Empirical Methods for the Analysis of the Energy Transition

Slide Set 8

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IDEA

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Technology Adoption in the Energy Transition

Technology adoption in generation as a main source of decarbonization

- Large scale
  - Wind and solar deployment.
  - Batteries.
  - Other technologies.
- Residential scale
  - Solar panels (and batteries).
  - Energy efficiency (appliances, cars).

Large and growing literature

- Large scale
  - Subsidies vs. carbon taxes (Reguant, 2019), learning-by-doing with subsidies (Gerarden, 2021).
  - Renewables and its location (Wibulpolprasert 2013, Callaway et al 2018, Lamp and Samano, 2023).
  - Production vs. investment subsidies (Johnston, 2019; Aldy et al, 2022).
  - Investment frictions (Johnston et al. 2023)
  - Battery adoption (Lamp and Samano, 2022; Karaduman, 2023; Butters et al 2023).
- Residential scale
  - Subsidy design (Borenstein 2017; Feger et al. 2022, Langer and Lemoine, 2022).
  - Discount factors of adoption, "Adoption gap" (Busse et al 2013; Allcott and Wozny, 2014; Anderson et al, 2013; DeGroote and Verboven, 2019).
  - Large literature on equity impacts: more on this next week.

Solar adoption and pricing

In vs. out

- Technology adoption can impact the sharing of the burden for fixed costs in the electric grid.
- Net metering has implications for other households, as typically it enables households with solar panels to avoid paying for high retail rates.
- This has been coined the “death-spiral”’’ similar to market unraveling, where households gradually exit the grid, but unclear if as relevant or “fast” in practice.
- Note: “death-spiral” dynamics arise for similar setting with natural monopoly of natural gas in buildings as households electrify (induction, heat pumps).


The New York Times

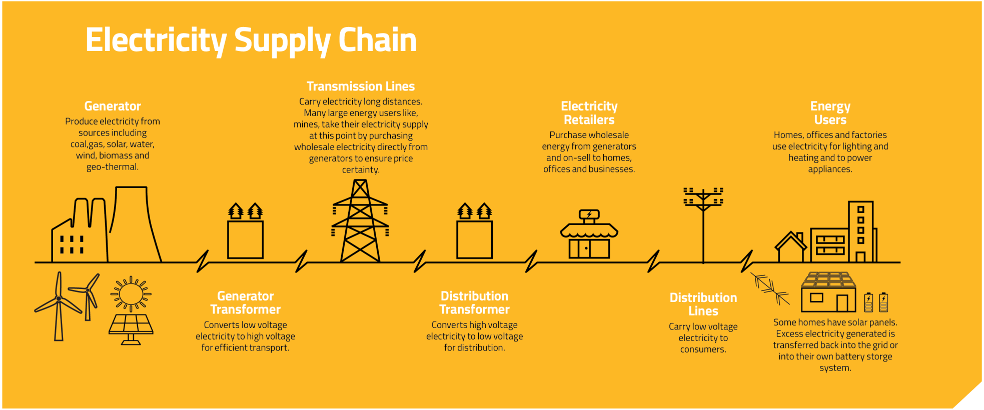
Nevada's Solar Bait-and-Switch

By Jacques Leslie

Feb. 1, 2016

Give this article

Who pays for the lines?



What is net metering (NEM)?

- Under net-metering, households will get the energy produced from their solar panels substracted from their demand.
- They are only charged for their net demand, e.g., at the monthly level.
- Traditionally, energy-based, so the implicit price for solar power is the **retail price.**

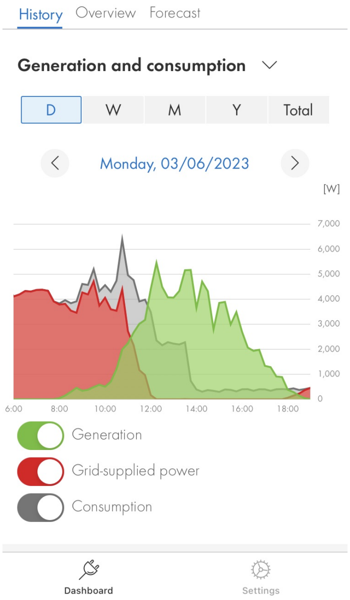
NEM can be a substantial subsidy

- Under traditional NEM expected the net present value (NPV) of solar panels can be much larger.
- This is due to the fact that the retail energy prices can be much larger than the marginal cost of electricity.

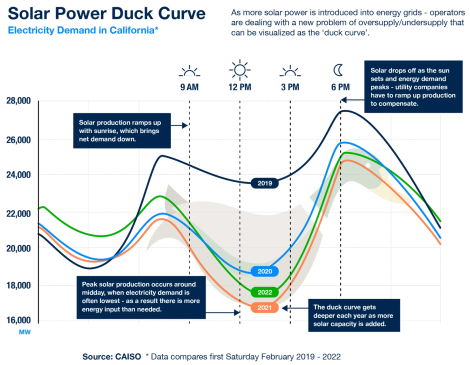
- Example: In California, there were **no fixed fees**: all the distribution network is paid via retail prices that are proportional to electricity consumption.

