Solar Installations and Property Values
An Examination of Ground Mounted, Primary Land Use, Two Plus Megawatt Solar Installations on the Total Estimated Market Value of Abutting Residential Parcels

MPP Professional Paper

In Partial Fulfillment of the Master of Public Policy Degree Requirements
The Hubert H. Humphrey School of Public Affairs
The University of Minnesota

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April 29, 2019

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Acknowledgements

This paper is a reflection of research made possible through the patience, generosity, knowledge, skill and sacrifice of many individuals.

1. A grateful acknowledgment is made to University of Minnesota professors Gabe Chan and Dan Milz for guidance and advice throughout the professional paper process.

2. Thank you to Ellen Anderson of the Institute on the Environment and Brian Ross of the Great Plains Institute for conceiving the project and getting it off the ground.

3. Thank you to Allison Hillstrom, Drew Turro, Andrew Butts, and Aaron Hanson for help in structuring the initial research and support throughout the process.

4. For guidance on public sources of utility data the author gratefully acknowledges Lise Trudeau of the Minnesota Department of Commerce.

5. Thank you to Jen Schumacher of 3M for unclouding some of the mysteries of data software.

6. Finally, this project could not have happened without the constant love, encouragement, patience and sacrifice of my wife Corinne. For all the nights and weekends caring for our son without help, for your constant encouragement, love and belief, and for everything you see in me that I cannot see in myself- Thank You.

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Introduction

This paper will examine the relationship of ground mounted, primary land use photovoltaic (PV)solar installations with a nameplate capacity greater than two Megawatts$_{AC}$ on abutting residential land parcels in the seven county Twin Cities Metro Area (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott and Washington Counties) in Minnesota. It will provide a more detailed analysis of the three counties with the largest number of installations (Carver, Dakota and Washington Counties) based on propensity score matching to determine a representative counterfactual control group based on Estimated Market Values at the parcel level determined by county assessors, as well as an example assessor's report on comparable property sales post solar facility installation similar to those employed by local governments and renewable energy developers in Minnesota, Illinois, Indiana and North Carolina.[1] Lastly, a variety of policy drivers will be examined to address the needs of communities and solar installation developers, based on the local effects of the installation in a specific location, community or county.

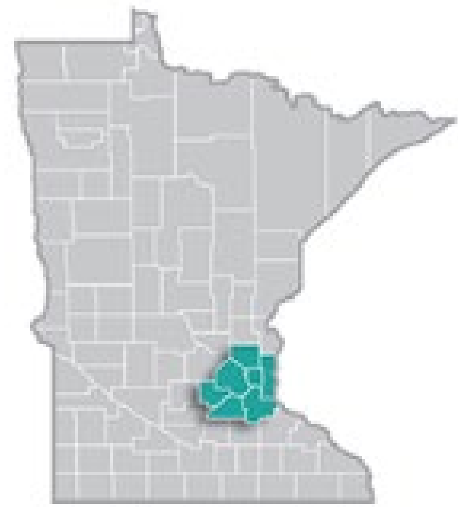

Figure 1. Twin Cities Metro Counties (Minnesota Employment and Economic Development, 2019)

Metro wide, there was no conclusive evidence on solar installations' effect on abutting parcel values. Results from the county level analysis were mixed. Nearly every county in 2018 had a negative dollar coefficient associated with parcels abutting solar installations. However, nearly all of those abutting parcels had negative dollar coefficients in 2014 as well, suggesting solar installation siting on land that was valued below county median prices. After adjusting for inflation, two counties saw marginal increases in the value of parcels abutting solar installations in the time span of the study (2014-2018), while three saw a decrease in the estimated value of abutting parcels with varying degrees of significance and non-significance. Overall, when all the qualifying installations across the Metro area were regressed together, the net effect was an approximate 30% rise (or in this case, less negative) in abutting property values that was statistically significant. In the detailed county analysis panel data from 2014 to 2018 were examined from Carver, Dakota, and Washington Counties. A fixed effects regression model was used on the Estimated Market Value over six determinants of parcel value in a pool with equal numbers of treated and counterfactual parcels. A difference in difference analysis indicated solar installations are nearly always sited on land that is valued less than its not abutting similar neighbors, but the abutment to a solar installation may raise the parcel's value, especially if the installation was built in 2017 or later.

Finally, this paper will make recommendations for further/future research to expand the literature surrounding solar installation impacts on property values in Minnesota and beyond. While there is a rich body of research in the academic literature pertaining to disamenities such as coal-burning power plants[2] and property valuation in proximity to perceived renewable energy

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[1] McGarr, 2018

[2] Blomquist, 1974

disamenities[3], this paper is germane to that literature, given the recent explosion of solar development in Minnesota and elsewhere, and the relative lack of available data surrounding those new solar installations and their relationship with nearby property values.

Area, Time	Change in 2018 Dollars	Significant at 5% Level
Metro, 2014/2018	$14,564	yes
Carver, Dakota, Washington (CDW) 2014/2018	-$3,788	yes
CDW 2014-2018 Panel	$12,837	yes
CDW 2014-2018 Panel Counterfactual	-$18,337	no
Difference in Difference	4,923	yes

Table 1. High Level Findings in Change in Parcel Values

Background

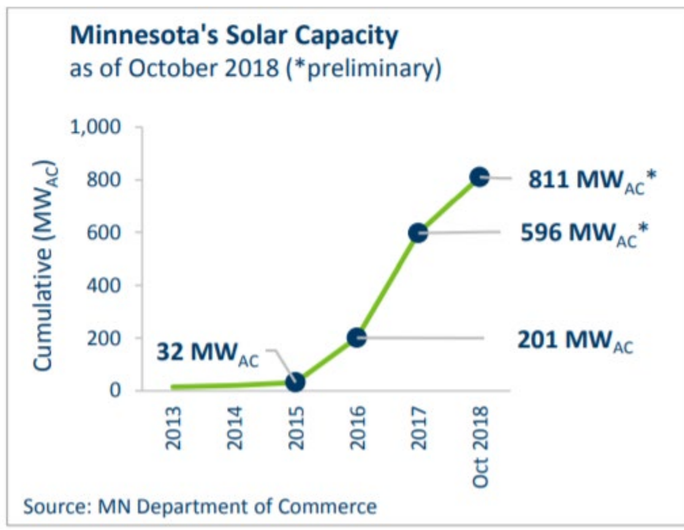

Figure 2. Minnesota's Solar Capacity (Minnesota Department of Commerce, 2018)

Minnesota has been the home of significant change in public policy and business policy in the past decade in the realm of electricity generation and sourcing. In 2013 the state passed legislation requirement that all public utilities have 1.5% of retail electricity sales be generated or procured using solar energy by 2020 and set a goal of procuring 10% of its retail electric sales from solar power by 2030[4]. In 2018, a study commissioned by the Minnesota Department of Commerce found that Minnesota could obtain 70% of its electricity needs with renewables and storage by 2050[5]. Later in 2018 the state's largest Utility, Northern States Power Company, aka, Xcel Energy made a voluntary commitment to have all its electric production be 100% carbon free by 2050[6]. That announcement was followed a few months later with a similar 100% clean energy commitment by one of the state's largest employers 3M[7].

These business and policy goals and commitments have created a market for immense growth in the solar industry. As Figure 2 illustrates, Minnesota went from having 32 MW of solar installed in

[3] Hoen et al., 2013
4 Minnesota Office of Reviser Statutes H.F. 729, 2013
[5] Minnesota Solar Pathways, 2018
[6] Xcel Energy, Your Clean Energy Future, 2018
[7] 3M News Center, 2019

2015 to having 882MW installed by the end of 2018[8,9]. The state ranked 8th in the nation in 2018 for installed solar capacity and the industry employed 4,602 workers at the conclusion of 2018[10]. While solar incentive programs like the state's Made in Minnesota[11] and Xcel's Solar*Rewards[12] have spurred residential solar development, over 90% of the state's solar generation comes from non-residential installations[13]. This generation is comprised of larger utility scale installations like the 100MW Aurora project and smaller community solar gardens (CSGs) that typically have a capacity of less than 10MW. Minnesota has been particularly proficient in the later-installing more CSG capacity in 2017 than the cumulative national CSG capacity in 2016[14].

The massive influx of solar capacity caught many communities by surprise. Many did not have appropriate ordinances and zoning codes in place to balance the interests and expectations of developers and community members. This led, and has continued to lead, to a wide array of styles and methods of installations being built from pollinator friendly, minimal land impact installations, to more industrial, land impacting installations. In recent years, several Minnesota communities and counties have imposed moratoriums on new solar construction[15] to allow the county time to "catch up" and ensure zoning and policy is in place to regulate future installations.

One of the chief concerns of community members is the fear that a new solar installation will be a visual disamenity, and thus reduce the value (and consequently resale potential) of their property[16] . Peer reviewed studies on other kinds of renewable energy generation sources like wind turbines have suggested there is no statistically significant negative impact on nearby property values[17], but there is no peer reviewed literature on solar installations, again, owing to it being a recent phenomenon and lacking mature property data. Much of the literature existing today stems from quantitative data from realtors and surveys of real estate professionals[18]. The results of the data analysis in this paper aim to be a stepping stone to greater clarity in the area of quantifiable parcel level valuation in relation to solar installations.

Existing Literature

Any instance of determining whether a phenomena has an impact on property values delves into the realm of amenities and disamenities. Amenities, or "goods" increase the value of nearby property while disamenities or "bads" devalue properties close by. In this instance the primary phenomena is the building of a solar generation facility, but other phenomena like the presence of transmission lines and green spaces also will impact how large scale solar installations affect estimated property values.

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8 Solar Energy Industry Association, 2019
9 Minnesota Department of Commerce, Solar Industry, 2019
10 Ibid 8
11 Minnesota Department of Commerce, Made in Minnesota 2019
12 Xcel Solar*Rewards, 2019
13 Minnesota Department of Commerce, Minnesota Renewable Energy Update 2018
14 ibid
15 Wright County, 2016
16 Nelson, 2017
17 Hoen, 2015
18 Rai. et al. 2018

Power Generation

In 1974 Glen Bloomquist authored "The Effect of Electric Utility Power Plant Location on Area Property Value," writing "It is found that in a residential community even a relatively small, clean power plant causes measurable damage [to property values] over two miles away." It found that property within 2.2 miles of a coal fired power plant loses 0.9% of its value for each 10% move closer to the plant. Bloomquist used a hedonic regression model, taking into account characteristics of the properties and structures on them, as well as demographic information. Bloomquist's results were roughly replicated 36 years later by Lucas Davis in the paper "The Effect of Power Plants on Local Housing Values and Rents" where using census tract level data he determined "Compared to neighborhoods with similar housing and demographic characteristics, neighborhoods within two miles of plants experienced 3-7 percent decreases in housing values and rents with some evidence of larger decreases within one mile and for large capacity plants".

Both of the prior studies examined coal fired power plants. Between 2010 and 2016 Ben Hoen of Lawrence Berkeley National Labs wrote a series of papers on his findings that proximity to onshore wind turbines finding "we find no statistical evidence that home values near turbines were affected in the post-construction or post-announcement/pre-construction periods. Previous research on potentially analogous disamenities (eg, high-voltage transmission lines, roads) suggests that the property-value effect of wind turbines is likely to be small…". The last line brings up an important caveats which will be discussed later, generation infrastructure is located near transmission lines which are a disamenity in and of themselves.

Transmission Lines

The existing literature is a bit more varied on the impact of transmission lines on property values, but the common theme is that transmission lines generally have a negative effect property values. In his 2012 paper "High Voltage Transmission Lines and Montana Real Estate Values" James Chalmers determines that the effects of power lines in Montana follow the same trends as they do on the eastern seaboard, namely "…the more heavily oriented the property to residential use, the more vulnerable it is to transmission line impact. Properties oriented more toward recreational use are much less vulnerable and properties in pure agricultural use generally show no price effects from the transmission lines whatsoever." This assertion is in line with the findings of Ted Tatos who, in 2016 found "…negative effects that differ by type of transmission line, and as in previous research, the effects diminish with distance. As with some previous research, the results also show some evidence of modest positive effects associated with proximity to large transmission lines, which may be related to greenways constructed beneath such lines." This creation of greenways and open spaces will be explored further in the discussion section.

