October 29th, 2021

Microgrids and Demand Flexibility

2021 Getting to Zero Forum

cadeo

Agenda

- Microgrid development today
- What is demand flexibility (and why do we care)?
- Value of demand flexibility to (micro and macro) grids
- Key technologies and considerations
- Case studies
  - Portland: Fire Station 1
  - Vancouver: Gloucester Industrial Park
- Conclusions and Recommendations

Microgrid planning/development today (such that it exists)

- Typically, microgrid design takes load as a given and then sizes to it based on a design outage
- Critical load planning is used to downsize load requirements in most cases
- Costs scale relatively linearly with:
  - Peak load (gensets and inverters), or
  - Total energy (battery packs, solar, onsite fuel)
- Remember that peak load is often defined based on much more conservative diversity factors and shorter durations (<10s) than grid planning (say for transformer sizing)

Pain points in microgrid deployment

Sales process

- How do we open more doors?

Business case

- How do we justify the high upfront cost?

Inverter sizing

- How do we keep size down while meeting needs?

Long duration outage sizing

- Will our microgrid withstand “the big one”?

Critical load planning

- What stays and what goes and when?

Thermal loads

- How do we maintain livability in extreme weather?

Leveraged funding

- How do we get more people to throw in money without too much trouble?

Utility program integration

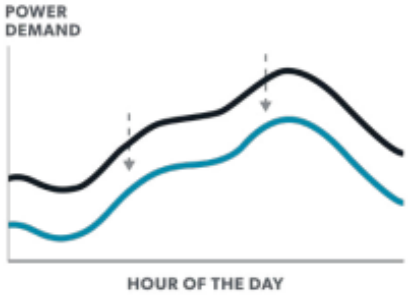
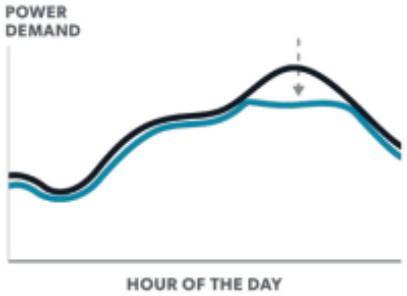
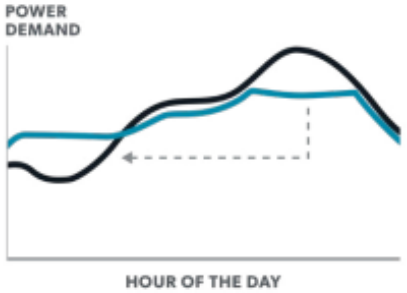
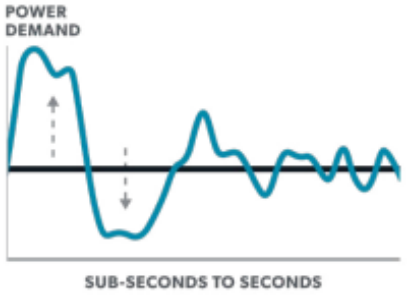
- How do we get utility money without having to open another regulatory docket?

Demand Flexibility

- Not just for utility programs anymore…

What is demand flexibility?

- Basically, anything that helps to reduce or shift load
- Much of the conversation in the industry has focused on utility/grid value, but demand flexibility is critical to resilience planning

	LOAD IMPACT	EXAMPLE MEASURE	EXAMPLE BENEFIT
Efficiency		Building has an insulated, tight envelope and an efficient HVAC system to reduce heating/cooling energy needs	Reduced costs of burning fuel to satisfy energy demand, and reduced emissions associated with lower fuel use
Shed Load		Building dims lighting system by a preset amount in response to grid signals while maintaining occupant visual comfort levels	Reduced investment in generation and transmission capacity due to lower peak demand
Shift Load		Connected water heaters pre-heat water during off-peak periods in response to grid signals	Reduced energy costs due to shifting consumption to cheaper hours of the day; avoided curtailment of renewables during off-peak periods
Modulate		Batteries and inverters autonomously modulate power draw to help maintain grid frequency or control system voltage	Reduced ancillary services costs, improved integration of variable generation resources (e.g., wind, solar)

Why do we care?

