An Increased Role for the Demand Side in Renewable Integration

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Outline

- Traditional planning and operation of the electricity system,
- Sector coupling,
- Why care about sector coupling?
- Fuel endowments and temporal fuel endowments,
- Adaptations to temporal endowments as a path to deep decarbonization.

Traditional planning and operation of electricity.

- Forecast electric demand, particularly peak:
  - Economic trends, known major new consumers.
- Build generation capacity to meet peak and procure fuels to provide energy.
- Dependence mostly one-way:
  - Peak demand implies generation capacity and need for fuel,
  - Some moderation of peak through demand response programs, including off-peak water heating.

Traditional planning and operation of electricity.

- Mostly one-way dependence is somewhat surprising given that electricity is the most volatile of all commodities at wholesale:
  - Due to lack of cheap storage,
  - Combined with relatively inflexible timing of demand.
- Until recently, electricity was the only commodity that exhibited negative prices.

Sector coupling.

- In essentially all other commodities, demand and timing would be modulated by supply conditions and resulting prices:
  - If bananas are expensive, I buy more apples,
  - Fill gasoline tank during the week to avoid weekend prices,
- We could say that there is coupling of demand-side to supply through prices.
- Typical supply chains also have coupling between stages of production with price elasticity and substitution.

Sector coupling.

- Electricity demand has historically been different!
- Historically few substitutes for electricity, so demand inelastic, with relatively inflexible timing:
  - I am not going to wash my clothes at 3am no matter how cheap electricity is at that time!

Why care about sector coupling?

1. Increased use of natural gas for electricity:
   - Pipeline capacity constraints (New England in US) or, binding production constraints/high prices of available supply (East Coast Australia),
2. Renewables result in greater variation in net load (load minus PV, wind, and run-of-river hydro production) than the variation in load:
   - Thermal generation capacity insufficiently flexible in some regions,
   - Gas tends to be more flexible than coal or nuclear.

Why care about sector coupling?

- If there was enough flexible generation without fuel limitations and without carbon concerns:
  - Would still build to meet peak and procure fuel,
  - Would not bother to talk about sector coupling on the supply or demand side!

Why care about sector coupling?

- Increased variability of net load together with emissions goals are forcing the consideration of sector coupling.
- Demand side is historically decoupled from electricity industry by design:
  - Most retail customers still see flat rates, with significant contribution by volumetric adders for T&D etc,
  - But we need to start thinking about coupling demand to supply!

Fuel endowment.

- Fuel endowment significantly guides generation choices:
  - Texas historically used coal, gas, and nuclear with fracking increasing gas supply (and therefore contribution of gas), flat terrain so little hydro,
  - Australia historically predominantly coal with some hydro,
- Stored energy in fossil and nuclear fuels and reservoir hydro allowed relatively unfettered temporal distribution of consumption, given enough generation capacity.

Temporal endowment.

- Wind and solar endowments have a temporal character.
- Consider coupling consumption decisions to time-varying production through demand response.
- What about storage, particularly batteries?
  - Current uses of utility-scale chemical battery storage primarily to provide "ancillary services" or in smoothing short-term fluctuations in renewable production.

Temporal endowment.

- Is large-scale battery storage the answer to managing all time-varying production?
  - At current prices of $100/kWh of capacity, assuming around 3000 round-trip cycles over life, and even ignoring financing costs, a round-trip battery charge and discharge costs around $30/MWh energy stored,
  - Round-trip cost of storage is roughly the same as the average ERCOT wholesale price of electricity,
  - So, storing *most* energy in batteries would significantly increase overall costs.

