Rate design in a decarbonized world

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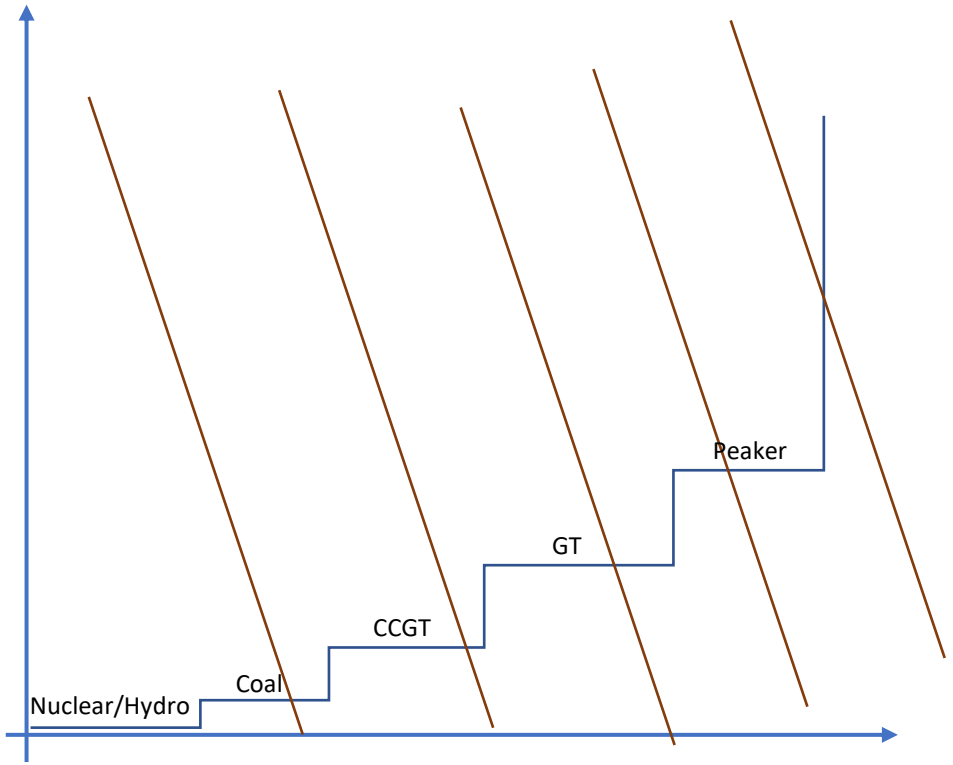
Features of a decarbonized power sector

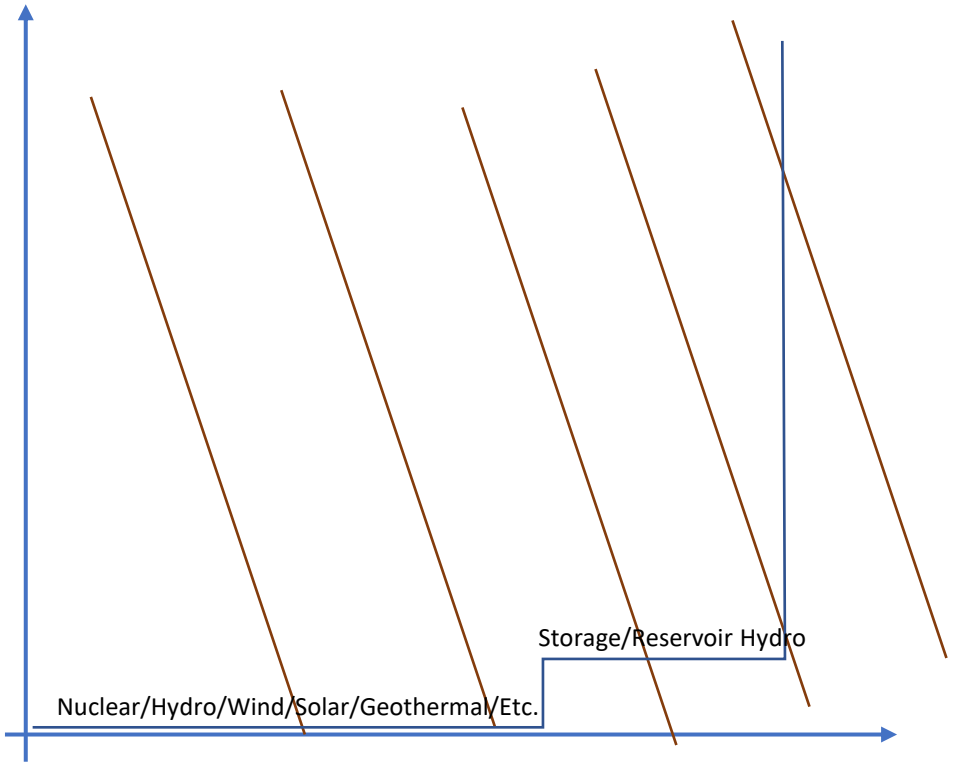
- We expect deeply-decarbonized systems to be dominated by near-zero marginal cost generation
  - Zero marginal cost, but high CAPEX sources
  - Solar, wind, nuclear, hydro, geothermal all fit this description
- Large penetration of storage
  - Expectations of future prices becomes the marginal cost of these resources
- More distributed generation
  - Likely correlated with income

