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Feeding People & The Grid:

A Q-Methodology Study of Stakeholder Perspectives
on Agrivoltaic Systems in Texas

Dissertation Defense | March 27, 2026 | 1:00p

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Dissertation Defense Roadmap

Suggested Flow (~25 Minutes – not including Q&A)

WHY	1	Introduction & Motivation	3 min
	2	Literature Review & Research Gaps	3 min
	3	Research Questions	1 min
HOW	4	Conceptual Framework & Methodology	3 min
WHAT	5	Results: Factor Solution & Perspectives	5 min
	6	Consensus, Divergence & Discussion	4 min
CLOSING	7	Conclusions & Research Contributions	4 min
	8	Limitations & Future Research	2 min
	9	Q&A with Committee	TBD

ITS PERSONAL: NIMBY(ism)

JONES LAND RANCH

Introduction: Why Texas?

The Growing Tension

*Texas faces a **critical challenge**: How do we meet surging energy demand while protecting the agricultural land that feeds our communities?*

#1
Solar energy producer in the United States

127M
Acres of agricultural land in Texas

$25B
Texas agricultural economy value

83%
of U.S. solar built on agricultural land

Agrivoltaic systems is the co-locating of solar panels with agricultural production (farming & grazing) and offers a potential solution, but adoption hinges on understanding **stakeholder perspectives**.

Introduction: The Research

Problem Statement

*How do key **stakeholders**, farmers, landowners, policymakers, energy developers, and community members **perceive the opportunities and barriers to agrivoltaic adoption in Texas?***

Why This Matters

- Most agrivoltaic research focuses on **technical/economic performance** and not on the people who must adopt the technology
- Policy makers, developers, and farmers need **evidence-based insights into stakeholder values** to design effective incentives and outreach
- Texas's unique context (ERCOT market, strong property rights, climate vulnerabilities) **demands Texas-specific research**
- **No prior study has used Q-methodology to examine agrivoltaic stakeholder perspectives** in the U.S.

Significance

This study bridges the gap between technical agrivoltaic research and the human dimensions of adoption, providing actionable insights for stakeholder engagement in Texas.

Literature Review

Agrivoltaic Systems

Dual land-use models, crop compatibility, global landscape (Barron-Gafford et al., 2019; Dupraz et al., 2011)

Texas Context

Agricultural economy, ERCOT energy market, solar expansion, land-use pressures

Stakeholder Theory

Social license to operate, adoption barriers, distributional equity (Boutilier & Thomson, 2011)

Q-Methodology

Studying subjectivity (Stephenson, 1953; Brown, 1980; Watts & Stenner, 2012)

Key Insight: *Extensive technical literature exists globally, but stakeholder perspective research, particularly using systematic methods like Q-methodology remains scarce, especially for the U.S. and Texas.*

Gaps in the Literature

Geographic Bias

The majority of agrivoltaic research has been conducted in Europe (France, Germany, Italy) and East Asia (Japan, South Korea). U.S. studies are limited to a handful of states (Arizona, Illinois). No study has focused specifically on Texas, the nation's largest solar producer with a $25B agricultural economy.

Technical Focus

Existing literature overwhelmingly focuses on technical performance: panel configurations, crop yield impacts, energy output optimization, and engineering specifications. The human dimensions stakeholder values, adoption barriers, social acceptance are few and far between.

What's Missing

- No **Q-methodology** studies of agrivoltaic stakeholders in the United States
- Limited research on **how stakeholder values** (not just economics) shape adoption decisions
- No systematic framework for **tailoring engagement strategies by stakeholder perspective**
- **Texas's unique regulatory context** (ERCOT, property rights culture) completely unexamined

Research Questions

RQ1

What distinct **stakeholder perspectives** exist regarding agrivoltaic systems in Texas?

