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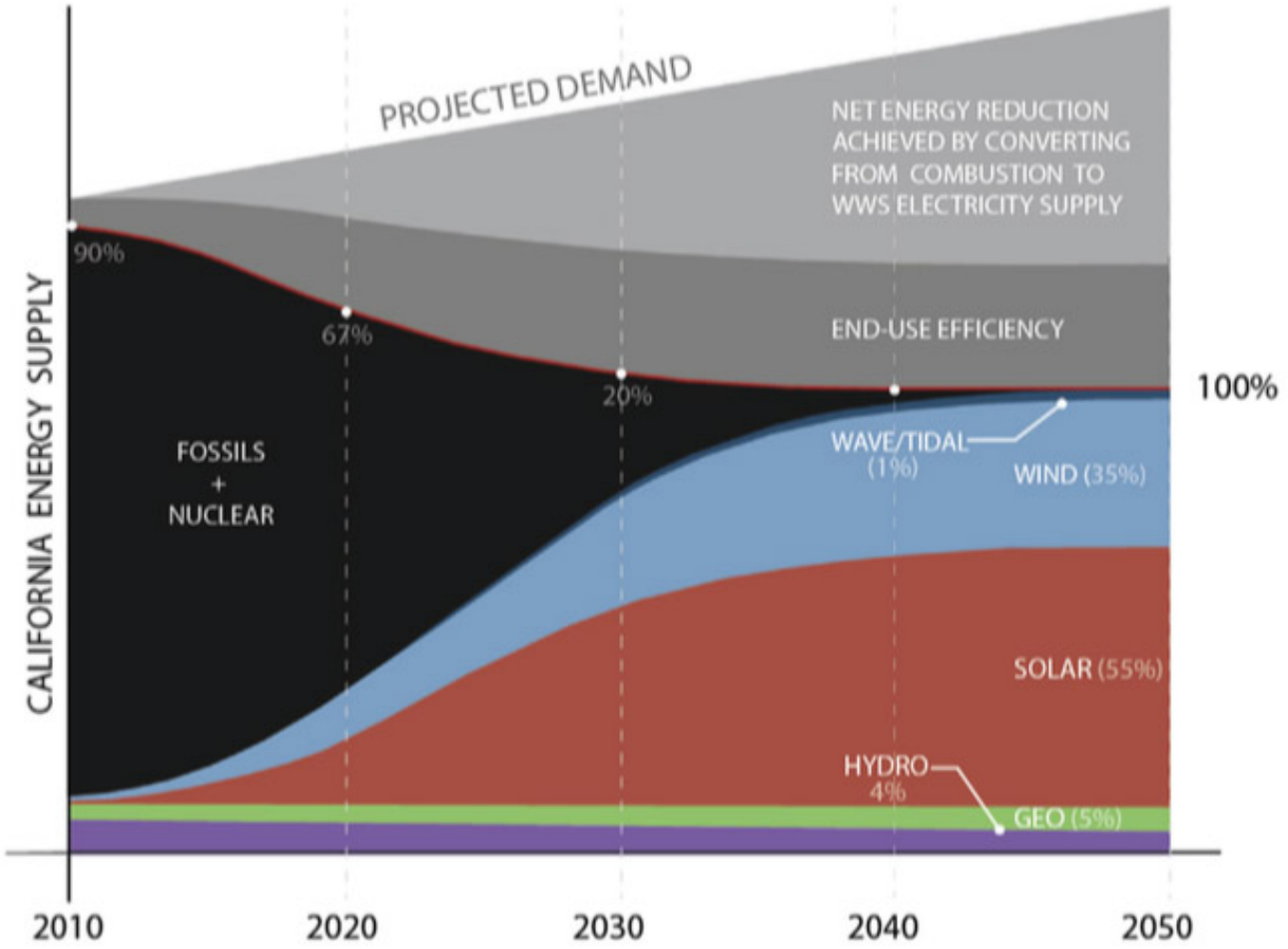
ENVS 119 - Energy & the Environment
12 - Wind Power

Today

- Mid-term comments
- Assign. #4 Q/A
- Wind and the West
- Wind comes from?
- CA wind capacity
- Demo and Wrap-up

