Do Energy Savings Grow on Shade Trees?

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Motivation

Energy Efficiency

- Major national priority and policy focus (e.g. retrofit rebates, TOU pricing, building codes)

Shade Trees

- Target peak-hour load reductions
- Rigorous policy evaluation possible with remote sensing

Lack of Evidence

- Panel data on shade loss

Research Questions

How does tree shade impact residential energy use?

- Cost-savings
- Seasonal patterns
- Tree characteristics

Can tree policies provide cost-effective energy savings?

Preview

Causal Identification

- Trees lower summer electricity consumption
- Trees only affect energy when shading houses
- Effects increase with canopy size

Economic Importance

- Shade trees can reduce energy use by 20%

Tree Removals (Gainesville, FL)

2007

2011

Tree Removals (Gainesville, FL)

2007

2015

Gainesville Data

Tree Permits *(2000-2016)*

- 1,383 residential tree removals, required for all large trees
- Issue date, property address

Energy Bills *(2000-2016, GRU)*

- Monthly electricity and natural gas bills, linked to address

Spatial Data

- Aerial Imagery *(2001 and 2011)* ➔ Canopy loss area
- Sun Position *(hourly, monthly)* ➔ Shade loss
- Property and building location

Fixed Effects Model

$$y_{itm} = \alpha_{tm} + \alpha_{im} + \beta\, TR_{itm} + \varepsilon_{itm}$$

y_{itm} energy consumption *(kWh, therm)* for house i in year t and month m

α_{tm} fixed effects for billing period *(year*month)*

α_{im} fixed effects for house-month *(house*month)*

TR_{itm} indicator variable equal to one in **periods after tree removal**

ε_{itm} error term (clustered by house)

β average effect of tree removal on energy consumption

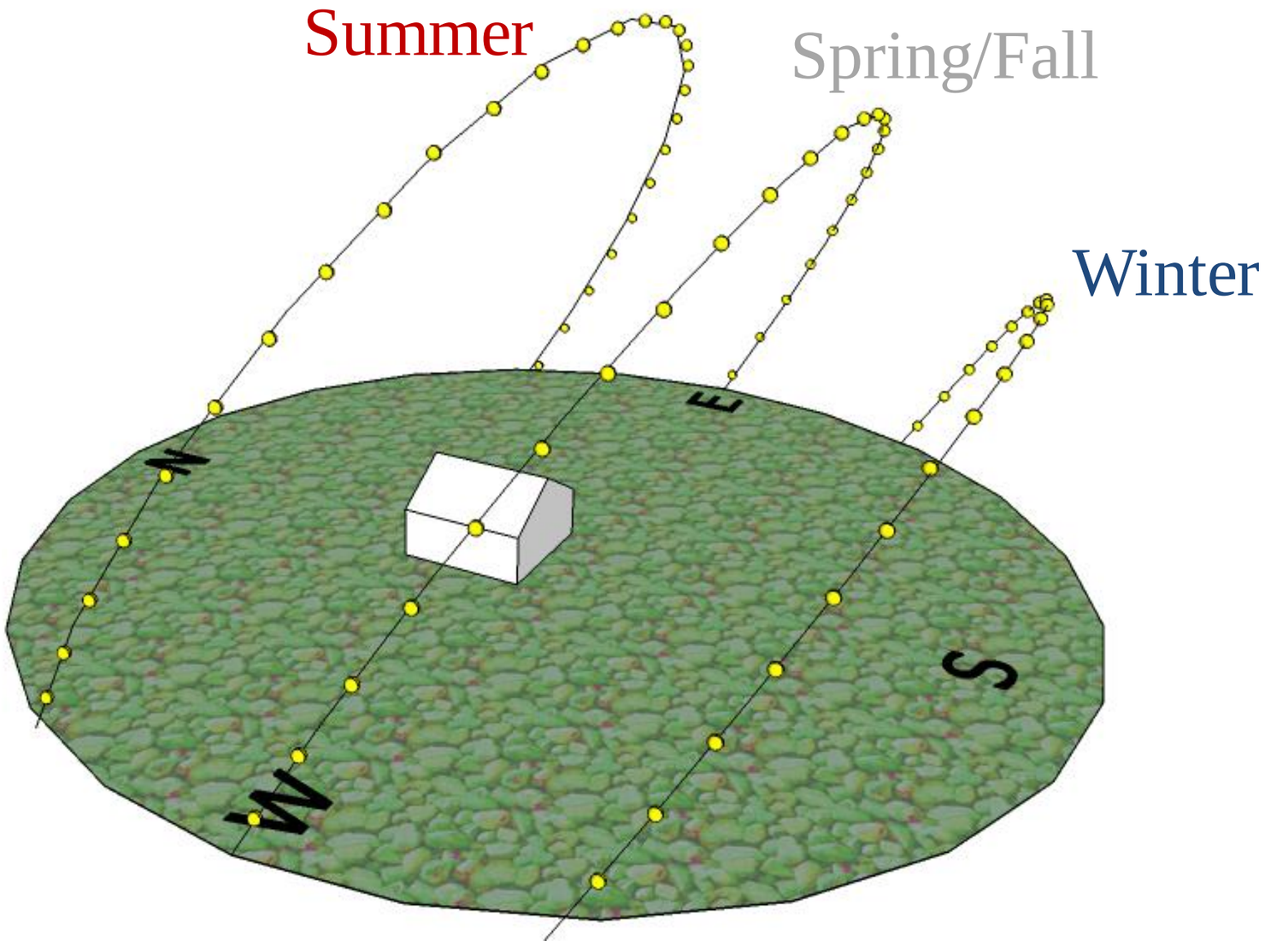
*Sample restricted to houses that are treated by end of study period

