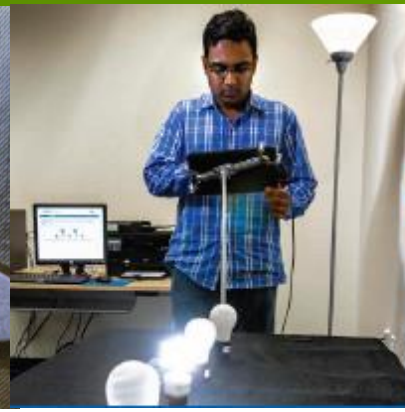
Energy, GHG, and User Behavior Nexus with Plug Loads: Looking Forward thru 2030



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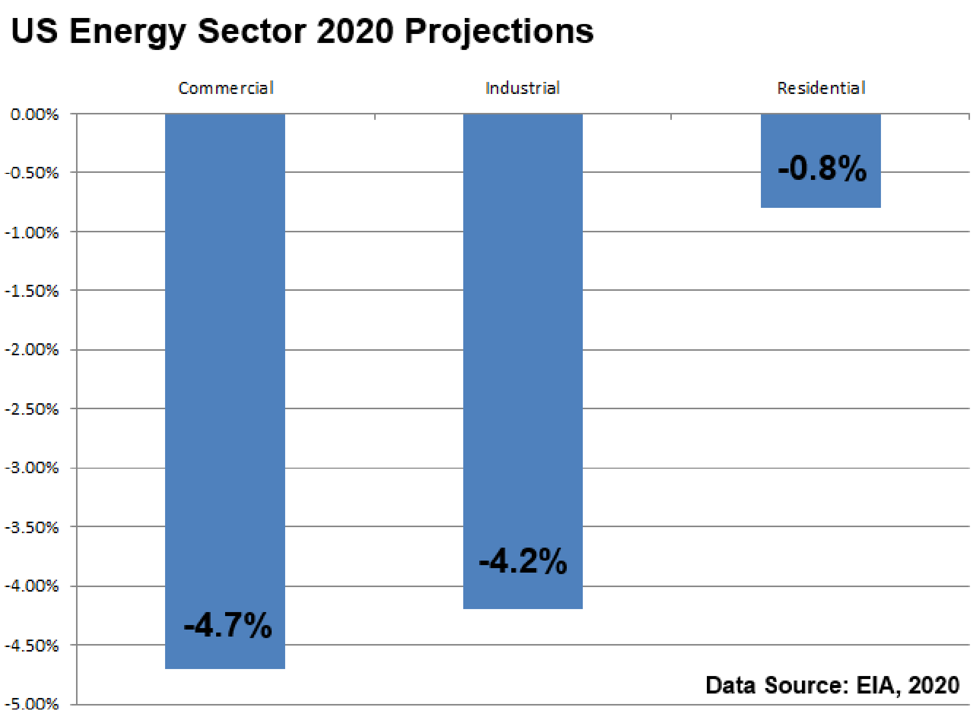
Discussion Outline

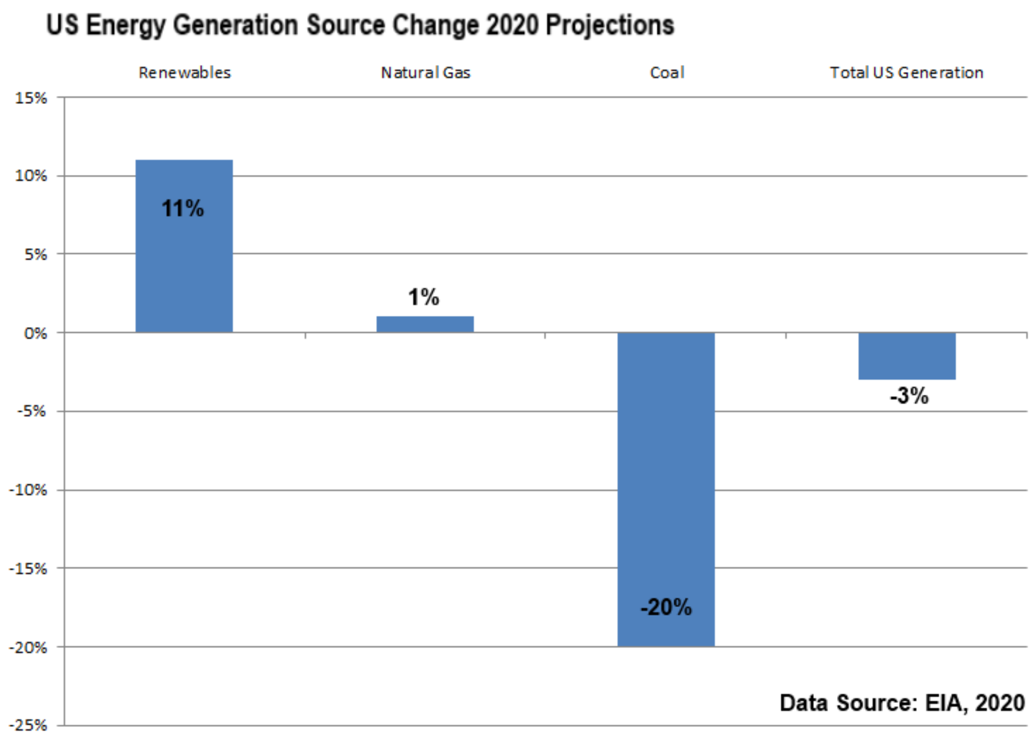
- COVID-19 and energy usage: are we flattening the “Duck” Curve?
- CA GHG progress and goals check-in
- Strategic device GHG evaluation methodology
- Behavioral considerations in plug load GHG targeting
- Applications and feasibility bounds for residential battery storage

2020 Updated EIA Projection

US EIA short-term energy forecast (April 7, 2020) in light of COVID-19:

- **US GHG reduction will accelerate to -7.5% in 2020 (-2.7% in 2019), largely due to economic contraction and mild weather.**
- **Electrical energy generation will be affected -3% from decreased demand**