CA Energy Revolution
Wind + Solar + Conservation



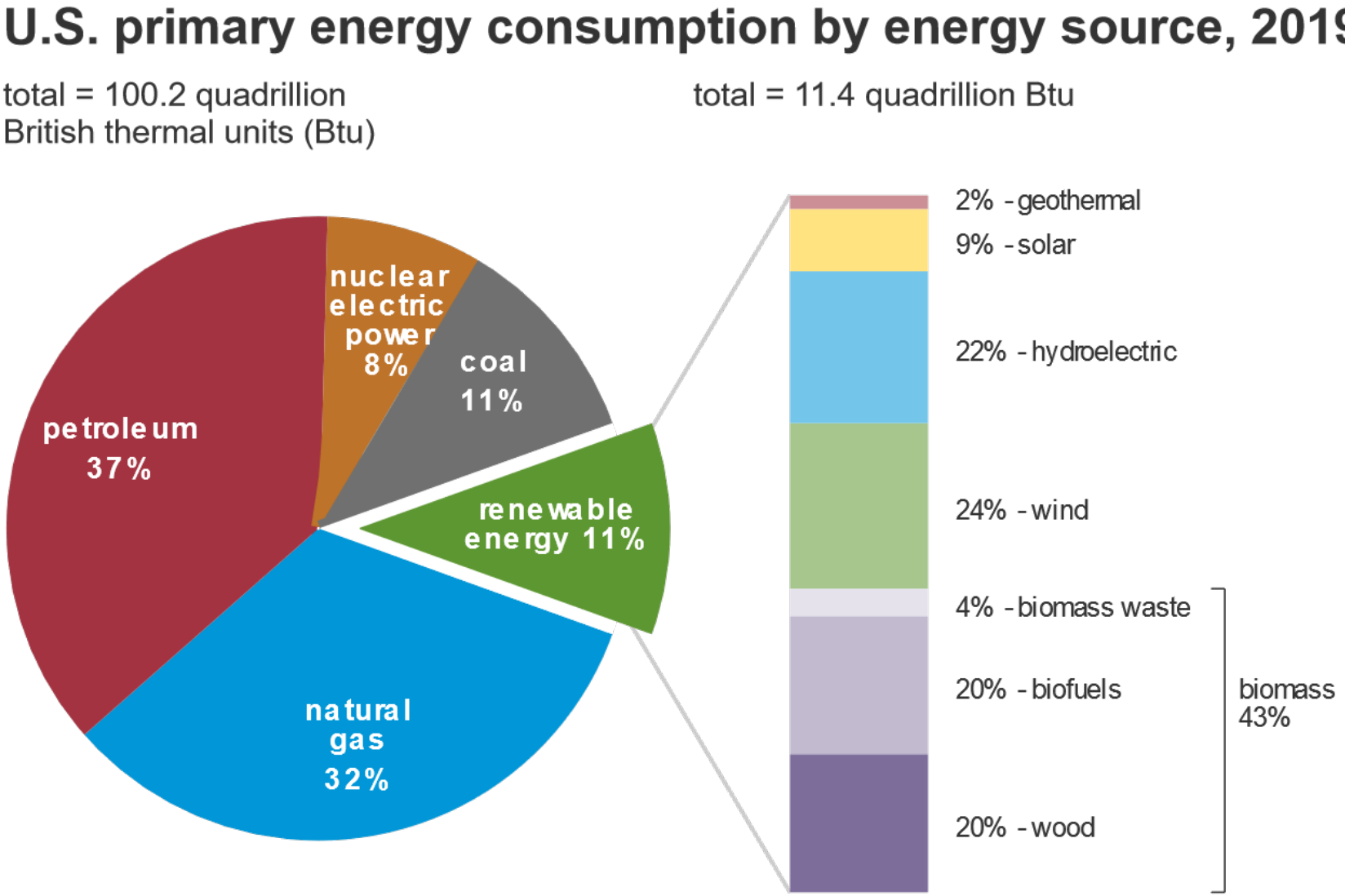
A roadmap for repowering California for all purposes with wind, water, and sunlight, 2014, Stanford

Where does the wind energy come from?

