Active and Passive Energy Storage Technologies

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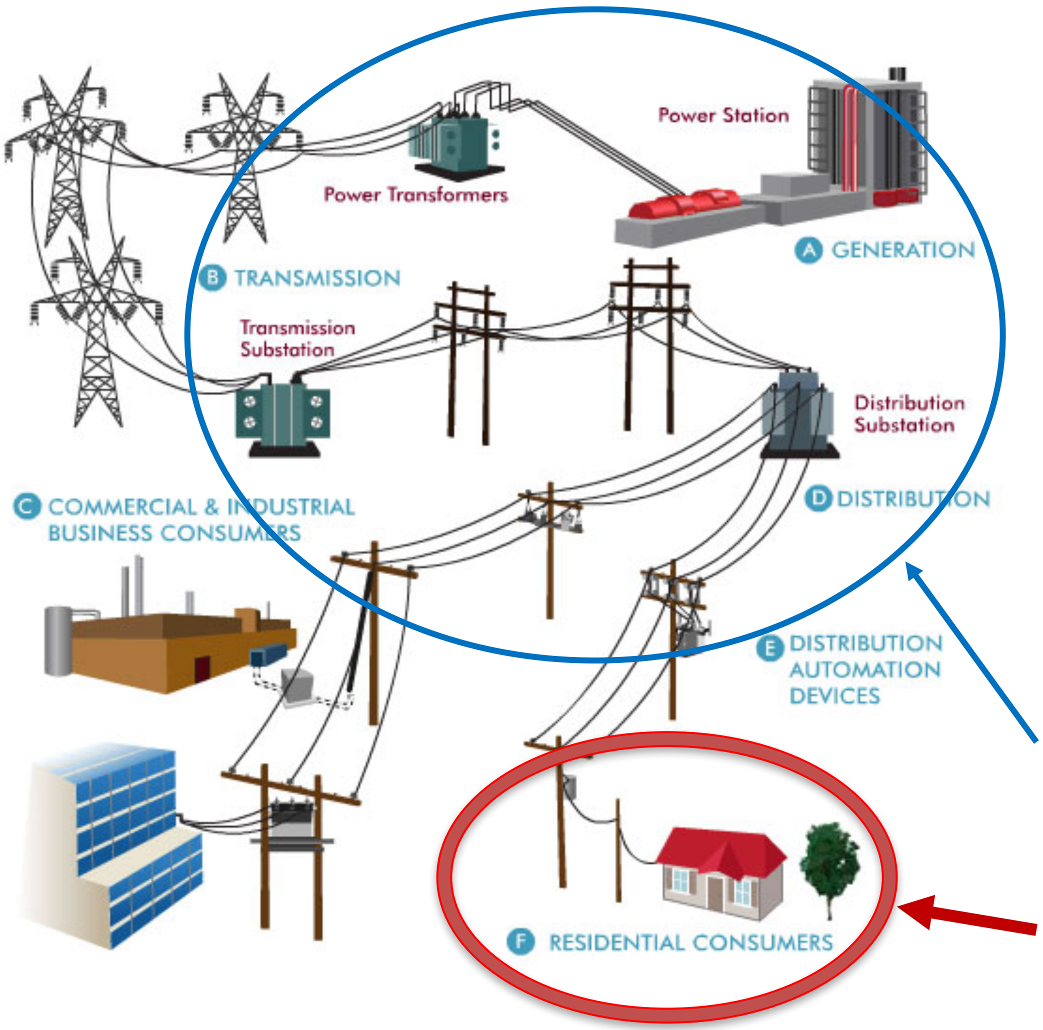
Te Whare Wānanga o Otāgo
NEW ZEALAND

GREEN Grid project: 2012–2018



"Exploring the **future of New Zealand's electricity grid** under conditions of **higher levels of renewable and distributed generation**, and **changing demand profiles**"

Led by University of Canterbury

University of Otago led by Centre for Sustainability

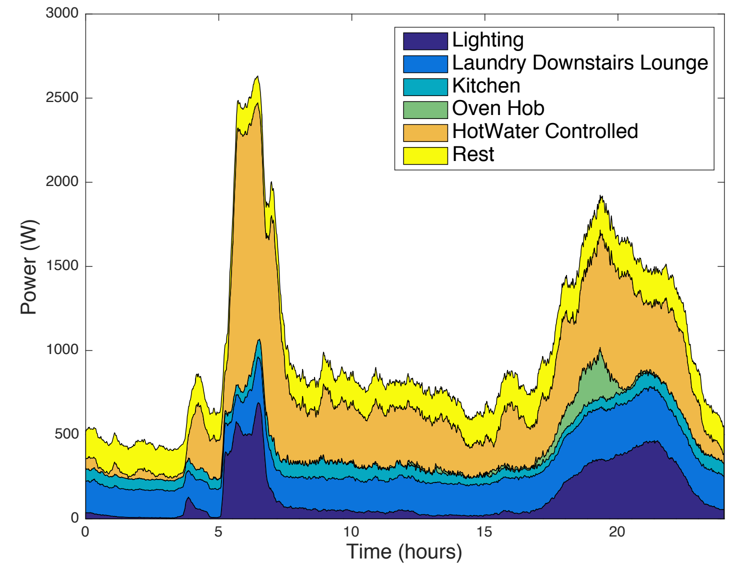
Data from households

- Gridspy data
  - Circuit level monitoring

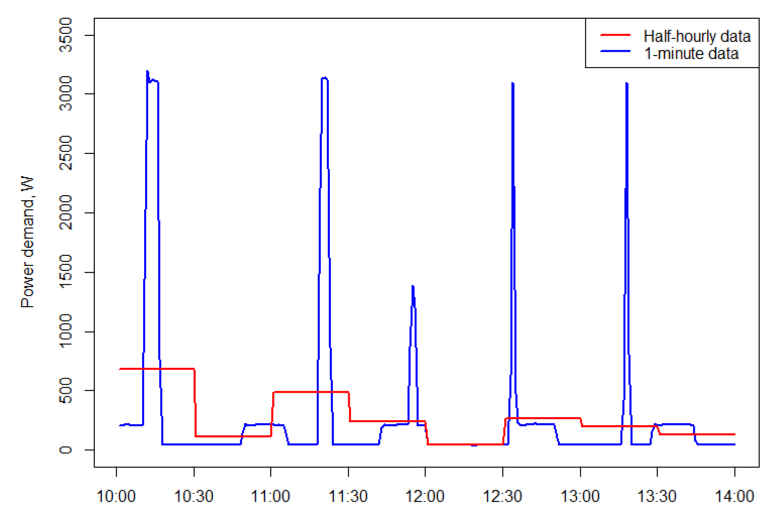
    (can identify main appliances)
  - Minute time resolution
  - 40+ households
  - >2 years of monitoring
- Household surveys
  - Demographics
  - Time-use diaries (see Kiti's poster)

https://gridspy.com

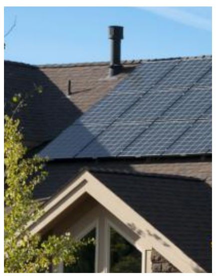
End use breakdown –Workdays
Stacked area graph