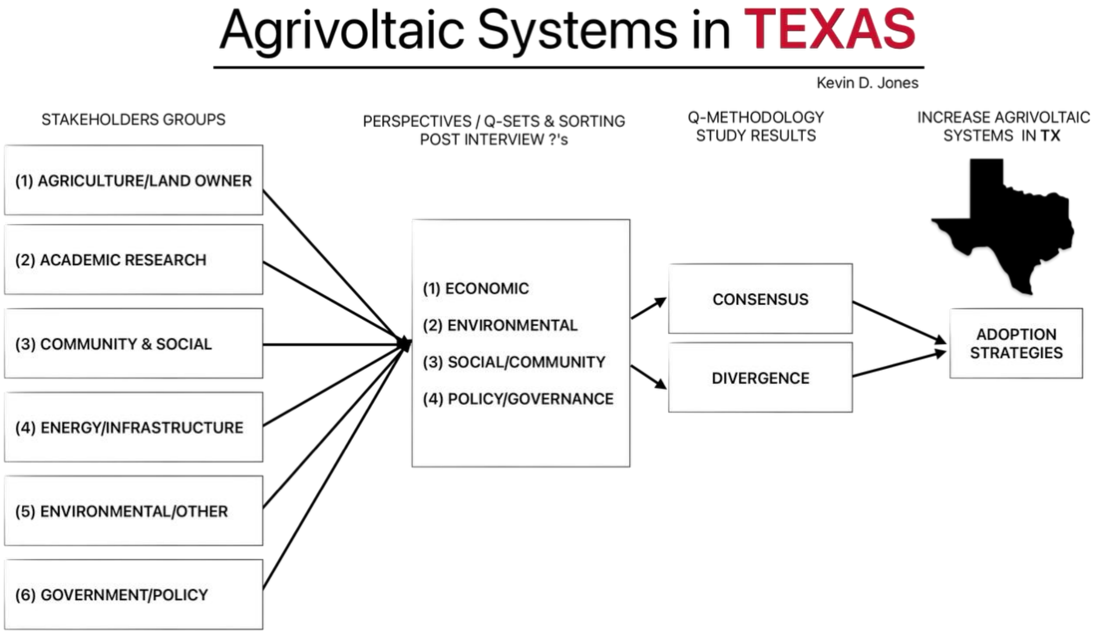
RQ2

How do stakeholders in Texas **prioritize economic, environmental, social, and policy considerations** when evaluating agrivoltaic systems?

RQ3

In what ways do stakeholder perspectives on agrivoltaic systems in Texas **converge or diverge across identified viewpoints**?

Conceptual Framework



Wüstenhagen's Triangle

Social acceptance across three dimensions: community, market, and socio-political

Stakeholder Theory

Identifies who matters and how their interests shape adoption outcomes

Sociotechnical Systems

Grounds technology adoption in the interaction between technical and social systems

Theories: *No single framework captures the full picture. The integrated model maps stakeholder categories through data collection instruments to reveal consensus, conflicts, and adoption strategies.*

Q-Set: 24 Statements Across Four Domains

- Economic (E1–E6)
- Environmental (EN1–EN6)
- Social (S1–S6)
- Policy (P1–P6)

Why Q-Methodology?

A systematic method for studying subjectivity and revealing shared perspectives

What Is Q-Methodology?

- Combines qualitative and quantitative techniques to study human subjectivity
- Participants rank-order statements (Q-sort) on a forced distribution grid
- Factor analysis identifies clusters of shared viewpoints, not individual opinions
- People are the "variables" [...] small samples appropriate (Watts & Stenner, 2012)

Why It Fits This Study

- Captures diverse stakeholder views without requiring large samples
- Reveals hidden patterns of agreement and disagreement across groups
- Well-established in environmental, agricultural, and energy research
- Ideal for exploring understudied topics where dominant viewpoints are unknown