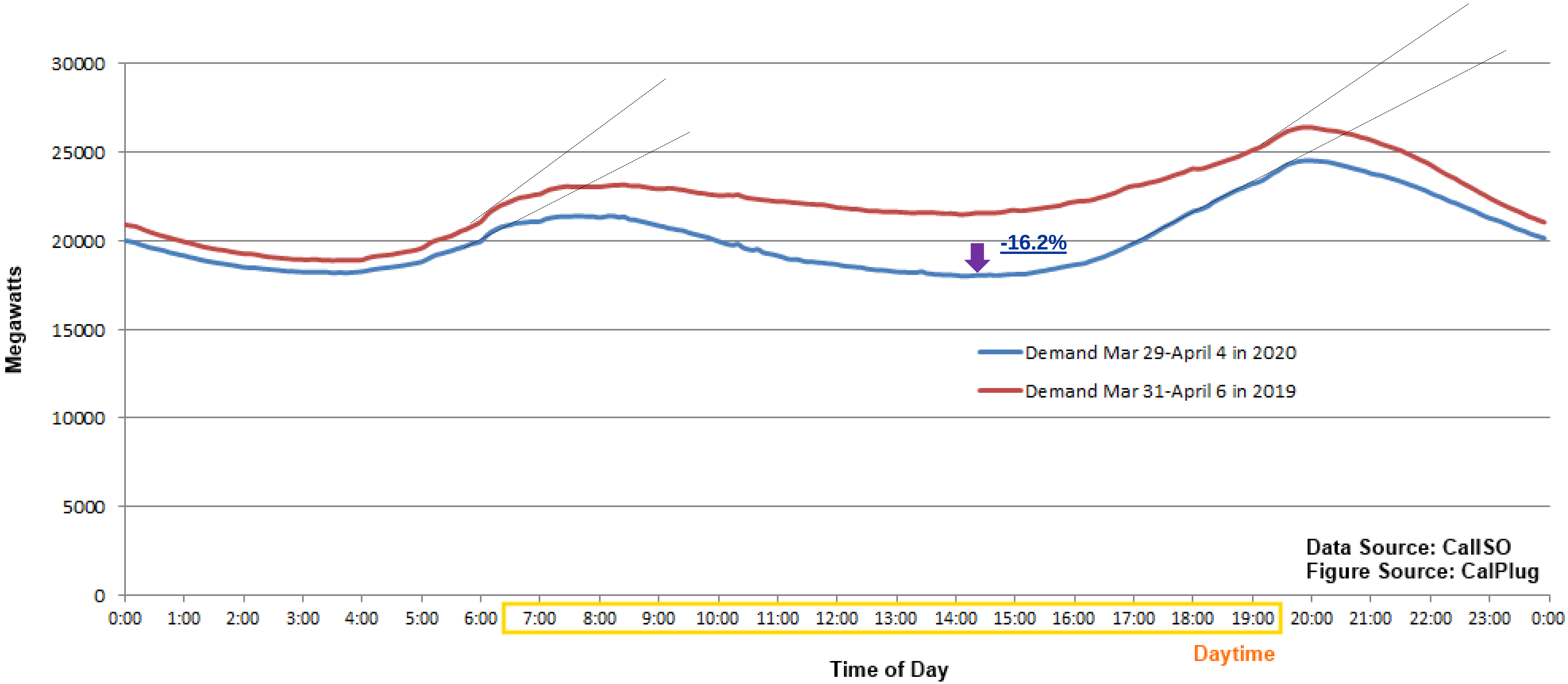




Power Usage Comparison in California during CA Gov. Stay at Home Order for COVID-19

Energy demand average hour by hour across a week

- Substantially reduced midday demand, reduced evening demand
- Peak ramping changes



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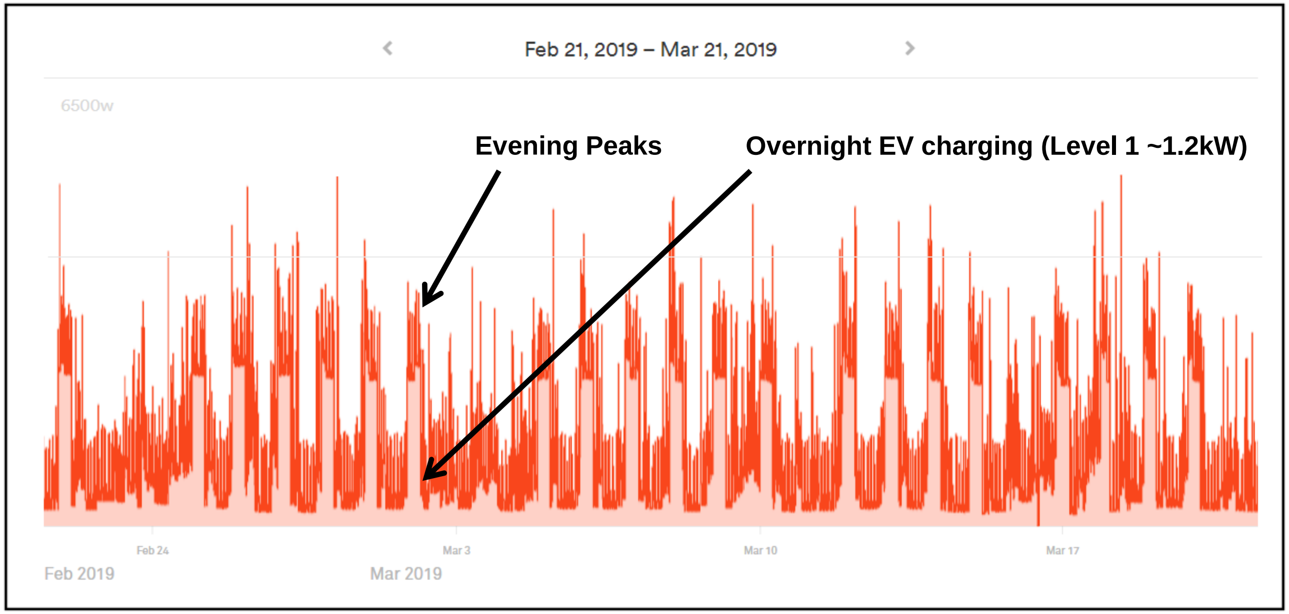
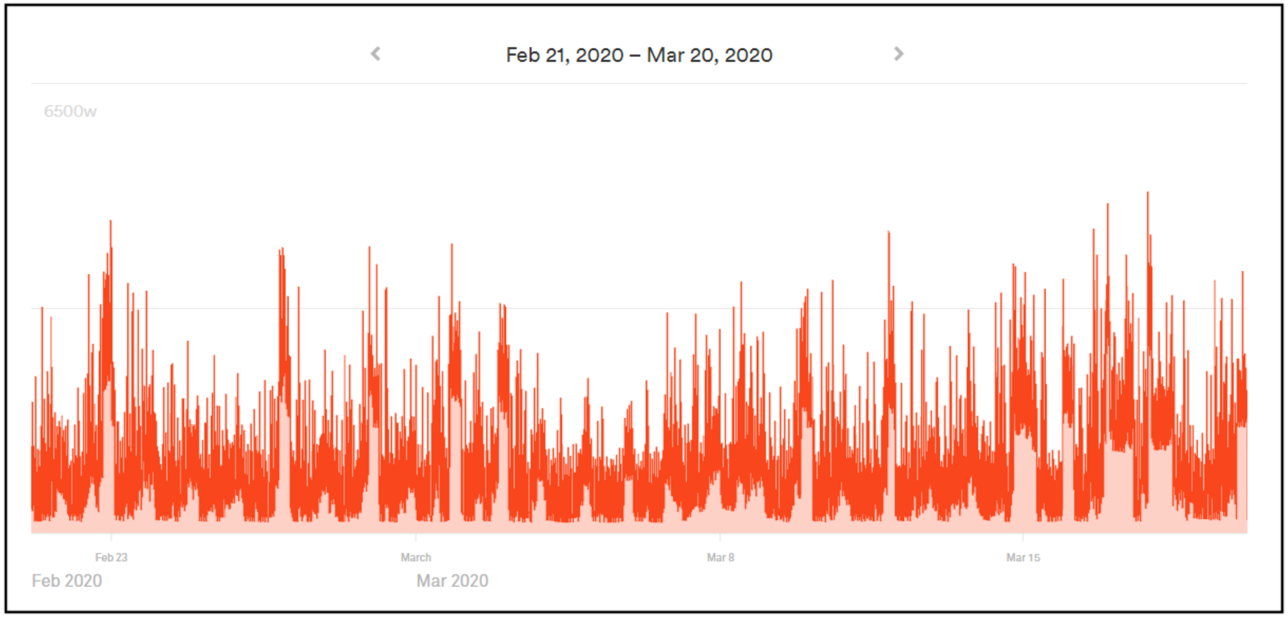
Mike's Antidotal COVID-19 Quarantine Residential Power Study (n=1)

