Economics & Finance

Zero Carbon Analytics

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Zero carbon, zero cost: Rooftop solar savings for Japanese households

Key points:

- The 1.5°C Paris Agreement target is at risk. Deploying renewables is key to keeping temperatures down and mitigating the risks of extreme weather events.
- If countries do not act quickly, not only will climate impacts worsen, but governments, businesses and households will also miss out on savings from transitioning to cleaner fuels.
- Wind and solar are two proven technologies that are the most effective at cutting power sector emissions while increasing electricity supply. Modular solar technologies offer a number of benefits at the household level.
- Policy interventions such as tax credits and feed-in-tariffs, have been shown to increase adoption of rooftop solar across the UK, EU and US.
- Zero Carbon Analytics calculated that Japanese households with solar panels in FY 2020 would have saved on average nearly 135% compared to those without, receiving a net benefit of JPY 37,422 (USD 353).
- Households saved over JPY 143,000 (USD 1,352) in total from reductions in electricity bills and payments from the sale of excess solar power.

The need for climate mitigation

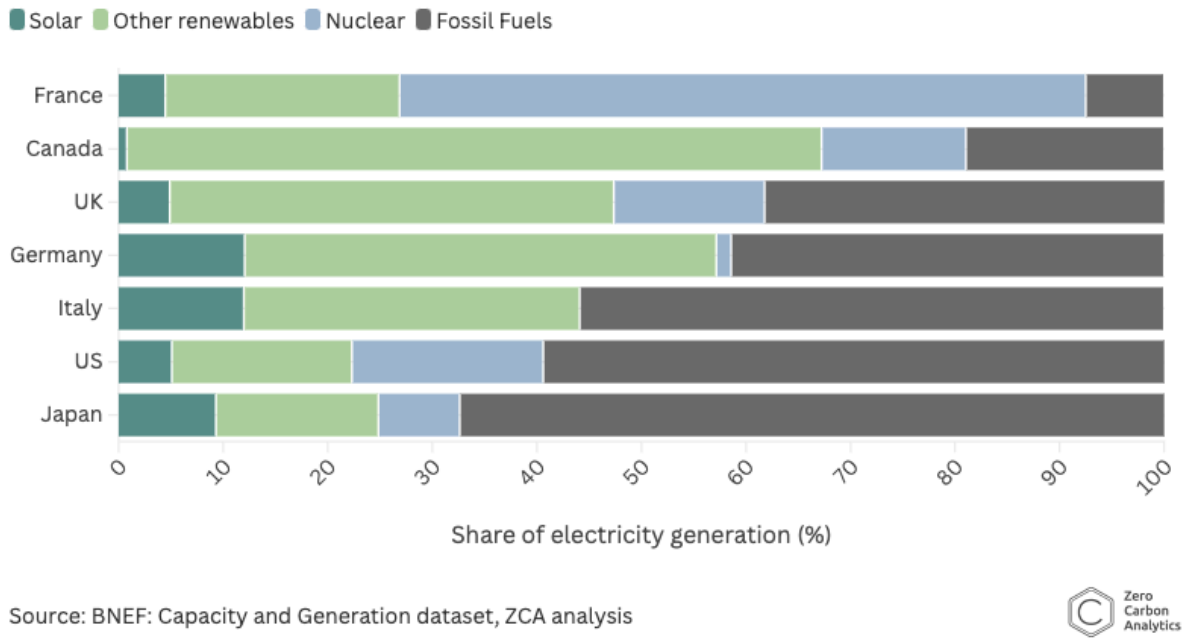
The current climate trajectory shows that we are increasingly likely to exceed the United Nations Paris Agreement goal of limiting the rise in average global temperatures to 1.5°C above pre-industrial levels by 2050.[1] This is the threshold beyond which climate impacts become increasingly intolerable to humans and nature. The Intergovernmental Panel on Climate Change (IPCC) has assessed that every fraction of a degree matters. For each additional 0.1°C above the threshold, the intensity and frequency of temperature and precipitation extremes increase, as do droughts in some regions.