- If you want to know why demand flexibility matters to microgrids, talk to any off-gridder (or someone from a region with poor reliability)
- There are use cases discussed in the off-grid literature:
  - Total energy efficiency
  - Peak load efficiency
  - Conversion efficiency
  - Fuel switching
  - Load shifting
  - Curtailment planning
  - Load sinks
  - Thermal storage

Grid/System Value

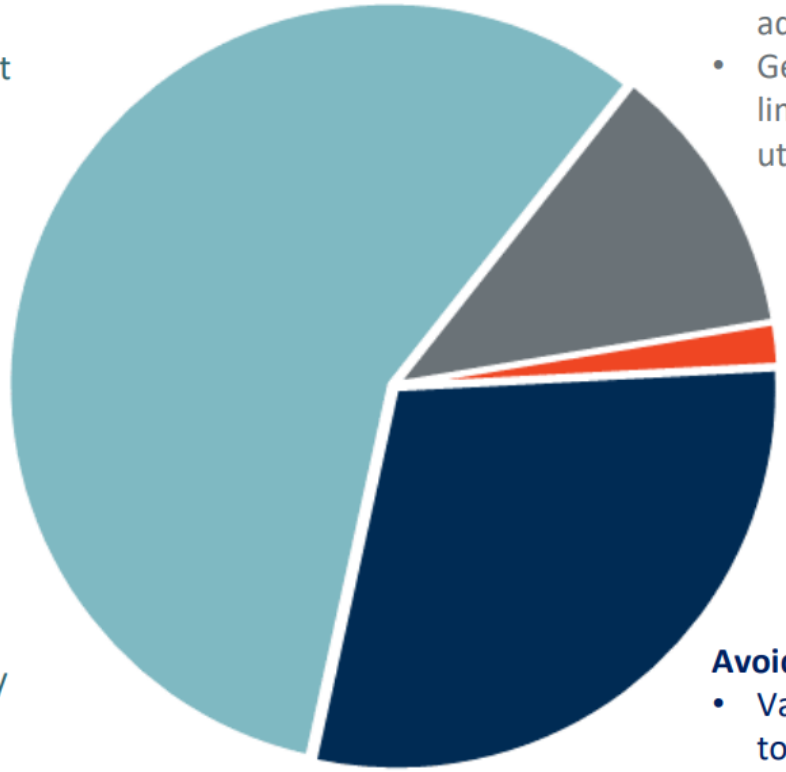
- Flexibility breaks down in a few categories
  - Avoided Cost of Capacity (generation, transmission, and sometimes distribution)
  - Avoided Cost of Energy
  - Avoided Cost of Ancillary Services
  - Avoided Carbon Emissions
- These value vary considerably across utilities/markets
- In general, load flexibility creates most of its value through generation capacity and wholesale energy arbitrage

National Assessment of Load Flexibility

2030 Annual Benefits of National Load Flexibility Portfolio

Avoided Generation Capacity, *$9.4 billion/yr (57%)*

- Value based on avoided cost of gas-fired combustion turbine, assuming no near-term peaking capacity need in some regions
- Capacity remains the dominant source of load flexibility value through at least 2030
- Capacity value will vary significantly by region; load flexibility poised to provide most capacity value in regions with pending capacity retirements, supply needs in transmission-constrained locations, or unexpected supply shortages



Avoided Transmission & Distribution Capacity, *$1.9 billion/yr (12%)*

- Value includes system-wide benefits of peak demand reduction, plus added benefit of geographically targeted T&D investment deferral
- Geo-targeted T&D deferral opportunities are typically high value but limited in quantity of near-term need; this value is likely to grow as utility T&D data collection and planning processes improve

Ancillary Services, *$0.3 billion/yr (2%)*

- Value accounts only for frequency regulation and assumes a need equal to 0.5% of system peak demand; additional value may exist if considering other ancillary services products
- Frequency regulation provides very high value to a small amount of capacity; in our analysis, the full need for frequency regulation can be served through a robust smart water heating program

