

# Energy Communities and the Sustainable City: An Insurance-Based Framework for Monetizing Positive Externalities and Territorial Value Creation – Evidence from the PART'Extern Project

*Rashmi Cannane<sup>1</sup>, Patrice Auclair<sup>1\*</sup>, Marie-Gabrielle Méry<sup>2</sup>, and Rafik Absi<sup>1,3†</sup>*

<sup>1</sup>Laboratoire de Recherche en Éco-Innovation Industrielle et Énergétique LR2E, École Supérieure d'Ingénieurs ECAM-EPMI, 13 Boulevard de l'Hautil, 95092 Cergy-Pontoise, France

<sup>2</sup>Seinergy Lab, 17 Rue Albert Thomas, 78130 Les Mureaux, France

<sup>3</sup>Quartz-Lab, École Supérieure d'Ingénieurs ECAM-EPMI, 13 Boulevard de l'Hautil, 95092 Cergy-Pontoise, France

**Abstract.** This paper presents the operational research conducted within the PART'Extern project (2023–2025), led by ECAM-EPMI in partnership with Seinergy Lab and supported by ADEME and PUCA. The project develops a structured and transferable methodology to identify, assess, and economically valorize the positive externalities produced by participatory renewable energy initiatives, with a particular focus on collective self-consumption schemes. The research bridges operational research, territorial governance, and sustainable finance through an integrated valuation framework. It resulted in (i) a methodological guide for stakeholders, (ii) a portfolio of quantified benefit sheets translating environmental and social impacts into economic indicators, and (iii) an innovative model assessing insurance-related value linked to risk reduction and enhanced territorial resilience. Findings demonstrate that making externalities visible, measurable, and economically translatable can transform intangible territorial benefits into bankable value. By strengthening financial robustness and facilitating access to public and private funding, this framework contributes to the consolidation of energy communities as long-term actors of the sustainable city. More broadly, the study advances research at the intersection of energy governance, territorial economics, and sustainable finance by proposing an operational and replicable approach to unlocking hidden territorial value.

---

\* Corresponding author: [auclair.patrice@wanadoo.fr](mailto:auclair.patrice@wanadoo.fr)

† Corresponding author: [r.absi@ecam-epmi.com](mailto:r.absi@ecam-epmi.com)

Keywords: Positive externalities; Energy communities; Collective self-consumption; Economic valuation; Territorial value; Energy transition; Sustainable finance; Applied research; Governance innovation.

## **1 Introduction**

### **1.1 Context and Motivation**

The energy transition requires innovative approaches that reconcile environmental objectives with economic sustainability. Participatory energy communities have emerged as a promising model to democratize access to renewable energy while generating shared value at the territorial level [1,2,3]. However, their economic viability is often limited because many of the positive externalities they create remain unrecognized and non-monetized [4,5,6,7,8].

The PART'Extern project, led by ECAM-EPMI in collaboration with Seinergy Lab and supported by ADEME and PUCA, addresses this gap by developing methodologies to identify, quantify, and economically valorize the positive externalities generated by collective self-consumption and local renewable energy initiatives [1,9,10].

### **1.2 Problem Statement and Research Objectives**

The central challenge is to design a robust, replicable framework for translating hidden socio-environmental benefits into measurable economic value [4,5,6]. Achieving this can expand access to both public and private financing and strengthen the financial models of energy communities.

The specific objectives of the project include:

- Developing a structured methodology for externality identification and valuation [2,3,7],
- Creating operational tools such as benefit sheets and communication materials [1,8,9],
- Engaging with stakeholders (public agencies, grid operators, and local partners) to validate and refine the methodology [10,11],
- Exploring monetization pathways, including insurance-related value and other financial leverage mechanisms [4,5,6].

### **1.3 Structure of the Paper**

The paper is organized as follows: Section 2 presents the institutional and scientific context, including ECAM-EPMI, Seinergy Lab, and the PART'Ener and PART'Extern projects. Section 3 details the methodology for identifying, quantifying, and monetizing positive externalities. Section 4 presents the results, highlighting key findings and illustrative case studies. Section 5 discusses the implications for public and private financing and policy. Finally, Section 6 concludes with lessons learned and perspectives for replicating the framework at a broader scale.

## 2 Key Activities, Achievements, and Project Contributions

The PART\*Extern project involved a multi-phase process aimed at identifying, quantifying, and monetizing the positive externalities of participatory energy communities. The activities and outcomes can be grouped into four main phases: immersion and conceptual understanding, development of methodological deliverables, synthesis and academic formalization, and strategic and business-oriented analysis.