2023 saw the world's first year-long breach of the 1.5°C limit, and 2024 is likely to be even hotter. Delaying climate mitigation means climate impacts such as heat waves will get worse, leading to greater economic losses in the long term. Deploying renewables is key to keeping temperatures down by reducing greenhouse gas emissions from fossil-based power generation. Japan has the lowest share of clean energy generation among the G7 countries and the highest share of fossil fuel generation in its energy mix (Figure 1). Around 9% of electricity generation came from solar, around 8% from hydroelectric, but less than 2% from wind in 2023. Its G7 peers are progressing more rapidly in the energy transition

[1] The 1.5C target is generally accepted to mean a 20-year average, rather than a single year.

leaving Japan in last place in the G7 target of "achieving predominantly decarbonised electricity sectors by 2035".

Fig. 1: G7 share of electricity generation in 2023



Source: BNEF: Capacity and Generation dataset, ZCA analysis

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A study by the Renewable Energy Institute (REI) showed that Japan can supply over 80% of its electricity from renewables by 2035. This would reduce the cost of fossil fuels for power generation by 80%, representing a savings of around JPY 4 trillion (USD 28.4 billion) annually in overseas capital outflow.[2] As well as ramping up offshore wind capacity, which will be crucial to reaching this target, there is significant scope to increase solar power generation, including from residential rooftop solar.

Fuelling the future with savings

While there are many solutions to reduce power sector emissions while increasing electricity supply, two proven technologies that are the most effective at cutting emissions at scale in the short term are wind and solar. They are also among the most cost-effective solutions. The IPCC has found that wind and solar energy have the highest potential contribution to net emissions reductions at the lowest cost across all sectors by 2030.

What are the benefits of rooftop solar for households?

Solar photovoltaic (PV) is a modular technology which means it can be deployed at different scales suited to different contexts. The Japanese government defines commercial and industrial solar as systems with generation capacity above 50 kW. Anything below 10 kW is categorised as residential solar, and refers to rooftop systems households use primarily for self-consumption. Though renewable technologies such as solar panels incur a high initial cost for households, this is outweighed by the long-term economic benefits such as protection against high retail electricity prices, and avoided costs from climate impacts. Some benefits of rooftop solar include:

[2] The exchange rate used is the monthly average exchange rate from 2023.

- **Environmentally friendly:** Solar is a renewable energy source that doesn't produce harmful greenhouse gases while operating.
- **Short lead times:** Rooftop solar is simple to deploy, and scaling is modular and rapid. For instance, Pakistan imported 13 GW of solar modules in six months in 2024, over a fifth of the country's total installed power capacity in 2023.[3] This enabled more households to switch to rooftop solar to counter rising power prices, resulting in the lowest consumption of grid electricity in four years.
- **Solar systems work year-round:** Solar panels work best in sunny conditions, but still perform at lower levels in cloudy weather, with efficiency continuously improving. For example, despite the UK having lower solar PV potential than Japan, solar supplied over 20% of the country's electricity in February 2022.
- **Savings:** Households can save on utility bills after covering the initial capital outlay for solar panels, with savings varying depending on electricity use, system size and power ratings. Savings increase when there are high retail electricity prices, mostly set by fossil fuels.

Rooftop solar savings around the world

Consistent policy incentives are needed to make rooftop solar affordable for lower-income households. Policies such as tax credits and feed-in-tariffs (FiT) – an instrument designed to incentivise renewables by guaranteeing an above-market price to producers that are proven to drive rapid adoption – are also crucial for maximising household savings.

US

In 2024, a Berkeley Lab study found that rooftop solar reduced the energy bill burden for over three quarters of adopters in the US, including repayment of installation costs. The median customer saw an annual bill saving of USD 1,987. Factoring in repayment of the solar system, the median saving was USD 691 annually, meaning that energy costs fell from 3.3% of the median household income to 1.3%.

The Inflation Reduction Act, the US's flagship energy transition legislation, has helped to lower the cost of rooftop solar installations through the extension of the Residential Clean Energy Credit. This tax credit was created to help working families save on their monthly utility bills and "shield themselves from volatile fossil energy prices", according to the US Treasury. It covers up to 30% of the installation cost for rooftop solar through to at least 2034. Around 1.2 million households claimed this credit in 2023 totalling around USD 6.3 billion.

