Abstract

Issued in 2018, Executive Order B-55-18 mandates a 40% reduction in greenhouse gas emissions from the 1990 levels by 2030, with the goal of achieving carbon neutrality by 2045. But, California is falling short of meeting these targets. To address this, local governments must intensify their efforts by generating sufficient renewable energy to match their consumption. This paper proposes a model for establishing an energy community in Bolinas, California, by advancing existing frameworks and integrating Elinor Ostrom's principles of self-governance. The analysis also explores local consumption and production trends within the broader context of California's utility renewable production to estimate necessary infrastructure capacity solutions.

Table of Contents

Introduction

Elinor Ostrom, in her work *Governing the Commons*, poignantly notes, "Hardly a week goes by without a major news story about the threatened destruction of a valuable natural resource." This observation is particularly resonant when considering the largest tragedy of the commons: global warming. Primarily fueled by greenhouse gas emissions from energy use, neither government regulations nor market mechanisms have done enough to fully transition to clean energy. California, a state known for its environmental activism, is not on target to meet its emissions reduction goals (Petersen). Localizing the issue of climate change and leveraging historically proven self-governance systems can more effectively reduce emissions from energy consumption compared to traditional governmental and private sector interventions.

Mancur Olson describes in *The Logic of Collective Action* that the larger the group, the less it will further its common interest. This theory explains why international cooperation to combat global warming has been so unsuccessful (Harris). However, Olson acknowledges that collective action is related to how noticeable each person's actions are. Making the problem more actionable to the individual by encouraging local level solutions bridges the gap between the abstract reality of climate change and meaningful progress (King). The viability of this method is supported by the fact that local governments have authority or important influence over roughly 35 percent of California's GHG reduction potential (Boswell) (Kammen et al.).

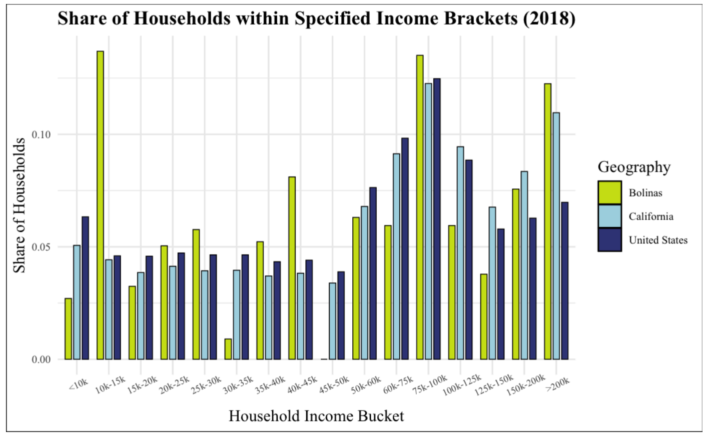
Localized action requires a framework to manage and deploy community resources. Ostrom developed a theory of this management approach through empirical studies of existing self-governance systems. Sethi and Somanathan explored how self-governance entails community-driven methods where locals organize systems to manage scarce resources effectively. Moreover, scholars such as Olsson and Folke have observed that self-governance often evolves in response to crises in resource availability, a principle applicable to the urgent need to reduce energy emissions. Traditionally viewed as a system with minimal state intervention, the government can play a significant role in enabling self-governance. In early 20th-century Japan, for instance, state legislation encouraged the development of self-governance systems (Sarker et al.).

This solution is critically dependent on its global dissemination. Therefore, providing a replicable model for locally reducing emissions by generating enough renewable energy to meet local energy consumption needs through self-governance is of paramount importance.

I — Bolinas

Bolinas, California is an unincorporated coastal community located in West Marin, surrounded by national parks like Muir Woods and Point Reyes National Seashore. Bolinas has a long history of grassroots environmentalism — it waged a successful campaign to control development through a moratorium on new water meters and organized efforts to clean up the 1971 oil spill, all without a mayor or a city hall (Brown). At the heart of the *Bolinas Community Plan* is the guiding principle: "What we can do for ourselves will more likely get done." This sentiment mirrors this study's exploration of local action and self-governance as a path to curtail emissions from energy use. Consequently, Bolinas represents an exemplary model for studying the institution of energy communities.

Bolinas can provide valuable lessons for statewide policy evaluation. Its economic diversity, reflected in both the income distribution and the variety of industries—including agricultural, artisanal, and technology sectors—mirrors the state of California's. This similarity allows us to analyze the impact of historical policies and predict the effects of future ones. Additionally, Bolinas's small population of 1,280 allows for complete data collection, avoiding the need for complex sampling methods like random sampling. In addition, its geographical isolation, in effect, serves as a controlled environment for testing policies with minimal external influences.



However, despite these advantages, many unique characteristics of Bolinas—such as its older and less racially diverse population, history of environmental activism, predominantly left-leaning electorate, and unincorporated status—limit the generalizability of findings. Nonetheless, Bolinas and its residents do not exist in a vacuum. They are full participants in the statewide shifts and policies affecting California, face many of the same problems as other communities, and are aware of the solutions that others have proposed or implemented. While the insights from Bolinas provide valuable perspectives that could inform statewide strategies, applying these lessons more broadly requires thorough and cautious evaluation to ensure their relevance and effectiveness.