### 2.1 Conceptualization and Methodological Foundations

The initial phase focused on consolidating the theoretical framework and understanding the multi-stakeholder ecosystem [2,3,7,12,13]. Key tasks included:

- Reviewing and critically analyzing existing methodological guides to improve clarity, coherence, and operational applicability.
- Studying the concept of insurance-related value, which quantifies benefits such as backup capacity during outages, flexibility for grid balancing, and avoided network investments [4,5,6].
- Engaging with institutional (ADEME, PUCA) and industrial partners to align methodological assumptions with practical requirements.

### 2.2 Development of Operational Deliverables

The project produced several concrete outputs to facilitate the identification and monetization of externalities:

- **Methodological Guide:** Structured into five chapters covering fundamental concepts, externality identification, quantification, monetization, and practical tools (interview grids, calculation models, visual aids). A hybrid approach combining Pigouvian and Coasean frameworks was implemented to link systematic identification with participatory validation [2,3,7].
- **Benefit Sheets:** Twenty standardized documents summarizing the environmental, social, and economic benefits of energy communities, including quantitative data, case illustrations, and practical recommendations [1,8,9].
- **Insurance Value Model:** A detailed calculation framework translating indirect benefits into economic metrics, supporting both project valuation and financing strategies [4,5,6].

### 2.3 Synthesis, Academic Formalization, and Dissemination

- Condensed the full methodological guide into a concise reference document for practitioners.
- Formalized the **insurance value concept** in a draft scientific article, establishing theoretical foundations based on real options theory, insurance economics, and electrical system analysis.
- Developed visual presentation materials to communicate key findings and methodologies to diverse stakeholders.
- Explored hybrid approaches integrating human expertise and AI-assisted data analysis for externality identification [1,10,11,14].

## 2.4 Strategic Analysis and Business Development

- Conducted a competitive landscape study to position the methodology within the broader market of impact evaluation and monetization services.
- Designed a Business Model Canvas identifying potential clients, value propositions, distribution channels, and revenue streams, emphasizing the economic leverage of quantified externalities.
- Analyzed stakeholder interviews to refine methodology applicability and ensure alignment with institutional, industrial, and local actor expectations.
- Prepared guidelines for future project extensions, including digitalization and deployment in other territorial energy initiatives [1,7,8,9].

### Summary of Contributions

Through these activities, the PART'Extern project produced a comprehensive, replicable framework for operationalizing the monetization of positive externalities in energy communities. The outputs provide both methodological rigor and practical tools for policy-makers, developers, and investors, enabling enhanced financial sustainability and scaling of local renewable energy initiatives.

## 3 Results

The PART'Extern project produced significant outputs advancing the operationalization and monetization of positive externalities in participatory energy communities. The results span methodological development, conceptual innovations, stakeholder validation, and insights for strategic implementation.

### 3.1 Major Project Deliverables

#### Methodological Guide

A comprehensive methodological guide was developed to enable systematic identification, quantification, and monetization of positive externalities [1,2,3,4,5,6]. The guide, structured into five chapters, integrates:

- Fundamental concepts and accessible definitions;
- Externality identification based on a hybrid approach combining Pigouvian and Coasean frameworks;
- Quantification and monetization methodologies;
- Practical tools including interview grids, evaluation templates, and illustrative case studies.

A total of 52 externalities were identified and organized into six coherent categories, each documented in a standardized benefit sheet. These sheets describe the mechanisms generating the benefit, indicators for measurement, and recommended valuation methods. The guide thus serves as both a scientifically rigorous framework and a practical operational tool for developers, policymakers, and other stakeholders.

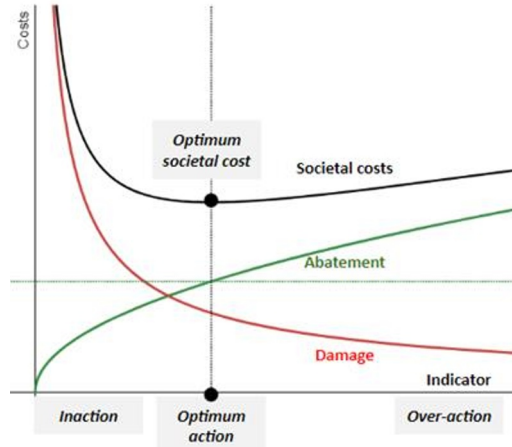
#### Insurance Value Model

The insurance value model represents a key conceptual and practical innovation [4,5,6]. This model quantifies the indirect economic contributions of energy communities, including:

- Backup capacity in case of outages;
- Flexibility for grid balancing;

- Avoided network investments.

The model integrates theoretical foundations from real options theory and insurance economics to assign economic value to previously invisible benefits. Its formalization provides a structured basis for project financing and investment assessment (Fig. 1).