Observed Changes:

- Substantial screen time increase: PC, television, mobile devices, etc.
- Power tool increase (repairs & work)
- Extra freezer purchase & use
- EV usage decrease (all vehicles)
- Cooking at home (gas), electric cookers, BBQ (gas), distiller
- Small kitchen appliance increase, increase in food storage and prep devices (8% sales increase)
- Less daily structure, dinner earlier in evenings, less rushed for daily tasks before bedtime.
- Increased clothes washing and hot water (gas)
- Space-heating increase (gas)

Y-Y non-controlled factor →



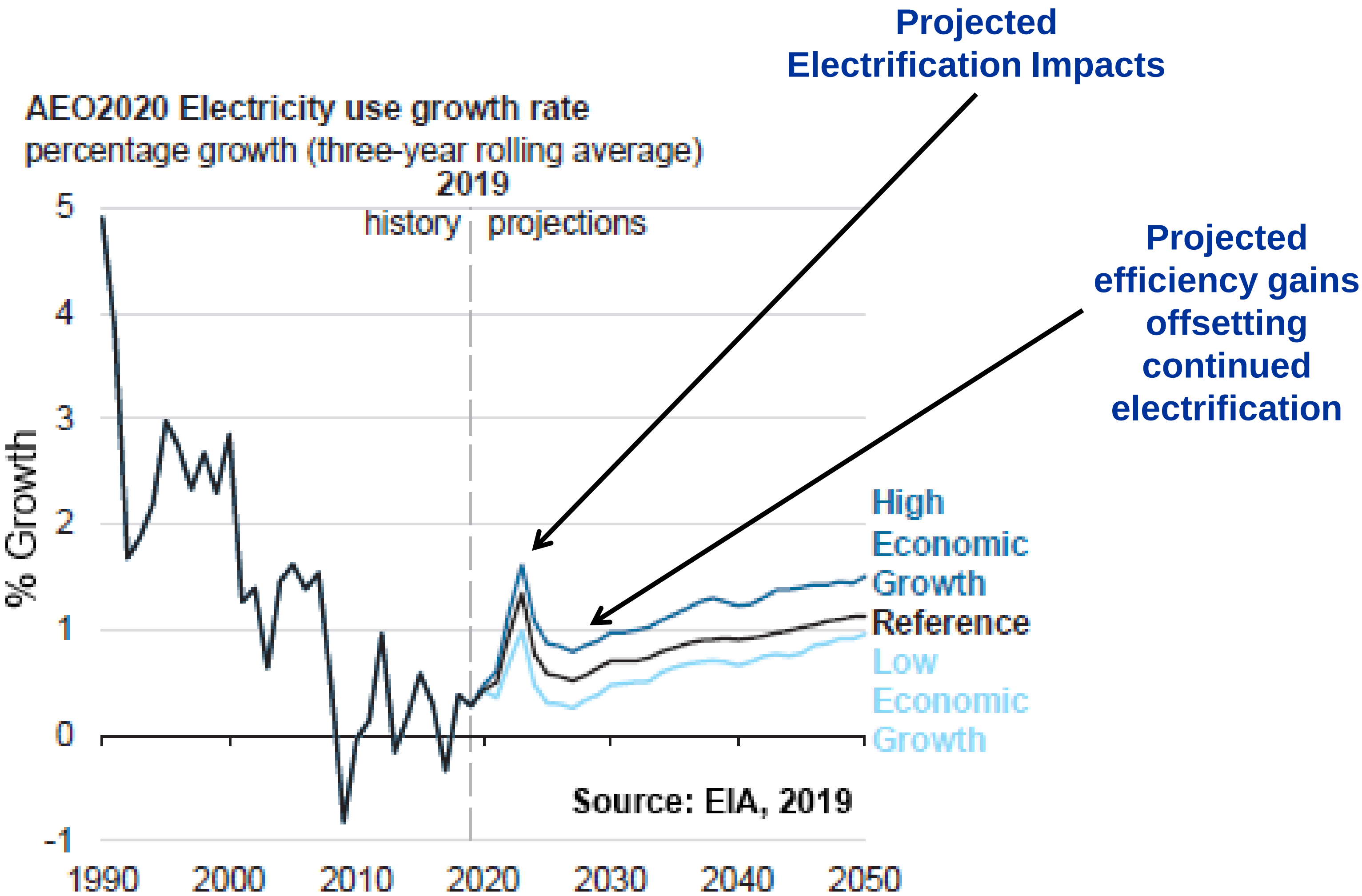


Section Conclusions

- Screen time increase consistent with other localized disasters
- Specific increases largely offset by contractions
  - Residential: Reduced EV usage, reduced peak usage, changes in patterns of use
  - Commercial: Reduced operational hours, standby loads consistent
  - Transportation: Reduced total driving miles, vehicle substitution
  - Medical: Reduction in elective procedures, increase in specific aspects of COVID-19 treatment
- GHG reduction largely due to economic contraction, projections for renewable deployment reduced for 2020
- Dispatched renewable loads used during period versus consumption focused alternates.
- Shock to system – short and long-term effects (connectivity, remote usage), indirect effects to PLs