Pressure on rate design

- These features put pressure on current rate design, especially rate designs for residential consumers

Wholesale Prices in a deeply-decarbonized world





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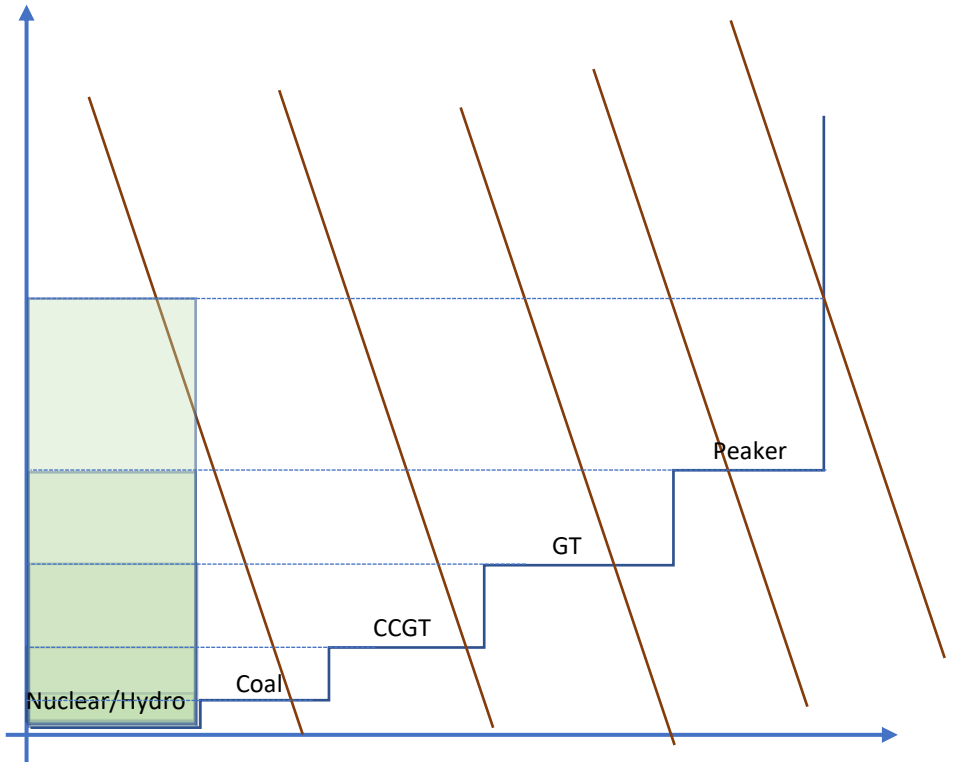

