

# Agriculture and Solar Farms: Exploring Preferences for Utility-scale Solar Energy in Local Communities

Jian Chen, Hongli Feng

Department of Economics, Iowa State University  
Center for Agricultural and Rural Development, Iowa State University



IOWA STATE UNIVERSITY

Contact: Jian Chen, email: [chenjian@iastate.edu](mailto:chenjian@iastate.edu).

## Introduction

Utility-scale solar energy offers a promising path to renewable energy transition in the U.S. However, its fast growth has caused concerns about localized impacts, especially land-use conflicts with agricultural production and compromising the aesthetics of local landscapes. Studies concerning the formal assessment of land-use issues and the trade-offs between localized agricultural land-use impacts of such projects and their associated economic/environmental implications in local communities are limited in existing literature.

There is a lack of perspective from public officials, whose views may differ from the general population due to their distinct roles and responsibilities within the community. Their perspectives matter more in the development process for such projects at the local level. Furthermore, land use for solar projects has become a controversial topic, with various information sources that emphasize different effects. Research has shown that negative, positive, and peer information can influence preferences differently, but the effects of different types of information on preferences for utility-scale solar projects are not well understood.

## Objectives

- Quantify trade-offs between land use and environmental/economic factors for utility-scale solar.
- Investigate how different stakeholder groups value the attributes of solar projects and the associated trade-offs.
- Study how preferences for solar projects are affected by different information treatments.

## Data and Methods

- We conducted the survey across six Great Lakes states: Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin.
- Information treatments:**
  - Categories of information: no (control), peer, positive, negative information
  - Participants were randomly assigned to one of the four survey versions
  - Attention-check questions followed after the information content
- Discrete choice experiment:**
  - D-optimal design: two blocks of 12 choice tasks
  - Participants were randomly assigned to one of the two survey blocks, each containing six choice scenarios
  - High uncertain responses (certainty=1 or 2) were removed from the analysis

Table 1. Attributes and Levels in the Discrete Choice Experiment

| Attributes  | Levels   |
|---|--|
| Land quality of the occupied farmland                                   | Low (150 bu/acre)<br>Medium (180 bu/acre)<br>High (210 bu/acre)                              |
| Expected carbon emissions reduction relative to coal-fired power plants | 40,000 tons per year<br>70,000 tons per year<br>100,000 tons per year                        |
| Expected annual lease payment to landowners                             | 2 times prevailing cash rent<br>4 times prevailing cash rent<br>6 times prevailing cash rent |
| Expected savings on the monthly electricity bill for your household     | \$0; \$5; \$25; \$45   |

Suppose your community is considering a 50 MW solar project that will run for 25 years, generate electricity to serve about 8,500 homes, and occupy 375 acres of cropland. Under consideration are 2 potential plans, Plan A and Plan B, for the solar project that are the same except for four factors as listed below, along with their average values based on publicly available data.

- Land quality:** The average corn yield for medium-quality land in the U.S. Midwest is 180 bushels per acre (bu/acre).
- Cropland cash rent:** The average cropland cash rent for cropland in the U.S. Midwest is about \$250 per acre per year.
- Carbon emissions reduction:** A 50 MW solar project could reduce carbon emissions by 40,000 tons annually over its life cycle if replacing generation from natural gas, and by 100,000 tons if replacing generation from coal.
- Average electricity bill:** The average electricity bill for residential customers in the U.S. Midwest is about \$120 per month, or \$1440 per year.

There is also an option of not developing the solar project, which means no farmland will be converted. In the following, we ask you to indicate whether you prefer **Plan A**, **Plan B**, or **No Solar Project** in 6 scenarios.

| Scenario 1  | Plan A                        | Plan B                       | No solar project          |
|---|-------------------------------|------------------------------|---------------------------|
| Land quality of the occupied site (as indicated by corn yield in bushels/acre)            | Site I - Medium (180 bu/acre) | Site II - High (210 bu/acre) | No conversion of farmland |
| Expected life cycle carbon emissions reduction relative to fossil fuel-fired power plants | 40,000 tons per year          | 70,000 tons per year         | 0                         |
| Expected annual lease payment to landowners   | 2 times prevailing cash rent  | 4 times prevailing cash rent | 0                         |
| Expected savings on the monthly electricity bill for your household                       | \$45                          | \$5                          | 0                         |
| Which plan are you more likely to support in your jurisdiction?                           | <input type="checkbox"/>      | <input type="checkbox"/>     | <input type="checkbox"/>  |

