Is Solar Contagious?

Going solar in a group

Vote Solar
November 2014

Vote Solar

Vote Solar is a non-profit grassroots organization working to fight climate change and foster economic opportunity by bringing solar energy into the mainstream.

Since 2002 Vote Solar has engaged in state, local and federal advocacy campaigns to remove regulatory barriers and implement the key policies needed to bring solar to scale.

www.votesolar.org

Vote Solar's Group Energy - Program Update

Since 2012 administering limited-time group procurement programs.
3.5 MW of new residential PV capacity to date.

Employer Programs

- Employee engagement in community / corporate sustainability goals.
- Pool the power of existing groups.
- Use internal communication channels.

SF SunShares

- Round 1: 1,000 registrants and 400+ kW in 3 months
- Round 2: Currently underway; 15% discount + contractor rebates

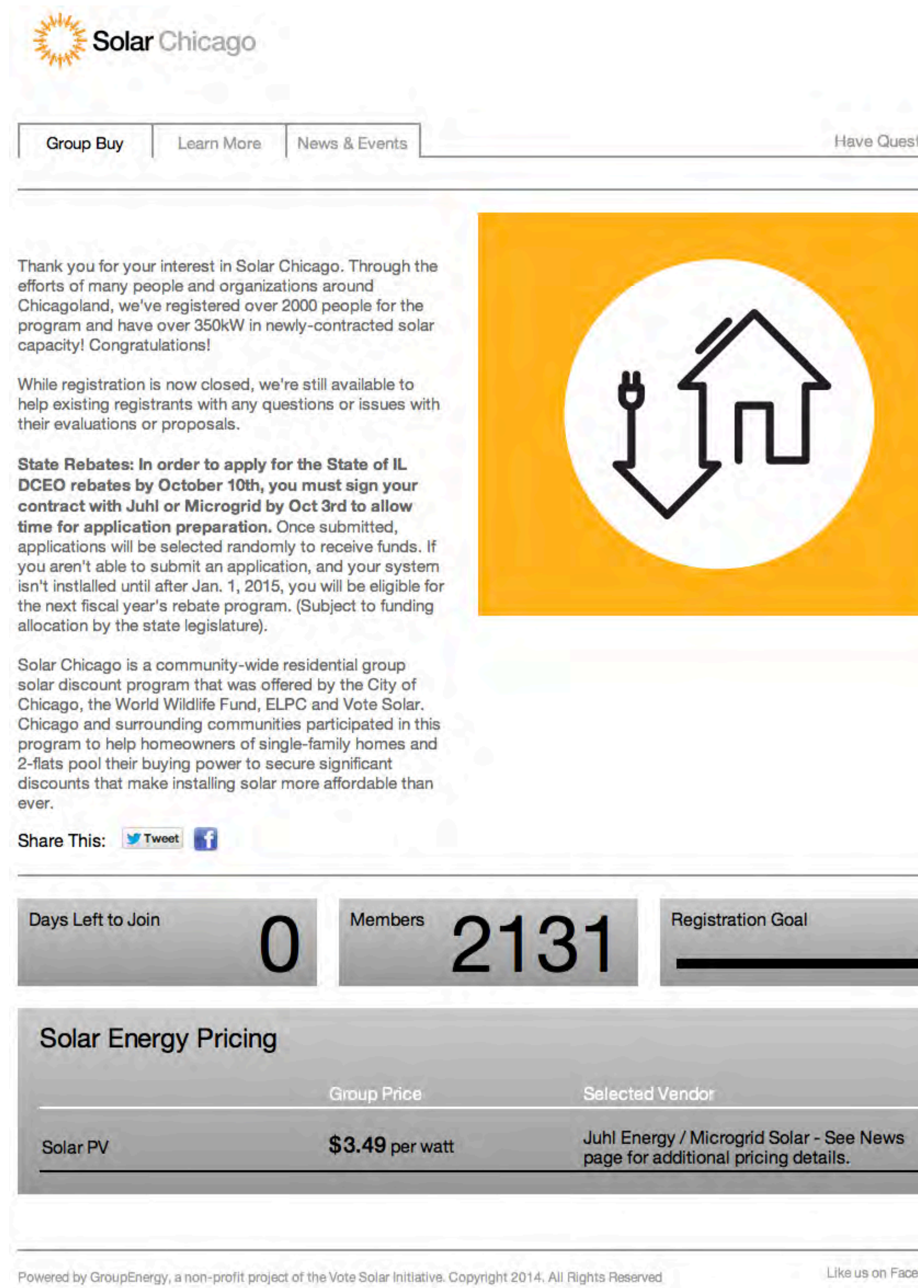
ommunity Programs

- Solar Chicago - Hard to do market.
- Sept. 30th registration deadline.
- Pricing started at $3.49/watt
- 25% discount
- Contractor incentive = $3.19/watt

)15 Programs

- Peninsula SunShares – Community wide
- San Diego – Employer
- NYSERDA – Employer

uestions? jessie@votesolar.org



Spatial Patterns of Solar Photovoltaic System Adoption: The Influence of Neighbors and the Built Environment

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**Yale University

Vote Solar Webinar

November 19, 2014

Outline

Courtesy of: Wikimedia Commons

Overview

- Why do people install solar PV?

- Many reasons… but recent work has suggested the importance of:

1. “Peer” or “neighbor” effects – Bollinger & Gillingham (2012) in California, Muller & Rode (2013) in Germany

2. Area Geography/Built Environment – Bronin (2012) in Connecticut

Research Objectives

To understand the patterns of spatial diffusion of residential PV systems in Connecticut, 2005-2013

↓

WHERE?

To explore the factors underlying these patterns

↓

WHY THERE?

Integrating Methods

- Identify statistically significant clusters of PV systems.
- Identify spatial patterns of diffusion.

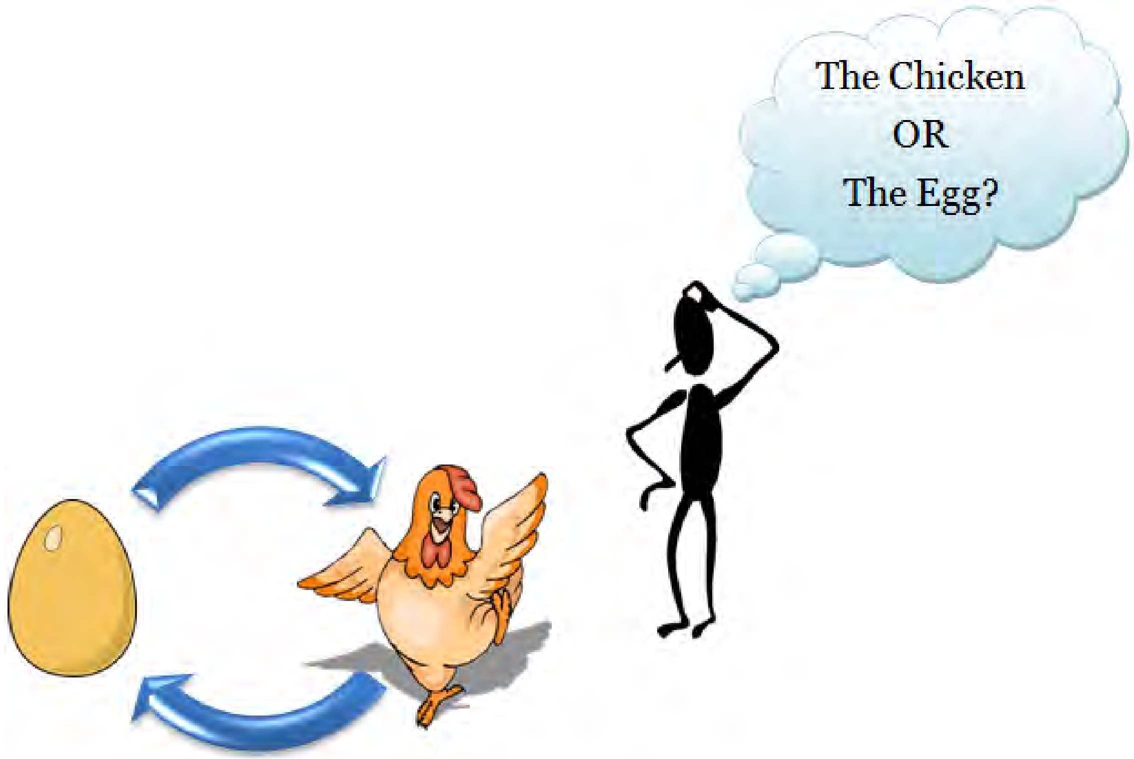
WHERE?