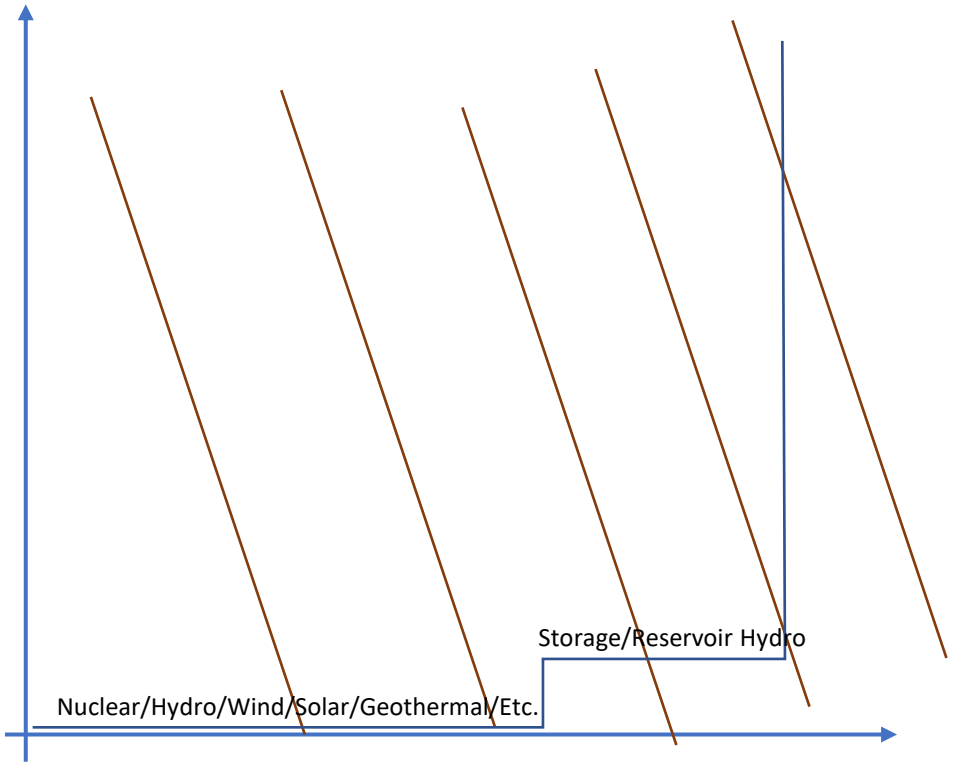

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Two common features of current rate designs

First: Paying for Transmission and Distribution

- Often have small connection charges
  - => This means Transmission and Distribution (T&D) has to be paid for by charging a "mark up" for energy
- Some systems have an explicit volumetric charge to pay for T&D
- Some systems have increasing block pricing where revenue from the higher blocks cover T&D
- Both make the marginal price of electricity too high

Two common features of current rate designs

Second: Prices are constant over time

- Rates tend to exhibit very little variation over time

Decarbonization requires us to rethink rate design

My bill!

Costs depend on kWh

Connection Charge

Costs that do NOT depend on kWh

Total Charges for Electricity

Supplier (CONSTELLATION NEWENERGY, INC.)		
Meter 7119486		
Generation Service Charge	1102 kWh X .10800	$119.02
Subtotal Supplier Services		$119.02
Delivery		
(Rate A1 R1 RESIDENTIAL)		
Meter 7119486		
Customer Charge		$7.00
Distribution Charge	1102 kWh X .07056	$77.76
Transition Charge	1102 kWh X -.00177	-$1.95
Transmission Charge	1102 kWh X .04437	$48.90
Revenue Decoupling Charge	1102 kWh X .00267	$2.94
Distributed Solar Charge	1102 kWh X .00341	$3.76
Renewable Energy Charge	1102 kWh X .00050	$0.55
Energy Efficiency	1102 kWh X .01714	$18.89
Subtotal Delivery Services		$157.85
Total Cost of Electricity		**$276.87**
Total Current Charges		**$276.87**

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What do we learn?

- First, I use a lot of electricity!
- Second, energy is < ½ the volumetric charge
  - Energy: 10.8¢/kWh
  - Distribution: 7.1¢/kWh
  - Transmission: 4.4¢/kWh
  - Other things: 2.8¢/kWh
- Third, constant volumetric charge across all hours

My rate: 324 won/kWh

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Time to take T&D out of volumetric rates