How certain are you of your choice, on a scale of 1 to 5? (1 = very uncertain; 5 = very certain)

1     2     3     4     5

Figure 1. An Example of the Choice Scenario Shown to Participants

### Survey implementation:

- Executed online through the Qualtrics and was administrated via Dynata
- 11,685 survey invitations were distributed
- 3102 completed responses, implying a 26.5% response rate

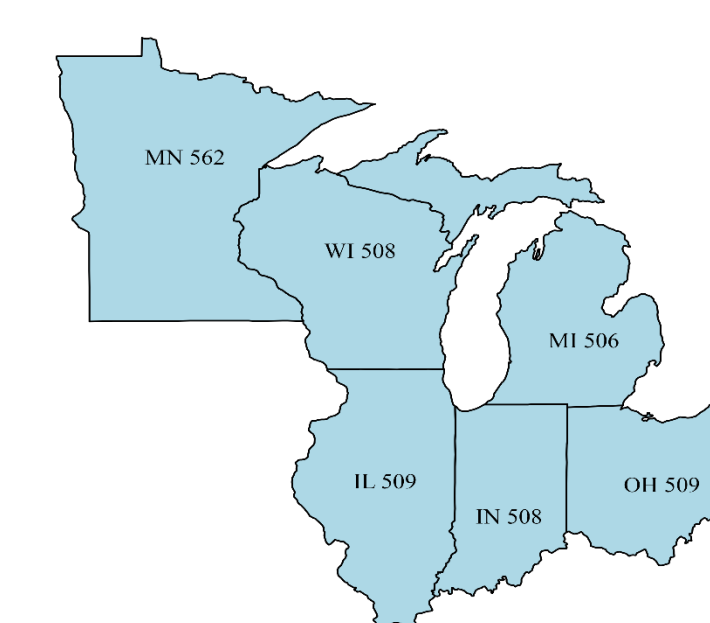


Figure 2. Survey Responses by States

## Empirical Model

- Attribute-based discrete choice model (random parameter logit):

$$U_{ijt} = ASC + \beta_{CM,i} Carbon\_medium_{ijt} + \beta_{CH,i} Carbon\_high_{ijt} + \beta_{L,i} Lease_{ijt} + \beta_{B,i} Bill_{ijt} + \beta_{FM,i} Farmland\_medium_{ijt} + \beta_{FH,i} Farmland\_high_{ijt} + \varepsilon_{ijt}$$

- $ASC$ : alternative specific constant (ASC) for “no solar project” option;
- $\varepsilon_{ijt}$ : error term, assumed to follow a type I extreme value distribution;
- All attribute coefficients and the  $ASC$  are classified as random and normally distributed.

## Results

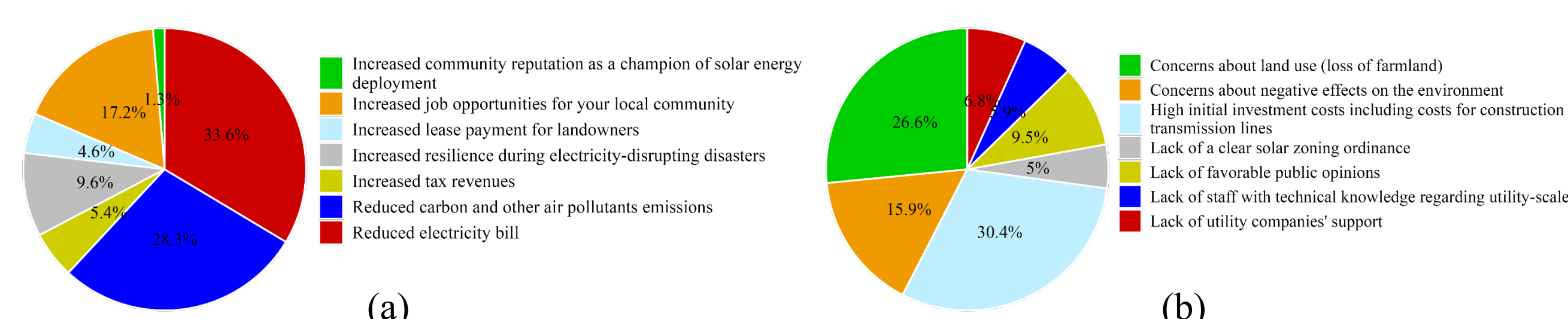


Figure 3. Rating of the most important benefit (a) and challenge (b) associated with utility-scale solar projects for local communities