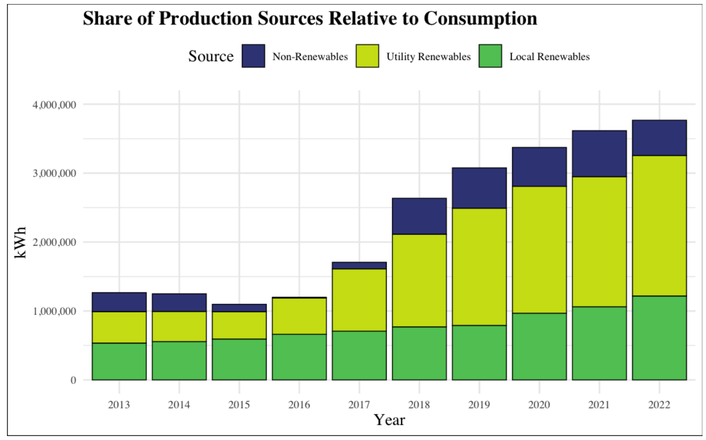
II — Energy Communities

Energy communities (ECs) involve local groups generating, managing, and distributing renewable energy tailored to their specific needs. Individuals engage in ECs most frequently due to either gain, such as reducing energy costs, or normative considerations, such as addressing climate change (Dóci & Vasileiadou). ECs represent a shift from a centralized electricity system, dominated by vertically integrated monopolies, to a more decentralized and democratized model (Dincer and Abu-Rayash). One example of such a framework is provided by the European Union (EU), which defines ECs as legal entities actively involved in various stages of the energy supply chain, based on the voluntary participation of their members or shareholders (Lode et al.). As participants in the EU's internal electricity market, ECs compete with traditional utilities, leading to efficiency gains, competitive prices, and enhanced service standards (Regulation (EU) 2019/943).

As outlined in a report from the Institute for Local Self-Reliance, the benefits of ECs are categorized into four themes: renewable energy, distributed generation, community scale, and local ownership. Renewable energy provides price certainty and offers health advantages to local residents. Distributed generation minimizes transmission costs and losses and promotes resilience during larger grid failures. Community scale strikes a balance in the economies of scale challenge in power generation and enables a more equitable transition. Local ownership generates economic benefits within the host community and reduces the concentration of political and economic power in the electricity sector.

III — Descriptive Statistics

To match Bolinas's electricity consumption entirely with local renewable electricity production, 2,490,157 kWh of additional production was needed in 2023. When considering the average share of renewables in California's utilities, 511,362 kWh of additional production is needed in 2022. Sorting for Bolinas's zipcode, production and consumption data are collected from [California Distributed Generation Statistics] and [Pacific Gas and Electric Company Energy Data Request-Public Data Sets] respectively.



Utility data is determined through to the California Energy Commission's power content labels. The following figure shows the interplay of consumption, production, and utility trends between 2013 and 2022 as the power content labels for 2023 have not been released yet.

IV — Capacity Solutions

Below are the scales of several capacity solutions for the Bolinas community to consider. The scope of developing local clean energy infrastructure is bounded by the third goal of the *Bolinas Community Plan*, which states: "The expansion or addition of public utilities should correlate with the growth rates projected by the plan."

Solution 1: Matching Total Local Consumption

The total electricity consumption in 2023 was 3,869,824 kWh, or around 3.87 GWh. Matching this would ensure that Bolinas is entirely self-sufficient in its energy supply. A single 1.5 MW turbine is estimated to generate 498.9 MWh, or around 4,989,000 kWh annually.

	Land Use	**System Requirements**	**Cost**
Wind	127.9 acres	Single 1.5 MW Turbine	Installation: $4,905,000 Maintenance: $58,500/yr

Solution 2: Addressing the Non-Local Consumption Gap

This approach involves generating all electricity from locally produced renewable sources to match the annual non-local consumption gap of 2,490,157 kWh, or around 2.49 GWh. This would ensure that Bolinas electricity consumption is entirely sourced from local renewables.

	Land Use	**System Requirements**	**Cost**
Solar	11.75 acres	Ground-mounted, 1-axis tracking, 1,362.2 kWp	Installation: $2.043 million Maintenance: $23,440/yr

	Land Use	System Requirements	Cost
Wind	76.77 acres	Nine 100 kW Commercial Turbines	Installation: $5.694 million Maintenance: $35,100/yr

Solution 3: Offsetting the Non-Renewable Consumption Gap

By targeting the annual non-renewable consumption gap of 511,362 kWh, or around 0.5 GWh, this strategy would not ensure that the energy supplied by Pacific Gas and Electric Company to Bolinas is 100% renewable. However, it would mean that an equivalent amount of consumption would be offset within California's larger grid, contributing to statewide renewable goals.

	Land Use	System Requirements	Cost
Solar	2.36 acres	Ground-mounted, 1-axis tracking, 279.74 kWp	Installation: $534,303 Maintenance: $4,814.33/yr
Wind	17.06 acres	Two 100 kW Commercial Turbines	Installation: $1.265 million Maintenance: $7,800/yr

Solution 4: Generating Excess Renewable Energy

This scenario supposes Bolinas also generates power for neighboring communities. A single utility turbine is estimated to annually generate 13,530 MWh, or around 13,530,000 kWh.

	Land Use	System Requirements	Cost
Wind	281.4 acres	Single 3.3 MW Utility Scale Turbine	Installation: $5,775,000 Maintenance: $135,300/yr

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V — Existing Support

The move to institute an energy community for Bolinas is supported by preexisting legal frameworks, local and regional politics, and grid infrastructure.

The legal framework is established by the California Public Utilities Act of 1913, which recognizes the Bolinas Community Public Utility District (BCPUD) as a publicly owned utility (POU) with the authority to govern water, sewer, solid waste, drainage, and parks and recreation services. Most POUs also provide electricity to their regions through local governance, overseeing the generation and purchase of electricity, the distribution of electricity over power lines to their communities, and the implementation of local energy efficiency and renewable energy programs. POUs are not-for-profit, so POU electric rates are about 18 percent lower on average than other electric utility rates (California Municipal Utilities Association). For example, the Trinity Public Utilities District (TPUD) delivers 100% carbon-free electricity to its customers through its hydroelectric dam at the lowest electric rates in the State, keeping more than $7 million annually in our local economy and investing over $3 million a year in local labor (Trinity Public Utilities District). BCPUD is well-positioned to broaden its services to include electrical utilities.