- Present evidence for spatial peer effects
- Examine evidence for built environment drivers.
- Evaluate policy implications.

WHY THERE?

Issues in Identifying Peer Effects

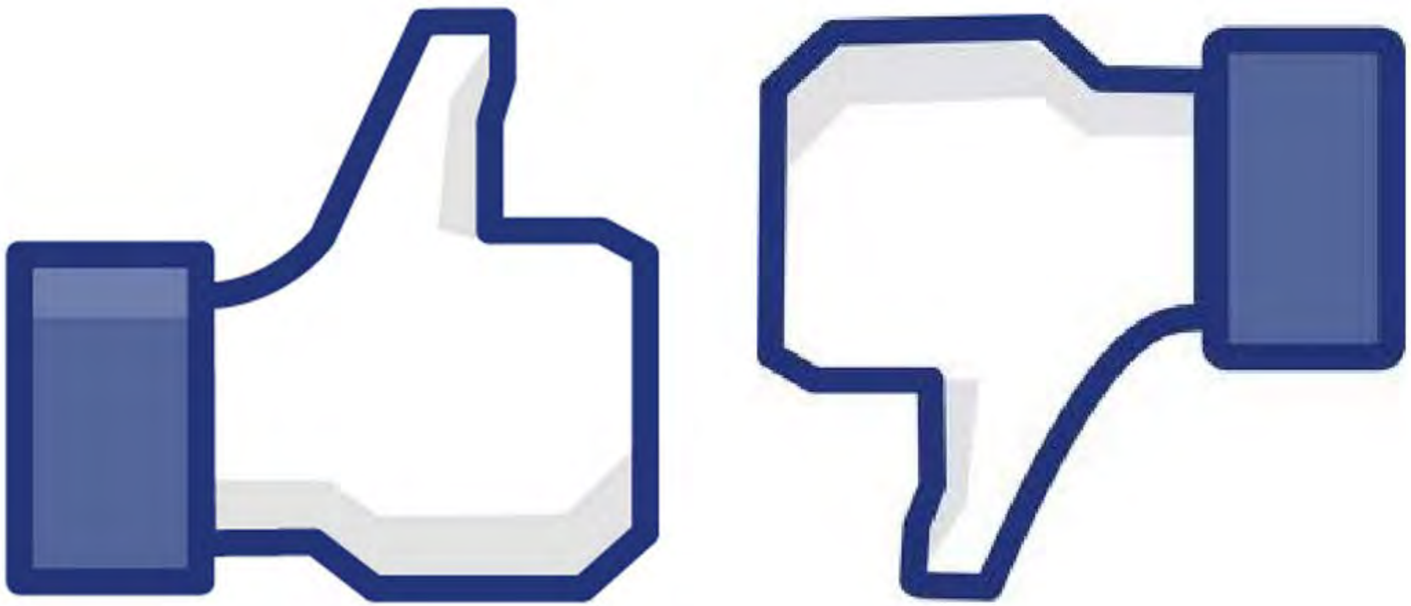
- **Simultaneity –** Manki's reflection problem, where one affects their peers just as the peers affect them. Not a problem here because the additional adoptions are determined within a temporal buffer.



Courtesy of Wikicommons

Issues in Identifying Peer Effects

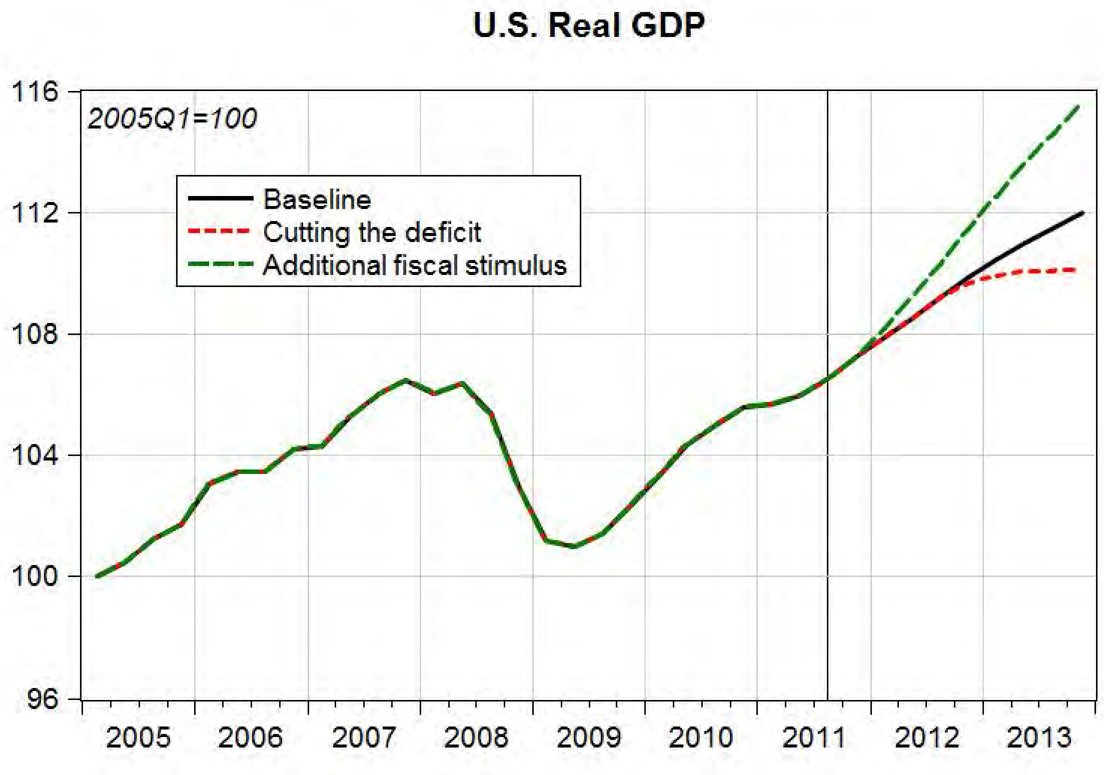
- **Endogenous Group Formation –** Self-selection into a group. It is unlikely people move to an area for solar PV. We use block group-quarter fixed-effects to address common preferences, even if they change over time.



Courtesy of Wikicommons

Issues in Identifying Peer Effects

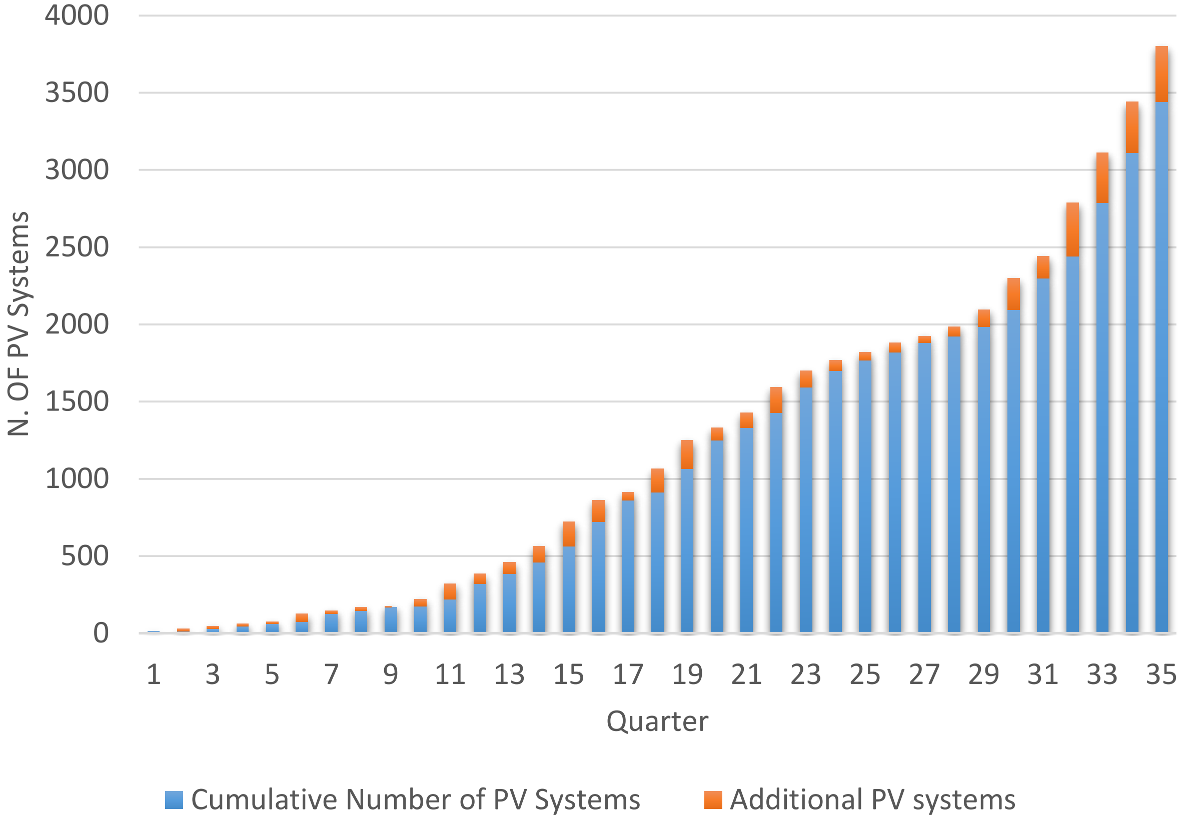
- **Correlated Unobservables –** Other factors affecting neighbors at the same time. We again control for these with fixed effects.