- Solar energy drives temperature differences,
- Kinetic energy of Earth's rotation drives Coriolis forces that affect prevailing winds
- 1% of solar energy becomes kinetic energy of wind: globally 2 PW (petawatts),
- Potential = ~100x human power consumption (in the US >100% of all electricity)

Wind energy (US) = 24% of renewables

U.S. primary energy consumption by energy source, 2019

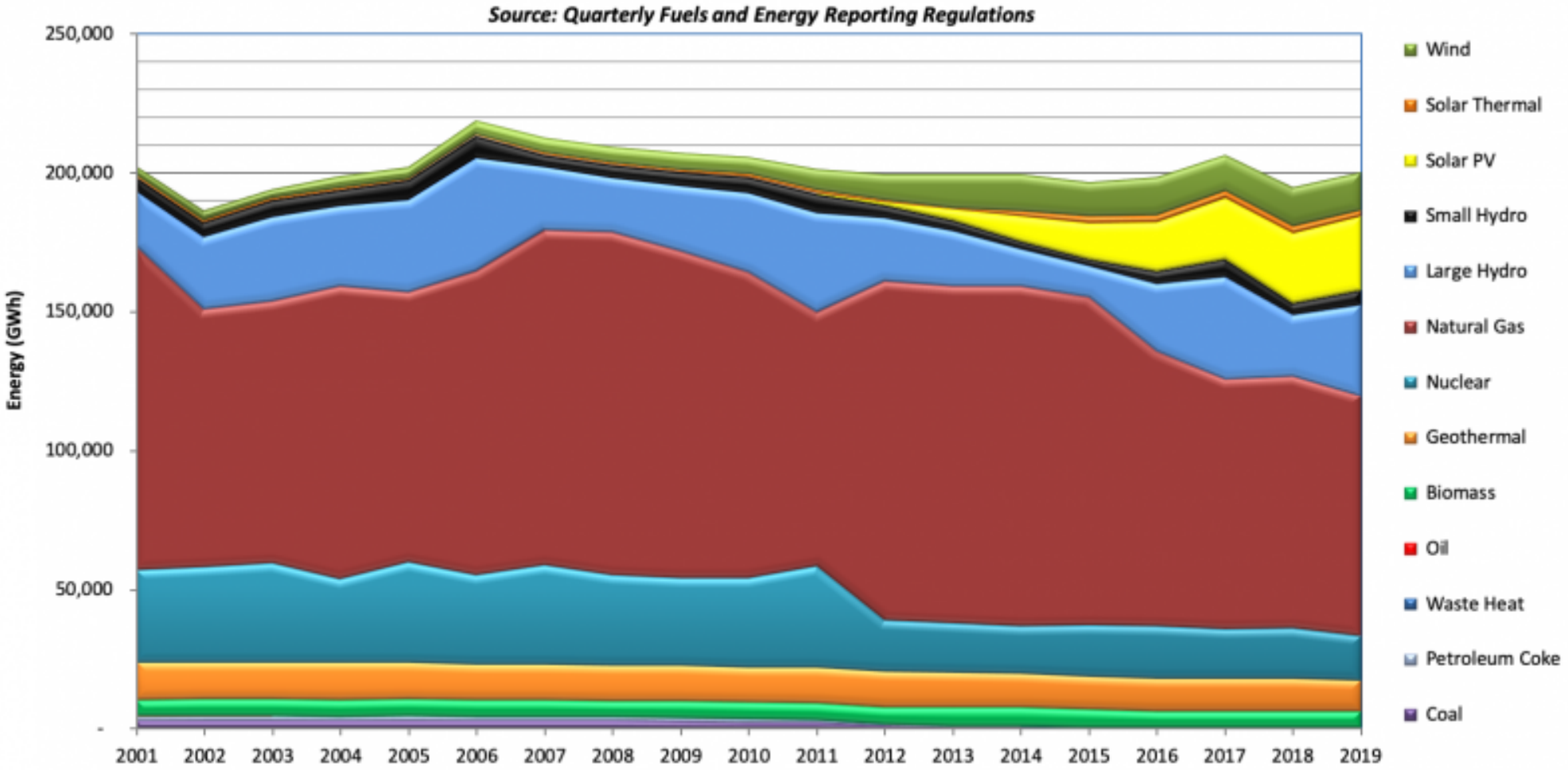


Note: Sum of components may not equal 100% because of independent rounding.
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2020, preliminary data

