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Inquiry-Based Learning in Renewable Energy Education: A Systematic Review of Conceptual Understanding, Energy Literacy, and Scientific Thinking Skills

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ABSTRACT

Renewable energy education has become an essential component of science, STEM, engineering, environmental, and sustainability education because energy transition requires learners who can understand complex energy systems, evaluate evidence, and reason about socio-scientific trade-offs. Inquiry-based learning is a promising pedagogical model for this purpose because it engages learners in questioning, investigation, data interpretation, explanation construction, and reflection. This systematic literature review synthesizes education-relevant renewable-energy studies from a Scopus-exported dataset containing 193 records. Because the dataset was dominated by technical, forecasting, optimization, and energy-management studies, the review adopted a focused title-and-abstract screening strategy to identify studies with direct or adjacent relevance to renewable energy education, learner outcomes, public education, workforce preparation, campus sustainability, community energy, and energy literacy. Thirty studies were included in the thematic synthesis. The findings indicate that renewable energy education is most frequently operationalized through engineering curriculum reform, micro-credentials, school and campus renewable-energy infrastructure, community-based projects, entrepreneurship education, workforce skills mapping, and public awareness initiatives. Across these contexts, inquiry-compatible learning is supported by authentic energy data, local energy problems, hands-on or simulation-based tasks, and socio-economic decision-making. The review argues that inquiry-based renewable energy education should move beyond factual content delivery toward conceptual understanding, energy literacy, scientific thinking, systems reasoning, and sustainability-oriented action competence. The article concludes with a conceptual framework and future research agenda for strengthening empirical inquiry-based renewable energy education.

Keywords: inquiry-based learning; renewable energy education; energy literacy; scientific thinking; conceptual understanding; sustainability education; STEM education

1. INTRODUCTION

Renewable energy education has become increasingly important as schools, universities, communities, and professional-training systems respond to climate change, energy transition, decarbonization, and the demand for green skills. Renewable energy is not only a technical issue involving solar photovoltaics, wind turbines, hydropower, hydrogen, battery storage, smart grids, and community energy systems. It is also a pedagogical issue because learners must understand energy transformation, efficiency, intermittency, infrastructure, affordability, justice, and sustainability-oriented decision-making.

Inquiry-based learning is highly relevant for renewable energy education because the topic can be investigated through observable phenomena, measurable data, experimental systems, local infrastructure, and community problems. In inquiry-oriented classrooms, students can ask questions about solar-panel efficiency, compare design variables in wind turbines, evaluate household energy choices, interpret campus energy data, or assess community acceptance of renewable-energy projects. These activities position students as evidence users and knowledge builders rather than passive recipients of technical facts.

The provided Scopus export shows that the broader renewable-energy literature is dominated by technical topics such as machine learning forecasting, grid optimization, microgrid management, storage systems, electric-vehicle charging, and smart-grid control. This creates a gap for a pedagogically focused synthesis. Although technical studies are essential for the energy transition, they do not necessarily explain how renewable energy should be taught, how learners develop energy literacy, or how inquiry-based activities can support conceptual understanding and scientific thinking.

The purpose of this systematic literature review is therefore to synthesize studies that connect renewable-energy content with educational, social, community, workforce, or learner-oriented outcomes. The review is guided by four research questions: (1) How is inquiry-compatible learning implemented in renewable energy education? (2) What renewable-energy topics and learning contexts are most frequently addressed? (3) What learning outcomes are reported in relation to conceptual understanding, energy literacy, and scientific thinking? and (4) What pedagogical challenges, enabling factors, and research gaps influence implementation?

2. MATERIALS & METHODS

2.1 Review Design and Data Source

This article follows a systematic literature review logic using the dataset provided by the user as the evidence base. The primary source was a Scopus-exported plaintext dataset dated 5 June 2026. The export contained 193 bibliographic records. A second document, the reference summary, provided bibliographic details and abstracts for the records. A third document, the research notes, supplied the developed title, core argument, outline, and preliminary extraction tables.

The review was designed as a thematic SLR rather than a meta-analysis because the included studies differ substantially in research purpose, population, methodology, and outcome type. The evidence base includes curriculum reform, micro-credential development, environmental awareness surveys, campus energy-system case studies, community renewable-energy projects, household energy-choice studies, labor-market analyses, and socio-economic analyses of renewable-energy adoption.

2.2 Search Strategy

The conceptual search strategy combined three blocks: inquiry-based learning terms, renewable-energy education terms, and learning-outcome terms. The guiding Boolean search string was:

("inquiry-based learning" OR "inquiry learning" OR "guided inquiry" OR "open inquiry" OR "structured inquiry" OR "scientific inquiry") AND ("renewable energy education" OR "renewable energy learning" OR "solar energy education" OR "wind energy education" OR "sustainable energy education" OR "energy literacy") AND ("conceptual understanding" OR "energy literacy" OR "scientific thinking"

OR "scientific reasoning" OR "critical thinking" OR "problem solving")

Because the supplied Scopus export retrieved many technical renewable-energy records, the screening process prioritized studies that included education, learning, student, school, university, curriculum, training, public awareness, community learning, skills, or educational-outcome dimensions.

