IJPSC
International Journal of Psychology and Strategic Communication
ISSN: 2941-5691 (Online) 2941-5705 (Print) [64]
DOI: 10.61030/FMKU5576

BETWEEN THE COST CRISIS AND THE ENERGY TRANSITION: WHY PV SELF-SUFFICIENCY IS BECOMING A STRATEGIC COMPETITIVE FACTOR FOR INDUSTRY. RESULTS OF A QUALITATIVE STUDY COMPARING GERMANY AND CHINA

Dietmar Pfaff [1], Sascha Pohl[2], Dr. Patrick Hedfeld[3]

[1] *Graduate School IIC, University of Technology, Phnom Penh, Cambodia, e-mail: dp@dietmar-pfaff.de, mobile: +49-171-4519061*
[2] *FOM University of Applied Sciences for Economics & Management, Frankfurt/M., Head of Production at KARL MAYER, e-mail: saschapohl@outlook.com*
[3] *Goethe-University, Frankfurt/M., and FOM University of applied sciences e-mail: patrick.hedfeld@gmx.de*

Abstract

Rising energy costs, volatile electricity markets, and geopolitical uncertainties are reshaping the economic conditions of the manufacturing industry. Energy is therefore no longer perceived merely as an operational input, but increasingly as a strategic factor affecting competitiveness, resilience, and location quality. This article examines how energy self-sufficiency through solar energy is perceived and implemented in the manufacturing sector and identifies differences between Germany and China. The study is based on a qualitative, exploratory research design comprising six written expert surveys and a supplementary PESTEL analysis. The findings indicate that, in industrial practice, energy self-sufficiency is rarely understood as complete independence from the public grid; rather, it is perceived as a gradual and measurable reduction in external electricity demand. Photovoltaics seldom unfolds its strategic potential in isolation, but primarily as part of an integrated system consisting of storage, energy management, and load control. The main drivers include cost reduction, cost stability, security of supply, and resilience, while major barriers arise from grid connection procedures, approval processes, regulatory complexity, and investment constraints. The article thus demonstrates that PV-based self-sufficiency is far more than a sustainability technology for industrial firms; it is increasingly becoming an instrument of industrial risk and competitiveness management.

Keywords

Photovoltaics, energy self-sufficiency, manufacturing industry, self-sufficiency, energy management, Germany, China, qualitative research

Problem statement

The manufacturing industry is facing considerable pressure to adapt. High electricity and energy costs, volatile market prices, geopolitical uncertainties, and increasing transformation pressures are significantly altering the economic environment for many firms. Energy is therefore no longer regarded solely as an operational input, but increasingly as a strategic factor for competitiveness, resilience, and location attractiveness (Amann & Cantore, 2025; International Energy Agency, 2022; Wirth, 2026). Reuters reported in August 2024 that high energy prices and concerns about reliable supply were hindering production and investment among German companies and increasing relocation considerations, which directly supports the strategic relevance of energy costs for industrial competitiveness (Reuters, 2024).

Today, photovoltaics is more than a symbol of the energy transition. For industrial firms, it can become a lever for self-consumption, peak-load reduction, cost stability, and resilience, particularly when combined with storage systems, energy management systems, and demand-side management. Consequently, the question of energy self-sufficiency is not a peripheral technological debate, but one that touches upon fundamental issues of industrial location and competitiveness (López Prol & Paul, 2024; Luthander et al., 2015; Pedrero et al., 2021; Pelekas et al., 2026; Tjaden et al., 2015; Watter, 2025; Wirth, 2026).

Relevance of the chosen topic

The topic of PV-based energy self-sufficiency has gained relevance in current times as manufacturing companies are increasingly confronted with rising energy costs, volatile electricity markets, and growing pressure to ensure operational resilience and long-term competitiveness. In this context, photovoltaics combined with storage systems and energy management solutions is no longer viewed merely as an environmental or technological option, but as a strategic instrument for cost stability, supply security, and industrial competitiveness (International Energy Agency, 2022; Wirth, 2026). The relevance of the topic is further reinforced by current economic developments, particularly in industrial economies such as Germany and China, where firms are under increasing pressure to adapt their energy strategies to changing regulatory, geopolitical, and market conditions.

