climate Change Risks for San Diego

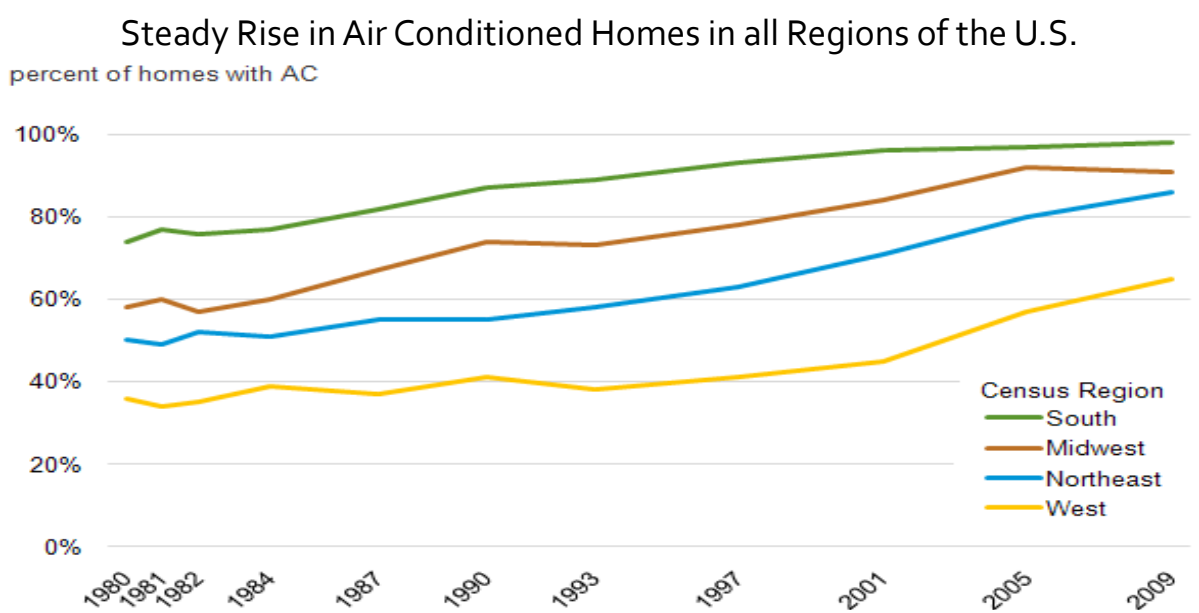
- Extreme temperatures
- Sea-level rise
- Mass movement (erosion)
- Flooding
- Drought
- Wildfires

Climate-driven changes are projected to account for approximately 7% of the total **increase** in peak **energy demand**.

-San Diego Bay Adaptation Strategy

Increasing Temperatures

"On any hot summer afternoon, about one-third of the electricity that's being consumed is being used to drive air conditioners." -*Claudia Chandler*, California Energy Commission



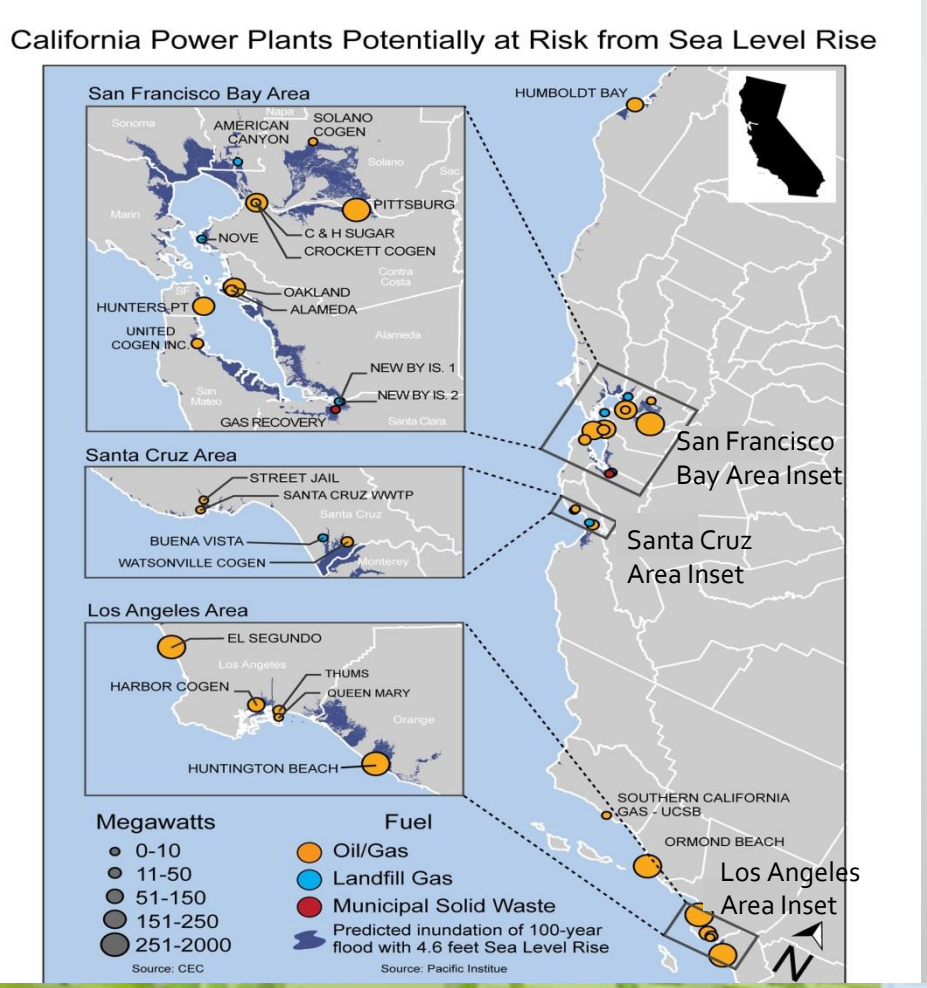
Source: U.S. Energy Information Administration

- Annual energy consumption is expected to increase more than **60%**, mostly due to increased demand for summer cooling.