The expansion of BCPUD services to include electrical utilities aligns with local politics in the *Bolinas Community Plan*, which advocates for the integration of alternative energy sources to fulfill Bolinas's self-sufficiency and independence goals. The plan also emphasizes that limiting human impact on the environment is one of its most crucial objectives, stating that "protecting the environment—including plant and animal wildlife as well as the landscape—is more than a legal duty under the Environmental Protection Act." Synthesizing these objectives requires conservation measures to mitigate the disturbances caused by developing clean energy infrastructure on the local environment. As such, the plan highlights potential sites on the Bolinas peninsula suitable for energy production, contingent on the infrastructure not adversely affecting other natural or man-made systems. For example, the "Sewer Pond Property" could be leased from BCPUD, which could enhance land use efficiency.

County and state-level support also exists for developing the generation infrastructure necessary for Bolinas as an energy community. The Marin County Civil Grand Jury, citing Pacific Gas and Electric Company's (PG&E) unreliable[1] electric transmission infrastructure, recommended the establishment of microgrids in western Marin by 2024 to enhance resilience against power outages (Halstead). Identifying stressors such as climate change and electrification, the jury designated western Marin as a priority area for pilot microgrids due to its status as a particularly disadvantaged community. Marin Clean Energy (MCE), a community choice aggregator in Marin County, can assist[2] in developing this infrastructure due to its expertise, stakeholder relationships, and significant funding for similar initiatives. Moreover, in 2021, the California Public Utilities Commission (CPUC) allocated $200 million for a statewide microgrid incentive program, aimed at supporting vulnerable communities affected by grid outages and testing new technologies or regulatory approaches to guide future actions (Decision 23-04-034).

Foundational grid infrastructure to support this transition exists in Bolinas, from a substation that steps down high-voltage electricity to distribution-friendly levels, to power lines that deliver electricity to local consumers. This infrastructure is owned by PG&E, but can be acquired by community members for local governance through negotiations with PG&E and obtaining CPUC approval. There is precedent for this in TPUD, which negotiated the $600,000 purchase of PG&E facilities in 1989 (Trinity Public Utilities District). PG&E has previously considered attaching a generator to the Bolinas substation to mitigate electricity interruptions from the main grid during power shutdowns (Halstead). Thus, acquiring the grid infrastructure and permanently generating power from locally produced renewable energy sources is feasible.

VI — New Governance Structure

Incorporating Elinor Ostrom's principles of self-governance into Bolinas as an energy community takes the existing frameworks a step further by providing a structured, step-by-step approach to managing local energy production. Here's how her eight principles can be integrated to instituting an energy community in Bolinas:

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[1] Due to the degradation of aging power lines and increased frequency of climate events such as wildfires, storms, and heatwaves, etc.

[2] MCE notably has a $9 million resiliency fund for customer-owned solar and storage installations, a $750,000 grant for microgrids at critical facilities, and $500,000 in federal funding for energy storage. Dana Armanino, Marin County's senior sustainability planner, said that MCE might be better positioned than the county to lead local microgrid development. Jackie Nunez, an MCE spokeswoman, says that MCE is already providing technical support and funding to create microgrids at five sites in western Marin, including a school, a community center, a health center, and a fire station.

1. *Clearly defined geographical and resource boundaries* reduce confusion and conflict, streamlining community resource management. Participant boundaries should extend to members within the BCPUD. Specify which infrastructural components—including generators, transmission lines, and battery storage—are under local ownership.
2. *Local governance must adapt* to environmental, economic, and social contexts. Environmental strategies must optimize underutilized spaces to minimize ecological impact and consider Bolinas's geographic characteristics to maximize production efficiency. Economic rules should facilitate equitable installation and maintenance cost distributions, incorporating models like scaled financing[3] or Pay-As-You-Save[4] (PAYS) programs for lower-income residents. Social processes must be inclusive in order to encourage widespread community involvement and ownership of energy initiatives.
3. *Participatory decision-making is vital* because people are more likely to follow rules they helped create. It is important to represent as many people as possible, including both residents and local businesses, in the decision-making processes regarding how energy resources are managed and used. This democratic approach promotes a sense of ownership and responsibility.
4. *Commons should be monitored* to ensure adherence to rules and smooth operation. Community members can promote energy conservation by encouraging habits like turning off lights when leaving a room and keeping the fridge door closed to reduce unnecessary energy use. Meter readings should be used to track consumption to inform electricity bills.
5. *Sanctions for those who abuse the commons should increase in severity with each violation.* For instance, during the "extremely serious" drought of 2009, BCPUD imposed a daily water consumption limit of 150 gallons per service connection. Residents exceeding the limit received written warnings for the first two offenses and had their water cut off after the third (Prado & Rodgers).
6. *Conflict resolution mechanisms should be straightforward, accessible, and affordable,* emphasizing informal processes to reduce costs and avoid high legal fees.
7. *Commons require the legal authority to manage local energy resources,* allowing the community to set and enforce rules autonomously without excessive interference from higher government levels, unless it strengthens the community's resource management capabilities.
8. *Commons work best when nested within larger networks.* Community-owned electricity generation should fall under the jurisdiction of BCPUD as a publicly owned utility. If renewable power generated exceeds storage capacity, it should be supplied to California's electricity grid. Depending on the ability to acquire the foundational grid infrastructure from PG&E, governance might have to operate in tandem with utilities.

[3]Scaled financial models could adopt the approach of California's proposed policy, which has since been shelved, that opted to set electricity rates based on income (Plachta) (St. John).

[4] The PAYS program is a utility bill financing model that lets customers pay for solar installations through their utility bills (Bickel et al.).

VII — Infrastructure Challenges

Intermittency

Renewable energy relies on fluctuating natural resources, resulting in daily and seasonal variability. Coupled with changes in consumption patterns, mismatches between energy supply and demand arise, necessitating energy storage solutions. The 2016 seasonal comparison between local production and consumption in Bolinas illustrates the intermittent nature of solar-dependent renewable energy, with production nearly meeting consumption in the summer. However, the absence of adequate storage solutions meant that reliance on non-renewable sources was still necessary during periods of peak demand. Ideally, with effective storage solutions, total energy production would equal total consumption across the year, using storage to address the fluctuations and achieve a net zero energy balance.