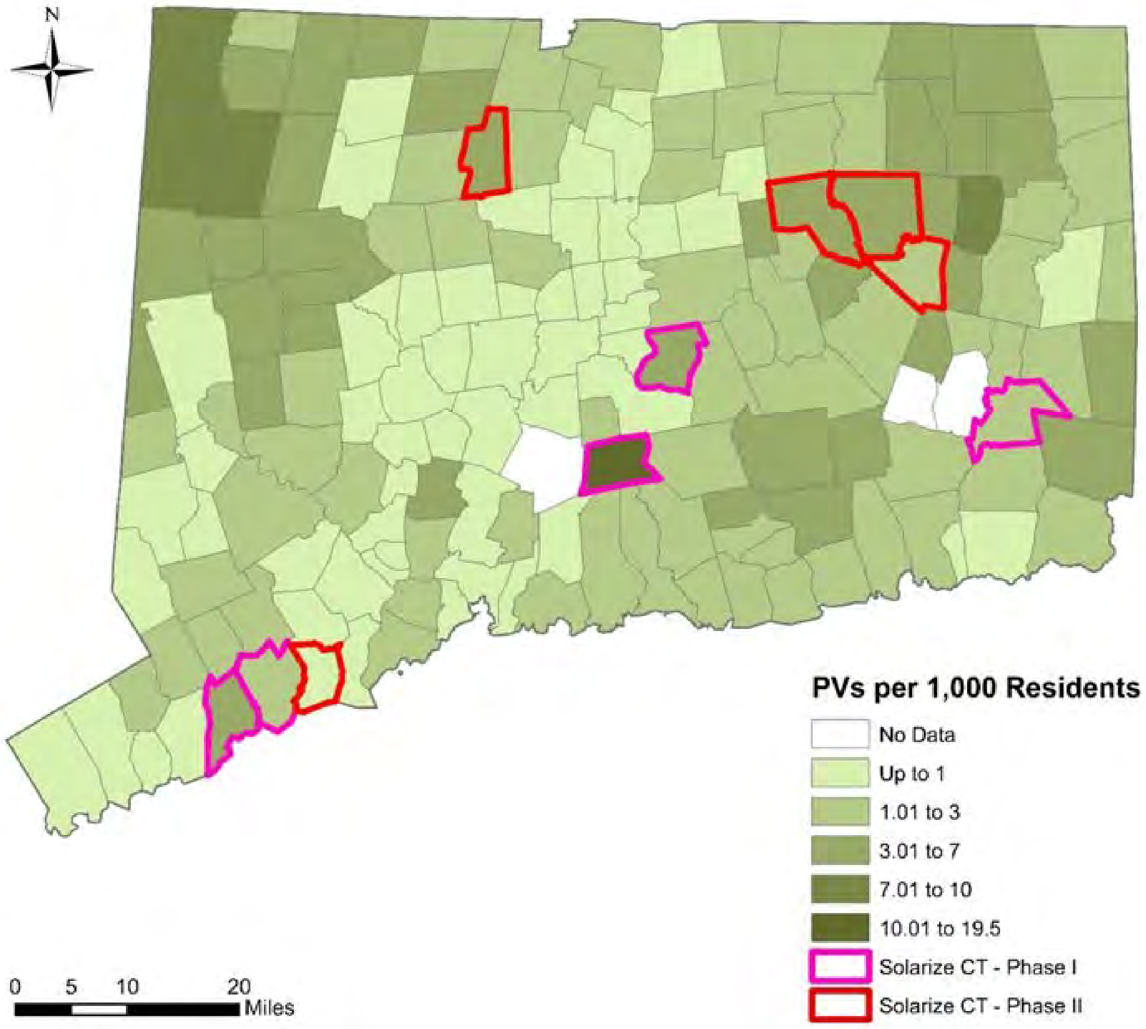
Courtesy of Wikicommons

Connecticut: Small and Active

- **#3 Best solar state in "Solar Power Rocks" Rankings.**
- **Generous rebates, incentives, and Solarize Program.**
- **Good solar radiation.**
- **#3 Highest electricity prices (17.34 cents/kW).**
- **SolarizeCT**
- **Residential program initiated in 2004.**



Connecticut: Small and Active



- **State strategies implemented at town level.**
- **Large socioeconomic differences among towns.**
- **Uneven distribution across towns (lowest jurisdictional level).**

CEFIA Data

PV Systems, 2004 - September 2013.

- Source: Connecticut Energy Finance and Investment Authority (CEFIA).
- Use: locations, counts, proximity values.
- Temporal coverage: 2004-2013. 2004 data used as temporal lags in t-1.
- Fields: Address, Application date.

Table 1. Summary Statistics

Variable	Mean	Std. Dev.	Min	Max	Source
Count of new PV systems by block group and quarter	0.04	0.27	0	18	CEFIA (2013)
Installed base	0.48	1.24	0	39	CEFIA (2013)
Average neighboring Installations, 0.5 Miles - 6 months	0.005	0.08	0	5	Calculated
Average neighboring installations, 0.5 to 1 mile - 6 months	0.006	0.09	0	6	Calculated
Additional number of new installations, 1 to 4 mile - 6 months	0.05	0.57	0	58	Calculated
Average Neighboring Installations, 0.5 Miles – 12 months	0.009	0.17	0	16	Calculated
Average Neighboring Installations, 0.5 to 1 mile - 12 months	0.008	0.16	0	14	Calculated
Average Neighboring Installations, 1 to 4 mile - 12 months	0.067	0.88	0	72	Calculated