Sea Level Rise

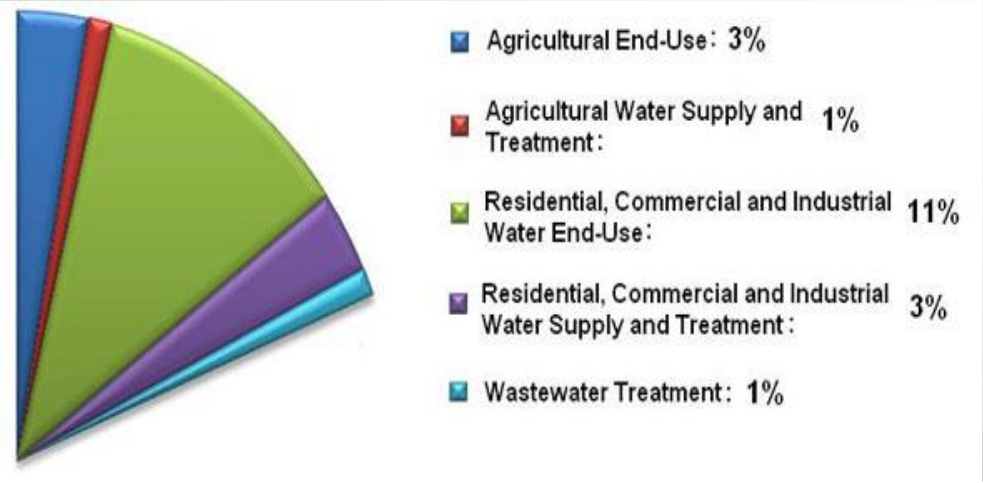
- Given a 1.4m (4.6ft) rise scenario, 25 power plants along the California coast could be flooded but none in San Diego are at risk within this century.
- Erosion and flooding from sea level rise could pose a threat to above-ground electricity transmission and distribution, causing outages or safety issues.

Source: National Climate Assessment



Drought: Water-Energy Nexus

- Water-related electricity use is 48 terawatt-hours (TWh) per year and accounts for **nearly 20%** of California's total electricity consumption.

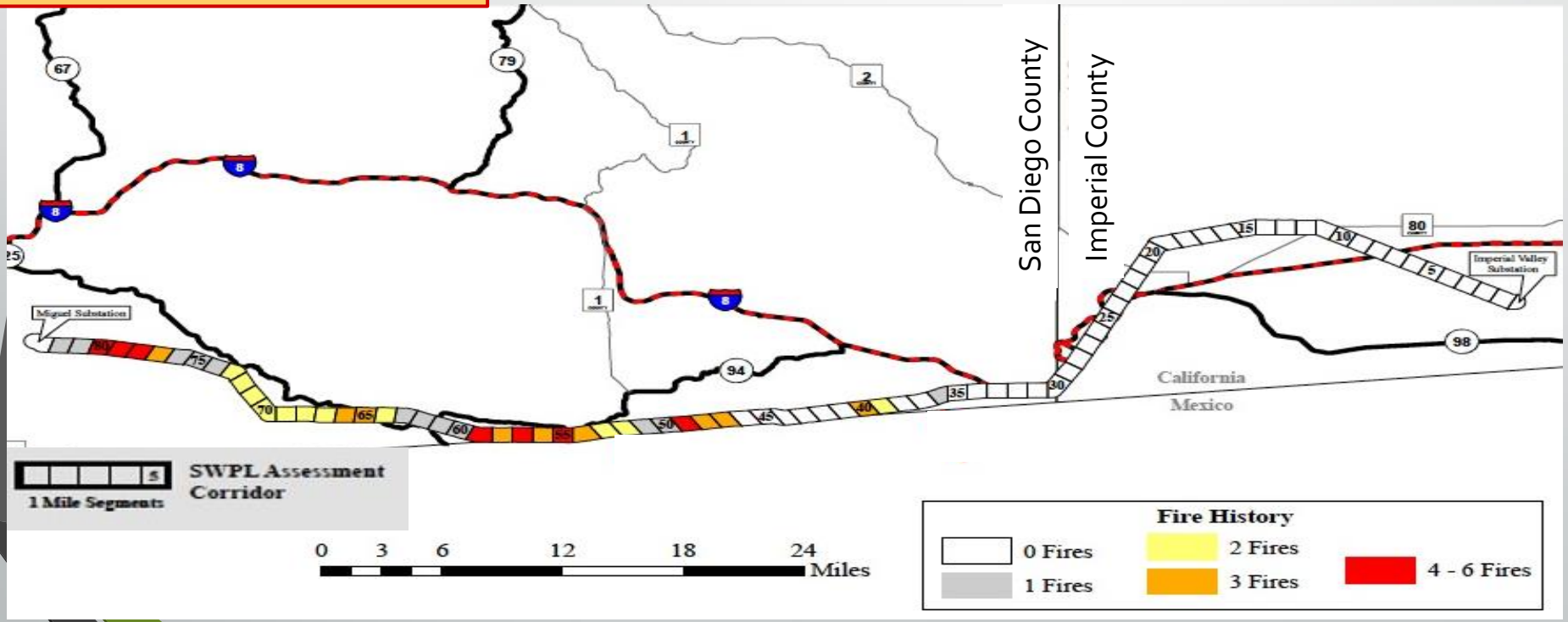


Source: CA Gov. Refining Estimates of Water-Related Energy Use in California

- Drought will place **higher constraints** on power production at existing facilities and permitting of new power plants.

Transmission lines passing through San Diego are at **risk for outages** as a result of wildfires—especially the Southwest Powerlink.