Based on the selected capacity solution, it's essential to determine the number of large-scale storage solutions needed. Tesla Megapack presents a commercial-scale battery solution, with each unit storing approximately 1,927 kW of energy. This comes at an estimated cost of $2,081,060, with an additional $802,200 for installation (Visconti).

Scale

For nearly a century, conventional wisdom has held that larger-scale power generation results in lower-cost electricity (Hirsh). However, there are limits to economies of scale in solar and wind power (Farrell). Solar power remains competitive at almost any scale, and community solar projects may represent the optimal balance, capturing economies of scale while delivering power locally to avoid high transmission costs. While individual wind turbines benefit significantly from increased scale, wind farms gain less from larger sizes, with most savings realized in relatively small projects. Additionally, the cost of transmitting power from the largest wind farms to urban centers may not justify the savings, compared to building smaller farms nearer to demand (Farrell).

VIII — Funding

Securing funding for capacity solutions is challenging due to high costs, but several grants from state and federal governments, the CPUC, and PG&E can provide substantial support. The Local Government Challenge grant program, which aims to enhance energy performance and reduce GHG emissions in California, is particularly suitable. The program recently allocated $7.2 million for Energy Innovation Challenge grants and $3 million for Small Government Leadership grants. MCE secured a $1,720,343 grant to develop the NavigaDER tool, which helps CCAs reduce GHG emissions. With its experience and strong stakeholder relationships, MCE is well-positioned to assist Bolinas in acquiring this grant.

Furthermore, the Marin County Civil Grand Jury report strongly recommends that "private funding should be aggressively explored" for microgrids in West Marin (Halstead).

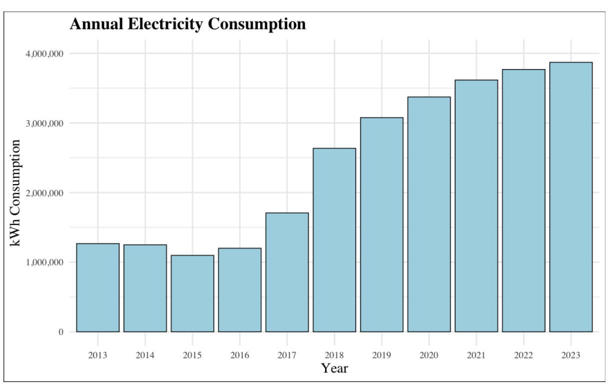
Bolinas has successfully secured public funding in the past, raising over $300,000 through resident donations to provide free COVID-19 and antibody testing for all its residents (Scipioni). Public funding poses challenges, as federal and state securities laws designed to protect the public from fraud and risky investments create barriers for community-scale renewable energy projects seeking a broad investor base. Grocery and housing cooperatives bypass these barriers by allowing members to invest funds without restrictions, ensuring that economic benefits are shared among member-owners. Additionally, crowdfunding regulations offer exemptions to these securities limitations (Farrell).

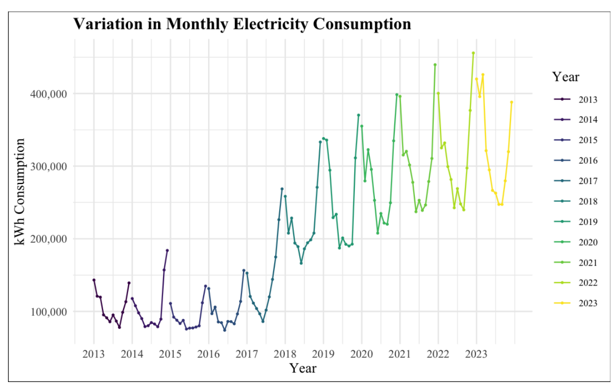
Appendix A — Trends

Bolinas Electricity Consumption

All consumption data was sourced from Pacific Gas and Electric Company's (PG&E) Energy Data Request-Public Data Sets,[5] as Bolinas's single power line is managed by PG&E. Updated quarterly, these datasets provide a detailed breakdown of both gas and electric usage, segmented by ZIP code, month, year, and customer type (residential, commercial, agricultural, and industrial). PG&E explicitly disclaims all warranties concerning the data's accuracy or fitness for specific purposes. There are sporadic data entries for the non-residential customer class because there aren't enough unique entries to meet the privacy regulations, so the consumption statistics generated from this data use residential electricity data as a proxy for the community's overall consumption. Additionally, the absence of comprehensive gas usage data complicates the assessment of the trade-offs between gas and electricity reliance due to multiple private gas suppliers in Bolinas.

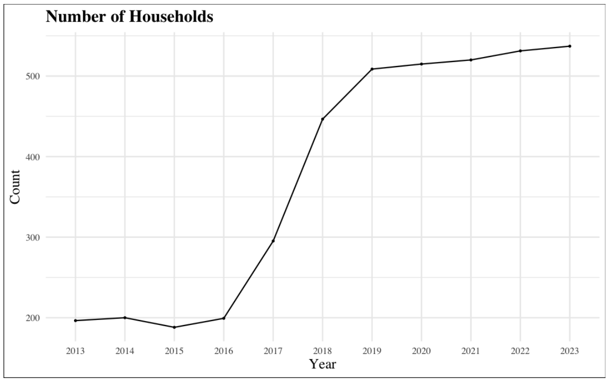
In 2023, Bolinas consumed 3,869,824 kWh of electricity, marking a substantial uptick over the past decade. Consumption fluctuates seasonally, peaking between May and July and dipping to its lowest levels from November to January. These trends are respectively noted below.