Data

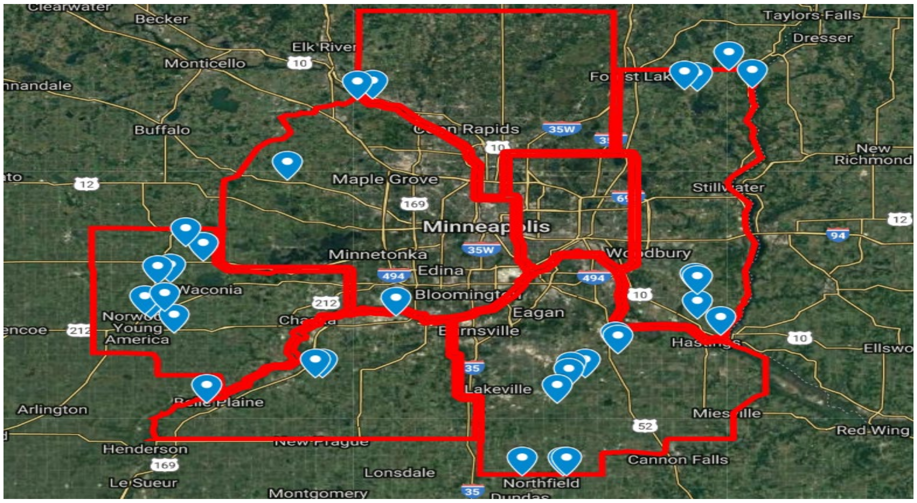

Figure 3. Two+ MW_{AC} Solar Installations in Twin Cities Metro Area

Data for this analysis were obtained through the Minnesota Geospatial Commons[19,20]. Parcel level data was obtained and analyzed using GIS software ArcMap 10.5.1 and Stata 15SE. Locational and interconnection data on the solar installations were obtained via several sources. The first is the Minnesota eDocket filing system, which is a receptacle for, among other things, all formal documentation of activities, plans and comments of the utilities throughout Minnesota. Dockets used in this research included: 13-867 (Community Solar Gardens Program), which included Xcel's end of year reports[21], and 18-59 and 19-38 (Certification for Qualifying Facility Status- Federal Form 556). Latitude and Longitude coordinates as well as physical addressed gleaned from the reports in all three dockets were confirmed with publicly available aerial imagery. Locational data were also obtained from working files from the University of Minnesota's Institute on the Environment Energy Transition Lab Solar Pollinators research team. Finally, interconnection data were also obtained from the Energy Information Administration (EIA) Electric Power Monthly report on Utility Scale generating Units[22] .

Table 1 provides a summary of 32 solar installations in the seven county Metro area where data was obtainable and Figure 3 shows the special distribution of the installations across the Metro Counties. It should be noted that public information on solar installations has become much more readily available in the past two years, coinciding with the dramatic increase in number of facilities installed. Table 1 reflects data as of approximately December 2018. There have been more installations in the Metro since then, and there may be installations that fit the study criteria that have not been taken into account.

Installation Name	Plant ID Number	Interconnection Date	Capacity (MW_{AC})	County
Connexus	62061	10.2018	3.3	Anoka

[19] Minnesota Geospatial Commons, 2019

[20] MetroGIS Regional Parcel Dataset Attribute Detailed Descriptions, 2018

[21] Xcel, 2017 Annual Report

[22] EIA, 2019 Utility Scale Generating Units

Benton	60695	12.2016	5	Carver
Gladden	61495	3.2018	3	Carver
Hwy 7	60488	2.2017	4.9	Carver
Lind	60966	8.2018	4	Carver
MSC-Carver-Kreye	60958	12.2017	5	Carver
Nesvold	60958	1.2018	3	Carver
Porter Way	61500	3.2018	5	Carver
West Waconia	60534	6.2017	9.7	Carver
330th Street West	61478	1.2018	4.95	Dakota
Empire	60631	12.2016	7	Dakota
Equuleus	61363	8.2017	5	Dakota
Farmington	60832	2.2017	5	Dakota
Feely	61478	7.2018	5	Dakota
Northfield	60717	12.2016	4.95	Dakota
Rosemont	60714	12.2016	5	Dakota
Ursa	60712	1.2017	4.5	Dakota
Waterford	61452	11.2017	2.7	Dakota
Corcoran Kaat	61453	11.2017	5	Hennepin
Gibbon	62010	9.2018	3.3	Hennepin
Blue Lake	60632	12.2016	3.9	Scott
Country Trail South	61521	12.2017	4.5	Scott
Pueblo	61522	12.2017	3	Scott
South Street West	61509	3.2018	4.95	Scott
Argo Navis	61183	4.2018	3	Washington
Cottage Gove CSG1	61483	4.2018	5	Washington
Cottage Grove DG	61983	10.2018	4.875	Washington
Forest Lake	60837	7.2017	5	Washington
Hastings	60525	5.2017	5	Washington
McHattie	61545	2.2018	4	Washington
Scandia	61585	7.2018	2.3	Washington
Scandia Trail	61585	1.2018	5	Washington

Table 1. Twin Cities Metro Solar Installations

Methodology and Definitions

As stated previously, the data examined here pertain to ground mounted, primary land use photovoltaic (PV) solar installations larger than $2MW_{AC.}$

Ground mounted: Solar panel system affixed to racking or posts inserted into the ground or ballasted (affixed to weights) on top of the ground. Excludes all rooftop solar.

Primary Land Use: Land at solar installation's main use is housing solar panels. Excludes mixed use facilities that combine solar land use with agriculture or animal husbandry. Does not exclude installations planted with pollinator friendly habitat.

Photovoltaic array: "An interconnected system of PV modules that function as a single electricity-producing unit. The modules are assembled as a discrete structure, with common support or mounting. In smaller systems, an array can consist of a single module[23]. "

$2MW_{AC}$: There is some dispute over what constitutes "utility scale solar". The EIA defines it as anything over $1MW_{AC}$[24]. However, the National Renewable Energy Lab refer to utility solar as $5MW_{AC}$ or greater[25]. In an effort to compromise, but still capture a reasonable amount of data, this paper settled on $2MW_{AC}$, given that is the projected average size of all community solar installations to come online between 2016 and 2020[26].

Estimated Market Value and Metro County/Minnesota Assessors: The baseline unit of measurement in this study the Total Estimated Market Value (EMV) of a parcel. The total EMV is a combination of the assessed value of the land and the assessed value of the structure(s) on the land. The determination of these values is mandated and governed by Minnesota Statute 272.03, where market value is "the usual selling price . . . at the time of assessment." Defined further, it is "the price that could be obtained at a private sale or an auction sale, if the assessor determines that the price from an auction sale represents an arms-length transaction. The price obtained at a forced sale shall not be considered[27]." Appraiser, working for county assessment departments are obligated to determine "the value and classification of real estate be established as of January 2 each year[28]." A physical examination of the property is required every five years where the appraiser gathers physical information on the characteristics of the property and structures[29]. The Minnesota's State Board of Equalization requires its appraisers to deliver "the overall level of assessment to be between 90% and 105% of market value" in order to retain licensure[30]. This last requirement gives the county level assessor data derived from the Minnesota Geospatial Commons its credibility as an adequate substitute for actual sales data.

[23] Department of Energy, 2019 Solar Energy Glossary
[24] EIA, 2019 Most U.S. utility-scale solar photovoltaic power plants are 5 megawatts or smaller

[25] Mendelsohn, 2012 Utility-Scale Concentrating Solar Power and Photovoltaics Projects: A Technology and Market Overview
[26] Ibid 24
[27] Minnesota Office of Revisor, 2018
[28] Carver County, 2019
[29] Ibid
[30] Ibid

Initially, parcel data were collected on 32 solar installations and 335 parcels directly abutting those installations across the seven Twin Cities Metro Counties. The Metro counties area was selected as the area of analysis for two primary reasons.

1) *Data Availability*. The geospatial commons is an aggregator of input from county level GIS professionals. As of December 2016, 20 Minnesota counties had made their GIS parcel data free and open in the commons[31], including all seven metro counties (Figure 4). This represented a large, continuous block of data.
2) *Customers*. The seven county Metro house roughly 3.1 million of Minnesota's 5.6 million residents[32]. It is also the bulk of Xcel Energy's service territory, which currently administers the Minnesota Community Solar Program. Community Solar Gardens (CSGs) make up the majority of solar installations in Minnesota and the program currently stipulates subscribers must be in the same county as a CSG or in a contiguous county[33]. Thus, the Metro area has the most people in areas where there is significant solar development in residential/rural interface with detailed reporting.

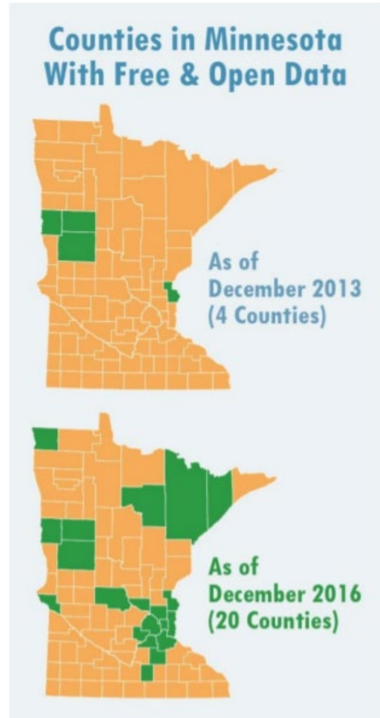

Figure 4 Minnesota Counties with Free and Open GIS Data (Minnesota Geospatial Advisory Council, 2016)

Exclusions

Ramsey County was not a part of the analysis, given it does not currently house any solar installations that meet the 2+ MW_{AC} ground mounted, primary land use installations. Anoka, Hennepin, and Scott Counties were excluded from detailed analysis due to either a lack of abutting residential parcels (Anoka) or non-standard coding in the geospatial commons, leading to a higher level of interpretation and extrapolation, thus less replicable modeling.

Initially, median values of each county were determined for every year from 2014 to 2018 and charted against the median abutting parcel value of each solar installation in their respective counties. The medians were taken of parcels that were assigned a value in the geospatial commons, excluding parcels that were given a value of 0- primarily state owned land, DOT right of way and businesses receiving tax incentives. The objective of the analysis was to determine the effect on residential properties.

Endogenous Siting

The siting of solar installations did not occur randomly. Developers select sites based on a myriad of factors including access to interconnection infrastructure, proximity to existing load, shading levels, condition of land, and ultimately, the ability to secure the appropriate permitting from applicable governing bodies. All of these factors lead to solar installations landing in locations

[31] Minnesota Geospatial Advisory Council Outreach Committee, 2017
[32] Minnesota Department of Administration, 2018
[33] Minnesota Department of Commerce, 2019, Tips About Community Solar

that share a common set of characteristics. These characteristics of the independent variables will be correlated to the error term of the regression model which leads to less accurate coefficients on the independent variables. To combat this a variety of models and lenses are used to manipulate the data into clearer pictures.

First, this study tracks the changes of median tract prices over time across the entire metro. This acts a baseline quality control test. By incorporating the weight of all the data points across the Metro area a general trend is generated with which to compare more sensitive models.

Second, models using fixed effects are employed in the concentrated (Carver, Dakota, Washington) observations. By utilizing fixed effects modeling the effects of the characteristics that do not change over time are controlled, reducing their final impact on the dependent variables.

Finally, a counterfactual pool of observations was assembled using propensity score matching. This has the power to suggest what would have occurred in a similar space if an installation had not been built. While none of these methods or models cure every ill of endogeneity, but by combining the partial images that each one of these approaches offers, a clearer picture begins to emerge around the relationship between solar installations and the land that abuts them.

Process

The high potential for confounding variables in real estate can make it difficult to measure the impact on a specific set of properties, including residential properties. In an effort to make appropriate comparisons the data were cleaned to remove all parcels that were not homesteaded or had no finished square footage on the parcel. This ensures cases of single family homes that dominate the style of structure abutting solar installations are not being compared to commercial/industrial parcels or large multi-unit dwellings like apartment complexes. This process resulted in the exclusion of the only installation in Anoka County, and a significant number of the abutting parcels in Scott County. The remaining abutting properties were then regressed on the rest of the parcels in the county under the following model:

$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + i.\beta_5 x_5 + i.t + \varepsilon$ where:

Y= Estimated Market Value

$\beta_0 = constant$

$x_k = independent\ variable$

x_1= *finished square feet*

x_2=*acres of parcel*

x=*number of stories of structure*

x_4= *age of structure*

i.x_5= *dummy variable for presence of garage*

$i.t$= *dummy variable for treatment (in this case abutment to solar installation)*[34]

ε = error term

[34] MetroGIS Regional Parcel Dataset Attribute Detailed Descriptions, 2018

Regressions were run on data from 2018 and compared against regressions run on 2014 data. The year 2014 was chosen to determine a baseline, as nearly all Metro solar installations were built between 2016 and 2018, thus avoiding phenomena described in literature where land prices are depressed in the period of time after the announcement of a building and its completion[35] . In 2014, the coefficients on the determinant indicating a parcel was abutting the future site of a solar installation were predominantly negative, indicating widespread siting on land that was valued less than parcel not abutting the future site. This provided a baseline of parcel value as well as the determinants of estimated market value on parcels, including abutting's effect, but no control group. To achieve that end, a detailed analysis of the three counties with the largest number of solar installations was done in Carver, Dakota and Washington Counties. Ramsey County had no installations, Anoka County had one, with no abutting residential properties, Hennepin County had two installations that were dropped from the detailed analysis due to data processing limitations and Scott County had four installations, two of which had no abutting residential properties and the other two having fewer than 10 combined residential properties.

In creating a counterfactual, propensity score matching was utilized to build a pool control data that mimicked the treated parcels (ones abutting solar arrays) as closely as possible. Peter C. Austin describes propensity scores as:

> *"The probability of treatment assignment conditional on observed baseline characteristics. The propensity score allows one to design and analyze an observational (nonrandomized) study so that it mimics some of the particular characteristics of a randomized controlled trial. In particular, the propensity score is a balancing score: conditional on the propensity score, the distribution of observed baseline covariates will be similar between treated and untreated subjects"*[36]

Data from 2018 in the three detailed counties were analyzed on a county by county basis using *teffects* propensity score modeling[37] to select non-abutting parcels in the respective counties that were the closest match to the abutting parcels in based on the variables described above.

