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**ENERGY FOR
GROWTH HUB**

CONNECTING
THE WORLD TO
A HIGH-ENERGY
FUTURE

**Carnegie
Mellon
University**

Emerging Nuclear

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Emerging Nuclear Technologies

- Over 50 companies in US working to commercialize advanced nuclear reactors.
- In general: much smaller, modular fabrication, non-water coolant. Also floating and offshore designs.



Generation Characteristics

- Zero emissions when operating. Very low life-cycle emissions, similar to wind.
- Significantly less water consumption, or no water consumption for some designs.
- Ramping & Load-Following: Currently 5%/minute, new designs will be better.
- Can provide frequency regulation, operating reserves, blackstart capabilities. Hard to get with other low-carbon options.

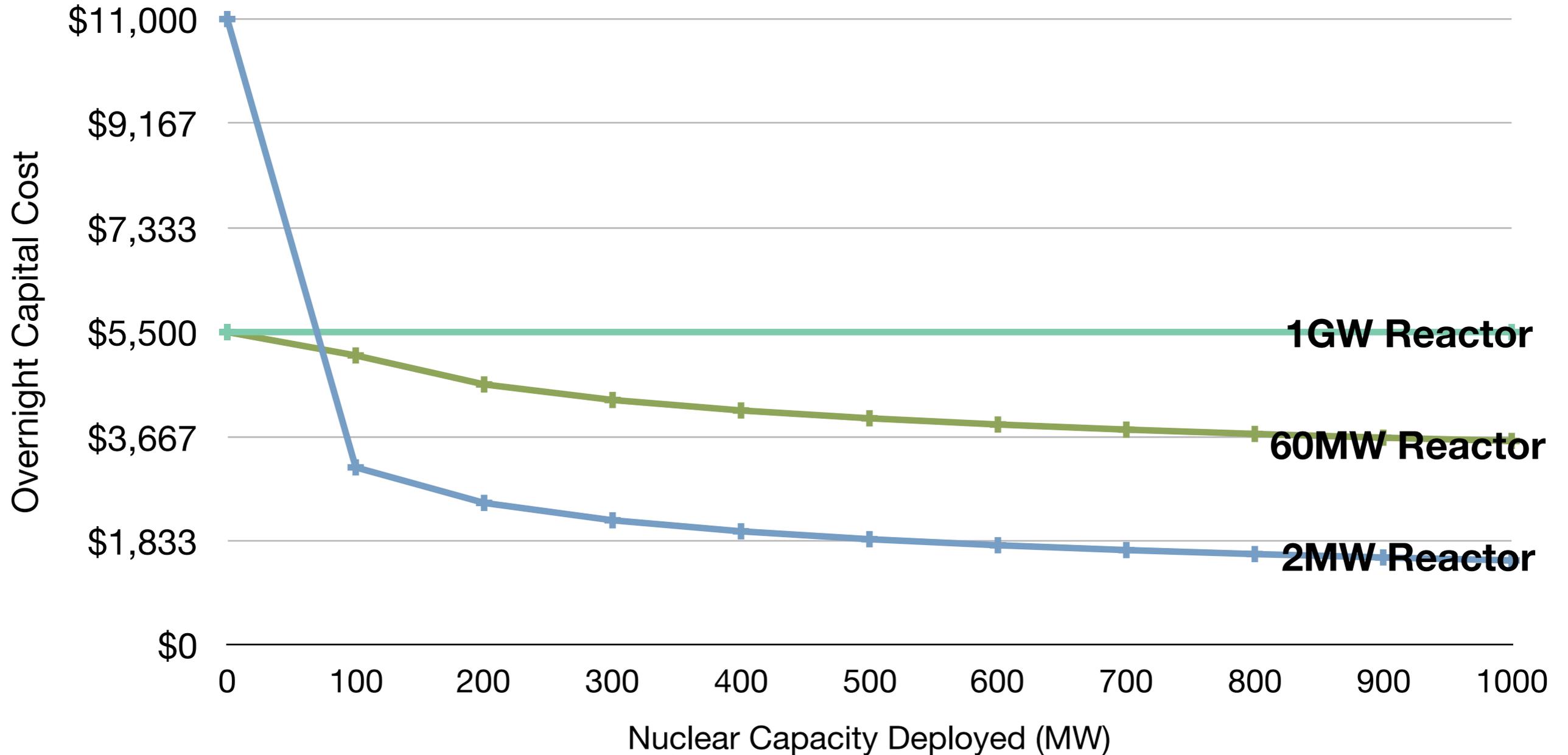
Jenkins et al. "The benefits of nuclear flexibility in power system operations with renewable energy." *Appl. Energy* 222, 872–884 (2018).