Wildfire Is A Serious Threat

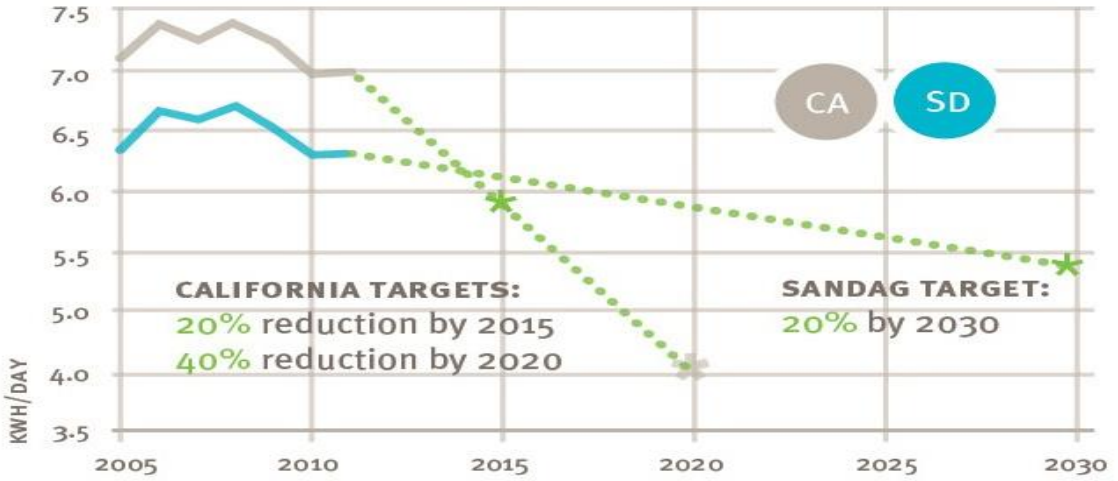


Source: CA Gov.

Meeting Our GHG Reduction Targets

- SANDAG has recommended a **20% reduction** in per capita electricity usage **by 2030** to keep total regional electricity consumption flat and meet **mandated targets** (AB32 and SB375) as our population and economy grow.

Per Capita Residential Energy Consumption Per Day by County, 2011

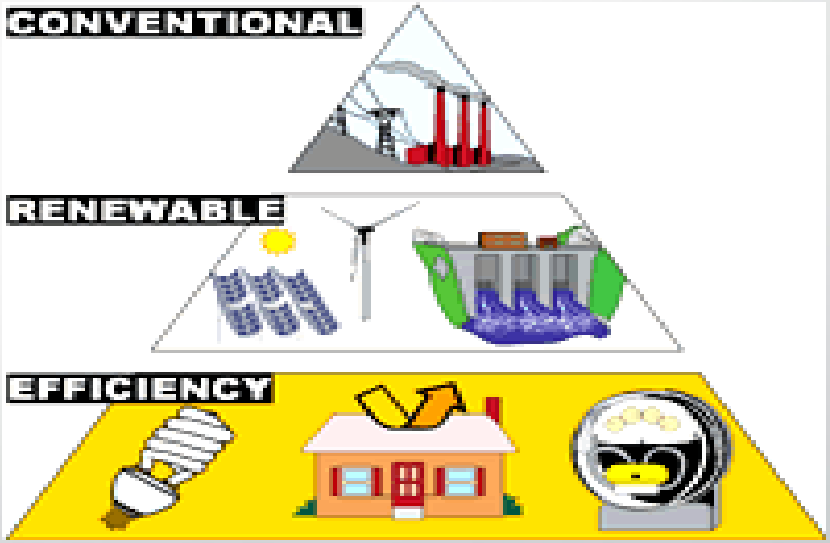


Source: Equinox Center 2012; California Energy Commission 2012; CA Dept. of Finance 2012

Meeting Our Energy Demands and GHG Targets

- The state's **"preferred loading order"** to meet increasing demand for electricity:

1. Decrease demand by increasing energy **efficiency and conservation**
2. Meet new generation needs first with **renewable resources**
3. Meet rest of needs with fossil fuels



Source: SANDAG, July 2009

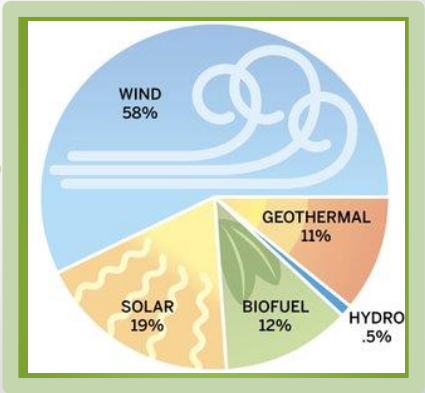
Resilient Solutions

Building a resilient energy system in San Diego

Building a
RESILIENT ENERGY SYSTEM

Improved Energy Efficiency

Harnessing Renewable Energy



Integrating New Technology

- Cogeneration
- Distributed Energy

Improving Energy Efficiency

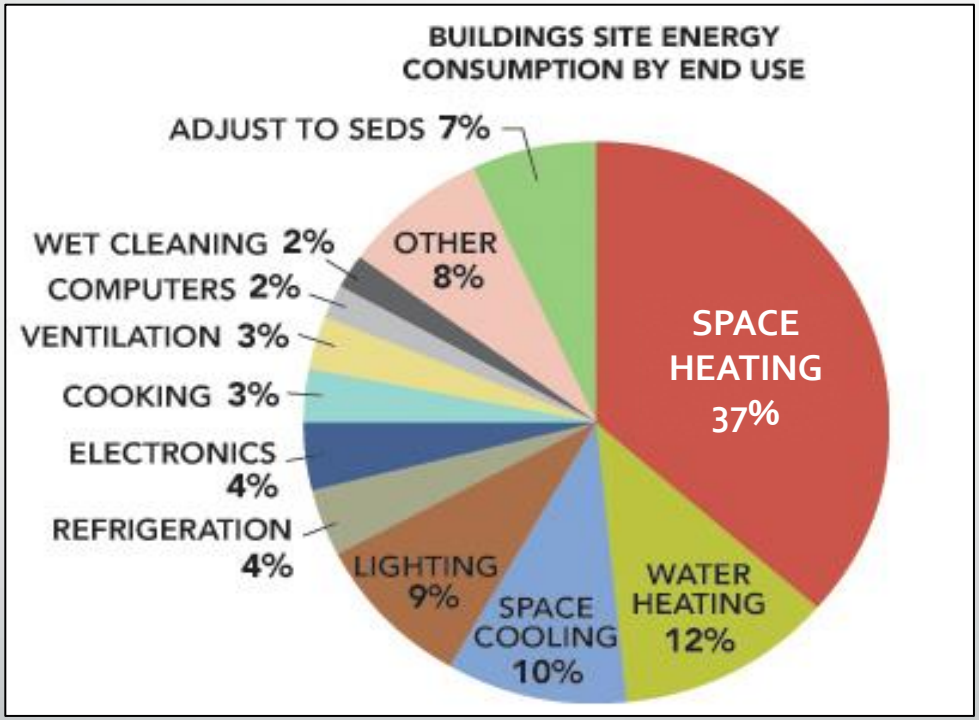
Generating more energy at lower costs

U.S. Energy Consumption By Sector

29% Transportation

41% Buildings (Commercial & Residential)