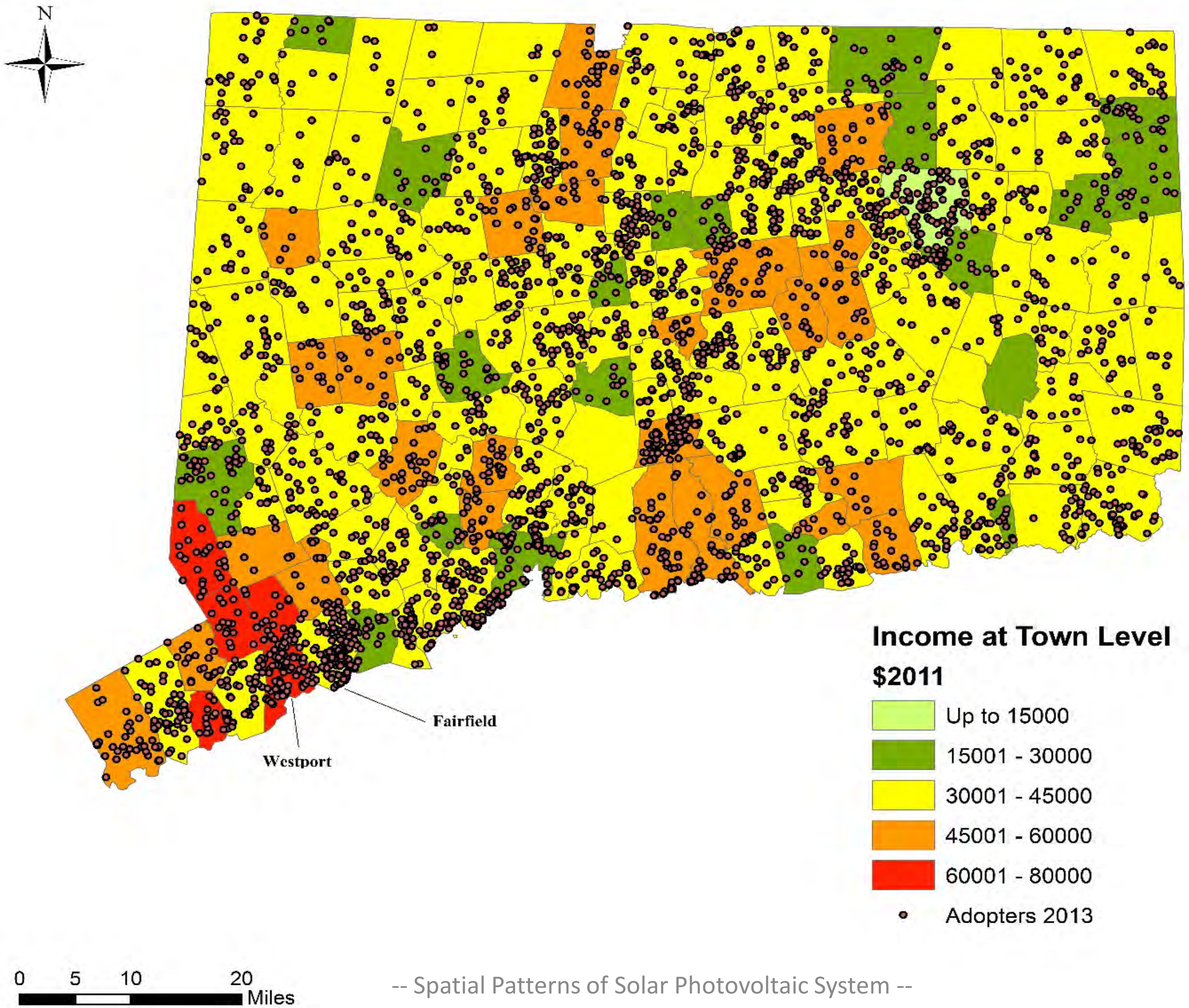
Demographic Data

Census demographics at the block group level (600-3,000 people).

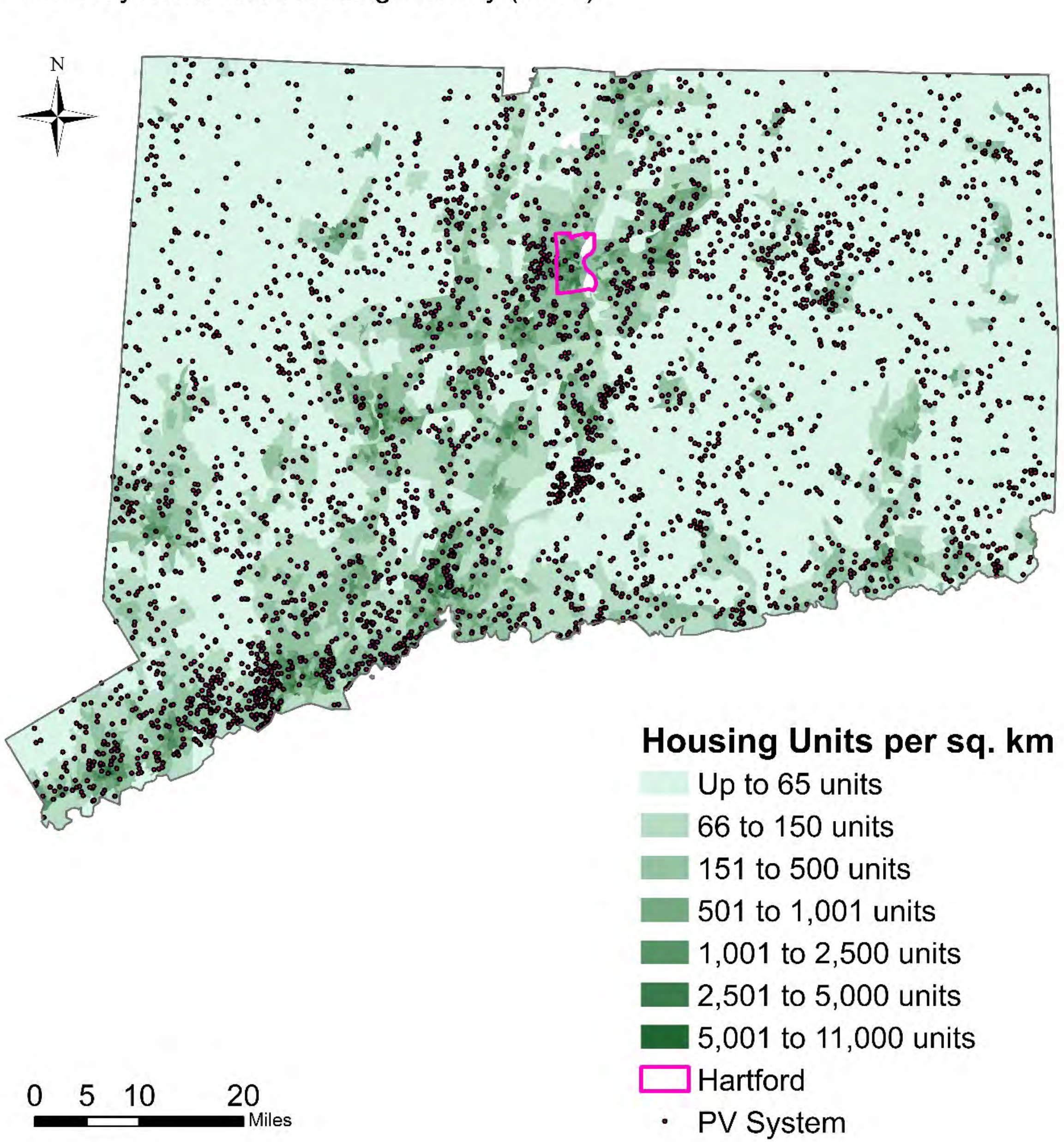
- **Housing:** # of Housing units; housing density; % renters;
- **Income:** Median household income;
- **Demography:** % of white; % of black; % of Asians; median age; median age in oldest 5%;
- **Politics:** % of democrats; % of minor parties (incl. 'Green);
- **Macroeconomics:** Electricity costs; % unemployment;
- **'Peers' Programs:** SolarizeCT

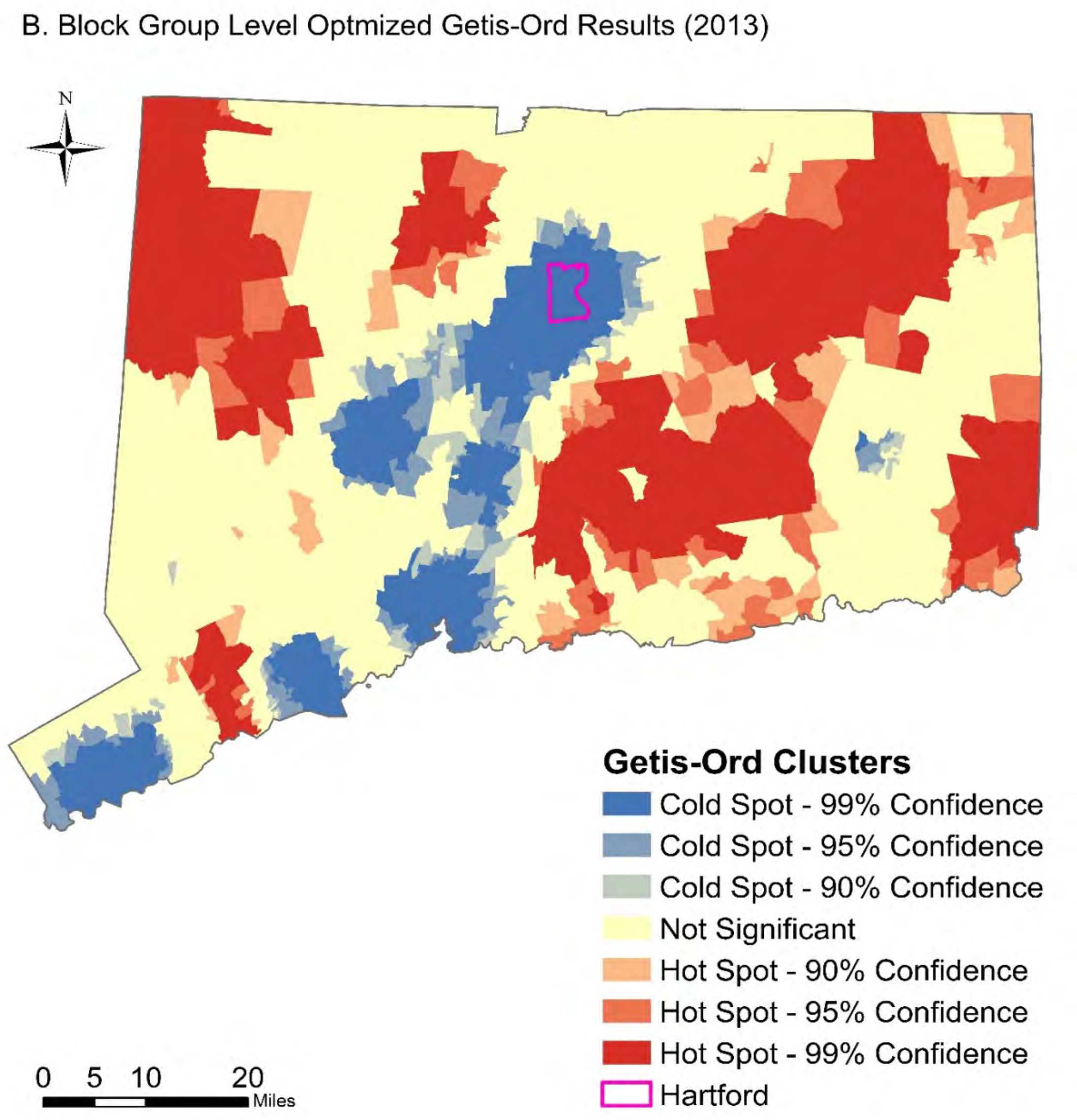
- Use: Interpolation process (quadratic).
- Final Use: Block Group characteristics.
- Prices adjusted by inflation, in $2013.