Two reasons

- First, it will become more and more regressive

- Second, it hinders electrification

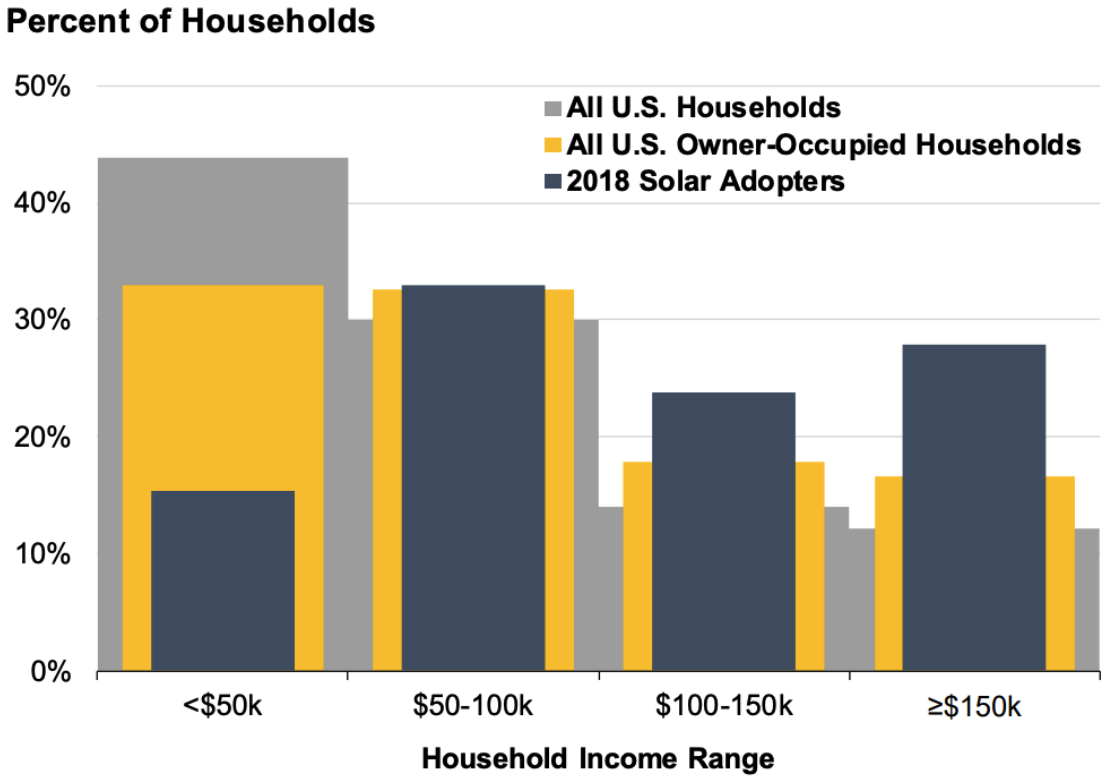
Volumetric charges used to work well

- One of the goals of rate design is often to **cross-subsidize** low-income households
  - Have high-income households pay a larger share of T&D

- Volumetric charges and increasing block pricing do this, or used to do this
- Historically, high-income households consumed more electricity, on average
  - So, high-income households paid more toward T&D than low-income households
  - Not a very efficient way to cross-subsidize, but still worked

But, now…

- High-income households are more likely to install rooftop solar
- If they are paid the full retail rate for the electricity they generate (net metering), they will pay nearly **zero** for T&D



Notes: Based on all states in the data sample. Incomes are consolidated into this set of bins in order to conform to Census statistics, which are provided in $50k increments for incomes ≥$100k, and which group all incomes ≥$150k for owner-occupied households.

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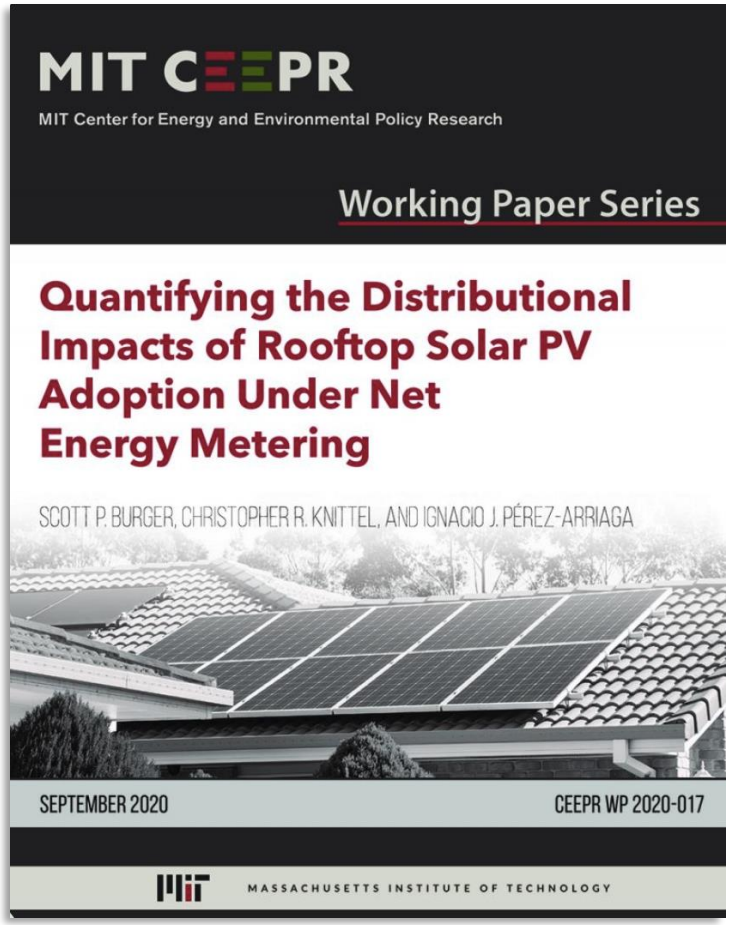
Is rate design still progressive?