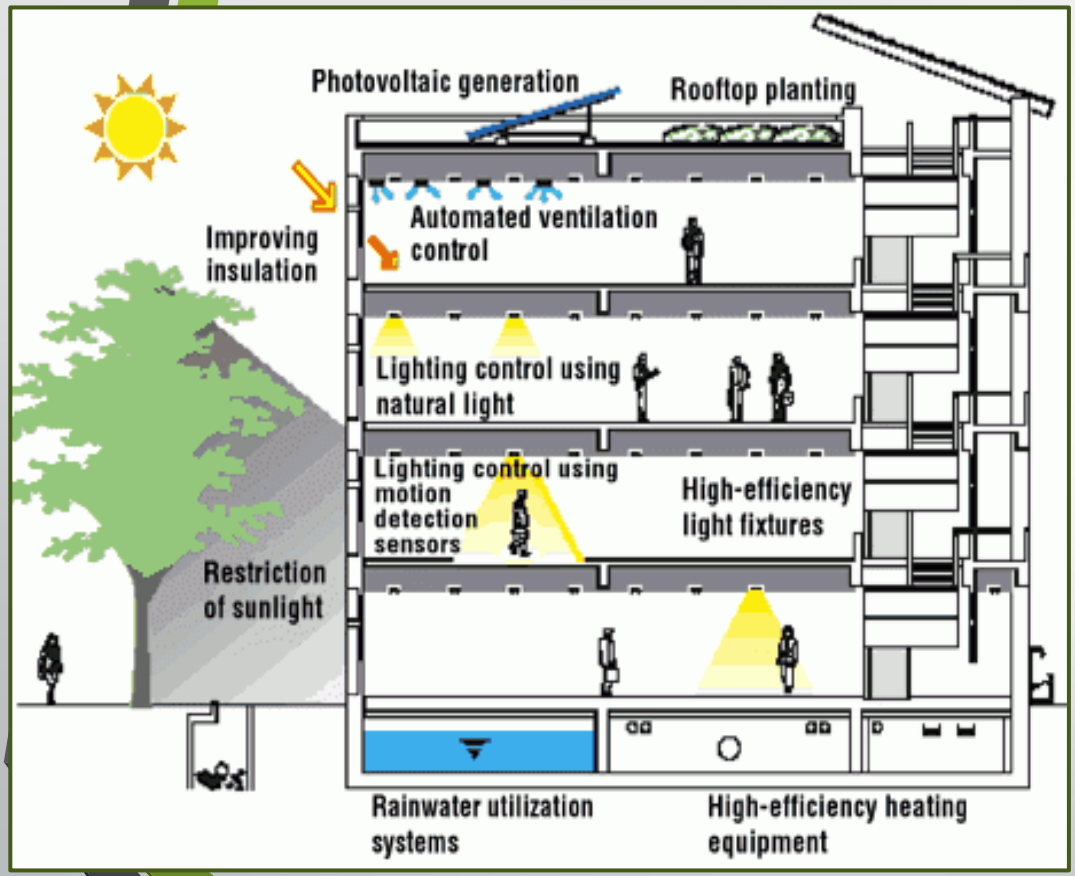
30% Industrial



Source: Buildings Energy Data Book, US Dept. of Energy

Improving energy efficiency costs significantly less than investing in new generation and transmission.

Increased temperatures in San Diego can heighten energy consumption by buildings especially for space cooling.



Source: EcoMENA

Green building design reduces:

- Heat loss & heat gain
- Urban heat island effect
- Stormwater runoff temperatures
- Overall energy consumption

San Diego is home to the world's 1st Platinum LEED certified airport terminal

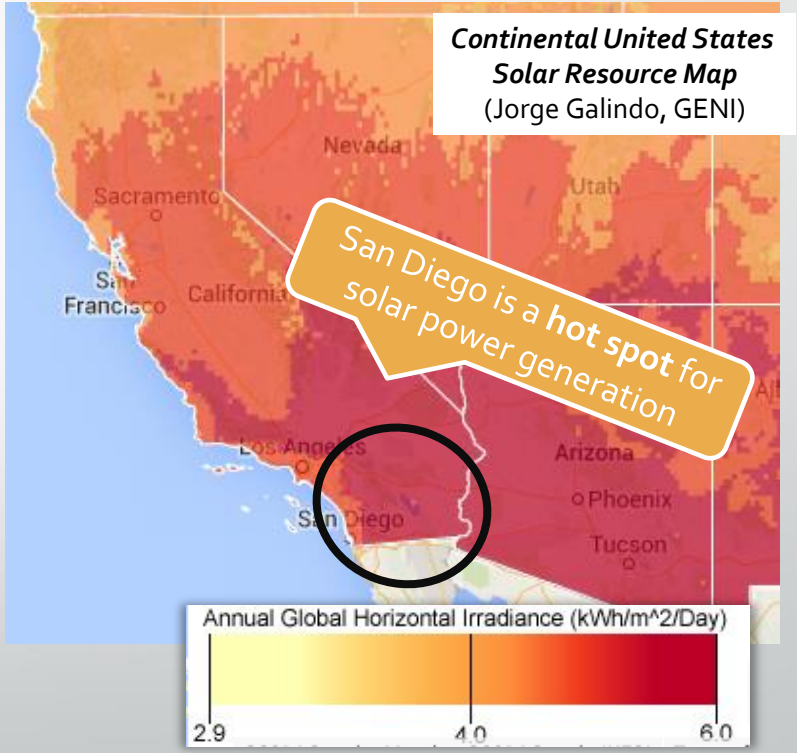
- Natural & energy efficient lighting
- Reflective roof
- Lighting/HVAC control technology