US Projected Electrical Energy Use

Setting the stage: Energy use drives emissions considerations



California GHG Goals and Progress

- **Acceleration in yearly GHG reductions per year required to meet 2030 goals!**
- **Almost 30 years late to 3030 on present trajectory**
- **Transportation, Natural events (wildfires), landfill emissions lagging contributors**
- **CARB plan relies heavily on cap and trade/carbon offsets**
- **Electric power sector is a leader, but electrification will increase demand, a major source of GHG reduction along with blend**

California greenhouse gas emissions by sector and targets through 2050
million tons carbon dioxide (CO2) equivalent

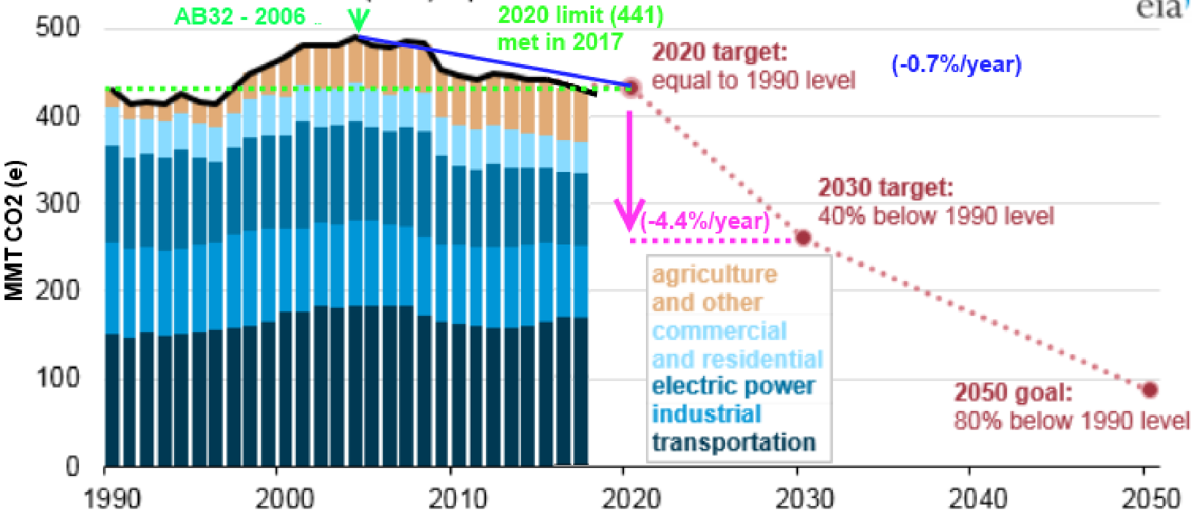
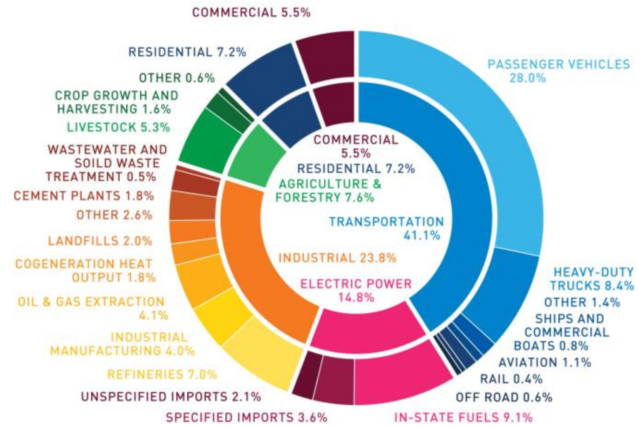
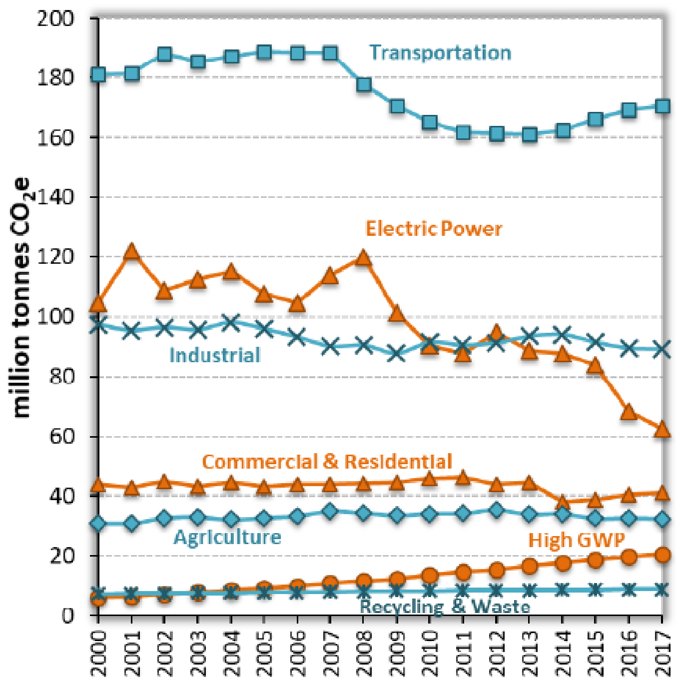


Figure 2. Greenhouse Gas Emissions by Source
CALIFORNIA, 2017



NEXT 10 CALIFORNIA GREEN INNOVATION INDEX. Data Source: California Air Resources Board, California Greenhouse Gas Inventory –