Matched parcels were selected based on propensity scores' similarity to treated parcels and the parcel's 2018 value was compared against its 2014 (adjusted for 2018 dollar) value. Medians were then derived from the control groups and the abutting groups and a difference in difference was obtained for each county's data.

The weakness of this approach was reducing pools of hundreds of thousands of data points down into a sample of dozens or hundreds greatly magnifies the standard errors, especially given several of the independent variables are applicable to a large swath of the data points (i.e. the vast majority of the observations have a garage on the parcel. This reduces the power of the propensity score to create a model that mirrors the treatment group.

While useful, there was no spatial element to the data, and real estate analysis generally has a special element, especially when deriving comparable properties, to account for neighborhood and geographic impacts. To address this gap in the analysis, a parcel comparison of sale data post construction of the solar installation was completed. Given the lack of data in the literature, up to now

[35] Ibid 17
[36] Austin, 2011
[37] Social Science Computing Cooperative, 2015

this has been a preferred method for data gathering and presentation on solar impacts on property values[38,39].

County Analysis

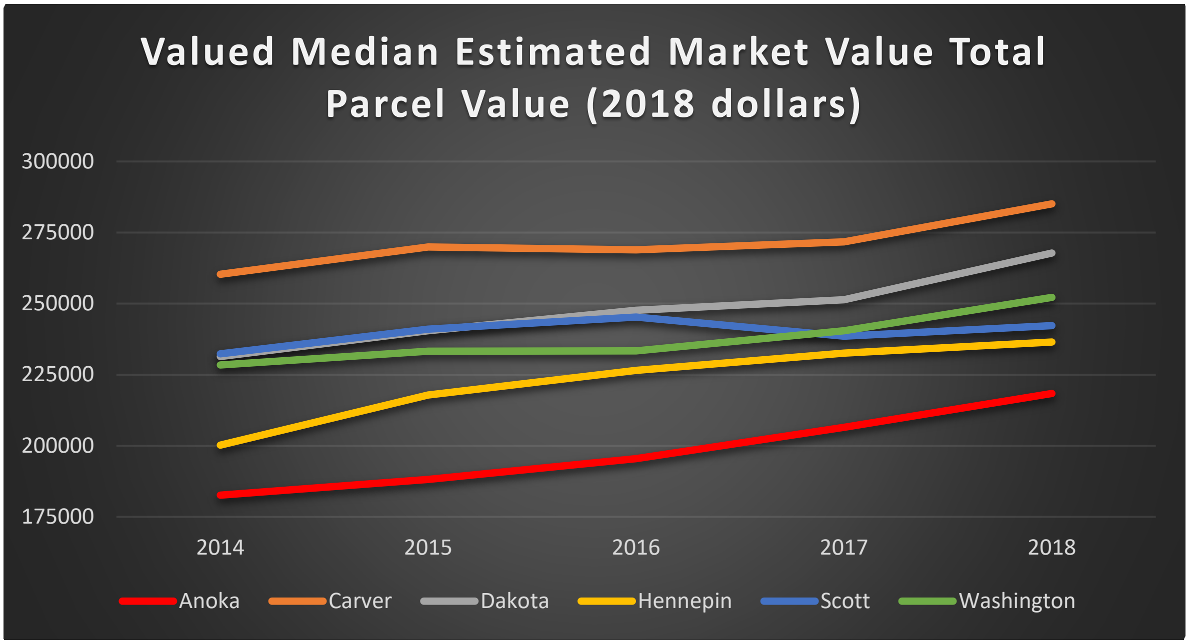

Figure 5. Median Value of Parcels by County in Metro Area

The first step in the analysis was to evaluate the changes in estimated market value of parcels at the county level over time. 2014 was selected as a baseline year because the earliest solar installation in this study was built in 2016. By starting in 2014, parcel values could be examined across all counties free from any impact that new construction or the announcement of new construction of solar installations would bring. Figure 5 depicts the median parcel value of all valued parcels in the six counties of analysis. After adjusting for inflation, the general trend is an increase in estimated market value at the parcel level across all counties. Figures 6-11 depict the median parcel value abutting each solar installation in a given county from2014-2018 compared to the county median estimated parcel value. The yellow dot demarcates the assumed announcement date of construction, in this case, one calendar year prior to the interconnection date. In some instances the announcement date was earlier, but data were not available for all installations. The number in parenthesis is the number of parcels abutting each installation from which the median value was derived.

[38] Ibid 1
[39] Kirkland, 2018

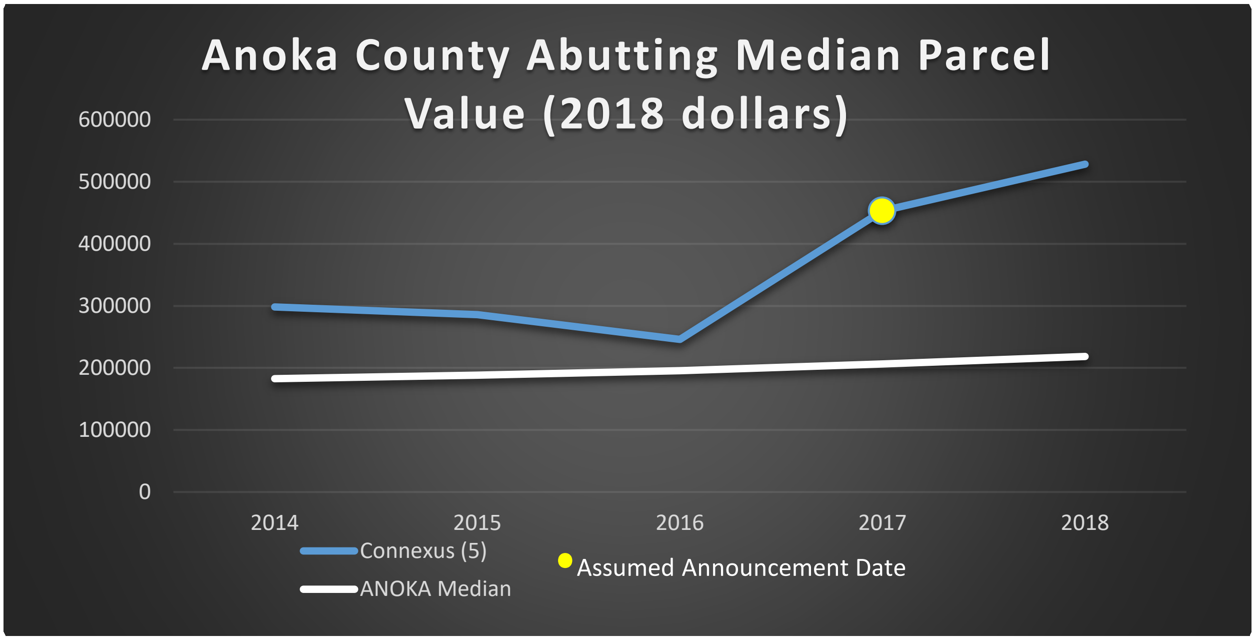

Figure 6. Anoka County Median Parcel Value vs. Solar Installation Abutting Median Value. Number of abutting parcels in parenthesis.

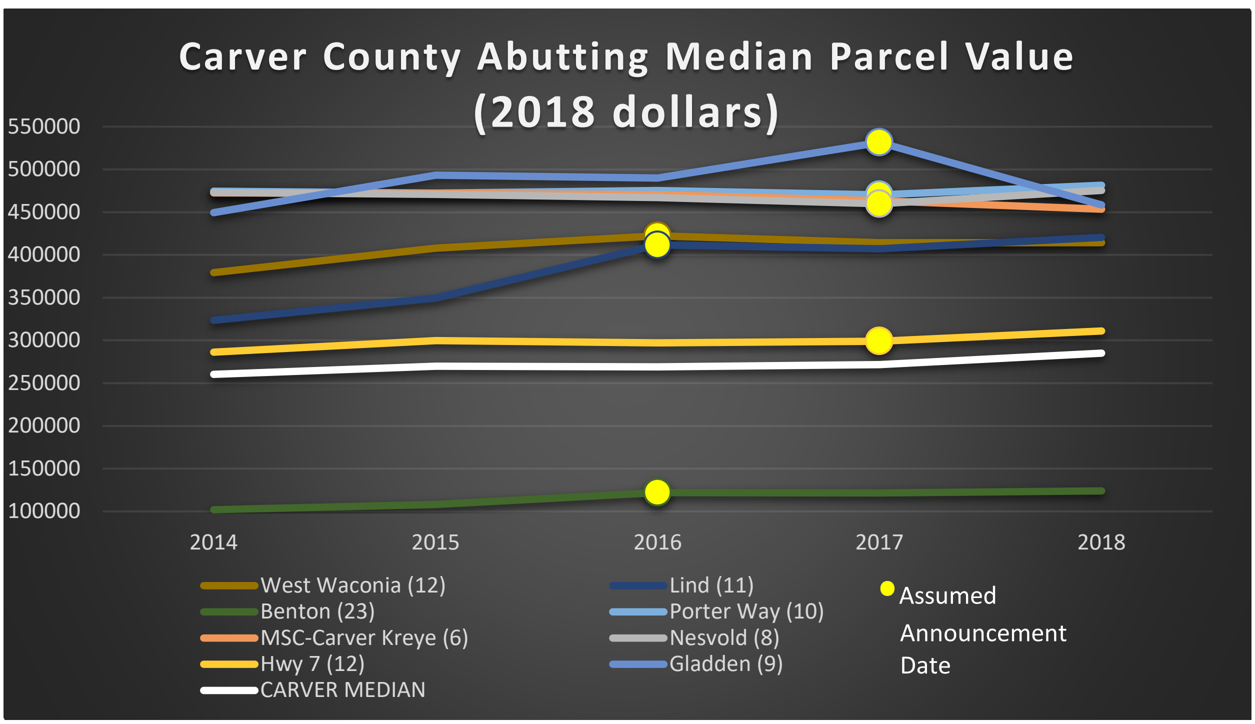

Figure 7. Carver County Median Parcel Value vs. Solar Installation Abutting Median Value. Number of abutting parcels in parenthesis.

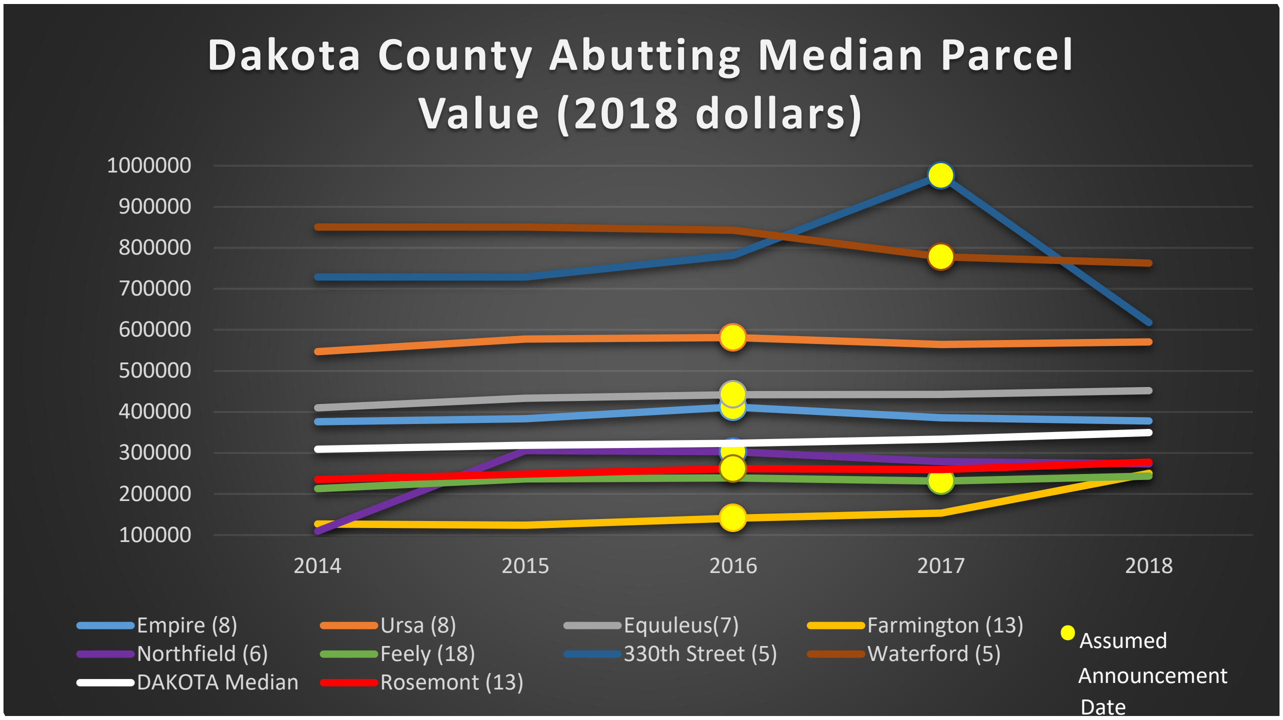

Figure 8. Dakota County Median Parcel Value vs. Solar Installation Abutting Median Value. Number of abutting parcels in parenthesis.

