Socio-Economic Aspects of Energy Storage

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Natalia Fabra

Universidad Carlos III de Madrid, EnergyEcoLab, CEPR

Energy Storage and the Energy Transition

- The **transition to carbon-free power markets** requires massive investments in renewable energy.
- Electricity storage technologies play a fundamental role in smoothing the **variability** and **intermittency** of renewables.
- The widespread adoption of storage crucially depends on the **investment incentives** of businesses and households.
  - Incentives depend on **market structure** and **regulation**.
- And it has **distributional implications**:
  - Across generation technologies.
  - Across consumers.

Economics (and economists) come in!

Questions from an economist's perspective

1. **Grid-scale electricity storage**:
   - Which type of regulation to promote investments in storage?
   - Does it matter who owns the storage facilities?
   - Should hybrid power-storage plants be promoted?
   - How does storage a ect other generation technologies?
   - And nal consumers?

2. **Behind-the-meter electricity storage**:
   - A substitute or a complement for grid-scale storage?
   - Are investment incentives a ected by retail electricity pricing?
   - And by the regulation of rooftop solar generation?
   - What are the distributional implications across consumers?

3. **Hydrogen as energy storage**:
   - Which type of regulation to promote investments in green hydrogen?
   - Does it matter what we consider to be green hydrogen?

The Economics of Grid-Scale Electricity Storage

Do electricity markets provide socially optimal incentives to **operate** and **invest** in storage facilities?

The social value of electricity storage:

- Storage reduces generation costs.
- Contributes to security of supply.
- Facilitates the integration of renewables.
- Supports grid management and reduces grid investment.

Socially Optimal Storage Decisions

- Minimize generation costs:
  - Charge when low marginal costs and discharge when high.
  - Taking into account start-up/ramping costs.
  - ! This smooths production and the cost/price pattern.
- Guarantee security of supply.

Socially Optimal Investment Decisions

- Invest so that the additional investment cost equals the additional private + social bene ts:
  - Reduction in production costs, start-up and ramping costs.
  - Reduction in back-up capacity or grid investments.
  - Reduction in future investment costs (learning economies).
  - Promotion of renewable energies.

Privately Optimal Investment Decisions

Are social and private incentives aligned?
Does it matter who owns the storage facilities?

If small storage owners (no price impact):

- Charge when prices are low and discharge when high.
- ! If prices re ect marginal costs, exposing storage to market prices induces optimal storage decisions.
- ! Capacity under-investment (externalities not internalized).

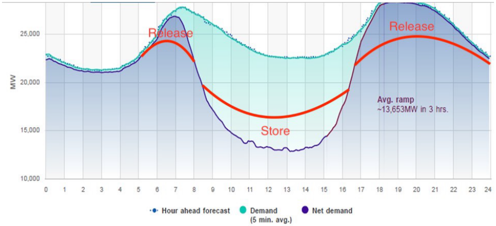
Privately Optimal Investment Decisions

If large storage owners (their decisions impact prices):

- Smooth quantities charged/discharged to avoid price e ects.

! This distorts storage decisions (smaller cost reductions).

! Capacity under-investment.



The Duck: CAISO Total Demand and Net (of Solar and Wind) Demand for Feb 7, 2019
(source: http://www.caiso.com/TodaysOutlook/Pages/default.aspx)

Vertical Integration Generation-Storage

Does it matter who owns the storage facilities?
Should we allow joint ownership generation-storage?

- Hotly debated question:
  - California ! Utilities mandated to invest in storage capacity.
  - Texas ! Utilities not permitted to own storage capacity.
  - FERC ! System Operators not allowed to use storage.
- The answer should depend on the type of rm:
  - Small vs. Large storage owners.

Vertical Integration Generation-Storage

Small hybrid renewable-storage plants:

- They use storage to avoid energy spills.
- Storage increases the **private + social value** of renewables.
  - It reduces generation costs.

Large vertically integrated firms:

- They smooth storage decisions to avoid price effects on its storage + generation.

! Strong infra-utilization of storage capacity.

- Low value of storage capacity (depresses generation profits).

! Even larger under-investment in storage capacity.

Some Regulatory Implications So Far

- In the absence of other instruments (e.g., subsidies, capacity markets...), **under-investment in storage capacity.**
- The problem is made worse when storage is in the hands of large rms, vertically integrated with generation.

Regulatory solutions

- Regulators need to decide how much storage capacity they want to procure, and provide capacity support:
  - Provide capacity payments while still exposing storage owners to the price signal.
  - Use auctions to determine capacity payments.
  - Eligibility criteria: ban large rms and incumbent generators.
- Promote hybridization renewables-storage.