Demo - mini-wind Turbine

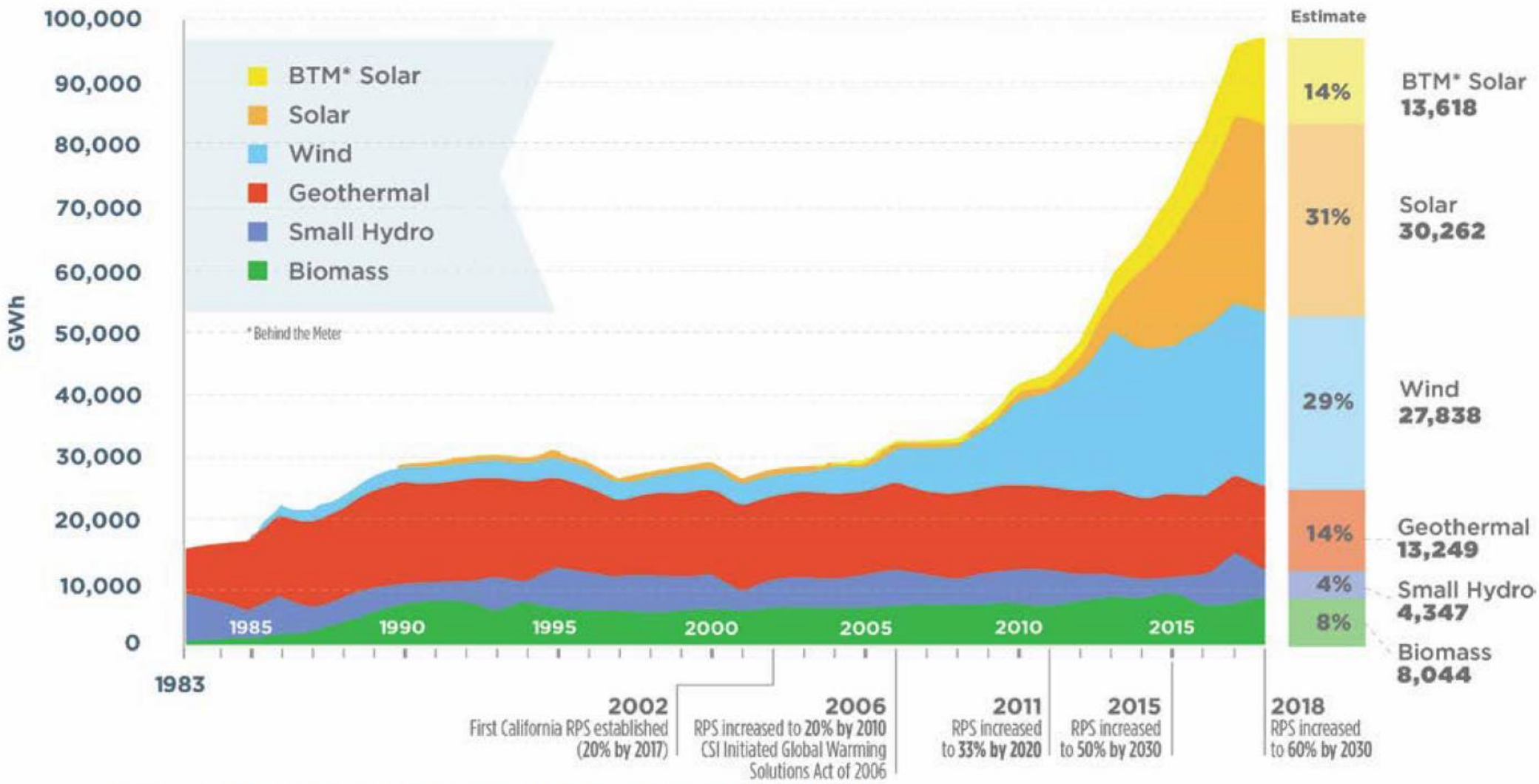
© Benoit Delaveau - Thames & Kosmos Wind Power Science Kit

In-State (CA) Electric Generation



Source: California Energy Commission 2020
https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/electric-generation-capacity-and-energy