2.3 Eligibility Criteria

Studies were included when they addressed renewable energy, sustainable energy, clean energy, distributed energy, or energy transition in a way that was relevant to education, learning, awareness, community capacity, workforce preparation, or learner outcomes. Studies were excluded when they were purely technical, such as forecasting, optimization, power-system control, or equipment diagnosis studies with no educational or learner-oriented dimension.

2.4 Screening and Selection

The initial dataset contained 193 Scopus records. Title-and-abstract screening excluded 120 records that were primarily technical and lacked pedagogical relevance. Seventy-three records were assessed for education, community, workforce, or learning relevance. Forty-three were excluded because they did not provide a clear instructional context, learner outcome, public-education focus, or education-adjacent implication. Thirty studies were retained for thematic synthesis. The PRISMA-style flow is shown in Figure 1.

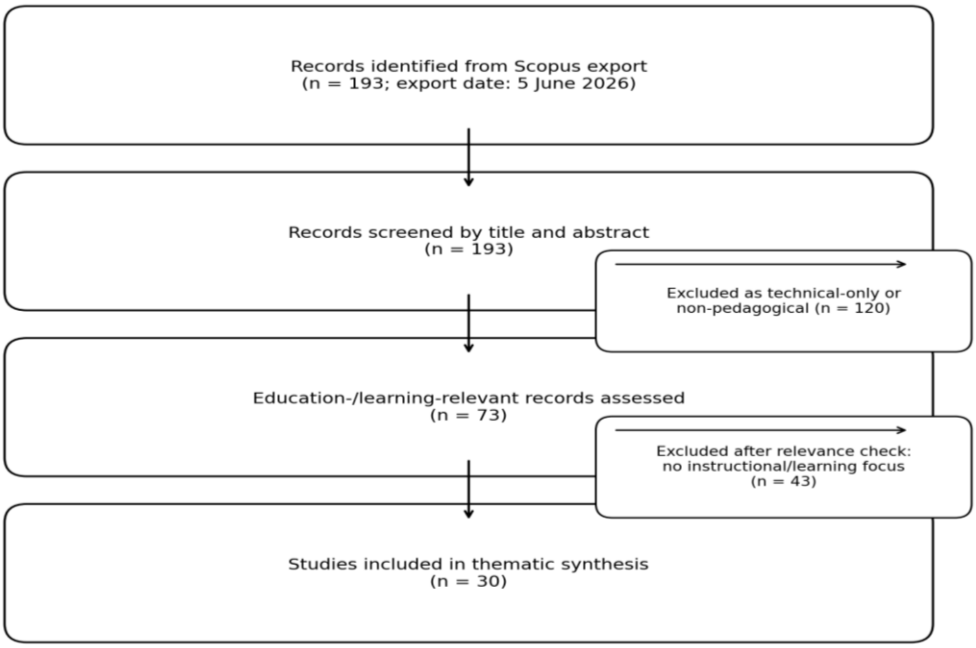

Figure 1. PRISMA-style flow diagram for the abstract-level screening process.

2.5 Data Extraction and Synthesis

Data were extracted into four thematic matrices: instructional designs, renewable-energy topics and learning contexts, learning outcomes, and implementation challenges. The extracted fields included reference, learner group, educational context, renewable-energy topic, learning activity, assessment method, reported finding, enabling factor, implementation challenge, and implication for inquiry-based renewable energy education. The synthesis used thematic aggregation, looking for recurring patterns across educational levels, contexts, renewable-energy technologies, and learning outcomes.

LITERATURE REVIEW

3.1 Inquiry-Based Learning as Constructivist Pedagogy

Inquiry-based learning is grounded in the constructivist assumption that learners build understanding through active engagement with phenomena, evidence, and explanation. Rather than receiving information as finished knowledge, learners formulate questions, design or follow investigations, collect and interpret data, construct explanations, and reflect on the credibility of their conclusions. Different forms of inquiry vary in teacher guidance: structured inquiry provides procedures and questions, guided inquiry provides scaffolds while allowing learner decision-making, and open inquiry gives learners substantial autonomy.

Renewable energy is well suited to inquiry because it involves variables, data, uncertainty, systems, and trade-offs. For example, learners can investigate how solar irradiance, panel orientation, shading, temperature, or storage capacity influences energy output. They can also examine why renewable-energy adoption is shaped by cost, infrastructure, policy, community trust, and equity. This makes renewable energy a bridge between scientific inquiry and socio-scientific reasoning.

3.2 Renewable Energy Education and Energy Literacy

Energy literacy refers to the ability to understand energy concepts, interpret energy systems, evaluate energy choices, and make informed decisions about energy use and sustainability. Renewable energy education contributes to energy literacy when it connects scientific principles with environmental responsibility, technological design, economic feasibility, and civic decision-making.