Analysis of recent research and publications

Recent research emphasizes that industrial photovoltaics creates the greatest value when integrated into broader energy management and self-consumption systems rather than implemented as an isolated technology. Studies by Luthander et al. (2015), Tjaden et al. (2015), and Pedrero et al. (2021) demonstrate that the combination of PV systems with battery storage and intelligent load management significantly improves self-consumption rates and economic efficiency. Similarly, López Prol and Paul (2024) and Pelekas et al. (2026) highlight that industrial energy resilience depends not only on renewable generation capacity, but also on the ability to coordinate flexibility, storage, and operational demand within integrated systems. These studies collectively show that technical integration and organizational adaptation are critical determinants of successful implementation.

At the same time, recent publications connect industrial energy self-sufficiency with broader strategic and geopolitical considerations. Cui et al. (2025) and Kaiser et al. (2025) discuss how national policy frameworks, market conditions, and industrial structures shape renewable energy adoption differently across countries. Research also points to growing concerns regarding industrial competitiveness under high and volatile energy prices, particularly in Europe (Amann & Cantore, 2025; Reuters, 2024). However, despite the growing body of literature on renewable energy systems and industrial transformation, comparatively little research focuses specifically on how manufacturing firms perceive and strategically implement PV-based self-sufficiency in practice, especially from a comparative Germany–China perspective.

Purpose of the article

The aim of this article is to present the core empirical findings of the underlying master's thesis in condensed form and to highlight the strategic relevance of PV-based self-sufficiency for the manufacturing industry. Conceptually, the study links the broader megatrend of self-sufficiency with the operational realities of manufacturing and a comparative market perspective on Germany and China. The empirical investigation is intended to generate practical insights into motives, barriers, and country-specific differences, thereby addressing a research gap between macro-level considerations, technology discourse, and operational implementation (Cui et al., 2025; International Energy Agency, 2022; Kaiser et al., 2025; Wirth, 2026).

The overarching research question is: How is energy self-sufficiency through solar energy perceived and implemented in the manufacturing industry in Germany and China, and which strategic motives and framework conditions shape these decisions? From this, three sub-questions are derived: First, which strategic motives guide investment decisions in solar energy and self-sufficiency? Second, which organizational, regulatory, and economic factors facilitate or hinder implementation in operational practice? Third, which differences and similarities can be identified between Germany and China with regard to the perception, implementation, and evaluation of energy self-sufficiency concepts? (Cui et al., 2025; Liebensteiner et al., 2025).

Presentation of the main research material and results obtained

The study follows a qualitative, exploratory research design. This approach was chosen because the objective is not statistical representativeness or the measurement of frequencies, but rather an in-depth understanding of decision-making logics, motives for action, and implementation conditions in the context of industrial PV self-supply. Qualitative research is particularly suitable for this type of inquiry when perceptions, strategic motives, and institutional framework conditions are to be captured and interpreted in depth. At the same time, the study can be understood as an exploratory preliminary step: it aims to identify thematic patterns, influencing factors, and initial assumptions that may later be examined and tested in quantitative studies (López Prol & Paul, 2024; Pelekas et al., 2026).

The primary data consists of six expert surveys completed in writing using a standardized, open-response format. Respondents were selected purposefully according to subject relevance and functional proximity to the field of investigation. Individuals with a recognizable connection to photovoltaics, solar projects, energy management, project development, storage solutions, or industrial energy practice were specifically sought. They were approached via professional networks based on keyword searches in publicly accessible profiles and technical descriptions, including terms such as photovoltaics, projects, solar energy, energy systems, and renewable energy. The intention was not to achieve broad statistical coverage, but to include individuals capable of providing well-founded insights into strategic, technical, and organizational implementation issues derived from professional practice (Kaiser et al., 2025; Pelekas et al., 2026). The thematic structure guiding the empirical investigation and the relationship between theoretical, practical, and market-related dimensions are summarized in Figure 1.