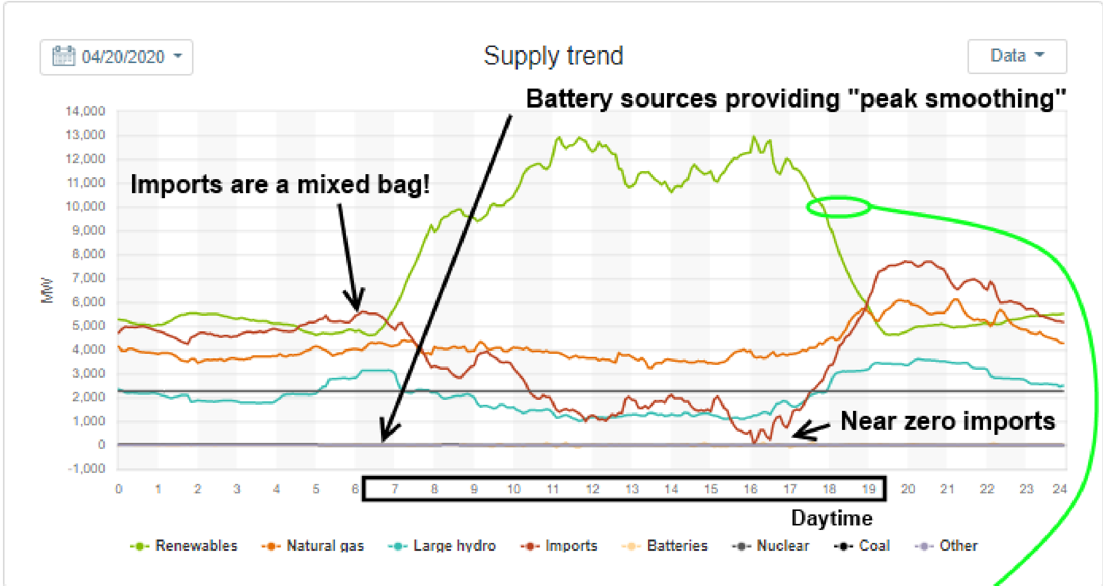
GHE Estimation for Energy Supply

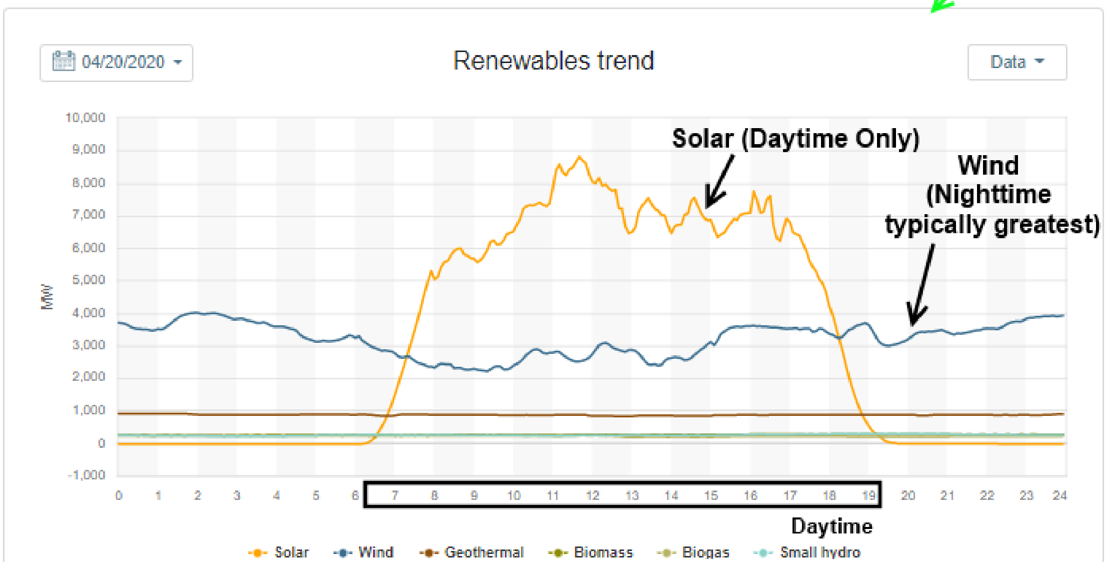
GHG per kWh proportional to source blend + embodied carbon for generation and transport (an estimation wide span!)

Note: March and April are typically mild months in CA with ample generation and low demand

Source	Median g CO2/eq. KWh
Coal (PC, Combined Cycle)	820
Gas (combined cycle)	490
Biomass – Dedicated	230
Solar PV – Utility scale	48
Solar PV – rooftop	41
Geothermal	38
Concentrated solar power	27
Hydropower	24
Wind (Onshore)	11
Nuclear	12
Battery	3* (added factor)

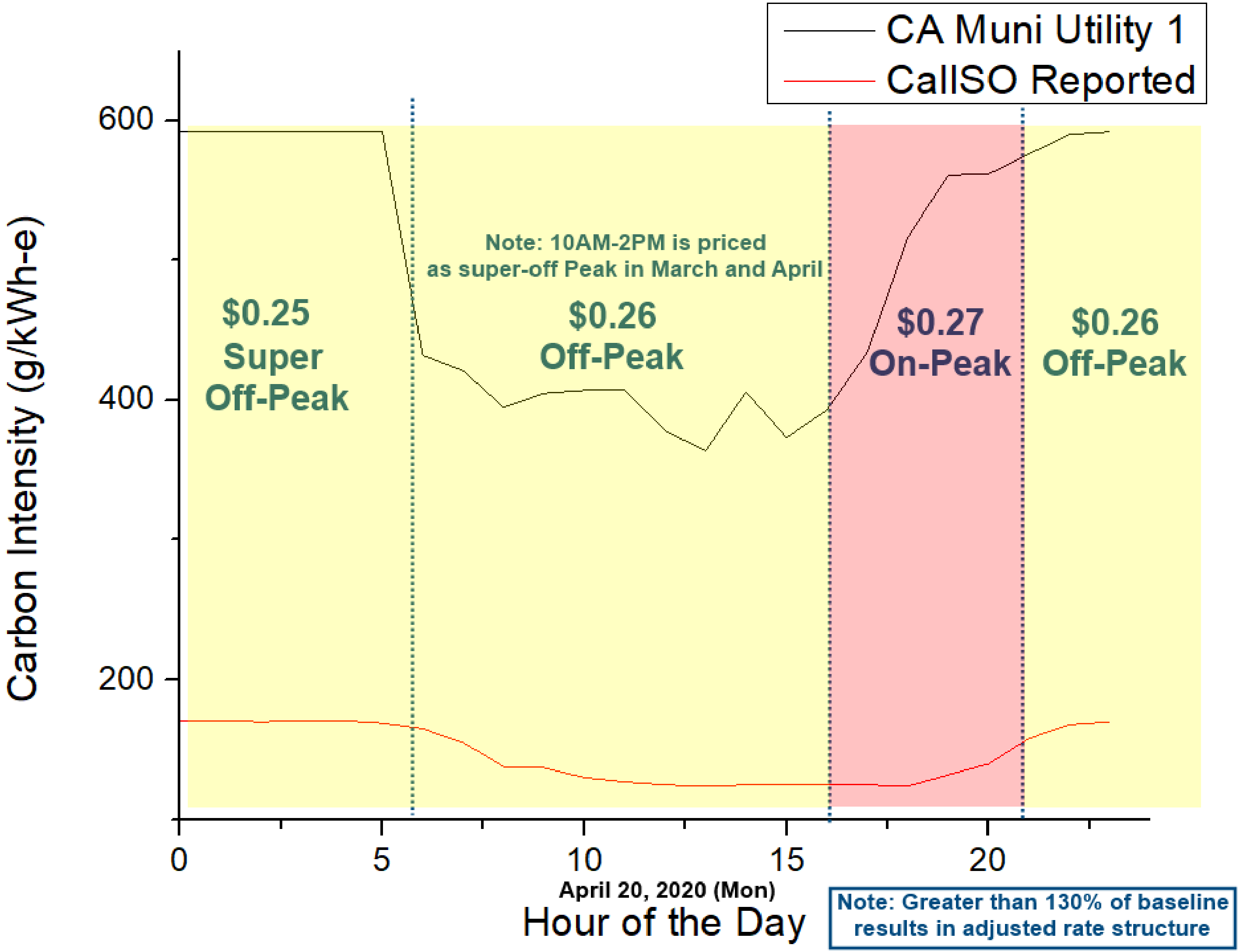
Data Source: Krey,V, et. al., IPCC, Annex III, 2014; Baumann,2017