Data Collection Process

Using QMethodSoftware.com for online Q-sort administration

1 Develop Concourse ▶ **2** Select Q-Set ▶ **3** Recruit P-Set ▶ **4** Configure Q-Sort ▶ **5** Administer Online

Q-Sort Distribution Grid

MOST DISAGREE — NEUTRAL — MOST AGREE

-4	-3	-2	-1	0	+1	+2	+3	+4
(1)	(2)	(3)	(4)	(4)	(4)	(3)	(2)	(1)

- **24 statements** across **4 domains** (Economic, Environmental, Social, Policy) × 6 statements each
- **Forced distribution grid:** −4 to +4 (distribution: 1-2-3-4-4-4-3-2-1)
- **P-Set:** 39 participants across 6 stakeholder categories
- **Surveys:** Pre-sort demographics + post-sort reflections

Participant Demographics

39 usable Q-sorts from 48 recruited stakeholders (81.3% usable response rate)

Stakeholder Category	n	%
Energy/Infrastructure	11	28.2
Community Member	9	23.1
Agricultural/Landowner	8	20.5
Academic/Research	6	15.4
Government/Policy	4	10.3
Environmental/Other	1	2.6

48 Emails Sent

41 Initial Responses

39 Usable Q-Sorts

81% Usable Response Rate

Data Analysis Process

From raw Q-sorts to meaningful stakeholder perspectives

1 Correlation Matrix → **2** Factor Extraction → **3** Determine # of Factors → **4** Factor Rotation → **5** Interpret Factors

- **Step 1:** 39 × 39 person-by-person correlation matrix (741 pairwise correlations)
- **Step 2:** Principal Component Analysis (PCA) extraction from correlation matrix
- **Step 3:** Kaiser-Guttman criterion (eigenvalues > 1.0), scree plot, interpretability → 4 factors retained
- **Step 4:** Varimax orthogonal rotation. Significance threshold: ±0.527 ($p < .01$ for 24 items)
- **Step 5:** Composite Q-sort arrays, distinguishing/consensus statements, post-sort reflections

Results: Four-Factor Solution

61.1% of total variance explained — 31 of 39 participants loaded on a factor

F1 **The Environmental Stewards**

16 sorts — 26.0% variance

Prioritize environmental benefits: water conservation, soil protection. Reject claims of environmental harm.

F2 **The Community-Centered Pragmatists**

7 sorts — 16.0% variance

Emphasize policy frameworks and government incentives. Support transparent governance for adoption.

F3 **The Economic Optimists**

5 sorts — 13.0% variance

Focus on dual-income economic potential. See agrivoltaics as policy solution for energy and agriculture.

F4 **The Skeptical Traditionalists**

3 sorts — 6.1% variance

Express skepticism about business model. Concerned about community division and fairness.

5 Consensus Statements | 7 Non-loading Participants | 1 Confounded Sort

Factor 1: The Environmental Stewards

16 defining sorts | 26.0% variance explained

Highest-Ranked Statements (+4 to +3)

- EN1 (+4): Agrivoltaic systems are well-suited for Texas because they reduce water use and protect crops from extreme heat
- S5 (+3): Public opposition to solar in Texas is mostly due to poor communication rather than the technology itself
- P1 (+3): Texas should actively incentivize agrivoltaics to balance energy leadership with farmland preservation

Lowest-Ranked Statements (−4 to −3)

- EN2 (−4): Solar panel installations disrupt soil conditions and create long-term environmental harm
- EN6 (−3): Reducing agricultural production for solar infrastructure threatens long-term food security
- P2 (−3): Government incentives for agrivoltaics unfairly interfere with free markets

Stakeholder Composition

- Community Members (4)
- Energy/Infrastructure (4)
- Academic/Research (3)
- Agricultural/Landowner (3)
- Government/Policy (1)
- Other (1)

Key Interpretation

Largest and most diverse factor. Evaluates agrivoltaics primarily through an **environmental lens**: **water conservation**, **soil protection**, **ecological integration**. **Draws from all 6 stakeholder categories**: ***environmental framing transcends professional boundaries.***

Factor 2: The Community-Centered Pragmatists

7 defining sorts | 16.0% variance explained

Highest-Ranked Statements (+4 to +3)