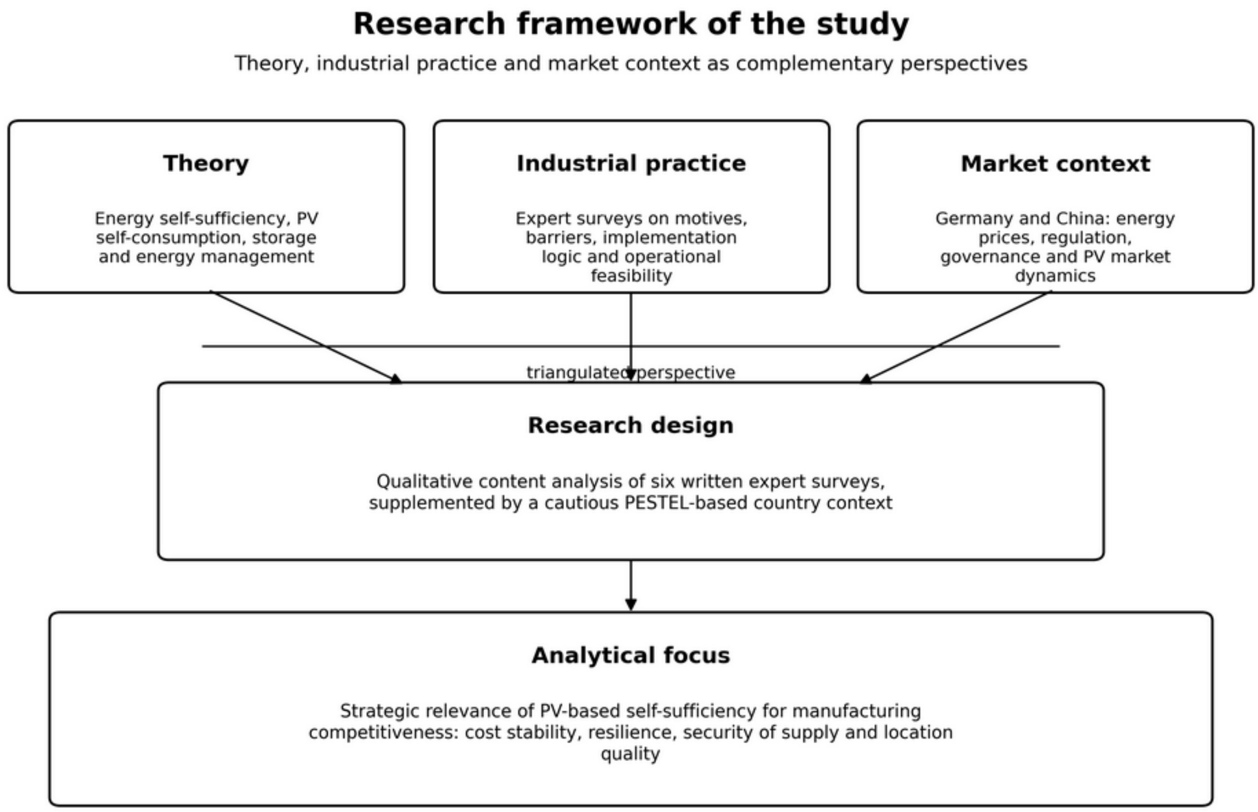

Fig. 1: Research framework of the study: Theory, practice and markets
Source: Compiled by authors

In anonymized form, the sample can be characterized as a combination of industrial user perspectives, project development and implementation perspectives, and research or system perspectives. This heterogeneity was deliberate, as it enabled the study to capture not only technical assessments, but also economic, organizational, and contextual viewpoints. The case selection therefore followed a targeted, problem-centered sampling strategy: actors were included who either influence decisions directly or possess substantial experience with the planning, implementation, evaluation, or classification of PV self-supply (Cui et al., 2025; Lal et al., 2026).

A standardized, open, guideline-based questionnaire was employed as the survey instrument. The guiding questions were derived from the research question as well as from the theoretical and practical groundwork of the thesis, especially the chapters dealing with energy self-sufficiency, photovoltaics, business models, technical and organizational implementation, and challenges in practice. The interview guide therefore specifically addressed the following aspects: the understanding and relevance of energy self-sufficiency, the role of solar energy in manufacturing, investment motives, business models such as CAPEX, contracting, and PPAs, load profiles and self-consumption, storage and energy management, organizational implementation, perceived barriers, and differences between Germany and China. The questions were designed to ensure comparability across cases while simultaneously leaving sufficient openness for respondents to articulate differentiated practical experiences (Liebensteiner et al., 2025; López Prol & Paul, 2024; Pelekas et al., 2026).

The supplementary country context was incorporated only in a cautious manner. It does not constitute an independent focus of the article, but serves solely to contextualize the empirical statements. The primary data was analyzed using qualitative content analysis according to Mayring with the support of MAXQDA. First, overarching deductive categories were developed from the theoretical framework and the questionnaire; subsequently, inductive subcategories were derived from the material itself. The responses were anonymized, only slightly smoothed linguistically where necessary, and left unchanged in substance. This rule-based coding procedure made it possible to systematically identify recurring patterns, contrast cases, and highlight country-specific differences, while maintaining close proximity to the empirical material (Mayring, 2010).