Avoided Energy Costs, *$4.8 billion/yr (29%)*

- Value accounts for reduced resource costs associated with shifting load to hours with lower cost to serve; does not include consumer benefits from reductions in wholesale price of electricity
- Energy value is best captured through programs that provide daily flexibility year-round, such as Auto-DR for C&I customers, TOU rates, EV charging load control, and smart water heating

Stakeholder Value

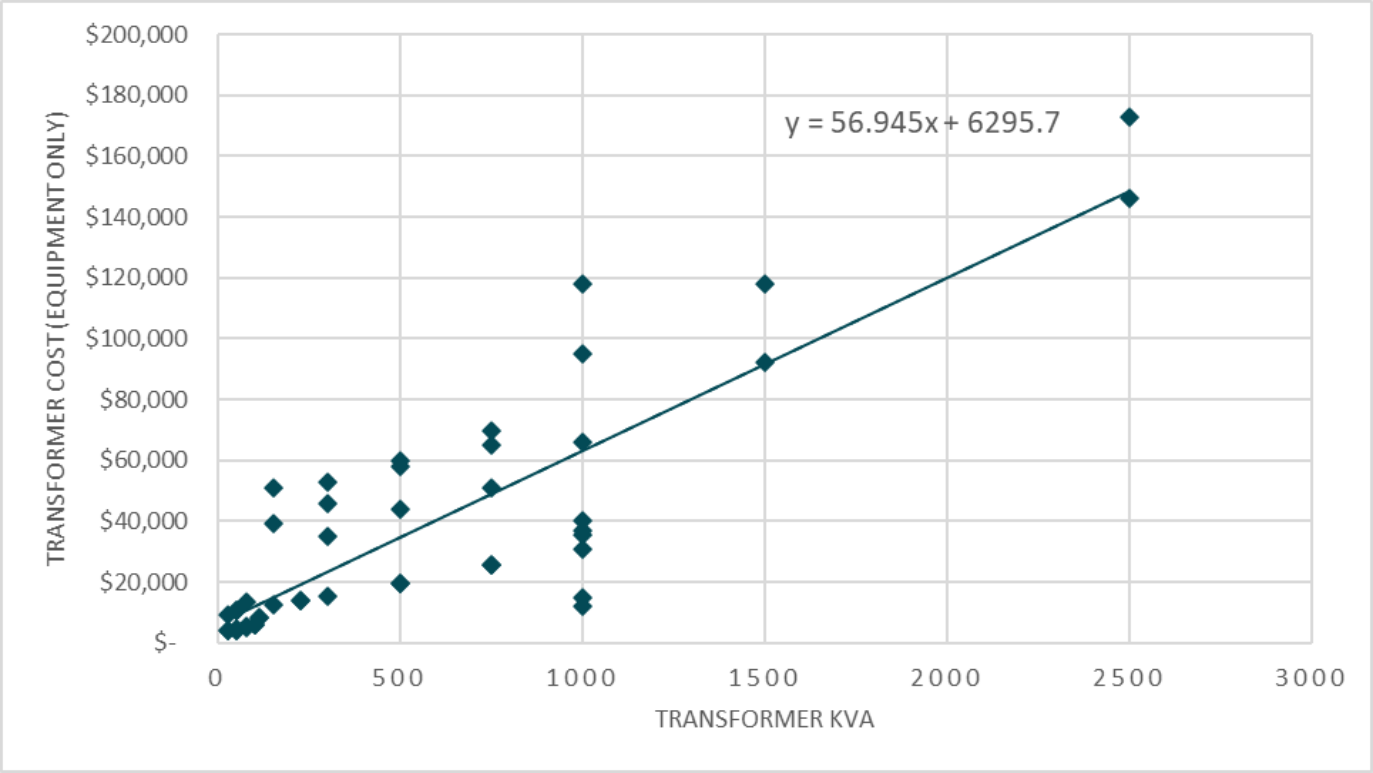
- There are many (not necessarily mutually exclusive) groups of that can potentially reap value from flexibility:
  - Developers
  - Tenants
  - Owners
- These values differ based on the context
  - Residential/commercial/multifamily
  - New/existing construction
- Most value tends to fall to the tenant/owner