- We find, for Illinois, that after roughly 25% solar PV penetration current rates become **regressive**

- Simple idea: Suppose there were 1,000 people just like me:
  - Paying $100 in energy and $100 in T&D
- The wealthy ½ install solar sized to be net zero
  - Their energy costs go away, that's okay
  - Their T&D costs do not go away
  - T&D costs for the remaining ½ have to double!



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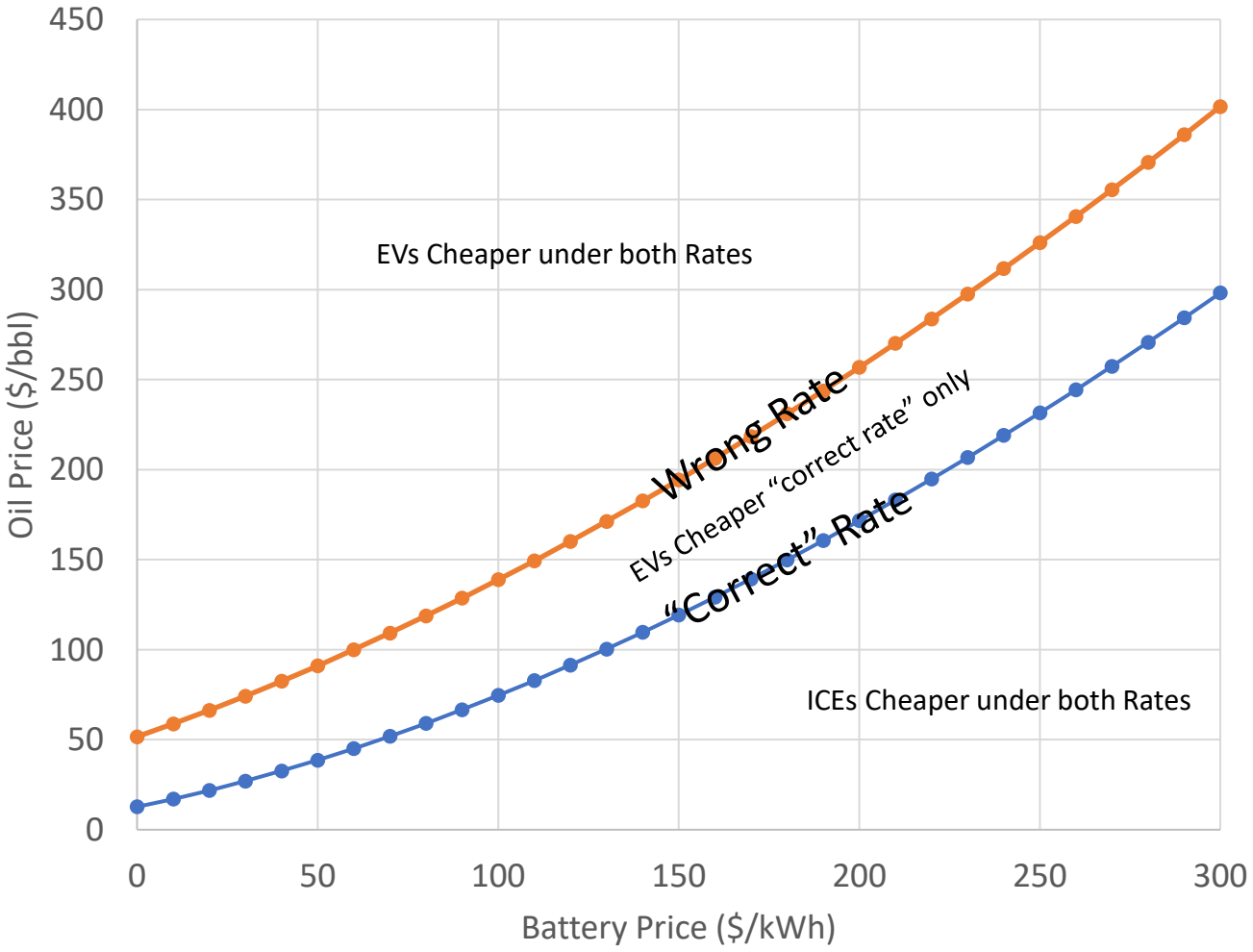
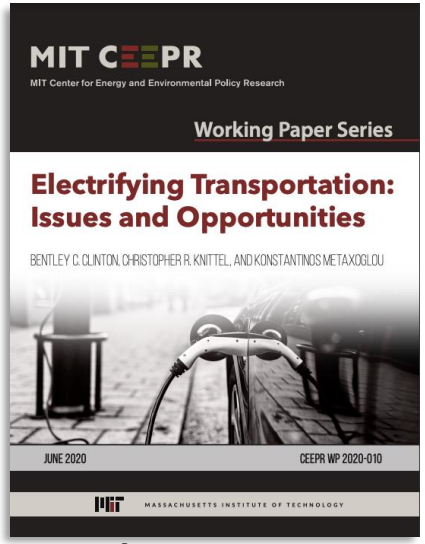
High volumetric charges hinder electrification