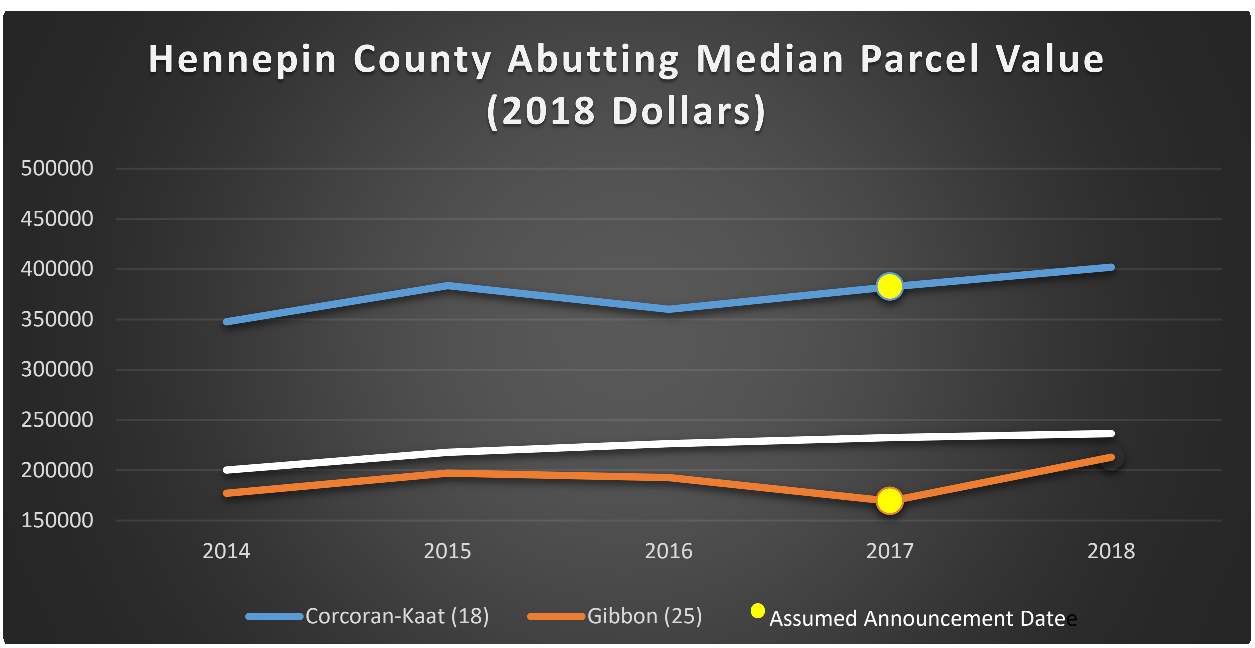

Figure 9. Hennepin County Median Parcel Value vs. Solar Installation Abutting Median Value. Number of abutting parcels in parenthesis.

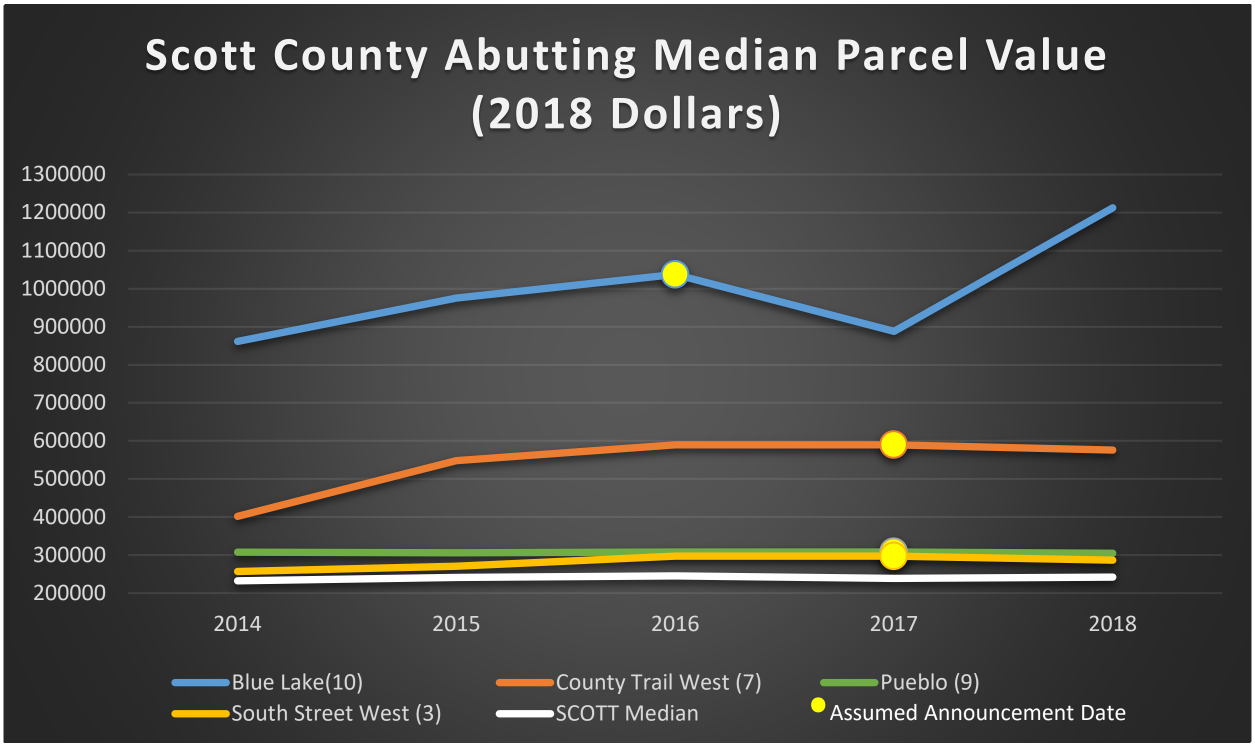

Figure 10. Scott County Median Parcel Value vs. Solar Installation Abutting Median Value. Number of abutting parcels in parenthesis.

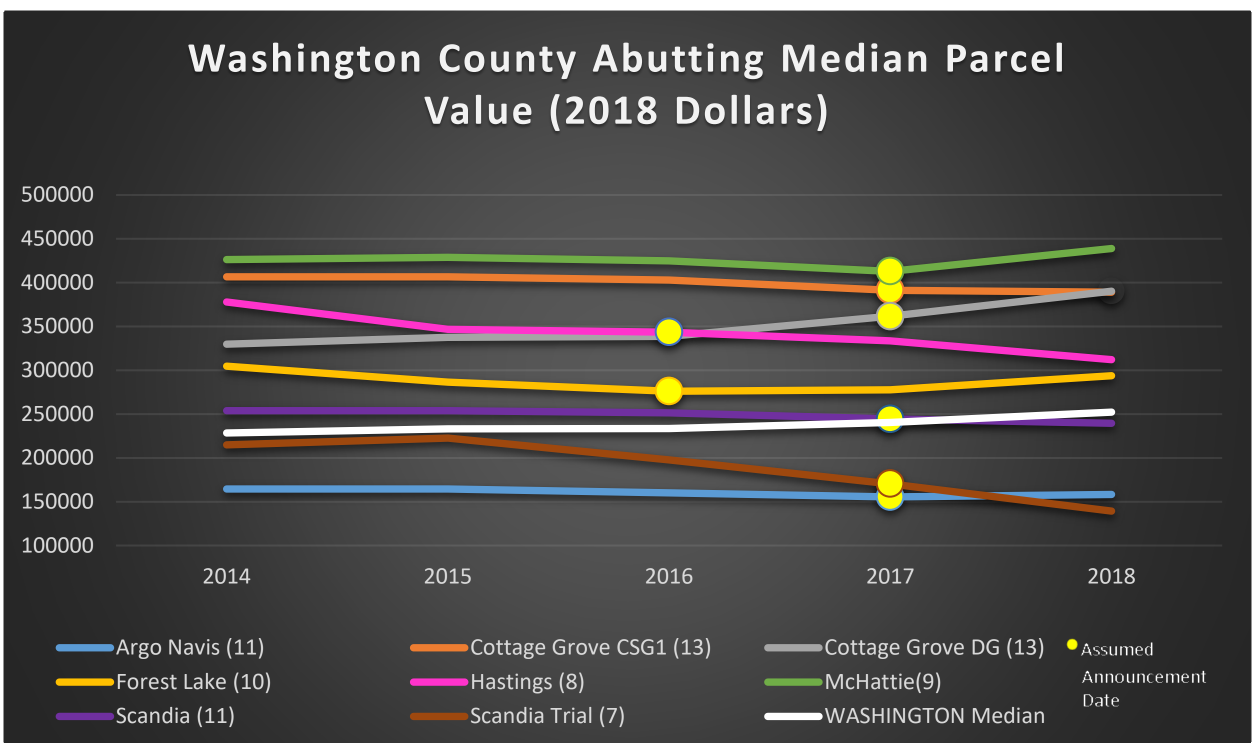

Figure 11. Washington County Median Parcel Value vs. Solar Installation Abutting Median Value. Number of abutting parcels in parenthesis.

Again, this first examination of the data includes all abutting parcels and all valued parcels in a given county. An initial examination of the graphs would indicate that the median county parcel value is lower than the majority of median values of solar installations. However, this number is skewed by the rural nature of the sites. A number of abutting parcels are large and designated for primarily agricultural use (fields). The sheer volume of acreage lifts the value of the parcel above the median value of a given county parcel. Installations that have a high number of residential parcel abutting them such as Farmington, Rosemont and Feely in Dakota County, Benton in Carver County and Gibbon in Hennepin have markedly lower median parcel values than the county medians. This was illustrated in the second step of analysis when the estimated total value of residential properties were regressed on a series of value indicator variables in 2014 and again in 2018.

The second step of the county analysis was to compare the residential parcels in the baseline year of 2014 to the residential parcels in 2018 after all installations had been built. The regression described in the previous section was applied to 2014 and 2018 for a rough before and after image. The coefficient "abut" acted as a spatial placeholder for 2014, demarcating the parcels that would have abutted the solar installation had it been built. Regressions were run for each individual county (Table 3) and then aggregated to for a metro wide analysis (Table 2). (Note Anoka County was omitted, given its only solar installation had no residential parcels).

Metro Area

VARIABLES	2014	2018
Finished Sq. Ft.	139.4***	129.3***
	(0.352)	(0.165)
Parcel Acres	7,229***	7,238***
	(34.24)	(21.08)
Structure Stories	27,966***	-14.70***
	(574.4)	(0.171)
Age of Structure	92.64***	-127.9***
	(11.21)	(1.788)
Garage Present	47,812***	17,997***
	(1,070)	(509.6)
Abutting	**-41,062*** **	**-26,498*** **
	(12,007)	**(6,240)**
Constant	-66,888***	25,697***
	(1,551)	(576.6)
Observations	368,054	402,814
R-squared	0.441	0.843

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2. Descriptors of the Twin Cities Metro Area Homesteaded Parcels with Finished Square Feet 2014 vs. 2018

Framed another way, Table 3 displays the 2018 results while controlling for the estimated market value in 2014:

VARIABLES	Total Estimated Market Value
Abutting	-20,042***
	(4,820)
Estimated Market Value in 2014	0.424***
	(0.000783)
Finished Square Feet	51.95***
	(0.185)
Parcel Acres	4,121***
	(16.81)
Stories	-72.81***
	(0.175)
Age	-582.4***
	(1.638)
Garage	15,301***
	(414.8)
Constant	91,368***
	(477.9)
Observations	344,947
R-squared	0.917

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: 2018 Parcel Values Controlling for 2014 Prices

	Anoka 2014	Anoka 2018	Carver 2014	Carver 2018	Dakota 2014	Dakota 2018	Hennepin 2014	Hennepin 2018	Scott 2014	Scott 2018	Washington 2014	Washington 2018
Variables												
Finished Sq. Ft.	N/A	N/A	191.6***	208.1***	113.7***	114.4***	320.9***	288.1***	141.8***	116.3***	180.0***	172.8***
	N/A	N/A	(1.380)	(1.447)	(0.245)	(0.241)	(0.920)	(0.848)	(1.345)	(0.767)	(0.595)	(0.545)
Parcel Acres	N/A	N/A	6,204***	5,824***	7,274***	6,839***	-629.2***	-114.9	8,974***	8,503***	9,917***	9,375***
	N/A	N/A	(53.38)	(63.68)	(28.74)	(30.34)	(125.5)	(124.8)	(77.48)	(68.67)	(61.71)	(59.84)
Structure Stories	N/A	N/A	-80,280***	-106,997***	2,048***	-13,233***	-83,914***	-66,201***	46,317***	-21,109***	-74,442***	-77,826***
	N/A	N/A	(2,135)	(2,554)	(509.6)	(500.2)	(1,093)	(1,249)	(1,769)	(1,727)	(992.9)	(922.6)
Age of Structure	N/A	N/A	-584.3***	-758.5***	-415.6***	-327.7***	588.2***	367.0***	-891.9***	-341.8***	-375.6***	-407.4***
	N/A	N/A	(32.93)	(37.22)	(13.07)	(9.045)	(22.73)	(15.63)	(33.95)	(38.12)	(14.51)	(13.70)
Garage Present	N/A	N/A	50,195***	12,081***	-18,475***	16,227***	10,013**	27,342***	41,594***	7,516***	27,445***	29,257***
	N/A	N/A	(5,094)	(4,121)	(811.8)	(712.2)	(4,517)	(2,430)	(3,723)	(2,552)	(1,294)	(1,261)
Abutting Installation	**N/A**	**N/A**	**-18,841**	**-68,365*** **	**19,443***	**-2,610**	**-25,940**	**-10,502**	**-85,404*** **	**-102,001*** **	**-91,429*** **	**-82,042*** **
	N/A	N/A	(20,852)	(21,409)	(10,765)	(10,505)	(35,078)	(36,192)	(36,473)	(38,307)	(17,213)	(16,775)
Constant	N/A	N/A	56,378***	130,098***	28,565***	49,308***	-133,971***	-83,866***	-4,594	43,532***	78,325***	113,122***
	N/A	N/A	(6,368)	(5,672)	(1,444)	(1,165)	(4,965)	(2,869)	(5,031)	(4,654)	(2,028)	(1,905)
	N/A	N/A										
N	N/A	N/A	26,803	27,562	103,209	105,167	130,105	155,384	36,263	40,032	71,615	74,669
R-squared	N/A	N/A	0.584	0.556	0.780	0.781	0.579	0.531	0.456	0.529	0.674	0.682

Table 4. County Level Regressor Coefficients on Total Estimated Market Value- 2014 and 2018.