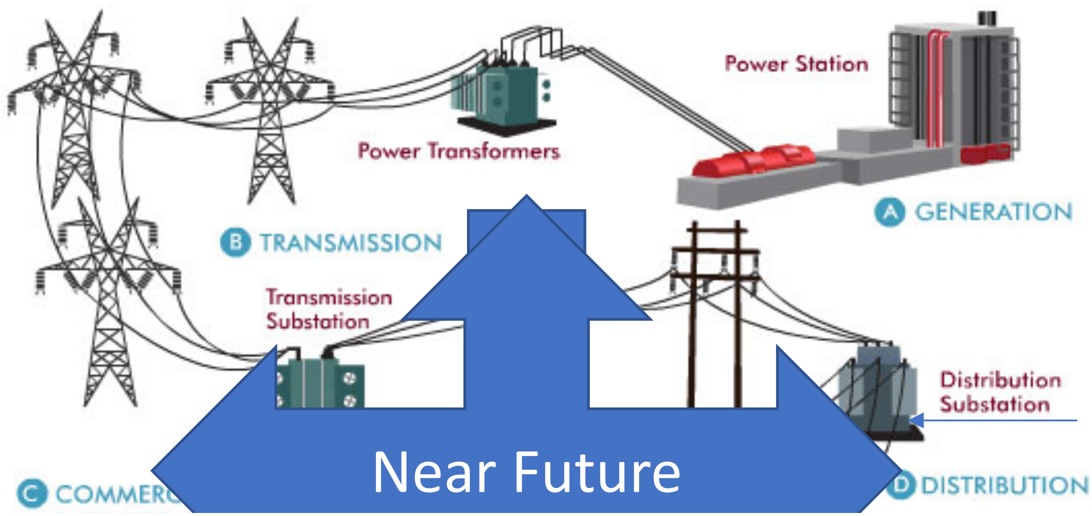


Time resolution comparison



Electricity Grid Changing Dramatically





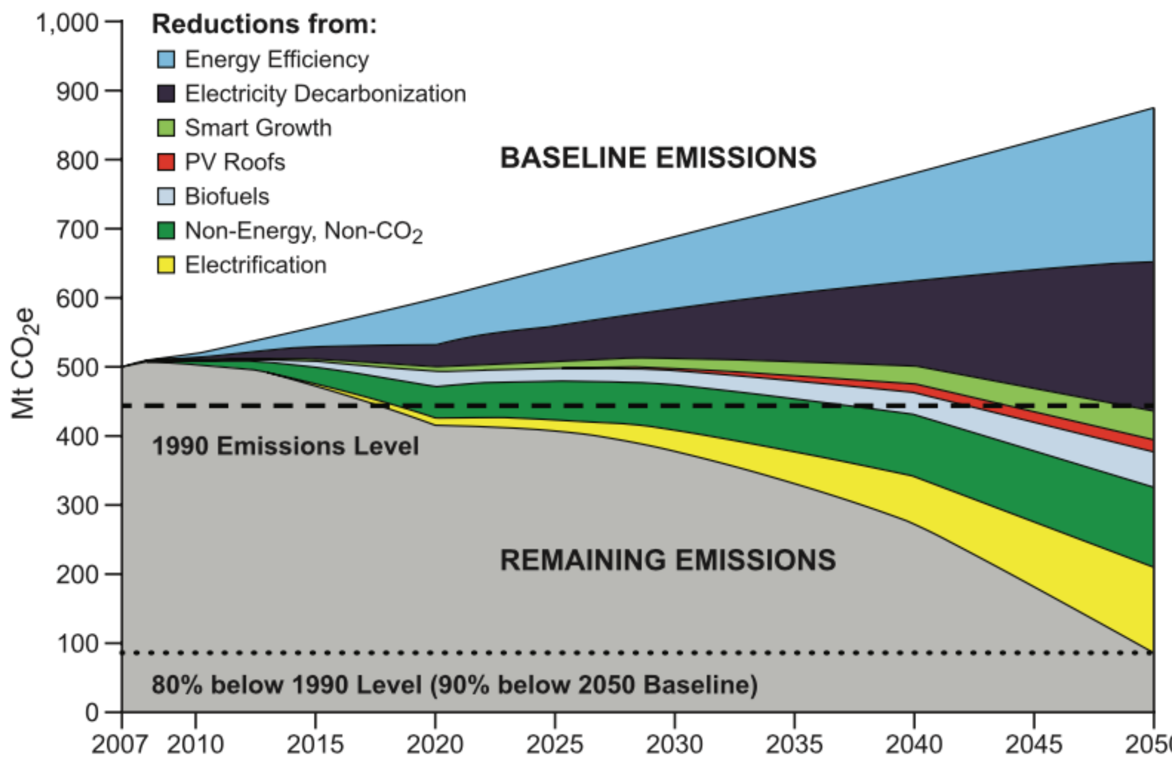
- Greater amount of variable renewables (wind, solar, etc.)
- Self-generation
- Greater efficiency (net zero energy houses etc.)
- New appliances, smart/connected etc.
- Electric cars

Deep GHG reductions require greater electrification

Two step plan

1. Increase % of renewable electricity
2. Electrify heating and transport

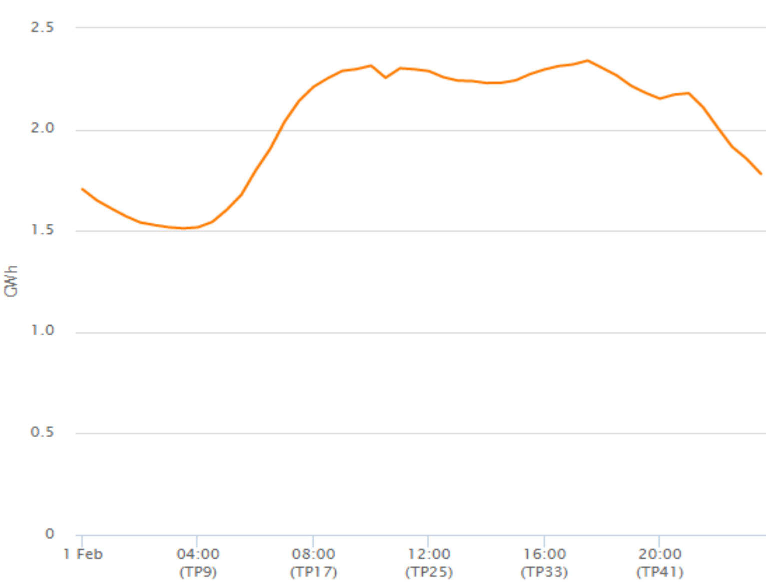
Technology Path for California



Williams et al. Science, 335, 53 (2012)

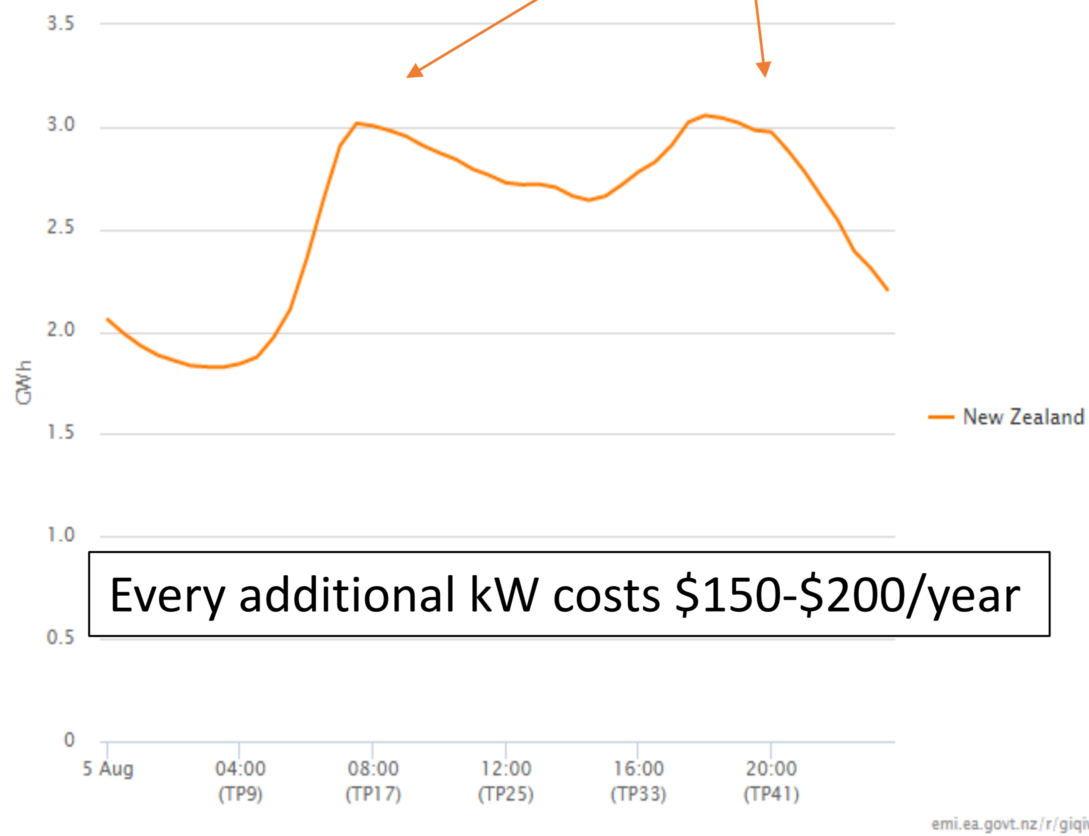
Variability is important—Peak demand drives costs

2 February 2016



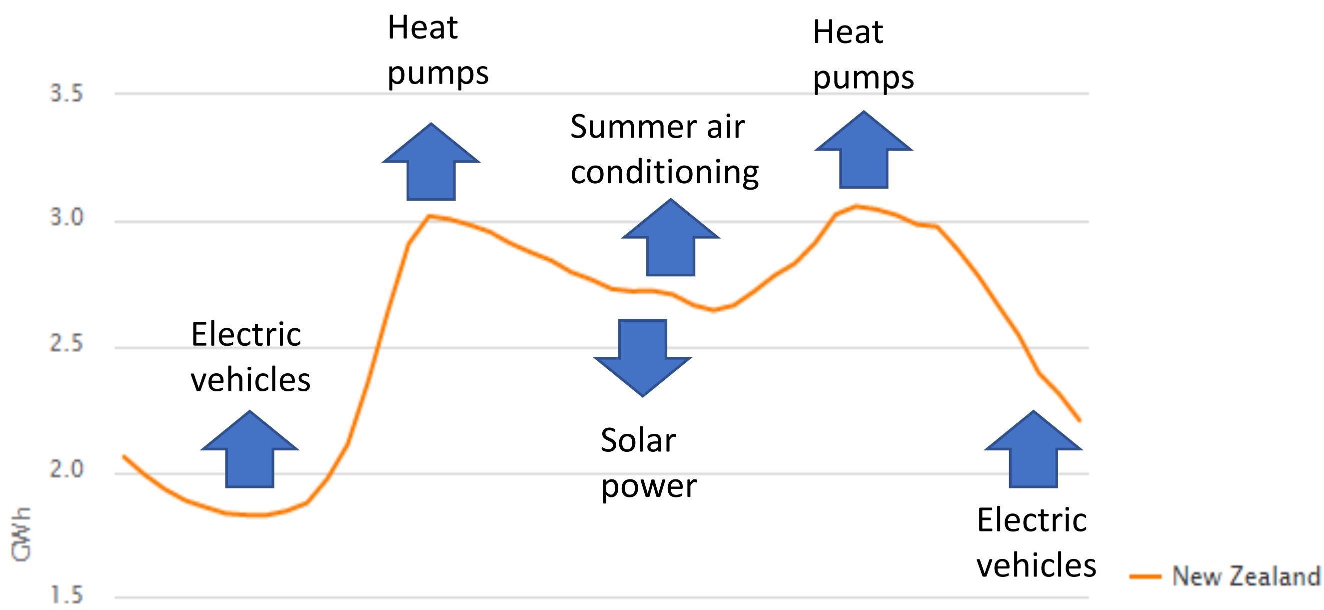
5 August 2016

Expensive infrastructure required!