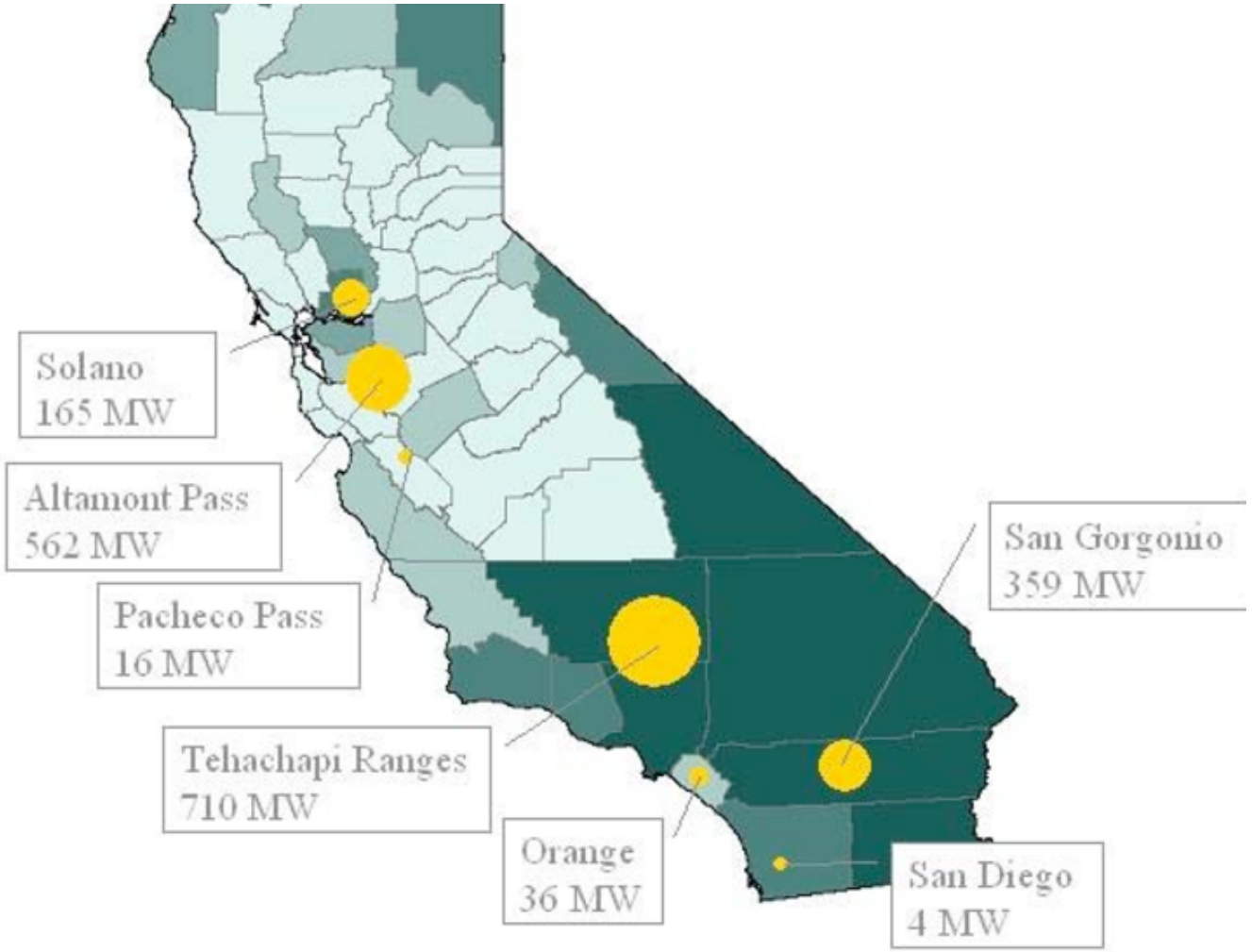
CA Renewables is Booming!