**Fig. 1.** Graphical Representation of the Insurance Value.

### Calculation of Insurance Value

Investment and policy decisions often rely on a trade-off between mitigation costs and inaction costs [4,5]. The total societal cost for a given level of action ( $x$ ) is:

$$C_{\text{societal}}(x) = C_{\text{mitigation}}(x) + C_{\text{damages}}(x) \quad (1)$$

Graphically, this forms a bell-shaped curve, with the minimum representing the optimal societal cost [6], i.e., the level of action maximizing overall economic efficiency. The optimum occurs when the marginal mitigation cost equals the marginal cost of damages [6]:

$$\frac{dC_{\text{mitigation}}}{dx} = -\frac{dC_{\text{damages}}}{dx} \quad (2)$$

Using simplified cost functions (parabolic for mitigation and hyperbolic for damages), the optimal action level  $X_{\text{optimum}}$  is:

$$X_{\text{optimum}} = \left( -\frac{\beta b}{\alpha a} \right)^{\frac{1}{a-b}} \quad (3)$$

The insurance value corresponds to the economically optimal investment that minimizes total societal costs while increasing resilience:

$$\text{Insurance Value} = \alpha \cdot (X_{\text{optimum}})^a \quad (4)$$

This approach treats mitigation as a form of insurance against future risks from inaction.

### Mathematical Calculation of the Internalization Rate

Internalization Rate via Insurance Value

The internalization rate measures the share of mitigation costs actually covered by investments, relative to the optimal insurance value [4,5,6]:

$$\text{Internalization Rate} = \frac{\text{Actual Investment}}{\text{Insurance Value}} \quad (5)$$

It accounts for different types of contributions:

- Regulatory obligations (taxes, quotas, standards)
- Market mechanisms (certificates, carbon pricing)
- Voluntary initiatives (ESG commitments, CSR programs)

A rate below 100% indicates underinvestment compared to the optimal level, meaning positive externalities are not fully leveraged.

### Defining a Minimum Internalization Threshold

When full internalization is not feasible, a minimum threshold should be set to ensure a fair sharing of costs and benefits. The threshold depends on the type of externality:

- Public or common externalities (climate, air quality): collective impacts requiring contributions from the state, companies, and local authorities [7,8,12,13].
- Private or club externalities (microgrids, local communities): benefits shared within a smaller group [9,10,11].

For public externalities, the minimum threshold ( $\rho$ ) must ensure that residual damages remain below the optimal societal cost (CSO) [6] (Fig. 2):

$$Damages(\rho) \leq CSO \quad (6)$$

where:  $0 < \rho < 1$  is the internalization rate,  $Damages(\rho)$  are the residual costs borne by society, CSO is the optimal societal cost if full internalization were achieved.

This mechanism is based on the principle of social consent: as long as residual costs are acceptable, partial contributions by stakeholders are considered equitable.

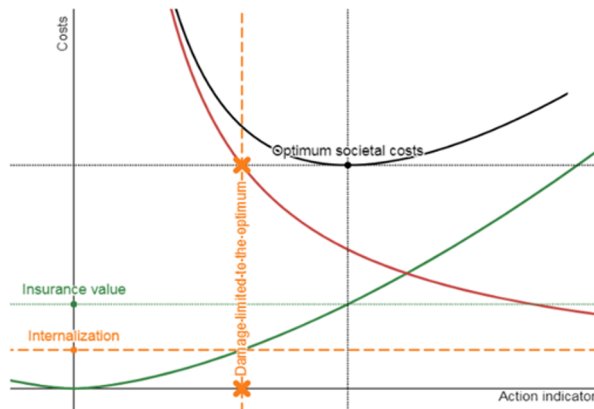


Fig. 2. Internalization Threshold to Cap Residual Damages at the Optimal Societal Cost (CSO).

## 3.2 Validation by Institutional Stakeholders

### ADEME

ADEME acknowledged the robustness of the hybrid methodology, noting its ability to combine methodological rigor with field applicability. The clear distinction between monetizable and non-monetizable benefits was particularly valued, allowing accurate evaluation without overestimating impacts. ADEME indicated interest in incorporating aspects of the methodology into national project funding and future calls for proposals.

### Seinergy-Lab and Local Communities

Field-level validation by Seinergy-Lab demonstrated that the guide and associated tools enhance the ability of local operators to communicate the full spectrum of project benefits,

from environmental to social and territorial impacts. This operational feedback confirms the methodology's usability and relevance in real-world energy community deployment.

### **3.3 Lessons Learned and Challenges**

#### **Conceptual Complexity**

The project required navigating complex economic concepts, such as positive externalities, insurance value, and hybrid valuation approaches. Systematic literature review and iterative validation were essential to ensure conceptual clarity and operational relevance.

#### **Multi-Stakeholder Coordination**

Managing diverse expectations across institutional, industrial, and local partners was a key challenge. Stakeholder mapping and tailored communication strategies were employed to align methodological outputs with practical and strategic requirements.