Every additional kW costs $150-$200/year

Future NZ electricity use: Greater supply and demand variability



Greater renewables also increase supply variability

- E.g. 4000 MW of extra wind (to become 100% renewable) requires extra 80 MW of frequency keeping (or latent capacity)

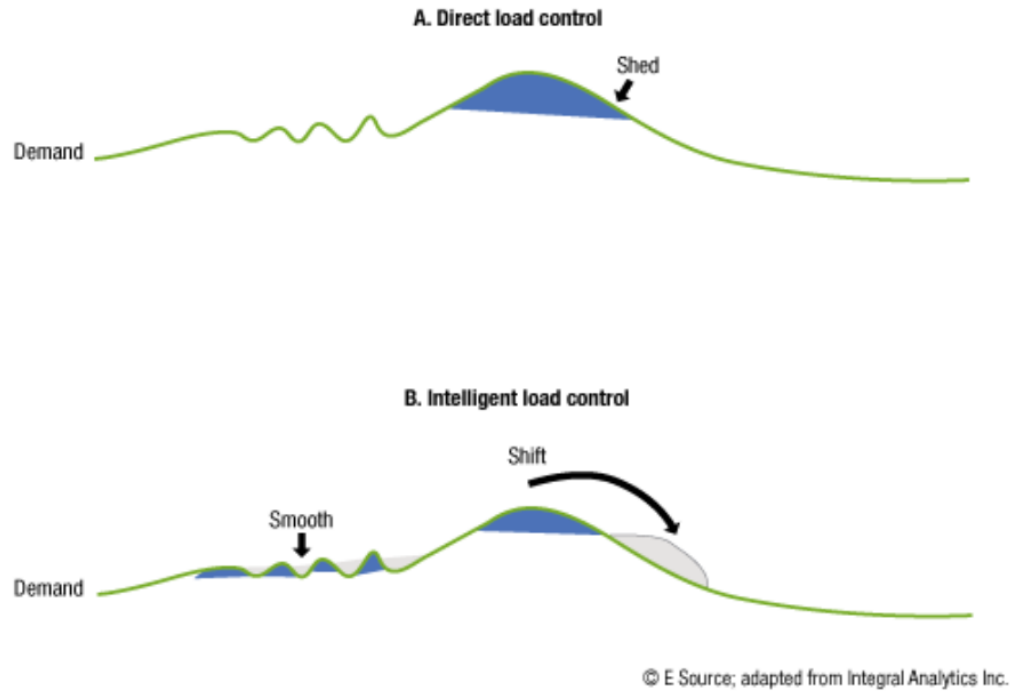
J. Schipper, A. Wood, C. Edwards, A. Miller, Impacts of Renewable Generation on Frequency Quality, Green Grid Conference 2017

Storage – intelligent load control

Active storage (e.g. Batteries)
- Control charging and discharging

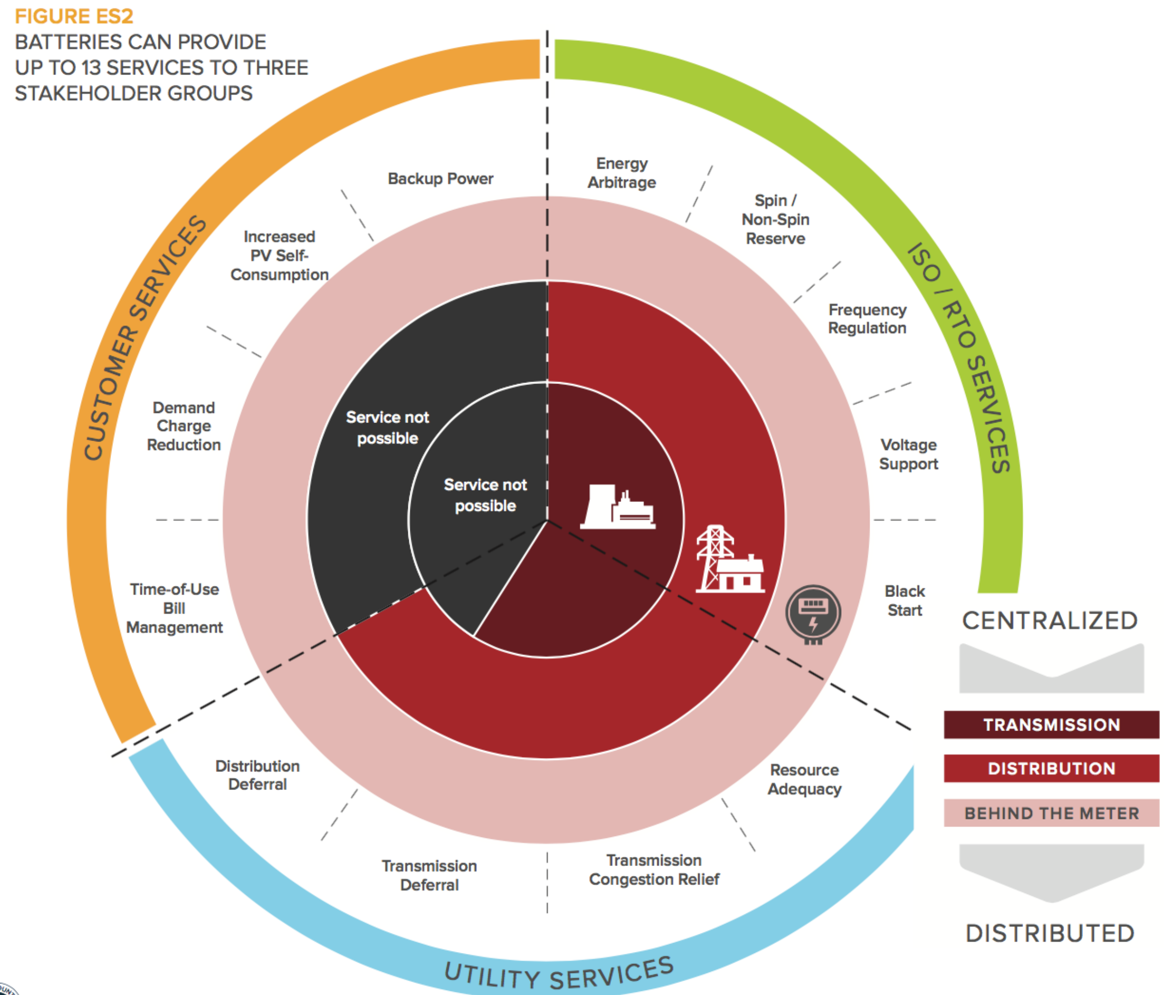
Passive storage (e.g. hot water cylinders)
- Only control charging

With intelligent control both can shift load



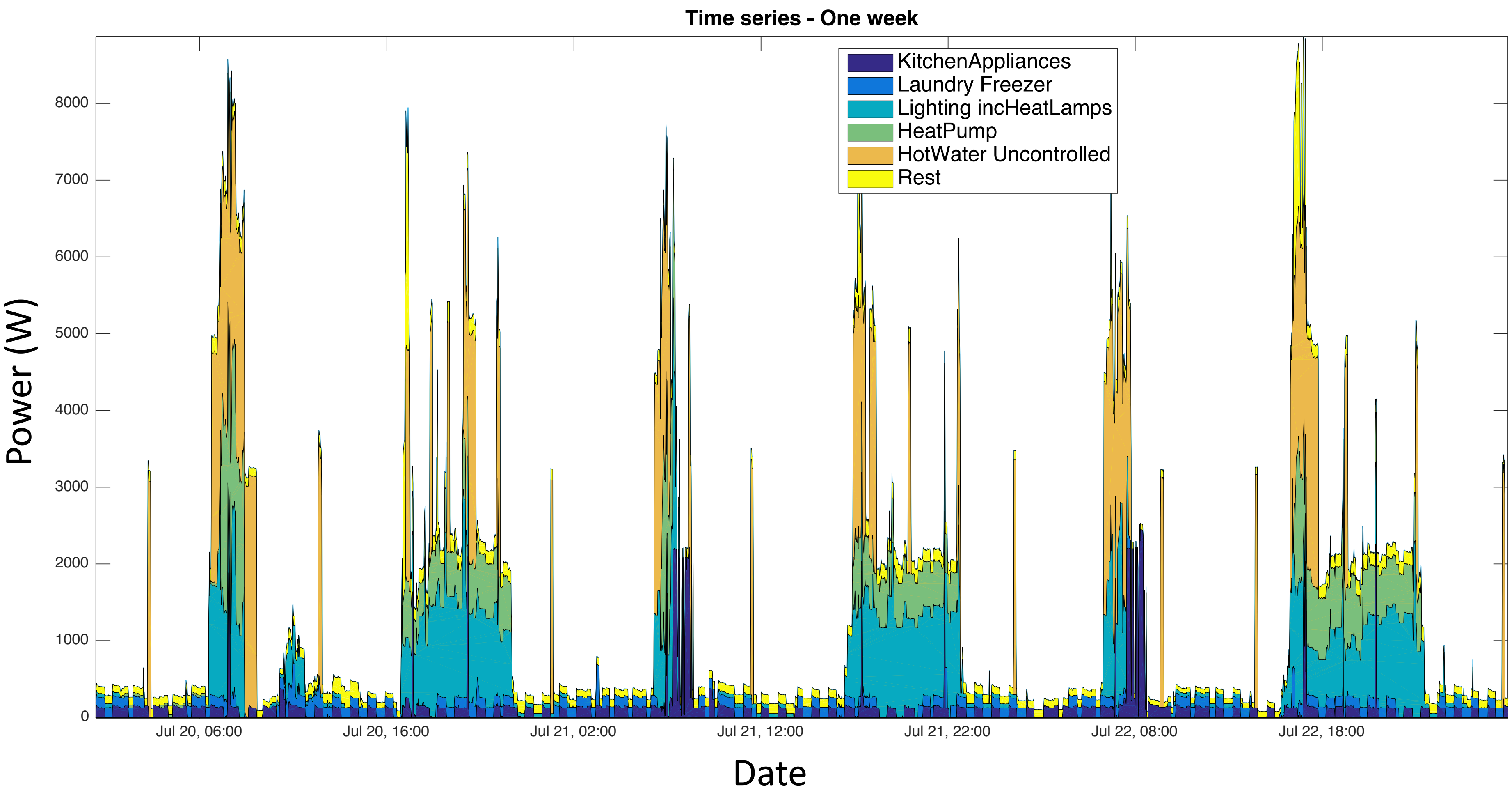
D. Paodorson, Battery Killers: How Water Heaters Have Evolved into Grid Scale Energy Storage Devices, An E Source White paper (2014)