The reviewed literature suggests that renewable energy education appears in multiple learning contexts: engineering programs, micro-credentials, public education, school infrastructure, university campuses, community renewable-energy projects, entrepreneurship education, workforce training, and policy-oriented learning. This diversity implies that inquiry-based renewable energy education should not be limited to laboratory experiments; it should also include community inquiry, data inquiry, design inquiry, and socio-economic inquiry.

3.3 Scientific Thinking Skills in Renewable Energy Inquiry

Scientific thinking skills in renewable energy inquiry include asking investigable questions, identifying variables, designing experiments, interpreting data, using models, evaluating evidence, comparing alternatives, and justifying decisions. When learners examine renewable energy as a real-world system, scientific thinking expands into systems thinking, risk analysis, ethical reasoning, and sustainability-oriented decision-making.

RESULT

4.1 Inquiry-Oriented Instructional Designs in Renewable Energy Education

The first theme concerns how renewable energy education is designed. The included studies show that inquiry-compatible renewable energy education is implemented through curriculum-integrated experiential learning, modular micro-credentials, school-based public education, community-based problem-solving, entrepreneurship education, workforce skills mapping, and applied design learning.

Friman (2024) illustrates curriculum-integrated experiential learning in engineering education by combining laboratories, lectures, expert discussions, and online courses. De Rosa et al. (2024) show how micro-credentials can support flexible lifelong learning in urban renewable energy and sustainable fuels. Friman et al. (2022) position schoolchildren as a channel for preparing public acceptance of distributed energy systems. Yoon et al. (2021) demonstrate how school facilities can become solar-energy learning environments through building-integrated photovoltaic design. Together, these studies suggest that inquiry-based renewable energy education requires authentic contexts, not merely textbook explanations.

4.2 Renewable Energy Topics and Learning Contexts

The second theme identifies the topics and contexts used for renewable energy learning. Solar energy is the most visible and accessible topic because it can be observed in school façades, campus PV systems, residential applications, and community energy planning. Wind, hydropower, battery storage, distributed energy systems, smart grids, energy communities, and hybrid renewable systems also appear as learning contexts.

Campus-based studies are especially valuable for inquiry-based education because they provide real operational data and visible energy infrastructure. Alfraidi (2025), Zukowski and Sobolewski (2025), and Icaza-Alvarez and Borge-Diez (2025) show that university campuses can be used to analyze PV design, battery storage, net-zero transition, hybrid energy systems, and techno-economic feasibility. Community-level studies, such as Alam et al. (2021), Lucas and Carvalhosa (2022), and Ahmed (2026), extend renewable energy education beyond classrooms by connecting technology with community ownership, local data, and equity.

4.3 Learning Outcomes: Conceptual Understanding, Energy Literacy, and Scientific Thinking

The third theme concerns learning outcomes. The included studies rarely measure inquiry-based learning outcomes directly, but they provide strong evidence of education-adjacent outcomes such as conceptual understanding, environmental awareness, green consumer values, green entrepreneurial intentions, workforce readiness, applied energy reasoning, sustainability understanding, and community problem-solving capacity.

Szeberényi et al. (2022) found that education level alone did not guarantee stronger environmental awareness among students, which supports the need for more active and reflective learning. Singh et al. (2023) emphasized societal education for nurturing green consumer values and renewable-energy reliance. Sobczak et al. (2025) linked entrepreneurship education with interest in renewable energy investment and innovation. Ahmed (2026) showed that renewable-energy deployment can affect educational attainment but that benefits are uneven across communities. These findings reinforce the argument that inquiry-based renewable energy education should develop not only technical knowledge but also energy literacy, equity reasoning, and sustainability-oriented action competence.

4.4 Pedagogical Challenges, Enabling Factors, and Research Gaps

The fourth theme reveals that the challenges of renewable energy education are not only instructional. They are social, economic, institutional, technological, and equity-related. Public acceptance of renewable heating depends on trust, perceived benefits, affordability, and community engagement (Magnani et al., 2026). Rural acceptance is shaped by age and awareness (Chomać-Pierzecka et al., 2025). Household clean-energy choices are influenced by education, income, infrastructure, and access to credit (Ahmar et al., 2022). These factors indicate that energy literacy must include socio-economic reasoning.

Enabling factors include teacher and curriculum readiness, access to low-cost experimental systems, digital simulations, local energy data, stakeholder co-design, community engagement, policy transparency, and workforce alignment. However, the central research gap remains the lack of direct empirical studies that test inquiry-based learning models in renewable energy education using validated instruments for conceptual understanding, energy literacy, and scientific thinking.

5. INTEGRATED CONCEPTUAL FRAMEWORK

Figure 2 summarizes the conceptual framework emerging from the review. Inquiry-based renewable energy education can be understood as the alignment of inquiry processes, renewable-energy content, learning contexts, and learning outcomes. The framework suggests that renewable energy learning becomes pedagogically powerful when learners move through inquiry processes while engaging with authentic energy systems and producing evidence-based explanations or decisions.