Tree Removal Effects By Fuel Type

Variables	(1) Electricity log(kWh)	(2) Electricity kWh	(3) Natural gas log(therms)	(4) Natural gas therms	(5) Combined energy log(kWh)	(6) Combined energy kWh
Tree removal effect	0.0546***	34.35**	-0.034	-0.0074	0.0468***	35.76*
	(0.018)	(14.05)	(0.022)	(0.53)	(0.018)	(20.30)
R-squared	0.562	0.673	0.777	0.777	0.599	0.686
Observations	219,118	219,118	158,515	168,909	220,459	220,459
Residences	1,383	1,383	1,110	1,110	1,383	1,383

Notes: Each regression includes residence-by-month-of-year dummies and month-by-year dummies. Standard errors are reported in parentheses.

Sun Path By Season

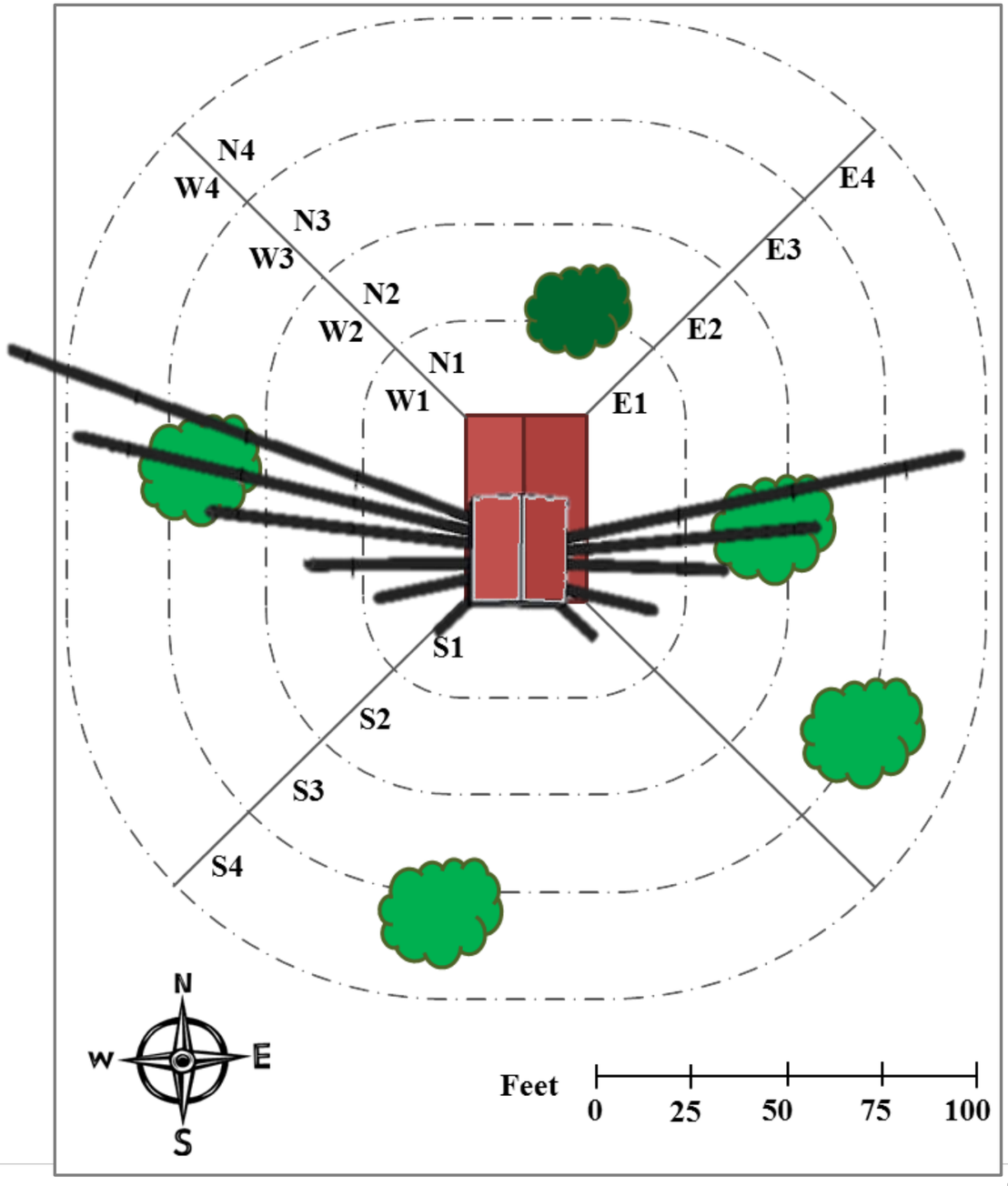


Sun movements shift shade supply

→ Quasi-experimental variation in shade from tree removals

Shade on House (June 21st)