The value of storage increases as it becomes more distributed

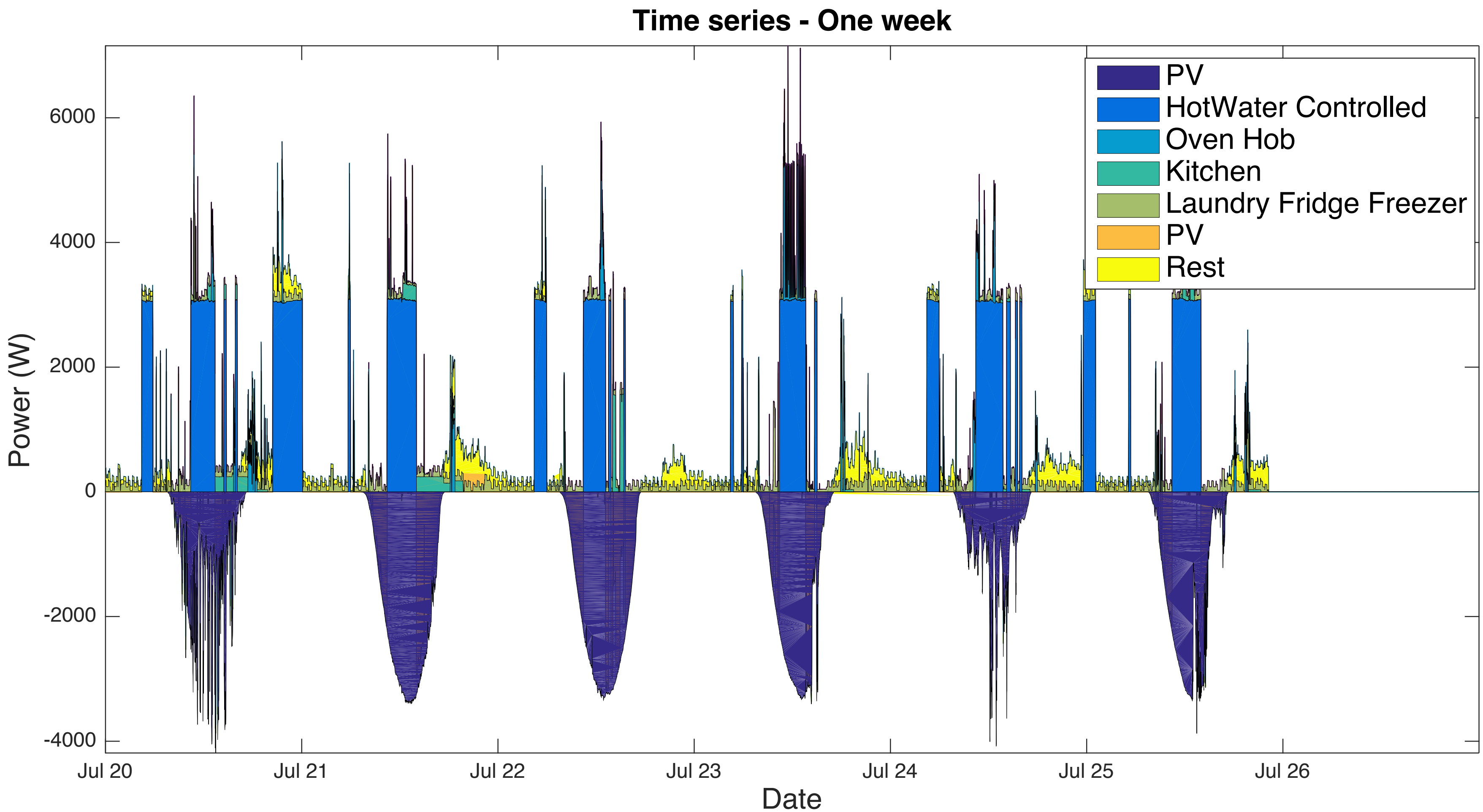


RMI, The Economics of Battery Storage

Household electricity demand

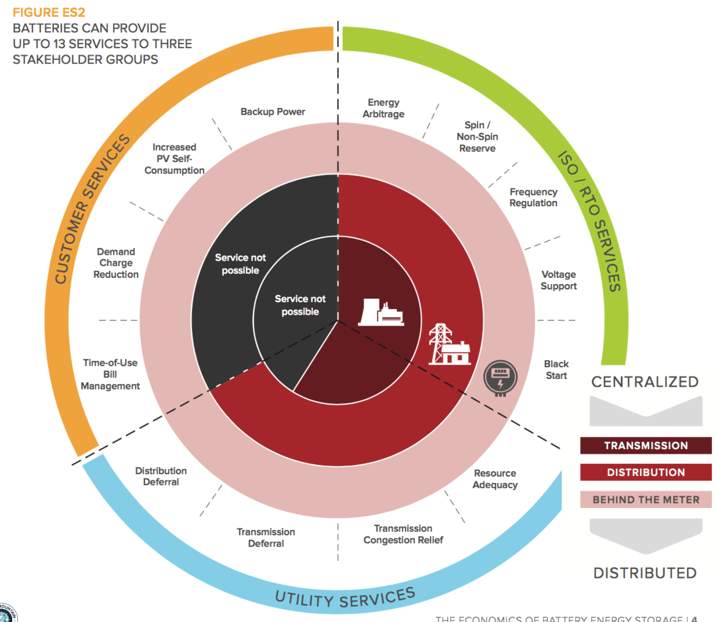


Household with PV



Storage at the household level has multiple stakeholders

- What lines companies want:
  - Reduce network peaks
  - Have control (e.g. Ripple control)
- What generators want:
  - Deal with variable demand and supply
- What householders want:
  - Reduce electricity bills (e.g. time of use or peak consumption charges)
  - Maximize self-consumption
  - Have control



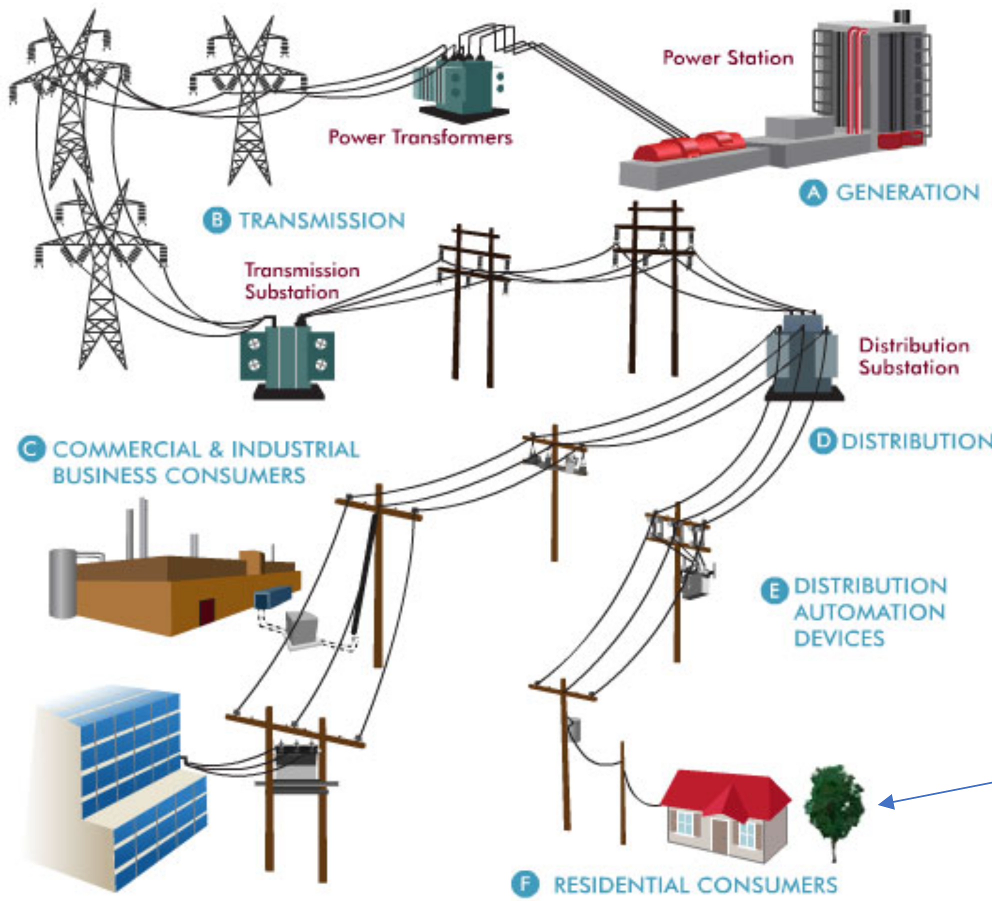
RMI, The Economics of Battery Storage

Gridspy data provides insights into household storage options

- Batteries
  - Where in the electricity grid should battery storage go?