Adoptions and Income, 2013



Adoptions and Housing Density, 2013

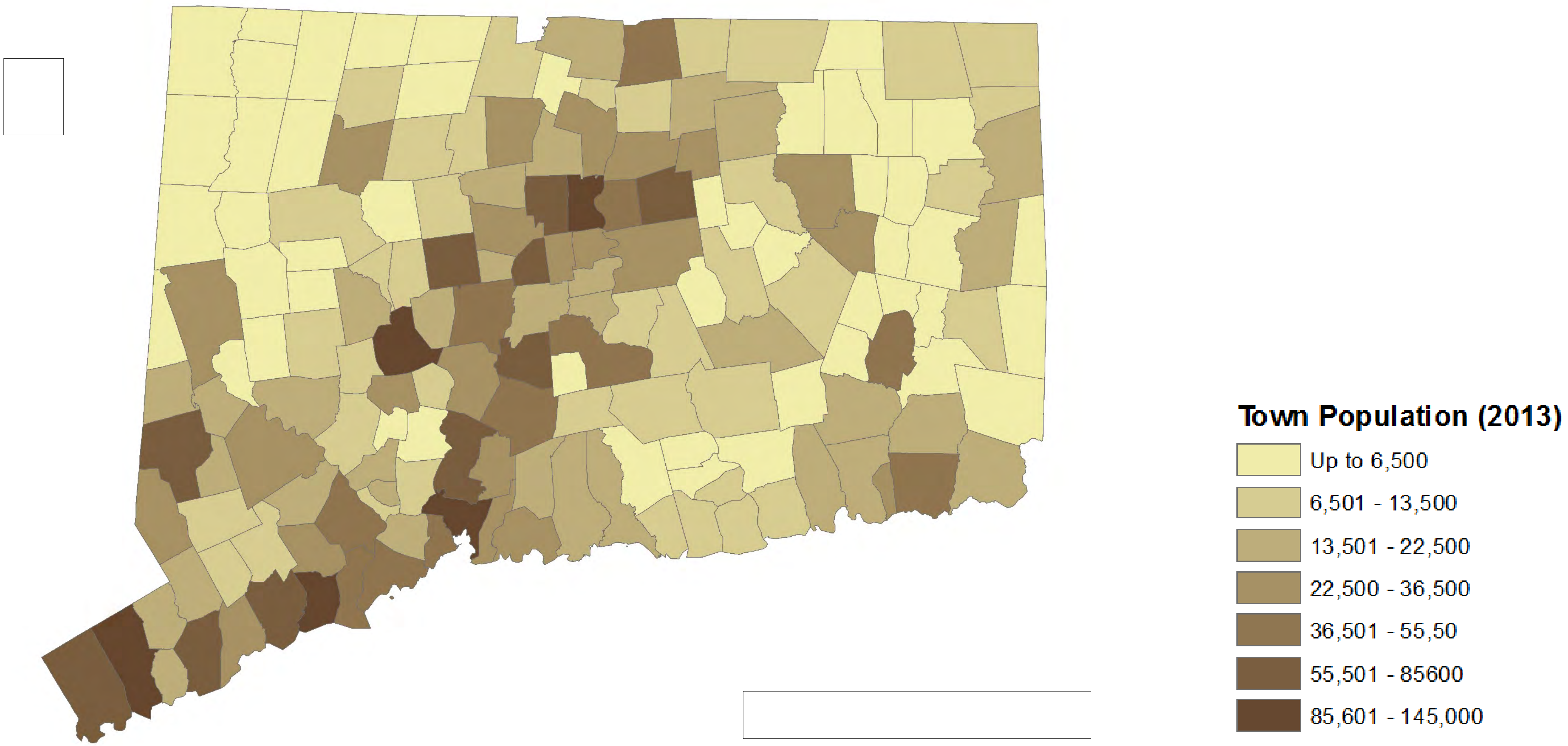




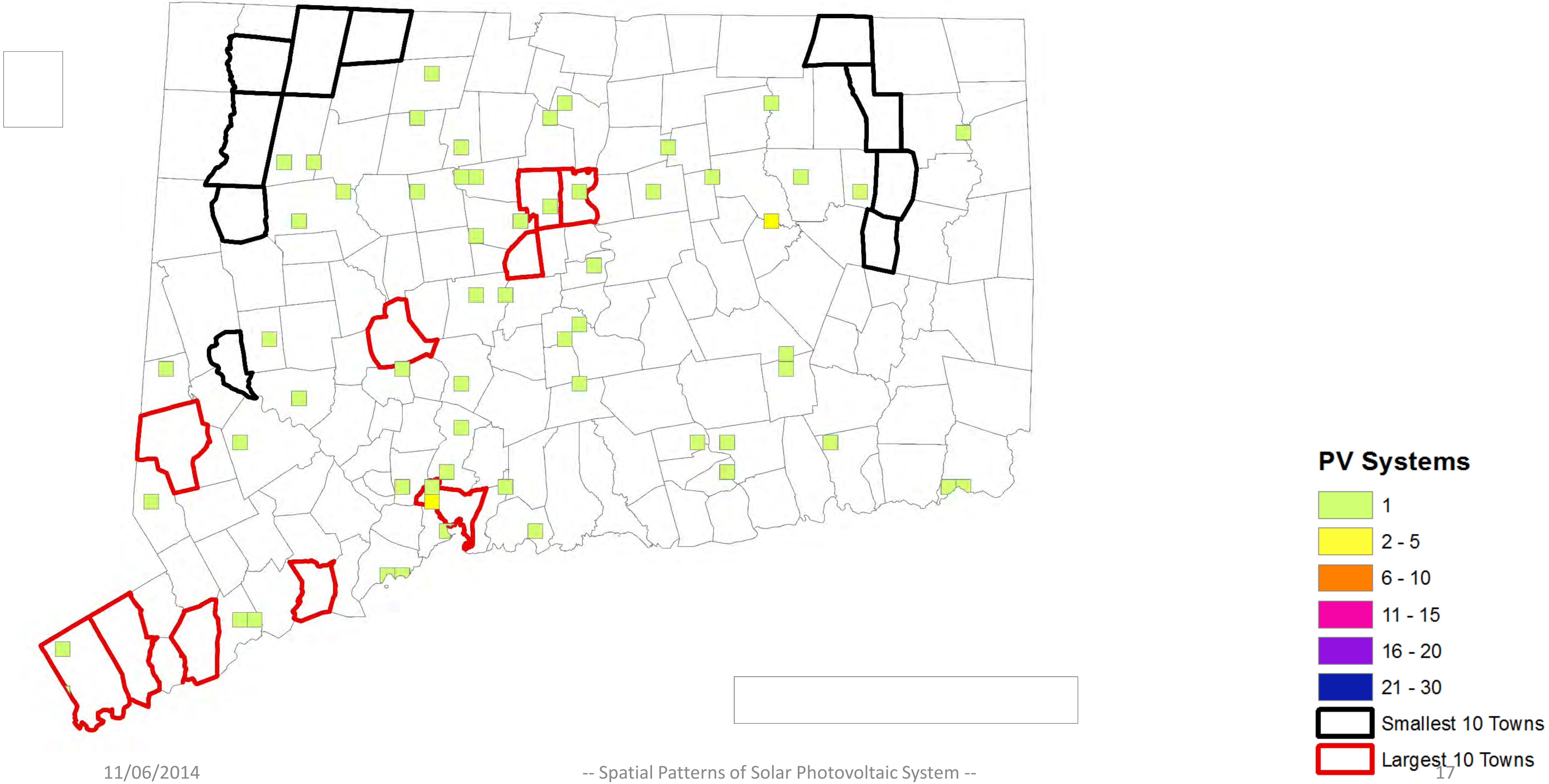
Getis-Ord: Hotspots

1. Larger towns are cold hotspots;
2. Rural areas have higher adoptions;
3. Low adoption follows higher population density; and
4. Income is not a driver.