Source: CalISO

Energy Supply Cost and GHG Comparison



Note: Greater than 130% of baseline results in adjusted rate structure

Cost Peak Categories

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Note: Example rates shown based on SDG&E TOU-EV1 Plan

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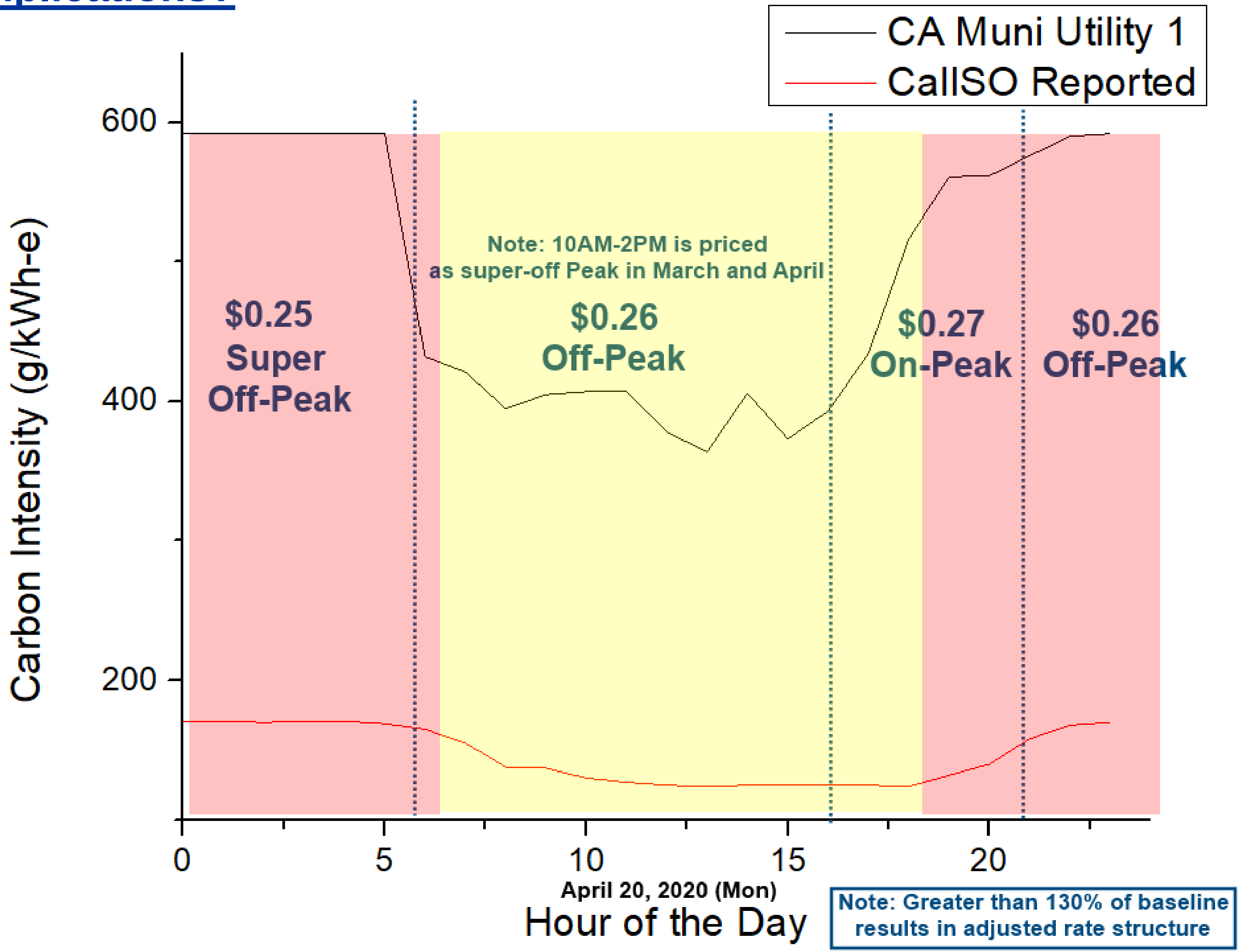
Energy Supply Cost and GHG Comparison