Shining Cities Report
(Environment American Research & Policy Center)

Table ES-1. Top 20 Solar Cities by Total Installed Solar PV Capacity, End of 2013*

Principal City	State	Cumulative Solar PV Capacity (MW)	Cumulative Solar PV Capacity Rank
Los Angeles	CA	132	1
San Diego	CA	107	2
Phoenix	AZ	96	3
San Jose	CA	94	4
Honolulu	HI	91	5

Renewable Energy
San Diego's Solar Power Potential



***San Diego** is capable of expanding its solar power production because of its high annual global horizontal irradiance (GHI).*

Solar Energy Systems in San Diego

- ***University of San Diego*** holds the largest solar power system on a private campus
- ***Park View Terrace*** is 1 of 7 solar-powered affordable housing projects in California by Community HousingWorks

Solar Energy Systems

(New York Times)

During **Hurricane Sandy** only systems ***with attached batteries or generators*** produced energy when electric grid was offline.

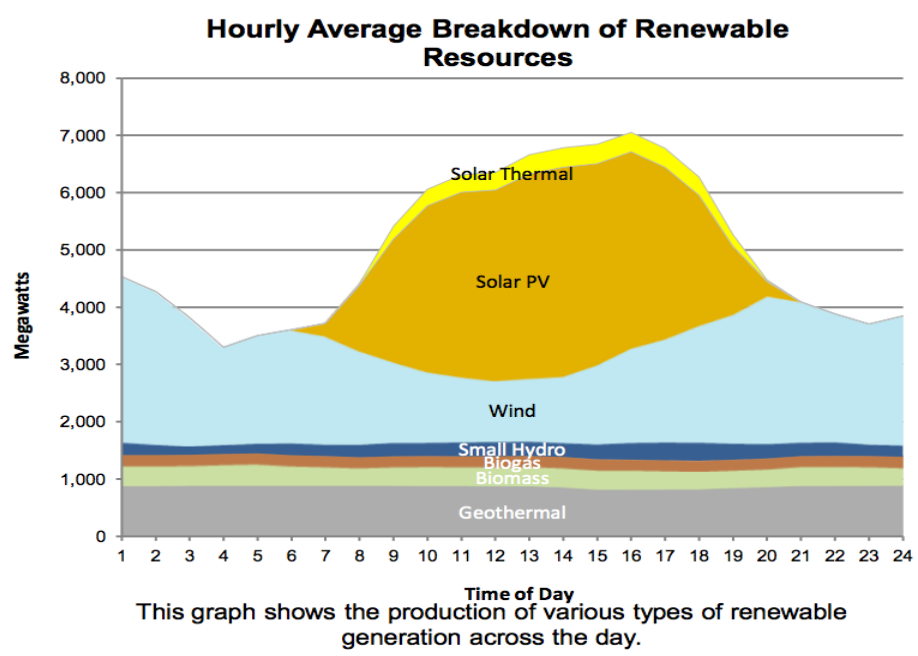
Advantages

- Reduces pollution
- Protects consumers
- Helps the economy
- Enhances resilience:
  - Reduces strain on grid & prevent blackouts
  - Backup energy source during outages

Disadvantages

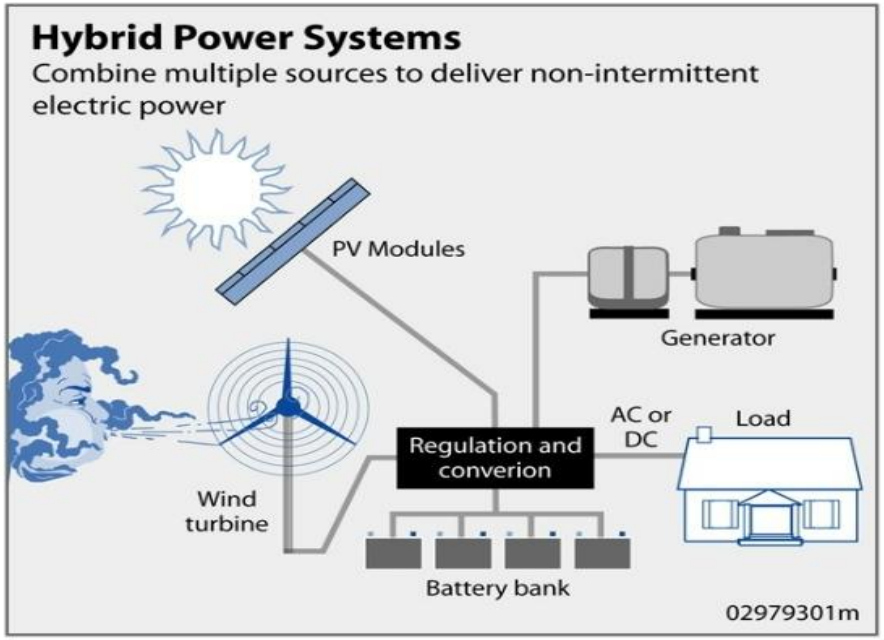
- Some systems are not completely "off-grid"
- High cost of adding backup battery storage
- Battery backup is not suitable for areas vulnerable to flooding

Photovoltaic-Wind Hybrid Energy Systems



(July 9, 2014, California ISO)

Peak operating times for wind and solar systems occur at **different** times of the day and year.



(US Dept. of Energy)

Hybrid systems make it possible to use these renewables **continually**. Batteries and generators provide energy when they are not available.