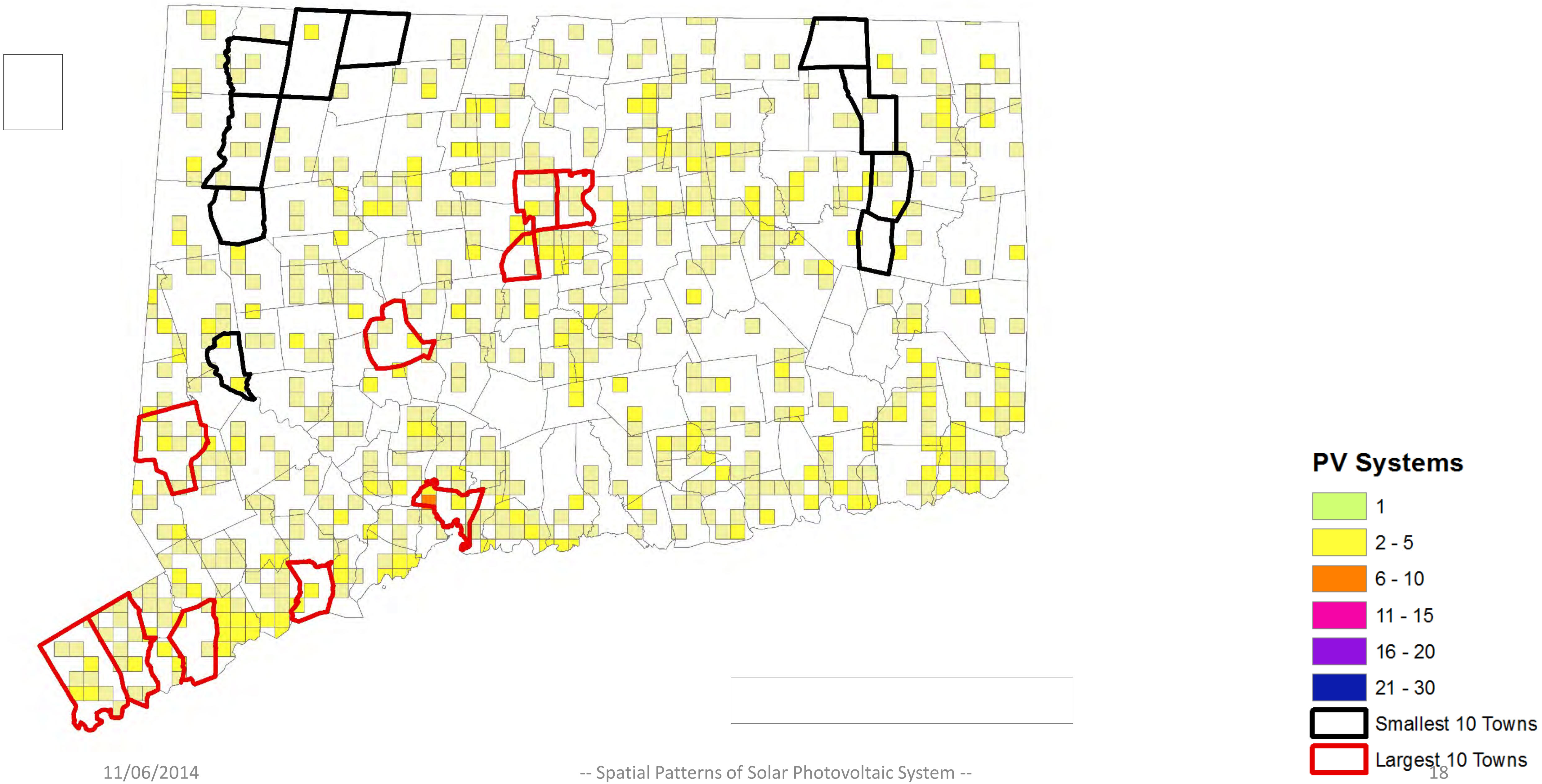
Town Population, 2013



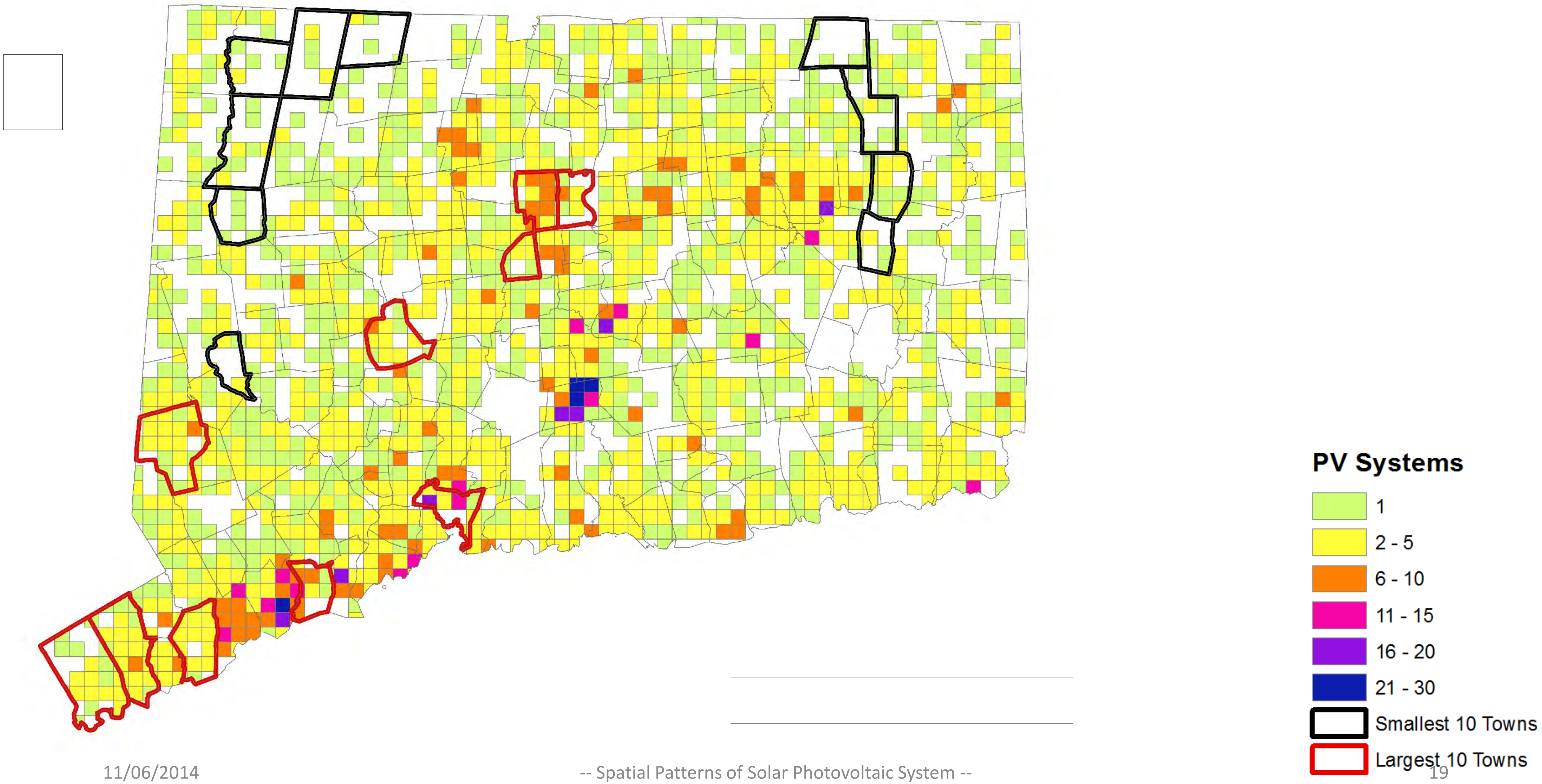
Adoption within 2.25 sq.km, 2005



Adoption within 2.25 sq.km, 2008



Adoption within 2.25 sq.km, 2013



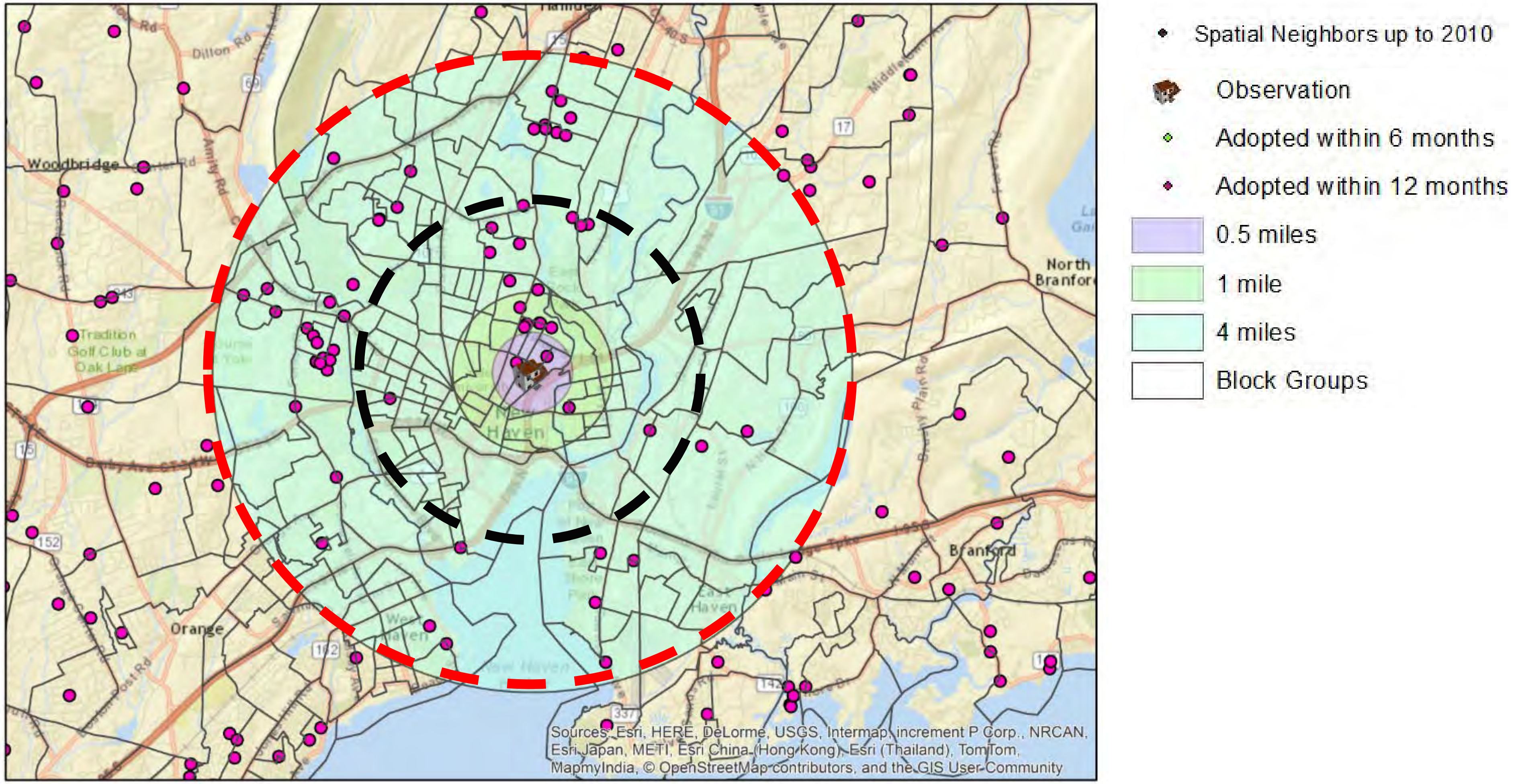
Key Variable: Spatiotemporal Band

Create a variable for the number of neighbors who adopt solar PV within a radius of an adopter