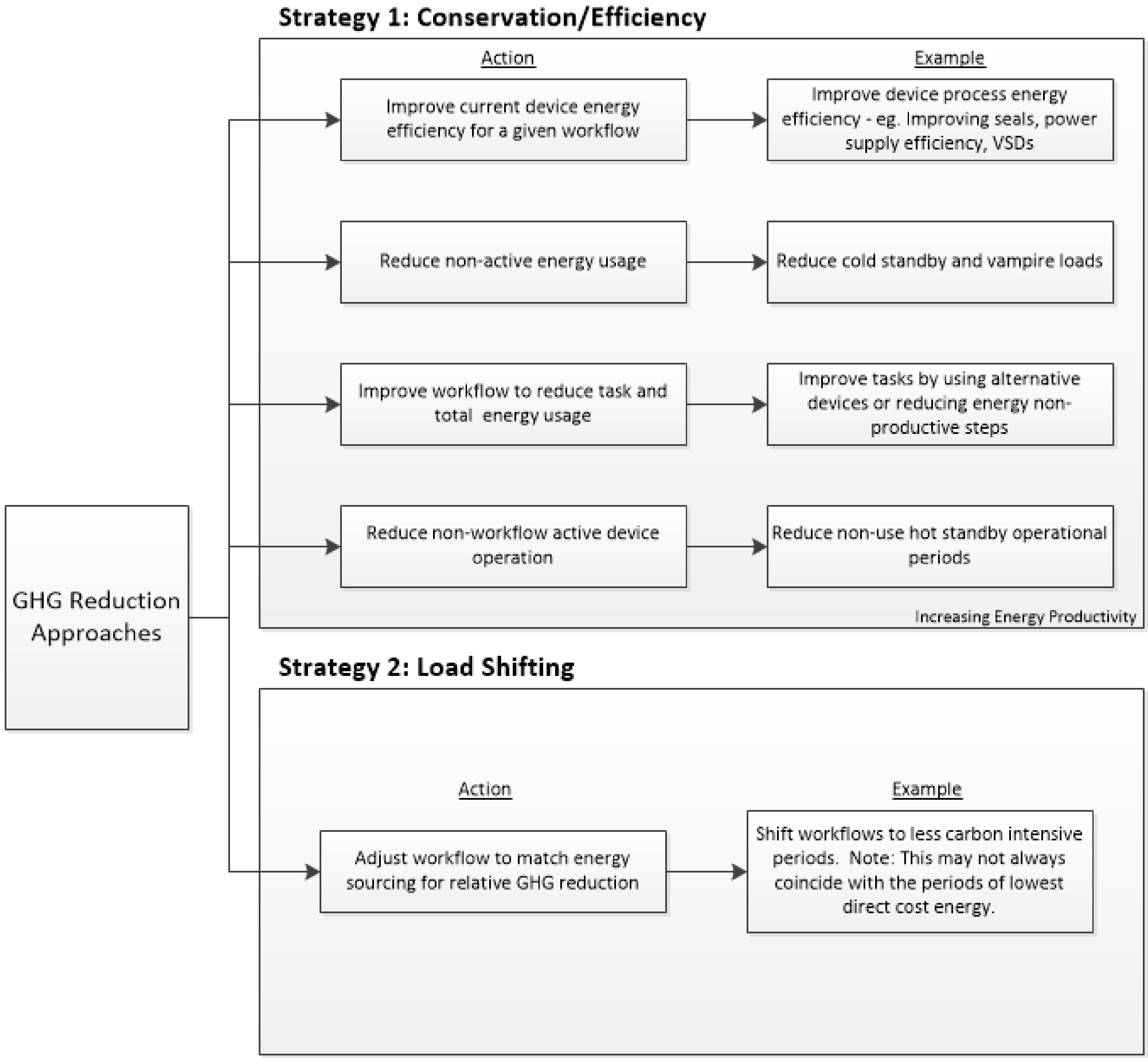
What are the carbon impacts of shifting versus reduction and load flexibility and cost implications?



GHG Peak Categories

Note: Example rates shown based on SDG&E TOU-EV1 Plan

Targeting GHG Reduction in Devices and Processes



Equivalency with Load Shifting for GHG Emissions

EE/EC versus Load Shifting comparison for GHG Emissions:

A relationship can be made between EE/EC and GHG efforts for a given usage schedule and daily/seasonal generation blend

1KW load, 24 hour operation, constant energy use (e.g. resistive pool heater)
2 GHG periods 120g/kWh for 6 hours/day, 180g/kWh for 18 hours/day
2 Price periods: Low- \$0.20/kWh for 16 hours/day, High-\$0.30/kWh for 8 hours/day
3 hour overlap with \$ on-peak and carbon on-peak (assume start on overlap)

Daily Energy Reduction	Daily Usage Shift	Daily Price Penalty
1%	3.12%	\$0.08
10%	28%	\$0.66

CalPlug's PLSIM 2 (pre-release) will include this model calculation with an arbitrary schedule

- **As the GHG blend is more consistent, diminishing returns occur**
- **Pricing is largely set around peak demand management not direct GHG management. Evening base load considerations –supply/demand mismatch.**
- **GHG assessment metrics limited at current time in CA workpapers: analysis figure of merit does not strongly assess GHG impact directly versus peak and total yearly consumption.**

Strategy Behavioral Considerations

Coordinated control strategies can be effective for both load shifting and EE efforts for GHG reduction. Considerations for strategy effectiveness, user (preference) tolerance / process tolerance, solution stability, and financial incentive/price impact

Example EE/EC versus Load Shifting Strategies for Selected Residential Plug Loads:

- **Refrigerator**
  - **Shifted Load – Defrost cycle, set-point/hysteresis band adjustment (minor)**
  - **EE/EC – User alerts/encouragement, insulation improvement, mechanical improvement**
- **Television**
  - **Shifted Load- Limited without user action**
  - **EE/EC – Reduction of active and standby load, engagement sensing for wasteful use reduction**
- **Water Heating**
  - **Shifted Load - Triggered set-point/hysteresis band adjustment, recirculation**
  - **EE/EC – On demand Set-point/hysteresis band adjustment, recirculation, insulation, technology implementation, tank design, storage capacity**
  - **Note the hybrid overlap in this category for some approaches**