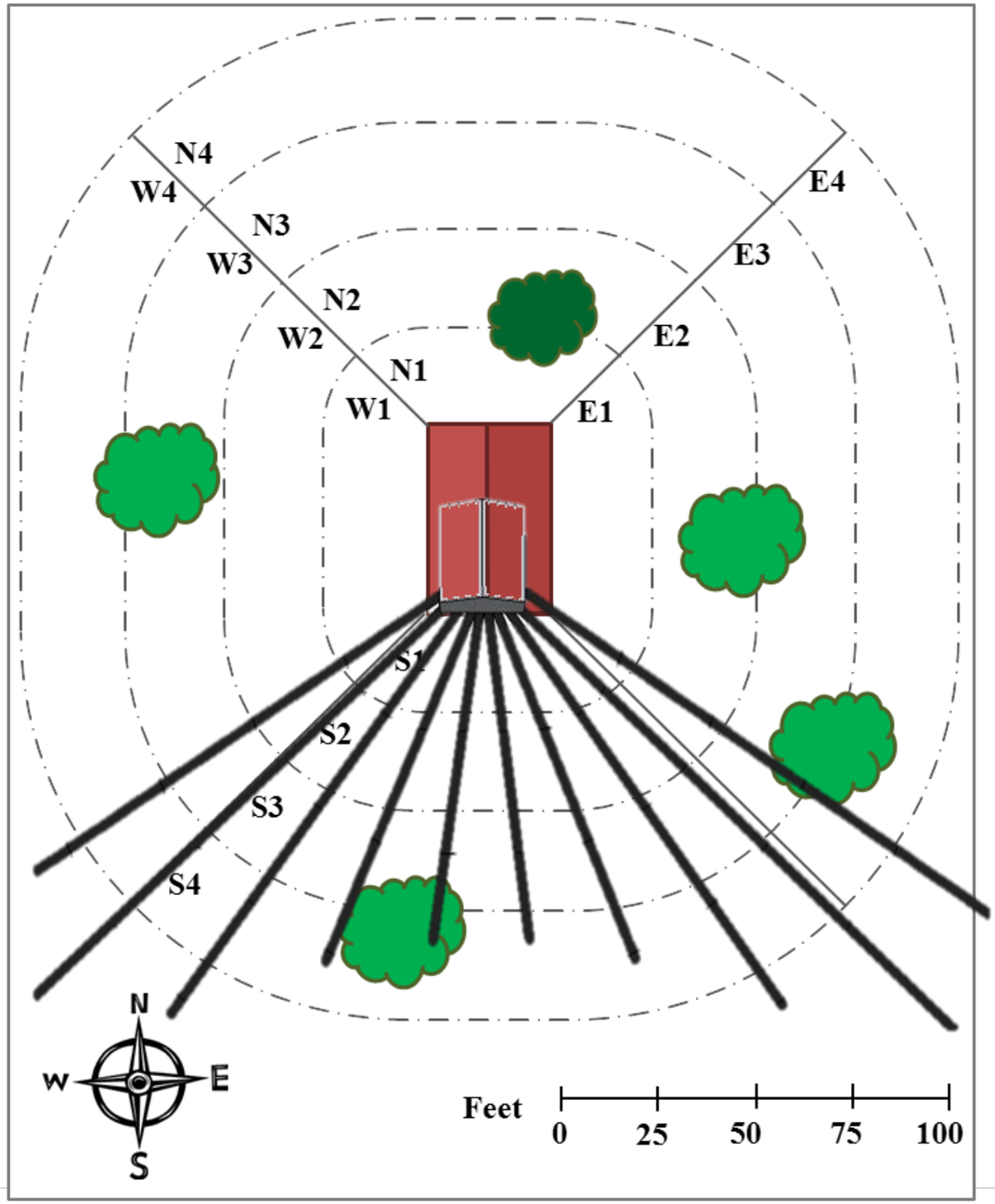
Summer



Shade area

- Hours when sun and tree align to shade house

Shade on House (December 21st)



Define 12 shade areas

- Shade on a house in each month