Source: California Energy Commission, staff analysis November 2018

CA Wind on Land

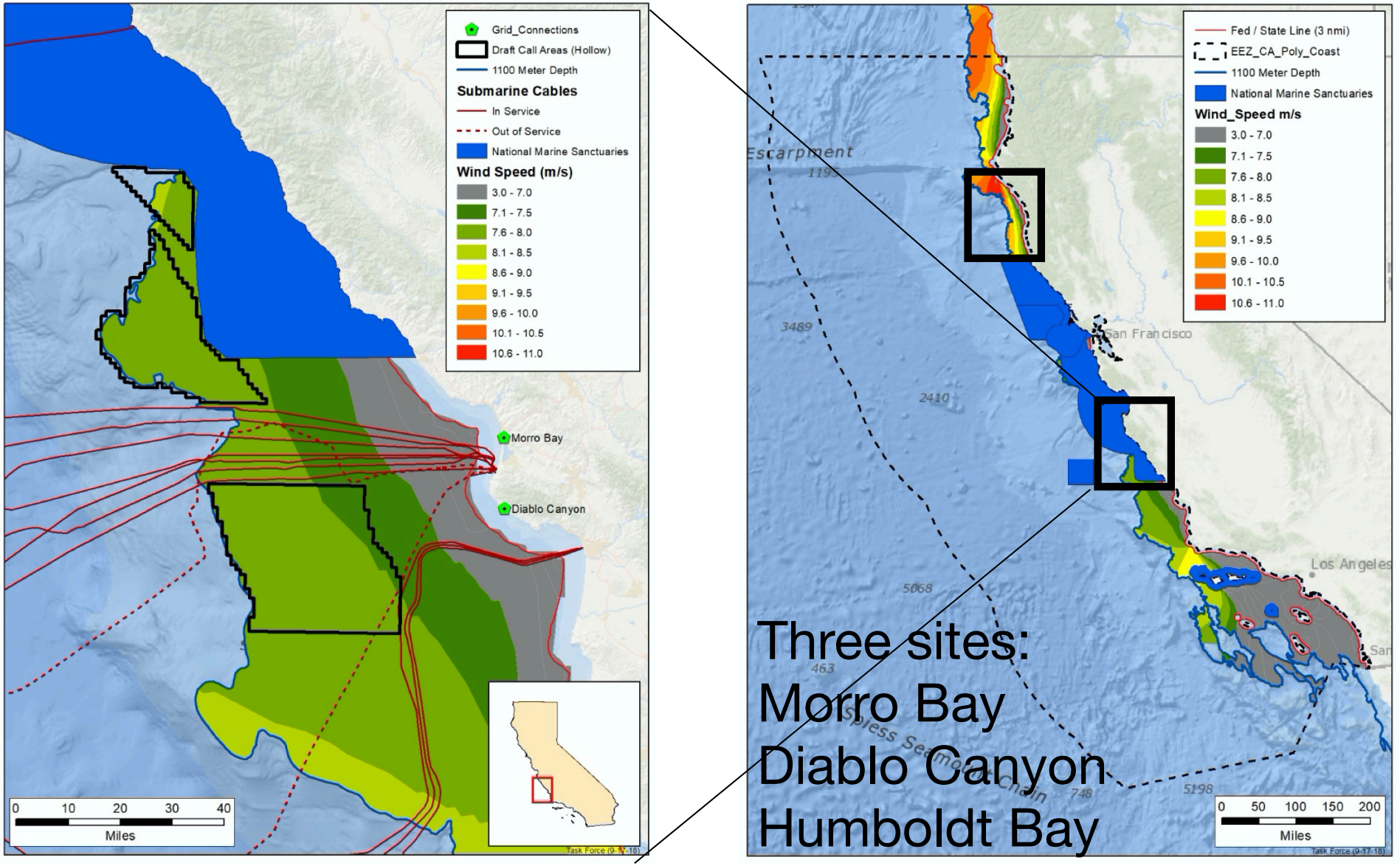
Updated Capacity (2019)
Altamont Pass (330 MW)
Imperial County (264 MW)
Pacheco Pass (17 MW)
San Diego (181 MW)
San Gorgonio Pass (655 MW)
Shasta County (101 MW)
Solano County (1,028 MW)
Tehachapi Pass (2,925 MW)
Commercial & Industrial Installations (34 MW)
Total : 5,535 (MW or 5.5 GW)



Source: Data compiled by CalWEA from the U.S. Wind Turbine Database. See https://eerscmap.usgs.gov/uswtdb/ 2019

Source: STRATEGIC VALUE ANALYSIS - ECONOMICS OF WIND ENERGY IN CALIFORNIA
D. Yen-Nakafuji, 2005

CA Wind Potential Offshore = +16 GW by 2030



Source: Bureau of Ocean Energy Management, Pacific Renewable Energy Activities , 2018

Wind Power Math

Power varies with the cube of wind speed
If wind speed doubles, it has 2x2x2 = 8 times the power

$$P\ (\text{Watt}) = \mathbf{0.5} \times \boldsymbol{\rho} \times \mathbf{C_p} \times \mathbf{v^3} \times \mathbf{A_S}$$