Sources of Stakeholder Value

- Wide range of benefits depending on the context
- On high end, nonresidential new construction in areas with many program offerings could save a substantial amount through a combination of
  - Reduced upgrade costs
  - Rate management
  - Program participation
- On lower end, existing construction in areas with flat NEM rates and no programs would likely save very little, except in cases where flexibility can be used to reduce upgrade costs associated with electrification or interconnection

New Connection Costs

- Primary cost savings comes from reducing transformer sizing at construction (or new lump load)
- While this is typically lumpy, on average costs are about $55/kVA
- Adjusting for power factor and load diversity:
  - Site demand reduction of 1 kW = savings of ~$30

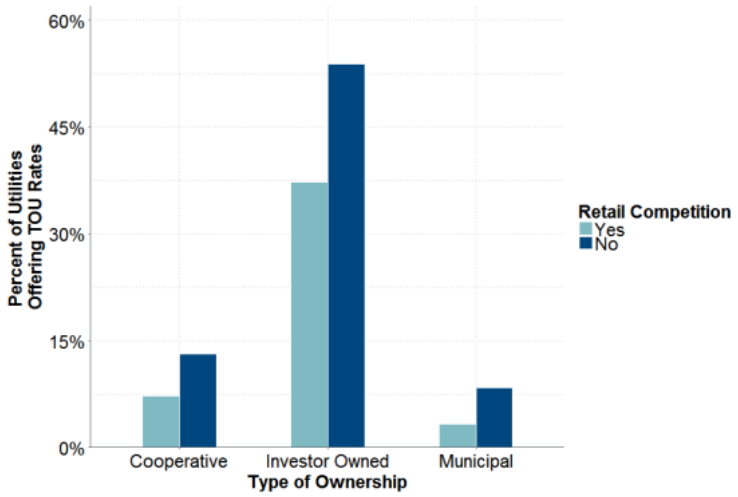


Source: https://www.nrel.gov/docs/fy18osti/70710.pdf
https://data.nrel.gov/submissions/101

Bill Savings: Residential TOU

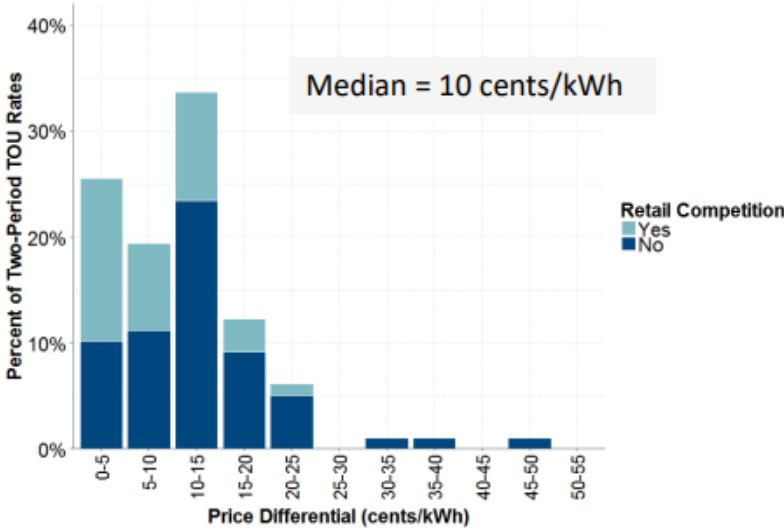
- Utilities increasingly offering/requiring time-of-use rates for residential customers
- Typical load shift observed 3%
- Load shift increases by up to 10% when enabled with technology
- Total bill savings typically in the 5-15% ranges

Share of Utilities Offering TOU (by Type of Utility)