EU

In response to the gas crisis that followed Russia's invasion of Ukraine, EU member states spent around EUR 651 billion (USD 685 billion) to shield consumers from rising energy prices between September 2021 and June 2023. To address gas shortages, the International Energy Agency (IEA) advised Europe to deploy around 60 GW of new solar in 2023. SolarPower Europe, an industry association, found that rooftop solar installations grew by 9%, 106% and 240% year-on-year in 2022 in Germany, Spain and Italy, respectively. They estimated that this would have led to energy bill savings of 22%, 40% and 64%, respectively. As a result, model households in these three countries with rooftop solar saved up to EUR 2,935 (USD 3090) in energy bills in 2022.

[3] BNEF (2024), Pakistan power capacity dataset, available via BloombergNEF platform, accessed 11th November 2024.

Households were able to unlock these savings through various policy incentives for rooftop solar. In Germany, a successful FiT incentive system helped to spur an initial solar PV boom. Subsequent reductions in these remunerations under a 'breathing cap' slowed expansion, and in 2022, the FiT was increased for newly commissioned PV systems to support further take up. Both Spain and Italy have introduced various financial incentives for rooftop solar, such as simplified compensation for generation surpluses and tax deductions for self-consumption in Spain and a 110% 'Superbonus' tax credit in Italy that drove solar installations to jump by 24% in the second half of 2022.[4]

UK

In the UK, the Energy and Climate Intelligence Unit (ECIU), an organisation that supports informed debate on these issues in the UK, simulated the savings from households with rooftop solar panels. It found that households meeting half of their power needs from solar panels in 2022 saved GBP 510 (USD 632) in 2022 on their energy bills and GBP 615 (USD 768) in 2023. Total savings for the 1 million UK households with solar panels totalled GBP 800 million (USD 999 million) in 2023.

A large proportion of solar panels in the UK were installed under the FiT, highlighting the impact of this incentive for technology take up. However, the FiT was reduced in 2013 and closed to new joiners in 2019. ECIU views this policy rollback as a missed opportunity that likely contributed to slowing the rate of solar installations.

Using government data, ECIU found that an average of 7,300 solar units were installed monthly between 2011 and 2021, with a significant peak of 55,000 in November 2011. It calculated that if this level of installations had been maintained, 600,000 additional homes would have solar panels installed each year. As a result, the UK would have saved an extra GBP 5.1 billion (USD 6.4 billion) in 2023.

The ECIU outlined its research on savings – and related costs of inaction – in its 2022 report, The Cost of Not Zero. The findings highlight how the pace and priorities of government energy policies affect households, sparking a short debate at the UK House of Lords and featuring in a major media outlet.

Simulation for households savings from rooftop solar panels in Japan

The scarcity of available sites for solar parks in Japan means rooftop solar will be important to reach the country's net zero goals by 2050. The government aims for 108 GW of solar capacity by 2030. However, leading solar consulting firm RTS Corporation projected back in 2018 that 150 GW of solar was achievable, primarily through rooftop solar installations on homes, office buildings and warehouses. To support this target, and the capital's decarbonisation strategy, new homebuilders in Tokyo from April 2025 will be required to install rooftop solar panels.[5]

Zero Carbon Analytics has simulated household savings in Japan from installed rooftop solar panels using ECIU's methodology framing of a missed opportunity to maximise rooftop solar. That analysis compared peak installation rates in 2011 against actual installation rates through 2021. In this case, we looked at what households would have