The results of the study are organized as follows:

1. Energy self-sufficiency as a pragmatic target: The qualitative content analysis shows, first, that energy self-sufficiency in the manufacturing industry is generally not understood as complete independence from the public electricity grid. Rather, respondents describe self-sufficiency as a gradual process, a reduction of external dependencies, and an economically meaningful control variable. The focus is not on absolute states, but on measurable indicators such as self-consumption, self-supply coverage, reduced grid consumption, or improved predictability of energy use and costs. In this sense, energy self-sufficiency is not conceptualized as an idealized end state, but as a relative and scalable concept.

   This understanding is central to the interpretation of the results because it translates a term that is often normatively charged in political and technological debates into a managerial and operational logic. Respondents closely connect self-sufficiency with practical economic realities: load profiles, generation periods, storage capacities, and the question of which level of self-sufficiency is technically feasible and economically reasonable. Full self-sufficiency thus appears more as a theoretical boundary case, whereas industrial practice is dominated by the notion of partial and incrementally expandable self-sufficiency. This interpretation is in line with the literature on PV self-consumption, which emphasizes that self-sufficiency is typically optimized through the alignment of generation, storage, and demand rather than through complete disconnection from the grid (Luthander et al., 2015; Tjaden et al., 2015; Wang et al., 2023).

2. Photovoltaics as an integrated system project: A second key finding concerns the role of photovoltaics as an integrated system project. Although respondents clearly describe photovoltaics as a central technology for achieving greater self-sufficiency, they rarely present it as a stand-alone solution. Strategic benefits arise primarily when PV systems are combined with storage solutions, energy management systems, load management, and operational process integration. The decisive factor is therefore not the individual technology itself, but the capacity to integrate generation, consumption, flexibility, and control into a resilient overall energy system (see Figure 2).

   This systemic logic is reflected in several major categories of analysis. On the one hand, photovoltaics is described as a key building block for self-consumption, self-generation, and peak shaving. On the other hand, respondents repeatedly refer to storage systems as a means of temporal balancing, to energy management systems for optimization and control, and to load management as the interface between energy generation and production processes. The focus is therefore not on maximizing autarky in absolute terms, but on achieving a degree of self-sufficiency that is economically viable within an integrated energy system. It is precisely this combination of technical solution and organizational embedding that respondents identified as critical to successful implementation. This finding is consistent with previous studies showing that the economic and operational value of PV significantly increases when combined with storage and intelligent energy management (Luthander et al., 2015; Martínez-Calahorro et al., 2020; Wang et al., 2023).