High Level County Discussion

An initial examination of the coefficients from both regression yields multiple points for discussion, three of which will be examined in this section. The first being every county and the metro wide analysis yielded a negative coefficient on the parcels that abutted solar installations in 2018. However, nearly all of those counties and the metro as a whole had negative coefficients on those parcels in 2014. Finally, the statistical significance of the "abutting" regressor at the county level is mixed, but on the metro level is statistically significant at the 99% level for 2014 and 2018.

To be most cost effective, solar installations need many things, but two of the most important are close proximity to an interconnection point (access to the electric grid), and close proximity to demand or load for the electricity produced. This means an ideal location for a solar installation is near transmission lines and near people. This could offer some explanation on the negative coefficients on the 2014 parcels. Transmission lines are an established disamenity[40], accounting for property devaluations of up to 45% in places[41]. If the most desirable parcels are the ones near transmission lines, developers will be building solar installations on land that is already sited next to a disamenity and this devalued. Conversely, the development of 10 plus acres of solar panels creates a buffer zone between many parcels and the transmission lines, which may contribute to some of the 2018 coefficients being less negative than 2014, after adjusting for inflation. The instances of 2018 coefficients being more negative than their 2014 counterparts may be due in part to new construction of addition transmission lines.

At the county level, the only counties with statistically significant coefficients on the abutting regressor in both 2014 and 2018 were Scott and Washington, as well as the Metro wide analysis. Scott County's results indicated a roughly $17,000 devaluation in parcel value (with an s.e. of 38,000) while Washington County saw an increase in parcel value of approximately $9,000 (with an s.e. of 16,775). The metro wide analysis illustrated an increase in parcel value of nearly $15,000 (with an s.e. of 6,240). One thing to keep in mind is that Scott and Washington counties had the highest rates of parcel splits and sales between 2014 and 2018 abutting the solar installations. This is significant given the measurement metric is Total Estimated Market Value, which is an aggregate of the estimated market value of the land and the estimated value of all the structures on the land. If a parcel were split in order to sell open space to a developer, but that parcel kept the original parcel ID number, the parcel would only be assessed for the value of the land after the split, losing the value of the structure, resulting in an artificially low new Estimated Market Value outside of any external effect.

Given the lack of consistency one way or the other at the county level, policy drivers will be discussed later on recommended action on solar installations as amenities and disamenities.

[40] Hoen, 2016

[41] Wyman and Mothorpe, 2018

Carver, Dakota, Washington and Panel Analysis

Across the Metro region 32 solar installations were identified for study. Twenty seven of those facilities lay within Carver, Dakota and Washington County. Incidentally, these three counties had the most uniform coding structure within the Geospatial commons. Hennepin and Scott Counties had entries in the database, but many were qualitative as opposed to quantitative (i.e. listing "Rambler" instead of number of stories in a house description). In an effort to maintain representative data while still capturing most of the treated parcels the researcher decided to remove Scott and Hennepin county data from the detailed analysis.

In delving into the detailed analysis, the first step was to get a rough picture of the determinants of parcel value. This was done by regressing the Estimated Market Value of the parcel data from 2014 and 2018 on its descriptors as described in the methodology with the following regression results:

VARIABLES	Carver 2014	Carver 2018	Dakota 2014	Dakota 2018	Washington 2014	Washington 2018
Finished Sq. Ft.	191.6***	208.1***	113.7***	114.4***	180.0***	172.8***
	(1.380)	(1.447)	(0.245)	(0.241)	(0.595)	(0.545)
Parcel Acres	6,204***	5,824***	7,274***	6,839***	9,917***	9,375***
	(53.38)	(63.68)	(28.74)	(30.34)	(61.71)	(59.84)
Structure Stories	-80,280***	-106,997***	2,048***	-13,233***	-74,442***	-77,826***
	(2,135)	(2,554)	(509.6)	(500.2)	(992.9)	(922.6)
Age of Structure	-584.3***	-758.5***	-415.6***	-327.7***	-375.6***	-407.4***
	(32.93)	(37.22)	(13.07)	(9.045)	(14.51)	(13.70)
Garage Present	50,195***	12,081***	-18,475***	16,227***	27,445***	29,257***
	(5,094)	(4,121)	(811.8)	(712.2)	(1,294)	(1,261)
Abutting	**-18,841**	**-68,365*** **	**19,443***	**-2,610**	**-91,429*** **	**-82,042*** **
	(20,852)	**(21,409)**	**(10,765)**	**(10,505)**	**(17,213)**	**(16,775)**
Constant	56,378***	130,098***	28,565***	49,308***	78,325***	113,122***
	(6,368)	(5,672)	(1,444)	(1,165)	(2,028)	(1,905)
Observations	26,803	27,562	103,209	105,167	71,615	74,669
R-squared	0.584	0.556	0.780	0.781	0.674	0.682

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5. Determinants of Estimated Market Value, All Homesteaded Parcels with Finished Square Feet- 2018.

Across all three counties the number of finished square feet, acres in the parcel, and presence of a garage were significant in adding to the estimated parcel value as expected, while each additional year of age of the primary structure on a parcel detracted from its value. The number of stories a structure had had a counterintuitive negative sign across all three counties. Tests for multicoliniarity did not result in rejecting the null hypothesis of no multicoliniarity. Further examination will be required in the first place to determine if there is an error in the model or if split level houses are so undesirable their increased square footage is not enough to offset their appearance. Finally, parcels that abutted solar installations were associated with negative coefficients across the counties, two of which were significant at the 5% level.

Each county had a negative coefficient on “abutting” in 2018 and tow of the three had a negative coefficient in 2014, indicating the abutting properties were estimated to be worth less than their non-abutting counterparts by anywhere from $2,000 to 82,000 dollars. However, only one county’s results (Washington) were statistically significant in both years. The data from Carver and Dakota counties indicate a reduction in parcel value between 2014 and 2018 (after adjusting for inflation), but again, did not have statistically significant findings in one or more of the observation years.

Next, the data from the three counties were combined and regressed on the same model with the following results:

VARIABLES	C,D,W 2014	C,D,W 2018
Abutting Installation	-35,373***	-39,161***
	(9,484)	(9,706)
Finished Square Feet	111.4***	117.2***
	(0.307)	(0.303)
Parcel Acres	7,774***	7,494***
	(27.74)	(29.10)
Stories	-8,307***	-23,394***
	(616.7)	(617.6)
Age	-465.0***	-656.6***
	(11.06)	(10.11)
Garage Present	22,377***	28,471***
	(858.8)	(902.3)
Constant	58,721***	98,941***
	(1,447)	(1,386)
Observations	201,686	207,398
R-squared	0.558	0.567

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.01

Table 6. Coefficients on Carver, Dakota and Washington Counties 2014 vs 2018

In this measurement across three counties the estimated value of the parcel declined a little less than $4,000 over five years. With the mean value of a residential parcel across these three counties determined to $282,000, that decline equates to 1.4% of the parcel value over the time of the study.

In an effort to determine what would have happened to a given set of parcels had a solar installation not been built, a counterfactual group was assembled using propensity scoring as described in the methodology. The same regression was applied to this balanced group of treated (abutting) and control parcels. When broken up county by county the propensity matched coefficients can be described by Table 6 below:

VARIABLES	Carver 2014	Carver 2018	Dakota 2014	Dakota 2018	Washington 2014	Washington 2018
Abutting	**-10,124**	**-3,799**	**-22,167**	**-32,749**	**-19,477**	**-24,068**
	(16,763)	**(23,981)**	**(49,034)**	**(47,413)**	**(23,407)**	**(28,782)**
Finished Square Feet	82.45***	182.4***	4.314	31.07	170.4***	193.7***
	(17.30)	(14.87)	(45.29)	(42.55)	(25.38)	(22.96)
Parcel Acres	5,506***	5,017***	8,481***	8,021***	5,317***	4,804***
	(198.2)	(276.3)	(762.1)	(817.9)	(382.3)	(484.8)
Stories	-15,156	-71,240**	68,064	55,461	-82,640**	-86,449**
	(26,921)	(32,837)	(70,680)	(62,830)	(31,907)	(35,004)
Age	-1,356***	-1,264***	-813.0	-857.0	-1,011***	-831.5**
	(233.8)	(324.2)	(1,062)	(1,053)	(310.8)	(384.8)
Garage Present	202.79	21,030.06	-12,502.43	-10,139.23	52,834.6	16,426
	(26078.25)	(32,288.8)	(73,726.94)	(66,995)	(38,632.54)	(39,087.98)
Constant	202,974***	135,924***	156,559	175,474	174,391***	173,084***
	(33,829)	(43,934)	(130,464)	(136,801)	(52,347)	(63,565)
Observations	112	112	56	56	60	60
R-squared	0.894	0.839	0.739	0.717	0.836	0.784

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6. Determinants of Estimated Market Value, Treated and Counterfactual based on Propensity Score Matching.

In the counterfactual example, Carver County saw its parcel values improve while Dakota and Washington saw declines. However, none of the abutting coefficients were statistically significant at the 5% or even 10% level.

Carver, Dakota and Washington County Panel Data

Up to this point the data have been examined in a before and after fashion. To more closely examine the year on year variation a panel data set was created on parcels with homestead claim and finished square feet on property from 2014 to 2018, again utilizing Carver, Dakota and Washington counties again for reason enumerated above, plus the additional constraint of computer processing ability. The initial data gathering utilized the software Excel which has a maximum of one million rows of data. Five years of county wide parcel observations from Carver, Dakota and Washington tallied over 930,000 observations, making additional years or counties impossible given the constrains of the study.

After assembling five years of parcel data and running a Hausman test for random vs fixed effects appropriateness, a fixed effects model was established. Similar to the models used up to this point, the only wrinkle is the panel model contains an “ever abut” regressor as well as an “abut” regressor. “Ever abut” is a dummy variable noted with a one if a parcel ever abutted a solar installation between 2014 and 2018, 0 if otherwise, while “abut” took on a time component- noted with a one in the year an installation was built and in the years following, o if otherwise. The fixed effects model was run on the data resulting the coefficients illustrated in Table 7 below:

VARIABLES	Fixed Effects	Counterfactual
Ever Abutted	-20,642*	-
	(11,408)	-
Year Abutted	12,837***	-18,337
	(4,934)	(14,653)
Age	-642.1***	-383.6
	(48.63)	(274.6)
Garage Present	22,494***	61,559**
	(1,028)	(29,770)
Finished Square Feet	62.08***	73.54***
	(0.925)	(23.72)
Stories	22,067***	-19,863
	(614.0)	(26,697)
Parcel Acres	4,313***	4,177***
	(135.6)	(263.8)
2015	8,607***	-74,145***
	(178.2)	(11,447)
2016	10,792***	10,278
	(196.6)	(11,954)
2017	18,117***	17,304
	(232.0)	(14,651)
2018	29,321***	30,447*
	(258.5)	(17,319)
Observations	929,705	1,056
R-squared	0.048	0.401
Number of pin	185,941	504

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8. Carver, Dakota and Washington County Parcel data 2014 and 2018

To find the difference in difference, two new variables were created and added to the model. Here in column 1,"post" is a dummy variable, 1 if in the time period after a farm was built, 0 if otherwise, and "treatpost" is 1 if parcel is abutting and post the treatment (farm built) 0 if otherwise. Colum 2 are the coefficient results for the propensity score matched counterfactual group.

	1	2
VARIABLES	Dif in Dif	Counterfactual
Ever Abutted	-28,669**	-48,657
	(11,550)	(79,529)
Year Abutted	12,654***	28,685
	(155.9)	(19,959)
Parcel Treated and Year Abutted	20,841***	5,068
	(4,739)	(21,888)
Parcel Acres	3,977***	4,217***
	(136.1)	(279.0)
Stories	23,316***	-12,102
	(616.1)	(28,213)
Finished Square Feet	68.20***	75.00***
	(0.925)	(25.17)
Garage Present	26,337***	65,547**
	(1,031)	(31,476)
Age	1,119***	-428.7
	(41.94)	(290.4)
Constant	49,734***	150,213**
	(2,726)	(66,934)
Observations	929,705	1,056
R-squared	0.039	0.327
Number of pin	185,941	528

Standard error in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9. Difference in difference and counterfactual for panel data for Carver Dakota and Washington Counties 2014-2018

Discussion

After examining high level data from the across the Twin Cities Metro, in depth data from the most populous counties in terms of solar installations and panel data from 2014 to 2018 on parcels abutting solar installations, the results remain inconclusive on the effect of large scale solar installations on abutting parcel values.