Section Conclusions

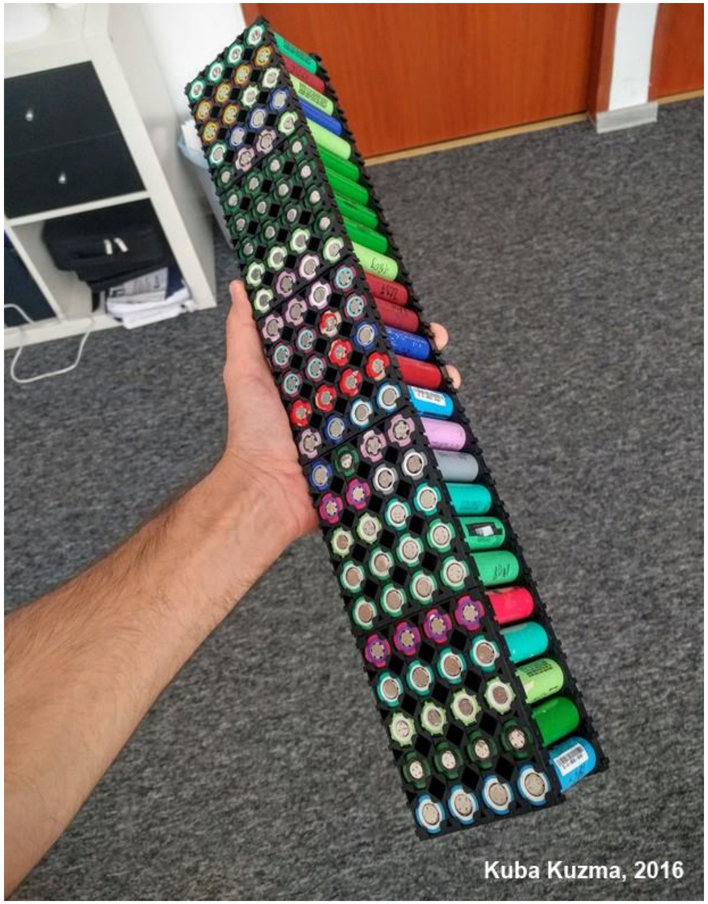
- Metric of GHG reduction does not fully align with energy reduction and cost of energy reduction.
- Matching operation with time required for peak load reduction or GHG reduction (load shifting) thru control signals and load shifting implies connectivity/system control/integration
- The operation of many residential small plug loads (at the current technology state) do not benefit greatly from connectivity enabled features (directly) for energy/GHG reduction without substantial user impact. (See CalPlug's 2020 report for SDG&E and Fraunhofer/CTA's 2015 connected devices report)
- Still plenty of non-connected EE/EC opportunities in residential plug loads.
- Some classes of major appliances can benefit from conenctivity, especially for scheduling automatic maintenance features, cycle delays, or processes that permit abbreviated or paused cycles.

Section Conclusions (contd.)

- Generally, commercial plug and process loads (office, building, specialized process) have substantially more connected and coordinated application potential
  - Workflow driven, clear process/policy, clear(er) ownership and responsibility
  - Consistent device management
  - Gap considerations: common/shared use devices

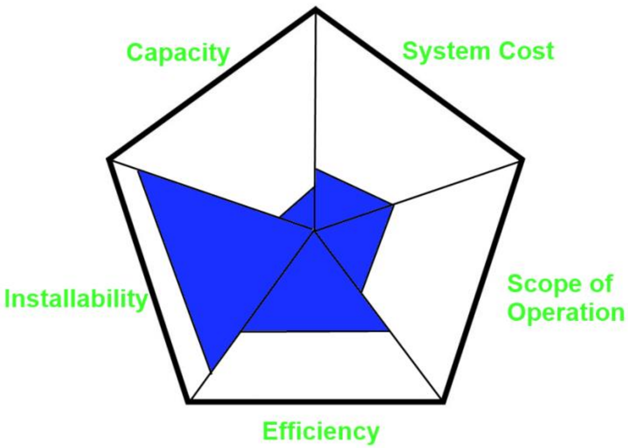
Useful Range of Function/Feasibility for Residential Battery Storage

- **Purpose/Application**: Solar overproduction capture / islanded-microgrid, structure power backup, peak load reduction
- **Scope**: Whole home, dedicated power bus/ breaker, dedicated and scalable circuit(s), individual device (e.g. UPS, garage door backup)
- **Scale/Cost/Installability**: "Computer" UPS (low cost, low capacity, user installable) to whole home panel level (high cost, high capacity, specialized tech/electrician), or even an integrated V2G system (mid. cost, high cap.)
- **Efficiency/Transfer Rate**: Variable based on size, application, and cost. Intelligent frequency/waveform control output
- **Lifetime**: Consumables and device longevity

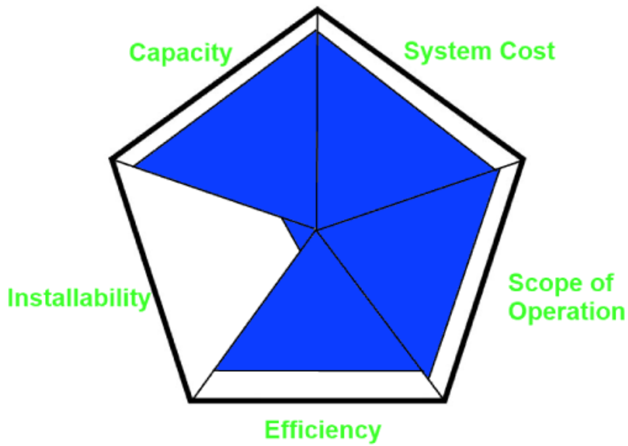


1kWh of 18650 Lithium-ion cells

Battery Application Optimization



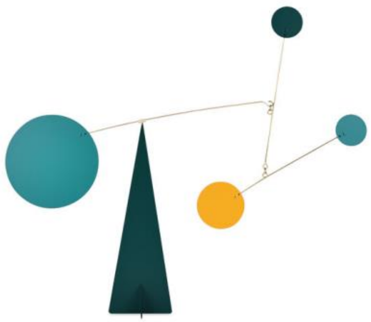
Single Circuit/Device Battery



Whole-home Battery

A 3-5 year payback period (~50% lifetime) for 1-2 kWh user-install/replaceable system possible with substantial peak load and substantial rate difference

- **Small scoped system for a single or set of managed or circuit-connected devices**
- **Payback period highly dependent on cell cost/lifetime and system efficiency**
- **Peak and cost management applications with utility sourced energy are not necessarily GHG focused**
- **GHG impact is highly dependent on GHG intensity of charging energy and displaced energy that would have been sourced**



A question of balance

Conclusions

- Shocks to the system provide opportunities, much more to see for short and long term impacts due to COVID-19. Short term plug load impact is minor considering other impacts. Keeping low efficiency devices out during purchases of new devices (especially with low supply – panic purchases) as well factory preconfigured devices favoring early and continued efficient use.
- Major work is required for California to reach 2030 GHG goals, especially with changes due to electrification.
- Evaluation metrics and goals must be established to lead the discussion for GHG focused utility programs, codes and standards, and manufacturer best practices for plug loads.
- EE/EC and load shifting can play complimentary roles GHG reduction strategies.

Conclusions (contd.)

- Targeting EE/EC approaches can keep goals and strategies to achieve them in perspective.
- Different plug load device categories and sector (residential vs. commercial) have different usage requirtements that may change most cost effective approaches for GHG reduction.
- Home battery systems have varied targeted uses and should be viewed as a continuum with commercial optimization points, many strategies may be feasable targeting microgrids (esp. in post solar net-metering age), power backup, and peak management.

Thank You!