- Smart hot water Cylinders
  1. Potential for electricity grid?
  2. Potential for rooftop PV optimization?

Active Storage - Where in the grid should battery storage go?



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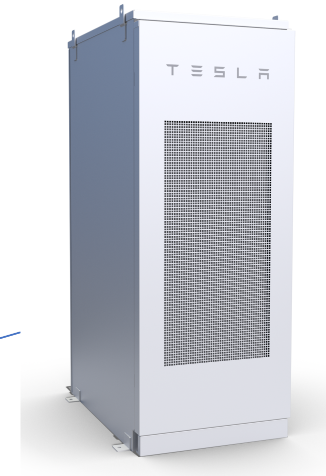

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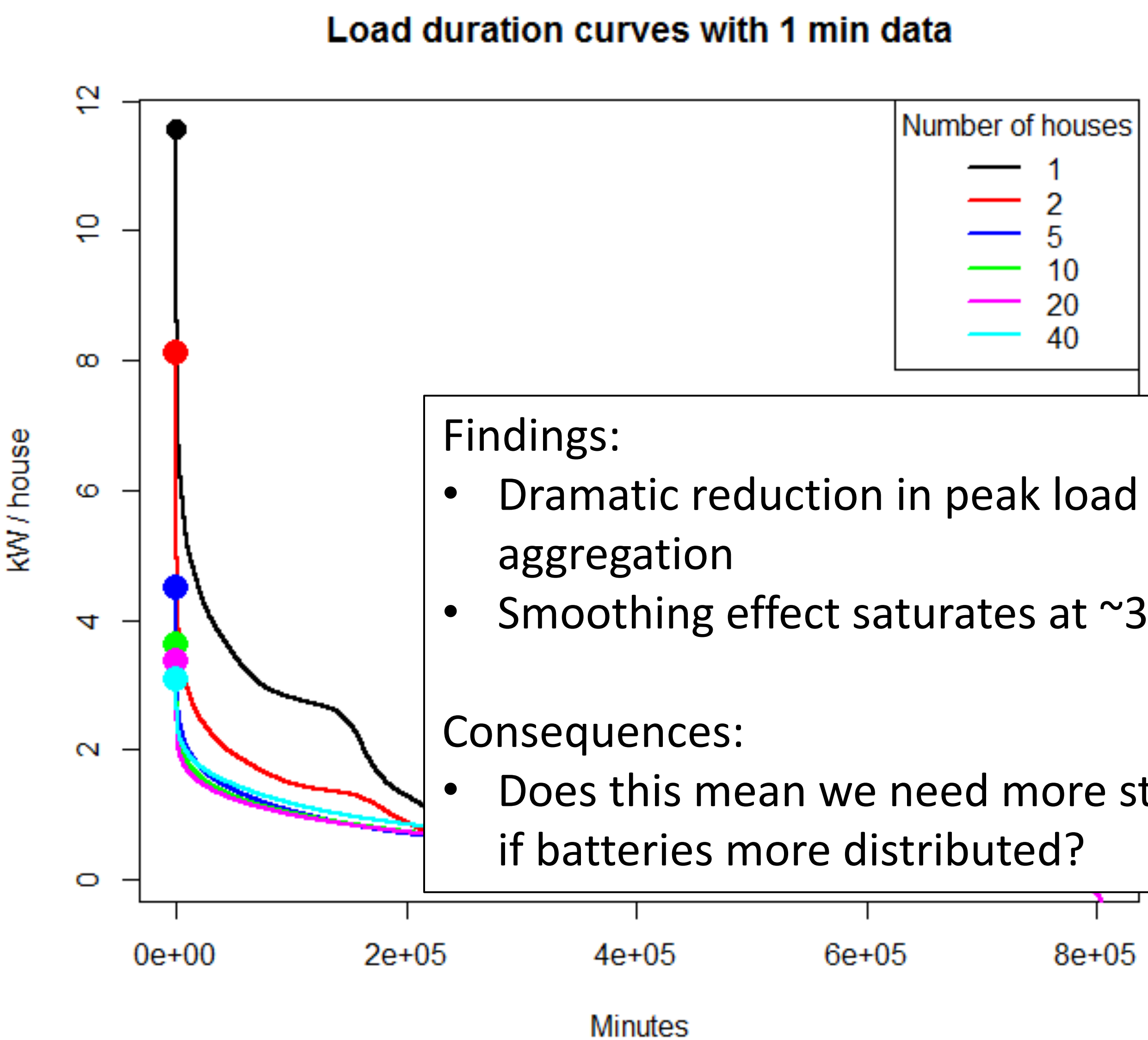
Effect of aggregation



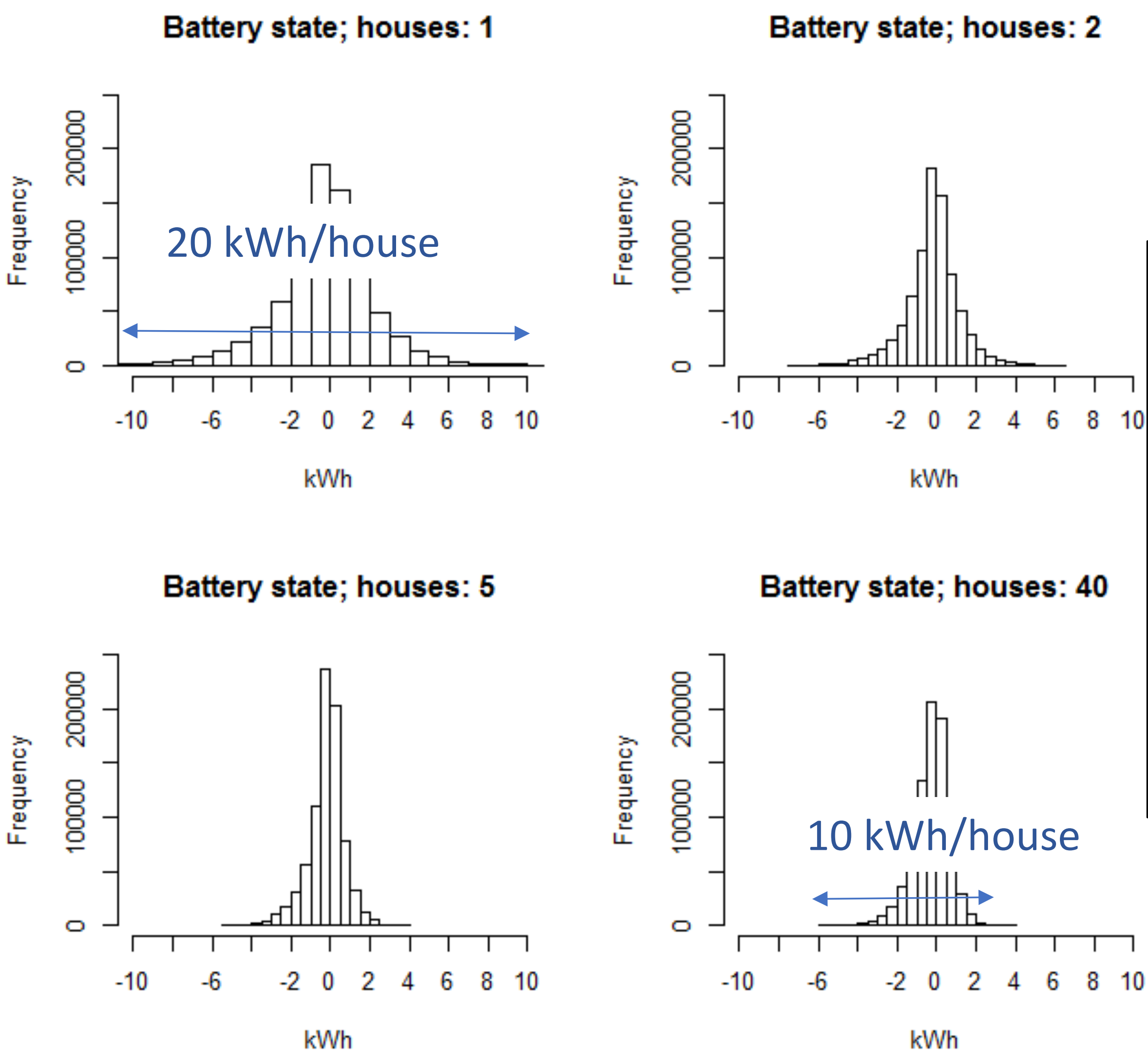
Findings:

- Dramatic reduction in peak load with aggregation
- Smoothing effect saturates at ~30 houses

Consequences:

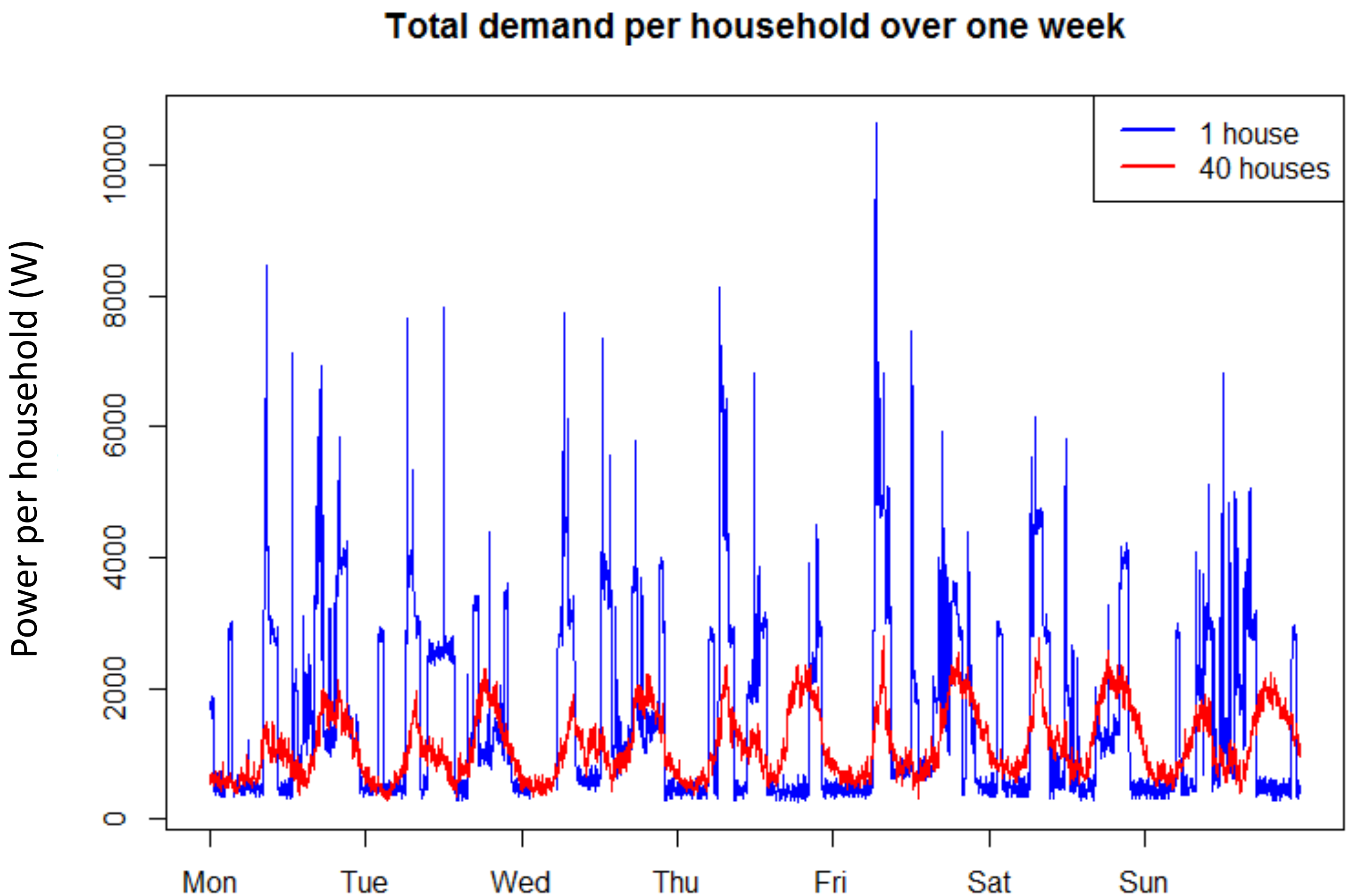
- Does this mean we need more storage per house if batteries more distributed?

What capacity battery?

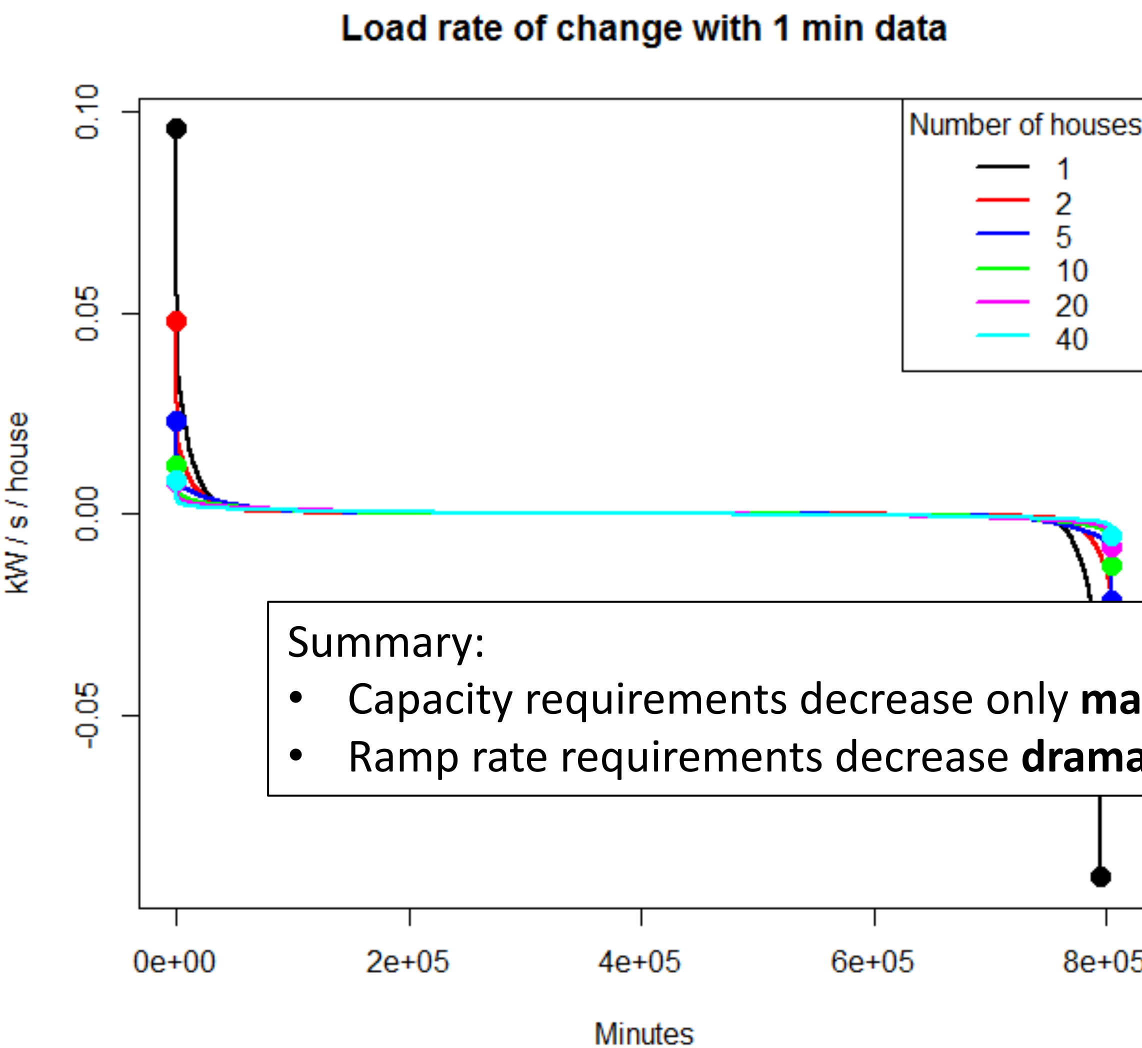


- Not much difference after 5 houses
- Less than factor of 2 difference between 1 and 40
- How can we understand this?