Distributional Effects of Grid-Scale Storage

- Storage impacts electricity price patterns, a ecting:
  - Generators, depending on when they produce.
  - Consumers, depending on when they buy.
- Distributional implications depend on:
  - Which technologies generate when (relative to when storage charges/discharges).
  - Which consumers consume when.

Distributional Effects: across Technologies

Renewable energies:

- Renewables benefit from storage as it reduces curtailment.
- Renewables that produce when storage charges (discharges) benefit from (are harmed by) storage.

Other generation technologies:

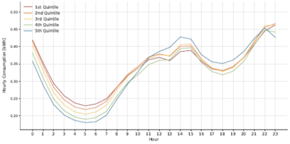
- Storage reduces peak prices
  ! it hurts peaking plants (hydro, CCGTs, peakers).
- Storage tends to reduce average prices
  ! it hurts base-load plants.

Distributional Effects: across Consumers

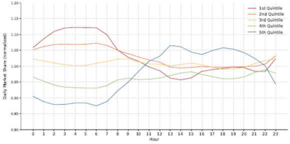
Households:

- Equipment is an important determinant of consumption (heating, AC), which is also correlated with income.
- Low-income households consume relatively more during the night and winter.

! Likely progressive impacts in solar-dominated systems (but results are highly dependent on equipment patterns).



(a) Hourly consumption patterns [kWh]



(b) Normalized consumption shares [%]

Distributional Effects: across Consumers

Industrial consumers and SMEs:

- If they have the exibility to consume when prices are lower, storage makes them worse o (storage smoothes prices).
- If they do not, then the e ect will depend on the correlation btw their demand and prices.
  - If they consume at peak times, storage makes them better o .
  - If they consume at o -peak times, storage makes them worse o .

The Economics of Behind-the-Meter Storage

- Consumer-sited storage assets:
    - Stand-alone batteries and storage heaters.
    - Storage systems coupled with rooftop solar.
    - Electric vehicle eet.
- From a social perspective, the value of behind-the-meter generation+storage is similar to the value of hybridization.
- For private users, the value of storage is given by arbitrage pro ts, i.e., **retail price** di erences (including fees & taxes).

The Economics of Behind-the-Meter Storage

- ! Incentives to invest in storage are highly dependent on retail pricing policies and rooftop solar policies:
  - Weak incentives under time-invariant retail prices and net-metering.
  - + Strong incentives under time-of-use prices or dynamic pricing, if no net-metering, and if increasing block pricing.

Distributional Effects: across Consumers

- Storage compounds the distributional e ects of behind-the-meter generation.

Potential for regressive distributional effects

- Investment costs ! Low-income households cannot a ord it.
  - More than 80% of solar owners belong to the top 3 income quintiles (Barbose et al. (2021)).
- Price savings only for high-income households.
- Additional savings from retail prices (access tari s, taxes...).
- But peak price reduction also bene ts households without storage.

The Economics of Hydrogen as Storage

Hydrogen can provide storage,
but its development **faces challenges**.

1. \Chicken-and-egg" problem:
   - Demand side does not invest in hydrogen adaptation because hydrogen is not yet available.
   - Supply side does not invest in hydrogen production because there is no demand for hydrogen.
2. Further uncertainties facing investors:
   - Hydrogen price uncertainty.
   - Electricity and carbon price uncertainty.
   - Technological uncertainty.
   - Policy and regulatory uncertainty.

Hydrogen as Energy Storage: Regulation

Blending as a "take-off" policy:

- Through auctions, gas TSO could procure green hydrogen and inject it in the gas pipelines.
  - Creates certain demand for green hydrogen.
  - Activates economies of scale and learning externalities.

How to define what is green H2?

- Trade-o exible vs. stringent policies:
  - Flexible policies:
    - e.g., electricity with green certificates...
    - Stronger incentives to invest in storage at the cost of increasing electricity demand when renewables not available.
  - Stringent policies:
    - e.g., electrolyzer connected to the renewable plant...
    - Ensures electrolyzer consumes renewable electricity at the cost of making investments more costly.

Conclusions

1. Firms will have incentives to support R&D into energy storage only if they expect to benefit from it.
2. This is determined by market structure and regulation.
3. Positive externalities created by storage often imply that a pure-market solution is not socially optimal.
4. Other market failures in electricity markets (market power) might distort storage decisions.
5. Potentially large distributional effects must be assessed and corrected if needed.

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Thank You!

natalia.fabra@uc3m.es
http://energyecolab.uc3m.es/

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