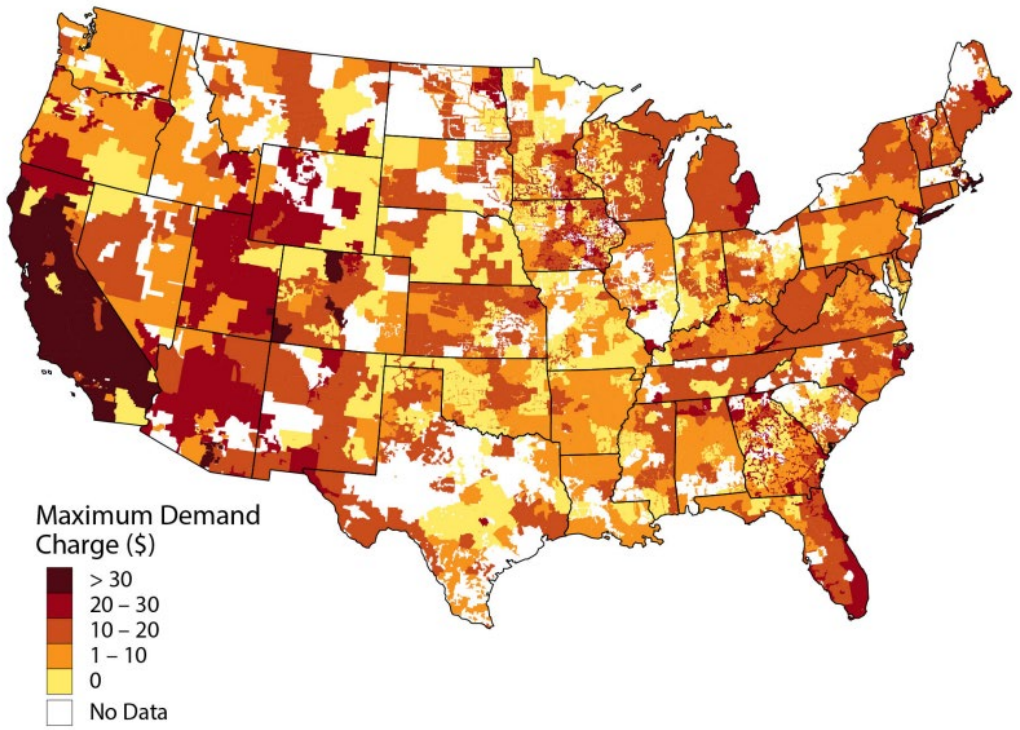
Sources and notes: Brattle analysis of 2015 EIA-861 data. Political subdivisions, retail power marketers, and other utilities are excluded in the above chart due to sample sizes less than ten.

Price Differential in Two-Period Rates



Bill Savings: Nonresidential Demand Charges and TOU

- Most medium/large commercial buildings face some form of demand charge
- Typically range from $5-$25/kw-mo
- Roughly one quarter of buildings face charges>$15
- Savings scale roughly linearly with demand charges
- TOU charges typically correspond to wholesale rates (~$0.005-$0.01/kWh differential)



Source: https://www.nrel.gov/docs/fy17osti/68963.pdf

Bill Savings: Solar Utilization

- Increasingly, states are moving away from net metering, toward either Resource Value of Solar, wholesale rate compensation, or zero export tariffs
  - HI is the extreme with zero net export
  - Red states tend to go for wholesale compensation
  - Blue states tend to be at NEM then transition to something between wholesale and retail as penetrations increase
- Roughly 1/3 – 2/3 of solar is exported to the grid
- Wholesale rates are typically $0.03/kwh vs retail rates of approximately $0.12 for residential and $0.09 for nonresidential

Program Incentives

Residential

- ~$50 per year for HVAC
- ~$20-25 per year for WH
- ~$200-500 per year for battery
- ~$25 per year for smart inverter

Nonresidential

- ~$25-$100/kw-yr for ADR (through utility and/or aggregator)
- ~$50/thermostat-year