Why this is valuable:
NEIGHBORS
- If aggregate at BG: 0
- Spatial distance: 66

Let's Add time!

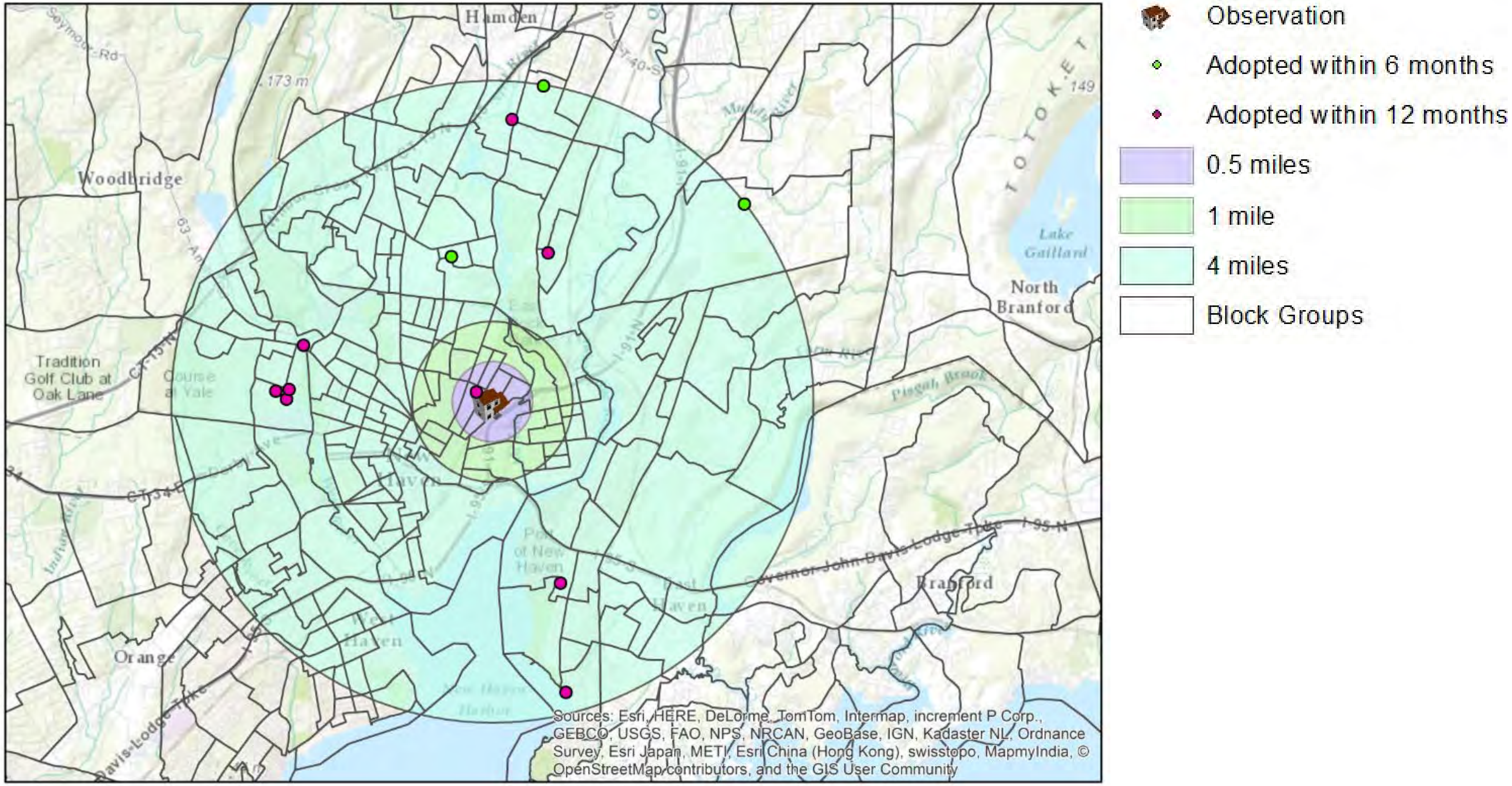
- Exclude simultaneous installs
- Examine installs both 6 or 12 months prior



Spatiotemporal Band

Advantages:

1) Reduces Aerial (i.e., spatial) Error.
2) Eliminates Simultaneity.