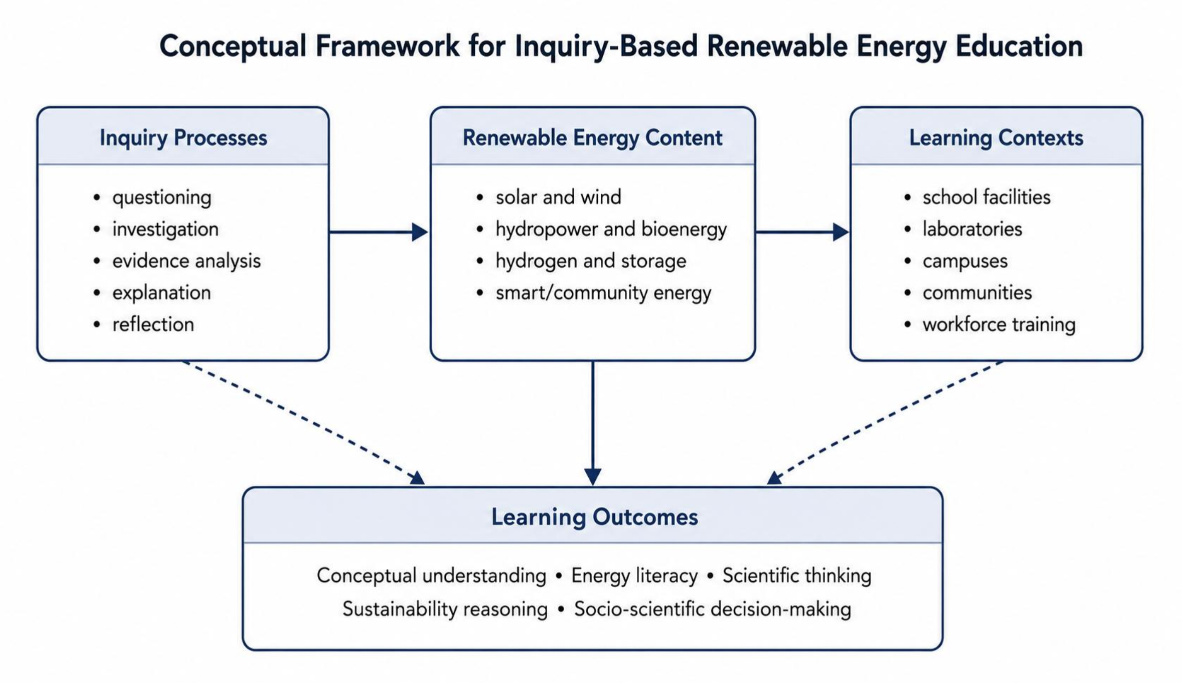

Figure 2. Conceptual framework for inquiry-based renewable energy education.

The framework also highlights that renewable energy education should integrate scientific inquiry with socio-scientific inquiry. Students should learn how energy technologies work, but they should also investigate who benefits, who faces barriers, how costs are distributed, how communities perceive renewable-energy infrastructure, and how energy transition can support educational and human-development outcomes.

6. DISCUSSION

Overall, the review indicates that renewable energy is an authentic and interdisciplinary context for inquiry-based learning. The topic is conceptually rich because it involves physics, environmental science, engineering, economics, policy, and ethics. It is also practically rich because it can be observed through solar panels, wind turbines, campus energy systems, household energy behavior, community energy planning, and local sustainability problems.

The strongest contribution of inquiry-based learning is that it can transform renewable energy from a list of technologies into a process of investigation and reasoning. Students can examine how a solar panel's output changes under different conditions, how a community can reduce dependence on diesel generators, how a campus can approach net-zero readiness, how household factors affect clean-energy choices, or how local communities evaluate renewable-energy projects. These learning tasks strengthen conceptual understanding because students must connect scientific principles to observed outcomes.

The review also shows that energy literacy requires more than technical knowledge. Public acceptance, affordability, institutional trust, socio-economic vulnerability, energy poverty, and equity repeatedly appear in the included studies. Inquiry-based renewable energy education should therefore include questions about justice, policy, finance, and community engagement. This is consistent with the broader role of sustainability education, which asks learners to understand complex systems and make evidence-informed decisions.

Another important finding is that university campuses and schools can serve as living laboratories. Studies of PV systems on university buildings, net-zero campus transition, hybrid renewable systems, and solar modules on school façades provide concrete examples of how institutions can turn infrastructure into learning resources. These contexts allow learners to work with real data, evaluate design alternatives, and connect scientific concepts with institutional sustainability goals.

However, the review also exposes an evidence gap. Most included studies are not direct experimental studies of inquiry-based renewable energy learning. Many are education-adjacent studies that imply learning potential rather than measure inquiry outcomes directly. Future research should therefore conduct intervention studies comparing structured, guided, and open inquiry models in renewable-energy topics and should use validated instruments to measure conceptual understanding, energy literacy, scientific thinking, systems thinking, and sustainability behavior.