- The expectation is that to decarbonize transport/heating/cooking, we will shift to electricity
- But, high volumetric charges disincentivize electrification
  - Especially true in the US where natural gas and gasoline are (relatively) cheap

- Example: Electric Vehicles

An example





- In this paper, we allow you to calculate, for every oil price, what battery prices have to be for EVs to be cheaper than ICEs
- Suppose oil prices are $125/bbl
  - @24.5¢/kWh batteries have to be less than $82/kWh
  - @10.8¢/kWh batteries have to be less than $155

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Pressure for time-varying rates will increase

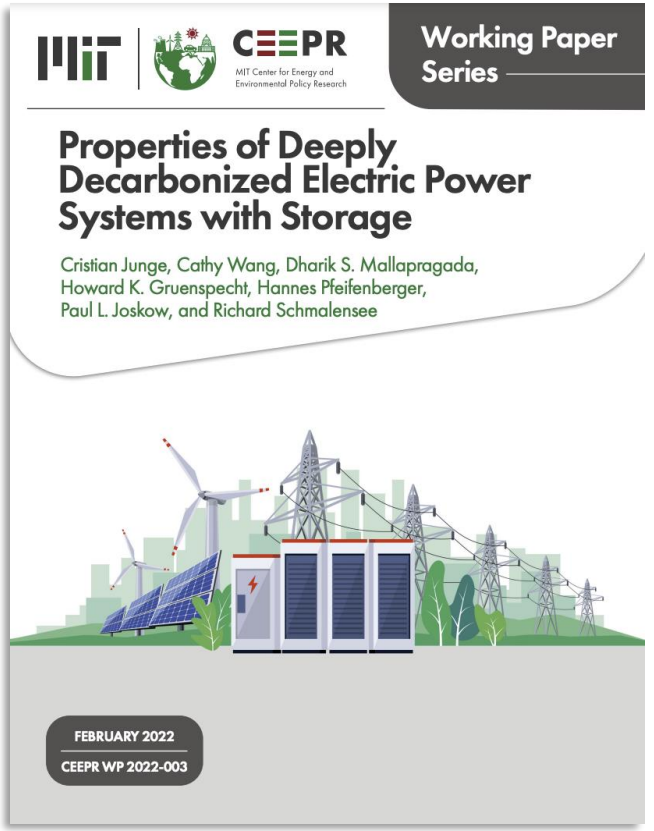
Basic economics

- Basic economics tells us consumers should face the true price of the product
  - If not “deadweight loss”/waste is created
  - This is true whether prices are too high or too low

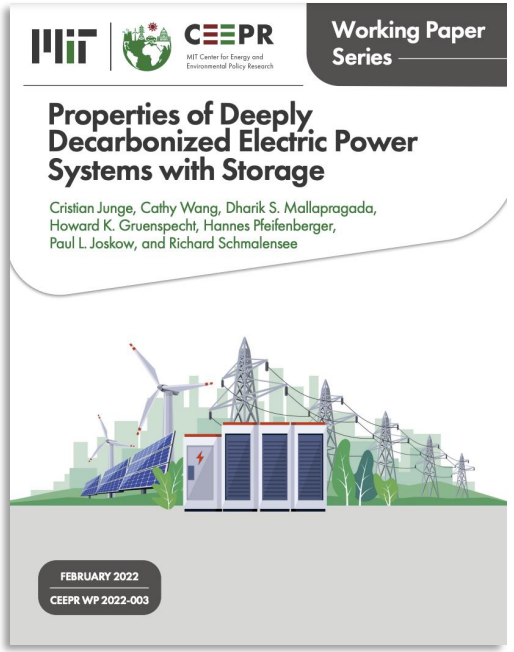
- This means that my energy price should vary with wholesale prices
  - It doesn’t