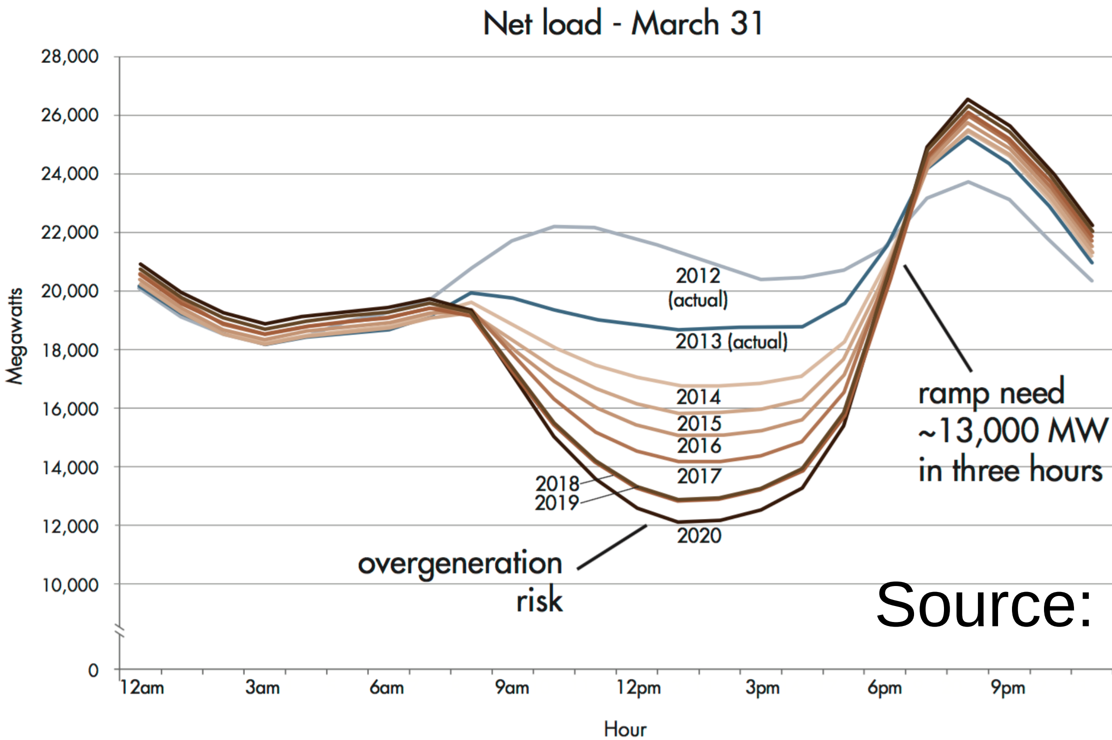
Temporal endowment.

- Despite continued decreases in chemical battery storage costs, they are currently far too expensive to fully support deep decarbonization,
- Tesla Virtual Power Plant demonstrates a role for storing some energy in chemical batteries:
  - Currently dependent on Federal and State subsidies.

Temporal endowment.

- Variability of wind and solar are challenging the ability to meet electric load in several regions.
- The mismatch between PV production and electric load is especially significant for California:
  - The California ISO coined the term “duck curve” to describe the shape of that state’s net load.
  - On a mild sunny day, the net load falls so low that other generation cannot follow it down and then net load rises rapidly again in the evening as the sun goes down.

Temporal endowment.



Source: CAISO

- "Duck curve" also becoming problematic in Australia and likely wherever there is considerable uncontrolled rooftop solar.
- Not as problematic in Texas.

Temporal endowment.

- Different regions historically adapted by using their energy endowment of fuel.
- Similarly, increasing renewables will necessitate adapting to the temporal endowment:
  - Include coupling consumption more strongly to renewable supply through demand response options.
- Wind and solar have different temporal endowments.

Temporal endowment.

- Wind:
  - Inland in several regions is strongest at night and during Autumn, Winter, Spring,
  - Near-shore typically strongest in afternoon, particularly in Summer.
- Solar:
  - Coincides with solar day,
  - Modulated by cloud cover.
- Significant further increases in renewable penetration must confront the temporal endowment and adapt to it.

Possible adaptations: Supply-side.

- Build shares of inland and near shore wind and solar capacity to better match typical load shape, particularly in peak season,
- More agile thermal capacity to provide for net load, predominantly gas where available,
- Storage,
- Spill renewables.

Possible adaptations: Demand-side and Behind-the-meter.

- More variability in retail tariffs and *exposure of retail to wholesale prices*,
- More active demand-side modulation through *retailer—customer agreements*,
- *End-use storage of product* or service as adaptation to temporal endowment, including new or growing uses of electricity.