Data from across the metro that include parcels that are homesteaded and have finished square feet in 2014 and 2018 indicate parcels that abut solar installations increase in value by about $14,500

(Table 2). The move from a coefficient of -$41,062 (standard error of 12,007) to -$26,498 (standard error 6,240) is statistically significant in both years. This is juxtaposed with Carver and Dakota counties, which host over 50% of the solar installations in the metro, showing coefficients with devaluations of $50,000 standard errors 137,139 and 21,409) and $20,000 (standard errors 10,765 and 10,505) respectively (Table 4). Neither of these observations is statistically significant at the 5% level in both observational years, but the trend throughout the high level, more scrutinized and panel data indicate some level of negative valuation of parcels abutting solar installations.

Similarly, when the three counties that host over 80% of the solar installations were examined, the aggregate total in the coefficient change between 2014 and 2018 was about -$3,800 (changing from a coefficient of -35,373 with an s.e of 9,484 to -39,161 with an s.e. of 9,706-see Table 5), or 1.4% of the mean residential parcel value in those three counties. When a counterfactual data pool is examined, none of the abutting coefficients are statistically significant at the 5% level with one county (Carver

The panel data paint a different story. The model, with outputs described in Table 7 indicates that parcels that at some point between 2014 and 2018 abut a solar installation (noted with regressor 'ever_abut')are worth $20,642 (stand error 11,408) less than those parcels that do not abut a solar installation. *However*, once the solar installation is built (noted by regressor 'abut') the parcel value rises $12,837 (standard error 4,934). This finding is amplified in Table 8 where a difference in difference analysis is illustrated for 2017. Again, if a parcel is ever abutting a solar installation it is reduced in value -$28,669 standard error 11,550, statistically significant at 5%). Once the year in which the installation is built occurs, as noted by variable "post," parcels in the control and treatment group increases by $12,654 (standard error 155.9) and parcel that are in the treatment group after the installation is built increase by $20,841 (standard error 4,739 making it significant at the 5% level). This increase of 7.4% is still below the median parcel value percentage increases indicated in the high level analysis, but it is approaching those levels, suggesting adverse effects on parcel values may be endemic to the site and not reflective of the presence of the solar array. Similar coefficients were derived from the control group made up of propensity score matches but none were significant at the 5% level (Tables 7,8).

A more in depth examination of this data would not be complete without a more thorough investigation of the nature of split parcels abutting solar installations. Given the nature and time constrains of this study, all data that did not have identical property identification numbers in 2014 and 2018 were discarded. However, even some of the properties that remained in the data set were split in a way that dramatically affected their total estimated market value (i.e. parcels being split with a new parcel ID given to the portion with the residential structure, while the original parcel ID retained only the value of the land). A closer examination of these splits and transfers will paint a more veritable picture of the effects of the solar installation itself.

Another factor impacting parcel values is their proximity to transmission lines. As discussed earlier, solar developers prize land that is near existing transmission lines and also near load, or where people will be using that electricity. The scientific literature has a long history describing negative links between property values and transmission lines,[42,43,44] but have also been documented to have a

[42] Chalmers, 2012
[43] Hoen, 2016
[44] Wyman and Mothrope, 2018

positive impact when transmission lines allow access and views of greenspace under the lines[45]. Early versions of solar installations in Minnesota were more likely to lay gravel and move earth, making the solar installation more industrial in appearance and thus more visually similar to established visual disamenities, whereas in 2016 Minnesota passed HF 3353 which mandated pollinator habitat best practices be followed if a solar installation markets itself as "pollinator friendly"[46] . This led to developers voluntarily committing to self -imposed benchmarks of pollinator friendly habit, which is much more visually similar to the green space amenities described by Tatos et al. toward the end of 2016 and into 2017 where panel data describe an uptick in parcel values abutting solar installations.

Externalities

No analysis of an infrastructure development would be complete without an examination of the externalities it creates. In the past, power producing infrastructure has been examined through the lens of its negative externalities like air pollution noise pollution and unsightliness, given they tended to be highly visible and impactful to the community. Positive externalities such as job creation and tax base bolstering have also been examined to a lesser extent. Solar installations differ from traditional power generation infrastructure in that they do not emit air or water pollution, they are largely silent, and less visible from far distances. The negative externalities surrounding solar installations have been discussed already in that some communities feel they detract from the visual aesthetic and that they take prime farmland out of production. Supporters of solar installations have called attention to the positive externalities including potential for pollinator habitat, avoided pollution, opportunity for aquifer recharge tax base bolstering and productivity of land[47,48].

As discussed earlier, solar installations increase the tax base of the communities that house them[49], create opportunities for aquifer recharge[50] , as well as offer an opportunity for pollinator habitat[51]. The complaint is that they do not fit in the traditional aesthetic of rural Minnesota. To capture the monetary value of some of these externalities, the metro wide impact of parcel values will be examined as well as the production of land utilize for solar vs prime farmland for corn.

Sun vs Corn

The Clean Energy Resource Teams recently examined the productivity of an acre of prime farmland for corn vs solar production. The USDA Economic Yearbook indicates that since 2010, 30-40% of the corn grown in the United States is used to produce ethanol[52]. The total number of BTUs from an acre of prime farmland growing corn to be turned into ethanol is 40,967,074.3 Btus/acre, while the number of BTUs from an acre of solar panels is 485,981,054.8 Btus/acre. This is an 11.86 to 1.00 solar to ethanol ratio (for full calculations see Appendix E). In terms of externalities, farmland is nearly 12 times

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[45] Tatos, 2016
[46] MN Office of Revisor HF 3353, 2016
[47] Nelson, 2017
[48] Minnesota Dept. of Commerce, 2019
[49] Ibid
[50] CERTs, 2019
[51] MN Office of Revisor HF 3353, 2016
[52] USDA, 2019

more productive when housing solar (in terms of BTUs) while requiring none of the applicants to the land that end up as water pollution such as nitrate and phosphate.

Value of Land

The Metro wide regression indicated that between 2014 and 2018 the median value of parcels abutting solar installations increased $20,000. The panel data across that same time period indicated that abutting parcels were valued about $28,000 less than non-abutting parcels, but the addition of a solar installation was associated with a 32,000 increase, resulting in a $4,000 net gain. These values represent a 2-7 percent increase in parcel value between 2014 and 2018. If applied to all 32 sites in the metro that is an increase of between $130,000 and $640,000 in parcel value, while mitigating carbon intensive energy production.

This begs the question of why there is not more solar development. If the economics indicate installations increase parcel values, why is there not more of a rush to put them in? The answers may lie the difficulties of grid transition from continuous resources to intermittent resources and landowner values, both of which can provide more than enough fodder for studies of their own.

To address this ambiguity and others, a slate of policy recommendations is laid out in the next section to address the positive and negative implications of solar installations moving forward.

Policy

The modeling above did not provide consistent conclusive evidence of impacts of solar installations on abutting land parcels one way or the other. As such, this portion will examine policy approaches to large scale/CSG interactions with abutting parcels on a negative and positive basis.

Assumption 1: Solar Installations have a Negative Impact on Abutting Parcel Values

If future data indicates solar installations are indeed a disamenity, thereby having a negative effect on nearby parcel values, there are several policy options that are already being exercised by private companies and governments to reconcile with property owners.

Good Neighbor Funds

Several renewable energy developers operating in Minnesota have included payments to the communities where they build. These “Good Neighbor Funds” can take many forms, including one time payments to landowners that live nearby the infrastructure, recurring yearly payments or a percentage of the installation generated funds being set aside for distribution in the communities.

An example of the last model is Minnesota based wind and solar developer Geronimo Energy’s Odell Wind Farm Community Fund. Geronimo makes an annual contribution of $40,000 to a 501(c)(3) organization, which then solicits proposals for charitable works in communities where the energy infrastructure is located[53]. Past awards funded local volunteer fire department gear, 4-H projects, and local municipal upgrades[54] . Solar developer Cypress Creek sponsors local workforce development

[53] Odell Wind Farm, 2019
[54] Cross-Counties Connect, 2017

programs,[55] while the Scott County Commissioners negotiated post-secondary education fund contributions from renewable developers building in their county[56].

Eminent Domain

Minnesota has legislation codified and executive branch goals pertaining to solar generation and carbon free energy. It also has one of the most diverse utility systems in the country with 125 municipal utilities and 45 cooperatives[57]. To meet those goals some of the states' 125 municipal electric providers may have to expand their generation capacity. In Minnesota, local governments can exercise eminent domain to convert private property into public use[58], as in the case of procuring land for a publicly owned electric generation facility. While generally onerous, this may have more appeal if the government is compelled to compensate the landowner for the "highest and best use"[59] of the land, which very well may be above perceived market value.

Restructure Solar Tax Policy

Currently, Minnesota's Community Solar Gardens are exempt from local property tax[60], thus they do not directly fund local tax bases after installation. Part of the rational was to keep costs low to drive solar production, while another part dealt with equity. The model of CSG development following its 2013 inception was to enable access to solar to those that did not have the space or capability otherwise. Compelling the owners and operators of CSGs to pay property tax would raise the local tax base and potentially increase the level of services in a community, thereby offsetting the disamenity, but doing so would raise a series of equity questions around access outside the scope of this paper.

Assumption 2: Solar Installations have a Positive Impact on Abutting Parcel Values

Alternately, as the models described earlier suggest, solar installations may not pose any significant impact on abutting parcels, or even be considered a community amenity. If this is the case, communities may pursue siting policies to take advantage of the net positive impact of the installation.

Brightfields

Spearheaded by the Metropolitan Council, there is an effort in Minnesota to put solar installations on capped landfills[61]. Small, proof of concept projects have been completed in Hutchinson, MN, and there is a bill before the Minnesota Legislature to fund a study on future development[62] . While this strategy has proven viable in states like Massachusetts, there is policy revision necessary for this to be successful on a wide scale in Minnesota. Currently landfill remediation is funded by the Closed Landfill Program (CLP), which is funded by public bonding. Currently there are multiple restrictions in place on the type of activities allowed on such land, including restrictions on private entities using the

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55 Cypress Creek, 2019
56 Scott County Board of Adjustment, 2016
57 Chan et al., 2019
58 Minnesota Office of Revisor 117.031, 2018
59 Ibid
60 Kluempke, 2019
61 CERTS, 2019
62 Pratt, 2019

land for profit[63]. However if resolved, Brightfields may prove to be one of the best returns on investment, given how much value the parcels used as landfills stand to gain by the addition of a positive externality vs. the value stood to be gained or lost if the parcel was starting as differently valued farmland.

Looking Ahead/ Areas of Future Research

As stated above, there are several avenues to pursue in expanding this research, noting that all of them will get easier (or at least have more robust data) with time. More solar installations will get built and more counties, municipalities and communities will strike balances on their needs with developers. As this progresses, more parcels near and abutting solar installations will sell, creating a richer data pool from which to draw meaningful conclusions. Previous research in this topic area has focused on attitudes of local real estate professionals in the private and public sector[64]. It found many of those professionals estimate the impact of solar on property values no be "none," but a significant number also responded with an answer of a negative impact[65]. With all this in mind, further research could include:

1) In depth county or even community analysis. With so many factors in property value being influenced at a micro level in a small geographic area, there would be immense value in diving deeper into a county or even community, especially if it has multiple installations like Jordan, Scandia, Norwood Young America or Cottage Grove.
2) Comparison of rural installations vs. residential interface installations. In more agrarian settings, more people's livelihoods are tied to the land and its productivity. The USDA National Agricultural Statistics Survey found the rent for cropland in Minnesota in 2018 was $167[66], while developers have paid over $1000 per acre per year[67]. Carver County Minnesota rejected multiple solar installations' permits on the grounds that they were not consistent with "rural and natural surroundings.[68]" Measuring how values of maintaining a "rural and natural surrounding" compare to earning a livelihood would be useful as well.
3) Siting of Solar on Disamenities. There has already been movement in Minnesota to site solar panels on disamenities like closed landfills. Under the title of "Brightfields", Twin Cities stakeholders are exploring how to follow a model implemented in Massachusetts of locating solar where there is little risk of lowering property values[69] . Providing a clearer picture of the relationship of renewable energy, external disamenities and property values would be invaluable for future citing considerations.
4) Further analysis of the relationship between solar installations and transmission lines. With transmission lines being a known disamenity, a greater understanding of how the value and sale prices of parcels fluctuate based on the quantity, style and location of transmission lines. Examining the relationship between new construction of lines and interconnection into existing

[63] Minnesota PCA, 2019
[64] Rai et. al., 2018
[65] Ibid
[66] USDA, 2018
[67] Krohn, 2018
[68] Carver County Board of Commissioners, 2018
[69] Massachusetts Department of Environmental Protection, 2019

infrastructure and its effects on local parcel levels will be instrumental in answering the question of solar installations' effects on real estate values.

Conclusion

The effect of ground mounted, primary land use solar installations with a nameplate capacity greater than 2 MW_{AC} remains inconclusive. There is strong evidence that parcels abutting solar installations have a lower total estimated market value than their non-abutting counterparts, but that has yet to be extricated from the effect of the installation itself. Data that had statistically significant observations in 2014 *and* 2018 tended to indicate a rise in parcel value from 2014 to 2018, while the more common instance was a decline in value with one or both observation years not being statistically significant.