Cogeneration

Combined Heat & Power (CHP)

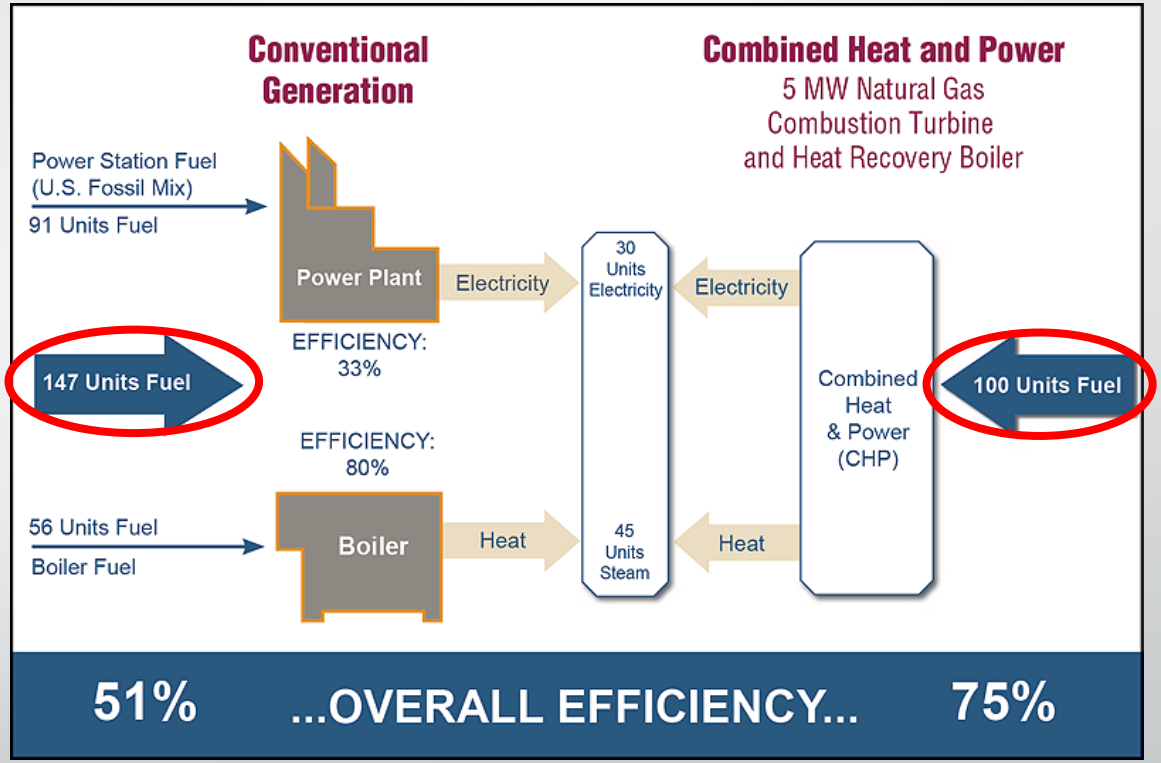
3 Public Utilities Department Buildings in San Diego Already Utilize CHP:

- *Point Loma Wastewater Treatment Plant*
- *North City Water Reclamation Plant*
- *South Bay Water Reclamation Plant*

Industrial Processes: *Waste heat is **collected** and put back into a system or other parts of a process.*

Residential Units: *MicroCHP units provide **electric power** for appliances and **supply heat** for hot water and space heating.*

Units fuel needed to produce 75 units of useful energy…



Source: EPA

Distributed Energy

Shifting from large, centralized systems to small-scale, neighborhood based systems

Distributed energy systems generate

6.5%
of total
US electricity

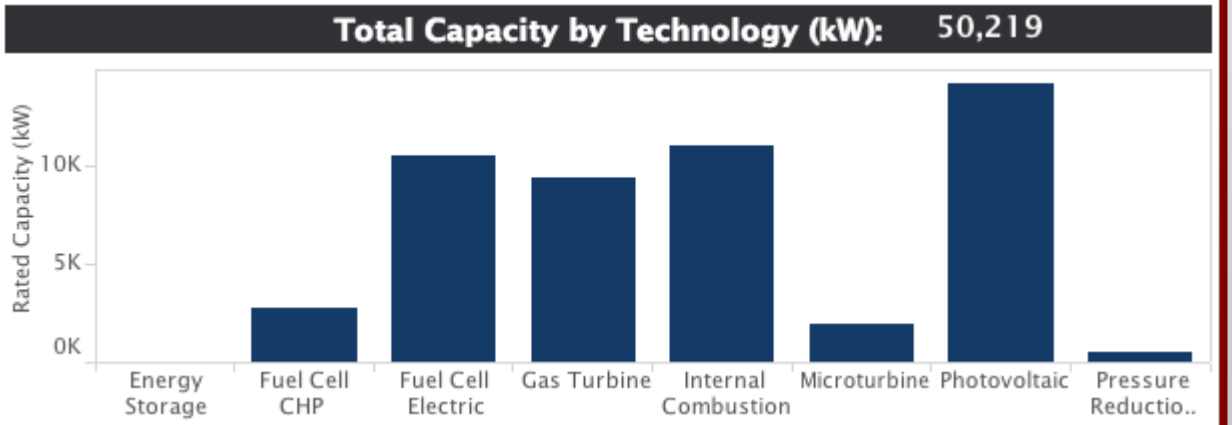
1.6%
of total
San Diego electricity

3 Major Technologies

- Microgrid (UCSD)
- Fuel Cells
- Microturbine

San Diego: Self-Generation Incentive Program (SGIP)
administered by the Center for Sustainable Energy
in the SDG&E service territory

SGIP Statistics in SDG&E Service Territory
(Center for Sustainable Energy)