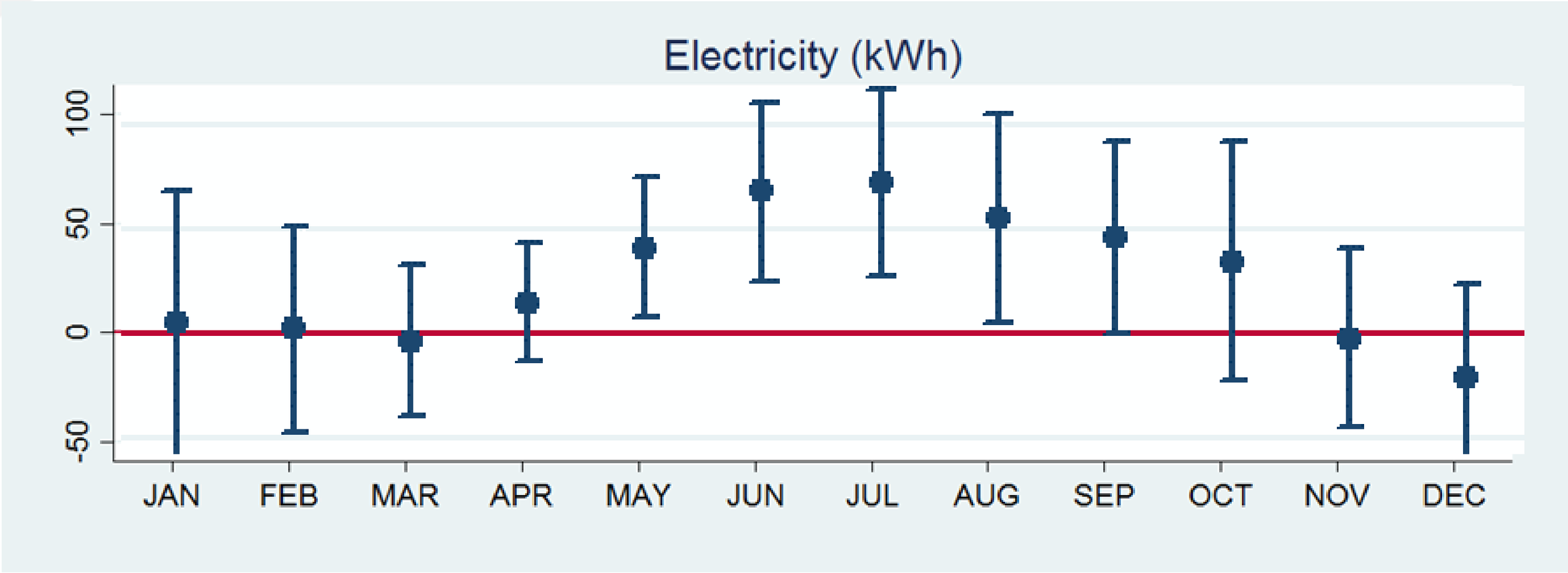
TR * Month-of-Shade

(i) Timing of removals

(ii) Timing of shade loss

Winter

Electricity Effects By Month of Shade Loss



[*more*]