Renewable penetration => greater volatility

- We can see this in data and in simulations
- Junge et al. (2022) characterize prices in the Texas ERCOT market under different carbon constraints
  - Ranging from no constraint to totally decarbonized
- Several interesting results follow



Properties of decarbonized prices



- Average prices increase
  - Not surprising, we are adding a constraint to the market
- Variances are not necessarily monotonic
  - As you decarbonize you get a larger and larger share of prices near zero driving down the variance
    - E.g., 99% of totally decarbonized prices are below $2.5/mWh
    - 61% of prices under a constraint of 5g/kWh are below $2.5/mWh
- “Order statistics” increase dramatically
  - You get a few very, very, high prices

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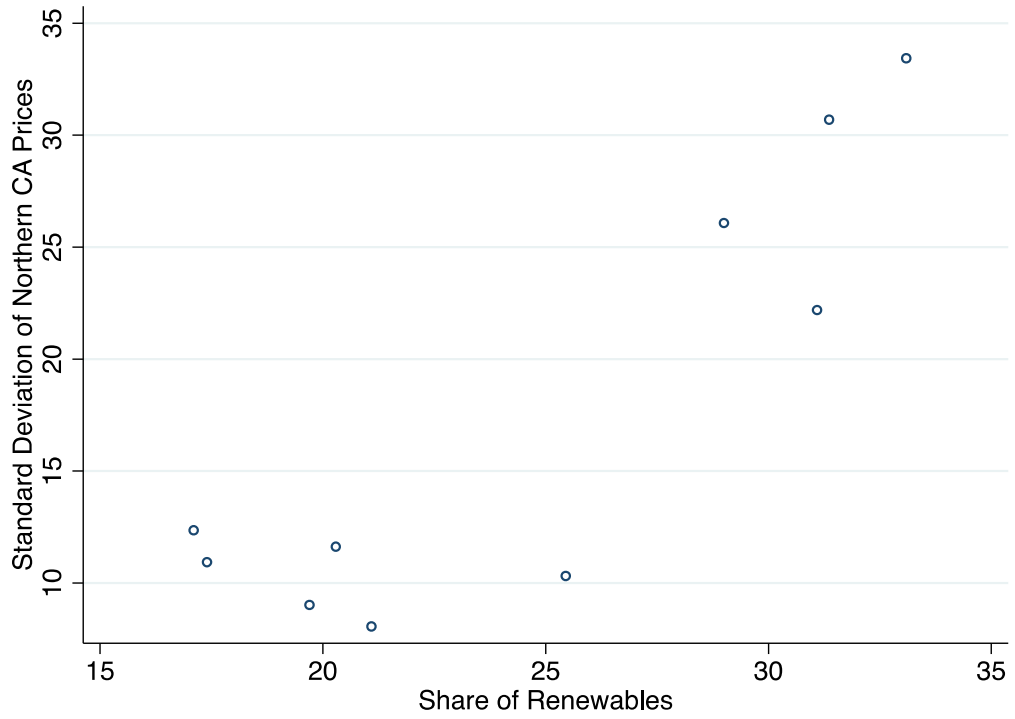
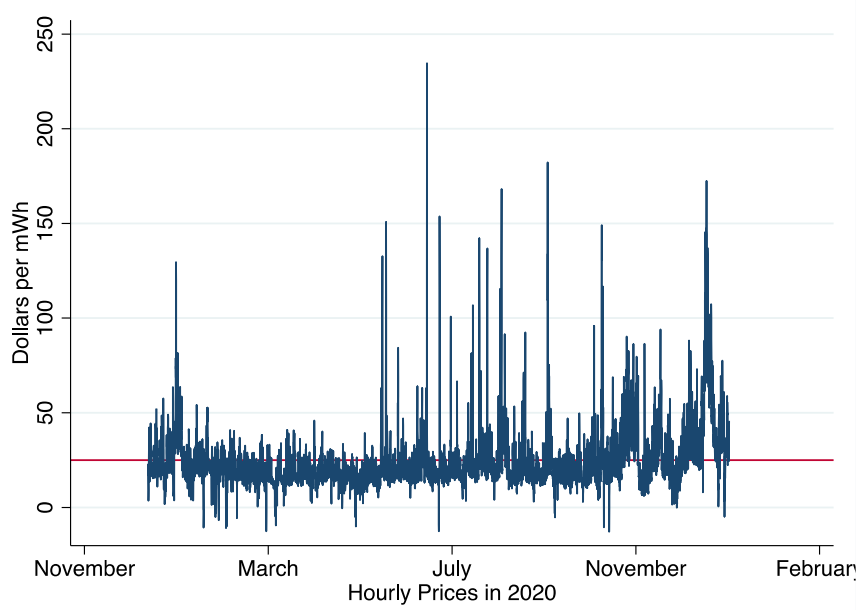
Actual price data, California