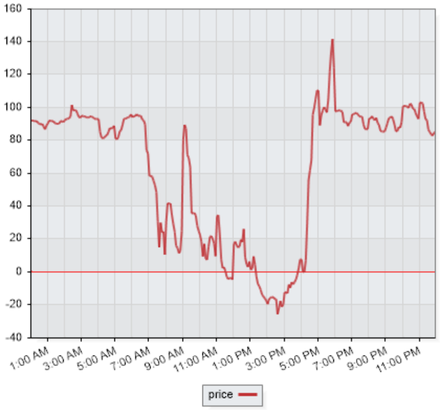
A growing challenge

- Demand of electricity is not always well-timed with solar production.
- Net-metering is equivalent to assuming that HHs produce electricity when they need it.
- With few customers, this might be manageable.
- However, with more and more households, one needs to properly incentivize consumption at the right time (which implicitly promotes battery adoption).



The duck curve and wholesale market prices





Can systems afford these transfers?

- This has led to an evolution of net metering policies in many states and countries, which cannot afford to continue this subsidization.
  - For example, in the Belgian case, regulator introduced fixed fees to participate in net-metering (proportional to installed capacity).
  - Nevada and California have gradually renegued on their net metering schemes to make them more equitable.

What is the "correct" NEM policy?

- With the duck-curve effect, traditional NEM subsidies tend to be even larger (as consumer retail prices are typically not real-time).
- More and more, NEM policies tend to separate self-consumption of solar power vs. "mismatched" consumption of solar power.
- This distinction is enabled by smart meters, as traditionally the old-fashioned NEM was the easiest.
- **Updated NEM**:
  - If self-consumption, it cancels demand and it tends to cancel retail price obligation (or something close to it).
  - If pouring it into the grid ("mismatched"), household receives a different price, based on retail competitive offers, wholesale day-ahead or real-time prices, or regulated "avoided cost."

Net-metering vs. net-billing payoffs

- **Net metering 1.0**
  - Pay and receive constant retail price for consumption or generation.

$$Bill = p^r \sum_t (d_t - q_t)$$

- **Net metering 2.0 (net billing)**
  - Receive retail price only if consumption is coincidental.
  - Receive wholesale price if consumption is non-coincidental.

$$Bill = \sum_t (p^r 1(d_t - q_t \geq 0) + p^w 1(d_t - q_t < 0))(d_t - q_t)$$

Net-metering as a subsidy

- Net-metering can be a substantial subsidy to solar entry.
- Seen as an incentive for solar entry at the early stages of the technology.
- No longer viable from a financial and equity perspective, but its modification can be highly controversial.

Empirical papers of Solar Adoption

Adoption of solar panels has been on the rise

- Rooftop solar panels are less profitable than large scale.
- Several factors sill make them attractive:
  - Massive decline in solar costs.
  - Subsidies at several levels (federal, regional, municipal): installation costs or as per-kwh adder.
  - Retail tariffs that make rooftop production more valuable than wholesale.
  - Resilience motives.
- Papers study how these subsidy programs have evolved, how to better design them, etc.

DeGroote and Verboven (2019)

- **Question:** Do HHs inefficiently discount solar PV beneifts?
- **Context:** Belgian subsidy scheme (inv. and production-based) with several policy breaks, 2006-13.
- **Data:** Detailed technology-adoption data at individual HH level, other complementary data.
- **Methods:** Discrete choice single agent dynamic estimation with absorbing states.
- **Results:** Discount rate in the order of 15%, potentially better to focus on upfront subsidies.

Subsidies and Time Discounting in New Technology Adoption: Evidence from Solar Photovoltaic Systems†

By Olivier De Groote and Frank Verboven*

We study a generous program to promote the adoption of solar photovoltaic (PV) systems through subsidies on future electricity production, rather than through upfront investment subsidies. We develop a tractable dynamic model of new technology adoption, also accounting for local market heterogeneity. We identify the discount factor from demand responses to variation that shifts expected future but not current utilities. Despite the massive adoption, we find that households significantly discounted the future benefits from the new technology. This implies that an upfront investment subsidy program would have promoted the technology at a much lower budgetary cost. (*JEL* C51, D15, Q48, Q58)

Feger, Pavanini, and Radulescu (2022)

- **Question:** What is the optimal pricing policy for solar panels?
- **Context:** Switzerland solar subsidies and tariff design, 2008-14.
- **Data:** Annual data on prices, electricity consumption, income, wealth, solar panels, building characteristics.
- **Methods:** Full-solution dynamic mode w/ estimation (Rust, 1987) + welfare objectives for policy design.
- **Results:** Marginal incentives to solar panels can be more cost efficient and progressive than investment subsidies.

Welfare and Redistribution in Residential Electricity Markets with Solar Power

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An increasing number of households installing solar panels and consuming the energy thus produced raises two challenges for regulators: network financing and vertical equity. We propose alternative tariff and subsidy designs for policymakers to incentivize solar panel adoptions and guarantee that network costs are recovered, while trading off efficiency, equity, and welfare motives. We estimate a structural model of energy demand and solar panel adoption, using a unique matched dataset on energy consumption, prices, income, wealth, solar panel installations, and building characteristics for 165,000 households in Switzerland from 2008 to 2014. Our counterfactuals recommend the optimal solar panel installation cost subsidies and two-part energy tariffs to achieve a solar energy target. We show that, relative to installation cost subsidies, relying on marginal prices to incentivize solar panel adoptions is more cost efficient and progressive across the income distribution, but generates a larger aggregate welfare loss.

Key words: Energy, Photovoltaics, Income distribution, Welfare, RDD, Structural estimation

JEL Codes: D12, D31, L94, L98, Q42, Q52

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