7. IMPLICATIONS

7.1 Implications for Educators

Educators should design renewable energy learning around investigable problems. Instead of asking students only to define renewable energy, teachers can ask students to test how panel angle affects solar output, compare energy storage scenarios, model household energy choices, or evaluate whether a local community project is socially and economically feasible.

Guided inquiry may be especially appropriate because renewable energy concepts can be complex. Teachers can provide scaffolds such as data sheets, simulation tools, concept maps, and guiding questions while still allowing students to interpret evidence and justify decisions.

7.2 Implications for Curriculum Designers

Curriculum designers should integrate renewable energy across science, STEM, engineering, environmental education, entrepreneurship, and citizenship education. The review suggests that energy literacy should include technical understanding, economic reasoning, environmental awareness, and community decision-making. Micro-credentials and modular learning pathways can support flexible learning for students and professionals.

7.3 Implications for Researchers

Researchers should move from descriptive renewable-energy education studies toward intervention-based research. There is a need for quasi-experimental studies, longitudinal studies, validated assessment instruments, classroom design studies, teacher professional-development research, and comparative studies across educational levels and cultural contexts.

Limitations

This draft review is limited by the dataset provided. The Scopus export was broad and heavily oriented toward technical renewable-energy studies, particularly machine learning forecasting, optimization, smart grids, and energy management. As a result, the final synthesis includes many education-adjacent studies rather than only direct inquiry-based learning studies.

The screening was conducted at the title-and-abstract level using the provided bibliographic records and reference summaries. A final publishable SLR would require full-text screening, independent reviewer agreement, formal quality appraisal, and database expansion to education-focused sources such as ERIC, Web of Science, and discipline-specific STEM education databases.

CONCLUSION

This systematic literature review argues that inquiry-based learning offers a strong pedagogical pathway for renewable energy education. Renewable energy is an ideal context for inquiry because it involves observable phenomena, measurable variables, authentic infrastructure, socio-economic trade-offs, and urgent sustainability challenges. Inquiry-based learning can support conceptual understanding, energy literacy, scientific thinking, systems reasoning, and sustainability-oriented decision-making.

The review identifies several promising learning contexts: engineering curricula, micro-credentials, school-based solar infrastructure, campus energy systems, community-owned renewable-energy projects, public education, entrepreneurship education, and workforce training. These contexts provide authentic problems and evidence sources that can be transformed into inquiry-based learning activities.

At the same time, the review shows that direct empirical evidence on inquiry-based renewable energy education remains limited. Future research should design and evaluate inquiry interventions that explicitly target renewable energy concepts and assess learning outcomes using robust measures. The field would benefit from research that connects classroom inquiry with real energy systems, local community problems, and equity-oriented sustainability goals.

Declaration by Authors

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APPENDIX A. EVIDENCE EXTRACTION TABLES

Table 1. Essential summary of findings on inquiry-oriented instructional designs in renewable energy education.

References	Education Level / Target Learners	Instructional Design	Renewable Energy Topic	Learning Activity / Educational Approach	Key Pedagogical Finding
Friman (2024)	Undergraduate engineering students	Curriculum-integrated experiential learning	Renewable energy technologies, smart grids, sustainable energy systems	Professional laboratories, in-person lectures, expert discussions, and online courses integrated into an Electrical and Electronics Engineering curriculum	A holistic curriculum combining theory, laboratory experience, industry exposure, and digital learning can prepare future engineers for sustainable energy transitions.
De Rosa et al. (2024)	Students and professionals	Modular lifelong-learning design	Urban renewable energy and sustainable fuels	Stackable micro-credentials co-designed with stakeholders and informed by labor-market analytics	Micro-credentials provide flexible green upskilling and reskilling when renewable energy learning is aligned with workforce needs.
Friman et al. (2022)	Schoolchildren and wider community	Community-oriented public education	Distributed energy systems and renewable energy	Schoolchildren are positioned as community learning agents for preparing acceptance of distributed energy systems	School-based renewable energy education can influence public awareness, energy efficiency behavior, and community readiness for decentralized systems.
Szeberényi et al. (2022)	Primary, secondary, and university students	Awareness-based environmental learning	Renewable energy use and environmental awareness	Large-scale student survey on renewable-energy attitudes and environmental awareness	Higher education level does not automatically guarantee stronger renewable-energy awareness, indicating the need for more active, inquiry-oriented learning.
Sobczak et al. (2025)	University students	Entrepreneurship-oriented renewable energy learning	Renewable energy investment, green entrepreneurship, sustainable development	Surveys and interviews on economic knowledge, environmental knowledge, self-efficacy, and entrepreneurial intention	Renewable energy education can cultivate green entrepreneurial intentions when it connects sustainability, economic feasibility, innovation, and self-efficacy.
Arcelay et al. (2021)	Renewable energy workforce, education centers, policymakers	Competency-based training design	Renewable-energy sector skills and Industry 4.0 transition	Skills mapping and prediction of future job-profile requirements	Renewable energy education must anticipate future technical, digital, and sustainability competencies.
Pilipczuk (2024)	Education systems and future renewable energy workforce	Labor-market-responsive education design	Renewable energy employment and workforce development	Literature and statistical analysis of employment trends and competency changes	Education systems need rapid adaptation to renewable-energy labor-market demand.
Ahmed (2026)	Community-level educational outcomes	Equity-oriented renewable energy learning context	Renewable energy deployment and educational attainment	Causal and spatial analysis linking renewable energy projects with educational outcomes	Renewable energy development can influence educational outcomes, but equity gaps require place-based and