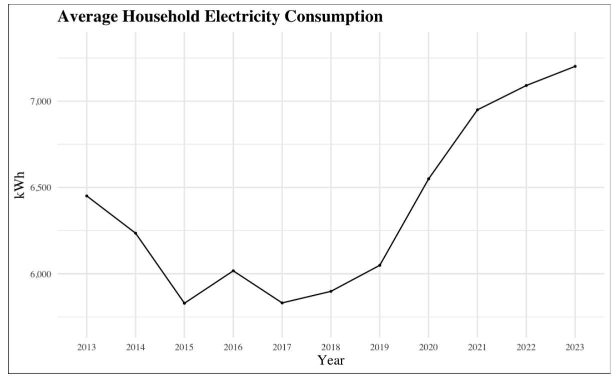




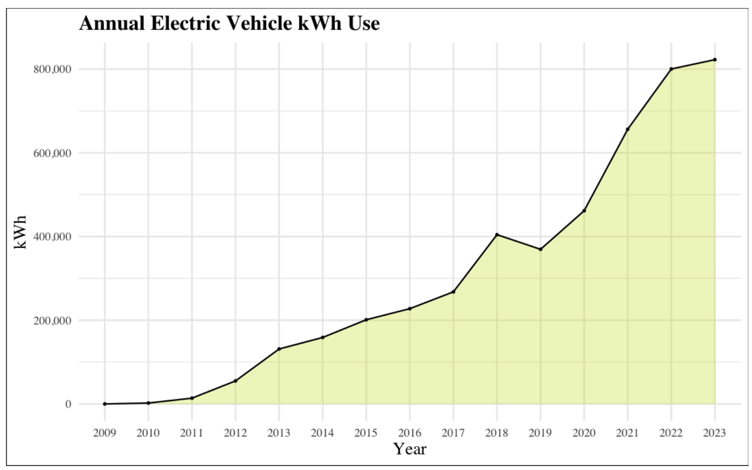
The increase in total electricity consumption is primarily attributed to two factors: an increase in the number of households and a rise in average electricity use per household. In Bolinas, the growth of household numbers is limited due to a water moratorium that restricts new real estate development (Bernstein). Additionally, future trends in average electricity usage are uncertain and will depend on various influencing factors.

[5]These reports adhere to California Public Utilities Commission Decision 14-05-016. They meet data aggregation rules requiring at least 100 Residential and 15 Non-Residential customers, with no single Non-Residential customer accounting for more than 15% of total consumption. If these criteria aren't met, consumption data is merged with an adjacent ZIP code to comply.





One factor influencing the average household energy consumption is the shift toward electrification, where households consume more electricity in place of natural gas. This trend is evident in the increased usage of electric vehicles (EVs), necessitated by the closure of Bolinas's only gas station, with the nearest alternative 12 miles away. EV adoption is measured using the CEC Zero Emission Vehicles (ZEVs)[6] registration data, although the accuracy is compromised because the DMV cannot differentiate between new vehicle sales and total vehicle registrations. The impact of EV adoption on total electricity consumption is estimated to increase daily electricity load by 2.9 kWh or 1,5058.5 kWh annually (Burlig et al.). The figure below charts the cumulative annual increase in electricity usage attributable to EVs.



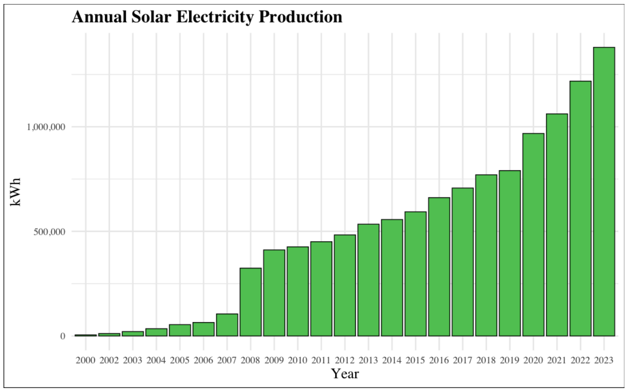
Bolinas Renewable Production

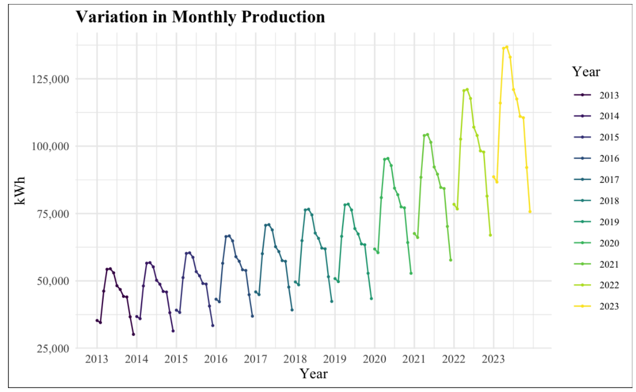
All production data was sourced from from the California Distributed Generation Statistics (CDGS), administered by the California Public Utilities Commission (CPUC)[7]. The CDGS tracks interconnected renewable energy systems, including solar panels, wind turbines, and other forms of distributed generation that are linked to the utility grid. This dataset categorizes projects as active, pending, or decommissioned. For this analysis, the focus is solely on active projects, thereby overlooking the potential impact of decommissioned projects on historical data and pending projects on future outcomes. In Bolinas, all active interconnected projects are solar panels.