Table 2. Estimates in Willingness-to-Pay Space Across Stakeholders and Information Treatments

| Variable                         | Full sample (1)  | Stakeholder groups  |                        |                   |                    | Information treatments |                   |                   |                   |
|----------------------------------|------------------|---------------------|------------------------|-------------------|--------------------|------------------------|-------------------|-------------------|-------------------|
|                                  |                  | Public official (2) | General population (3) | Non-landowner (4) | Landowner (5)      | No (6)                 | Peer (7)          | Positive (8)      | Negative (9)      |
| Mean parameters                  |                  |                     |                        |                   |                    |                        |                   |                   |                   |
| ASC                              | -59.60*** (6.74) | -399.54*** (133.25) | -45.05*** (5.50)       | -43.72*** (7.05)  | -327.53*** (95.13) | -55.01*** (13.99)      | -49.51*** (10.41) | -83.28*** (16.84) | -61.16*** (15.27) |
| Carbon emission reduction-medium | 5.67*** (0.82)   | 6.56 (5.64)         | 5.47*** (0.82)         | 4.87*** (0.81)    | 17.05*** (5.46)    | 6.74*** (1.55)         | 6.97*** (1.72)    | 6.47*** (1.79)    | 3.96*** (1.79)    |
| Carbon emission reduction-high   | 8.16*** (1.28)   | 7.28 (8.94)         | 7.16*** (1.28)         | 6.96*** (1.24)    | 29.74*** (9.13)    | 7.77*** (2.47)         | 10.38*** (2.99)   | 11.88*** (2.81)   | 5.51*** (2.69)    |
| Lease payment to landowners      | 1.42*** (0.33)   | 1.54 (2.45)         | 1.34*** (0.34)         | 1.05*** (0.34)    | 4.66*** (1.91)     | 1.23* (0.63)           | 1.72** (0.70)     | 0.89 (0.76)       | 1.88*** (0.71)    |
| Medium quality farmland          | -0.23 (0.96)     | 10.08 (8.20)        | -0.45 (0.94)           | 0.18 (0.91)       | -6.90 (5.83)       | -1.48 (1.72)           | -2.10 (2.03)      | 2.01 (2.11)       | 1.32 (2.05)       |
| High quality farmland            | -6.35*** (1.42)  | -6.06 (11.68)       | -6.74*** (1.36)        | -4.84*** (1.34)   | -27.41*** (10.35)  | -6.09** (2.56)         | -8.44*** (3.02)   | -3.49 (2.99)      | -7.95*** (3.05)   |
| Standard deviation parameters    | Yes              | Yes                 | Yes                    | Yes               | Yes                | Yes                    | Yes               | Yes               | Yes               |
| Observations                     | 49500            | 4338                | 45162                  | 41082             | 8328               | 12438                  | 12357             | 12297             | 12408             |

- There are significant disparities in how stakeholders – public officials vs. the general population, and landowners vs. non-landowners – value different project attributes.
- The type of vignette presented significantly affects individual preferences, even with minimal exposure to peer, positive, or negative information.

Table 3. Heterogeneous Preference Across States (estimates in WTP space)

| Variable                         | Illinois (1)      | Indiana (2)       | Michigan (3)      | Minnesota (4)      | Ohio (5)         | Wisconsin (6)     |
|----------------------------------|-------------------|-------------------|-------------------|--------------------|------------------|-------------------|
| Mean parameters                  |                   |                   |                   |                    |                  |                   |
| ASC                              | -48.83*** (14.56) | -54.47*** (16.31) | -59.33*** (14.80) | -155.80*** (31.45) | -24.38*** (7.53) | -39.40*** (10.38) |
| Carbon emission reduction-medium | 5.73*** (1.78)    | 4.47** (1.90)     | 7.93*** (2.41)    | 8.18*** (2.58)     | 5.84*** (2.01)   | 4.32** (1.90)     |
| Carbon emission reduction-high   | 8.34*** (3.05)    | 4.75 (3.30)       | 9.23** (3.61)     | 15.45*** (4.24)    | 8.27** (3.23)    | 9.19*** (2.82)    |
| Lease payment to landowners      | 2.00*** (0.73)    | 1.16 (0.90)       | 2.40*** (0.91)    | 2.37*** (1.09)     | 0.54 (0.76)      | 1.04 (0.79)       |
| Medium quality farmland          | 3.46 (1.98)       | -1.10 (2.22)      | 2.39 (2.81)       | -4.55 (3.13)       | -1.81 (2.24)     | 2.03 (2.21)       |
| High quality farmland            | -6.48*** (2.96)   | -2.31 (3.70)      | -3.23 (3.82)      | -26.73*** (5.66)   | -4.78 (2.99)     | -4.77 (3.07)      |
| Standard deviation parameters    | Yes               | Yes               | Yes               | Yes                | Yes              | Yes               |
| Observations                     | 8070              | 8211              | 8058              | 9105               | 7953             | 8103              |