					culturally responsive educational strategies.
Alam et al. (2021)	Local communities and students	Community-based problem-solving model	Community-owned small hydropower	Community planning, ownership, operation, maintenance, and benefit allocation	Community renewable-energy projects can provide authentic contexts for operational knowledge, managerial skills, and local problem-solving.
Yoon et al. (2021)	Elementary school facilities / school-based context	School-based applied renewable energy design	Solar photovoltaic modules for educational facilities	PV façade design using 3D modeling and solar-irradiation analysis	School buildings can become visible renewable-energy learning environments linking solar energy concepts with infrastructure and sustainability.
Gajdzik et al. (2024)	Households and public education audiences	Economic-awareness learning model	Sustainable energy consumption and energy efficiency	Survey-based analysis of economic awareness and sustainable energy behaviors	Economic literacy and knowledge of energy-saving strategies can support more responsible energy behavior.
Gârdan et al. (2023)	Energy consumers and public learners	Attitude-oriented renewable energy learning	Renewable energy use during energy crisis	Survey-based model of concern, perceived utility, social influence, attitudes, and behavior	Renewable energy education should address perceived usefulness, social influence, and environmental concern in addition to technical knowledge.

Table 2. Essential summary of findings on renewable-energy topics and learning contexts in inquiry-based education.

References	Renewable Energy Content	Learning Context	Instructional Resource / Learning Environment	Inquiry-Compatible Student Task	Main Finding
Friman (2024)	Renewable energy technologies, smart grids, sustainable energy systems	Undergraduate electrical and electronics engineering education	Professional laboratories, lectures, expert discussions, online courses	Investigate how renewable energy and smart-grid technologies support transition	Holistic engineering curricula strengthen understanding by combining theoretical, laboratory, expert-led, and digital experiences.
De Rosa et al. (2024)	Urban renewable energy and sustainable fuels	Lifelong learning for students and professionals	Stakeholder-designed micro-credentials	Explore renewable-energy skills for urban sustainability and green jobs	The framework created 74 micro-credentials for technical and non-technical learners.
Friman et al. (2022)	Distributed energy systems and renewable energy	Schoolchildren and community public education	School-based public education for community acceptance	Investigate how renewable-energy knowledge influences household and community behavior	Educating schoolchildren is proposed as a pathway for preparing communities to accept distributed energy systems.
Szeberényi et al. (2022)	Renewable energy use and environmental awareness	Primary, secondary, and university students	Questionnaire study involving 2,180 students	Reflect on renewable-energy use, environmental attitudes, and adoption barriers	Higher education level did not automatically correspond to stronger environmental awareness.

Yoon et al. (2021)	Solar photovoltaic modules for school façades	Elementary school facilities in South Korea	PV façade design, 3D visualization, solar irradiation analysis	Investigate how school buildings can function as solar-energy learning sites	The proposed PV façade design generated an estimated 307,734 kWh/year.
Zukowski & Sobolewski (2025)	Photovoltaic systems and hybrid wind–PV systems	University campus sustainability context	Experimental PV system, design simulations, economic analysis	Analyze PV design options and evaluate campus energy efficiency	Campus PV systems can support applied inquiry through real design, energy-yield, and economic data.
Alfraidi (2025)	Net-zero campus transition using PV and battery storage	University campus in Saudi Arabia	Optimization model using real building load data	Examine how PV and storage systems can achieve seasonal net-zero balance	The optimized case used a 3,500 kW PV array and 560 kW/2,800 kWh battery storage.
Icaza-Alvarez & Borge-Diez (2025)	Hybrid renewable systems: PV, wind, hydrokinetic, batteries, generators	Research campus in Ecuador	On-site meteorological data, RESMUCC platform, Homer Pro simulation	Compare hybrid renewable configurations and cost-energy trade-offs	The lowest-cost hybrid configuration reached USD 0.33/kWh.
Alam et al. (2021)	Community-owned small hydropower	Rural community and local students in Japan	Community-based SHP project, planning, operation, maintenance	Investigate local renewable-energy potential and community problem-solving	Community projects can become authentic learning contexts for technical operation and sustainability.
Ahmed (2026)	Renewable energy deployment and educational outcomes	Canadian communities including Indigenous populations	Causal and spatial analysis of 1,037 renewable-energy projects	Examine how renewable-energy projects relate to educational attainment and equity	Renewable-energy deployment increased education scores on average, but benefits were uneven.
Arcelay et al. (2021)	Renewable-energy workforce skills under Industry 4.0	Workforce, education centers, policymakers	Skills database and future job-profile analysis	Identify future skills needed for renewable-energy careers	Renewable-energy education should align with digital, technical, sustainability, and Industry 4.0 competencies.
Lucas & Carvalhosa (2022)	Renewable energy communities and PV pairing	Community-level energy planning	Georeferenced energy profiles and statistical learning	Investigate how household or community load profiles can be paired for PV utilization	Community energy data can support inquiry into complementarity, surplus reduction, and local energy planning.