In 2023, the estimated annual renewable energy output for Bolinas was projected at 1,379,667 kWh. This figure was calculated using the European Union Photovoltaic Geographic Information System (PVGIS) calculator, which transformed the system size data (measured in kilowatt peak, kWp) from the Community Distributed Generation System (CDGS) into expected monthly and annual energy production (in kWh). The calculator also takes into account several

[6] Battery Electric Vehicles (BEV), Plug-in Hybrid Electric Vehicles (PHEV), and Fuel Cell Electric Vehicles (FCEV)
[7]Authorized by CPUC Decision (D.)14-11-001

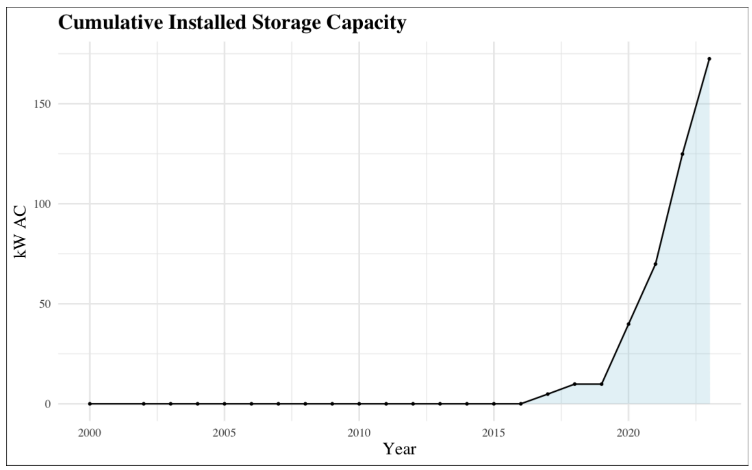
crucial factors such as the system size, tilt, and azimuth, specifically adjusting for Bolinas's unique geographical coordinates. The accompanying figures illustrate the overall trend in solar production, as well as the seasonal variability in energy output.





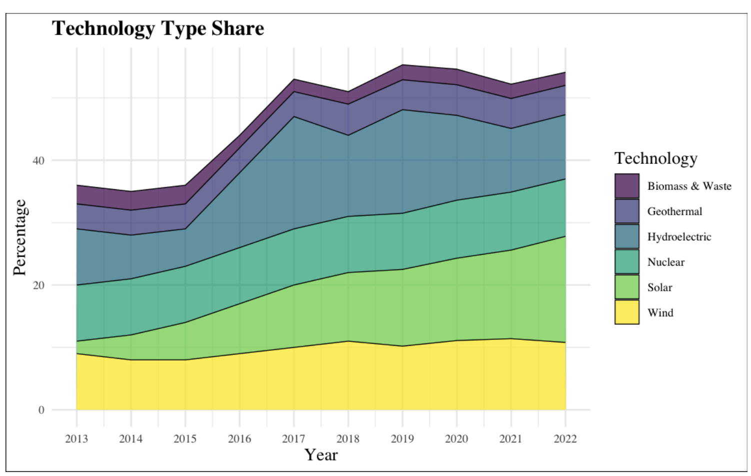
Storage

Before 2016, the area's solar installations lacked storage systems. By 2023, there was 150 kW AC of battery storage. Additionally, 19 out of 119 projects featured "Solar Net Energy Metering (SNEM) Paired Storage," which combines solar power with battery storage. This setup allows customers to export stored energy back to the grid, earning net energy metering credits to reduce their electricity bills.



California Utility Renewable Production

In 2022, renewable energy sources contributed 54.1% of California's electricity generation. This figure includes wind, solar, nuclear, geothermal, biomass, biowaste, and hydroelectric power. Notably, large hydroelectric and nuclear power are not eligible for California's renewable energy target, which aims for 60% renewable sources by 2030. The remaining energy production in California primarily comes from natural gas and coal. This data shows the development of renewable energy's contribution to California's electricity generation from 2013 to 2022. The percentages, calculated



annually by the CEC power content labels through the Power Source Disclosure (PSD) program, are based on the electricity sold to California consumers in the previous year.

Appendix B — Capacity Calculations

Data from several National Renewable Energy Laboratory (NREL) studies was used to estimate the land use, system requirements, and costs for solar and wind options. These preliminary figures provide an initial understanding of the size and expense of each system. For comprehensive design and financial assessments, consultation with a solar or wind energy professional is strongly recommended.

System size and land use for the solar panel installations in San Francisco were determined using NREL's report on solar power plant land requirements. The systems used 1-axis tracking technology with an energy production efficiency of 1,828 kWh/kW. The system sizes, derived by dividing the annual energy needs by this efficiency, were 1,362.23 kW and 279.74 kW, based on annual requirements of 2,490,157 kWh and 511,362 kWh, respectively. The land needed for these installations was 11.75 acres and 2.36 acres, calculated by converting energy requirements to GWh and applying a land use intensity of 4.72 acres/GWh/year. Installation and maintenance costs were based on NREL's cost benchmarks for ground-mounted systems. The costs were $1.50 per watt for the larger system and $1.91 per watt for the smaller one, covering components like modules and inverters, as well as labor and permitting. Total installation costs were approximately $2.043 million for the 1,362 kW system and $534,303 for the 279.74 kW system. Annual maintenance costs were estimated at $17.21 per kW, totaling $23,440 for the larger system and $4,814 for the smaller system.

Wind turbine system size and installation costs are determined by NREL's Cost of Wind Energy Review. Land requirements for wind power, as per NREL's Land-Use Requirements of Modern Wind Power Plants in the United States, average 0.3 hectares per MW for the turbine pad, access roads, and permanent structures for the direct impact area. But, the total area needed, including all turbines and infrastructure for operational efficiency, safety, and compliance, averages about 34.5 hectares per MW.

$$\text{Annual Generation (MWh)} = \text{Net Annual Production (MWh/MW/yr)} \times \text{Turbine Rating (MW)}$$

$$\text{Land Area} = \text{Turbine Rating (MW)} \times \text{Land Requirement (hectares/MW)}$$

Utility Scale Turbine

- Annual Generation = 4,100 x 3.3 = 13,530 MWh ≈ 13,530,000 kWh
    - Turbine Rating = 3.3 MW
    - Net Annual Production = 4,100 MWh/MW/yr
- CapEx = 1,750 $/kW, OpEx = 41 $/kW/yr
    - CapEx Total = 3,300 kW × $1,750/kW = $5,775,000
    - OpEx Total per year = 3,300 kW × $41/kW/yr = $135,300/yr
- Area = 3.3 MW × 34.5 ha/MW = 113.85 ha × 2.471 acres/ha = 281.22 acres