Bidiurnal cycle dominates battery capacity requirements



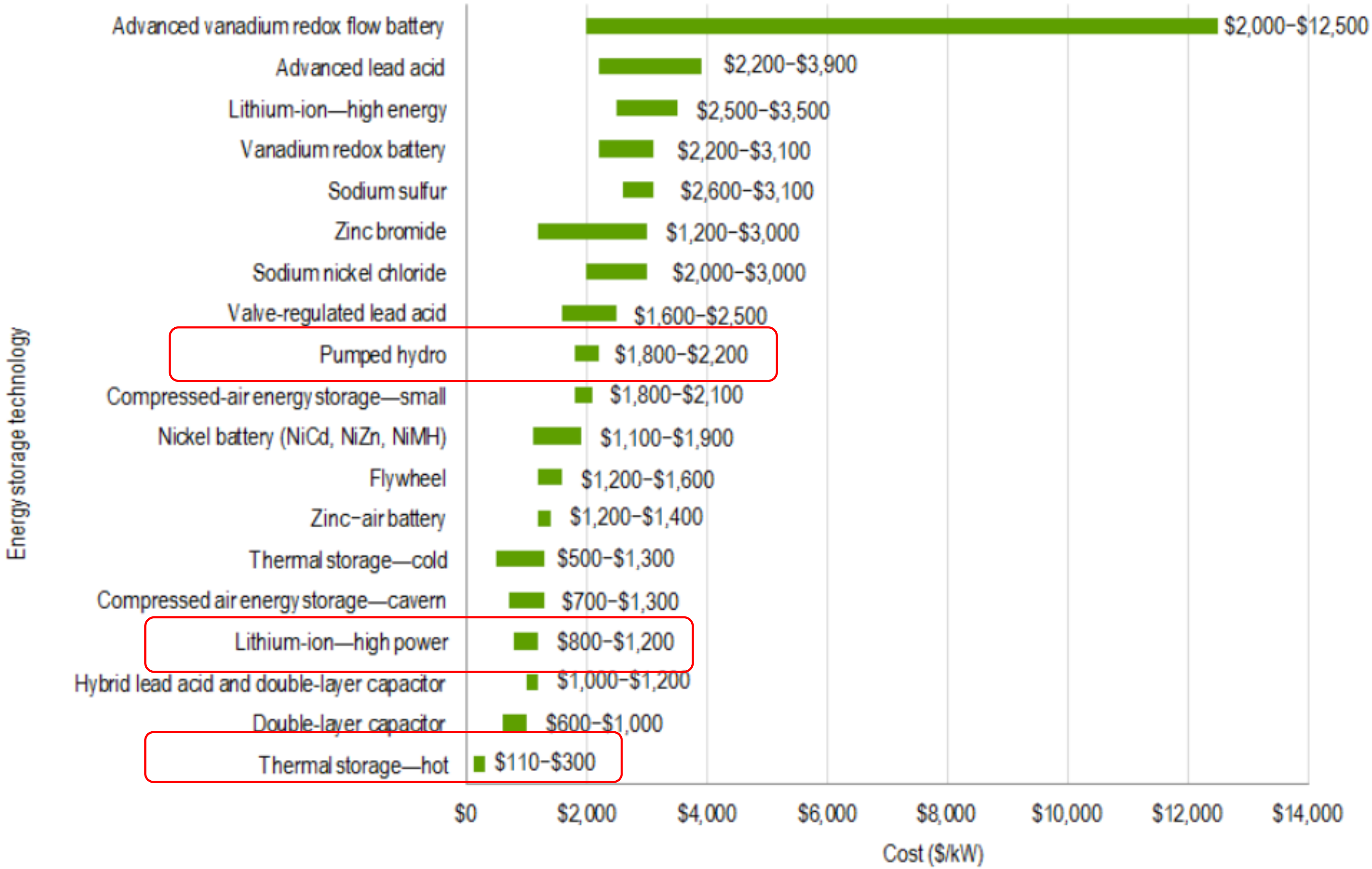
What about ramp rate?



Summary:

- Capacity requirements decrease only **marginally** with scale
- Ramp rate requirements decrease **dramatically** with scale

Smart Hot Water Cylinders -1



Notes: kW = kilowatt, NiCd = nickel cadmium, NiMH = nickel metal hydride, NiZn = nickel zinc.

Smart Hot Water Cylinders -2

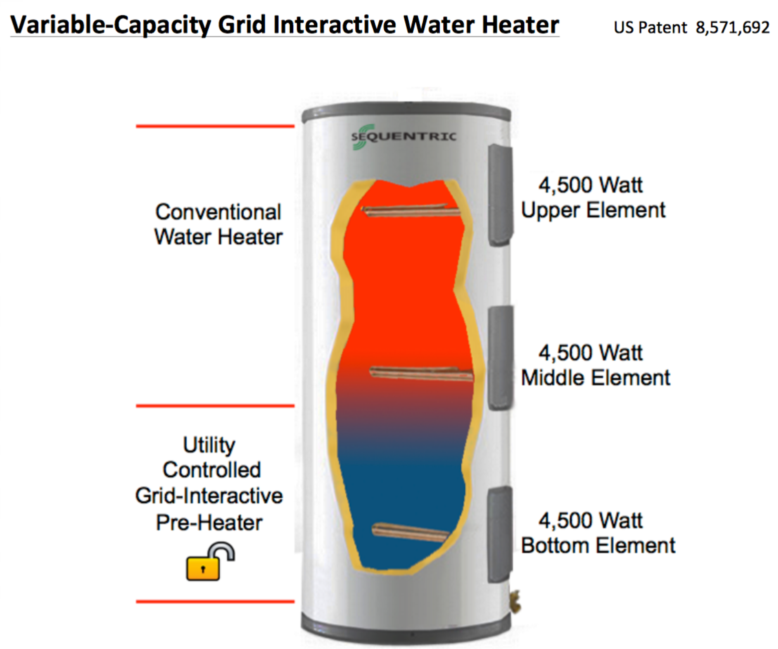
Seffes Corp

Hawaii Trial

- 499 hot water cylinders (each 12kWh capacity)
- Communicate with grid operator through cloud

www.steffes.com

Sequentric



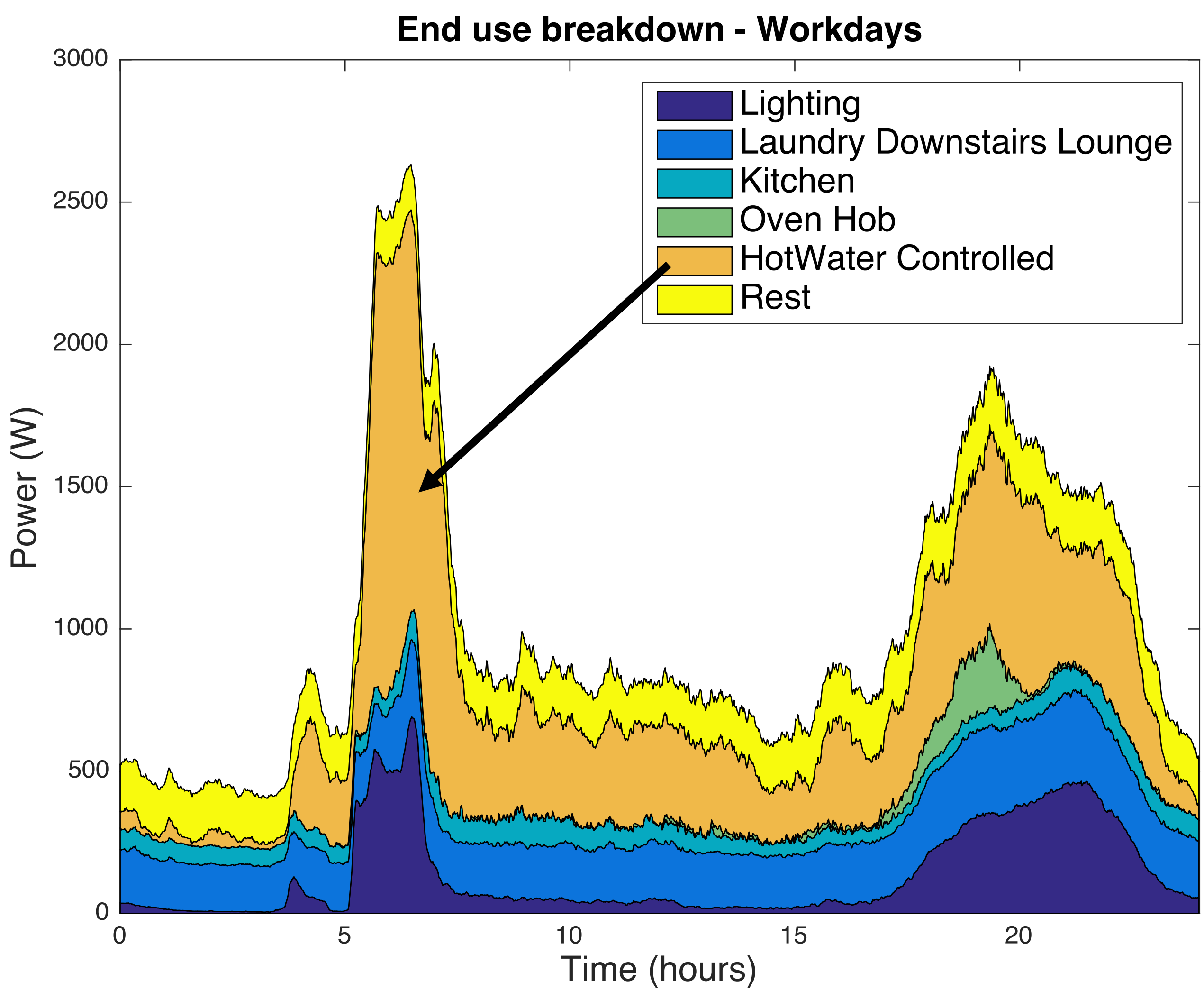
www.sequentric.com

D. Paodorson, Battery Killers: How Water Heaters Have Evolved into Grid Scale Energy Storage Devices, An E Source White paper (2014)