Table 3. Essential summary of findings on learning outcomes in inquiry-based renewable energy education.

References	Learning Outcome	Assessment Method	Inquiry-Compatible Activity	Reported Effect / Finding	Implication
Friman (2024)	Conceptual understanding of renewable energy technologies and smart grids	Curriculum review of a revised BSc program	Laboratory learning, lectures, expert discussions, online learning	The revised curriculum aimed to equip future engineers with deeper understanding of renewable systems and smart grids.	IBL should combine theory, laboratory investigation, expert interaction, and digital resources.

De Rosa et al. (2024)	Green upskilling, renewable-energy knowledge, professional competence	Micro-credential framework validated through job-market data analysis	Modular learning pathway for students and professionals	The framework produced 74 micro-credentials for technical and non-technical learners.	IBL can benefit from modular, competency-based tasks aligned with workforce needs.
Szeberényi et al. (2022)	Environmental awareness and renewable-energy attitudes	Survey of 2,180 students	Reflection on renewable-energy use and perceived barriers	Higher education levels did not necessarily show higher environmental awareness.	Renewable energy learning should move beyond exposure to active inquiry and reflection.
Singh et al. (2023)	Green consumer values, renewable-energy reliance, societal capacity building	Quantitative analysis of education and renewable-energy values	Societal education on long-term renewable-energy benefits	Green consumer values can be nurtured through education and understanding of long-term renewable-energy benefits.	IBL should connect renewable-energy concepts with daily decisions and community values.
Sobczak et al. (2025)	Entrepreneurial intention, economic awareness, environmental knowledge, self-efficacy	Surveys and in-depth interviews	Entrepreneurship education linked to renewable energy investment	Entrepreneurship education can increase interest in renewable energy as an economically viable and environmentally friendly solution.	IBL should include entrepreneurial problem-solving and feasibility analysis.
Pilipczuk (2024)	Renewable-energy workforce readiness and green skills	Literature study and statistical analysis	Analysis of renewable-energy labor-market needs	Education systems need to adapt rapidly to renewable-energy labor-market demand.	IBL should align with authentic renewable-energy practices and green job requirements.
Arcelay et al. (2021)	Future skills for renewable-energy job profiles	Skills mapping and prediction	Identification of digital, technical, and sustainability skills	A unified skills database can guide training planning for businesses, education centers, and policymakers.	IBL should develop digital, analytical, and problem-solving competencies.
Yoon et al. (2021)	Applied understanding of solar PV efficiency and building-integrated energy	Design and simulation	PV façade investigation in elementary school buildings	The study estimated 307,734 kWh/year of potential energy production.	School infrastructure can become an authentic solar-energy inquiry environment.
Alfraidi (2025)	Sustainability understanding and net-zero campus reasoning	Mathematical optimization using campus data	Analysis of PV and battery storage configurations	Optimized PV and storage systems can meet building-level demands and achieve seasonal net-zero balance.	Campus systems support inquiry involving data analysis, optimization, and sustainability reasoning.
Zukowski & Sobolewski (2025)	Applied energy-efficiency reasoning and techno-economic evaluation	Long-term PV analysis, simulations, NPV/IRR	Evaluation of PV panel arrangements on a university building	A 210 kWp PV system could generate 166,392 kWh/year with strong economic feasibility.	Campus PV systems develop ability to evaluate energy yield, design alternatives, and feasibility.
Ahmed (2026)	Educational attainment and equity in renewable-energy transition	Causal and spatial analysis of 1,037 projects	Place-based analysis of renewable-energy deployment	Renewable-energy projects increased education scores by an average of 6.11 percentage points, but Indigenous communities gained less.	IBL should address equity, place, and culturally responsive energy learning.

Alam et al. (2021)	Community problem-solving skills, operational knowledge, local management capacity	Community-owned small hydropower case study	Community planning, ownership, operation, maintenance	The project generated local revenue and supported community problem-solving and student education.	Community projects offer authentic inquiry into local energy potential and sustainability.

Table 4. Essential summary of findings on challenges, enabling factors, and research gaps.