Large Turbine

- Annual Generation = 3,326 x 1.5 = 498.9 MWh ≈ 4,989,000 kWh
    - Turbine Rating = 1.5 MW
    - Net Annual Production = 3,326 MWh/MW/yr

- CapEx = 3,270 $/kW, OpEx = 39 $/kW/yr
    - CapEx Total = 1,500 kW × $3,270/kW = $4,905,000
    - OpEx Total per year = 1,500 kW×$39/kW/yr = $58,500/yr
- Area = 1.5 MW × 34.5 ha/MW = 51.75 ha × 2.471 acres/ha = 127.87 acres

Commercial Turbine

- Annual Generation = 2, 846 x 0.1 = 284.6 MWh ≈ 284,600 kWh
    - Turbine Rating = 100 kW = .1 MW
    - Net Annual Production = 2,846 MWh/MW/yr
- CapEx = 6,327 $/kW, OpEx = 39 $/kW/yr
    - CapEx Total = 100 kW × $6,327/kW = $632,700
    - OpEx Total per year = 100 kW × $39/kW/yr = $3,900/yr
- Area = 0.1 MW × 34.5 ha/MW = 3.45 ha × 2.471 acres/ha = 8.53 acres

Appendix C — Energy Community Examples

1. People's Power Solar Cooperative: The cooperative employs a multi-stakeholder membership model, financed by community members who purchase $100 shares. It installs cooperatively owned residential solar projects on single-family homes in Oakland, California, using cooperative law to circumvent complex community solar regulations and enable collective ownership and operation.
2. Shungnak-Kobuk Community Solar: The project equips 100% of households in the Alaskan Shungnak and Kobuk communities with renewable power and is owned collectively by the two tribes as an independent power producer. It features a 223 kW solar array and battery storage, enabling local diesel generators to shut off for an average of 8-10 hours daily during the daylight season.
3. Fox Islands Electric Cooperative Wind Farm: This cooperative serves the 1,950 members of the Vinalhaven and North Haven island communities in Penobscot Bay, Gulf of Maine. The majority of electrical energy is generated locally by a community-owned 4.5 megawatt wind farm featuring three turbines, although some is imported via submarine cable from the mainland. The wind farm was established following a decisive vote to address high energy costs on the islands.

Appendix D — Benefits of Energy Communities, Expanded

Equity

Energy communities (ECs) facilitate a more equitable transition to renewable energy by lowering entry barriers for low-income households. This is particularly important to places like Bolinas, where, according to the CADGStats Low-Income Solar PV Data SET, there are no solar installations currently listed under programs like SASH (Single-family Affordable Solar Homes), MASH (Multi-family Affordable Solar Housing), and DAC-SASH (Disadvantaged Communities - Single-family Affordable Solar Homes). By offering a more accessible option, community-scale projects can fill this gap and broaden the deployment of renewable resources for underrepresented demographics.

Increasing access to ECs also reduces the energy burden for low-income families, ensuring they enjoy similar rate reductions as wealthier households. The "energy burden,"—the portion of income a household spends on residential energy costs—is three times higher nationally for low-income households than their wealthier counterparts (DOE, 2018). About 25%

of U.S. households face a high energy burden, with 13% experiencing severe strain, spending over 6% and 10% of their income on energy bills respectively (Drehobl et al., 2020). Homes in economically deprived areas tend to be less energy efficient, exacerbating the energy burden for the most vulnerable (Huaccha). Providing cost-effective electricity alternatives makes electrification a more feasible option for low-income individuals.

Local ownership of solar installations has significant economic and job creation benefits for host communities. Specifically, each MW of solar capacity installed not only generates about $2.5 million in local economic activity but also creates approximately 20 construction jobs, according to Farrell. Moreover, local ownership helps decentralize the concentration of political and economic power in the electricity sector. Over a 25-year lifespan, each MW of solar capacity can redirect an additional $5.4 million from utility shareholders to the local community. Looking ahead, projections suggest that shared solar could contribute 5-10 gigawatts of new power capacity over the next five years. This expansion could retain up to $364 billion annually in electricity sales within local economies, reducing the flow of funds to large utility companies (Farrell).

Economics

Distributed generation reduces transmission costs and associated losses, which have been rising by approximately 10% annually among California's three major investor-owned utilities. Efficiency losses during transmission range between 7% and 14% (Farrell). Additionally, it enhances resilience in the event of broader grid failures by supporting local power generation for essential community facilities like hospitals. For example, during the PG&E power shutoff on October 27, 2019, nearly half of Marin County's cellphone transmission sites failed. In the following days, service disruptions continued, with significant impacts on local residents, including those in senior housing centers such as the Villas at Hamilton in Novato and Bennett House in Fairfax, who experienced prolonged power outages (Halstead).

Community-scale solar installations are a strategic response to the challenge of achieving economies of scale in power generation. These mid-sized projects (between 5 and 10 MW) are shown by the Institute for Local Self Reliance to be the most cost-efficient per kilowatt-hour, benefiting from both economies of scale and relatively lower capital costs compared to larger installations. Commercial solar systems enhance efficiency through technologies like tracking, which can increase energy output by 30%, thus reducing the levelized cost of electricity. Utility scale projects incur higher capital and significant transmission costs which can diminish their cost advantage. Despite these costs, solar power remains competitive in the market across various scales, even at residential levels in regions with higher electricity rates, i.e., California and the Northeast.

Renewable energy sources such as wind and solar provide price stability, as they do not depend on purchased fuel. The cost of generating electricity from these naturally occurring and free resources remains consistent, ensuring predictable energy pricing. Moreover, these energy sources reduce environmental externalities, leading to health benefits for local communities.

Politics

For nearly a century, electric utilities have enjoyed the status of regulated monopolies and are now acutely aware of how the shift towards more distributed energy sources and local ownership alters cost dynamics. A 2014 report from Berkeley Labs articulated that while an increase in solar adoption won’t be bad for ratepayers, it would be bad for utility shareholders

(Satchwell et al.). The differing impacts of distributed solar on customers versus shareholders help to clarify the political landscape surrounding solar energy.