Table 4. Heterogeneous Preference Across Urban and Rural Regions (estimates in WTP space)

| Variable                         | Urban (1)         | Rural (2)        |
|----------------------------------|-------------------|------------------|
| Mean parameters                  |                   |                  |
| ASC                              | -66.64*** (10.78) | -56.66*** (7.65) |
| Carbon emission reduction-medium | 6.56*** (1.15)    | 5.23*** (1.17)   |
| Carbon emission reduction-high   | 10.50*** (1.71)   | 6.96*** (1.81)   |
| Lease payment to landowners      | 1.08** (0.49)     | 1.87*** (0.48)   |
| Medium quality farmland          | -0.79 (1.29)      | 0.48 (1.36)      |
| High quality farmland            | -5.17*** (1.84)   | -6.63*** (2.07)  |
| Standard deviation parameters    | Yes               | Yes              |
| Observation                      | 22302             | 27198            |

Table 5. Estimates of Factors Influencing the Ranking of Land Use Challenge

|                                     | Not or slightly challenging | Moderately challenging | Highly challenging |
|-------------------------------------|-----------------------------|------------------------|--------------------|
| Rooftop_adopt_plan (0/1)            | 0.005 (0.012)               | 0.004 (0.011)          | -0.009 (0.023)     |
| Community_part_int (1/2/3)          | 0.017** (0.008)             | 0.015** (0.007)        | -0.031** (0.014)   |
| Municipal_cooperatives (0/1)        | 0.003 (0.009)               | 0.003 (0.008)          | -0.005 (0.017)     |
| Reference = Male                    |                             |                        |                    |
| Gender = Female                     | -0.032*** (0.010)           | -0.027*** (0.008)      | 0.059*** (0.018)   |
| Age                                 | -0.001* (0.000)             | -0.001* (0.000)        | 0.001* (0.001)     |
| Education                           | -0.013*** (0.005)           | -0.012*** (0.005)      | 0.025*** (0.010)   |
| Reference = Democrats               |                             |                        |                    |
| Political affiliation = Republican  | -0.056*** (0.011)           | -0.051*** (0.010)      | 0.107*** (0.021)   |
| Political affiliation = Independent | -0.022* (0.012)             | -0.017* (0.009)        | 0.038* (0.022)     |
| Political affiliation = Others      | -0.056*** (0.020)           | -0.051*** (0.021)      | 0.107*** (0.041)   |
| Household income                    | 0.004 (0.004)               | 0.004 (0.003)          | -0.008 (0.007)     |
| Farm operation (0/1)                | -0.126*** (0.016)           | -0.111*** (0.014)      | 0.238*** (0.029)   |
| Observations                        |                             | 3091                   |                    |

- There is preference heterogeneity across states, particularly in the valuation of high carbon reduction, lease payments to landowners, and the use of high-quality farmland for solar projects.
- Concerns over farmland use vary significantly, with respondents in Illinois and Minnesota placing greater value on preserving high-quality farmland.

- Urban and rural communities share similar preferences for various factors of utility-scale solar projects. The estimated effects are almost the same or only differ slightly.

- Rooftop\_adopt\_plan**: whether the respondent has installed rooftop solar panels or plans to adopt them in the next five years.
- Community\_part\_int**: degree of interest the respondent has in participating in community solar projects if available.
- Municipal\_cooperatives**: whether the respondents' electricity supplier is a municipal utility or a cooperative.
- Respondents' perceived land use challenges vary with their interest in community solar, family farming background, and some demographics (i.e., gender, age, education, and political affiliation).

## Discussion

- Our study helps to inform debates about the trade-offs related to land uses and utility-scale solar at the local community level with primary data collection and quantitative estimates.
- Our study also contributes to existing literature and discussion regarding a more comprehensive cost-benefit assessment that incorporates behavior factors to understand the value of utility-scale solar projects to local communities.
- Policymakers and developers should account for diverse stakeholder perspectives and regional variations and use effective information dissemination strategies when designing policies and compensation schemes to alleviate siting conflicts.

## Future Study

- A follow-up study is planned to examine how long the vignette effects persist and how balanced information affects between-group differences.

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