References	Implementation Challenge	Enabling Factor	Research Gap	Recommendation	Educational Implication
Magnani et al. (2026)	Public acceptance of renewable district heating is constrained by socio-economic vulnerability and willingness to pay.	Trust in institutions, clarity of benefits, community engagement, economic incentives	Limited evidence on how public perceptions shape realistic adoption of renewable heating.	Integrate socio-economic awareness and community engagement into renewable energy education.	Students should investigate technical feasibility together with affordability, social trust, and acceptance.
Chomać-Pierzecka et al. (2025)	Rural communities may support energy transition unevenly, with attitudes influenced by age and awareness.	Diagnostic surveys and local perception studies	Rural public attitudes remain underexplored compared with technical and policy studies.	Use local community problems as inquiry cases.	Students should investigate how age, location, and social background influence acceptance.
Mykhei et al. (2025)	Renewable energy development faces political, legislative, administrative, and public-concern barriers.	Transparency, education, financing, local community involvement	Limited integration of policy analysis and public education.	Include policy, governance, and communication in learning tasks.	IBL should develop ability to evaluate systemic barriers, not only scientific principles.
Ahmar et al. (2022)	Clean energy choices in rural households are affected by income, household size, infrastructure, education, and markets.	Higher education, school-going children, access to credit, infrastructure	Household clean-energy adoption remains context-dependent in developing regions.	Connect energy concepts with household decision-making.	Energy literacy should include social, economic, and infrastructural factors.
Sart et al. (2025)	Renewable energy transition may slow due to financial obstacles, volatility, and weak institutional support.	Education, income, economic freedom, sustainable finance instruments	Education is often treated as a background variable rather than a central adoption mechanism.	Strengthen learning on renewable-energy finance, policy, and sustainability.	Students should examine how education and financial systems influence adoption.
Carayannis et al. (2022)	Renewable energy investments require knowledge-oriented competencies that may be underdeveloped.	Learning and growth, ICT, R&D capacity	Limited integration of knowledge-economy competencies into renewable-energy education.	Align learning with ICT, innovation, and R&D competencies.	IBL should build information collection, innovation analysis, and evidence-based solution design.
Di Nucci et al. (2023)	Community renewable-energy projects face transferability barriers across institutional contexts.	Policy learning, good-practice transfer, enabling local conditions	Few studies examine how successful community models can be transferred.	Use comparative case inquiry.	Students should compare cases and reason about context and transferability.

Nallainathan et al. (2025)	Renewable-rich standalone microgrids face reliability issues and uneven cost allocation.	Sector-specific demand analysis and TOPSIS decision methods	Educational-sector demand is rarely discussed in renewable-energy reliability planning.	Use school/campus energy-demand data for reliability inquiry.	IBL can help students understand reliability, fairness, and cost allocation.
Sołtysik et al. (2021)	Energy demand and prosumer profitability can be disrupted by crises such as COVID-19.	Prosumer support schemes and sensitivity analysis	Limited educational attention to crisis effects on renewable-energy consumption.	Include scenario-based inquiry on prosumer models.	Students should investigate how disruptions influence energy behavior and economics.
Boumaiza (2024)	P2P energy trading faces scalability, security, and decentralization challenges.	Blockchain-based systems	Limited connection between technical P2P systems and public understanding.	Use simplified community energy trading simulations.	IBL can support understanding of energy democracy and local exchange.
Matos et al. (2024)	Renewable energy communities need accurate consumption forecasts for storage, purchase, and sale decisions.	Machine learning, solar forecasts, storage data, market prices	Community energy management is rarely translated into student-accessible tasks.	Develop inquiry projects with simplified community energy data.	Students can learn systems thinking by linking production, consumption, storage, and prices.
Gonçalves et al. (2025)	Scaling renewable energy communities is difficult due to intermittency, price volatility, and heterogeneous consumption.	Reinforcement learning, P2P trading, energy pools, ML infrastructure	Advanced models are rarely converted into educational frameworks.	Translate complex models into classroom simulations or guided inquiry.	IBL can introduce optimization, uncertainty, and collaborative decision-making.
Babajide & Brito (2021)	Solar PV adoption may be limited by high initial investment where diesel generators are common.	Fuel savings and effective policy	Energy-access studies are often disconnected from renewable-energy learning.	Use energy-access problems as inquiry cases.	Students should evaluate renewable energy as a solution to energy poverty and environmental risks.
Łącka et al. (2024)	Renewable energy, educational spending, and CO_2 emissions have complex short- and long-term relationships.	Long-term education investment	Education–renewable-energy–emissions relationships remain context-specific.	Integrate emissions-data analysis into inquiry learning.	IBL should help students analyze data, causality, and trade-offs.
Azam et al. (2023)	Fossil-fuel energy and poverty can reduce human-development outcomes.	Education, employment, green energy, life expectancy	Renewable-energy studies underemphasize human development and education outcomes.	Connect renewable-energy inquiry with development indicators.	Renewable energy education should develop socio-scientific reasoning about justice and development.

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