Exposure of retail to wholesale prices.

- Many C&I customers are at least partially exposed to wholesale prices:
  - Main demand response in ERCOT is still due to "4 coincident peak" setting of transmission prices.
- Experience of residential retail customers of Griddy real-time tariffs in summer 2019 not very promising:
  - Some customers found that they did not really want to be unhedged against wholesale price fluctuations!

Retailer-customer agreements.

- Many customers prefer retailer to continue historical role in hedging against wholesale price fluctuations!
- Still allows for innovative arrangements that increase sector coupling:
  - Enchanted Rock retailer in ERCOT has installed generators in HEB supermarkets to provide backup power during outages,
  - Can also generate in non-outage conditions when wholesale prices are high.

Retailer-customer agreements.

- Such distributed thermal generation has unclear implications for decarbonization:
  - Lower distribution losses, but
  - Possibly more emissions per unit electricity.
- Other retailer-customer arrangements possible that do not involve distributed generation:
  - Involving end-use storage of product or service.

Low effort end-use storage.

- Off-peak water heating,
- Timed/Controlled *slow EV charging* at night in regions with inland wind, and during day for regions with high solar, (https://rossbaldick.com/research-updates-on-average-rate-charging/)
- *AC pre-cooling* to better align daily demand variation with solar production, store "cool," (https://rossbaldick.com/theres-more-than-one-way-to-deal-with-a-duck-curve/)

EV charging.

- In ERCOT, inland wind peaks in the middle of the night:
  - Ideal time for at-home charging of electric vehicles, particularly if charging is spread out over many hours during night between evening arrival home and morning departure,
- Photovoltaic (PV) production is typically maximum at solar noon:
  - EV charging during day, but completed well before sundown, can similarly help align consumption with solar production.

AC pre-cooling.

- In addition to emerging loads such as EV charging, what other ways can better utilize photovoltaic production?
- Typical electricity net load peaks:
  - Morning and evening in Winter,
  - Late afternoon to evening in Summer.
- AC pre-cooling can better align consumption in Summer with solar production.

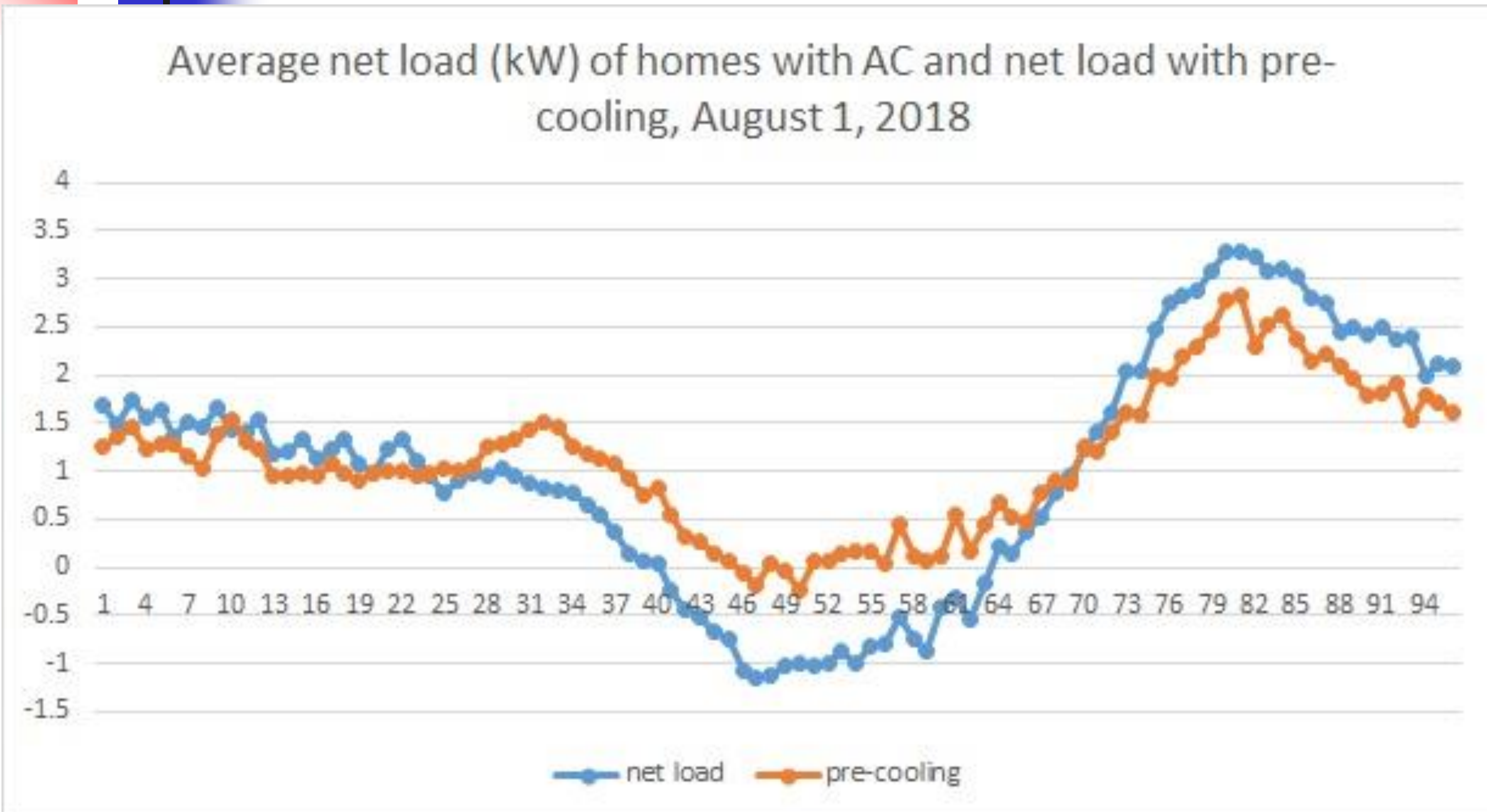
AC pre-cooling.