Potential Market

- Diablo Canyon will close by 2025 (maybe keep it open?)
- New nuclear aiming to be cost-competitive with natural gas.
- California will consume ~420TWh electricity annually by 2045, 40% can be from non-renewables low-carbon generators = 168 TWh or ~10 Diablo Canyons
- Non-electric uses: industrial applications, desalination, hydrogen production.

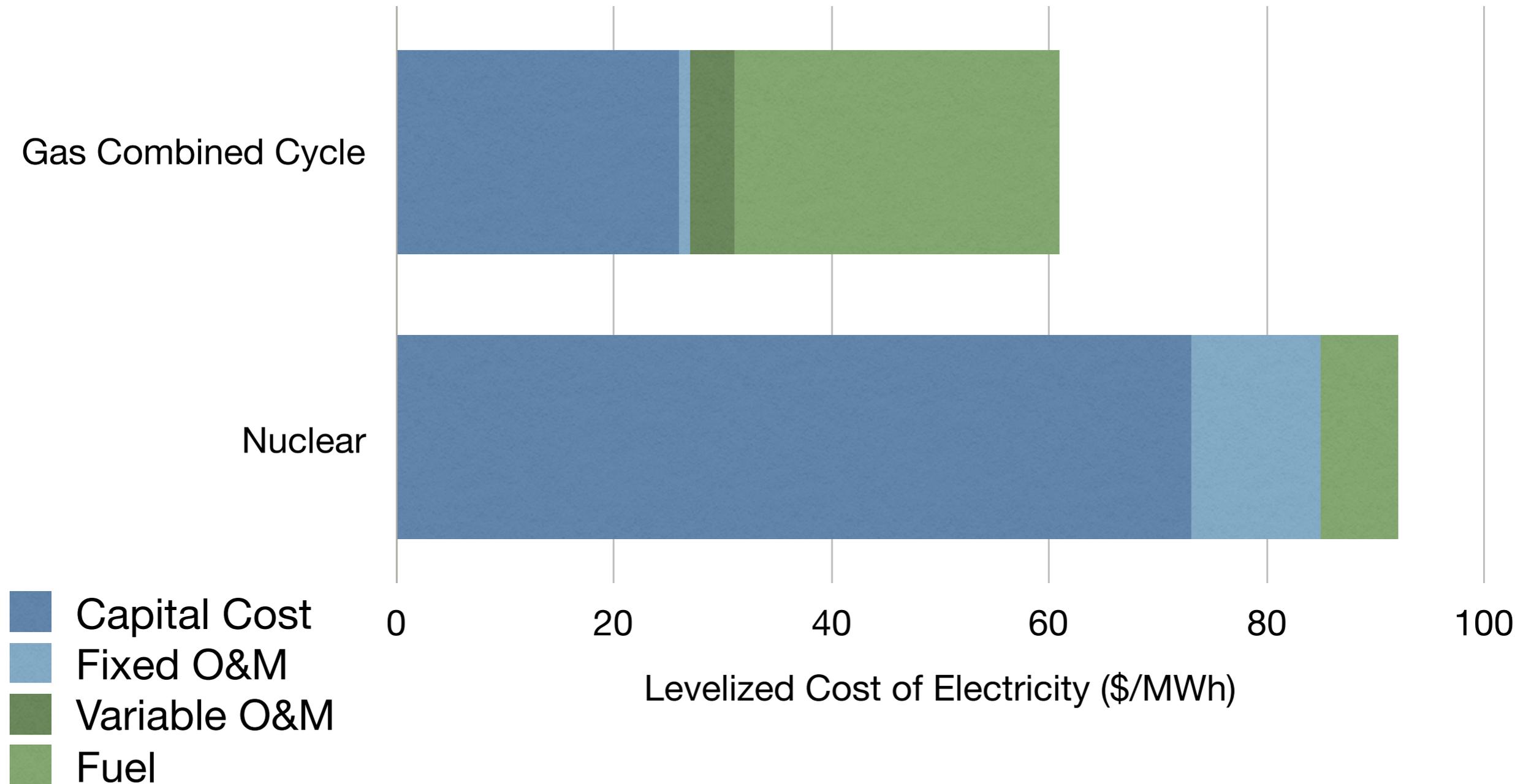


Cost Trends



Lovering, J. R., Yip, A. & Nordhaus, T. Historical construction costs of global nuclear power reactors. *Energy Policy* **91**, (2016).