Observing the data over time via panel data indicated that after controlling for fixed effects, parcel value substantially, but the results were not replicable in a counterfactual pool of control observations.

Solar installations prize land that is near both people and transmission lines, a combination that has an established history of lowering parcel values. Also, the method of tracking property in this study was susceptible to skewing if parcels were split and a parcel retained its Parcel Identification Number (PIN) but no longer housed a structure worth hundreds of thousands of dollars.

Given the ambiguity still surrounding the effects of installations on parcels, it would be prudent for policy makers to have a variety of tools with which to address solar installations regardless of whether they pose a disamenity or amenity. Established practices like developers creating "Good Neighbor Policies" with the communities in which they operate and continuation of production taxes will keep a steady revenue stream flowing into communities should installations eventually be determined a disamenity. On the other hand, if they are a net positive for a community, planners can leverage them by placing them in areas that suffer depreciation in other ways, similar to what Massachusetts has implemented and Minnesota is seeking to implement with their "Brightfields" program of siting solar on closed landfills.

Other studies have indicated the most cost effective way to generate the volume of electricity needed to satisfy recent goals like the One Minnesota Clean Energy Plan is for more emphasis on even larger scale installations like Minnesota's Aurora Project[70]. Following this policy track would decrease the number of installations necessary, but increase the impact of the ones that are built, heightening the importance of good data on solar impacts.

As solar production has exploded in the past three years in Minnesota, each passing year will yield more quality data on parcel and property sales making a clearer, more accurate description of solar installations' impact on the value of the parcels nearby. Armed with this data, solar developers, communities, utilities and policy makers will be able to make more informed choices in striking a balance between their different goals, needs and drivers.

[70] Minnesota Solar Pathways, 2018

Appendix A. Median Parcel Value by County 2014 vs. 2018

32 Installations of 2+MW

335 Abutting Properties

	2014 Median	2018 Median	Change	2014 Mean	2018 Mean	Change
Anoka	$182,638	$218,400	**+19.6%**	$233,174	$277,498	**19.0%**
Carver	$260,336	$285,100	**+9.5%**	$345,151	$384,104	**11.2%**
Dakota	$231,298	$267,800	**+15.7**	$309,169	$349,738	**13.1%**
Hennepin	$200,234	$219,200	**+18.1**	$304,197	$375,699	**23.5%**
Scott	$232,352	$242,300	**+4.3**	$316,211	$337,222	**6.6%**
Washington	$228,430	$252,200	**+10.4**	$305,613	$321,491	**9.2%**

5 in Anoka, 91 in Carver, 85 in Dakota, 43 in Hennepin, 29 in Scott, 82 in Washington

Solar Installation and County Wide Parcel Trends (adjusted for 2018 Dollars)

Anoka

	2014 Median	2018 Median	Change	2014 Mean	2018 Mean	Percent change
Anoka	$182,638	$218,400	**+19.6%**	$233,174	$277,498	**+19.0%**
Connexus	$283,050	$396,200	**+40%**	$297,983	$528,240	**+77.3%**

Carver

	2014 Median	2018 Median	Change	2014 Mean	2018 Mean	Percent change
Carver	$260,336	$285,100	**+9.5%**	$345,151	$384,104	**+11.2%**
West Waconia	$379,374	$414,200	**+9.2%**	$336,011	$346,883	**+3.24%**
Lind	$323,618	$420,600	**+30.0%**	$431,545	$451,718	**+4.67%**
Benton	$101,972	$124,000	**+21.6%**	$299,051	$266,221	**-10.98%**
Porter Way	$474,774	$481,550	**+1.4%**	$522,421	$515,880	**-1.25%**
MSC Carver-Krete	$472,601	$453,550	**-4.0%**	$504,719	$484,133	**-4.08%**
Nesvold	$473,237	$475,500	**+0.5%**	$556,168	$551,637	**-0.81%**
Highway 7	$286,306	$311,050	**+8.6%**	$337,486	$346,366	**+2.63%**
Gladden	$449,515	$458,600	**+2.0%**	$396,273	$1,023,656	**+158.32%**

Dakota

	2014 Median	2018 Median	Change	2014 Mean	2018 Mean	Percent change
Dakota	$231,298	$267,800	+15.7	$309,169	$349,738	13.1%
Empire	376194	378200	0.53%	861833	927812	7.66%
Ursa	547013	570650	4.32%	888598	963025	8.38%
Equuleus	410114	452000	10.21%	466294	500371	7.31%
Rosemont	235214	277700	18.06%	333370	362546	8.75%
Farmington	127200	250500	96.93%	127624	226473	77.45%
Northfield	109498	273900	150.14%	131475	271033	106.15%
Feely	213113	243650	14.33%	310256	313883	1.17%
330th Street	728856	617800	-15.24%	595381	545900	-8.31%
Waterford	850650	762700	-10.34%	743929	694480	-6.65%

	2014 Median	2018 Median	Change	2014 Mean	2018 Mean	Percent change
Hennepin	$200,234	$219,200	+18.1	$304,197	$375,699	23.5%
Corcoran-Kaat	$347,680	$402,000	15.62%	$405,418	$461,944	13.94%
Gibbon	$177,020	$213,000	20.33%	$221,747	$271,876	22.61%

Hennepin

Scott

	2014 Median	2018 Median	Change	2014 Mean	2018 Mean	Percent change
Scott	$232,352	$242,300	+4.3	$316,211	$337,222	6.6%
Blue lake	$869,451	$1,212,500	40.75%	$790,314	$1,338,740	69.39%
Pueblo	$405,816	$575,900	43.33%	$561,501	$560,514	-0.18%
Country Trail West	$310,403	$304,800	-0.85%	$454,045	$433,688	-4.48%
South Street West	$258,856	$286,400	11.50%	$329,363	$408,433	24.01%

Washington

	2014 Median	2018 Median	Change	2014 Mean	2018 Mean	Percent change
Washington	$228,430	$252,200	**+10.4**	$305,613	$321,491	**9.2%**
Argo Navis	$164,512	$158,400	**26.62%**	$242,653	$307,236	**2.06%**
Cottage Grove CSG1	$406,616	$389,100	**3.75%**	$392,771	$407,508	**1.43%**
Cottage Grove DG	$329,766	$390,200	**9.58%**	$388,808	$426,054	**25.43%**
Forest Lake	$304,644	$293,800	**-10.19%**	$266,950	$239,740	**2.23%**
Hastings	$377,890	$312,100	**-4.83%**	$1,055,840	$1,004,875	**-12.45%**
McHattie	$426,438	$438,900	**7.09%**	$423,729	$453,789	**9.10%**
Scandia	$253,870	$239,500	**-2.97%**	$250,825	$243,373	**-2.97%**
Scandia Trail	$214,968	$139,300	**-34.69%**	$332,299	$217,029	**-31.31%**

Appendix B- Data Coding Assumptions

The data from the Minnesota Geospatial Commons is a collection of data compiled from county level GIS professionals. In several circumstances, the coding of attributes required judgment on converting abbreviations or vales to numeric values to be utilized in Stata.

1) All Yes/no entries were converted to “0” for no and “1” for yes.
2) Most counties submitted data for Home Style as number of stories. However in cases where Home style data was submitted as a qualitative expression, stores were estimated based on 1200 square feet per floor per the 2010 Census Bureau median finished square feet per Midwest house.[71]
3) Dakota County did not report the presence of a garage, but did report square feet of garage. Assumed all parcels that had square feet of garage had a garage in general.

MetroGIS Regional Parcel Dataset -Attribute Detailed Descriptions

STANDARD PARCEL ATTRIBUTES – REGIONAL PARCEL DATASET Regional Parcel Attribute	**Field Name**	**Field Description**	**Field Type**	**Field Width**
Unique County ID	COUNTY_ID	Three digit FIPS and State standard county code.	text	3
Unique Parcel ID	PIN	Unique regional parcel ID comprised of the county PIN with the county code and dash appended to the front.	text	17
House Number	BLDG_NUM	The building or house number of the parcel. (Things like fractional house numbers should be included with this field.)	text	10

[71] Census Bureau, 2010

Street Prefix Direction	PREFIX_DIR	Street prefix direction for the parcel. Domain = N, S, E, W, NE, NW, SE or SW (as defined in USPS Pub. 28 Appendix B http://pe.usps.gov/cpim/ftp/pubs/Pub28/pub28.pdf)	text	2
Street Prefix Type	PREFIXTYPE	Street prefix type (e.g. Hwy) for the parcel.	text	6
Street Name	STREETNAME	Street name for the parcel. If a county is unable to provide the individual street data fields (direction, type, etc), they may be provided as a combined data element in this field.	text	40
Street Type	STREETTYPE	Street type abbreviation for the parcel (as defined by USPS Pub. 28 Appendix C. http://pe.usps.gov/text/pub28/pub28apc.html#508hdr2)	text	4
Street Suffix Direction	SUFFIX_DIR	Street suffix direction for the parcel. Domain = N, S, E, W, NE, NW, SE or SW (as defined in USPS Pub. 28 Appendix B http://pe.usps.gov/cpim/ftp/pubs/Pub28/pub28.pdf)	text	2
Unit Information	UNIT_INFO	Additional unit information for the	text	12

		parcel for condominiums, etc. (e.g. Unit 5B, Suite 8, etc.)		
City (actual)	CITY	Name of city or township in which the parcel actually resides (not the mailing address city).	text	30
City (mailing)	CITY_USPS	The mailing address city for the parcel as defined by the USPS.	text	30
ZIP Code	ZIP	ZIP code for the parcel.	text	5
ZIP 4 Extension	ZIP4	The four digit zip code extension for the parcel.	text	4
Legal Description Plat Name	PLAT_NAME	The legal description plat name (this is often synonymous with the subdivision name).	text	50
Legal Description Block	BLOCK	The legal description block within the plat.	text	5
Legal Description Lot	LOT	The legal description lot within the block.	text	5
Polygon Acreage	ACRES_POLY	The calculated acreage of the polygon within the GIS spatial data. (numeric field with two decimal places)	numeric	11(2 dec) ESRI Precision 10 Scale 2
Deeded Acreage	ACRES_DEED	The deeded acreage of the parcel. (numeric field with two decimal places	numeric	11 (2 dec) See Above
Use Type 1	USE1_DESC	Description of use type 1.	text	100

Use Type 2	USE2_DESC	Description of use type 2.	text	100
Use Type 3	USE3_DESC	Description of use type 3.	text	100
Use Type 4	USE4_DESC	Description of use type 4.	text	100
Multiple Uses	MULTI_USES	Flag (Y/N) to indicate if multiple uses exist.	text	1
Landmark/Business Name	LANDMARK	Name of the predominant landmark or business on this parcel.	text	100
Owner Name	OWNER_NAME	The full name of the owner. The format should be last name first where available. Inclusion of multiple owners is up to each county.	text	50
Additional Owner Name	OWNER_MORE	Field for additional owner information where available (e.g. joint owner or additional first name first format).	text	50
Owner Address	OWN_ADD_L1 OWN_ADD_L2 OWN_ADD_L3	Mailing address of the owner. Up to three lines may be used. Typically line1 is street address and line2 is city, state & zip, but other variations exist.	text	40 each
Taxpayer Name	TAX_NAME	The full (first and last) name of the taxpayer. The format (e.g. last name first or last name last) and inclusion of	text	40

		multiple taxpayers is up to each county.		
Taxpayer Address	TAX_ADD_L1 TAX_ADD_L2	Mailing address of the taxpayer. Up to three lines may be used. Typically line1 is street address and line2 is city, state & zip, but other variations	text	40 each
TAX_ADD_L3		exist.		
Homestead Status	HOMESTEAD	Homestead status (Y = yes, N = no, P = partial) .	text	1
Estimated Market Value - Land	EMV_LAND	Land estimated market value	numeric	11
Estimated Market Value - Buildings	EMV_BLDG	Building estimated market value	numeric	11
Estimated Market Value - Total	EMV_TOTAL	Total estimated market value	numeric	11
Tax Capacity	TAX_CAPAC	Tax capacity of the parcel	numeric	11
Total Tax	TOTAL_TAX	Total tax of the parcel	numeric	11
Special Assessments	SPEC_ASSES	Special assessment value due and payable in the current year.	numeric	11
Tax Exempt Status	TAX_EXEMPT	Tax exempt (Y/N)	text	1
Exempt Use 1	XUSE1_DESC	Description of exempt use type 1.	text	100
Exempt Use 2	XUSE2_DESC	Description of exempt use type 2.	text	100
Exempt Use 3	XUSE3_DESC	Description of exempt use type 3.	text	100

Exempt Use 4	XUSE4_DESC	Description of exempt use type 4.	text	100
Dwelling Type	DWELL_TYPE	Type of dwelling (e.g. single family, duplex, etc.)	text	30
Home Style	HOME_STYLE	Home style description (e.g. rambler, split entry, etc.)	text	30
Square Footage	FIN_SQ_FT	Finished square footage	numeric	11
Garage	GARAGE	Garage (Y/N)	text	1
Garage Square Footage	GARAGESQFT	Garage square footage	text	11
Basement	BASEMENT	Basement (Y/N)	text	1
Heating	HEATING	Type of heating in use	text	30
Cooling	COOLING	Type of cooling in use	text	30
Year Built	YEAR_BUILT	Year built	numeric	4
Number of Units	NUM_UNITS	Number of residential units.	text	6
Last Sales Date	SALE_DATE	Date of last sale	date	8
Last Sales Value	SALE_VALUE	Value of last sale	numeric	11
School District	SCHOOL_DST	Unique school district number	text	6
Watershed District	WSHD_DIST	Watershed district or watershed management organization name	text	50
Green Acres	GREEN_ACRE	Green acres status (Y/N)	text	1
Open Space	OPEN_SPACE	Open space status (Y/N)	text	1

Agricultural Preserve	AG_PRESERV	Agricultural preserve status (Y/N)	text	1
Ag. Preserve Enrolled	AGPRE_ENRD	Agricultural preserve enrolled date	date	8
Ag. Preserve Expiration	AGPRE_EXPD	Agricultural preserve expiration date	date	8
Parcel Polygon to Parcel Point and PIN Relationship Code	PARC_CODE	This field is used to provide information about the relationship between parcel polygons, parcel points and unique tax parcel identifiers (PINs).	numeric	2

Appendix C: Appraiser Mock Up

To add a spatial component to the analysis, a mock property assessment based on paired sales analysis is included. To fill the void of academic literature on the topic, professional appraisers are hired to value the properties around solar installations just as they would other properties. Appraisal firms like CohnReznick, LLP[72] in Illinois and Kirkland[73] in North Carolina have taken the lead in early solar installation appraisals.