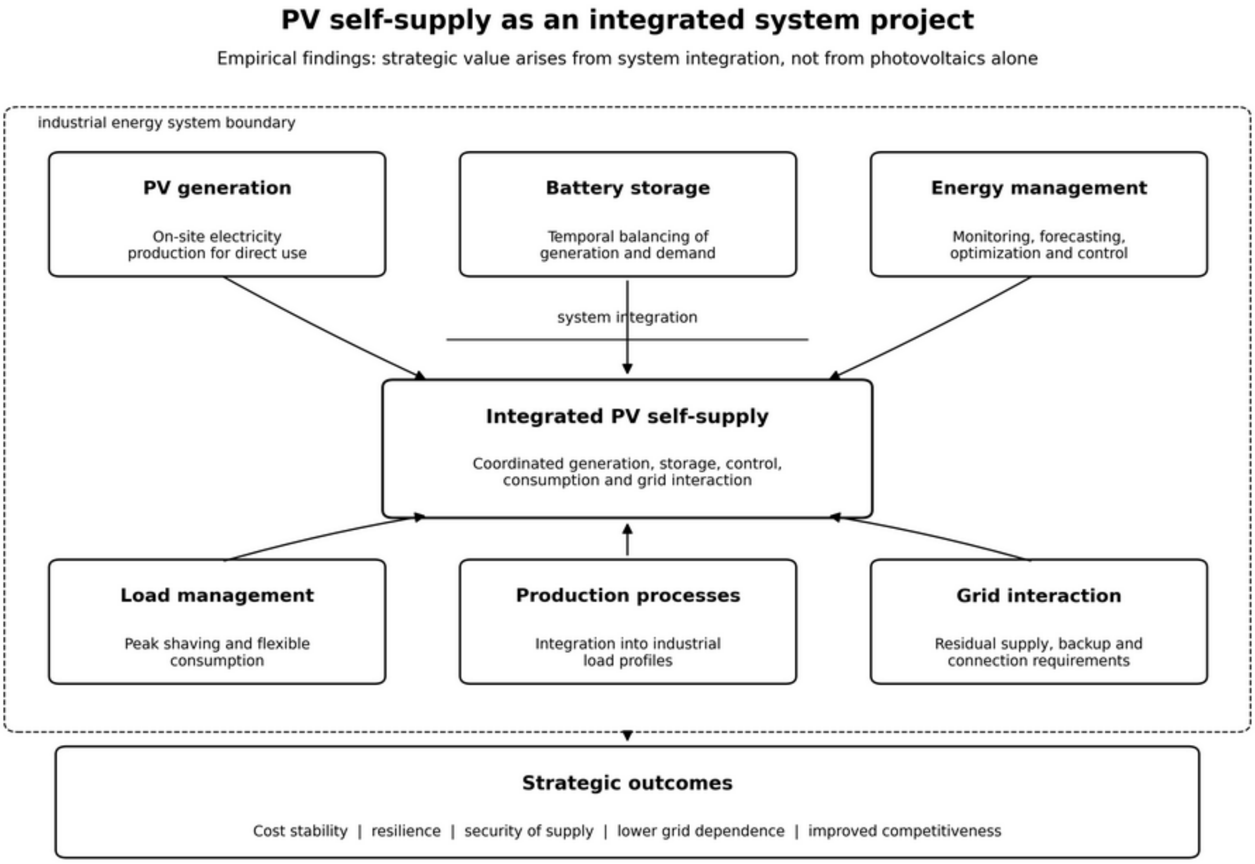

Fig. 2: PV self-supply as an integrated system project.
Source: Compiled by authors

3. Drivers, barriers, and country context: With regard to drivers, economic and strategic motives clearly dominate the interviews. Cost reduction, cost stability, and greater predictability of energy procurement are mentioned particularly frequently. For manufacturing firms, this predictability is especially important because energy costs directly affect production costs, pricing, and competitiveness. In addition, security of supply and resilience play a major role: several respondents describe self-sufficiency as a means of partially reducing dependence on volatile markets and making the company more robust against external price shocks. Sustainability and ESG objectives are also mentioned as relevant drivers, though rarely in isolation; instead, they are typically linked to economic and strategic considerations. This pattern corresponds with prior studies that identify economic attractiveness, stabilization of electricity costs, and improved local energy use as key drivers of self-consumption-oriented PV deployment (Martínez-Calahorro et al., 2020; Pedrero et al., 2021).

On the barrier side, grid connection processes, permitting requirements, bureaucratic burdens, regulatory complexity, and investment constraints are especially prominent. Several statements indicate that the core challenge does not lie in photovoltaic technology itself, but rather in its integration into existing operational, regulatory, and infrastructural structures. These include lengthy coordination procedures, uncertainties concerning metering and grid-connection concepts, questions of economic viability, and the difficulty of integrating technical solutions into actual load profiles and organizational processes. The interviews therefore suggest that implementation success depends to a large extent on institutional clarity, internal coordination, and systemic planning.

A comparison between Germany and China reveals differences particularly with regard to governance, implementation speed, and institutional logic. Germany appears more rule-based, federal, and process-driven; grid connection, permitting procedures, and technical system conditions significantly influence the pace of implementation. China, by contrast, appears more strongly shaped by industrial policy, decentralization, and scaling dynamics, albeit with regionally differentiated implementation practices. For the interpretation of the interviews, it is crucial to note that the same technology is evaluated and implemented differently under different institutional conditions. The differences therefore lie less in the fundamental level of interest in photovoltaics than in the mode and speed of implementation. This interpretation is broadly compatible with comparative work on photovoltaic market development and policy support in Germany and China (Quitzow, 2015; Wen et al., 2021).