Environment

Approximately 73.2% of global greenhouse gas emissions originate from the energy sector (Ritchie). Despite high costs associated with emissions from energy consumption, the inelastic nature of its demand suggests that significant reductions are feasible through supply-side changes (Jia & Lin). These changes include transitioning from high-emission energy sources, such as coal, fossil fuels, and natural gas, to cleaner alternatives like wind, solar, and nuclear power. Much of our energy is channeled through the electricity grid, which standardizes power from both high-emission and clean sources into kilowatt-hours. By shifting the grid entirely to clean energy, we can immediately impact emissions from energy consumption. However, for energy use outside the grid, such as in gasoline-powered vehicles, transitioning to electric alternatives is necessary to harness this cleaner energy.

In support of this, scenario-based stock models assessing pathways for reaching California's emissions reduction goals emphasize that low-carbon electricity must become the predominant energy supply (Baik & Benson). Recent U.S. studies exploring paths to reduce emissions also highlight the importance of end-use energy efficiency, increased electrification, and carbon capture and storage (CCS). For instance, Jacobson et al. explored a renewable-only energy system for California, emphasizing a potential 44% reduction in end-use power demands through enhanced energy efficiency. Similarly, Wei et al. underscored the dual benefits of electrification—improved efficiency and a shift from fossil fuels to low greenhouse gas-emitting energy sources—as crucial for meeting emission targets. Furthermore, Yang et al. (2015) identified CCS as a pivotal technology in achieving the most cost-effective emission reductions, despite the importance of all low-carbon resources. Though there are other ways to reduce emissions, economy-wide assessments of California's decarbonization maintain that a grid powered by renewables is essential.

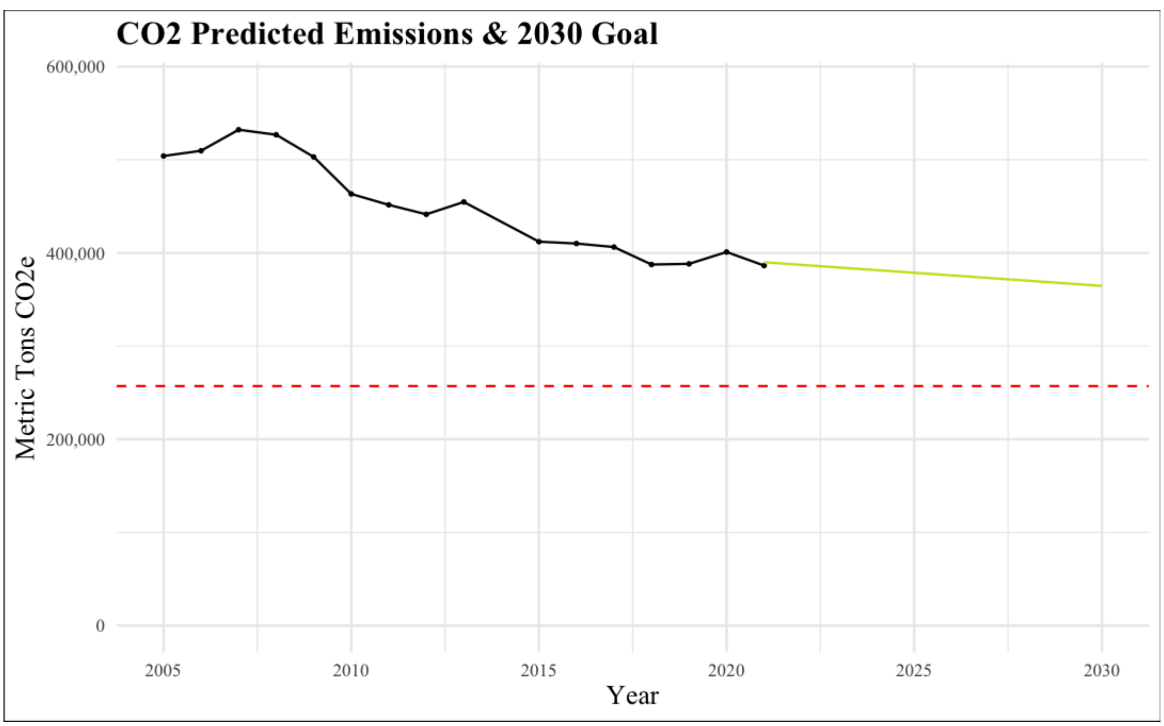
In 2018, recognizing the importance of clean electricity, California passed Senate Bill 100, which established a Renewable Portfolio Standard (RPS) of a 60 percent clean electricity grid by 2030 and a 100 percent by 2045. As a result, emissions from California's electricity sector have decreased by 44% since 2000, despite a 3% increase in overall electricity demand (Jacobson et al). The reduction in emissions is attributed to the increased share of renewable energy within the state's energy mix. Since 2010, combined solar and wind generation increased by seven-fold to reach 23% of total in-state generation shares in 2020 (California Air Resources Board). Wind generation in California has remained relatively constant since 2015, which indicates the expansion in solar capacity has been responsible for much of the growth in the state's generation of renewables.

Appendix E — Share of Household Income Brackets (2013 - 2021)

The below figure expands upon the one in section "1— Bolinas" for the year 2018 to show how the share of household income brackets in Bolinas compares to the rest of the United States between 2013 and 2021. The data is collected from the US Census Bureau. The household income is divided into 16 brackets ranging from "<10k" to ">200k", with each label representing specific income ranges. Use the 2018 visualization in "1— Bolinas" for more specific bucket breakdowns.

Appendix F — Predicted Emissions in Marin County's Unincorporated Communities

This chart illustrates the [emissions for unincorporated communities in Marin County](). Using a generalized additive model, the data indicate that this area is not on track to achieve California's target of reducing emissions to 40% below 1990 levels by 2030.



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