Shade Canopy Loss

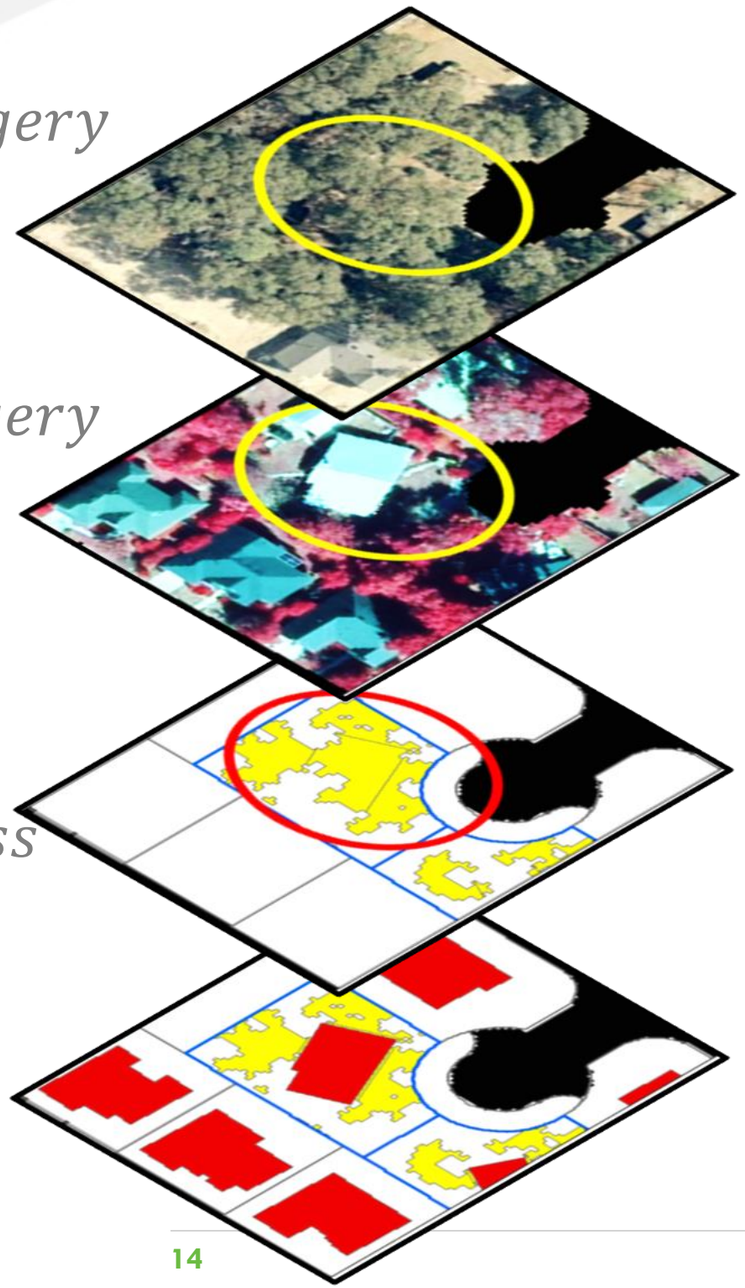
2001 *imagery*

2011 *imagery*

⇩

canopy loss

building footprint



ΔShade = f(canopy size, location, sun path)

Shade Canopy Loss Area (m^2)

