Study Guide: The Rise of Solar Power

This study guide provides a comprehensive overview of solar power, its remarkable growth, current status, challenges, and future prospects, drawing directly from the provided source.

I. Overview and Remarkable Growth

- **Exceeding Expectations:** Even major environmental groups like Greenpeace **significantly underestimated the growth of solar power**. In 2010, Greenpeace projected 335,000 megawatts of installed solar photovoltaic capacity by 2020, but by the end of 2018, the world had already surpassed this, reaching over 480,000 megawatts globally.
- **From Fringe to Mainstream:** Solar has transitioned from a "fringe and very expensive technology to what is effectively now mainstream" for new electricity generation in the U.S..
- **Contribution to New Capacity:** In 2018, **solar accounted for approximately 30% of all new power capacity added to the grid in the U.S.**.
- **Increasing Share of Electricity Generation:** In the U.S., solar power's contribution to electricity generation **leapt from a mere 0.1% in 2008 to around 2.3% in 2018**.
- **California's Leadership:** States like California are spearheading this transition with "bold solar targets, incentives, and regulations." For instance, **every new home built in California after 2019 must generate as much energy as it consumes**, primarily through efficiency and solar installation. California also met its goal of **a million solar rooftops by the end of 2020**.

II. Driving Force: Plummeting Costs

- **Dramatic Price Reduction:** The surge in solar installations has been largely driven by a **steep decrease in the price of photovoltaics**.
    - Since the 1970s, costs have dropped tremendously: from about **$5 a watt (50 cents or more per kilowatt-hour) to 1-2 cents per kilowatt-hour** for the best large commercial applications today. This represents a **factor of 50 reduction**.
    - For rooftop systems, the effective cost can be **under 10 cents per kilowatt-hour** with proper financing and location.
- **China's Influence:** This massive price drop is largely attributed to **China's heavily subsidized solar power manufacturing program**, which created a worldwide glut of solar panels in the late 2000s, forcing companies globally to innovate and cut costs to survive.
- **Economic Competitiveness:** Solar has transformed from "essentially the most expensive form to **one of the cheapest**" and can now **compete on economics alone in many parts of the country**. In places like Hawaii and California, **solar plus storage is often more cost-effective than natural gas contracts**.

III. Types of Solar Installations

- **Rooftop Solar (Residential):**

    - The average rooftop panel system in the U.S. cost about **$12,500 after tax credits in 2019**.
    - Customers typically **break even after about seven to eight years** due to lower electricity bills and then see significant savings.
    - Financing options like **solar loans or panel leasing** can help defray upfront costs.
    - Despite market improvement, only about **2% of single-family detached homes have solar**.
    - It is **rarely seen on apartments or office buildings** due to lack of monetary incentive for landlords.
- **Utility-Scale Solar Plants:**
    - A large percentage of new solar capacity comes from these plants, which **produce hundreds of megawatts of electricity** and feed into the grid.
    - In 2018, utility-scale projects generated **66.6 million megawatt-hours of energy in the U.S.**, enough to power about **6.4 million homes** and representing **69% of the country's total solar energy production**.
    - Plants around **200 megawatts in size are proving to be the most cost-effective**, leveraging economies of scale for competitive pricing. Larger sizes can face challenges with suitable land and transmission capacity.
    - These are crucial for providing solar power to a wider range of customers, especially those in cities or without rooftop access.
- **Corporate Buy-in:** There's a growing commitment from corporations to renewable energy. In 2018, corporations more than doubled their clean energy purchases from 2017. For example, **Facebook alone signed contracts for about 2.4 gigawatts of renewable energy in 2018**, exceeding the entire U.S. residential solar market combined. This corporate involvement is vital for a carbon-free future, as businesses consume about two-thirds of all power.

IV. Challenges and Limitations

- **Intermittency:** Solar power is **intermittent**; the sun isn't always shining, and panels are much less effective in cloudy or shady environments. This means customers often rely on non-renewable energy sources at night.
- **Energy Storage Costs:** While solar panel costs have dropped dramatically, the cost of **energy storage solutions like lithium-ion batteries is still relatively high**, though also falling. For example, a Tesla Powerwall battery for residential use costs $7,600, not including installation.
- **Upfront Costs:** Despite the overall price decrease, installing solar can still involve a **large upfront cost** for consumers, particularly without solar-friendly financing options.
- **Permitting Process: Permitting for rooftop solar takes time and money**, adding to costs and delays, which can be a significant challenge to large-scale residential deployment if policy environments are not supportive.

V. The Role of Energy Storage

- **The "Last Puzzle Piece":** Energy storage is seen as the "last puzzle piece" to make intermittent sources like solar and wind a reality for 100% of power needs.

- **Addressing Intermittency:** To compete with the reliability of fossil fuels, solar farms need to **generate energy on demand**, not just when the sun shines, requiring "shock absorbers" in the form of batteries to cover momentary power gaps.
- **Falling Battery Costs:** The average cost for lithium-ion batteries **fell 85% from 2010 to 2018**, reaching $176 per kilowatt-hour.
- **Solar Plus Storage Competitiveness:** This cost reduction has made **solar plus storage systems cost-competitive with natural gas alternatives in many geographies**, already winning bids against natural gas in places like Hawaii and California.
    - Solar power with storage is now often more economical than "peaker plants," which only operate when demand is high. Southern California Edison, for example, chose a solar plant with a large battery over a natural gas peaker plant in Oxnard.
- **Lithium-Ion Limitations and Future Directions:**
    - Experts predict **lithium-ion battery costs will bottom out around $70-$100 per kilowatt-hour**.
    - While economical for replacing peaker plants and smoothing short-term gaps, lithium-ion is **not a good option for storing energy for weeks or months** due to massively increased electricity costs.
    - Researchers are exploring "new horizons" beyond lithium-ion, including **flow batteries (liquid batteries), high-temperature nickel metal hydride batteries, and non-chemical/non-battery-based storage**.
    - Examples include Bill Gates' fund backing longer-duration liquid batteries aiming for one-fifth the price of lithium-ion, and Sandia National Labs experimenting with **molten salt thermal energy storage** (using concentrated sunlight to heat salt, then converting it to steam to power a turbine, similar to a coal plant but with solar as the heat source).
- **The Grid as a Battery:** For residential solar, the **grid itself often acts as a battery** through "net metering" policies, allowing customers to sell excess energy back to the grid for credits.

VI. Future Outlook and Policy Importance

- **Continued Growth:** Solar installations are expected to **continue to rise as prices fall and incentives and regulations spur development**.
- **Policy Driving Adoption:** Government policies and incentives are crucial for driving the adoption of energy storage, just as they did for solar panels. California utilities, for instance, have a **storage mandate to meet 2% of their peak demand by 2020**.
- **Path to 100% Renewables:** With roughly **20% of peak demand available in storage**, a mix of solar, wind, geothermal, and biomass, all backed by storage, could allow for a **renewable-only system** capable of carrying through even long lulls.
- **Solar as the Norm:** In the near future, it will become "a little bit odd to see new homes that don't have solar on the roof," as it becomes a standard part of the landscape. This marks an **"inexorable march toward a transition to a zero-carbon economy"**.