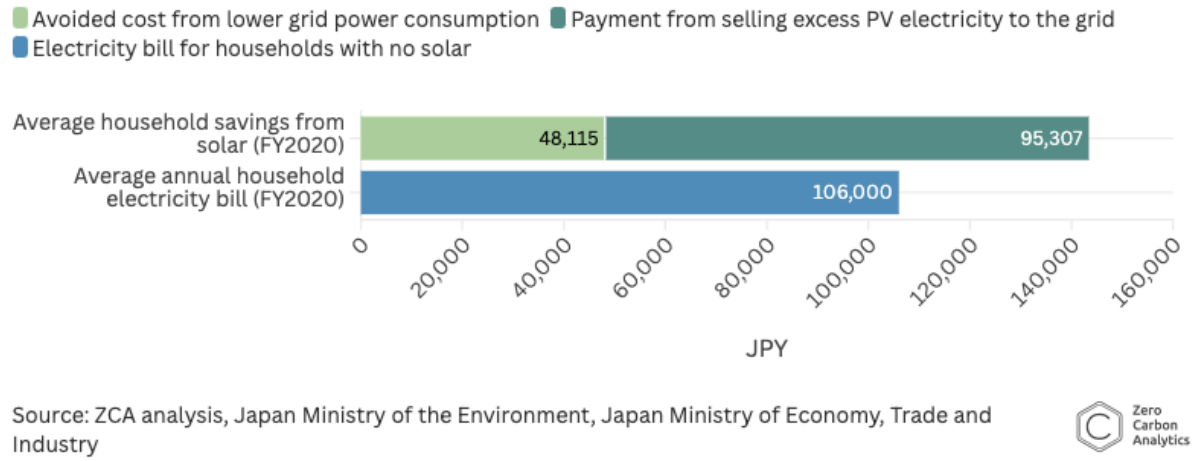
[4] BNEF (2022), The Rush to Build Rooftop Solar and Batteries in Europe, available via BloombergNEF platform, accessed 27th November 2024.
[5] This is subject to conditions from the Tokyo Metropolitan Government.

saved if the Tokyo mandate had been introduced earlier in 2020 (when a similar law was passed in California) and at a larger scale to impact all households in Japan.[6]

Our analysis showed that a home consuming 30% of the power generated by solar panels would have avoided buying JPY 48,115 (USD 454) worth of electricity from the grid in FY 2020.[7] Selling the excess solar generation back to the grid would have raised a payment of JPY 95,307 (USD 899) in FY 2020 using the FiT in place at the time. Therefore, a household with solar panels would be JPY 143,422 (USD 1,352) better off in this simulation.

The average annual electricity bill per household in FY 2020 was JPY 106,000 (USD 1,000). This means Japanese households with solar panels would have saved nearly 135% compared to those without. Therefore, households received a net benefit of JPY 37,422 (USD 353) in FY 2020.

Fig. 3: Estimated households savings from solar panels in Japan FY 2020



Source: ZCA analysis, Japan Ministry of the Environment, Japan Ministry of Economy, Trade and Industry

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Rooftop potential in Japan

Japan has the potential to become a leader in rooftop solar to accelerate its efforts to boost its clean energy share. In 2023, Japan ranked sixth globally in residential solar power capacity (Figure 2). Under the current trajectory, Japan's rooftop solar installations are set to reach 8 GW annually by 2030, according to Tokyo-based consultancy RTS Corp. However, there is plenty of untapped potential as an accelerated scenario could see installations reach 14 GW per year.