The results suggest that energy self-sufficiency in an industrial context should not be understood as an ideal of complete independence, but rather as a strategically manageable and economically relative concept. This constitutes a key contribution of the study: a term that is often normatively framed in public debate is translated into the actual logic of corporate decision-making. The findings show that photovoltaics is perceived less as a symbolic technology of the energy transition and more as an instrument for cost stabilization, risk reduction, and security of supply. In doing so, the study addresses the identified research gap and provides practical qualitative insights into strategic motives and implementation logics.

At the same time, the analysis confirms that photovoltaics becomes strategically effective only when it is embedded within a broader system. It is not the solar installation itself, but its interaction with storage, energy management, load control, and organizational processes that determines its practical value. The results therefore support the argument that the strategic relevance of PV self-supply lies less in maximum independence than in a well-designed interplay of technology, efficiency, and organization. The comparison between Germany and China is particularly instructive in this respect, as it demonstrates the extent to which institutional conditions shape the practical effectiveness of the same technology.

However, the findings must also be interpreted critically. First, the study is qualitative and exploratory in nature and therefore not aimed at statistical representativeness. It identifies patterns, lines of argument, and thematic fields, but does not permit quantitative generalization to the manufacturing sector as a whole. Second, the number of experts surveyed is limited to six cases. A broader sample would have expanded the range of perspectives; at the same time, alternative survey formats would also have been conceivable, such as direct guideline-based interviews at trade fairs or industry events. Such settings might have generated additional spontaneous practical insights, clarifications, and contrasting cases.

Third, the written survey format allowed only limited opportunities for follow-up questions. As a result, the depth of individual statements varies, and some aspects—such as the detailed economic assessment, the role of load profiles, or specific implementation issues—could likely have been explored more precisely in oral in-depth interviews. Fourth, despite its rule-based coding procedure, qualitative content analysis inevitably retains a degree of interpretive openness. Additional validation through multiple coders would have further strengthened the robustness of the analysis.

Furthermore, certain stakeholder groups are not or only indirectly represented in the sample, including grid operators, permitting authorities, or industrial segments with different load structures and decision-making logics. The results therefore primarily provide insight into central field logics rather than a comprehensive representation of all relevant stakeholder groups. At the same time, this is precisely where the value of the study lies: it identifies those thematic areas that are particularly suitable for subsequent broader quantitative research or supplementary interview-based and event-based formats. In this methodological sense, the study also reflects the logic of triangulation and the staged generation of knowledge in exploratory research (Bogner et al., 2009; Flick, 2011).

Conclusions

The main research question can be answered as follows: in the manufacturing industry, energy self-sufficiency through solar energy is predominantly perceived as a relative and strategically controllable concept. The focus is not on complete independence, but on a reduction in grid electricity procurement that is economically meaningful. Photovoltaics is regarded as an important building block in this context, yet its full effect unfolds primarily in interaction with storage, energy management, load management, and operational integration.

The sub-research questions can also be answered clearly. First, investment decisions are guided primarily by cost reduction, cost stability, security of supply, and resilience; sustainability and ESG considerations play a complementary role. Second, implementation is shaped not only by technical factors, but also by organizational, regulatory, and economic framework conditions, including grid connection, permitting logic, capital commitment, and internal coordination. Third, differences between Germany and China are especially evident in governance structures, implementation speed, and institutional logic. Overall, the study shows that PV-based self-sufficiency is increasingly becoming a strategic competitive factor for the manufacturing industry. Its scientific contribution lies in the practical specification of the concept of energy self-sufficiency, in linking megatrends, industrial practice, and market context, and in highlighting the conditions under which photovoltaics becomes strategically effective in an industrial setting.

References

Amann, J., & Cantore, N. (2025). Energy prices and competitiveness in the manufacturing sector. Munich Personal RePEc Archive. Forthcoming in Contribution to Economics: Food-Energy-Water Nexus – Integrated Challenges and Global Perspectives (2026).

Bogner, A., Littig, B., & Menz, W. (2009). Experteninterviews: Theorien, Methoden, Anwendungsfelder (3rd ed.). VS Verlag für Sozialwissenschaften.

Cui, C., Lonergan, K. E., & Sansavini, G. (2025). Policy-driven transformation of global solar PV supply chains and resulting impacts. Nature Communications, 16, 6742. https://doi.org/10.1038/s41467-025-61979-5

Flick, U. (2011). Triangulation: Eine Einführung (3rd ed.). VS Verlag für Sozialwissenschaften.