- Air-conditioning (AC) is a significant contribution to net load after the sun goes down:
  - In Texas, residential consumption in summer greatly exceeds that in spring and fall,
  - Summer peak consumption is driven by AC load during times of high temperatures that persist into evenings and after sundown.

AC pre-cooling.

- Cool house during peak of solar irradiance,
- Advantages:
  - Reduces exports from rooftop solar to the electric distribution system,
  - Reduces the "ramp rate" of net load,
  - Reduces the peak of net load.
- Pre-cooling will result in higher energy consumption by 2% to 8% overall:
  - Analogous to "round-trip losses" in a battery storage system, and roughly the same magnitude,
  - But no capital purchase necessary!

AC pre-cooling.



- Blue curve shows typical “duck curve”
- Red curve suggests how pre-cooling can help.

AC pre-cooling.

- Won’t consumers balk at spending more money on higher electricity usage to pre-cool their homes?
- New TOU rates in California will have lower prices during the day:
  - Consumers may be willing to do their laundry, dishes, and electric-vehicle charging – and pre-cool their homes — in the afternoon,
- Griddy real-time prices and other retail offerings in ERCOT will be lower during middle of the day with high solar.

Higher effort end-use storage.

- Chillers and dedicated cool storage for AC,
- Chemical processes such as air separation, store oxygen and nitrogen,
- Other industrial demand response, including data centers and Bitcoin miners,
- Electrolysis to produce hydrogen.

Higher effort end-use storage.

- More radical use of "demand following supply" such as water pumping, storing gravitational potential energy (https://rossbaldick.com/pumping-water-uphill-storing-energy-without-batteries/)

Demand following supply.

- Deliberately change consumption based on renewable production:
  - Power mechanical loads from a variable speed drive with the drive frequency adapted to renewable production:
    - Water pumping,
    - Air-conditioning,
  - Partially or fully replace thermal generation as the "swing" resource.

Conclusion

- Foreseeable levels of battery storage will be insufficient to cost-effectively fully support deep decarbonization,
- No other storage options in ERCOT such as pumped storage hydroelectricity,
- Sector coupling can facilitate renewable integration by responding to the temporal endowment of renewables,
- On the demand-side, several examples utilize end-use storage to adapt to the temporal endowment.