# From Energy Poverty to Collective Power: A Coordination Game Approach to Community Based Renewable Transitions


## Extended Abstract

Decentralized renewable energy systems are increasingly framed as a central pathway for achieving climate mitigation, energy resilience, and more equitable access to electricity. Solar generation paired with battery storage can reduce emissions, support peak load management, and improve local reliability. Yet a persistent gap separates technical feasibility from actual implementation, especially in dense urban settings where distributed infrastructure requires collective planning, shared investment, and long term cooperation. Many community level projects fail not because costs or engineering alone are prohibitive, but because coordination among stakeholders does not emerge or does not persist. This study addresses that gap by developing an analytical framework that explains how structural, cultural, and institutional conditions shape coordination incentives and collective adoption of decentralized energy systems, with a specific focus on community operated microgrids.

The study examines a setting where coordination challenges are especially salient: the Israeli Ultra Orthodox community, a culturally cohesive population characterized by high internal trust in religious leadership and relatively low trust in state authorities. In multiple localities, a substantial portion of households rely on privately operated diesel generators to supply electricity during Sabbaths and religious festivals. Although rabbinic rulings allow use of grid electricity in some interpretations, stricter norms lead many households to adopt generator based electricity as a form of religious stringency. The resulting system functions through informal networks installed and operated by aggregators, often with limited safety oversight and weak integration with formal energy governance. While the practice addresses a religious need, it is also inefficient, polluting, noisy, and costly, and it may deepen energy poverty among low income households. At a system level, this setting also illustrates how decentralized energy behavior can be socially embedded, shaped by norms, internal authority, and collective expectations rather than by standard consumer choice models.

The empirical motivation is substantial. Approximately 65,000 Ultra Orthodox households are estimated to rely on diesel generators during Sabbaths and religious festivals, producing more than 136,000 tonnes of $CO_2$ emissions annually. Generator electricity is typically priced far above grid electricity. At the time of the study, household payments for generator electricity were estimated at roughly NIS 2.5 to NIS 3 per kWh, compared to a grid price of approximately NIS 0.52 per kWh. This price gap suggests that any transition to safer and cleaner decentralized solutions must be evaluated simultaneously through environmental, economic, and social lenses, including energy poverty effects.

Against this background, the study advances a central research question: how do social, cultural, and institutional conditions influence coordination in decentralized renewable energy adoption beyond purely techno economic factors. To address this question, we employ a mixed methods design integrating qualitative fieldwork, techno economic modeling, and game theoretic analysis. The core contribution is to translate empirically grounded social mechanisms into explicit participation constraints and equilibrium conditions within a formal coordination framework.

## Methods and research design

The study was conducted during 2023 and 2024 and proceeded through four integrated stages.

First, qualitative data were collected to identify the social and institutional mechanisms that shape adoption. We conducted 23 semi structured in depth interviews with stakeholders from government, local authorities, academia, and the private sector, including engineers specializing in energy storage technologies. We also conducted four focus groups across different regions of Israel with 19 Ultra Orthodox male heads of household, including generator users and non users. This sampling choice reflects cultural norms in which discussions about electricity practices and generator use are typically held among men. Interviews and focus groups explored affordability constraints, perceived safety, trust and legitimacy, cooperation expectations, regulatory barriers, and the role of internal authority in collective decision making. Data were analyzed using thematic analysis, with triangulation across sources to strengthen validity.

Second, quantitative economic and technical data were collected to parameterize feasibility. Data included cost structures for solar and storage, installation and operational costs, charging costs, efficiency and degradation parameters, discounting assumptions, electricity tariffs, and emissions factors. Sources included stakeholder interviews, professional literature, technical specifications, and official datasets related to the Israeli electricity sector and environmental damage estimates.

Third, we developed an economic model to estimate the levelized cost of electricity under storage based electricity scenarios. The model calculates discounted costs including capital expenditure, operating expenses, and charging costs, divided by discounted effective energy output accounting for round trip efficiency and degradation over time. Sensitivity analysis was performed across a range of storage costs and discount rates to assess feasibility conditions and identify threshold effects.

Fourth, we constructed a formal game theoretic model to represent stakeholder coordination. Building on the qualitative themes and quantitative thresholds, we specified an asymmetric simultaneous coordination game capturing interactions among households, local authorities, and government bodies. Players' utilities incorporate monetary components such as investment costs, savings, opportunity costs of public land or rooftops, project management costs, and incentives, alongside socially embedded components reflecting social utility, trust based cooperation, and indirect benefits such as energy security and emissions reduction. The game structure allows us to identify equilibrium outcomes and the conditions under which a cooperative transition can occur.

## Key empirical findings

The qualitative findings converge around three binding adoption conditions.

Affordability is a necessary condition. Participants repeatedly emphasized that any alternative to generators must reduce the effective cost burden or at minimum avoid imposing additional expenses on households, particularly in low income segments. High

baseline spending on generator electricity makes the community sensitive to price and financing terms. Participants also expressed concerns about how costs would be distributed across heterogeneous building types and whether non participants would be forced to subsidize participants. This highlights the importance of modular participation and targeted deployment designs.

Perceived safety is equally binding. The current generator based system is widely recognized as noisy, polluting, and potentially hazardous, yet enforcement is difficult and informal networks persist. Safety concerns also apply to any proposed storage based solution. Participants and stakeholders stressed that adoption would require credible assurances regarding fire safety, installation standards, and responsible oversight. Without a trusted safety narrative, even a cheaper solution may fail.