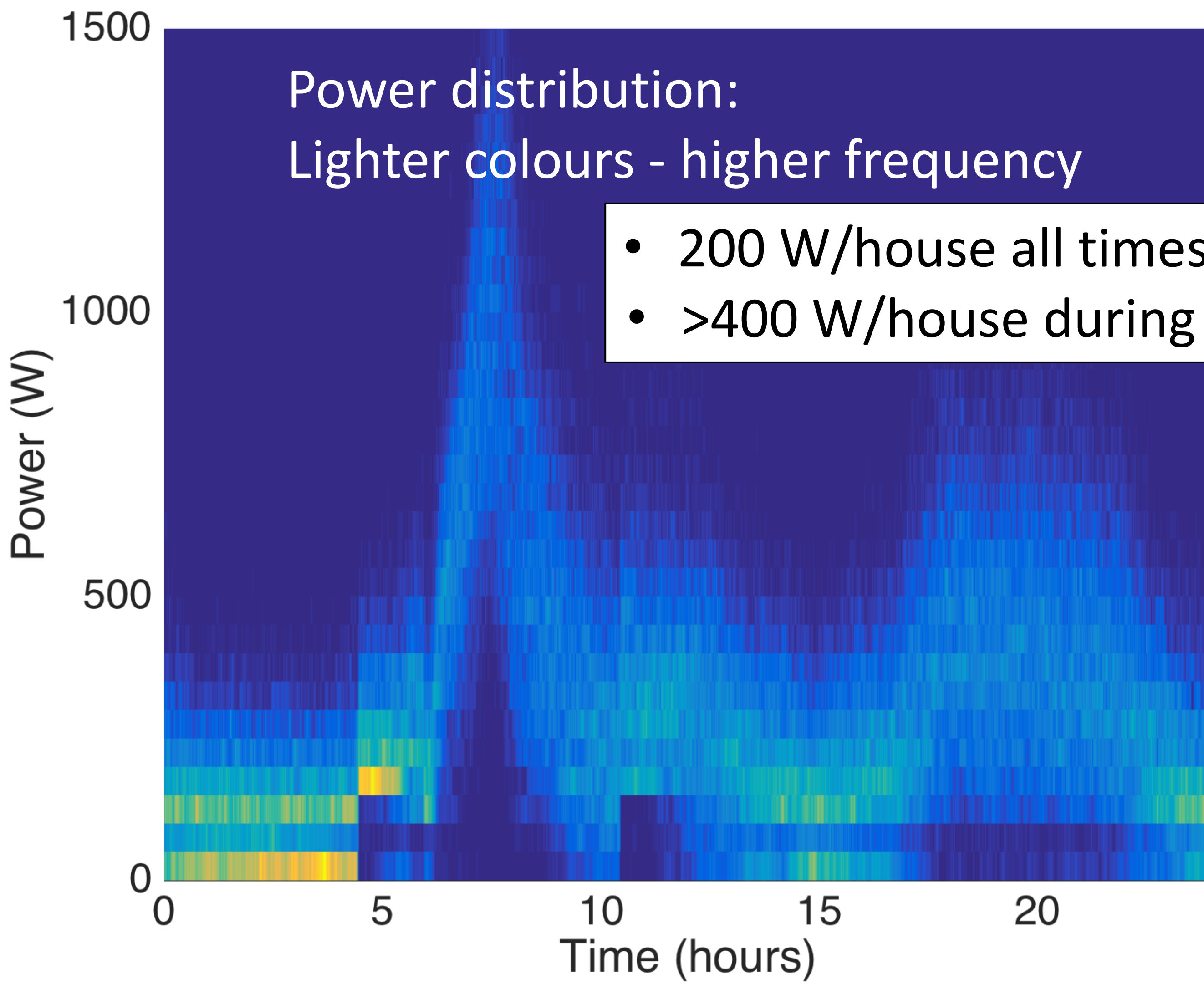
Hot water cylinders in NZ

- ~30% of household energy usage
- Year round guaranteed load
- Up to 50% of household demand during peaks
- Storage capability (~10 kWh) (Tesla Power wall 7kWh)
- Fast response
- Widespread ownership nationwide (~70%)
- Ripple control outdated (only load shedding) and varied use across networks

Hot water electricity demand



Hot water power usage per house



- 200 W/house all times
- >400 W/house during peaks

National-scale potential for hot water storage.

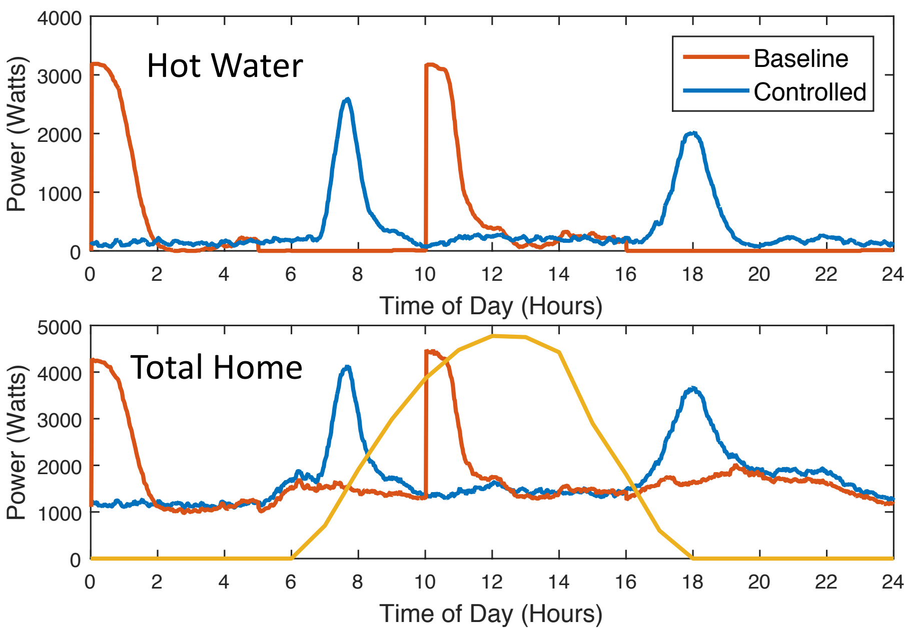
- Assume 200 W/cylinder of shiftable load (available at all times, more during peaks) and 5kWh storage capacity

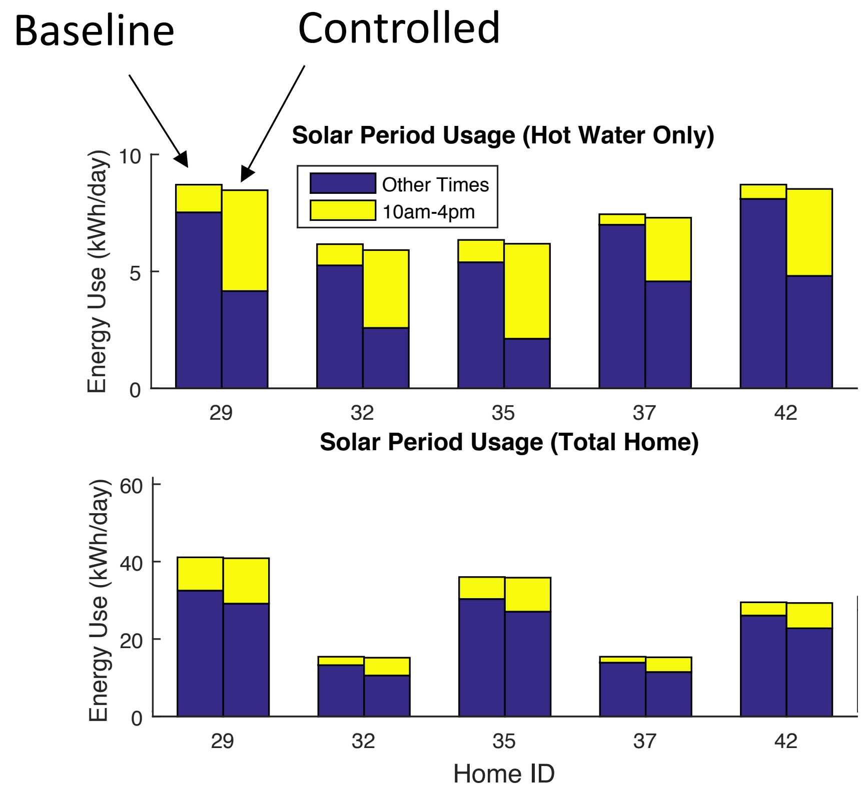
- 200 W $\times$ 400,000 cylinders = 80 MW
  - Capacity required for frequency keeping with additional 4000 MW wind (NZ 100% renewable electricity)

- 5kWh $\times$ 400,000 cylinders =2 GWh

- We have developed a hot water cylinder model to explore more detailed scenarios (see Jefferson's poster)

Maximize self-consumption of solar





(see Jeffersons' poster)

Conclusion

- Household Storage
  - Value increases as energy storage becomes more distributed
  - Multiple stakeholders
  - High variability in electricity demand at household level
- Batteries
  - Aggregating smooths loads up to ~30 houses
  - Capacity requirements decrease only **marginally** with scale
  - Ramp rate requirement decrease **dramatically** with scale
- Smart hot water cylinders
  - Don’t overlook! Potentially low cost energy storage
  - Huge potential to benefit grid (>90% penetration, 10 kWh)
  - Grid-scale capacity >80 MW (2GWh)
  - Can significantly increase self-consumption of rooftop solar
  - Hot water cylinder model developed to explore opportunities

Primary Funder

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TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI VICTORIA UNIVERSITY OF WELLINGTON

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