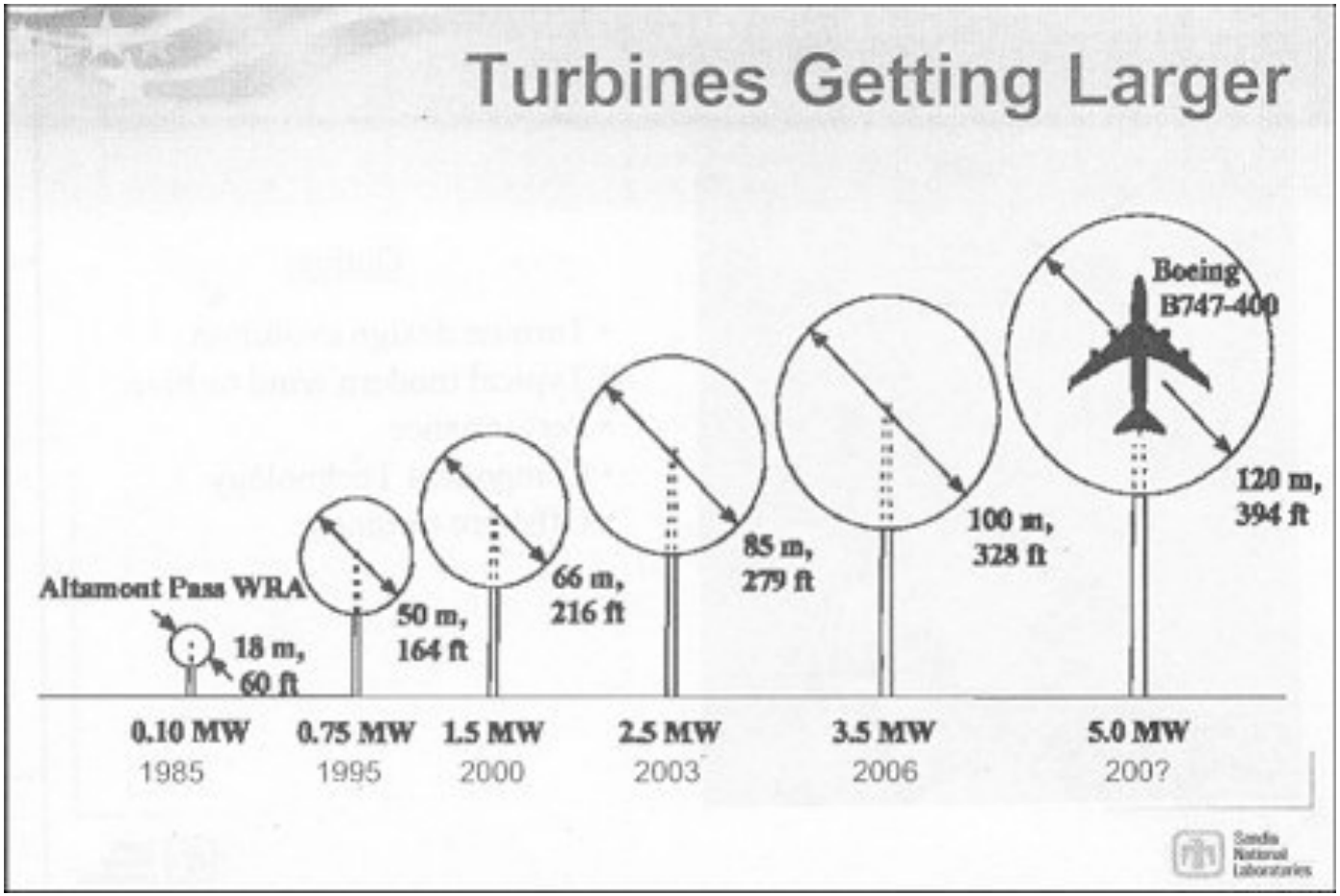
ρ: 1.2 kg/m^3 High density air results in more power (lower altitude and temperature)

Cp: efficiency coefficient, no units, Betz limit ≈0.593 usually between .4 and .5