- P1 (+4): Texas should actively incentivize agrivoltaics to balance energy leadership with farmland preservation
- P3 (+3): Clear statewide regulations would increase trust and reduce conflict around agrivoltaic development
- S1 (+3): Agrivoltaics are more socially acceptable than traditional solar farms because they preserve agricultural identity

Stakeholder Composition

- Energy/Infrastructure (4)
- Agricultural/Landowner (2)
- Community Member (1)

Lowest-Ranked Statements (−4 to −3)

- P2 (−4): Government incentives unfairly interfere with free markets and private land decisions
- P4 (−3): Additional regulation threatens Texas's tradition of private property rights
- S6 (−3): The visual impact of agrivoltaic systems negatively affects rural landscapes

Key Interpretation

Dominated by energy professionals (4/7). Strongly supports government incentives and clear regulations. Believes agrivoltaics need institutional frameworks to succeed, not just market forces.

Factor 3: The Economic Optimists

5 defining sorts | 13.0% variance explained

Highest-Ranked Statements (+4 to +3)

- P5 (+4): Agrivoltaics provide a realistic policy solution to meet Texas's energy demand while keeping land in agriculture
- E3 (+3): The dual-income model provides Texas farmers with long-term financial stability
- E5 (+3): Leasing even a small portion of farmland for agrivoltaics can significantly improve overall farm viability

Stakeholder Composition

- Government/Policy (3)
- Agricultural/Landowner (1)
- Energy/Infrastructure (1)

Lowest-Ranked Statements (−4 to −3)

- E6 (−4): Solar development inflates land prices, making it harder for young farmers to access land
- EN4 (−3): The environmental benefits of agrivoltaics are overstated and only occur under ideal conditions
- E4 (−3): Solar lease agreements expose farmers to long-term financial and contractual risks

Key Interpretation

Dominated by government officials (3/5). Views agrivoltaics through economic development and policy lens. Strongly endorses dual-income model while dismissing land price inflation and contractual risk concerns.

Factor 4: The Skeptical Traditionalists

3 defining sorts | 6.1% variance explained

Highest-Ranked Statements (+4 to +3)

- S5 (+4): Public opposition to solar in Texas is mostly due to poor communication rather than the technology itself
- P3 (+3): Clear statewide regulations would increase trust and reduce conflict around agrivoltaic development
- S4 (+2): Solar leasing divides rural communities by rewarding some landowners while disadvantaging others

Lowest-Ranked Statements (−4 to −3)

- E1 (−4): Agrivoltaic systems strengthen Texas's pro-business environment
- E2 (−3): Agrivoltaics primarily benefit solar developers, while farmers receive only marginal gains
- E5 (−3): Leasing even a small portion of farmland can significantly improve farm viability

Stakeholder Composition

- Agricultural/Landowner (2)
- Community Member (1)

Key Interpretation

Smallest factor: landowners and community members. Most skeptical of agrivoltaic business model. See public opposition as reflecting genuine social tensions, not just miscommunication. Concerns about fairness and community division are central.

Consensus Statements

Five statements ranked similarly across all four factors

#	Statement	F1	F2	F3	F4	Dir.
S7	Agrivoltaics well-suited for TX (water conservation)	+4	+1	+2	+2	**Agree**
S9	Shading improves soil moisture and crop resilience	+2	+2	0	+1	**Agree**
S8	Solar installations disrupt soil conditions	−4	−2	−1	0	**Disagree**
S10	Environmental benefits are overstated	−2	−2	−3	−1	**Disagree**
S22	Regulation threatens private property rights	−1	−3	0	0	**Disagree**

Key Insight

All groups agree on **environmental suitability** of agrivoltaics for Texas. **Regulation is not seen as a threat** to property rights, even in Texas. These consensus statements provide a foundation for policy development.