Estimation equation

$$PVcount_{i,t} = \alpha + \boldsymbol{N}_{\boldsymbol{i},t}\,\beta + \boldsymbol{B}_{i,t}\,\gamma + \boldsymbol{D}_{i,t}\,\theta + \pi\,S_{i,t} + \mu_i + \phi_t + \varepsilon_{i,t}$$

$PVcount_{i,t}$ is the number of new PV system adoptions in block group i at time t;

$\boldsymbol{N}_{i,t}$ contains the spatiotemporal neighbor variables (separate regressions for 12 mon prior and 24 mon prior);

$\boldsymbol{B}_{i,t}$ contains built environment variables;

$\boldsymbol{D}_{i,t}$ contains socioeconomic, demographic, and political affiliation variables;

$\boldsymbol{S}_{i,t}$ is a dummy variable identifying the presence of SolarizeCT installations in block group i in quarter t;

μ_i are block group fixed effects;

ϕ_t are time dummy variables; and

$\varepsilon_{i,t}$ is a mean-zero error term

Results: Spatial Peer Effects!

Table: *Primary Specifications for Installations in Previous 6 Months*

	Year-Quarter Dummies	BG FE & Year-Quarter Dummies	BG FE & Time trends	BG Year-Semester-FE
Average Neighbors within 0.5 Miles	0.51*** (0.0110)	0.49*** (0.0996)	0.49*** (0.0996)	0.44*** (0.1000)
Average Neighbors 0.5 to 1 Mile	0.38*** (0.0106)	0.38*** (0..0828)	0.038*** (0.0828)	0.39*** (0.0832)
Average Neighbors 1 to 4 Miles	0.11*** (0.0016)	0.11*** (0.227)	0.11*** (0.0227)	0.12*** (0.0224)
R-squared	0.25	0.24	0.24	0.19
Observations	90,090	90,090	90,090	90,090

Notes: Dependent variable is the number of installations in block group (BG) in a year-quarter. An observation is a BG-year-quarter. Standard errors clustered in parentheses. * denotes p<0.10, **p<0.05, and ***p<0.010.

Results: Built Environment & Solarize

Table: *Primary Specifications for Installations in Previous 6 Months*

	Year-Quarter Dummies	BG FE & Year-Quarter Dummies	BG FE & Time trends	BG Year-Semester-FE
Housing Density (0.001s)	-0.0066*** (0.0008)	-0.0091*** (0.0016)	-0.0091*** (0.0016)	0.0014 (0.0097)
% of Renter-occupied Houses	-0.00029*** (0.000)	-0.00045*** (0.0001)	-0.00045*** (0.0001)	-0.0011 (0.0004)
Median Household Income ($10,000)	0.0048** (0.0002)	0.00058 (0.0005)	0.00058 (0.0005)	0.0038 (0.0047)
SolarizeCT	0.80*** (0.0114)	0.77*** (0.1127)	0.77*** (0.1127)	0.87*** (0.2001)
Race Variables	X	X	X	X
Political Affiliation	X	X	X	X

Notes: Dependent variable is the number of installations in block group (BG) in a year-quarter. An observation is a BG-year-quarter. Standard errors clustered in parentheses. * denotes $p<0.10$, ** $p<0.05$, and *** $p<0.010$.

Results: Peer Effects

Table: *Diminishing Neighbor Effects with Time Prior to Installation*

	Block-Group-Year-Semester FE			
	6 Months	12 Months	Since 2005	Installed Base
Average Neighbors within 0.5 Miles	0.44*** (0.1000)	0.22** (0.1048)	0.040** (0.0164)	
Average Neighbors 0.5 to 1 Mile	0.39*** (0.0832)	0.051 (0..0752)	0.023* (0.0136)	
Average Neighbors 1 to 4 Miles	0.12*** (0.0224)	0.081*** (0.0140)	0.031*** (0.0019)	
Installed Base				0.27*** (0.0279)
R-squared	0.19	0.19	0.34	0.34
Observations	90,090	90,090	90,090	90,090

Notes: Dependent variable is the number of installations in block group (BG) in a year-quarter. An observation is a BG-year-quarter. Standard errors clustered in parentheses. * denotes p<0.10, **p<0.05, and ***p<0.010.

Main Findings: Spatial Peer Effects

- ❖ Spatial peer effects lead to more installations.
- ❖ Within 0.5 miles over a 6 month period, 1 more neighbor installing increases adoption by 0.44 PV systems at the block group-level
- ❖ Translates to 26.4 in the average town over a six month period.
- ❖ Effects fade as distance increases but extend to at least 4 miles
- ❖ Effects fade as time passes.
- ❖ The SolarizeCT program greatly increases adoption.
- ❖ These particular estimates are only valid retrospectively (may change in the future).

Main Findings: Built Environment

- Small and medium-sized centers are the engine of diffusion process.
- Housing density and tenure reduce adoption.
- Owner-occupied areas are dominantly where we see adoption.
- The overall influence of tenure and housing type requires further research with more detailed data (only partly available).

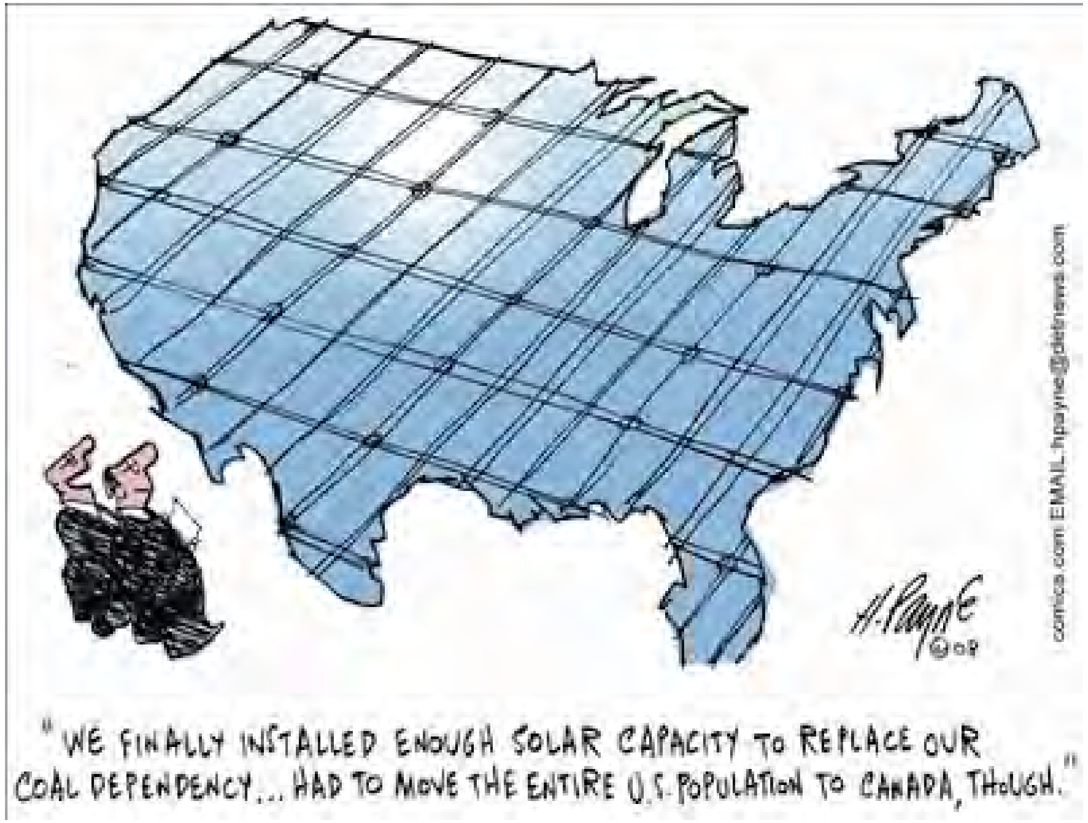
Policy/Marketing Implications

- Efforts to leverage peer effects hold great promise (e.g., SolarizeCT, yard signs, Facebook, etc.)
- Observability or visibility as well as word-of-mouth are likely to be drivers of neighbor effects.
- More work on the policy side is necessary if we hope to see much adoption by rented or multifamily households (e.g., sub-metering).

Policies Moving Forward

- ❖ CT Green Bank is actively looking to expand its programs in low-income/high density areas.
- ❖ CT is considering repealing the ban against smart metering, which may lead to more sub-metering.
- ❖ CT has continued Solarize programs after 2015.

Thank you for your time



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