#### **Balancing Rigor and Pragmatism**

Ensuring methodological rigor while maintaining operational usability required iterative refinement of deliverables. The process emphasized a balance between thoroughness and the practical constraints of project implementation, resulting in tools that are both scientifically robust and actionable.

## **4 Conclusions**

The PART'Extern project demonstrates significant advances in the operationalization and monetization of positive externalities generated by participatory energy communities. The methodology developed combines scientific rigor with field applicability, providing a robust framework for identifying, quantifying, and valorizing both tangible and intangible benefits.

The methodological innovations, including the comprehensive guide, standardized benefit sheets, and the insurance value model, offer concrete tools to enhance the economic viability of energy communities and to support strategic decision-making for both developers and policymakers. By systematically capturing environmental, social, and economic externalities, the approach enables a broader recognition of the value created by renewable energy projects beyond mere energy production.

Multi-stakeholder validation—from ADEME, and local operators such as Seinergy-Lab—confirms the practical relevance and adaptability of the methodology. The hybrid approach, which combines participatory and analytical evaluation frameworks, ensures both reliability and operational feasibility, facilitating its integration into ongoing energy transition initiatives.

Looking forward, the methodology opens several avenues for further development:

- Short-term deployment across additional energy community projects to strengthen financial and operational sustainability;
- Medium-term innovation in digitalization and AI-assisted evaluation to streamline externality identification and monitoring;
- Long-term extension to other sectors of the ecological transition where capturing and valorizing positive externalities remains a key challenge.

In summary, PART'Extern provides a transferable, scientifically grounded, and practical framework to support sustainable energy transitions. The project illustrates how rigorous methodological development, combined with stakeholder engagement and operational validation, can accelerate the recognition and economic valuation of positive externalities, ultimately contributing to more resilient, inclusive, and impactful renewable energy initiatives.

## Acknowledgments

This research was funded by the French Agency for Ecological Transition (ADEME), grant number 22ESD0047. The study was conducted as part of the PART'Extern project, with financial support from ADEME (the French Environment and Energy Management Agency), and within the framework of the ENERCOM/“Énergie en commun” research call, co-led by PUCA (Plan Urbanisme Construction Architecture) and ADEME. The analyses and conclusions presented in this paper are the sole responsibility of the authors. The authors also wish to thank all stakeholders and experts who contributed through discussions and feedback during the project.

## References

1. Auclair, P.; Méry, M.-G.; Ramanamandimby, M.; Absi, R. Revealing Hidden Externalities for Collective Strategic Action. *Sustainability* 18, 1570 (2026). <https://doi.org/10.3390/su18031570>
2. Scitovsky, T. Two Concepts of External Economies. *J. Polit. Econ.* 1954, 62, 143–151.
3. Coase, R.H. The Problem of Social Cost. *J. Law Econ.* 1960, 3, 1–44.
4. Hanley, N., & Spash, C. L. *Cost-benefit analysis and the environment*. Edward Elgar Publishing, 1993.
5. Nordhaus, W. D. *Managing the global commons: The economics of climate change*. MIT Press, 1994.
6. Pearce, D., Atkinson, G., & Mourato, S. *Cost-benefit analysis and the environment: Recent developments*. OECD Publishing, 2006.
7. Ostrom, E. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press, Cambridge, UK, 1990.
8. Reed, M.S. Stakeholder Participation for Environmental Management: A Literature Review. *Biol. Conserv.* 2008, 141, 2417–2431.
9. Avelino, F.; Wittmayer, J.M. Shifting power relations in sustainability transitions: A multi-actor perspective. *J. Environ. Policy Plan.* 2016, 18, 628–649.
10. Walker, G.; Devine-Wright, P. Community and decentralised energy: Emotions, identity and public engagement. *Energy Policy* 2008, 36, 497–500.
11. Ferreira, E.; Sequeira, M.M.; Gouveia, J.P. Sharing Is Caring: Exploring Distributed Solar Photovoltaics and Local Electricity Consumption through a Renewable Energy Community. *Sustainability* 2024, 16, 2777. <https://doi.org/10.3390/su16072777>
12. Abadeço, M.; Rodrigues, M.J.; Ferrão, P.; Luz, G.; Freitas, S.; Brito, M.C. Solar Self-Consumption and Urban Energy Vulnerability: Case Study in Lisbon. *Sustainability* 2024, 16, 6635. <https://doi.org/10.3390/su16156635>

13. Geels, F.W. Socio-technical transitions to sustainability: A review of criticisms and elaborations of the multi-level perspective. *Curr. Opin. Environ. Sustain.* 2019, 39, 187–201.
14. Markard, J.; Geels, F.W.; Raven, R. Challenges in the acceleration of sustainability transitions. *Environ. Res. Lett.* 2020, 15, 081001.