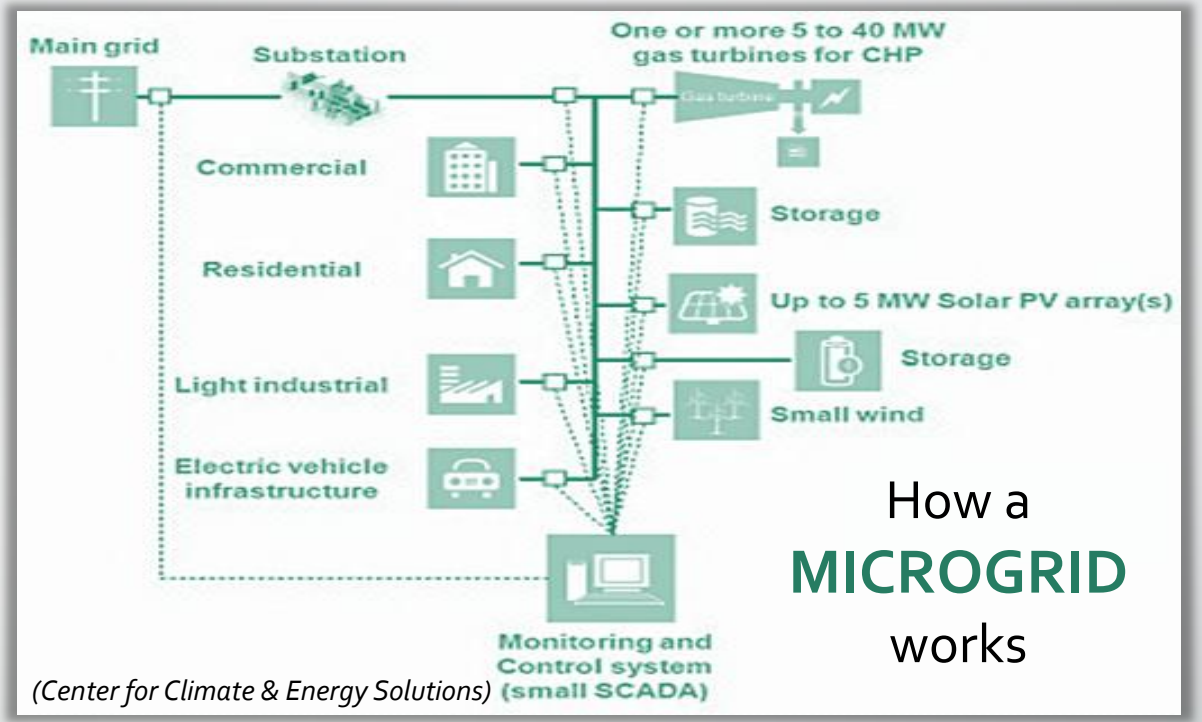
Microgrids

Advantages

- Easy renewable integration
- Reduces peaking power demand
- Lowers GHG emissions
- Reduces amount of electricity lost
- Configurable with CHP systems

Disadvantages

- Natural gas-fueled DG is not as efficient as natural gas-fired generation from the grid
- Efficiency improved only when CHP and renewables are included
- High cost of technologies



(Center for Climate & Energy Solutions)

UC San Diego's Energy Innovation park produces 85% of the university's electricity.

Fuel Cells

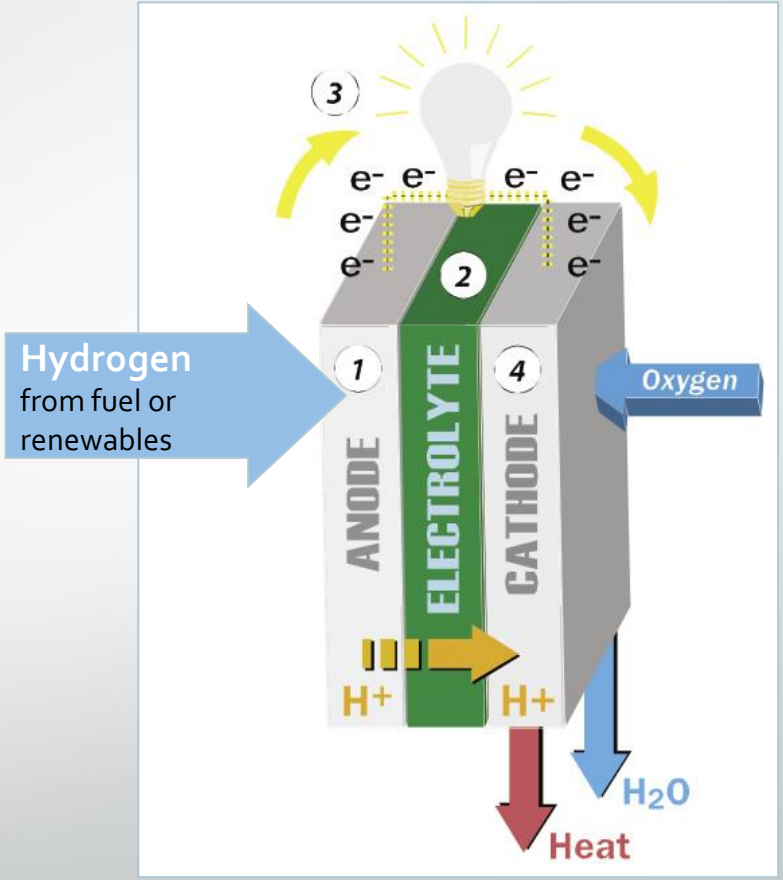
Generates electricity and heat through an electrochemical process using oxygen and natural gas, waste biogas, or hydrogen from renewable sources.

Advantages

- Electrical efficiencies between 40 to 60% (higher than combustion-based systems)
- Less CO_2 emissions
- Can be used to store excess energy from renewable sources

Disadvantages

- Most use natural gas and fuel
- High cost
- Susceptible to corrosion



(Center for Climate & Energy Solutions)