Areas of Stakeholder Disagreement

Three dimensions where perspectives diverge

Economic Distribution

Who benefits? Environmental Stewards & Economic Optimists see win-win; **Skeptical Traditionalists** see benefits flowing to developers, not farmers.

Role of Government

Pragmatists strongly favor incentives (S19: +4) and regulation (S21: +3). **Traditionalists** are wary. All reject the idea that regulation threatens property rights.

Social Acceptance

Traditionalists see opposition as genuine social tensions (S17: +4); **Stewards** focus on environmental merits. Information provision alone won't resolve conflict.

Conclusions: Research Questions Answered

RQ1

(1) What distinct **stakeholder perspectives** exist regarding agrivoltaic systems in Texas?

Four distinct perspectives identified (61.1% variance). Stakeholder views are multidimensional not simply "for" or "against" agrivoltaics but filtered through different value frameworks (environmental, policy, economic, social).

RQ2

(2) How do stakeholders in Texas **prioritize economic, environmental, social, and policy considerations** when evaluating agrivoltaic systems?

Professional affiliation/Stakeholder Category alone does not determine perspective. **Factor 1** drew from all 6 categories. However, energy professionals concentrated in **Factor 1** & **Factor 2**, government in **Factor 3**, agricultural landowners in **Factor 4**. Values matter more than job title or group.

RQ3

(3) In what ways do stakeholder perspectives on agrivoltaic systems in Texas **converge or diverge across identified viewpoints**?

Five consensus statements show broad agreement on environmental benefits and openness to regulation.
Key tensions: economic fairness, scope of government involvement, and community acceptance dynamics.
Disagreements reflect values, not information gaps.

Research Contributions

First Q-Study of Agrivoltaic Stakeholders in Texas

This is the first study to apply Q-methodology to examine stakeholder perspectives on agrivoltaic systems in Texas — and one of the first in the United States. Demonstrates Q-methodology's utility for capturing subjective dimensions of renewable energy siting.

Advances Stakeholder Theory

Positions are shaped by value orientations and beliefs, not just structural attributes (profession, economic interest). Aligns with social license to operate literature (Boutilier & Thomson, 2011).

Reframes the Policy Challenge

Primary barriers are social and institutional, not environmental or technical. Shifts the focus from environmental persuasion to equitable governance design.

Tailored Communication Strategies

Factor-specific engagement approaches for each perspective group

F1: Environmental Stewards

Lead with environmental co-benefits: water conservation, soil health, biodiversity, pollinator habitats. Use scientific evidence and ecological framing.

F2: Community Pragmatists

Focus on governance, policy alignment, and transparent decision-making. Show how projects fit state energy policy and local economic development.

F3: Economic Optimists

Lead with financial data: lease revenue, diversification, long-term stability. Use case studies from successful installations.

F4: Skeptical Traditionalists

Address fairness, community division, and contractual protections directly. Use peer testimonials from other farmers. Most careful engagement needed.

Limitations of the Study

Sample Size
39 Q-sorts ~ appropriate for Q-methodology but limits population-level claims

Geographic Scope
Texas-specific context (ERCOT market, property rights)

Self-Selection Bias
Direct/snowball sampling may overrepresent engaged stakeholders

Cross-Sectional
Perspectives captured at one time point ~ views likely evolve as technology matures and geopolitical environments change

Q-Set (24 items)
Cannot capture all viewpoints; **aesthetic**, trust, intergenerational concerns may be underrepresented

Online Administration
Via QMethodSoftware.com — less depth than in-person sorting but faster data collection

Researcher Subjectivity
Factor naming involves judgment — mitigated by grounding in data and post-sort responses

Feeding People & The Grid:

Questions & Discussion

Thank you for your guidance and support

Dr. Saleha Khumawala (Chair) | Dr. Esther Bailey | Dr. Partha Krishnamurthy

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Appendix

Implications for Practice & Policy

Agricultural Stakeholders

Economic case resonates with some, but concerns about contractual risks, community division, and fairness must be addressed. Extension services should emphasize decommissioning protections.