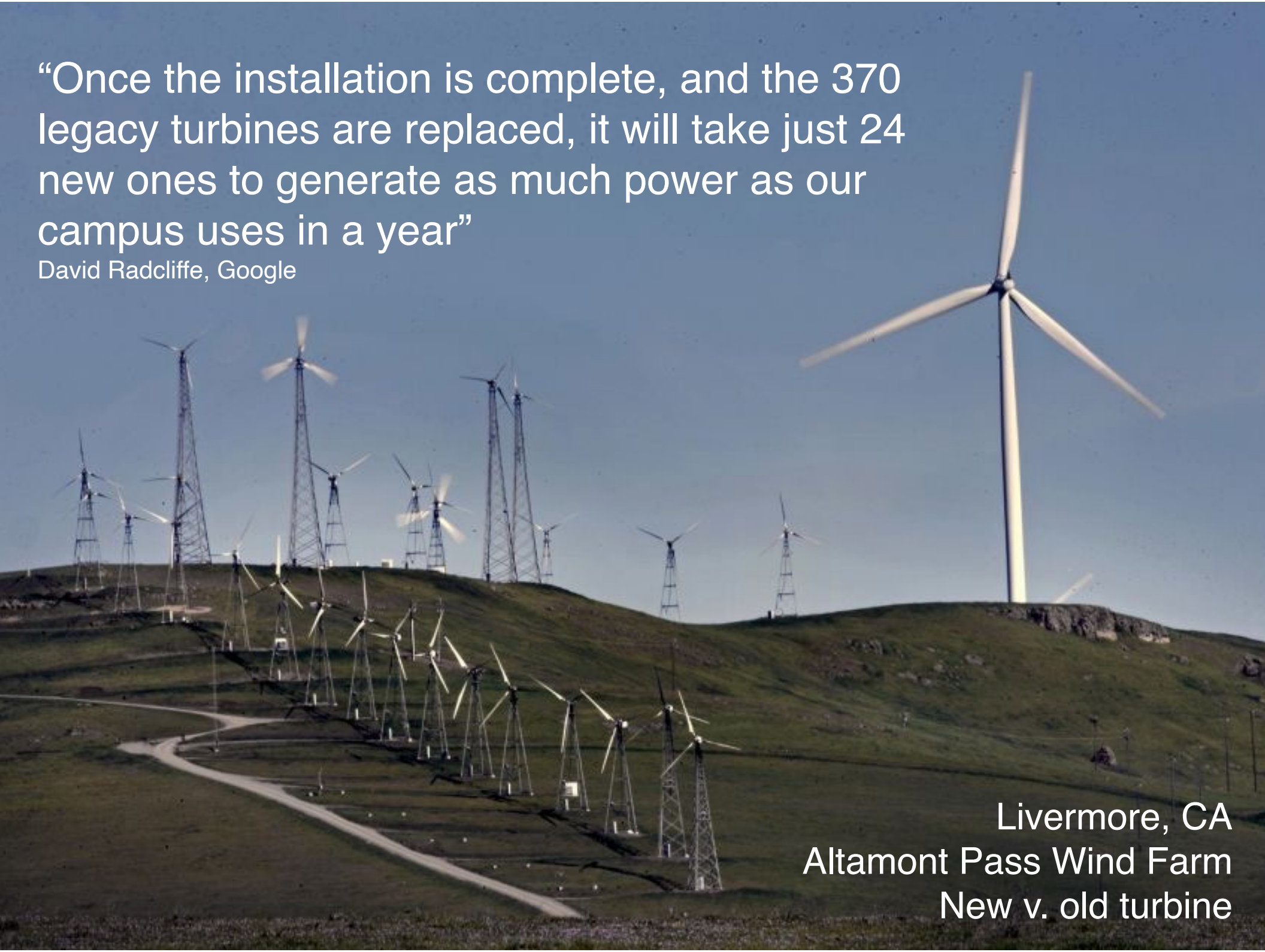
V^3: meter per second: Doubling of the wind speed results in an 8 fold increase in power

A_S: m^2, area swept by blade; slight increase in blade length, increases the area greatly ($A = \pi r^2$)

Wind Turbine (Larger = Cheaper electricity)



Enercon E-126 Emden, Germany 413 foot diameter 7 MW
20 million kWh/year - $2M /year of revenues


“Once the installation is complete, and the 370 legacy turbines are replaced, it will take just 24 new ones to generate as much power as our campus uses in a year”
David Radcliffe, Google
Livermore, CA
Altamont Pass Wind Farm
New v. old turbine

Wind Issues

- Social issues: **“not in my back yard”** - *...strong, consistent support for renewable energy, but widespread local resistance to siting renewable energy projects.*
- Problem of **intermittency** (better storage or more robust transmission -grid- needed)
- Landscape context, aesthetics,
- Birds mortality, habitat loss
- Impact on commercial resources (e.g., fishing, tourism)