Alignment with community norms and internal authority is the third binding condition. Environmental motivations were not described as primary drivers of adoption. Instead, legitimacy depends on compatibility with religious requirements and endorsement by trusted local leadership. Trust asymmetries were evident: interviewees and focus group participants expressed higher confidence in municipal and religious authorities than in central government bodies. This implies that coordination pathways must be mediated through trusted intermediaries rather than relying only on national level directives or market incentives.

These themes directly informed model construction. Behavioral factors that appeared sporadically but were not consistently linked to participation decisions were excluded from the formal model to avoid generic over specification. The final parameter set captures recurrent constraints that operate as binding conditions in strategic interactions.

Techno economic results and energy poverty implications

Economic modeling indicates that storage based electricity can significantly reduce the cost relative to generator electricity, though outcomes depend strongly on storage cost and financing conditions. The estimated levelized cost of electricity from storage based solutions at the time of study was approximately NIS 1.905 per kWh under baseline assumptions. A two dimensional sensitivity analysis shows substantial variation, with lower storage costs and lower discount rates producing markedly lower levelized costs. For example, under favorable conditions the levelized cost can fall well below NIS 1 per kWh, while under unfavorable combinations it remains above NIS 1.5 per kWh. These results highlight the critical role of investment conditions and technology costs in determining affordability thresholds.

Energy poverty implications emerge when comparing electricity expenditures to household income. Using the common threshold in the literature where domestic energy spending above 10 percent of income indicates energy poverty, generator based electricity can push low income households into or deeper into energy poverty. Storage based electricity, even if not as low as grid prices, can reduce the burden and potentially shift households below the threshold under favorable scenarios. In this sense, coordinated adoption is linked to distributive outcomes, not only aggregate cost efficiency.

Game theoretic framework and equilibrium insights

The asymmetric coordination game formalizes stakeholder interdependence. Households face investment costs to connect to the system, but gain savings and additional direct and indirect utilities when the project is implemented. Local authorities incur opportunity and project management costs but gain social utilities and may receive government incentives. Government bodies incur regulatory and incentive costs but gain indirect utilities such as enhanced energy security, reduced infrastructure burdens, and emissions reduction benefits. Importantly, utilities include a cooperation parameter that increases with the number of cooperating players, reflecting the empirically observed role of trust, collective expectations, and authority mediated coordination in cohesive communities.

The model identifies two distinct Nash equilibria. The first is a non cooperative equilibrium representing a fragmented outcome where coordination fails and the community remains in the generator based status quo. The second is a cooperative equilibrium in which all players support adoption, producing a Pareto superior outcome with lower costs, improved safety potential, and emissions reduction benefits. The existence of both equilibria depends on participation constraints for each player. For households, cooperation is stable only when the combined benefits exceed both the investment costs and the alternative of continuing to pay generator electricity costs. For local authorities, cooperation is stable only when social utilities scaled by cooperation and any incentives exceed opportunity and management costs. For government bodies, cooperation is stable only when indirect benefits scaled by cooperation exceed incentives and regulatory costs.

A central insight is that the cooperative transition is threshold dependent. If storage costs are too high, if discount rates are unfavorable, or if trust and legitimacy conditions are weak, incentives become misaligned and the system remains trapped in the inferior equilibrium. Conversely, when affordability, perceived safety, and cultural legitimacy converge, cooperation becomes individually rational for each actor and the system can shift to the superior equilibrium. In this framing, decarbonization and energy poverty alleviation are treated as public goods that depend on coordination rather than on technology availability alone.

## Contributions and implications

The study offers two main contributions.

Theoretical contribution: While coordination games are well established in energy economics, this study integrates socially embedded mechanisms into a formal coordination framework in an empirically grounded way. Qualitative evidence on trust asymmetries, internal authority, and norm based cooperation is translated into explicit participation constraints and equilibrium conditions, rather than being treated as background context. This yields a socio strategic analytical lens for studying decentralized transitions in culturally cohesive and weakly regulated settings.

Practical contribution: The framework provides actionable leverage points for policy and planning. First, locally anchored coordination is critical. Municipalities and trusted local actors can function as intermediaries that increase legitimacy and strengthen cooperation incentives. Second, program design must be threshold sensitive. Policies should target the binding constraints of affordability, safety credibility, and normative alignment rather than assuming homogeneous participation. Third, modular and targeted deployment can reduce

distributional resistance and avoid imposing costs on non participants. Fourth, incentives and regulatory support should be designed to reduce uncertainty and enable favorable financing conditions that move the system across the affordability threshold identified by the techno economic model.

## Limitations

The analysis reflects current economic and technical conditions that may change with technology cost trajectories, tariff structures, and regulatory developments. Game parameters are stylized representations informed by qualitative findings and quantitative thresholds rather than precise behavioral estimates. Finally, the empirical focus is one community. While conceptual transferability is supported by the coordination mechanisms identified, empirical generalization should be approached cautiously and tested in additional settings.

## Conclusion

Decentralized microgrids can enable cleaner, safer, and more resilient electricity supply, but their adoption requires coordinated action under conditions shaped by social norms, trust, and institutional alignment. By integrating qualitative evidence, techno economic thresholds, and a formal asymmetric coordination game, this study explains why communities may remain trapped in a polluting and costly status quo even when alternatives exist, and under what conditions a cooperative transition becomes feasible. The findings suggest that just and inclusive energy transitions in culturally cohesive communities depend on aligning affordability, safety, and legitimacy through locally anchored governance and targeted policy interventions.