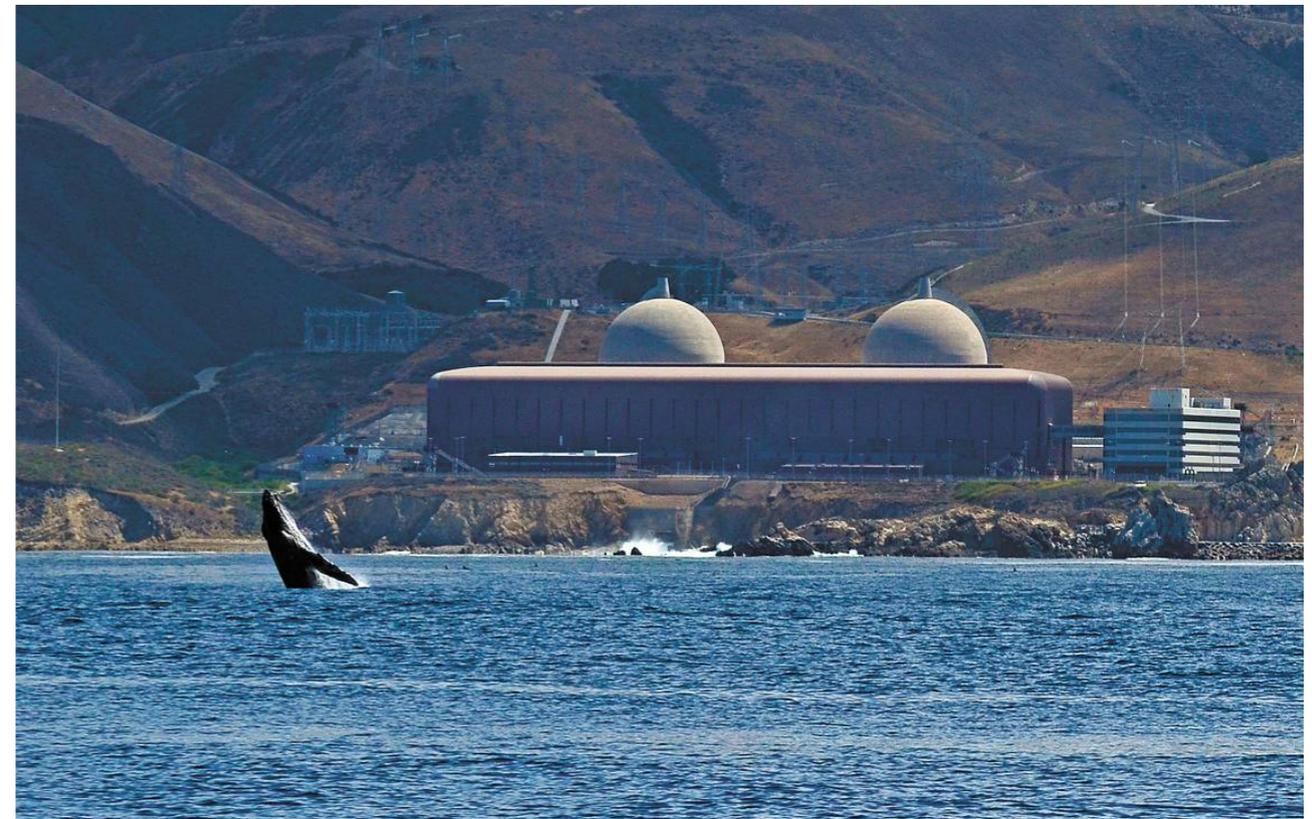
Fixed vs. Variable Costs



Data from: Lazard (2014) "Lazard's Levelized Cost of Energy Analysis – Version 8.0"

Major Challenges

- Cost & Financing
- Not valued as low-carbon
- California's ban on new nuclear
- Lack of regulatory model for private and industrial owner/operators



Policy Recommendations

- Remove ban.
- Technology-neutral incentives for low-carbon energy: clean energy standards, state-supported loans, tax credits, etc.
- Develop pilot program for industrial and commercial ownership of microreactors.
- Streamline approval for new nuclear on brownfield sites.
- Study role of nuclear-renewable hybrid systems.

Closing Thought: Land Use Intensity of Energy