Solar Industry

Tailor engagement by perspective: environmental co-benefits for Stewards, governance for Pragmatists, economics for Optimists. Address Traditionalist concerns proactively.

Policy & Regulation

Consensus rejection of S22 provides political cover for regulation. Voluntary standards can incentivize best practices without triggering property-rights resistance.

Community Engagement

Move beyond one-size-fits-all. Diagnose dominant perspective before engagement. Use factor-specific communication strategies.

Recommendations for Future Research

Methodological

- Replicate across multiple states with diverse samples
- Longitudinal Q-studies to track perspective shifts over time
- Compare PCA vs. Centroid extraction; Varimax vs. manual rotation

Substantive

- Include utility companies, environmental groups, tribal communities
- Study perspective changes after direct exposure to agrivoltaic projects
- Extend to other dual-use land technologies (wind-agriculture, floating solar)

Applied

- Develop stakeholder engagement frameworks based on factor profiles
- Design and test perspective-tailored communication materials
- Create rapid stakeholder assessment tool for developers

Q-Sort Questions (24)

Approach

- Q-sorts: Participants rank statements about AVS on a distribution grid
- Factor analysis to identify clusters of viewpoints
- **Software:** QMethodSoftware

Q-Sort Domains (24 Statements Total)

Economic

E1–E6 • 6 statements

Environmental

EN1–EN6 • 6 statements

Social/Community

S1–S6 • 6 statements

Policy/Governance

P1–P6 • 6 statements

Q-Set Statements: Economic (E1–E6)

E1. Agrivoltaic systems strengthen Texas's pro-business environment by allowing farmers and energy developers to profit from the same land.

E2. Agrivoltaics primarily benefit solar developers, while farmers receive only marginal financial gains.

E3. The dual-income model of agrivoltaics provides Texas farmers with long-term financial stability.

E4. Solar lease agreements expose farmers to long-term financial and contractual risks that outweigh the benefits.

E5. Leasing even a small portion of farmland for agrivoltaics can significantly improve overall farm viability.

E6. Solar development inflates land prices, making it harder for young and beginning farmers to access land in Texas.

Q-Set Statements: Environmental (EN1–EN6)

EN1. Agrivoltaic systems are well-suited for Texas because they reduce water use and protect crops from extreme heat.

EN2. Solar panel installations disrupt soil conditions and create long-term environmental harm to farmland.

EN3. Shading from solar panels improves soil moisture and crop resilience in hot Texas climates.

EN4. The environmental benefits of agrivoltaics are overstated and only occur under ideal conditions.

EN5. Integrating native vegetation and pollinator habitats into agrivoltaic systems enhances biodiversity.

EN6. Reducing agricultural production for solar infrastructure threatens long-term food security in Texas.

Q-Set Statements: Social/Community (S1–S6)

S1. Agrivoltaics are more socially acceptable than traditional solar farms because they preserve agricultural identity.

S2. Even agrivoltaic projects are viewed by many rural Texans as industrial intrusions into farming communities.

S3. Agrivoltaics help keep family farms intact and support generational land transfer.

S4. Solar leasing divides rural communities by rewarding some landowners while disadvantaging others.

S5. Public opposition to solar in Texas is mostly due to poor communication rather than the technology itself.

S6. The visual impact of agrivoltaic systems negatively affects rural landscapes and community character.

Q-Set Statements: Policy/Governance (P1–P6)

P1. Texas should actively incentivize agrivoltaics to balance energy leadership with farmland preservation.

P2. Government incentives for agrivoltaics unfairly interfere with free markets and private land decisions.

P3. Clear statewide regulations would increase trust and reduce conflict around agrivoltaic development.

P4. Additional regulation of agrivoltaics threatens Texas's tradition of private property rights.

P5. Agrivoltaics provide a realistic policy solution to meet Texas's energy demand while keeping land in agriculture.

P6. Once farmland is used for solar, it is unlikely to ever return fully to agricultural production.