Microturbines

Small turbines fueled by natural gas, hydrogen, propane, or diesel

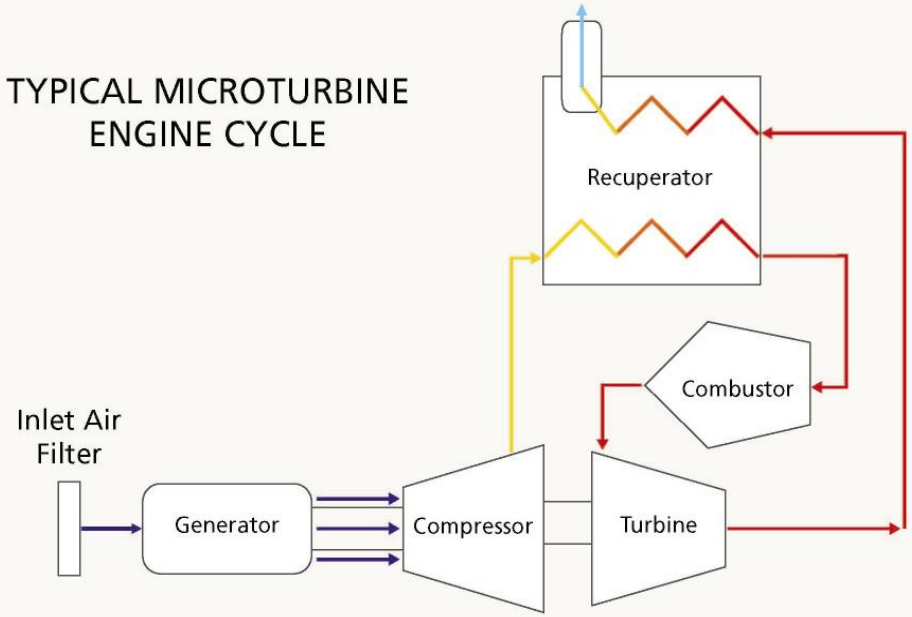
Advantages

- Higher efficiency when integrated with cogeneration system
- Compact size
- Long maintenance intervals

Disadvantages

- Parasitic load loss
- Loss of output and efficiency at high temperature and elevation

Schematic of Microturbine System with Cogeneration Configuration



(Capstone Turbine Corporation)

Recuperators capture waste heat from turbine to be reused to heat gases in the combustor produce energy.

San Diego's diverse resources allows us to integrate a broad range of resilient energy solutions. But they need the help of…

- *Local governments*
- *Federal programs*
- *Partnerships with local utilities*
- *Financial Institutions*
- *Homeowners*

Los Vecinos, San Diego's 1st LEED-certified Platinum, 100% solar-powered affordable housing.

Stay tuned to learn about energy in other sectors!

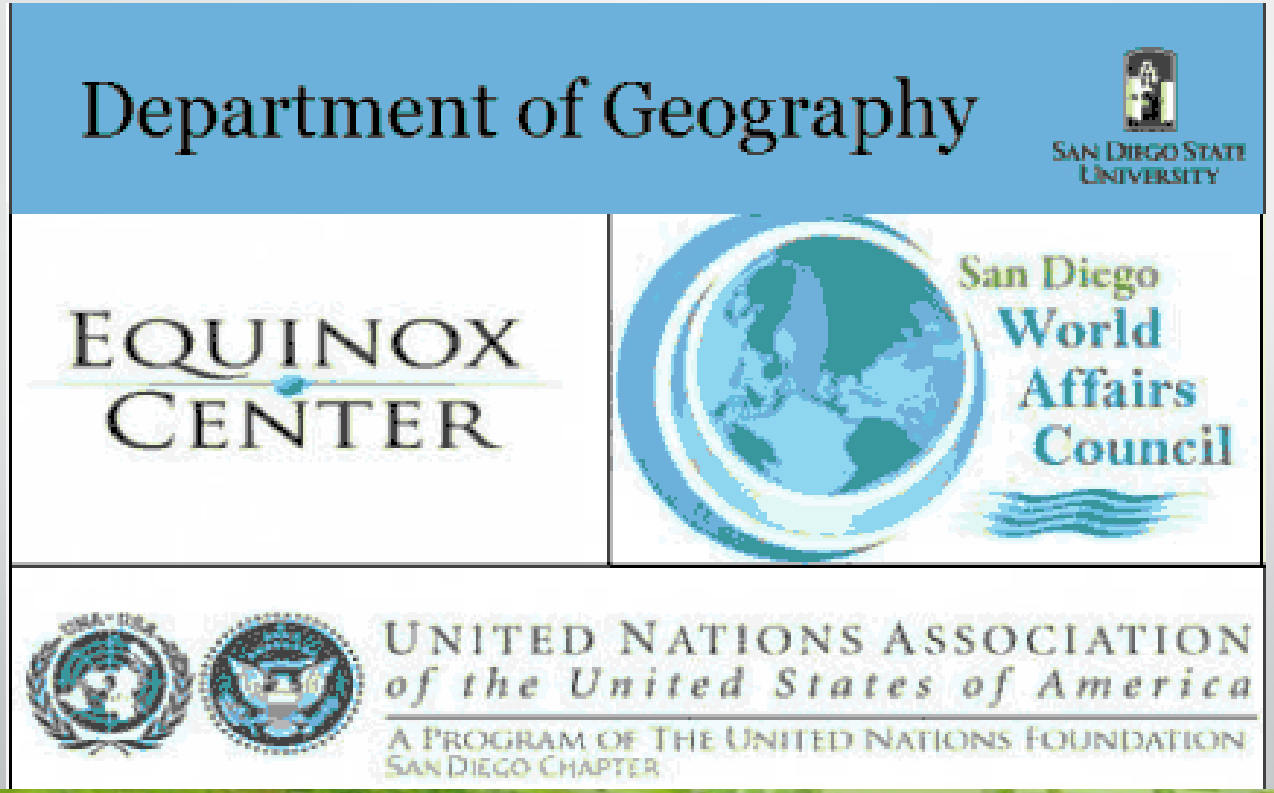
- Transportation – July 17
- Agriculture & Food – July 24
- Waste – July 31

Host & Sponsors

Hosted by:

Sponsored by:

Partners


Department of Geography
San Diego State University
EQUINOX CENTER
San Diego World Affairs Council
UNITED NATIONS ASSOCIATION of the United States of America
A Program of The United Nations Foundation
San Diego Chapter

Further Information

Contact Information

- Cameron Bernhardt: cbernhardt15@cmc.edu
- Amy Syvrud: ajs8at@virginia.edu
- Byron To: byronktoby@gmail.com
- Aly Zamora: zamoraa@sandiego.edu