Reduced Upgrade Costs

- Use of smart inverters and/or advanced load flexibility can dramatically reduce interconnection costs where they can provide volt-VAR/reactive power support
- Implementing this functionality significantly increases hosting capacity in DER penetration areas
  - Can avoid system upgrades in these areas on the order of $150k-$300k (cost to install new voltage regulator/LTC)
- Panel upgrade
  - Residential: ~$1k-$2k
  - Commercial: ~$3k-$4k
- Service upgrade
  - Highly variable, ranging from $1.5k to $30k

Key Technologies

Key technologies

- Focus is often on large loads in terms of either energy and/or capacity
- Considerations:
  - Likely outage duration and season
  - Use of gensets
  - Use of heating fuels (either primary or secondary)
  - Is the site energy-constrained peak constrained, or both?
  - How does it vary by season?

Key technologies: thermal loads

- To minimize coincident demand and system size requirements, thermal storage is critical
- Can also serve as a load sink in cases of excess generation

Heating and cooling

- WEATHERIZATION!
- Passive heating/cooling
- Inverter-driven heat pumps
- ERVs/HRVs
- Thermal storage

Water heating

- Advanced water heating controls
- Heat pump
- Active solar
- Electric boilers

Key technologies: controls and process

- Controls play an important role managing discretionary loads
- Also important when looking at long-term curtailment planning

EV charging

- Smart charging
- V2B

Miscellaneous loads (things with resistance elements or motors)

- Heat pump dryers
- 220V splitters
- Smart breakers
- Building management systems

Case Studies

Fire Station 1

- Primary fire station for City of Portland
- Solar + storage + genset microgrid for seismic resilience
- Smart HVAC controls used for efficiency and DR
- Load flexibility included to cover cost of integration into utility system and reduce interconnection costs
- Bureau chose to subsequently enroll all other stations in DR program

Gloucester Industrial Park

- Initially a demand response pilot targeted at deferring substation upgrade at industrial park
- Through engagement with customers and site-level analysis, found storage could be deployed cost-effectively
- When not managing distribution peaks, resources could be used for demand charges management and momentary outages

Conclusions and Recommendations

Microgrid planning/development with demand flexibility

- Identify your needs based on the application
- Identify constraints (solar potential, room for storage, onsite fuel limits)
- Take an “integrated resource planning” approach to microgrid design
  - Consider “demand-side” measures alongside “supply-side” measures
  - Create levelized costs of capacity and energy
    - Potentially bin for different outage scenarios (short-term/long-term, winter/summer)
  - Optimize measure mix, accounting for outside funding/value streams

Considerations by microgrid type

Design event				End use fuels		Configuration	
Fire season	Seismic	Winter storm	Hurricane/ tropical storm	All electric	Dual fuel	Solar + storage	Solar + storage + genset
Impaired solar irradiance, low fuel availability	Likely long duration	Poor solar irradiance, high heating needs	Strong solar irradiance, low HVAC needs	High energy/capacity needs during winter	Fuel reliability/ storage considerations	Balancing more difficult, winter constrained	O&M costs for low-value genset (during non-outages)

Near-universal recommendations

- Weatherization has value across nearly all scenarios, since HVAC is the biggest and most volatile load to serve
- Water heating controls are a low-cost solution that provides value in nearly all contexts
- If you're building a microgrid that isn't participating in DR/rate management, you're doing it wrong
- Consider how the microgrid will operate not only during design outage, but also longer duration

Specific recommendations

Fire season/Seismic

- Efficiency-first approach to account for potential fuel shortage

Winter storm

- For human safety, will need either passive design and/or onsite fuel

Hurricane/ tropical storm

- Focus on process loads

All electric

- Consider DC-motors/inverter-driven end uses
- Capacity-focused (DR) approach to manage site demand

Dual fuel

- Consider dual-fuel end-uses (like heat pumps) that can optimize fuel to context

Solar + storage

- Find load sinks for excess gen to keep storage kWh needs down

Thanks!

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