THE PARADOX OF "RENEWABLE ENERGY STORAGE": ECONOMICS AND EMISSIONS

Eric Hittinger, Rochester Institute of Technology
Inês Azevedo, Carnegie Mellon University
Policy Makers are also thinking about “Renewable Energy Storage”

- The New Jersey Board of Public Utilities’ Office of Clean Energy proposed that some renewable energy funding be shifted from wind/solar to renewable energy storage.
- Germany has launched a subsidy program for energy storage linked to residential-level Solar PV.

http://cleantechnica.com/2013/04/12/nj-may-start-funding-renewable-energy-energy-storage/
What is Renewable Energy Storage?

My Definition: *Any form of bulk energy storage used to time-shift renewable energy to more useful times of day.*

I’m not addressing:

• Energy storage for other services (such as frequency regulation)
• The value of storage if you are transmission constrained
The problem with “Renewable Energy Storage”

Energy storage has become increasingly associated with “renewable energy”

Energy storage is perceived as a technology that can or does lead to lower emissions by the electricity sector

But this way of thinking about energy storage is misleading
The operation of bulk energy storage has two effects that tend to increase emissions


2. Storage is less than 100% efficient.

Note: This effect still holds when you charge your storage from renewable energy sources.

Image: http://greensmith.us.com/applications/peak-shifting/
The Research Questions

For different locations in the US,

• How does revenue from bulk energy storage change when it is limited to charging from renewable energy?

• What are the net emissions from the operation of bulk energy storage, with and without this limitation?
The Approach

In each of 34 locations, assume a co-located wind farm and energy storage system
- 100 MW wind farm (Data from EWITS and WWD)
- 80 MWh of storage, 20 MW maximum charge/discharge, 75% round-trip efficiency

Using hourly market clearing price data from local or nearest market, determine the revenue-maximizing operation of storage
- Both perfect and imperfect information
- With and without charging limited to wind energy

Use “marginal emission factors” (MEFs) to determine the net emissions resulting from operating the storage
Locations
Under perfect information, storage is charging/discharging frequently, taking advantage of every price fluctuation.
Without knowledge of future energy prices, storage is more conservative and operates less frequently.
When storage is also constrained to charge only from wind energy, this further limits its ability to cycle.

![Electricity Prices and Storage Operation](image_url)
Bulk energy storage revenue varies significantly

• Given Perfect Information about future electricity prices, storage earns an average of 90% more revenue (range: 60% to 150%)
• When constrained to charge from wind energy, storage earns an average of 8% less revenue (range: 1% to 22%)
Emissions effects are calculated using “Marginal Emissions Factors”

For 1400 plants: location, fuel type, stack height and hourly emissions of \( \text{CO}_2, \text{SO}_2, \text{NO}_x, \text{PM}_{2.5} \)

Example: Temporal trends

Net CO$_2$ emissions due to storage are significant

Average US coal plant emissions: 950 kg CO$_2$/MWh
Average US natural gas plant emissions: 500 kg CO$_2$/MWh

Scenario: perfect information, charging from the grid

Net NOx emissions from storage vary widely, but are generally small or negative

Average US coal plant emissions: 2.5 kg NOx/MWh
Average US natural gas plant emissions: 1.2 kg NOx/MWh

Net $\text{SO}_2$ emissions from storage vary over an order of magnitude and can be quite large.

Average US coal plant emissions: 6 kg $\text{SO}_2$/MWh
Average US natural gas plant emissions: 0.25 kg $\text{SO}_2$/MWh

Specific conclusions:

– Limiting bulk energy storage to charging from renewable energy is inefficient, reducing potential revenue by 5-10%.

– Regardless of the source of energy, bulk energy storage has significant emissions, varying by location.

General conclusions:

– **Energy storage is not a “green” technology**: Whether bulk storage is used to maximize revenue or shift energy to higher demand hours, system emissions are increased.

– **Energy storage is not a “renewable energy” technology**: Rather, it is used to improve operational and economic efficiency, regardless of the root cause.
Questions!
MEF Example

Marginal Fuels, 2006-2011:
MRO Region (Midwest)

The scenarios/locations that result in the most revenue tend to produce the greatest emissions.