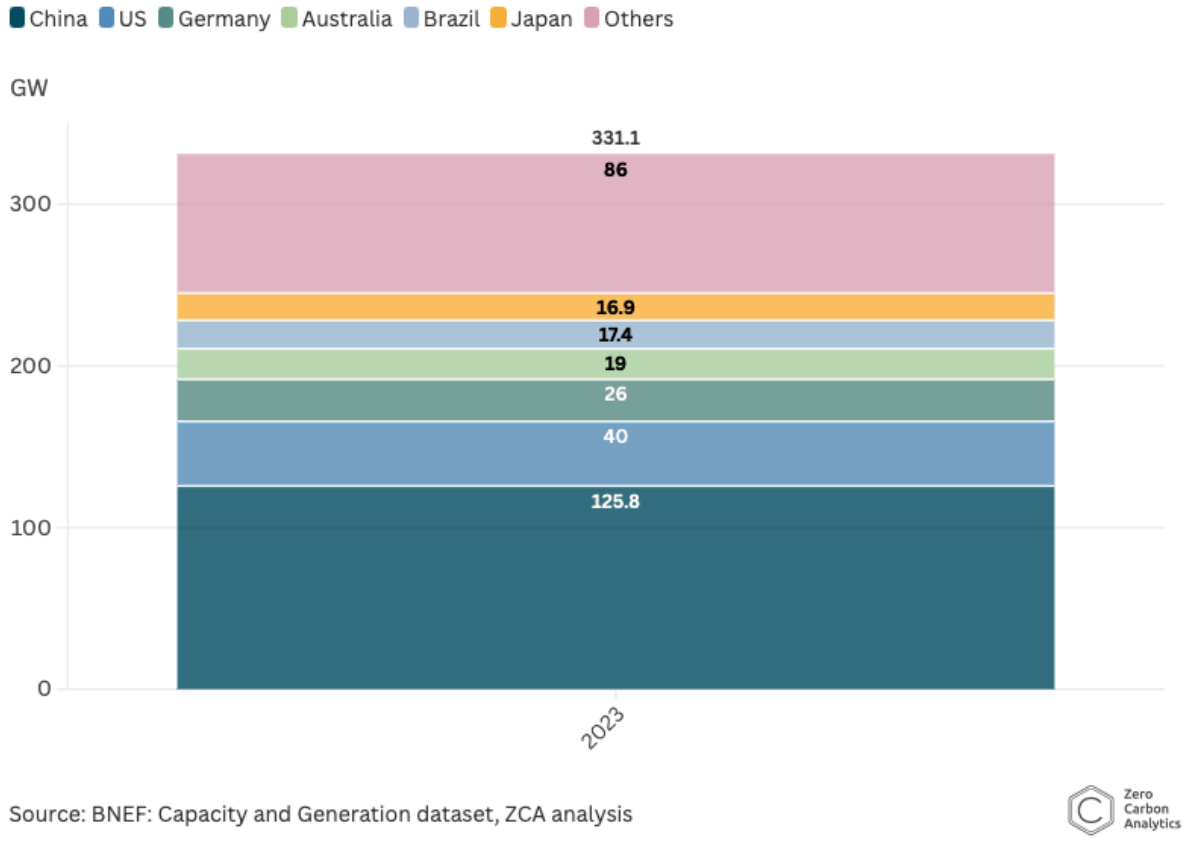
Rooftop solar is particularly appropriate for Japan, where the mountainous terrain makes large-scale solar parks difficult to install at scale without creating environmental damage.

[6] The methodology takes the following exogenous variables into account for the Japanese fiscal year 2020 (April 2020 to March 2021): cumulative installed capacity and generation of PV, cumulative installed capacity and number of households with rooftop PV, average electricity consumption and bill per household, the proportion of solar that can be used in a home, the subsidy for installing solar panels and the FiT rate for residential solar. Using the exogenous variables, we were able to calculate: the capacity factor and average power ratings of rooftop PV, estimated annual generation from rooftop PV per household, solar energy consumed and energy bought from the grid in the year 2020 and the average electricity unit price per household.

[7] The exchange rate used is the monthly average exchange rate from 2020.

For households, this mature technology offers the benefits of short lead times for installation and higher energy security once set up is complete. Households can unlock energy bill savings with supportive policies that provide certainty and make upfront costs manageable.

Fig. 2: Global installed capacity for residential solar 2023



Source: BNEF: Capacity and Generation dataset, ZCA analysis

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The Japanese government is developing its Seventh Strategic Energy Plan, which sets out the country's decarbonisation strategy to 2040. Although financial incentives such as the FiT, feed-in premium and auctions are in place for solar, the pace of renewable deployment has been slow and the recent policy focus on new commercially unproven technologies such as hydrogen risks diverting state support from where it would be most effective.[8] To quickly mobilise rooftop solar and unlock savings for households, access to low-cost finance to lower the upfront costs is needed. This can be done through accelerating policy initiatives such as the FiT, reducing the barriers to entry by enabling them to recoup their initial investment more quickly.

[8] BNEF (2024), Japan Policy Coverage, available via BloombergNEF platform, accessed 26th November 2024.