The methodology is based on Paired Sales Analysis, which is the same premise as a propensity score to determine a matched control group. The premise is to compare properties that are as identical as possible in as many things as possible except for the variable being studied, to determine the effect of that variable, in this case, abutting a solar installation. The mock below utilizes data from Zillow to find sales of abutting parcels after the announcement date and manually match them with other parcels based on the following criteria if at all possible:

1) Finished square feet within 10%
2) Last sale date with 12 months
3) Lot size within an acre, up to 2 acres, at which point the value of additional acres diminishes per acre
4) Number of bedrooms within 1
5) Number of Bathrooms within 1
6) Year built/ remodeled within 25 years
7) Within 5 miles, or 10 in rural settings

[72] Ibid 1
[73] Ibid 34

Installation 1: *West Waconia* is located near the town of Norwood Young America in Carver County, Minnesota, in a primarily rural area, totaling 75 acres. Surrounding uses consist of agricultural land, some with homesteads, and single family homes. One adjoining property had a sales date after announcement of the installation.

Installation 1	[illegible]	[illegible]uare
Control Area Sales ([illegible]	[illegible] installation	[illegible]
Abutting Sale (test)	Yes, solar installation built by sale date	$212
Difference		15%

Installation 2: *Farmington* solar installation is located on the south side of the town of Farmington, Minnesota (population 23,000 in 2017) in Dakota County. The installation is built on 35 aces and is bordered to the north by a subdivision of new construction and to the east west and south by agricultural land. This is a rich environment for comparison, for many of the homes in the subdivision were built around the same time, with the same materials in similar styles. Thus the only differentiating factor is abutment to the Farmington Solar installation. The interconnection was in February of 2017, thus the assumed announcement knowledge threshold is February of 2016. All sales took place after February of 2016.

Installation 2	Potentially affected by solar installation	Median Price per square foot (2018$)
Control Area Sales (3)	No, Not abutting solar installation	$135
Abutting Sale (test)	Yes, solar installation built by sale date	$138
Difference		3%

Installation 3: Forest Lake

Forest Lake solar installation is located halfway between the towns of Forest Lake and Scandia, Minnesota in Washington County. The installation is built on 20 aces and is bordered on all sides by agricultural land, some of which is homesteaded. The interconnection was in July of 2017, thus the assumed announcement knowledge threshold is July of 2016. All sales took place after July of 2016.

Installation 3	Potentially affected by solar installation	Median Price per square foot (2018$)
Control Area Sales (3)	No, Not abutting solar installation	$147
Abutting Sale (test)	Yes, solar installation built by sale date	$142
Difference		4%

Appendix C.1.-Mock Appraiser data

Installation 1: West Waconia (test parcel listed first)

Last Sale Price	Square Feet	Sale Price/Sq foot	Last sale date	Lot Size (acres)	Bed	Baths	Year Built	year remodel	distance from test (miles)	pin
$300,000	1416	$212	11.21.16	4	3	1.75	1971	1982	N/A	110010900
$255,000	1460	$175	3.28.2017	10	3	1	1950	1976	3.6	10180100
$265,000	1344	$197	6.12.2017	4.69	4	1.75	1978		3	20360610
$250,500	1359	$184	10.26.16	3	3	2	1954		4.8	110250320

Installation 2: Farmington (test parcel listed first)

Last Sale Price	Square Feet	Sale Price/ Sq foot	Last sale date	Lot Size acres	Bed	Baths	Year Built	Distance from test (miles)	PIN
$305,409	2216	$138	7.24.2016	0.17	5	3	2016	N/A	142450002090
$312,000	2350	$133	5.22.2016	0.23	4	3	2016	0.3	142450006010
$338,000	2313	$146	7.18.2016	0.27	5	2.5	2016	0.3	142450003070
$299,251	2216	$135	10.27.2016	0.26	5	3	2016	0.2	142450004131

Installation 3: Forest Lake

Last Sale Price	**Square Feet**	**Sale Price/Sq foot**	**Last sale date**	**Lot Size (acres)**	**Bed**	**Baths**	**Year Built**	**Distance from test (miles)**	**PIN**
$485,000	3408	$142	7.18.18	5.57	4	2	1987	NA	1803220310003
$470,000	3203	$147	1.16.2018	2	3	3	2006	4.3	1503220440008
$600,000	3274	$183	12.6.2018	2.04	3	2.5	2004	4.2	2203220110019
$415,000	3302	$126	9.20.2017	1.5	4	4	2004	1.4	703220320012

Appendix D. TESTS/Stata Output

I. Summary of Carver, Dakota, Washingotn 2014 data

```
. sum
```

Variable	Obs	Mean	Std. Dev.	Min	Max
name	0				
pin	0				
emv_tot~2018	201,686	282758.2	156448.9	8268	8169844
fin_sq_ft	201,686	1997.034	831.2904	20	16586
emv_sqft	201,686	143.4994	79.6844	8.55	20075
acres_poly	201,686	1.485403	8.491464	0	820.99
stories	201,686	1.511691	.4106144	1	3
age	201,686	37.6608	24.46043	5	1059
homestead	201,686	1	0	1	1
garage	201,686	.9000129	.2999836	0	1
basement	0				
green_acre	201,686	.0056325	.0748386	0	1
abut	201,686	.0005999	.0244864	0	1
year_built	201,686	1981.339	24.46043	960	2014
zip	0				
county	201,686	2.221894	.6625964	1	3
v17	0				
v18	0				
v19	71,674	276644.6	157875	7800	7707400
emv_total	130,012	261299.9	141311.2	10900	6900600

II. Summary of Carver, Dakota, Washingotn 2018 data

```
. sum
```

Variable	Obs	Mean	Std. Dev.	Min	Max
farm_name	0				
pin	0				
emv_total	207,398	316147.6	159737.2	7800	1.14e+07
fin_sq_ft	207,398	2043.353	854.8209	234	28192
emv_sqft	207,398	161.4832	64.5507	8.55	6639.24
acres_poly	207,398	1.406721	8.071199	0	820.99
stories	207,398	1.518768	.4124937	1	3
age	207,398	36.03733	24.60285	1	277
homestead	207,398	1	0	1	1
garage	207,398	.9275403	.2592482	0	1
basement	0				
green_acre	207,398	.0049856	.0704326	0	1
abut	207,398	.000569	.023846	0	1
year_built	207,398	1982.963	24.60285	1742	2018
zip	0				
county	207,398	2.227133	.66433	1	3

III. Summary of panel data

```
. summarize
```

Variable	Obs	Mean	Std. Dev.	Min	Max
farm_name	0				
county_pin	0				
pin	929,705	7.18e+11	9.53e+11	1.00e+07	3.60e+12
acres_poly	929,705	1.390618	7.90258	0	820.99
homestead	929,705	1	0	1	1
emv_tot~2018	929,705	296350.3	151738	0	8577900
stories	929,705	1.508152	.4197094	1	3
fin_sq_ft	929,705	2022.258	833.632	20	13395
garage	929,705	.9244524	.2642731	0	1
year_built	929,705	1981.553	23.89262	1742	2018
green_acre	929,705	.004937	.0700905	0	1
emv_sqft	929,705	152.3764	72.50094	0	20075
age	929,705	34.49553	23.93227	0	276
abut	929,705	.0002076	.0144066	0	1
county	929,705	2.236301	.649178	1	3
year	929,705	2016	1.414214	2014	2018
ever_abut	929,705	.0005464	.023369	0	1
v18	929,705	8088.161	111854.4	-6283786	8449472
v19	929,705	2107.47	113170.6	-8422755	7913546
v20	929,705	6330.995	15900.53	-1201938	763563
v21	929,705	11252.52	14817.52	-526812	2084824
v22	929,705	27779.15	33724.6	-993330	3510694

IV. Hausman test for Fixed Effects vs. Random Effects

	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	fe_reg	re_reg	Difference	S.E.
ever_abut	-20642.31	-34122.87	13480.56	8575.577
acres_poly	4313.486	6975.731	-2662.245	132.7958
stories	22067.08	7645.608	14421.47	443.5373
fin_sq_ft	62.08392	100.5207	-38.43676	0.8839693
garage	22494.26	32113.15	-9618.885	791.3194
age	-642.0622	-625.8951	-16.16709	47.68913
1.abut	12837.46	14517.99	-1680.529	160.9131
year				
2015	8607.044	8346.519	260.5247	46.22997
2016	10792.09	10424.79	367.2927	93.50454

2017	18117.37	17424.82	692.5548	152.7812
2018	29321.02	28612.62	708.401	189.1463

Coefficients ---

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(10) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 4707.95

Prob>chi2 = 0.0000 (Reject Null of Random Effects being most appropriate)

(V_b-V_B is not positive definite)

V. Average Treatment Effect (Propensity Score Matching)

a. Washington

```
. teffects psmatch ( emv_total2018 ) ( ever_abut fin_sq_ft acres_poly stories age garage)

Treatment-effects estimation                   Number of obs      =    331,705
Estimator      : propensity-score matching     Matches: requested =          1
Outcome model  : matching                                     min =          1
Treatment model: logit                                        max =         14
------------------------------------------------------------------------------
             |              AI Robust
emv_tot~2018 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ATE          |
   ever_abut |
    (1 vs 0) |   49742.47   4011.636    12.40   0.000     41879.81    57605.13
------------------------------------------------------------------------------
```

b. Dakota

```
. teffects psmatch ( emv_total2018 ) ( ever_abut fin_sq_ft acres_poly stories age garage)

Treatment-effects estimation                   Number of obs      =    485,713
Estimator      : propensity-score matching     Matches: requested =          1
Outcome model  : matching                                     min =          1
Treatment model: logit                                        max =          3
------------------------------------------------------------------------------
             |              AI Robust
emv_tot~2018 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ATE          |
   ever_abut |
    (1 vs 0) |  -33859.13   12113.53    -2.80   0.005    -57601.22   -10117.04
------------------------------------------------------------------------------
```

c. Carver

```
.   teffects psmatch ( emv_total2018 ) ( ever_abut fin_sq_ft acres_poly stories age garage)

Treatment-effects estimation                   Number of obs      =    112,015
Estimator      : propensity-score matching     Matches: requested =          1
Outcome model  : matching                                     min =          1
Treatment model: logit                                        max =         17
```

emv_tot~2018	Coef.	AI Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
ATE						
ever_abut						
(1 vs 0)	5505.927	19045.19	0.29	0.773	-31821.96	42833.81

Appendix E. Land Productivity Calculations[74]

SOLAR

- 1 MW solar ann. output = 1,424,329 kWh/year (range: 1,351,973 to 1,485,329 kWh)
    - Source: NREL PV Watts - Worthington, MN location
- 1,424,329 kWh x 3412 Btus = 4,859,810,548 Btus
- 1 MW solar takes up 10 acres as conservative figure
- 4,859,810,548 / 10 acres = **485,981,054.8 Btus/acre**

ETHANOL

- 191 bushels/acre = Annual Output in MInnesota for 2018
    - Source: USDA NASS - MN Ag News - Crop Production Aug. 10, 2018
- 1 bushel of corn yields 2.81 gals of under-natured ethanol
    - Source: EIA - Corn Ethanol Yields Continue to Improve May 13, 2015
    - Source 2: USDA, ICF Report: A Life-Cycle Analysis of the Greenhouse Gas Emissions of Corn-Based Ethanol, p. 22
- 191 bushels/acre x 2.81 gallons of ethanol/ bushel = 536.71 gallons of ethanol per acre
- 1 gallon of ethanol = 76,330 Btus
    - Source: U.S. DOE, Alternative Fuels Data Center - Fuel Properties Comparison
- 76,330 Btus x 536.71 gallons of ethanol per acre = **40,967,074.3 Btus/acre**

Comparison: 485,981,054.8 Btus/acre Solar to 40,967,074.3 Btus/acre Ethanol

[74] Ebinger, 2019

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