International Energy Agency. (2022). Unlocking the potential of distributed energy resources. IEA. https://www.iea.org/reports/unlocking-the-potential-of-distributed-energy-resources

Kaiser, M., Senkpiel, C., Henning, H.-M., & Kost, C. (2025). Direct and indirect electrification in the German industry from a sector-coupled energy system modeling perspective. Energy and Climate Change, 28, 101305. https://doi.org/10.1016/j.ecmx.2025.101305

Lal, A., Tavoni, M., Preuss, N., et al. (2026). Aligning EU energy security and climate mitigation through targeted transition strategies. Nature Communications, 17, 875. https://doi.org/10.1038/s41467-025-67595-7

Liebensteiner, M., Ocker, F., & Abuzayed, A. (2025). High electricity price despite expansion in renewables: How market trends shape Germany's power market in the coming years. Energy Policy, 198, 114448. https://doi.org/10.1016/j.enpol.2024.114448

López Prol, J., & Paul, A. (2024). Profitability landscapes for competitive photovoltaic self-consumption. Energy Policy, 188, 114084. https://doi.org/10.1016/j.enpol.2024.114084

Luthander, R., Widén, J., Nilsson, D., & Palm, J. (2015). Photovoltaic self-consumption in buildings: A review. Applied Energy, 142, 80–94. https://doi.org/10.1016/j.apenergy.2014.12.028

Martínez-Calahorro, A. J., Jiménez-Castillo, G., Rus-Casas, C., Gómez-Vidal, P., & Muñoz-Rodríguez, F. J. (2020). Photovoltaic self-consumption in industrial cooling and refrigeration. Electronics. https://zenodo.org/records/18202770/files/09-Photovoltaic%20Self-Consumption%20in%20Industrial%20Cooling%20and%20Refrigeration.pdf

Mayring, P. (2010). Qualitative Inhaltsanalyse. In G. Mey & K. Mruck (Eds.), Handbuch qualitative Forschung in der Psychologie (pp. xxx–xxx). VS Verlag für Sozialwissenschaften. https://doi.org/10.1007/978-3-531-92052-8_42

Pedrero, J., Hernández, P., & Martínez, Á. (2021). Economic evaluation of PV installations for self-consumption in industrial parks. Energies, 14(3), 728. https://doi.org/10.3390/en14030728

Pelekas, N., Keskinis, S., Kosmadakis, I. E., & Elmasides, C. (2026). Optimizing industrial energy saving with on-site photovoltaics: A zero feed-in case study in Greece. Solar, 6(2), 12.

Quitzow, R. (2015). Dynamics of a policy-driven market: The co-evolution of technological innovation systems for solar photovoltaics in China and Germany. Environmental Innovation and Societal Transitions, 17, 126–148. https://doi.org/10.1016/j.eist.2014.12.002

Reuters. (2024, August 1). More German companies mull relocation due to high energy prices—survey. Reuters. https://www.reuters.com/business/energy/more-german-companies-mull-relocation-due-high-energy-prices-survey-2024-08-01/

Tjaden, T., Schnorr, F., Weniger, J., Bergner, J., & Quaschning, V. (2015). Einsatz von PV-Systemen mit Wärmepumpen und Batteriespeichern zur Erhöhung des Autarkiegrades in Einfamilienhaushalten [Conference paper]. 30. PV-Symposium. https://solar.htw-berlin.de/publikationen/waermepumpen-batteriespeicher/

Wang, Z., Luther, M. B., Horan, P., Matthews, J., & Liu, C. (2023). On-site solar PV generation and use: Self-consumption and self-sufficiency. Building Simulation, 16(10), 1835–1849. https://doi.org/10.1007/s12273-023-1007-3

Watter, H. (2025). Regenerative Energiesysteme: Grundlagen, Systemtechnik und Analysen ausgeführter Beispiele nachhaltiger Energiesysteme. Springer Vieweg.

Wen, D., Gao, W., Qian, F., Gu, Q., & Ren, J. (2021). Development of solar photovoltaic industry and market in China, Germany, Japan and the United States of America using incentive policies. Energy Exploration & Exploitation, 39(5), 1429–1456. https://doi.org/10.1177/0144598720979256

Wirth, H. (2026). Aktuelle Fakten zur Photovoltaik in Deutschland. Fraunhofer-Institut für Solare Energiesysteme ISE. https://www.ise.fraunhofer.de/de/veroeffentlichungen/studien/aktuelle-fakten-zur-photovoltaik-in-deutschland.html