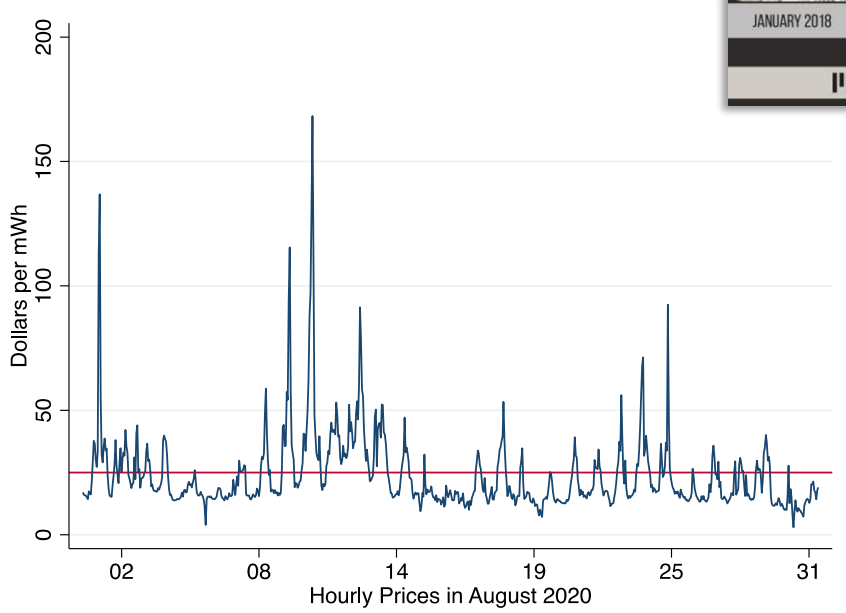
- We are starting to see this in real systems
- Share of renewables in CA was 17.1% in 2011 and increased to 33.1% in 2020
- How is this related to the standard deviation of prices?

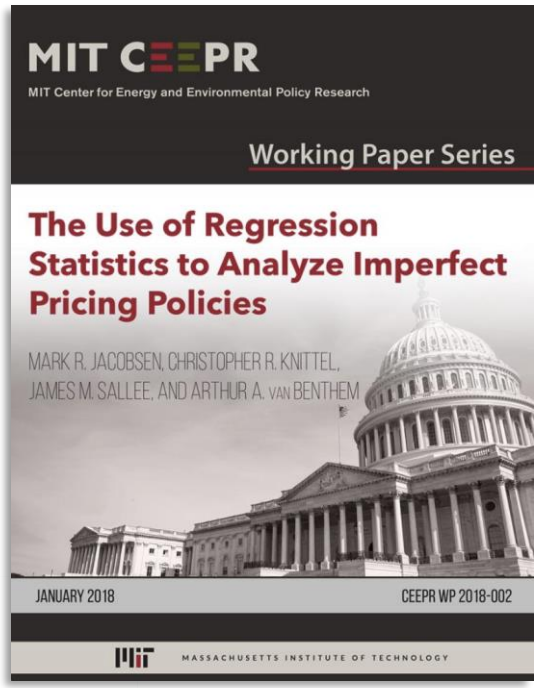


Flat rates create inefficiency

- The greater volatility in wholesale prices will lead to greater inefficiency from **flat** rates







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Wrapping up

- Our rate design was based on “old” power systems
  - No option for wealthy consumers to “cut the cord”
  - We were willing to include many costs into the volumetric charge
  - Prices varied over the day and season, but not as much as we expect them to going forward
- This new regime will require new rate designs
- Higher connection charges and more time-varying prices