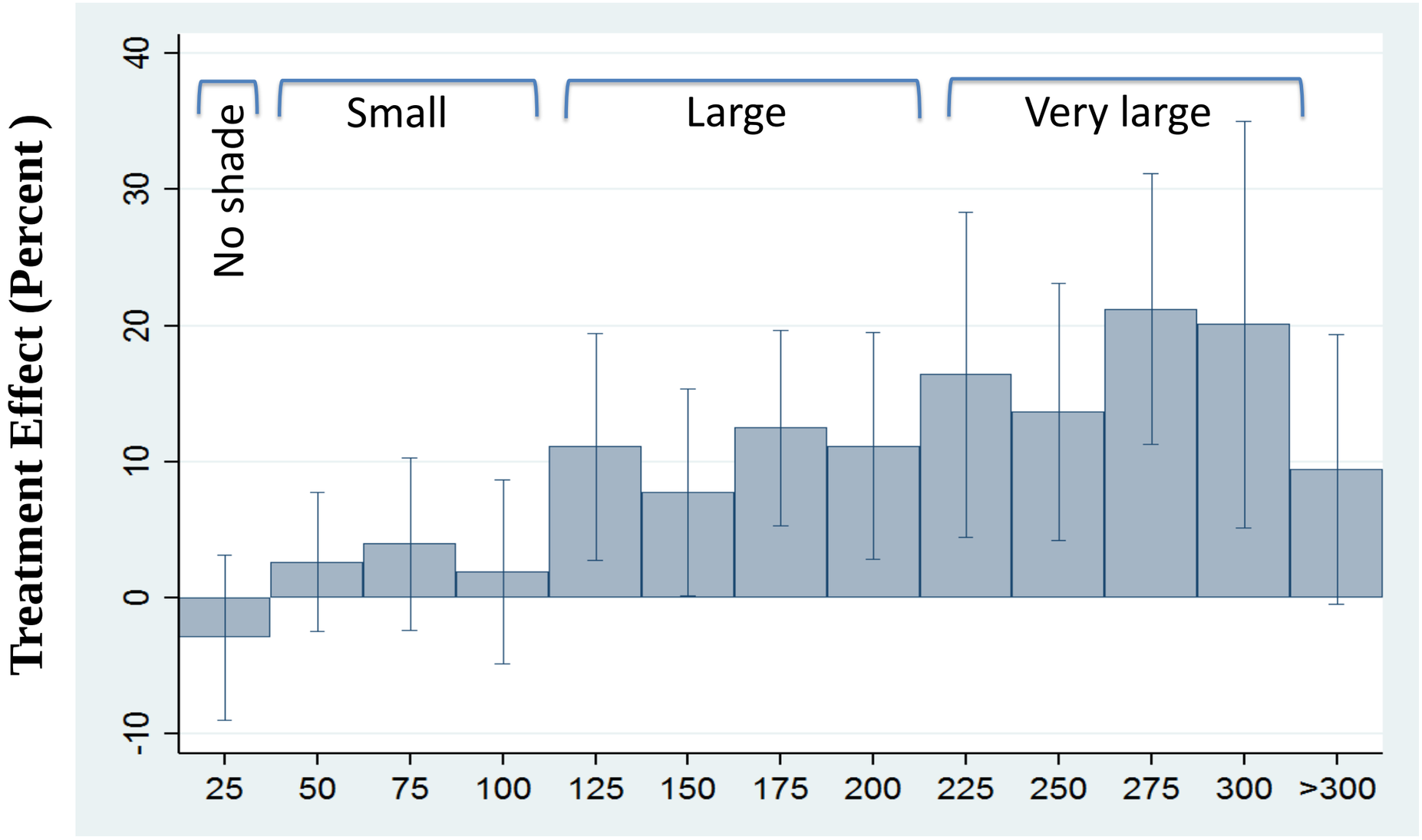
(i) Timing of removals

(ii) Month of shade loss *(sun path)*

(iii) Amount of shade *(canopy size)*

[*more*]

Shade Effects By Canopy Size (25m^2 Bins)



[*more*]

In Summary

Identification

- Shade loss depends on sun position, tree location, canopy size.
- Trees only affect energy when shading houses
- Effects increase with canopy size

Falsification Tests

- *Air-conditioning*: No effects during winter, or natural gas.
- *Shade*: No effect in months *without* shade loss (any size canopy)

Some Context

Value

- **Large tree = $1,600** upgrade to more efficient air-conditioner

Tree Policy

- Energy savings comparable to building codes *(Kotchen 2015)*.
- Cheaper ‘negawatt’ than retrofit rebate programs *(Maher 2016)*.

Conclusions

- Large trees reduce energy bills by 5%, on average, and as much as 20% for some months

- Private benefits (up to $1,500+) comparable to common energy-efficiency investments

- Policies targeting green infrastructure may provide cost effective energy savings

Thanks.

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